A new physically based parameterization for wind-wave stresses under strong winds

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The ability to estimate flux exchanges between the sea-surface and the atmosphere has tremendous importance on weather prediction and climate simulations. These exchanges are influenced by wave processes - growth and decay, and turbulent interactions at the air-sea interface. For momentum, the ensemble of these exchanges is presented as the sea-surface drag \( (C_d) \), which increases with (10-m high) wind intensity till about 20-30 m/s, and decreases thereafter. The reason for this decrease remains less understood, mainly due to (i) our inability to explicitly measure the individual wind-wave exchanges, and (ii) the inability of existing semi-empirical parameterizations to explain the \( C_d \) behavior. To this end, we developed a physically based stress parameterization for a coupled wind-wave model, capable of reproducing both wave growth and wave breaking stresses at the air-sea interface. The advantage of such a numerical approach, over field experiments, is that it allows us to investigate the different processes under different constraining environments, in-order to disentangle the factors in play on \( C_d \). Our coupled model enables a two-way interaction between the ocean-waves and turbulent flow, and can simulate (i) the main turbulent eddies of the air-flow, and (ii) the wind-wave interactions. After evaluating the model against published field experiments we use it to explore the impact of wave growth and wave-breaking on the \( C_d \) under strong winds. Our results demonstrate that under strong winds the air-flow gets separated from the sea-surface, a process associated with wave-breaking, resulting in the turbulent flow sensing a smoother surface as against an actually rough sea surface, thereby decreasing \( C_d \). Finally, our model allows us to investigate the sensitivity of \( C_d \) to different influencing factors under strong winds.