Potential impacts of tropical cyclone inner-core convective activity on the predictability of rapid intensification

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Predictions of significant changes in tropical cyclone (TC) intensity, such as rapid intensification (RI), have emerged as a more challenging topic than forecasting TC tracks, since intensification of TCs involves multi-scale physical processes with significant contributions from convective-scale phenomena. Before the onset of RI, intensifying TCs are known to experience a precession process, in which tilted vortex rotates counter-clockwise to develop axisymmetric structure. From both modeling and observational studies, there is an agreement in the qualitative features of precession process among TCs, but the quantitative features, such as the vortex tilt magnitude, the duration of the precession process and whether or not the vortex is able to complete the precession process, vary among TCs. The predictability of the variety of precession process and subsequent RI is reported to be ultimately dominated by the chaotic nature of moist convection. Given the large influence of RI on the TC intensity forecasts, the further understandings in its uncertainty sources are necessary.

In this study, mechanisms that determine the variability of these precession processes are explored through sets of sensitivity and ensemble forecast experiments. We have used the Pennsylvania State University’s experimental real-time ensemble Kalman filter analysis of Hurricane Harvey (2017) that assimilated GOES-16 all-sky satellite radiances (which has an equivalent monitoring capability to Himawari-8) in convection-permitting Weather Research and Forecasting model (WRF-ARW) simulations. This analysis resulted in a highly accurate forecast of intensity and track, and realistically represented the storm’s rapid intensification. Starting with an analysis based on 18 hours of cycling data assimilation, we have conducted sensitivity experiments in which we reduced the initial atmospheric moisture amount by 5 to 20 %. Even initialized with the same wind field, and with fully developed convective updrafts and organization, the vortex tilt magnitude and the duration of precession are significantly modified by the inner-core moist processes. We explore the characteristics of the vortex structures that underwent short/long/uncompleted precession process, together with the theoretical background for these varieties of precession process by using a simplified toy-model. The results have implications for the design of future observation networks tasked with providing constraint on predictions of convections and rapidly intensifying tropical cyclones.

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