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A New Tool for Coupled Simulations of the BALTEX Area: RCAO

Ralf Döscher *(ralf.doescher@smhi.se)*

H.E. Markus Meier *(markus.meier@smhi.se)*

Rossby Centre, Swedish Meteorological and Hydrological Institute SMHI, Norrköping, Sweden

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General

Coupled model systems covering ocean, ice, atmosphere, soil and rivers in the Baltic area open possibilities to assess coupled processes as well as transports of substances and energy within the system. Such a quantification of budgets of heat and freshwater is a major goal of BALTEX. Moreover, the performance of individual coupled component models such as ocean or atmosphere can be improved (compared to standalone runs with observed forcing) during the development process. Some model inaccuracies become apparent only in a coupled system. For long forecast or scenario experiments, coupling is mandatory. For these reasons, SMHI's Rossby Centre has developed an interactively coupled model, the Rossby Centre Atmosphere Ocean model RCAO.

The Coupled System RCAO

Since the Rossby Centre has been founded in 1997, state-of-the-art 3D models for atmosphere (RCA, Rummukainen et al., 2001) and ocean (RCO, Meier et al., 2002) have been developed. RCA includes a soil scheme and river runoff routing. RCO includes a dynamic-thermodynamic sea ice model. The coupling of both models is described together with a validation of fluxes and ocean quantities by Döscher et al. (2002). The coupled model domain covers the European continent and parts of the North Atlantic Ocean, the Nordic Seas and the Arctic (see Fig.1). Only the Baltic Sea is interactively coupled. Sea surface quantities outside the Baltic are given as one-way forcing, i.e. from observations or global models. In general, ocean surface quantities are passed to the atmosphere and atmosphere-ocean fluxes are returned to the ocean. Momentum is not yet fully flux coupled. Instead, 10-m wind velocities are passed and momentum fluxes are calculated in RCO.

The ocean and atmosphere models are coupled via the OASIS coupler. Both components run as individual executables synchronized by the third executable OASIS. The system is about to be ported to the standard message passing interface MPI-1. Due to this standard, RCAO can be used on a wide range of parallel computers including Linux clusters. The future development of cou-

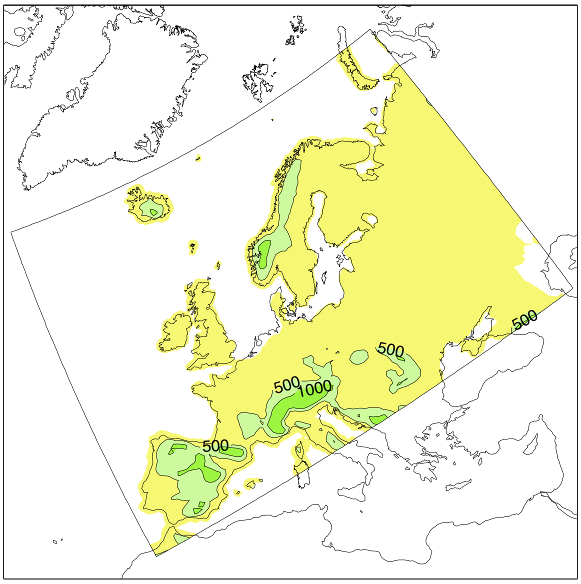

Figure 1: *RCAO model domain for hindcast runs, covering most of Europe and parts of the North Atlantic Ocean and Nordic Seas. Only the Baltic Sea is interactively coupled.*

pling techniques and algorithms will closely follow the standards set by the EU project PRISM (*Programme for integrated earth system modelling)*, where RCAO is represented as a regional component. PRISM aims at facilitating coupling of different components of the earth system, including regional-to-global coupling.

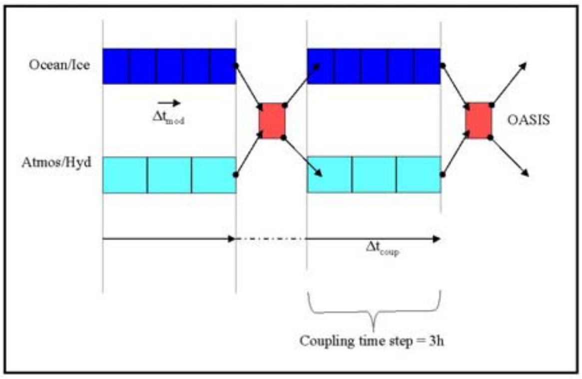

Figure 2: *The coupling scheme of RCAO. Atmosphere and ocean run in parallel.*

The coupling scheme in Fig. 2 illustrates the time sequence of interaction between atmosphere and ocean. Ocean and atmosphere run in parallel. After running through a coupling time step of 3 h, information is exchanged via the coupler. Diurnal cycles are represented. Ocean and atmosphere are forced with fields from the preceding coupling time step. All fluxes are averaged.

Applications

A 5-year verification run has been carried out, forced by ERA-15 data at the lateral boundaries of the atmosphere model. Results are presented by Döscher et al. (2002). Sea surface temperature matches observations very well, while the sea ice extent is somewhat overestimated due to a bias in longwave downward radiation (see Fig. 3). Shortwave and sensible heat flux fit fine with observations. Latent heat flux shows an overestimation in fall. Overall, the accuracy of fluxes is considered state-of-the-art. The system is free of drift, does not need flux corrections and is suitable for multi-year climate runs.

The cycles of heat and freshwater in the validation run have been analysed by Meier and Döscher (2002). Annual mean heat fluxes through the ocean-atmosphere interface nearly balance each other (shortwave 105 Wm^{-2}, longwave -53 Wm^{-2}, sensible -10 Wm^{-2}, latent -41 Wm^{-2}). That finding is in agreement with other studies, either model or observation based. In comparison with an associated standalone ocean run, forced by observations, the amplitude of the seasonal cycle of heat in RCAO is increased. This can be attributed to the above mentioned deficiencies in the coupled downward longwave radiation and latent heat flux (see Fig. 3). Despite these differences, horizontal annual and seasonal mean heat flux patterns are similar in the standalone ocean and the coupled ocean. The mean seasonal cycle of freshwater is simulated realistically. Ocean dynamics have a quite large impact on horizontal mean heat and freshwater flux patterns. These patterns are similar in the coupled and uncoupled ocean. 5 years of integration time is considered rather short for a stable balance. Longer coupled hindcast runs will need to be done.

SweClim **Newsletter on Internet at**
http://www.smhi.se/sgn0106/rossby/sweclim/nyhetsbrev.htm

RCAO is currently applied to control and scenario climate runs based on global model simulations from Hadley Centre HC (HadAM3) and DMI/MPI (ECHAM/OPYC3), each 30 years long. The control runs show generally realistic means for ocean and atmosphere surface quantities. First results are published in the SweClim Newsletter No. 12, June 2002. The mean SST is realistic. The associated scenario runs (A2 scenarios) give a distinct reduction of sea ice extent. However ice-free winters have not been found.

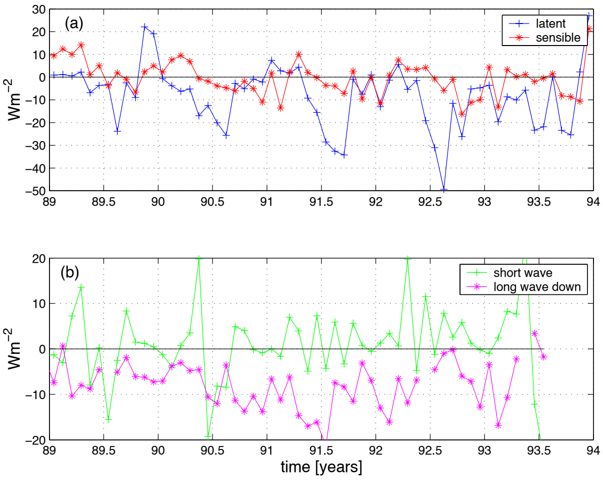

***Figure 3**: Monthly mean average latent /sensible heat flux error (a) for the Baltic Sea: difference between the coupled model and daSilva observation. Monthly mean heat flux error of shortwave and longwave radiation (b), estimated by comparison with land stations: 11 stations from the SMHI network for shortwave and 3 stations from the SMHI network together with 3 stations from the Global Energy Balance Archive (GEBA).*

These Rossby Centre control and scenario runs are part of an ensemble of model runs carried out by the EU project PRUDENCE (*Prediction of regional scenarios and uncertainties for defining European climate change risks and effects*) in order to quantify the uncertainty of predictions of future climate. RCAO will be further developed during the forthcoming years at the Rossby Centre.

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Modelling Baltic Sea Climate for the Period 1902-1998

H.E. Markus Meier *(markus.meier@smhi.se)*
Rossby Centre, Swedish Meteorological and Hydrological Institute SMHI, Norrköping, Sweden

Frank Kauker *(fkauker@awi-bremerhaven.de)*
Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

Introduction

In cooperation between the Rossby Centre at the Swedish Meteorological and Hydrological Institute and the Alfred Wegener Institute for Polar and Marine Research, the decadal variability of the Baltic Sea system has been investigated. The work is part of the Swedish Regional Climate Modelling program (SWECLIM). Sensitivity experiments for the period 1902-1998 have been performed using a 3D coupled ice-ocean model for the Baltic Sea. The model used is the Rossby Centre Ocean model RCO (Meier, 2001; Meier and Faxén, 2002; Meier et al., 2002). The atmospheric forcing for this period has been reconstructed utilizing a statistical model (Kauker and Meier, 2002). The following questions have been addressed:

- Is the performance of 3D general circulation models good enough to perform 100-year simulations of the Baltic Sea?

- Is the quality of the reconstructed atmospheric data set sufficient to model climate and decadal variability of the Baltic Sea?

- What is the reason for the decreased frequency and intensity of major saltwater inflows since the mid-1970s? In general, what is the influence of salt- and freshwater inflows on decadal variability of salinity in the Baltic Sea ?

Atmospheric Forcing

Whereas 100-year long records of river runoff and sea level data in the Kattegat are available, an observational data set of atmospheric surface fields applicable to force a coupled ice-ocean model of the Baltic Sea is missing. High resolutions in space and time are required. Therefore, we developed a statistical model using a Redundancy Analysis to reconstruct daily sea level pressure (SLP) and monthly surface air and dew-point temperature, precipitation, and cloud cover fields on a 1°×1° regular horizontal grid for the Baltic Sea region. A gridded atmospheric data set based on synoptic stations, which is available for the period 1970-1998, is used as input to the statistical model to calculate redundancy modes. The predictor fields are depending on the predictand variables: 100-years of SLP at 18 positions, 100-years of sea-surface air temperature on a 5°×5° regular horizontal grid, and 100-years of precipitation on a 2.5°×3.75° regular grid. Spatial patterns are selected by maximizing predictand variance during the 'learning' period 1980-1998. The remainder period 1970-1979 is used for validation. The statistical model works reasonable well for all variables. We found the highest skill for SLP and the lowest skill for cloud cover.

Model Validation

RCO has been integrated for the period 1902-1998 starting from observed initial conditions. We found good results for simulated sea levels, salinities, saltwater inflows, and sea ice coverage. Figure 1 shows the time evolution of a vertical salinity profile in the eastern Gotland Basin. The minima of lower layer salinity during the 1930s and during the 1990s and the pronounced maximum during the 1950s are simulated correctly. Even individual major saltwater inflows are reproduced well, e.g. the events in November / December 1951 and in January 1993. The halocline depth is somewhat underestimated compared to observations and simulated decadal variations are smaller than observed.

Annual mean net precipitation, i.e. precipitation minus evaporation, is shown in Figure 2. For the period 1902-1998, it amounts to 2,030 m^3s^{-1}. The inter-annual variability is large with a minimum of -384 m^3s^{-1} (1975) and a maximum of 3,917 m^3s^{-1} (1981). This result is somewhat higher compared with earlier results by Rutgersson et al. (2002). For the period 1901-1998, they found a long-term average value of 1,152 m^3s^{-1} using a linear regression relationship between net precipitation, river runoff and maximum ice extent. The difference between the two estimates is of the order of the estimated bias (Rutgersson et al., 2002).

In Figure 3, the simulated freshwater storage anomaly is shown. Our results are very similar to freshwater storage calculated from observations by Winsor et al. (2001). We also found that the freshwater storage anomaly and the accumulated freshwater inflow are well correlated.

Sensitivity Experiments

A series of sensitivity experiments have been performed to answer the question what causes the observed decadal variability of salinity in the Baltic Sea. In a **first experiment**, a run with climatological monthly mean river runoff and precipitation of the period 1902-1970 was conducted. The mean seasonal cycle does not include river regulation as the construction of dams in Sweden and Finland became conspicuous since the 1970s. The variability of the freshwater content is clearly reduced showing the important impact of runoff variations on decadal time scale. However, there is still significant decadal variability left in the system which can only be explained by saltwater inflow variations. In a **second sensitivity experiment**, additionally the daily SLP fields are high-pass filtered with a cut-off period of four years. Consequently, decadal variability of the surface wind fields is not considered. In this experiment most of the simulated freshwater content variability is removed (Figure 3). A **third sensitivity experiment** was performed with a series of random years for SLP, surface wind and sea level in Kattegat but with observed freshwater inflow, i.e. saltwater inflows occur randomly in time but with the statistics for the period 1902-1998. The results confirm that the accumulated freshwater inflow can modify the intensity of occurring saltwater inflows significantly. Increased runoff and precipitation hamper mainly the saltwater transport through Bornholm and Stolpe Channel whereas the transport through the Danish Straits is relatively less affected. The role of river regulation is addressed by **a fourth sensitivity experiment** for the period 1942-1998 with climatological monthly mean river runoff and precipitation of the period 1902-1970 and observed inter-annual variability, i.e. the positive trend of winter runoff is removed and a mean seasonal cycle of natural river discharge is applied. This experiment showed that river regulation has almost no impact on Baltic Sea salinity. During the 1920s and during the 1980s runoff, precipitation, and westerly winds in the Baltic proper were larger than the climatological mean. In accordance with the results found by Meier et al. (2002) increased wind speed does not significantly change the intensity of a major Baltic inflow or the deepwater flow between Arkona Basin and Bornholm Basin. However, the entrainment of the deepwater flow through the Stolpe Channel is significantly reduced and the volume of high saline water in the Gotland Basin decreases causing a stagnation period.

