BALTEX

Baltic Sea Experiment

World Climate Research Programme / Global Energy and Water Cycle Experiment
WCRP GEWEX

Second Study Conference on BALTEX

Juliusruh, Island of Rügen, Germany
25 - 29 May 1998

Conference Proceedings

Editors : E. Raschke and H.-J. Isemer

Organized and co-sponsored by
GKSS Research Center Geesthacht, Germany

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GKSS
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Preface

Since the first conference, which was held in 1995 in Visby, Gotland, the BALTEX has now more definitive contours. Many groups have participated in joint research efforts, whose results require now an intensive review. Therefore, a Second Study Conference on BALTEX has been arranged at Hotel Aquamaris on the island of Rügen near the southern coast of the Baltic Sea in May 1998. More than 120 contributed papers and 13 invited overview presentations will present results in meteorology, hydrology and physical oceanography from the first BALTEX research period 1994 - 1998. Contributions from institutions and groups in more than 20 countries are related to the key topic of BALTEX, the water and energy cycles of the entire Baltic Sea drainage basin. The conference is also expected to contribute to preparations for *BRIDGE*, the main BALTEX observational and modelling period scheduled for the years 1999 to 2001. The conference has been organized by the BALTEX Science Steering Group in cooperation with the GKSS Research Center Geesthacht, Germany.

In the proceedings of this Study Conference the invited and contributed papers, both oral presentationsand posters, are published in alphabetical order related to the first author's family name.

The editors wish to thank all individuals who have been involved in various stages of the preparation for the conference. Contributions of the conference programme committee members Jerzy Dera, Carl Fortelius, Zdislaw Kaczmarek, Sirje Keevallik, Wolfgang Matthäus, Anders Omstedt and Valery Vuglinsky are much appreciated. Many thanks also for the stimulating engagement of the local organizing committee: Rüdiger Brandt, Sieglinde Hartmann, Wiebke Jansen, Sylvia Knaup and Cord Ruhe.

The financial support through GKSS Research Center Geesthacht, Germany for the conference, and in particular for printing of this volume, is gratefully acknowledged. Several other institutions and organisations have agreed to co-sponsor the conference. We wish to express our warmest thanks to all of them.

Geesthacht, May 1998

Ehrhard Raschke and Hans-Jörg Isemer
Editors

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BRIDGE
The central modelling and observational period in BALTEX - actual planning status

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The Main BALTEX Experiment (*BRIDGE*) will be a central element in the BALTEX program. It is suggested to be conducted as the main observational and modelling phase of the program. *BRIDGE* will be conducted in the period from **October 1999 to December 2001.** Modelling and observational activities during *BRIDGE* will be divided into

1) **a continuous base-line observational program** (comparable to the PIDCAP level) during the entire 27 months period, and

2) **specific enhanced observational programs** confined to limited periods of a few months duration. The latter will include the following periods:

   - January/February 2000
   - August/September 2000
   - April/May 2001.

This presentation discusses the present deficiencies in the observational systems as well as in the data assimilation and modelling systems. Numerous recommendations for a beneficial realisation of *BRIDGE* have recently been made which are published in the strategic plan for *BRIDGE*. These include also administrative and financial implications. Most important issues to be considered include the functioning of the operational observational networks at their maximum capacity, enhancement of the observational systems to cover the whole study area, especially with weather radar and radio sounding data, and the organisation of special field campaigns. An equally important task is the enhancement and consolidation of the BALTEX data management structure in order to get the quality controlled observations into the data bases of the designated BALTEX Data Centres. In this context the satellite data represent a special issue. Perhaps the most challenging task is to organise the post-processing of the data. This requires the identification and nomination of those centres capable to perform extra data assimilation runs using the special *BRIDGE* data. Only then the various research groups can have relevant data for their studies which are expected to solve many of the remaining questions related with the energy and water budgets of the atmosphere, hydrosphere and ocean.

In the presentation the response to the *BRIDGE* plan of the national meteorological and hydrological institutes as well as of the research institutes will be analysed. On the basis of the analysis first views about the level of participation, the content of the desired obsevational programs, the functioning of the new data base routines and envisaged data assimilation and modelling activities are obtained. The possibilities to finance the *BRIDGE* will be also discussed.

VERTICAL REFLECTIVITY PROFILES TO DETECT RADAR MIRAGES (ANAPROP)

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1. Introduction

Anomalous propagation (anaprop), analogous to the upper mirage in the visual wavelengths, is still a major problem in radar meteorology. Anaprop echoes from terrain features as hills and coasts often gives echos of 50-60 dBz, equivalent to severe thunderstorms. Anaprop echoes from sea waves may be comparable in strength to those from moderate precipitation and also form similar patterns. Doppler radars usually effectively exclude anaprop echos caused by terrain features simply by thresholding echos with doppler velocity close to 0 m/s. This, however, does not work for sea waves, since they generally move with velocities of a few m/s. Moreover, the range of doppler radars is often much less, about one half of the non-doppler radar or mode. Therefore the doppler can only be used for part of the non-doppler surveillance area.

For a radar situated close to a coast, anaprop is a frequent phenomenon over the sea when the sea water is cold relative to the air. An inversion (duct) in which part of the beam may become trapped, Fig. 1, is then formed. Climatologically, this is most common during spring and early summer, and the frequency of anomal propagation over 'inland' seas as the Baltic and the English Channel have a maximum during these seasons, though anaprop also occurs during other seasons. During warm months with a relatively cold sea surface a radar close to the coast and with a free horison, as our Gotland radar, may observe anaprop nearly every day. Since conventional precipitation observations are scarce over seas, radar is the most important precipitation estimator there. Over land anaprop generally appears during late night/early morning when a radiation inversion has formed. While it is generally possible for an experienced observer to identify anaprop, it is much more difficult for an automatic routine to do so. Automatic routines for precipitation estimation and forecasting are gaining importance. Therefore methods able to identify anaprop out to the non-doppler range are required. This paper describes a method for anaprop identification using a detailed vertical reflectivity profile from non-doppler radars. A *reflectivity profile* in this context is reflectivity as a function of the antenna elevation angle. We have mostly used elevation angles from about half the beam-width to one and a half beam-width. Precipitation gives smooth, unbroken reflectivity profiles, while anaprop, from land or sea (sea clutter) has uneven and/or broken profiles, Fig. 2. To get detailed reflectivity profiles we use a scanning scheme characterized by small antenna elevation steps (0.1°) in the lowest elevation angle region. Table 1 shows the scheme we first used for this project. Later, when we found angles below about 1.3° most important for our analysis we introduced more evenly distributed angles above 1.2°.

Table 1. The scan scheme. Antenna elevation number is given by 'no' *and angle in degrees by* 'deg'.

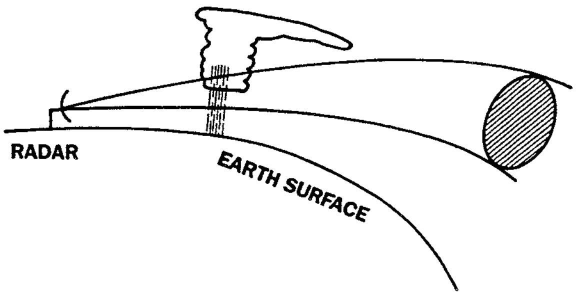
no	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
deg	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.5	3.0	4.0	10.0

For the analysis we work with data from the non-doppler mode of our Ericsson Doppler weather radars. We use polar volume data, with a resolution in azimuth of 0.85° and in range of 2 km. The maximum range is 240 km.

Not only meteorological parameters determine a radar's susceptibility to anaprop. A radar with a free horison is much more sensitive to propagation conditions than one sheltered by surrounding objects as trees and buildings, which can block the lowest part of the main lobe and the side lobes. In order not to affect the radars main purpose, surveying precipitation using a low antenna elevation angle, such obstacles should not reach more than about 0.1° above the antenna.

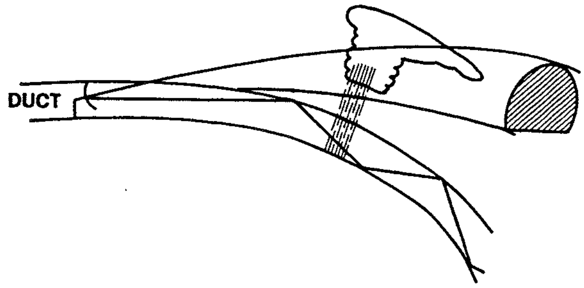
NORMAL PROPAGATION WITH PRECIPITATION

The precipitation fills the pulse. The met. radar eq. applies. Precipitation gives fairly stable echos and smooth reflectivity profiles.



ANAPROP, WITH PRECIPITATION

Echos from both the guided and freely propagated part of the pulse can give uneven reflectivity profiles. Does the met. radar eq. apply?



ANAPROP, WITHOUT PRECIPITATION

Part of the pulse is guided in the duct. Coasts, mountains and sea waves give scintillating echos and uneven reflectivity profiles.

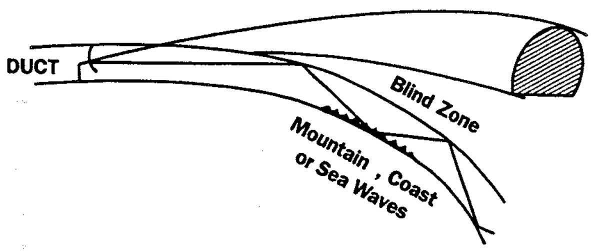


Fig. 1. Conceptual model of radar wave propagation during different propagation conditions (left and above).

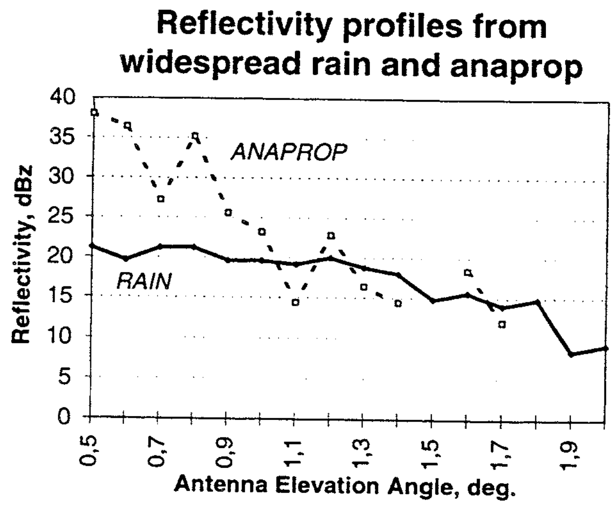


Fig.2. Characteristic reflectivity profiles in precipitation and anaprop. Note that the horisontal axis scale is antenna elevation angle.

Water exchange of the Stockholm archipelago on ecologically relevant time scales. A cascade modeling approach

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Abstract

From a water exchange point of view the major Baltic archipelagos display an impressive complexity determined not only by the sheer number of multiple water passages between the numerous basins but also by the intricately varying hypsographic features of these basins, rendering such areas an almost fractal character. This characteristic certainly applies to the Stockholm archipelago with its more than 10^5 islands of varying sizes, spanning the spectrum from major islands to small skerries. This complexity provides the reason for its hitherto being exempted from modeling studies other than rather crude box model approaches. Archipelagos are, however, considered to be of utmost ecological importance (e.g. nutrient dynamics and fish spawning) as well as for their economical and recreational values, motivating the present attempt to improve the quantitative understanding of their functioning, departing from water exchange estimates.

Traditionally the Stockholm archipelago is partitioned into three parts: the inner, the middle and the outer archipelago. This subdivision fortunately also coincides with differing water exchange regimes. The inner archipelago is dominated by comparatively larger basins that are interconnected by a limited number of straits. This configuration of basins is therefore well suited for a discrete basin model approach by partitioning the area into a set of subbasins that are only resolved vertically (DB-domain). The advantage of this approach over 3D-models is the possibility for enhanced vertical resolution and improved strait exchange formulation which outweighs the disadvantage of neglected horizontal resolution within the basins. This is arguably true on ecologically relevant time scales of about one week or longer. The water exchange on shorter time scales is mainly caused by sea level fluctuations and the local wind stress. The dominating exchange process is induced by the marked freshwater discharge and the vertical mixing (produced by both wind stress and ship propellers) which combine to form the estuarine circulation. The baroclinic intermediate exchange process (*sensu* Stigebrandt), driven by the density fluctuations along the Baltic interface also contributes significantly.

The entire actual archipelago spans roughly a semicircular area with a radius of approximately 60 km. Due to Ekman pumping, considerable density variations may occur along this periphery, inducing such intermediate circulation. Measurement data to adequately resolve these density variations do not exist. Instead, an attempt is made to provide this missing forcing information by linking the middle archipelago perimeter to a 3D-model of the Baltic with a fine resolution grid size of 0.5 nautical miles (n.m.). This fine resolution model (FR-domain) is externally driven by atmospheric forcing (heat dynamics and wind stress) and the density variation at the model's border. It is *a priori* deemed to be capable of adequately resolving both the interfacial straits and the outer archipelago's complicated hypsography, but would demand an overly massive computing capacity if extended to comprise the entire Baltic. Therefore the FR-domain model of the outer archipelago is interfaced with an existing coarse resolution model of the entire Baltic (CR-domain) with a grid size of 5 n.m. and its open border located in the Kattegat. The DB-domain of the combined inner and middle archipelagos is thus interfaced with the FR-domain along an irregular geographic border and the FR-domain in turn connects to the CR-domain along a geometrically regular border. At both these interfaces, the larger scale dynamic information (density profile and surface elevation) is passed on to the inner and more articulate of these cascade coupled models.

The aspired merit of this arrangement of cascading numerical models is that computational effort is allocated to domains where it best contributes to an overall numerical efficiency. It would for instance be numerically wasteful to resolve the basins of the inner archipelago to the same spatial scale as the width of the interconnecting straits of the middle archipelago in an attempt to resolve the entire area as an all-encompassing 3D-model. Likewise the DB-approach is poorly adapted to model the outer part of the archipelago. For model validation an appropriate measurement program exists with salinity and temperature data covering almost 10 years of continuously and regularly visited stations. Some preliminary computational results will be presented.

THE HYDROLOGICAL CYCLE IN THE ECHAM4 MODEL OVER THE BALTEX AREA

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Long-term simulations with the ECHAM4 model using different horizontal resolutions are being investigated in respect of their ability to reproduce the mean hydrological cycle over the BALTEX area. For comparison the data from the reanalyses by ECMWF and NCEP as well as a wide range of other climatological values including river discharge observations are used. The annual cycle of precipitation at some key stations is represented by the model mostly within the limits of uncertainty, which is quite large, but with a too small annual variability, i.e. probably too much precipitation in winter and too little in summer. In contrast to our expectations the highest resolution model version T106 gives not a superior performance compared to the lower resolution model versions. There is an overestimation of precipitation in summer by the reanalyses of NCEP and NASA and an underestimation in winter by all reanalyses, especially by the reanalysis of ECMWF.

Although the river Vistula/Wisla/Weichsel is represented in a T42 model only by two grid points, it is used for further investigations in respect of the time variability because it is the largest river basin with a long time series of river discharge observations. The long-term annual mean observed river discharge agrees with the precipitation minus evaporation values for this area by the ECHAM4 T42 model, forced with variable observed SSTs. The interannual variability of these data show a weak impact from the El Niño / La Niña events in the simulations as well as in the observations, stronger in the simulations. The interdecadal variability in both time series show a similar amplitude but no similarities in the phases, suggesting that this scale is not forced by the ocean temperatures or that there is a model problem. Largest disagreement can be found for the last 20 years.

The interannual variability of precipitation (1979-1992) for the catchment of the river Vistula/Wisla/Weichsel is realistically represented by the ECMWF reanalysis for all four seasons. One cannot expect that the simulations with the ECHAM4 T42 models reproduce same interannual variability as observed because the SSTs contribute only partly to this variability but the amplitude of the variability is reproduced realistically though with a bias as mentioned above. The same applies for other places in the BALTEX area.

The work is still in progress and more recent results will be shown in the conference.

DEEP-SEA MIXING IN THE BALTIC SEA IN RELATION TO WIND ENERGY

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1. Introduction

The parameterization of vertical diffusion in numerical ocean models is of great importance and interest. One reason is that it affects the stratification of the ocean, which is strongly coupled with the large-scale circulation [*Cummins et al.*, 1990]. Further, it has important secondary effects on the coupling to the atmosphere, since the sea surface temperature depends strongly on the vertical diffusion.

Two-equation turbulent closure models such as the k-ϵ model have been rather successful in predicting vertical diffusion in regions of high large-scale shear such as the upper ocean [*Mellor and Durbin*, 1975; *Omstedt et al.*, 1983]. In the deep ocean, however, most of the mixing is believed to result from the breaking of internal waves, probably intermittent in time and space. Since internal waves cannot be resolved in present-day Ocean General Circulation Models, the mixing due to internal waves must be parameterized as a subgrid-scale process.

Today's state of the art is to parameterize the vertical diffusion coefficient K as inversely proportional to the buoyancy frequency N, or $K = \alpha N^{-1}$ [*Gargett*, 1984], where α is a local constant tuned for today's climate. A future goal, however, must be to find a parameterization of K for the deep ocean which is not only correct on climatological time scales, but depends on the varying energy density of the internal wave field and its forcing.

In the world oceans the most important source of internal wave energy seems to be the barotropic tide interacting with the local topography [*Sjöberg and Stigebrandt*, 1992]. Another important source of internal waves is the wind, which may transfer energy to the internal wave field by generating inertial currents in the upper ocean. The Baltic Sea is ideal as a laboratory to study the transfer of energy from the wind to the internal wave field, since tides are practically nonexistent in the Baltic Sea. It is the aim of this presentation to show some results from an attempt to correlate the vertical energy flux density in the deep ocean, as calculated from observations (Axell, 1998, submitted; hereafter referred to as A98), with the energy flux densities obtained from two different models of energy transfer from the wind.

2. Methods

On the average, there is a correlation between u_*^3 and the energy flux from the wind to inertial currents [*D'Asaro*, 1985], where u_* is the friction velocity in the surface layer of the ocean. If we assume that the inertial currents mainly lose energy by radiating internal waves into the deep ocean, then the vertical energy flux density F_w due to the wind, which is given by

$$F_w = \gamma \rho u_*^3, \tag{1}$$

should correlate with the vertical energy flux in the deep ocean. In the above, γ is a nondimensional constant of the order of one.

Another approach is to force a slab model of the ocean with the local wind field to simulate the build-up and dissipation of inertial currents in the upper ocean. This way, the system has a certain memory of earlier wind events, which is physically attractive. Neglecting nonlinear terms and using a linear friction term, the equations of motion are

$$\frac{du}{dt} - f\,v = \frac{\tau_x}{\rho H} - r\,u; \quad \frac{dv}{dt} + f\,u = \frac{\tau_y}{\rho H} - r\,v, \tag{2}$$

where f is the Coriolis parameter, τ is the wind stress, H is the depth of the mixed layer, and r is a friction coefficient. The rate at which the kinetic energy of the inertial currents is lost is then $r(u^2+v^2)$ W kg^{-1} [*D'Asaro*, 1985]. Hence, if this energy is lost to the internal wave field, the vertical energy flux density F_{ic} due to inertial currents is given by

$$F_{ic} = r\,\rho H\,(u^2+v^2). \tag{3}$$

Equation (2) was solved numerically with different combinations γ, H and r. In addition, since the energy may need some time to reach the deeper layers, different time lags ΔT between the model-generated fluxes and the

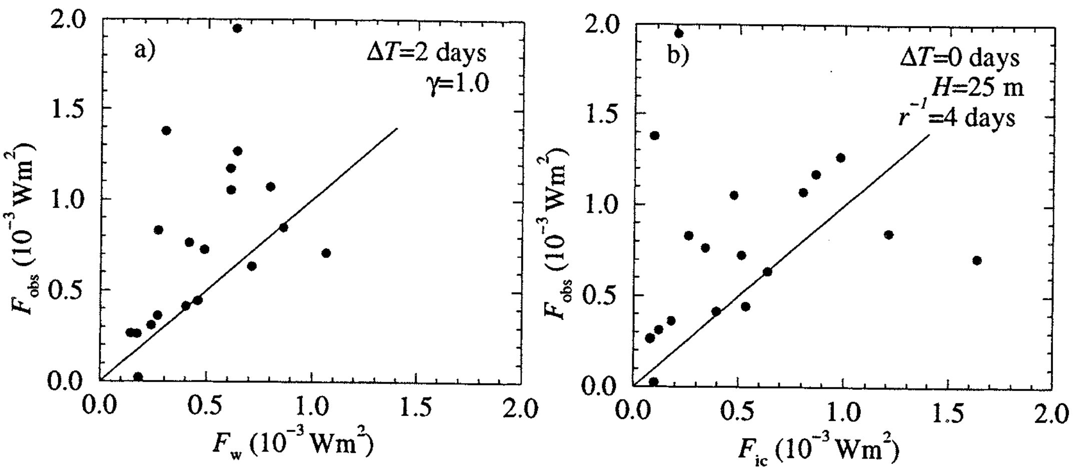

Figure 1: Comparison between observed (F_{obs}) and modeled vertical energy flux densities. The left panel shows the result for F_w, and the right panel shows the results for F_{ic}. The lines indicate a 1:1 relationship between the modeled and observed fluxes.

observations were tested for best results. The wind stress forcing was computed by using wind observations from the area (the Baltic proper), and the model was run from 1964–1997.

The deep-sea flux densities of energy in A98 were calculated from changes in potential energy below the 150-m level in the Gotland Deep, by using historical data. Because nonadvective periods were selected (see A98 for details), the changes in potential energy were due to vertical diffusion, assumed to be the result of breaking internal waves. The corresponding energy fluxes at the 150-m level from the different subperiods could then be compared with the different parameterizations of the energy flux from the mixed layer [Equations (1) and (3)].

3. Results and Discussion

The results from the two parameterizations (1) and (3) are illustrated in Figure 1a) and b), with $\gamma = 1.0$, $H = 25$ m and $r^{-1} = 8$ days, which gave best results. The degree of scatter in data is rather large for both models. The correlation coefficients are 0.48 for F_w ($\Delta T = 2$ days) and 0.24 for F_{ic} ($\Delta T = 0$ days), respectively. It should be noted, however, that some of the scatter is most certainly due to uncertainties in the observations. Further, if we had used $\gamma = 0.5$ in the calculation of F_w [*D'Asaro*, 1985], the modeled energy flux had been far too small to explain the energy fluxes observed by A98. When it comes to the slab model, it is possible that a variable H could improve the results of F_{ic}. However, the present results indicate that the slab model, although physically more appealing, does not yield better results than the flux derived directly from the friction velocity u_*.

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WATER BUDGET OF THE DARSS-ZINGST BODDEN CHAIN

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1. Introduction

The Darss-Zingst Bodden chain is a very shallow German estuary with a narrow connection to the Baltic Sea. The area of the Bodden chain is about 200 km^2 and its average depth amounts to 2 m. Therefore, these lakes are assessed to be very shallow. Decisive for the distribution of nutrients in the Bodden chain is the water exchange. The monthly distribution of the water budget components is described e.g. by Correns and Mertinkat (1974) and Mertinkat (1992). Beside the mean annual water exchange, the water exchange of extreme water level rises, extreme events of precipitation and extreme events of river inflow should be investigated.

2. Description of the water budget of the Darss-Zingst Bodden chain

For a detailed calculation of the water budget balance the whole Bodden chain is subdivided into four Bodden lakes (1. Saaler Bodden, 2. Bodstedter Bodden, Kappel Stream and Prerow Stream, 3. Barther Bodden, Barth Stream, Fit and Zingst Stream and 4. Grabow) (see Figure 1).

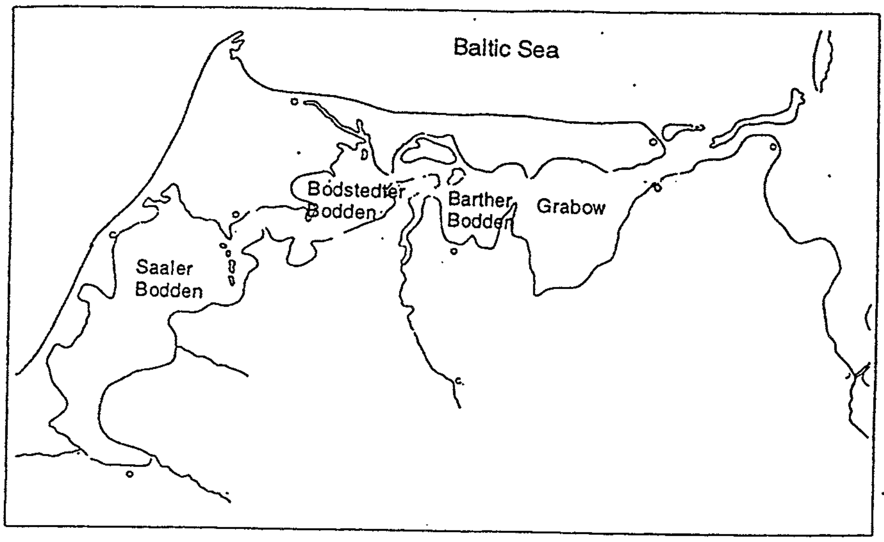

Figure 1: Map over the Darss-Zingst Bodden chain

For each Bodden lake a separate water budget balance equation is constructed. Then, the four equations build up an coupled equation system. The water budget of a Bodden lake is determined by components like the water exchange with the two neihbouring Bodden lakes or respectively the Baltic Sea, the precipation, the evaporation, the river inflow and the net storage or respectively the loss of water during the time period of investigation. The water exchange between the Bodden lakes (inflow and outflow) are the unknown components in the water budget balance equations. The sign of the water exchange component decides about inflow and outflow.
The precipitation and river inflow data are taken from the surrounding measure stations. They are weighted by the corresponding Bodden area. Available data of precipitation and river inflow are daily data. The storage or the loss of water in the individual Bodden lakes during the investigated time period is calculated using differences of water levels. Daily water level data of the Bodden lakes are calculated from hourly measured data. The rate of evaporation over the water surface is calculated by an approach of Brutseart (1982). It is a combination of the evapotranspiration from the surrounding land and a term for the local advection. The advection term is a function of the wind speed over the Bodden lakes, the fetch, and the difference between the vapor pressure at the land surface and the saturation vapor pressure at the lake surface, which can be obtained from the water surface temperature. This temperature is measured only in the vicinity of Zingst. Thus, that measurements have to be considered as representative for the whole Bodden lakes. The wind speed over the Bodden lakes is determined by means of the observa-

tions at Barth and a application of a wind atlas (Hinneburg et. al., 1997). The evapotranspiration over land is determined using the energy balance at the soil surface. The determination requires the knowledge of the individual components of the energy balance equation like radiation, fluxes of sensible, latent and soil heat. These components are determined using the air temperature, the vapor pressure, the wind speed, the global radiation and the acceptances of the soil heat flux and the canopy resistance. The energy balance is determined by hourly measured data, then daily values of the evaporation are calculated. To calculate the advection term an exact description of the air mass to the transition from land to water is necessary. Here, a southerly and a northerly stream are to destinguished. If the air is coming from northerly directions, then it is supposed that the air is mainly influenced by the Baltic Sea, because the land between the Baltic and the Bodden lakes is very small. In this case the calculated evaporation is based on Data of Zingst. It is located in the north of the Bodden lakes. In the other case (southerly winds) the evaporation is calculated using data of Barth. All data necessary to determine the water budget are available since 1981.

3. Results

We calculated the components of the annual water budget as well as of the extreme events, such as periods of extreme water level rise, of extreme precipitation and of extreme river inflow. In determining the annual water budget the storage terms were calculated from the water level differences of the beginning and the end of a month. Extreme events of water level rises are considered as periods with an increase of the water level at the water gauge Barth from NN (Normal zero) up to the annual 1% percentil. Extreme precipitation periods are considered as periods with an increase of the precipitation from nearly zero up to the annual 1% percentil and the subsequent decrease. Extreme river inflows are defined in an analogously manner. In table 1 different components of the water budget as water supply and water loss, precipitation, evaporation and river inflow are shown for the annual average and for the average of periods with extreme water level rises, of extreme precipitation and extreme river inflow.

water budget	water supply in 10^6 m^3	water loss in 10^6 m^3	precipitation in 10^6 m^3	evaporation in 10^6 m^3	river inflow in 10^6 m^3
annual	570,7	582,0	115,6	201,5	287,1
extr. water level rise	105,9	5,2	4,1	5,2	11,1
extr. precipitat. period	22,7	26,3	8,0	3,8	6,0
extr. river inflow period	26,1	26,4	2,7	2,4	18,8

Table 1: Different components of the Bodden chain water budget for annual investigations and for investigations of extreme water level rise, extreme precipitation and extreme river inflow periods.

Conclusion

The annual evaporation rate over the Bodden lakes is almost twice the size of the annual precipitation rate. One reason is probably the high surface water temperature of the Bodden lakes. The water supply of an extreme water level event amount to about 1/5 to 1/6 of the annual mean.
On average the water supply is almost just as high as the water loss at extreme precipitation and extreme river inflow events.

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RETRIEVAL OF CLOUDS WATER CONTENT USING SATELLITE DATA IN SUMMER 1997 IN EASTERN EUROPE

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Using specially developed methods of retrieval of the meteorological characteristics on the basis of multispectral satellite information the estimation of *Cu* and *Cb* water content and liquid water path (LWP) over territory of Poland and Nortn-West of Russia in summer 1997 is conducted. The correlation between clouds water content and precipitation is investigated. On a particular example possibility of using of the multispectral satellite information for monitoring floods and estimation of clouds water content and LWP is demonstrated.

Alongside with clouds water content the estimations of such characteristics as clond top temperature, cloud top height, cloud thickness and cloud fraction are obtained. The estimation of splashing down zones on territory of Poland in the summer of a 1997 is conducted. Is shown that the results obtained on the basis of the satellite data will be well agreeed the data obtained using ground meteorological observations.

The offered methods allow to carry out operating estimation of water content and LWP and recognition of praecipitans clouds.

SNOW IN THE BALTIC BASIN - DIAGNOSTICS AND MODELLING

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Snow is extremely important for the hydrology of the Baltic basin; in the northern and eastern parts the snow dominates the hydrology in the sense that most of the annual runoff volume occurs as a consequence of snowmelt. When there is snow on the ground, the radiation exchange with the atmosphere is different from during non snow covered conditions; and when there is snow on the ground there is no groundwater recharge.

While there is a permanent snow cover throughout the winter in the northern and eastern parts of the Baltic basin, in the south some winters the snow cover only stays for shorter periods; the snow may disappear and re-appear during a winter. The regional snow distribution is shown in the paper including the annual variability. The snow is not evenly distributed within a river basin because of temperature and precipitation variations with height, and because of snow drift and interception. Most snow is found in forest openings. Examples are shown.

The river regimes in the Baltic basin are determined or highly influenced by the snow conditions as is shown in the paper; the influence is different in small and in large basins. Extreme flows are related to different types of generating events. In the large river basins the very high flows occur when there is much snow and the snow melt occurs late in spring. In small basins rain on snow, although rare, causes very high stream flows.

Since there are many lakes within the Baltic basin, and the lakes influence the hydrology in attenuating flows and retaining high regional evaporation losses also during dry periods, lake ice and snow on ice are included in this paper about snow in the Baltic basin. Lakes may remain ice covered also after most or all of the snow in a river basin has disappeared. There may be inundation because of ice blockage at lake outlets or in river bends further downstream. Some statistics of lake ice thickness are given. The ice strongly effects the heat balance of a lake. These effect is shown in the paper using observations and heat balance calculation.

Time scales in snow hydrology range from the length of the snow covered season (months or half the year) down to the time required for a moisture flux to move through a thin ripe snow cover (hour or less than an hour). The spatial scales include distances from the short travel distance of overland flow to storm water inlets in urban environments, over hill slopes length in forests, over the size of open fields, to sub-basin scales or even to full large river basin scales. It is discussed in the paper, when and in what way different snow processes need to be accounted for when computing runoff, and which resolution is required.

Different kinds of snow models are reviewed including simulation routines for snowmelt and refreezing as well as for severe winter conditions. The snow models are coupled to runoff models and it is discussed which models that are suitable for different purposes and for simulating hydrologic processes in different environments.

Finally the water balance of different regions within the Baltic basin is compared for years with long and short lasting snow cover, since the snow and the ice not only control the river basin runoff but also influence the evaporation losses.

Climate modelling of the Baltic Sea catchment area

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Despite the fundamental importance of water for society, we still have insufficient knowledge of the different components of the hydrological cycle; precipitation, evapo-transpiration, storage of water in lakes and aquifers and river run-off. Even more difficult is it to determine how the hydrological cycle may change in a future climate with an altered concentration of greenhouse gases, ozone and aerosols caused by anthropogenic influences. Major scientific efforts are now being devoted to increasing our knowledge in this important field. This research is being undertaken over a broad area, incorporating major observational programmes and different indirect ways to estimate the hydrological cycle with the help of advanced numerical models. Precipitation has a very fine, almost fractal scale, and is virtually impossible to sample from the standard synoptic stations. Measurements are almost exclusively confined to the populated land areas of the earth. For the ocean areas conventional precipitation data are missing. An efficient approach to improve our understanding is to apply a combination of high resolution numerical modelling and systematic observations studies of the different components of the hydrological cycle. The BALTEX programme is here particularly suitable since it incorporates a proxy ocean area.

The numerical experimentation programme for BALTEX has undertaken a series of numerical models at different resolution. I will in the presentation mainly use results from hydrostatic models at ultra high resolution, equivalent to a meshwidth of 10-20 km, but integrated for several months. Normally, the high resolution models have been forced by operational analyses at the boundaries at 6 hours resolution.

Validation against high resolution precipitation data show in general a very good agreement, assuming the synoptic pattern is correct, but indicates generally a slightly higher precipitation rate (5-10%) than observed. It is suggested that this is probably due to prescribed SST data for the Baltic Sea which cannot adjust fast enough to changing weather conditions. Coupled model integration show slightly weaker fluxes and hence reduced precipitation. Cloud and radiation in the model integrations vary much more than precipitation with some pronounced systematic model differences. Water vapour has been validated against high time resolution GPS measurements of vertically integrated water vapour. Agreement is surprisingly good but with an indication of slightly more water vapour in the model data.

The largest model differences concern soil moisture and the water storage capacity in the soil. For models where the soil water is properly initialized, simulation of river flooding such as in Odra in July and August 1997 is surprisingly well reproduced.

The high resolution models have also been tested in a climate mode, where boundary data instead is obtained from a global general circulation model simulation. As in previous investigations, results show a strong dependence of the global model. Large scale systematic errors in the global simulation may thus effect the limited area results in a detrimental way.

CORRELATION OF PRECIPITATION ESTIMATES DERIVED FROM THE GOTLAND WEATHER RADAR AND THE DMSP SSM/I DURING BALTEX PIDCAP

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During PIDCAP data from the Gotland radar were sampled, timed according to the overpasses of the Defense Meteorological Satellite Program (DMSP) satellites F10, F11, and F13. These satellites carry the Special Sensor Microwave/Imager, a multi-channel microwave radiometer suitable to detect and quantify precipitation. Three dimensional volumes of reflectivity data were collected from the Gotland weather radar. This allowed for precipitation estimates at different altitudes. The radar and SSM/I datasets were combined using methods which accounted for the frequency-dependent, low spatial resolution of the SSM/I. In order to avoid ambiguities within the SSM/I data, the dataset was reduced to measurements over sea with no influence from land.

The derived dataset reveals insights in the detectability of precipitation at different spatial scales as well as in problems associated with the combination of SSM/I and radar data, e.g. for the purposes of validating SSM/I data. Comparing the combination results for CAPPI and Pseudo-CAPPI image types, it is shown that the use of Pseudo-CAPPI imagery gives unrealistic correlations of SSM/I with radar data at low altitudes, since Pseudo-CAPPI data consists of data measured at higher altitudes at distant ranges. For low altitude CAPPI data, the covered region is limited to a small circle around the radar where almost no combined data are found for the low-frequency SSM/I channels. For altitudes above 2 km and up to the top of the precipitation systems, high correlations between SSM/I and radar data are found. Correlation coefficients exceed 0.7 at the SSM/I frequencies 19 GHz and 37 GHz for the entire dataset. At 85 GHz highest negative correlations are found at altitudes around 7 km, reflecting the dominant influence of scattering from precipitation-sized ice particles. These general features, however, vary strongly for different meteorological situations.

INTERNAL MODEL VALIDATION - A NECESSITY FOR CONFIDENCE IN WATER BALANCE PARAMETERISATION

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Climate modellers as well as hydrological modellers are well aware of the uneasy feeling of suspicion that their models are suffering from compensating errors. The statement that the model might be right for the wrong reason is one of the more popular in the modelling debate. Nevertheless the problem is often overlooked as long as the end result by the model is acceptable. This attitude may be accepted in weather forecasting or hydrological simulations when the climate is stable. It is, however, dangerous in a changing climate where the role of some of the processes may change. If the aim is to understand the water and energy cycle of the Baltic basin, as is the case within BALTEX, we definitely have to address the problem. We need do be able to describe each individual process realistically and with confidence. Internal model validation has been pointed out in the BRIDGE plan as a way towards this goal.

The problem of internal validation of the individual physical processes of models is a complex one. Normally lack of representative data on the same format and scale as in the model is the main obstacle. Sometimes, as in the case of soil moisture, differences in definitions and scientific jargon hinders the process. In water balance parameterisation the most relevant variables to analyse are snow pack and soil moisture storage. Snow data are normally available as depths only or as the areal extension of snow. More seldom basin-wide observations of snow water equivalents can be used except for in basins with great economic importance, as those used for hydroelectric power production. Soil moisture data are even more rarely found, but some records can be found from small scale research basins, in particular collected during the intense data collection periods of the International Hydrological Decade and Programme (IHD and IHP). The problem is to make optimal use on these data so that they can be integrated into the validation process.

It is not realistic to believe that we will be able to compare the grid square output from a climate model with direct observations of snow and soil moisture over the grid. It is, however, possible to look at the parameterisation isolated and to compare with observations. This has been done several times in hydrological modelling with encouraging and sometimes surprising results. Examples of internal validation of the snow component of the HBV-model can be found in the work by Sandén and Warfvinge (1992), Braun et al, (1994) and Lindström et al. (1997). Soil moisture simulations have been validated internally by Andersson and Harding (1991) and by Sandén et al. (1992) among others. Examples from these works will be shown in the presentation. In cases basin runoff is dominated by snowmelt, validation of the runoff simulation can be considered as a relatively good validation of the snow component of the model. This is the situation in many of the rivers of northern Scandinavia.

One way of bridging the scale gap between small research plots and climate models would be to use the more scale independent hydrological models as communication link. This means that these models are carefully tested on the best small scale observations we can find. This will, at least, answer the question whether we have the fundamental dynamics right. After this process we will hopefully have increased the confidence in these models, and are ready to use them for validation of courser scale atmospheric land parameterisation of climate models.

The BALTEX programme is now facing the problem of internal process validation of its models. This must be done carefully so that we do not conserve approaches which are not physically sound but develop realistic parameterisation schemes. Even though the scale problem is a difficult one to solve when comparing model results with observations, we must not neglect the information value of observations in this process.

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TRANSPORT OF DENSE, NEAR-BOTTOM WATERS IN THE STOLPE CHANNEL AND RELATED MESOSCALE HYDRODYNAMIC STRUCTURES.

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Investigations in the Stolpe Channel area have been carried on for last decade during regular cruises by IO PAS. Main purpose was monitoring of the near-bottom transport of dense, high saline waters inflowing from the Bornholm Basin. Horizontal resolution and frequency of these measurements were usually not sufficient to observe the mesoscale features with the scale of baroclinic Rossby deformation radius. Since 1994 intensified field programme has been introduced with special attention paid on high-resolution CTD transects laying between the Bornholm Deep and Gdańsk Basin, especially in vicinity of the Stolpe Sill and in the Stolpe Channel.

The Stolpe Channel plays substantial role as the only possible way for deep transport of inflowing, oxygen-rich and highly saline, waters from the Bornholm Deep towards the downstream basins of the Baltic. But overflow from the Bornholm Basin to the following channel is strongly dependent on the halocline height above the sill depth (60 m) and the salinity differences between deep layers of these pools. Moreover, deep water transport through the Stolpe Channel is controlled by the direction and speed of dominating winds (Krauss and Brügge, 1992). Inflow to the Stolpe Channel as a result of the filling up the Bornholm Deep with dense, saline waters and rising the halocline above the sill depth is observed mainly during the major inflows (last in January 1993). The high-resolution CTD measurements, comprising part of the Bornholm Basin, the Stolpe Sill and being continued in the Stolpe Channel revealed other possible mechanism of the dense waters transport over the sill. Different stages of the overflow of saline waters along the sill slope, separating the dense plumes and further transport within the Stolpe Channel support an idea of the 'splash-like' character of deep water flow in the downstream direction. The time series of near-bottom currents together with salinity changes (fig. 1), obtained during measurements at the top of the Stolpe Sill in 1997, are good confirmation of earlier conclusions based on salinity/density distributions. During such events maximal salinity observed over the sill can rise significantly (more than 3 - 4 psu over the mean value for stagnation period, reaching up to 16 psu), which is followed by strong decrease of salinity (sometimes to less than 9 psu) during next stage. Separated lenses of the dense, highly saline water originating from the Bornholm Basin are transported along the eastern slope of the sill. Although 'going-on' generation of the isolated plume is rarely caught during field measurements (because of short lasting of this event), the water bodies with high salinity and often anomalous temperature are commonly found along the Stolpe Channel axis. Such mechanism of dense water transport, possibly due to wave-like or other mesoscale motions in the Bornholm Basin, has a great influence on deep flow in the Stolpe Channel.

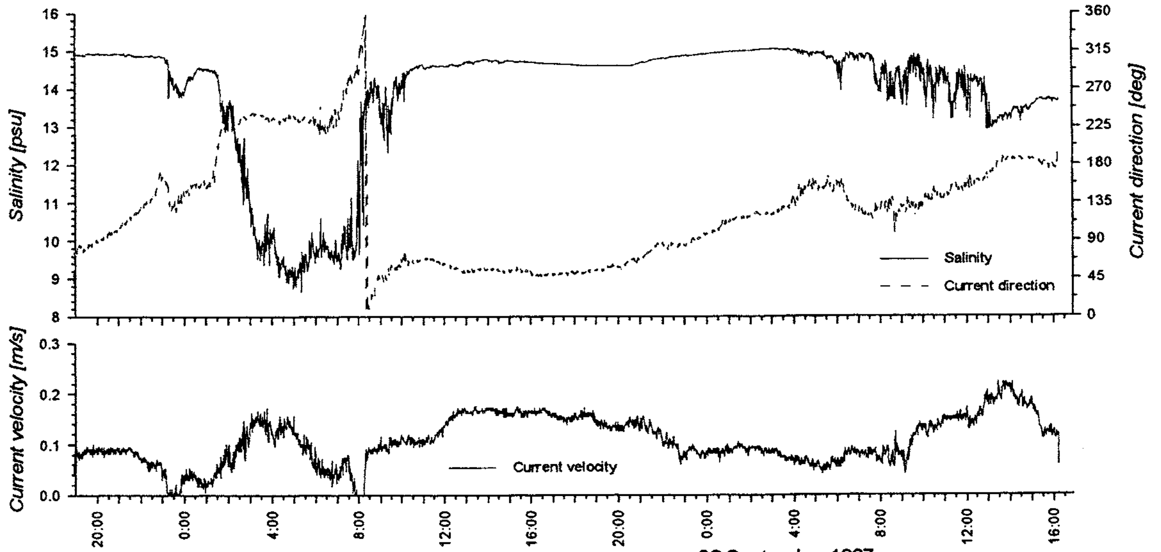

Fig. 1. Time series of salinity [psu], direction [deg] and velocity [m/s] of current in near-bottom layer over the Stolpe Sill, September 1997.

Dense-water transport in the deep channels may be approximated by a sum of the density- and wind-driven component (Elken, 1996). Irregular dense water inflow from the Bornholm Basin together with variable wind forcing may result in development of the mesoscale peturbations of the deep flow. Saline water plumes, entering into the Stolpe Channel, do not propagate continuously along the channel axis but are stopped probably by the bottom topography. As a result high energetic baroclinic eddies with scale of Rossby radius are formed in deep layers, being a reason of significant displacement of the isopycnals. Such circulation patterns were observed either in shape of first mode eddies (characterised by isohalines apraisal in the centre - fig. 2a) or second mode lens-like density structures (fig. 2b) with isohalines lifted up above the halocline and shifted down below (in agreement with classification by Elken, 1986). Repeated CTD transects allowed to estimate the lifetime of the eddy disturbance on more than week (in some cases structure observed with several days interval remained stable with only little transformation). Distributions obtained during several cruises showed existence of peturbations with diameter about 40 km (November 1995) as well as less extended structures with diameter comparable with channel width (10 - 20 km, February 1996, January 1997, March 1997, November 1997). Maximal displacement of isopycnals characteristic for observed eddies exceeded 20 m. Around the eddy core, where rotational speed is maximal, regions of intensified mixing were clearly visible as well as small bodies of water circulating at the eddy periphery. Within the deep lenses water of anomalous temperature was found, originating not only from the Bornholm Basin deep layers but in some cases also from upper saline layers of the Gdańsk Basin during the opposite flow under unfavourable wind conditions.

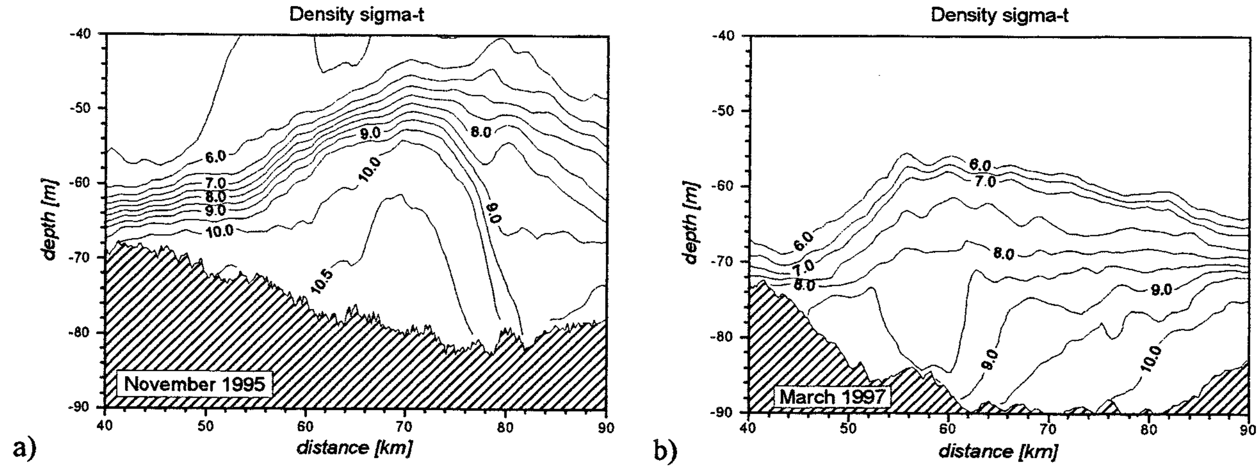

Fig. 2. Distribution of the isopycnals within first (fig. a) and second (fig. b) mode eddy in the Stolpe Channel.

High-resolution CTD transects, comprising the Stolpe Channel and Gdańsk Basin, revealed that together with weak cyclonic circulation in background (assumed on basis the raising of isohalines) the dense water plumes can be transported (if only they are intensive enough) into the Gdańsk Basin. Such pattern of circulation is in a good agreement with assumption about buffering role of the Gdańsk Basin for the downstream transport.

Besides of mesoscale eddies with well-developed density structure, wave-like disturbance of halocline with different vertical amplitude and horizontal scale were observed in the Stolpe Channel during high-resolution measurements. These energetic fluctuation of the mean deep flow of dense water are suspected to be the topographic or near-inertial (with period more than 14 h) waves, arising under coupled influence of atmospheric forcing and bottom topography (presence of sill and bottom roughness). The near-slope current jets identified by tilted isopycnal at the cross-sections were found, being one of the possible mechanism of generation thermohaline anomalies in deep layers. Strong mixing and intrusive patterns were observed in regions where halocline contacted slopes of the channel.

The intensified mesoscale motions (baroclinic eddies, deep thermohaline anomalies, fronts, wave-like phenomena, current jets) as well as more frequent 'splash-like' overflow above the Stolpe Sill were noticed during autumn and winter periods (November 1995, 1997; January, March 1997, February 1996). The absence of thermal stratification (due to autumn cooling and convection) allowed the strong winds to influence directly on deep layers causing erosion of halocline and intensification of dynamical processes.

THE METEOROLOGICAL OBSERVATORY IN LINDENBERG AND THE LITFASS FACILITIES - A CORE BASE FOR A BALTEX CLOUD/PRECIPITATION - LAND SURFACE PROCESSES EXPERIMENT

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The German Weather Service (DWD) currently runs a five-year research program (LITFASS = Lindenberg Inhomogeneous Terrain - Fluxes between Atmosphere and Surface: A Long-term Study) in order to determine the area-averaged turbulent fluxes of energy and momentum over a heterogeneous landscape around Lindenberg. These fluxes shall be representative for a horizontal scale of about 10 km (while the typical patch scale is between 10^2 to 10^3 m) corresponding to the size of a grid cell in the present operational NWP model of the DWD. The LITFASS-project is closely related to the BALTEX program since

- the scientific goals of LITFASS meet some of the BALTEX objectives, in particular concerning the atmosphere - land surface coupling (long-term monitoring and process studies), the formulation of high-resolution atmospheric models, and the development of scale aggregation schemes for treating small-scale non-homogeneity in the surface characteristics,
- the topography around Lindenberg is typical for large regions of eastern Central Europe and hence for a major part of the southern BALTEX area.

The LITFASS experimental area is centered at the Meteorological Observatory in Lindenberg, a research department of DWD. The monitoring program of the observatory includes a standard synoptic weather station, standard radiosoundings four times a day, a comprehensive radiation measurement program (BSRN station), and the operation of two wind-profiler / RASS systems (1292 MHz, 482 MHz for remote wind and temperature profiling over height ranges of 0.2 ... 4 km and 0.5 ... 12 km, respectively). Currently, a boundary layer field site close to the observatory is becoming operational including a 100 m meteorological tower, a surface layer profile mast, a radiation measurement complex and a test field for the measurement of soil temperature, soil moisture and ground heat flux. Within the frame of LITFASS, a hydrological monitoring program has been set up in the Lindenberg area including measurements of the run-off and precipitation at about 10 respectively 20 locations. By the end of 1998, a network of five energy budget monitoring stations will be installed over different types of surface (meadow, agricultural fields, forest, lake) for determination of the surface energy fluxes employing different types of SVAT models.

In May-June 1998, a field experiment will be carried out in the Lindenberg area within the frame of LITFASS but with strong emphasis on the BALTEX process study strategy stimulated by a close cooperation with GKSS Geesthacht. Turbulent fluxes which are representative for different horizontal scales will be derived from eddy-correlation measurements over different types of land surfaces, from spatially integrating scintillometer measurements of structure function parameters, from remote sensing data, and from airborne measurements using the HELIPOD sonde and high-resolution aircraft instrumentation. Special attention is also given to water vapour and cloud measurements using ceilometers, different types of lidars (DIAL, Raman lidar), a cloud radar, a cloud video-camara and microwave radiometry. Areal precipitation information will be available from the weather radar at Berlin, about 65 km to the north-west of the experimental area. Details of the experimental design and of the data evaluation strategy will be presented in the paper.

The LITFASS monitoring program will be continued over the next three years thus covering BRIDGE, the main BALTEX experiment. The Lindenberg and LITFASS facilities are offered to the BALTEX community for a cloud/precipitation - land surface experiment to be conducted in summer, 2000.

NUMERICAL MODELLING OF THE WAVE CLIMATE IN THE SOUTHERN BALTIC SEA

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INTRODUCTION

In order to improve the understanding of the susceptibility of the Baltic Sea to external forcing, greater knowledge of the interaction between coastal and offshore areas in the overall material balance, is required. This, in turn, calls for knowledge about the wave climate because the waves often act as the main agent for material transport. The present study constitutes a first step in this respect and the results are employed in the *BA*ltic Sea *SY*stem *S*tudy (*BASYS*), which is a major research project sponsored by the European Union aiming to investigate the sediment and material dynamics in the southern Baltic Sea. In general, wave information from the southern Baltic Sea is scarce and no long-term observations exist from which a wave climate may be determined. Thus, there is a need to employ numerical modeling technology to obtain the long-term wave climate, and this forms the main objective of the present study.

The numerical spectral wave generation and propagation model *WAVAD* (see e.g., Resio 1981, Resio and Perrie 1989) was used in this study together with measured time series of wind to derive the wave climate over 19 years at different sites in the southern Baltic Sea. *WAVAD* uses a computational grid discretized in quadratic elements to calculate wave generation, propagation, and decay in both deep and shallow water. From input of wind speed and direction at user-specified time intervals together with a bathymetry grid, the model calculates the evolution of the directional-frequency spectrum, from which wave heights, periods, and directions can be derived. *WAVAD* has been validated against a large amount of field data (Hubertz et al. 1991) and is a third-generation wave model, which implies that there are no *a priori* assumptions about the spectral shape. Instead, the spectrum is allowed to develop freely using a discrete spectral formulation. The computational grid, of resolution ~ 15 km^2, together with location of wind and wave measurement gages, are shown in Fig. 1.

PROCEDURE AND RESULTS

Prior to the long-term wave simulations, the model was validated against wave measurements from one site off the south Swedish coast (Kåseberga) and two sites off the Polish coast (Lubiatowo and Kolobrzeg). The validation showed that the model is capable of accurately predicting the significant wave height and peak spectral wave period and direction from the input of wind data and bottom topography. A comparison between measured and calculated significant wave heights (H_{mo}) from the Swedish south coast is shown in Fig. 2.

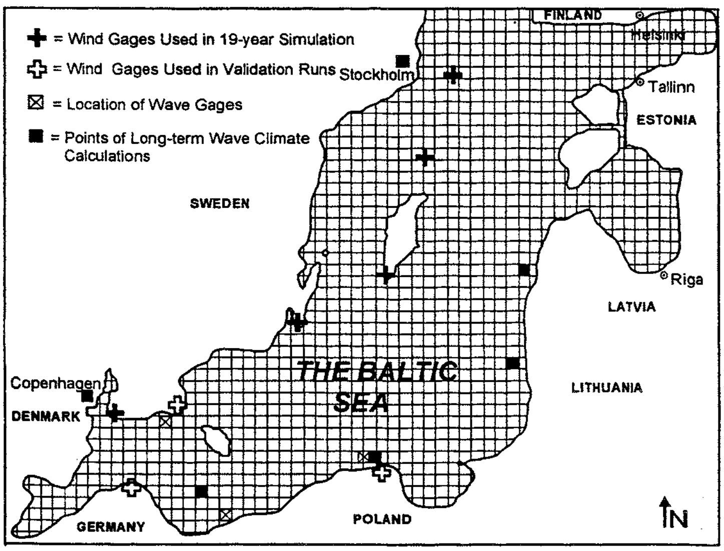

Fig. 1. Computational grid together with location of wind/wave gages and specific calculation points.

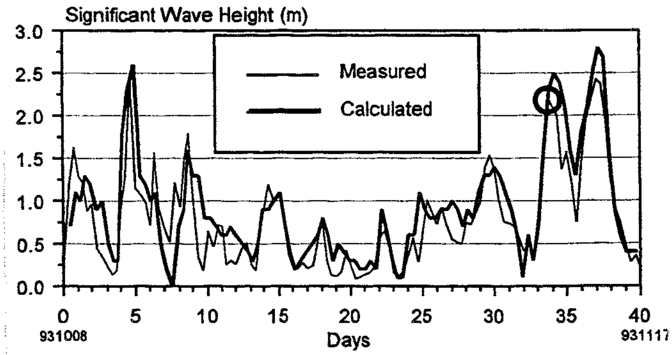

Fig. 2. Measured and calculated wave heights at Kåseberga, south Sweden.

The frequency spectrum could also be calculated with acceptable accuracy (Fig. 3), whereas predicted directional-frequency spectra typically displayed less directional spread than what was measured, most likely depending on simplified spatial variation of the input wind field. After model validation long-term simulations were performed with *WAVAD* using 19-year long time series of wind data as input (measurements every 3 hr). In Fig. 4 is the calculated wave climate presented at four sites, that is, in the outer part of Pomeranian Bay and outside the Polish, Lithuanian, and Latvian coasts.

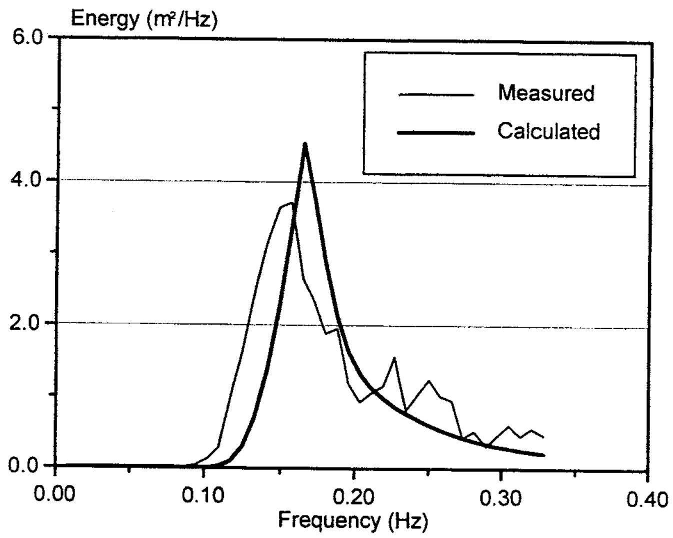

Fig. 3. Calculated and measured frequency spectra at Kåseberga, south Sweden.

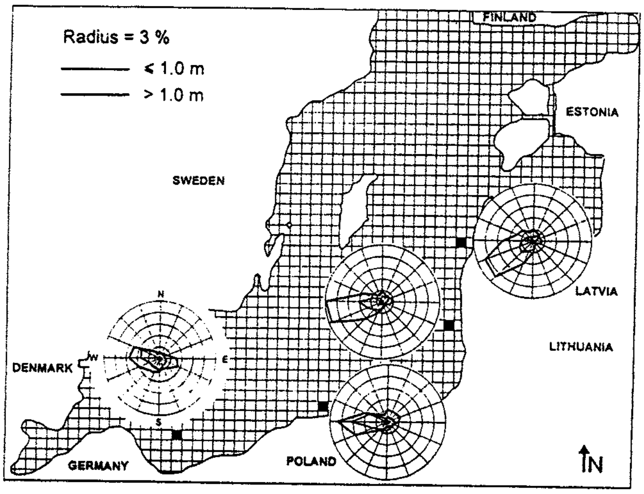

Fig.4. Directional distribution of significant wave height over 19 years at the four study sites.

The water depth was around 20 m at all locations were the long-term wave climate was obtained. The simulations produced 19-year long time series of H_{mo}, T_p, and θ_m every 3 hrs, from which empirical distributions were derived. Fig. 4 shows the directional distribution for $H_{mo} \leq 1.0$ m and $H_{mo} > 1.0$ m at each of the four studied sites. The SW and W components are dominant at all locations, especially at the locations outside the Polish, Lithuanian, and Latvian coasts. Thus, even though the fetch lengths are greater in the northern direction for these locations, the properties of the wind climate, i.e., dominant W and SW winds, determine the local wave climate characteristics. As seen in Fig. 4 there is a difference in the prevailing wave direction for respective location, not only because of the wind climate, but also depending on the geometry of the southern Baltic Sea.

ACKNOWLEDGEMENTS

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REMOTE SENSING OF TURBULENTWATER VAPOR TRANSPORT USING DIFFERENTIAL ABSORPTION LIDAR AND RADIO–ACOUSTIC SOUNDING

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In order to demonstrate the suitability of ground based remote sensing for detailed boundary layer studies including the investigation of turbulent tranport processes an extended field test was performed. The experiment was tied to ASEPS, which was conducted as a pilot experiment in the frame of BALTEX in September 1996 on the island of Gotland. The MPI installed a Wind Temperature Radar (WTR), which is a small version of an FM–CW–Rass for wind and temperature profiling, and the DIAL for water vapor measurements. In addition a Micro Rain Radar and a ceilometer have been operated at the field site, which was ideally located close to the shoreline on a rather flat peninsula. On the nearby small island of Östergarnsholm the groups of A.S. Smedman from Uppsala and J. Höjstrup from Risö performed in situ flux measurements during part of the experiment time.

After initial problems with some of the subsystems all instruments performed well, about 140 hours of high resolution data for combined vertical wind and water vapor profiles has been collected on 18 days. It was possible to run the combined systems almost continuously over more than a day, precipitation and fog were the main restrictions for the lidar operation except for rather short service periods. The WTR was alternating between two modes, in one of which high resolution vertical wind profiles were acquired for about 90 min, and in the other the wind vector field with lower resolution was measured for about 30 min.
The quantities which can either be measured directly or derived from the combined high resolution data include:
average profiles of wind (vector), temperature, and humidity
variance profiles of vertical wind and humidity (with 10 s temporal and 60 m vertical resolution throughout the boundary layer)
covariance (flux) profiles of water vapor–vertical wind
boundary layer height

The data analysis is still in progress, since new tools have to be developed for interpreting the wealth of data. As just one example Fig. 1 shows latent heat flux profiles retrieved from the high resolution wind– and humidity data using the eddy correlation technique. The systematic differences in the flux profiles from 4 selected profiles on a single day demonstrate very clearly that this technique, which was developed at the MPI [Senff, 1994; Bösenberg, 1997], is a powerful tool for the investigation of small and mesoscale processes in the lower troposphere. It should be particularly emphasized here, that the combination of data from the 2 active remote sensing instruments is the most important advantage of this new measurement approach, and that high performance is required from both instruments to achieve the necessary accuracy and resolution.

The wealth of data in particular on the vertical distribution of many crucial parameters which has been obtained in this first field experiment with the new remote sensing instruments have led to strong efforts to use these data for comparison with output from mesoscale models. A period from this experiment has been selected for comparison of different high resolution models in a joint European project, for a future similar experiment close cooperation between modelers and experimentators has been established (PEP in BALTEX, NEWBALTIC). It is expected that these comparisons will lead to significant improvements of the understanding of the atmospheric water cycle at least for the experiment area.

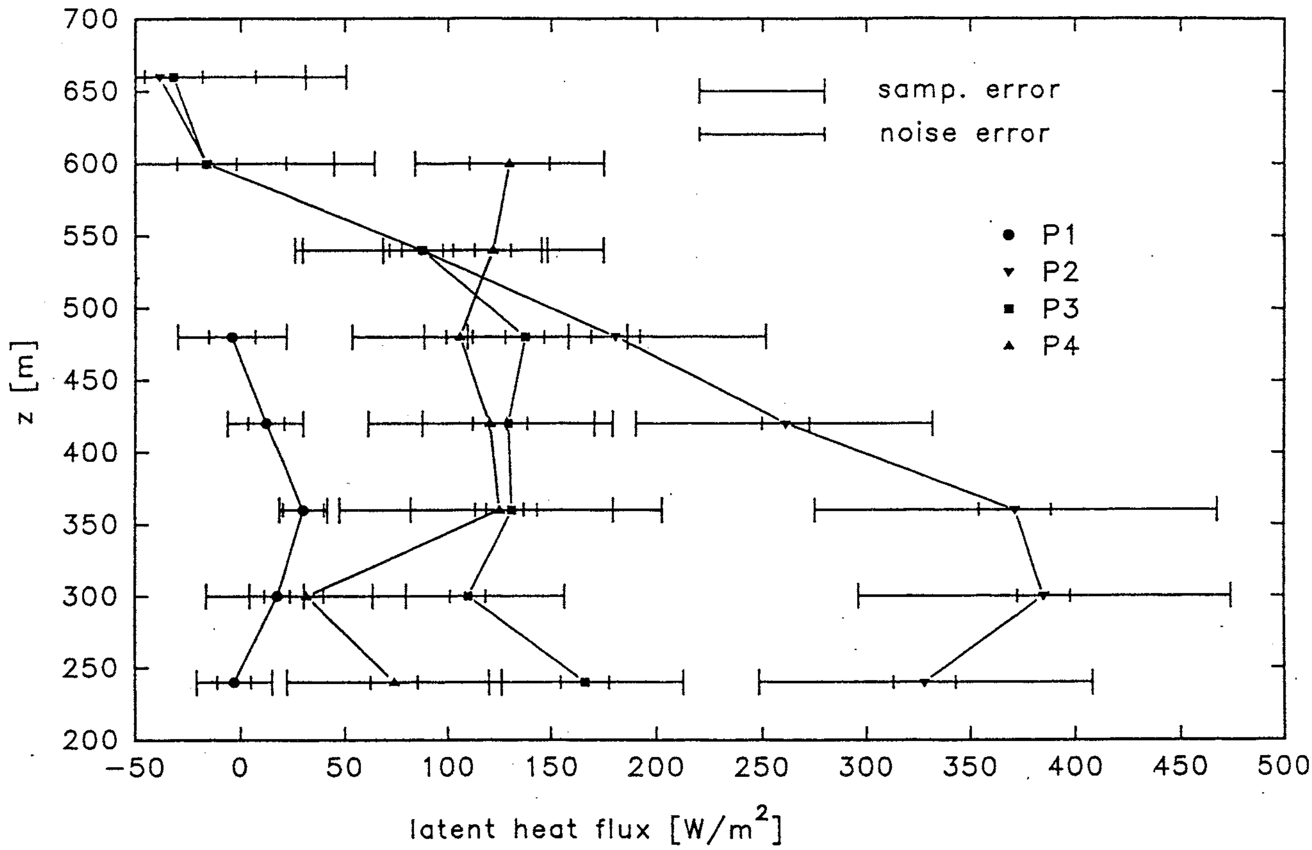

Figure 1: Four selected profiles of the vertical water vapor flux on September 13, 1996, each averaged over approx. 1 hour. Selection has been made to represent different conditions occuring during a single day.

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VALIDATION OF REMO USING SYNOPTICAL OBSERVATIONS

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1. Introduction

BALTEX is one of the five Continental Scale Experiments of the Global Energy and Water Cycle Experiment (GEWEX). Its major tasks are the determination of the water and energy cycles over the Baltic Sea and its catchment areas, to develop a coupled ocean/land/atmosphere model and to develop transportable methodologies in order to contribute to basic needs of climate- and environmental research. Within BALTEX the regional model REMO is used to determine the energy and water budgets over the Baltic Sea and its catchment areas with high spatial and temporal resolution. REMO is based on the „Europa Modell" of the German Weather Service.
Validation of models is an essential component of any scientific forecasting system. Validation is necessary to assess the state of the art of the model, to improve parameterisations and to provide users with information needed to make use of the forecasts.
Within BALTEX three main research periods have been defined to set up models and to calculate energy and water budgets : Winter 1986/87, 1992/1993 and the PIDCAP (BALTEX Pilot Study for Intensive Data Collection and Analysis of Precipitation) period. In this study model output for June 1993 and for the PIDCAP period are taken to compare the model results with observational data.

2. Data

For the above mentioned periods the national services of 10 countries whose territory lies in the Baltic Sea catchment area have provided all available observations of precipitation gauges and synoptical stations. The data is stored at the BALTEX Meteorological Data Center (BMDC) which was established at the German Weather Service in Offenbach, Germany. Data from the Baltic States, Russia, Belarus and Poland were first collected at the BALTEX Secretariat at GKSS Research Center in Geesthacht, Germany. For the PIDCAP period data from over 7000 precipitation stations and over 400 synoptical stations are available and were used in this study.

Model simulations for June 1993 and PIDCAP were carried out using REMO with a horizontal resolution of 1/6° (approx. 18 km). Initial and boundary conditions for REMO were provided by hourly data from REMO (1/2° horizontal resolution) which in turn was driven by analyses on a 1/2° grid obtained from the German Weather Service (DWD). Consecutive 30 hr forecasts starting each day at 0 UTC were performed. For the PIDCAP period we also used analyses data for the HIRLAM model directly as initial and boundary data. These data were provided by the Danish Meteorological Institute.

3. Results

Regarding the monthly mean values over the entire model area (Tab.1) we find that the model overestimates the 2m air temperature in June 1993 and August 1995 by 0.7°C and 0.4°C, respectively. In September 1995 the difference between the model and the observations vanishes and in October 1995 the model underestimates the observation by 0.3°C. The dewpoint is underestimated by the model in all four months. The difference between air temperature and dewpoint is a measure of humidity. The difference between model and observation of this quantity is positive in all four months, indicating that the model it is too dry in the 2m level compared to the observations. The mean monthly differences are relatively small and they are very general measures of the accuracy of the model. Not only for hydrological purposes regional values and daily or 3-hourly values are much more interesting and show a more complex behaviour of the model. A daily cycle in the differences between the model and the observations and regional differences can be found. During night time the dewpoint is underestimated up to 2.8°C. In contrast during daytime the dewpoint is overestimated by the model up to 1°C. There seems to be a correlation of these differences with precipitation and cloud cover.

The comparison of daily sums of precipitation for all those grid boxes where measurements were available shows a quite good agreement in the day to day variation of the precipitation but the model systematically overestimates the amount of precipitation (Fig.1). There are also sometimes differences in the geographical distribution of the precipitation, even on days when the areal averages over the whole catchment area are quite close to the observed values.

		Observation	REMO	Difference (REMO - Obs.)
August 1995	Temperature (2m) °C	17.5	17.9	+ 0.4
	Dewpoint (2m) °C	11.7	11.1	- 0.6
	Pressure (surface) hPa	1014.4	1013.8	- 0.6
	Precipitation mm d^{-1}	2.0	2.5	+ 0.5
September 1995	Temperature (2m) °C	12.7	12.7	0.0
	Dewpoint (2m) °C	9.1	8.8	- 0.3
	Pressure (surface) hPa	1012.5	1011.2	- 1.3
	Precipitation mm d^{-1}	2.7	3.5	+ 0.8
October 1995	Temperature (2m) °C	10.2	9.9	- 0.3
	Dewpoint (2m) °C	7.3	6.7	- 0.6
	Pressure (surface) hPa	1019.1	1019.1	0.0
	Precipitation mm d^{-1}	1.1	1.6	+ 0.5

Table 1: Monthly mean values of 2m air temperature, 2m dewpoint surface pressure and precipitation, averaged over all REMO grid boxes where the specific measurements are available.

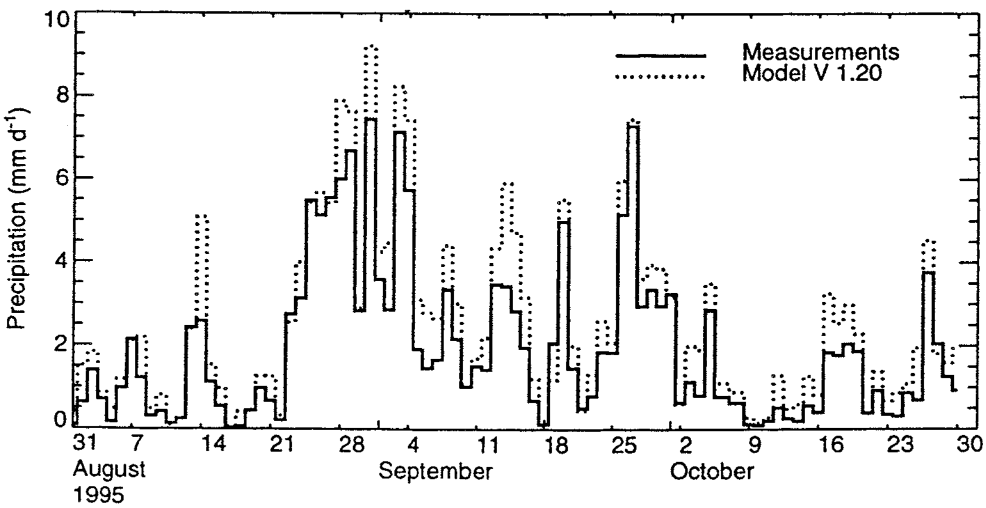

Fig. 1: Daily sums of precipitation, averaged over all REMO grid boxes where measurements are available.

Assessment of flood risk in the lower Odra river region

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Stages and flows within the lower Odra river network are determined from one side by sea level and winds, from the other by waters' inflow from upstream.

Odra river mouth reach is under strong sea influence. Low and mean flows of Odra have no greater importance for the distribution of stages in it. For low flows in Odra and strong winds from north-western sector a storm swell can be noticed upstream even up to Gozdowice cross-section. A swell amplitude, after passing along Szczecin Bay is decreased, then – mowing subsequently upstream – increases again. During storm swells maximum stage increments at Widuchowa cross-section are often as high as at the sea. Flood waves mowing downstream the lower Odra are flattened by Miêdzyodrze polders and do not make an essential flood eminence. High flows in Odra produce smaller stage increments downstream to Gryfino than average storm swells.

Assessment of flood risk in the lower Odra river network was done on the basis of analysis of the '97 flood wave and storm swells of the few last years. The analysis quotes the results of simulation of these events using the model of unsteady flows in the lower Odra river network.

Considering '97 flood wave passage downstream the lower Odra an attempt of estimating impact of the Miêdzyodrze polders on it was made.

Assessment of flood risk in the lower Odra river network was performed on the basis of water level hydrographs provided by Maritime Institute network of gauge stations. In this network water stages are measured in continuous way at 23 cross-sections. The Maritime Institute network of gauge stations is shortly presented.

EVAPORATION OVER THE BALTIC SEA

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Evaporation is a major term in the energy and water cycle of the Baltic Sea. In the present study the evaporation was estimated from interpolated fields using a bulk parameterization according to $E = -\rho\, C_E\, U_{10}\, \Delta q$,
where ρ is the air density, C_E the bulk transfer coefficient for water vapor, U_{10} the wind speed at a height of 10m, and Δq the difference of specific humidity air-sea.

Wind speeds at a height of 10m were estimated from geostrophic winds by using ageostrophic coefficients, defined as the ratios of 10m to geostrophic wind speed. They were derived by a comparison of analysed geostrophic wind fields with wind observations performed on voluntary observing ships in 1992-1993. The ageostrophic coefficients depend on the distances to the coast with onshore and offshore winds. That accounts for the effect of changing roughness in the coastal zone on the wind speeds at 10m height and results in a decrease of evaporation in coastal waters. An example of the estimated ageostrophic coefficients is given in Figure 1. The calculated wind speeds at 10m height agree well with ship wind observations, which were not used to evaluate the ageostrophic coefficients (Figure 2).

To investigate the influence of the boundary layer parameterization on evaporation several parameterization schemes were applied on the data (Table 1). The resulting mean annual evaporation rates for 1992-1994 range from 458 to 664mm/y depending only on the chosen parameterization scheme.

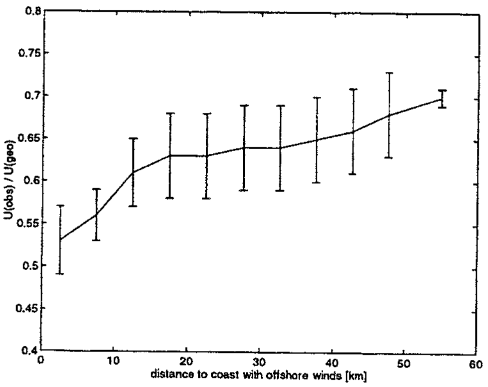

Figure 1: Ratio of the 10m to geostrophic wind speed as a function of the distance to the coast with offshore winds. The bars indicate the variability due to changes in distances to the coast with onshore winds taking the number of available observations into account, too. The distance is set to 55km for all cases having distances to the coast with offshore winds of more than 50km.

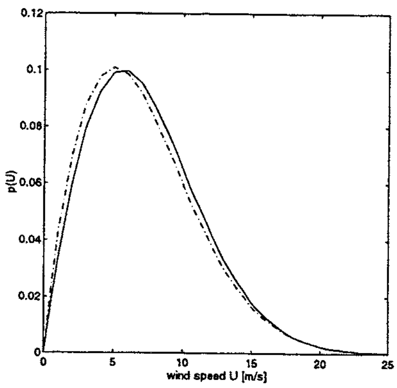

Figure 2: Weibull distribution of observed (full line) and analysed (dashed line) wind speeds at 10m height in 1994.

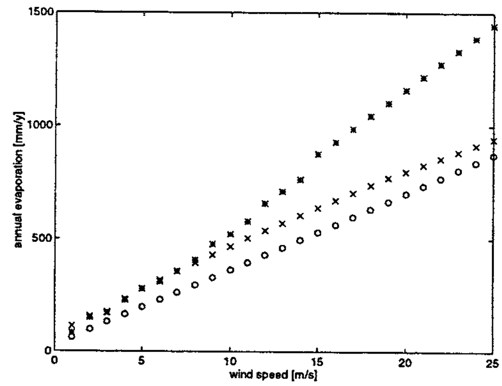

Figure 3: Annual evaporation [mm/y] for parameterization schemes 2(x), 4(o), and 6(*) (see Table 1) as a function of the 10m wind speed [m/s]. $T_{air} = 283K$, $T_{sea} = 285K$, and $\Delta q = -1.084 g/kg$.

Boundary Layer Model	C_D of	C_H and C_E of	evaporation [mm/y]
(1) Liu and Blanc(1984)	Kondo(1975)	roughn. Reynolds no.	617
(2) Liu and Blanc(1984)	Smith et al.(1992)	roughn. Reynolds no.	567
(3) Large+Pond(1981,82)	Large+Pond(1981)	Large+Pond(1982)	501
(4) Smith(1988)	Smith(1980)	DeCosmo et al.(1996)	458
(5) Smith(1988)	Smith et al.(1992)	DeCosmo et al.(1996)	461
(6) no	no	Bunker(1976)	664

Table 1: Mean annual evaporation for 1992 to 1994 estimated from the IfM Kiel analysis using different boundary layer parameterizations as given in the Table.

More in detail Figure 3 shows the differences in evaporation for three of the parameterization schemes (1, 4, and 6, see Table 1). Differences are of the order of 25 % and more even for small air-sea humidity differences. Generally deviations between the schemes are smaller for stable than unstable stratification.

From Figure 3 it is obviously that the boundary layer parameterization used by Bunker et al.(1997) (scheme 6, Table 1) produces for unstable conditions an extreme overestimation of evaporation for wind speeds exceeding about 10m/s at air-sea temperature differences of -2K. Because Figure 2 depicts that wind speeds over the Baltic Sea are often higher, an overestimation in evaporation is to be expected using this parameterization. That agrees well with results of a study of Isemer and Hasse (1987). Using the model of Liu and Blanc (1984) in its original formulation (scheme 1, see Table 1) instead of Bunker's coefficients gave only slightly smaller rates of evaporation. Furthermore it is the only one of all schemes investigated in the present study, where the resulting evaporation depends strongly on the chosen drag coefficient (Table 1), although different drag coefficients lead to minor changes of stability only. Thus, it can be assumed that annual evaporation rates estimated by using boundary layer parameterization schemes of Smith(1988) or Large and Pond (1981/1982) are more reliable.

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POTENTIAL IMPACT OF CLIMATE CHANGE ON THE HYDROLOGICAL REGIME IN LATVIA.

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Abstract

The hydrological elements of a river basin are formed under the direct influence of atmospheric climate. In recent years, there has been an increasing concern of the changes in global climate induced by greenhouse gases, especially CO_2. One of the most significant potential consequences of climate change may be alterations in the regional hydrologic cycles

This paper describes the application of the HBV model for the simulation of hydrological consequences of climate change in the Lielupe River basin in Latvia. The input data for the HBV model are the daily values of temperature, precipitation and the monthly means of potential evapotranspiration.
In the process of work, the observed meteorological input data were modified on the basis of a General Circulation Model (GCM). Results represent doubling of the natural carbon dioxide (CO_2) content in the atmosphere, these conditions can be observed around the year 2050.
For modifying the meteorological data the UK GCM transient experiment and GCM "GENESIS" results were used.
Modified for climate change, the meteorological data were entered into the calibrated HBV model and the daily runoff values were calculated for a period of 10 years.
The Lielupe River is the second largest river discharging into the Gulf of Riga: its drainage basin is 17,600 km2. The basin was divided into 13 subbasins. The Sudrabkalni subbasin with the best calibrations results was used in the first stage of the work.

A comparison of the modified for climate change runoff with the modelled for normal conditions and observed runoff presented a possibility to make some conclusions about the proposed changes in the river regime.
The monthly distribution of the observed and modelled for climate change flows reflects the consequences of generally more humid conditions (Fig.1)

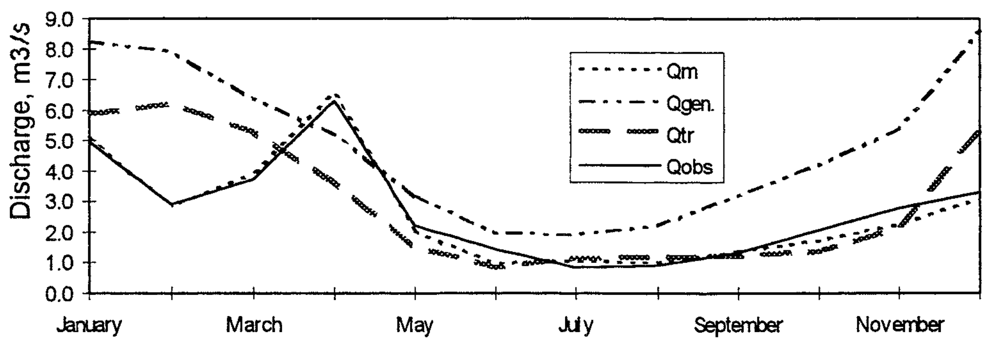

Fig.1 Monthly distribution of observed (Qobs), modelled for normal conditions (Qm) and for climate change (Qtr, Qgen) flow.
Viesite-Sudrabkalni (1984-1993)

The modelled for climate change flow in the winter months becomes higher and coincides with rising temperature. The spring snowmelt shifts to earlier periods . A smaller rise of flow is observed in the summer months (Fig.2).

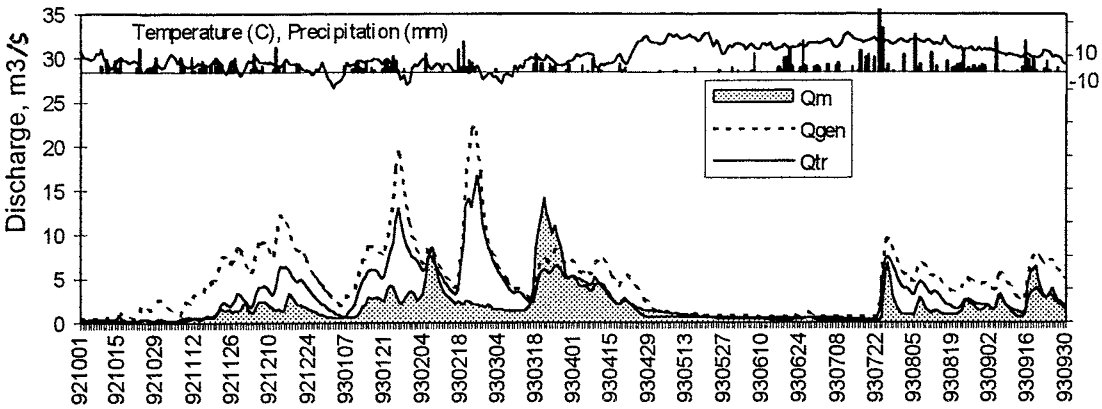

Fig.2 Modelled for normal conditions (Qm) and for climate change (Qtr, Qgen) flow. Viesite-Sudrabkalni (1993)

The distribution of the annual mean flow values shows the same pattern for the whole investigated period as it was noted by the general view. An increase of the annual mean flow as a result of climate change is observed .
Table 1 presents the observed and modelled values of annual mean flow using climate change scenarios.

	Qobs(m3/s)	Qm(m3/s)	Qtr(m3/s)	Qgen(m3/s)
1984	1.9	2.0	2.2	3.8
1985	2.5	2.6	2.8	4.7
1986	3	3.2	3.5	5.5
1987	2.7	2.2	2.5	4.7
1988	2.5	2.6	3.4	5.5
1989	3.3	3.4	3.5	5.1
1990	3.7	3.6	4.0	6.1
1991	2.3	2.1	2.2	4.1
1992	2.5	2.5	3.0	4.5
1993	-	2.5	2.8	4.5

Tablel. Observed and modelled annual flow Viesite-Sudrabkalni

The calculations made for all subbasins in the Lielupe River basin, yielded similar results as a whole. The modelling approaches presented have some uncertainties but they have a potential for further applications and development. For water management purposes, for example, the discharge data should be converted to river water quality data, which should be applied in small river basin management.

SOME ASPECTS OF MASS TRANSFER MODELLING IN VARIOUS COASTAL ZONES

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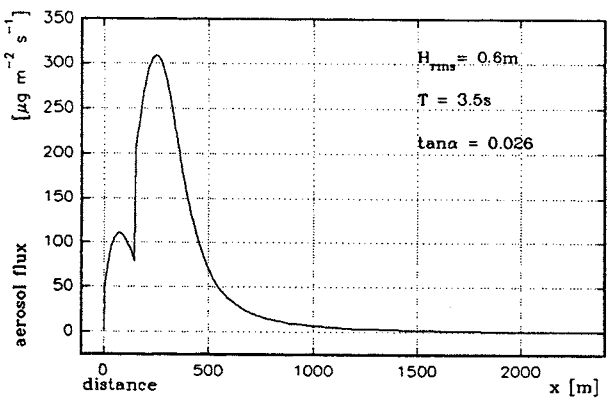
Coastal areas are especially active in terms of sea - air mass exchange. Such areas play an important role in investigations of production and dynamics of marine aerosols (Derks and Stive, 1984; Massel, 1987; Petelski and Chomka, 1996). The effect of the dissipation of wind-wave energy on mass emission and the model of aerosol emission within the coastal zone are discussed in the paper. The model is based on a wave-energy equation (Thornton and Guza, 1982; Thornton and Guza, 1983), where bathymetry is taken into consideration (Chomka and Petelski, 1997). The effect of the sea bottom profile on aerosol emission is discussed in relation to numerous implementations of the model. The logarithmic relationship between the total aerosol emission flux from the coastal zone and the tangent of the bottom slope is demonstrated, and the total aerosol emission from a coastal zone with a smooth sea - bed is compared with that from a coastal zone with a rough bed.

A lot of calculations were carried out to obtain the values of aerosol flux for variety of the sea bed. In each case different characteristics of the sea bed, such as slope, roughness as well as the sea depth, were assumed. Here are exemplary findings for two different kinds of the sea bed:

a.



b.

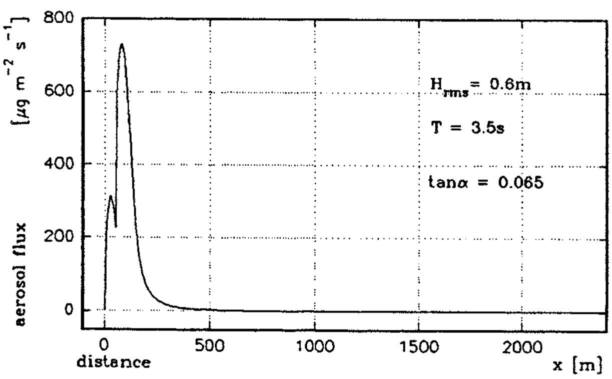


Fig. 1. Aerosol emission flux for a constant sea bottom slop ($\tan \alpha = 0.026$) (a), ($\tan \alpha = 0.065$) (b)

Fig. 1a refers to the gentle slope of the sea bottom, i.e. $\tan \alpha = 0.026$, whereas Fig. 1b to the slope where $\tan \alpha = 0.065$. The graphs indicate that the emission flux is greater for the steep bottom. In Fig. 1b the maximum value is twice as great as in Fig. 1a. The average emission flux for the tangent of the angle of the sea bottom's slope of 0.026 is 40.8 $\mu g m^{-2} s^{-1}$, whereas for the tangent of the angle of the slope 0.065 is 30.4 $\mu g m^{-2} s^{-1}$. Hence the steeper the sea bottom's sloppier the greater are the values of the emission flux in its maximum, however the emission from the entire coastal zone is lower at the same time.

Also real sea bed profiles were used to determine the bed's influence on the aerosol emission in coastal zones. The date came from the international experiments BAEX (Lubiatowo station, Poland) and TABEX (Prerija station, Lithuania). The real-sea-bottom-related experiments proved the theoretical analysis, and led to the interesting following conclusions:

- the slope of the sea bottom within the coastal zone has decisive effect on aerosol emission; the steeper the slope of the sea bottom the smaller values of the emission from the coastal zone
- the total emission from the coastal zone is higher from over the bottom of the smooth profile than from the rough bottom. The bigger the amplitude of the sea bottom the smaller is the total emission and the average value of the emission from the coastal zone;
- local values of the aerosol emission flux behave reversely to the total emission; the maximum values of the emission flux occur where there is maximum shoal. The steeper local slope of the sea bottom the bigger are the values of the maximum emission flux;
- the emission flux does not depend on boundary condition at the deep water and is entirely determined by the depth in the shallower - active part of the zone;
- for each wave size outside the coastal zone there is such an area, within the zone, from which the emission will not increase despite the general increase in the undulating. This means that the width of the wave breaking zone is a parameter which accurately describes the quantity of aerosol emission from the coastal zone.

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INFLUENCE OF SEASONAL RIVERINE INFLOWS ON THE BALTIC WATER VOLUME 1901-1990

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Mean monthly riverine inflows into the Baltic in the period 1901 - 1990 have been compiled from source data taken from hydrometric readings. The few figures missing from the early decades of this century could be calculated using correlation analysis since the outflow of the rivers in question were very strongly correlated. The fundamental statistical characteristics were calculated for the measurement series obtained and were subsequently subjected to stochastic analysis. The riverine inflow was shown to affect the volume of water in the Baltic and the mean Baltic Sea level. According to the calculations, the mean monthly riverine inflow was 37.1 km^3; the variability of the inflow was characterised by a standard deviation of 13.4 km^3, which corresponds to a change in the mean Baltic Sea level of 9.5 cm and a deviation of 3.4 cm. However, the spectral characteristics demonstrate that the Sa and Ssa periods, dominant in the periodic structure, display considerable phase shifts with respect to variations in the Baltic water volume. For this reason, the linear correlation coefficient of the two data series is not significant. Calculations of the autospectrum have shown that the series in question displays a very strongly marked annual period, followed by much weaker and gradually subsiding periods due to the harmonic components of the fundamental annual period. Comparison of the mean monthly data on the variability of the Baltic water volume with the riverine inflow shows very clearly that the mean volume flowing into the Baltic is almost equal to the variability of the volume of water in the basin. However, the substantial phase shift means that there is no direct, linear, temporal dependence between the two data series. Computations were also performed on the basis of parametric stochastic processes in order to determine whether it would be possible to forecast the mean monthly inflow of freshwater into the basin and to define the autoregressive features of the phenomenon. The practicability of ARMA(1,1), ARMA(2,1) and AR(n), n = 1,....., 20 processes was tested. All the parameters were calculated using the maximum likelihood method. Application of the Akaike test and diagnostic computations have shown that the AR(15) process is an optimum approximation of this series. It should be noted that the autoregressive coefficients of the process cover a period of one year and the shorter oscillations indicated in the periodic structure. A forecast with a lead time of one time step reduces the persistence forecast by 24%, and displays other characteristics of the parametric stochastic process applied here.

Determination of land surface parameters from SSM/I passive microwave brightness temperatures with a surface emission model

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The knowledge about the distribution of soil moisture and vegetation parameters is extremely important to drive and validate numerical models on all spatial scales. Because of the lack of in situ measurements we need satellite data to obtain a full area coverage. Microwaves form the only portion of electromagnetic waves that allow truly quantitative estimates of soil moisture using physically based models. Unfortunately the only satelliteborne sensor in space (SSM/I: Special Sensor Microwave /Imager) operates at frequencies exceeding 19 GHz, which are not very well suited for soil moisture estimation, since vegetation tends to attenuate the radiation emitted from the soil at frequencies higher than 5 GHz. However, SSM/I brightness temperatures form a unique 10 year global data set. Timeseries for 1989 for 19 GHz polarisation difference $\left[PR = \frac{(TB_{19v} - TB_{19h})}{(TB_{19v} + TB_{19h})}\right]$ show strong annual cycles with different amplitudes. Radiative transfer simulations with a surface emission model suggest that they are related to changes in vegetation cover and water content. Variability on shorter timescales is investigated for May and June 1993. For this period REMO forecasts and in situ measurements are used to determine the soil moisture index API (antecedent precipitation index). Timeseries for 10 climatological stations of the German Weather Service show trends comparable to those in 1989. Correlation between PR and the API vary between .59 and .7 for five stations, at four stations the timeseries show the expected shape with a decrease in PR when the soil dries up.

