WRFDA 2009 OVERVIEW

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Acknowledge:

NCAR/ESSL/MMM/DAG, NCAR/RAL/JNT/DATC,
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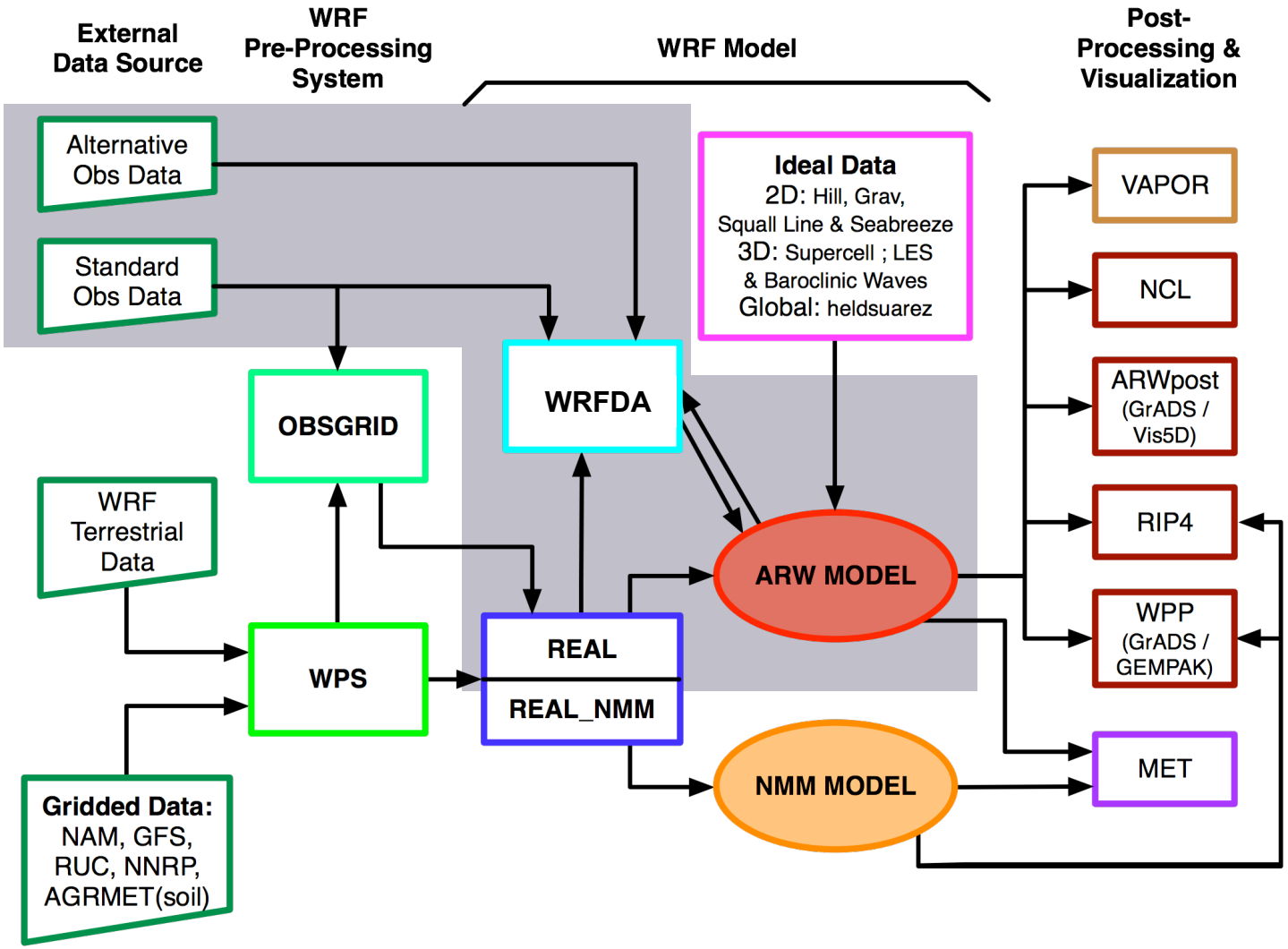
KMA, CWB, CAA, BMB, EUMETSAT

June 2009

Outline

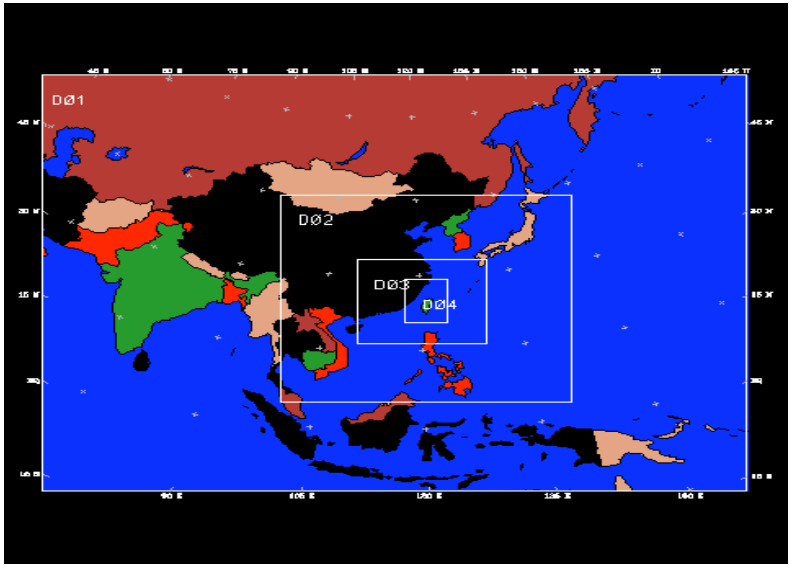
1. WRFDA overview
2. A few new capabilities
   - 4D-Var (optimization and public release)
   - Radiances (public release)
   - WRF-NMM interface
   - Global ARW interface
   - Multi-variate humidity analysis
   - Hybrid Var/ETKF (tutorial and monthly experiment)
   - Outerloop and QC
   - Forecast sensitivity to observations
3. Future plan and summary