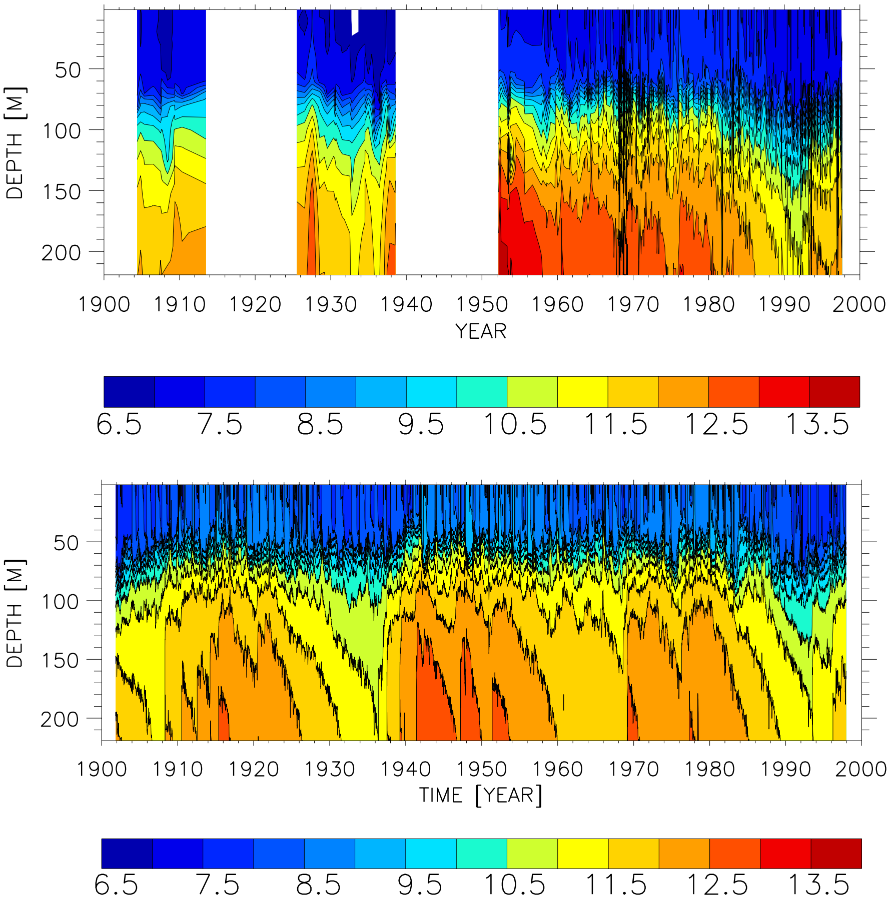

Figure 1*: Isohaline depths (in psu) in the eastern Gotland Basin (BY15): (top) observations and (bottom) model results. Observations are not available for periods covering the world wars.*

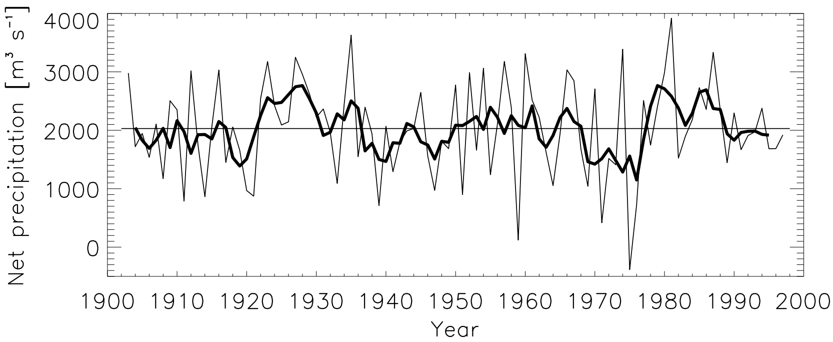

Figure 2*: Annual mean net precipitation (in* $m^3 s^{-1}$ *) to the Baltic Sea. In addition, the 4-year running mean (thick line) and the total mean for the period 1902-1998 (horizontal line) are shown.*

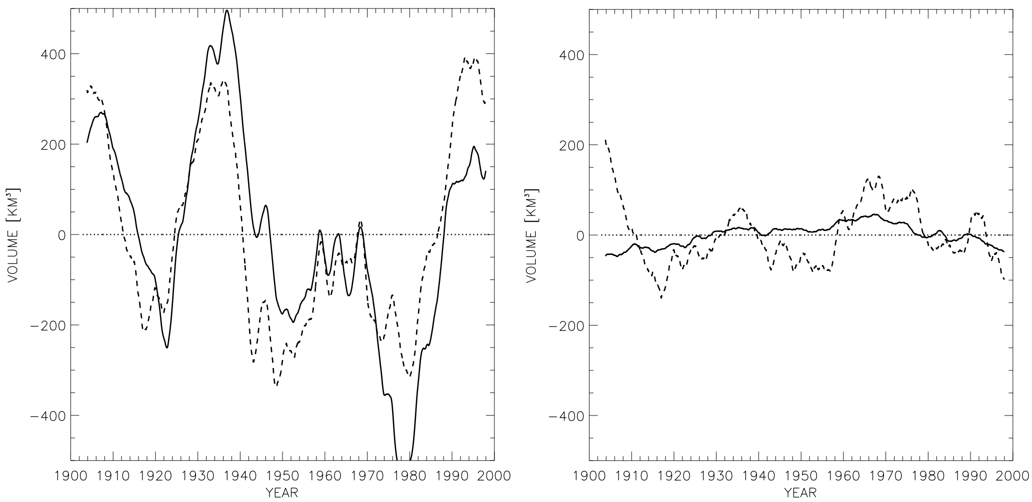

Figure 3*: 2-year running mean of accumulated river runoff and net precipitation anomaly and 2-year running mean of freshwater storage anomaly (in* km^3*): (a) reference experiment (left), (b) as (a) but with climatological monthly mean river runoff and precipitation of the period 1902-1970, and with 4-year high-pass filtered SLP and corresponding surface wind (right).*

A detailed description of the results of the sensitivity experiments is given by Meier and Kauker (2002).

Conclusions

1) Baltic Sea climate of the period 1902-1998 is simulated realistically with RCO. The reconstructed atmospheric forcing data have high quality.

2) The total mean salinity of the Baltic Sea amounts to about 7 psu. Decadal variations are of the order of 1 psu. No long-term trend is found during the century.

3) About half of the decadal variability of Baltic Sea salinity is related to the accumulated freshwater inflow.

4) The second half of the decadal variability of mean salinity is related to decadal variations of the volume transports through Stolpe Channel caused by the low-frequency variability of the SLP over Scandinavia. Stronger westerly winds cause increased eastward surface-layer transports. Consequently, the mean eastward lower-layer transport through the Stolpe Channel is reduced. Thus, the entrainment of the deepwater flow between Bornholm Basin and the eastern Gotland Basin decreases.

5) If river regulation is assumed to change the discharge seasonality but not accumulated runoff on decadal time scale, the impact of river regulations on Baltic Sea variability is negligible.

6) The decadal variability of fresh- and saltwater inflows are correlated and closely linked to the large-scale atmospheric circulation.

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Numerical Simulation of the Geographical Sources of Water for BALTEX Precipitation

Michael G. Bosilovich, *NASA Goddard Space Flight Center / Data Assimilation Office, Greenbelt, MD, USA (mikeb@dao.gsfc.nasa.gov)*

Yogesh Sud*, NASA/Climate and Radiation Branch, Greenbelt, MD, USA*

Siegfried D. Schubert*, NASA/Data Assimilation Office, Geenbelt, MD, USA*

Gregory K. Walker*, NASA/Climate and Radiation Branch, Greenbelt, MD, USA*

Koster et al. (1986) used passive tracers to follow incoming atmospheric water from surface evaporation through the atmosphere, until it was precipitated. In this way, the geographical source of water for all precipitation could be identified. While these simulations were very coarse (8°×10°) and of short duration (only one season long), the work demonstrated a methodology of numerical calculation of the local and remote sources of precipitation within the model's simulation. In this methodology, each source requires a new three-dimensional prognostic array in the General Circulation Model (GCM), which is often not feasible with limited computational resources. Since that study, the tracer methodology has seen limited use (Druyan and Koster,1989, and Numagati, 1999). In recent years, there has been increasing focus on the atmospheric water cycle, especially with respect to the intensity and climate change of the regional water cycle (Morel, 2001). The water tracers provide a diagnostic link between evaporation, precipitation, moisture transport and the timescale that water resides in the atmosphere.

Recently, we have adapted the passive tracer methodology to the NASA Data Assimilation Office (DAO) Finite Volume GCM (FVGCM) to simulate the movement of regional sources of water (following Koster et al, 1986; and documented by Bosilovich and Schubert, 2002, in the NASA

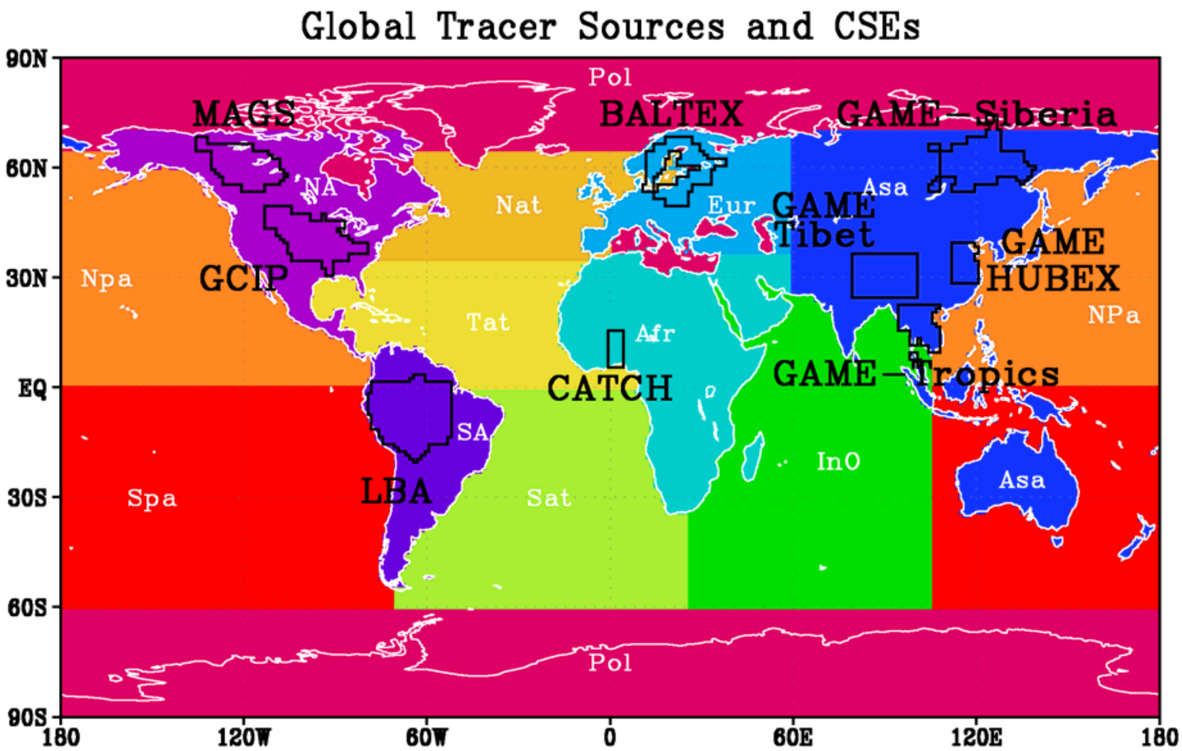

Figure 1: *Colored regions indicate the large-scale source regions for each of 12 WVTs. The Sources are NA, North America; Sam, South America; Eur, Europe; Afr, Africa; AsA, Asia-Australia; Npa, North Pacific; Spa, South Pacific, Nat, North Atlantic; Tat, Tropical Atlantic; INO, Indian Ocean and Pol, Polar (both north and south are included in one WVT for convenience). The area of each CSE is outlined on the map, and is based on Roads et al. (2002).*

NASA GEOS GCM). These passive tracers are termed Water Vapor Tracers (WVTs) because they simulate the model's water vapor prognostic variable at the model time step. The model dynamics and physics compute tendencies for the WVT in proportion to the model's water vapor. While the WVTs evolve according to the model dynamics and physical parameterisations, they are entirely passive, in that they do not affect the simulated hydrological cycle. Evaporation within a limited region is used as the source for a WVT. Figure 1 identifies 12 large-scale regions and each region represents a continental or oceanic source of water, in the form of evaporation, to the atmosphere. Following Bosilovich and Schubert (2002), we can diagnose the amount and location of precipitation that falls because of evaporation from each region.

The FVGCM uses semi-Lagrangian advection that is particularly useful for tracer calculation (Lin and Rood, 1996). The model uses the NCAR CCM3 physical parameterisations. We have run the FVGCM at 1°×1.25° resolution for 15 years using real time varying SSTs from 1986-2000. In this paper, we present the simulation of large-scale continental and oceanic sources of water to precipitation in BALTEX, and compare it to other high latitude GEWEX Continental Scale Experiments (CSEs). In a recent GEWEX new letter article, we review briefly all the CSEs (Bosilovich et al. 2002). The area of each CSE is defined identically to Roads et al (2002) (Figure 1).

Figure 2 shows the mean annual cycle of water sources for BALTEX, MAGS and GAME Siberia CSEs. In BALTEX, the dominant sources of water for precipitation are the North Atlantic Ocean (winter) and Europe continental (summer). While this makes qualitative sense, the WVT diagnostics permit quantitative evaluation. Further, we can identify other subtle tendencies in the circulation. For example, in late summer, 15 % of BALTEX precipitation originates as evaporation from continental North America. A regular source of water comes from the Tropical Atlantic Ocean.

