Adopting NCEP's Hybrid 4DEnVar DA to FV3GFS

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NGGPS FV3

FV3 selected as the dynamical core component of NGGPS
- hydrostatic and non-hydrostatic options
- Initial prototyping (mostly) with GFS physics
- lots of technical work to adapt new dynamical core for use with current data assimilation system

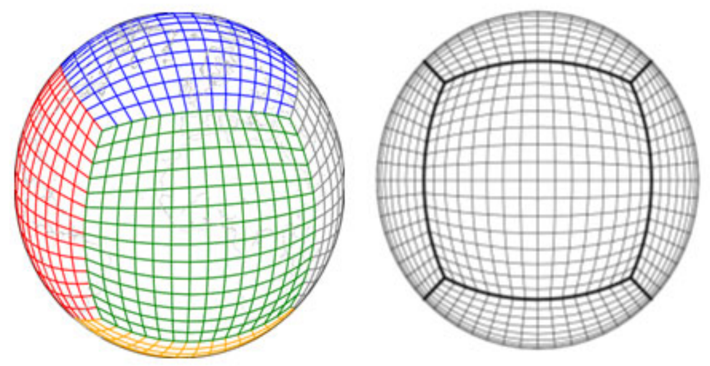

Figure 1: Representation of the FV3 grid with tiles and faces (Courtesy NOAA-GFDL)

Grid
- Model uses cube-sphere Gnomonic grid
- DA infrastructure utilizes rectilinear grid
- This creates short-term technical challenges and need to consider best longer term strategy

FV3GFS DA Implementation Timeline

FY2018
- Q2: TE GOES16, JPSS, COSMIC-2, etc.
- Q2: Adopt H4DEnVar DA for FV3GFS DA
- Q3: Experimental Implementation of FV3GFS in parallel

FY2019
- Q2: increased vertical resolution and higher model top
- Q4: Implement FV3GFS

FY2020
- Q3: JEDI Unified Forward Operators
- Q4: JEDI native grid solver

Testing Paradigm

Cold start forecasts from GFS initial conditions
- **C768** (~13km) L64
- Historical cases and near real-time (over a year's worth of simulations)

Low resolution cycled DA
- C384 Control + C192 Ensemble (80 members) L64

Full resolution cycled DA at real-time
- C768 Control + C384 Ensemble (80 members) L64
- Evolving system with new developments added regularly as they mature at low resolution

Higher ensemble resolution (1:2) in the FV3 experiments compared to the current operational GFS (1:3)

Cycled DA components:
- Background Error Covariance from GSM
- Stochastic physics consisting of SPPT and SHUM. SKEB off.
- NSST assimilation ON.
- GFDL Microphysics in FV3

Hydrostatic v/s Non-hydrostatic

- Tested **hydrostatic** version of the FV3 model with the same data assimilation and compared against **non-hydrostatic** version and **GSM**
- From high-resolution cold start forecasts
  - RMSE and ACC are slightly better
- From low-resolution cycled DA perspective
  - Comparable RMSE and ACC
  - Stratosphere / upper Troposphere slightly better in hydrostatic version
  - Both FV3 versions worse than GSM in the Stratosphere / upper Troposphere.

