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

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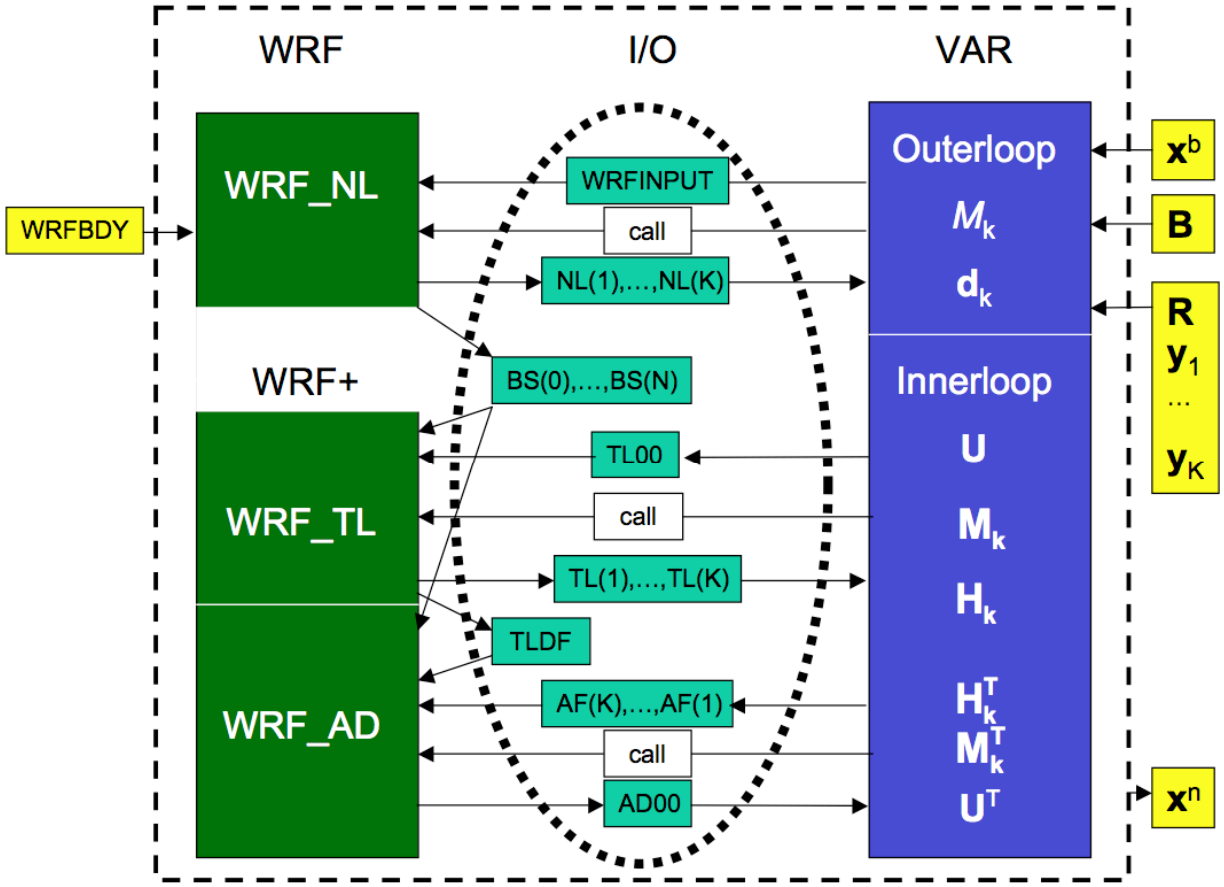
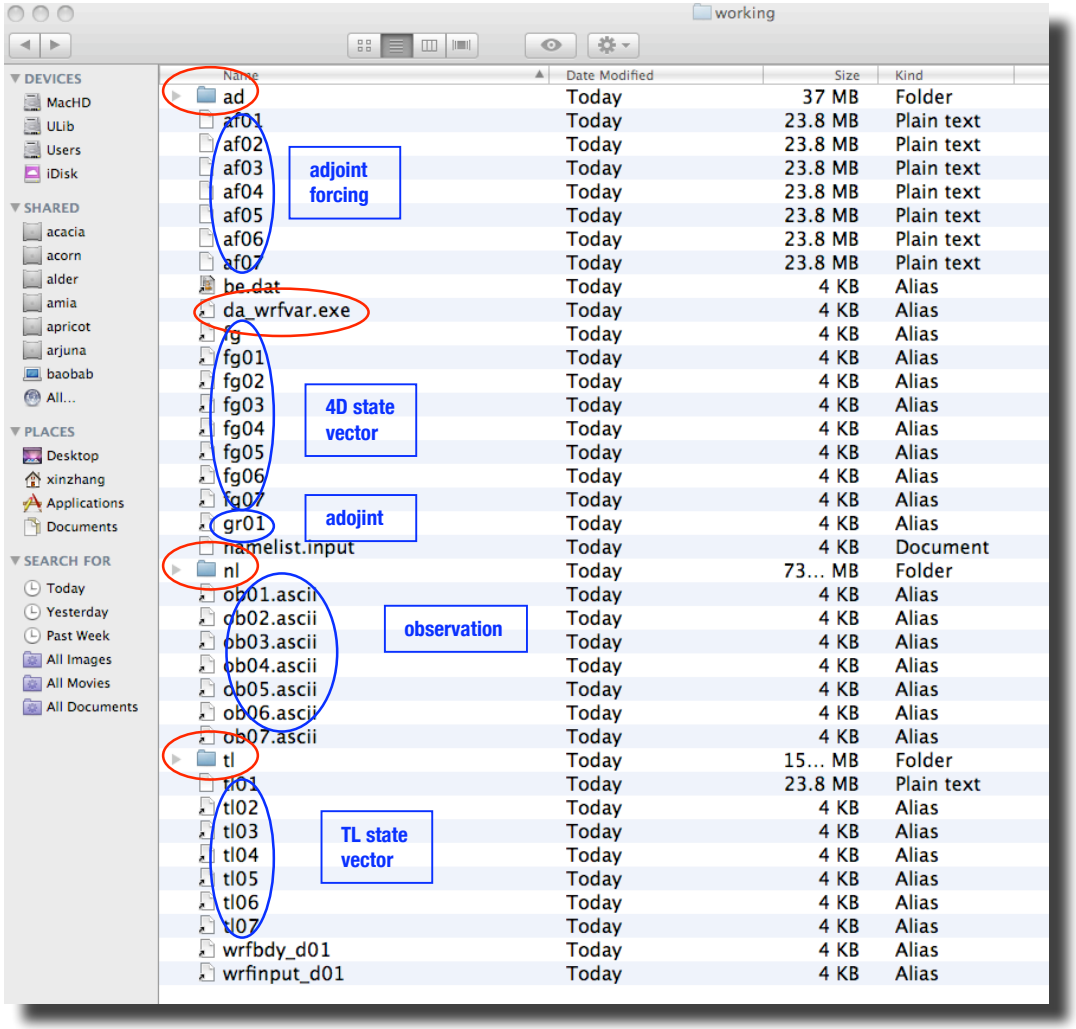
Structure of WRF 4D-Var



