



International Baltic Earth Secretariat Publication No. 11, February 2017

Baltic Earth Science Plan 2017



Impressum

International Baltic Earth Secretariat Publications

ISSN 2198-4247

International Baltic Earth Secretariat

Helmholtz-Zentrum Geesthacht GmbH

Max-Planck-Str. 1

D-21502 Geesthacht, Germany

www.baltic.earth

balticearth@hzg.de

Photos by Marcus Reckermann

The Science Plan provides the vision, structure, ongoing and envisaged activities of Baltic Earth. By conveying an overview of our open research network, it promotes participation and engagement by interested scientists and stakeholders. More detailed information about specific topics, research and outreach activities is available on the web pages of the Baltic Earth Working Groups.

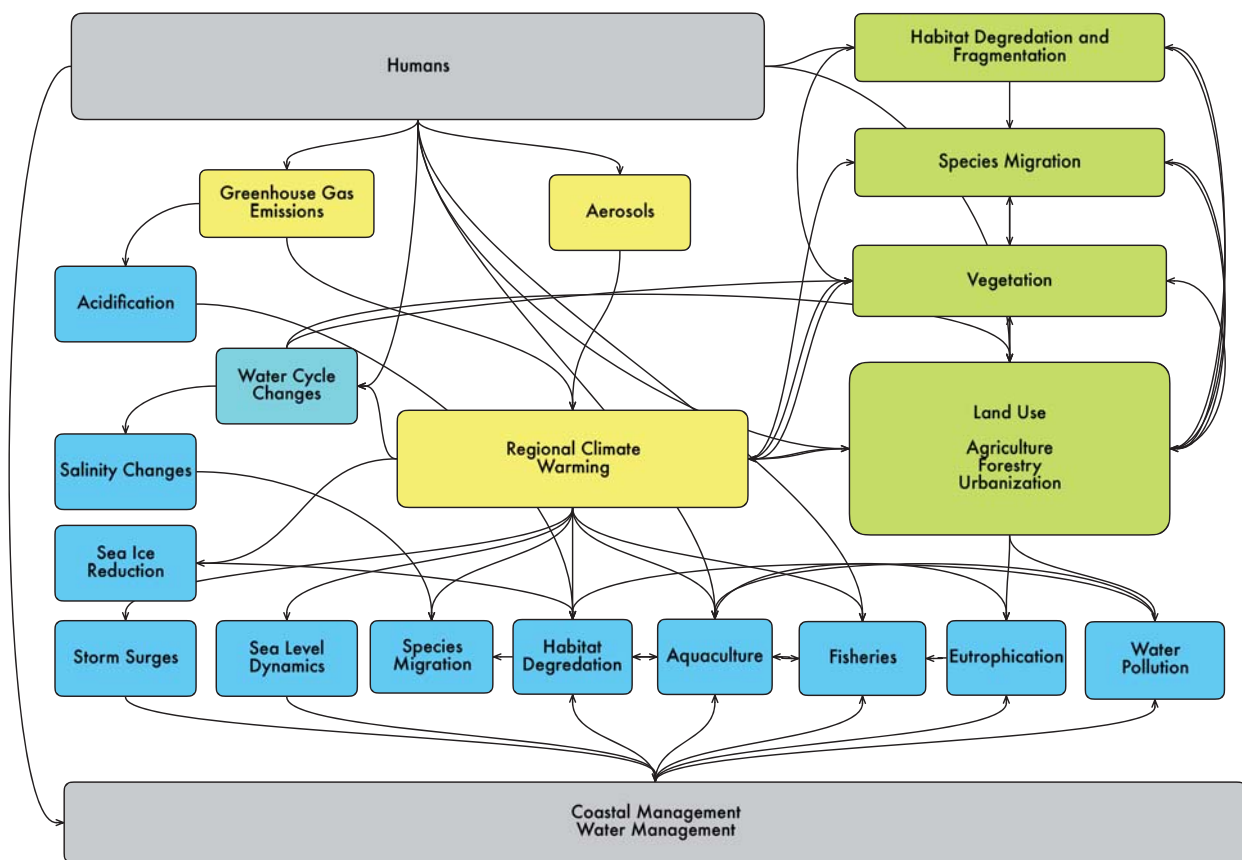
Vision

Baltic Earth strives to achieve an improved Earth System understanding of the Baltic Sea region as the basis for science-based management in the face of climatic, environmental and human impact in the region. Baltic Earth brings together a broad international research community around core scientific issues identified as fundamental to informing societal efforts to achieve sustainability in the region. These “Grand Challenges” are tackled through joint research efforts, workshops, conferences and capacity building events accompanied by a continuous process of synthesis of the current state of knowledge. Communication with stakeholders and research funders aims to ensure impact and relevance of the research. Baltic Earth targets the atmosphere, land and marine environment of the Baltic Sea, its drainage basin and nearby areas with relevance for the Baltic Sea region.

This is Baltic Earth

The Baltic Sea drainage basin covers about 20% of Europe, with roughly 85 Million people living at the shores of the Baltic Sea. In the highly populated south, the temperate climate hosts intensive agriculture and industry while in the northern part, the landscape is boreal and rural. The semi-enclosed Baltic Sea has a complex bathymetry, large horizontal and vertical gradients in salinity and extended hypoxic and anoxic bottom areas. The Baltic Sea is characterized by a large freshwater supply from the catchment area, long retention times of water masses and an excess of nutrients entering the sea. With further warming and associated changes in the hydrological cycle, a change in salinity and nutrient status is expected, with consequences for marine ecosystems and their services for human use.