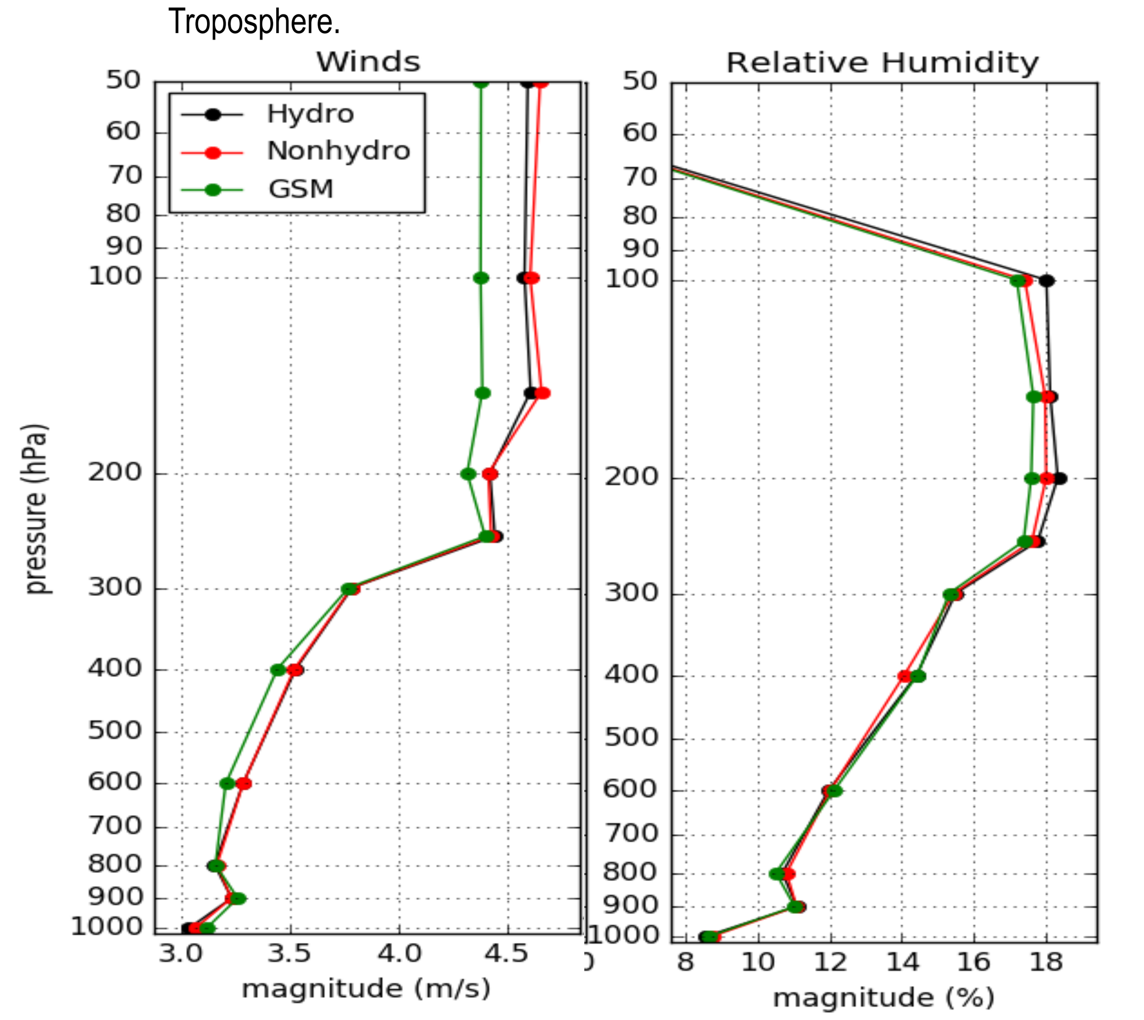

Figure 2: Global RMSE winds (left) and relative humidity (right). Comparing operational version of the GFS (green) with the hydrostatic (black) and non-hydrostatic (red) version of the FV3 model.

Stochastic Physics

- Use of **stochastic physics** (SHUM+SPPT) show modest improvements in DA
- Comparisons shown with **multiplicative** inflation

