

Session Summaries

This document presents a very brief overview over the presentations in the oral sessions of the conference. Each session is preceded by a short session description, as given in the conference website. For a more in-depth look, refer to the abstracts in the Proceedings book, available via the conference webpage: <https://baltic.earth/events/details/heringsdorf2026>

Session A: Climate variability and teleconnections (summarized by Itzel Ruvalcaba Baroni)

The "Climate variability and teleconnections" session collectively underscored the critical role of atmospheric and oceanic linkages in shaping the climate and ecosystem of the North Atlantic and Baltic Sea regions. Research utilizing Single-Model Initial-condition Large Ensembles (SMILEs) reveals that external drivers, particularly anthropogenic aerosol emissions, significantly influence the low-frequency variability and connectivity between North Atlantic and European sea surface temperatures and precipitation. These large-scale patterns, including the North Atlantic Oscillation and the polar jet stream, act as primary drivers for regional weather, storms, and temperature fluctuations, which in turn cascade into biogeochemical processes like oxygen dynamics and ocean acidification within the Baltic Sea. The frequency and intensity of Major Baltic Inflows (MBIs), essential for the region's ecological health, are shown to be directly triggered by specific atmospheric circulation phases linked to the jet stream, highlighting the need for improved predictability models. Furthermore, the integration of historical ship logbook data from the 17th century onwards provides a unique long-term perspective on these teleconnections, offering valuable insights into past climate variability and enhancing our understanding of current and future climate dynamics.

Session B: Natural hazards and their impacts (summarized by Matthias Gröger)

The session covered a wide range of natural hazards and emphasized recent progress in the analysis of their drivers as well as their impacts on human welfare and economy. New concepts to quantify and mitigate economic damages were presented. The contributions gave new insights on trends in specific hazards such as wildfires, storms and floods in the historical context. Several contributions focused on extreme flooding, storm surges, and wave conditions, including case studies, seasonal risk assessments, as well as approaches to reconstruct storm events and analyses of changing sea levels. The session also promoted new perspectives about the upwelling related risk for entrainment of deoxygenated waters into the shallow litoral marine environment. Likewise, many contributions were dedicated to the challenges about ongoing coastal erosion, emphasizing their environmental impacts and the need for adaptation strategies such as managed retreat or mitigations. Overall this session highlighted the need for integrated cross-national hazard assessments.

Session C: Baltic Optics: Advancing ocean colour science and applications in the Baltic Sea (summarized by Eefke van der Lee)

The first Optics session at a Baltic Earth conference featured 8 oral presentations and 2 posters.

Jan Oliver Eisermann started the session by presenting an interactive visualisation technique whereby a part of the coast was realistically recreated digitally using drone data and hydroacoustic bathymetry. The aim is to make the invisible underwater world, in this case especially seagrass, more accessible to stakeholders in order to communicate changes in the Baltic Sea ecosystem more visually, interactively and intuitively.

With satellite data being only available at the sea surface the spatial and temporal coverage is high, but data on the vertical structure of chlorophyll-a is missing. Dominik Lis proposed a method to estimate vertical profiles of chlorophyll-a from remote-sensing reflectance combined with statistical and machine-learning methods.

Returning to drones and seagrass Eike Schütt showed what problems are faced when upscaling results from UAVs to satellites. Even though Sentinel-2 is relatively highly resolved the fine-scale fragmentation and patchiness of submerged aquatic vegetation habitats leads to biased or uncertain estimates of vegetation metrics. Using an intermediate data layer from UAVs and training of a regression model this problem of scale mismatch is addressed.

In order to reduce the nuisance of clouds Mirosław Darecki presented a method of gap-filling cloudy satellite data with data from computer models whereby the satellite-derived estimates of chlorophyll-a and phycocyanin were first improved by using a new support vector regression algorithm.

Sławomir Woźniak looked into another element of the Baltic Seas optical complexity, the particle sizes of suspended matter by comparing optical and biogeochemical measurements on unfiltered and size-fractionated sea water samples. Mean spectral slopes of the beam attenuation coefficients by particles varied clearly between particle size fractions.