Climate change, as well as other anthropogenic and natural changes in the atmosphere, on land and in the sea, exerts different pressures on the natural and human-shaped environment of the region. These pressures include regional warming, declining sea ice cover, sea level rise, deoxygenation, acidification, changing precipitation and runoff patterns as well as changing frequency of high impact events like storm surges, floods, drought and heat periods. Characterisation of these pressures, and synthesis of the state of scientific knowledge about their causes and impacts, has been a core goal of the BALTEX and Baltic Earth climate change assessments (BACC I and II). It has been shown that the observed environmental changes are often caused by a mixture of interwoven factors, among them climate change and its associated impacts, eutrophication, pollution, fisheries, land cover change and others. Each of these factors has a scientific and a societal dimension,



Scheme of different drivers in the regional Earth system and their interrelations. No claim is made for completeness regarding the different drivers and linkages.

which are often interdependent, and which makes the identification of a single or even dominant factor responsible for the change difficult. Baltic Earth strives to analyse these factors and processes in order to identify knowledge gaps and research needs for the coming years, to provide the scientific basis for management decisions and policy making, and to help finding solutions for the challenges society faces now and in the future. The Baltic Sea region is among the best studied regions in the world from several disciplinary perspectives, with good data availability, and with many scientific and management aspects providing an analogue for comparison to other regions. In this sense, the Baltic Sea region may act as a laboratory for reasoning about similar issues in other regions.

Baltic Earth inherits the scientific legacy and researcher network of BALTEX which ended in June 2013 after 20 years of successful activity (www.baltex-research.eu). Baltic Earth builds on the infrastructure (secretariat, conferences, publication series) and international scientific network of BALTEX (people and institutions) but represents a new, more holistic perspective on the Baltic Sea region, encompassing processes in the atmosphere, on land and in the sea, as well as processes evoked by and feeding back on human activity.

A unifying endeavour that underpins many joint activities of Baltic Earth aims to articulate Grand Challenges for research on issues of fundamental importance for informing the science-based management of the environment of the Baltic Sea region. Building on the tradition of scientific synthesis established during the BALTEX programme with the BALTEX Assessment of Climate Change for the Baltic Sea Basin, BACC 2008 and 2015, Baltic Earth catalyses a research community-wide process to identify the most pressing scientific issues, knowledge gaps and uncertainties and promotes efforts to address them through new studies, collaborations, synthesis and the development of tools. Six Grand Challenges, each associated to a responsible Working Group, will underpin the activities of Baltic Earth in the coming years.

Products of Baltic Earth include scientific assessments of specific topics, peer reviewed scientific papers, outreach publications for stakeholders and the public, research projects, workshops, seminars and conferences. Baltic Earth is also committed to capacity building and educational activities with the establishment of regular Baltic Earth Summer Schools. The regular Baltic Earth Conferences in the tradition of the BALTEX Study Conference provide a scientific platform for the exchange of research outcomes and ideas, and constitute a key forum for the identification of new and updated Grand Challenges. Baltic Earth will be internationally embedded, collaborating with science communities with common regional or thematic foci in Europe and the world.

Baltic Earth Grand Challenges

The Grand Challenges are the central topics around which the science encompassed by Baltic Earth revolves. These topics reflect current issues which scientists feel have a strong relevance for the scope and vision of Baltic Earth. Over time, new topics may be added and old ones discontinued as societal and research priorities change and new compelling issues attract the interest of scientists. Review and possible revision of challenge topics in broad discussion among the scientific community of Baltic Earth will occur in conjunction with the biennial science conference, topical workshops, assessments and other activities. Dedicated Working Groups form the working level of the Grand Challenges.

The following section provides a short overview of each of the current Grand Challenges addressed by Baltic Earth.



1. Salinity Dynamics

Background, knowledge gaps and relevance

Spatial and temporal variations in Baltic Sea salinity are not only controlled by oceanographic processes but are also driven by changes in the water and energy cycle. Salinity is an important factor controlling ecosystem functioning and biodiversity, in particular in the brackish Baltic Sea with its pronounced horizontal and vertical gradients. Salinity in the Baltic Sea depends on the water exchange with the world ocean which is restricted by the narrows and sills of the entrances area, on river runoff and on the difference between precipitation and evaporation over the Baltic Sea. In the long-term mean, high-saline water from outside enters the Baltic Sea and low-saline water leaves it because of the freshwater

surplus. The bottom water in the deep sub-basins is ventilated mainly by large saltwater inflows. These events occur randomly during the winter season at intervals of one to several years. During the period 1983 – 1993, saltwater inflows were completely absent, giving rise to diverse speculations. However, recent research suggests that stagnation periods over ten years have appeared approximately once per century during the past thousand years. That makes them rare events but they are obviously a natural phenomenon. However, longer periods of salinity reduction are probably not natural.

Indeed, scenario simulations suggest an enhanced hydrological cycle in the northern Baltic Sea region causing increased precipitation and runoff leading to decreased salinity in the Baltic Sea. However, due to large biases

in projections of the regional water balance, in wind fields and the global sea level, it is still unclear whether the Baltic Sea will become less or more saline. Since the Baltic Sea ecosystem has adapted to the present salinity regime, even small changes in salinity may exert stress on marine fauna and flora with associated consequences on species distributions and biodiversity.

As the present understanding of salinity changes is still very limited, more detailed investigations on regional precipitation and evaporation patterns (runoff), atmospheric variability (wind), salt water inflows, the exchange between sub-basins and turbulent mixing processes are needed. Furthermore, there is also a need for new climate projections with improved coupled atmosphere-ocean model systems. Suggested key research areas are the interrelation between decadal climate variability and salinity, and water mass exchange. Detailed studies on the regional salinity distribution and variability and associated circulation patterns, including salinity fluxes between the coastal areas and the open sea and within the sub-basins, should help to fill open knowledge gaps.

Potential activities

Potential activities include both observation and modelling. Dedicated research cruises like the ones performed during the 2014-2016 inflow period, and the deployment of moorings to measure e.g. salinity, oxygen and currents are needed to improve the inventory of observational data. Modelling activities using new model approaches, the calculation of salinity budgets and process studies should help to understand advection and diffusion of saltwater in the Baltic Sea. Review articles will summarize the current state of knowledge, and workshops and special sessions at conferences (e.g. on the recent inflow events) shall promote the communication and exchange of ideas and results.



