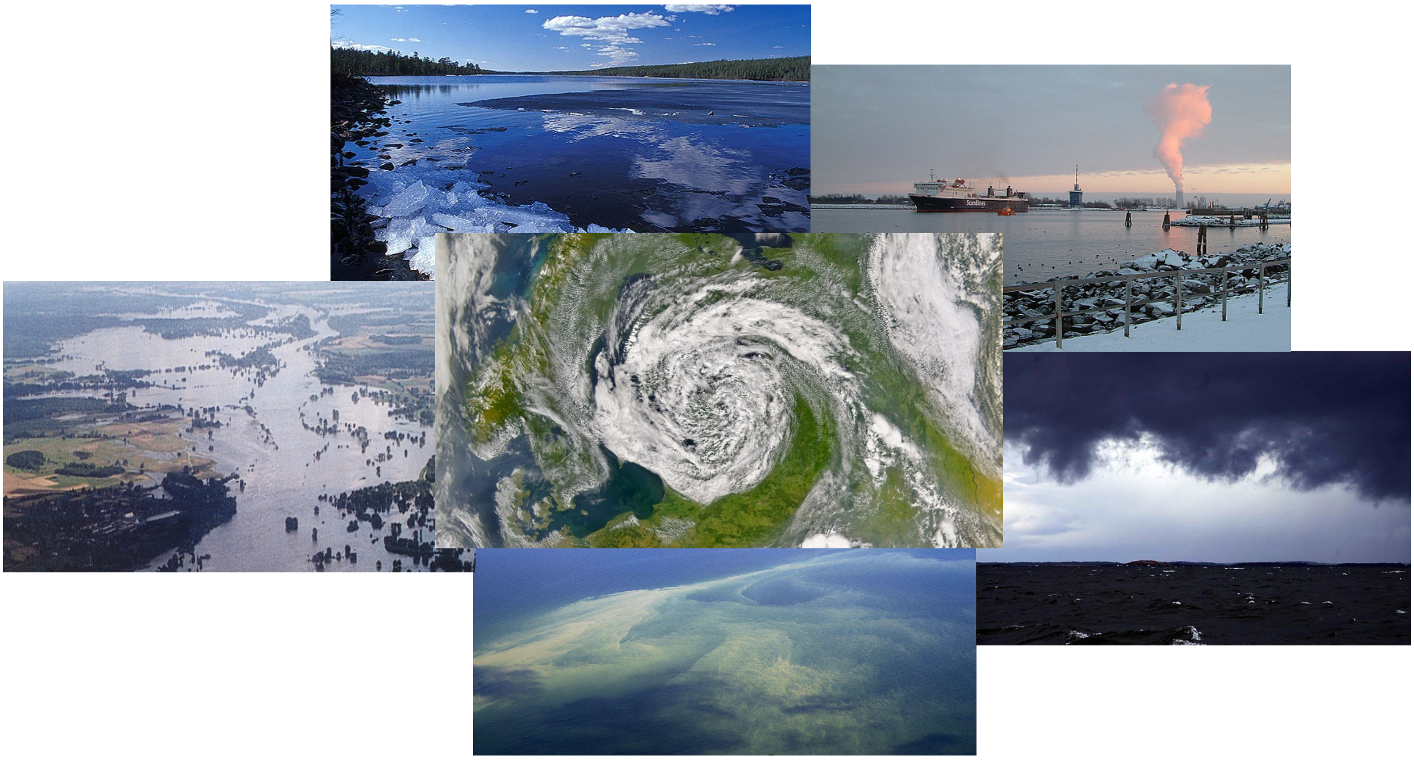
BALTEX Phase II
2003 – 2012



Science Framework and Implementation Strategy

Foreword

BALTEX (the Baltic Sea Experiment) was launched in 1992 as a Continental-scale Experiment (CSE) of the Global Energy and Water Cycle Experiment (GEWEX) within the World Climate Research Program (WCRP). The research focus of BALTEX has primarily been on the hydrological cycle and the exchange of energy between the atmosphere and the surface of the Earth, because they control and regulate the climate in a fundamental manner. The study region of BALTEX is the Baltic Sea and its huge catchment region, which constitutes a unique European water basin, creating specific demands on models and scientific concepts.

Numerous scientific achievements obtained during Phase I of BALTEX now call for application in other areas, where knowledge on and modelling capabilities of the water and energy cycles in the climate system are fundamental. A Science Plan for BALTEX Phase II was therefore published in early 2004 which suggests to enlarge the scientific scope of the programme and strives to contribute to generating not only physical but also environmental policy- and stakeholder-relevant information. The BALTEX Science Steering Group, at its 15th meeting in Risø, Denmark, implemented a writing team with the mandate to establish the present *Science Framework and Implementation Strategy* for BALTEX Phase II. This document intends to work out more details of the scientific background and rationale, and link these to potential implementation activities. Extension of BALTEX research will in particular include areas such as climate variability and climate change studies, scenarios of future climate, budgets and transport of harmful substances, improved understanding and prediction of extreme events like floods, and climate or environmental impact studies that respond to social needs and support decision makers in the broader context of Global Climate Change issues. An important aspect of BALTEX Phase II will be a more holistic approach towards observing, understanding and modelling major environmental and socio-economic aspects relevant for the entire Baltic Sea basin. Parts of the BALTEX Phase II research activities will thus contribute to the build-up of a high resolution integrated modelling capability for Northern Europe, embedded in an Earth System Model.

The intention of this *Science Framework and Implementation Strategy* is to provide a plan readable on its own, taking into account possible repetitions with - but also extensions to - the Science Plan published earlier. It is our wish to thank the writing team members and the numerous scientists who have contributed in various ways to this document. We all like to stress that the BALTEX Phase II research goals and potential activities are understood as invitations for joint research activities and cooperation, creating benefit for all involved, for a better understanding of the entire Earth system, and finally, an accelerated approach to sustainable development.

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Executive Summary

Since its foundation in the early 1990s, the research focus of BALTEX has primarily been the exploration, modelling and quantification of the various *physical* processes determining the space and time variability of the energy and water cycles of the Baltic Sea and its catchment region, the Baltic Sea basin. Numerous goals have been reached in particular in the following areas: Collection and exploitation of *in situ* and remote sensing data, the re-analysis of existing data sets, data assimilation as well as the development of coupled models and the implementation of process studies including field experiments. A particular major success was the building and first applications of two coupled modelling systems for the Baltic Sea - atmosphere - land surface system, including sea ice, lakes and rivers.

The numerous scientific achievements of BALTEX Phase I now call for application in other areas where knowledge on and modelling capabilities of the water and energy cycles in the climate system are fundamental. A Science Plan for BALTEX Phase II has therefore been published in early 2004, which defines 6 major objectives including several specific goals with the overall strategy to enlarge the scientific scope of the programme and to contribute to generating also environmental policy- and stakeholder relevant information.

An important aspect of BALTEX Phase II will be a more holistic approach towards observing, understanding and modelling major environmental and socio-economic aspects relevant for the entire Baltic Sea basin. Parts of the BALTEX Phase II research activities will thus contribute to the build-up of a high resolution integrated modelling capability for Northern Europe, embedded in an Earth System Model.

The structure of this *Science Framework and Implementation Strategy* document follows the six major objectives as defined in the Science Plan for BALTEX Phase II.

BALTEX Phase II Objectives

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

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

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

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

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

Objective 6
Education and outreach at the international level

Objectives 1 to 4 are basically addressing science issues, while objectives 5 and 6 are related to strategic and political issues which will have to be pursued as cross-cutting activities in the context of all four science objectives. The Science Plan explained the scientific objectives in terms of several related major goals. This *Science Framework and Implementation Strategy* suggests how to achieve these goals and describes *potential activities* as more concrete implementation measures. It also specifies additional data needs and highlights the desired involvement of stakeholders.

The objectives of BALTEX Phase II are shortly outlined as follows:

Objective 1:
Better Understanding of the Energy and Water Cycles over the Baltic Sea Basin

Potential Activities

- Regional Analysis and Re-analyses for Different Variables for specific Purposes
- Further Development of Models and Model Improvement
- Closing the Energy and Water Budget on a High Level of Confidence
- Improvement of Quantitative Precipitation Forecast
- Evaluation of Models and Data Sets for their Use in Climate Impact Analysis and Environmental Issues

While BALTEX research has met to a large extent BALTEX Phase I objectives, gaps still exist and further research is needed for a more comprehensive fulfilment of the original BALTEX aims. Future BALTEX research related to this objective will therefore mainly contribute to further improving the physical understanding of processes, related modelling capabilities, and the quantitative estimation of important water and energy cycle parameters. Major goals include the evaluation of regional models with increasing and unprecedented detail with the particular perspective to support climate and environmental studies and to develop strategies for climate and environmental impact assessments. BALTEX will continue to establish and better explore more comprehensive observations from the entire Baltic Sea basin, including new satellite data. The further development of modules of coupled regional models for the atmosphere, the land surface including rivers and lakes, and the Baltic Sea including sea ice will be pursued. While some basin-wide estimates of atmospheric water transport divergence derived from re-analysis data sets, agree coincidentally within 10 to 20 % with basin-wide runoff estimates, individual components of the water and energy cycle show sometimes drastic mismatch and even unphysical direction of fluxes. A major future goal therefore remains to establish more reliable estimates of budgets and fluxes, i.e. to close the energy and water budgets at lower uncertainty.

Objective 2:
Analysis of Climate Variability and Change since 1800, and Provision of Regional Climate Projections over the Baltic Sea Basin for the 21st Century

Potential Activities

- Reconstruction History of Climate in the past 200 Years as well as detailed Re-analysis of “Weather” during the past 40 Years
- Detection and Attribution of Climate Change
- Scenarios based on Evolving Global and Regional Forcing and Response
- Assessment of Climate Change for the Baltic Sea Basin

Extended observations of climate parameters are available in the region, which should be exploited in concert with model studies. As for most regions, there are specific regional challenges of global climate change for the Baltic Sea basin. The combined effects of climate change and socio-economic changes are largely unknown at present. BALTEX Phase II will contribute to the detection of regional climate change in the Baltic Sea basin, and to a better understanding of the physical mechanisms that are behind climate variability and change. One aim is to discern between natural and anthropogenic causes and thus to contribute to attribution studies. Another is to study the contributions of large-scale control and locally/regionally generated forcing on the Baltic Sea basin climate. A further major aim for BALTEX Phase II is to develop projections of future climate variability and change by means of sensitivity analyses and model studies.

Charting past climate variability and change, and providing regional climate projections for the future over the Baltic Sea basin will become a major research component in BALTEX Phase II.

Objective 3:
Improved Tools for Water Management

Potential Activities

- High Resolution Hydrological Modelling
- Improvement of Parameter Estimates for distributed Hydrological Models
- Coupling Hydrological Models to Regional Climate Models
- Analysis of the Consequences of Climate Change for Hydrology and Water Resources Management
- Hydrological Modelling with Radar-derived Precipitation Applications

In the context of BALTEX Phase II research the envisaged improvement of tools for water management aims particularly at assessing how both present and future climate variability impacts on the water resources in the Baltic Sea basin, and how to quantify and reduce the associated risks caused by climate extremes. This objective is therefore closely related to the former one, however, with a specific water-related focus and tailored for a dedicated user and stakeholder community with its specific requirements. BALTEX Phase II goals include the further development and application of coupled atmospheric-hydrological models to be used for improved assessment of the availability of water resources in today's and future climate. Different modelling systems shall be applied 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. BALTEX will consider socio-economic drivers by explicitly taking 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. Another goal is to develop further flood forecasting models.

Objective 4:
Gradual Extension to Air and Water Quality Studies

Potential Activities

- Input, Dispersion, Transport and Fate of Nutrients and Pollutants
- Integration of Biogeochemical Models in existing Coupled Regional Climate Models
- Integration of the Complete Carbon Cycle
- Use of Novel Data Sources and Techniques

With this objective BALTEX will explore and establish links between climate and environmental processes and research. The major aim is to gradually integrate environmental modelling into physical modelling concepts obtained in BALTEX Phase I. Whenever necessary - if data and knowledge are missing - BALTEX will define and execute appropriate observation concepts as suggested in the Science Plan for BALTEX Phase II. A particular goal is to enhance the capability to model pollution dispersion by using recent progress in dynamical modelling, particularly through coupled regional models, within the BALTEX community. It is envisaged to start the inclusion of nutrient and carbon cycles into the existing BALTEX modelling platforms. Important aspects of this research area are the exploitation of observational data, but BALTEX will also engage in field experiments that address missing or insufficiently known processes relevant for environmental issues. BALTEX aims at using recent developments in remote sensing of water and environmental parameters and novel flux measuring techniques of environmental components.

Objective 5:
Strengthened Interaction with Stakeholders and Decision Makers

Potential Activities

- Organisation of Dedicated Workshops with Stakeholder Participation
- Identification of Information Requirements of Decision Makers
- Elaboration of Adaptation Strategies to Climate Change in the BALTEX Region
- Identification of Fundable Research Activities

BALTEX Phase II research will take advantage of stakeholder involvement in a more pronounced way compared to Phase I. Important in this context is the involvement governmental organisations such as national hydro-meteorological services, but interaction with other stakeholders such as policy decision makers, international organisations (for example the European Environment Agency, EEA), companies and small enterprises in various sectors will also be strengthened and established. The selection of topics is driven by societal needs and is therefore a dynamical process. BALTEX envisages to install a dedicated working group which will promote a lively and fruitful interaction between scientists and stakeholders.

Objective 6:
Education and Outreach

Potential Activities

- Identification of Relevant Stakeholders and Users
- Intensification of Contacts between Scientists and Stakeholders/Users
- Organization of Stakeholder/User-relevant Workshops
- Organisation of BALTEX-related Summer Schools as well as the Integration of BALTEX relevant Topics into National and International Study Programmes including Master and Ph.D. Theses
- Preparation of relevant Study Material for Secondary Schools
- BALTEX-related Evening Lectures
- Establishment of a Web Site dedicated to the General Public

The rationale for BALTEX Phase II as outlined mainly in Chapters 2 to 5 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 education and outreach of BALTEX at all relevant levels, ranging from local to international and global. This 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 can be largely divided into 1) stakeholders and users, 2) scientists, 3) students, and 4) the general public.

Scientific Cooperation and Contribution to GEWEX / WCRP and other International Programmes

Ever since its launch in the early 1990s, BALTEX has successfully contributed to meeting the objectives of the Global Energy and Water Cycle Experiment (GEWEX). As an approved GEWEX Continental-scale Experiment, BALTEX is actively participating in the GEWEX Hydrometeorology Panel (GHP). The revised objectives and the planned potential activities outlined in this document are obviously in line with and support meeting the revised objectives of GEWEX Phase II, which have recently been defined for the period until 2012. GEWEX is a global project of the World Climate Research Programme (WCRP), which has recently launched the *Coordinated Observation and*

Prediction of the Earth System (COPES) initiative with the major aim to facilitate prediction of the Climate/Earth system variability and change for use in an increasing range of practical applications of direct relevance and benefit to society. Through the envisaged contribution to develop a regional component of an Earth System model for the Baltic Sea basin, and also through its climate change and variability research components, BALTEX Phase II has a clearly defined commitment to contribute to WCRP/COPES. BALTEX therefore continues to be firmly anchored in GEWEX and WCRP.

The extended BALTEX Phase II objectives cover aspects of both CLIVAR (Climate Variability and Predictability) and CliC (Climate and Cryosphere), two other major WCRP global projects. In addition, the gradual extension of BALTEX research activities to air and water quality studies opens the option for a closer cooperation with projects of the International Geosphere-Biosphere Programme (IGBP) such as LOICZ (Land-Ocean Interactions in the Coastal Zone). The Baltic Sea basin is currently proposed to become an IGBP Integrated Regional Study Area, where closer links to regional LOICZ studies in the Baltic Sea coastal regions are desirable. The Earth System Science Partnership (ESSP), a joint initiative of all four coordinated global change programmes, including WCRP and IGBP, has the major objective to conduct integrated studies of the Earth system to explore the changes occurring in the system and implications for global sustainability. One of the joint ESSP projects already established is the Global Water System Project (GWSP), where BALTEX intends to contribute to, in cooperation with other in particular IGBP projects. The closer link between BALTEX and LOICZ is seen as a regional cooperation in the global frame of both ESSP and GWSP.

Contents

Introduction

"Our ability to understand and predict weather, climate and global climate change depends critically on our capability to observe and model the processes governing the hydrological cycle and the energy cycle of the climate system. Water vapour is the dominating greenhouse gas, and water in form of clouds plays a major role in controlling the climate on earth. Water, as snow or ice on the ground, on lakes and on the ocean alters drastically the heat, moisture and momentum exchanges between these media and the atmosphere. The fresh water supply to the oceans is of major importance for the circulation in the ocean and the associated vertical exchange of heat and salinity."

The above has been stated at the beginning of the introduction to the Initial Implementation Plan for the Baltic Sea Experiment (BALTEX) published in 1995 (BALTEX, 1995). These statements were – and still are – a basic rationale for the conduction of GEWEX, the Global Water and Energy Cycle Experiment, and its Continental-scale Experiments (CSE) such as BALTEX. In order to address the above cited issues and to reduce the uncertainties in our understanding of the hydrological and energy cycles of the climate system at the regional scale, BALTEX (1995) formulated the following three major objectives:

BALTEX Phase I Objectives, formulated in 1995:

- 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
- To develop transportable methodologies in order to contribute to basic needs of climate, climate impact, and environmental research

Research in BALTEX has focussed on the study of the regional water and energy cycles over the entire Baltic Sea catchment[1], including the Baltic Sea as a major European marginal sea. Therefore, BALTEX includes a strong marine research component which makes BALTEX a unique CSE in the GEWEX context. Working closely together, meteorologists, hydrologists and oceanographers have considerably improved the understanding of these cycles and thus our ability to model the coupled atmosphere-land-ocean system in the BALTEX region.

With more than 10 years of BALTEX research conducted at the European level since the launch of the programme, it is time to answer questions such as "what have we learnt from BALTEX ?", "what are

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

the achievements of BALTEX so far ?" and "what may be concrete implementation measures for the second phase of BALTEX ?" Therefore, a science plan for the second phase of BALTEX (BALTEX Phase II) was recently established (BALTEX, 2004) which defines revised scientific objectives and strategies for the programme. For each of the science objectives, a number of major goals were formulated.

Following definitions in BALTEX (2004), the years 1993 to 2002 will be referred to as BALTEX Phase I and BALTEX Phase II relates to the ten-years period 2003 to 2012 throughout this document.

BALTEX Phase I: 1993 – 2002

BALTEX Phase II: 2003 - 2012

The focus during BALTEX Phase I has been primarily 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 have prepared the path for the application of BALTEX model systems in other research areas where the physical understanding and modelling skills of the water and energy cycles are of fundamental importance. Examples for such research areas include climate variability and climate change studies, scenarios of future climate, the transport of nutrients and harmful substances, an improved understanding and prediction of extreme events like floods, and climate or environmental impact studies that respond to social needs and support decision makers in the broader context of Global Climate Change issues, related to the Baltic Sea basin (BALTEX, 2004).

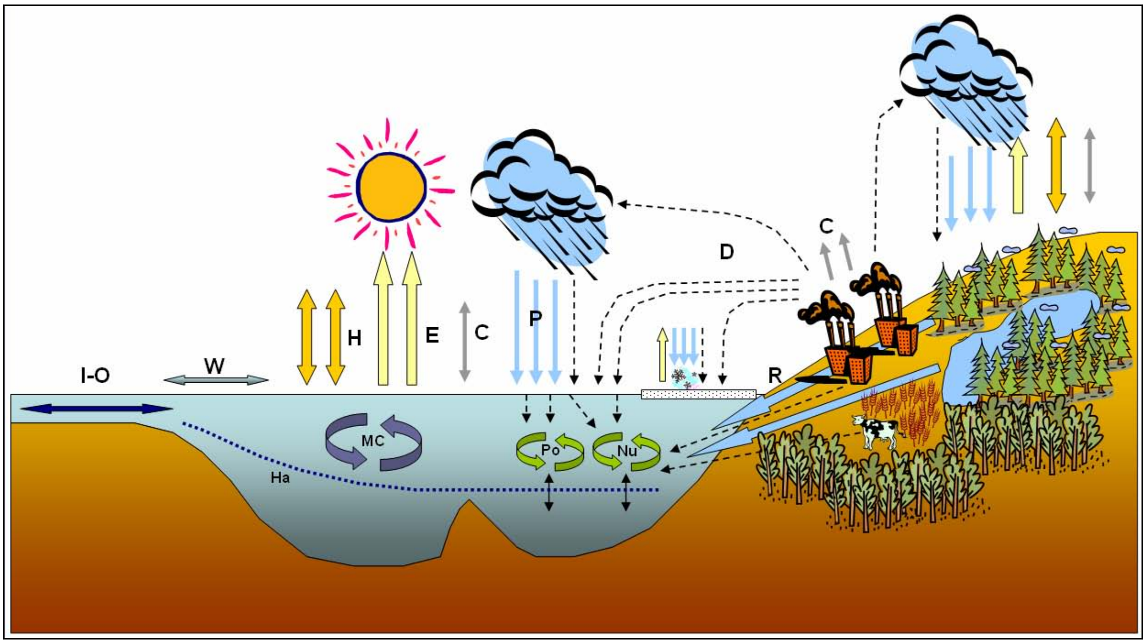

Fig. 1.1 Conceptual sketch of the Baltic Sea basin with major processes in the water and energy cycle, as investigated in BALTEX Phase I. New to Phase II are the integration of pollution, eutrophication and the carbon cycle (Po = Pollutants, Nu = Nutrients, C = Carbon, mainly as CO_2), indicated by dotted and grey arrows. Pollutants include heavy metals and persistent organic pollutants (POPs). Nutrients and pollutants from anthropogenic activities (hoseholds, agriculture, industries) enter the Baltic Sea through atmospheric deposition (mainly nitrogen) and riverine runoff. Climate changes resulting in changed temperatures, runoff and ice cover extent and duration, have a direct effect on these fluxes. I-O = In- and Outflow through the Danish Straits, W = Momentum Flux, H = Heat exchange including radiation, E = Evaporation and Transpiration, P = Precipitation, D = Atmospheric deposition R = Runoff, MC = Mixing and Convection, Ha = Permanent Halocline.

Within BALTEX Phase I, an international network of partnership for research has been created. Four data centres for meteorology, oceanography, hydrology and radar data have been established and are now important centres for information exchange and research. Two coupled atmosphere – land – sea ice – ocean models for climate variability and climate impact studies have been developed. This, as well as the inclusion of a marginal sea, is unique for GEWEX continental-scale Experiments, and make BALTEX developments also applicable to other regions on the globe. Thus BALTEX research is now in a position to take the next step into the development of regional Earth system models for extended applications.

Regional Earth system modelling in turn requires a grid infrastructure for which BALTEX with its international cooperation and contacts has created an ideal basis. The BALTEX region constitutes a perfect test bed not only for model development, validation and developments in satellite techniques but also for grid technologies - ”The Baltic Grid’’ (see Chapter 7.2 for details).

BALTEX Phase II will in particular build upon achievements related to the third BALTEX objective claiming that sufficient progress has been made in developing *transportable methodologies in order to contribute to basic needs of climate, climate impact, and environmental research* (see previous page). BALTEX Phase II will not follow an entirely new research plan but enlarge the scientific scope and thus strengthen the outreach of BALTEX in a significant way. BALTEX Phase II will continue to pursue those objectives and aims from Phase I of the programme that have so far not been met in a satisfactory manner. A main goal in BALTEX Phase II is to provide a solid framework for and execute environmental investigations and more realistic climate scenarios and climate impact studies.

The Baltic Sea Basin

The Baltic Sea basin covers about 2.1 million km^2 or 17% of the European continent, and encompasses territories of 14 countries[2] with a population of 85 millions (Figure 2). Climate conditions vary substantially from sub-arctic regimes in northern Scandinavia to moderately humid temperate zones in southern Poland, thus providing for high spatial and temporal variability. The Baltic Sea basin belongs to those regions in the World with a large north-south gradient in hydro-meteorological characteristics, which makes this region unique among European water basins, creating specific demands on models and scientific concepts. The Baltic Sea itself is a unique brackish marginal sea with complex hydrography and strongly variable sea-ice conditions. The basin‘s net annual water discharge to the Atlantic Ocean is comparable to major river systems such as the Mississippi and Mackenzie Rivers. Recent floods and devastating storms hitting the basin have increased the public and political awareness of the risks that climate and climate change may imply on Northern Europe.

The Baltic Sea and its rivers are not only a resource for fishery, hydropower and transportation; the region is also an area of increasing importance for tourism, leisure and water sports. In view of recent harmful incidents (*e.g.* traffic accidents in the Baltic Sea, and disastrous floods like in Sweden and Poland) research dedicated to the entire Baltic Sea basin for the assessment, mitigation of and adaptation to the risk is urgently needed. The application of coupled regional atmosphere/ocean/land models developed by the BALTEX science community that are nested into global coupled atmosphere/ocean/land models allow more detailed projections of climate change in the Baltic Sea basin for various scenarios of human activities at the global scale. This input is needed for mitigation measures like the enforcements of the Kyoto Protocol but also for adaptation to possible climate change.

Some countries in the eastern Baltic Sea basin have experienced considerable political, industrial and socio-economic changes in recent years. These rapid changes form a new challenge for the sustainable development of the Baltic Sea region and create growing demands for policy-relevant scientific information. In 2004, Poland, Lithuania, Latvia and Estonia became members of the European Union

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[2] Clockwise around the Baltic Sea: Denmark, Norway, Sweden, Finland, Russian Federation, Estonia, Latvia, Lithuania, Belarus, Ukraine, Poland, Slovakia, Czech Republic, Germany.

(EU), and therefore eight EU member states now encircle the Baltic Sea, thus increasing the EU research interest in the BALTEX region.

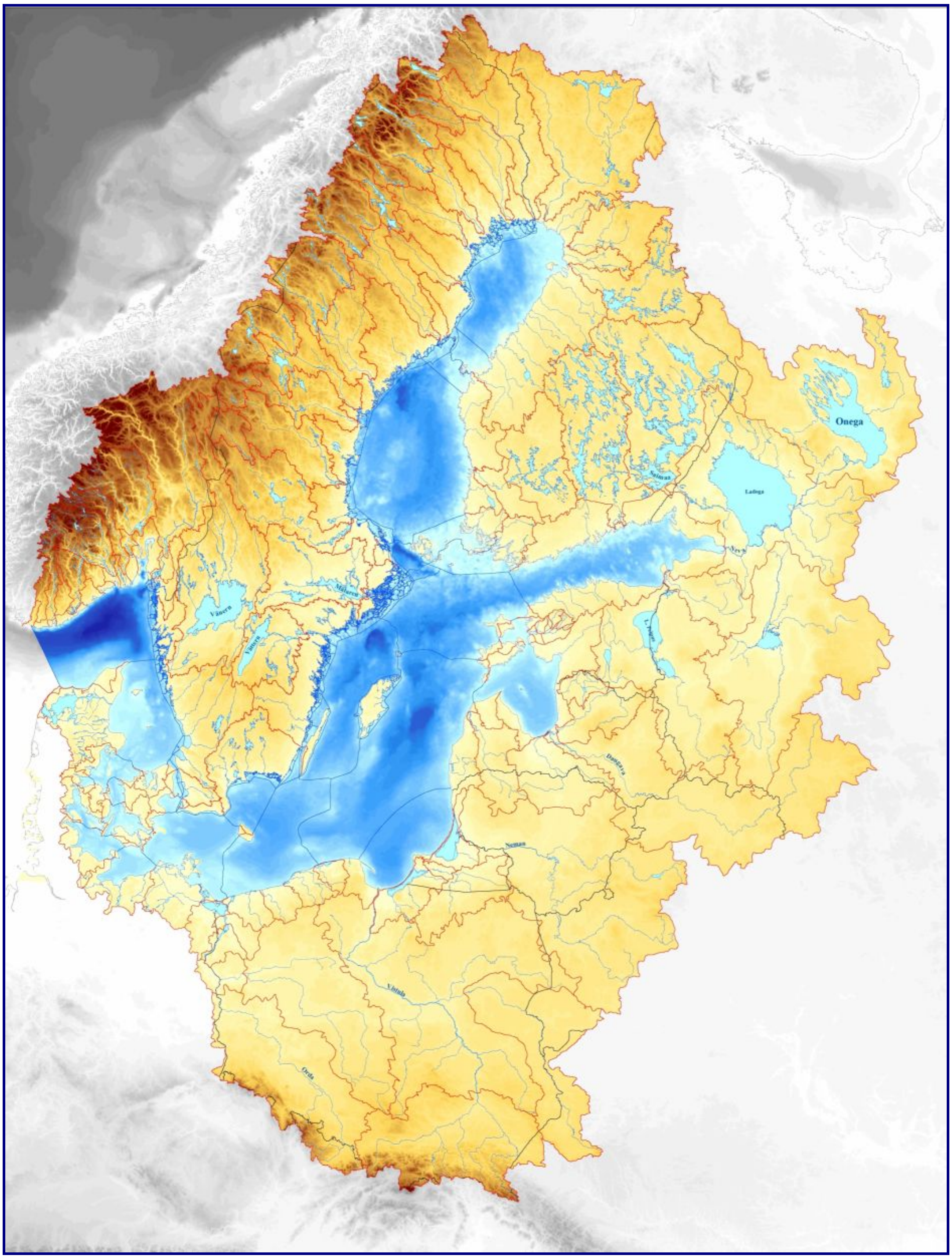

Fig. 1.2 The Baltic Sea basin. Map by courtesy of SMHI, Sweden.

