

## BALTEX: 20 Years and Two Successful Phases in Baltic Sea Regional Studies

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The Baltic Sea Experiment (BALTEX) was founded in 1993 to study the hydrological cycle and energy fluxes between the atmosphere and the land surface, including rivers and lakes. It has been a GEWEX project since its creation and is the only Regional Hydroclimate Project (RHP) with an oceanographic focus centered on the Baltic Sea.

In its almost 20 years of existence, BALTEX has undergone remarkable development. Phase I (1993–2002) focused exclusively on hydrometeorological research—exploring and modeling the various mechanisms determining the space and time variability of energy and water budgets of the Baltic Sea region (BALTEX 1994). Ten years later, the scope of BALTEX was extended to topics related to climate variability and change, and water management and biogeochemistry, then termed “air and water quality” (Phase II, BALTEX 2004, 2006a). Further new aspects were the strengthened interaction with decision makers with an emphasis on regional climate change impact assessments, and education and outreach at the international level. Thus, the scope of BALTEX has been broadened considerably, with a dedicated extension to matter fluxes, regional climate change assessments, and outreach activities (Reckermann et al., 2011).

### *BACC and BACC II*

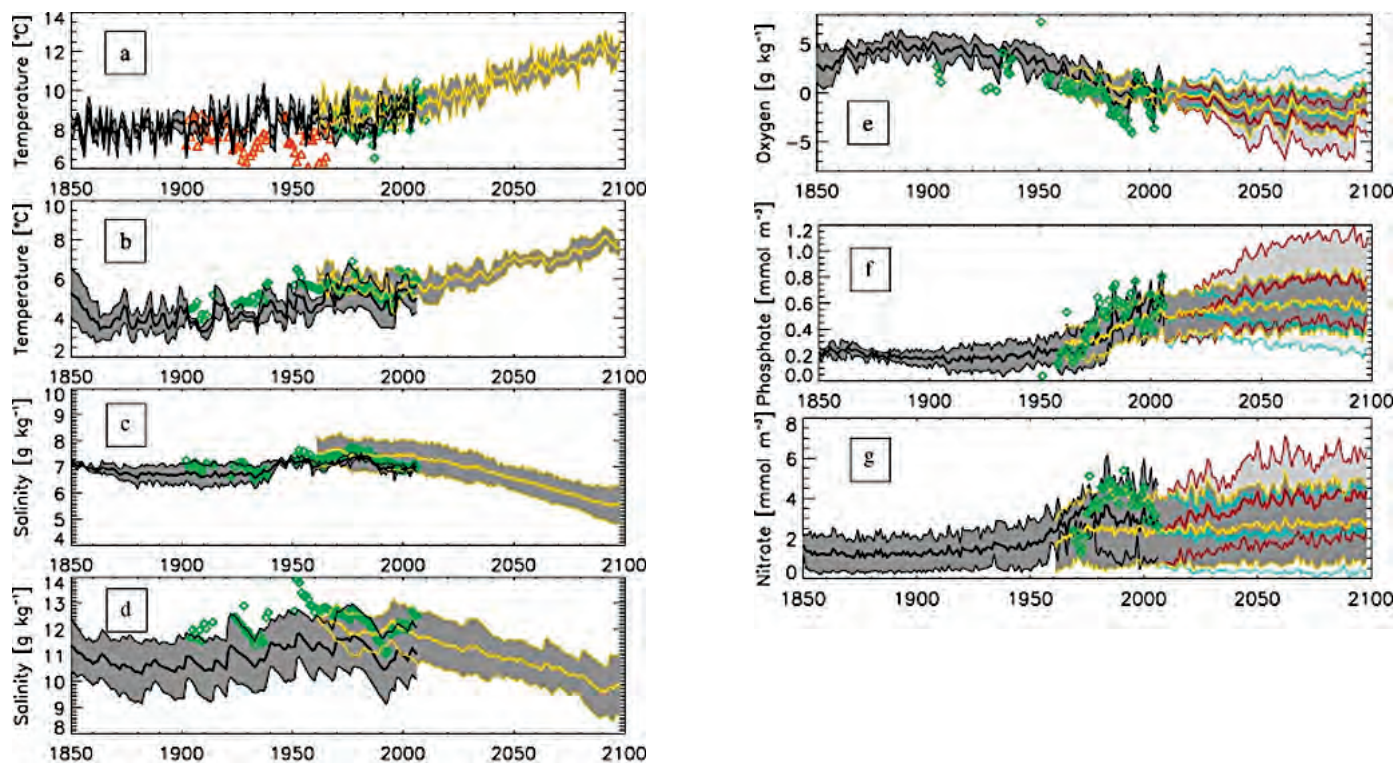
The aim of the BALTEX Assessment of Climate Change for the Baltic Sea Basin (BACC) is to bring together consolidated knowledge on climate change and its effects on the Baltic Sea Basin. The first BACC report was compiled by a consortium of 84 scientists from 13 countries neighboring the Baltic Sea (BACC Author Team, 2008) and covers various disciplines related to climate research and related impacts. The Baltic Sea region represents an old cultural landscape and the Baltic Sea itself is among the most studied areas in the world. Thus, there is a wealth of information in thousands of publications, concerning past climate conditions in the region. A large part of the information had not been available to the English-speaking research community, as the eastern part of the Baltic Sea Basin had been behind the “iron curtain” until the early 1990s. The challenge was to install a writing team that could do “paper mining” in its home countries and compile the material into a comprehensive, well-written assessment book. Besides looking at past and current climate change, the BACC report presents climate projections until the year 2100 using the most sophisticated regional climate models available, and an assessment of climate change impacts on terrestrial, freshwater, and marine ecosystems of the Baltic Sea basin. Now, six years after its publication, an update to the BACC book is in preparation.