An overview of the adjacency effect and the current discussion on how to handle it was given by Victor Lion. Two adjacency effect correction methods were introduced and compared based on Sentinel-2 data showing adjacency effects can be reduced with open access tools.

Bronwyn Cahill addressed the issue of different estimates for water quality products for the western Baltic Sea depending on which regional Copernicus product is used in the area where products overlap. In order to assess their suitability, the products will be compared with dedicated in situ optical measurements.

Last but not least Kamila Haule studied the optical signatures of oil droplets and oil-coated microplastics in seawater using laboratory experiments and radiative transfer modelling. The inherent optical properties were calculated from the complex refractive index of selected pure oils and microplastics and particle size distributions and an “oil index” was proposed.

In addition to these talks, two posters were presented. Bronwyn Cahill introduced the ISOLUME project on coastal darkening and artificial light at night. This project studies the changes and effects of light intensity, location, timing and spectra with the aim of developing monitoring strategies and policy frameworks. Anja Lindenthal introduced the NECCTON project on ecosystem modelling. This project aims to extend the Copernicus modelling effort in the Baltic Sea to higher trophic levels by including a fish model and to light availability by including a bio-optical module.

Session D: Bridging scales: From small-scale turbulence to basin-wide circulation (summarized by Sławomir Sagan)

Session presentations focused on improving understanding of Baltic Sea coastal and shelf processes, particularly the role of fine-scale dynamics, advanced autonomous observations, and high-resolution modelling in controlling circulation, mixing, oxygen conditions, and ecosystem function. The session gave a full picture of the key process in the scales and their role in mass and energy transfer, while also pointing to the novel instrumentation and methodologies of observation.

Taavi Liblik shared results of deployment of micro-autonomous underwater vehicle (AUV) in three Baltic coastal environments. The AUV successfully captured fine-scale physical and biogeochemical

features, demonstrating that it can fill important observational gaps in coastal and estuarine monitoring and support future Baltic Sea research. **Urmas Lips** examined small-scale ocean processes (submesoscale dynamics) that influence mixing, energy transfer, and tracer transport in the Baltic Sea. He showed that these processes play a significant role in large-scale circulation and ecosystem dynamics, while highlighting remaining knowledge gaps. **Peter Holtermann** presented the long-term observations in the western Baltic Sea which reveals frequent short-lived hypoxic (low-oxygen) events, even in shallow waters. He emphasised the need for continuous monitoring. **Sebastian Neubert** and co-authors developed a modular, IoT-enabled monitoring platform capable of long-term autonomous operation in shallow coastal waters. Initial deployments successfully captured rapid environmental changes, demonstrating the system's potential for comprehensive ecosystem monitoring. In her presentation **Kai Salm** reported on using high-resolution glider observations in the Gulf of Finland, and showed how frontal dynamics reshape phytoplankton distributions vertically without substantially changing total biomass. She pointed out that submesoscale processes help maintain subsurface chlorophyll maxima and support productivity under nutrient-limited conditions. **Enriko Siht** presented results of combining current-meter observations with high-resolution modelling in research of circulation patterns in the Central Baltic. He then showed the noticed improvement in our understanding of regional currents, transport pathways, and their environmental impacts across multiple timescales. At the end of the session, **Germo Väli** presented how high-resolution model simulations reveal that submesoscale processes significantly enhance vertical saltwater transport and overturning circulation, particularly in the northern Baltic. While overall transport patterns resemble those in lower-resolution models, small-scale dynamics strongly influence mixing and halocline ventilation.

Session E: Future projections of the Baltic Sea region (summarized by Leonie Barghorn)

Regional Earth system modeling, natural variability, marine heatwaves, shared socioeconomic pathway scenarios, projected changes in significant wave height, anthropogenic climate change, model ensembles, model uncertainty, coupled models, (objective) model calibration, perturbed parameter ensembles, surrogate models

The session was started by a highlighted Early Career Scientist contribution. **Safonova et al.** explored how the extent of marine heatwaves could change in the future based on a large ensemble of dynamically downscaled climate projections. Further, they conducted an uncertainty analysis to assess how model uncertainties and natural variability limit the accuracy of the projected marine heatwave areas at the surface and the bottom of the Baltic Sea.

