Based on the spectral locality of forecast error, the correlation of 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, and equivalent linearization for water subsistence. To examine this method, we performed OSSEs and assimilated simulated MWI TBs for a typhoon case.

3. New EnVA scheme

3.1 Sampling error damping methods (DuNE)

Based on the spectral locality of forecast error, the correlation of precipitation-related observations, such as satellite microwave imager (MWI) brightness temperature (TB) into Cloud-Resolving Models (CRM).

In the EnVA scheme, we calculate the analysis for the clear regime, different observation locations, and the analysis for each regime. We calculate the analysis for the cloudy-rainy regimes.

Hence, the retrieval results in searching the conditioned (a posteriori) PDFs given observation $Y$ (4) can be written as follows:

$$p(x) = f(Y) = \frac{f(Y)}{f(Y)}, \quad \sum_{x \in \Omega} p(x) = E(Y)$$

In the EnVA scheme, we calculate the analysis for the clear regime, assuming zero $P$ and $q$. 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.

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: $p(x|Y) \propto \sum_{x \in \Omega} p(x|Y)$).

Then, the conditioned (a posteriori) PDFs given observation $Y$, can be written as follows:

$$p(x|Y) = \sum_{x \in \Omega} p(x|Y)$$

Hence, the retrieval results in searching the conditioned regime probability $w(x) = Pr(Y=x|Y)$ and the analysis for each regime.

In the EnVA scheme, we calculate the analysis for the clear regime, assuming zero $P$ and $q$. 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.

3.3 Equivalent linearization for water subsistence increments

In order to derive consistent water subsistence increments, we chose $P$ and RTW as the EnVA control variables, and calculated the increments by the equivalent linearization:

$$Q^* - Q^0 = \Sigma_{x \in \Omega} \Sigma_{x \in \Omega} (X^* - X^0)$$

The covariance $\Sigma_{x \in \Omega}$ and $\Sigma_{x \in \Omega}$ were calculated from the NE.

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