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Prediction of Extreme Storm Surge Levels using Recurrent Artificial Neural Networks.

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Accurate prediction of extreme storm surges is very important for coastal flood mitigation, e.g. coastal defence structures, early warning systems, as they may results in severe flooding, wave attacks and coastal erosion. The contribution of meteorologically induced components may be as significant as that of astronomical components under the extreme weather, such as typhoon and midlatitude storms. The tremendous increase in offshore/onshore activities requires improved extreme storm surge forecasting techniques. Therefore, the prediction of extreme storm surges is an important and vital task, which is a very complex engineering problem including diverse factors such as the atmospheric pressure, wind speed and direction, wave setup, rainfall, coastal topography and in estuarine zones also river discharge. In areas with a wide continental shelf a travelling external surge may combine with the locally generated surge and waves, possibly including a significant interaction between tide and surge. Wave heights at the coast are controlled largely by water depth conditions. So the effect of tides and surges on waves must also be considered. Moreover, waves may also contribute to the total water level by means of wave setup through radiation stress. These processes are well understood but hardly predicted by the existing prediction models for storm surges, even by assuming that a good bathymetry and wind forcing are available. Other interactions between surges and waves include the processes of surface wind-stress and bottom friction as well as depth and current refraction of waves by surge water levels and currents, and some of the details of these processes are still not well understood. In fact, this still represents a complex nonlinear problem that cannot be solved efficiently by conventional numerical methods. Moreover, available methods cannot account for the effect of previous water level on the current water level during storms.

More specifically, the current research focuses on developing an operational Artificial Neural Networks (ANN) model for the prediction of extreme storm surges that accounts for the high nonlinearity of the processes at Cuxhaven, Germany. We have taken the advantage of the increasing availability of measured water level data for Cuxhaven and developed a Nonlinear Autoregressive with eXogeneous inputs (NARX) neural network model, so the effect of previous water levels is also included in the model. The input deck of the NARX model consists of two groups:

(i) All input factors (the tidal forecasts, wind speeds and wind directions, and barometric pressure for Cuxhaven station in addition to Elbe river discharge from Teufelsbrück station and water level from Aberdeen station) with time delay between 0 and 19 time steps to include also the current state of input factors.

(ii) water level at Cuxhaven with time delay between 1 and 19 time steps to include only the previous 19 time steps without the current water level (since it will be the predicted water level).

The developed model is validated using the Error index (EI) and correlation coefficient with observed data. The first results of the verification show that, the proposed neural network methodology is promising as an operational tool for the prediction/forecast of extreme storm surge.

Unfortunately, in some locations the long-time series of observed water level and inputs for the NARX model are not always available to train it. For such situations the research is in progress towards the combination of hydrodynamic numerical models and ANN. By establishing this combination, the numerical results will be corrected by the ANN model using shorter series of observed water level during training. Moreover, the input deck for the ANN model will include also external surge, river discharge and meteorological forces in order to account for the nonlinear interaction between all extreme storm surges components.