BALTEX Newsletter

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

DEKLIM

DEKLIM - German Climate Research Programme Status Seminar

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The German Climate Research Programme DEKLIM conducted its first major Status Seminar during 6 to 8 October 2003 in Bad Münstereifel, Germany. Scientific progress achieved within the programme since 2001 were presented to both the scientific community and the public. One of the four major research areas within DEKLIM, entitled "Regional Process Studies in the Baltic Sea Area" is dedicated to BALTEX (DEKLIM-BALTEX), see also the article on DEKLIM in the BALTEX *Newsletter* No. 5. DEKLIM-BALTEX is organised as a multidisciplinary research network comprising 8 projects with the major objective to explore how changes in the atmosphere, the sea and the land surface affect the climate in the Baltic Sea region. These projects are providing important contributions to the evaluation phase of BALTEX Phase I.

The present *Newsletter* is largely dedicated to DEKLIM results. The following six articles are papers originating from the DEKLIM-BALTEX research priority and are based on presentations given at the DEKLIM status seminar.

Contents

DEKLIM project websites at
http://www.deklim.de

4th Study Conference on BALTEX
at Gudhjem, Bornholm, Denmark
24 –28 May 2004

2nd Announcement and
Call for Papers
available on Internet:
http://www.gkss.de/baltex/

Abstract Deadline: 31 January 2004

Registration Deadline : 15 March 2004

Modeling Soil Frost and Snow for BALTEX: Module Development, Data Assimilation, and Evaluation

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Frozen ground and snow are frequent conditions in the Baltic region. These features strongly affect the exchange of heat, water, and trace gases at the land surface-atmosphere interface. To estimate these fluxes for the Baltic region without prior-calibration - an important goal within GEWEX – soil frost and snow metamorphism processes have to be treated in detail and the distributions of soil moisture and temperatures have to be reasonably well for monitoring, earth observation and simulation purposes.

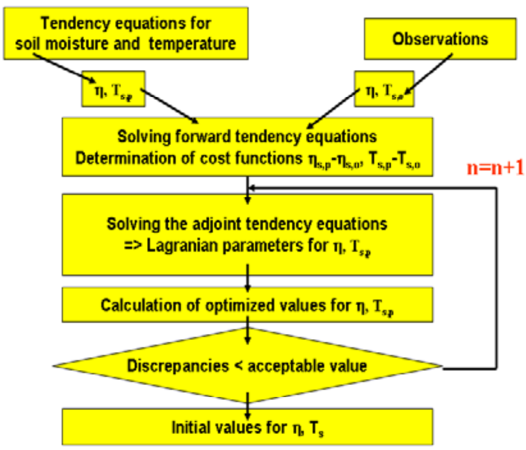

Figure 1: *Schematic view of data assimilation.* T_s *and* η *stand for soil temperature and moisture, the subscripts o and o for predicted and observed.*

We developed for and included in the hydro-thermodynamic soil-vegetation-scheme (HTSVS Kramm et al. 1996) soil freezing and thawing, the related release and consumption of latent heat energy, effects of frozen soil layers on vertical fluxes of heat and moisture, water uptake by vertically variable root distributions, the temporal variation of soil albedo, snow albedo and snow emissivity, and a multi-layer snow metamorphism model (Mölders et al. 2003a, Mölders and Walsh 2003).

We have developed a soil 4D-Var data assimilation scheme to derive the maximum benefit from the few available measurements of soil moisture and temperatures for initialisation, the first one with a complexity as given by HTSVS model. HTSVS generated observations of these quantities and skin temperatures derived from NOAA-15 Advanced Very High Resolution Radiometer data are assimilated into the modified HTSVS using an advanced spatio-temporal data analysis, which consistently combines both the in situ and satellite based data. As schematically illustrated in Figure 1 the basic principle of the variational data assimilation is to find the model state that minimizes the difference between the observed and predicted value - called the cost function – that requires knowledge of the quantity's local gradient with respect to the initial state, which is supplied by the adjoint of the tangent linear version (e.g., Elbern et al., 1999; Elbern and Schmidt, 2001) of the relevant model, here the modified HTSVS. This tangential linear model has been developed by differentiating the equations of the modified HTSVS.

Project website at
http://www.gi.alaska.edu/~molders/deklim.htm

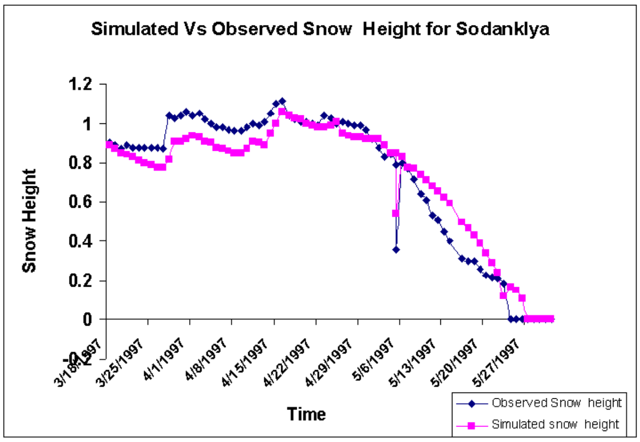

Figure 2: *Snow height as simulated for and observed at Sodankylä, Finland 3/12-5/30/1997.*

The modified HTSVS has been evaluated offline with NOPEX and WINTEX data (Fig. 2). Evaluations show a slight under-prediction of snow height during late winter, which may be due to catch deficiencies of snowfall. In spring, snow height is slightly over-estimated so that the time of total melt-up of the snow pack is slightly delayed. According to sensitivity studies this discrepancy can be attributed to the lack of long-wave downward radiation data, and the choice of the parameterisation for them (Mölders et al., 2003b). Sensitivity studies on initial data showed the importance of proper initialisation (Mölders et al., 2003b; Mölders and Walsh, 2003), and the need for data assimilation.

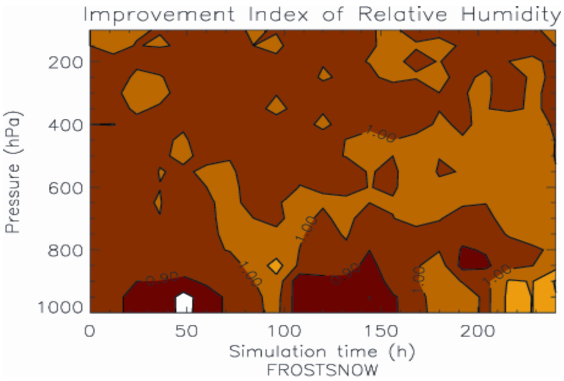

Figure 3: *Improvement index, I, for predicted relative humidity; I>1 degradation, I=1 no change, I<1 improvement.*

To evaluate transferability, offline evaluations were performed with data from outside the Baltic region (e.g., Mölders et al., 2003b). Evaluation of soil temperatures with ATLAS data for 1998 to 2002 is ongoing and has shown so far that the modified HTSVS predicts the diurnal and seasonal course of soil temperature well (Spier and Mölders, 2003). The modified HTSVS was implemented in MM5 and simulations were performed without and with snow module, alternatively without and with frost module over Alaska for March 1-11, 2001 600 UT (Mölders and Walsh, 2003), and July 20-23, 2001 600 UT. Forecasts skills calculated for these simulations using NCEP re-analysis data show that our activities improved prediction of relative humidity (Fig. 3) and air temperature.
Assimilation of HTSVS generated observations of soil moisture and surface temperatures have been performed for snow-free conditions first (Fig. 4). The assimilation procedure for the snow module has been tested with artificial observations of snow temperature. Performed identical twin experiments documented the assimilation procedure's potential to improve significantly model performance. Assimilating real ATLAS soil data improved soil temperature at all depths. Soil moisture predicted by the model without assimilation is almost independent on depth and appears to be too high at all depths except for the 15cm depth. Thus, assimilation improves soil moisture at all depths with observed deficiencies.

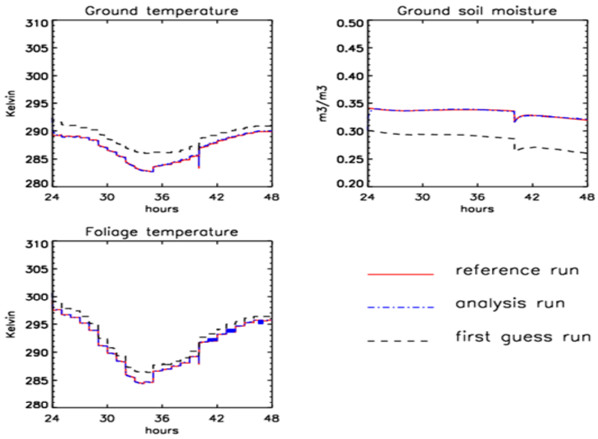

Figure 4: *Data assimilation of soil and surface temperatures.*

Future studies will apply the developed assimilation procedure for the HTSVS using other available data sets and within the modified MM5 package for the Baltic region.

Acknowledgements
We thank L. Hinzman for the ATLAS-, and the WINTEX LAPP groups for their data. BMBF funded our activities under contract 01LD0036. A. Cherry and P. Spier were 50% co-funded by NSF.

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Regional Evaporation at Grid and Pixel Scale over Heterogeneous Land Surfaces (EVA-GRIPS)

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The basic issue of BALTEX is the study of the energy and water cycle in the Baltic Sea region. The determination of the area-averaged evaporation and sensible heat flux over a heterogeneous land surface is fundamental for the simulation of the regional energy and water budget. This is also the major issue of EVA-GRIPS. EVA-GRIPS is funded under cluster 3 "Regional Process Studies in the Baltic Sea Area (BALTEX)" of the current Climate Research Programme (DEKLIM) of the German Federal Ministry of Education and Research. The funding period is 2002 to 2004. The spatial scale considered in EVA-GRIPS corresponds to the grid scale of a regional atmospheric NWP or climate model (here in particular the "Lokal-Modell", LM, of the Deutscher Wetterdienst, DWD, and the model REMO of the BALTIMOS group), but also to the pixel scale of currently available satellite images. Through a combination of near-surface and boundary layer observations, the analysis of satellite data and numerical simulations EVA-GRIPS aims at testing and implementing concepts for the description of area-averaged turbulent fluxes into four land surface schemes namely TERRA (Majewski, 1991) and TOPLATS (Beven and Kirkby, 1979) as part of LM, SEWAB (Mengelkamp et al., 1999) as part of an hydrological model and the land surface scheme of REMO.

Experiment and modelling activities focus on an area of roughly 20 km x 20 km around the Meteorological Observatory Lindenberg (MOL) of DWD. The continuous measurement program of the MOL – which is a CEOP reference site (Beyrich, 2003) – formed the basis for a major field experiment (the LITFASS-2003 experiment) in May and June, 2003.

