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Artificial Neural Network forecasting of storm surge water levels at major estuarine ports to supplement national tide-surge models and improve port resilience planning

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Effective prediction of tidal storm surge is of considerable importance for operators of major ports, since much of their infrastructure is necessarily located close to sea level. Storm surge inundation can damage critical elements of this infrastructure and significantly disrupt port operations and downstream supply chains. The risk of surge inundation is typically approached using extreme value analysis, while short-term forecasting generally relies on coastal shelf-scale tide and surge models. However, extreme value analysis does not provide information on the duration of a surge event and can be sensitive to the assumptions made and the historic data available. Also, whilst regional tide and surge models perform well along open coasts, their fairly coarse spatial resolution means that they do not always provide accurate predictions for estuarine ports.

As part of a NERC Environmental Risks to Infrastructure Innovation Programme project, we have developed a tool that is specifically designed to forecast the North Sea storm surges on major ports along the east coast of the UK. Of particular interest is the Port of Immingham, Humber estuary, which handles the largest volume of bulk cargo in the UK including major flows of coal and biomass for power generation. A tidal surge in December 2013, with an estimated return period of 760 years, partly flooded the port, damaged infrastructure and disrupted operations for several weeks. This and other recent surge events highlight the need for additional tools to supplement the national UK Storm Tide Warning Service. Port operators are also keen to have access to less computationally expensive forecasting tools for scenario planning and to improve their resilience to actual events.

In this paper, we demonstrate the potential of machine learning methods based on Artificial Neural Networks (ANNs) to generate accurate short-term forecasts of extreme water levels at estuarine North Sea ports such as Immingham. An ANN is configured to take advantage of far-field information on developing tidal surges provided by tide gauges in NW Scotland (the 'external surge'), supported by observations of wind and atmospheric pressure and the predicted astronomical tide at Immingham. Missing data can cause problems with ANN models and a novel aspect of our implementation is the use of multiple redundant inputs (nearby tide gauges that experience a high degree of surge coherence) to synthesise a single external surge input. A similar approach is taken with meteorological forcings, creating an ANN that is resilient against data drop-outs within its input vector. The ANN generates 6 to 24 hour surge forecasts at Immingham with accuracy better than the present UK Storm Tide Warning Service. These can be used to cross-check national forecasts, generate more accurate estimates of likely flood depths, timings and durations and trigger planned responses to severe forecasts. Crucially, this capability can be 'owned' by the port operator, which encourages the development of a shared understanding of storm surge hazards and the challenges of port resilience planning between scientist and stakeholder.