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Has the project BALTEX so far met its original objectives?

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After more than six years of build-up and basic research, the Baltic Sea Experiment (BALTEX) undergoes a transition into its second phase, where major attention is paid to provide a long-term data set, covering at least two complete seasonal cycles. This new phase called *BRIDGE*, is part of a world-wide effort to study energy and water cycles and also related fluxes of carbon and other constituents over continental-scale regions. Some of the major findings obtained during the first phase of BALTEX are summarized in this paper.

Introduction

Large deficits were identified in our knowledge of the energy and water cycles in our climate system and their impact on climate variability. Therefore, about 20 years ago the GEWEX (Global Energy and Water Cycle Experiment) was established (e.g., Chahine 1992) to coordinate and focus the related world wide research activities within the WCRP (World Climate Research Program). Within GEWEX, major efforts were supported to study with high priority energy and water cycles over continental-scale areas of North and South America, Eastern Asia and Europe. During that phase, an international group defined the Baltic Sea Experiment (BALTEX) with the major objectives (*see* Raschke *et al*. 1998):

— To explore and model the various mechanisms determining the space and time variability of energy and water budgets of the BALTEX region and their interactions with surrounding regions;
— To relate these mechanisms to the large-scale circulation systems in the atmosphere and oceans over the globe, and
— To develop transferable methodologies in order to contribute to basic needs of climate, climate impact, and environmental research.

After more than six years of active research a first assessment of this project should be performed. This paper will only briefly summarize some results of BALTEX research activities and is intended to introduce the other BALTEX-papers of the special issues. A much more detailed description of BALTEX and its major findings is given in Raschke *et al.* (2001) while the series of papers in the two special issues provides much more specific details.

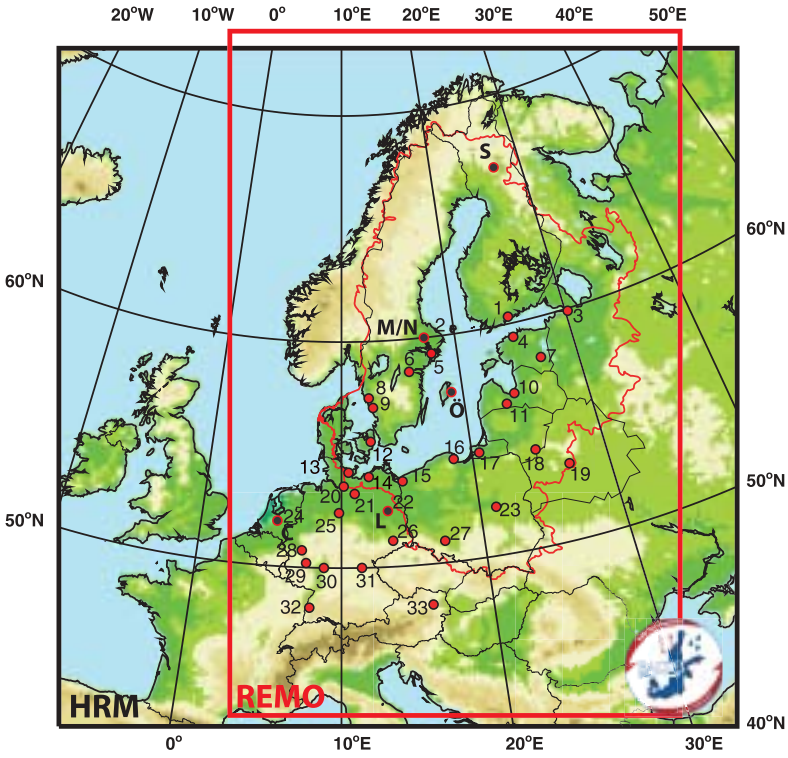

Fig. 1. The Baltic Sea catchment (thin red line) and locations of research groups contributing to BALTEX (red circles). The thick red line indicates the area covered by regional numerical models.

The BALTEX project

Preparatory scientific work for BALTEX began already in 1992 and involved different groups in Finland, Sweden, Denmark and Germany. The more formal organization of the project was developed later, after sufficient funds were raised to support an international secretariat and its activities and in particular to support the collection of observations of precipitation and runoff from stations which are not regularly reported in the world-wide GTS (Global Telecommunication System) of WMO (World Meteorological Organization). This latter activity enabled several countries of the eastern coast of the Baltic Sea to participate actively in BALTEX.

