Application of EnVar using the mixed-lognormal PDF of and a new displacement correction method for precipitation to all-sky MWI TB assimilation

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1. Introduction

- The goal of the present study is to assimilate all-sky microwave imager (MWI) brightness temperature (TB) into Cloud-Resolving Models (CRM) .
- For better assimilation, we introduced a non-Gaussian Probability Distribution Function (PDF) and a new displace correction method for precipitation into the Dual-scale Neighboring Ensemble(DuNE)-based variational assimilation scheme (Aonashi et al, 2016).

2. Assimilation system basis

- 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
- DuNE: NE method estimated forecast error correlation C, using ensemble members for neighboring grid points.
  In order to reduce the sampling error further, we horizontally divided the NE forecast error into large-scale portions and deviations.
- DuNE-EnVar: A variational scheme that minimize cost function in DuNE forecast error subspace (Lorenc 2003)

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

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

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

3. Methods

3.1 Introduction of a non-Gaussian PDF

- We validated the fitness of existing non-Gaussian PDF models to the precipitation forecast error of various disturbance cases with the chai-square values of Lien et al (2016): $\bar{\chi}^2 = \frac{1}{N}\sum_{i=1}^{N}(X_i - X_i^e)^2/\sigma^2, \ X_i^e = \bar{X} + \sigma F(i)$

Variable (PDF model)	U (Normal)	PT (Normal)	Precip (Normal)	Precip (Mixed normal)	Precip (Log-normal	Precip (Mixed log-normal)
Low	0.1424	0.1514	0.4387	0.2704	0.3766	0.1866
Baiu	0.1409	0.1781	0.7697	0.5682	0.6591	0.2511
T0404	0.1377	0.1834	0.8362	0.5463	0.7363	0.2283
T1306	0.1344	0.1608	0.9351	0.5086	0.9169	0.2611
T1411	0.1376	0.1582	0.8351	0.3740	0.7946	0.2091
T1518	0.1342	0.1400	0.7948	0.4235	0.7659	0.2318

- Based on the results, we chose the mix-lognormal distribution as the precipitation forecast error PDF.
- We introduced rain-free and rainy PDF regimes to the EnVar in order to apply the mix-lognormal distribution. $\Pr(\vec{X}^f) = \sum_{j=1}^{J} w^{f,j} \Pr(\vec{X}^{f,j} : \bar{X}^{f,j}, P^{f,j})$

3.2 A new precipitation displacement correction method

- In addition to DEC method of Aonashi and Eito (2011), we developed a new method for grid points without PDF regimes match with the observation.

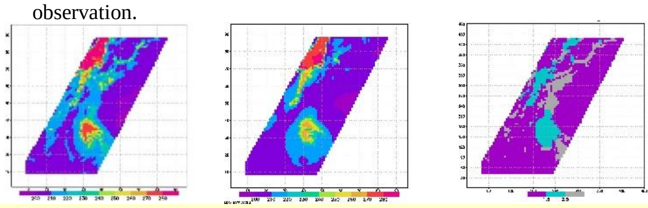


Fig.1:(left) GMI TB19v observation (K) for 2015/9/7/14 UTC (mid) TB19v cal from CRM NE (right) PDF regimes (rain-free or rainy) with the highest likelihood.

- This method introduced pseudo PDFs as the regional average of NE forecast error PDFs (deviation part) which belonged to the same regime (rain-free, weak rain, or heavy rain) as the observation of the target point.
- We decided the horizontal scales of the averaging based on the similarity of precipitation forecast error.

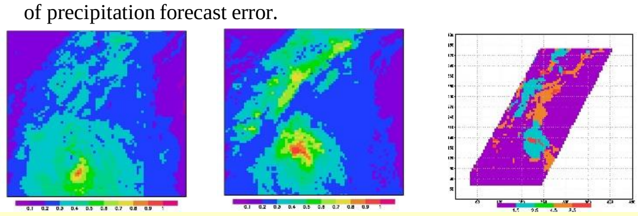


Fig.2: Similarity of precip forecast error for (left) weak rain and (mid) heavy rain points (right) PDF regimes (including pseudo regimes) with the highest likelihood.

