Science Plan

for

BALTEX Phase II

2003 - 2012

Contents

Foreword

The Baltic Sea Experiment (BALTEX) was launched during the early 1990s as one of the first Continental-Scale Experiments (CSEs) within the Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Programme (WCRP). Its major objective was to explore and model the various mechanisms determining the space and time variability of energy and water budgets and transports within the Baltic Sea basin, thus investing the atmosphere, the land surface with rivers and lakes, the Baltic Sea and its sea ice. During Phase I of BALTEX, covering the period 1993 to 2002, major scientific results and research infrastructure at the European level have been achieved. Examples include coupled regional general circulation models for the entire Baltic Sea area giving new detailed water and heat budget estimates, and meteorological, hydrologic and oceanographic data sets and dedicated data centres. The numerous achievements of BALTEX Phase I now call for a more intensive application in other fields where knowledge on the water and energy cycle is fundamental.

Therefore, the BALTEX Community has started making plans for enlarging the scientific scope and thus strengthening the outreach of BALTEX. At its 14th meeting held in Lund, Sweden in November 2002, the BALTEX Science Steering Group (BSSG) suggested to write a Science Plan for BALTEX Phase II. A Science Plan Writing Team was established which presented a draft plan at the 15th BSSG meeting held September 2003 in Roskilde, Denmark, where revised objectives for BALTEX Phase II were approved by the BSSG and the Writing Team was given the mandate to finalize the plan.

In the following, the Science Plan for BALTEX Phase II is presented. It outlines the strategic research background for **BALTEX Phase II in the time period 2003 to 2012**. The plan enforces the application of BALTEX Phase I achievements to areas such as climate variability and climate change studies including scenarios of potential future climate, and environmental investigations related to nutrients and pollutants. Impact studies responding to social needs and supporting decision makers in a broader context of Global Change issues related to the Baltic Sea basin are envisaged to accompany the research efforts during BALTEX Phase II. Activities will more closely be discussed with and are expected to be applied by larger user communities, going beyond WCRP's science community, including water resource managers and intergovernmental bodies for the Baltic Sea and its catchments. It is also important to note that future BALTEX research will continue meeting objectives of Phase I, in particular reducing uncertainties of estimates of water and energy cycle components in the Baltic Sea basin.

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Executive Summary

The objectives of BALTEX Phase II are:

1. **Better understanding of the energy and water cycles over the Baltic Sea basin**

2. **Analysis of climate variability and change since 1800, and provision of regional climate projections over the Baltic Sea basin for the 21st century**

3. **Provision of improved tools for water management, with an emphasis on more accurate forecasts of extreme events and long-term changes**

4. **Gradual extension of BALTEX methodologies to air and water quality studies**

5. **Strengthened interaction with decision-makers, with emphasis on global change impact assessments**

6. **Education and outreach at the international level**

This plan outlines aims for BALTEX in the time period 2003 to 2012. The objectives for BALTEX Phase II include science issues (basically objectives 1 to 4 given above) and strategic or political issues covered by objectives 5 and 6.

1 Better understanding of the energy and water cycles over the Baltic Sea basin
This objective relates to Phase I of BALTEX, the objectives of which were defined in the first science plan for BALTEX (BALTEX 1994) as follows:

- To explore and model the various mechanisms determining the space and time variability of energy and water budgets of the BALTEX region and this region's interactions with surrounding regions;

- To relate these mechanisms to the large-scale circulation systems in the atmosphere and oceans over the globe.

While BALTEX research has met to a large extent BALTEX Phase I objectives, gaps still exist and further research is needed for fulfilment of the original BALTEX aims. Therefore, the two basic objectives of BALTEX Phase I continue to be valid also for Phase II. The main goals for a better understanding of the energy and water cycles over the Baltic Sea basin are:

- To obtain better and more comprehensive observations from the entire Baltic Sea basin, including new satellite data;

- To develop further the numerical regional models for the atmosphere, the land surface including rivers and lakes, and the Baltic Sea including sea ice;

- To evaluate, in increasing detail, regional models used for climate and environmental studies and to develop strategies for climate and environmental impact assessments;

- To close the energy and water budgets at lower uncertainty.

2 Analysis of climate variability and change since 1800, and provision of regional climate projections over the Baltic Sea basin for the 21st century

Major goals with regard to this second objective of BALTEX Phase II are:

- To contribute to detection of regional climate change;
- To understand the physical mechanisms that have caused past climate variability and change, whether of natural or anthropogenic origin, in the BALTEX region, thus contributing to attribution studies;
- To study the contributions of large-scale control, and locally/regionally generated forcing, on the regional climate system;
- To develop projections of future climate variability and change, by means of sensitivity analyses and model studies.

3 Provision of improved tools for water management, with an emphasis on more accurate forecasts of extreme events and long-term changes

Major goals with regard to this third objective of BALTEX Phase II are:

- To develop further and apply coupled atmospheric-hydrological models for improved assessment of the availability of water resources in today's and future climate;
- To apply different modelling systems in selected river basins to assess the impact of climate variability and change on the hydrological regime including the occurrence and severity of extreme events;
- To explicitly take account of the societal use of groundwater and surface water resources, as well as man-made changes of land use, in studies of the future risk of water shortage and impacts of extreme events.

4 Gradual extension of BALTEX methodologies to air and water quality studies

In summary, major goals with regard to this 4th objective of BALTEX Phase II are:

- To enhance the modellers' capability for pollution and dispersion calculations by implementing recent progress in climate modelling within the BALTEX community such as coupled models;
- To initiate first steps towards inclusion of the nutrient-carbon cycles and the full carbon cycle into the BALTEX modelling platforms;
- To use recent developments of remote sensing of water and environmental parameters; to use novel flux measuring techniques such as Relaxed Eddy Accumulation of environmental components;
- To engage in field experiments that address environmental issues.

1 Introduction

Climate and the environment of the 21st century are governed by a combination of natural and anthropogenic factors. Population and per capita consumption of the Earth's resources have grown tremendously during the last century. In a few generations the fossil fuel reserves, except for coal, will largely be exhausted. A large part of the land surfaces has been transformed by direct human activities and more fertilisers than ever before are applied in agriculture. Also a large portion of the available freshwater is used by mankind. The atmospheric concentrations of all long-lived greenhouse gases have substantially increased and the amount of nuclear and other waste is steadily growing. In this situation a better understanding of the Earth system is crucial for our approach to a sustainable development. We need to be able to deal with both natural and anthropogenic influences, separate them, and incorporate them in predictive tools.

Our ability to understand and predict the Earth environment depends critically on our capability to observe, understand, and model the processes governing the energy, water and material cycles of the climate system. Water vapour dynamics is for example of crucial importance. But also snow and ice on the ground and sea ice are part of a positive feedback via surface albedo. The availability of water in soils affects the way in which heat and moisture enter the atmosphere. The land surfaces in turn are coupled to the oceans by freshwater and nutrient transports in rivers, with major consequences to the dynamics and biogeochemistry of the oceans. The two major weather – thus climate – related disasters, droughts and floods are just facets of the global water cycle and have profound consequences for agriculture, hydropower, transportation and tourism.

There is insufficient knowledge about the water, energy and material cycles in the Earth system, partly because of poorly understood processes but also because of the very high temporal and spatial variability of the processes. To address these issues, GEWEX, the Global Energy and Water Cycle Experiment has been established as a major project of the World Climate Research Programme (WCRP) in order to observe, model and predict the hydrologic cycle and energy fluxes in the atmosphere and at the surface of the Earth. The major objectives of GEWEX are to measure and model all components of the global water and energy cycle, to improve these tools by using the new global satellite data sets, and to investigate the relations between the availability of water resources and climate variations. The development, validation and application of coupled model systems with new land surface schemes are an essential element of GEWEX.

BALTEX, the Baltic Sea Experiment, is the European Continental-Scale Experiment (CSE) of GEWEX that covers the whole water catchment of the Baltic Sea, including the sea[1] (Figures 1 and 2). 85 million people live in the BALTEX region in 14 countries that undergo in parts large political, industrial and socio-economic changes. The BALTEX region shows large seasonal, inter-annual and regional variations in climate, which is primarily due to its location between the North Atlantic Ocean and Eurasia with very large seasonal and inter-annual variations in general atmospheric circulation. It has been shown that many aspects of regional climate in northern Europe, including the Baltic Sea basin, vary in concert with the North Atlantic Oscillation (NAO). The water and energy cycles of the Baltic Sea basin are affected by a number of features, for example, by different landscape types that change the processes controlling air-sea and air-land interaction, by topography and the complex coastlines, and by many lakes and islands. The complex bathymetry of the Baltic Sea with narrows

[1] This region will be referred to as *Baltic Sea basin* or *BALTEX region* throughout this document.

straits and channels, the permanent strong stratification and the heterogeneous sea ice structure influence the dynamics of the Baltic Sea. As a consequence, the water and energy cycles in the region are determined by many processes at different time and space scales. The BALTEX region is unique among the GEWEX CSEs because it encloses a major marginal sea and, therefore, BALTEX includes a strong oceanographic research component.

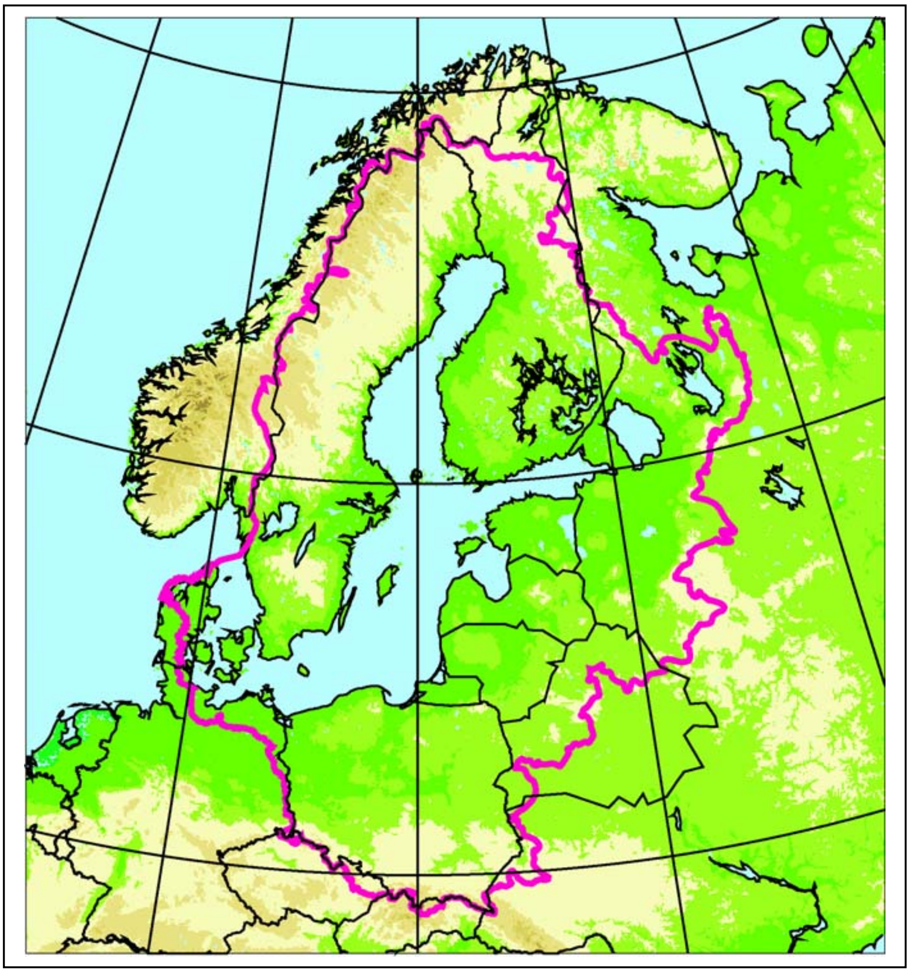

Figure 1: *Parts of northern and central Europe showing the* ***Baltic Sea basin*** *boundary (purple) and political borders (black).*

The BALTEX area stretches from tundra with discontinuous permafrost in northern Finland to sub-humid deciduous forest climate in parts of Poland, it reaches up to small mountain glaciers in Sweden and surmounts the tree line in the Tatra mountains in southern Poland. It also contains some of the northern-most metropolitan areas on our globe including a mega city (St. Petersburg). A special challenge is the integration of research infrastructure in very diverse countries.

