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Wave downscaling using machine learning

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Future changes in the wind wave climate due to atmospheric changes can intensify present erosion and flood risk. Knowledge on both mean and extreme wave climate is necessary for understanding changes in sediment dynamics and flood events at the coastline. In order to assess potential wave changes, ensemble nearshore wave projections are required for covering the entire range of wave conditions and also the large uncertainties related to future climate states. However, nearshore wave projections are not available for most coastal regions due to the excessive computational effort required for dynamically downscaling ensemble offshore wave data. As a result, the large relative contribution of waves to coastal flooding and erosion is commonly omitted in the assessment of those hazards. In this context, machine learning models can be an efficient tool for downscaling ensemble global wave projections if they are able to accurately simulate the non-linear processes of wave propagation due to their low computational requirements. Here, we analyse the performance of three machine learning methods, namely random forest, multivariate adaptive regression splines and artificial neural networks, for downscaling the wave climate along the coast of Florida. We further compare the performance of these three models to the multiple linear regression, which is a statistical model frequently used, although it does not account for the non-linearities associated with wave propagation processes. We find that the three machine learning models perform better than the multiple linear regression for all wave parameters (significant wave height, peak and mean periods, direction) along the entire coastline of Florida, which highlights the ability of these models to reproduce the non-linear wave propagation processes. Specifically, random forest shows the best performance and the lowest computational training times. In addition, this model shows a remarkably good performance in simulating the wave extreme events compared to the other models. By following a tree bagging approach, random forest can also provide confidence intervals and reduce the tuning process. The latter is one of the main disadvantages of the artificial neural networks, which also show a high performance for wave downscaling but require more training and tuning effort. Although the significant wave height and the periods can be simulated with very high accuracy (R^2 higher than 0.9 and 0.8 respectively), the wave direction is poorly simulated by all models due to its circular behaviour. We find that a transformation of the direction into sine and cosine can improve the model performance. Finally, we downscale an ensemble of global wave projections along the coast of Florida and assess potential changes in the wave climate of this region.