Achievements of BALTEX Phase I

BALTEX Phase I has generated active research covering the whole field of advanced modelling and data studies in meteorology, hydrology and oceanography. 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.

Phase I Achievements: Atmosphere

- Improved understanding of sea-atmosphere and land-atmosphere interaction in the BALTEX region through observational studies and offline model evaluation and through numerical studies with coupled models.
- Improved knowledge on precipitation and evaporation over the BALTEX region through new instruments, radar estimates and satellite sensors.
- Development of improved remote sensing techniques to determine *e.g.* precipitation rates by weather radar, precipitable water by GPS and cloud climatologies by AVHRR.
- Improvement of understanding and modelling of cloud physics, cloud-radiation interaction and precipitation initiation.
- Development of retrieval methods for cloud liquid water path from passive imagers and optimized estimates of the spatial distribution of liquid cloud water.
- Assessment of model liquid water path, cloud vertical structure and cloud overlap with microwave, lidar and cloud radar observations and the impact on radiation.
- Development of fully coupled atmosphere-land-ocean models of the Baltic Sea basin for present day and climate change applications.

Examples include the first coupled regional models for the entire Baltic Sea basin and improved water budget estimates through newly assimilated data sets. Also special observing periods, such as the Pilot Study for Intensive Data Collection and Analysis of Precipitation (PIDCAP) in 1995, and BRIDGE, the major enhanced observational period within BALTEX during 1999 to 2002 with dedicated additional observations, were conducted in the frame of BALTEX. BALTEX projects are still ongoing in different countries funded mainly by institutional and national sources.

Phase I Achievements: Hydrology and Runoff

- A database of monthly river flow has been compiled and made available through the BALTEX Hydrological Data Centre.
- Large-scale hydrological models of river flow to the Baltic Sea exist.
- Improved communication between meteorologists and hydrologists resulting in a better understanding of the water cycle and the modelling of it.
- Lateral water transport through runoff routing has been applied in climate models.
- Efforts to improve flood forecasting schemes with the help of regional atmospheric models for specific river basins have been made.
- Climate change scenarios of impacts to the water cycle in the Baltic Sea basin have been performed.

BALTEX Phase I has marked a significant advance in research on regional meteorology, hydrology of the Baltic Sea basin as well as oceanography of the Baltic Sea including sea ice. Results of BALTEX are documented in more than 250 peer-reviewed journal articles and numerous reports. Special journal volumes dedicated to the four BALTEX Study Conferences held in 1995, 1998, 2001 and 2004 provide comprehensive insight to BALTEX results. 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), *Boreal Environmental Research* (2002, Volume 7, No 3 and 4), and *Nordic Hydrology* (2005, Volume 36, Issues 4-5). Achievements of BALTEX Phase I have been compiled in a detailed state-of-the-art report (BALTEX, 2005)

Phase I Achievements: Baltic Sea including sea-ice

- Meteorological, hydrological, ocean and ice data are now available for the research community through BALTEX data centres.
- Progress in understanding of the strong impact of large-scale atmospheric circulation on Baltic Sea circulation, water mass exchange, sea ice evolution, and changes in the ocean conditions of the Baltic Sea.
- Progress in understanding of the importance of strait flows in the exchange of water into and within the Baltic Sea.
- Progress in understanding of intra-basin processes.
- Ocean models are introduced to Baltic Sea water and energy studies.
- Development of turbulence models and 3D ocean circulation models for Baltic Sea.
- Advances of thermodynamic and dynamic coupling between the atmosphere, sea ice, and the sea; field experiments and modelling studies have yielded new results on local and regional surface fluxes and the interaction of the atmospheric boundary layer, sea ice, and open water.
- Progress in understanding the interaction between sea ice dynamics and thermodynamics.
- Advanced understanding of effects of river discharge and ice melt on the oceanic boundary layer below sea ice.
- Advanced understanding of the role of the large-scale atmospheric circulation for the ice conditions in the Baltic Sea.

The Objectives of BALTEX Phase II

BALTEX Phase II Objectives

Objective 1
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Objectives 1 to 4 are basically related to science issues, while objectives 5 and 6 address strategic and political issues which will be pursued as cross-cutting activities in the context of all four science objectives. The six major objectives are structuring elements for this Science Framework and Implementation Strategy document with one chapter being devoted to each objective (chapters 1 to 6). *Major goals* for each of the four scientific objectives were formulated in the Science Plan for BALTEX Phase II (BALTEX, 2004); these are summarized and, if required, extended in chapters 1 to 6. The latter elaborate on how to achieve these goals and describe *potential activities* as more concrete implementation measures. They also specify additional data needs, outline aspects of data management and highlight the desired involvement of stakeholders and plans for education and outreach at the international level.

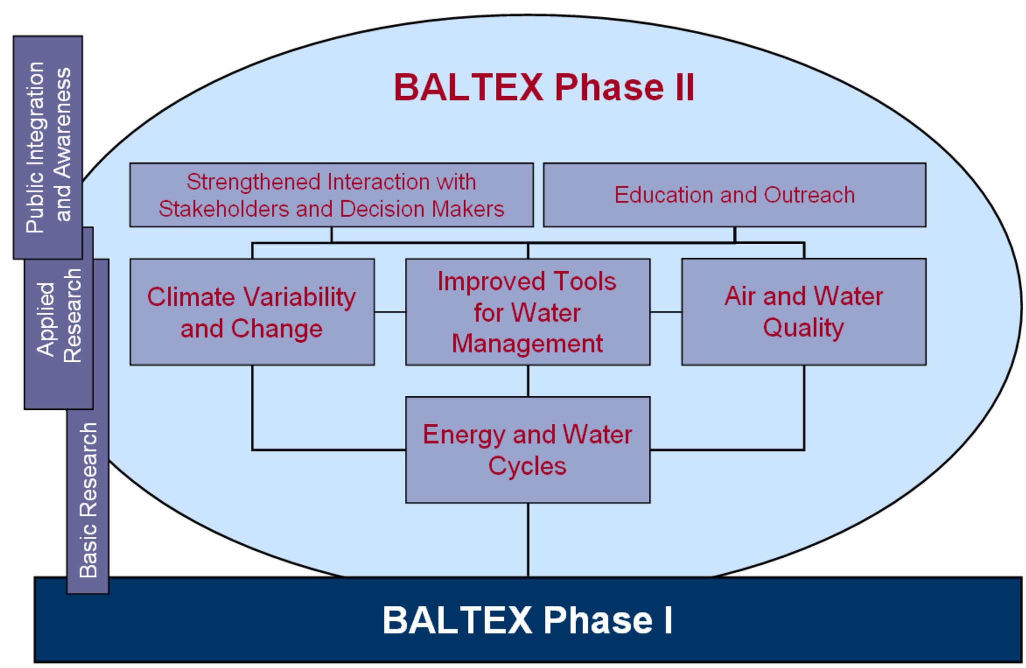

Fig. 1.3 BALTEX Phase II objectives defined as basic and applied research components, and public integration and awareness activities.

Chapters 7 to 10 mainly deal with organizational issues, such as the definition of a road map towards implementing BALTEX II measures until 2012, and the status of ongoing activities (chapter 7), an overview of BALTEX data management provisions and activities (chapter 8), the detailed outline of organisational structures within BALTEX including short descriptions of current and future working groups (chapter 9), and finally the embedding of BALTEX research within the international research arena and the cooperation with related research programmes (chapter 10).

1. Better Understanding of the Energy and Water Cycles

Better understanding of the energy and water cycles – this first objective indicates that, despite significant progress made so far towards meeting the prime objectives of BALTEX Phase I, gaps still exist which require continuation of BALTEX research. In view of the extended objectives of Phase II, the research components related to this objective aims at providing a solid framework for enhanced environmental investigations and more realistic climate studies. Based on the achievements of BALTEX Phase I, models and data sets will have to be upgraded and extended in order to properly meet the objectives defined for Phase II. New data sources and model concepts must be exploited to achieve the much more demanding requirements and special goals of BALTEX Phase II detailed in Chapters 2, 3 and 4.

1.1. Major Goals

- To evaluate in increasing detail regional models used for climate and environmental studies, and to develop strategies for climate and environmental impact assessments.
- To obtain better and more comprehensive observations from the entire Baltic Sea basin, including new satellite data, in particular to cope with regional resolution requirements.
- 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 lower the uncertainty when closing the energy and water budgets from measurements.

1.2. How to achieve these Goals

1.2.1. Evaluation of Regional Models

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

Regional models are indispensable to better understand the feedback mechanism between atmosphere, land and ocean at the regional scale. Only regional model experiments will satisfy the needs for a better understanding of the current climate of the Baltic Sea basin, its past and its future. Such experiments have, however, no meaning without proper validation of the models for this purpose. A systematic approach for the evaluation of the models needs to be further developed. In addition to standard parameters, this approach needs to include also the fluxes, the budgets and processes in order to ensure that models give “the right answers for the right reasons”. Especially in view of the extended objectives of BALTEX Phase II detailed in Chapters 3 and 4 of this document, uncertainties and limitations of models and their results must be clearly defined and convincingly communicated for the education of both users and decision makers.

Strategies for climate and environmental impact assessments must be developed based on using regional models. This includes coupling and forcing of regional models with results from global models, as well as other aspects of the design of model investigations. Account must be made of the role of natural variability, inherent uncertainties of future forcing scenarios, as well as of known shortcomings of global and regional models, *e.g.* concerning some aspects of precipitation, land surface evolution and ecological feedback mechanisms not yet included in many models. In parallel, regional climate models as well as their input and validation data sets still need considerable improvement. The accuracy and availability of such data is of crucial importance.

In view of the above, BALTEX Phase II research will focus on the following three main issues outlined in sections 1.2.2 to 1.2.4.

Fig. 1.4 Strong rain shower near a lake in northern Sweden. Precipitation intensity may change drastically at small spatial scales requiring high-resolution data sets such as combinations of radar, *in-situ* and satellite data for a quantitative estimation of precipitation at low uncertainty. (Photo: Holger Nitsche)

1.2.2. Better and more Comprehensive Observations from the Baltic Sea Basin

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

Of utmost importance are longer-term and more detailed area-covering quantitative precipitation estimates based on measurements for:

a) better constraining estimates of the energy and water cycle based on observations alone,
b) better documenting and understanding the development and causes of extreme events,
c) quantitative input to hydrological models of various scales,
d) the extension of BALTEX to water quality and more general environmental issues, and finally
e) a more comprehensive and quantitative model evaluation.

Of special importance for the Baltic Sea basin is the quantification of solid precipitation, which dominates precipitation during the cold seasons in many regions of the Baltic Sea basin. Of equal importance are observations of snow accumulation and melting at ground.

The impact of water vapour, clouds and aerosols on the regional radiation balance components – including its variability - needs to be estimated from both surface and satellite observations. Better estimates of the radiation budget from independent measurements will lead to more stringent quantitative measures to evaluate regional model performance due to its strong impact on the total energy balance of atmosphere, ocean and soil.

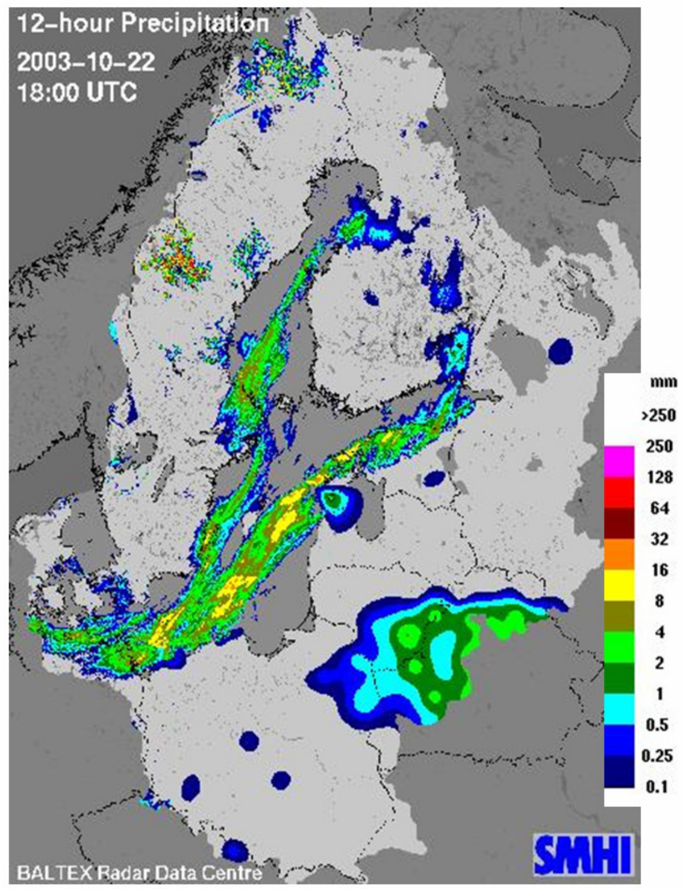

Fig. 1.5 12-hour accumulated, gauge-adjusted precipitation based on BALTRAD composites on 22 October 2003, 6 to 18 UTC. The horizontal resolution in most of the basin is 2x2 km. Note the lower resolution in the south-eastern part where no weather radar coverage was available at that time and only in-situ gauge observations are used. (by courtesy of Jarmo Koistinen, FMI, and Daniel Michelson, SMHI.

Due to the stronger focus on water management issues in BALTEX Phase II (see Chapter 3), better estimates of soil water, its phase (frozen or liquid) and its spatial and temporal distribution including information on the behaviour of aquifers need much more attention. Besides existing and upcoming powerful monitoring systems based on passive and active microwave sensors for estimating the upper layer soil moisture, also river runoff estimates using satellite techniques (*e.g.* by combining digital elevation maps with conventional altimetry, or by high resolution altimetry using higher frequency sensors including Lidar techniques) need to be further developed or exploited. Variations of the gravity field of the Earth due to changes in the soil water column could be applied for this issue. Despite its currently very low resolution (at least several hundreds of kilometres) this information might provide valuable integral measures to validate model derived fluctuations in the catchment water table. A forward modelling approach based on the output of coupled regional hydro-meteorological models would be a first step to better understanding and later use of this information. The potential of the techniques mentioned above for the initialisation of and assimilation in adequately extended hydro-meteorological models needs to be exploited together with the use of river discharge data for an improved constraint of distributed hydrological models. Combining all data sources in a variational-type assimilation approach is expected to lead to a better description of soil characteristics in the basin and quantitative modelling of the energy and water cycle.

To close the energy and water balance at the catchment level with reduced uncertainties, reliable error estimates of available runoff data, and continuous measurements of in- and outflow through the Danish straits are indispensable. Attention should also be paid to measurements of dense bottom currents in the Baltic Sea in order to better model or parameterize their important influence on water mass circulation and mixing. Baltic Sea ice is a very sensitive component of the Baltic Sea basin climate system; it requires more detailed investigation of its variability under current climate conditions. New satellite sensors with all weather capability (*e.g.* passive and active microwaves, SSMIS, AMSR, ERS, later SMOS, HYDROS; see Chapter 8.3 for details) are available nowadays for this purpose and need to be exploited. Similar data with lower quality do exist (SMMR and SSM/I), which could be used to extend such data sets back to the late 1970s.

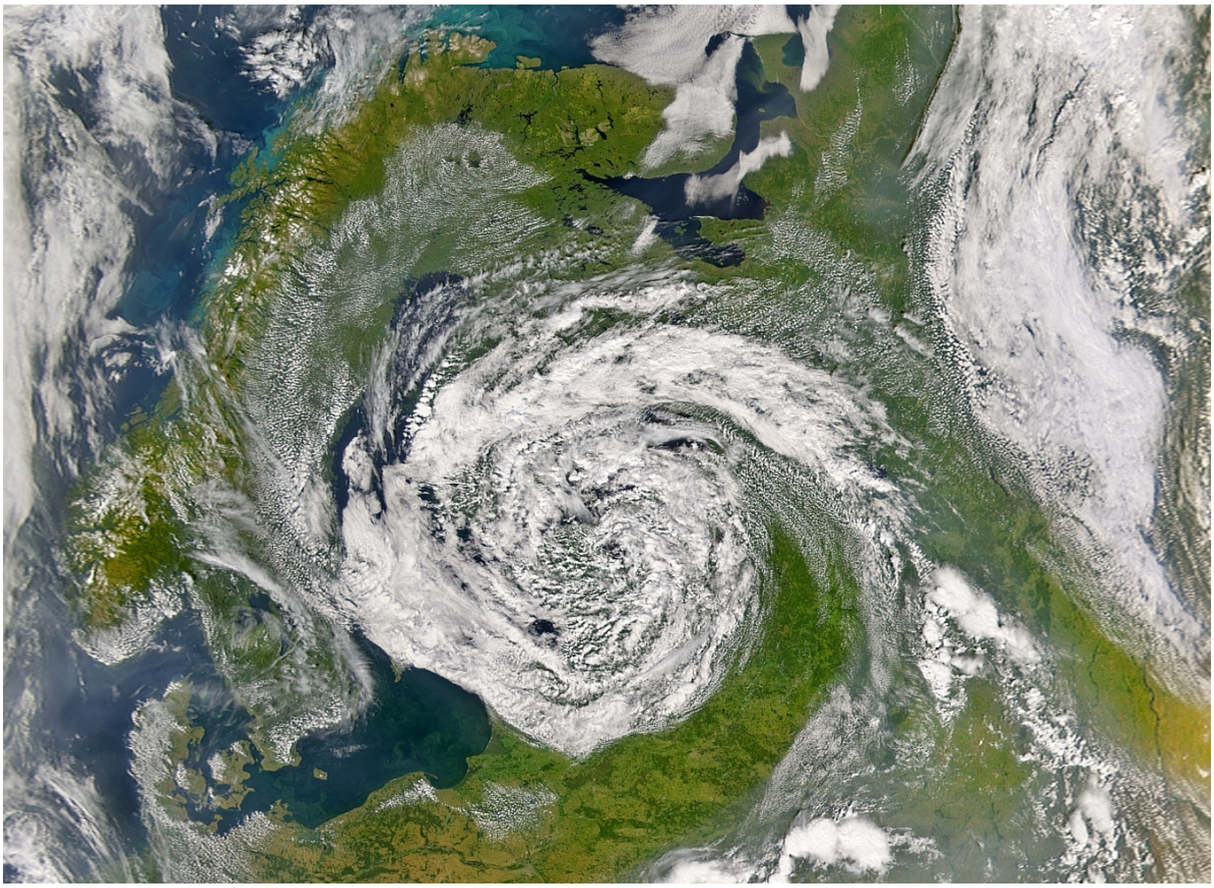

Fig. 1.6 A well-developed cyclone over the eastern Baltic Sea basin, as seen by the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) on July 30, 2004. (SeaWiFS, NASA/Goddard Space Flight Center, GeoEye).

The new objectives of BALTEX Phase II require much more detailed, quality improved regional re-analysis data sets composed from the available data sets based on appropriate models. These data sets should quantify the state and the variability - as well as their uncertainties - of the regional climate system including all relevant climate system components. Besides for the climate system change studies described in Chapter 2, such data sets will serve for a more detailed process-based model evaluation (see below), provide important input for the solution of various water management issues put forward in Chapter 3, and support a variety of environmental studies as suggested in Chapter 4.

Finally, the continuation and extension of super observation sites for the atmosphere and the land surface at e.g. Sodankylä, Lindenberg, and Cabauw and their integration in the Coordinated Enhanced Observing Period (CEOP, see Chapter 10.3) is a pillar in the BALTEX Phase II observational programme. They have in common high quality observations of the tropospheric column, including clouds and aerosol, and the soil down to generally 2 meter depth. Besides the basic meteorological parameters these observation sites are able to provide higher level products, like local budget estimates of energy and water. These measurements are therefore of prime importance for regional model evaluation, for inclusion and/or evaluation of regional re-analysis data sets, and for the development and improvements of parameterisations related to atmospheric boundary layer structure and clouds. Monitoring of atmospheric composition should be extended in a coordinated manner (in terms of *e.g.* type of substances to be monitored, and method of measurement) in order to allow for model validation studies with regional aspects.

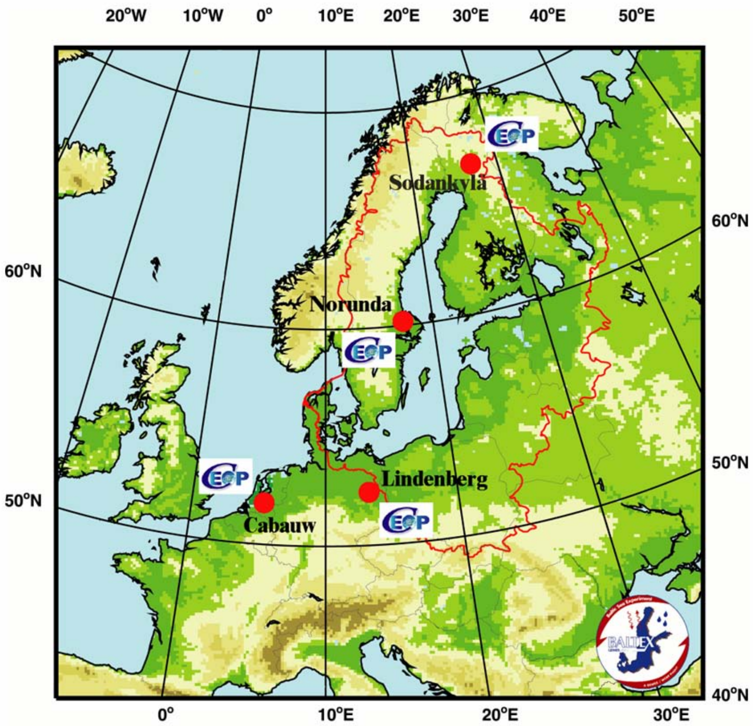

Fig. 1.7 Location of major observational sites which provided reference site data for CEOP (Coordinated Enhanced Observing Period) Phase I during 2002 to 2004.

1.2.3. Development of a Complete Numerical Regional Climate Model System

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

A major achievement of BALTEX Phase I is the establishment of two regional coupled climate models. The objectives of BALTEX Phase II need, however, a higher stage of operability, versatility and reliability of these models. These requirements necessitate upgrades concerning the quality of the model components, the coupling strategies, and extensions leading towards a regional Earth system model. For this, improved modelling of the soil water table and the inclusion of aquifers should be considered. Of utmost importance are improved physical parameterisations for the all-important exchange processes between surface water bodies, the land surfaces including ground water and aquifers and the atmosphere. The inclusion of biological components of the climate system in regional climate models needs stronger efforts, including the factors or substances influencing vegetation growth and development. The representation of the physical exchange processes still suffers from inadequately resolved scale discrepancies between the different components, which also accounts for large differences between model results and measurements. Improved and physically based modelling of soil water should be pursued along the same lines, especially for the objectives laid down in Chapter 3, because these approaches enlarge considerably the potential to use independent measurements for assimilation and validation. Estimates of soil moisture expected from new sensor types, for example, can be used much more efficiently, if soil moisture means the same in both model and real world.

Of similar importance is precipitation initiation and development, in particular in the context of coupling atmospheric with hydrological models on smaller scales. Improved parameterisation schemes and the potential for increased spatial resolution down to the kilometre scale need to be considered. The influence of aerosol variability especially during cloud and precipitation initialisation should be considered in atmospheric model components. In the ocean component, bottom boundary currents need to be better described, because of their importance for water mass circulation and mixing. Concerning sea ice models, more sophisticated simulations of sea ice characteristics such as different ice classes should be included to allow for a better physical description and comparability with observations.

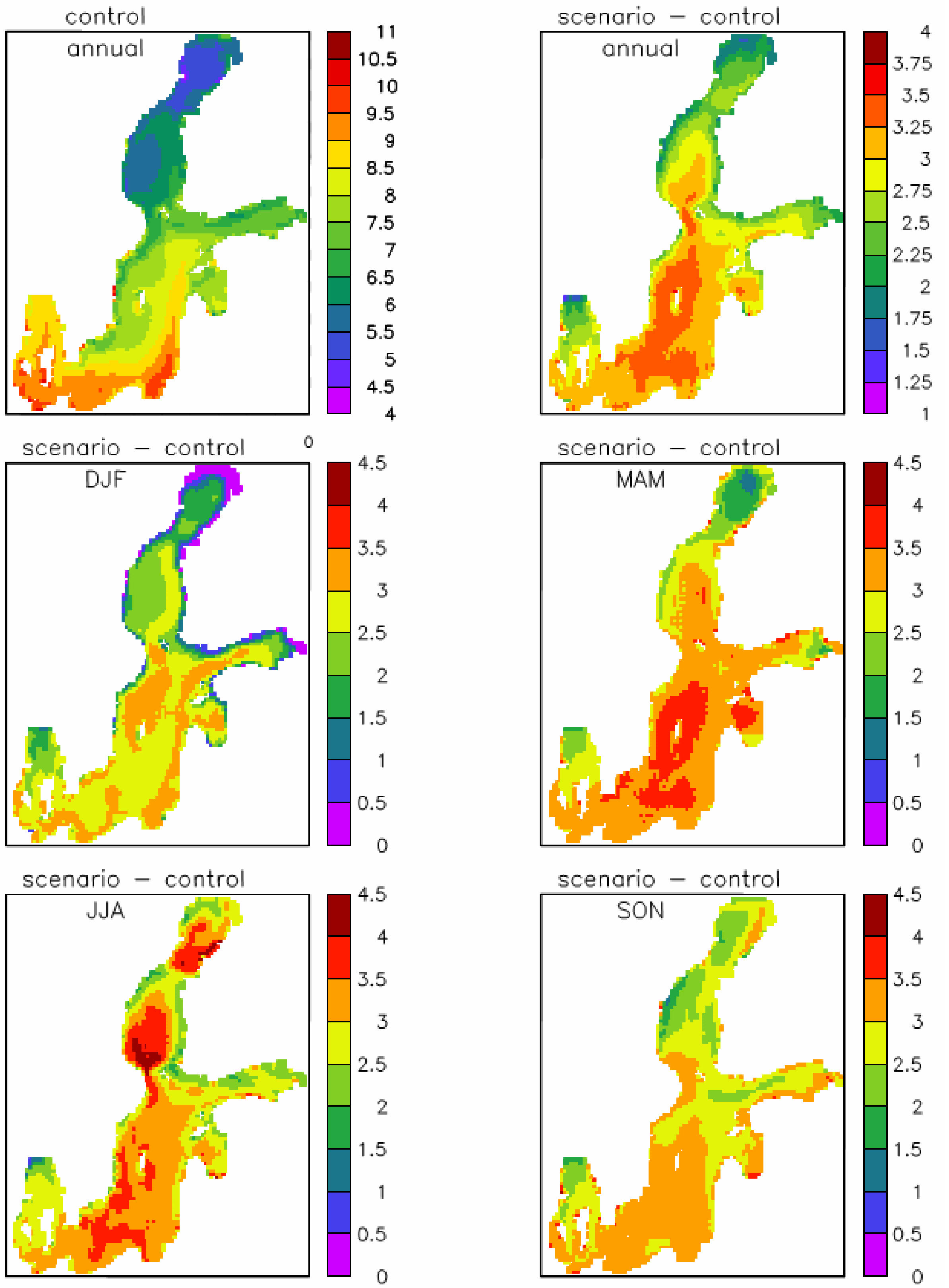

Fig. 1.8 Sea surface temperature in the Baltic Sea, simulated for the time period 2071-2100 by the coupled model system RCAO of the Rossby Centre, SMHI, Norrköping, Sweden. RCAO is one of the two major coupled regional modelling systems developed during recent years in the frame of BALTEX. Upper left panel shows annual mean temperature (°C) averaged for the period 1961-1990 (the control run). All other panels show differences of a scenario ensemble mean minus the control run (°C). Upper right panel shows annual mean differences, others show winter (DJF), spring (MAM), summer (JJA) and autumn changes (SON) (by courtesy of Ralf Döscher, SMHI).

