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Use of Ensembles in Research and Operations to Quantify Uncertainty

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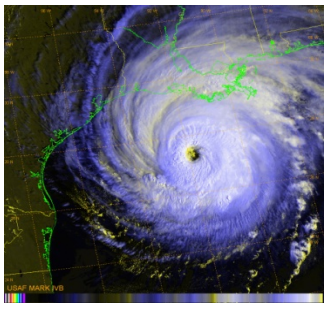
Research & Development
Quarterly AFWA CRADA Meeting
Offutt AFB



Use of Ensembles at AER Research & Operations

- Research
  - Used to capture geophysical flows for data assimilation and characterize 3D forecast uncertainty.
  - Close to the source ensembles.
- Operations
  - Significant post-processing needed make the information ready for decision makers.
  - eCast: 15-day ECMWF ensemble for station temperatures in the US.
  - hCast-SR: 5-day real-time hurricane forecasts based on an ensemble of forecast tracks.

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eCast – ensemble forecasts for the energy industry

Surface temperature forecasts (daily hi/lo temps) using

- 51 ECMWF ensemble members (15 days)
- 21 GFS ensemble members (15 days)
- MEX MOS (7-days) [must beat this to have a valuable product]

- Bias is a 1st order problem; ensemble spread is a 2nd order problem.
- Bias is removed from the ensemble mean with a multi-dimensional Kalman filter

Go to eCast demo at weather.aer.com

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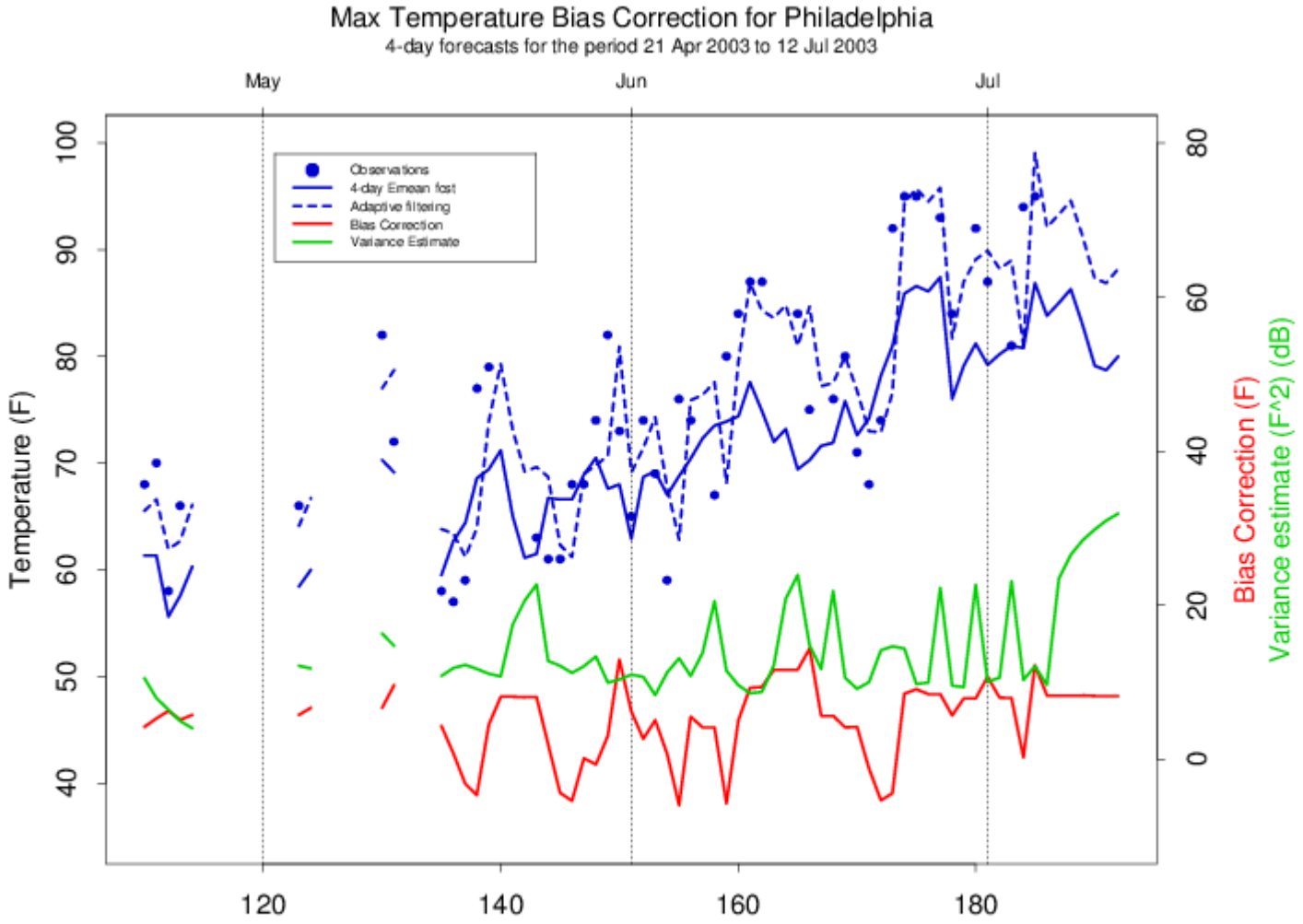
eCast – 1D Kalman filter example



