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Performance Comparison of the European Storm Surge Models and Chaotic Model in Forecasting Extreme Storm Surges

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Storm surge modeling has rapidly developed considerably over the past 30 years. A number of significant advances on operational storm surge models have been implemented and tested, consisting of: refining computational grids, calibrating the model, using a better numerical scheme (i.e. more realistic model physics for air-sea interaction), implementing data assimilation and ensemble model forecasts. This paper addresses the performance comparison between the existing European storm surge models and the recently developed methods of nonlinear dynamics and chaos theory in forecasting storm surge dynamics. The chaotic model is built using adaptive local models based on the dynamical neighbours in the reconstructed phase space of observed time series data.

The comparison focused on the model accuracy in forecasting a recently extreme storm surge in the North Sea on November 9th, 2007 that hit the coastlines of several European countries. The combination of a high tide, north-westerly winds exceeding 50 mph and low pressure produced an exceptional storm tide. The tidal level was exceeded 3 meters above normal sea levels. Flood warnings were issued for the east coast of Britain and the entire Dutch coast. The Maeslant barrier's two arc-shaped steel doors in the Europe's biggest port of Rotterdam was closed for the first time since its construction in 1997 due to this storm surge.

In comparison to the chaotic model performance, the forecast data from several European physically-based storm surge models were provided from: BSH Germany, DMI Denmark, DNMI Norway, KNMI Netherlands and MUMM Belgium. The performance comparison was made over testing datasets for two periods/conditions: non-stormy period (1-Sep-2007 till 14-Oct-2007) and stormy period (15-Oct-2007 till 20-Nov-2007). A scalar chaotic model with optimized parameters was developed by utilizing an hourly training dataset of observations (11-Sep-2005 till 31-Aug-2007). The comparison results indicated the chaotic model yields better forecasts than the existing European storm surge models. The best performance of European storm surge models for non-storm and storm conditions was achieved by KNMI (with Kalman filter data assimilation) and BSH with errors of 8.95cm and 10.92cm, respectively. Whereas the chaotic model can provide 6 and 48 hours forecasts with errors of 3.10cm and 8.55cm for non-storm condition and 5.04cm and 15.21cm for storm condition, respectively. The chaotic model can provide better forecasts primarily due to the fact that the chaotic model forecasting are estimated by local models which model and identify the similar development of storm surges in the past. In practice, the chaotic model can serve as a reliable and accurate model to support decision-makers in operational ship navigation and flood forecasting.