Impact of Satellite Rainfall Assimilation on Weather Research and Forecasting Model Predictions over the Indian Region

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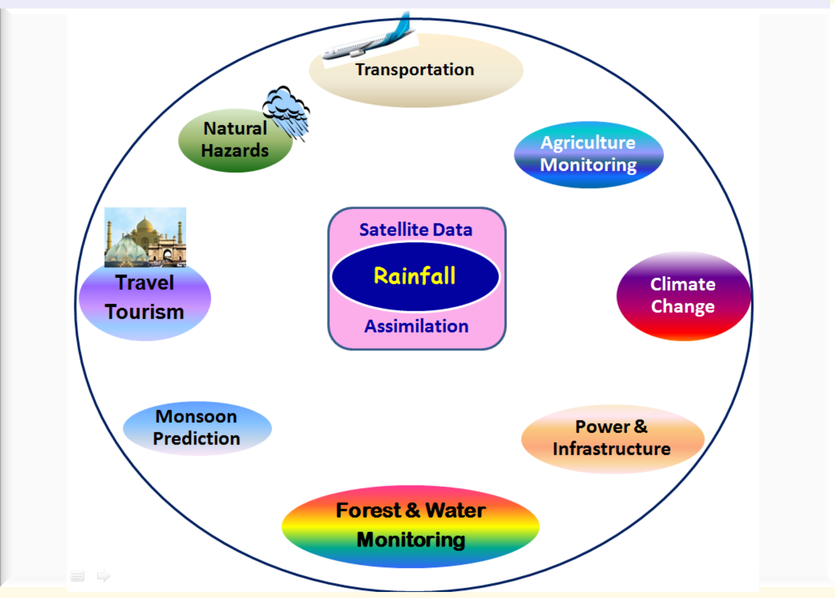
ABSTRACT

Rainfall is probably the most important parameter that is predicted by numerical weather prediction models. In this study, the Weather Research and Forecasting (WRF) model and its four-dimensional variational data assimilation system are used to assimilate the Tropical Rainfall Measuring Mission (TRMM) 3B42 and Japan Aerospace Exploration Agency (JAXA) Global Satellite Mapping of Precipitation (GSMaP) retrieved rainfall. A total of five experiments are performed daily with and without assimilation of rainfall data during the entire month of July 2011. Separate assimilation experiments are performed to assess the sensitivity of WRF model forecast with strict and less strict quality control. Assimilation of rainfall improves the forecast of temperature, specific humidity, and wind speed during Indian Summer Monsoon 2011. Domain average improvement parameter of rainfall forecast is also improved over the Indian landmass when compared with NOAA Climate Prediction Center Morphing technique and Indian Meteorological Department gridded rainfall.

INTRODUCTION

Rainfall is a highly variable parameter that varies in scales from few meters to several kilometers. The importance of accurate rainfall observation and forecast are widely recognized. Rainfall forecast is one of the most crucial and least accurate outputs available from numerical weather prediction (NWP) models. Since rainfall affects society directly or indirectly, the accuracy and skill of rainfall prediction at varying spatiotemporal scales are strongly desirable. An assessment of the quality of the rainfall forecast is important to understand the strengths and deficiencies of current assimilation/forecast systems and also in view of future weather/climate projection. Rainfall forecast from the NWP models has improved over the last decades with the continuous progress in both numerical model and data assimilation techniques [Benedetti et al., 2005; Bauer et al., 2011; Lopez, 2011]. However, still there is a need to explore the new opportunities for model development through the use of data from active and passive sensors jointly [Benedetti et al., 2005; Pu et al., 2002; Bauer et al., 2011]. Rainfall assimilation is considered as one of the important approaches to improve the weather forecasts, because rainfall observation includes the atmospheric information in terms of humidity, temperature, and winds and also contributes to the model atmospheric energy budget [Marecal and Mahfouf, 2003].

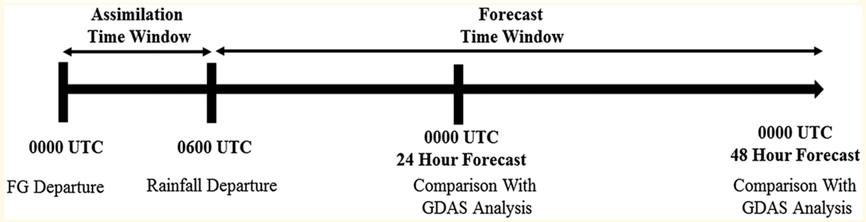


METHODOLOGY

The Weather Research and Forecasting (WRF) [Skamarock et al., 2008] model and its 4-D-Var data assimilation [Huang et al., 2009] system are used in this study to assess the impact of rainfall assimilation in a regional forecast modeling framework over the Indian region of south central Asia. Due to non-Gaussian distribution of the rainfall observation, it is obligatory to evaluate the characteristics of strict (3 times the observation minus background departure) and less strict (5 times the observation minus background departure) quality control (QC) in data assimilation, which is one of the main objectives of this study. Additionally, merged rainfall products from TRMM 3B42 and JAXA GSMaP are used in this study for both the cases of rain (when model rainfall value is greater than zero) and no-rain (when model rainfall value is equal to zero) over the entire domain compared to earlier studies in which swath data were used for assimilation. Preparation of separate background error covariance matrices for rain/no-rain cases is required for the rainfall assimilation, which may be the scope of future research.

