Dual-Scale Neighboring Ensemble Variational Assimilation of Satellite Microwave Imager Brightness Temperatures for Typhoon ETAU

Kazumasa Aonashi* (aonashi@mri-jma.go.jp), Kozo Okamoto*, and Tomoko TASHIMA#
*Meteorological Research Institute (MRI) / JMA #RESTEC

1. Introduction

- The goal of the present study is to assimilate precipitation-related observations, such as satellite microwave imager (MWI) brightness temperature (TB) into Cloud-Resolving Models (CRM) .
- To handle the nonlinearity of precipitation-related observations, we developed ensemble-based variational data assimilation (EnVA) methods (Zupanski 2005; Aonashi and Eito 2011) .
- We developed new EnVA scheme that included a sampling error damping method, multi-regime PDF assumption.
- To examine this method, we performed experiments which assimilated AMSR2, GMI, and SSMISTBs for a Typhoon Etau (T1518) case.

2. Assimilation system basis

- EnVA: A variational scheme that minimize cost function in ensemble forecast error subspace (Lorenc 2003)

$$J(x) = J(\Omega) = \left(x - \overline{x^f}\right)^T \mathbf{P}^{-\mathbf{f}}\left(x - \overline{x^f}\right) + \left(y - H(x)\right)^T \mathbf{R}^{-1}\left(y - H(x)\right)$$

$$x - \overline{x^f} = P_e^{f/2} \circ \Omega \qquad P_e^{f/2} = \left(x_1^f - \overline{x^f}, x_2^f - \overline{x^f}, ,,, x_N^f - \overline{x^f}\right)$$

$\mathbf{P^f} = \mathbf{P_e^f} \circ \mathbf{S}$: **S** spatial localization

  - Analysis variables :U,V, W, PT, ratio of (qv+qc+qci) to qvs (RTW), precipitation rate (Pr), and surface pressure (Ps)
- CRM: JMA-NonHydrostatic Model (JMA-NHM; Saito et al., 2006)
  - Operationally used in the meso-scale NWP system in JMA (5 km res.)
  - Cloud microphysics based on 3-ice bulk scheme

3. New EnVA scheme

3.1 Sampling error damping methods (DuNE)

- Based on the spectral locality of forecast error, the correlation C between locations $x1$ and $x2$ are expressed as a weighted moving average:

$$C_{sl}(x1, x2) = \int C(x1+s, x2+s) L_{sl}(s) ds$$

- A neighboring ensemble (NE) method estimated C at the target grid point, using ensemble members for neighboring grid points.

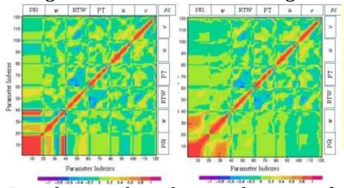


Fig.1; The vertical cross correlation between PR, *w*, RH, PT, *u*, *v*, and Ps at a point with weak precipitation
(left) calculated by the conventional method.
(right) calculated by the NE method.

- In order to reduce the sampling error further, we horizontally divided the NE forecast error into large-scale portions and deviations, and calculated the horizontal correlation of the combination of precipitation-related and other variables for the deviations.
- In the EnVA scheme P_e^f consists of large-scale portions and deviations.

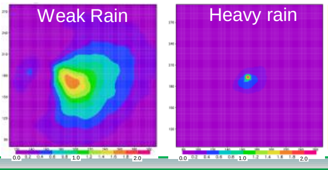


Fig.2: Analysis increment of U (m/s) generated by assimilating pseudo-RAOB. The area is 1000km X 1000km.

This shows expected scale variation according to precipitation conditions.

