

# WRFDA: the 2010 Update and Recent Development

Hans Huang

National Center for Atmospheric Research

(NCAR is sponsored by the National Science Foundation)

## Acknowledge:

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AFWA, USWRP, NSF-OPP, NASA, AirDat, PSU,  
KMA, CWB, CAA, BMB, EUMETSAT



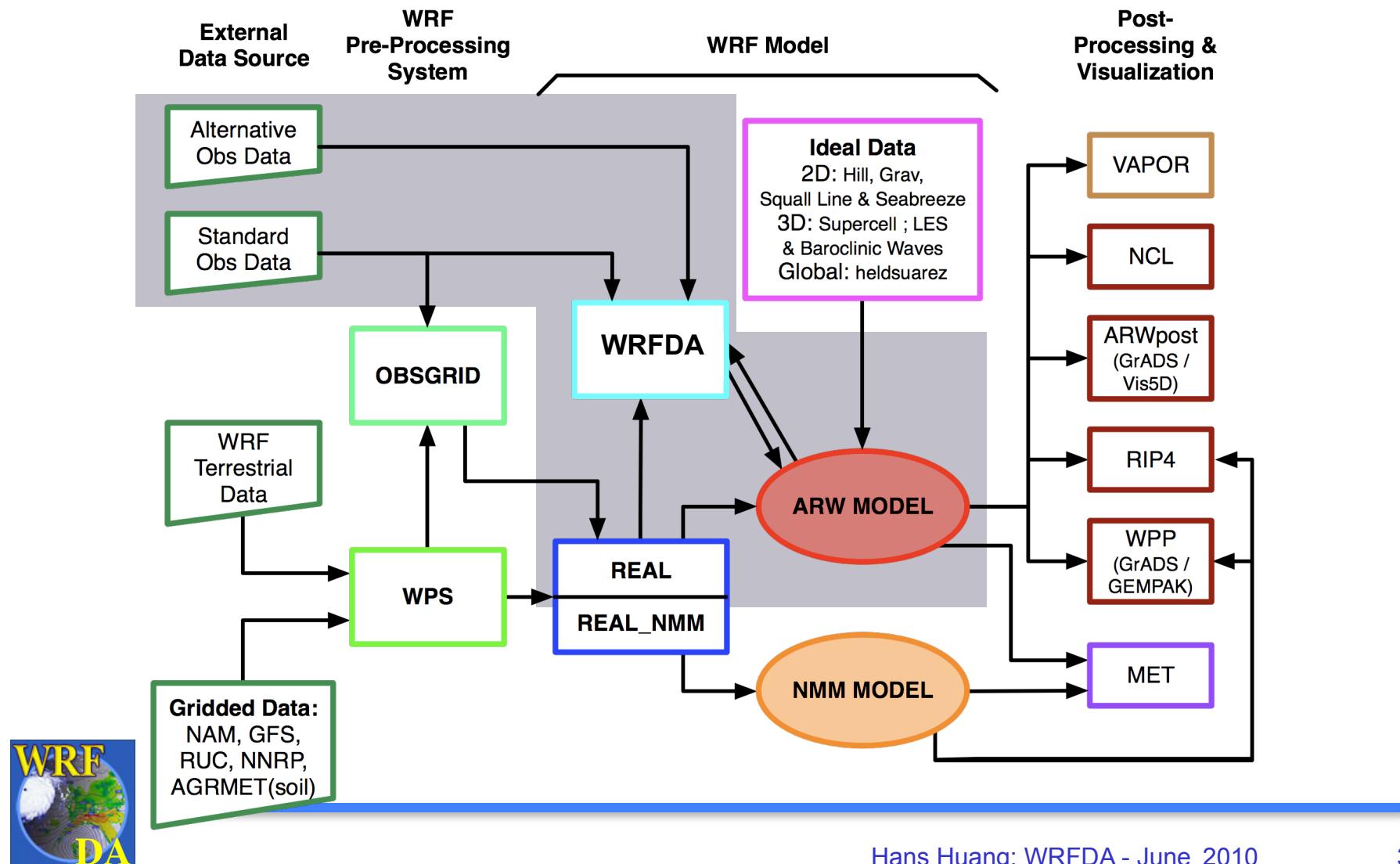
# Outline

1. WRFDA 2010 overview
2. WRFDA 2010 update
  - 4D-Var optimization
  - Forecast sensitivity to observations
3. Recent developments
  - CV6 – Multivariate humidity analysis
  - Hybrid 4D-Var/EnKF



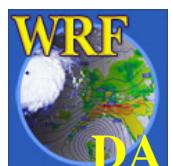
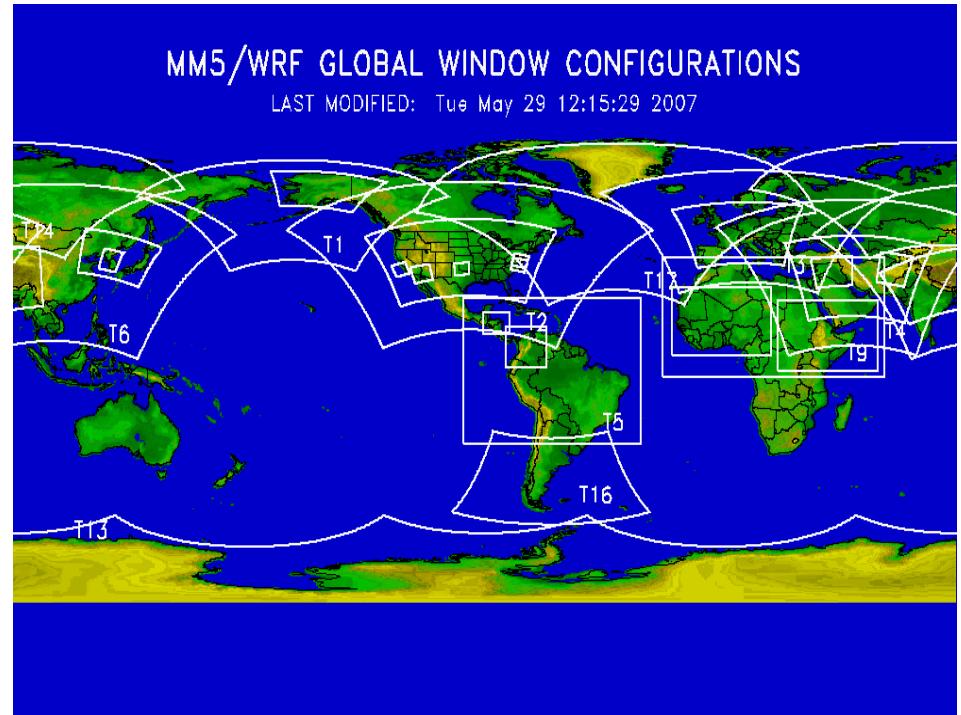
# WRFDA in the WRF Modeling System

## WRF Modeling System Flow Chart



# WRFDA

- **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/NESL/MMM/DAS (Data Assimilation Section, also supporting WRF/DART)
  - NCAR/RAL/JNT/DAT (Data Assimilation Team, also supporting GSI)
- **Observations:** Conv. + Sat. + Radar (+Bogus)



# [www.mmm.ucar.edu/wrf/users/wrfda](http://www.mmm.ucar.edu/wrf/users/wrfda)

The screenshot shows a web browser window displaying the WRFDA Model Users Site. The title bar reads "WRFDA Model Users Site". The address bar shows the URL "http://www.mmm.ucar.edu/wrf/users/wrfda/". The page itself has a green header with the text "WRFDA USERS PAGE" and a map of the Northern Hemisphere. Below the header is a navigation menu with links to Home, Analysis System, User Support, Download, Doc / Pub, Links, and Users Forum. On the left, a sidebar contains links to "wrf-model.org", "Public Domain Notice", and "Contact WRF Support". The main content area features a section titled "WRF Data Assimilation System Users Page" with a welcome message about the WRFDA system. It also mentions the NCAR's role in maintaining and supporting the code. To the right, there is a sidebar titled "ANNOUNCEMENTS" listing various releases and events.

