



4th Baltic Earth Conference, Jastarnia, Poland

30 May - 3 June 2022



“Assessing the Baltic Sea Earth system”

Conference and session summaries

baltic.earth/hel2022

The 4th Baltic Earth Conference took place in Jastarnia on the Hel peninsula, opposite of the metropolitan area of Gdynia, Sopot and Gdansk in Poland. It was co-organized by the International Baltic Earth Secretariat at Helmholtz-Zentrum Hereon and the Institute of Oceanology of Polish Academy of Science (IO-PAN).

127 scientists from the Baltic Sea region and beyond were on site, 116 presentations were given, of which 10 authors presented online. 48 posters were presented in a dedicated external tent outside of the Hotel during a 2h poster session and supported by 1min presentations by authors.



(Photo: Tomasz Jankowski, IO-PAN)

The conference was opened by three distinguished representatives of the host region: **Slawomir Sagan**, the vice director of the scientific host institution Institute of Oceanology, Polish Academy of Science (IO-PAN); **Tyberiusz Zygmunt Narkowicz**, the mayor of the city of Jastarnia; and **Tomasz Herman**, the vice-chair of Puck county.

The scientific opening session featured keynote speeches by five speakers, with topics spanning from the geological structure and history of the Hel peninsula (**Szymon Uścińowicz**), a summary of the recent knowledge of climate change in the Baltic Sea (**Markus Meier**), results of from the CMIP6 project phase (**Torben Koenigk**, online), climate change impacts on species, communities and ecosystems in the Baltic Sea (**Markku Viitasalo** and **Erik Bonsdorff**, online), to an overview of multiple drivers and hazards for the coastal environments and how to cope with them (**Mike Elliott** et al. online).

Scientific sessions spanned the Baltic Earth range of topics. Each session was concluded by a short discussion on the state of science and open research questions. Two special talks of overarching relevance were not allocated to sessions: **Anders Omstedt** and **Hans von Storch** on BALTEX and Baltic Earth history and achievements, and finally, **Hans von Storch** on the achievements and contributions of the 2022 Nobel Prize laureate Klaus Hasselmann, for climate and environmental science.

The title of the conference “Assessing the Baltic Sea Earth system” refers to a series of assessment reports authored by Baltic Earth author groups, the BEAR reports (Baltic Earth Assessment Reports).

These reports represent the wrap-up documents of the first phase of Baltic Earth, which is terminated with this conference. A second phase will be prepared within the next two years and will be launched at the 5th Baltic Earth Conference in 2024.

BEAR authors gave keynote speeches in their respective sessions and thus gave overviews over the work that had been done.

Social events of the conference were the icebreaker on Monday evening, the excursion to Hel with a visit of the marine mammals station “Fokarium” of Gdansk University, including a tour around the station, extensive explanations and a dedicated presentation, and a guided tour through Hel on Tuesday evening, and the conference dinner on Thursday evening. A dedicated young scientist’s event in which 39 young scientists participated, was organized on Wednesday evening.

It is intended to publish a Special Issue of the conference contributions, in an international scientific journal, for interested authors. Details and deadlines will be communicated in early autumn.

Oral session summaries

These are short summaries of the oral sessions. Allocation of submitted abstracts to any of the predefined session was often easy, but sometimes difficult, and some talks could have appeared in another session with the same justification. For details and content-related conclusions, as well as information on poster content, the reader is referred to the extended abstracts in the conference proceedings volume (<https://baltic.earth/hel2022>).

