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Wave data prediction and reconstruction by recurrent neural networks at the nearshore area of Norderney

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Sea level rise, a possible increase in frequency and intensity of storms and other effects of global warming exert pressure on the coastal regions of the North Sea. Also storm surges threaten the basis of existence for many people in the affected areas. As well as for building coastal protection or offshore structures, detailed knowledge of wave data, especially the wave height, is of particular interest. Therefore, the nearshore wave climate at the island Norderney is measured by buoys since the early 1990s. Caused by crossing ships or weather impacts, these buoys can be damaged. This leads to a huge amount of missing data in the wave data time series, which are the basis for numerical modelling, statistical analysis and developing coastal protection.
Artificial neural networks are a common method to reconstruct and forecast wave heights nowadays. This study shows a new technique to reconstruct and forecast significant wave height measured by buoys in the nearshore area of the Norderney coastline. Buoy data of the period 2004 to 2017 from the NLWKN – Coastal Research Station at Norderney were used to train three different statistical and machine learning models namely linear regression, feed-forward neural network and long short-term memory (LSTM), respectively. An energy density spectrum was tested against calculated sea state parameter as input. The LSTM – a recurrent neural network – is the proposed algorithm to reconstruct wave height data. It is especially designed for sequential data, but was performed on wave spectral data in this study for the first time. Depending on the input parameter of the respectively model, the LSTM can reconstruct and forecast time series of arbitrary length.
Using information about wind speed and direction and water depth, as well as the wave height of two neighboring buoy stations, the LSTM reconstructs the wave height with a correlation coefficient of 0.98 between measured and reconstructed data.
Unfortunately, the forecasting and reconstruction error of extreme events is highly underestimated, though these events are of great interest for climate and ocean science. Currently, this error is being specifically attempted to improve. Compared to numerical modeling, the machine learning approach requires less computational effort. Results of this study can be used to complete spatial and temporal wave height datasets, providing a better basis for trend analysis in relation to climate change and for validating numerical models for decision making in coastal protection and management.