Correcting for Position Errors in Variational Data Assimilation

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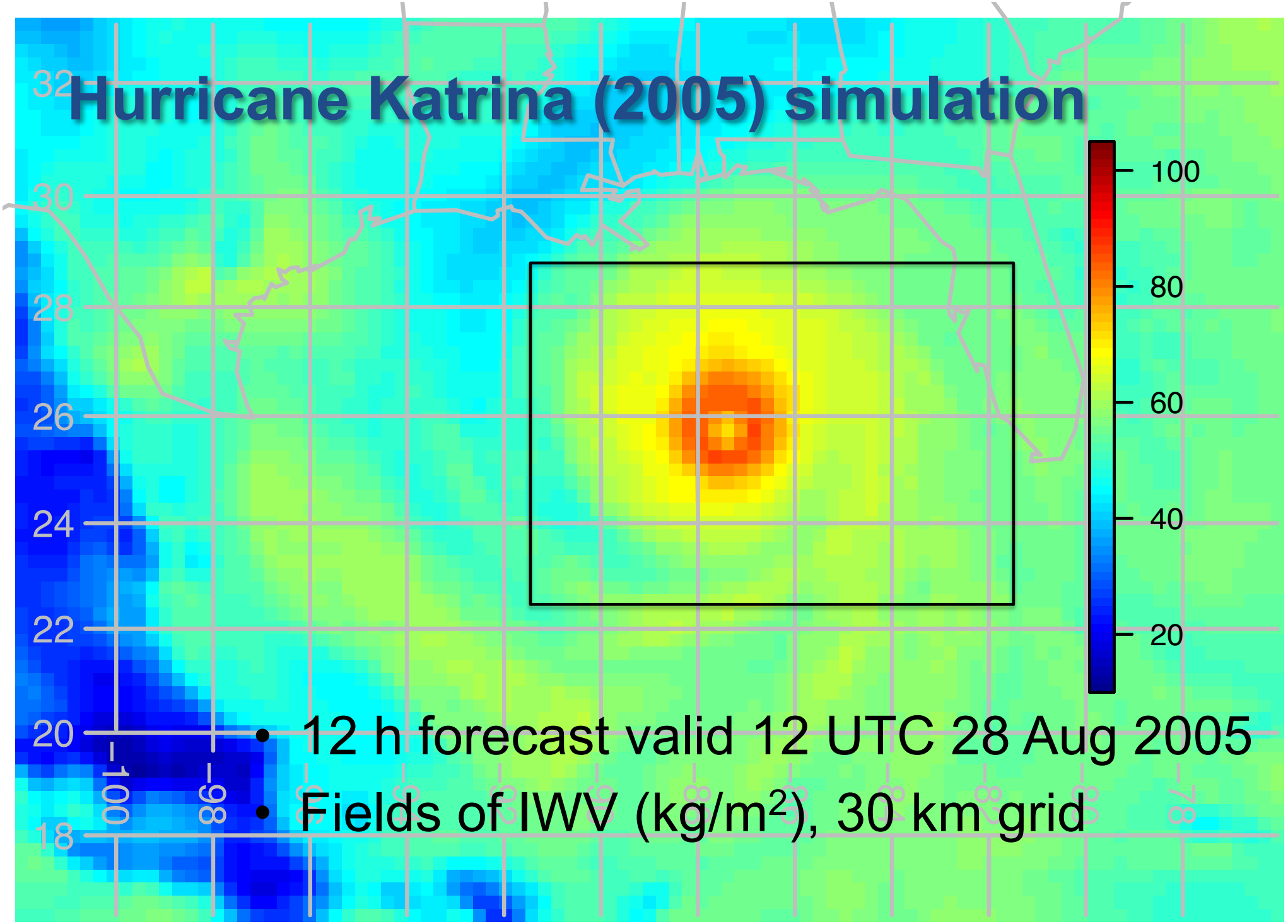
Introduction :: Feature Calibration and Alignment (FCA)

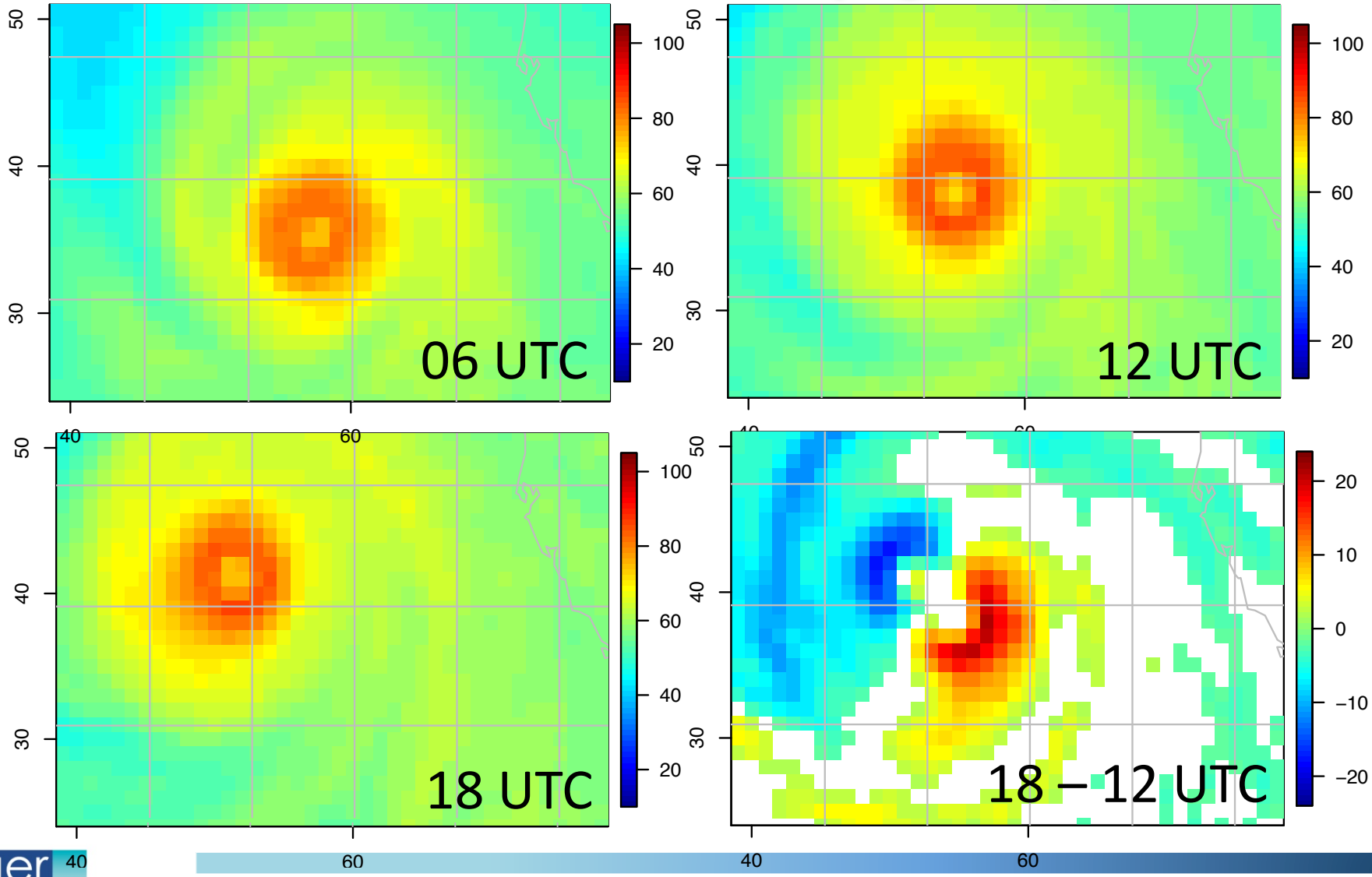
- For cloud-related fields, position errors of features are both common and problematical
  - Non-Gaussian error statistics
  - Poor convergence of variational analysis schemes
- FCA represents errors (or differences) in terms of errors of alignment and errors of amplitude and “random” errors
  - Here we do not consider FCA amplitude errors
  - Developed in context of WRFDA pre-processor