BALTEX has been established as an international research programme during the early 1990s with the publication of the BALTEX Science Plan in 1994 and the Initial Implementation Plan for BALTEX in 1995. Both documents (BALTEX 1994, 1995) laid the scientific foundation and rationale for phase I of BALTEX during the years 1994 to 2002. BALTEX Phase I has generated an active research covering the whole field of advanced modelling and data studies in meteorology, hydrology and oceanography (e.g. Raschke et al., 2001). Major research elements of BALTEX include the collection of *in situ* and remote sensing data, re-analysis of existing data sets, data assimilation, numerical experiments and coupled modelling, and process studies including field experiments. It has brought major results both in scientific knowledge and research infrastructure at the European level. Examples include the first coupled regional models for the entire Baltic Sea basin with improved water budget estimates through newly assimilated data sets.

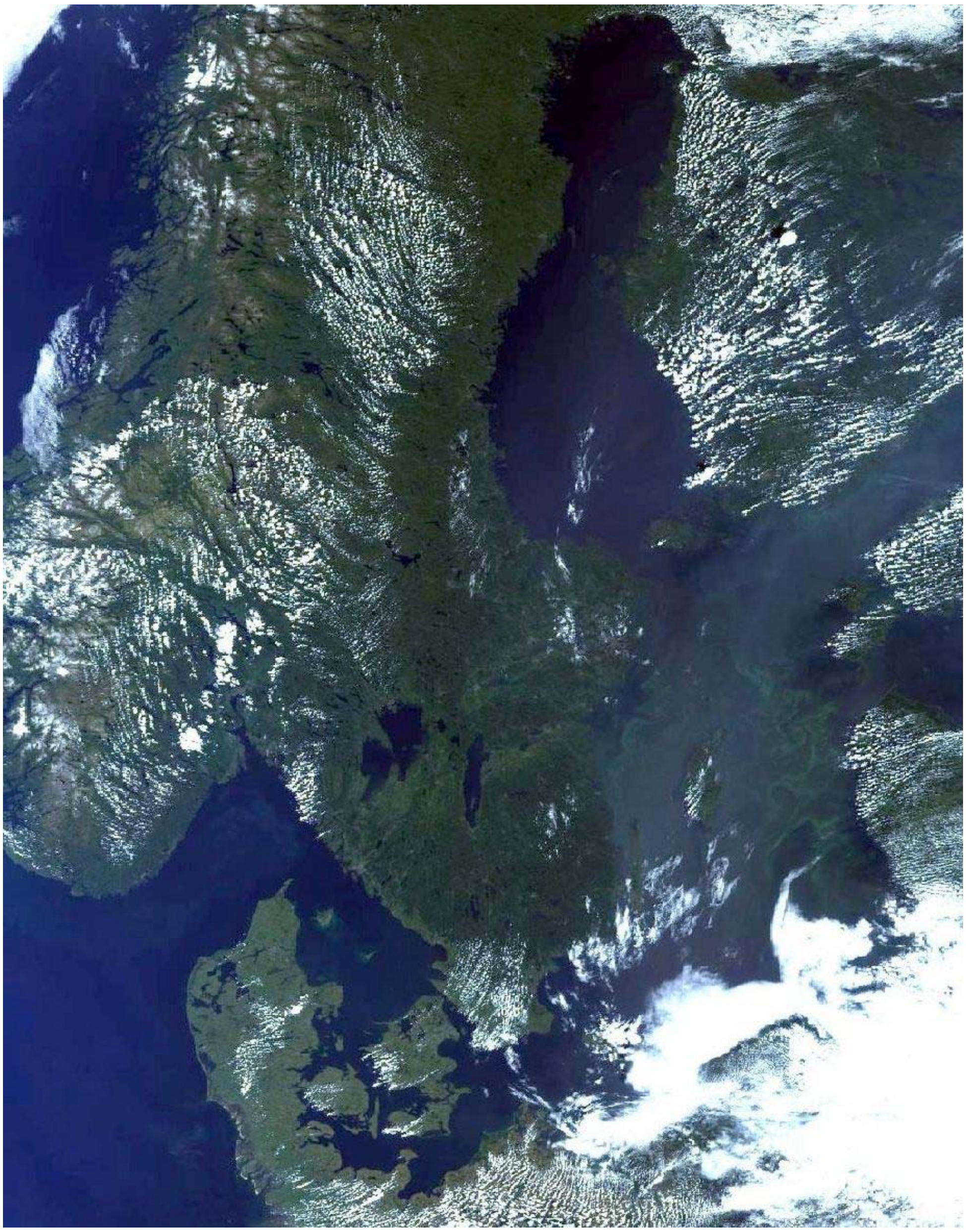

Figure 2: *Parts of the Baltic Sea basin as seen from ESA's ENVISAT satellite on 15 July 2003.*

Also, special observing periods (such as PIDCAP[2] 1995, and BRIDGE 1999 to 2002) with dedicated additional observations were conducted in the frame of BALTEX, and BALTEX projects are still ongoing in different countries funded by institutional, national and European

[2] Pilot Study for Intensive Data Collection and Analysis of Precipitation, August to November 1995

sources. Results of BALTEX are documented in more than 200 peer-reviewed journal articles including several dedicated journal volumes and overview publications, and a regular series of international conferences and workshops have been held. The infrastructure of BALTEX includes a science steering group, several working groups, four dedicated data centres for meteorological, hydrological, oceanographic and radar data and an international secretariat.

The focus in BALTEX Phase I has primarily been on process understanding and modelling of physical aspects of the water and energy cycles of the Baltic Sea basin. The numerous achievements of BALTEX in these fields now call for a more intensive application in other areas where the physical understanding and modelling skills of the water and energy cycles is of fundamental importance. Examples for such areas include climate variability and climate change studies including scenarios of future climate, environmental investigations related to the transport of harmful substances, and climate or environmental impact studies responding to social needs and supporting decision makers in a broader context of Global Change issues related to the Baltic Sea basin. BALTEX Phase II will not define an entirely new research plan but enlarge the scientific scope and thus strengthen the outreach of BALTEX. BALTEX Phase II will continue to pursue those objectives and aims from its Phase I, that have so far not been met in a satisfactory manner.

The present science plan defines the general objectives of BALTEX Phase II and explains the science strategy for the second phase of BALTEX in the years 2003 to 2012. These objectives, which were considered by the BALTEX Science Steering Group (BSSG) at its 14th meeting in Lund, Sweden, November 2002, and finally approved at the BSSG's 15th meeting in Roskilde, Denmark in September 2003, are generally in line with those of GEWEX and other GEWEX CSEs, some of which have already moved into their second phase in the recent past, with similar related programme changes to more application-oriented objectives.

The Objectives of BALTEX Phase II are:

1. **Better understanding of the energy and water cycles over the Baltic Sea basin;**

2. **Analysis of climate variability and change since 1800, and provision of regional climate projections over the Baltic Sea basin for the 21st century;**

3. **Provision of improved tools for water management, with an emphasis on more accurate forecasts of extreme events and long-term changes;**

4. **Gradual extension of BALTEX methodologies to air and water quality studies;**

5. **Strengthened interaction with decision-makers, with emphasis on global change impact assessments;**

6. **Education and outreach at the international level.**

The structure of this plan is as follows: Sections 2 to 7 explain each of the objectives and their linkages in more detail. Section 8 outlines elements of the existing and planned data management of the programme, and section 9 elucidates links to other major international and national programmes.

2 Better Understanding of the Energy and Water Cycles over the Baltic Sea Basin

During BALTEX Phase I major progress has been reached in observational and modelling programmes, as well as in research co-operation and infrastructure including the build-up of four dedicated BALTEX data centres. Also remote sensing data have been evaluated to increase our understanding about the regional distribution of different parameters such as cloud distribution from satellites (Figure 3) and precipitation fields from Doppler radars.

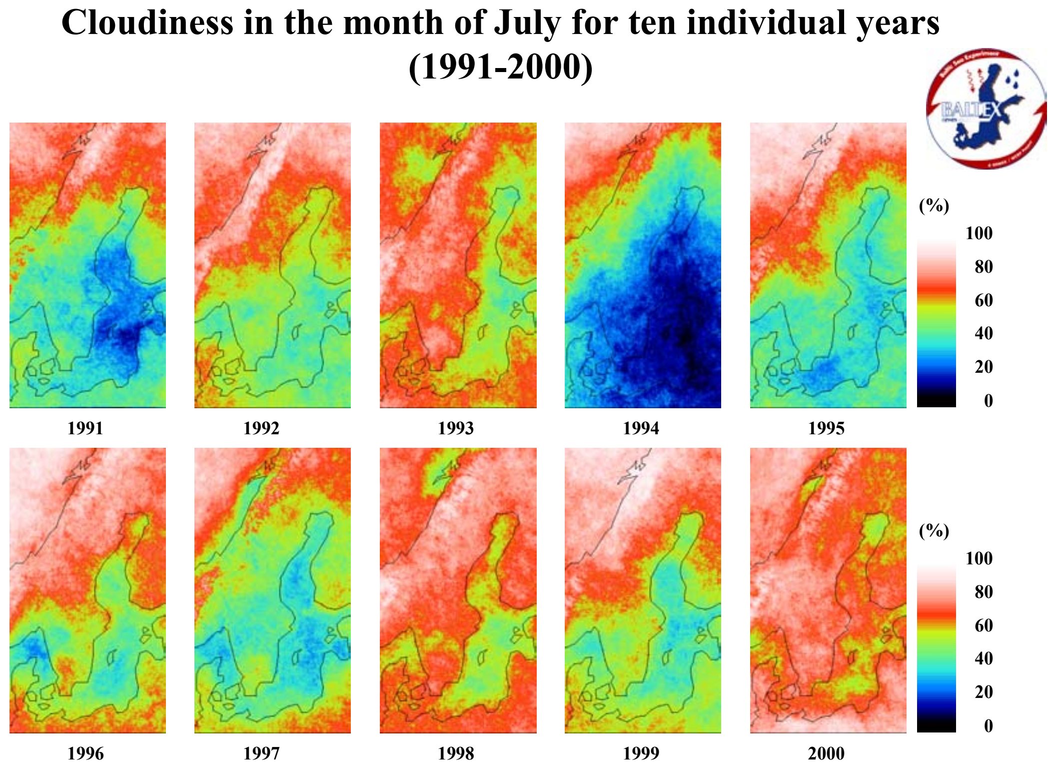

Figure 3: *Cloud cover for July during the 1990s illustrating large regional and interannual variations (Karlsson, 2001).*

