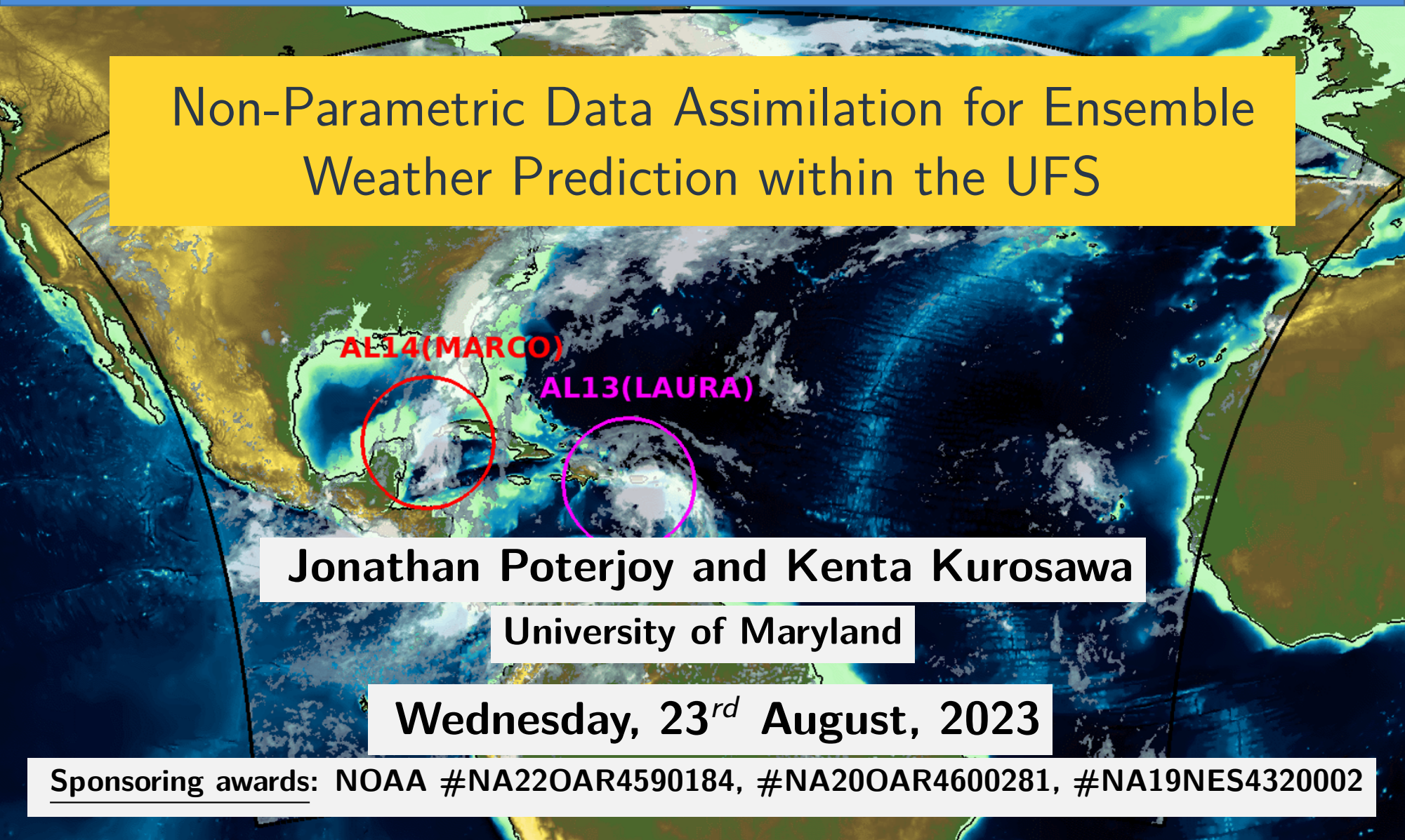
Non-Parametric Data Assimilation for Ensemble Weather Prediction within the UFS



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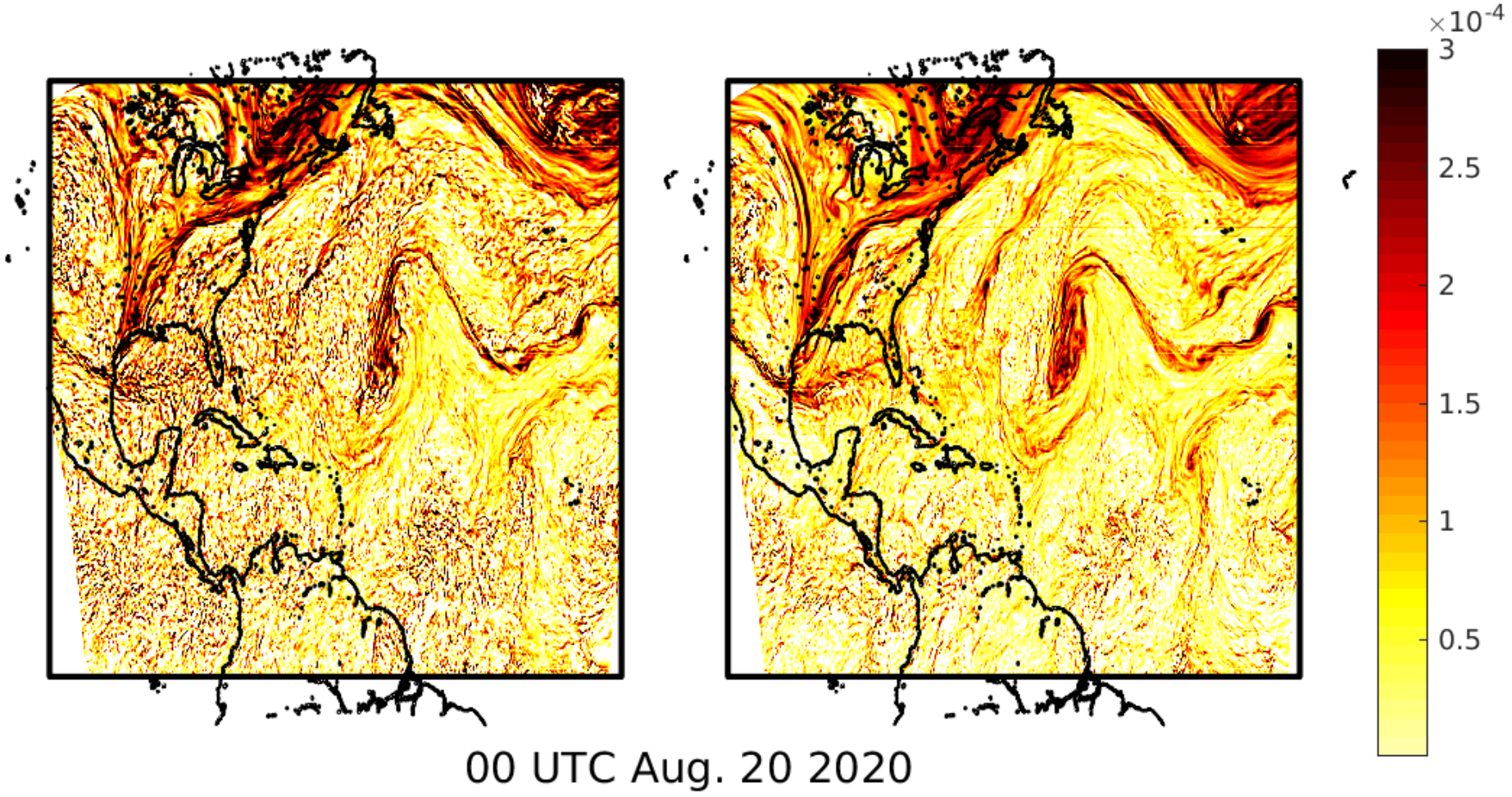
Wednesday, 23rd August, 2023