Summary

- Adjusting forecast IC in perfect model case
  - 2d fields: IWV in a TC case
  - 3d fields: pseudo-radiosondes (same TC case)
- Effect of removing alignment errors on covariance matrix
- Adjusting background using AIRS window channel BTs in a cloudy case.


Hurricane Katrina (2005) simulation
32
30
28
26
24
22
20
18
-100
-98
100
80
60
40
20
• 12 h forecast valid 12 UTC 28 Aug 2005
• Fields of IWV (kg/m²), 30 km grid

Katrina simulation IWV (kg/m^2)

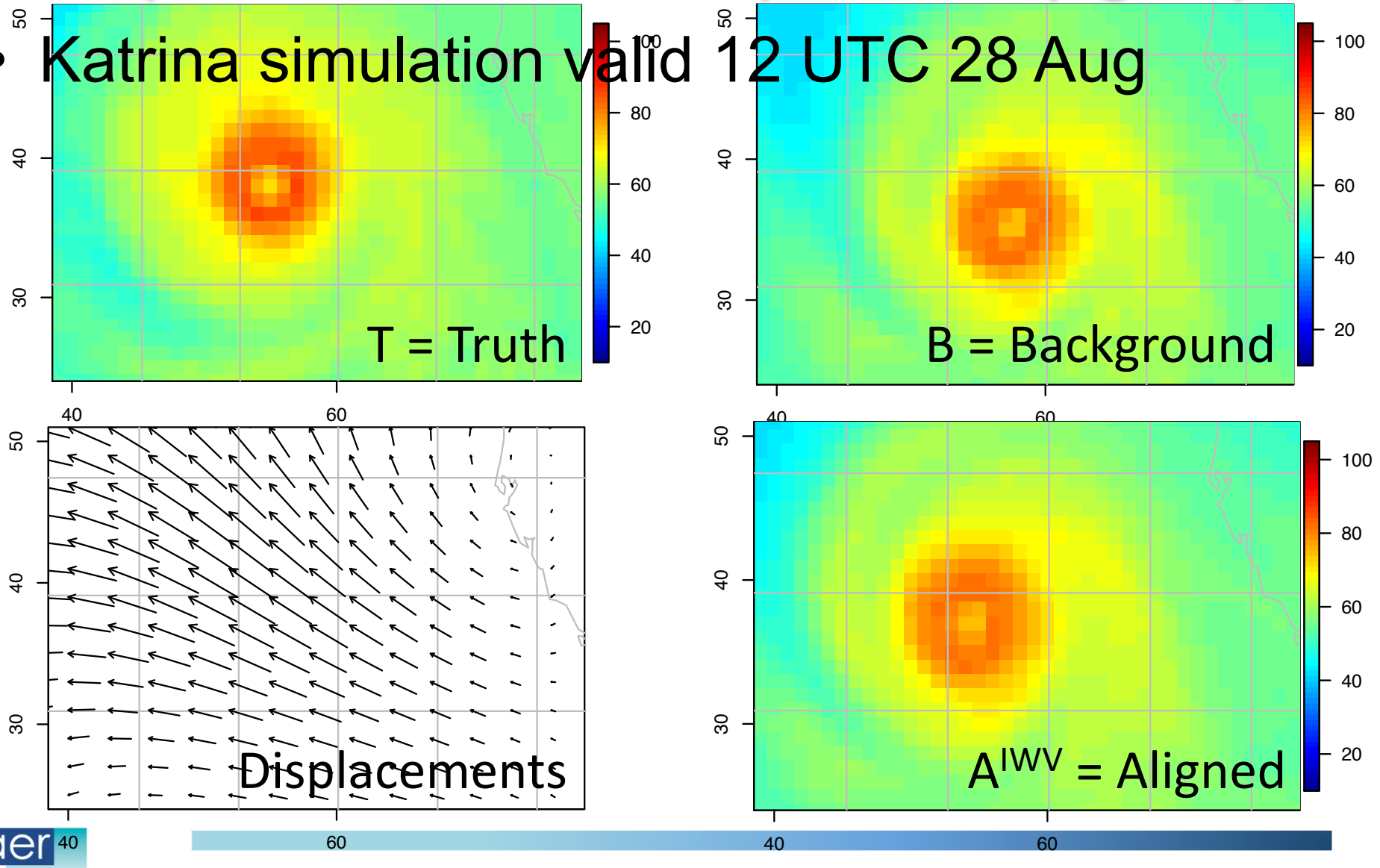


Grassotti et al. 1999 FCA

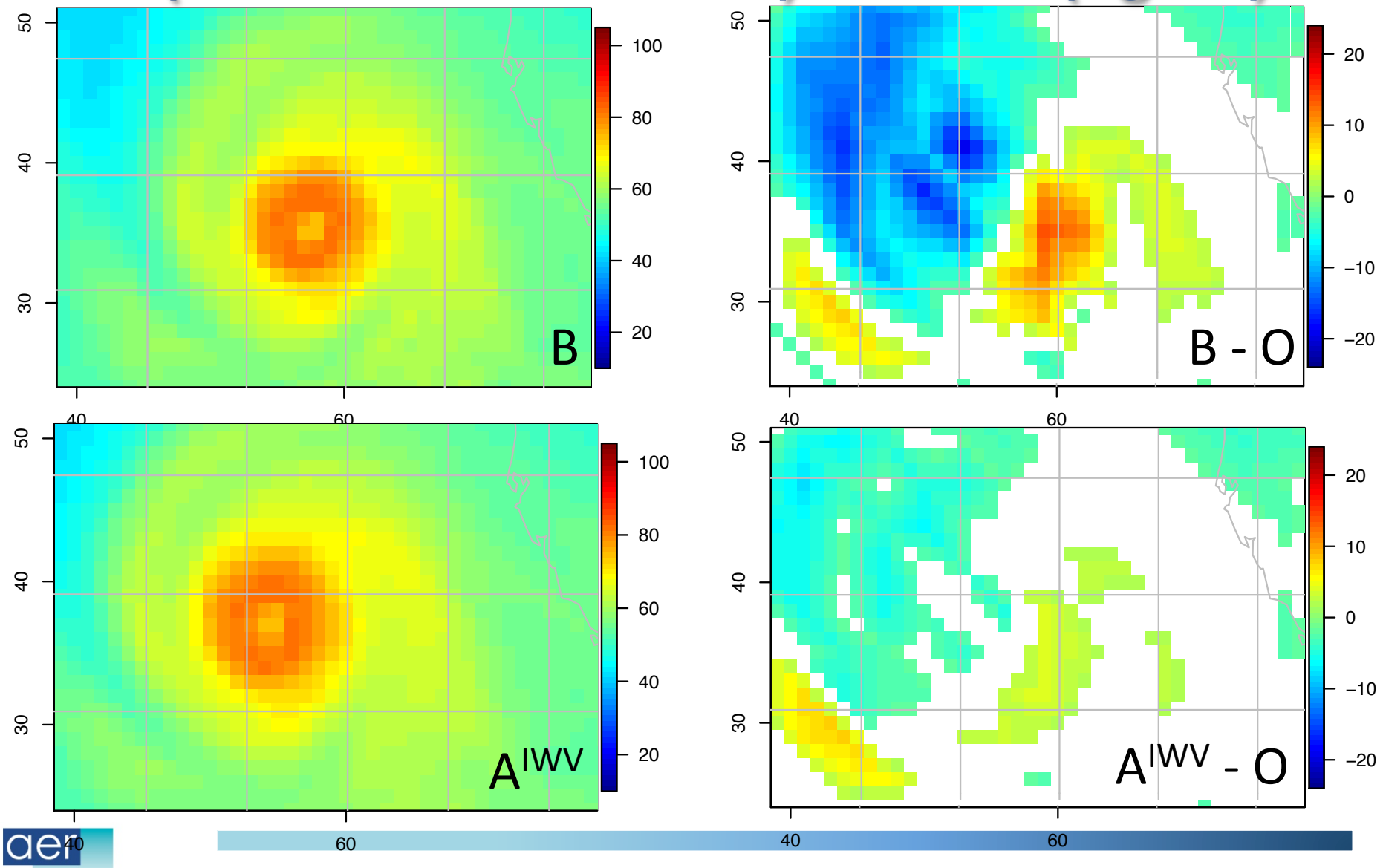
