Hybrid Data Assimilation without Ensemble Filtering

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Outline

Variational Formulations

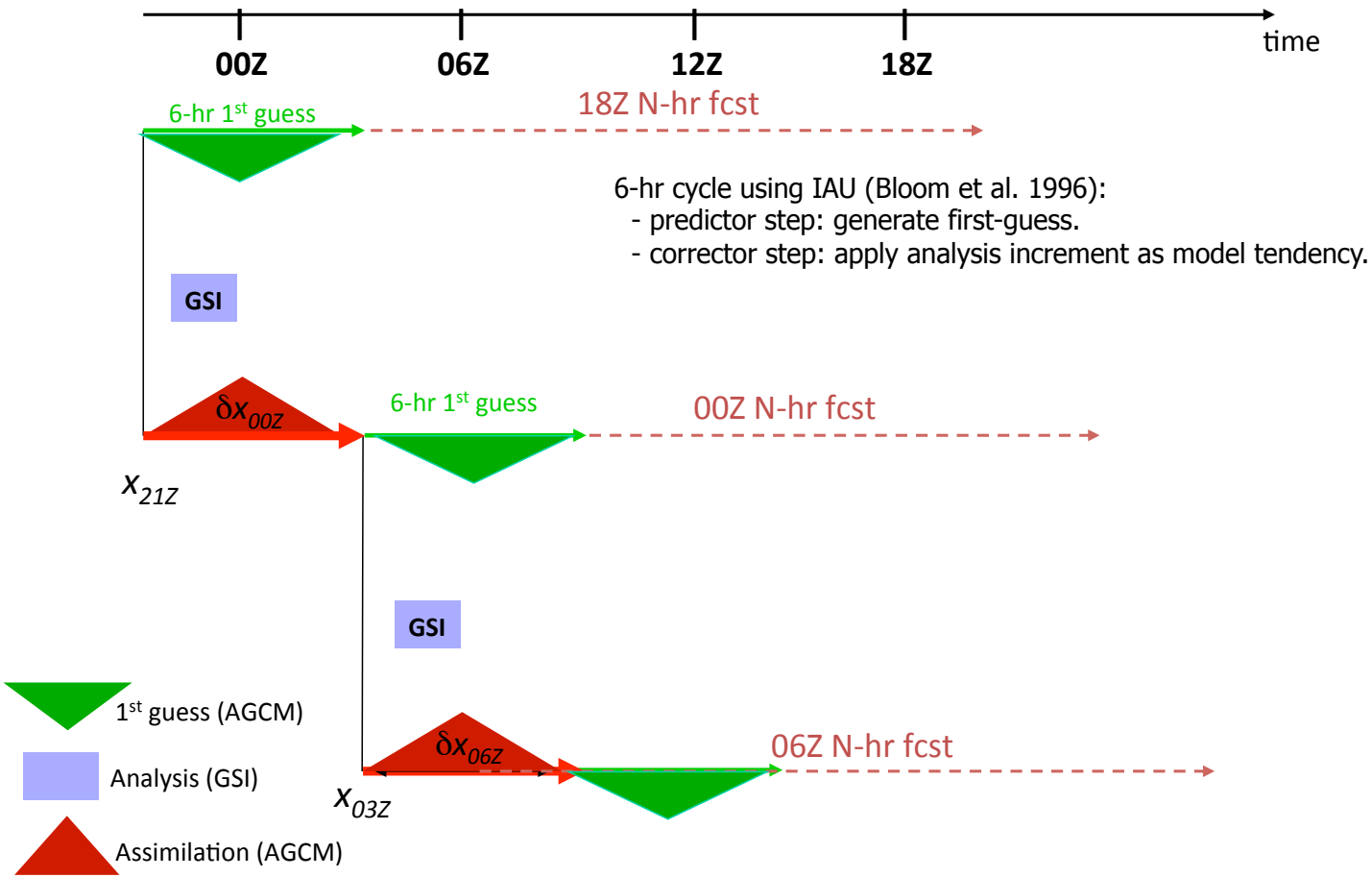
FGAT 3dVar-ensemble Hybrid:

$$J(\delta\mathbf{x}) = \frac{1}{2}\,\delta\mathbf{x}^T\mathbf{B}_h{}^{-1}\delta\mathbf{x} + \frac{1}{2}\sum_{k=1}^{K}[\mathbf{H}_k\delta\mathbf{x} - \mathbf{d}_k]^T\mathbf{R}_k^{-1}[\mathbf{H}_k\delta\mathbf{x} - \mathbf{d}_k] + J_x$$

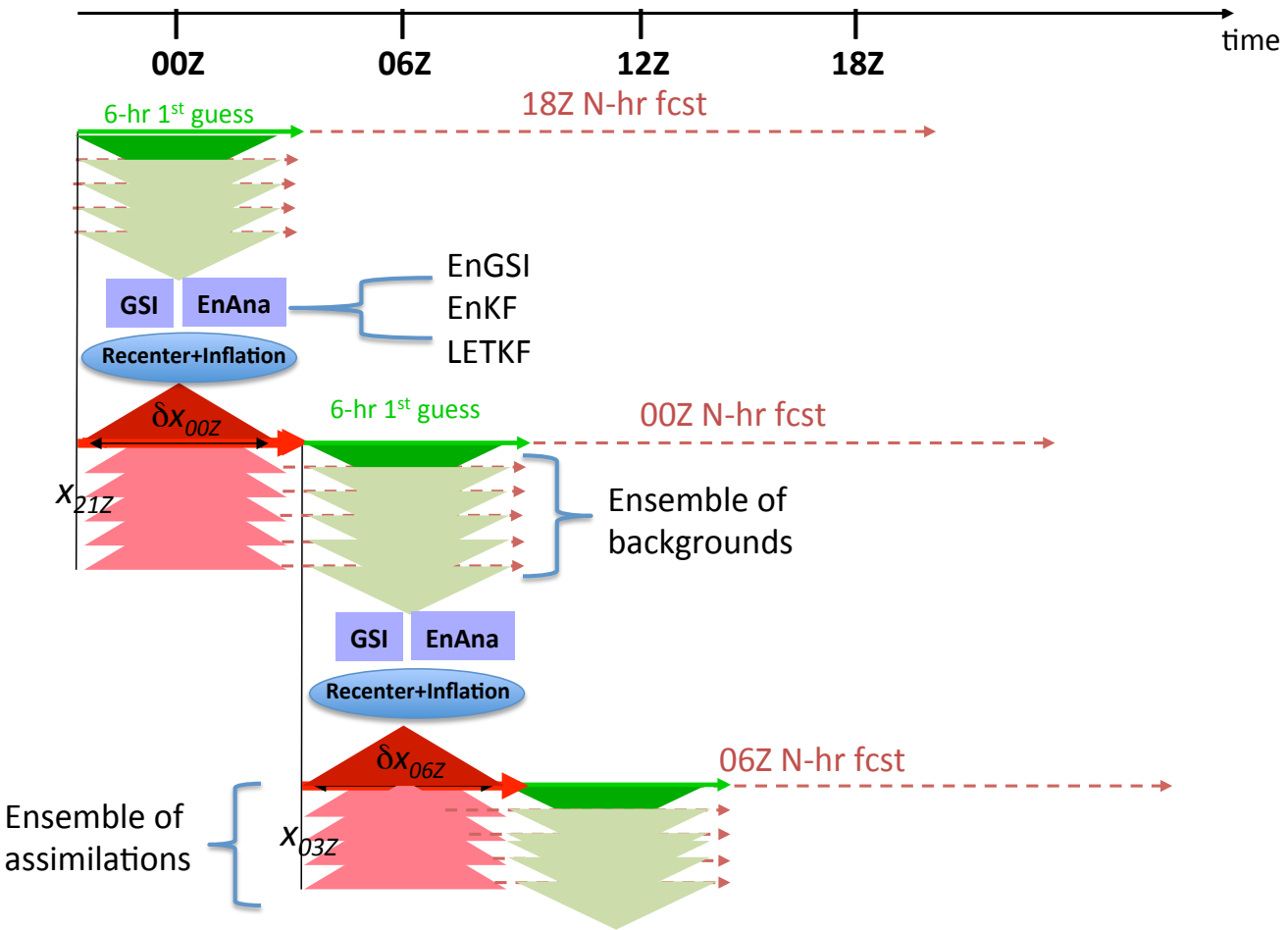
where

- $\mathbf{B}_h = \beta\mathbf{B} + (1-\beta)\mathbf{B}_e \circ \mathbf{C}$ is a *hybrid* of static and ensemble-based error covariances, $\mathbf{B}$ and $\mathbf{B}_e$ respectively
- $\mathbf{C}$ is a localization error covariance of compact support
- the control variable changes to be $\delta\mathbf{x} = \delta\mathbf{x}_0 + \sum_m^M \delta\mathbf{x}_m^e \circ \alpha_m$, for an ensemble with a total of M members $\delta\mathbf{x}_m^e$
- GMAO and NCEP get $\delta\mathbf{x}_m^e$ by using the EnKF plus inflation