2: Land-Sea biogeochemical linkages

Background, knowledge gaps and relevance

Eutrophication is a key environmental problem in the Baltic Sea having adverse impacts on water quality and ecosystem health with implications for recreation and tourism, fisheries and science-based management. Nutrient inputs interact with other drivers such as rising CO₂ concentrations, climate warming and changing precipitation regimes, altering biogeochemistry, food-webs and ecosystem dynamics through pathways and feedbacks that are still incompletely understood. Riverine loads of nutrients are strongly influenced by agricultural land cover and practices and are sensitive to the effects of climate warming on soil mineralisation processes and by the amount and seasonal distribution

of runoff, in turn influenced by rainfall patterns. The pathways of key substances such as nitrogen and phosphorus after entering the marine system are still not completely understood, yet have consequences for ecosystem health, may spawn undesirable events such as excessive algal blooms and affect ecosystem services such as fisheries. Baltic Sea waters are rich in carbon. Dissolved organic carbon (DOC) derived from decomposition and leaching of organic matter from peatlands, forests and lakes is a major carbon source for the Baltic Sea, particularly from the boreal catchments of the northern basins. DOC concentrations in streamflow and marine waters are increasing in the Baltic Sea region, as in many parts of the world. Little is known about the fate of the DOC, its biogeochemical activity, or

interactions with nutrient cycles and phytoplankton production. The potential decoupling of carbon uptake and inorganic nutrient availability is a major uncertainty in the causal link between eutrophication and hypoxia. The extent and variability of oxygenated and anoxic bottom waters play a pivotal role in the reflux of nutrients and carbon from the sediments. Factors controlling the retention of nutrients and carbon in the sediments, in particular under changing oxygenation levels, are in need of better quantification.

Coupled regional models of terrestrial vegetation dynamics and biogeochemistry exist but cannot yet fully account for transport, transformations and modifications of biogeochemical fluxes in drainage networks. Coupling to coastal zone or marine system models would be valuable to inform science-based management. On the data side, there are many gaps limiting the development and evaluation of comprehensive models. These include assessments of submarine groundwater seepage, of acknowledged importance for the Baltic Sea biogeochemistry. Regional studies are needed to elucidate the contrasting mechanisms and drivers dominating the dynamics of the forest-dominated northern and agriculture-dominated southern basins. While the influence of riverine loads of various substances is well recognised, gaps exist within present databases.

Potential activities

Potential activities include the development of land-ocean system models. Suggested key research areas in this field are investigations on the carbon, nitrogen and phosphorus cycles towards an understanding of primary production mechanisms and organic matter transformations in the Baltic Sea, transformations and pathways of terrestrial organic matter, and the influence of the terrestrial input on the carbonate system. Furthermore, the extension of databases with missing terrestrial loads data of the key chemical substances (e.g. from Neva River) should be pursued. Review papers and dedicated workshops will provide a platform to discuss the scientific results.



3: Natural hazards and extreme events

Background, knowledge gaps and relevance

A natural hazard is a naturally occurring extreme event with a negative effect on people or the environment. Natural hazards may have severe implications for human life as they potentially generate economic losses and damage ecosystems. A better understanding of their major causes and implications enables society to be better prepared and to save human lives and mitigate economic losses. Many natural hazards are of hydro-meteorological origins (storms, waves, flooding, droughts) and are often caused by a mixture of several factors (e.g. a storm surge in combination with precipitation and river runoff, which might generate extreme flooding).

Average changes in the recent climate in the Baltic Sea region are relatively well described, but the uncertainty is much larger for extreme conditions. These extreme events pose a substantial threat to infrastructures or ecosystems albeit their relative rareness. The shortage of available data on these events reduces the statistical significance in the analysis and the capability to predict them.

This is generally well recognized regarding infrastructure such as dam safety and urban flooding risks, but the range of ecosystem services at risk is more poorly defined, from vital societal functions such as drinking

water supply to biodiversity. The resilience and adaptation capability of terrestrial and marine ecosystems and organisms as well as human society to environmental changes depends very much on the future severity and frequency of extreme events.

There are meteorological implications of global warming, which may be the cause for changed frequencies of these extreme events. Storm tracks on the Northern Hemisphere seem to have shifted slightly northward during the last century as a consequence of global warming, and there are indications of additional Northern Hemisphere circulation changes due to the significant reduction of Arctic ice cover. Their connections, however, are not clearly understood and described, and there is a need to further investigate this with a Baltic Sea perspective. Hence, key processes and factors (e.g. atmospheric circulation, Arctic sea ice, snow) responsible for the changes in extreme events in the study region as well as their interlinkages, need to be better understood. An improved understanding of air-sea-land processes and the development of more detailed models is crucial.

Potential activities

Potential activities include the improvement of monthly to seasonal prediction systems and probabilistic estimates of the extreme events, a specific attribution analysis of past extreme events to elucidate the possible role of anthropogenic forcing factors, and an analysis of the vulnerability of key societal functions to changed hydro-meteorological extremes. Furthermore, it should be investigated if and how environmental goals are compromised by changing extremes such as droughts, floods or heat waves, including responses of the carbon cycle and the Baltic Sea carbon budget. Review papers and workshops will provide a discussion platform to help achieve the goals.



4: Sea level and coastal dynamics of the Baltic Sea

Background, knowledge gaps and relevance

Sea level dynamics in the semi-enclosed Baltic Sea are driven by meteorological, astronomical, hydrological and geological factors. The sea level varies at different time scales ranging from hours to seasons, decades and millennia. Relevant drivers are, among others, variations in wind and sea level pressure, river runoff, sea ice cover, the expansion of the water column due to thermosteric effects, land uplift, subsidence, and sediment accumulation. The effects of such drivers on Baltic Sea sea-level can be regionally and temporally quite heterogeneous. An assessment of the variability and change

of sea level during the period of instrumental measurements is needed to improve forecasting on short to medium time scales and to reduce uncertainties associated with projections of future sea-level rise.

The sea level records in the Baltic Sea sampled by tide gauges belong to the best and longest data in the world. Several high-resolution satellite products allow the analysis of absolute sea level changes, as opposed to relative coastal changes, and model reconstructions of the past and projections for the future become increasingly available for mean and extreme sea level variability.