- Compare two-dimensional forecast field(s) and corresponding observations
- Derive a set of two-dimensional displacement vectors that improves the alignment of features in the 2-d forecast field and observations
  - minimize misfit to observations
  - use nonlinear optimization, cost function gradient from adjoint of displacement
  - impose additional constraints on displacements: smoothness, non-divergence, etc.

FCA (Grassotti et al. 1999) for IWV (kg/m^2)

- Katrina simulation valid 12 UTC 28 Aug



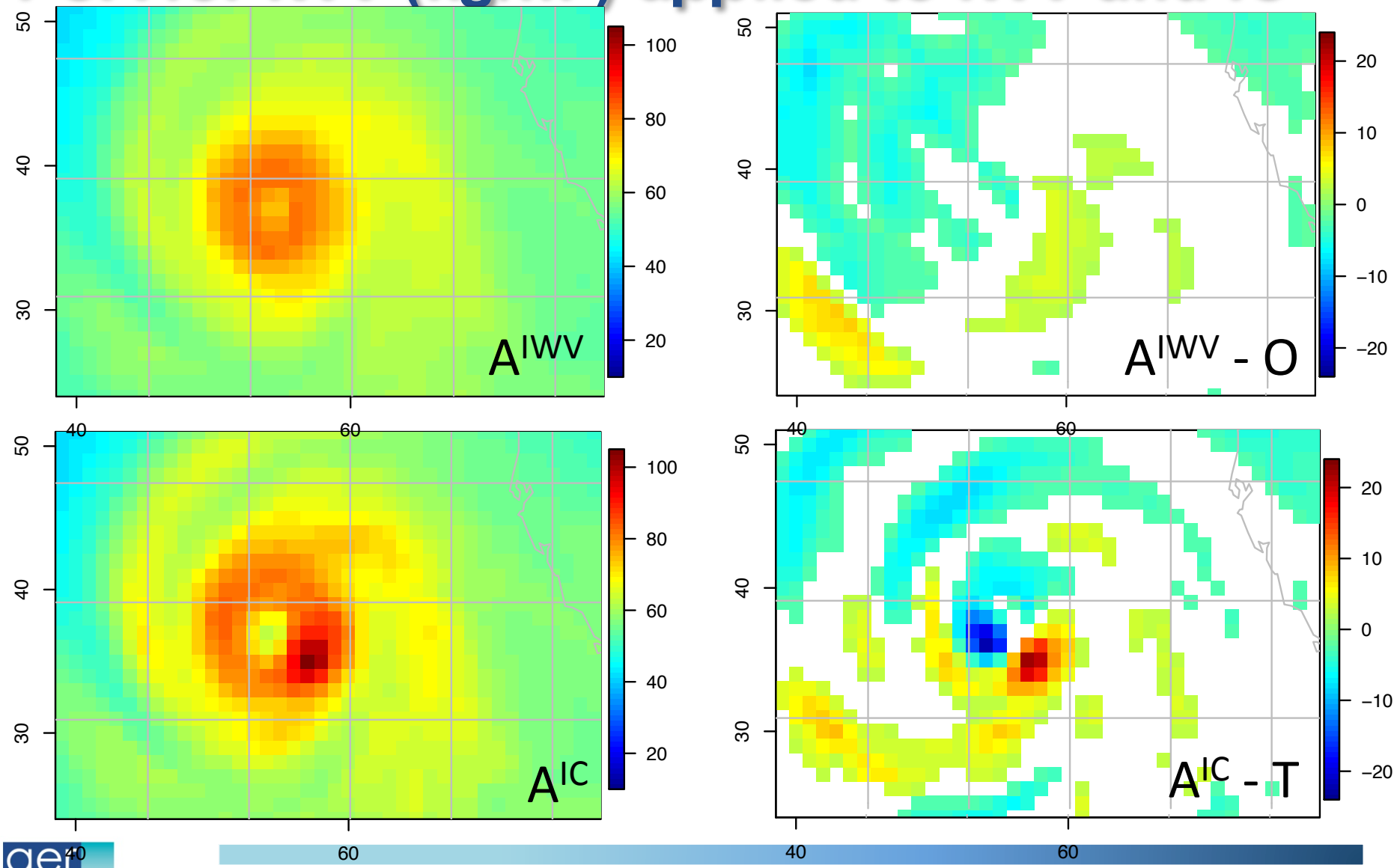
FCA (Grassotti et al. 1999) for IWV (kg/m^2)



