MULTI-SCALE WAVE MODELLING; FIELD VALIDATION IN FAXE BAY, DENMARK

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INTRODUCTION

Access to local nearshore wave climate conditions on a detailed spatial scale is important for many coastal engineering practices. These include assessing the flood risk of coastal infrastructure, designing coastal protection measures, and estimating sediment transport processes and wave run-up. The present study displays a multi-scale wave modelling approach using the numerical wave model SWAN (Booij et al., 1999) together with field data applied in the southern Baltic Sea. The main objective of the study was to investigate the possibility of employing a single wave model for seamless simulations over several scales in time and space, from offshore to nearshore, including the effects of grid size and resolution. Validation with extensive field data was a crucial part of the study.

CASE STUDY AREA

The area of interest in this study is the southern Baltic Sea. The southwestern part, the Arkona basin, is one of the shallowest parts of the Baltic Sea, excluding the Danish straits. The mean depth is 23 m, and the deepest part is 53 m (Rosentau et al., 2017). The surrounding coastlines are predominantly composed of sedimentary deposits that are easily eroded. The area also hosts intense ship traffic (Soomere et al., 2012), facilitating the transportation of both goods and people. The combined effect of these characteristics reinforces the need for comprehensive knowledge of local wave climate conditions.

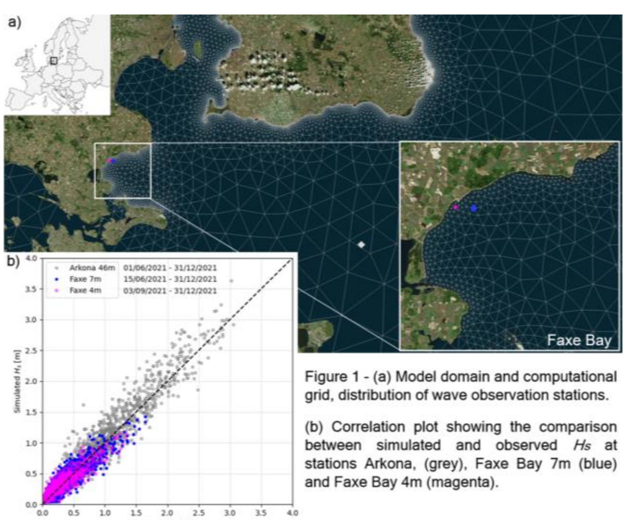

Figure 1 - (a) Model domain and computational grid, distribution of wave observation stations.

(b) Correlation plot showing the comparison between simulated and observed *Hs* at stations Arkona, (grey), Faxe Bay 7m (blue) and Faxe Bay 4m (magenta).

METHOD

Wave simulations were conducted using SWAN, a third-generation spectral wave model (Booij et al., 1999), with input from the ERA5 reanalysis wind at 10-m elevation (Hersbach, et al., 2018) and bathymetry from the EMODnet Bathymetry Consortium (2020). A part of the model domain, along with the structure of the flexible computational grid, is shown in Fig. 1a. The mesh structure was generated using OceanMesh2D (Roberts et al., 2019) and the grid resolution changes throughout the model domain. Finer resolution is required in the nearshore to accurately resolve the wave dynamics (Zijlema, 2010). In the deep-water parts of the model domain, a coarser resolution is sufficient, thereby reducing the computational time. Hence, the resolution of the cells ranges from a maximum 25 km in offshore regions and 0.2 km at a minimum in the nearshore areas.
Validation of the model was based on wave observations from offshore buoys, e.g., the buoy operated by Federal Maritime and Hydrographic Agency of Germany (Bundesamt für Seeschifffahrt und Hydrographie, BSH) in the Arkona Basin, and on wave measurements conducted during 2021 by two surface acceleration buoys deployed at 4 and 7 m in Faxe Bay, Denmark (Fig. 1a). The wave buoys recorded at a frequency of 5.82 Hz in bursts of 23 minutes (Obscape B.V., n.d.). In addition, pressure sensors were also placed at about 2-m depth to measure wave height, period, and direction.

RESULTS

The validation of the wave transformation focused on Faxe Bay in the southern Baltic Sea; similar studies were performed for the Swedish south coast. Validation between simulated and observed results showed agreement in both the offshore and nearshore coastal areas (Fig. 1b). The results demonstrate that the model can resolve the wave transformation from deep to shallow water, including dissipation. Comparing the time series of nearshore measurements and simulations (Fig. 2) shows good agreement regarding the timing and magnitude of single events. The analysis indicates that the wave climate in Faxe Bay is characterized by relatively mild conditions. The significant wave heights rarely exceed 1.5 m in the measured time series. Although, it should be noted that these largest wave heights are slightly underestimated in the model simulation.
This multi-scale approach generates in a single model-setup result of local wave climate conditions on a detailed spatial and temporal scale for further analysis. The results also indicated that the wave dissipation in the bay must be accurately described because of its flat and shallow shoreface.

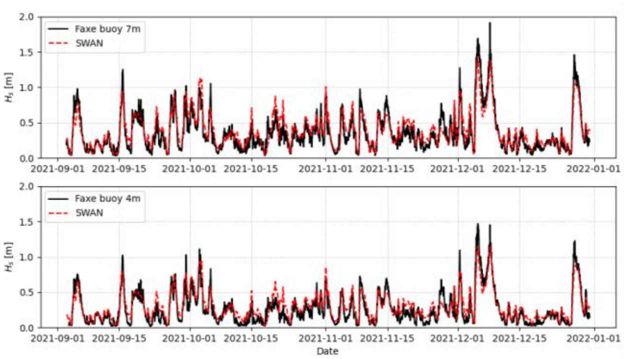

Figure 2 – Time series comparison with observed (black) and simulated (red) *Hs*, for stations in Faxe Bay at 7 m and 4 m, respectively.

DISCUSSION & CONCLUSION

The underestimation of the peaks in the wave timeseries observed at the two nearshore stations (Fig. 2) could potentially be explained by limitations in the input data used. Future simulations should test the performance of the model by using wind input of finer temporal resolution, e.g., one hour. This can potentially benefit the results and capture the largest peaks in the wave height time series but would evidently increase the computational time. The results presented shows that the SWAN model can be used for seamless simulation of wave climate over varying scales with varying resolution. The simulated results show agreement with observations both offshore and nearshore. However, some limitations exist regarding the input data used in the model application. Resolution of the available bathymetry data and accuracy in the wind forcing field.

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