THE ODRA FLOODING EVENT 1997: CHARACTERISTIC OF THE PROCESS OF RISING AND DEVELOPMENT AND ANTI-FLOOD MANAGEMENT

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1. Introduction

Floods on The Odra river are a natural event and occurred in far and near past. Reliable information comes from the beginning of 19th century, when systematic meteorological observations, as well as water level in rivers started. According to available information large floods on The Odra river and its side streams occurred quite frequently, among others in 1816, 1838, 1854, 1870, 1903, as well as in 1958, 1977, 1981 and several on smaller scale. This year flood on The Odra river and some of its side streams was larger than any one before.
Flood in July 1997, particularly in the upstream part of The Odra and Nysa Kłodzka characterised with exceptionally rapid rise of water level. On The Odra, its upstream side streams as well as Nysa Kłodzka with side streams, culminating water levels and flows exceeded all previously noted absolute maximums. The situation in the middle part of The Odra was worsened by risen water levels in its side streams.

2. Analysis of hydrological and meteorological conditions

A factor influencing somehow the scale of the flood was the limitation of soil retention capacity in the period of time before the flood. Several days before the flood there were intense rains of 10,0 to 40,0 mm and locally over 50,0 mm. In the middle part of The Odra basin the rains were smaller.
The direct reason for the occurrence of rains in the scale not encountered before were the rains related to a low pressure system, which occurred on July 4th with the centre east of Poznań. In next days this low pressure system gradually but systematically expanded.
Warm and very humid tropical air has flown over the Central and Eastern Europe, while cool polar sea air has flown from the north west over Western Europe and Poland. Advection of coolness covered several kilometres thick layer of atmosphere.
On July 7th frontal occlusion slowly passing from Poland over the Czech Republic arrived over the Sudety Mountains, causing an increase in atmosphere instability and increase of cloud thickness to 12 km. In connection with the orographic factors this front caused the occurrence of very strong rains with varying and very high intensity.

3. Atmospheric precipitations between July 5 and 9 1997

The rainfalls, which were the direct cause of the flood started on July 5th, 1997 at 16.00 to 19.00 on the area of upper Odra and between 20.00 and 22.00 in the basin of Nysa Kłodzka, lasting constantly 60 to 70 hours, i.e. about 3 days and nights, about 24 hours longer in the basin of the upper Odra and Olza - till July 9th. They covered fully the basin of upper and middle Odra, upper Warta and upper Vistula. The centre of rainfall field was located in the area of the upper Odra and eastern part of Nysa Kłodzka basin, covering an extended area south-east of Beskid Wysoki, through Wysoki Jesenik and Niski Jesenik, Śnieżnik Kłodzki massif to Sowie Mountains. The area covered by very intensive rainfalls was about 12 thousand sq.km. In the remaining part of the Odra basin the level of rainfalls was 2-3 times lower. The average intensity of the strongest rainfalls was 7 to 10 mm per hour and maximum up to 30 mm/h. During the period of 5 days (05-09.07.97) the highest sums of rainfalls were:

a) In the basin of upper Odra on Lysa Hora (CR) - 586 mm (06.07-234 mm); Sance 617 mm (06.07 - 230mm).
b) In the basin of Nysa Kłodzka in Międzygórze station (Poland) 455 mm (06.07- 200 mm) and Kamienica 484 mm (6.07 - 180 mm).

For all measuring stations in the river basin of upper and middle Odra, the measured heights of rainfalls were 150 - 250 % of the standard for average sums of rainfalls for July of the 1961-1990 period. Over 250 % of the standard, locally up to 300 %, was observed in the eastern part of Nysa Kłodzka basin in Międzygórze (347,2 %), Kamienica (241,1 %) and Stronie Śląskie (296,7 %). Particularly high indexes 403,9 % and 368,3 % were observed in the basin of Biała Głuchołaska in the Czech Republic in the measuring stations Zlote Hory and

Jesenik. In northern and western directions the height of rainfalls dropped and the indexes of rainfalls, apart of stations in the area of upper Bóbr basin (150-250 %), were within the range of 50-100 %.

4. Formation and developing of the flood wave

Water freshet in mountain side streams, both in Czech Republic and in Poland, started several hours after the beginning of the rainfall, while in the limit profiles of the Odra the freshet occurred after 10 hours.
In Nysa Kłodzka basin, due to very steep terrain drops and exceptionally high intensity of rainfalls (10-25 mm/60 min) this time was significantly shorter.
Concentric system of upper Odra side streams results in cumulating of the risen waters of side streams in the centre of the valley near Ostrava. In July 1997 all side streams rose simultaneously, however in the formation of the culminating flood wave in the upper Odra, due to the water management in retention reservoirs and spatial distribution of rainfalls, the main role was played by the waves of upper Odra and Opava. The waves of these rivers overlapped in the culminating phase, giving a high wave in Bohumin, corresponding to the state of 660 cm. The next stage of development of Odra wave occurred in the area of inflow of Odra right side stream river Olza. High flows of its ascending part caused further development of the Odra wave, which achieved a flow rate of 2700 cu.m / s. The flood wave formed in the upper part of the Odra reached the level of 1045 cm on the indicator in Miedonia. A characteristic feature of the Odra flood wave in its upper part (Bohumin, Chałupki, Miedonia) was a rapid water freshet, which reached 400 cm within less than 12 hours. Water level indicators from Chałupki to Nysa Kłodzka outlet were flooded (Fig. 1).
The wave moving along the river bed develops further at the inflow of Nysa Kłodzka to Odra. Risen waters of this side stream (including the release from the Nysa reservoir 1500 cu.m/s), overlapped on the ascending part of Odra wave. The process of overlapping of flows, culminating one of Nysa Kłodzka and high flow of the Odra, caused also the acceleration of the Odra wave in Brzeg (Górny) - Most, Oława and Wrocław by about 20 hours. Side streams: Oława, Ślęza, Bystrzyca and Widawa, as well as Kaczawa, Barycz, Bóbr and Nysa Łużycka in the outlet sections culminated several days earlier, preceding the main flood wave passing along the Odra. They were very significant, because they largely filled the retention of the river. The enormous flood wave moving along the Odra river bed was subjected to the flattening process to a much less degree than it should have been.
Occurrence of rainfalls in the period of 17/18 - 21/22.07 caused the next rising of waters both in the upper Odra and its side streams. The main centre of rainfalls this time was located in the area of Central and Western Sudety Mountains. These precipitations caused the second wave on the Odra river and its side streams, which joined with the first one, creating a wave with the length of 150 - 200 km. The flood wave at the whole length of the Odra exceeded all previous absolute maximums observed in 1813, 1854, 1903, 1938, 1977 and 1985.

5. Evaluation of freshet height

The size of the flood is best illustrated by the observed maximum states and their comparison with previous absolute maximums.
Comparing the observed or obtained by means of levelling method water levels to previously highest ones it should be concluded that they were exceeded at the whole length of the Odra from its spring to Gozdowice (Fig. 1). Absolute maximums were also exceeded on Nysa Kłodzka and its left side streams.
The maximum flow in Bohumin and Chałupki, border cross sections, was determined as 2160 cu.m./s. The maximum flow increases at the point of Olza outlet and in Miedonia was already 3102 cu.m./s. The flows in Koźle, Krapkowice and Opole were evaluated to be 3290 - 3500 cu.m/s. In the profile of Nysa outlet the wave top was formed with very high outflows from Nysa Kłodzka, which in its outlet to the Odra exceeded 1200 cu.m/s, as well as flows of the ascending part of the Odra wave. During culminating the flow was determined to be 3540 cu.m/s, which in Wrocław - Trestno rose to 3650 cu.m/s. The wave passed through the northern part and the centre of Wrocław, flooding it in 35 - 40 %.
Downstream from Wrocław, due to numerous leaks through embankments, slow but systematic flattening of the wave is observed. The culminating flows from 3200 cu.m/s decrease and reach the level of 3050 cu.m/s in Cigacice. A slight increase occurs in Połęcko and Słubice after joining with risen waters from Bóbr and Nysa Łużycka.

The yearly maximum flows from the years 1946 - 1997 were subjected to probabilistic analysis. Uniformity of sequences was determined. The flows, which occurred during the flood in July 1997 at particular water level indication cross sections in the longitudinal profile of the Odra and Nysa Łużycka significantly differ from the data previously observed (1974 - 1997). They exceed the values of p=1% and p=0,1% (Fig. 2). From the theoretical curve of exceeding probability it may be seen that the probability is of the order of p=0,01%, i.e. 10.000 years flow. The lowest probability of occurrence p=0,01% was for flows in Brzeg Most, Oława and Trestno (3530-3650 cu.m/s). Along the Odra river its value increases, reaching the value from p=0,03% to 0,06% at the section from Brzeg Dolny to Słubice, i.e. from 3300 years water to 1660 year water. On Nysa Kłodzka and its side streams the maximum flows reached the probability of occurrence in the range from p=0,01% to p=0,06% (Fig. 2).

6. Warnings and operational forecasts

Warning - forecast of high rainfalls together with hydrological report were passed to the users 33 hours before the occurrence of the events. The Odra, because of the size of the wave and flood danger, as well as due to its international character, was the main point of focus for hydrological operational services of IMGW. For the water level indicators of upper and middle Odra located on the section from Chałupki to Słubice (584,1 km) the total of 594 forecasts was made. Due to the interest of Germans, for water indicators Nietków and Połęcko 62 and 65 forecasts respectively were made, while for the border profile Słubice 65. The average correctness of the forecasts was within the range of 92,5 - 97,1%, maximum 99,0 - 100% and minimum 80,0-86,0%.
Polish operational services fulfilled its obligations towards foreign partners, i.e. Germany and Czech Republic. There are mutual co-operation systems, however due to the size of the flood, the agreed system of 3 times daily information was aborted and changed to information every 3 hours, and in case of special request every hour (Połęcko level indicator for Germany).

7. Conclusions

The flood of July 1997 was a test of the embankment system, as well as hydrotechnical systems of anti-flooding protection of Odra cities and IMGW hydrometeorological services. It is necessary to verify and modify the whole system of the anti-flooding protection for the Odra basin, including the construction of retention reservoires, because a flood of the similar size may repeat in near future.

River	Water gauge	Maximum		Difference	
		so far H [cm]	1997 H [cm]	Δ H [cm]	Δ H [%]
ODRA	Odry	317	387	70	22.1
	Svinov	433	820	387	89.4
	Bohumin	556	660	104	18.7
	Chałupki	675	705	30	4.4
	Krzyżanowice	844	912	68	8.1
	Miedonia	838	1045	207	24.7
	Koźle	818	947	129	15.8
	Krapkowice	811	1032	221	27.3
	Opole	604	777	173	28.6
	Ujście Nysy	709	768	59	8.3
	Brzeg Most	658	730	72	10.9
	Oława	722	766	44	6.1
	Trestno	666	724	58	8.7
	Rędzin	746	1030	284	38.1
	Brzeg Dolny	946	970	24	2.5
	Malczyce	772	792	20	2.6
	Ścinawa	657	732	75	11.4
	Głogów	673	712	39	5.8
	Nowa Sól	659	681	22	3.3
	Cigacice	649	682	33	5.1
	Nietków	700	667		
	Połęcko	556	596	40	7.2
	Słubice	634	637	3	0.5
	Gozdowice	649	659	10	1.5
	Widuchowa	783	760		

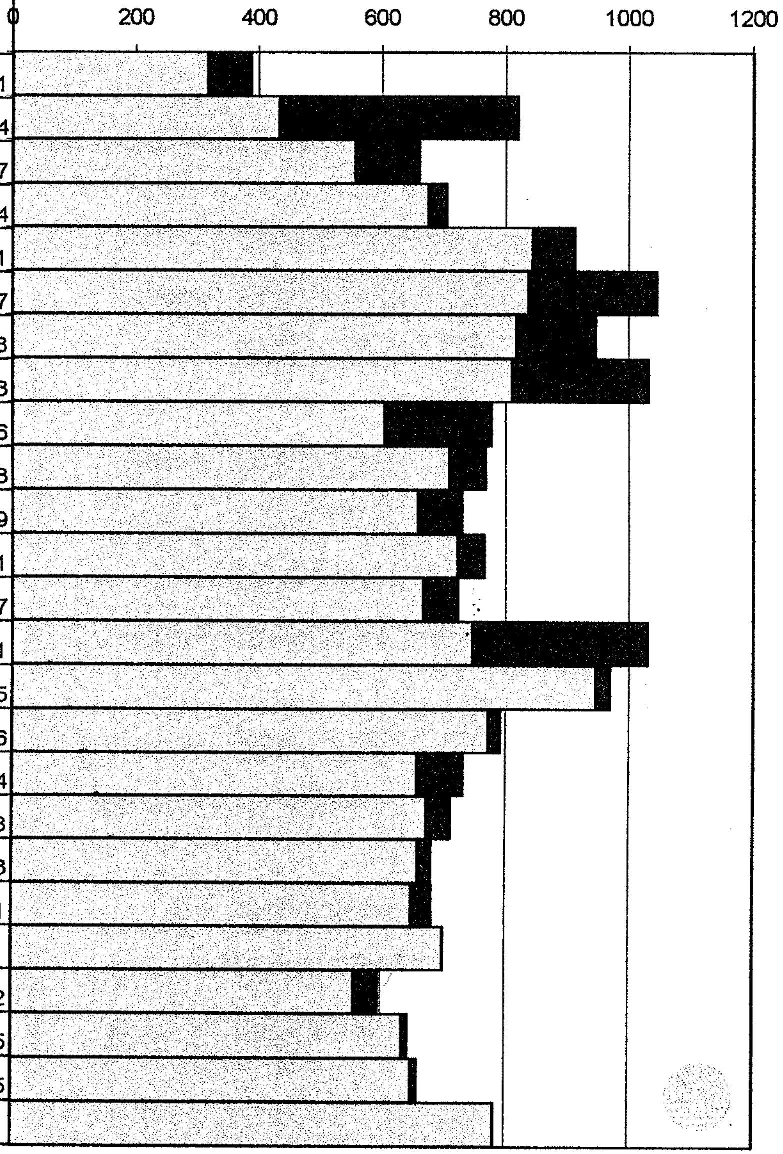

Fig. 1. Absolute maximum water levels along the Odra river

so far 1997

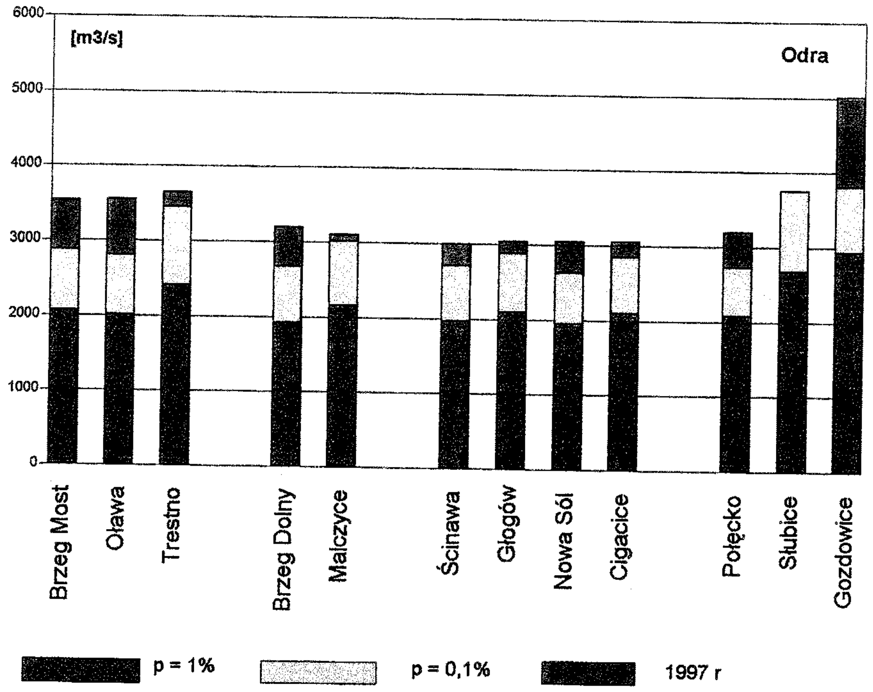

Fig. 2. Yearly maximum outflows with probability of exceedance p=1% and 0,1%, due up to now probability curve and recent ouflow in July 1997

EFFECTS OF TILL DRAINAGE ON THE HYDROLOGICAL REGIME OF A WATERSHED

A. Dumbrauskas[1], L. Iritz[2], R. Larsson[2] and A. Povilaitis[1]

The "Visby Programme" administrated by the Swedish Institute is supporting a co-operation study *to evaluate the effect of till drainage on hydrological regime and on water quality in Lithuania.* This paper presents the effect of till drainage on hydrological regime within field scale (≤ 0.15 km^2) and catchment scale.

The model chosen for this study was the MIKE SHE (Version 5.21) system developed at the Danish Hydraulic Institute (DHI, 1996). The idea was that the SHE model simulated sub-processes in the case study catchment (Lapiene River basin) for drained and undrained conditions then the outputs from these two cases were compared. There was detailed database available for drained conditions (Dumbrauskas, 1988) therefore the model was calibrated and verified for the observations from that time period (however the calibration and verification interval was split). Although, the model physically based, it was necessary to calibrate it for the study catchment. The calibration was a cumbersome work, however, it provided much information on the parameter sensitivity and variability. Finally, the calibrated parameters were accepted for the MIKE SHE validation then for the investigation of the effect of drainage on hydrological regime. The model set-up for the undrained condition was the same as for the till drained one but the drains were omitted. It was not possible to verify the model for the undrained condition because there was no observation at that time (i.e. before 1968), therefore, the same model parameters were accepted in both conditions.

The study area is a part of the Lapiene River basin and is located about 15-km northwest from Kaunas City in Lithuania. It is a relatively flat relief and the whole area is used for agriculture. The slopes range from 0.5 to 3.9 per cent and they are mainly directed towards the river Neris (the second longest river in Lithuania). The parent material of the soils in the catchment is moraine. The dominating soil types are sod-gleyic dernopodzolic clay loam and clay. The case study catchment area is drained to 92 %. The high extent of drainage is an important specialty of the Lithuanian landscape that has significant influence also on the hydrological conditions. This human interaction is also quite common in other countries of the BALTEX region, therefore, it was important to study the hydrological effects of it.

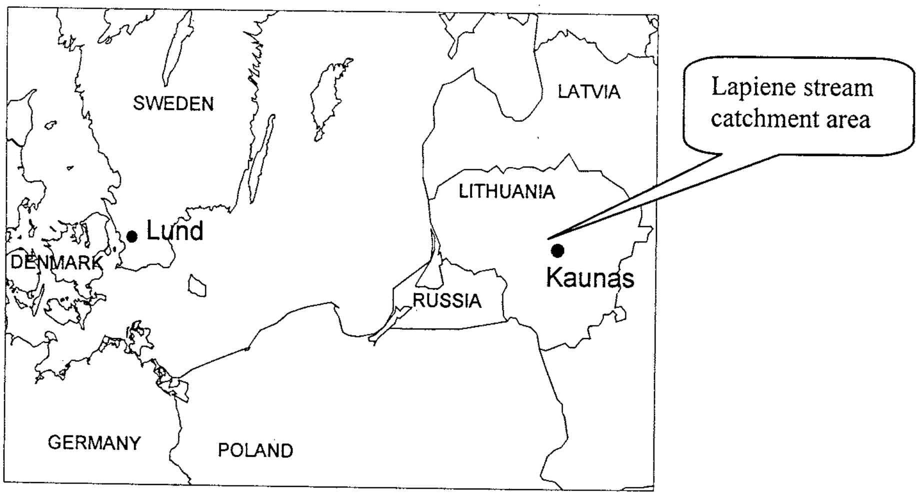

Fig.1 Location of the research area

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Agriculture is a basic branch in the Lithuanian economy that was intensively developed during the recent decades. Large land reclamation works were made for draining the soil water surplus in agriculture areas. It was necessary because the average annual precipitation ranges from 550 to 820 mm and evapotranspiration 450 to 600 mm, respectively. Ceramic and plastic pipes have been installed during last four decades on large areas and as a result in total 2.6 million ha or 80 per cent of the farmland is drained today. However, drainage is also associated with certain disadvantages. The gain at one point (e.g. the creation of new agricultural land) is followed by loss at another one (e.g. reduction of the diversity in the ecosystem). A direct effect of a drainage system is a lower average ground water level. The systematic lowering of ground water level creates better thermal and moisture conditions for crops, but can also have serious side-effects on the agricultural production and on nature conservation, forestry and landscape (e.g. it can cause subsidence).

The numerical tests made by the SHE model consisted of evaluation of the drainage effects on the hydrological regime in the Lapiene River catchment under existing soil, topography, cropping, vegetation and climate conditions. A set of simulations was performed using the same input of meteorological data, vegetation and calibrated parameters for both the drained and undrained modelling options. The simulation aimed at establishing relationships between the effects of drainage and physical characteristics of the system.

The results have shown that the effect of drainage on the evapotranspiration process is more evident at the beginning of vegetation period (April-June) than in the summer time. The rate of evapotranspiration is higher under undrained field conditions. However, no remarkable difference was found in evapotranspiration rates between drained and undrained scenarios for period of July-September.

The drained scenario showed much greater variation of soil water content during spring floods while the undrained one remained fairly constant for the same period. The drained scenario indicated a faster response to the rainfall that was seen on the runoff outputs.

A direct effect of drainage was a lower groundwater level (GVL). It, of course, resulted in the decrease of volumetric soil water content in the soil top layer and in lower rates of evapotranspiration. The variation in water head elevation for the drained scenario was not significant while the water head elevation for the undrained one showed wide fluctuations. The largest difference in water head elevations between drained and undrained conditions was noticed during high flow phase in spring. In addition to that, the biggest effect of drainage on GVL decrease was found at the lower topographic points in the catchment.

The dynamics of water inflow to the river from the drained and undrained sub-catchments of different size area were analyzed as well. Thus, the hydrographs computed for the entire catchment in drained conditions indicated both a later peak discharges and larger runoff volume. The delay of peak flow in drained scenario appeared because the main part of the water reaching the land surface was accumulated in the topsoil layer and then released through drains. In undrained scenario, overland flow appears faster because the soil toplayer is almost saturated.

In drained scenario, the total runoff volume was larger from most of the soil types because the pipes drew down the water table deeper than it would have happened in natural conditions. The results have shown that the difference in water outflow from drained and undrained areas is more significant in small (field)-scale case than in catchment scenarios. It can be explained by the fact that the river-aquifer exchange has more dominant role for the water inflow to the river in catchment scale than in filed scale. It means that the drainage influence is degreasing in catchment scale and the river regime is approaching the natural one.

In general, the conclusion can be drawn that *drainage has the biggest effect on hydrological regime during spring and autumn time flood periods. More evident effect has for small-scale areas then for large-scale.*

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THE WAVEFRONT PROJECT: GROUND-BASED GPS METEOROLOGY IN EUROPE

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The WAVEFRONT project is a collaboration with partners in four European countries and is supported by the EC Environment and Climate Program. The project started in September 1996 and lasts for three years. The aim of the project is to develop the technique of using signals from Global Navigation Satellite Systems (GNSS) to measure the variations in atmospheric water vapour above receivers on the surface of the earth. The Global Positioning System (GPS) is the presently dominating one and is used in the project, even though future activities may very well also include other satellite systems.

Comparison experiments between data from microwave radiometers and GPS typically give agreements in the range 1–2 kg/m^2. Transportable radiometers have been used together with permanently installed radiometers and GPS receivers. One experiment was carried out in the area of Madrid, Spain, and the other at Onsala on the Swedish west coast.

Three different software analysis packages using identical GPS input data are evaluated: (1) the Bernese software developed at the University of Berne, (2) the GAS software of the University of Nottingham, and (3) the GIPSY software from the Jet Propulsion Laboratory. We investigate the impact of using different networks in terms of size and shape, different statistical parameters in the models, and different elevation cut-off angles for the GPS observations.

We will give the status of the archive of estimates of the water vapour content at about forty continuously operating GPS sites in Europe. The archive consists of GPS estimates of the water vapour content as one hour averages. The results from this project will be a two year long time series.

GPS data also have a potential for the improvement of weather forecasts. Therefore, near real-time applications as well as a study of the possibilities to estimate the three-dimensional distribution of water vapour are described. The critical parameter for near real time operation is the accuracy of the orbits used for the satellites. Both postprocessed and forecast orbit parameters have been evaluated.

MONITORING OF ATMOSPHERIC WATER VAPOR USING GROUND-BASED GPS RECEIVERS

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The number of GPS sites in the catchment area of the Baltic Sea has been growing steadily during the last five years. The number of permanently installed receivers are now in the order of 40. Using GPS data and accurate ground pressure data from these sites it is possible to determine the Integrated Precipitable Water Vapor (IPWV). This estimation process can now be made more or less automatic. We will present results obtained from our GPS processing and comparisons between the GPS estimates and the results inferred from the water vapor radiometer at the Onsala Space Observatory. We show root-mean-square (rms) agreements of the order of 1 mm in IPWV. In addition to the radiometer data comparisons, we compare the GPS results with radiosonde data at four sites in Sweden and Finland where launches are made reasonably close (distance <40 km) to the GPS receivers. The application of near real-time estimation of the water vapor is presently limited by the accuracy of the satellite orbit determination. We will present and discuss ongoing work in this field.

UNSTEADY FLOW MODELLING IN THE LOWER ODRA RIVER NETWORK INCLUDING ATMOSPHERIC PRESSURE AND WIND FORCES

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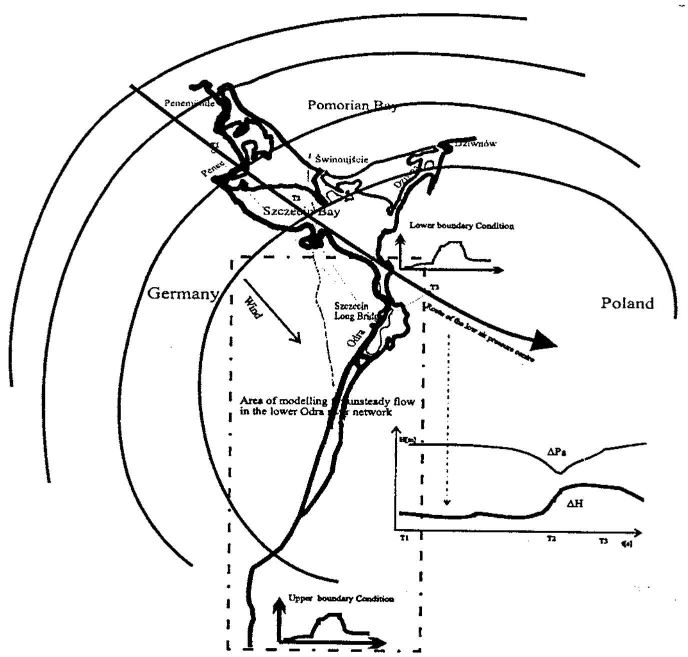
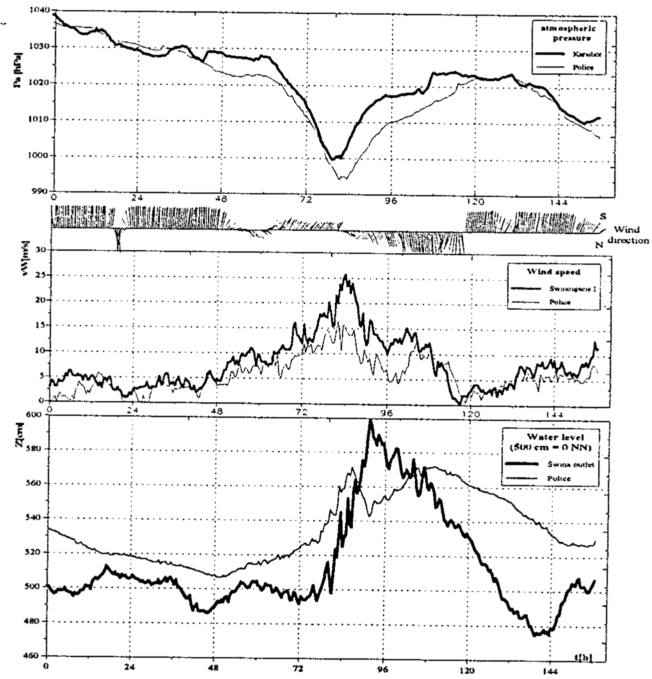
Modelling the response of a river estuary to transient boundary conditions and external forces that are usually generated trough storms caused by the passage of deep low atmospheric pressure systems, has a variety of applications ranging from offshore structures to operational forecasting of hydraulic environment. Accurate predictions of the maximum currents, water levels and waves generated by the storm phenomena has primary importance in these fields. That is also important in the Odra river estuary. When extremely low atmospheric pressure systems (further called on cyclones) were passing near the region of Odra river outlet, significant increasing of water levels had been observed (40-50 cm in Szczecin) up to cross-section of Widuchowa. It was gradually attenuated from Widuchowa in the upper part of the river system. These water levels changes are known as barotropic waves. In the author's opinion, they should be treated not only as response of the river system to transient boundary conditions but also as its response to directly acting external forces of the transient atmospheric pressure and wind. Analysing these relationships for simple case of single straight channel using analytical methods has showed the importance of atmospheric pressure term in description of unsteady flow in channel when near the channel passes relatively deep and rapid cyclone system. The similar problem is here considered for real system of river estuary – Odra river network and for real storm situations. Both atmospheric pressure field and surface wind are included into numerical modelling of the river network hydraulic and these two factors are probably the most important in producing unsteady flow in river outlet. One of a typical situation being modelled is shown on the picture bellow.



Schema of typical situation in Odra river outlet connected with passing low atmospheric pressure system over the region.



Atmospheric pressure (upper), wind direction and speed (the middle) and water levels (bottom) at Police and at Świnoujście in 8.04-14.04 1997

Numerical modelling was carried out using one-dimensional model for unsteady flow simulation in topographically and geometrically complicated river systems. The model has been first combined with the term taking into account influence of air pressure changes in time and space. Atmospheric pressure field was given as a function $P_a(x,y,t) = P_{a,0} - \Delta P_a(t) \cdot f(r)$ approximated from measurements and meteorological data. Wind field near the water surface was given as an approximation of measurements or is calculated from atmospheric pressure field using Hess' method. Model equations of one-dimensional unsteady flow in real watercourse were taken as follows:

$$\frac{\partial Q}{\partial t}+2\beta\frac{Q}{A}(1+k_1)\frac{\partial Q}{\partial X}+\left(1-\beta\cdot F_r(1+k_1)\right)\frac{\partial Z_w}{\partial X}=\frac{1}{\rho gA}\cdot\left(\frac{\tau_w}{H}-\frac{\tau_d}{R_h}\right)-\frac{Q}{gA^2}\cdot q_b+\frac{F_r}{B}(1+k_1)\left(\beta\frac{\partial A}{\partial X}\Big|_z+A\frac{\partial \beta}{\partial X}\Big|_z\right)+\frac{\partial P_a}{\partial x} \tag{1}$$

$$B\frac{\partial Z_w}{\partial t}+\frac{\partial Q}{\partial x}=q_b(x,t) \tag{2}$$

Relationship between bottom stresses τ_b and wind stresses τ_w was given by: $\tau_b M_b - \tau_w = u_0 \rho c_1 / H$

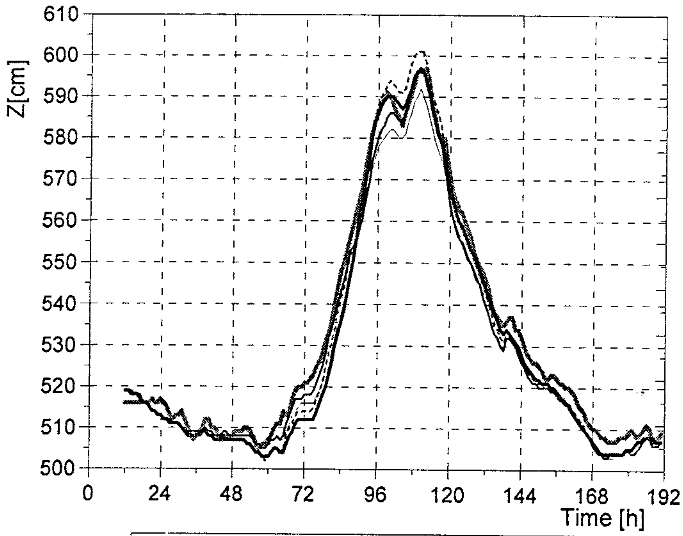
with $\tau_w = \rho_a \cdot K_w \cdot (1 - M_w / M_b)\cdot W_{10}^2 \cdot \cos(W,x)$, $\kappa_0 = (1/3) g n^2 R_h^{-1/3}$, $c_1 = 3\kappa_0 M_b u_0 H$ (3)

All branches in the given network were binding at nodes by nodal condition:

$$F(Z_{wi})\frac{\partial Z_{wi}}{\partial t}=\sum_{j\in wi} Q_j + Q^{e}_{wi}\ , \quad \underset{wj\in wi}{\forall} Z_{wj}=Z_{wi} \tag{4}$$

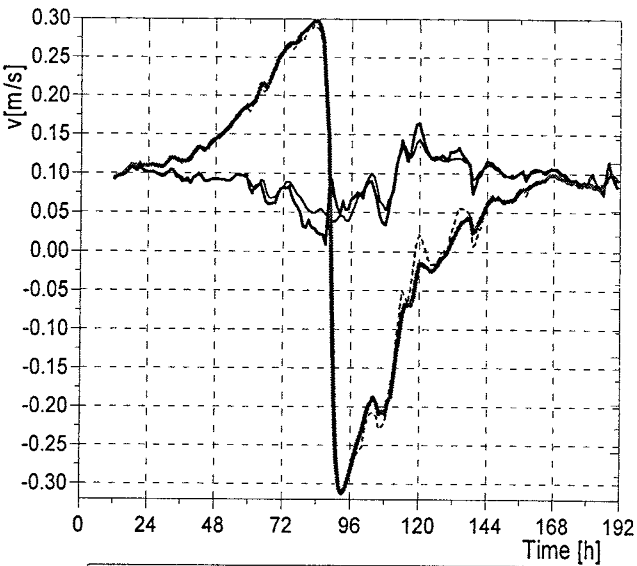
with: $F(Z_{wi})$ - retention area of the „*wi*" node, Q^e_{wi} - external inflow/outflow to the „*wi*" node.

The main purpose of this research was to find, how including the two factors into process of modelling could change obtained solutions in terms of accuracy and utility. It was also analysed, how a cyclone passing over or near Odra estuary could change its flow pattern. One simple example of obtained results is demonstrated here below.



Measured and calculated water levels (10-17.05.95) at Pomorzany crossection - river Odra network

- Measured
- calculated without Pa and wind
- calculated including only Pa effect
- calculated including only wind
- calculated with both Pa and wind



Calculated mean flow velocity for period 10-17.05.95 at Przekop Parnicki (c.156) - river Odra network

- calculated without Pa and wind
- calculated including only Pa effect
- calculated including only wind
- calculated with both Pa and wind

Additionally, an analysis of the response of Odra river hydrodynamics to the theoretically assumed different moving cyclones has been analysed taking into account their relative direction, speed and radial distance and its results are summarised in this paper.

IMPROVING THE ATMOSPHERIC WATER BUDGET OF A FORECASTING SYSTEM USING A LINEAR ERROR MODEL

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The atmospheric water budget during the winter 1986/87 over northern Europe and the northern Atlantic was derived from the Swedish meso HIRLAM reanalysis experiment carried out within the NEWBALTIC project (EU: ENV4-ct95-0072). The short range forecasts in this experiment were found to suffer from a considerable systematic drying out of the atmosphere (fig. 1). An attempt was made to relate this drying to systematic deficiencies in the parameterized evaporation and precipitation in the HIRLAM system using a linear regression model of the vertically-integrated forecast error.

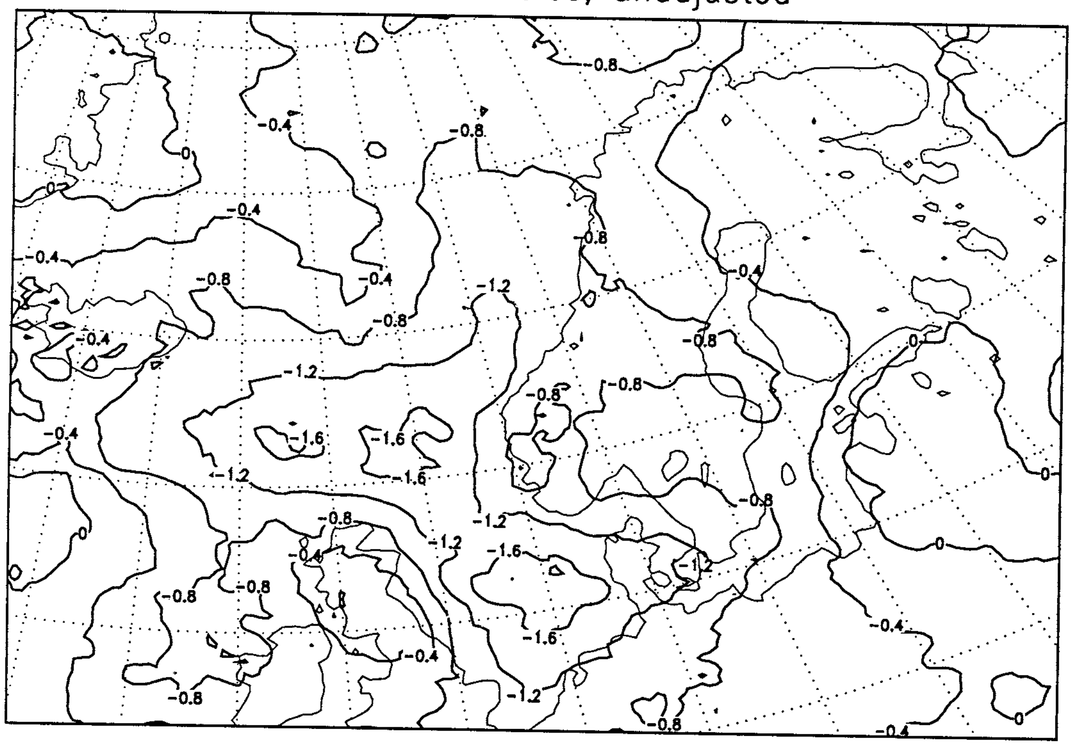

Figure 1: The systematic error in the vertically integrated atmospheric water content in 12-hour forecasts. The contour interval is 0.4 mm/day, the period is Dec. 16, 1986 to Feb. 14, 1987.

The vertically-integrated atmospheric water budget reads, neglecting the minor contribution from cloud water, $T = T_d + E - P$,where T is the computed rate of change of atmospheric water content, T_d is the contribution to T from advection of water vapour, E and P are the parameterized evaporation and precipitation, respectively. In order to search for systematic errors in E and P, an adjusted tendency $T^* = T_d + \alpha E - \beta P$ was formed. The time-independent multipliers α and β were then determined at every gridpoint by minimizing the mean squared difference between T^* and the observed tendency, the latter being obtained from successive initialized analyses.

Applying this simple method to reduce the instantaneous forecast error has a considerable impact on the systematic spurious drying (fig. 2). The facor β acting on the precipitation is essentially equal to one everywhere. Its average over the domain is 1.03 and its standard deviation is 0.05. No marked departures from unity are seen even in regions of heavy and persistent precipitation. Thus the reduction in the systematic forecast error is brought about exclusively by adjusting the evaporation. The factor α is more variable spatially than the factor β. Over the sea, however, its value is generally close to 1.2. Over land it is more variable. Values around two dominate over the British Isles and the western parts of the continent. In the eastern parts and over most of Scandinavia the values fluctuate between 0 and 2, but the physical significance of the coefficient is uncertain here because of the small generally evaporation in these regions.

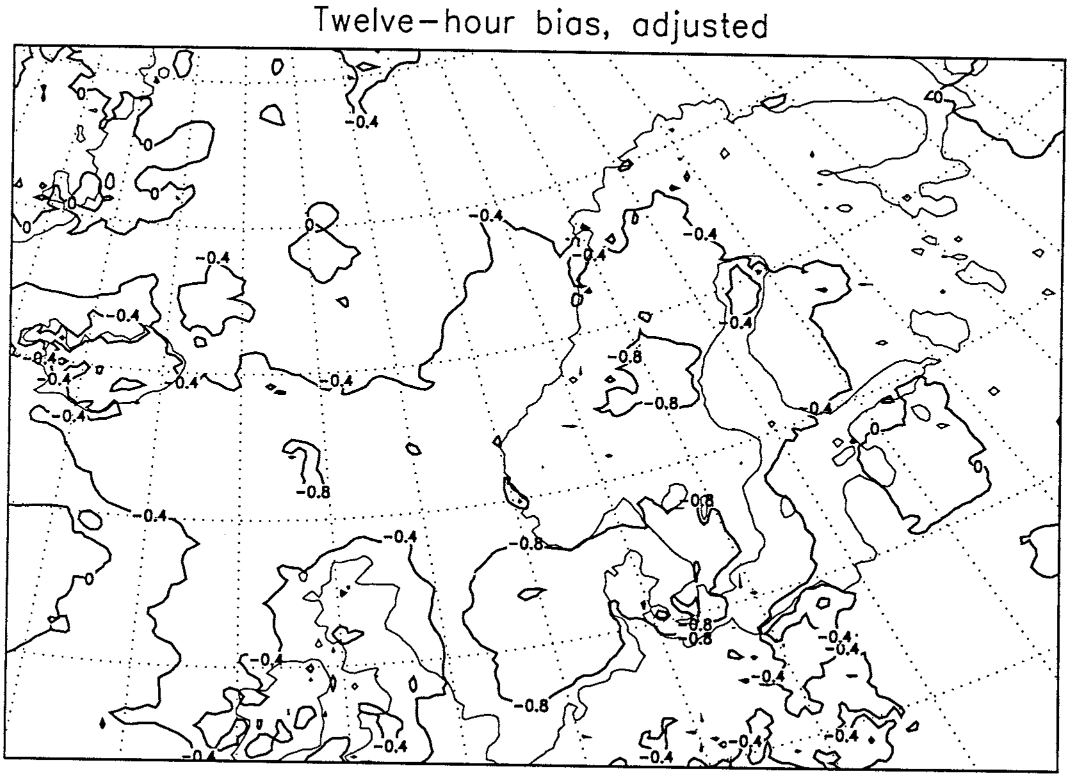

Figure 2: As fig. 1, but fore the adjusted forecasts.

It is concluded that oceanic evaporation is systematically underestimated in the forecast model, probably by at least 20 percent. The reasons for this bias are not necessarily to be found in the evaporation scheme alone, but likely involve the interaction of this scheme with the rest of the forecast model.

COMPARISON OF SHIP GAUGE AND RADAR PRECIPITATION MEASUREMENTS OVER THE BALTIC SEA

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There are only few in situ measurements of precipitation over sea due to lack of rain gauges suitable for use on moving ships. Hence a special ship rain gauge had been developed at the Institut für Meereskunde, Kiel. These are operated on several ferries to continuously measure precipitation over the Baltic Sea. Areal coverage of precipitation over the Baltic Sea is available from weather radar composite imagery from those radars within the NORDRAD collaboration, available every 15 minutes (figure 1). Comparison of these two methods has been made at the location and time of precipitation measurements of the ships. Good agreement was found in the mean (figure 2), despite of considerable scatter for short term averages. No systematic deviations were found e.g. depending on distance between ship and radar.

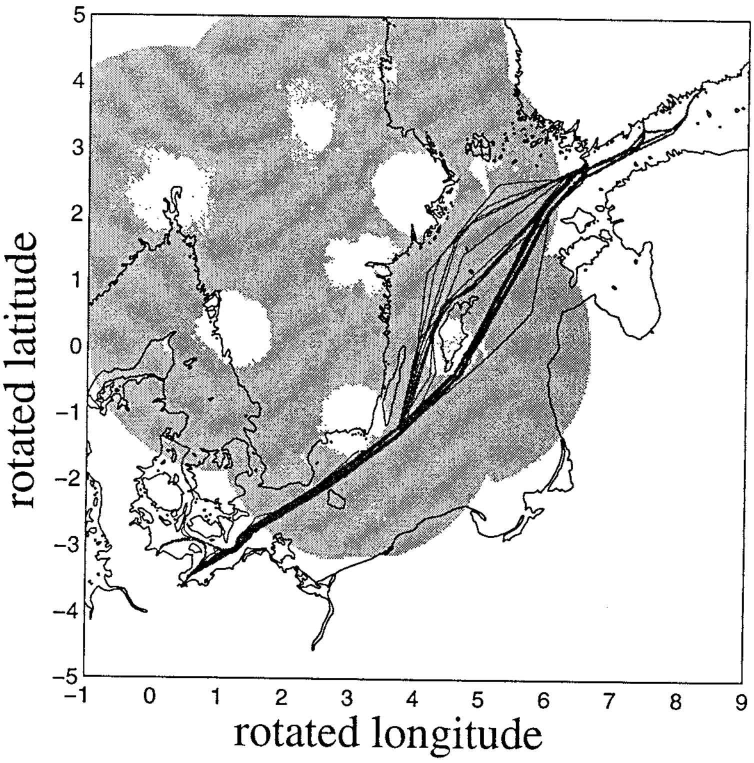

Figure 1: **Area covered by the NORDRAD radar network.** *The tracks of four Baltic Sea ferries during the PIDCAP- period are also shown. For better comparison with numerical weather forecasts REMO / EM rotated coordinates have been used in this plot.*

Additionally, measurements from a ship rain gauge mounted on an offshore mast at the Darss Sill were compared to the radar operated by the Deutscher Wetterdienst at Rostock. These radar estimates are adjusted to land based precipitation measurements. The totals of radar estimates and precipitation measured at ships agreed quite well, too.

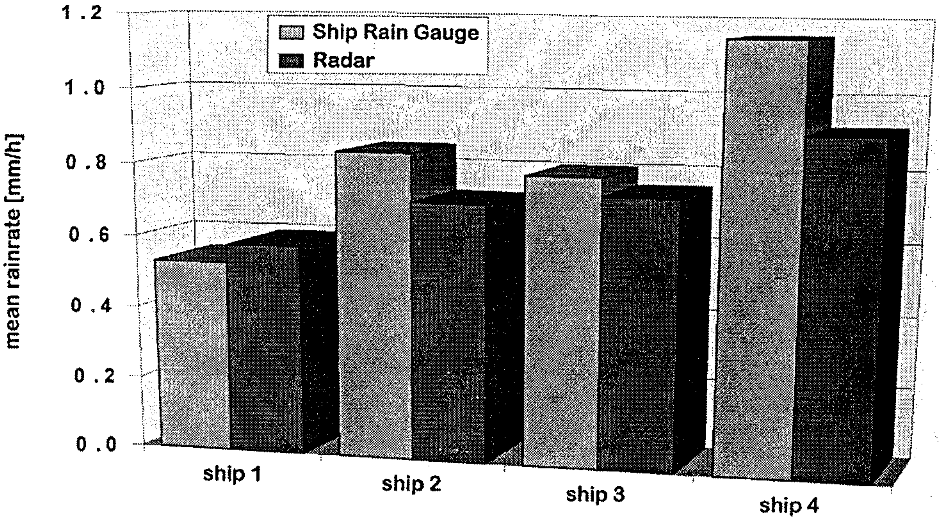

Figure 2: **Mean rain rates at the ship's individual positions.** *In situ measurements (light grey) and interpolated radar results (dark grey) are shown for the period Aug. 13th to Oct. 23rd 1995.*

Both investigations were performed for the PIDCAP period, under late summer/early fall conditions. These investigations should be extended in time to contain measurements from other synoptic conditions.

Acknowledgement

We thank Mr. J. Riedl from the Deutscher Wetterdienst for making the Rostock-radar data available for us. The help of the POSEIDON SCHIFFAHRTS OHG is explicitly appreciated.

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Hasse, L., M. Grossklaus and K. Uhlig, 1994: New ship rain gage. In: Instruments and observing methods, report No. 57, World Meteorological Organisation, Geneva, WMO/TD-No. **588**, 97 - 101.

APPLICATIONS OF SATELLITE MICROWAVE OBSERVATIONS FOR A VERIFICATION OF REMO

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In order to investigate the hydrological cycle of the BALTEX-region, one of the main scientific aim of BALTEX, numerical models will be applied. Such models need, however, a careful verification. The goal of our work is to use satellite observations, in particularly those in the microwave spectral range, for a verification of the numerical results of REMO, one of the main models used for BALTEX. This verification will be done by the method of Newtonian iteration which was first used by Rodgers (1976) to retrieve temperature profiles from remote measurements of thermal radiation.

The output parameters of REMO (i.e. temperature and humidity profiles, surface wind, cloud water) are used as input for the radiative transfer model to calculate the miccrowave radiances at satellite level. These simulated temperatures are compared whith those measured by the Special Sensor Microwave/Imager (SSM/I) on the DMSP-satellites.

The Newtonian iteration is applied to minimize the differences between the observed and the calculated microwave radiances depending on the variation of the geophysical parameters. In our method we use only those geophysical parameters which contribute most to the microwave signal of SSM/I, e.g. total precipitable water, surface wind, liquid water content. These three modified parameters which describe the actual state of the atmosphere are compared with the original output of REMO to estimate its accuracy. For cloud free cases the problem is nearly linear and a solution is found after a few steps. Including cloudy situations the problem becomes nonlinear and more iteration-steps are required.

Calculations for May 1993 show that REMO overestimates total precipitable water by 1.7 kg/m^2 (Fig. 1) and underestimates surface wind speed by 1.2 m/s on average. REMO has problems calculating liquid water content. From these results and considering the widely used Bulk Parametrisation, where the evaporation E is a function of the mean wind speed and air-sea difference of the specific humidity, one can estimate that the mean evaporation should be about 18 W/m^2= 0.6 mm/day higher than calculated by REMO. The discovered discrepancies must have a large effect on the hydrological cycle as derived from REMO simulations.

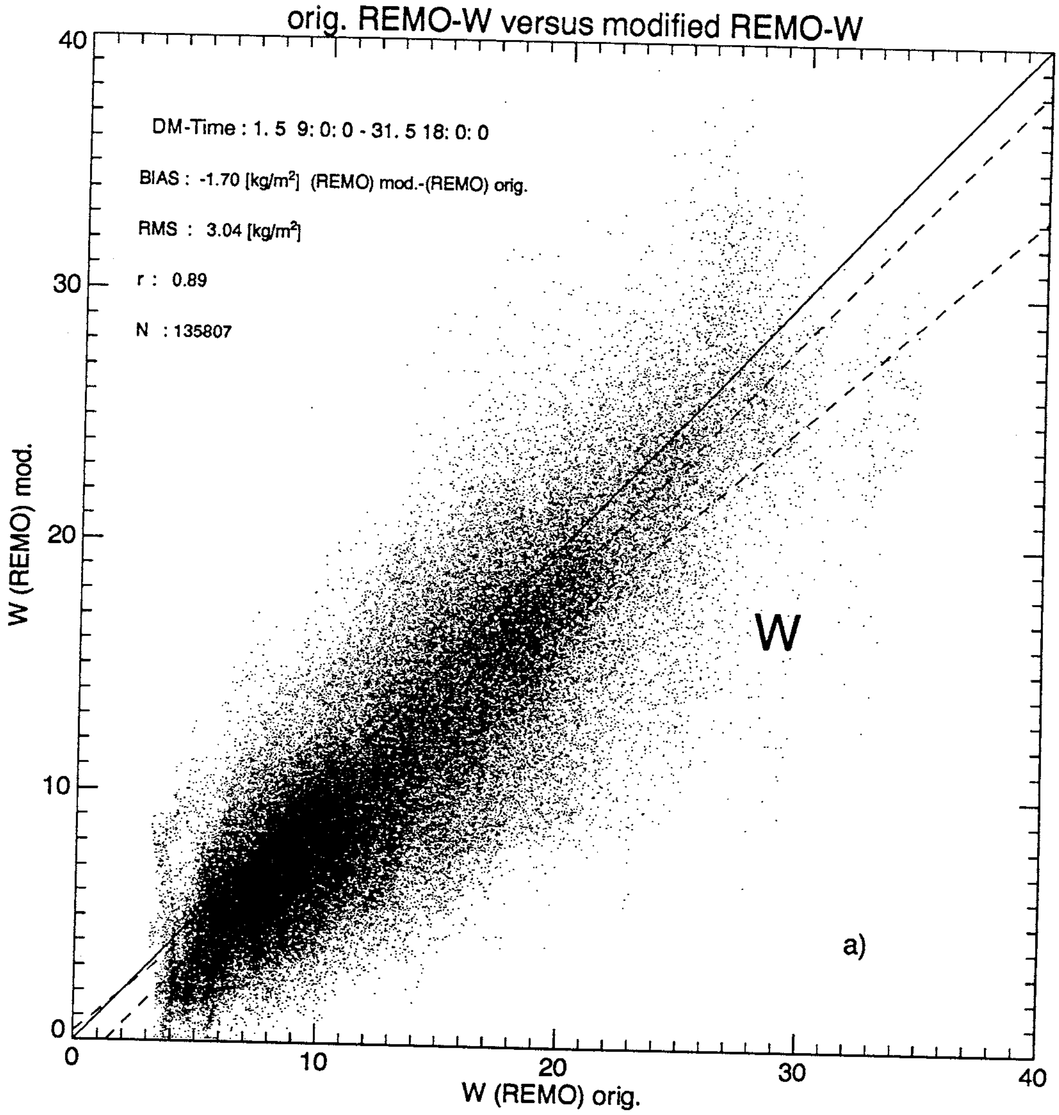

Figure 1: *Comparison of actual (x-axis) and modified (y-axis) REMO simulation of total precipitable water (May 1993).*

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[1] **Rodgers**,C.D.;1976:
Retrieval of Atmospheric Temperature and Composition From Remote Measurements of Thermal Radiation. Reviews of Geophysics and Space Physics, Vol. 14, No. 4, 609-624.

Hydrologic macro-modelling: experiences from NOPEX.

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Abstract

In connection to climate change studies a new hydrologic field has evolved - regional hydrological modelling or hydrologic macro modelling, which implies a repeated application of a model everywhere within a region with a global set of parameters. This is to mirror the way meteorological models are operated and to allow coupling with such models. The experience of application of a physically based distributed hydrological model ECOMAG to river basins within the NOPEX southern region with this purpose is presented with a stress on the problem of defining and estimating global parameters. The model considers the main processes of the land surface hydrological cycle: infiltration; evapotranspiration; thermal and water regime of the soil; snowmelt; formation of surface, subsurface and river runoff; and groundwater. The spatial integration of small and meso-scale non-homogeneity of the land surface is a central issue both for definition of fundamental units of the model structure and for determination of representative values for model calibration.

USING LARGE-SCALE HYDROLOGIC MODELING TO REVIEW RUNOFF GENERATION PROCESSES IN GCM CLIMATE MODELS

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Abstract

Cooperative climate research within NEWBALTIC (Numerical Studies of the Energy and Water Cycle of the Baltic Region) led to a novel comparison between hydrologic and atmospheric models. The Swedish HBV hydrologic model was used as a water balance model of total runoff from land to the Baltic Sea (HBV-Baltic). The 25 subbasins, ranging from 25 000 to 144 000 km², are shown in Figure 1. This macroscale model application aimed at representing the daily water balance as closely as possible while keeping detail to a minimum. Input included basin characteristics—topography, land use and lake storage—together with gridded daily synoptic precipitation and air temperature. The available 12-year record of monthly total runoff to the Baltic Sea was evenly divided for use in calibration and verification of the *base condition*. Figure 2 shows daily model results summarized for the total Baltic Drainage Basin—an area of just over 1 600 000 km². Calibration and verification periods are shown in the figure; modeling results extending beyond the available record are also shown. Modeled runoff discharge matches well with recorded discharge and the water balance volume error, shown as "accumulated difference" in Figure 2, is low. Results for each of the five main Baltic Sea drainage basins are of similar character, but with some variation from north (best) to south (worst).

Results from the base condition run gave us confidence that the HBV-Baltic model could be used to represent the water balance of the Baltic Sea Drainage Basin at large scales. Output from the model was summarized for the main Baltic Sea basins; of particular interest are elements not typically measured or known from actual conditions. These include snow water equivalent, evapotranspiration and the state of soil moisture. It is recognized that these model output variables are not exact measures of the processes they represent, but they can be used as relative measures. A long history of experience and validation with the HBV model provides some sureness that they are reasonably-calculated by the model.

The HBV-Baltic model was used to review runoff generation processes in a 10-year simulation of the current climate made with Max-Planck's ECHAM4 GCM model. The global T106 run used SST (sea-surface temperature) forcing data from 1979-1988. GCM precipitation and 2m-temperature outputs for the Baltic region were used as input forcing to HBV-Baltic, which was run for the entire simulation period. Comparisons of output from HBV-EC4 (HBV-Baltic with ECHAM4 input) to direct output from ECHAM4 were made, together with comparisons to HBV-Base (HBV-Baltic base condition). A convenient way to review results over different time periods is with duration curves summarizing output variables in terms of frequency of occurrence. Figure 3 shows duration curve results for the three cases. Soil moisture is represented by *soil moisture deficit (smd)*, as it is the amplitude of change for this variable that is of most interest. As the "runoff" produced by ECHAM4 is not "river runoff", but rather instantaneous point runoff similar to "excess precipitation", an internal variable of matching characteristics is plotted from HBV-Baltic. This is referred to as *runoff generation* in Figure 3.

Using HBV-Base values as a point of comparison, the results show HBV-EC4 with higher snow amounts and drier soil conditions (higher smd). Runoff generation is higher under high flows and lower under low flows for both ECHAM4 and HBV-EC4. ECHAM4 results for both snow and smd lie relatively close to HBV-Base values. Variation in evapotranspiration between the model cases is not highly pronounced, but there is a clear trend of lower evapotranspiration for the HBV runs during low evaporation months. Figure 4 shows that the average precipitation pattern from ECHAM4 is both higher than recorded observations and of different seasonality. Taken together, these results indicate a potential bias by ECHAM4 in its snow and soil moisture routines. One outcome is that if precipitation were to be more accurately represented by ECHAM4, then the snow would tend to be underrepresented. These conclusions are not definite, but they are encouraging as this type of comparison leads to a more in-depth look at the internal processes of both hydrologic and climate models. Improving the modeling schemes in both can lead us nearer to the future success of coupled models.

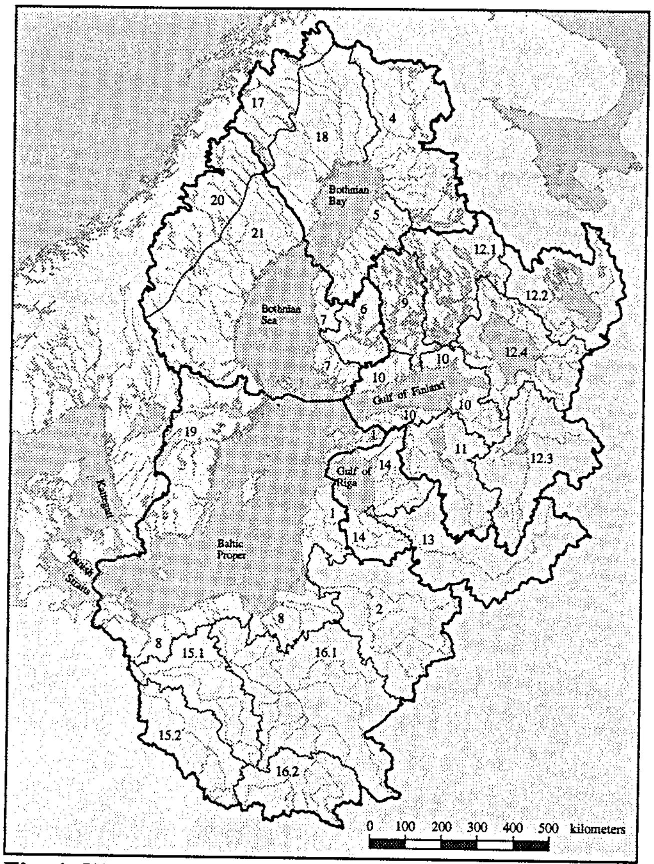

Fig. 1. HBV-Baltic basin boundaries. The five main Baltic Sea drainage basins are outlined with thick lines; numbered subbasins are shown with thin lines.

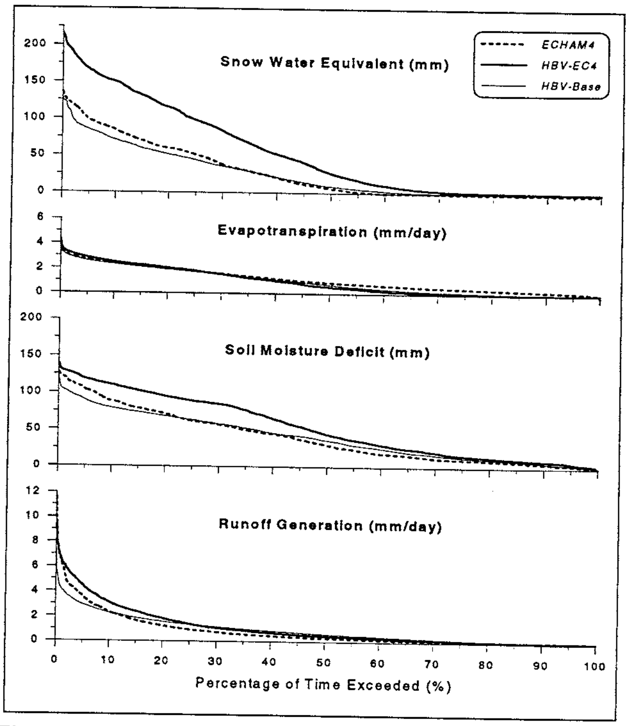

Fig. 3. Results—shown as daily duration curves—for ECHAM4, HBV with ECHAM4 forcing, and HBV Base Condition (1980-1994).

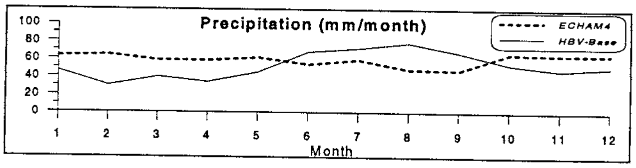

Fig. 4. Average Monthly Precipitation

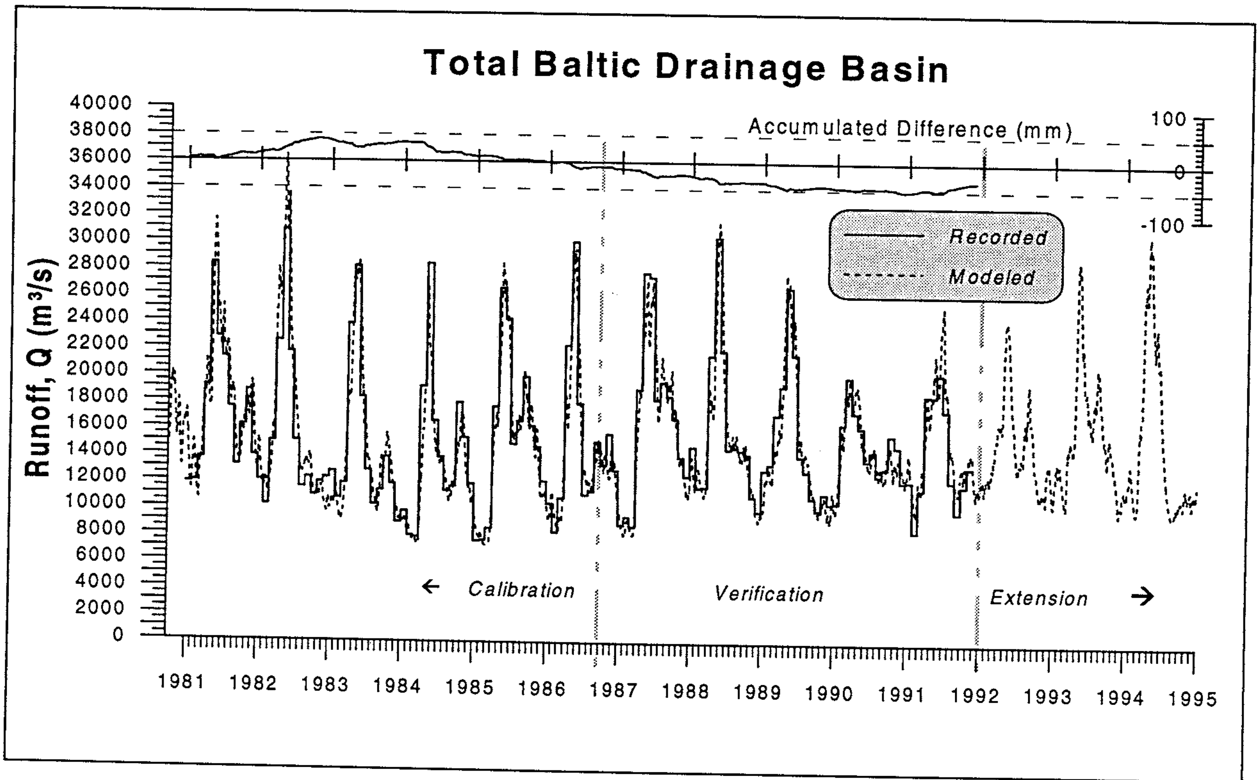

Fig. 2. HBV-modeled daily runoff discharge over both calibration and verification periods—*Base Condition.* Volume error is shown as *accumulated difference*. The model extends beyond available flow records.

COMPARISON OF IN SITU MEASUREMENTS AND MODEL FORECASTS OF PRECIPITATION OVER THE BALTIC SEA

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Numerical weather forecast models are becoming more and more important for the determination of mesoscale precipitation fields. Due to possible differences in precipitation over land and sea it is necessary not only to compare the model results to land based in situ measurements but to extend these intercomparisons to the sea. This is being done with aid of precipitation measurements at large ferry ships sailing between Germany and Finland. In order to overcome the problems associated with rainfall measurements at moving ships special ship rain gauges are used.
Intercomparisons have been performed using precipitation forecasts given by three numerical models. The corresponding data sets have been created using different modes of operation and horizontal resolutions:

model	operated at	mode	resolution
Europamodell	DWD[1], Offenbach	operational	1/2 deg.
REMO	MPI[2], Hamburg	climate	1/6 deg.
REMO	GKSS[3], Geesthacht	operational	1/6 deg.

These studies are focussed at the PIDCAP period (August to November, 1995). The technique applied for the comparisons with the in situ measurements was to interpolate the simulated precipitation to the respective ship's locations and to calculate the total precipitation for both the model results and the measurements as a function of model longitude. The fact that all the three models use the same rotated coordinates makes it easier to compare the individual results.

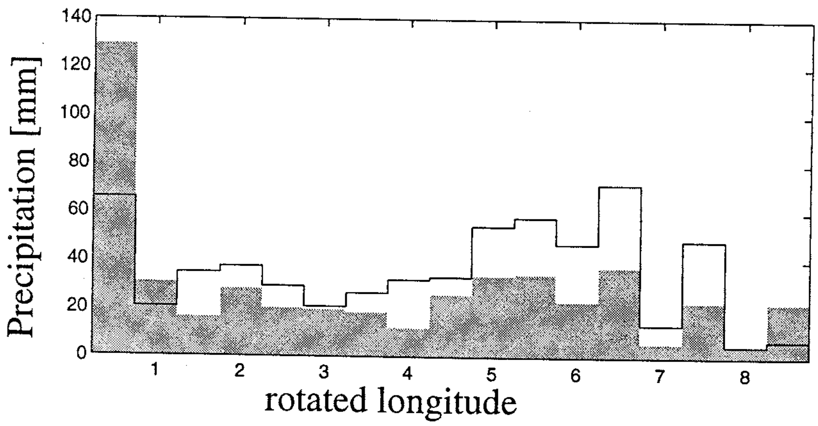

Figure 1: *Cumulated precipitation along the ship's track. The abszissa ranges from Kiel in the West to Kotka (SE Finland) in the East. Measurements (shaded columns) and 'Europamodell' forecasts (solid line) are shown for the period Aug. 13th to Oct. 31st 1995.*

Although all three models have the same basic model physics implemented distinct differences in the simulation of precipitation are obvious. However, one should keep in mind that it is not feasible to intercompare the results of two models having different horizontal resolutions, because the individual grid boxes do not represent the same area.

[1] Deutscher Wetterdienst
[2] Max-Planck-Institut für Meteorologie
[3] Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt

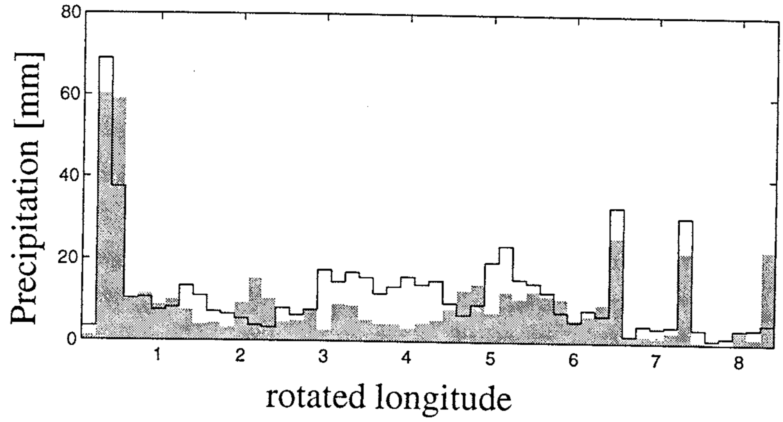

Figure 2: *Cumulated precipitation along the ship's track. The abszissa ranges from Kiel in the West to Kotka (SE Finland) in the East. Measurements (shaded columns) and MPI–REMO forecasts (solid line) are shown for the period Aug. 13th to Oct. 31st 1995.*

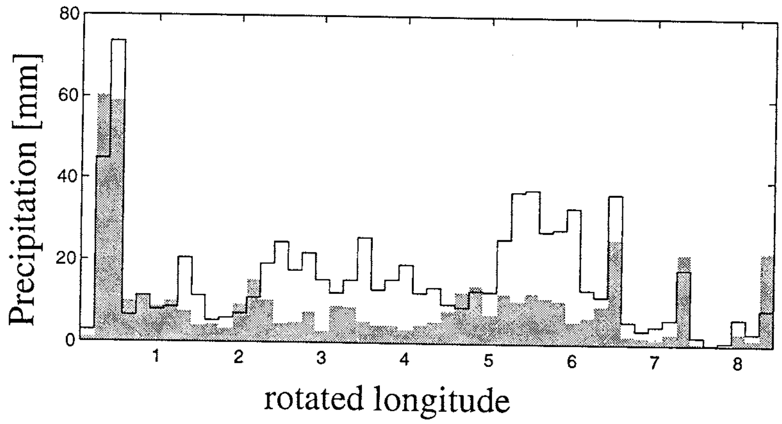

Figure 3: *Cumulated precipitation along the ship's track. The abszissa ranges from Kiel in the West to Kotka (SE Finland) in the East. Measurements (shaded columns) and GKSS–REMO forecasts (solid line) are shown for the period Aug. 13th to Oct. 31st 1995.*

With regard to the facts that the ships are non stationary and that rainfall probability is rather small, this late summer/early fall restricted studies can be characterized as spot checks of model forecasts. Hence we extended this investigation to the years 1996 and 1997. For this period of time only the data from the operational 'Europamodell' were available. It shows that the relation between measured and simulated precipitation varies quite strongly throughout the considered years. A general overestimation of modelled precipitation could not be found. Not only to strengthen the validity of studies like this it is sensible to enhance the resolution of the 'Europamodell' in the future.

Acknowledgement
We thank the Deutscher Wetterdienst for making the results of the 'Europamodell' available. The help of the POSEIDON SCHIFFAHRTS OHG is explicitly appreciated.

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Hasse, L., M. Grossklaus and K. Uhlig, 1994: New ship rain gage. In: Instruments and observing methods, report No. 57, World Meteorological Organisation, Geneva, WMO/TD-No. **588**, 97 - 101.

Comparison of regional sensible and latent heat flux estimates from NOPEX

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Introduction

The problem of spatial integration of land surface parameters over a non-homogeneous land surface and especially the estimation of regional (grid) surface fluxes is a central issue for a series of land surface experiments performed and being performed. The NOPEX region consists of surface elements of coniferous/mixed forest and agricultural land with scattered mires, lakes and urban areas. The area is therefore well suitable for studying the inter- and intra-patch variability of energy. Intensive experimental campaigns were carried out in 1994 and 1995. Local measurements from masts gave point estimates of sensible and latent heat fluxes. These measurements can be combined to provide weighted averages with respect to landscape classes. A method to derive the direct integrated sensible heat flux from information on the evolution of the mixed layer based on radiosoundings has been applied for the NOPEX area by Gryning and Batchvarova (1999). Averaged fluxes has been obtained from measurements performed by aircraft along flight legs. Regional flux estimates for the whole area has been made using regional hydrological and mesoscale meteorological modelling. A comparison between the regional fluxes obtained from the 5 methods is presented in Gottschalk *et al.* (1999). In this paper we limit the comparison to the regional fluxes estimated from mast measurements, radiosoundings and hydrological modelling.

Methods

Weighted averages. Two of the sites, Norunda (forest) and Tisby (agricultural), had almost unbroken data records during the two experimental campaigns and these 'golden' sites are naturally playing a special role in the estimations. To arrive at regional flux estimates several steps were taken. As a first step, the best possible weighted average was estimated using all data available. Then the flux based estimated from all available data were calibrated to the flux estimated using only Norunda and Tisby data. In this way regional flux estimates were derived from measurements at Norunda and Tisby only. These sites represent the dominant land use classes of the NOPEX area.

Mixed layer evolution method. The theoretical framework is a zero order mixed layer model, that accounts for atmospheric neutral and unstable conditions. The basic idea is that the mixed layer grows in response to the surface heating and momentum flux. Knowing the mixed layer evolution from radiosoundings and taking into account the effect of the momentum flux, an estimate of the sensible regional heat flux can be determined. All the parameters that are needed in order to apply the model can be obtained from radiosoundings.

ECOMAG - a distributed hydrological model. The ECOMAG model (Motovilov, Gottschalk and Engeland 1997), has now been adapted for application to Boreal conditions. It describes the processes of soil infiltration, evapotranspiration, thermal and water regimes of soil, surface and subsurface flow and groundwater and river flow and also snow accumulation and snowmelt.

Results and Discussion.

Figure 1 shows the regional sensible heat flux derived from the weighted averages based on mast measurements (Norunda and Tisby) compared with estimates of regional sensible heat flux derived by the mixed layer evolution method (applied for three days in 1994, and 6 days in 1995). The comparison covers daytime (period covered by radiosonde launches), as well as the aircraft flight periods (typically 2 hours during the early afternoon). Generally the agreement is good. Figure 2 shows the regional latent heat flux derived from the mast measurements versus the daily mean latent heat flux estimated by the distributed hydrological model. The agreement is also in this case good.

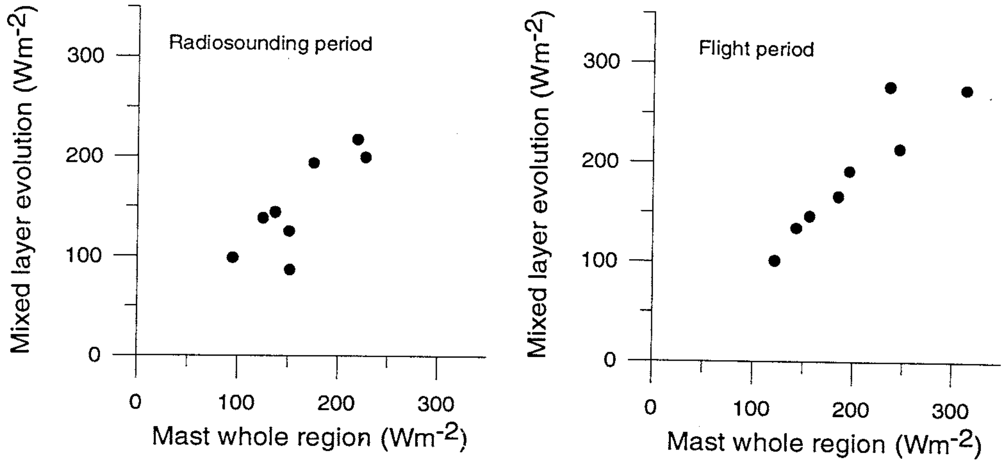

Figure 1. Regional sensible heat fluxes estimated from the Mixed Layer Evolution Method plotted against weighed average mast measurements. Left panel for the day (period covered by radiosonde measurements), and left panel for the aircraft measuring periods (typically 2 hours during midday).

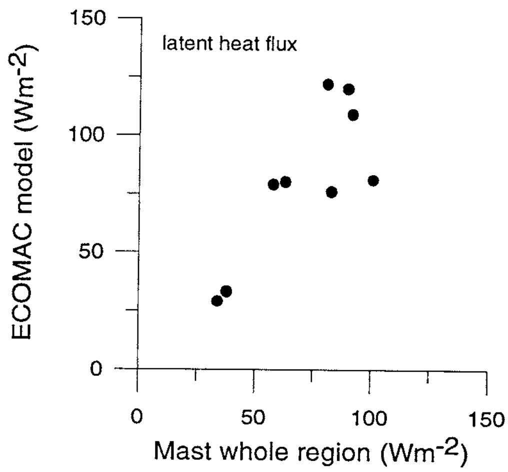

Figure 2. 24 hour averaged regional latent heat flux determined by the ECOMAC model plotted against weighted average mast measurements.

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Simulation of stratification and ice conditions in the Baltic Sea during the period 1961 – 1993

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A time-dependent prognostic model is used to simulate the stratification and ice conditions in the Baltic Sea, including the Kattegat and Belt Sea. In the model, the Baltic Sea is divided into 10 sub-basins with high vertical resolution. The flows between sub-basins are calculated using simple steady state dynamical formulas, e.g., geostrophic and Ekman flows. A sea-ice model reproduces the thickness distribution in each sub-basin. The model is forced by observed weather over the Baltic, sea level in the Kattegat and river runoff. At the border to Skagerrak the salinity and temperature is given as annual cycles derived from observations.
The model is able to simulate the succession of stagnant periods in and renewals of the Baltic Sea deep waters with only weather, sea level and river runoff as input. The time evolution of stratification above the halocline in the Baltic Sea is well simulated by the model.

The model is used to quantify time-scales and diapycnal mixing in various parts of the Baltic Sea. The dynamical importance of the binding of freshwater in sea-ice during the winter is also analyzed. At the conference some first results are given.

Coupling of atmospheric, ocean and lake models for BALTEX mesoscale re-analysis purposes

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1. Introduction

Spatially and temporally consistent atmospheric data sets are needed for the study of energy and water budgets within the BALTEX project. These data sets are created by the application of data assimilation techniques together with high resolution atmospheric models. When such data assimilation is applied to historical data sets, we usually refer to this as atmospheric re-analysis. The SMHI contributes to the BALTEX project with such mesoscale atmospheric re-analysis. The main tool for the SMHI re-analysis is the HIRLAM data assimilation and forecasting system. SMHI also contributes to validation of atmospheric models, to development and tuning of physical parameterization schemes and to the development of coupled lake and Baltic Sea models within BALTEX.

2. A coupled lake model

Initially, a simple model for lake temperatures and lake ice thicknesses was developed (Ljungemyr et al., 1996). The model was verified independently, and it was also used for the re-analysis for the winter 1986/87. The initial lake model was a slab model based upon energy conservation and it treated the lakes as well-mixed boxes with depths represented by the mean depths. The model is forced by near surface fluxes calculated from total cloudiness, air temperature, air humidity and low level winds. A data base, describing 92,000 Swedish lakes, provides the model with lake mean depths, areal sizes and locations. When the model is used for parameterization of lake effects in the atmospheric model, all the smaller lakes and the fractions of larger lakes within each horizontal grid square of the atmospheric model are parameterized by four model lakes, representing the lake size and mean lake depth distributions. A sensitivity test showed great interannual variations of the ice-covered season, which implies that lake models should be used instead of climate data. The results from an experiment with two-way coupling of the lake model to the atmospheric model were verified by comparing forecasted weather parameters with routine meteorological observations. These results showed that the impact of lake effects could reach several $^{\circ}C$ in air temperatures close to the surface.

The simple slab lake model has recently been improved by the introduction of a vertically resolved model for the deeper lakes, including also a parameterization of vertical turbulent transports within the lakes and horizontal variations in the ice cover. The improved lake model system, including the vertically resolved model for deeper lakes, has been extended to include all lakes within the HIRLAM model integration area. This generalized lake model system was applied for the BALTEX mesoscale re-analysis of the winter 1992/93.

3. Coupling between the ocean model system BOBA/PROBE and HIRLAM

The coupling between a high resolution weather forecasting model and an ocean model has been investigated (Gustafsson et al., 1998). It was demonstrated by several case studies that improvements of short range weather forecasting in the area of the Baltic Sea require an accurate description of the lower boundary condition over sea. The examples were taken from summer situations without sea ice as well as from winter situations with extreme sea ice conditions. It was furthermore demonstrated that the sea state conditions may change considerably within forecasting periods up to 48 hours. This implies the necessary application of ocean models, two-way coupled to the weather forecasting model.

An advanced 2.5 dimensional ice-ocean model BOBA/PROBE has been coupled to the HIRLAM forecasting system. The ice-ocean model includes two- dimensional, horizontally resolved, ice and storm surge models and a one-dimensional, vertically resolved, ocean model applied to 31 Baltic Sea regions. The two-way coupling between HIRLAM and BOBA-PROBE was used for the re-analysis of 1986/87 and 1992/93. The ocean model system is forced by forecasts of surface pressure, 10 meter winds, 2 meter temperature, 2 meter humidity and total cloudiness from HIRLAM. SST observations from the Baltic Sea are assimilated in the ocean model system. The ocean model system provides forecasts of sea-surface temperatures and sea ice concentration to be used as the HIRLAM initial lower boundary condition.

The application of the coupled model system to the mesoscale re-analysis for BALTEX showed that it is necessary to apply data assimilation for the sea state variables in order to avoid drift of the coupled model system towards less realistic model states. A succesful application of a simple assimilation of sea surface temperatures was introduced. The observed sea surface temperatures are first subject to a horizontal filter in order to restrict the influence to a larger horizontal scale of the model sea state. Then the differences between these filtered observed and the model sea surface temperatures are used to construct a modified sensible heat flux that is applied as a form of a "nudging" (or flux correction) term to the ocean model equations over a time period of several hours. It turns out that this "nudging" is sucessful in avoiding the drift away from realistic sea state conditions.

Mesoscale atmospheric re-analysis for the winters 1986/87 and 1992/93

Mesoscale atmospheric re-analysis has been carried out for the periods 15 December 1986 - 15 February 1987 and 1 December 1992 - 31 January 1993. For both periods, the HIRLAM data assimilation was first applied at a grid resolution of 55 Km and with 16 vertical levels. These coarse resolution analyses were then used as lateral boundary conditions for data assimilation and forecast runs with a grid resolution of 22 km and with 24 vertical levels. Input observations were radiosonde, radio wind, land surface, ship and aircraft observations.

Results from the re-analysis will be presented and the impact of the coupled models will be demonstrated and discussed.

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MODELLING OF THE ICE THICKNESS REDISTRIBUTION

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Pack ice is a mixture of several ice types and open water. Each ice type is characteristics of its own thickness, temperature, roughness etc., and has an effect on the ice dynamics, and heat and momentum exchange between the atmosphere and the ocean. Present ice models resolve an amount of the open water, the mean ice thickness and distinguish ridged ice from level ice. That approach has been extended and a new ice thickness redistribution model has been formulated where the pack ice is decomposed to open water, two different type of undeformed ice, rafted ice and rubble ice. The ice thickness distribution model has been included to a coupled ice-ocean model and numerical experiments has been made for the winter 1994. The benefits of the extended ice classification is a better description of the minimum ice strength and thus gives more realistic ice velocities when thin ice is present. Also the different thermodynamic growth/melting rates of the ice types can be introduced to the model, hence giving more detailed seasonal evolution of the pack ice. In addition, the five level ice thickness distribution model gives more information about the surface properties (surface temperature, albedo, roughness) of pack ice.

MACROSCALE HYDROLOGICAL MODELLING FOR THE MACKENZIE RIVER BASIN

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In order to answer questions concerning the effects of possible climatic change on land and water resources we need an accurate model of the global hydrological cycle. Such a model will have fully coupled components for the atmosphere, the ocean, the land phase hydrology and the vegetation. Suitable coupled atmospheric-ocean models have been available for some years in the form of general circulation models (GCM). Such models maintain the hydrology only in a crude way, resulting from different scale requirements and inefficient coupling of hydrological and atmospheric components and from neglecting lateral flows of the land-phase in most of the GCMs. The long term goal of this research is to develop a appropriate macroscale hydrological model suitable for incorporation into such a global model.

As a part of this long-term goal, work over the last 2 years has concentrated on primary macroscale simulations using the SLURP hydrological model (Kite et al., 1997) and on evaluating data from various atmospheric models for the hydrological simulations (Kite and Haberlandt, 1997). One special aspect has been the investigation of optimal precipitation interpolation and assimilation for scarcely observed regions using geostatistical methods (Haberlandt and Kite, 1997). Besides, first results towards the effects of the scales of the atmospheric forcing and of the land-phase hydrological component on the resulting simulations could be obtained. This paper will report on these investigations, which are part of the Mackenzie Basin GEWEX Study (MAGS).

Figure 1 shows recorded and simulated flows using SLURP for the outlet gauge of the Mackenzie Basin. While results for the outlet of the basin are already quite satisfying, flow simulations for several smaller subbasins are poor. Future modelling activities will include a better consideration of cold region processes like permafrost and ice dynamics in rivers and lakes. It is also intended to do further work towards a more distributed description of processes and parameters within elementary simulation areas using statistical distribution functions.

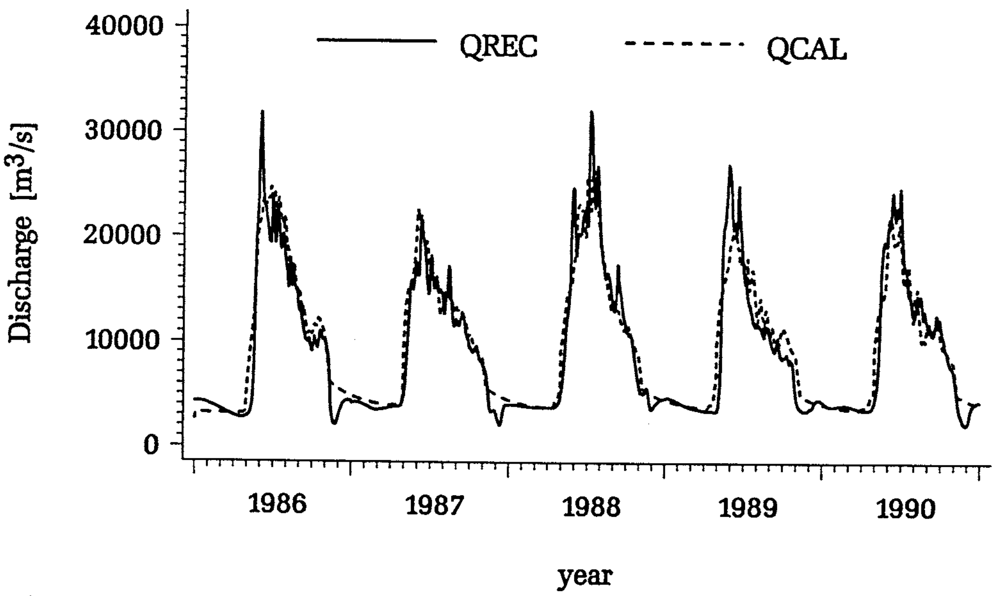

Figure 1: Mean monthly flows for "Mackenzie River above Arctic Red River" recorded (REC) and simulated with SLURP (using GCM, NCAR, RFE and observed data); (the associated time for averaging is indicated in Table 1)

Table 1 lists the atmospheric data sets used in the hydrological model and Figure 2 shows simulation results with these data using the SLURP hydrological model. The atmospheric forcing resulting from the GCM still performs very poorly in the hydrological simulations, although there are 39 relevant GCM grid points within the Mackenzie region. Best results have been achieved using the Regional Finite Element (RFE) model in forecast modus. However, one important question is, if these results hold for climate simulations, when those limited area models have to rely completely on GCM boundary conditions and cannot be updated regularly by observations. Answers to that question may be obtained by researching appropriate downscaling methods.

Basin	Atmospheric model	Spatial Scale	Variables used	Time period
Mackenzie	CCC GCM	~ 400 km	P, T_a, Hu, R	12 hr data for 10 years
	NCAR/NCEP	~ 200 km	P, T_a, Hu, R	6 hr data for 1986-90
	RFE NWP	50/35 km	P, T_a, Hu	12 hr data for 10/94 - 9/96
	Climate Network	81 stations	P, T_a, Hu, R	daily data for 1986-90

P - precipitation, T_a - air temperature, Hu - humidity, R - radiation

Table 1: Data used from atmospheric models and climate network

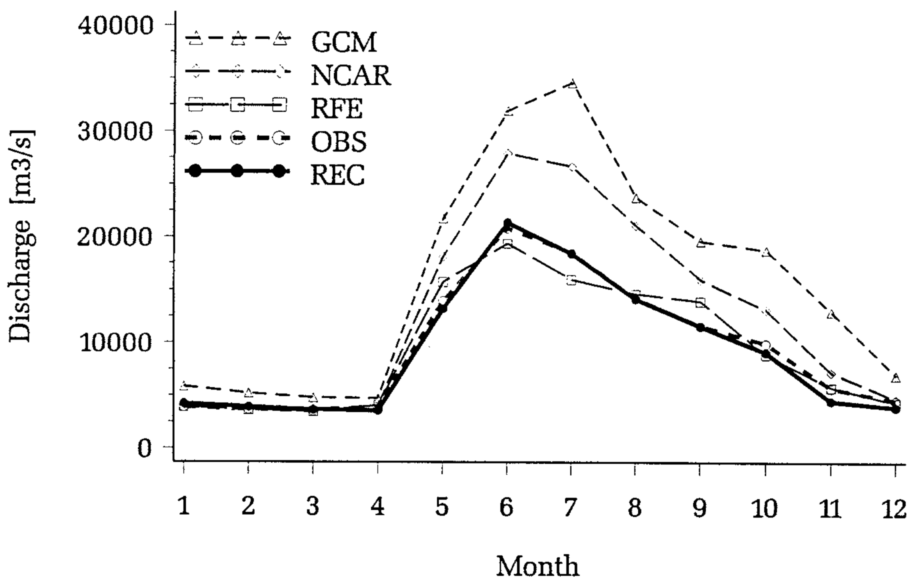

Figure 2: Mean monthly flows for "Mackenzie River above Arctic Red River" recorded (REC) and simulated with SLURP (using GCM, NCAR, RFE and observed data); (the associated time for averaging is indicated in Table 1)

Basic condition for building, verification and application of macroscale models is the sufficient availability of climate data. This is true especially for poor observed regions like the Mackenzie Basin with only one precipitation station per 22000 km^2. Investigations towards optimal precipitation interpolation and assimilation using additional information for hydrological modelling have been carried out. Their potential and limitations will be shown in context with the scale dependence for such tasks.

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A Coupled High Resolution Atmosphere - Ocean Model for the BALTEX Region

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The major objective of the BALTEX program is to provide validated, coupled modelling tools for explaining and predicting the energy and water processes in the climate system, consisting of the atmosphere, continental surfaces and the ocean (International BALTEX Secretariat, 1997). To contribute to this aim, the atmospheric regional model (REMO) from Max-Planck-Institute for Meteorology has been coupled to the Kiel Baltic Sea model (BSMO). The 3-dimensional atmospheric model REMO is based on the Europa-Modell (EM), the main weather forecast model of the German Weather Service (DWD). It is used in the so-called climate mode, i.e. during the whole integration only the lateral boundary fields were updated every 6 hours (Jacob et al., 1997). The horizontal resolution is 1/6° on the rotated longitude/latitude grid, this is equivalent to approximately $18 \times 18\,km^2$. The vertical distribution of the 20 model levels is the same as in the EM. The Kiel Baltic Sea Model is a 3-dimensional eddy-resolving baroclinic model with a horizontal resolution of approximately $5 \times 5\,km^2$ and a discretization of 28 levels in the vertical (Lehmann, 1995). Until now, these two models have been run seperately and both were forced with DWD analyses or forecasts, respectively.

As a first step towards a fully coupled system some sensitivity studies have been done varying the surface boundary conditions in both models. The simulations were performed for the PIDCAP period from August to October 1995. Firstly, REMO was run by using DWD analyses as boundary conditions. Atmospheric parameters produced by this run were used as forcing for the Kiel Baltic Sea Model. For a further run of REMO we replaced the DWD-SSTs in the BALTEX region with BSMO-SSTs achieved from the previous run. These BSMO-SSTs are in some situations, when rapid cooling occurs, quite different from DWD-SSTs and closer to satellite observed SSTs (Fig. 1, lower panel). As a result of these changed lower boundary condition, among other things, REMO calculated heat fluxes are different (Fig. 1, upper panel). From the end of August to the beginning of September major changes occured in the eastern Gotland Basin. For instance on August 31st a difference of 3°C in SST causes a reduced latent heat flux of 200 Wm^{-2}. According to that, also precipitation is reduced in this region. Whereas the different SSTs have only a slight effect on the dynamic variables.

