Four-dimensional Variational Data Assimilation of TRMM Data in Tropical Cyclone Prediction

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1. Introduction

Many studies have indicated that inclusion of rainfall data into numerical models can improve the accuracy of numerical weather prediction (e.g. Krishnamurti et al. 1993). Recently, Pu et al. (2002) assimilated the Tropical Rainfall Measuring Mission (TRMM)/TRMM Microwave Imager-derived surface rainfall rate (SRR) into the Goddard Earth Observing System with the one-dimensional + four-dimensional data assimilation technique (Hou et al. 2000) in the numerical simulation of a mature tropical cyclone. This study is to explore this idea further by directly assimilating the SRR data in a higher resolution model using the National Center for Atmospheric Research Mesoscale Model Version 5 (MM5) four-dimensional variational (4DVAR) data assimilation system. Results of several experiments to evaluate the impact of these data on the prediction of rainfall, track and intensity of Tropical Cyclone Danas (2001) during its initial development are presented.

2. Experiment design

A two-way interactive and triply nested MM5 model (54km x 18km x 6km) is employed in four experiments (Table 1). The initial conditions are derived from the NCEP/AVN analyses. Two experiments are conducted with (NB) and without (CTL) the SRR data (Fig. 1a). Since the initial AVN analysis contains a poor representation of the tropical cyclone vortex, two other experiments (BNT and BT) are conducted with a bogus vortex assimilated into the initial conditions (Zou 2000). All simulations are conducted for 72 h (3 Sep – 6 Sep 2001) during which Danas intensified into a typhoon and made an abrupt turn (Fig. 1b).

To include as much available data as possible but to avoid the spatial correlation for high-resolution data (such as in the 6-km inner domain), the SRR data are directly assimilated in the 18-km domain. The MM5 4DVAR system minimizes the least-squared differences between the SRR observations and the rainfall rates generated by the MM5 model averaged over a 6-h analysis window. The minimization procedure is stopped after 30 iterations.

3. Results

a. Rainfall distribution

Inclusion of the SRR data obviously improves the rainfall prediction, with the BT experiment giving the largest improvement (Fig. 2).

b. Track and intensity

Inclusion of the SRR data improves the track in all the experiments (Fig. 3a), with the BT experiment giving the most significant improvement. The minimum sea-level pressure (SLP) prediction is also the best in the BT experiment (Fig. 3b). In general, experiments with the SRR data produce a more intense tropical cyclone.

References

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TABLE 1. Design of numerical experiments

Numerical expt.	Bogus vortex?	Model initial condition
Control (CTL)	No	NCEP/AVN prediction without TMI SRR
NB	No	NCEP/AVN prediction with TMI SRR
BNT	Yes	NCEP/AVN prediction without TMI SRR
BT	Yes	NCEP/AVN prediction with TMI SRR

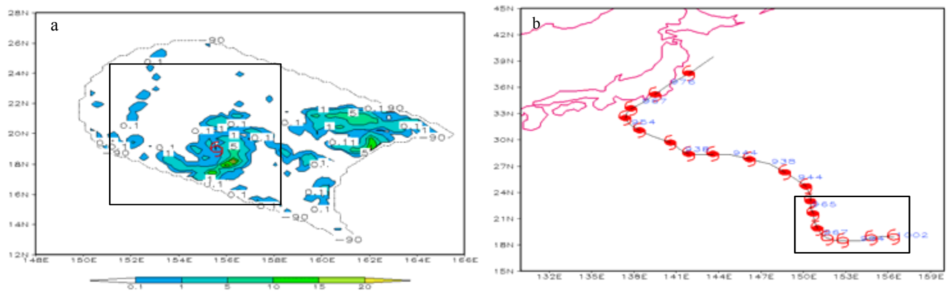

Fig. 1. (a) TRMM/TMI SRR (mm h^{-1}) at 0509UTC-0512UTC on 3 Sep 2001. The "-90" contour indicates the observed area and the SRR data inside the rectangle are assimilated. (b) Track of Danas from 00UTC on 3 Sep 2001 at 12-h intervals. The rectangle indicates the simulation period.

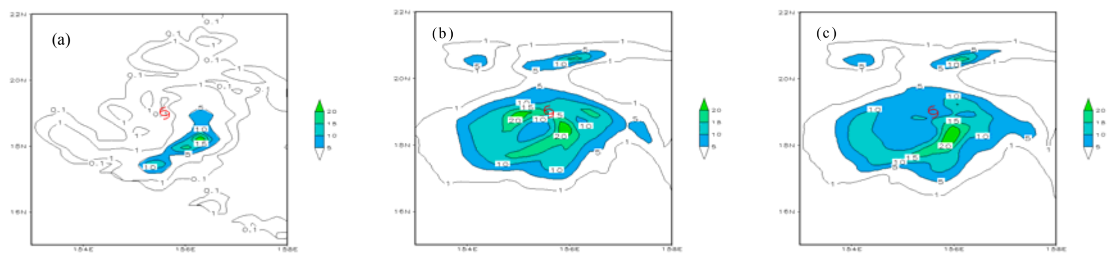

Fig. 2. (a) TRMM/TMI SRR, and simulated SRR in experiment (b) BNT and (c) BT at 0509-0512UTC 3 Sep 2001. Unit: mm h^{-1}.

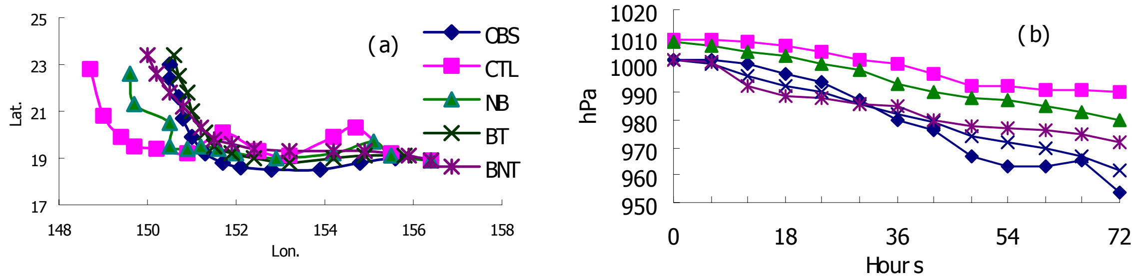

Fig. 3. Observed and predicted (a) tracks and (b) minimum SLP of Danas from 00UTC 3 Sep 2001.