Eddy correlation instruments were placed at 13 sites over different land use types and vertical profiles in the boundary layer were sampled by lidar and radar. A set of scintillometers, a helicopter borne turbulence probe HELIPOD (Bange et al., 1999) and an infrared camera for surface photography on board a Tornado aircraft as well as satellite images completed the set of instruments. The spatial sampling and footprint scales of this suite of measurement systems covered five orders of magnitude (10^{-1} .. 10^{4} m for the sampling scale) and three orders of magnitude (10^{1} .. 10^{4} m for the footprint scale), respectively.

Pronounced differences in surface characteristics (e.g. surface temperature) can be found over the different types of land use in the LITFASS area (Figures 2 and 3).These differences in land use and surface characteristics result in significant evaporation differences both in numerical models and estimated from satellite data (Figure 4). The direct intercomparison of LM results and NOAA images does not only reveal spatial patterns due to surface heterogeneity but also differences in magnitude and in the spatial distribution of evaporation which have to be investigated in detail. EVA-GRIPS will therefore combine model and satellite data with the in-situ measurements to finally analyse the representativeness and validity of the evaporation parameterisation in atmospheric models.

Locally measured water vapour fluxes over different types of land use were found to show significant differences (Figure 5). Area averages of grid-size representative fluxes will be derived from the surface observations over various land use types by a suitable averaging strategy and will be compared to the fluxes determined from area-averaging measurement systems (Helipod, scintillometers, lidar-radar combination).

Participants in EVA-GRIPS:

GKSS Forschungszentrum Geesthacht GmbH; Deutscher Wetterdienst (DWD) - Meteorologisches Observatorium Lindenberg (MOL); Meteorologisches Institut der Universität Bonn; Institut für Geophysik und Meteorologie der Universität Köln; Technische Universität Dresden, Institut für Hydrologie; Universität Hannover, Institut für Meteorologie und Klimatologie; Universität Bayreuth, Abteilung Mikrometeorologie; Technische Universität Braunschweig, Institut für Luft- und Raumfahrtsysteme; Max-Planck-Institut für Meteorologie, Hamburg; University of Wageningen, The Netherlands.

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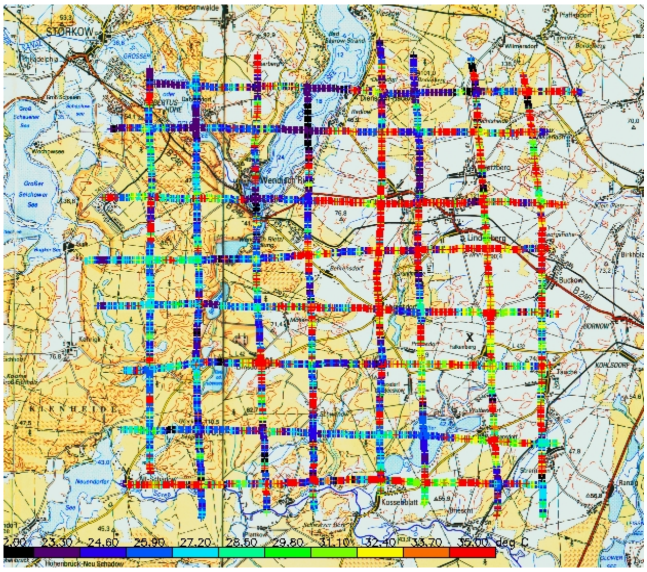

Fig. 2: *Regional distribution of surface temperature in the LITFASS area measured by the Helipod during a grid flight pattern on June 17, 2003 (picture by J. Bange, TU Braunschweig)*

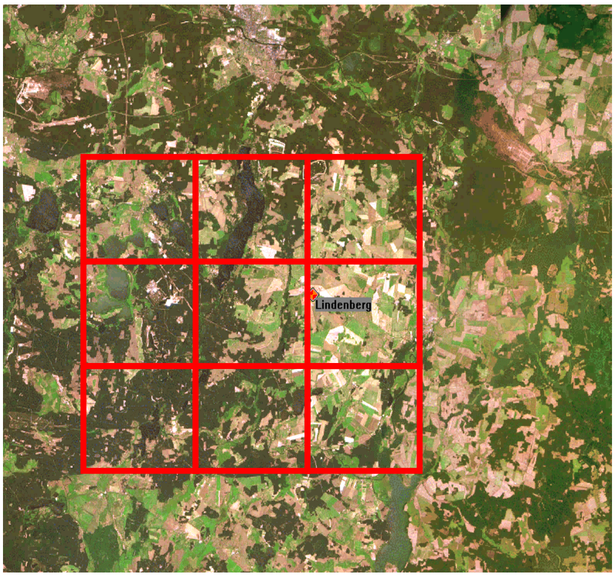

Fig. 1: *Arial view of the experimental site and LM grid boxes, photo taken from CD, "Deutschland aus dem All" 1997, Herold Business Data AG*

EVA-GRIPS website at
http://w3.gkss.de/KSH/EVA_GRIPS/home.htm

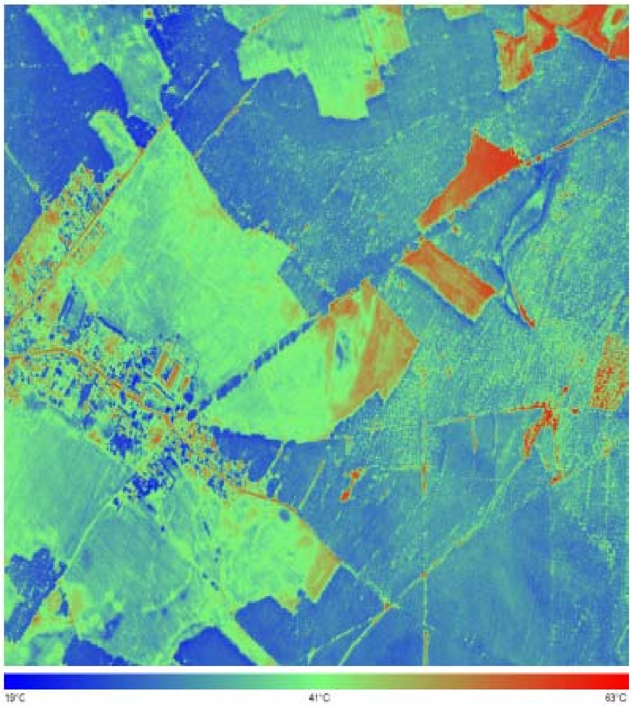

Fig. 3: *Calibrated infrared surface temperature. Photo taken from the Tornado aircraft over a small part of the LITFASS area on June 17, 2003 (picture by J. Bange, TU Braunschweig)*

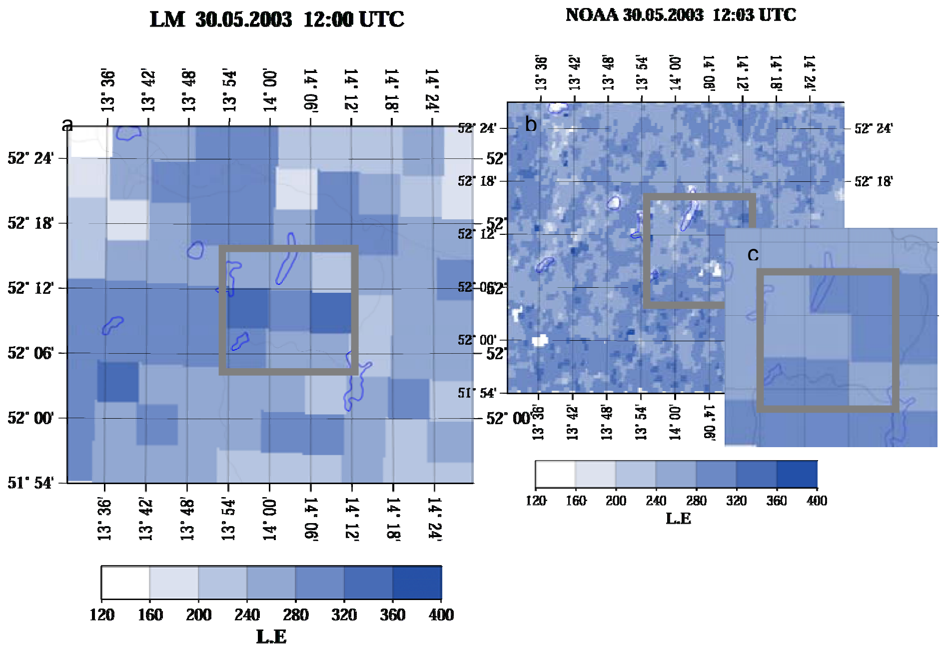

Fig. 4 (EVA-GRIPS): *Evaporation over the LITFASS area on May 30, 2003, around noon, left: LM simulation, right: derived from NOAA data – (figure by C. Heret and F. Berger, TU Dresden)*

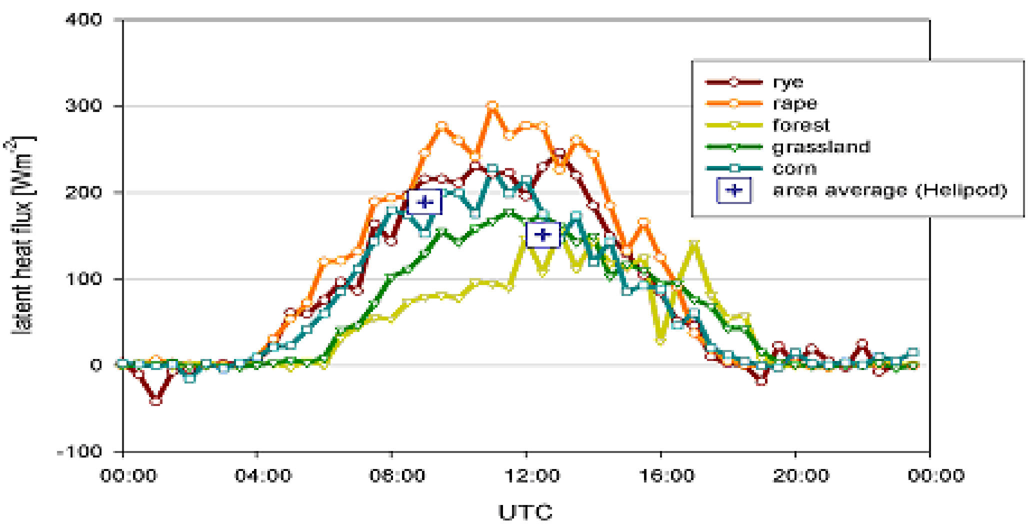

Fig. 5 (EVA-GRIPS): *Diurnal cycle of latent heat flux over various land use types for June 7, 2003 (figure by M. Mauder, University of Bayreuth, including data by GKSS, DWD and TU Braunschweig)*

Towards an Operational Soil Moisture Analysis Based on Screen Level Observations and Remotely Sensed Data

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For most applications in hydrology and meteorology root zone soil moisture is of fundamental interest, since the spatial distribution of this parameter determines evapotranspiration and consequently the water and energy exchange between the land surface and the atmosphere. For a given amount of radiative energy available at the surface, the partitioning between the latent heat and sensible heat determines the structure of subcloud layer entropy and water, the boundary layer clouds, the height of cloud base and consequently precipitation. Measurements of root zone soil moisture are extremely difficult to obtain even on small spatial scales. Consequently, the analysis of soil moisture in numerical weather prediction (NWP), soil-vegetation-atmosphere-transfer and pure hydrological models has to rely on the model output itself, screen level parameters (2 m temperature T_{2m} and relative humidity rH), satellite observations of surface soil moisture, and observed streamflow. All these observations are proxy data for root zone soil moisture and are difficult to assimilate.

