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# Improved Initialization and Prediction of Clouds with Satellite Observations

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# Introduction

Approaches for the initialization of clouds with satellite radiances

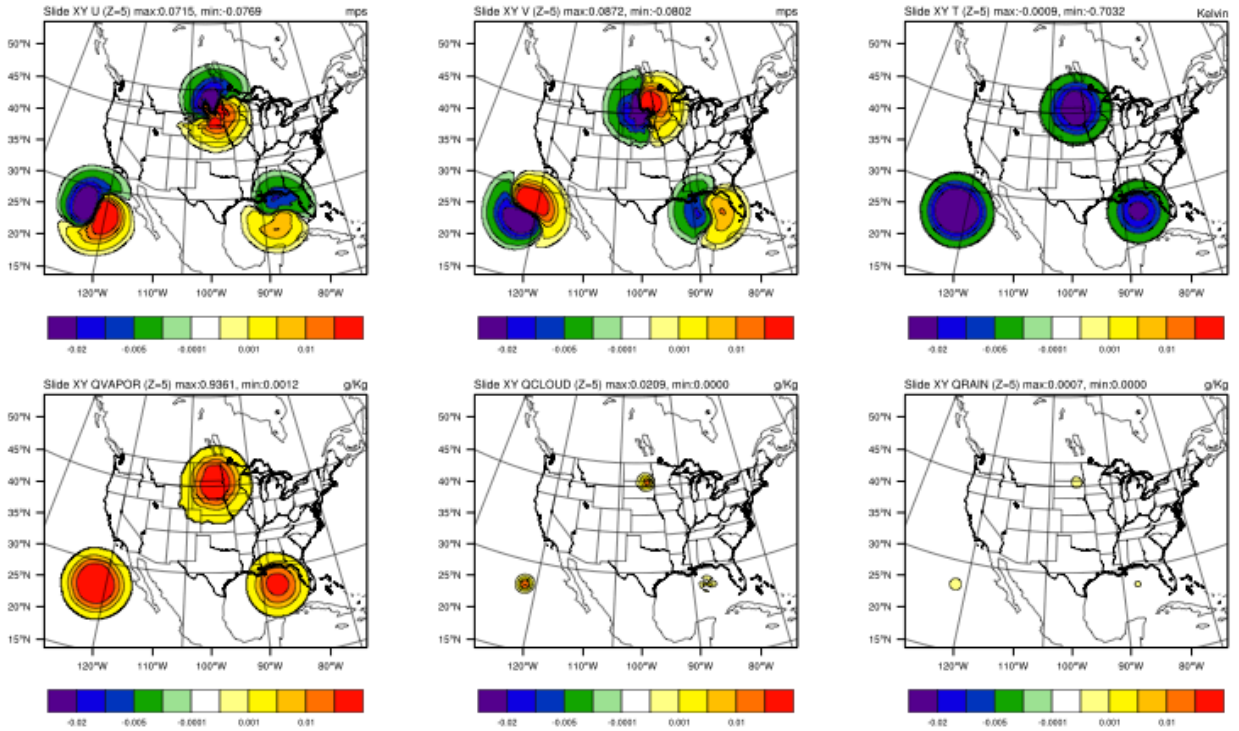
- Nowcasting
  - COP + advection
  - 3D cloud fraction + WRF dynamical transport
- Oklahoma U. / GSI-RR cloud analysis
- Expansion of analysis control variable
  - Total water + linearized physics
  - **Microphysical variables**

# Outline

- Control Variable Transform
- Processing of Cloudy Satellite Observations
- Experimental Demonstration

# Pseudo Single Observation Test

Poster Descombes et al.




- Multivariate covariances for qc, qr, qi, qsn
- Binning option: dynamical cloud mask
- Vertical and Horizontal autocorrelations via Recursive Filters
- 3D Variance

# Ensemble/Variational Integrated Localized (EVIL)

Ensemble covariance included in 3D/4DVar through ***state augmentation***
(Lorenc 2003, Wang et al. 2008, Fairbairn et al., 2012)

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

$$\delta\boldsymbol{x} = \beta_c\delta\boldsymbol{x}_c + \beta_e\delta\boldsymbol{x}_e \quad \text{with} \quad \begin{cases} \delta\boldsymbol{x}_c = \mathbf{B}^{1/2}\boldsymbol{v} \\ \delta\boldsymbol{x}_e = (P_f \circ C_\alpha)^{1/2} v_\alpha \end{cases}$$

