Improving GSI 3DVAR-Ensemble Hybrid Data Assimilation System for Mesoscale Application with the Rapid Refresh

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Hourly Updated NWP Models

The Rapid Refresh (RAP) is an operational hourly updated regional numerical weather prediction system for aviation and severe weather forecasting.

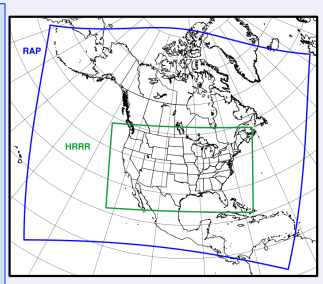
The High-Resolution Rapid Refresh (HRRR) is a real-time hourly updated CONUS convection-allowing model.

Rapid Refresh (RAP)

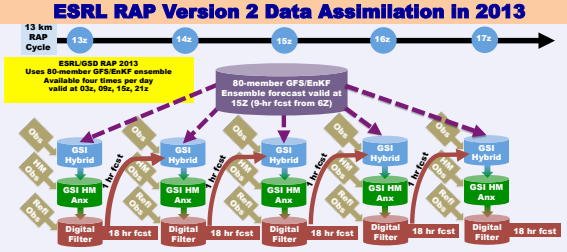
- **NCEP operational since May 2012**
- 13 km horizontal North American grid
- WRF-ARW dynamic core
- 6-species bulk cloud microphysics
- Hourly cycled land-surface fields
- GSI data assimilation – hybrid in ver 2
- GSI non-variational cloud/precipitation hydrometeor (HM) analysis
- Diabatic Digital Filter Initialization (DDFI) using hourly radar reflectivity
- Twice daily partial cycles from GFS atmospheric fields after 6h spin-up

Version 2 -- NCEP operational implementation planned Dec 2013

- **Has GSI hybrid assimilation using 80 member GFS/EnKF 9h ensemble fcsts (0.5 ensemble, 0.5 static BEC)**



ESRL RAP Version 2 Data Assimilation in 2013



RAP Hybrid/Ensemble Assimilation

Potential Benefits

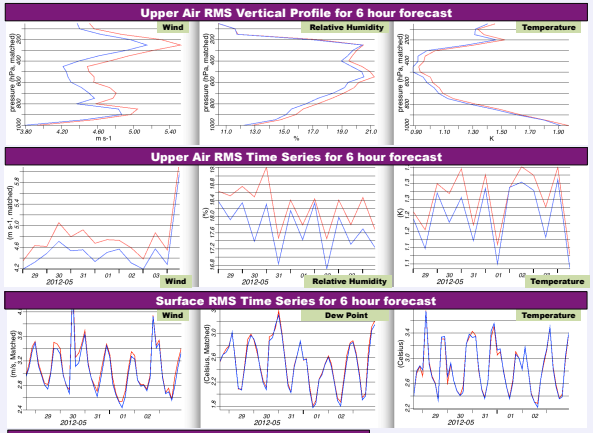
- Situational awareness NWP through *hourly updated* high-resolution assimilation cycles can be improved from flow dependent analysis
- Lower troposphere and frontal structures for cold- and warm-season (largely convective) systems are highly anisotropic, and benefit from flow dependence in bkg error covariance
- Cloud/hydrometeor variables are also anisotropically distributed in these systems, needing situation-dependent balance among T, Qv, and cloud variables in analysis

Challenges

- High-resolution hourly update cycles require huge computation cost and short cut-off time
- Ensemble forecasts need to be completed very quickly
- Ensemble forecasts tends to converge in hourly updated assimilation cycle (poor spread, especially for surface / lower trop.)
- For cloud analysis and severe weather, ensemble requires special physical configuration suitable for cloud and severe weather analysis

RAP Hybrid Test: 3DVAR versus Hybrid

Blue - RAP with Hybrid DA Red - RAP with 3DVAR DA



Test Configuration

- Retrospective test from May 28th to June 4th, 2012
- GSI Hybrid with half Ensemble BE (bkg err) and half Static BE
- Use full resolution GFS/EnKF ensemble forecast
- Analysis on full-resolution RAP grid
- Use 6-hourly available GFS/EnKF ensemble forecast

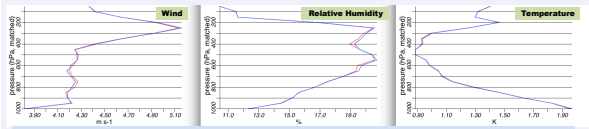
Summary of 3DVAR versus Hybrid

- RAP GSI **hybrid** assim clearly improves RAP 6h forecasts for all upper air fields. Improvement consistent in time (only 6h shown) and at different vertical levels.
- Wind forecast is improved most, next is moisture, temperature is improved least among three fields
- Middle to upper-air levels show stronger improvement; low level and surface forecast impact is nearly neutral.
- Precipitation forecast impact is neutral except in US West CSI over 0.5 inch.
- Successful ensemble forecasts used by GSI hybrid is key of a successful GSI hybrid analysis
- The GFS/EnKF ensemble forecast low level spread is insufficient for RAP hybrid assimilation to make improvement at those levels

RAP Hybrid Test: Hybrid Tuning

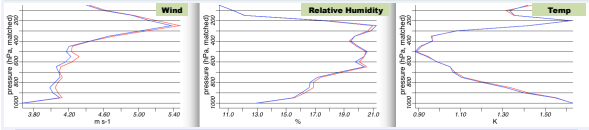
All Statistics here are upper air RMS vertical profile for 6 hour forecast

Blue – Hybrid, 3X coarser GFS/EnKF Fcst Red - Hybrid, 1X GFS/EnKF Fcst



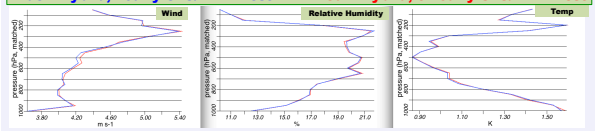
Summary: The GSI hybrid using coarser GFS/EnKF ensembles produces the same quality forecast as one using original resolution GFS/EnKF, which indicates the major improvement from hybrid is in larger scale component of fields.

Blue – Hybrid, 75% Ensemble BE Red - Hybrid, 50% Ensemble BE



Summary: Strong Ensemble BE component in hybrid assimilation can further improve wind and RH forecast, but the improvement is limited.

Blue – Hybrid, hourly GFS/EnKF Fcst Red - Hybrid, 6-hourly GFS/EnKF Fcst



Summary: The GSI hybrid with hourly GFS/EnKF ensemble forecast valid at each hourly analysis time gives a very slight benefit over one with 6h available ensemble forecast. Again, indicates that the *current* RAP GSI hybrid assimilation mainly improve mid- to upper-tropospheric error.

RAP Hybrid Future Work

- Further tune hybrid parameters, such as localization, ratio of ensemble BE and static BE, vertical variance of this ratio
- Test RAP GSI hybrid using regional ensemble forecasts initialized from GFS/EnKF ensemble forecast to increase spread in low levels and create covariances for multi-species hydrometeor fields as used in RAP and HRRR
- Build and test RAP EnKF system
- Test North American Rapid Refresh Ensemble (NARRE) by 2016, co-development between ESRL and NCEP/EMC

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