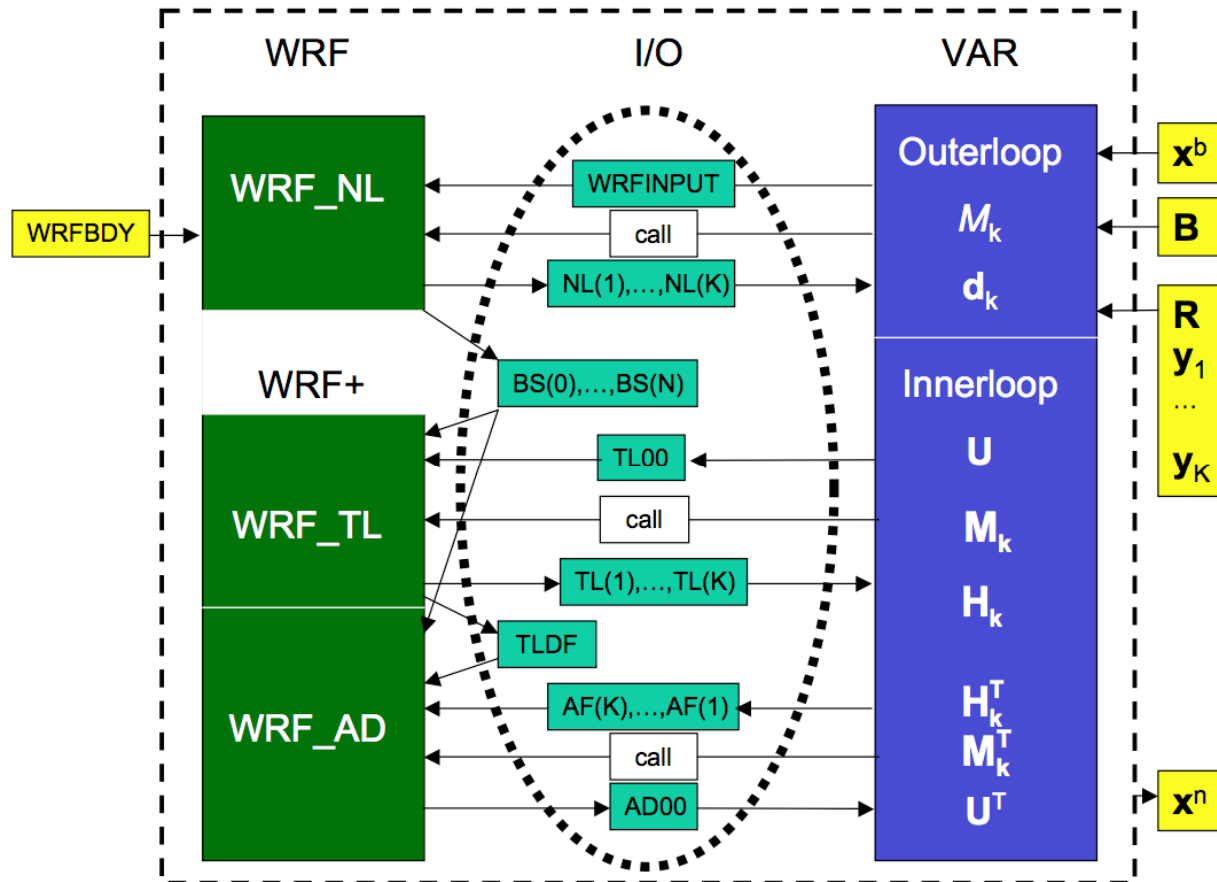


# **Performance of WRF 4D-Var System: Scientific and Software Engineering**

**Xin Zhang, Xiang-Yu Huang and Yong-Run Guo**  
**National Center for Atmospheric Research**

# Structure of WRF 4D-Var



# Structure of WRF 4D-Var (Cont'd)

Name	Date Modified	Size	Kind
ad	Today	37 MB	Folder
af01	Today	23.8 MB	Plain text
af02	Today	23.8 MB	Plain text
af03	Today	23.8 MB	Plain text
af04	Today	23.8 MB	Plain text
af05	Today	23.8 MB	Plain text
af06	Today	23.8 MB	Plain text
af07	Today	23.8 MB	Plain text
be.dat	Today	4 KB	Alias
da_wrfvar.exe	Today	4 KB	Alias
g	Today	4 KB	Alias
fg01	Today	4 KB	Alias
fg02	Today	4 KB	Alias
fg03	Today	4 KB	Alias
fg04	Today	4 KB	Alias
fg05	Today	4 KB	Alias
fg06	Today	4 KB	Alias
fg07	Today	4 KB	Alias