Current operational analyses methods use screen level parameters only. Within the framework of the various Land Data Assimilation Studies(LDAS) for Europe (ELDAS), North America (NLDAS) and the Globe (GLDAS) new assimilation techniques for satellite observations have been developed and tested. Radiative transfer models are key elements in the data assimilation system since they link the state variables (e.g. soil moisture, surface temperature) and the observations (e.g. infrared and microwave brightness temperatures). Within the framework of DEKLIM (German Climate Research Programme) radiative transfer models for the application as observation operators in data assimilation systems have been developed. In this article results for the Southern Great Plains Hydrology Experiments (e.g. Jackson et al. 1999) are presented. Due to the high density and quality of observations this study area is one anchor point for the development and validation of the new global analysis scheme, which is planned to become operational at ECMWF in 2005.

Remote Sensing of Soil Moisture
Due to penetration depths ranging from several millimetres (X-band) to centimetres (L-band) the frequency range from 11 to 1.4 GHz can be used for surface soil moisture retrievals and data assimilation applications. Although it is well known that L-band sensors are the most promising instruments current research also addresses higher frequency applications, since space-borne observations at C- and X-band have been available since the late 70's (SMMR, TMI, AMSR-E, AMSR). Satellite-borne passive microwave observations at L-band will be available from 2007 on through the SMOS (Soil Moisture / Ocean Salinity) mission.

In order to address the question whether passive microwave measurements from satellites can be used to improve operational soil moisture products, an extensive comparison between experimental soil moisture data sets derived from airborne L- and C-band observations and operational products namely ERA40, ECMWF operational soil moisture analysis and ERS scatterometer derived soil moisture, was performed for the SGP99 Experiment. When compared to in-situ observations the accuracy of L-and C-band derived volumetric surface soil moisture (Fig. 1) was found to vary between 2% and 3%, absolute (Gao et al. 2003, Drusch et al. 2003). The errors in the operational data sets vary from ~8% to 14% depending on the data set and the soil state. Consequently, it can be concluded that measurements from low frequency passive microwave radiometers have the potential to substantially improve operational data sets obtained from NWP models (Drusch et al., 2003). Results for the TMI retrievals can be found in Wood et al. (2003).

Data Assimilation Experiments at ECMWF
Data assimilation experiments were performed using the single column version of the land surface model of ECMWF's Integrated Forecast System, a simplified Extended Kalman Filter (sEKF) and the Land Surface Microwave Emission Model. In general, the sEKF is a sequential real time assimilation scheme. Its complexity lies between 3DVar methods and a full 4DVar assimilation scheme. sEKF is based on the idea of minimizing the classical cost function as in variational methods. However, under the assumption of a quasi-linear problem close to the background state, the linearized observation operator can be approximated by a one-sided finite difference in the sEKF, which will be obtained through perturbed model runs.

Project Website:
http://www.meteo.uni-bonn.de/mitarbeiter/mdrusch/pages/deklim/hyper_sat1.html

In order to investigate potential benefits of L-band data, brightness temperatures and screen level parameters were assimilated in different combinations. In addition the sEKF technique has been compared to the operational Optimal Interpolation scheme (OI). The comparison between OI and the sEKF has been performed using data from the First ISLSCP field experiment (FIFE) and the SGP97 experiment. Both assimilation systems were able to distinguish between atmospheric and soil controlled periods. The overall soil water was adjusted by the same amounts, but the sEKF system simulated increments increasing from the first to the third layer whereas in OI they are equally distributed. When compared to obser-

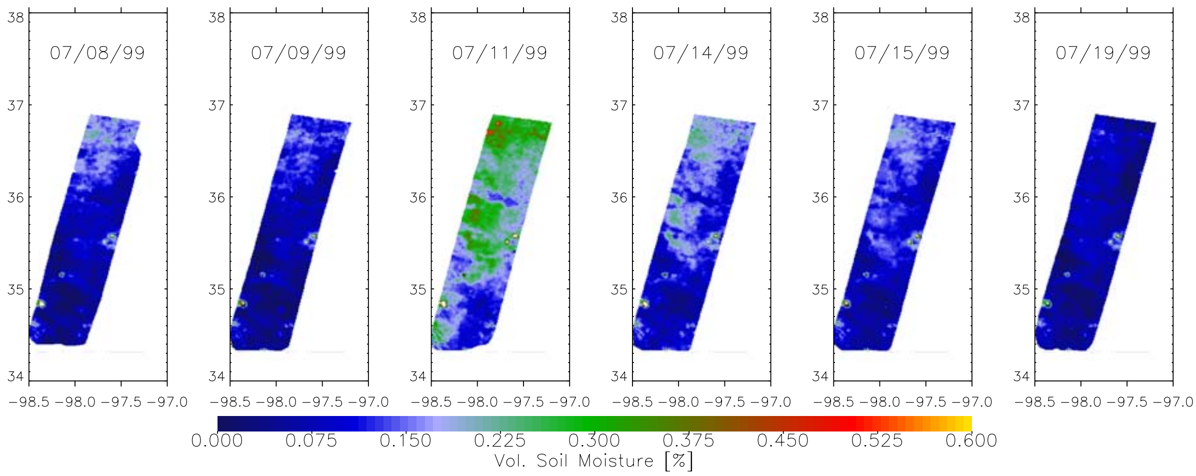

Fig. 1 (Drusch et al.): *C-band derived soil moisture for the SGP99 experiment region (from Drusch et al. 2003)*

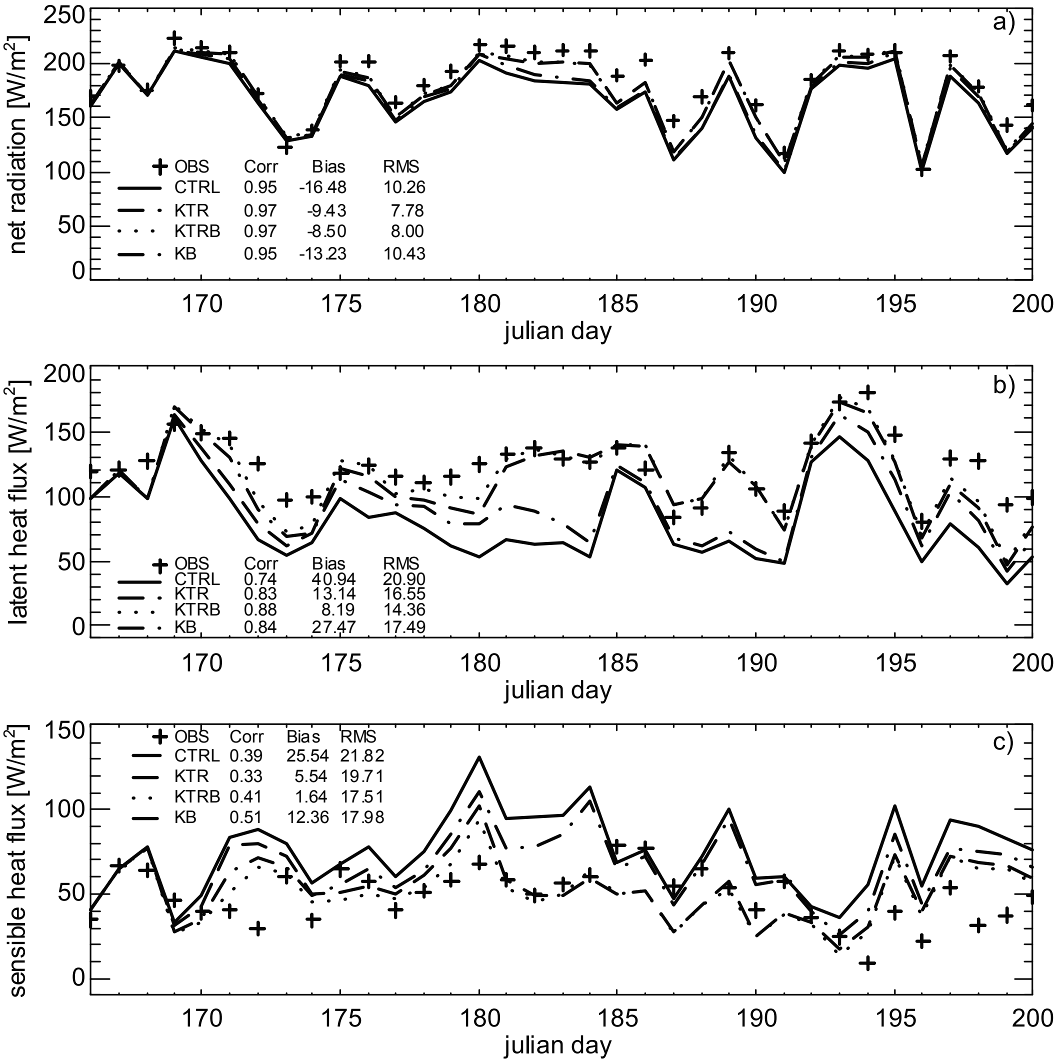

Fig. 2 (Drusch et at.): *Temporal evolution for 15.6.-19.7.1997 of daily mean a) net radiation, b) latent heat flux, and c) sensible heat flux simulated by the control run (ctrl), assimilation runs with T_{2m} and rH (KTR), $T_{brightness}$ (KB), and T_{2m}, rH and $T_{brightness}$ (KTRB) (from Seuffert et al. 2003a).*

vations it could be shown that the assimilation based on the synergy of the different observations gives more consistent results with regard to the prediction of net radiation, heat fluxes and near-surface soil moisture (Fig. 2).

A comparison with independent observations from the MUREX (Monitoring the Usable Soil Reservoir Experimentally) site in France showed that the prediction of sensible heat flux, root zone and near-surface soil moisture benefits from the assimilation of all three observation types (T_{2m}, rH_{2m}, $T_{brightness}$) (Seuffert et al., 2003b). Within ELDAS the data assimilation system described in this study will be further validated using additional observation points in the European area.

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Accurate Areal Precipitation Measurements over Land and Sea (APOLAS)

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Acronyms used: DWD = Deutscher Wetterdienst, IfMK = Institut für Meereskunde an der Universität Kiel, MIH = Meteorologisches Institut Universität Hamburg, MPIfM = Max-Planck-Institut für Meteorologie, MRR = Micro Rain Radar, OD = Optical Disdrometer, SRG = Ship Rain Gauge, WR = Weather Radar, VRP = vertical reflectivity profile, *Z-R*-relation = Relation between radar reflectivity and rain rate.

