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Ensemble-Based All-Sky Infrared and Microwave Radiance Assimilation for the Analysis and Prediction of Tropical Cyclones and Severe Thunderstorms

During the past five years, the Penn State Center for Advanced Data Assimilation and Predictability Techniques (ADAPT) has been devoted to the development and application of techniques to assimilate all-sky radiance at both infrared (IR) and microwave (MW) bands. For radiance from IR imagers, we have developed the Adaptive Observation Error Inflation (AOEI) error model that is able to provide more Gaussian innovations, the Adaptive Background Error Inflation (ABEI) to help initiating clouds in the model where mismatches of cloud conditions between the observations and the model predictions occur, and a channel synthesizing technique to reduce errors associated with uncertainties from surface emissivity for the window channels. We have also tested the feasibility of using principal component analysis (PCA) to select channels and compress information content for IR hyperspectral sounders. For the MW bands, we have tested the influence of different scattering properties of non-spherical particles instead of homogeneous soft spheres on microwave radiance simulated by the Community Radiative Transfer Model (CRTM), and built look-up tables of scattering for CRTM that are consistent with the assumed particle size distributions of different microphysics schemes.

With the help of these techniques, we have successfully assimilated all-sky IR radiance observations from the Advanced Himawari Imager (AHI) onboard the Himawari-8 satellite and the Advanced Baseline Imager (ABI) onboard the GOES-16 satellite using the PSU WRF-EnKF data assimilation system for convection-allowing analyses and predictions of several tropical cyclones (TCs) in the western North Pacific and north Atlantic basins as well as severe thunderstorms in the Great Plains of the United States. It is found that significant improvement on the track and intensity predictions of the TCs can be gained by assimilating all-sky IR radiance observations over the data-sparse regions of the open ocean with the structure of the TC improved as well. For severe thunderstorms, accurate probabilistic prediction of the mesocyclone tracks can be achieved even before the initiation of the thunderstorms as observed by the weather radars, and a forecast lead time of 20 to 40 minutes can be gained compared with assimilations of radar reflectivity and radial velocity observations.

Built upon the success of the predictions of Hurricane Harvey (2017) with the assimilation of all-sky IR radiance observations from ABI, we have also started exploring the assimilation of all-sky MW radiance observations from the Global Precipitation Measurement (GPM) project for TC predictions. Preliminary results indicate that MW observations are able to compensate the lack of hydrometeor distributions beneath the cloud top from IR observations, which may potentially lead to improved analyses of the structure of the TC. However, how to better constrain the model when IR and MW observations are simultaneously assimilated is still an open question, and we are currently actively exploring different treatments of the radiance observations.

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