Extend Hsiao et al. (2010) displacement algorithm for 3d model IC

- Goal is to apply 2d displacement vectors to 3d model fields without disturbing model balance
- Direct displacement of: winds (u,v,w), SLP, RH, hydrometeor mixing ratios, potential temperature
  - All along model surface, except
  - Potential temperature along constant height surfaces
- Recalculate derived quantities: pressure, specific humidity, temperature, hydrostatic geopotential, dry air mass
- Nonhydrostatic geopotential is not displaced

FCA for IWV (kg/m^2) applied to IWV and IC

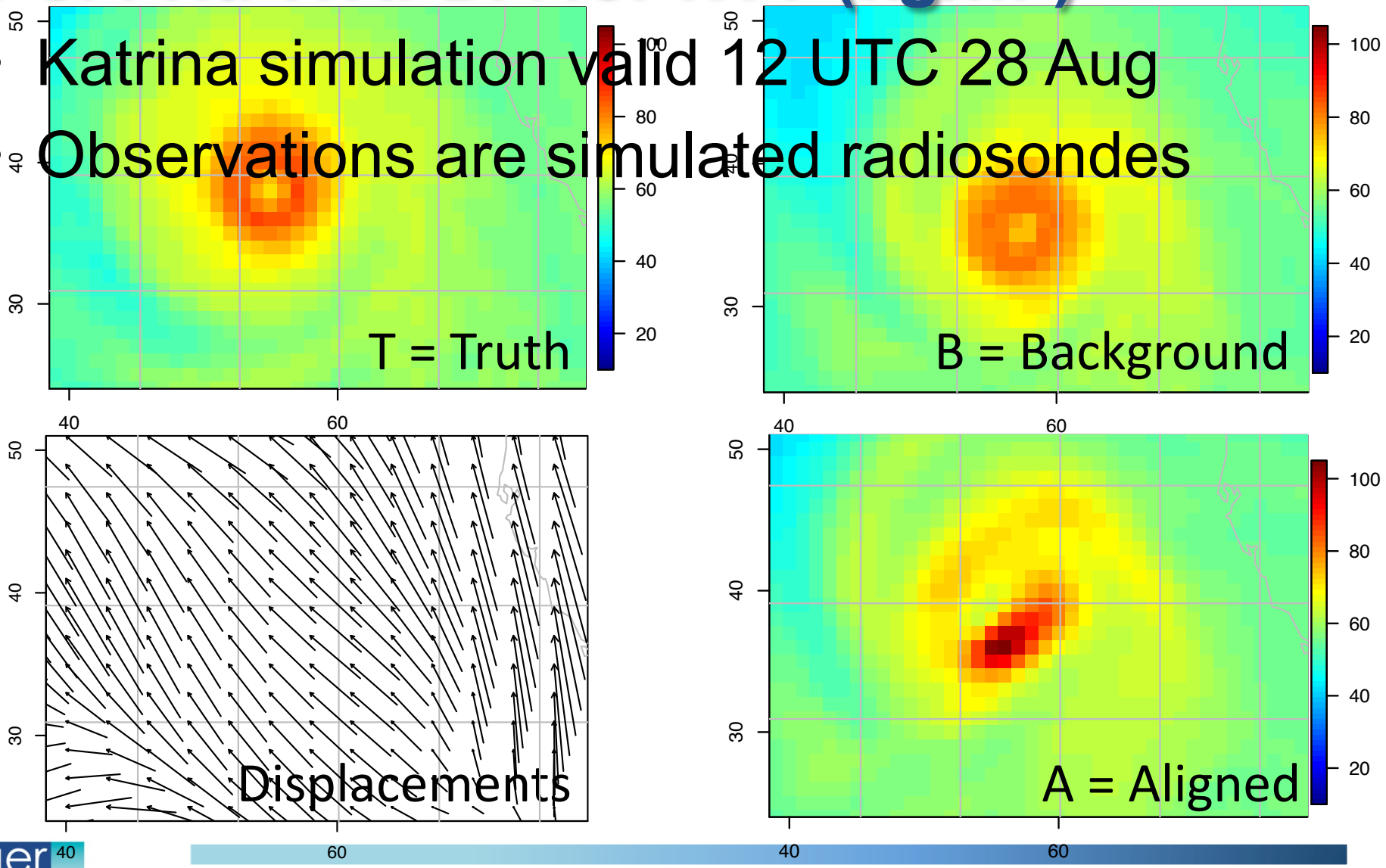


WRFDA preprocessor implementation

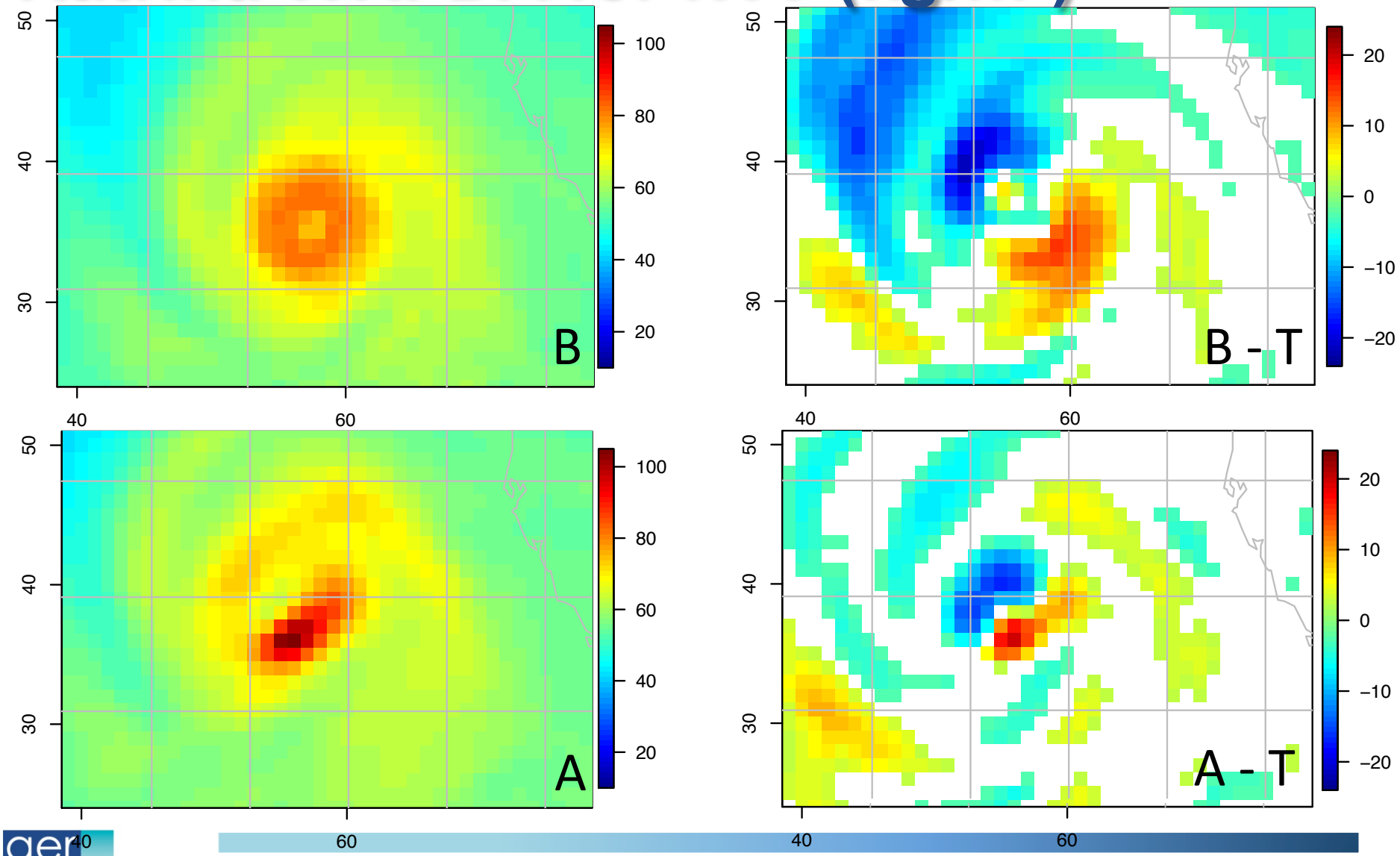
- Hijack u and v for displacements