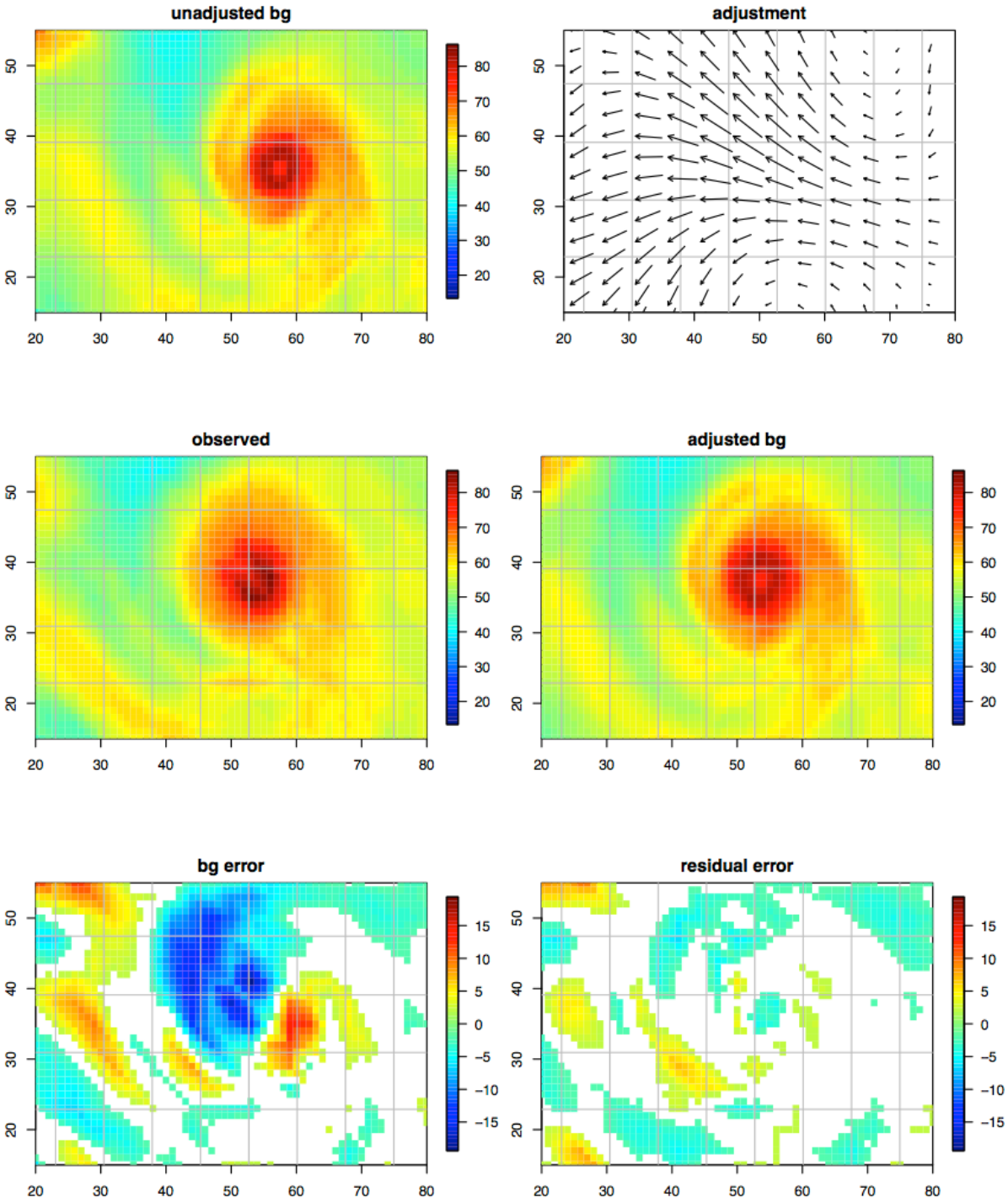
**NEW ALGORITHM**: update of the ensemble perturbations inside the Variational analysis through Lanczos minimization (without external EnKF)

# Forecast Calibration & Alignment

Hurricane Katrina OSSE

Synthetic observations (TCPW)

