24th Conference on IOAS-AOLS, 13 January 2020, Boston, Massachusetts

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Testing the Feature Alignment Technique (FAT) with Multiple Storms

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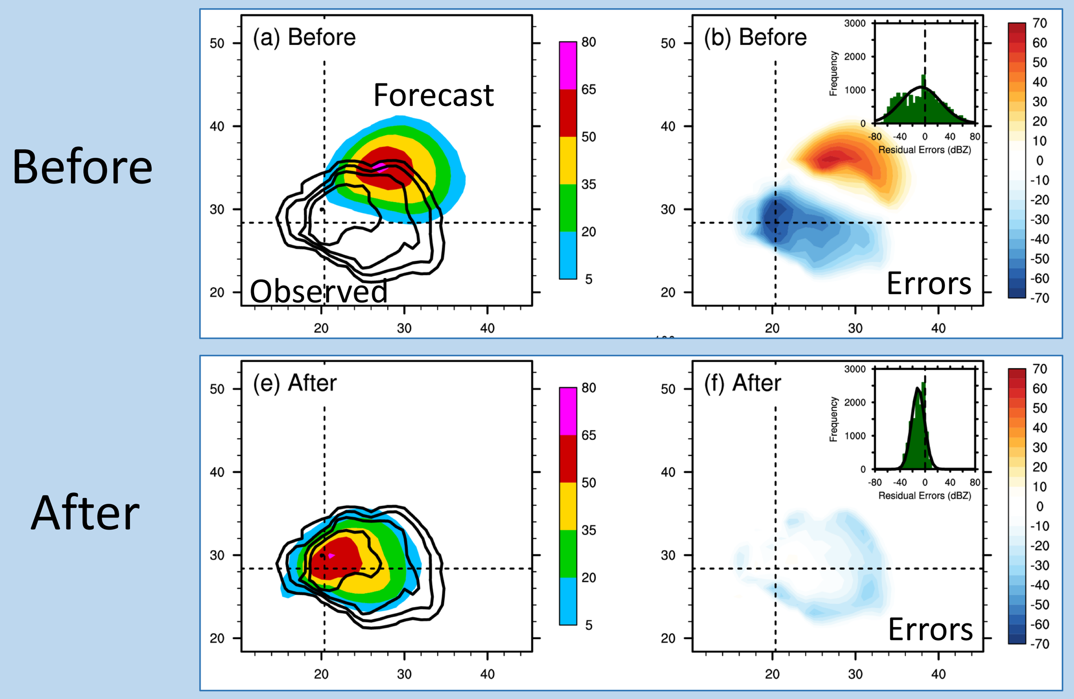
Background

- A goal of Warn-on-Forecast (WoF) is to develop ensemble-based forecasting systems that produce accurate probabilistic forecasts of severe weather for operational warning settings.
- As some WoF-related studies have indicated, an ongoing issue in storm-scale, short-term forecasts is storm displacement errors.
- Generally, forecast storms propagate faster than observed storms.
- To help alleviate these storm displacement errors, Stratman et al. (2018) implemented a new version of the feature alignment technique (FAT; Nehrkorn et al. 2014, 2015) into CM1-LETKF.
- Using observing system simulation experiments (OSSEs), we tested the FAT on an idealized *single* supercell case.



- Those experiments indicated the potential benefits of alleviating storm displacement errors during the data assimilation process by reducing location and intensity errors.
- However, the impacts of using the FAT with multiple storms in a WoF data assimilation and forecast system (WoFS) are unclear.

What is the FAT?

- Minimizes cost function between a forecast and observed field to produce a 2-D field of displacement vectors, which are applied to model state variables prior to data assimilation.

$$J = J_r[\mathbf{y}, H(\mathbf{x}), \mathbf{a}, \mathbf{b}] + J_p(\mathbf{a}, \mathbf{b})$$

$$\mathbf{a} = \delta\mathbf{i}; \mathbf{b} = \delta\mathbf{j}$$

Residual $$J_r = \sum_{n=1}^{N_o} \frac{[y_n - x_n(i_n + a_n, j_n + b_n)]^2}{\sigma_{o,n}^2}$$