Sponsoring awards: NOAA #NA22OAR4590184, #NA20OAR4600281, #NA19NES4320002

Which one comes from DA?



250-mb absolute vorticity for posterior member and 24-h forecast valid at same time.

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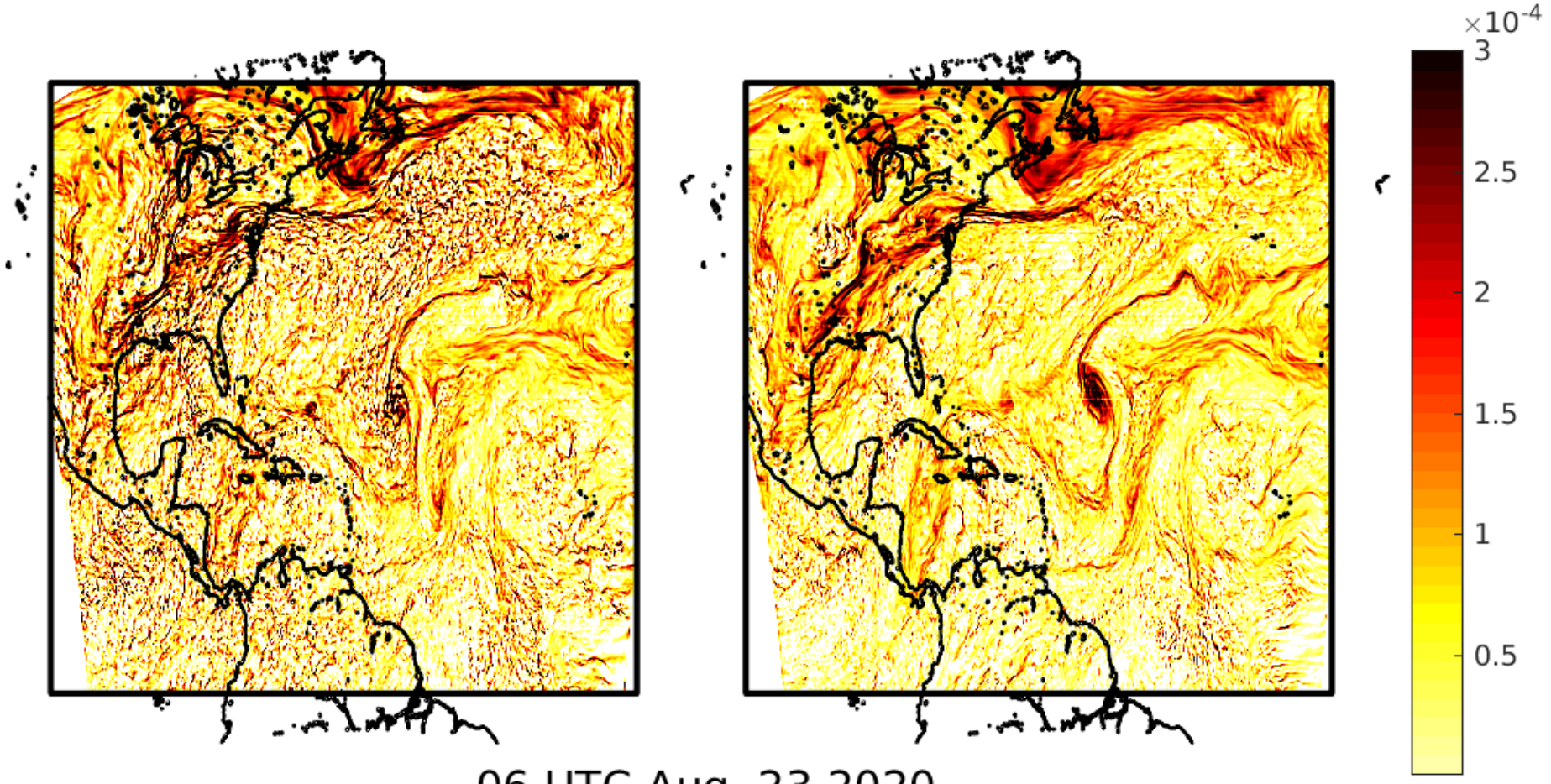
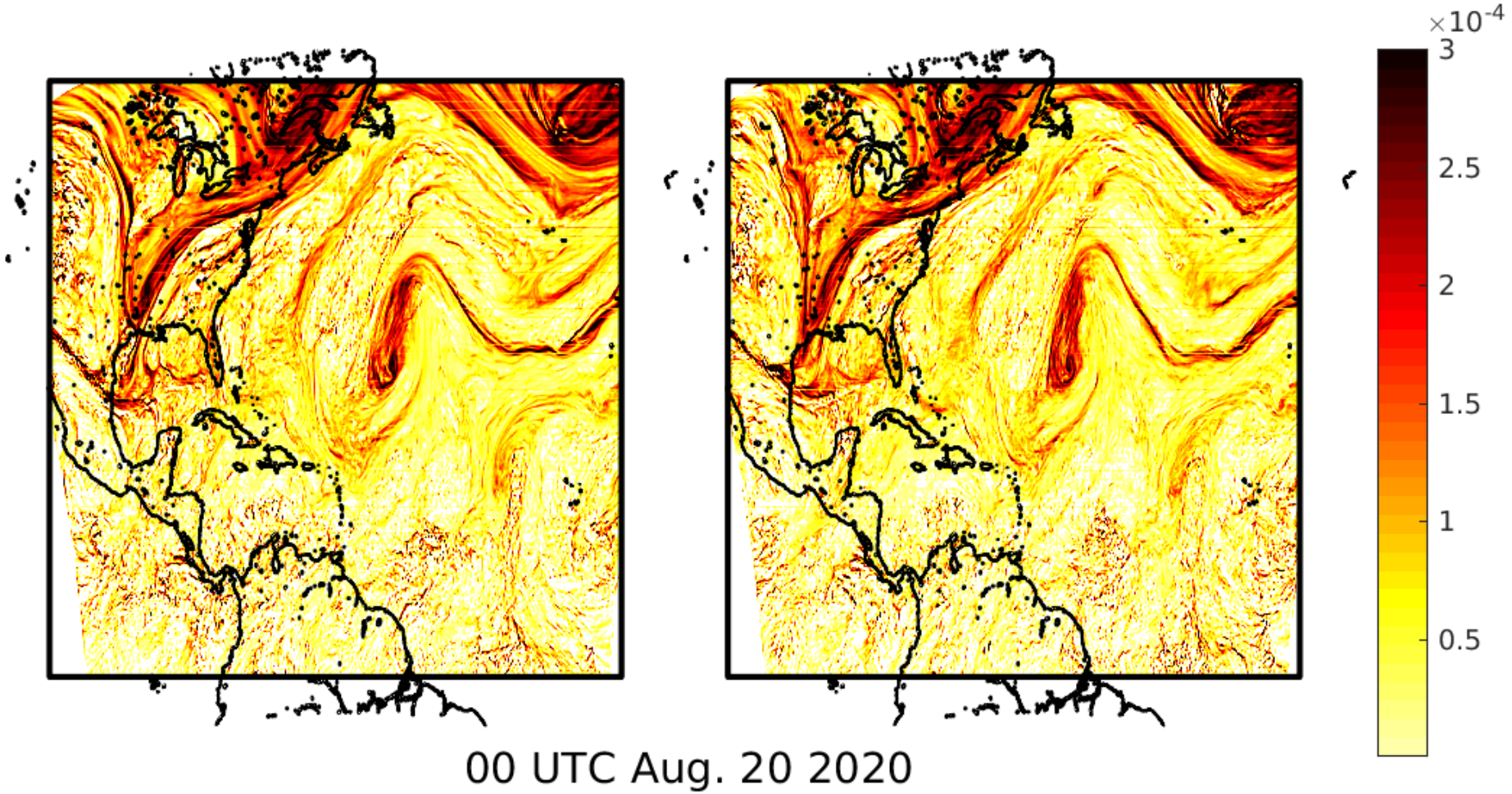


