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Preface

The **6th Baltic Earth Conference**, held in Heringsdorf, Usedom, Germany, from 13 to 17 April 2026, brings together the international research community focused on advancing understanding of the Baltic Sea region as a coupled Earth system. Organized every two years in a Baltic Sea neighbouring country, the conference provides a platform for scientific exchange, interdisciplinary dialogue, and collaboration.

Baltic Earth aims to improve Earth system understanding of the Baltic Sea region as a basis for science-based management in response to climatic, environmental, and human pressures. By linking research across the atmosphere, land, and marine environment, it promotes an integrated perspective on processes shaping this vulnerable region. Since 2025, the **International Baltic Earth Secretariat** has been jointly hosted by the **Leibniz Institute for Baltic Sea Research Warnemünde (IOW)** and the **Institute of Oceanology of the Polish Academy of Sciences (IOPAN)**, marking the transition to **Baltic Earth 2.0**.

This year, the conference attracts **over 120 international scientists**, including a strong representation of early career scientists. The conference has also been endorsed as a **UN Ocean Decade Activity** under the United Nations Decade of Ocean Science for Sustainable Development, highlighting its contribution to advancing ocean science and supporting sustainable solutions.

The abstracts collected in this volume reflect the breadth and interdisciplinary nature of current Baltic Earth research. The scientific programme is organized around **ten thematic sessions** aligned with the Baltic Earth Science Plan:

1. Climate variability and teleconnections
2. Bridging scales: From small-scale turbulence to basin-wide circulation
3. Natural hazards and their impacts
4. Sea level and coastal change
5. Biogeochemistry of the Baltic Sea – Linking observations and modelling
6. Baltic Optics: Advancing Ocean Colour Science and Applications in the Baltic Sea
7. Adaptive governance under multiple drivers of change in the Baltic Sea
8. Marginal Seas – Humans and Environment
9. Future projections of the Baltic Sea region
10. Philosophical aspects of Baltic Sea Earth system research

Together, these sessions highlight the diversity of contemporary Baltic Sea research, from physical processes and biogeochemistry to governance and conceptual perspectives on Earth system science. This abstract book provides a record of the contributions presented at the conference and reflects the vitality and collaborative spirit of the Baltic Earth community.

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Keynote Speeches

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Predicting the Black Sea state at weather and climate scales

The Black Sea is the largest euxinic basin in the world ocean. Oxygen is only present in the first 80-120 m and below that depth, the basin contains huge pools of hydrogen sulfide and ammonia. Since several decades, the equilibrium of the Black Sea vertical structure has been affected by eutrophication and warming with the progressive disappearance of the Cold Intermediate Layer and the rising of the main oxycline. These changes will potentially significantly affect the Black Sea physics, biogeochemical cycles and biology over the next decade.

We use the Biogeochemical Model for Benthic and Hypoxic Influenced areas (BAMHBI), coupled to the hydrodynamic model NEMO and to the regional atmospheric model (MAR) to predict the Black Sea physical and biogeochemical state at weather and climate time scales.

The NEMO-BAMHBI-data assimilation prediction system is used to daily forecast the Black Sea biogeochemical state in the frame of the Black Sea marine forecasting center of the marine Copernicus service. Climate projections are also performed until the end of the century under two scenarios of changes (SSP1, SSP5). A trait-based distribution model based on neural network is developed to connect the environmental conditions predicted by NEMO-BAMHBI with benthic biodiversity and functions and to explain the Black Sea state recovery after eutrophication and hypoxia.

We also present results from a stochastic version of the NEMO-BAMHBI prediction system extended with a radiative transfer model to assimilate satellite reflectance. This ensemble version is obtained by considering the uncertainty on inherent optical properties. Satellite reflectance are then assimilated using an ensemble Kalman filter.

Finally, a model emulator based on deep learning (diffusion models) is tested as an economic alternative of the physical-law based NEMO BAMHBI model. In particular, we test the capacity of the AI- based model to simulate the oxygen state and bottom hypoxia when assimilating earth observations provided by satellites.

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Baltic Sea salinity: A complex interplay between small scale physics, basin geometry and large scale forcing

The Baltic Sea's salinity dominated stratification is a consequence of a balance between intermittent inflow events bringing saline water from the neighbouring Kattegat and a large input of freshwater primarily from rivers. Both of these drivers could change considerably as a consequence of global warming and large uncertainties persist in their future trajectories. A consequence of these large uncertainties is that even the sign of future Baltic Sea salinity changes is hard to pin down. Here we will discuss an approach, which is complementary to regional climate projections, where Baltic Sea salinity is given a functional representation in terms of these drivers. More specifically, a state-of-the-art regional ocean model is used to estimate a Taylor polynomial giving Baltic Sea mean salinity as a function of freshwater forcing and salinity changes in the North Atlantic. Key results are that the polynomial can be used to infer salinity changes without having to run a model and the coefficients of the polynomial give information about the bulk effects of the drivers and their interactions.

Water mass transformation through small scale mixing is another agent determining the stratification of the Baltic Sea. A new paradigm for the overturning in the global ocean has shown how bottom intensified mixing and an insulating bottom boundary condition sets up a circulation where water is rising in bottom boundary layers and sinking in the interior. Here, similar ideas are applied to the Baltic Sea. The resulting picture is an overturning circulation strongly constrained by the hypsographic curve, with strong transformation occurring

in certain depth ranges. However, it is also noted that these transformation hotspots are not visible when water mass transformation is visualized in buoyancy space, indicating that the effect of these hotspots is spread naturally over a large range of water masses.

Natascha Oppelt

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Where land and ocean meet: Remote sensing of Baltic coastal zones

Coastal regions of the Baltic Sea are among the most dynamic and optically complex environments on Earth. They form rapidly changing interfaces where physical, biogeochemical, ecological, and societal processes are tightly coupled and are highly relevant for climate mitigation, biodiversity conservation, and coastal adaptation. Yet, observations and models still struggle to consistently capture coastal dynamics across spatial and temporal scales, particularly in shallow, turbid waters. Over the past two decades, advances in Earth Observation (EO), data processing, and computing power have opened new possibilities for monitoring water quality, coastal morphology, and vegetated habitats, particularly seagrass meadows and other blue-carbon systems. Recent developments in optical, hyperspectral, and radar satellite missions, complemented by UAVs and in situ observations, increasingly help to close the long-standing gap between terrestrial and marine monitoring in the Baltic Sea. This keynote synthesizes experiences and lessons learned from remote sensing applications for Baltic coastal mapping and monitoring, ranging from satellite-based retrievals of water constituents and benthic vegetation to hyperspectral in situ networks and AI-supported data fusion across sensors and scales. Particular emphasis will be placed on: (i) the challenges of observing shallow, optically complex coastal waters; (ii) the value of harmonized, long-term EO data for detecting trends and extremes; and (iii) pathways for integrating remote sensing products into ecosystem models, blue-carbon assessments, and coastal adaptation planning. Looking ahead, the talk outlines a vision for “seamless” coastal sensing in the Baltic, combining satellite, airborne, and in situ observations in the coastal zone. This perspective directly links core Baltic Earth priorities on sea-level and coastal change, biogeochemistry, and micro- to basin-scale processes with emerging concepts such as digital coastal twins and nature-based climate solutions in coastal and marine environments.

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New challenges for ocean governance: Climate change, biodiversity, deep-sea mining and shadow fleets

The oceans are increasingly becoming the focus of global ecological, political, economic and geopolitical challenges. Diverse uses, human intervention, and advancing climate change are leading to biodiversity loss and endangering the vulnerable marine ecosystem. In addition, there are questions regarding the regulation of deep seabed, as well as maritime security issues (e.g., shadow fleets). The current international law of the sea – which forms the basis for global ocean governance – is a framework agreement that needs to be further specified and cannot provide satisfactory answers to these complex challenges. Further international regulations and multilateral initiatives are needed.

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Partners in CLIME: Cooperation between HELCOM and Baltic Earth as a key element in science-based regional climate policy

As the triple planetary crisis of climate change, biodiversity and pollution accelerates, the Baltic Sea is heavily impacted by all three dimensions of the crisis. To quote the 2023 State of the Baltic Sea Report: “The Baltic Sea is under increasing impacts from climate change and biodiversity degradation catalyzed by eutrophication, pollution, land use and resource extraction.” It should be noted that the impact of climate change on Europe, including the Baltic Sea Region, is more pronounced than the global average, marginal seas warm faster than the open ocean and the Baltic Sea is warming faster than any other regional sea. This is already becoming evident as precipitation in the northern reaches of the Baltic Sea is increasing, ice cover is declining, the frequency and duration of marine heatwaves is growing, and distribution patterns of species are shifting northwards.

Against this somber background, the Baltic Sea Region does, however, offer an encouraging example of successful science-policy cooperation in seeking to tackle the challenges of climate change, exemplified by the long-standing cooperation between the Helsinki Commission (HELCOM) and Baltic Earth. Since 2018, this cooperation – the fulcrum of which is the joint HELCOM-Baltic Earth Expert Network on Climate Change (EN Clime) – has contributed to reducing the lag between scientific work and policy implementation, establishing an exchange that forms the basis of informed, science-based decision-making within HELCOM. Perhaps the most visible output of this joint endeavor is the HELCOM-Baltic Earth Climate Change Fact Sheet, first published in 2021, revised in 2024 and currently being updated with a view to publishing a third edition by the end of this decade.

As HELCOM continues to implement its 2021 Baltic Sea Action Plan, which takes account of climate change as a cross-cutting, overarching issue (a so-called “Horizontal Topic” in the diction of the Plan) and starts looking beyond the Plan’s 2030 target date, cooperation between the Commission and Baltic Earth will continue to be a key element in regional efforts to mitigate and cope with the impacts of a shifting climate.

Oral Presentations

Session 1

Climate variability and teleconnections

Externally forced low-frequency variations in European climate

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The European climate is characterized by a pronounced variability on various time scales which complicates the detection of responses to external drivers like anthropogenic greenhouse gas emissions. One powerful tool to disentangle internal climate variability and responses to external drivers are so-called Single-Model Initial-condition Large Ensembles (SMILEs). As the name indicates, these are large ensembles of (global) model runs which are similar except for their initial conditions. Hence, all ensemble members evolve with their distinct realization of internal variability but exhibit the same response to external drivers which can be extracted by computing the ensemble mean. In a previous study, we employed two SMILEs to explore links between sea surface temperature (SST) variability in the North Atlantic and marginal European seas (including the Baltic Sea). One main outcome was that mainly the externally-forced components of the European and North Atlantic SSTs are connected. However, this link was not present throughout the whole period (1850-2100) and its strength likely depended on changes in shortwave downward radiation, suggesting an influence of anthropogenic aerosol emissions. The latter exhibited pronounced changes over the past decades which had a variety of climate impacts. Our present study extends those results to other climate variables, in particular precipitation. We additionally conduct a so-called Low Frequency Component Analysis to extract the dominant modes of low-frequency variability, i.e., in the multidecadal range. The previously identified, likely aerosol-related, signal is among the first two modes of low-frequency variability in both annually and seasonally averaged precipitation and SST data. We compare these findings to a single-forcing SMILE in which all external drivers except anthropogenic aerosol emissions were kept constant to further investigate how past changes in aerosol emissions impacted European low-frequency variability.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Abstract No. 41

Teleconnections to the Baltic Sea region: Controls, predictability and consequences

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Teleconnections between the North Atlantic and the Baltic Sea region are shaped by the polar jet stream and are critical drivers of weather and climate in the region, thereby impacting the physical and biogeochemical properties of the Baltic Sea ecosystem. This review synthesizes how key circulation features and modes of climate variability, including the North Atlantic Oscillation, atmospheric blocking and the Atlantic Multidecadal Variability, influence the Baltic Sea region. By examining existing literature data and observational and climate model data, we summarize links to temperature, precipitation, storms and other key indicators from synoptic to multidecadal time scales. We then assess how these climate controls cascade into ecosystem relevant processes, namely oxygen dynamics, primary productivity and ocean acidification. Although physical links are already established, the pathways connecting large-scale atmospheric patterns to biogeochemistry are still poorly constrained, partly because dedicated field studies and targeted model experiments are limited. We outline priority research needs to enhance near-term predictability and reduce uncertainty in future projections for the Baltic Sea.

Early Career Scientist (ECS) contribution

Three centuries of weather observations on board of Danish ships: First results from ROPEWALK (Rescuing Old data with People's Efforts: Weather and climate Archives from Logbook records)

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ROPEWALK, funded by the AP Møller Mærsk Fund, is a joint initiative of the Danish National Archive and the Danish Meteorological Institute, which aims at digitizing and transcribing all weather observations in Danish ship journals and logbooks stored in the Danish National Archive, consisting of more than 750 shelf metres beginning as early as the 1680s. With the exception of the Napoleonic wars, the data is complete. Ship journals over large parts of the Northern Atlantic are kept in the archive, with two regions of particular interest, Greenland and the Øresund: The Greenlandic Trade Company had a monopoly for commerce with the colony of Greenland for nearly 200 years. These "Greenland Voyages" to western Greenland were conducted several times per year, starting as early as 1721. Weather observations from these voyages often include detailed sea ice observations. Every ship passing the sound or belts in Denmark had to pay for passage between 1426 and 1857. To ensure payment, Danish war ships were placed at strategic locations in Øresund and Great Belt. Weather observations on board of these ships go back to the end of the Little Ice Age. Up to roughly 1750, the data consists of diary-like daily note in free text. Starting in the 1710s, observations are recorded as numbers in preprinted tables. We have scanned and transcribed this latter dataset, which took 13 person-years, resulting in 2.1 million images covering more than 2.5 TB of data. Then we constructed a data model, trained a machine learning algorithm and conducted quality control both in an automatised way and (in a subproject) with the help of high school students. Free text data will be considered later. We are now able to present first results. When the project is finished, all transcribed data will be made publicly available for future research.

Abstract No. 105

Regional and multi-level atmospheric circulation controls on Baltic Sea inflows variability

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Typically, the water exchange between the Baltic Sea and the North Sea is limited by narrow straits and high freshwater runoff, resulting in prevailing outflow conditions. Sporadic inflows of saline water are essential for maintaining the salt balance and ecological health of the Baltic Sea. Major Baltic inflows (MBIs) are classified as events when saline water reaches the deep central basins, replacing deep, low-oxygenated waters with oxygenated surface water that sinks to depth after passing through the shallow Danish Straits. The trigger of sporadic inflow events lies in the atmosphere, and the direct atmospheric forcing consists of two phases: first, high pressure with easterly winds lasts over the Baltic Sea region, followed by strong westerlies. The intensity and impact of each inflow event are determined by the duration, strength, and temporal succession of these atmospheric phases. Notably, the predictability of MBIs is enhanced by assessing whether the atmospheric circulation during the year with inflow deviates from the climatological average. Another source of predictability lies in the upper atmospheric levels, as the signal of transformation in atmospheric circulation begins at higher levels, starting with the jet stream. This underscores the necessity of analysing atmospheric circulation throughout the entire atmospheric column, employing flexible methodologies that accommodate varying spatial and temporal resolutions. This study conducts a sensitivity analysis using circulation classifications, systematically varying spatial domains, pressure levels, and time periods. The results offer key insights for scientific understanding and environmental management, clarifying event variability and aiding detection through atmospheric parameters.

Session 2
**Bridging scales: From small-scale turbulence
to basin-wide circulation**

Abstract No.12

High-resolution mapping of Baltic Sea coastal dynamics using a micro-AUV

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Coastal and transitional areas of the Baltic Sea exhibit strong spatial gradients, rapid atmospheric forcing responses, and complex mixing processes between riverine and marine waters. These regions remain challenging to observe with existing platforms, leaving important Baltic Earth process studies undersampled. To assess the capabilities of emerging autonomous tools, we carried out eleven missions with a micro-autonomous underwater vehicle (micro-AUV) across three contrasting areas in 2025: the shallow estuarine Bay of Matsalu, the highly variable Suur Strait, and the strongly stratified coastal slope of the Baltic Proper. The micro-AUV provided high-resolution transects and vertical profiles from < 2 m to > 100 m depth, resolving fine-scale structures. Observed features included (i) an estuarine frontal system with sharp thermohaline and biogeochemical gradients, (ii) submesoscale intrusions, (iii) multiple interacting water masses, (iv) a persistent near-bottom turbidity maximum, and (v) a dual coastal upwelling structure associated with thermocline and halocline shoaling under easterly winds. Comparison with reference measurements confirmed high accuracy for temperature and salinity, as well as strong correspondence for chlorophyll-a and turbidity. The AUV's maneuverability and speed ($1.5\text{--}3\text{ m s}^{-1}$) enabled near-synoptic mesoscale mapping and operation in shallow, complex topography where other autonomous moving platforms face difficulties. Our results demonstrate that micro-AUVs can enhance Baltic Sea observing systems by filling a critical gap in the existing observing system. Their ability to capture estuarine exchange, submesoscale variability, and benthic processes makes them valuable tools for targeted campaigns, adaptive sampling, and contributions to the Baltic Earth research agenda.

Submesoscale dynamics in the Baltic Sea

Urmas Lips ^{1*}, **Kai Salm** ¹, **Germo Väli** ¹, **Taavi Liblik** ¹, **Lars Arneborg** ², **Louise C. Biddle** ³, **Anna I. Bulczak** ⁴, **Evridiki Chrysagi** ⁵, **Małgorzata Falarz** ⁶, **Peter Holtermann** ⁷, **Jaromir Jakacki** ⁴, **H. E. Markus Meier** ⁷, **Martin Mohrmann** ³, **Kai Myrberg** ⁸, **Per Pemberton** ², **Lars Umlauf** ⁷

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The roles of submesoscale processes in energy transfer across spatial scales and in the redistribution of tracers are still poorly understood. They are characterised by an $O(1)$ Rossby number, i.e., high vertical vorticity, and an $O(1)$ balanced Richardson (Rib) number, i.e., linked to strong spatial buoyancy gradients. Due to ubiquitous lateral density gradients generated by salinity differences and wind-driven upwelling events and fronts, the Baltic Sea serves as a natural laboratory for investigating submesoscale processes. Recent advances in in-situ observations, remote sensing, and numerical modelling have brought more attention to them in this stratified sea area. We present examples of studies of submesoscale processes in the Baltic Sea, where their occurrence and development have been linked with processes at adjacent scales, including upwelling events, fronts, and baroclinic currents in geostrophic balance, as well as small-scale turbulence. Submesoscale subduction at fronts is suggested as a major contributor to mixing in the interior subsurface layers. We introduce an updated scheme of energy transfer across spatial scales that includes instabilities and feedback loops in the submesoscale range. This analysis demonstrates that SMS processes may substantially influence large-scale dynamics and tracer distributions in the Baltic Sea. Gaps in knowledge of SMS dynamics and potential further steps to address them will be highlighted.

Abstract No. 59

From hours to seasons: Temperature and Oxygen dynamics in shallow Baltic waters – lessons from the Boltenhagen Observatory

Peter Holtermann^{1*}, **Carl Bukowski**², **Michael Naumann**¹, **Oliver Thiele**¹, **Soeren Ahmerkamp**¹, **Volker Mohrholz**¹, **Uwe Krumme**²

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Coastal hypoxia is a growing global threat to marine ecosystems. While deep waters of the Baltic Sea have been nearly permanently anoxic since the mid-20th century, near-coastal hypoxia—defined here as hypoxic conditions in waters shallower than 20 m—has received less attention. However, over the past decade, evidence suggests an increase in such events in the Baltic Sea. To better understand the spatial and temporal dynamics, as well as the intensity of coastal hypoxia, we established a long-term observatory in the western Baltic Sea near Boltenhagen, an area used by both commercial and recreational fishers. Since July 2021, the observatory has continuously measured water velocity, temperature, and bottom oxygen concentrations along a depth gradient (5–25 m) using moored sensors and an acoustic current meter. A major challenge of the deployment was the strong biofouling of oxygen sensors during the summer months. These measurements are complemented by regular research cruises with CTD and MSS casts. A striking finding is the occurrence of short-term hypoxic events, even in the shallowest parts of the study area. These events can last less than half a day and reach oxygen levels lethal to higher organisms. Due to their brevity, they are difficult to capture with conventional monitoring and require continuous, high-resolution measurements. The long-term, high-resolution time series now allows for statistical analysis of such events. Process investigations reveal that these intense hypoxic pulses result from a complex interaction: they are driven by the coastal upwelling of deep hypoxic water, modified by local turbulent mixing and lateral transport, and amplified by significant oxygen consumption at the seafloor and in the water column. Specifically, particle camera measurements revealed an extremely high particle density below the halocline during summer months. Incubation experiments confirm that these abundant particles act as a major oxygen sink for the whole marine system.

Flexible design of a multiparametric monitoring system for the observation of shallow-water processes in the Baltic Sea

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The systematic exploration of coastal regions and shallow-water environments in the Baltic Sea is gaining renewed prominence in contemporary marine research. These zones account for about 15 % of the total Baltic Sea area and are presumed to exert a strong influence on the marine ecosystem. This is due to the dynamic interactions between the atmosphere, seawater, and marine sediments, which drive biological and chemical processes. This contribution presents the conceptual design and implementation of a resilient, IoT-enabled monitoring platform engineered for high adaptability across a wide range of deployment sites, operational depths, and sensor configurations. In addition to standard oceanographic parameters—water temperature, pressure, conductivity, dissolved oxygen concentration, turbidity, chlorophyll-a, and FDOM—the system integrates a current profiler and an autonomous DNA sampler. The individual monitoring stations featuring sensor-specific configuration control and supporting an energy-efficient operating mode that enables autonomous long-term use for more than six months. The architecture is largely decentralized in a IoT-based networking framework ensures continuous data availability and facilitates the automated registration of heterogeneous platforms, deployments, sensors on a central server. Since January 2025, the prototype has been in continuous operation in the Mecklenburg Bay off the coast of Nienhagen (Germany) at a depth of 12 m. Initial observations show rapid changes between stratified and mixed states of the water column, pronounced resuspension events, and strongly fluctuating oxygen concentrations. A significant event in this context was the spatially limited fish kill from August 25 to 28 between Markgrafenheide and Heiligendamm (around Rostock, Germany).

Abstract No. 74

Vertical reorganization of spring phytoplankton at fronts: Insights from a high-resolution glider mission

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Understanding how physical processes across scales structure phytoplankton distributions in shallow, strongly stratified coastal seas remains a major challenge. We analyse the data of an 11-day measurement campaign, including high-resolution glider mission in the Gulf of Finland (Baltic Sea, 5–15 May 2016) that captured both the presence and the breakdown of subsurface chlorophyll-a maxima (SCMs). SCMs were consistently positioned below the stratification maximum and confined to $\sigma \sim 4.8\text{--}5.2 \text{ kg m}^{-3}$, aligning with a persistent cross-frontal density gradient. During the early part of the mission, SCMs followed sloping isopycnals, reflecting subduction of chlorophyll-rich water into the stratified interior. Subsequent modest adjustments in stratification – weakening of coastal N^2 and offshore shoaling of the mixed layer – were accompanied by vertical reorganisation of SCMs, including secondary maxima and vertically smeared layers. A dynamical hotspot where σ - and depth-trends of SCM reversed sign, coinciding with an isopycnal-slope reversal characteristic of frontal interaction zones that enhance vertical exchange, was revealed. Wavenumber spectra showed temperature behaving as a passive tracer, whereas chlorophyll spectra flattened at isopycnal surfaces with SCM, suggesting biological modification and partial decoupling from physical stirring. Despite substantial variability in stratification and SCM structure, depth-integrated biomass remained laterally uniform, indicating that frontal dynamics primarily reorganise biomass vertically rather than horizontally. We suggest that such vertical structuring of springtime phytoplankton by submesoscale frontal processes favours SCM formation, thereby allowing biomass to remain relatively high under conditions of nitrogen depletion in the surface mixed layer.