The next step was the development of a fully coupled model system. Therefore the Baltic Sea model was incorporated into REMO as an optional subroutine. The interface between both models organizes the exchange of the mutual forcing at the common boundary. That means the interface has to provide REMO calculated heat fluxes, radiation fluxes, wind stresses, precipitation and mean sea level pressure on the BSMO grid, as well as the BSMO calculated SSTs on the REMO grid. The frequency of information exchange can freely be chosen and was set to 6 hours in the first coupled run. The SSTs from the coupled run show a similar behaviour compared to the BSMO-SSTs from the experiment with no feedback to the forcing fields (Fig. 1, lower panel). On the one hand this indicates that – in this experiment – mainly minor changes in the dynamic variables of the atmospheric model occur due to different SSTs. On the other hand this points out that the Baltic Sea model responses reasonably to the REMO calculated fluxes. This is not obvious, because until now the BSMO was forced by atmospheric variables and the flux calculation routines in the Baltic Sea model are not exactly the same as in REMO. Thus it is a good result that the Baltic Sea model has no drift when it's forced by REMO fluxes instead of atmospheric variables and the coupling was realized without any flux corrections. Finally, we have to remark that another reason for the non existing drift in the coupled system could be the strong constraint of lateral boundary conditions for the atmospheric model. Further we don't know whether the coupled model shows a drift during longer simulation periods. Therefore we have to extent our experiments to longer runs with different atmospheric conditions.

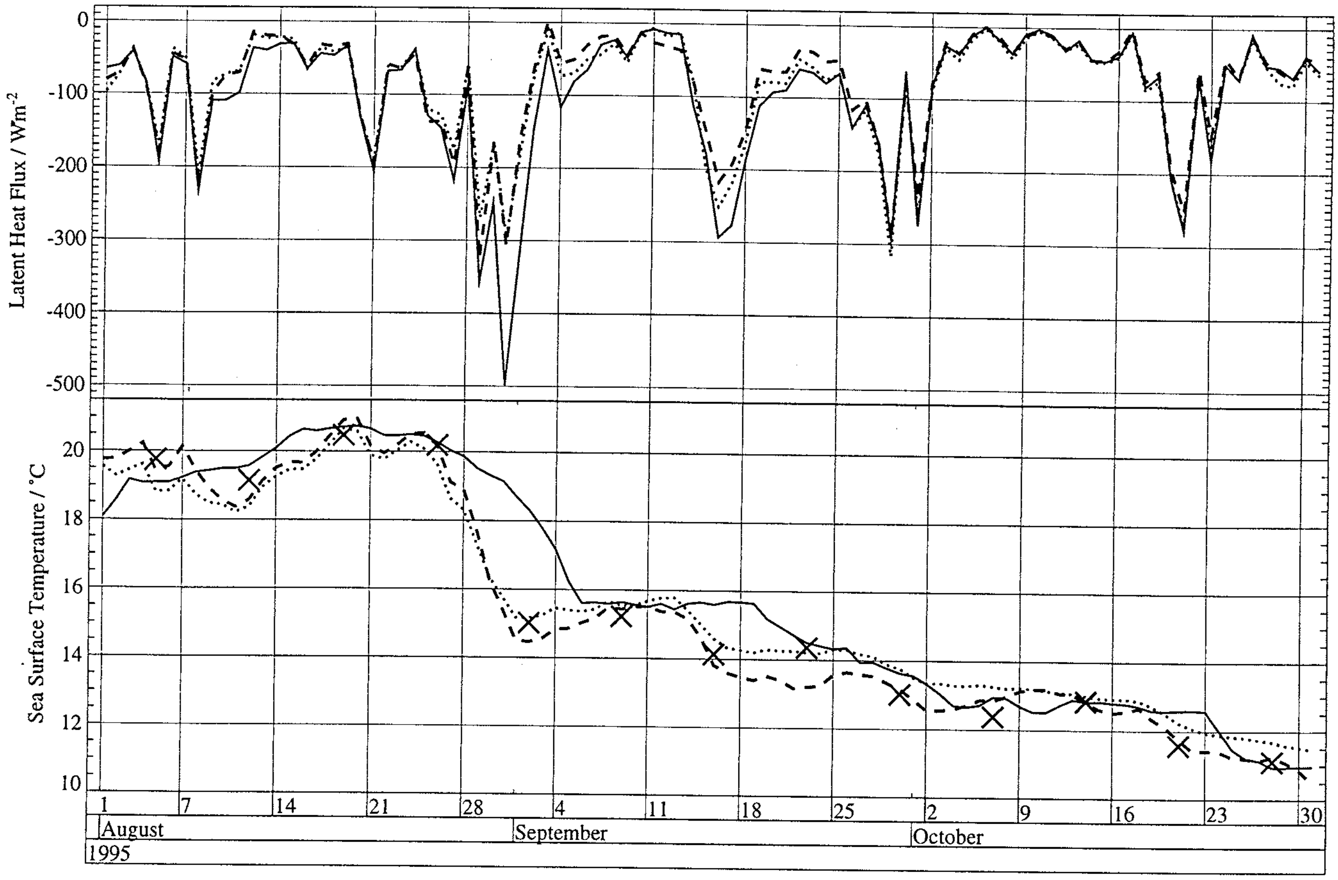

Figure 1: (Lower panel) Sea Surface Temperatures (SST), crosses: satellite observed SST from weekly charts, solid line: SST from DWD analyses (0.5° EM), dotted line: SST from BSMO (forced by REMO) dashed line: SST from the coupled run. (Upper panel) REMO calculated latent heat flux (LHF) mean over 6:00 to 12:00, solid line: LHF from the first run with DWD-SST, dotted line: LHF from the second run with BSMO-SST, dashed line: LHF from the coupled run. All values are means over a 1° × 2° *wide region in the eastern Gotland Basin.*

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NOPEX and WINTEX - Achievements and future plans

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The importance of the northern hemisphere boreal forest zone and its interaction with the climate system is well recognised today. Uncertainties in our knowledge concern, e.g., the role of the forest in the global carbon balance, it's hydrology and it's exchanges with the atmosphere. The size of it's vegetation, the structure of it's soils, the presence of wetlands and lakes, and the harsh winter climate make studies of boreal forests difficult and resource-demanding. IGBP-BAHC has, thus, prioritised studies to be carried out within two large-scale boreal land-surface experiments, NOPEX in northern Europe and BOREAS in north America.

The NOPEX project is concentrated on measurement efforts in the first phase. Modelling and analysis is gradually taking over as time progresses. Measurement activities are focussed on two goals. One goal is to secure intensive measurements of fluxes and states over many years. This is carried out within the Continuous Climate Monitoring (CCM) programme. An other goal is to increase knowledge about agreggation of sub-grid-scale processes to scales relevant for modelling of heat, water, and carbon budgets in meso- and larger-scale models. Measurements required to meet this goal are carried out within time-limited Concentrated Field Efforts (CFEs). Modelling and analysis activities are carried out in two main groups depending on scale. Local-scale process studies focussing on SVAT (Soil-Vegetation-Atmosphere Transfer) modelling are made to increase our knowledge about specific processes of importance in the boreal landscape, e.g., the net carbon flux as depending on photosynthesis and transpiration, the importance of rain and snow interception on latent and sensible heat fluxes to the atmosphere. Regional-scale studies are aimed at the modelling of atmospheric and hydrologic phenomena based on data from a range of scales and coverages. The use and development of remotely-sensed satellite data is a key element in these studies.

The NOPEX project launched it's first concentrated field effort (CFE1) in May-June 1994. During CFE1 around 100 researchers from 15 different countries worked within the NOPEX region around Uppsala, Sweden. This region is characterised by a large degree of patchiness, with a dominating forest cover interspersed with small and large patches of agricultural land, wetland, and lakes. Activities during CFE1 included many stations for fluxes of water, heat and carbon dioxide, synoptical runoff measurements, airborne flux measurements and a set of remote sensing activities, both airborne and ground-based. The second CFE took place in April-July 1995 and attracted more than 100 researchers from 22 countries. CFE1 and CFE2 were intended to study processes relevant for spring and summer conditions. They were also aimed at educating a new north-European science community with a capacity to further develop and work together in a format which was originally defined by the HAPEX-Mobilhy experiment in southwest France in 1986.

Long-term measurements of surface states and fluxes at an agricultural (the Marsta Meteorological Observatory, MMO) and a forest site (the Central Tower Site, CTS, at Norunda Common) have been conducted in the NOPEX region since spring 1994. Besides "traditional" measurements of states in the soil, vegetation, and lower part of the atmosphere, flux measurements within the CCM programme has become a pioneering undertaking followed by international network programmes like EUROFLUX, MEDIFLUX, and AMERIFLUX. The radiometric station at MMO is one of the best equipped in the Baltic Sea catchment area. Four small catchments are instrumented in order to allow careful determination of the hydrological balance as well as the study of scale aggregation in hydrological modelling.

Data from the CCM and CFE programmes are all stored in the System for Information in NOPEX (SINOP). This database, which is available online over Internet, can be accessed by Principal Investigators (PIs) within NOPEX. A carefully elaborated data policy has been set up to meet the needs both of researchers who want unrestricted access to data and the data owners (many of them PhD students) who want to be the first to publish results from the measurements. Data from CFE1 and CFE2 will be released for public use on 1 January 2000 or slightly before as an integrated part of the NOPEX Special Issue of *Agricultural and Forest Meteorology*, scheduled for sale in late 1998 or in 1999.

A second phase of NOPEX was opened with the WINTEX project. WINTEX is a EU-funded project aiming at the planning of a coming full-scale winter CFE sometimes in 1999/2000 or 2000/2001, i.e., coinciding with the BALTEX BRIDGE period. The WINTEX planning project includes modelling, remote-sensing, and development of measurement techniques. Two different types of winter conditions have been identified as important to follow. Winter weather, i.e., below-zero temperatures and continuous snow cover allows for studies of soil freezing, snow metamorphism, stable boundary-layer conditions with strong temperature gradients close to the surface. Such conditions can only be met far north and NOPEX has, thus, extended its coverage with a northern region centred on the Sodankylä Meteorological Observatory (SMO) in north Finland, representing the northern edge of the boreal forest zone. Winter weather further south are more commonly represented as a long series of alternating snow and bare-ground periods. The dynamics of these periods and the large amounts of released and captured latent heat in their transition phases are difficult to handle in present-day hydrological and meteorological models. Investigations in the southern (and original) NOPEX region is ideally suited to study such conditions.

A pilot CFE (CFE3) was carried out in Sodankylä and Uppsala in March 1997. The aim of this CFE was both to get a first set of data to test various models during winter conditions and to evaluate the suitability of various equipment and measurement methods during variable and severe winter conditions. Continuous measurement of radiative and convective fluxes were carried out with enhanced control and maintenance as part of the established CCM programme at MMO and CTS in the southern NOPEX region. The basis for a new CCM station was established at SMO in the northern NOPEX region. New techniques of specific interest during winter conditions included scintillometry, LIDAR and continuous, unattended measurement of snow depth and temperature profile. Special efforts were undertaken at MMO and CTS to automate quality control with the aim of minimising the need for human intervention in the measurements. Such interventions are difficult and sometimes impossible during winter and must be limited as far as possible to guarantee unbroken data series. Since weather is unpredictible beyond a week's time and most experiments require much longer lead time, unbroken, longterm measurements is the only means to capture seldom occurring weather events which may have a major importance for energy and water balances at the surface. Airborne measurements were also undertaken during CFE3 both in the southern and the northern NOPEX region. The airborne activities were coordinated such that also a

BALTEX experiment in the Bothnian Bay could benefit from the presence of the British Met Office C-130 research aircraft.

Modelling and analysis activities in NOPEX is presently gaining momentum, primarily on the basis of results from the CFEs and the CCM program in 1994-96. Individual achievements have resulted in a series of PhD dissertations and a rapidly growing number of papers in the international literature. Highlights in achievements up til early 1998 are, e.g., the discovery of the boreal forest as a net source of carbon dioxide, extension of the Monin-Obukhov theory to profiles in the roughness sublayer above a forest, identification of the 1-km-scale as a meaningful distance where soil moisture can be aggregated to a grid average with remaining physical significance, the dominating influence of the forest cover on the aggregated fluxes of heat and water vapour from a terrain of mixed fields and forest. Work has started on the full two-way coupling of a hydrological regional-scale model and an atmospheric meso-scale model and efforts are done to provide useful algorithms for microwave satellite sensors (which can used independently of cloud cover and insolation). Bogs and lakes, which are specific landscape elements in the boreal zone have been studied to show their influence on aggregated fluxes and states at scales where such elements can not be resolved.

QUANTIFICATION OF CONVECTION FROM GRIDSCALE BUDGETS

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1 Introduction

A goal of BALTEX is to quantify the processes establishing the water and energy cycle in the atmosphere over the Baltic Sea's catchment. Convection is an important process as it establishes an interaction between different scales and as it is not routinely measured.

2 Method and Results

Our method of diagnosing convection (DIAMOD) is to quantify the sub-gridscale process by the necessity of a closed budget for each grid-box. We describe convection in terms of the vertical eddy flux $c(p) \equiv \frac{c_p}{g}\overline{\vartheta'\omega'}$ of equivalent temperature ($\vartheta = T + c_p^{-1}Lq$). We use the analyzed fields of the ECMWF on a scale of 50 km, 50 hPa and 12 h.

Fluxes retrieved from analyzed fields of the Deutschland-Model of the DWD will be compared with those gained from data of the ECMWF. Results of DIAMOD (ECMWF) will be presented for the PIDCAP period. Typical convective situations can be identified: Convection penetrating most of the atmosphere, stratiform precipitation or convection in the boundary layer. Fig. 1 shows the increase of deep convection during the PIDCAP-period, while the number of boundary layer like situations decrease. Averaged columns are shown in Fig. 2. Only 16 % of the columns are either unclassified or had to be rejected because of bad data.

3 Acknowledgments

This work has been financially supported by the EC Environment and Climate Research Programme (contract ENV4-CT95-0072, Climatology and Natural Hazards) and by the Austrian Ministry of Science, Transport and Art. The Central Institute for Meteorology and Geodynamics, Vienna, provided the synoptic data. Further thanks go to ECMWF for providing access to its data base.

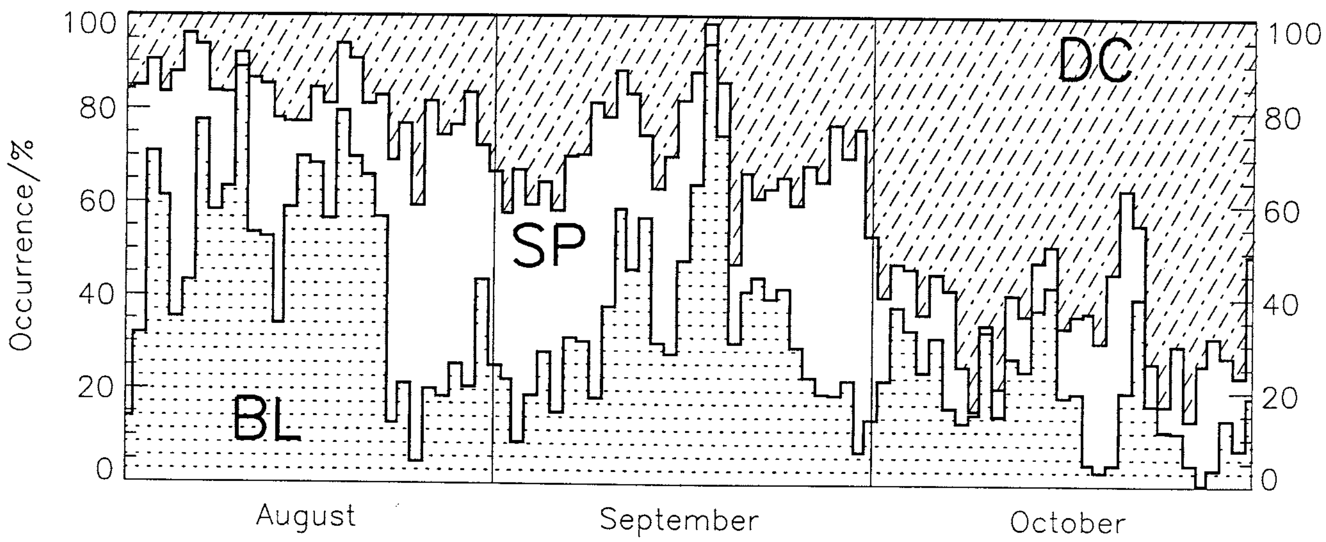

Figure 1: Timeseries of relative occurrence for three types of convection: Boundary layer (BL), stratiform precipitation (SP) and deep convection (DC). PIDCAP-Period 1. Aug - 31. October 1995; 12 UTC ± 6h; drainage basin of the Baltic Sea.

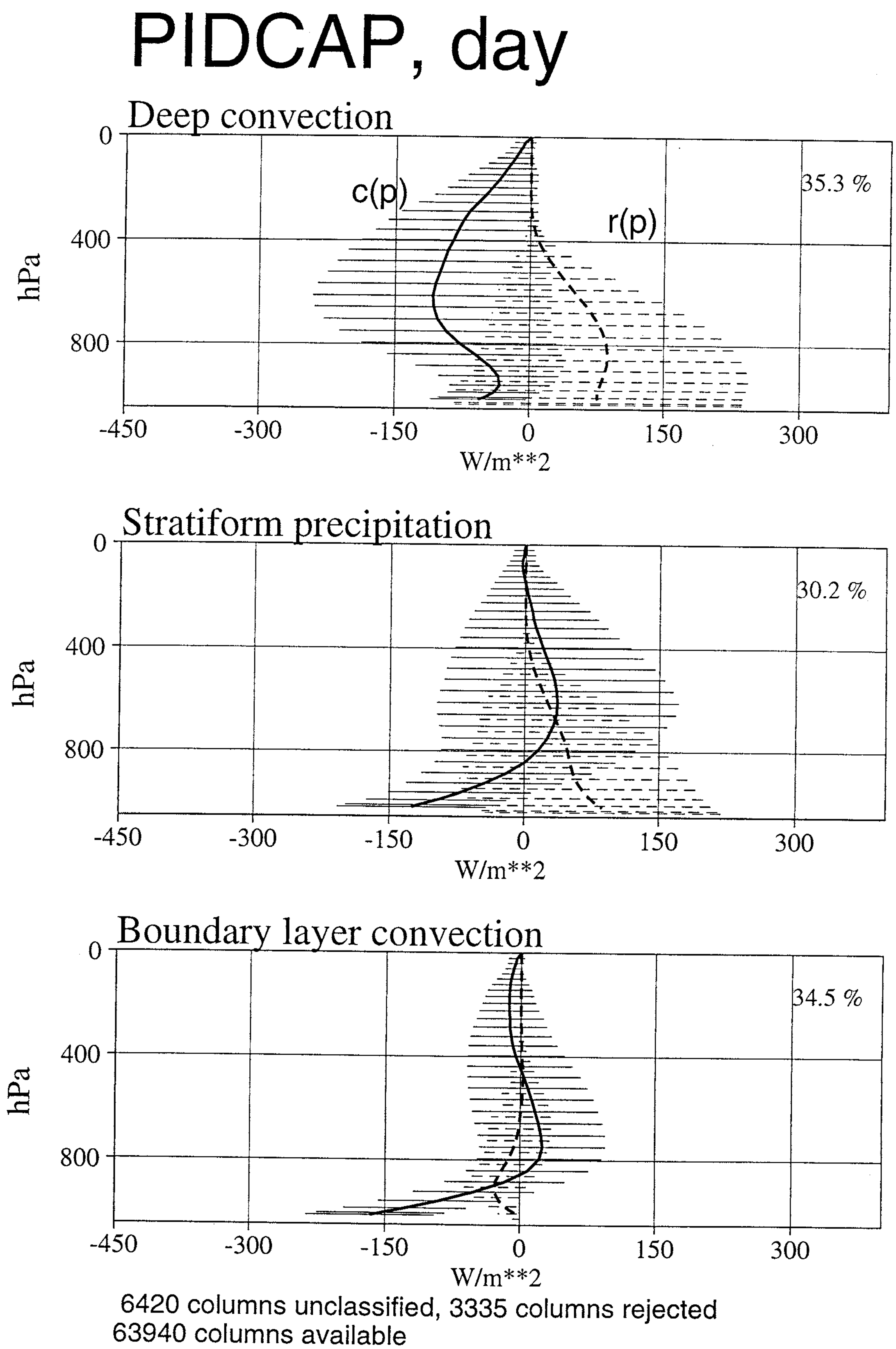

Figure 2: Classified types of convection for the PIDCAP-Period for 12 UTC ± 6h as in Fig.1. Plotted are the average profiles of the convective flux $c(p)$ (solid) and of the rain flux $r(p)$ (dashed). Also shown are the standard deviations of the sampling.

ENERGY FLUXES ABOVE A SNOW COVERED SURFACE DURING WINTEX-CFE3 IN SODANKYLÄ

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Background

An intensified effort of atmospheric boundary and surface layer measurements was carried out at the Sodankylä Meteorological Observatory of FMI and at the Uppsala Marsta and Norunda sites in Sweden during 12-26 March 1997 as part of the WINTEX project and the NOPEX programme. The field experiment was third in the series of NOPEX concentrated field efforts (CFE's) of which the two former had been carried out in 1994 and 1995 during May-June-July in Uppsala.

The objective of the winter campaign was to test various measurement methods and techniques for the establishment of a full scale winter campaign in 1999-2001 adjoint with the BALTEX Bridge experiment. The data can be also used to test parameterisations of the winter time atmospheric boundary layer in numerical weather prediction or climate models. Measurements were also used to test parameterisations of the thermodynamic processes in snow hydrological models.

Measurements

The experimental measurements at Sodankylä co-ordinated by the FMI consisted of the vertical temperature profiles within and just above the snow pack, PTU soundings launched every three hours at synoptic observation times, cloud detection with a Vaisala LIDAR CT75K ceilometer, surface solar and terrestrial radiation components. Also other measurements belonging to the routines of the observatory were benefited. In addition, a group of the Risø National Laboratory from Denmark and of the Defence Research Establishment Division of NBC Defence in Umeå from Sweden operated an instrument mast with four fast response sonic anemometer-thermometers placed at 3, 6, 12 and 18 m heights and an open path IR-analyser for water vapour fluctuations placed at 18 m above the snow surface. The group from the Agricultural University of Wageningen performed sensible heat flux measurement with a wide aperture bichromatic scintillometer.

The snow micrometeorological measurements consisted also of manual determinations of the vertical distribution of snow liquid water content made at a few day intervals depending on the occurrence of rain/snow and snow melt. Snow micrometeorological measurements were extended until end of the existence of snow cover (May).

The newly introduced Vaisala CT75K Lidar ceilometer was tested for continuous monitoring of the cloud base height and cloud depth. . The signal was also analysed to see whether the height of inversion could be detected. The device was rented from the Vaisala Inc. for use during the intensive period of CFE3 and operated continuously at Sodankylä with a recording interval of 15 min. The ceilometer data on cloud height were verified against the 3-hourly PTU-soundings.

A significant component of WINTEX was the airborne measurements with the Hercules C-130 aircraft, operated by the UK Met. Office Meteorological Research Flight and funded by the Training and Mobility of Research Programme of the European Commission within the framework of the STAAARTE project. A total of about 24 effective flight hours was dedicated to WINTEX in March 1997 in the Uppsala and Sodankylä regions. The C-130 was fully instrumented for the measurement of the chemical composition and physical structure of the atmosphere as well as for the remote sensing of the properties of the terrain surface.

Results

Two point models with different snow process representations were tested to assess the necessary level of complexity to compute radiative and turbulent energy fluxes at the snow surface. UEB (Utah Energy Balance Snow Accumulation and Melt model) was chosen as a simple modelling approach, which derived the relevant energy fluxes at the snow/air interface but treated the snow pack as one layer. SNTHERM represented a sophisticated model to simulate mass and energy transfer in detail at the snow pack boundaries and within the snow cover. The performance of the UEB was checked against both the measurements and the results of the SNTHERM, which was also tested using the information on internal snow cover properties. The eddy correlation measurements by other project groups on the turbulent energy transfer were used to check the modelled fluxes.

The one layer UEB-model showed reasonable performance for the overall mass and energy balance during the spring 1997 after the parameters of the albedo procedure were adjusted for snowmelt conditions. The latent heat flux calculated by the UEB was close to the measured flux and the SNTHERM results. The modelled sensible heat fluxes deviated slightly from each other, and from the measurements; during day time the measured upward sensible heat flux at three meter height above snow was larger than the modelled heat flux, Figure 1. This was due to the additional solar heating on coniferous trees not accounted for by the model parameterisation. The latent heat flux measured at 18 m height above snow agreed very well with the measured flux except for the periods of snow fall. Overall the correspondence between the calculated and eddy-correlation based measured estimates of latent and sensible heat exchange over snow and under strong inversion was very good considering the small values of the fluxes and difficult conditions for the measurement.

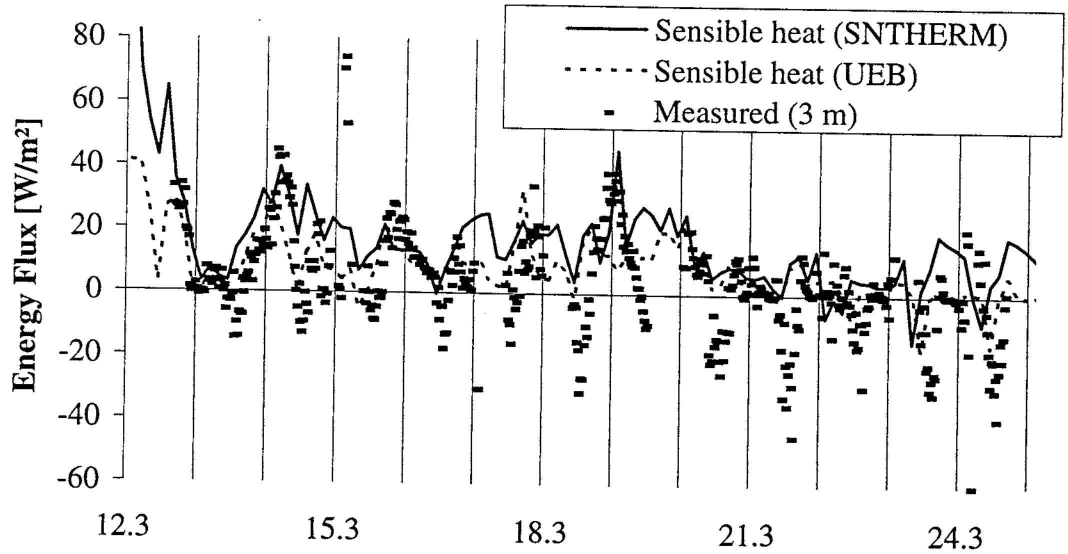

Figure 1. Sensible heat flux (negative values indicate an upward flux) above a snow covered surface at Sodankylä during WINTEX-CFE3 in March 1997. Measured fluxes were obtained with the eddy covariance technique by the Risø National Laboratory, Denmark, and the Defence Research Establishment Division of NBC Defence in Umeå, Sweden. The a sonic anemometer-thermometer at a 3 m height above snow was used. Modelled fluxes were calculated for pure snow surface while the measured heat fluxes included an additional contribution due to solar radiation heating the sparse coniferous forest during mid day hours.

The climate of short-range predictions with the Europa-Modell compared to observations

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Almost six years of monthly mean atmospheric water and energy budgets averaged over the BALTEX region based on short range (6h to 30h) numerical weather predictions with the Europa-Modell of the German Weather Service are available. Additionally, monthly mean fields of surface and TOA energy fluxes as well as surface water fluxes are available for most of the time. Whereas the results of the first half of the period (February 1992 to May 1994) suffer from some major model changes, in the following period a fairly stable model version was used operationally.

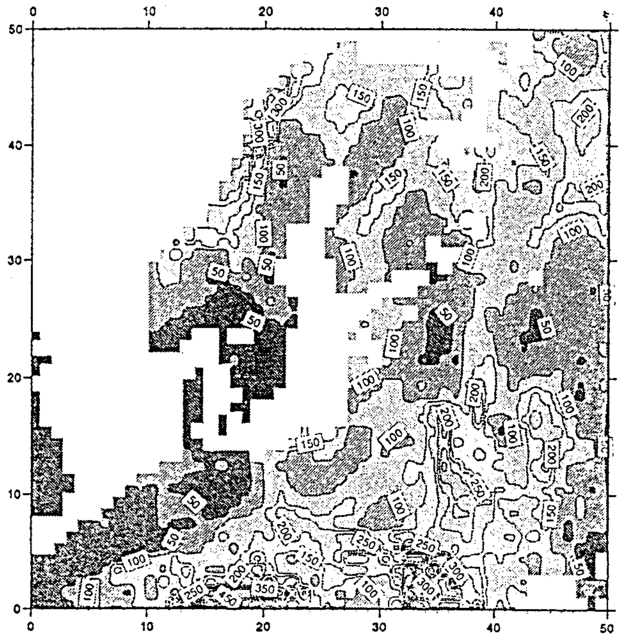
The model climate will be presented. Part of the model results will be compared to the respective observations available. The ability of the forecast model to cope with observed annual and regional variations will be investigated on the basis of monthly mean data.

As a preliminary example, Figure 1 a) - c) shows the distribution of model precipitation for August, September and October 1995 (PIDCAP) for the land areas of a region slightly larger than the BALTEX area. Compared to preliminary precipitation distributions presented by Rubel (1996) the Europa-Modell is able to simulate the main regional differences quite well. Some remarkable examples are the dry regions in southern Scandinavia and northern Sweden in August (Fig. 1a)). In September (Fig. 1b)) again northern Sweden shows low precipitation amounts, whereas high precipitation amounts are observed and simulated in southern Scandinavia and the eastern parts of Poland. Northern Sweden, Poland, and northern Germany are generally dry in October (Fig. 1c)), whereas higher precipitation amounts in the BALTEX-region are confined to northern Finland.

Other elements to be compared are the evaporation distribution over the Baltic Sea and the soil water content in regions, where measurements are available.

Reference: F. Rubel, 1996: PIDCAP Quick Look Precipitation Atlas. Zentralanstalt für Meteorologie und Geodynamik, Wien, Publ. Nr. 374, 97 pp.

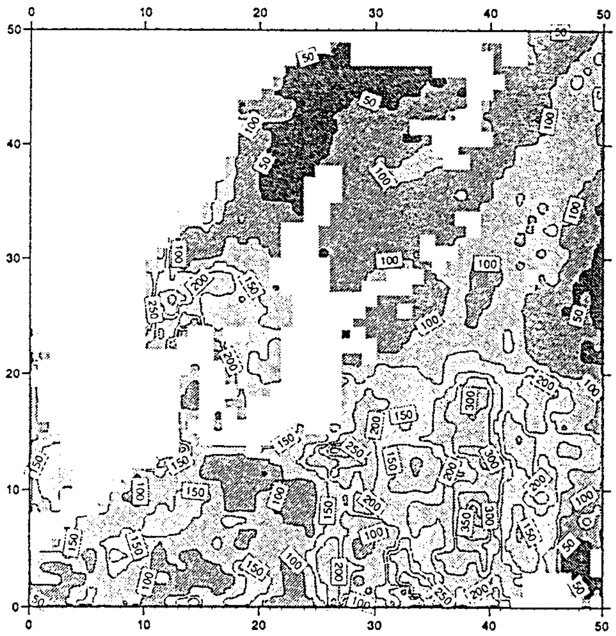
Figure 1: Monthly precipitation (mm) simulated by the Europa-Modell of the German Weather Service



Total Precipitation (mm)

1 - 31 Aug 1995

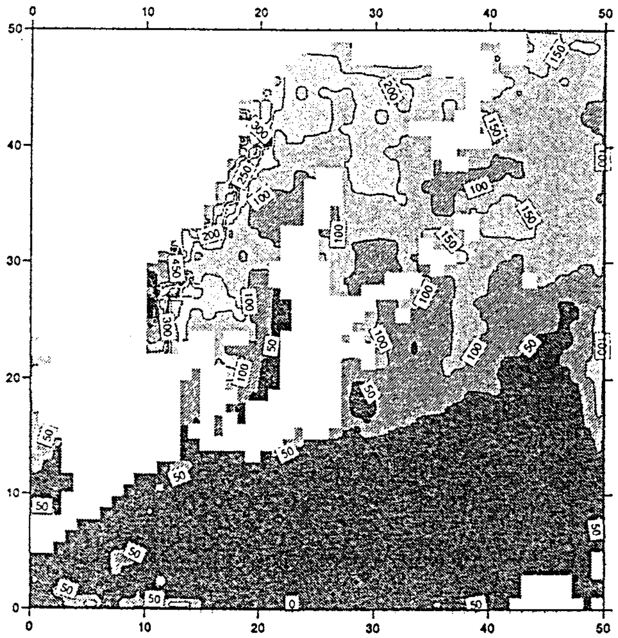
Fig. 1a



Total Precipitation (mm)

1 - 30 Sep 1995

Fig. 1b



Total Precipitation (mm)

1 - 31 Oct 1995

Fig. 1c

Heating of the upper layer of the sea: a case study

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Heating of the upper layer of the sea was investigated in the Baltic Sea Proper on the eastern coast of Gotland as a by-product of a pilot experiment of DIAMIX-project, a sub-project of BALTEX. Two hydrographic sections out from the coast of Gotland were observed with three days intervals three times (5, 8 and 10 of June 1997). Heat content of the upper 50 m layer, that represents the layer above the cold winter water, was calculated and the increase of the heat content between the surveys was computed. The weather situation during the cruise was exceptionally stable with continuous sun shine, no clouds and average wind speed 4.5 m/s from east-south-east with only minor variability. The temperature profiles in the sea had large vertical gradients in the very surface showing strong surface heating and very weak mixing. In such exceptionally calm and sunny conditions the solar radiation seems to explain much of the increase in heat content of the upper layer of the sea. The role of advection seemed to be relatively small. The measured mean current speed from moored observations during the experiment was about 5 cm/s. The role of turbulent heat fluxes on the heat budget was minor. The sensible heat flux varied in direction and the latent heat flux was small, too.

Sea ice concentration at the Baltic Proper - A digital 1° data set for 1964 to 1995

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Introduction

Under present climate conditions sea ice is forming at the surface of the Baltic Sea in every winter. Both the regional extent and the length of the ice seasons show large interannual variations (e.g. Seinä and Palosuo 1993). Even during mild winters at least parts of the Bothnian Bay and the Gulf of Finland are ice-covered, while during extremely severe ice winters almost the entire Baltic Sea may freeze at its surface. The presence of sea ice influences the physical conditions at the air-sea interface, in particular the vertical fluxes of heat, momentum and matter. Hence, knowledge of the regional distribution, the type and the time-evolution of the sea ice is required for calculation of in particular the energy- and water budgets of the Baltic Sea. In particular for long-term climatological budget studies digital sea ice data sets are required in order to e.g. correct air-sea heat fluxes (both turbulent fluxes of latent and sensible energy, and radiation fluxes).

At present the only digital climatological sea ice data set known to the author exists for the period 1963 to 1979. This data set has been used e.g. for the establishment of a comprehensive ice atlas of the Baltic Sea (SMHI and FIMR 1982). Unfortunately the digital version of this data set has been found out to be difficult to access. Hence, in the course of a project on estimating heat fluxes at the surface of the Baltic Proper a sea ice data set for this part of the Baltic Sea has been digitised based on routine ice maps. This data set is now available in computer-readable format.

The digital data set

Routine SST and ice maps for the Baltic Sea published twice-a-week by the Swedish Meteorological and Hydrological Institute (SMHI) have been used for creation of the digital sea ice data set. Only the Baltic Proper (Figure 1) has been included so far and the 32-years period 1964 to 1995 has been considered. The establishment of the digital data set was done manually by overlaying a 1° latitude/longitude gridnet on top of each individual ice map and estimating the area covered by ice within each 1° gridbox. The Baltic Proper covers 45 different 1° boxes or parts of them (Figure 1). The ice-covered area is expressed in percentage units (ice-covered area divided by total area) and has been estimated with a precision of 10 % within each gridbox. This quantity is referred to as ice concentration in the following. The different ice types indicated in the maps are considered and both the total and the effective ice concentrations were computed using mean effective ice concentrations given in the SMHI maps.

In the Baltic Proper sea ice occured during 21 winters in the period 1964 to 1995 (Figure 2). 439 individual SMHI ice maps from these 21 years were digitised. Hence, the basic form of the data set includes total and effectice sea ice concentrations for 45 grid boxes in the Baltic Proper for as much as 439 ice maps, which cover 21 ice winters in the period 1964 to 1995.

The data set has been used e.g. for correcting evaporation estimates based on ship observations in the Baltic Proper (Isemer and Lindau 1998, this volume). Examples of the sea ice development in individual years as well as results of a comparison with data from Seinä and Palosuo (1993) and investigations on the relation of maximum ice concentrations to air temperature over the Baltic Sea will be shown at the conference.

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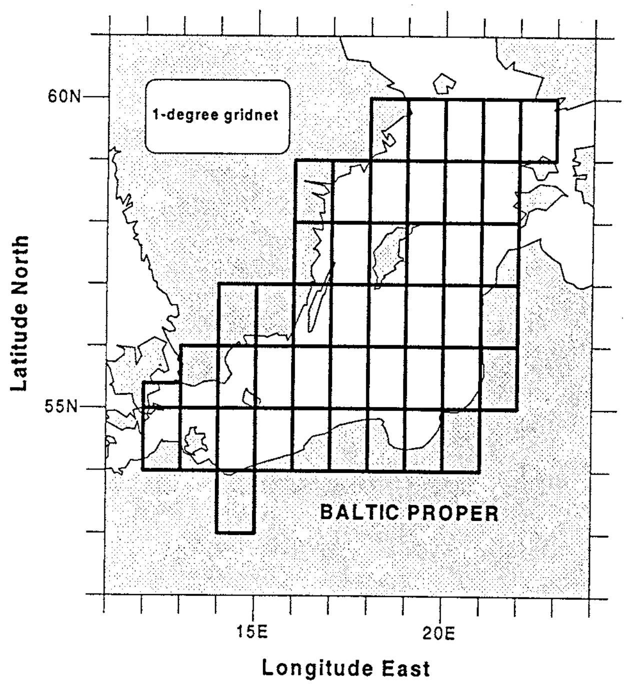

Figure 1: 1 degree latitude/longitude gridnet of the Baltic Proper area covered by the digital sea ice data set.

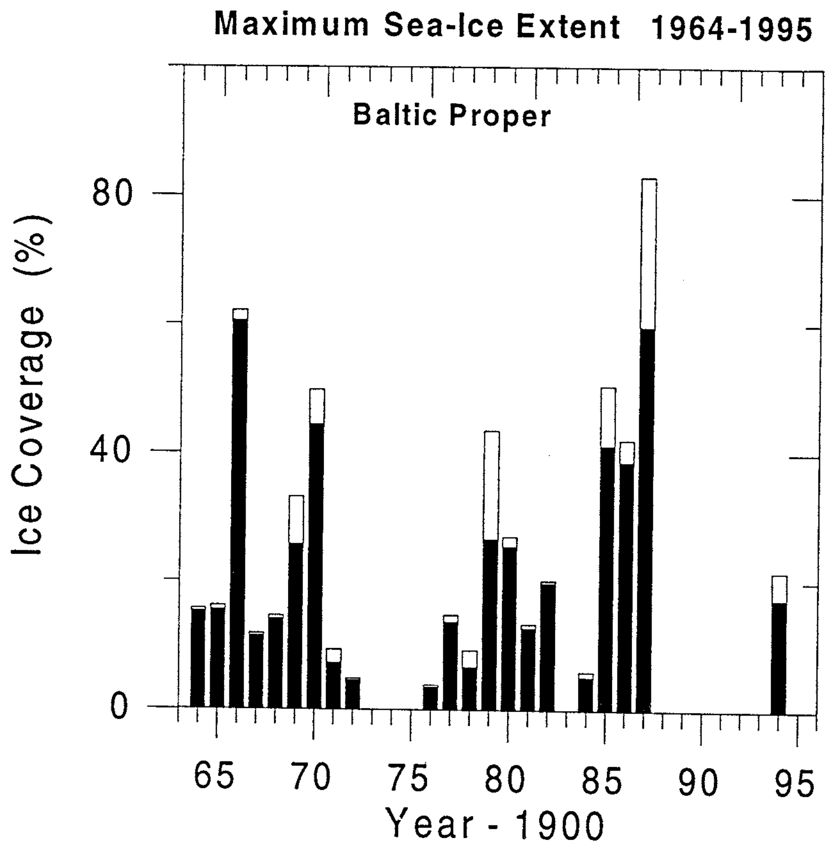

Figure 2: Maximum effective (black columns) and total (black and white columns) sea ice concentration for the Baltic Proper during the period 1964 to 1995 based on the digital sea ice data set.

Climatological estimates of precipitation and evaporation over the Baltic Proper based on COADS

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Introduction

Weather observations and measurements made aboard of voluntary observing ships (VOS) have frequently been used to estimate water and energy budgets over the global ocean or parts of the latter. For climatological investigation of these budgets on time scales of decades up to a century VOS reports are the only area-covering source of information from the open ocean. A portion of the COADS data set (Comprehensive Ocean-Atmosphere Data Set, see Woodruff et al., 1987) covering the time period 1964 to 1995 is used here in order to estimate the water balance (evaporation and precipitation) at the surface of the Baltic Proper.

Evaporation

Evaporation is calculated by applying a bulk formula to VOS measurements of sea surface temperature (SST), air- and dewpoint temperature, air pressure and wind speed. The individual approach is applied, that means, evaporation is calculated for each individual set of observations within a VOS report. Various schemes for the bulk transfer coefficient have been suggested during recent years. For this study we rely on those of Large and Pond (1982). Evaporation estimates are corrected in the presence of sea ice using a recently established sea ice data set (Isemer 1998). Measured quantities aboard of VOS are subject to measurement biases and uncertainties some of which have recently been explored with more detail. Corrections of these biases are considered in the present study and include

- the application of a revised Beaufort equivalent scale to wind speed estimates (Lindau 1994),
- the correction of SST measured by intake thermometers (Kent et al. 1993),
- the correction of a radiation bias of both air- and dewpoint temperature as a function of solar radiation and wind speed (Kent et al. 1993).

The net effect of these corrections is an increase of evaporation of order 10 % in the long-term annual mean compared to the uncorrected estimates. Details will be given at the conference. One remarkable result with respect to evaporation is the east-west difference of evaporation across the Baltic Proper (Figure 1) of order 25 % in the long-term annual mean. This feature is mainly caused by the configuration of the SST and air-temperature fields.

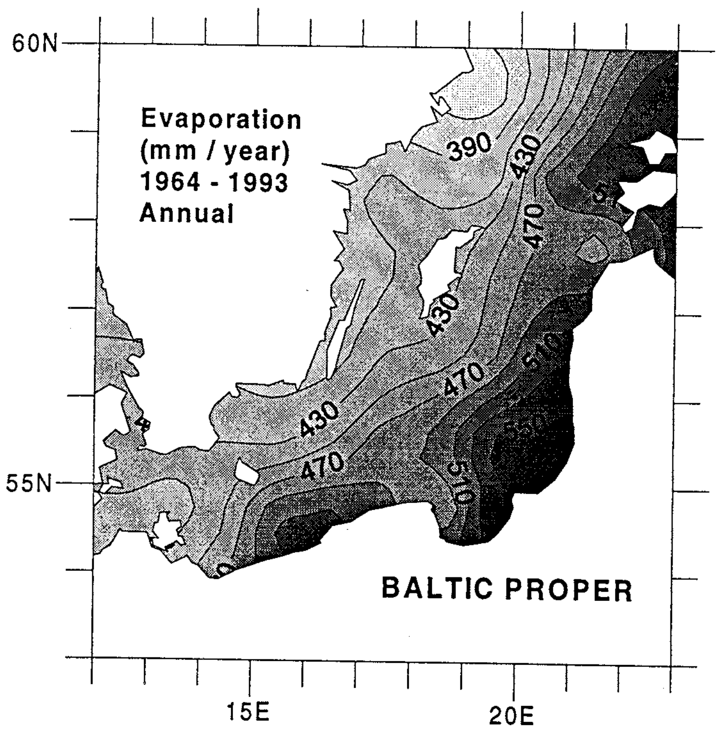

Figure 1: Regional distribution of annual evaporation in the Baltic Proper 1964 to 1995 (mm/year).

Precipitation

In order to utilise the considerable amount of marine observation from VOS a simple rain algorithm has been derived which uses only the operationally ship-reported meteorological parameters. This method is based on earlier studies by Tucker (1961) and Dorman and Bourke (1978). For the derivation of the algorithm we used daily rain measurements from 24 years aboard of stationary light ships in the German Bight. These vessels were equipped by a conical marine rain gauge exerting only a small flow distortion (Schmidt 1990). Nevertheless, we corrected the unavoidable underestimation of rain amount due to high wind speeds by a formula adopted from Hasse et al. (1997). In our algorithm the monthly mean precipitation is obtained as a function of only two weather code observations: the present weather (ww) and the specific humidity. Applying our algorithm on the light ships' weather and humidity reports, more than 70% of the interannual variability and 96% of the annual cycle's variance can be explained (Figure 2). Global application of this algorithm leads to a good agreement with satellite estimates and reasonable results compared to calculations of evaporation.

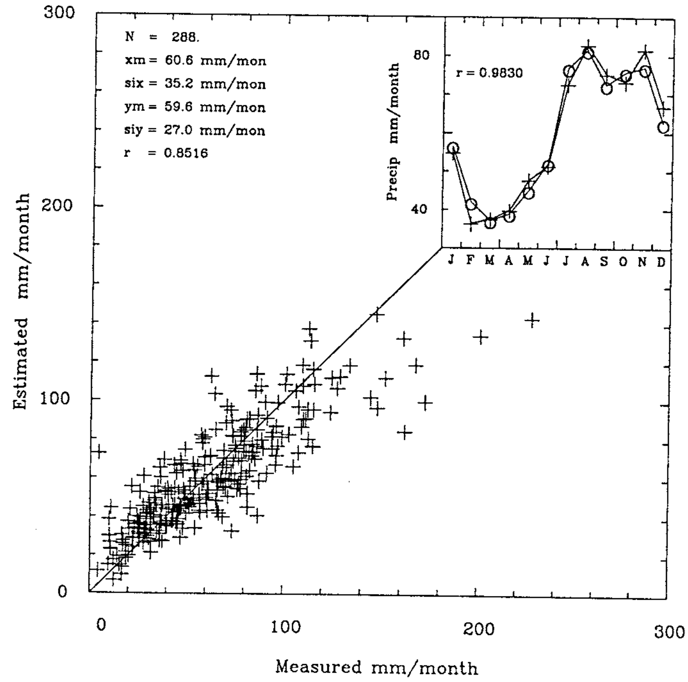

Figure 2: Precipitation for individual months from 1949 to 1972 in the German Bight. Measurements from light vessels are compared to results of the rain algorithm applied to light ships' weather observations and humidity measurements. Small upper right figure gives estimated (O) and measured (+) monthly precipitation averaged over the 24-years period.

The climatological results for evaporation E, precipitation P, and P minus E over the Baltic Proper including measures of seasonal and interannual variability will be presented and discussed at the conference. From the precipitation records established in this study it appears that during the decade of the 1980s the Baltic Proper has received more precipitation than before and in the early 1990s. This causes a change in the sign of P minus E leading to a slightly positive budget for e.g. 1981 to 1994 (Figure 3) but a negative one for e.g. 1964 to 1979.

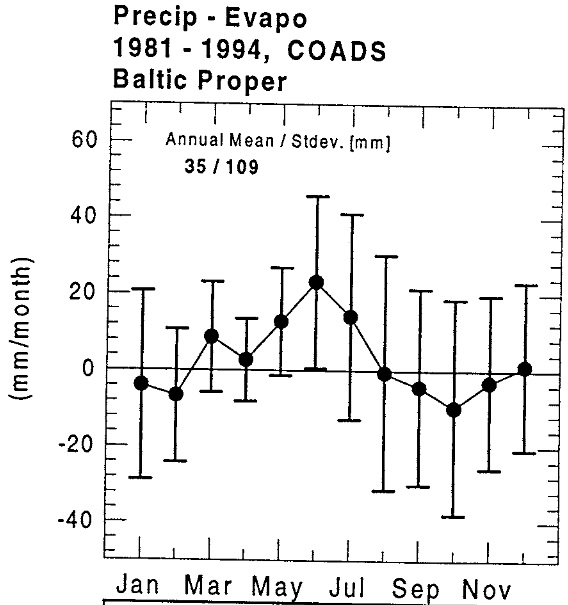

Figure 3: Annual cycle of precipitation minus evaporation at the surface of the Baltic Proper during 1981 to 1994 (mm/month). Vertical bars indicate the standard deviations of the individual monthly means. The long-term annual mean is only 35 mm with an interannual standard deviation of 109 mm.

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The water balance at the surface of the Baltic Proper - Comparison of observations and model results

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Introduction

Analysis of the climatological budgets of evaporation and precipitation at the surface of the Baltic Sea is an important component of the BALTEX research program. Together with the river runoff to the Baltic Sea these two quantities determine the net outflow from the Baltic Sea catchment to the North Atlantic Ocean. Both quantities are not measured over the Baltic Sea except during specific, short-time field experiments. In particular climatological information including average values and measures of seasonal and interannual variability is difficult to establish and has to be taken from either application of parameterisations to basic in-situ observations or model results. Recent progress in obtaining both quantities from remote sensing data are promising, however, reliable data sets from satellites and weather radar are too short in general to derive climatological information. The purpose of this study is to compare two different climatological data sets of evaporation and precipitation, which have recently been established in the frame of BALTEX, with results of a global climate model. The following three compilations are included in this study:

- meteorological observations onboard of voluntary observing ships from COADS,
- model results from the Baltic Sea model PROBE-BALTIC (SMHI-97),
- model results from the global climate model ECHAM4-T106.

Both the COADS and SMHI-97 results cover the period 1981 to 1994 while the ECHAM4-T106 data cover a 10-years period with realistic sea surface temperature (SST) forcing data from 1979 to 1988.

COADS

Probably the most comprehensive data set of meteorological standard observations from voluntary observing ships (VOS) is the Comprehensive Ocean Atmosphere Data Set (COADS, see Woodruff et al. 1987). The VOS data coverage of COADS is sufficient in the Baltic Proper and the western Baltic Sea while too few observations are available in e.g. the Gulf of Finland and the Bothnian Sea in order to derive reliable climatological estimates. This limitation confines the present comparison to the Baltic Proper. Evaporation is calculated using a bulk formula dependent on SST, air temperature t_a , dewpoint temperature t_d and wind speed u. Wind speed and stability-dependent transfer coefficients of Large and Pond (1982) are used and the individual approach is applied, that means, evaporation is calculated for each individual set of observations (SST, t_a, t_d, u). Evaporation estimates are corrected in the presence of sea ice (Isemer 1998). Precipitation is derived from the present weather observations (ww) and t_d of the VOS reports. This method is based on Tucker (1961), who suggested to use ww for rain estimates, and further developments by Dorman and Bourke (1978). The parameterisation used here was derived from simultaneous precipitation measurements and ww observations on light vessels in the German Bight (Isemer and Lindau 1998). COADS provides for observations and measurements from the open Baltic Sea with, however, a somewhat random distribution in both space and time.

ECHAM4-T106

The global climate model ECHAM4 (Roeckner et al. 1996) has been integrated for a 10 years long climate simulation on a T106 (approximately 1° x 1° latitude/longitude) resolution. Monthly mean SST based on ship observations were used to drive the model for the period 1979 to 1988 (Gates 1992). Evaporation is calculated by using a bulk formula dependent on wind velocity and humidity at the lowest model level as well as the saturation specific humidity at SST and sea level pressure. Stability-dependent transfer coefficients are approximated following Louis (1979). For this study grid points of the Baltic Proper south of 60.5° N are considered.

SMHI-97

An alternative method for calculating the evaporation is to use an ocean model that gives the correct feedback on SST and the sea ice. The Baltic Sea model by Omstedt and Nyberg (1996) has been applied to calculate the evaporation. In the model, the Baltic Sea was treated as 13 sub-basins with high vertical resolution and the evaporation was calculated using a bulk formula and transfer coefficients suggested by Friehe and Schmitt (1976). The model was verified extensively against SSTs, sea ice and vertical profiles of temperature and salinity. Calculated SST and sea ice values were taken from the Baltic Sea model, while the atmospheric data needed in the bulk formula are routine 3-hourly synoptic observations at seven coastal stations. A two-dimensional univariate optimum interpolation scheme using isotropic autocorrelation functions as spatial weights was applied to 12-hourly routine precipitation measurements at land stations and some light vessels around and in the Baltic Sea, respectively, in order to construct 1° x 1° latitude/longitude precipitation fields for the Baltic Sea. Grid-point data over the Baltic Proper from this data set have been extracted and are used in this study. See Omstedt et al. (1997) for results, in particular also for other Baltic Sea sub-basins.

Some Results

Table 1 summarises the long-term budgets and their interannual variability. Mean evaporation as well as the annual cycle (Figure 1) is in good agreement having in mind the completely different data sources, processing procedures and the uncertainties included. ECHAM4 seems to underestimate evaporation in particular during summer months. Noteworthy is however that both SMHI-97 and ECHAM4 indicate a higher interannual variability. The annual cycles of precipitation from COADS and SMHI-97 are in remarkably good agreement while ECHAM4 seems to overestimate precipitation in the long-term mean. ECHAM4 also shows a different annual cycle (Figure 2), which might be related to an unrealistic representation of the Scandinavian orography due to the coarse model resolution. The reason for this discrepancy is currently being investigated. As with evaporation COADS indicates a smaller interannual variability compared to both ECHAM4 and SMHI-97. Further results and implications for e.g. future strategies with respect to the BRIDGE phase in BALTEX will be given and discussed at the conference.

	COADS (1981-94)	**SMHI-97 (1981-94)**	**ECHAM4-T106 (1979-88)**
	Mean / Stdev.	Mean / Stdev.	Mean / Stdev.
Precip.	535 / 123	584 / 74	679 / 79
Evap.	501 / 48	521 / 76	478 / 83
P - E	35 / 109	63 / 99	201 / 93

Table 1: Mean annual sums and standard deviations of the individual yearly sums of precipitation, evaporation and the difference precipitation minus evaporation (P-E) at the surface of the Baltic Proper. Units are mm/year.

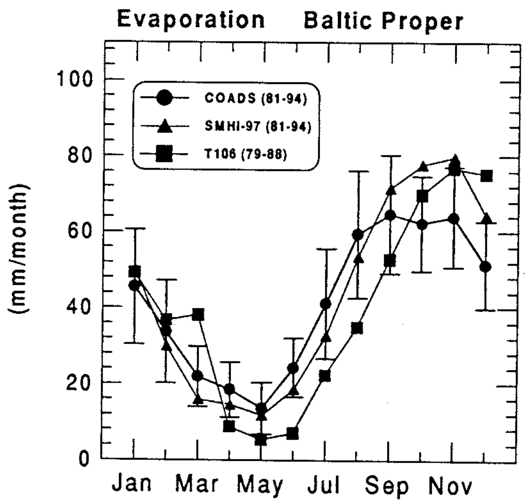

Figure 1: Mean annual cycle of evaporation (mm/month) for the Baltic Proper from the COADS (dots), SMHI-97 (triangles), and ECHAM4-T106 (squares). Vertical bars indicate standard deviations of individual monthly values of the COADS.

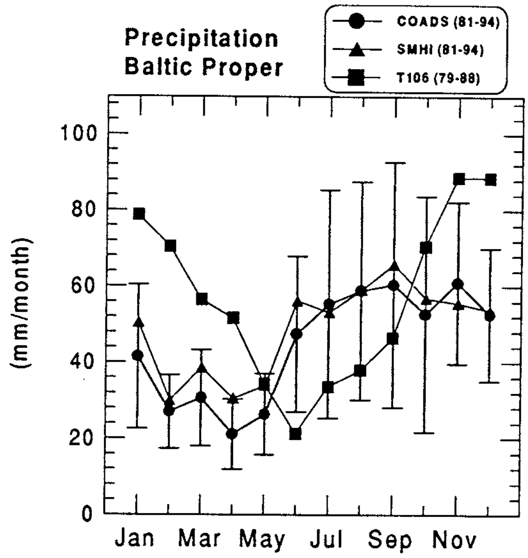

Figure 2: As in Figure 1 but for precipitation.

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VARIATIONS OF STRUCTURE AEROSOLS IN THE BOTTOM LAYERS OF ATMOSPHERE OF SOUTHERN COAST OF A FINNISH GULF

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In the article were shown the results of an experimental research of the quantitative contents and size distribution of aerosol particles in the bottom layers of atmosphere. An influence of the role different factors to formation and evolution of aerosols was considered.

Alongside with consideration aerosolise characteristics, the concentration of elements in tests of atmospheric air (aerosols) and snow were obtained by x-ray fluorescence analysis, is measured also. The measurements included determination of element structure on 20 elements. The analysis of data has shown certain similarity dispersity of aerosols in all points of measurements, influence of antropogeneous sources on change of size distribution of aerosol and element structure of particles.

The cycle of researches was carried out in Petergoff in 1993, 1994, 1996 and in 1997. Data about dispersionary structure are obtained, i.e. function of distribution of particles on the sizes dN/dR for several series of measurements and accounts of distributions of a surface of particles on the sizes dS/dR and volumetric distributions of particles on the sizes dV/dR are spent.

The estimation of the sizes of particles atmospheric aerosols, spent on the basis of experimental data is described bimodal distribution: "thin" fraction (0,4-0,7 mkm) and "coarse" fraction (0,9-4 mkm). Therefore, we can deals with different mechanism of generation of atmospheric aerosols. The first maximum may be connect with particles of a photochemical origin and processes enlargement of a photochemical fraction. Sources these aerosols, mainly, are human activity and transport. By source of other fraction, as the rule, is a spreading surface, mechanisms of destruction of breads (soil erosion) and also industrial dusty aerosols. Analysing experimental curves, it is possible to tell, that the contribution aerosols of the given origin in autumn period of supervision was insignificant, opposite to summer one.

The quantitative contents of aerosols in the bottom layers of atmosphere depends in a greater degree on the local factors. Such factors are sources of particles and climatic conditions of the given district, which define mechanisms of transformation, carry and removal of particles from atmosphere. The aerosol's contents can change owing to processes of carry-directed movement of air weights (advection and convection) and diffusion.

The dependence of concentration and size distribution of aerosol particles from speed of a wind has twice character. On the one hand, at increase of speed of a wind receipt in atmosphere aerosols with spreading surfaces (wind generation), on the other hand grows, growing thus turbulence the exchange of air weights strengthens carry of particles to higher layers atmosphere. This dependence is well observed and for particles with $d < 0,7$ mkm and for $d > 4$ mkm. Large particles sediment at the expense of easing of a turbulence exchange. The maximum of concentration is observed at speed of a wind 2 m/s.

The analysis of curve dependence of distribution of particles on the sizes from temperature for autumn period (1996, 1997) has not revealed certain laws. However, on the diagrams there is the increase of concentration aerosols for average for period of measurements of temperature (6°C). It is possible to explain essential cool in current of period of measurements. There was the reorganisation of temperature stratification atmosphere, owing to that and change of concentration aerosols was observed. Analysing daily average given for summer periods (1993, 1994), increase of concentration aerosols with growth of temperature was found out. This dependence it is possible to explain by amplification convection with growth of temperature, therefore in item of supervision more particles with spreading surfaces heavily act. But it is necessary to take into account, that with increase of temperature rise of aerosolise particles by convective flows and turbulence in higher layers amplifies.

The researches of daily average given and experimental curves have found out increase of concentration aerosols with increase of relative humidity by condensation of growth of finer particles, which being integrated give the significant contribution to generation of particles of the greater size. The reduction of concentration of particles with increase of humidity on experimental curves it is possible to explain by presence of different sources of aerosols: particles of a sea and continental origin. At increase of humidity of a particle of sea salt, i.e. soluble nucleuses turn in drops of a solution. In accordance with further growth of relative humidity their size is increased and they rather quickly fall.

The analysis of a daily course of concentration of aerosolise particles has revealed some rules. It is possible to tell, that in atmosphere natural balance of quantity aerosols is supported: generation particles (morning - midday), drain aerosols for the account sedimentation (evening - night) and capture of aerosolise particles by deposits. Daily course of concentration and size distribution of antropogeneous aerosols mainly is defined by local sources.

In work seasonal variability of the contents aerosols on the basis of average functions of distribution of particles on the sizes in autumn (1996,1997) and summer (1993,1994) periods was considered. In autumn period a maximum in region 0,4 microns is observed. In summer period both the region of 0,4 microns and the region of 0,7-0,9 microns two one we considered In summer period increase of concentration of particles is observed: as first (dispersionary origin), and second (dust, vegetation, products of destruction soil) faction. The autumn period, as a rule, is accompanied by rains, therefore by the reason of low concentration big aerosols consists in delete of aerosols by clouds and deposits.

INFLUENCE OF DIFFERENT PHYSICAL PARAMETERIZATION SCHEMES ON THE WATER AND ENERGY BALANCE OF THE BALTIC DRAINAGE BASIN

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Introduction:
Within the BALTEX (BALtic sea EXperiment) project the hydrological and energetic budgets of the Baltic Sea drainage basin are under investigation with the aim to understand the water and energy cycle more completely. The budgets are influenced by meteorological phenomena on different time and space scales including the range from single episodes to multi year climate simulations. Extremes, interannual and decadal variabilities are of interest.

The atmospheric regional climate model REMO has been used to study the water cycle of the Baltic Sea and its drainage basin. In order to investigate the influence of numerical schemes and physical parameterizations sensitivity studies have been performed for time periods of days, months and years.

REMO has been developed at the Max-Planck Institute (MPI) to simulate regional climate. The model is based on the operational forecast model (EM/DM) of the German Weather Service (DWD). REMO has been extended to allow for alternative use of either the physical parameterization package from DWD or the physical parameterization schemes of the global MPI climate model ECHAM4. Therefore is it possible to compare two physical parameterization schemes within one dynamic framework. The above mentioned physical parameterization schemes differ mainly in the formulation of the parameterization of the soil physics, radiation and vertical diffusion. The convection schemes as well as the cloud physics are similar.

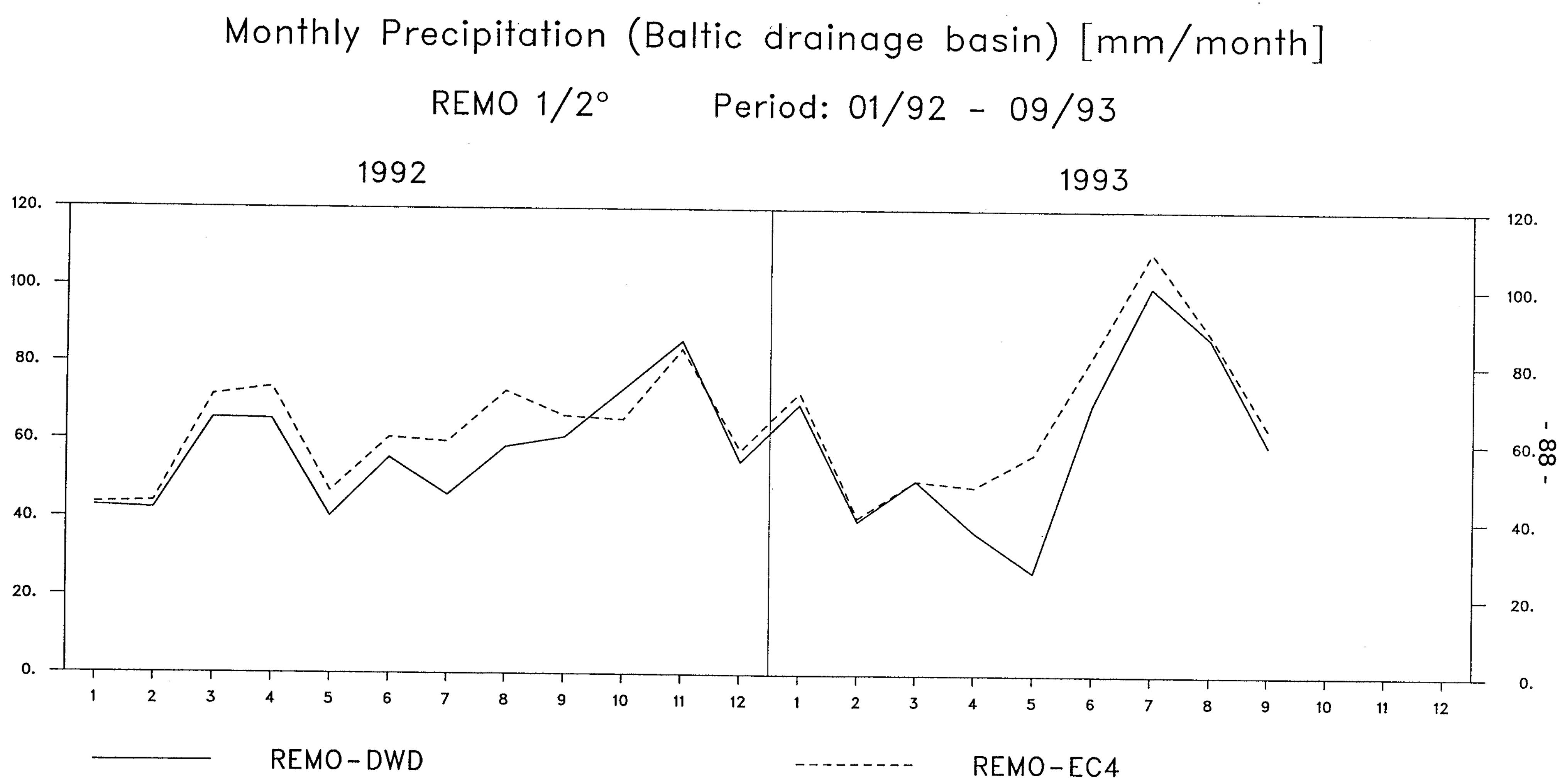
For the period of 21 months (1st of January 1992 to 30th of September 1993) continuous simulations with both physical parameterization schemes on 0.5° model resolution have been carried out using analyses fields provided by DWD as initial and lateral boundary conditions.

Results:
The comparison of the results calculated with the DWD-physics and the ECHAM4-physics shows that the annual cycles of the monthly total precipitation over the Baltic drainage basin have a similar behaviour during the winter months but differences during the summer (see figure). The annual cycles over water are very similar throughout the year, while over land major differences occur during the summer months.

A detailed investigation of the annual cycles of the surface energy balance over land shows that the net solar radiation at the surface is stronger using ECHAM4-physics, especially during summer. During the winter months the net solar radiation is similar; in spring and fall differences of about 20 W/m^2 can be seen. During June the differences increase up to approx. 50 W/m^2. This leads to enhanced sensible and latent heat fluxes during the summer months in the calculation with the ECHAM4-physics.

One of the key issues of BALTEX is to determine the water balance over the Baltic Sea. First results from the above mentioned simulations for 21 months indicate that for the first half of 1992 and for the period of January to August 1993 the water balance was positive (more precipitation (P) than evaporation (E)), while the signal during the second half of 1992 was not clear. There are only differences in the amount of monthly P-E, the trends are similar.

Ongoing work:
A detailed investigation of the differences in the annual cycles of the water and energy budgets including a comparison to observations is under way.


Monthly Precipitation (Baltic drainage basin) [mm/month]
REMO 1/2°
Period: 01/92 - 09/93
1992
1993
120.
100.
80.
60.
40.
20.
0.
1
2
3
4
5
6
7
8
9
10
11
12
REMO-DWD
REMO-EC4

ODRA FLOODING, JULY 1997, SIMULATED WITH REMO

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Introduction:

The extreme event of the Odra flooding in July 1997 caused catastrophical damage in certain areas close to the river. The observed runoff maxima at the Odra mouth for July 1997 reached values of about 2700-3000 m^3/s measured as inflow into the Baltic Sea. Two meteorological situations led to the extreme precipitation events in the Odra drainage basin.

Within the BALTEX (BALtic sea EXperiment) project the hydrological and energetic budgets of the Baltic Sea drainage basin are under investigation with the aim to understand the water and energy cycle more completely. Therefore it is important to study meteorological phenomena and their extremes on different time and space scales which are influencing mean budgets as well as the variability.

The atmospheric regional climate model REMO developed at the Max-Planck Institute (MPI) has been used to simulate the meteorological situation. The model is based on the operational forecast model (EM/DM) of the German Weather Service (DWD). REMO has been extended to allow for alternative use of either the physical parameterization package from DWD or the physical parameterization schemes of the global MPI climate model ECHAM4. To calculate the river runoff, a hydrological discharge model developed by Hagemann and Duemenil at MPI has been used.

As sensitivity studies, simulations with different physical parameterization schemes (DWD - scheme and ECHAM4 - scheme), horizontal resolutions (0.5° and 0.16°) and domain sizes have been carried out using analyses fields provided by DWD as initial and lateral boundary conditions. The simulations started 1st of June calculating continuously until 31st of July.

Results:

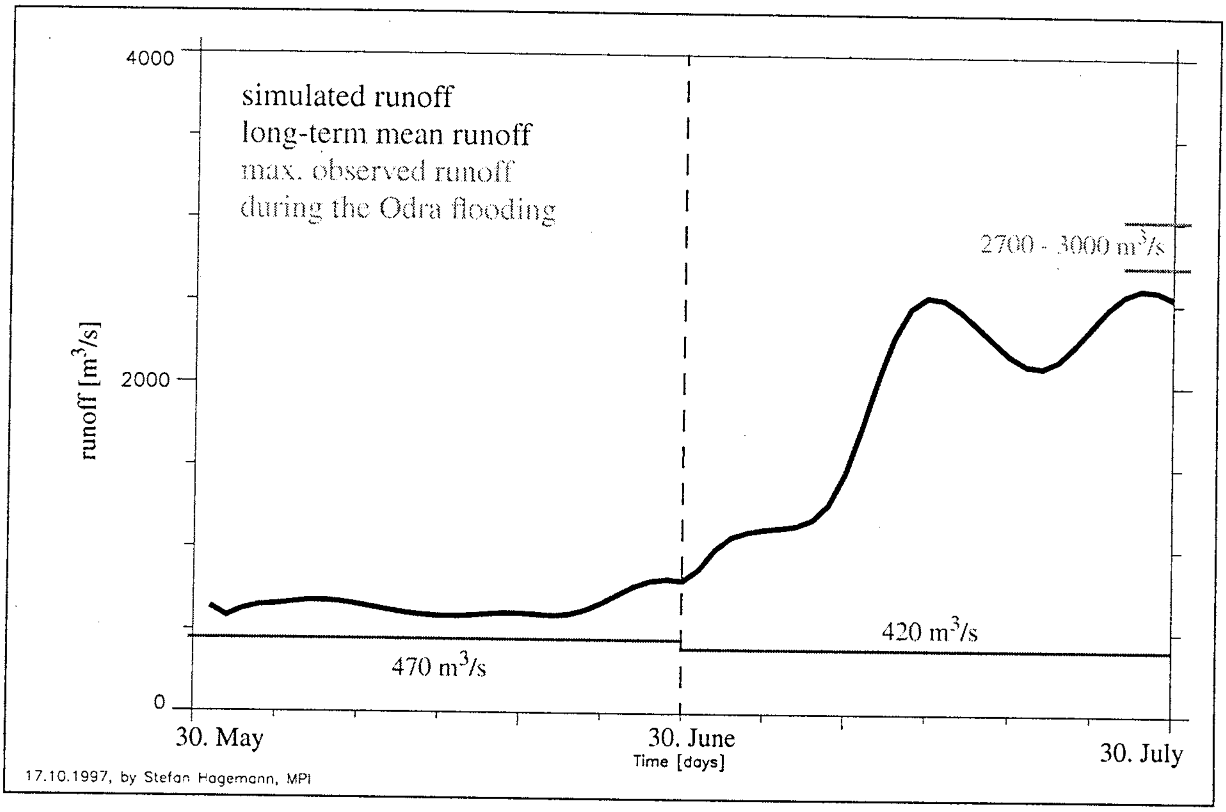
Precipitation:
During the first episode (4th of July to 7th of July 1997), area averages of more than 150 mm and extremes of more than 300 mm of precipitation have been observed. The comparison between observed and calculated precipitation on 0.16° model resolution shows a good agreement on the area averages. However the 0.5° - simulations show almost no precipitation for both physical parameterization packages. This is due to differences in the observed and simulated large scale flow.

calculated: > 120 mm (DWD-scheme), 80 mm (ECHAM4-scheme)
observed: > 150 mm

Runoff:
A good agreement can be seen between the calculated and observed runoff maxima at the Odra mouth. The following figure shows the long-term mean runoff (in June 470 m^3/s and in July 420 m^3/s), the maximum observed runoff duirng the Odra flooding (2700 - 3000 m^3/s) and the time series of the calculated runoff (maxima in July: 2500-2600 m^3/s).

Ongoing work:

A detailed investigation of the meteorological situations which led to the extreme events and an comparison with observations is under way. Within this work it should be clarified which processes led to the heavy precipitation, and why the development of the meteorological situations depends so much on the model resolutions.


4000
2000
0
runoff [m³/s]
simulated runoff
long-term mean runoff
max. observed runoff
during the Odra flooding
2700 - 3000 m³/s
420 m³/s
470 m³/s
30. May
30. June
Time [days]
30. July
17.10.1997, by Stefan Hagemann, MPI

Humidity assimilation into the mesoscale model

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Works on numerical weather prediction in Poland restarted in 1994, shortly after an important decision of our scientific authority to create selected supercomputer centers in Poland. We decided to implement of an existing model (Unified Model of United Kingdom Meteorological Office) what saved us at least few years of the effort. Project, started initially as an initiative of few individuals, quickly reached the phase of scientific investigations and got a support from IMWM and ICM. From 1th May 1997 the system is running on every day basis in quasi-operational regime.

The system developed till now consists a complete numerical weather prediction system and is used to perform meteorological forecasts for atmospheric perturbations below the synoptic scale of horizontal dimensions from tens to thousand kilometers. Such task forms the problem with lateral boundary conditions, which should be known during the all period of integration. In our case boundary conditions are extracted from forecasts produced by a regional (larger) model in our supporting centre in Bracknell. The main components of the system are: data transmission from Bracknell to Warsaw, preliminary processing and quality control of observations, assimilation of new data into the model, hydrostatic, primitive equations numerical model, data visualisation tools and the system of a distribution of results to the users.

Transmission of lateral boundary conditions and observation files is based on the ftp protocol and is controlled by Korn shell script according to the schedule (eight times per day, approximately every three hours). The program is able to detect the delay or an abruption of the transmission and to initiate repetitive transmission of missing data. One time per day the large (15 Mb in size) file with boundary conditions is transmitted.

Important part of the system is quality control of the raw observational data. Data are checked in order to detect the possible random errors and to eliminate or correct erronous observations. Such filtering of observations is required because of high sensibility of the system which is likely to produce the unrealistic forecast based on the erronous data. The quality check detects errors by performing several tests, in particular by comparing the observation to the forecast background and by comparing data from surrounding stations.

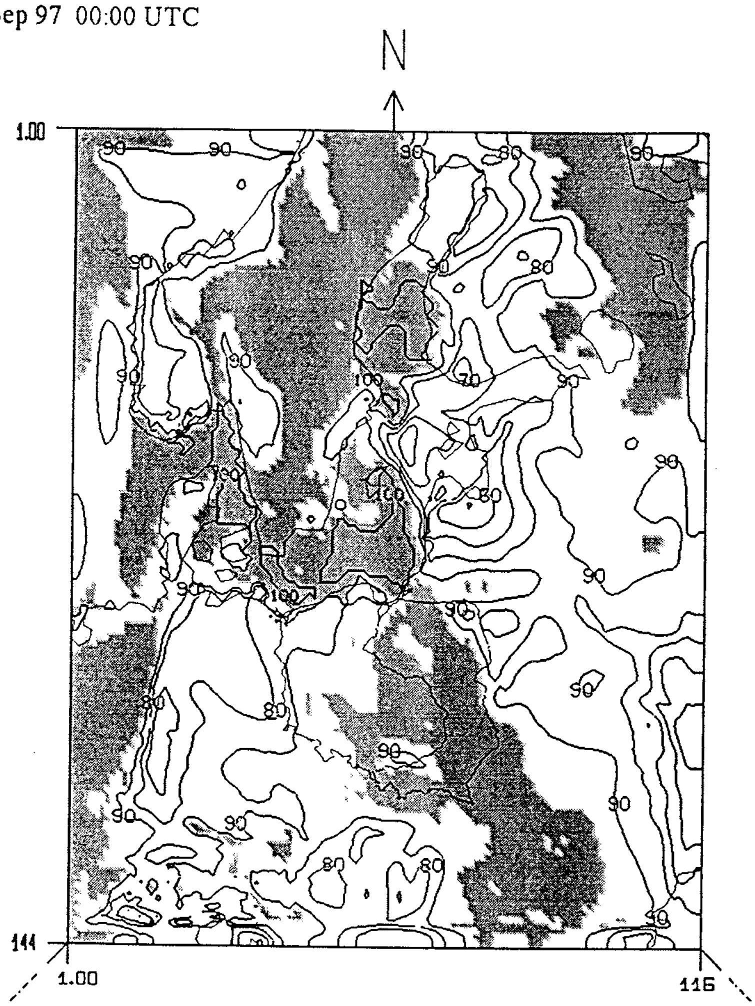
The assimilation process means an insertion of reliable data into the model. The problem of data assimilation for the mesoscale model is related to problems with a balance between information included in new observations and the state of the atmosphere described by the model. In our system, following the original UKMO suite, the Analysis Correction method developed by Lorenc (1) was implemented. The method is variational, and the optimal initial state is achived based on variational minimization of a cost function. In a case of meteorological data, the cost function is represented by a sum of two components, first measuring the fit to the observations while the second one measuring the consistency with our prior knowledge about the state of the atmosphere. In our system the continuous data assimilation is used. The new information is coming every three hours and all observation within three hours time window are assimilated to the model. We using data mainly from about 800 surface synoptic stations and 35 radiosondes. Additionaly satellites and aircraft observations are used.

The forecasting model is based on hydrostatic primitive equations in Eulerian form. The equations are presented in spherical coordinates in horizontal with a hybrid coordinate in vertical. The resolution of the model is about 17 km and model used 144 by 116 grid points on each of 31 levels. Time integration is based on efficient split-expicite alghoritm with a longer advection step devided into few shorter adjustment steps. Most physical processes used in climate version of the model is also used in mesoscale.

The paper is concentrated mainly on the assimilation of humidity data into the model. Humidity is comming into the model from two sources: surface synoptic observations and sondes. For most observations, the assimilation deals with two kinds of errors: the instrument error and the representativness error, which is referred as the small scale disturbances sampled by the observations, but which the model is incapable of representing. For global models in some cases the representativness error is considered so large that it is impracticable to use the observation. In mesoscale such local effects are important and should be incorporated into the model.

Surface data comprise land synop and marine surface data from ships and buoys. Information about relative humidity from these sources is used. Such statistics as probability of gross error, mean and rms of differences observation - background, rms of observations, rms of background for selected months will be presented. On Fig. 1 relative humidity field at 1.5 m over surface is presented. Values above 95% are shaded and describe area with fog.

02 Sep 97 00:00 UTC



Vertically distributed data are taken mainly from radiosondes. The radiosonde system provides a standard set of measurements of wind speed and direction, temperature and dewpoint temperature. The dewpoint data provides information on moisture and is combined with the temperature data to provide the moisture information as relative humidity. Radiosonde reports contain lot of an information on standard and on nonstandard levels and describe a detailed picture of the atmosphere in selected location. The vertical averaging converts radiosonde levels on to the model layers. Such averaging provides the assimilation with information wich is consistent with the model resolution and simplifies the subsequent processing as each report can then be treated in a similar way regardless of how many levels it originally contained.

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Numerical modelling of water circulation in the Baltic Sea by the Princeton Ocean Model - preliminary results

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Abstract

Preliminary results of numerical experiments with an application of the Princeton Ocean Model - code (cf. Blumberg and Mellor, 1987; Mellor, 1993) to calculate wind - and density - driven circulation in the Baltic Sea are presented. The model domain (10° 45' E - 29° 15' E; 53° 50' N - 65° 50') comprises the Baltic Sea with the Gulf of Bothnia, the Gulf of Finland and the Gulf of Riga and was considered as closed basin. Model resolution (horizontal - 15' x 10' i.e. about 10 Nm and vertical - 12 levels of $\sigma-$ coordinate) allow to analyse only general pattern of water movements in the Baltic Sea.

Following numerical experiments were carried out:

1. Diagnostic and semi- diagnostic calculations (cf. e.g. Sarkisyan et al., 1986) - to estimate steady - state climatic circulation for selected months (July, August, September and October) and runs were performed with POM - code in diagnostic mode and prognostic one, subsequently. Model was forced by montly mean climatic fields of wind stress and density. Wind stress components were estimated by the help of standard method based on wind velocity determined from distribution of atmospheric pressure (the multi-year averaged fields) and using relationships between surface and geostrophic wind and square law with constant drag coefficient equal to $2.5 \cdot 10^{-3}$. Deflection angle (counterclockwise) equal to 18° and correction coefficient for wind velocity equal to 0.7 were applied. Density fields were estimated by the Mamayev's simple state equation (Mamayev, 1970) on the basis of the multi-year averaged monthly mean fields of the sea water temperature and salinity from Lenz (1971) and Bock (1971) atlases for selected months.

2. Prognostic simulations for the PIDCAP period (August - October) were perfomed. As initial data for model parameters, their values calculated in previous semi - diagnostic and diagnostic runs, were used. In these simulations the model was forced by wind stresses and surface heat fluxes. Heat surface fluxes and wind stresses were calculated on the basis of forcing fields available from Institue of Marine Research, Kiel, interpolated into the model numerical grid by subroutine supplied with forcing data. Wind stress components were estimated in similar way as in diagnostic runs with deflection angle equal to 15° and with drag coefficient dependent on wind velocity. Surface fluxes of sensible and latent heat were calculated by means of Launiainen's method (cf. e.g. Launiainen, 1979: Launiainen and Vihma, 1990). Short and long wave radiation were evaluated by formulae proposed in literature (cf. e.q. Pivovarov, 1972; Stevenson, 1982; Rozwadowska (1991).

Main attention was paid to the southeast part of the Baltic Sea, where complex bottom topography essentially influences water movements and for that region the results of numerical simulations are presented. Hydrodynamic conditions and variability of water exchange between the Gulf of Gdańsk and the Baltic Proper along the longitudinal section in the vicinity of the open boundary of the Gulf are also analysed.

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CHANGES OF SYNOPTIC WATER DATA IN THE SOUTH - WESTERN BALTIC SEA

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1. Introduction

The aim of this study is to investigate the changes of synoptic water data like records of water levels, water temperature and salinity along the south-western Baltic coastline. Time series of mean annual values as well as those of annual extreme values are used. Long records of water level data tracing back to the year 1812 are the core for more advanced investigation which include the eustatic rise in sea levels or the relative movement between land and water level, corresponding to the relative sea level rise in the south-western Baltic region.

2. Investigations

The Baltic sea is a closed sea with low salinity and behave like a lake in temperature terms. In order to investigate the change to water levels in a more global sense, the use of water temperature and salinity data enable us to approach the problem more physically. The annual cycle of water temperature has a normal distribution, therefore global changes in temperature are included in changes of water temperature of the south-western Baltic sea. Changes in salinity may indicate inflow or exchange of high saline water of the north sea via the Belts. Therefore anomalies in the above mentioned time series (water level data, water temperature and salinity) will be investigated in statistical terms. In addition, the time series and trend corrected time series of annual extreme water levels (storm surge water levels) permit to make assessments basing upon the theory of probabilities on the frequency of occurrences of storm surges.

2. Results

The centennial change or relative change of the mean mater level (MW) along the south-western Baltic coastline varies in the range of 4 cm/100 years at the station Swinemünde (s. Fig. 1) to 13 cm/100 years at the station Travemünde during the period with a minimum of 60 to a maximum of 175 years at various stations.

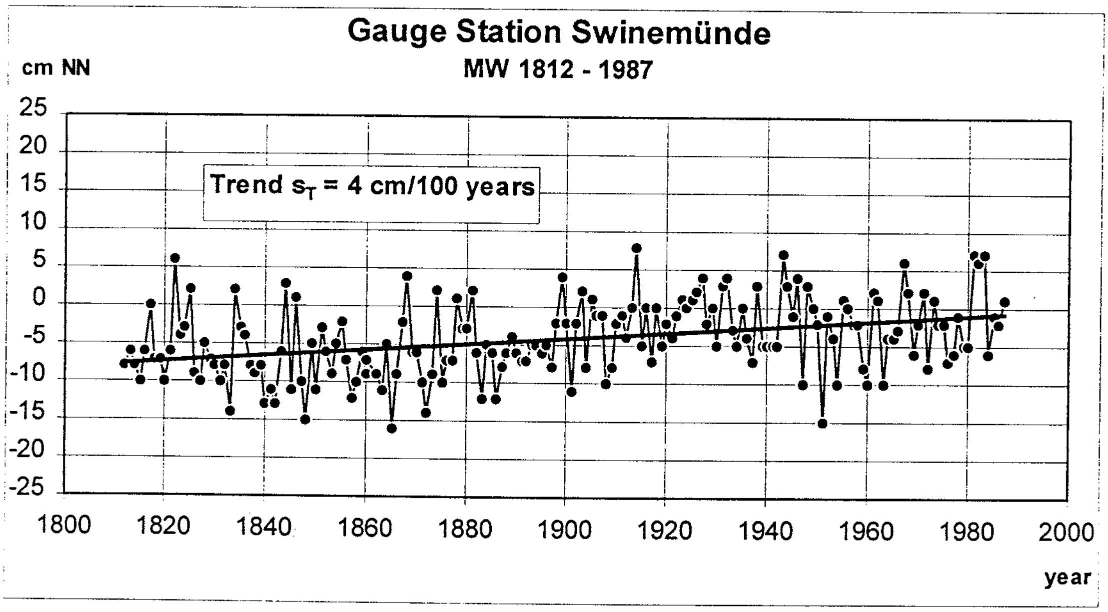

Fig. 1: Station Swinemünde, Records of Mean Water Level (MW) from 1812 until 1987

In comparison to the behaviour of the North Sea, the mean water levels at the Baltic Sea shows a behaviour similar to the mean sea level (MSL) of the North Sea. The almost tide-free Baltic Sea may be regarded as a damped gauging station of the North Sea. The time series of the mean water levels at the Baltic at different stations show similar trends and almost the same annual fluctuations due to meteorological conditions and have therefore been combined to one time series of MW of a synthetic station called „South-western Baltic Sea".The relative rise of MW or relative sea level rise of the synthetic station „South-western Baltic Sea" is about 13 cm/100 years during the last 150 years.

The storm surge of 12th. - 13th. November 1872 on the south-west Baltic Sea coast caused water levels at such an enormous height that has not been observed again even since. The storm tide in November 1872 with a level of NN + 316 cm (n.S.) at the Travemünde gauging station represents in relation to the general weather situation a singular event which stands out from the time series of annual maxima water levels (s. Fig. 2).

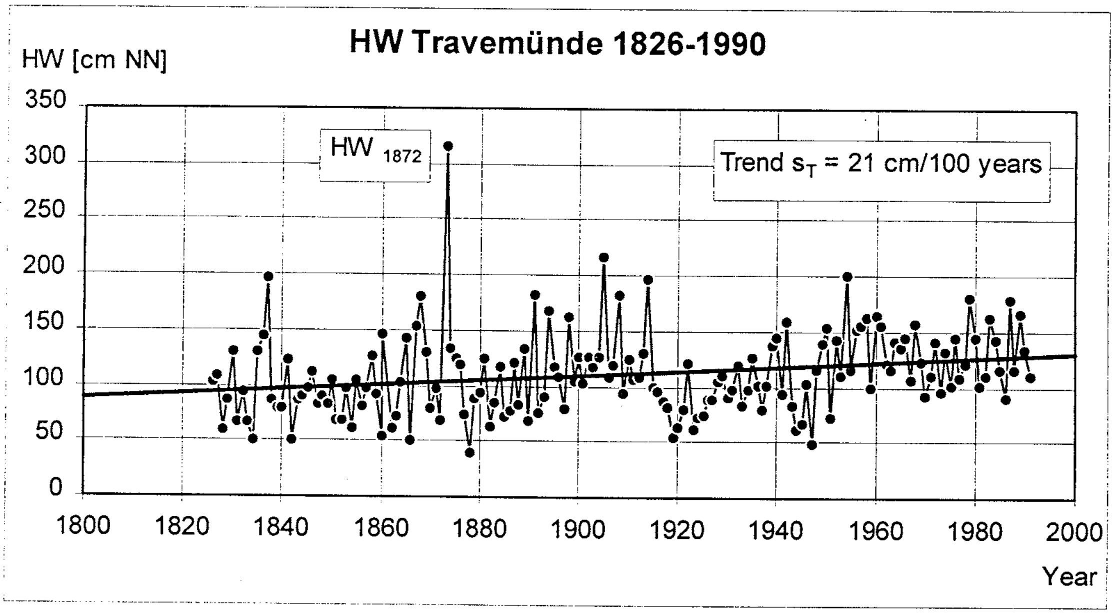

Fig. 2: Station Travemünde, Records of annual maxima HW from 1826 until 1991

The statistical analysis of annual maxima series at the Travemünde gauge with 15 different distribution functions has given no significant differences concerning the goodness of fit, which is here expressed by the mean error. For this reason, none of the fitted function can be particularly recommended or rejected. For choosing a design flood on the Baltic coast it is therefore the individual structural safety requirement and particular site that ought to be taken as a basis - provided that the statistical analysis of the time series of data at other gauging stations leads to similar results. The statistical analysis, however, is useful in so far as an order of magnitude can be given concerning the water level, which is here e.g. for 250-years return values within the range between NN + 2,50 m and NN + 3,10 m depending on the distribution function.

As regards the construction of coastal protection structures on the Baltic Sea, it may be stated that a dimensioning based on the extreme storm surge of the year 1872 contains sufficient safety. Accordingly, dimensioning of coast protection measures for the future on the basis of the storm surge in 1872 and in consideration of the secular rise seems to approx. 20 cm has been taken into account.

The detailed results of the analysis of the water level data (long-term gauging stations: Travemünde, Wismar, Warnemünde, Stralsund, Arkona, Sassnitz, Greifswald, Swinemünde and short-term gauging stations: Kamminke, Stagniess, Ückermünde, Wittower Ferry), water temperature and salinity data along the south-western Baltic coastline are presented in the full paper.

RADIATION FLUXES BALANCE OF THE SEA-ATMOSPHERE SYSTEM FOR THE SOUTHERN BALTIC REGION

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Our original radiation transfer model, first presented at Visby (Dera et al. 1995*), was applied to determine the following radiation fluxes in the southern Baltic region:

- the flux reaching the Earth's atmosphere,
- the flux absorbed and scattered upward in the atmosphere,
- the direct solar rays flux reaching the sea surface,
- the diffuse solar flux (scattered downward by the atmosphere) reaching the sea surface,
- the total solar flux reaching the sea surface,
- the total flux reflected by the sea surface,
- the total flux entering the water column,
- the flux scattered upwards by the water body and leaving the sea surface,
- the flux absorbed in the water column:
  - that absorbed by the water itself,
  - that absorbed by phytoplankton pigments,
  - that absorbed by admixtures other than phytoplankton pigments,
- the photosynthetically stored radiation flux,
- the effective infrared radiation flux at the sea surface.

The model has been developed for application of satellite images as the main source of input data. However, since the relevant satellite data are not yet available, a long-term meteorological and bio-optical standard data collection has been used in the computations. The mean monthly fluxes and their balances for the southern Baltic region, divided into 20 sub-regions, have been obtained for each month of the year.

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SATELLITE SENSING TECHNIQUES AND APPLICATIONS FOR THE PURPOSES OF BALTEX

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Abstract

A review of satellite sensing techniques and applications suitable for use in validation and modelling activities in BALTEX is presented. Special emphasis is given to data and mature applications available during BRIDGE. For atmospheric simulations and studies, in particular sensors measuring radiation budget quantities, cloud properties, moisture content and precipitation are mentioned. Sensors measuring ice conditions and sea state parameters are identified for oceanographical applications and sensors measuring snow conditions and surface conditions are listed for hydrological studies. As a summary, the following satellites and sensors will be the main satellite data sources: the SCARAB instruments on the RESURS, METEOR and ENVISAT satellites, the CERES instrument on the EOS-AM1 satellite, the AVHRR and ATOVS sensors on the NOAA satellites, the MVIRI and SEVIRI sensors on the METEOSAT satellites, the SAR instruments on the ERS, Radarsat and ENVISAT satellites and the SSM/I instrument on the DMSP satellites. Of particular interest is also radio occultation measurements of the radio signals from the GPS satellites.
The need for a central BALTEX co-ordination facility (a satellite data function) with the objective to compile and transfer satellite data from various processing centres to BALTEX research groups is particularly stressed.