There is still incomplete knowledge on short term sea level variations. In particular, the linkages between the sea levels of the Baltic and North seas and the North Atlantic on the one hand, and the impact of large scale atmospheric circulation patterns such as the North Atlantic Oscillation on the other hand needs to be better investigated.

Climatic factors responsible for the observed and projected long-term trends and multi-decadal variations in Baltic Sea sea level through the 20th and 21st centuries need to be examined as well. A quantification of multi-decadal trends in the wind regimes, salinity, and glacial isostatic adjustment or sea-ice cover, together with changes in ocean dynamics in the North Atlantic is essential for improving detection and attribution of anthropogenic signals in Baltic Sea sea-level rise and variability. Consistent analysis of all data sets will help to quantify the relative importance of the different factors contributing to Baltic Sea sea level dynamics.

A reliable modelling of future mean and extreme sea level changes and their effects on coastal morphology on time scales from seasons to decades remains an ultimate goal. Although the data basis for the analysis of Baltic Sea sea-level is very favourable, a systematic comparison of tide gauges and high resolution satellite products is just beginning and needs to be further pursued.

Potential activities

A review of the existing knowledge and challenges in Baltic Sea sea-level research is envisaged. The network of researchers in Baltic Sea sea level research should be maintained and fostered, by organising workshops or sessions at international conferences, and options for joint international research should be reviewed, also together with other regional sea level groups, in particular with the North Sea community. Common products to be developed could be a (meta-) database of Baltic Sea sea-level data and assessments of past, ongoing and future variability and change of the regional sea level.



5: Regional variability of water and energy exchanges

Background, knowledge gaps and relevance

Knowledge of the water and energy cycles in the Earth system is an inherent part of regional climate studies. It has been the focus of 20 years of BALTEX activities and remains one of the grand challenges for the scientific community. However, the understanding of the processes and their incorporation into reliable models remains insufficient, which is evident by the poor performance of recent climate models in simulating the hydroclimate.

During BALTEX major progress has been reached in observational and modelling activities, as well as in scientific collaboration and infrastructure including the build-up of dedicated BALTEX data centres. Also remote

sensing data have been evaluated to increase our understanding about the regional distribution of different parameters such as cloud distribution from satellites and precipitation fields from Doppler radars.

It is well known today that precipitation and evaporation are among those parameters causing the largest problems for weather prediction, meteorological reanalysis and regional climate studies. Although new knowledge has been gained with regard to the water and energy cycles, still major improvements are needed. For instance, regional climate studies based upon coupled atmosphere - land-surface-ocean models still suffer from biases in simulated precipitation and evaporation with the result that most coupled models do

not have a closed water cycle and hydrological applications need bias correction when the output of regional climate models is used. Although there now exist a few estimates of the components of the water cycle in the Baltic Sea region, results of the various, applied methods differ considerably and for most methods uncertainty estimates are not available.

The assessment of numerous hydrological studies for the different sub-basins of the Baltic Sea catchment area reveals that the approaches to calculate the water cycle over land differ and are not coordinated. Hence, homogeneous datasets for the whole catchment area are lacking with the consequence that in hindcast simulations, Baltic Sea models are usually driven by runoff from hydrological models instead of measurements.

Baltic Earth aims to continue the efforts of the past BALTEX program and to contribute to the WCRP Grand Challenges and the GEWEX Science Questions.

Potential activities

A review on the knowledge on river runoff to the Baltic Sea and dedicated workshops and sessions at conferences are planned. Observation activities envisaged include the measurement of hydrological and atmospheric exchange processes from the surface to the top of the atmosphere at different time scales for various spatial scales and an analysis of the natural variability of energy and water components including the quanti-

fication of changes in extremes and the determination of probabilities of their occurrences (for the last century up to now). The combination of conventional measurements with new remote sensing products, potentially with high resolution variability in time and space, will allow a better description of the processes. New model parameterizations considering e.g. an improved understanding of cloud-aerosol-feedback mechanisms, of cloud processes and of atmospheric boundary layer processes should be developed to hind- and forecast short- and long-term water and energy exchanges of the past century and of the future century, respectively. In particular, high-resolution process-oriented hydrological modelling will be promoted to allow, together with long-term measurements, an assessment of past and current hydrological changes and to project future runoff and salinity changes in the Baltic Sea.



6: Multiple drivers of regional Earth system changes

Background, knowledge gaps and relevance

Societal efforts to manage the marine, terrestrial and atmospheric environment of the Baltic Sea region and to promote a sustainable human presence – meeting present societal needs without deleterious impacts on the conditions passed on to future generations – are hindered by incomplete understanding of the complex of drivers, interactions and historical factors responsible for the current detrimental state of the environment and ecosystems. Such gaps in understanding inhibit reliable predictions of how the marine system and the surrounding land areas, watershed and atmosphere may respond to ongoing and future projected trends in multiple drivers, or to management interventions. The

Second Assessment of Climate Change for the Baltic Sea Basin focused on regional climate change and its associated impacts, including the documentation of regional detection and attribution efforts, but also highlighted a mixture of interwoven factors, such as eutrophication, pollution, fisheries, hydrographic engineering, agricultural and forestry practices and land cover change, responsible for the current situation and of potential importance as drivers of future changes. Current observational datasets, system understanding and available modelling tools are insufficient to ascribe key dimensions of change to a single or even dominant factor or to construct credible scenarios of future changes. Two overall problem complexes concern the causes and impacts of eutrophication and climate change. Studies in

these areas have traditionally been pursued by separate communities of researchers using different methods and approaches, adopting a diversity of baseline datasets and scenarios, and focusing on different spatial and temporal scales. There has likewise been relatively little collaboration across the science-social science divide, or between terrestrial, freshwater and marine scientists in related fields.

