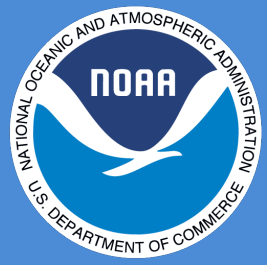

HU-2: Accelerate the development of the Hurricane Analysis and Forecasting System

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NOAA Atlantic Oceanographic and Meteorological Laboratory

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Main topics

Primary objective: Implement novel data assimilation methodology for aircraft reconnaissance and all-sky radiance data assimilation in HAFS.

Sub-goals:

- Holistic testing of HAFS components (Var, EnKF, measurement operators, etc.)
- Optimize clear-air data assimilation strategies
- Explore potential for non-stop sequential data assimilation
- Test new filter methodology (particle filter and hybrid with EnKF)

Ongoing experiments

Current configuration uses 6-km grid spacing for ensemble and deterministic model domains.

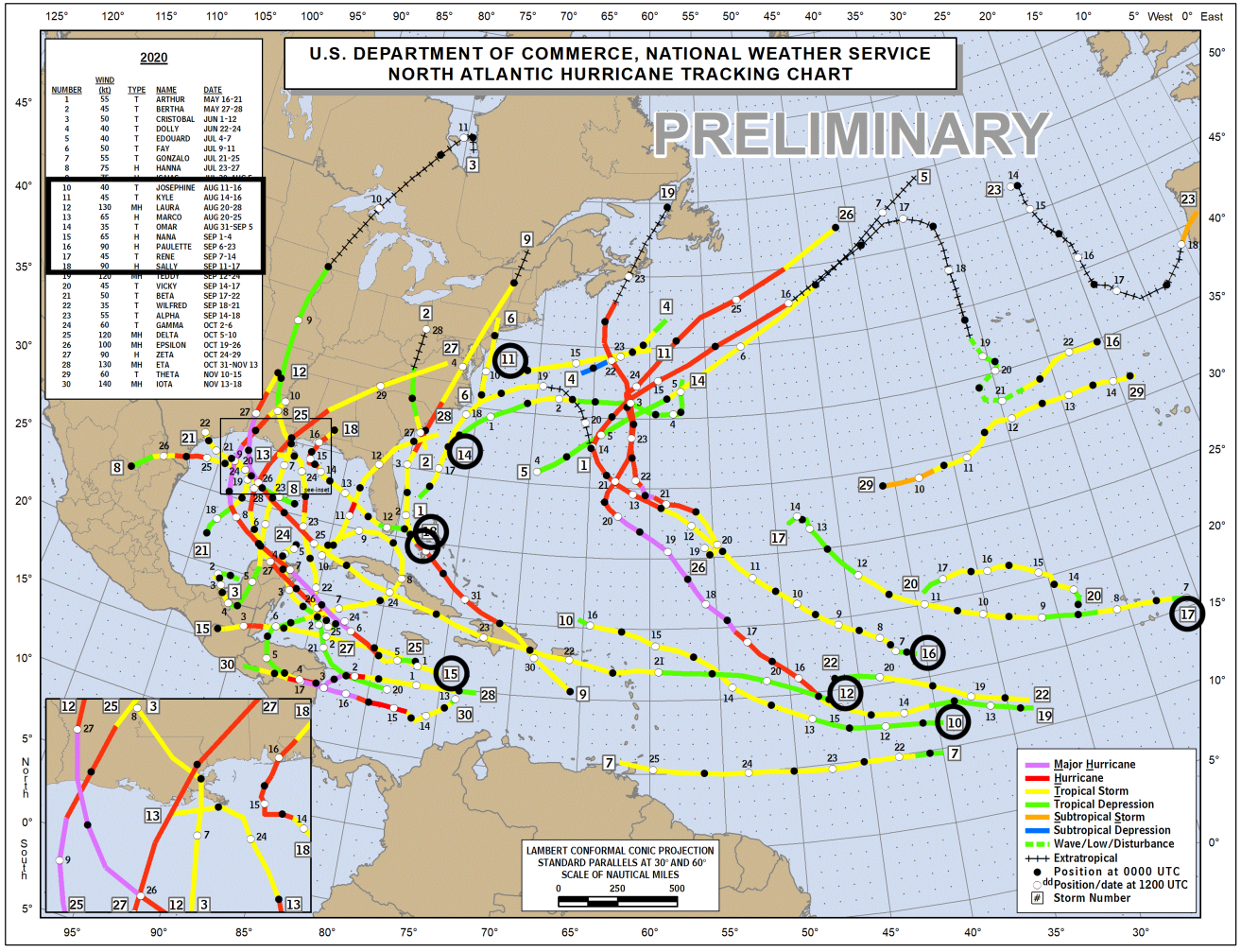
Comparisons:

- Clear-air radiance DA (three different bias options)
- EnKF vs. E3DVar
- EnKF vs. local PF