1. Introduction

The BALTEX program offers a unique opportunity to validate and develop techniques to retrieve geophysical parameters from satellite measurements through the definition of comprehensive observation and model databases. At the same time (and perhaps more important), a sub-set of the wealth of satellite data can be used in model validation and in studies of physical processes. This paper discusses both these aspects of satellite data usage in BALTEX, however with prominence given to the second aspect. The most important satellite data sources and applications are presented according to their potential applications in the separate disciplines meteorology, hydrology and oceanography. Special emphasis is put on the identification of satellite data or products derived from satellite data which are suitable and mature for model validation and/or assimilation purposes in BALTEX. Such data may either be output data from advanced and mature processing schemes or quantities directly extracted from satellite sensor measurements. Also, new promising satellite data and processing techniques that could be of value for limited and more dedicated studies of physical processes in BALTEX (e.g., for use in case studies) will be mentioned. The time frame considered here is the lifetime of the BRIDGE experiment (1999-2001).

2. Satellite data for meteorological studies

2.1 Data for atmospheric models in validation and assimilation activities

There are two main aspects of atmospheric modelling for which satellite data would be of great importance for model validation and assimilation purposes in BALTEX, namely the description of radiation balance and the spin-up problem. The first aspect concerns the formulation of processes determining the fundamental radiative forcing of atmospheric circulation systems. Secondly, the spin-up problem is related to deficiencies in the assimilation of observations in models which result in unrealistic initial model fields. Both these aspects are crucial for the simulation of the atmospheric part of the hydrological cycle in the Baltic region.
Satellite measurements are obviously suitable for validation of modelled conditions at the top of atmosphere (the upper boundary for atmospheric models). A key parameter here is the earth radiation budget (ERB). Direct measurements of this parameter will be available from the ScaRaB (see Acronym list) sensor on the ENVISAT-1, METEOR and RESURS satellites (Bess et al., 1997) and the CERES instrument on the EOS-AM1 satellite. The spatial resolution of these measurements will be approximately 60 km at nadir except for CERES which

will allow a resolution of 21 km. Since the radiation climate is he
the atmosphere ("the cloud forcing effect"), data from the operational meteorological satellites (mainly the geostationary METEOSAT and the polar orbiting NOAA satellites) should also be of interest. Most of their sensors (e.g., AVHRR, MVIRI and in the future SEVIRI) are mainly designed for cloud observation purposes and cloud parameters derived from these measurements can be used to estimate ERB. Such parameters are available from the ISCCP project (Rossow et al., 1996) but on a rather coarse horizontal resolution (see Fig. 1). However, studies of regional conditions in the BALTEX area require data at a much improved horizontal resolution (≈10-20 km) in order to detect regional or even local scale features in the radiation climate. The reason is that these features are resolved by the used high resolution general circulation models in BALTEX (Hollman et al., 1997). Such high resolution datasets (see Fig. 2) are presently under construction at a few operational centres (Karlsson, 1997) and special actions will enable access to such data in BALTEX. Of great importance here is the EUMETSAT establishment of several satellite application facilities (SAF). A Climate SAF (Hechler, 1997) will be defined where one important objective is to compile high quality satellite datasets on cloud properties.

The same kind of cloud information is also of interest for validation studies of the spin-up problem (Karlsson, 1996). Spin-up problems are most often manifested as an underestimation of cloud cover, vertically integrated cloud liquid water and precipitation during the first hours of model integration. Several of these parameters are often best monitored in satellite imagery, especially if uniform and large area coverage is requested.

The spin-up problem can be explained as caused by two main deficiencies in present assimilation techniques. Firstly, unrealistic spatial structure functions are used to interpolate observations into the initial fields of the model and, secondly, a lack of adequate observations exists for the description of moisture and precipitation fields. BRIDGE will serve as an important testbed for the development of new data assimilation techniques aiming at finding a remedy for these two deficiencies. Within the framework of variational data assimilation (Gustafsson et al., 1997) or, alternatively, the nudging technique (Lorenc et al., 1991), a utilisation of satellite data not presently used by models can be foreseen. The idea is to rely more on the atmospheric model to spread the information in space and time. This will be more advantageous for the use of satellite data since these are distributed more randomly in time compared to conventional observations. The new techniques allow also assimilation of new parameters (e.g., satellite-measured radiances) which are non-linearly related to the original model variables and this will naturally favour the use of satellite data. Satellite data with the largest potential to be assimilated in models during BRIDGE are integrated water vapour extracted from surface-based measurements of the modulation of radio signals from the GPS satellites (radio occultation measurements - see Kuo et al., 1996), integrated water vapour from the microwave SSM/I instrument on the DMSP satellites and infrared and microwave radiance measurements by the ATOVS instrument on the NOAA satellites.

2.2 Data for physical process studies and algorithm development

Studies of precipitation and evaporation over the Baltic Sea will naturally be an important topic in BALTEX due to the present lack of reliable knowledge of these parameters (see also next section). More or less indirect measurements of precipitation from satellite are available from several sensors but, so far, most attempts to use this information for accurate estimations of precipitation at the surface have shown very limited skill (Allam et al., 1993). Best results have been found when using passive microwave data over ocean areas (e.g., SSM/I data - see Simmer, 1996). Continued research is necessary to find reliable algorithms and to extend the usage to coastal and land areas. The next NOAA satellites will carry both traditional VIS/IR instruments (AVHRR/3) and microwave instruments (the AMSU part of ATOVS), thus increasing the possibilities for creating multispectral algorithms. Some benefit and experience will also be gained from the TRMM mission (although not covering the BALTEX area) containing an even more advanced set of multispectral sensors. Despite the fundamental problems of measuring precipitation rates from satellite, it is believed that satellite data will have an important role as a complement to weather radar measurements and conventional observations in future operational precipitation analysis systems.

The fundamental role of clouds through their interaction with radiation processes must be addressed further. This concerns especially the description of the three-dimensional cloud field and the optical and

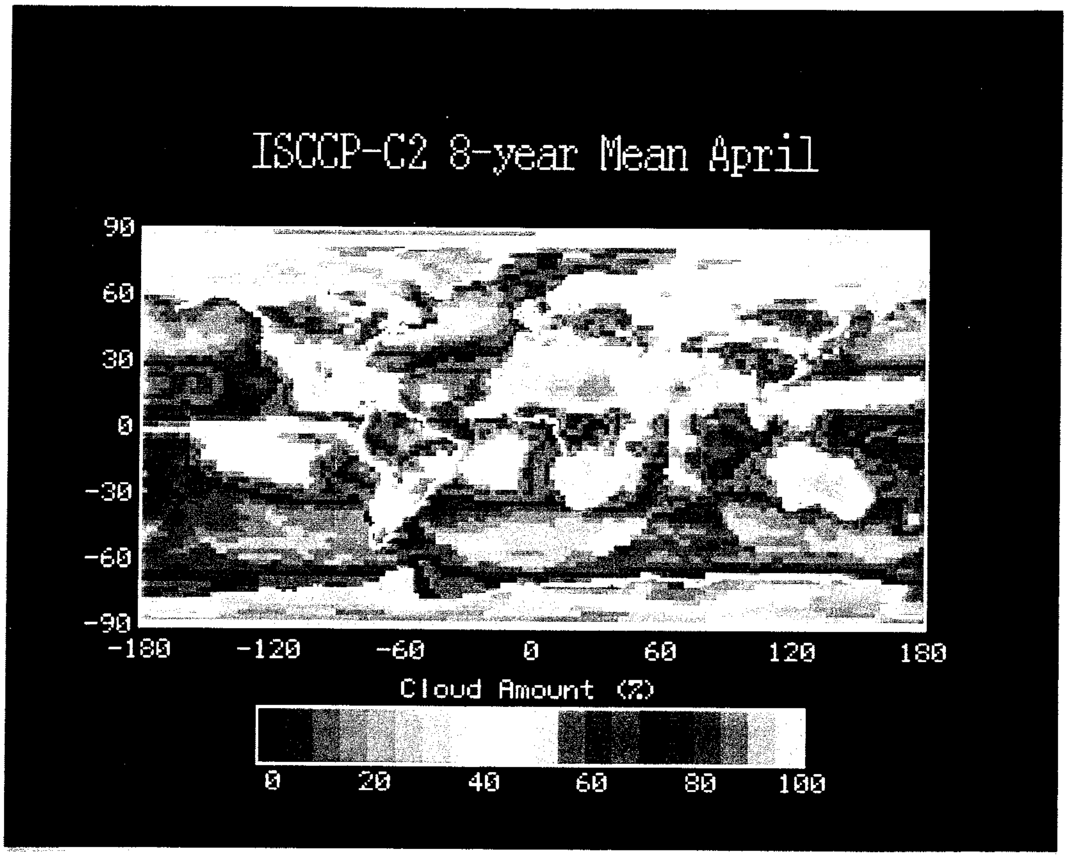
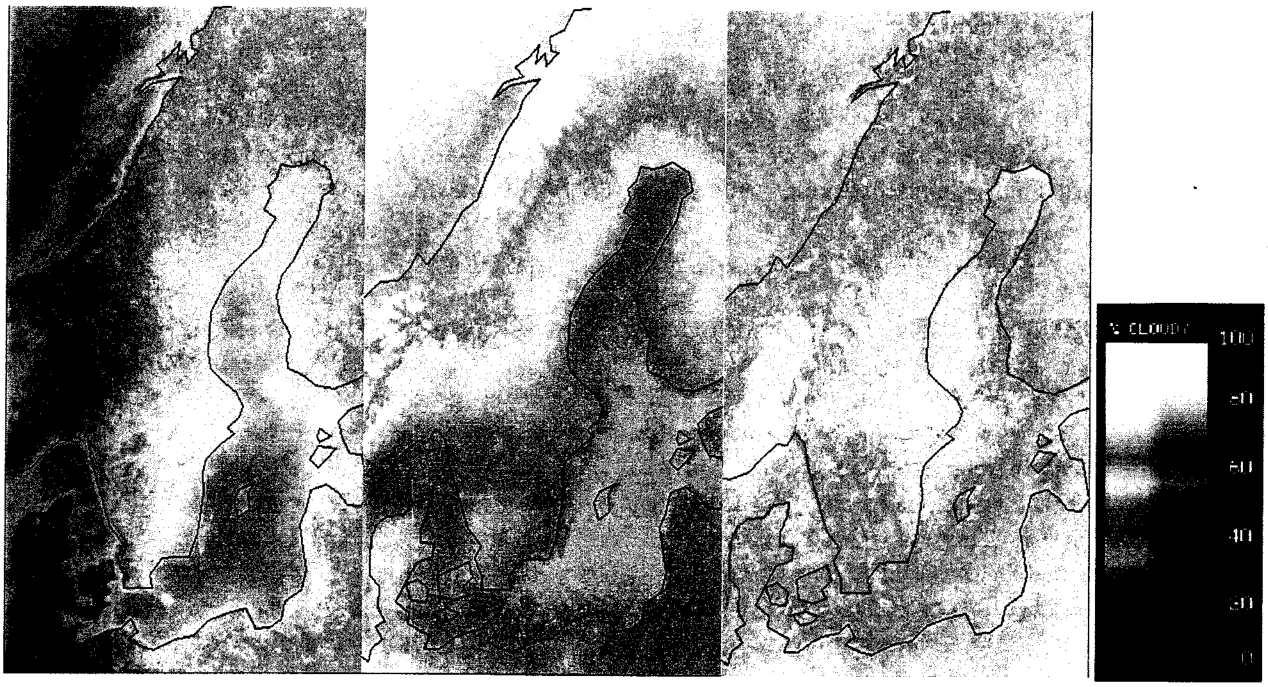


Figure 1 *Global 8-year mean (1983-1991) of cloud cover in April from ISCCP. Horizontal resolution is approximately 250 km (however based on a sampling with 30 km horizontal spacing).*



April **July** **December**

Figure 2 *Scandinavian six-year mean (1991-1996) of cloud cover for April, July and December at 4 km resolution derived from AVHRR data (the SCANDIA model operated at SMHI).*

micro-physical properties of clouds. Many satellite data sources may play a role here (e.g., NOAA-AVHRR/ATOVS, DMSP-SSM/I and METEOSAT-MVIRI/SEVIRI).

Although some intensified measurements of atmospheric profiles in the BALTEX area will be realised, there will still be a lack of data for the detailed description of the three-dimensional atmospheric structure to be used in models. Experiments using new profiling information from the ATOVS instrument is foreseen and possibly also studies based on GPS radio occultation measurements from low orbit satellites (as discussed by Höeg and Syndergaard, 1995). Both these new data sources have a potential to provide an increased spatial resolution of retrieved temperature and moisture profiles.

Satellite measurements of conditions at the earth surface is naturally of great interest for atmospheric models (by influencing the lower boundary conditions) and for special physical process studies. For land areas, it is especially the estimation of soil moisture, evaporation and surface albedo that could benefit from satellite measurements. Parameters derived from NOAA-AVHRR data could be of interest here (e.g., NDVI indices, surface reflectances, cloud conditions). Information on ocean, lake and snow conditions is discussed in the context of hydrological and oceanographical applications in the next section.

3. Satellite data for hydrological and oceanographical studies

3.1 Data for hydrological and oceanographical models in validation and assimilation activities

A very important and well established satellite-based technique of measuring the thermal conditions of the ocean surface is the estimation of sea surface temperatures (SST) from NOAA-AVHRR measurements. SST estimations are used in many applications, from climate studies to operational applications. Assimilation of SST data will be an important task for oceanographical models (also when linked to atmospheric models) in BALTEX. SST data for inland lakes might also be of some interest for hydrological models.

Ice coverage and ice conditions are other important parameters for oceanographical models describing conditions in the Baltic Sea. Ice analyses based on blended observation types including satellite observations will be available for BALTEX. A satellite data source of increasing interest is high resolution radar measurements (SAR measurements) since they are available also in cloudy and dark conditions. SAR data will be available from the ERS-2, Radarsat and ENVISAT satellites during BRIDGE. An example of a Radarsat SAR image is shown in Fig. 3. Measurements of sea ice concentrations and ice roughness with as good as 20 m horizontal resolution will be obtained.

Snow cover and snow depth observations are of great importance for hydrological modelling. Since this information is very scarcely available from ground measurements, attempts to use satellite observations will be made. Potential data sources will be NOAA-AVHRR, DMSP-SSM/I and SAR instruments.

3.2 Data for physical process studies and algorithm development

Several factors in the hydrological cycle and water balance of the Baltic Sea is still fairly unknown. Especially, the precipitation and evaporation over the Baltic Sea remains to be more accurately estimated. Precipitation algorithms based on satellite data may become important here as a complement to weather radar data (as previously discussed in section 2.2). SST estimations will certainly be one of the necessary data sources used for estimations of evaporation over the Baltic Sea and lakes in the region. Satellite schemes for deriving the corresponding quantity over land (LST) is not as mature as for SST but some progress can be seen (Costa et al., 1997).

Despite the obvious potential of using microwave SAR data for ice studies, much work is still anticipated before reliable operational applications are established. A specific problem is to identify a separable SAR signal from wet snow (both over land and ice areas). If this is successful, also hydrological applications for snow cover and snow depth monitoring might be possible.

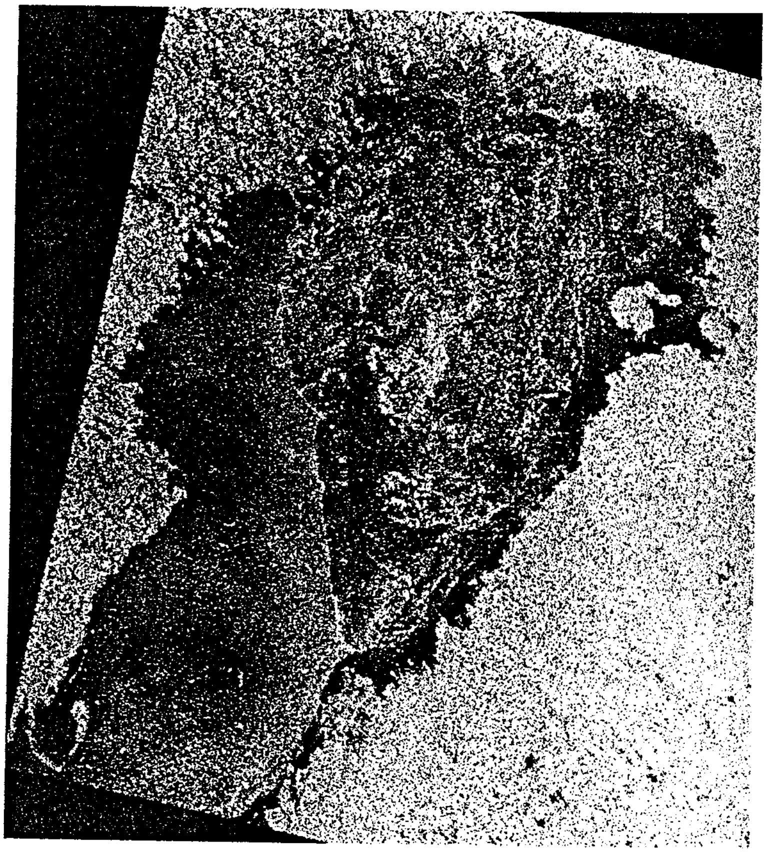


Figure 3. *An example of a 500 m resolution Radarsat SAR image over the Bothnian Bay 12 March 1997.*

An uncertainty in oceanographic modelling is the formulation of the energy transfer of the uppermost layers of oceans as depending on the extinction coefficient. The launch of the SeaWiFS instrument in 1997 enables ocean colour measurements which can be utilised for estimations of the extinction coefficient.

4. Final remarks

The use of satellite data normally requires a quite advanced technical equipment for reception of the data. In addition, a large amount of pre-processing is often necessary to transfer raw data to useful radiances (or other quantitities). When considering that these requirements are true and normally unique for any particular of the earlier mentioned satellite sensors, it is obvious that all of the required satellite data can hardly be provided by one single processing centre in the BALTEX region. Consequently, the establishment of a co-operation between several processing centres to make data available for BALTEX studies seems necessary. A special central BALTEX satellite data function is therefore proposed for this purpose.

List of Acronyms

AIP	Algorithm Intercomparison Program
AMSU	Advanced Microwave Sounding Unit, component of ATOVS
ATOVS	Advanced Tiros Operational Vertical Sounding instrument, first instrument launched 1998
AVHRR	Advanced Very High Resolution Radiometer, on the NOAA polar orbiting satellites
BALTEX	BALTic sea EXperiment
BRIDGE	The Main BALTEX Experiment, planned for 1999-2001
CERES	Cloud and Earth's Radiant Energy System, on polar orbiting EOS satellites
DMSP	Defense Meteorological Satellite Program, USA.
ENVISAT	ENVIronmental SATellite, ESA, polar orbiting satellite, first launch in 1999
EOS	Earth Observation System, satellite series included in the international MTPE program, first launch (AM1) in 1998
ERB	Earth Radiation Budget
ERS	European Remote Sensing satellite, ESA
ESA	European Space Agency

EUMETSAT	EUropean METeorological SATellite organisation
GPCP	Global Precipitation Climatology Project
GPS	Global Positioning System satellites
ISCCP	International Satellite Cloud Climatology Project
LST	Land Surface Temperatures
METEOR	METEORological satellite, Russia, polar orbiting satellite
METEOSAT	Geostationary METEOrological SATellite, EUMETSAT
MSG	Meteosat Second Generation, first satellite launched in 2001
MTPE	Mission To Planet Earth, international research program for provision of long term global observations from satellites
MVIRI	Meteosat Visible and InfraRed Imager
nadir	At the sub-satellite point
NDVI	Normalised Difference Vegetation Index
NOAA	Polar orbiting satellite operated by National Oceanographic and Atmospheric Administration, USA
RESURS	Resource satellites, Russia, polar orbiting satellite
SAR	Synthetic Aperture Radar, on ERS, Radarsat and ENVISAT satellites
ScaRaB	Scanner for Radiation Budget
SAF	Satellite Application Facility, EUMETSAT
SeaWiFS	Sea viewing Wide Field Sensor, launched in 1997
SEVIRI	Spinning Enhanced Visible and InfraRed Imager, on MSG, launched in 2001
SSM/I	Special Sensor Microwave Imager, carried by the polar orbiting DMSP satellites
SST	Sea Surface Temperatures
TRMM	Tropical Rainfall Monitoring Mission, launched in a low-inclination orbit in 1997

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TRENDS IN ESTONIAN CLOUD COVER (1955-1995)

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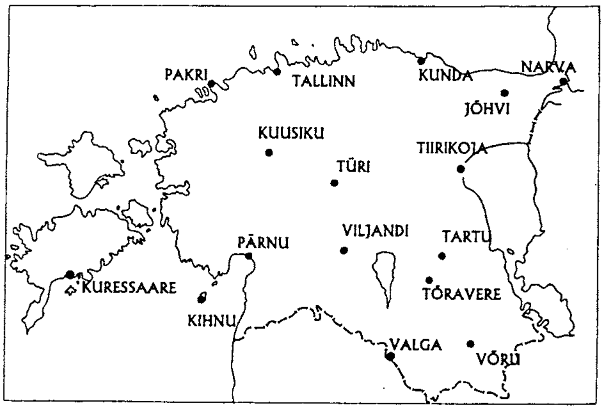
1. Introduction

It has been noted that during last decades cloud amount has increased both over land and the ocean (IPCC, 1996). The aim of the present study is to investigate, if such trends can be discovered also in Estonia. For this purpose, 41-year time series of monthly mean cloud amount in 16 meteorological stations have been analysed. Estonia covers 45 200 km^2. Therefore, there is approximately a meteorological station per 50 km. The stations are shown in the Figure.



Meteorological stations in Estonia

2. Climatological background

Cloud cover in Estonia is determined by geographical location of the country on the way of cyclones moving from the Atlantic Ocean to the east. Additionally, differences in ground properties modify the features of the cloud cover at different stations.

The number of cyclones over Estonia is the largest in late autumn and the smallest in early summer. Cloud amount follows this annual course, being maximal in November-December and minimal in June.

3. Data

In the present paper, total and low cloud amounts are considered. The monthly mean values have been calculated as averages of all observations made during this month. During the period 1955-1965 four observations were made daily, since 1966 the number of daily observations is eight. The time-series for Jõhvi is somewhat shorter: Here the observations were started in 1958. Shorter gaps are also in the data sets of some other stations and changes can be noted in the location of a few stations.

For each station linear trends have been calculated for total and low cloud amount for monthly and annual averages. Significance of the trends have been estimated on at least 90% level.

4. Trends in annual values

The maximal positive trend in annual total cloud amount was found at Narva, the easternmost of the stations. The slope of the trend line was 0.035 (in tenths per year). The maximal negative trend in annual total cloud amount was recorded at Kuusiku, a station in mid-Estonia. Here the slope was -0.011. The annual mean amount of low clouds has the largest positive slope of 0.028 at Viljandi and the largest negative slope of -0.032 at Türi. These are both continental stations in mid-Estonia.

5. Trends in monthly values

All over Estonia significant (on the 90% level) positive trends in total cloud amount as well as in low cloud amount can be noticed in March. Most of them are significant on the 95% level. Significant negative trends are frequent in May and October. In October no significant positive trends can be found at these stations, in May the trend of total cloudiness is positive and significant only at Narva.

6. Low clouds and circulation in March

Depending on the station, in March the amount of low clouds has increased during these 41 years by 1.2 - 3.2 tenths. This leads to an idea that there should exist a certain factor that causes the increase in low cloud amount all over Estonia. This idea is also confirmed by correlation between different stations that is the highest in March: In 95% of cases 75% of the dispersion of low cloud amount at one station can be described by dispersion at any other station. Correlation between low cloud amount at different stations shows the weakest decrease with the distance between stations in March. This shows that local factors do not have strong influence on low cloudiness in March.

At our disposal were the time series of European daily circulation patterns according to the classification of Hess and Brezowsky (Gerstengarbe and Werner, 1993, and personal communication) for the period of 1955-1993. From this time series it can be drawn that the number of days with zonal circulation in March has increased by 7 days and the number of days with meridional circulation has decreased by 8 days. Therefore, the described increase in low cloud amount can be explained by changes in European circulation.

Acknowledgments

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MODELING FLOODS FOR THE PRESENT STATE OF ST. PETERSBURG FLOOD PROTECTION BARRIER

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The City of St.Petersburg located in the shallow and narrow head of the Neva Bay since its foundation has suffered from flooding 300 times (number 300 was in 1994). The most catastrophic ones occurred in 1691 (340 cm?), in 1723 (273 cm), in 1726 (270 cm), in 1752 (280 cm), in 1777 (321 cm), in 1824 (421 cm), in 1924 (380 cm), in 1955 (293 cm) and in 1975 (281 cm). These floods lead to human losses and damages and therefore St.Petersburg is need of flood protection. In 1979 the construction of the Flood Protection Barrier across the Neva Bay on its border with the Gulf of Finland was started. The length of the Barrier is 25 km and after construction it will consist of 11 dams. Between them 6 water-sluices and 2 navigation passages will be located. There will be 2 water-sluices (B1, B2) in the South Gate of the Bay and 4 water sluices (B3 -B6) in the North Gate. The water sluices consists of 10-12 sections 28 m wide with openings between them 24 m wide each. During floods each segment will be closed with segment lock. Navigation passage C1 (200 m wide and 16 m deep) in the South Gate is for ocean ships and it will operate the whole year, while navigation passage C2 (110 m wide and 7 m deep) is for local ships and it will operate only in ice-free period. The navigation passages will be equipped with rolling gates that will be kept in a special camera and during floods will roll over a plate.

The Barrier was nearly complete as to civil works but since 1988 the construction was almost stopped as it was concluded that the Barrier is the main cause of water pollution in the Bay. Three commissions of experts were organized and two of them concluded that the role of the Barrier is not clearly understood. However, the third one concluded that the Barrier should be dismantling. After that, in 1990, an International Commission coordinated by Delft Hydraulics was set up. The International Commission stated that the Barrier produced localized ecological change in its vicinity. Ecological management can mitigate these changes. Now there is a decision of the Russian Government to complete the Barrier but due to lack of finances the construction is going on very slowly.

At present the Barrier has gaps which can not be closed in the case of a flood. Except for a temporal technological gap in the North Gate with width 167 m (TM D7) all other gaps are in the South Gate. They include a passage for navigation 940 m width, water sluices B1 and B2 and temporal gap (TM D2) 125 m width. Water sluices B3 - B6 in the north part can be closed. The total area of openings in the Barrier now is 14932 m^2, from which 3720 m^2 or 25%, can be closed, but 11212 м^2 (75 %) will remain open during floods which may come in the near future.

The paper presents results of the mathematical modeling of possible water levels in St.Petersburg and velocities in the Barrier gaps for floods of different intensity for the present state of the Barrier. Some long-term weather forecasts indicated that climate over Baltic Sea may become more severe. One of the aims of this study was to estimate the influence of closing of water sluices B3 - B6 on decrease of water levels in St.Petersburg. Modeling of two floods was done: of 18 November 1824 (the most catastrophic one) and of 15 October 1955 (flood with very high intensity of water level rise). Hydrodynamic modeling system *CARDINAL* was used. The *CARDINAL* model is a user-friendly computer program working under Windows-95 for the simulations of the long wave dynamics and dispersion of pollutants in any complicated area using the depth-averaged shallow water equations for 2D conditions and the equations of a non-steady boundary layer for 3D conditions. Boundary-fitted curvilinear coordinates (BFC) and mapping of a given domain onto a canonical one are used in the model. The BFC method may achieve a fine grid resolution in important regions and more accurate solutions than using the rectilinear grids. The equation of dispersion of pollutants is solved by the third & first orders implicit up-stream finite-differences. This solution method does not diffuse pollutants much, but does prevent numerical oscillations. For the closing of equations different semi-empirical models of turbulence are introduced. The computer package was used in different organizations for the realization of dozens of projects. New, more refined model of the Neva Bay and the Eastern Gulf of Finland (EGF) was produced for this study because the Barrier elements which determine flood penetration (0.01 km^2) are 5 orders less than the whole model area (1340 km^2). The grid consists of 32745 points with steps that varied from 20 m in the Barrier gates to 1 km in the west part of the computational domain. This grid approximates the Barrier as an object with complex configuration, especially in the navigation gaps. All forts (small artificial islands), underwater military lines and fairways are also included in the model. On the west boundary (cross section cape Schepelevo - Ozerki) time histories of surface level were assigned. These data were determined using data in St.Petersburg. It is considered that level along the west boundary was about 50 cm less, then in St.Petersburg. Local wind was not taken in consideration though its role is about 50 cm in average.

Consider first results of the simulation of the flood of 15 October 1955 for the conditions when all gates are opened. According to measurements water level in St. Petersburg achieved 293 cm in 5 hours, so the intensity of this flood was rather high: 58 cm per hour in average. Maximum water level rise in Schepelevo was assigned equal to 230 cm. Maximum water level rise achieved according calculations 175 cm in Kronshtadt and 208 cm in St. Petersburg. Before the Barrier water level rise achieved 285 cm along the north coast near Tarkhovka - Sestroretsk and 260 cm along the south coast near Malaya Izhora. For this intensive water level rise the Barrier is the most obstacle: maximum level in St.Petersburg was less then in Schepelevo on 22 cm. Maximum velocities in C1 gap, B4 and B5 achieved 6 - 6.5 m/s. In all cases big eddies developed on both sides of the gaps inside the Barrier during penetration of floods. Next results refer to the same flood but for the conditions when water sluices B3 - B6 are closed. Their closing leads, according to the modeling, to decrease of water level raise in St. Petersburg on 48 cm: from 208 to 160 cm, i.e. on 23%. The same water rise as in St.Petersburg, 160 cm, was received for Kronshtadt, so decrease here was 15 cm or 8% only. Total maximum discharge through the Barrier gaps decreased on 28 % (up to 52600 instead 73400 m^3/s). Maximum velocities received for temporary openings TM D7 in the North Gate, then in B1, then in C1 gap. Maximum velocities in C1 gap achieved 7.4 m/s near its south edge. Craters with water level fall up to 80 cm were obtained before the gaps. Big gradients of surface level are obtained in the South Gate in the Neva Bay.

Consider now results of simulations of the most catastrophic flood in St.Petersburg of 18 November 1824. In 12 hours water level in the City increased on 421 cm. Intensity of water level raise in this case was not so high as during the flood of 1955: it was 35 cm/hour in average. Maximum level in Schepelevo was assigned equal to 370 cm. For the variant when all gates of the Barrier were opened maximum water level achieved according computations 368 cm in Kronshtadt and 401 cm in St. Petersburg. Water level in St.Petersburg exceeded water level in Schepelevo on 34 cm. For such floods the Barrier with all gates opened is much less obstacle than for floods with bigger intensity as flood of 1955. Before the Barrier water level achieved 408 cm along the north coast near Tarkhovka - Sestroretsk and 395 cm along the south coast near Malaya Izhora. Maximum velocities are obtained in TM D7 and in B4. Velocities at the south edge of the C1 gap achieved 5.5 m/s. Simulation of the same flood, but for conditions when water sluices B3 - B6 are closed revealed that the closing decreased levels in St. Petersburg from 401 to 340 cm, i. e. on 16 %. Maximum water level in Kronshtadt was 324 cm. Closing of the North Gate (excluding TM D7) leaded to increase of water level before the Barrier along the north coast near Tarhovka - Sestroretsk from 408 to 425 cm (4%). As in the previous cases maximum velocities obtained in TM D-7, then in C1 gap. Velocities at the south edge of C-1 gap achieved 7.35 m/s, and 3.28 m/s at the north one.

Computations presented in this paper revealed that the Barrier it its present conditions with all gates opened, when there is C1 gap with area 7990 m^2 is practically 'transparent' for the most floods but can reduce the ones with short periods as the flood of 1955. Closing of B3 - B6 will lead to additional decrease of level on 16 - 23% for flood with velocity of water level raise in the range 58 - 35 cm/h. At the same time the closing will lead to approximately the same in percents increase of velocities in the openings. Velocities in opened gates can reach 7.5 - 8 m/s. These extremely high velocities certainly will lead to erosion in TM D2 and TM D7 and sliding of ground into C1 navigation gap. The erosion will increase if B3 - B6 would be closed. Sliding of ground from walls around foundation pit may lead in a very short time to its destroy and into filling of the navigation passage C1. Erosion in TM D7 will lead to loss of stability of piles and destroy of the road that connects now Kronshtadt with St.Petersburg. To determine values of erosion additional study is required. At present there is a decision not close B3- and B6 during any flood. It should be also noted high water level rise before the Barrier in resort zones of Tarkhovka-Sestroretsk and Malaya Izhora.

The work presented in the paper was done as part of the Russian-Netherlands project "Integrated Water Management in St.Petersburg Region".

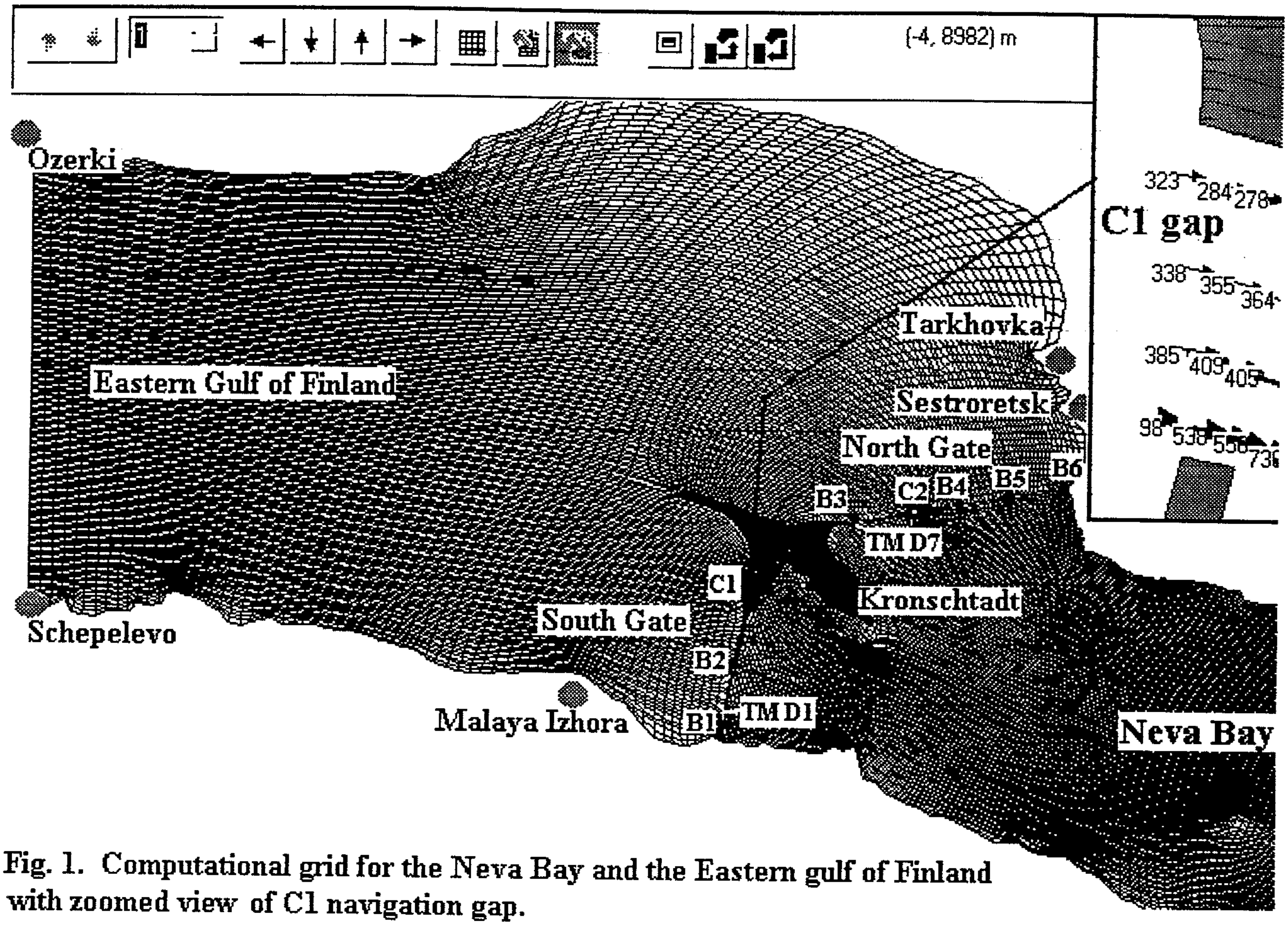

Fig. 1. Computational grid for the Neva Bay and the Eastern gulf of Finland with zoomed view of C1 navigation gap.

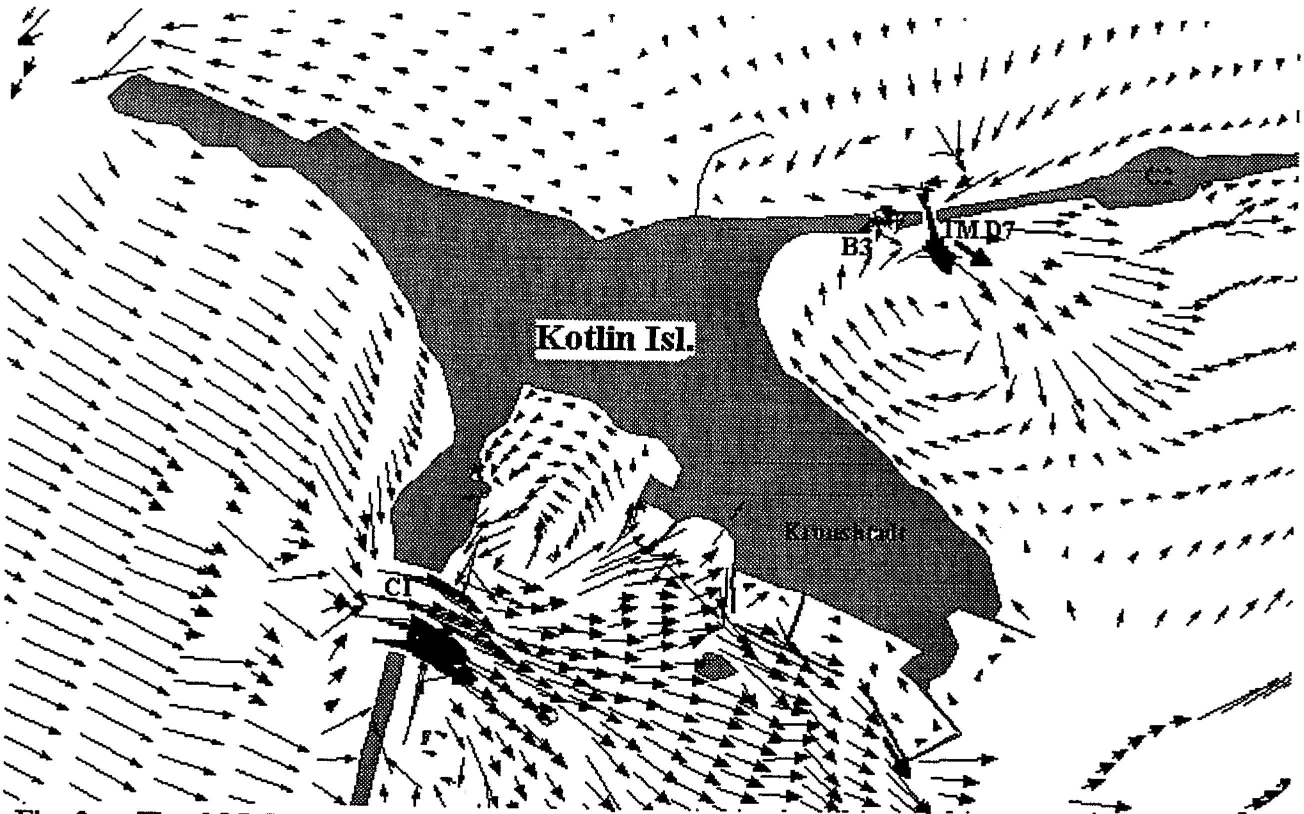

Fig. 2 Flood 15 October 1955. Present state of the Barrier. B-3,B-4,B-5 and B-6 are closed. Velocity field at the moment of maximum discharge through the Barrier. 20 h 47 min.

INVESTIGATION OF ATMOSPHERIC HUMIDITY IN A NUMERICAL MODEL USING DETAILED MODEL DIAGNOSTICS AND GPS, SSM/I, AND GROUND-BASED MICROWAVE RADIOMETER DATA

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The total amount of atmospheric humidity as well as its spatial distribution are of primary importance for a correct numerical simulation of the atmospheric water budget. This paper presents an investigation of the humidity fields of the BALTEX-Modell (BM) and Europa-Modell (EM) of the DWD focusing on a validation of the vertically integrated water vapour content (IWV) in analyzed and predicted fields and a better understanding of the modifications of humidity fields during data assimilation as well as the model spin-up of precipitation.

The study concentrates on the PIDCAP period (August to October 1995) for which a reanalysis was run at the DWD using the BM, a version of the operational EM with a horizontal resolution of 1/6 degrees and 30 vertical levels. The BM model domain covers the entire Baltic Sea catchment area; hourly lateral boundary values for the BM are provided by the EM. Atmospheric analyses are performed every 6 hours on the model grid using the operational intermittent optimal inerpolation scheme. Snow cover is analyzed every 6 hours, the sea surface temperature once daily. In addition to results from the BM assimilation, the operational EM with 0.5° degrees horizontal resolution and 20 vertical levels is used for this study.

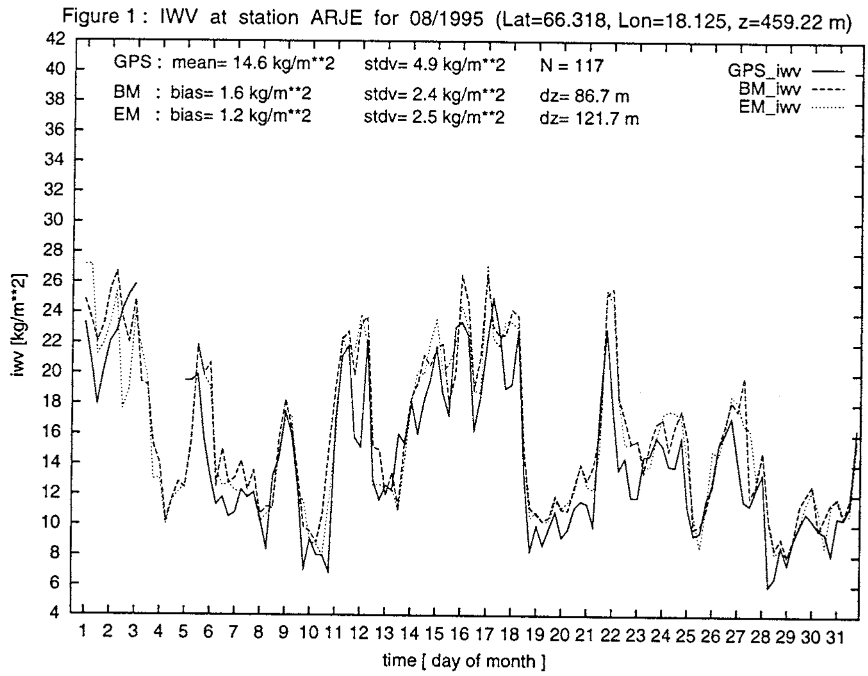
For the PIDCAP period, IWV estimates have been derived from Global Positioning System (GPS) data by the Onsala Space Observatory/Chalmers Institute of Technology, Sweden, for 25 GPS sites of the Swedish and Finnish networks. Additionally, IWV retrievals based on Special Sensor Microwave/Imager (SSM/I) data have been processed at the Institut für Meereskunde Kiel, Germany, for the period 20 August to 31 October 1995. SSM/I retrievals provide a complementary data set being available over sea only, whereas the permanent GPS stations are located over land. Since both data sources are not yet used in the assimilation, they represent independent data sets for validation. Overall statistics as well as results for single stations will be presented (see exemples in **Figures 1,2**). The reproduction of the observed temporal and spatial variability by analyses and forecasts will be discussed.

A third data source for validation of IWV is provided by retrievals from ground-based measurements of the microwave radiometer of the Potsdam Observatory of DWD. The radiometer having been in operational use only in 1996, data of a different period (in 1997) are used in the comparison to EM and DM (Deutschland-Modell) values (not shown here). Additionally, radiosoundings are used as a conventional reference for both the IWV and vertical humidity profiles. The comparison of the four different observational data sets and the model values will aid to detect a possible model bias or deficiencies in the measurement or retrieval techniques.

Apart from the observational studies, an investigation of model humidity and precipitation will be shown using statistics based on detailed diagnostic model output produced during the PIDCAP reanalysis with the BM for the whole model area and several sub-domains within the Baltic catchment area. Again, results for the BM are compared to those of the EM. The diagnostics reveal that the model spin-up is limited to about the first 3 hours after each analysis (in both BM and EM, not shown) resulting in reduced precipitation and increased cloud water content. Futhermore, the modifications of water vapour content and humidity profiles during data assimilation and short range forecasts are studied laying emphasis on systematic changes and their causes. This diagnostic study aims at detecting possible deficiencies in the humidity analysis with the goal to later make use of the additional humidity information contained in remote sensing data like GPS and SSM/I data.

Figure 1 shows an example of a time series of IWV at the GPS site Arjeplog (solid line) for August 1995 together with the corresponding IWV values of the analyses from BM and EM (dashed and dotted lines, respectively). The variations in water vapour as observed by GPS measurements are very well reproduced by both BM and EM analyses: Sudden strong advection of very dry or very moist air (e.g. on 11/08, 18/08 and 21/08) as well as smaller events (e.g. between 13/08-18/08 or 19/08-21/08) are well modelled. However, discrepancies are visible in absolute values. The statistical comparison for ARJE in August 1995 results in a moist bias of 1.6 kg/m^2 for BM (model minus GPS values) with a standard deviation (stdv) of 2.4 kg/m^2. Results for the EM are comparable with a bias of 1.2 kg/m^2 and a stdv of 2.6 kg/m^2.

Statistics comparing results for analyses and forecasts of the EM are given in **Figure 2**. The top panel shows the bias (EM minus GPS values), the bottom panel the standard deviation (stdv) for August, September, and October 1995 (averaged over all GPS stations). The model IWV values are systematically higher than the GPS estimates by about 2.7-3.0 kg/m^2. This represents a deviation of about 13% of the total (model) IWV value in August and 18% in October. The results are very similar for analyses and 6-h forecasts, whereas a larger stdv for the 48-h forecasts reflects forecast inaccuracies. A part of the differences between model and GPS is to be attributed to the GPS estimates. Comparisons of GPS IWV to water vapour radiometer and radiosonde data have revealed a systematic underestimation of the IWV derived from GPS by about 1.-1.6 kg/m^2 (Emardson et al., 1997).



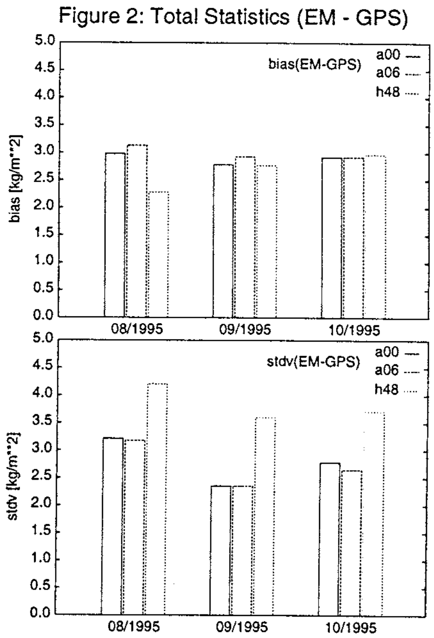


Fig. 1 (left): Time series of IWV values (in kg/m^2) for August 1995 (at 00, 06, 12, 18 UTC each day), derived from GPS data at the Swedish site Arjeplog (solid line, no data available between 3 August, 6 UTC, and 4 August, 18 UTC) and corresponding values derived from BM and EM analyses (dashed and dotted lines, respectively). Mean values, bias (model minus GPS), standard deviation, and the difference in station height (dz, bilinearly interpolated model orography minus height of GPS site) for BM and EM, as well as the mean GPS-IWV and its standard deviation, and the number N of comparison items are given at the top of the figure.

Fig. 2 (right): Statistical comparison of IWV derived from the EM to IWV retrievals from GPS for the months of August, September, October 1995 for initialized analyses (a00, solid bars), 6-h forecasts (a06, dashed bars) and 48-h forecasts (h48, dotted bars) as bias (EM - GPS, top) and standard deviation (bottom) in kg/m^2.

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Hydrological and meteorological determination of physical fields changeability in the coastal area of the Pomeranian Bay.

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1. Introduction

The Pomeranian Bay is the estuarian region, where river and sea waters mix together. In the coastal zone physical features of sea water (water temperature and salinity) are determinated mostly by changeable amount of river input and weather conditions like air temperature and wind. The salt water inflow from the North Sea, convection and advection processes in the area, depth, the shape of line coast as well as land closeness are the other factors. The influence of each factor as well as interactions between them cause the great changeability of physical features in that region. The work presents the results of studies on the influence of hydrological (the input of the Odra River) and weather conditions (circulation conditions and air temperature) on physical features (water temperature and salinity) in the Polish coastal zone of the Pomeranian Bay.

2. Description of the study

Daily mean salinity values at Międzyzdroje (the southern coast of the Pomeranian Bay) were analysed and compared with the discharge values of the Lower Odra River at Gozdowice and water level differences data as measured at Świnoujście (the mouth of the Świna Strait) and Trzebież (the southern coast of the Szczecin Bay) using descriptive statistical methods. Next cross-corelation, simple and multiple regression analyses were performed to find relations between examined parameters. On another hand daily mean water temperature values as measured at Międzyzdroje and Gozdowice as well as air temperature values at Świnoujście were analysed and compared to obtain statistical relations between them. Circulation conditions were taking into consideration to understand the physical processes occuring in the area. The period 1971-1983 was taken into examination. The special emphasis was put into the Odra flooding events.

3. Results

The Odra River drains into the Pomeranian Bay (situated at the southern coast of the Baltic Sea) through a branched system of water flows and prior transformation of waters in the Szczecin Bay. Hence mean monthly values of salinity at coastal zone reached the minimum in April although the maximum of the river inflow was observed in March. In the second half of the year while the river input was usually inconsiderable there were found no relations between monthly salinity and discharge values of the Odra River.

In the periods of low water of the Odra there were found only slightly significant relations between the Odra discharge and salinity at Międzyzdroje. On the contrary during the Odra flooding events there were obtained statistically significant relations between salinity in the coastal zone and water discharge at Gozdowice as well as water level differences as measured at Świnoujście and Trzebież. In case of the Odra flooding event in summer 1977 the mean time for waters of the Odra (from Gozdowice) to reach Międzyzdroje was 12 days. The change of salinity at Międzyzdroje as a result of the change of slope between water levels at the Baltic coast and Szczecin Bay followed in 3 day lag (Fig. 1).

Circulation conditions modified relations between examined parametrs. During the Odra flooding events when air circulation from southwest to north was prevailing relations between the Odra discharge and salinity at Międzyzdroje were the strongest. Relations were poorer when air circulation from northeast to south was noticed. Convection processes were observed in the periods of prevailing circulation from northeast to south.

Mean water temperature of the Odra River was higher than water temperature in the coastal area of the Pomeranian Bay from February to August and lower from September to January. Mean air temperature was lower than sea water temperature during all the year.

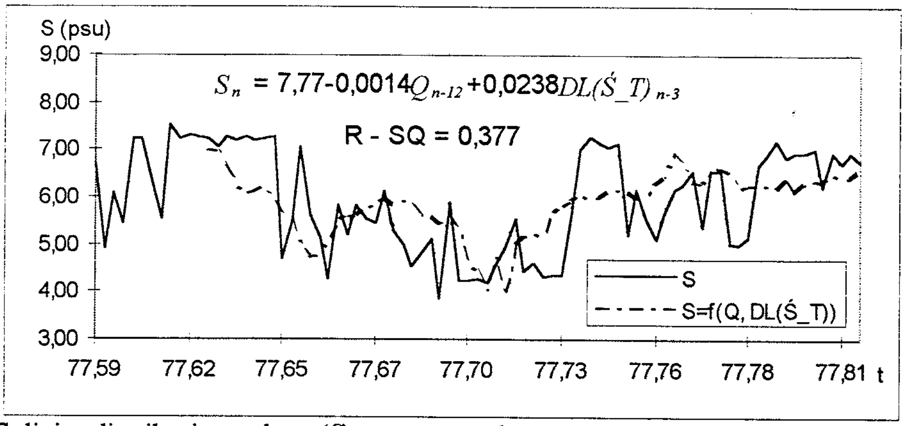

Fig. 1. Salinity distribution values (S) as measured *in situ* at Międzyzdroje and obtained from multiple regression function using discharge values of the Odra River (Q in m^3/s) and water level differences data as measured at Świnoujście and Trzebież (*DL(Ś_T)* in cm) during the Odra flooding event in the term of period between 4th of August to 25th of October, 1977. R-SQ is correlation coefficient squared.

The change of water temperature at Międzyzdroje was quicker when air temperature was the forcing factor. The mean time for the reaction of inshore water was 1-2 days. When temperature of the Odra River forced the sea temperature, the change of inshore water temperature followed in 6-7 days. Correlation coefficients received as a result of synchronous relating water temperature values at Międzyzdroje with water temperature values at Gozdowice and air temperature values at Świnoujście were highly statistically significant. Hence it was possible to describe water temperature at the coastal zone of the Pomeranian Bay using equations of simple and multiple regression. In case of the Odra flooding event in summer 1977, the equation of multiple regression explained almost 95 % of all the cases (Fig. 2).

It was found that the influence of water temperature of the Odra on sea temperature was stronger than the effect of air temperature, especially during air circulation from southwest to northwest directions. The influence of air temperature was increased when circulation from northeast was noticed. In that case the effect of water temperature of the Odra was decreased. Moreover it was found that during the Odra flooding events the influence of water temperature of the Odra was increased and the effect of air temperature was decreased.

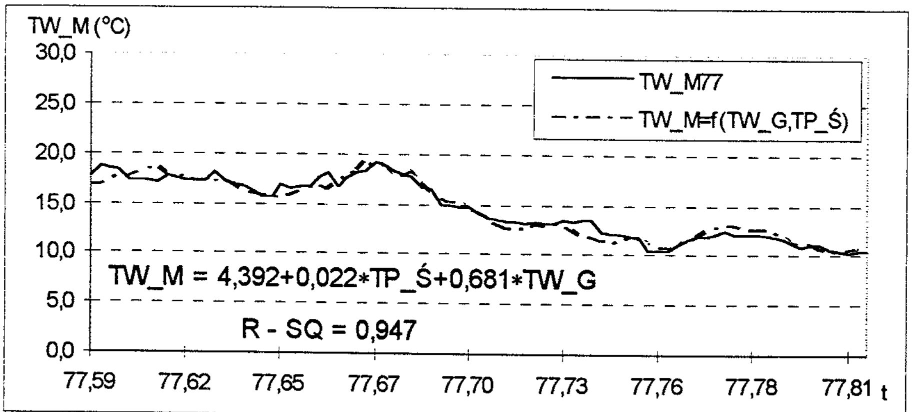

Fig. 2. Water temperature at Międzyzdroje (*TW_M*) as measured *in situ* at Międzyzdroje and obtained from multiple regression function using water temperature as measured at Gozdowice (*TW_G* in °C) and air temperature at Świnoujście (*TP_Ś* in °C) during the Odra flooding event in the term of period between 4th of August to 25th of October, 1977. R-SQ is correlation coefficient squared.

4. Conclusions

In the periods of the Odra flooding events physical features in the coastal area of the Pomeranian Bay were determined mainly by the river input. The influence of circulation conditions was a modifying factor. In the periods of low water the effect of circulation conditions on physical features in the coastal area of the Pomeranian Bay was increased. The influence of air temperature on inshore water temperature was increased as well.

UNCERTAINTY ANALYSIS ON THE EVAPORATION AT THE SEA SURFACE

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1. Introduction

Evaporation at the sea surface plays an important role in the budgets of energy and water. Thus, the water vapour flux at the sea surface has to be estimated with a sufficient accuracy. The most widely used method is the so-called bulk method, where bulk transfer coefficients are introduced to relate the mean values of humidity, wind speed, and temperature observed at a reference height z_R (usually z_R = 10 m) in conjunction with the measured sea surface temperature to the fluxes of water vapour, momentum, and heat (e.g., Kraus and Businger, 1994). These bulk transfer coefficients, however, are frequently taken from the literature so that the effects owing to thermal stratification, wind-wave interaction, gustiness, inappropriate fetch conditions close to the shore etc. cannot be addressed in a reliable manner. Moreover, the transfer of momentum, heat and water vapour across the thin molecular-turbulent sublayer adjacent to the sea surface is strongly controlled and limited by molecular transfer properties, no matter how irregular the sea surface may be, but the relative importance of this sublayer cannot be expressed by such bulk transfer coefficients. Therefore, to obtain bulk transfer coefficients and, hence, reliable results on evaporation at the sea surface from numerical atmospheric models not only the turbulent exchange, but also the transfer across the sublayer has to be parameterised in an adequate manner.

The purpose of our project is to quantify the uncertainty that parameterisation schemes, empirical quantities and the limited accuracy with which input data can be observed contribute to water vapour fluxes predicted with mathematical models. Here, the influence of different parameterisation schemes to describe the transfer across the interfacial sublayer over aerodynamically smooth sea surfaces on the evaporation as a whole is elucidated.

2. Theoretical Background

The vertical transfer of water vapour, Q, from the sea surface may be written as (see, e.g., Sheppard 1958)

$$Q = -\rho\left(D_q + K_q\right)\frac{\partial q}{\partial z} \quad , \tag{1}$$

where $\partial q/\partial z$ is the vertical gradient of the specific humidity, and where D_q and K_q are the molecular diffusivity and the vertical eddy diffusivity for water vapour, respectively. The latter is *customarily* approximated by K_h, the vertical eddy diffusivity of heat (see, e.g., Kraus and Businger, 1994). Considering Monin-Obukhov scaling and integrating this flux-gradient relationship over the constant flux layer, $0 \le z \le z_R$, provides

$$E = -\, r_{a,q}^{\;-1}\,\rho\left(q_R - q_s(T_g)\right) = -\rho\, C_q\, U_R\left(q_R - q_s(T_g)\right) = -\rho\, u_*\, q_* = \text{const.} \tag{2}$$

Here, $q_s(T_g)$ is the saturated specific humidity at the sea surface, T_g is the absolute temperature at the surface, q_R is the specific humidity at reference height, z_R, U_R is the corresponding wind speed, C_q is the bulk transfer coefficient for water vapour (often called Dalton number), and $r_{a,q}$ is the total bulk resistance of the air against water vapour transfer. The latter quantity is defined by $r_{a,q} = r_{t,q} + r_{mt,q}$, where $r_{t,q}$ is the bulk resistance of the fully turbulent region of the surface layer given by (e.g., Kramm, 1989)

$$r_{t,q} = r_{t,h} = \int_{z_r}^{z_R} K_h^{-1}\, dz = \frac{1}{u_*\,\kappa}\left(\ln\frac{z_R}{z_r} - \Psi_h(\zeta_R, \zeta_r)\right) \quad , \tag{3}$$

and $r_{mt,q}$ is the resistance of the underlying interfacial sublayer expressed by (see, e.g., Kramm et al. 1996)

$$r_{mt,q} = \frac{1}{u_*\, B_q} \quad \text{with} \quad B_q^{-1} = Sc_q \int_0^{\eta_r} \frac{d\eta}{1 + Sc_q\, K_m/\nu} = \frac{q_r - q_s(T_g)}{q_*} \quad . \tag{4}$$

Here, z_r is the lower boundary of the fully turbulent region of the surface layer (i.e., the height of the molecular-turbulent sublayer), $\zeta = (z - d)/L$ is a non-dimensional height, L is the Monin-Obukhov stability length, u_* is the friction velocity, $\eta = u_*\, z/\nu$ is a normalised height, $\eta_r = u^*\, z_r/\nu$ is the roughness Reynolds number, K_m is the eddy diffusivity for momentum, B_q is the sublayer Stanton number of water vapour, and $\Psi_h(\zeta_R, \zeta_r)$ is the integral similarity functions of heat and water vapour for the interval $[\zeta_R, \zeta_r]$ within the surface layer (e.g., Kramm, 1989). Similar expressions can be derived for the sensible heat flux. The vertical wind profile is given by

$$U_R = U_r + \frac{u_*}{\kappa}\left(\ln\frac{z_R}{z_r} - \Psi_m(\zeta_R, \zeta_r)\right) \quad , \tag{5}$$

where U_r can similarly be determined like B_q in Eq. (4) by arbitrarily setting $Sc_w = 1$ (see Fig. 1). The quantity $\Psi_m(\zeta_R, \zeta_r)$ is the integral similarity function of momentum for the interval $[\zeta_R, \zeta_r]$ within the surface layer (e.g., Kramm 1989).

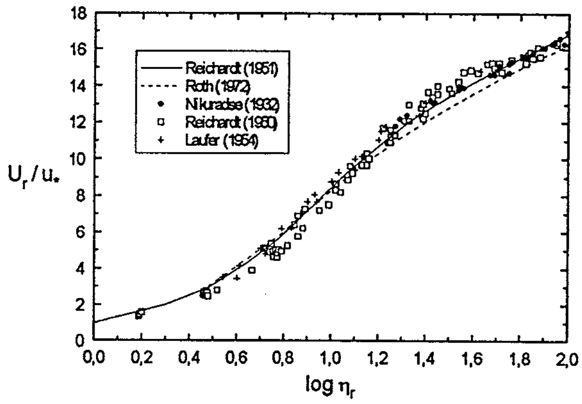

Fig. 1: Non-dimensional velocity profiles in the interfacial sublayer over aerodynamically smooth surfaces calculated on the basis of the integral expression in Eq. (4) with $Sc_i = 1$, where Roth's modified Heisenberg spectral model and Reichardt's (1951) K_m/ν-approach are considered, and compared with the laboratory measurements by Nikuradse, Reichardt, and Laufer (from Kramm et al., 1996).

3. Results

Typical results from the numerical investigation of the evaporation at the sea surface for different thermally stratified atmospheric flow are listed in Tab. 1. These results were derived with two different K_m/ν-approaches for the interfacial sublayer, namely Reichardt's (1951) semi-theoretical approach, $K_m/\nu = \kappa\,\{\eta - \eta_D \tanh(\eta/\eta_D)\}$ which well fits measured data (see Fig. 1), and Sheppard's (1958) simple approach $K_m/\nu = \kappa\,\eta$ which is unable to describe the transition range from a purely viscous to the fully turbulent transfer. The latter is applied, for instance, in the Penn State/NCAR mesoscale model MM5. Obviously, using Sheppard's approach provides nearly 50 per cent larger water vapour fluxes and, hence, latent heat fluxes compared to those derived with Reichardt's approach. The same is true for the amounts of sensible heat fluxes. These differences are mainly caused by the different values of the sublayer Stanton number. Based on these results we conclude that parameterisation schemes for the interfacial sublayer must be verified, not only on the basis of laboratory data as Reichardt's K_m/ν-approach, but also on the data from field experiments.

Tab. 1: Predicted values of sensible (H), and latent heat (E), total atmospheric ($r_{a,q}$), and turbulent resistances ($r_{t,q}$), the sublayer Stanton number (B_q), Monin-Obukhov stability length (L), friction velocity (u_*), and bulk transfer coefficient for water vapour (C_q). The predictions were performed for (a) stable case: $U_R = 6.0$ m s^{-1}, $\Theta_R = 287$ K, $q_R = 6.5$ g kg^{-1}, $T_g = 285$ K, and (b) unstable case: $U_R = 6.0$ m s^{-1}, $\Theta_R = 284$ K, $q_R = 6.0$ g kg^{-1}, $T_g = 285$ K.

H W m^{-2}	E W m^{-2}	$r_{a,q}$ s m^{-1}	$r_{t,q}$ s m^{-1}	B_q^{-1}	L m	u_* m s^{-1}	C_q	Remarks
-11.8	30.8	205.5	137.7	10.9	40.2	0.16	$8.1\cdot10^{-4}$	Reichardt's approach
-17.3	45.0	140.7	106.0	7.0	52.6	0.20	$1.2\cdot10^{-3}$	Sheppard's approach
7.5	50.4	155.9	93.6	11.2	-47.2	0.18	$1.1\cdot10^{-3}$	Reichardt's approach
11.2	72.3	108.5	76.3	7.3	-63.3	0.23	$1.5\cdot10^{-3}$	Sheppard's approach

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Land surface model for use within climate model ECSib and Ecological studies

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Atmospheric and ecological models often parameterize the same processes, though with different complexity. Soil water is an important term of net primary production and geographical vegetation patterns. Soil water , through its effects on the partitioning of net radiation into latent and sensible heat, is also an important determinant of climate. Ecological models often use a simple model, updated monthly to model soil water. Some of the land surface parameterizations for atmospheric models use the same equations, though with fewer soil layers (three layers corresponding to diurnal, seasonal and annual time scale). Vegetation is important for many ecological studies because it determines the rate of CO_2 during photosynthesis and is important for hydrologic and atmospheric studies because of its effect on the latent heat flux. The most detailed parameterizations of vegetation are often found in the land surface models used with atmospheric models [1,2]. It may be summarized as follows: effects of leaf area on the absorption of solar radiation at the surface, sensible heat flux and latent heat flux; biochemical fluxes; and the soil heat fluxes, which are important due to the effects of soil temperature on biochemical fluxes, the surface energy budget and soil hydrology.

The land surface model considered in this report is an extension of this earlier model development [3]. The model is a blend of the ecological processes, the hydrological processes and surface fluxes common to the land surface models used with atmospheric models. With the requirement that the model is implemented globally, many surface type needed to be included. Proposed version of the land surface model combines a rather complete accounting for physical factors to assess the interaction of the atmosphere with the surface and availability for including in the general circulation model ECSib [3,4]

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FEATURE OF THE CLOUD SYSTEMS OF THE CYCLONES DIRECTED TOWARDS UKRAINE FROM THE BALTIC SEA REGION

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Investigation of distributions of thermodynamic characteristics which determine frontal cloudiness formation and structure was carried out with aid of 2-D and 3-D diagnostic numerical models. There was develop the special method construction of nowacasting models of fronts which are observed in the real synoptic conditions. In more cases their cloud systems were conducted by field experimental investigation. Rawinsonde, aircraft, satellite data and radiolocation observations of frontal cloudiness and appropriate synoptic charts were initial data for the study and simulations of real fronts over Ukraine in winter seasons.

Satellite data were obtained from NOAA satellite as a part of High Resolution Picture Transmission (HRPT) data stream. Cloud fraction, top temperature, top height, optical thickness , liquid water path and the type of cloudiness were retrieved using AVHRR data. Retrieved data are used for development and verification of cloud numerical schemes, for varying degree of simplification tend to be commonly adopted in numerical nowacasting and forecasting models, for combined analysis of frontal cloud system passing over Ukraine.

More than 100 frontal zones which moved on the above region from the different directions were analysed.

To study structure of thermodynamic characteristics' fields the active and passive thermodynamic zones were distinguished. Active thermodynamic zones are places where horizontal temperature gradients are not equal zero (hyperbarocline zone, HBZ), thermodynamic condensation and updrafts are present. Simulated ice supersaturation zones were analysed in the frontal zone structure investigation. There are 3 main groups of frontal systems which determine the weather in Ukraine in winter seasons. They move from: south (S); south-west (SW); west and north-west (WNW).

Frontal zones of the (S) group frequently consist of pair warm fronts. Their thermodynamic structure is characterised by the large HBZ significant ice supersaturation layers. Time development examination of such thermodynamic zones and connected with them cloudiness systems has pointed at keeping (12-15 h) of their movement directions and intensities of processes.

Frontal zones of the (SW) group differ from previous ones. They frequently consist occluded and cold fronts and have smaller HBZ , the significant ice supersaturation layers especially in cold frontal systems were absence. Cloudiness of the SW fronts was insignificant, ragged and not precipitate.

Frontal zones of the (WNW) group are divided on 2 parts: WNW-1 and WNW-2. Thermodynamic fields and cloudiness of WNW-1 are similar to the above (S) ones. Thermodynamical structure of WNW-2 is characterised by small smashed HBZ and by ice supersaturation of significant streaking-out into small extent layers. Cloudiness of the WNW-2 group is insignificant, broken, but precipitate.

Obtained features of frontal cloudiness structure and thermodynamic characteristics can be used as a basis for to construct of regional diagnostic and prognostic models of frontal cloudiness and precipitation. Some example of combined analysis of fronts of WNW cyclone will be considered in more detail.

INVESTIGATION OF THE CURRENT FIELD BY MEANS OF SHIPBORNE ADCP DURING THE FIELD EXPERIMENT IN THE GULF OF GDAŃSK

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The paper presents the observations of the flow field within central part of the Gulf of Gdańsk, which have been carried out during POLRODEX'96 experiment in August 1996. The goal of that experiment it was collection of the sea current data in order to verify numerical model calculations and to study the method of the flow field reconstruction. Applying of the new method for sea current investigation as the result of new measuring technique implementation into routine oceanographic work seems to be very promising way for the sea dynamic studies as well as for numerical models verification.

Velocity observations using shipboard Acoustic Doppler Current Profilers (ADCP) still are fraught with difficulty in interpretation. When one deals with current meters he has repeated observations at fixed locations and it is simple matter to calculate any periodical components of the flow. Moreover, ADCP measurements carry advantages and disadvantages. As an advantage, we acquire observations at wide range of depths frequently covering almost entire water column. The disadvantage is that the observations are acquired only wherever the ship happens to be, so that the sampling intense when the ship stops to do a CTD sample or other measurements and sparse when the ship is travelling rapidly. However if the cruise route is properly planned then dense and widely distributed in space measurements allow for calculation of the current vectors in the nodes of the selected grid using the method of interpolation. The results of different approaches to solve the problem of the best reproduction of real flow field are presented as well.

In order to cover selected area entirely, the measurements were carried out along five parallel transects with 15 s frequency of the collected bins. Due to the ship speed the distance between each single measurement was equal approximately 75 meters. The flow fields were examined at two depths, i.e.: 10 and 20 meters by means of the Shipboard Acoustic Doppler Current Indicator CI-60 FURUNO placed on board of RV Baltica both on 2nd and on 13th of August. On the basis of the results of the measurements quasi-synoptic flow fields were reconstructed (Fig. 1). It made possible to compare them with the results from the HIROMB (High Resolution Operational Model of the Baltic) forecasts. The comparison of the reconstructed flow fields and numerical calculations showed slightly different patterns of the flow in the Gulf of Gdañsk for both cases of the numerical calculation. The statistical analysis of differences is presented also (Fig. 2). Besides details of statistical results it is clearly seen that model did not reproduce current velocities well. In order to find any regularity of the differences distribution it is discussed their spatial layout as well. In general, the differences are increasing from the centre of the gulf toward east and west longitudes. It may be concluded that the worst results of numerical calculations are close to the coastline.

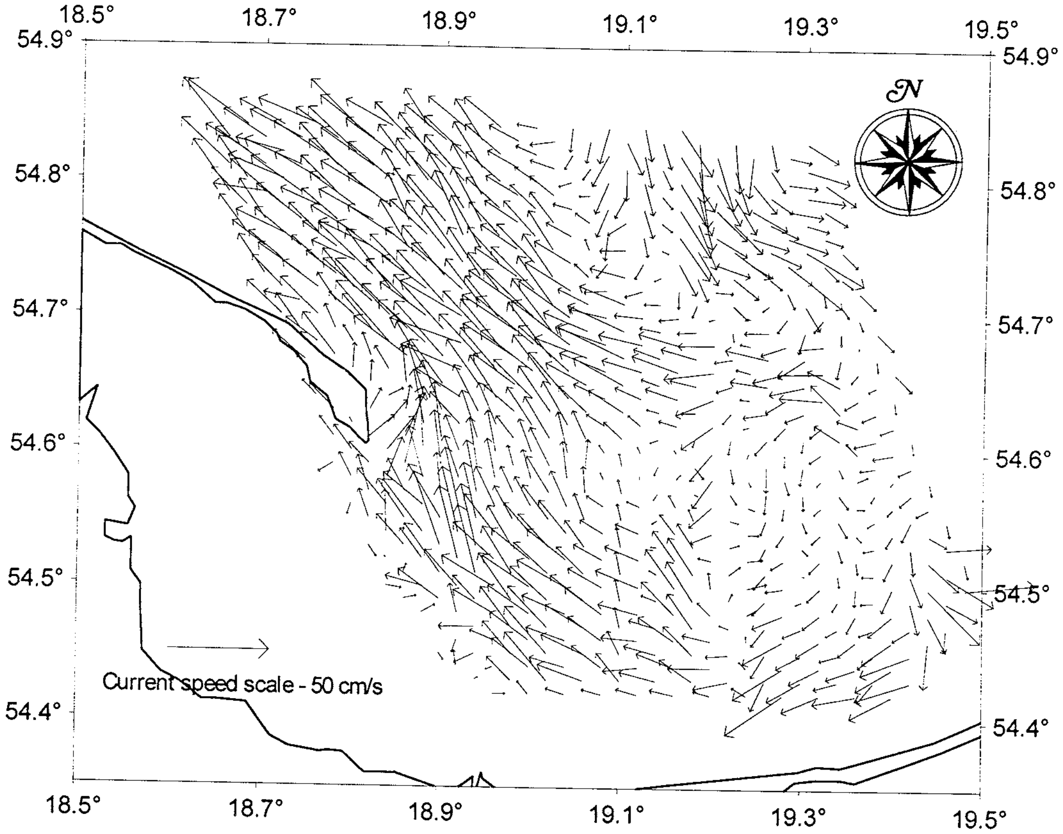

Fig. 1. Current vectors at 10 m depth, interpolated on the basis of ADCP data collected in the Gulf of Gdansk during cruise of RV BALTICA on 13 August 1996

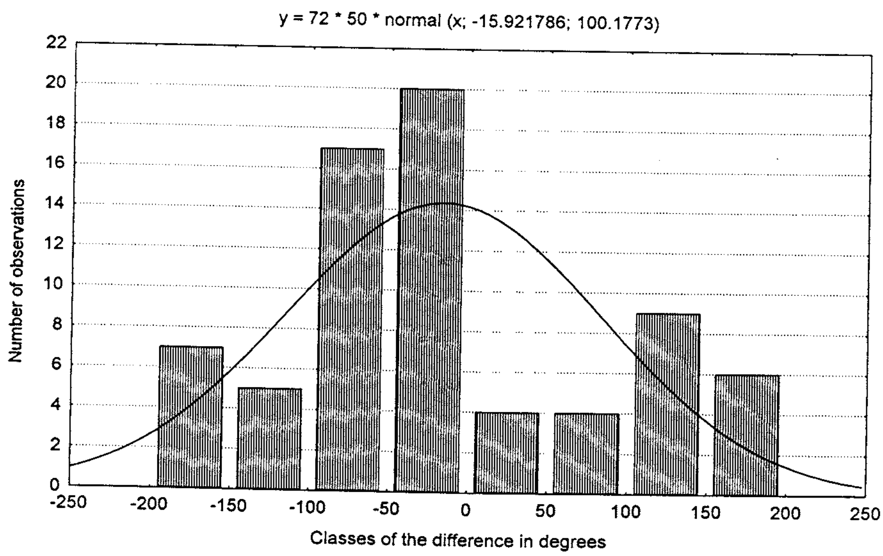

Fig. 2. Histogram of the differences between measured and modelled values of the currents direction in the Gulf of Gdansk on 13 August 1995

OPTICAL THICKNESS OF THE BALTIC AEROSOLS.

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The proper parametrisation of the aerosol optical properties is important for both atmospheric correction in remote sensing and parametrisation of solar radiation fluxes at the surface. This paper addresses the variability in the aerosol optical thickness over the Baltic Sea and relates it to meteorological conditions. The aerosol optical thickness spectra were retrived from solar radiation measurements and meteorological observations made during several cruises on the Baltic Sea, mainly to the Southern and Western part of the Baltic Proper.

Two methods of estimation of the aerosol optical thickness were applied. The direct (exact) method is based on measurements of the direct component of irradiance at the sea surface in 8 spectral bands (412, 443, 490, 510, 555, 670, 765, 865 nm). In the indirect method, Baltic aerosols are assumed to be a mixture of model aerosol types with strictly defined optical properties, i.e. maritime, continental, and urban types. The aerosol thickness is retrived from broadband spectral global irradiance measurements (VIS, IR) using radiative transfer parametrisation.

A New EU Project SFINCS (Surface Fluxes in Climate System) - Aspects Relative to the Baltic Sea Area

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ABSTRACT

This Project focuses on parameterization of the sub-grid scale air-sea/air-land turbulent fluxes of heat, momentum and passive scalars (henceforth flux-parameterization) for use in climate, weather prediction and other atmospheric models. The project participants are Risø National Laboratory (Denmark, Co-ordinator); Max Planck Institute for Meteorology (Germany); Uppsala University (Sweden), Swedish Meteorological and Hydrological Institute (Sweden); National Observatory of Athens (Greece). The overall goal is to fill the gap between modern knowledge on the physical nature of turbulence and currently employed old-fashioned flux-parameterization.

Speed up of modern computers has inspired rapidly increasing spatial resolution and accuracy of operational models. This progress, however, is impeded by the lack of flux-parameterization that reflects non-local properties of the planetary boundary layer (PBL) turbulence. The conventional surface-layer similarity theory as well as turbulence closures in operational use are both unable to reproduce non-local transport of momentum, heat and passive scalars. As a result the surface fluxes are ill-founded in extreme cases of strong convection and strong static stability. The key role in this problem is played by large-scale semi-organised structures, disregarded within the traditional concept of a turbulent flow as composed universally of fully organised (mean) and fully chaotic components.

Advanced theoretical concepts of the PBL turbulence together with recent evidence from field measurements and numerical large-eddy simulation studies provide sufficient basis for better understanding and realistic parameterization of the effects of non-universal semi-organised structures on the vertical transport. Modern generation of the climate and weather prediction models provide convenient tools for incorporation and testing of new modules such as the flux parameterization. In the scope of the Project SFINCS, the above recent achievements are further extended to develop an improved parameterization of turbulent fluxes at the air-sea/air-land interface in the interests of modelling the atmosphere and the sea. This work includes (i) theoretical analysis of non-local transport properties of atmospheric PBLs, and development of an improved flux-parameterization for extreme cases of strong convection and strong static stability, (ii) verification of new theories and parameterization schemes using data from measurements, and (iii) implementation and validation of new recipes in global and regional climate and weather prediction models (the climate-model chain ECHAM-REMO-GESIMA and the weather prediction model HIRLAM). In both micrometeorological experimental studies and case studies with climate and weather prediction models particular attention is paid to the Baltic Sea and the Mediterranean Sea areas.

Properties of internal waves in the Gotland Basin with relevance to diapycnical mixing.

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Abstract:

The DIAMIX project aims at a better parameterisation of diapycnical mixing in circulation models of the Baltic Sea. In June 1997 a pilot study in the eastern Gotland Basin has been performed in order to test instruments and methods suitable to meet the objectives of DIAMIX.

In particular nine repeated CTD sections have been made along the mean gradient of the topography off the east coast of Gotland. Sections have been repeated in pairs of half a inertial period apart. By this technique sub-inertial and near-inertial motions could be separated. Subinertial motions were low perhaps due to the weak atmospheric forcing during this part of the season. Near inertial motions with vertical scales of about 10m and horizontal scales of 1 km where observed within the whole water column along the section. In order to resolve this features measurements with towed undulating CTD are neccessary.

Time series with ADCP, thermistor chain, and temperature-conductivity recorder with a sampling time of 1 minute have been performed for ten days. ADCP measurements were reliable for current variations of time scales larger than one hour. Current fluctuations due to internal waves with periods less than one hour have horizontal scales less than the separation length of the ADCP beams causing noise in the ADCP record. Current and temperature fluctuations have been separated by filtering in sub-inertial (T > 20h), inertial (20h > T > 7h), and non-rotational bands (7h > T > 1h), respectively. Potential and kinetic energy of all bands have been analysed in the physical space and of the inertial and gravity wave band in the frequency – wavenumber space. The results are compared with ocean internal wave spectra.

BALTIC AIR-SEA-ICE STUDY - A FIELD EXPERIMENT OF BALTEX

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1. Objectives

The overall objective of the Baltic Air-Sea-Ice Study (BASIS) is to create and analyse an experimental data set for optimization and verification of coupled atmosphere-ice-ocean models. The specific objectives cover

1) Investigation of water budget and momentum and thermal interaction at the air-ice-sea interfaces
2) Investigation of the atmospheric boundary layer (ABL), especially close to the sea ice margin
3) Investigation of the ocean boundary layer (OBL)
4) Investigation of the sea ice and its dynamics
5) Validation of coupled atmosphere-ice-ocean models.

2. Work content

The field experiment is carried out in the Gulf of Bothnia in February-March, 1998 (Fig.1). Airborne measurements of the ABL are made using both a research aircraft and a helicopter, the latter carrying the Helipod measuring device. Those measure the properties of atmospheric turbulence and radiation in various heights, and clouds. Ground-based measurements of the ABL include radiosonde soundings at five stations at the coasts of the Gulf of Bothnia. The soundings are made four times a day. The central working platform is *R/V Aranda* anchored in the ice. Meteorological buoys, two meteorological masts, a sonic anemometer, radiation sensors, and the ship weather station are used to observe the ABL properties at this ice station. A meteorological mast, various turbulence instruments and radiation sensors measure on the land-fast ice at the Swedish coast. The ice and surface properties are investigated by remote sensing and surface-based measurements. The latter include thermistor chains through the ice and snow, laser profilometry of the surface roughness, and snow and ice sampling. The sea ice concentration and movement are studied by remote sensing and buoy observations. Totally, some 10 drifters detect the ice motion. The ocean boundary layer is studied by large-scale hydrographic sections before and after the 3-week-long ice station. Current measurements are made using ADCPs and current meters below the ice, and thermistor chains are mounted below the ice. The OBL turbulence is investigated by ultrasonic and electromagnetic eddy flux measurements below the ice.

3. Results expected

The field data supported by various modelling studies shall yield data sets and information of:

- atmospheric water, heat and momentum budgets
- turbulent and radiative fluxes in the ABL above inhomogeneous ice and water surface
- ice and snow properties, ice concentration and drift, ice roughness
- ground truth data for remote sensing
- turbulent fluxes and OBL structure below the ice
- oceanic heat budget
- improved process parameterizations for the coupled atmospheric and marine models.

The duration of the project is 1997-2000 and EU/MAST has granted the funding applied. A preparatory experiment pre-BASIS was carried out in March 1997 in the Gulf of Bothnia.

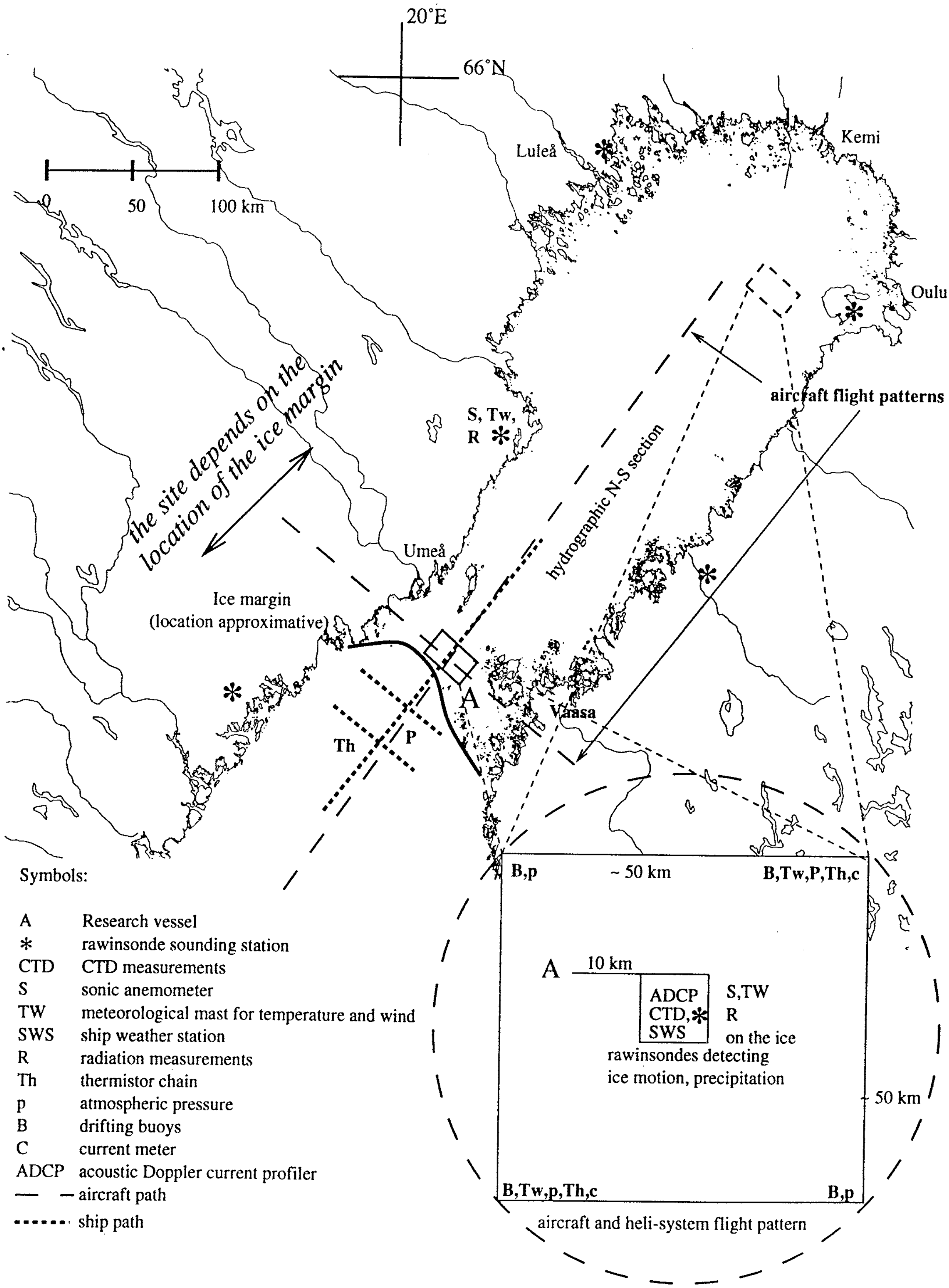

Figure 1. Map of the research area in the Gulf of Bothnia. The measurement activities at the main experiment site are shown in the lower right-hand corner. The experiment data will be completed by meteorological synoptic and sounding station data.

BALTIC SEA MODELLING INCLUDING COUPLED ICE-OCEAN AND ICE-OCEAN-ATMOSPHERE MODELS

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Abstract

Understanding the role of the Baltic Sea in energy and water cycles requires models for the relevant transport processes. Models must be capable of accurately representing the response of currents and sea level to direct forcing by wind, and by wind-induced changes of sea level in the Kattegat leading to exchange flows through the Danish Straits. The models must further describe the response of the circulation to forcing by river runoff, precipitation/evaporation and by melting/freezing, with specific emphasis on freshwater budget and thermohaline circulation. A quantification of the energy and water cycle requires the utilization of coupled numerical systems. After 4 years of BALTEX research it is now useful to review the progress in modelling and give an outlook of future requirements and developments.

1. Introduction

The investigation of the energy and water budget of the Baltic Sea and its catchment area is one main aim of BALTEX. The understanding of the role of the Baltic Sea in energy and water cycles requires models for the relevant transport processes. The models must describe the response of the circulation to forcing by river runoff, precipitation/evaporation and by melting/freezing with specific emphasis on the freshwater budget and thermohaline circulation. Due to the strong interaction of atmosphere, ice and ocean a quantification of the fluxes between the components requires the utilization of coupled numerical systems. From the oceanographic point of view, the components ice, ocean and atmosphere are strongly interacting, whereas, to the hydrology less distinct re-coupling exists. The atmosphere provides the forcing for the ice-ocean system, namely, momentum, salt and heat fluxes which include precipitation, evaporation and radiation. A re-coupling of the ocean to the atmosphere is provided by sensible and latent heat fluxes. In case of sea ice, the oceanic heat flux to the atmosphere is strongly reduced or even prevented. However, the back-scattered short-wave radiation is strongly affected by the increased albedo. In case of open water, the atmospheric fluxes can act directly on the ocean surface, and in case of ice, the fluxes act on the ice surface and the ocean receives a modified forcing, depending on ice dynamics, thickness and compactness. The ocean, in turn, supplies heat and momentum fluxes to the lower ice surface, thereby strongly modifying the ice evolution. The net fresh water flux which is a combination of evaporation/precipiation and river runoff is a further component which has a strong impact on the water mass exchange with the North Sea and the salinity distribution within the Baltic Sea (Fig. 1). River runoff has a regional impact on the local salinity distribution and also affects due to its volume flow and dynamics the transports through the Danish Straits.

After 4 years of BALTEX research, it is now useful to review the progress in modelling and give an outlook of future requirements and developments. In view of BRIDGE, the Main BALTEX Experiment (1997), which is planned to take place from April 1999 to March 2001, it is important to identify deficiencies in the numerical models and try to remedy most of the problems during the preparation phase of the experiment.

Following the BALTEX Implementation Plan, a number of oceanographic modelling projects were planned, which will be discussed in the following.

- Baltic Sea response to atmospheric and hydrological forcing

- Development of a coupled ice-ocean model for the Baltic Sea
- Thermohaline circulation and long-term variability of the Baltic Sea
- Development of a coupled atmosphere-ice-ocean model of the Baltic Sea

In general, modelling activities appear to be in a good shape and progress, except three-dimensional model simulations of the thermohaline circulation and long-term variability of the Baltic have not been started yet. However, first results from a 15 year integration with the process model PROBE-Baltic (Omstedt and Nyberg, 1996) has been recently presented. The three-dimensional ocean modelling in the oceanograpphc community of the Baltic Sea is mainly based on the GFDL-type ocean model (Geophysical Fluids Dynamics Laboratory; Bryan, 1969; Cox, 1984; Semtner, 1974; Killworth et al. 1991) with a free surface and the modular descendants MOM 1 & 2 (Modular Ocean Model). But there are also other models available which differ more from technical aspects such as grid-types (B- and C-grid), the vertical discretization (z-, sigma-coordinates or sigma layers), the horizontal resolution than from the physics involved. A comparison of the different models could be helpful to explore the specific potential of the different verisons. Up to now, no such model intercomparison has been scheduled for the oceanographic models applied to the Baltic Sea.

With respect to oceanographic data assimilation which is also a part of the Baltic Sea modelling the situation is less encouraging, there is no ocean general circulation model available which assimilates the full range of hydrographic observations.

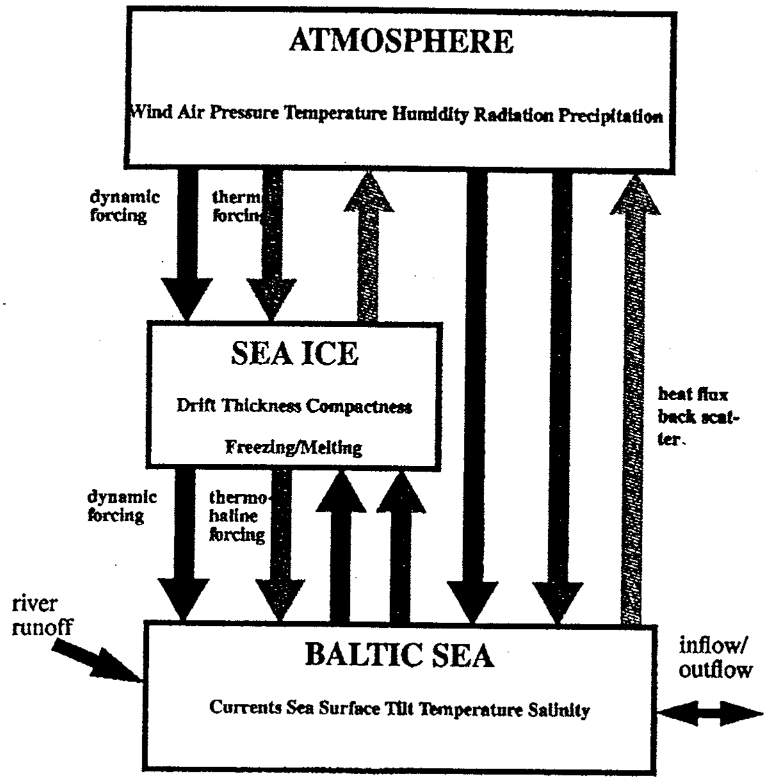

Figure 1: Fluxes in a coupled atmosphere-ice-ocean model

2. Baltic Sea response to atmospheric and hydrological forcing

The modelling efforts within BALTEX are directed towards the development and verification of models which describe relevant components of the energy and water cycle in the BALTEX region. The models must be suitable to describe the physical state of the Baltic Sea in response to atmospheric and hydrological forcing, including its variability on time scales from weeks to decades, on spatial scales ranging from 10-20 km to the entire basin size. With respect to the water budget, the models must be able to describe the transport of water and salt through the Danish Straits which requires an understanding of the dynamics of the in- and outflow processes and of the thermohaline circulation and mixing processes which determine the long-term distribution of water masses in the Baltic Sea. Besides short-term modelling of specific hydrographic situations with reasonable initial conditions for the sea state, simulations which cover time scales from years to decades need at least ice to be additionally considered.