EnKF (Gaussian DA)

24-h Forecast

Which one comes from DA?



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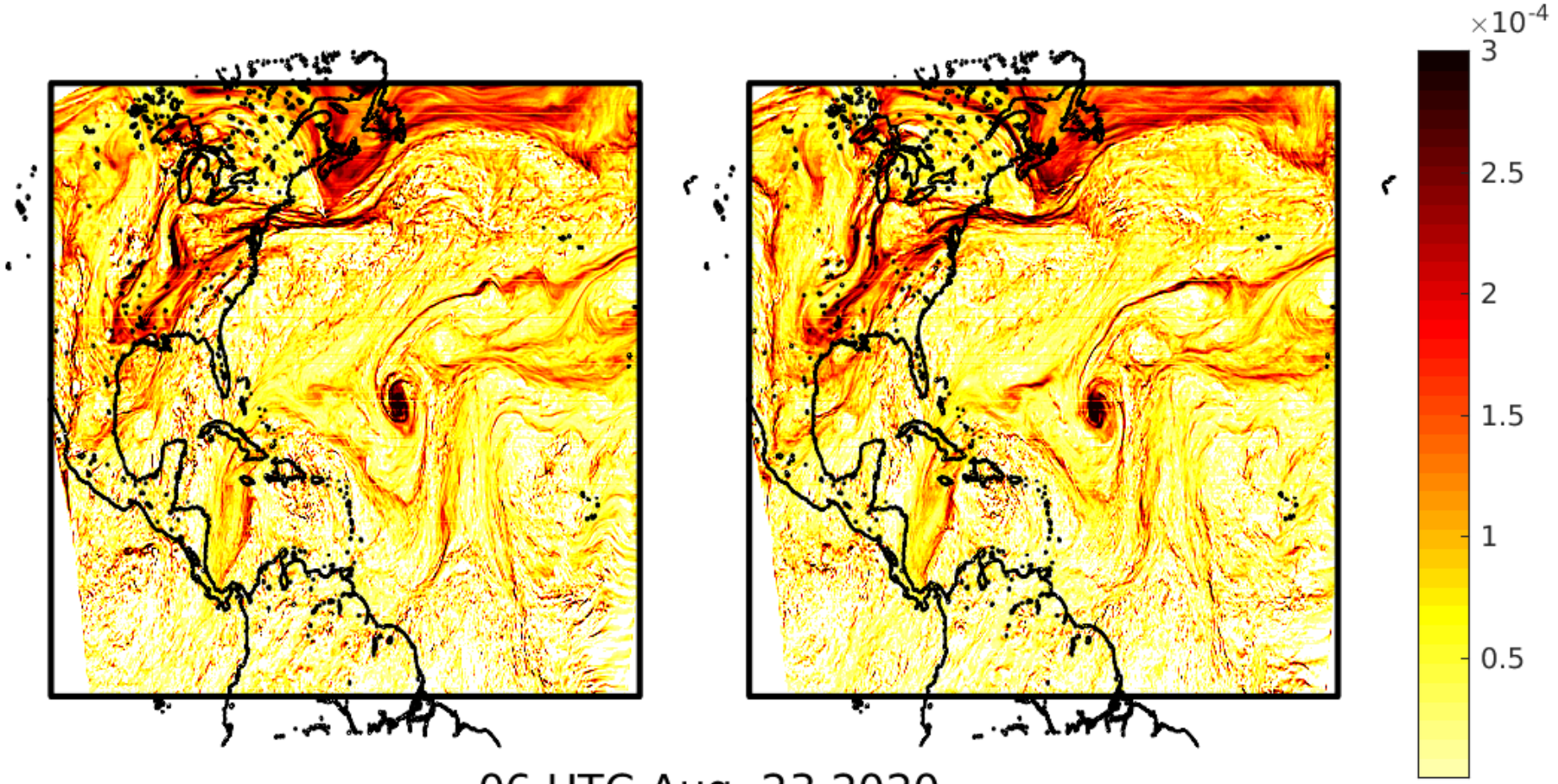
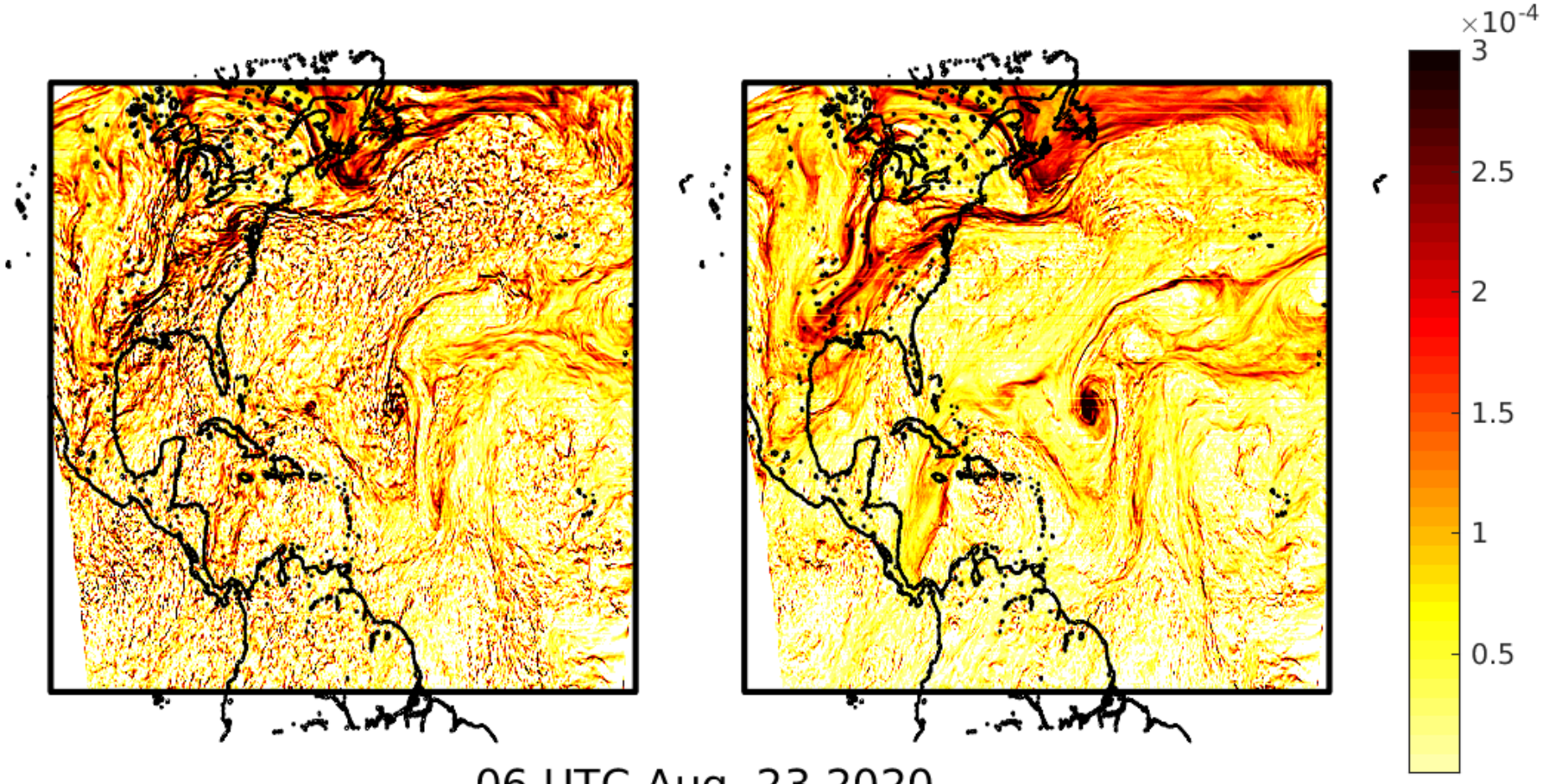


24-h Forecast

Particle filter (Non-parametric DA)

Which one comes from DA?