IAU-based 3dVar DAS Schematic



IAU-based Hybrid 3dVar DAS Schematic



Problem Statement

- Hybrid DA schemes include both multiplicative and additive inflation
- Evaluations in GEOS DAS suggest:
  - Hybrid approach provides noticeable improvements only when using additive inflation, i.e., EnKF alone doesn't do it
  - Forecasts from EnKF analyses plus additive inflation result in mild spread within the background time window
  - It seems that much of the initial (analysis) spread can be simulated with additive inflation alone
  - Appreciable background spread is obtained in the latter case

Question: how does hybrid-DA perform when the ensemble filter is dropped and an ensemble of analyses is created from simply additively inflating the central analysis?

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Hybrid Experimental Setting

- Central DAS: 0.5^o outer and inner loops; 72-levels
- 32 Ensemble Forecasts: 1.0^o; 72-levels
- GSI Hybrid/Static **B**: 50% / 50%
- TLNMC applied to both static & hybrid covariances
- Vertical & horizontal localizations applied to ensemble **B**
- Add/ve perturbations scaled from NMC-like 48-24hr forecasts
- Experiment period (after spin up): April 2012

EnKF

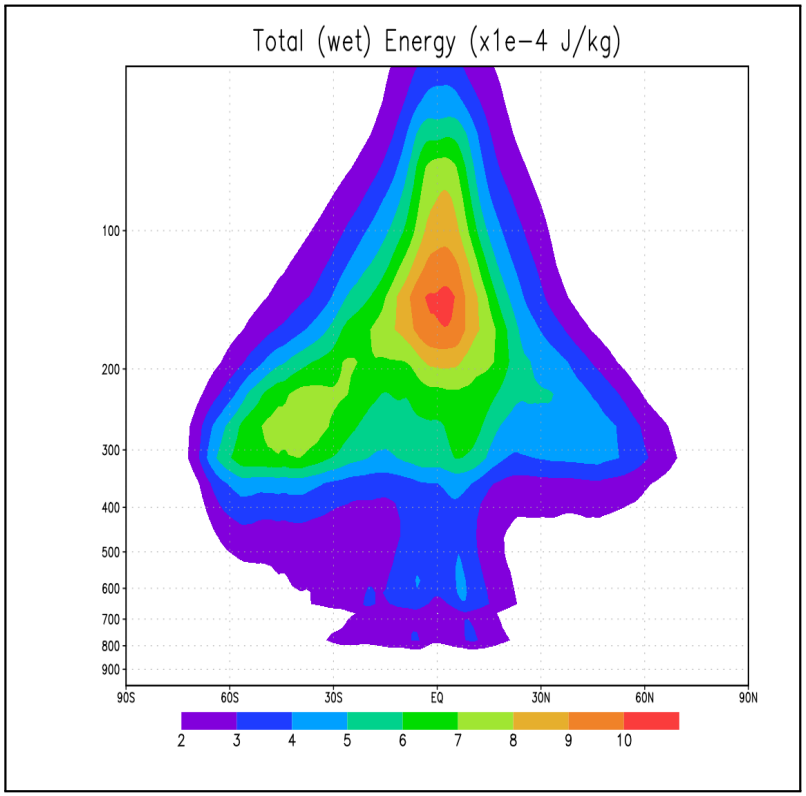
- Additive perturbation: 0.25
- EnKF (full obs but precip)

Filter-Free

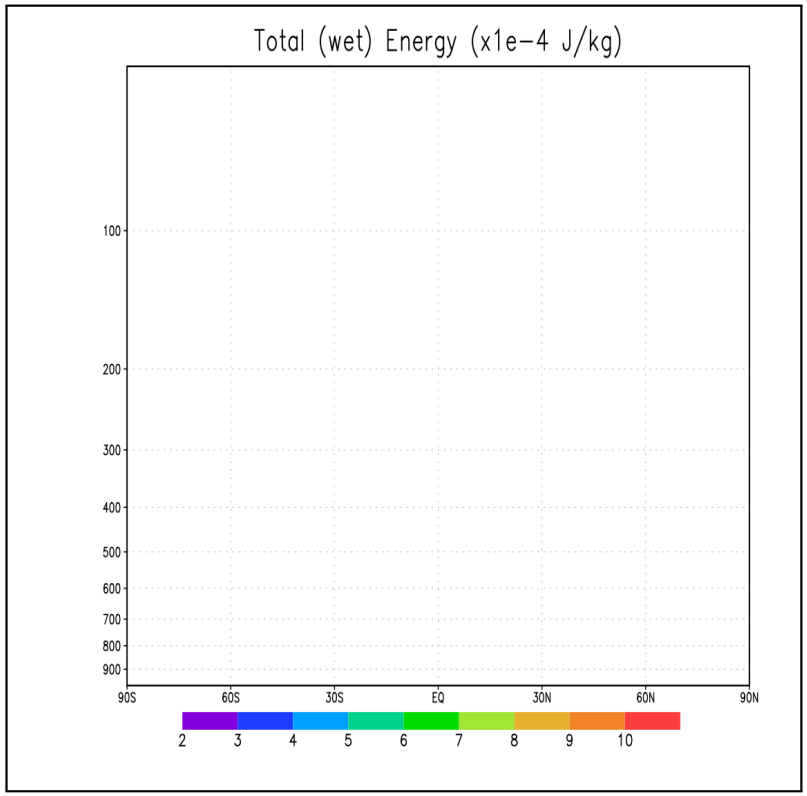
- Additive perturbation: 0.6
- No Ensemble Filtering

0-hr Analyses Spread (before additive inflation)