About the Project

Novel precipitation sensors are tested and their potential to improve the quality of precipitation measuring networks is investigated. There is an urgent need for efficient precipitation measurement technologies because existing in-situ measuring networks do neither meet today's requirements of the scientific community nor the operational needs of meteorological or hydrological services. This situation is aggravated because the traditional precipitation measuring networks degraded in many areas of the world during the past decades mainly for economic reasons.

It is obvious that radar based precipitation measurement is on the way to become the most important source of precipitation data in the future, and corresponding investments into weather radar networks on national and international scale have been made or are underway. Regardless of the unquestioned potential of weather radar for precipitation measurements this technology suffers still from essential deficits. For any quantitative radar based rain fall estimate additional data sources must be included in order to overcome the ambiguity between radar reflectivity and surface precipitation. The conventional approach uses climatologic in-situ surface precipitation data in order to establish statistical relations between surface precipitation and radar reflectivity. While this calibration method forces annual mean values to be consistent with in-situ data, it does not account for the vast variability of various factors entering the relation between radar reflectivity and surface precipitation on shorter time scales which are typical for rain events. Thus an important potential of radar rain fall measurements, namely its superior spatial and temporal resolution, cannot be fully exploited. This project aims at the mitigation of some of the major deficits by using novel precipitation sensors to support the quantitative retrieval of precipitation not only for mean values but also on an instantaneous basis. The members of the consortium are from research institutions involved in the sensor development and from the German weather service being in charge of the German weather radar network.

Specific Goals

Physically based calibration of radar rain fall retrievals

Mainly two sources of ambiguity of radar rain fall retrieval are under consideration in this project:

- The unknown actual shape of the drop size distribution in the radar volume and hence the unknown actual *Z-R*-relation

- Various processes occurring on the fall path of hydrometeors from the radar volume down to the surface resulting in a height dependence of the radar reflectivity (VRP).

In the conventional rain fall retrieval approach fixed *Z-R*-relations are assumed, which imply fixed relations between rain rate and shape of the drop size distribution – an assumption which contradicts even commonplace experience. In more advanced schemes areal or seasonal variations of *Z-R*-relations are allowed for. Due to the earth´s surface curvature weather radar measurements – particularly at greater distances from the radar – take place at considerable heights over ground. On the fall path the water flux can be modified due to the precipitation generation process within the cloud or evaporation below the cloud. The transition through the melting layer is connected with a significant modification of the *Z-R*-relation. In addition, the shape of the drop size distribution can be modified on the fall path due to various microphysical processes, as for example coalescence, break-up of large drops or evaporation. Some of these processes are conservative with respect to the water flux, others are not. All these processes which cause a height dependence of the radar reflectivity in a given rain event are summarily referred to as "VRP". It is obvious that the use of global Z-R-relations and disregarding the VRP represent major sources of error, and that any additional piece of information about the actual drop size distributions and the VRP will improve radar rain fall retrievals.

Precipitation over Sea

One important advantage of radar measurements is the areal coverage not only over land but also over coastal seas (in case of the Baltic Sea of the complete sea area). Radar precipitation fields were analysed for the Baltic Sea area by Michelson et al. (2000) and Rutgersson et al. (2001) by including various auxiliary data sources. Unfortunately, the most important data source, namely in-situ precipitation data, is usually missing over sea due to the lack of adequate sensors. To some extent this gap is being closed for the Baltic Sea by novel rain gauges developed at IfMK (Hasse et al., 1998). These SRGs were designed for operation at wind-exposed sites, i.e. also for shipborne operation. Clemens and Bumke (2002) reported on first spatial precipitation distributions over the Baltic Sea based on such in-situ measurements onboard of voluntary observing ships. A further substantial improvement of the retrieval quality with respect to this purely statistical approach is expected by gaining more knowledge about the micro-physics of rain over sea, which may differ significantly from land conditions.

Methodology

Novel sensors, which have the potential to provide the missing information discussed above, were installed at two sites of the German Baltic Sea shore (Zingst, Westermarkelsdorf/Fehmarn) and on the research vessel "ALKOR" cruising primarily in the Baltic Sea. The new sensors include ship rain gauges, optical disdrometers (Großklaus et al. 1998), micro rain radars (Peters et al., 2002), and a high frequency sodar (MPIfM). In order to get confidence in the characteristics and performance of these sensors they are cross compared at the field sites for longer periods. As the mentioned sites are within the covered range of weather radars, which are located in Rostock and Hamburg respectively, simultaneous MRR- and WR-measurements in common radar scattering volumes are analysed (Wagner et al., 2003). Characteristic profiles of micro-physical parameters of rain fall are extracted from MRR Doppler spectra obtained during several years of observation. A data base for describing the specific shapes of maritime drop size distributions and profiles of radar reflectivity is collected with ODs installed onboard of "ALKOR" and for reference at various land sites.

Preliminary Results

Figure 1 shows comparisons of the radar reflectivity factor Z measured by the Rostock weather radar and the MRR in Zingst respectively. The observed high correlation is not self-evident, as the wavelengths of both radars are very different, and the Rayleigh approximation, which is valid for the WR, does not hold for the MRR. Therefore, Z had to be calculated via the drop size distribution, obtained from the MRR. This result is encouraging enough to further explore synergies which can be achieved by full utilization of height resolved drop size distributions provided by the MRR.

In figure 2 mean profiles of various rain parameters, derived from the Zingst MRR, are shown for different rain rates. They show a remarkable feature in the highest rain rate class (R > 20 mm/h): The mean fall velocity, which is defined here as the first moment of the Doppler spectrum, decreases with increasing height and falls even below the corresponding fall velocities of the weaker rain rates. This structure cannot be related to the melting level, because the analysis was restricted to heights safely below the melting level during summer (May-September). The changing fall velocity is rather an indication for a significant transformation of the drop size distribution on the fall path. The apparent loss of small drops on the fall path is explained by coalescence. The increasing relevance of this process with increasing rain rate is in qualitative agreement with theory (Hu and Srivastava, 1995). The lowest panel shows the ratio of rain rate profiles derived from MRR drop size spectra versus rain rates which would be obtained with a fixed *Z-R*-relation. According to these profiles, high rain rates would be severely underestimated by WR using *Z-R*-relations, which were established (as usual) on the basis of surface measurements.

Figure 3 shows mean drop size distributions obtained with ODs at different measuring sites. ALKOR represents "maritime" conditions whereas the site in Kiel is considered as a "land"-site due to the land mass in (westerly) upwind direction. Westermarkelsdorf is an "intermediate" site in this respect as the fetch with sea conditions is strongly variable within the westerly sector. According to this analysis the drop size distributions differ mainly in the small drop fraction. There are obviously significantly less small drops in rain over sea than over land, with corresponding consequences for the *Z-R*-relation.

Outlook

The results are considered preliminary and must be further cross-checked to exclude possible artifacts. For example some apparent discrepancies between the different sensor outputs, which were not discussed here, have still to be resolved. A necessary future step to harness the local information, provided by the in-situ and profiling sensors, for improved areal precipitation analysis is the development of an intelligent areal extrapolation procedure, which for example utilizes the signature of WR reflectivity patterns. Synchronized local data, which are collected at separate sites in the course of this project, will serve for validation of such schemes.

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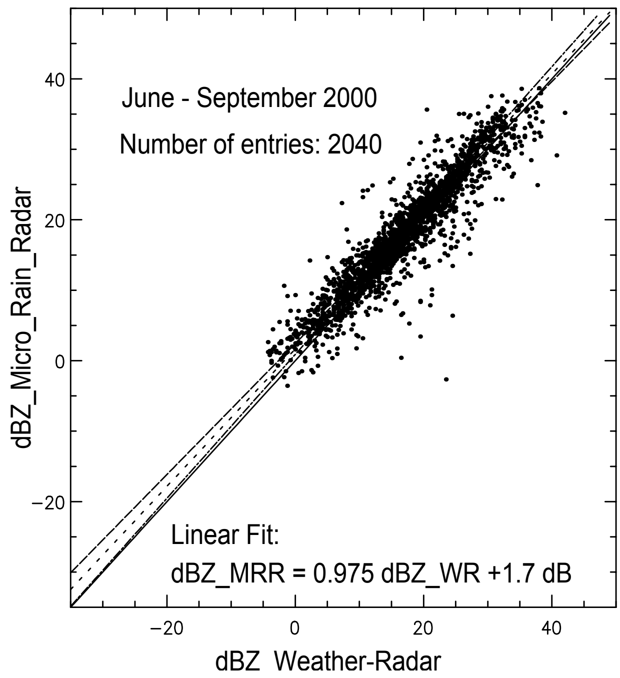

Figure 1 (APOLAS): *Comparison of radar reflectivity, as obtained from MRR measurements over Zingst versus WR-Rostock measurements. MRR measuring height = 1100m, averaging time = 1 min, WR range = 55 km.*

APOLAS on Internet at
http://miraculix.dkrz.de/~gerhard/apolas.html

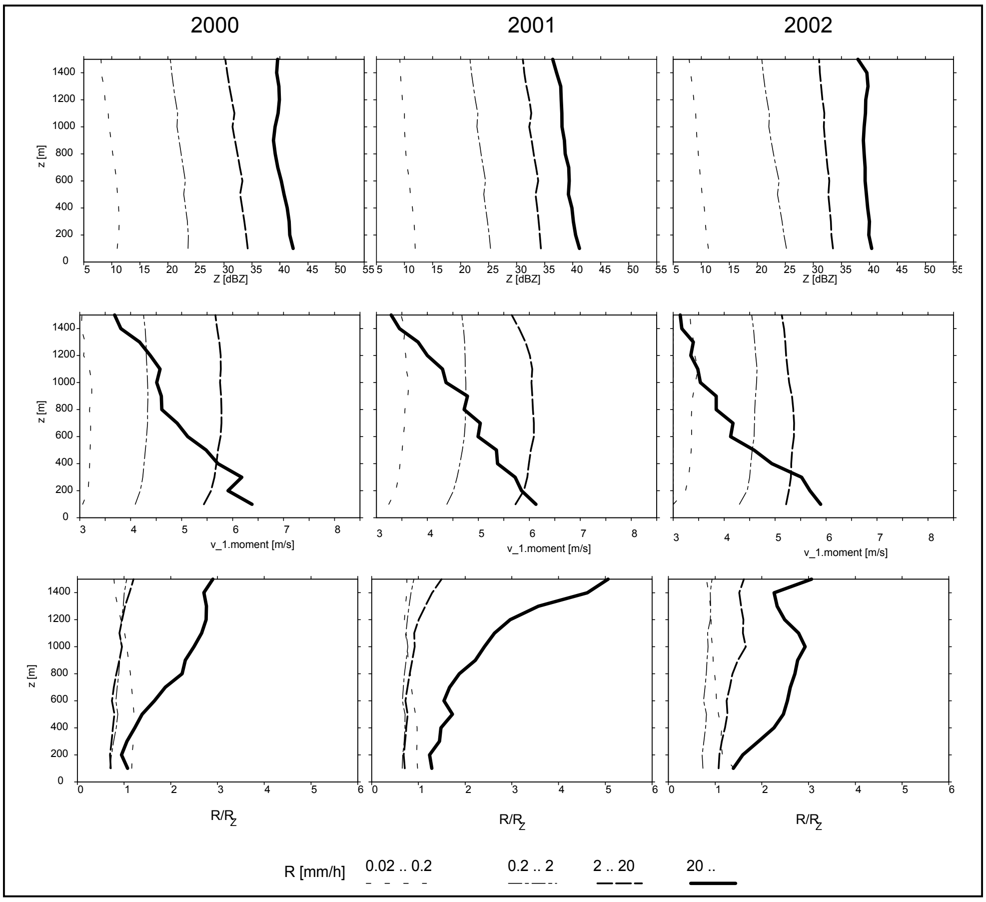

Figure 2 (APOLAS): *MRR profiles of various rain parameters sorted according to rain rate classes for three subsequent years (summer months). Top: Radar reflectivity factor, Middle: "Mean" fall velocity (1st moment of the Doppler spectrum). Bottom: Rain rate profile derived from drop size distributions of the MRR divided by rain rate profiles derived with a fixed Z-R-relation.The total number of rain events (minutes with rain detected) ranges from about 11000 to 20000 in the different years.*