Penalty $$J_p = \lambda_s J_s + \lambda_d J_d + \lambda_m J_m + \lambda_b J_b$$

Divergence $$J_d = \sum_{n=1}^{N_o} \left(\frac{\partial a_n}{\partial i_n} + \frac{\partial b_n}{\partial j_n}\right)^2$$

Magnitude $$J_m = \sum_{n=1}^{N_o} \left(\frac{a_n}{S}\right)^2 + \sum_{n=1}^{N_o} \left(\frac{b_n}{S}\right)^2$$

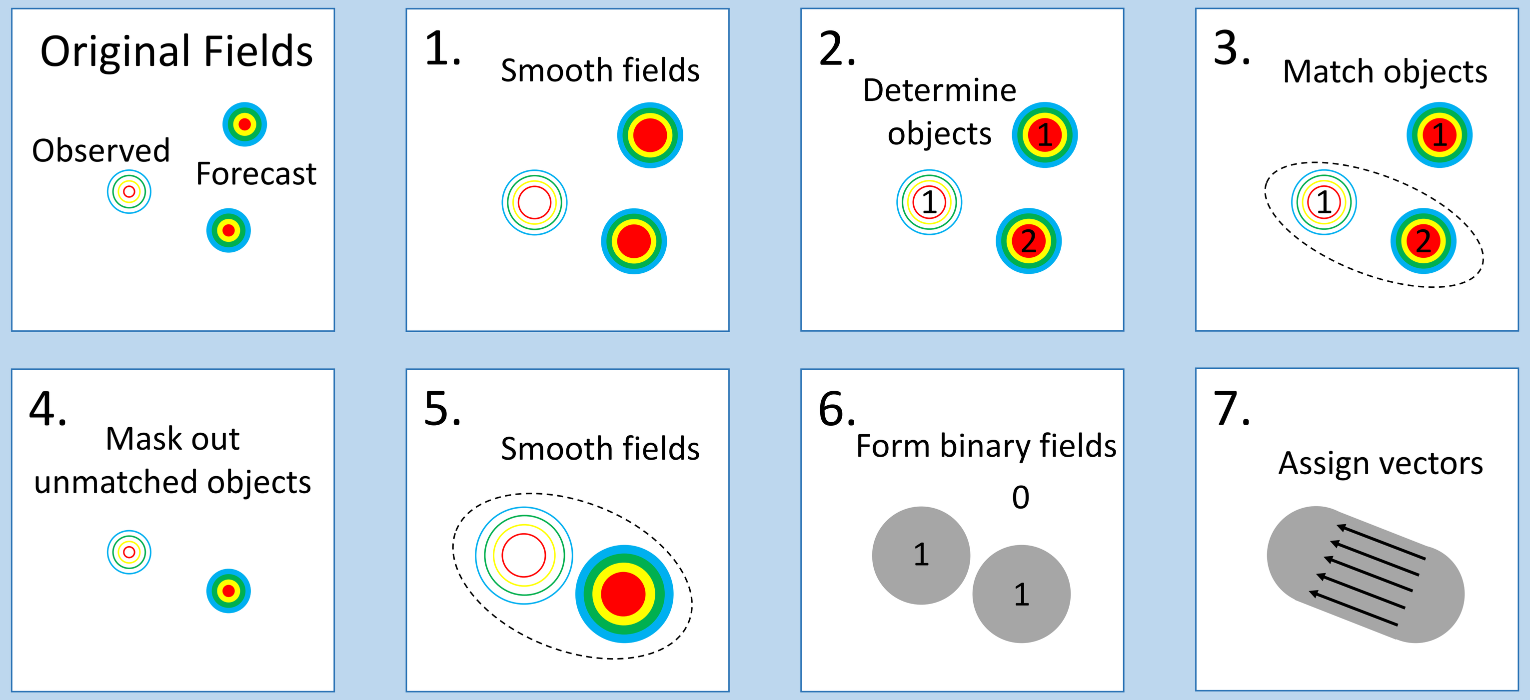
Barrier $$J_b = \sum_{n=1}^{N_o} \left(\frac{a_n}{S}\right)^{20} + \sum_{n=1}^{N_o} \left(\frac{b_n}{S}\right)^{20}$$