Nikolaus Groll used an ensemble of eight climate projections to analyze projected changes in significant wave height in the Baltic Sea. He found large variations in spatial patterns and magnitudes of change. On average, an increase of significant wave heights is projected, in particular in the highemission scenarios.

Accurate future regional climate projections require well-calibrated coupled earth system models. **Voelker et al.** presented efforts to calibrate the atmospheric component of a Baltic Sea Earth System Model (IOW-ESM) utilizing perturbed parameter ensembles and surrogate models. Although some biases remained, the downward-directed shortwave radiation and thus also 2-m air temperatures over the Baltic Sea could be significantly improved.

The session was ended by **Ehlert et al.** who introduced the German natESM initiative working towards a national earth system modeling community and infrastructure. They provided an overview of the structure of the initiative and in particular the collaboration between scientists and Research Software Engineers which is a key component. Finally, they raised the question how this initiative could align with Baltic Earth and other existing regional earth system modeling efforts.

Session F: Adaptive governance under multiple drivers of change in the Baltic Sea (summarized by Kari Hyytiäinen)

Keywords: Wild card events; business stakeholder conceptions; emerging contaminants; emission modelling; GIS tools; catchment-to-coast management; environmental policy; eutrophication

The session opened with Jamie Jenkins on low-probability, high-impact “wild card” events, reporting a thought experiment that identified plausible future wild cards in the Baltic Sea environment and probing how existing models (biogeochemical, ecological, agent-based) can assess impacts and guide policy. Jean-Pierre Imbrogiano then used a phenomenographic design to show how members of diverse Finnish, German, and Polish businesses hold contrasting conceptions of “protecting the Baltic Sea,” leading to divergent practices. Next, Helmke Hepach presented long-term data indicating that despite EU-driven nutrient declines, coastal hypoxia is intensifying due to warming and stratification, prompting a reevaluation of MSFD thresholds, limits to further reductions, and integration into a management-planning tool. The session closed with Alena Seidenfaden addressing emerging pharmaceutical pollutants from wastewater treatment plants and introducing an open-source QGIS plugin that estimates emissions, tests mitigation scenarios, and, validated in five countries, supports participatory, adaptive management.

Session G: Biogeochemistry of the Baltic Sea - Linking observations and modelling (summarized by Tamara Zalewska and Karol Kulinski)

Session 5 of the 6th Baltic Earth Conference addressed the complex chemical and biological dynamics of the Baltic Sea, focusing on the intersection of human activity, policy-driven changes, and natural environmental responses. The oral presentations are summarized below across three primary thematic pillars:

1. Eutrophication Trends and Functional Indicators

Several studies assessed the long-term impacts of nutrient reduction and the development of new metrics for monitoring ecosystem health. **Tamara Zalewska** provided an overview of the southern Baltic, where total nitrogen and phosphorus inflows have decreased by 31% and 67%, respectively, since the late 1990s—a direct result of HELCOM policies and EU regulations. Despite this success, rising water temperatures due to climate change are intensifying blooms and extending the growing season. **Adolf Konrad Stips** introduced the Trophic Transfer Index (TTI) to measure how efficiently energy moves through the food web. His findings highlighted a significant 17-year hysteresis (lag) between nutrient load reductions and ecosystem recovery. Furthermore, **Itzel Ruvalcaba Baroni** presented the intensity of phytoplankton spring blooms as a robust, region-specific indicator for assessing eutrophication status in the open sea, bridging the gap between coastal and offshore management.

