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Application of Ensemble-based Forecast Sensitivity to Observations Metric to a Mesoscale Convective Initiation Case using the GSI-based EnKF System

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Motivation

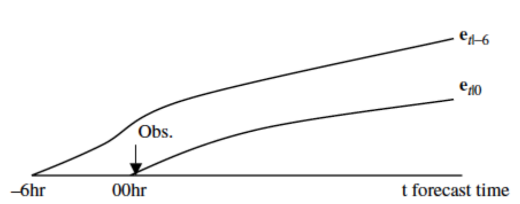
- Nationwide "Network of Networks" initiative – observations from government and private sectors combined to form single nationwide observing network
- Important to determine the value of each observing system on forecast
- The Ensemble-based Forecast Sensitivity to Observations (EFSO) metric of Kalnay et al. (2012) can estimate the impact from observations on a forecast, using readily-available products from any ensemble filtering system. It is analogous to the adjoint method of Langland and Baker (2004). With EFSO, we can evaluate the impact of any subset of observations on a forecast without need for separate data denial experiments or adjoint.
- **Utility of EFSO specifically for convective-scale forecasting is examined, using a case study from 15 May 2013.**
- **Localization is needed to obtain accurate estimates from EFSO, but proper localization complex due to dependencies (spatial, cross-variable, time-forecast).**

EFSO

Ensemble-based **F**orecast **S**ensitvity to **O**bservations (Kalnay et al. 2012)

$$J_{Actual} = \frac{1}{2}\left(\mathbf{e}_{t|0}^T\mathbf{e}_{t|0} + \mathbf{e}_{t|-1d}^T\mathbf{e}_{t|-1d}\right) \qquad \mathbf{e} = \overline{\mathbf{x}}^f - \overline{\mathbf{x}}^a$$

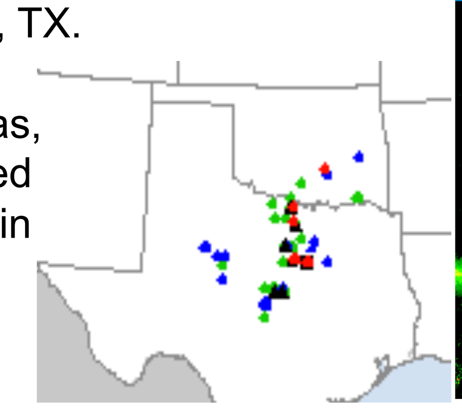
$$J_{EnsembleEstimate} = \frac{1}{K-1}\left(y - H\left(\overline{\mathbf{x}}_{0|-1d}^b\right)\right)^T \mathbf{R}^{-1}\left[\rho_I \circ \left(\mathbf{Y}_0^a\mathbf{X}_{t|0}^{fT}\right)\right]\left(\mathbf{e}_{t|0} + \mathbf{e}_{t|-1d}\right)$$



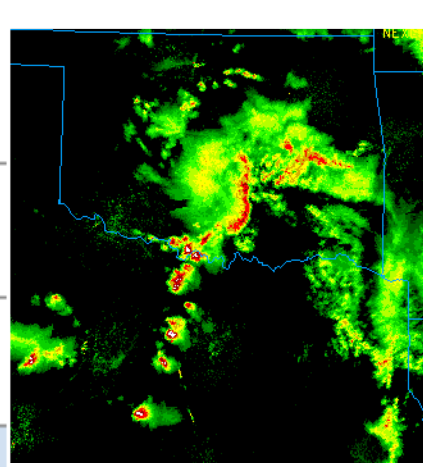
ρ_I is localization function, which acts on ensemble covariances between the analysis (in obs space) and a forecast of some length. Note that this localization function is different from localization used during assimilation (ρ_A), though they are related and shown to be linked together (Gasperoni and Wang 2014). Proper choice of ρ_I should take into account ρ_A as well as time-forecast and spatial considerations.

