Project: **1338**

Project title: **CliNSBaS – Climate change impacts and adaptation in the North Sea – Baltic Sea region**

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Report period: **2025-11-01 to 2026-10-31**

Maximum of 2 pages including figures. 9 pt minimum font size.

Progress report

a) EURO-CORDEX regional ocean ensemble

Using the ICON-NEMO coupled regional climate model (Maurer et al., 2025), a total of 4 climate simulations for the years 1950-2100 were conducted using the SSP3-7.0 and SSP1-2.6 scenarios and two different AOGCMs (MPI-ESM-HR and EC-EARTH_Veg) as laterally driving models. Both the atmosphere and the ocean part participate in the EURO-CORDEX ensemble. The necessary preparational works and spin-ups for these simulations were carried out as ocean-only simulations at DKRZ. DWD analyzed the historical period of the simulations together with numerous other simulations in EURO-CORDEX in their initiative of „Referenzensemble“. Both simulations were considered as part of the ensemble.

The ocean results and additional atmospheric parameter of the climate simulations are currently undergoing post-processing and are expected to be archived in the DKRZ archive in the near future.

Since 2022 BSH provides a regional ocean ensemble and observational data as part of its activity in the DAS-Basisdienst “Klima & Wasser” via the website https://das.bsh.de/. An update of the ocean data to the SSP scenarios is planned, since the data available on the DAS BSH website is widely used and has to be kept up to date. Thus, six more simulations for each SSP3-7.0 and SSP1-2.6 scenario have to be carried out during the next phase. This update depends on a reference ensemble for the North Sea and the Baltic Sea, which the DWD will not complete until the last quarter of 2026. This reference ensemble states a selection of EURO-CORDEX simulations spanning a reasonable bandwidth of possible future climate evolutions. Most of these runs were heavily delayed which also partly explains the unused storage capacity in the archive.

The ocean only simulation with NEMO, driven by ERA5 data which was carried out at DKRZ during the project period 2024/2025, was used in the evaluation and comparison paper by Maurer et al. (2025).

Furthermore, substantial effort was carried out to enable and assess wetting-and-drying capabilities in the NEMO v4.2.0 framework. This included the development and implementation of several code modifications to improve numerical stability at coarse resolution, such as new wetting-and-drying mask formulations, smoothing approaches, bottom-drag adaptations, and extensions for z-partial-step coordinates. Extensive testing was performed using idealized benchmark cases and one-year sensitivity experiments to evaluate the influence of bathymetric variations, grid resolution, and algorithmic modifications on model stability and performance. The work culminated in a five-year climate simulation with active wetting-and-drying, which was systematically compared against the reference NEMO-NBS configuration with respect to tides, sea surface height, salinity, temperature, and sea ice, providing a comprehensive assessment of the feasibility and consequences of introducing wetting-and-drying processes into the modeling framework.

b) Future Storm Surge Risk in the German Bight

This part of the project investigated how climate change may affect wind surge frequency and extreme water levels in the German Bight. We applied a statistical storm surge model (Schaffer et al., 2025) to a multi-model ensemble of nine CIMP6 climate models, covering three future emission scenarios (SSP2-4.5, SSP3-7.0 and SSP5-8.5). To make the statistical model applicable to the climate projections, we adapted and retrained it using three-hourly wind data from the ERA5 reanalysis.

We analysed projected changes in seasonal wind surge frequency and investigated the wind conditions associated with high surge events. In addition, we combined projected wind-driven surges with regional sea-level rise projections to estimate future high-water levels at Cuxhaven – a tidal gauge serving as a proxy for the German Bight. This allowed us to assess the relative contributions of changing wind conditions and sea-level rise to future extreme water levels.

The results show an increase in winter wind surge frequency and a decrease in summer, with stronger changes under higher-emission scenarios. By the end of the century, the frequency of water levels exceeding present-day storm surge thresholds could increase substantially (Fig. 1), with sea-level rise identified as the dominant contributor to this increase. The analysis provides a multi-model assessment of future storm surge risk and its underlying drivers in the German Bight and is currently under revision for publication in *Natural Hazards* (Schaffer et al., preprint).

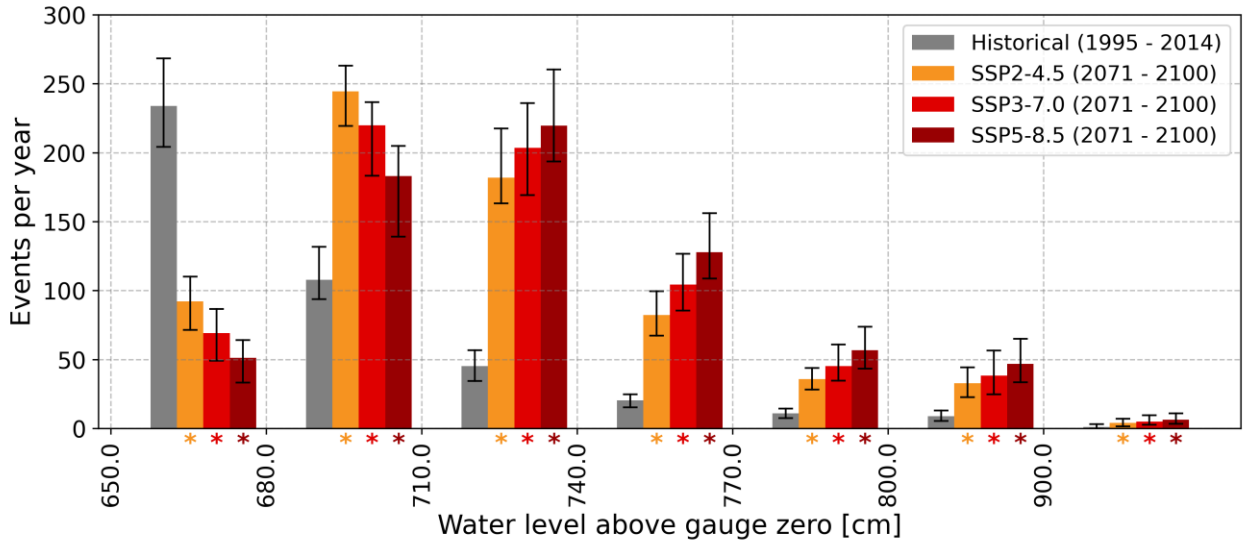


Figure 1 Histogram (ensemble mean) of winter (DJF) water levels above gauge zero (number of 3-hourly time steps) at Cuxhaven for the historical period (1995-2014; gray), representing the combined effect of mean high water (MHW) and historical wind surges. Projections for the end of the century (2071-2100; reddish colors) include the combined effect of MHW, projected wind surges, and projected SLR under different SSP scenarios. Wind surges (historical and projected) are based on the output of the statistical storm surge model applied to the CMIP6 multi-model ensemble. Water levels are grouped into 30 cm bins from 650 cm to 800 cm and into 100 cm bins from 800 cm to 900 cm. Stars indicate statistically significant changes. Vertical error bars represent the ensemble spread