Project: **1490**
Project title: **Morphology of German Bight**
Principal investigator: **Wenyan Zhang**
Report period: **2025-05-01 to 2026-04-30**

Progress report

During the current allocation period, the DKRZ resources were mainly used for hydro-morphodynamic simulations and post-processing related to the morphology of the German Bight and Wadden Sea, with a focus on sand wave migration near the Norderney coast, storm-driven coastal erosion, and preparation of the next generation of ecosystem-coupled simulations. The numerical work was combined with long-term observation and remote-sensing data analysis, and the main outcomes are currently being prepared in manuscripts.

1. Numerical modeling results for Wadden Sea morphology and sand wave migration

A major result of the current period is the analysis of morphological change in the shoreface of the East Frisian Islands, with particular focus on the sand wave field near Norderney. The study combines 25 years (1998-2022) of bathymetric observations from the TrilaWatt project, 17 years (2009-2025) of satellite images, and hydro-morphodynamic simulations. The objective is to identify the key drivers of morphological change and to quantify the migration behavior of sand waves in the foreshore area.

The observational and satellite analyses show that the Wadden Sea exhibits complex and spatially heterogeneous morphological change controlled by multiple environmental drivers. In the Norderney foreshore, sand waves display bidirectional migration with rates of about 100-150 m/yr and strong seasonal variability. Remote sensing is particularly useful for mapping sand wave crest positions over long periods, but its temporal coverage is limited because clear sand wave signatures are mostly visible during spring and summer under favorable image conditions.

The numerical model successfully reconstructed the alternating erosion and deposition patterns within the sand wave field and reproduced migration directions and rates of approximately 100 m/yr, in agreement with the observational estimates. The simulations reveal that the sand wave field is controlled by the combined action of alongshore currents, waves, and tides. An important finding is the pronounced seasonal variability of sand wave activity: migration is strongest during winter, when wave activity and coastal currents are enhanced, whereas migration becomes weak or negligible during calmer summer conditions. These results provide a process-based explanation for the observed spatial and temporal patterns and improve our understanding of Wadden Sea morphodynamics and risks to coastal infrastructure. **This work is included in a manuscript currently under preparation.**

2. Storm-event modeling with XBeach

A second key activity during the report period was the setup and testing of XBeach for event-scale storm impact simulations along the Norderney coast. The model setup for storm Xaver (2013) has been established successfully. Initial simulations show that storm-induced coastal erosion can reach about 0.6 m, accompanied by strong offshore sediment transport during the event. These results demonstrate the capability of the model framework to quantify short-term erosion, dune response, and cross-shore sediment redistribution under extreme forcing. The XBeach setup now provides the basis for future scenario studies that will assess storm impacts under changing climate conditions.

3. Machine-learning-based morphology analysis

In parallel to the process-based numerical modeling, machine-learning methods were further developed to investigate whether coastal morphological units can be learned and predicted efficiently from large bathymetry datasets. This work combines numerical model results with data-driven analysis and aims to improve the consistency, interpretability, and usability of large coastal topography and bathymetry datasets. The scientific goal is to better identify the spatial characteristics of coastal morphological units and to test whether machine-learning methods can support their classification and prediction**. The related manuscript is currently under preparation and will be continued in the next allocation period.**

4. Development of mussel-bed and seagrass impact simulations

The planned extension toward ecosystem-engineering effects is under active development. During the current period, the basin-scale hydro-wave-sediment model required for these studies has been set up and is currently under parameter testing. The next step is to represent mussel-bed and seagrass effects through modified roughness, wave attenuation, and sediment stabilization in order to quantify their influence on hydrodynamics, sediment transport, and morphological evolution in the German Bight and Wadden Sea. This development forms a major scientific component of the next allocation request.

5. Output and outlook

The main scientific advances of the current period are: (i) process-based reconstruction of sand wave migration near Norderney with rates consistent with observations, (ii) identification of strong seasonal control by waves and coastal currents, (iii) establishment of an event-scale storm erosion model for Xaver 2013, and

(iv) continued development of machine-learning methods for coastal morphology research. These achievements (as described in Figure) provide a strong basis for the next allocation period, in which climate scenarios, ecosystem impacts, and data-driven morphology analysis will be combined more systematically.

