

Upgrade of the NCEP GFS to a 4D Hybrid Ensemble Variational Data Assimilation

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The National Centers for Environmental Prediction (NCEP) is upgrading the GFS Analysis and Forecast System in May, 2016. The upgrade includes changes to both the Global Data Assimilation System (GDAS) and to the GFS Global Spectral Model and post-processing software.

The GDAS changes include an upgrade of the 3D Hybrid Ensemble Variational to a 4D Hybrid Ensemble Variational Data Assimilation System, where the 4D increments are constructed by figuring out the best combination of 4D ensemble perturbations. The ensemble provides an updated estimate of situation dependent background error every hour as it evolves through the ensemble window. The weights for ensemble members are kept constant throughout the assimilation window. This 4DHybrid uses 50 outer and 150 inner iterations with variational quality control turned on after 25 iterations. This flow dependent statistical estimate is combined with a fixed estimate; the weights for static and ensemble are 12.5% and 87.5%, respectively. Tangent Linear Normal Mode Constraint (TLNMC) and Digital Filter Initialization (DFI) are used in the ensembles while additive error inflation is removed. Ozone cross co-variances are also in the 4DHybrid, and localization is reduced to 50% in the troposphere.

Other changes to the GDAS include the following:

- Assimilation of all sky Advanced Microwave Sounding Unit (AMSUA) Radiances;
- Assimilation of Advanced Very High Resolution Radiometer (AVHRR) winds and monitoring of Visible Infrared Imaging Radiometer Suite (VIIRS) winds;
- Implementation of Geostationary Operational Environmental Satellites – R series (GOESR) data readability;
- An update of the Community Radiative Transfer Model (CRTM) to v2.2.1 with bug fixes in wind direction, including use of FAST Microwave Emissivity Models (FASTEM6 and FASTEMX) reflection correction for cloudy situations;
- Improved bias correction for aircraft observations;
- Modified relocation and storm tracking to allow hourly tropical cyclone relocation;
- Modified thinning/weight in time for Atmospheric Motion Vectors (AMVs) and radiances.

The changes to the GFS Global Spectral Model and post-processing software include corrected land surface characteristics for grassland and cropland categories to reduce summertime warm and dry biases over the Great Plains, upgraded convective gravity wave drag, and an upgraded tracer adjustment in the semi-Lagrangian dynamic core.

There are also changes to model products, including a new Global Forecast Icing Severity (GFIS) icing severity parameter, improved Global Forecast Icing Potential (GFIP) products, the addition of an hourly forecast product out to 120 hours, and the addition of five more vertical levels (7, 5, 3, 2, and 1 hPa).

This upgraded system was tested using more than three years of forecasts plus the Hurricane Sandy case. New evaluation methodologies were developed in coordination with other NCEP centers and National Weather Service regional headquarters and forecast offices. Maps of three months of real time operational and upgraded forecasts were available to operational forecasters for evaluation, and selected case studies recommended by forecasters were conducted on more than three years of forecasts.

Objective verification against observations and the model's own analyses showed that week 1 forecasts were significantly improved except in the upper stratosphere. The upgraded system produced much smaller analysis increments. Anomaly correlations for 5 day forecasts of 500 hPa improved significantly by .004 in the Northern hemisphere and .007 in the Southern Hemisphere, with larger improvements for zonal wavenumbers 10-20. RMS errors of selected atmospheric fields decreased by 10% for day 1 forecasts, 4% for day 3 and 2% for day 5 when verified against the model's own analyses. Forecasts of 2 m temperatures and dew points and 10 m winds verified against surface observations over the continental United States and Alaska improved significantly. RMSE errors for 96 hour forecasts of 2m temperature and dew point improved by 2% in the western United States and 3% in the east while 96 hour forecasts of 10 m winds improved by 4% in the west and 8% in the east when verified against surface stations. The new system further increased a GFS tendency towards too much drizzle, but showed significant improvement in forecasting 2-25 mm/day precipitation thresholds over the continental United States. Forecasts of CAPE over the United States and jet streams showed significant improvement. Forecasts of tropical storm genesis, track and intensity also improved. Synoptic evaluation of the new GFS yielded no major new concerns; the operational and experimental systems often produced very similar forecasts with the GFSX performing better in some cases. An extensive evaluation site is available at:

<http://www.emc.ncep.noaa.gov/gmb/noor/4dGFS/synergy%20announcementjan08.htm>

This implementation followed a new implementation procedure with a considerably longer official evaluation period and more active engagement with and participation of the other NCEP centers and NWS regional headquarters and forecast offices.