WRFDA Model Users Site

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

Most Visited ▾

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## WRFDA USERS PAGE

Home Analysis System User Support Download Doc / Pub Links Users Forum

wrf-model.org

Public Domain Notice

Contact WRF Support

### WRF Data Assimilation System Users Page

Welcome to the users home page for the Weather Research and Forecasting (WRF) model data assimilation system (WRFDA). The WRFDA system is in the public domain and is freely available for community use. It is designed to be a flexible, state-of-the-art atmospheric data assimilation system that is portable and efficient on available parallel computing platforms. WRFDA is suitable for use in a broad range of applications across scales ranging from kilometers of regional mesoscale to thousands of kilometers of global scales.

The Mesoscale and Microscale Meteorology Division of NCAR is currently maintaining and supporting a subset of the overall WRF code (Version 3) that includes:

ANNOUNCEMENTS

[WRF Tutorials - January 26 - February 5, 2009, Boulder, Colorado.](#)

[WRF Version 3.1 Release Information](#)

[WRF Version 3.0.1.1 Release: August 22, 2008](#)

[WRF Var Version 3.0.1.1 Release: August 29, 2008](#)

New 'Known Problems' posts for V3 [WRF](#) (1/6/09) and [WPS](#) (8/4/08)

The 9th WRF Users' Workshop was held June 23 - 27, 2008 in Boulder, Colorado. [Workshop Presentations](#) is now online.



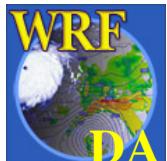
# WRFDA tutorials

- 21-22 July, 2008. NCAR.
- 2-4 Feb, 2009. NCAR.
- 17-24 Feb, 2009. Kunming, Yunnan, China.
- 18 April, 2009. South Korea.
- 20-22 July, 2009. NCAR.
- 15-31 Oct, 2009. Nanjing, China.
- 1-3 Feb, 2010. NCAR.
- 10 April, 2010. Seoul, South Korea.
- **3-5 August 2010. NCAR.**



# Tutorials at NCAR

- |  |                        |
|--|------------------------|
| 1. WRFDA Overview                      | Practice               |
| 2. Observation Pre-processing          | 1. obsproc             |
| 3. WRFDA System                        | 2. wrfda (3D-Var)      |
| 4. WRFDA Set-up, Run                   | 3. Single-ob tests     |
| 5. WRFDA Background Error Estimations  | 4. Gen_be              |
| 6. Radar Data                          | 5. Radar               |
| 7. Satellite Data                      | 6. Radiance            |
| 8. WRF 4D-Var                          | 7. 4D-Var              |
| 9. WRF Hybrid Data Assimilation System | 8. Hybrid              |
| 10. WRFDA Tools and Verification       | 9. Advanced (optional) |
| 11. Observation Sensitivity            |                        |



# WRFDA 3.2

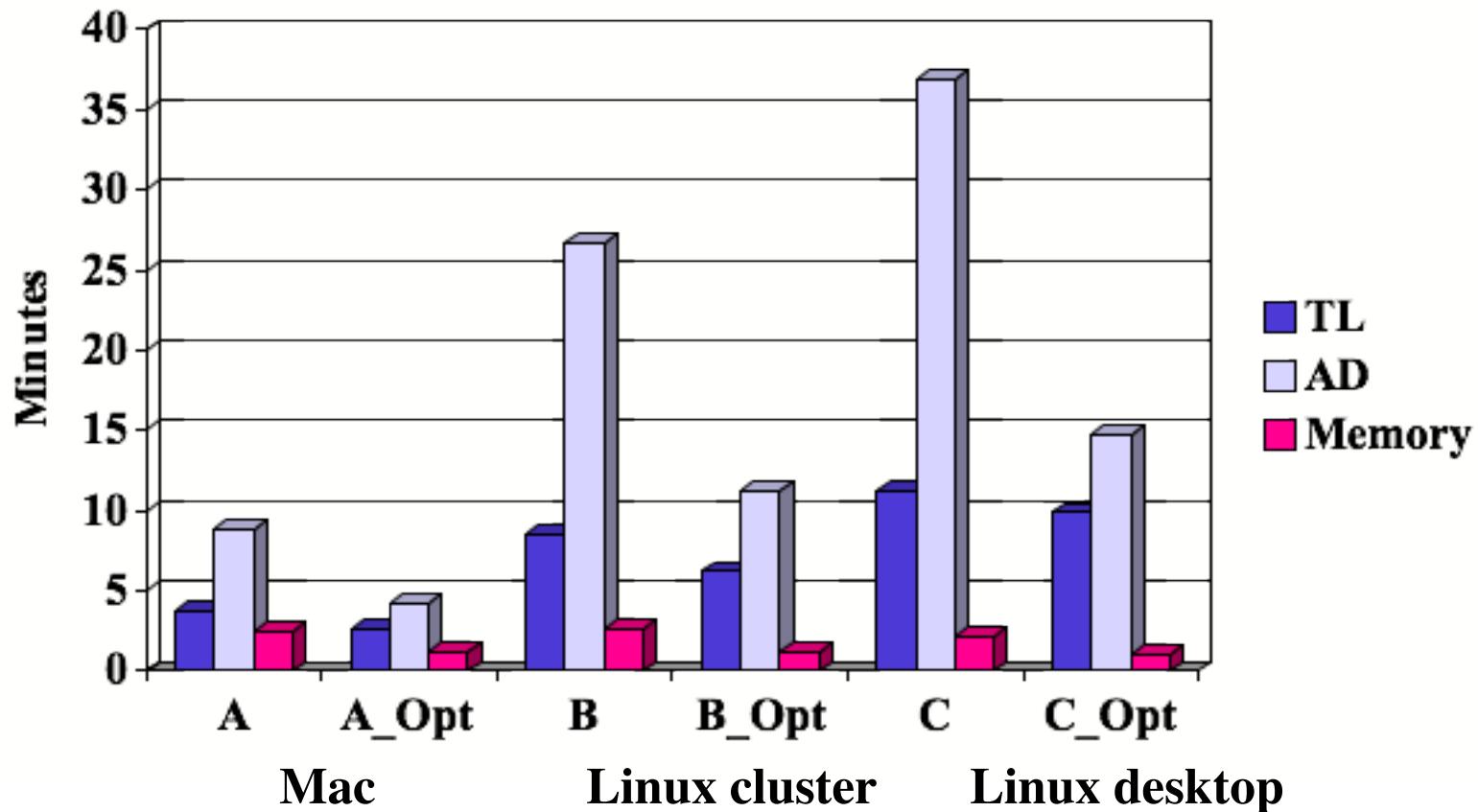
## (April 2010)

- Bug fixes.
- Optimization of TL, AD and 4D-Var.
- Forecast Sensitivity to Observations.  
(the Lanczos minimization algorithm; the adjoint of analysis; etc.)
- Further development of hybrid code.  
(vertical localization; 3D alpha control variable; etc.)
- Using PrepBufr format in 4D-Var.