Early Career Scientist (ECS) contribution

Circulation of the Central Baltic from current meter observations and numerical simulations

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Currents and circulation patterns play a key role in redistributing heat, salt, and other substances, thereby shaping the environmental conditions in the Baltic Sea. In 2022, a measurement campaign was carried out as part of the Central Baltic Circulation Experiment (CABLE), during which an array of acoustic current meters was deployed for half a year. In parallel, we conducted a decade-long numerical experiment using a high-resolution GETM setup. We used the observations to evaluate the model's performance. We then incorporated observational constraints to improve the simulated fields. Initial results showed that agreement between the observations and the model was strongest near the coasts. Offshore currents were less well reproduced, although several key features—such as a strong deep current at the Fårö sill—were apparent in both the observed and modelled fields. By combining CABLE observations with high-resolution simulations, we investigate the current structure, circulation, and transport of the Central Baltic across synoptic, seasonal, and interannual timescales. Our work advances understanding of regional circulation, its governing dynamics, and its environmental impacts.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Abstract No. 81

Role of small-scale processes in saltwater transport in the Baltic Sea: Results from a high-resolution modelling study

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High- and low-resolution model simulations with grid spacings of 250 m and 1 n.m., respectively, are used to study the distribution of saline water mass in the Baltic Sea. Both simulations include additional tracers marking concentration and age of inflowing high-saline water, which allow quantification of differences between model simulations. Results indicate larger surface and bottom concentrations in the high-resolution simulation, but more complicated differences in age. Saltwater tracer transport is more persistent in the low-resolution simulation, but the patterns and magnitudes of net transport are similar in both runs. Horizontal volume transports are also similar in both model runs; the halocline ventilation is slightly higher in the high-resolution simulation. Striking differences occur in the vertical transport from below to above the halocline – although the patterns are similar in the southern part of the Baltic Sea, significantly stronger vertical velocities occur in the northern part of the sea in the high-resolution simulation, indicating large contribution from submesoscale processes to the vertical exchange. Overall, the overturning circulation in different regions of the Baltic proper is stronger in the high-resolution simulation. Subsurface eddy activity in the halocline is much higher in upwelling regions, such as the Gulf of Finland, western coast of Gotland Island, and Gdansk Bay, but also in regions dominated by saltwater inflows – the Stolpe Channel, Bornholm Channel, and southern part of eastern Gotland Basin. Nevertheless, in those regions, the total kinetic energy is also the highest.

Session 3

Natural hazards and their impacts

Abstract No. 11

Assessing hazard and impact of extreme flooding in Pärnu, eastern Baltic Sea

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Low level populated areas are vulnerable to high water levels. A flooding becomes more serious if the high water level persists for a long time and coincides with cold weather. Such an event occurred in January 2005 at Pärnu, when a storm surge happened on the background of excess water volume in the Gulf of Riga. The highest water levels here are jointly influenced by three major drivers: the water volume of the entire Baltic Sea that changes on multi-weekly scale, water occasionally pushed by a sequence of cyclones into the gulf for 1–2 days and local storm surges with a duration of a few hours. Each of these drivers can contribute up to about 1 m to the resulting water level. This “statistically almost impossible water level” (3.05 m) left strong impression on society and has motivated the city of Pärnu to search for practical and cost-effective measures to reduce the damage and risk. In this case study, we (i) analyse the impact of different estimates of extremely high water levels in conjunction with changing climate on various areas, (ii) investigate which areas need to be protected and which should adapt with the floods, (iii) study how to prevent, minimize and mitigate the damage. Additionally, strategies of risk reduction and resilience building are discussed. The detailed technical solutions with cost estimates are shown. This work will be used for local management and as a blueprint for similar studies in other cities in the Baltics.

Early Career Scientist (ECS) contribution

Automated classification of atmospheric circulation types for compound flood risk assessment: CMIP6 model analysis utilising a deep learning ensemble

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The simultaneous occurrence of high river discharges and storm surges represents a substantial hazard for many low-lying coastal areas. Potential future changes in the frequency or intensity of such compound flood events are therefore of utmost importance. To assess such changes, large and consistent ensembles with storm surge and hydrological models are needed, but are hardly available. Often the occurrence of compound flood events is linked to the presence of certain atmospheric circulation types. Future changes in the frequency of such patterns can be directly inferred from available climate simulations. A frequently used classification of atmospheric circulation types are the so-called “Großwetterlagen” by Hess and Brezowsky. In this study, possible future changes in the occurrence of these “Großwetterlagen” were analysed using data from 31 realisations of CMIP6 climate simulations for the emission scenarios SSP1-2.6, SSP3-7.0, and SSP5-8.5. Given the subjective nature of the classification, a deep learning ensemble for the automatic classification was developed and applied. In winter, a higher frequency of the atmospheric pattern Cyclonic Westerly towards 2100 could be inferred as a robust result among all models and scenarios. As this circulation type is potentially associated with compound flooding in some parts of the European coasts, this points towards potentially increasing risks from compound flooding in the future.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Abstract No. 19

Derivation of the seasonal damage risk of Baltic Sea storm surges and concepts for minimization

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The Baltic Sea storm surge from 19 to 21 October 2023 caused considerable damage. Facilities requiring individual protection were particularly affected. Compared with historical storm surges, extensive data is available for the event in question. This includes:

- time series of water levels and sea conditions,
- surveys of the location of the affected facilities,
- information on potentially affected property value,
- documentation of the extent and nature of the direct and indirect damage that occurred.

Areas with inadequate dykes, marinas, campsites and tourist infrastructure suffered significant damage. Past storm surge statistics were used to develop the seasonality of damage risk. A measure of damage risk is defined by superimposing the seasonal distribution of the property value on the seasonal storm surge frequency. This measure can be used to develop specific protection concepts. Preventive measures that are already implemented during the winter season, such as clearing moorings and campsites, reduce the risk during the winter months. At present, additional precautionary measures must be implemented during the transition period in order to cover the above-mentioned categories of precautionary measures. The analysis of the hydrological data of the storm surge provides insights into the necessary response times and the course of the damage that occurred. These can be used to develop individual, implementable protective measures. During the 2023 event, the response time was approximately two days to implement countermeasures. Realistically feasible immediate measures to minimise damage include:

- timely evacuation of people from the danger zone,
- removal of mobile property from endangered areas,
- securing assets that cannot be removed promptly by minimising the stresses to which they are exposed.

The Marina facility is used to illustrate measures that could minimize damage during storm surges.

Analysis of floods, wildfires and windstorms in Europe and their impacts in the years 1950–2020 using the HANZE database

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This study examined the occurrence and impacts of floods, wildfires and windstorms in Europe between 1950 and 2020, with particular emphasis on the Baltic Sea region. Using the HANZE database, which provides harmonised information for 42 European countries, the analysis focused on the number of events and their socio-economic consequences. Four categories of impacts were analysed:

- the proportion of the affected area relative to the total area of the region or country,
- the number of fatalities,
- the number of people affected,
- the economic losses expressed in millions of euros (2024 values).

The comparative analysis for the Baltic Sea region revealed clear differences between the three types of hazards. The South Baltic countries recorded both a higher number of floods and substantially greater flood-related damage than the northern Baltic states. Wildfires were infrequent across the Baltic Sea region and their impacts were minimal compared with those observed in Southern Europe. Windstorms showed the most variability: while they occurred regularly throughout the region, the frequency of events and the magnitude of their impacts differed noticeably between countries. The study highlights that in the Baltic Sea region floods represent the most significant natural hazard, both in terms of frequency and impact, followed by windstorms, whereas wildfires play a minor role in shaping regional risk.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Abstract No. 30

Microbial communities as universal sensors of anthropogenic pollution in the Baltic Sea

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Microorganisms constitute the majority of all organisms across ecosystems and occupy an exceptionally broad range of ecological niches. As a result, they respond sensitively to diverse environmental and anthropogenic signals. Advances in environmental DNA (eDNA) sequencing now allow us to capture the composition of microbial communities across a wide taxonomic range in a rapid and cost-effective manner. At the same time, these methods generate unprecedented volumes of data for microbial ecology, enabling and necessitating the adoption of modern machine learning approaches. In this talk, we summarize recent work from our group that combines machine learning with environmental microbiome research aiming to establish microbial communities as universal sensors of anthropogenic pollution and environmental change in the Baltic Sea region. Our studies show that microbial assemblages exhibit characteristic responses to a wide range of anthropogenic compounds, including pharmaceuticals, herbicides, UV filters, antifouling paint particles (and associated heavy metals), and even explosive residues such as TNT. In parallel, we have generated extensive eDNA datasets with exceptional spatial and temporal resolution and developed new analytical tools inspired by recent advances in computational linguistics. Finally, we present first results from collaborations with environmental agencies exploring how microbial biomonitoring, coupled with machine-learning methods, can be integrated into official environmental monitoring frameworks.

Early Career Scientist (ECS) contribution

Responding to coastal erosion with managed retreat in the Baltic Sea

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Coastal erosion poses challenges to Baltic Sea coastal states, and climate-driven shifts in e.g. sea level, ice cover, and wind (and wave) patterns require effective adaptation strategies. In the 1970s and 1980s, mapping Coastal Hazard Zones was a common management response. By the 1990s, managed retreat (or realignment), where infrastructure loss or relocation is accepted to permit natural shoreline movement, often in the context of Integrated Coastal Zone Management, was increasingly recommended. However, managed retreat implementation has remained limited. Many cited cases of managed retreat represent wetland restoration rather than genuine retreat which requires accepting the loss or relocation of built assets. The well-known Markgrafenheide–Hütelmoor (Germany) realignment highlights this distinction with a ring-dike constructed to protect a village, with only agricultural and conservation land being effectively abandoned. Coastal setback policies that reduce the need for managed retreat exist in several Baltic Sea states. However, they often face political resistance and are frequently disregarded or overridden by local and regional authorities. Whether dedicated managed retreat policies are needed remains an open question as scientific advances now enable better prediction of high-risk areas. Improved knowledge of spatially variable drivers and their effects supports more targeted and proactive management under present and future climate scenarios. Using Estonia as an example, the distance between the shoreline and the nearest infrastructure was measured. Of the 2,468 km of coastline (mainland and major islands), 15% has infrastructure within 20 m (defined as the +1 m MSL contour), 24% within 40 m, 31% within 60 m, and 52% within 150 m of the coast. These data, combined with shoreline type and historical change records, help identify infrastructure that requires protection or abandonment under current and accelerated erosion scenarios. Extending this approach across the Baltic Sea region could support more consistent, evidence-based adaptation planning.

Evaluation of the temporal and spatial changes in the extreme sea levels in the Baltic Sea

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Coastal flooding poses one of the most serious threats to the low-lying coastal regions. For coastal engineering and urban planners, information on the return values of extreme sea level events is essential. In the Baltic Sea, extreme water levels are driven by multiple processes operating on different timescales and following different probability distributions which leads to spatially varying coastal vulnerability. Future projections and return values of extremes are commonly estimated using the Generalized Extreme Value (GEV) distribution. The GEV distribution is defined by three parameters: the location parameter, representing the typical magnitude of extremes; the scale parameter, describing the variability of the maxima; and the shape parameter, which determines the heaviness of the distribution tail. Classical extreme value analysis assumes that these parameters remain stationary over time. However, climate change and long-term variability in forcing mechanisms can lead to nonstationarity in extreme-value behaviour. In this study, we investigate systematic changes in the GEV parameters using observational water-level records from 60 stations along the Baltic Sea coast. The temporal coverages of the datasets range from over 130 years to approximately 40 years. We find evidence of significant changes and of possible regime shifts in all three GEV parameters across all stations. Notably, changes in the parameters along the western coasts of the Baltic Sea differ significantly from those along the eastern coasts, both in direction and timing. Nevertheless, some coherent regional patterns emerge, with similar changes occurring simultaneously across groups of stations.

An intensive upwelling event of hypoxic water at the southern Baltic Sea coast in September 2025 – A rare phenomenon or quite common?

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Large-scale upwelling events of deep water are a common oceanographic process in the world ocean, but little is known about the development of small-scale, pulsed upwelling events in nearshore areas. For example, the Baltic Sea generally shows high eutrophication levels and is heavily polluted by land-based inputs of nitrogen and phosphorus. These inputs, combined with the long residence time of deep water, have led to the intensified accumulation of biomass from algal blooms on the seafloor over decades. This promotes the seasonal development of oxygen-depleted zones from late summer to autumn, when organisms die and sink to the bottom, and oxygen is consumed during biomass decomposition. The exact situation in shallow coastal areas is largely unknown, as permanently oxygen-depleted water masses do not typically occur here, but rather appear in short periods, some of which last only a few hours (Holtermann et al., Abstract No. 59). Despite their brevity, these anoxic events can have a strong impact on the coastal ecosystem. Here, we describe an upwelling event that led to the mortality of fish and benthic organisms between 24 and 28 September 2025 along the southern Baltic Sea coast. A key question is the extent and frequency to which such wind-driven upwelling events may have occurred in the past, and whether their frequency and intensity have changed over time. This is analysed using long-term wind data from the Warnemünde weather station since 1954.

Abstract No. 101

Modelling-based reconstruction of the high water levels and waves that occurred during Storm Babet in October 2023 along the Schleswig-Holstein Baltic Sea coast

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Only limited hydrodynamic measurements, particularly of waves, are available for the severe storm surge in October 2023 along the Schleswig-Holstein coast. To enable a detailed assessment of hydrodynamic conditions, especially nearshore, a hindcast of local water levels and waves was conducted along the entire Schleswig-Holstein Baltic Sea coast. A high-resolution, coupled hydrodynamic–numerical model chain for the North Sea and Baltic Sea was applied, developed within the joint research project Baltic Sea Coast 2100 (2019–2023). Meteorological forcing was provided by CoastDat-3 reanalysis wind fields. Overall, model performance was rated good to very good. Deviations between simulated and observed water levels at peak storm surge were generally below 10 cm, which is critical for accurately reproducing water-depth-dependent nearshore coastal waves. At the time of maximum observed significant wave height, mean absolute errors at coastal stations were 0.3 m for significant wave height, 0.2 s for peak wave period, and 3.2° for mean wave direction. Based on the prevailing easterly storm conditions and coastal exposure, two hotspots of increased hydrodynamic loads were identified, both associated with severe damage to coastal protection structures and marine infrastructure. The first hotspot is located in Kiel Bay between Schleimünde and Booknis/Wabs south of Damp. In the nearshore transition zone down to water depths of about 10 m, significant wave heights reached approximately 3.6 m with peak periods up to 8 s from easterly directions. The second hotspot is situated in Lübeck Bay between the east coast of Fehmarn and Grömitz, where significant wave heights of up to about 3.5 m occurred in deeper waters, driven by east-northeasterly waves with peak periods of up to 7 s. These results document the intense hydrodynamic loading caused by the severe easterly storm surge and highlight the critical role of wave-induced loads for coastal protection and maritime infrastructure.

Session 4

Sea level and coastal change

Abstract No. 4

Resonant sub-hourly sea level and current events in river mouths: An example from Varna Channel

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Current and sea level observations conducted over three months on the 2.4-km-long and 300-m-wide channel between Varna Lake and the Black Sea revealed that moderate sub-hourly dynamics are occasionally interrupted by high-amplitude oscillations, evident in both the sea level and current records. Oscillation packets, with a main period of about 20 minutes, were nearly synchronous in all three novel Hydromast observation stations installed within the EU ILIAD project for the ocean digital twin. A small signal delay of a few minutes from the seaward point towards upstream was noticed, corresponding to the phase speed of a long gravity wave over a depth of about 7 m. The maximum changes in current and sea level - up to 0.8 m/s and 0.8 m, respectively, over 10 minutes - are harmful to ship navigation, harbor operations, and coastal management. In terms of hydrodynamics, such changes follow mostly linear dynamics, and non-linear advection remains below 10% of the acceleration terms. The peaks in observed energy spectra correspond to a quarter-wave resonance in the system sea-channel-upstream lake. The resonant excitation of the events was studied using a 1D barotropic model. During one of the events, moderate meteorological conditions prevailed; the strong channel oscillations started abruptly and lasted a few periods. This event is interpreted as a meteotsunami. The second high-amplitude event occurred more than 5 h after landward winds above 10 m/s. High sub-hourly meteorological variations, including wind gusts, were observed during this event, likely to force resonant oscillations in the channel. Approaches to detect and forecast strong sub-hourly oscillations are discussed, including the coasts of the Baltic Sea.

Interactions between vessel traffic, wave forcing and sedimentation in a shallow coastal channel

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Shallow coastal channels in the Baltic Sea often require regular dredging to stay navigable, but the balance between natural coastal processes and maintenance activities is not always clear. In Estonia, the Rukki Channel forms the most critical part of the only shipping route between the mainland and Hiiumaa, making its reliability important. The channel has repeatedly lost depth due to sedimentation, even though dredging has been carried out, yet there has been no detailed assessment of how waves and seabed dynamics contribute to this development. Over the last decade, twice-yearly high-resolution bathymetric surveys, together with records of dredging, provide a basis for distinguishing natural seabed change from human intervention. A notable characteristic of the channel is that it is used by identical shallow-draft ferries following the same route. Their repeated movements create a persistent central sediment mound that interacts with naturally driven accumulation processes. To understand how waves may contribute to sediment movement, numerical wave modelling with SWAN forced by ERA5 is used. Instead of focusing on individual events, long-term patterns of wave exposure are taken to describe general hydrodynamic conditions around the channel. Bathymetric differencing shows that sediment accumulates along the central axis of the channel, while areas on both sides remain remarkably deeper. Some of these changes appear during periods without dredging while others occur after longer periods of increased wave activity. The combined use of repeated seabed measurements and simplified wave-forcing indicators helps identify where natural drivers reinforce the effects of ferry traffic. This study demonstrates how observational records together with basic modelling can clarify long-term sedimentation mechanisms in a shallow coastal channel. Applying similar approaches to other shallow coastal areas would support assessment of navigational risks and more effective planning of maintenance strategies.

Early Career Scientist (ECS) contribution

Abstract No. 53

Mapping elevation and elevation changes in the North and Baltic Sea

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The sea level is used to define the national height references for centuries. In recent years, the marine sector gained importance and many applications as safe and efficient satellite-based navigation, the expansion of offshore wind energy or the adaptation to climate change require precise geodetic information. In order to fulfil these growing user requirements, the German Federal Agency for Cartography and Geodesy (BKG) processes observations of satellite altimetry to derive regionalized sea level products with a special focus on accuracy and consistency with other national geodetic products. We use observations from satellite altimetry since 1992 to map and monitor the sea level. We focus on the North and Baltic Sea and integrate several regional high-resolution models and parameters in order to improve the results. As a reference for the altimetric measurements we use the geoid model of the internationally unified Baltic Sea Chart Datum 2000 (BSCD2000). We validate the satellite observations using measurements on the offshore research platform FINO2 and other tide gauges along the coast. A comparison between satellite altimetry and different hydrodynamic models documents the quality of both types of data and could help to improve both datasets in future. We present our recently released first products of mean sea surface height and time series for specific areas. Furthermore, we also present our strategy of combining satellite altimetry with different other observation techniques of sea level changes and land uplift to map and monitor elevation and elevation changes in the German coastal zone and the surrounding seas.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Data-driven investigation of the free surface elevation probabilistic characteristics

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Wind-generated surface waves are inherently random and irregular, making a complete deterministic description unattainable. Yet, accurate knowledge of their statistical properties is essential for engineering applications and for understanding ocean dynamics. To deepen this understanding and build more efficient wind-wave models, machine-learning approaches are likely to become increasingly valuable. Recent progress in physics-informed machine learning (PIML) has transformed fluid mechanics by combining data-driven approaches with physical constraints, enabling more robust and generalizable models, and will likely revolutionize physical oceanography as well. In this study, we apply state-of-the-art PIML techniques to identify probabilistic characteristics of wind waves, focusing on the probability density function (PDF) of free-surface elevations. Our approach extracts the underlying distribution directly from data, without relying on restrictive assumptions or classical approximations. We use field measurements collected in Skulte, Latvia, during August–September 2022. The dataset includes pressure time series and 3D velocity profiles, providing a detailed description of wave dynamics. Building upon existing PIML architectures, we developed a framework capable of inferring an accurate and efficient probabilistic model of wind waves. Preliminary results show promising agreement with theoretical expectations and previous studies. The dataset was provided by Kevin Parnell and colleagues from Tallinn University of Technology (TalTech), together with the Latvian Institute of Aquatic Ecology. Our findings highlight the potential of PIML for improving probabilistic wave modelling and set the foundation for future applications in coastal engineering and environmental monitoring.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Spatial pattern of coastal changes of the southern Baltic from airborne laser bathymetry (ALB)

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The effects of constant, very intensive changes occurring in coastal zones can pose a real threat to infrastructure and local communities. In the context of observed climate change, sea level rise, and the increasing number and intensity of storm events, it is crucial to precisely monitor changes along the coast and to determine scenarios for coastline development in support of broadly defined coastal safety. However, shallow coastal areas are very difficult to study due to the need to use separate measurement methods for the land and underwater parts, as well as their technical limitations, which do not allow for obtaining a complete picture of the coast, leaving gaps between measurements in the profiles. The presented research demonstrates the application of airborne laser bathymetry (ALB) technology in monitoring the southern coast of the Baltic Sea, carried out by the Maritime Office in Szczecin in 2023 and 2024. It covers a technical description, validation of the method's accuracy, a discussion of its advantages and limitations, and the first results showing the spatial pattern of morphological changes over a one-year period. The results, showing the full morphology of the coastal zone, including the nearshore, foreshore, and backshore, were obtained simultaneously for the first time as part of regular coastal monitoring rather than as part of experimental recordings of selected sections. These data, covering a height range from 8 m water depth to the dune and cliff top, provide a unique opportunity to observe sediment pathways, highlighting areas of intense erosion and local sediment deposition. They also allow calculation of the exact volumes of material transported from the eroded terrestrial part to the underwater part and determination of the sediment balance. This first-ever comprehensive picture of coastal changes could significantly contribute to a full understanding of coastal functioning.

SWOT reveals gradient reversals in Baltic rivers

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River-sea transition zones challenge traditional disciplinary boundaries, as their dynamics are shaped by both fluvial and coastal processes. The Tidal Freshwater Zone (TFWZ) has emerged as a unifying concept to describe these transitional reaches, yet uncertainties remain regarding the drivers of water level variability, backwater effects, and material exchange, which is particularly true in where tides are negligible. Semi-enclosed basins such as the Baltic Sea exemplify this knowledge gap, as coastal water levels are primarily governed by other coastal drivers, such as wind and atmospheric pressures, rather than tidal oscillations. Here, we investigate the extent to which non-tidal coastal forcing propagates upstream into Baltic rivers, generating persistent backwater conditions within the TFWZ. We use water surface elevation observations from the Surface Water and Ocean Topography (SWOT) mission Pixel Cloud (PIXC) product to quantify spatiotemporal patterns of water level variability along 41 of the largest rivers in the Baltic Sea catchment area. By comparing downstream and upstream transects, we identify periods and locations where elevated coastal water levels influence riverine hydraulics. Our results reveal widespread and recurrent backwater effects extending tens of kilometers upstream, linked to wind-driven sea level anomalies. These findings demonstrate that coastal-river coupling in the Baltic basin is stronger than commonly assumed and highlight the importance of atmospheric forcing in shaping freshwater-marine exchange in weak tidal systems. This study provides new insights into the functioning and condition of Baltic TFWZs, raising important concerns of Baltic coastal dynamics under changing climatic conditions.