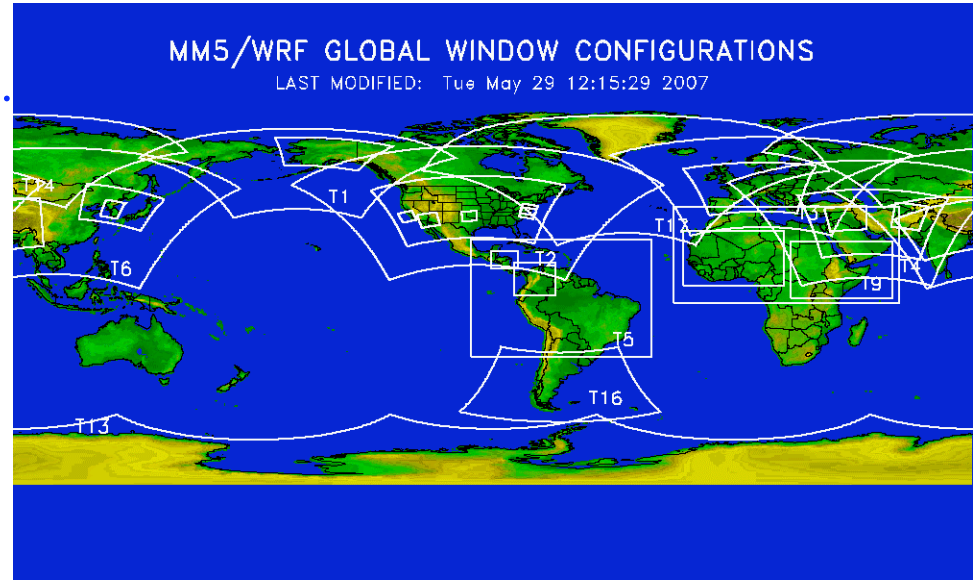
WRFDA in the WRF Modeling System



WRFDA Overview

- **Goal:** Community WRF DA system for
  - regional/global,
  - research/operations, and
  - deterministic/probabilistic applications.
- **Techniques:**
  - 3D-Var
  - 4D-Var (regional)
  - Ensemble DA,
  - Hybrid Variational/Ensemble DA.
- **Model:** WRF (ARW, NMM, Global)
- **Support:**
  - NCAR/ESSL/MMM/DAG
  - NCAR/RAL/JNT/DATC
- **Observations:** Conv.+Sat.+Radar





WRFDA tutorials

- 21-22 July, 2008. NCAR.
- 10-14 Nov, 2008. CWB, Taiwan.
- 2-4 Feb, 2009. NCAR.
- 17-24 Feb, 2009. Kunming, Yunnan, China.
- 18 April, 2009. South Korea.
- 20-22 July, 2009, NCAR

WRF-Var tutorial agenda and presentations
http://www.mmm.ucar.edu/wrf/users/wrfda/tutorial.html

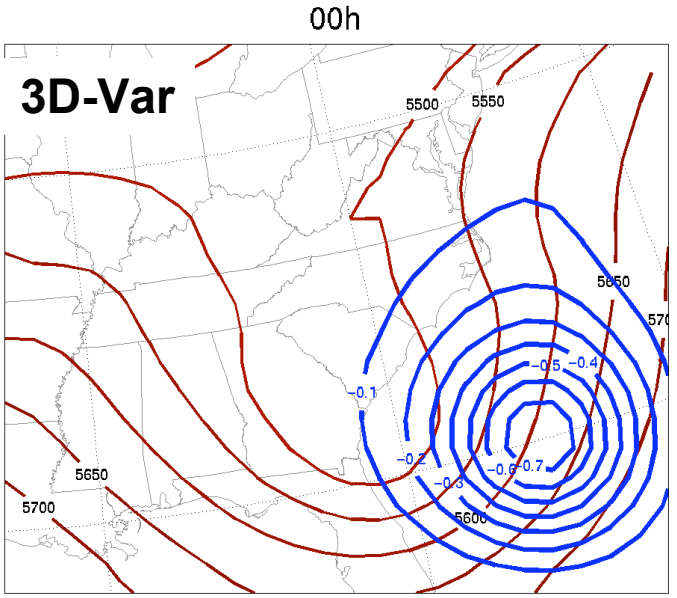
WRF-Var online tutorial and user guide

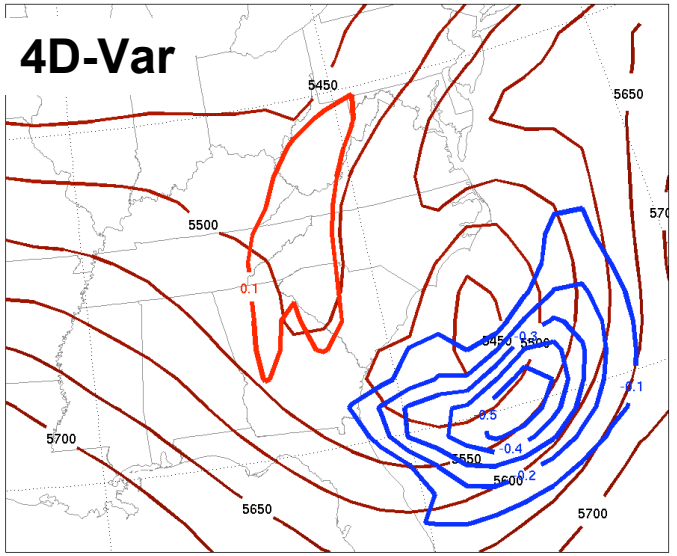
http://www.mmm.ucar.edu/wrf/users/wrfda/Docs/user_guide_V3.1/users_guide_chap6.htm

WRFDA
http://www.mmm.ucar.edu/wrf/users/wrfda

WRFDA 4D-Var Summary

- A component of WRFDA.
- Linear/adjoint models based on WRF-ARW.
- Status:
  - Parallel code, JcDFI, limited physics.
  - Delivered to AFWA in 2006 and 2007. (2008 -)
  - Current focus: PBL/microphysics, optimization.
- Advantages of 4D-Var
  - Flow-dependent response to obs
  - Better treatment of cloud/precip obs
  - Forecast model as a constraint
  - Obs at obs-times
- **Code released in WRF3.1**
- Huang et al., 2009, MWR.