Smoothness $$J_s = \frac{1}{\left(\frac{\Delta d}{(\Delta L)^2}\right)^2} \sum_{n=1}^{N_o} \left(\frac{\partial^2 a_n}{\partial i_n^2} + \frac{\partial^2 a_n}{\partial j_n^2}\right)^2 + \frac{1}{\left(\frac{\Delta d}{(\Delta L)^2}\right)^2} \sum_{n=1}^{N_o} \left(\frac{\partial^2 b_n}{\partial i_n^2} + \frac{\partial^2 b_n}{\partial j_n^2}\right)^2$$

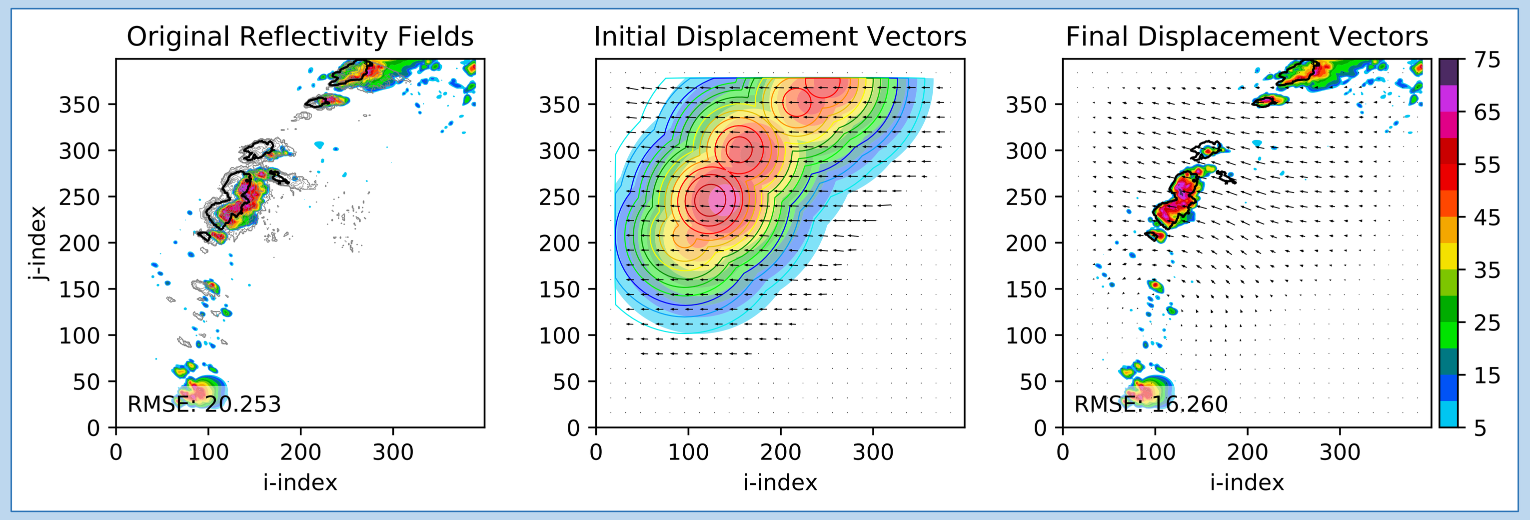
Nehrkorn, T., B. Woods, T. Auligné, and R. N. Hoffman, 2014: Application of feature calibration and alignment to high-resolution analysis: Examples using observations sensitive to cloud and water vapor. *Mon. Wea. Rev.*, **142**, 686–702.
Nehrkorn, T., B. K. Woods, R. N. Hoffman, and T. Auligné, 2015: Correcting for Position Errors in Variational Data Assimilation. *Mon. Wea. Rev.*, **143**, 1368–1381.
Stratman, D. R., C. K. Potvin, and L. J. Wicker, 2018: Correcting Storm Displacement Errors in Ensembles Using the Feature Alignment Technique (FAT). *Mon. Wea. Rev.*, **146**, 2125–2145.

FAT Process

1. Read in forecast and observed composite reflectivity fields.
2. Form a first-guess field of displacement vectors using object merging and matching.



