

Improved Initialization and Prediction of Clouds with All-Sky Satellite Radiances

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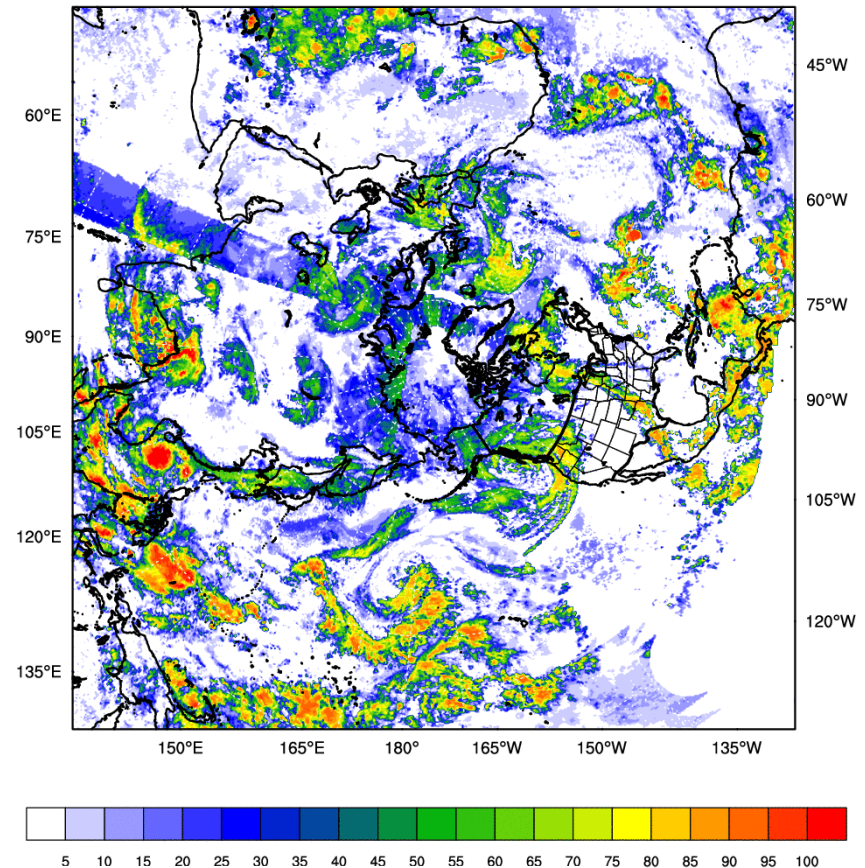


Acknowledgments: Thomas Nehrkorn, Brian Woods, Gael Descombes, Francois Vandenberghe, Glen Romine, Greg Thompson, Dongmei Xu. Partial funding provided by the Air Force Weather Agency

Cloud Initialization: Two Approaches

1. **Nowcasting:** Multisensor Advection-Diffusive nowCast (MADCast)

- Retrieval of cloud fraction profiles
- Interpolation to 3D gridded fields
- Dynamical transport with WRF (no physics)
- Rapid Update Cycling
- Synergy b/w multiple IR sensors
AIRS, IASI, CrIS, MODIS, GOES, SEVIRI, MTSAT, FY-2
- NRT application to solar energy fcst



Cloud Initialization: Two Approaches

2. NWP combined analysis

Method

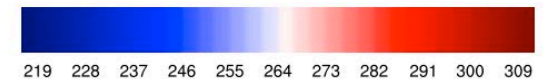
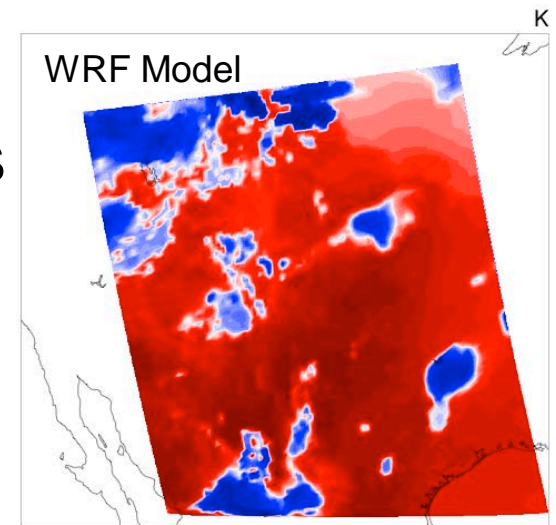
State augmentation to include cloud microphysics model variables (q_c , q_i , ...)