Early Career Scientist (ECS) contribution

Session 5
Biogeochemistry of the Baltic Sea
– Linking observations and modelling

Potential impacts of future offshore renewables on Baltic Sea hydrodynamics and hypoxia

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Offshore renewable energy (ORE), including the production of green hydrogen coupled to the production of offshore wind (OW) energy, is emerging as a pivotal component of ambitious decarbonization strategies in the Baltic Sea region. The required large-scale OW infrastructure impacts both atmospheric and ocean dynamics, with potential consequences for the marine ecosystem. The Baltic Sea ecosystem is already under significant pressure by multiple human activities, with hypoxia posing a particularly critical challenge due to limited water exchange, stratification, important sediment nutrient legacy and eutrophication. In this study, we use the coupled physical-biogeochemical model system SCHISM-ECOSMO to demonstrate the regional impact of a potential future industrial-size OW farm with coupled offshore hydrogen production in the Baltic Sea. We apply parameterizations to represent surface wind speed reduction and underwater structure drag by the offshore wind farm, and explicitly simulate waste heat and brine discharge associated with offshore hydrogen production. Our results illustrate the consequences of planned large-scale ORE infrastructure for hydrodynamics in the Baltic Sea and explore potential ecosystem impacts over seasonal to inter-annual time scales. The model results provide new insights into the impact of ORE on coastal sea dynamics and biogeochemistry and raise awareness for potential changes in the particularly vulnerable Baltic Sea ecosystem.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Salinity anomalies from density measurements in the western Baltic Sea

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Since summer 2020 the BSH takes samples for density measurements in the German EEZ within the western Baltic Sea during its seasonal monitoring cruises in summer and winter. These samples are used to determine their reference salinity from conductivity and a suitable estimate of their absolute salinity from density. For Standard Water these quantities are identical but for Baltic Sea water they differ due to deviations in the salt composition. The salinity anomalies calculated as the difference between absolute and reference salinity are used to characterise the deviation of the salt composition from that of Standard Water using a linear mixing model of Baltic Sea and Standard Water. By dividing the total data set into subsets of surface and bottom data, summer and winter data and so on this procedure leads to more specific observations. Moreover, these splittings can be done for each survey separately resulting in respective time series of the determined salt composition anomalies. Commonly, the salt composition anomaly in the Baltic Sea is mostly attributed to dissolved calcium carbonate (CaCO_3) discharged by river run-off as Ca^{2+} and $(\text{CO}_3)^{2-}$ thus contributing to alkalinity and influencing carbon chemistry and pH. Therefore, this work can help to detect changes and trends of coastal hydrology and gives some information with respect to ocean acidification. However, the known seasonal effects of biological activity are also seen and partly disguise long term trends. It is found that the salinity anomalies at the bottom are generally larger than at the surface with the largest difference in summer. While the salinity anomalies at the bottom are similar in summer and winter, they are smaller in summer at the surface indicating surface processes in summer. Although the time series are still too short to allow for inferences, they show some distinct signals yet.

Phytoplankton spring bloom intensity as an indicator for eutrophication in the open North-East Atlantic Ocean and Baltic Sea

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The North-East Atlantic Ocean and the Baltic Sea are undergoing pronounced human-induced eutrophication — a true code blue for our seas — driven by excessive accumulation of nutrients. This leads to phytoplankton and harmful algal growth, which increase seabed hypoxia and degrade overall water quality. While both climate change and human-induced eutrophication influence phytoplankton dynamics, their combined effect remains unclear, particularly regarding future impacts. The need for coordinated, basin-scale assessment and management has recently been boosted through the project CodeBlue, funded by the Sustainable Blue Economy Partnership. This European project aims to strengthen integrated approaches for developing effective, long-term eutrophication mitigation policies across the North-East Atlantic Ocean and Baltic Sea by harmonizing existing work and creating new “what-if” simulations. These include three hindcast simulations: current conditions, reduced riverine nutrient inputs and no-climate change, and two climate projections. Operational indicators for eutrophication in both HELCOM and OSPAR include summer chlorophyll-a and winter nutrient concentrations in the water column. In HELCOM, the phytoplankton spring bloom intensity, a complementary indicator to summer chlorophyll-a, provides information on the most intensive but short-lived phytoplankton growth period and was included as a pre-core indicator in 2015. However, the intensity of the spring bloom determining good environmental status in the open ocean has not yet been established. Here, we apply the latest developments of the phytoplankton spring bloom intensity to the open Baltic Sea and assess possibilities to combine the existing method with the “what-if” simulations to be produced within CodeBlue. Our preliminary results—both from model and observations—show that while the method can be harmonized for the entire Baltic Sea, the chlorophyll concentration limit determining the start and end of the spring bloom is highly spatio-temporal dependent. Overall, our findings suggest that a region-specific approach could lead to a robust spring bloom indicator for the open sea.

Abstract No. 24

A new lens on eutrophication: Trophic transfer index, lags, and hysteresis in the Baltic Sea (1950–2020)

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We present a long-term assessment (1950–2020) of Baltic Sea eutrophication using the Trophic Transfer Index (TTI). We assume that in a healthy ecosystem the transfer of produced carbon to higher trophic levels is tightly coupled to production, which is reflected by a high TTI. Our results reveal significant structural ecosystem changes in 1974, 1988, and 2012. Cross-correlation analysis confirms a lag of at least 17 years between changes in nutrient load and subsequent TTI response. Furthermore, we find strong hysteresis effects; the ecosystem remains in a sub-Good Environmental Status (sub-GES) despite load reductions, indicating a shifting baseline. Primary drivers of this degradation were increased cyanobacteria abundance and a decreasing dissolved inorganic nitrogen (DIN) to phosphorus (DIP) ratio. Simulations indicate this DIN:DIP decrease was caused primarily by hydrodynamically triggered phosphorus release from sediments, rather than changing riverine loads. The TTI based assessment is compared with that based on traditional indicators (bulk DIN, DIP, oxygen, chlorophyll), analogies and differences are highlighted. We also introduce a method for estimating TTI from measured data using artificial neural networks. While TTI analysis hints at a slow, recent recovery, this signal is contradicted by traditional indicators, indicating that further research is needed to understand whether the Baltic Sea environment is, finally, recovering from its former degraded status.

Tracing basal food sources and trophic dynamics of herring larvae in the Vistula Lagoon using compound-specific stable isotope analysis of amino acids

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The trophic support of fish larvae provides insight into carbon and nitrogen flow through food webs, reflecting the sources and transformations of organic matter in the Baltic Sea. Spring-spawning herring (*Clupea harengus*) rely on seasonal phytoplankton and zooplankton blooms, yet the pathways linking basal food sources to larval growth remain poorly resolved. Here, we evaluate compound-specific stable isotope analysis of amino acids (CSIA-AA) as a tool to quantify larval trophic positions and contributions from different primary producers, in comparison with traditional bulk stable isotope analysis. Larvae, mesozooplankton, particulate organic matter (POM), and sediment were collected during two spring 2025 campaigns at two stations in the Vistula Lagoon. Larval growth was substantial, with standard lengths increasing from 18 to 28 mm and dry weights rising tenfold. Bulk $\delta^{15}\text{N}$ of larvae remained remarkably stable across all sampling events, indicating a consistent trophic position, despite substantial variation in $\delta^{15}\text{N}$ of POM and zooplankton. In contrast, $\delta^{13}\text{C}$ increased over time, suggesting an initial reliance on terrestrial/riverine organic matter or methanotrophic sources that gradually shifted to in-situ primary production. CSIA-AA is expected to refine trophic position estimates and resolve contributions from distinct primary producers without requiring site-specific baselines. By linking larval feeding ecology to basal food sources, this approach provides mechanistic insight into nutrient flow, carbon assimilation, and early life-stage development, illustrating how trophic interactions mediate biogeochemical processes in the Baltic Sea.

Abstract No. 31

Changes in nutrient chemistry by episodic oxygen supply in the halocline

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As part of an estuarine system, the central Baltic Sea receives almost permanently inflows of haline oxygenated water in the deep water that compensate outflow at the surface. This is due to a density gradient between the higher salinity water in the Belt Sea and the fresher brackish water in the north-eastern Gotland Basin. However, depending on the properties of the intruding water and how it mixes on its way to the central basin it could interleave in the appropriate halocline layer in the central basin according to its density. These differently preformed water parcels bring oxygen to the central basin and considerably alter the nutrient chemistry. This process is investigated in the eastern Gotland Basin using regular monitoring data and sequences of highly-resolved profiling measurements from the GODESS mooring, in order to estimate short-term changes in nutrient concentration, over time and space. GODESS data allows to assess the dynamics of temperature, salinity, dissolved oxygen, and turbidity data on six to twelve-hour time intervals, over the deployment periods of several weeks to a few months. Classic oxygen, hydrogen sulfide and nutrient measurements of water samples were used to interpret the profiling mooring's high resolution sensor data. In turn, the high-resolution sensor readings are used to bridge the gap in coarse monitoring data in order to gain an understanding of the spatial and temporal dynamics of the processes occurring during oxygen intrusion in the halocline, with turbidity indicating oxygen consumption.

Nutrient levels in the southern Baltic in 1969–2024 – Impacts of ecological politics and climate change

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Eutrophication is one of the main pressures affecting the functioning of the Baltic Sea ecosystem. The most significant source of nitrogen and phosphorus compounds reaching the Baltic are rivers, which carry 77% of total nitrogen and 88% of total phosphorus. Measures taken during the geopolitical transformation and after Poland's accession to the EU, primarily involving wastewater management and agricultural activities, have significantly reduced the inflow of nutrients into the sea. Considering the recommendations to reduce nutrient inflow by 25% for N-TOT and 60% for P-TOT compared to the reference period of 1997-2003, a reduction of 31% for N-TOT and 67% for P-TOT was achieved in 2023. This was reflected in a decline in dissolved inorganic nitrogen in the southern Baltic Sea (including the deep-water region) after 1997. This represents a reversal of the trend observed since 1969. Phosphate concentrations did not show a significant trend throughout 1969-2024, nor did total phosphorus. The most surprising pattern of change was observed in total nitrogen concentrations. They declined from the early 1980s to the 1990s, reaching their lowest values during the study period. Following this, a significant increase in N-TOT concentrations was observed after 1997, most likely due to climate change, which led to rising Baltic water temperatures. A significant change in the rate of temperature increase in the southern Baltic occurred in the mid-1990s. The temperature change throughout the period is 0.7°C per decade, and since 1998, an increase of 0.9°C has been recorded. This causes an intensification of blooms and an extension of the growing season, affecting the assimilation capacity of nitrogen taken directly from the atmosphere, which increases the N-TOT load in the southern Baltic ecosystem. In 2019, after the hottest year in 2018, the trend reversed again, indicating a decrease in N-TOT concentrations in the following years until 2024.

Abstract No. 66

Dynamics of biological rates in shallow water over the course of the year and consequences for our understanding of the coastal filter

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Shallow waters of only a few meters depth, on which the current Shore to Basin project at the Leibniz Institute for Baltic Sea Research is focused, are insufficiently understood. These regions are extremely dynamic, subject to close coupling of physical and biological processes and close interaction between processes in sediments and in the water column. As a result, physical/biogeochemical modeling of these coastal areas is unsatisfactory, and there is a lack of understanding of coastal processes for the entire Baltic Sea. Over the past years, we measured rates of nitrogen fixation, nitrification, primary production, nitrate uptake, Dissimilatory Nitrate Reduction to Ammonium (DNRA), and denitrification at various shallow sites to better understand the fate of nutrients in the coastal filter. The coastal filter is described as collection of biogeochemical processes altering the fate of nutrients during their passage towards the open sea. Sampling campaigns and measurements were conducted quarterly to monthly over a full seasonal cycle in the Odra lagoon and at the open coast near Rostock. We found that the role of internal cycling process in lagoons are dominating over the filter function. Our data reflect some seasonality in denitrification and DNRA rates but they were much less pronounced than expected as they were likely regulated by other factors such as wind events causing resuspension and currents, nutrient release, sediment type and light climate. Competing processes influenced each other, particularly in the light-flooded area of the Baltic Sea. These results show the necessity to integrate rate measurements into coastal filter models, especially with climate change further altering coastal ecosystems.

Using observations and DIVAnd interpolation tool to calculate anoxic and hypoxic area with error fields in the Baltic Sea

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The Baltic Sea has experienced intermittent hypoxia and anoxia since it became predominantly brackish around 8,500–8,000 years ago, but oxygen conditions have worsened sharply in recent decades due to rising anthropogenic pressures. Since the 1960s, deep waters in the central Baltic Sea have remained permanently anoxic, and seasonal anoxia is now increasingly observed in many shallow areas. Quantifying the extent of hypoxia/anoxia has long been central to assessing ecosystem status, including impacts on fish stocks, benthic communities, and eutrophication. Although methods for estimating low-oxygen areas differ across countries and regions, they generally yield comparable results. However, current approaches seldom include uncertainty estimations linked to data gaps. Despite extensive monitoring efforts and long oxygen time series, data scarcity persists, especially for earlier periods and specific basins. Here, we applied the multidimensional variational analysis (DIVAnd) framework, an advanced interpolation method that combines observations with background fields and bathymetry. DIVAnd generates continuous three-dimensional oxygen fields that closely match observations while respecting a series of pre-determined and informed constraints, such as preventing interpolation between unlinked basins (e.g., sills, narrow straits, and complex coastlines) and optimally representing the spatial distribution and density of observations over time. From these interpolated 3D fields, we derived depth layers representing oxygen concentrations below 180, 90, and 0 $\mu\text{mol/L}$, which were used to estimate total hypoxic and anoxic areas in the Baltic Proper, along with associated error matrices. While resulting estimates align with previous assessments, the explicit quantification of uncertainties highlights regions and periods most affected by observational gaps. Overall, the DIVAnd based approach provides robust, spatially explicit estimates of hypoxic and anoxic areas in the Baltic Sea from 1960 to 2024, together with uncertainty maps that enhance confidence in the results and clarify how errors relate to individual observations.

Abstract No. 72

Multidecadal variability of hypoxia in the Baltic Sea and Major Baltic Inflows: Is there a connection?

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The Baltic Sea is one of the marginal seas prone to hypoxia due to its limited water exchange and permanent haline stratification. During the 20th century, the hypoxia in the central Baltic Sea deep basins expanded dramatically, with the most notable increase occurring in the 1950s. At the same time, in 1951, the largest ever measured Major Baltic Inflow (MBI) occurred, an event that transported dense, saline, oxygen-rich water from the North Sea along the bottom into the deep central Baltic Sea. It is thought that this event, despite ventilating the deep central Baltic Sea basins, also increased haline stratification, which triggered the expansion of hypoxia in the central Baltic Sea, later fueled by the elevated nutrient load from land. In this study, we applied a 3-dimensional regional coupled hydrodynamic-biogeochemical model to investigate the effects of the 1951 MBI and MBIs in general on the multidecadal variability of hypoxic volume in the deep central Baltic Sea basins. We conducted a set of sensitivity experiments with modified external forcing in which the 1951 MBI, or MBIs in general, were suppressed. We found that the 1951 MBI does not significantly affect the multidecadal variability of either stratification or hypoxia in the deep central Baltic Sea basins. All its effects cease within a decade after occurrence. MBIs in general, however, significantly strengthen stratification across the Gotland subbasins, but amplify hypoxia in the Bornholm Basin and the western Gotland Basin. Despite some regional differences, the multidecadal positive trend in hypoxia in the deep central Baltic Sea basins persists across all sensitivity experiments, making eutrophication the single major driver of elevated hypoxia in these basins.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Pockmark research and assessment of submarine groundwater discharge in outer Puck Bay (southern Baltic Sea)

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The submarine groundwater discharge (SGD) is “all flow of water through continental and insular margins from the seabed to the coastal ocean, regardless of fluid composition or driving force” (Burnett et al., 2003). SGD is a significant hydrological process that affects the water balance and chemical composition of coastal and offshore waters (Moore, 2010). In this study, hydroacoustic methods were used to quickly identify potential areas of active groundwater discharge in outer Puck Bay. Bathymetric surveys were carried on the R/V Oceanograf over 18 days in the study area, where depths were greater than 10 m, to map the seafloor and identify potential SGD zones - pockmarks. This methods significantly reduced the time required for identifying SGD zones compared to earlier methods based on pore water chloride analysis, which involved time-consuming sample collection in this region. Further analysis of chloride ion in pore water and thermohaline structure confirmed that the identified structures at the bottom (pockmarks) were freshwater discharge sites rather than gas seepages. The magnitude of submarine groundwater discharge (SGD) was estimated to vary from $1.5 \cdot 10^{-2}$ to $5.7 \cdot 10^{-2}$ $L \cdot m^{-2} \cdot h^{-1}$ in August 2020, $2.9 \cdot 10^{-2}$ to $18.9 \cdot 10^{-2}$ $L \cdot m^{-2} \cdot h^{-1}$ in December 2020, and $1.2 \cdot 10^{-2}$ $L \cdot m^{-2} \cdot h^{-1}$ in February 2024, indicating seasonal variability in the intensity of SGD. The study results provide a better understanding of the submarine groundwater discharge phenomenon in Puck Bay.

References:

- Burnett, W.C., Bokuniewicz, H., Huettel, M., Moore, W.S., Taniguchi, M., 2003. Groundwater and pore water inputs to the coastal zone. *Biogeochemistry* 66, 2–22. <https://doi.org/10.1023/B:BIOG.0000006066.21240.53>
- Moore, W.S., 2010. The effect of submarine groundwater discharge on the ocean. *Annu. Rev. Mar. Sci.* 2, 59–88. <https://doi.org/10.1146/annurev-marine-120308-081019>

Early Career Scientist (ECS) contribution

Abstract No. 109

Are the increasing summer total alkalinity concentrations in the Vistula River a side effect of HELCOM's actions of reducing nutrient loads from land?

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Continental rivers, including the Vistula, flow through a limestone-rich catchment area and are an important net source of total alkalinity (TA) for the Baltic Sea. TA concentrations in the Vistula vary significantly seasonally, decreasing from approximately 4050 $\mu\text{mol/kg}$ in winter to approximately 2000 $\mu\text{mol/kg}$ in summer. Our studies, conducted at the lower section of the Vistula for nearly nine years with a two-week resolution, indicate that one of the causes of this seasonality is calcium carbonate precipitation induced by strong phytoplankton blooms in spring and summer. As a result of intensive organic matter production, CO₂ consumption leads to an increase in pH, which in turn causes calcium carbonate supersaturation and precipitation, leading to a decrease in TA concentration. Although these processes require further quantitative confirmation, preliminary time-series analysis indicates that summer TA concentration minima in the Vistula increase slightly over time. At the same time, a year-on-year decline in nutrients and summer levels of particulate organic carbon (POC, a measure of primary production) in the Vistula are observed – both of these are the result of HELCOM's long-standing efforts to reduce N and P loads to counteract eutrophication of the Baltic Sea. Is this coupling between the increase in summer TA concentrations in the Vistula River and the decrease in POC and nutrients merely a coincidence? Or perhaps the seasonal changes in Vistula TA concentrations are a side effect of large-scale activities related to the implementation of HELCOM's goals of reducing nutrient loads from land? And if so, whether and to what extent have HELCOM's nutrient load reductions caused unintended changes in Baltic TA levels that counteract Ocean Acidification? Although not everything has yet been experimentally confirmed, this presentation aims to integrate data-based conclusions with theoretical hypotheses, thereby identifying existing knowledge gaps and thus the research needs to verify them.

Session 6
**Baltic optics: Advancing ocean colour science
and applications in the Baltic Sea**

Abstract No. 44

Variability of optical properties and composition of size-fractionated suspended particulate matter samples from the surface waters of the southern Baltic Sea – another element of the region's optical complexity

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Inherent optical properties (IOPs) and various bulk composition characteristics of suspended particles were measured in original and size-fractionated surface water samples collected in the southern Baltic Sea. Measured IOPs included the spectral beam attenuation coefficient of particles, the spectral scattering coefficient of particles, and the spectral absorption coefficients of particles, depigmented (non-algal) particles and phytoplankton. The bulk composition of suspended particles' assemblages was characterised by measuring the mass concentrations of suspended particulate matter (SPM), particulate organic matter (POM), particulate inorganic matter (PIM), and phytoplankton pigments including chlorophyll a (Chl-a). All optical and biogeochemical measurements were performed concurrently on original/unfiltered seawater, as well as on size-fractionated seawater samples obtained by filtration using a combination of meshes and membrane filters. This allowed us to determine the contribution of three distinguished particle size fractions - very small (VS), small (S) and combined medium and large (ML) particles - to the bulk SPM and Chl-a concentrations, as well as to the various optical coefficients analysed. Our original samples were characterized by a large variability in bulk particulate matter composition, with noticeable compositional differences between the distinguished particle size fractions. We documented that the contributions of the VS, S, and ML fractions to the analysed optical coefficients were largely variable between individual samples; however, in most cases, the contributions of the S fraction were the highest. We also documented clear differences between particle size fractions in the mean spectral slopes of the beam attenuation coefficients by particles, and in the mean values of the SPM-specific coefficients of scattering by particles and absorption by depigmented particles, as well as the Chl-a-specific coefficients of absorption by phytoplankton. Furthermore, several examples of best-fit statistical relationships were determined between optical characteristics of suspended matter and selected biogeochemical ratios describing changes in the proportions and composition between particle size fractions.

Towards sustainable water quality products for the western Baltic Sea

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Reliable satellite-based water quality products can provide valuable information that improves and supports operational monitoring in German coastal waters. However, current Copernicus Marine Service products show varying results when global and regional datasets overlap, particularly in the western Baltic Sea. These inconsistencies, combined with systematic differences between satellite- and in-situ-derived chlorophyll, turbidity and light attenuation parameters, limit their suitability for mandatory assessments under the MSFD. We address this challenge through a structured assessment of Copernicus water quality products, with a particular focus on the shallow coastal waters of the western Baltic Sea. The assessment includes: a systematic inventory and analysis of all relevant Copernicus water quality products; an in-situ optical measurement campaign in 2026 with ship-based sampling, shallow water moorings and hyperspectral radiometry in the western Baltic Sea; and a comprehensive evaluation of the products based on robust matching methods. The resulting datasets will be used to evaluate satellite reflectance and derived products and to quantify accuracy, spatio-temporal consistency and systematic deviations. The results will include prototype workflows for the long-term validation of Copernicus products in shallow coastal areas, recommendations for optimised optical in-situ measurements, and suggestions for improving satellite-based monitoring of German waters.

Abstract No. 64

Optical signatures of oil droplets and oil-coated microplastics in seawater: Laboratory experiments and radiative transfer modeling

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Dispersed oil droplets are among the most harmful micro-pollutants in the marine environment. Unlike surface oil slicks, whose detection and monitoring are well established, current knowledge of dispersed oil pollution does not yet allow reliable remote detection. Although dispersed droplets influence radiative transfer in seawater, isolating their optical effect from that of other optically active constituents, such as phytoplankton, dissolved organic matter, and suspended sediments, remains challenging. Meanwhile, microplastic pollution has become widespread in marine environments. Microplastic particles tend to associate with oil droplets via hydrophobic interactions, forming oil-microplastic agglomerates, often in the form of oil-coated microplastics. While these agglomerates have been studied in terms of their physical and chemical properties, their impact on water-leaving light and ocean-colour signals has not yet been systematically investigated. Both dispersed oil and oil-coated microplastics act as optically significant components, influencing the inherent and apparent optical properties of seawater. Their impact can be quantified using numerical radiative transfer modelling, provided that their inherent optical properties are known. The combination of oil and microplastics—which is likely to occur in the natural environment—is expected to enhance the optical contrast between natural and contaminated seawater. In this study, the complex refractive index of selected pure oils and microplastic samples was measured in the laboratory, and combined with particle size distributions to calculate the inherent optical properties of dispersed oils and oil-coated microplastics. These data were then incorporated into a radiative transfer model implemented in Hydrolight software. The results identify the conditions under which dispersed oil and oil-coated microplastics can be optically detected, and provide a proposed “oil index” as a primary indicator of possible dispersed oil pollution in the water column. This approach offers a foundation for future optical monitoring strategies of microplastic-associated oil contamination.

Early Career Scientist (ECS) contribution

Challenges in nearshore Ocean color remote sensing: A review of the adjacency effect

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Optically complex inland and coastal waters, such as those of the Baltic Sea, remain challenging targets for accurate water-leaving reflectance retrieval from optical satellite sensors. High water turbidity, seabed influence, spatial heterogeneity, and the proximity of land surfaces all contribute to these challenges. Together with atmospheric scattering, surrounding land is a major driver of spectral blending and distortion of the target water spectrum, which is known as the adjacency effect (AE). This effect can lead to significant uncertainties in satellite-derived products, including chlorophyll-a and other water quality estimates. Current discussions in the ocean color community center on how to handle AE-impacted pixels in standard Level-2 products, whether to correct them explicitly, flag them, or mask them. However, simple masking of nearshore pixels is inadequate for many Baltic Sea applications, as AE can extend several kilometers offshore. These pixels are critical for seagrass monitoring, benthic habitat mapping, and other coastal ecosystem applications. We synthesize current understanding of how AE emerges in aquatic high-contrast environments, how it affects quantitative remote sensing retrievals, and how it can be mitigated. We review key methodological advances and highlight open-access tools for AE quantification and correction. To demonstrate practical implementation, we applied RAdCor and T-Mart, which have recently shown promising performance, to a Sentinel-2 MSI scene of the Osterseen Lake District south of Munich (Germany). The case study demonstrates that both algorithms effectively reduced AE in the near-infrared, while residual effects remained in the visible range. These findings align with broader trends emphasizing the need for continued algorithm refinement, operational applicability, and evaluation in diverse environments.