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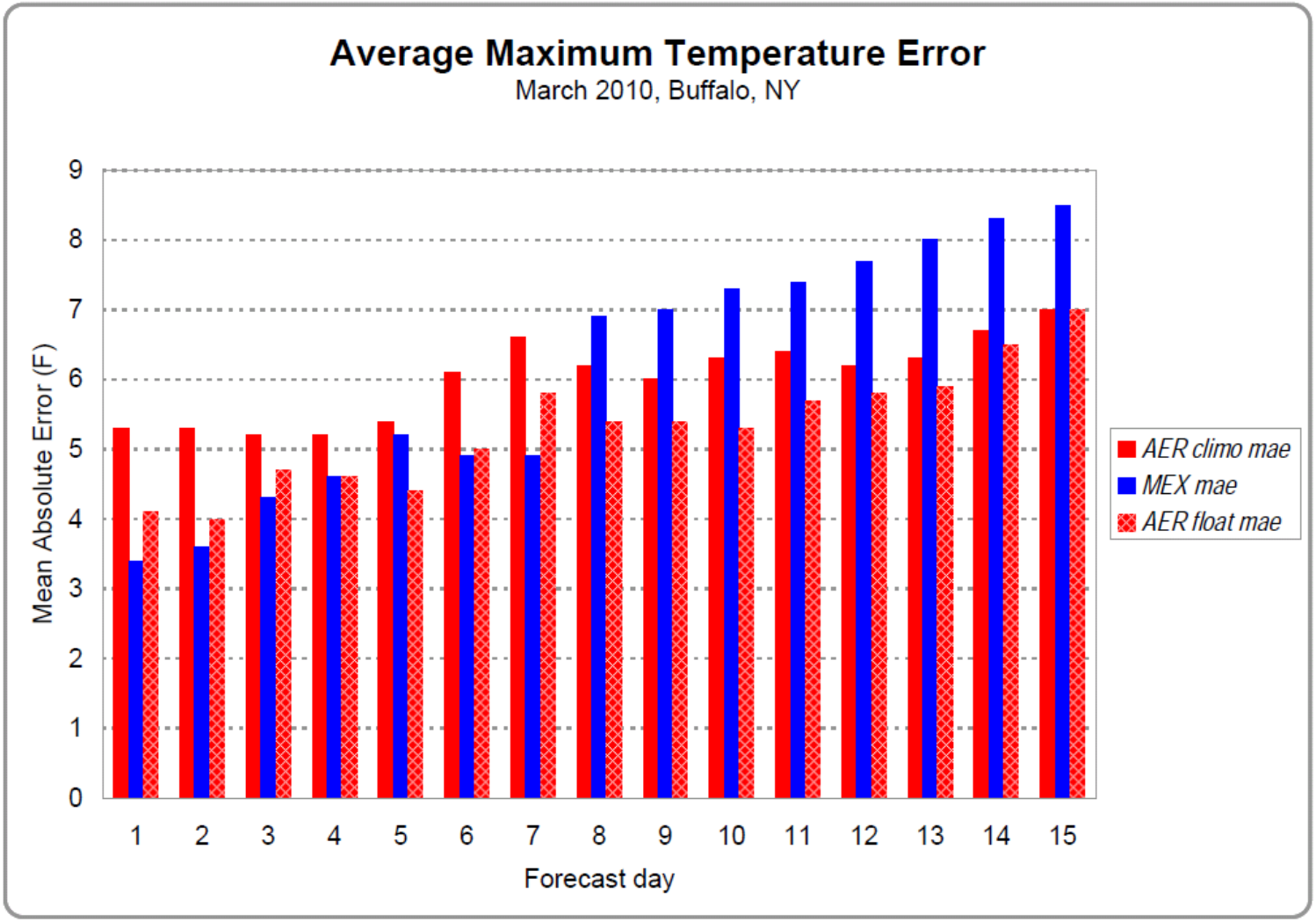
eCast – example Kalman filter models