1.2.4. Closing the Energy and Water Budgets

- *To close the energy and water budgets from measurements at lower uncertainty*

Water and energy budget estimates based on improved measurements *e.g.* of precipitation and turbulent and radiation fluxes must be established for much longer periods than available to date in order to better understand both storage in and exchange between regional climate system components. Such estimates will serve as integral measures for assessing the reliability of regional climate models, and therefore the investigated periods need to span years to decades instead of only months to a few years, as has been possible in the past. Precipitation fields of improved quality for longer time periods and better temporal and spatial resolution are urgently needed for this task. It will have to be explored whether gravity variations detectable from current and future satellite missions (GOCE, CHAMP, GRACE - see Chapter 8.3 for details) can provide sufficiently accurate integral measures of the variability of water stored in the ground and aquifers; our current knowledge of these parameters is considered poor at best. Astonishingly enough, the radiation budget of the atmosphere and the surface are still known to an insufficient degree to serve as a real constraint for other components of the energy budget. Radiation provides the sole energy input to the Earth climate system as a whole; on the regional scale lateral influx considerably complicates the situation putting an even stronger requirement on the quality of the estimation of the radiation budget components. As regional climate models approach reality, a basis will exist for improved regional re-analysis data sets, to be useful *e.g.* for closing the energy and water budget at lower uncertainty.

1.3. Involvement of Stakeholders

The involvement of stakeholders also for the basic science issues portrayed in this section is of extreme importance for its success. Environmental agencies, at both national and international level, as well as national hydrological and meteorological services are responsible for establishing most of the observational data sources and - at least in part - for the development of regional climate models, both of which form the basis of the research efforts in BALTEX. Communication with these stakeholders will have to be intensified with the view that their active contribution to BALTEX is a major prerequisite for obtaining dependable results – not only with regard to a better physical understanding and modelling of the energy and water cycles, but also with regard to the extended objectives put forward in Chapters 2 to 4.

Frequent exchange of information between the agencies and the BALTEX research community about, for example, documented model and data deficiencies and BALTEX achievements in model and data improvements will foster active cooperation and stronger involvement of agencies, and stakeholders in general. An open and unrestricted access to data sources is still of prime importance for this first objective of BALTEX Phase II. BALTEX is presently revising its data exchange policy in close cooperation with relevant data providers (see Chapter 8.4), and a dedicated BALTEX Working Group on Data Management was recently re-established. Since the new objectives of BALTEX Phase II relate much more directly to both the interests and the responsibilities of these stakeholders, an information strategy hinting to the applicability of BALTEX achievements is expected to improve the willingness of the stakeholders to cooperate. Capable research groups working on model components also relevant for regional climate modelling can be found at many national services. Thus, model improvement efforts will benefit from a closer interaction by involvement of these groups in BALTEX.

1.4. Potential Activities

Potential activities, contributing to a better understanding of the energy and water cycles of the BALTEX region, can be grouped in the following areas of research.

1.4.1. Regional Analysis and Re-analyses of Different Variables for Specific Purposes

Global re-analysis data sets like ERA-40 (the 40 years re-analysis of the European Centre for Medium-Range Weather Forecasts, ECMWF, see www.ecmwf.int/research/era/) and the NCEP

(National Centre for Environmental Prediction, USA) products (www.cdc.noaa.gov/cdc/reanalysis/) have a number of shortcomings, which need to be improved or extended for BALTEX Phase II. Observations of clouds and precipitation need to be included in a regional re-analysis which should be performed on finer spatial scales. Especially precipitation fields should be made available over land areas with resolutions down to a few kilometres on at least a daily base for use *e.g.* in hydrological studies and analysis of extreme events. This requires the merging of Radar data with surface observations and possibly with satellite data. Also wind fields over the Baltic Sea are required in higher resolution in order to remove the influence of land effects. New radiation parameterisation schemes should be implemented to better estimate the components of the surface radiation budget *e.g.* from satellite observations. Error estimates should be an integral part of the derived fields. Addressing the last 40 years is also very relevant for the analysis of climate variability and change (Chapter 2), see section 2.4.1 in particular.

Generally, there is not one regional analysis data set available serving all purposes in BALTEX Phase II. In this broad view, at least five types are envisioned and should be established:

1. Re-analysis data sets for a better understanding of the current climate: This re-analysis will include all available measurements of the past 10 to 20 years assimilated in a regional dynamic model system.
2. A full re-analysis, which exploits all local data, is sensitive to changes in the observational coverage. A less sensitive approach is to assimilate large-scale features instead, provided by a global re-analysis. Obviously, such an approach returns less skilful reconstructions but, with its likely lower sensitivity to data inhomogeneity, it thus allows a better estimation of long-term trends and low-frequency variability. Such efforts have already been implemented, and the results are used for assessing changing climate conditions; however, further improvements, in particular with better spatial resolution, shall be pursued, in particular for the Baltic Sea basin.
3. Re-analysis data sets in climate change and variability studies: The spatial and temporal homogeneity of measurements is of highest importance in order to suppress spurious trends and variability caused by temporal changes of data availability (see also Chapter 2.4.1).
4. Re-analysis data sets with reduced model influence. These data sets should be based on as few model assumptions as possible (intelligent interpolation) in order to be used as independent data sources for regional climate model evaluation.
5. Re-analysis data sets using models run in climate mode, without data assimilation. This serves the purpose of the development and evaluation of models applied for future projections (see Chapter 2.4.1).

1.4.2. Further Development of Models and Model Improvement

All important exchange processes between ocean, atmosphere and the land surface are acting on scales not well resolved in the current models. Model improvements should be directed to explicitly taking into account the appropriate scales by either adapting the model resolution to the process, or by developing adequate parameterisations. Examples are in- and outflows and dense bottom currents within the Baltic Sea, sea ice diversity, air-sea interactions in coastal regions, precipitation generation and development, effects of land surface heterogeneity on fluxes of energy and matter, ground-water and runoff generation.

Components of regional climate modelling systems, which still need to be developed further, are more detailed treatments of aerosol effects on cloud and precipitation development, inclusion of dynamic vegetation and substances influencing vegetation growth and development (*e.g.* CO_2, N_2), as well as improved treatment of lakes and aquifers.

Further improvement of the increasingly complex regional climate models needs the involvement of an increasing number of researchers often situated in different groups. An adequate organisational structure needs to be set up, which allows for an efficient communication between model developers to better exploit existing knowledge and resources and to shape and implement standards for code development and module coupling. The high quality monitoring of the tropospheric column and the land surface at the three super sites Lindenberg, Cabauw and Sodankylä provides the most complete data sets currently available for these tasks. These sites should therefore be integrated in the model development network, thus also taking advantage of their experienced scientific staff.

1.4.3. Closing the Energy and Water Budget on a High Level of Confidence

Closure of the energy and water budget of the Baltic Sea basin means to independently estimate the different exchange fluxes between the reservoirs (ocean, atmosphere, land) with sufficient accuracy. This potential activity will carefully evaluate existing data sets, *e.g.* the re-analysis data sets to be developed as described in section 1.4.1, with respect to the fluxes between major reservoirs including error characteristics. Eventually emerging inconsistencies in the energy and water balance will be used to trace down deficient data characterisations or assumptions used when computing the fluxes, thus successively narrowing down uncertainties and better understanding the different energy and water flows in the regional climate system. The results will also provide benchmarks for a system approach to the evaluation of regional climate models.

1.4.4. Improvement of Quantitative Precipitation Forecast

The quality of Quantitative Precipitation Forecast (QPF) is an essential limiting factor of our ability to understand and model the energy and water cycle. Several national initiatives are planned or already exist, aiming to improve QPF in specific regions by further developing model performance and data assimilation, and by conducting dedicated field experiments. An effort shall be made to connect BALTEX to these initiatives in order to participate in the new developments. BALTEX will also draw attention to the specific problems of QPF in the Baltic Sea basin caused for example by the interaction of the Baltic Sea with the atmosphere and the increasingly important role of solid precipitation and the specifics of land surface-atmosphere interactions in a Nordic environment. Quality advances of the QPF have a direct influence on the quality of flood forecasts (see Chapter 3 for details).

1.4.5. Evaluation of Models and Data Sets for their Use in Climate Impact Analysis and Environmental Issues

Regional climate model and data comparisons should be performed at different scales. Regional-scale flux estimates such as those resulting from activity 1.4.3 shall be used for evaluation of coupled climate models. For an improved evaluation of coupled models, the communication structure put forward in activity 1.4.2 includes scientists and groups which are conducting and exploring field measurements. This will allow for a more efficient, timely and intelligent use of available measurements and resources. In turn, it will lead to the setup and execution of more focussed monitoring programs, instrument development, and field experiments necessary for improved evaluation of different model components and the models as a whole.

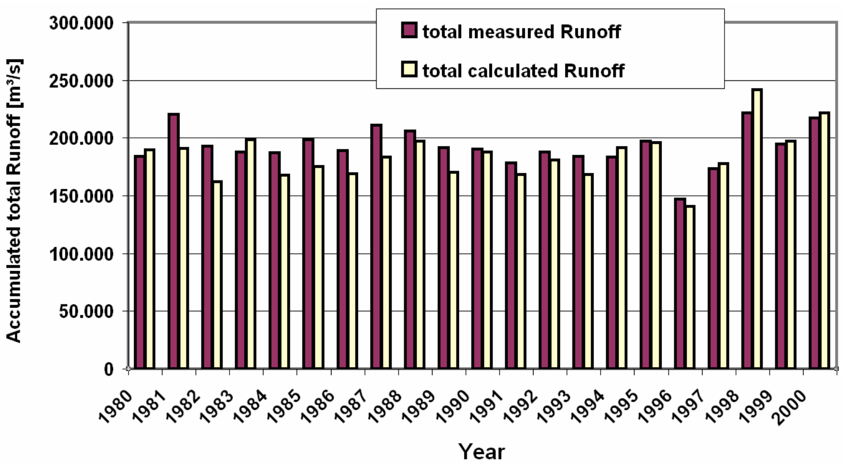

Fig. 1.9 Accumulated total runoff into the Baltic Sea from 1980 - 2000. Comparison of measured meteorological data and simulated runoff calculated by the coupled model system BALTIMOS (by courtesy of Daniela Jacob, MPI for Meteorology, Hamburg)

1.5. Specific Data Needs

A wide spectrum of observational data is required to properly address this objective. One prerequisite is the continuous further build-up of the archives of the existing BALTEX Data Centres (see Chapter 8.1). The presently archived data types need to be continuously extended to cover the future time period until the end of the BALTEX research period. Extensions of the already archived data types – and periods presently covered - are key for a better understanding of the energy and water cycles, and the specific additional requirements are formulated as a major goal of this objective in section 1.2.2. A further specific requirement is the access and exploration of new and existing satellite data, as detailed in sections 1.2.2 and 8.3.

2. Analysis of Climate Variability and Change

2.1. Major Goals

- To contribute to detecting regional climate change
- To understand the physical mechanisms behind past climate variability and change, whether of natural or anthropogenic origin, in the BALTEX region; and to contribute to attribution studies
- To study the balance between large-scale control and locally/regionally generated forcing of the regional climate system
- To develop projections of future climate variability and change, by means of sensitivity analyses and model studies

2.2. How to achieve these Goals

To achieve the BALTEX Phase II major goals on climate variability and change requires a number of approaches. Past and present efforts on collecting, quality-controlling and analysing instrumental and, partially proxy, data from the past and from recent and ongoing monitoring have to be continued and extended. With the help of such data, reconstruction of climate and weather beyond, or outside the availability of instrumental data, is to be pursued. The use of dynamical models will allow a better organising and expanding of the knowledge on past and observed climate. Modelling is used to guide detection studies and to facilitate attribution studies. Modelling is also the comprehensive tool to prepare projections of possible future conditions.

Improved understanding of the physical system, as well as the further development of regional modelling (see Chapter 1) is important for the continuing progress in analysing and understanding climate variability and change. Modelling studies and efforts on climate variability and change, in turn, contribute to the expansion of the BALTEX scope to biochemical, environmental and ecosystem aspects. Thus, there are major links between this and the other major scientific objectives of BALTEX Phase II.

2.2.1. Detection and Attribution of Regional Climate Change

- *To contribute to detecting regional climate change;*
- *to understand the physical mechanisms behind past climate variability and change, whether of natural or anthropogenic origin, in the BALTEX region; and to contribute to attribution studies;*
- *to study the balance between large-scale control and locally/regionally generated forcing of the regional climate system.*

A central concept is that of detection and attribution. The former is the identification of phenomena beyond the range of undisturbed conditions. The latter concerns the causal linkage of such phenomena to driving factors, including the anthropogenic ones.

Detection cannot be made relative to an absolute reference state, to which a change would be contrasted. As no such period is available (*i.e.,* a period that we would know was not affected by any evolving external factor), detection should be attempted in relative terms, with respect to some chosen reference period. In such a case, attribution studies could be designed in terms of incremental changes in possible forcing factors. Obviously, the definition and characterization of the reference period needs careful consideration. A practical choice might be the Climate Normal Period 1961-1990. Detection should be a multi-parameter exercise, including a variety of statistical parameters, aspects like time rates of changes, and others. Identification of such forcing factors that drive compensating changes is an additional dimension of the work, as is checking for consistency in found phenomena across the different components and aspects of the global and regional climate system. The choice of parameters and processes relevant for detection studies should be guided by three main considerations: (i) chance of detection (guidance from theory, past analogues and climate change projections), (ii) stakeholder relevance and (iii) the likelihood of identification of the most likely underlying causes.

Given success in the detection studies, attribution can follow to attempt a quantification and separation between different forcing factors. Sensitivity studies should be used to explore the different response characteristics of the elements of the Baltic Sea basin system to potential forcing factors. This knowledge is then used to determine the most likely combination of causes that can be attributed to the observed variability and change. Coupled to this is the question of how much the climate system of the BALTEX region is forced from the region itself, and how much is imported from outside the region.

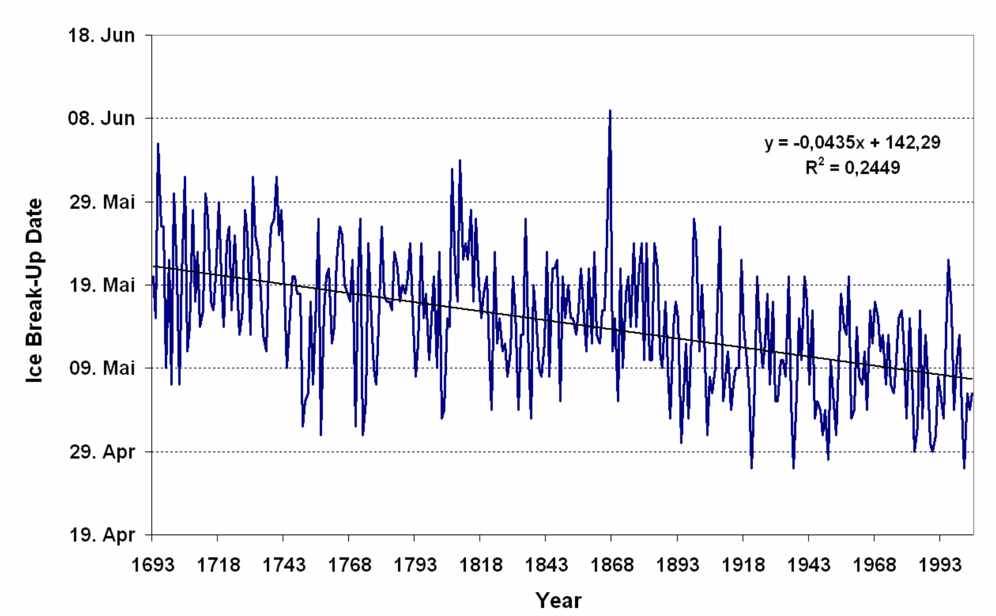

Fig. 2.1 Ice break-up dates of the Tornionjoki river (Northern Finland) from 1693 until 2005 (by courtesy of Raino Heino, FMI).

2.2.2. Projections of Future Climate Variability and Change

- *To develop projections of future climate variability and change, by means of sensitivity analyses and model studies.*

In the construction of future regional projections and scenarios, the following three components should be accounted for: i) unforced or natural variability of the global and the regional system, ii) anthropogenically driven modifications of the global system (in terms of, *e.g.,* air temperature, sea level and circulation patterns), and iii) regional forcing scenarios for land and water use, the release of substances, and other management issues relevant for the environment. Future projections and scenarios should address also the unavoidable uncertainties embedded in the driving global and regional scenarios due to the inherent uncertainties in the climate system science and the evolution of climate system forcing on both the regional and global scales.

2.3. Involvement of Stakeholders

The stakeholders with interest in this major objective of BALTEX Phase II are i) the public at large, ii) national authorities with responsibility for *e.g.* infrastructure and the environment, iii) international agencies and organizations including the European Environment Agency (EEA) and the Intergovernmental Panel on Climate Change (IPCC), and iv) actors involved in policy-making, enterprises, and corporate institutions that need to factor changing climate into long-term planning decisions.

On the one hand, stakeholders require reliable and useful knowledge about past climate change, present variability and the occurrence of extreme and rare events[3]. Also, stakeholders increasingly need detailed, consistent and useful descriptions of possible and plausible future climate variability and change. Of special concern are the identification of robust changes and the separation of these from more uncertain ones. Another major goal should be a simplification of the issues, such as ruling out those facets of climate change that are not significant for a particular stakeholder.

On the other hand, research needs knowledge from stakeholders. Plausible and possible perspectives for changes of land use, river regulations, regional emissions of aerosols, and other regional or local agents influencing the regional and local climate are required for comprehensive future projections and scenarios. Stakeholders should also be encouraged to provide scenarios of other anthropogenic factors (*e.g.,* release of harmful substances), which will influence the BALTEX region (*e.g.,* ecosystem functioning) in conjunction or in addition to climate forcing and change. This latter aspect is especially important in the context of extensions of BALTEX data and modelling studies beyond the physical climate system.

2.4. Potential Activities

2.4.1. Reconstruction History of Climate in the past 200 Years as well as Detailed Re-analysis of "Weather" of the past 40 Years

Regional re-analysis as well as other reconstructions are needed in studies of climate variability and change. One focus will be on the past 200 years which allows for studies on natural climate variability, the action of natural forcing factors, and extremes, see below. Another focus will be on the past 40 years, where the increasing range of novel observations and measurement campaigns allows for increasingly more physical and targeted basic and applied process studies, and model evaluation. The availability of global re-analyses such as ERA-40 and NCEP (National Centres for Environmental Prediction) products give a particular rational for the past 40 years. The focus on the past few decades will also contribute to better understanding of the physical background of the processes which determine the water and energy cycle in the Baltic Sea basin, as described in more detail in Chapter 1.4.1. In this context, BALTEX Phase II is in line with the World Climate Research Programme/Coordinated Observation and Prediction of the Earth System (WCRP/COPES) strategy which suggests using the 1979-2009 period to develop reference climate data sets and advanced forecasting techniques (see also Chapter 10).

The variables considered are foremost the conventional geophysical ones describing the atmosphere, hydrology, the ocean and sea ice. For much of the period, available data allow the reconstruction of state variables. In the second half of the 20th Century, possibilities to address process-level

[3] Here, we refer not only to *extreme* events that occurred and have caused major consequences, but also to the likelihood of the occurrence of events being normal but at the same time *rare*.

observational data, such as on fluxes, increase, which should be exploited. Addressing quantities such as land use and ecosystem-based indicators is also a new application topic.

Valuable and so far unused information on the past climate of the Baltic Sea basin exists and needs to be identified, collected and made available in digital form for further processing. Past data may need homogenization, *i.e.,* it must be ensured that their information content does not change over time, for example through influences by changing observation procedures or local conditions.

For provision of accurate past and present climate data, assimilation is essential. However, regional re-analysis by means of models without data assimilation is needful when evaluating and developing models to be applied for, *e.g.*, future projections. Models without assimilation give rise to biases in parameters and also phase-shifts. However, off-line models or models with assimilation can host spurious sources and sinks and thus mask "bad model behaviour" or give rise to unphysical behaviour. Thus, re-analysis data sets with no assimilation, *i.e.* model runs in climate mode for the past and present periods are also needed.

Reconstruction methods should include dynamical downscaling with limited area models for the atmosphere, ocean and hydrology as well as statistical downscaling and extrapolation techniques. Given that the amount of directly acquired data diminishes with "backwards time", proxy data are needed to complement direct measurements in time, physical space and parameter space as well as for cross-evaluations. Again, this has bearing on (multi-) decadal variability and detection. In addition to existing proxy data, such as from tree rings, the inclusion of new proxy data sets will be valuable for regional (multi-) decadal variability and detection studies. Within this chapter, re-constructed and re-analysed data are especially needed for potential activities described in sections 2.4.2 and 2.4.4.

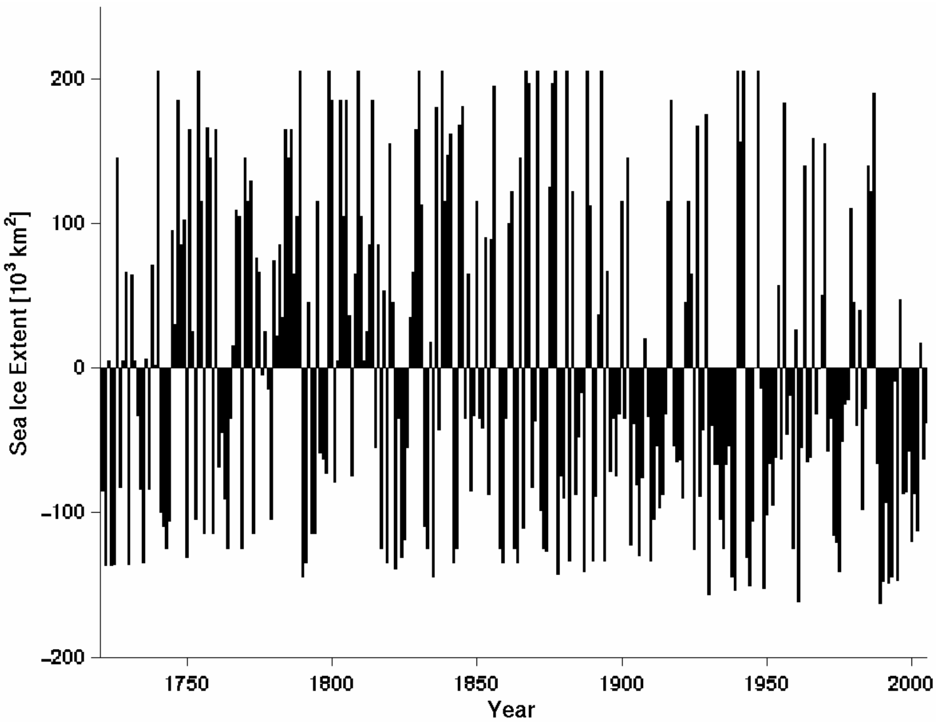

Fig. 2.2 Annual maximum Baltic Sea ice extent since 1720, expressed as deviation from the long-term mean. Data based on various types of observations (data by courtesy of FIMR).

2.4.2. Detection and Attribution of Climate Change

Signs of long-term change and apparent emergence of extreme weather need to be assessed for possible consistency with natural low-frequency variability and rare but nevertheless normal extreme events, or whether they are indicators of ongoing systematic change outside the conventional climate and weather variability. In the latter case, climate change is “detected”. Possible causes are then screened and tested, and the combination of factors best explaining the observed phenomena is determined – thereby giving an “attribution” of the response to causes. The list of causes to be tested will contain global climate change due to elevated greenhouse gas concentrations, regional and/or global land use change, river regulation and elevated atmospheric aerosol amounts. Where ecological systems are considered, also causes not related to climate must be considered, such as the emission of harmful substances into water bodies or the introduction of new species. If the attribution is made to persistent (increasing, decaying) factors, then one may expect the climatic change also to persist (increase, decay), which is relevant knowledge to stakeholders.

2.4.3. Scenarios based on Evolving Global and Regional Forcing and Response

Limited area climate models are now readily available and have already been used to some extent to generate regionalization of global climate change scenarios. These regional models should be extended to estimate also the effect of regional modifications of the land surface and water management, as well as to incorporate additional climate system components. For some impact-related variables, such as ocean waves and catchment-scale hydrology, dynamical models already exist, but are not yet exploited to their full potential in climate-length and climate change studies. Further development of models of terrestrial, fresh-water and marine ecosystems, is also foreseen. To begin with, increasing efforts should be spent to construct and use such impact models to study the practical impacts of climate change in the region. The research question of how extensive regional climate system models should be pursued for the BALTEX region is important. The most faithful tools are interactive climate-impact model systems as they avoid loss of information in between climate and impact modelling and can allow for two-way feedback. Alongside the use of dynamical models, expert judgment and use of statistical and stochastic modelling will remain important as well.

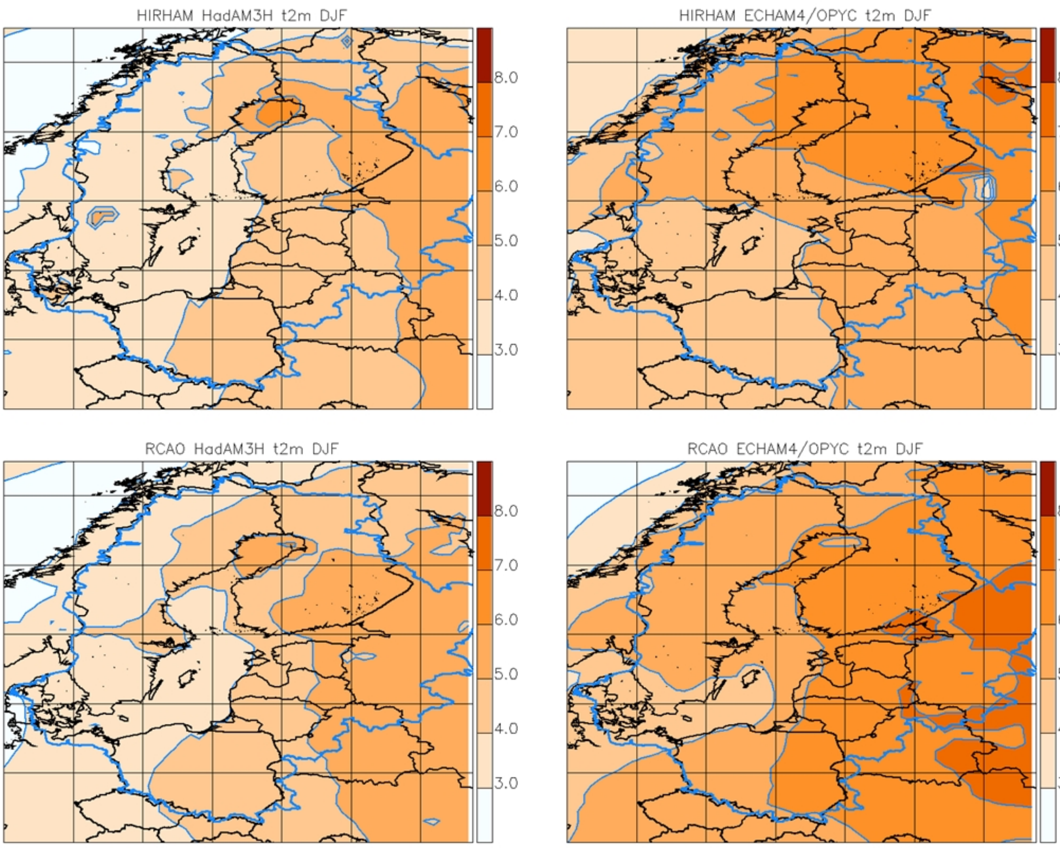

Fig. 2.3 Regional climate model simulated temperature changes in ºC for winter (DJF) between the periods 1961-1990 and 2071-2100 using the SRES-A2 emissions scenario. The upper plots show results from the HIRHAM Model and the lower plots are from the RCAO Model. Plots on the left used GCM boundary conditions from HadAM3H; plots on the right used ECHAM4/OPYC3. The Baltic Sea basin is indicated by the thick blue line. (Note: ECHAM4/OPYC3 scenario simulations used as boundaries are different for the two RCM downscaling experiments.) Produced within the EU-funded PRUDENCE project (by courtesy of Ole Bøssing Christensen, Danish Meteorological Institute)

2.4.4. Assessment of Climate Change for the Baltic Sea Basin

While the above three activity areas deal with the elaboration of new knowledge, provide new data sets and new applications of dynamical models, this fourth activity area aims at a consolidation and integration of distributed, already existing knowledge about historical and current (1800–today) change and expected future changes. It assembles, integrates and assesses available knowledge of the ongoing climate change and its impacts in the Baltic Sea basin. As such, the activity contributes both to IPCC and now also to HELCOM (The Baltic Marine Environment Protection Commission), see below. The work will be structured in subsections dealing with (i) historical and current change, detection and attribution, (ii) expected and possible climate change and (iii) the impact of climate change on both marine and terrestrial ecosystems, and more generally, (iv) on the regional environment and society. A concrete initiative for a *BALTEX Assessment of Climate Change for the Baltic Sea Basin (BACC)* has already been initiated in 2004 with the aim to publish a comprehensive assessment book by the year 2006. BACC/BALTEX has also undertaken to establish a joint venture with HELCOM in the sense, that the BACC material will be used for a two-volume HELCOM Thematic Assessment Report, to be published in 2006 and 2007. This potential activity is also seen as one important example for *knowledge integration* in BALTEX, see Chapter 7.2.