Challenges

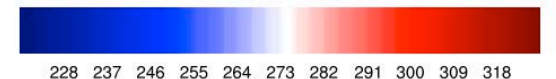
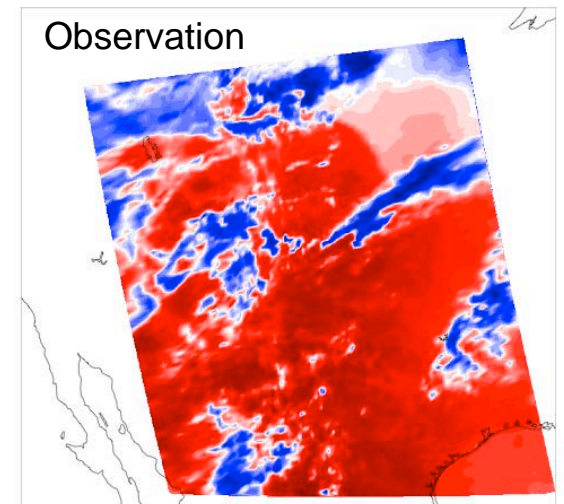
- Non-linear observation operator
- Non-Gaussian error distributions
- Underdetermined problem
- Complex balance
- Significant model errors

Goals

- Fit observations at initial time
- Sustain cloud increments in forecast

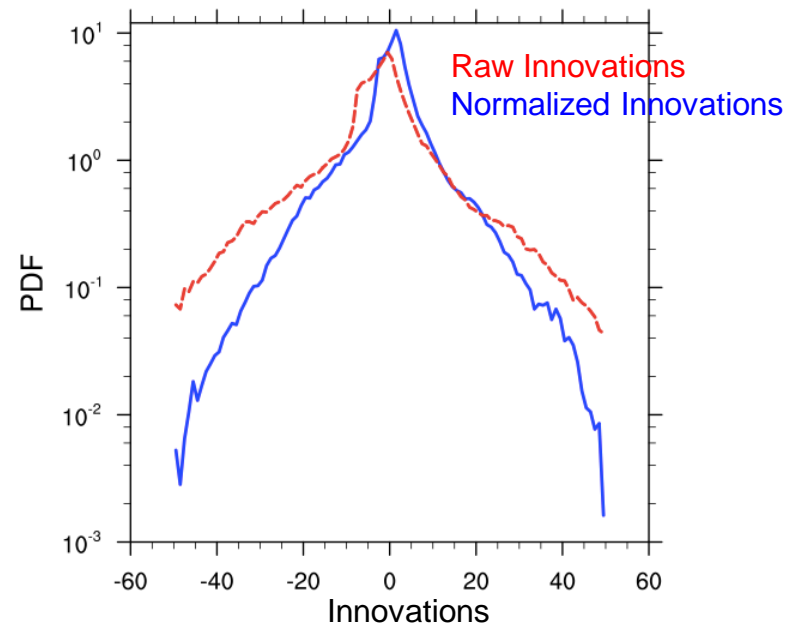
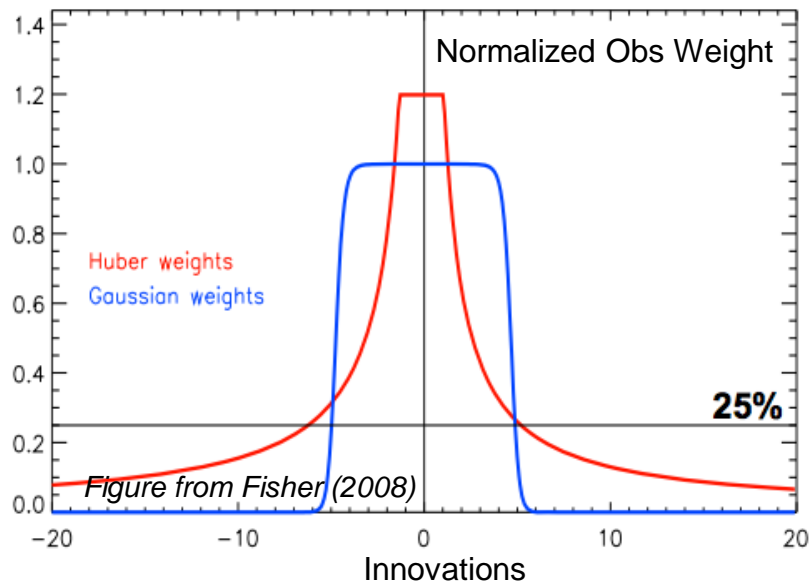


AIRS #787



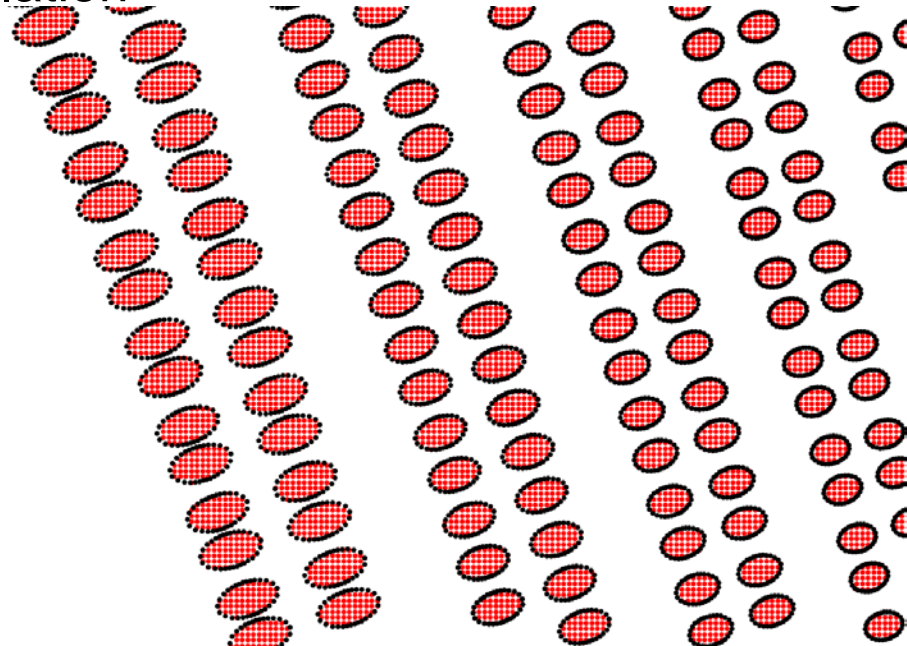
Processing of All-Sky Satellite Radiances

