P 610

Application of Mesoscale Ensemble-based Sensitivity Analysis to Observation Targeting

Aaron Hill, Chris Weiss, and Brian Ancell, Atmospheric Science Group, Texas Tech University

Observation Targeting

- Relating a change in forecast uncertainty (variance) to changes in initial conditions via assimilating additional observations from "targeted" regions
- Target regions are determined by a maximum reduction in forecast variance

$$\delta\sigma = \frac{covar^2(J,x)}{var(x) + var(ob)}$$ (Ancell and Hakim 2007)

- Variance reduction is positive-definite
- More observations reduce uncertainty
- Has been applied on synoptic scales (Torn and Hakim 2008) but can it translate to the meso- and convective scales where non-linearity is large?
- Errors in the position of drylines and subsequent convective initiation has shown to be prevalent amongst mesoscale forecasts (Coffer et al. 2013)
- An example of targeted regions for 2-m temperature, dewpoint, and specific humidity can be seen in Figure 1 to improve a 24-hr forecast of max reflectivity in north Texas

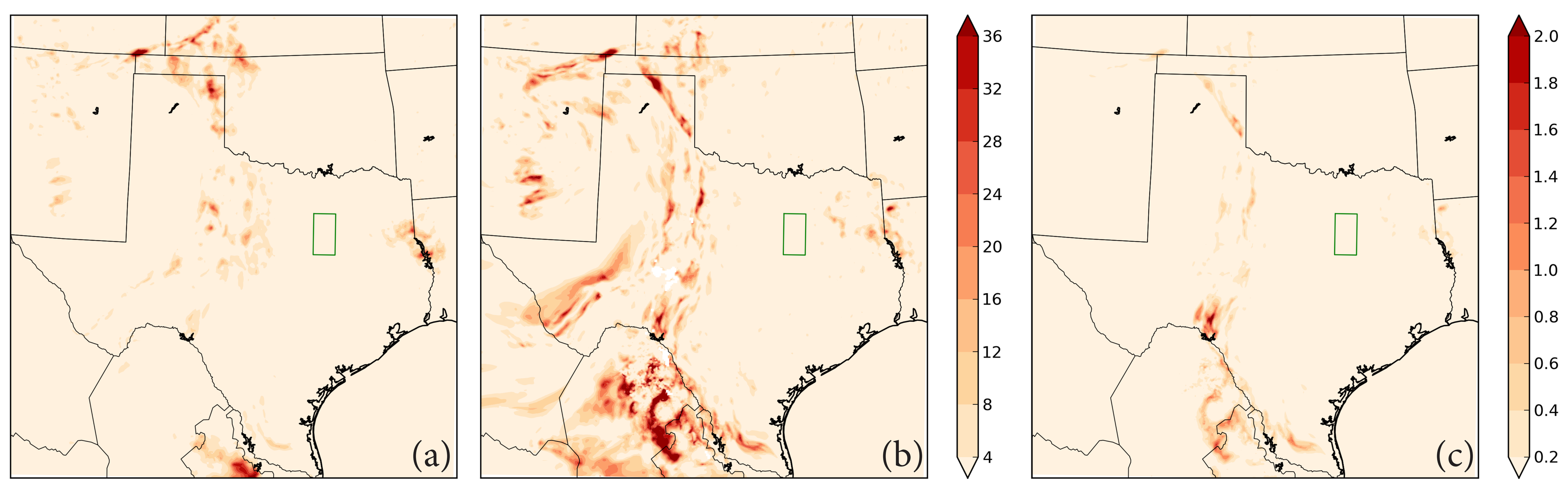

Figure 1. Estimated variance reduction of max column reflectivity (dBZ²) at forecast hour 24 in north-central Texas by assimilating (a) 2-m temperature (K), (b) 2-m dewpoint (K), and (c) 2-m specific humidity (g kg⁻¹) observations at analysis time. Green rectangle represents the response function region at forecast hour 24.