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



Weak constraint with digital filter

$$J = J_b + J_o + J_c$$

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

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

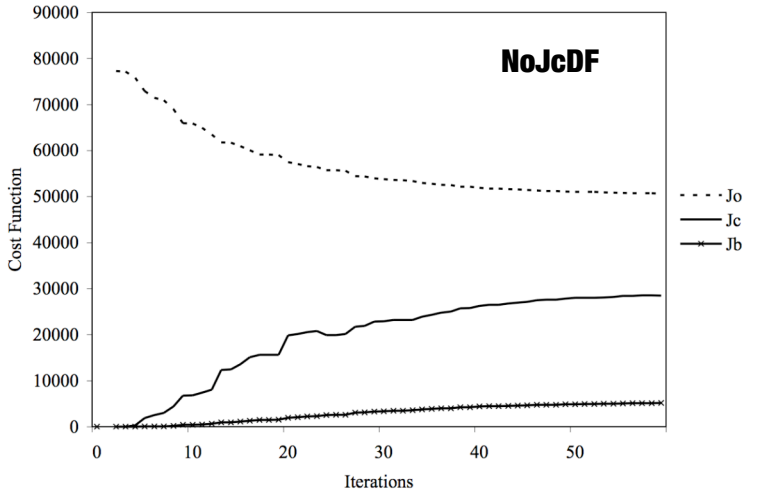
$$J_c(\mathbf{x}_0) = \frac{\gamma_{df}}{2}\left[\left(\delta\mathbf{x}_{N/2} - \delta\mathbf{x}^{df}_{N/2}\right)^T \mathbf{C}^{-1}\left(\delta\mathbf{x}_{N/2} - \delta\mathbf{x}^{df}_{N/2}\right)\right]$$

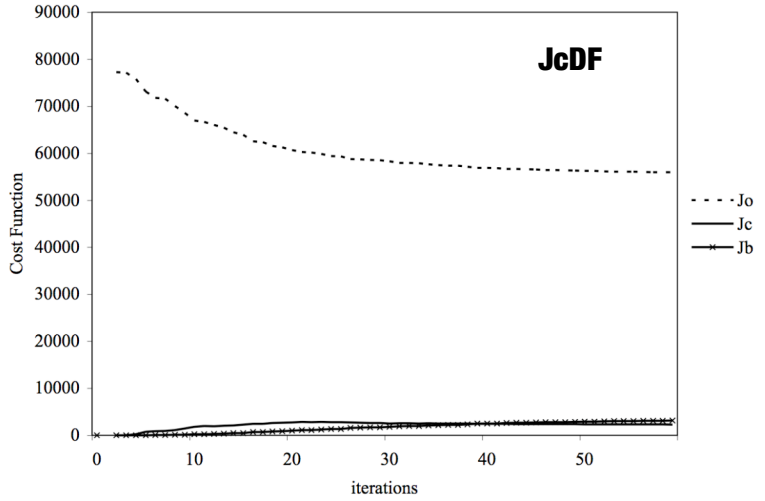
$$= \frac{\gamma_{df}}{2}\left[\left(\delta\mathbf{x}_{N/2} - \sum_{i=0}^{N} f_i\delta\mathbf{x}_i\right)^T \mathbf{C}^{-1}\left(\delta\mathbf{x}_{N/2} - \sum_{i=0}^{N} f_i\delta\mathbf{x}_i\right)\right]$$

$$= \frac{\gamma_{df}}{2}\left[\left(\sum_{i=0}^{N} h_i\delta\mathbf{x}_i\right)^T \mathbf{C}^{-1}\left(\sum_{i=0}^{N} h_i\delta\mathbf{x}_i\right)\right]$$

where:

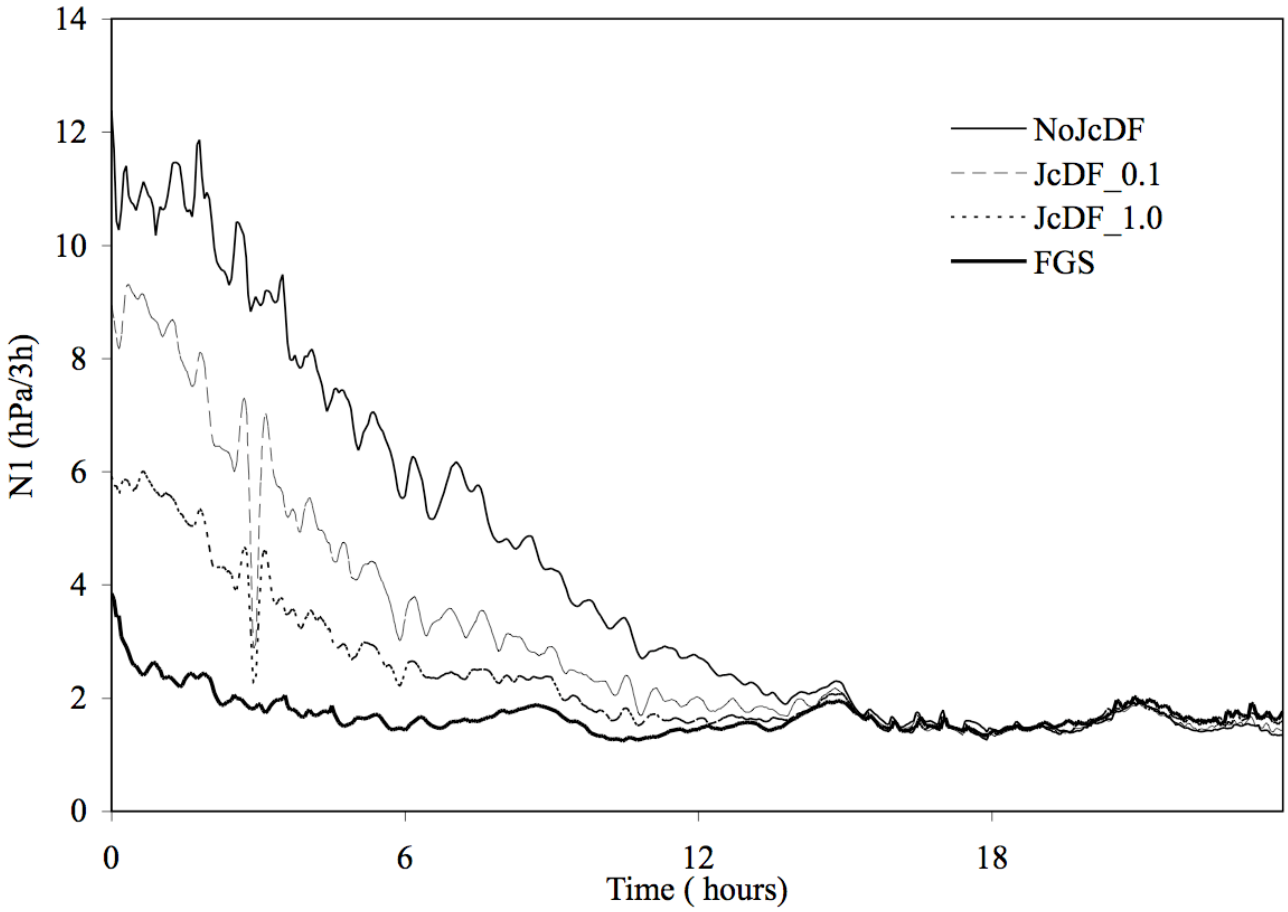
$$h_i = \begin{cases} -f_i, & if\ i \neq N/2 \\ 1 - f_i, & if\ i = N/2 \end{cases}$$





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.

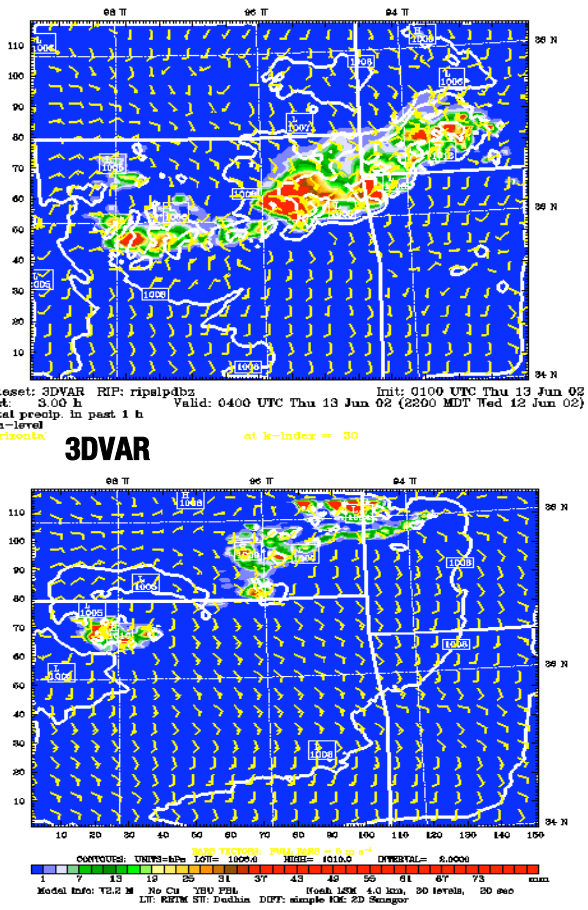
- 3DVAR -----3DVAR analysis at 2002061301Z used as the initial condition, and boundary condition from NCEP GFS. Only Radar radial velocity at 2002061301Z assimilated (total # of data points = 65,195).