gr01	Today	4 KB	Alias
namelist.input	Today	4 KB	Document
nl	Today	73... MB	Folder
ob01.ascii	Today	4 KB	Alias
ob02.ascii	Today	4 KB	Alias
ob03.ascii	Today	4 KB	Alias
ob04.ascii	Today	4 KB	Alias
ob05.ascii	Today	4 KB	Alias
ob06.ascii	Today	4 KB	Alias
ob07.ascii	Today	4 KB	Alias
tl	Today	15... MB	Folder
tl01	Today	23.8 MB	Plain text
tl02	Today	4 KB	Alias
tl03	Today	4 KB	Alias
tl04	Today	4 KB	Alias
tl05	Today	4 KB	Alias
tl06	Today	4 KB	Alias
tl07	Today	4 KB	Alias
wrfbdy_d01	Today	4 KB	Alias
wrfinput_d01	Today	4 KB	Alias

# Weak constraint with digital filter

$$J = J_b + J_o + J_c$$

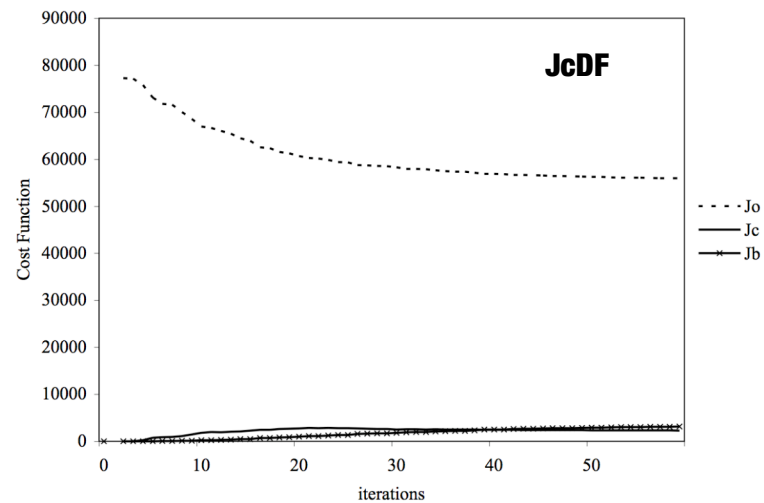
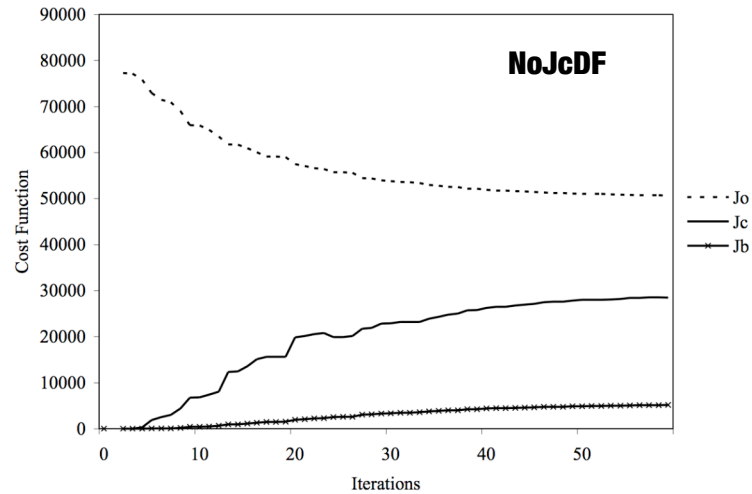
$$J_b(\mathbf{x}_0) = \frac{1}{2} [(\mathbf{x}_0 - \mathbf{x}_b)^T \mathbf{B}^{-1} (\mathbf{x}_0 - \mathbf{x}_b)]$$

