Progress Report

1. Title and PIs
Multi-model Ensemble Reanalysis System (MERS) Using the 4D-Local Ensemble Transform Kalman Filter (4D-LETKF)
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2. Initiation Year and Planned Duration
2009 for 3 years

3. Project Goal:
In response to Dr. Steve Lord's request, the primary goal of this project was changed to the investigation of the hybrid data-assimilation system performance for the reanalysis based on the currently operational GSI 3DVar. The second goal, which was the original goal of this project, is the development of a pilot data assimilation system for the next generation reanalysis of the coupled atmosphere-ocean system based on the Ensemble Kalman Filter (EnKF) approach and a multi-model ensemble (MME) approach.

4. Status, Progress, and Accomplishment
a. Hybrid data assimilation system for reanalysis.
In order to assess the hybrid data-assimilation system performance for the reanalysis, we are implementing the system in the SPEEDY model. As an atmospheric general circulation model with the simplified physical parameterizations and the coupling capacity to the ocean and land-surface models, the SPEEDY is computationally efficient and allows us to conduct various types of the experiments while developing the schemes tailored for the reanalysis. The SPEEDY also offers the feasibility towards the future development for the reanalysis of the coupled atmosphere-ocean(-land) system. Moreover, the state-of-the-art EnKF is readily available for the SPEEDY based on the Local Ensemble Transform Kalman Filter (LETKF).
i) We have implemented the 3DVar data assimilation system using the SPEEDY model for the three types of observing networks (sparse, realistic, and dense) using the matrix square root of the background covariance **B** for preconditioning (Figures 1 and 2).
ii) To tailor the 3DVar data assimilation system for the NCEP GSI system, we are currently implementing the recursive filter for **B** and the preconditioning procedure based on **B** itself. Our hybrid data assimilation system will be built on this 3DVar system using the ensemble available from the LETKF.
iii) We have developed a new hybrid method based on LETKF. An advantage of this method is the simplicity in treating the data-assimilation system s the fully coupled hybrid, as opposed to the current one-way coupling from the EnKF to the hybrid. Like the extension from the LETKF to 4DLETKF is trivial, the extension to the 4D hybrid data-assimilation system will be straightforward based on this new method.
b. Coupled atmosphere-ocean data assimilation system for the reanalysis
The focus of this investigation is how to handle the different temporal scales present in the atmosphere and the ocean for the reanalysis. The development is currently pursued using the highly nonlinear, idealized coupled atmosphere-ocean model.

i) We have successfully implemented the 4DVar into the ocean component of the coupled model. In order to handle the slow temporal scales present in the ocean effectively, we have implemented the quasi-static scheme.
ii). We have successfully implemented the parameter estimation scheme in the 4DVar for the atmospheric flux estimation.
iii) We have successfully implemented the 4DLETKF into the coupled atmosphere-ocean model. We have applied the "localization" between the models to effectively remove the spurious correlations generated by the finite size ensembles. This "localization" scheme, along with the 4D scheme, will play a key role for the reanalysis of the coupled ocean-atmosphere system with different temporal and spatial scales.

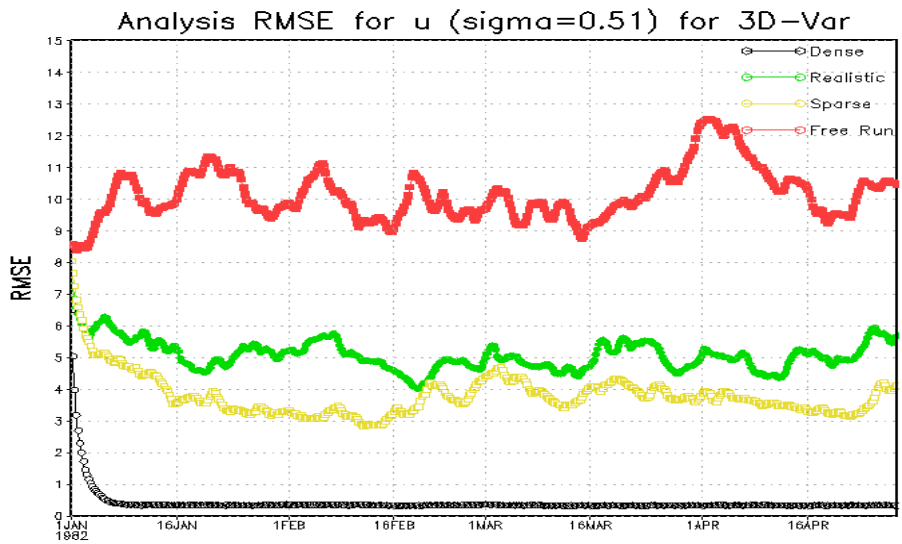

Figure 1. RMSE of the 3DVar performance for the three observing system, i.e., dense (black), realistic (green), sparse (yellow).

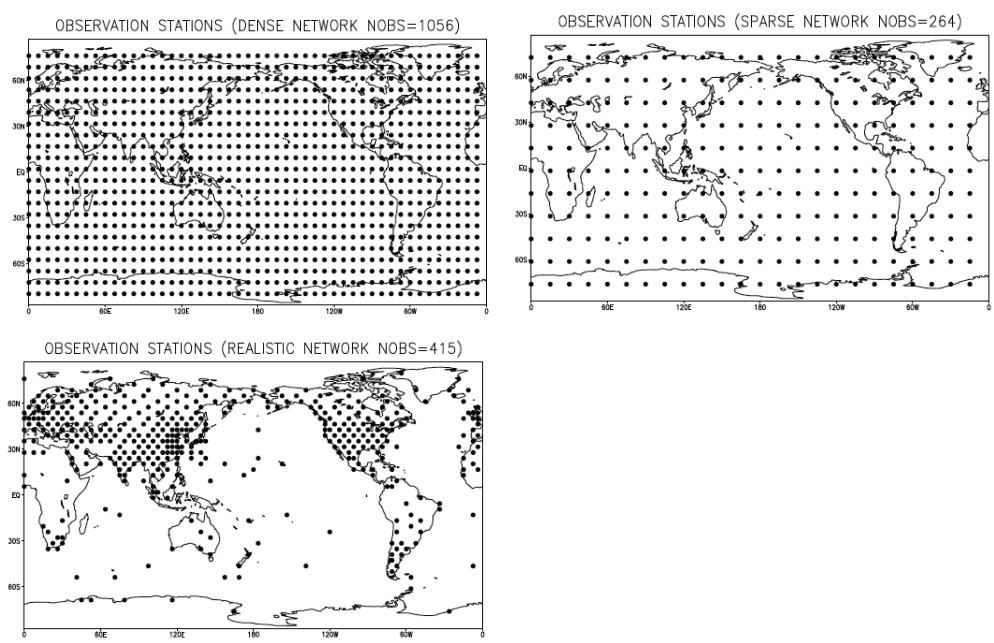

Figure 2. Observing network.