Session 1: Salinity dynamics

Summarized by Kai Myrberg, Andreas Lehmann and Marcus Reckermann

The session featured 6 oral presentations. The session started with a keynote on the current state of knowledge on the salinity dynamics of the Baltic Sea by **Andreas Lehmann** et al., which is one of the ten BEAR reports. A 30-year variability has been found for surface and bottom salinity, river runoff and salt transport across the Darss Sill. There is no clear long-term trend of the mean salinity of the Baltic Sea, even if, during the last 40 years, surface salinity has decreased, and the lower layer salinity increased. It has been widely speculated that MBIs play the most crucial role in the development of deepwater salinity. Still, recent studies show that the frequency of major saltwater inflows did not change. At regional scales, in addition to the interaction with the main Baltic Sea, the salinity regime of estuaries and lagoons is closely related to the local water balance components, including river runoff, precipitation, and evaporation. So, in the changing climatic conditions, the development of the salinity regime at regional scales may have various basic-specific features that might be diverse from corresponding trends in the main Baltic Sea. **Simo Siiriä** et al. described on drivers and uncertainties in projected future salinity of Gulf of Bothnia. They stated that local changes in salinity within the Gulf of Bothnia are affected by stratification, changes of current patterns and river inflows, although its general salinity development is largely determined by the changes in the Baltic Proper. **Aarno Kotilainen** et al. talked about wintertime deep-water formation/convection in the Baltic Sea. They found that a marked environmental change occurred in the late 1950s when the input of re-worked terrigenous material stopped suddenly and the bottom water conditions switched from oxic to hypoxic at different water depths at all sites. During the last decade there has been various periods with

changing intensity of inflows. After the early 1990s only the major saline water inflow of 2003 was able to effectively ventilate the bottom. There is an urgent need to include the winter-time deep-water formation process in ecosystem modelling approaches. **Anna Bulczak** et al. studied turbulent mixing in the Slupsk Furrow, the connection between Bornholm and eastern Gotland Basin by analyzing microstructure observations in 2019-2021. Slupsk Furrow is a major pathway of saline water inflow to the eastern basins. **Verónica González-Gambau** et al. showed first results from remote surface salinity observations in the Baltic Sea using SMOS satellite data. The data set (product) has been generated for the period 2011-2019 and is freely distributed through the BEC FTP service (<http://bec.icm.csic.es/bec-ftp-service/>). **Rafael Catany** et al. studied the challenge of Sea Surface Salinity satellite retrievals in the Baltic Sea. It came out that SSS satellite products for the Baltic Sea can be potentially useful to monitor the salinity development but there are still challenges in the calibration of the satellite data.

In the discussion, salinity dynamics was lively debated with respect to changing salinity conditions due to climate change and how sophisticated measurements could be used to better understand or monitor the salinity evolution of the Baltic Sea.

Session 2: Biogeochemical functioning and development: From catchment to the open sea

Summarized by Juris Aigars and Marcus Reckermann

This session was divided in three parts, and featured 12 oral presentations. The first part, which focused on the carbon cycle and exchanges, started with the keynote speech by **Karol Kulinski** et al. on the BEAR article on the biogeochemical functioning of the Baltic Sea. Then, **Marcin Stokowski** et al. talked about the marine CO₂ system in the Vistula and Oder estuaries and potential implications for the Baltic Sea. **Anna Rutgersson** presented the work of **Lucía Gutiérrez-Loza** et al. on how air-sea CO₂ exchanges in the Baltic Sea are controlled under high and low wind speed conditions. **Martti Honkanen** et al. finally presented an estimate of the net carbon production in the Bothnian Sea during the spring bloom using $p\text{CO}_2$ data.

During the second part of the session, findings on robustness of trophic network and carbon flows (**Labuce et al.**), evaluation of nitrogen fixation in the Baltic Sea (**Schneider et al.**), as well as oxygen dynamic in the Baltic Sea (**Naumov et al.**) and seasonal hypoxia in the Gulf of Riga (**Stoicescu et al.**) were presented. In respect to these presentations, the discussion (on Day 2) mostly centered on nitrogen fixation. The evidence that nitrogen fixation is not actually dependent on temperature *per se* but rather from temperature increase, triggered a discussion on the necessity to further pursue research on nitrogen fixation issues, as apparently much is still unknown and under debate.

The third part mostly focused on nutrient transport and transformations. **Marc.J. Silberberger** et al. started with a talk on benthic nutrient, carbon, and oxygen fluxes in the coastal zone and their importance on macrofaunal communities. **Alberto Elizalde** et al. presented a riverine phosphorus transport assessment, and **Marta Borecka** et al. reported on the potential use of the N₂/Ar ratio to estimate denitrification and anammox variations in the water column. Finally, **Werna Werna** and Stefan Forster showed laboratory studies of microphytobenthos primary production and respiration in sandy permeable sediments from the southern Baltic Sea.