Early Career Scientist (ECS) contribution

Remote estimation of vertical chlorophyll-a profiles in the Baltic Sea for satellite applications

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Chlorophyll-a (Chl-a) concentration is a widely accepted proxy for phytoplankton biomass and an important indicator of primary production and marine ecosystem status. While satellite observations provide extensive spatial and temporal coverage, they are inherently limited to the near-surface layer, leaving a substantial information gap regarding the vertical structure of Chl-a within the water column. This limitation is particularly critical in the Baltic Sea, where strong vertical gradients, seasonal stratification, and complex bio-optical conditions lead to highly variable and often subsurface chlorophyll maxima. Accurately reconstructing vertical Chl-a profiles is therefore essential for improving ecosystem understanding and for enabling more effective use of satellite data, including their assimilation into ecohydrodynamic models. The objective of the work presented in this contribution is to demonstrate how the inclusion of additional remote-sensing reflectance (Rrs) information can improve the accuracy of vertical Chl-a profile estimation, particularly when combined with modern statistical and machine-learning methods. The analysis is based on more than 1100 in situ observations collected during research cruises of R/V Oceania between 2011 and 2024. The proposed methodology focuses on modelling the vertical distribution of Chl-a using surface information and the optical properties of seawater, specifically remote-sensing reflectance (Rrs) which can be measured both in situ and by satellite sensors. The ultimate goal of this framework is to enable the integration of satellite observations with information describing the water column. In this contribution, the first step of this process is presented, in which Rrs is incorporated as an additional predictor in the model. The performance of the reconstructed Chl-a profiles was evaluated using standard statistical metrics calculated over depth-resolved observations. The results demonstrate that our approach can significantly improve the estimation of vertical Chl-a distributions ($\log_{10}\text{RMSE} < 0.72$, $R^2 > 0.6$) compared to existing parameterizations based solely on surface values of Chl-a.

Early Career Scientist (ECS) contribution

Bridging the resolution gap: Using drones to scale in-situ observations of aquatic vegetation to Sentinel-2

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Seagrass and other submerged aquatic vegetation (SAV) form crucial coastal ecosystems, providing habitat, nursery grounds, food resources, and carbon sequestration. Despite their importance, effective monitoring remains challenging. Traditional diver- or boat-based in-situ surveys are limited by habitat accessibility and high operational costs. They therefore typically record a limited number of point measurements or transects, often failing to capture the full spatial extent and fragmentation of SAV habitats. Over the past decade, satellite remote sensing has become a valuable complement to field surveys, offering synoptic, repeatable, and cost-efficient monitoring of coastal environments. However, fine-scale fragmentation and patchiness of many SAV habitats create significant challenges when comparing point-based field measurements to satellite pixels. For instance, pixels of the widely used Sentinel-2 MSI sensor represent areas of 100 m². This scale mismatch complicates model calibration and validation of satellite-derived SAV products, leading to uncertain or biased estimates of derived vegetation metrics. In this study, we address this scale mismatch by integrating centimetre-scale multispectral imagery from uncrewed aerial vehicles (UAVs) as an intermediate data layer to upscale in-situ point observations to the spatial resolution of Sentinel-2. In the UAV data, we apply colour space transformations and unsupervised clustering to detect SAV at centimetre-scale and aggregate resulting maps to pixel-level fractional SAV cover estimates consistent with the Sentinel-2 grid. These UAV-derived coverages then serve as training data for a flexible processing pipeline encompassing Sentinel-2 data pre-processing, feature engineering, eXplainable AI-guided feature selection and training of a LightGBM regression model. We demonstrate our approach in Puck Lagoon, Poland, a shallow coastal environment with highly fragmented benthic vegetation. Our approach provides a practical pathway to improve model calibration, reduce scale-related uncertainty, and enhance the reliability of large-scale, satellite-derived SAV mapping and monitoring products.

Early Career Scientist (ECS) contribution

Abstract No. 95

Bringing Baltic seagrass to life: Interactive visualisation from multi-scale UAV data

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Thanks to advances in remote sensing and immersive visualisation, it is now possible to communicate changes to the Baltic Sea ecosystem in a new way. Here, we present a novel workflow for the high-fidelity visualisation of Baltic seagrass meadows, based on spatial data collected by UAV. Seagrass ecosystems are sensitive indicators of environmental variability and stressors and require detailed, scale-adaptive representations to support scientific interpretation, stakeholder engagement and scenario-based discussions on future coastal change. Our approach integrates centimetre- to decametre-scale UAV imagery, marine photogrammetric products and hydroacoustic bathymetry to create a unified virtual environment enriched with assets. Using a real-time 3D rendering platform (Epic Unreal Engine 5), we combine digitally reconstructed outcrops with physically responsive assets representing seagrass, sediment textures and water dynamics. This asset-based method overcomes the limitations commonly encountered with direct mesh or point-cloud imports, such as poor rendering resolution, thereby improving both scientific fidelity and perceptual realism. The resulting virtual environment enables users to explore the structure of seagrass meadows and potential climate-driven shifts in species distribution. By embedding dynamic processes (e.g. vegetation motion induced by waves, light attenuation gradients and changes in water clarity), the platform facilitates the enhanced transfer of knowledge regarding marine optical characteristics. This facilitates dialogue across disciplines concerning the monitoring of ecosystems and the assessment of environmental change in Baltic coastal waters. Beyond expert analysis, the immersive setting is a powerful medium for communicating scenario-based insights to policymakers, educators and the general public. It transforms abstract geospatial datasets into intuitive spatial experiences, counteracting the misconceptions that are often caused by idealised imagery. Our scalable solution, which can be deployed on head-mounted displays and mobile devices, offers a versatile tool for promoting environmental awareness, supporting informed decision-making and enhancing the visibility and understanding of seagrass meadow dynamics in the Baltic Sea.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Advances in satellite-based retrieval and assimilation of chlorophyll-a concentration and cyanobacteria abundance in the Baltic Sea within the SatBałtyk system

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Despite many years of development, satellite algorithms for estimating chlorophyll-a concentration in the surface layer of the Baltic Sea still exhibit limited accuracy and do not fully meet user requirements. Their performance remains significantly lower than that achieved for most other water bodies, primarily due to the complex optical properties and pronounced biogeochemical variability of the Baltic Sea. Within the SatBałtyk project, continuous efforts have therefore been undertaken to develop improved algorithms for chlorophyll-a and other biogeochemical parameters, increasingly based on advanced statistical approaches, including machine learning and artificial intelligence. This presentation introduces a new satellite algorithm for chlorophyll-a retrieval based on Support Vector Regression (SVR). Following a comprehensive comparison of several machine-learning techniques, SVR with a polynomial kernel was identified as the most effective method, owing to its ability to capture complex non-linear relationships between remote-sensing reflectance and chlorophyll-a concentration. The algorithm utilizes selected spectral reflectances and a set of reflectance ratios, which were identified through iterative testing and systematic performance evaluation. Algorithm performance was assessed using standard statistical metrics, including Mean Squared Error (MSE), Root Mean Squared Error (RMSE), the coefficient of determination (R^2), and Mean Absolute Percentage Error (MAPE). The results demonstrate a clear improvement in predictive skill, exceeding the accuracy of most operational chlorophyll-a algorithms currently applied in the Baltic Sea. Within the updated SatBałtyk framework, phycocyanin concentration—used as a proxy for cyanobacteria abundance—is also estimated using a newly developed satellite algorithm. The resulting satellite-derived chlorophyll-a and cyanobacteria products are subsequently assimilated into a hydrodynamic model. The presentation discusses the impact of assimilating these biogeochemical variables on model performance and introduces a final operational product that integrates satellite observations with model simulations, highlighting the benefits of the proposed algorithms and the combined satellite–model approach.

Session 7
**Adaptive governance under multiple drivers
of change in the Baltic Sea**

Wild cards in the Baltic Sea – Are we ready for the unexpected?

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Real-world changes often unfold abruptly, driven by unexpected events—so-called wild card events. These are low-probability, high-impact occurrences that are difficult to predict but can have disruptive and lasting consequences for ecosystems, societies, or economies. We are interested in plausible wild card events, and how such discontinuities could be meaningfully accounted for in mitigation scenarios. The aim of this work is to assess the capacities of currently available modelling tools to assess the potential consequences and mitigation possibilities of various wild card events. This research is ongoing and focuses on the Baltic Sea and its catchment area as a case study. The aim is twofold: first, to develop a holistic understanding of weak signals and different types of wild card events that are currently unexpected but plausible, and that could significantly affect the Baltic Sea ecosystem—either positively or negatively. Second, the research evaluates the capacity of existing modelling frameworks (such as biogeochemical, ecological, and agent-based models) to assess the consequences of such low-probability but high-impact events – in case they occur – on the state of the marine ecosystem. As a first step, we organized a knowledge co-creation process during the Baltic Sea Science Conference in May 2025. This shared thought experiment engaged participants in identifying a broad set of plausible wild card events, which were then grouped into meaningful clusters based on their type or the severity of their potential impacts. In the second step, we will assess the consequences of these event clusters and evaluate how existing models can assess their impacts and support management responses, and identify "model readiness" to plausible wild card events. This step will be undertaken as expert elicitation via survey, workshops and iterative consensus-building, and is an ongoing process.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Abstract No. 17

Understanding how to protect the Baltic Sea: An assessment of conceptions among business organizations

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Ecosystems are complex and so are the efforts needed for their protection. Yet, in public and practical discourse, certain ideas of environmental protection prevail as standard operating procedures, such as the reduction of pollution sources as well as the increase of resource efficiencies. In this project, I deploy a phenomenographic research design to reveal how organization members of Finnish, German, and Polish businesses that belong to very diverse industries, operating both at sea and on land, understand in different ways what it means to protect the Baltic Sea. Using semi-structured interviews as primary data, the phenomenographic approach leads to the presentation of the diverse, separate, and often conflicting conceptions that people hold about a phenomenon, and how, in dependence of these conceptions, they would subsequently also engage in diverging practices. Using the phenomenographic insights as a state-of-the-art of contemporary protection practices, I delineate what it could mean for governance actors who aim to entice business organizations to advance to more sophisticated conceptions of ecosystem protection.

Early Career Scientist (ECS) contribution

Adaptive GIS tool for authorities to predict emission loads of emerging contaminants from point sources into Baltic Sea catchments

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The Baltic Sea is one of the most polluted water bodies in the world. Improving its water quality requires measures in the sea itself, but also in its catchment. Human pharmaceuticals are key emerging contaminants that mainly reach surface waters via wastewater treatment plants (WWTPs). Future emissions are expected to increase due to socio-demographic changes and other factors. An ageing population consumes more pharmaceuticals, which is a realistic scenario for many rural areas in the Baltic Sea region. To reduce emissions of micro-pollutants from point sources, recent EU legislative developments, such as the Urban Wastewater Treatment Directive, require Member States to upgrade selected WWTPs with advanced treatment. However, this legislation does not consider numerous small WWTPs in typical rural areas, a risk-based prioritisation and developing cost-effective mitigation measures is challenging when considering numerous small WWTPs and complex water systems. We developed an open-source QGIS-plugin to predict WWTP emission loads for substance specific risk maps and to enable à priori assessment of mitigation scenarios. The adaptive tool allows decision-makers to adjust the inputs at several instances if relevant expertise or additional monitoring data is available. The steady-state model uses yearly average flow data and per capita pharmaceutical consumption. Its flexibility enables the integration of updated consumption rates and flow data over time, making it applicable across all Baltic Sea countries. At the same time, the tool remains functional by using default values provided in data pools. In this study, we tested the QGIS-plugin in Finland, Germany, Latvia, Sweden and Poland. Results showed that estimates correspond well with monitoring data at WWTP discharges and in water bodies. Mitigation scenarios were tested and revealed potentially improved quality but also unchanged situations upstream. Finally, our participatory modelling approach supports the authorities in charge to accomplish their tasks and develop effective mitigation scenarios directly.

Abstract No. 97

Impacts of eutrophication in the Western Baltic Sea – Where are we and where do we need to go?

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The Western Baltic Sea is characterized by a strong salinity gradient with saline water entering through the Skagerrak and flowing through the Danish Straits further South. Above lies the fresher Baltic Sea water. Local inputs of inorganic and organic nutrients have led to enhanced organic matter production, which, among other things, has resulted in more frequent coastal hypoxia. The long-term ecological research (LTER) station Boknis Eck is located in the Eckernförde Bay and has been monitored for physical, chemical and ecological changes since 1957. Our data from the station show that recent EU-wide regulations and technological advancements contributed to decreasing nutrient concentrations in the region. However, despite these reductions, coastal hypoxia is intensifying. Rising temperatures due to climate change have counteracted these nutrient reductions by intensifying stratification of the water column, with warmer, fresher water lying on top of colder North Sea water, enhancing bacterial oxygen demand. We here analyze historical developments in nutrients and resulting organic matter availability at Boknis Eck to reevaluate current nutrient thresholds set by the MSFD to reach the “good environmental status”. On the other hand, we analyze the limits of socially acceptable and hence feasible regulative approaches. We explore options of further nutrient input reductions by comparing the time-series results with emphasis on environmental impacts of decreasing inorganic nutrient concentrations to insights of empirical research on the barriers of farmers complying with EU-wide nutrient regulations such as the EU Nitrate Directive. Last but not least, we present an outlook on how these data and acceptance analysis results will be integrated in a digital tool for testing environmental management strategies in the Western Baltic Sea.

Seeing the obvious, missing the complex: Public threat perceptions and adaptive governance in the Baltic Sea

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The Baltic Sea ecosystem provides essential ecological functions and socio-economic benefits for the surrounding region, yet it is increasingly stressed by multiple, interacting drivers of change. Long-standing pressures such as eutrophication, hazardous substances, habitat degradation, and overfishing are now compounded by climate change and biodiversity loss, resulting in a critical ecological state of the basin. Effective and adaptive governance of the Baltic Sea therefore requires not only scientific knowledge of these stressors, but also an understanding of how they are perceived by the public, whose support is crucial for implementing and sustaining management measures. This study investigates public perceptions of environmental threats to the Baltic Sea among residents and visitors of the Island of Rügen and the Greifswalder Bodden. Data were collected through 628 standardized face-to-face interviews. While respondents expressed high overall awareness of and concern about environmental problems in the Baltic Sea, their assessments of the ecosystem's condition were often overly optimistic. Participants most frequently identified highly visible and media-prominent threats, such as plastic pollution and oil spills. In contrast, less perceptible and more complex drivers of ecological degradation—including climate change, biodiversity loss, heavy metal contamination, and underwater noise—were mentioned far less frequently. The findings indicate a substantial gap between scientifically documented pressures on the Baltic Sea and public threat perceptions, likely shaped by media coverage and local socio-economic contexts. From an adaptive governance perspective, this mismatch poses a challenge for addressing cumulative and long-term drivers of change. The study highlights the importance of strengthening science–media communication and participatory approaches that actively engage local communities, correct misconceptions, and integrate public understanding into adaptive marine governance strategies in the Baltic Sea region.

Session 8
Marginal Seas – Humans and environment

From limnology to oceanography, where Engineered Oxygen Supply (EOS) and ocean deoxygenation meet

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Ocean deoxygenation is a growing global threat to marine biodiversity, ecosystem services, and coastal economies. Engineered Oxygen Supply (EOS) is put forward here as a potentially impactful restoration measure for hypoxic and anoxic marine environments, providing short-to-medium term mitigation opportunities while minimising greenhouse gas emissions and nutrient pollution and, ultimately, stabilizing the environmental system in the long term (Wallace et al., 2024; Handmann et al., 2024). Potentially useful EOS technologies have evolved within the limnology and water-treatment communities since the mid-20th to 21st Centuries, using methodology that clearly could scale to marine applications (Singleton and Little, 2006); however, they are novel and have not yet been explored for much of the oceanography, ocean biogeochemistry, climate science, and socioeconomic communities (Handmann et al., under review). Furthermore, in timely combination with green hydrogen production, which generates oxygen as a by-product, EOS could be positioned within broader climate adaptation and sustainability frameworks. To manage this innovative technique responsibly and sustainably, a transdisciplinary approach to establishing a sound scientific, ecological, technical, economic, ethical, legal and governance basis is mandatory. Projected global ocean deoxygenation, combined with the current limitations of mitigation strategies, underscores the need for a thorough assessment of potential EOS techniques from multiple stakeholder and disciplinary perspectives. Building upon our shared experience of working with EOS through international and interdisciplinary partnerships, we put forward a case study that demonstrates how collaborative ocean science can create ripples of innovation and meaningful connections across multiple UN Sustainable Development Goals.

References:

Singleton and Little 2006 - Environmental Science & Technology, 2006

Wallace et al., 2024 - Mitigation and Adaptation Strategies for Global Change, 2024

Handmann and Wallace 2024 - Global Change Biology, 2024

Handmann et al., under review - Reviews of Geophysics, submitted 10/2025

Early Career Scientist (ECS) contribution

Sustainable marginal seas' environment – A global challenge

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Marginal seas are parts of the world's ocean located in the transition zone between the continents and the oceans. Their semi-enclosed physiography restricts exchange with the open ocean, and the influence of the landmass is significantly greater compared to open shelf seas. Overexploitation of the resources of these sea areas, their coasts and catchment areas, coupled with climate change, is placing marginal seas under heightened adverse impact pressure, leading to progressive environmental degradation worldwide. This situation necessitates new, holistic management approaches to reconcile environmental protection with economic use. This problem can no longer be viewed as a regional issue for affected regions but rather represents a global challenge. Objectives defined by the UN Sustainable Development Goals (SDGs) can be applied to marginal seas. The Key Messages (KM) of the latest IOC Ocean Report 2024 provide a suitable framework for a status analysis. Our work offers a generalized approach to comparing marginal seas in terms of their sustainable protection. From the multitude of parameters for a generalized comparison of individual marginal seas, we propose, in addition to physiographic properties, internationally published data on parameters related to the KMs of Clean Ocean, Healthy and Resilient Ocean, Productive Ocean, Predicted Ocean, and Safe Ocean, with particular consideration given to the role of marginal seas in the sustainable use of renewable energies. We illustrate the principle of the concept using examples of marginal seas, highlighting their diversity regarding their geological, oceanographic, climatic and ecological conditions. Additionally, we shed light on the socio-economic development of the communities living along the coasts and drainage areas of the selected marginal seas.

A global assessment of thermal stressors in marginal seas

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Enclosed marginal seas (EMS) are critical hotspots of (often endemic) marine biodiversity and play a key role in supporting the sustainable development of the blue economy. However, EMS face severe pressures from both pollution and accelerating climate warming. Yet, despite their importance, they remain largely neglected in global climate assessments. In this study, we present the first global analysis of warming rates and marine heatwave (MHW) emergence—two of the most detrimental thermal stressors for marine ecosystems — across 19 major marginal seas. Our findings reveal that most EMS have recently entered a period of peak warming trends unprecedented since the onset of the industrial era. Even under the most optimistic climate mitigation scenarios consistent with the Paris Agreement, EMS are projected to continue warming substantially, with more than 60% of their total area likely to experience near-permanent MHW conditions by mid-century. These results suggest that current mitigation targets alone will be insufficient to prevent profound ecological transformations in these vital marine ecosystems

Comparing marginal seas: Workflow for benthic biodiversity and functional assessment

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Marginal seas are dynamic transition zones shaped by strong gradients in salinity, temperature, and sedimentary processes, anthropogenically impacted by the economic use of coastal waters, and characterized by diverse ecosystems with different habitats and marine life. Biodiversity components are essential because they determine how marginal sea ecosystems function, respond to environmental gradients, and maintain resilience across highly variable settings. To improve cross-system understanding, we present a feasibility study for analysing benthic macrofaunal biodiversity and ecosystem functioning in selected marginal seas worldwide, including the Baltic, Black, Adriatic, Red, and several American and Asian systems. The workflow integrates quantitative abundance datasets with global trait repositories to derive taxonomic richness, functional diversity metrics such as Functional Richness (FRic) and Functional Evenness (FEve), and density of main functional groups. Core ecological traits – feeding mode, mobility, sediment position, body size, reproductive strategy, and bioturbation potential – are harmonised across taxa using standardized trait vocabularies. This approach allows direct comparison of benthic communities across environmentally heterogeneous systems. Case studies from the Baltic Sea and other marginal seas illustrate patterns of functional organization, data limitations, and both shortcomings and benefits of using relatively simple scalar indicators derived with consistent methodology for incorporating ecosystem functioning and biodiversity in large-scale assessment across diverse marginal sea environments.

Comparison study on fossil diatom record from marginal seas and their response to 4.2 ka event: Northern South China Sea and Southern Baltic Sea

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The 4.2 ka event, has been broadly registered across North Atlantic and adjacent area, Mediterranean, Middle East and North Africa, Indus area and China (e.g., Andersen et al., 2004; Arz et al., 2006; Bakke et al., 2010; Bini et al., 2019; He et al., 2022; Weiss et al., 2016). This disturbed climate change was considered to have been played a crucial role in ancient society collapse of Neolithic cultures. While, a debated view that like most other periods in Holocene, the “4.2 ka event” is not a globally significant climate excursion (McKay et al., 2024). Whatever, paleoceanographic and paleoclimatic study from marginal seas need more records to expound the spatial distribution and driving forces of this event with crossing hemispheres linkage, and the influences in biosystem. In order to enhance understanding of global climate linkage between low and high latitude zones and their impact on ecosystem in marginal seas, a comparison study is on-going to fossil diatom, a sensitive indicator in marginal seas. In northern South China Sea (SCS), a higher resolution profile from Pearl River Estuary recorded diatom absolute abundance (DAA) rapid drop after 4.2 ka BP, with decreasing of warm-water species and more sandy sediments, indicated a cooling climate trend. In the Beibu Gulf, Sonne-219 Cruise’s core shown the same phenomena of fast decreasing on DAA and warm-water species, with sediments granularity fluctuation. In southern Baltic area, during subboreal period, local diatom assemblage zone was documented change crossing the 4.2 ka BP, e.g., from Oder River mouth in Poland and Neolithic archaeological sites in Sventoji, Latvian coast. Both sea-areas shown turnover the trend of Optimate Middle Holocene to cool condition, but the N-SCS has more obvious fluctuation in diatom flora. That makes sense to know global climate change feedback and ecosystem effective.

Early Career Scientist (ECS) contribution

Abstract No. 102

From sediment chemistry to biomarkers: early evidence of pollution impact on macrofauna in the Gulf of Gdańsk (Baltic Sea)

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Chemical pollutants significantly affect the environmental status of the Baltic Sea and are regarded as one of the major global drivers accelerating biodiversity loss in marine ecosystems. However, the key relationship between chemical contamination and changes in the biodiversity of benthic communities remains insufficiently understood. In addition, assessing the effects of a single substance on marine organisms in toxicity studies may be inadequate, because such studies often do not take into account the impact of the entire mixture of compounds present in the environment. Moreover, to increase the efficiency of environmental assessment in marine monitoring, the use of effect-based methods (EBMs) is currently recommended; these methods rely on so-called biomarkers to determine the health status of key populations. Comprehensive integration of chemical data with effect-based biological methods in ecologically important species may shed new light on current approaches to environmental risk assessment of the Baltic. This study presents a preliminary assessment of the effects of chemical contamination on benthic macrofauna by combining chemical analyses, biochemical markers, and biodiversity indices of benthic macrofauna. Environmental surveys were conducted in the Gulf of Gdańsk in 2024 as part of the Detect to Protect project (“New approaches to determining the effects of chemical pollutants to protect Baltic Sea biodiversity”). During the surveys, samples of macrofauna and sediments were collected from reference and contaminated sites. Sediment and organism samples were analyzed for a range of contaminants, including heavy metals, persistent organic pollutants, and phenols. At each site, individuals of a key species: *Mytilus trossulus* and *Macoma balthica*, were collected. Bivalves tissues were analyzed for the activity of selected enzymes to assess the impact of the detected contaminants on the health status of the entire population.