- Revisited QC: extended Gross and First-Guess check
- Huber Norm: robust definition of observation error



Processing of All-Sky Satellite Radiances

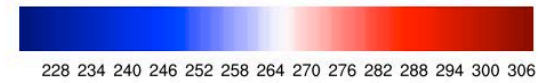
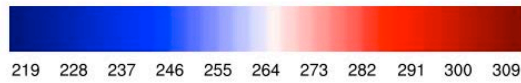
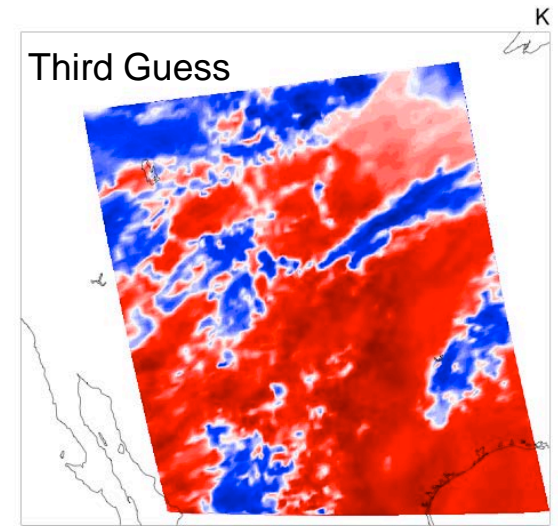
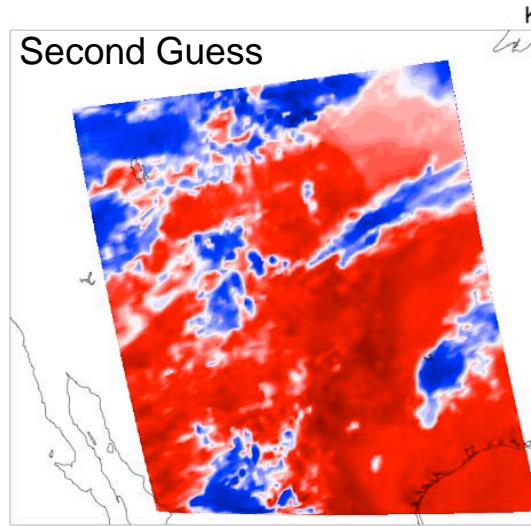
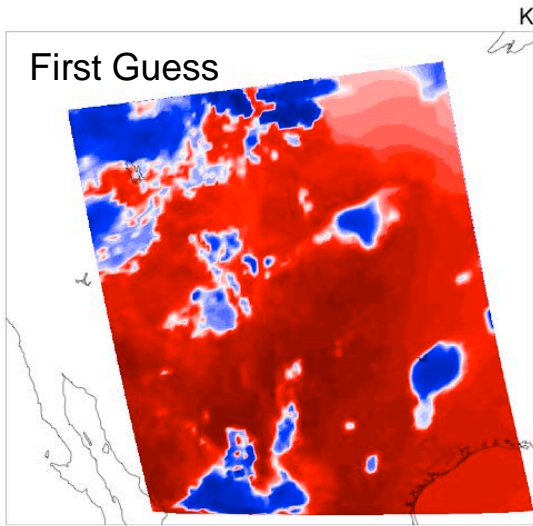
- **Revisited QC:** extended Gross and First-Guess check
- **Huber Norm:** robust definition of observation error
- **Bias Correction:** Variational Bias Correction (unchanged predictors)
- **Land Surface:** T_{skin} and ϵ_s introduced as a sink variable
- **Field of View:** Advanced interpolation
(AIRS & IASI)



