Improved simulation of meteorological systems over India: Impact of assimilating satellite observations using 3DVar and EnKF

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ABSTRACT

The main objective of this thesis study is to investigate the impact of assimilating satellite observations for simulating various mesoscale weather features over the Indian region. The influence of background error covariance in determining the impact of satellite observations is the main focus of the present thesis study.

The impact of assimilating humidity information from MeghaTropiques SAPHIR (Sounder for Probing Vertical Profiles of Humidity) radiances in simulating three tropical cyclones that formed over the Bay of Bengal is investigated in chapter 3 of this thesis. The three dimensional Variational (3DVar) assimilation technique is used in the Weather Research and Forecasting (WRF) model. SAPHIR radiances have moderate positive impact in the simulation of various cyclone features in terms of minimum sea level pressure, maximum wind speed, area average temperature anomaly, relative vorticity as well as accumulated rainfall.

WRF 3DVar utilizes a static background error covariance matrix ($\mathbf{B}$) which is estimated using the National Meteorological Center (NMC) method. The various balance relations between the model variables are expressed through regression relations in this method. The formulation of the above-mentioned regression relations influence the background error correlations in 3DVar system. This significantly impacts the spread of observation information between the various grid points as well as model variables. This thesis study explores the two formulations - cv5 and cv6 - available in the WRF 3DVar system. The influence of the formulation of $\mathbf{B}$ is investigated in chapter 4 by performing assimilation of conventional as well as satellite radiance observations from the Advanced microwave sounding unit (AMSU-A) using cv5 and cv6 options. Three case studies involving the simulation of monsoon depressions over the Indian region are performed comparing the impacts of cv5 and cv6 options. It is seen that the moisture field is maximum impacted by the cv6 formulation of $\mathbf{B}$. Model simulations of horizontal wind divergence, moisture convergence, temperature anomaly, relative humidity as well as rainfall are seen to be moderately influenced by the choice of formulation of $\mathbf{B}$.

The impact of using cv5 and cv6 options in the 3DVar assimilation of SAPHIR radiances is investigated in the Chapter 5 , by considering the simulation of three tropical cyclone cases over Bay of Bengal. The simulation of tropical cyclones are also impacted in a moderate way by the choice of B matrix used.

3DVar techniques have the disadvantage of utilizing a static B. The evolution of background errors, are, hence not represented adequately in 3DVar assimilation technique. Flow-dependent B using ensembles provides a method to alleviate this disadvantage. Chapter 6 explores the use of ensembles to provide $\mathbf{B}$. Ensemble Kalman filter technique is used to assimilate satellite wind observations from Oceansat-2 satellite in the simulation of two heavy rainfalls during the north east monsoon as well as the simulation of a monsoon depression. It is seen that the use of EnKF method in assimilating observations provide positive impact on the simulation of these mesoscale weather phenomena as compared with assimilation using 3DVar method. The present thesis study, thus, indicates the significant role of $\mathbf{B}$ in determining the impact of satellite data assimilation over Indian region.