Ensemble Modelling of Tides, Surge and Waves

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ABSTRACT

This study aims to use a generically integrated meteorological and hydrodynamic ensemble modelling system to quantitatively assess the effect of uncertainties arising from the numerical weather prediction (NWP) on the tide, surge and wave forecasts. The modelling system was applied to the English and Bristol Channels for the storm events occurred between 25th and 30th October 2004. The model results show that the accuracy of the predicted surge and waves can be considerably improved by the ensemble approach, particularly in predicting the storm peaks, when short-term predictions (T+2 day) are used.

KEY WORDS: Ensemble predictions; uncertainty; tide, surge and wave modelling; English and Bristol Channels; storm events; POLCOMS; ECMWF EPS.

INTRODUCTION

The UK coastal areas are increasingly at the risk of flooding by the sea. The recent report shows that a water level that had an average likelihood of occurring once every 100 years in 1900 now has an average likelihood of occurring on average every 10 to 25 years along the south coast of England (Haigh et al, 2009). The rising sea level is now acknowledged as a real threat to a huge number of human lives and properties in coastal areas. In addition, the global climate change is also likely to affect the intensity and the frequency of the severe storms over the UK, which may substantially increase the risk of wave overtopping over the coastal defences (IPCC, 2007).

In order to alleviate the threat of coastal flooding, it is essential to develop an accurate tide, surge and wave forecasting system to provide early warning of severe storms so that appropriate mitigating measures can be put in place. However, like the forecasts in fluvial flooding, the coastal flooding forecasts are likely affected by the uncertainties arising from the numerical predictions. These uncertainties are thought to stem from the imperfect initial conditions, boundary conditions and/or model physics in meteorological and hydrological/hydrodynamic models (Cloke and Pappenberger, 2009; Flowerdew et al, 2009; Bocquet, 2009).

The ensemble method is an effective approach to assess the effect of the model uncertainty by producing not only one, but several forecasts. Each forecast uses slightly different initial conditions, boundary conditions, and/or model physics, with the aim of sampling the range of forecast results that are consistent with the uncertainties in the model and observations (Palmer, 2006).

Following the success of the use of ensemble method in weather forecast, the coastal modellers have been increasingly using this probabilistic approach to develop the ensemble models for storm surge (Flowerdew et al, 2009) and waves (Bocquet, 2009; Cao et al, 2009; Peel and Lalbeharry, 2009) to support a risk-based coastal flooding forecast system. Although many fruitful results have been achieved, the knowledge of the effects of uncertainties from weather forecast on the coupled tide, surge and wave predictions is still rather limited.

This study is to use a generically integrated meteorological and hydrodynamic modelling system to quantitatively assess the effect of uncertainties arising from the weather forecast on the coupled tide, surge and wave predictions using the ensemble approach, as a part of the UK NREC funded project (EPIRUS), so that the risk of coastal flooding and erosion from the extreme storm events can be studied (Zou et al, 2008). This paper outlines the nested modelling system used and presents the results of the model applications to the south-west coasts of the UK for the storm events occurred between 25th and 30th October 2004.

MODEL SYSTEM

In order to track the propagation of uncertainties from the meteorological model to the coastal hydrodynamic model, an integrated ensemble meteorological and tide, surge and wave model system within a one-way downscaling framework, as shown in Figure 1, is used. A state-of-the-art tide and surge model POLCOMS, coupled with a third-generation wave model, ProWAM, is used to transform the ECMWF EPS meteorological information to the hydrodynamic conditions, with the tidal boundary conditions provided from the CS3 model in forms of harmonics to the downscaling computational domain. Since these models have been