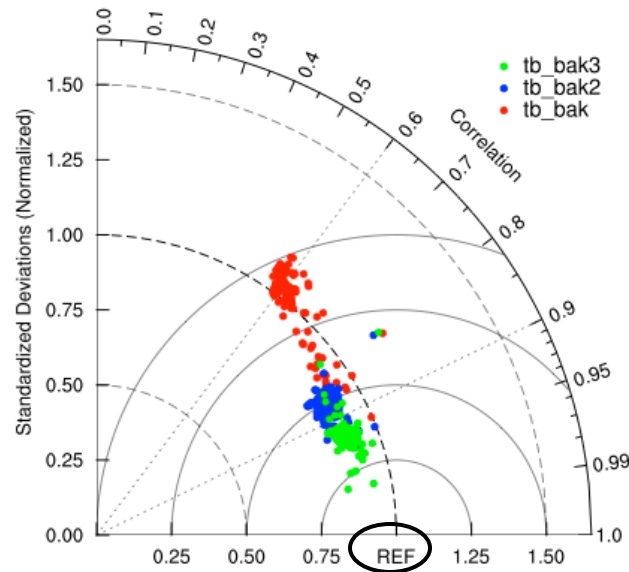
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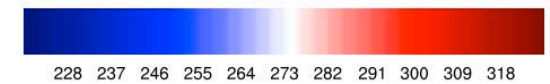
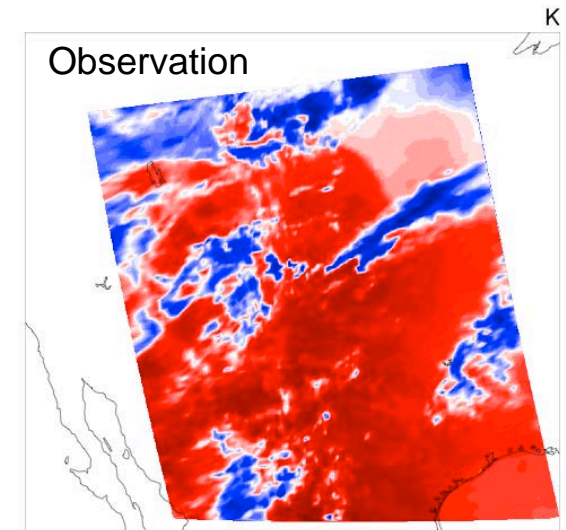
- **CRTM Jacobians:** modified base state (floor and ceiling values)
- **Middle Loop:** Multiple re-linearizations of observation operator



Update of
 q_{cloud} , q_{ice} in WRF



Observations



Ensemble/Variational Integrated Localized (EVIL)

Variational DA with ensemble covariance via *state augmentation*

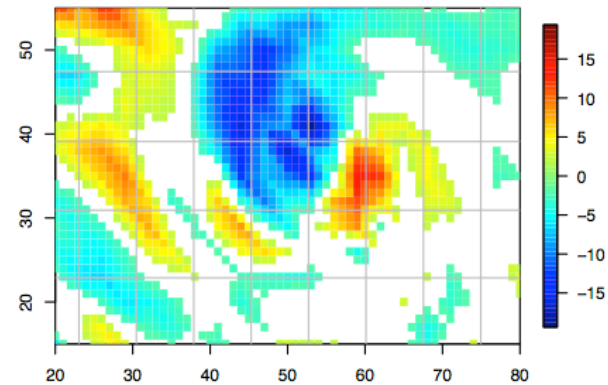
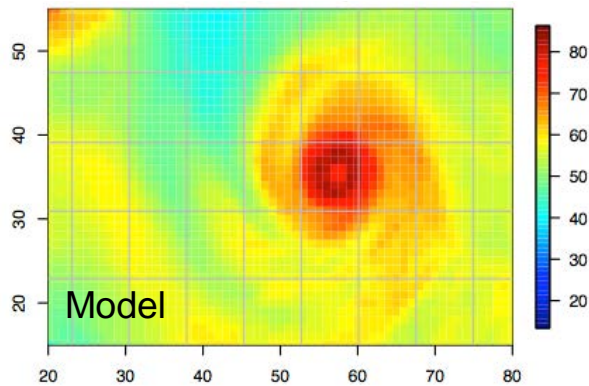
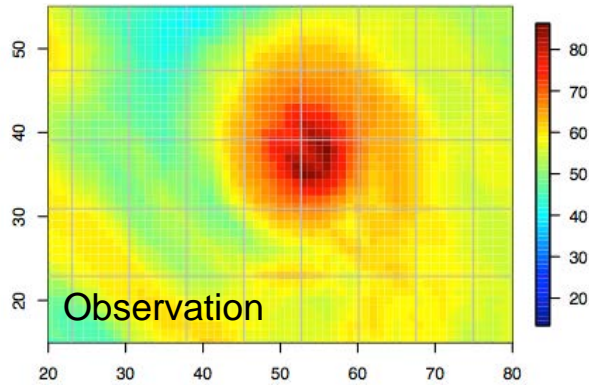
(Lorenç 2003, Wang et al. 2008, Fairbairn et al., 2012)

$$\delta \mathbf{x} = \beta_c \delta \mathbf{x}_c + \beta_e \delta \mathbf{x}_e \quad \text{with} \quad \begin{cases} \delta \mathbf{x}_c = \mathbf{B}^{1/2} \mathbf{v} & \text{Stationary multivariate} \\ & \text{covariance model including clouds} \\ \delta \mathbf{x}_e = \mathbf{P}_f \circ \mathbf{C}_\alpha^{1/2} \mathbf{v}_\alpha & \text{Localized [+ filtered]} \\ & \text{ensemble covariance} \end{cases}$$

$$J(\mathbf{v}, \mathbf{v}_\alpha) = J_o + \frac{1}{2} \mathbf{v}^T \mathbf{v} + \frac{1}{2} \mathbf{v}_\alpha^T \mathbf{v}_\alpha$$

NEW ALGORITHM: Variational DA updates the ensemble perturbations using products of Lanczos minimization
(without separate EnKF)