In BACC II, scheduled for publication in 2014, more than 100 contributing authors will assemble the latest knowledge on climate change and its impacts in the Baltic Sea region and will integrate it with the findings of the first BACC report. Some of the aspects that will be emphasized in BACC II include sea level change, socio-economic impacts, impacts on urban regions, and an attempt to attribute regional impacts to anthropogenic climate change. The chapters are peer reviewed, and will be presented and discussed at the international BACC II Conference in Tallinn, Estonia in September 2012. For a summary of BACC, see BALTEX 2006b and Reckermann et al., 2008. Recent information on BACC II is available at: <http://www.baltex-research.eu/BACC2/>.

### *The BONUS Projects*

BONUS is a funding scheme of the European Commission and national funding organizations established to “integrate Baltic Sea system research into a durable, cooperative, interdisciplinary, well-integrated, and focused multinational program in support of the region’s sustainable development” (<http://www.bonusportal.org>). Three BALTEX projects have been funded thus far, which are all concerned with the impact of the changing conditions in the future on the marine environment of the Baltic Sea: (1) the Assessment and Modeling of Baltic Ecosystem Response (AMBER); (2) Baltic-C; and (3) the advanced modeling tool for scenarios of the Baltic Sea Ecosystem to support decision-making (ECOSUPPORT). The latter two are briefly described below. They all contribute to the vision of a regional Earth Model System, but also have a very practical relevance for exploring options for developing software tools and models.

The goal of ECOSUPPORT is to assess the combined future impacts of climate change and industrial and agricultural practices in the Baltic Sea catchment basin of the Baltic Sea ecosystem. The major output of ECOSUPPORT is a multi-model system tool to support decision makers. The tool is based on scenarios from an existing state-of-the-art coupled atmosphere-ice-ocean-land surface model for the Baltic Sea catchment area, marine physical-biogeochemical models of differing complexity, a food web model, statistical fish population models, and new data on climate effects on marine biota. It is a challenging new approach to integrate different model “worlds” in order to generate benefits for Baltic Sea management. **The results suggest that the impact of changing climate on Baltic Sea biogeochemistry might indeed be significant** (see figure on page 10). The projected warming of the Baltic Sea is an important driver in relation to eutrophication and it is expected to reduce its water quality in terms of the chosen ecological quality indicators. According to the results, the efficiency of nutrient load reductions will be smaller in a future climate compared to the present climate, emphasizing the need for political action to reduce nutrient flows into the Baltic Sea (Meier et al., 2012a; Wake, 2012). A compilation of papers has just been published (“ECOSUPPORT—Different Ecosystem Drivers under Future Climate Scenarios in the Baltic Sea,” AMBIO Special Issue; see also



Simulated ensemble averages and observed annual mean water temperatures (a, b) and salinities (c, d) at Gotland Deep in the central Baltic Sea at 1.5 m (a, c) and 200 m (b, d) depth, annual mean oxygen concentrations at 200 m depth (e), and winter (January–March) mean surface phosphate (f) and nitrate (g) concentrations. Shaded areas denote the ranges of plus/minus one standard deviation around the ensemble averages.

The various nutrient load scenarios (1961–2098) are shown by colored lines (REF–yellow, BSAP–blue, BAU–red) and the reconstruction (1850–2006) by the black line. Nutrient load scenarios were calculated as:

- REF – current nutrient concentrations in rivers and current atmospheric deposition;
- BSAP – reduced nutrient concentrations in rivers following the Baltic Sea Action Plan (HELCOM, 2007b) and 50 percent reduced atmospheric nitrogen deposition;
- BAU – business-as-usual for loads from rivers assuming an exponential growth of agriculture in all Baltic Sea countries and current atmospheric deposition.

