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Regional nearshore wave height prediction using a mixed-data CNN-LSTM neural network and dynamic bathymetric maps for the East Frisian North Sea

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Rising sea levels and a potential increase in intensity and frequency of storm events due to climate change are increasingly intensifying flood risks caused by storm surges in the coastal areas of the North Sea. The ebb tidal delta (ETD) sandbanks off the coast of the East Frisian Islands change dynamically – a single storm surge may change them significantly – and, as a natural barrier, exert a huge impact on the nearshore wave climate.
Therefore, accurate predictions of storm surge wave heights are of particular interest and essential for coastal protection. Typically, these predictions are made by time-consuming numerical models like the third-generation wave model SWAN. Therefore, we designed a machine learning method that reasonably accelerates these simulations and wave height predictions and, for the first time, takes the ETD dynamics into account. To train the model, we created a dataset by driving an unstructured grid SWAN model with in-situ measurements of wave heights (also used for model validation), water level, and wind as boundary conditions. A dynamic bathymetric input was used by simulating various potential ETD bathymetries with geostatistical variogram analysis and random field simulation. Our proposed method is a mixed-data CNN-LSTM neural network for wave height prediction. While CNN neural networks are designed for processing image data (spatial bathymetric maps), LSTM units are optimized for processing long-term time series data. The model is capable of predicting nearshore wave heights after training with the SWAN-generated events and multiple simulated bathymetries. While the SWAN model took about 60 days to simulate 6480 events, our proposed neural network improved the computational time for a single event by a factor of 100.
These results can be used to explore potential future sea states under the influence of climate change and their local impact on the East Frisian coast in no time, as well as to warn the inhabitants of the affected areas and to install location-specific e.g. sandbags and flood protection walls by using the latest water level and wind forecasts as input.