April 3rd, 2012 Case Study

- Convection developed in the early afternoon over north Texas
- Observations from the West Texas Mesonet (WTM) are withheld from assimilation to determine which station would have the largest impact on variance reduction
- Station with the largest predicted impact is selected, 2-m temperature is assimilated, and new variance is assessed
- This process is repeated for five stations and three response functions (Figure 2)

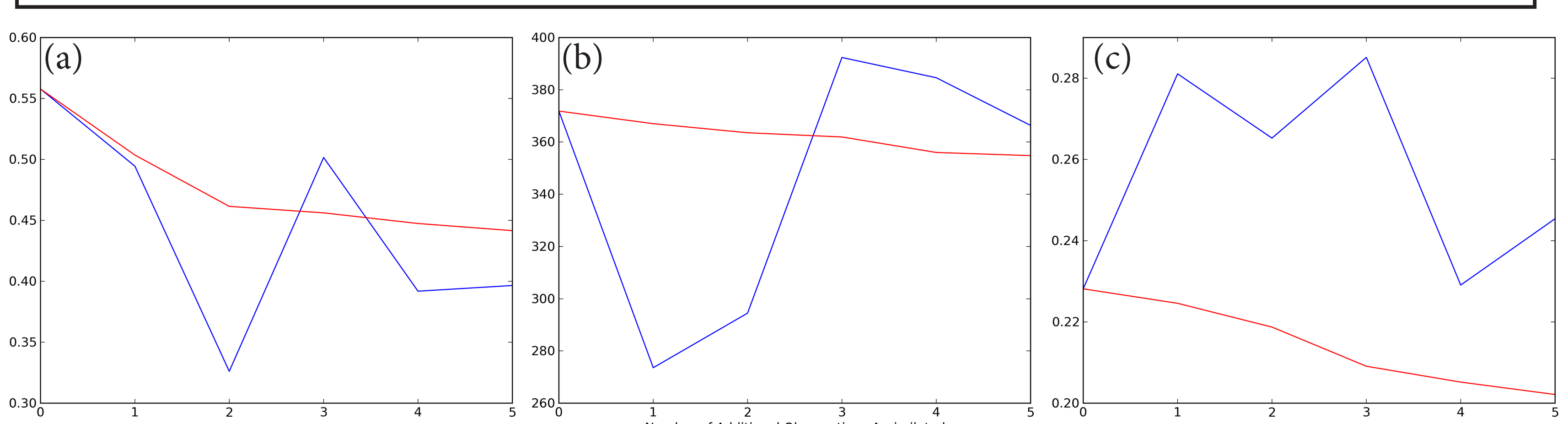

Figure 2. Expected variance reduction (red) and actual variance reduction (blue) by assimilating targeted 2-m temperature (K) observations from five different stations for response functions (a) averaged 2-m temperature (K²), (b) max column reflectivity (dBZ²), and (c) max column vertical velocity (m² s⁻²) within the response region (see green box in Figure 1).

- An assimilation procedure with the Data Assimilation Research Testbed (DART; Anderson et al. 2009) and Weather and Research Forecasting (WRF) V3.3.1 model is used with two, one-way nested inner domains as seen in Figure 3 (only domain 3 is considered here)

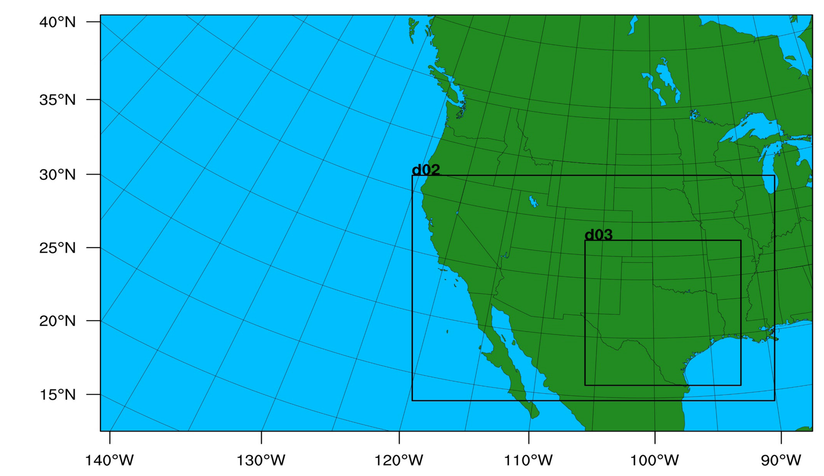

Figure 3. Domain configuration for nested DART-WRF simulations.

- It appears the assimilation of targeted surface temperature observations had negative and positive effects on forecast variance, for the three selected response functions (Figure 2)
- Is there a problem? Why are the results not consistent with theory?