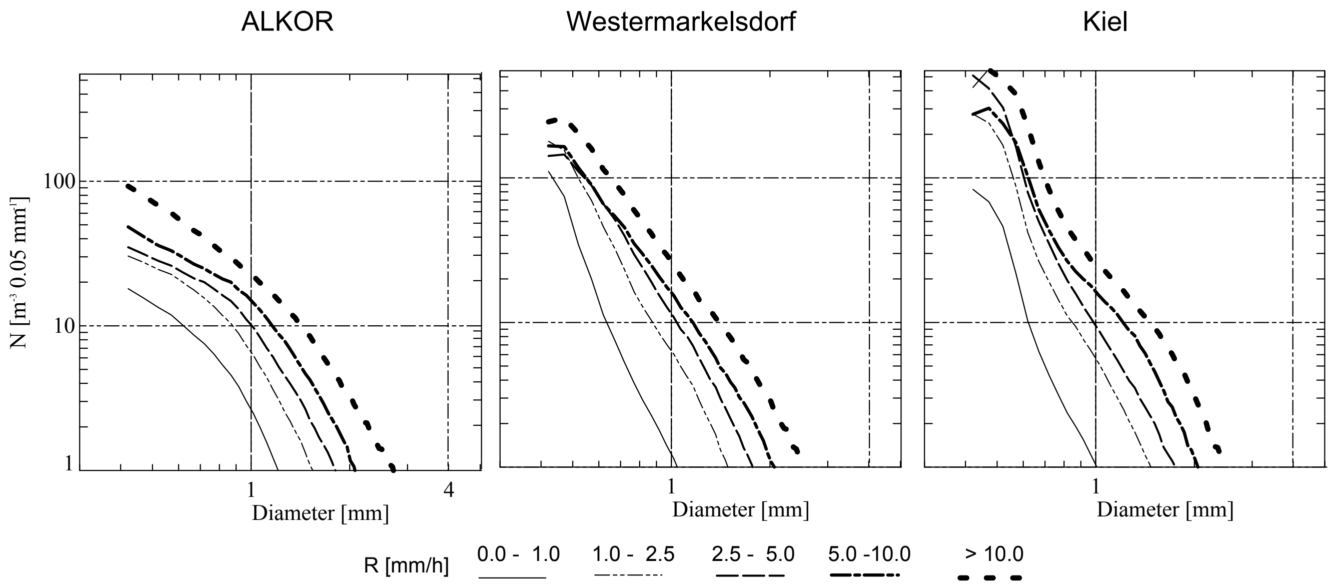

Figure 3 (APOLAS): *Drop size distributions (1 min averages) measured at different sites representing maritime (ALKOR), intermediate (Westermarkelsdorf), and land (Kiel) conditions. The total number of rain events (minutes with rain detected) ranges from about 6000 to 25000 at the different sites.*

Integrated Baltic Sea Environmental Study (IBSEN): Analysis and Simulation of Hydrological and Ecological Variability in the last 1000 Years

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In the framework of the Integrated Baltic Sea Environmental Study (IBSEN), the hydrological and ecological variability in the last 1000 years will be simulated and analysed with respect to the two strongest climatic signals during the last 1000 years: the Medieval Warm Period (1130-1170 AD) and the Little Ice Age (LIA) at the sun spot Late Maunder Minimum (LMM, 1670-1710 AD). These periods will be compared to the last 40 years in the 20th century which cover the 1960s cold period and the 1990s warm period. The applied methods are time slice experiments for the three periods forced by a 1000 years climate simulation using a complex model hierarchy. The model output will be analysed with statistical models which are linked to environmental data sets and sediment records. IBSEN is still ongoing and selected results are presented: LIA simulation, temperature reconstruction, and cyanobacteria blooms.

IBSEN on Internet at
http://www.io-warnemuende.de/projects/ibsenweb/en_index.html

The LIA Simulation

The LIA can be well reproduced with the global model ECHO (Fig. 1) and the regional model REMO. The sun spot minimum in combination with volcanic activity results in a reduction of the Gulf Stream and the Kuroshio circulation and the anticyclonic vorticity of the wind field during the LIA (E. Zorita, pers. comm.). The global near-surface temperature in the model exhibits a larger variability than the control run. Two clear minima, at the end of the 17th century and beginning of the 19th century, are simulated. These minima occur almost simultaneously (after a 2-3 year lag) with known minima in the solar activity, the LMM and the Dalton Minimum, respectively. During the first half of the LMM, the NAO has a negative phase allowing cold Siberian air to penetrate deeply into Europe. During the second half, the NAO shifts into a positive phase, thus contributing to warming which marked the end of the LMM (Fischer-Bruns et al. 2002). The simulated event is a worldwide phenomenon, which is associated with the largest anomalies in the North Atlantic.

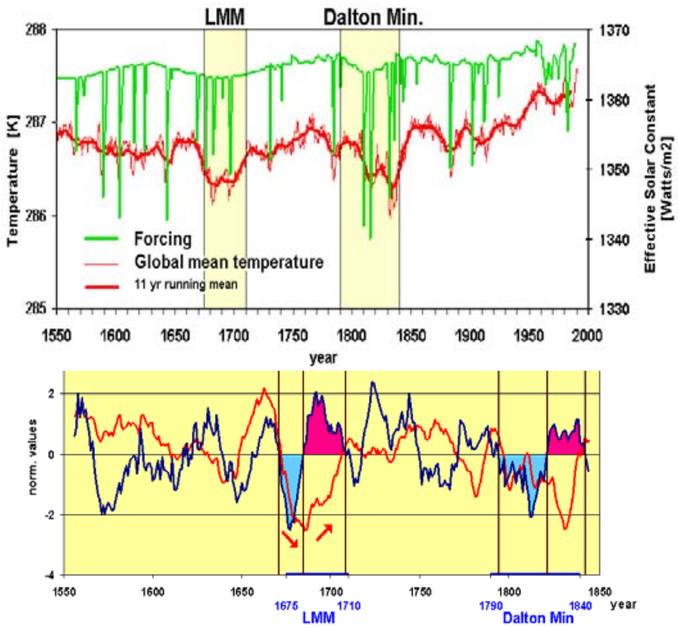

Fig. 1: *Above: Model forcing (green) and global mean temperature (red). Below: NAO index (black) and global mean temperature after Fischer-Bruns et al. (2002).*

Temperature Reconstruction

Using 60 surface sediment samples (0-1cm) of Uk'37 index of alkenons in Emiliania huxleyi along the salinity gradient from Skagerrak to the Arkona Basin allows a reconstruction of the sea surface temperature (SST) during the time of blooming – in general during May (Fig. 2). A comparison of the reconstructed SST with satellite pictures during May 2000 and model results for May 1989/1990 shows a good agreement. These results indicate that Uk'37 index is a good proxy for SST during May.

Similar analyses have been performed for benthic foraminiferal faunal composition to reconstruct the bottom temperature. 110 different species were grouped by PCA into three benthic foraminiferal assemblages. 14C-AMS dates of benthic foraminiferal calcite calibrated to calender years (Stuiver et al. 1998) were used to construct a time scale. Since Melonis barleanum is known to calcify close to oxygen isotopic equilibrium with the ambient bottom water (Labracherie et al. 1989), the stable oxygen isotopic composition of M. barleanum was used to calculate ambient bottom water temperatures. As a first check of the validity of this approach might serve that calculated temperatures of between 7 and 8°C in the most recent samples nicely match today's bottom water temperatures in the Skagerrak area (Stabell et al. 1985, Brückner, in prep.).

Cyanobacteria Blooms

A simulation with the 3D coupled physical biogeochemical model ERGOM (Neumann 2002) was carried out for the years 1979-1993 with realistic forcing taken from the ERA-15 dataset to investigate the inter-annual variability in blooms of cyanobacteria (CB). Late summer atmospheric and hydrographic conditions have an impact on the development of the bloom. Calm, sunny weather leads to a strong, shallow thermocline and high sea surface temperature which are favourable conditions for massive CB blooms with strong surface accumulations. However, the variability of the environmental conditions in summer cannot explain the strong inter-annual variability of CB. There is an influence of the wintertime hydrographic conditions half a year in advance of the bloom which is not that obvious.

The phytoplankton bloom starts each year in March in the southern Baltic Sea from the wintertime nutrient concentrations. Large parts of the Baltic Proper and the Gulf of Finland are limited by nitrogen leaving behind an excess of phosphorus in the surface layer in late summer. This

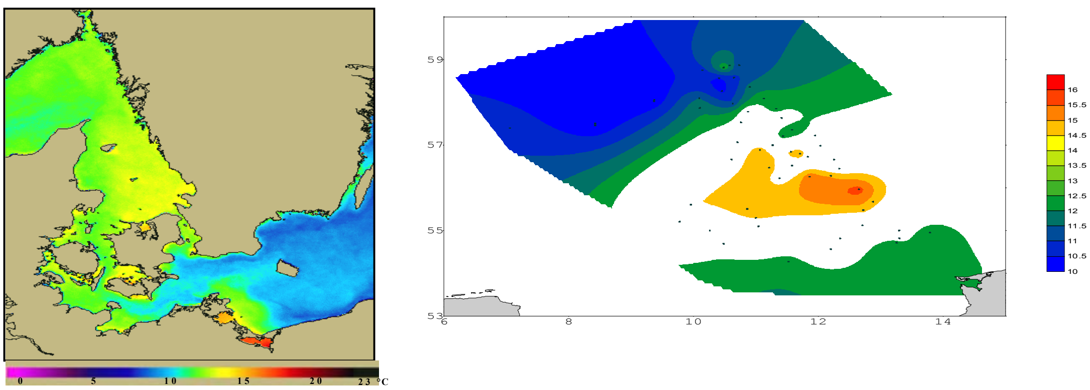

Fig. 2: *Left: SST in May 2000 in the Skagerrak - Kattegat area from NOA AVHRR (Data source: BSH, image processing, Siegel IOW). Right: SST calculated from alkenones in surface sediments (Blanz, in preparation).*

phosphorus pool is a necessary condition for blooms of CB and suggests the possibility to estimate the potential for CB blooms from the knowledge of surface layer nutrient concentrations before the onset of stratification in March/April. In other words, the potential of a late summer CB bloom is determined as early as February by the excess phosphorus (eDIP mmol m-3 = DIP mmol m-3 - DIN mmol m-3 / 16) in the surface layer.