2. Hypoxia, Inflows, and Oxygen Dynamics

Research in this area utilized advanced modeling and high-resolution data to track oxygen levels in deep basins. **Lena Viktorsson** demonstrated the utility of the DIVAnd interpolation tool to reconstruct continuous 3D oxygen fields from 1960 to 2024, providing the first robust estimates of hypoxic areas with explicit error matrices. Investigating the role of Major Baltic Inflows (MBIs), **Lev Naumov** concluded that while the massive 1951 MBI increased haline stratification, it was not the primary driver of long-term hypoxia; instead, eutrophication remains the dominant cause of oxygen depletion. Supporting this, **Joachim Kuss** used high-resolution profiling from the GODESS mooring to illustrate how episodic inflows of saline water interleave within the halocline, bringing essential oxygen and fundamentally altering nutrient chemistry in the eastern Gotland Basin.

3. Integrated Coastal Processes and Emerging Biogeochemical Factors

This section merges the impacts of human infrastructure with specialized studies on coastal dynamics and chemical anomalies:

- **Infrastructure and Modeling: Jan Kossack** modeled the potential impacts of future industrial-scale offshore wind farms and green hydrogen production, noting that infrastructure drag and the discharge of waste heat and brine could influence local hydrodynamics and hypoxia.
- **Riverine and Coastal Feedback: Karol Kuliński** explored an unintended side effect of nutrient reductions in the Vistula River: increasing summer total alkalinity. This suggests that fewer phytoplankton blooms result in higher pH and less calcium carbonate precipitation, which may help mitigate ocean acidification. In shallow lagoons, **Maren Voss** found that internal biological cycling often overrides the expected "coastal filter" function, necessitating the integration of actual biological rate measurements into future models.
- **Novel Tracking and Detection: Marta Małgorzata Misiewicz** used hydroacoustic methods to identify pockmarks in Puck Bay, confirming they are active sites of seasonal freshwater groundwater discharge. Regarding food webs, **Marc Silberberger** employed compound-specific stable isotope analysis to track the diet of herring larvae, observing a transition from terrestrial/riverine organic matter to in-situ primary production. Finally, **Jan H. Reißmann** investigated salinity anomalies in the western Baltic, linking them to dissolved calcium carbonate from river runoff and its subsequent impact on carbon chemistry and pH levels.

Conclusion: The oral presentations in Session 5 highlight a Baltic Sea in transition. While political efforts have successfully reduced land-based pollution, the ecosystem's recovery is slow and increasingly hampered by climate change. The integration of high-resolution observations with novel modeling techniques remains essential for managing the biogeochemical health of this vulnerable region.

Session H: Sea level and coastal change (summarized by Kevin Parnell)

Scope: Variability and change of mean and extreme sea level; waves, storm surges, currents, seiches, variations in wind and sea level pressure, river runoff, effects of sea ice, inflows, thermosteric effects, land uplift/subsidence and their effects on sea level/sediment transport/coastal changes; projections of future sea level rise, observed and projected long-term trends and multi-decadal variations

Two of the six oral presentation referenced river and river mouth dynamics. Elken discussed current and sea level observations at short time scales in the channel between Varna Lake and the Black Sea, and Jansson demonstrated gradient reversals and backwater effects in rivers draining to the Baltic Sea. Three papers presented developments in data acquisition and analysis. Schröder discussed challenges in mapping sea surface elevation and elevation changes in the North and Baltic Seas. Grzonka introduced methods to extract water surface elevation distributions directly from observations. Dudzinska-Nowak demonstrated advances in obtaining bathymetric data in the challenging shallow coastal zone using airborne laser bathymetry instruments. The relative influence of vessel traffic versus wave forcing in sedimentation patterns in a dredged channel was reviewed by Utso.

The poster presentations covered a diverse range of topics. Kelpšaitė-Rimkienė discussed the apparently simple but actually difficult examination of aeolian sediment transport capture with traps. Long-term shoreline changes were discussed by Dudzinska-Nowak in the light of the dating of submerged forests, and Uścińowicz discussed accelerated erosion processes that led to a change from a coastal barrier to a cliffed coast. Shorter term coastal processes were reviewed in the context

of relationships between meteorological and sea level data (Liu), Baltic Sea storms (Łabuz), and surface waves as they influence bottom sediment transport (Reinart).