Displacement analysis in WRF (dWRF)

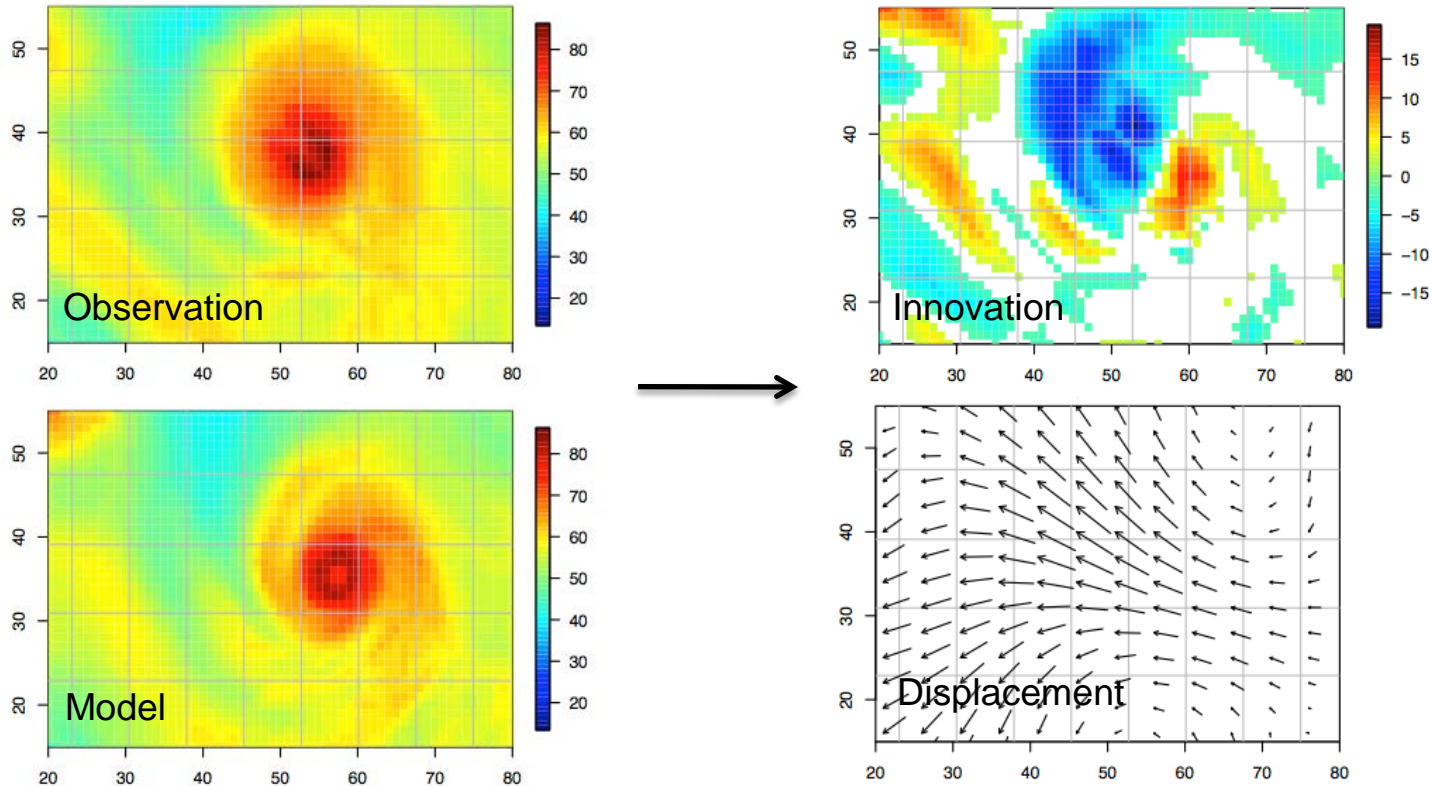


Innovation



- Hurricane Katrina OSSE
- Synthetic observations (TCPW)

Displacement analysis in WRF (dWRF)



Assimilation system can operate in two modes:

