A 4DEnVAR data assimilation system without vertical localization using the K computer

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Like the ensemble Kalman filter, the ensemble variational method (EnVAR) uses localization to remove unrealistic correlations between distant points due to a limited number of ensemble members. This also helps to increase the rank of background error covariances, thus maintaining stability of data assimilation systems. However, localization results in imbalance in analysis fields, which degrades forecast quality especially in the cases like heavy rainfall events or tropical cyclones where strong vertical correlations are expected.

Localization is employed by introducing a predefined function to taper correlations at distant points to zero, and usually separated into horizontal and vertical localization. Here the same localization function is applied for all grid points without considering physical processes there, e.g. no differentiation between intense rain and no rain. Thus, vertical localization is clearly the main source for imbalance in analysis fields. This can be avoided if the number of ensemble members is in the order of 1000, which can be achieved using the K computer.

When vertical localization is not employed into EnVAR, the same weight is applied for all grid points in each vertical column to determine analysis increments. This reduces the computational cost by a factor of the number of vertical levels (about 40) compared to the case using vertical localization. Since the number of ensemble members increases from the order of 100 to the order of 1000, the computational cost increases by a factor of 10-20. That means EnVAR without vertical localization in fact consumes less computational cost than EnVAR with vertical localization. Thus, when not employing vertical localization, all computational resources are almost used for integrating ensemble members and generating analysis perturbations.

To demonstrate the benefit of EnVAR without vertical localization, a four dimensional EnVAR system using 1600 ensemble members has been developed in the K computer. The system was built around the operational limited area model NHM of Japan Meteorological Agency (JMA). The deterministic EnKF method combined with the block GMRES method was used to generate analysis perturbations. This ensures consistency between analyses and analysis perturbations when the same Kalman gain is used in both cases. The system was applied for prediction of several heavy rainfall events in Japan. The forecast results are shown to outperform those of the operational 4DVAR system of JMA.

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