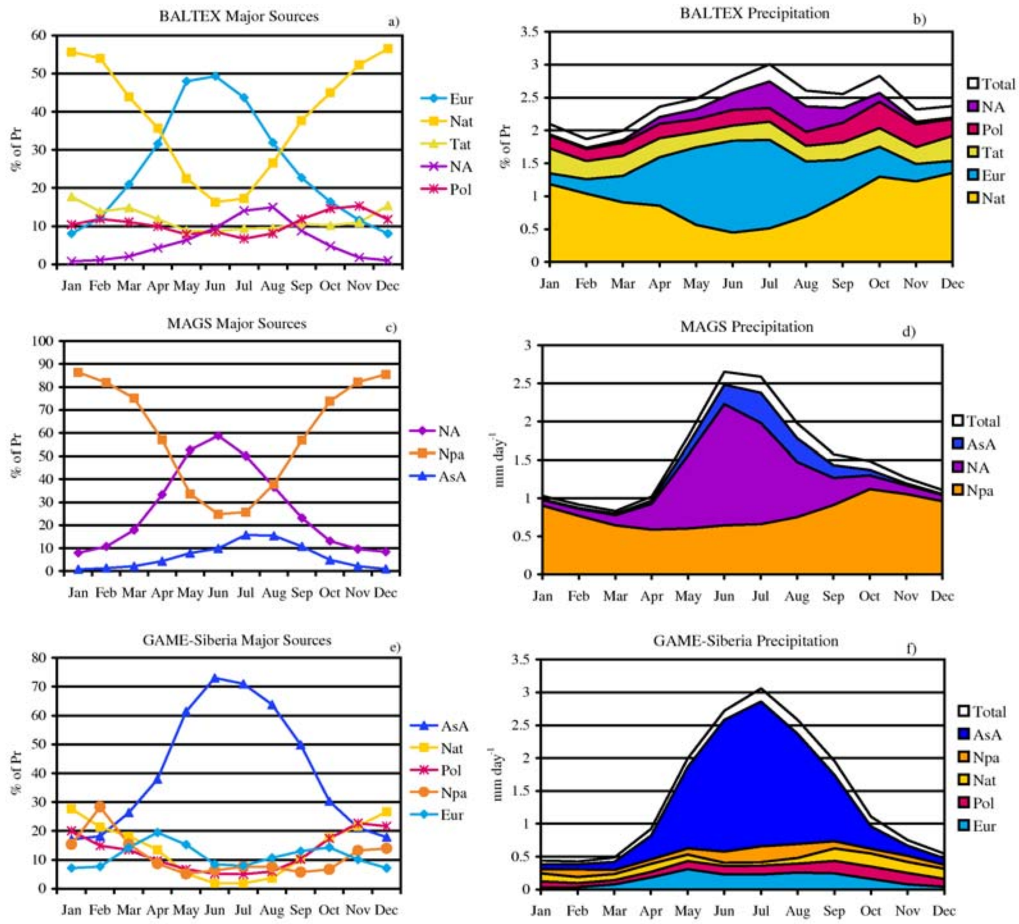

Figure 2: *Mean annual cycle of the dominant sources of water that occurred as precipitation in each of the CSEs. Percent contributions to BALTEX, MAGS and GAME Siberia (a, c, e respectively), and actual contributions in mm day^{-1} (stacked atop each other) with total precipitation (b, d, f respectively). Colours correspond to the geographical regions in Figure 1.*

MAGS contrasts BALTEX in that the amplitude of the annual cycle of precipitation is somewhat stronger. This is related to the increase of continental sources in late spring and early summer. In addition, the Asian continent contributes some precipitation to MAGS in late summer. The GAME Siberia CSE sources are predominantly continental. The sources from Europe increase in late spring until autumn. In order to identify the original oceanic source of the water, the land parameterisation would also need to delineate different sources of water (e.g. Numagati, 1999).

Precipitation recycling is defined as the amount of water that evaporates from a region that precipitates before leaving that region. Because BALTEX is not one of the specified source regions, its recycling cannot be determined quantitatively in this simulation. However, Europe is a source region (Figure 1), and the precipitation recycling in Europe can be computed. Figure 3 shows the mean annual percentage of precipitation that is recycled in Europe. The maximum occurs in June and the minimum occurs in December and January. While these values are essentially exact in the model integration, there are some uncertainties based on the methodology.

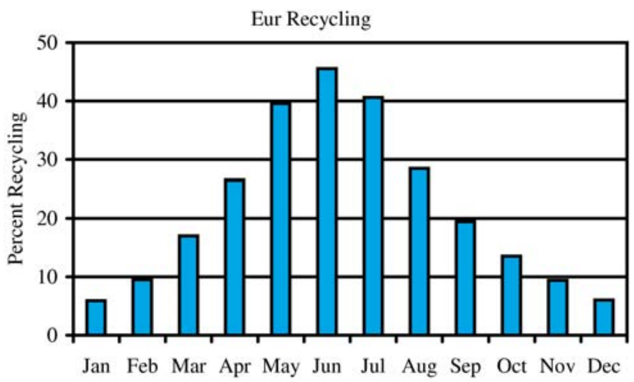

Figure 3: *Mean annual cycle of precipitation recycling in Europe (percent).*

For example, water that evaporates from the British Isles and precipitates over mainland Europe would still be considered recycled. Likewise, one must consider that this is a numerical simulation, and the data are subject to model and parameterisations uncertainties.

The WVTs provide a diagnostic tool to evaluate the hydrologic cycle in atmospheric numerical models. The diagnostic considers the instantaneous evaporation and precipitation rates as well as transport processes. Such diagnostics should be useful in evaluating the water cycle of extreme conditions such as flood and drought, as well as the intensity of regional water cycles in climate change experiments. Of course, the quality of the WVT diagnostics depends on the veracity of the GCM simulation. At present, we are implementing the WVT diagnostics in the NASA DAO Data Assimilation System to evaluate real data case studies and the impact of water vapour assimilation on the hydrologic cycle. These diagnostics may be useful in other studies, such as synoptic meteorology, mesoscale meteorology and paleoclimatology. It may also be possible to validate the WVT diagnostic data with precipitation isotope data.

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Use of Bulk Richardson Numbers to Determine the Height of the Marine Atmospheric Boundary Layer

Sven-Erik Gryning *(sven-erik.gryning@risoe.dk)*
NOPEX Representative at the BALTEX SSG,
Wind Energy Department, Risø National Laboratory, Roskilde, Denmark

Ekaterina Batchvarova
National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences, Sofia, Bulgaria

Summary

Based on measurements at Christiansø and simulations with the HIRLAM model it is found that critical Richardson numbers for the height of the marine atmospheric boundary layer are smaller than over land - we found critical Richardson numbers around 0.03 to 0.05 to perform best over the Baltic Sea.

Introduction and Theory

The height of the marine atmospheric boundary layer is important for several reasons, which are central to the scientific objectives of BALTEX. The water that evaporates from the sea surface into the atmosphere is dispersed vertically through the action of turbulence and becomes mixed over the whole atmospheric boundary layer. Because the top of the boundary layer to a high degree acts as a lid, it is one of the parameters that controls the water content in the marine air, and therefore has a feed back on the evaporation from the water surface. The marine atmospheric boundary-layer depth influences the formation of clouds and therefore is important for predictions of climate variability and change.

Typical output from Climate and Numerical Weather Prediction models consists of coarse hourly profiles of wind, temperature and humidity on a rough vertical and horizontal grid. The height of the atmospheric boundary layer does not form a part of the output, but has to be estimated from the available output data, usually by use of bulk Richardson numbers, that vary in their definition. Starting at the lower model level the bulk Richardson number is determined at successively greater heights by use of linear interpolation between adjacent model levels. The boundary layer top is assigned to the height where the

Richardson number exceeds a given value - the so-called critical Richardson number.

Sørensen (1998) suggests the bulk Richardson number for the layer between the surface and the height z above the surface:

$$Ri_B = \frac{g\,z(\theta(z)-\theta(s))}{\theta(s)(u(z)^2+v(z)^2)} \quad (1)$$

The quantities $\theta(s)$ and $\theta(z)$ are the potential virtual temperatures at the surface (by *Sørensen* (1998) taken as the lowest model level) and height z, respectively, $u(z)$ and $v(z)$ are the horizontal wind components at height z, and g is acceleration due to gravity. *Vogelezang and Holtslag* (1996) suggest a Richardson-number where the wind is defined with respect to the lowest model level (typically 30 m), and a term that accounts for surface friction has been added:

$$Ri_B = \frac{g\,z(\theta(z)-\theta(s))}{\theta(s)\left[(u(z)-u(s))^2+(v(z)-v(s))^2+bu_*^2\right]} \quad (2)$$

where b is a parameterisation constant, recommended to be 100. Originally the critical Richardson-numbers for both methods are determined from measurements of the height of the boundary layer over land. For both methods the critical Richardson number is taken as 0.25.

The expressions treat the wind-velocity influence differently. In equation (1) the wind speed is taken at the given height. Equation (2) applies the difference between the lowest model level and the actual height, and the surface boundary layer is accounted for through an additional friction-velocity term. This term can be large compared to the wind-profile contribution. Then the boundary-layer height is determined mainly from the temperature profile and the friction velocity. Over water owing to the small roughness length the wind speed is typically high with small friction velocity. Hence over water the Richardson number suggested by *Sørensen* (1998) would tend to predict a higher boundary layer as compared to the Richardson number suggested by *Vogelezang and Holtslag* (1996).

Measurements

For this study we used radio soundings of the marine atmospheric boundary layer that were carried out on Christiansø, a small island in the southern part of the Baltic Sea (Figure 1). The measurements were a part of the EU-funded project *Pilot Study on Evaporation and Precipitation over the Baltic Sea* (PEP-in-BALTEX).

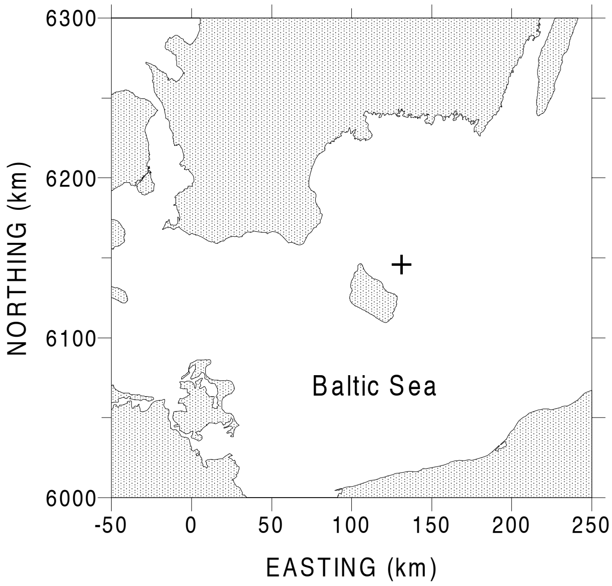

Figure 1: *Map of the southern part of the Baltic Sea with land surfaces dotted. Bornholm is the island in the centre. The cross shows the location of Christiansø east of Bornholm. Co-ordinates refer to UTM34.*

During an observation period from 24 October to 5 November 1998 a total of 24 radio soundings were performed at Christiansø. Here we only consider the measurements from the part of the period with northerly wind - 30 October to 3 November 1998. The air that reached Christiansø had a water fetch to the nearest coast of about 100 km. The meteorological conditions were characterised by heat flux from the sea to the atmosphere, creating an unstable atmospheric boundary layer over the sea. Gryning and Batchvarova (2002) give details. The development of the marine atmospheric boundary layer was inferred from the air temperature and humidity radiosonde profiles.

Modelling

Both Richardson-number methods were used to extract the marine atmospheric boundary-layer height over Christiansø from hourly output of the Numerical Weather Prediction model HIRLAM. Gryning and Batchvarova (2002) found for the experiment at Christiansø that the Richardson number of *Sørensen* (1998) is systematically higher than for *Vogelezang and Holtslag* (1996), and their critical Richardson numbers predicts marine atmospheric boundary layers over Christiansø that are higher than the measured ones. This suggests, considering the low roughness of the sea surface, that there is dependence between the surface roughness and the critical Richardson-numbers and that the dependence is not the same for the two Richardson-numbers. The critical Richardson number that gave the overall best fit to the measurements of the marine atmospheric boundary layer height was found to be 0.03 for the method suggested by *Sørensen* (1998) and 0.05 for *Vogelezang and Holtslag* (1996). This is illustrated in Figure 3 where it also is evident that the *Vogelezang and Holtslag* (1996) method for this limited set of measurements gives a slightly better overall fit than *Sørensen* (1998).