1. Models

model	description
1305	KF : bias + 4 nearest grid points; initialized with equal weights for all grid points (`0.0 0.25 0.25 0.25 0.25`)
1301	Cressman-type interpolation of 4 nearest grid points
1306	KF : 1305 + climatology ; initialized with equal weighting of points, zero weight of climo (`0.0 0.25 0.25 0.25 0.25 0.0`)
1307	KF : 1306, with heavier initial weight to climo (`0.0 0.125 0.125 0.125 0.125 0.5`)
1308	KF : bias + climo + (4 grid points - climo); i.e. climo w/ each points' deviation from climo; initial weight (`0.0 1 0.25 0.25 0.25 0.25`)
climatology	

eCast – example Kalman filter models



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hCast-SR: hurricane risk assessment

CME Hurricane Index (developed by Carville Re):

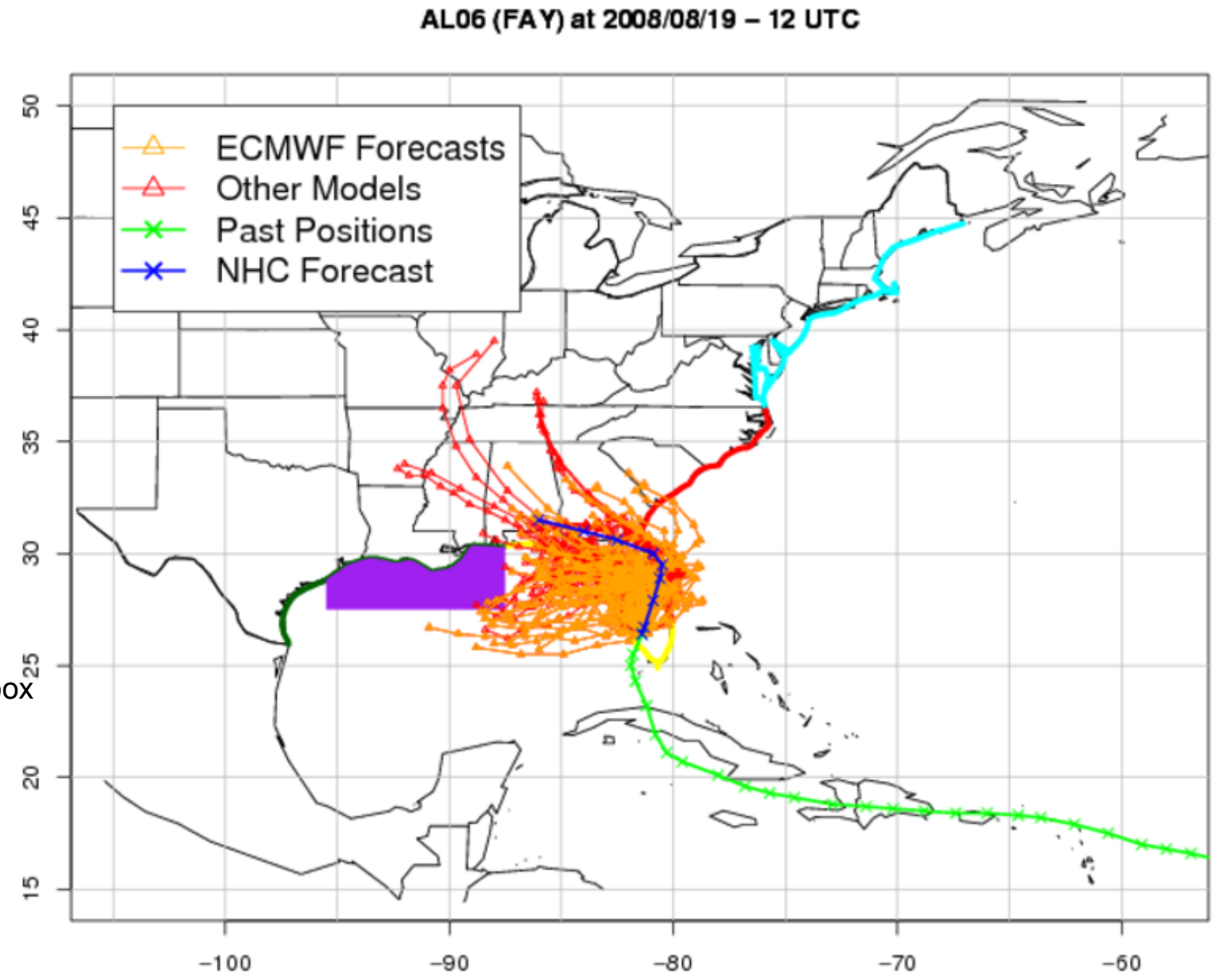
$$CHI = \left(\frac{V}{V_0}\right)^3 + \frac{3}{2}\left(\frac{R}{R_0}\right)\left(\frac{V}{V_0}\right)^2$$