Therefore, the following chain of causal connections is suggested in order to explain a large part of the inter-annual variability of CB blooms: high NAO ⇒ high wind stress/less ice cover ⇒ high mixed layer depth ⇒ high eDIP concentration ⇒ high potential of CB blooms and vice versa. Figure 3 shows this chain as simulated with ERGOM.

Acknowledgement
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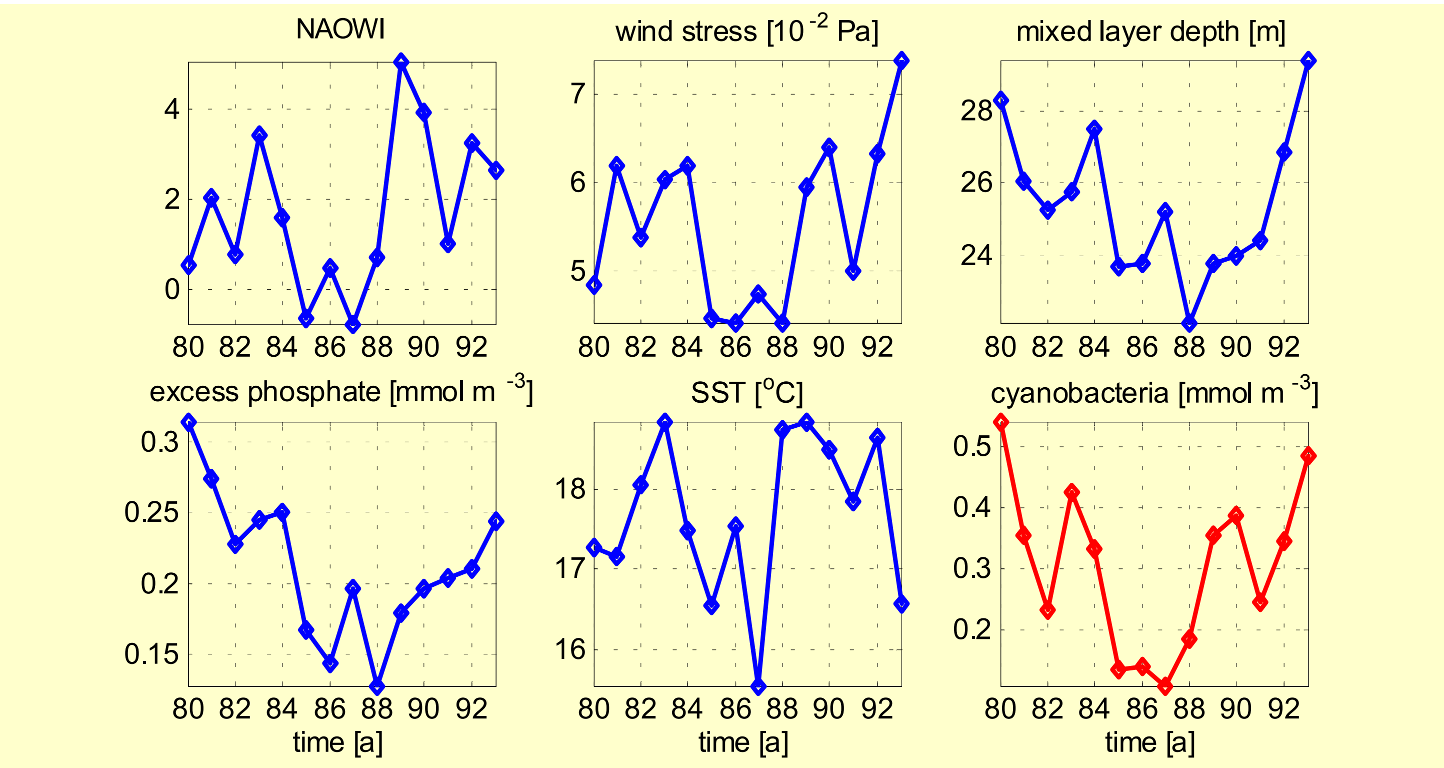

Fig. 3: *Time series of the NAO winter index, the wind stress, the mixed layer depth, the excess phosphate, the SST and the biomass of cyanobacteria simulated with the present climate run (after Janssen et al. 2003). Mean of model area for all variables except NAOWI.*

Salt Water Inflow 2003 - Simulated with the Coupled Modeling System BALTIMOS

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A fully coupled model system for the Baltic Sea region, called BALTIMOS, was developed in the frame of DEKLIM/BALTEX 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 (Figure 1). The model system consists of high resolution model components (atmosphere 18 km, 20 levels; ocean-ice 5 km, 60 levels; hydrology 18km) which are coupled via surface fluxes. The development of the model system is a combined effort of 10 different German institutions (see BALTEX *Newsletter* No. 4) with the focus on model validation rather than long-term climate simulation (which will be performed later). Thus, the simulated water and energy budget of the Baltic Sea area undergoes a comprehensive validation which is carried out by the project partners. More detailed articles about the model validation will be given in following BALTEX-*Newsletters*.

A highlight of first model results of BALTIMOS presented at the DEKLIM Status Seminar in October 2003 in Bad Münstereifel, Germany is the successful simulation of the major Baltic inflow in January 2003.

Between January 16th and 25th an inflow of highly saline, cold and extremely oxygen-rich water from the North Sea was recorded at Darss Sill. Calculations using the sea level difference of about 50 cm at the Landsort gauge yield an estimate of 180 km^3 (for comparison the annual river runoff is about 450 km^3). The reason for this exceptional inflow which is the only possibility to renew the deep water of the central Baltic Sea and to improve the oxygen situation there is an unusual low water level (20-30 cm below normal at gauge Stockholm) at the beginning of the inflow due to stable high pressure over Scandinavia and associated north-easterly winds. From January 11th the wind turned to westerly directions and the wind speeds increased reaching about 20 m/s during January 15th (Figure 2). The western Baltic Sea level suddenly lowered to -80 cm and a strong inflow was forced. The intrusion continued with heavy fluctuations until the wind began fading on January 18th, leaving the Stockholm level risen to 25 cm above normal.

More information on the major inflow event in January 2003 see
www.io-warnemuende.de/research /salzwassereinbruch2003.html

This exceptional event has been simulated with BALTIMOS. The fully coupled simulation started at 1st of December 2002 and lasted until the end of July 2003. Figure 2 shows wind speed vs. direction of the SYNOP station “Arkona” (island of Rügen) compared to the BALTIMOS results of the appropriate grid box for January 2003. Despite the principal difficulty of comparing a point measurement (station) with a representative value for the area of a whole grid box (model result) there is a good agreement between them. In particular the shift from easterly winds in the beginning of January to strong westerly winds in the middle of January is represented.

As can be seen from Figure 3, switching the atmospheric forcing from uncoupled (SMHI Meteorological data base, 24 years uncoupled ice-ocean-only-run started in 1979) to fully coupled atmosphere-ocean mode causes no abrupt adjustments in the Baltic Sea. In accordance to observations, the highly saline water entered the Bornholm Basin in the end of January. Unusual warm water entering the Bornholm Basin in September 2002 led to temperatures between 14C - 15C in depths between 60 and 70 m. This persistent warm water anomaly in the Bornholm Basin was finally displaced by the inflow in January 2003. The warm water anomaly stimulated sprats to unusual early spawning.

The first results of the fully coupled atmosphere-land-ocean model BALTIMOS demonstrates the powerful applicability of coupled numerical simulations.

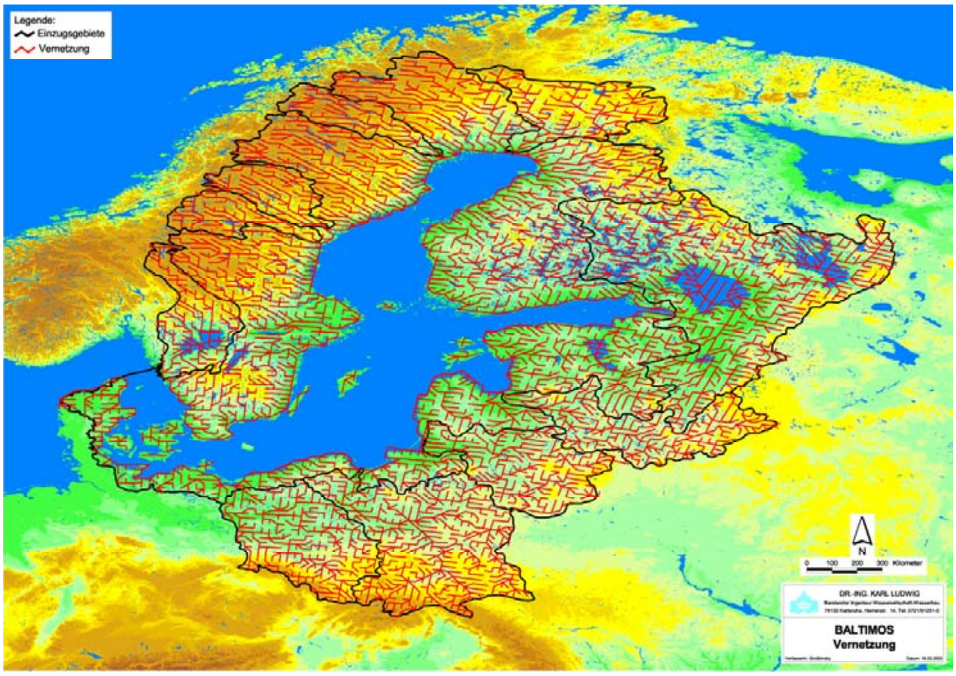

Figure 1: *BALTEX catchment area and river routing scheme of BALTIMOS.*

***Figure 2**: Wind speed [m/s] (upper panel) and wind direction [deg] (lower panel) for January 2003: Measurements at the SYNOP-Station "Arkona" (red) and BALTIMOS simulation for the appropriate grid box (black).*