15 May 2013 Case Study

- 7 tornadoes, including EF4 in Hood County, TX and an EF3 in Johnson County, TX.
- Initiation after 2200 UTC in N. Texas, with storms initially discrete, initiated from increased differential heating in the afternoon, but later congealed into a line



Courtesy of Storm Prediction Center

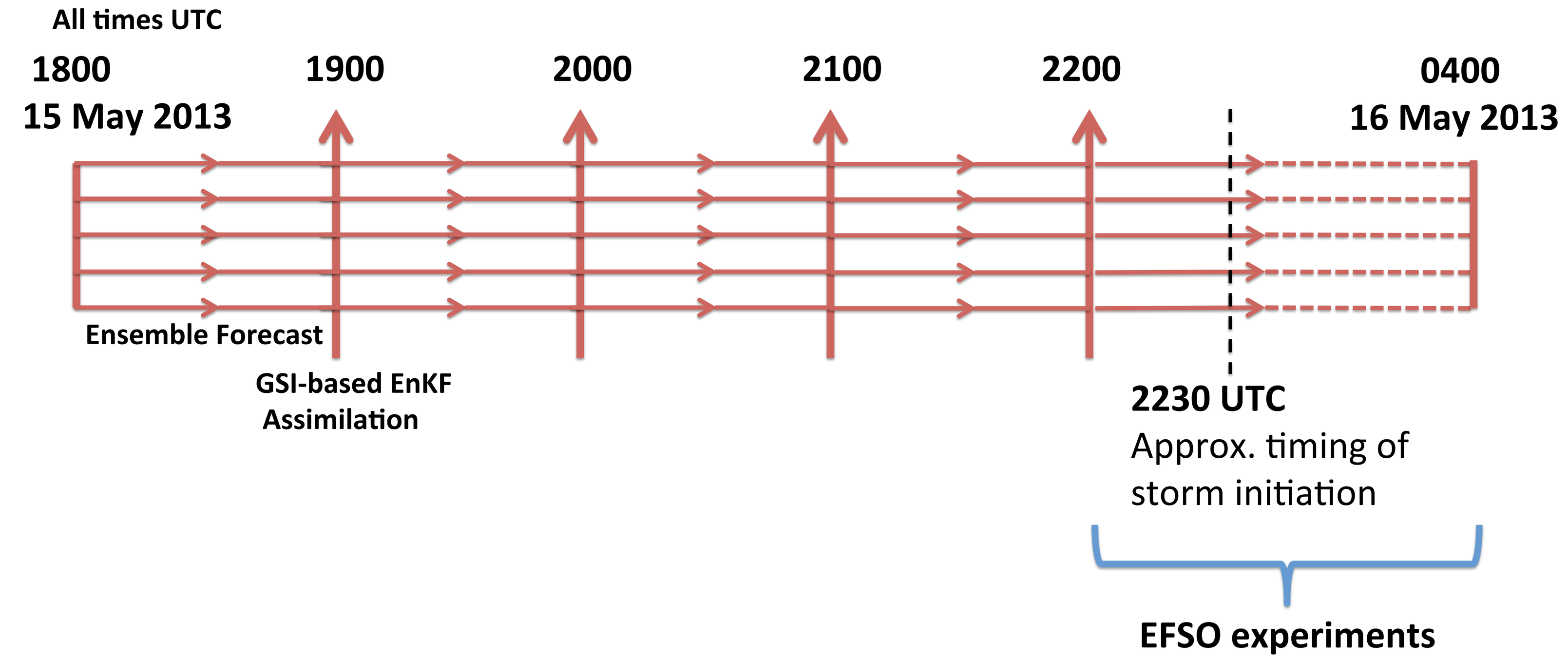


Courtesy of http://www2.mmm.ucar.edu/imagearchive/

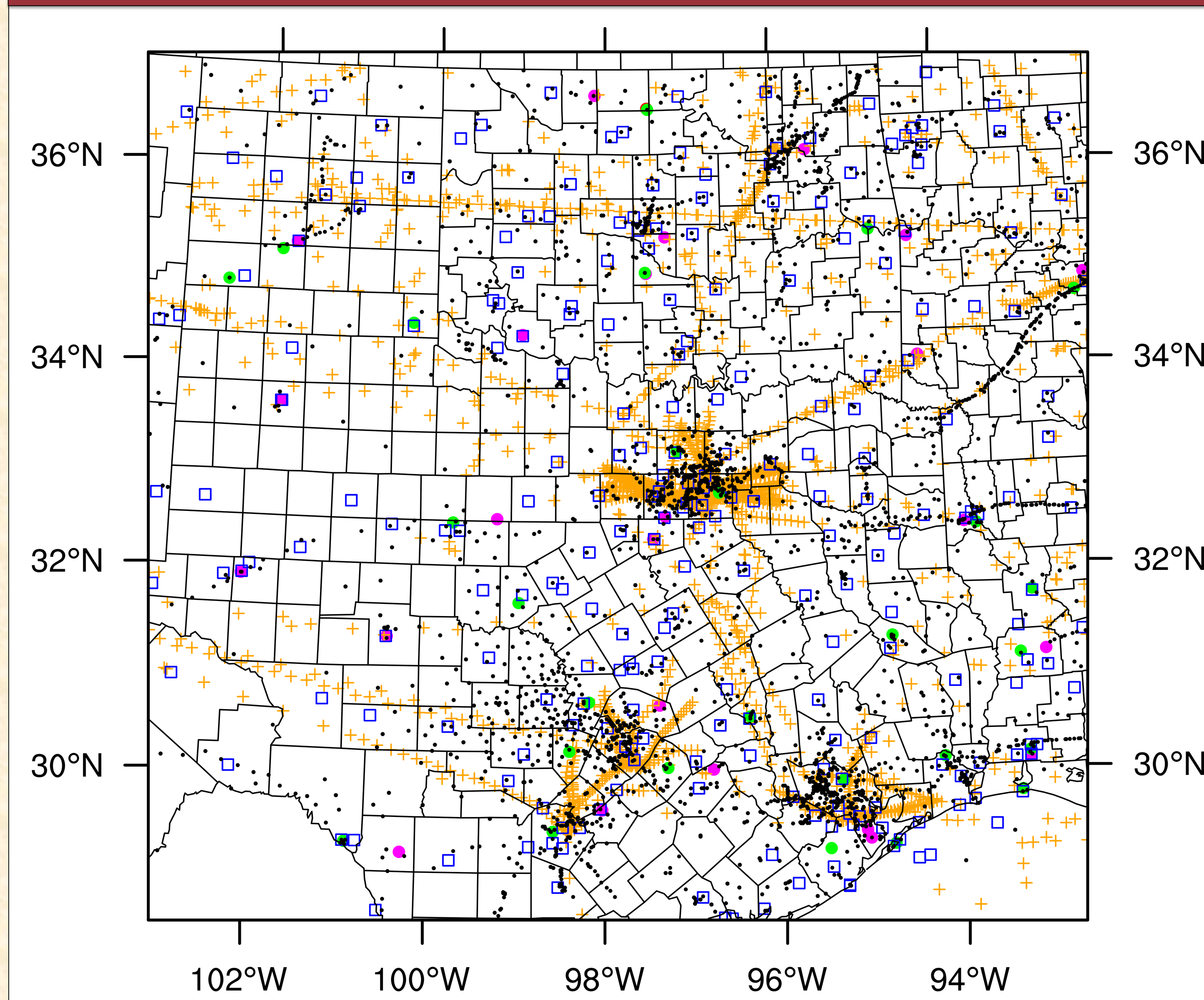
Image to the right – Numerical domain for experiments and observation locations. Orange crosses – aircraft observations, Magenta dots – GPS precipitable water observations, Green dots – RAOB and wind profilers, Blue squares – ASOS/Synoptic METAR surface observations, Black dots – Mesonet observations (from various sources such as Oklahoma Mesonet, Citizen Weather Observer Program, Weather Bug surface stations, etc.)

Experiment Design

- WRF-ARW with GSI-based EnKF
- Single domain, 3-km horizontal grid resolution, 400 X 400-km domain
- Observations assimilated from NDAS prepbufr file format
- 40-member ensemble initialized using "random-cv" method from a 12-km NAM analysis
  - Eventually will be combined ensembles from GEFS and SREF, so each ensemble has unique boundary condition
- Hourly cycling starting at 1900 UTC, after 1-hr spinup period, ending at 2200 UTC (final analyses)
- Data-denial and EFSO experiments focus on forecasts after assimilation period