2.5. Specific Data Needs

Both instrumental and proxy data from the past and recent and ongoing monitoring need to be extended and continued, respectively. Further work is needed to compile and analyse data on state variables. Where possible, efforts should be spent to attain more information on budgets and at process-level, *i.e.* on fluxes. Use of climate information from remote sensing platforms, such as operational European environmental satellites should be explored also in climate variability and change studies.

Increasing availability of new data sets and products from the Satellite Application Facilities (SAF) of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) can become an asset. A wealth of information is available from the European Centre for Medium-Range Weather Forecasts (ECMWF) re-analysis and analysis products, especially for the study of indicators and detection. The various BALTEX Data Centres (Chapter 8.1) should be further developed to offer additional resources for climate studies, and storage of even regional re-analysis data, such as downscaled global re-analysis, as it becomes available, should be pursued.

Other specific data needs are global climate simulations which have to be analysed and to be used to force regional dynamical and statistical downscaling models. Even the early part of the period in focus might be probed in such a way, and the access to and availability of data from proxy archives is to be improved for the same part of the period.

3. Improved Tools for Water Management

3.1. Major Goals

The main objective for improving tools for water management is to assess how both present and future climate variability impacts on the water resources in the Baltic Sea basin, and how to quantify and possibly reduce the associated risks caused by climate extremes.

- 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 develop, validate, and 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 assess future risk of water shortage and extreme events by explicitly taking account of the societal use of groundwater and surface water resources, as well as man-made changes of land use
- To develop further flood forecasting models

3.2. How to achieve these Goals

Both well-established operational and experimental science-driven hydrological models will be applied in the Baltic Sea basin including semi-distributed models, water balance models and distributed, process-oriented models. Basin-wide modelling as well as catchment specific studies should be carried out. Results from such modelling will be closely analysed and compared to each other, and discussed in relation to the performance of regional climate modelling schemes. Coupling of atmospheric and hydrological models at regional and even smaller scales should be aimed for in an effort to develop more precise and reliable forecasting tools. It is expected that higher spatial resolution of atmospheric models and a better coupling with the surface including the effects of subscale landscape structures will improve quantitative precipitation forecast (section 1.4.4), the latter being the corner stone of flood forecasting systems. Moreover, hydrological models should play a role for the validation of climate models, thus exploiting their predictive power for the state of the soil and runoff characteristics. Finally, hydrological models shall be used as a tool for the creation of water resources scenarios.

A focus on both surface water and groundwater resources is needed to address societal needs for water management, as is hydrological modelling over a range of scales. This will impact on the analysis, design and optimisation of various uses, such as water supply, groundwater recharge, irrigation, storm sewers, river regulation, levees, spillways, bridges, and other infrastructure. Water management is not limited solely to issues of quantity, but water quality and nutrient transport play an important role in the usability of water and its ecological impacts on the Baltic Sea.

The Baltic Sea basin includes many lake-rich areas that are both an integral part of the hydrological cycle and an important resource to local communities. Lakes can provide water supply and be a source of groundwater recharge to local aquifers. Many of the larger lakes are regulated for purposes of hydropower production and/or navigation. Changes in either water quantity or quality can have substantial impact on users and local ecosystems.

Phase I of BALTEX identified four specific river basins (Torne, Daugava, Vistula, and Odra) for detailed hydrological studies and intercomparison, however, not all of these studies were completely fulfilled. In Phase II, detailed subbasin-scale studies should also be a priority, and more emphasis should be given to their implementation. The decision of where such studies are carried out should be based on 1) type of application, 2) availability of data, 3) and specific climate issues. Examples of two basins that were studied in more detail during Phase I and would be likely candidates for further study in Phase II are the Torne River Basin in the north and the Odra River Basin in the south.

With the above general considerations in mind, specifics on how to achieve the four major aims within this objective follow.

3.2.1. Development and Validation of Coupled Hydrological-Atmospheric Models

- *To develop further and apply coupled atmospheric-hydrological models for improved assessment of the availability of water resources in today's and future climate*

Although considerable progress has been made in coupled hydrological-atmospheric modelling, further work is required. Some groups have focused on improving the representation of hydrology directly as an integral part of their atmospheric model, while others have linked existing or modified hydrological models to atmospheric models. Both approaches need further work and efforts are needed to assess how applicable these approaches are to water resources management. A relevant question which remains is "how usable are the hydrological outputs from atmospheric models and at what scales." Thus, efforts towards improving precipitation forecasts concerning quantity and timing should be strengthened (Chapter 1.4.4). This necessitates enhanced research of the physics of precipitation process including the role of aerosol and the initiation of precipitation, and the implementation of the findings into atmospheric models. A better representation of hydrology and soil moisture and their subscale variability leads to a more realistic representation of near surface processes in atmospheric modelling, which will also feedback into improving quantitative precipitation forecasts due to the role of the atmospheric boundary layer in precipitation initiation. On the other hand, the typically larger-scale atmospheric modules of the coupled systems must provide downscaling techniques in order to serve the hydrological counterpart at the right scale. Thus, scaling considerations are a major issue for both subsystems when coupling both regimes. A particularly valuable use for improved coupling between hydrological models and atmospheric models would be forecasting of floods. Work to investigate the quality of forecasts - both atmospheric and hydrological - with higher resolution numerical weather prediction (NWP) models should be pursued.

Coupled modelling should be accomplished at the 10-20 km scale with the present state-of-the-art atmospheric models and conceptual-type hydrological models. When aiming at a model resolution of 1 km, a further development of coupled model systems based on non-hydrostatic atmospheric models and distributed process-oriented hydrological models should be carried out. In such an effort the hydrological model should replace the traditional land surface scheme in the atmospheric component. Detailed analyses of the two-way coupled system should be performed, and the advantages and limitations of such model complexes need to be determined. In particular the ability to model and forecast extreme meteorological and hydrological events should be analysed.

3.2.2. Development and Validation of Hydrological Models for BALTEX Selected River Basins

- *To develop, validate, and 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*

During BALTEX Phase I, large-scale hydrological models providing reasonable estimates of total river flow to the Baltic Sea were developed. The total inflow into the sea allows us to make generalised statements on the hydrology of large, regional drainage basins, but it does not provide the details necessary to analyse individual river systems and local drainage basins. More detailed models representing finer basin scales can provide more useful information for water managers on how extremes in both the present climate and the future climate will impact on specific river basins. Representation of groundwater at such scales is a component that is presently lacking and should be addressed. A better representation of the physical processes and exchanges of lakes is also needed. In addition to providing more detailed information for water managers, the model development part under this objective will play an integral role for analysing hydrological outputs from atmospheric models and contribute to the development of coupled models as detailed in the first aim of this objective, see section 3.2.1 above.

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

- *To assess future risk of water shortage and extreme events by explicitly taking account of the societal use of groundwater and surface water resources, as well as man-made changes of land use*

The hydrological modelling developed to meet the first two aims should be used together with outputs from the analysis of climate variability and climate projections (see Chapter 2). Driving hydrological models with both retrospective and future climate scenarios provides detailed information for water resource managers on how hydrological regimes respond to changing conditions. More details on projected effects of past, present and future climate variability, as well as man-made changes of land use, will greatly enhance the knowledge base of water managers. This will allow them to make risk assessments on the performance of their respective systems under variable climate conditions. A number of uncertainties associated with both the scenarios and modelling techniques exists, and attempts to account for them must be pursued in this work. This will partially be addressed by using many different scenarios.

3.2.4. Improvement of Flood Forecasting

- *To develop further flood forecasting models*

Real-time flood forecasting is a specific area where society is expected to have a direct benefit from improvements in soil moisture assessment, weather forecasting and remote sensing techniques. In association with improvements of coupled hydrological-atmospheric models (see section 3.2.1), improvements in data assimilation techniques and the use of new data, *e.g.* radar and satellite observations of rain and clouds, should be pursued. Driving hydrological models with ensemble forecasts from NWP models is already being tested. This will need further development of both the theoretical basis and practical implementations. Inputs from now-casting methods *e.g.* based on satellite and radar observations have also been used on a limited basis and should be further developed and tested in hydrological models. Downscaling of the output of weather forecast models to the usually much smaller scales of the hydrological counterparts is an important issue, especially in relation to precipitation. Questions to be answered include, for example “can new methods for estimating precipitation from radar help to give better hydrological forecasts”, and “what is the benefit in initialising hydrological modelling with remotely-sensed soil moisture and snow water content estimates”.

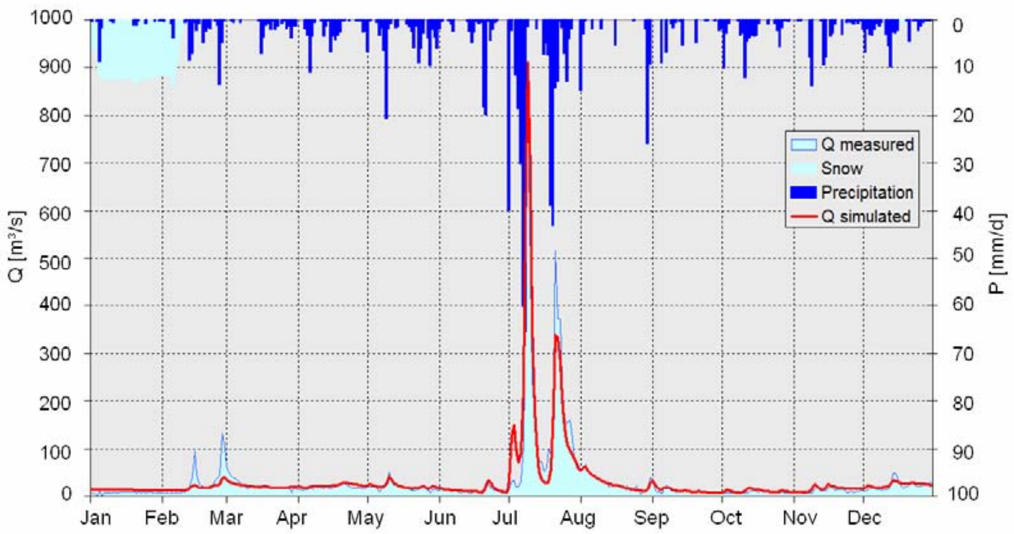

Fig. 3.1 Precipitation P (measured) and runoff Q (measured and simulated) in 1997 at Otmuchow, Nysa Klodzka reservoir, Poland). Runoff was modeled by the Precipitation-Runoff model for the whole Odra basin (SEROS), validation period was 1995-1999. Peaks show the extreme flooding events in July 1997 (by courtesy of Theo Mengelkamp, GKSS).

3.3. Involvement of Stakeholders

Within water management, the potential stakeholders range from international and national agencies to individual landowners. Their involvement will vary according to the type and scale of projects initiated. Examples are dam owners/operators, national rescue services, municipal water suppliers, farmers, newly established EU water district authorities, national environmental agencies *etc*. In some cases, the stakeholders may even provide potential funding sources for research projects. Stakeholders should help define the types of studies to be performed, provide additional inputs for researchers where possible and make active use of delivered results to improve performance of management tools.

3.4. Potential Activities

As pointed out above, potential activities cover a range of applications, model scales, data needs and coupling to meteorological models. A few specific examples are listed below.

3.4.1. High Resolution Hydrological Modelling

For investigating the impact of present day climate and climate change on distributed runoff and other hydrological variables, high resolution hydrological modelling is needed. It could be accomplished by 1) conducting (or adapting) compatible nationwide hydrological studies in all Baltic countries using basin-based hydrological models with sub-basin resolutions of 200-500 km^2, or 2) using macro scale hydrological models that cover the Baltic Sea basin with horizontal grid resolutions approaching 0.2 to 0.1 degrees. This would provide comprehensive, detailed mapping of runoff, groundwater recharge and other hydrological variables, as well as a platform to perform a wide range of hydrological modelling activities.

3.4.2. Improvement of Parameter Estimates for Distributed Hydrological Models

Within distributed hydrological modelling, it has proven difficult to link model parameter values to measurable basin characteristics. Prediction in Ungauged Basins (PUB), an International Association of Hydrological Sciences (IAHS) decade initiative, aims at improving our ability to estimate hydrological characteristics in basins where river discharge measurements are unavailable. This would be carried out by performing regional hydrological model applications and calibrations to estimate runoff characteristics and model parameters. Trials to relate runoff characteristics and parameter values to land use and soil type classes would then be conducted. A suite of different hydrological models could be used to test the robustness of the results. This should be closely associated with the work described above for high resolution hydrological modelling.

3.4.3. Coupling Hydrological Models to Regional Climate Models

Emphasising improvement in the hydrological components of regional climate models (RCMs), existing hydrological models for large catchments should be coupled to RCMs. Various coupling procedures should be tested and the performance of the models compared. The feasibility of common coupling procedures and common routing systems shall be investigated and optimum coupling procedures defined for a range of system applications. For validation, means and variability of present-day climate simulations from the coupled models at different scales should be compared to meteorological and hydrological observations. Of particular importance 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. New satellite techniques (*e.g.* the Gravity Recovery and Climate Experiment "GRACE") should be used for validation.

3.4.4. Analysis of the Consequences of Climate Change for Hydrology and Water Resources Management

Detailed basin and aquifer oriented studies of the consequences of projected climate change impacts on hydrology and water resources management need to be carried out. The appropriate modelling tools could either be forced hydrological models or regional coupled model systems. Assessing general trends in groundwater recharge and runoff, as well as future variability including extreme events are the primary foci. Different aspects of water management will be considered, including groundwater abstraction to water supply and irrigation, storage in reservoirs for hydropower and water supply, adequacy of reservoir spillways, protection of lowlands by levees, lakes and rivers as recipients for treated waste water, drainage by storm sewers, and others. Reliable estimates of, among others, the load of nutrients to lakes and costal areas are important for the water quality studies described in Chapter 4. Basin and aquifer studies at different scales are needed, and linkages to stakeholders would be particularly important in this project.

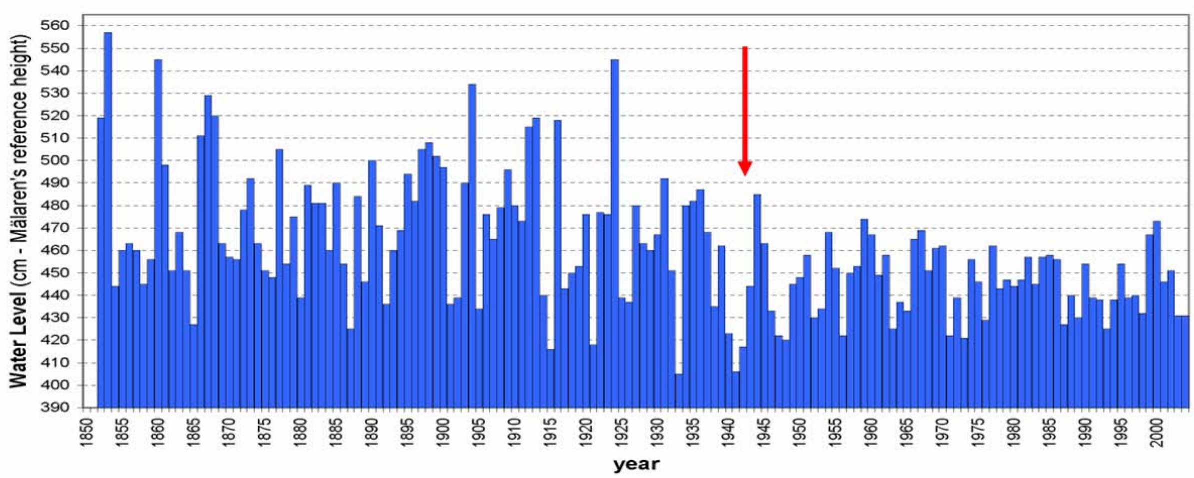

Fig. 3.2 Water level of Lake Mälaren (Sweden) since 1850. River regulation started in 1943 (red arrow) and resulted in a significant decrease of extreme flooding events (by courtesy of Phil Graham, SMHI).

3.4.5. Hydrological Modelling with Radar-derived Precipitation Applications

Radar data have the potential to become an important input for real-time flood forecasting. So far, radar data have been of limited use in hydrological models due to quality problems and insufficient adaptation of the hydrological models to radar information. This is continuously being improved on both sides, and the BALTEX Radar Data Centre now has several years of archived radar data for development use (see Chapter 8). Hydrological models should be driven with radar-derived precipitation for selected catchments. These should then be evaluated on the basis of both long-term and flooding events, and compared to results using other sources of precipitation forcing.

3.5. Specific Data Needs

High quality, long record precipitation and temperature datasets of good spatial coverage are essential for good performance in hydrological modelling. Accurate precipitation datasets are particularly important and alternative data sources like re-analysed data that lead to better estimates of Baltic Sea basin-wide precipitation and evapotranspiration. Data from microwave sensors of the GPM/EGPM mission (European Contribution to the Global Precipitation Mission) should be explored, whenever possible. In this context, the application of standardised corrections to measured precipitation should be given particular attention. Also, disaggregating of precipitation data based on Radar measurements should be pursued. BALTEX scientists will cooperate with and contribute to COST action 731 ("Propagation of Uncertainty in Advanced Meteo-Hydrological Forecast Systems") in order to address issues associated with the quality and uncertainty of meteorological observations from remote sensing and other potentially valuable instrumentation.

River discharge is important for calibration and evaluation of model results. Most of the river discharge records in the BALTEX Hydrological Data Centre are currently monthly. For specific basins selected for more detailed study, daily river discharge observations shall be obtained from the national hydro-met agencies.

Estimates of evapotranspiration in both hydrological and atmospheric modelling are particularly susceptible to uncertainty. National agencies and other relevant data holders will be contacted in order to collect relevant datasets, *e.g.* remotely sensed temperature and soil moisture content of the land surface layer, that help to improve both calculation and validation of evapotranspiration, into BALTEX Data Centres.

4. Gradual Extension to Air and Water Quality Studies

The fourth objective for Phase II is an entirely new extension to BALTEX. The aim is to gradually extend BALTEX research to eutrophication and pollution studies in the Baltic Sea catchment. Prior to defining related goals, this chapter will therefore start by briefly summarizing the background and rationale for the suggested extension.

Background

Anthropogenic eutrophication is caused by excess aquatic loads and atmospheric deposition of nutrients into the Baltic Sea and inland water bodies, associated with urbanisation and intensive industrial and agricultural production. Eutrophication increases phytoplankton and macro-algae production, leading to oxygen deficiency in deeper layers by microbial decomposition, which in turn may lead to fish kills, reduced biological diversity and death of bottom dwelling animals.

Nutrient concentrations in the Baltic Sea have increased considerably since the 1940s. In 1998, an overall 50% reduction target for nutrient inputs to the Baltic Sea was proclaimed by HELCOM (The Baltic Marine Environment Protection Commission). Since then, most countries around the Baltic Sea have reduced their point sources, but with smaller reductions for nitrogen than for phosphorus. The overall reduction of loads from diffuse sources has been less successful in most countries. For nitrogen, about 75% of the total load is waterborne, e.g. enters the Baltic Sea by rivers and point sources, and about 25% is airborne. For phosphorus, atmospheric input is only 1-5% of the total load, while the bigger share enters the Baltic Sea through waterborne sources (HELCOM, 2005). These gross values may vary substantially depending on the sub-basin, the compound and the season. Recent estimates indicate that the load from agriculture and managed forestry contributes to approximately 60 % of the waterborne nitrogen load, and nearly 50 % of the waterborne phosphorus load to the Baltic Sea (HELCOM, 2005). The largest reduction achieved for arable leaching is mainly related to the economic breakdown of the agricultural sector in the transition countries. So far it has been difficult to monitor these effects, which are mainly due to large storage of nutrients in the soil and water systems.

Results from the EU project MEAD (Marine Effects of Atmospheric Deposition) have shown that air-sea fluxes of ammonia close to source regions can be much higher than previously estimated, and that these inputs can be comparable in magnitude to wet deposited nitrogen. Model results from MEAD showed different patterns of turbulence intensity (and therefore different patterns of dry deposition) depending on model resolution. The results of the high resolution model showed that turbulence intensity is higher close to the coast than previously thought and that the pattern of intensity depends on the position of islands.

Combining model and experimental results showed that ammonia is deposited primarily as ammonia gas and therefore its deposition is fundamentally controlled by the turbulence intensity in the region. Gas phase nitric acid (HNO_3) in contrast reacts rapidly with aerosols such as sea salt, changing nitrogen into the particle phase as nitrate. Since HNO_3 has a higher deposition velocity than nitrate aerosols, this process actually decreases the deposition of oxidised nitrogen to surface waters 10 km offshore and beyond. These findings are still to be considered as preliminary results and therefore further research on air-sea fluxes and reactions in the marine atmosphere will be carried out based on new and improved measuring techniques. Accurate determination of the dry deposited flux of nitrogen from the atmosphere to the surface waters requires much higher resolution coupled meteorological and chemical modelling than is currently achieved. This will be a focal point in future research.

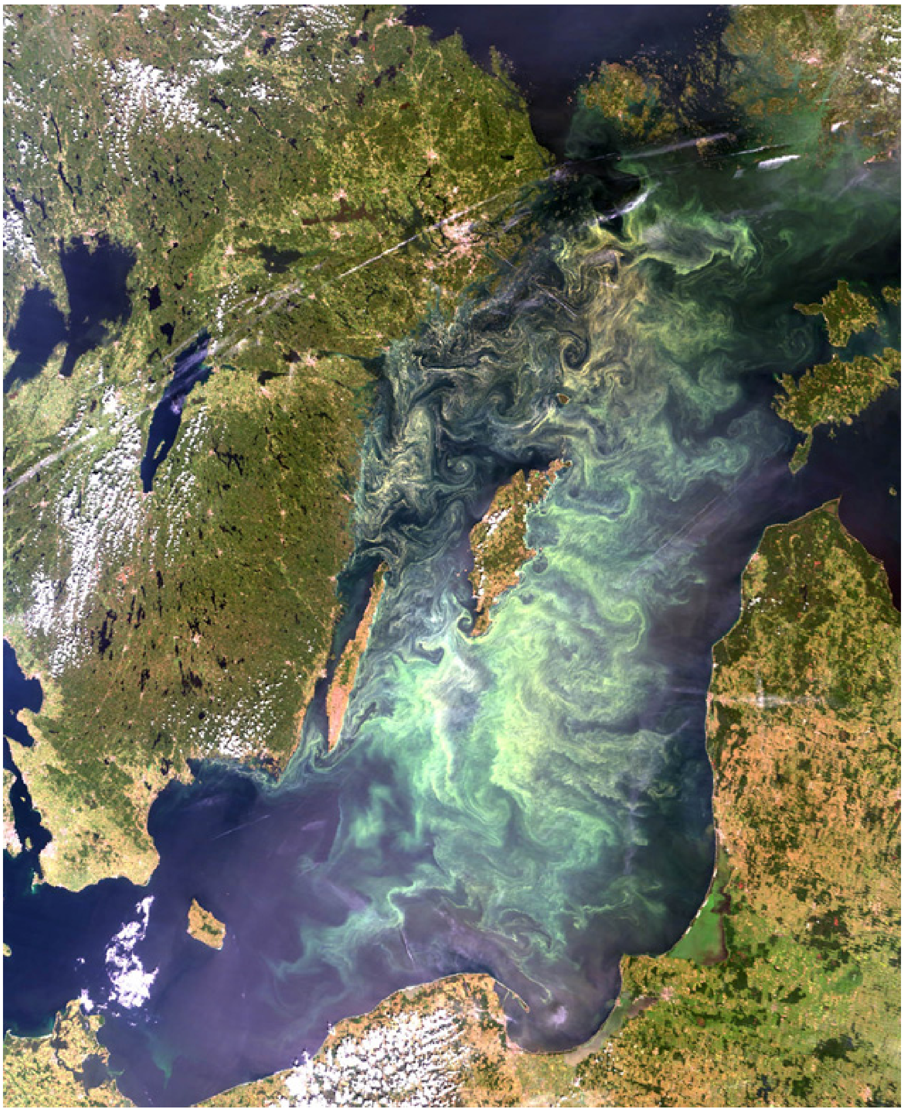

Fig. 4.1 A bloom of cyanobacteria in the Baltic Proper as seen from satellite on 11 July 2005. Algae blooms are a regularly occurring phenomenon in the central Baltic Sea and may have negative effects on the environment. The 2005 cyanobacteria bloom has been considered a strong event compared to earlier years. (Modis/Aqua data from NASA, processed by SMHI)

While eutrophication is caused by the increased input of natural components such as nitrogen and phosphorus, pollution defined as input of toxic substances and other material which threatens the Baltic Sea environment is completely man-made. It has been increasingly evident that the Baltic Sea region is a sink for many toxic pollutants, such as heavy metals and POPs (Persistent Organic Pollutants) which originate from industrial and agricultural activities both inside and outside the region. The transport includes wind-driven air masses, rivers and water currents, and ice-drift. Long-range airborne transport of pollutants, with subsequent releases in rain and snow over the Baltic Sea catchment deposits pollutants on land, in riverine melt water, and in the highly productive surface layers of the Baltic Sea. The carbon system is closely connected to the biogeochemical processes of the ecosystem. In particular, the surface water CO_2 partial pressure (pCO_2) reacts extremely sensitive upon changes in the CO_2 system caused by biological activity and thus a coupling between the eutrophication problem and climate issues (e.g. control of CO_2 uptake) exists. Increased nutrient inputs and phytoplankton concentrations are hypothesized to enhance CO_2 uptake. However, oxygen depletion as a result of too high nutrient input may lead to CO_2 emission.

The interaction between the atmosphere and the sea has substantial influence on the marine and atmospheric environment. Surface fluxes can be estimated with various techniques, such as eddy correlation, profile, inertial dissipation, bulk, and relaxed eddy accumulation methods. The most direct is the eddy correlation method but it is difficult to apply over the open sea due to movements of the platform (ship) and flow distortion caused by the structure of the platform. The bulk method, which provides the connection between the gradient and the fluxes, is commonly applied although the dependence of the transfer coefficient on atmospheric stability and the state of the sea is still not settled. The relaxed eddy accumulation is a promising novel technique to measure fluxes of constituents that are too low in concentration to be measured by the eddy correlation technique. Dependence between the height of the marine boundary layer and the wind and concentration profile in the marine atmosphere has recently been suggested, and recent measurements indicate a connection between the exchange processes and the marine boundary layer height.

In recent years, significant progress has been made in developing and coupling circulation and biogeochemical models on the one hand and atmospheric-hydrological and transport-chemistry models on the other hand. BALTEX Phase II will take advantage of this development and will include pollution and dispersion processes into regional circulation models, in particular the coupled regional models developed in Phase I of the programme, and will further promote the improvement of existing biogeochemical models and their coupling with climate models within the BALTEX modelling platform. One goal will be the simulation of ecosystem responses to changes in atmospheric forcing.

Transports and fluxes of matter connected to the water cycle finally end up in the Baltic Sea, which acts as the "collector" of nutrients and pollutants. The Baltic Sea and its marine ecosystem is therefore a key indicator for the environmental status of the entire Baltic Sea region. Research aspects related to this objective of BALTEX Phase II will therefore to some extent focus on the Baltic Sea and its marine ecosystem.

4.1. Major Goals

- To foster the coupling of climate and biogeochemical models and enhance the modelling capability for dispersion processes of nutrients and pollutants by implementing these into regional coupled atmosphere-land-ocean models including sea ice, rivers and lakes.
- To promote the integration of the carbon cycle into biogeochemical models and to initiate first steps towards including these into the BALTEX modelling platforms
- To continue establishing and exploring more comprehensive observations into data sets for development and evaluation of modules and models, and to stimulate field experiments to study exchange processes of pollutants, nutrients, and carbon over sea and land including ice and snow.