# 4D-Var optimization (Cheng)

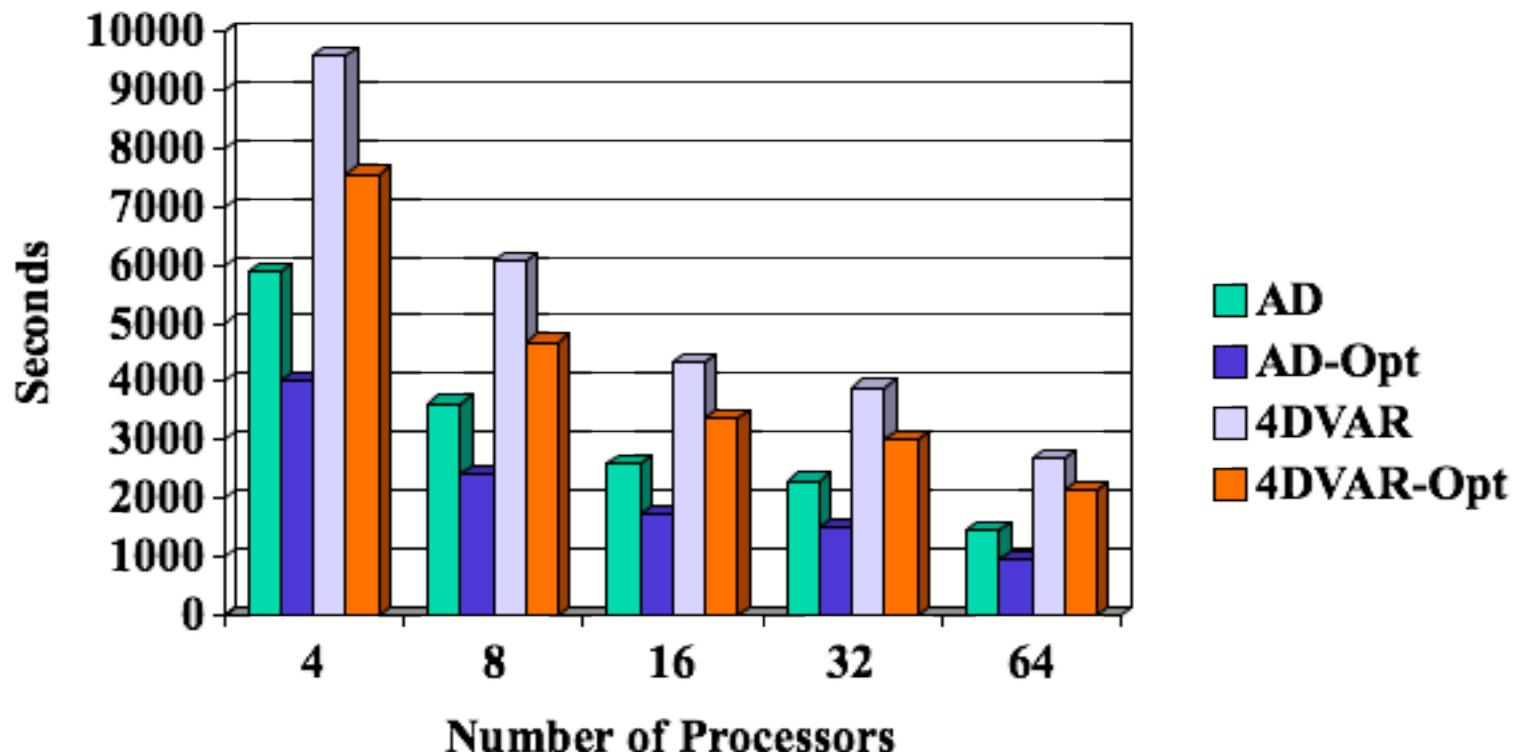
## Single processor



Grid: 140x97x57

# 4D-Var optimization (Cheng)

## Multiple processors

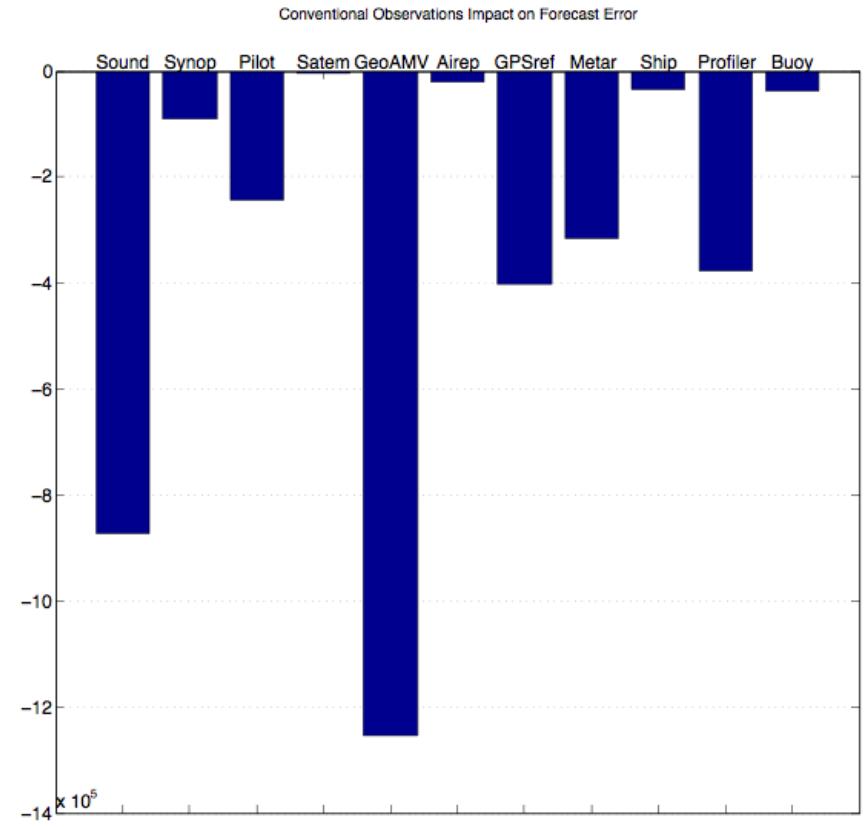
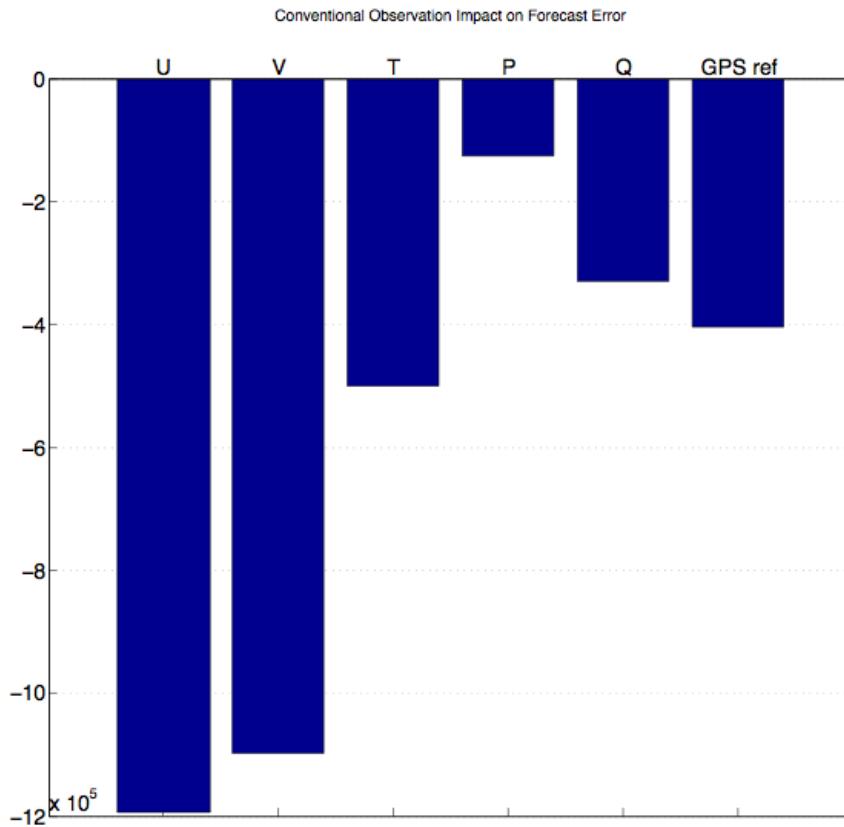