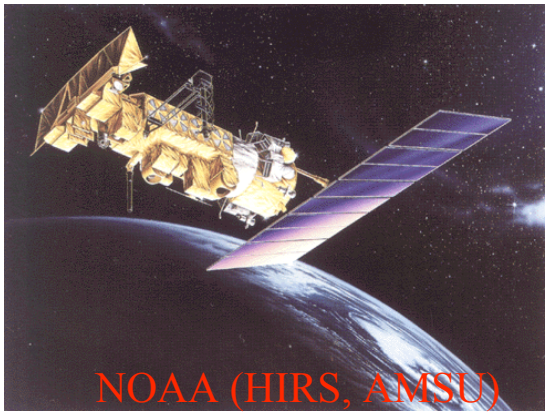


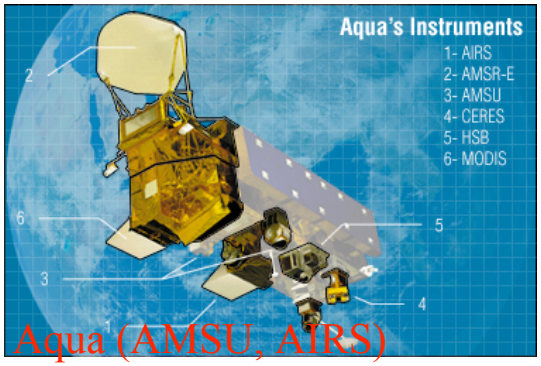


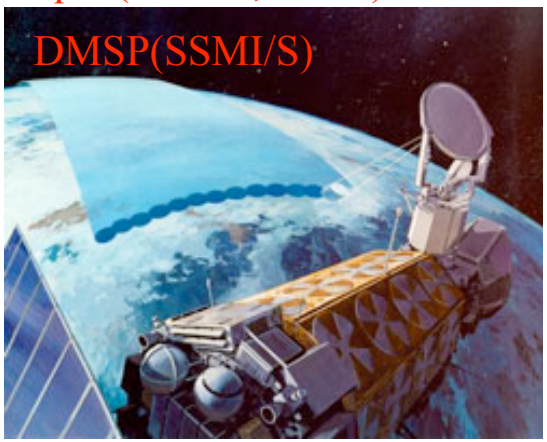
WRFDA Radiance Assimilation Status

(Liu and Auligne)

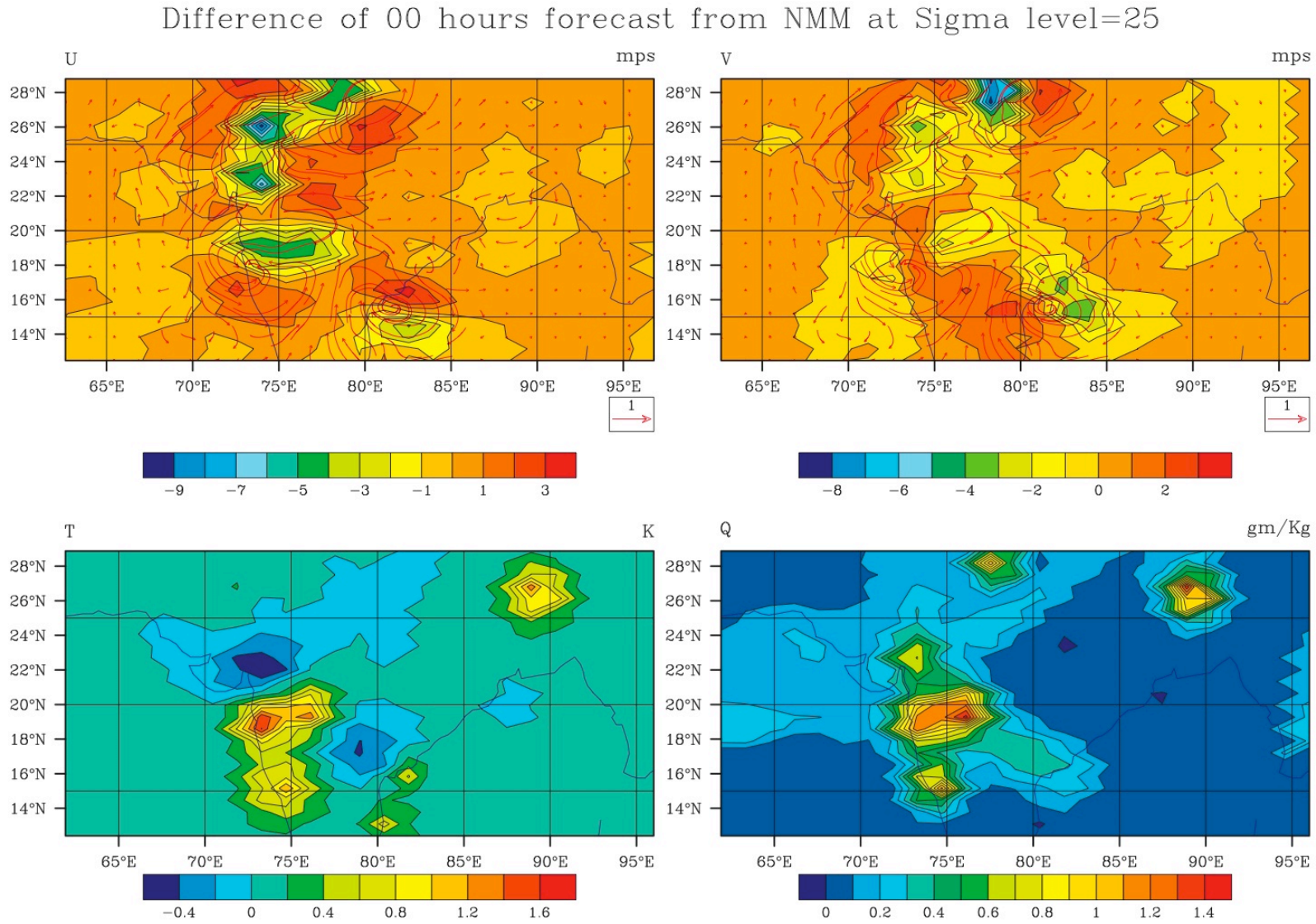
- BUFR 1b radiance ingest.
- RTM interface: RTTOV **or** CRTM
- NESDIS microwave surface emissivity model
- Range of monitoring diagnostics.
- Quality Control for HIRS, AMSU, AIRS, SSMI/S.
- Bias Correction (Adaptive, *Variational in 2008*)
- Variational observation error tuning
- Parallel: MPI
- Flexible design to easily add new satellite sensors
- **Code released in WRF3.1**
- Instruction session on Friday!!