EnKF-based hybrid

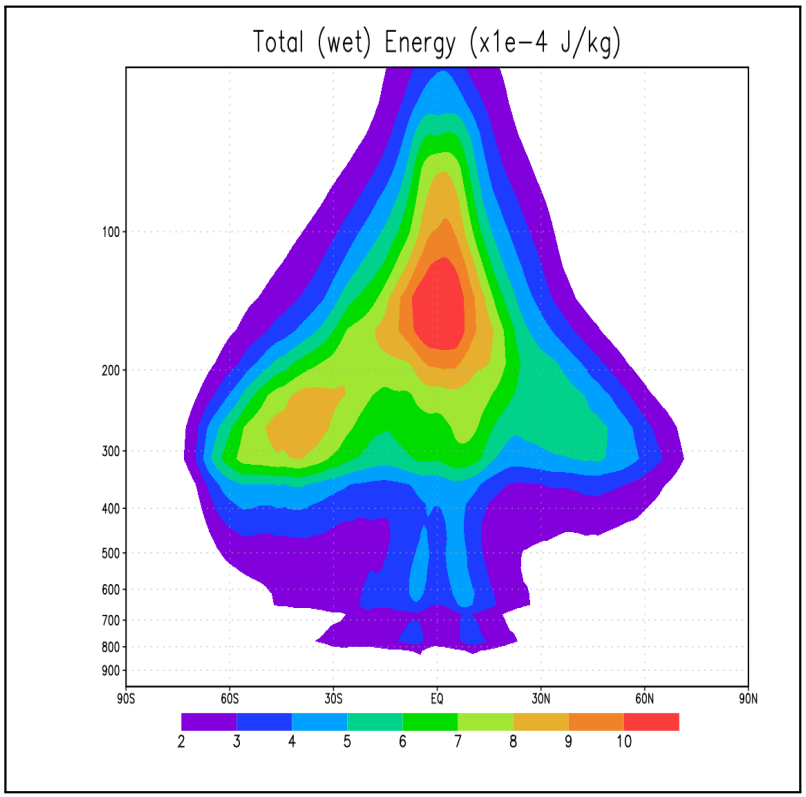


Filter-Free hybrid

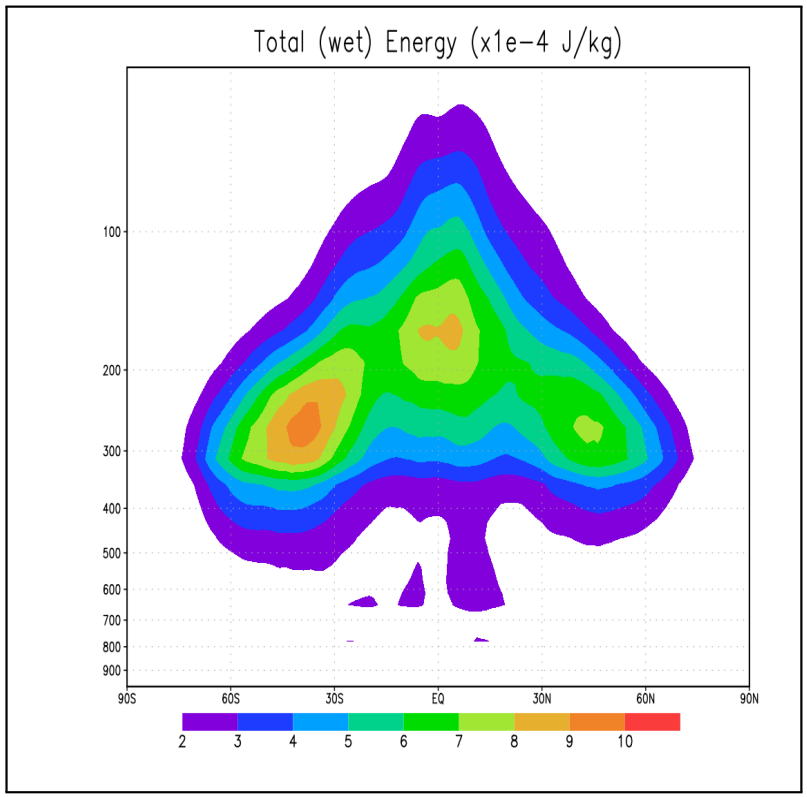


3-hr Background Spread

EnKF-based hybrid

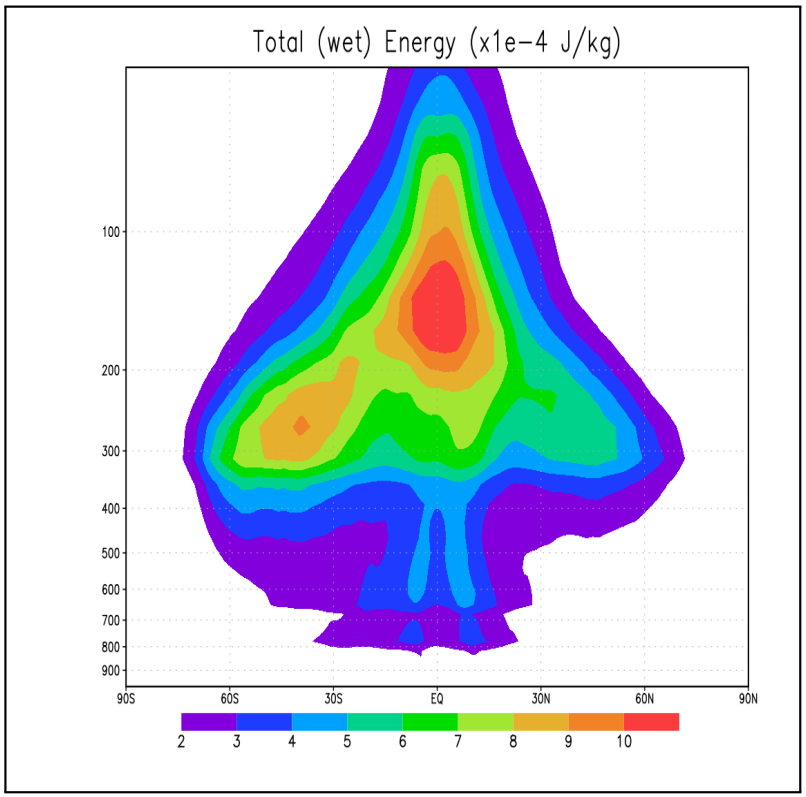


Filter-Free hybrid

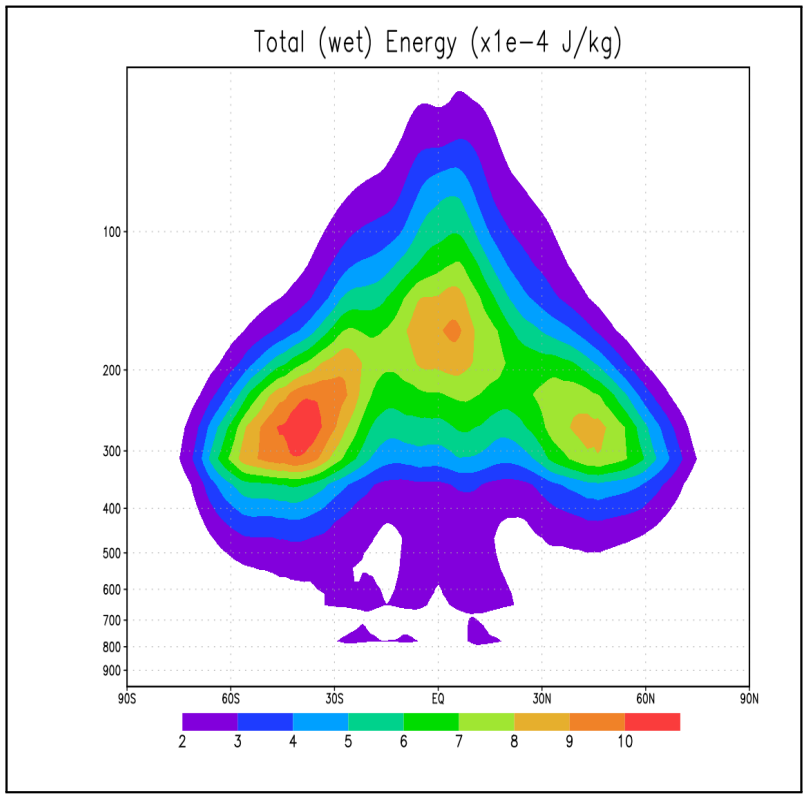


6-hr Background Spread

EnKF-based hybrid

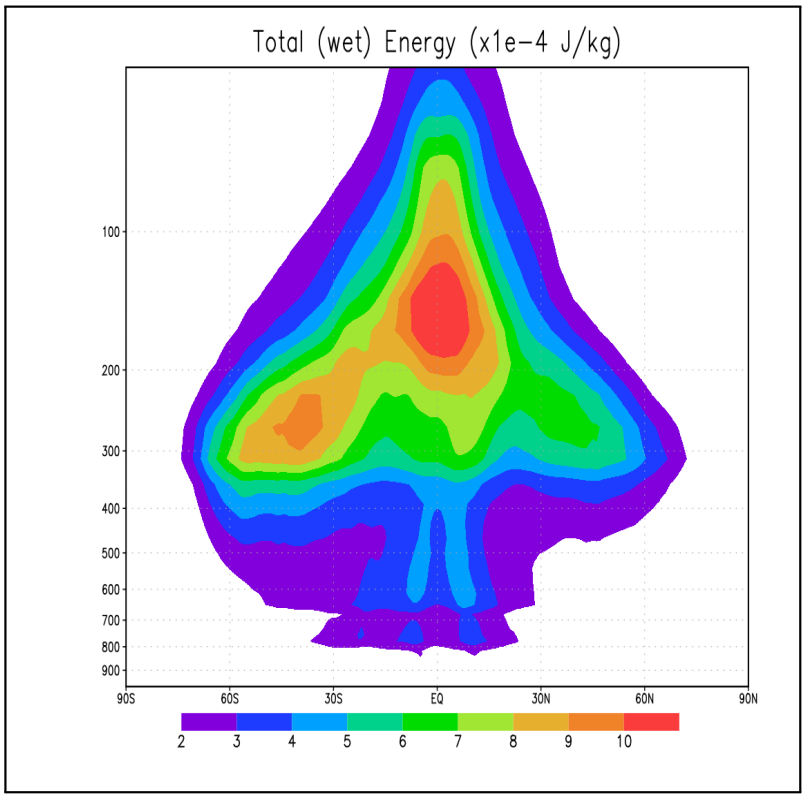