The BALTEX area covers the entire drainage basin of the Baltic Sea (Fig. 1) which extends over an area of about 2.1 mill. km^2. The annual net discharge of the Baltic Sea into the North Sea amounts to about 470 km^3 of water, which is equivalent to the discharge of other major river systems. The climate within the BALTEX area ranges from nearly mid-latitude continental in the south to sub-polar conditions in the north.

Four data centers have been established at national weather, hydrological and oceanographic services to collect, archive and distribute meteorological, hydrological and oceanographic data. A rather complete data set PIDCAP (Precipitation Intensive Data Collection and Analysis Period), mainly on precipitation but also on runoff and other meteorological, hydrological and oceanographic parameters was collected from observations during the three months of September, October and November 1995 (Isemer 1996). This still is a widely used data set in model development and validation and in process-oriented studies. The scientific progress and strategy of BALTEX are steadily reviewed by the BALTEX Science Steering Group (BSSG), whose members come from all participating countries and cover the three prime disciplines, involved in this project. Close relations were established to the other Continental Scale Experiments of GEWEX, which follow similar goals (e.g., Stewart *et al.* 1998).

In the beginning of BALTEX, several working groups were established to define specific issues (e.g., required process studies, radar net-

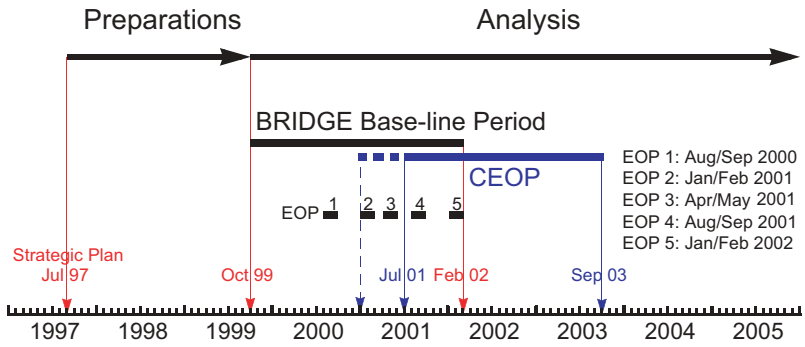

Fig. 2. Schedule of major activities within BALTEX.

work, modeling, etc.) and to encourage scientists to participate in this long lasting experiment. Particular attention was paid to the model validation and coupling, to specific field experiments over land and over sea and to the radar network over the entire area. The project never received central funding from a single organization, but individual components were supported by various national funds and in several projects by the European Union.

The overall time plan for the project is outlined in Fig. 2. BALTEX/*BRIDGE* is now focusing its efforts in collecting data, from both observations and modeling, during a period of about two years to meet the three major scientific objectives mentioned above. This period will be completed in fall 2002 and overlaps with the similar world-wide effort CEOP (Coordinated Enhanced Observation Period) of GEWEX, which also provides data for the validation of satellite products. A major period for analyses will take another 3–4 years after completion of *BRIDGE*.

At present, about 50 groups from 14 European nations declared their interest in contributing to BALTEX research goals or using the BALTEX data. They receive support from national sources; some are part of EU-funded projects (e.g., CLIWA-NET: BALTEX Cloud Liquid Water Network; visit http://www.knmi.nl/samenw/cliwa-net). Earlier, the European Union financially supported basic numerical studies within the project NEWBALTIC (Bengtsson 2000).

The new BALTEX-phase *BRIDGE* consists of two major components:

— Enhanced Observing Periods (EOP) are carried out to complement the baseline components covering the entire period. Five such EOPs are planned for specific problems, such as the cloud-aerosol and radiation interaction, investigated in the European project CLIWA-NET, others will concentrate on oceanographic and in particular sea ice studies and on water and energy exchange over vegetated areas (*see* Fig. 2).

— Primary attention in the next years will be paid to the numerical investigation of the water and energy budget of this region and its relation to global scale circulation anomalies in the atmosphere and ocean.