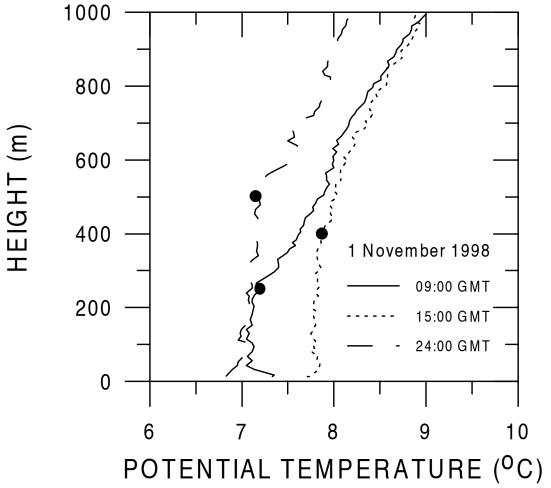

Figure 2: *Examples of radiosonde profiles of potential temperature on November 1, 1998. Bullets indicate the subjectively estimated boundary-layer heights.*

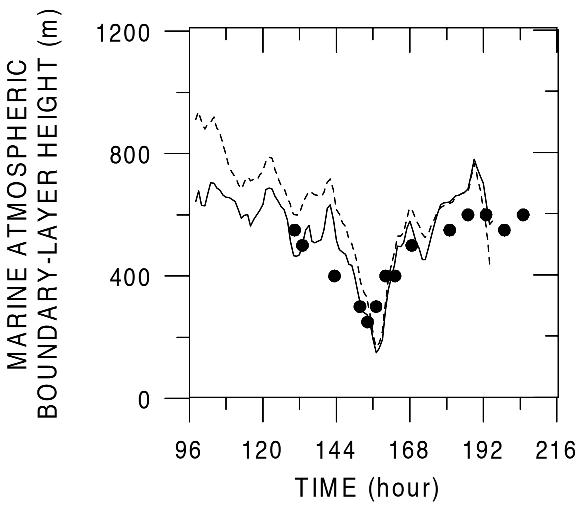

Figure 3: *Height of the marine atmospheric boundary layer during the part of the observational period with northerly wind. The dashed line illustrates the boundary-layer height predicted by the method of Sørensen (1998) when applying a critical Richardson number of 0.03, the full line shows the predictions of the Vogelezang and Holtslag (1996) with a critical Richardson number of 0.05. Bullets show measurements. On the x-axis, hour 96 and 216 corresponds to midnight 29/30 October and 3/4 November 1998 respectively.*

It is a pleasure to acknowledge fruitful co-operation with Anna Rutgersson and Ann-Sofi Smedman. We thank the Swedish Meteorological and Hydrological Institute for the data from the HIRLAM simulations. The project was supported by the European Union (ENVC4-CT97-0484).

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Soil Moisture Detection From Satellite

Ralf Lindau *(rlindau@uni-bonn.de)*

Clemens Simmer *(csimmer@uni-bonn.de)*
Member of BALTEX SSG, both at Meteorological Institute, University of Bonn, Germany

Tamara Mikhnevich*, Republikan Hydrometeorological Centre, Minsk, Belarus*

The study of regional process in the Baltic Sea region is a major research area within DEKLIM (German Climate Research Program), accomplished by eight project consortia. One of it, BALTIMOS (BALTEX-Integral Model System) aims at the development and validation of a coupled model system in the Baltic Region. A central scientific task within this project will be the coupling of the atmospheric model REMO with a hydrological surface model. For the validation of the surface model and its coupling, long-time satellite microwave measurements from the Scanning Multichannel Microwave Radiometer (SMMR) will be used, containing area-covering information about the parameters which are important for the interaction between soil and atmosphere. These data is globally available for the period 1978 to 1987 so that in a first step an uncoupled 10-years climate run of REMO (1979 to 1988) will be examined, in order to assess the quality of the surface modelling at the begin of this project.

However, no commonly accepted algorithm for retrieving the soil moisture from satellite observations exists so far. Other problems arise due to the low spatial resolution of the satellite sensor. The footprint of the lowest microwave channel (6.63 GHz), which contains the major soil moisture information, has a size of about 100 by 150 km so that small scale moisture features are missed.

Therefore, direct ground measurements from 21 stations in Belarus are used to investigate the temporal and spatial structure of soil moisture and to determine the potential of satellite observations, by comparing satellite and ground measurements. The direct soil moisture measurements have a temporal resolution of ten days and cover a period from a few years at most stations up to twenty years available at two stations.

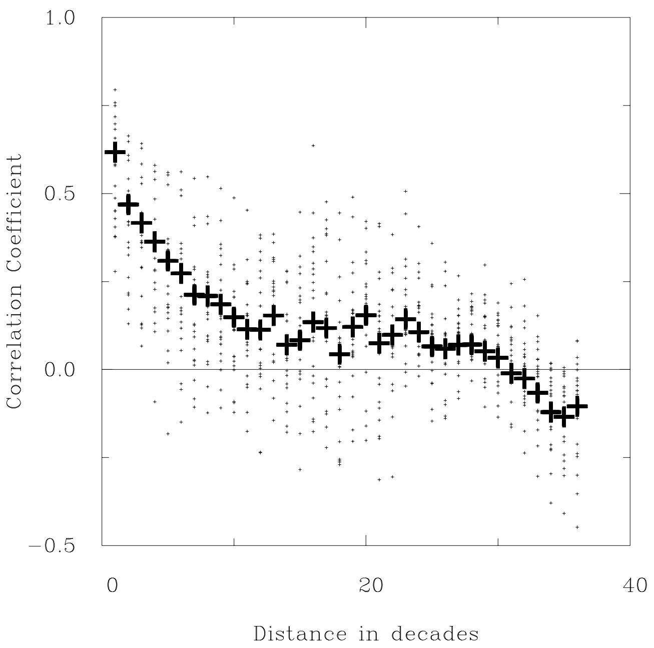


Figure 1: *Autocorrelation between soil moisture measurements in Belarus as a function of temporal separation. Small crosses depict the temporal correlation at individual stations, the larger crosses give the overall value.*

From these data the memory function of soil moisture is estimated by calculating the temporal autocorrelation for fixed positions (Figure1). For time differences of 10 days a correlation of 0.62 is obtained, decreasing to 0.31 for 50 days. Fitting an exponential function yields a temporal correlation length of about 60 days. Considering the spatial correlation at fixed time, performed by the comparison of corresponding measurements at different stations, shows correlation coefficients of about 0.5, strongly varying from station pair to station pair (not shown). A decrease for distances between 30 km, which is the closest distance of two stations, and 300 km is hardly perceptible. This indicates already that a considerable fraction of the soil moisture variability occurs on smaller scales.

When the total number of 21 stations is grouped into four clusters comprising between three to seven stations, each cluster covers an area comparable to the size of an SMMR pixel. Averaging the soil moisture measurements within the clusters reduces the total variances by more than 40%, showing that this fraction of the total variance is caused by small scale variability. Thus, satellite observations are only able to explain less than 60% of the soil moisture variance, just due to the low resolution. Consequently, the correlation coefficient between individual observations from space and from ground cannot be higher than 0.75.

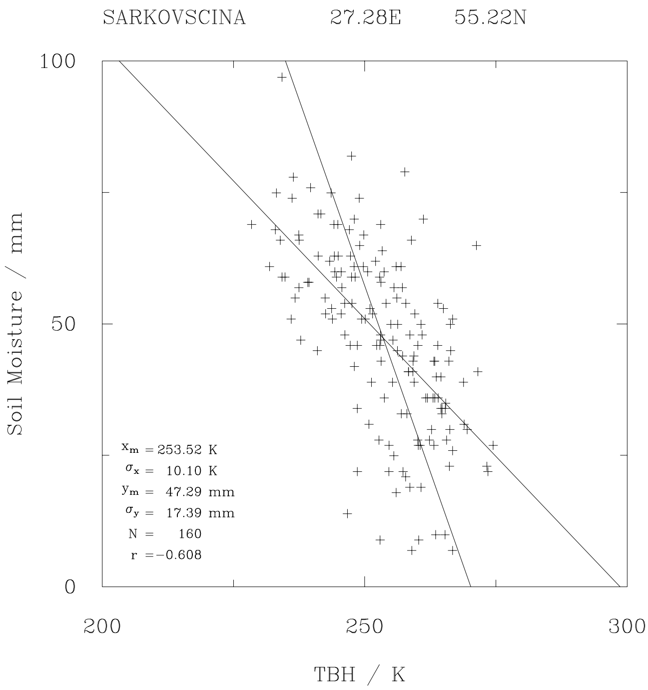
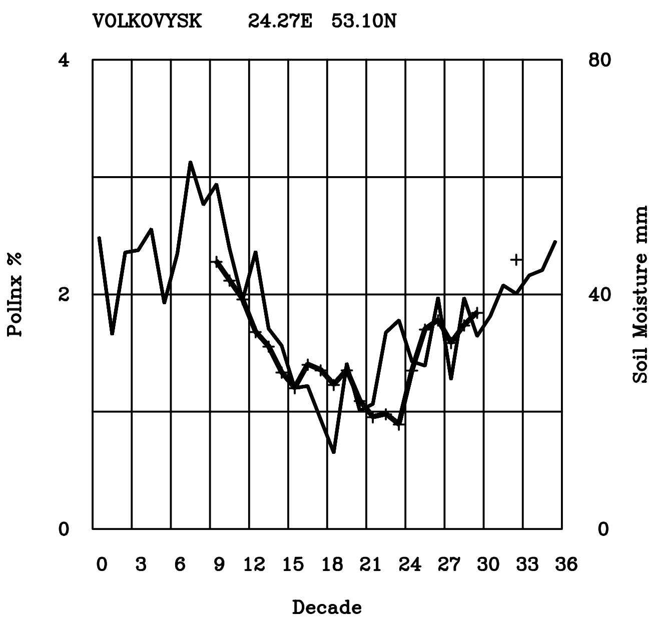


Figure 2: *Measured soil moisture compared to horizontal polarized brightness temperature from SMMR for the period 1980 to 1987 at the station Sarkovscina in Belarus.*

The simple comparison of direct soil moisture measurements from a long-year time series with the brightness temperature received at the satellite shows already a good agreement (Figure 2). The correlation between satellite observation and direct soil moisture measurement amounts to 0.6. Taking into account above described strong reduction of small-scale variability by the satellite, this is an extraordinary good result. It follows that satellite measurements may help to deduce area-covering soil moisture fluctuations. Even the derivation of absolute soil moisture values seems to be attainable, since not only the annual cycle but also the mean difference between two stations are well reproduced by the satellite (Figure 3).



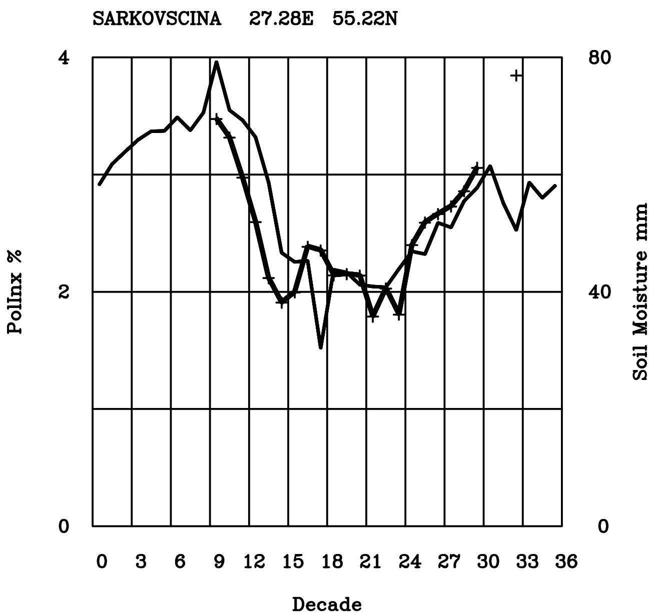


Figure 3: *Mean annual cycle (1980 - 1987) of soil moisture at two Byelorussian stations (Volkovysk, top; and Sarkovscina, bottom) together with satellite observations. The thin lines indicate the polarization index at 6.6 Ghz, the fat line shows the direct measurements, carried out each 10 days, which is denoted by the crosses. The left ordinate scale refers to satellite, the right to direct observations.*

We acknowledge receipt of soil moisture data for this study from the Republican Hydrometeorological Centre, Minsk, Belarus, through the BALTEX Meteorological Data Centre at the German Weather Service in Offenbach, Germany.

Why did low level clouds in Europe become less opaque?

Hartmut Graßl *(grassl@dkrz.de)*
Chair of the BALTEX SSG, Max-Planck-Institute for Meteorology, and Meteorological Institute at Hamburg University, Hamburg, Germany

Olaf Krüger *(olaf.krueger@dkrz.de)*
Meteorological Institute at Hamburg University, Hamburg, Germany

The backscattering of solar radiation by water clouds is a key contribution to planetary albedo that is now comparably well know to be close to 30 percent. Using satellite data from 1981 to 1999 (NASA Pathfinder Data Set) we tried to find cloud albedo changes due to the indirect aerosol effect. Our hypothesis was the following: If air pollution by sulfur dioxide (SO_2) and nitrogen oxides ($NO_x = NO + NO_2$), that leads to aerosol particle formation, can be detected at all, it should be visible in Eastern Central Europe after the collapse of the former East Block.

Comparing two 4 year periods, namely 1985 to 1989 (excluding 1987 because of partly missing data) and 1996 to 1999 we found: Low level cloud albedo (reflectance as seen by AVHRR) shrank by about 2 percent over western and eastern Central Europe from the late 1980s to the late 1990s both in winter (NDJF) and summer (MJJA), i.e. cloud optical depth diminished because of lower cloud droplet numbers in a less polluted atmosphere (see Figure 1 and *Krüger and Grassl, 2002*).

What arguments can we give that we are not misled by natural variability?

