The Air-Sea Interface and Surface Stress in Hurricanes

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Unresolved physics near the air-sea interface including surface waves are among the weakest components in hurricane prediction models. Air-sea interaction dramatically changes from moderate to very high wind speed conditions (Donelan et al. 2004; Holthuijsen et al. 2012). Despite recent progress and the fact that current wave models provide very useful predictions of the sea state, these parameterized models still need improvement. In our recent work, we analyze the Kelvin-Helmholtz (KH) instability mechanism at the air-water interface. Rapid disruption of the interface under very high wind speeds, resembling the KH instability at an interface with very large density difference, was reported in laboratory experiments (Koga 1981) and numerical simulations (Soloviev et al. 2012). Kelly (1965) and Farrell and Ioannou (2008) showed that gustiness results in the near-instantaneous parametric KH instability of the air-sea interface, while the gusts are due to stochastically-interacting waves and atmospheric turbulence. The rectified stochastic forcing enters multiplicatively in this theory and produces an exponential wave growth, augmenting the growth from the Miles (1959) theory as the turbulence level increases. Here we complement this concept by accounting for the two-phase environment near the mean interface, which introduces additional viscosity in the system (turning it into a rheological system). The two-phase environment includes air-bubbles and re-entering spray (spume), which eliminates a portion of the wind-wave wavenumber spectrum that is responsible for a substantial part of the air sea drag coefficient. The previously developed KH-type interfacial parameterization (Soloviev and Lukas 2010) has been merged with two different versions of the wave growth model. The unified parameterization in both cases exhibits the increase of the drag coefficient with wind speed until approximately 30 m/s. Above this wind speed threshold, the drag coefficient either nearly levels off or even slightly drops (for the wave growth model that accounts for the shear) and then starts again increasing above approximately 65 m/s wind speed. Remarkably, the unified parameterization reveals a local minimum of the drag coefficient wind speed dependence around 65 m/s. The existence of such a minimum may contribute to the rapid intensification from storms to major hurricanes. The subsequent slow increase of the drag coefficient with wind above 65 m/s serves as an obstacle for further intensification. Such dependence may explain the observed bi-modal distribution of tropical cyclone intensity. Implementation of the new parameterization into operational models is expected to improve predictions of tropical cyclone intensity and the associated wave field.

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