NCAR bluefire

Grid: 140x97x57

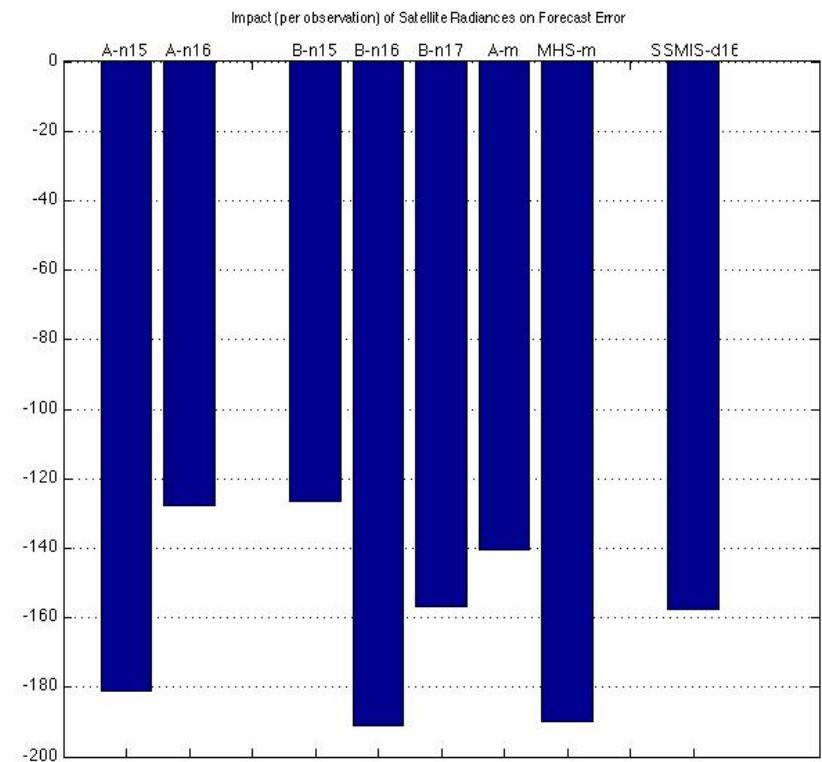
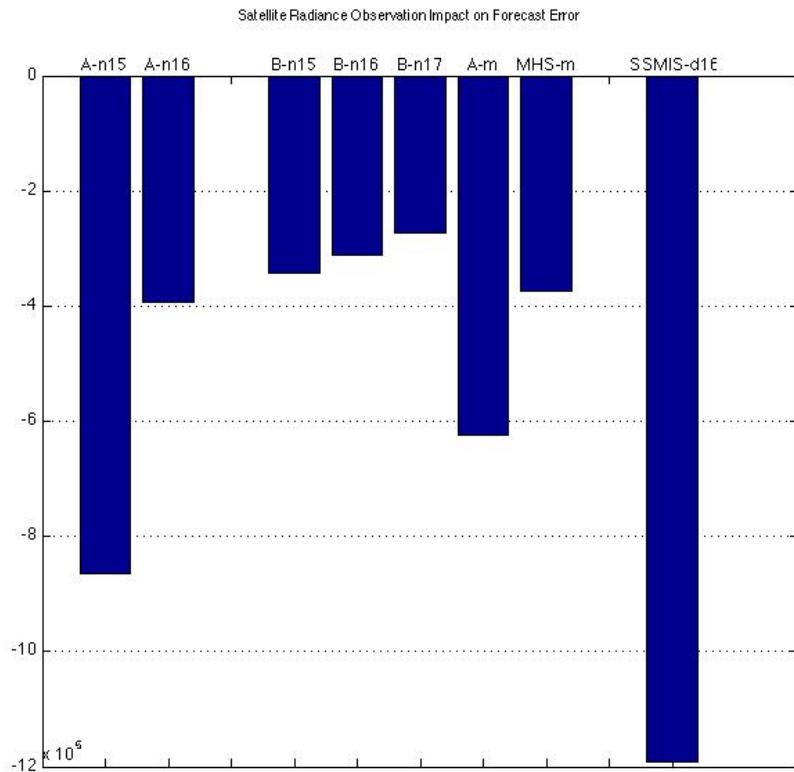
# Forecast Sensitivity to Observations (Auligne)