- 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

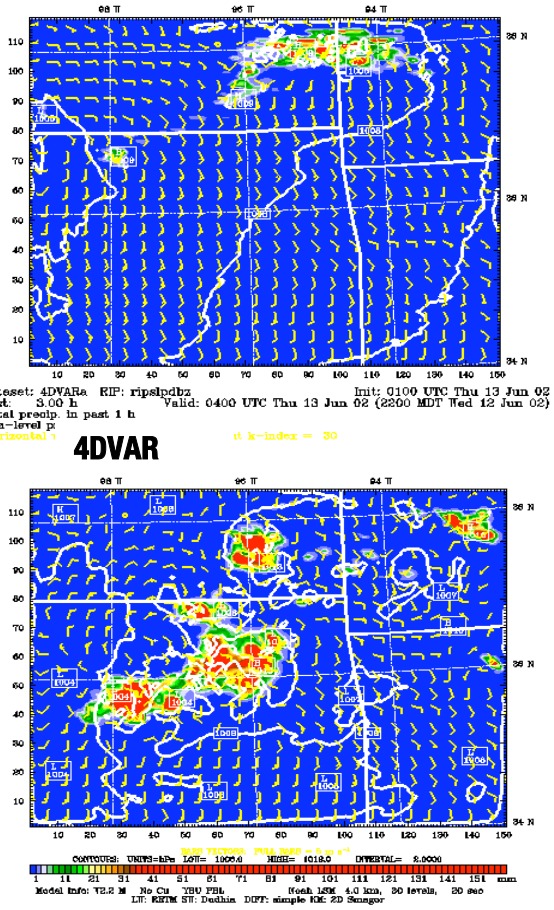
Dataset: TRUTH RIP: ripslpdbz Init: 0100 UTC Thu 13 Jun 02
Fcst: 3.00 h Valid: 0400 UTC Thu 13 Jun 02 (2200 MDT Wed 12 Jun 02)
Total precip. in past 1 h
Sea-level pressure