There is a need for increased cooperation among researchers having specialised knowledge of different components of the coupled biophysical-societal system of the Baltic Sea region, in the dynamics of which an understanding of the inter-related role of multiple drivers and their impacts on regional Earth system changes may be sought. Key disciplines include meteorology and climate science, oceanography, hydrology, marine, terrestrial and freshwater ecology, microbiology and biogeochemistry, as well as economists, human geographers, political scientists and engineers. A more integrated researcher effort needs to be complemented with an identification of key missing datasets on drivers and responses, their variations over past decades and across the region. A consensus should be sought on the relevant interactions to explore and the key knowledge gaps that need to be filled in order to develop reliable predictive models, applicable at the regional scale of the Baltic Sea.

Potential activities

Potential activities include the organization of conferences and workshops to bring different disciplines together and do syntheses, agree on datasets and data gaps, scope out the system to model with its key components and their interactions, and design model experiments. The development of coupled Earth system models capturing interactions between atmospheric, marine and land compartments/processes, as well as responses to anthropogenic forcing such as emissions and land use is a key long-term goal.

Instruments and Activities

Participating scientists contribute to Baltic Earth by sharing their time, expertise and research findings with the Baltic Earth community. New results and findings which are of interest to the Baltic Earth and wider scientific and stakeholder communities including the general public, shall be published on the Baltic Earth website, on social media and blogs, by publication in the Baltic Earth Newsletter and Secretariat Publication Series, and as peer-reviewed research and review articles and assessment reports. Generally, contributing scientists are expected to do their Baltic Earth-related research and travel to meetings and conferences on their own expense, as there is no central budget for Baltic Earth. It is desirable that contributing scientists are active in applying for Baltic Earth-related research funding at the national and international level, to facilitate collaboration and joint research activities. An engagement by the research institutions which are active in the Baltic Earth-related scientific fields is strongly desirable because Baltic Earth is a joint activity by definition.

Working Groups

Working Groups are the centres of activity within Baltic Earth. Working groups are established to cover either a dedicated topic or element treating or directly being related to the Baltic Earth Grand Challenges, or a topic or element cross-cutting through several or all challenges. For the latter type, Working Groups have been established on Outreach and Communication, Education, Regional Climate Change Assessments, System modelling and analysis, and Scenarios. For current members of the Working Groups, see the Baltic Earth website.

Assessments

Assessment reports of the state of the current knowledge of specific scientific fields are a central product of Baltic Earth. Following the example of the BALTEX (2008) and Baltic Earth (2015) Assessments on Climate Change for the Baltic Sea basin, the assessment reports will be

multi-authored and state the current, consensual knowledge of a specific topic but also identify cases of disagreement, and thus help to pinpoint knowledge gaps, which require further research. Assessments can be in the form of text books (like the BACC assessments), or as journal review papers or series of papers.

Networking activities

Networking activities are vital for maintaining an active and creative scientific network. The purpose is to provide an arena for scientific discussions around the Baltic Sea as well as to communicate findings within the network and continuously develop the Grand Challenges. Regular Baltic Earth conferences shall stimulate an active process to identify new Grand Challenges as well as major activities involving stakeholder discussions. In addition to the specific Baltic Earth conferences, sessions with Baltic Earth focus are organised at other conferences (e.g. BSSC and EGU). Conferences workshops and seminars on specific topics are organised by the different working groups, targeting the needs of the Grand Challenge development, aligned with BESSG meetings or other meetings, or as stand-alone events.

Capacity building

Introducing and educating young scientists is a crucial part of the work within the network. This is important for the maintenance and vitalisation of the network, but also a mean to broaden the arena of scientific discussions. Summer schools of 1-2 weeks duration are organised regularly with different foci. Summer schools are open for undergraduate and graduate students, and young scientists active in the Baltic Sea region, or from outside the region, but also with interest in the focus of the specific school. Specific seminars and conference sessions at conferences shall provide a platform for young scientists to help them grow into the scientific world, but also allow a new and fresh perspective for the established scientific community.

Data resources

Data relevant for Baltic Earth research cover a wide range of disciplines, data types, periods, geographical extent, frequency and spatial resolution. There is an ongoing development of data bases and data centres covering a variety of disciplines partly or entirely of relevance for Baltic Earth science, collected by other organisations e.g. WDCC, GRDC, ICOS, national weather and hydrological organisations. Baltic Earth will use and continue existing resources (e.g. on the Baltic Earth website) to develop a meta-data centre with data sources relevant for the network and the Grand Challenges. In addition, there will be a continuous identification of new data needs for current and future Grand Challenges. Concerted actions concerning field campaigns to acquire necessary observational data will be pursued.

Models and Scenarios

The Baltic Sea and the surrounding region has been the target for numerous modelling studies, building on model development by climate and marine and atmospheric research centres as well as University-based groups in several of the Baltic Sea countries. Modelling capacity in the region includes atmospheric, marine oceanographic, ecosystem and biogeochemical modelling, terrestrial ecosystem, carbon cycle, agricultural and forest production modelling. Earth system models coupling the atmospheric, marine and terrestrial domains are hosted by national climate centres in several countries. Frontiers in regional Earth system modelling include the integration of linkages and feedbacks across domains such as the role of land-sea nutrient fluxes for marine ecosystem dynamics and sea surface-atmosphere greenhouse gas exchange.

Models are useful for process studies, but also for the production and elaboration of scenarios of potential future changes and policy impacts. Scenarios are not

predictions, but provide a framework for analysis and discussion of future changes in the context of specific assumptions and trends. They thus provide an important tool for planning and policymaking. Initiatives to develop future scenarios for the Baltic Sea region have included the BONUS projects ECOSUPPORT, AMBER, Baltic-C and BalticAPP to develop future scenarios for the Baltic Sea area. The IPCC-catalysed Shared Socio-economic Pathways Framework is also being “downscaled” to the Baltic Sea region in terms of descriptors such as land-cover change.