Filter-Free hybrid

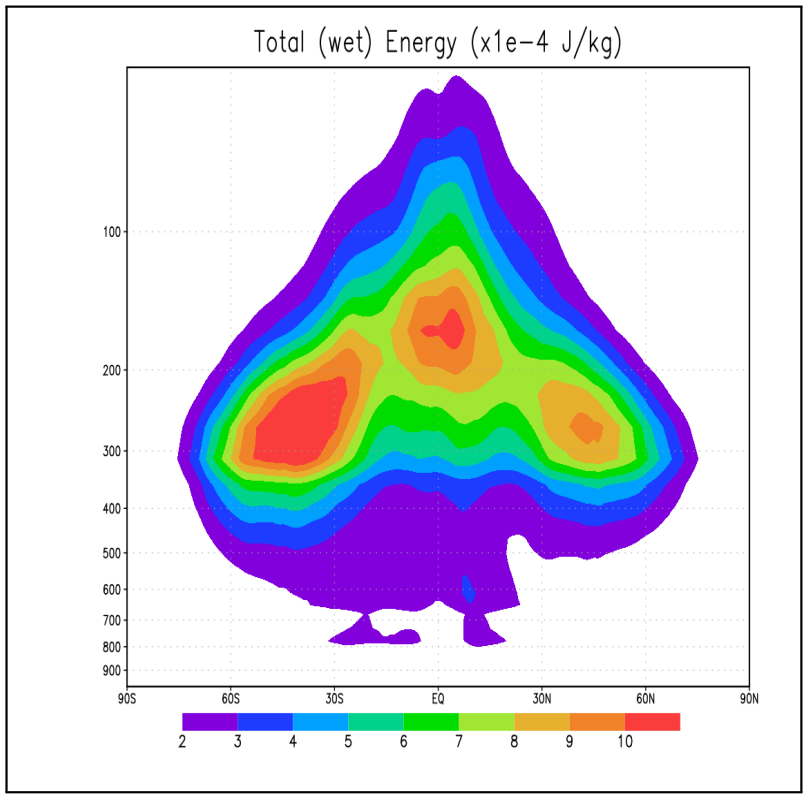


9-hr Background Spread

EnKF-based hybrid

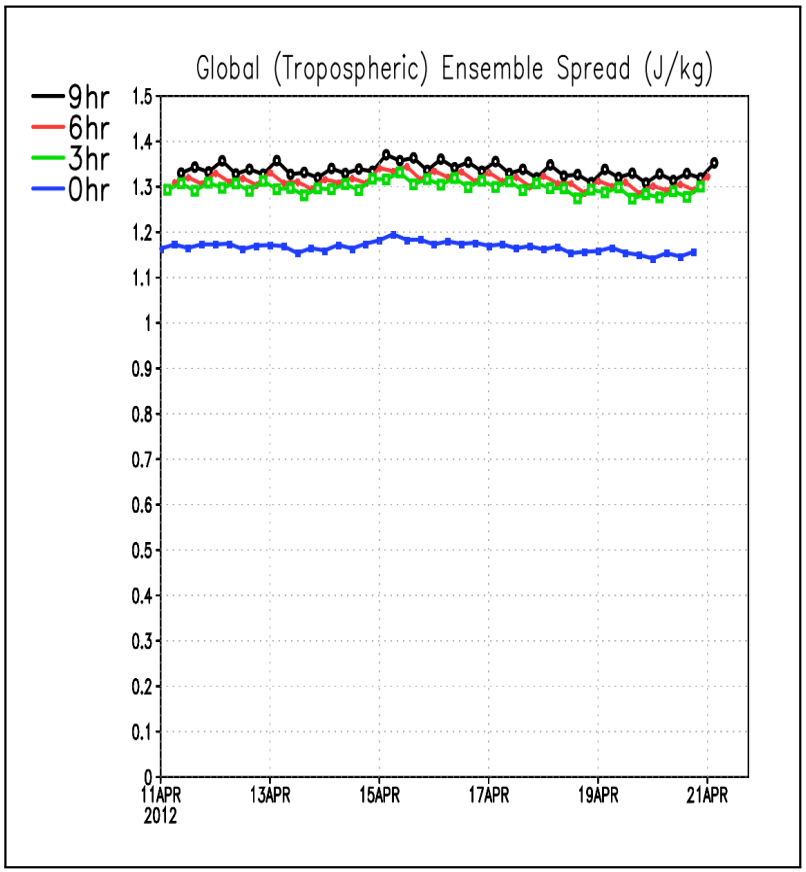


Filter-Free hybrid

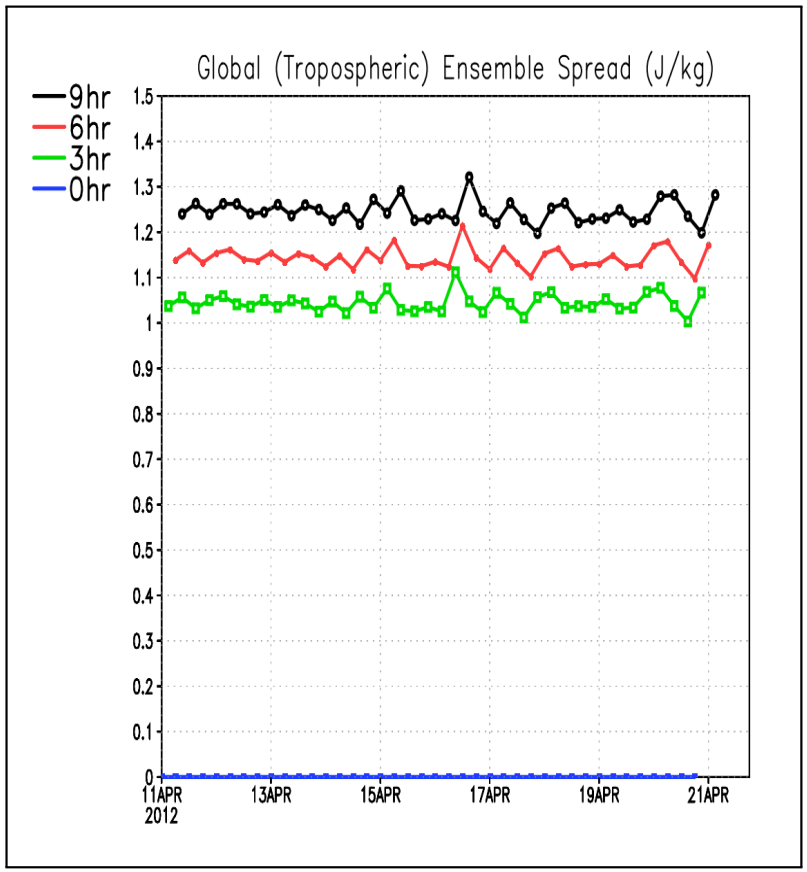


Spread within 9-hr Background Period

EnKF-based hybrid

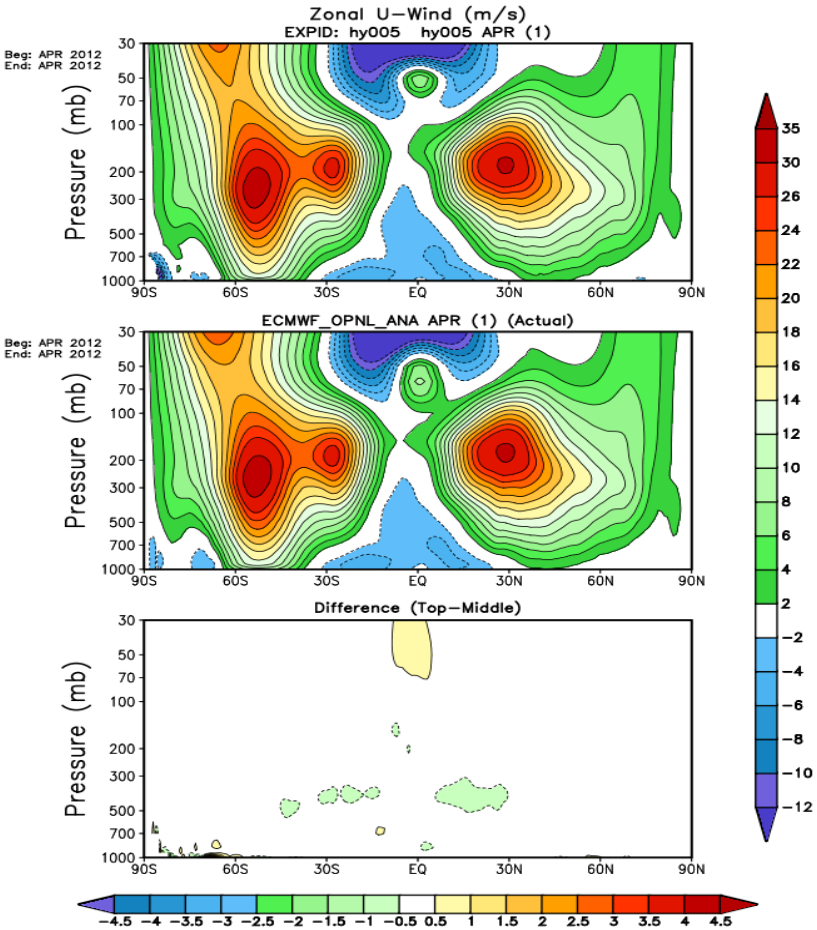


Filter-Free hybrid

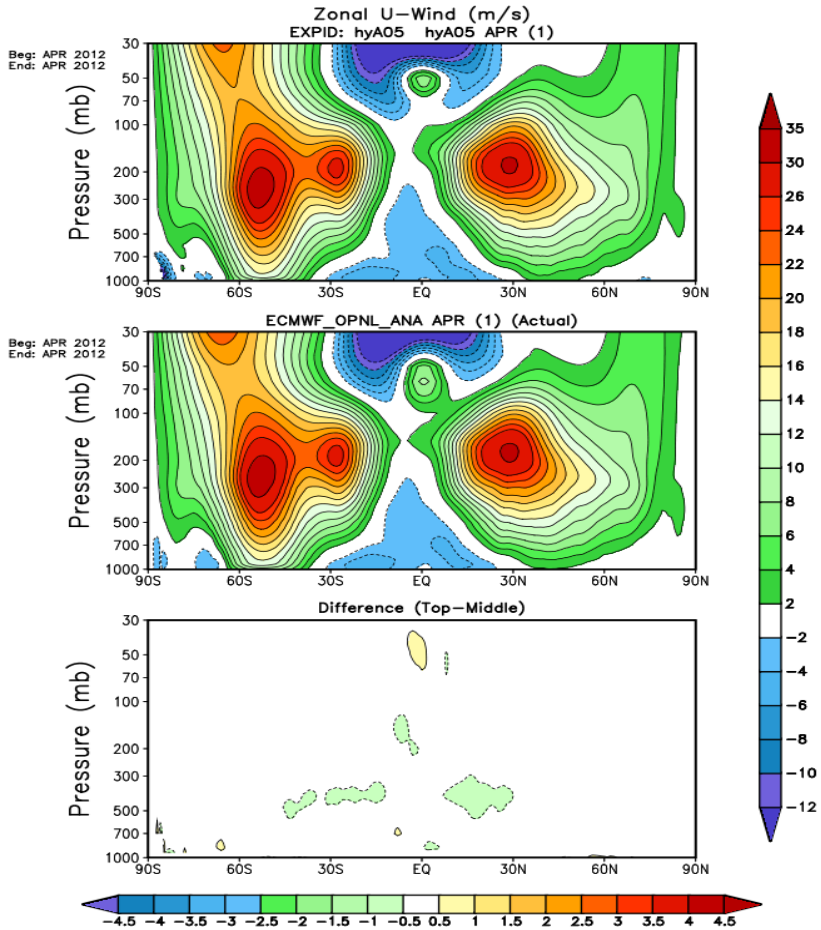