$$J_o(\mathbf{x}_0) = \frac{1}{2} \sum_{k=1}^K [(\mathbf{H}_k \mathbf{x}_k - \mathbf{y}_k)^T \mathbf{R}^{-1} (\mathbf{H}_k \mathbf{x}_k - \mathbf{y}_k)]$$

$$\begin{aligned} J_c(\mathbf{x}_0) &= \frac{\gamma_{df}}{2} [(\delta \mathbf{x}_{N/2} - \delta \mathbf{x}_{N/2}^{df})^T \mathbf{C}^{-1} (\delta \mathbf{x}_{N/2} - \delta \mathbf{x}_{N/2}^{df})] \\ &= \frac{\gamma_{df}}{2} \left[ \left( \delta \mathbf{x}_{N/2} - \sum_{i=0}^N f_i \delta \mathbf{x}_i \right)^T \mathbf{C}^{-1} \left( \delta \mathbf{x}_{N/2} - \sum_{i=0}^N f_i \delta \mathbf{x}_i \right) \right] \\ &= \frac{\gamma_{df}}{2} \left[ \left( \sum_{i=0}^N h_i \delta \mathbf{x}_i \right)^T \mathbf{C}^{-1} \left( \sum_{i=0}^N h_i \delta \mathbf{x}_i \right) \right] \end{aligned}$$

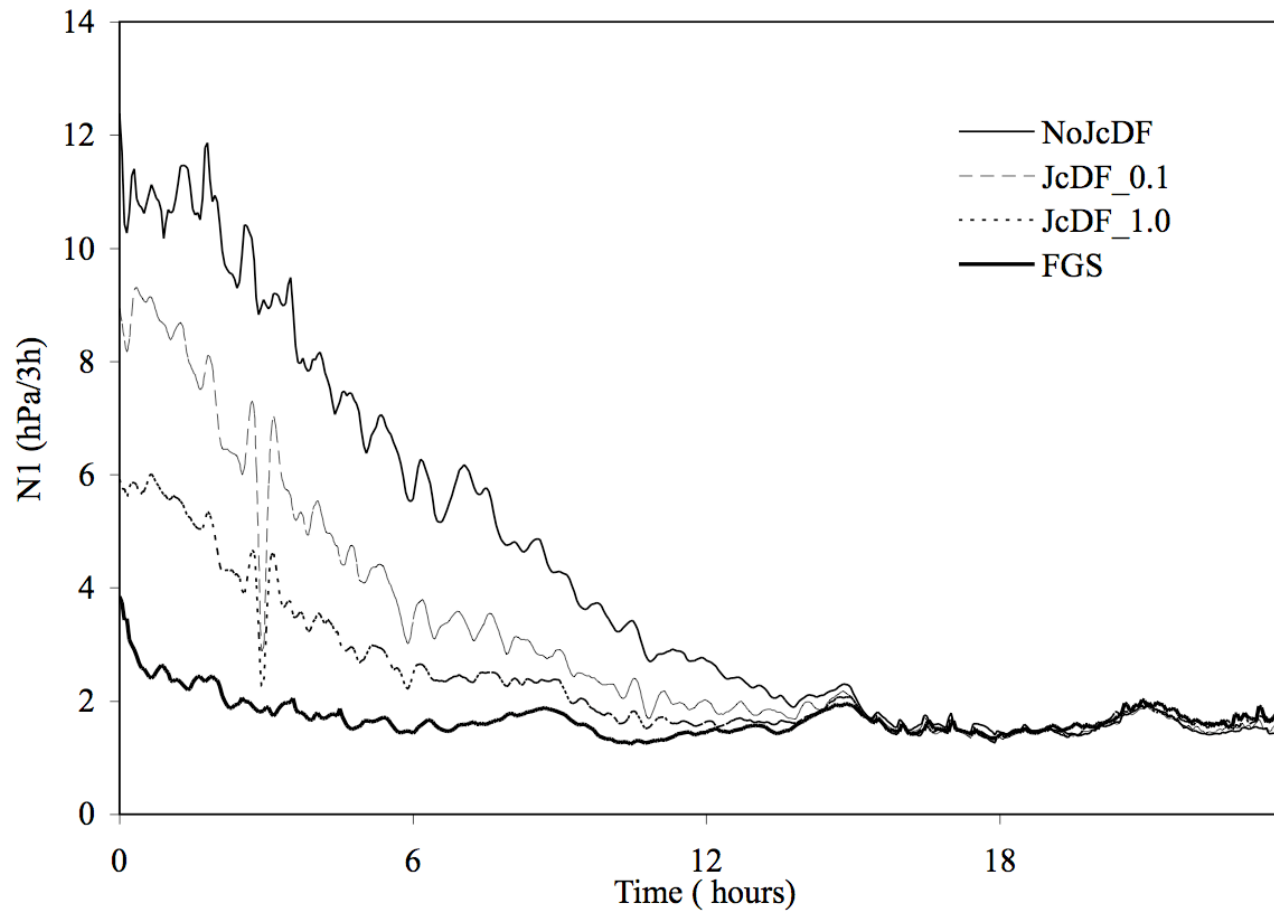
where:

$$h_i = \begin{cases} -f_i, & \text{if } i \neq N/2 \\ 1 - f_i, & \text{if } i = N/2 \end{cases}$$



# Weak constraint with digital filter

(domain averaged surface pressure variation)



# First radar data assimilation with WRF 4D-Var

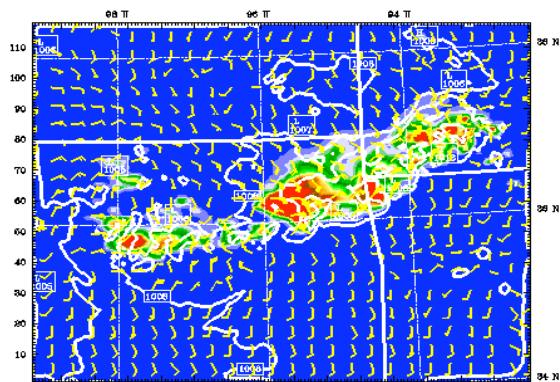
- **TRUTH -----** Initial condition from TRUTH (13-h forecast initialized at 2002061212Z from AWIPS 3-h analysis) run cutted by ndown, boundary condition from NCEP GFS data.
- **NODA -----** Both initial condition and boundary condition from NCEP GFS data.
- **3DVAR -----**3DVAR analysis at 2002061301Z used as the initial condition, and boundary condition from NCEP GFS. Only Radar radial velocity at 2002061301Z assimilated (total # of data points = 65,195).
- **4DVAR -----** 4DVAR analysis at 2002061301Z used as initial condition, and boundary condition from NCEP GFS. The radar radial velocity at 4 times: 200206130100, 05, 10, and 15, are assimilated (total # of data points = 262,445).

# Hourly precipitation at 03h forecast

Dataset: TRUTH RIP: ripslpdbz Init: 0100 UTC Thu 13 Jun 02  
 Fcst: 3.00 h Valid: 0400 UTC Thu 13 Jun 02 (2200 MDT Wed 12 Jun 02)  
 Total precip. in past 1 h  
 Sea-level pressure  
 Horizontal velocity

**TRUTH**

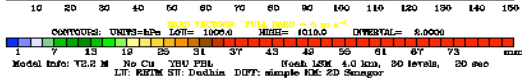
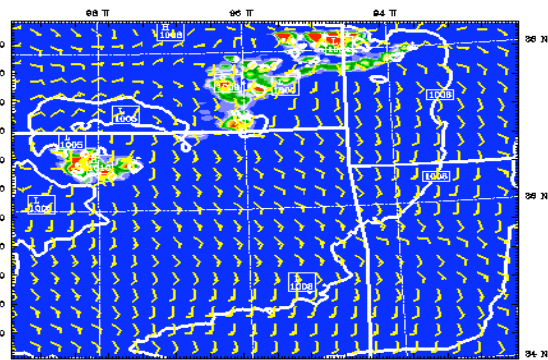
at k-index = 30