  - Background function measures size of displacements
- Apply displacement to 3-d model fields
  - Parallel implementation, inner loop linearized about current estimate of the displacements
- Otherwise standard 3dvar
  - Usual control variable, but only mid-level u, v are active
  - Existing minimization
    - Conjugate gradient in inner loop with linearized displacements; nonlinear adjustments in outer loop
  - Existing obs operators
    - Therefore this approach is applicable to all obs types supported by WRF Variational DA
    - Following example uses simulated “radiosondes”

FCA via WRFDA for IWV (kg/m^2)

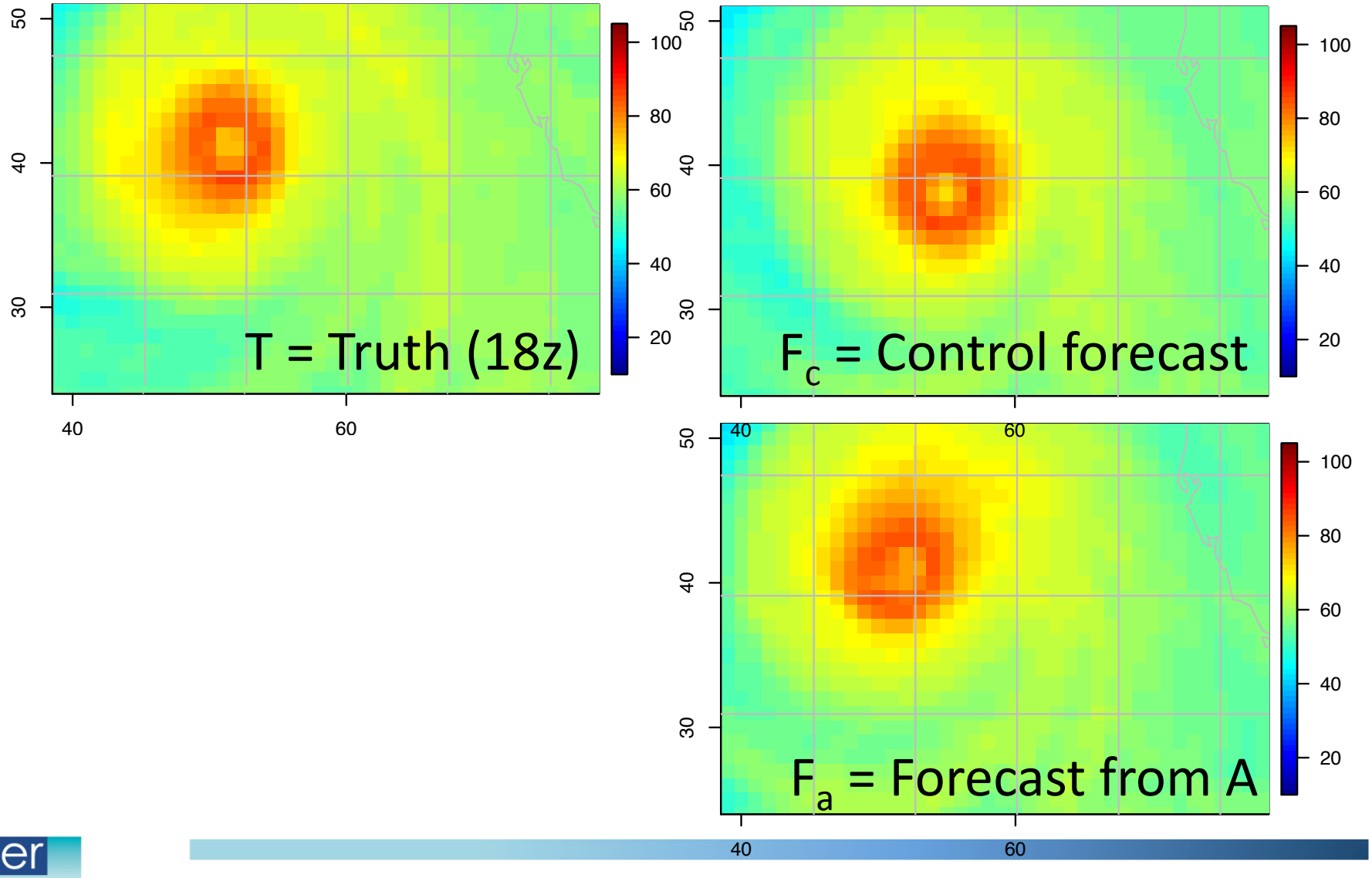
- Katrina simulation valid 12 UTC 28 Aug
- Observations are simulated radiosondes



