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The impact of wave source terms and coupling strategies on the accuracy of the UKC4 regional coupled atmosphere–ocean–wave forecasting system during extreme events

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Prediction of severe natural hazards requires accurate forecasting systems. Recently, there is a tendency to move towards more integrated solutions, where different components of the Earth system are coupled to better reproduce the physical feedbacks between them. Atmosphere–wave coupling should, in principle, improve the momentum flux because there is more detail in the two-way feedback due to the atmosphere receiving a more realistic picture of the surface roughness. However, the coupling between the ocean surface and the wind might become less efficient at transferring momentum during large storms.

This study focuses on rapidly developing waves under extratropical storms to understand the sensitivity in atmosphere–wave present generation source terms and coupling strategies. Here, we analyse the effect of momentum transfer to fast growth waves during both long and fetch limited conditions using the Met Office regional atmosphere–ocean–wave coupled research system for the northwestern (NW) European shelf (UKC4).

Two different sets of numerical experiments are conducted focusing on the atmosphere–wave components. The first one explores the sensitivity to two different wave source parameterizations, ST4 and ST6, and uses a two-way feedback coupling strategy (A2W) where a sea-state dependent surface roughness modifies the atmospheric momentum budget. In the second set of simulations, the impact of the coupling strategy is assessed. The A2W approach using ST6 physics is compared against a simpler one-way strategy (A1W) where no wave feedback on the atmospheric model exists and the wind stress is directly passed to the wave model (WAVEWATCHIII) ensuring conservation of momentum.

Results demonstrate that ST6 physics allows for a faster wave growth than the currently used ST4 parameterization but might degrade low to mid energy wave states for the NW shelf. ST6 versus ST4 difference in wave growth is larger for higher wind speeds and short fetches. The experiment with ST4 and A2W consistently under-predicts the wave growth in those locations across the NW shelf where fetch dependence is an important factor (i.e., seas at the E of Ireland and the UK for storms coming from the NW-WNW). The implementation in the wave model of physics that

depend solely in the wind input (ST6) with the A1W coupling strategy appears to improve growth of young wind-seas, reducing bias in those locations where the storms are underestimated. The analysis of the transfer of momentum across the air-sea boundary layer shows that forecasts of large wave events may require a different coupling approach. The slower wave growth seems to be related to an underestimation of the momentum transfer computed by the wave model when coupling the wind speeds (A2W). This suggests that coupling the wind speeds to the wave model and allowing this to calculate the momentum transfer from the atmosphere to waves and ocean underestimates the transfer by a few percent. For very young to young wind seas, this can be overcome when the surface stress is computed by the atmospheric model and directly passed to the ocean (A1W).