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Early Career Scientist (ECS) contribution

Highlighted Presentation

Evaluating the productivity of marginal seas using remote sensing data

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Marginal seas are among the most productive marine environments and contribute disproportionately to regional carbon cycling, fisheries production, and ecosystem services. Satellite ocean-colour observations since the late 1990s have provided an unprecedented view of marine primary productivity at basin and global scales. Merged productivity datasets spanning more than two decades reveal strong spatial contrasts between ocean basins and coastal regions, with many marginal seas emerging as productivity hotspots. Interpreting these patterns, however, requires careful consideration of the optical environment that regulates underwater light availability and shapes signals detected by remote sensing. This presentation examines how optical properties influence the interpretation of productivity patterns in three contrasting marginal seas: the Baltic Sea, the northern Adriatic Sea, and Disko Bay (Greenland). The analysis focuses on differences in inherent optical properties (absorption and scattering by phytoplankton, coloured dissolved organic matter, and suspended particles) and apparent optical properties such as reflectance and diffuse attenuation. These properties determine the underwater light climate controlling phytoplankton growth and influence the interpretation of satellite-derived chlorophyll concentration and productivity. The Baltic Sea represents a strongly CDOM-influenced system where high absorption by terrestrial dissolved organic matter reduces light penetration, particularly in the blue spectral region. The northern Adriatic Sea is characterised by strong riverine inputs, episodic sediment resuspension, and recurrent phytoplankton blooms, producing highly variable optical conditions in coastal waters. Disko Bay represents a high-latitude environment where glacial meltwater plumes, seasonal sea-ice retreat, and rapidly changing stratification shape both optical conditions and bloom phenology. Comparing these three optical regimes illustrates how differences in water composition and light climate influence ecosystem productivity and the interpretation of long-term satellite observations in marginal seas increasingly affected by eutrophication, riverine inputs, and climate-driven change.

Session 9

Future projections of the Baltic Sea region

Connecting national and regional Earth System Modeling efforts through natESM

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At the heart of the natESM initiative in Germany lies the vision to create a world-leading, multiscale, seamless, and ready-to-use Earth system modelling capability that supports research, operational applications, training, and education. Our mission is to cultivate a community in which resources and expertise are shared, paving the way for the next generation of Earth system modelling. In this presentation, I will introduce the structure and guiding principles of natESM, highlighting its modular architecture, the sprint-based collaboration model between scientists and Research Software Engineers, and ongoing efforts to improve the coupling and coordination between components such as atmosphere, land, and ocean systems. By connecting national infrastructure with regional expertise, natESM could provide a foundation for joint progress toward more integrated simulations of the Baltic Sea and its catchment. Beyond advancing physical and biogeochemical understanding, such integration also opens perspectives for improved regional assessments and impact modelling. The talk invites exchange and discussion on how such synergies might evolve in the future.

Abstract No. 25

Natural variability restricts the detection of changes in marine heatwave area extent in future projections of the Baltic Sea

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Marine heatwaves (MHWs) are discrete prolonged events of anomalously warm water. The Baltic Sea is prone to them due to its fast response to the global positive temperature trend, especially in the shallow coastal zone. MHWs forecasting is important for marine management and for assessing ecological conditions. The yearly MHWs area is one of the parameters describing these events and represents the yearly average of the daily extent of a certain MHW class. We analysed a 48-member ensemble of scenario simulations for the Baltic Sea (study period 2005–2098), averaging across different ensemble dimensions. This allowed us to estimate how natural variability and Earth System Models (ESMs) uncertainty affect the projected MHW areas, both at the surface and at the bottom. We found that both surface and bottom MHW areas are influenced by natural variability. It plays the major role until approximately 2065, after which ESMs-related uncertainty becomes dominant. Uncertainties associated with the shared socioeconomic pathways and sea level rise scenarios are very minor.

Early Career Scientist (ECS) contribution

Highlighted Presentation

Projected 21st-century changes in significant wave height in the Baltic Sea: An ensemble approach

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Storms and associated marine hazards pose a significant risk to the environment and society in the Baltic Sea region. Anthropogenic climate change is expected to alter mean and extreme meteorological and oceanographic conditions, which will have an impact on the regional wave climate. A combination of IPCC CMIP3 and CMIP5 scenarios, multiple global and regional climate models, and alternative initial conditions was used to assess the response of mean and extreme wave conditions to 21st-century climate change. This was done using an ensemble of eight future projections. Across the ensemble, the spatial pattern and magnitude of change in significant wave height by the year 2100 varies considerably. Pronounced multi-decadal variability emerges within the individual ensemble members during the 21st century, indicating that the greatest differences from the reference climate will not necessarily occur at the end of the century. While most regions exhibit an increase in significant wave height towards the end of the century, the amplitude of change differs between median and extreme conditions. The temporal variability of the ensemble median remains high throughout, and projections forced by high-emission scenarios yield larger responses than those under low-emission pathways. Differences relative to the North Sea are also evident and will be discussed. These results emphasise the importance of ensemble approaches and temporal sampling when assessing coastal risk and adaptation in the Baltic region.

Abstract No. 46

Perks and perils of objectively calibrating regional Earth system models

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The dynamical downscaling of global climate scenarios with coupled regional Earth system models is one of the most important tools to deliver accurate and applicable predictions for communities. However, uncertainties related to model setups are often systematic and exhibit spatiotemporal structures. Calibrating such systems and quantifying systematic model uncertainties thus remain a central challenge, as bias corrections typically violate fundamental physical principles, such as mass and energy conservation, and may lead to unrealistic local climate sensitivity. Here, we apply a range of objective calibration strategies to identify optimal model setups for the individual components of the Baltic Region Earth System Model, IOW-ESM. In particular, model sensitivities to changes within a set of parameters are identified using perturbed parameter ensembles and various types of surrogate models. It is thus possible to optimize the parameter set regarding a chosen set of metrics. Comparing a range of surrogate models and optimization techniques, we find that all optimization strategies have limits in their applicability. In particular, the danger of overfitting the parameter sensitivities is large, and global optimization algorithms in high-dimensional spaces tend to find non-optimal local error minima. Keeping these limits in mind, we were able to significantly reduce model biases of the downward-directed shortwave radiation at the surface and improve the 2-meter temperature over the Baltic Sea.

Session 10
**Philosophical aspects of Baltic Sea Earth
system research**

Abstract No. 1

Ideas that shaped the understanding of the Earth System in the Baltic Basin

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Understanding the Earth System in the Baltic Basin has been shaped by several key ideas developed over the years. The presentation aims to highlight important concepts that have influenced Baltic Basin Earth System Science and is part of an effort to write a book that makes research accessible to the next generation of students and scientists, and is a part of the Baltic Earth Working Group of Philosophy. Only a few ideas are presented during the conference and input from all conference participants is welcome. We aim to focus on key ideas, the initial articles, the evolution of the concept, contributions to Earth Sciences, and future challenges. Some of the important concepts are related to ideas about:

- Earth System Science,
- Observations, maps, and monitoring,
- Mathematical models,
- Complex systems and simplifications,
- Glaciation and land uplift,
- Drainage basin concept,
- Land surface dynamics,
- Estuarine circulation,
- Internal waves and eddies,
- Sea ice drift, plastic behavior, and thermodynamic,
- Oxygen, nutrients, and anoxic bottom water,
- Marine acidification,
- Limited or unlimited marine resources,
- Humans and nature,
- Anthropocene era,
- Climate and climate change,
- Future and stochastic variations,
- Reflection on science and society.

During the presentation, I will illustrate some of these ideas (e.g., Earth System Science and Drainage Basin Concept) and discuss how they have influenced our understanding of the Earth System. They are just examples, and other examples are open for discussion during the conference.

Closing the water gaps: Understanding freshwater discharges and their nutrient and pollutant loads from land to sea

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This paper examines the interactions of surface, ground, and coastal waters across the land-sea interface. The interactions are complex and include, e.g., double roles of groundwater. Across the world's coastlines, including that of the Baltic Sea Drainage Basin (BSDB), parts of the total seaward groundwater flow and its nutrient and pollutant loads go first into the streams and rivers on land and further through them to the sea, while other parts go directly to the sea as submarine groundwater discharge (SGD). Both parts are subject to important knowledge gaps, emerging as major differences between estimates from various perspectives, e.g., with surface or total terrestrial water focus, or by tracer methods on the seaside. For consistent, realistic understanding and better quantification and management of discharges across the Baltic and other coastlines, such gaps need to be recognized and bridged. Along with essential data and simulation agreements, the gaps emerge when synthesizing and comparing results from different studies worldwide. For example, hundreds of simulations across widely different coastal conditions show total SGD – defined as the sum of freshwater and recirculating seawater components – to be a largely determinable function of the fresh groundwater flow to the sea and the sea salinity. Fine-resolution data for how local water fluxes vary along coastlines further show why discharge quantifications diverge when assessed at small scale, locally at the coast, versus at large scale over entire national or regional coastlines, such as the whole BSDB coast. Overall, the synthesis and the deciphering of the synthesized results open new avenues to closing the land-sea gaps toward improved understanding and projection of how water flows and their nutrient and pollutant loads from land to sea may respond to climate change and other environmental stressors and disturbances across the BSDB and worldwide.

Poster Presentations

Session 1

Climate variability and teleconnections

Abstract No. 3

Thermal anomalies in the south-eastern Baltic and their links to atmospheric circulation patterns

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In this study, we examine the properties of air masses and their changes during thermal-anomaly days in the southeastern Baltic region over 1951–2020. Atmospheric circulation associated with these anomalies is analysed using the Hess–Brezowsky (HB) classification, based on ERA5 reanalysis data. Thermal anomalies are identified from regionally averaged daily surface air temperature values (53.75°–56.5° N, 21°–26.75° E), using the 10th and 90th percentiles as thresholds for cold- and heat-anomaly days, respectively. To assess the influence of climate change, we compare atmospheric parameters linked to anomaly days between an early period (1951–1985) and a later period (1986–2020). Circulation-type (CT) frequencies indicate a marked shift in the occurrence of anomaly-favouring patterns. CTs responsible for at least 70% of anomaly days during the early period increase their aggregate contribution from 4% to 14% in the later period. In summer, 12 CTs are associated with summer heat-anomaly days (SHD) and 11 with summer cool-anomaly days (SCD). SHD occur mainly under BM and TRW circulation types, whereas SCD are most frequent during WZ and NWZ. In winter, 6 CTs dominate winter warm-anomaly days (WWD), while 13 CTs are characteristic of winter cold-anomaly days (WCD). WWD are primarily linked to WZ circulation type, whereas WCD are associated mainly with HFA and BM. Thermal anomalies intensify in the later period. Mean temperatures during summer anomaly days increase by ~1 °C, and those during winter by ~2 °C. The 500-1000 hPa thickness exhibits increases for all anomaly types, with the strongest signal during WWD. The altitude of the 0°C isotherm during WWD increases nearly twice as much as during summer anomalies. Specific humidity at 925 and 950 hPa levels rise across all anomaly types except WCD, for which no significant change is detected. These results correspond to a 95% confidence level, which was assessed with Welch's t-test.

Early Career Scientist (ECS) contribution

Shifts in precipitation phases in Lithuania

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Climate change causes significant changes in the phase composition of precipitation in Lithuania. Rising temperatures in the northern hemisphere mid-latitudes during the cold season are leading to a decrease in solid precipitation and an increase in liquid and mixed precipitation. These changes are impacting the regional climate, the hydrological cycle, ecosystems, and the quality of life. However, accessing changes in the phase composition of precipitation remains a significant challenge. Automatic weather stations that record precipitation amounts are often unable to accurately determine the phase of precipitation because they lack integrated sensors that can distinguish between rain, mixed precipitation, and snow. As a result, precipitation type is often determined based on indirect indicators such as air temperature. This study also used indirect indicators to analyze changes in the phase composition of precipitation during the cold season (November–March) in Lithuania between 1951 and 2024. Daily precipitation and air temperature data from 18 meteorological stations were used in this research. Additionally, data from the Vilnius University meteorological station were used to assess the recurrence probability of different precipitation types as a function of air temperature and humidity. The study showed that the amount of solid precipitation in the analyzed area decreased slightly, although these changes were generally not statistically significant. However, during the cold season, the total amount of precipitation increased, resulting in a statistically significant decrease in the proportion of solid precipitation across almost the entire study area. Between 1951 and 1980, solid precipitation accounted for an average of 37.6% of the total precipitation during the March–November period. In contrast, between 1991 and 2020, this number decreased to 24.9%. Even in January, a significant change has been recorded: the share of solid precipitation amount has fallen from 56.6 to 33.1%.

Early Career Scientist (ECS) contribution

Abstract No. 27

Comparing simple wave models with measurements and sophisticated models in the Gulf of Riga

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Design and coastal management are based on site specific wave information. As measurements are scarce and short, modelling is used to produce wave data. Depending on the problem and funding, simple methods are frequently used instead of complicated wave models with space and time varying forcing. This approach is apparently sufficient in open ocean conditions where spatial variations in wave properties are normally limited. The situation is different in nearshore areas of complicated shapes, where wave properties can be highly variable. The use of default settings of wave models means that possible errors remain unknown, and employing data with substantial uncertainties could lead to structural failures or too expensive structures. We study the magnitude of possible errors by comparing the output of simple wave models (such as the stationary/non-stationary fetch-based SPM model or the SWAN model forced with one-point homogenous wind) and the sophisticated multi-nested SWAN wave model forced with ERA5 winds with wave measurements in various nearshore locations in the Gulf of Riga, eastern Baltic Sea. The modelled results are compared with records of different length spanning over more than fifteen years. It is shown that in many locations simple models or models forced with homogenous wind yield good results, while sophisticated models are dependent on site-specific tuning of parameters. Surprisingly, stationary models yield better results in selected locations. The outcomes of our analysis provide several site-specific hints for practical coastal engineering.

Early Career Scientist (ECS) contribution

Abstract No. 69

Marine cold spells in the Baltic Sea

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Marine cold spells, characterized by anomalously low sea surface temperatures, play a crucial role in shaping marine ecosystems and have significant socioeconomic implications. Unlike the extensively studied marine heatwaves, research on marine cold spells remains limited, particularly in the Baltic Sea, one of the fastest-warming seas globally. Its semi-enclosed nature, strong seasonal variations, and sensitivity to atmospheric–oceanic changes make it an ideal case study region for examining the occurrence and impacts of cold spells under ongoing climate change. This study analyzes marine cold spell characteristics in the Baltic Sea from 1982 to 2023 during the extended summer–autumn season (June–November). The Cold spell occurrences declined, with coastal events being more intense ($\approx 4^{\circ}\text{C}$) than offshore ($\approx 3^{\circ}\text{C}$). The marine cold spell event duration has decreased, especially in the western Baltic Sea. The decline is mainly driven by a sustained sea surface temperature warming trend of $\approx 0.05^{\circ}\text{C}$ per year, with interannual variability being secondary. Cold spell parameters derived from detrended sea surface temperature data remove long-term warming and were used to assess cold spell variability. In recent years, coastal regions, especially upwelling zones, have experienced fewer and shorter cold spells, consistent with other regions, but their intensity has significantly increased (0.047°C per year since 2006). These intensifications may be linked to large-scale atmospheric circulation patterns such as the North Atlantic Oscillation (NAO), Scandinavian pattern (SCAND), and East Atlantic pattern (EA).

Early Career Scientist (ECS) contribution

Abstract No. 71

Sea ice in the Baltic Sea during 1993/94–2020/21 ice seasons from satellite observations and model reanalysis

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This study investigates the sea ice characteristics of the Baltic Sea using Copernicus satellite and model reanalysis data products from 1993 onward. Our primary focus is on assessing the performance of the latest Copernicus model reanalysis product in estimating the ice season evolution compared to the satellite dataset. The model estimates an earlier start to the ice season; it generally matches satellite data regarding the season's end. In addition, the model ice thickness is compared with the ice chart-based data. Across the Baltic Sea, declining trends for sea ice are observed. The sea ice characteristics during the recent period (2007/08–2020/21) show decreased sea ice fraction and thickness compared to the preceding period (1993/94–2006/07) of the study. The decrease in sea ice thickness is greater than 50% in some areas during the spring season. The trend analysis in the study reveals a uniform pattern toward shorter ice seasons (the most prominent being in Bothnian Bay with a range of approximately 1–3 days/year of decline in ice season), reduced sea ice extent (SIE) and reduced mean ice thickness (reaching up to -0.7 cm/yr).

Early Career Scientist (ECS) contribution

Applying machine learning for downscaling wind in Danish waters

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To understand and quantify wave and hydrodynamic conditions at a given project (e.g. OFW, coastlines or harbours) we rely on numerical modelling of hydrodynamics forced primarily by wind, air pressure and water level from hindcast data. The hindcast data covering Baltic Sea comes in different spatial scales, from high-resolution regional models such as NORA3 (3km) to the global weather models such as ERA5, CFSR (~20 km). Experiences show that particularly for smaller water bodies the higher resolution meteorological models have a profound effect on the accuracy of describing build-up of waves and water levels. For engineering design for future conditions, most projects rely on offsetting historical water levels while maintaining the historical wind conditions. While there is some justification in this, e.g. from the derived maps produced by the Danish Meteorological Institute, the methodology appears inconsistent with the methods employed to assess the present climate. Based on our experiences we find that the direct use of climate change datasets for forcing wave and hydrodynamic models is limited by 1) ready-to-use datasets and 2) the spatial resolution of datasets. In this study, we have adapted a Machine Learning approach for downscaling weather data. The approach is based on a Generative Adversarial Network (GAN), consisting of two deep neural networks, a Generator and a Discriminator, trained simultaneously to improve each other. The algorithm relies essentially on pattern recognition and its ability to generate realistic images. The GAN is trained on a high-resolution hindcast dataset after which the trained GAN model is used to predict high-resolution wind using RCM or GCM results as input. We present here examples of our validation of the downscaling capabilities of the GAN method and discuss the potential advantages of using the GAN method to quantify waves and hydrodynamics in the Baltic Sea and in Danish waters.

Abstract No. 79

Wind and storminess in the Baltic Sea region and their temporal variability in relation to jet stream parameters and large-scale atmospheric circulation patterns

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Climate variability in the Baltic Sea region is strongly influenced by large-scale atmospheric circulation. There has been considerable research linking regional climate variables to atmospheric circulation patterns, but less so to jet stream dynamics. In recent years various parameters have been presented for the characterisation of the jet stream and its variability. This investigation aims to analyse wind and storminess in the Baltic Sea region and Estonia and their variability in relation to the jet stream, and possibly also to some atmospheric circulation patterns. For this annual and seasonal wind variations from 1940 to 2024 are analysed using daily mean data from ERA5, the same dataset is also used to derive jet stream parameters and circulation patterns.

Early Career Scientist (ECS) contribution

Variability of river runoff to the northwestern Black Sea under climate change

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Hydroecological processes in the northwestern part of the Black Sea (NWBS) are largely controlled by freshwater inflow from major rivers, primarily the Danube and the Dnipro. In recent decades, river runoff in this region has been increasingly affected by climate change, leading to changes in both the magnitude and variability of freshwater discharge and, consequently, the ecological state of the marine environment. Understanding long-term changes in river runoff is therefore essential for assessing hydroecological responses of the NWBS. This study analyzes the variability of river runoff from the Danube and the Dnipro using long-term observations of mean monthly discharges recorded at closing hydrological sections located closest to the river mouths. Data for the Danube River at the Reni gauging station cover the period 1981–2024, while data for the Dnipro River at the Kakhovka Hydropower Plant represent the period 1981–2021. All hydrological data were obtained from the State Water Cadastre of Ukraine. Mean monthly discharges were converted into monthly and annual runoff volumes to evaluate long-term trends, interannual variability, and seasonal runoff distribution. The results show that the annual runoff volume of the Danube exceeds that of the Dnipro by more than five times on average. Since 2000, both rivers have exhibited a persistent tendency toward decreasing annual runoff volumes accompanied by increasing interannual variability. Such changes were not evident during the earlier period of 1981–1999. An increase in the coefficient of variation for both rivers during the recent period indicates growing instability of the runoff regime. Spring snowmelt remains the dominant phase of runoff formation for both rivers, contributing approximately 40–43% of the annual runoff volume. During 2000–2024, however, spring runoff volumes decreased in most months, except for March on the Danube, indicating an earlier onset of spring floods. These changes reflect the influence of contemporary climate change overall clearly.

Session 2
**Bridging scales: From small-scale turbulence
to basin-wide circulation**

A three-decade spatiotemporal evaluation of Baltic Sea salinity content

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Conventional salinity diagnostics—typically based on discrete depth layers or spatial averages—do not adequately capture the three-dimensional structure of salt storage. Although salinity varies with depth, the meaningful measure of how fresh or saline a system arises from its integrated salt budget, not from individual layers. Layer-based approaches, therefore, introduce unnecessary dimensional complexity and can obscure the cumulative influence of vertical variability. These limitations are especially pronounced in the Baltic Sea, where strong horizontal gradients and complex bathymetry further challenge traditional stratification-focused methods. To address these issues, this study employs a depth-integrated Salinity Content (SC) metric, defined as the mass of absolute salt per unit area. Using 30 years (1993–2023) of ocean reanalysis data, we compute monthly SC fields for the Baltic Sea at 1-nautical-mile resolution and up to 56 vertical levels. To isolate underlying dynamics, we evaluate four scenarios: (1) raw SC, (2) deseasonalized SC anomalies, (3) depth-normalized SC, and (4) a combined deseasonalized and depth-normalized product designed to reduce bathymetric biases and emphasize water-mass properties. K-means clustering is applied to each scenario to identify coherent spatial regimes. Spatial clustering reveals the regional organization of water-column salt content, while temporal clustering yields time series of interannual variability expressed as representative spatial patterns. Elbow-method diagnostics confirm distinct and physically interpretable clustering structures across all scenarios. Together, these analyses provide a unified framework for identifying persistent structural features and evolving salinity regimes in the Baltic Sea. Removing seasonal effects and depth-related biases reveals clearer long-term signals that are often masked in conventional layer-based diagnostics. Overall, the SC framework offers an integrated, physically grounded method that improves salt-budget estimates, clarifies long-term spatial change, and supports climate-impact assessments in semi-enclosed seas.

Early Career Scientist (ECS) contribution

Abstract No. 62

Analysing Baltic Sea extreme events in five years of glider observations

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The Baltic Sea was warming rapidly at about 0.5°C per decade during the past 4 decades and has an increasing trend of heatwaves. Despite reductions in nutrient inputs, intense cyanobacteria blooms persist, and anoxic bottom waters continue to expand. Four decades of monitoring with CTDs, moorings, and Argo floats have documented major changes, but each method has relatively low temporal or vertical resolution. To close this gap, the Voice of the Ocean Foundation runs five glider-based Baltic Observatories, that are operating continuously since up to five years. These autonomous platforms provide high-resolution, persistent measurements that capture both short-term extreme events and longer-term shifts. Their uninterrupted presence often allows direct identification of processes preconditioning heatwaves, blooms, and deoxygenation. Long time series of satellite SST, and long-term CTD monitoring allows for the development of full-depth climatologies for some locations in the Baltic Sea. The use of observational climatologies reveal subsurface heatwaves and their effects on oxygen concentrations, while avoiding misleading influences of eventual model biases. During bloom events, chlorophyll maxima typically form near the mixed-layer base, with both chlorophyll and temperature profiles tightly controlled by mixed-layer depth. Beneath the mixed layer, cooler intermediate waters provide refuges during heatwaves, though these are increasingly constrained by a long-term shoaling Baltic halocline and expanding anoxic deep waters. Deep layers remain largely isolated from atmospheric forcing and respond mainly to horizontal advection, with repeated late-summer warm and saline inflows that are contributing to the long-term warming below the halocline, especially in the Bornholm Basin. The continuous observations also capture relatively rare events such as transient halocline eddies or intense phytoplankton coagulation and sinking which underscores the role of sustained, high-resolution glider observations in resolving the dynamics and impacts of extreme events in the Baltic Sea.