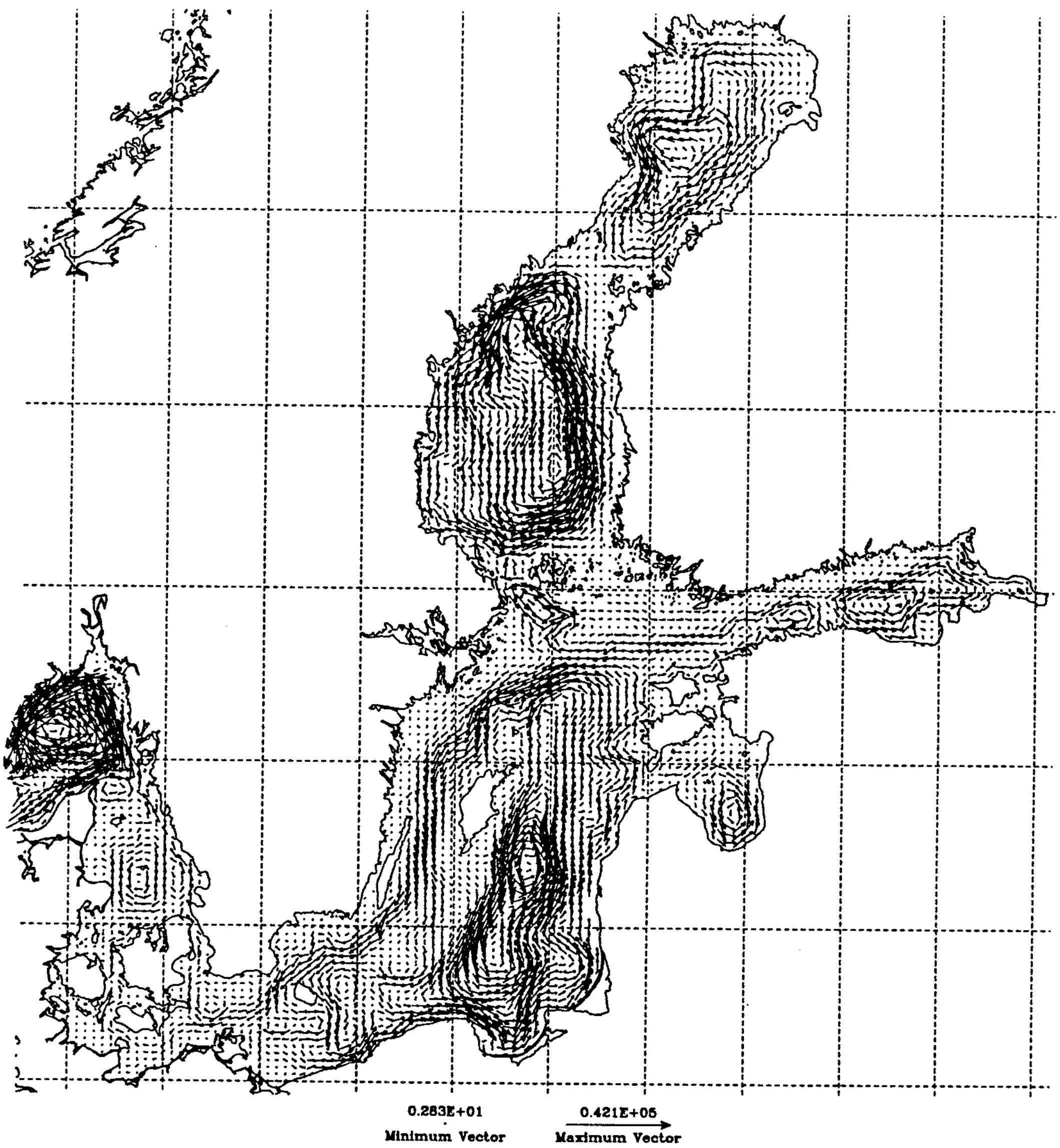

Figure 2: *Annual average of the barotropic circulation [m^3/s] for 1992*

The years 1992/93 which were chosen to be of particular interest for BALTEX have been simulated extensively. Lehmann (1997) presented results from an uncoupled run of the Kiel Baltic Sea model which was forced by atmospheric data provided by the Europa-Model (EM; Majewsky, 1991) of the German Weather Service (DWD, Deutscher Wetterdienst Offenbach) and river runoff (Bergström and Carlsson, 1994). The model was integrated for the years 1992/93 starting in Januray 1992 from initial distributions of temperature and salinity which represented a typical winter situation in the Baltic Sea. From the model run, mean circulation and averaged volume transports were calculated (Fig. 2). The annual mean of the barotropic circulation for the specific years shows only minor deviations. The circulation in the Baltic Proper is determined by a cyclonic circulation pattern comprising Bornholm and Gotland Basin, with water entering by a branch from the Gulf of Finland and through the Åland Sea. Through the Bornholm Gat water is leaving this circulation cell with a further flow through the Arkona Sea and the Danish

Straits feeding the Baltic Current. Within the subbasins, there are cyclonic circulation patterns with the net transport between the basins is determined by the river runoff into the subbasin, each. The internal barotropic circulation between Gotland and Bornholm Basin ($1000 - 2000\,km^3/year$) is about an order of magnitude higher compared with the total river runoff to the Baltic Sea ($470\,km^3/year$). On the annual average, the water volume which is supplied by the river runoff leaves the Baltic Sea through the Danish Straits. Thus, the net volume flow from the Baltic Sea into the North Sea corresponds to the river runoff modified by the net effect of precipitation minus evaporation. The rates of evaporation and precipitation for the year 1993 are dislayed in Fig. 3. The precipitation rates were prescribed from monthly mean values (Dahlström, 1986), whereas, the evaporation rates were diagnostically calculated from atmospheric parameters and from the simulated sea surface temperatures. The simulated mixed layer temperatures were verified against SST's observed from satellite. The evolution of the mixed layer temperature was satisfactorily simulated by the model. However, during spring and summer modeled sea surface temperatures lay 1-3 ^0C below the observations. Thus, the calculated evaporation rates underestimated the real conditions. The simulated total annual volume flow out of the the Baltic Sea for 1993 amounted to $\sim 495\,km^3$ including $22\,km^3$ from the precipitation surplus.

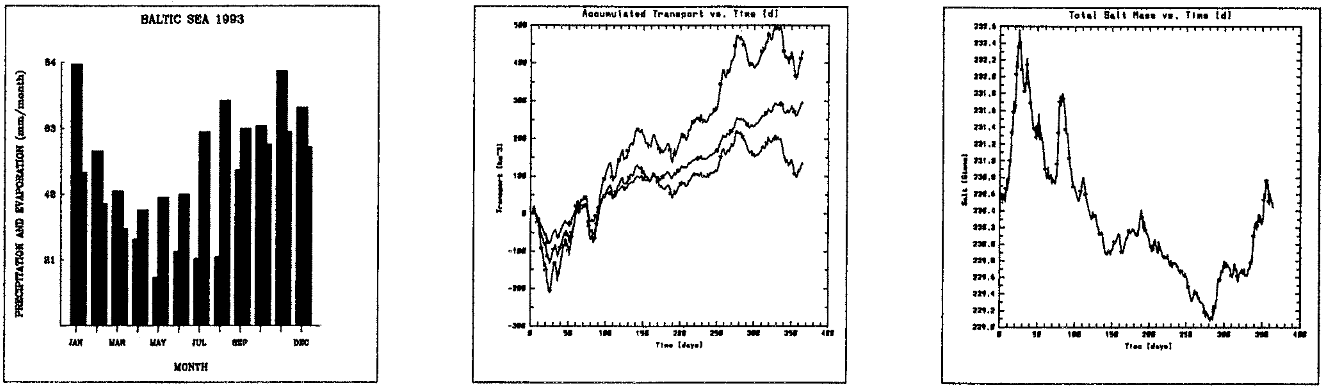

Figure 3: *Left:Rates of precipitation (blue) and evaporation (red) [mm/month] of the total Baltic Sea for 1993. Precipitation rates are taken from Dahlström, 1986. Middle and right: Accumulated volume transport through the Danish Straits (A:Sound, B: Great belt, C: total) and total salt content of the Baltic Sea for 1993.*

The model results give a first estimate of the heat, salt and water budget of the Baltic Sea (Fig. 3), however the results show also the limitation of the simulation. Compared with observations, the accumulated transports through the Danish Straits for the year 1993 are underestimated by the model, and hence the salt flux into the Baltic Sea is also underestimated. Three aspect are mainly responsible for uncertainties in the simulation of the volume and salt transport. Firstly, EM surface wind data underestimate the real conditions espically for high wind speeds. Secondly, the western boundary condition of the ocean model (Lehmann, 1995) fails in case of strong wind forcing from western directions, i.e. the pile-up of water in the Kattegat is not satisfactorily simulated. Thirdly, the initial conditions for temperature, salinity and sea surface elevation represent mean values for a typical winter situation, they cannot be prescribed from observations for the whole Baltic Sea. To remedy these deficiencies, a better representation of the atmospheric parameters is necessary which may be achieved by coupled atmosphere-ice-ocean models, and additionally, the western boundary condition must be improved to simulate the fluctuations of the sea surface elevation in the Kattegat more realistically. Furthermore, assimilation of hydrographic parameters into the model could improve the simulation.

A further problem of three-dimensional baroclinic modelling is the parameterization of the vertical turbulent mixing. Meier (1997) compared different turbulence closure schemes for a three-dimensional regional model of the western Baltic Sea. The most sophisticated mixed layer model seems to be the $k - \epsilon$ turbulence model. Additionally, two prognostic equations for the turbulent kinetic engery (TKE) and the dissipation of TKE have to be solved at every grid point of the three-dimensional model. Compared to the Richardson number dependent parameterization which underestimates the mixed layer depths, the second moment turbulent closure model improves the mixed layer dynamics considerably (Fig. 4).

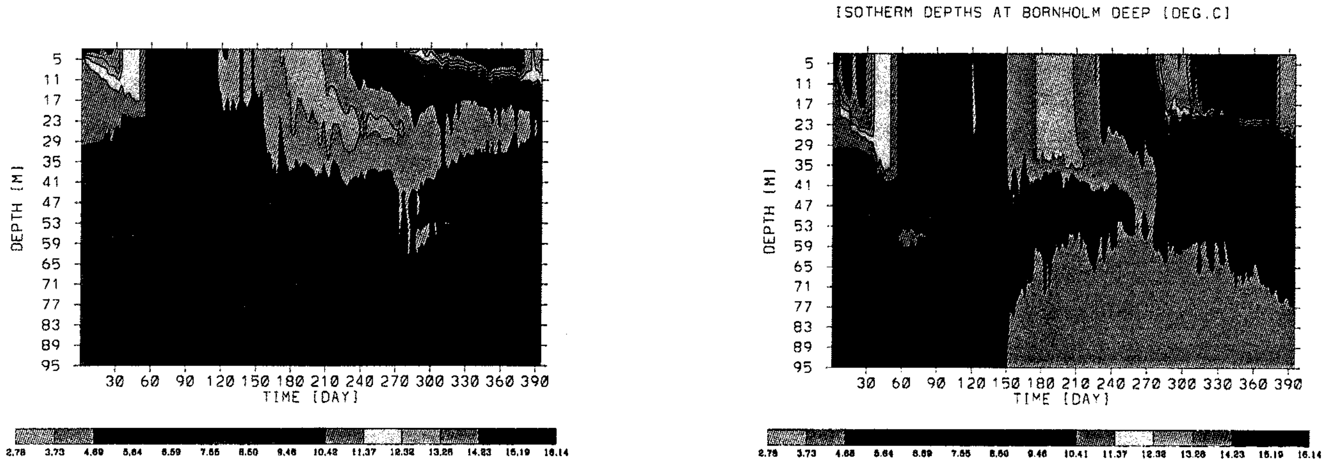

Figure 4: *Isotherm depths (in °C) at Bornholm Deep from September 1992 to September 1993; left: Richardson dependent friction parameterization; right: $k-\epsilon$ turbulence model (Meier, 1997).*

3. Development of a coupled ice-ocean model of the Baltic Sea

The circulation of the Baltic Sea and the water mass exchange with the North Sea are influenced by ice coverage during the winter season. Ice occurs annually in the Baltic. On average the annual maximum sea ice extent is 45% and the length of the ice season is 6 months in the northern parts. Ice plays a major role at the air-sea interface and largely modifies the momentum transfer and the exchange of heat, freshwater and other materia between atmosphere and ocean. Freezing and melting of ice have also notable effects on the stratification of the Baltic Sea water masses. Thus, including thermodynamics and dynamics of sea ice is essential for a realistic description of the annual cycle of the external forcing of the Baltic Sea.

The Baltic Sea is located in the Seasonal Ice Zone with first year ice forming every year. During the last 100 years the maximum ice extent has ranged from 12 to 100 % and the length of the ice season varied from 4 to 7 months. First ice appears in the innermost bays of the Bothnian Bay during mid-November. In a normal winter, the entire Bothnian Sea, Sea of Åland, Gulf of Finland and the northernmost part of the Baltic are also covered by ice. In severe ice-winters additionally the Kattegat, the Belt Sea, the Sound and large parts of the Baltic Proper are ice covered. Several different types of ice are found at sea. As the ice moves with currents and winds, leads (openings in sea ice) and ridged ice are formed. Due to the mechanical deformation, the sea ice becomes rough and ice keels of several meters deep (5-15 m) are frequent with deep keels up to 28 m have been measured in the Bothnian Bay. During calm conditions, columnar ice starts to grow when cooling has passed the freezing point. The ice growth is, however, most sensitive to snow which reduces the growth rate. During windy conditions, frazil ice forms which may generate pancake ice. Old ice, which is melting, is usually called rotten ice and has a much reduced albedo compared to snow covered sea ice.

As can be seen from the description above, sea ice is a complex physical component of the Baltic Sea. For a realistic simulation of the circulation of the Baltic Sea and the water mass exchange with the North Sea, sea ice and its coupling to the ocean has to be considered. Sea ice is a rather rigid film of complex morphology at the ocean-atmosphere interface. It strongly modifies the fluxes between ocean and atmosphere. In recent years, several ice models and coupled ice-ocean models of the Baltic Sea have been developed (Omstedt and Nyberg, 1996; Haapala and Leppäranta, 1996; Kleine and Skylar, 1996; Schrum, 1997; Lehmann, 1997). Within the EU-MAST project BASYS (Baltic Sea System Study) the Subproject 6 (Baltic Sea Ice) has the aim to couple and systematically improve an eddy-resolving general circulation model of the Baltic with an ice model and compare its results with observations from field cruises and satellite data. In a systematic assessment, the ability of the coupled ice-ocean model to reproduce currents and stratification in the basins of the Baltic, ice formation, coverage, drift and melting will be investigated. BASYS/SP6 will simulate and compare mild, normal and servere winters (mild: 1992/93, normal:1993/94, severe: 1986/87).

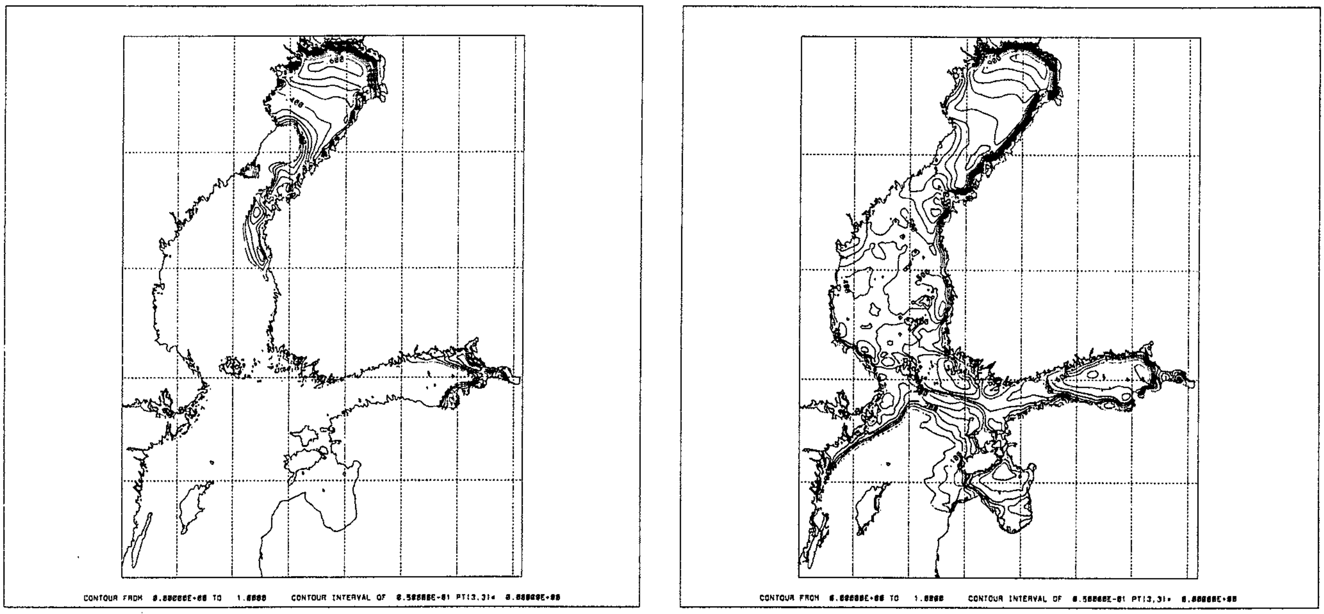

Figure 5: *Ice thickness (in m) for the mild winter 1992 (left) and the normal winter 1994 (right) from coupled ice-ocean simulations.*

Ice thicknesses and ice edges for the winters 1992 (mild) and 1994 (normal) at the end of February are displayed in Fig. 5. Both simulations were started from Januray with the same initial oceanic temperature and salinity distribution, but were forced with the corresponding atmospheric forcing provided by the SMHI data base. The simulated ice edges and thicknesses are in good agreement with observed ice conditions, however the ice extent for February 1992 is slightly overestimated. The specific atmospheric conditions are controlling the ice evolution, whereas the initial heat content of the Baltic Sea and the corresponding oceanic heat flux are of secondary importance.

4. Thermohaline circulation and long-term variability of the Baltic Sea

In order to understand the mean circulation and water mass distribution as a consequence of highly variable atmospheric forcing, river runoff and the water mass exchange with the North Sea, integrations over 10-20 years should be performed. Three-dimensional simulations of the thermohaline circulation of the Baltic Sea require a huge amount of computer power and resources. The investigation of the long-term variability of the Baltic Sea needs at least a reasonable understanding and modelling of mesoscale and mixing processes within the Baltic Sea and the water mass exchange with the North Sea. This demands a horizontal resolution of the three-dimensional models at least in the order of the internal Rossby Radius, and a high vertical resolution which allows a reasonable description of the flow of dense saline water intruding into the Baltic Sea and its further flow as a dense bottom current. The horizontal advection and diffusion of saline water maintains the perennial haline stratification in the central Baltic Sea. Three-dimensional simulations which have been performed so far (e.g. Lehmann, 1995 & 1997; Schrumm, 1997) show the basic weakness, to maintain the haline stratification after intergrations of one or two years which is mainly a result of a wrong or underestimated description of the water mass exchange with the North Sea. To remedy this problem, Meier and Krauss (1995) prescribed in a regional model of the western Baltic Sea observed sea surface elevations and vertical salinity distributions along the models boundary in the northern Kattegat. The water mass exchange, in terms of volume flows, between Kattegat and the Baltic Sea is mainly driven by the instantaneous sea level difference between these seas. Thus a knowlegde of the along-strait gradient of sea level determines together with the stratification and corresponding baroclinic flows the advection of salt into the Baltic Sea. However, sea level data for long-term investigations of the thermohaline circulation in the Baltic Sea are not always easy available. Furthermore, the sea surface inclination of any cross-section through the Baltic Sea or the Kattegat/Skagerrak area is not a linear function. Data assimilation methods could be helpful to improve the simulation of sea level and hence the volume tranport through the Danish Straits (Meier and Krauss, 1995).

While three-dimensional circulation models suffer from the correct simulation of advective-diffusive processes which determine the thermohaline circulation and its long-term variability of the Baltic Sea, process models which are much faster than three-dimensional models could be helpful for comparison and process studies (Omstedt and Nyberg, 1996). The model PROBE-Baltic has been run for 15 years, starting from 1 November 1980. The model treats the Baltic Sea as 13 sub-basins with high vertical resolution, horizontally coupled by estuarine and barotropic circulation and vertically coupled to a sea ice model which includes both dynamic and thermodynamic processes. The results (Fig. 6) indicate that the main physical processes as in- and outflows as well as vertically and frontal mixing and river runoff were treated in a realistic way. Furthermore, the seasonal maximum ice extent could be well captured by the model.

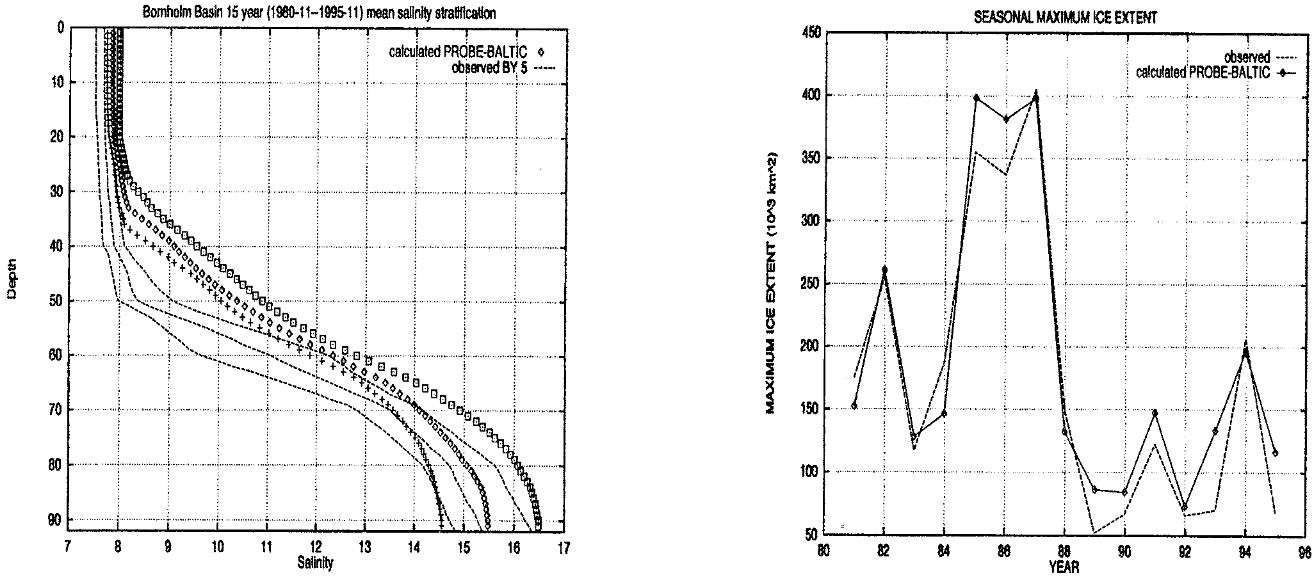

Figure 6: *Left: Median salinity profiles based upon observations and calculations from 1 November 1980 to 1 November 1995. The curves are medians, the first and third quartiles. Right: Observed and calculated seasonal maximum ice extent for the Baltic Sea. (Omstedt and Nyberg, 1996; Omstedt, 1997)*

5. Development of a coupled atmosphere-ice-ocean model of the Baltic Sea

One of the main aims of the modelling efforts within BALTEX is to develope a complete coupled atmosphere/ocean/land surface model. Some progress has been achieved since the last BALTEX Science meeting. The evolution of a complete system including the components atmosphere, ice/ocean and land is twofold. One branch is directed to a better understanding of the coupling of the land surface models to the atmosphere, and the other aims at the coupling of atmosphere with ice-ocean models.

At the SMHI, a high resolution weather forecasting model has been coupled to an advanced 2.5-dimensional ice-ocean model. The ice-ocean model includes two-dimensional, horizontally resolved ice and storm surge models and a one-dimensional, vertically resolved ocean model applied to 31 Baltic Sea regions. The coupled model system is applied operationally at the SMHI. From case studies it could be demonstrated that improvements of short range weather forecasting in the area of the Baltic Sea require an accurate description of the lower boundary condition over sea. Sea state variables used in the model influence the weather forecast both directly on the local scale due to the local impact of the surface fluxes of sensible and latent heat, and on the regional and larger scales. The convective snow bands during winters with cold air mass outbreaks over the open water of the Baltic Sea are extreme examples of the influence of sea state variables on the regional scale (Gustafsson et al., 1997).

In a joint effort, the Kiel Baltic Sea model has been coupled to the atmospheric model REMO (Regional Model) of the MPI Hamburg (Jacob and Podzun, 1997; Hagedorn et al, 1997). The three-dimensional model REMO is based on the operational forecast model of the DWD. It is used in the so-called climate mode with the physical paramterizations which are implemented in the Europa-Model. The horizontal resolution is 1/6° on the rotated longitude/latitude grid. This is equivalent to approximately $18x18\,km^2$. The Kiel Baltic Sea Model is a three-dimensional eddy-resolving baroclinic model with a horizontal resolution of approximately $5x5\,km^2$ (Lehmann, 1995 & 1997). For a reference run, these two models have been run seperately and both were forced by DWD analysis or forecasts, respectively. The models were two-way coupled via the fluxes of heat, water and momentum (Fig. 1). The coupled atmosphere-ocean system has been applied to the PIDCAP period (July-October 1995). From the coupled simulation, it turned out that the sea state variables influence the evolution of the regional climate over the Baltic Sea even if the simulation period is so short. While the basic structures of the pressure field were hardly affected by the difference in heat fluxes compared with the reference run (SST's from DWD analysis), there were remarkable deviations in the surface wind field and precipiation patterns.

6. Concluding remarks

During recent years much progress in Baltic Sea modelling has been achieved. In view of BRIDGE, coupled ice-ocean and atmosphere-ice-ocean models will be available for the simulation of the energy and water cycle of the Baltic Sea. The most challenging task for the oceanographic modelling community will be the investigation of the thermohaline circulation and long-term variability of the Baltic Sea on the time scale of decadal climate variability. To simulate the water mass exchange with the North Sea and to describe turbulent and mesoscale processes in the Baltic Sea, three-dimensional models with high vertical and horizontal resolution are necessary. But this requires an enormous amount of computer power and resources. The Kiel Baltic Sea coupled ice-ocean model with a horizontal resolution of 5 km and 28 vertical levels needs at least 240 CRAY-T90 CPU hours for the simulation of one year. To cover the whole spectrum of mesocale processes a grid refinement especially for the area of the Danish Straits and an extension of the model area to the whole North Sea would be necessary, but at the moment this is not feasible with available computer power. Furthermore, long-term simulations may require the utilization of assimilation methods which, additionally, will increase the requirments on computer power. However, less expensive methods such as nudging or partial re-initialisation of temperature and salinity fields by observations into a current model run are available and may be used to improve the simulation of the thermohaline circulation and its long-term variability.

While process models seem to reproduce fairly well thermohaline structures and the long-term variability of the Baltic Sea, three-dimensional baroclinic models suffer from the realistic description of advective-diffusive processes. It should be noted that process models such as the PROBE-Baltic have specific as well as general limitations. The horizontal resolution is limited by the number of specified thermodynamic basins. A refinement of these regions is one possiblitiy but on the long-term objective three-dimensional horizontally resolved models are necessary which are able to resolve the mesocale dynamics of the Baltic Sea.

With respect to coupled atmosphere-ice-ocean modelling, the progress achieved so far is encouraging, so that for BRIDGE coupled atmosphere-ice-ocean models will be available.

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EVALUATION OF THE ECHAM4 CLOUD AND TURBULENCE SCHEME FOR STRATOCUMULUS

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An evaluation of the cloud-turbulence scheme used in ECHAM4 has been performed for a simulation of stratocumulus. The physical scheme (the cloud and turbulence scheme) of the ECHAM4 model is also frequently used within regional atmospheric models concerning BALTEX (like REMO, RACMO, HIRLAM, etc). This motivated us to study the ECHAM4 cloud-turbulence physics in rather controled conditions. The turbulence scheme is a 1.5 order *E-l* closure scheme with a prognostic equation for the turbulent kinetic energy and a diagnostic length scale. For ECHAM4 this diagnostic length scale is computed as a function of the moist Richardson number Ri_g. The cloud scheme consists of the Sundqvist scheme (for an extensive description of these schemes see Roeckner et al. 1996). We tested the performance of these schemes in a one-dimensional version for a simulation of a nearly stationary stratocumulus cloud. This case is defined for the EUCREM (European Cloud-Resolving Modeling) project. For this case extensive measurements and results of Large Eddy Simulation (LES) models are aviable, against which the performance of cloud and turbulence parameterizations are evaluated. The evaluation is focussed on both numerical and physical aspects of the cloud and turbulence parameterizations.

Figure 1 shows a typical example of the performance of the standard ECHAM4 cloud-turbulence scheme obtained with the ECMWF 31 level vertical resolution and a time step of 90 seconds. It shows two characteristic properties of this scheme for the present stratocumulus case. First, the cloud cover is very intermittent, and shows signs of instability. Second, the average cloud thickness is rather low compared to measurements and LES results, which show an average thickness of more than 90 %. The first property was found to be related to the formulation of the turbulence scheme, and in particular to the formulation of the turbulent length scale. As mentioned above, the ECHAM4 scheme uses a formulation of this length scale as a function of the moist gradient Richardson number Ri_g. It turned out that for cases with low windshear (as for the present case), this function becomes singular and the turbulent length scale becomes unrealistically large (two or more orders larger than the boundary layer height). This leads to instability of the turbulent kinetic energy equation, which subsequently feeds into the turbulent fluxes and the cloud scheme. Removing this instability by limiting the tubulent length scale to a physical realistic value indeed leads to a stable evolution of the cloudcover. However, the second property remains; the cloud thickness still decreases significantly to about 70 %. It was found that this property is mainly related to a timestep dependency of the cloud scheme; for smaller time step this reduction of the cloud cover does not occur. (This time step dependency can be removed by a few modifications in the present coding of the cloud scheme)

An *E-l* turbulence scheme may represent nonlocal physics (the transport of turbulent kinetic energy into the inversion) that could be responsible for cloud top entrainment. This is one of the reasons for the present popularity of this closure — it is relatively simple, but does contain entrainment physics, thus circumventing the need for an explicit entrainment closure. However, we found that with the Richardson-dependent formulation of the length scale used in ECHAM4 (nearly) no entrainment is generated by the physical scheme. We also tested an alternative formulation of the length scale (proposed by Brinkop and Roeckner 1995) based on E and static stability, and with this scheme realistic entrainment rates are obtained, but (as discussed below) only when using a high vertical resolution.

Sensitivity experiments showed that for the present 1.5 order closure, cloud top entrainment is extremely sensitive to the vertical resolution. With the ECMWF 31-level resolution (approx. 250 meters for the

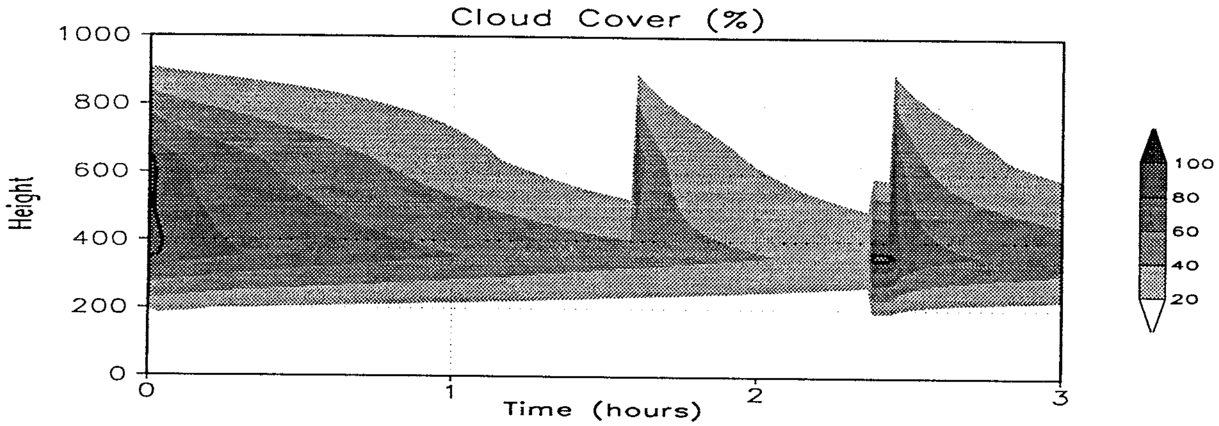

Figure 1: Time evolution of the cloud cover for the standard turbulence and cloud scheme.

cloudy layer), the physical turbulence scheme does not generate (or only very little) entrainment On the contrary, numerical errors dominate the solution. These numerical errors tend to generate an entrainment rate that keeps the cloud top stationary, and the entrainment therefore just balances the large scale subsidence imposed. These results are rather robust, and do not seem to depend on the formulation of the length scale. Results obtained with a resolution of 25 meters, however, show a different behavior. The entrainment rate is clearly influenced by the physical scheme (e.g., the transport of kinetic energy into the inversion; the turbulent length scale) and the entrainment rate is nearly independent of the subsidence (Lenderink and Holtslag, 1998) .

In summary, we find that a 1.5 order *E-l* closure model with the Richardson dependent formulation of the length scale (as presently used in the ECHAM4 model) leads to instability of turbulence scheme for cases with low windshear. In addition, we also find that this scheme is not able to give a realistic cloud top entrainment rate for the present case. On the other hand, with an alternative formulation for the length scale (similar to the one proposed by Brinkop and Roeckner 1995) entrainment can be simulated realistically. However, from a practical point of view these results should be considered in the light of the dependency of the results on the vertical resolution. For the present simulation of stratocumulus, the *E-l* closure scheme turned out to depend strongly on the vertical resolution; for low resolution the numerics completely dominate the solution, and the formulation of the turbulent length scale is of little (as long as it doesn't give rise to instability) importance — a situation which changes only for a very high resolution (25 meters) in which the turbulent length scale does become important (Cuijpers and Holtslag, 1998).

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OBSERVATIONS OF INERTIAL PERIOD MOTIONS DURING THE DIAMIX PILOT SURVEY.

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Current measurements with moored ADCPs were made at water depths 85 and 170 m in two locations 30 km apart along the middle section of the DIAMIX area during the period June 4-25, 1997. Temperature and salinity were measured at discrete levels by self-recording instruments attached to the rigs. At both locations inertial period currents are quite pronounced in the whole water column all the time. We have studied motions in a narrow band around the inertial frequency and present and discuss results on variability in time and space as well as horizontal and vertical coherence. At the deep mooring there were particularly strong and persistent currents in and below the halocline region due to an anticyclonic eddy structure. Possible interaction between the eddy and inertial period motions is discussed.

Comparison of REMO's Total Water Vapour Content with Observations

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In order to investigate the energy and water balance of the Baltic Sea and its catchment, the commonly used regional models, as REMO, has to be validated with observation data. One of the most important parameters for the hydrological cycle is the vertically integrated atmospheric water vapour content.

For the PIDCAP period from August to October 1995 three independent data sources of the observed total water vapour content are used for the comparison with REMO results. Over land surfaces, ground based measurements from GPS (Global Positioning System) stations (Elgered et al., 1996) were used. Values over sea are provided by radiosonde ascents of the research vessel Alkor and satellite observations from the Special Sensor Microwave/Imager (SSM/I). Land influences, a great problem for satellite data in small scaled sea regions, are removed.

In a first step the observation data sets are compared mutually. SSM/I and radiosonde measurements are in good agreement. Individual observations have a correlation of 0.94 and the mean difference between both data sets is only 0.2 kgm^{-2}.

The information about the vapour content coming from point measurements at GPS stations in Sweden and Finland is distributed over the area by a quadratic exponential function. In this way GPS data can be combined with SSM/I observations. Figure 1 gives an example for the morning overpass of August 27. In coastal areas where contributions come from both data sets, a comparison of them is possible. For the period August 20 to October 31 we found a mean value of 15.85 kgm^{-2} for SSM/I and 15.40 kgm^{-2} for GPS data.

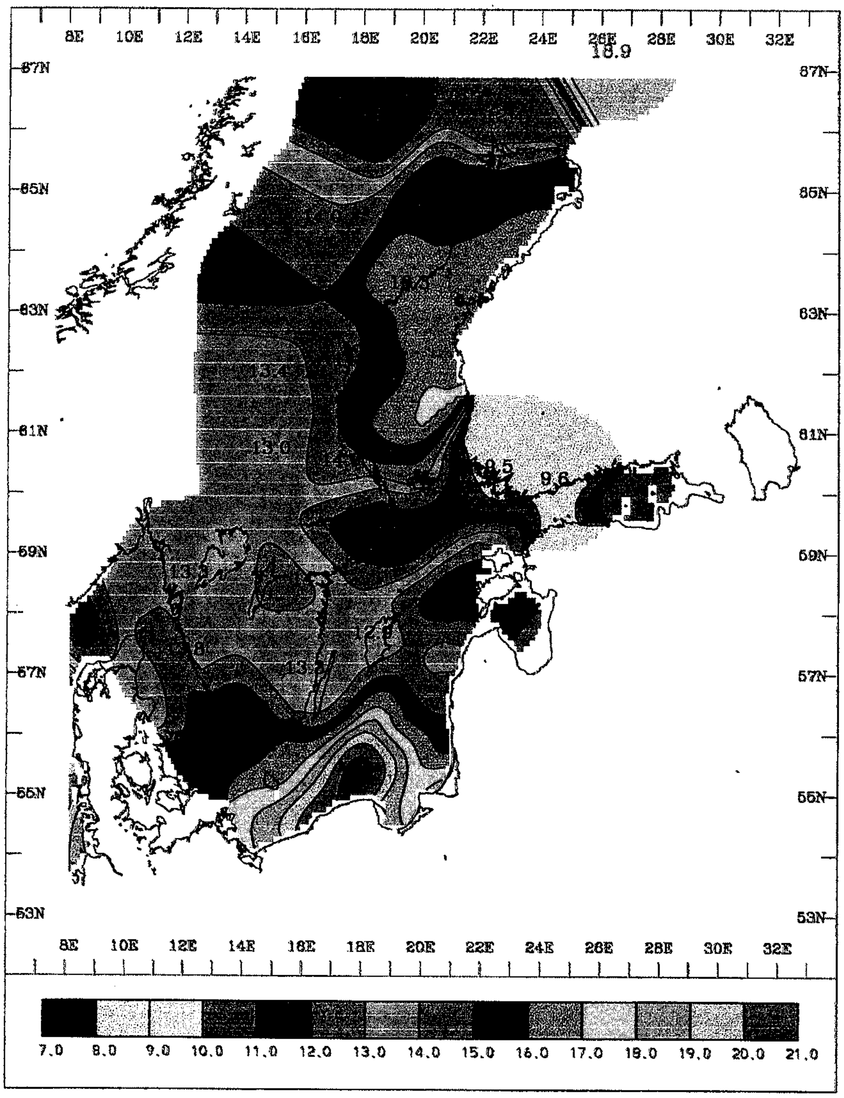

Figure 1: *Total water vapour content from the combined data sets of SSM/I and GPS for August 27 1995, 8:00 - 12:00. Numbers give the measured water vapour content for the different GPS stations.*

For the comparison with REMO results some information about the temporal and spatial distribution of the variance of atmospheric water vapour is needed, because REMO results and the observational data sets have different resolutions in time and space.

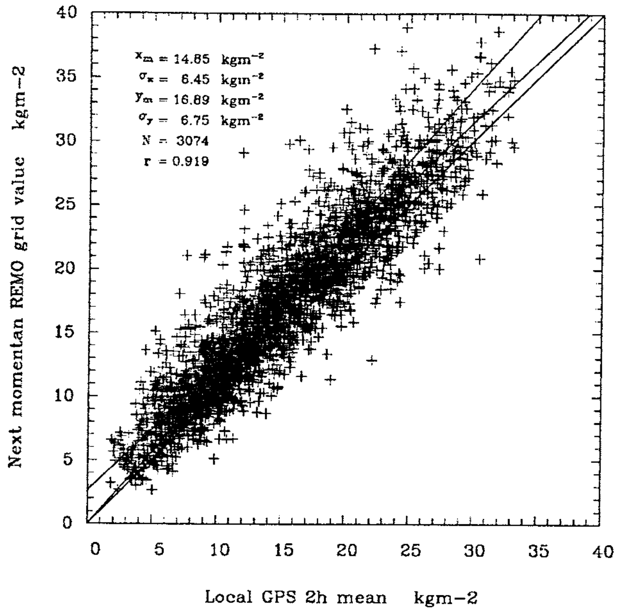

Figure 2: *Comparison of total water vapour from GPS and from REMO for the period August 20 to October 31 1995.*

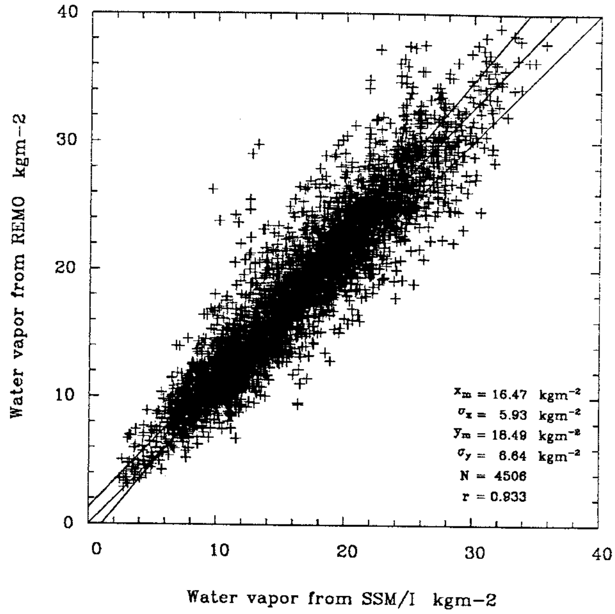

Figure 3: *Total water vapour from SSM/I and from REMO. In order to make the variance comparable, both data sets are avaraged over 6 by 6 REMO grid points.*

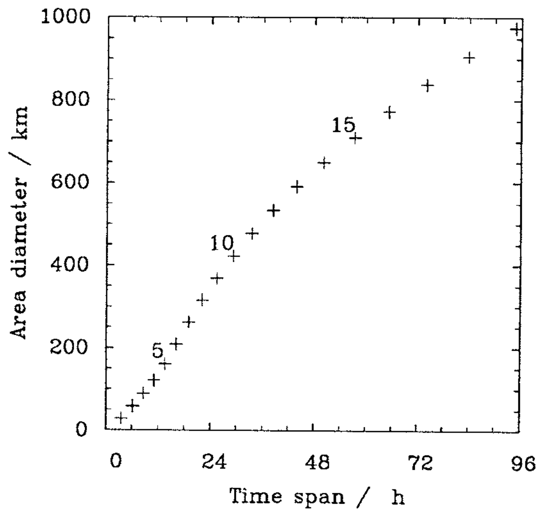

Figure 4: *Variance of water vapour included in different time and space scales. Numbers give the obtained variance in* kg^2m^{-4}.

Using GPS data we computed the variability of water vapour for different time and space scales (Fig.4). Spatial averaging over an area of 18 by 18 km, as performed by REMO, corresponds to a temporal averaging over about 2 hours: a variance of less than 1 kg^2m^{-4} is lost, which is small compared to total variance of about 40 kg^2m^{-4}. Thus, 2 hour means of GPS data are comparable to REMO results (Fig.2). Compared to such GPS means, REMO overestimates the total water vapour by about 2.0 kgm^{-2} accompanied by an overestimation of the variance by about 10%.

The spatial resolution of the SSM/I retrieved water vapour is a mixture of the different SSM/I channel resolutions, and difficult to determine exactly. However, averaging REMO and SSM/I results over an area of 100 by 100 km certainly equalize the different resolutions (Fig.3). Apart from the fact that marine atmospheres contain in general more water vapour, the comparison with SSM/I (Fig.3) shows nearly identical results as the comparison with GPS data (Fig.2). REMO is biased by 2.0 kgm^{-2} and overestimates the variance slightly.

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LAPP: A European Arctic Process Study on the borders of BALTEX

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General Circulation Model (GCM) results predict large changes of climate in northern latitudes. There is thus a strong possibility that the major climate change in the BALTEX area will occur in its northern area. Possible changes to snow cover, soil freezing and energy balance within this region will have very important hydrological and atmospheric impacts for the Baltic region. The BALTEX area is not isolated and the consequences of climate change on surrounding areas such as the Barents Sea and the pan-European Arctic will also have an impact within the BALTEX area.

Changes in the water and energy balances are pivotal to the predicted release of greenhouse gases in the Arctic regions. Plant growth and soil carbon release are largely governed by summer season length, radiation input, frequency and amount of summer rainfall events, soil temperature and soil moisture levels. To predict how the Arctic regions will react to any climate change, it is first neccessary to measure these complex interactions through measurement and then using these measurements to develop or modify predictive land surface models.

The Land Arctic Physical Processes (LAPP) project, an EC Framework IV shared cost experiment, involving teams from the United Kingdom, Finland, Norway and Denmark, is currently improving our understanding of the effect of global warming on the water, energy, carbon dioxide and methane fluxes in the European Arctic through a programme of measurement and modelling of the basic physical processes involved in the exchange of these fluxes between the soil, vegetation, and the atmosphere.

Detailed studies of surface climatology, micrometeorology and soil hydrology are being made at four sites in the European Arctic: Ny-Ålesund in Svalbard, Zackenberg in east Greenland, and Kaamanen and Kevo in northern Finland. These sites were chosen to provide contrasts in latitude, climate, hydrology, vegetation and soil carbon.

During 1996 and 1997 the sites in northern Finland, just outside the border of the BALTEX area, have provided simultaneous measurements of radiation balance, eddy correlation measurements of evaporation, carbon dioxide and methane fluxes together with soil temperature and soil moisture measurements and (at the Kevo site since the autumn of 1996) long term continuous climate measurements. These measurements are ongoing with a further measurement programme planned for May-September 1998. At Kevo, this measurement programme is being linked with hillslope hydrology measurements from within the Barents Sea Impacts Study (BASIS) during 1998.

A general overview of the LAPP programme in the context of BALTEX is presented. The results show considerable variability in the energy, water and carbon dioxide balances across typical terrains within the European Arctic and between years. These differences are due to variations in the length of the active snow-free season, radiation input, air temperature, frequency and amount of rainfall, and soil temperature and soil moisture. In terms of carbon dioxide, these hydrological factors create a varying balance between vegetation assimilation and soil carbon release. Such variation of the carbon balance is compounded by the wide variety of surfaces found in the European Arctic ranging from sparse mountain birch forest through mire to polar semi-desert. This variability is best investigated by developing Soil-Vegetation-Atmosphere-Transfer (SVAT) models calibrated with the LAPP data.

The LAPP measurements are being used to improve and calibrate current SVAT models for use in predicting climate change in the Arctic. One such model is MOSES (the UK **M**eteorological **O**ffice **S**urface **E**nergy **S**cheme), the SVAT model within the UK Meteorological Office General Circulation Model. The important linkage between SVAT and hydrological models is also being addressed within LAPP using the Nordic HBV hydrological model. Preliminary results from the use of MOSES are also presented.

It is highly likely that impact of climate change on the European Arctic will affect the hydrology of the BALTEX area through changes in the length of the snow-free period, precipitation patterns, soil moisture and soil temperature. These changes will create feedbacks to the energy partitioning, cloud cover, streamflow and groundwater recharge and will almost certainly alter the hydrological and carbon balances of the region, factors which may profoundly modify the latitudinal limits for plant species.

LARGE SCALE HYDROLOGICAL MODELLING OVER THE ELBE REGION

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A grid related conceptual hydrological model is presented, describing the processes of vertical and horizontal water movement separately. Atmospheric forcing is done by measured daily mean values of precipitation, air temperature, humidity, pressure, wind speed and sunshine duration delivered by fixed climatological stations (1). Vertical processes, like evapotranspiration, fast runoff and baseflow generation are described by the VIC-2L model (3, 4), a two layer SVAT scheme. It includes a canopy layer and an upper and lower soil layer. A reasonable hydrologically runoff mechanism considers the variation of infiltration capacity, in the upper layer within a grid box. The effects of spatial subgrid variability of soil moisture therefore is included - it describes the saturation excess runoff in a parametrized manner. In the lower layer drainage is represented by the Arno scheme. Evapotranspiration is calculated according to the Penman- Monteith relationship. The actual evapotranspiration is dependent of the canopy layer and the transpiration from each vegetation class. For the spatial scale this model is set up on a rotated grid of about 1/6 degree of the atmospheric regional scale model (REMO) used in the BALTEX project (2). For the time scale the physical processes of the water balance are solved on a daily base. Output quantities are time series of fast runoff, baseflow and evapotranspiration for each grid point. Horizontal water movement is divided into transport processes inside a grid box and transport processes between neighboring grid boxes, both are described by linear routing functions. With the help of this horizontal scheme the sum of modeled fast runoff and baseflow can be routed to the outlet of prescribed gauges and can easily be compared with measured streamflow. At first a calibration procedure for a prescribed time period has to be set up, finding an optimal parameter set for this time period. Calibration parameters for the SVAT model are the thickness parameter of upper and lower layer and the shape parameter of the variable infiltration capacity curve. For the horizontal scheme measured discharge at the outlet of a catchment is used for partitioning of total runoff in fast runoff and baseflow. With the additional help of measured rainfall a proper unit hydrograph inside a grid box can be found by an iterative scheme between effective rainfall and discharge. For the river network a kinematic wave solution with time constant celerity and diffusivity is determined.

The model area includes the German part of the Elbe river basin, with the catchments of Saale, Mulde, Schwarze Elster and Havel Spree of about 80.000 km^2. An inflow boundary condition is given by the gauge station Schoena at the Czechisch border, including the whole drainage area of the Czech part of the Elbe river. For atmospheric forcing and streamflow datasets from 1984 up to 1993 were used. As calibration period the time interval 1992 was chosen. Time series of gridded fast flow, baseflow and evaporation for the whole time period 1984 up to 1993 where simulated with the VIC-2L model. With the help of an appropriate unit hydrograph and kinematic wave fast runoff and baseflow was routed to the outlet of the subcatchments and then to the outlet of the whole area at Neu Darchau. The measured inflow condition at Schoena was routed as a kinematic wave to the outlet at Neu Darchau. Measured and simulated total runoff was compared for the whole time period (Table 1).

Table 1: Results for simulation for different catchments.

River Gauge Station	catchm. area km^2	precipitation mm/y	evaporation mm/y	calculated runoff mm/y	measured runoff mm/y	correlation
ELBE						
Neu - Darchau	131.950	621	451	167	154	0.92
Magdeburg	94.949	631	454	174	173	0.93
SAALE						
Calbe Griz.	23.719	611	440	169	144	0.82
MULDE						
Bad Dueben	6.171	747	497	247	292	0.85
HAVEL/SPREE						
Ketzin	16.173	580	435	142	126	0.67

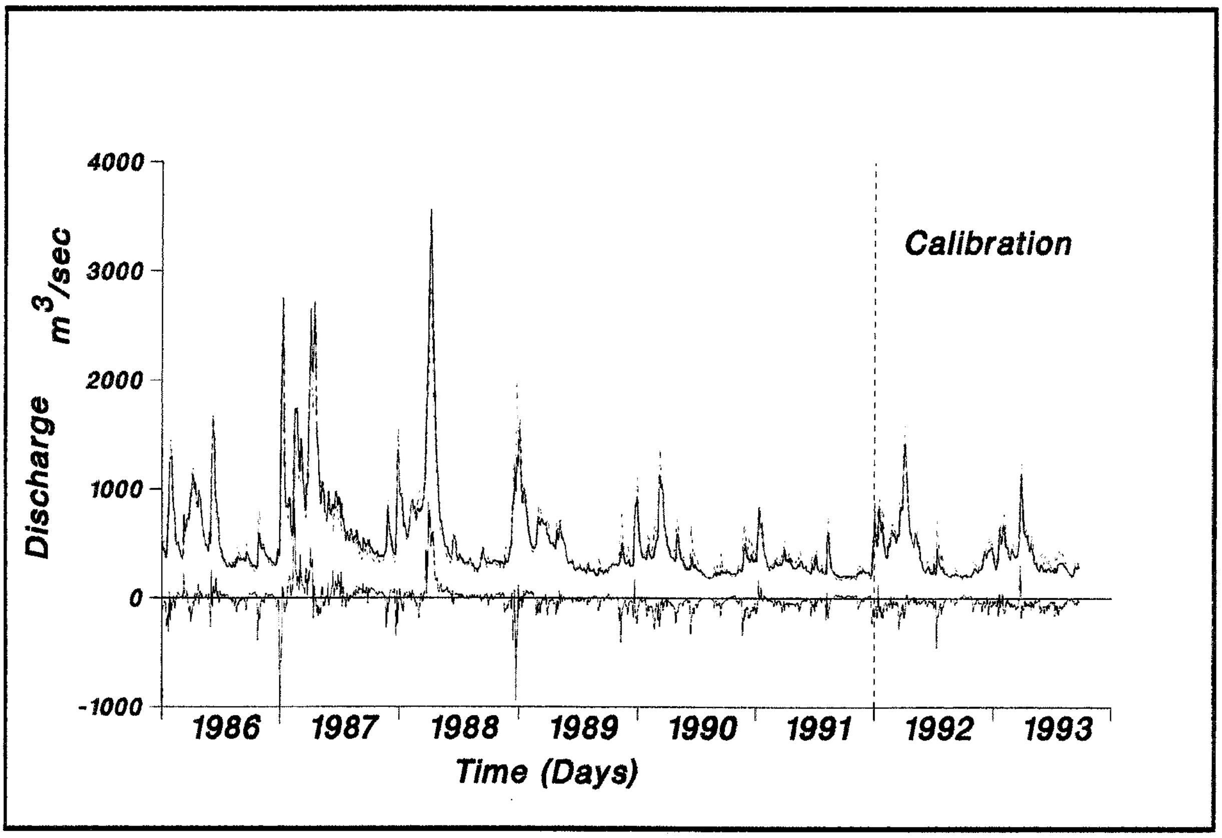

Figure 1: Comparison of time series of measured and calculated discharge at the gauge station Magdeburg, with the meaning: solid line: measured curve, red: calculated values. The lower curve (blue) shows the difference between measured and simulated discharge.

Measured and simulated discharge are in good agreement. Some discrepancies are shown for snow and ice processes.

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An Optical Disdrometer for Measuring Size and Velocity of Hydrometeors

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1. Introduction

For a long time scientists from many fields of research have been interested in measuring size and velocity of particles. In this paper the characteristics of a prototype of an optical disdrometer, based on single particle extinction measurements, are presented. Particles are detectable in the diameter range from approx. 0.3 to 10 mm having velocities of up to 10 m/s. Advantages of the new system are:

- It is a low-cost, robust and easy to handle device. Therefore it is realistic to install disdrometer networks, thus investigating the representativity of 'point' measurements and investigating small scale variability.
- Small drops are reliably detected. This is of interest for investigating scavenging and chemical effects. Furthermore, by selecting the appropriate of-the-shelf components the measuring range may be modified down to the size of cloud drops.
- Snow measurements are possible. With assumptions on the shape of snow flakes also their velocity can be estimated. This information is useful for 'present weather sensors' and for interpreting results from weather radar systems in wintertime, especially in alpine regions, where hydrometeors in the radar volume usually consist of snow.

First the instrument is described, then results from field operations are presented and compared with data from standard instruments. Finally, ideas for the future development are outlined.

2. Measuring System

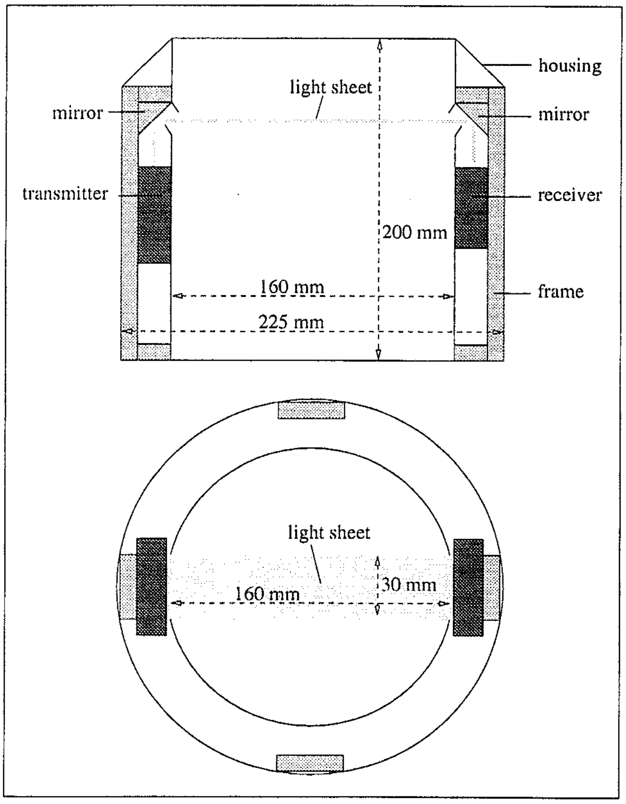

Fig. 1: Front- and top-view of optical disdrometer

The basis of the instrument is a commercially available sensor, producing a horizontal sheet of light (160mm long, 30mm wide and 1mm high). This is produced by a 780 nm laser diode with a power of 3 mW. In the receiver the light sheet is focused on a single photo diode. Transmitter and receiver are mounted in a housing for protection (Fig. 1). The light sheet is folded by two mirrors to keep the instrument size small. Particles passing through the light sheet cause a decrease of the output signal by extinction and therefore a short reduction of the initial voltage. The amplitude of the signal is a measure of particle size, the duration of the signal a measure of particle velocity.

The analysis of the signal consists of the following steps: removal of the DC-part, inversion, amplification and filtering. Then a fast AC/DC-conversion is done followed by the detection of the maximum value, the signal duration and the time between two particles. These three quantities are stored for each particle for further calculation of distributions (size, velocity, energy, etc.) and integral values (i.e. rain rate, radar reflectivity, liquid water content). For rain measurements the device is calibrated with drops of known size at terminal fall velocity.

3. Results and Comparison with Standard Instruments

First measurements of rain drop spectra have been conducted from May until July 1997. The optical disdrometer was placed near a Joss/Waldvogel disdrometer (within 1 m) on the roof of a small building in the Forschungszentrum Karlsruhe (FZK). For the comparison of drop size spectra the results of the optical disdrometer were calculated in time intervals of one minute and for 20 drop size classes of the Joss/Waldvogel disdrometer.

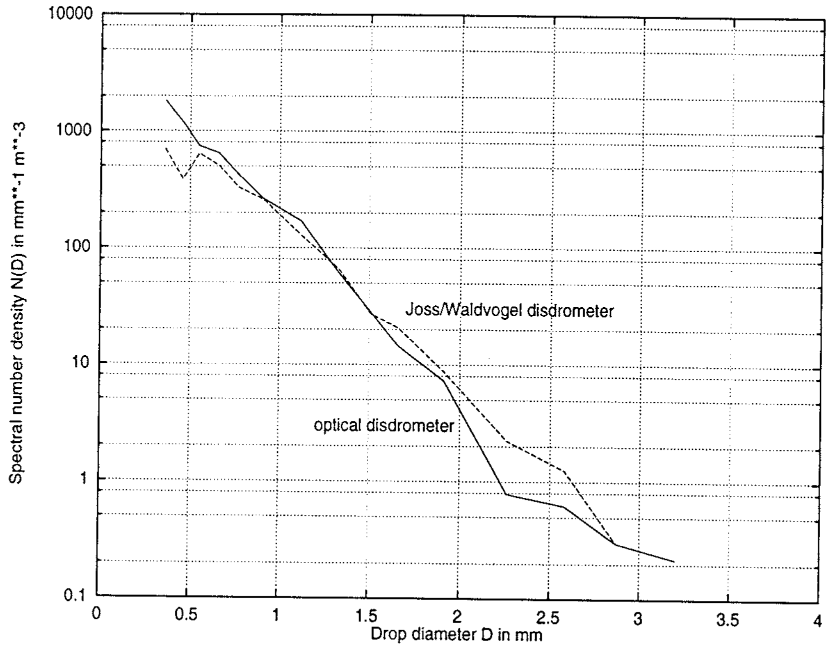

Fig. 2: Mean spectral number density, 21 May 1997, 6:11 to 6:20 CET

A ten-minute convective event on 21 May 1997 was chosen for the comparison. For each instrument the mean spectral number density was calculated as a function of drop diameter (Fig. 2). There is good agreement between the measurements of the optical and the Joss/Waldvogel disdrometer in the diameter range from 0.7 mm to 2 mm, but there are differences in the range of small drops where the Joss/Waldvogel disdrometer is known to have problems with accustic noise. In the range of larger drops the number density is rather low and the observed differences may result from practical reasons (missing or eroneous data because of faulty transmission or instrumentation).

As a second example for integral data the daily rain sums were compared, measured by both disdrometers (O, J) and additionally also by a Hellmann rain gauge (H). For ten days in the period from May until July 1997 data of all three measuring devices were available. The table shows the daily rain sums in mm. For most days they agree within less than one millimeter of rain, only on 5 July the differences are a little bit larger.

	18 May	20 May	21 May	17 June	18 June	21 June	22 June	4 July	5 July	6 July
O	**2.0**	**6.6**	**3.5**	**17.0**	**0.8**	**17.6**	**6.3**	**0.2**	**13.4**	**1.1**
J	**2.9**	**7.2**	**4.8**	**16.3**	**1.0**	**18.2**	**6.6**	**0.7**	**17.0**	**1.3**
H	**2.3**	**5.3**	**3.6**	**15.4**	**1.3**	**17.9**	**5.6**	**0.1**	**16.1**	**1.0**

4. Summary and Future Development

A new low-cost optical disdrometer was presented and results of real rain measurements were compared with data from a Joss/Waldvogel disdrometer and a Hellmann rain gauge. The overall agreement is good.

Error considerations yielded an uncertainty for single drops of approx. $\pm 100\ \mu m$ plus $\pm 7\ \%$ of drop diameter and ± 0.3 m/s for drop velocities. This is valid for the whole measuring range when comparing drop concentration in the 20 size classes of the Joss/Waldvogel-disdrometer. The discribed optical disdrometer should soon be commercially available.

Future development may include: investigate use of velocity information to eliminate edge effects; estimate effects of drops splashing on the housing; measuring snow in winter; combine the optical disdrometer with a vertically pointing radar; reduction of size of the electronics; investigate applications in industrial particle recognition technology; testing of a modified sensor to extend the measuring range towards smaller drops (10 mm light sheet $\rightarrow$ 100 μm smallest diameter, 1 mm light beam $\rightarrow$ 10 μm cloud particles).

SINOP – THE NOPEX DATABASE

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SINOP (System of Information in NOPEX) contains data from NOPEX concentrated field efforts (CFEs) giving spatial coverage and continuous climate monitoring (CCM) giving temporal coverage. The database is presently available on-line for all principle investigators of NOPEX. Data from CFE1 and CFE2 as well as corresponding periods of the CCM program will be made freely available to the scientific community on CD-ROMs in connection with the publishing of the NOPEX Special Issue of Agricultural and Forest Meteorology. The general objectives of an information system are threefold: to guarantee data *retrievability*, *usability*, and *queriability*, the final goal of the information system being to make it a public information source. If we are promising long-term data-series, as in the NOPEX CCM program, with a life span exceeding both Ph.D. programs and normal research programs we can not rely on the memory or notes of individual researchers for future usefulness of the collected data. The output from the instruments used must be coherent and time stable to guarantee comparability in a set of variables. This can be achieved by inter-comparison and calibration programs. There has been some reluctance by participants to contribute data to SINOP, but as the use of SINOP increases it will become increasingly interesting to be the originator of data sets with a high quality control status. Data growth is presently in the order of 20 Mb/day from the CCM program. There is thus a need for developing automated algorithms that can perform data quality control and warn if quality is poor.

MODELLING THE HEAT AND MOISTURE TRANSPORT IN THE "AIR - VEGETATION - SNOW - SOIL" SYSTEM OF THE BALTIC SEA DRANAGE BASIN

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The problem of the modelling hydrological and energy cycles over the Baltic Sea drainage basin is considered. A special attention is paid to the problem for the cold season when (i) the heat and moisture exchange between the atmosphere and land is very much influenced by the presence of the snow cover, and (ii) the upper layer of the soil is frozen. The summer season case is also considered.

The description of a local one-dimensional model of the heat and moisture transport in the "air - vegetation - snow - soil" system is given. The land surface is treated to be bare or covered by snow and/or vegetation. For proper description of the vegetation effects, the two-layer evaporation model is incorporated as a submodel. This evaporation model was tested in Finland and Sweden on an agricultural crop, a willow stand and a boreal forest. The results of the model testings showed that the model accuratly reproduces the energy and water fluxes from the canopies and the soil.

The heat transport in the snow cover is computed by the heat conductivity equation. The special attention is paid to computation of processes of the heat and moisture transport in the soil, including the cases of its freezing and thawing. The most important innovation here is the consideration of different physical states of the soil water by taking into account the processes of condensation/evaporation and freezing/melting. To describe mathematically the heat and moisture transport in the soil, it is assumed that all of physical processes involved are one-dimensional since, in general, the vertical gradients of the temperature and moisture are significantly greater than their horizontal gradients. Besides that, the soil heat and moisture transport is characterized as cross-diffusive one since the flux of any substance (temperature, water vapor, liquid water) is defined both by its own gradient and by the gradients of other substances. It is also taken into account that the soil can contain the vegetation root zone.

To verify the model, the process of the autumn-winter soil freezing was successfully simulated. The input data for numerical experiments are extracted from the measurements at the following russian meteorological stations of the Baltic Sea drainage basin: Tikhvin (the autumn period, 28 October – 30 November 1972, and the winter period, 15 December 1972 – 5 March 1973), Leningrad region and Kargopol' (1 November 1972 – 30 April 1973), Arkhangel'sk region. The model verification has also been done for period with active vegetation (June 1995). Measured data for boreal forest, NOPEX region are used. The results of our model calculations compare favorable with data.

Preliminary results from tower and radio-sound measurements performed in the northern part of the Baltic Sea during winter conditions.

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Radio soundings and mast measurements were performed on a the North East coast of Sweden at the beginning of 1998. At the site there was a 24m high tower erected with turbulence and profile measurements. The profile system consisted of three levels with temperature and wind sensors. The turbulence was studied with two instruments, one sonic anemometer-thermometer sensor at 10 m and one hot wire instrument at 2 m. The sampling rate was 1 Hz for the slow response instruments and 20 Hz for the turbulence instruments. The measurements will be compared with data collected on an island in the southern part of the Baltic Sea, Östergarnholm, which is equipped with similar instruments. The main interested in this presentation is directed towards studies of the sensible heat fluxes for the two locations. Results of comparisons of the sensible heat flux measurements at two levels with two different instruments will also be presented. It has been found that the sensible heat flux measured with the sonic anemometer is higher than the fluxes measured with other instruments. This is probably a result of the measuring technique. The sonic anemometer uses the speed of sound, assuming the air to be dry. In the atmosphere the air always contains water vapour. Hence, the fluxes considered as sensible heat flux always contains some percentage latent heat flux.

1997 FLOOD ON VISTULA RIVER

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1. Introduction

Vistula River is the largest river of Poland and the second largest river of the Baltic Sea basin (after Newa). Its total length is 1 092 km with the source on the Barania Mountain at the elevation of 1 220 m above MSL. The catchment of Vistula amounts to 194 300 km^2, of which 89% is within Polish borders. The catchment of Vistula which is within Polish territory occupies 55% of the total Poland's area. Hydrographically Vistula is divided into three sections. Upper Vistula, Middle Vistula and the Lower Vistula. The catchment is very asymmetric: 73% create right hand tributaries. Normal precipitation over the catchment varies from 1 700 mm in high mountains in the south to 450 mm in the central lowland plains. The average precipitation amounts to 600 mm. The catchment is characterized with high evaporation and thus the outflow coefficient in an average year is only 27%. The average annual outflow is 32 km^3 which results in the average discharge to the Baltic Sea of 1 014 m^3/s. The minimum and maximum annual outflow of Vistula to the sea is 37 and 20 km^3 respectively. Discharge of Vistula is nonuniformly distributed over time. High discharges occur in spring during thawing of snow and ice and also in July due to high precipitation in the mountains. The last period of 12 years (1982 - 1993) was very dry which resulted in the decrease of average annual discharge to the sea to 894 m^3/s. Vistula River is characterized with one of the highest flood potential among all Central European rivers.

2. Floods on the Vistula

There are 4 types of floods which occur on the Vistula River:
- Thaw floods (in spring) when high discharges result from melting of snow and ice, very often accompanied by intensive rains and low ground retention caused by frozen soil.
- Precipitation floods caused by intensive rains predominantly in mountain regions (catchments of Soła, Raba, Skawa, Dunajec and San). 1997 flood can be compared to flood of 1934 by its character and intensity.
- Winter floods which occur either in the beginning of cold periods during ice cover formation, or during spring ice run. This situation is aggravated by the fact that Vistula River flows from south to north. Spring ice breakup starts about 10 days earlier in the south when northern reach of the river is still frozen. These floods usually occur along the Lower Vistula. Dramatic flood occurred in 1982 along the upper part of Włocławek Reservoir.
- Storm floods which usually take place along the estuary section of Vistula River thus endangering the area of Żuławy. These floods are caused by high discharges accompanied by wind upwellings in the Bay of Gdańsk or in Elbląg Lagoon. Dangers of this type foods are intensified by the possibility of ice collection on the sedimentation cone at the mouth of Vistula.

3. 1997 flood on Vistula River

Precipitation flood which occurred on the Odra and Upper Vistula Rivers was caused by 3 series of rains (3-10 July, 15-23 July and 24-28 July). It was important that this precipitation fell on already saturated soil which resulted from June precipitation. The first series of precipitation was the most intensive. The rise of flood stages on Vistula started on the 6 of July and was caused mainly by flood waves reaching the main river channel from tributaries. In many cross-sections the maximum water elevations from previous floods were exceeded by 25 to 70 cm. Along the whole Upper Vistula Section alarm stages were exceeded. In Kraków the culmination water stage was only 35 cm lower than absolute maximum from 1970. Flood discharge was close to 2 300 m^3/s which is about 2% probability occurrence. Floods also occurred on the tributaries of the Middle Vistula. Their maxima were 10 to 40 cm lower than absolute maxima from previous years. In general flood stages on all tributaries were higher than on the main channel of Vistula. In downstream direction of the main Vistula channel flood wave decreased and in Warsaw maximum discharge only slightly exceeded 5 000 m^3/s which was close to the probability of 10% and reached the alarm stage.

VOLUME AND SALT TRANSPORTS IN THE BALTIC SEA AND ITS SUBBASINS

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One of the main aims of BALTEX is the determination of the water, heat and salt budget for the Baltic Sea and its drainage basins. As there aren't any long-term measurements of transports in the Baltic Sea available, results of three dimensional high resolution models have to be used to calculate the budgets. At the Institute of Marine Research in Kiel a coupled ice-ocean model for the whole Baltic has been developed since many years and validated against observations. The oceanic component is based on primitive equations, with horizontal resolution of 5 km and 28 vertical levels specified. The ice model is based on the Hamburg Sea Ice Model, with the same horizontal resolution. Identical fields of temperature and salinity may be taken from monthly mean values or from hydrographic observations interpolated onto the model grid. Atmospheric forcing is taken from the SMHI data base.

The model is integrated for two years starting in January 1992 until December 1993 including the latest major salt water inflow event which led to drastic changes in the salinity distribution in the Baltic Sea. Based on monthly mean model data volume transports as functions of salinity between the different subbasins are calculated. Due to the fresh water input mainly into the Bay of Bothnia and the Bay of Finland and due to the inflow of high saline water from the Kattegat into the Baltic a two layered estuary is established. The calculated monthly mean transports are analysed with respect to seasonal changes and correlated to the forcing functions.

One of the results is that the mean vertical integrated transports for 1992 and 1993 are very similar. The interannual variability seems to be small compared to the seasonal. Therefore these two in detail analysed years turn out to be typical for the horizontal circulation pattern in the Baltic Sea. Due to the lack of data the long-term mean of the vertical circulation couldn't be analysed because the residence time of the Baltic Sea is much longer than the investigated integration period.

Towards a coupled hydrological and meteorological mesoscale model: soil moisture initialisation.

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Lars Gottschalk and Kolbjörn Engeland, Department of Geophysics, University of Oslo, Norway.
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Abstract

One of the main objectives of the inter-European multi-disciplinary NOPEX (NOrthern hemisphere climate Process land surface EXperiment) project, which is one out of a few prioritised full-scale land-surface experiments within the IGBP-BAHC framework, is to give incitements for model development based on high quality data sets. Of special importance is the coupling between the atmospheric and hydrological processes, aiming at regional estimates of energy and water exchange. The NOPEX two concentrated field efforts (CFEs) during June 1994 and April-July 1995 provide such high quality data sets for a Boreal environment. A distributed hydrological model (ECOMAG) and a meso-scale meteorological model (MIUU) have been both separately applied to the NOPEX area. These models are the two basic components that at present are modified to allow coupling experiments. Both models work at a 2 by 2 km grid net. The heterogeneous soil moisture fields produced by the ECOMAG model for this grid net have been used to initialise the MIUU model. The simulated fields by this initialisation are compared to those initialised from homogeneous soil moisture conditions. The results of the simulations are evaluated and compared with regional flux estimates for the NOPEX area from mast, radiosonde and aircraft measurements. Experiments of this kind are found very important in the process of validating and conforming the model structures.

SIMULATION AND OBSERVATION OF RUNOFF ON A LOCAL SCALE

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Abstract

Land surface schemes in atmospheric models describe the exchange of momentum, heat and moisture between the soil surface and the atmosphere. Usually these schemes are calibrated and optimized with respect to the turbulent fluxes with the forcing data (mean atmospheric variables) and validation data (fluxes) being measured at the local scale on a tower. If soil temperature and moisture data are available the storage of heat and water in the soil can also be compared to the simulated values. There is, however, usually no information on the horizontal runoff. Errors in the simulation of the water balance terms accumulate in the runoff estimation.

On larger scales runoff can be considered as an integral quantity representing the outflow of a river catchment or part of it. The locally generated runoff is transported into the river and routed through the river system to a gauging station. Data from this station and the estimated river runoff can be compared in order to validate the model system of runoff generation and routing scheme. This approach was applied during PILPS phase 2c (Project for Intercomparison of Land Surface Parameterization Schemes) over the Arkansas - Red River catchment and is presently used to estimate the runoff in the Odra catchment. It is implicitly assumed that the local runoff generation by the land surface scheme yields reasonable runoff estimates.

The land surface scheme SEWAB (Surface Energy and Water Balance) was calibrated with respect to the turbulent fluxes with data from the FIFE experiment and through participation in PILPS phase 2a (Cabauw data). This presentation shows results from a validation procedure with respect to runoff generation on a local scale.

The research area is sited northwest of Cork in the south of Ireland. It encompasses a 14.5 Ha catchment. The site is gently sloping to a stream. The slope decreases from 5 % uphill to 3 % downhill. The site is agricultural grassland, whereas the dominant plant species is perennial ryegrass, typical of the landuse and vegetation in this part of the country. The bedrock geology is Devonian Sandstone. The soil profile is characterised by a top 5 cm humus layer overlying a dark brown A horizon of sand texture to a depth of 20 cm. The yellowish-brown B horizon of sand texture grades into a brown gravely sandparent material at about 30 cm. The groundwater level depth reaches 3 m at hill top and 1 m at the outflow. The field instrumentation comprises three water content reflectometer (TDR), two rain gages, a class A evaporation pan, two water level recorders, an infrared gun and an automatic weather station including net radiometer, air temperature, relative humidity, barometric pressure, surface temperature, soil temperature, soil heat flux plates, rainfall, wind speed and wind direction. The data are available as 20 min averages over a half year period.

The climate is temperate and humid, from the influence of the warm Gulf Stream in the North East Atlantic Ocean. Mean annual precipitation in the Cork region is about 1100 mm. The rainfall regime is characterised by long duration events of variable intensity and total depth which occur at any time of the year. Short duration, high intensity events, occurr mainly in summer.

The energy and water balance of the surface and the soil layer down to 3 m depth are simulated with the land surface scheme SEWAB. This scheme is based on the one-layer concept for vegetation. In the soil the diffusion equations for heat and moisture are solved on a multi-layer grid. Particular attention is given to the runoff generation which separates fast surface runoff, intermediate flow and slow baseflow.

The tuning of SEWAB to the particular experimental setup and the comparison of simulated and observed runoff are discussed.

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PRECIPITATION OBSERVATION AND ANALYSIS FOR THE BALTEX MAIN EXPERIMENT

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The Baltic Sea Experiment is unique in that the countries located in its region collectively contain a number of independent precipitation observation and analysis systems consisting of: a high density network of conventional and automatic weather observation systems, a large number of weather radar systems, ship-mounted rain gauges, and a number of numerical weather prediction models. The BALTEX Main Experiment (BRIDGE) has the potential to provide datasets from these systems along with the ability to comprehensively analyse the data both alone (quality control) and together (higher level products). Doing so will provide us with precipitation information for a number of applications including:

- budget studies,
- derivation of a precipitation climate for the BALTEX region, emphasizing the Baltic Sea,
- validation of modelled precipitation,
- validation of satellite-derived precipitation estimates,
- evaluation of the value of various precipitation observation systems

This abstract outlines the preparations for BRIDGE, related to observing and analysing precipitation, taking place at SMHI R&D. These activities will concentrate on the improved use of weather radar from the Swedish national network including the establishment of a comprehensive archive, the analysis of radar data from the BALTEX Radar Data Centre (BRDC), and the generation and evaluation of high level precipitation products.

The Swedish weather radar network consists of 11 C-band Doppler systems, most of which are located proximate to the Baltic Sea. The current network's logistics must be improved in order for it to be used to its full potential both during and after BRIDGE. Among the issues which must be addressed is the improved transfer of data from the radar nodes to a central data processing and archiving facility. The EU-financed project "PEP in BALTEX" has given us the ability to address this issue. The project will help us further develop methods presented by Andersson *et al.* (1997) to conduct quality control of so-called polar volumes of weather radar data. SMHI's first ever radar data archive will also be established during the first half of 1998. Both reflectivity and radial wind velocity data will be archived for use in PEP and BRIDGE.

The BRDC will hopefully be established during 1998 and be up and running prior to the start of BRIDGE. The BRDC and its functions were defined by the BALTEX Working Group on Radar (WGR, 1996). The logistics of the BRDC ideally involve creating a radar network comprising those radars used in the NORDRAD network along with radars operated by at least DMI and the DWD for the duration of BRIDGE. The BRDC would collect and process data, generate precipitation products and both distribute and archive them in as close to real time as possible. A prototype network of this kind, used for research and development purposes during BRIDGE, should generate a number of tangible benefits for participating weather services and should lead to the improved use of radar in the BALTEX region. It should also be emphasized that the consistent use of radar provides the only source of observational data covering the majority of the Baltic Sea.

Higher level precipitation products will be generated from multisource observational and model data. The observational database created at the BALTEX Meteorological Data Centre (BMDC), along with data from ship gauges operated by Institut für Meereskunde in Kiel (ref), radar data from the BRDC, and numerical weather prediction model fields will be collected and analysed using the Mesoscale Analysis System (MESAN) developed at SMHI (Häggmark *et al.* 1996). The system is based on optimal interpolation where multisource observations can be integrated to produce 2-D best estimate fields of precipitation. PEP in BALTEX will allow us to further develop MESAN for use both before and during BRIDGE. Precipitation fields will be generated, distributed and archived during BRIDGE within the framework of the BRDC. An additional task which will be performed by SMHI is an evaluation of the relative importances of the different observation sources in generating MESAN fields. This should provide information on the value/contribution of these sources in analysing precipitation both for land and for sea.

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Past, present and future wind climate on the Polish coast of the Baltic Sea

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The present paper characterizes the Empirical Orthogonal Functions of daily mean wind vector on the Polish coast of the Baltic Sea using results of 15 years of meteorological observations, 1971-1985 at coastal stations. For this data set and particular seasons the empirical transfer functions between large scale air-pressure and the wind field were computed by means of Canonical Correlation Analysis and Redundancy Analysis. Computed canonical and redundancy maps show significant dependence of local wind field on the large scale circulation. Local processes explained by the fourth pairs of canonical maps do not play too significant role in stormy seasons when air mass flow is strong and characterized by high steadiness. In summer this processes are explained by the third and the fourth pairs of canonical maps and can not be neglected. Additionally a relationship between large scale air-pressure and pressure at selected stations located in the Baltic Sea Basin was calculated. Total redundancy index has a very high value for all seasons except for summer.

Reconstruction of wind vectors was performed using NCEP's pressure data, 1899-1994. The general skill of the applied model is high, especially for the zonal components and for stormy seasons (autumn, winter). The reconstructed time series show annual/seasonal and multi-annual/multi-seasonal variability. Statistically significant trends can not be detected for the reconstruction period bur sub-periods when zonal or meridional components were intensified are easy to find. Analysis of pressure differences between stations located in the southern Sweden and at the Polish coast confirm results gained from wind vector's analysis.

Results of ECHAM-3, T42, time slide experiment for doubled concentration of CO_2 were used to estimate a future wind climate. In the respect to „control run" wind vectors components calculated for $2xCO_2$ are varying in range ± 8m/s independently on location with long-term means (30 years) equal to zero. In spite of that fact it is worth to point out that same other changes in character of variability were found.

Long-standing forecast for spring snow-melt flood of the Western Dvina River

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We researched the forecasting dependencies of two snow-melt flood elements: runoff volume and maximum levels at the located areas of Vitebsk and Polotsk.

The main factors forming the character of spring-time snow-melt flood are as follows:

- water equivalent of snow cover;
- quantity of precipitation's during the flood period;
- soil moisture;
- depth to which the soil is frozen.

The Western Dvina River is a plainsriver with dominating snow nourishment (feeding). A considerable part of the annual runoff (almost 50 per cent) is received because of snow-melt floods in spring.

Spring-time flood forecasting boils down to invention of diagrams of ties that express dependence of runoff volume's (or maximum level's) quantity on total amount of water come from the catchment.

We have invented the following dependencies:

1. surface runoff equals „f" (sum of water equivalent of snow cover and precipitation; winter-time flow);

2. flood's maximum level equals „f" (look comments in the 1st item).

Exactness of the forecast is 80 - 90 per cent and its lead time is 20 - 40 days.

Numerical experiments on the influence of surface cover changes upon the processes of the atmospheric water cycle in the southern Baltic Basin

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Abstract

Since human began to grow crop and to build settlements, the Earth's surface was modified. Different landuse types and slopes yield different fluxes of momentum, moisture and heat due to variations in water availability, surface temperature, plant and soil parameters. These differences also affect evapotranspiration, cloud and precipitation formation as well as runoff by complicate non-linear feedback mechanisms.

In the Baltic Basin surface cover changes occur due to urbanization (e.g., along the coast for purposes of tourism), freezing of the Bodden, changed agricultural practice, floods, etc.. The effect of anthropogenic and natural surface cover changes on the local evapotranspiration, cloud and precipitation formation is investigated. In doing so, numerical studies were performed with the non-hydrostatic meteorological model (GESIMA; Kapitza et al. 1992, Eppel et al. 1995) for different regions of the southern Baltic basin and different synoptic conditions. Such investigations are important in gaining understanding of relatively short-range weather forecasting. Moreover, they may aid to understand the feedback mechanisms of land modification in the hydrologic cycle of the Baltic Basin.

Generally, the landuse changes do not influence the predicted quantities of state above the ABL in all the simulations. Because of the higher energetic input during the daytime the fluxes predicted for the various landscapes differ more strongly than during the nighttime. In most of the cases the predicted variables of state as well as the water and energy fluxes differ over and downwind of the areas of landuse changes.

Five simulations were performed which assumed the recent landscape, three different flooding stages of the river Odra as well as a landuse change from grassland to marshland and from agriculture to grassland. The flood alone or the flooding of the Ziltendorfer Niederung slightly decrease evapo(transpi)ration, cloudiness and rainfall in the immediate vicinity of the surface change. In the domain-average, however, the flooding of the Ziltendorfer Niederung and the flooding of the Oderbruch as well as the conversion of grassland and agriculture to marshland and grassland, respectively, enhance evapotranspiration, cloudiness and rainfall rates. The wet and dry anomalies being a part of the land surface conversions must exceed a certain size to obtain an appreciable difference in cloud and precipitation formation. For flooded areas, the differences in the thermal, hydrologic and the dynamic characteristics of the surface strongly affect the surface fluxes, (water supply, heating), the vertical motions and consequently cloud microphysics. If flooding increases the water supply to the atmosphere or not, will also depend on the former landuse of the flooded area. Only the flooding of the Oderbruch significantly affects the near-surface horizontal wind field, and, hence, strongly affects the moisture convergence. Due to the resulting stronger lifting of moist air in the North of Frankfurt the formation of precipitating particles was initiated earlier than in the origin landscape. This means that the combination of dynamics and the increased water vapor supply modifies the atmospheric water cycle the strongest of all the assumed 'Odra'-scenarios.

As pointed out before the magnitude of the changes in the variables of state and the fluxes depends on the kind of landuse conversion, the horizontal extension of the converted patches and whether the resulting dynamic, hydrologic and thermal effects counteract or enhance each other. The results showed that the same landuse conversions lead to differences in both directions. Furthermore, the effects of landuse changes (e.g., increased wind speed), which may enhance a process (e.g., evapotranspiration), may be compensated by other changes (e.g., reduced water deficit, lower temperature, increased stability), which may decrease the same process.

A further set of simulations was performed for the south-western German Baltic coast. Herein, different scenarios of urbanization were assumed, namely, a randomly distributed urbanization and a scenario with a preference for urbanization along the coast. The results of both the studies substantiate that urbanization enhances cloud and precipitation formation in the lee of the large cities. Urbanization hardly affects the atmosphere in the case of small cities. Only where small cities grow in an area covered by grassland, evapotranspiration appreciably enhances in the downwind of the grown settlements. Sensitivity studies showed also a reduction of the domain-averaged 24h-accumulated precipitation for urbanization in the landscape with additional lakes. Due to the urbanization both greater sensible and latent heat fluxes occur. Nevertheless, the domain-averaged Bowen-ratio will be shifted towards higher values if the cities grow. On average, the atmosphere becomes warmer and drier.

Although in the lee of large cities precipitation may grow, in the domain-average the urbanization studies deliver less precipitation than the studies without urbanization. This is caused by the lower domain-averaged evapotranspiration. The locally enhanced precipitation may be explained as follows. Due to the higher diffusion coefficients and the lower heat capacity of settlements the surfaces heat more strongly in the grown conurbation than over the reference land cover or the surrounding land during the daytime. Hence, the air temperatures slightly increase over the urban area as well as downwind of them. Therefore, the vertical motions are also enhanced in these areas. For continuity reasons the lifted air is replaced by moist air advected from the rural land. Above the grown conurbation the vertical wind component grows significantly. As a consequence of the strong lifting of moist air, greater amounts of ice, and, by melting, rainwater are achieved in the urbanization studies than in the reference case.

Only in the lee of large cities the air may get appreciably moister during the nighttime in the case of cloudiness. Here, the evaporation and sublimation of rainwater and ice, and the related evaporative cooling and cooling by melting significantly cool the lower ABL. In the cloud layer the ABL of the urbanization study is warmer than that of the study without urbanization due to the greater release of latent heat by the higher condensation and deposition, freezing (of rainwater to graupel) and riming rates.

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Rain detection and determination of rain rates with the SSM/I radiometer over land by calibration with in situ measurements

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C. Simmer

Within BALTEX soil moisture and precipitation over land are investigated by the *Special Sensor Microwave/Imager* (SSM/I) installed on the DMSP satellites. The SSM/I radiometer measures the intensities at the frequencies of 19, 22, 37 and 85 GHz. The 85 GHz radiation ($\lambda = 3,5$ mm) is reduced in a measureable extent by extinction and scattering due to raindrops while the lower frequencies remain mostly uneffected. On this basis it is possible to detect rain and to derive corresponding rain rates. For May and June 1993 the SSM/I measurements are correlated with in situ measurements in order to classify the SSM/I measurements into rain and no rain cases. For this validation in situ data with a temporal resolution of 1 minute are available from about 155 rain gauges in Germany.
Preliminary results of this work were presented at EGS in Vienna 1997. The results and the methods have been worked out in more detail and expanded. Comparison with results of literature is presented. The results are applied to determination of monthly amounts of precipitation.
The rain detection was investigated with the algorithm according to *Grody* (1991). The coefficients for this algorithm have been recalculated with linear regression for the BALTEX area since they are assumed to be dependent on the underlying surface. By the *Grody* algorithm approx. 75% of the rain cases and approx. 75% of the no rain cases were correctly identified. We then trained neural networks directly in order to predict 'rain' or 'no rain' which increased the number of correctly detected rain and no rain events significantly to approx. 90% each.
For the determination of rain rates the in situ measured rainrates are plotted versus the Scattering Index which is determined by the brightness temperatures of the different SSM/I frequencies (Fig. 1). The data considerably scatter around the corresponding regression line. The main reason for the variation of the data is the local rain measurement of one rain gauge while the Scattering Index represents a 'mean' value for the whole larger field of view of the SSM/I. For one Scattering Index a 'mean' rain rate for the field of view can be obtained from the linear regression. The uncertainty of this mean rain rate should be considerably lower than the scattering of each in situ measurement. In a second approach we used neural networks to predict mean rain rates. The results of this method correspond to those obtained by the above regression algorithm and the algorithm according to *Ferriday* (1993) (Fig. 2).
In a further approach the results of the rain detection and the determination of

rain rates were used to calculate the amount of the monthly precipitation for Germany as a whole. The amount of the monthly precipitation determined by the SSM/I measurements are 98 mm (Mai) and 89 mm (June) compared to the amounts of 75 mm and 76 mm, calculated from in situ measurements by the DWD. These results and their uncertainties will be further investigated and discussed.

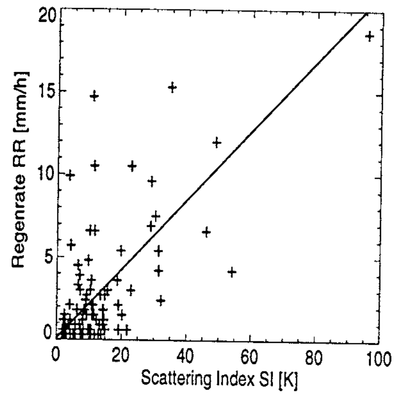

Figure 1: *Scatter diagram of the in situ rain rates versus the Sacttering Index. The straight line is the result of a linear regression*

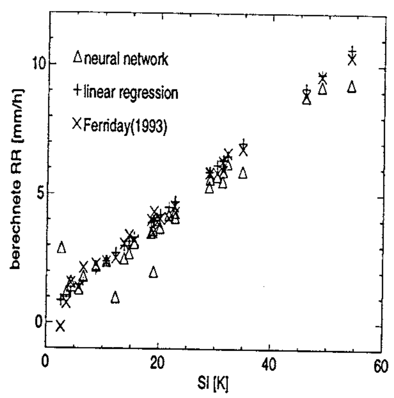

Figure 2: *Rainrates calculated with different algorithm plotted versus the corresponding Scattering Index*

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GERB: A NEW EARTH RADIATION BUDGET DATASET

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Besides its enhanced imaging radiometer SEVIRI the first Second Generation METEOSAT (MSG) will carry an instrument dedicated to measure the Earth Radiation Budget (ERB). From the year 2000 on, the Geostationary Earth Radiation Budget (GERB) instrument will be the first opportunity to measure ERB components from space with a temporal resolution of 15 minutes. In contrast to previous ERB missions such as ERBE and ScaRaB this is sufficient to resolve the diurnal cycle. Geostationary instruments so far provide data with only limited (narrowband) spectral coverage so that ERB estimates are based on extrapolation of the spectral information. GERB will provide both, spectral broadband measurements and high temporal resolution and therefore allows new studies of the diurnal cycle, tropical convection etc. The GERB instrument is currently being built by a British - Belgian - Italian consortium. The spectral bandpass reaches from 0.32μm beyond 30μm. A quartz filter inserted at every second image limits the bandpass to the region of reflected solar radiation.
Within the framework of a EU sponsored project, a whole series of new products of GERB data are developed. The planned products so far are:

Product type	Temporal resolution	Spatial resolution	Positional accuracy	Wavelength range
Radiance	2.5 min	Footprint of GERB pixel	3 km	SW
Radiance	2.5 min	Footprint of GERB pixel	3 km	'Total'
Flux	15 min	100 x 100 km	3 km	SW
Flux	15 min	100 x 100 km	3 km	LW
Flux	1 day	100 x 100 km	5 km	SW
Flux	1 day	100 x 100 km	5 km	LW
Flux	1 month	100 x 100 km	5 km	SW
Flux	1 month	100 x 100 km	5 km	LW
Flux products using additional data from SEVIRI, ScaRaB, NOAA or CERES	15 min to 1 month	100 x 100 km	3 km	Variable

While the data from GERB will provide a uniquely valuable source of information on the diurnal cycle of the Earth's radiation, even greater benefits will be obtained by combining data from GERB with data from other instruments in low Earth orbit . These synergetic products will also allow to extend the useful area towards the poles so that the Baltic sea can be covered. Examples of products under consideration follow. These will be revised once our survey of user needs is complete.