TRUTH



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

NODA



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

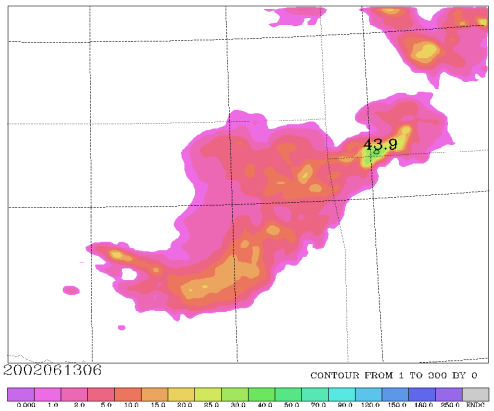
3DVAR

Dataset: 4DVARa 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

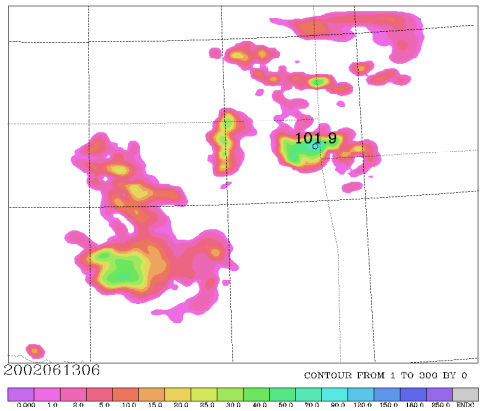
4DVAR

