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Sea Spray in Air-Sea Enthalpy and Momentum Exchanges in Tropical Cyclones

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Under tropical cyclones, sea spray is produced by breaking waves and direct disruption of the air-sea interface. The influence of sea spray on tropical cyclone intensity and intensification has not been well understood. There are serious questions regarding the most appropriate methods for the incorporation of sea spray in tropical cyclone models. These include momentum and enthalpy fluxes at the air-sea interface due to spray, the airborne sea-salt particles inducing boundary layer convection and clouds (Woodcock 1958, Spund et al. 2014), and other related factors. Here, we study the effect of spray on thermodynamics of tropical cyclones using a Volume of Fluid to Discrete Phase (VOF to DPM) transition model. Due to dynamic remeshing, VOF to DPM resolves spray particles ranging in size from tens of micrometers to a few millimeters. The generated water particles that satisfy the condition of asphericity are converted into Lagrangian particles involved in a two-way interaction with the airflow. This model has been partially verified at the UM RSMAS Surge Structure Atmosphere Interaction facility (Vanderplow et al. 2020). A recent addition of the ANSYS Fluent Evaporation-Condensation model also allows us to model spray evaporation and related heat and enthalpy fluxes. A substantial part of the smallest particles was suspended in the turbulent airflow and evaporated, and thus contributed less to the total air-sea enthalpy flux. The temperature of the largest particles was close to the temperature of the water layer, which contributed more to the enthalpy flux. This resembled the effect of negative feedback on the enthalpy flux (Peng and Richter 2019). Results of the numerical simulation showed a dramatic increase of spray generation under major tropical cyclones (Cat. 3-5). Under major tropical cyclones, most sea spray (including large particles-spume) is suspended in the turbulent airflow and is then subject to the negative feedback. Consequently, in major tropical cyclones the effect of sea spray is expected to be more significant in the momentum budget rather than enthalpy flux at the air-sea interface. This result may explain the nearly constant enthalpy exchange coefficient observed in laboratory and oceanic experiments on tropical cyclones. This is also consistent with the formation of an “aerodynamic drag well” around a wind speed of 60 m/s, which can explain the process of rapid storm intensification (Soloviev et al. 2017).