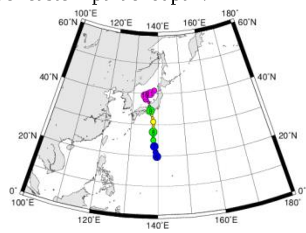
3.2 Multi-Regime PDF

- In order to address non-Gaussianity, we assume that a priori PDFs of physical variables are expressed as the mixture of two regimes (clear and cloudy-rainy regimes $\Pr(\vec{X}^f) = \sum_{j=1}^{J} w^{f,j} \Pr(\vec{X}^{f,j} : \bar{X}^{f,j}, P^{f,j})$
- Then, the conditioned (a posteriori) PDFs given observation Y, can be written as follows: $\Pr(\vec{X}^a \mid \vec{Y}) = \sum_{j=1}^{J} w^{a,j} \Pr(\vec{X}^{a,j} : \bar{X}^{a,j}, P^{a,j})$
- Hence, the retrieval results in searching the conditioned regime probability $w^{a,j} = \Pr(r = j \mid \vec{Y})$ and the analysis for each regime.
- In the EnVA scheme, we calculate the analysis for the clear regime, assuming zero Pr and qc. we calculated analysis for the cloudy-rainy regime in cloud-rain certain areas.
- Multi-regime assumption also allowed us to use simplified forward calculation for the clear regime, different observation errors and QCs in the EnVA.

4. Results of Assimilation Experiments

4.1 Meteorological Case

- Typhoon Etau (T1518) caused heavy rain (over 600mm/2day) and floods over eastern part of Japan.



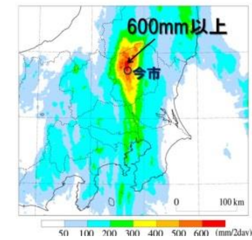


Fig.3: (left) Observed Typhoon track for Etau
(right) 24 hour precipitation for 9-10th Sep.

4.2 Assimilation Experiments

- We executed 52-member ensemble forecast started at 00UTC 7th.
- Using the EnVA scheme, we performed EnVA FA cycle which assimilated GMI, SSMIS, and AMSR2 TBs (10v,18v,23v, 36v, and 89v) .
- CRM forecast started with analysis for ensemble mean at 17 UTC 8th.

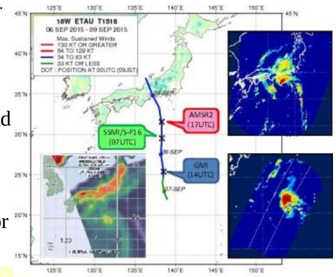


Fig.4: The MWI data assimilated in the FA cycle

4.3 Impact on Analysis & forecast

- The assimilation made large-scale analysis increments for relative humidity, surface pressure, and horizontal wind speeds.

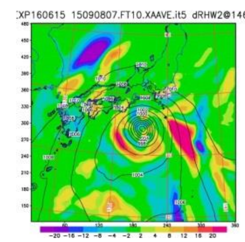


Fig. 5: Analysis increment of RH(H=1460m) for ensemble mean at 17 UTC 8th.

- The assimilation significantly improved a CRM precipitation forecast up to 30 hours, in particular, by strengthening and stagnating a rain band over the Kanto Plain.

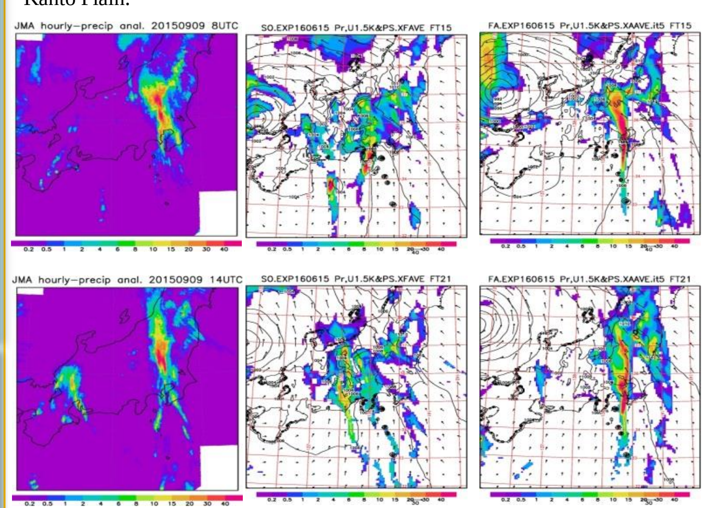


Fig. 6: Hourly precipitation for 08UTC (upper) and 14 UTC 9th (lower)
Radar Obs(left), CRM forecast w/o TB assim. (center), and CRM forecast w TB assim. (right)

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