CHI Index was offered for trading at the CME in 2008 for the first time.

Trading the CHI Index is a means of transferring insurance companies' risk.

Trading is defined for 6 geographic regions on the CME:

1) Gulf Coast
2) Florida
3) Southeast
4) Northeast
5) Entire US Atlantic/Gulf Coast
6) CHI-Cat-in-a-box



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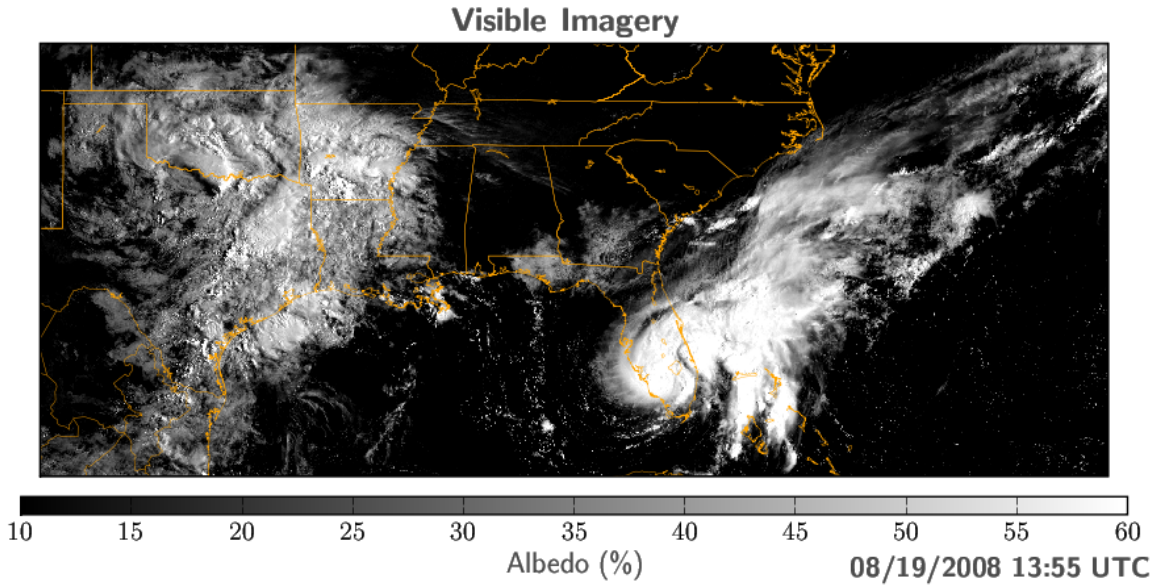
hCast-SR: hurricane Fay (2008)