At the end of the session reference was made to the renewed Research Topic under Baltic Earth 2, RT4 Sea Level and Coastal Change, led by Ralf Weisse and Kevin Parnell.

Session I: Philosophical aspects of Baltic Sea Earth system research (summarized by Sonja Ehlers)

Omstedt summarizes ideas which shaped the understanding of the Earth System in the Baltic Basin. He invites the conference participants to provide input regarding this topic. The goal is to write a book for the next generation of students and scientists.

Destouni et al. investigate the interactions of surface, ground, and coastal waters across the land-sea interface. The aim is to better understand freshwater discharges and their nutrient and pollutant loads from land to sea.

Session J: Marginal Seas – Humans and Environment (summarized by Jan Harff and Jinpeng Zhang)

The Baltic Sea ranks among the most thoroughly researched regional seas, as a semi-enclosed sea bordering the open ocean, the Baltic—much like other comparable seas—faces increasing threats from shifting natural and anthropogenic impact factors. This global pressure on marginal seas, their coastlines, and their catchment areas is driven primarily by climate change and the overexploitation of their resources. Consequently, there is a need for generally applicable strategies to ensure sustainable development. This theme was the focus of the "Marginal Seas Session" at the 6th BE Conference, which featured seven lectures and seven posters presented onsite and online by participants from the Baltic and Scandinavian countries, the Ukraine, China and the USA. Within the frame of a research concept described in general by the lecture of **Harff and Greene** the following thematic focal points emerged from lectures, posters and the discussions:

Comparison of Marginal Seas

One of the pivotal steps toward the disciplinary advancement of marginal sea sciences involves the systematic classification of marginal seas as interfaces between continents and oceans. In this context, it is crucial to consider not only their current state but also the specific developmental trajectory of each individual marginal sea—ranging from its pristine, natural baseline to its current, anthropogenically impacted phase. **Zhang** focused his interpretation of paleontological data along the Holocene time scale. In a comparative study of the northern shelf of the South China and the southern Baltic Sea, he paid particular attention to the global dimension of the impact of the 4.2 ka climate event on the paleo-environment of the respective regional sedimentary basins. As examples of the effects of climate change and sea-level fluctuations on coastal evolution, **Wang** relying on seismic profiling correlated sediment cores reconstructed in her poster the paleogeography of the Beibu Gulf (SCS) and the Baltic Sea during the Late Pleistocene and Holocene. In doing so, the author placed special emphasis on the differences between these two types of marginal seas, which she described through the lens of source-to-sink modeling. Benthic biodiversity constitutes, a key parameter for characterizing the status of marginal seas and, consequently, for comparing them—precisely because benthic communities respond to environmental gradients and maintain resilience across highly variable settings. **Gogina et al.** presented in their lecture concept and first results of a feasibility study for analyzing benthic macrofaunal biodiversity and ecosystem functioning in a selection of globally distributed marginal seas. The parameters involved integrate quantitative abundance datasets with global trait repositories to derive taxonomic richness, functional diversity metrics and the density of major functional groups. As illustrative examples, the authors compared Disko Bay, the Salish Sea, and the Baltic Sea based on seafloor substrate characteristics (utilizing the

"dbSeabed" database). **Kratzer** used in her online lecture satellite ocean colour (optical) observations to compare Baltic Sea, Adriatic Sea and Disko Bay (Greenland). The analysis focused on differences in inherent optical properties to understand productivity in these three marginal seas: Whereas the Baltic Sea represents a system where high absorption by dissolved organic terrestrial matter reduces light penetration, the Adriatic Sea is characterized by strong river inputs, whereas Disko Bay represents a polar environment, where meltwater plumes and stratification determine the regime.