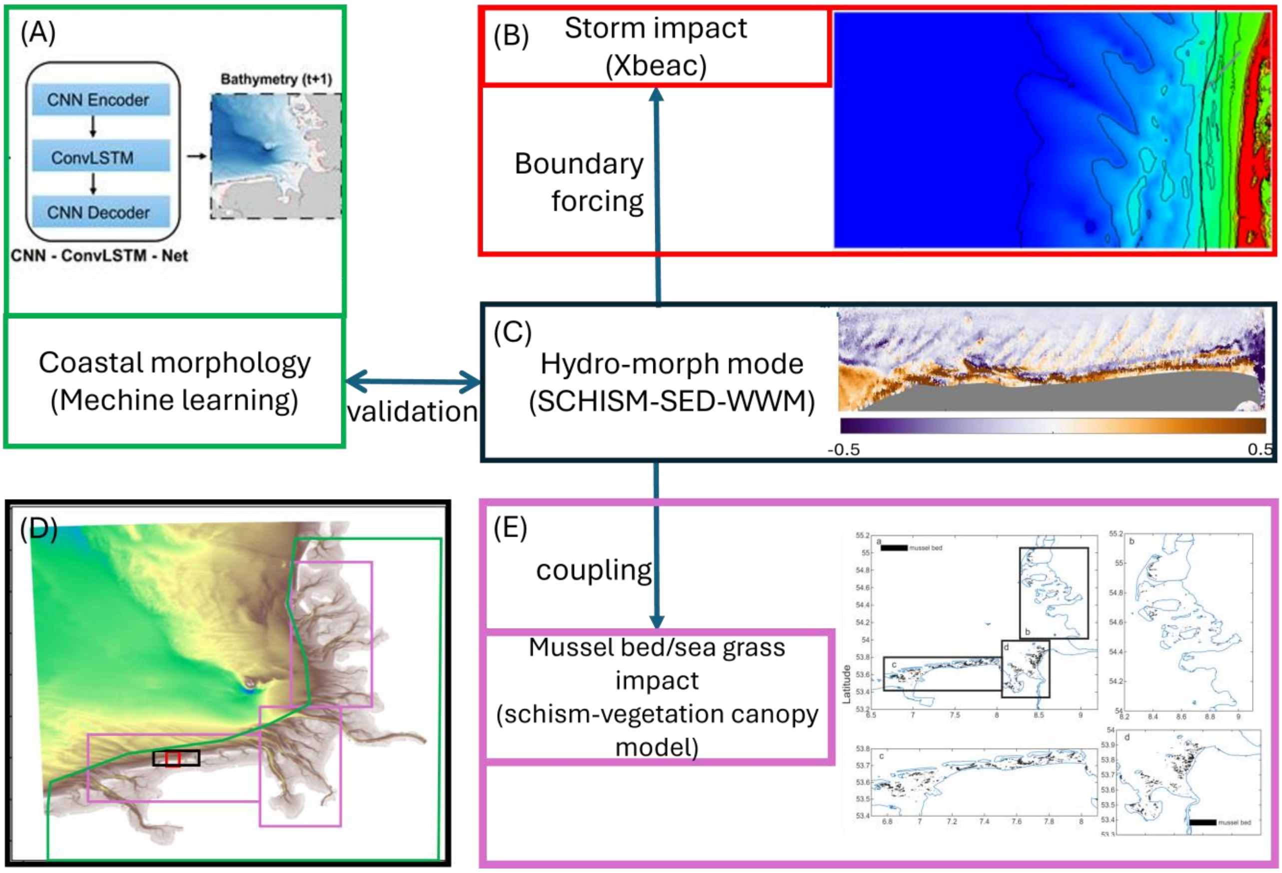

Figure. graphical structure of project Morphology of German Bight. (A) coastal morpholgy stufy base on ML. (B) storm impact on sandy beach. (C) numerical modeling result of sand wave migration. (D) map of German Bight, and the researches' location in corresponding color box. (E) Mussel bed map of Wadden Sea