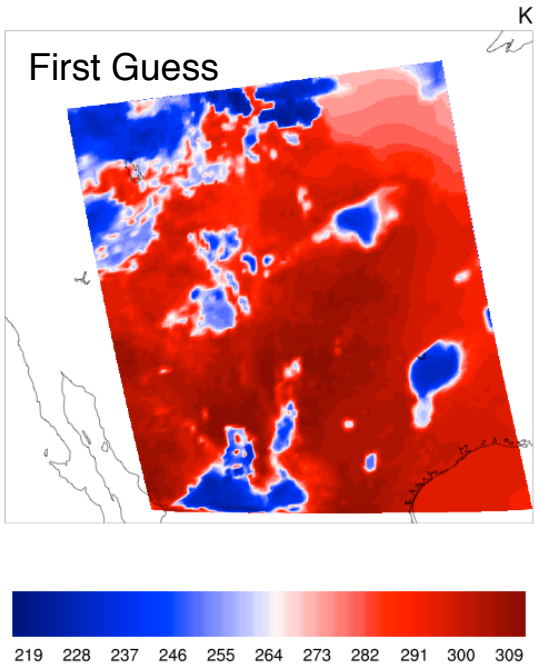
Balanced displacement

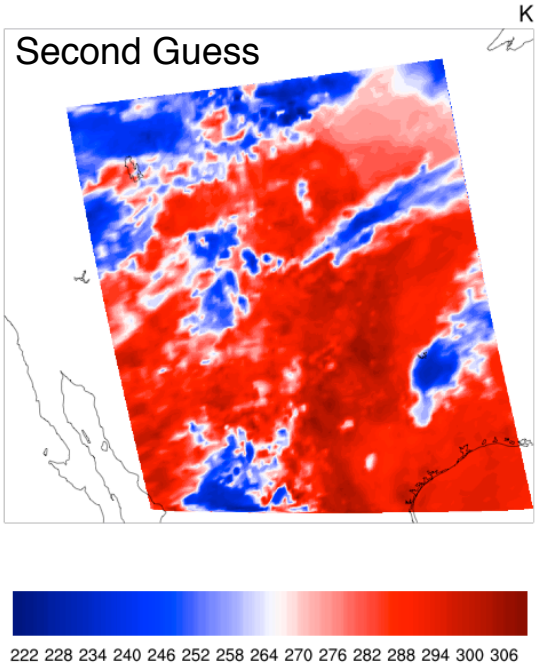


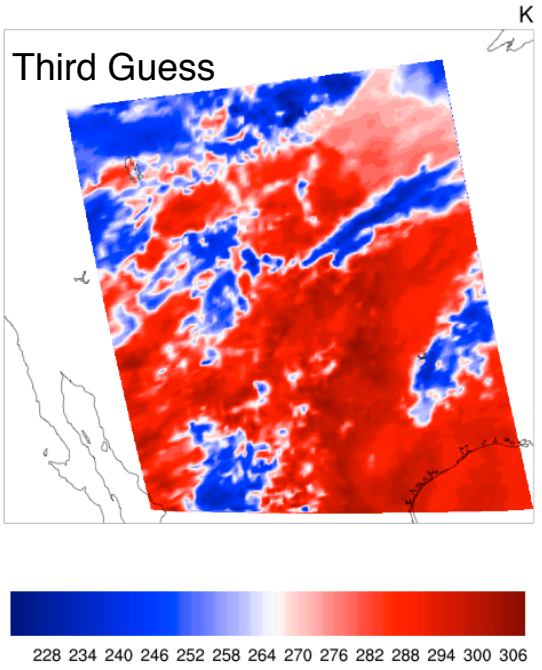

Nehrkorn et al., MWR 2013 (*submitted*)

# Unified Processing of Cloud-affected Satellite data

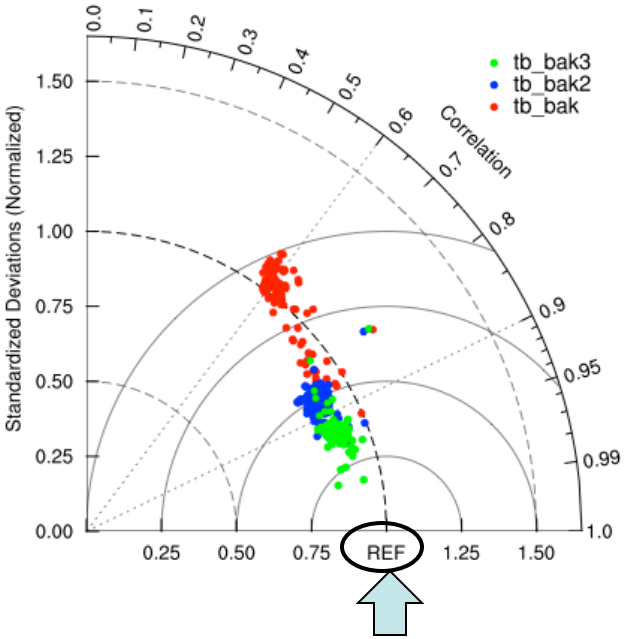
- Unified processing for Radiances and COP Retrievals
- VarBC: Variational Bias Correction (unchanged predictors)
- Revisited QC: extended Gross and First-Guess check
  (to conserve cloudy data)
- Huber Norm: robust definition of observation error
- Land Surface: $T_{skin}$ introduced as a sink variable
- Field of View: advanced interpolation scheme
- CRTM Jacobians: rescaled base state
  (floor and ceiling values for cloud parameters)
- Middle Loop: Multiple re-linearizations of obs. operator