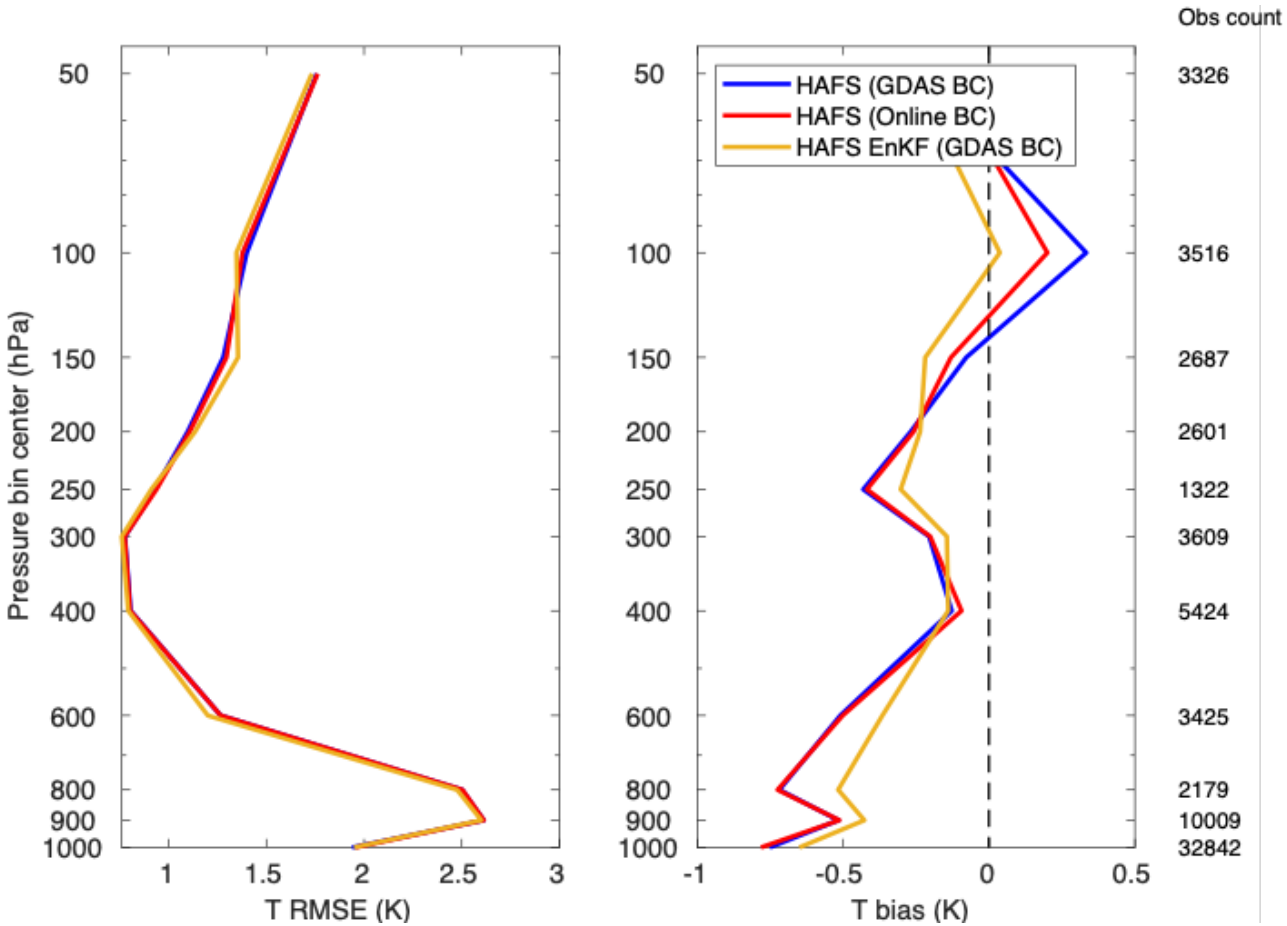
The second and third set of comparisons do not re-center ensemble perturbations about Var solution.

Timeline

Aug. 11 – Sept. 18, 2020



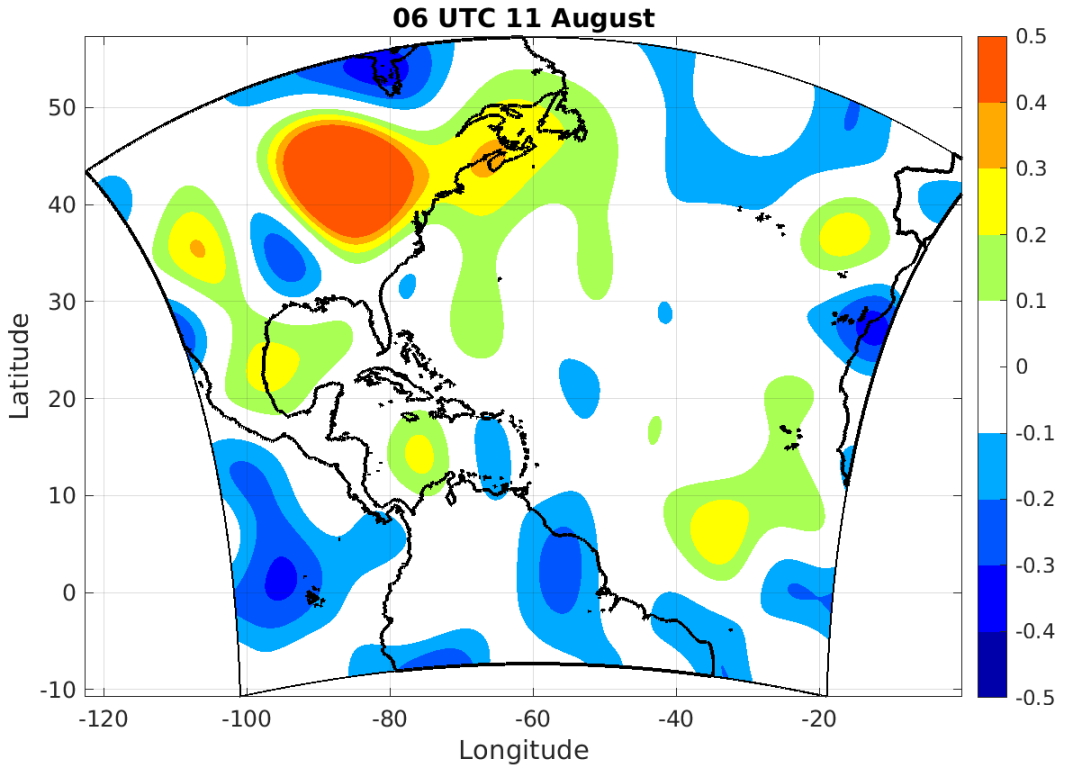
Prior obs-space statistics (week 1)



- Online BC reduces bias in stratosphere and mid-troposphere
- Current HAFS Var is less accurate than EnKF (most notable errors in T and water vapor)

Caveats: Var benefits from FGAT; EnKF benefits from ensemble mean

Spatial differences: Var vs. EnKF



- 500-mb T difference (Var minus EnKF mean)
- Wavelengths $<$ 1000 km removed with low-pass filter

- Var solution tends to be cooler and dryer over most of troposphere (ongoing work).

Local PF: code development

Heavily revised GSI local PF code for efficiency.

Testing in HAFS:

EnKF

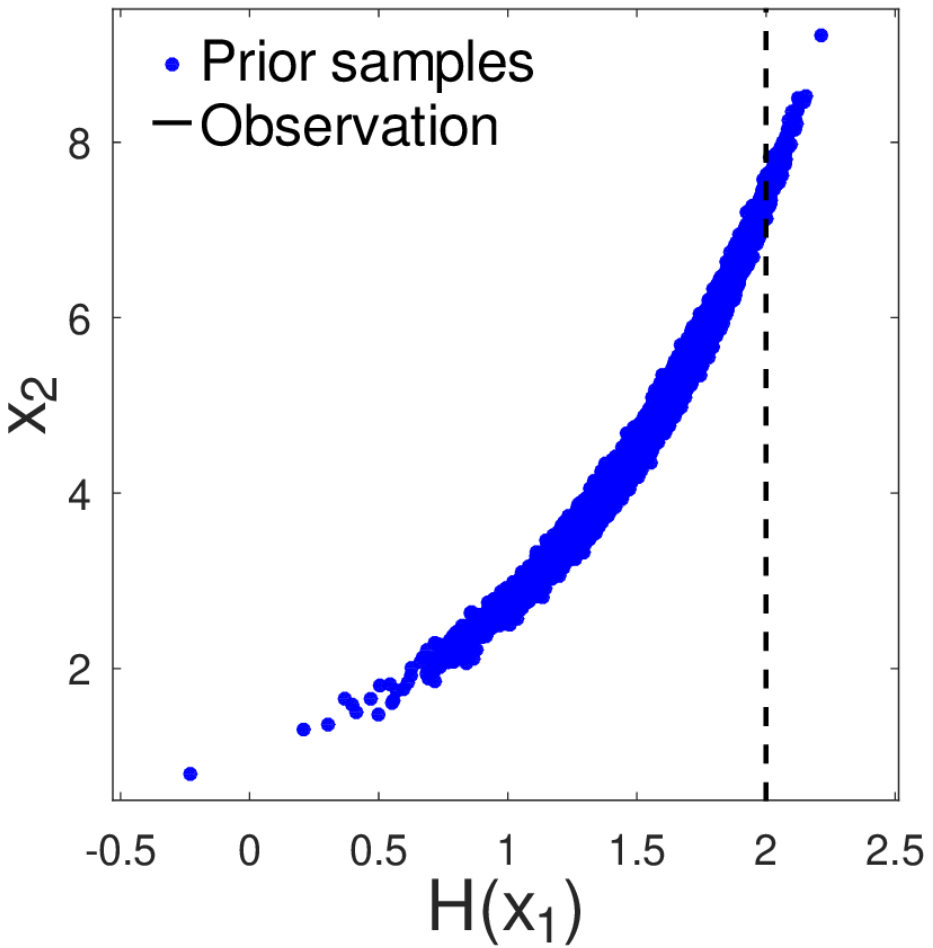
60 nodes 1 task/node 40 threads : ∼7 min

Local PF

60 nodes 1 task/node 40 threads : ∼14 min

PF-EnKF implementation

Idealized application



Prior:

$$\mathbf{x} \sim N(\bar{\mathbf{x}}, P)$$

$$\bar{\mathbf{x}} = \begin{pmatrix} 5 \\ 5 \end{pmatrix}$$

$$P = \begin{pmatrix} 1.01 & 1.00 \\ 1.00 & 1.00 \end{pmatrix}$$

Observation:

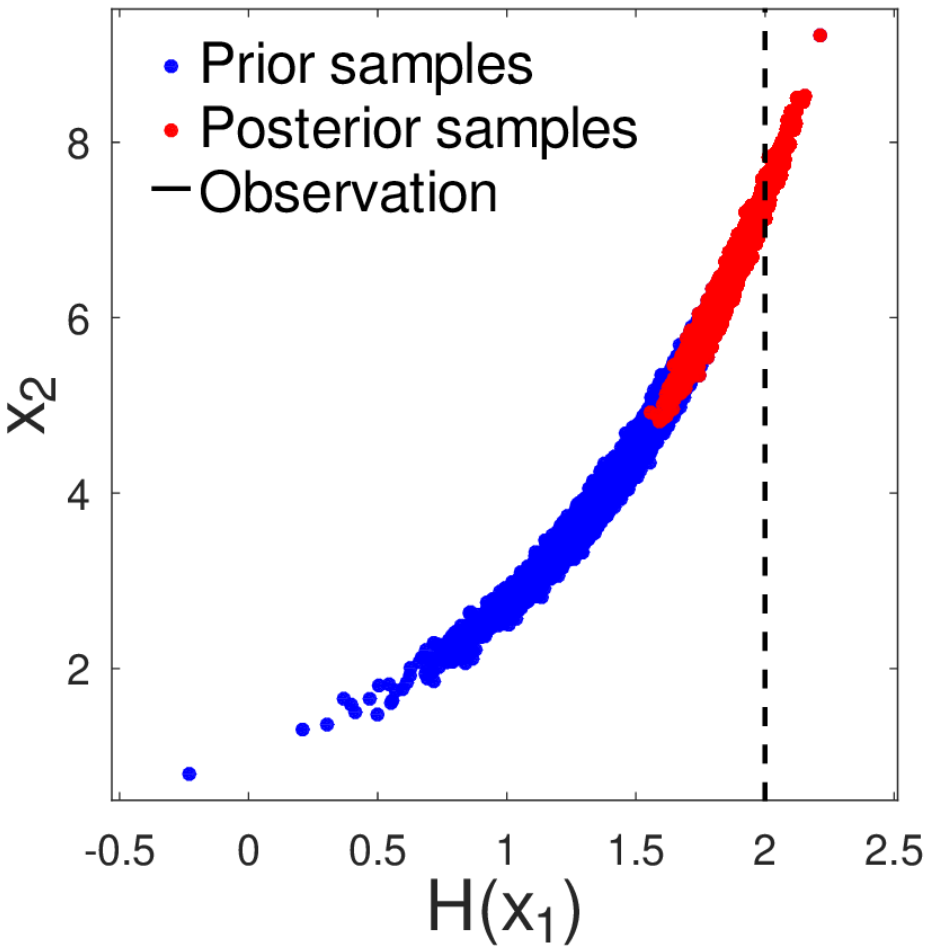
$$y = H(\mathbf{x}^{true}) + \epsilon$$

$$\epsilon \sim N(0, 0.1)$$

$$H(x) = ln(|x_1|)$$

PF-EnKF implementation

Bayesian posterior (PF)