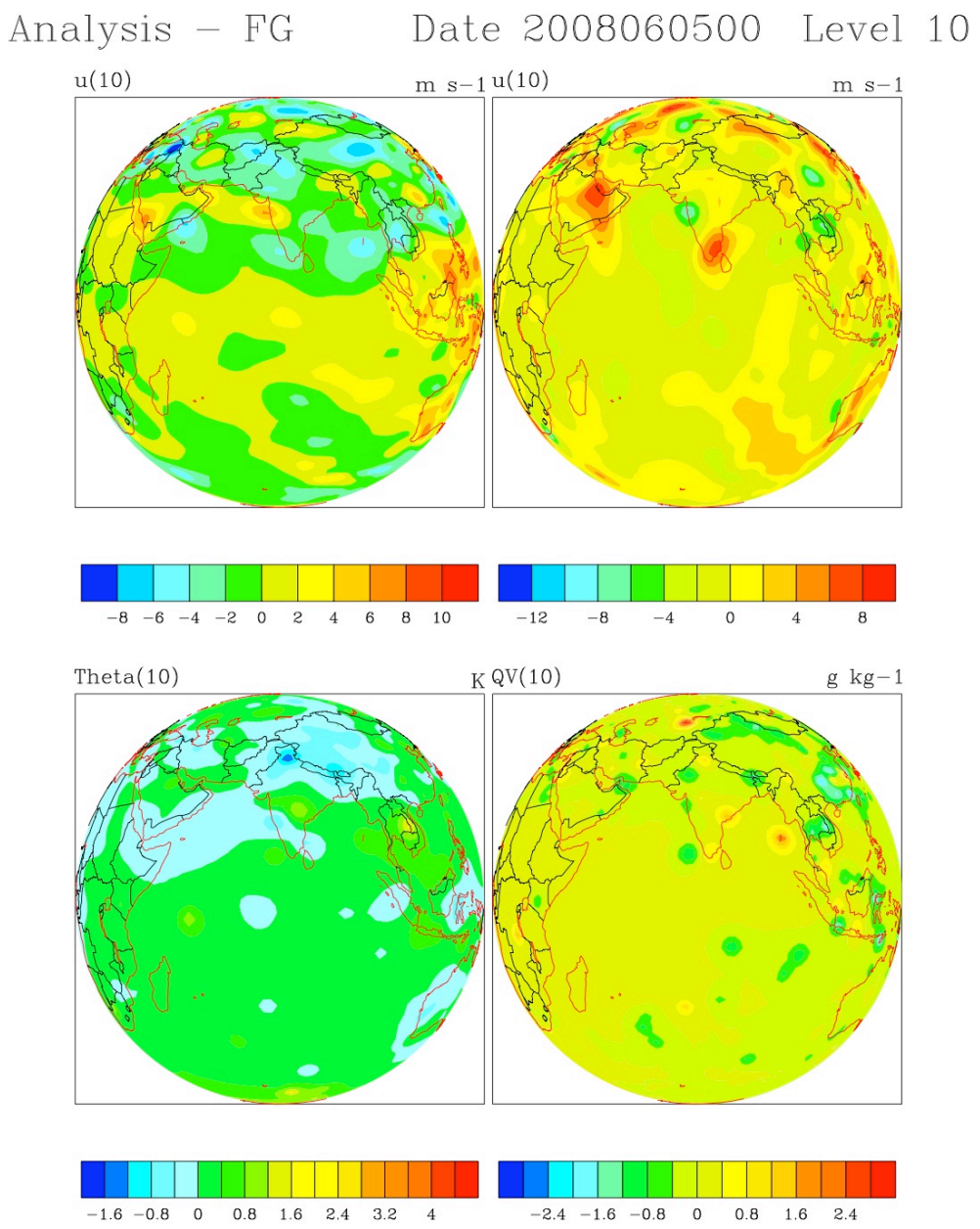


WRFDA and NMM (Pattanayak and Rizvi) Analysis increments



Global WRFDA (Rizvi and Duda)

Analysis increments



Multivariate humidity analysis (Krysta and Rizvi)

$$Q_u(i,j,k) = Q(i,j,k) - \sum_{l=1}^{N_k} reg_Q(i,j,k,l) * T(i,j,l)$$

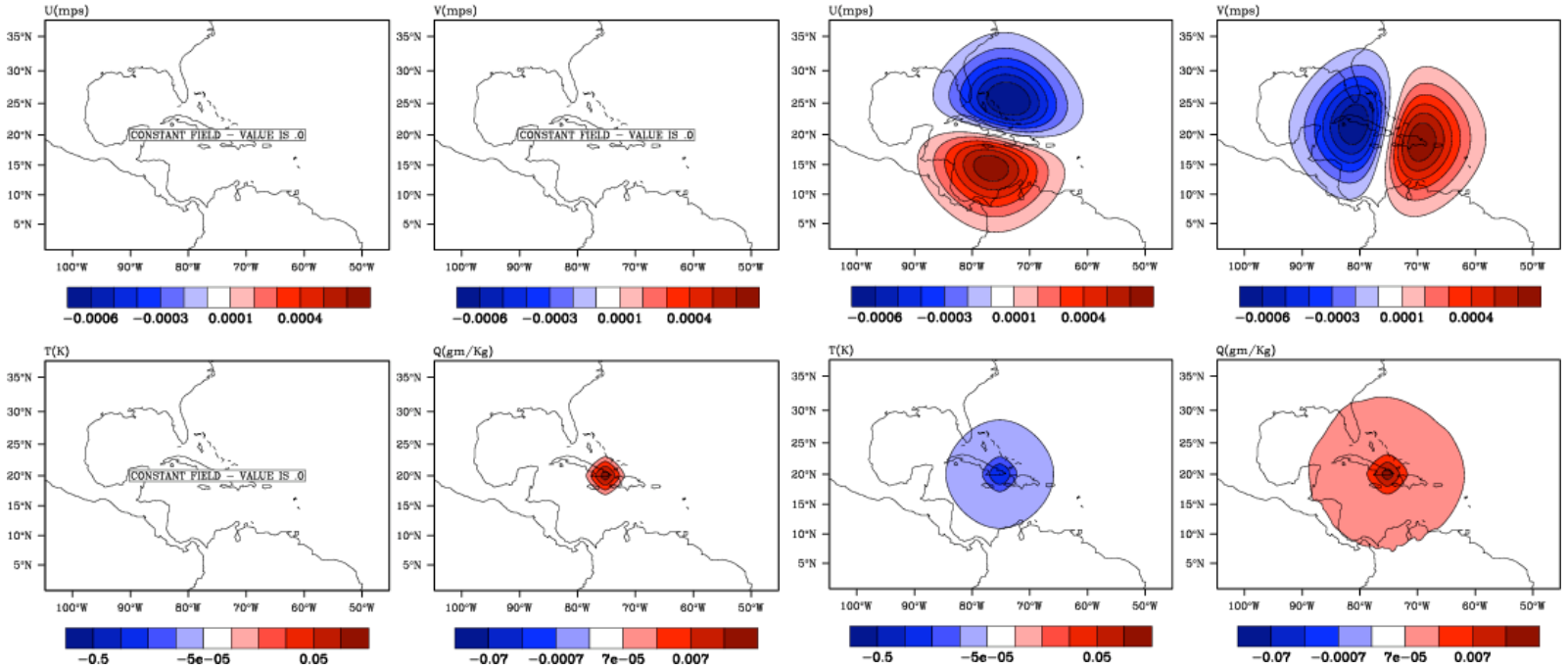
$$reg_Q(i,j,k,l) = \frac{< T(i,j,l), Q(i,j,k) >}{< T(i,j,l), T(i,j,l) >}$$