Dataset: 3DVAR RIP: ripslpdbz Init: 0100 UTC Thu 13 Jun 02  
 Fcst: 3.00 h Valid: 0400 UTC Thu 13 Jun 02 (2200 MDT Wed 12 Jun 02)  
 Total precip. in past 1 h  
 Sea-level pressure  
 Horizontal velocity

**3DVAR**

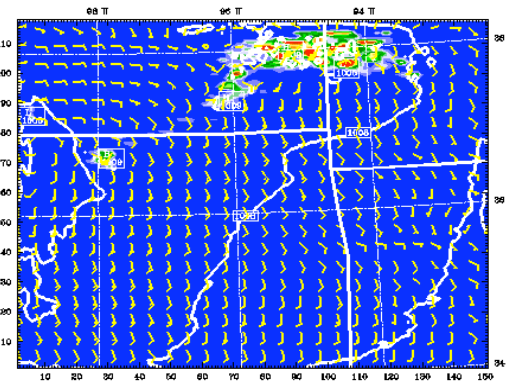
at k-index = 30



Dataset: FG RIP: ripslpdbz Init: 0100 UTC Thu 13 Jun 02  
 Fcst: 3.00 h Valid: 0400 UTC Thu 13 Jun 02 (2200 MDT Wed 12 Jun 02)  
 Total precip. in past 1 h  
 Sea-level pressure  
 Horizontal velocity

**NODA**

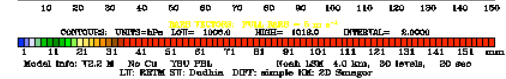
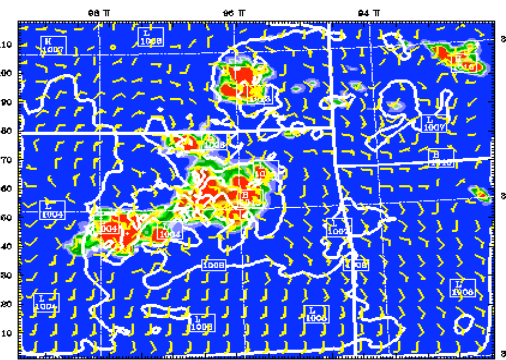
at k-index = 30



Dataset: 4DVAR RIP: ripslpdbz Init: 0100 UTC Thu 13 Jun 02  
 Fcst: 3.00 h Valid: 0400 UTC Thu 13 Jun 02 (2200 MDT Wed 12 Jun 02)  
 Total precip. in past 1 h  
 Sea-level pressure  
 Horizontal velocity

**4DVAR**

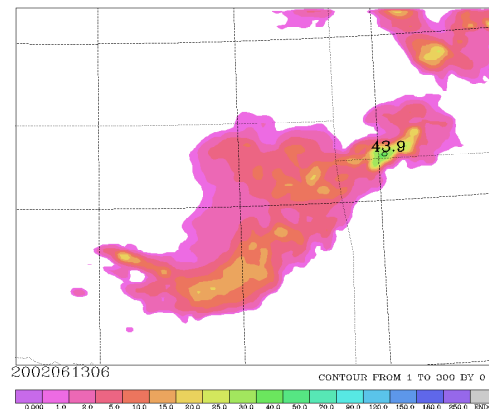
at k-index = 30



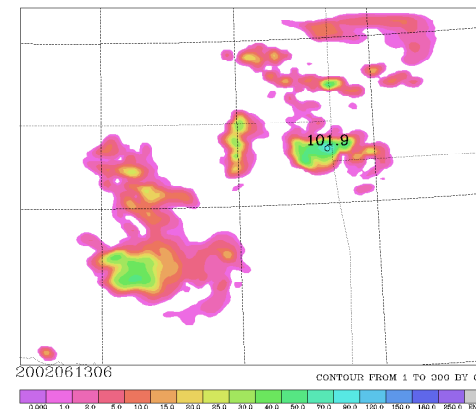
# Radar data assimilation (cont'd)