Early Career Scientist (ECS) contribution

Abstract No. 83

A lean 3D Lagrangian suspended sediment-plume simulator for offshore wind farm construction

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The rapid offshore wind farm development in the Baltic Sea, including large projects in the Gulf of Riga, increases the need for reliable but efficient tools to help evaluate the environmental impact of plumes of suspended sediment generated by construction work. We introduce a lightweight 3D Lagrangian particle model designed as a post-processor for existing hydrodynamic products. The model employs time-varying, layered current velocities from Copernicus to advect particles in the column of water above high-resolution GEBCO bathymetry, using trilinear interpolation in space and time. The horizontal subgrid dispersion is modeled with a random walk with a tunable eddy diffusivity coefficient. The vertical motion of particles similarly combines constant class-dependent settling velocities with a stochastic random walk within a tunable vertical diffusivity profile, with separate seasonal shapes for stratified summer and mixed winter conditions. The boundaries at the surface and at the bottom are modeled with purely reflective and probabilistic depositional conditions, respectively. The model uses only a small set of physically interpretable parameters and uses standard gridded current data as its only energy input. The included diagnostic tools include suspension time distributions, concentration profiles, horizontal cloud growth, and deposition footprints. We present a set of scenarios designed to be representative of offshore wind farm construction activity and discuss the role of this model as a complementary, low overhead alternative to fully coupled biogeochemical models, where the cost of a larger set of modeled processes is often shifted to that of obtaining and aggregating appropriate input data.

Session 3

Natural hazards and their impacts

Future changes in compound precipitation and wind extremes in the Baltic States under CMIP6 projections

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The negative socioeconomic impact of precipitation and wind extremes is exaggerated when these phenomena coincide. Such events are referred to as compound precipitation and wind extremes (CPWEs). In this study, CMIP6 climate model projections were used to evaluate future changes in the frequency, spatial distribution, and intensity of CPWEs in the eastern part of the Baltic Sea region. The NASA NEX-GDDP-CMIP6 database was used to derive daily precipitation and mean wind speed data from five CMIP6 models, which represent different parts of the equilibrium climate sensitivity spectrum, and two SSP scenarios (SSP2-4.5 and SSP5-8.5). 1995–2014 was used as a baseline period while projections of CPWE characteristics were analysed during mid-century (2041–2060) and late-century (2081–2100). CPWE events were defined as days when both precipitation and maximum wind speed exceeded their respective 98th percentile thresholds at the same grid point. Depending on the CMIP6 and SSP scenario used, an increase of 0.2–3.4 events/decade is projected by mid-century, rising to 0.7–4.5 events/decade by 2081–2100. According to data from most models, the recurrence of CPWE is expected to increase during the cold season (October–March) more than during the warm season (April–September). However, the changes in the number of most severe CPWEs, when both variables exceed the 99.9th percentile value, are not uniform – some models predict an increase of such extremes, while others predict a decline. As the first study of its kind in the Baltic States, these findings are significant for climate change adaptation planning and for mitigating the risks and socio-economic impacts associated with extreme weather.

Early Career Scientist (ECS) contribution

Abstract No. 37

Socio-economic vulnerability to compound river–coastal flooding in Klaipėda under climate change

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Compound river floods pose threat to Baltic Sea coastal cities when several hydrometeorological processes act simultaneously. Klaipėda, located at the mouth of the Akmenė–Danė (Dangė) River, is sensitive to these processes. Such floods are especially common during storms, when wind-driven surges in the Klaipėda Strait block the Dangė River from flowing into the Curonian Lagoon. Compound floods threaten port infrastructure and densely populated areas along the river. This study quantitatively assesses compound flood hazard and risk and the associated socio-economic vulnerability of residential districts of Klaipėda located along the Dangė River. We analyse long-term water-level rise in the Klaipėda Strait and discharge records of the Dangė River in order to identify typical compound-flood conditions. Using the HEC-RAS model, we create flood scenarios for the Dangė River, assuming that climate change could cause water levels in the Baltic Sea and the Curonian Lagoon to rise by 1 m. This assessment is intended to support the development of long-term climate change adaptation measures that can reduce future social and economic losses. Using ArcGIS Pro tools, flood risk zones were identified in the city of Klaipėda, taking into account flood scenarios, the number of buildings, residents, and economic entities affected by flooding, and the extent of transport infrastructure. Based on this data, the vulnerability of residential areas is assessed separately for each component and, after combining all components, in an integrated format. The results clearly show the areas where measures already need to be taken to reduce future social and economic losses and highlight areas where it would be appropriate to start implementing targeted long-term actions to promote adaptation to climate change and increasingly frequent extreme hydrometeorological events. The study emphasizes the need to integrate complex flood processes and socioeconomic vulnerability into Klaipėda's spatial planning, building regulations, and climate change adaptation strategies.

Early Career Scientist (ECS) contribution

Extreme value analysis on wave-driven near-bed water speeds in the eastern Gulf of Riga

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Understanding the dynamics of underwater flow speeds is essential for evaluating sediment mobility, near-bottom stresses and coastal morphodynamical responses. Such information is used in coastal engineering and planning of marine infrastructure, where accurate estimates of near-bed flows support risk assessments and design criteria. We analyse extreme values of underwater flow speeds obtained from measurements in the Gulf of Riga near Skulte (57°19'16.6" N, 24°23'33.8") [Eelsalu, Piho et al., 2025. Exponential distribution of wave-driven near-bed water speeds under short-crested waves: a case study in the eastern Gulf of Riga, the Baltic Sea. Proceedings of the Estonian Academy of Sciences, 74(1), 23–42. <https://doi.org/10.3176/proc.2025.1.03>]. Recordings were conducted between 02.08.2022 and 08.09.2022 using Acoustic Doppler Velocimeter (ADV) and nine hydromasts deployed in approximately 4 m deep of water. The local wave climate is intermittent, characterised by long periods of calm conditions interrupted by short energetic episodes. During the campaign, the maximum significant wave height reached about 2 m. The observed flow-speed distributions are close to the exponential distribution, with parameters varying across instruments. This indicates that moderate and large flow speeds occur more frequently than expected from classical wave-driven distributions of flow speed (e.g. Rayleigh or Forristall distribution). It is likely that variability and intermittency of the flow properties contributed to heavy-tailed behaviour at moderate and high velocities. To quantify the extremes, we apply block-maxima method with the Generalized Extreme Value (GEV) distribution, as well as the Peak-Over-Threshold (POT) approach using the Generalized Pareto (GPD) distribution. Due to strong serial correlation in the data, careful selection of block sizes and POT thresholds is required. Estimates based on different methods diverge notably, especially for longer return periods. Across all locations, the resulting extreme-value parameters indicate the presence of heavy tails and demonstrate non-negligible probabilities of unusually large near-bed flow speeds for longer return periods.

Abstract No. 76

Adhesive-adsorptive signatures of biofouled seawater solid substrata versus biotic and abiotic trophic status indexes

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The aim of this study was to determine the adhesive and adsorption properties of model solid substrates (plastics, glass, minerals), including the rate of biofilm formation in the initial stage of their formation in the marine environment, which is crucial for further colonization and the effectiveness of biocolony development. Surface wettability-energetics parameters: surface free energy, work of adhesion and spreading, Gibbs excess ratio, 2D adsorptive pressure etc. were determined from dynamic contact angles analyzed with Chibowski's approach (Pogorzelski et al., 2013; Grzegorzczak et al., 2018) on a model solid-seawater system, water samples were collected at shallow regions of the Baltic Coast (Mechelinki, 54°26' N, 18°37' W) weekly in the period from March 10, to July 14, 2025. For comparative purposes, the structural, morphological, and photosynthetic properties of biofilm colonies were determined using complementary techniques i.e., confocal laser scanning microscopy for the biofilm surface morphology characterization (Grzegorzczak et al., 2022), and photoacoustic spectroscopy (PAS) system was to determine photosynthetic properties of biofouled substrata (Boniewicz-Szmyt et al., 2023). A trophic status of the water body was determined according to the following parameters: pH, dissolved O₂, N, P, Chl-b concentrations, primary production, and Secchi depth; also taken from SatBałtyk System data base (available at <http://satbaaltyk.iopan.gda.pl>). Seasonal correlations were sought between the adhesion parameters of the substrates and the biotic and abiotic trophic parameters of the water body. The data follow so-called Baier's bioadhesion efficiency dependence on surface energy, correlations were found between adhesion parameters and structural features of the biofilm structure (covered surface fraction, concentration of individuals, formation rate, fractal dimension, roughness, biovolume, etc. (Grzegorzczak et al., 2022)). Submerged substrata wettability signatures could become further novel trophic state indicators.

References:

- Pogorzelski, S. J., et al., *J. Mar. Syst.* 2013, 119-120, 50-60
Grzegorzczak, M., et al., *Front. Mar. Sci.* 2018, 5, 363
Grzegorzczak, M., et al., *Materials*, 2022, 15, 6351
Boniewicz-Szmyt, K., et al., *Oceanologia*, 2023, 65, 194-201

Evaluating the applicability of EOF analysis to characterise extreme storms in the southern Baltic Sea: insights from REMO and Copernicus atmospheric pressure fields

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Extreme events, such as storms, have been highlighted as one of the key research topics for the Baltic Sea region. Large-scale atmospheric circulation influences local wind wave conditions. Due to the shape of the Baltic Sea, high variability in the directions of winds generating the most extreme storm events with respect to wave heights has been observed. As storm events are usually a result of the low-pressure system moving in the vicinity of the Baltic Sea, its trajectory and position relative to the areas of high pressure are crucial for the development of extreme wave heights in different areas. Winds from certain directions, even though they meet the definition of storm winds over Baltic, that is 15–17 m/s, will rarely result in an extreme wave event. In the approach applied in our study, extreme storms are identified on the basis of wind wave parameters rather than meteorological variables, as is usually done. One of the objectives of our work is to relate the selection criteria and the evolution of such wave-defined storms to the corresponding variations in the leading EOF principal components, as well as to the characteristic evolution of local atmospheric pressure associated with these storms in selected areas. Empirical Orthogonal Function analysis was applied to the sea level atmospheric pressure anomaly fields over central and northern Europe. Our aim was to identify common features in the spatial distribution and temporal evolution of atmospheric pressure fields during the analysed storm events in several selected basins of the southern Baltic Sea. Within our study, we examine the relationships between the EOF principal components and local atmospheric pressure at selected sites in the southern Baltic. An important element of our research is a comparative analysis of atmospheric pressure time series extracted from two different modelling systems: REMO and Copernicus.

Early Career Scientist (ECS) contribution

Application of excitation–emission spectroscopy for microplastic detection in seawater

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Plastic pollution in seas and oceans has become a significant global problem. Plastic waste enters aquatic systems, where it gradually breaks down into smaller fragments, leading to an increasing concentration of microplastics. This process intensifies pressure on marine ecosystems. Microplastics are considered a serious threat to marine life due to their potential toxic properties. Therefore, detecting microplastics is crucial for protection of the marine environment. However, microplastic detection in seawater is challenging due to complex analytical procedures. For this reason, there is a need to develop methods that allow fast and simple microplastic detection. The aim of this study is to evaluate the usefulness of a fluorescence-spectroscopy-based method for detecting microplastic contamination in seawater. Samples of consumer-derived plastics were used as model materials. Fluorescence spectroscopy was applied as the analytical technique for microplastic detection. To eliminate the influence of natural fluorophores present in seawater, artificial seawater was used. The artificial seawater samples were contaminated with fragments of consumer microplastics. In the obtained excitation–emission matrices (EEMs) characteristic fluorescence maxima were detected which indicated the presence of microplastics in the water. Moreover, the excitation–emission spectra revealed shifts in fluorescence maxima and an increase in fluorescence intensity in samples containing microplastics that had undergone long-term water ageing. This may indicate interactions between plastics and water as well as the release of microplastic-derived compounds into the marine environment. The results suggest that fluorescence spectroscopy is a promising tool for detecting microplastics in marine ecosystems.

Competing hypotheses for submarine landform genesis in the Baltic Sea: Landslide or groundwater seepage?

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What process formed one of Sweden's most prominent submarine landforms off the coast of Blekinge in the southern Baltic Sea? In 2014, the Swedish Geological Survey mapped the seafloor off the coast of Blekinge and discovered distinct submarine landforms at depths of 50–60 m. The most notable feature extends 12–14 km in length and 6–18 m in height, and is composed of glacial clay overlying glacial sediments. Traditionally interpreted as Sweden's largest submarine landslide, its origin has recently been questioned. A 2025 pre-site survey by Stockholm and Södertörn Universities revealed sediment compositions and morphologies inconsistent with a landslide origin. Instead of mass-wasting deposits, the area exhibited features indicative of sediment collapse and seepage, including flat upper slopes of varved glacial clays, steep escarpments up to 14 m high with basal layers of stones, gravel and sand, and sand-dominated deposits where landslide debris would be expected. These observations suggest an alternative hypothesis for the landform's origin: submarine groundwater discharge through permeable layers within the glacial clays, rather than formation by a single landslide event. This project tests two competing hypotheses: formation by landslide versus collapse driven by groundwater discharge and sediment undermining. Understanding the genesis of this landform is crucial for assessing submarine slope stability, evaluating potential tsunami risks and advancing knowledge of environmental processes, including nutrient and carbon fluxes in the Baltic Sea. It will also determine whether this is an ongoing process or a past event that can be dated. The project further investigates two coastal areas in Sweden and Estonia, respectively, where traces of an abrupt sea-level rise were recorded approximately 8000 years ago.

Abstract No. 117

Hydrometeorological conditions of ice formation development and threats to the South Baltic coast and lagoons in 2021, 2024, 2026

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Cold winters leading to the development of ice cover along the southern coast of the Baltic Sea and its lagoons have become rare in recent years. This study analyses the most recent periods of ice formation and the hydro-meteorological conditions responsible for ice shove along the southern Baltic coast, including the Pomeranian Bay, the Gulf of Gdańsk, and the lagoons of Szczecin, Puck, and Vistula. The analysed events occurred in February 2021, January 2024, and January/February 2026. Shore ice forms in four types of piled structures: (a) ice pressured on the coastal slope, (b) grease ice ridge consisting of ice and freezing water, deposited during wave action, (c) ice piles-ridges composed of different ice and (d) ice hummock ridges formed by wind-driven ice floes pushed during rising water. These phenomena are short-lived and variable within a single winter season. Conditions in February 2021 led to the formation of pressured ice and grease ice ridges along the Pomeranian Bay coast under wave action from the NW. In January 2024, grease ice ridges, hummock ice and piles (and other shoves) formed along the Puck Lagoon (N coast) and the Vistula Lagoon (S coast) under different wind and wave directions following a short ice-cover period. In January 2026, ice ridges and piles developed along the southern shore of Szczecin Lagoon and near the Vistula mouth at the Vistula Spit (under N wind and wave). In February 2026, pressured ice forms originating from freezing water along the entire southern Baltic coast during low air/ sea temperatures. The height of these ice forms and the ice type result in varying impacts on coastal zones, including seabed and shoreline erosion, vegetation damage, and destruction of infrastructure.

Abstract No. 125

Simulating complex hydrodynamics in a small marina using Smoothed Particle Hydrodynamics

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Wave induced currents in harbors and particularly in small, semi-enclosed marinas pose significant operational and safety challenges. Strong and irregular flows can make vessel navigation and mooring difficult. They may also disrupt daily port operations and weaken the structural stability of quays, breakwaters and other coastal infrastructure. Understanding the origin, behavior and intensity of these currents is therefore essential for coastal engineers and harbor management authorities. Their dynamics in restricted basins can be strongly modulated by harbor geometry, wave resonance, ship generated motions, and conditions under which a vessel's natural oscillation frequency coincides with that of infragravity waves. Infragravity waves are especially hazardous in narrow marina basins, where they may generate persistent shoreward currents or intermittent high-energy jets. Solitary waves with distinct physical characteristics can further induce transient harbor resonance, amplify natural oscillations, and increase the risk of mooring failures and other operational disturbances. In addition to these internal processes, small harbors along the Baltic Sea coast may also be exposed to meteotsunami events, which can trigger rapid changes in water levels and flow conditions, potentially with severe implications for port infrastructure. To address these challenges, this study presents the first application of a Smoothed Particle Hydrodynamics (SPH) model to a small marina in the Klaipeda Strait, South-Eastern Baltic Proper. The mesh-free SPH method is particularly well suited for simulating wave driven currents in complex, dynamically evolving harbor geometries, offering robust capabilities to resolve infragravity wave dynamics and extreme event scenarios. By integrating high resolution SPH simulations with available in situ measurements, the study aims to improve understanding of hydrodynamic processes within the marina and to support the development of more resilient operational and risk management strategies.

Early Career Scientist (ECS) contribution

Session 4

Sea level and coastal change

Evaluation and optimization of Aeolian sand trap designs

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Understanding of aeolian sediment movements is critical for predicting dune evolution and managing coastal and desert ecosystems. Sand traps remain one of the most effective and widely used instruments for quantifying horizontal sand flux, alongside other measurement methods. This study aims to identify the optimal design for sand traps along Lithuania's sandy coast, explicitly targeting the dynamic dune systems of the Curonian Spit. We focus on two established designs - the Big Spring Number Eight (Fryrear) trap and an omnidirectional cylindrical trap - and evaluate their appropriateness for local monitoring applications. To determine the optimal sand trap and monitoring site design, we employ computer simulations that replicate the distinctive aeolian conditions of the Curonian Spit to determine the most effective design for the region. These simulations account for prevailing wind patterns, seasonal variations, and the typical dimensions of sand grains. We examine the influence of trap shape, intake configuration, and vertical positioning on capture efficiency and sensitivity to wind direction through airflow modelling and particle trajectory analysis. The modelling of the sand trap prototype is carried out using a Computational Fluid Dynamics (CFD) framework that employs a Finite Volume Method (FVM) solver to evaluate aerodynamic performance and sand-capture behavior accurately. The insights gained from the simulations will facilitate the development of a functional prototype suitable for Lithuanian coastal regions. This prototype will be utilized on-site as part of a long-term monitoring program to detect changes in aeolian transport associated with recent modifications in dune vegetation cover. The study seeks to improve our understanding of sediment redistribution on the Curonian Spit by integrating numerical modelling with empirical observations, thus creating a more rigorous methodological framework for selecting sand traps that support effective coastal management and restoration initiatives.

Abstract No. 29

Influence of surface waves on the transport of natural and anthropogenic sediments in the western Baltic Sea

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In the shallow regions of the Baltic Sea, sediment dynamics are strongly influenced by surface waves. This is particularly relevant for the transport of fine sediments brought into the coastal ocean by humans, as these sediments can easily be remobilized and potentially affect the ecosystem. In the Bay of Kiel, over 1 million cubic meters of dredged sediment have been dumped in 2024/2025 as part of the effort to widen the Kiel Canal, a major shipping route connecting the Baltic Sea and the North Sea. There are concerns that the dumped material may increase turbidity and negatively impact the recreational areas as well as marine protected areas nearby. To address these concerns, we monitor sediment dynamics in this area by combining continuous observational data from buoys deployed around the dump site with regional high-resolution numerical modeling. Here, we present the results of our coupled hydrodynamic–spectral wave–sediment transport model for a period during which significant dredging activities occurred simultaneously with strong winds. The windy conditions generated big waves with significant wave heights of about 2 m, enhancing wave-induced turbulence and increasing the resuspension of sediment, thus resulting in higher turbidity. Our simulations enable us to distinguish the increased turbidity caused by natural factors from that caused by the anthropogenic dumping of dredged material. Furthermore, we can use our coupled model to analyze the relevant sediment transport processes, to better understand the influence of waves on sediment dynamics, including radiation stress, vertical mixing and resuspension. These results support the assessment of the potential environmental impact of human activities on marine ecosystems by closing observational gaps, and improve our understanding of sediment dynamics in shallow coastal seas.

Early Career Scientist (ECS) contribution

Shoreline changes of the southern Baltic coasts during the Late Holocene in light of dating submerged forests

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Among the palaeogeographical data useful for reconstructing the positions of former shorelines, particularly valuable are outcrops of organic sediment layers (peats, fossil soils), and especially fossil tree trunks found in their natural position in the beach zone developed along the edges of sandy barriers. Outcrops of such layers in the coastal zone of the southern Baltic have been known for a long time, but only the results of radiocarbon dating allow, in some cases, an assessment of shoreline movements, as indicated by Rosa (1984). On the beaches of the Polish Baltic coast, peat outcrops with tree stumps, underlain by lagoon sediments, have been found at several locations. This supports the assumption that the entire complex of lagoon and marsh sediments formed in the landward zone of the barrier and that the entire barrier has moved landward. Dating of peat layers and tree trunks in their natural position found in the contemporary beach zone, combined with the geomorphological setting, including the width of the barriers and the extent of the coastal dune sediment accumulation belt, has enabled estimation of the rate of southward movement of the barrier coasts. The presence of numerous depressions filled with biogenic sediments (Krzymińska and Przeździecki 2001), deposited before the Littorina transgression and located on the seabed north of the modern cliff and dune shores, is documented both by direct data (underwater drilling) and indirect data, in particular large peat lumps, detrital gyttja, and lacustrine mud deposits containing freshwater malacofauna washed up on the beach after heavy storms. These drowned landscapes are expected to have been inhabited by Holocene hunter-gatherers, as indicated by evidence from neighbouring areas (Kurzyk 2024; Hartz et al. 2014) and by stray finds in the region. A detailed reconstruction of coastal retreat is a prerequisite for targeted underwater archaeological surveys in the context of the ERC SyG SUBNORDICA.

Abstract No. 55

In-situ meteorological and Sea level dataset from coastal stations along the Estonian coastline during 2000-2025

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Coastal change in the Baltic Sea region is strongly influenced by variations in wind, air pressure, sea level highlighting the need for improved environmental data time-series to support climate adaptation, coastal planning, and sustainable use of maritime space. A high-frequency meteorological and sea-level dataset has been collected, quality assessed, and made publicly available by the Department of Marine Systems (MSI) at Tallinn University of Technology (TalTech). The dataset comprises observations from 19 coastal stations distributed along the Estonian shoreline and spans from the early 2000s to late 2025. It includes seven key variables—wind direction, wind speed, wind gust, air temperature, humidity, air pressure, and sea level—recorded at 10-minute intervals. The resulting long-term, high-resolution record provides valuable input for studying regional climate trends, improving weather and coastal hazard forecasting, and developing adaptation strategies for the climatically sensitive Estonian coastal zone. By making these observations publicly accessible, the dataset supports more informed and resilient climate-related decision-making in the Baltic region.

Early Career Scientist (ECS) contribution

Abstract No. 115

Morphological transformation of a coastal barrier into a cliff: Evidence from the Polish Baltic coast

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Coastal zones worldwide are undergoing continuous and often rapid transformations driven by climatic, oceanographic as well as geological processes; and the highly erosion-prone shores of the southern Baltic Sea exemplify these dynamic changes. This study focuses on a coastal barrier located near Lubiatowo on the Polish Baltic coast, being a region increasingly exposed to energetic storm conditions. The aim of this research is to demonstrate that a morphological shift from a barrier-type coast to a cliffed coastline is not only theoretically possible but already observable under specific environmental constraints. In particular, we examine the combination of hydrodynamic forcing and geological structure that governs this transformation. Our methods integrate detailed geomorphological mapping, analysis of historical shoreline changes and assessment of both terrestrial and marine geological settings. These are supported by observations of storm impacts, with special emphasis on high-energy winter events that accelerate erosional processes. Findings indicate that repeated storms, superimposed on a persistent sand deficit in the nearshore seabed - the principal “reservoir” for post-storm beach and dune recovery - systematically suppress rebuilding barrier. Where the onshore geology provides limited mobile sediment yet includes low-cohesive or low-consolidated units, erosional scarps steepen and local failures initiate, promoting the emergence and headward growth of cliffed segments. Together, storm frequency/intensity and the lithological setting (marine and terrestrial) create conditions under which a barrier can cross a tipping point and evolve into a cliffed coast. This barrier-to-cliff conversion has significant implications for hazard, ecology and management, marking a step-change from recoverable beach-dune erosion to sustained slope retreat on sediment-starved coasts.

