Development of CReSS-Hybrid-LETKF for improving cloud-scale predictability

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In convective-scale data assimilation, the Local Ensemble Transform Kalman Filter (LETKF) has become the dominant methodology. However, LETKF requires a large number of ensemble forecasts, resulting in substantial computational cost, and the independent preparation of ensemble forecasts has posed a significant obstacle for many research groups. In recent years, the Japan Meteorological Agency (JMA) Mesoscale Ensemble Prediction System (MEPS) has been made available through the Japan Meteorological Business Support Center and the Meteorological Research Institute’s senjou-kousuitai database, substantially lowering the barrier to conducting LETKF-based assimilation experiments. MEPS consists of 21 ensemble members and adopts an initial perturbation strategy based on singular vector methods. A distinctive feature is that ten perturbations are generated for both the global-scale and mesoscale fields, targeting regions where forecast error growth is expected. In this study, we developed an LETKF system based on the code released by the RIKEN Data Assimilation Research Team. The parallelization strategy and observation operators were improved, and a new function was implemented to interpolate ensemble perturbations onto forecast grid points. This enables LETKF execution with an array structure consistent with the domain decomposition of the cloud-resolving model CReSS, facilitating seamless coupling with forecast integration. Furthermore, following Kotsuki and Bishop (2022), we introduced a hybrid approach that blends ensemble-based and climatological background error covariances. As an initial performance evaluation, pseudo-dropsonde observations (wind direction, wind speed, temperature, and humidity) were assimilated using LETKF. The results show analysis increments for various prognostic variables, as illustrated in Fig. 1. A case study of the Baiu front around Kyushu was examined using JMA MEPS at 18 UTC on 23 June 2024 as initial conditions. Ensemble forecasts were conducted at 4-km resolution, and ensemble perturbations were derived from the 2-h forecast valid at 20 UTC. These perturbations were then used for LETKF assimilation in CReSS at 1-km resolution. Approximately 100 km south of the Baiu front, ensemble perturbations were small, and the hybrid method effectively compensated through climatological error covariance, demonstrating its beneficial role in regions of weak ensemble spread.

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