Firstly, we avoided volcanic influence by excluding the 1982 to 1984 (El Chichón) as well as the 1991 to 1993 (Pinatubo) period. Secondly, we averaged over 4 years to damp interannual variability. Thirdly, we could see the comparably low cloud albedo near to SO_2 emission centres (Upper Silesia, Bitterfeld area, etc.) in winter, indicating that the concomitant emission of black carbon (soot) and the small amount of SO_2 conversion

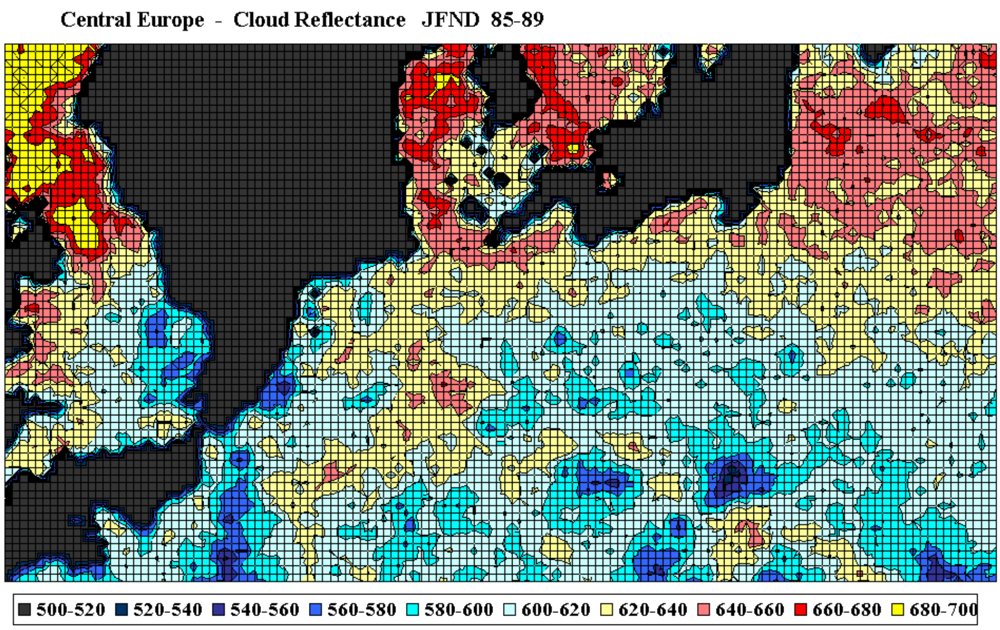


Figure 1: *Mean cloud reflectance derived from AVHRR channel 2 over parts of Central Europe in thousandths for winter (January, February, November, December) from 1985 to 1989.*

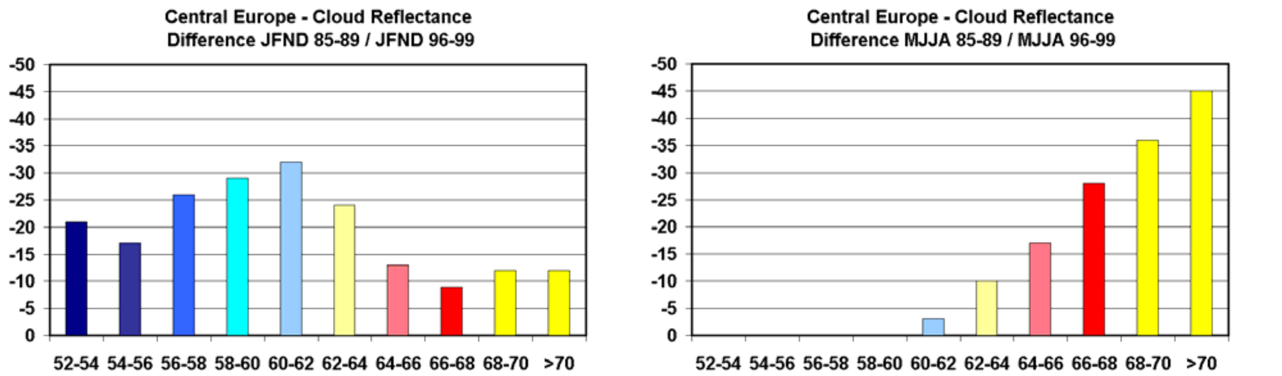


Figure 2: *Decrease of cloud reflectance in thousandths (ordinate) from 85-89 to 96-99 for different reflectances (colours from Fig. 1) for winter (left) and summer (right) periods.*

into sulphates close to the sources are impacting on cloud albedo as well.

In summer cloud albedo was spatially more homogeneous, but the reduction of cloud albedo due to lower emissions (environmental measures in OECD countries and partial collapse of industries in countries with economies in transition) reached the same level. Fourthly, we observed nearly no cloud albedo change in Western Europe outside major emission centres.

What are the consequences of this anthropogenic influence on water clouds?

First of all they look less opaque from below and less brilliant from above. Secondly, clean air acts enhance incoming solar radiation at the surface both during clear and cloudy conditions and thus reduce the masking of global warming by higher turbidity. In other words, they can accelerate warming due to an enhanced greenhouse effect. Thirdly, the albedo reduction is strongest close to the emission sources, especially in winter, and in summer for a larger area around the emission sources.

Similar studies for a larger area in Europe as well as China and North America are under way.

Reference

Krüger, O. and H. Grassl (2002): The indirect aerosol effect over Europe, Geoph. Res. Letters, in press.

Recent Swedish Contributions to BALTEX and *BRIDGE*

Anders Omstedt *(anders.omstedt@gvc.gu.se)*
Co-chair of the BALTEX SSG and Chairman of the Swedish Working Group on BALTEX, University of Göteborg, Sweden

Several interesting programs and research activities that are closely related to BALTEX are taking place in Sweden. Below they are shortly outlined with some relevant papers listed.

Göteborg University

At Göteborg University we are now forming a ***Baltic Sea research*** group that will be the hub for several Baltic Sea initiatives. Two new PhD students have started this spring. A joint BALTEX/*BRIDGE* project between Göteborg University and Institute of Oceanology, Sopot, Poland has started. Göteborg University is also involved in the SWECLIM and MARE programs and has taken the initiative to arrange two international workshops during 2002. The first one is "Fourth Workshop on Baltic Sea Ice Climate", 22-24 May 2002, Norrköping, Sweden.

The second one is "Processes of importance for the large-scale salinity distribution of a semi-enclosed sea as the Baltic", 4-6 November 2002, Kristineberg, Sweden. The DIAMIX program (coordination Anders Stigebrandt) is now in a writing phase.

Some recent papers are:

Axell, L.B, 2002: Wind-driven internal waves and Langmuis circulation in a numerical ocean model of the southern Baltic Sea. J. Geophysical Research in press.

Gustafsson, K. E., 2002: Tidal energy losses by baroclinic wave drag and their importance for the thermohaline circulatin. Ph D. thesis, Earth Sciences Centre, Göteborgs University, No A 80, Sweden.

Gustafsson, B.G., 2001: Quantification of water, salt, oxygen and nutrient exchange of the Baltic Sea from observations in the Arkona basin. Continental Shelf Research, 21, 1485-1500.

Omstedt, A., and D. Chen (2001): Influence of atmospheric circulation on the maximum ice extent in the Baltic Sea. J. Geophysical Res, 106, No. C3, 4493-4500.

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Stigebrandt, A., Lass, Liljebladh, Alenius, Piechura, and Hietala, 2002: DIAMIX - An experimental study of diapycnal deepwater mixing in the virtually tide-less Baltic Sea. Boreal Research. In press.

Winsor, P., J. Rodhe, and A. Omstedt, 2001: Baltic Sea ocean climate: An analysis of 100 yr of hydrographic data with focus on the freshwater budget, Clim. Res., 18, 5-15, 2001.

Lund University

Lund University is now creating a Centre for Studies of **BioGeoSphere Dynamics**, including Department of Geology, Climate Impact Group, Department of Ecology, Department of Physical Geography and Ecosystem Analysis, Department of Physical Geography. An impressive initiative for measuring fluxes over land is organised by A. Lindroth, A. Grelle, L. Klemedtsson, M. Nilsson and T. Christensen. Measurements are made continuously by eddy-covariance method from several ecosystems in Sweden. Lund University will host the BALTEX Science Steering Group Meeting in November this year.

For information on
SWECLIM* and *MARE
see
http://www.smhi.se/sweclim
http://www.mare.su.se

Some recent papers are:

Lundblad, M., and A. Lindroth, 2001: Transpiration of a coniferous forest in relation to weather and stand characteristics. Basic and Applied Ecology (in press).

Lagergren F. and A. Lindroth, 2002: Transpiration of Pine and Spruce in a Swedish forest: Response of individual trees to weather and soil moisture. Agricultural and Forest Meteorology (in press).

Gustafsson, D., Lewan, E., van den Hurk, B.J.J.M., Viterbo, P., Grelle, A.,Lindroth, A., Cienciala, E., Mölder, M., Halldin, S. and Lundin, L.-C., 2002: Boreal-forest surface parameterisation in the ECMWF model - 1D test with NOPEX longterm data. Journal of Applied Meteorology (accepted).

Uppsala University

Studies on air-sea interaction are an active research field at Uppsala University. The measuring site at Östergarnsholm (PEP in BALTEX) has continued and new PhD students are analysing the data. In May 2002, Anna Sjöblom made her PhD defence at Uppsala University. The atmosphere-ocean coupling will be addressed in joint research efforts between Uppsala and Göteborg University.

Some recent papers are:

Hennemuth B., Rutgersson, A., Bumke K., Clemens, M., Omstedt A., Jacob D., and A-S Smedman, 2002: Net precipiation over the Baltic Sea for one year using several methods. Submitted.

Smedman A-S, Högström U., Rutgersson, A., Gryning S-E, Peters G., Hennemuth-Oberle, B, Tammelin B., Hyvönen R., Omstedt A., Michelson D., Andersson T., Bumke K and Clemens M, 2002: Precipitation and Evaporation Budgets over the Baltic Sea: Observations and Modelling. In manuscript.

Sjöblom, Anna, 2002: The Turbulent Structure of the Marine Atmospheric Boundary Layer and its implications for the inertial dissipation method. Dissertation for the Degree of Doctor of Philosophy in Meterology, Uppsala University.

Chalmers

Chalmers is working on the GPS information. The **GPS technique** appears to be a valuable tool for climate applications as the time series becomes longer. GPS data were compared to climate models [Jacob et al. 2001]. We have also assessed the possibility of using GPS data for climate monitoring. The first seven years of data indicate regional as well as seasonal differences in the water vapour trends over the area of Sweden [Gradinarsky et al. 2002]. Winter and summer trends in the atmospheric water vapour content show a high degree of consistency but regional differences over the area of Sweden can be seen.

Some recent papers are:

Gradinarsky, L.P., J.M. Johansson, H.R. Bouma, H.-G. Scherneck, and G. Elgered, 2002: Climate monitoring using GPS. Physics and Chemistry of the Earth, in press.

Jacob, D., and 15 co-authors, 2001: A comprehensive model intercomparison study investigating the water budget during the BALTEX-PIDCAP period. Meteorology and Atmospheric Physics, 77, 19-43.

Swedish Meteorological and Hydrological Institute SMHI

SMHI is strongly involved in the BALTEX work and the main activities are summarized below:

Re-analysis of the BALTEX/BRIDGE period

The BALTEX*/BRIDGE* reanalysis project presented the first results at the Åland conference in summer of 2001. During the autumn, however, a serious bug was found in the surface scheme. The analysis was restarted again and finished in March 2002 (Fortelius et al., 2002). The results are compared with atmospheric state observations and direct measurements of near ground fluxes. The atmospheric parameters compare well with SYNOP and radiosonde data. Precipitation compares well with estimates by BRDC (BALTEX Radar Data Centre) and precipitation estimates provided by Franz Rubel. The momentum and sensible heat flux compare reasonably with the inland Finnish site Hyytiälä and the marine site Östergarnsholm. The largest discrepancy compared to observations is found in evaporation and runoff. The runoff is heavily underestimated compared to HBV simulations mainly due to an overestimation of the evaporation. Two articles are in preparation. The first one concerns the comparison of the precipitation with BRDC and Franz Rubel. The second will discuss the comparison with observation and close the atmospheric water as well as the surface heat and water budget for the period. Parallel to the reanalysis a similar run has been performed but without data assimilation in order to try to answer questions about the capability of the model to produce reliable budget estimates without data assimilation. The results are not yet analysed.

Runoff

Development of improved runoff modelling in the Baltic Sea catchment continues. Recent improvements to the Rossby Centre Regional Climate Model (RCA) include better representation of sub grid variability in soil moisture parameterization and river routing (lateral flows) of runoff to the Baltic Sea. Use of the HBV-Baltic hydrological model continues to provide estimates of observed river discharge to the Baltic Sea, updated for 2000/2001 using synoptic precipitation and temperature observations. A contribution has been made to the HELCOM Fourth Periodic Assessment of the State of the Environment of the Baltic Marine Area, 1994-1998.

SMHI made a significant contribution to the experimental design and dataset creation for the

PILPS Phase 2e high latitude land surface scheme intercomparison organised under GEWEX. The land surface scheme of the RCA Model also participated in the inter-comparison, which included models from other GEWEX Continental Scale Experiments.

Development of a coupled atmosphere-ocean regional climate model and on the heat and water cycles

The Rossby Centre regional models for ocean/sea ice (RCO) and atmosphere/land surface (RCA) have been coupled during 2001 into one model system called RCAO. See the lead article in this *Newsletter*.

Regional climate scenarios

The work on future regional climate scenarios and their impacts on the Baltic Sea region including e.g. freshwater flows to the Baltic Sea and the Baltic Sea itself has continued. In addition to the further developments of the regional climate models and simulation techniques, new regional simulations are presently being conducted. These will be conducted using the coupled RCAO system mentioned above, forced with global model results from two climate modelling centers in the form of a number of 30-year time slices for the present-day and future scenarios A2 and B2 (viz. IPCC SRES).

Cloud parameterisation

Within the EU (European Union) FP5 (5th Framework Programme) project CLIWA-Net, a prototype network of 12 cloud observation stations has been operated for 2 common periods, the second of which in April-May 2001 to measure the vertically integrated cloud liquid water path (LWP), cloud base height and integrated water vapor. Four modelling groups (Rossby Centre, KNMI, ECMWF and DWD) made 36 hour forecasts on each day of the campaign to evaluate the simulation of clouds and cloud liquid water in the models. Also satellite retrievals clouds were made available for the models. The ground based measurements and model-integrations are being used to assist in developing algorithms to retrieve LWP from the AVHRR sensor data, over land. The Rossby Centre has led the work-package on parameterisation development. The primary works has been on evaluating the vertical structure of simulated clouds, using cloud penetrating radar observations from 3 of the sites. The sensitivity of cloud simulation to vertical resolution and type of parameterisation approach is receiving particular attention. In the summer of 2001, the BBC campaign (see also BALTEX *Newsletter* #3) was held in the Netherlands in which the distributed cloud observational network was brought together into a mesoscale network for the evaluation and observation of cloud mesoscale dynamics and organization. In particular the role of model horizontal resolution is being addressed.