It is well known today that precipitation and evaporation are among those parameters causing the largest problems for weather prediction. This is also true for meteorological reanalysis such as the NCEP/NCAR data. Although new knowledge has been gained with regard to the water and energy cycles, still major improvements are needed. Different aspects of the Baltic drainage basin's water and heat cycles are given for example in Bergström and Carlsson (1994), Karstens et al., (1996), Graham (1999), Omstedt and Rutgersson (2000), Bengtsson (2001), Jacob et al. (2001), Raschke et al. (2001), Rubel and Hantel (2001), Rutgersson et al. (2001, 2002), Meier and Döscher (2002), Roads et al. (2002), Hennemuth et al. (2003), and Ruprecht and Kahl (2003). A more comprehensive overview on results related to the understanding of these cycles can also be found in special journal issues dedicated to the three BALTEX Study Conferences in 1995, 1998 and 2001 and to a major modelling project funded by the European Union . These include issues of *Tellus* (1996, Volume 48 A, No 5), *Meteorologische Zeitschrift* (2000, Volume 9, No 1 and 2), *Meteorological and Atmospheric Physics* (2001, Volume 77, No 1-4), and *Boreal Environmental Research* (2002, Volume 7, No 3 and 4).

During BALTEX Phase I, we have got an improved understanding of for example the river discharge to the Baltic Sea, but still we do not know the errors of the data sufficiently. Most studies have demonstrated that the net freshwater flux to the Baltic Sea is positive; however, because of the few precipitation measurements over the sea the uncertainty is still large. Detailed air-sea studies in the marine as well as in the land surface boundary layers have open up several basic questions regarding the energy and water exchange mechanisms, calling for better understanding and need for new parameterisation methods. The in- and out-flows to the Baltic Sea are highly variable and distributed between the Little and Great Belt and the Sound. Continuous measurements of these flows are needed to close the water and heat budgets of the Baltic Sea drainage basin. New measurements in the Baltic Sea (Figure 4) have demonstrated the complex dynamics of inflows and bottom boundary currents that are not yet understood or resolved in today's Baltic Sea ocean models. Sea ice field studies illustrate complex heterogeneous structures, features that also have not yet been introduced in most modelling efforts.

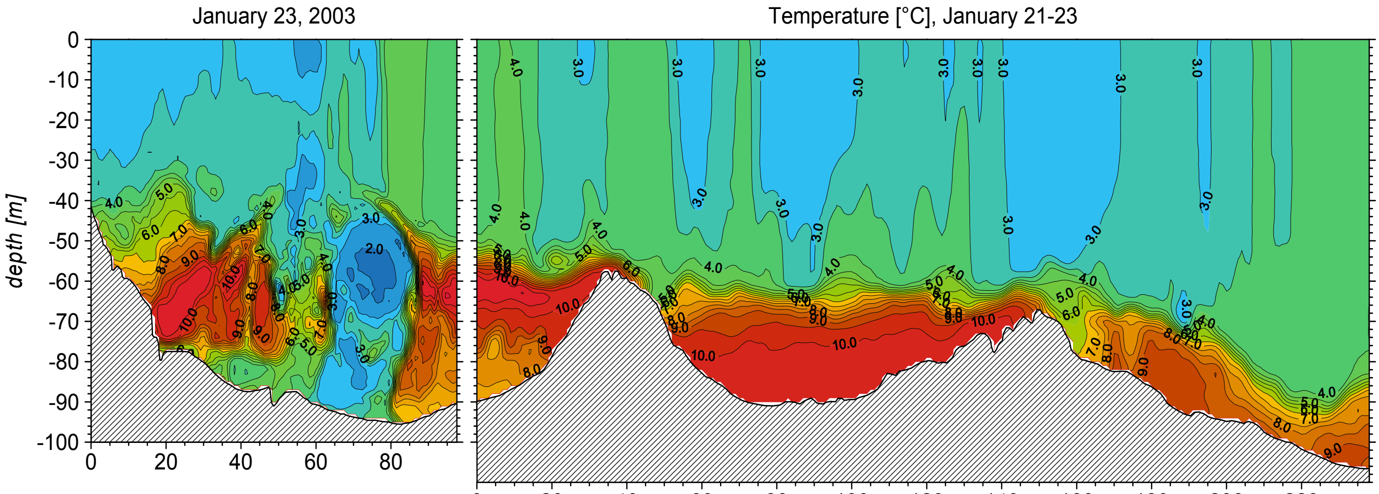

Figure 4: *Measured temperatures in the Bornholm Basin (left) and the Stolpe Channel (right) during January 2003. The left figure illustrates a cold water inflow entering into a warm bottom water in the Bornholm Basin. In the right figure one can notice a Stolpe Sill overflow with unusual warm temperatures (courtesy of Jan Piechura, Institute of Oceanology, Sopot, Poland).*

The atmosphere/land-surface/ocean model coupling and the development of regional climate models has started. Two different regional coupled model systems have been established in the frame of BALTEX (e.g. Döscher et al., 2002; Jacob et al., 2003) and are currently being tested and improved. Problems do still exist, for example, the treatment of lateral boundaries in the regional climate models is still problematic. The need for a further improvement of our understanding of the water cycle can also be illustrated in Table 1, showing that several methods are now available but few estimates for all components exist and uncertainty estimates are often not given. When comparing different methods one needs to consider the same observation period, as done for example in BALTEX phase I during the PIDCAP[3] and PEP-in-BALTEX[4], each of which included only a few months, as well as during the BALTEX / *BRIDGE* period[5]. But now even longer periods need to be studied during BALTEX Phase II.

[3] Pilot Study for Intensive Data Collection and Analysis of Precipitation, August to November 1995
[4] Pilot Study of Evaporation and Precipitation over the Baltic Sea, EU-funded project 1998-2000
[5] October 1999 to March 2002

The results from the regional coupled models illustrate a quite large difference in the calculated energy and water budget components depending on which GCM model has been used for lateral forcing. Also regional climate models driven by present day GCMs seem to give too high precipitation. More realistic results have been achieved by using meteorological fields from re-analysed data as lateral boundary conditions. This approach will be further explored during phase II of BALTEX

2.1 Summary of Major Goals

In summary, major goals with regard to **the first objective of BALTEX Phase II "***better understanding of the energy and water cycles over the Baltic Sea basin"* are:

- To obtain better and more comprehensive observations from the entire Baltic Sea basin, including new satellite data;
- To develop further the numerical regional models for the atmosphere, the land surface including rivers and lakes, and the Baltic Sea including sea ice;
- To evaluate, in increasing detail, regional models used for climate and environmental studies and to develop strategies for climate and environmental impact assessments;
- To close the energy and water budgets at lower uncertainty.

METHOD	Q_i	Q_o	Q_o-Q_i	Q_f	(P-E)	Storage Change
One early estimate			14.94	13.83	1.26	0.15
Runoff estimates				14±4		
Ship observations					0.70	
Some ocean modelling estimates	50±?	65±?	15±5	14±4	1.5±1	0±0.5
Atmospheric observations during one year					1.8±0.6	
Some atmosphere modelling estimates			24±7	20±5	4±2	
One coupled modelling estimate using two GCM forcings			27±4	22±3	5±1	

Table 1: *Some water budget component estimates for the Baltic Sea (the Belt Sea and the Kattegat excluded). Units are 10^3 m^3 s^{-1}. The flows are denoted by: River run-off (**Q_f**), net freshwater flux (**P-E**), inflow (**Q_i**), outflow (**Q_o**) and storage change. Different periods and methods have been used.*

3 Analysis of past Climate Variability and Provision of Future Climate Projections on the BALTEX Region

3.1 Concern

The BALTEX region is characterised by large seasonal contrasts in climate, due to its geographical location, variable topography and the existence of the Baltic Sea. As evidenced by available long records of e.g. air temperature, precipitation, river run-off to the Baltic Sea, the regional sea ice conditions, and the Baltic Sea salinity, much of the interannual variability can be related to remote influences, such as variations in concert with the North Atlantic Oscillation (NAO). Regional long records also hint to switches and trends in the regional climate system.

Prior to and during the early part of the 20th century, the main forcing of large-scale climate change consisted of natural factors, like solar output. According to the Intergovernmental Panel on Climate Change (IPCC, 2001), the balance of scales has during the recent 3 to 5 decades tipped in favour of anthropogenic factors. However, due to the larger regional climate variability, it is still difficult to discern the anthropogenic influence in the same way as has been accomplished on the global scale. The problem, by and large, consists of detection (Is there a change?) and attribution (If there is a change, what is its cause?) parts. These questions pose major scientific challenges, but are also paramount to guide political decisions, planning and management nationally, regionally and globally.

Anthropogenic influence on the global climate as well as regionally is believed to accentuate. This is not in contrast to the fact that climate has varied and varies due to natural causes. To improve the understanding of natural climate variability in the region, including variability generated locally due to internal or external causes and variability generated outside the region and imported to the region, is still important by itself. The natural control of the climate system is also the background the anthropogenic forcing projects on. A simplistic view on how this will occur is to speak of a forced long-term trend of climate change, with superimposed or parallel-occurring natural variability. It should, however, be remembered that climate variability and extremes are also likely to change with the anthropogenic forcing.

It is clear, not in the least in light of recent extreme situation, that the natural environment, as well as human systems, are vulnerable to climate variability and change. This is of concern also in the BALTEX region, and calls for better knowledge, so that the challenges posed can be managed.

3.2 State of the art

Climate variability and change were not focal topics of BALTEX Phase I. However, its contributions to relevant data collection and process studies are notable. Combined with the results of other networks and projects, such as development of climate modelling, Phase I nevertheless provides a foundation for future work on these topics.

To date we can conclude that the climate in the Baltic Sea area is warmer and the sea ice extent is less than in the 19th century. There are also indications of increased precipitation amount and higher values per event during the last few decades. Some of the regional variations evidenced by long records have counterparts with variations on the global scale, whereas others do not. An example is the regional warmth in the 1990’s that was synchronised with global warmth, whereas the regionally warm 1930’s, did not stick out the same way in the global mean (Figure 5).