## Real data experiments

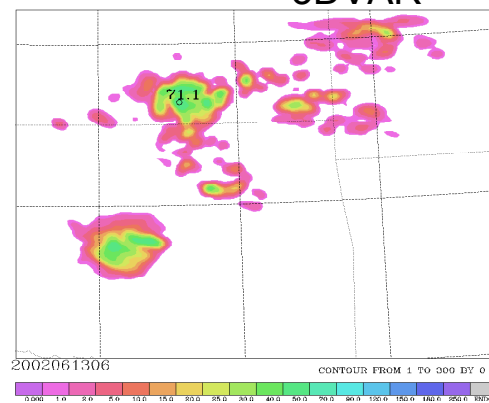
OBS



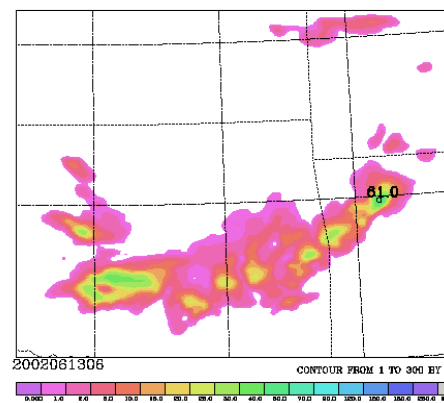
GFS



3DVAR



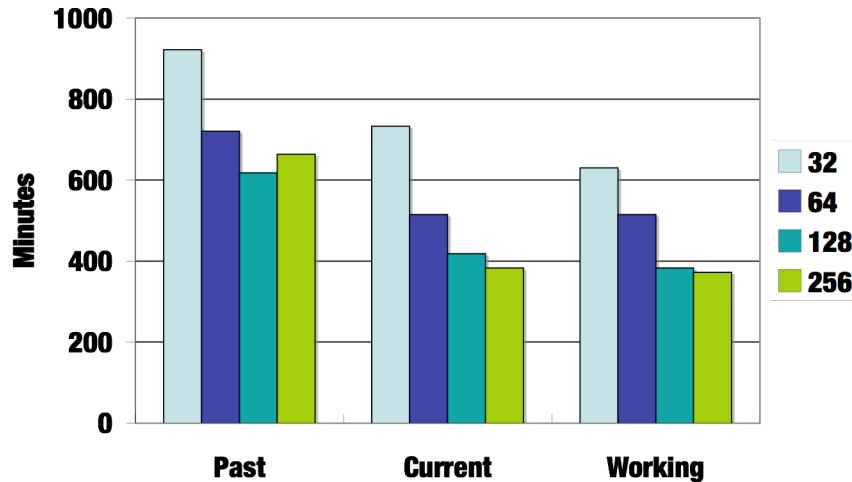
4DVAR



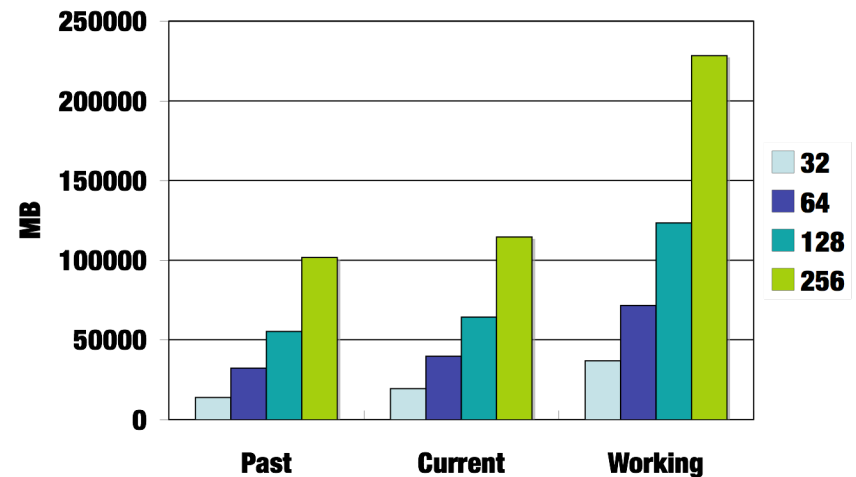


# Computational Efficiency of IKE hurricane case on NCAR Bluefire

WallClock Time (63 Iterations)