Outreach and Communication

The goal of Baltic Earth outreach activities is to provide an arena for scientific exchange and discussion to communicate findings within the Baltic Earth research community and to other researchers, but also to stakeholders and society at large. An important instrument, next to the website and social media is the production of outreach products like newsletters, summary booklets and other outreach publications for non-scientists in English and the languages of the Baltic Sea countries. Presentations and other side-events at stakeholder conferences are used to discuss the current scientific knowledge with non-scientific professionals (practitioners, politicians, corporate representatives) to facilitate the joint elaboration of sustainable solutions.

How to contribute to Baltic Earth

Scientists from all relevant academic disciplines are invited to participate in Baltic Earth. There are many ways to contribute. Articles are welcomed for the Baltic Earth Newsletter; contributions are solicited for other Baltic Earth publications from time to time. Joining a Baltic Earth Working Group is a way to be actively involved in developing and progressing Baltic Earth scientific activities. Interested scientists are invited to approach the respective Working Group chairperson directly (details on the Baltic Earth website).

Organization

Baltic Earth Science Steering Group (BESSG)

Baltic Earth is led and managed by the Baltic Earth Science Steering Group. The panel consists of scientists representing research institutions whose research activities have a strong relevance for Baltic Earth research. As far as possible, scientists from all countries of the drainage basin and from all disciplines relevant for Earth system science participate in the panel. The steering group has the responsibility to provide scientific and strategic leadership to Baltic Earth. For current members of the BESSG, see the Baltic Earth website.

Baltic Earth Senior Advisory Board (BES-AB)

The Baltic Earth Senior Advisory Board provides advice to the Baltic Earth Science Steering Group (BESSG) in terms of strategy and overall directions. Decisions are not taken by the BESAB. For current members of the BESAB, see the Baltic Earth website.

International Baltic Earth Secretariat

The International Baltic Earth Secretariat (IBES) serves as a focal support point for Baltic Earth and is located at and funded by the Helmholtz-Zentrum Geesthacht in Germany. Its tasks include the support of the Baltic Earth Science Steering Group, Working Groups and Panels in their activities, and the preparation and communication of international Baltic Earth meetings, workshops, seminars and conferences and other activities. Furthermore, the Secretariat coordinates the drafting and finalization of reports (e.g. BACC I and II, meeting reports, proceedings, special issues, etc.). The Secretariat produces the Baltic Earth Secretariat Publication Series (see Annex) and runs the website and social media accounts.

International scientific cooperation

By definition, Baltic Earth has an international and interdisciplinary but regional focus. Collaboration across national and regional borders and scientific disciplines is crucial to achieve the goal to establish a better understanding of the regional Earth system of the Baltic Sea region for the benefit of the environment and people. Cooperation has been established in BALTEX and Baltic Earth with the following organizations, while it should be noted that this list is dynamic and evolving and by no means exhaustive.

GEWEX and WCRP

The Global Energy and Water Cycle Exchanges project (GEWEX) of the World Climate Research Programme (WCRP), and was the international mother organization of the Baltic Earth predecessor BALTEX from 1993 until 2013. The GEWEX Regional Hydroclimate Projects (RHP) focus on the investigation of the hydrological cycles on the regional scale in order to understand and improve the prediction capabilities of continental to regional hydroclimates. Baltic Earth and specifically its Grand Challenge #5 on "Understanding regional variability of water and energy exchanges" intends to continue the work of BALTEX and be represented in GEWEX as an RHP. Furthermore, Baltic Earth Grand Challenges 1 (Salinity dynamics), 3 (Natural hazards and extreme events) and 4 (Regional sea level rise) are closely related to the Grand Challenges of WCRP (www.wcrp-climate.org/grand-challenges).
www.gewex.org
www.wcrp-climate.org

Future Earth

Future Earth is a major international research platform striving to provide the knowledge and support to accelerate efforts towards a sustainable world. Future Earth brings together existing research programmes on global environmental change and aims to be a platform for international engagement to ensure that knowledge

is generated in partnership with society and users of science. It is open to scientists of all disciplines, natural and social, as well as engineering, the humanities and law. Baltic Earth aims to be part of the Future Earth project consortium with the goal to analyze the factors and processes shaping the regional environment including the human sphere in order to identify knowledge gaps and research needs to provide the scientific basis for sound management decisions. The Baltic Sea region can be seen as a laboratory or case study of issues facing the world in quest of a sustainable future. In this sense, Future Earth would be a logical global network for Baltic Earth as a regional activity to be part of.

www.futureearth.org

BSSC

The Baltic Sea Science Congress has drawn a large research community, mostly biologist, oceanographers and geologists to their conferences which are scheduled every second year and are usually hosted by large research institutions at the Baltic Sea coasts. Baltic Earth envisions a close collaboration with BSSC, enlarging the scope to the atmospheric research and catchment basin hydrology as well as regional climate science and modelling.

NOSCCA

BACC, the Baltic Earth Assessment of Climate Change for the Baltic Sea basin, has a counterpart in the North Sea region: The North Sea Climate Change Assessment (NOSCCA) is a similar effort for the North Sea region. The two activities are complementary and may foster synergies across the two regions in Northern Europe.

noscca.hzg.de

EGU General Assembly

Together with NOSCCA, Baltic Earth organizes a joint session on regional climate change and its impacts in the North and Baltic Sea regions at the annual EGU General Assembly. www.egu2016.eu

Cooperation at the science-policy interface

HELCOM

HELCOM (Baltic Marine Environment Protection Commission - Helsinki Commission) is the governing body of the Convention on the Protection of the Marine Environment of the Baltic Sea Area. It was established to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental cooperation with vision of a healthy Baltic Sea environment in a good ecological balance, supporting a wide range of sustainable economic and social activities. In both 2007 and 2013, HELCOM relied on the BALTEX and Baltic Earth expert network for their Thematic Assessment reports on Climate Change in the Baltic Sea area. The close collaboration in the course of BACC I and BACC II is envisaged to continue. HELCOM is an important stakeholder at the interface between science and policy in the Baltic Sea region.