Comparison w/ ECMWF: Zonally-Averaged Monthly Mean U-Wind

EnKF-based hybrid

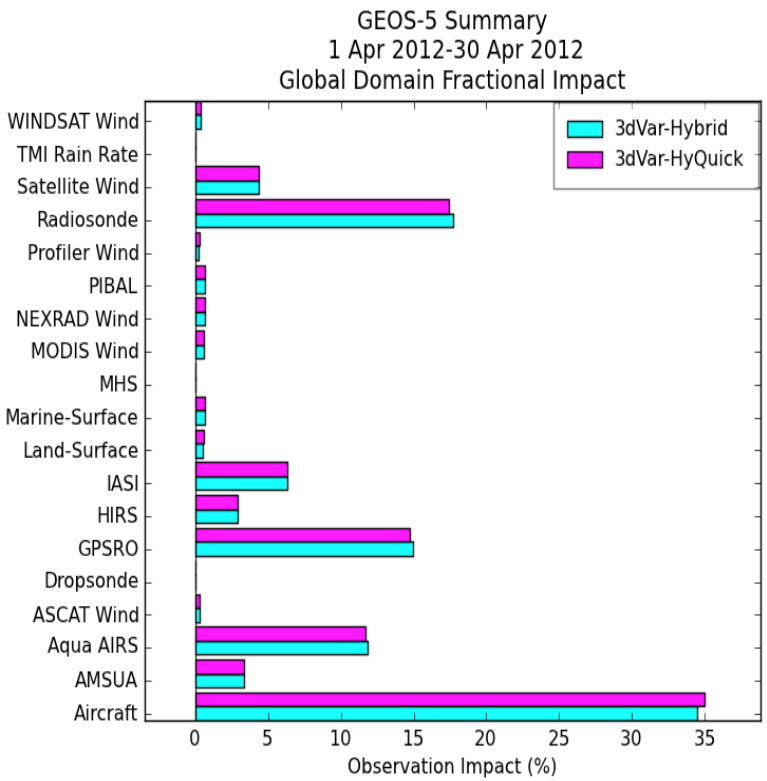


Filter-Free hybrid

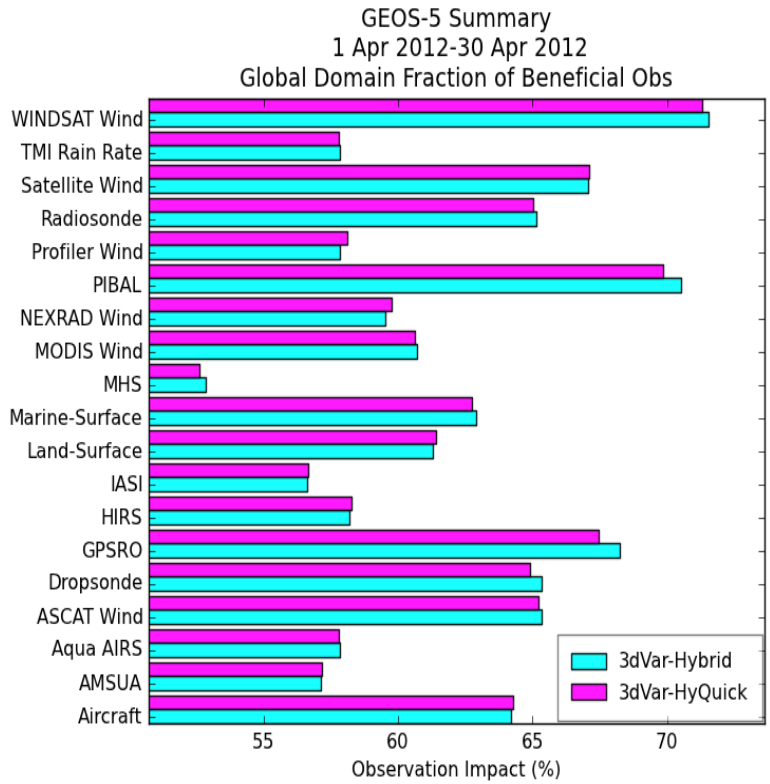


Observation Impact on Analysis

Fractional

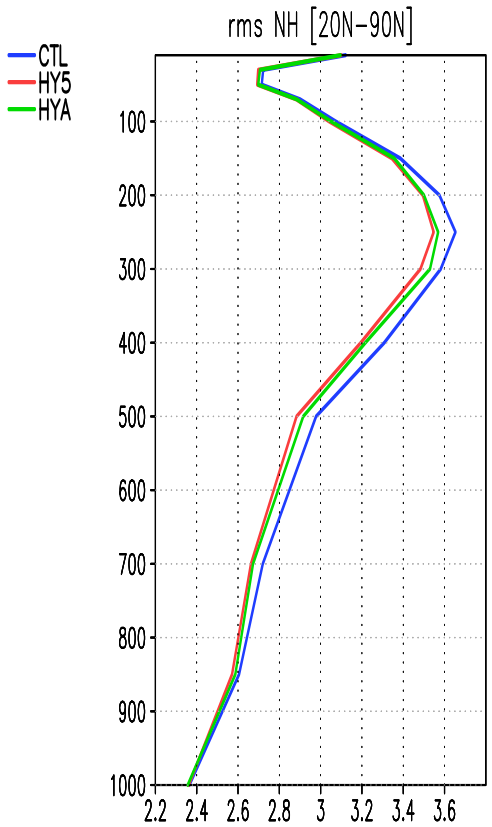


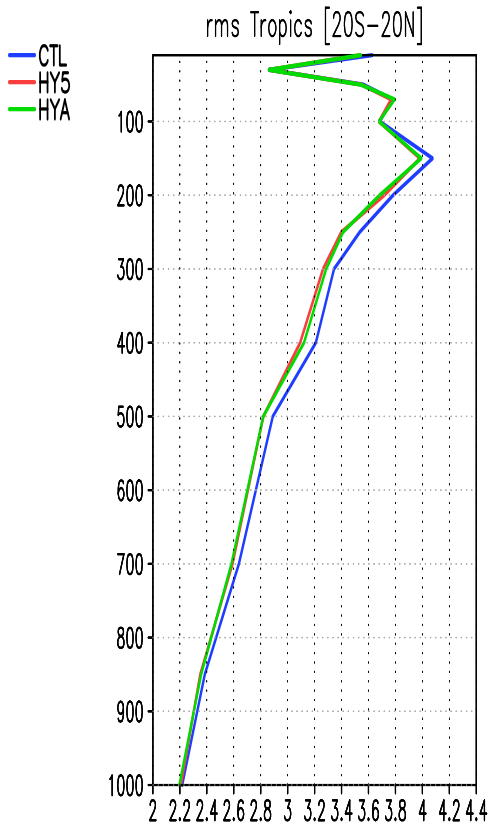
Beneficial

