Displaced Ensemble variational assimilation to incorporate MWI TBs into a CRM for Typhoon Conson

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GPM (Global Precipitation Measurement)

Core Satellite
- Dual frequency
- Precipitation Radar
- GPM Microwave Imager

Constellation Satellites
- Microwave radiometers

TRMM
- TMI
- PR

Aqua
- AMSR-E

ADEOS-II
- AMSR

DMSP
- SSM/I

NOAA
- AMSU-B

Concept of GPM
GOAL: Ensemble-based Variational Assimilation System to incorporate MWR TBs into CRMs

MWR TBs are functions of various atmospheric and surface variables

- Cloud Particles
- Frozen Precip.
- Snow Aggregates
- Melting Layer
- Rain Drops
- Water Vapor
- SST, Winds

3 mm-3cm

MWR TBs

Scattering

Radiation

0℃

Ensemble-based Variational Assimilation System

JMANHM (Saito et al., 2001)
- Resolution: 5 km
- Grids: 400 x 400 x 38

Resolution: 5 km
Grids: 400 x 400 x 38
OUTLINE

Introduction

Ensemble-based Variational Assimilation (EnVA)
  Methodology
  Problems in EnVA for CRM

Displacement error correction (DEC)+EnVA
  Methodology

Application results for Typhoon CONSON (T0404)

Summary
Minimize the cost function with non-linear Obs. term.

\[ J_x = 1/2 (\overline{X} - \overline{X}_f)P_f^{-1} (\overline{X} - \overline{X}_f) + 1/2 (Y - H(\overline{X}))R^{-1}(Y - H(\overline{X})) \]

Assume the analysis error belongs to the Ensemble forecast error subspace (Lorenc, 2003):

\[ \overline{X} - \overline{X}_f = P_e^{f/2} \circ \Omega \]

\[ \Omega = [\overline{w}_1, \overline{w}_2, \ldots, \overline{w}_N] \]

\[ P_e^{f/2} = [\overline{X}_1^f - \overline{X}_f, \overline{X}_2^f - \overline{X}_f, \ldots, \overline{X}_N^f - \overline{X}_f] \]

Forecast error covariance is determined by localization:

\[ \mathbf{P}^f = \mathbf{P}_e \circ \mathbf{S} \]

Cost function in the Ensemble forecast error subspace:

\[ J(\Omega) = 1/2 \text{trace}\{\Omega' S^{-1} \Omega\} + 1/2 \{H(\overline{X}(\Omega)) - Y\}' R^{-1} \{H(\overline{X}(\Omega)) - Y\} \]
Problem in EnVA (1): Displacement error

- Large scale displacement errors of rainy areas between the MWI observation and Ensemble forecasts.
- Presupposition of Ensemble assimilation is not satisfied in observed rain areas without forecasted rain.

TMI TB19v (2004/6/9/22UTC)

Mean of Ensemble Forecast (2004/6/9/15UTC FT=7h)
Ensemble-based assimilation for observed rain areas without forecasted rain

Assimilation can give erroneous analysis when the presupposition is not satisfied.

Signals from rain can be misinterpreted as those from other variables.

Displacement error correction is needed!
Problem in EnVA (2): Sampling error
Forecast error corr. of W (04/6/9/15z 7h fcst)

Heavy rain (170,195)

Weak rain (260,210)

Rain-free (220,150)

Severe sampling error for precip-related variables
Displacement error correction (DEC)+EnVA

- Methodology
- Application results for Typhoon CONSON (T0404)
  - Case
  - Assimilation Results
  - Impact on precipitation forecasts
In addition to $\bar{X}$, we introduced $\bar{d}$ to assimilation. The optimal analysis value maximizes:

$$\arg \max P(\bar{X}, \bar{d} | Y, \overline{X}^f)$$

$$P(\bar{X}, \bar{d} | Y, \overline{X}^f) = P(\bar{d} | Y, \overline{X}^f)P(\bar{X} | \bar{d}, Y, \overline{X}^f)$$

Assimilation results in the following 2 steps:

1) DEC scheme to derive $\bar{d}^a$ from $P(\bar{d} | Y, \overline{X}^f)$

2) EnVA scheme using the DEC Ensembles to derive $\bar{X}^a$ from $P(\bar{X} | \bar{d}^a, Y, \overline{X}^f)$
Assimilation Procedures

CRM Ensemble Forecasts

\[ J_d = \frac{1}{2} (Y - H(\tilde{X}^f(\tilde{d})))' R^{-1} (Y - H(\tilde{X}^f(\tilde{d}))) + |\tilde{d}|^2 / 2 \sigma_d^2 \]

Displacement Error Correction

\[ (\tilde{X}^f, P^f, H(\tilde{X}^f)) \]

Ensemble-based Variational Assimilation

\[ J_x = 1/2 (\tilde{X} - \tilde{X}^f(\tilde{d})) P^{-1}_f (\tilde{X} - \tilde{X}^f(\tilde{d})) + 1/2 (Y - H(\tilde{X})) R^{-1} (Y - H(\tilde{X})) \]

MWI TBs
Case (2004/6/9/22 UTC) TY CONSON

Assimilate TMI TBs (10v, 19v, 21v) at 22UTC

RAM (mm/hr)
CRM: JMANHM (Saito et al, 2001)
- Resolution: 5 km
- Explicitly predict hydrometeors

Ensemble forecasts
- 100 members started with perturbed initial data at 04/6/9/15 UTC (FG)
- Geostrophically-balanced perturbation (Mitchell et al. 2002) plus Humidity

- Plane-parallel model (4stream approx.)
- Mie Scattering (Sphere)
TB19v from TMI and CRM outputs

FG: First guess

DE: After DEC

TMI

ND: NoDE+ EnVA

CN: DE+ EnVA
RAM and Rain mix. ratio analysis (z=930m)
RH (contours) and W (shades) along N-S
Hourly Precip. forecasts (FT=0-1 h) 22-23Z 9th
Hourly Precip. Forecasts (FT=3-4 h) 01-02Z 10th
Summary

Ensemble-based data assimilation can give erroneous analysis, particularly for observed rain areas without forecasted rain.

We developed an ensemble-based assimilation method that uses Ensemble forecast error covariance with displacement error correction.

The application results (T0404) showed that the assimilation of TMI TBs alleviated the large-scale displacement errors and improved precip forecasts.

The scheme also avoided misinterpretation of TB increments due to precip displacements as those from other variables.
Thank you for your attention.

End