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Effects of bubble and sea spray generation on air-sea exchanges in hurricane conditions

A. Soloviev (1) and R. Lukas (2)

(1) Oceanographic Center, Nova Southeastern University, Florida, USA, (2) Department of Oceanography, University of Hawaii at Manoa, Hawaii, USA

(soloviev@nova.edu, Fax 1 954 262 4098 / Phone 1 954 262 3659; rlukas@hawaii.edu, Fax 1 808 956 9222 / Phone 1 808 956 7896)

Breaking waves intermittently disrupt the air-sea interface. With increasing wind speed, the sharp interface between the air and water disappears for longer intervals. Under extreme conditions of very high wind speeds, the concept of the air-sea interface becomes problematic: A two-phase environment with gradual transition from bubble-filled water to spray-filled air is formed. This mixed-phase environment changes the dynamics and thermodynamics of air-sea interaction especially within tropical cyclones. The effects of bubbles and sea spray appear to be of crucial importance for air-sea exchanges in tropical cyclones. These effects can also be important for extratropical winter storms. Further developing the "sandwich model" of tropical cyclones proposed by Barenblatt et al. (2005) and Makin (2005), we consider the Kelvin-Helmholtz (K-H) instability of the air-sea interface as a mechanism leading to disintegration of short wavelets and intense generation of sea spray (spume). Spume drops, which have been largely unaccounted for in previous models (as well as in in-situ measurements), provide a link between the sea spray generation function and the regime of limiting saturation. This analysis has led us to a nondimensional criterion for the K-H instability of the short wavelets in the form: $K = u_{*a}/\sqrt{g\sigma_s\rho_w/\rho_a^2}$, where u_{*a} is the friction velocity in air, σ_s is the surface tension, g is the acceleration due to gravity, ρ_w is the water density, and ρ_a is the air density. A new parameterization of the air-sea momentum and mass flux based on K is, in particular, able to elucidate the behavior of the effective drag coefficient with increasing wind speed during hurricane

conditions.