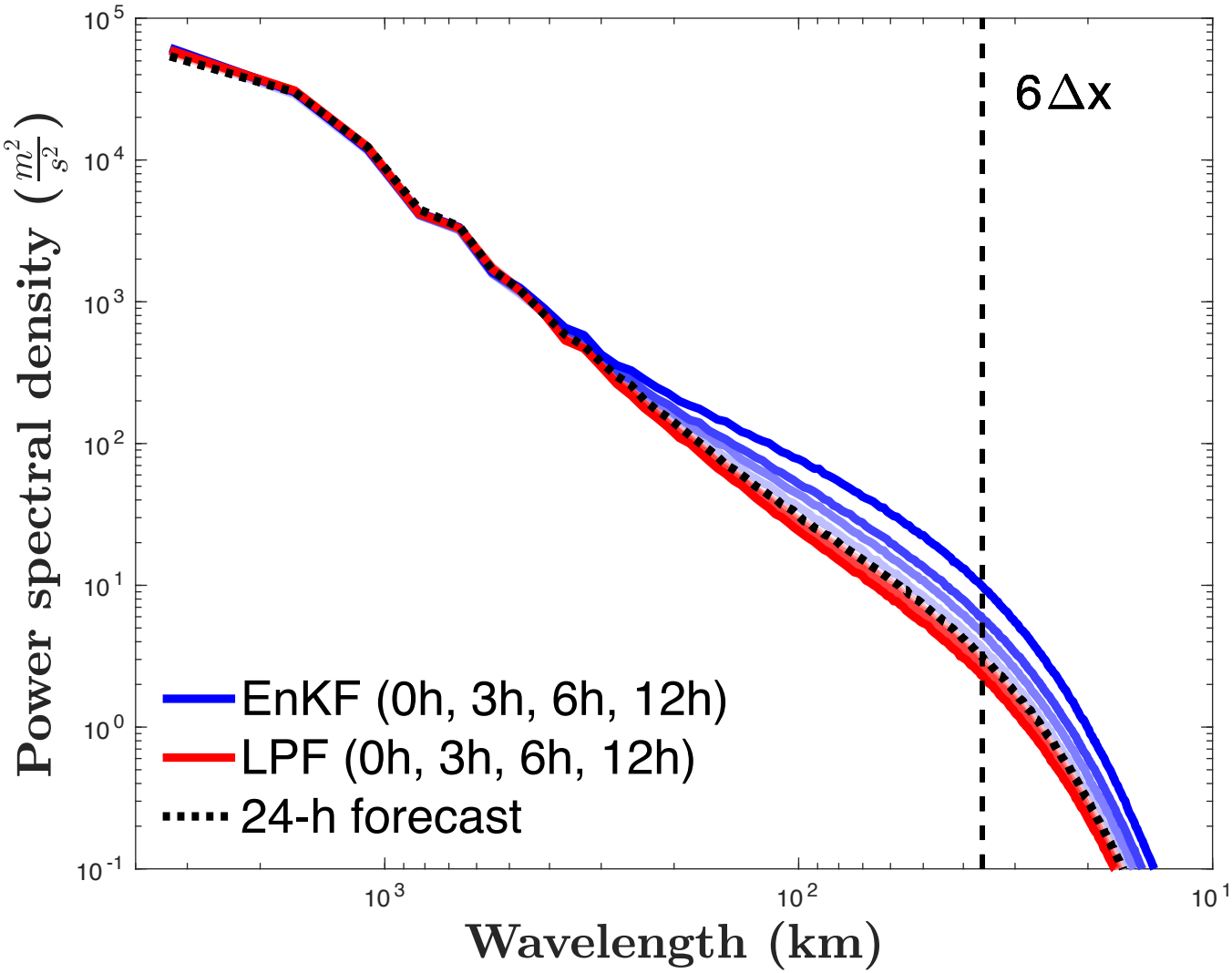


EnKF
(Gaussian DA)

Particle filter
(Non-parametric DA)

Gaussian DA-induced bias in KE spectrum

Average zonal Kinetic energy spectrum for single members:



Combining particle filters with Var

One objective is to explore implications of replacing the EnKF with LPF for prediction systems that run EnVar.

Motivation:

- Most prediction systems rely on EnVar for practical reasons; e.g., use of a high-resolution deterministic "control."
- EnKF is typically used to update ensemble—to provide future background error covariance for EnVar.
- EnKF members are re-centered on EnVar analysis.

Combining particle filters with Var

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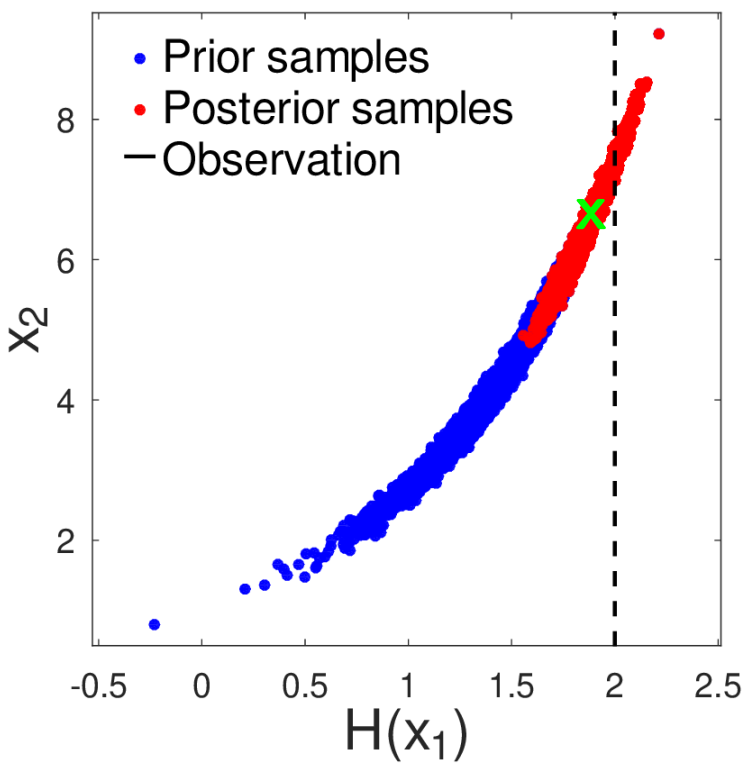
Motivation:



i. Posterior tends to be closer to a Gaussian than the prior.