For comparison, observations from monitoring cruises at Gotland Deep [green diamonds, in panel (a) since 1970 only] and from the ship Svenska Björn, operated during 1902–1968 [orange triangles in panel (a)], were used (from Meier et al., 2012a).

Meier et al., 2012b). For more information, see the website at: <http://www.baltex-research.eu/ecosupport/>.

The overall objective of Baltic-C (building predictive capability regarding the Baltic Sea organic/inorganic carbon and oxygen systems) is to improve our understanding of the Baltic Sea carbon system, including the acid-base (pH) balance. This is done by developing and applying a new integrated ecosystem model framework based on the cycling of organic carbon ( $C_{org}$ ) and carbon dioxide ( $CO_2$ ) in the Baltic Sea and its drainage basin, taking into account fluxes across the atmosphere and sediment interfaces. Seawater pH is among the most important factors controlling life in marine systems, and acidification could severely alter and threaten marine ecosystems. Understanding pH changes in coastal regions characterized by high biological production and various anthropogenic mechanisms, such as climate change, land-use change, eutrophication, and over-

fishing, is therefore crucial. The overall aim of Baltic-C is to provide a tool which can be used to support the management of the Baltic Sea. For more information, see the Baltic-C website at: <http://www.baltex-research.eu/baltic-c/>.

#### Outreach Activities

The outreach activities in BALTEX Phase II have been manifold. BALTEX scientific conferences, summer schools, and publications in peer-reviewed journals, conference proceedings, books, a BALTEX publication series, and a newsletter are regular outreach channels. Collaborations with political stakeholders have been a special emphasis during recent years.

In connection with BACC and BACC II, there is close collaboration with the intergovernmental Baltic Marine Environment Protection Commission (Helsinki Commission, HELCOM; <http://www.helcom.fi>). HELCOM used the BACC report as

the basis for the HELCOM Thematic Assessment 2007 on “Climate Change in the Baltic Sea Area” (HELCOM 2007a), which was officially adopted by representatives of the Baltic Sea riparian states in March 2007. This means that the countries adopt this material as recommendations for legislative measures. Another collaboration with a political organization in the Baltic Sea area was the joint international conference on “Adapting to Climate Change—Case Studies from the Baltic Sea Region” in Hamburg, Germany, together with the Baltic Sea States Subregional Cooperation (BSSSC). This organization represents the subregional political level (counties and municipalities) in all Baltic Sea states and fosters international collaboration of these entities.

In 2009, a summer school on “Climate Impacts on the Baltic Sea—From Science to Policy” was organized by BALTEX on the Danish Baltic Sea island of Bornholm. The expert lectures were turned into a textbook, mainly aimed at students and scientists, but also at political and administrative decision makers (Reckermann et al., 2012). As the Baltic Sea region has a well-developed international framework for monitoring, assessing, and managing its marine ecosystems, the book provides a good case study for other regions where such management is being organized.

An interesting BALTEX outreach product, which is based on the BACC book and regional climate scenarios processed and used by the Northern German Climate Office, is the booklet “Ostseeküste im Klimawandel (Baltic Coast in Climate Change).” This 63-page booklet, written in German, translates the main scientific findings on regional climate change and its implications into everyday language for the general public (Meinke and Reckermann, 2012). It is regarded as a pilot study for producing similar products based on BACC II material in English and all the Baltic Sea languages.

Workshops and conferences are the glue of a scientific community, and are particularly important in BALTEX. Since 2003 (launch of Phase 2), there have been 19 conferences and workshops organized by BALTEX, both for scientists and regional decision makers and environmental managers. The large study conferences on BALTEX, which are organized every three years, bring together the Baltic Sea research community to present and discuss BALTEX topics. The 7<sup>th</sup> Study Conference on BALTEX will take place 10–14 June 2013 on the Swedish island of Öland. A full list to conferences and publications (with links) is available on the BALTEX website at: <http://www.baltex-research.eu>.

#### Future Prospects

After two successful phases, BALTEX is now transitioning into something new. The new program may be renamed, as the scientific scope and organization may be different. Currently, a dedicated working group appointed by the BALTEX Science Steering Group (BSSG) is elaborating on recommendations for a future scientific program, including specified “grand challenges.” These will be presented to the BSSG in September 2012 and the new program is expected to be of-

ficially launched at the 7<sup>th</sup> Study Conference on BALTEX. While concrete objectives and goals cannot be presented at this stage, it is nevertheless possible to anticipate the direction of the new program towards further promoting an interdisciplinary regional Earth system approach for the Baltic Sea Basin, encompassing the physical, chemical, biological, and socio-economic spheres as far as appropriate. In this respect, research towards an Earth system description and modeling on the regional scale in its various aspects is an ambitious challenge for the future.

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