4.2. How to achieve these Goals

4.2.1. Including Pollution and Dispersion Processes into Regional Circulation Models

- *To foster the coupling of climate and biogeochemical models and enhance the modelling capability for dispersion processes of nutrients and pollutants by implementing these into regional coupled atmosphere-land-ocean models including sea ice, rivers and lakes.*

Existing biogeochemical models should be gradually integrated and coupled with hydrological and atmospheric models to comprehensively describe the dispersion processes of nutrients and pollutants. Within BALTEX Phase I, coupled atmosphere-land-ocean models of the Baltic Sea catchment have been developed and applied. In Phase II, inputs, dispersion and transport, as well as transformation and the fate of nutrients and pollutants shall be investigated by coupling biogeochemical sub-modules for aerosols and substances into regional coupled atmosphere-land-ocean models of the Baltic Sea. For this purpose, relevant existing models and necessary extensions or modifications should be identified.

As a first step, nutrients and pollutants (heavy or trace metals and POPs) should be identified and selected for which sufficient data exist so that they can be successfully implemented into coupled models. Nitrogen and phosphorus compounds are generally the limiting nutrients for primary production in the Baltic Sea. Especially the extensive cyanobacterial blooms which may cover large parts of the Baltic Sea every summer are strongly dependent on phosphorus availability. Large data sets are available for these compounds. Their complex cycles including the redox transformations in the anoxic deep waters have been simulated in biogeochemical models, and efforts should be made to link these with meteorological, hydrological and atmospheric models to extend their scope to distribution and transport processes in air, sea and on land. Emphasis should be put on the atmospheric transport of gases, aerosols and particles.

For trace metals, the following different biogeochemical transformations and pathways must be considered:

1. ***Riverine input**:* Data are available about the riverine input of trace metals into the Baltic Sea and the direct input from point sources. Due to the incomplete regional coverage of the measurements, extrapolation procedures were applied which involve considerable uncertainties. Nevertheless, the data provide an acceptable basis for first attempts to model the distribution of trace metals in the Baltic Sea.

2. ***Atmospheric transport and deposition:*** Data on emissions from anthropogenic land-based sources, concentrations in ambient air and precipitation as well as dry and wet deposition fluxes to the water body and the drainage basin of the Baltic Sea for the priority metals lead, cadmium and mercury have been reported. Those data have been derived both from measurements and model simulations. However, the available observational data are still scarce with a limited spatial coverage. They mainly refer to monitoring stations at coastal sites and, in some cases, do not allow an overall assessment of the atmospheric input of heavy metals to the Baltic Sea.

3. ***Internal transformations and sedimentation:*** According to the mode of interaction of dissolved trace metals with particles, two different types of trace metals are distinguished: “nutrient-like” and “scavenged” trace metals. The cycling of nutrient-like trace metals (e.g. cadmium, Cd) widely resembles that of phosphorus and nitrogen compounds. Many studies concerning the distribution coefficient of Cd have been published and the data may be used to make a first step to model the distribution of Cd representing the nutrient-like trace metals. In a second step, scavenged trace metals should be included in the model. Scavenged trace metals (e.g. lead, Pb) interact preferentially with mineral particles such as iron and manganese oxides. Finally, in a third step the formation and changes of anoxic conditions in the Baltic Sea deep water should be taken into account. A special case is the chemical behaviour of mercury (Hg) in seawater. Mercury is transported into the Baltic Sea mainly as oxidized Hg, but may be reduced photochemically or biochemically to elemental Hg. Since elemental mercury is volatile, it may escape into the atmosphere by gas exchange.

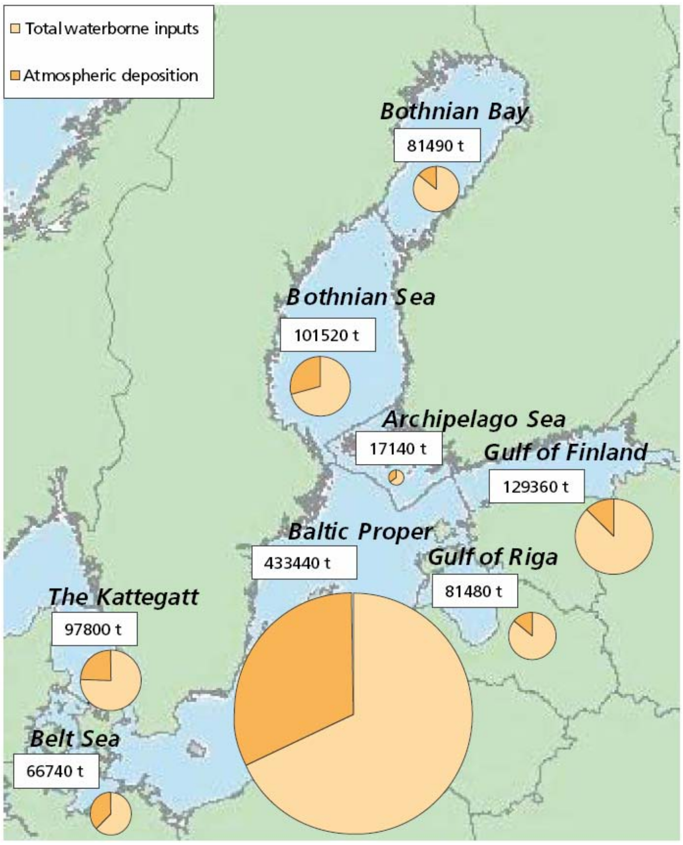

Fig. 4.2 Proportion of airborne and waterborne nitrogen inputs into the Baltic Sea sub-regions in 2000. From *HELCOM, 2005.*

4.2.2. Towards extending Biogeochemical Models by integrating the Complete Carbon Cycle

- *To promote the integration of the carbon cycle into biogeochemical models and to initiate first steps towards including these into the BALTEX modelling platforms*

Any modelling approach to describe the carbon cycle must include an ecosystem module. Since nutrients limit biological production, ecosystem models in general focus on the cycling of nutrients in order to simulate the production and decomposition of biomass. Most of them consider only the organic carbon and ignore the interaction with the marine CO_2 system. BALTEX will promote research involving the CO_2 system in order

- to balance the CO_2 gas exchange between the Baltic Sea and the atmosphere. In contrast to the atmospheric pCO_2, the surface water equilibrium pCO_2 shows a marked spatial and seasonal variability and thus controls the air/sea CO_2 exchange. Since the surface pCO_2 is mainly controlled by biological activity, any approach to model the air/sea CO_2 balance must be based on an ecosystem model that includes the CO_2 system;
- to introduce additional variables for the validation of ecosystem models,
- to simulate potential changes of the Baltic Sea CO_2 system using different scenarios for climate changes and anthropogenic nutrient loads, and to estimate the implications for the ecosystem functioning and for the role of the Baltic Sea as a source/sink for atmospheric CO_2.

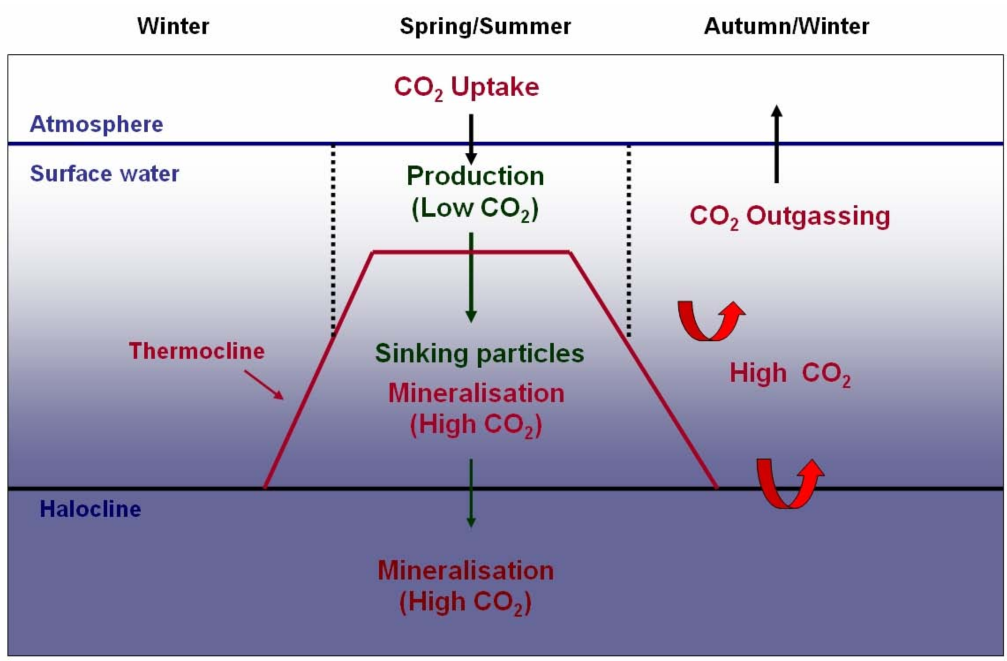

Fig. 4.3 Relationship between mixing/stratification and CO_2 seasonality in the Baltic Proper. CO_2 is taken up by surface waters in the productive spring and summer while respiration in winter results in a net outgassing to the atmosphere. Particle sedimentation export organic carbon to the deep waters, where it is remineralized to CO_2 which may be mixed up to the surface layer by convection (by courtesy of Bernd Schneider, IOW).

4.2.3 Inclusion of new Data Sources and Measurement Methods for the Improvement of Parameterisation and Model Validation

- *To continue establishing and exploring more comprehensive observations into data sets for development and evaluation of modules and models, and to stimulate field experiments to study exchange processes of pollutants, nutrients, and carbon over sea and land including ice and snow.*

Remote sensing from satellites increases the potential of high resolution monitoring of the terrestrial and marine environment by providing high resolution information on temperature, soil moisture, sea ice extent, sea surface roughness, swell and ocean colour (see also Chapter 8.3). Monitoring and short term field experiments should be carried out on moving and stationary platforms to investigate the processes which control exchanges of energy, water, and biogeochemical components such as nutrients and carbon, between air and sea, land, snow and sea ice. Newly developed technologies for flux measurements of gases and particles (i.e. relaxed eddy accumulation and inertial dissipation) will be applied. These data will form a basis for the development and validation of satellite retrieval algorithms, and for flux parameterisations of environmental substances for model development as well as model validation. Furthermore, meteorological measurements over land should be complemented with nutrient flux measurements.

4.3. Involvement of Stakeholders

It is necessary to involve stakeholders at an early stage in the environmental modelling process to obtain reliance in model results, and to ascertain that stakeholder questions are answered in a comprehensive way. Stakeholder contacts are also necessary for researchers to obtain detailed information on several environmental variables, which serve as input to the models. The most important stakeholders are:

- HELCOM (Helsinki Commission)
- EEA (European Environment Agency)
- ICES (International Council for the Exploration of the Seas)

- Research institutions
- Authorities (including governments) at national, regional and local level
- Industry
- Farmers
- Fisheries and aquaculture
- Tourism
- General public and media

4.4. Research Needs and Potential Activities

The model systems and related experience elaborated during BALTEX Phase I should be exploited by environmental impact models in BALTEX Phase II (*e.g.* meso-scale air pollution models, riverine-nutrient transport models, biogeochemical models). Such models are of vital importance to serve decision makers in environmental policy. Chemical sub-modules for aerosols and substances such as carbon, nitrogen and ozone should be linked to the coupled ocean-atmosphere-land surface models developed in BALTEX Phase I.

4.4.1. Input, Dispersion, Transport and Fate of Nutrients and Pollutants

BALTEX has developed tools to model the distribution of conservative seawater constituents which are transported by advection and mixing. However, nutrients and most heavy metals, and especially those which have toxic effects, behave non-conservatively and undergo physical and biogeochemical transformations. The quantification and integration of these processes into models requires extensive research efforts and should be a primary activity. A precondition for modelling the distribution of nutrients and pollutants is the availability of data for atmospheric and riverine inputs. With respect to atmospheric transport and deposition, the overall research needs should focus on the adaptation of the most advanced atmospheric chemistry and transport models suited for the simulation of transport, transformations and deposition of air constituents on adequate spatial and temporal scales. Such models will have to be extended and/or restructured fundamentally to address the current understanding of atmospheric nitrogen and phosphorus, as well as heavy metal and POP distribution, including the complex physical and chemical transformations and air-sea exchange processes of mercury species.

This will require research with respect to the:

- Coupling of biogeochemical sub-modules to atmosphere-land-ocean models of the Baltic Sea
- Characterization and quantification of air-water and air-soil exchange processes, which may significantly influence the atmospheric deposition level over the Baltic Sea and its drainage basin, respectively. This will include field campaigns including the atmospheric boundary layer parameters and flux measurements to close existing gaps in knowledge of nutrient, pollutant and biogeochemical transformation processes in air, sea and inland waters as well as soils for model validation and database construction.
- Investigation of physical and chemical transformations of non-conservative tracers and its implementation into coupled models
- Establishment of links to hemispheric or global models to improve initial and boundary concentration fields of regional models. Recently performed model simulations for mercury show that global background concentrations contribute by about 40 % of the total atmospheric input to the Baltic Sea. This indicates that emission reductions in Europe would only have a limited effect on the reduction of the total mercury load of the Baltic Sea.
- Integration of atmospheric deposition and other environmental modelling techniques to encompass the entire Baltic Sea ecosystem and to address the total cycle of heavy metals.

4.4.2 The Carbon Cycle

BALTEX Phase II will provide the framework for research aiming at the description of the Baltic Sea carbon cycle. It will thus extend its modelling activities, beyond the hydrographical and hydrological processes, to biogeochemical models. BALTEX will not deal with the further development of the biological model components since this is pursued at many institutions dealing with ecosystem research. Instead, BALTEX will focus on the description of processes that are specifically related to the carbon/CO_2 cycling, and will aim at integrating these into biogeochemical models. This will require research concerning the:

- Parameterization of the gas exchange transfer velocity. Currently used parameterizations of the transfer velocity are only wind speed dependend. They show large discrepancies both with regard to the type of the function and the magnitude of the predicted transfer velocities.
- Input of alkalinity by river water derived from geologically different regions in the watershed area. Dissolution of calcium carbonate in rain and river water constitutes the main contribution to the Baltic Sea alkalinity and controls the storage capacity of seawater for CO_2. Changes in environmental factors such as temperature, precipitation amount/chemistry and atmospheric CO_2 concentrations may modify the alkalinity input and thus affect the total CO_2 in the Baltic Sea.
- Input of dissolved organic carbon. Organic carbon may be released from soils in the watershed area and transported by river water into the Baltic Sea. The labile fraction may be decomposed by bacteria thus adding CO_2 to the Baltic Sea and modifying the air/sea CO_2 balance.
- Decrease of the Baltic Sea alkalinity by acidic precipitation. Acidic atmospheric trace constituents are deposited to the Baltic Sea mainly by precipitation. The consequence is a decrease in alkalinity and a lower storage capacity for CO_2.

Moreover, BALTEX will support and extend current CO_2 measurement programmes in the Baltic Sea which provide data for the validation of model simulations, and which can be used for process parameterizations. It is intended to deploy autonomous measurement systems on platforms or commercial ships in order to obtain high resolution long-term time series. Measurements of the pCO_2 which are presently performed continuously on a cargo ship may be used for model validation.

4.5. Specific Data Needs

Environmental data are needed to describe and quantify the distribution of pollutants, components of the carbon and nutrient cycles, and selected components of the ecosystem. Although these data are partly available from the continuous monitoring programmes around the Baltic Sea, it has to be identified which data are required in which spatial and temporal resolution in order to suffice modelling requirements for validation. Remote sensing from satellites has demonstrated its potential for high resolution monitoring of the terrestrial and marine environment and provides crucial data such as sea surface temperature and ocean colour to estimate algal occurrence and concentration, as well as other parameters. Dedicated field measurements and experiments (ground truth data) must be performed to calibrate the satellite data wherever there are gaps in existing monitoring programmes.

Parameters to be investigated include sea surface temperature, roughness and colour; the production of bubbles, sea spray and white caps, water surface enlargement due to waves, the occurrence of swell, PAR (Photosynthetically Active Radiation) at the surface, PAR attenuation by phytoplankton, suspended particulate matter and Yellow Substance (“Gelbstoff”), phytoplankton concentrations (Chlorophyll *a* and the occurrence of filamentous cyanobacteria, nutrient and pollutant (trace metals and POP) concentrations, and the depth of the upper mixed layer.

Monitoring and short-term field experiments should be carried out on moving and stationary platforms to investigate the processes controlling the air-sea/land/snow exchanges of energy, nutrients, carbon and pollutants. These data sets will form the basis for flux parameterisation of other environmental substances and for model validations. Novel technologies for flux measurements of gases and particles (i.e. Relaxed Eddy Accumulation) shall be applied. Fluxes of momentum, latent and sensible heat, and quantities describing the sea state shall be measured in the marine boundary layer, together with air-sea exchanges of CO_2, gaseous and particulate nitrogen.

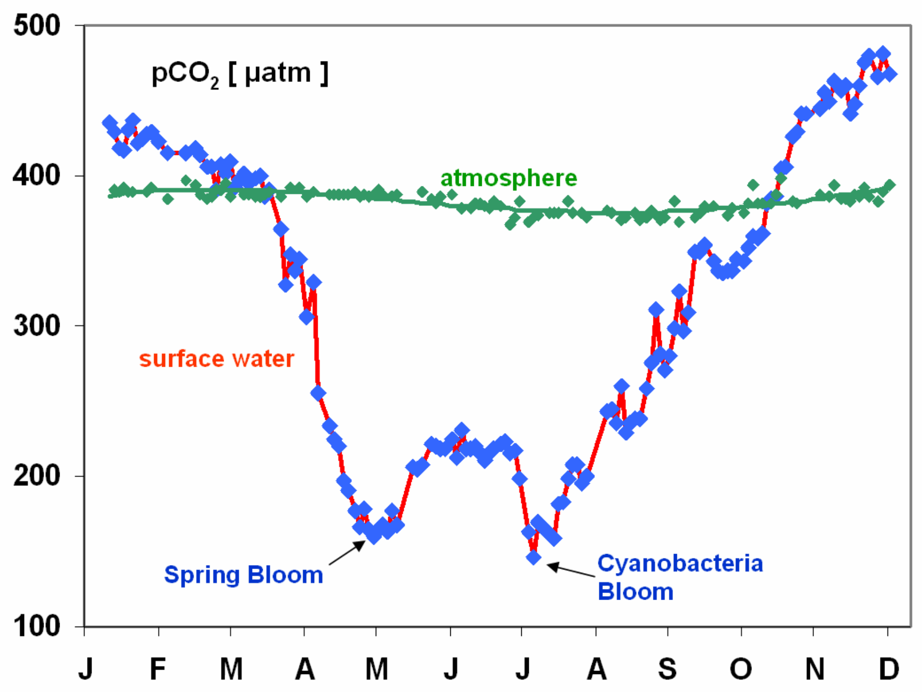

Fig. 4.4 Annual cycle of the CO_2 partial pressure (surface water and atmosphere) in the northern Gotland Sea as measured automatically on the cargo ship FINN-PARTNER in 2005 (by courtesy of Bernd Schneider, IOW).

5. Strengthened Interaction with Decision Makers

As global change research results are expected to be policy-relevant, BALTEX Phase II research goals should take advantage of stakeholder involvement from the beginning. It is our wish to establish at least one working group with members from both governmental and non-governmental organisations. The selection of the themes is driven by the societal needs and its ordering does not give any priority. The working group should start activities immediately after the adoption of this strategy. The new BALTEX Phase II goals and the related implementation measures are new approaches for the Baltic Sea basin, and the suggested stakeholder involvement can also be seen as an additional motivation for trans-disciplinary research in the fields covered.

5.1. Interaction with Governmental Organisations

The impact of the scientific work on society can be viewed, in a simplified fashion, as a chain of events starting from basic research programs, leading to applications by service organisations and finally ending as benefits for the society and economical life. The governmental organisations including research and service institutes may thus be considered as stakeholders from the point of view of academic research programs, such as BALTEX. As the governmental institutes, for example national Hydro-meteorological Services, often perform research of their own, they can also be considered as partners of the research programs.

The governmental organisations thus have at least two different roles to play:

i. To serve the whole society with information and facts in the area of their responsibility;
ii. to develop the services in their field of competence.

As a first step, dedicated workshops for stakeholders will be organized with the aim to acquire a common understanding of these roles of the governmental organisations in the context of the BALTEX programme. The focus of these discussions should be on common responsibilities and opportunities. Examples include the cooperation with respect to an assessment of climate variability and change for the Baltic Sea basin, background material on the “National Communication on Climate Change”, a common view on quality assurance of the reporting to the Baltic Marine Environment Protection Commission (HELCOM) and the European Environment Agency (EEA), the common use of large investments in model systems, and data policy.

5.1.1. Suggested Activities

The governmental agencies and institutes are encouraged to compile their common needs to address the BALTEX community. The scope may even be broader and wider than outlined in the BALTEX Phase II Science Plan. For instance, not only the impacts of climate change but also how to adapt to the envisaged impacts, tailored with relevant risk analyses, could be listed as needs. Some suggestions are detailed in section 5.3, see below.

5.1.1.1. Data

One important way to facilitate the research inside BALTEX is by creating and making available data sets that, as far as possible, meet the needs of the research as defined in this document. The specification of the data sets should be done in cooperation with the science community. A dedicated Working Group on Data Management has therefore already been established and will make provisions for the organization of data exchange (see Chapter 9.2).

5.1.1.2. Climate Research

Climate change and its interaction with the environment concern many stakeholders and decision-makers. The national agencies and institutes with responsibilities for meteorology, hydrology and oceanography form a key group in this respect. The application of the coupled regional models established in the frame of BALTEX allows a more detailed projection of climate change in the Baltic Sea basin for various scenarios of human behaviour at the global scale. This input is needed for mitigation measures like enforcements of the Kyoto Protocol but especially for the adaptation to ongoing climate change. The United Nations (UN), through its Framework Convention on Climate Change (UNFCCC), put obligations on all states and especially on the so-called Annex I countries, including all 14 countries having territories in the Baltic Sea basin. The member countries report back to UNFCCC with periodic “National Communication on Climate Change”. Participating countries should therefore have an interest to discuss for example with the coupled modelling community in BALTEX the setup of model runs enlarging the return for the countries. There are at least two chapters in the national reports, namely “Research and systematic observations” and “Education, training and public awareness”, where BALTEX would be an active contributor to.

Another example is the *BALTEX Assessment of Climate Change for the Baltic Sea Basin (BACC*), which has already been initiated in 2004 with the aim to publish a comprehensive assessment book by the year 2006. The BACC material will be used for a two-volume HELCOM *Thematic Assessment Report*. Stakeholder involvement is highly desirable in that project. Thus it may lead to a common product from all the states in the BALTEX region as a possible input for the fourth IPCC assessment already under preparation. Furthermore, an active participation of governmental organisations in the development of coupled model runs such as regional scenarios is desirable.

5.1.1.3. Funding

An important area for the governmental organisations is, in cooperation with the research groups, to formulate research applications, seek funding from national and international sources and actively participate in the performance of the research work. In this respect the governmental organisations should also allocate own resources to the research work.

5.2. Interaction with Non-Governmental Decision Makers

The national governmental organisations are the main stakeholders for BALTEX. However, BALTEX interacts also directly with other decision makers ranging from international organisations like the European Environment Agency (EEA) to national, regional and local ones, as well as to small enterprises in for example the fisheries sector, to farmers, and to international companies like the ones in the energy sector. The involvement of stakeholders within each thematic research direction of BALTEX Phase II is detailed in sections 1.3, 2.3, 3.3 and 4.3. The public at large and tourism in particular are also stakeholders and decision makers of relevance for BALTEX. The interaction with these is described in more detail within the chapter “Education and Outreach” (Chapter 6).

Decision makers may play a similar role within BALTEX. Their overall expectation is to receive answers to questions concerning issues such as climate change, water management and water quality for the BALTEX region. Therefore it is necessary to include the decision makers to help define projects and to involve them at an early stage of research to obtain tailored model results. They might even provide funding sources for research projects or help to find funding sources.

On the other hand, research needs knowledge from stakeholders and decision makers, e.g. detailed information on several environmental variables, which serve as input to models are needed. Furthermore plausible and possible perspectives for future changes of land use, river regulations, regional emissions of aerosols and other regional or local agents influencing the regional and local climate are needed for a realistic construction of projections and scenarios. Stakeholders shall also be encouraged to provide scenarios of other anthropogenic factors (*e.g.,* release of harmful substances), which will be acting on the Baltic Sea environment (*e.g.,* ecosystem functioning) in conjunction or in addition to climate forcing and change. This latter aspect is important especially given extensions of BALTEX data and modelling studies beyond the physical climate system.

In the following section, examples of BALTEX research with a high potential for applications – and therefore stakeholder involvement – will be given.

5.3. Examples of BALTEX Research with a high Application Potential

5.3.1. Adaptation of Security Infrastructure

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 – in conjunction with climate change projections - also allows a careful interpretation of projection of changes for the coming few decades as basis of the adaptation of security infrastructure like dykes and dams and its planning. BALTEX scientists will establish contact and cooperation with panning authorities, preferably in a dedicated working group on “Infrastructure Adaptation” to changed climate variability with emphasis on water cycle parameters and the coming decades. Participation of particularly scientists developing coupled model systems is envisaged, 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.

5.3.2. 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. This knowledge constitutes one of the main cornerstones for coastal zone management. BALTEX will establish cooperation with other programmes such as LOICZ (see Chapter 10.6), and with relevant management authorities in order to maintain a multidisciplinary discussion platform for the development of strategies for coastal zone management based on regionalized sea level variability and change. In addition to topics like coastal defence this should involve also consequences of changes in the physical system for ecosystems.

5.3.3. Prediction of Floods, Snow Cover and Hydropower Potential

The models used for the projection of regional climate change can also be used for 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 new applications for meteorological and hydrological services that participate in BALTEX Phase II. Because the starting fields for the forecasts need information about near surface ocean structure as well as soil and groundwater storage growing 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 in the North Atlantic. User will be addressed and cooperation will be established, whenever improvements have become evident with a potential for rapid application. However, their full potential can only be exploited if seasonal predictions of climate anomalies show more skill for the Baltic Sea basin. Should such skill emerge during BALTEX Phase II, contacts to insurance companies, distributors of oil, hydropower companies operating large reservoirs and authorities responsible for water supply, to name just a few, should be established jointly with meteorological and hydrological services.

5.3.4. Reduction of the Eutrophication of the Baltic Sea

Discharge of nutrients into the Baltic Sea 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 trace gas and aerosol transport as well as 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 accelerated oxygen depletion in parts of the Baltic Sea below the seasonal thermocline or the halocline. The environmental protection agencies of countries in the Baltic Sea basin will be invited to cooperate with scientists in order to test eutrophication reduction scenarios that involve projections of future wastewater, future NO_x emissions and sewage treatment plant construction policies. BALTEX will specifically coordinate its activities with HELCOM, the Baltic Marine Environment Protection Commission.

5.3.5. Groundwater Changes Caused by a Changed Water Cycle

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 (sometimes less than 100 mm per year), rather small changes in precipitation amount and timing as well as land use can lead to substantial changes in groundwater availability and quality. Therefore, many drinking water supply authorities or companies have a high interest in reliable information on potential groundwater changes. For the inclusion of tested groundwater modules into the coupled models, we need to get input from the groundwater research and application communities. The joint research has to start at the beginning of BALTEX Phase II.

6. Education and Outreach

The rationale for BALTEX Phase II as outlined in Chapters 1 to 4 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 education and outreach of BALTEX at all relevant levels, ranging from local to international and global. This 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) stakeholders and users, 2) scientists, 3) students, and 4) the general public.

6.1. 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. Chapter 5 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 further 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 feedback with users shall effectively be maintained. Secondly, specific individual contact missions of key scientists to stakeholders will be instrumental, in particular in the build-up phase of the contacts. Thirdly, specific workshops targeted for users will be conducted which are described in more detail within Chapter 5.

6.2. Scientific Exchange

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. Both the BALTEX website (www.gkss.de/baltex) and the BALTEX *Newsletter* contribute to dissemination actions targeted mainly to researchers and academia in general. More than 250 peer-reviewed journal articles, including several special BALTEX issues have been published. All these 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 Chapters 2 to 4).

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. Apart from the given framework of GEWEX, exchange with the other major international research programmes, projects and initiatives will be established and intensified in BALTEX Phase II, as described in Chapter 10.

6.3. Academic Training

This outreach component will include training and education measures at different university and post-university levels. In particular three aspects will have to be considered in the academic education and training component: (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 theses, doctoral theses, 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.

Additionally, BALTEX will strengthen its cooperation with the Baltic University Programme (www.balticuniv.uu.se). This programme, initiated in 1991, is a network of 180 universities in 14 countries and other institutions of higher learning throughout the Baltic Sea region. It may well be the largest international university network worldwide and is coordinated at Uppsala University, Sweden. The Programme deals with issues of interest for BALTEX, such as sustainable development and environmental protection in the Baltic Sea region. It develops university courses, conferences, summer schools, textbooks and projects in cooperation with authorities, municipalities and others (including an urban forum project financed by the EU in the framework of the INTERREG Programme). It attracts several thousand students a year (*e.g.* over 8000 students in 2003).