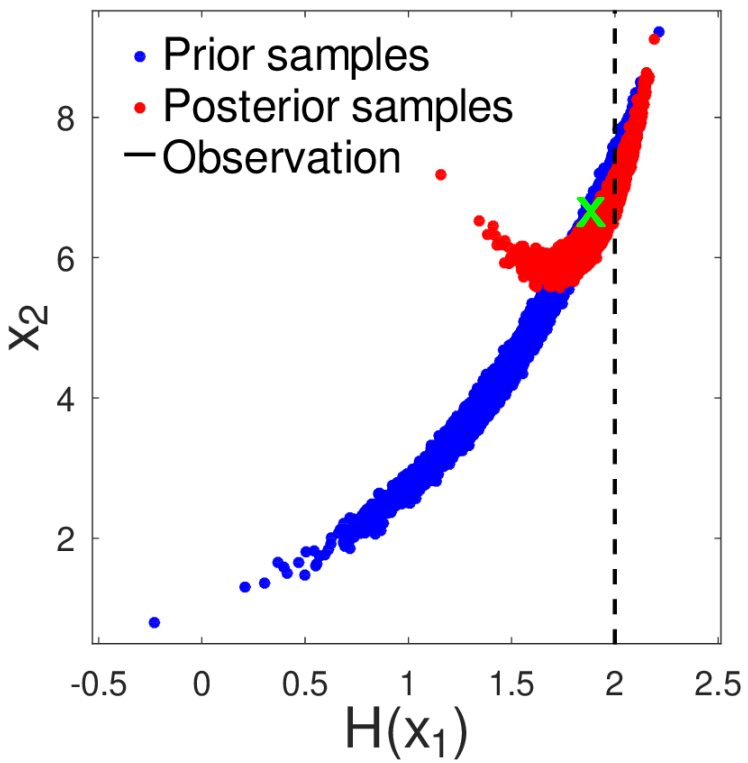
ii. Re-centering posterior ensemble on Var analysis is okay, as long as the distribution is close to Gaussian.

← **Var analysis** alongside **PF members** following assimilation.

Combining particle filters with Var

One objective is to explore implications of replacing the EnKF with LPF for prediction systems that run EnVar.

Motivation:



iii. Incremental 3DVar/4DVar can solve moderately nonlinear DA problems through an outer loop (e.g., **x** on left).

iv. Posterior targeted by Var is more consistent with PF than EnKF.

← Var analysis alongside **EnKF members**.

Combining particle filters with Var

DA comparisons:

- "EnKF-Var" $\leftarrow$ HAFS ensemble updated with EnKF and Var
- "PF-Var" $\leftarrow$ HAFS ensemble updated with LPF and Var

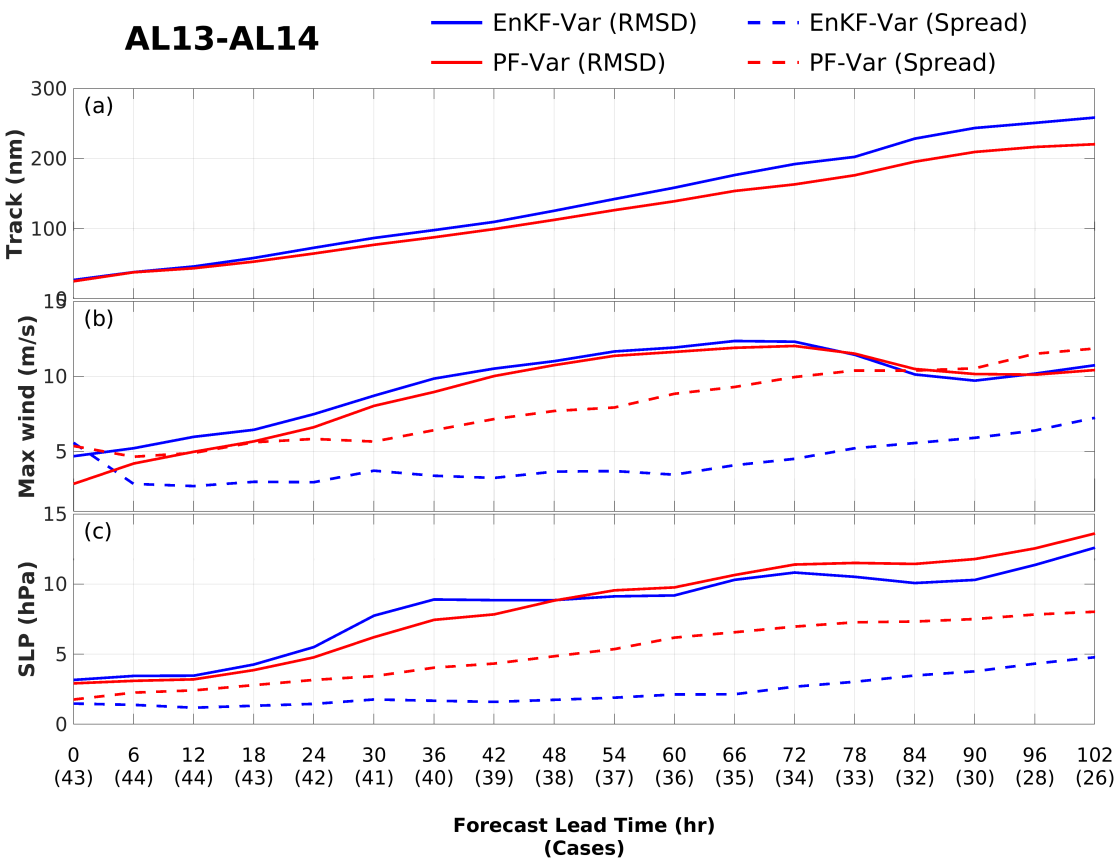
In both experiments, role of EnKF or LPF is to update 40 HAFS ensemble members about a variational analysis.

