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Effects of Sea State and Small-Scale Currents on Air-Sea Fluxes in the Northwest Tropical Atlantic Ocean

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The Northwest Tropical Atlantic is characterized by the strong North Brazilian Current (NBC), its rings, and numerous mesoscale eddies, which ceaselessly interact with the persistent trade winds and trade cumuli. Near the coast, the ocean stratification is maintained by the Amazon and Orinoco river discharges, which control the vertical mixing and the near-shore circulation dynamics. Breaking waves and swells are ubiquitous under the trade winds, and hence, the wave-induced mixing and wave-mediated air-sea fluxes are expected to modulate the eddy variability and low-level clouds. Our study aims to enhance understanding of the air-sea fluxes mediated by the mesoscale ocean currents and surface waves and evaluate their impacts on the ocean and atmosphere.

High-resolution ocean model (ROMS) and wave model (WW3) simulations are conducted for the period of the ATOMIC/EUREC4A experiments. The model surface state variables are used to compute offline the air-sea heat and momentum fluxes using the latest COARE v3.6 bulk flux algorithm under various sea state conditions induced by surface waves, ocean currents, and their interaction. The results demonstrate that considering the spatial variability in sea states via wave slope and wave age (e.g., swells and wind-seas) leads to enhanced spatial variability in drag coefficient and wind stress. Comparison to wind stress estimated using the wind-speed dependent formulation, meaning that COARE makes sea state assumptions under given wind, indicates that, at any given time, wind and wave in fact, rarely match those assumptions. The swells (wind-seas) decreases (increases) the sea surface roughness length, drag coefficient, and wind stress by 10-15%. However, we find that the sea state impact on turbulent heat flux is negligible.

More importantly, we also show that considering the ocean currents in the COARE algorithm yields much stronger spatio-temporal variations in not just the wind stress but also turbulent heat fluxes. The intense and small-scale current fields in this region are associated with the NBC and its rings, smaller mesoscale eddies, and filamentary density fronts associated with the freshwater plumes. The surface currents associated with these small-scale energetic features alter the relative wind speed and thus the air-sea fluxes depending on the directional alignment between the wind and current; the increase (decrease) in both the wind and heat fluxes by ~20% is found with the current and wind are in the opposite (same) direction wind. Moreover, this relative wind effect appears to be reinforced by wave direction as well, also via the directional alignment between

waves and currents, since the waves are mainly aligned with the trade wind in this region.

Further analyses are underway to examining the seasonality of the modulation by the wave-current interaction, quantifying the role of the freshwater distribution, and exploring the time-mean influence on the low-level clouds. The results from the ocean and wave modeling efforts will guide our ongoing fully coupled ocean-atmosphere (and wave) model simulations to quantify their impacts on the atmosphere, including low-level clouds.