The collection and analysis of climate system data back in time, at present, and in the future forms the basis of understanding and monitoring the regional climate. Causal linkages to underlying mechanisms need, however, to be understood, in order to build up better predictive capacity for decision-making such as on climate, planning of regional infrastructure, management of natural resources, agriculture and forestry and for protecting the environment. At the same time it is true that not only the future but also the past is dotted with holes in our understanding, some of the climate records being patchy, otherwise of lacking quality, or in some cases almost non-existent.

Climate system modelling is used to complement observed regional climate system variability and change, to study the causes, and to make projections of future changes, under different assumptions of anthropogenic influence (e.g. Räisänen et al., 2004). Many of the important details that matter in the regional climate system are finer than the scales presently studied in global models. This means that the regional climate system needs to be studied in addition to global modelling. Typical regional climate models run presently at 20-50 km resolution, which is up to a factor 10 finer than in most global climate modelling. Global models will undoubtedly push towards higher resolution in the future. At the same time, regional modelling will be able to go for catchment-scale resolution, at least down to 10 km or so. In extended-length Baltic Sea ocean modelling, resolutions typically down to 2 nm (about 3.6 km) are already in use (Meier et al., 2003). Nevertheless, the appropriate toolbox of models needs to include global modelling and regional modelling, as well as statistical techniques to analyse the results. Modelling does not replace measurements or process studies. Rather, modelling, field studies, monitoring and process studies complement each other.

Within BALTEX, two advanced, coupled regional atmosphere-ocean models are available. These are RCAO (Döscher et al., 2002) at the Rossby Centre of the Swedish Meteorological and Hydrological Institute (SMHI) and BALTIMOS (Jacob et al., 2003) developed in a German consortium led by the Max-Planck-Institute for Meteorology in Hamburg. So far, these models have been used for process studies and budget studies within BALTEX Phase I, as well as to interpret data collected during, e.g., the intensive observation periods, such as BRIDGE.

3.3 Innovation and Approach

The BALTEX region provides a unique regional-scale possibility to study the variations and interrelationships of the climatic and environmental system consisting of the land areas, the atmosphere, the waterways and the sea during the period since the 18th century using a variety of instrumental data. The available time series vary in geographical and temporal extent, and quality. As the period since 1800 has been marked by the growing anthropogenic influence, the data reflect a variety of mechanisms and causes. Research questions include separating between large-scale influence and local factors driving variability and changes in both the climate and the environmental conditions in the region, as well as the balance between natural and anthropogenic drivers, and the mechanisms by which these lead to the observed behavior.

Charting past climate variability and change, and providing regional climate projections for the future over the Baltic Sea basin will belong to BALTEX Phase II. The capability to model the coupled regional climate system will be further developed and extended from covering the physical climate system (atmosphere, land surface, Baltic Sea, runoff) to incorporate elements of vegetation and other climate system components deemed relevant. Model development, and evaluation, is to be related to the observed past climate variability, as well as the present one using also novel observation types and results from enhanced measurement periods. As the time scale of the Baltic Sea itself is in some respects a few decades, and the same might be true for the natural remote influence, the longest possible hindcast (also known as "perfect boundary condition") simulations need to be promoted (Meier and Kauker, 2003). Utilisation of ERA-40 data (Simmons and Gibson, 2000) will be instrumental, although even other sources including proxy data will need to be considered, especially prior to the mid-1900's. To provide scenarios of future climate will build on global scenarios, interpreted into further detail by regionalisation techniques. Coupled regional modelling is foreseen as a central method for this, although insights should be provided also with e.g. statistical techniques. Sensitivity studies should also be pursued, to identify key mechanisms and potential crucial levels of forcing where a basically linear response gets replaced by a more abrupt one.

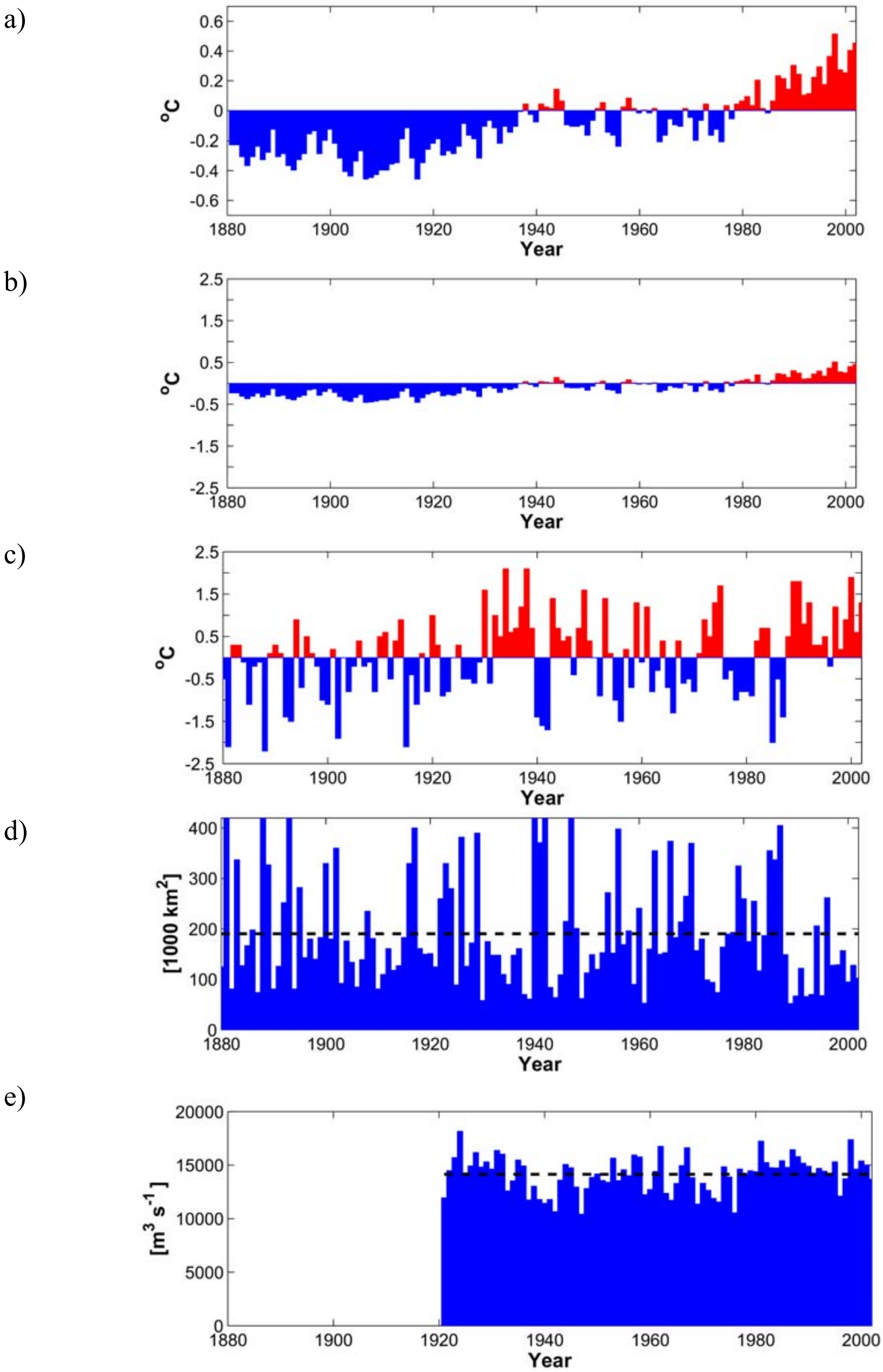

Figure 5 (see opposite page): (a) *Variations of the Earth's surface temperature from 1880 to 2002 shown as anomalies of the 1880 - 2002 mean (courtesy of NOAA). (**b**) As (a), but shown with a different vertical axis to facilitate comparison with (**c**) variations of the mean surface temperature in Sweden*[6] *(courtesy of Hans Alexandersson, SMHI). Note both the different global and regional variability/change prior to the latest decade and the different magnitude of interannual temperature variability on the global and the regional scale. (**d**) Maximum sea ice extent in the Baltic Sea 1880 - 2002 (data from Finnish Institute of Marine Research).* ***e)*** *Total annual river runoff to the Baltic Sea 1921 - 2002 (data from the BALTEX Hydrological Data Centre up to 1998 and HBV-simulations by SMHI for 1999-2002). In (d) and (e), absolute values are shown and the dashed line is the mean value of the period.*

It is clear, of course, that in order to reach beyond sensitivity and case studies, ensembles of scenarios need to pursued, to enable the provision of quantitative estimates of future. These, in turn, serve as a starting point for impact studies not directly catered for by climate models, as a basis for discussions of political measures and targets on climate and climate-related issues, as well as input to practical decision-making by enterprises and authorities in the Baltic Sea region.

3.4 Summary of Major Goals

In summary, major goals with regard to **the second objective of BALTEX Phase II** "*analysis of climate variability and change since 1800, and provision of regional climate projections over the Baltic Sea basin for the 21st century*" are:

- To contribute to detection of regional climate change;
- To understand the physical mechanisms that have caused past climate variability and change, whether of natural or anthropogenic origin, in the BALTEX region, thus contributing to attribution studies;
- To study the contributions of large-scale control, and locally/regionally generated forcing, on the regional climate system;
- To develop projections of future climate variability and change, by means of sensitivity analyses and model studies.

4 Model Development with Emphasis on Extreme Events and Long-term Changes

4.1 Concern

In the southern parts of the Baltic Sea basin water resources are scarce in comparison to demands. However, during the last decade several extreme hydrological flooding events have occurred in this area. Most tragic was the flooding in Poland and the Czech Republic in the summer of 1997, where some 100 lives were lost. Also, the recent flooding in the summer of 2002 in the Czech Republic and Germany was a major catastrophe. In 1995 the highest flood in the past century occurred in Norway and Sweden. Repeatedly it has been confirmed that the physical planning and development of infrastructure are not always in harmony with the natural hydrological variability. The climate aspect of droughts and floods is obvious.

[6] A similar analysis for the entire BALTEX region is still lacking at present.

Recently, the sensitivity of the hydropower production to climate has been strongly emphasised by mild winters and reduced snow packs. Hydropower production covers some 50 % of Sweden's demand for electricity and 25 % of Finland's. Most of the major northern river systems are therefore regulated. In some rivers, up to 70 % of the mean annual runoff can be stored for electricity production in wintertime. The range of annual variability in hydropower production in Sweden, due to climate variability, corresponds to the output from six out of the twelve nuclear reactors in the country. The Nordic countries are all influenced by demands and availability of hydropower, since they have a common electricity market. This influence will become more pronounced in the future due to rapid market development of expansion of transmission lines.