Memory Usage (63 Iterations)



**Past: Before optimization**

**Current: Eliminate the disk IO for basic states**

**Working: Reorganizing adjoint codes, reduce re-computation.**

# Radar Assimilation Case on IBM bluefire

Domain size:151x118x31

Resolution:4km

Time-step: 20s

Time window:30m

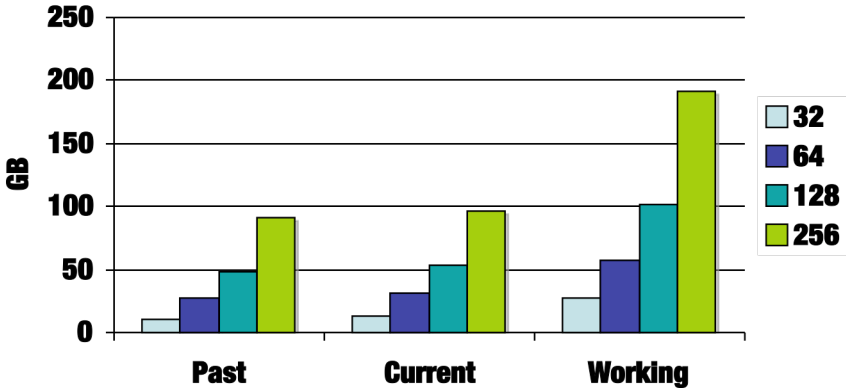
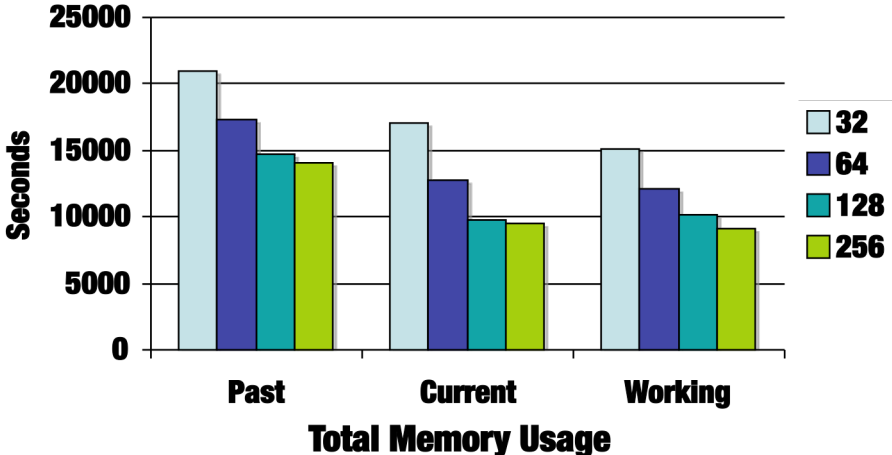
# of iterations: 60

Obs.: OSSE radar wind

# of obs.: 262,517

Obs Freq: 5m

Wall-clock time



# Release of WRFDA V3.1

The screenshot shows a web browser window titled "WRFDA Model Users Site" with the URL "http://www.mmm.ucar.edu/wrf/users/wrfda/". The browser's address bar and search engine (Google) are visible. The page content includes a green header with "WRFDA USERS PAGE" and a navigation menu with links: Home, Analysis System, User Support, Download, Doc / Pub, Links, and Users Forum. A search box is located on the right side of the header. The main content area features a section titled "WRF Data Assimilation System Users Page" with a welcome message and a paragraph describing the WRFDA system. A sidebar on the left contains links for "wrf-model.org", "Public Domain Notice", and "Contact WRF Support". A right sidebar titled "ANNOUNCEMENTS" lists several updates, including "WRF Tutorials", "WRF Version 3.1 Release Information", "WRF Version 3.0.1.1 Release", and "WRF Var Version 3.0.1.1 Release". The browser's status bar at the bottom shows "Done".

WRFDA Model Users Site

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

Most Visited

Gmail - Inbox - hans.xy.huang... Google Calendar WRFDA Model Users Site

## WRFDA USERS PAGE

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

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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.

Done