New analysis control variables are

- Stream function
- Unbalanced part of velocity potential
- Unbalanced part of Temperature
- Unbalanced part of pseudo relative humidity
- Unbalanced part of surface pressure

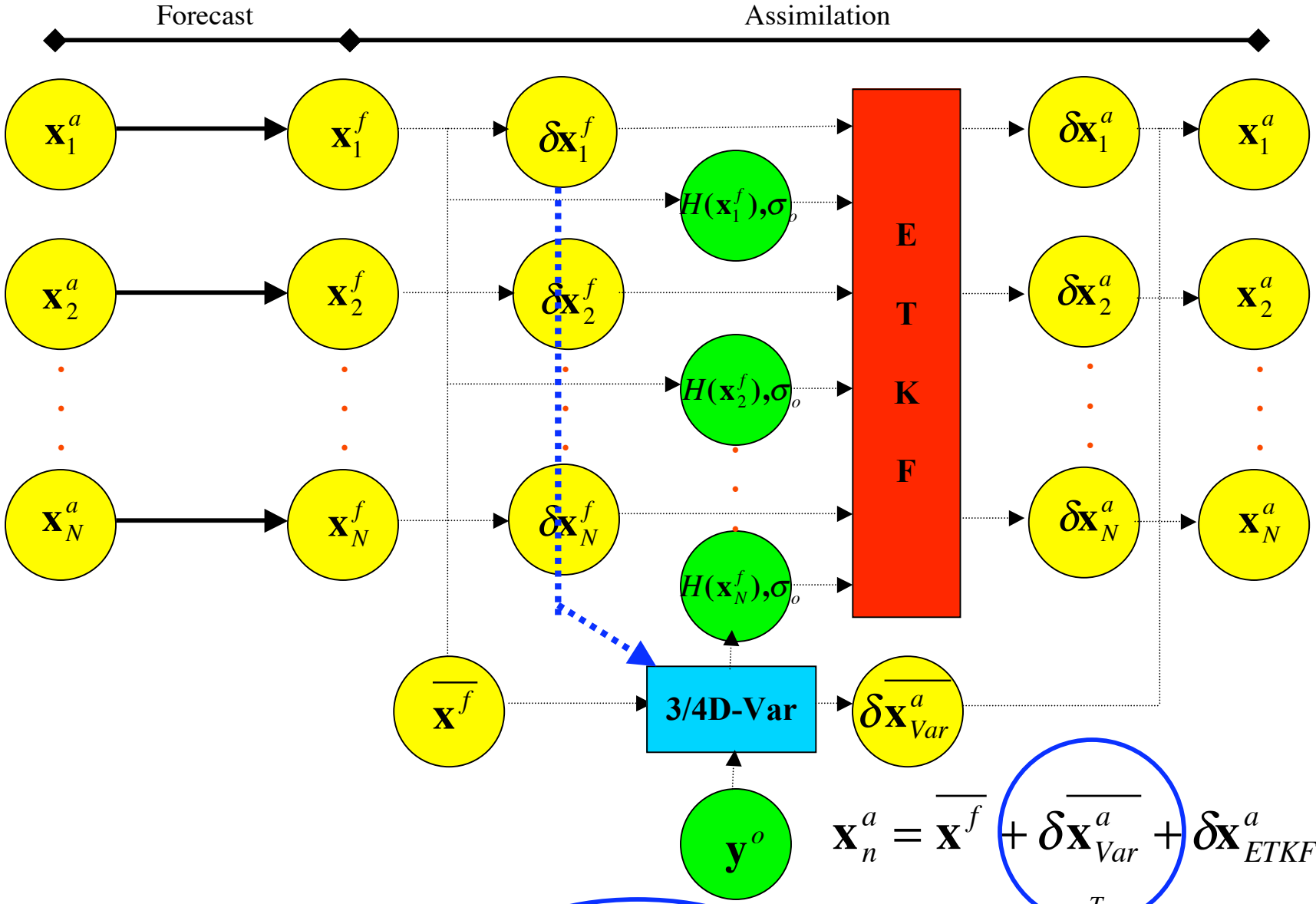
Single observation response (1 g/Kg Moisture innovation)

T8 45 Km Domain 104x94x57



Current **Next**

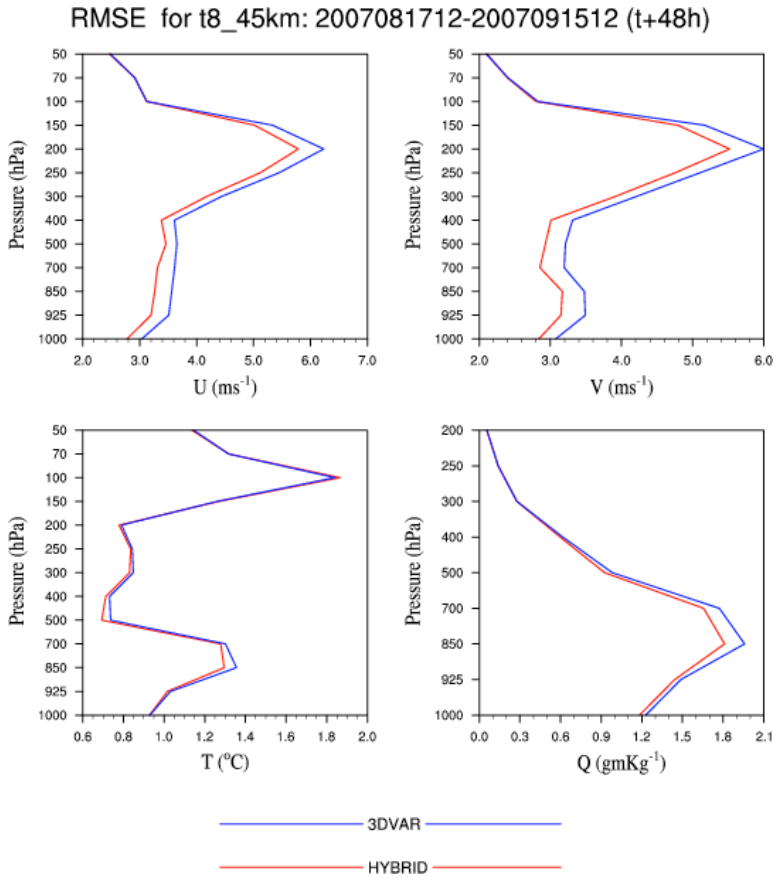
Cycling WRF/Var/ETKF System (Hybrid DA)