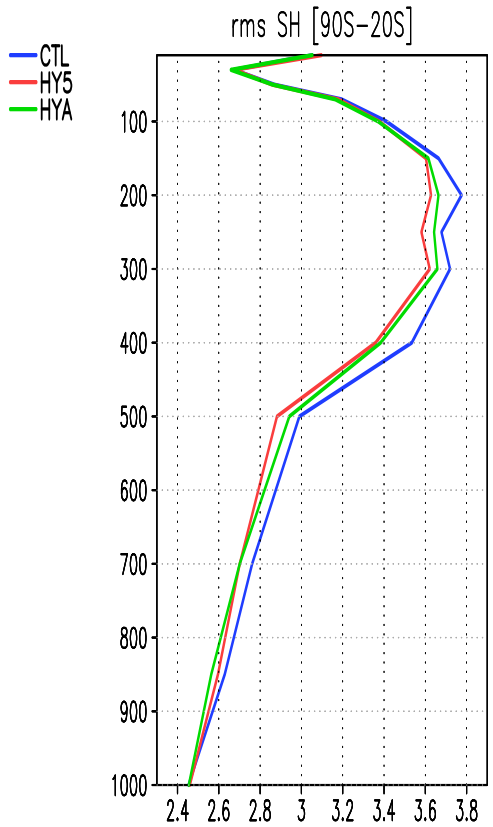


6-hour

Raob Zonal Winds

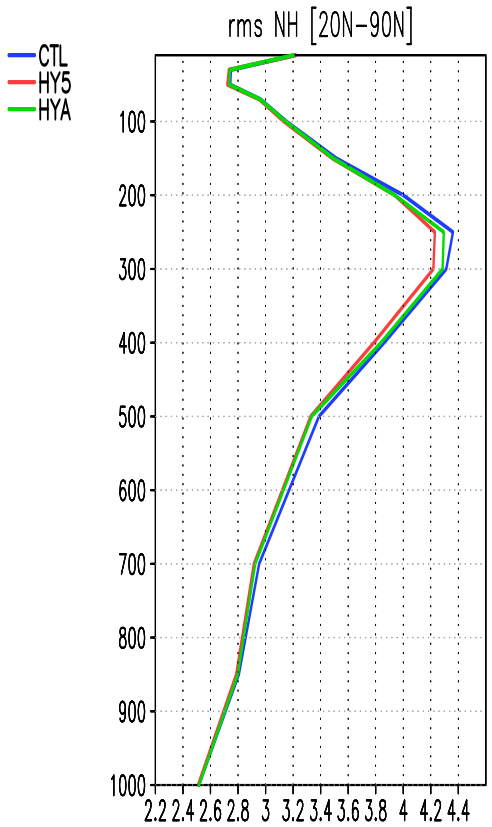


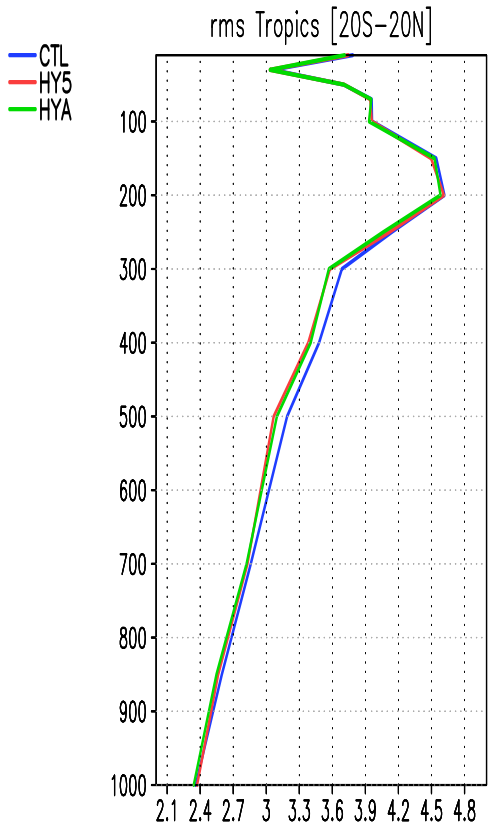


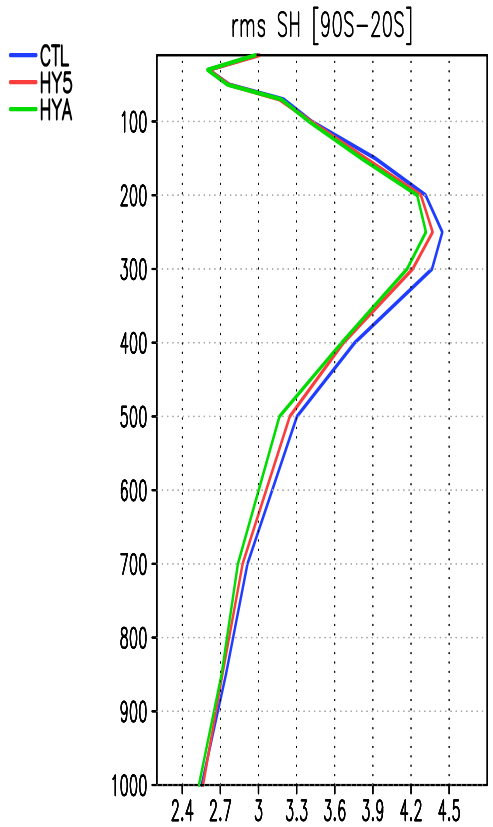


24-hour

Raob Zonal Winds

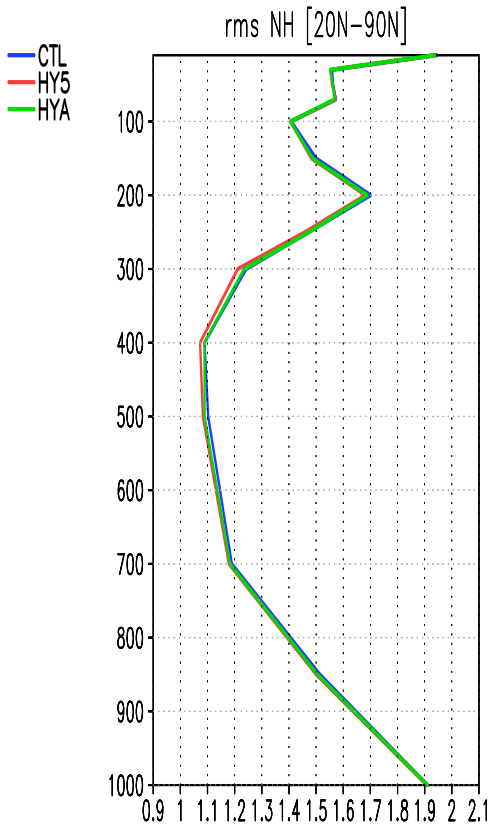


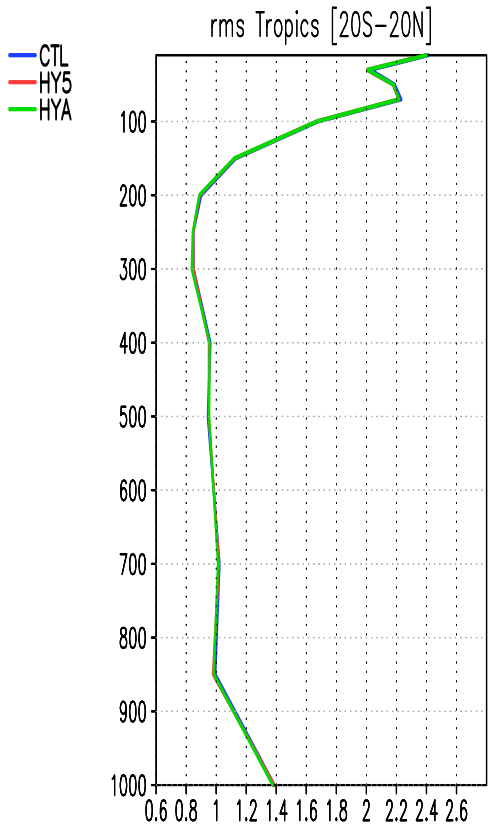


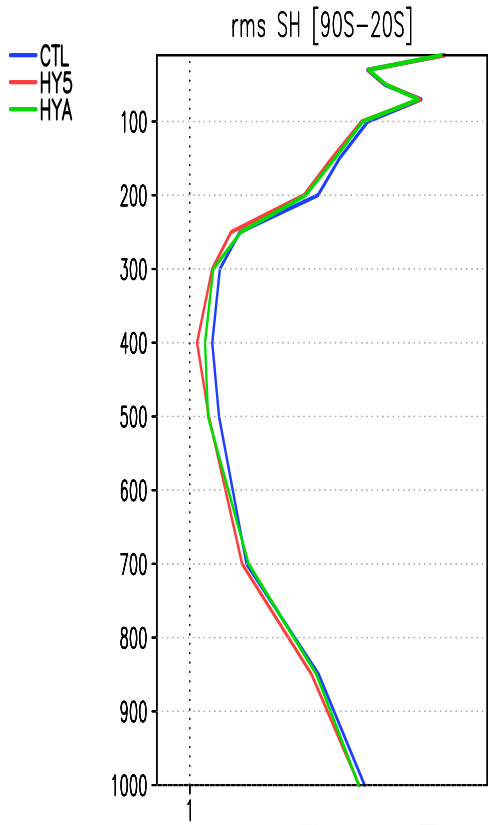


24-hour

Raob Temperatures

