

WRF-(4D)Var

Xiang-Yu Huang[†], Qingnong Xiao, Wei Huang, Dale Barker,
Ying-Hwa Kuo, John Michalakes, Zaizhong Ma[‡]

National Center for Atmospheric Research

[†] On leave from Danish Meteorological Institute,
Copenhagen, Denmark

[‡] On leave from Institute of Atmospheric Physics, Chinese
Academy of Sciences, Beijing, China.

Outline

1. WRF-(4D)Var project
2. WRF-(4D)Var formulation
3. Current status
4. Near future plan

WRF-(4D)Var project

Supported by AFWA

Schedule

- **FY04: prepare.** (wrf model, simplified model, testing TAF on wrf subroutines.)
- **FY05: construct.** [4D-Var framework, basic (dry) wrf TL and AD components, initial experiments.] – stage I and stage II.
- **FY06: refine.** (more physics, parallel code, extensive testing.) – stage III and stage IV.

Why 4D-Var?

- Use observations over a time interval, which suits most asynoptic data.
- Use a forecast model as a constraint, which ensures the dynamic balance of the analysis.
- Implicitly use flow-dependent background errors, which ensures the analysis quality for fast developing weather systems.

Important issues

- *H* observation operator, including the tangent linear operator **H** and the adjoint operator **H^T**.
- *M* forecast model, including the tangent linear model **M** and adjoint model **M^T**.
- **B** background error covariance (N*N matrix $\sim 10^{14}$).
- **R** observation error covariance which includes the representative error (K*K matrix 10^{12}).

WRF-(4D)Var

- H , \mathbf{H} and \mathbf{H}^T : WRF-3DVar (with modifications)
- \mathbf{R} : WRF-3DVar
- \mathbf{B} : WRF-3DVar

- M : WRF model
- \mathbf{M} and \mathbf{M}^T :

- WRF-4DVar framework

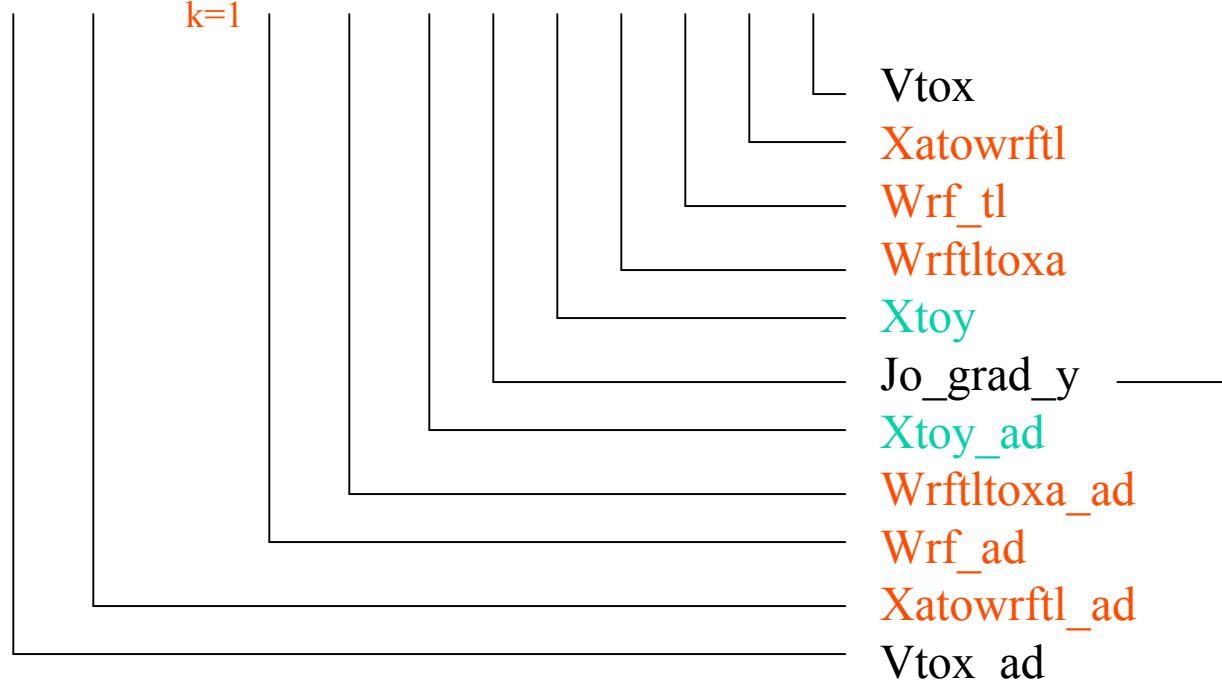
Black – WRF-3DVar
 Green – modification required
 Blue – existing (for 4DVar)
 Red – new development