Verification:

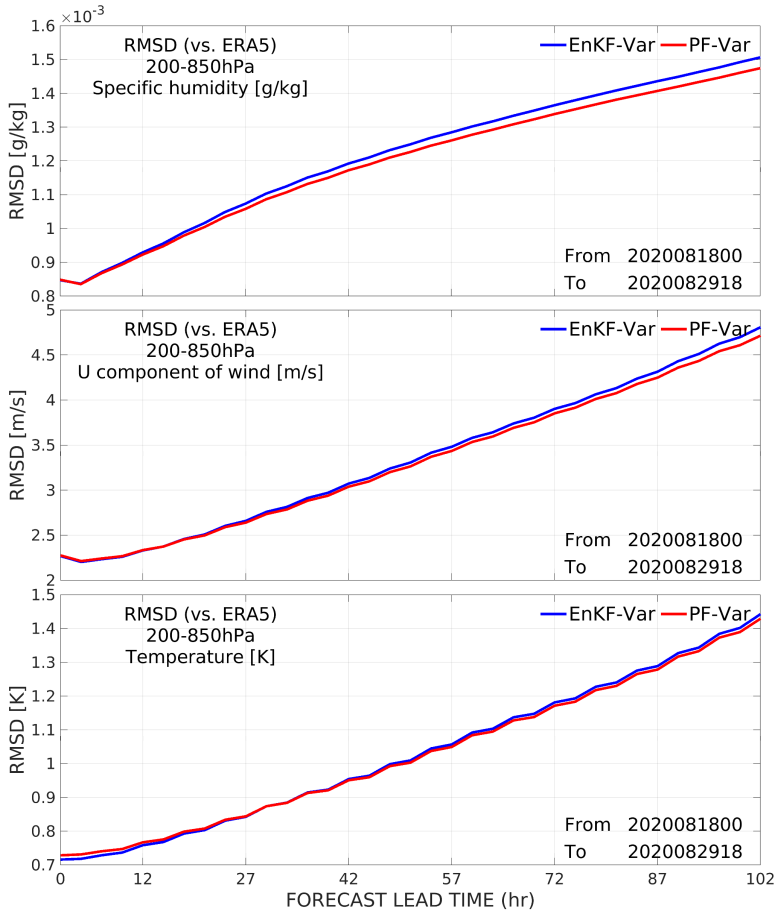
- 10-member forecasts generated every 6 h for 2 weeks
- Storm features verified using NHC Best Track data
- Synoptic scale features verified using ERA5

Verification (2 weeks of forecasts)

Track and intensity RMSEs for Laura and Marco (2020)



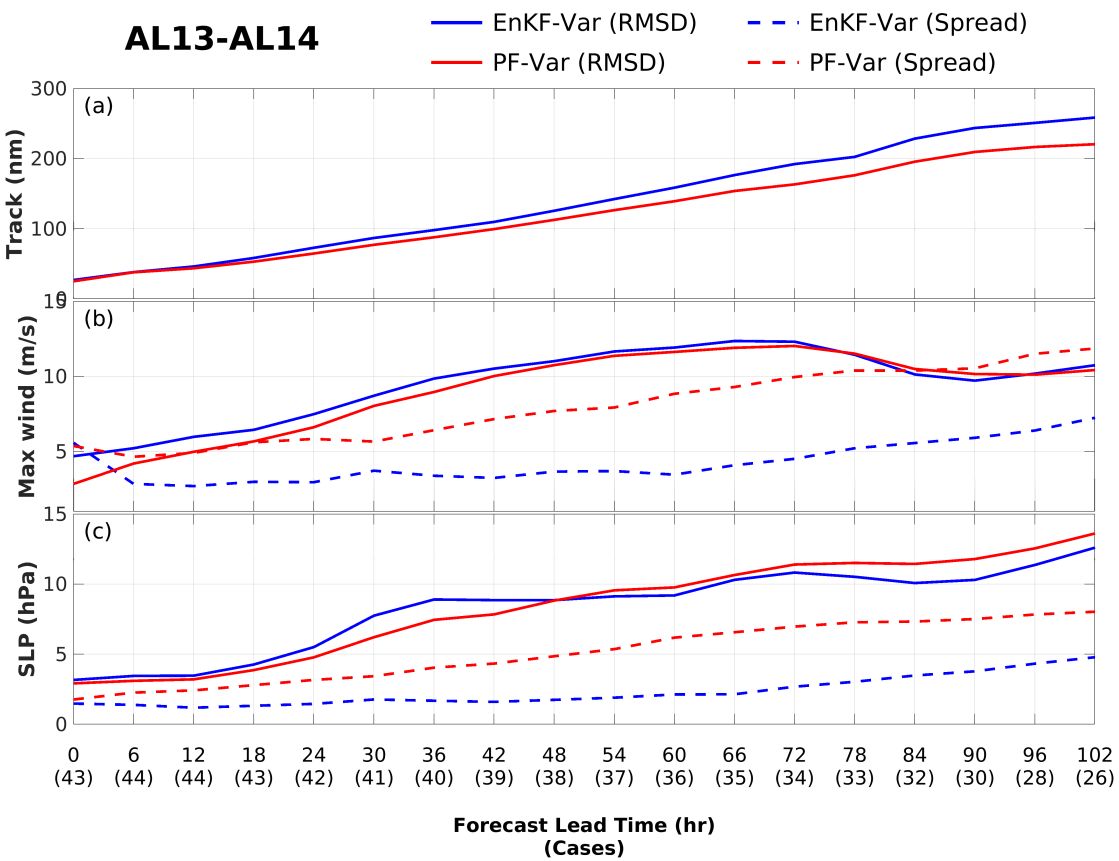
Domain-average RMSEs from ERA5



- Currently testing with 2023 HAFS-A and HAFS-B; preliminary results shows similar improvements with LPF-Var.

Verification (2 weeks of forecasts)

Track and intensity RMSEs for Laura and Marco (2020)