4. Results of Assimilation Experiments

4.1 Meteorological Case

- Typhoon Etau (T1518) landed on Sep. 8th, 2015, and caused heavy rain(over 600mm/2dy) and floods over eastern

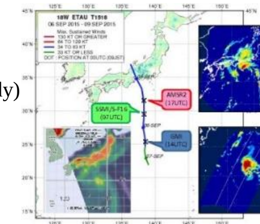
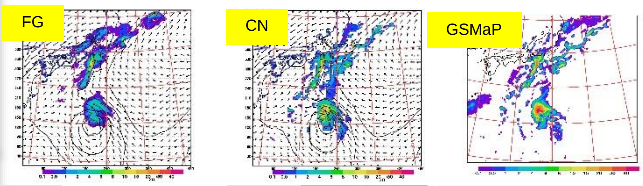


Fig.3: Observed Typhoon track for Etau and The MWI data assimilated in the FA cycle

4.2 Single Observation Experiments

- We executed 52-member ensemble forecast started at 00UTC 7th.
- To check the EnVar, we performed experiments which assimilated GMI TBs for 14UTC 7th ,and compared with GSMaP precip analysis:

CN: The EnVar of the present study
FG: First guess for the EnVar (no Assimilation)
GD: Assimilation using normal PDF model, w/o displacement correction
MLD: Assimilation using mixed log-normal PDF model, w/o displacement correction



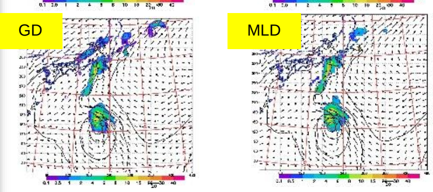


Fig. 4: Analyses of 1hr precip (shade), Ps (contour), Winds(H=1460m) , and GSMap precip for 14 UTC 7th

- The results showed that the EnVar of the present study made precipitation analysis close to the observation, and modified surface pressure and horizontal wind analysis around the typhoon.
- The introduction of the mixed-lognormal PDF strengthened precipitation analysis for heavy rain areas, compared to the normal PDF. The use of the pseudo PDFs eliminated the precipitation displacement error of the analysis.

4.3 Validation of Forecast Analysis Cycle

- Using the EnVar scheme, we performed FA cycle using TBs observed with GMI (14UTC 7th),SSMIS(07UTC 8th), and AMSR2(17UTC 8th).
- FA improved CRM forecasts for heavy rain around the typhoon center up to 6 hours and a heavy rain band associated with the typhoon for more than 24 hours.

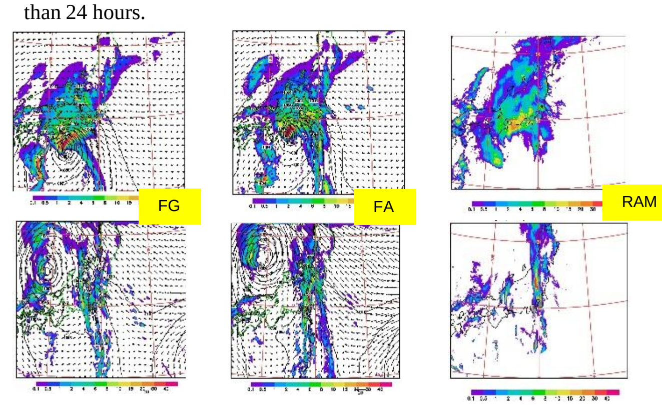


Fig. 5: Hourly precipitation (upper) for 20UTC 8th (FT03h) and (lower) 17 UTC 9th (FT24h) (left)CRM forecast w/o TB assim, (center) CRM forecast given by FA. (right) Radar Obs.

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