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Wind stress: Which formulation for coastal applications?

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The accurate parameterisation of momentum and heat transfer across the air-sea interface is vital for realistic simulation of the atmosphere-ocean system. In many modelling applications accurate representation of the wind stress is required to numerically reproduce surge, coastal ocean circulation, surface waves and turbulence. Different formulations can be implemented and impact the accuracy of: the instantaneous and long-term residual circulation; and the generation of coastal storm conditions. This, in turn, affects predictions of storm impact, sediment pathways, and coastal resilience to climate change. The specific numerical formulation needs careful selection to ensure the accuracy of the simulations. We investigate two wind stress formulae widely used in respectively the ocean circulation and the storm surge communities. We focus on an application to the NW region of the UK, which is a specific case study area in two UK projects: the first investigating the evolution of coastal sediment systems and sediment pathways at the mesoscale (iCOASST: integrating coastal sediment systems), and the second investigating effective coastal adaptation to enhance resilience of coastal power stations to climate change (ARCoES: Adaptation and Resilience of Coastal Energy Supply).

We employ model-data comparisons at two nearshore and one estuarine ADCP stations in Liverpool Bay, which is a hyper-tidal region of freshwater influence with vast intertidal areas. The period of study (February-March 2008) covers both calm and extreme conditions to fully test the robustness of:
(i) The 10 m wind stress component of the CORE (Common Ocean Reference Experiment) bulk formulae used in operational barotropic-baroclinic global circulation modelling. The full set of formulae consists of methods to parameterise a set of atmospheric variables.
(ii) The Charnock parameterisation used in barotropic surge modelling to capture increased surface roughness due to the presence of waves on the surface stress due to the 10 m wind components.

In this coastal application a 180 m Liverpool Bay model is nested such that the tide-surge and baroclinic influence from the European Continental Shelf and more locally within the Irish Sea, forces the boundaries. The full CORE bulk formulae includes: air temperature, relative humidity, cloud cover, atmospheric pressure and surface wind stress, to represent the transfer of heat and momentum fluxes across the atmosphere-ocean boundary in addition to the inverse barometer effect. This set up along with riverine inputs allows a realistic barotropic-baroclinic simulation of the circulation within the study area. The full CORE bulk formula is initially used to represent the complete atmospheric forcing; a second simulation then replaces the wind stress parameterisation within the CORE bulk formulae with that of the Charnock parameterisation. More accurate coastal circulation is generated using the Charnock method for surface wind stress. Problems with the CORE bulk formulae are identified with offshore wind conditions. Our conclusion is that the Charnock parameterisation produces better surge and coastal wind driven currents.