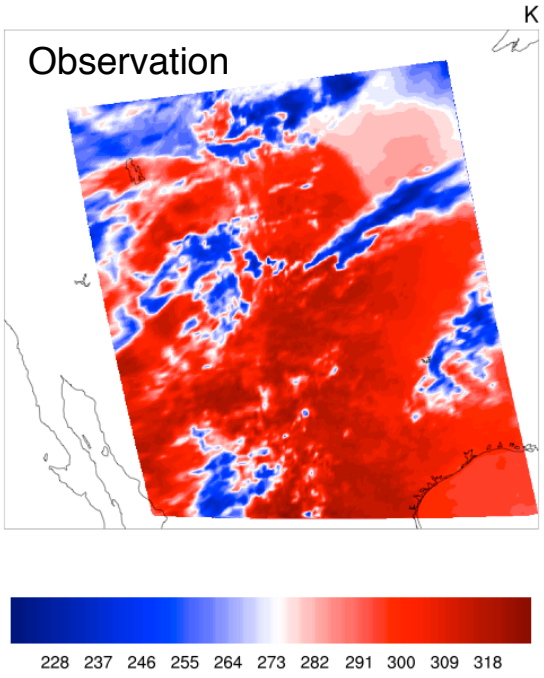




# Update of $q_{cloud}$, $q_{ice}$ in WRF




Observations




*AIRS Window Channel #787*

# Experimental Framework

WRF-ARW model, CONUS 15km, Thompson microphysics

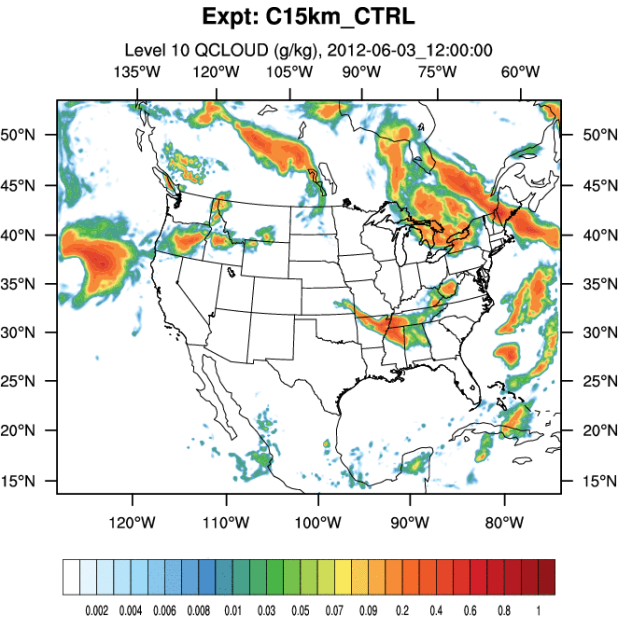
First Guess = Mean of 50-memb ens. from EnKF expt (Romine)

Single analysis at 20012/06/03 (12UTC), 5 middle-loops

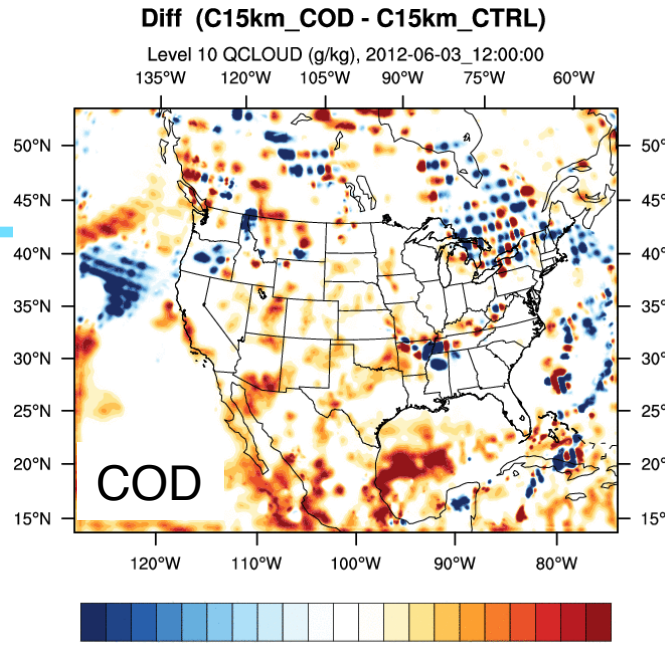
GOES-Imager: Radiances (Thompson) & COD (Uwisc.)

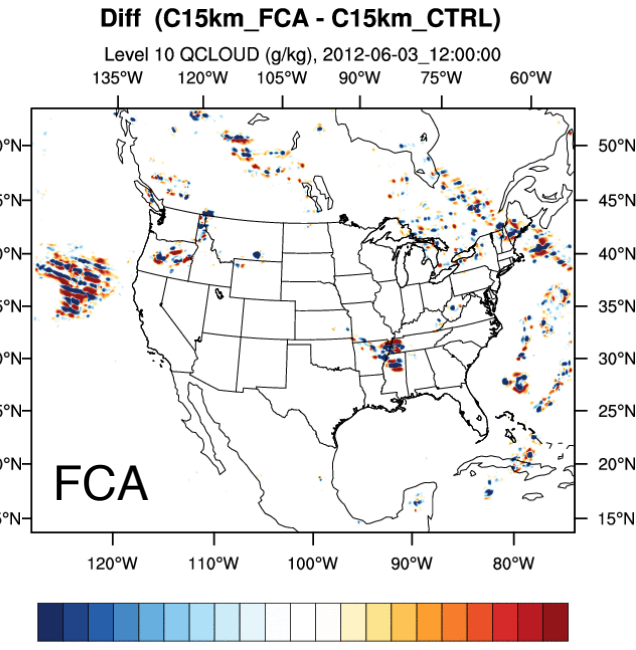
- CTRL — no DA
- COD — Cloud Optical Depth (3DVar)
- FCA — Cloud Optical Depth (Displacement)
- 3DVAR — Radiances (3DVar)
- EVIL — Radiances (Hybrid)