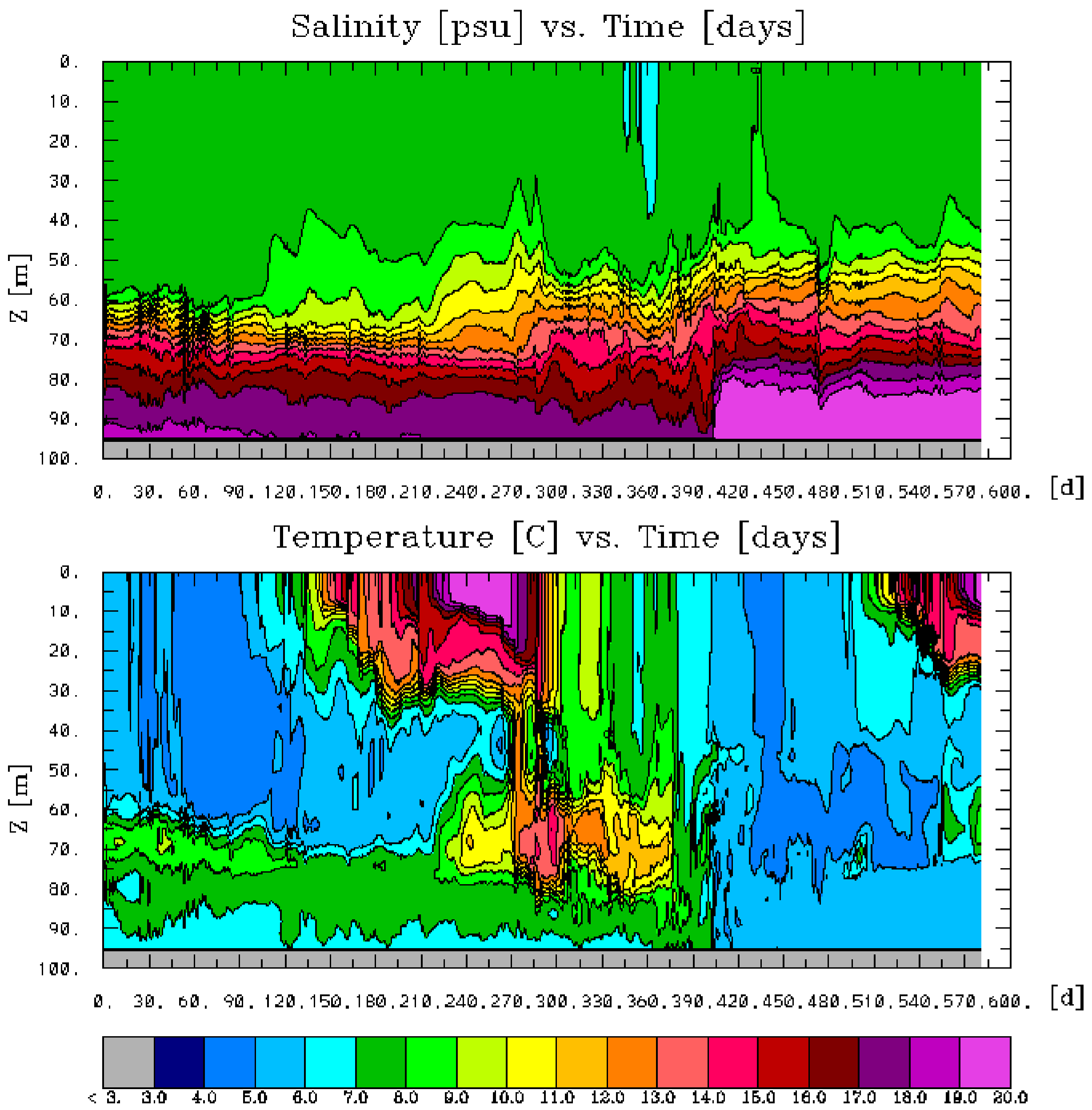

Figure 3 (BALTIMOS): *Time series of vertical profiles of salinity [psu] (upper panel) and temperature [°C] at Bornholm Deep vs. time from January 2002 until July 2003 .*

Simulated Sea Surface Temperature and Sea Ice in different Climates of the Baltic Sea

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The physical state of the Baltic Sea is strongly tied to the state of the regional atmosphere. Global warming as a consequence of atmospheric greenhouse gas increase can be expected to affect the Baltic's physical water quantities and sea ice in the future. In this newsletter we point to an ensemble approach to quantify possible changes in mean quantities and interannual variability together with estimates of uncertainty related to the emission scenario and the global model. Detailed results can be found in Döscher and Meier (2004) for temperature and heat fluxes and in Meier et al. (2004) for sea ice and impact on the Baltic's seal habitat.

Models and Method

We utilize the regional Rossby Centre Atmosphere Ocean model (RCAO) to dynamically downscale global control and scenario simulations. The global models are HadCM3/AM3 from Hadley Centre (short: HC) and ECHAM4/OPYC3 from Max Planck Institute for Meteorology (short: MPI, runs carried out at Danmarks Meteorologiske Institut). Both global systems have been run from 1961 to 2100 with increasing greenhouse gas and aerosol emissions based on the scenarios A2 and B2 as defined by the Intergovernmental Panel on Climate Change (Nakicenovic et al. 2000).

RCAO is an interactively coupled atmosphere-ocean model (described by Döscher et al., 2002) applied to Northern Europe. Details on the component models can be found in Jones et al. (2004) for the atmosphere (RCA) and in Meier et al. (2003) for the ocean and ice model (RCO). Dynamic downscaling has been carried out for today's climate (1961 - 1990, 'control run') and for a future time slice (2071-2100, 'scenario run').

Sea Surface Temperature

The mean sea surface temperatures (SST) for the different runs are given in table 1 together with climatological observations. SST mean values of the control simulations show only small positive biases of less than 0.55 C. These differences correspond to a generally too warm surface air temperature over Europe in the regional atmosphere model (Räisänen et al., 2003a), mostly based on too warm summer months in an area extending from south-eastern Europe to the Baltic Sea (Räisänen et al., 2003b). A cold SST bias is found in December. This is likely caused by heat flux deficiencies (latent and long wave). The consequence is a slight overestimation of sea ice extent.

The ensemble mean surface warming is 2.9 C. The uncertainties due to the emission scenario and the global model are indicated by the differences between the individual experiment's signals. Warming is stronger for the A2 cases (3.4 C or 45.7% on average) and smaller for the B2 cases (2.4 C or 32.6% on average), consistent with the greenhouse gas scenarios and the associated global mean GCM and regional mean RCM surface air temperature (Räisänen et al., 2003a). Surface warming based on MPI scenarios is stronger than HC-based increases by 0.9 C. This difference is again consistent with differences in the regional atmospheric temperature. Sea surface warming is strongest during the period May to September for all cases.

Interannual variability of Baltic Sea SST is increased by up to 0.5 C in terms of standard deviation of individual monthly means. The frequency distribution for SST (i.e. the distribution of colder and warmer than normal years) is smoothed in northern basins during the colder period of the year due to melting ice.

	mean (SST)	SST change scenario-control in K	SST change scenario-control in %	Mean max annual ice in 10^9 m^3	Change of mean max annual ice in 10^9 m^3	Change of mean max annual ice in %
Observations	7.2	-	-	-		
HCCTL	7.7	-	-	42.4		
MPICTL	7.3	-	-	46.9		
HCA2	10.7	+ 3.0	+ 39	7.1	-35.3	-83
MPIA2	11.1	+ 3.8	+ 53	4.1	-42.1	-90
HCB2	9.6	+ 1.9	+ 25	10.2	-32.2	-76
MPIB2	10.2	+ 2.9	+ 40	8.2	-38.7	-83
average change	-	+ 2.9	+ 39		-37.1	-83

Table 1. *29-year mean SST and sea ice volume. The SST observations are climatological monthly means calculated by Janssen et al. (1999) . Model runs are denoted as combination of the name of the driving GCM and the type of run, e.g. HCCTL or MPIA2.*

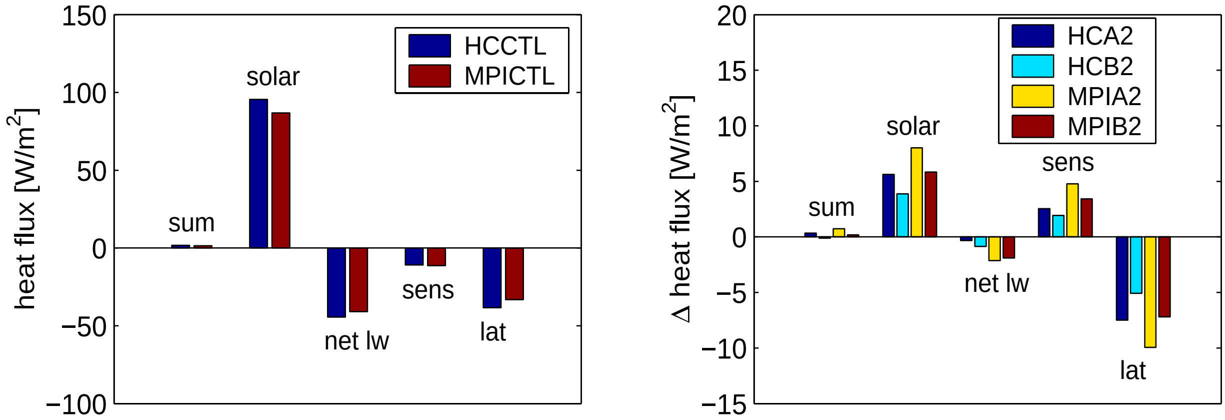


***Figure 1** Left: Overall mean heat flux from the atmosphere to the ice/ocean system in components: Shortwave ('solar'), net longwave ('net lw'), sensible ('sens'), latent ('lat') and the sum of all components. Right: Differences between heat fluxes of scenario and control experiments. Figure taken from Döscher and Meier (2004).*

Atmosphere-to-Ocean Heat Flux

The Baltic Sea heat budget has been calculated for control and scenario experiments. The overall mean heat flux components together with changes are given in Fig. 1. MPI and HC control runs show similar total surface heat fluxes between 1 and 2 Wm^{-2}. Under a warmer climate, our scenarios suggest only little change of the total budget. However, the component fluxes show a clear and coherent change: solar radiation is increased, net longwave radiation (incoming - outgoing, out of the ocean) is increased, sensible heat flux (out of the ocean) is reduced and latent heat flux (out of the ocean) is increased. The amplitude of change is higher in the MPI case, corresponding to the higher SST change.

The heat flux changes are due to changes in atmospheric conditions (Räisänen et al., 2003a): Cloudiness in the scenarios is reduced over large parts of Northern Europe, moisture is reduced and wind speed is increased. This leads to increased solar radiation and increased latent heat flux. The latter reduces the air water temperature difference and thus the sensible heat flux is reduced. The increased net longwave flux is attributed to the increased SST.

