Impact of Ensemble Derived Flow-dependent Background Error Covariance in a Data Assimilation System for Regional-scale NWP model

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by

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Abstract

The background error covariance (BEC) in Three-dimensional variational (3DVAR) data assimilation (DA) system is static and lacks information about the flow-conditions of the day while advanced DA algorithms like Ensemble Kalman Filter provides flow-dependent BEC information. A hybrid ensemble–variational (HYBRID) DA system combines the flow-dependent information from the ensemble DA system in the variational DA framework. The research work examines the impact of ensemble derived flow-dependent ensemble error covariance in 3DVAR DA system for short-range forecasts using Weather Research and Forecast model. The forecasted wind, temperature, and rainfall from the assimilation experiments are verified against corresponding observations. Evaluation of short-range forecasts during the Indian summer monsoon indicates that the flow-dependent ensemble BEC in 3DVAR has systematically improved the forecast when compared to traditional 3DVAR experiments. More specifically, the rainfall forecast skill is superior in HYBRID experiments as compared to 3DVAR. The rainfall forecasts in convection-permitting resolution are validated against 746 telemetric rain gauge observations over the Karnataka state shows higher quantitative precipitation forecast skill in HYBRID system than 3DVAR towards the later stages of DA cycling. Assessment of short-range forecast of landfalling tropical cyclones (TC) over the Bay of Bengal (BoB) indicates that the use of flow-evolving ensemble error covariance in the 3DVAR system has reduced the TC position and intensity errors in the analysis. However, adding more weights to the ensemble error covariance term in the 3DVAR cost function has not shown any significant improvements. The forecasts from HYBRID analysis outperform 3DVAR forecasts by reducing TC track forecast error. The impact of assimilated observations can be dependent on many factors in a DA system including data quality control, preprocessing, skill of the model, and the DA algorithm. Studies have been conducted to

understand the differences and similarities in the impact of observations assimilated by two different DA algorithms. Evaluations on the impact of INSAT-3D Atmospheric Motion Vectors (AMV) observations with and without flow-dependent BEC in 3DVAR DA system are performed for short-range forecasts of the Indian summer monsoon. The satellite AMV observations show a more relative impact in HYBRID, with 77% and 71% improvement for wind and tropical temperature as compared to 3DVAR. Incorporating AMV shows substantial improvement in the forecast of landfalling TC in HYBRID than in 3DVAR DA system. Furthermore, the assimilation of AMV observation in HYBRID shows improved skill scores for quantitative precipitation forecast. The final objective of the thesis is to quantify the impact of flow-evolving BEC for the convective scale DA system. In this study, retrieved rainwater and water vapor from radar reflectivity are incorporated in HYBRID DA system to understand thunderstorms over northeastern region of the Indian subcontinent. The results indicate that assimilation of radar observations enhances the quantitative precipitation skill scores in both HYBRID and 3DVAR DA system. No significant impact of HYBRID DA system in rainfall forecast is observed.