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Dual-Scale Neighboring Ensemble Variational Assimilation for a Cloud-Resolving Model

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1. Introduction

The purpose of the present study is to develop an Ensemble-based Variational Assimilation (EnVA) scheme with sampling error damping method for the Cloud-Resolving Model (CRM). This is because, in ensemble-based assimilation schemes for CRMs, sampling error is serious, in particular, for precipitation-related variables (precipitation rate, vertical wind speed) because they are confined in rainy areas.

2. Dual-Scale Neighboring Ensemble Variational Assimilation method

Based on the CRM ensemble forecast error analyses for various precipitation cases, we developed the sampling error damping method that consisted of a Neighboring Ensemble (NE) method and a dual scale separation of NE. The NE method approximated the forecast error correlation using NE members within a reduced-grid box (5 x 5 grids in the present study) based on the spectral localization assumption. In the dual scale separation, we divided the NE forecast error into large-scale portions (13 x 13 grid averages in the present study) and small-scale deviations so as to reflect the horizontal scale differences in forecast error between precipitation-related variables and others.

In order to introduce the sampling error damping method to the three-dimensional EnVA, we assumed that the EnVA analysis increments were subject to the dual scale NE forecast error subspace. In addition, we introduced a vertical reduce approximation using the primary Singular Value Decomposition (SVD) modes of the vertical cross correlation of the dual scale NE forecast error. Since the SVD modes were mutually independent, the three-dimensional cost function of EnVA resulted in that for the horizontal component of the analysis increment of the each SVD mode. Then, we horizontally diagonalized the background term of the cost function using the horizontal correlation of the NE forecast error. We used the conjugate gradient scheme to solve the nonlinear minimization of the cost function, and obtained the optimal analysis increment for the ensemble mean. Then, we calculated the analysis increments for ensemble members with the analysis error covariance at the reduced grids.

3. Results of OSSEs

In order to examine the EnVA scheme, we performed OSSEs for several meteorological disturbance cases. The results show that the NE method was successful in producing plausible analyses of precipitation-related variables from the simulated surface precipitation even for grid points where less than 20 % of the ensemble members forecasted precipitation, and that the dual scale separation of NE made spatial scale changes in analysis increments in correspondence with precipitation rates. The EnVA scheme was also successful in retrieving precipitation flags and precipitation profiles from the simulated multi-channel microwave brightness temperatures that were non-linear functions of various precipitation-related variables.

Keywords: Ensemble-based variational data assimilation, Neighboring ensemble, Dual-scale separation, GPM, GCOM, microwave imager