Initial Condition Differences

- 2-m temperature and 2-m dewpoint exhibited the largest differences between two subset means (Figure 4)
- Two subsets were classified, ones that produced convection (max column reflectivity > 0) within the response function region at forecast hour 24 and those that did not
- Differences at initial time were primarily located along a pre-existing dryline and area of convection
- Differences translated in time and space towards the response function region at forecast hour 24 (Figure 4 c,f)

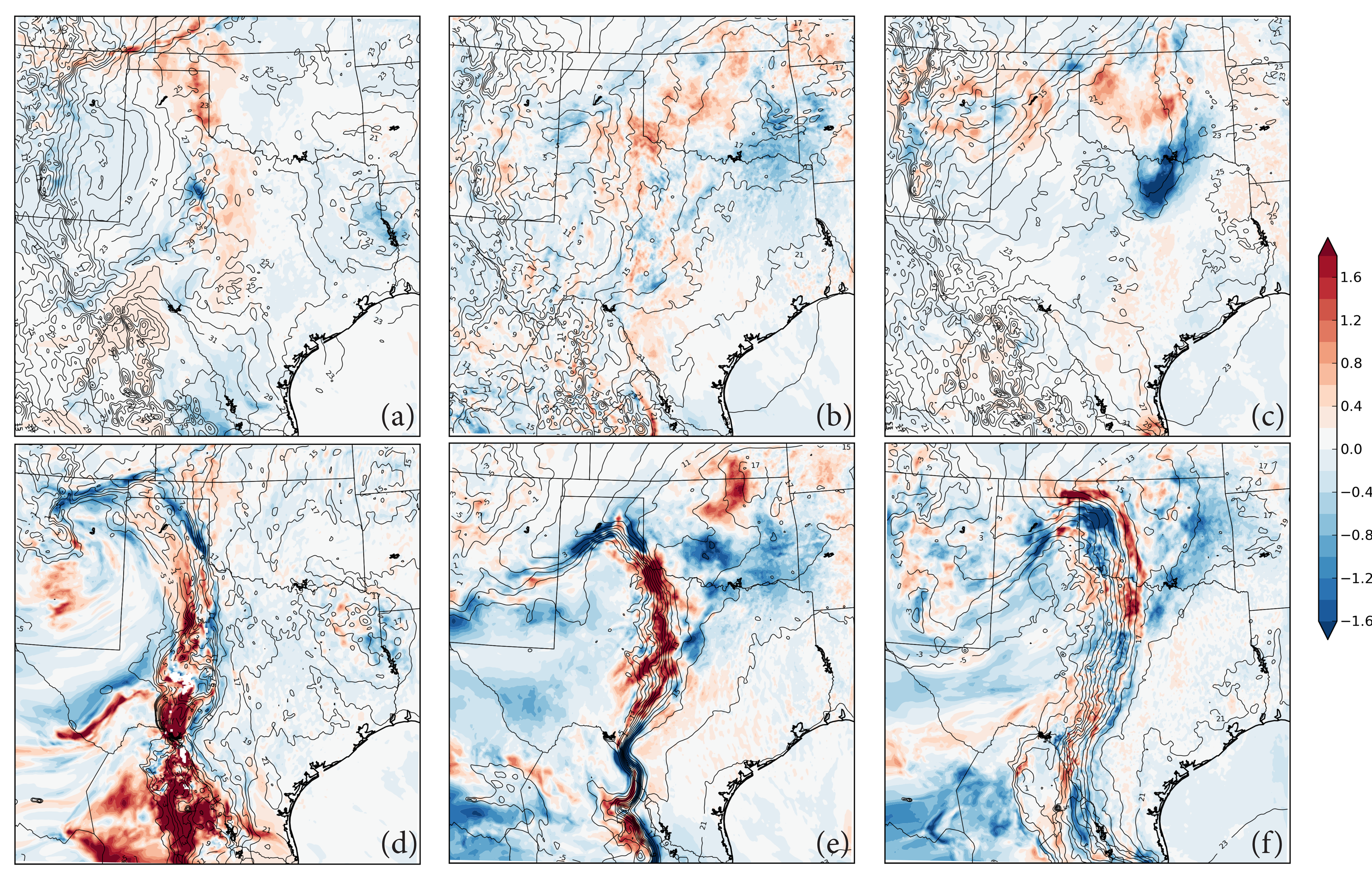

Figure 4. Convection producing members (max column reflectivity > 0) within the response function region (see green box in Figure 1) at response time minus non-convection producing members (shaded) at forecast hours 0 (left), 12 (middle), and 24 (right) for variables (a)-(c) mean 2-m temperature (K) and (d)-(f) mean 2-m dewpoint (K). Contoured is the subset mean of convective producing members for each respective variable every 2 K.