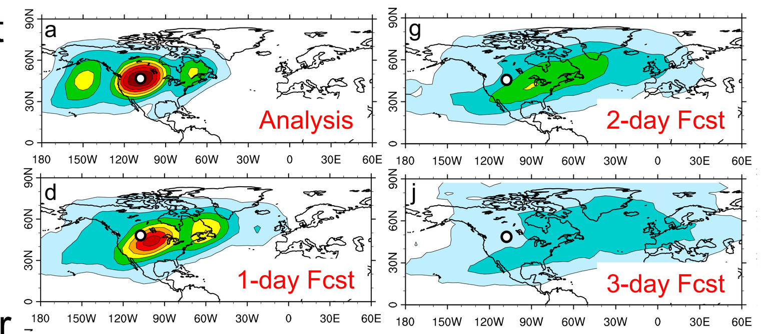
Observation Network



Adaptive Localization Methods for EFSO

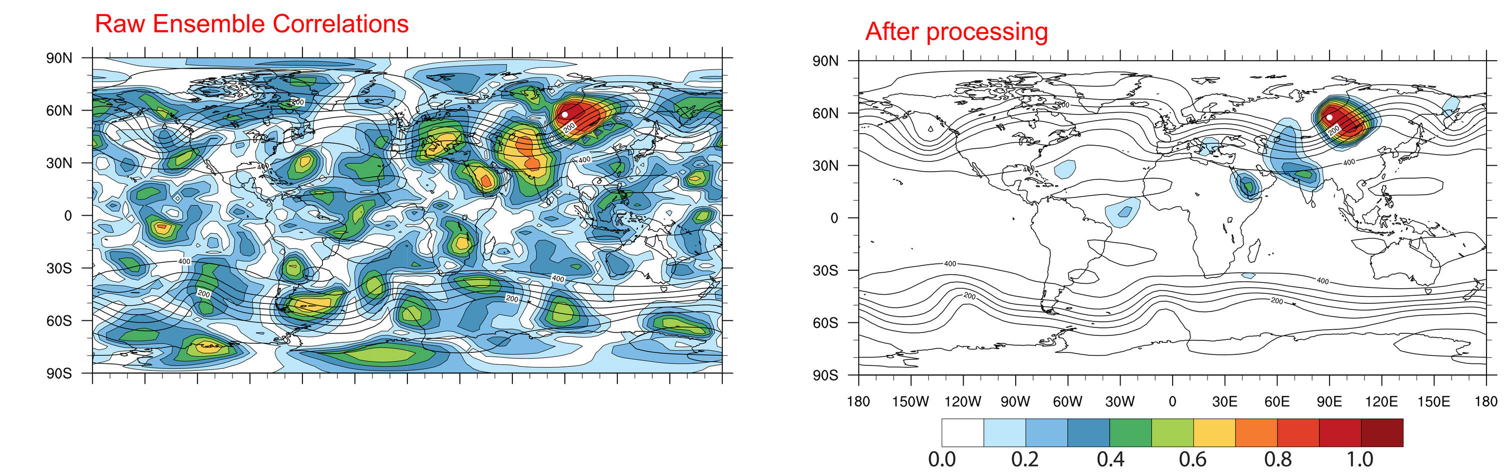
1. Regression Confidence Factor (RCF) – Uses groups of ensembles
   - Based off of Anderson (2007) 'hierarchical filter' or 'group filter'
   - Captures underlying dynamical correlations of model in time, space, and among different variables.
   - Shown to be skillful for two-layer model EFSO calculations (Gasperoni and Wang 2014)
   - How to apply for EFSO at convective scale? Online smoothing process, or averaging over composites

$$\beta_{l,j} = \frac{\left(\mathbf{HX}_0^a\mathbf{X}_{t|0}^{fT}\right)_{l,j}}{\left(\mathbf{HX}_0^a(\mathbf{HX}_0^a)^T\right)_{l,l}} \qquad RCF = \frac{\left[\left(\sum_{i=1}^m \beta_i\right)^2 \Big/ \sum_{i=1}^m \beta_i^2\right] - 1}{g-1}$$



Example of RCF capturing underlying model time-forecast dynamics

2. Ensemble Correlations Raised to a Power (ECO-RAP) localization (Bishop and Hodyss 2009)



3. Other methods may be considered, such as Empirical Localization of Anderson and Lei (2013), or using parameters derived from RCF (offset, maximum magnitude, east-west span, north-south span) to automatically tune an elliptical GC function (Gasperoni Wang 2014)

Research Focus

Data Denial Experiments – To establish impact of subsets of observations, and to use for comparison in EFSO estimations

Focus in Convective Initiation – Specifically timing/location (in N. Texas) as well as mesoscale environment.

Compare and contrast adaptive methods for EFSO – How to apply these methods for effective use in convective-scale observation impact estimation. Key focus on localization capturing "errors of the day", given high nonlinearity of model for convective scales

Vertical Profiles – How do adaptive methods handle vertical localization, and does it lead to more accurate impact estimates.

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