- Information on the vertical distribution of liquid water, ice and other aerosols using 15-minute GERB and SEVIRI radiances, LEO radar and lidar, available IR sounder profiles of the temperature above optically thick clouds and microwave sounder retrievals.

- Near real-time information on the bi-directional reflectance and the consistency of calculated fluxes using 15-minute GERB and SEVIRI radiances, estimated fluxes at the GERB spatial resolution and simultaneous, co-located LEO multi-directional data (e.g. POLDER, MISR).

- Time averaged (daily, monthly and annual) fluxes over the GERB field of view using 15-minute GERB and SEVIRI radiances, with simultaneous collocated LEO (CERES or ScaRaB) SW, LW and narrow-band radiances

In addition to delivering radiation flux products at the GERB spatial resolution, the synergy of SEVIRI and GERB data allows one to produce a high spatial resolution (about 5km) product for specified regions and limited time periods. Such a radiation budget product will fulfil the user needs of groups running mesoscale and cloud scale models. There are already several methods available for Narrow-to-Broad-Band (NTB) conversion of spectral radiances. The disadvantage of all these methods is, that they were developed for a particular sensor and cannot simply be transferred to different instruments without further work. All of these methods were derived either from radiative transfer calculations or by empirically combining narrow and broad band satellite data. The major problem of all the empirically derived NTB algorithms is that the data used was not from the same satellite, causing shifts in observation time and viewing geometries. With MSG, having GERB and SEVIRI on board, it is optimally designed to test and optimise NTB algorithms implemented during the GERB pre-launch phase. In addition, the large variety of narrow band SEVIRI channels, comparable to those of other operational satellites, will enable one to transfer an optimised NTB algorithm to a different satellite. We will implement and test an improved algorithm that will take data from GERB and SEVIRI and will produce broad band fluxes from narrow band data. The application of such an algorithm to current and future narrow band data from LEO satellites will enable one to produce GERB like products for the polar regions. There is also a specific use of this algorithm in the calibration of the SEVIRI instrument.

Beside increasing the spatial resolution of the GERB products, the SEVIRI spectral radiances will also be used to produce estimates of basic cloud physical and optical properties within each GERB IFOV. Such a combined cloud/radiation product allow one to derive conceptual models of cloud processes that are needed in order to improve the performance of cloud resolving models and to derive the kinetic energy from the potential energy. During the pre-launch phase we will test, modify and optimise methods based on common techniques for use with SEVIRI data. For measurements within the visible and near infrared, the major advance of the SEVIRI is the addition of a 1.6μm channel giving the possibility to look at cloud optical thickness and particle sizes during daytime. The combination of window channels at 3.8, 8.7, 10.8 and 12 μm can be used for instance to determine night-time cloud particle size and phase. In general it is planned to derive the fractional coverage, temperature/height, optical thickness, emissivity, liquid/ice water path and an index on particle size and phase. In addition, it is planned to get some information on cloud layers. For instance an optically thin high cloud over a low cloud can be detected probably by use of the SEVIRI channel at 13.4 μm, while the low cloud will be detected by the combination of spectral window visible and infrared channels.

The BALTEX community is invited to suggest new products according their specific needs. These suggestions could be incorporated if feasible within the EU project.

Possibilities to determine wind over oceans using satellite synthetic aperture radar

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Sea surface wind characteristics are currently measured by scatterometers onboard satellites. However, the resolution of the measurements is of the order of 50 km which is too coarse for e.g. the Baltic Sea. By using synthetic aperture radar (SAR) the resolution can be largely improved, which is not only of importance for small seas but also for ice covered areas where leads and polynyas could possibly provide wind information. Such data, once validated, can also be used as input to high-resolution weather forecasts models or as ground truth to validate those models. However, to make this possible, many problems of the SAR as a wind indicator have to be overcome.

This paper presents a study of the possibilities to retrieve sea surface wind speed from SAR images over the Baltic Sea. The data set is composed of 15 images acquired between 1994 and 1997 by ERS-1/2 over an area situated between Åland and Gotland. The wind speed is extracted from the images over areas of 10×10 km^2 using the most recent C-band models (CMOD4 and 5 from ECMWF, CMOD-IFR2 from IFREMER), relating the backscattering coefficient to the wind speed and direction and the radar beam incidence angle. In this way, the SAR is more or less used as a scatterometer, for which the models are made. However, the SAR gives only one measurement whereas the scatterometer on board ERS-1/2 gives three. So the wind direction has to be estimated separately. In some cases the wind direction can be estimated from wind streaks in the SAR images. Presently the wind direction is taken from in situ data from four weather stations situated in the area (Utö and Bogskär in Finland, Svenska Högarna and Gotska Sandön in Sweden) and weather forecast model (HIRLAM). The results are compared to both in situ and HIRLAM derived wind speeds.

Studies are made on the different special cases encountered, to determine the possibilities and limitations of the retrieval. For example, rain and snow have some effect on the backscattering coefficient of the sea surface, depending on their intensity. Too low and too high wind speeds pose also some problems. Certain cases of failure are still not explained. Statistics of the different sources of data and results are also compared for consistency.

In the final paper we plan to include meteorological considerations in collaboration with the scientists at SMHI participating in the project.

CHARACTERIZATION OF LAND-SURFACES IN THE BALTIC BASIN BY MODELLING DIURNAL TEMPERATURE WAVES EXTRACTED FROM METEOSAT-IR DATA

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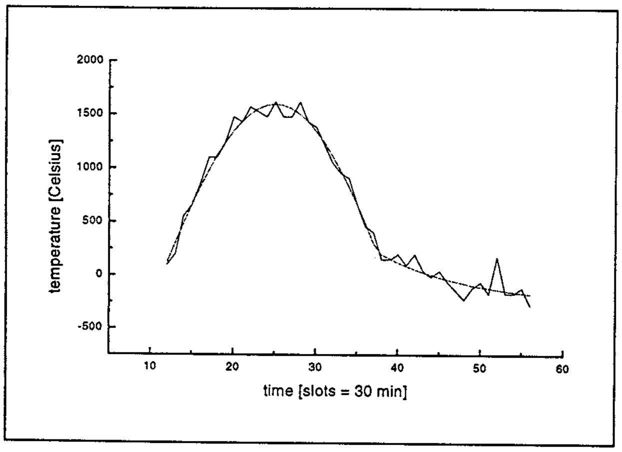
The diurnal wave of land surface temperature (LST) is one of the key components of the energy budget. The only feasible way to access the LST of large areas is remote sensing. IR data are often contaminated with clouds. Therefore, a method was developed to yield a quantitative description of the diurnal LST wave not only for case studies in permanently cloudfree situations.

The diurnal temperature waves were extracted from sequences of METEOSAT-IR measurements. Cloud detection was carried out with temporal and spatial dynamic thresholds derived from monthly minimum VIS counts and maximum IR brightness temperatures. Atmospheric correction was calculated with MODTRAN using ECMWF analysis of temperature and humidity profiles (14 levels) with one degree grid resolution. After gross cloudmasking, the time - sequence for each pixel was determined. For further processing only permanently-clouded pixels were rejected. Then, a model consisting of a harmonic and an exponential term was fitted to the pre-processed temperature waves, describing the effect of the sun and the decrease of the surface temperature at night, respectively. The fitting procedure is performed automatically and unsupervised by a Levinberg-Marquardt least-squares scheme. The diurnal thermal behaviour of every METEOSAT pixel is completely characterized by a set of six parameters (see Fig. 1). Comparisons of measured temperature waves with modelled diurnal waves allow to detect clouds which have not been detected in the previous steps.

The relationship between these parameters and some surface characteristics will be presented for the south-western part of the Baltic basin for the summer of 1996. The long - term thermal behaviour of land-surfaces, e.g. seasonal changes, is then described by the variation of the parameters with time.



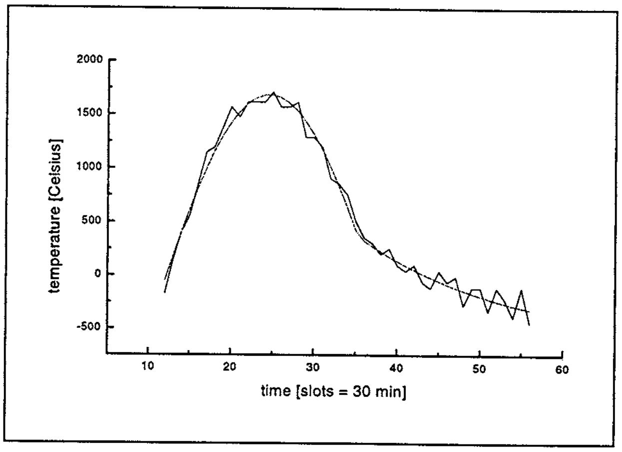


Figure 1: Diurnal LST waves on the 17.4.96 derived from METEOSAT IR measurements for Jylland (left) and Mecklenburg-Vorpommern (right). The modelled (smooth) curves describe the diurnal temperature waves with six parameters, e.g. the maximum of the LST and the attenuation constant are found to be 16.0°C / 4 h 09 min (left) and 16.9°C / 8 h 51 min (right). The extracted set of parameters allows further analysis of the LST.

The following results will be presented:
1. Examples for the model parameters describing the diurnal temperature wave: position of maximum, amplitude, residual temperature, width of cosine, onset of exponential decrease and attenuation constant
2. Interpretation of the parameters with features of land-surfaces, e.g. vegetation, elevation

CLOSING THE ENERGY AND WATER CYCLES OF THE BALTIC SEA

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Does the Baltic Sea gain or lose fresh water from the atmosphere? Does the Baltic Sea gain or lose energy from the atmosphere? How much water and energy leave the Baltic Sea through the entrance area? Can we close the energy and water budgets only by using measurements from Baltic Sea entrance area? These are questions that require energy and water cycle studies. As the energy and water cycles are closely linked, they can not be studied in isolation, but requires consistent methods, where both models and measurements are used. In the modelling, ocean models are important tools, which is illustrated during this presentation where we have applied the PROBE-BALTIC model [*Omstedt and Nyberg*, 1996]. The energy and water cycles were calculated and analysed using this model and observations from meteorological stations, water levels from the Kattegat and river runoff. The time period considered was from November 1980 to November 1995, thus a 15 year period.

The direct coupling between the energy and water cycles are through the turbulent latent heat flux, which cools the sea surface and removes water from the Baltic Sea through evaporation, but several other energy and water fluxes need also to be considered, Figure 1. The water balance, Figure 1 a, is controlled by the net out-flow from the Baltic Sea, the river runoff and the meteorological runoff (precipitation minus evaporation rates). On a long term mean the water flows balance, but on shorter time scales this is not true.

In the calculations of the evaporation rates we have used the ocean model and also considered the reduction of evaporation due to sea ice [*Omstedt et al.*, 1997]. The in- and out-flows were also calculated and the river runoff data were taken from observed monthly means [*Bergström and Carlsson*, 1994]. The water balance for the Baltic Sea was evaluated by comparing measured and calculated mean salinities in the Baltic proper, illustrating the importance of considering the meteorological runoff to the Baltic Sea [*Omstedt and Axell*, 1998].

The energy balance of the Baltic Sea water body, Figure 1b, is controlled by the net heat flow (equal to the sum of the sensibile heat flux, the latent heat flux, and net long wave radiation) from the open water surface and the sun radiation to the open water surface, the heat flow between water and ice, the sun radiation through the ice, the heat flow from river water and the heat flows associated with the in- and out-flows through the Baltic Sea entrance area. As a long term mean the sum of the energy fluxes balance, but on a shorter time scale this is not the case.

The energy balance calculations illustrates that the Baltic Sea, as long-term means, is controlled mainly by the difference between net heat flow and the short-wave radiation in the open water areas. The energy balance of the water body in the ice covered region is due to the the heat flow from water to ice and the sun radiation that penetrates the ice. The energy cycle was evaluated by comparing the measured and calculated annual maximum ice extent. Also the long term mean values of the different energy fluxes were compared with some meteorological estimates.

The calculations illustrates that the total energy balance of the Baltic Sea is almost in local balance with the atmosphere, but the Baltic Sea gains some energy from the atmosphere that is advected out through the Danish Sounds. However, the fluxes show large seasonal, regional and interannual variations.The importance of applying ocean models in energy and water balance studies is illustrated and the problem of closing these cycles will be further discussed during the seminar.

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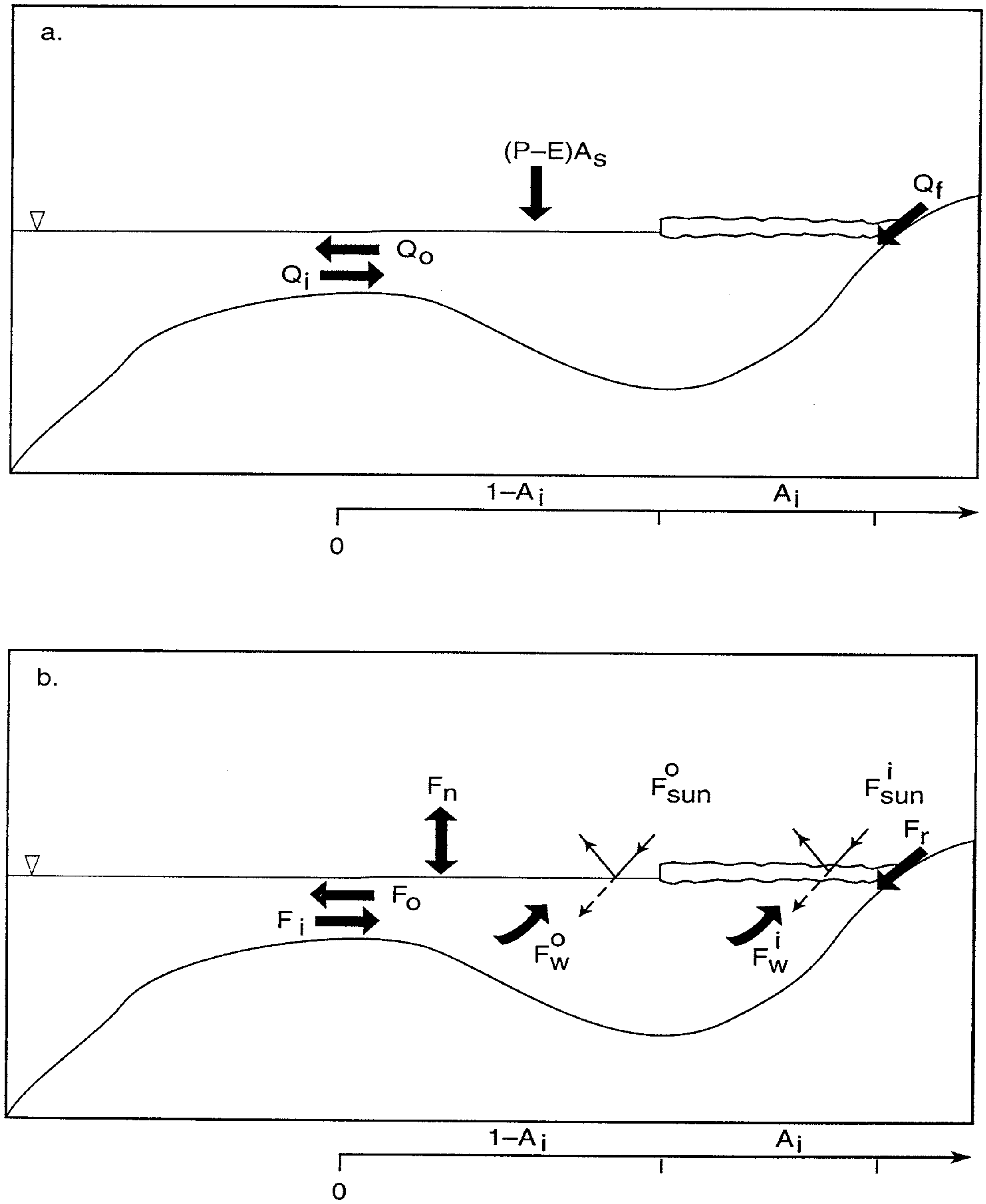

Figure 1: The main components in the water (a) and energy (b) cycles of the Baltic Sea. The water flows are Q_i and Q_o, in resp. out flow through the Danish Sounds, Q_f the river runoff, $(P-E)A_s$ is the precipitation minus the evaporation for the areas not covered with ice. The heat fluxes are F_i and F_o, in and out flow of heat through the straits, F_n is the net heat flow from the open water surface to the atmosphere. F^o_{sun} and F^i_{sun} are the sun radiation to the open water and through the ice respectively, F^o_w and F^i_w are the heat flows fron deep layers and from the water to the ice and F_r is the heat flow from river water.

VARIATION OF WAVE-DEPENDENT DRAG COEFFICIENT DURING THE REAL STORM IN THE BALTIC SEA

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ABSTRCT

A proper estimation of air flow over sea waves play an important role in in wave, storm surge, wind fields prediction. Most hydrological models assume the drag coefficient to be dependent only on the local wind speed. However this is significant simplification and as it is known (Donelan 1997, Janssen 1991) the drag coefficient depends also on the existence of wave and the stage of theirs development. The third generation wave model WAM4 is used for study of sea age dependence of the drag coefficient in the Baltic Sea during the real storm.

INTRODUCTION

In neutrally stable conditions a wind profile has a logarithmic dependence.

$$u(z) = (u_*/\kappa)\ln(z/z_0) \tag{1}$$

where: u_* is a friction velocity which is relate with surface stress $u_* = \tau^{1/2}$, κ is a Kármán constant (here $\kappa=0.41$) and z_0 is the roughness length. To relate the surface stress to the wind speed at a given height the drag coefficient C_d. is usually used:

$$\tau = C_d(z)u^2(z) \tag{2}$$

For the logarithmic profile defined by (1)

$$C_d = \kappa^2/\ln^2(z/z_0) \tag{3}$$

C_d. depends on the roughness length z_0 and the height of observation. Over the sea Charnock proposed the following relation for roughness length:

$$z_0 = \alpha u_*^2/g \tag{4}$$

where g is a gravity acceleration and α is so-called Charnock parameter. Since the parameter α is constant, the roughens length depends only on wind speed. Field observations (Komen et al. 1994) indicate that the roughness length and drag coefficient depend also on the sea state. The measure used for sea state development is so-called wave age c_p/u_*, where c_p is the phase speed of the peak of the wave spectrum. The young wind sea – $c_p/u_*=5\div10$ – is rougher the old wind sea with $c_p/u_*=25$.

Sensitive dependence of the aerodynamic drag on the wave age is described by Janssen's quasi linear theory of wind-wave generation (Janssen 1991) where both the effect of the waves and the effects of air turbulence on the mean wave profile are taken into account. In this theory is investigated the influence of wind generated gravity waves on the air flow. From a consideration of the momentum balance of air it is found that the kinematic stress is given (Janssen 1991) by the following formula:

$$\tau = \left(\kappa U(z_{obs})/\ln(z_{obs}/z_0)\right)^2 \tag{5}$$

z_{obs} is the mean height above the waves and roughness lenght is equal:

$$z_0 = \hat{\alpha}\tau/g\sqrt{1-\tau_w/\tau} \tag{6}$$

τ_w is the stress induced by gravity waves (wave stress) and $\hat{\alpha}$ is a constant. Therefore parameter α in Charnock formula for roughness length (3) is not further constant but depends on the wave stress.

$$\alpha = \hat{\alpha}/\sqrt{1-\tau_w/\tau} \tag{7}$$

MODELLING RESULTS

Strong wave-wind interaction is evident for the young wind sea. For the old wind sea there is only weak coupling between wind and waves. Additionally the recent field observation (Donelan 1997) shows also that presence of counter- and cross-swells can results in drag coefficients that are much larger then the value for a pure wind sea. The question arise how big is influence of sea age on the air flow, parameterized by the drag coefficient, during the real storm.

Janssen's quasi-linear theory of wind wave generation is used in the third generation wave prediction model WAM4, so WAM4 model includes sea state dependence of a drag coefficient. WAM4 model is also a coupling model and therefore description of the momentum transfer at the air-sea interface is improved (Komen et al. 1994).

The WAM4 model is used for modelling of the drag coefficient C_d during the real storms in the Baltic Sea. The results are compared with the drag coefficient C_{dCh} calculated for the logarithmic wind profile (1) with roughness length z_0 using Charnock formula (3) which does not include dependence on the sea state. The Charnock constant $\alpha = 0.0185$. The results are presented in proportion.:

$$P_{Cd} = 100 \cdot \frac{C_d - C_{dCh}}{C_d}$$

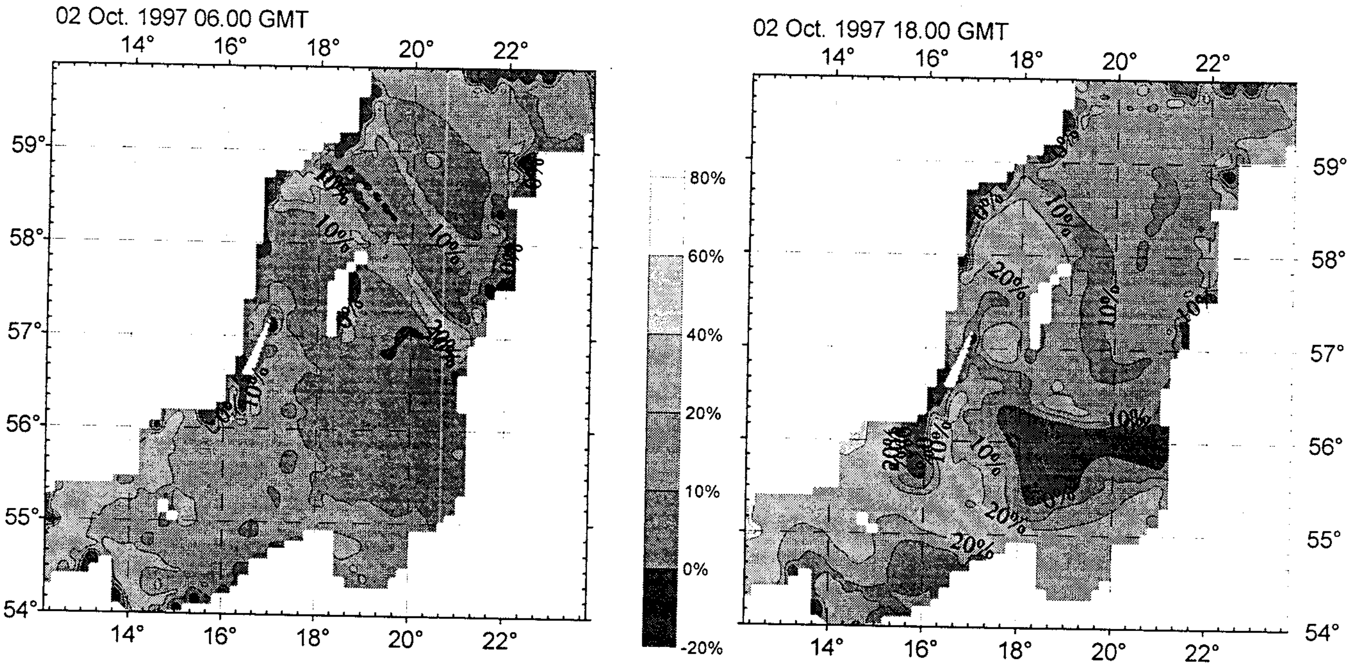

Fig. 1. Contour plots of coefficient P_{Cd} (%) which indicates of difference between sea state dependent and sea state independent drag coefficient.

Two examples of variability of the coefficient P_{Cd} (%) for the storm in the Baltic Sea which occurred from the 1st Oct. till 6th Oct. 1997 are shown in Fig. 1. The value of the drag coefficient which includes the wave age dependence is even more then 60% higher then the drag coefficient independent on the wave age.

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DIAGNOSTIC STUDY OF THE SEVERE STORM OVER POLAND ON 28 MARCH 1997.

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In the BALTEX program the diagnosis of specific weather phenomena and radar data retrieval play an important role leading to a better knowledge of atmospheric processes and providing for refinement of data assimilation methods. An example of such kind of diagnostic study is presented.

The cyclonic explosive vortex has been captured by a meteorological radar fitting precisely into the radar domain 400x400 km. The radar echo displacement allowed for the wind analysis refinement. As a result 3D mass and wind fields were retrieved with a horizontal grid step 4 km and vertical 100 m.

A small, non-significant wave on the polar front that come far from Atlantic, when passing over British Islands and Northern Sea, get a strong explosive cyclogenetic impulse and passing eastward over northern Poland caused severe damage and documented death of at least eleven persons. The passage of a cyclonic vortex has been fortunately captured by meteorological radar at Legionowo (52° 24' N, 20° 58' E), near Warsaw. At 12 UTC the centre of the vortex occurred about 30 kilometres north-east from radar. At the same time the radiosonde measurements on the relatively dense network surrounding the area, including Legionowo, were at our disposal. To perform the analysis of the event the following corresponding data have been collected: the GRID GTS UKMO output, surface SYNOP from 62 national Polish network, satellite infrared series over Europe. The key is the reflectivity data on the grid of 100x100 with the grid step 4km at 700,1000,1500,2000,3000,4000, and 5000 m levels. Although the Legionowo radar is not a Doppler one, its coverage was fortunately enough large (400kmx400km) that at 12 UTC the whole vortex fit with the area.

The analysis has been kept on a grid domain 100x100x100 with the vertical griding every 100m. The case study went on by two ways: one is the traditional synoptic approach and the second, an essential mesoscale study, was the numerical objective analysis and diagnosis. The simple adjoint method of Qiu and Xu was adopted and modified for retrieving horizontal (and vertical) displacements. After proper averaging and reinterpolation, horizontal mass fluxes allowed on precise anelastic deduction of a vertical component. Then the traditional thermodynamic retrieval approach after Gal- Chen is applied to deduce pressure and temperature fluctuations.

The analysis has revealed some interesting features and generally confirmed the previous opinion on the impact of a dry stratospheric intrusion on explosive cyclogenesis process, giving a refreshing view on many details of a motion structure. The vertical distribution of the pressure is fairly regular and understandable. We have got negative fluctuations in the front (eastward) lower part of the section and positive in the rear lower part of the vortex. In the upper troposphere this structure is transposed. Gradients of nonhydrostatic pressure represent the driving forces distribution. The retrieved potential temperature fluctuations as compared with synoptic analysis, show higher diversity although the basic picture remains similar: a warm conveyer belt in front and a cold air in the rear part of the vortex. The cold air does not however form a wall but might be regarded as a cold core of a lower troposphere jet. The nonhydrostatic pressure field related to the horizontal relative motion is also calculated and possibly represent well the rotating structure of the vortex.

Fig.1 presents the radar echo at 2000m asl and associated horizontal streamlines of retrieved relative motion, whilst Fig.2 illustrates the basic (direct) wind velocity field projected onto central W-E vertical plane and associated streamlines of the direct and relative motion.

The whole work should be regarded rather as a Gnostic then diagnostic process in recognition how explosive cyclones behave.

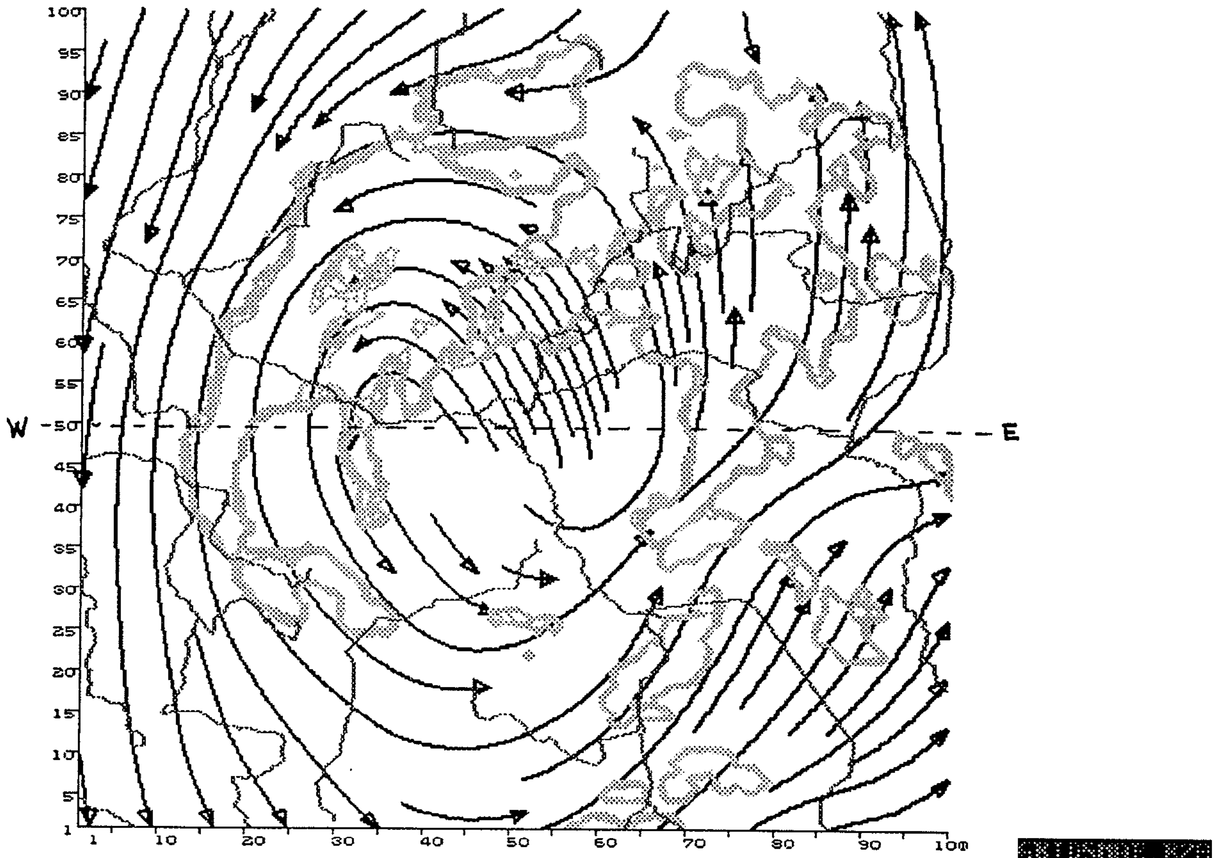

Fig. 1 Radar echo at 2000m height and associated horizontal streamlines of retrieved relative motion.

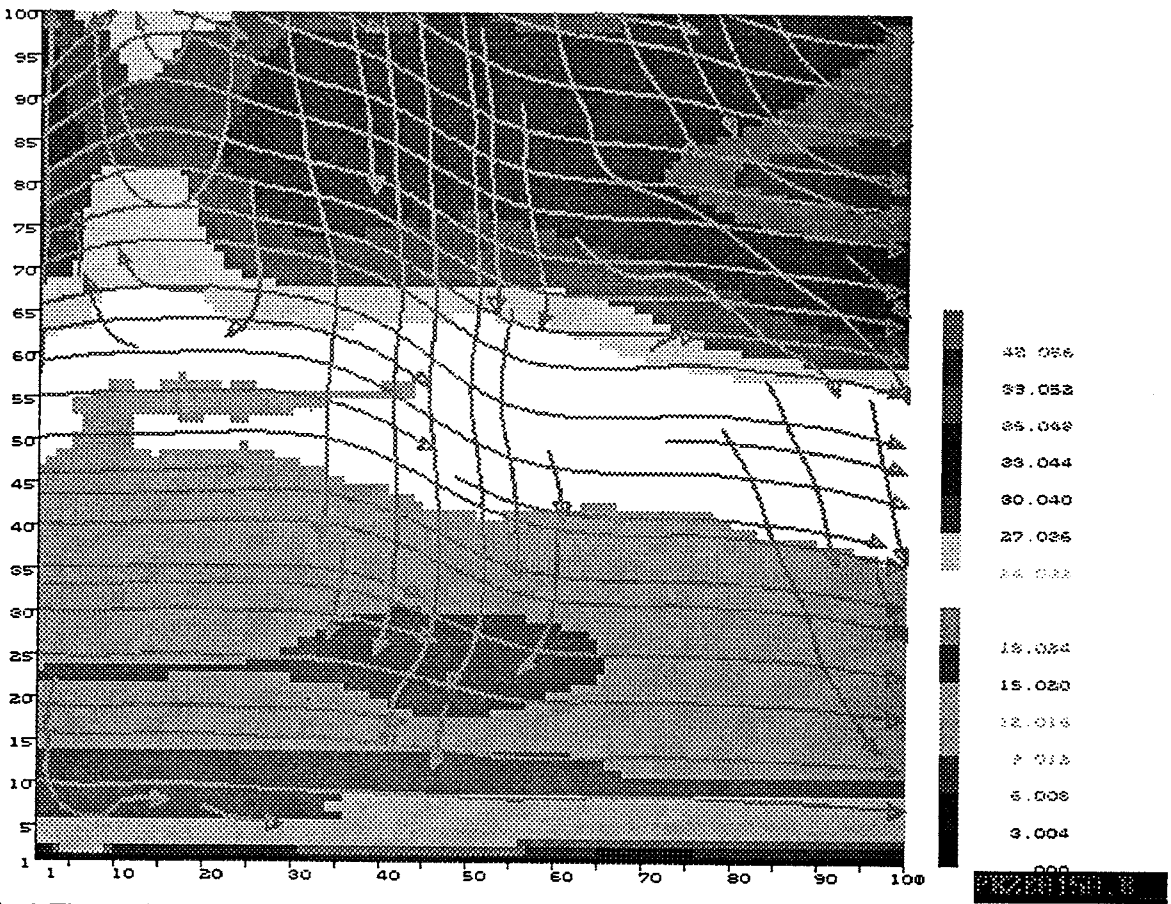

Fig. 2 The vertical W-E section of direct velocity field and associated streamlines of direct and relative motion.

AIR-SEA MASS EXCHANGE IN COASTAL ZONE

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This paper presents the results of investigation designed to determine the exchange processes between the sea and the air above the coastal zone. The rich emission of droplets from the sea surface is one of effects differentiating the near-sea atmospheric layer over coastal zone from the others surface layers. Emission of water sprays from the sea surface also called mechanical evaporation interact with turbulent fluxes of momentum τ, heat H, and moisture E, in the water-adjacent layer to produce fluxes of momentum τ_k, heat H_k, and moisture E_k carried by droplets.

Spray emitted from the sea surface contributes significantly to the air- sea exchange of heat and mass. This hypothesis is most readily proven by describing air-sea exchange under storm conditions. During a heavy storm, spray emission from the water surface is so intensive that the heat, latent heat and momentum it carries may exceed the turbulent fluxes. Bortkovskiy's (1983) have confirmed this. The importance of spray droplets to air-sea exchange of heat and water vapour has also been demonstrated by laboratory experiments (Anisimova et al., 1991; Panin et al., 1994). When winds are weak , however, the postulated hypothesis, though still valid, does not hold so well, as wil be demonstrated. Under such conditions, the droplets do not act as a heat transporting medium, but do influence the thermal structure of the air-sea interface. The droplet emitted from the water surface affect the vertical temperature profile in the air surface layer, and hence the turbulent fluxes passing through it. The mechanisms involved are illustrated by the numerical model of thermal structure of the air-sea interface (Petelski, 1986; 1996). Experiments conducted with this model have shown that even very small latent and sensible heat fluxes carried by sea spray can result in turbulent fluxes by one order of magnitude.

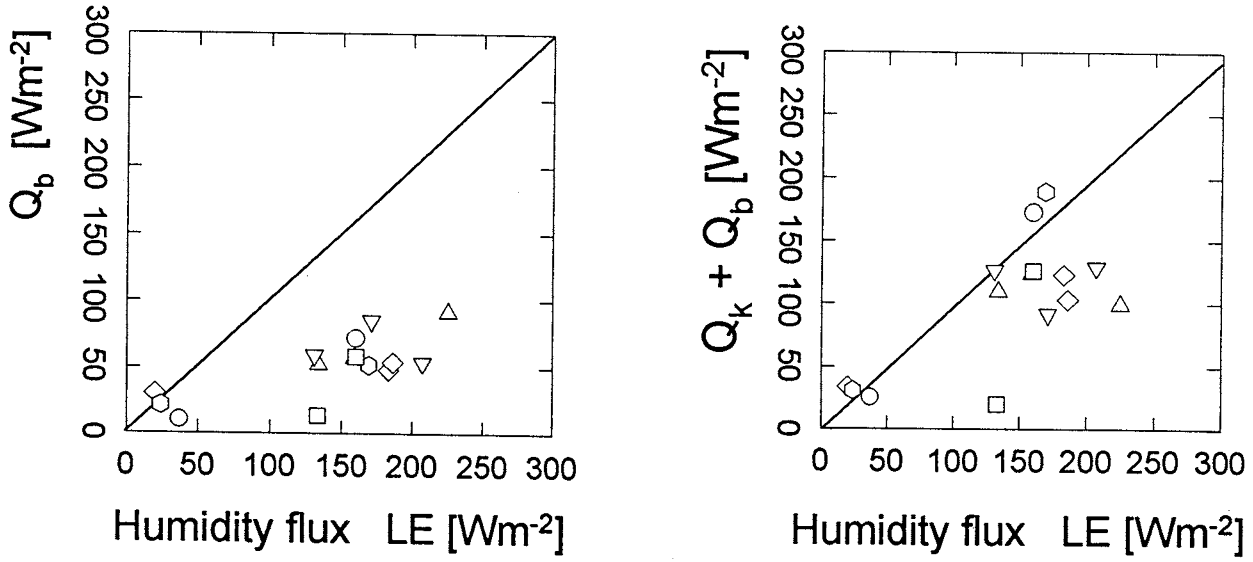

Fig. Comparison between measured humidity flux LE and flux calculated by bulk formula $Q_b = LE_b$ and flux carried by droplets $Q_k = LE_k$, were L is coefficient of latent heat.

In the costal zone because of breaking waves nearly always exist sea spray emission and fluxes τ_k, H_k, E_k. In this paper the sea spray emission fluxes E_k were compared with the measured turbulent fluxes of vapour E and calculated from bulk parametrization E_b. The fluxes of water droplets were calculated from aerosol emission fluxes. The fluxes of aerosol particles emission from the sea surface were determined from the vertical and horizontal gradients of aerosol concentration (Petelski and Chomka, 1996). The data were collected in the coastal zone of the southern Baltic Sea from the board of s/y 'Oceania" and from the land station in Lubiatowo during the Baltic Aerosol Experiment in October 1993. Aerosol formation was measured with six-stage impactors working simultaneously and located at different heights. Turbulent fluxes were measured during experiment by the group from the institute of Water Problems R.A.S, Moscov. The relevant zero moment of the waving spectrum obtained by a wavegraph were delivered by the Institute of Hydrotechnical Construction, PA S.

The obtained results point out to a very important role of emission of droplets in the mass exchange in the coastal zone. Humidity fluxes E_k transferring sea water to the atmosphere through droplets are of comparable magnitude to turbulent fluxes E in this zone. Equations of the bulk type cannot be used for the parametrization of evaporation from coastal zone because these formulas give inadequate results. The right parametrization of evaporation in this zone has to take into consideration droplets mechanism of mass exchange.

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MEASUREMENT OF RAIN PROFILES WITH A VERTICALLY LOOKING DOPPLER RADAR

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The method, how to derive quantitative drop size distributions and rain parameters from a vertically looking Doppler radar, has already been described by Atlas et al. (1973). Although much methodological research was stimulated by this proposal the application of the method was limited by the high technical effort. This situation changed due to the introduction of radar wind profilers, which deliver the required data in their normal operation mode as a "by-product". In addition, low cost micro radars are now available, which are designed for this application (Klugmann et al., 1996, Loeffler-Mang et al., 1998). In contrast to scanning weather radars the measurement with profilers is only local, but but it is quantitative by taking into account the actual drop size distribution $N(D)$, which may deviate considerably from an average model distribution. The Doppler spectra are converted into $N(D)$ using the known relations between droplet diameter D and fall velocity v, and between $N(D)$ and spectral radar reflectivity factor $z(v)$ respectively.

We describe here measurements obtained with a 1235 MHz radar wind profiler. At this wavelength (24.3 cm) the conversion of Doppler spectra into rain parameters is particularly simple because the scattering cross section is well described by the Rayleigh approximation and the attenuation of radio waves can be neglected. According to Richter (1993) one obtains the rain parameters using the following relations.

Dropsize distribution:	$N(D) = z(v)D^{-6}\partial v/\partial D$	
Differential liquid water content:	$lwc(D)dD = (\pi/6)\rho_w N(D)D^3 dD$	(ρ_w = density of water)
Total liquid water content:	$LWC = \int lwc(D)dD$	
Differential rain rate:	$rr(D) = (1/\rho_w)lwc(D)v(D)$	
Total rain rate:	$RR = \int rr(D)dD$	

The deviation of large droplets from sphericity can be included in refined algorithms (Klugmann and Richter, 1995), but the most questionable assumption - namely a vanishing vertical wind component - remains. Several of the above mentioned studies address this problem. Richter (1993) has shown for the boundary layer that the corresponding rain rate error may reach 30 % occasionally but is typically within ±10 % for stratiform rain and for averaging intervals of 5 min or more.

In September 1996 a pilot experiment was conducted at the east-coast of the isle of Gotland to characterize the boundary layer over the Baltic Sea using combined remote sensing systems including a 1235 MHz radar profiler (See also Boesenberg et al., this volume). In order to demonstrate, which information about rain can be derived from these measurements we show here a rain event from 12 September 1996, 01:00–02:00 UT.

Figure 1 (top left) shows contours of rain rates between 240 and 1600 m with 60 m height resolution and 10 s time resolution. The freezing level is at 1100 m during this time. Above this altitude the algorithm yields a dramatic overestimation of precipitation rate, because here snow flakes are the scattering particles. The apparent enhancement is so strong, that it is easily distinguished from real structures of the rain profile and is thus providing a useful information about the temperature profile. The slight increase of rain rate in the lowest range gate is probably also an artefact due to a residual range dependence of the radar signal after corrections have been applied.

A slope of rain bands is very often observed. Usually the onset of rain occurs first in the highest altitude, which is consistent with the tilt of virgae due to the wind profile. Sometimes – e.g. at 01:16 UT – the rain does not reach the ground which is probably caused by evaporation. As expected, this behaviour is more pronounced for small droplets, as to bee seen in the differential rainrate at $D = 0.5$ mm (middle left) and it is not observable at $D = 1.0$ mm (bottom left). We see also, that the overestimation of rain above 1100 m is only caused by apparently small droplets. Due to the small fall speed of snow flakes the calculated particle diameter is small at this altitudes with a very high apparent number density according to the D^6-dependence of the radar reflectivity factor.

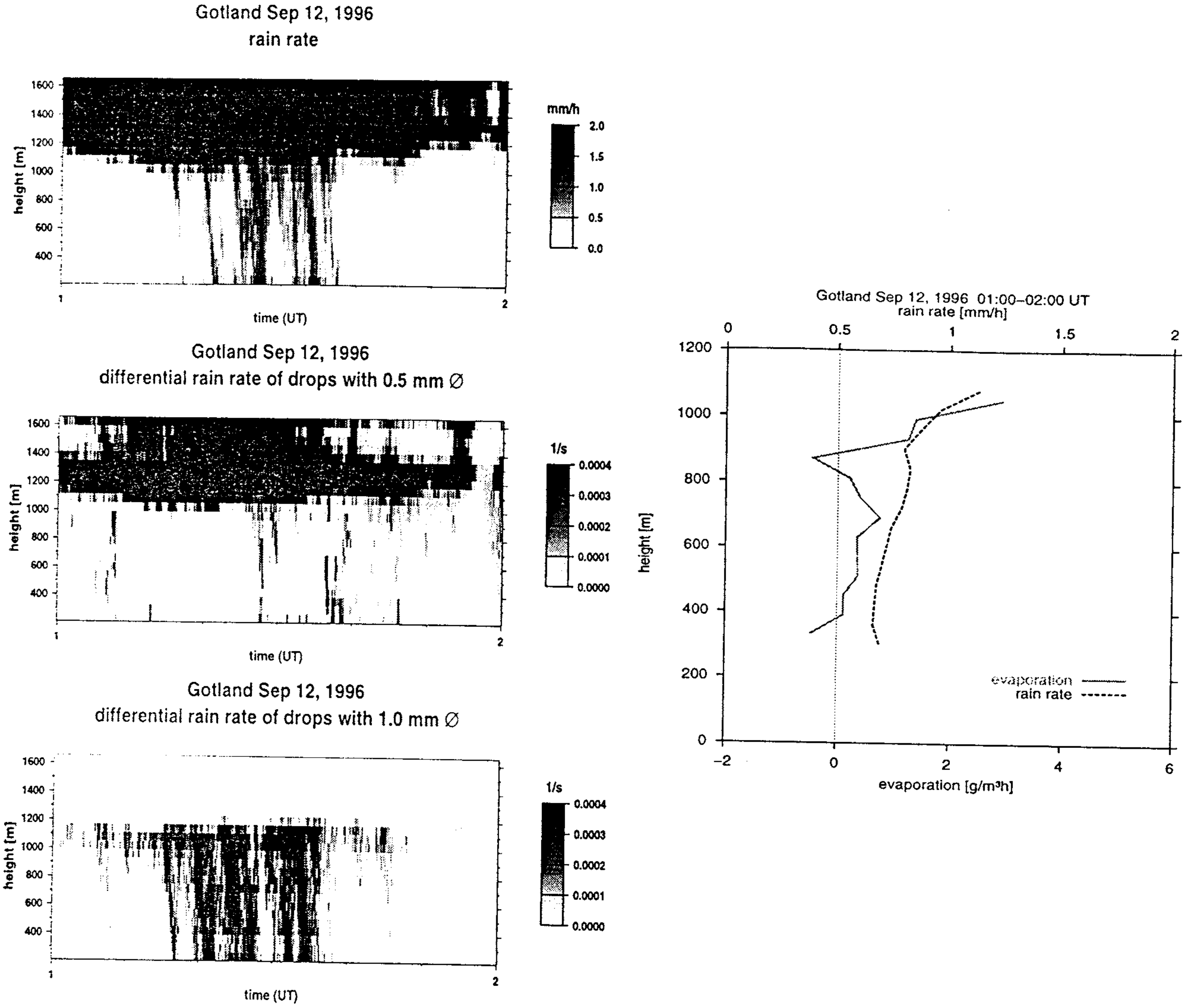

Fig. 1: Left: Rain rate contours, Right: Mean rain rate and evaporation profile.

In the 1-hour-mean profile of rain rate together with the evaporation, derived from the rain gradient (right), the altitudes below 300 and above 1100 m have omitted. By converting the evaporation- into cooling-rate it can be shown that this process is a significant source – if not dominating – for buoyancy production in the raining boundary layer.

It is planned to operate micro radars at three Baltic Sea sites over a period of 18 months together with surface precipitation and turbulent flux instruments in the frame of PEP (Precipitation and Evaporation Project). All sites are in the range of operational weather radars so that the data sets also provide a new means for weather radar calibration.

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NUMERICAL SIMULATION OF FRONTAL CLOUD SYSTEMS WITH TAKEN ACCOUNT OF DETAIL MICROPHYSICS AND DIFFERENT MECHANISMS OF CLOUD AND PRECIPITATION FORMATION

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During a number of years combined theoretical and field studies of winter frontal clouds have been carried out at the Ukrainian Hydrometeorological Research Institute. As result, the fundamental theory of stratiform frontal cloud and precipitation formation have been developed. The ultimate goals of this theoretical study are to construct the numerical models simulating microphysical processes in supercooled winter frontal clouds with different condition for the cloud and precipitation formation; to work up their finite-difference solution schemes; to explore to how extent the different microphysical processes and thermodynamical conditions can influence on the cloud and precipitation formation and development.

The used set of primitive thermodynamic equations include equations for the wind components, temperature, specific humidity of air and a set of kinetic equations for cloud particles size distribution functions (small and large drops, single crystals, aggregates). The advection, diffusion, inertial, pressure gradient, particle sedimentation, grows (evaporation) by deposition, freezing, nucleation, coagulation continuous growth of large drops, ice particles and snowflake etc. were taken into consideration. The nucleation processes have been parameterised. The application of this method to more complicate problems of cloud and precipitation formation inside the turbulent atmospheres of the Earth and other planets forced including additionally the equations simulating the different cloud condensable components (ex.g. ammonia into Jupiter atmosphere). The presence of crystals of different forms forced including the additional equations.

The solution schemes of non-steady partial differential equations have been constructed and numerical experiments have been carried out. The developing solution schemes based on splitting methods let to exclude the some items in equations with aim to isolate several processes and to consider them in more detail. The stability of the solution scheme is examined by theoretical investigation and numerical experiment testing.

One-, two- and three-dimensional time-dependent and time- independent models simulated the macro, meso and micro processes in stratiform cloud and winter frontal cloud systems have been developed. One-dimensional models that included into consideration detailed description in evolution of cloud particles (drops, crystals, nuclei, snowflakes, etc.) were constructed and used for study of microphysical processes. Two- and three- dimensional models were constructed to study the evolution of frontal rainbands and interaction between the dynamics and cloud microphysics evolution features. Two-dimensional numerical models with nested (or stretched) grids were constructed to simulate large and small meso-scale structure development. Special attention was devoted to the construction of initial meteorological fields. Several theoretical steady-state models of an atmospheric front were constructed. The special method was developed for constructing models simulating real synoptic situations. These models were often used for a nowacasting of frontal cloud systems that have been conducted by field experiments.

One- two- and three-dimension nowacasting and forecasting numerical models of winter frontal systems passing over Ukraine and have been subjects to measurement and observation in the steppe part of Ukraine were constructed with aim to develop a better understanding of the frontal cloudiness and its precipitation development on winter frontal and cyclonic situations and for identification conditions that provide the best potential of frontal rainbands to produce precipitation in different regions of Ukraine. Two-dimension model with nested and stretched grids was used to simulate of convective cell embedded into stratiform cloudiness. The some results of study is as follows:

The structure of simulated atmospheric fronts in occluded cyclones exhibited many features described earlier for other regions in midlatitudes and apparently of common character: hyperbaroclinic zones of different mesoscales, small and large mesoscale rainbands, embedded convective cells, wave-like features of cloud and precipitation evolution and etc.

The qualitative estimations of instability in frontal zones implied that large rainbands can apparently be generated in large baroclinic zones with stable stratification. In instable zones mainly small mesoscale rainbands with embedded convective cell formed. The convective cells in separate moments their evolution exhibited the dramatic cloud dynamics and microphysics features. The some conditions that forced embedded convection on frontal rainbands were identifying.

The precipitation amounts are defined chiefly by cloud dynamics. The influence of microphysical mechanisms is significant if there is inability of the total activity to realise all the moisture capable of sublimation. There is question of which of the precipitation formation mechanisms have the optimal conditions. In the absence of these conditions, the other mechanisms starting or intensify and can form the precipitation successfully enough.

ABOUT COUPLING OF EUROPEAN CIRCULATION PATTERNS AND ESTONIAN PRECIPITATION FIELDS

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The large-scale atmospheric circulation is an important driving force of the surface climate. Several attempts have been made to relate the atmospheric circulation to local weather. In general, the first stage is the classification of the atmosperic circulation and the second stage is the assessment of the relationship between the categories of the classification and the local weather elements.

The aim of the work is to investigate coupling of larger scale atmospheric circulation and distributions of daily precipitation over Estonia. For describing the circulation over Europe the Grosswetterlagen (atmospheric circulation patterns) have been chosen. In Europe the Grosswetterlagen have been used for many decades, time series of daily records begin in 1881. This manual system classifies for each day the atmosheric circulation over Europe and the eastern part of the North Atlantic Ocean. Precipitation over Estonia during two periods 1966-1976 and 1984-1993 has been analyzed. The precipitation is based upon Estonian meteorological stations daily data.

Statistical analysis of precipitation distributions has been made. The main rain-bringing circulation patterns for Estonia are all connected to cyclonic circulation over Europe: North West cyclonic (NWz), North cyclonic (Nz) and West cyclonic (Wz) patterns. The link between circulation patterns and precipitation was investigated separately for a winter and a summer half year. Variability of spatial distributions of precipitation during different circulation patterns has been investigated. It depends on the atmospheric circulation pattern how similar are the spatial distributions of precipitation corresponding to different days during the same pattern. For pattern West cyclonic (Wz) because of dominating frontal precipitation the patterns of precipitation are similar for different days. But there are also patterns when local rainfall often occurs (e.g. BM - Central European Ridge) and therefore spatial distribution of rainfall is very different on the different days.

Spatial distribution of daily precipitation is strongly linked to the atmospheric circulation and the further step will be modeling of it as a coupled process.

SZENARIO – ASSESSMENTS OF NUTRIENT ENTRIES FROM THE WHOLE ODRA BASIN INTO THE POMERANIAN BAY

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Since 1996 a Polish-German joint research project[1] is running to investigate the non-point source nutrient entries from agriculturally used areas towards the rivers of the Odra drainage basin and towards the coastal seas (RP1). The results from this project can be used to develop regionally differentiated strategies for the reduction of agricultural nutrient emissions based on the overall entries towards the Baltic Sea.

This time the overall matter entries from point sources (communities and industries) and non-point sources (RP1) through the rivers of the Odra basin towards the Pomeranian Bay (RP2) are investigated in a second Polish-German joint research project[2] which is compatible to RP1 and was started in 1997. Our focus of this project lies on the study of retention, retardation and elimination processes along the main rivers. Besides of catchment emissions was taken into consideration there impact of the matter processes of the Pomeranian Bay and the Arkona Sea. The environmental legal and economic aspects of such processes as well as the possibilities to take influence of an efficient reduction of matter entries will be studied also into a separate part of this project.

For RP1 the report deals with results of the first working phase. Using data on the level of municipals the agricultural primary surpluses of nitrogen and phosphorous was calculated on a catchment scale using an algorithm, it was tested in similar investigations carried out in 1992/94 in East Germany. The matter entries towards the rivers were calculated with consideration of erosion processes conditional upon surface runoff, the seepage and the way-time behaviour groundwater recharge and movement in typical aquifers. A Geographic Information System (GIS) was developed for the whole Odra basin. It contain the data base of all necessary informations like precipitation, potential evapotranspiration, soil covering and land use, soil types, river network, lakes, water divides, depth to the groundwater surface and the hydraulic properties of aquifers (thickness and saturated hydraulic conductivity). The maps digitised, have had a scale of 1 : 300 000 or smaller. An mainly part of the work was to make the different databases of both countries consistent.

The realisation of the relative simple and therefore robust methodology with GIS techniques and its examination was carried out in four catchments of the Odra basin (Uecker, Plonia, Olawa and Ciesielska Woda). The works to all non-point agricultural emissions are finished.

To investigate the reduction processes along the main rivers towards the Pomeranian Bay rivers will be divided in compartments of 30 up to 50 km. Such compartments should be relative morphological homogenously. In detailed regional geomorphological studies a first refinement of compartments was developed. Further essential information for dividing rivers are the situation of the tributaries, the point and non-point sources taken from

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[1] RP1 – Research Project 1
Investigation on the quantity of diffuse entries in the rivers of the catchment area of the Odra and the Pomeranian Bay to develop decision facilities for an integrated approach on waters protection – Diffuse entries in rivers of the Odra Basin –

Sponsored by transform-Programm/Umweltbundesamt

[2] RP2 – Research Project 2
Model-based status-quo and scenario analyses of water pollution directed on deriving strategies and decision-support tools for preserving and management of water resources by example of the Odra River and adjacent coastel ses, taking into consideration scientific, economic and legal aspects
- Oder Basin/Baltic Sea InterRelations (OBBSI) -

Sponsored by Volkswarenstiftung

RP1 as well as the position of gauging and water quality stations. The entry points of large communities or industrial sites will be taken into consideration especially.

Box models will be developed to describe the reaction dynamics of the several compartments using the morphological data and measured discharge and water quality data of rivers. These several box models will be combined to a model system describing the most important structures of the Odra basin. After verification with existing measured time series this model system can be used to simulate scenarios for expected loads in the future situations. The results can used directly for decision-support from ISKO, HELCOM and Polish or German authorities. RP2 will be finished in the 2000.

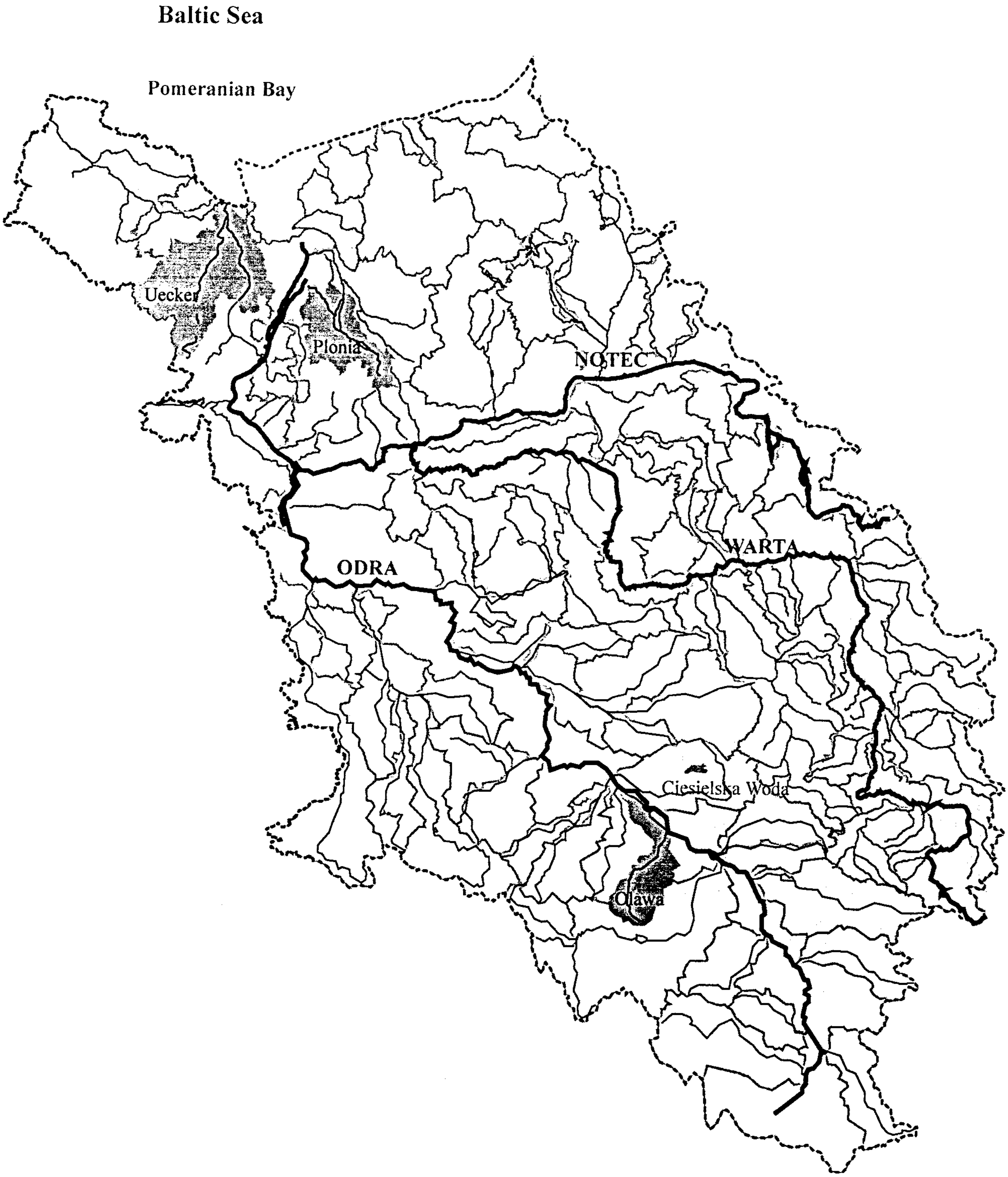

Fig.: Odra drainage basin - hydrography and positions of testing catchments

A NUMERICAL SIMULATION OF THE ANNUAL CYCLE OF THE THERMOHALINE FIELDS IN THE BALTIC SEA

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In the Baltic Sea, the vertical temperature stratification indicates clear annual cycle depending on the air-sea heat exchange. The thermocline starts to develop in spring and continues until the late summer when the heat flux into the sea is mainly positive. During that time the thermocline depth varies in response to the local winds and short-term heat loss events due to the passage of colder air masses, but not exceeding the 60 m depth. During fall and winter, the seasonal thermocline disappears in response to the vertical convection due to cooling at the sea surface. Vertical salinity stratification is more persistent, especially in the open sea. The permanent halocline is located between 60 and 120 m depth. In some of the Baltic Sea sub-basins the seasonal halocline develops due to annual cycle in the river runoff.

A free surface version of the 3D GFDL Brian-Cox model was used to simulate evolution of the Baltic Sea thermohaline fields in 1993-94. Some modification of the model were implemented according to the objectives of the investigation and to take into account the special features of the Baltic Sea. First, the vertical mixing of Pacanowski and Philander (1981) was included. Second, the algorithm for dense water overflow and following spreading in the near bottom layers was implemented. Third, the compensation mechanism for the ice cover formation depending on the sea water freezing temperature was included in the form of rigid lid conditions for the wind stress.

The model area was chosen 12°00'-29°50'E, 54°00'-60°30'N with 2 nm horizontal resolution and 30 vertical layers. The vertical grid steps of 5 m for the 0-130 m depth, 10 m for the 130-150 m depth, 20 m for the 150-170 m depth and 30 m for the 170-200 m depth were specified to resolve thermocline and halocline properly.

The model was forced by temporally varying wind fields and heat flux. The river discharges (monthly means) and water exchange through the Danish Sounds from the south-west and through the Åland Sea from the north were accounted by budget-type boundary conditions.

The Baltic Proper (Gothland Deep) and the Gulf of Riga were chosen to evaluate the model results. The choice was made to account for the evolution of the thermohaline fields in two areas with different hydrophysical conditions. The Gulf of Riga is shallow basin (maximum depth of 55 m) strongly influenced by fresh water supply from rivers. The water column is totally mixed down to the bottom in late fall. The seasonal cycle of the river runoff and intermittence of the more saline water inflows from the Baltic Proper over the sill in the Irbe Strait causes development of the seasonal halocline in the Gulf of Riga. The central Baltic Proper is deep and less influenced by rivers, which gives the opportunity to study the persistence of the permanent halocline and development of the seasonal thermocline.

The model results gave qualitatively good agreement with observed fields. The vertical thermal structure evolved in response to the air-sea heat exchange. The positive heat flux was responsible for the thermocline development which was similar in the Gulf of Riga and in the Baltic Proper. Strong wind events caused the thermocline erosion followed by thermal re-stratification during calm periods. The influence of the wind events was indicated also in the halocline causing disturbances in the depth of the isohalines. The seasonal thermocline was destroyed by the convection during atmospheric cooling. In the central Gulf of Riga, the water column was mixed down to the bottom during late fall and winter convection. During the ice covered period, the water column in the Gulf of Riga started to stratify by salinity due to the development of estuarine two layer circulation. The stratification strengthened in spring after the ice melting and because of the increased river inflow. The vertical haline structure developed also in response to the water exchange between the Gulf of Riga and the Baltic Proper. Strong saline water inflow events occurred during persistent southerly winds. Short-term wind variability generated the water mass back-and-forth oscillations in the strait between the Gulf of Riga and the Baltic Proper together with the enhanced mixing.

Invited overview presentation at 2nd BALTEX Study Conference

CONCEPTUAL VERSUS PHYSICALLY-BASED HYDROLOGICAL MODELS: WHICH MODELS TO BE USED FOR BALTEX PURPOSES ?

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Introduction – hydrological modelling approaches

The two traditional approaches in hydrological modelling are the conceptual and the physically-based ones, as illustrated by e.g. the HBV (Bergström, 1995) and the MIKE SHE (Refsgaard and Storm, 1995). The conceptual models are used in either a lumped or a semi-distributed mode. A lumped model implies that the catchment is considered as one computational unit, whereas a semi-distributed model uses some kind of distribution, either in subcatchments or in hydrological response units, where areas with the same key characteristics are aggregated to sub-units without considering their actual locations within the catchment. Examples of hydrological response units considered in semi-distributed models are elevation zones, which are relevant for snow modelling, and combinations of soil and vegetation type, which may be relevant for evapotranspiration (and hence runoff generation) modelling. A distributed model, on the other hand, provides a description of catchment processes at georeferenced computational grid points within the catchment. A physically-based model may be used as either fully distributed or, in certain cases, semi-distributed.

The fundamental difference between the conceptual and the physically-based models lies in their process descriptions and the way spatial variability is treated. The physically-based models contain equations which have originally been developed for point scales and which provide detailed descriptions of flows of water, solutes and energy. The variability of catchment characteristics is accounted for explicitly through the variations of hydrological parameter values among the different computational grid points. This approach leaves the variability within a grid as un-accounted for, which in some cases is of minor importance but in other cases may pose a serious constraint. The conceptual models (irrespective of whether they are used in a lumped or a semi-distributed mode) uses empirical process descriptions, which have built-in accounting for the spatial variability of catchment characteristics. The conceptual models have been developed for and are very good at describing runoff generation and overall water balances, but generally fail to provide details of water flows and soil moisture storages as well as descriptions of fluxes of solutes and energy.

Several intercomparison studies of lumped conceptual, semi-distributed conceptual and distributed physically-based models have indicated that their respective capability of predicting catchment runoff are almost identical (e.g. Refsgaard and Knudsen, 1996). The question of which model type to use for BALTEX purposes thus boil down to the question of what the purpose of the hydrological modelling is. Hence for keeping track of runoff and water balances the conceptual models are adequate and suitable. However, if the purpose is extended with a wish to provide descriptions of the spatial pattern of soil moisture and energy fluxes, then the only option left is the physically-based models.

The HBV conceptual model has already successfully been established for runoff simulations of the Baltic Sea catchment (Bergström and Carlsson, 1994). The key data used for this exercise are hydrometeorological time series (precipitation, temperature, potential evapotranspiration for a large number of stations). To use physically-based models at the same scale requires the following two problems to be solved:

- Readily available data from national, regional or global databases must be used. In addition to hydrometeorological data also used by conceptual models, data on topography, soil type, land use and geology must be available. In order to use a physically-based model at such large scale in practise these additional data must be readily available in digital form.
- A consistent methodology for upscaling/aggregation of physically-based models for use at the BALTEX scale is required. Due to the large catchment area the computational grid sizes will inevitably be so large (1 km^2 or larger) that it is impossible explicitly to resolve all the variability of catchment characteristics.

Therefore, the upscaling/aggregation methodology must somehow also consider the variability existing within each grid area.

The presentation will discuss the possibilities of overcoming these two problems and present examples of MIKE SHE applications to large scale modelling.

Global and regional databases

Digital global and regional databases of interest for large scale hydrological modelling such as in BALTEX are rapidly becoming available in these years. Examples include 1x1 km^2 DEM's available over the Internet and the GISCO database containing amongst others soil type and land cover for most of Europe. Together with suitable transfer functions they can provide very useful input data for large scale modelling. The key gap generally remaining when looking for readily available global data appears to be geological data. Whereas inclusion of geological data generally is very important, these data are not so crucial for the rather surface oriented research carried out within BALTEX.

Upscaling of physically-based models for application to BALTEX scale

The complex interactions between spatial scale and spatial variability is widely perceived as a substantial obstacle to progress in this respect (Blöschl and Sivapalan, 1995; and many others). Often a distinction is made between the terms upscaling and aggregation. Thus, upscaling is a special case of spatial aggregation, namely one in which the objective is to transform the point parameter values into 'effective' block parameter values, such that the microscale equations in the model become valid at the macroscale. A principal difference between aggregation and upscaling is that whereas aggregation can be defined irrespective of a model operating on the aggregated values, upscaling must always be defined in the context of a model that uses the parameters that have been scaled up (Heuvelink and Pebesma, submitted)

The research results on the scaling issue reported during the past decade have, depending on the particular applications, focussed on different aspects, which may be categorised as follows:

- subsurface processes focussing on the effect of geological heterogeneity;
- root zone processes, including interactions between land surface and atmosphere; and
- surface water processes focussing on topographic effects and stream-aquifer interactions.

The effect of spatial heterogeneity on the description of subsurface processes has been the subject of comprehensive research for two decades, see e.g. Dagan (1986) and Gelhar (1986) for some of the first consolidated results and Wen and Gómez Hernández (1996) for a more recent review. The focus in this area is largely concerned with upscaling of hydraulic conductivity and its implications on solute transport and dispersion processes in the unsaturated zone and aquifer system, typically at length scales less than 1 km.

The research in the land surface processes has mainly been driven by climate change research where the meteorologists typically focus on length scales up to 100 km. Michaud and Shuttelworth (1997), in a recent overview, conclude that substantial progress has been made for the description of surface energy fluxes by using simple aggregation rules. Sellers et al. (1997) conclude that "it appears that simple averages of topographic slope and vegetation parameters can be used to calculate surface energy and heat fluxes over a wide range of spatial scales, from a few meters up to many kilometers at least for grassland and sites with moderate topography". An interesting finding is the apparent existence of a threshold scale, or representative elementary area (REA) for evapotranspiration and runoff generation processes (Wood et al., 1988; Wood et al. 1990; Woods et al., 1995). Famiglietti and Wood (1995) concludes on the implications of such an REA in a study of catchment evapotranspiration that "the existence of an REA for evapotranspiration modelling suggests that in catchment areas smaller than this threshold scale, actual patterns of model parameters and inputs may be important factors governing catchment-scale evapotranspiration rates in hydrological models. In models applied at scales greater than the REA scale, spatial patterns of dominant process controls can be represented by their statistical distribution functions". The REA scales reported in the literature are in the order of 1 – 5 km^2.

The research on scale effects related to topography and stream- aquifer interactions has been rather limited as compared to the above two areas. Saulnier et al. (1997) has examined the effect of the grid sizes in digital terrain maps (DTM) on the model simulations using the topography-based TOPMODEL. They concluded that in particular for channel pixels the spatial resolution of the underlying DTM is important. Refsgaard (1997) using the distributed MIKE SHE model to the 440 km^2 Danish Karup catchment with grid sizes of 0.5 km, 1 km, 2 km and 4 km, found that the discharge hydrograph shape was significantly affected for the 2 and 4 km grids as compared to the almost identical model results with 0.5 and 1 km grids. He concluded that the main reason for this change was that the density of smaller tributaries within the catchment was smaller for the models with the larger grids.

Many researchers doubt whether it is feasible to use the same model process descriptions at different scales. For instance Beven (1995) states that "... the aggregation approach towards macroscale hydrological modelling, in which it is assumed that a model applicable at small scales can be applied at larger scales using 'effective' parameter values, is an inadequate approach to the scale problem. It is also unlikely in the future that any general scaling theory can be developed due to the dependence of hydrological systems on historical and geological perturbations." Similarly, Wen and Gómes Hernández (1996) emphasise the fundamental problems in the different upscaling techniques.

The research within BALTEX mainly deals with scaling of root zone processes, while the subsurface processes and stream-aquifer interaction play minor, although not uninteresting, roles. A key challenge as compared to the experiences reported in the literature is then how to make use of the physically-based model at large scale without possibility for detailed calibration at that scale, when we know that its physically-based equations are developed for small scales. Such model can only be stated as well proven for small scales, and the few attempts made so far to use it on scales above 1,000 km^2 have applied calibration at that scale (e.g. Refsgaard et al. 1992; Jain et al., 1992). The basic upscaling methodology proposed for this purpose is based on a semi-distributed approach:

- The basic modelling system is of the distributed and physically-based type. For application at *point scale* (where it is not used spatially distributed) the process descriptions of this model type can be tested directly against field data.
- The model is used with (equations and) parameter values in each horizontal grid point representing *microscale* conditions. The microscale is selected as a scale for which previous tests have indicated that the model is able to describe the basic processes satisfactorily (50 – 200 m).
- The smallest horizontal discretization in the model is the *grid scale* or grid size (1 – 5 km) that is larger than the microscale. This implies that all the variations between categories of soil type and crop type within the area of each grid can not be resolved and described at the grid level. Input data that vary at microscale, and whose variations are not included in the grid scale model representation, are distributed at the macroscale so that their statistical distributions are preserved at that scale.
- The results from the microscale modelling are then aggregated to *macroscale* (10 – 50 km) and the statistical properties of model output and field data are then compared at macroscale.
- For applications to larger scales than macroscale, such as *BALTEX scale*, the macroscale concept is used, just with more grid points. This implies that the BALTEX scale can be considered to consist of several macroscale units, within each of which the microscale statistical variations are preserved and at which scale the predictive capability of the model thus lies.

The microscale considered is not point scale, but rather a field scale characterised by 'effective' soil and vegetation parameters, but assuming only one soil type and one vegetation type. Thus the spatial variability within a typical field is aggregated and accounted for in the 'effective' parameter values. Physically-based models have previously at many occasions documented their ability to describe conditions at field scale by use of effective parameters (e.g. Jensen and Refsgaard, 1991a,b,c). In the aggregation to macroscale the variations among soil types and crops are preserved statistically, although they are not correctly georeferenced. A field scale is typically 1 ha, whereas the model grids used are 2-3 orders of magnitude larger. The macroscale may be an entire catchment, but would for larger scale representations such as the Baltic Sea catchment be subareas of maybe 100 model grids. This implies that the macroscale model does not pretend to provide a correct description at a grid scale, because the within-grid variation of soil and vegetation types are not described at that scale. However, at the macroscale, the statistical properties of the model aim at describing well the statistical properties of field conditions.

Conclusion

Both the conceptual and the physically-based models are required for BALTEX. The two model types have different capabilities, potentials and limitations:

- The conceptual models are today ready for operational use for simulation of runoff at the BALTEX scale. Thus for establishing overall water balances for the Baltic Sea catchment this model type can provide significant contributions. The conceptual models can easily be semi-coupled with atmospheric models in such a way that the atmospheric model generates input for the hydrological model, but due to incompatible spatial resolution and lack of energy balance description it is not possible to make a suitable feedback mechanism to the atmospheric model.
- The physically-based models enable a more detailed description of hydrological processes with a better spatial resolution, which is of great importance for the research on land surface-atmosphere interactions. Thus this model type makes it possible to simulate spatial land surface patterns which are directly compatible with available spatial remote sensing data. Because physically-based models contain spatial information on soil moisture and easily enables inclusion of standard SVAT schemes, they can be fully coupled with atmospheric models with mutual feedback mechanisms.

In brief, it may be concluded that at present the conceptual models comprise a major operational potential, whereas the distributed models have the major research potential of interest in a BALTEX context.

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MEASURED AND MODELLED HYDRODYNAMICS IN VISTULA ESTUARY

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Vistula Estuary situated in the southern part of the Bay of Gdańsk (Fig.1) is characterized by complex hydrodynamic conditions due to:

- interactions between fresh water discharged by Vistula river and weakly saline waters of the Bay;
- changeable meteorological conditions over the area;
- complicated bathymetry and diversified coast-line.

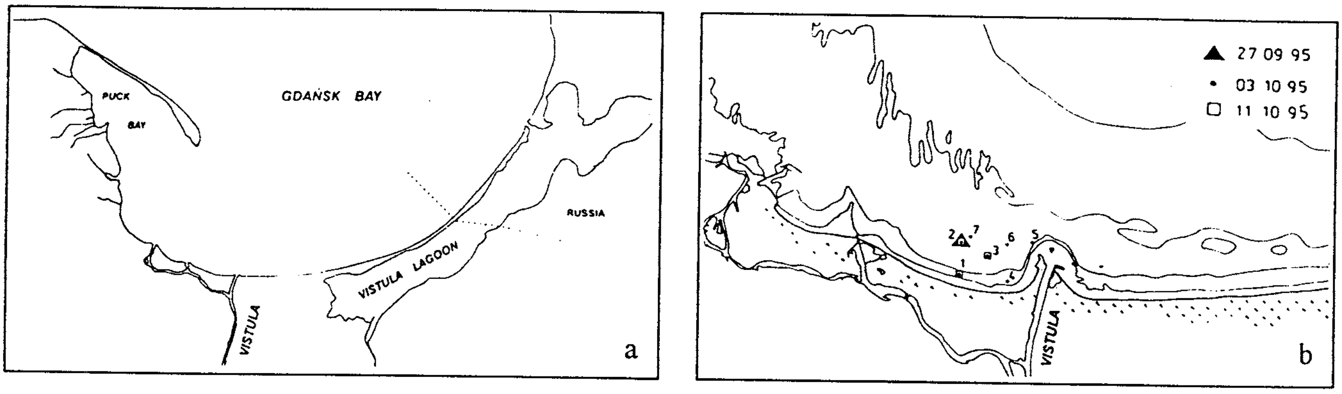


Fig.1 Geographical position of the Bay of Gdańsk (a), and location of measurements in the Vistula Estuary (b)

Better understanding of the natural phenomena, achieved by observations carried out by sophisticated field measurements, result in better representation by numerical models. Below as an example measured *in situ* and calculated by numerical model hydrodynamic conditions in Vistula Estuary are presented.

Field measurements in September/October 1995 covered short-term (locations 1-7, Fig.1) and long-term (location 2 – 3 gauges installed on depths: 3.0 m, 7.5 m, 13.5 m, Fig.1) registrations of water currents, salinity, temperature, changes of free surface elevation. Short-term registrations depict very changeable conditions, especially in the upper-most and lower-most parts of the water column (see Figs 2, 3).

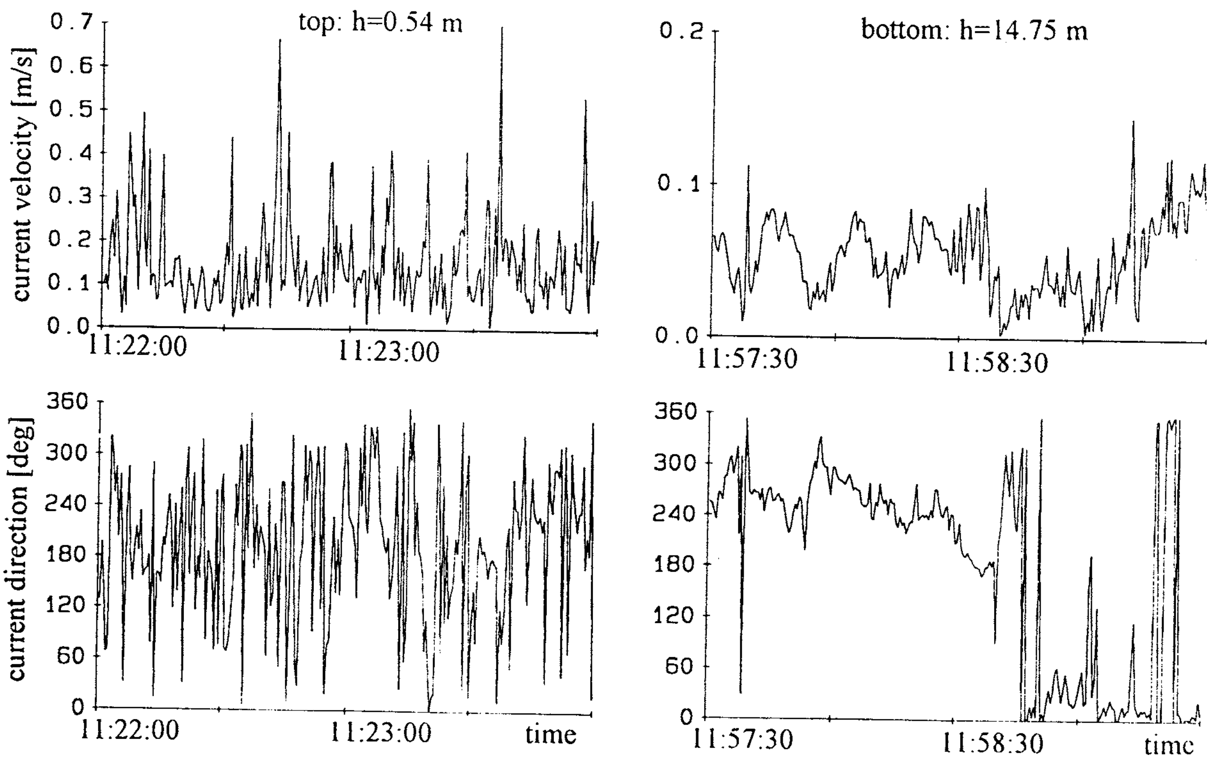


Fig.2 Short-term registrations of currents velocity and direction in location 2 – 27.09.95; top and bottom.

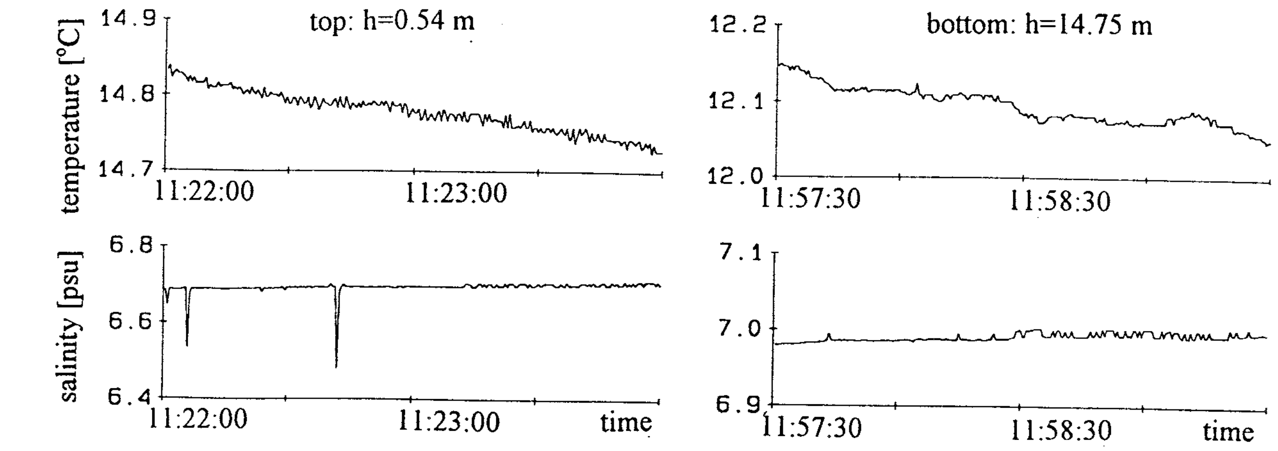
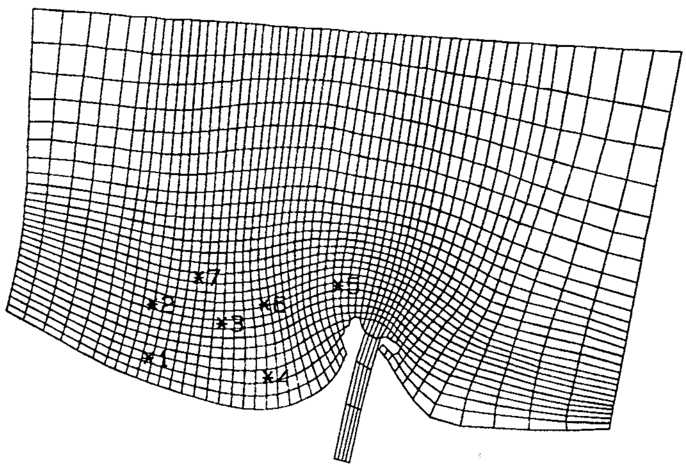


Fig.3 Short–term registrations of temperature and salinity in location 2 – 27.09.95; top and bottom.

Numerical model for the Vistula Estuary, set-up based on TRISULA (WL-Delft Hydraulics), solves equations of motion under the shallow water assuption. The area of Vistula Estuary is covered in horizontal by curvilinear orthogonal grid in horizotal (Fig. 4a) and in vertical uses 20 layers in sigma coordinates (Fig. 4b).

a.

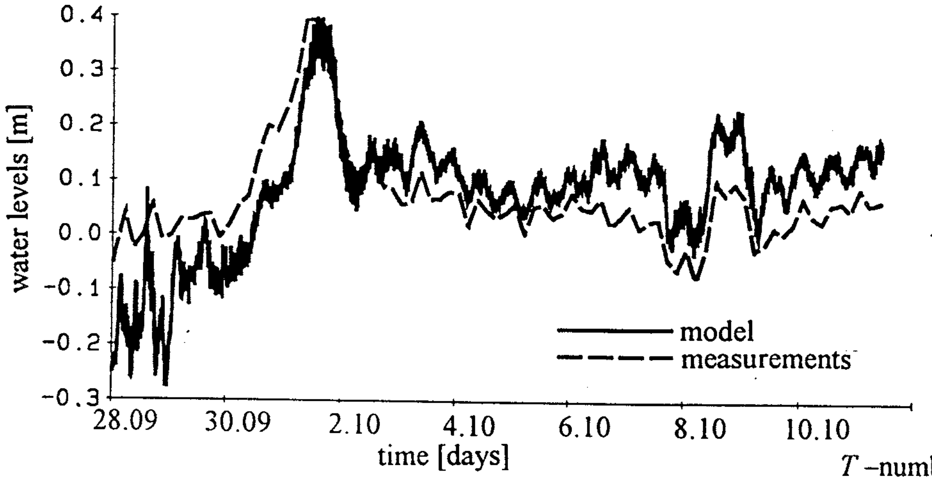


b.

Layer no.	Thickness [%]
1	0.5
2	1.0
3	2.0
4	4.0
5-10	5.0
11-16	7.5
17-19	5.0
20	2.5

Fig.4 Model discretization (a) in horizontal plane, (b) in vertical.

The reliabilty index RI (Leggett and Williams, 1981) calculated for the measured and modelled water level variations in location 2 (Fig. 5) is equal 1.007, where RI is defined as:



$$RI = \frac{1 + \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left[\frac{1-\frac{Y_t}{X_t}}{1+\frac{Y_t}{X_t}}\right]^2}}{1 - \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left[\frac{1-\frac{Y_t}{X_t}}{1+\frac{Y_t}{X_t}}\right]^2}}$$

T –number of data points in a time series;
Y_t - observation for time t;
X_t - model result for time t.

Fig.5 Measured and calculated water level variations in location 2

Energy and water cycle components from remote sensing and atmospheric model data

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One major goal of BALTEX is to quantify the components of the energy and water cycle over the Baltic Sea catchment area. This can be achieved by analysing measured and model generated data over the BALTEX area for representative time periods. Our contribution to this goal is the use of remote sensing and model generated data.

Model data are produced by the regional atmospheric model REMO on a spatial resolution of approximately 18km. The temporal resolution used for this study is one hour. REMO is run in a forecast mode with a prediction time of 30h. The output covers all components of the energy and water cycle. However, in this study we concentrated on those parameters also available in the remote sensing data. These parameters are cloud cover, liquid water path, water vapour path, and radiative flux densities. The availability of the remote sensing data also sets restrictions to the time periods used. These time periods are June 1993, March 1994, and August - October 1995.

1. ISCCP

The aim of the International Cloud Climatology Project (ISCCP) is a global cloud climatology with a time resolution of one month and 250km horizontal resolution. Data from both geostationary and polar orbiting satellites form the basis of several stages of processing. The intermediate data product ISCCP-DX, derived for individual instantaneous satellite fields of views (FOV) ranging from 4 to 7 km in size at nadir with a horizontal sampling rate of 25 to 30 km and a time resolution of 3 hours, can be used here. Until now, the product is available for a few months only. One of these is June 1993. Among the DX variables, there is the cloud flag CLOUD. CLOUD is a binary variable and takes the values 1 or 0 if the ISCCP cloud detection mechanism considers a cloud or not, respectively. The CLOUD values are converted to the model grid by taking the average within a grid box. Because of the horizontal resolution, not in every REMO grid box a CLOUD value is given. Also, the satellite coverage of the BALTEX area is far from perfect. Especially at 2100 and 2400 UTC, almost only METEOSAT data is available up to about 60^0 N. A third reason for data gaps is that the ISCCP has to use a detection mechanism based on radiative transfer model analysis. This detection mechanism is sometimes unable to decide between cloudy or clear sky, i.e. along coastal lines, and gives an undefined value. A typical DX data set is shown in the figure for June 15 at 1500 UTC.

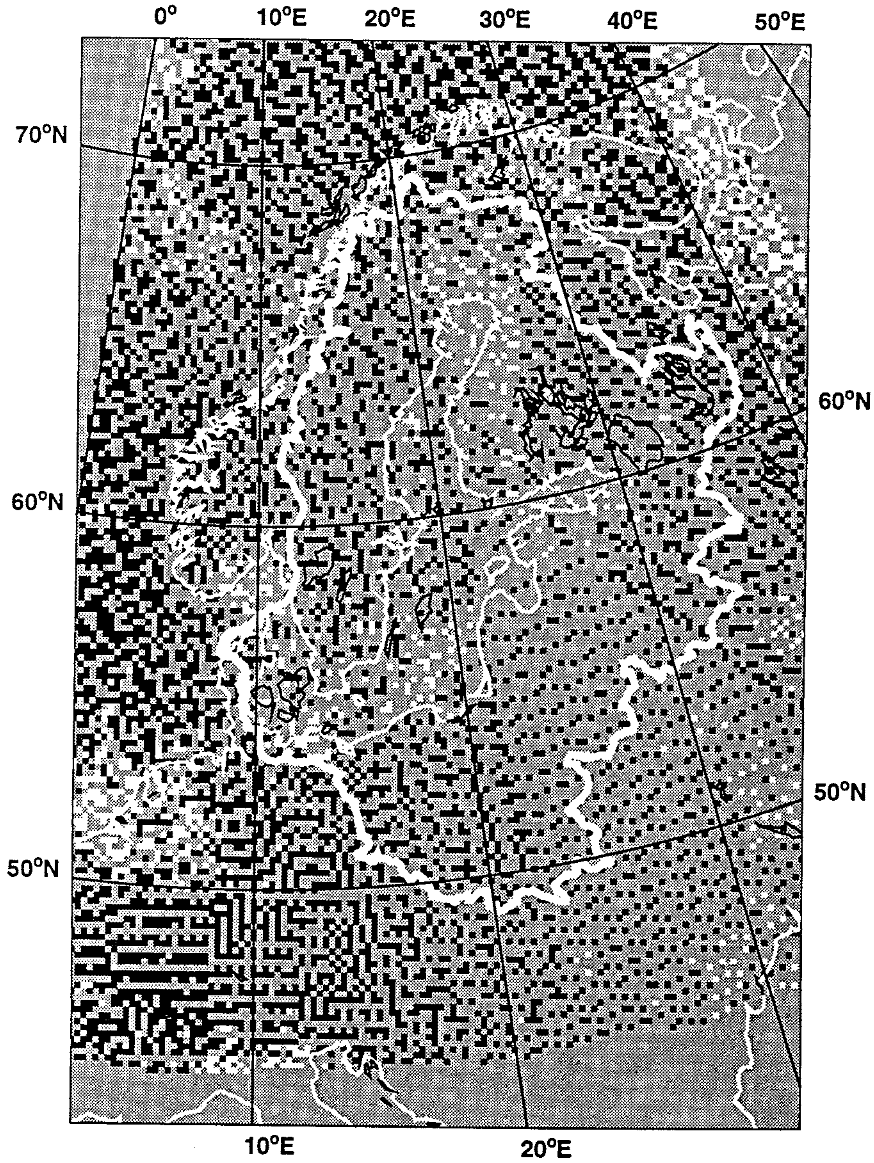
2. ScaRaB

As part of this study, we use data from the well-calibrated Scanner for Radiation Budget (ScaRaB) experiment to compare regional satellite estimates of the top of the atmosphere (TOA) earth radiation budget (ERB) over the BALTEX area against that calculated by REMO. Since the variability in the regional TOA ERB is mostly determined by the interaction of clouds with radiation, such a comparison gives inside into how reliably a regional model can describe the development of clouds, a major component of the energy as well as the water cycle in the atmosphere.

The ScaRaB experiment, a French-Russian-German co-operation, is a successor of the American Earth Radiation Budget Experiment (ERBE) and is designed to measure the short-wave and long-wave components of the ERB within a high accuracy on scales of about $250x250km^2$. To fulfil our goal, these data are used to derive regional ERB products on a scale of about $18x18km^2$. The data of the ScaRaB instrument are limited to the lifetime of the mission, March 1994 to February 1996, and during its lifetime to the roughly two overpasses per day. In order to derive a complete diurnal cycle and also to extend the investigations to times at which no ScaRaB data are available, a synergy with data from operational satellites as NOAA-AVHRR and METEOSAT has to be done.