Data Centres

SMHI is running the BALTEX Hydrological Data Centre (BHDC), the BALTEX Radar Data Centre (BRDC) and is currently implementing the Oceanographic Data Centre for BALTEX (ODCB). See also the article on implementation of the ODCB by B. Håkansson and P. Axe in this Newsletter.

Some recent papers are:

Bowling, L. C., and 24 co-authors, 2002. Simulation of high latitude hydrological processes in the Torne-Kalix basin: PILPS Phase 2(e) - 1: Experiment description and summary intercomparisons. *Glob. Planet. Change* (accepted).

Fortelius, C. Andrae, U. and Forsblom, M., 2002. The BALTEX regional reanalysis project. Accepted by Boreal Environment Research.

Graham, L. P. and Bergström, S., 2001. Water balance modelling in the Baltic Sea Drainage Basin - Analysis of meteorological and hydrological approaches. *Meteorol. Atmos. Phys. 77,* 45-60.

Haapala, J., Meier, H. E. M. and Rinne, J. 2001. Numerical investigations of future ice conditions in the Baltic Sea. Ambio 30:4-5, 237-244.

HELCOM 2002. Fourth Periodic Assessment of the State of the Environment of the Baltic Marine Area, 1994 -1998. *Baltic Sea Environment Proceedings*, Helsinki Commision, Helsinki, (in press).

Meier, H. E. M. 2001. On the parameterization of mixing in 3D Baltic Sea models. *J. Geophys. Res. 106(C12),* 30,997-31,016.

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Samuelsson, P., Bringfelt, B. and Graham, L. P. 2002. The role of aerodynamic roughness for runoff and snow evaporation in land surface schemes - Comparison of uncoupled to coupled simulations. *Glob. Planet. Change* (accepted).

Van den Hurk, B. J. J. M., Graham, L. P. and Viterbo, P. 2002. Comparison of land surface hydrology in regional climate simulations of the Baltic Sea catchment. *J. Hydrol. 255,* 169-193.

DEKLIM

The BALTIMOS Validation Strategy

Daniela Jacob *(jacob@dkrz.de)*
Coordinator DEKLIM program and BALTIMOS project; Max-Planck-Institute for Meteorology, Hamburg, Germany

The BALTIMOS project, which is funded within the German DEKLIM program, can be seen as a major contribution to the international BALTEX research. In this project a fully coupled model system for the Baltic Sea region, called BALTIMOS, will be developed by linking existing model components for the atmosphere (model REMO), for the ocean including sea ice (model BSIOM), for the hydrology (model LARSIM) as well as for lakes and vegetation.

In addition, a comprehensive validation of the coupled model for the Baltic Sea and its catchment area will be performed using data from a period of about one decade. Validation is a necessary condition in order to achieve reliable estimates of the water and energy budgets for the Baltic Sea area not only for present climate conditions but also for future large-scale climate changes.

DEKLIM **project websites at**
http://www.deklim.de
BALTIMOS website available at
http://www.baltimos.de

All partners will develop the validation strategy within the project in a joint effort: experimentalists and modellers. In the following the current state of the strategy will be presented.

Evaluation period: 1980 to 2003, validation period: 1999 to 2002. For simulations within the evaluation period the model can be under development, however for the validation period the model version must be frozen. This is planned to do around New Year 2002/2003. The decision on this will be made during the next weeks.

The basin will be subdivided into 4 sub-basins for intensive studies. All data sets for validation will be prepared for the horizontal resolution of the REMO grid. For each parameter one partner within the project is responsible to coordinate the validation of this variable.

Observed and retrieved data sets:

Precipitation associated to large scale conditions as well as convective; Cloud top pressure, cloud top phase, cloud type, optical depth, liquid water path and total cloud cover; Water vapour; Soil moisture; Fluxes at the surface (see: Baseline Surface Radiation Network – BSRN); Snow cover and depth; SST; Sea-ice cover; River run-off.

The statistics will be done for land and water points separately for the diurnal cycles, monthly means and annual cycles as well as intensity and frequency of meteorological and hydrological extremes.

The following simulated variables / parameters will be validated:

Precipitation: amount, rate, duration, structure (number of cells, space and time distribution of the cells); Clouds: Cloud top pressure, cloud top phase, cloud type, optical depth, liquid water path and total cloud cover; Water vapour content; Water: SST, fractional ice cover, river run-off into the Baltic Sea; Land: snow cover/ water equivalent, soil moisture, evaporation, radiation and vegetation coverage.

It is very important to quantify uncertainty ranges for the validation data, which take into account the averaging in space and time. In addition, a homogenisation of the observations has to be done, because of the different data sources and associated accuracies. Finally, the project partner need to agree on the level of precision, in which they define the accepted deviation between model results and observations. The model validation will primarily focus on water cycle components. A multitude of observations ranging from in situ measurements to surface- and satellite-based measurements will be applied. Observations made during BALTEX/BRIDGE and its intensive measurement campaigns will also be used and they will be related to the present climate condition.

The BALTIMOS group invites the BALTEX community to take part in this validation exercise or just comment on the above mentioned strategy. Please send an email to : jacob@dkrz.de.

DEKLIM

BASEWECS
Baltic Sea Water and Energy Cycle Study

Andreas Lehmann *(alehmann@ifm.uni.kiel.de)*
Member of the BALTEX SSG and BASEWECS project coordinator, Institute for Marine Sciences IfM, Kiel, Germany

BASEWECS is a contribution to the German Climate Research Program DEKLIM. The project started in May 2001 and will continue until April 2004. BASEWECS aims at the investigation of the influence of the Baltic Sea and its annual ice coverage on the water and energy budget of the BALTEX area. The main objective is the determination of the energy and water budget of the Baltic Sea for the *BRIDGE* period, October 1999 to February 2002. Additionally, mean climate conditions of the Baltic Sea as well as their variability including the detailed analysis of extreme events will be investigated. Modelling results from the *BRIDGE* period will be related to the present climate conditions based on the analysis of the past 23 years (1979-2001). An accurate determination of the energy and water cycle can only be obtained by the combined usage of coupled models and observations. Numerical investigations within BASEWECS are performed by a three-dimensional coupled sea ice-ocean model of the Baltic Sea (BSIOM) which is forced by observed atmospheric and river runoff data (SMHI meteorological data base and river runoff). Model results of BSIOM (total Baltic Sea, 5 km horizontal resolution, 60 levels vertically) are stored 6-hourly. In total, 2.6 Terrabytes of model data are online accessible by a robot storage system. Results of BASEWECS will contribute to BALTEX and to the development and validation of the integrated coupled atmosphere-land-ocean-sea ice model BALTIMOS of the Baltic Sea catchment region. Modelling, analysis, validation and data assimilation in BASEWECS is done in cooperation with four subprojects.

BASEWECS website at
http://www.ifm.uni-kiel/ fb/fb1/tm/research/baltex/BASEWECS

Subproject A (Institute for Marine Sciences Kiel, IfM-Kiel): ***Energy, water, salt and sea ice cycle of the Baltic Sea***

The water budget of the Baltic Sea is determined by river runoff, the net effect of precipitation minus evaporation, in- and outflow through the Danish Straits and variations of the mean sea level (storage). River runoff and sea levels along the coasts can easily be measured by the corresponding observational systems. Whereas, the highly fluctuating in- and outflow through the Danish straits can only be recorded by sophisticated technical equipment. Measurements of precipitation over the open sea are difficult to obtain because of the high spatial and temporal variability. For the energy budget, the net consumption of radiation depends strongly on cloud cover and the sea surface temperature. The evolution of the heat content of the Baltic Sea is controlled by the heat exchange with the atmosphere and internal heat fluxes which in turn are due to advection and turbulent mixing. Sea ice modifies heat and momentum fluxes between ocean and atmosphere (Figure 1).

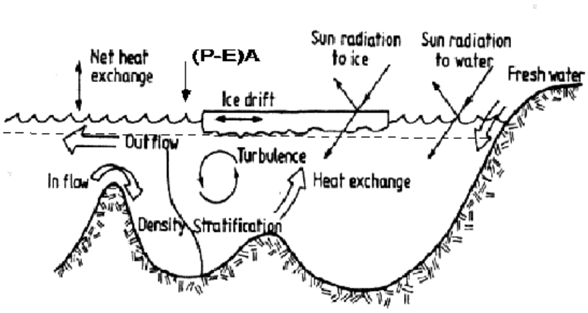

Figure 1: *Main components of the energy and water cycle.*

A closing of the energy and water budget of the Baltic Sea can thus only be achieved by the combined usage of coupled numerical models and observations. Main contributions to BASEWECS are:

- Modelling the response of the Baltic Sea (stratification, currents and sea surface elevation) during the BRIDGE-period; calculation of water, salt, heat and sea ice budgets;

- Analysis of a 23-year model run to obtain the present climate conditions and their variability, and relation of the results of the *BRIDGE* period to this climatology;

- Validation of model results against temperature, salinity and current measurements and observed sea level elevations;

- Model improvement with respect to mixed layer dynamics and sea ice dynamics / thermodynamics (in cooperation with subproject B, see below);

- Hydrographical measurements during EOPs (*BRIDGE* Enhanced Observational Period).

- Preparation of the coupled sea ice-ocean model to be implemented into the integrated model system BALTIMOS;

- Computation of the energy and water budget and comparison with the results of BSIOM.

Subproject B (Institute for Baltic Sea Research Warnemünde, IOW): *Energy balance of the turbulent surface mixed layer*

The turbulent kinetic energy available for distributing heat and salt in the surface mixed layer depends on the amount of energy flux transferred from the wind to the sea surface and mechanisms transporting the energy down in the water column. The accurate modelling of this process in ocean circulation models depends critically on the parameterisation of the involved physical processes (Figure 2). There are indications that present parameterisations need to be improved since they do not consider the role of gravity waves in the vertical distribution of turbulent kinetic energy in the surface mixed layer. Main contributions to BASEWECS are:

- To measure profiles of turbulent kinetic energy and Reynold stresses as well as the dissipation of turbulent energy in the surface mixed layer of the Baltic Sea under different wind forcing and stratification conditions.

- To compute the budget of the small scale turbulence energy of the surface mixed layer and relate it to wind forcing and stratification.

- To compute the exchange coefficient of momentum in the surface mixed layer from profile measurements of both Reynold stress and mean current.

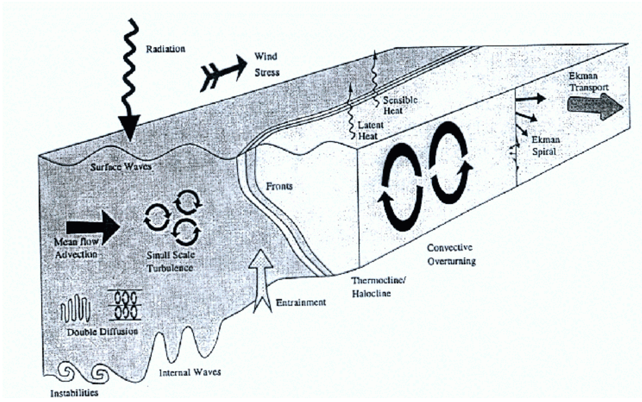

***Figure 2:** Mixing processes in the ocean.*

- Time series measurements of stratification and currents at Darss Sill and hydrographical measurements in the western Baltic Sea.

- Contribution to model validation and improvement (subproject A) with respect to turbulent mixing and mixed layer dynamics.

Subproject C (Institute for Marine Sciences Kiel, IfM-Kiel): *Water mass exchange through the Fehmarn Belt*

Three narrow straits connect the Baltic Sea with the North Sea: the Sound, the Little and Great Belts. The in- and outflow through these straits is not precisely known due to considerable temporal and spatial variability in the current field. The resolution of models currently applied to this region is mostly too coarse to describe the flow through the narrow straits specifically. To better understand this issue, sustained autonomous time series are required which collect on routine basis information on currents and water mass properties with good accuracy and temporal resolution at key sites in the in- and outflow areas (Fig. 3).

***Figure 3:** Map of Fehmarn Belt with mooring position and CTD/ADCP sections.*

Main contributions to BASEWCS are:

- To monitor continuously current, temperature and salinity in the Fehmarn Belt during the *BRIDGE* period (project life time).

- To enhance the scientific understanding of the mechanisms controlling the currents in the Fehmarn Belt and to measure stratification and currents (ship based ADCP) during 3 cruises per year in the Fehmarn Belt and the surrounding area.

- To determine the relative importance of the major straits for the water mass exchange between North and Baltic Sea.

- To contribute to model validation and improvement (in cooperation with subproject A).

Subproject D (Technical University Dresden): ***Monitoring of the sea level of the Baltic Sea with different techniques to validate oceanographic models***

The main objective of the subproject is to gain sea level heights and height changes at the coast as well as in the open sea to validate and improve the coupled sea ice-ocean model of the Baltic Sea. At the coast, observations from tide gauge stations will be used. Over the open sea, satellite altimeters will record sea level heights along their tracks. Permanent GPS and sea level measurements at existing MARNET stations will supplement the observations (Figure 4). Main contributions to BASEWES are:

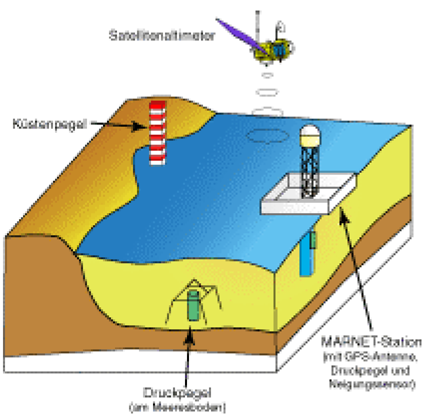

Figure 4: *Geodetic techniques to measure sea level heights.*

- Determination of sea level variations by in-situ measurements in the open sea.

- Determination of sea surface height based on remote sensing data and measurements of tide gauges.

- Reduction and comparison of sea level measurements.

- Validation of sea level variations obtained by the coupled sea ice-ocean model (BSIOM).