4.2 Scientific Questions

The ultimate goal is to assess the future of the climate and its impact on the water resources in the drainage basin of the Baltic Sea with a view to its socio-economic aspects. A way to do this is by feeding hydrological models with high-resolution simulations of today's climate as well as scenarios representing, e.g., 100 years from now. Such an analysis will be unique in that it will be based on newly developed advanced regional coupled model systems and several different hydrological models. Hereby the uncertainty can be addressed. The analysis should cover both extremes and average conditions in the entire Baltic Sea basin as well as in some of its main river basins. As an additional benefit, strategies and techniques for coupling of regional models may become available. Particular questions to address are the linkage of the groundwater and the surface water resources and their joint response to a changed climate as well as the response of lakes including lake ice.

Both well-established and newer hydrological models should be applied to major rivers. The results should be closely analysed and compared to each other, and to the performance of regional climate modelling schemes. The application to the entire Baltic Sea basin represents a scale very seldom used in hydrology, but here meteorological and hydrological modelling can meet. However, coupling of atmospheric and hydrological models at regional and even smaller scales should be aimed at in an effort to develop more precise and reliable forecasting tools. Moreover, hydrological models should play a role for the validation of climate models and be a tool for the creation of water resources scenarios.

4.3 Development and Validation of Hydrological Models for BALTEX large River Basins

Hydrological modelling of large river basins in the Baltic Sea basin will be needed for water resources assessments. For the whole Baltic Sea basin the semi-distributed HBV model has previously been successfully set up (Graham, 1999, 2000). It is, however, far from being trivial to establish more physically-based distributed large-scale models. While detailed information on surface parameters is available at the Internet, the description of the subsurface is generally much less detailed. This is a basic problem for the parameterisation of hydrological models, and a strong impediment for developing calibration-free models. The insufficient subsurface description implies that models still need scale-dependent calibrations. Thus, there is a need for developing modelling tools that to a larger extent can overcome this problem. By analysing a number of selected large river basins using different types of models a dedicated effort in this regard should be aimed at. New GIS-based models, where the hydrology is imbedded in a GIS framework, are emerging, while other models have been supplemented with interfaces to GIS tools. The optimal way forward is not yet obvious.

The transport of nutrients to the Baltic Sea can be addressed by expanding hydrological models with transport modules. This opens up for new requirements to model construction, calibration and validation. Existing models must be further developed in order to provide reliable calculations of the distributed input to the Baltic Sea.

4.4 Development and Validation of Coupled Hydrological-Atmospheric Models

Coupled hydrological-atmospheric models should be developed at scales smaller than previously practised. At 10 km resolution dedicated hydrological models should supplement the land surface schemes applied in atmospheric models in order to improve the prediction capability in large catchments. At 1 km scale highly distributed hydrological models should be coupled to non-hydrostatic atmospheric models in order to obtain an optimal dynamic downscaling to smaller catchments. The effects of a full coupling should be analysed in detail and be compared to the previously applied on-way coupling in which atmospheric conditions are forcing the hydrological models without feed-back to the atmospheric system. The limitations implied by the large computational efforts involved in the full model coupling must be investigated in detail as well. The abilities of the models to provide long-term simulations to assess water availability as well as short-term runs to forecast extreme events should be thoroughly investigated.

For the purpose of validation, means and variability of today's climate runs of coupled atmosphere-hydrology models at different scales should be compared to meteorological and hydrological observations. In the validation effort the modelling of all the important processes must be addressed. A particular and important application area is the ability to model extreme hydrological and meteorological events. Thus, detailed frequency studies of modelled as well as observed time series should be performed and compared.

4.5 Studies of Climate Change Impacts on Water Resources Availability and Extreme Events

For selected river basins coupled hydrological-atmospheric models should be run under the existing climate as well as under different future climate change scenarios. This will give an opportunity for assessing crucial changes in, for example, water resources availability, irrigation need, power production potential and dam safety. There are many uncertainties involved in the assessment of future water resources due to both the change in environmental conditions affecting water resources (e.g. change in vegetation) and the future anthropogenic impact on land use (which in some catchments may be even more important than the large-scale change). Assessment of the use of groundwater resources must be included in the analysis. Time series of groundwater use should be established, and the abstraction of groundwater must be an integral part of the modelling efforts and assessments.

In dam safety studies, as well as in other areas where the risk of extreme events plays a major role, the change in frequency and severity of extreme events like floods and droughts is crucial. Thus, there is a need for detailed studies on how frequency curves may change in response to climate change and variability. Since assessment of changes in extremes are subject to far more uncertainty than changes in mean values, this task is far from being trivial. There is, however, a strong request for models that can predict the changes in frequency and severity of future extremes.

4.6 Real-time Flood Forecasting

The current methodologies for real-time forecasting of flooding and other extreme events, which may lead to severe damage of infrastructure and/or natural resources, need further development taking the possible improvements due to the emergence of coupled hydrological-atmospheric models into account. Appropriate methodologies should be developed for application to flood-prone catchments in the Baltic Sea basin. Because of the vast differences in catchment size a suite of different models and coupling procedures should be considered. Moreover, in order to obtain systems that most effectively can take real-time observations into account, data assimilation procedures must be developed for both meteorological and hydrological data.

The value of improved real-time forecasting should be subject to a dedicated study. How improved forecasts can be used to mitigate adverse impacts of floods is of great interest. The common assumption is that large amounts of money can be potentially saved by such improved systems. Improved forecasting skills, however, must go hand in hand with improvements in flood management procedures. Can the management systems be operated in such a way that they can significantly benefit from more precise and earlier forecasts? This is an equally important question.

4.7 Summary of Major Goals

In summary, major goals with regard to **the third objective of BALTEX Phase II** "*provision of improved tools for water management, with an emphasis on more accurate forecasts of extreme events and long-term changes*" are:

- To develop further and apply coupled atmospheric-hydrological models for improved assessment of the availability of water resources in today's and future climate;
- To apply different modelling systems in selected river basins to assess the impact of climate variability and change on the hydrological regime including the occurrence and severity of extreme events;
- To explicitly take account of the societal use of groundwater and surface water resources, as well as man-made changes of land use, in studies of the future risk of water shortage and impacts of extreme events.

5 Exploring Linkages between Climate and Environmental Processes

5.1 Problem and Approach

The aim is to gradually integrate existing groups that hold specific knowledge on environmental modelling and measurements and that can take advantage and implement BALTEX methodologies wherever appropriate. The modelling efforts should, at least in the beginning, be confined to the environmental issues that are important for climate studies and predictions. Integration with BALTEX can improve the capability on modelling of atmospheric transport and fluxes of gases, aerosols and particles as well as of the transport and biogeochemistry in the Baltic Sea. It should identify the relationship between today's scientific shortcomings and strength for climate predictions with present day's assessment of the environment. A prominent example where BALTEX methodologies can be applied is the study and modelling of the eutrophication of the sea. The atmospheric nitrogen originates from mainly urban areas as oxidized nitrogen or from agricultural and farming activities. The nitrogen reaches the sea through rivers, atmospheric deposition and coastal point sources. The pathways for the nitrogen to the sea involve chemical, hydrological and meteorological processes at different spatial and temporal scales. The nutrient input to the sea can result in eutrophication and locally short-term low oxygen levels that connects to transport and biogeochemistry in the sea. Nutrient-rich marine water is a major sink for CO_2 due to uptake by phytoplankton. However in less nutrient-rich and warm waters the ocean can become a source. Modelling of the eutrophication is a fine example where atmospheric, hydrological, oceanographic and biogeochemical processes plays together on a large range of scales – like the climate issues dealt with in BALTEX. Other examples are the formation of photochemical smog and its effect on climate parameters.

The linking and transfer of the BALTEX methodologies to air and water quality studies should be done gradually and piecewise to secure BALTEX continuity, concentrating initially on the research areas where the activities of the present groups are well established and experienced. This deals with the numerical climate model predictions as well with theoretical and experimental investigations of the fluxes.

5.2 Theoretical Issues

Many of the trace gases of interest exhibit a tremendous spatial variability (e.g. nitrogen compounds) due to their rapid chemical reactivity with other ambient species and/or due to horizontal heterogeneity of the underlying surface in terms of uptake/emissions. However use of BALTEX model capabilities and with the growing skill of statistical and dynamical downscaling of atmospheric land and sea surface processes within the BALTEX community, this problem constitute a promising basis for advances in air and water quality modelling and studies.

The exchange processes of energy and water, and to a lesser degree CO_2, over land and the associated aggregation techniques in patchy forest/agricultural landscapes have been investigated experimentally in the NOPEX and LITFASS experiments, and model-wise in BALTEX. The exchange processes were found to be quite different for momentum and heat. Interesting recent result are that for snow covered patchy forested landscapes at high latitudes the effective albedo critically depends on the elevation of the sun. In the BASIS experiment it was found that even the heat balance over the ice-covered sea was influenced by forest on the small islands of the archipelago. Over the sea the exchange of trace gases is controlled by the fine structure of the turbulence near the surface. For example the role of wave breaking, bubble bursting, turbulent bursts and coherent structures near the surface are believed to be important for the exchange process but are not explicitly considered in the parameterisations used presently. Also there are evidence that the effect of swells can be substantial although presently neglected.

A considerable synergetic effect can be obtained by combing the experience that has been achieved through recent experimental efforts carried out in the Baltic Sea basin with the traditions and methods of the scientists working with environmental problems. A special issue dealt with by the environmental scientific community and only marginally in connection with BALTEX are flux parameterisations of gaseous compounds, which has a fast reaction rate relative to the turbulence scales, which must be evaluated together, as is the case of e.g. ammonia and nitric acid. The study of these problems can be of mutual benefit for both communities.

5.3 Modelling Issues

The BALTEX modelling concept involves coupling of meteorological and oceanographic/hydrological models. This includes the interaction between land surfaces, coastal topography and wave fields. The BALTEX modelling system can be a platform for a model system that links (nutrient) transformation processes and pathways in air, water and the marine environment. The effort should start with simple extensions of the BALTEX modelling activities and become gradually more ambitious. It will require parameterisations of deposition of trace gases as well as adaptation of the parameterisations to the modelling complex.

Inclusion of the full carbon cycle in the BALTEX modelling concept is another issue of large interest. On one hand, the linkages between the CO_2 concentration in the atmosphere and processes controlling energy exchanges at the land surface need to be implemented into the models for better predictions of future climate. On the other hand, assessments of future carbon cycles require accurate information about the temporal and spatial distribution of energy and water; the BALTEX modelling concept can be the platform for such analysis.

