Hybrid 4DEnVar at NCEP

Rahul Mahajan, Daryl Kleist, Catherine Thomas, Yanqiu Zhu, and John Derber

Hybrid EnVar

The use of hybrid covariance models, which combine a fixed climatological estimate with an ensemble-based representation, has become quite popular for numerical weather prediction (NWP). One such method for incorporating localized covariances from an ensemble within the variational framework utilizes an augmented control variable (ensemble-var, or EnVar), and has been implemented in the operational NCEP data assimilation system (Gridpoint Statistical Interpolation, GSI). As first proposed in Lorenc (2003) and igniting preconditioning for simplicity, the ensemble correlation (with an extension for 4DVAR) for such an algorithm can be written as:

\[ f(x, t) = \frac{\sum_{i=1}^{n} \beta f}{\sum_{i=1}^{n} \beta f(x_i) + \sum_{i=1}^{n} \beta f(x_i) - \sum_{i=1}^{n} \beta f(x_i)} \sum_{i=1}^{n} \beta f(x_i) \]

Where \( B \) is the static background error covariance, \( R \) the observation error covariance, \( M \) the observation operators, \( y \) the observation innovation, \( \alpha \) the control variable used to enforce localization. The total analysis increment is then constructed to be a linear combination of static \( x \) and ensemble contributions:

\[ x = M \sum_{i=1}^{n} \beta f(x_i) \]

where \( M \) is chosen to be the identity model and the single static contribution is valid through the entire assimilation window as in hybrid 3DEnVar (as is the time invariant). The ensemble correlation is prescribed as a linear combination of ensemble perturbations weighted by the control variable. The operator \( T \) represents a transform (interpolation) between the ensemble perturbations and deterministic resolution if using a dual-resolution configuration. The contribution of static and ensemble respectively is controlled by the weighting parameters \( \beta_{f} \) and \( \beta_{e} \). NCEP employs an 80 member ensemble updated with an Ensemble Kaiman Filter in the global data assimilation system (GDAAS) and global forecast system (GFS). Pre-implementation tests showed that going from 3D- to 4D-Var to hybrid 4DEnVar is 3D-Var. Further increase in resolution of the ensemble is being tested.

All-Sky MW Radiance Assimilation

In the previous operational hybrid 3DEnVar/4DEnVar, the clear-sky approach of radiances data assimilation was employed. With the development effort made for all-sky conditions on modifying and assessing quality control, observation error assignment, bias correction, and background error covariance in the EnVar framework, the possibility of all-sky microwave radiance assimilation in the Gridpoint Statistical Interpolation (GSI) analysis system has been developed at the NCEP. Because the GFS output does not provide snow and precipitation profiles, the AMBUS-A cloudy radiances affected by non-precipitating cloud over oceans are assimilated in this study. In this section, we will present the configuration of the all-sky microwave radiance assimilation and discuss in more detail about observation error, bias correction, cloud water background error variance and ensemble spread. Outstanding issues and ongoing/future work are also presented.

- Clear sky data + radiances affected by thick and thin clouds
- AMSU-A channels 1-5, 15 currently assimilated
- New all-sky radiance bias correction strategy (Zhu et al, 2014)
- Situation-dependent observation error inflation: AMSu-A observation error re-tuned
- Additional quality control: cloud effect (Gaer et al, 2013) and emisivity sensitivity screening
- Precipitation regions are excluded
- Only initial implementation of the capability
- Approximately 10% increase in observations

FY16 Implementation

Putting together all the above mentioned components, for most metrics and lead times, 4D hybrid is significantly better than the 3D counterpart (Fig. 4 and Fig. 5). The forecast improvements are not nearly as large as what was found in moving from 3DVAR to hybrid 3DEnVar, but still better.

Looking Forward

There is still significant room for improvement relative to the 4D configurations carried out to thus far. Work is underway to improve the initialization (using 4D incremental analysis update), explore the use of an legitimate outer loop as is done on 4DVAR, and reducing the negative impacts from the static, time-invariant contribution to the hybrid solution. Additional testing with increasing the ensemble analysis resolution is also underway.

References