- Standard (*i.e.* additive increments)
- Displacement

Experiment

CONUS domain, 15km resolution, WRF-ARW model, Thompson microphysics

Single analysis at 20012/06/03 (12UTC), 10 middle loops

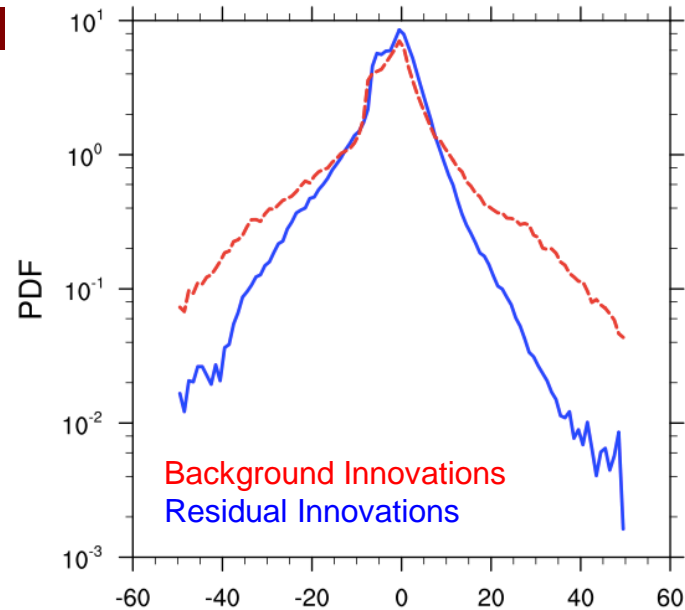
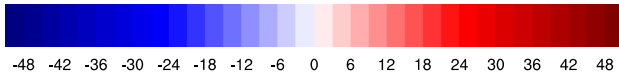
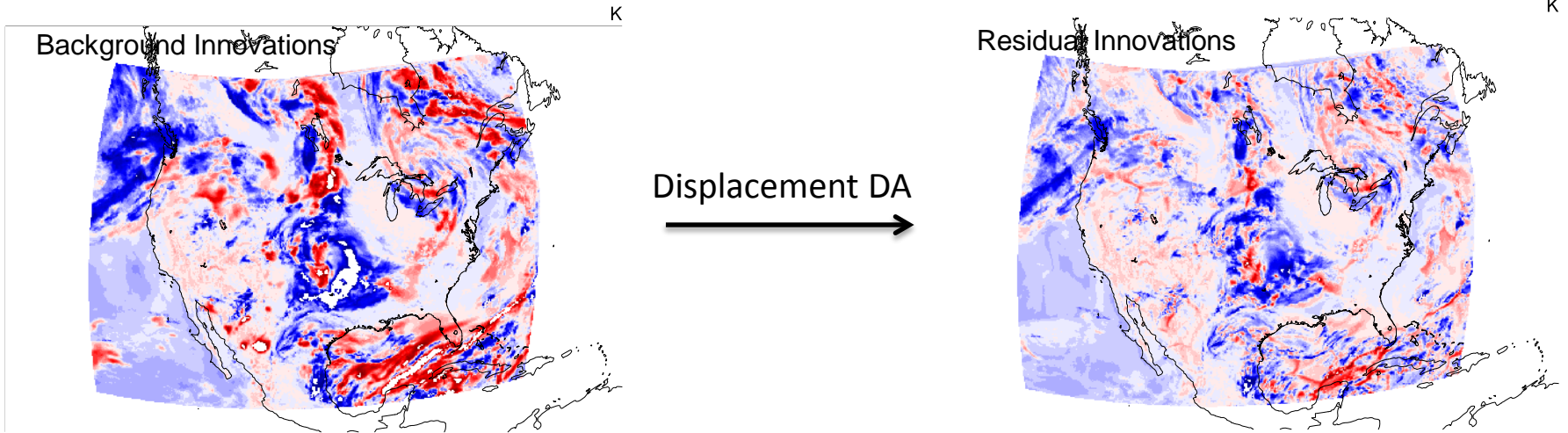
First Guess = Mean of 50-member ensemble from EnKF experiment