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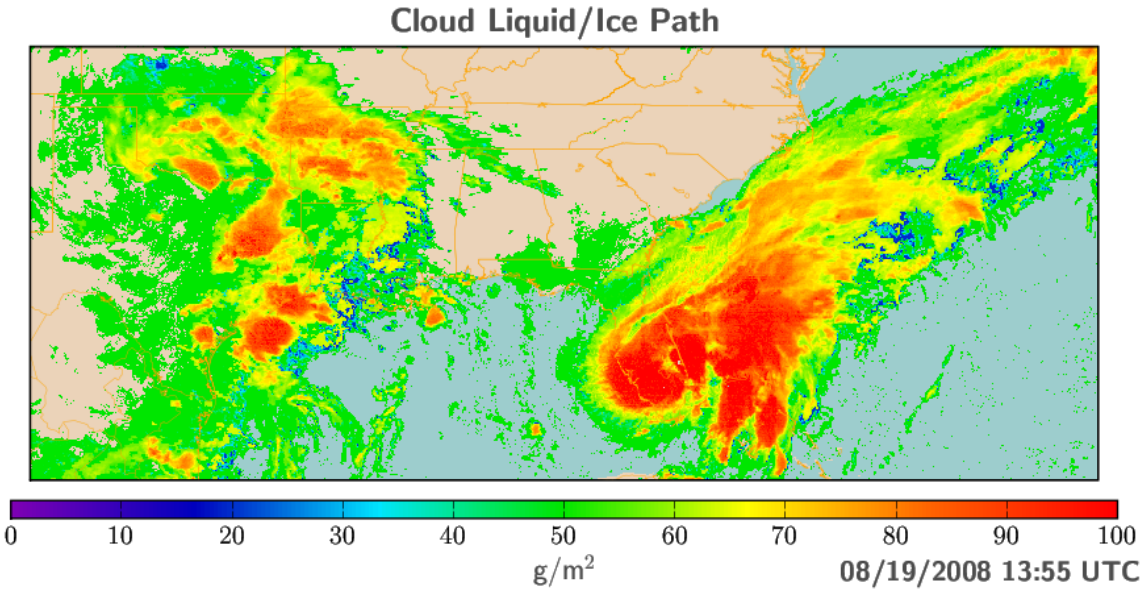
hCast-SR: hurricane Fay (2008)



Go to hCast-SR demo at weather.aer.com

Ensemble data assimilation

SBIR research project with the Navy to introduce ensemble methods into ocean data assimilation

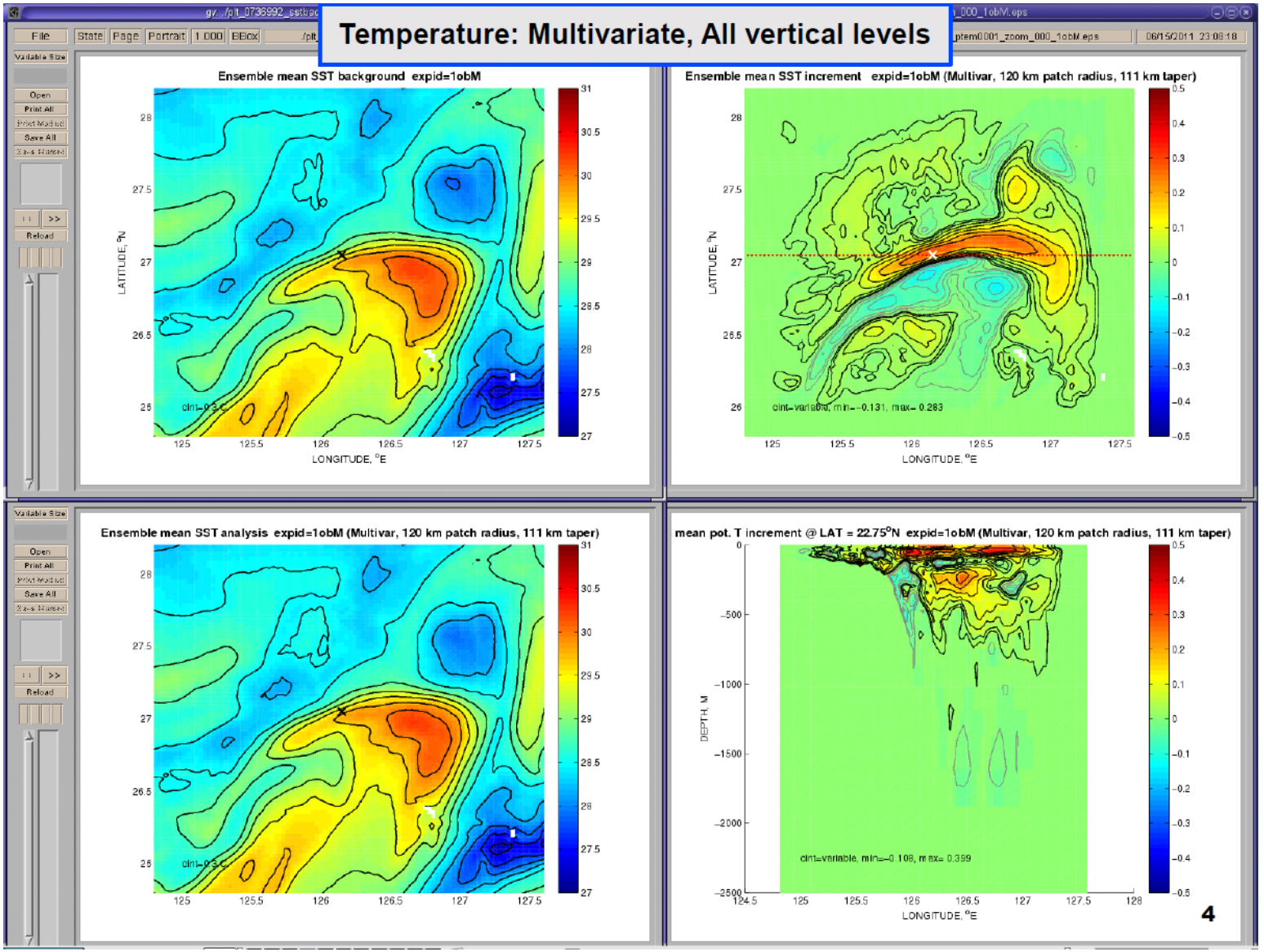
Local Ensemble Transform Kalman Filter adopted (ref below)

