**Uncertainty in rainfall prediction of land-falling tropical cyclones over India: Impact of data assimilation**

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**Abstract**

Realistic prediction of heavy rainfall associated with extreme weather events is one of the challenging task for scientific community. The heavy rainfall is common over India due to the organized convective systems such as land-falling tropical cyclones, thunderstorms, inland monsoon depressions, off-shore vortices, etc. High resolution meso-scale models showed reasonable skillful predictions; however, the predictions can be improved by incorporating realistic land surface conditions, advanced atmospheric data assimilation, etc over the Indian region.

Considering TC predictions, high resolution Advanced WRF (ARW) at 9 km horizontal grid spacing showed skillful track and intensity predictions over India. Model provides guidance for peak rainfall amount due to a land-falling cyclone, however, the distribution of rainfall, still, have uncertainty. For example, in case of Phailin (2013), ARW model predicted accurate track (< 100 km for 4 day forecast) and landfall location (28 km error for 4 day lead) with realistic intensity during landfall. The model also predicted rainfall well in terms of amount (40 cm during landfall day, close to IMD station rainfall of 38 cm), but, model failed to predict the location of peak rainfall activity i.e. northern parts of Odisha.

Experiments with assimilation of Doppler weather radar (DWR) reflectivity and radial wind are conducted under two scenarios: (i) when a TC center is away from the radar coverage and the outer bands are covered (TC environment), (ii) when a TC is within DWR range (inner core). Under first scenario, DWR provided realistic large scale environment and thus improved the track prediction. Spatial distribution of rainfall is improved and is mainly due to the improved track forecast. More gains were seen in intensity, track, and thus, in rainfall structure when assimilated inner core DWR observations which provides more realistic initial organization/asymmetry and strength of the TC vortex. It was found that the ice-phase microphysics has a notable impact on inner core reflectivity assimilation and thereby improving rainfall structure.

In case of TC Nilam (2012), there was heavy to very heavy rainfall over the land after making landfall where model fails to predict the post-landfall activity in real-time. This real-time forecast uses slab land model which does not consider the soil moisture conditions during integration. Experiments with Noah land model showed limited improvement in rainfall activity over the land which is mainly due to improper initial soil moisture and temperature (SM/ST) fields. Further experiments have been carried to initialize the model with the assimilated-SM/ST fields obtained from high resolution land surface data assimilation system (HRLDAS). When the model is initialized with assimilated SM/ST fields, the rainfall prediction has been improved both qualitatively and quantitatively.

**Key words:** Heavy rainfall, summer monsoon, tropical cyclones, thunderstorms, Variational data assimilation, WRF model