## Conventional Data



# Forecast Sensitivity to Observations (Auligne)

## Satellite radiances



# **WRFDA 3.2.1**

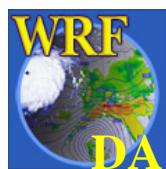
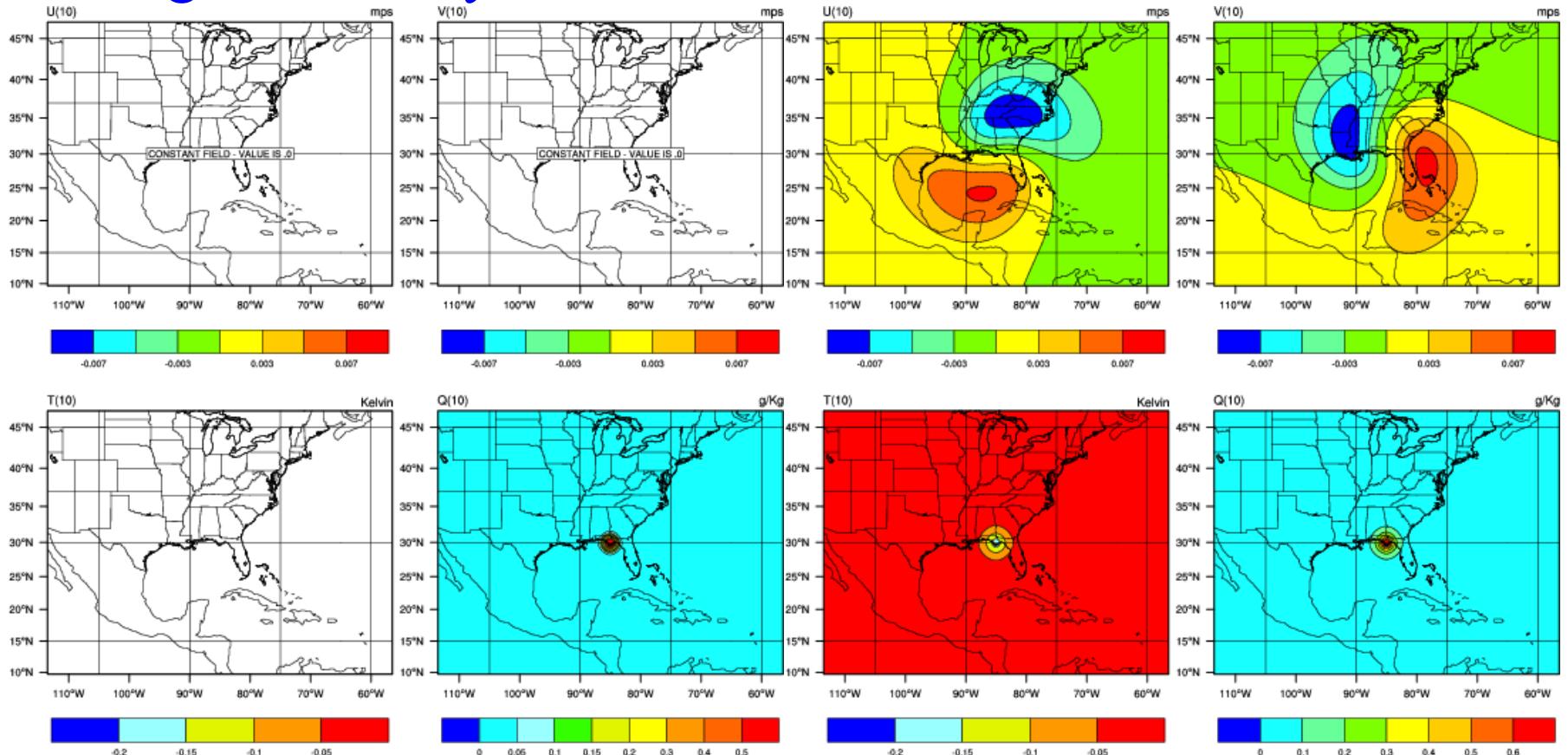
## **(July-August 2010)**

- Bug fixes.
- Enhanced support for radiance assimilation on platforms with Intel and GFORTRAN compilers.
- CRTM interface upgrade to version 2.0.2.
- RTTOV interface upgrade to version 9.3.
- Lateral boundary control in 4D-Var.
- **CV6 – Multivariate analysis for humidity.**
- A prototype single executable 4D-Var.



# CV6 – Multivariate humidity analysis (Rizvi, Krysta and Huang)

## Single humidity observation test

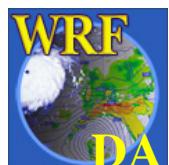


Old BE

New BE

# WRFDA

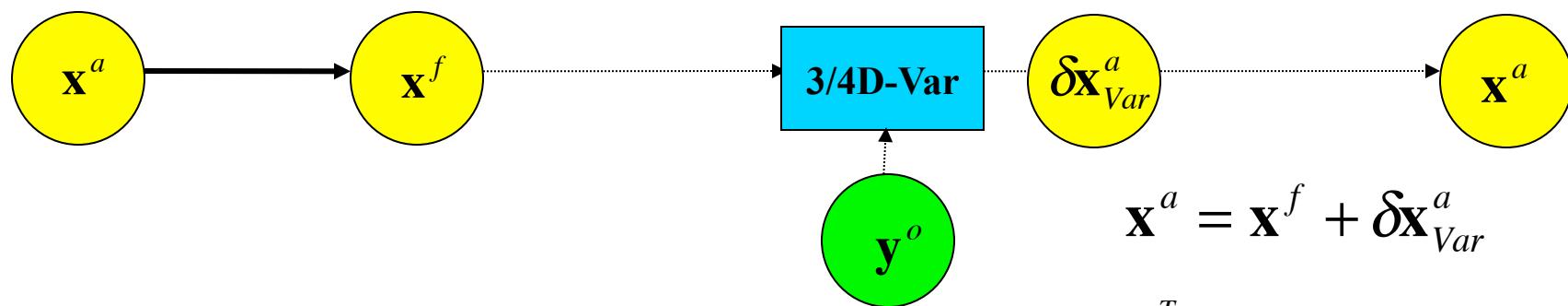
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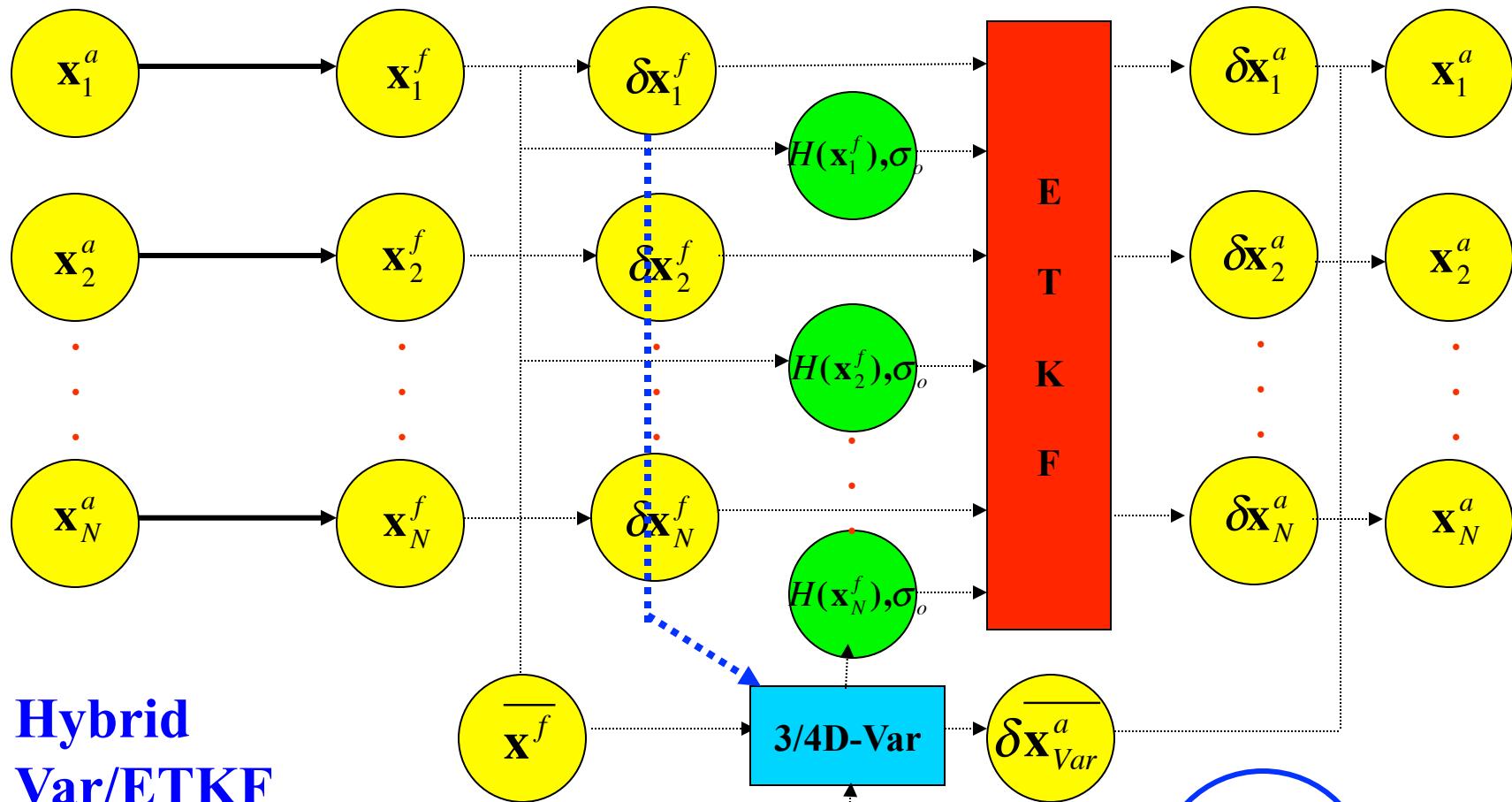
# WRFDA