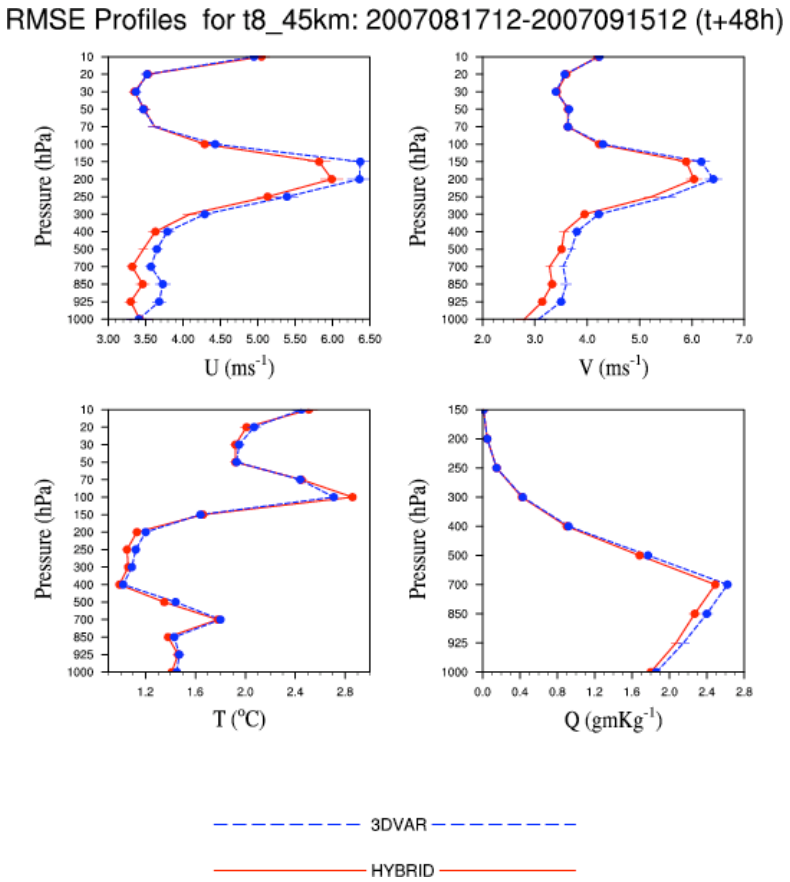
$$\mathbf{x}_n^a = \overline{\mathbf{x}^f} + \delta\overline{\mathbf{x}_{Var}^a} + \delta\mathbf{x}_{ETKFn}^a$$

$$J = \frac{W_b}{2}\delta\mathbf{x}_0{}^T\mathbf{B}_o^{-1}\delta\mathbf{x}_0 + \frac{W_\alpha}{2}\mathbf{a}^T\mathbf{A}^{-1}\mathbf{a} + \frac{1}{2}\sum_{i=0}^{n}\left[\mathbf{H}_i\delta\mathbf{x}(t_i) - \mathbf{d}_i\right]^T\mathbf{R}_i^{-1}\left[\mathbf{H}_i\delta\mathbf{x}(t_i) - \mathbf{d}_i\right]$$

Verified with ECMWF data (T106)



Verified with conventional obs.



Hybrid gives better RMSE scores for wind compared to 3D-VAR.

(Demirtas et al. 2009)

The incremental formulation (in the general form, $\mathbf{x}^{\mathbf{g}} \neq \mathbf{x}^{\mathbf{b}}$!)

$$J = \frac{1}{2}\left(\delta\mathbf{x} + \mathbf{x}^{\mathbf{g}} - \mathbf{x}^{\mathbf{b}}\right)^{T} \mathbf{B}^{-1}\left(\delta\mathbf{x} + \mathbf{x}^{\mathbf{g}} - \mathbf{x}^{\mathbf{b}}\right) + \frac{1}{2}\left(\mathbf{d} - \mathbf{H}\delta\mathbf{x}\right)^{T} \mathbf{R}^{-1}\left(\mathbf{d} - \mathbf{H}\delta\mathbf{x}\right)$$

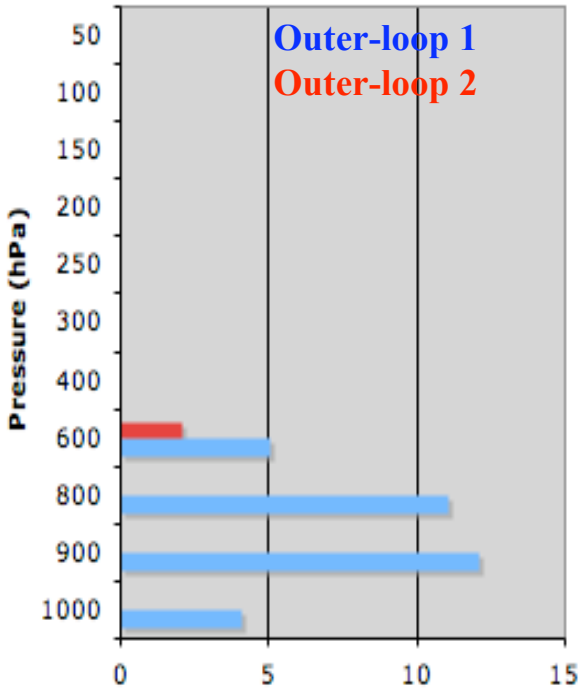
$$\mathbf{d} = \mathbf{y} - H\left(\mathbf{x}^{\mathbf{g}}\right)$$

Outer-loop:

d (and QC, etc) … nonlinear!