Abstract No. 118

Baltic Sea storms in diverse weather conditions – Analysis of case studies and threats to the coast at the turn of 2025 and 2026

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This study presents short-term and highly dynamic of the sea-level changes along Baltic Sea coasts, that were observed over a three-week period at the turn of 2025 and 2026 (26 December 2025 to 17 January 2026). These changes resulted from dynamic meteorological conditions associated with numerous low-pressure systems passing over the southern and northern parts of the Baltic Sea. Their effects included successive high sea-level events generated by strong winds from varying directions, leading to the development of storm surges within 1-2 days. Rapid shifts in wind direction caused abrupt sea-level fluctuations across the entire Baltic Sea and its gulfs, ranging from -0.7 m to +1.2 m AMSL. Under NW–NNW winds, sea level rose to +0.7–1.2 m AMSL along the west and central southern Baltic coasts (Germany, Denmark, Scania, and Poland). Elevated levels were also recorded in the Gulf of Riga, reaching +0.8 m AMSL, and in the Gulf of Finland, up to +0.6 m AMSL. Westerly winds (W) resulted in sea-level rise of up to +0.65 m AMSL along the eastern Baltic coast (Russia, Lithuania, and Latvia). Under S–SSW winds, sea-level increases reached +0.6 m AMSL on the eastern coast and +0.4 m AMSL in the Bothnian and Riga Gulfs. Southwesterly (SW) winds produced the highest sea levels in the Gulf of Riga, up to +0.75 m, and in the Gulf of Finland, up to +0.5 m AMSL. Under S-SSE winds, the highest sea levels occurred in the inner Bothnian Bay, +0.55 m AMSL. Easterly to northeasterly winds (E-NE) caused sea levels to rise to +0.8 m along the Scania coast and to +1.15–1.2 m AMSL along the southern and eastern coasts of the western Baltic in Germany and Denmark. Such elevated sea levels resulted in erosion of beaches, including dune systems.

Session 5
Biogeochemistry of the Baltic Sea
– Linking observations and modelling

Abstract No. 6

Climate change and eutrophication effects on cyanobacteria and planktic green algae summer blooms between 1991-2023 in the northern Baltic Sea

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We studied the biomasses and abundances of microscopic cyanobacteria and green algae in the Archipelago Sea, northern Baltic Sea, from 1991 to 2023. Phytoplankton samples were collected monthly from a monitoring site using a plankton net at depths of 0—25 meters. Phytoplankton were identified to species level or, in some cases, to higher taxonomic levels. The numbers of species/taxa were counted and biomasses were estimated based on cell volume. The amounts and biomasses of cyanobacteria and microscopic green algae increased significantly in July and August during the 30-year study period. This is the first part of the study where we aim to clarify the role and effects of SST, marine heatwaves, wind conditions, nutrients (phosphate phosphorus and ammonium nitrate), salinity and NAO on cyanobacterial and planktic green algae blooms from mid to late summer during the study period. Archipelago Sea is highly eutrophicated. Climate change is expected to exacerbate the situation by increasing nutrient loading due to increased winter river runoffs and increased oxygen consumption by organisms. In addition, rising water temperatures enhance bloom conditions for cyanobacteria. Reductions in nutrient loads, according to HELCOM, would compensate eutrophication caused by climate change. The combined effects of future climate change and nutrients entering the sea will be reflected on the microorganism and phytoplankton communities and the entire food chain.

Early Career Scientist (ECS) contribution

Abstract No. 8

Using a river plume to define a water quality assessment unit

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Excessive riverine nutrient inputs are a main driver of eutrophication in marine waters. Thus, identifying areas most affected by river plumes is a key challenge for effective water quality management. Transitional waters, which are affected by river plumes, but also have open sea characteristics, are usually merged with larger open sea assessment units. This leads to non-representative spatial units, whose unreliable assessment results cannot support the implementation of measures in order to improve the water quality. An example for this mismatch is the Oder (Odra) river plume area in the southern Baltic Sea. Before the separation of Pomeranian Bight from the open Bornholm Basin, the whole assessment unit got a bad classification in HELCOMs holistic assessments. We propose an improved layout for the assessment unit that better captures the spatial heterogeneity by following the distribution of the Oder nutrients and pollutants in the sea. By applying a one-way ANOVA, we can find the optimal river plume assessment unit layout, whereas a smaller assessment unit only near the river mouth is best for dissolved nutrients, while a larger area is better, if chlorophyll-a is assessed.

Abstract No. 47

Mercury levels in the tissues of two cyprinid fish species Bream (*Abramis brama*) and Roach (*Rutilus rutilus*) from the southern Baltic Sea lagoons

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Mercury, a potent neurotoxin, persists in the marine environment despite decreases in anthropogenic emissions, undergoing both bioaccumulation and biomagnification. Particular attention is drawn to the Vistula Lagoon and the Szczecin Lagoon - areas highly exposed to inputs of municipal, agricultural, and industrial pollution from the Vistula and Oder river basins. Both water bodies are shallow, semi-enclosed basins strongly influenced by river inflows. Their hydrological conditions promote the accumulation of mercury and its transfer into aquatic organisms, including common fish species that play a key role in the movement of metals within the trophic network. Cyprinid fish, which constitute an important component of the diet of predatory species, may play a key role in transferring this element to higher trophic levels. The aim of the study was to determine the total mercury (THg) content in roach and bream inhabiting both lagoons and to examine its distribution among various tissues and organs, such as muscle, liver, heart, brain, and kidney, which provides a better understanding of the mechanisms of accumulation within the organism and the potential pathways of transfer within the trophic network. THg analyses were performed using a DMA-80 mercury analyzer. This research addresses a critical knowledge gap concerning mercury distribution among internal organs of non-commercial fish species in brackish coastal ecosystems. Understanding tissue-specific accumulation patterns is essential for evaluating both ecological risks and potential human exposure through higher trophic levels.

Early Career Scientist (ECS) contribution

Winter sets the table: Early-season phosphorus favours summer proliferation of *A. flosaquae*

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Cyanobacteria are key contributors to summer primary production in the Baltic Sea, where seasonal accumulations of diazotrophic species, most commonly *Aphanizomenon flosaquae* and *Nodularia spumigena*, affect ecosystem processes and nutrient cycling. However, the factors that regulate their biomass remain only partly understood. This study examined nearly four decades of monitoring data (1976–2024) collected from four stations arranged along the Daugava river transect in the Gulf of Riga. The aim was to determine how nutrient availability, salinity, and river discharge influence both the composition and magnitude of summer cyanobacterial blooms. Additional observations from monitoring stations across all Latvian territorial waters (2023–2025) were used to evaluate the distribution of *A. flosaquae* with developed heterocysts - specialized cells that indicate active diazotrophy. While both taxa co-occurred, *A. flosaquae* dominated the biomass. A Generalized Additive Model (GAM) revealed that winter dissolved inorganic phosphorus (DIP) was the strongest and most consistent predictor of its summer biomass. This indicates a 'legacy' effect where winter phosphorus availability sets the stage for summer bloom development. Hydrological parameters such as salinity and river runoff had limited influence on *A. flosaquae* dynamics. In contrast, *N. spumigena* showed no response to any shifts in measured nutrient and hydrological parameters, highlighting species-specific differences in bloom regulation. Further analysis of heterocyst patterns indicated that higher *A. flosaquae* biomass in the Gulf of Riga corresponded to more heterocyst-containing filaments, whereas these specialized cells were rarely observed in *N. spumigena* and the *A. flosaquae* open Latvian territorial waters. These findings demonstrate that winter phosphorus supply is a species-specific regulator of diazotrophic cyanobacteria dynamics in the Gulf of Riga, while nitrogen availability and physical conditions act as secondary factors.

Early Career Scientist (ECS) contribution

Abstract No. 88

Mercury in the sediment–bottom water system of the Gulf of Riga, Baltic Sea

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Mercury is a highly toxic and persistent pollutant that bioaccumulates and biomagnifies in marine food webs, posing risks to ecosystems and human health. Although investigated in the Baltic Sea for decades, mercury contamination patterns remain regionally fragmented. One insufficiently recognized area is the Gulf of Riga. Each year, more than half a ton of mercury enters the gulf, about eighty percent via rivers, mainly the Daugava River. Restricted water exchange favors mercury retention and accumulation in bottom sediments. This study assessed mercury concentrations in surface sediments and near-bottom water in the Latvian sector of the Gulf of Riga and adjacent waters, addressing a regional knowledge gap. Sampling was conducted at twenty stations in November 2025 aboard the r/v Oceania. In addition, near-bottom physicochemical parameters were analyzed to characterize environmental conditions controlling mercury distribution and mobility. Mercury concentrations in surface sediments ranged from 1.9 to 138.0 ng g⁻¹ d.w., with elevated values recorded in the central accumulation basin. Mercury level in sediments was strongly associated with sediment water content, organic matter content, and reducing conditions, indicating preferential retention in fine-grained, organic-rich deposits. Although sediment mercury concentrations did not exceed established sediment quality thresholds, the highest values remained above estimated preindustrial background levels, reflecting a persistent anthropogenic imprint. Compared with previous decades, sedimentary mercury concentrations were lower, which may suggest reduced atmospheric and riverine inputs, although the currently available data do not allow firm conclusions regarding a long-term decline. Near-bottom water mercury concentrations ranged from 0.3 to 3.2 ng L⁻¹ and showed no correlation with sediment mercury level, suggesting control by dynamic processes or local sources rather than bulk sediment composition. Overall, the results indicate moderate contamination and point to an ongoing recovery of the Gulf of Riga from historical mercury pollution, while highlighting the continued role of internal cycling in shaping present-day mercury dynamics.

Funding: This study was conducted within the Interreg Baltic Sea Region project “MUNIMAP: Baltic Sea Munitions Remediation Roadmap”, co-funded by the European Union (<https://interreg-baltic.eu/project/munimap>).

Early Career Scientist (ECS) contribution

Abstract No. 96

Phytoplankton community composition and its influence on primary production in the southwestern Baltic Sea

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Boknis Eck, a long-term coastal monitoring station in Germany's southwestern Baltic Sea, provides a critical platform to investigate climate-relevant marine ecosystem processes. As part of the KIMMCO project, which aims to assess the natural climate protection potential of phytoplankton in the SW Baltic Sea, we combine classical time-series monitoring with emerging bio-optical techniques to better understand phytoplankton's role in carbon cycling. KIMMCO focuses on improving biomass and speciation data using new methods (e.g., sensor, imaging, and satellite), while constraining the role of phytoplankton in CO₂ and CH₄ fluxes. Within this framework, our study links phytoplankton community composition with physiological state to interpret seasonal variability in carbon fixation. Since November 2025, we have been conducting monthly measurements at Boknis Eck using LabSTAF fast repetition rate fluorometry to quantify gross primary production and key photo-physiological parameters across the water column. These data are combined with group-specific biomass estimates from microscopy and imaging to derive group-specific productivity trends. By comparing physiological performance with biomass distribution, we identify which phytoplankton groups are most efficient in driving carbon fixation under natural seasonal variability. This approach reveals how community succession and photo-acclimation strategies influence the system's overall biological carbon uptake. By integrating physiology and taxonomy, we aim to provide a mechanistic understanding of primary production dynamics. This enhances the interpretation of long-term monitoring data and supports the development of more comprehensive management tools for the future. Our findings support KIMMCO's broader objectives by clarifying how phytoplankton variability modulates CO₂ drawdown, which is essential for forecasting biogeochemical responses to climate change in the Baltic Sea and similar coastal environments.

Early Career Scientist (ECS) contribution

Abstract No. 113

Trophic Transfer Index (TTI): Methodology, challenges, and application to marine eutrophication assessment

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We present the methodological development and implementation of the Trophic Transfer Index (TTI), a novel functional indicator for assessing eutrophication. Unlike static metrics based on biogeochemical concentrations (biomass, nutrients, and oxygen), the TTI quantifies the dynamic coupling of the planktonic food web. We premise that in a healthy ecosystem, the transfer of produced carbon to higher trophic levels (Grazing Rate, GR) is tightly coupled to Primary Production (PPR). The TTI algorithm comprises three computational steps: (1) Lag identification: determining the temporal lag (τ_{\max}) that maximizes the Pearson correlation (R_p) between PPR and GR, thereby distinguishing natural physiological delays from eutrophication-driven decoupling; (2) Efficiency assessment: calculating the Spearman rank correlation (R_r) between PPR and trophic transfer efficiency (TTE = GR/PPR) at the identified lag; (3) Index definition: deriving the final index as $TTI = \max(R_p, R_r)$. We address critical challenges in applying this algorithm by using biogeochemical simulations, before applying it to real-world data. These include handling signal-to-noise ratios during low-productivity periods ("winter masking"), optimal window length for the correlation analysis and, crucially, the selection of appropriate functional groups. For instance, comparative sensitivity analysis in the Black Sea highlighted the necessity of excluding low palatable, "dead-end" grazers (e.g., the dinoflagellate *Noctiluca*) to avoid masking the true energy transfer signal. Validating the method against long-term Baltic Sea simulations (1954–2022), the TTI successfully resolved distinct ecosystem regimes (1974, 1988, 2012) and quantified a 17-year hysteresis response to nutrient loads—dynamics invisible to traditional concentration metrics. Finally, we demonstrate an Artificial Neural Network (ANN) approach to estimate TTI from standard monitoring variables, bridging the gap between complex theoretical indices and operational monitoring.

Abstract No. 120

Nitrogen gain and loss in changing coastal lagoon ecosystems of the Baltic Sea

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Coastal shallow lagoons play a crucial role in regulating nitrogen (N) fluxes to the sea. Located at the interface between land and marine environments, these systems are often characterized by long water renewal times and high biogeochemical activity, which strongly influence N dynamics and its transport to adjacent coastal waters. Seasonal variability in N inputs can significantly affect both the direction and pathways of N cycling in lagoons, potentially shifting their ecological role from sinks in spring to sources during summer. In the present project, we investigate the two largest Baltic coastal lagoons (the Curonian and Vistula), which differ primarily in riverine inputs and eutrophication status (hypertrophic versus eutrophic). Across seasons, we quantified two contrasting N transformation pathways: nitrogen loss via dissimilatory reduction and gain via biological dinitrogen (N₂) fixation. Our results indicate that the hypertrophic Curonian Lagoon, which receives higher external nutrient loads, exhibits greater nitrogen retention along its biogeochemical pathways. The legacy of eutrophication, particularly the accumulation of organic matter in sediments, strongly influences nitrogen loss processes and reveals different lagoon responses. In contrast, N gain was more pronounced in the less eutrophic Vistula Lagoon, likely driven by differences in pelagic community structure and the need to maintain high productivity. Overall, the findings suggest that coastal lagoons function as effective N biogeochemical reactors that regulate nutrient loads to the Baltic Sea. However, it remains uncertain to what extent N inputs from currently unquantified pathways, such as benthic N₂ fixation, may influence the balance between N-loss and N-gain processes. Understanding whether benthic N₂ fixation can substantially offset N removal is essential for predicting how these systems will respond to changing environmental conditions.

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Abstract No. 121

To remove or not to remove? Beach wrack management and coastal mercury cycling

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Beach wrack accumulation is a common phenomenon along Baltic coasts and is often perceived as a nuisance in tourist areas. However, wrack deposits may also represent an active biogeochemical compartment influencing coastal contaminant cycling. The aim of this study was to determine whether beach wrack removal affects mercury distribution, speciation, and transformation processes in the coastal zone. The research was conducted in the coastal zone of Puck Bay, one of the most valuable biodiversity hotspots of the Baltic coast, characterized by extensive seagrass meadows and high ecological sensitivity. Monthly sampling was carried out between April and November 2019 at three stations: one managed municipal beach in Puck, where wrack was regularly removed during the tourist season, and two non-managed stations in Rzucewo, where wrack accumulated naturally. Total mercury, labile and stable mercury fractions, and methylmercury were measured in beach wrack and underlying sediments. Beach wrack was identified as a significant mercury reservoir: nearly 90 percent of mercury occurred in labile, potentially bioavailable forms, with the most toxic form, methylmercury, accounting on average for approximately one quarter of the total mercury pool. Comparisons between managed and unmanaged sites indicate that wrack accumulation enhances local methylmercury formation and alters mercury partitioning in coastal sediments, whereas total mercury concentrations were less sensitive to wrack removal. These findings suggest that beach wrack management influences mercury speciation and transformation processes rather than bulk mercury loads. From a coastal management perspective, wrack removal may therefore modify local mercury cycling dynamics, with implications for ecosystem exposure and biogeochemical functioning in sensitive Baltic coastal zones.

Funding: This study was conducted within the Interreg Baltic Sea Region project “CONTRA – Baltic Beach Wrack: Conversion of a Nuisance into a Resource and an Asset”, co-funded by the European Union (<https://www.beachwrack-contra.eu>).

Early Career Scientist (ECS) contribution

Storm Johannes–driven anoxic upwelling in the central Baltic Sea

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Expansion of hypoxic and anoxic waters is a major concern in the Baltic Sea, where oxygen deficits have reached unprecedented levels. Upwelling processes are well documented during the seasonally stratified period, with summer upwelling in the Baltic Proper typically sourced from the cold intermediate layer. In contrast, wintertime upwelling events remain poorly investigated. Here, I present evidence of anoxic deep-water upwelling along the eastern coast of the Baltic Proper during winter conditions. A mooring deployed at 25 m depth west of Saaremaa Island (eastern Baltic Proper) recorded a short-lived but pronounced upwelling event in late December 2025–early January 2026. The event followed northerly Storm Johannes, which generated offshore transport in the upper layer and a compensating onshore flow in the deep layer. Rapid increases in salinity and the disappearance of dissolved oxygen indicated the arrival of anoxic water from below the permanent halocline at shallow coastal depths. Current measurements suggest that the onshore flow of deep water toward the coast persisted for more than a day after anoxia was first detected, allowing the upwelled water potentially to spread across the nearshore zone. After the event relaxed, the upper layer showed a modified water properties, indicating mixing between former surface water and intruding deep water. These observations demonstrate that strong winter storms can induce episodic upwelling of anoxic deep water in the central Baltic Sea and promote vertical exchange between deep and upper layers. A precondition is the presence of anoxic water at relatively shallow depths (80–90 m). The observed event may represent a previously overlooked pathway linking deep-water oxygen deficiency to coastal environments and may become a regular feature under current poor oxygen conditions.

Session 6

Baltic optics: Advancing ocean colour science and applications in the Baltic Sea

Abstract No. 119

Indicators of changing lightscapes in underwater marine ecosystems – the ISOLUME project

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Marine lightscapes, which describe the distribution and quality of light in marine environments, are key indicators of ecosystem health. These environments are experiencing rapid, poorly understood changes, primarily driven by coastal darkening (reduction of water transparency due to increased particulate and dissolved organic matter) and rapid expansion of pollution from artificial light at night (ALAN). Coastal darkening and ALAN are driven by climate change, evolving lighting technologies, land-use shifts, and increasing anthropogenic pressures. Such changes are expected to impact marine ecosystems and their functioning, beginning at the lower trophic levels. The ISOLUME project, a consortium of 11 European partners, seeks to answer critical questions regarding the drivers, sources, and ecological consequences of coastal darkening and ALAN. The project investigates how these stressors alter four critical dimensions of light: intensity, location, timing, and spectra in the European seas. By combining an interdisciplinary team, historical datasets, remote sensing, and advanced modelling, ISOLUME will determine long-term trends in coastal darkening, the transition from sodium vapour to LED lighting impacts on underwater exposure to ALAN, and the ecological impacts of coastal darkening and ALAN on marine ecosystems. Outcomes of the ISOLUME project will be used to develop new monitoring strategies and policy frameworks to mitigate adverse effects and promote sustainable marine management. The ISOLUME project is supported by the JPI Oceans Changing Marine Lightscapes Initiative. ISOLUME has been endorsed by the Intergovernmental Oceanographic Commission (IOC) as part of the UN Ocean Decade of Ocean Science for Sustainable Development 2021-2030.

Abstract No. 123

Integrated ecosystem modelling for Baltic Sea monitoring in NECCTON project

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The Copernicus project NECCTON (New Copernicus Capability on Trophic Ocean Networks) delivers new modelling products for marine environmental monitoring, with a focus on European marginal seas where biodiversity is increasingly threatened by anthropogenic pressures and climate change. For the Baltic Sea, the physical model NEMO was coupled with ERGOM and extended via FABM to include the Hereon E2E fish model and the bio-optical module OASIM in a three-year simulation framework. This integrated setup improves the regional biogeochemical modelling system and provides new products such as fish biomass, enabling assessment of biodiversity dynamics and trophic interactions. Strong land-use impacts further affect the Baltic Sea by altering light availability through increased turbidity and eutrophication. The influence of coloured dissolved organic matter (CDOM) on light penetration can be modelled via surface reflectance and evaluated against satellite observations. CDOM, represented as a tracer, strongly influences surface reflectance in the Baltic Sea and supports validation of the modelling system against remote-sensing products. Incorporating such bio-optical components enhances the representation of light-driven processes and strengthens the system's capability for ecosystem monitoring and assessment.

Session 7
**Adaptive governance under multiple drivers
of change in the Baltic Sea**

Abstract No. 54

Modelling local climate sensitivity to deforestation in the hemiboreal zone: An Estonian case study

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Due to its transitional location, global deforestation experiments often overlook the unique area between temperate and boreal forests, known as the hemiboreal zone. This poster seeks to address this gap by presenting a regional climate modelling experiment designed to analyse the sensitivity of the local climate to total deforestation with a specific focus on the hemiboreal zone. The experiment employs the Rossby Centre Regional Atmospheric Climate Model (RCA4) to downscale the Baltic Sea region and its surrounding area over a 31-year historical period, using a setup previously validated against observational and reanalysis data. The experiment comprises two simulations: one representing Estonia in its naturally forested state and another in which all Estonian forests are artificially removed and replaced with natural open land. This simplified approach focuses the land-use change on the contrast between natural areas with tree cover and those without. The research examines the biogeophysical effects of deforestation, including changes in albedo, surface roughness, and evapotranspiration, while omitting changes in the carbon cycle. The results indicate that different meteorological parameters exhibit varying degrees of sensitivity to deforestation, further influenced by proximity to the coast and time of the year. In addition to sensitivity metrics, shifts in parameter distributions and extreme values are studied. The findings suggest that deforestation in the hemiboreal zone produces limited but measurable biogeophysical effects, highlighting the need to better understand transitional forest zones.

Early Career Scientist (ECS) contribution

Abstract No. 122

Munitions in the sea – Removal of wrecks and munitions from European seas

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European seas contain several million tonnes of conventional and chemical munitions dumped after past conflicts. These long-lasting, toxic legacies continue to pose risks to marine ecosystems, human health, fisheries, offshore infrastructure, and coastal economies. As corrosion progresses, the potential release of explosive compounds and associated hazardous substances increases, making coordinated European action increasingly urgent. A number of ongoing EU and nationally-funded initiatives are advancing knowledge on the detection, mapping, environmental behaviour, risk assessment, and management of submerged munitions. Projects including CAMMera, MMinE-SWEEPER, MUNI-RISK, MUNIMAP, REMARCO, CONMAR, BorDEX, and BaltWreck are generating scientific, technological, and governance solutions across European sea basins, particularly in the Baltic and North Sea regions. Munitions in the Sea serves as a collaborative umbrella connecting these initiatives into a coordinated European knowledge and action platform. Through strengthened cross-project cooperation and the JPI Oceans Knowledge Portal, www.munitionsinthesea.eu, Munitions in the Sea promotes harmonised methodologies, shared data infrastructures, sustained monitoring strategies, and science-based decision-support frameworks for removal or in situ management of wrecks and munitions. By bridging research, innovation, regulatory authorities, and operational stakeholders, this network supports efficient, evidence-based responses to one of Europe's most complex underwater legacies. The initiative contributes to improved environmental protection, maritime safety, and sustainable blue economy development, while reinforcing adaptive governance across European marginal seas.