1. Convert atmospheric variables (GFS) → ocean model variables
2. Demonstrate with toy- and then real-sized problems

Szunyogh, I., E. J. Kostelich, G. Gyarmati, E. Kalnay, B. R. Hunt, E. Ott, E. Satterfield, and J. A. Yorke, 2008: A local ensemble transform Kalman filter data assimilation system for the NCEP global model. *Tellus A*, **60 (1)**, 113–130, doi:10.1111/j.1600-0870.2007.00274.x.

Ensemble data assimilation

single observation tests using a **L**ocal **E**nsemble **T**ransform **K**alman **F**ilter



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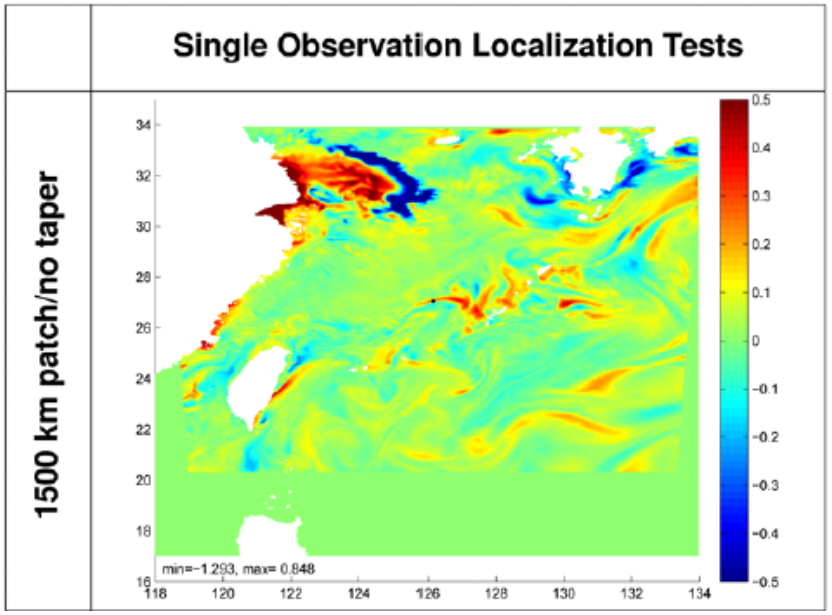
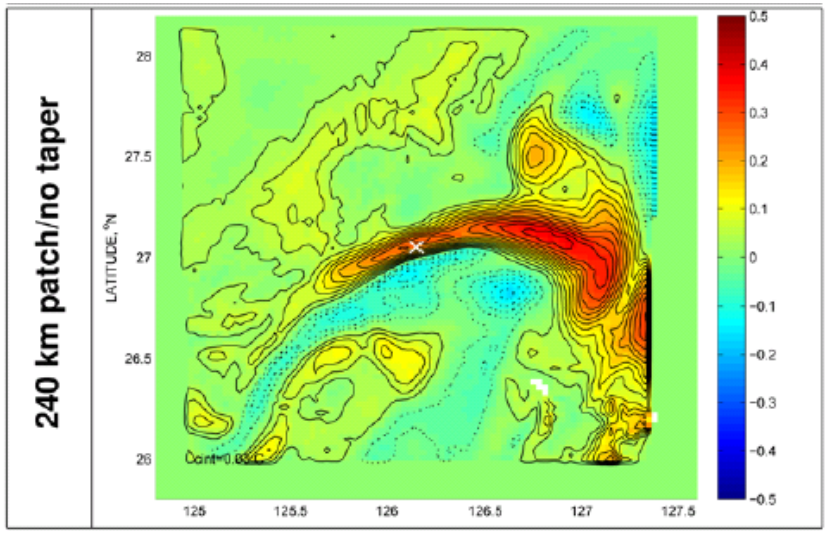
Ensemble data assimilation