Marginal Seas Under Pressure

The key question in marginal sea research concerns the differing responses of various marginal sea types to the global challenges of climate change and the increasing exploitation of their resources. The effects of these stressors are particularly evident in the trends of indicator variables, which represent the following trends and were addressed at the conference:

Heat waves

In addition to pollution severe pressure is put on marginal Seas by accelerating climate warming. In their lecture **Gröger et al.** presented in his lecture the first global analysis of warming rates and marine heat wave emergence – two of the most detrimental thermal stressors for marine ecosystems. The study is based on a classification of 19 marginal seas considering oceanographic status parameters. The study reveals that most marginal seas have entered a period of peak warming trends, whereby future projections predict a continuation of this development.

Pollution

According to the lecture of **Zialkowska et al.**, chemical pollutants significantly affect the environmental status of the Baltic Sea and are a significant driver of biodiversity loss. To monitor the complex impact of various pollutants, the authors recommend the use of effect-based methods (EBMs) that rely on biomarkers. Feasibility studies have been conducted in the Gulf of Gdansk, Baltic Sea. The biomarker-based early warning system for sediment pollution was described in more detail by **Strode et al.** in their poster outlining the results of a case study in the Gulf of Riga. **Ehlers et al.** introduced by their poster new challenges in the scope of marginal seas pollution by highlighting metallic debris and wet wipes. Solid anthropogenic metal core concretions as well as foil-like wet wipes frequently adhere to submarine concrete constructions and hard ground that started to become a challenge for environmental geoscientists.

Other anthropogenic pressures

Gogina et al. by their poster compared Fehmarn Belt and Oder bank in the Baltic Sea regarding sediment substrate, biodiversity of macrofauna, meiofauna and anthropogenic impact such as trawling pressure discovered that meiofauna and macrofauna do not respond synchronously to environmental gradients and anthropogenic disturbance. Instead, as previously discovered for other marginal seas they form partially independent ecological layers, whose decoupling offers a multidimensional view on assessing ecosystem recovery after official stopping bottom trawling. **Ovcharuk et al.** investigated the effect of abrupt changing the northern river discharge to the Black Sea after destruction of Kakhovka hydropower dam due to combat operations in the south-eastern Ukraine. The sudden discharge in 2 weeks of 40 % of the annual runoff of the Dniro River caused the sudden transport of large amount of contaminated sediments to the Black Sea, additionally the seasonal regulation of the river outflow stopped, so that extensive construction work is necessary to repair the damage.

Management marginal seas sustainable development

Ocean deoxygenation is a growing global threat to marine biodiversity, ecosystem services, and coastal economies. **Handmann et al.** introduced in their lecture Engineered Oxygen Supply (EOS) as a method of restoration measure for hypoxic and anoxic marine environments. While minimizing greenhouse gas emissions and nutrient pollution are repairing oxygen depletion on decadal time scale, EOS is providing short-to-medium term mitigation opportunities.

Data and models

Miluch et al. introduced by their poster a model of the Vistula Delta sedimentary architecture, driven by geological data synthesized by different types of offshore data (boreholes, seismic and seismoacoustic surveys, multi-beam bathymetry) and onshore data (boreholes, airborne laser scanning). This data hub can serve as base for numerical comparison with river mouth systems of other marginal seas. **Oppelt et al.** reported by their poster about the „CoastSense“ program of the University of Kiel, Germany, structured along five tightly coupled axes, from seamless Land to Sea (L2S) monitoring to Ocean to Society (O2S) data to policy infrastructures. CoastSense will support coupled Earth system and impact modelling.

Summarizing the results in comparison with the outcomes of the 5th Baltic Earth conference in 2024 we confirm that the plans of 2024 helped to proceed on our way to better understanding of marginal seas systematics. This fact is approved by the results in marginal seas' taxonomy based on oceanographic parameters. Progress is also visible in understanding cause-effect relationship of marginal seas' parameters exemplified by sea bed substrates and biodiversity variables. On the other side we have to strengthen our forces to assign generalized management strategies for sustainable development marginal seas. To hit this target a special co-operation with the Baltic Earth Working Group on „Multiple drivers of Earth System Changes“ is recommended.