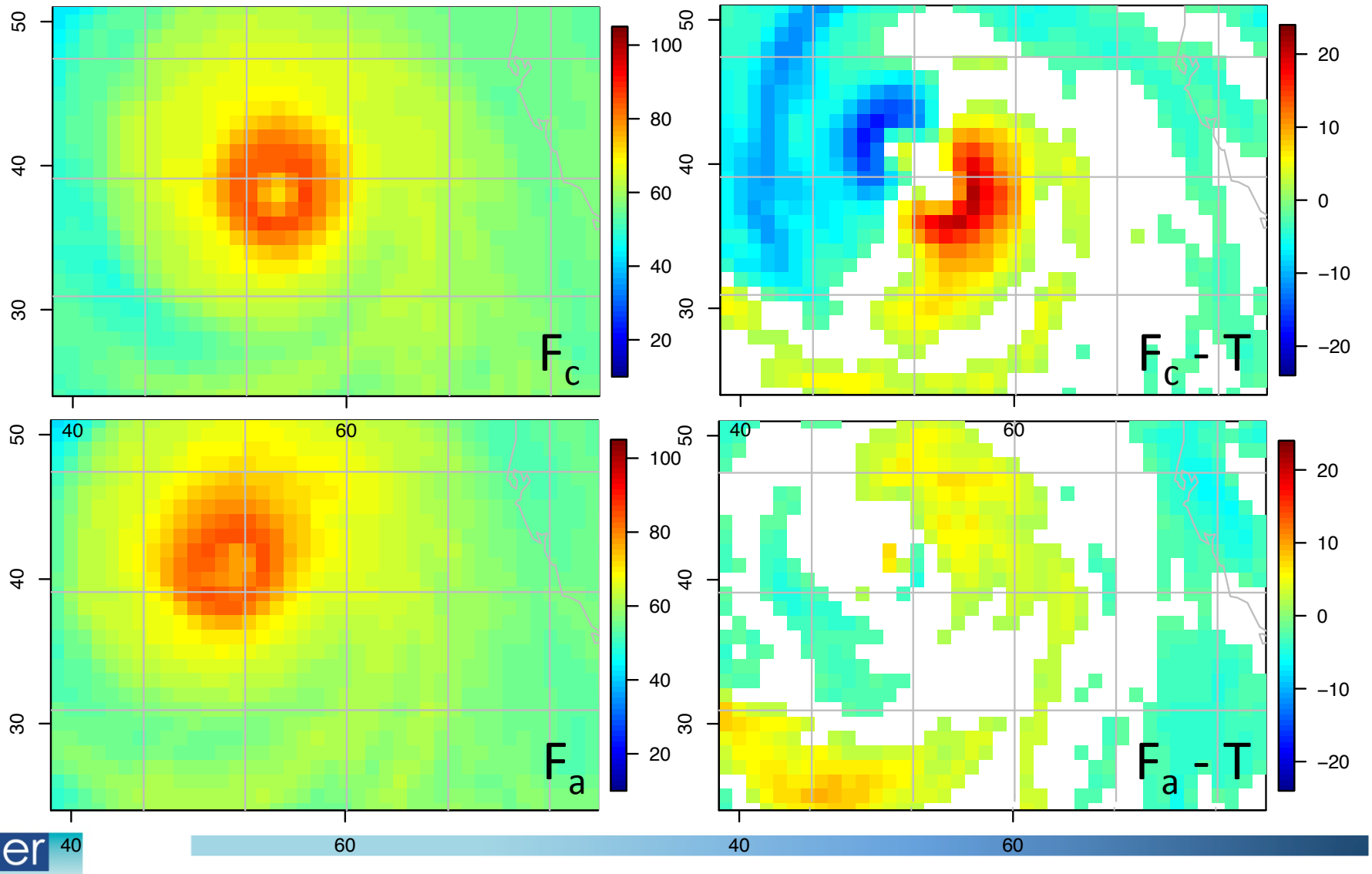
Katrina WRFDA for IWV (kg/m^2)



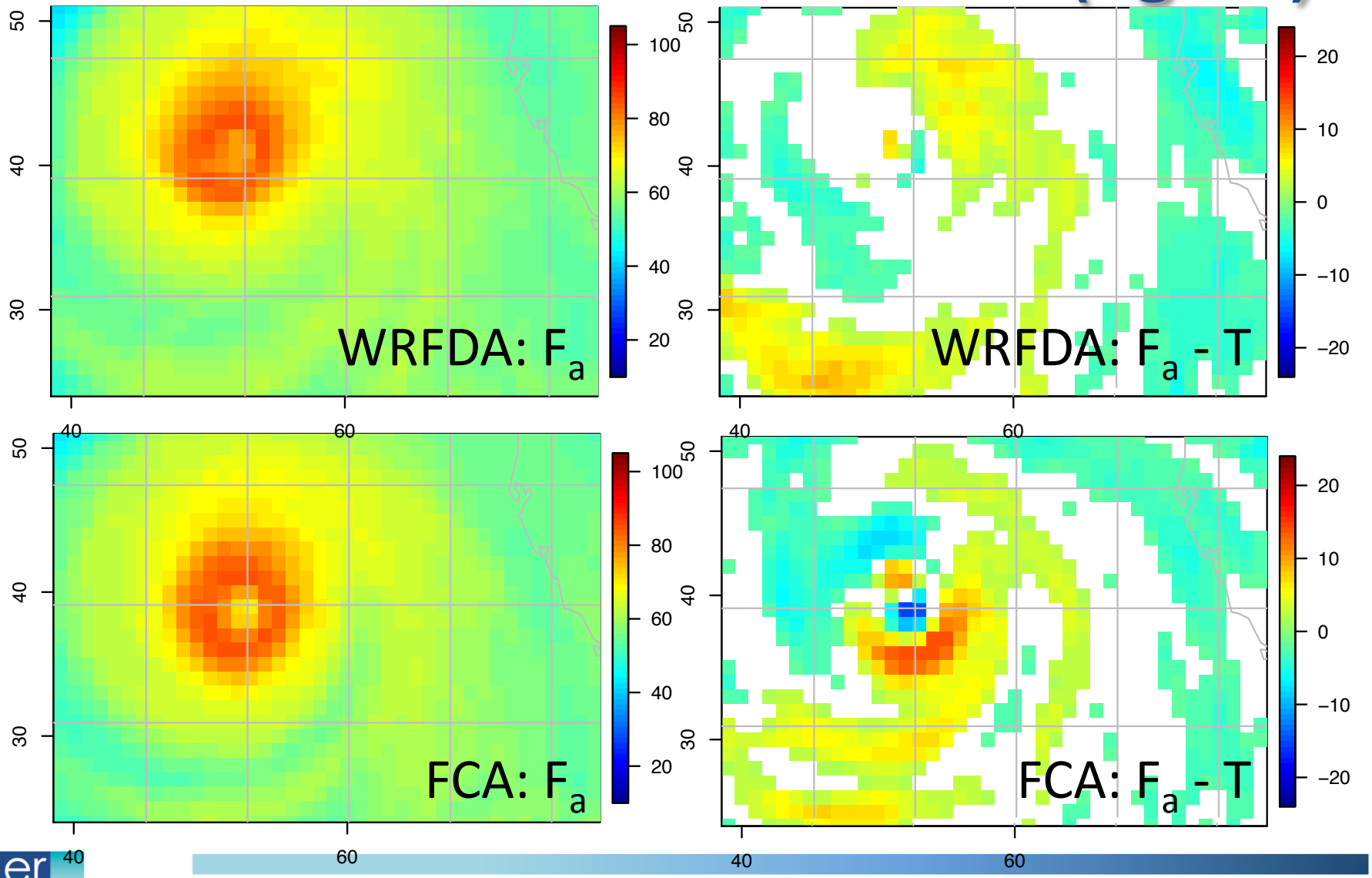
Katrina WRFDA 6-h forecasts IWV (kg/m^2)