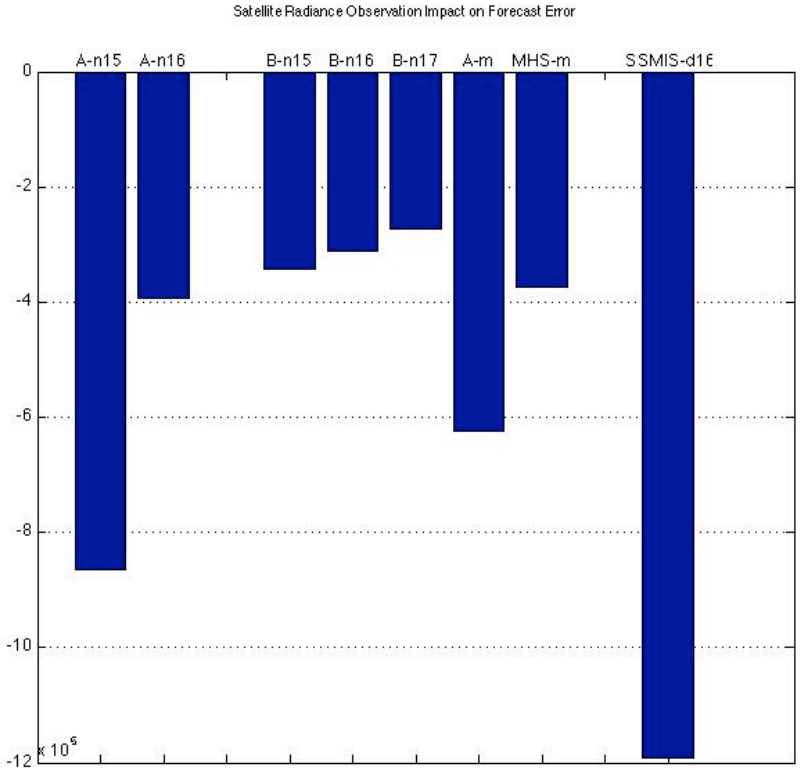
Inner-loop: minimization

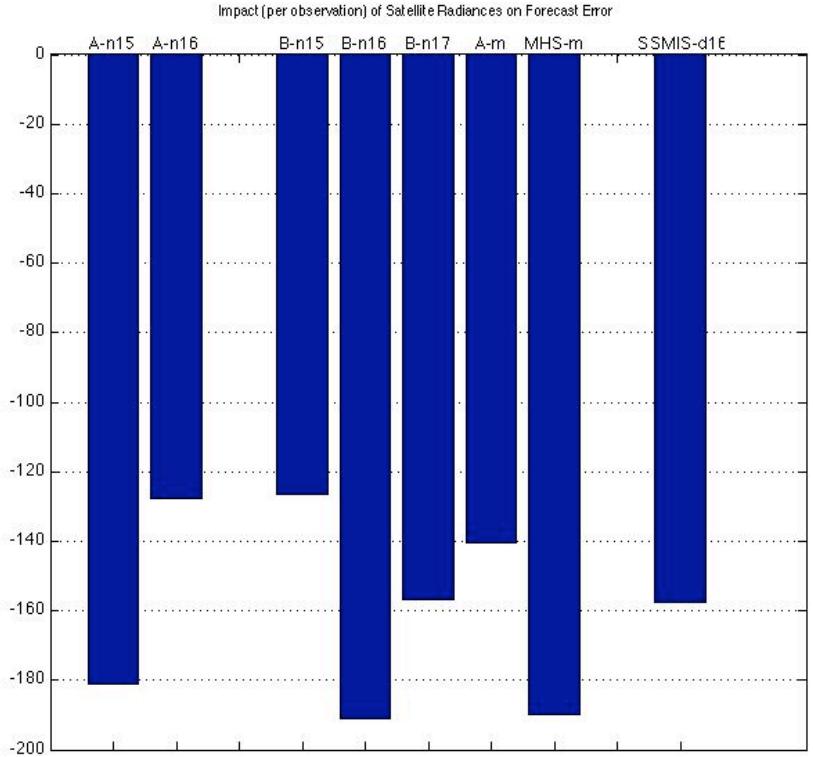
update $\mathbf{x}^{\mathbf{g}}$



Number of rejected sondes

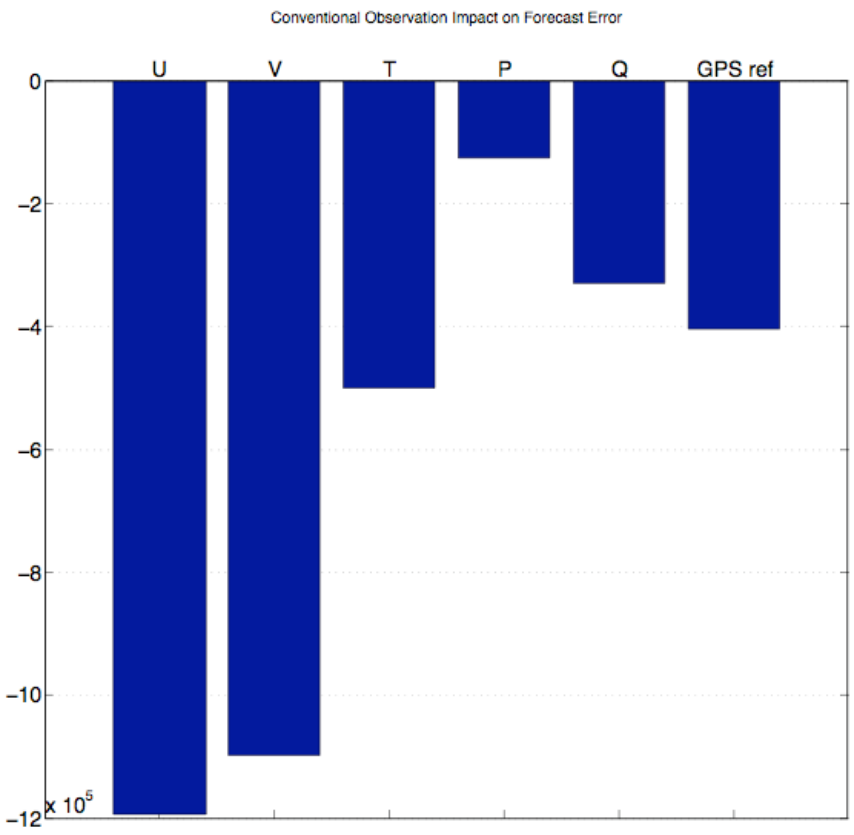
Observation Impact: Satellite radiances

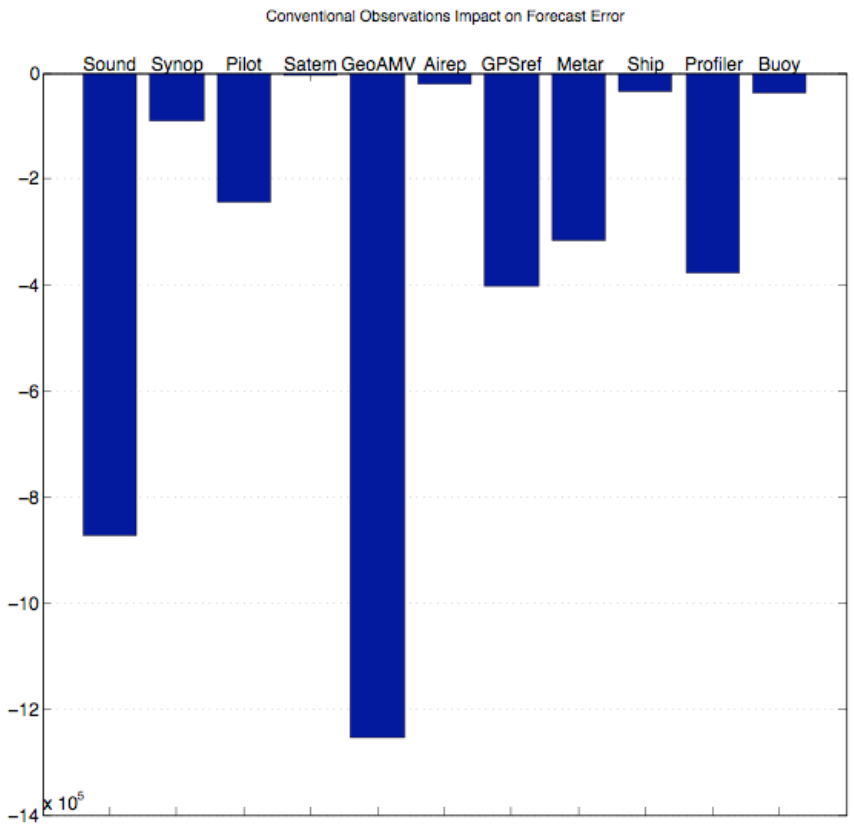




From Auligne

Observation Impact: Conventional Data





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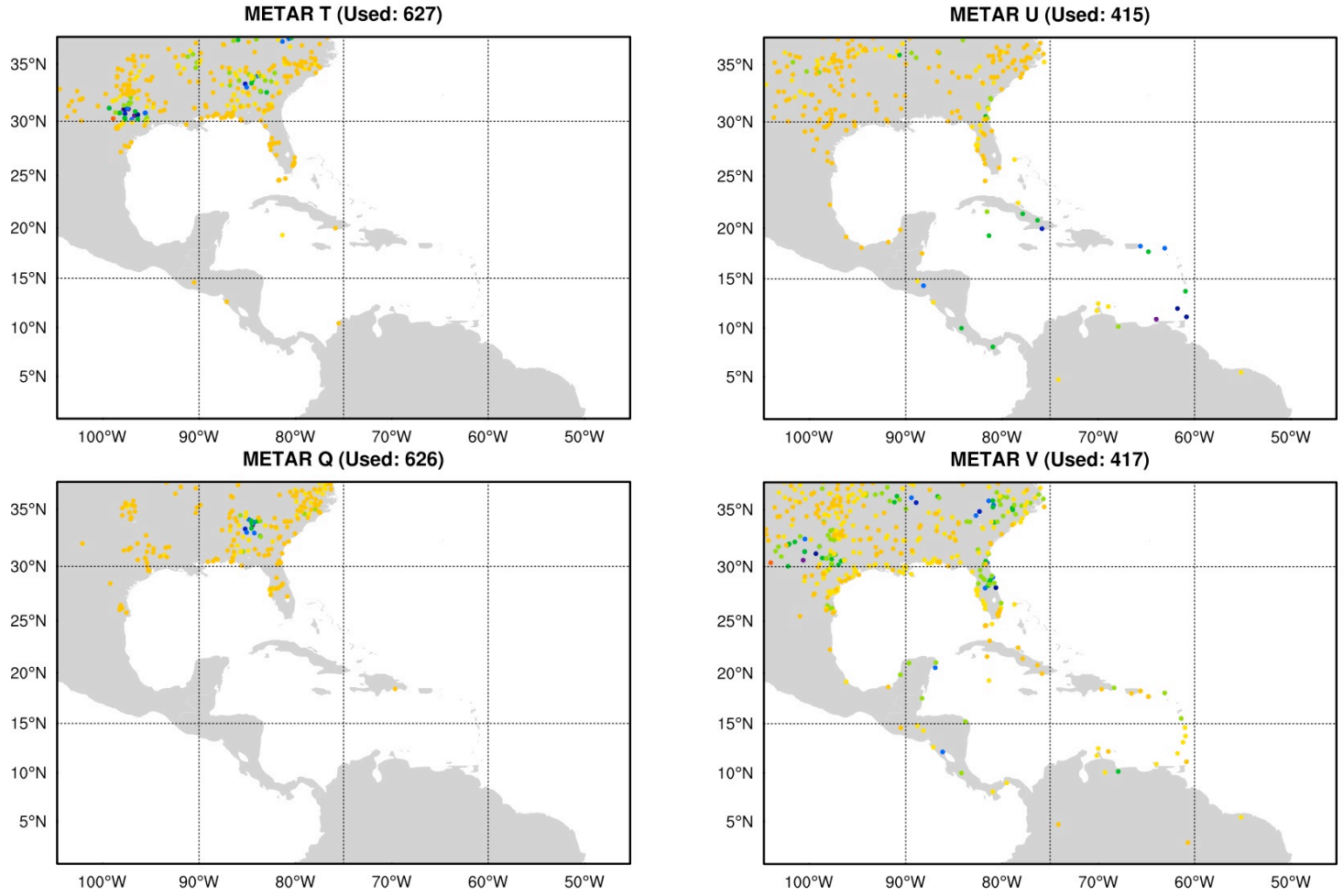

Future Plans

General Goals:

- Unified, multi-technique WRF DA system.
- Retain flexibility for research, multi-applications.
- Leverage international WRF community efforts.

WRF-Var Development (MMM Division):

- 4D-Var (additional physics, optimization).
- Sensitivities tools (adjoint, ensemble, etc.).
- EnKF within WRF-Var -> WRFDA.
- Instrument-specific radiance QC, bias correction, etc.

Data Assimilation Testbed Center (DATC):

- Technique inter-comparison: 3/4D-Var, EnKF, Hybrid
- Obs. impact: AIRS, TMI, SSMI/S, METOP.
- New Regional testbeds: US, India, Arctic, Tropics.

Applications:

- Hurricanes/Typhoons
- OSEs and OSSEs
- Reanalysis (Arctic System Reanalysis)