## 3/4D-Var

3D-Var: Barker et al. 2004  
4D-Var: Huang et al. 2009



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



**Hybrid  
Var/ETKF**  
*(Wang et al. 2008)*



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

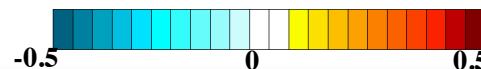
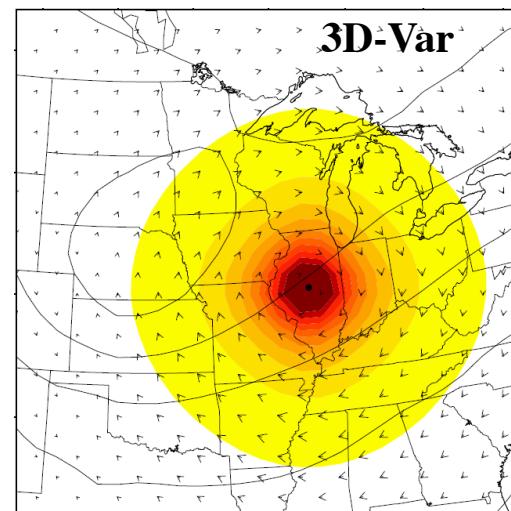
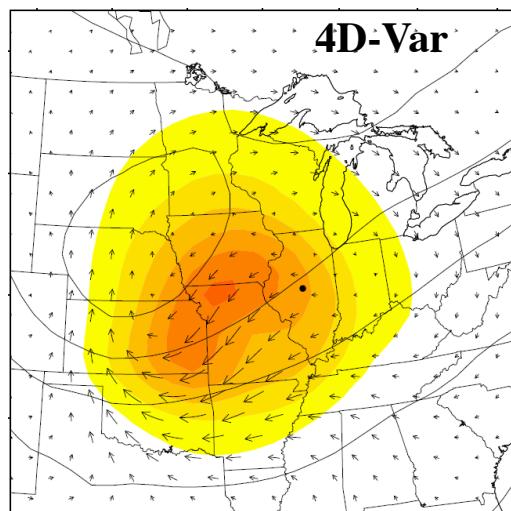
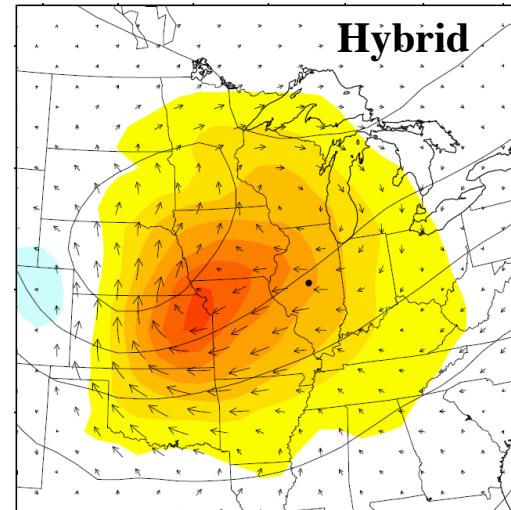
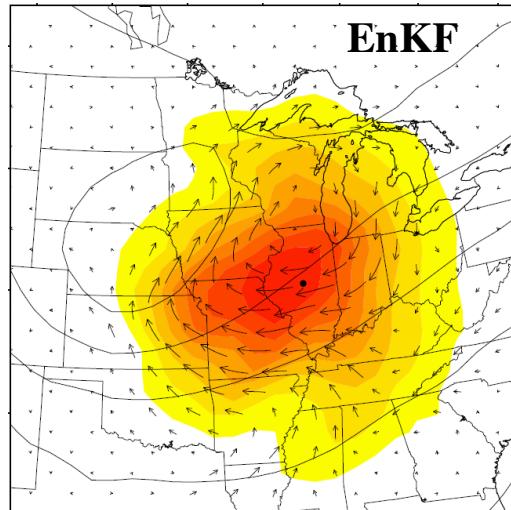
# Weakness and strength of DA methods

Zhang, M. (PSU), Zhang, F. (PSU), Huang, X.-Y. (NCAR), Zhang, X. (NCAR)

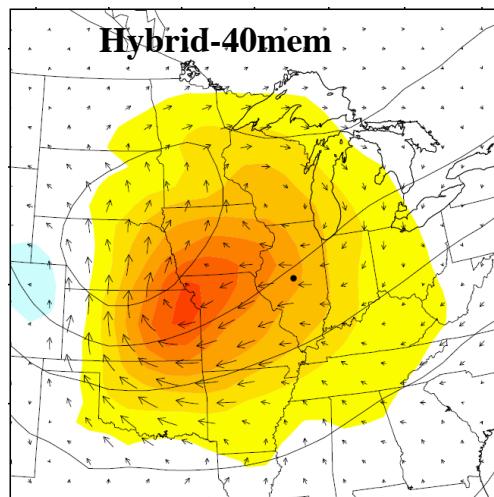
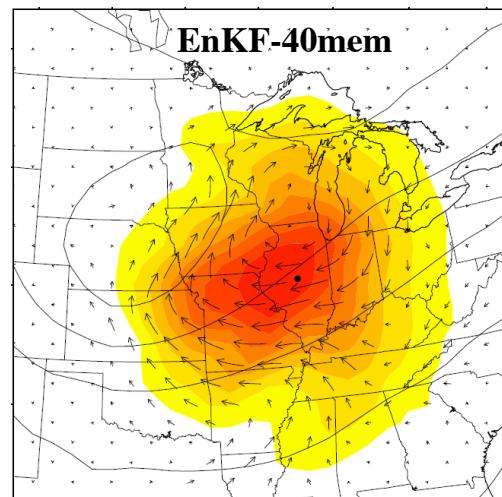
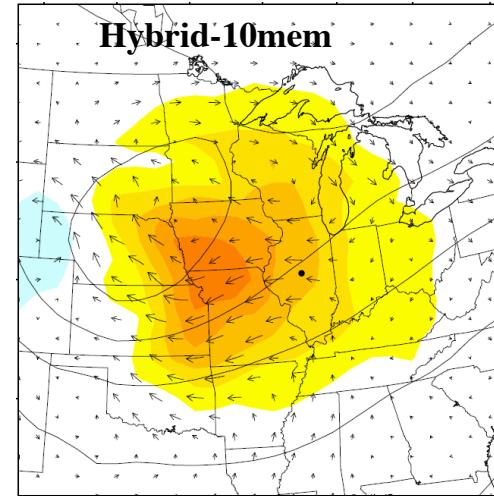
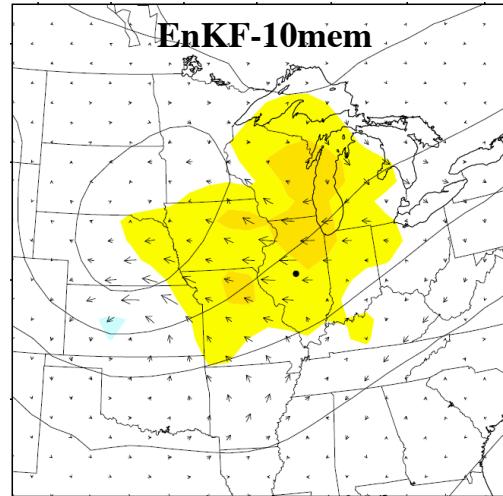
- 3D-Var:
  - Low cost
  - Lack of flow-dependent
- 4D-Var:
  - Trajectory fitting for asynchronous observations
  - Model as a (strong/weak) constraint
  - Implicit flow-dependent estimation
  - Poor background error covariance at t=0
  - Difficulties in TL and AD
  - High cost
- EnKF:
  - Flow-dependent B [Ensemble forecasts]
  - Easy coding and maintenance
  - Sensitive to the quality of ensembles
  - Sampling errors
  - Non-linear operators
- Hybrid: Get the best from both EnKF and 4D-Var



