BENEFITS AND LIMITATIONS OF A COUPLED WAVE-SURGE MODEL FOR AUSTRALIAN EXTREMES

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INTRODUCTION

Extreme sea levels result from a combination of a range of factors that include long term mean sea level variability, astronomical tides, storm surges due to atmospheric pressure and wind, wave breaking, and other regional dynamics. Numerical circulation/storm-surge models are frequently used to predict water levels over broad areas with the outputs used for planning or emergency management applications. Recently, coupled wave-circulation models have been shown to improve extreme sea level predictions through the inclusion of wave setup that results from the transfer of momentum of breaking waves into sea level at the shoreline. Other studies have shown that the representations of surface wind drag can be improved when the sea state is considered, and this can directly influence the amplitude of storm surges at the coast. However, most coupled wave-circulation model studies have been undertaken for relatively small computational domains and for a limited range of coastal morphologies and storm types. In this paper we assess the benefits and limitations of using a coupled wave-circulation model to predict extreme sea levels and determine wave effects for a broad range of coastal morphologies and extreme storm events all around Australia. Simulated events occurred in three oceans and considered tropical cyclones, a cyclone undergoing extratropical transition, and a large mid-latitude extratropical low-pressure system.

METHODS

We used a coupled wave and three-dimensional circulation model (SCHISM-WWMIII) on a common unstructured grid as in Roland et al. [2012] to determine the importance of different components (wind, atmospheric pressure, wave processes, wave-varying surface friction) to the residual water level. The unstructured mesh (~100s m resolution at the coast) and implicit time-stepping scheme enabled wave and hydrodynamic processes to be simulated over regional or continental-scale domains whilst retaining critical complexities. The coupling allowed for the option of improved wave-dependent wind stress formulations and for the quantification of wave setup that is the focus here. Atmospheric forcing for extratropical storm events was provided by the JRA-55 reanalysis. For tropical cyclones, the Holland parametric wind model was used to derive synthetic vortices that were merged with the JRA-55 broad scale circulation.

RESULTS

Extreme sea level predictions generally improved when wave setup was included with the coupled model for most sites and events, however, these wave effects were often secondary to other assumptions implicit in modeling extreme events. Wave setup computed with the coupled model was highly variable both spatially and temporally, ranging between 0 and 0.45 m (0-35% of maximum storm surge height). In the case of Tropical Cyclone Yasi in Queensland, including wave-dependent wind friction in the coupled model had a large impact on predicted water levels (Figure 1). However, accurate wind and pressure forcing were still the largest source of uncertainty for this event. Although the coupled wave-surge model presented a useful tool to predict extreme water levels and wave effects, significant challenges still exist when attempting to model these processes at the regional or continental scale.

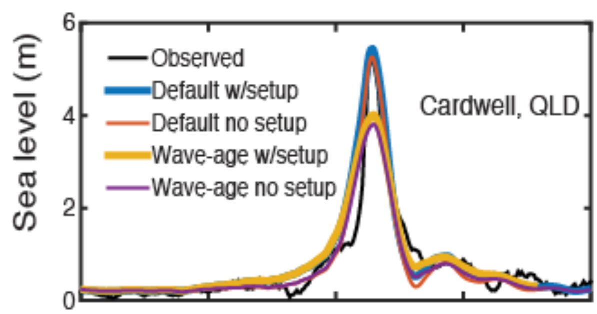

Figure 1 - Predicted residual sea levels for Tropical Cyclone Yasi showing the relative contributions of wave setup and wave-dependent wind stress to storm surge.

REFERENCES

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