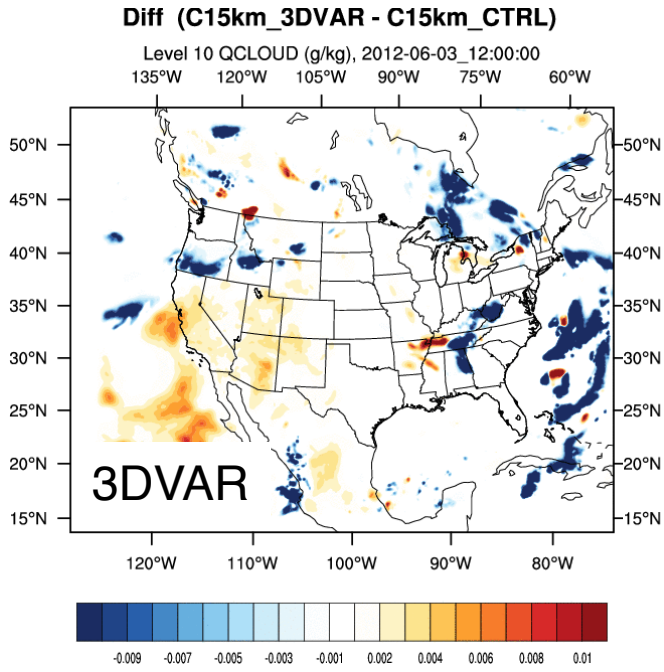
# Analysis increments

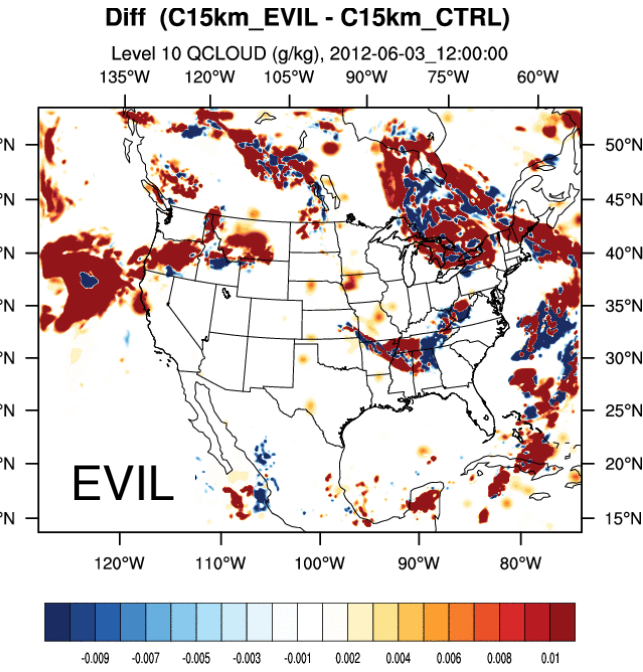



$q_{cloud}$
Level 10



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