Ancell, B. C. and G. J. Hakim, 2007: Comparing ensemble and adjoint sensitivity analysis with applications to observation targeting. *Monthly Weather Review*, **135**, 4117-4134.

Anderson, J., T. Hoar, K. Raeder, H. Lui, N. Collins, R. Torn, and A. Avellano, 2009: The data assimilation research testbed. *Bulletin of the American Meteorological Society*, **90**, 1283-1296.

Coffer, B. E., L. C. Maudlin, and P. G. Veals, 2013: Dryline position errors in experimental convection-allowing NSSL-WRF model forecasts and the operational NAM. *Weather and Forecasting*, **28**, 746-761.

Torn, R. D. and G. J. Hakim, 2008: Ensemble-based sensitivity analysis. *Monthly Weather Review*, **136**, 663-677.

- The theory requires a relationship between forecast metric and initial conditions to be linear and the response function Gaussian, not bi-modal as it appears to be in this case (see Figure 5)
- The presence of such a bi-modal type response function likely renders the theory developed by Ancell and Hakim (2007) and Torn and Hakim (2008) inaccurate
- These initial condition differences may be a factor in the increase of forecast metric variance, which doesn't follow the observation targeting theory

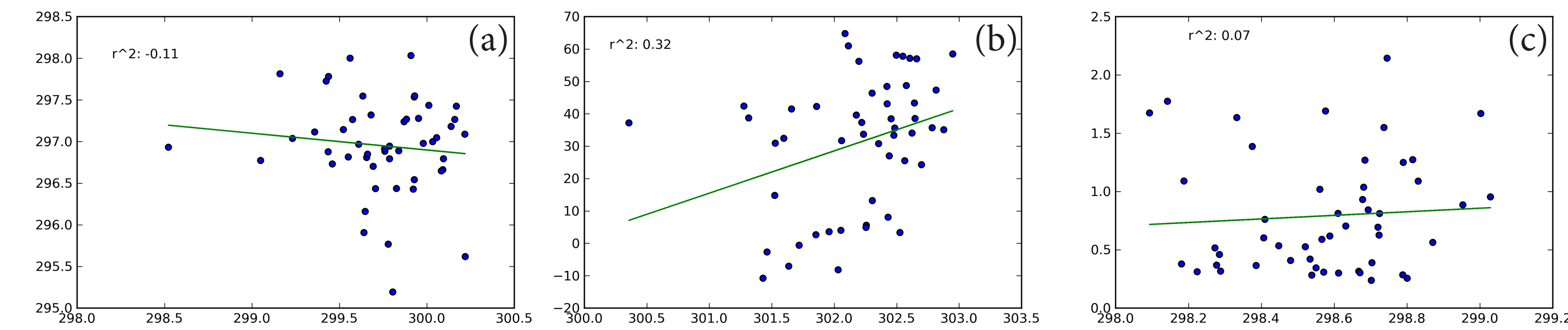

Figure 5. Scatter of response functions (a) average 2-m temperature (K), (b) max column reflectivity (dBZ), and (c) max column vertical velocity (m s⁻¹) at forecast hour 24 within a response function region (see green box in Figure 1) versus initial condition 2-m temperature (K) at a point identified as a targeting region in west Texas. Green line is the linear regression fit to the scatter. Correlation coefficient identified in upper left corner.

Summary

- Observation targeting can be applied easily using a data denial approach to assess how West Texas Mesonet observations improve predictability of mesoscale dryline convective-initiation
- Assimilated target observations provided mixed results, sometimes reducing forecast variance and other times increasing it
- Variance increasing when target observations are assimilated could be a result from bi-modal distributions of chosen response functions, which violates targeting theory
- Can theory of observation targeting be useful on the meso- and convective scales? If not, why not?

Future Work

- Use convective-based response fuctions that are continuously distributed across the ensemble members and don't exhibit bi-modal signatures (e.g. low-level shear, moisture gradients)
- Use more dryline cases to determine climatological targeting areas for dryline convective-initiation in the Southern Plains
- Mobile observing with TTU StickNet platforms and radiosondes, ensemble-based sensitivity and targeting in real-time, and using targeted observations to reduce forecast error
- Do targeted observations hold value over non-targeted observations when assimilated?
- Use observation targeting to improve prediction of other mesoscale phenomena (e.g. winter weather, wind)

Acknowledgements

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