Session 3: Natural hazards and extreme events

Summarized by Anna Rutgersson and Marcus Reckermann

This topic had 5 oral presentations. **Anna Rutgersson** et al. gave the BEAR keynote on natural hazards and extreme events in the Baltic Sea region. In a case study on compound extreme events (e.g. a storm surge and a concomitant flash flood from precipitation) in the Swedish city of Halmstad, **Kevin Dubois** et al. showed that while the probabilities for such multiple extreme events are rather low, they have increased and their impacts can be very high, and the magnitude is sensitive to the statistical methodology. **Simo Siiriä** et al., in his second oral presentation, projected possible probabilities of future marine heat waves. Using sedimentary data, **Karolina Leszczyńska** et al. tried to reconstruct which are the major factors responsible for flooding events following storm surges. **Rain Männikus** and **Tarmo Soomere** described water level extremes and their variations in the Gulf of Riga.

The discussion was oriented around the needs of improved reanalysis, in particular for detection and attribution studies. It is necessary to evaluate what society needs (this can be very local). There was expressed a need for system evaluations (rather than process analysis). Further research should also be focused on small scale events, not presently well resolved by present methods/models.

Session 4: Sea level dynamics and erosion

Summarized by Anders Omstedt and Kevin Parnell

During the afternoon, six presentations were given, starting with **Kevin Parnell** et al. presenting the BEAR report led by **Ralf Weisse**, who was unable to attend. **Jani Särkkä** et al. presented calculations on sea level extremes from synthetic low-pressure systems and, at present, mainly along the Finnish coast. **Hagen Radtke** et al. presented results from an ensemble of CMIP5 climate downscaling and analyzed the projected changes in sea level around the Baltic Sea. **Laura Nesteckyte** et al. presented a study of sea-level change in the Klaipeda Strait. **Magnus Hieronymus** et al. presented a new method for sea level bias corrections using neural networks. Finally, **Maris Eelsalu** et al. discussed the attributions of coastline change due to climate change. The session gave a broad overview of the activities and effects of climate change on sea levels and coastal erosion.

During the second part of the 'Sea level dynamics and coastal erosion' session, five presentations were given. **Loreta Kelpšaitė-Rimkienė** et al. discussed the natural and human drivers of shoreline change in the Klaipėda area of Lithuania. This was followed by a similar discussion for the southern Baltic Sea coast, focusing on coastal protection from a mainly engineering perspective, presented by **Piotr Szmytkiewicz** et al. The coastal protection theme was furthered in a presentation by **Joanna Dudzińska-Nowak** et al. who discussed coastal erosion and protection, concentrating on the impact of hydro-engineering structures and protection measures on changes of the coast. **Htun Sone** et al. reported on climate change and coastal hydrodynamics on the southwest Baltic Sea coast, using a modelling approach. **Jakub Śledziowski** et al. provided details of a UAV LIDAR methodology for monitoring coastal cliffs, the test site being on the Polish coast. The session demonstrated the importance of investigation of shoreline change and the responses to it in the Baltic Sea.

Session 5: Regional variability of water and energy exchanges

Summarized by Marcus Reckermann

Only 3 presentations were with this session which has a strong oceanographic focus. **Taavi Liblik** et al. gave a keynote talk on the variability of water column properties in a downwelling area in Estonian coastal waters (not a BEAR topic). On the contrary, **Maris Skudra** et al. investigated upwelling characteristics in the Gulf of Riga. **Waldemar Walczowski** et al. gave an overview of the usability of Argo floats in the shallow Baltic Sea.

Session 6: Human impacts and their interactions

Summarized by Marcus Reckermann

Also for this session, only 3 presentations were allocated. **Marcus Reckermann** et al. gave the keynote talk on the BEAR article on human impacts and their interactions in the Baltic Sea region. **Michał Gintowt** et al. presented a literature review on human-induced threats to the benthic habitats in Puck lagoon, Gdansk Bay, Poland, covering 120 years of research. **Mary A. Zeller** et al., finally, investigated the impacts of benthic fishing methods on the redox state of marine sediments in the Fehmarn Belt, western Baltic Sea.