It is also planned to conduct a thorough climatological investigation of the entire region covering a longer period of several decades.

Some preliminary results

Atmospheric models of the German and Scandinavian weather services were developed over the time. They are currently subject to improvements of their internal physics packages and in particular the routines describing exchange processes at their lower boundaries (vegetated land surfaces, lakes and the Baltic Sea). The findings of BALTEX have influenced this development (Jacob *et al.* 2001). For instance, BALTEX made considerable progress to describe the formation and dissipation of snow layers and their contribution to soil moisture. This coupling is now fully interactive. Many validation studies were carried out involving all models. Jacob *et al.* (2001) also reported about a joint project where remarkable disagreement between model results for identical boundary conditions were found,

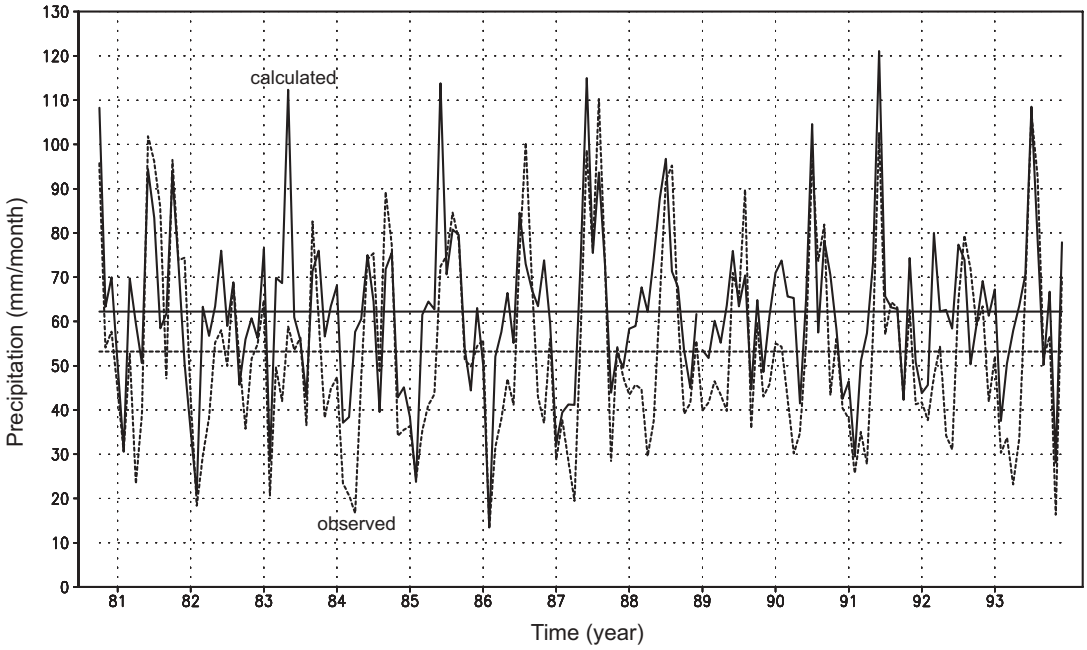

Fig. 3. Time series of the calculated (solid line) and measured (dashed line) mean precipitation budget of the entire BALTEX model area.

and which need to be minimized through substantial changes in model parameterizations and also, possibly, in numerics. An intercomparison of measured and calculated precipitation shows that modeled values overestimate the long-term average precipitation by 5%–8% (Fig. 3). Long-term measurements of atmospheric water vapor (e.g., from GPS data) could help to identify the processes causing this systematic error.

Various process-oriented field studies aimed to address the first objective have been conducted at major stations in Germany, Sweden and Finland (*see* Fig. 1) to help improve the simulation of spatial averages of evapotranspiration. These studies include NOPEX (Northern Hemisphere Climate-Processes Land-Surface Experiment), LITFASS (Lindenberg Inhomogeneous Terrain — Fluxes between Atmosphere and Surface: a Long-term Study), CLIWA-NET, and others (for more details *see* Raschke *et al.* 2001). These data are still being analyzed and some preliminary results are reported in other papers of the BALTEX Conference. Additionally, first measurements of sea ice dynamics and its effects on the air-sea interaction were obtained in the Gulf of Bothnia. The near-bottom transport of salty, nutrient- and oxygen-rich water was measured along a transect in the Baltic Proper during the field campaigns of DIAMIX (Dynamics of wind-forced DIApycnal MIXing in the stratified ocean). It showed that this water mass occasionally penetrates from the Kattegat into the Baltic Sea. This 'fresh' ocean water is of vital importance for the biosphere within the Baltic Sea.