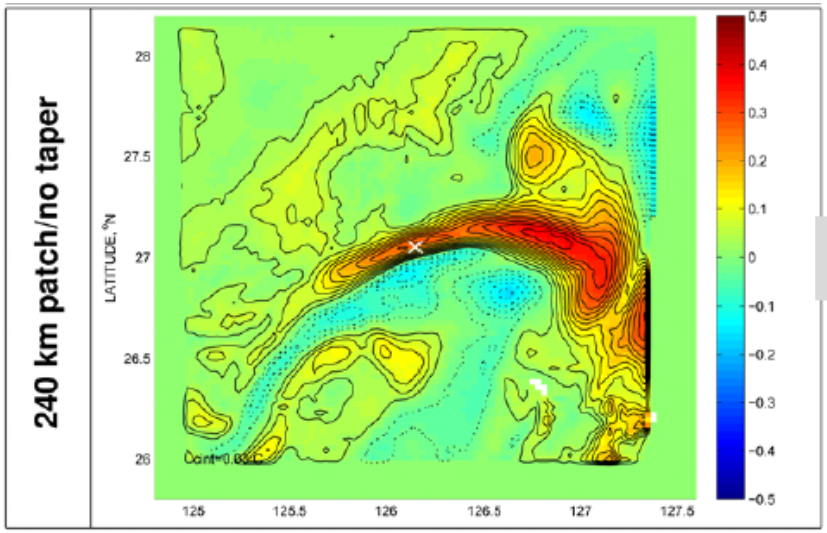
36-member ocean ensemble



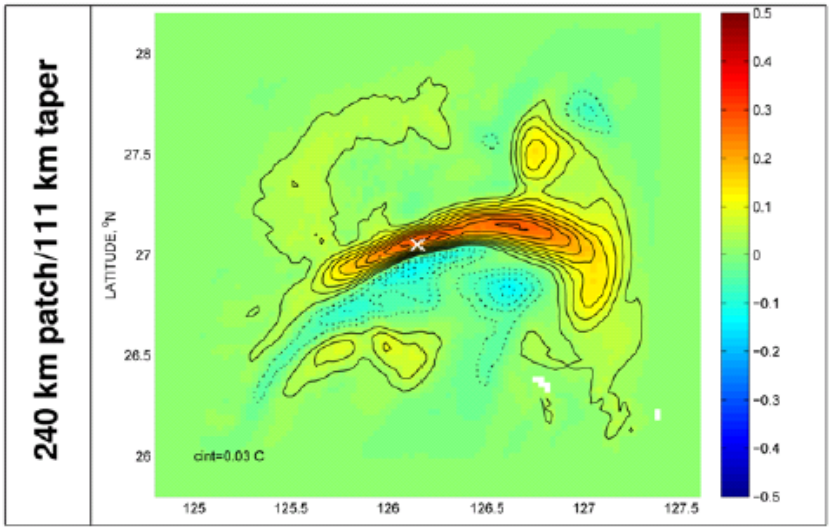
Localize observation influence, gross horizontal