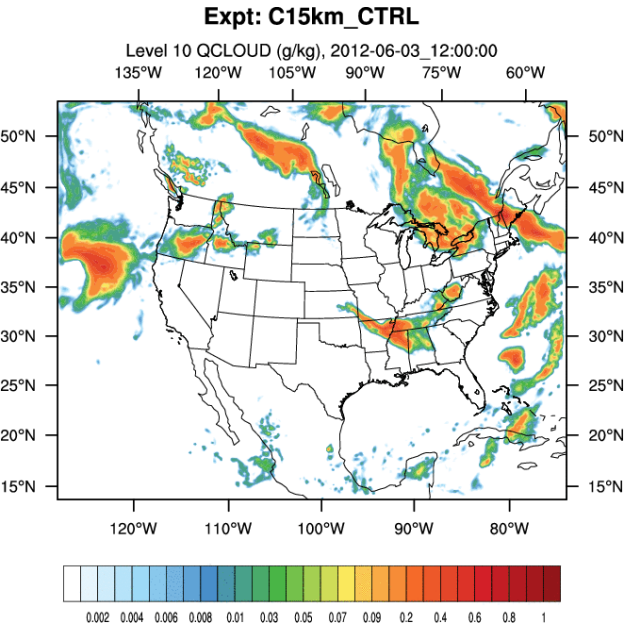
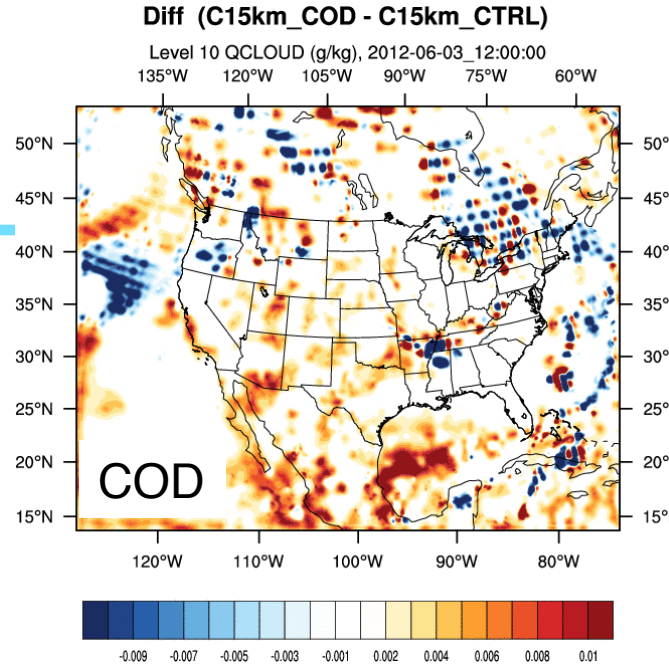
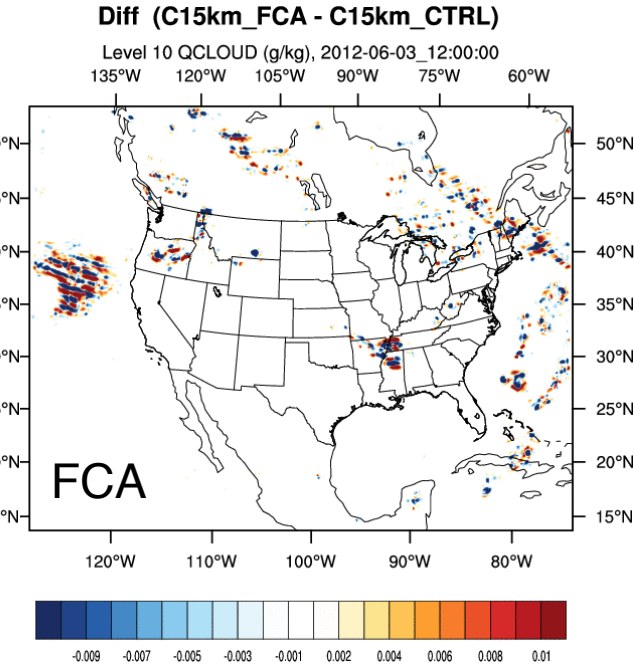
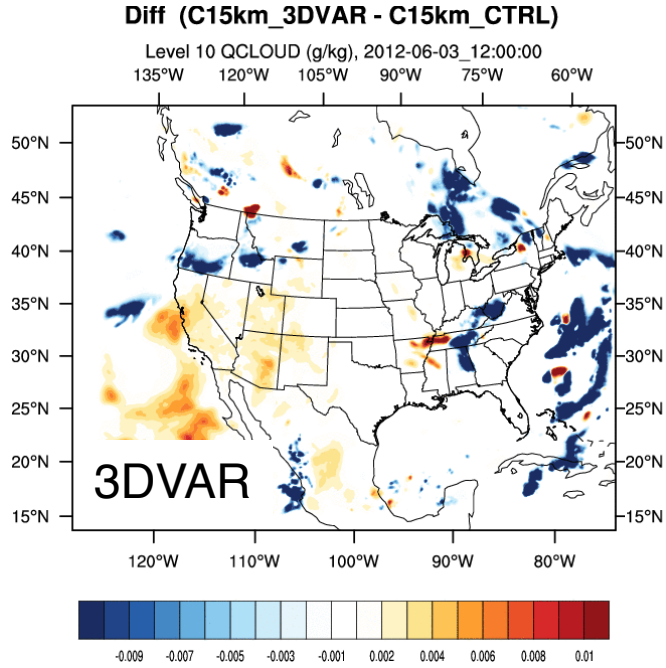
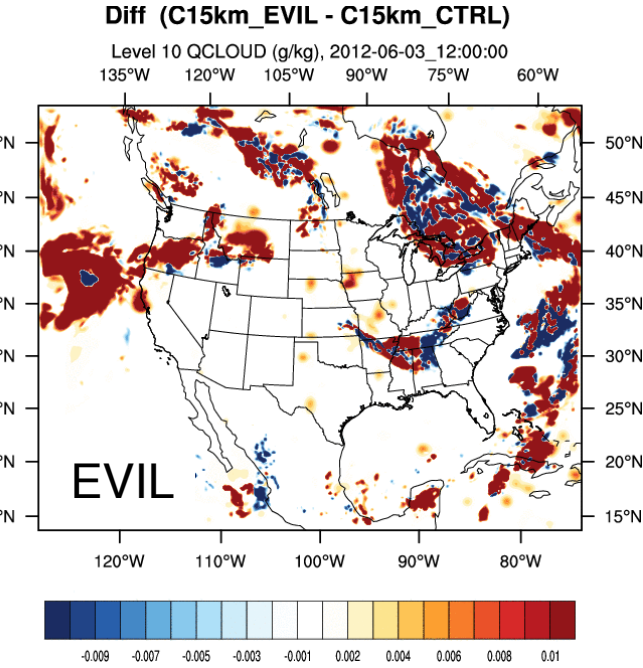


