1. Introduction

Microwave Radiometer (MWR) brightness temperatures (TBs) are particularly sensitive to hydrometers. To address the nonlinearity of TBs and the flow-dependency of the the Cloud-Resolving Model (CRM) forecast error covariance, Ensemble-based variational data assimilation method has been proposed (Zupanski 2005).

Though, there often exist large-scale displacement errors of the CRM rain forecasts. Accordingly, use of Ensemble forecast error covariance is not appropriate for data assimilation, particularly in observed rain areas without forecasted rain.

In order to solve this problem, we propose the Ensemble-based assimilation method that uses Ensemble forecast error covariance with displacement error correction.

2. TBS, CRM, and RTM used

2.1 TMI TBs

TRMM Microwave Imager (TMI) is a 5-frequency, 9-channel, conical-scanning MWR that measures at 10, 19, 21, 37, and 85 GHz.

2.2 CRM

JMA-NHM with horizontal resolution of 5 km (Saito et al. 2006).

We chose low-frequency TBs (10, 19, and 21 GHz) with vertical polarization as the input of the assimilation system.

2.3 RTM

Plane-parallel 4-stream RTM program of Liu (2004). We chose low-frequency TBs (10, 19, and 21 GHz) with vertical polarization as the input of the assimilation system.

3. Assimilation Method

We introduced displacement error $\Delta$ in addition to the CRM variables $x$.

The conditional probability of $x, \Delta$, given the observed TBs ($y$) and the first guess $x^* = P(x|y)$ can be written as:

$$P(x, \Delta|y) = P(\Delta|x, y)P(x|\Delta, y)$$

3.1 Displacement error correction scheme

We transformed $P(\Delta|x, y)$ using the Bayes' theorem:

$$P(\Delta|x, y) = P(x|\Delta, y)P(\Delta|y)$$

$$J_{\Delta} = 2/(h - H(X)(y)) + 1/2\Delta(x)^T\Delta$$

Global Gaussian distribution of $\Delta$. Minimizing the cost function $J_{\Delta}$ (Hoffman and Grassotti 1996):

1. Transformation of $\Delta$ into control variables in wave space;
2. Gradient of $J_{\Delta}$ is calculated with finite difference approximation;

3.2 Ensemble-based variational assimilation scheme

Cost function $J_x$ that corresponds to $P(x|y)$ (Lorenc 2003):

$$J_x = 1/2(X - \bar{X})P_x^{-1}(X - \bar{X}) + 1/2(t - H(X)(y))(t - H(X))$$

$X = (x_1, \ldots, x_N, \Delta_1, \ldots, \Delta_N)$, $\bar{X} = \bar{x}_1, \ldots, \bar{x}_N$, $P_x^{-1} = \sum_{i=1}^{N} P_x^{-1}(i)$, $P_x^{-1}(i) = \mathcal{S}$ (weighting function), $P_x^{-1} + S + \mathcal{S}$.

Minimizing the cost function $J_x$ to derive the optimum state $x^*$:

1. Eigenvalue decomposition of $S$:
2. Transformation of $\Delta$ into control variables:

We approximated Ensemble analysis error covariance $P_x$ to derive $x^*$ of each Ensemble members, following Zupanski (2005).

4. Results

We applied this assimilation method to assimilate TMI TBs at 22 UTC 9th June 2004.

To make the first guess for the assimilation, we performed CRM Ensemble forecasts started at 15 UTC.

4.1 Assimilation results

FG (the first guess): There existed large-scale positional differences in rainy areas

In particular, FG had no rain areas around the observed feeder band.

DE (after the displacement error correction): The calculated TB pattern was improved near the Typhoon center. Weak rain areas were made around the observed feeder band and warm sector.

CN (the analysis of the data assimilation system): The assimilation brought the rain pattern close to RAM. High TB19v areas were built up around the observed feeder band and warm sector.

4.2 Impact on CRM forecasts starting 22 UTC 9th June

- FG gave large-scale positional forecast errors and no rain areas over sea south of Okinawa after 1 hour of the time integration.
- DE alleviated the positional forecast error in the warm sector. Though, DE failed to maintain the feeder band after 1 hour.
- CN was successful in maintaining the rain areas in the observed feeder band.

This indicates that both displacement error correction and variational assimilation schemes were essential for the improvement.

5. Summary

In order to assimilate MWR TBs, we developed the Ensemble-based assimilation method that uses Ensemble forecast error covariance with displacement error correction. We applied this method to assimilate TMI low-frequency TBs for a Typhoon case (9th June 2004). The results show that this method alleviated large-scale positional errors of the precipitation areas, and both displacement error correction and variational assimilation schemes were essential for the improvement.

References:


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