www.helcom.fi

BONUS

BONUS is the joint Baltic Sea research and development programme which is jointly funded by the BONUS member states together with the EU. It acts as the premier funding source for applied and basic environmental research in the Baltic Sea region and many research projects from the BALTEX and Baltic Earth communities have been funded by BONUS (Baltic-C, Amber, ECOSUPPORT, Sheba). BONUS may benefit from the Baltic Earth network by being provided with a common knowledge base and open research questions on which future BONUS (or its successors) funding schemes may be constructed on.

www.bonusportal.org

CBSS

The Council of the Baltic Sea States is a political forum for regional inter-governmental cooperation. The Members of the Council are the eleven states of the Baltic

Sea Region as well as the European Commission. Baltic Earth is part of the Baltic Sea Region Climate Dialogue Platform of the EU Strategy for the Baltic Sea Region Horizontal Action (HA) Climate, to facilitate an extensive climate dialogue for the region, and is represented regularly at the Climate Dialogue Platform Round Tables. www.cbss.org/strategies/horizontal-action-climate

BSSSC

The Baltic Sea States Subregional Co-operation (BSSSC) is a political network for decentralized authorities (sub-regions) in the Baltic Sea Region. Together with BSSSC, BALTEX co-organized a Conference on “Adapting to Climate Change - Case Studies from the Baltic Sea Region” to give practitioners and decision makers at the regional political level in the Baltic Sea Region a platform to present and discuss concrete examples of regional or local adaptation to climate change. Baltic Earth intends to continue the collaboration with BSSSC. www.bsssc.com

Other thematically related international stakeholders are ICES (International Council for the Exploration of the Sea) and OSPAR (Oslo Paris Commission to protect the marine environment of the North-East Atlantic). Contact has also been established in the form of presentations and sessions at conferences with the group of Southern Baltic Sea Parliamentarians (a network of members of regional parliaments in the south-western Baltic Sea region, namely the German Länder, the Polish Woiwodships and the Kaliningrad region (Russia), and the Fehmarn Belt Days, a platform for stakeholders from the Fehmarn Belt Region (Denmark, Southern Sweden, Northern Germany) to discuss key issues and cross-border collaboration.

Selected publications

- BACC I (2008).** BACC Author Team (2008) Assessment of Climate Change for the Baltic Sea Basin. Regional Climate Studies, Springer-Verlag Berlin Heidelberg, 474 pages (download via <http://www.baltic.earth/BACC2/>)
- BACC II (2015)** BACC II Author Team (2015) Second Assessment of Climate Change for the Baltic Sea Basin. Regional Climate Studies, Springer International Publishing, 501 pages (download via <http://www.baltic.earth/BACC2/>)
- BALTEX Phase II (2003 - 2012): Science Framework and Implementation Strategy (2006).** International BALTEX Secretariat Publication No. 34, April 2006 (download via <http://www.baltex-research.eu/publications/ibsp.html>)
- BALTEX Phase II (2003 – 2012): Revised Objectives (2009).** A summary amendment to the BALTEX Phase II Science Framework and Implementation Plan. International BALTEX Secretariat Publication No. 44, November 2009 (download via <http://www.baltex-research.eu/publications/ibsp.html>)
- Climate change in the Baltic Sea Area. HELCOM thematic assessment in 2007.** Baltic Sea Environment Proceedings No. 111 (download at <http://www.helcom.fi/lists/publications/bsep111.pdf>)
- Climate change in the Baltic Sea Area. HELCOM thematic assessment in 2013** Baltic Sea Environment Proceedings No. 137 (download at <http://www.helcom.fi/lists/publications/bsep137.pdf>)

List of acronyms and abbreviations

AMBER	Assessment and Modelling of Baltic Ecosystem Response (a BONUS project 2009-2011)
BACC	BALTEX (BACC I) or Baltic Earth (BACC II) Assessment of Climate Change for the Baltic Sea region
BALTEX	The Baltic Sea Experiment
Baltic Earth	Earth system science for the Baltic Sea region
BalticAPP	Wellbeing from the Baltic Sea - Applications combining natural science and economics (a BONUS project 2015-2018)
Baltic-C	Building predictive capability regarding the Baltic Sea organic/inorganic carbon and oxygen systems (a BONUS project 2008-2011)
BESAB	Baltic Earth Senior Advisory Board
BESSG	Baltic Earth Science Steering Group
BONUS	Joint Baltic Sea research and development programme by BONUS member states and the EU
BSSC	Baltic Sea Science Congress
BSSSC	Baltic Sea States Subregional Co-operation
ECOSUPPORT	Advanced modeling tool for scenarios of the Baltic Sea ecosystem to support decision making (a BONUS project 2009-2011)
EGU	European Geophysical Union
Future Earth	International research platform providing the knowledge and support to accelerate our transformations to a sustainable world
GEWEX	Global Energy and Water Exchanges
GRDC	Global Runoff Data Centre
HELCOM	Helsinki Commission (Baltic Marine Environment Protection Commission)
IBES	International Baltic Earth Secretariat
ICES	International Council for the Exploration of the Seas
ICOS	Integrated Carbon Observation System
NOSCCA	North Sea Climate Change Assessment
OSPAR	Oslo Paris Commission to protect the marine environment of the North-East Atlantic
RHP	Regional Hydroclimate project (of GEWEX)
WCRP	World Climate Research Programme
WDCC	World Data Centre Climate

Baltic Earth Science Steering Group members (alphabetically, as of June 2016)