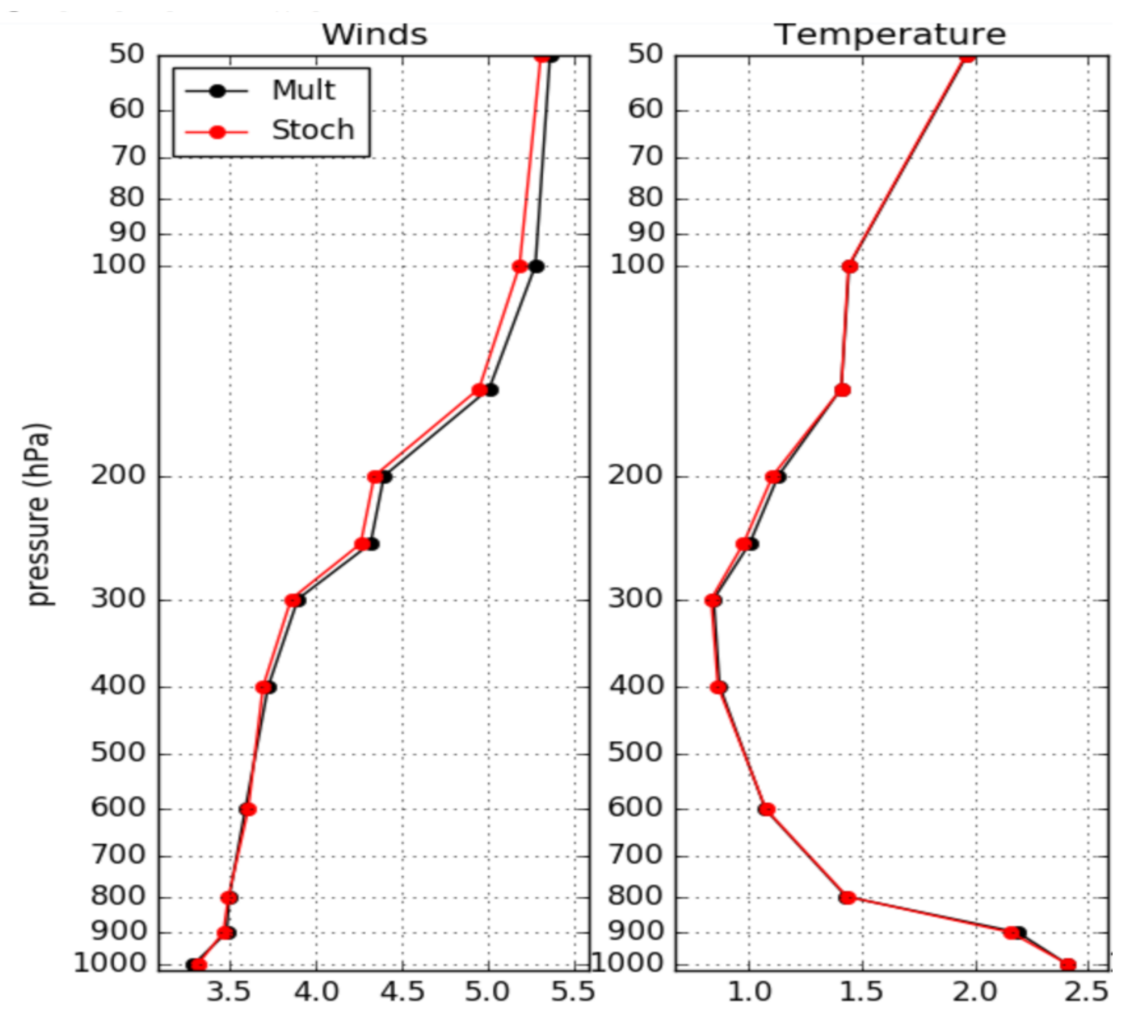

Figure 3: Global RMSE winds (left) and temperature (right). Comparing multiplicative inflation (black) with stochastic physics (red) in the same FV3 cycled data assimilation system at low resolution.

Low resolution Cycled DA

Putting together all the above mentioned components, and comparing with operational version of the model:

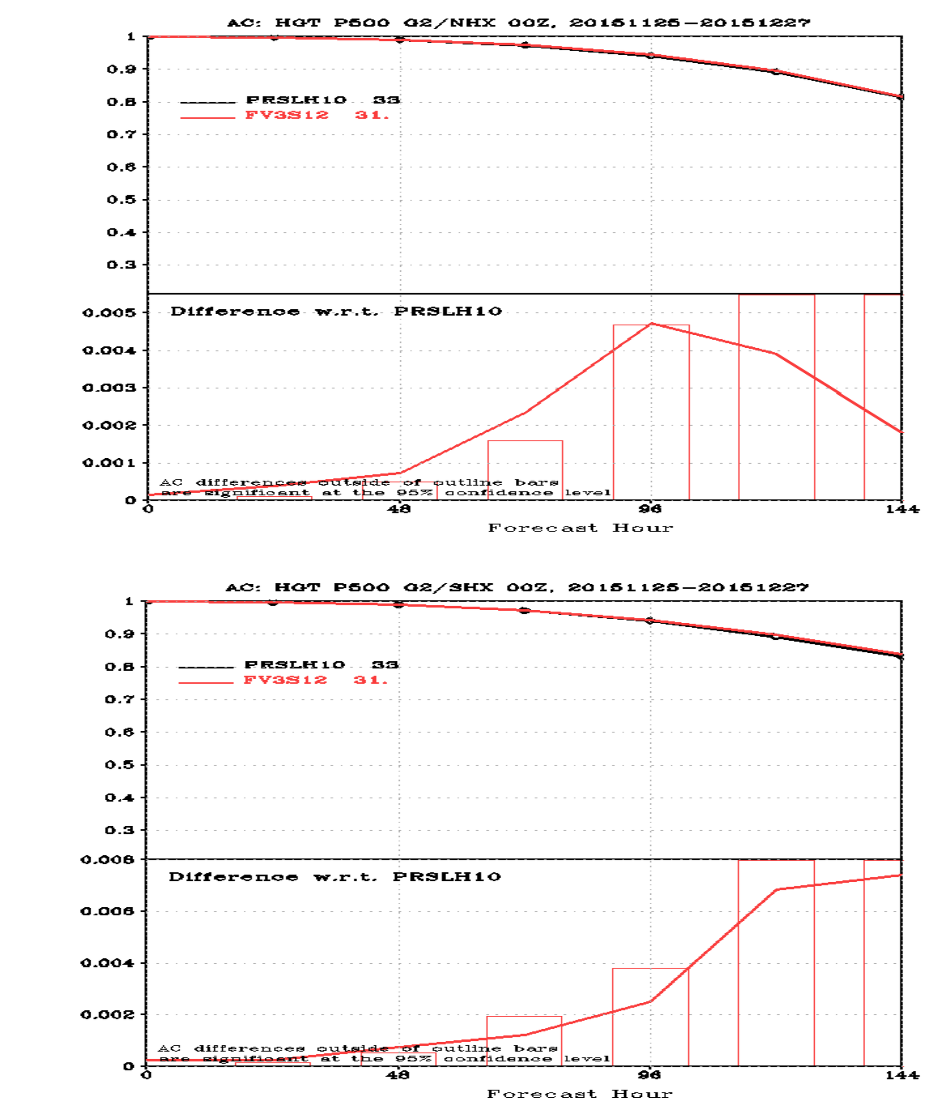

*Figure 4: Time-averaged 500 hPa anomaly correlation for the Northern Hemisphere (top) and Southern Hemisphere (bottom) for the **FV3GFS** (red) and **GSM** (black) experiments for forecasts from the 00 UTC analyses as a function of lead time as well as the difference (lower panels). The 95% confidence threshold for a significance test (derived from a standard t-test) is also plotted in the lower panels. The experiments are conducted at low resolution.*