WRF-(4D)Var formulation

Outer-loop: $\left[\begin{array}{l} \text{innovation} \\ \left[\text{wrf_nl} \right] \end{array} \right]$

$$J'_{\chi^n} = \chi^n + \sum_{i=1}^{n-1} \chi^i + \mathbf{U}^{-\mathbf{T}} \mathbf{S}_{\mathbf{V}-\mathbf{W}}^{\mathbf{T}} \sum_{k=1}^K \mathbf{M}_k^{\mathbf{T}} \mathbf{S}_{\mathbf{W}-\mathbf{V}}^{\mathbf{T}} \mathbf{H}_k^{\mathbf{T}} \mathbf{R}^{-1} [\mathbf{H}_k \mathbf{S}_{\mathbf{W}-\mathbf{V}} \mathbf{M}_k \mathbf{S}_{\mathbf{V}-\mathbf{W}} \mathbf{U}^{-1} \chi^n + H_k(\mathbf{M}_k(\chi^{n-1})) - \mathbf{y}_k]$$

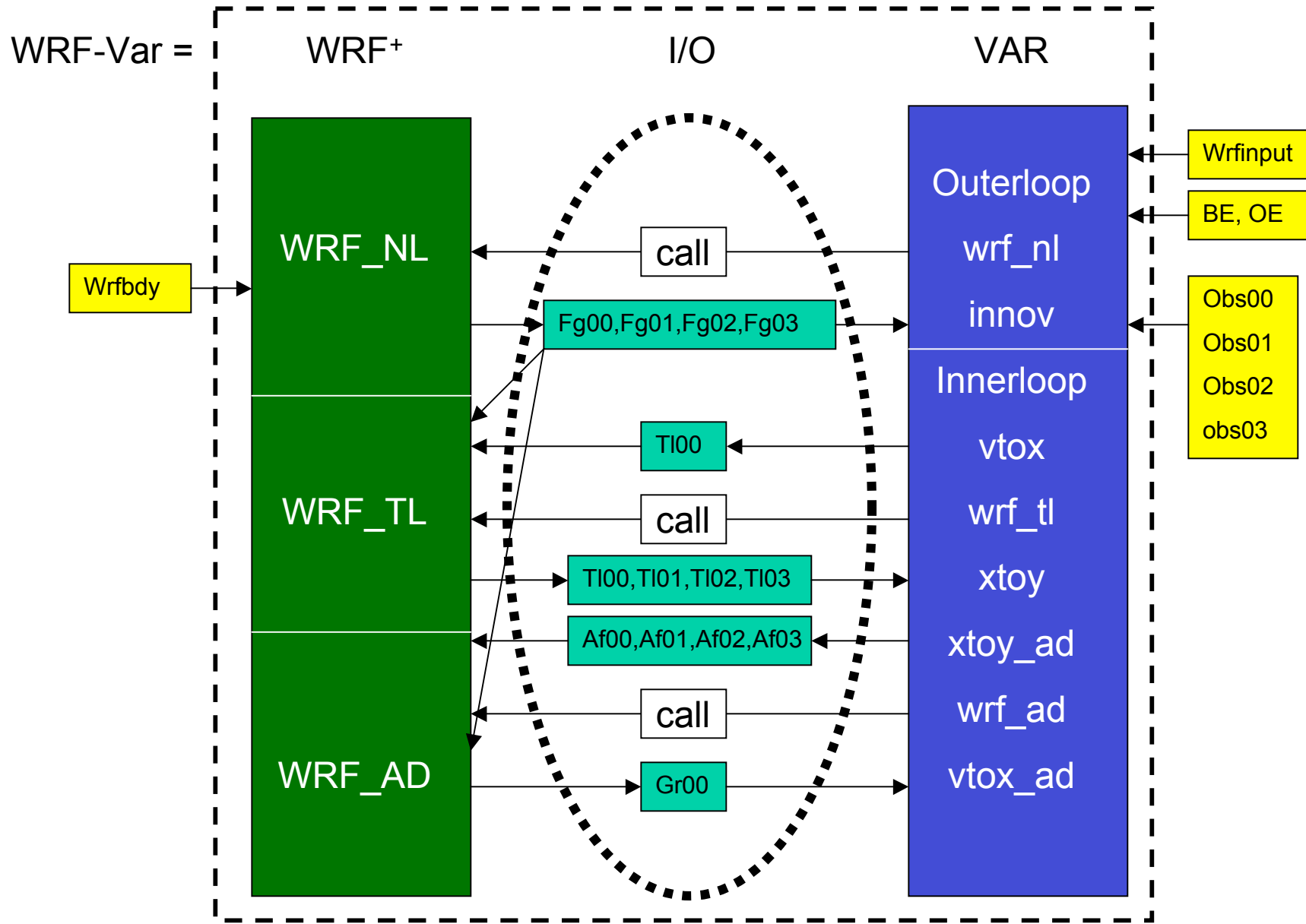
Inner-loop:



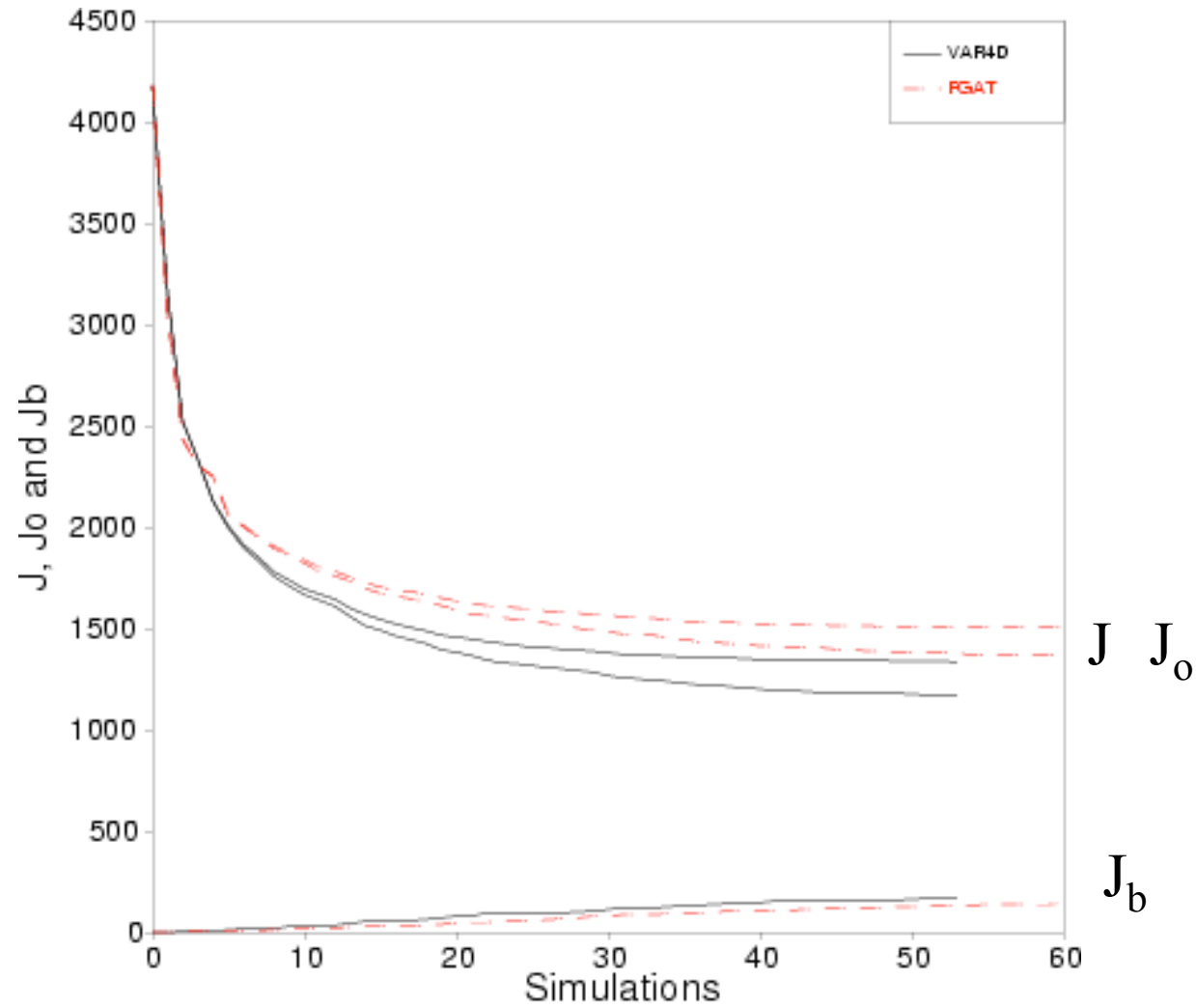
Stage I. Prepare VAR (start from WRF-3DVar) - finished.