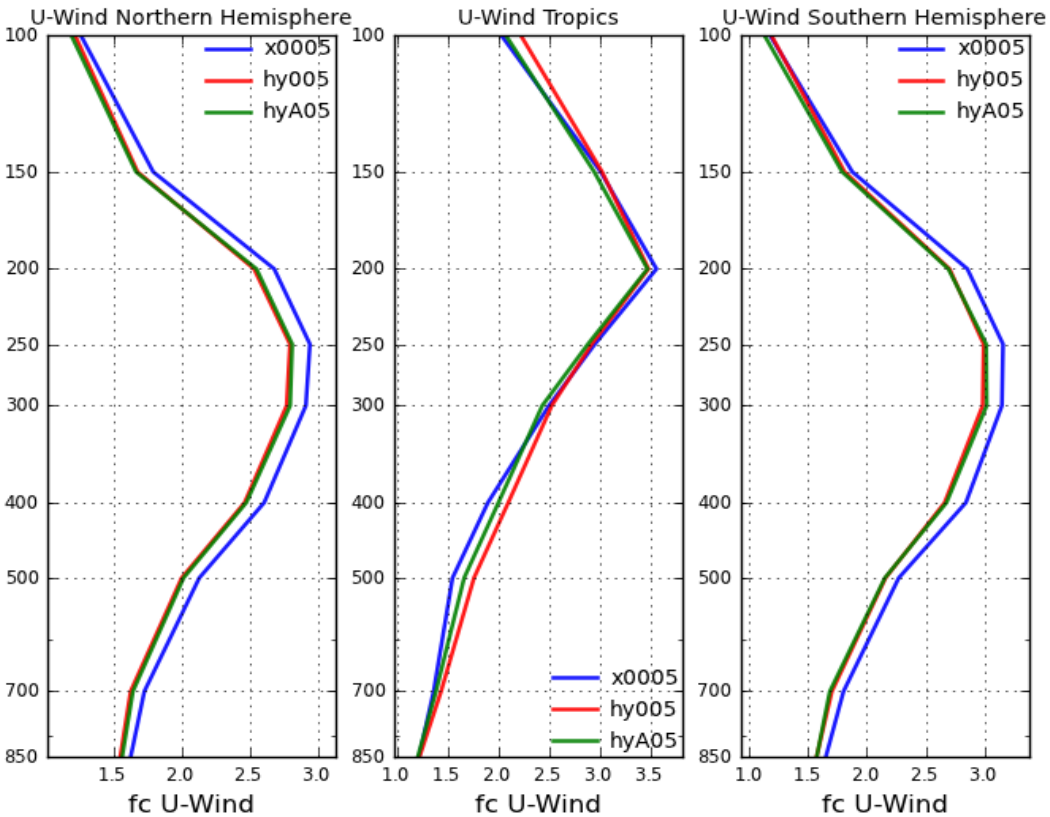






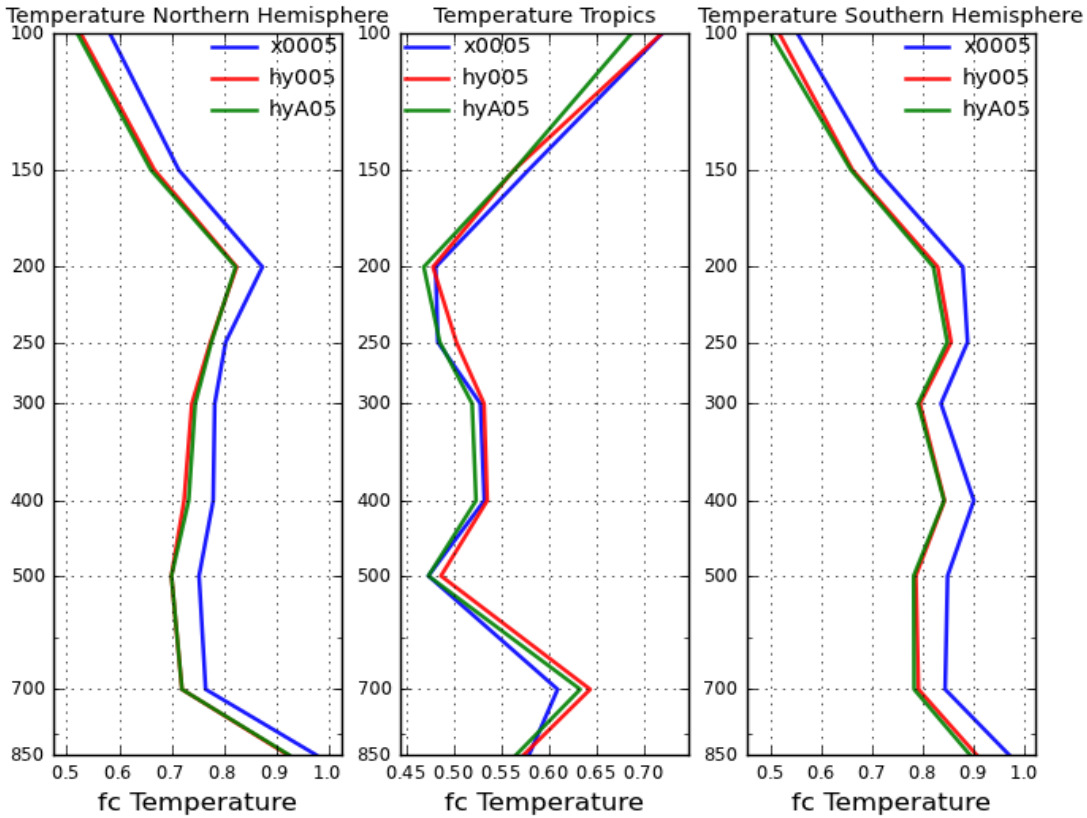
24-hour: Zonal Winds

NH Tropics SH



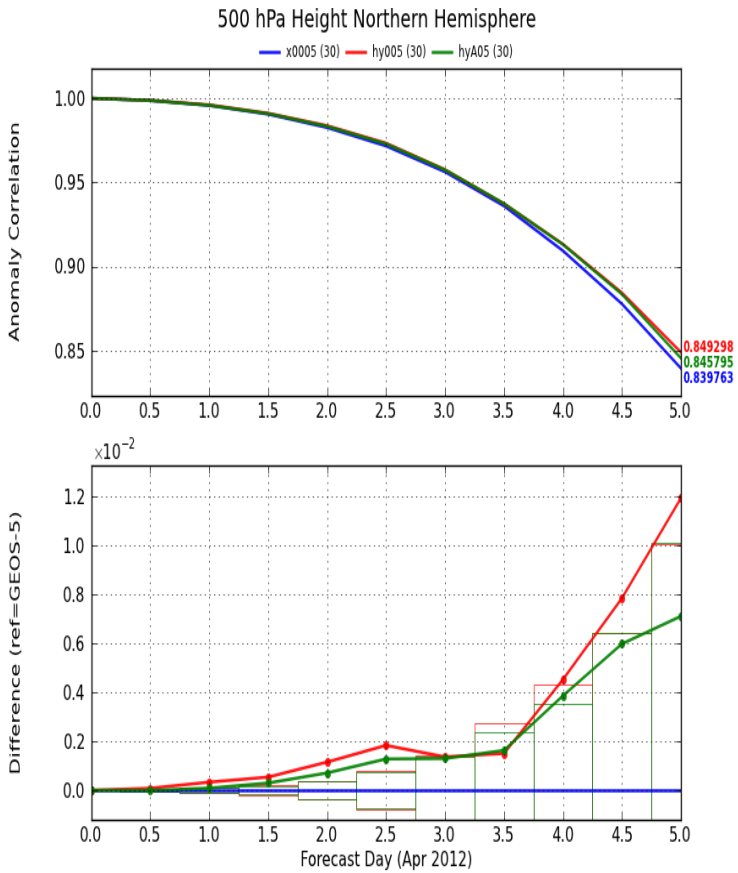
24-hour: Temperature

NH Tropics SH

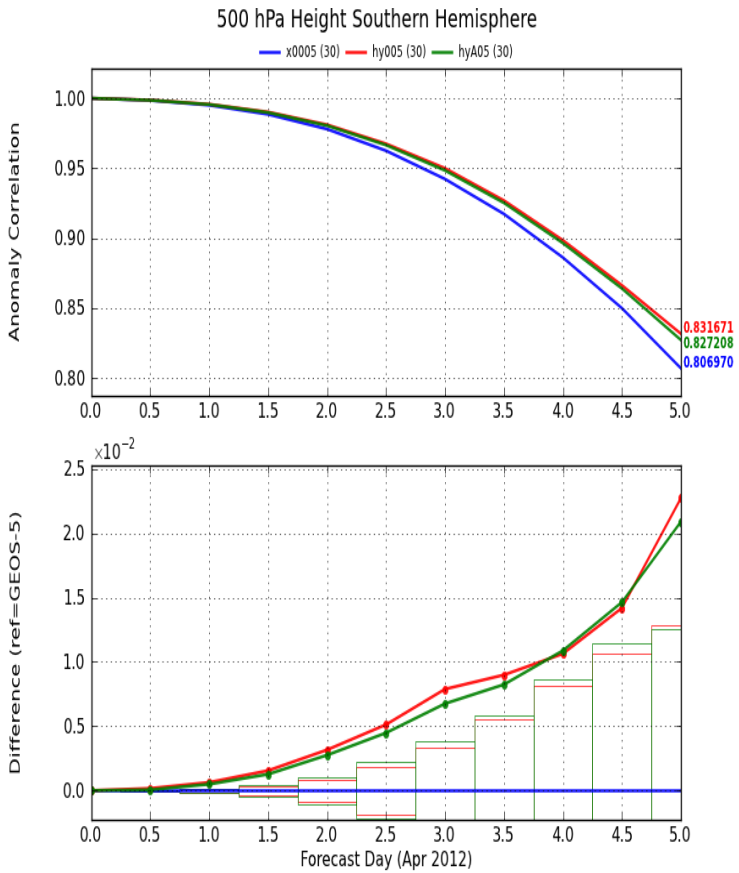


Anomaly Correlations: H500

Northern Hemisphere



Southern Hemisphere



Summary

Advantages of Filter-Free Hybrid

- Really inexpensive way of generating ensemble
- Avoid maintenance of two analysis systems
- Avoid contradictions when calculating impact of obs on forecasts

Other Points

- Will examine role of imbalance in the ensemble spread
- Will study skill of NMC-like perturbations more closely
- Ongoing preliminary 4d-EnsVar exp point to similar conclusions