Strengthened links with the Russian-German Master program for applied polar and marine sciences “POMOR” will also be sought. This program was initiated by the State University of St. Petersburg, the University of Bremen, the Alfred-Wegener Institute of Polar and Marine Research and the Leibniz Institute of Marine Sciences at the University of Kiel in cooperation with several universities in northern Germany. The program has been running since 2001 and it is supported by the German Service for Academic Exchange (DAAD). In 2004, twenty graduates for master's degree received their diplomas.

6.4. 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 have already been used in the past; however, their effectivity and success can be increased in the future. 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. 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 Chapter 5. 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 in the 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 help to prepare school courses including practical laboratory experimental and theoretical lectures in collaboration with teachers, who will specify the level of contents and presentation measures to adapt to the experience level of the youth. Involvement in school programmes may serve as a multiplier for the general public, as not only pupils themselves but also their parents will be reached by the programme.

Current research topics of the BALTEX programme including up-to-date research questions and results will be offered to existing pupil laboratories or pupil courses 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. A collaboration with already existing projects like “CarboSchools” (www.carboschools.org) and the NaT-Working project of the Leibnitz Institute for Marine Research in Kiel, Germany (nat-meer.ifm-geomar.de), as well with ongoing projects in all BALTEX countries is envisaged.

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. The organisation of “Open Days” in research institutes involved in BALTEX research will be a further important activity to reach the public.

6.5. Implementation of Education and Outreach

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 coordination across the various scientific topics of the programme and target sectors of the society to be addressed. Coordination of these activities is envisaged to be assured through implementation of a specific BALTEX Working Group on Public Relation. Nevertheless, to carry out all envisaged education and outreach activities, funding for the scientific work together with these elements is indispensable.

7. Road map and Initial Implementation

7.1. Road Map and Milestones

BALTEX has moved into its second phase with both a renewed commitment to addressing Phase I objectives, in particular to filling gaps in our knowledge related to basic processes of the water and energy cycles, and new objectives related to climate variability and change, tools for water management, and air and water quality studies. A detailed time plan including deliverables and milestones related to the major goals and various potential activities defined within the four major new objectives in chapters 1 to 4 is difficult to establish at present. Instead, a simplified time line is given indicating the expected time periods with core activities contributing to meeting the major goals for BALTEX Phase II (Fig. 7.1). For details on major goals please refer to Chapters 1 to 4. The International BALTEX Study Conferences, planned following past traditions for the years 2007, 2010 and finally 2012 will establish natural milestones where progress will be reviewed and future plans and implementation documents are expected to be established accordingly. Further milestones which are defined in close agreement with a related draft road map established for GEWEX at the end of 2005 are indicated as numbered bullets for objectives 1 to 3 of BALTEX Phase II, which have direct relevance for GEWEX Phase II.

GEWEX-related Milestones for BALTEX Phase II

Better understanding of the water and energy cycles

1 Establish and discuss independent estimates of the water and energy budgets over land and sea, based on observations, re-analysis products such as ERA-40, and model results (2007).

2 Complete independent estimates of the water and energy budgets over land and the sea for the period 1980 to 2005[4] as input to the GEWEX CSE-related activities (2008).

3 Active contribution to the pan-GEWEX collaborative global water and energy budget study (2009).

4 A BALTEX "state-of-the-art" Baltic Sea basin energy and water cycle product complete with error bars will be produced and discussed. This product will provide the best estimates of the water cycle variables and analysis of the ability to close the Baltic Sea basin (and sub-basins) water budget for the period 1980 to 2010[5] (2010).

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[4] Adjustments of this period according to final GEWEX plans and others such as for COPES may be necessary.
[5] As footnote 1.

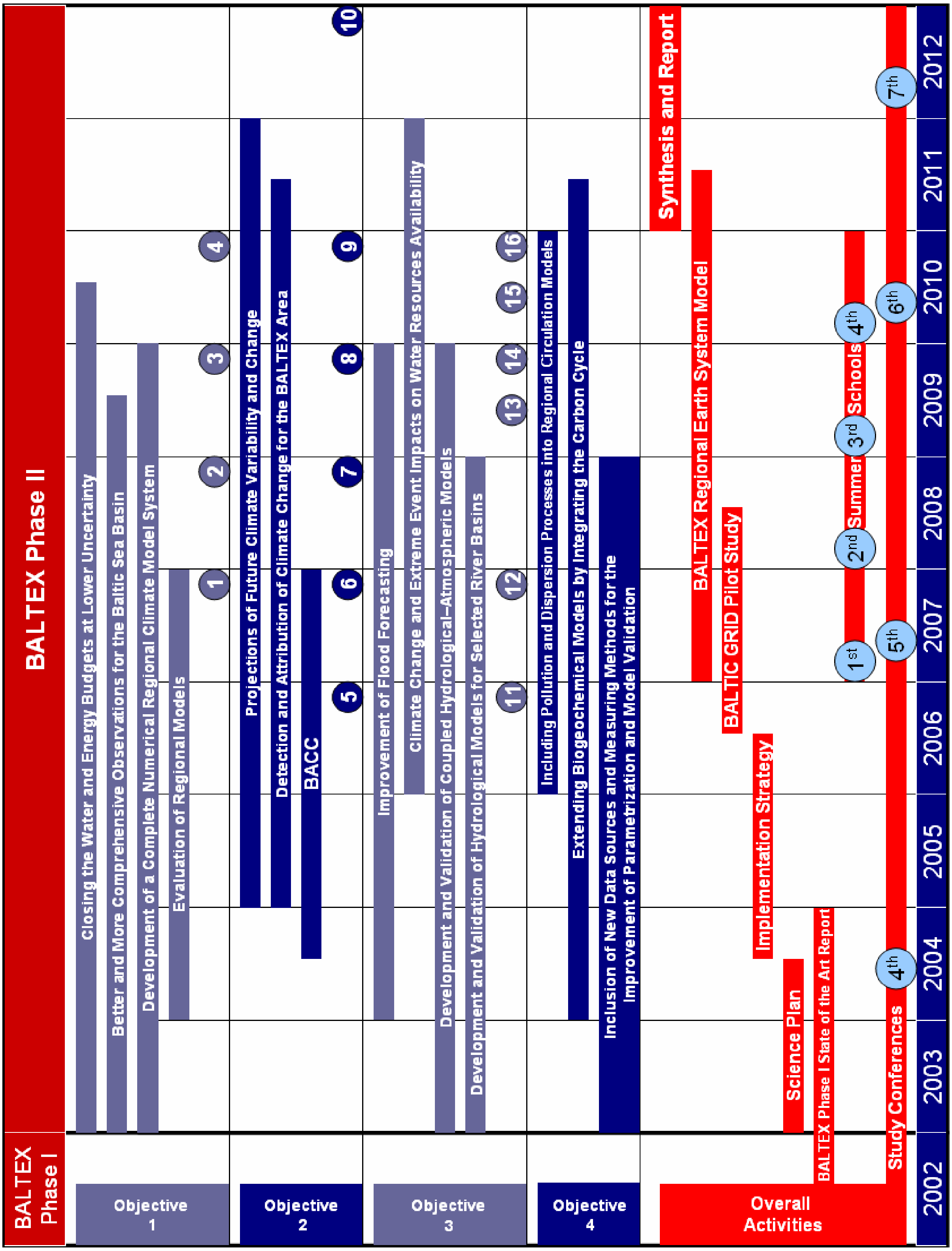

Fig. 7.1 Time line with core activities contributing to major BALTEX Phase II goals and overall activities. Numbered bullets refer to GEWEX-related milestones, see text.

Analysis of climate variability and change

5 Based on the BACC assessment, identify research priorities and gaps related to identification and attribution of regional climate change as well as to projections of future climate variability and change (2006).

6 Through a dedicated workshop or conference, assess impacts of regional climate change and variability on both marine and terrestrial ecosystems in the Baltic Sea basin (2007).

7 Establish and discuss climate projections for the 21st century using the coupled regional models for the Baltic Sea basin (2008).

8 Establish ensemble climate projection products including error estimates for the Baltic Sea basin (2009).

9 A research quality long term energy and water budget data set (complete with error bars) including both observational and model outputs will be produced, and discussed, for use in climate trend and variability analysis, model initialization and validation studies (2010).

10 Update the assessment of climate change and variability for the Baltic Sea basin as a final document originating from BALTEX (2012).

Improved tools for water management

11 Identify specific river basins with the potential for a close cooperation between researchers and management authorities with the aim to jointly improve and develop flood forecast model tools. Implement related projects at the international level (2006).

12 Assess the present performance of flood forecasting models in different regions of the Baltic Sea basin and identify future cooperation for projects dedicated to flood forecasting improvement. Implement related projects at the international level (2007).

13 Establish and discuss assessments of the availability of water resources based on ensemble climate projections for the 21st century in cooperation with water management authorities in selected river basins and for the entire Baltic Sea basin (2009).

14 Provide an assessment of the role of land-atmosphere interactions during major wet and dry (drought) periods, specifically for the 1995 to 2004 period, as a contribution to pan-GEWEX activities (2009).

15 Provide assessments of water resources including ground water based on ensemble climate projections for the 21st century for the entire Baltic Sea basin. Establish long-lasting cooperation or joint-ventures with river basin management authorities for selected river basins with the view to continuously update water resources assessments (2010).

16 Assess improvements in flood forecasting models in different river catchments in the Baltic Sea basin (2010).

7.2. Initial Implementation Measures

7.2.1. Assessment of Climate Change for the Baltic Sea Basin

One important tool of knowledge integration constitutes the establishment of review and assessment reports dedicated to specific science issues relevant for BALTEX. A particular concrete initiative in this context is the *BALTEX Assessment of Climate Change for the Baltic Sea Basin (BACC).* Besides an overall assessment of the Baltic Sea basin climate, BACC will include the assessment of past and current climate change, the projection of future climate change on the Baltic Sea basin, and climate related ecosystem changes. BACC will assemble and integrate knowledge from both inside and outside the BALTEX programme and its scientific areas. An important element of BACC is the comparison with the historical past until about 1800 to provide a framework for the severity and unusualness of the change. Also changes in relevant environmental systems, due to climate change, shall be assessed – such as changes in hydrology, ecosystems and ocean waves.

BACC will deliver an assessment book and the overall format will be similar to the IPCC (Intergovernmental Panel on Climate Change) process, with author groups for the individual chapters, an overall summary for policy makers, and an external review process. The BACC initiative has started in September 2004 and the assessment book is expected to be published in 2006. BACC constitutes one major implementation measure for the fourth potential activity defined in Chapter 2, see section 2.4.4.

The BACC assessment book will entail information for stakeholders in different areas. A particular application has recently been defined jointly between representatives of the Helsinki Commission (HELCOM) and BALTEX/BACC. HELCOM, the Baltic Marine Protection Commission, has the role and status of an intergovernmental international organisation with all countries bordering the Baltic Sea and the European Union being Contracting Parties. HELCOM undertakes to publish Thematic Assessment Reports with the general aim

i) to provide information in order to make sound decisions to restore the Baltic Sea ecosystem to reach good ecological status, and to support the implementation of the HELCOM objectives and actions;
ii) to provide policy relevant information for targeted users at national and Baltic-wide level,
iii) to provide input to pan-European and global forums such as EU, UNEP and IMO;
iv) to raise general public awareness of the Baltic Sea and HELCOM actions.

A joint BALTEX/HELCOM project was defined with the major objective to establish a two-volume HELCOM Thematic Assessment Report on *Effects of climate change on the Baltic Sea.* The material for this report will largely be based on the findings of the planned BACC book, with additional reorganisation and editing according to the specific HELCOM requirements. The HELCOM report is planned to be published in 2007 and the related BACC and HELCOM actions, including workshops, a review process and an international conference, are jointly coordinated.

7.2.2. Earth System Modelling and Baltic Grid

To understand the Earth system and, more specifically, how weather patterns, climate and the environment interact is one of the greatest challenges of our time. Population and per capita consumption of the Earth's resources have grown steadily during the last century and human impact on the Earth system has reached a level where we can foresee large future damages if actions are not taken at national and international levels. To describe and understand the Earth system dynamics and how physical, chemical and biological processes interact, but also the role of human activity in this system is therefore crucial knowledge for our society.

Furthermore, for knowledge integration and synthesis within BALTEX Phase II the development of a regional Earth system model is essential. The aim of Earth system modelling is the understanding of the complex Earth system, the controlling processes and the impact of man. Such models integrate our knowledge of the Earth system and account for the coupling between physical and biogeochemical processes in its components. Earth System Models (ESMs) are needed to understand large climate variations of the past and to predict future climate changes. Thus, an ESM can integrate the knowledge gained in the four objectives of BALTEX Phase II, and will use additional data which will be provided by measurements and new satellite sensors.

The Max Planck Institute for Meteorology (MPI-M), Germany, jointly with other international institutes has initiated a new community effort towards the development of an integrated ESM. This model system, called "COSMOS" (Community Earth System Models), will represent physical, chemical and biological processes in the atmosphere, ocean and on land. Within the COSMOS program the development of a global ESM is planned. The aim is to set up a system model based on tested model components which will be coupled via the Programme for Integrated Earth System Modelling (PRISM) standards. Regional coupled modelling systems, which have been established within BALTEX, can be seen as regional pilot systems in COSMOS. This can be the nucleus of the first regional pilot study area within COSMOS.

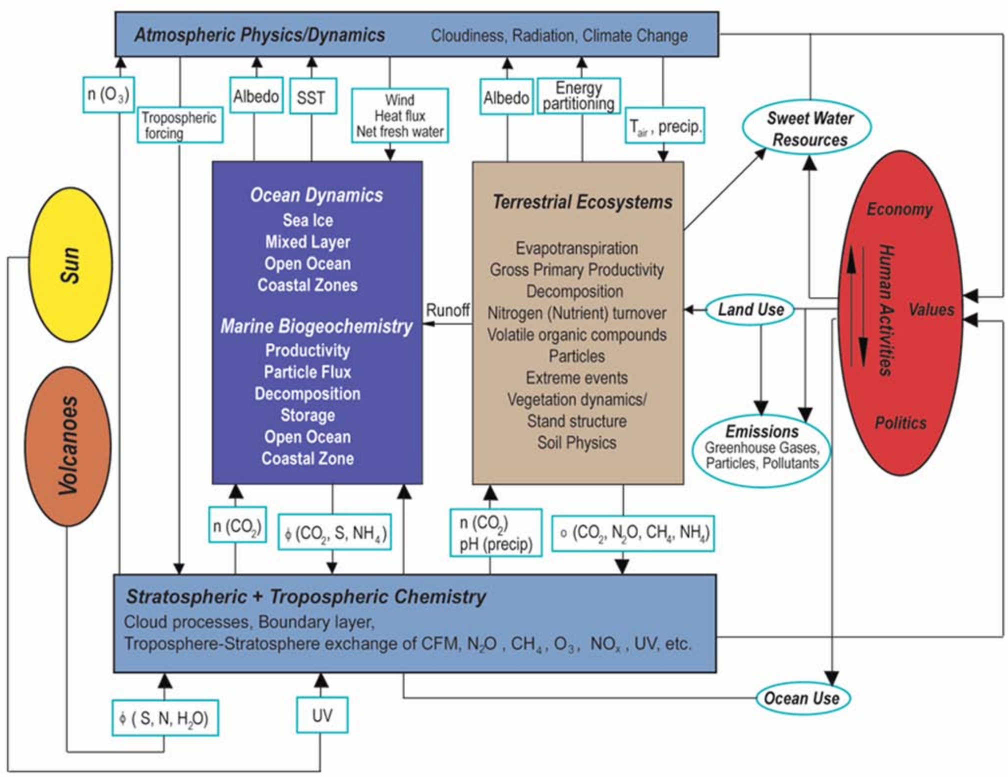

Fig. 7.2 Diagram of the Earth system showing the different spheres and coupling processes to be described in an Earth system model (Max Planck Institute for Meteorology, Hamburg)

Regional Earth system modelling belongs to the group of Grand Challenge problems with long model runs on supercomputers and high data storage requirements. Regional Earth system modelling of the BALTEX region requires an infrastructure for which BALTEX with its international cooperation and contacts has created an ideal basis.

With the development of a regional ESM, BALTEX Phase II steps into e-science and grid technologies. Grid technologies will allow scientific communities to develop better ways to share and analyse very large data sets, for the benefit of both, the quality and quantity of scientific output. These upcoming technologies will integrate resources and provide an infrastructure to access advanced computing capabilities and databases. Grid technologies will provide a communication network and support the origin of virtual organisations which share skills, core competencies and resources. BALTEX with its international connections and data centres will directly benefit from grid technologies. The BALTEX region constitutes an ideal test bed not only for model development, validation and developments in satellite techniques but also for grid technologies - ”The Baltic Grid“. In the near future, scientific experiments (models and observations) will become more detailed and complex via improved modelling tools and new observational techniques such as new satellite sensors. This will cause a tremendous increase in information and data. Thus, the emphasis for the Baltic Grid until 2012 will be put on the extension and intensification of the communication network to share expertise and databases rather than distributed computing.

It is in particular the Baltic Grid and COSMOS initiatives which will create the most obvious BALTEX contributions to the revised research strategy COPES (Observation and Prediction of the Earth System) of the World Climate Research Programme (WCRP). See section 10.4 for more details. Therefore, a suitable first step towards Earth system modelling and BALTIC Grid will be a “*Pilot Grid Project*” which is planned in the early phase of BALTEX Phase II. The Pilot Grid project constitutes one possible realisation of grid projects within BALTIC Grid.

7.2.3. Grid Pilot Project

One of the major objectives of BALTEX Phase I was the development of coupled atmosphere-land-ocean-models for the Baltic Sea basin. This aim has been achieved, and two coupled systems have been developed: the Regional Coupled Atmosphere-Ocean Model (RCAO) at the Rossby Centre (Sweden), and the coupled model system in the Baltic Region of the German research project "BALTIMOS" at the MPI-M (Germany). For BALTEX Phase II, these models will be further developed and applied for BALTEX research, and will produce large amounts of data. These data are of very high scientific potential, and the analysis, validation and improvement of the models need international collaborations of different scientists, not only modellers. These models produce consistent data sets which are and will be unique for the Baltic Sea catchment.

The Pilot Grid Project will concentrate on the period from 1999-2004. This period includes the BRIDGE period and recent extreme inflows to the Baltic Sea as well as extreme summers and flooding. Thus this period is extraordinarily well suited to study extreme events in the Baltic Sea basin.

A synthesis of BALTEX BRIDGE is missing up to now. With the modelled data and corresponding observations, a synthesis would now be possible providing for a detailed quantification of the energy and water cycle of the Baltic Sea basin. It should be stressed that the pilot grid project is interdisciplinary and comprises analyses from observations including satellite data and model data. It thus requires the combined expertise from observers and modellers.

The grid idea within the pilot study is mainly to share resources (model data, observations and expertise) within the existing BALTEX communication network which have to be further explored. Within international collaborations, which have to be defined, a free information and data exchange with respect to the BALTEX data policy is expected. In addition to the planned simulations, re-initialisations (nudging) and data assimilation will be performed. Thus, data from the BALTEX Data Centres as well as additional observations (hydrographical and satellite data) will be needed. Furthermore, these data are important for process studies and model validation. The following objectives are planned to be dealt with in the Pilot Grid Project:

- Quantification of the energy and water cycle for the period 1999-2004, including precipitation and evaporation;
- Quantification of corresponding uncertainties;
- Detailed investigation of coastal regions of the Baltic area (coastal ocean and atmospheric boundary layer);
- Analysis of extreme events and "Großwetterlagen" (forcing and response);
- Analysis of sea ice evolution, comparison with new satellite data and observations;
- Detailed investigation of atmosphere-ocean and atmosphere-sea ice-ocean fluxes;
- Detailed analysis of water mass exchange between the deep basins of the Baltic Sea.

8. BALTEX Data Management

8.1. 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. 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 centres and data centre functions. With upcoming grid data projects the role of the data centres may increase tremendously. There is a special need that BALTEX Data Centres be involved and cooperate with data grid projects. In this context connections between BALTEX Data Centres and WDCs (World Data Centres) such as GRDC (Global Runoff Data Centre) and GPCC (Global Precipitation Climatology Centre) will have to be further elaborated and exploited.

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

i) 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) BALTEX Hydrological Data Centre (BHDC), operated by the Swedish Meteorological and Hydrological Institute (SMHI) in Norrköping, Sweden,
iii) BALTEX RADAR Data Centre (BRDC), operated by SMHI, Norrköping, Sweden,
iv) Oceanographic Data Centre for BALTEX (ODCB), operated by SMHI, Vastra Frolunda/ Göteborg, Sweden.

8.2. Specific Data Needs for BALTEX Phase II

As specified in Chapters 1 to 4, there are specific data requirements for BALTEX Phase II. These go beyond the data needs of the first phase of BALTEX and are mostly not covered by the data centres yet. Overall there is a need to extend standard observations of atmospheric, oceanographic and hydrological parameters for longer term and detailed area coverage for extended application in climate research. In the following the specific data needs of Chapter 1 to 4 are shortly listed. Apart from the listed ones satellite data are especially important for BALTEX Phase II. The needs for this type of data are summarized in Chapter 8.3.

"Better understanding of the energy and water cycles" (Chapter 1) requires:

- Long-term and more detailed measurements of solid precipitation, snow accumulation and melting on the ground.

- Better estimates of the impact of water vapour, clouds and aerosol on the regional radiation balance.
- Inventories of trace gas and aerosols emissions as well as fluxes of nutrients and pollutants.
- Estimates of soil water, its phase and spatial and temporal distribution including the behaviour of aquifers.
- Error estimates of available runoff data.
- Continuous measurements of in- and outflow through belts and straits.

"Analysis of climate variability and change" (Chapter 2) requires:

- Extended instrumental and proxy data from the past and from recent and ongoing monitoring.
- More information of the interactions between atmosphere, land and ocean (driving fluxes).
- Data from downscaled global re-analysis and global climate simulations.

"Improved tools for water management" (Chapter 3) require:

- High quality, spatially extended, long record precipitation and temperature datasets.
- River discharge datasets on daily time steps.
- Temperature and soil moisture measurements to estimate evapotranspiration.

"Air and water quality studies" (Chapter 4) require:

- Time series of flux measurements.
- Long-term measurements of ice and snow conditions on land.
- Assessment of existing environmental data sets.
- Assessment of existing land surface characteristics and emission data.

Generally, specific data needs comprise both observational data 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. Moreover, specific archiving of data on emission, transport and deposition of *e.g.* trace gases such as nitrogen compounds and CO_2 aerosols is desirable for BALTEX Phase II. On the other hand, there exist already various data bases and data centres in charge of collecting and managing environmental data (*e.g.*, EMEP, EEA, WMO). All these will be taken into account before starting to establish new BALTEX data centres. A dedicated working group will address this issue. Additionally, the EU is currently preparing a directive (INSPIRE) to enhanced data accessibility, which may change the status of certain data.

8.3. Satellite Data

BALTEX currently has no central satellite data facility. But important satellite data are processed and held available at several organisations contributing to BALTEX including the Free University of Berlin, Germany; University of Bonn, Germany; Max-Planck-Institute for Meteorology, Germany; Swedish Meteorological and Hydrological Institute, Sweden and Chalmers University of Sweden.

The Satellite Application Facility for Climate Monitoring (CM-SAF) of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) headed by the German Weather Service (DWD) in Offenbach is a natural further candidate to be included in BALTEX. The CM-SAF generates and archives high quality data sets on a continuous basis for a) monitoring of the climate state and its variability, b) analysis and diagnosis of climate parameters to identify and understand changes in the climate system, c) input for climate models to study processes in the climate system on a European and/or global scale and for climate prediction, d) validation of climate and NWP models, and e) planning and management purposes.

The CM-SAF concentrates, however, on operational meteorological satellites with emphasis on Meteosat Second Generation (MSG) as the core satellite. The increasing importance also of non meteorological satellite data and the fast development of new sensor techniques (see below) require a dedicated BALTEX data centre function for satellite data, which will go beyond the responsibilities of the CM-SAF. This data centre should be primarily a metadata centre which informs about available satellite data by technical information and example files, possible products and expert groups to contact, data availability, data sources, and data policy. A strong cooperation with upcoming grid projects in this area of research is essential for a satellite data centre function.

At the Institute for Space Science of the Free University of Berlin, new retrieval techniques are developed and applied to different types of satellite data. To assure the quality of the products, validation exercises are performed due to cross-satellite comparisons, ground truth and aircraft measurements. The satellite data centre of the institute provides atmospheric and oceanic products derived from SEVIRI, MERIS and MODIS in near real time. All products are displayed at the internet-homepage of the Institute for Space Science. This service is not mandatory and depends on the availability of external funding. Beyond this already existing service, the Institute may be a potential candidate to take over the responsibility for the satellite data facility.

BALTEX Phase II will strongly benefit from the following new satellite data:

AMSR-E (Advanced Microwave Scanning Radiometer – Earth Observing System) is a passive microwave radiometer sensing microwave radiation (brightness temperatures) at 12 channels and 65 frequencies ranging from 6.9 to 89 GHz. AMSR-E estimates geophysical parameters supporting several global change science and monitoring efforts, including precipitation, oceanic water vapour, cloud water, near-surface wind speed, sea surface temperature, soil moisture snow cover, and sea ice parameters. All of these measurements are critical to understanding the earth climate, and thus for BALTEX Phase II.

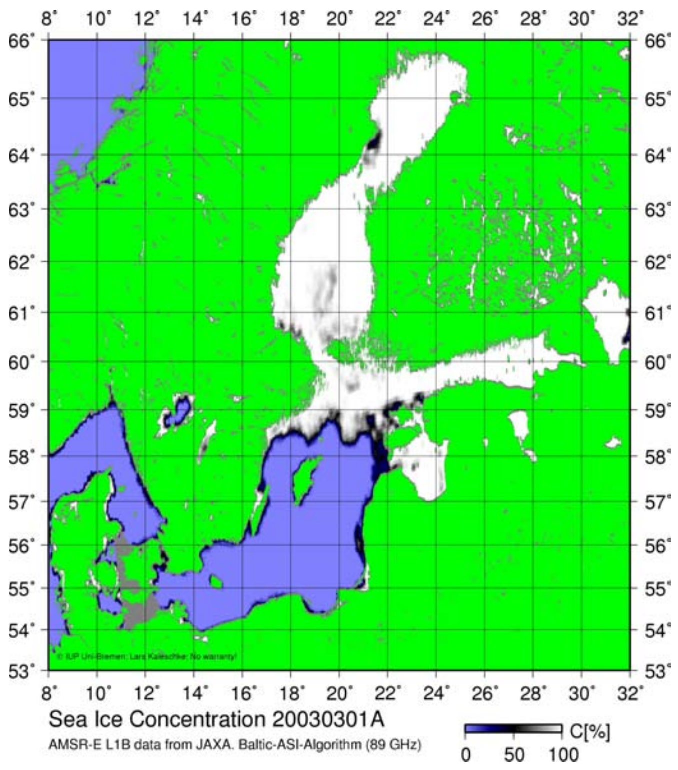

Fig. 8.1 AMSR-E sea ice map of the Baltic Sea, showing the day of maximum sea ice extent in 2003 (1 March). Daily AMSR-E sea ice maps are available via *http://iup.physik.uni-bremen.de:8084/baltic/baltic.html*

GRACE (Gravity Recovery And Climate Experiment) measures the gravity field of the Earth. This field is highly variable in both space and time, and is an integral constraint on the mean and time variable mass distribution of the Earth. GRACE is expected to lead to an improvement of several orders of magnitude in gravity measurements and to allow much improved resolution of the broad to finer-scale features of Earth's gravitational field over both land and sea. GRACE will lead to improved geoid information necessary for altimetry. The GRACE mission together with other existing sources of data will greatly improve our understanding of hydrology and oceanography, in addition to geodesy, glaciology and solid Earth sciences. Changes in soil moisture column can be retrieved for areas of 200 x 200 km with an accuracy of better than 1 cm.