Fit to Observations

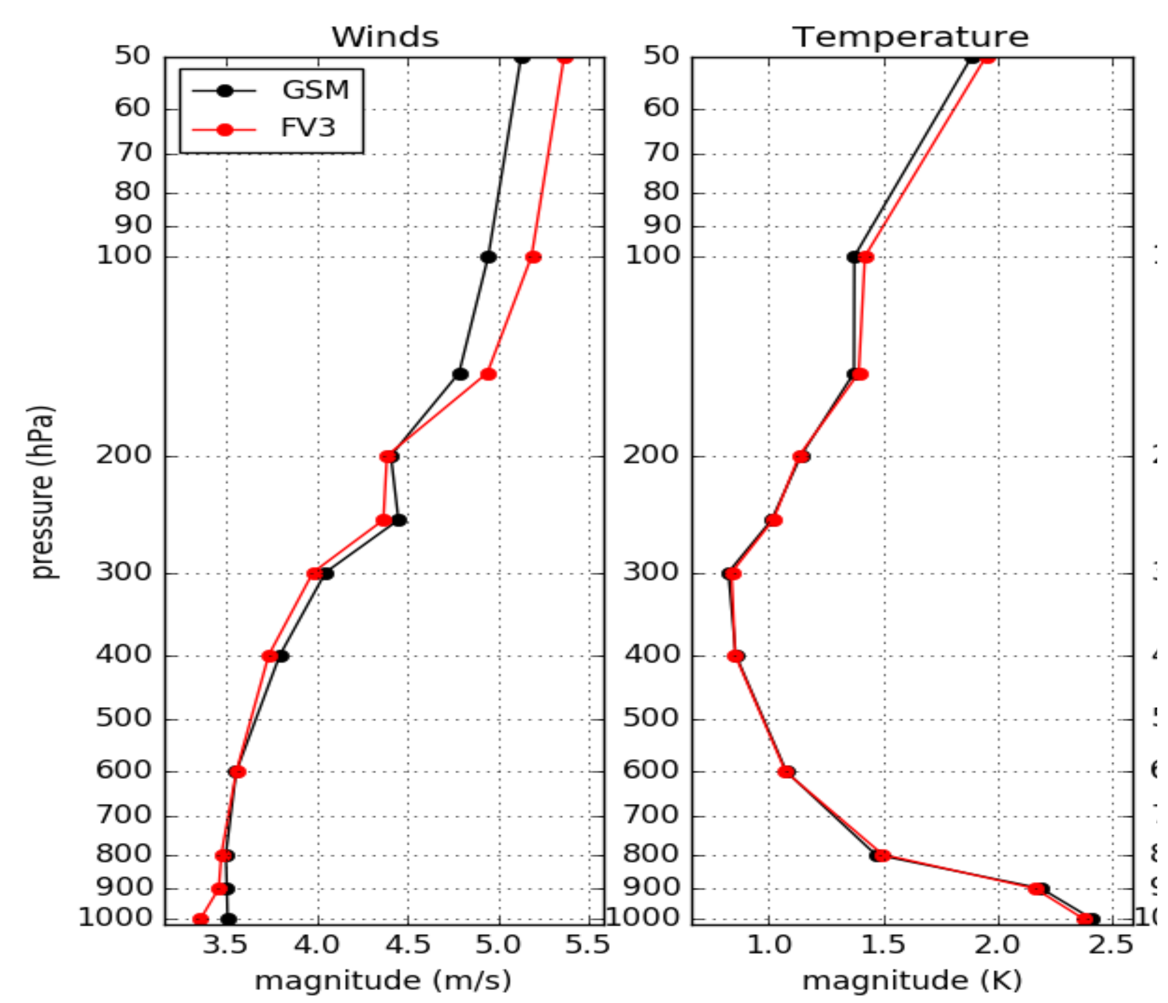

Figure 5: Fits to observations comparing FV3 (red) with operational GFS (black). Note the degradation in the fits above 200hPa in both winds (left) and temperature (right). The fits are computed against Radiosonde observations.

Full Resolution Near Real Time

A full resolution parallel has been running in near real time since July 2017. As and when development at low-resolution is carefullly vetted, it is implemented in the full resolution realtime. The realtime system currently has all the components that will be implemented in operations as a beta version in June 2018.