So far only one time series of the continental water supply to the Baltic Sea exists, based on the HBV-model (Swedish Conceptual Hydrological Model for Runoff Simulation) which calculates the total runoff from each major river basin. Fig. 4 summarizes recent runoff calculations for each major river basin. It shows that the Baltic Sea receives most of the runoff from continental areas during the snowmelt season, totaling in May to twice as much as the annual average. Further and more intensive climate studies (second objective) are however desirable.

Several studies of the water and energy balance for the Baltic Sea only (e.g., Omstedt

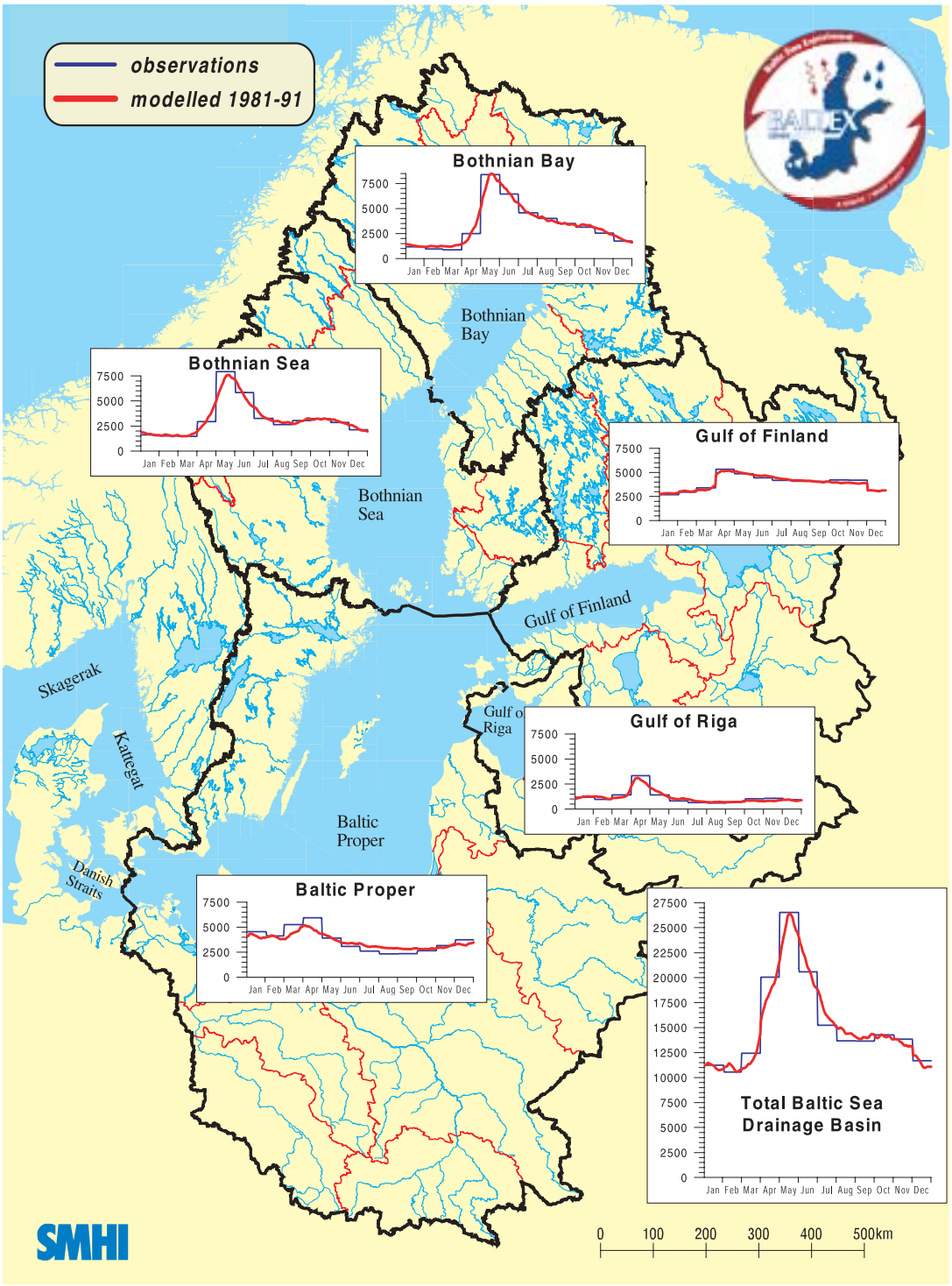

Fig. 4. Daily freshwater flow into the major sub-basins of the Baltic Sea, calculated with the HBV-model using meteorological input data.

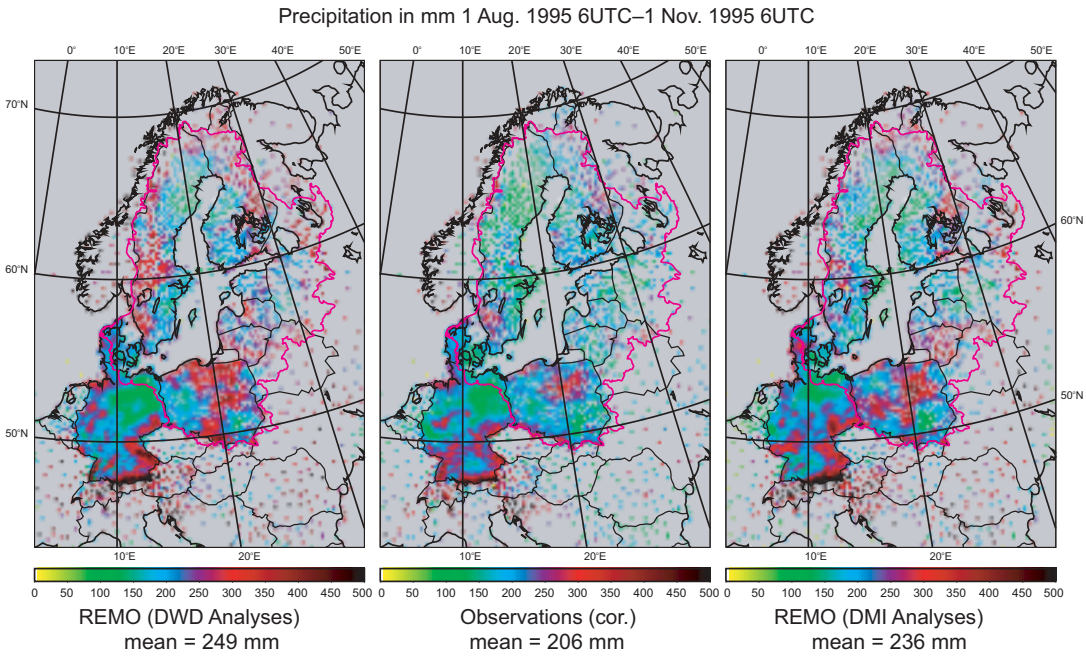

Fig. 5. Measured precipitation during the PIDCAP period (central panel) versus modeled precipitation with analyses of the DWD (German Weather Service) and DMI (Danish Meteorological Institute). Each dot indicates a grid area with at least one rain gauge station.

and Rutgersson 2000) and for the entire drainage basin still need to be complemented by those with longer time series of data and with a better than annual resolution. Such an example obtained from numerical modeling is shown in Fig. 5 (from U. Karstens, pers. comm.).

Particular attention was paid to the correction of all precipitation measurements during the PIDCAP-period. Rubel and Hantel (1999) were able to show that the records of most rain gauges in the BALTEX area need corrections of up to +15% due to losses of water by atmospheric turbulence and evaporation. Figure 6 shows their results obtained with data from the PIDCAP period.

Satellite data of clouds and radiation budget components were used in several model validations. These still show considerable differences with model simulations for the same period, suggesting that major improvements in the model performance are required. However, the retrieval of cloud and radiation budget information from such data is also subject to some error, and needs to be investigated.