- Improvement of the prognosticated sea level frequency domain by assimilation of observed sea level heights.

The Oceanographic Data Centre for BALTEX

Philip Axe *(Philip.Axe@smhi.se)*

Bertil Håkansson *(Bertil.Hakansson@smhi.se)*

Oceanographic Data Centre for BALTEX, Swedish Meteorological and Hydrological Institute SMHI, Vastra Frolunda/Göteborg, Sweden

At their 12th meeting in De Bilt, Netherlands, the BALTEX Science Steering Group (BSSG) recommended the creation of an Oceanographic Data Centre for BALTEX (ODCB). A meta-databank had been established previously at the Finnish Institute of Marine Research (FIMR), collecting information on data sources and archives relevant to the BALTEX Oceanographic community. With the exception of a small amount of sea level data however, only meta-data was stored in this databank.

The principle objective of this new data centre is to build up and maintain a data archive to serve the oceanographic community within BALTEX. The Swedish Meteorological and Hydrological Institute has offered to host this data centre at the Oceanographic Laboratory at Nya Varvet, Gothenburg.

The laboratory acts as the National Oceanographic Data Centre for Sweden, collecting, quality controlling, banking and reporting data from Sweden’s fixed oceanographic monitoring platforms, as well as data sets collected from both research and environmental monitoring cruises. In turn, the laboratory reports data to international databanks (such as the International Council for the Exploration of the Sea, ICES), and contributes (and in some cases co-ordinates) projects contributing to the implementation of the European, Nordic and Baltic Ocean Observing Systems (EuroGOOS, NOOS and BOOS).

The data centre will continue the function of the meta-data centre established by FIMR and will create links and participate in data exchange with the data centres at ICES, the Institute for Baltic Sea Research (IOW) in Warnemünde, Germany, and the other BALTEX data centres. In addition, it will collate and archive oceanographic data collected during BALTEX. The responsibility for quality control of data will lie primarily with the data providers, though the data centre will establish (or more likely, adopt) common and harmonized formats for the exchange of data between the Centre, the Providers, and the Users. The final objective for the Centre is to provide 'user-friendly' access possibilities, while following a data exchange policy similar to that already used by the other BALTEX data centres.

The first priority for the data bank is to archive data from the BALTEX-*BRIDGE* period, covering October 1999 to December 2002. This will then be extended to cover 2003 and 2004, to serve the Co-ordinated Enhanced Observing Period (CEOP). Depending upon the success of this work, and the support and interest from the community, the Centre may undertake work to extend the data periods both forwards and backwards in time.

The base-line observations to be banked by the ODCB relate to the in- and outflows through the Baltic entrance areas, as well as sea levels, sea surface temperatures (SST) and sea ice extent throughout the Baltic. These observations consist of high frequency temperature, salinity and current data from fixed platforms and moorings in the Baltic entrance area, as well as gridded data products from SAR (for sea ice) and IR-radiometer (for SST). While high (hourly or higher) frequency sea level data will be banked in each gauge's local (vertical) reference frame, meta-data (such as benchmark and levelling information, and local meteorological data) is necessary to make full use of the data, so will be requested from the data suppliers.

During the Enhanced Observations Periods, the data bank will archive the hydrographic survey data for the whole of the Baltic and Kattegat. The data bank will also archive data from special field activities, such as the high- resolution hydrographic data, current profiler (ADCP) and ice data collected in the BALTEX-related projects DIAMIX, PEP-in-BALTEX, and BASIS.

The centre's data exchange policy follows the general BALTEX policy. This requires the registration of data users, the transfer of data between data providers, the centre and data users without charge, the restriction of data use to the registered user (i.e. not to third parties) for purely scientific (non-commercial) studies designed to meet BALTEX objectives.

As with the other BALTEX data centres, the Oceanographic Data Centre will require data users to send a copy (preferably electronic) of publications arising from use of ODCB to both the data centre and to the BALTEX Secretariat. This enables the effectiveness of the ODCB to be judged, and the decision made as to whether to extend the work of the centre to cover periods beyond the *BRIDGE* and CEOP periods. Finally the ODCB will seek to promote communication between data providers and users.

To meet these objectives, a relational database system has been set up to archive (initially) sea level data and associated meta-data, and the first data have been received, from Estonia. Data providers will shortly be contacted and asked to provide details of their sea level measurement stations, including levelling information, and a web interface will be constructed to allow user registration to access data.

Implementation of ODCB is continuously guided by a BALTEX ODCB panel appointed by the BSSG at their 12th meeting in November 2001. For further information about the ODCB, contact Philip Axe or Bertil Håkansson at SMHI.

Cabauw:

One of the BALTEX Reference Sites for CEOP

Fred Bosveld *(fred.bosveld@knmi.nl)*
Cabauw site manager for CEOP; Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands

With its extensive in-situ and ground based remote sensing instrumentation the Cabauw Experimental Site for Atmospheric Research is particularly suited to be one of the reference sites in CEOP.

Since 1972, the Royal Netherlands Meteorological Institute (KNMI) operates a meteorological research facility at Cabauw in the Netherlands. Increasing problems with air pollution at that time was one of the motivations for the construction of

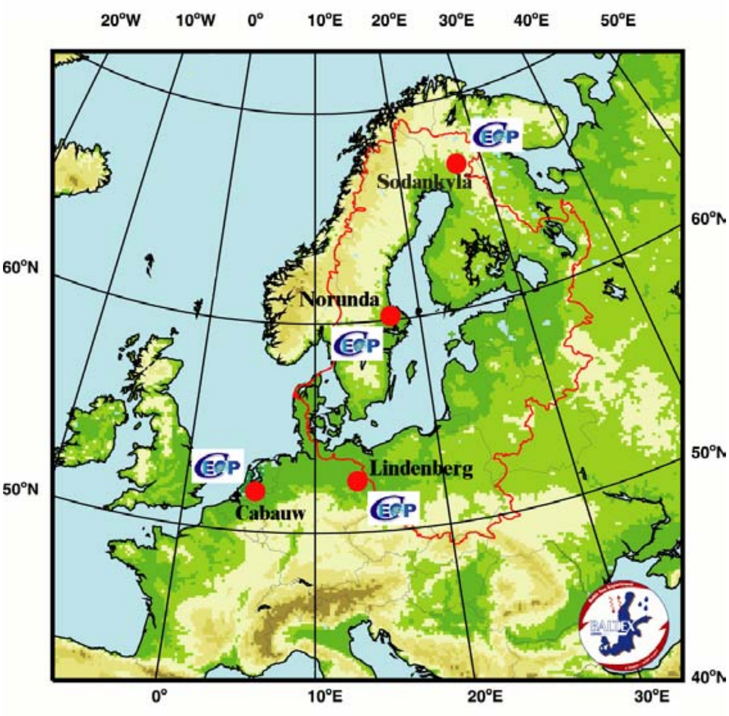

Figure 1: *Locations of BALTEX Reference Sites for CEOP.*

the 213-m high meteorological tower. The main research theme at that time was turbulent transport in the atmospheric boundary layer and its relation with the land surface. A good overview of scientific results from that period can be found in van Ulden and Wieringa (1996). The Cabauw tower is situated 25 km South-West of De Bilt, one of the synoptic stations in the Netherlands, where a rain radar is operated and where radiosondes are launched.

Technical developments during the 1980's made it possible to perform long term measurements. This resulted in a continuous observational programme of profile and surface flux measurements for the period 1986-1996 (Beljaars and Bosveld, 1997). The data are used for many model evaluation studies among which the Project for Intercomparison of Land surface Parameterisation Schemes (PILPS phase 2). Data are available on request.

After a period of renovation the mast is operational again since May 2000. Profile and radiation measurements are now based on the same standard procedures as for the operational meteorological network in the Netherlands. This applies to instrumentation, maintenance, calibration and quality control. Since September 2000 an eddy correlation system is operational for the measurements of surface fluxes of latent and sensible heat, momentum and carbon dioxide.

Cabauw data on Internet
http://www.knmi.nl/~bosveld

Information on CESAR
http://www.irctr.tudelft.nl/projects/cesar

Figure 2: *The 213 m meteorological tower with its booms at 20 m intervals. Three different boom direction can be exploited to avoid mast interference. Booms can be put in vertical position for instrument maintenance*

In the beginning of the 1990's research interest within KNMI extended to cloud dynamics and cloud-radiation interaction. This resulted in the extension of Cabauw with remote sensing instruments. In 1994 a 1290 Mhz wind profiler/RASS became operational and in 2001 a ceilometer and a 35 Ghz Cloud radar were installed.

During the 1990's it was recognized that atmospheric research in the Netherlands would greatly benefit from a cooperation of various national institutes. This is particularly so with ground based remote sensing where observations with different instruments at the same site greatly enhance the capability of characterising important physical parameters of clouds. In May 2002 the Cabauw Experimental Site for Atmospheric Research (CESAR) was officially established. In this consortium cooperate besides KNMI, Delft University of Technology (DUT), Eindhoven University of Technology (EUT), National Institute of Public health and the Environment (RIVM), Energy Research Foundation (ECN), Netherlands Organisation for Applied Scientific Research (TNO-FEL), Wageningen University & Research (WUR) and the European Space Agency (ESA-ESTEC).

The objective of CESAR is:

To set-up and operate at the Cabauw site an observational facility with a comprehensive set of remote sensing and in-situ equipment to characterize the state of the atmosphere, its radiative properties and interaction with the land surface, for the study of physical processes, climate monitoring and validation studies.

At present CESAR partners operate a 3Ghz cloud radar and a GPS receiver (DUT), an aerosol lidar (RIVM), a CO_2 concentration analyser for measuring concentration profiles (ECN), and a scintillometer for estimating regional heat fluxes (WUR). As an associate partner, Bonn University operates a microwave radiometer.

Figure 3: *The 1290 Mhz windprofiler/RASS system which give wind and temperature profiles in the atmospheric boundary layer.*

Cabauw has been the host of many special experiments. Recent examples are the Tropospheric Energy Budget Experiment (1995-1996) in which a comprehensive data set was obtained of fluxes and atmospheric profiles including an auxiliary forest site in the centre of the Netherlands and including a cloud detection network (Feijt and van Lammeren, 1996). During the summer of 2001 Cabauw hosted the BALTEX *BRIDGE* Cloud Campaign. This year Cabauw played a role in the European RECAB project and it hosts the CREX'02 rain campaign. In 2003 the 4D-Clouds campaign will take place around Cabauw.

At this stage Cabauw data for CEOP encompass surface fluxes of rain, energy and radiation; tower profile data of wind, temperature and humidity; horizontal wind and sonical temperature from the windprofiler/RASS profiles; echo strength and vertical motion from the cloud radar; cloud layer heights from the ceilometer and sky radiative temperature from an infrared radiation thermometer.

Literature

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Deep Water Transport in the Stolpe Channel

Agnieszka Beszczynska-Möller
(abesz@iopan.gda.pl)
Jan Piechura*, (piechura@iopan.gda.pl),*
Member of the BALTEX SSG, both at Institute of Oceanology PAS, Sopot, Poland

In agreement with BALTEX recommendations, the Institute of Oceanology PAS performed intensive field programs in the southern part of the Baltic proper. Measurements by means of the towed scanning CTD probe and vessel-mounted ADCP comprised an area between the Arkona Basin and the southern Gotland Basin with special attention paid to the Stolpe Channel and Stolpe Sill. The horizontal resolution of performed measurements was of order of several hundred meters, enabling to resolve mesoscale features within the internal Rossby radius (2-5

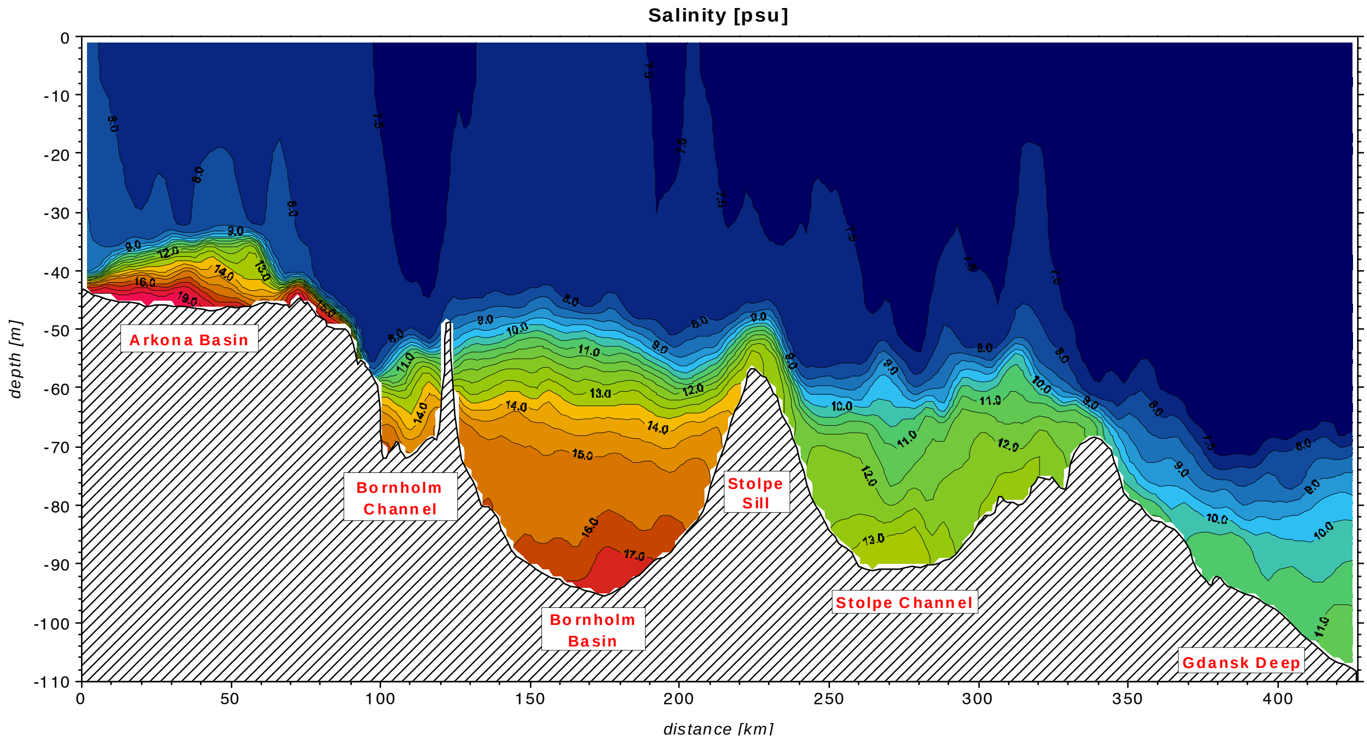

Figure 1: *Distribution of salinity at the cross-section along the deep basins of the Baltic Proper observed in January 2001, IO PAS data.*

km in the investigated area). Re-analysis of existing data sets, aimed at estimation of the deep water exchange was also done.