Session 7: Sustainable management options

Summarized by Marcus Reckermann

Tarmo Soomere gave the session keynote (not a BEAR topic) on challenges for sustainable management of seas and shores, globally and in the Baltic Sea. This was further elaborated by **Kevin Parnell** and Tarmo Soomere in the presentation on future management options for the Baltic Sea coasts. To finalize this session, **Martin Stendel** and A.J. Kronegh presented a Danish digitization project for weather observations. ROPEWALK is a project to digitize weather information on board ships from three centuries, serving as handy reanalysis data.

Session 8: Analyzing and modeling past and future climate changes

Summarized by Ole B. Christensen and Markus Meier

Session 8 was multifaceted including both observational and model-based presentations. Overview talks by Ole B. Christensen, Erik Kjellström, Matthias Gröger presented the current state of modelling of current and projected future climate change in the Baltic region. Three recent BEAR papers dealing with atmospheric and oceanic changes as described with models were summarized. There are perspectives in further development of high-resolution atmospheric models and of coupled atmosphere-ocean regional models, which would probably further help quantifying future climate change as well as the uncertainty in these projections. The current EURO-CORDEX ensemble gives clear indications about, e.g., future temperature and many aspects of precipitation; at the same time, models still do not agree on future wind changes nor on changes in summer average precipitation. Model shortcomings regarding cloudiness and incoming solar radiation need to be studied in the future. The coupling between atmosphere and ocean is very important, though with mostly local effects over the coupling region.

Effects of future climate change on sea ice and marine heat waves were analyzed by Per Pemberton and Matthias Gröger, respectively.

Teleconnection mechanisms of importance to the Baltic region were analyzed. Andreas Lehmann talked about changes in the NAO index and its influence on, e.g., Baltic Sea sea level elevation. Florian Börgel analyzed various CMIP6 models and focused on the interaction between the Atlantic Multidecadal Oscillation and the NAO and on the impact on the Baltic Sea region climate.

Various observational records were analyzed on climatological time scales from years to millennia. The seasonality of incoming short-wave radiation has been shifting towards cloud cover reduction earlier in spring, as reported by Pii Post. Longer-time reconstructions were presented by Varvara Bokuenko. Tamara Zalewska analyzed ocean climatological indices for the latest 60 years for the Southern Baltic indicating a large warming, and Nikolaus Groll presented new wave hindcasts for the Baltic Sea, using different atmospheric forcings. Modeled wind data in the Bay of Gdansk was presented by Witold Cieślakiewicz

While very different in their respective subjects, the presentations in this session demonstrated the large magnitude of projected future climate change as well as the sensitivity of the Baltic region to such changes.

In the discussion, the need for focus on scientific issues as opposed to engineering ones was emphasized by Hans von Storch.

Session 9: Marginal Seas

Summarized by Jan Harff

The natural environment of marginal seas and their coastal zones are increasingly threatened by climate change induced rising sea-level, floods, storms, tsunamis, coastal erosion and environmental hazards. The Baltic Earth scientific network, together with the DDE Marginal Seas Task Group, promotes since 2020 comparative studies of marginal seas' functionality in order to contribute to generalized concepts of sustainable management of the marine and coastal environment of marginal seas in different climatic zones and geological-tectonic settings. At the 4th Baltic Earth Conference, for the first time, a topical session on comparative studies of marginal seas was organized whereby case studies from the Baltic Sea, North Sea, South China Sea, Salish Sea and the South African shelf offshore Mpondoland were introduced and discussed online and face-to-face. Three general sub-topics were discussed:

Coastal morphogenesis and paleogeography

Wenyan Zhang et al. (online) introduced first results of a research project, which was launched in 2021 on initiative within the frame of the Deep-time Digital Earth Big Science Program of the IUGS and Polish, Chinese and German project partners. One of the key objectives of the project "Morphological evolution of coastal seas – Past and Future" is the reconstruction of coastal shelf morphology, paleo-coastline and hydrodynamics of the three exemplary Eurasian marginal seas, differently influenced by glacial isostatic adjustment: Baltic Sea, North Sea and South China Sea during the Last Glacial Cycle (last 130 kyr), and in particular in the post-glacial period (last 20 kyr). Based on a conceptual model, existing data sets retrieved from data bases (FAIR principle), the interrelation of eustatic sea-level change and isostatic displacement of the Earth's crust have been used to generate paleogeographic

scenarios. One target of this project is the development of models to describe spatial wide range sediment transport - regarded one of the main challenges defined by Baltic Earth (Grand Challenge 4).

Paleoenvironment and onset of anthropogenic impact

To show the functionality of marginal seas, the interrelation of geo-, bio- anthroposphere and climate in the onset of anthropogenic pressure and climate change is to be identified by the reconstruction of the paleoenvironment on the time span from Late Pleistocene to Holocene and Anthropocene. On the time scale from millennia to seasons, the paleoenvironment is to be reconstructed by “decoding” proxy data from the sedimentary record. **Jinpeng Zhang** et al. (online) presented the results of proxy-sediment data analysis for sea-level fluctuation, coastline migration and paleodynamics on the shelf offshore the Yangtze River, Yellow River and Pearl River, in the South China Sea during the Late Pleistocene to Holocene. Sedimentological processes controlled by climate cyclicity can be similarly studied by the interpretation of sediment proxy data offshore Mpondoland, South Africa. **Hayley Cawthra** et al. (online) combined exemplarily sedimentological and archaeological records and reconstructed how hunter-gatherers adapted to coastline change during and across glacial-interglacial phases.

Strategies for sustainable development of marginal seas coastal realm

Densely populated river mouth systems serve currently often as hot spots of anthropogenic impacts affecting not only the nearshore areas of the river mouths but also the marginal seas the rivers merge and even the global ocean. Several international research projects are currently studying the impact of big cities to the adjacent coastal and marine environment. **Joanna Waniek** et al. (online) focused on the northern shelf of the South China Sea by studying organic pollutants. The results shall contribute to general questions about the “fingerprint” of the megacities in coastal seas mapped and the function of the sediments in these regions with respect to anthropogenic pressure. **Gary Greene** et al. and **John Delaney** et al. (both online) reported about the Urban Seas national concept of the US to improve the environment of industrialized coastal embayments, estuaries, or marginal seas. This concept is supposed to include comprehensive data analyses including economy, energy potential, physical environment, ecology, education and cultural aspects, but also the perception of management strategies by the local community. The basic principle is based on a comparison of the study areas with the aim of their classification and thus the determination of general management strategies. A comparable approach for the classification of marginal seas was presented by **Marcus Reckermann** et al. who proposed a matrix to visualize for the Baltic Sea region the interrelations of different driving natural and anthropogenic factors including climate to the regional environment of the Baltic Sea. The method can be regarded as a base to develop general classification methods for marginal seas.

Summarizing, the complexity of marginal seas’ systems require generalized models to describe the invariant part of the diversity of types of marginal sea. These models can help to provide standardized solutions for sustainable development of the marine and coastal environment. Generalized models require the comparison of marginal seas by standardized data sets. These data sets need to describe not only the current functionality, but have to include the history from the pristine paleo-environment to the current anthropogenically impacted systems. The time span to be represented by data trending from millennial to the seasonal scale include paleodata derived by “decoding” of sedimentary proxies to current monitoring directly measured data. The interpretation of proxy data demands a cooperation between geoscientists, climatologists, historians and archaeologists. In addition to the diffuse influence of anthropogenic effects such as agriculture or deforestation, hotspots in densely populated coastal zones play an important role in the interrelation between geosphere, ecosphere, climate and anthroposphere. In order to optimize the effect of sustainable management, the subjective

perceptions of coastal residents should be taken into account in addition to measured data for the parameterization of models. The special research of river mouth systems and the influence of human activities on the environment of the adjacent marginal seas should be investigated, comparatively for different climatic zones and different geological settings.