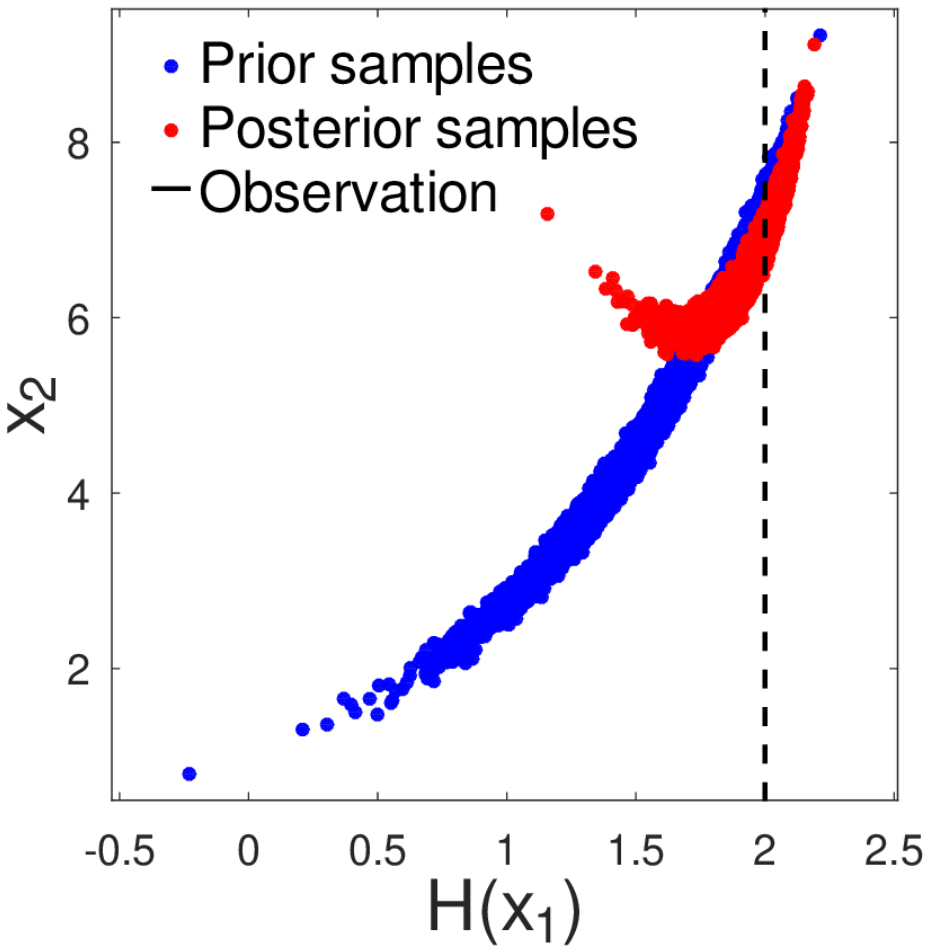
Posterior:

- With large sample sizes, a PF provides an accurate estimate of the posterior distribution.

$$p(\mathbf{x}|y) \quad \propto \quad \sum_{n=1}^{N_e} \delta(\mathbf{x} - \mathbf{x}_n) p(y|\mathbf{x})$$

PF-EnKF implementation

EnKF posterior samples



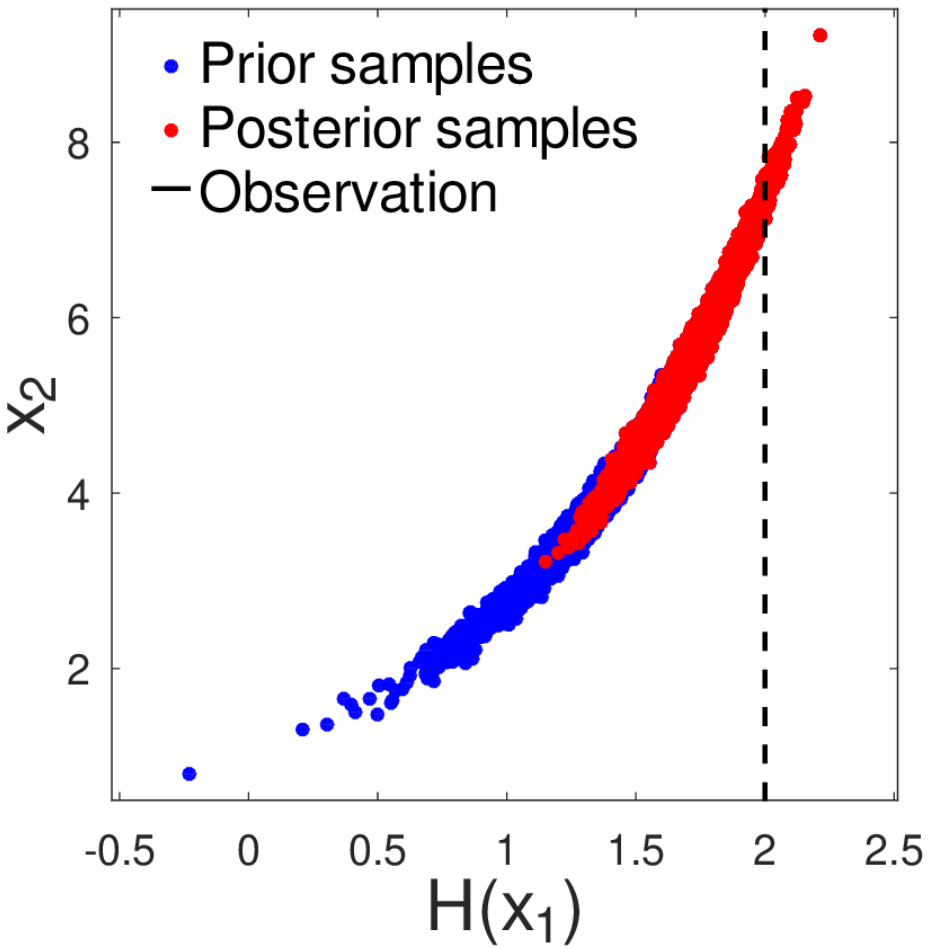
Posterior:

- Non-Gaussian joint obs-model space prior poses challenges for EnKF.

$$p(\mathbf{x}|y) \quad \propto \quad N(\bar{\mathbf{x}}, P)p(y|\mathbf{x})$$

PF-EnKF implementation

Hybrid PF-EnKF: partial PF update



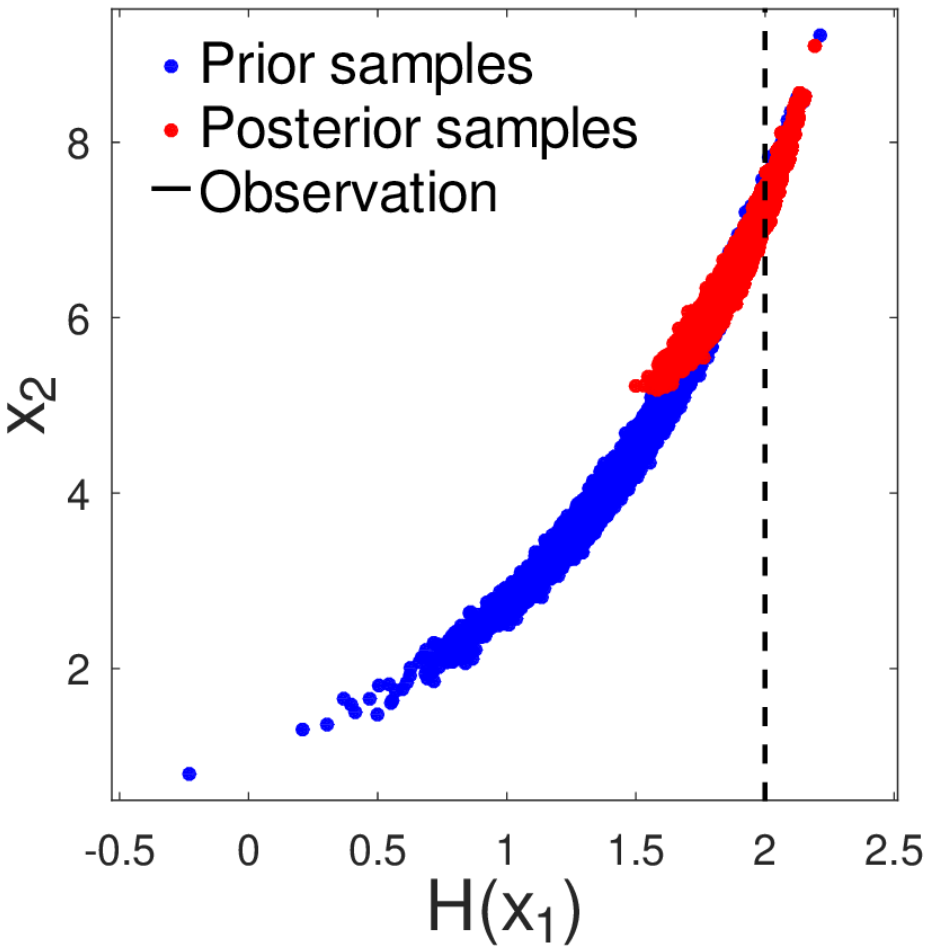
Posterior:

- Different approximations of the prior density can be made during iterations.
- Example: PF update is performed first using only portion of likelihood.

$$p(\mathbf{x}|\hat{y}) \quad \propto \quad \sum_{n=1}^{N_e} \delta(\mathbf{x}-\mathbf{x}_n) p(y|\mathbf{x})^{0.2}$$

PF-EnKF implementation

Hybrid PF-EnKF: partial EnKF update



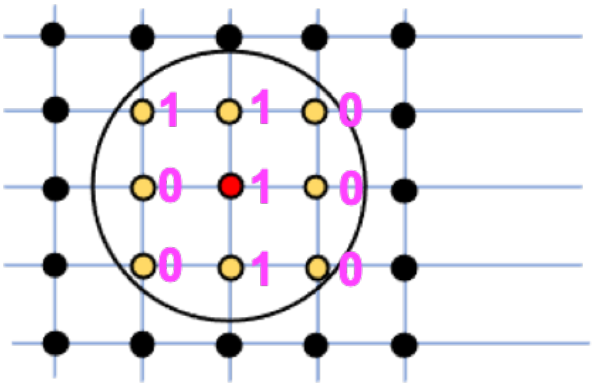
Posterior:

- Different approximations of the prior density can be made during iterations.
- Example: EnKF update is performed second using remaining part of likelihood.

$$p(\mathbf{x}|y) \quad \propto \quad N(\hat{\bar{x}}, \hat{P})p(y|\mathbf{x})^{0.8}$$

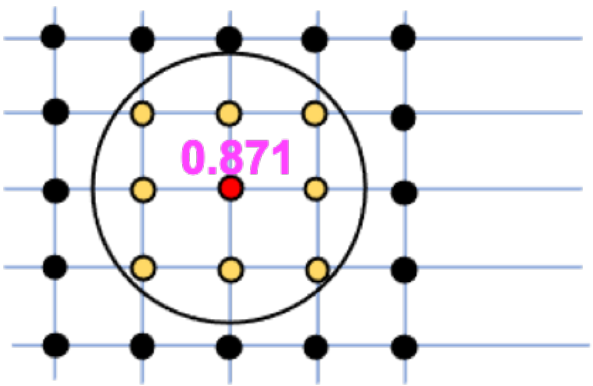
Adaptive hybrid parameter

Currently exploring the use of multivariate hypothesis testing to specify amount of PF vs. EnKF update:



Step 1:

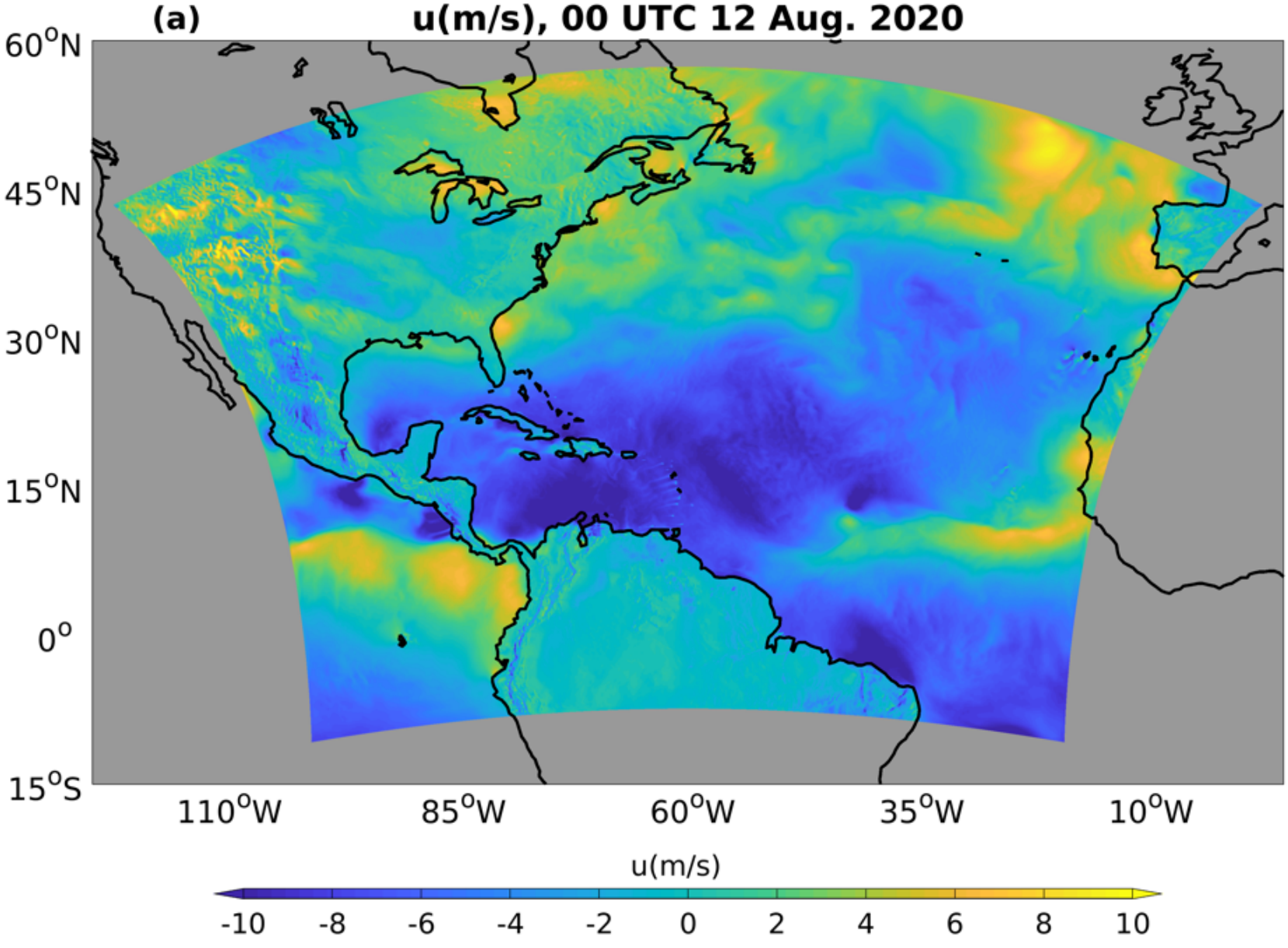
- Perform a bivariate Shapiro-Wilk test in state-space and obs-space for each variable and its neighbors.