Katrina WRFDA 6-h forecasts IWV (kg/m^2)

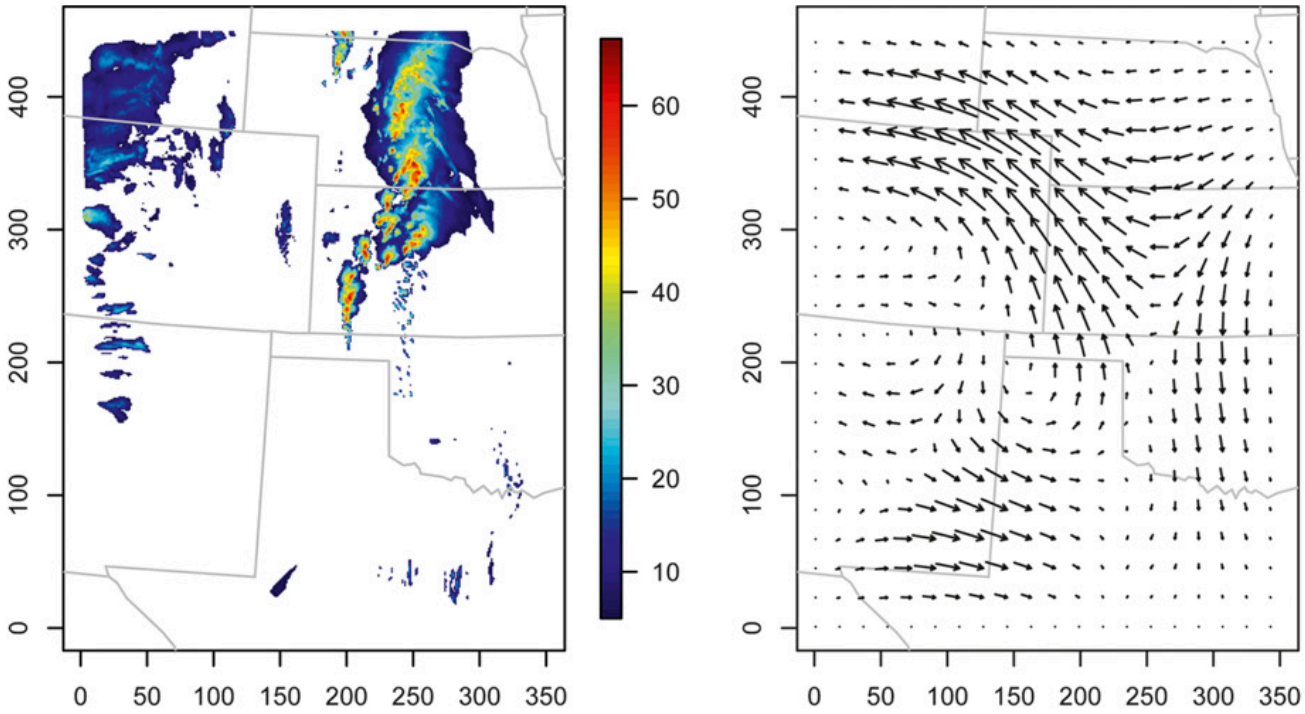


Katrina FCA 6-h forecasts IWV (kg/m^2)



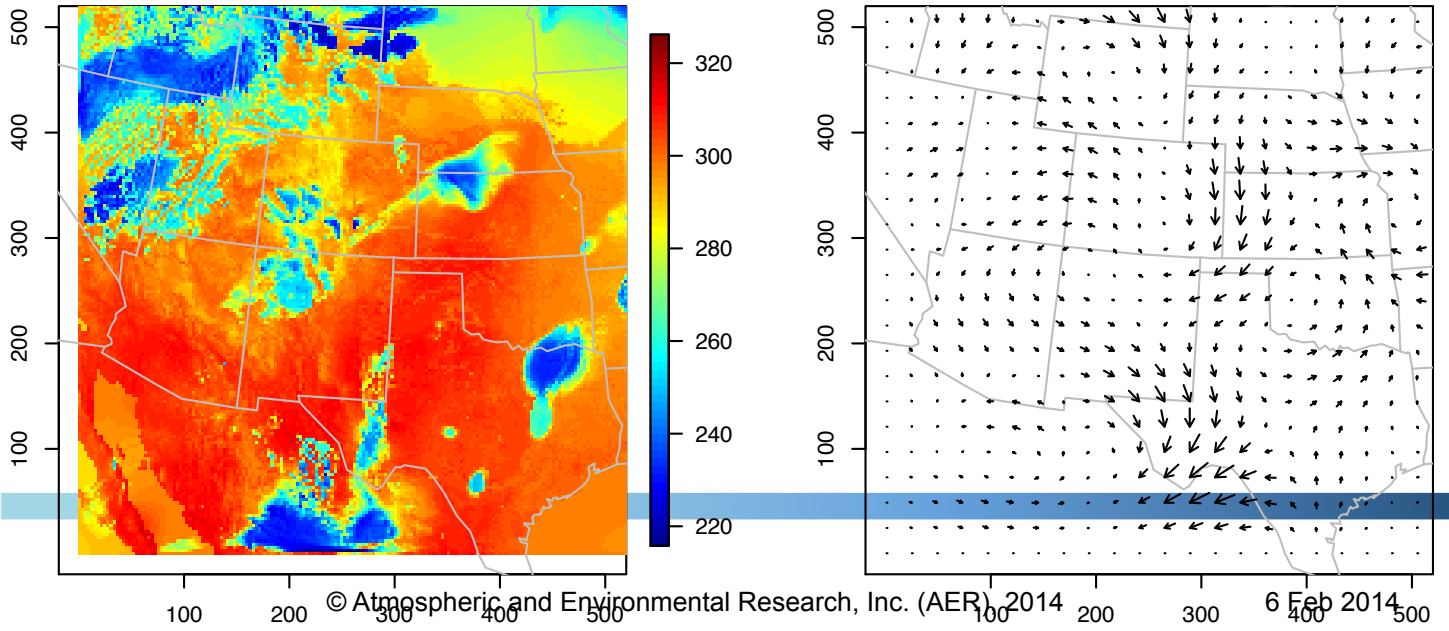
FCA and ensemble errors for composite reflectivity (dBZ)