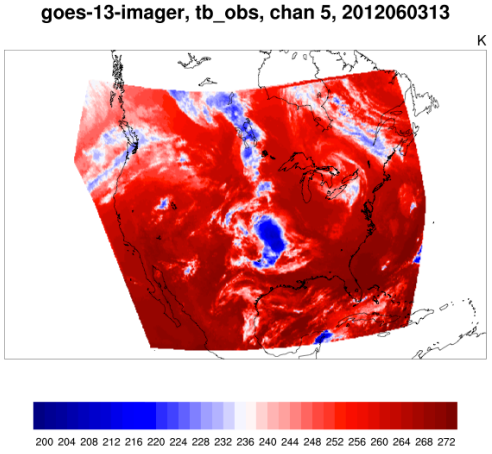



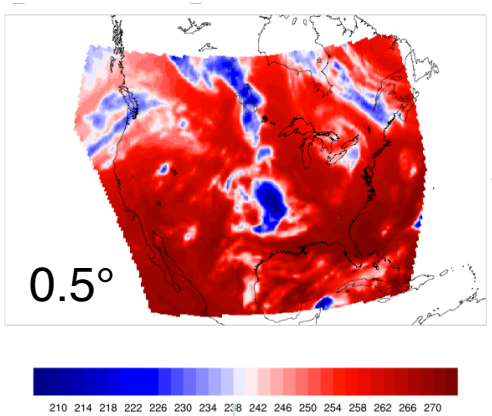



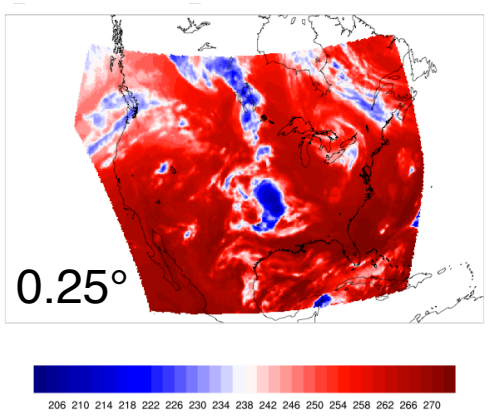



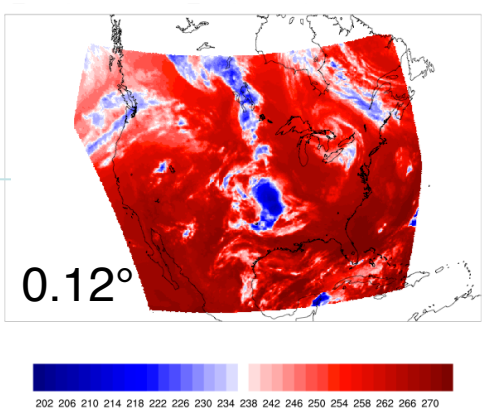

$q_{cloud}$
Level 10

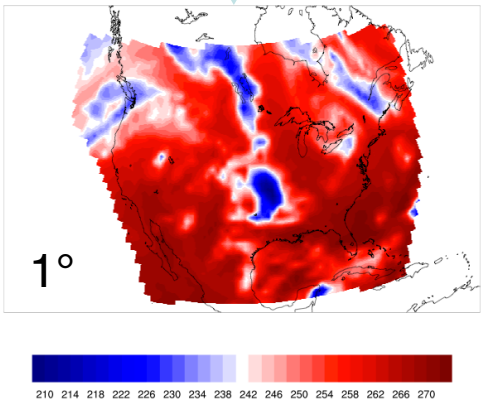
# Multi-scale verification

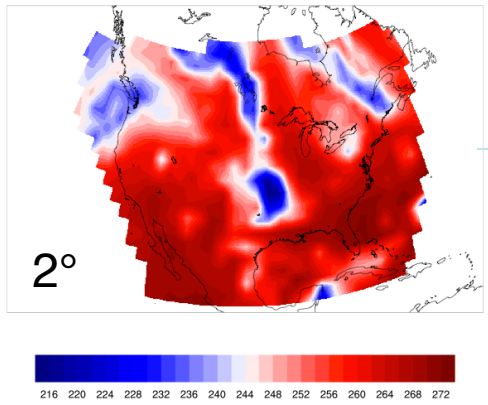


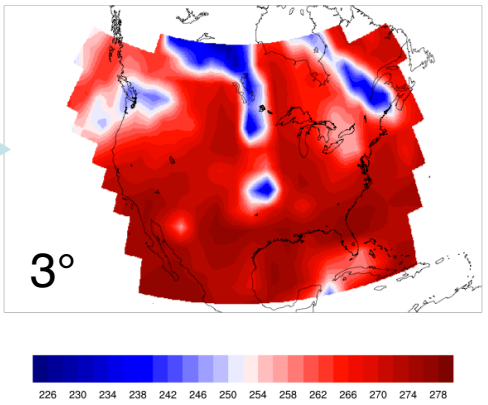



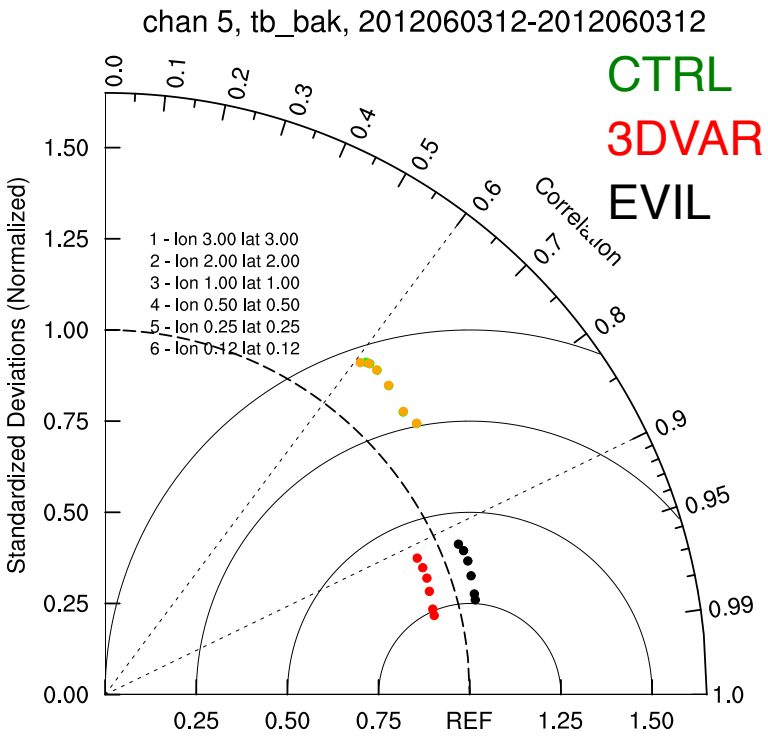



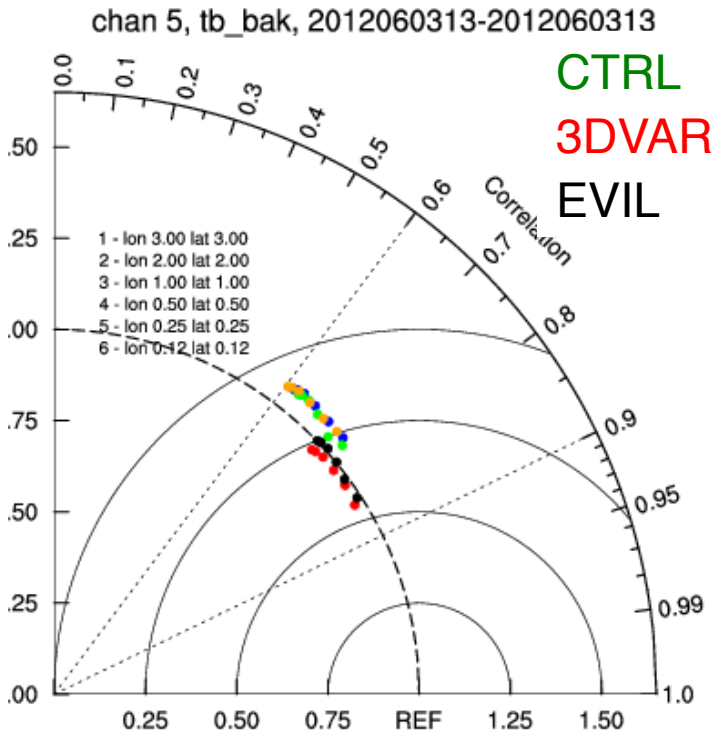



# Multi-scale verification

## Analysis




## Forecast




- ✓ Impact of all-sky radiances on forecast up to 3-4h
- ✓ Best forecast with EVIL system

# Conclusion

- Expansion of analysis vector to clouds
- Multivariate, flow-dependent background errors
- Displacement pre-processing
- Updated processing of cloud-affected satellite data
  (bias correction, QC, interpolation, RTM, middle-loop)
- Sustained impact in short-term forecast
- More work required…

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