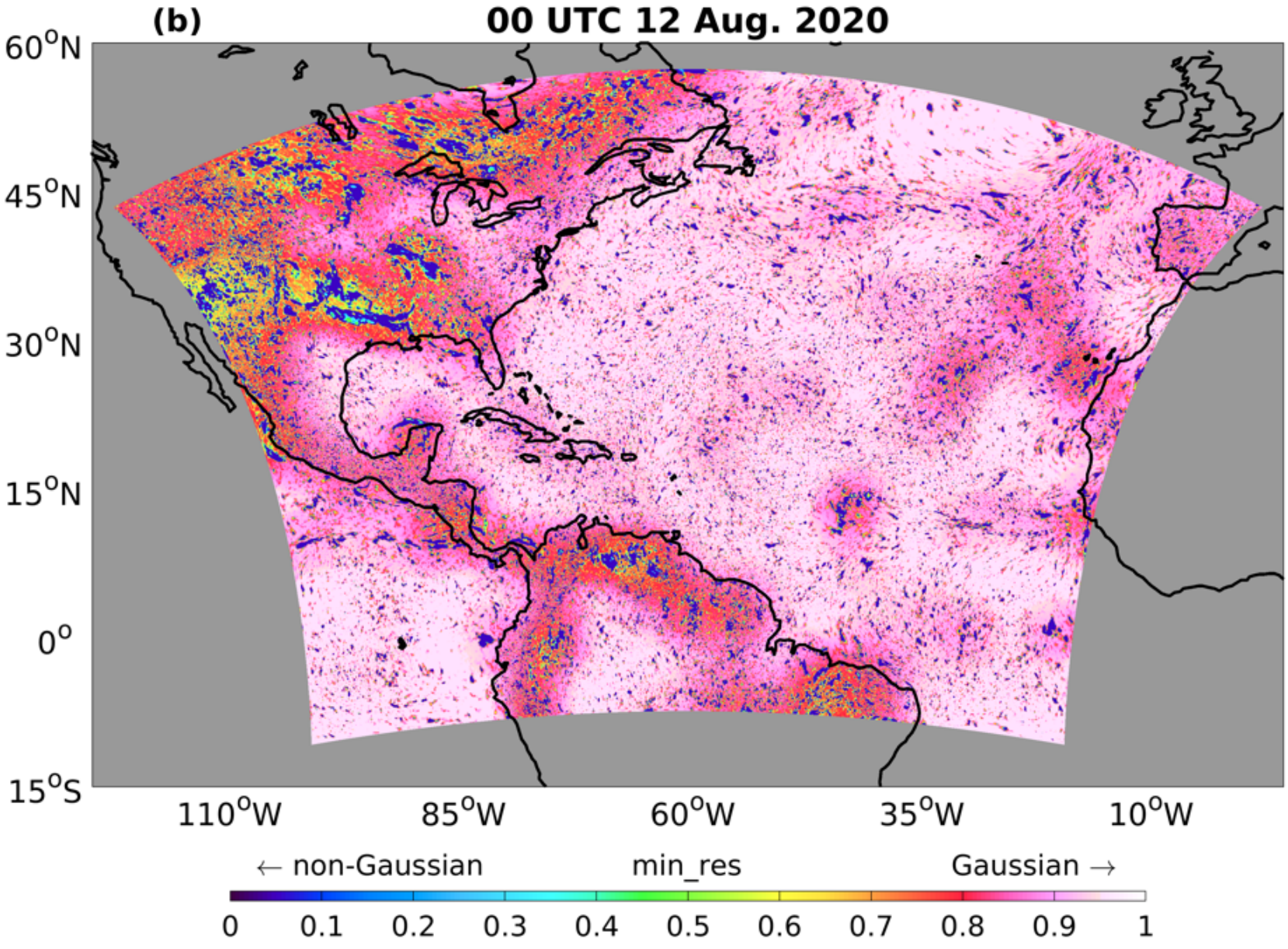
Step 2:

- Calculate weighted average of result using localization function.