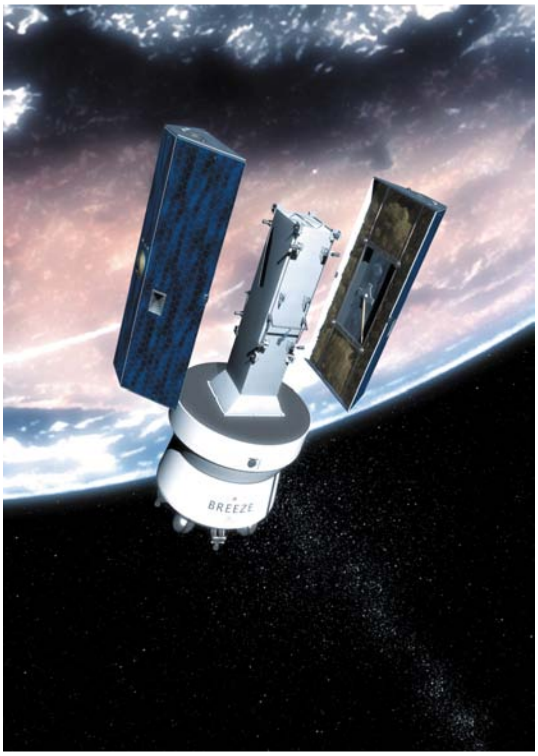

Fig. 8.2 GRACE "twins" in orbit (German Air and Space Agency, DLR)

The **GOCE (Gravity Field and Steady-State Ocean Circulation Explorer)** mission will measure high-accuracy gravity gradients and provide global models of the Earth's gravity field and of the geoid. An accurate global geoid model will contribute to an improved understanding of ocean circulation, which plays an important role in energy exchanges around the globe. It will also lead to an improved insight into sea-level changes. Both topics are relevant for BALTEX Phase II.

HYDROS (Hydrology Satellite) uses a low-frequency L-band active and passive instrument design for global mapping of soil moisture and freeze/thaw state while minimizing unwanted vegetation and atmospheric effects. HYDROS will combine the attributes of active and passive microwave sensing to meet the resolution and accuracy requirements for soil moisture and freeze/thaw state observations. Revisit time is about 3 days; climatological soil moisture estimates (passive instrument) have a resolution of 40 km, while surface condition including low quality estimates of soil moisture will be available at 5 km resolution. The satellite is planned to be launched by the end of 2009.

MERIS (Medium Resolution Imaging Spectrometer Instrument) measures the solar radiation reflected by the Earth in the visible and near infrared spectral bands. The primary mission of MERIS is the measurement of sea colour in the oceans and the coastal areas. Knowledge of the sea colour can be converted into measurements of chlorophyll pigment concentration, suspended sediment concentration and of aerosol loads over the marine domains. MERIS is also capable of retrieving cloud top height, water vapour total column, and aerosol load over land with a resolution of about 300 m and a revisit time of 3 days.

MetOp (Satellites of the EUMETSAT[6] Polar System) will carry a set of heritage meteorological instruments provided by the United States and a new generation of European instruments (*e.g.* the advanced SCATtermoeter ASCAT, or the Infrared Atmospheric Sounding Interferometer IASI) that offer improved remote sensing capabilities to both meteorologists and climatologists. The new instruments will augment the accuracy of temperature and humidity measurements wind speed and wind direction measurements, especially over the ocean, and profiles of ozone in the atmosphere. The

[6] European Organisation for the Exploitation of Meteorological Satellites

present plan is to launch three MetOp satellites sequentially to maintain the service for at least 14 years, starting in 2005.

MODIS (Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra MODIS and Aqua MODIS satellites. They are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths ranging from the visible to the thermal infrared with resolutions from 250 m to 1 km. 44 standard products are derived ranging from total water vapour content, cloud mask and top height to land and ocean surface characteristics. These data will improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere

SEVIRI (Spinning Enhanced Visible and Infrared Imager) is the main instrument on MSG (Meteosat Second Generation), the geostationary satellite observing the BALTEX region. Its mission is to continue the meteorological mission of the current Meteosat programme with enhanced performance and climate observation capability. The central 12 channel instrument SEVIRI allows climate monitoring through spectral channels providing observations of the earth's surface, observation of cloudiness, an experimental total ozone channel, and special efforts to provide high absolute radiometric accuracy of the data. The temporal resolution is 15 minutes, but spatial resolution for the BALTEX region is in the range from 5 to 20 km.

GERB (Geostationary Earth Radiation Budget) is the second instrument on board of MSG. Its measurements allow the determination of accurate broadband radiances at top of the atmosphere, both solar and terrestrial. These data can be used to evaluate in a first step all available numerical models with respect to the radiation budget at top of the atmosphere. This is necessary to quantify the available energy for the earth-atmosphere system and will therefore serve the aim of BALTEX Phase II to close the energy budget at lower uncertainty. The data can further be used to combine SEVIRI and GERB measurements to infer also radiant flux densities at surface and with some assumptions at different atmospheric levels. The temporal resolution is 15 minutes, where the spatial resolution is 44.6 x 39.3 km (North South x East West) at nadir.

Additionally, routinely produced **Eumetsat MPEF (Meteorological Products Extraction Facility)** data from MSG are available to quantify the state of the atmosphere and routinely monitor its short-time variability. The currently derived products are Atmospheric Motion Vectors (AMV), Clear Sky Radiances (CSR) and Cloud Analysis (CLA). Future products are in progress, like the Multi-Sensor Precipitation Estimate (MPE), the Global Instability Index (GII) and cloud microphysical properties. Their temporal and spatial resolution varies dependent on the inferred parameter.

SMOS (Soil Moisture and Ocean Salinity mission) will provide global maps of soil moisture and ocean salinity by capturing images of emitted microwave radiation around the frequency of 1.4 GHz (L-band). SMOS will carry the first-ever, polar-orbiting, space-borne, 2-D interferometric radiometer. Soil moisture data can be used for hydrological studies and data on ocean salinity are vital for improving our understanding of ocean circulation patterns. Data coverage and spatial resolution will be 3 days and about 40 km, respectively. SMOS is due for launch in 2007.

SSMIS (Special Sensor Microwave Imager Sounder) is the DMSP follow on instrument to DMSP SSMI/T1T2 instruments. This data can provide a variety of microwave - derived information about atmospheric temperature, moisture and precipitation as well as surface products. The information is similar to NOAA'S AMSU-A & AMSU-B instruments plus a channel at 6 GHz. Spatial resolution ranges from 15 km to 75 km depending on frequency.

Integrative activities performed within the EU-ESA initiative **GMES (Global Monitoring for Environment and Security)**, such as GEMS (Global Earth-system Monitoring using Space and *in-situ* data) or PROMOTE (PROtocol MOniToring for the GMES Service Element), should be also taken into account through dedicated coordination and/or specific collaborations.

8.4. Data Policy

It is a prerequisite for the success of BALTEX to have an open approach to the exchange of all relevant information concerning the programme. In particular, all data and data products, such as, but not limited to those obtained from operational observation networks, field experiments and process studies, as well as modelling activities and climate archives should be available as freely as possible for non-commercial research purposes within the BALTEX research community.

Meeting BALTEX Phase II objectives will require access for research to a large variety of data, see previous sections. *Data providers* are generally all organisations which create and have property rights for data relevant for the programme. *Data users* include all organisations or individuals who wish to have access data for BALTEX research. To facilitate data exchange between *data providers* and *data users*, dedicated *BALTEX Data Centres* have been established for specific, frequently required data in the fields of meteorology, hydrology and oceanography (see section 8.1). Further *BALTEX Data Centres* may be established in the future or the terms of reference for existing centres may be adapted, if required. While BALTEX *data users* generally wish to receive all types of relevant data in an unrestricted manner, with as little delay as possible and free of charge, the *data providers'* interest is generally to protect their data to a certain extent for the sake of their own (or other projects') scientific, and sometimes commercial exploitation.

A data policy for BALTEX Phase II was established in order to regulate the above outlined interests in a balanced way, see Annex 1. For this purpose, the existing BALTEX data exchange policy, which has been established and applied during BALTEX Phase I has been thoroughly revised in order to take into account both the new data requirements for Phase II of the programme to the extent presently defined (see sections 8.2 and 8.3), and existing national and international data exchange regulations with relevance for a European research programme such as BALTEX.

All countries in the Baltic Sea basin are members of the World Meteorological Organisation (WMO) and the majority of these countries are European Union (EU) member states. Denmark, Sweden, Finland and Germany are members of ECOMET (the Economic Interest Grouping of the National Meteorological Services of the European Economic Area), which has set up a detailed list of meteorological information to be exchanged and distributed including the economical value of such data. BALTEX and GEWEX belong to the project family of the World Climate Research Programme (WCRP), the latter being sponsored by WMO, the International Council for Science (ICSU) and UNESCO's Intergovernmental Oceanographic Commission (IOC). Therefore, the BALTEX Phase II Data Policy (Annex 1) makes reference to regulations of WMO, IOC, ECOMET, the European Union (EU) and United Nations (UN).

The data policy for BALTEX Phase II endorses the principle of free and unrestricted data exchange. The no-restriction principle shall in particular mean that no financial implications are involved for any BALTEX data exchange, except for delivery costs, if unavoidable. The policy limits free access to BALTEX data to certified *BALTEX data users* and defines the certification procedure, the latter is the same as already used in BALTEX Phase I.

The BALTEX Science Steering Group (BSSG), at its 17th meeting in Poznan, Poland, decided to establish a dedicated BALTEX Working Group on Data Management (BWGD). BWGD is established by and reports to the BSSG. The primary objective of the BWGD is to assist the BSSG in the coordination and facilitation of all data management activities and issues between *data providers*, data centres and *data users*, relevant for the BALTEX programme (see Chapter 9.2 for more details). A particular task for BWGD will be the establishment of a new BALTEX Data Management Plan, as a detailed extension to this Implementation Strategy.

9. BALTEX Organisational Structure

9.1. BALTEX Science Steering Group (BSSG)

BALTEX is led and managed by the BALTEX Science Steering Group. The steering group has the responsibility to organize and maintain the programme efficiently and in accordance with the general structures of GEWEX and other projects within the WCRO and ESSP. Presently (Spring 2006) it consists of 24 members, representing the major research fields of BALTEX all over the BALTEX region (for names and affiliation, see Annex II).

Terms of Reference for the BALTEX Science Steering Group are:

- To undertake all overall planning, monitoring and coordination of the BALTEX programme,
- to supervise and review the work of the various working groups and panels,
- to report to the GEWEX SSG and to the relevant national authorities,
- to provide necessary links to other relevant projects and programmes, and to assure cooperation wherever possible, and
- to promote and seek support for BALTEX.

9.2. Working Group on Data Management

The BALTEX Working Group on Data Management (BWGD) has been established in 2005. It reports to the BALTEX Science Steering Group (BSSG). The primary objective of the BWGD is to assist the BSSG in the coordination and facilitation of all data management activities and issues between data providers, data centres and data users, relevant for the BALTEX programme. The BWGD members shall represent data providers, data centres and data users in a balanced manner. The membership is at the same time expected to reflect the science disciplines contributing to BALTEX Phase II, as appropriate. The initial BWGD membership is to be found in Annex II. The BWGD will normally conduct its activities by correspondence (in particular electronic mail); however, it will meet when required, at least annually.

Terms of Reference of the BWGD are:

- To serve as the principal advisory group in all matters pertaining to BALTEX data management activities and issues and the coordination and exchange of BALTEX data among data providers, data centres and data users,
- to establish and periodically review both the terms of reference and the membership of the BGWD, to be finally approved by the BSSG,
- to revise and propose updates of the BALTEX data policy including individual data exchange restrictions and access procedures, to be finally approved by the BSSG; such propositions

should be in compliance with regulations of major international relevant organisations such as WMO,[7] ECOMET[8],and the EU directives,

- to undertake appropriate action for the implementation and continuous monitoring of the BALTEX data policy,
- to establish and maintain an inventory of BALTEX data requirements for BALTEX research,
- to facilitate the access to data for BALTEX researchers by
  - getting the BALTEX data policy known and accepted by data owners,
  - establishing and maintaining an inventory of available and new data archives and data sources,
  - developing ideas for specific data sets;
  - monitoring the performance of the BALTEX Data Centres,
- to develop and draft a BALTEX Data Management Plan, as a detailed extension to the BALTEX Phase II Implementation Plan, to be finally approved by the BSSG, and
- to initiate the establishment of and continuously review a BALTEX data management WWW website, preferably linked to the BALTEX "homepage" on WWW. This website is expected to inform on relevant data management issues for BALTEX data providers, BALTEX Data Centres and archives, as well as BALTEX data users.

For further details on BALTEX data management see Chapter 8.

9.3. Working Group on Radar

The BALTEX Working Group on Radar is successfully in place since beginning of the BALTEX programme. See Annex II for the group´s present membership. Its terms of reference are:

- To establish and maintain a structure for the exchange of radar data (not necessarily in real time), covering the BALTEX region, by proposing (i) the type of products to be exchanged and the priorities for their implementation, considering the needs for research in Meteorology, Hydrology and Oceanography, and (ii) exchange formats for the radar data in the BALTEX region,
- to maintain an inventory of radars installed in the BALTEX region and recommend ways to extend the radar coverage over the entire BALTEX region in order to meet the scientific objectives of BALTEX,
- to recommend radar related research and enhanced observation periods to meet the scientific objectives of BALTEX,
- to regularly inform and advice the BALTEX SSG about ongoing developments and progress, and
- to keep close contact with the other BALTEX working groups.

9.4. Working Group on Energy and Water Budgets

At the 18th BSSG Meeting in Lindenberg, October 2005, the establishment of a new Working Group on Water and Energy Budgets was decided. Terms of reference and membership still have to be finalized. Given here is a general description of the scope of the new working group:

During BALTEX Phase I major effort was contributed to understand the physical processes determining the water and energy budgets of the Baltic Sea and its drainage basin. Observations have been analysed, unfortunately they are not continuous in space and time. In addition, two fully coupled regional modelling systems simulating the water and the energy cycles have been developed, and successfully validated against observations.

In BALTEX Phase II, these systems can now be utilized in several ways: they can recalculate the past for example to determine the impact of the large scale circulation on the regional climate, or analyse

[7] World Meteorological Organisation
[8] The Economic Interest Grouping of the Meteorological Services of the European Economic Area

the decadal variability of the water and energy budget. For future periods, the systems can be used to dynamically downscale global climate change effects to investigate possible changes in means and extremes in the Baltic Sea region. The systems can also be used as intelligent interpolators to create climate information on the budgets in times and regions were observations are sparse.

The new working group can be seen as a core groups to initiate, collect and synthesise studies of budgets like water and energy in BALTEX. A first focus can be attributed to the analyses and understanding of the variability of the water and energy budgets on different time periods: 1999-2003, 1980-2005, 1960-2000, and 1900-2100.

Besides this activity, the new WG could establish close links to GEWEX/GHP and contribute to the global assessment of the water and energy budgets with results from BALTEX. Here, one topic could be to identify the role of the process understanding, which has been achieved within BALTEX, in the GEWEX activities. Additional activities of the WG could be to stimulate proposals and to actively look to research funding within the BALTEX area.

9.5. Working Group on BALTIC GRID

At the 18th BSSG Meeting in Lindenberg, October 2005, the establishment of a new Working Group on BALTIC GRID was decided. Terms of reference and membership still have to be finalized. Given here is a general description of the scope of the new working group:

The main task of the Working Group on BALTIC GRID will be the initiation and conduction of the pilot study. Members will be the leading scientists of the different subprojects plus one representative of the BALTEX Secretariat. The draft terms of reference are as follows:

- To conduct the BALTIC GRID Pilot study,
- to set up international collaborations,
- to initiate and conduct interdisciplinary research within BALTEX Phase II,
- to initiate resources sharing (expertise, observations including satellite and model data), and
- to promote scientific core groups for the initiation of projects funded by the EU and national funding agencies.

For details on BALTIC GRID see also Chapter 7.2.

9.6. Working Group on BALTEX Web Site Content

At the 18th BSSG Meeting in Lindenberg, October 2005, the establishment of a new Working Group on Web Site Content was decided. Terms of reference and membership still have to be finalized. Given here is a general description of the scope of the new working group:

A new objective of BALTEX Phase II under the headline „Education and Outreach“, is the dissemination of information to stakeholders, students and the general public (see Chapter 6). The internet as a basic information platform is of particular relevance in this aspect. The main challenge for a new BALTEX web site for the general public will be the „translation“ of hard science talk into a language the average educated laymen can understand and relate to.

Draft terms of reference for the new BALTEX Working group on BALTEX Web Site content are:

- To provide the technical basis for a new BALTEX web site with easily accessible different sections for scientists and the general interested public;
- to process and present scientific BALTEX results in illustrated articles so they are comprehensible and of interest for the general public,
- to propose topics of relevance to BALTEX to be presented on the web site, and
- to make provisions for the translation of the public section of the web site into the BALTEX languages.

9.7. The International BALTEX Secretariat

The International BALTEX Secretariat (IBS) as a focal support point for BALTEX is located at the GKSS Research Center in Geesthacht, Germany. The BALTEX Secretariat´s tasks cover in particular:

- To support the BALTEX Science Steering Group and all Working Groups and Panels in their activities, and to provide preliminary reviews of their work,
- to maintain connections with all participating research groups and with all operational data and numerical modelling centres for BALTEX,
- to cooperate closely with the BALTEX Data Centres in order to coordinate aspects of data storage and exchange, content of data bases, and the data exchange policy within the BALTEX research community,
- to prepare for international BALTEX meetings and provide assistance for reports to the GEWEX Science Steering Group, the JSC of WCRP and other relevant international groups, and
- to inform all participants about ongoing activities which may be of relevance to their work.

Since January 2002, GKSS is the only sponsor of the IBS, covering not only salaries for the IBS staff members (see Annex II), but also substantial infrastructure and travel support.

10. Scientific Cooperation

10.1. Overview

Since its launch in 1992, BALTEX has successfully contributed to meeting objectives of the Global Energy and Water Cycle Experiment (GEWEX). Together with seven other GEWEX Continental-scale Experiments (CSEs), BALTEX is actively participating at the GEWEX Hydrometeorology Panel (GHP) and several of its working groups. GEWEX is a global project of the World Climate Research Programme (WCRP), which has recently launched the "Coordinated Observation and Prediction of the Earth System" (COPES) initiative. COPES is a global strategy and aims at providing a frame in which all WCRP projects may contribute to joint objectives in a coordinated manner. Other WCRP projects with particular relevance for BALTEX in the COPES context are CliC and CLIVAR. BALTEX Phase II has a clearly defined commitment to contribute to WCRP/COPES, and continues therefore to be firmly anchored in GEWEX and WCRP.

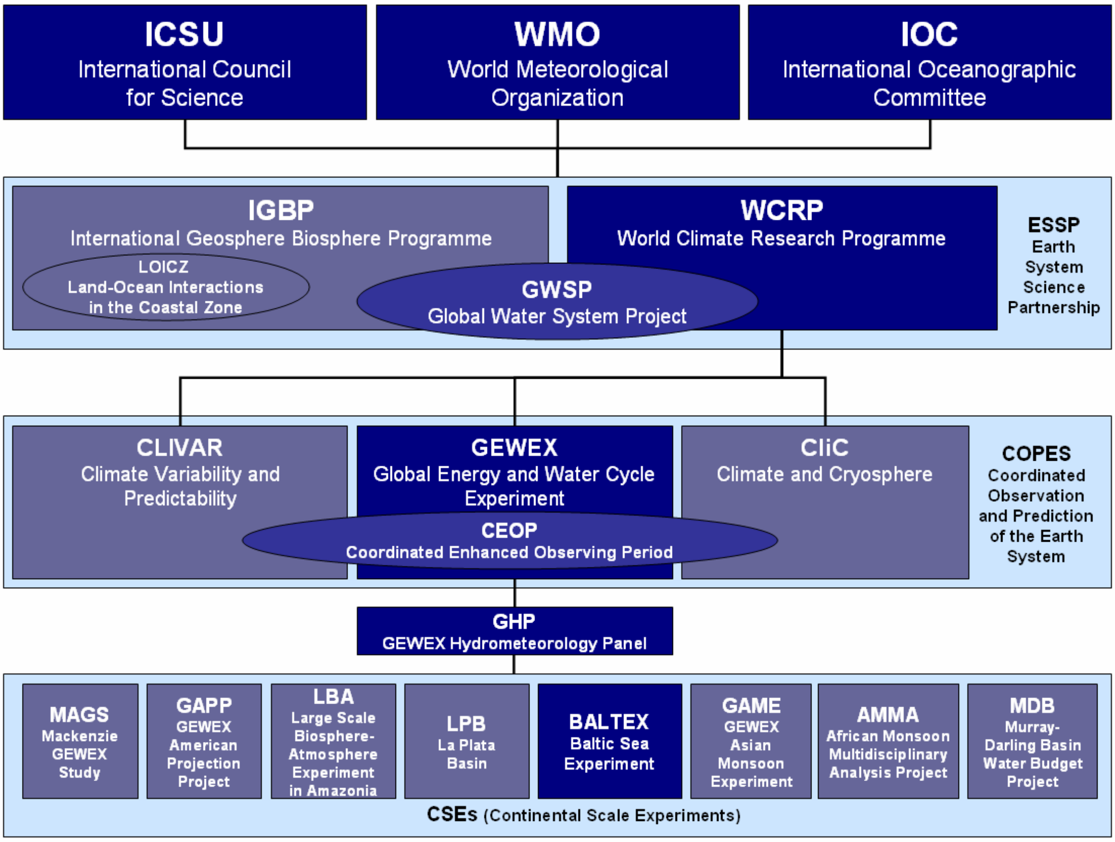

Fig. 10.1 Global and regional research programmes and projects relevant for BALTEX, as outlined here.

In particular the gradual extension of BALTEX research activities to air and water quality studies opens the option for a closer cooperation with projects of the International Geosphere-Biosphere Programme (IGBP) such as LOICZ (Land-Ocean Interactions in the Coastal Zone). Being firmly anchored in one of the global change programmes (GEWEX) and contributing to at least another global programme (IGBP), BALTEX is addressing objectives of the Earth System Science Partnership (ESSP), a joint initiative of all four coordinated global change programmes[9]. One of the joint ESSP projects (inter-programme projects) already established is the Global Water System Project (GWSP), where BALTEX intends to contribute to, in cooperation with other, in particular IGBP projects. The following sections outline the contributions and relations to the mentioned programmes and initiatives in more detail.

10.2. GEWEX

The **Global Energy and Water Cycle Experiment (GEWEX)** is a project initiated by the World Climate Research Programme (WCRP) to observe, understand, model and predict the hydrological cycle and energy fluxes in the atmosphere, at land surface and in the upper oceans. GEWEX is an integrated study ultimately contributing to WCRP's main goal of predicting global and regional climate. By definition, BALTEX is a GEWEX Continental-scale Experiment (CSE) with the overarching aim to address GEWEX objectives in a major water catchment, the Baltic Sea basin. Since its launch in 1992, BALTEX has successfully contributed to meeting objectives of GEWEX. Also GEWEX has recently revised its objectives for Phase II which is expected to span the time period until 2012. The revised objectives of GEWEX Phase II (see *e.g.* WMO, 2001) are:

- To produce consistent descriptions of the Earth's energy budget and water cycle and their variability and trends, and data sets for the validation of models,
- to enhance the understanding of how the energy and water cycle processes contribute to climate feedbacks,
- to develop improved parameterisations encapsulating these processes and feedbacks for atmospheric circulation models,
- to interact with the wider WCRP community in determining the predictability of energy and water cycles, and
- to interact with the water resource and applications communities to ensure the usefulness of GEWEX results.

It is obvious that BALTEX Phase II objectives are directly contributing to GEWEX objectives at the regional scale. For both BALTEX and GEWEX, the revised objectives for Phase II constitute a logical further development and the objectives of BALTEX Phase II have been defined in accordance with those of GEWEX Phase II. For both GEWEX and BALTEX, the improvement of process understanding and models remains a central strategic aim, thus enhancing efforts to fill existing knowledge gaps in these areas, thereby continuing to address Phase I objectives. Topics with higher importance in both GEWEX and BALTEX are now climate variability and climate change issues. Both strive to closer interact with stakeholders.

BALTEX is actively participating in the GEWEX Hydrometeorology Panel (GHP) and several of its working groups. Besides several global projects and initiatives, seven other CSEs, together with BALTEX, are contributing to GEWEX through GHP, all with a regional focus, either major rivers in different continents such as the Mackenzie, Mississippi (with an extension to the entire continental United States territories), Amazon, La Plata and Murray Darling, or climate regions of interest such as the Asian Monsoon System and West Africa. The respective CSEs include[10] MAGS (Mackenzie GEWEX Study), GAPP (GEWEX America Prediction Project), LBA (Large Scale Biosphere-Atmosphere Experiment in Amazonia), LPB (La Plata Basin), MDB (Murray Darling Basin), GAME

[9] IHDP (International Human Dimensions Programme) and DIVERSITAS (International Programme on Biodiversity Science) are not explicitly discussed here, but may have marginal relevance for BALTEX.

[10] Status as of January 2005

(GEWEX Asian Monsoon Experiment) and the recently endorsed new AMMA (African Monsoon Multidisciplinary Analysis). GHP activities encompass diagnosis, simulation, and experimental prediction of regional water budgets, process and model studies aimed at understanding and predicting the variability of the global water cycle, with an emphasis on regional coupled land-atmosphere processes. GHP efforts are also central to providing the scientific basis for assessing for example the consequences of climate change on the global hydrological cycle and its impact on regional water resources.

In summary, GEWEX will - through GHP - address the following principal scientific questions:

- Are the Earth's energy budget and water cycle changing?
- How do processes contribute to feedback and causes of natural variability?
- Can we predict these changes on timescales up to seasonal to inter-annual?
- What are the impacts of these changes on water resources?

BALTEX continues to firmly engage in GHP and GEWEX, and BALTEX progress and developments will regularly be reported to GEWEX conferences and workshops of relevant GEWEX bodies such as GHP.

10.3. CEOP

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 may be seen as the fore-runner of a new global observing and prediction system because it (1) 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, (2) involves – at present – 9 major numerical prediction centres that offer their global analyses to the scientific community, and (3) has established a global network of at present more than 30 reference sites (mostly from the CSEs) that deliver, in addition to routine observations including radio soundings, energy and water fluxes at the surface, meteorological tower and soil data. 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). Three sites have most recently stated their preliminary intention to continue providing relevant data also during the second phase of CEOP beyond 2004. Another present and future BALTEX contribution to CEOP is the maintenance of the CEOP model output data archive function provided by the Model and Data Group (a German science community service) that is in charge of the World Data Centre for Climate in Hamburg, Germany.

10.4. WCRP / COPES

The **World Climate Research Programme (WCRP)** was established in 1980 to develop the fundamental scientific understanding of the physical climate system and climate processes needed to determine to what extent climate can be predicted and the extent of human influence on climate. WCRP is cosponsored by the International Council for Science (ICSU), the World Meteorological Organization (WMO), and the Intergovernmental Oceanographic Commission (IOC) of UNESCO. The programme encompasses studies of the global atmosphere, oceans, sea and land ice, and the land surface which together constitute the Earth's physical climate system. In order to implement, coordinate and guide research activities necessary to meet WCRP objectives, WCRP has launched several global core projects. Of central importance for BALTEX is GEWEX, the Global Energy and Water Cycle Experiment, which defines those objectives at the global scale, which BALTEX aims to meet at local to continental scales, see section 10.2. Other WCRP core projects with particular relevance for BALTEX are CLIVAR (Climate Variability and Predictability) and CliC (Climate and Cryosphere).

WCRP has recently both reviewed its progress and at the same time suggested a revised research strategy for the time period to 2015 entitled **Observation and Prediction of the Earth System (COPES)**. COPES is planned to be built on existing (and future) WCRP projects, and provides a context in which scientists will be able to perform their research. Wherever possible, new experiments, studies, and observational activities will be carried out through the existing WCRP core project structure, with the option of an evolving structure, if necessary. The term 'Earth System' expresses the increasing breadth of climate system research, and it requires application of more holistic approaches to understand, model and predict the components of the climate system and their interactions.

The COPES discussion document (available *e.g.* at http://www.wmo.ch/web/wcrp/), which is currently still debated in the scientific community prior to final approval by the Joint Scientific Committee (JSC), describes several objectives and priorities which are of relevance for BALTEX. Through COPES, WCRP projects will determine the feasibility and expected skill of seasonal climate prediction in all regions of the globe with currently available models and data. This important exercise should be repeated periodically as observational systems and models evolve. Secondly, the techniques for ensemble prediction of climate variability and change will be further developed and tested. A third objective of COPES is to determine the scientific basis for, the best approaches to, and current skill of projections of regional climate change at several time scales. The WCRP Conference held in Geneva, 1997, had approved the following priorities for this decade:

- Assessing the nature and predictability of seasonal to interdecadal climate variations at global and regional scales,
- providing the scientific basis for operational predictions,
- detecting climate change and attributing causes, and
- projecting the magnitude and rate of human-induced change, *e.g.* as input for IPCC or UNFCCC.

COPES tries to implement these research priorities. COPES will use the 1979-2004-2009 period to develop reference climate data sets and advanced forecasting techniques. This period will be used for retrospective forecasts of variations on time scales up to decadal.

It is evident that in particular the second science objective of BALTEX Phase II (see Chapter 2) is directly responding to the above outlined COPES objectives and priorities. The planned establishment of an Earth System Model for the Baltic Sea basin as part of the COSMOS project, as outlined in Chapter 7.2, is designed as a BALTEX contribution to COPES.