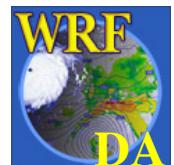
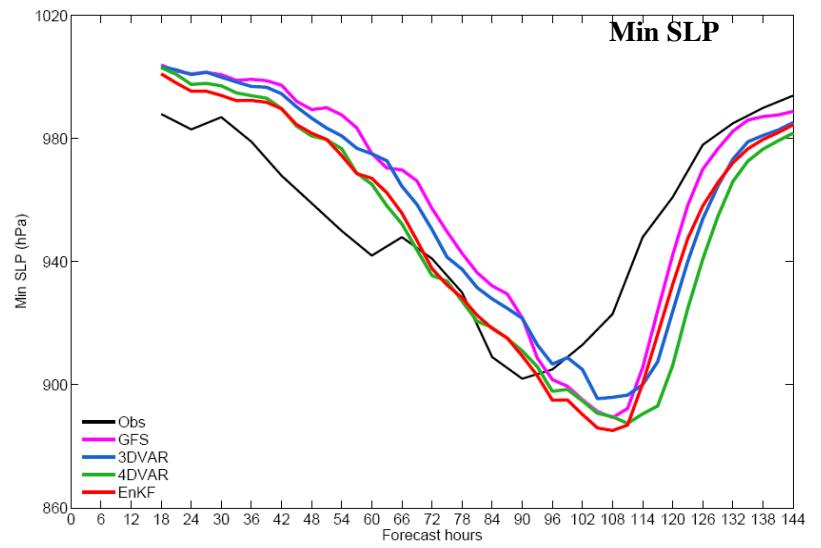
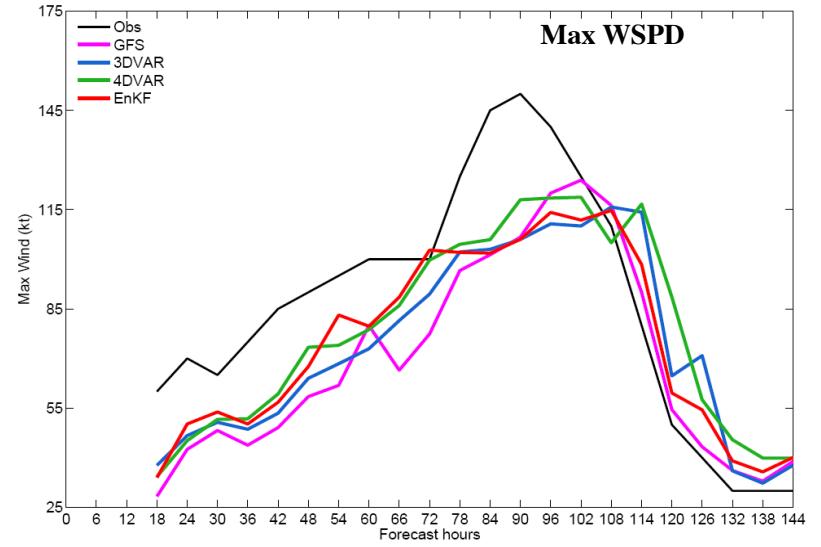
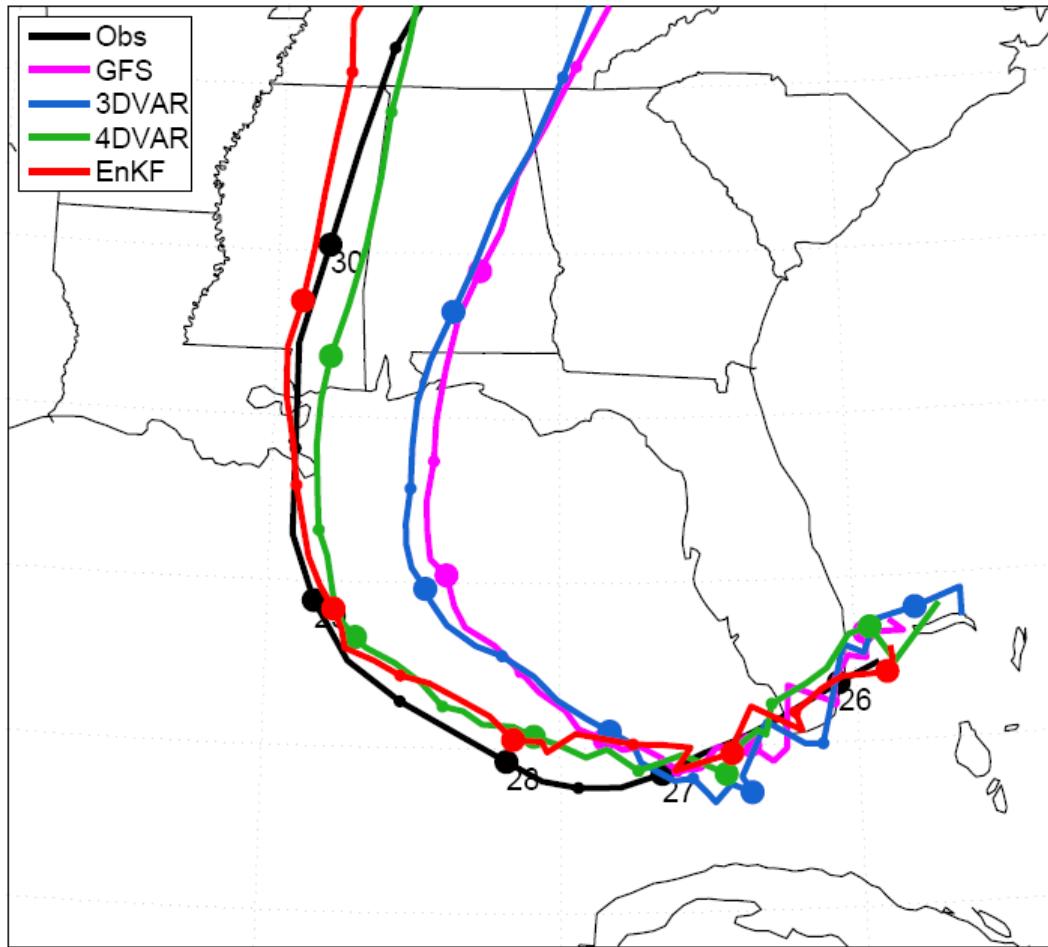
Temperature (shaded) and horizontal wind (vector) increments