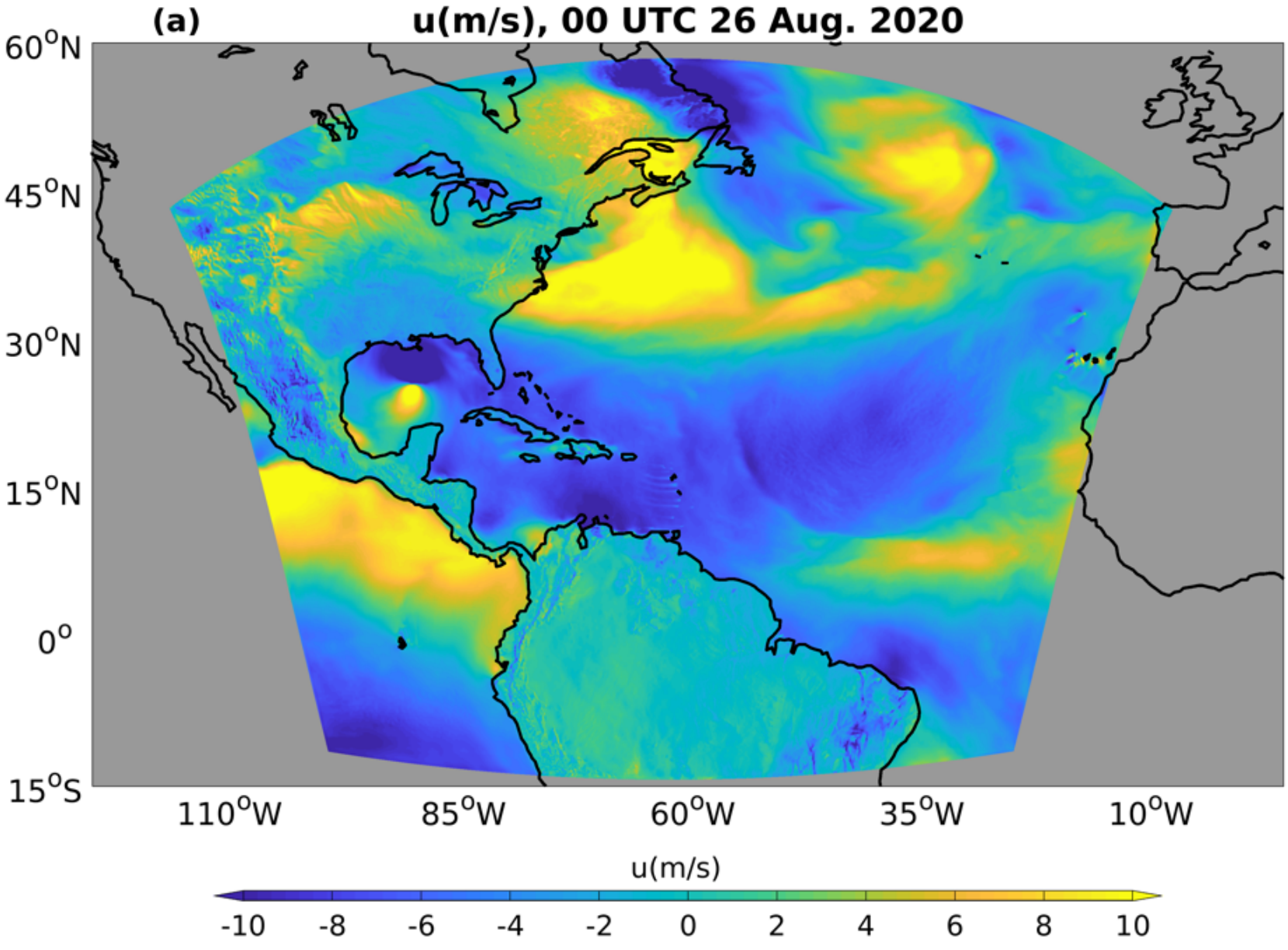
Adaptive hybrid parameter



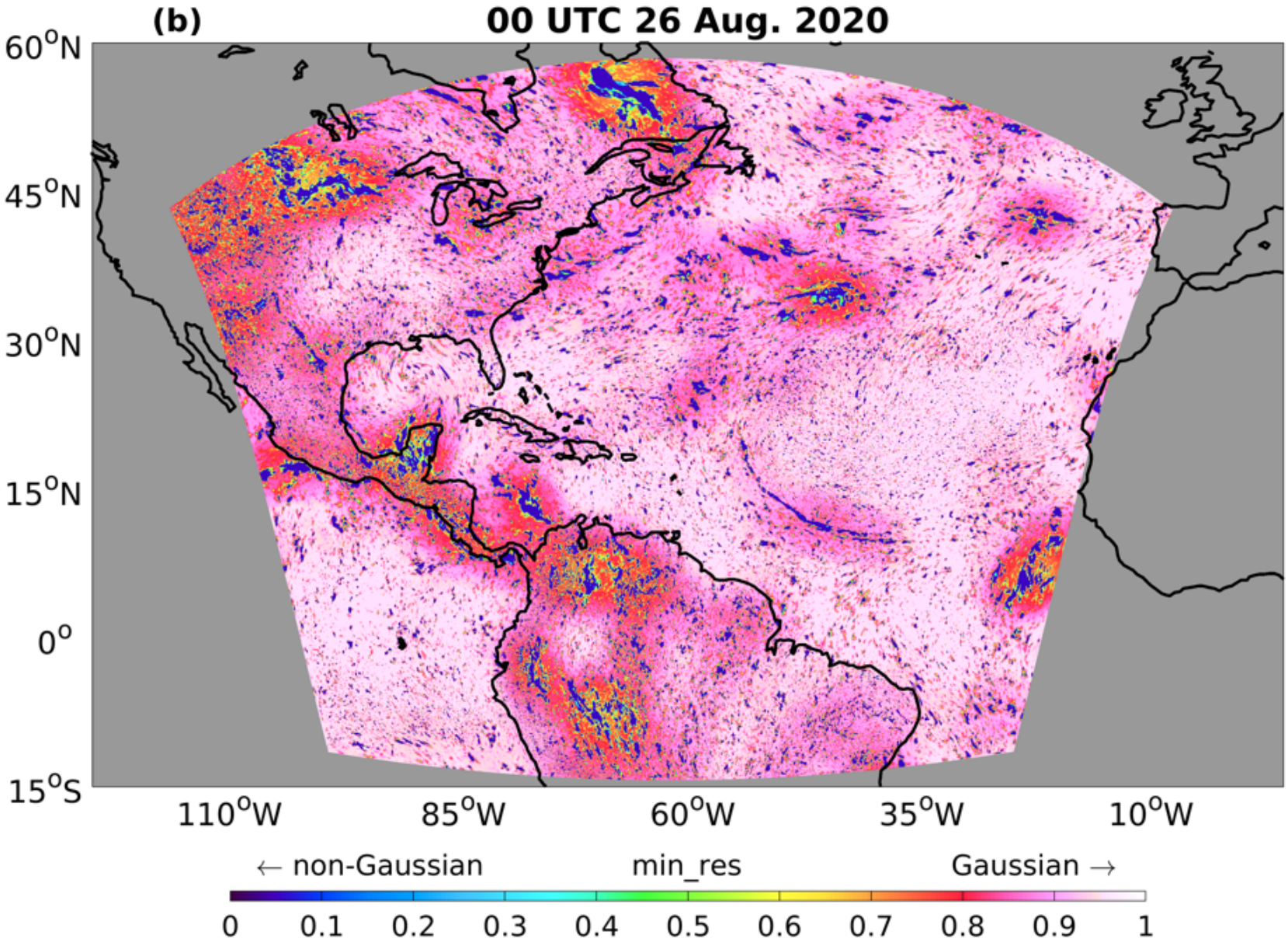
Adaptive hybrid parameter



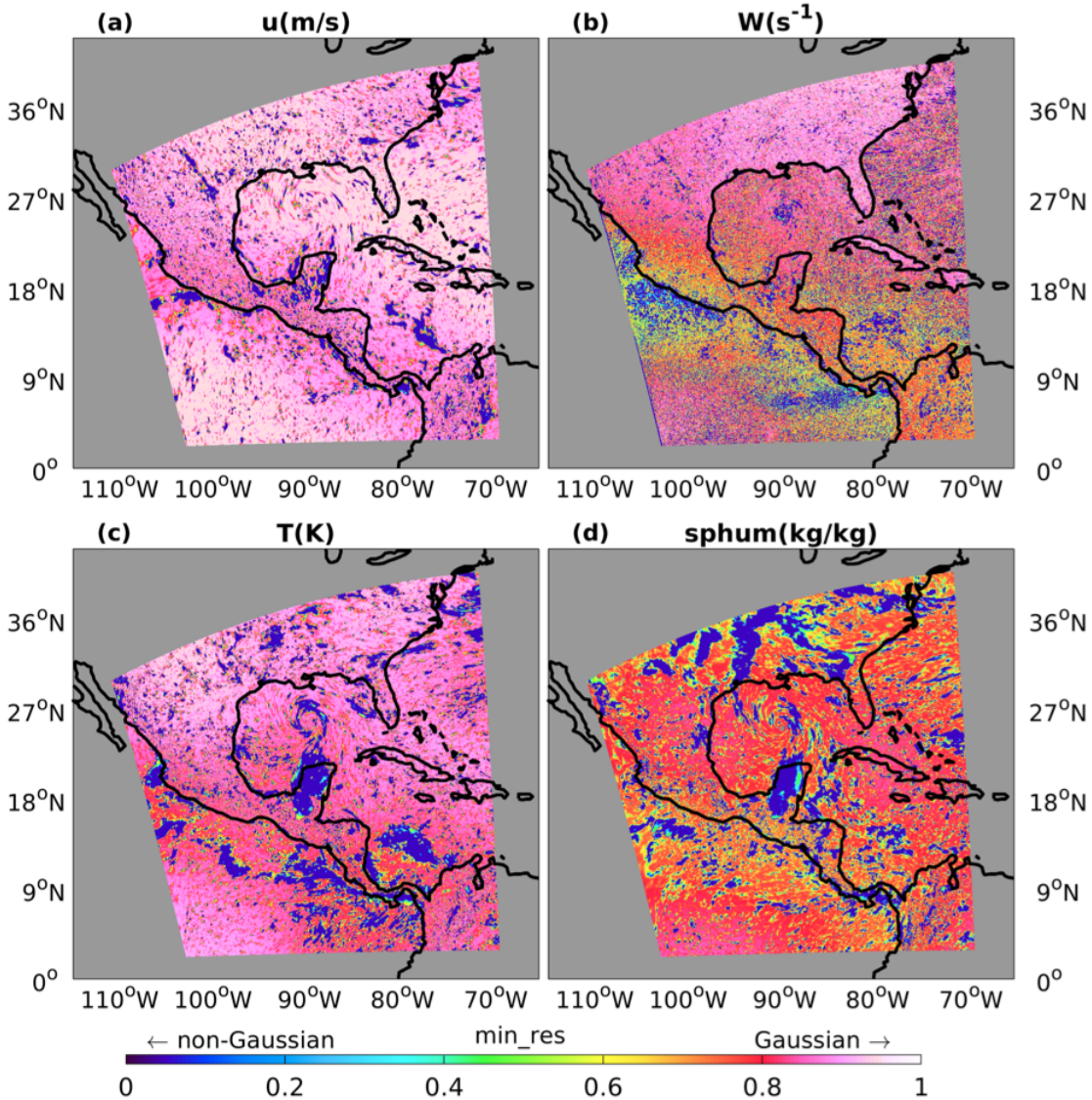
Adaptive hybrid parameter



Adaptive hybrid parameter



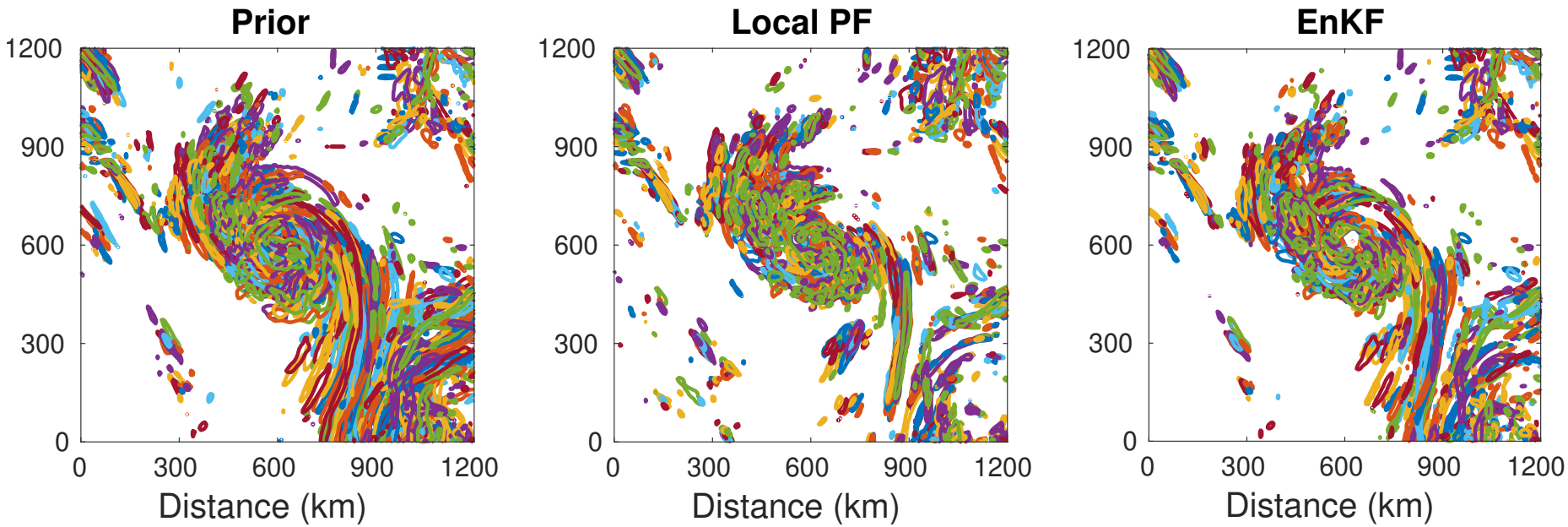
Adaptive hybrid parameter



- Results are flow-dependent
- Can differ tremendously across variables

HAFS ensemble update

Wavelengths $>$ 150 km removed



- Zoom-in view near Laura for vorticity field (first 20 members)
- Note that PF performs larger update in SW quadrant

Summary

Numerous experiments currently underway:

- Testing of HAFS components (Var, EnKF, etc.)
- Optimize clear-air data assimilation
- Explore potential for non-stop sequential data assimilation
- New filter methodology (particle filter and hybrid with EnKF)

Continue to work with HAFS group (EMC, AOML, OU, Univ. Albany) to establish a robust prediction system capable of both operations and R2O efforts.