3. GPS

The above mentioned remote sensing data have the advantage of a good spatial data coverage, but for specific times. The Global Positioning System (GPS) derived data has the vice versa characteristics: a high temporal resolution, but at specific geographical locations. The temporal resolution of the atmospheric water vapour path length is 5 minutes for each of the available data sets of the 25 GPS station in the BALTEX area. The target period in this study is the PIDCAP period August - October 1995.
The results of the GPS derived water vapour are compared with REMO forecasts and analyses data for the Europamodell (German Weather Service), T213 (ECMWF), and HIRLAM (Danish Meteorological Institute).



ISCCP cloud flag (white = 0, black = 1, grey = not defined)
JUNE 15, 1993, 1500 UTC

Measured and modelled water transport in the Odra estuary for the Odra flood period July/August 1997

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The Szczecin lagoon is the interface between the Odra river and the Baltic Sea. The connection to the Baltic Sea is via the three exits of rivers Swina (about 70 % of the total water transport), Dziwna and Peenestrom.

In recent years knowledge on impact of the lagoon for water quality and the transformation of dissolved and suspended matter in the Odra water has improved considerably due to several international projects in the area (GOAP, TRUMP, ODER, ...). The present knowledge on water transport through the Szczecin lagoon is restricted to summer situations with low to moderate fluxes from upper Odra river. A difficulty in the investigations are estimates for the processes in extreme events due to the lack of data. For instance in winter times the lagoon is normally ice covered and therefore the installation of measuring platforms is difficult. The period of the spring highwater of the Odra river is for instance not well covered with coherently measured data. Therefore the highwater period in July/August 1997 of the Odra river provided for the scientific community an important opportunity to learn about the transport and transformation processes in the Szczecin lagoon and to determine the the water transport into the Baltic Sea for the period of such an extreme event.

In the western part of the lagoon two automatic stations have been set up that reported hydrographic and meteorological data directly to the GKSS research institute. It also reached other interested parties online by internet. A pontoon was moored in the wester lagoon that was used for taking water samples and for radar and video observations of surface waves and windfield patterns on the water surface. In the polish part of the lagoon (Zalew Wielki) the research vessel Ludwig Prandtl of GKSS was given permission by Polish administration to measure hydrographic and meteorological parameters. The main profiles were run across the entrance of the Odra river into the lagoon near to Trzebiez and in the Swina river near to Kasibor.

The main transports took place in the Zalew Wielki and could be documented by ship profiles with measurements of currents, water quality parameters and of primary production. An obvious feature have been the strng seiges that were measured by the current meters. The seiges will produce a considerable error in the estimates of the water fluxes since current amplitudes of .25 m/s were meaured at one of the stations.

A not yet completely answered question is the quantitative water transport in the different places of measurement along the lower part of Odra river and through the Szczecin lagoon and the straits to the Baltic Sea. The different measurements for the extreme fluxes are not always mutually consistent.

In the lagoon itself current patterns form, that are important for the flushing and retention capabilities. The current patterns were estimated by measuring with automatic stations the drift of water bodies and compare that with model results that were achieved with different assumptions on border values.

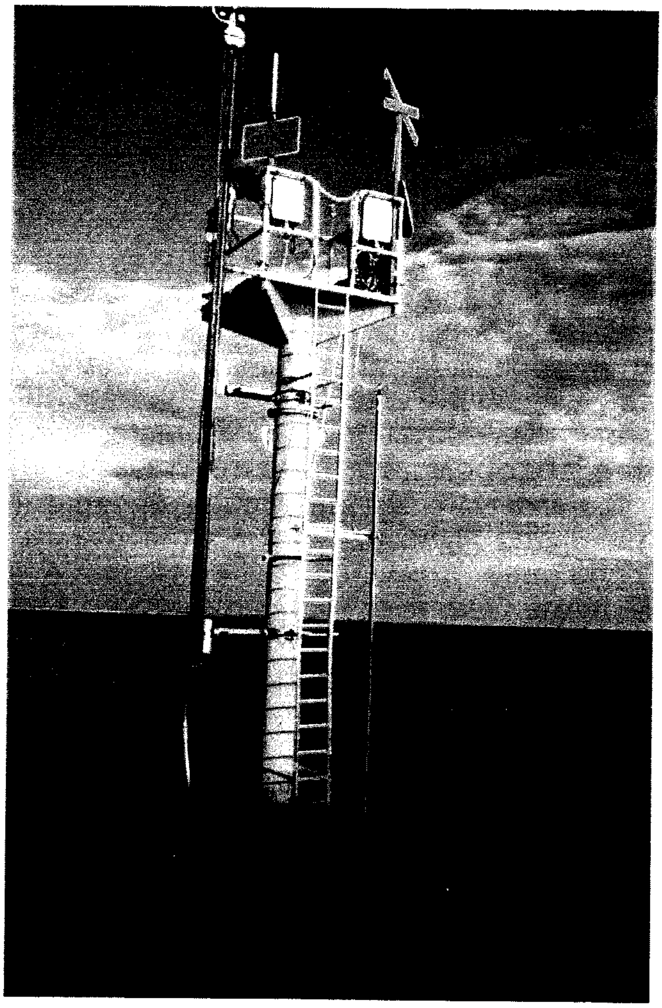

Fig 1: View of pile that was used to on line transmission of hydrographic and meteorological data.

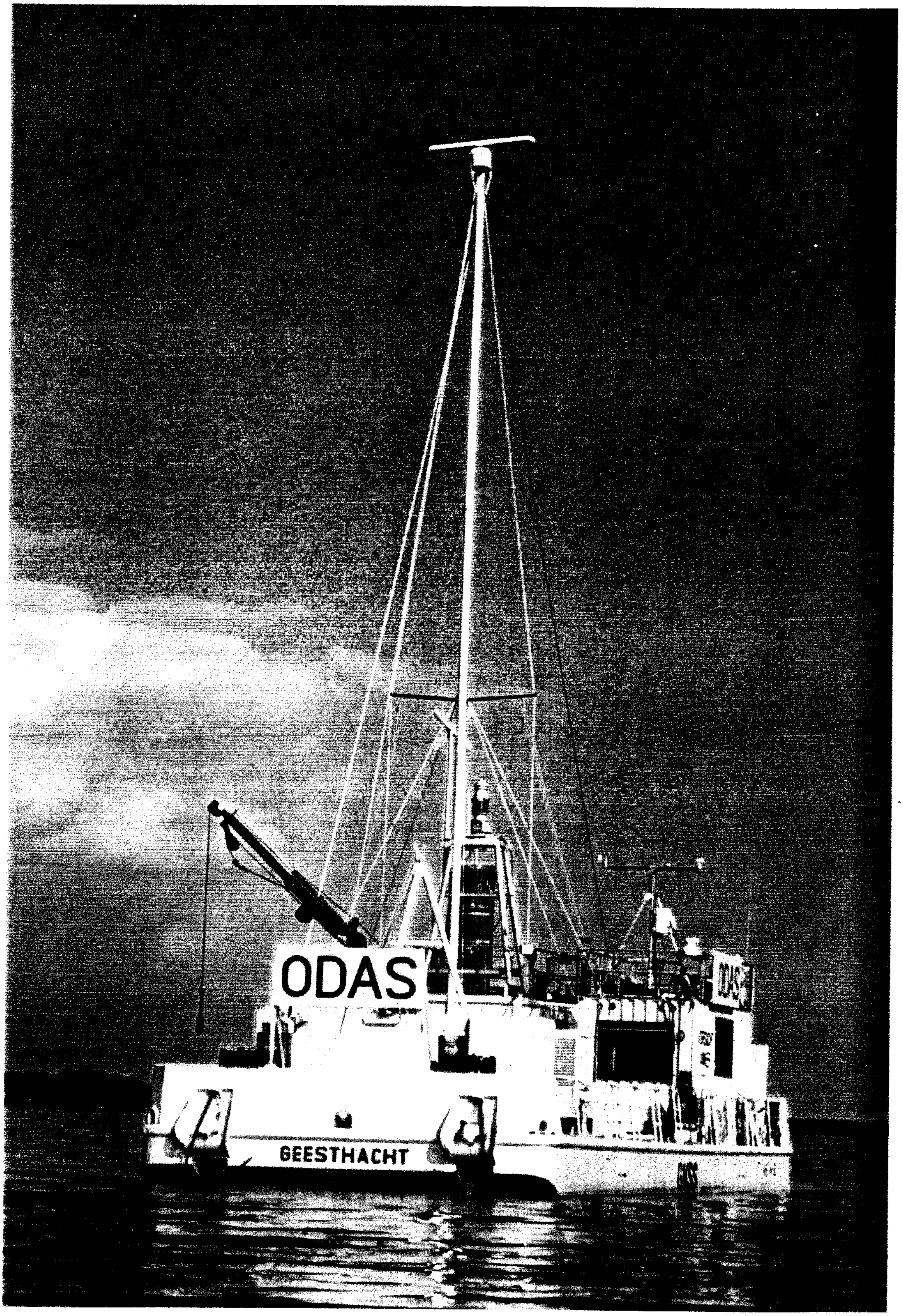

Fig. 2: Pontoon for radar and optical sea surface images and for sampling of SPM.

Fig 3 : Research vessel „Ludwig Prandtl" for hydrographic measurements in coastal waters

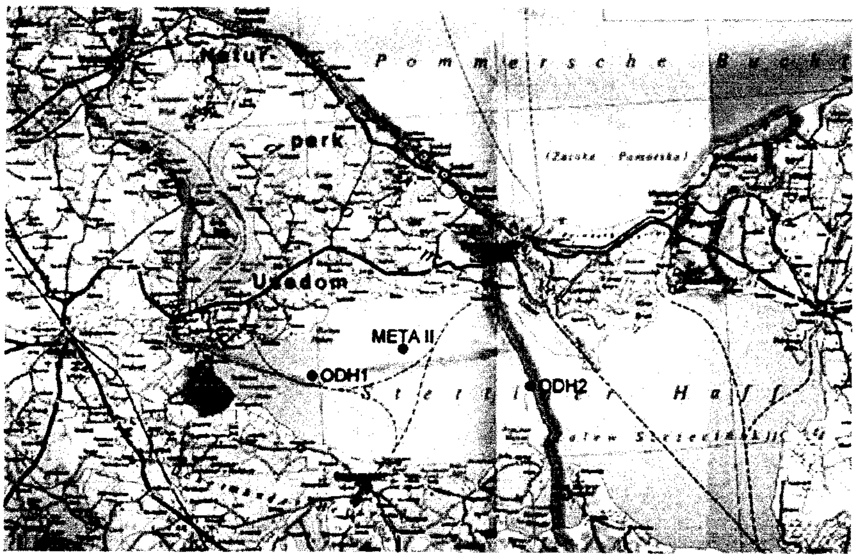

Fig 4 : Locations of stationary platforms for on line data transmission.

LARGE-SCALE CORRECTION OF RAIN GAUGE DATA

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1. Introduction

Precipitation values from gauge measurements are systematically too low and must be corrected. For example, the field experiment after *WMO Solid Precipitation Intercomparison* standard in Jokioinen, Finland, indicates that the Nordic rain gauges caught about 70 % (shielded gauges) to 50 % (unshielded) of the true solid precipitation. In the case of liquid precipitation the underestimation is less severe, but still 5 to 8 % (Førland, 1996).

Although several correction models for operational use have been proposed, only a few data sets of corrected precipitation data are published (Legates and Willmott, 1990). The reason is that the meteorological data needed for the correction models are usually not available at the location of the gauges. This typically holds for the 6 000 rain gauges collected by the BALTEX Meteorological Data Centre.

2. The Dynamic Correction Model

To correct the rain gauges within the Baltic Sea Drainage Basin, the *Dynamic Correction Model* proposed in the *Manual for Operational Correction of Nordic Precipitation Data* was selected.

The main effect causing the underestimation of precipitation is due to the distortion of the wind field around the gauge. The trajectories of the precipitation particles are deflected in a way that less particles reach the catchment area of the gauge. This effect is particularly large during conditions of snow and high wind speed. It is represented by the correction factor k. In the *Dynamic Correction Model*, k is a function of wind speed, temperature and rain intensity. Typical values of k are summarised in Fig. 1. Also, standardised corrections for wetting and evaporation loss have been implemented.

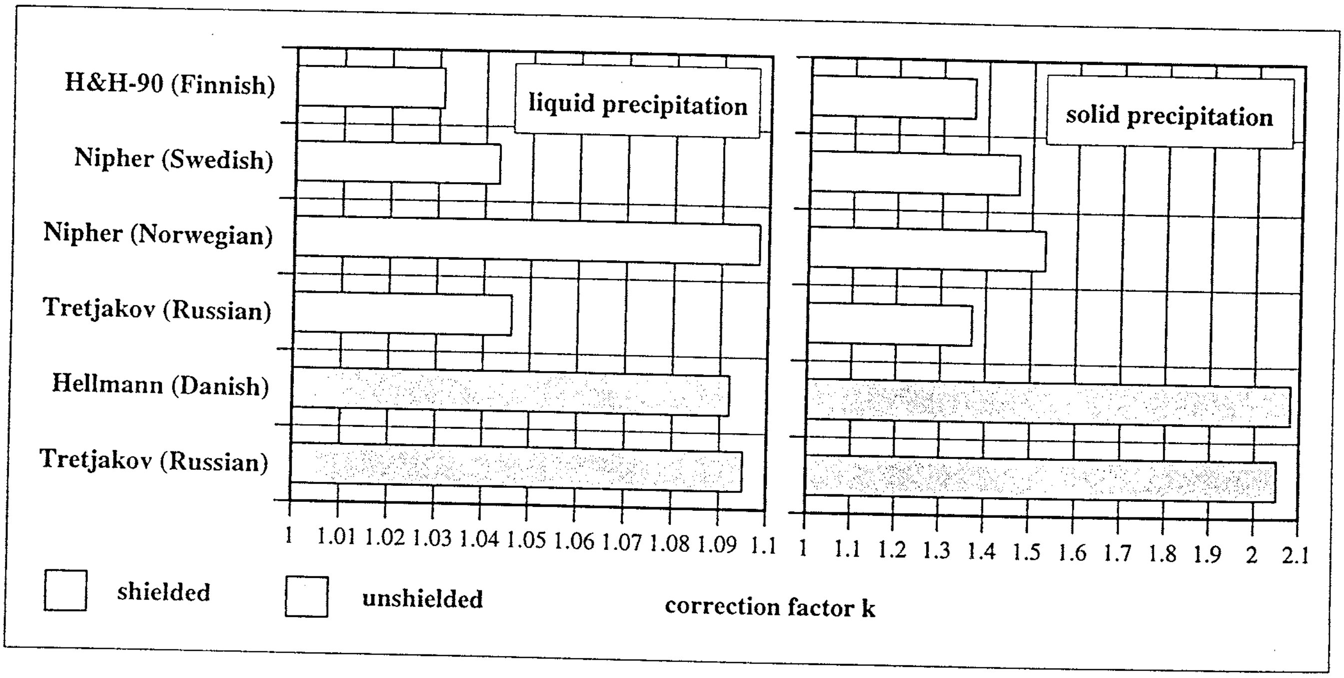

Fig. 1 Correction factors for the predominantly used gauge types in the Baltic Sea Drainage Basin. Mean values for Jokioinen, Finland, based on the field experiment 1987-1993 (after Førland 1996).

3. Results and Outlook

The input data for the correction model (wind, temperature and rain intensity, estimated from 6-hourly measurements), are available at the 600 synoptic stations. At the locations of the other gauges (about 6 000), the input data are interpolated from the synoptic network. With this method only a large scale correction which eliminates the systematic underestimation of the rain measurements in a statistical sense, is possible. First results for the aerodynamic correction factor k are given in Fig. 2.

In our first attempt to estimate the daily precipitation patterns within the Baltic Sea Drainage Basin we used raw SYNOP data only (resolution 55 km, see Rubel, 1996). The next step was to use the extended BALTEX data comprising quality checked but uncorrected data (resolution 18 km, see Rubel et al., 1997). In the present attempt we have incorporated only corrected data. At the conference this improved precipitation analyses will be presented.

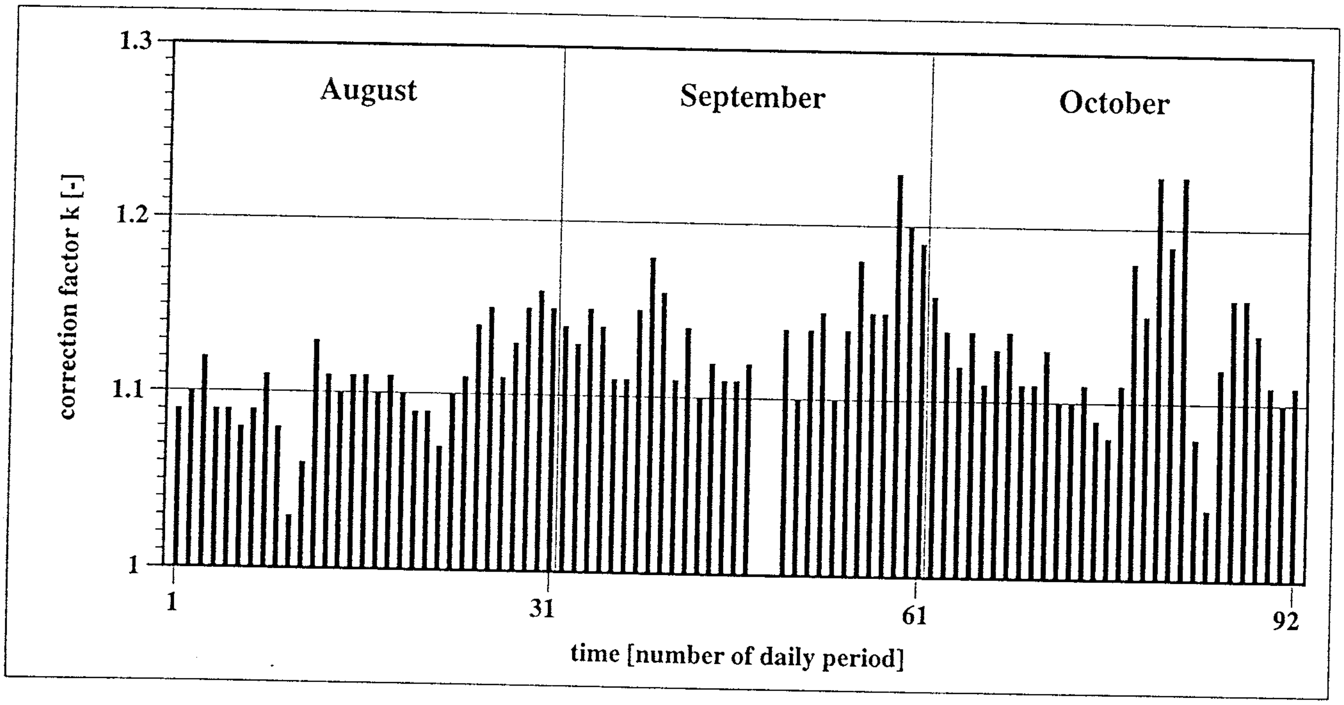

Fig. 2 Mean correction factor k for daily precipitation values during the PIDCAP period August to October 1995. The mean corrections are calculated from point corrections of about 300 selected gauges within the BALTEX model domain. The predominant gauge type is Hellmann unshielded. Some gauges are located in montaineous regions with increasing snow measurements from August to October, resulting in a slight trend to higher maximum values of the correction factor k in October.

Acknowledgments
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Rainfall-runoff simulation for the Odra flood event 1997

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Introduction

The flood event in July 1997 in the Odra drainage basin was one of the biggest and most devasting floods during the past centuries. It was caused by heavy precipitation over the southern part of the drainage basin. At some places up to 500 mm precipitation were observed within 5 days which is about 550 % of the average precipitation depth in July. Measured discharge and water stage reached maximum values at many gauge stations since the start of the observations. In this paper rainfall-runoff computations for the flood period are analysed with a distributed hydrological model.

Rainfall-runoff model

A distributed hydrological model, which is set up on a rotated grid with a horizontal resolution of 18 km, is used for the presented rainfall-runoff computations. The vertical energy and water fluxes between atmosphere, vegetation and soil are described with the land-surface parameterization scheme SEWAB (Mengelkamp et al. 1998). SEWAB calculates the amount of runoff for each grid box. Horizontal transfer processes from runoff into streamflow are calculated by linear impulse response functions, a unit hydrograph within a grid box and a kinematic wave solution for river routing (Lohmann et al. 1996). Hence, calculated runoff can be routed to the outlet of subcatchments and compared with measured discharge. Atmospheric forcing is given from SYNOP stations located near and in the Odra drainage basin. Spatial and temporal interpolation procedures were applied to provide forcing data for each grid box.

Rainfall-runoff simulation

The rainfall-runoff model is calibrated for the Odra drainage basin using data from the time period 1992-93. The computations for the flood event are done with these calibrated model parameters and starts in April 97 to initialize the model. The results of the rainfall-runoff computations during the flood event will be analysed and compared with observed discharge.

During the flood some events and measures, like break of embankments, flooding of lowlands and flood management of reservoirs and polders, had a big influence on the flood wave transformation in the Odra and tributary rivers and the flood wave travelling time. Such influences can not be simulated with a linear routing scheme, so the difference between measured and calculated discharge at selected gauge stations with regard to these effects have to be analysed. Also a discussion of model improvements, e.g. modification of model parameters, to simulate such effects is given.

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Application of a distributed hydrological model to the Odra drainage basin

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Introduction

On the First BALTEX hydrology workshop in Warzawa 1996 four river catchments (Torneälv, Neva, Odra, Daugava) were chosen for more detailed hydrological model investigations (BALTEX 1997). For such investigations an extensive long term hydrological and meteorological data set has to be build up. In a first step for the Odra catchment an appropriate data set for the years 1992 and 93 is available. The implementation of a distributed hydrological model to the Odra drainage basin and runoff simulations are presented.

Hydrological model

The hydrological model is set up on a rotated grid with a resolution of 1/6 degree (about 18 km) like the atmospheric regional scale model (REMO) used in BALTEX. The vertical energy and water fluxes between atmosphere, vegetation and soil are described with the land-surface parameterization scheme SEWAB. SEWAB solves the coupled system of the **S**urface **E**nergy and **Wa**ter **B**alance equations considering partly vegetated surfaces (Mengelkamp et al. 1998) and calculates the amount of runoff for each grid box. The soil column is divided into a variable number of soil layers, here 5 layers are assumed. For base flow simulation two linear reservoirs with different half times are attached to the lowest soil layer. In this application the model is run on a 30 minute time step. To provide atmospheric forcing such as precipitation, air temperature, air pressure, wind speed, relative air humidity and solar radiation for each grid box spatial and temporal interpolation procedures are applied.

The large scale horizontal water transport scheme describes both the time runoff takes to reach the boundary of a grid box and the water transport in the river network (Lohmann et al. 1996). By this calculated runoff can be routed to the outlet of subcatchments and compared with measured discharge. The horizontal transfer processes from runoff into streamflow are described by linear impulse response functions: The unit hydrograph within a grid box and a kinematic wave solution with constant celerity and diffusivity in the river network. The required model parameters are found by an optimization procedure using observed precipitation and streamflow.

Odra drainage basin

The Odra drainage basin is typically for the southern part of the BALTEX region. The predominant part of the drainage basin is lowland with a precipitation of 550 mm/year the climate is dry compared to other BALTEX regions. Only in the mountainous regions the precipitation can reach values around 1000 mm/year. As a result the runoff rate for the Odra drainage basin is only about 145 mm/year. The modelled catchment area up to the gauging station Gozdowice is 110000 km^2. Runoff data from 26 gauging stations are available to carry out distributed parameter determination and model calibration. The meteorological data base consists of 350 precipitation, 70 climate and 22 synop stations.

Results

Figure 1 shows the calculated and measured discharge at the gauging station Sieradz for 1992 and 1993. The upstream catchment area of Sieradz (8140 km^2) belongs to the river Warta, a main tributary to the Odra. In general the measured discharge is met by the calculation; the correlation is 0.92. The highest discharge values are at the end of winter and are partly snowmelt induced. The differences between measured and calculated discharge might result from the model itself, e. g. the simulation of snow and melting processes, but also from accuracy of the meteorological and hydrological measurements.

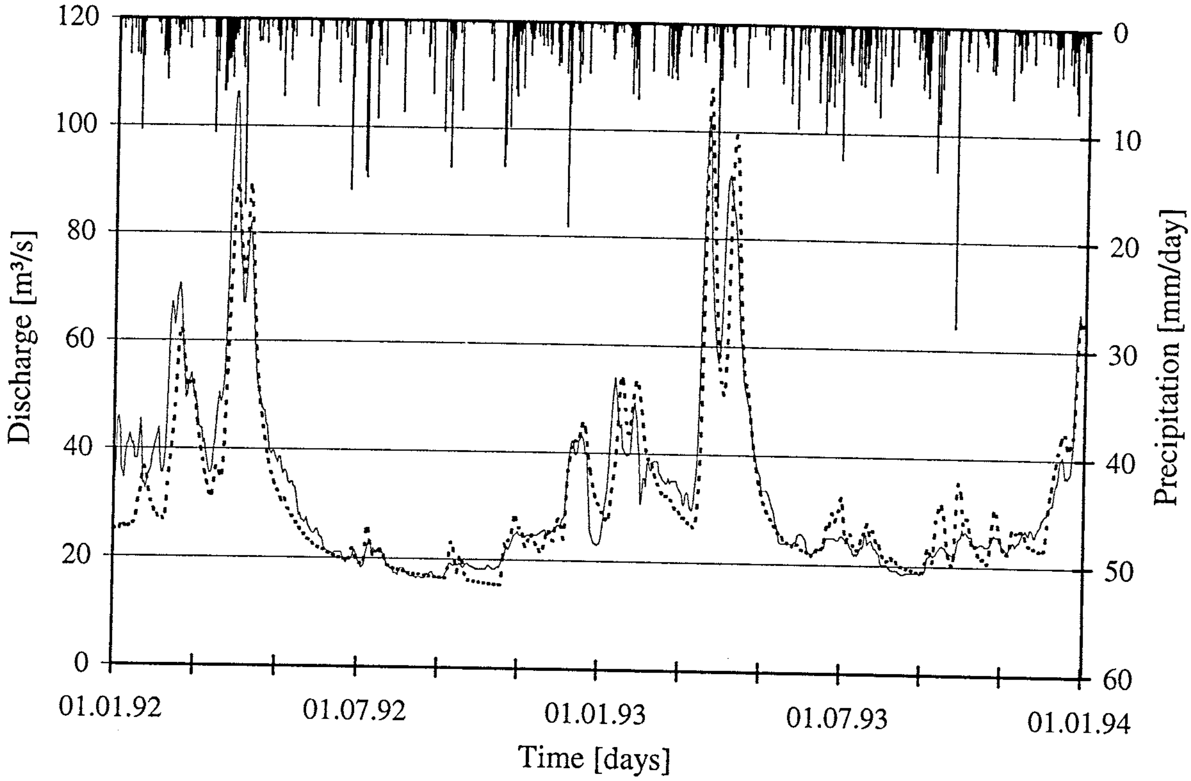

Figure 1: Daily measured (solid) and calculated (dotted) discharge at the gauging station Sieradz and daily precipitation in the upstream catchment area (8140 km^2).

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THE BALTEX FIELD EXPERIMENTS – AN OVERVIEW

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The BALTEX scientific objective to "explore and model the various mechanisms determining the space and time variability of energy and water budgets" needs special efforts to trace down the relevant processes and to develop strategies for their observations. The very complex structure of the BALTEX region leads to processes which are unique in this area e.g. saltwater intrusion through the Danish Straits and its distribution into the different basins or to processes which are typical for an area with large spatial inhomogenities e.g. land-sea breeze circulations or cold air outbreaks. Since such processes in general are not fully resolved in the numerical models their effects must be parameterized. Thus, validation of the current parameterization schemes is an additional objective of process studies.

The Initial Implemention Plan proposes four field experiments of first priority which fulfill the mentioned tasks:

- Cloud / Precipitation / Air-Sea Interaction Experiment
- Cloud / Precipitation / Air-Land Surface Experiment
- Atmosphere-Ice-Ocean Experiment
- Baltic Sea Vertical Advection and Mixing Experiment

Two problems stand out for the experiments

- interaction between the different components: atmosphere, sea, ice and land surface;
- convection and mixing, including cloud and precipitation and turbulent fluxes at interfaces or within the sea.

From the viewpoint of numerical modelling asked the first for coupled models and the later for sufficient parameterization schemes. Thus, field experiments and numerical experiments must work together very closely to be successful.

Four field experiments are now underway

- Pilotstudy of Evaporation and Precipitation in the Baltic Sea (PEP in BALTEX)
- Lindenberg field campaigns
- Baltic Air-Sea-Ice Study (BASIS)
- Dynamics of Wind-forced Diapycnal Mixing in the Statified Ocean (DIAMIX)

Their importants for BALTEX and in particular for the different models are discussed.

LATENT HEAT FLUX OVER THE BALTIC SEA (MEASURED AND MODELED)

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1. INTRODUCTION

The latent heat flux, or evaporation, is of great importance for both energy and water cycles over the Baltic Sea. Evaporation controls to a large extent clouds and rain formation in the atmosphere. It cools the sea surface and affects the salt balance in the ocean. The latent heat flux is thus one of the main parameters in the water cycle and it is also of great importance in the energy cycle.

There exist several methods of determining the latent heat flux over sea and the most common for practical applications is the bulk formulation, Equation (1).

$$E = \rho\overline{w'q'} = \rho C_E u_z (q_s - q_z) \tag{1}$$

E describe the vertical turbulent flux of latent heat, ρ is the air density. u_z and q_z are mean wind and humidity at level z and q_s is the humidity at the surface. The kinematic heat flux $(\overline{w'q'})$ is determined from Reynolds averaging. C_E is the transfer coefficient for latent heat. Stability dependence of the transfer coefficient is often included. The value of C_E as well as how the stability should be included are factors of interest as well as the validity of Equation (1). Due to difficulties of performing direct measurements of evaporation very few such measurements exist over sea and in general the latent heat flux is assumed to behave according to expressions developed for the sensible heat flux and mostly based on data over land. At Östergarnsholm, a small island outside of Gotland continuous evaporation measurements have been performed since December 1996. These measurements will be presented together with a comparison with calculations with Equation (1) and evaporation data from a large scale model (HIRLAM).

2. METHOD

The measurements are obtained using the eddy correlation technique. High frequency fluctuations of the vertical wind (w') are measured with a sonic anemometer and correlated with high frequency fluctuations of humidity (q') in order to get the evaporation. A closed path infrared gas analyzer give the humidity fluctuations. The measuring system is explained more carefully in *Grelle and Lindroth* [1996]. Due to limited frequency response of the system the high frequency part of the measurements are damped. This can be corrected for and the correction is of the order of 10% of the total flux.

3. RESULTS

Data from 1997 will be showed and a comparison with HIRLAM results fro the same period performed. Early results imply that the model overestimates the latent heat flux. The same tendency have been seen in other investigations as well. In *Gustavsson et al.* [1998] evaporated calculated with the HIRLAM model was larger than calculated by other methods.

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A COMPARISON BETWEEN MEASURED AND MODELED SENSIBLE HEAT AND MOMENTUM FLUXES USING A HIGH RESOLUTION LIMITED AREA MODEL (HIRLAM)

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1. INTRODUCTION

When climate change and long term studies of the atmosphere are of interest the coupling between air and ocean will be of increased importance. One of the main interests of BALTEX is to determine the water and energy budgets over the Baltic Sea and its drainage basin [*BALTEX*, 1995]. Different methods of determining these budgets have given quite different results. Important parts of these budgets are the turbulent surface fluxes of heat, water and momentum over sea. Measurements of fluxes as well as standard meteorological parameters are very sparse over sea, so it is of great interest to have access to a good model in order to be able to determine these fluxes. If a model is being used for simulating the fluxes it is necessary to know the accuracy of the turbulent fluxes calculated by the model. In this study direct flux measurements of sensible heat and momentum over the sea are compared with the fluxes given by a limited area model (HIRLAM), [*Källén*, 1996]. The HIRLAM model is a 3-D model covering the northern part of Europe, it is used operationally as a short-range weather forecast model at the SMHI and some other institutes and could be a suitable tool for determining the surface fluxes over the entire Baltic Sea. The model results are here compared with direct flux measurements from Östergarnsholm, a small island east of Gotland in the middle of the Baltic Sea. This study is focused on the marine situation and only data with winds from the sea are used.

2. RESULTS

Open sea data from a period of 1 1/2 years, mostly summer and autumn data have been compared with archived HIRLAM data. Instrumentation and measuring site are described in [*Smedman et al.*, 1997]. Some problems of comparing a large scale model with point measurements will be discussed, in particular the land influence on a chosen grid point if it is partly covered by land. The agreement between measured and modeled sensible heat flux is in general rather good. Figure 1a shows scatter plots for the studied period, the sensible heat fluxes appears to be slightly overestimated especially for larger fluxes. For the whole period the virtual sensible heat flux is overestimated by 3.6 W/m^2 or 24 %. The overestimations appears to be largest in late autumn and winter.
The magnitude of the modeled momentum flux follows the measured rather well but is systematically overestimated by the model throughout the period, Figure 1b. The average overestimation is 0.03 kg/ms^2 or 50 % and is of the same order during all seasons.

Some of the reasons for differences between measured and modeled data will be further discussed. The accuracy of the flux parametrisation scheme is one important feature. A simple change of the constant in the Charnock equation (which relates the roughness length to the wind speed) improves the modeled momentum flux significantly. The calculation of surface fluxes using bulk formulas are very sensitive to SST (sea surface temperature) and wind speed, one degree higher SST doubles the sensible heat flux for the studied 8 months period and 1 m/s higher wind speed increases the mean surface stress by 35 %. This implies that accurate winds and sea surface temperatures are needed over the Baltic Sea.

The final conclusion is that a large scale model like HIRLAM can be used to calculate surface fluxes of sensible heat and momentum over the Baltic Sea. Further work need to be done to improve the parameterization scheme. The coastal zones must be handled with extra care. It is also of importance to get the correct SST values. With improved parameterization schemes and a correct SST the HIRLAM model can be used to derive reliable estimates of the water and energy cycles over the Baltic Sea as is the aim of the BALTEX project.

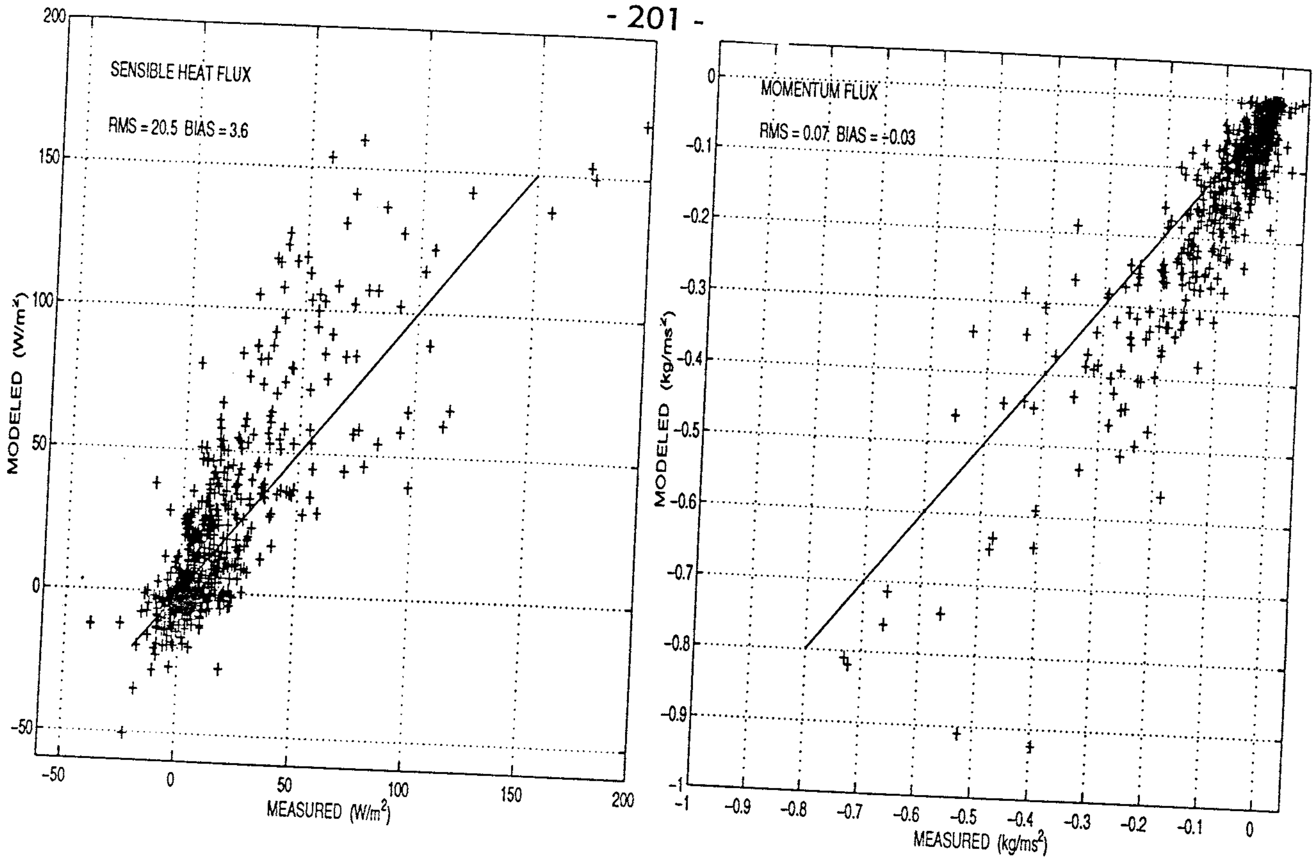

Figure 1: Fluxes measured at the Östergarnsholm site on x-axis, modeled with the HIRLAM model on y-axis a) Virtual sensible heat flux, b) Momentum flux

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SNOW AND SNOW ICE IN SEA ICE THERMODYNAMIC MODELING

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Abstract

A numerical one-dimensional fine grid ice thermodynamic model (referred as SIN model) was constructed accounting for the formation of snow ice, and the effects of snow metamorphism on heat diffusion in snow cover. The model recognises four different ice phases (ice, snow, snow ice and slush) and takes into account among others changing snow density profile with depth dependent heat conduction and specific heat parameters in both snow and ice cover.

The SIN ice model was tested against long-term observations from Kemi-Ajos ice station in the northern Baltic Sea and the results showed good consistence with the observations. The total ice and snow ice thickness and the whole melting season were very well reproduced by the model. Main discrepancies were found in early ice growth season and were probably caused mainly due to errors in estimating the in situ snow cover thickness from precipitation data.

Application of the Hamburg Shelf Ocean Model (HAMSOM) to the North Sea and the Baltic Sea while the Pidcap period (August-October 1995).

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Abstract:
The Hamsom model is applied to the North Sea and the Baltic Sea, in order to investigate circulation and hydrography,especially the stratification in both seas. Hamsom is a 3-D baroclinic circulation model, developed at the Institut für Meereskunde (University Hamburg) for investigations of shelf sea processes. The model is based on the non-linear primitive equations of motion, invoking the hydrostatic approximation, the equation of state and on non-linear equations for temperature and salinity. The numerical scheme of the circulation model is semi-implicit. Because of the semi-implicit scheme, the model is able to run without limitation due to the timestep. In this investigation a timetep of 20 minutes is used. The equations are discretized as finite differences on an Arakawa C-grid. The spherical grid has a horizontal resolution of $\Delta\varphi = 6'$ and $\Delta\lambda = 10'$. In the vertical, the model consists of 20 layers increasing in thickness from surface (5 m) to bottom (100 m).

The circulation model is coupled with a thermodynamic and dynamic sea ice model (M. Lepärranta, SMHI) which simulates the space and time dependent variations of ice thickness and ice compactness. Surface heat fluxes at the atmosphere-ice and atmosphere-ocean interfaces are calculated with standard bulk formulae. For the simulation of the Pidcap-period, the model will be forced with 3-hourly atmospheric data (pressure, air temperature, specific humidity and the wind-field) derived from the Europa Modell of the DWD. The river runoff rates are assumed as monthly means. Salt fluxes due to brine and freshwater release are also taken into account. The boundary conditions for temperature and salinity, as well as the sea surface elevation, are delivered from models of the Northwest European Shelf and of the North Sea (T. Pohlmann, D. Hainbucher, IfM). These models were integrated for the same period as the present model. The initial fields of salinity and temperature are made available by F. Jannsen (IfM) as climatolocigal mean values.

A prognostic hindcast, starting with climatological monthly means of temperature and salinity was carried out for the period of January 1982 to December 1988. A comparison of computed mean temperatures in the upper layers with observed weekly sea surface temperatures in the North Sea and the Baltic Sea shows that the model reproduces the sea surface temperature in a good agreement to the observations. The results show also a good agreement of regional scale structures between observations and computed data. In winter the ice conditions (thickness, compactness and ridging) were estimated as well. The results however show a slightly overestimation of the ice concentration. This discrepancy is due to the fact that the calculated sea surface temperatures are 1-2°C less than the observed ones. The simulation of the depth of the thermocline in the North Sea was modelled well for the summertimes. The depth of the thermocline in the Baltic Sea during the summer is smaller than in the North Sea, which is also reproduced by the model. The deepening of the thermocline in autumn coincidents with the decrease of the surface temperature. The thicknesses of the turbulent surface layers are comparable between the calculation and the observation. The salinity in deep areas, i.e. Gotland deep, is underestimated by about 1 PSU. This low salinity characteristic is preserved during the hindcast period. The modelled decrease, however, is in the same order of the observed decrease.

The prognostic model is able to describe the regionally differences of the two marginal seas using time dependent atmospheric weather conditions. The process of thermocline development was simulated realistically. The preservation of the permanent halocline and the water mass characteristics are simulated well. For the Pidcap-period we intend to investigate the influence of different parametrisations of the heat fluxes. This investigation should give us a better understanding of the importance of a correct atmospheric forcing. The results will be presented at the conference of BALTICS.

On the influence of North Atlantic sea-level variations on the water exchange between the Baltic and the North Sea

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The water exchange through the Danish straits is sensitive to the meteorologicaly forced sea-level variations in the North Sea. While this local forcing has time scales from hours to days there are also fluctuations with „periods" from weeks to years (Figure 1). These longer term changes can only partly be explained by the local meteorological conditions.

The inflow of salty North Sea water into the Baltic Sea is therefore very variable on different time scales. This results in the typical problems with renewal and ventilation of the bottom water in the Baltic Sea.

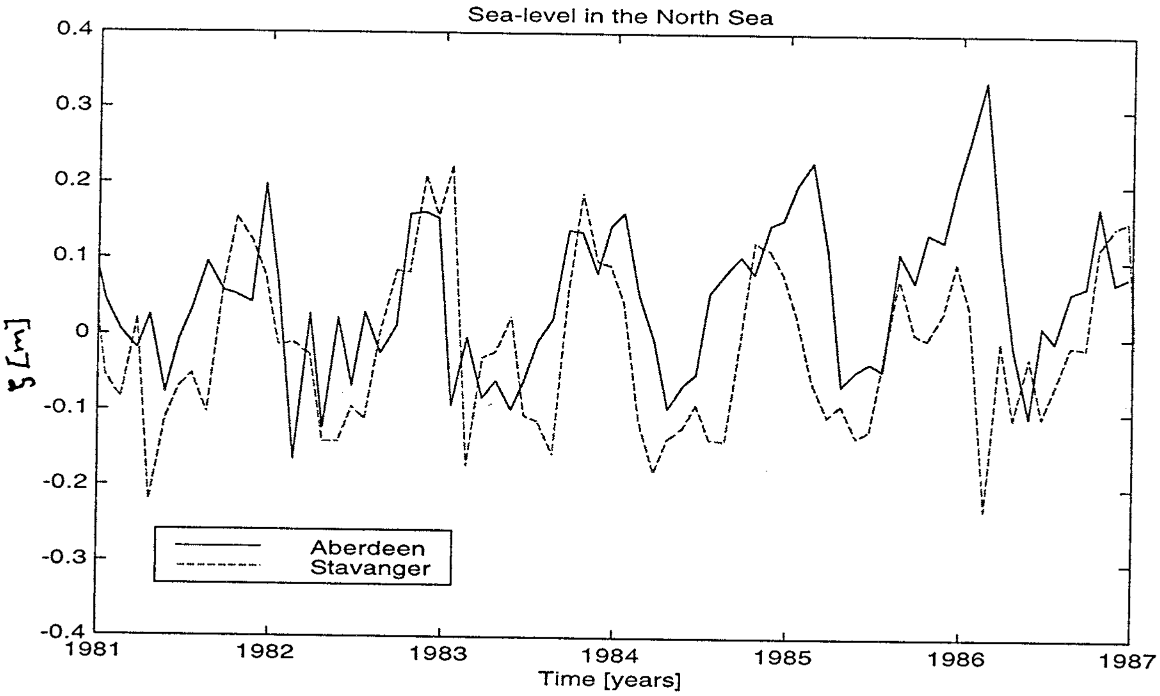

Figure 1: Monthly mean values from the Permanent Service for Mean Sea-Level

While the processes which lead to inflow and outflow situations in the Baltic Sea are mostly understood there are still problems in the application of numerical circulation models especially on longer time scales.

A procnostic high resolution 3D model for the coupled ice/ocean system is set up for the region of the North and the Baltic Sea. In a sensitivity studie the influence of external sea-level variations on the water exchange between North and Baltic Sea is investigated and different methods to include the effect of the sea-level fluctuations in the North Atlantic Ocean are tested for their improvements in the model simulations.

BENCHMARKING OF SURFACE FLUXES FROM A WEATHER PREDICTION MODEL WITH THE AID OF A BALTIC SEA MODEL

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In a weather prediction model the surface fluxes of heat, momentum, and water due to turbulence and radiative transfer must be parameterized. Direct validation of these fluxes is generally not possible because observations of both turbulence and transfer of radiation need special measurements which are rarely available. One possibility is to compare parameterized fluxes to estimations based on weather observations and semi-empirical formulas. Unfortunately, these kind of estimations are quite rough, so other validation strategies are clearly desirable.

The Baltic sea ice model of Haapala and Leppäranta (1996) produces an ice winter very similar to observed one when different fluxes are estimated using weather observations. In a set of experiments these flux estimates are replaced by data from a weather prediction model, and the resulting evolution of the ice cover in different runs are compared with each other and with the observed evolution. In this way the response of the ice-ocean model is used as an integral measure of the quality of the parameterized air-sea exchange.

Reference

Haapala, J. and M. Leppäranta, 1996: Simulating the Baltic Sea ice season with a coupled ice-ocean model. *Tellus*, **48A**(5), 622–643.

PEP IN BALTEX
A PILOT STUDY OF EVAPORATION AND PRECIPITATION IN THE BALTIC SEA.

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PEP in BALTEX is short for Pilot study of Evaporation and Precipitation in the Baltic Sea. BALTEX is one out of 5 GEWEX regional experiments which will explore, model and quantify the various processes determining the space and time variability of the energy and water cycle of the Baltic Sea and its cachment area. It is envisaged to have a main BALTEX experiment phase in 1999-2000 to integrate observations by numerical modelling and thus achieve a description of the Energy and Water cycle in all of the Baltic Sea Catchment area. PEP is designed as a pilot experiment to the main experiment, with the specific scope to study precipitation and evaporation over sea. For determination of precipitation at sea the main experiment needs to rely heavily on radar measurements. To test, improve and validate radar estimates of precipitation against in situ measurements, a pilot study prior to the main experiment is necessary. At the same time, PEP will provide data sets for the improvement of numerical models over the sea. PEP in this way is designed to sharpen our tools for the main experiment. The measurements in PEP will be concentrated along a transect from the northern coast of Germany to southwestern Finland.

For an 18 month period PEP will provide a comprehensive set of actual evaporation data measured with the eddy correlation technique, at 4 well exposed sites in the area as well as precipitation, measured with micro rain radars at 3 of these sites. This data set will be used within PEP for validation of routines for evaporation in 2 regional scale models and in a meso-γ-scale model and for improvements of those routines. The precipitation data will also be used for validation and calibration of weather radars for estimation of precipitation over the Baltic Sea. The micro rain radars will be calibrated against measurements with an optical disdrometer and a rain gauge which is designed for use on board ships.

During a one month period, intensive measurements will be performed at the 4 sites and from research vessel Alkor. These measurements will include: (i) Detailed boundary layer studies with a Differential Absorption Lidar (DIAL) operated side by side with a UHF RADAR/RASS at one site, providing not only profiles of meteorological parameters but also profiles of dissipation and turbulent flux of water vapour and momentum. (ii) Radio soundings at all 4 sites. (iii) RV Heinke will cruise the transect covering the four sites, measuring i.a. precipitation, with disdrometer and ship rain gauge. Figure 1 shows a map of the experimental set-up.

Six models will be employed to evaluate and compare areal evaporation (3 models) and precipitation (also 3 models) over the Baltic Sea for a 12 month period during 1998-99. This comprehensive intercomparison of a set of methods and models to determine the areal evaporation and precipitation over the Baltic Sea means taking an important step forward towards the solution of one of the most tricky issues of the BALTEX project, i.e. that of determining the net precipitation minus evaporation balance for the sea itself.

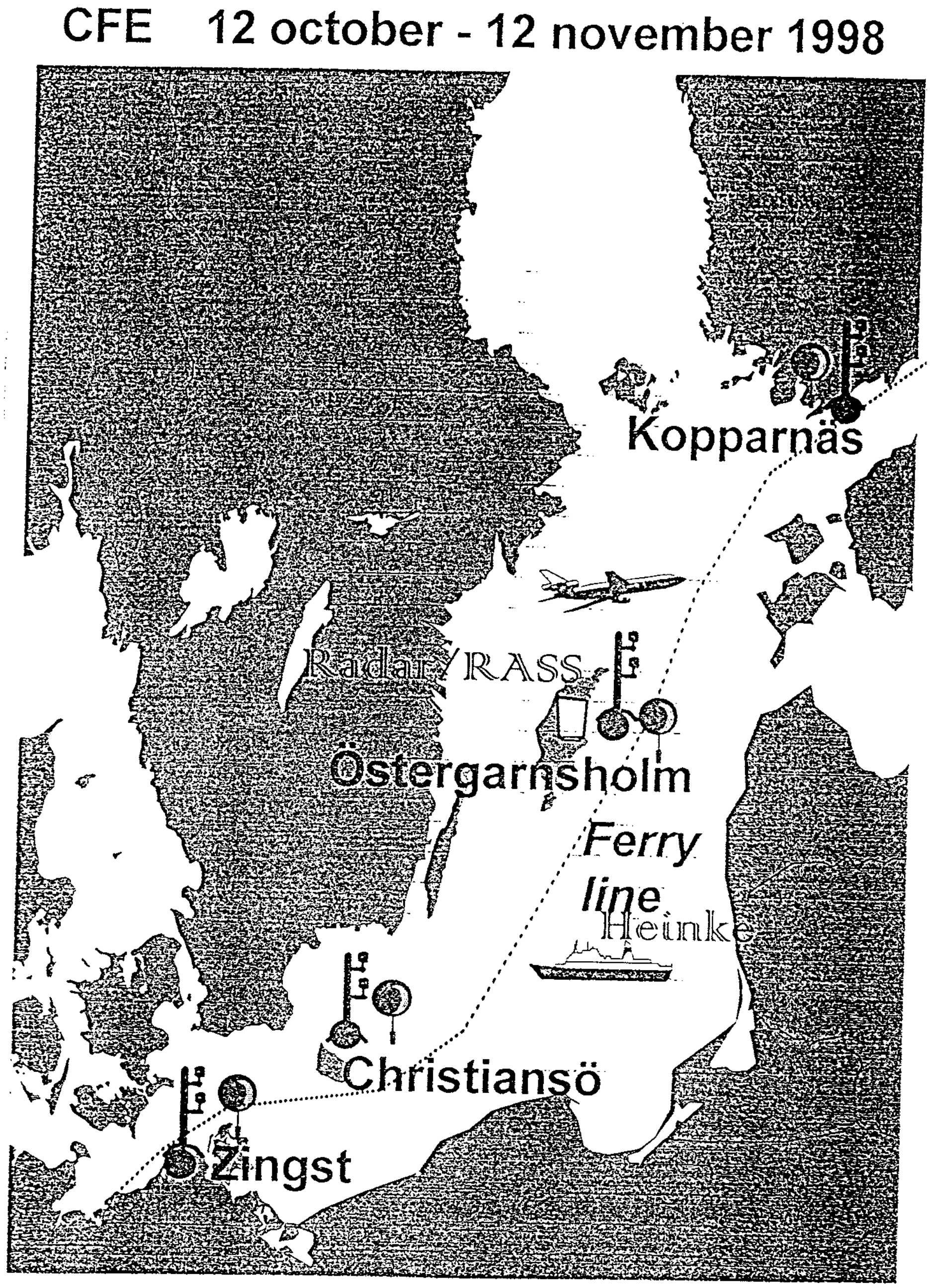

Figure 1. The experimental set-up during the PEP intensive field effort.

ON THE PROCESSES LEADING TO AND AFFECTED BY THE VARIABLE CLIMATE OF THE MACKENZIE RIVER BASIN

R. E. Stewart, Z. Cao, M.D. Mackay, R.W. Crawford and J. E. Burford (Climate Research Branch, Atmospheric Environment Service, Downsview, Ontario, Canada)

The Mackenzie River Basin of northwestern Canada covers about 20% of the country's land mass and the discharge from this region represents the largest North American source of fresh water for the Arctic Ocean. However, the climate of this region is characterized by large annual and inter-annual variations. For example, there is a very dramatic annual cycle of surface temperature with winter monthly average temperatures typically reaching -25 or -30°C, whereas these average values during the summer reach 15°C. There are correspondingly large pronounced annual cycles in other critical variables such as water vapour, precipitation, snowcover, and discharge. In addition, the inter-annual variations in this climate system are some of the highest anywhere in the Northern Hemisphere.

The Mackenzie Basin is also experiencing some of the greatest warming in the world. This is occurring in particular during the cold season and it is characterized by decadel warming rates of up to 2°C. However, this warming trend is very non-linear. It is characterized by large interannual variations that have increased in magnitude over the last two decades, beginning in the mid-70s. These large variations have furthermore resulted in the production of some of the coldest winter periods during the last couple of decades.

The processes associated with the observed warm and cold periods are being studied. There has been a general change in the large scale circulation that has altered advection of warm and cold air into the region and this has also affected the occurrence and strength of basin-scale circulations that lead to adiabatic heating that contributes very significantly to the observed warming. These secondary circulations develop in part from local topographic influences and are generally capped by a low level temperature inversion. Understanding warming therefore requires that these circulations be understood. In contrast, cold periods are always linked with advection from the high Arctic under conditions with little or no low level inversion.

Such variations in large scale and Basin-scale circulations are directly linked with variations in critical parameters such as temperature but they also greatly affect the water budgets and fluxes. Although one might expect that the generally increasing temperatures to be closely linked with an accelerated hydrological cycle, this is not necessarily the case. In reality, the magnitudes of the water budgets and fluxes are influenced by other complex feedbacks including, for example, the alteration of the ability of clouds to produce precipitation, the dryness of the boundary layer, and changes in the phase of precipitation.

Most of the processes and feedbacks associated with temperature perturbations affect, in one way or another, the amount and timing of the fresh water discharge from the Mackenzie River into the Arctic Ocean. The relations between discharge and the atmospheric properties can however be very complex and are sometimes even substantially affected by short-term episodic events. For example, a cold season freezing rain storm can coat the snowcover with ice, this reduces subsequent loss through sublimation, and greater discharge can occur.

A major effort is underway to ensure that the processes associated with warming and cooling periods are adequately represented within regional climate models. Not only do feedbacks such as mentioned above have to be captured, there are also major difficulties linked with the capture of the ice processes that control the rates at which many of the atmospheric processes operate under the variable conditions.

The progress being made in addressing the Mackenzie Basin's climate system is often applicable to other high latitude regions. For example, many of the processes associated with regional circulations are felt to be applicable to the Canadian Archipelago, and there are similarities with some other northern-flowing rivers.

In summary, the processes leading to and affected by the variable climate of the Mackenzie Basin are being understood, they are being incorporated into regional climate models, and implications for other regions and continental-scale experiments are being identified.

DYNAMICS OF WIND-FORCED DIAPYCNAL MIXING IN THE STRATIFIED OCEAN - PRESENTATION OF DIAMIX, THE VERTICAL MIXING EXPERIMENT OF BALTEX.

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Diapycnal mixing is the dominating process modifying water masses in the stratified water column below the upper layers of the sea. It is poorly understood and the lack of universally valid parametrizations of turbulence and mixing in the stratified ocean implies, for instance, that long-term model simulations of the development of the state of the oceans, e.g. for studies of climate, biogeochemical and ecological change, cannot be trusted. It is generally believed that winds and tides are the most important contributors to the energy required for diapycnal mixing beneath the surface layers. The Baltic Sea is particularly well suited for studies of deep-ocean mixing by winds since tides are vanishingly small.

DIAMIX aims at a novel investigation of diapycnal mixing in the stratified parts of a virtually tide-less sea. The ultimate goal is to develop improved parametrizations of atmospherically forced diapycnal diffusivity, including its dependence on wind and buoyancy forcing, horizontal and vertical distances to the sea bed and vertical stratification. To reach the goals of DIAMIX we will carry out two large surveys during two weeks each for summer and winter conditions, respectively. As experimental area we have chosen a 30 by 30 nautical miles 'closed' box immediately east of the southern part of Gotland, sufficiently great to cover the dynamical regimes of both the coastal zone and the open sea. The surveys will comprise measurements in fixed vertical cross-sections using 3 ships with hull mounted (or towed) ADCP and towed undulating CTD and 2 ships taking vertical profiles of turbulent dissipation and CTD. It also includes measurements to obtain time series of CT and currents in a number of fixed vertical profiles using moored instruments and, finally acquisition of the necessary meteorological data. The winter survey is planned for January 1999 and the summer survey for August-September in 1999 or 2000. A first pilot experiment was carried out in June 1997 and a second one will be carried out in June this year.

The experiment is designed in such a way that it should be possible to follow the pathways of energy, from atmospheric input through different dynamical modes to diapycnal mixing and dissipation at molecular scales. A key issue for the experiment is to estimate daily energy budgets of the DIAMIX box from the atmospheric input, dissipational losses by turbulence, storage changes of mechanical energy and advective and radiative sources and sinks at the open boundaries of the experimental box. Since all terms in the budget will be measured, the balance of the budget is a check of the measurements. This presentation concentrates on the theoretical basis for DIAMIX and the different terms in the energy budget are discussed in detail.

SEASONAL FORECAST OF MAXIMUM ANNUAL EXTENT OF SEA ICE COVER IN THE BALTIC SEA

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The 277-years series of maximum annual extent of sea ice cover in the Baltic Sea (MAESI) was analyzed. This series is the sum of 3 time series: first one it is from years 1720-1951 reconstructed by Jurva, the second one it is from 1952 to 1992 reconstructed and published (with first series) by Seina and Palosuo, while the last one was prepared in IMGW using the SMHI and Polish Ice-Service Ice charts. MAESI was expressed by the percentage by total surface of Baltic Sea.

The trends and periodicity were determined and used as the input data to forecast model formulated as ARIMA model. The forecast of MAESI in the winter 1995/96 (the input series from years 1720 to 1994/95) was calculated as equal to ~66% (real ~65%), for winter 1996/97 (input data up to 1995/96) was equal to ~36% (real 34%) when the forecast of the actual winter (197/98) is equal to ~30%.

SNOW COVER AND SURFACE ALBEDO IN ESTONIA

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The paper presents a survey on the investigations into snow cover duration and surface albedo in Estonia. The conclusion is made that the snow cover is an integrator of weather, and also an indicator of variations and fluctuations in climate. With the aim of descripting and determining the fluctuations in climate, we have recorded the parameters of snow cover and surface albedo during long time intervals and established their trends. Data gathered in Tartu-Tõravere Actinometric Station between 1953 and 1994 have been used for the determination of albedo. For other points in Estonian territory the albedo has been determined by an indirect method using the relationship between the albedo and the snow cover duration in the Tartu-Tõravere Actinometric Station. Investigations carried out have established the following facts:

1) The duration of snow cover, snow depth and surface albedo show noticeable differences within the range of Estonia: on islands, in coastal areas and the Central-Estonia plain their values are lower than in the Pandivere and Haanja uplands and have decreased everywhere over the time span 1962 to 1995,

2) the decrease of snow cover duration and albedo has varied over the Estonian territory: the number of snowy days and the value of surface albedo have decreased above all on islands, in the western coastal areas, in Central-Estonian plain and in the south-western part of Lake Peipsi. These are areas where the mean snow cover duration has its minimum,

3) in the winter months surface albedo has decreased by 0.17-0.22 between 1953 and 1995 in Tartu-Tõravere Actinometric Station,

4) changes in snow cover duration and surface albedo are most conspicuous in February and March, the albedo for the Estonian territory as a whole has decreased in March by 0.23 and snow cover duration 12,3 days between 1962 and 1995,

5) the decreasing trend of surface albedo over the Estonian territory for the same time interval is greatest in the Central-Estonian plain, in the south-western shore of Lake Peipsi and on island Saaremaa amounting to 0.25, while the lowest negative trend 0.12 is observed in Virumaa, where also the depth of snow is greatest.

Changes in snow cover duration and surface albedo have been caused by an increase of air temperature in winter months. A positive feedback occurs due to an increase in air temperature, which causes a decrease in albedo and this in turn increases the short wave radiaton budget, which intensifies the rise of temperature in winter and early spring.

At present we do not know wheather the regularities revealed by the above research are associated with irreversible changes in climate caused by anthropogenic activities or are due to shortlasting climatic fluctuations. In both cases the study of the problem would be of interest for understanding variations in weather and climate.

The purpose of further investigations is to study the local differences and variations in the snow cover duration, snow depth, water storage and surface albedo over the whole territory of Estonia with the aim of compiling an Atlas of the mentioned characteristics.

SIMULATION OF BOTTOM WATER FLOW DOWN IN THE BALTIC.

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A denser water motion down along inclined sea bottom is ruled by buoyancy effects. It should be taken into account in sea models simulating bottom denser water spreading. There are different ways to include buoyancy effects in a model. In the presented model it is made by including equation of motion for a vertical velocity instead of the hydrostatic approximation usually used. A set of the model governing equations involves tree-dimensional non-stationary non-linear equations of motion for the horizontal and vertical directions. It also includes equations of mass and salinity conservation and equation of the state. Equations of motion and mass conservation are transformed with the method of vector potential to three-dimensional equations of vector vorticity, vector and scalar speed potentials. Resulting currents velocity **u** is assumed as a sum of potential $\mathbf{u}_p$ l and rotor $\mathbf{u}_r$ components. $\mathbf{u}_p$ and $\mathbf{u}_r$ are found from scalar φ and vector ψ potentials accordingly.

$\mathbf{u}_p = \nabla \cdot \varphi; \quad \mathbf{u}_r = \nabla \times \psi.$

φ is obtained from equation $\nabla^2 \varphi = 0$. ψ is connected with vorticity by equation $\nabla^2 \psi = -\Omega$. Ω is calculated from equation of vorticity

$$\frac{\partial \Omega}{\partial t} + (\mathbf{u} \cdot \nabla)\Omega - (\Omega \cdot \nabla)\mathbf{u} - f_z \frac{\partial \mathbf{u}}{\partial z} - k_z \frac{\partial^2 \Omega}{\partial z^2} - k_l \nabla_l^2 \Omega = \mathbf{g} \times \nabla \rho.$$

For calculation of water salinity and density the following equations are used

$$\frac{\partial s}{\partial t} + u\frac{\partial s}{\partial x} + v\frac{\partial s}{\partial y} + w\frac{\partial s}{\partial z} = k_z \frac{\partial^2 s}{\partial z^2} + k_l \nabla^2 s$$

$$\rho = \rho_0 + \alpha_s s.$$

where the rectangular space co-ordinates (x, y, z) have an origin on the free surface; x is directed to the northern sea boundary, y is positive to left from x;z is positive normally downward to a bottom; u, v, w are x, y, z components of current velocity; ρ_0, ρ are standard and real sea water density respectively; s is salinity; k is coefficient of vertical eddy viscosity ,k_s, k_l are coefficients of vertical and horizontal diffusivity respectively; α_s is a coefficient of the saline contribution to density; g is gravitational acceleration; p is pressure; f is the Coriolis coefficient.

To experience the performed model it was applied to computation of a bottom saline water penetration into the Baltic sea. In the nature this process is episodic and depends on the number of different factors including the wind, free surface level at the sea entrance, river discharge etc. At the first step it is reasonable to apply the model to rather simplified physical conditions to make the model results interpretation more easy. That is why the computational area includes only the part of the Baltic Proper and has rectangular form. Only its southern side was accepted open. All others were taken as a coastal. The used bottom depth distribution was simplified, too (Fig.2). The island located in the area was considered as a ridge with a depth of 45 m. The used area includes two deep parts divided by the ridge. At the northern side is the relatively deep strait of 100m depth which connects these two deep parts. The saline water input was considered to be from the right side of the southern sea boundary close to the largest deepness at the depth from 75m and was reserved all along the computational period. The initial salinity was taken 6 pml and the salinity of input water was 16 pml. River discharge was not taken into account. But its influence on the salinity was approximated by accepting surface salinity equal to 6 pml for all computational period. The wind influence was neglected. The vertical diffusivity coefficients were taken as $k_s = 10^{-5} m^2 s^{-1}, k_v = 10^{-4} m^2 s^{-1}$ Smaller value for k_v leads to inner waves growth. A model area was covered by the grid of size 11x15 in lateral and 11 points in vertical directions with steps as big as 18km in horizontal and 15m in vertical directions respectively.

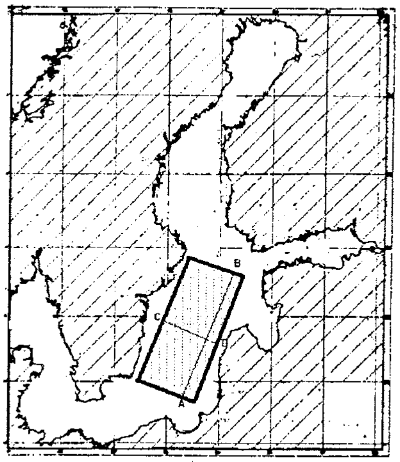


Fig.1.. Model area location

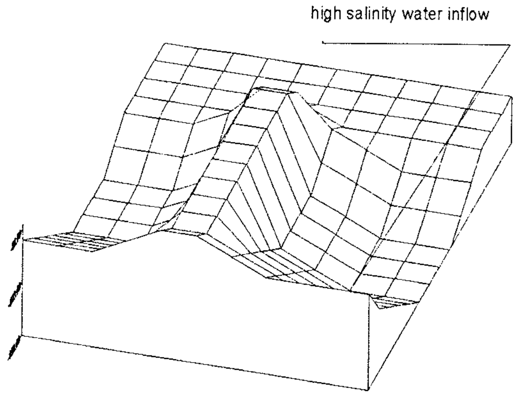
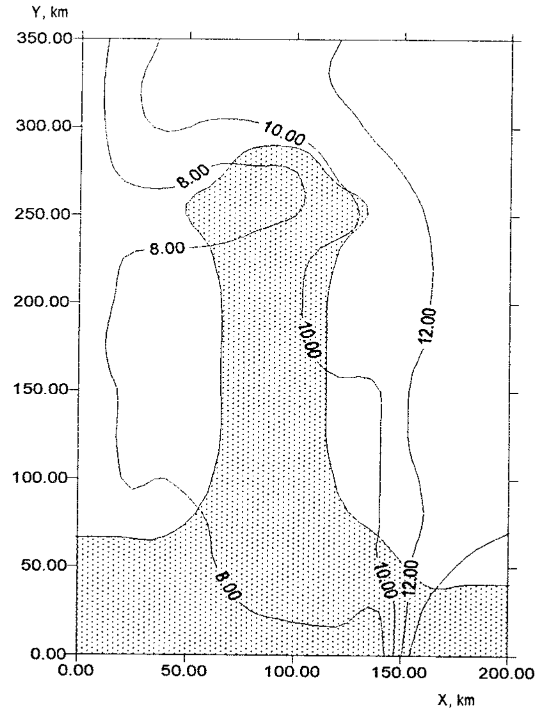


Fig.2. Bottom depth distribution.



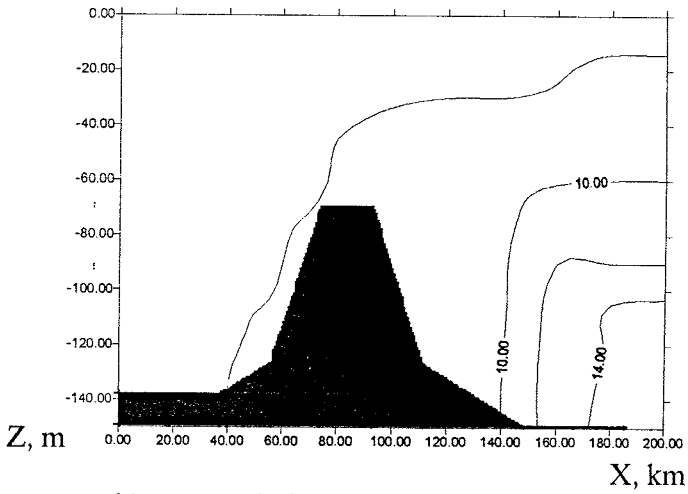


Fig.3. Computed bottom salinity distribution (dot-covered is area with depth less than 100 m).
Fig.4 Computed across sectional salinity distribution.

Computing made it possible to investigate the main features of bottom water flow down. Under the influence of lengthways density gradient countercurrent system is formed with the direction from the open border to the seaside at the bottom and in the opposite direction in the upper layer. By the action of Coriolis force cross components of vorticity and current are formed that deflects the bottom waters to the right to the south eastern bank and surface waters to the left to the central part of the sea. This results in formation of horizontal density gradient perpendicular to the shore line near the south eastern bank that both decreases circulation directed normally to the shore and increases currents along the south eastern bank. Thus the flow down of bottom water in the main along south eastern bank of the area is provided. From model results in two days transformed high salinity bottom water reached the strait and spread into the left deep area part (fig.3.). Some transformed water in the upper layer overcame the middle sill {fig.4.). The process of the bottom water spreading wasn't gentle and was disturbed by inner waves oscillations. The obtained results shown that the model presented simulated main feature of bottom saline water penetration into the Baltic sea and could be considered as a base for its development and its use for investigation of such processes.

GEWEX OBJECTIVES, ACHIEVEMENTS AND FUTURE PLANS

Paul F. Twitchell
International GEWEX Project Office

The Global Energy and Water Cycle Experiment (GEWEX) was initiated in 1988 by the World Climate Research Programme (WCRP) to observe, understand and model the hydrological cycle and energy fluxes in the atmosphere at the land surface and in the upper ocean. Water in its various phases plays a dominant role in nearly all aspects of the Earth's system. As vapour it is the Earth's most powerful greenhouse gas and main carrier of atmospheric energy. The objectives of GEWEX are:

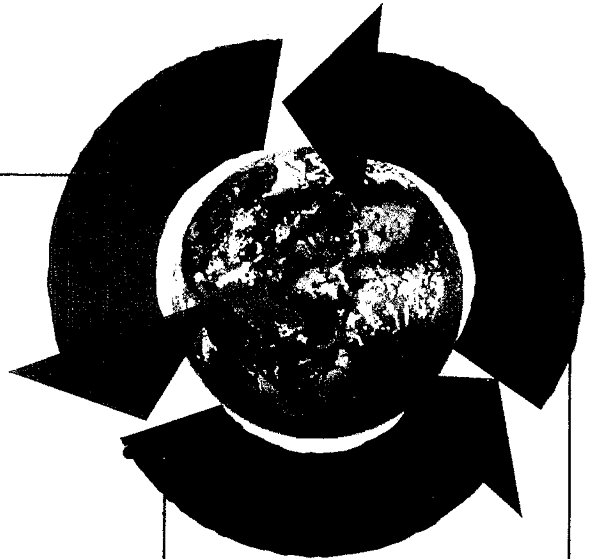
- Determine the Earth's hydrologic cycle and energy fluxes using global measurements.
- Model the global hydrologic cycle and assess its impact on the atmosphere, oceans and land surface.
- Develop the ability to predict variations in global and regional hydrological processes and water resources, as well as their responses to environmental change.
- Foster the development of observing techniques, and data management, and assimilation systems suitable for operational application to long-range weather forecasts, hydrology, and climate predictions.

The original scientific and technical objectives will be briefly reviewed before discussing some of GEWEX achievements that are advancing knowledge of the global energy and water cycle. These advancements are due to the opening of communication between specialists in many disciplines to exchange sound scientific judgement. A few comments on the cross-flow of information will be presented between the components of GEWEX as shown on the next page.

The discussion on achievements will be mentioned on a few projects under all three GEWEX categories: Radiation, Hydrometeorology, and Modelling and Prediction. The emphasis will be on the achievements of the Continental Scale Experiments (CSEs).

For each of the three major categories of GEWEX projects, as indicated in the figure, are panels. These panels are responsible for developing plans for their respective category. Again, as in the case of achievements, the focus of the plans discussion will be those promulgated by the Hydrometeorology Panel.

GEWEX WCRP Global Energy and Water Cycle Experiment



Hydrometeorology Projects

- GEWEX Continental-Scale International Project (GCIP)
- Baltic Sea Experiment (BALTEX)
- GEWEX Asian Monsoon Experiment (GAME)
- Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA)
- Mackenzie GEWEX Study (MAGS)
- International Satellite Land-Surface Climatology Project (ISLSCP)
- Global Runoff Data Centre (GRDC)

Modeling and Prediction Projects

- GEWEX Cloud System Study (GCSS)
- Project for Intercomparison of Land-Surface Parameterization Schemes (PILPS)

- International Satellite Cloud Climatology Project (ISCCP)
- Surface Radiation Budget (SRB) Project
- Global Water Vapor Project (GVaP)
- Global Precipitation Climatology Project (GPCP)
- Global Aerosol Climatology Project (GACP)
- Baseline Surface Radiation Network (BSRN)

MODELLING SPATIAL DISTRIBUTION PATTERNS OF APERIODIC OSCILLATING OXYGEN CONDITIONS IN THE BALTIC SEA.

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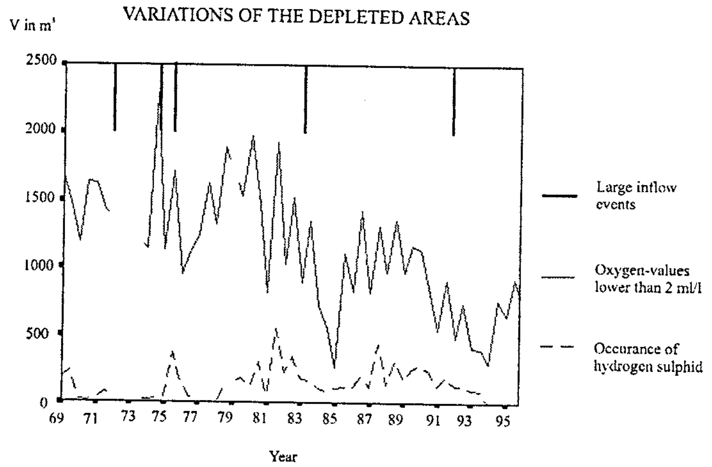
The deep water body of the Baltic Proper annually shows variations in the occurence of oxygen-depleted or oxygen-free and hydrogen-sulphide-containing water due to the bathymatric structure related to swells and basins. The sills between the deep basins restrict the exchange of water with the North Sea. Normal inflow events of salt- and oxygen-rich water from the North Sea have little impact on conditions in the Baltic. Only during major inflow periods the volume of water with a higher density crossing the sills is able to displace the bottom water in the deep basins. These inflow periods are irregularly and their consequences for the conditions in the deep basins depends on some variables as the volume and temperature of the inflowing water and the oxygen or hydrogen-sulphide concentrations in the deep basins.

Maps and diagrams describing the near-bottom oxygen conditions in spring and autumn of the period 1969-1996 are shown. A mathematical method is presented by which the oxygen conditions of the Baltic Sea bottom can be calculated. On the basis of the oxygen-distribution and the general hydrological regime the Baltic Proper was divided in four partial areas. Depth-related oxygen maps were established using the inverse distance-method basing on measuring points from standard stations which are irregularly distributed throughout the Baltic. A spline-function was used to describe the changes of the oxygen conditions with depth and to calculate near-bottom oxygen values. The partial maps were merged with a Kriging technique on the basis of the estimated semivariograms for the different years.

Now the variations of oxygen-conditions in the deep water body in the investigated period can be given by digital oxygen-concentration maps, maps showing the frequency of oxygen problems and line diagrams of the changing values of areas and volumes.



Variations of the volumes with oxygen-depletion in the Baltic Proper. Data are from spring and autumn in the period 1969-1996 (UNVERZAGT).

On the basis of the calculated volumes for the different basins (Bornholm Basin, Danzig Basin, Eastern Gotland Basin, Northern Central Basin and Western Gotland Basin) the change between different oxygen-conditions should be described using Markov-chains. Significant correlations between adjacent spells does exist up to two steps.

SOIL MOISTURE ASSIMILATION OVER EUROPE USING SATELLITE DERIVED SURFACE FLUXES

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1. Introduction

Surface energy balance formulations in numerical weather prediction (NWP) and climate models generally include a strong dependence on the amount of soil water available for evapotranspiration. Since the soil moisture volume has a long timescale in the model's hydrological cycle, systematic model errors associated to cloud formation, precipitation, and energy balance partitioning tend to accumulate in the prognostic evolution of soil moisture content. Resulting model drift in NWP-models must be confined by use of data. This paper explores the use of a combination of near-surface temperature and humidity, and satellite derived surface fluxes for this purpose.

2. Description of the satellite retrieval algorithm

The satellite retrieval algoritm labelled SEBAL (Bastiaanssen *et al.*, 1997) is designed for estimating surface energy balance components from synchronized multispectral images, in particular surface albedo, surface temperature and NDVI. Its basic principle is that it 'anchors' extremes in a scatterplot of surface albedo against surface temperature to extreme energy partitioning regimes. Pixels with low surface temperature and low albedo are associated with locations where all available energy is used for evaporation LE, thus sensible heat $H \approx 0$. On the other hand, high surface temperatures and surface reflectances are associated with areas where $LE \approx 0$. Evaporative fractions of intermediate pixels are obtained by interpolation.

SEBAL has succesfully been compared to ground-truth data collected during various large scale field experiments conducted under semi-arid conditions. Its performace under moderate climate conditions is currently being explored and improved. Parallel to the development of SEBAL, data-assimilation procedures for merging SEBAL products with NWP- forecasts for soil moisture nudging purposes are being designed.

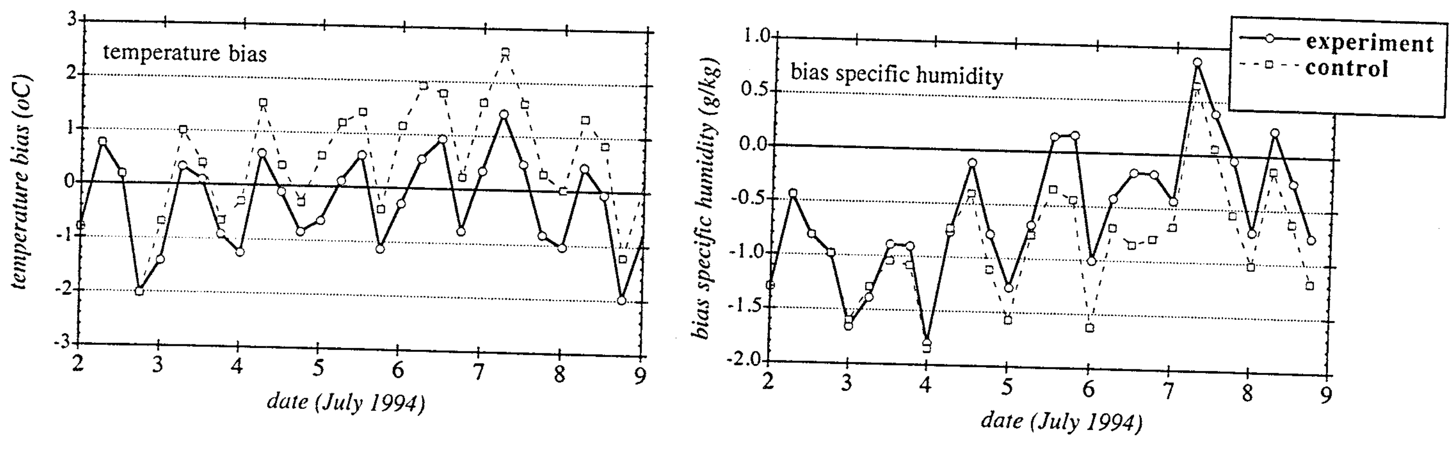

Figure 1: *Bias of 2m temperature and 2m specific humidity over Spain for 2 - 8 July 1994 for the control run without soil moisture adjustment, and the experimental run using SEBAL data. Shown are +30 - +48 hrs forecasts*

3. Results of a test-case in Spain

As a test case, two parallel series of seven 48-hour NWP forecasts using the RACMO model (Christensen and van Meijgaard, 1992) encompassing the Iberian peninsula were carried out for July 1994 (Van den Hurk *et al.*, 1997). In the first series (the control), soil moisture was treated as unmodified prognostic variable. In the second series (the experiment), RACMO first guess predictions of evaporative fraction $LE/(H+LE)$ were compared to SEBAL estimations. Soil moisture was adjusted in order to minimize the difference between RACMO and SEBAL products. The procedure resulted in a clear reduction of the bias of both 2m temperature and 2m specific humidity (Figure 1). This exercise showed that SEBAL contains signal that is compatible to information which is present in the SYNOPS near-surface quantities.

4. Perspectives for European-scale operation

A new test case is currently being explored. For this, three parallel series of RACMO runs are conducted for the entire European area in the period March - November 1995. The first series, the control run, shows a clear European scale bias of 2m temperature and specific humidity in the summer period (Figure 2). In the second series soil moisture is assimilated by using these biases of near-surface quantities only. This series of runs, which represents current practice at a number of weather centres, serves as comparison material for the third series, in which both near-surface quantities and SEBAL fluxes are merged with RACMO first guess calculations.

First results of this exercise show that SEBAL also contains signal compatible to SYNOPS data when operated on European scale. However, the accuracy of the SEBAL fluxes for moderate climate regions is not yet satisfactory, and this deserves further attention. Also, the data-assimilation procedure needs further fine-tuning in order to optimize its performance.

The test case has particular relevance for the BALTEX experiment. The period and area chosen coincide with the PIDCAP measurement campaign, allowing for local evaluation of surface energy balance components to field data. Detailed analysis of results for the BALTEX area are foreseen.

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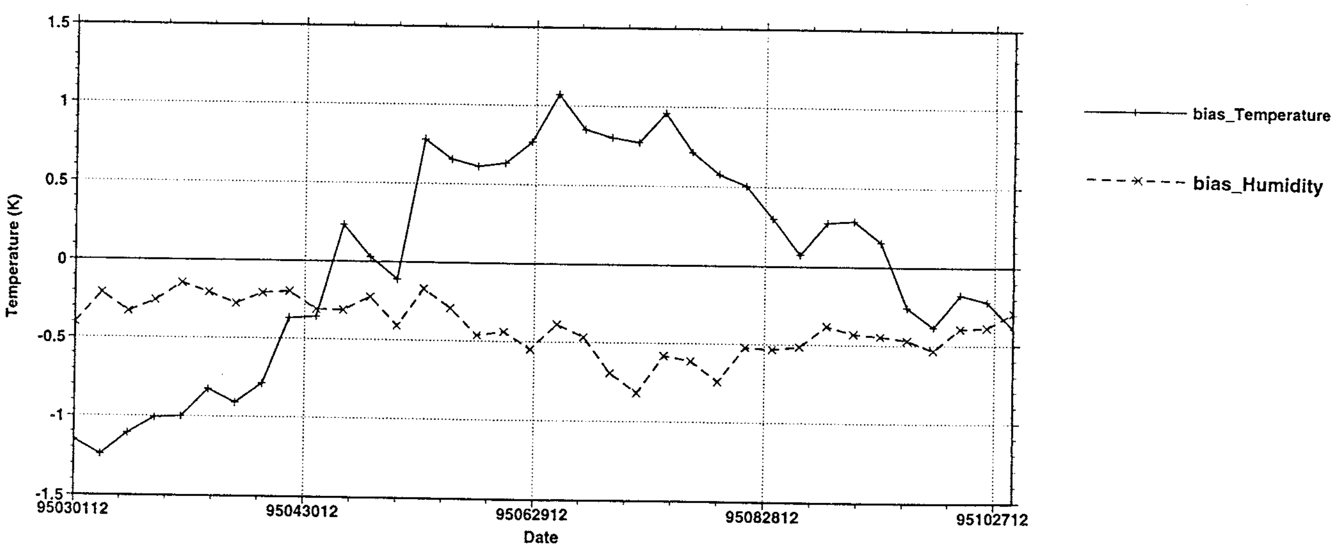

Figure 2: *Weekly averaged temperature and specific humidity bias for entire Europe between 1 March and 15 November 1995, calculated without soil moisture adjustment*

ANALYSING CLOUD OBSERVATIONS FROM GROUND AND SATELLITE

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1. Introduction

Clouds play an important role in our climate. Despite their importance, clouds and cloud-radiation interactions are represented only rudimentary in climate as well as weather forecast models. One reason is the lack of good quantitative observations of cloud characteristics (cloud cover, cloud structure, optical depth, droplet spectra) which hampers the development and validation of models. Satellites provide usefull data on global cloud statistics and corresponding radiation budgets (ISCCP, ERBE). To validate these global data sets on a regional scale, detailed measurements of the cloud cover and structure are necessary. For these reasons a Cloud Detection System (CDS) was installed in the Netherlands. It was operated for a two year period (1995/1996).

2. Cloud Detection System

The cloud detection system consists (CDS) of a network of stations for ground based remote sensing and a processing and archiving environment for AVHRR (Saunders and Kriebel, 1988) and Meteosat (de Valk et al., 1997) measurements. The ground based network observes the cloud base of the lowest layer. The satellites observe only the top of the highest layer. It is expected that a combination of the ground and satellite observations will provide a more complete picture of the cloud fields.

The network stations are located in a 120*120km^2 area in the Netherlands. Each station consists of a Lidar ceilometer (4 km range), a narrowband infrared radiometer (9.6 -11.5 μm spectral range) and a pyranometer. The cloud detection system is used to retrieve the following cloud characteristics: cover fraction, top temperature, base height, base temperature, reflectivity, optical thickness and IR-emissivity. Also the variability of these properties are important. Several tools are available for interpretation of the measurements such as data on the actual atmospheric conditions and radiative transfer models and meteorological analysis of a regional atmospheric model.

3. Results

The area averaged (overhead) total cloud cover is derived with three different methods and compared to the synoptical observations which were taken at the same place and time. Synoptical observations are compared with the area averaged total cloud cover as derived from: IR-radiometer (Fig. 1a), Meteosat observations (Fig. 1b)and a combination of those two (Fig. 1c). From the plots it is clear that the combination of the ground data and the Meteosat data reduces the variance significant (one octa for the area averaged cloud cover).

The CDS-data is presently used for model validation. To enable a direct comparison of observations and model-data it was chosen to plot the temperatures of the cloud layers instead of height. In Fig. 2. the cloud base temperatures from the IR-radiometer are plotted (squares) for January 6, 1995. The gray level of the squares is an indication of the cloud cover at that temperature level (white is clear sky, black indicates overcast). The cloud top temperatures are derived from the Meteosat data (broken line). The grey line is the 75% cloud cover contour from

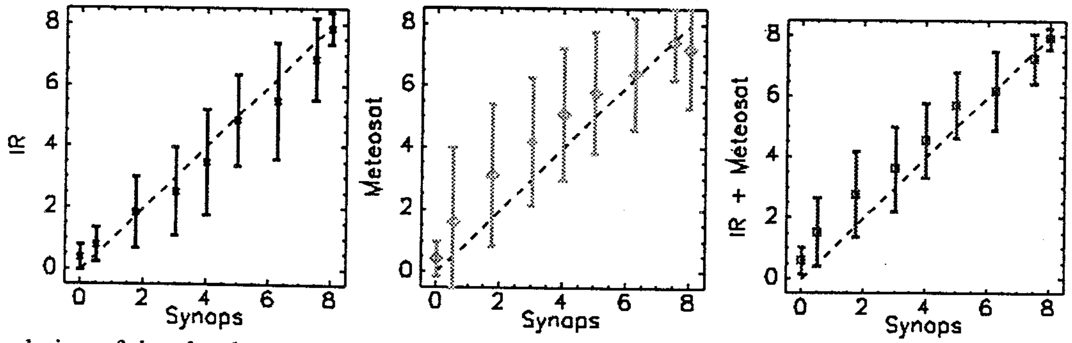

Fig. 1 Correlation of the cloud cover as derived from the CDS data with the synops for the period January/February 1995.

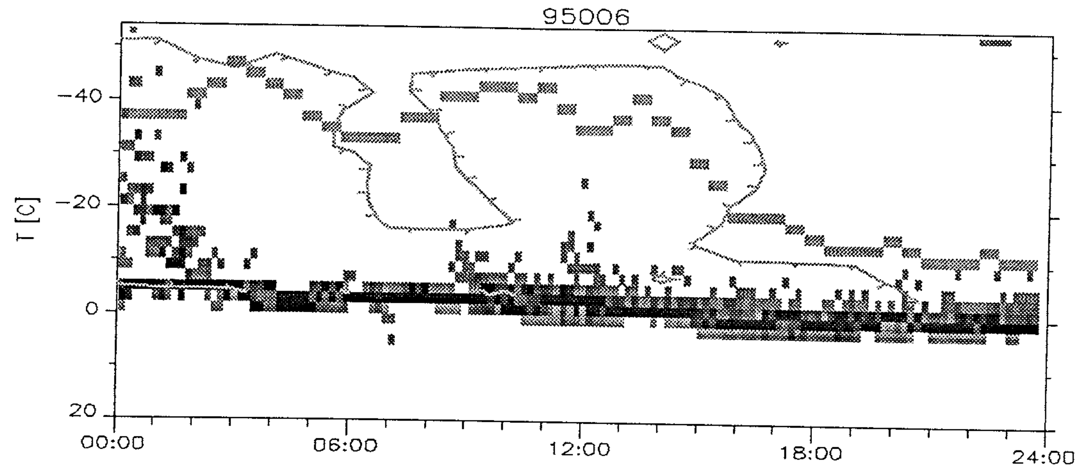

Fig. 2 Comparison of the CDS observations with output from the regional atmospheric model for January 6, 1995.

a regional atmospheric model with ECHAM-3 physics (Christensen and van Meijgaard, 1992) which was run in forecast mode (+6 - +30). For this day there is a good agreement between observations and model (Fig. 2). The actual clouds are very well represented by the model until the end of the day. Then the model clouds disappear while the observations still show the presence of stratus clouds.

4. Discussion

The CDS has been operated for a two year period. The concept of combining satellite and ground based observations improve the results signifcantly. With this set-up it is possible to reproduce the synoptical cloud cover observations. Inclusion of the ceilometer data in the cloud cover analysis is planned. As such the CDS data base is a valuable data set for model validation. In a very straightforward way it is possible to obtain objective information about the performance of a cloud parametrization over longer time periods. The additional data in the CDS data base on the atmospheric condition may help to identify the atmospheric processes of which the description in the parametrization needs to be improved. The data is also used for satellite retrieval validation.

Apart from total cloud cover it is possible to derive other cloud parameters like cloud emissivity. Algorithms have been developed and are being developed to derive other cloud properties like cloud size distribution (Feijt and van Lammeren, 1996), optical depth, emissivity and liquid water path.

Based on these results KNMI is planning to make the CDS also operational on a routine basis for weather and climate applications. This will provide a continous stream of high quality and objective data for model and satellite retrieval validation. Finally, the concept of the CDS is applicable to a larger area. World wide almost every airport has an operational lidar ceilometer. The geostationary satellites provide a (nearly) world wide coverage. So, combining these two data sources would really improve the operational cloud observations significantly. At the moment discussions have been started to investigate the possibility of applying the CDS-concept during the BALTEX-BRIDGE campaign (1999-2001) (BRIDGE, 1997).

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COMPARISON OF MODEL SIMULATED CLOUD PARAMETERS WITH OBSERVATIONS FROM GROUND AND SATELLITE

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Simulated cloud parameters such as layer cloud fraction and 2D cloud cover are directly compared with cloud observations analyzed with the KNMI Cloud Detection System (CDS). The CDS combines spatially well resolved satellite measurements with temporally detailed ground-based observations covering an area of 120x120 km^2 in the Netherlands. Data are available for a two-year period (1995/1996). The large-scale atmospheric flow governing the meteorological conditions in the CDS-area is simulated with a regional model (Christensen et al., 1996). At the lateral boundaries the model is forced by ECMWF analyzed fields. The study is carried out in parallel with two "state-of-the-art" cloud schemes in order to provide a wider viewpoint in evaluating the model behaviour.