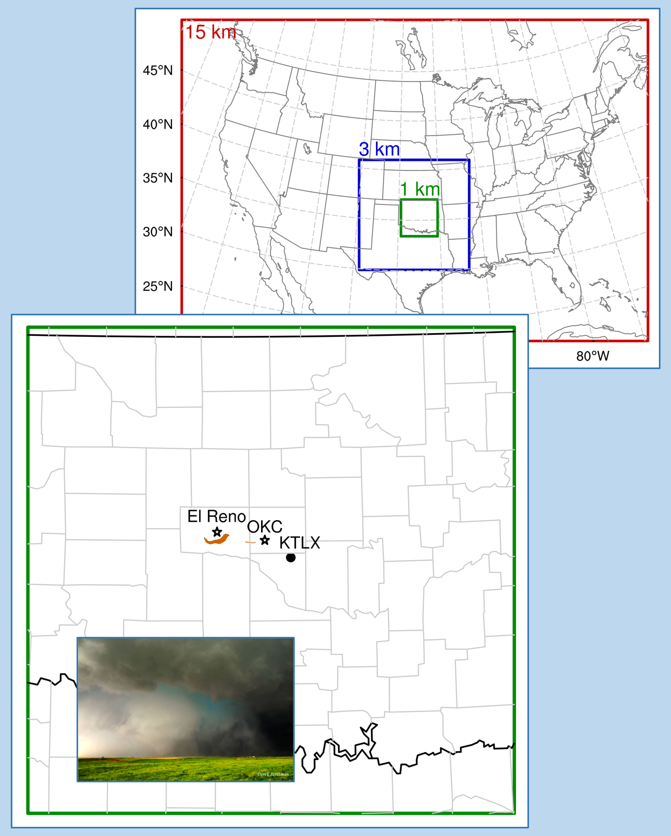
3. Run minimization function to determine the final 2-D field of displacement vectors.

