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The Impact of Wind-Wave Coupling on the Coastal Wind and Wave Simulations During Storms

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Abstract:

The momentum exchange at the air-sea interface is important, as it influences the winds in the atmospheric surface layer, dominates wave growth, and drives water currents. In this study, we examine different methods for estimating the momentum flux in a wind-wave coupling system and their impact on the wind and wave field calculation. We use two model components in the Coupled-Ocean-Atmosphere-Wave-Sediment Transport (COAWST) modeling system, namely the atmospheric model WRF and the ocean wave model SWAN. The examined methods for the momentum flux include six often-cited and often-used empirical parameterization schemes of roughness length (z0) through wave parameters such as wave age and wave steepness, Janssen (1991)'s method which calculates z0 through the integration of wind-input source function, and a new wave boundary layer model (WBLM, Du et al. 2017, 2018) method, which considers momentum and kinetic energy conservation through the air-sea interface. The WBLM is embedded in SWAN as a new wind-input source function, and at the same time provides an equivalent z0 through stresses as input to WRF. Numerical experiments are carried out through a number of storm simulations in the North Sea. Wind speed, wind direction, significant wave height, peak wave period, and z0 are validated with point measurements in the west coast of Denmark and Envisat Advanced Synthetic Aperture Radar (ASAR) observations of the ocean backscatter. Results show that, the empirical z0 parameterization schemes fail to reproduce z0 in storm conditions as well as in coastal areas. Janssen (1991)'s method tends to overestimate z0 in strong wind conditions. The WBLM method outperforms the other methods in terms of the magnitude of z0 in comparison with point measurements as well as the spatial distribution of it, in comparison with the Envisat ASAR backscatter. It is found that wind-wave coupling is important for wind estimations in coastal zones, as well as in high wind speed conditions and in fast varying wind condition. The wind-wave coupling through WBLM results in an average of 10% differences in the 10 m wind field in comparison with uncoupled simulations during storm winds.