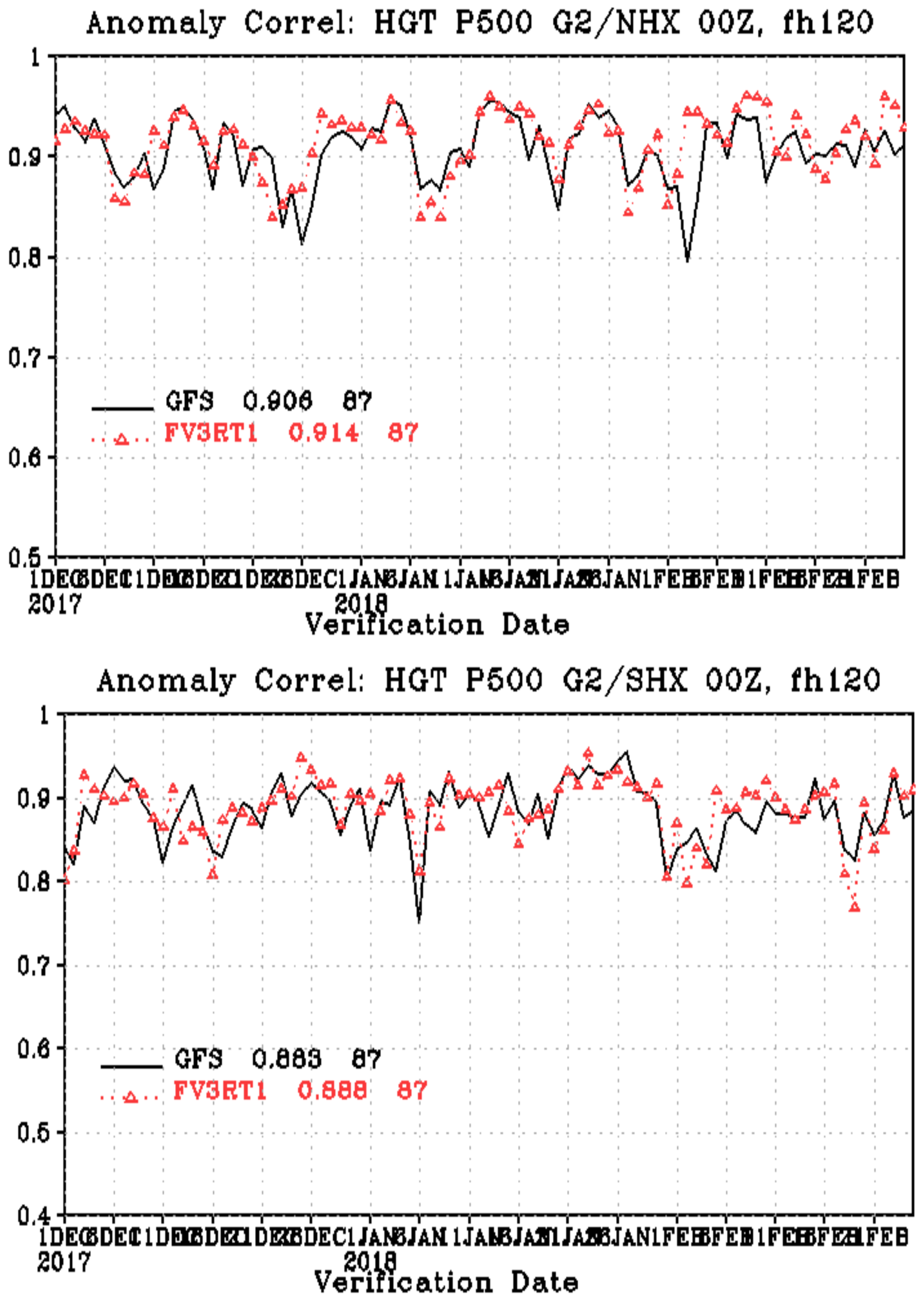

Figure 6: Time-series of5 day Anomaly correlation at 500hPa in NH (top) and SH (bottom) comparing the current operational GFS (black) with the FV3GFS (red).

Looking Forward

- Initialization through an IAU approach (FY19)
- Compute background error covariance based on FV3GFS forecasts (FY19)
- Use of time-lagged ensemble, waveband localization
- Higher model top and increased vertical resolution (FY19)
- Use of correlated observation errors
- Use of all-sky information
- Use of JEDI components e.g. UFO (FY20), OOPS on Native FV3 grid (FY22)