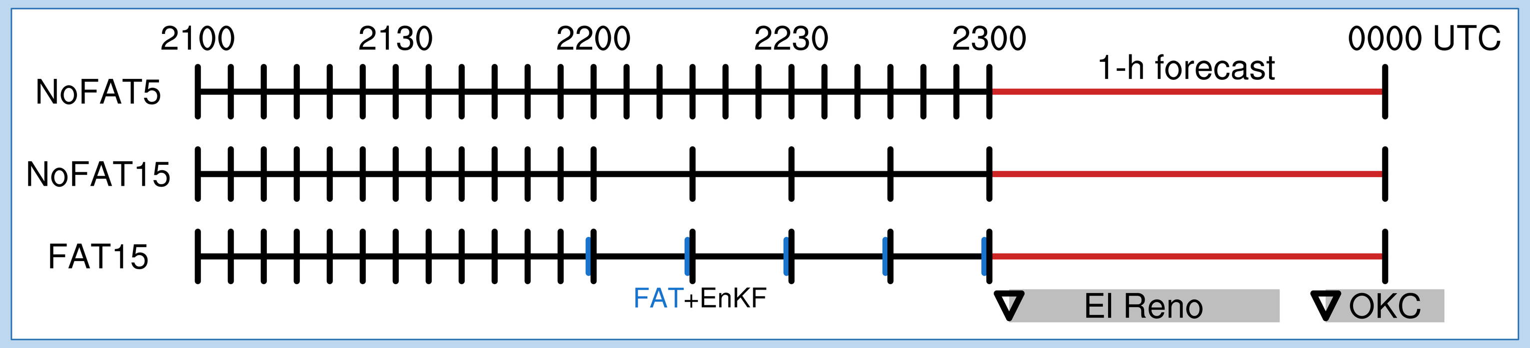


4. Update all model state variables at all levels using the 2-D field of displacement vectors.

Real-Data Experiment

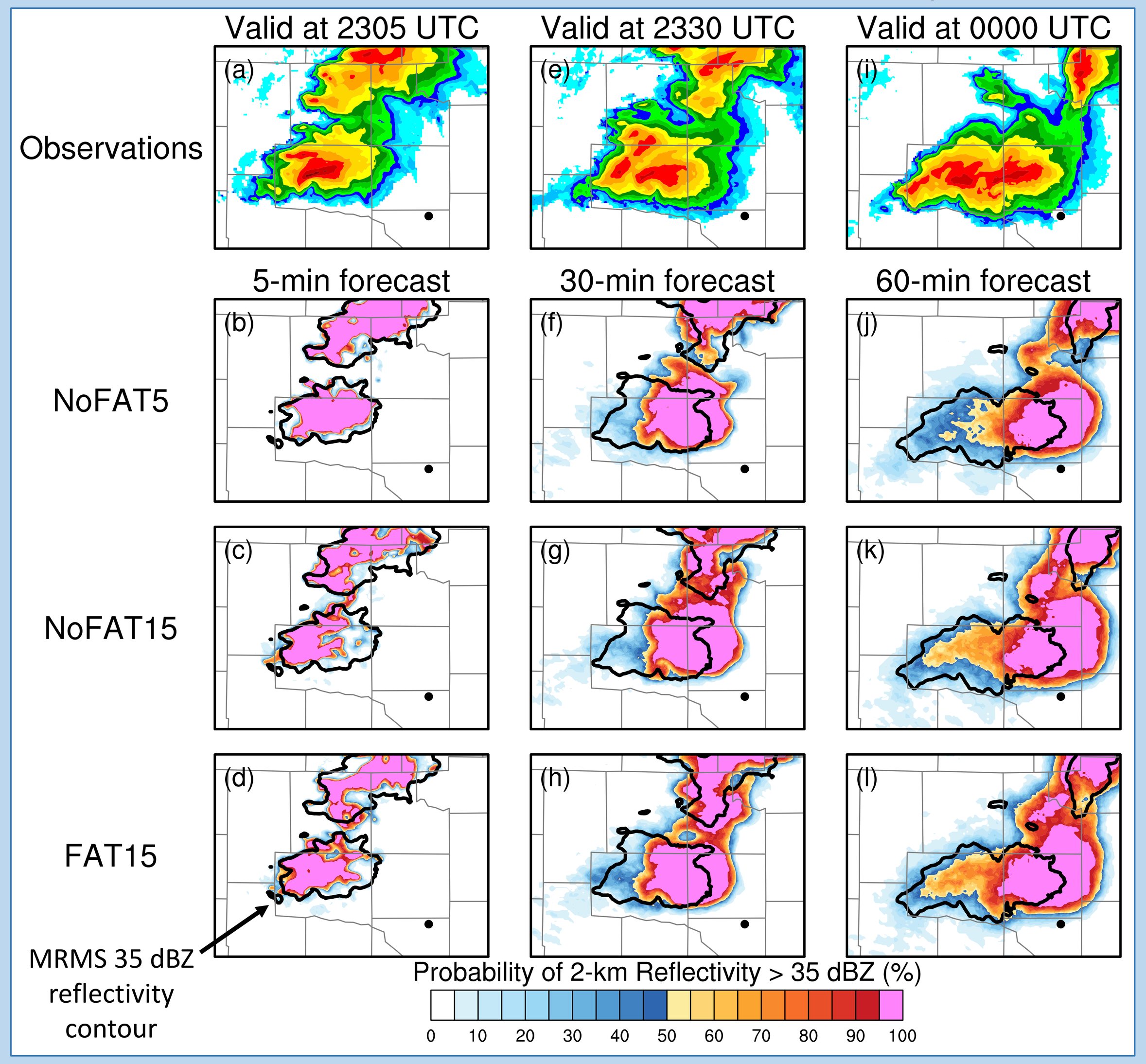
- GSI(v3.6) and EnKF(v1.2)
- WRF(v3.9.1.1)
- 3-km domain provides ICs and BCs
  - conventional observations only
- 400x400x51 grid points
- 1-km horizontal grid spacing
- Only KTLX radar data assimilated
  - reflectivity
  - radial velocity
- To focus on correcting phase errors:
  - First, 1 h of 5-min DA cycling
  - Second, 1 h of 15-min DA cycling
- FAT is completed prior to each DA step



