Sampling Error Damping Method for a Cloud-Resolving Model Based on Ensemble Forecast Error Analysis

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1. Introduction

To address the nonlinearity of MWR TBs and the flow-dependency of the Cloud-Resolving Model (CRM) forecast error, ensemble-based variational data assimilation (EnVA) method has been proposed (Zupanski 2005, Aonashi and Eito 2011). Though, there often exist serious sampling errors of the CRM ensemble forecasts. In order to solve this problem, some error-damping methods have been proposed.
We analyzed CRM ensemble forecasts to check the validity of presumptions of these methods. Based on that we developed the sampling error damping method that estimated plausible forecast error correlation for precipitation-related variables.

2. CRM ensemble forecasts

CRM: JMANHM with horizontal resolution of 5 km (Saito et al. 2006).

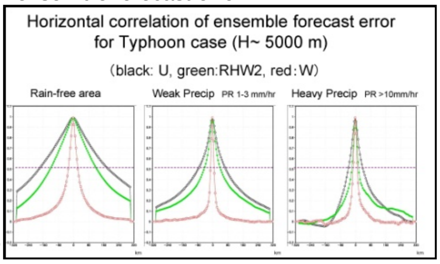
Ensemble forecasts: We performed 100-member 7-hour forecasts that started with initial values with geostrophically-balanced perturbation (Mitchell et al. 2002) plus humidity perturbation.

Cases: Typhoon ('04/6/9/15 UTC), Extra-tropical low ('03/1/26/21UTC), and Baiu front ('04/6/1/00 UTC)

3. Analyses of CRM Ensemble forecast error

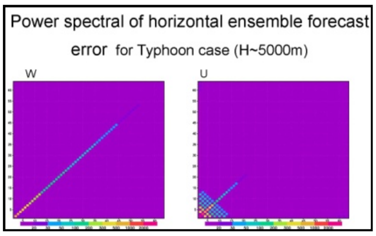
3.a Horizontal correlation of ensemble forecast error

1) Precipitation-related variables (precip, W) had narrow correlation scales (~ 15 km).
2) Horizontal correlation scales of the other variables (U, V, PT, RH) decreased (160 km -> 40 km) with precipitation rate.



3.b Power spectral of horizontal ensemble forecast error

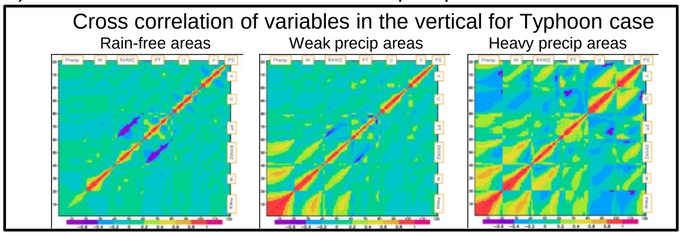
1) Diagonal modes are dominant for precipitation-related variables. Off-diagonal modes are negligible.
2) The other variables had significant amplitudes for low-frequency, off-diagonal modes.



3) The presumption of the spectral localization "Correlations in spectral space decreases as the difference in wave number increases" is valid for the CRM ensemble forecast error.

3.c Cross correlation of CRM variables in the vertical

1) Cross correlation between precipitation-related variables and other variables increases with precipitation rate.
2) Variables can be classified in terms of precipitation rate.



4. Sampling error damping method

4.a Neighboring ensemble

Spectral Localization (Buehner and Charron, 2007)

$$\hat{C}_{sl}(k1,k2)=\hat{C}(k1,k2)\hat{L}_{sl}(k1,k2)$$

When transformed into spatial domain

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

we approximated the forecast error correlation using neighboring ensemble (NE) members of the target points (5 x 5 grids).

4.b Separation of Large-scale and Local modes

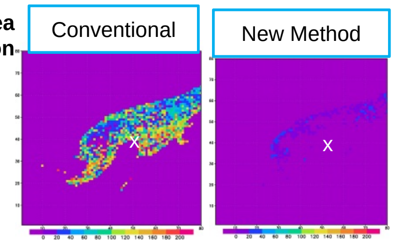
We need to address the scale differences between the precipitation- related variables and the other variables.

For this purpose, we separated the other variables into large-scale modes (average over 65 km) and local modes (derivation from the average).

Zero cross correlation was assumed between different modes.

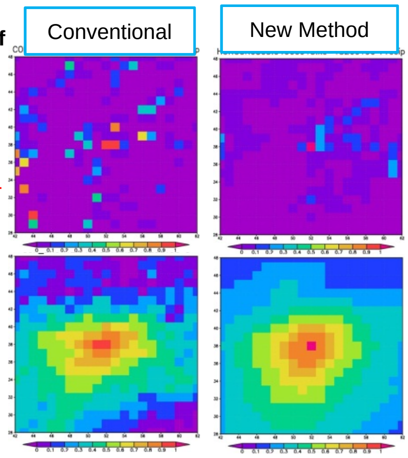
5. Application Results

Averaged distance of area with horizontal correlation of precipitation over 0.5: (Typhoon case, H~3 km)



The new method damped "False high correlation" induced by sampling error compared with the conventional ensemble method.

Horizontal correlation of Precipitation (upper) and U (lower) at large sampling error area (Point X):



Concentrated patterns for precip-related variables.

Large-scale patterns for the other variables (U,V etc).

The new method was successful in estimating plausible correlation patterns.

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