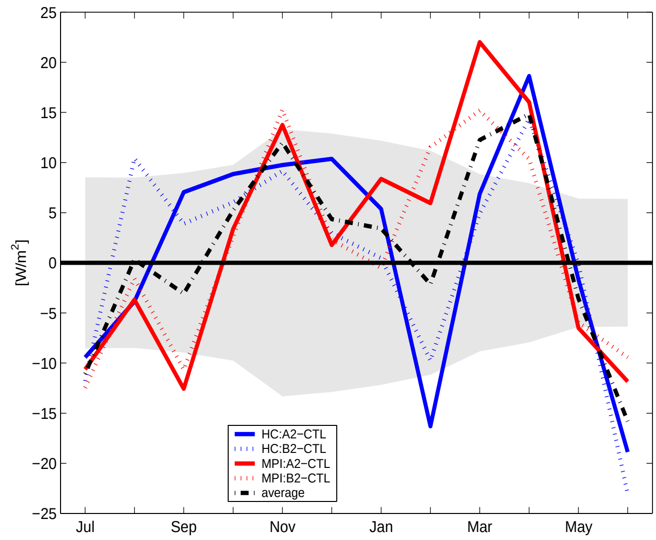


***Figure 2:** Difference between scenario and control run, positive into the ocean (the shaded area gives the approximate 95% confidence limit based on the standard deviations of the means). Figure taken from Döscher and Meier (2004.)*

The Baltic Sea takes up heat from the atmosphere during the warm months and returns heat during wintertime. Both control runs confirm this picture. Under a warmer climate, atmosphere-to-ocean heat fluxes show a different distribution over the seasons. The ensemble mean heat loss (black dash-dotted line in Fig 2 is reduced between October and February/March (exception: February), heat uptake is increased in April and heat uptake is reduced between May and July.

For information about the Rossby Centre see
http://www.smhi.se/sgn0106/rossby/sweclim/rc.htm

By arriving of the summer, any additional net heat transfer into the ocean is counteracted by a negative feedback mechanism: the warm ocean responds with increased heat release by longwave outward radiation and latent heat. Most of the larger peaks of the changes in Fig. 2 are outside the 95% confidence limit (the shaded area in Fig. 2, based on the maximum of standard deviations of the means of our six simulations). Thus they cannot be explained as caused by interannual variability only. This general picture is a robust feature of all our experiments independent of the scenario (A2 or B2) and the driving global model (MPI or HC). However, HC scenarios differ from this picture in February due to increased sensible heat loss to the atmosphere. These statements on confidence and conformance represent a progress.

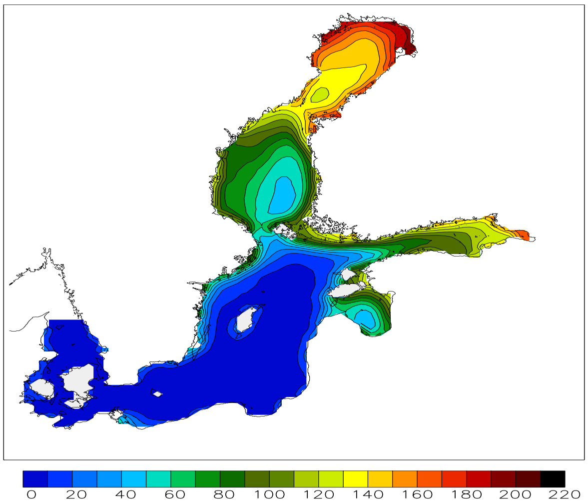
Locally, in the northern part of the Baltic, heat fluxes change by up to 30 Wm-2 in the ensemble mean when strong ice cover changes (during spring) occur, and when the latent heat flux changes most (during fall). The A2 scenarios give even higher differences (up to 40 Wm-2), but ho rizontal patterns of changes are similar for A2 and B2.

Sea Ice

The simulated mean annual maximum ice extent ('mean MIB') and the number of ice days in the control runs matches the observations (SMHI & FIMR, 1982) for the period 1961 – 1990 well. Ice extent and volume (Tab. 1) are dramatically reduced in the scenarios. The ensemble mean reduction of ice volume is 83%. Corresponding to the SST changes, reduction is stronger for MPI and A2 scenarios.

Large parts of the Bothnian Sea, the Gulf of Finland, the Gulf of Riga and the southwest archipelago of Finland are ice free in all scenarios. Severe ice winters do not occur anymore. However, sea ice is found in the Baltic in every single winter.

The number of ice days (Fig. 3a) shows a typical distribution as seen in observations, although the position of the Bothnian Sea minimum is shifted somewhat to the east. A local minimum of 120 to 130 days in the central southern Bay of Bothnia is found in control runs and in observations. The annual mean number of ice days is reduced for a warmer climate (Fig. 3b). In the A2 scenario, we find 25%, 59%, 92% and 84% less ice days at Kemi (Bay of Bothnia), Kotka (Gulf of Finland), Utö (Archipelago Sea) and Kihnu (Gulf of Riga).



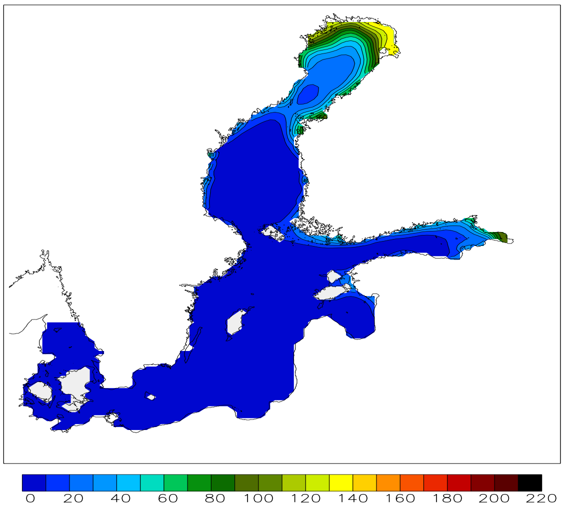


Figure 3: *Mean number of ice days as average of HC and MPI. Top: Control run. Below: A2 scenario run. Figure taken from Meier et al (2004).*

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Ninth Annual Meeting of the GHP
Lüneburg, Germany
22-26 September 2003

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The ninth annual meeting of the GEWEX Hydrometeorology Panel (GHP) was hosted by Hans-Jörg Isemer, GKSS Research Centre, Geesthacht, and Hartmut Grassl, Max-Planck-Institute (MPI) for Meteorology, Hamburg. The meeting began with focused workshops on five GHP initiatives. These workshops included: 1) Water and Energy Budget studies (WEBS), chaired by J. Roads; 2) Water Resources Application Project (WRAP), chaired by L. Martz; 3) Sources and Cycling of Water (SCW), chaired by M. Bosilovich; 4) Extremes, chaired by R. Stewart; 5) Predictability, chaired by J. Marengo. A workshop on the Coordinated Enhanced Observing Period (CEOP), chaired by Sam Benedict (international coordinator) was also held during the meeting. From its early beginnings as a GHP working group. CEOP eventually became a project of the World Climate Research Programme, with major contributions being made by GEWEX. Of particular interest during the workshop were the developing model data archives, described by H. Luther and M. Lautenschlager of MPI. The model data archive is a major contribution from the Baltic Sea Experiment (BALTEX). S. Williams described the extensive in situ data archive, which is a major contribution from the GEWEX Americas Prediction Project (GAPP). J. Matsumoto described the University of Tokyo remote sensing archive, which is a major contribution from the GEWEX Asian Monsoon Experiment (GAME). It should also be noted that all of the Continental-Scale Experiments are major contributors to the CEOP in situ measurements, model output, and remote sensing products. A number of additional presentations described developing science investigations that will be using the extensive international multi-sensor, model CEOP data sets.

After the focused workshops during the first 2 1/2 days, the official GHP meeting began with welcoming remarks by H. Grassl, and S. Sorooshian. J. Roads summarized the current status of the GHP and discussed the objectives of the meeting. During the next two days, the GEWEX Continental-Scale Experiments (CSEs) and affiliated CSE representatives, GEWEX and affiliated global projects, and the GHP working groups then made summary presentations of progress and plans for the coming year.

CSE reports were provided for: 1) the Mackenzie GEWEX Experiment (MAGS) by K. Szeto; 2) GAPP by R. Lawford; 3) the Large Scale Biosphere-Atmosphere Experiment (LBA) project by J. Marengo; 4) BALTEX by H. J. Isemer; 5) GAME by T. Yasunari; and 6) the Murray Darling Basin (MDB) by A. Seed. The GHP was especially interested in learning how these CSEs are planning to evolve in the near and long-term. Some of the original CSEs now have sunset dates for their projects and new regional initiatives will have to be undertaken for them to remain viable in the face of the many new challenges facing the scientific community.

Attendees at the 9th annual GHP meeting included: *(front row, left to right) K. Masuda, B. Rudolf, A. Hall, J. Roads, G. Sommeria, S. Köppen, S. Sorooshian, A. Sugimoto, T. Yasunari, J. Matsumoto, P. Aggarwal, K. Szeto; (back row, left to right) L. Horta, L. Martz, G. Takle, J. Tomasella, B. Rockel, D. Lettenmaier, S. Williams, J. Marengo, R. Stewart, S. Benedict, A. Seed, D. Noone, R. Lawford, J. Bradd, H. -J. Isemer, T. Maurer, H. Berbery*

In that regard, C. Mechoso made a persuasive presentation on why the affiliated La Plata River Basin experiment should now be considered for official status as a GEWEX CSE and the CSE representatives unanimously agreed that that the LPB would be able to eventually fully meet all of the established GHP criteria. The GHP will therefore be forwarding its recommendation to the GEWEX SSG that LPB be recognized as an official GEWEX CSE.

Presentations were also made from affiliated GEWEX global projects, including: 1) Thomas Maurer described the Global Runoff Data Center (GRDC), which will be working with GHP/WEBS; 2) B. Rudolf described the Global Precipitation Climatology Center (GPCC), which will also be working with GHP/WEBS. A. Hall of the International Organization of Hydrologic Sciences (IAHS) described the IAHS and its interest in working with GHP/WRAP on the IAHS Prediction in Ungauged Basins (PUB) initiative. D. Lettenmaier described aspects of the Global Water Systems Project (GWSP), which may also be useful for links to GHP/WRAP. P. Aggarwal of the International Atomic Energy Agency (IAEA) described the IAEA and its interest in using isotopes and working with GHP/SCW to understand water sources and sinks. Representatives of a few international regional model intercomparison projects were also invited to make presentations to the GHP. Takle described the US-based PIRCS project; J. Marengo described a beginning study over Brazil; B. Rockel described a potential project focused on the GHP CSEs. H. Berbery described regional modeling efforts for LPB. Currently these regional projects work independently, but given that each of them have substantial international involvement and are making substantial contributions to GEWEX/GHP transferability goals, it may be of interest to develop a GHP transferability working group. This will be explored further during the coming year. On the last day, summary presentations were made by the chairs of the various GHP working groups on their plans for the coming year. GHP/WEBS, WRAP, SCW are now actively developing project plans that will ultimately include GHP-wide papers; objectives and plans for these projects will be reported on at the GEWEX SSG in Jan. in Morocco. The 10th annual GHP meeting (August or September 2004) will be hosted by LPB in Montevideo, Uruguay.

Next issue of the BALTEX *Newsletter* (# 7)
Please, send articles to
isemer@gkss.de* or *baltex@gkss.de
before
30 March 2004

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.
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