GOES-Imager all-sky radiances

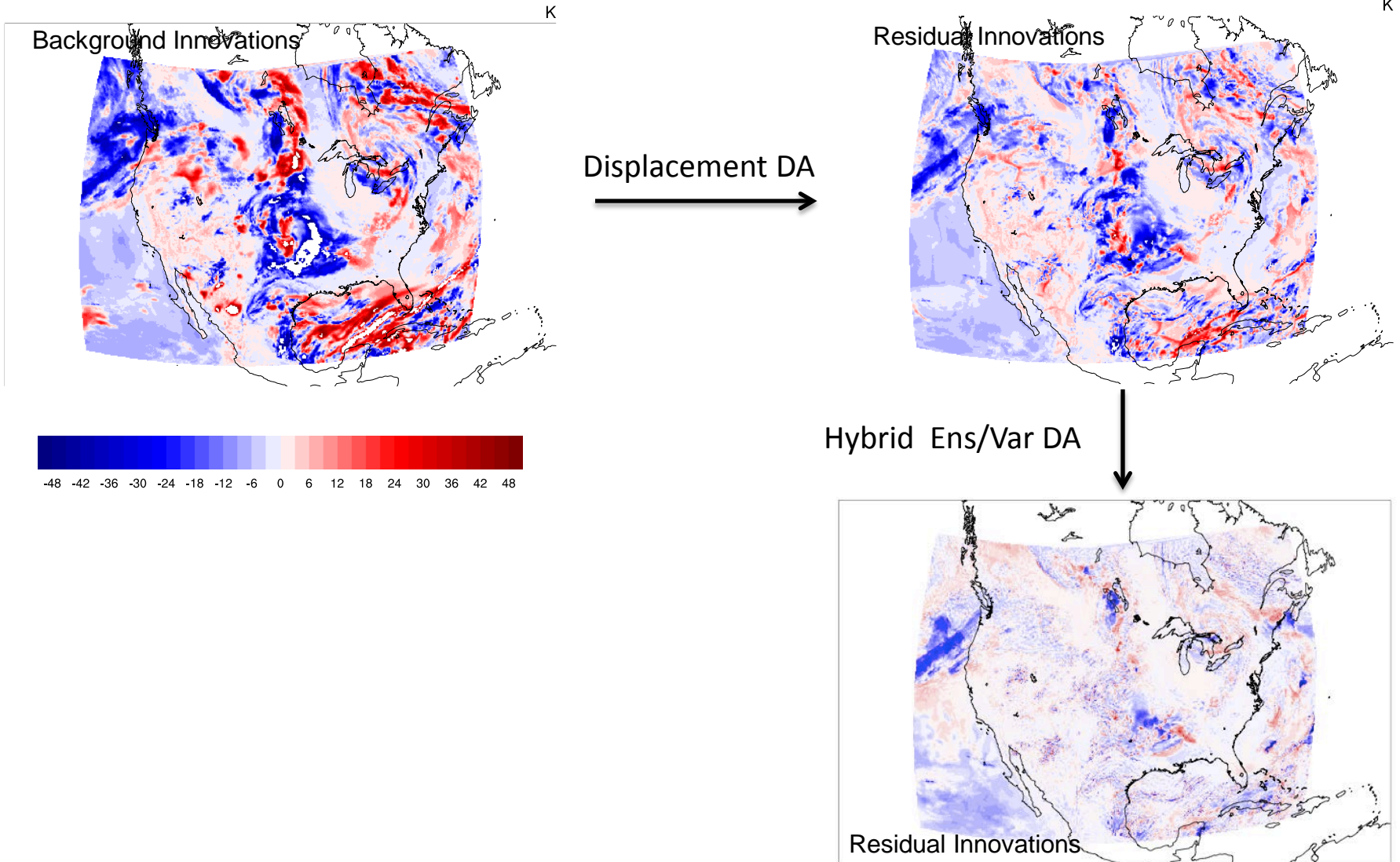
Experiments

- CTRL no DA
- EVIL-dWRF Displacement + Hybrid Var/Ens DA

EVIL-dWRF: Fit to Observations

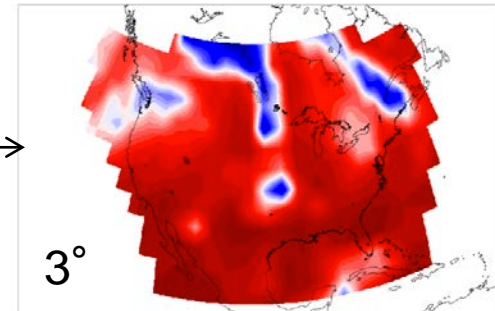
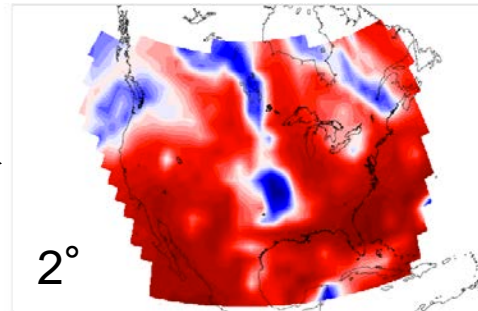
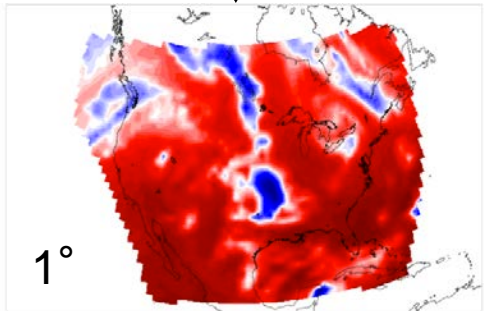
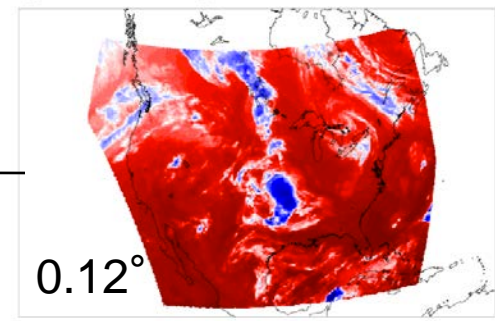
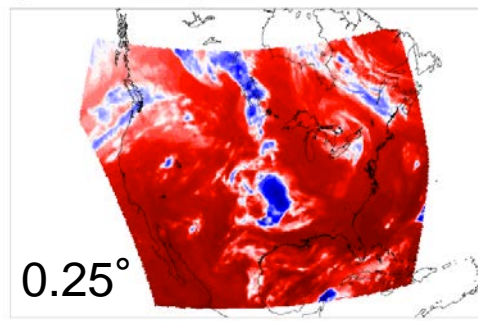
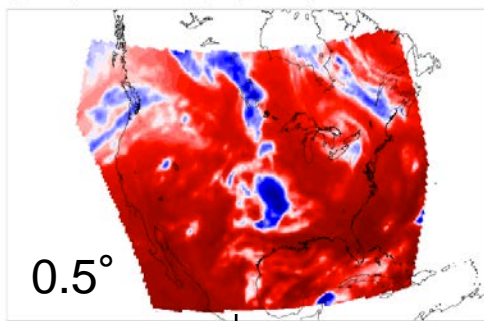
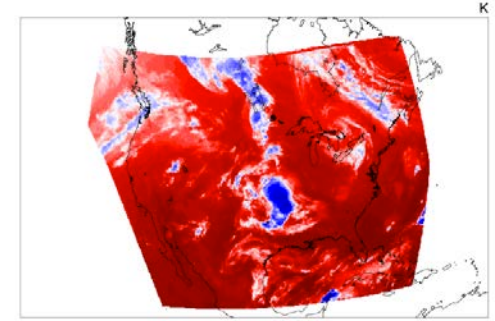


