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Air-sea momentum flux over breaking and non-breaking surface waves

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Above the air-sea interface, within the constant stress layer, the momentum flux partitions into turbulent and wave-induced (by non-breaking waves) and breaking wave components. Ahead of a breaking wave crest the airflow separates, causing a pressure drop on the leeside of the wave. This pressure drop leads to energy and momentum fluxes from wind to breaking waves, while reducing the turbulent stress in the air. By conserving air-side momentum and energy and also imposing the wave energy balance, we derive coupled equations governing the turbulent stress, wind speed, wave height spectrum, and breaking wave distribution (length distribution of breaking crests per unit surface area as a function of wave number). Furthermore, the “spatial sheltering effect” is introduced, so that smaller waves in airflow separation regions of breaking longer waves cannot be forced by the wind. The model yields the normalized roughness length (Charnock coefficient), which is generally consistent with previous laboratory and field measurements. For young strongly forced waves (laboratory conditions), the dominant breaking wave controls the total air-sea momentum flux. For field conditions, the entire spectrum of surface waves contributes to the momentum flux, which depends sensitively on the wave height spectrum.