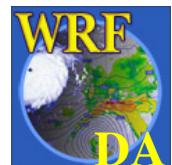
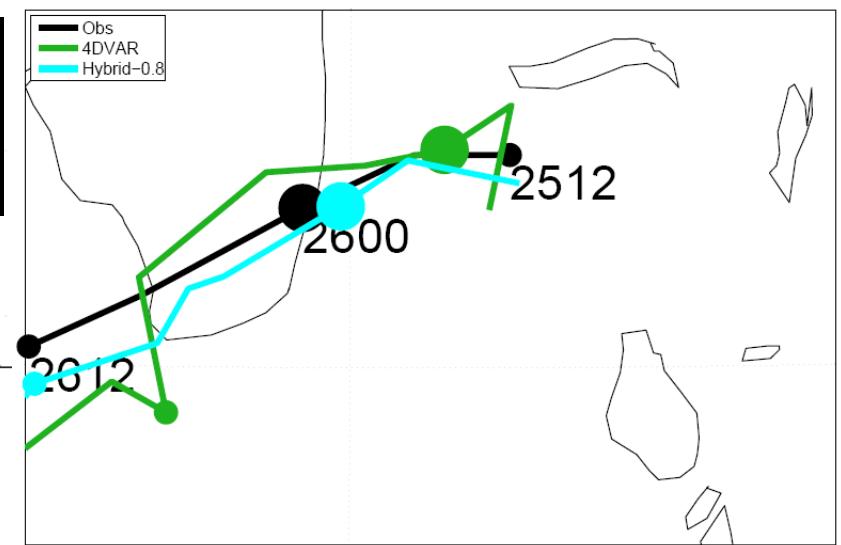
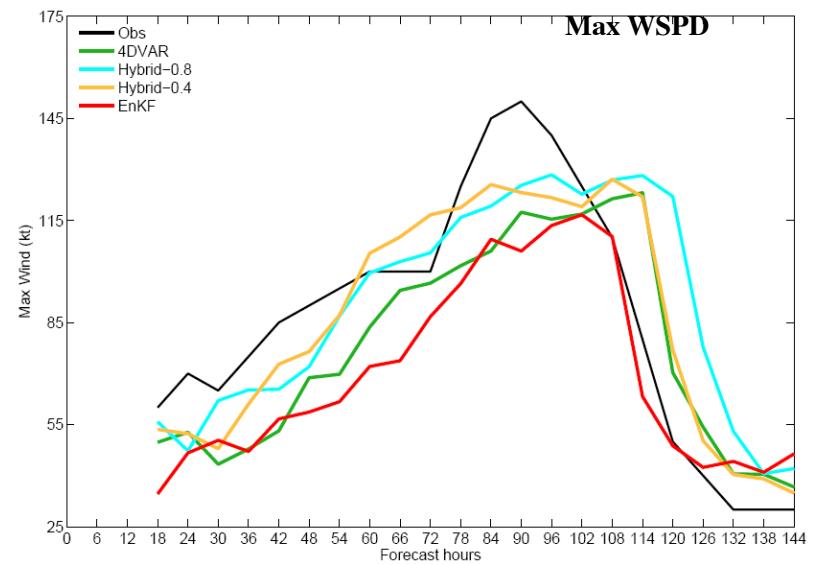
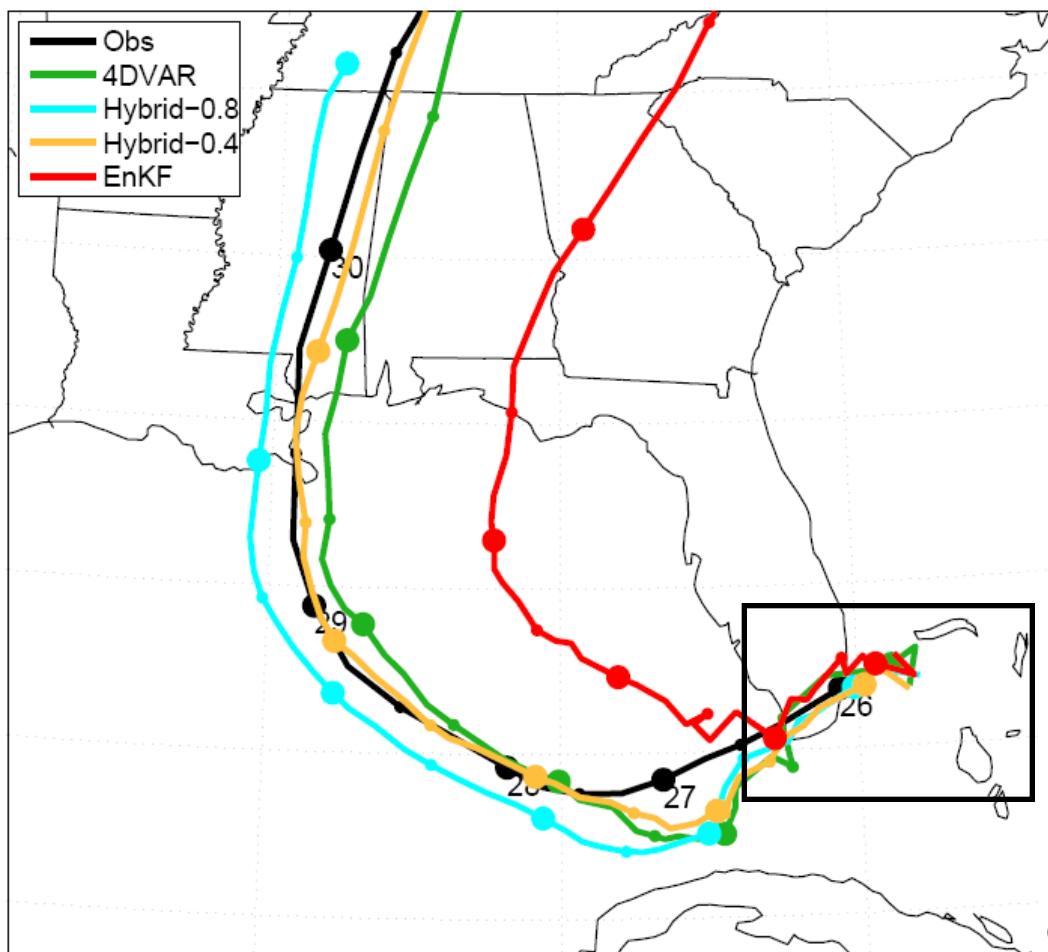
## Compare EnKF and Hybrid with small ensemble size (10 members)



## DA Performances on Track and Intensity forecasts



## DA performances with “bad” first guess



**Mean vertical profiles of U, V, T and Qv 12-h forecast RMSE  
( 06/01/2003 ~ 06/10/2003 with 12-h interval)**