EVIL-dWRF: Fit to Observations



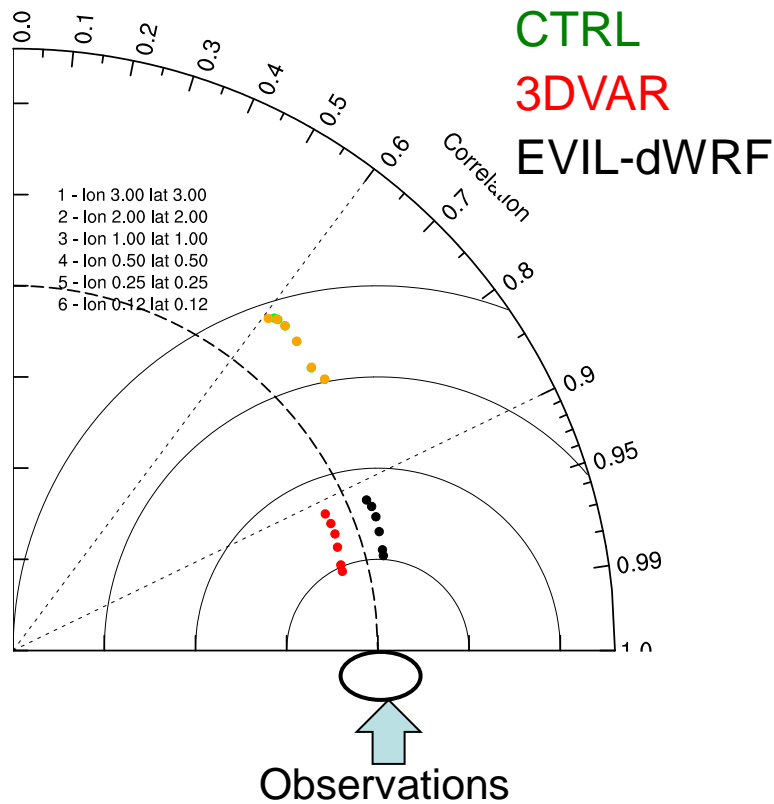
Multi-Scale Verification

GOES-Imager Ch5



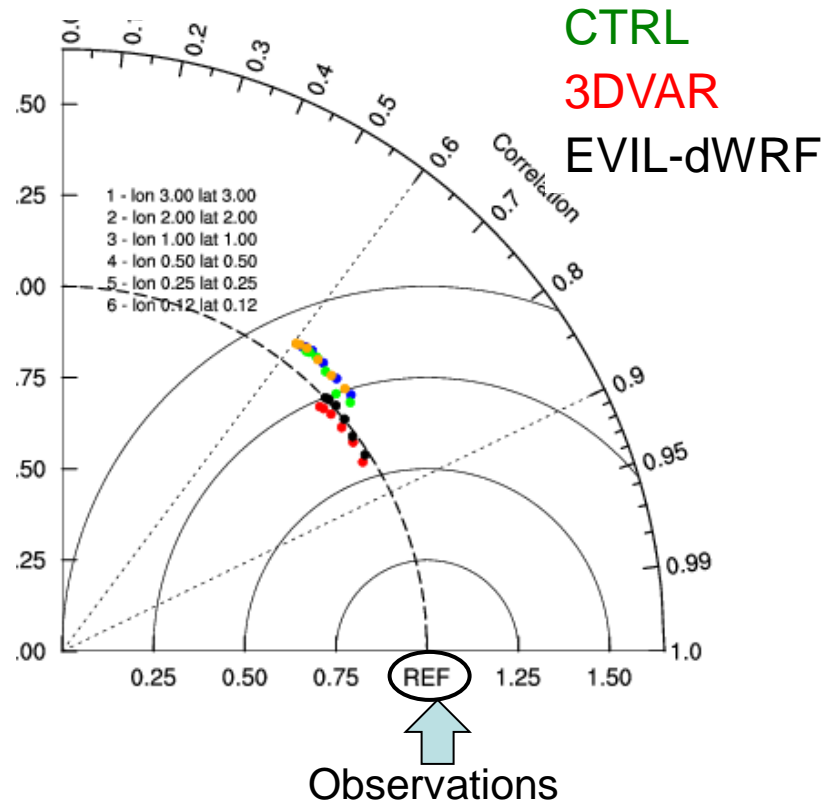
Multi-Scale Verification

Analysis



Forecast

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Conclusion: WRF Analysis and Prediction of Clouds

- **MADCast** Retrieval + Nowcasting of clouds (*tracers*)
- **EVIL** VAR/Ens hybrid assimilation of clouds (*microphysics*)
- **dWRF** Displacement technique to realign clouds features

→ fit observations at initial time

→ impact short-term cloud forecasts

Much more work required...