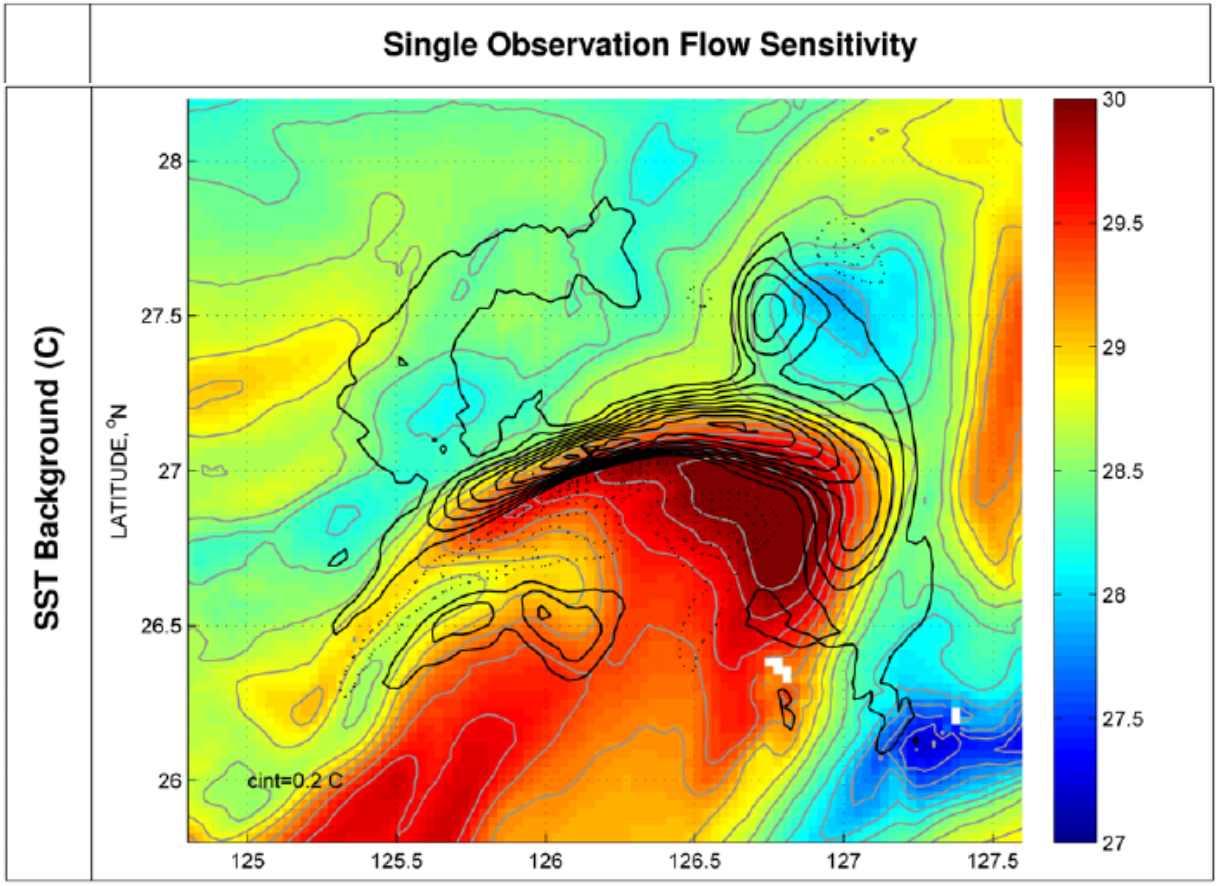
Ensemble data assimilation



Localize observation influence, via a taper function



Ensemble data assimilation



Summary of Ensemble Use

Ensembles can quantitatively estimate uncertainty.

- -This is very valuable where no observations exist.
- -Correlations in geophysical flow can be revealed if the ensemble is sufficiently large and conditioned to represent a realistic range of natural variability.

Ensembles require a lot of resources.

- -Research, OK; problematic for operations.

Ensembles produce a great deal of data that must be compressed/summarized to be practically useful.

- -Because an ensemble of forecasts provide so much potential information, answers to unconventional questions can be developed (e.g., CHI at time of landfall and probability distribution of CHI at that time).

Contact Information

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