A NOVEL HIGH-RESOLUTION STORM SURGE FORECAST FOR THE GERMAN BIGHT

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BACKGROUND

Storm surges are one of the most dangerous natural hazards in coastal areas and have the ability to cause great damages including fatalities. To be prepared when another storm surge hits the coast, reliable storm surge forecasts are indispensable. Storm surge warnings are routinely provided for selected tide gauge locations along a coastline through state-of-the-art forecast systems. In Germany, the Federal Maritime and Hydrographic Agency (BSH) (in cooperation with the German Weather Service (DWD)) have the responsibility for storm surge forecasts and warnings along the German North and Baltic Sea coastlines. The operational system in place for the North Sea consists of numerical weather forecast systems, a surge model and model output statistics. It provides accurate high frequency water level forecasts up to six days ahead at selected tide gauge sites (Müller-Navarra and Knüpfer, 2010), but not for the coastline in between. Spatial forecasts are, however, currently not available for two reasons: first, the shallow coast with complex morphological structures leads to strong non-linearities between individual sites hampering simple interpolation schemes (Arns et al. 2015). Second, tidal predictions are limited to tide gauge locations, which do not fall dry during low tide, since the traditional estimation of tidal coefficients requires complete time series covering both low and high waters.

OBJECTIVES

We present the results of a 3-year research project funded by the Federal Ministry of Education and Research (BMBF). The focus was on the development of a model chain providing real-time flood risk warnings for any coastal site. Therefore, a new methodology based on the combination of statistical and numerical models was developed in order to provide water level forecasts at a much higher spatial resolution for the entire coastline as actually given by tide gauges. A two-dimensional, depth-averaged barotropic tide-surge model was developed to simulate a water level hindcast for a period of at least 15 years for the examined area. The model domain covers the entire North Sea and parts of the northeast Atlantic in order to be able to capture external surges which can also have significant effects on storm surge water levels in the German Bight. A novel tidal prediction algorithm has been implemented to separate the simulated (with the numerical model) and observed total water levels into astronomical tides and surge residuals. The surge time series for each relevant coastal grid point will then be used for the development of empirical surge models based on a multiple linear regression. Such models enable to primarily describe barotropic adjustment processes of the ocean to wind stress forcing and sea level pressure fluctuations including nonlinear dependencies between wind and water levels. In the prediction mode, the empirical surge model will be forced with DWD wind and pressure forecasts derived from the numerical weather forecast systems. The predicted surge at a particular site will then be combined with the predicted astronomical tide for the same location to obtain the total water level forecast of the entire domain.

CONCLUSIONS

As shown in Figure 1 the general ability of the statistical model to properly describe the surge at specific tide gauge locations is very good. The coefficient of determination reaches values of above 0.8. Furthermore, the tidal prediction algorithm provides accurate results even for grid points which frequently fall dry. Hence, the determined water levels for the entire coastline are assumed reliable and representative. Nevertheless, the project results are actually in an optimization process and the underlying structure will individually be validated against observations at the gauged locations.

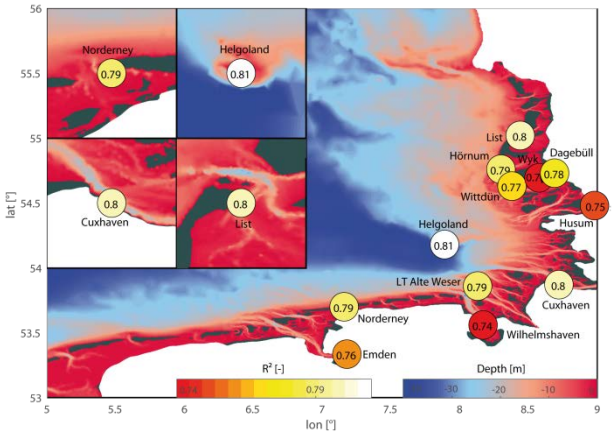

Figure 1 – Investigation area and bathymetric chart. The colored dots show the considered tide gauge locations and skill of the new forecast in term of the coefficient of determination.

REFERENCES

Arns, Wahl, Haigh, Jensen (2015): Determining return water levels at ungauged coastal sites: a case study for northern Germany. Ocean Dynamics 65 (4), 539-554.

Müller-Navarra and Knüpffer (2010): Improvement of water level forecasts for tidal harbours by means of model output statistics (MOS) – Part I (Skew surge forecast). Berichte des Bundesamtes für Seeschifffahrt und Hydrographie 47, 22 pp.