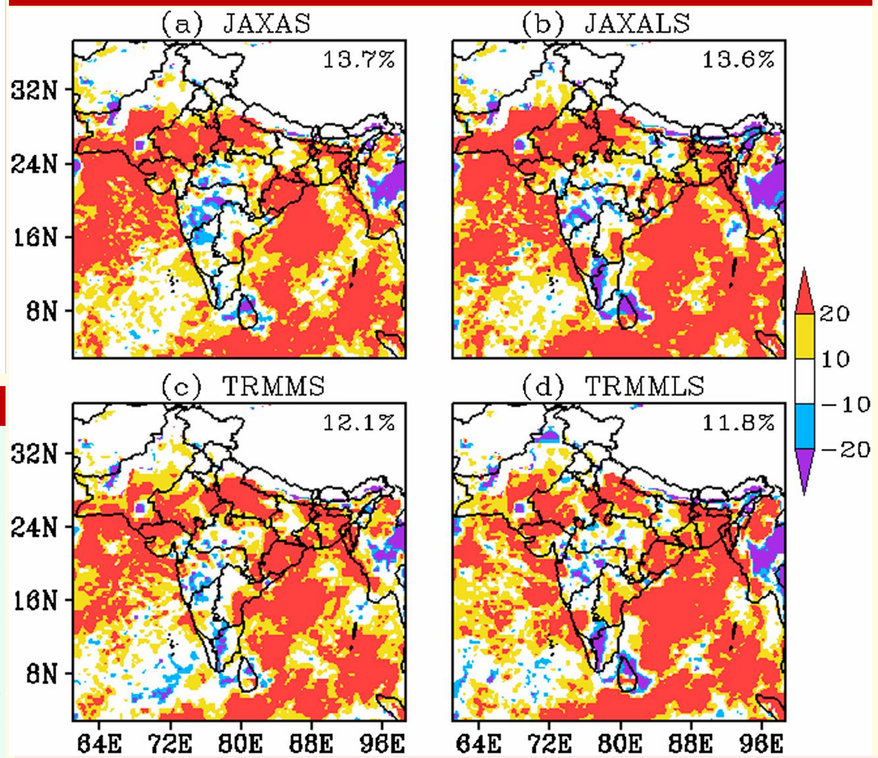
DESIGN OF EXPERIMENT

Schematic procedure to run the assimilation and forecast system. NCEP GDAS analysis is used as first guess at 0000 UTC, and rainfall data are assimilated at 0600 UTC. Thirty separate experiments are performed during July 2011.



Numerical Experiment	Data Used
CNT	No rainfall assimilation
JAXA strict (JAXAS)	JAXA rainfall with QC of 3 times the observation minus FG departure
JAXA less strict (JAXALS)	JAXA rainfall with QC of 5 times the observation minus FG departure
TRMM strict (TRMMS)	TRMM rainfall with QC of 3 times the observation minus FG departure
TRMM less strict (TRMMLS)	TRMM rainfall with QC of 5 times the observation minus FG departure

RESULTS AND DISCUSSIONS



Spatial distribution of improvement parameter in 24 h temperature forecast at 850 hPa from (a) JAXAS, (b) JAXALS, (c) TRMMS, and (d) TRMMLS experiments compared to control experiment. Domain average value of improvement parameter is also shown in the figure.

OVERVIEW OF THE FIT TO RAINFALL

For the successful rainfall assimilation, the observation minus analysis (OA; also known as analysis departure) is smaller than the observation minus background (OB; also known as background departure). The root-mean-square difference (RMSD) and mean difference are reduced after rainfall assimilation. Rainfall forecast from WRF analyses is closer to the rainfall observation compared to rainfall forecast from first guess. These results confirm the successful assimilation of TRMM 3B42 rainfall observations. Similar results are obtained when JAXA GSMaP rainfall observations are used for data assimilation experiments. Slightly smaller RMSD is observed in JAXA experiments.

CONCLUSIONS

- Rainfall assimilation improves the low-level temperature, moisture, and wind speed forecast.
- Results also show that rainfall assimilation improves the rainfall forecast.
- Large improvements are observed when JAXA GSMaP rainfall is used for assimilation compared to TRMM experiments.
- It is interesting to note here that in the first 24 h forecast, strict QC improves the forecast of temperature, moisture, winds, etc. But as the forecast length is increased from 24 h to 48 h, less strict QC experiments have more improvement compared to strict QC experiments.
- In this study, model analysis is also improved when no-rain information is used for assimilation which motivates the future research to use separate background error for precipitating and non-precipitating regions. Thus, assimilating the rainfall observation in the WRF model can be viewed as a positive step toward improving the accuracy of mesoscale numerical modeling for short-range weather forecast.

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