Radar data assimilation (cont'd)
Real data experiments

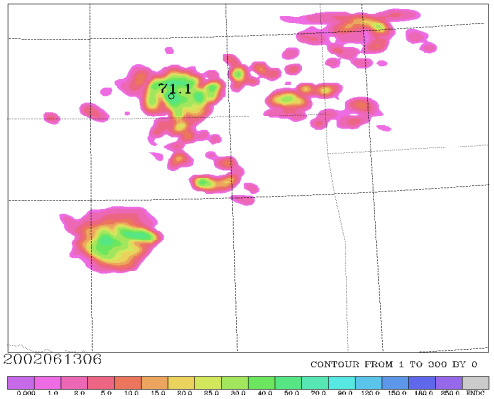
OBS



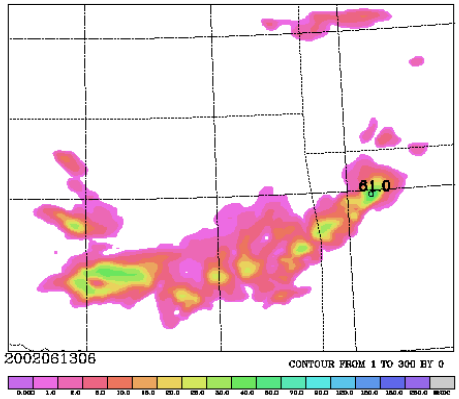
GFS



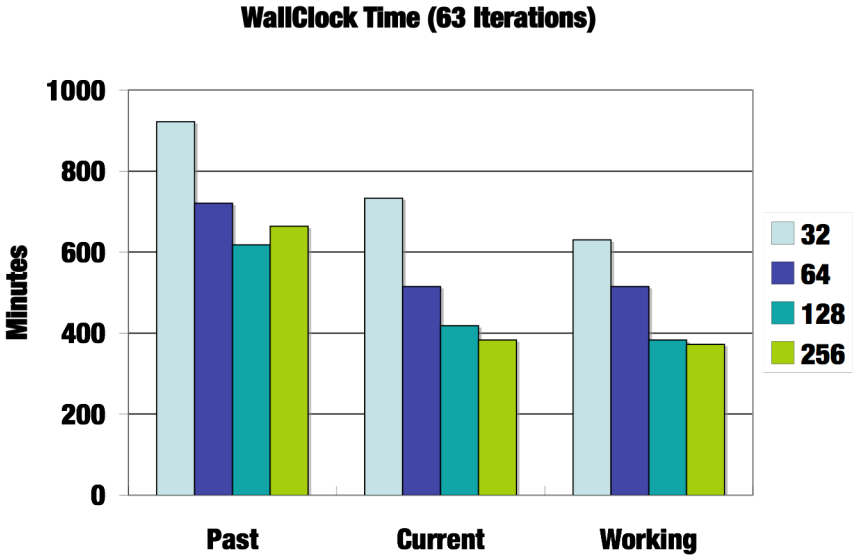
3DVAR

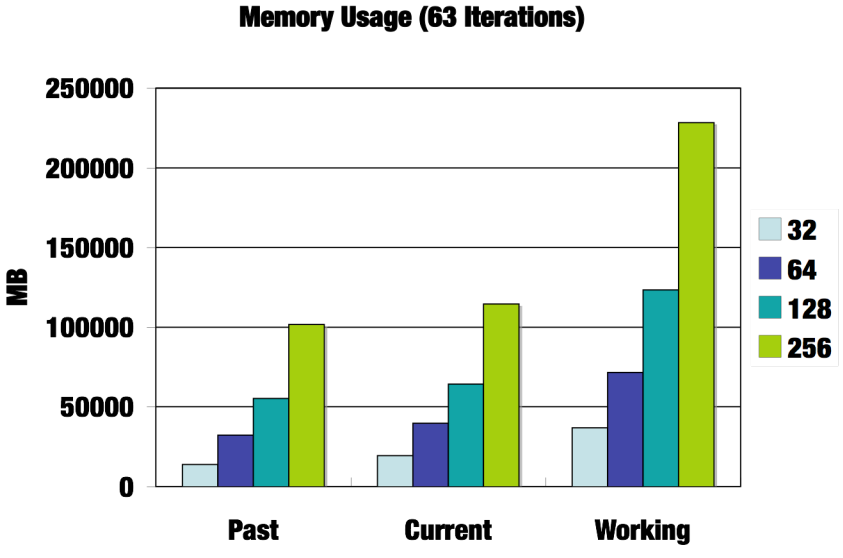


4DVAR



Computational Efficiency of IKE hurricane case on NCAR Bluefire