Considerable improvements were achieved in the modeling of water and energy exchanges within the top soil-layers and between them and the atmosphere. They also lead to improvements of the distributed modeling of the runoff within different river basins. These latter models are now applied in specific projects for flood forecasting (Mengelkamp *et al.* 2001).

Only very little attempts were made to meet the third objective (model transferability to other regions), which indeed is a general request for all GEWEX Continental Scale Experiments. Only one individual cooperation exists with a team of the Mackenzie-River basin study (MAGS) to exchange model and to analyze data of the planetary radiation budget over both areas.

Conclusive remarks

This introductory review had to be brief in the frame of this special issue. A more comprehensive scientific overview on BALTEX was recently published by Raschke *et al.* (2001). More details and some major achievements are described in more detail in the subsequent papers of the special issues

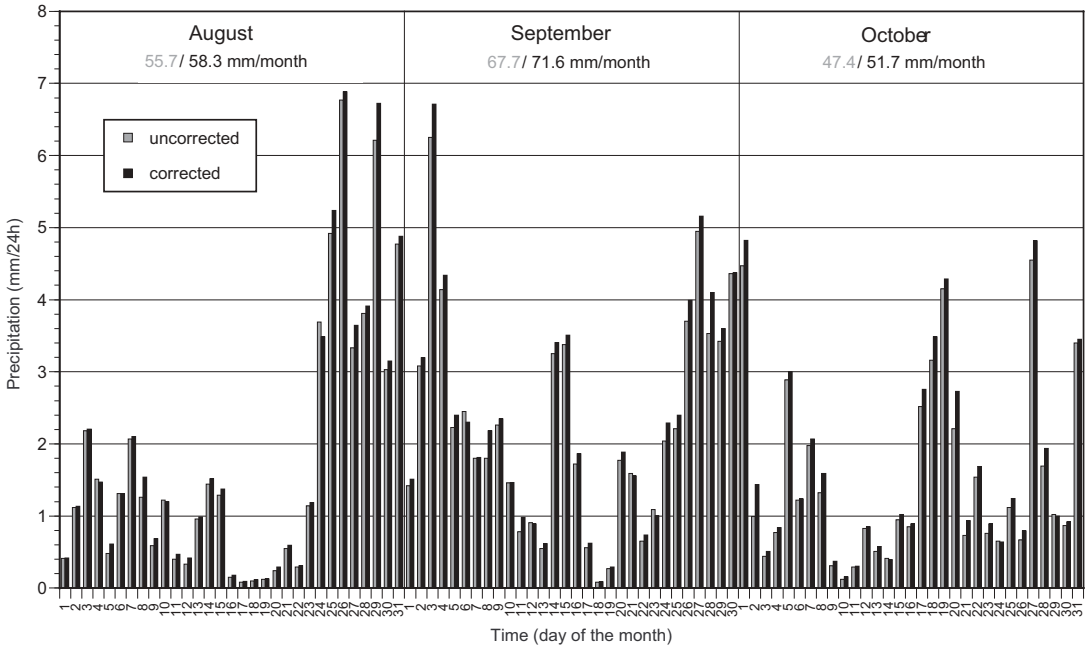

Fig. 6. Time series of daily precipitation averages (mm d^{-1}) within the Baltic Sea drainage basin based on uncorrected (gray) and corrected (black) rain gauge data during the PIDCAP period.

on BALTEX, reflecting various scientific investigation results which were presented at the Third Study Conference (Meywerk 2001) held from 2 to 6 July 2001 in Marieham, Åland, Finland.

In summary, we can state that the past work within the frame of BALTEX gained considerable interest from new teams from almost all BALTEX states and others in Europe, and resulted in many excellent studies. During the ongoing intensive model validation work, a new generation of models was implemented by the weather services, which now need to be adapted to the BALTEX region of interest. Nevertheless, a very first complete interactive simulation of the circulation over and within the Baltic Sea (Hagedorn *et al.* 2000) demonstrated an improvement of wind and sea surface temperatures forecasts. The hydro-meteorological model work led to projects for the development of flood forecasting systems, demonstrating a first immediate use of BALTEX results. Despite the need for still more basic research efforts, the present knowledge will be used in future studies of fluxes of matter in river basins and of the carbon exchange over the continental areas.

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