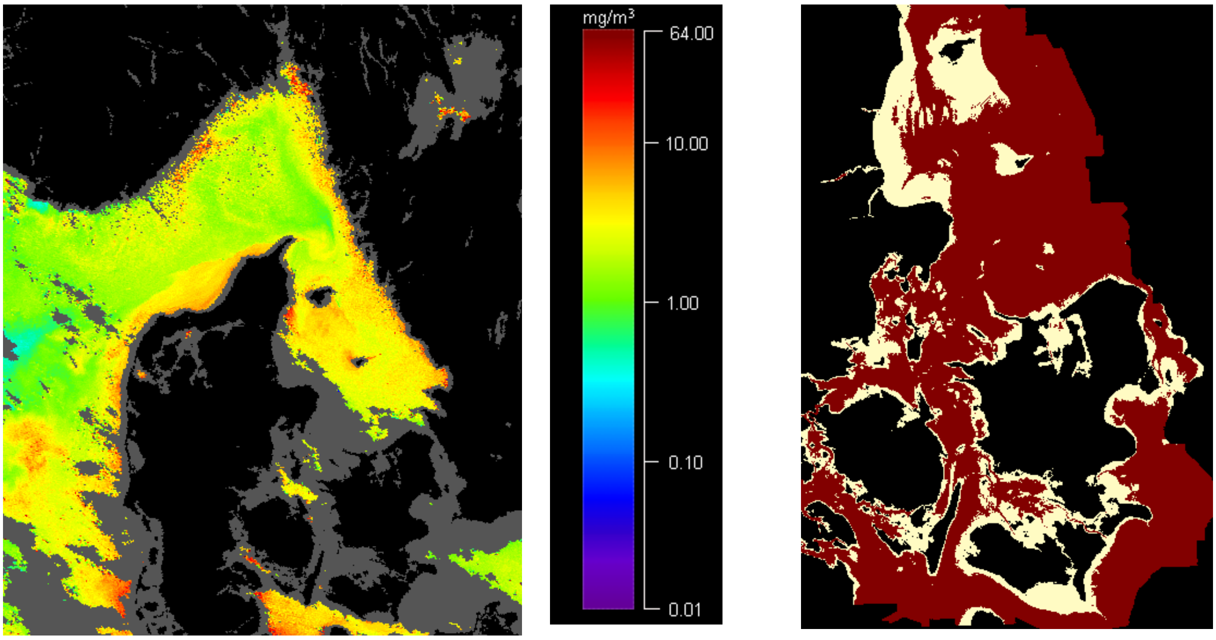

Figure 6: *The left panel shows a satellite image of the chlorophyll concentrations in Danish Waters (on 10 May 2001, derived from SeaWiFS; Hasager et al., 2003). The spatial variability is considerable but the high concentration around Læsø might partly be an artefact caused by shallow water, which illustrates one of the problems with this promising technique. The map to the right show areas of shallow water in the Danish Streats (areas with water depth less than 10 metres shown in white).*

5.4 Measuring Issues

Measurements of the energy and water fluxes in the atmosphere that are essential for BALTEX are based on well-recognised techniques, and in particular the eddy correlation technique is often applied. However this is not the case for most of the environmental trace gases that typically cannot be sampled at rates sufficient for reliable use of the eddy correlation technique to determine their fluxes. The relaxed eddy accumulation technique is a promising new tool for the estimation of fluxes. It does not require fast measurements of the tracer gases but the method is still in the development phase and needs further validation. Desirable would be innovative technologies that can provide directly the fluxes of trace gases. The ongoing theoretical and experimental work within BALTEX on the refinement of the flux parameterisations and coupling of meteorological and oceanographic/hydrological models could be combined with considerable synergetic effects with the continued instrument development and measurements of fluxes of trace gases for environmental applications. Both communities possess considerable experience on fluxes and their parameterisations. Flux parameterisation for environmental trace gases will have to be adapted in order for the BALTEX modelling framework to be used in environmental applications

Remote sensing is another promising tool under rapid development for monitoring of both the terrestrial and marine environment (Figure 6). The challenges are in part the resolution and parameterisations that relate geophysical quantities to the remotely sensed signatures. Present efforts and progress highly relevant for BALTEX researchers are on the surface temperatures, overlying winds, humidity and clouds. Additional challenges for the environmental community is to provide information on the distribution of marine algae and air-sea gas exchange rates, in particular water vapour and carbon dioxide, using proxies of indicators of the processes that govern these species. The whole issue of satellite based remote sensing of trace constituents and fluxes attract presently much attention and are generally considered a very promising tool for future endeavours to estimation those fluxes that are essential for objectives of BALTEX as well as for environmental communities.

5.5 Experimental Issues

BALTEX will continue to engage in field campaigns and these can adequately be enlarged or combined to address environmental issues as well. The conditions over sea-ice and snow covered landscapes is poorly investigated and little is known on the quality of the parameterisations that are applied in models. For sea conditions the presently used parameterisations of fluxes of energy and water on the local scale exhibit an unacceptable high uncertainty. Along with these experiments it is suggested to extent the efforts also to include measurements of fluxes of pollutants, preferably by use of different measuring techniques, both in order to test the techniques and instruments in the specific and sometime hostile environments, and in order to achieve measurements for development and validation of flux-parameterisations for environmental trace gases. Initially the efforts should be focused on local fluxes and with gradual extension to larger scales being presently an area for new insight and scientific challenges. One of the challenging issues for the BALTEX modelling methodologies in an environmental context is the nutrient-carbon cycle over water and land surfaces, where especially the processes during the transition period in the sub-arctic are virtually unknown, but also the processes over the sea are very uncertain and are ready for future studies.

5.6 Summary of Major Goals

In summary, major goals with regard to **the 4th objective of BALTEX Phase II** "*gradual extension of BALTEX methodologies to air and water quality studies*" are:

- To enhance the modellers' capability for pollution and dispersion calculations by implementing recent progress in climate modelling within the BALTEX community such as coupled models;

- To initiate first steps towards inclusion of the nutrient-carbon cycles and the full carbon cycle into the BALTEX modelling platforms;

- To use recent developments of remote sensing of water and environmental parameters; to use novel flux measuring techniques such as Relaxed Eddy Accumulation of environmental components;

- To engage in field experiments that address environmental issues.

6 Strengthened Interaction with Decision Makers, with Emphasis on Global Change Impact Assessments

6.1 Introduction

Global Change is driven by human activities and encompasses largely different phenomena like climate change and ozone depletion, but also globalisation of the economy with consequences for the ecosystem. Here we concentrate on *Global Environmental Change* impacts in a large catchment, the Baltic Sea basin, with a further emphasis on impacts by a changed water cycle.

Most environmental research is stimulated by the desire to be able to distinguish between the consequences of natural variability and of human disturbances for ecosystems and human society in order to take the appropriate measures to reduce disturbances and to protect society and the ecosystem against hazards. Its findings, therefore, are of high interest for decision makers, to adapt in an effective manner to Global Environmental Change or to protect humankind or sectors of society from environmental threats. But also the use of emerging medium-range forecasts of severe weather or short-term climate anomalies are of major interest for many and very different sectors of society. However, in both cases it has to be avoided just to communicate scientific findings to decision makers as the latter know better than natural scientists which facets of Global Change or severe weather have large impacts and how one reacts effectively, i.e., minimizes efforts and thus costs both for adaptation and mitigation measures. As the complexity of the Earth system will never allow precise forecasts and hence considerable uncertainty about its short- and long-term development will always remain, Global Environmental Change research has to give the full range of potential futures and its associated probabilities.

BALTEX thus wants to involve decision makers and stakeholders from the beginning of Phase II by formation of groups including representatives from private companies and local, regional or national services and agencies. The goal will be to identify and promote ways to transfer information to the stakeholders about what is being learned from the science, and to identify what needs to be answered by science.

6.2 BALTEX Goals with High Potential for Application

6.2.1 Infrastructure Adaptation

The full evaluation of long-term observations of rainfall, river discharge or levels, snow pack duration and snow water equivalent, lake- and sea-ice duration and thickness offers not only an assessment of observed changes in variability and thus extremes but also allows a careful projection of the development during the coming few decades as basis of infrastructure adaptation and planning. BALTEX will include planning authorities in a working group on “Infrastructure Adaptation” to changed climate variability with emphasis on water cycle parameters and the coming decades. Later this group shall be combined with the coupled model development group after the coupled models have been validated with observed variability changes and have become useful tools for the projection of future extremes in the water cycle.

6.2.2 Sea Level Variability and Change Estimates for Coastal Zone Management

The joint evaluation of all observations at sea level gauges in and around the Baltic Sea basin will give not only mean sea level fall or rise but also wind-driven variability. As this constitutes one of the main cornerstones for coastal zone management a Sea Level and Coastal Zone Management Group shall be established. It will serve as a multidisciplinary platform for an international exchange of findings and the development of strategies for coastal zone management. In addition to topics like coastal defence and dredging this will involve also consequences of changes in the physical system for the ecosystem and society.

6.2.3 Regional Climate Change

The application of the coupled regional models available to the BALTEX science community nested into global coupled atmosphere/ocean/land models allows a more detailed projection of climate change in the Baltic Sea basin for various scenarios of human activities on global scale. This input is needed for mitigation measures like enforcements of the Kyoto Protocol but also for the adaptation to ongoing climate change. The representatives of ministries responsible for the United Nations Framework Convention on Climate Change (UNFCCC) in BALTEX countries should therefore have an interest to discuss with the coupled modelling community the set-up of model runs enlarging the return for the countries.

6.2.4 Forecasting of Floods, Snow Pack and Hydropower Potential

The models used for the regional climate change estimates can also be used for short-term improved forecasting of floods, snowfall, snowmelt etc., if driven by global forecasting models, e.g. from the European Centre for Medium-Range Weather Forecasts (ECMWF). This allows many applications jointly with the meteorological services that participate in BALTEX Phase II. Because the necessary knowledge about ocean structure as well as soil and groundwater storage grows with the forecast time scale, this aspect of the application of BALTEX Phase II results needs also input from the developing upper ocean observing system. User groups should be formed whenever improvements have become evident that pave the way for rapid application. However, their full potential can only be exploited if seasonal predictions of climate anomalies show skill for the Baltic Sea basin. Should such skill emerge during BALTEX Phase II, groups including insurance companies, distributors of oil, hydropower companies operating large reservoirs and authorities responsible for water supply, to name just a few, should be formed jointly with meteorological and hydrological services.

6.2.5 Reduction of the Eutrophication of the Baltic Sea

Discharge of nutrients by rivers and deposition of nitrogen fertilisers from the atmosphere have led to eutrophication of large parts of the Baltic Sea. The coupled regional models augmented by modules of phytoplankton growth can be used as tools to assess impacts of measures to reduce air and water pollution on the biomass production in the Baltic Sea and related eutrophication, that often causes rapid oxygen depletion in parts of the Baltic Sea below the seasonal thermocline or the halocline. The environmental protection agencies of BALTEX countries will be invited to co-operate for the test of eutrophication reduction scenarios that involve projections of future wastewater, future NO_x emissions and sewage treatment plant construction policies.

6.2.6 Groundwater Changes Caused by a Changed Water Cycle

The availability of clean groundwater is an essential part of our life, as many of us get it as drinking water. As often only small parts of annual precipitation recharge groundwater (often less than 100 mm per year), rather small changes in precipitation amount and timing can lead to substantial changes in groundwater availability. Therefore, many drinking water supply authorities or companies have a high interest in potential groundwater changes. When BALTEX Phase II modelling includes tested groundwater modules into the coupled models, we need to get input from such research and application communities, for example we need to know from their groundwater time series how observed precipitation and groundwater use changes have altered groundwater level. The joint research has to start at the beginning of BALTEX Phase II.