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

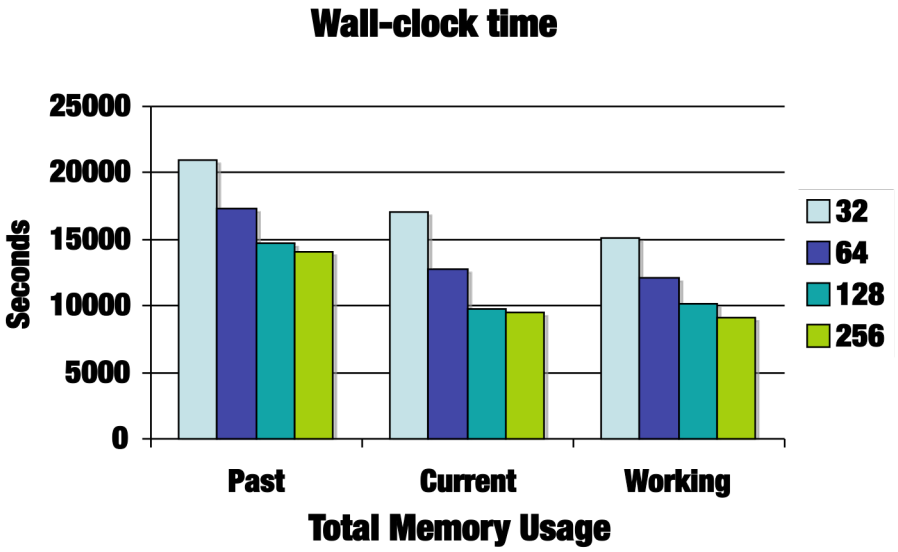
Time window:30m

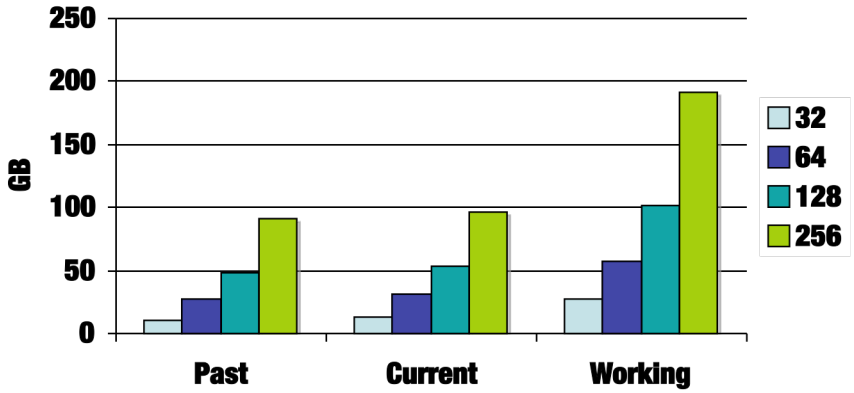
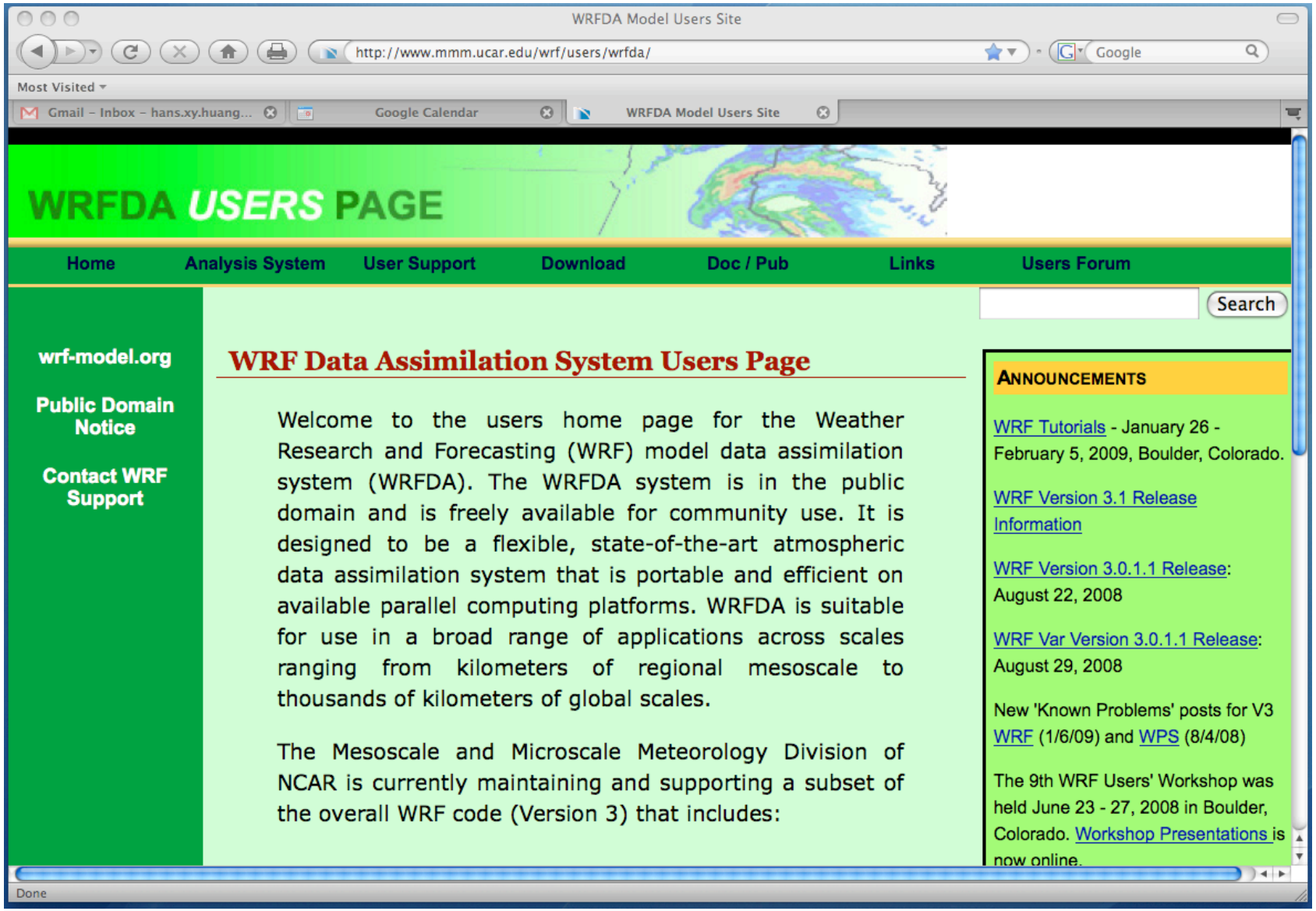
# of iterations: 60

Obs.: OSSE radar wind

# of obs.: 262,517

Obs Freq: 5m





Release of WRFDA V3.1