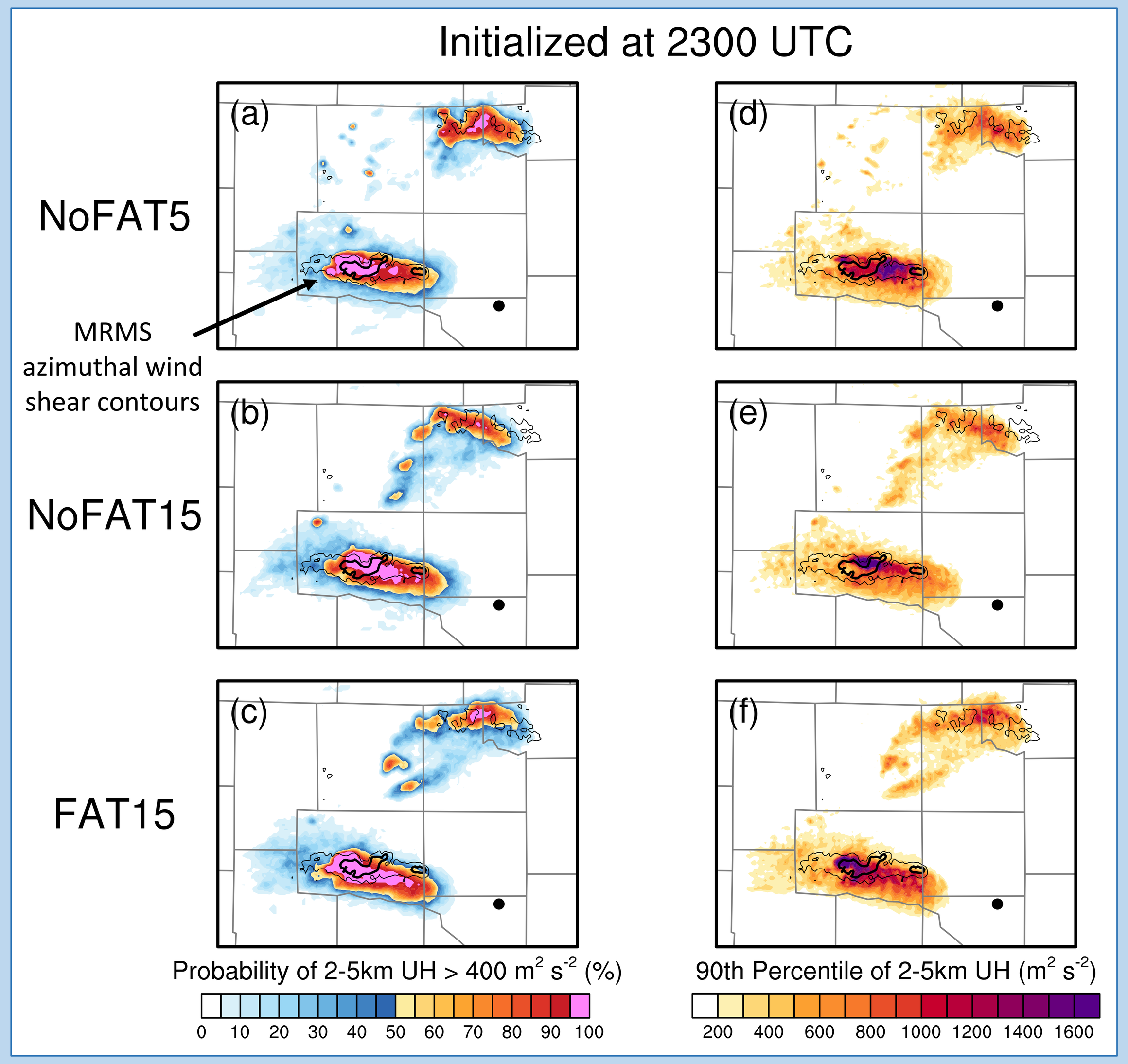


Preliminary Results

- Instantaneous Probabilities of 2-km MSL Reflectivity > 35 dBZ



- Probability and Intensity Swaths of 2–5-km Updraft Helicity



Summary

- These initial experiments indicate some potential benefits the FAT may provide the current experimental WoFS.

Future Work

- Further sensitivity testing of the FAT parameters with multiple cases.
- Test FAT with various DA cycling intervals (e.g., 5, 10, 15, 20, 30 min).
- Run multiple-storm OSSEs and additional real-data experiments.
- Make FAT run faster (currently takes up to 2 min per member).

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