7 Outreach at the International Level

The rationale for BALTEX Phase II as outlined in the previous sections clearly demonstrates the relevance of the programme for various sectors of the society. BALTEX will maintain a broad programme component with the overall objective to strengthen the outreach of BALTEX at all relevant levels, ranging from local to international and global. This *outreach* component of the programme shall promote and facilitate the dissemination, transfer, exploitation, assessment and broad take-up of past and future programme results. The character of the individual measures include in particular i) the creation of awareness, ii) dissemination of results of the programme, and, iii) dedicated education and training measures. The target groups to be addressed in society may be largely divided into 1) the general public, 2) stakeholders and users, and 3) academia.

7.1 The General Public

Traditional measures of information distribution via media accessible to the general public (such as television and newspaper) will be pursued in BALTEX phase II. Some of these measures were already used in the past, however, with sometimes little effect and success. The BALTEX website (www.gkss.de/baltex) will be complemented by a particular dissemination part dedicated to the general public, which will need specific amendments to the present website concerning content and language. This initiative will contribute to the general concept of *e-learning*.

A particularly effective way is seen in a direct interaction between scientists and the public and BALTEX will in particular establish and implement presentations and courses for the general public as follows:

a) as part of the regularly conducted Study Conferences on BALTEX,

b) as individual presentations in the frame of "open days" at universities and research institutions involved in the BALTEX programme,

c) by courses in the frame of adult evening schools,

d) by evening lectures to be held as part of entertainment programmes in particular at major vacation and recreation locations.

Actors in a) to d) will be scientists involved in the programme, but also stakeholders and users relevant for the programme, see section 6. It is considered important that scientists are prepared to create awareness by actively contacting the public also outside their own traditional platforms, such as science conferences and seminars, in order to contribute to overcoming reservations and fears of contact.

The time scale of impacts on society in areas which BALTEX is addressing may be of order of decades or beyond, and awareness in the public is particularly needed in the context of sustainability. Reaching in particular *the youth* is thus seen as an important aspect. The BALTEX programme will establish contacts to schools and establish school courses including practical laboratory experimental and theoretical lectures, where the level of the contents and the presentation measures are specifically dedicated to the experience level of the youth. Also, existing pupil laboratories or pupil courses will be asked to include water cycle issues dealt with in the BALTEX programme. Activities in this field will have a pilot character, in the sense that few specific schools will be contacted in order to establish an education programme jointly with scientists and teachers. As a forerunner to these activities, the BALTEX Study Conferences will have to include a particular *teacher education section,* where results from the science arena are presented in a way usable for teachers in their day-to-day pedagogic work.

Awareness creation in the context of sustainability is only one aspect of reaching the youth. Another one is creating interest, already at pupils' age, in a later professional carrier as a researcher in the scientific fields which BALTEX is addressing. Dedicated education and awareness creation is seen as one measure to reverse the present general trend of decreasing numbers of students in particular in geophysical sciences in many European countries in recent years.

7.2 Stakeholders and Users

Stakeholders and users are 'outstanding' in the context of outreach, because they will directly influence, and hence even steer aspects of the programme. Section 6 is alluding to the bi-directional interaction with stakeholders in more detail. In order to assure a true feedback mechanism between the scientific programme and users, it is important to include prominent representatives of all user communities into relevant bodies of the BALTEX programme, including the BALTEX Science Steering Group. It will be particularly through BALTEX bodies, that feed back with users shall effectively be maintained. Secondly, specific individual contact missions of key scientist to stakeholders will be instrumental, in particular in the build-up phase of the contacts. Thirdly, a series of specific workshops targeted for users will regularly be conducted.

7.3 Academia

Of the sectors addressed in this section, academia has been included the most in the context of outreach activities in Phase I of BALTEX, including global, European and national scales. Measures taken so far were mainly focussed on creating awareness and dissemination of results.

7.3.1 Dissemination of Results

BALTEX progress and developments are regularly reported to GEWEX (Global Energy and Water Cycle Experiment) conferences, and workshops of various bodies such as the GEWEX SSG, GHP (GEWEX Hydrometeorology Panel) and its subgroups, and CEOP (Coordinated Enhanced Observing Period), thus providing for dissemination of results to researchers at the global level. Since its beginning in the early 1990s, BALTEX has organised regular international conferences and workshops, with participation of scientists from many countries in Europe and beyond. The continuously updated BALTEX website (www.gkss.de/baltex) and a regularly published BALTEX Newsletter contribute to dissemination actions targeted mainly to researchers and academia in general. More than 200 peer-reviewed journal articles, including several special BALTEX issues have been published. All these mentioned activities will be maintained and strengthened in Phase II of the programme, where attention will be given to properly include the additional research areas which are new in Phase II (see in particular sections 3 to 6).

7.3.2 Education and Training

In particular three aspects will have to be considered in the education and training component for academia: (i) courses at universities for undergraduate and graduate students as well as for PhD students, as part of the regular degree course system, (ii) the conduction of regular one-week open summer schools focussed on all BALTEX Phase II topics containing courses at the PhD and post-doctoral levels, and (iii) the mobilisation of the academic offspring by including young scientists into the programme through diploma thesis, doctoral thesis, post-doc and other academic qualification studies. Implementation of these measures will be straightforward because numerous universities are actively involved in BALTEX and with the enlarged objective of Phase II this number is expected to increase.

7.4 Implementation Aspects

The specific activities under this section of the programme, necessary for improving the outreach of BALTEX, are naturally diverse in their form and frequency of implementation. They need to be implemented in such a way as to ensure co-ordination across the various scientific topics of the programme and target sectors of the society to be addressed. Co-ordination of these activities is envisaged to be assured through implementation of a specific *BALTEX Working Group on Public Relation*. Details will be given in the Implementation Plan for BALTEX Phase II.

8 Data Management

8.1 Data Policy

BALTEX and GEWEX belong to the WCRP project family, with WCRP being sponsored by the World Meteorological Organization (WMO) the International Council for Science (ICSU) and UNESCO's Intergovernmental Oceanographic Commission (IOC). It is thus appropriate that the policy for release and dissemination of BALTEX data should principally comply with the WMO policy, practice and guidelines for the exchange of meteorological, hydrological, and related data and products, as embodied in Resolution 40 of the Twelfth WMO Congress 1995 (CG-XII), and Resolution 25 of the Thirteenth WMO Congress 1999 (CG-XIII); that is, free and unrestricted exchange of *essential* data and products. Whenever possible, this policy shall be applied to *all* BALTEX data. The data policy for BALTEX Phase II endorses a free and unrestricted data exchange. The no-restriction principle shall in particular mean that no financial implications are involved for any BALTEX data exchange.

For all cases, where restrictions to a free exchange may be unavoidable, BALTEX has established an internal procedure where scientists wishing to receive BALTEX data from a BALTEX Data Centre need to follow rules laid down in a *BALTEX Data License Agreement*. This procedure is envisaged to be continued in BALTEX Phase II, whenever an entirely free and unrestricted data exchange may be impossible. The contents of the present BALTEX Data License Agreement will be critically reviewed for its application in BALTEX Phase II.

8.2 BALTEX Data Centres

Data relevant to BALTEX cover a wide range of disciplines, data types, periods, geographical extent, frequency and spatial resolution. The BALTEX programme has established an internal infrastructure in the form of dedicated BALTEX Data Centres for specific types of data. Several of these archives contain unique data sets with unprecedented features (Figure 7). This infrastructure will be maintained for BALTEX Phase II. With the extended objectives of BALTEX Phase II in mind requirements in this context are likely to increase compared to Phase I. Additional data types will be dealt with and may define the need for additional data centres or data centre functions.

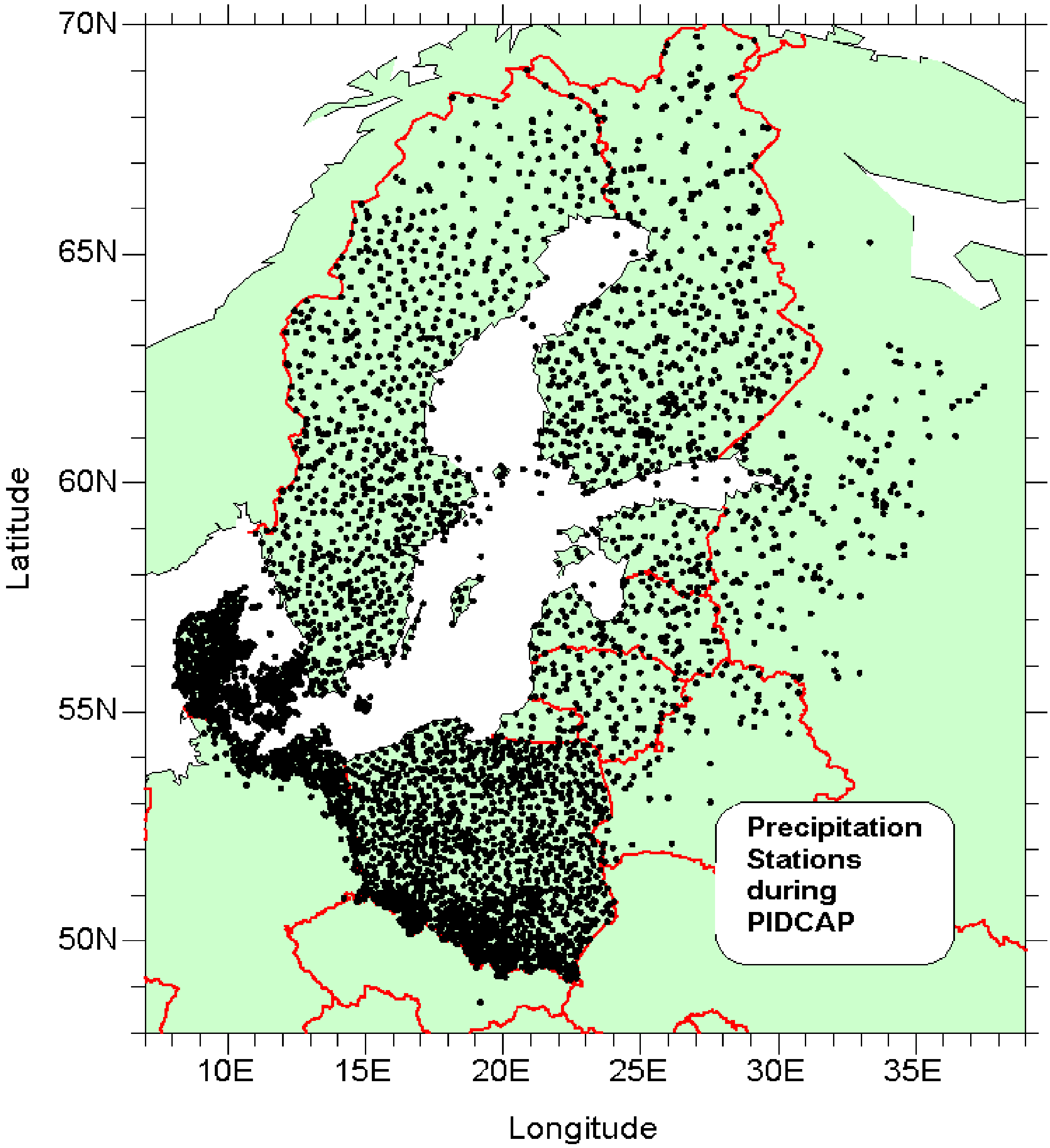

Figure 7: *Location of precipitation stations in the Baltic Sea basin with available data during PIDCAP. Daily precipitation sums from more than 3800 stations located in the BALTEX region are stored in the archives of the BALTEX Meteorological Data Centre. For the period 1996 to date the number of stations with available data varies between 3000 and 4000.*

At present, the following four major BALTEX Data Centres are in operation:

i) the BALTEX Meteorological Data Centre (BMDC), operated by the group *Model and Data* (a service group for Germany administered by the Max-Planck-Institute for Meteorology in Hamburg, Germany);

ii) the BALTEX Hydrological Data Centre (BHDC); and

iii) the BALTEX Radar Data Centre (BRDC), both operated by the Swedish Meteorological and Hydrological Institute, Norrköping, Sweden; and,

iv) the Oceanographic Data Centre for BALTEX (ODCB), operated by the Swedish Meteorological and Hydrological Institute, Vastra Frolunda/Göteborg, Sweden.

