

Regional 4DVar Assimilation Studies on Weather Systems Over India Using the WRF Model

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by

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Abstract

The present study aims to investigate the performance of state-of-the-art Weather Research and Forecasting (WRF) model in the simulation of weather systems over India through regional variational data assimilation (DA) methods. Initially, the present study examines the performance of the four-dimensional variational (4DVar) DA system over the three-dimensional variational (3DVar) DA system for the simulation of a few tropical cyclones (TCs) that formed over the Bay of Bengal region. The improved performance of the 4DVar experiments over the 3DVar counterpart has been quantified for the simulation of cyclone intensity and track by generating a large number (51) of analysis/forecast samples for the TCs investigated. Cyclic assimilations were carried out for the entire lifespan of the TCs at 6h interval, and short-range (48h) free forecasts were initiated from each of the analysis fields. The 4DVar analyzed fields were found to reproduce the initial structure of the TC vortex realistically well, as compared to the 3DVar analyzed fields. The study suggests that, on an average the 4DVar runs can contribute to an improvement of 17-50% in the intensity simulation and 22-57% in the track simulation of the TCs, at different forecast lead times, the above results are being significant at 99% confidence level. The improvement in the rainfall simulation with the 4DVar experiments are attributed to the improved representation of the humidity fields due to the model physics involved in the 4DVar minimization process.

The sensitivity of the 4DVar DA system to the different background error covariance (BEC) formulations have also been investigated in the present study. Three different BECs, which employ three different sets of control variables are utilized. Two of them employ stream function and velocity potential (ψ and χ) as momentum variables, whereas the third one utilizes horizontal wind components as momentum variables (uv -BE). Among the two BECs which employ ψ and χ as momentum variables, the $\psi\chi$ -BE method treats humidity as univariate, while the other method ($\psi\chi$ -MBE) treats humidity as multivariate. Three heavy rainfall events, that occurred over north Indian region are chosen as case studies to investigate the sensitivity of the 4DVar DA system to different BECs. Five cyclic assimilation were performed for each of the three rainfall cases by utilizing conventional surface and upper air observations together with the satellite derived winds. The analysis

fields obtained using uv -BE experiment were consistently found to be more closer to the radiosonde observations. The quantitative verification of rainfall forecast for 24h and 48h accumulated precipitation indicates that, in general the $\psi\chi$ -MBE experiment has better skill in reproducing the observed rainfall. Furthermore, it is noted that, employing the humidity variable in the multivariate form successfully suppresses the overestimation associated with rainfall forecast.

Further experiments were conducted to examine the sensitivity of the 4DVar DA system to different BECs during a fortnight of the Indian summer monsoon. Short-range rainfall forecasts (24h and 48h) were examined for the first 15 sample days during the month of July, 2017. Results from the above study were consistent with the earlier results for the heavy rainfall events; the analysis fields from the uv -BE experiments were found to be the closest to the observations. The rainfall forecast verification revealed a marginal improvement with the $\psi\chi$ -MBE experiment.

Lastly, the impact of assimilating ocean surface winds from scatterometer on board Scatsat-1, the Indian scatterometer in the simulation of Indian summer monsoon circulation and associated rainfall has been examined for the entire month of July, 2017. 4DVar assimilations (SCATSAT run) were performed once for each sample days (at 00Z) utilizing the Scatsat-1 winds, conventional surface and upper air observations in combination with the atmospheric motion vectors. Results of this experiment are then compared with two other runs, such as (i) run that assimilated the ocean surface winds from ASCAT (ASCAT run) instead of Scatsat-1 and (ii) the run that did not assimilate any scatterometer winds (CTRL run). Both the 24h and 48h rainfall forecasts for SCATSAT experiments were found to be consistently better as compared to the CTRL run for most of the rainfall thresholds. The comparative study of the results for SCATSAT experiment with the ASCAT experiment shows that, both the scatterometer runs have similar skill in reproducing the 24h rainfall. However, at 48h lead time, ASCAT experiment shows better rainfall forecast skills. Furthermore, the results indicated that the SCATSAT experiment has better probability of detection for most of the rainfall thresholds, as compared to the ASCAT run.