Juris Aigars	Latvian Institute of Aquatic Ecology, Riga, Latvia
Franz Berger	Meteorologisches Observatorium Lindenberg - Richard- Aßmann-Observatorium, Deutscher Wetterdienst, Tauche, Germany
Inga Dailidienė	Department of Geophysical Sciences, Klaipeda University, Lithuania
Jari Haapala	Finnish Meteorological Institute, Helsinki, Finland
Sirje Keevallik	Marine Systems Institute at Tallinn Technical University, Tallinn, Estonia
Karol Kulinski	Institute of Oceanology PAN, Sopot, Poland
Andreas Lehmann	GEOMAR Helmholtz-Zentrum für Ozeanforschung, Kiel, Germany
Markus Meier (Chair)	Leibnitz-Institute for Baltic Sea Research Warnemünde, Germany and Swedish Meteorological and Hydrological Institute, Norrköping, Sweden;
Kai Myrberg	Finnish Environment Institute, Helsinki, Finland
Anders Omstedt	Department of Marine Sciences, University of Gothenburg, Gothenburg, Sweden
Irina Partasenok	Centre for Hydrometeorology and Control of Radioactive Contamination and Environmental Monitoring of the Republic of Belarus, Minsk, Belarus
Piia Post	Institute of Physics, University of Tartu, Estonia
Marcus Reckermann	Helmholtz-Zentrum Geesthacht, Germany; Head of International Baltic Earth Secretariat
Gregor Rehder	Leibnitz-Institute for Baltic Sea Research, Warnemünde, Germany
Anna Rutgersson (Vice-Chair)	Department of Earth Sciences, Uppsala University, Sweden
Corinna Schrum	Institute of Coastal Research, Helmholtz-Zentrum Geesthacht, Germany
Benjamin Smith	Lund University, Lund, Sweden
Martin Stendel	Danish Climate Centre, Danish Meteorological Institute, Copenhagen, Denmark
Hans von Storch	Institute of Coastal Research, Helmholtz-Zentrum Geesthacht, Germany
Ralf Weisse	Institute of Coastal Research, Helmholtz-Zentrum Geesthacht, Germany
Sergey Zhuravlev	State Hydrological Institute (SHI) and St. Petersburg State University, Russia

Baltic Earth Science Plan Writing Team (alphabetically)

Markus Meier, Marcus Reckermann, Anna Rutgersson, Benjamin Smith

Baltic Earth Senior Advisory Board (alphabetically, as of June 2016)

Deliang Chen	August Röhss Chair, Department of Earth Sciences University of Gothenburg, Sweden
Jüri Elken (Chair)	Marine Systems Institute, Tallinn University of Technology, Estonia
Kay Emeis	Institute of Coastal Research, Helmholtz-Zentrum Geesthacht, Germany
Hans-Jörg Isemer	EU Projects Department, Helmholtz-Zentrum Geesthacht, Germany
Fritz Köster	National Institute of Aquatic Resources, Copenhagen, Denmark
Stanislaw Massel	Institute of Oceanology - Polish Academy of Sciences, Sopot, Poland
Jan Polcher	Laboratoire de Météorologie Dynamique du CNRS, France
Valery Vuglinsky	State Hydrological Institute, St. Petersburg, Russia
Ulla Li Zweifel	Professional Secretary, HELCOM Secretariat, Helsinki, Finland
Andris Andrusaitis (Observer)	BONUS EEIG, Helsinki, Finland

International Baltic Earth Secretariat Publications

ISSN 2198-4247

- No. 1 Programme, Abstracts, Participants. Baltic Earth Workshop on "Natural hazards and extreme events in the Baltic Sea region". Finnish Meteorological Institute, Dynamicum, Helsinki, 30-31 January 2014. International Baltic Earth Secretariat Publication No. 1, 33 pp, January 2014
- No. 2 Conference Proceedings of the 2nd International Conference on Climate Change- The environmental and socio-economic response in the Southern Baltic region. Szczecin, Poland, 12-15 May 2014. International Baltic Earth Secretariat Publication No. 2, 110 pp, May 2014
- No. 3 Workshop Proceedings of the 3rd International Lund Regional-Scale Climate Modelling Workshop "21st Century Challenges in Regional Climate Modelling". Lund, Sweden, 16-19 June 2014. International Baltic Earth Secretariat Publication No. 3, 391 pp, June 2014
- No. 4 Programme, Abstracts, Participants. Baltic Earth- Gulf of Finland Year 2014 Modelling Workshop "Modelling as a tool to ensure sustainable development of the Gulf of Finland-Baltic Sea ecosystem". Finnish Environment Institute SYKE, Helsinki, 24-25 November 2014. International Baltic Earth Secretariat Publication No. 4, 27 pp, November 2014
- No. 5 Programme, Abstracts, Participants. A Doctoral Students Conference Challenges for Earth system science in the Baltic Sea region: From measurements to models. University of Tartu and Vilsandi Island, Estonia, 10- 14 August 2015. International Baltic Earth Secretariat Publication No. 5, 66 pp, August 2015
- No. 6 Programme, Abstracts, Participants. International advanced PhD course on Impact of climate change on the marine environment with special focus on the role of changing extremes. Askö Laboratory, Trosa, Sweden, 24- 30 August 2015 International Baltic Earth Secretariat Publication No. 6, 61 pp, August 2015
- No. 7 Programme, Abstracts, Participants. HyMex-Baltic Earth Workshop: „Joint regional climate system modelling for the European sea regions“. ENEA, Rome, Italy, 5-6 November 2015. International Baltic Earth Secretariat Publication No. 7, 103 pp, October 2015
- No. 8 Programme, Abstracts, Participants. A PhD seminar in connection with the Gulf of Finland Scientific Forum: „Exchange process between the Gulf of Finland and other Baltic Sea basins“. Tallinn, Estonia, 19 November 2015. International Baltic Earth Secretariat Publication No. 8, 27 pp, November 2015
- No. 9 Conference Proceedings. 1st Baltic Earth Conference. Multiple drivers for Earth system changes in the Baltic Sea region. Nida, Curonian Spit, Lithuania, 13- 17 June 2016. International Baltic Earth Secretariat Publication No. 9, 222 pp, June 2016
- No. 10 Programme, Abstracts, Participants. Baltic Earth Workshop on "Coupled atmosphere-ocean modeling for the Baltic Sea and North Sea", Leibniz Institute for Baltic Sea Research Warnemünde, Germany, 7- 8 February 2017. International Baltic Earth Secretariat Publication No. 10, 24 pp, February 2017
- No. 11 Baltic Earth Science Plan 2017. International Baltic Earth Secretariat Publication No. 11, 28 pp, February 2017

International Baltic Earth Secretariat Publications
ISSN 2198-4247