The reference version of the model employs the physics package of the ECHAM global climate model (Roeckner et al., 1996). The condensation scheme, based on a formalism developed by Sundqvist, treats liquid water as a prognostic variable (Sundqvist, 1978). Cloud fraction, on the other hand, is essentially diagnosed from relative humidity. An alternative description is provided by the presently used cloud scheme in the ECMWF model. The scheme originated by Tiedtke treats both liquid water and cloud fraction as prognostic variables (Tiedtke, 1993). The various sources and sinks are formulated in terms of physical processes.

Results will be presented and discussed for episodes in the PIDCAP period in 1995. Special emphasis will be put on the last week of August 1995 when a profound northwesterly flow ended a long spell of hot and dry weather on the European continent. It is noted that the CDS area is well inside the model domain for BALTEX.

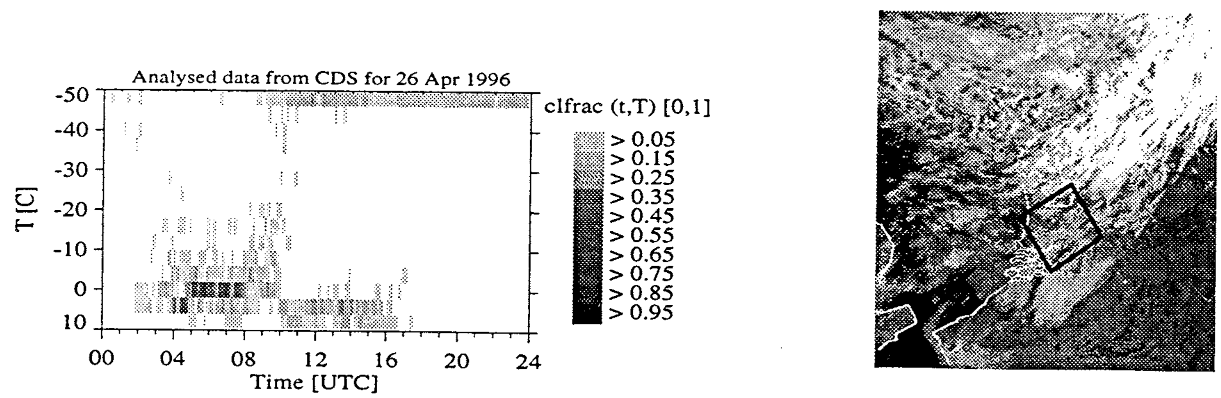

Figure 1: AVHRR channel 2 image (26 April 1996, 0744 UTC) of a cold front system over the northern parts of Germany and the Netherlands. The square in the centre of the image indicates the CDS area. Left panel shows a time-temperature(height) diagram of cloud fraction as analyzed from observations with the CDS network.

As an illustration we briefly discuss the results of a case-study on a weakening frontal system crossing the Netherlands. While thicker clouds produced some measurable rain in the northern regions, cloud fields tended to break up in the south as shown by the satellite image in Figure 1. During daytime the weather came under the influence of a high pressure ridge and low- and mid-level clouds gradually disappeared. However, cirrus fields, related to a warm front in the northwest, persisted. The spatial features of the model simulations (not shown) compare quite well with the satellite image, at least on the large scales. Both cloud schemes generate similar patterns. The differences arise on the southern edge where the frontal system is weakest. As shown in Figure 2, the ECHAM4 cloud scheme clearly generates more

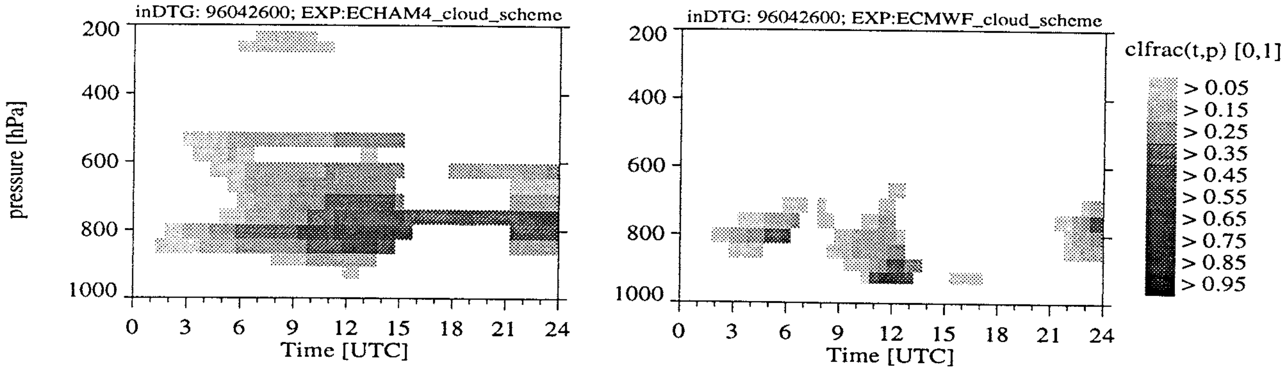

Figure 2: Time-pressure(height) diagrams of cloud fraction for a regional model gridpoint in the CDS-area for 26 April 1996. Left and right panel show results obtained with the ECHAM4 cloud scheme and the ECMWF cloud scheme, respectively. Compare with analyzed data in left panel of Figure 1.

cloud fraction in the CDS-area than the ECMWF cloud scheme. The latter compares better with the data. The simulated cloud amount at the end of the day is not found in the observations and is probably related to errors in the model flow. The observed cirrus is only partially captured by the ECHAM4 cloud scheme and not at all by the ECMWF scheme. This is related to the somewhat lower threshold relative humidity in the ECHAM4 cloud scheme.

So far, a number of case-studies has been performed for a variety of meteorological situations. From the results we state as a first preliminary conclusion that, in general, model simulated cloud parameters compare reasonably well with the observations, in particular those related to frontal systems. However, there are notorious drawbacks, e.g. low-level stratus, thin stratocumulus, and shallow cumulus. Direct comparison in convective situations is inherently complicated as the simulations strongly depend on the activity of the convection scheme and on its interaction with the boundary layer scheme. Secondly, in the majority of cases the cloud parameters obtained with the ECHAM and the ECMWF cloud scheme tend to be closer to each other than to the observations. This is somewhat surprising considering the fact that these cloud schemes have been developed from quite different concepts. It implies that all other model components are of relevance in the representation of cloud parameters. In particular, the other physical parameterization schemes are important since they provide the sources and sinks for the cloud schemes. It is therefore appropriate to say that in these type of studies the evaluation of cloud parameters concerns the performance of the entire atmospheric model rather than the performance of the cloud scheme in isolation from the rest of the model.

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If to take the Baltic Sea as a lake...

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It is customary to think that lake is one of the underlying surface agents for runoff formation. It influents on the river runoff as well as other agents such as wetland, karst, forest etc., and cannot express any regional water rescurse parameters. The possible deviation of lake outflow from "regional runoff norm" depends on lake's sizes and cannot be the simple variation of different water catchments withine one climate zone.

Using the method of lake usable storage coefficient elaborated by author [1] it is possible to divide and estimate quantitatively zonal (as the background) and local fluctuation of runoff (lake outflow) due to different grounds, karst, wetlands, afflux and so on. For example, the M = f(K,A) ratio, when M- lake outflow l/s·sqw.km., K – lake area index, A – lake level altitude m, for different catchments of Estonia looks as following:

M, l/s·km²

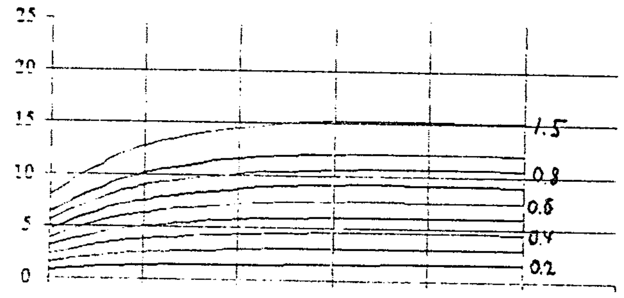


Fig.1 M=f(K,A) ratio for sand-gravel rocks, karst (discharge zone)

M, l/s·km²

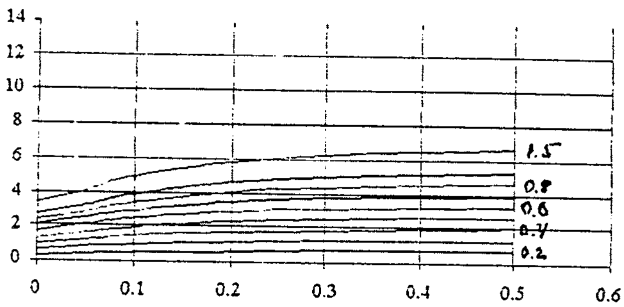


Fig.2 M=f(K,A) ratio for afflux events

The normal (background) dependencies of M=f(K,A) for Kola Peninsula, Estonia and Middle Ural looks as following:

Estonia
M, l/s·km²

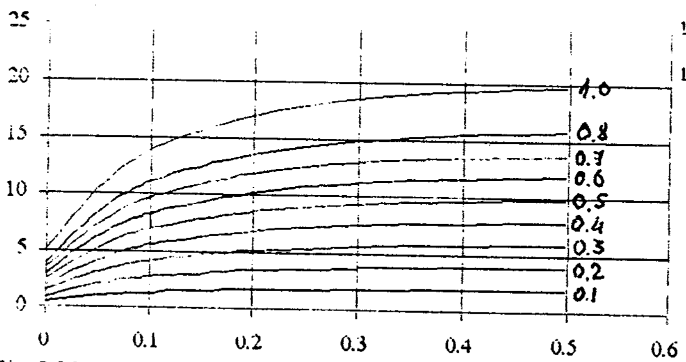


Fig.3 Normal M=f(K,A) ratio for Estonia

Middle Ural
M, l/s·km²

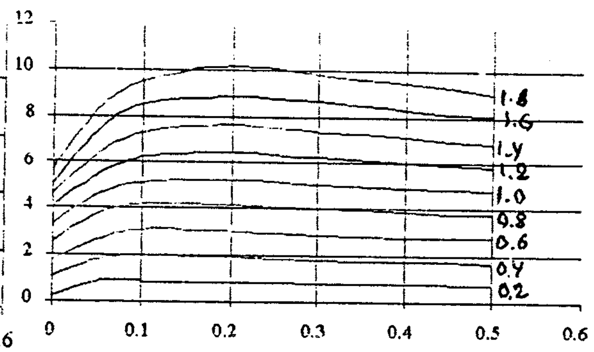
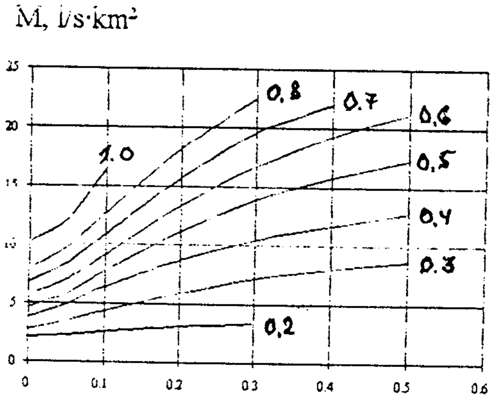


Fig.4 Normal M=f(K,A) ratio for Middle Ural

The difference between different regions depends on runoff losses due to evapotranspiration and evaporation from lake surface if K> 0.05. So, the differences between precipitation and total evapotranspiration (P – E) for these regions are 615, 258 and 136 mm. It is from catchment surface.

Kola Peninsula



A= 0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,1.0,1.5 and 2.0 m for Estonia
A= 0.2,0.4,0.6,0.8,1.0,1.2,1.4,1.6,1.8,2.0 m for Middle Ural
A= 0.2,0.3,0.4,0.5,0.6,0.7,0.8,1.0 m for Kola Peninsula

Fig.5 Normal M=f(K,A) ratio for Kola Peninsula

The crossed points of M-axis show M=f(A) ratio for rivers without lakes (K=0). These were estimated for the same lakes in supposing of lake absence.

The average error of outflow estimation for lakes with known sizes and lake level altitudes amounts to 8%, and altitude estimation for lakes with known sizes and outflow amounts 10% (this result was obtained for known lakes of Kola Peninsula, North European Part of the former USSR, Estonia, Middle Ural). The main feature of these graphs is they are efficient for lakes with any size of water mirror and catchment area – from small pond to great sea. The only demand on its creating and using is the examined lake has to have the natural regime of water level fluctuation.

The Baltic Sea is the largest brackish water body in the world with a total surface area of 377 400 km² and watershed area of 1 628 000 km²[5]. Its area index K amounts to 0.232. Supposing the average difference between precipitation and evapotranspiration for whole sea watershed are equal to 250 mm as it is in the geometrical center of this body, in Estonia [4,5], it is possible to use Estonian diagrams and relations for the water level altitudes and outflow estimation. The water level altitude can be assessed using level fluctuation's dependence on the average depth of lake accompanying to Estonian lakes located in moraine deposits [2,3]. For lakes with depth more than 6 m as well as for Baltic Sea the water level altitude is equal to 0.4 m. And then knowing Sea area index (0.232), level altitude (0.4 m) and having the M=f(A,K) ratio (fig.2) for Estonian lakes with afflux events (Baltic Sea has an afflux events from the North Sea, Skagerrak and Kattegatt Strait) we can estimate the outflow from Baltic Sea. It is equal to 2.4 l/s·km² (92,3 mm) or to 151.8 km³ of year water volume. Knowing long-term amount of precipitation – 680 mm, - it is possible to estimate evapotranspiration from the Baltic Sea watershed: 588 mm.

These level altitude and outflow are caused by precipitation, evaporation and river inflow to the Baltic Sea and can be called as balance's.

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Estimation of water, energy and heat amount that is brought by Estonian rivers to the Baltic Sea in 1986-87

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The approximate model elaborated for long-term water, energy and heat input from Estonia [1] to the Baltic Sea was used for 1986-87.

The climate parameters in 1986-87 comparing with long-term data were following:

	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	Year
Air temperature,C°	15.4	10.1	5.6	0.4	-4.2	-7.0	-6.3	-2.0	3.9	10.8	14.9	16.6	4.9
1986-87	15.0	7.5	5.8	3.2	-7.0	-16.7	-5.2	-6.7	2.5	10.0	13.7	15.2	3.9
Precipitation, mm	72	62	53	52	43	32	26	27	32	42	55	70	565
1986-87	104	100	32	43	58	26	38	15	6	71	87	46	637

Air temperature in 1986-87 was less than long-term one on 1°C in average. Winter months and March (excluding February) were colder significantly. Other months were very close to long-term data.

Next table shows 1986-87 water amount comparision with long-term data for eatch bay's slope and totally for Estonia coast

Water input, mln.m3		VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	Year
Finland Bay	%	119	129	127	130	120	93	126	96	91	123	152	155	122
Riga Bay	%	60	181	106	197	198	61	77	40	125	177	267	94	132
F.B. without Narva	%	127	144	102	104	96	53	60	43	74	102	138	93	95
Total with Narva:	%	110	139	121	151	144	84	116	82	102	134	164	148	125
Total without Narva:	%	86	167	105	166	162	58	71	41	108	147	211	93	118

Energy, mln.J		VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	Year
Finland Bay	%	160	169	97	98	93	62	66	50	71	101	139	96	94
Riga Bay	%	94	297	205	329	269	79	103	67	202	306	522	210	218
F.B. without Narva	%	162	170	96	97	92	62	64	48	70	100	138	93	93
Total with Narva:	%	150	192	121	158	137	67	74	54	101	135	187	110	121
Total without Narva:	%	151	193	121	158	137	66	73	53	101	135	189	108	121

Heat, 10^{12} J		VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	Year
Finland Bay	%	121	104	114	231	315	119	298	163	90.9	116	138	150	128
Riga Bay	%	62	138	103	385	495	42	75	35	88.3	152	224	89	138
F B. without Narva	%	110	105	96	188	179	151	80	49	57.2	85	107	82	95
Total with Narva:	%	112	110	111	280	382	98	255	126	89.8	124	147	144	130
Total without Narva:	%	79	126	100	320	354	94	78	41	78.1	127	176	86	122

On the graphs behind it is easy to see this information in absolute meanings of eatch item. It must be say that conditions of velocity and slope estimation were the same as in the long-term model. It is matter that energy amount in 1986-87 is lower than indeed. Amount of heating was estimated with the same accuracy.

Fig.1 Total water input to the Baltic Sea in 1986-87 comparing with the long-term data.

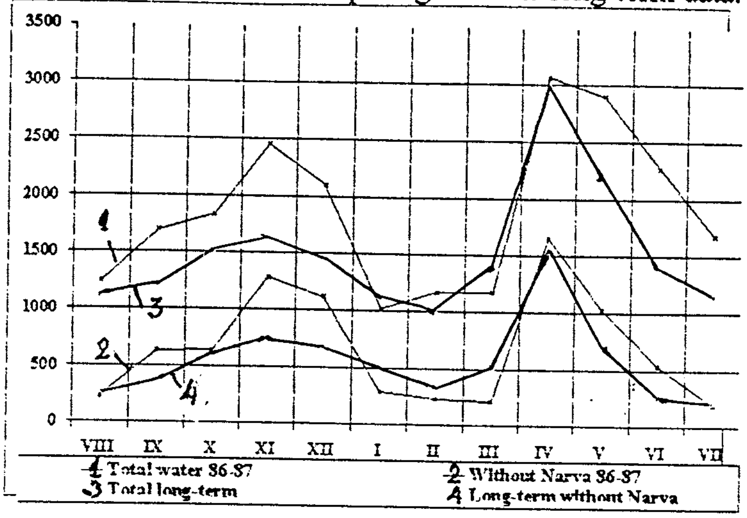


Fig.2 Total energy input to the Baltic Sea in 1986-87 comparing with the long-term data

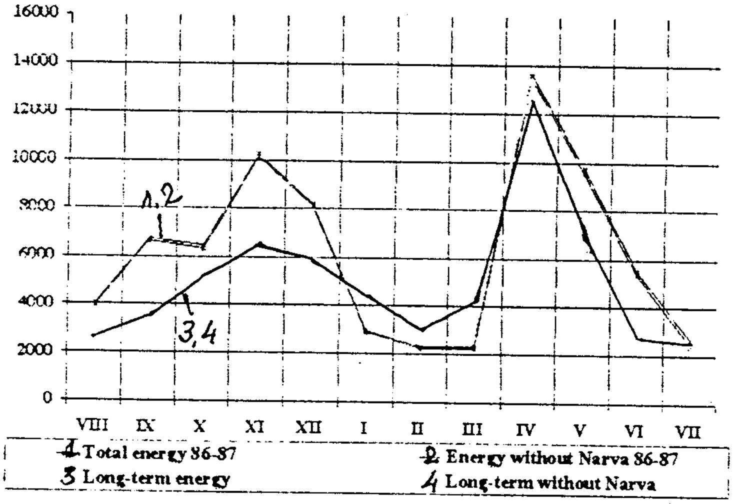
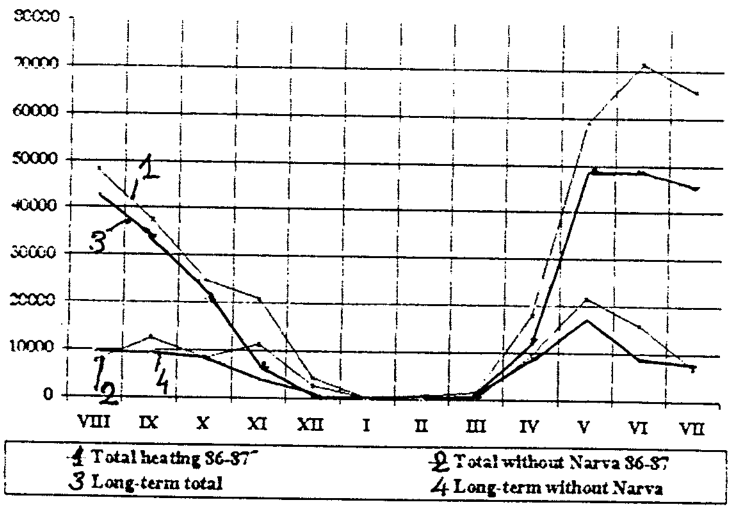


Fig.3 Total heat input to the Baltic Sea in 1986-87 comparing with the long-term data



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COMPARISON OF LATENT AND SENSIBLE HEAT FLUXES OVER BOREAL LAKES WITH FLUXES OVER A FOREST

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The seasonal and diurnal variation of latent and sensible heat fluxes above two boreal zone lakes and an adjacent coniferous forest were compared based on data from the NOPEX field campaigns. Heat fluxes over the lakes were estimated with the bulk aerodynamic method and those over the forest with the eddy-correlation method. The night-time latent heat flux, that was almost non-existent from the forest, was significant from the lakes during all summer months. The day-time flux from the lakes had on average its maximum value in the afternoon. The maximum flux from the forest occurred around noon. The differences in the latent heat supply between the two surface types was within ±60-80 Wm^{-2}, depending on the month and time of day. The monthly mean latent heat flux from the forest was higher than that from the lakes in May, in June and July the fluxes were about equal, and in August-September the lake values exceeded those of the forest. The sensible heat flux reached its maximum values over the forest near noon and over the lakes during the early morning and an excess supply of heat over the forest of up to 200 Wm^{-2} was found in comparison with the lakes during the mid-day hours. From May to August the monthly mean sensible heat flux was higher from the forest than from the lakes. The results of present study indicate that lakes may have a significant effect on area-averaged heat fluxes within areas with an abundance of lakes like those found typically in Scandinavia. The effect will depend on the season, the land-lake areal proportion and the lake size and depth distribution.

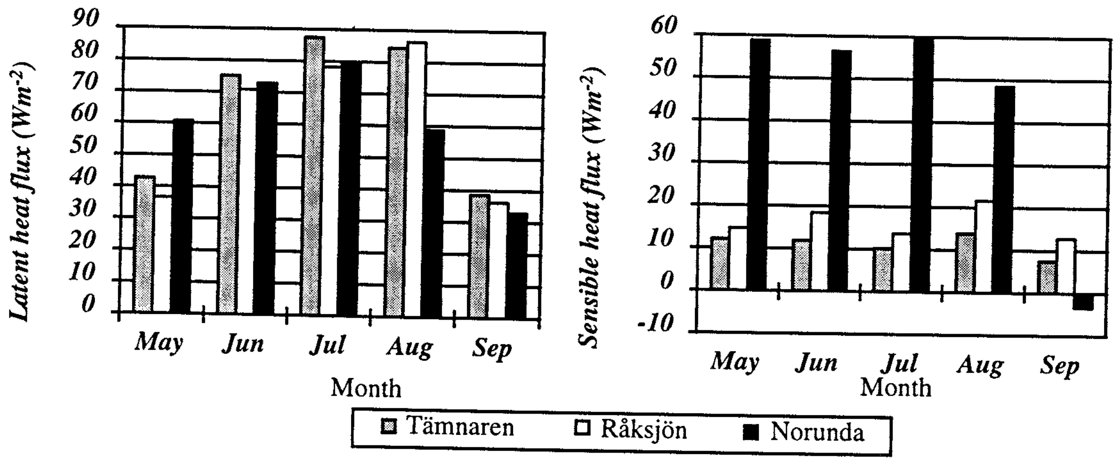

Fig. 1. Mean monthly latent and sensible heat fluxes on Lake Tämnaren and Lake Råksjön and over a forest (Norunda). Fluxes on the lakes were calculated with the bulk aerodynamic method. The Norunda values were obtained from eddy correlation measurements at a height of 35 m.

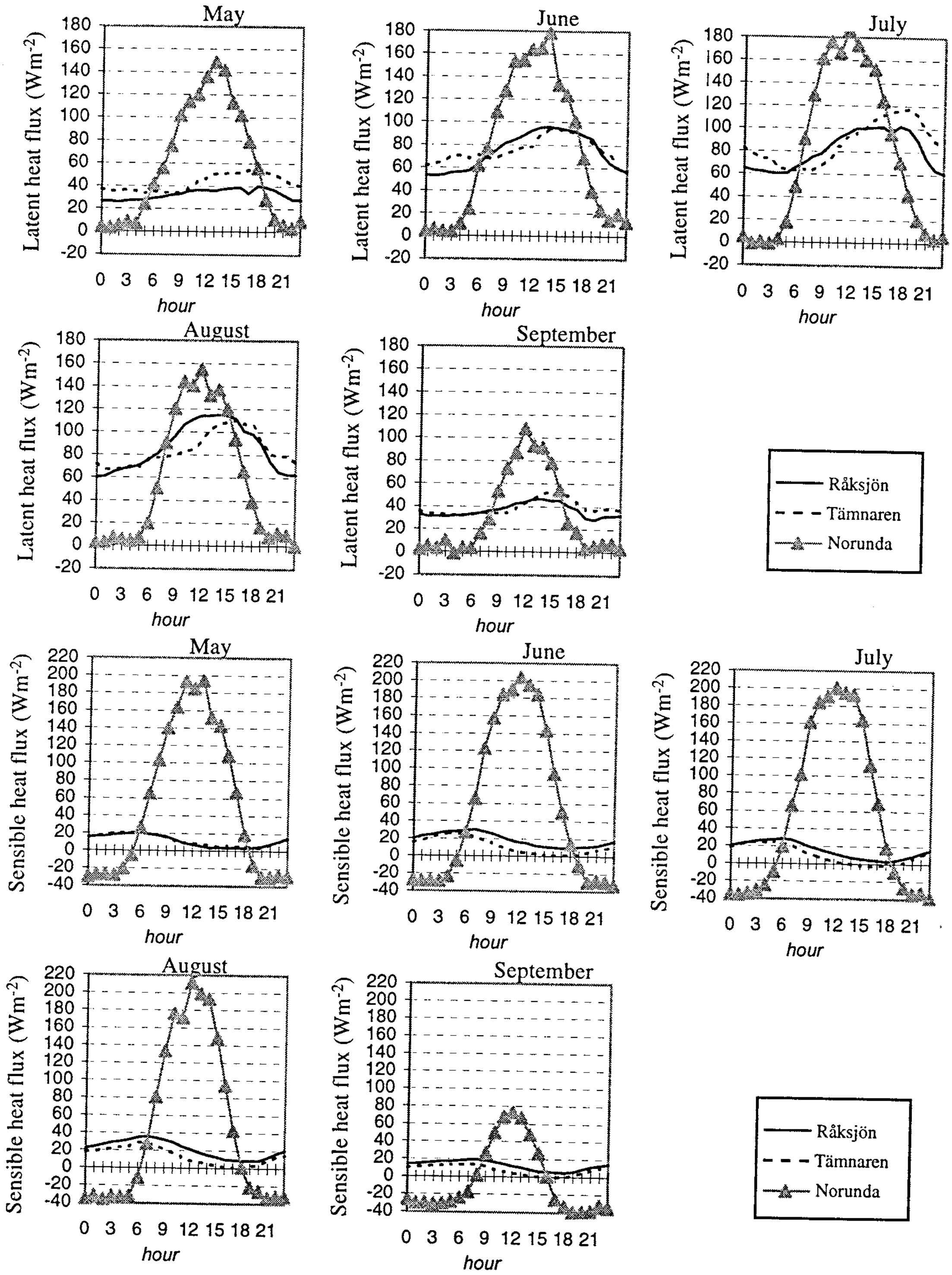

Fig. 2. Monthly mean diurnal variation of latent and sensible heat fluxes on Lake Tämnaren and on Lake Råksjön and over a forests (Norunda). Fluxes on the lakes were calculated with the bulk aerodynamic method. The Norunda values were obtained from eddy correlation measurements at a height of 35 m.

On peculiarities of the discharge hydrograph modelling for the basins with strong runoff regulation by reservoirs (Neva River basin case-study)

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The modelling system "Runoff-Erosion-Contamination" (REC) and its user interface are constructed by the standard circuit (or scheme, when modelling object is any river basin up to the outlet. Consequently, regular distributed system of representative calculated points and all needed parametric and accompanying information are attributed to this object.

Because of large lakes located in the modelling basin, the object under modelling must be considered as a system of subbasins. Under that, these subbasins are separated modelling objects with the outlets in points where river outflows from a lake. For the Neva River basin these objects are:

(i) the Lake Onega basin with the outlet in Svir at Power Plant dam;
(ii) the Lake Ilmen basin with the outlet in Volkhov at Novgorod;
(iii) the Lake Ladoga basin with the outlet in Neva at Shlisselburg;
(iv) the Neva River at Novosaratovka.

Due to the main modelling basin is a system of smaller subbasins it is need to use additional so called "transit" points located at the outlets from subbasins were included in the model to take into account inflow from upstream to downstream subbasins combined this complex basin.

The outflow from the Lake Onega is regulated by the Power Plant dam, unlike the outflow from the Lakes Ladoga and Ilmen. So, the model "output" for this subbasin is not the hydrograph, but the fluctuations of the Lake Onega water level. These simulated fluctuations may be compared with the observed lake Onega water level fluctuations.

Procedure of the runoff simulation for the subbasins carry out without any additional peculiarities. At the same time it is necessary to take into account that the substantial part of the Neva River basin is occupied by the numerous small lakes and areas with water surplus. Therefore, distributed by representative points "lakeness" and "wetlands" were included in the modelling system REC in direct form. The corresponding changes were made in the algorithms and software.

The Neva River basin is connected by the system of channels with the nearby basins of the White Sea, North Dvina River and Volga River. Some part of the river runoff is diverse from/to the Neva River Basin. This situation was reflected in the Modelling system and its user's interface by the including of "bifurcation" positive and negative points, situated at the channels.

The estimation of river inflow into the Baltic Sea - provision with information, peculiarities of forming, variability

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The river inflow into the Baltic Sea from the Russian part of its basin comes from an area of about 290 000 km^2. During the last 10 years the standard hydrological network of about 240 stations with river runoff observations has been functioned in this area.

The greater part of this considered territory belongs to the Neva River basin, which area within Russia is about 225 000 km^2 (76 % of the total runoff forming area). In this basin the hydrological network of 180 stations is functioning. The disposition of the stations on the territory, duration of observations (usually exceeds 30-40 years), reliability of data allow to estimate trustworthy the annual inflow into the Baltic Sea as well as its interannual and interseasonal changeability.

According to the present estimations about 79 km^3 of the river runoff form on the Russian part of the Baltic Sea basin. Besides, about 17 km^3 of the runoff formed in Finland, Poland, Latvia and Estonia come through the Russian territory as a transit into the Baltic Sea.

The most abounding in water river of the region is Neva River, its annual runoff is 74 km^3. On the second place is Velikaya river (4 km^3/year) and the third is Luga river (3 km^3/year). Neva River has a regulated flow because it flows through two biggest lakes of Europe - Lakes Ladoga and Onega. For other rivers in this region it is typical to have pronounced spring flood and autumn floods. The influence of man's activity on the runoff of the region is insignificant. In the Neva River basin the total water intake for communal use does not exceed 1.5 km^3/year, in other basins the value of the water intake is within the accuracy of runoff measurement.

In the presentation analyses of the water resources of the basin, peculiarities of time and space variability of the river inflow and considerations of the perspectives of application of hydrological data for modelling of the Neva River runoff will be given.

REGIONAL-SCALE ATMOSPHERIC MODELLING, DATA ASSIMILATION AND COUPLING TO LAND SURFACE PROCESSES FOR THE BALTEX REGION

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Regional scale atmospheric modelling: the motivation

The main motivation for limited area regional scale atmospheric modelling is the desire to focus the available computer resources on one's own area of interest or responsibility. This also allows the exploitation of data sources which are only locally available. These include observations designated for national usage and high resolution information on the underlying surface which often are not available in the same detail on a contintental or even global scale. Regional scale models furthermore allow to put emphasis on the prediction of local weather parameters, such as precipitation, screen level temperature, visibility, gusts and thunderstorms. By running a limited area model, many national weather services have aquired the necessary flexibililty to satisfy their costumers needs with respect to the product range and timing. Furthermore, limited area models have for many countries been the first step towards Numerical Weather prediction (NWP) and thus played an important role in acquiring and extending know-how.

Regional scale atmospheric modelling: the problems

Mathematically, the system of equations in NWP is of the hyperbolic type. This means, that the solution in the limited area is uniquely defined by the predictive variables on the inflow boundary together with the initial condition. Because of mathematical problems, in most practical applications boundary values are prescribed on all boundaries and the problem is thus ill-posed. Furthermore, even with moderate advection speeds, the solution in the interior domain is largely determined by the information entering from the inflow boundary after one day into the forecast. This problem becomes even more aggrevated when considering propagating Rossby- and gravity waves. One of the biggest concerns is the severe lack of information about the initial state. Since the regional scale models have higher resolution, the problem is more severe here than in the driving global models.

Regional scale atmospheric modelling: the experience

While the above objection about the ill-posedness of the problem is theoretically correct, experience has not demonstrated that it is a major practical issue. However, great care is required when interpolating from the coarser driving model to the finer resolution regional model. The dominating influence from the inflow boundary is of course largest under high windspeed conditions. The quality of the forecast in the interior domain in these cases is heavily dependent on the accuracy of the boundary values. Using the most up-to-date available boundary information has turned out to be crucial. Under low advection velocities, regional scale models posess internal predictability depending in the quality of the intial conditions for the limited area.

The lack of high resolution observations to reduce the initial underdetermancy is crucial, although not as dramatic as the ratio of typically 1 % of available observations over initial values to be specified might indicate. Three arguments can be brought forward, which help to reduce the problem:

Data assimilation: When used for NWP, most limited area models rely on fourdimensional data assimilation for defining the initial state. The basic idea is to combine observations from the present and earlier times through dynamical and statistical constraints. Typically, a forecast model is used to advance the information from previous observations forward in time. By this process, information from well observed areas can be transported to data void areas thus providing a likely estimate of the atmospheric state even in areas where no measurements are made. However, this estimate is sensitive to errors in the previous observations, to errors in their interpretation and usage and to errors in the forecast model used to bring the information forward in time.

Scale interaction: As the forecast models describe nonlinear processes, there is a transfer of information between the various scales represented in the model. A typical example would be the generation of a front or a squall-line from initially undisturbed conditions. Experience has shown, that models are able to properly simulate that process. Therefore, even if the intial state lacks the fine scale details, forecasts can nonetheless be realistic.

Forcing from lower boundary: An important process helping to generate fine scale details is the forcing from the lower boundary of the atmosphere. A typical example would be the chanelling of the flow by the earth's orography. In mountain areas, regional scale models can properly describe the deflection of the flow and the associated weather phaenomena. The finer the horizontal resolution of the model, the more realistic the representation of the lower boundary.

Although regional scale modelling aims at providing detailed weather forecasts, there has generally been some lack of success in this area. For instance, daily maximum temperature and precipitation forecasts are not yet as accurate as desired. One of the reasons is the insufficient attention the processes in the soil have received. Soil moisture is an important quantity, whose mis-specification can result in the wrong partitioning of the incoming solar radiation into sensible and latent heat fluxes. This has consequences for the daily evolution of temperature and moisture in the boundary layer and in convective situations also for precipitation. Progress can be made by extracting the implicit information on soil moisture contained in the observed screen level temperatures and moistures by a variational approach.

Regional scale atmospheric modelling: the prospects

Even if all the above arguments apply, there is still the chance that the intial state would need fine scale detail for the forecast to be successful in its early stages. For these cases, additional data sources need to be exploited. A prime candidate are remote sensing techniques, such as radars and satellites. For instance, radars provide kowledge about the disitribution in time and space of cloud droplets. Unfortunately, this information is not easily usable in data assimilation systems. They require an 'inverse modelling' approach, in which the predictive variables of the model, e.g. wind temperature and moisture are changed in such a way that the cloud droplets generated by the model agree with the droplets as seen by the radar.

With computer capacities increasing through the advent of parallel architectures, there will be further increases in resolution for the driving models and for the embedded limited area models. There are already plans for global models to be run at a resolution of 25 km and for regional models at 2 km. Still finer resolution meets with the scale dependance of predictability so that the emphasis of regional modelling will possibly shift towards the adaptation mode focusing on the response of the flow to very fine scale orographic forcing.

THE LATERAL BOUNDARY CONDITIONS IN A SHALLOW-WATER MODEL

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Limited-area models (LAM's) are used in numerical weather prediction and climate simulation to obtain better representation of high resolution features such as fronts, land and sea breezes, cloud cover, T_{2m} etc. They are also used in the BALTEX project to determine the energy and water cycles on different time scales over the Baltic sea area. The main disadvantage of using a LAM are the artificial lateral boundaries. Values at the boundaries have to be determined from an outer coarse mesh model covering a much larger area or from observations. Any errors or approximations in the boundary values could have an impact on the energy and water balances.

Mathematically, the lateral boundaries should only be prescribed where information is entering the model while not at outflow points. However, in a 3D baroclinic, hydrostatic model it is not possible to derive mathematically correct lateral boundary conditions. Therefore, a number of pragmatic formulations have been used which allows the mathematical solution to be specified at all boundary points. A boundary zone is introduced to dampen the numerical reflection at the boundary and to prevent the integration from becoming unstable. The most common lateral boundary treatment used today is the Davies' relaxation scheme, whereby the solution of the LAM is fitted gradually to the solution of the outer model in the boundary zone using some weight function. This relaxation is done for the mean sea level pressure, the velocity components, the temperature, the humidity and the cloudwater.

Although, the Davies scheme operates with apparent success, fictitious massfluxes over the boundaries could be expected when there is a large jump between the two solutions. Artificial divergence and vorticity could build up and be advected into the interior, particularly affecting fronts containing precipitation which cross the boundary zone. Already Tatsumi (1980) pointed out that the Davies scheme showed substantial noise in the vertical velocity pattern in the boundary zone of the same order as the values in the interior, a feature still noted in many models today. As long as the disturbance is local to the boundary it is more a cosmetic problem, but as smaller and smaller areas and larger steps in the resolution between the models are used, these problem might become of more importance.

In this presentation we have investigated the present Davies relaxation scheme. The weights can be chosen by an optimisation procedure found by Lehmann (1993). We have compared the expected reflection of the computational mode for the optimised weights and the weight functions used in HIRLAM and some other LAM's. We also look into the reason for the noise in the vertical velocities. The tests have been performed in a 2D shallow water model (SHW), which has the fundamental dynamic features of the atmosphere but avoids the complexities of the thermodynamics of a density-stratified fluid. The lateral boundary problem can be studied by prescribing an analytical Rossby wave moving from west to east (Fig 1.), which is not in complete balance, and thereafter observing the deviation between the numerical solution and the analytical solution, which is driving the model in the boundary zone.

An internally generated wave, not present in the driving term in the SHW model, lead to a shear in the wind component in the boundary zone (Fig 4.) which gave rise to spurious vorticity (Fig.2. and 3) and divergence. The noise is mainly noted as the wave is moving out of the area or when the tangential wind is large near the boundary. The size of the disturbance is of the same order as the interior wave as can be seen in Fig. 3. The shear in velocity and the corresponding large values of the vorticity were also found for the HIRLAM runs and were previously more noted as noise in the vertical velocity as already mentioned. The different weight functions primarily shift the area of spurious vorticity inwards or outwards depending on the strength of the forcing. The optimised weights had the smallest reflection and should therefore be preferred.

A possible improvement of the present scheme could be to relax the potential vorticity instead. This was originally included by Davies (1976) and will be attempted. We have also included an extra diffusion relaxation similar to Tatsumi (1980) which appears to make the solution somewhat smoother in the boundary zone. Further plans are to look at some less pragmatic solutions and to compare all the schemes in the SHW model before performing more tests in HIRLAM to investigate the impact on the water and energy balances.

References

Davies, H.C., 1976: A lateral boundary formulation for multi-level prediction models. *Quart. J. Roy. Meteor. Soc.*, **102**, 405-418.

Lehmann R., 1993: On the choice of relaxation coefficients for Davies' lateral boundary scheme for regional weather prediction models. *Meterol. Atmos.Phys.*, **52**, 1-14.

Figures

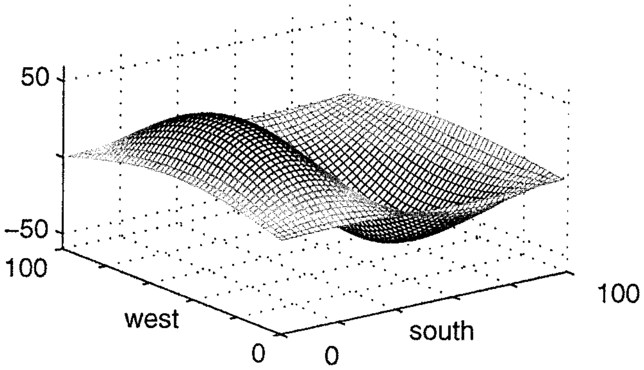

Fig 1. The Rossby wave height in meters on top of 10km fluid layer. (100*100 gridpoints, boundary zone: 8 gridpoints, dx=dy=30km)

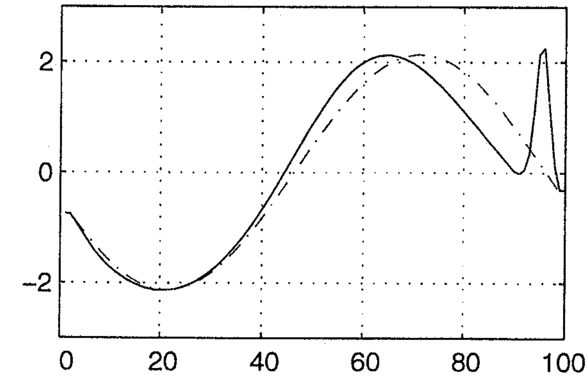

Fig 3. Midview (west-east) of the vorticity for the numerical solution (full line) and the analytical solution (broken line).

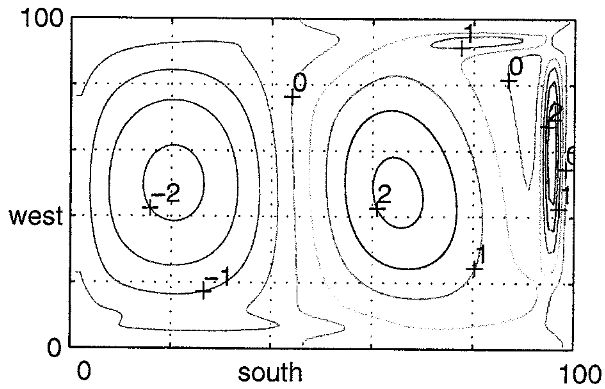

Fig 2. Contours of the vorticity for the numerical solution ($*1.0E6\ /s^2$)

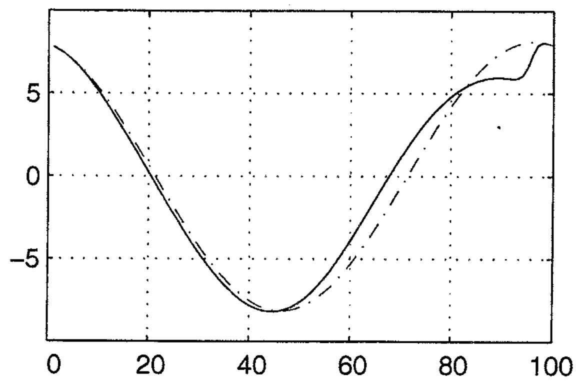

Fig 4. Midview (west-east) of the northern velocity, v (same captions as in Fig. 3.)

WATER BUDGET OF THE BALTIC SEA DRAINAGE BASIN SIMULATED WITH REMO

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Introduction:
The atmospheric regional climate model REMO has been used to study the water cycle of the Baltic Sea and its drainage basin for the period August to October 1995, a period of intense precipitation measurements and data collection. This contributes as a pilot study to BALTEX - the BALtic sea EXperiment project - which aims for a more detailed understanding of the hydrological and energetic budgets of the Baltic Sea drainage basin.

During this period a network of GPS stations in Sweden with the purpose to measure the isostatic movements of the Scandinavian peninsula was also used to measure the integrated water vapor in the atmosphere (Chalmers Institute of Technology in Gothenburg). Therefore it is possible to compare the vertically integrated specific humidity in the atmosphere as well as ground based precipitation with model results. The observations are based on data of approx. 4500 stations, which have been transformed tothe corresponding model grid, in order to compare the simulated results only at the grid points where observations are available. The GPS data are based on station data every 10 minutes. For the comparison, the GPS data are averaged to 6h intervals corresponding to the output of the model. Additionally, the standard deviation within each interval has been calculated.

REMO has been developed at the Max-Planck Institute (MPI) to simulate regional climate. The model is based on the operational forecast model (EM/DM) of the German Weather Service (DWD). REMO has been extended to allow for alternative use of either the physical parameterization package from DWD or the physical parameterization schemes of the global MPI climate model ECHAM4. Continuous simulations with both physical parameterization schemes on 0.16° resolution have been carried out using analyses fields as initial and lateral boundary conditions provided by the Danish weather service.

Results:
The comparison of the spatial distribution of observed and calculated precipitation shows a good agreement. The monthly mean simulated precipitation seems to be overestimated in September and October using the ECHAM4 physics, while the DWD physics underestimates August and October. Only for August 1995 the comparison of the ECHAM4 physics simulation with observations shows similar precipitation amounts over the Baltic Sea drainage basin.

Total monthly mean precipitaion (mm/month):

	calculated		observed
	DWD physics	ECHAM4 physics	
August 1995	53.1	57.8	57.7
September 1995	82.9	95.5	75.3
October 1995	37.4	57.0	40.8

As an example for the validation of model results with GPS data the time series for 3 months of the vertically integrated specific humidity from the simulation with ECHAM4 physics at the station Leksand is shown in the following figure. August and October show a high correlation between the calculated and measured data. Only in the middle of September the simulated meteorological situation differs strongly, and the calculated vertically integrated specific humidity shows big differences from the observations.

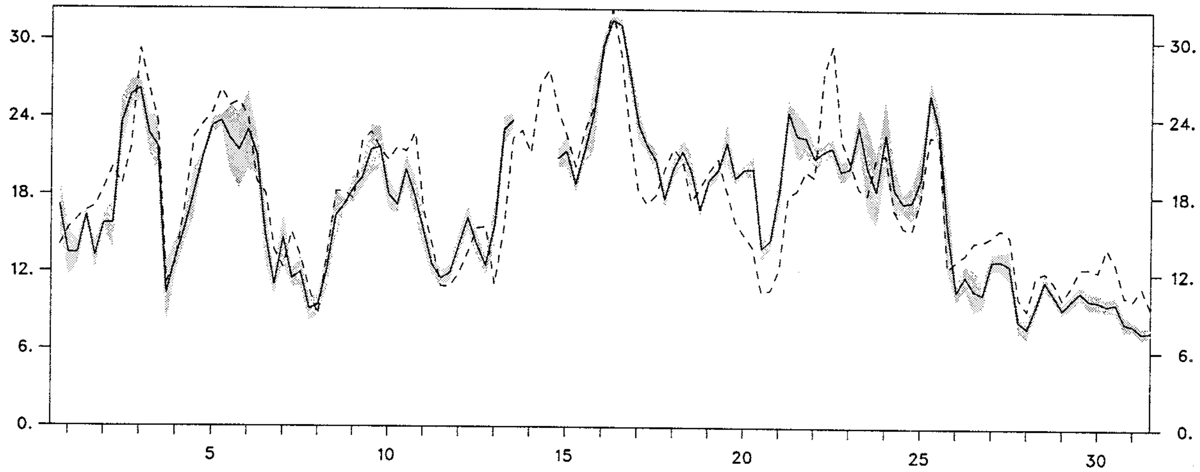
Ongoing work:
This period has been chosen for a detailed model intercomparison study within the NEWBALTIC EU-project. The main focus lies on the water and energy budgets simulated by different models.

Vertically integrated specific humidity [kg/m**2]

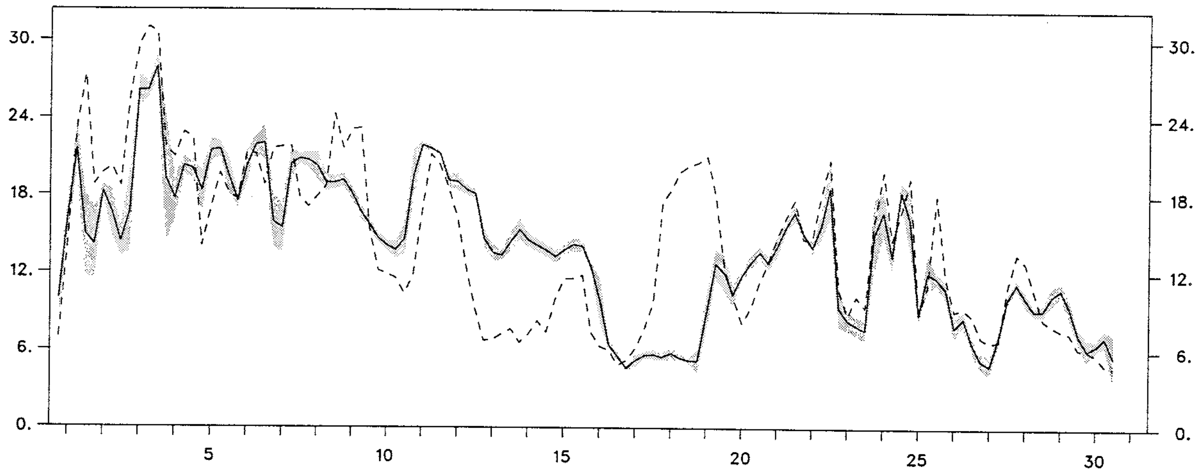
REMO-EC4 1/6° Analyses: HIRLAM

Station: Leksand (60.7°N,14.9°E)

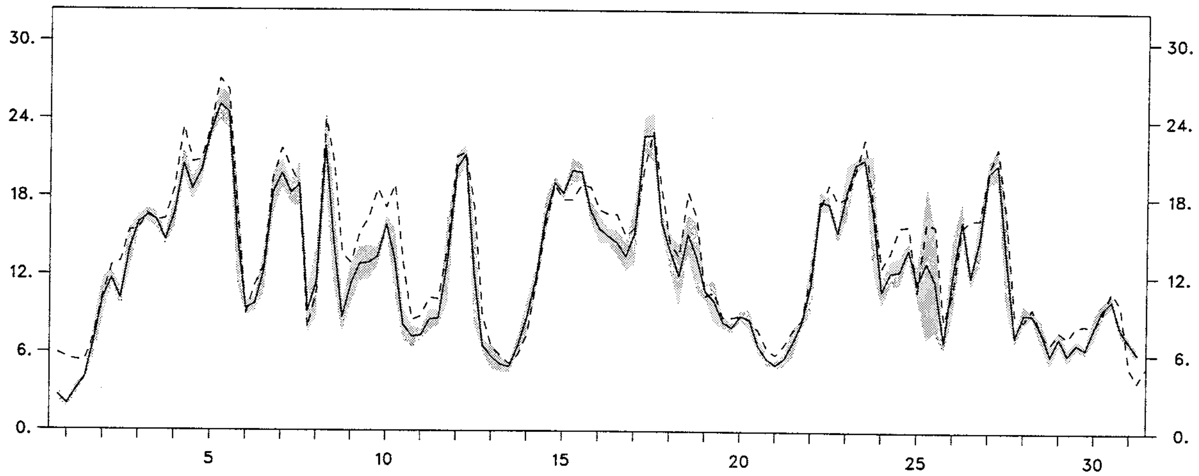
August 1995 mean: 17.6 bias: 0.3 corr: 0.85



September 1995 mean: 14.4 bias: 0.5 corr: 0.68



October 1995 mean: 13.8 bias: 1.2 corr: 0.96



observed + standard deviation ------- simulated

Short-term, seasonal and long-term changeability of sea level fluctuations in the Pomeranian Bay.

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1. Introduction

The changeability of sea level fluctuations presents an important geophysical, oceanographical and climatological problem. Water level fluctuations cause the changes of water depth and have an influence on the location of characteristic elements of coastal zone. The work presents the results of studies on the cheangeability of sea level fluctuations at Świnoujście. The station is in possession of the longest series of water level elevation data in the Baltic area (since 1811). In the study short-term, seasonal and long-term changeability of sea level fluctuations were studied.

2. Short-term changeability of sea level.

Short-term changes of sea level can be defined as the water level changes detected in time periods between a dozen or so minutes to a few days. Storm surges, caused by storm winds and low-pressure systems, are the most important among them. They can cause the flooding events. Storm surges, recorded in the years 1993-1995, confirmed their complicated nature and emphasized the important role of sea surface distortion due to dynamical movement of low-pressure system.

During the examined period of time there were noticed eight significant periods of storm surges. One kind of storm surges was observed on 14th of January, 1993. It surrendered clearly to the dynamic effect of low-pressure system and created by it so-called baric wave. In the period of the storm surge sea surface distortion occured due to the baric wave effect with its positive and negative phase. The speed of the low-pressure system (about 115 km per hour), that considerably influenced on magnitude of wave dynamic component, was an important factor. The distinctive feature of the storm surge was sudden increase and decrease of water level e.i. up to 70 cm per hour (Fig. 1). Such rapid decreases of sea level are difficult to predict and cause problems in maritime navigation.

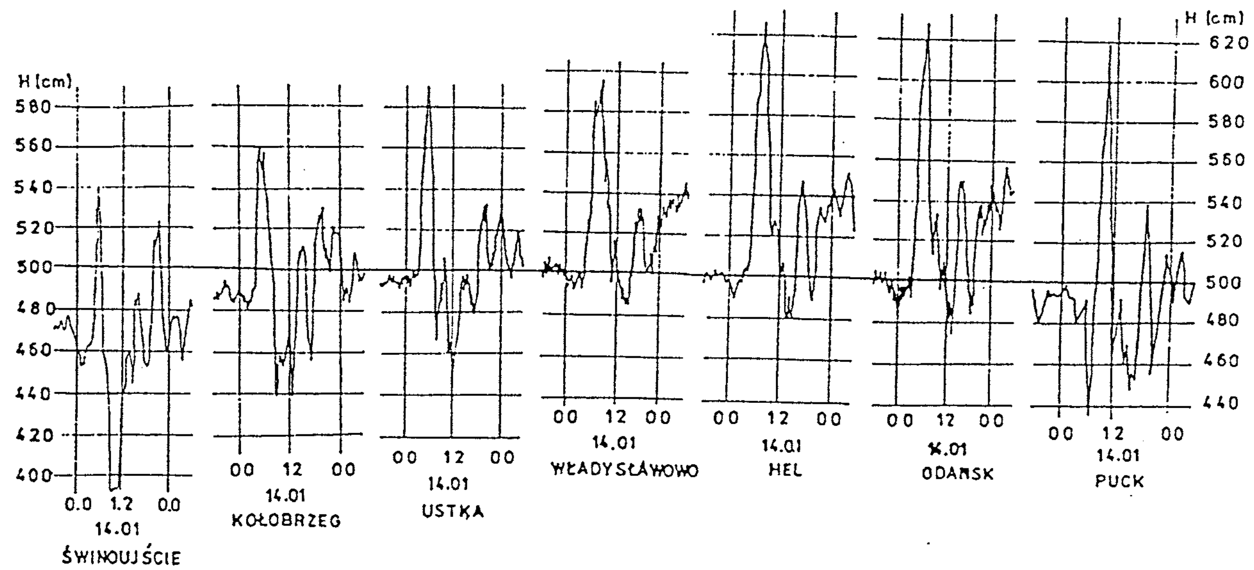

Fig. 1. Sea level changes along Polish coast for the period 13th of January, six p.m. to 15th of January, six a.m., 1993.

Another kind of storm surges was noticed between 3rd to 4th of November, 1995. Increase and decrease of sea level at the gauge Świnoujście lasted for 24 hours. The storm surge was connected with an extensive wind field over the all Baltic Sea. It was the biggest storm surge within the period 1995-96 and brought the serious financial damage in the Polish coastal area.

3. Seasonal changeability of sea level

Seasonal changes of sea level can be defined as the mean water level changes within the year. At the gauge Świnoujście minimum of water level is observed between March to May, while maximum - between July to September. Secondary minimum in November and secondary maximum in December are noticed as well. Such distribution of seasonal changes is caused originally by annual and semi-annual oscillations connected with radiation changes of the Sun as well as annual and semi-annual solar and lunar tide, according to the equation:

$$\Delta H_s = 53{,}2(1-3\sin^2\phi)\cos 2h$$

where: ΔH_s is an amplitude of sea level fluctuations due to semi-annual solar tide wave in mm.
Directly water level changes at Świnoujście are determined by the amount of sea basin filling dependent on the kind and direction of air circulation and wind systems.

4. Long-term changeability of sea level

There has been evident continuous increase of mean water level at gauge Świnoujście from the beginning of observational series, mainly due to gradual land decreasing. For the period 1811-1990 computed trend came to 0,045 cm per year. In recent a few dozen years the tendency of sea level increase has intensified at Świnoujście. For the period 1849-1990 calculated trend rose up to 0,07 cm per year. Simultaneously maximum water level values rose significantly (0,27 cm per year) and minimum water level values deepened considerably as well (-0,17 cm per year). It can certify about increasing climatic changeability in the recent semi-century (Fig. 2).

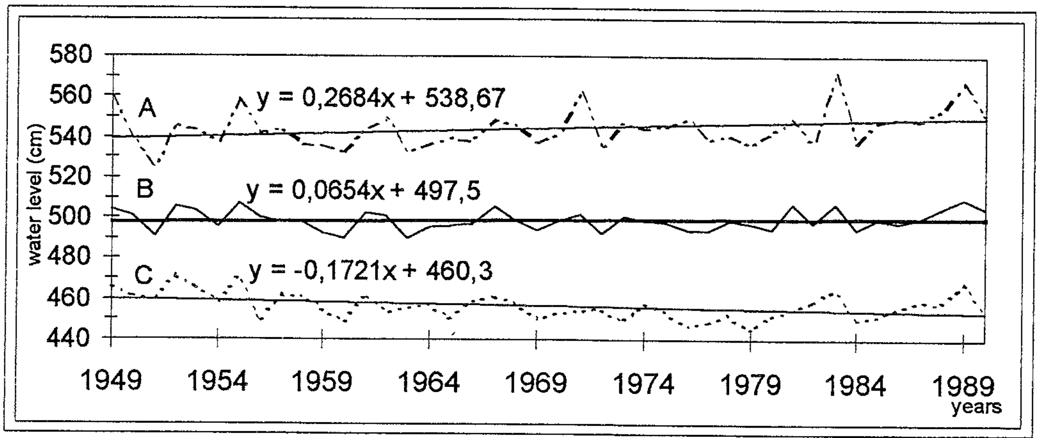

Fig. 2. Maximum (A), mean (B) and minimum (C) water level trends at gauge Świnoujście (1949-1990).

Summer Flood 1997 in the Odra Lagoon - Measurements and Numerical Models

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The Odra Lagoon is a semi-enclosed estuarine water of the Baltic Sea situated across the German-Polish border, having an area of about 687 km^2 and an average water depth of about 3.8 m. The flood in July/August 1997 was one of the most severe flood catastophes in the history of the river Odra. There are only a few events recorded dealing with the large amount of Odra discharge during that time. At the peak of the time series of water discharge recorded at Hohensaaten-Finow, a fresh water discharge of $Q_{max} \approx 3000$ m^3/s was measured, whereas the "normal" summer value is around $\overline{Q}$=545 m^3/s for the climatological average. The impact of this flood on the conditions within the Odra lagoon could be traced by the time series taken at different sites within the lagoon. The pile stations were equiped with a variety of measurement devices - e.g. current meter, attenuation and conductivity sensors and meteorological sensors, thus allowing to characterize water parameters of the water bodies passing by. In addition, the research vessel "Ludwig Prandtl" was on a cruise during that time. The ship took different tracks each day thus delivering information along profiles in the polish part of the lagoon. An ADCP was used to determine the water transport of the Swina and through various transsects of interest (e.g. border between the Kleine Haff and Wielki Zalew (Große Haff)).

In contrast to the attenuation records, salinity measurements turned out to be a good indicator for the propagation of a fresh water front within the lagoon. The passing of fresh water gives an easily detectable signal, showing a sharp transition between Odra lagoon water and fresh water with lower salinity coming from the Odra. There is a remarkable delay of about 2 weeks between the passage of the fresh water front at pile ODH2 (near the German-Polish border in the western part of the Wielki Zalew) and the arrival of this front in the western part of the Kleine Haff (pile station ODH1).

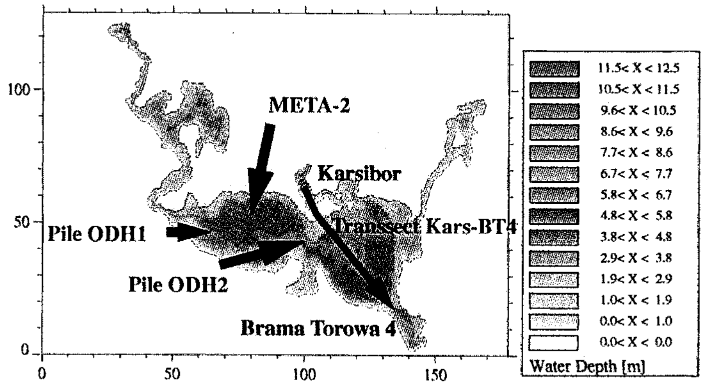
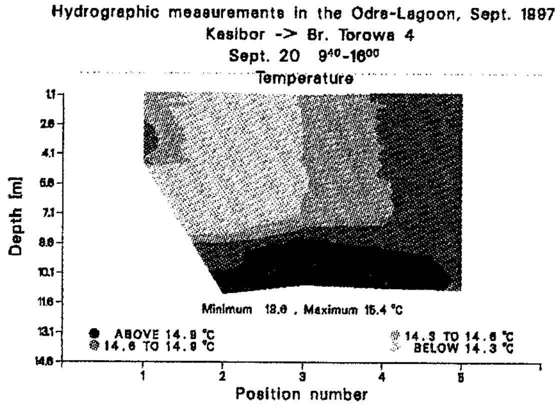
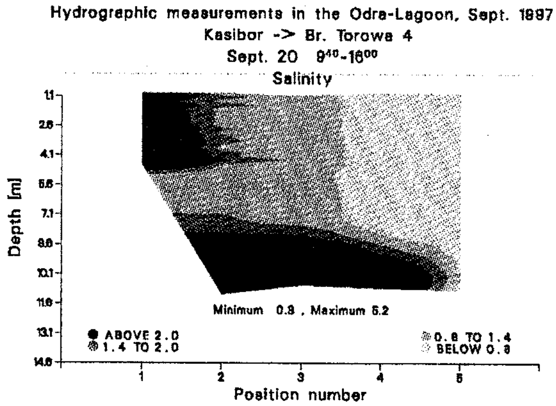


Figure 1: Bathymetrie of the Odra Lagoon with profile Karsibor/Brama-Torowa-4 and positions of pilestations ODH1/ODH2.

After a long period of constant outflow, the water exchange regime between Odra lagoon and Baltic Sea became "normal" again in September, showing the succession of outflow of Odra water and puls-like inflow of salt water from the Baltic Sea into the lagoon. Transsects and vertical profiles measured during such an event (fig.1) demonstrate the intrusion of a salt water front into the lagoon (fig.2). After having reached very low salinity values during the flood, this event marks the return to higher salinity values within the lagoon due to salt water supply from the Baltic.



(a) Salinity S



(b) Temperature T

Figure 2: A puls-like water inflow at the 19th and 20th of September 1997 formed a salt water front which propagated into the Odra Lagoon. The intruded salt water body was detectable as a combined salinity and temperature anomaly. (position number 1 refers to Karsibor; position number 5 refers to Brama-Torowa-4 at the inflow of river Odra into the Wielki Zalew near island Chelminek; position of the profile see also fig.1)

The water exchange rates of the Odra lagoon with the Baltic Sea were calculated for the flood period using the 3-dimensional hydrodynamical model TRIM3D. The simulations show the large contribution of the Swina Strait $\approx$ 70 % to the overall water exchange, while the two other branches - Peenestrom and Dziwna - contribute $\approx$ 20 % and $\approx$ 10 % respectively.

STOCHASTIC CHARACTERISTICS OF BALTIC WATER VOLUME FORCING 1928-1970

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The seasonal oscillations of the Baltic water volume were analysed with respect to the fundamental forces causing this phenomenon. The computations were performed basically with the aid of a multiple dynamic stochastic system of constant parameters enabling the combined and separate effects of the various exciting forces to be determined. In order to keep the computations stable with a relatively short data series, the number of inputs was restricted to three and four series. The computation data comprised mean monthly values. As a rule, the spectral characteristics were estimated using a Finite Fourier Transform with overlapping and the Hanning taper. The periodic structure of individual data series was determined using a Finite Fourier Transform, the amplitudes being obtained without the need for overlapping or the taper. The limited number of inputs to the system meant that an algorithm eliminating input series of little significance had to be applied in order to establish the fundamental exciting forces. The initial input series were the zonal component of atmospheric pressure gradients over the Baltic, the Danish Straits, and that area of the North Sea adjacent to the Skagerrak. This component was represented by the first and second Empirical Orthogonal Function (EOF) calculated from the longitudinal vectors of the gradients. The mean level of the North Sea and the mean atmospheric pressure field covered by the computation of the gradients were subsequent input series. Additionally, the mean monthly inflows of inland waters into the Baltic basin were used. According to the results of the computations, the fundamental exciting forces are the mean level of the North Sea, the first EOF of the gradients characterising the zonal circulation and the inflow of inland waters. The computations of a stochastic system with three correlated inputs enabled the influence of these exciting forces on the change in Baltic water volumes to be analysed. By applying parametric stochastic processes, the autoregressive properties of a series of variations in the Baltic water volume and the possibilities of forecasting the phenomenon were established.

A REGIONAL REANALYSIS FOR PIDCAP USING HIRLAM

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A regional reanalysis for the Baltic Sea catchment area has recently been performed at the Danish Meteorological Institute (DMI) for the PIDCAP (Pilot Study for Intensive Data Collection and Analysis of Precipitation) period from August 1 to November 30 1995. PIDCAP is one of the intensive observation periods in the Baltic Sea Experiment (BALTEX), with the main objectives to collect and analyze measured and estimated BALTEX area precipitation from different data sources, and to validate the output of regional models against such data sets. The PIDCAP reanalysis is aimed at carrying out diagnosis of the atmospheric energy and water budget in the BALTEX region, and providing a high quality analysis to the BALTEX research community. The reanalysis is achieved through delayed mode data assimilation with HIRLAM (HIgh Resolution Limited Area Model). HIRLAM is a cooperative regional NWP model developed by 9 European weather services. Optimum interpolation is used as the analysis scheme. At forecast step, which is intrinsically a part of the data assimilation cycle providing first guess fields, nonlinear normal mode initialization is used. The HIRLAM forecast model features prognostic equation for cloud water and a non-local first order turbulence parameterization. For the PIDCAP runs, a diagnostic procedure to calculate the budget components for the atmospheric energy and water cycle of the BALTEX area has been added. Comparing to operational mode, the present delayed mode data assimilation uses a more complete observational data set with longer cutoff time. The forecast step makes use of analyses instead of forecasts as lateral boundary conditions. As surface forcing, observed sea surface temperature and ice cover data have been used. Comparisons show that, due to these features, the reanalyses are able to provide a better description of the atmospheric states than the operational analyses. The model runs have been performed on double nested grids with a 6 hour assimilation window. The relatively coarse resolution run is conducted on a 146x146 horizontal grid mesh with 0.4 degree spacing, and 24 vertical levels. The ECMWF analyses is used as lateral boundary conditions at the forecast step. The reanalyses on coarse mesh are in turn used as lateral boundary conditions for the finer resolution run. The latter has same number of horizontal grid points but a spacing of 0.2 degree, and 31 vertical levels. By examining forecasts of various integration lengths from the HIRLAM reanalyses, it is concluded that there is no significant spin-up beyond 6 hours in the forecasts of surface fluxes or humidity fields related to phase changes. Thus a forecast length of 12 hours has been chosen in the reanalysis setup, which is believed to be sufficient for the purpose of regional diagnosis of water and energy. In addition, a series of 30 hour long forecast runs, initiated once per day at 00 UTC, have also been performed.

The value of a model simulation is enhanced if the results are validated by observations, preferably those independent data which are not used in the data assimilation. As a preliminary step to validate the PIDCAP reanalyses and the short range forecast initiated with reanalyses (R/F), observation data by ground-based Global Positioning System (GPS) and rain gauges have been used in comparisons. The emerging GPS technique provides a high quality alternative sensor for atmospheric humidity. Due to the sensitivity of atmospheric refractivity to water vapor, it is possible to infer time series of the vertically integrated water vapor (IWV) overlaying a GPS receiver. Numerous studies have demonstrated that GPS derived IWV data features at least equivalent, if not better, quality in comparison to those obtained by other instruments, such as radiosondes and water vapor radiometers. In addition, the ground-based GPS observation has the advantage that it can be made as frequent as every few minutes, providing an observational time series of the atmospheric IWV with a high temporal resolution. During the PIDCAP period, there were 25 continuously operating ground-based GPS stations in Sweden and Finland, all of them located in the BALTEX region. From these GPS measurements, an IWV data set with an extensive spatial and temporal coverage has been obtained, which enable us to compare the hourly mean IWV values for each GPS site to the corresponding HIRLAM simulations(Yang et al, 1998). In general, the comparisons indicate that HIRLAM reanalyses and R/F prediction have quantitatively good skills in reproducing the IWV spatial and temporal variations as depicted by GPS estimations. As an example, Table 1 shows the statistics comparing the simulated to GPS-derived IWV time series, averaged for all 25 sites with GPS receivers. The model data in Table 1 consists of simulations at 0.2 degree resolution, both by reanalyses and by R/F forecasts with integration length of up to 30 hours. The simulations are seen to agree rather well with the GPS data. At analysis time, the mean offset is close to zero, the rms difference is 2.4 kg m^{-2}, or 18% relative to the mean IWV, and the correlation is 0.94. For the forecasts with various integration lengths, the statistical fits remain well. Although the fit between the forecast and GPS estimation tends to deteriorate slightly with extended integration length, the correlation level remains as high as 0.93 for 30 hour long forecast, and the mean offset is merely +3 %. Comparing simulations at analysis time and the forecast at first and second 6 hour simulations, there seem to be no 'spin-up' in the short-range forecast of IWV. On the other hand, a close inspection of the results reveals that significant differences do occur in some weather situations, indicating that the use of GPS-data in data assimilation procedure is likely to improve model results, especially for periods when significant errors in phase or magnitude of model predictions occur. Further examination of the model results also shows that, at longer integration length, the model prediction of IWV tends to be more positively biased. The forecast error, in terms of RMS difference between model and GPS, tends to grow for increased IWV, and negative model bias is found for large IWV cases. Comparisons of the IWV simulation by 0.4 degree and 0.2 degree resolution reanalyses and forecasts show the results being very close.

TABLE 1. Comparison of the PIDCAP IWV time series from HIRLAM model and GPS estimations

	Paired number of data	GPS IWV kg m^{-2}	Model - GPS offset kg m^{-2}	Model - GPS offset/mean %	Model - GPS rms kg m^{-2}	Model - GPS rms/mean %	Correlation Model/GPS
GPS (Mean)		13.5					
Reanalyses	11244	13.4	-0.1	-0	2.4	18	0.94
6 hour forecast	67596	13.5	0.0	0	2.4	18	0.94
12 hour forecast	67596	13.7	0.1	+1	2.5	19	0.93
30 hour forecast	67596	13.9	0.4	+3	2.6	19	0.93

Finally, the simulated PIDCAP precipitation have also been compared to the analysis based on observations from a very densely distributed rain gauge network, with about three thousand stations and an averaged distance of 18 km. In terms of the area averaged daily precipitation, the simulated and observed time series are found to be in rather good agreement. Over the BALTEX land area, the correlation is at about 0.95, with the modeled precipitation generally higher than the analyzed one. These results indicate that the main features of the atmospheric water cycle is well described by the HIRLAM reanalyses. On the other hand, inclusion of more observational data, possibly more data types, will certainly be desirable to further validate the realism of the hydrological cycle described by the model system.

ACKNOWLEDGEMENTS

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Interannual variation of Changma in Korea

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The East Asian Summer Monsoon system is a submonsoon system of huge monsoon system. There are many characteristic weather systems in summer, such as Changma in Korea, Meiyu in China and Baiu in Japan. The rainy period, generally begins on the late June and ends on the middle of July, in Korea is called Changma. The study of interannual and intraseasonal variabilities of the East Asian Summer Monsoon and the study of Changma are one of important scientific issues and this phenomena have received considerable attention in recent year. During northern summer, the Asian summer monsoon has a major influence on the global circulation. The monsoon is developed in response to gradients in the large-scale heating distribution which may arise both from surface solar heating of the Asian continent and through atmospheric latent heating associated with convection over the warm-pool region of the West Pacific and Indonesia. In this Study, we mainly tried to analyze Changma variability on interannual time-scales. The possible existence of a relationship between activity of Changma and the phase of the El-Niño is also studied in this paper. As well as the sensitivity of the Changma strength to the variability of pressure over Northwest Pacific.

Climatological Features of Precipitation in Korea

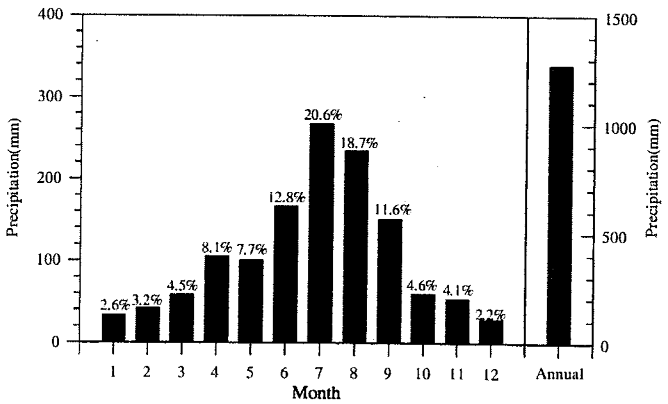

Fig.2 Climatological normals (1961-1990) of precipitation by month in Korea. Amount of precipitation is greatest in July, and then August and June, while lowest December and January. It indicated that more than half of annual precipitation is concentrated in summer (June, July, August) in Korea. The areal weighted annual mean precipitation in Korea is about 1,274 mm.

In this analysis precipitation data of 62 stations from 1961 to 1990 have been used. In Korea, annual precipitation is mostly concentrated in summer season due to quasi-stationary Changma front. Changma in Korea starts 21(south)~25(north) June and ends 21~24 July with the duration about 29~31 days. The ratio of precipitation during the Changma to the annual varies between 13% (in east coastal area) and 32% (in inland). It ıpears that the location and strength of precipitation are related to the distribution of topography in Korean peninsula.

Distribution pattern of monthly mean global precipitation and OLR has been studied using the NECP precipitation data(1979-1995) and the OLR data(1979-1993) with putting emphasis on the watching the behavior of Changma in Korea. Frequencies of OLR data are filtered out using a Murakami bandpass filter. In general the filtered mode describes variability on the intraseasonal time-scale by changing sign about three or four times within a season. It indicates that most of the intraseasonal Changma variability is related to north/south propagating relative long/short wave, one over the equatorial Pacific and the other over the continent.

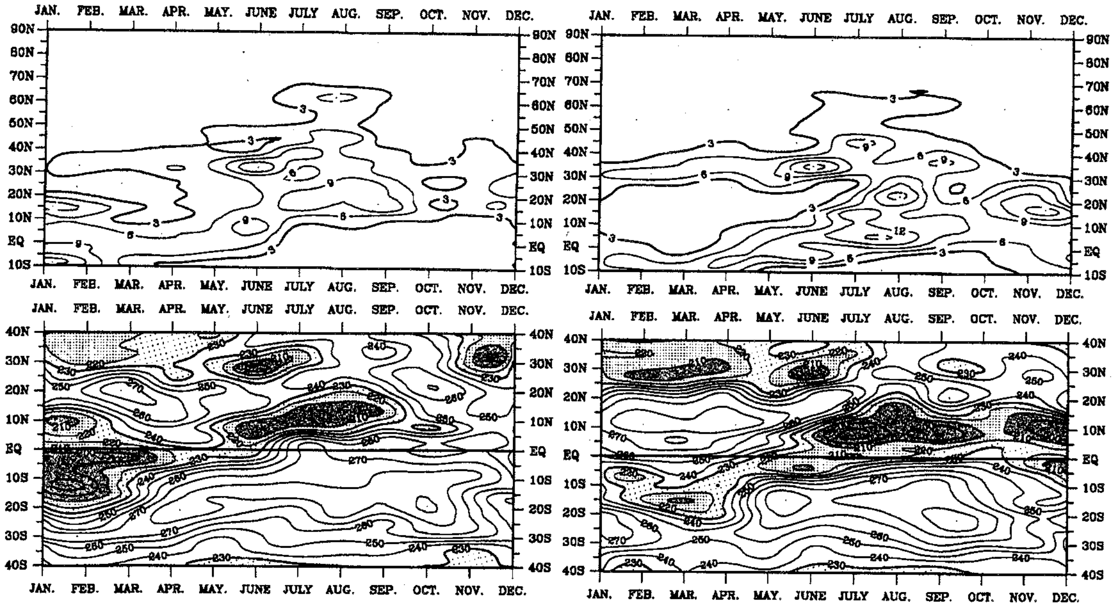

Fig. 4 The time variation of the amount of precipitation(top, mm/day) and OLR(bottom, W/m^2) in the area of 123.75°E-131.25°E for year 1982 (left)and 1983(right).

The above figures show mean precipitation between El-Niño years and normal years in the area of 123.73°E-131.25°E. The prominent features in El-Niño years are the expansion of dry period with the precipitation rate less than 3mm/day. In El-Niño years, the wet period with the precipitation rate more than 3mm/day near Korean Peninular(50° N - 65° N, 123.75° E - 131.25° E) and the dry period less than 3mm/day near north west Pacific(10° N - 30° N, 123.75° E - 131.25° E) tend to be longer than those in normal years.

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SENSIBILITY OF CIRRUS RADIATIVE FORCING TO CLOUD MICROPHYSICAL AND OPTICAL PROPERTIES

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1. Introduction

Cirrus clouds are believed in general to have potential 'warming' effect on the earth's system as that by greenhouse gases. However, the effect of cirrus clouds depends on the difference between reflective and absorptive properties of the clouds, which are relevant with cloud microphysical features and optical properties of cloud crystals. In this work, cloud radiative forcing (CRF) was estimated for cirrus clouds with various kinds of microphysical features that based on the field-measured results collected from ICE, EURCEX and FIRE (Koch, 1996; Gayet et al., 1996; Arnott et al., 1994) and with optically spherical and nonspherical ice crystals. Currently, there are several kinds of definition to CRF. The instantaneous cloud radiative forcing is chosen here and defined as changes in radaitive budget at the top of atmosphere due to the cloud effects.

2. Method

A cloud microphysics-radiation model is employed for this research. The evaluation of CRF is based on the same atmospherical fields and surface albedo.

Nonspherical shapes of ice crystals chosen in this work are hexagonal column and random fractals that both exist commonly in cirrus clouds. Previous research by Macke et al. (1996) indicates that the optical properties of the former, hexagonal column, could representative for those of all column type ice crystals. The polycrystals with highly complex shape denoted as fractals have smooth angular dependency and relatively large side scattering. The optical parameters of the nonspherical ice crystals are calculated by ray-tracking method.

Single-modal and bi-modal patterns of ice particle size distribution are considered for the estimation of CRF.

3. Results

It is found that pattern of crystal size spectrum (single-mode or bi-mode), shape of ice crystals (spherical or non-spherical), the mean size and concentration of ice crystals are the essential microphysical features of cirrus clouds influencing the cloud radiative forcing. It is also confirmed that the normal natural cirrus that with single-modal crystal size distributions and with relative large ice crystals have the positive cloud radiative forcing, i.e. the potential impact of greenhouse warming to the earth system. However, for contrail-induced cirrus with extreme microphysical features (i.e. with huge number of small ice particles), the cloud radiative forcing would be negative. It means that the contrail cirrus clouds have potential cooling effect on the earth system. It is also found that cirrus clouds with bi-modal size distribution of ice crystals tend to have less warming effect or even cooling effect when the second maximum mean size of ice particles are relatively large, comparing to single-modal size distribution of ice crystals with the same value of IWC. Cloud radiative forcing also depends greatly on the ice crystal shape (in this work, hexagonal column and random fractals). Since nonspherical ice particles have higher albedo effects, the radiative forcing of cloud containing nonspherical ice crystals is much lower than that with optically spherical particles. When the second maximum size is relative large (> 170 μm for IWC=10 mgm^{-3}), the radiative forcing of cloud with bi-modal size spectrum of nonspherical ice particles is negative.

4. Conclusions

The results of evaluating CRF in this work indicates that CRF is essentially sensitive to the pattern of the size distribution, mean size and shape of ice crystals. Cirrus clouds with large number of very small crystals (e.g. contrail cirrus) have 'cooling' potential impact to climate, in stead of 'warming' one.

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SEA ICE DRIFT IN THE BAY OF BOTHNIA: COMPARISON OF RESULTS FROM GPS DRIFTERS, ERS-2 AND RADARSAT SAR AND A NUMERICAL MODEL

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Abstract

Ice drift was measured with five GPS-drifters during the ZIP-97 campaign in March 1997 in the Bay of Bothnia. The data quality is quite good and the measurements provide an accurate information of ice mechanics on 10-20 kilometers spatial scale. The satellite observations of ice motion on the basin wide and intermediate scale derived from ERS-2 and RADARSAT SAR have obtained by NERSC. These data were used for the ice kinematics analysis and the comparison of model results.

A plastic ice model with 5 km fine grid resolution was used for the ice simulation. Thermodynamic part was neglected because our interest is in the ice dynamics. The observed characteristics of the pack ice were simulated realistically by the model. The ice was quite stationary near the fast ice zone, which indicated strong coastal alignment, whereas the ice outside showed substantial mobility. This feature was also resolved by the model. In addition, different ice rheologies and model parameters have been tested for this case. Comparison of model with ice displacements with sequential SAR data on the basin wide scale was also made, showing a good agreement.

SIMULATION OF ACTUAL EVAPOTRANSPIRATION AND RUNOFF FROM THE DAUGAVA RIVER BASIN

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Abstract

Total basin area of the Daugava River is 87900 km^2 (Figure 1). The mathematical model METQ96 is used for the simulation of actual evapotranspiration and runoff from the Daugava basin. METQ96 is a conceptual model for simulation ground and surface water flows, evapotranspiration, snow melt and related processes, including runoff routing. The model METQ96 has limited number of parameters which are estimated by calibration. The model is run on daily values of temperature, precipitation and air moisture. Meteorological data from 16 meteorological stations are used as input data to the model for simulations of the Daugava River basin. The model has been run for a 39 year period from 1956 till 1994.

For purpose of simulation the Daugava basin is divided into 22 subbasins. Thereafter, each subbasin is divided into large number of elemental basins according to the 5 types of land cover, differing by geological and geomorfological properties: agricultural lowlands, hilly agricultural land, forests, bogs and lakes. The division of each subbasin into the elemental basins is characterised by weight of 5 types of land cover in per cents. Evapotranspiration and runoff from each of the subbasins is calculated accordingly as the sum of evapotranspiration and runoff from all elemental basins.

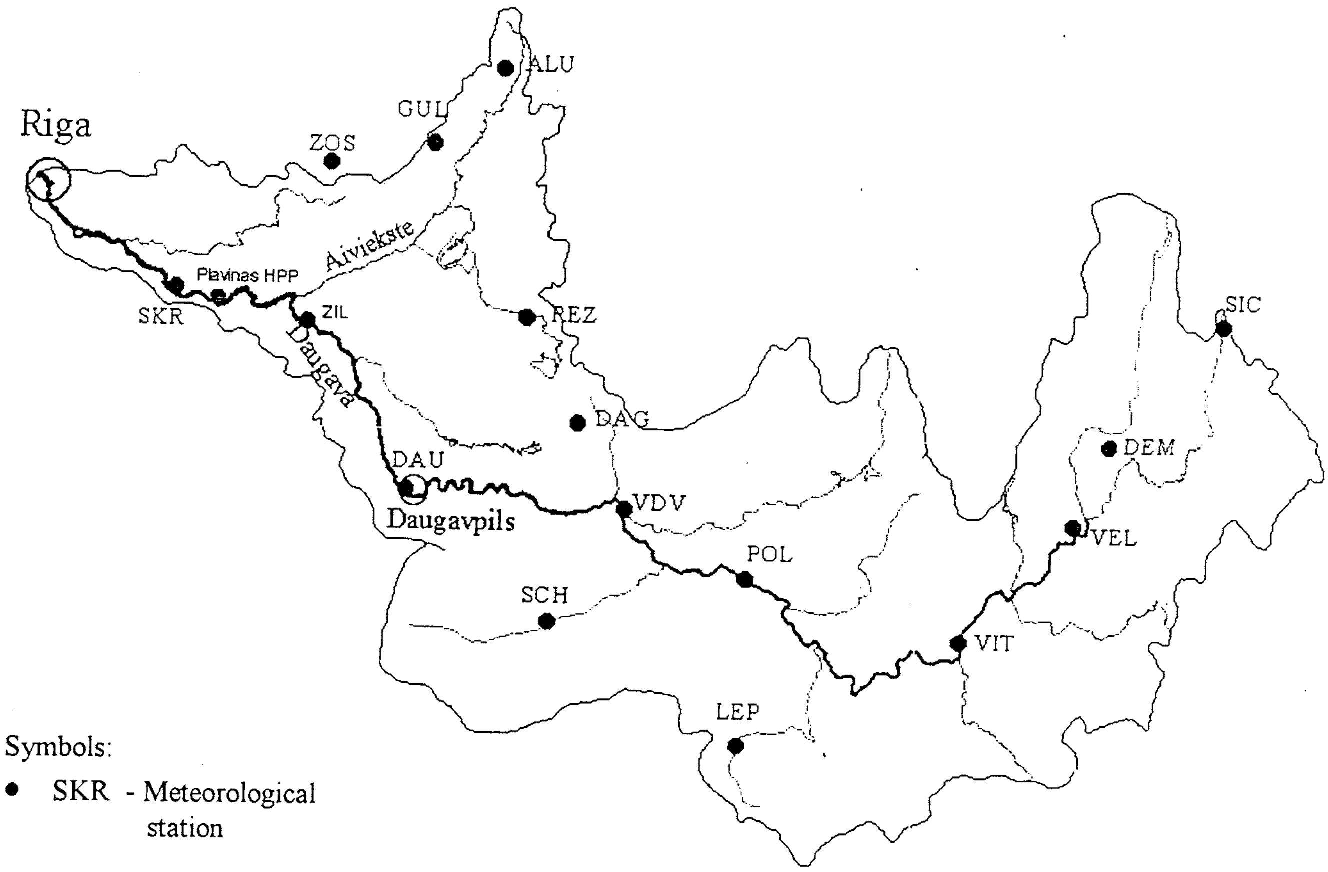


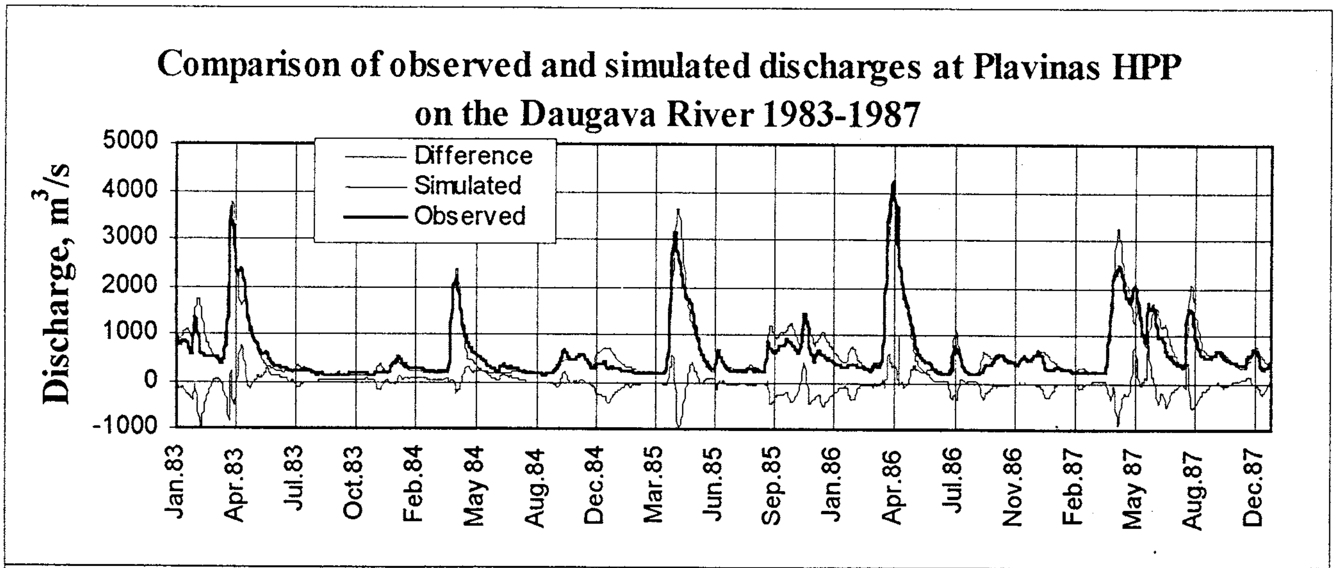
Figure 1. The scheme of the Daugava River basin.

The runoff from each of the subbasin then is routed through the channel. The channel routing for Daugava River is calculated by using linear reservoir model. The Daugava River channel is represented by a series of linear reservoirs. Different approach of runoff routing is used for the tributary Aiviekste. The peculiarity of the Aiviekste River is a very large flood-detention storage capacity. The equation which relates water storage in lowland S and outflow from lowland Q is derived. This equation is based on simulations by the hydraulic model.

The model METQ96 was verified on the base of daily discharge series from the Daugava stream gauging stations. The observed and computed hydrgraphs at Plavinas HPP (basin area 81300 km^2) for the period from 1984-1986 are shown at Figure 2. Deviations between observed and simulated discharges could be partly explained by insufficient meteorological input data to the model. Data from 16 meteorological stations can not well characterise spatial distribution of precipitation in 81300 km^2 large basin area.

Actual evapotranspiration from the Daugava River basin is calculated by simple approach assuming that evapotranspiration has linear relation with vapour pressure deficit. Evapotranspiration also depends from soil moisture content and groundwater level. Daily evapotranspiration values are used for the calculation of the latent heat flux. Simulated daily actual evapotranspiration values from the Daugava River basin are shown at Figure 2.

The results of the Daugava River basin simulation shows that the model METQ96 could be successfully used for the simulation of the actual evapotranspiration and runoff for large river basins.



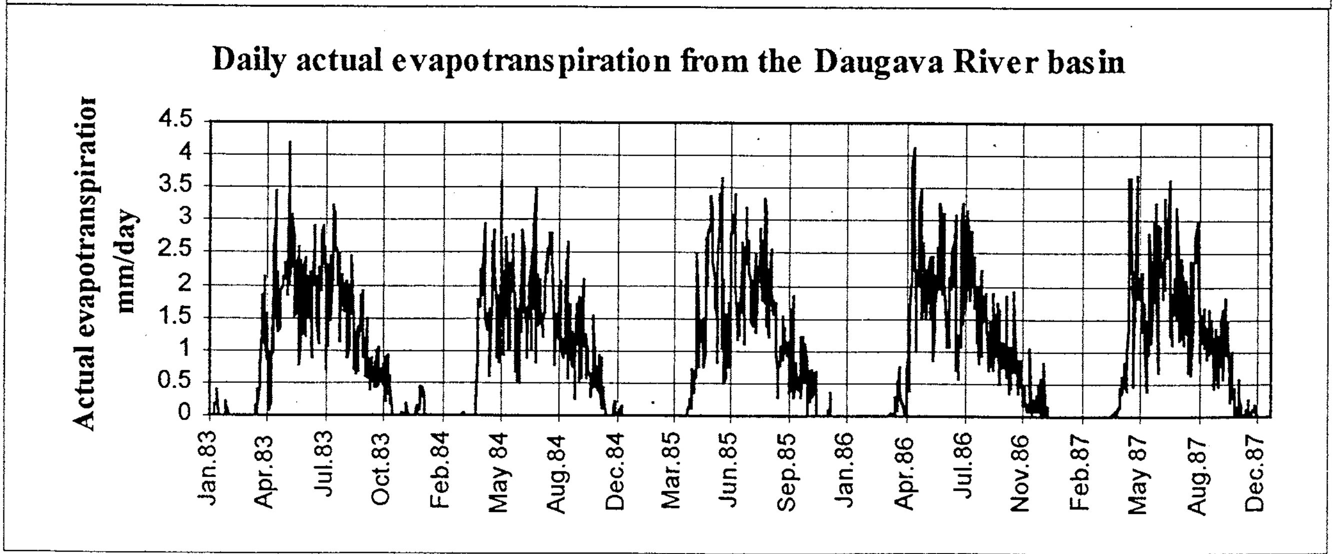


Figure 2. Simulation of actual evapotranspiration and runoff from the Daugava River basin 1984-1986.

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No. 1 : Minutes of First Meeting of the BALTEX Science Steering Group at GKSS Research Center in Geesthacht, Germany, May 16-17, 1994. August 1994.

No. 2 : Baltic Sea Experiment BALTEX - Initial Implementation Plan. March 1995, 84 pages.

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Copies are available upon request at the International BALTEX Secretariat.