No specific satellite data centre for BALTEX is in place. Instead, important satellite data are processed and held available at several organisations contributing to BALTEX including the Free University Berlin, Germany; University of Bonn, Germany; Swedish Meteorological and Hydrological Institute, Sweden; and Chalmers University, Sweden.

Basic new data aspects related to the extended objectives for BALTEX Phase II, compared to Phase I of BALTEX, include

1) longer time scales for studies of climate variability and change since 1860 related in particular to the second objective of BALTEX Phase II,

2) inventories of trace gas and aerosol emissions as well as fluxes of nutrients and pollutants.

Data referred to under 1) and 2) will be both observational records and model output. Time periods covered are decades up to two or more centuries (1800 to date). A whole suite of atmospheric, land surface, river and sea parameters related to water and energy cycles will have to be dealt with. It is special for northern Europe (Scandinavia but also the Baltic States) that several decade- to century-long records exist which will be key for e.g. model validation and analysis purposes. It will have to be explored whether specific archiving of data on emission, transport and deposition of e.g. trace gases (such as nitrogen compounds and CO_2) and their related aerosols is desirable for BALTEX. Several archives for the data mentioned under both 1) and 2) are already in place, although mostly with different regional focus and/or time periods covered. As technical and financial requirements for dedicated, new BALTEX data centres may be enormous, new and additional archiving efforts should be established gradually, based on availability of existing data and with a gradual extension from future experiments and model simulations. Detailed requirements for data types and formats will be the subject of the Implementation Plan for BALTEX Phase II. It is envisaged that the policy outlined in section 8.1 will be valid for both existing and new data centres or archives.

9 Links to other Research Projects and Programmes

BALTEX is only one of now eight Continental-Scale Experiments (CSEs) of GEWEX, the Global Energy and Water Cycle Experiment (Figure 8), a globally co-ordinated project of the World Climate Research Programme (WCRP), the latter sponsored by the World Meteorological Organization (WMO), the International Council for Science (ICSU) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO. As other CSEs also BALTEX widens its activities in Phase II, firstly, by a much stronger involvement of stakeholders that apply BALTEX results for a better water resource management, and secondly, by including research on water quality issues and ecosystem modelling of the Baltic Sea. The co-ordination of all CSEs via the GEWEX Hydrometeorology Panel (GHP) facilitates the exchange of experience and models, thereby accelerating progress in the understanding of the energy and water cycle of a region that is needed as the basis of any further research on biogeochemical cycles.

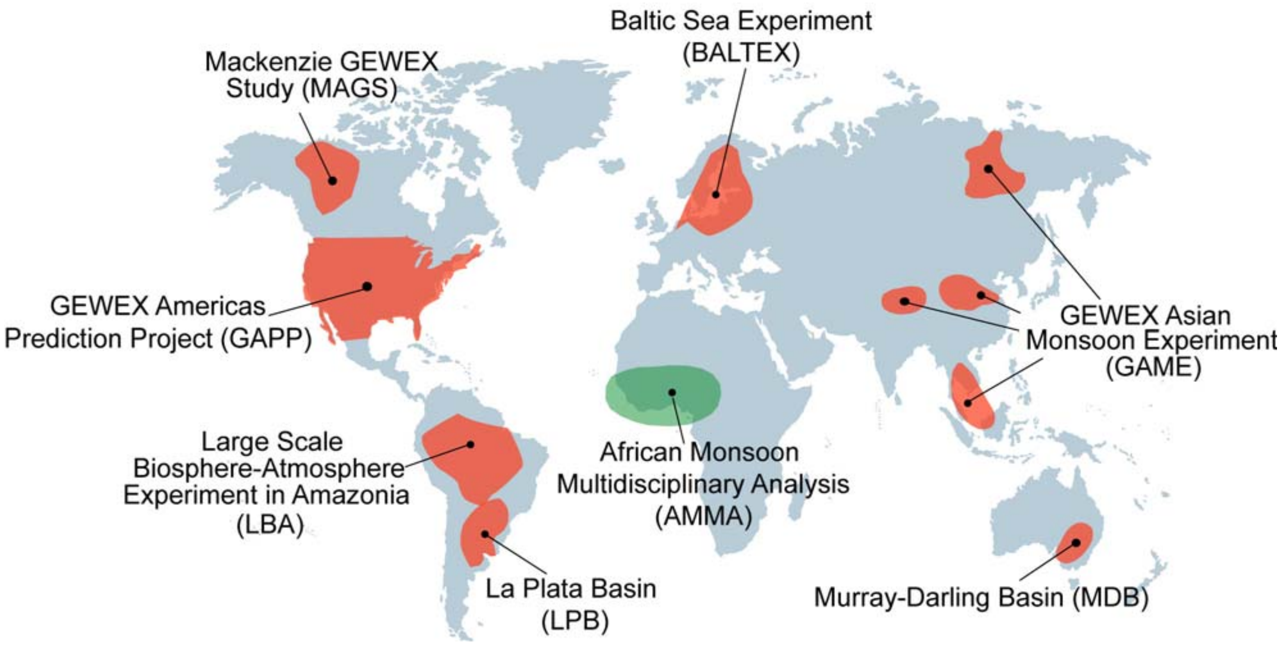

Figure 8: *GEWEX Continental-Scale Experiments as of 2004.*

Because climate anomalies, like El Niño, often have nearly global scale all CSEs have embarked in the Coordinated Enhanced Observing Period (CEOP), which has become, after being initiated by GEWEX, an element of WCRP, involving two other projects, namely the Climate Variability and Predictability Study (CLIVAR) and the Climate and Cryosphere Project (CliC). Through a joint observing period from October 2002 to December 2004 CEOP will for the first time catch the teleconnections between tropical and mid- and high-latitude anomalies of the water cycle. CEOP is the fore-runner of a new global observing and predicting system as it integrates new sensors on NASA’s (TERRA and AQUA), ESA’s (ENVISAT) and YAXA’s earth observation satellites into the existing operational meteorological satellite system, involves 9 major numerical prediction centres that offer their global analyses to the scientific community, and has established a global network of at present 39 reference sites (mostly from the CSEs) that deliver, in addition to routine observations including radio soundings, energy and water fluxes at the surface. In a 250 x 250 km^2 area around each reference site model output and satellite data are stored jointly to validate both satellite data and models. BALTEX contributes data from four reference sites (Cabauw, The Netherlands; Lindenberg, Germany; Norunda, Sweden; Sodankylä, Finland). CEOP has been accepted by the Integrated Global Observing Strategy Partnership (IGOS-P) as the pilot experiment for its water theme.

After the Amsterdam Open Science Conference of all Global Change Research Programmes (DIVERSITAS, IHDP, IGBP, WCRP) in July 2001 the scientific chairs and directors of these programmes launched the Earth System Science Partnership (ESSP) and the so-called interprogramme projects on carbon, water, and food and fibre. One of these, the “Global Water

Systems Project (GWSP)”, whose science plan will be available end of 2003, forms an ideal umbrella for the development of BALTEX Phase II as it combines all scientific disciplines dealing with water research from a physical, biological and chemical point of view with social sciences aspects of water and land use.

Overall BALTEX in its Phase II is well embedded in internationally co-ordinated research programmes and will make a major contribution to them and its deliverables will be used by water resource managers.

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List of Acronyms

AQUA	NASA Earth Observing System Satellite Mission
BALTEX	Baltic Sea Experiment
BALTIMOS	A German Research Project: A Coupled Model System in the Baltic Region
BASIS	BALTEX Air-Sea-Ice Study
BHDC	BALTEX Hydrological Data Centre
BMDC	BALTEX Meteorological Data Centre
BRDC	BALTEX Radar Data Centre
BRIDGE	Major enhanced observational period in BALTEX
BSSG	BALTEX Science Steering Group
CEOP	Coordinated Enhanced Observing Period
CliC	Climate and Cryosphere Project
CLIVAR	Climate Variability and Predictability Study
CSE	Continental-Scale Experiment
DIVERSITAS	International Programme of Biodiversity Science
ECMWF	European Centre for Medium-Range Weather Forecasts
ENVISAT	ESA Earth Observation Satellite
EOS	Earth Observing System
ERA-40	European Reanalysis and Data Assimilation Projet
ESA	European Space Agency
ESSP	Earth System Science Partnership
GCM	Global Climate Model
GEWEX	Global Energy and Water Cycle Experiment
GHP	GEWEX Hydrometeorology Panel
GIS	Geographic Information System
GWSP	Global Water Systems Project
HBV	Semi-distributed Hydrological Model
ICSU	International Council for Science
IGOS-P	Integrated Global Observing Strategy Partnership
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimensions Programme on Global Environmental Change
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
LITFASS	Lindenberg Inhomogeneous Terrain - Fluxes between Atmosphere and Surface: A Long-term Study
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration
NCAR	National Centre for Atmospheric Research
NCEP	National Centres for Environmental Predictions
NOAA	National Oceanic and Atmospheric Administration
NOPEX	Northern Hemisphere Climate-Processes Land-Surface Experiment
ODCB	Oceanographic Data Centre for BALTEX
PEP	Pilot Study of Evaporation and Precipitation over the Baltic Sea
PIDCAP	Pilot Study for Intensive Data Collection and Analysis of Precipitation
RCAO	Regional Coupled Atmosphere-Ocean Model
SeaWiFS	Sea-viewing Wide Field-of-view Sensor, a NASA satellite mission
SMHI	Swedish Meteorological and Hydrological Institute

SSG	Science Steering Group
TERRA	NASA Earth Observing System Satellite Mission
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WCRP	World Climate Research Programme
WMO	World Meteorological Organization
YAXA	National Space Administration of Japan

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