Early Career Scientist (ECS) contribution

Abstract No. 126

The Polish National Oceanographic Data Centre: Federated infrastructure for interoperable oceanographic data

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The National Oceanographic Data Centre (NODC) is a strategic component of Poland's research infrastructure dedicated to the coordinated management, long-term preservation, and open dissemination of marine environmental data. Its mission is to provide a coherent and interoperable framework for collecting, curating, and sharing oceanographic datasets generated through scientific research, environmental monitoring, and operational activities in the Baltic Sea, the North Atlantic, and polar regions. The Centre integrates multidisciplinary data resources, including physical, chemical, biological, and geological observations. These encompass hydrographic measurements, biogeochemical parameters, plankton and benthic community data, ichthyofauna observations, and records from autonomous platforms, research vessels, fixed stations, and satellite systems. By harmonising metadata according to international standards such as ISO 19115, SeaDataNet, and OGC specifications, the NODC ensures high data quality, traceability, and interoperability across national and European infrastructures. A core objective of the NODC is to implement the FAIR principles—making data Findable, Accessible, Interoperable, and Reusable—while advancing machine-actionable services that enable automated discovery, integration, and analysis. Through persistent identifiers, standardised vocabularies, and API-based access, the Centre supports advanced analytics, modelling, and AI-driven applications, including digital twin and forecasting solutions for marine ecosystems. The NODC also plays an important coordinating role within the broader European Open Science Cloud (EOSC) ecosystem, contributing to federated data discovery and cross-repository integration. By strengthening national data stewardship practices and aligning with European interoperability frameworks, the Centre enhances Poland's capacity to participate in international research initiatives and evidence-based policymaking. More than a repository, the National Oceanographic Data Centre serves as a collaborative platform connecting researchers, public administration, and technological partners. It provides a trusted foundation for sustainable marine management, innovation, and the long-term protection of marine environments.

Session 8
Marginal Seas – Humans and environment

Metallic debris and wet wipes are underresearched pollutants on marine coasts worldwide

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There is a large body of literature on the occurrence and effects of marine plastic debris such as lost fishing gear and single-use plastic items. In comparison, other types of marine debris are highly underresearched. Therefore, this study focusses on metallic marine debris and wet wipes (sanitary items) which are widespread pollutants whose effects on marine environments, however, are largely unexplored. Examples of metallic debris include discarded building materials, shipwrecks and munition that are common in the Baltic Sea. Our study examined solid anthropogenic metal core concretions (AMCCs) on German, Spanish and Japanese rocky shores that consisted of common building materials, such as discarded nails and screws, that had accumulated in rocky intertidal crevices in wave-sheltered environments. Most AMCCs were firmly rusted to the bedrock, contained anthropogenic debris (metal, sea glass) cemented with natural materials (molluscs shells, pebbles, sand) and formed solid anthropogenic substrates. Due to their stability, AMCCs may function as so far unexplored pathways for anthropogenic debris into geological records. Yet, AMCCs can easily be identified in the field and, thus, be used to track this marine debris type to explore these pathways and understand metallic debris dynamics on rocky shores. Furthermore, our study examined wet wipes which occur in oceanic and coastal environments worldwide. Due to their thin foil-like structure, wet wipes frequently adhere to hard substrates such as harbor walls and rocks. We found that wet wipes affected barnacles by completely sealing these sessile filter feeders from the environment. This may impair barnacle populations by making barnacle feeding, respiration and cross-fertilization impossible, especially as our lab examinations found that common commercially available wet wipes are highly durable and tear-resistant even when wet. Accordingly, we recommend monitoring AMCCs and wet wipes in the field to fully understand the geological and ecological effects of these underresearched pollutants.

Early Career Scientist (ECS) contribution

Abstract No. 39

From fluvial to tide-dominated systems: climate and sea-level forcing of late Pleistocene source-to-sink transitions in the western Hainan marginal Sea, South China Sea

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Stratigraphic reconstruction of marginal sea evolution provides critical baselines for understanding natural system responses to climate forcing prior to anthropogenic impacts. This study integrates high-resolution seismic reflection profiles with core data to decode climate–sea-level controls on Late Pleistocene source-to-sink transitions offshore western Hainan Island—a tropical marginal sea system in the northern South China Sea that offers a valuable contrast to Baltic-type systems. We identify two distinct sediment routing phases separated by the R2 sequence boundary: (1) glacial lowstand deposition characterized by valley-incised fluvial sands feeding a paleo-delta system; and (2) post-8.5 cal ka BP transgressive systems dominated by tidally reworked sand ridges with landward-dipping clinofolds following Qiongzhou Strait breaching. Intra-ridge age inversions reveal prolonged tidal reworking, while inter-valley marine sands with beachrock horizons document synchronous coastal environments. The 8.5 ka transition marks a geomorphic threshold where sea-level rise and strait opening triggered a system-wide shift from river-dominated to tide-dominated sediment dispersal. These buried sand bodies preserve a pre-anthropogenic sediment budget that quantifies natural shelf resilience to climate forcing—providing essential context for evaluating modern coastal change and informing sustainable management in marginal seas globally. By linking stratigraphic architecture to climate drivers, this work establishes a process-based template for paleoenvironmental reconstruction applicable to marginal sea systems worldwide, including the Baltic region.

Abstract No. 56

A multi-biomarker early-warning system for sediment pollution in the Gulf of Riga: Responses of *Monoporeia affinis* and *Macoma balthica*

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Chemical pollution represents one of the main threats to the Gulf of Riga (GoR) environment, and could negatively affect the health of its biota. In this study, we aimed to identify links between sediment contaminants and biological effects in the clam *Macoma balthica* and the amphipod *Monoporeia affinis*. Effect-based approaches identify active toxicants and their biological effects on biota, enabling better evaluation of potential impacts from pollutant mixtures. The main goal of this study was to assess chemical contaminants in GoR sediments and to attempt to link the observed contaminant levels with a range of biomarkers, including AChE, CAT, GST, GR, and TBARS in both *M. balthica* and *M. affinis*, as well as reproductive disorders in amphipods. Sediments for chemical analysis and organisms for biomarker analysis were collected from 18 stations in GoR, ranging in depth from 20 to 42 meters. The assessment of *M. affinis* reproductive health demonstrated significant negative effects, showing variability in embryo aberrations across specific sites within the GoR. Overall, 72% of the sites in the GoR exceeded the Good Environmental Status (GES) thresholds, indicating ongoing biological stress in the benthic community. Stations 119, 111, and 114A exceeded threshold levels for embryo deformation rates and the share of females with one or more deformed eggs, indicating impaired environmental conditions. These stations also showed stronger negative responses in the enzymatic biomarkers TBARS, GR and AChE in *M. affinis*, while *M. balthica* showed its highest AChE impact at station 114A. Results from coastal stations indicated that the Integrated Biomarker Response (IBR) index effectively detected elevated stress levels, with clams exhibiting greater sensitivity than amphipods. This study confirms that effect-based methods provide critical insights into biological responses to pollution, offering a robust approach for monitoring benthic ecosystem health beyond simple chemical concentrations.

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Decoupled benthic fauna responses to habitat variability and trawling in the Baltic Sea

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Benthic ecosystems of the Baltic Sea reveal strikingly divergent responses of meiofauna and macrofauna to habitat type, sediment structure, and trawling pressure. Baseline analyses from the Fehmarnbelt (muddy, higher-salinity) and Oderbank (sandy, low-salinity) marine protected areas demonstrate a pronounced decoupling between the two faunal compartments. Meiofaunal density and diversity were dramatically higher in the Fehmarnbelt, with harpacticoid copepods showing more than fourfold density differences and no shared species between regions. Macrofauna although less diverse in the Oderbank, reached far higher abundances there than in the Fehmarnbelt, likely reflecting contrasting sediment regimes and biogeochemical conditions. Across both regions, trawling intensity emerged as a key explanatory variable shaping benthic composition, particularly for meiofauna in the Fehmarnbelt, where multiple indicators of bottom-trawling pressure aligned with community shifts. Yet, time-series analyses in the Fehmarnbelt revealed high temporal variability without consistent pre-exclusion trends, underscoring the need for high-resolution post-exclusion monitoring. Together, these findings highlight that meiofauna and macrofauna do not respond synchronously to environmental gradients or anthropogenic disturbance. Instead, as previously was found for other marginal seas, they form partially independent ecological layers, whose decoupling offers a multidimensional view on assessing ecosystem recovery after the official exclusion of bottom trawling.

Impact of hydrological factors on the ecological state of marine areas of the northwestern Black Sea in the context of military actions

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Hydroecological conditions in the northwestern part of the Black Sea have been significantly altered by military actions in Ukraine, primarily through changes in hydrological and oceanographic processes. While many studies focus on direct pollution of marine waters, hydrological drivers underlying ecosystem degradation remain insufficiently addressed. Hydrophysical and hydrodynamic processes form the abiotic framework controlling the transport, mixing, and redistribution of energy, chemical substances, and biological components in marine ecosystems. Disturbance of these processes may therefore lead to substantial hydroecological consequences. This study examines the impact of military actions on hydrological conditions shaping the hydroecological state of marine areas in the northwestern Black Sea, with particular attention to the destruction of the Kakhovka Hydropower Plant dam in June 2023. The dam breach resulted in an abrupt release of approximately 16.4 km³ of freshwater into the marine environment within two weeks, equivalent to nearly 40% of the annual runoff of the Dnipro River. This extreme flood transported large volumes of pollutants accumulated in reservoir waters and bottom sediments into coastal marine areas. The spatial extent and intensity of marine pollution were governed by circulation patterns in the northwestern Black Sea. Numerical modeling and observational analyses indicate that, unlike typical flood events, transformed river waters penetrated the entire water column to depths of 15–20 m. Consequently, contaminated waters interacted not only with planktonic communities but also with benthic organisms and bottom sediments, increasing risks of bioaccumulation, hypoxia, and ecosystem degradation. Long-term impacts are expected due to the loss of runoff regulation previously provided by the Kakhovka Reservoir. Increased seasonal variability of river discharge, intensified spring floods, and reduced summer flows may enhance eutrophication, hypoxia, and salinization in coastal and estuarine systems. Overall, military-induced hydrological alterations represent a critical driver of hydroecological change and should be considered in environmental recovery planning.

Abstract No. 100

Coastal sensing – From pixels to processes to policy

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Coastal regions are rapidly changing interfaces where physical, ecological, technological, and societal processes strongly interact. However, observations, models, and governance are still largely organized in separate domains, limiting the translation of scientific knowledge into coastal management and policy. Kiel Marine Science (KMS) envisions the Centre for Coastal Sensing (CoastSens) to close this gap as an integrated university research infrastructure which combines innovative sensor systems, adaptive monitoring, AI-based data fusion, and a FAIR data-and-methods platform with socio-economic analysis and structured stakeholder engagement. CoastSens structures its research program along five tightly coupled axes, from seamless Land-to-Sea (L2S) monitoring to Ocean-to-Society (O2S) data-to-policy infrastructures. Harmonized protocols for inter-calibration across laboratory facilities, test basins, and field sites in the Baltic and North Sea will enable consistent, scale-aware products for coastal water quality, sediment dynamics, blue-carbon habitats, and coastal hazards, directly supporting coupled Earth-system and impact modelling. A dedicated interaction lab will embed governance, conflict analysis, and scenario exploration (e.g., nature-based solutions, coastal protection, multi-use) into the core of coastal sensing and modelling activities. As an open, University-based national reference centre, CoastSens will provide a web-based, FAIR-compliant platform which offers data, workflows, and model tools to the wider research community and to public authorities, thereby linking Baltic Earth priorities on microscale to basin-wide processes and coastal change with evidence-based coastal management. We will outline the scientific concept and ideas for the research building, and invite collaboration on joint observing and modelling efforts for the Baltic Sea.

Abstract No. 116

The Vistula Delta: Synthesising onshore and offshore data to obtain comprehensive geological model – state of the art and future outlook

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The Vistula River, discharging into the Baltic Sea, formed an extensive delta covering an area of approximately 2400 km². Nearly 30% of its area is nowadays submerged in the Gulf of Gdańsk, being separated from the inland part by the coastal barrier named Vistula Spit. Delta started to develop during Baltic Ice Lake stage under significantly lower sea level than present. Two main depositional units, characterized by occurrence of progradational clinofrom structures and several paleo-distributary channels, were identified. After vast part of the delta area was submerged during Littorina Transgression, it started to develop as an interior delta in a bay confined by morainic uplands from east and west. Simultaneous formation of Vistula Spit separated the embayment from the sea transforming bay into the lagoon. As northward prograding delta reached the barrier, Vistula Spit was being cut several times resulting in formation of river outlets discharging either directly to Gulf of Gdańsk or indirectly via the Vistula Lagoon. The aim of the presented study is to generate a comprehensive model, corresponding to Vistula Delta sedimentary architecture, which requires the integration of onshore and offshore geological data. The synthesis of different archive data collected by Polish Geological Institute – National Research Institute offshore (boreholes, seismic and seismoacoustic surveys, multi-beam bathymetry) and onshore (boreholes, airborne laser scanning), would allow to nominate areas demanding more detailed examination and eventually to reconstruct the paleogeographic evolution of Vistula Delta.

Early Career Scientist (ECS) contribution

Session 9

Future projections of the Baltic Sea region

Hydrodynamic modeling outputs for floodplain management in the Nemunas River Delta

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Flooding in the Nemunas River Delta is expected to intensify under climate change, requiring more effective flood management. This study applies an integrated modeling toolchain: Soil and Water Assessment Tool (SWAT), Shallow Water HYdrodynamic Finite Element Model (SHYFEM), and Hydrologic Engineering Center's River Analysis System (HEC-RAS), to represent the basin and coastal boundary conditions consistently. Downscaled Coupled Model Intercomparison Project Phase 5 (CMIP5) projections for two Representative Concentration Pathways (RCP4.5 and RCP8.5) were used from four global climate models: ICHEC, IPSL, HadGEM, and MPI. Climate model outputs were used as input to the SWAT model to simulate river streamflow and to the SHYFEM model to simulate water levels in the Curonian Lagoon and the Nemunas Delta coastal area. The resulting streamflow was used as the upstream boundary condition in the HEC-RAS model, while the simulated water levels served as the downstream boundary condition. Using these boundaries, HEC-RAS was applied to simulate historical (1975–2005), near-future (2020–2050), and far-future (2069–2099) scenarios. The results indicate that, under both RCP4.5 and RCP8.5, water level, flow velocity, and inundation area are projected to increase in the near- and far-future periods. Water depth is expected to increase by 0.2 m under ICHEC4.5 (2069–2099), 0.8 m under HadGEM8.5 (2069–2099), 0.6 m under IPSL8.5 (2069–2099), and 0.3 m under MPI8.5 (2069–2099). Flood inundation areas are projected to increase by 3.66% to 74.18%, with the largest changes under HadGEM8.5 (2069–2099) and the smallest under MPI8.5 (2020–2050). In the Nemunas Delta, these changes suggest that existing polders and pumping stations are likely to be submerged. To enhance resilience, additional upstream storage is recommended to temporarily retain peak flows and intense rainfall, delaying runoff before it enters the Delta. Installing real-time water-level sensors with alarms and raising riverbanks will also be required.

Early Career Scientist (ECS) contribution

Abstract No. 42

Toward a high-resolution coupled Earth System Model for the Baltic Sea: Advancing regional climate projections with the IOW ESM

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This project advances the development of a high-resolution regional Earth System Model (IOW ESM) for the Baltic Sea region, designed to dynamically downscale global climate simulations from the Coupled Model Intercomparison Project (CMIP). The IOW ESM couples the Modular Ocean Model version 6 (MOM6) for the Baltic Sea with the COSMO-CLM (CCLM) regional atmospheric model covering the EURO-CORDEX domain, enabling explicit representation of mesoscale processes and regional air–sea feedbacks. A key advancement is the implementation of consistent two-way ocean–atmosphere coupling, which more accurately captures thermodynamic and dynamic interactions at the air–sea interface than traditional one-way or uncoupled frameworks. Another improvement is the interactive treatment of lateral open boundary conditions in the ocean component, enhancing the simulation of sea surface height variability, barotropic inflow dynamics, and the integration of river runoff from the surrounding catchment. To improve model fidelity while preserving computational efficiency, a generic, automated tuning framework is applied to calibrate both individual components and the coupled system through multi-objective optimization of parameters across the atmosphere, ocean, and sea ice. We present results from a long-term IOW ESM hindcast simulation (1960–2024) using optimized parameters and compare them with corresponding uncoupled simulations, demonstrating the added value of the coupled system for regional climate impact assessments on coastal oceanography and biogeochemistry.

A database of dynamically downscaled CMIP6 climate projections for the Baltic Sea Region

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A high-resolution (22 km) regional climate modelling and dynamic downscaling environment has been developed, together with a database of historical and future atmospheric fields for 1979-2100 to support the Estonian climate change adaptation strategy. The regional climate modelling and dynamic downscaling environment is based on the RCA4 regional climate model developed by the Rossby Centre at the Swedish Meteorological and Hydrological Institute. The database includes dynamically downscaled CMIP6 projections from the NorESM2 global climate model for three emission scenarios: SSP2-4.5, SSP3-7.0, and SSP5-8.5. The database can be used as a standalone database for atmospheric variables or as an input for marine, lake and hydrological models. Although focused on Estonia, the modelling domain covers the broader Baltic Sea region, enabling applications beyond national boundaries. To facilitate open access, the dataset is hosted on the TalTech Department of Marine Systems IT infrastructure and distributed via an OpenDAP-enabled data-sharing environment using the netCDF format.

Adaptation to climate change: Regional scenarios for the Baltic Sea

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An ensemble of regional climate ocean simulations can answer numerous questions regarding sea level, water temperature, salinity, currents and sea ice. The regional climate ocean simulation ensemble is based on atmospheric forcing from five members of the EURO-CORDEX AR5 ensemble. The simulations were calculated for a thirty-year "historical" period (1971 - 2000), a thirty-year "near future" period (2031 - 2060) and one for the "far future" (2071 - 2100) for the RCP8.5 scenario. The ensemble was created as a common effort of BSH and DMI. It provides e.g. a substantial part of the data basis used for the German Strategy for Adaptation to Climate Change (Deutsche Anpassungsstrategie - DAS). This political framework to climate change adaptation in Germany laid the foundation to prepare for the impacts of climate change and reduce climate risks in a continuous process. The DAS core service "Climate and Water" provides monitoring and projection data to estimate requirements for climate change adaptation. In this study, we focus on the evaluation of the sea surface temperature (SST), which has a major impact on both ecological and economical aspects and therefore must be part of the adaptation strategy. Based on a comparison of all SST model results with observational data a bias correction is calculated for the individual ensemble members in the historical period, which than is also applied to the projected data. The results provide an impact assessment: Among other things, they establish a connection between the warming of the water surface and an extension of the bathing season with a significant increase in the number of days with water temperatures above 20 °C, which could promote the proliferation of Vibrio bacteria. The results are prepared for policymakers and practitioners engaged in coastal risk assessment and adaptation planning and is provided e.g. at <https://das.bsh.de>.

Projections of the Baltic Sea region: Highlights and challenges

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The Baltic Sea region poses a major challenge for regional ocean climate projections. In order to understand the changes in the dynamics of the Baltic Sea over century-long time scales, changes in the other components of the regional climate system (atmosphere, sea ice, land surface, etc.) should be taken into account. Baltic Sea salinity depends on the regional water cycle and the regional water cycle in turn depends on the global one. The Baltic Sea region lies within the sphere of influence of both the North Atlantic and the Arctic regions, meaning that changes in teleconnections have a major impact on the regional climate. Concerning the heat cycle, future changes in water temperature will be amplified by the ice-albedo feedback, as the northern Baltic Sea is seasonally covered by sea ice. Global climate models are too coarse to accurately resolve the details of such a setting, including the land-sea contrasts, orography, amplifying feedbacks via the sea ice cover, and other regional processes such as passing low-pressure systems and saltwater intrusions from the North Sea into the Baltic Sea. Hence, projections using global climate models are not suitable in this region and there is an added value of regional climate models with higher spatial resolution. Regional coupled atmosphere-ice-ocean-land climate models for the Baltic Sea region have been developed since more than 30 years. Several big national climate programmes and EU-funded projects have fostered the development of projections of the future climate of the Baltic Sea, including the marine ecosystem. The Baltic Earth programme, one of the regional Global Energy and Water Exchanges (GEWEX) hydroclimate projects, played a supporting and coordinating role in this. The presentation will summarise challenges and results of past activities related to Baltic Earth and present future plans of ongoing projects.

Session 10
**Philosophical aspects of Baltic Sea Earth system
research**

Abstract No. 50

Involving public authorities and citizen scientists in micro- and mesoplastic pollution monitoring

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This research, carried out within the Interreg Central Baltic Programme project CB0800451 “CLEAN Beach,” focuses on involving public authorities and citizen scientists in monitoring micro- and mesoplastic pollution on beaches. In order to expand monitoring efforts and provide practical tools for municipalities to gather data in areas beyond national scientific programmes, a harmonized sampling method is being developed. Providing easy to understand methodology and using sampling tools readily available to non-scientists allows stakeholders such as municipalities, waste management companies, NGOs and other interested parties acquire useful data themselves. The collected data can be incorporated into an existing online platform “ROSGIS” (<https://rosgis.syke.fi/>) where citizen scientists log their findings and can view inputs made by other users. To ensure data quality, scientists validate the submissions. Validated data can help identify pollution sources and support adjustments in policy for more efficient litter reduction at local and regional scales. Moreover, data collected in this way can be included in the European Marine Observation and Data Network (EMODnet). Within this project partner institutions in three Baltic Sea Region countries are co-developing a method suitable for both sandy and rocky beaches including harmonized protocols for micro- and mesoplastic pollution monitoring. Since cigarette butts are among the most littered items on beaches worldwide, a survey was launched to learn about beachgoer habits. In Latvia, preliminary survey results show that only 2.4% of 82 respondents never noticed cigarette butts at a beach. Clear majority of respondents (96.3%) are aware that cigarette butts cause harm to the environment, yet 42.7% admitted to have discarded cigarette butts outdoors and around half of respondents cited no access to waste bins as primary reason for doing so. More data will be gathered as such information deepens the understanding on behavior and finding solutions to reduce this type of pollution.

Early Career Scientist (ECS) contribution

Abstract No. 73

Some important concepts on climate and climate change

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The aim of the presentation is to present several selected ideas that have contributed to the development of research on climate and its changes, with particular emphasis on the Baltic Sea basin.

The North Atlantic Oscillation story:

It started in the end of 18th century on Greenland, where the missionary Hans Egede Saabye wrote in his diary „In Greenland all winters are severe, yet they are not alike. The Danes have notices that when the winter in Denmark was severe, as we perceive it, the winter in Greenland in its manner was mild, and conversely”. It was called a seesaw between temperatures in Greenland and northern Europe. Dove (1839) tried to explain it stating that it happens when the distance between two places exceeds the width of an air current and they thus come to lie in opposing currents. Walker and Bliss (1932) recognized this temperature seesaw as one of the effects of the North Atlantic Oscillation. This is how the history of research on the NAO and its impact on the climate of Europe and beyond began (based on Van Loon and Rogers, 1978).

The atmospheric fronts development story:

How far back do we have to go to its origins? Perhaps the forerunner was Luke Howard, who in the nineteenth century wrote about northerly and southerly winds blowing alongside each other, with the colder wedging in under the warmer and the warmer gliding up over the colder and causing rains. The theory of atmospheric fronts was formulated just after the first world war by Vilhelm Bjerknes. According to his main idea the storm develops in a clashing of two air masses, one warm, and one cold, along a well-defined boundary, which was called front. The theory was later developed by his son Jacob Bjerknes and Carl-Gustaf Arvid Rossby.

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