Forecasting Sea Level Maxima Using Machine Learning Models in the Baltic Sea

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Increasing sea levels and maximum events (including extremes) are expected to occur due to the changes occurring in our climate. The Baltic Sea region, which is surrounded by nine coastal countries is one of the most sensitive sea areas and is prone to coastal flooding caused by sea level maximum and extreme events. These maximum sea level events may be triggered by storm surges or a combination of different dynamics, for instance, a change in volume, local storms, North Atlantic Oscillation, atmospheric conditions, seiches, etc. Additionally, extreme water levels exhibit geographically heterogeneous patterns, and the study area also experiences one of the largest glacial isostatic adjustments (GIA) signals worldwide (that is also geographically un-uniform). As a result, forecasting sea level maxima, though challenging, is of great importance for safeguarding coastal communities, navigation, and engineering.

Machine and Deep Learning models (ML/DL) have been widely acknowledged as robust techniques in finding patterns and forecasting sea levels. This study explores different ML/DL methods such as Convolution Neural Networks, Recurrent-based Neural Networks, and hybrid ML techniques to forecast sea-level maxima. Also, whilst determining the best DL architecture is important, another significant aspect to be considered is the choice of input variables. In this study, the utilization of various input components such as air pressure, winds, salinity, temperature, etc. is considered.

So far, results of the 2D Convolution Neural Network (conv2d) for the whole Baltic Sea using the most relevant input factors (such as winds, pressure, and surface temperature), revealed discrepancies in average sea levels mostly distributed within ± 4 cm and R2 of 0.91. However, spatially, some larger RMSE values (>10 cm) were obtained at locations in the south-eastern section of the Baltic Sea and the conv2d model encountered challenges in forecasting the maxima values. Further examination of the eastern Baltic Sea using the Recurrent-based Neural Networks methods forced with high-resolution inputs also indicated similar accuracies and problems with forecasting of maximum. These approaches utilized so far highlight that specific methods and inputs should be considered for forecasting the extremes. Further examination of the different ML structures is investigated for this study. The resulting model will undergo evaluation for its explanatory power and identification of key factors influencing the model outcomes. The final model can serve as a timely pre-warning system for impeding potential flooding threats.