- FCA reduces variance and increases spatial scales of errors
- Use ensemble median in place of ensemble mean to preserve small scale detail
- 30 member background ensemble of 6-h 3-km WRF forecasts valid 04 UTC 28 Mar 2007



FCA for AIRS (window) channel 787

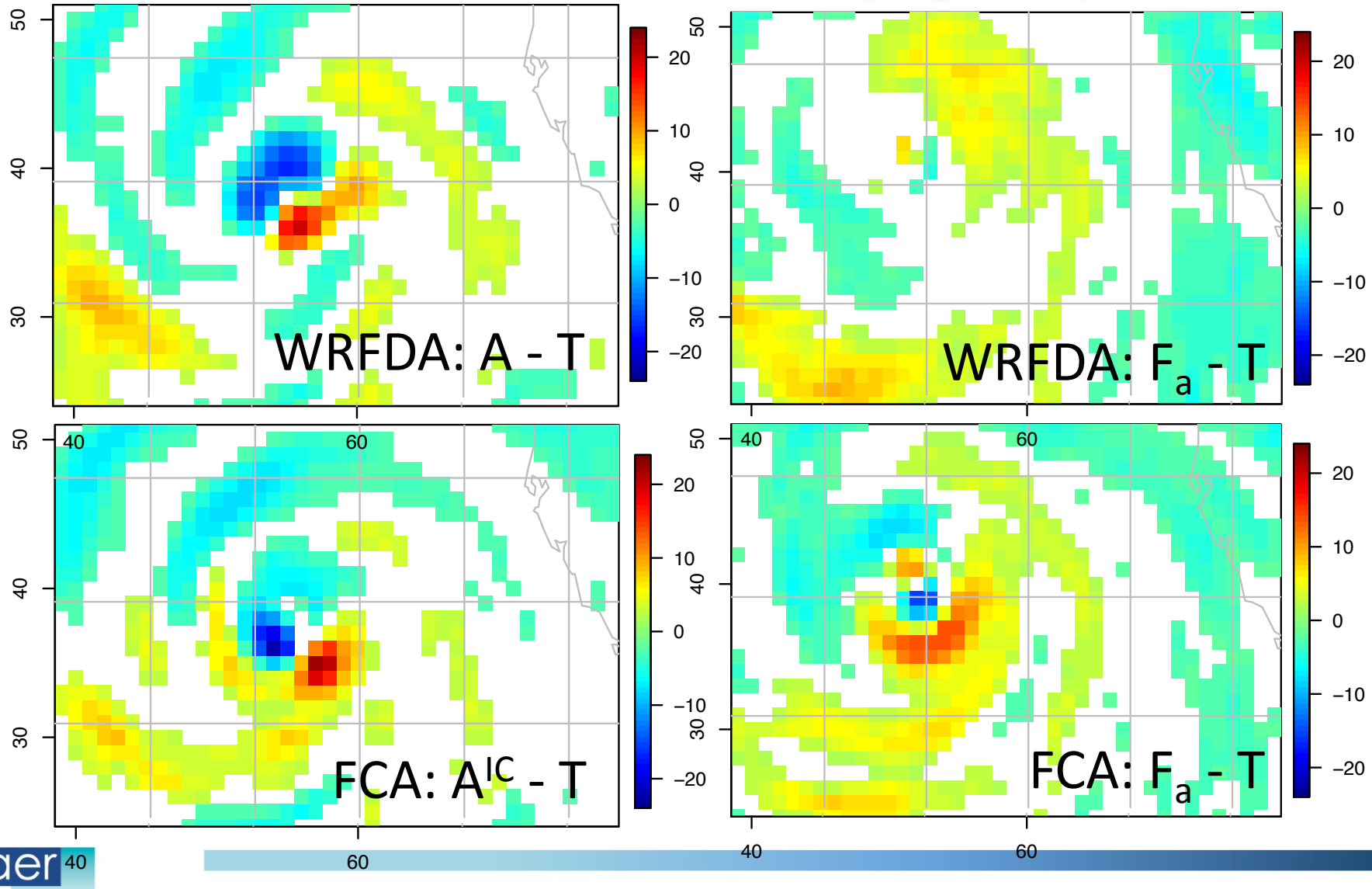
- Clouds stand out as cold in this channel
- Background is 2-h 4-km WRF forecast with explicit convection valid 20 UTC 6 Jun 2009
- Brightness temperatures derived from CRTM using the WRF forecast variables, including CLW, ice, rain, etc.
- After adjustment background and obs have stronger correlations for window channels



Conclusions

- 2d FCA displacements can be applied to a full model state
- Standard 3dVAR of u and v can be hijacked to yield displacements
  - Nominal covariances for u and v are satisfactory in TC case
- Using 3d “radiosonde” data in WRFDA improves forecast relative to using IWV in stand alone FCA
  - Even though IC for IWV are poorer
- FCA can explain a sizeable fraction (>10%) of variance for a background ensemble of radar observations (dBZ)
- For real data cloudy window radiances FCA noticeably reduces errors, but is limited by the background accuracy

Katrina differences IWV (kg/m^2)



Future work

- Tune / Derive background error covariances for displacement vectors
- Extend control vector for simultaneous application of additive/displacement corrections
- Improve short-term cloud forecasting with 2-h cycle of WRFDA using GEO imagery in FCA

Thank you

- Support from USAF as part of NCAR's advanced cloud analysis and forecast system (ACAPS)

- Grassotti et al., 1999, JAMC, doi:10/fprb35
- Hsiao et al., 2010, MWR, doi:10/bktnst
- Nehrkorn et al., 2014, MWR, doi:10/p5d

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