10.5. CliC and CLIVAR

Both CliC and CLIVAR are core projects of WCRP. BALTEX Phase II includes research aspects which contribute to both projects, in particular in view of the COPES strategy outlined in the previous section.

The principal goal of the **Climate and Cryosphere (CliC)** project is to assess and quantify the impacts of climatic variability and change on components of the cryosphere and their consequences for the climate system, and to determine the stability of the global cryosphere. CliC has the supporting objectives to: enhance the observation and monitoring of the cryosphere in support of process studies, model evaluation, and change detection; improve understanding of the physical processes and feedbacks through which the cryosphere interacts within the climate system; improve the representation of cryospheric processes in models to reduce uncertainties in simulations of climate and predictions of climate change. BALTEX Phase II will contribute to CliC through sea ice modelling in a fully coupled atmosphere/ocean/land-model of a large catchment including a marginal sea with ice cover over brackish water.

Climate Variability and Predictability (CLIVAR) is the core project in WCRP for studies of climate variability, extending effective predictions of climate variability and refining the estimates of anthropogenic climate change. CLIVAR is attempting particularly to exploit the "memory" in the slowly changing oceans and to develop understanding of the coupled behaviour of the rapidly changing atmosphere and slowly varying land surface, oceans and ice masses as they respond to natural processes, human influences and changes in the Earth's chemistry and biota. CLIVAR will advance the findings of two successfully completed predecessor projects: the Tropical Ocean and Global Atmosphere (TOGA) project, and WCRP's World Ocean Circulation Experiment (WOCE).

BALTEX Phase II will contribute to CLIVAR goals mainly through the exploitation of the forecasting skill on time scales of weeks to seasons stemming from soil moisture and/or sea ice cover in a marginal sea. But also the long meteorological and hydrologic time series evaluation over a major catchment and the regional climate change scenario calculations will allow contributing to reaching CLIVAR goals.

10.6. IGBP and LOICZ

The **International Geosphere-Biosphere Programme (IGBP)** was established by the International Council for Science (ICSU) in 1986 to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human actions. IGBP constitutes another major international global environmental change programme, together with WCRP (see above), IHDP and DIVERSITAS. All four programmes have recently established the Earth System Science Partnership (ESSP), which constitutes a joint science strategy and frame for closer cooperation (see next section). IGBP provides for integration of several major global and regional research projects and has defined several core projects.

One IGBP core project is **LOICZ (Land-Ocean Interactions in the Coastal Zone)**, which was founded in 1993 with the aim to initiate, coordinate and summarize coastal research in connection with global environmental change worldwide. Four research foci were identified:

1) Effects of Changes in External Forcing or Boundary Conditions on Coastal Fluxes,
2) Coastal Biogeomorphology and Global Change;
3) Carbon Fluxes and Trace Gas Emissions;
4) Economic and Social Impacts of Global Change in Coastal Systems.

A major achievement of LOICZ research was the establishment of a coastal typology that characterizes the global coast on a grid with ½° horizontal resolution, with respect to population, water quality, soil type as well as other parameters. Another large ongoing project is the worldwide survey of more than 200 river catchments (focussing on eutrophication, erosion/sedimentation problems, loss of biodiversity and pollution) that includes parts of the Baltic Sea.

In the second phase of LOICZ ("LOICZ II", defined for 2003-2012), research will be extended to the human dimension, i.e. the interaction of human population with the coastal areas. As a consequence, LOICZ is not only a core project of IGBP, but also a core project of the International Human Dimensions Programme (IHDP). The Scientific Steering Committee of LOICZ defined the following major research areas for LOICZ II:

- Vulnerability of coastal systems and hazards to human society,
- implications of global change for coastal ecosystems and sustainable development,
- anthropogenic influences on river basin and coastal zone interactions,
- biogeochemical cycles in coastal and shelf waters, and
- towards coastal system sustainability by managing land-ocean interactions.

The Baltic Sea coast line extends over several thousand kilometres, and the "coastal area" covers a significant fraction of the Baltic Sea basin, both on the marine and terrestrial side. BALTEX research has therefore covered regional aspects of the coast of the Baltic Sea, and BALTEX Phase II will enlarge these research aspects. LOICZ integrates and has stimulated several projects with a regional focus on the Baltic Sea or parts of it. Cooperation between BALTEX and LOICZ is envisaged especially within the following two main research areas of BALTEX Phase II:

1. Research addressing the 2nd science objective of BALTEX Phase II on "*Climate variability and change*" (Chapter 2) supports in particular the aim of LOICZ II dealing with "*Climate change and impacts on the coast*". It is envisaged that regional climate change scenarios, including those of sea level rise to be developed in BALTEX Phase II, are used by LOICZ groups as boundary conditions in order to investigate the impact on coastal ecosystem and human society.

2. Within its research contributing to a "*Gradual extension to water and quality studies*" (Chapter 4), BALTEX will connect to the experience established by LOICZ studies that have dealt with rivers, the coast and the sea in the Baltic Sea basin. One example is the national Swedish multidisciplinary MARE (Marine Research on Eutrophication) project, coordinated by Stockholm University, which established catchment-coast-sea models concerning nutrient input into the Baltic Sea. MARE has established - and is further developing - an internet-based decision-support system (NEST) integrating data and model results (http://www.mare.su.se/nest/). Another example, where BALTEX Phase II will benefit from LOICZ achievements is the LOICZ Biogeochemical Budget Site (http://data.ecology.su.se/MNODE/), where regional carbon/nitrogen/phosphorus data and budget models for numerous coastal areas of the world, including the Baltic Sea basin, have been compiled that can be used to produce global syntheses models of fluxes in the coastal zone. The knowledge built up in ecosystem modelling for the Baltic Sea is huge and BALTEX will establish cooperation with major institutions having experience in this field, such as Stockholm University, the Baltic Sea Research Institute (IOW) in Warnemünde, Germany, and the Finnish Institute for Marine Research (FIMR) in Helsinki, Finland.

BALTEX will establish links to and cooperation with other ongoing and future projects established in the frame of LOICZ and IGBP with a regional focus on the Baltic Sea basin, whenever of benefit for the participants and helpful to understand physical and biological aspects of the Baltic Sea basin using a holistic approach. The Baltic Sea basin is currently[11] proposed to become an IGBP Integrated Regional Study Area, where closer links to regional LOICZ studies in the Baltic Sea coastal regions are desirable.

10.7. ESSP and GWSP

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)** with the overarching aim to bring together researchers from diverse fields, and from across the globe, to undertake an integrated study of the Earth System, its structure and functioning; the changes occurring to the System; and, the implications of those changes for global sustainability. ESSP has undertaken to define joint projects with a focus on aspects of global change that are critical to human well-being, thereby drawing on the experience established in the four founding Global Change Programmes. ESSP Joint Projects are designed to span the interface between global change and global sustainability issues, while also gathering new knowledge about how specific processes function within the larger Earth System.

One of these is the **Global Water Systems Project (GWSP)**, which forms an ideal umbrella for the development of BALTEX Phase II as it combines all scientific disciplines dealing with climate and water research from a physical, biological and chemical point of view with social sciences aspects of water and land use. The Scientific Framework of GWSP (GWSP, 2005) identifies promising areas for close cooperation between GEWEX, and thus BALTEX, and GWSP. Based on this analysis and array of areas, BALTEX and GWSP could exploit synergies in the following fields, which were defined in close cooperation with the GWSP International Project Office:

[11] In early 2005, prior to publication of this document.

1) *Developing coupled models of changes in climate, land cover and hydrological processes.* The aim of this research, which should also include the development of scenarios, is to better understand the impacts of changes on regional climate, runoff, and water quality, and to determine the best management responses for conserving water.
2) *Creating inventories of surface water storage and its changes*. Such inventories, based on new satellite sensors and data processing methodologies as utilized by BALTEX, can be employed in the decision support systems planned by GWSP.
3) *Developing datasets of climate variability*. Datasets of historical climatic variability derived from satellite data, as well as datasets of possible future climate variability based on scenario-driven model outputs, are important to investigations of water-management strategies. Because the development of these kinds of datasets is very time consuming and expensive, data and experience should be shared between BALTEX and GWSP.
4) *Identifying impacts of water management.* The aim is to answer the question whether long term trends in runoff can be explained by changes in human manipulation of rivers or by variability/changes in climate. For this research long term datasets of climate and hydrologic variables obtained through BALTEX could be analysed in cooperation with GWSP.
5) *Utilizing regional climate models*. GWSP analyses the water system on the global scale. Since water management decisions are taken at local or regional scale, BALTEX regional climate model results could be incorporated into GWSP global analyses.
6) *Assessing climate change impacts on water availability*. The knowledge derived from BALTEX analysis of climate change will contribute to activities on climate change and water resources in GWSP. On the other hand, GWSP could contribute to BALTEX research by providing large scale scenarios for land and water use and by cooperating in reconstructions of historical climate.
7) *Investigating the effects of urbanisation on water resources*. Urbanisation has impacts on water systems, local water availability, and regional climate. Both BALTEX and GWSP are interested in a better understanding of various aspects of the water cycle and therefore could cooperate in the assessment of the important urbanization impacts on water resources.

In addition to the above topics, BALTEX and GWSP could cooperate in *developing tools*, such as databases or decision-support systems. Cooperation concerning *stakeholder involvement* and *education* and *outreach* activities at the international level could also be very fruitful.

10.8. PUB and IAHS

The research programme **Predictions in Ungauged Basins (PUB)** has been launched by the **International Association of Hydrological Sciences (IAHS)** as a decadal initiative aiming at reduced uncertainty in hydrological predictions. Predictions in hydrology address water quantity and quality, surface and groundwater, snow and ice, erosion and sedimentation etc. PUB is scientifically driven but at the same time a policy relevant science expected to make a significant contribution to sustainable management of water resources throughout the world. Although PUB has its own scientific agenda, it cooperates closely with other programmes as for example UNESCO's international hydrological programme HELP (Hydrology for the Environment, Life and Policy). PUB has an open structure building on the efforts of self-organised working groups and is coordinated by a scientific steering group.

The PUB science programme focuses on the estimation of predictive uncertainty, which in many basins can be considerable for a number of reasons, including the lack of measured key-variables like stream flow. Generally, a prediction system includes (a) a hydrological model that describes the processes of interest; (b) a set of model and landscape parameters; and (c) a model forcing, *e.g.* a set of meteorological input values that drive the model. The predictive uncertainty is caused by (1) errors in the model forcing; (2) an imperfect model structure; (3) the use of non-optimal model parameters; and (4) errors in measurements used for model calibration. It originates from an insufficient observational basis and modelling limitations caused by the inherent multi-scale heterogeneity of the hydrological system both in space and time. PUB puts focus on improved understanding of the hydrological system and development of new methods for quantification of hydrological variables. The expected outcome includes a new generation of hydrological models and efficient utilisation of the rapidly expanding remote sensing opportunities. By the end of the decade PUB is foreseeing new innovative methods for hydrological predictions with significant reductions in the predictive uncertainty.

The hydrological modelling efforts in BALTEX should be connected to PUB. BALTEX can provide regional hydrological model studies and related model development. More importantly, by cooperation with PUB, BALTEX can benefit from the experience obtained in other research groups, thereby accelerating improvements for research in both studies.

10.9. EU Projects

Several projects launched and funded through the 5th and 6th Framework Programmes for Research of the European Union (EU) are directly and indirectly contributing to BALTEX objectives. It is expected that the forth-coming 7th EU Framework Programme will also open funding possibilities for projects addressing BALTEX Phase II objectives.

An important example of a recently started project is *Ensemble-based predictions of climate changes and their impacts* (ENSEMBLES), which will be outlined here in more detail.

The ENSEMBLES project is a major Integrated Project funded through FP6 (6th Framework Programme of the European Commission) with the main objective of assessing modelling uncertainties quantitatively by creating large simulation ensembles using both global and regional models with a focus on the European area; these simulations will be used to formulate probabilistic climate change statements. As such, the project does not focus on the BALTEX region, but one outcome of ENSEMBLES will be the existence of a large quantity of regional model simulations generated in a systematic way and covering the BALTEX region. The ENSEMBLES project started in September 2004 and will continue for 5 years.

At least 9 regional models will be used in scenario mode for Europe and the period 1950-2050, three of these even 1950-2100, at around 20 km resolution. Prior to this, regional models are evaluated in the context of downscaling the ERA-40 re-analysis. Both of these exercises will generate a wealth of data that can be used also in BALTEX research.

Apart from the modelling, many impact models will be using model output in the ENSEMBLES project. The studies include hydrological, agricultural, wind energy/damage impact models. Since several groups and organisations which are actively participating to BALTEX also participate in ENSEMBLES, the Baltic area will be covered by several analyses, though the exact details are not determined yet. Through of ensembles of climate change simulations, statements of probabilistic nature will also be possible for the output of impact models.

Another example is the *European Network of Excellence for Ocean Ecosystem Analysis (EUR-OCEANS).* EUR-OCEANS is an EU funded Network of Excellence under Framework 6, organized in work packages and regional „systems“, one of which is the Baltic Sea. The overall networking objective of EUR-OCEANS is to achieve lasting integration of European research organisations on global change and pelagic marine ecosystems and the relevant scientific disciplines. Presently, there are 160 EUR-OCEANS principal investigators at 66 member organisations, located in 25 countries.

The overall scientific objective of EUR-OCEANS is to develop models for assessing and forecasting the impacts of climate and anthropogenic forcing on food-web dynamics (structure, functioning, diversity and stability) of pelagic ecosystems in the open ocean. To reach this goal, EUR-OCEANS will favour the progressive integration of research programmes and facilities of major research institutes in Europe. The joint programme comprises networking, data, and model integration, jointly executed research on pelagic ecosystems end-to-end, biogeochemistry, an ecosystem approach to marine resources and within-system integration. Furthermore, activities to spread excellence are targeted at researchers (training and education), socio-economic users, and the public.

A close collaboration between the BALTEX and the EUR-OCEANS networks with respect to some research fields, especially modelling hydrographical, atmospheric and oceanographic processes, as well as the integration of these processes into biogeochemical modelling systems, will be of mutual benefit. A common goal is to study the impacts of climate change on the biogeochemistry and ecology of the Baltic Sea.

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12. List of Acronyms and Abbreviations

AMMA	African Monsoon Multidisciplinary Analysis
AMSR-E	Advanced Microwave Scanning Radiometer - EOS
AMSU	Advanced Microwave Sounder Units
AMV	Atmospheric Motion Vectors
AQUA	NASA satellite
ASCAT	Advanced SCATterometer
AVHRR	Advanced Very High Resolution Radiometer
BACC	BALTEX Assessment of Climate Change for the Baltic Sea Basin
BALTEX	Baltic Sea Experiment
BALTRAD	BALTEX Radar Network
BALTIMOS	German research project: "A coupled model system in the Baltic Region"
BHDC	BALTEX Hydrological Data Centre
BMDC	BALTEX Meteorological Data Centre
BRDC	BALTEX Radar Data Centre
BRIDGE	The major enhanced observational period within BALTEX
BSSG	BALTEX Science Steering Group
BWGD	BALTEX Working Group on Data Management
CEOP	Coordinated Enhanced Observing Period
CHAMP	Challenging Mini satellite Payload
CLA	Cloud Analysis
CliC	Climate and Cryosphere
CLIVAR	Climate Variability and Predictability
CM-SAF	Satellite Application Facility for Climate Monitoring
COPES	Coordinated Observation and Prediction of the Earth System

COSMOS	Community Earth System Models
COST	European Cooperation in the field of Scientific and Technical Research
CSE	Continental-scale Experiment
CSR	Clear Sky Radiances
DAAD	German Service for Academic Exchange
DIVERSITAS	International Programme of Biodiversity Science
DMSP	Defence Meteorological Satellite Program
DWD	German Weather Service
ECHAM4/OPYC3	A coupled global atmospheric/ocean circulation model
ECMWF	European Centre for Medium-Range Weather Forecasts
ECOMET	Economic Interest Grouping of the National Meteorological Services of the European Economic Area
EEA	European Environment Agency
EGPM	European Global Precipitation Measurement
EMEP	Cooperative programme for monitoring and evaluation of the Long-range transmissions of air pollutants in Europe
ENSEMBLES	Ensemble-based predictions of climate changes and their impacts – EU Project
EOS	Earth Observing System
ERA-40	40 years re-analysis data set provided by the ECMWF
ERS	European Remote Sensing Earth Observation Satellites
ESM	Earth System Model
ESSP	Earth System Science Partnership
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EUR-OCEANS	European Network of Excellence for Ocean Ecosystems Analysis
EU	European Union
FIMR	Finnish Institute of Marine Research
FMI	Finnish Meteorological Institute
GAME	GEWEX Asian Monsoon Experiment
GAPP	GEWEX America Predictions Project
GCM	Global Circulation Model
GERB	Geostationary Earth Radiation Budget
GEWEX	Global Energy and Water Cycle Experiment
GHP	GEWEX Hydrometeorology Panel
GII	Global Instability Index
GEMS	Global Earth-system Monitoring using Space and *in-situ* data
GMES	Global Monitoring for Environment and Security
GOCE	Gravity Field and Steady-State Ocean Circulation Explorer
GPCC	Global Precipitation Climatology Centre
GPM	Global Precipitation Mission
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GRDC	Global Runoff Data Centre
GWSP	Global Water System Project
HadAM3H	A global circulation model
HELCOM	Baltic Marine Environment Protection Commission (Helsinki Commission)
HELP	Hydrology for the Environment, Life and Policy
HIRHAM	A regional atmospheric climate model
HYDROS	Hydrology Satellite
IAHS	International Association of Hydrological Sciences
IASI	Infrared Atmospheric Sounding Interferometer
ICES	International Council for the Exploration of the Seas
ICSU	International Council for Science
IGBP	International Geosphere – Biosphere Programme
IHDP	International Human Dimensions Programme
IMO	International Maritime Organization

INSPIRE	Infrastructure for Spacial Information in Europe
INTERREG	Funding programme to stimulate interregional cooperation in the EU
IOC	Intergovernmental Oceanographic Commission
IOW	Baltic Sea Research Institute Warnemünde, Germany
IPCC	Intergovernmental Panel on Climate Change
LBA	Large Scale Biosphere-Atmosphere Experiment in Amazonia
LOICZ	Land-Ocean Interactions in the Coastal Zone
LPB	La Plata Basin
MAGS	MacKenzie GEWEX Study
MARE	Marine Research on Eutrophication
MDB	Murray Darling Basin
MEAD	Marine Effects of Atmospheric Deposition (Stockholm University)
MERIS	Medium Resolution Imaging Spectrometer Instrument
MetOp	Satellite of the EUMETSAT Polar System
MODIS	Moderate Resolution Imaging Spectroradiometer
MPE	Multi-sensor Precipitation Estimate
MPEF	Meteorological Product Extraction and Distribution Service
MPI-M	Max-Planck-Institute for Meteorology
MSG	Meteosat Second Generation
NASA	National Aeronautics and Space Administration
NaT-Working	Cooperation between natural scientists and secondary schools in Germany
NCEP	National Centre for Environmental Predictions, USA
NEST	MARE´s internet-based decision-support system
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
ODCB	Oceanographic Data Centre for BALTEX
PAR	Photosynthetically Active Radiation
PIDCAP	Pilot Study for Intensive Data Collection and Analysis of Precipitation
POMOR	Russian-German Master program for applied polar and marine sciences
POP	Persistent Organic Pollutant
PUB	Prediction in Ungauged Basins
PRISM	Programme for Integrated Earth System Modelling
QPF	Quantitative Precipitation Forecast
RCAO	Regional Coupled Atmosphere-Ocean Model
RCM	Regional Climate Model
SAF	Satellite Application Facilities
SeaWIFS	Sea-viewing Wide Field-of-view Sensor
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SMHI	Swedish Meteorological and Hydrological Institute
SMMR	Scanning Multi-channel Microwave Radiometer
SMOS	Soil Moisture and Ocean Salinity mission
SRES-A2	Special Report on Emission Scenarios – High emission scenario
SSG	Science Steering Group
SSM/I	Special Sensor Microwave Imager
SSMIS	Special Sensor Microwave Imager Sounder
TERRA	NASA Satellite
TOGA	Tropical Ocean and Global Atmosphere Project
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WCRP	World Climate Research Programme within ESSP
WDC	World Data Centre
WMO	World Meteorological Organisation
WOCE	World Ocean Circulation Experiment
YAXA	National Space Administration of Japan

ANNEX I: BALTEX Phase II Data Policy

Meeting BALTEX Phase II objectives will require access for research to a large variety of data. Data providers are generally all organisations which create and have property rights for data relevant for the programme. Data users include all organisations or individuals who wish to have access data for BALTEX research. To facilitate data exchange between data providers and data users, dedicated BALTEX Data Centres have been established for specific, frequently required data necessary to meet BALTEX objectives as detailed in the BALTEX Science and Initial Implementation Plans.

CONSIDERING the need for free and unrestricted exchange of information for research between the participants of BALTEX as a condition for success and for the possibility to achieve the objectives of the Programme,

NOTING that the majority of the participants of the BALTEX Programme are situated in member countries of the European Union, that all the participant are situated in countries that are members of the World Meteorological Organisation (WMO), and, Denmark, Finland, Germany and Sweden are members of the European Cooperation in Meteorology (ECOMET),

NOTING ALSO that 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),

NOTING FURTHER the WMO Data 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),

NOTING FURTHER the IOC Oceanographic Data Exchange Policy, in particular Resolution IOC-XXII-6 of the 22nd session of the IOC assembly held 2003,

RECOGNIZING the UN/ECE Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters, dated 25 of June 1998, (the Aarhus Convention), and the Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information and repealing Council Directive 90/313/EEC,

RECOGNIZING ALSO that the definitions of Environmental Information established by both the Aarhus Convention and by the Directive 2003/4/EC on public access to environmental information includes all information handled within the BALTEX Programme,

BEARING IN MIND the Directive 2003/98/EC of the European Parliament and of the Council of 17 November 2003 on the re-use of public sector information encouraging the member states to make available more publicly held information for re-use, and

EMPHASIZING the principle of free and unrestricted exchange of information as paramount for all research and education,

THE EXCHANGE OF INFORMATION BETWEEN DATA PROVIDERS, BALTEX DATA CENTRES AND BALTEX DATA USERS SHALL BE UNDER THE FOLLOWING CONDITIONS:

ARTICLE 1: Definitions

For the purposes of this Data Policy,

1.1 *BALTEX Data* means any information in written, visual, oral, electronic or any other form:

- On the state of the elements of the environment, such as air and atmosphere, water, soil, land, diversity and its components, including chemical substances, and the interaction among these elements;
- from the Baltic Sea, it's drainage basin or an area large enough to run regional Climate models covering the Baltic Sea Basin,

- necessary for research purposes to meet BALTEX objectives as detailed in the BALTEX Phase II Science and Initial Implementation Plans.

BALTEX data comprise observed *in situ* and remote sensing data, model output, and any product of the latter.

BALTEX Data also include all additional metadata information.

1.2 *Data Providers* are organisations or individuals who create, have property rights for and agree to share *BALTEX Data* by delivering *BALTEX Data* either to *BALTEX Data Centres* or directly to *BALTEX Data Users*.

1.3 *BALTEX Data Users* are organisations or individuals who wish to have access to *BALTEX Data* for their own BALTEX research purposes, which has been qualified as an official BALTEX project. The certification as a *BALTEX Data User* follows a specific procedure outlined in Appendix 1.

1.4 To facilitate data exchange between *Data Providers* and *BALTEX Data Users*, a limited number of dedicated *BALTEX Data Centres* have been established for specific, frequently required *BALTEX Data*. By definition, *BALTEX Data Centres* may either redistribute *BALTEX Data* to *BALTEX Data Users* or identify *Data Providers* for direct data exchange between the latter and *BALTEX Data Users*.

ARTICLE 2: Exchange of Information

Any *Data Provider* and *BALTEX Data Centre* receiving a request from a *BALTEX Data User* to provide *BALTEX Data* to be used for research purposes within the BALTEX programme shall execute such a request without undue delay.

BALTEX Data Centres may redistribute *BALTEX Data* only to *BALTEX Data Users*.

ARTICLE 3: Charges

Concerning data delivery to *BALTEX Data Centres*: No financial reimbursement may be charged for the delivery.
Concerning data delivery and re-distribution to *BALTEX Data Users*: No financial re-imbursement other than delivery costs may be charged for the delivery.

ARTICLE 4: Restrictions

4.1 It is understood that *BALTEX data* shall be delivered to *BALTEX Data Centres* and re-distributed to *BALTEX data users* only for scientific studies designed to meet BALTEX objectives. Commercial use and exploitation of *BALTEX data* by either the *data users* or the *BALTEX Data Centres* is prohibited, unless specific permission has been obtained from the *data providers* concerned in writing.

4.2 The re-export or transfer of *BALTEX data* (as received from either *data providers* and/or *BALTEX Data Centres*) between a *BALTEX data user* and any third party is prohibited.

4.3 *BALTEX data user* shall properly acknowledge and make reference to the origin of *BALTEX data*, whenever the latter are used for publication of scientific results. A minimum requirement is to reference the BALTEX programme and the respective *BALTEX Data Centre*, or *BATEX Data Centres.*

APPENDIX

BALTEX Data User identification

An important restriction is that *BALTEX data* will be passed only to registered *BALTEX Data Users.* Identification of *BALTEX Data Users* will be done by members of the BALTEX SSG only, as was decided at the 4th meeting of the BALTEX SSG (June 1996, Sopot, Poland). A list of registered *BALTEX Data Users* will be stored at the BALTEX Secretariat and at the *BALTEX Data Centres*. Registration as a *BALTEX Data User* is performed upon request of the user and is subject to the following procedure.

Identification of *BALTEX Data Users* must be on the department level and has to include the name of the Principle Investigator, his/her complete address, the participants at the BALTEX project in question who will work directly with *BALTEX data*, and a short description of the project the *BALTEX data* are needed for. A specific *BALTEX data user* identification form has been established which is mandatory to be used for the identification process. The project description should be short; the entire completed form must not be longer than one page. The request has to be approved by at least one member of the BALTEX SSG preferably from the same country as the potential *BALTEX data user*. In the course of the project any change of the research group membership has to be notified to the BALTEX Secretariat.

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Photo credits

Cover (centre and clockwise from top): A cyclone over the eastern Baltic Sea basin (SeaWiFS Project, NASA/Goddard Space Flight Centre, GeoEye); Rostock harbour in winter (Marcus Reckermann, GKSS); A storm front over the Baltic Sea (Riku Lumiaro, FIMR); A blue-green algae bloom in the Gulf of Finland (Riku Lumiaro, FIMR); The Odra river on 22 July 1997 near Czelin, Poland (A. Kwapiszewski, from: Dubickiego A, Sloty H. and Zielinskiego J. (Eds.): Dorzecze Odry – Monografia Powodzi Lipiec 1997, Instytut Meteorlogii I Gospodarki Wodnej, Poland); Melting ice in spring in a Swedish lake (Holger Nitsche, Berlin). *Page 11:* April in the Schlei Fjord, western Baltic Sea (Marcus Reckermann, GKSS). *Page 18:* A mountain creek in northern Sweden (Christine Dorka, Hamburg). *Page 19:* Rain shower in northern Sweden (Holger Nitsche, Berlin). *Page 21:* A cyclone over the eastern Baltic Sea basin (SeaWiFS Project, NASA/Goddard Space Flight Centre, GeoEye). *Page 28:* The advance of spring at the Porkkala Peninsula, Gulf of Finland (Hanna Virta). *Page 34:* Drowned homestead in the Odra depression, Germany, after the devastating flooding event of July 1997 (ddp). *Page 40:* Rostock harbour in winter (Marcus Reckermann, GKSS). *Page 41:* Cyanobacterial bloom in the Balic Proper on 11 July 2005 (Modis/Aqua by NASA, modified by SMHI). *Page 49:* Power plant Jänschwalde in the Lusitania region, Germany (Vattenfall). *Page 53:* Students from local schools are introduced to Baltic Sea research with sea excursions complementing class projects at school, an initiative of "NaT-Working Marine Research" at IFM-GEOMAR in Kiel, Germany, here in cooperation with "Hohe Tied e.V." (Avan Antia, IfM-GEOMAR). *Page 56:* Rostock harbour entrance with lighthouse (Marcus Reckermann, GKSS). *Page 62:* The Baltic Sea and most of its basin seen from space on 1 April 2004 (SeaWiFS, NASA/Goddard Space Flight Centre, GeoEye). *Page 68:* The Rapa river delta, Northern Sweden (Sven Dietrich, Dresden). *Page 72:* A cable ferry across the Vistula river, Poland (Hans-Jörg Isemer, GKSS).

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