Changes of stratification and water masses distribution in the deep basins were analysed along the sections, starting in the Arkona or Bornholm Basin and continued through the Stolpe Channel towards the Gdansk Deep. An example of the salinity distribution is shown in Figure 1. A bottom pool of dense water in the Arkona Basin was usually found as well as a strong baroclinic flow through the Bornholm Channel. In the Bornholm Basin a cyclonic circulation prevailed with a deep current along the southern rim.

Detailed investigations revealed that, during stagnation periods, overflows of highly saline water from the Bornholm Basin into the Stolpe Channel occur mostly in the form of short-lasting pulses. During these events, separated volumes of dense water (1-2 km^3) are transported over the Stolpe Sill. As a result of the intermittent overflow, salinity of the deep water transported over the sill can vary significantly (by 6-7 psu) during several hours. Baroclinic deep flow into the Stolpe Channel is not only related to the halocline depth and salinity distribution in the Bornholm Basin but also strongly influenced by wind forcing. The highest correlation of dense water transport over the Stolpe Sill was found for easterly winds.

Deep dense water enters the Stolpe Channel along the southern slope. Downstream it moves into the deepest part of the channel and towards the northern slope as a result of transverse transport in the near-bottom Ekman layer. The observed flow pattern in the Stolpe Channel is strongly dependent on the wind, which is also confirmed by results of numerical modelling. Northerly and easterly winds significantly intensify the eastward flow of dense water in the deep layer. For these wind directions a typical flow pattern is a wide eastward stream in the middle of the channel and weaker opposite flows along the slopes. Comparison of current fields, calculated from density fields and measured by ADCP, suggests that a well-defined geostrophic baroclinic current in the deep layer is usually modified by superimposed barotropic flow. The highest values of the net volume transport were observed during predominating north-easterly winds, when downstream baroclinic current in the deep layer was coupled with the strong eastward barotropic flow. Net volume transport in the whole water column reached 200.000 m^3/s while for the deep layer (with salinity higher than 8 psu) it was equal to about 80.000 m^3/s. Volume transport of highly saline water in the near-bottom layer (salinity higher than 11 psu) exceeded 30.000 m^3/s with averaged current velocities of 30-40 cm/s. In most cases, the observed downstream volume transport in the deep layer of the Stolpe Channel

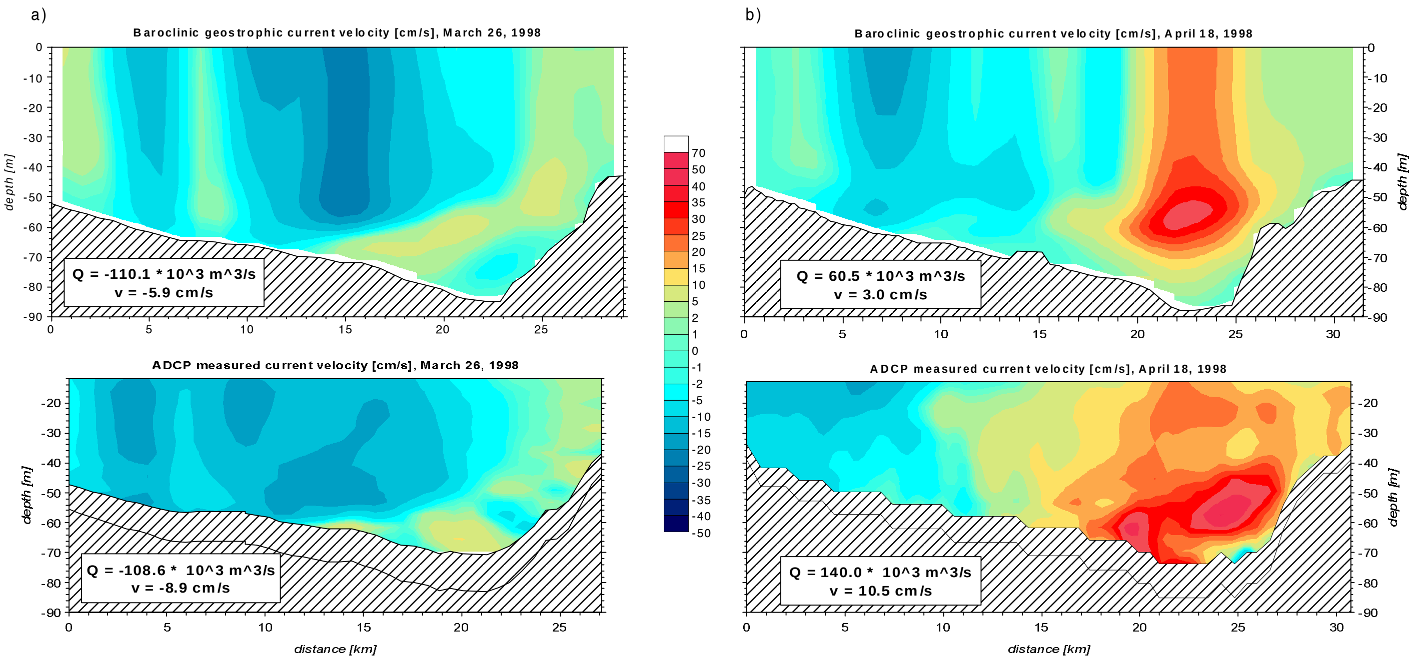

Figure 2: *Typical flow patterns under westerly (a) and strong easterly (b) winds at the section across the deepest part of the Stolpe Channel. Upper plots show calculated baroclinic geostrophic current velocity, lower plots depict ADCP measured current velocity. Net volume transport (Q) and averaged current velocity (v) are given for each section.*

is of the order of 10.000-20.000 m^3/s. Westerly and southerly winds result in westward net volume transport in the whole water column, but only for very strong and long-lasting winds a downstream flow in the deep layer can be blocked. In most cases, a wide and intensive westward flow in the middle or northern part of the channel is coupled with the opposite but much weaker near-bottom current. Even during westward net volume transport through the whole section, amounting to about 110.000 m^3/s, the eastward flow ranged between 2.000-3.000 m^3/s and was mostly maintained in the deep layer with salinity higher than 11 psu. Examples of typical flow patterns in the Stolpe Channel under easterly and westerly winds are shown in Figure 2. The highest values of the deep water transport was observed during late autumn and winter months.

Baroclinic eddies with diameters of order of a few Rossby radii (tens km) and rotational velocities of 30-40 cm/s were commonly found in the halocline and deep layers of the Stolpe Channel as a result of intermittent dense water overflows. Cyclonic eddy-like disturbances, comprising highly saline water in the core and moving with the advection velocity of a few cm/s are considered to support the deep dense water transport.

Very complex and highly variable deep water exchange through the Stolpe Channel reveals a need of measurements with appropriate time and spatial resolution. Future plans of IO PAS investigations include continuation of high-resolution hydrographic measurements at selected cross-sections repeated several times per year as well as recording of time series with use of the oceanographic buoy located in the Stolpe Channel.

BALTEX SSG Meetings 2002 - Defining Objectives of BALTEX Phase 2

Hans-Jörg Isemer *(isemer@gkss.de)*
Head International BALTEX Secretariat;
GKSS Research Centre, Geesthacht, Germany

Two regular BALTEX Science Steering Group (BSSG) meetings are on the schedule of the year 2002. This higher-than-usual meeting frequency is due to the important process of defining objectives for BALTEX phase 2. 2002 may be seen as the transition year from phase 1 to phase 2 of BALTEX. At BSSG's 13^{th} regular meeting at Estonian Businees School in Tallinn, Estonia, 17 to 19 June 2002, an extended discussion lead to the establishment of 5 major objectives for BALTEX phase 2, which were considered still as draft to be fine tuned and discussed in the community. A final decision is now expected from the 14^{th} BSSG meeting, to be held at Lund University in Sweden, 18 to 20 November 2002. In concert with defining objectives, actions will be initiated for revisions of the BALTEX Science and Implementation Plans and for establishing funding proposals to the European Union's up-coming 6th Framework Programme. Also this forthcoming BSSG meeting will be accompanied by a scientific workshop, this time entitled *Achievements of and Perspectives for the BALTEX Programme*. Detailed BSSG meeting minutes are available in the International BALTEX Secretariat Report Series and may be requested from the BALTEX Secretariat.

Participants at the 13th BSSG meeting held 17 to 19 June 2002 at the Estonian Business School in Tallinn, Estonia

Next issue of the BALTEX *Newsletter* (# 5)
Please, send articles to
isemer@gkss.de* or *baltex@gkss.de
before
31 December 2002

Special Issue on BALTEX in Boreal Environment Research 2002, Vol. 7 (3)

Hans-Jörg Isemer *(isemer@gkss.de)*
Head International BALTEX Secretariat;
GKSS Research Centre, Geesthacht, Germany

A special journal issue dedicated to the 3rd Study Conference on BALTEX is now available in *Boreal Environment Research (BER) 2002, Vol. 7, No 3*. The volume contains 16 conference papers, which passed the BER review process. The subsequent BER issue (Vol.7, No 4) will contain the second portion of BALTEX conference papers. The BER editorial board, together with several special editors and numerous reviewers did a great job in organising a two-volume special issue on BALTEX, which I herewith like to appreciate thankfully on behalf of the BALTEX research community.

The following papers appear in *Boreal Environment Research Vol.7, No 3*:

1. Raschke, E.; J. Meywerk and B. Rockel: Has the project BALTEX so far met its original objectives ?

2. Döscher, R.; U. Willén, C. Jones, A. Rutgersson, H. E. M. Meier, U. Hansson and L. P. Graham: The development of the regional coupled ocean-atmosphere model RCAO.

3. Fortelius, C.; U. Andræ and M. Forsblom: The BALTEX regional reanalysis project.

4. Lorant, V.; N. MacFarlane and R. Laprise : A numerical study using the Canadian Regional Climate Model for the PIDCAP period

5. Pirazzini R.; T. Vihma, J. Launiainen and P. Tisler: Validation of HIRLAM boundary-layer structures over the Baltic Sea.

6. Kücken, M.; F.-W. Gerstengarbe and P. C. Werner: Cluster analysis results of regional climate model simulations in the PIDCAP period.

7. Etling, D.; G. Harbusch and B. Brümmer: Large-Eddy-Simulation of an off-ice airflow during BASIS.

8. Gryning S.-E. and E. Batchvarova: Marine boundary-layer height estimated from the HIRLAM model.

9. Crewell, S.; M. Drusch, E. van Meijgard and A. van Lammeren: Cloud observations and modelling within the European BALTEX Cloud Liquid Water Network.

10. Hollmann, R. and A. Gratzki: The satellite derived surface radiation budget for BALTEX.

11. Koistinen, J. and D. B. Michelson: BALTEX weather radar-based precipitation products and their accuracies.

12. Feijt, A.; D. Jolivet and E. van Meijgaard: Retrieval of the spatial distribution of liquid water path from combined ground-based and satellite observations for atmospheric model evaluation.

13. Sepp, M. and J. Jaagus: Frequency of circulation patterns and air temperature variations in Europe.

14. Post, P.; V. Truija and J. Tuulik: Circulation weather types and their influence on temperature and precipitation in Estonia.

15. Okulov, O.; H. Ohvril and R. Kivi: Atmospheric precipitable water in Estonia, 1990 – 2001.

16. Oesterle, H.: Selection of representative stations by means of a cluster analysis for the BAMAR region in the PIDCAP period.

BALTEX is the European continental-scale experiment within the Global Energy and Water Cycle Experiment (GEWEX). It constitutes a research programme focussing on water and energy cycles in the climate system of the entire Baltic Sea basin with contributions of more than 10 countries. GEWEX has been launched by the World Meteorological Organisation (WMO), the International Council for Science (ICSU) and UNESCO's Intergovernmental Oceanographic Commission (IOC), as part of the World Climate Research Programme (WCRP). The scientific planning of BALTEX is under the guidance of the BALTEX Science Steering Group, chaired by Professor Hartmut Graßl, Max-Planck-Institute for Meteorology, Hamburg, Germany. The BALTEX *Newsletter* is edited and printed at the International BALTEX Secretariat with financial support through the GKSS Research Centre Geesthacht, Germany. It is the hope, that the BALTEX *Newsletter* is accepted as a means of reporting on plans, meetings and work in progress, which are relevant to the goals of BALTEX, as outlined in the Scientific and Initial Implementation Plans for BALTEX.

The editor invites the scientific community to submit BALTEX - related contributions to be published in this *Newsletter*. Submitted contributions will not be *peer-reviewed* and do not necessarily reflect the majority's view of the BALTEX research community. Scientific material published in this *Newsletter* should not be used without permission of the authors.

Please, send contributions to the BALTEX *Newsletter*, requests for BALTEX-related documents, suggestions or questions to the International BALTEX Secretariat via

GKSS Forschungszentrum Geesthacht GmbH
International BALTEX Secretariat
c/o Dr. Hans-Jörg Isemer
Max-Planck-Straße 1
D - 21502 Geesthacht
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Phone: +49-4152-871661
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