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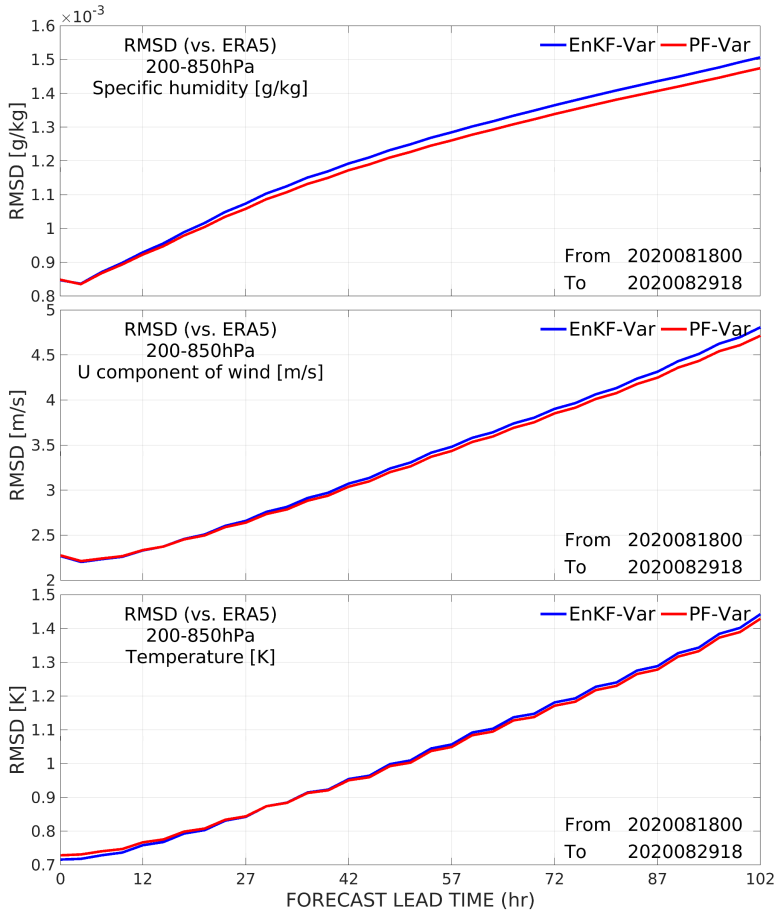
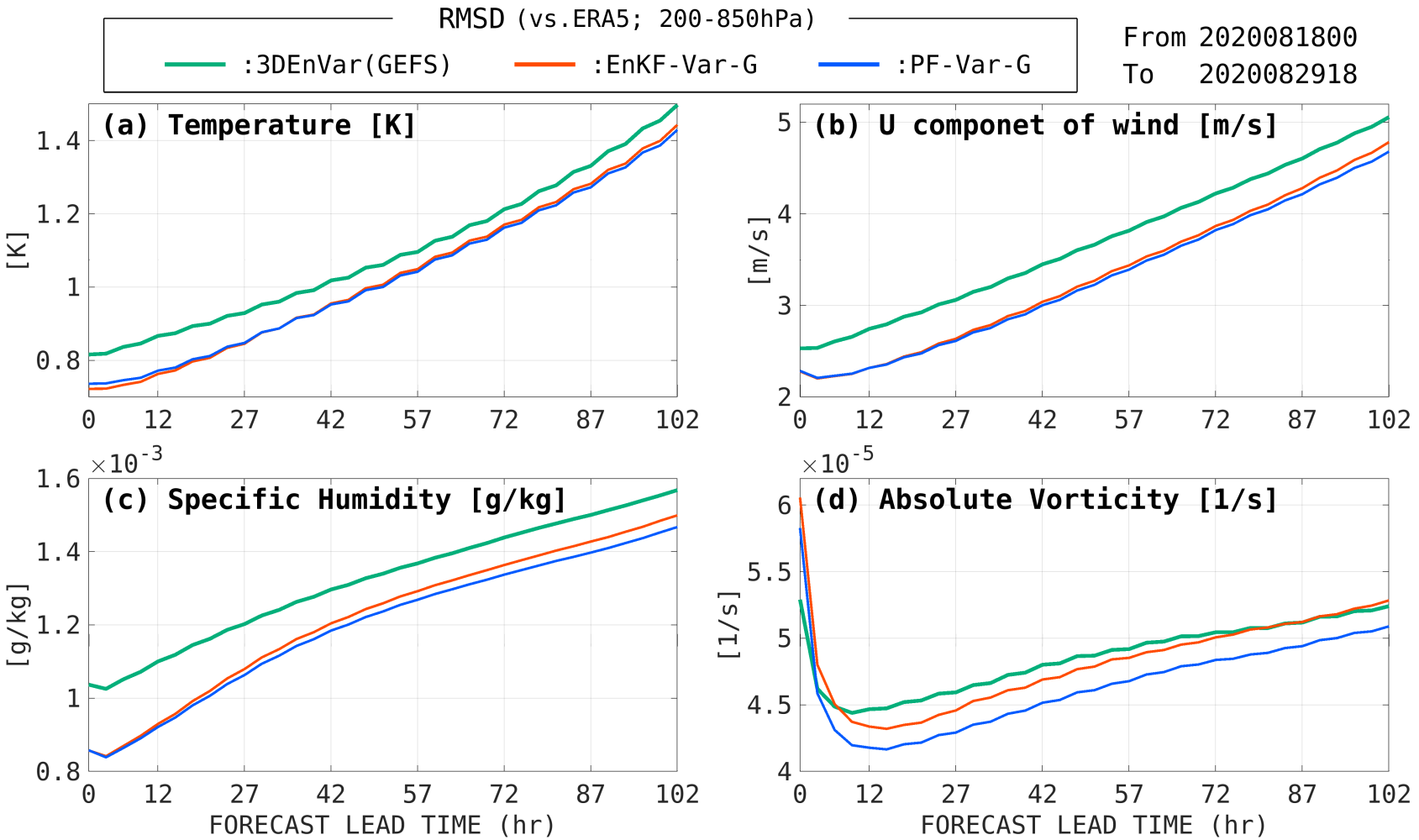


- LPF will soon be applied for hourly-updated GFS (FY23 WPO Innovations for Community Modeling Competition).

Deterministic forecasts from Var

Domain-average RMSEs from ERA5



Summary

Localized particle filters now provide a feasible non-Gaussian option for NWP.

Tangible benefits over EnKF already seen in HAFS, despite decades of effort designing weather prediction systems around Gaussian methods.

Opens the door to new research: (i) *non-Gaussian likelihoods*, (ii) *novel measurements*, (iii) *replacing QC with appropriate choices for obs error distributions*, etc.

References

Kurosawa, K. and J. Poterjoy, 2022: A statistical hypothesis testing strategy for adaptively blending particle filters and ensemble Kalman filters for data assimilation, Mon. Wea. Rev. (published online).

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Poterjoy, J. 2022a: Implications of multivariate non-Gaussian data assimilation for multi-scale weather prediction. Mon. Wea. Rev., In press.

Poterjoy, J., 2022b: Regularization and tempering for a moment-matching localized particle filter. Q. J. Roy. Meteor. Soc., In press.