Subroutine	Comments	Current status
innovation	Break H to H_k	Ready due to FGAT
wrf_nl	Exists	Start with a system call
vtox	The same as in 3DVAR	Ready
wrf_tl	New development	Start with I
xtoy	Break \mathbf{H} to \mathbf{H}_k	Done
Jo_grad_y	Can be applied for all obs win	Ready
xtoy_ad	Break \mathbf{H}^T to \mathbf{H}_k^T	Done
wrf_ad	New development	Start with I
vtox_ad	The same as in 3DVAR	Ready

Stage II. Use separate executables, communicate through I/O



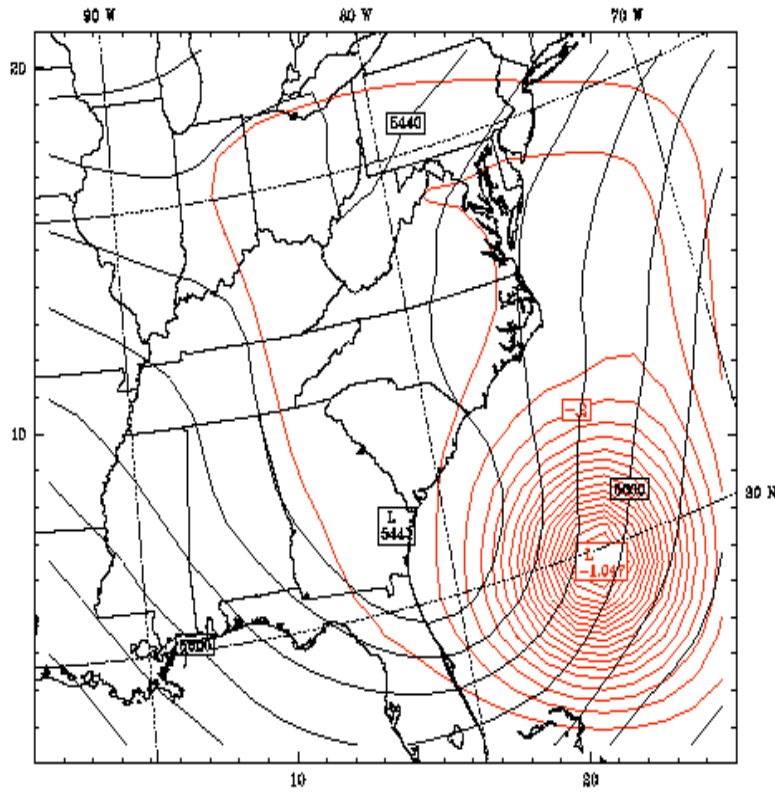
The first WRF-4DVar run



500mb θ increments at 00h to a 500mb T observation at 03h

Dataset: mytest RIP: rip Init: 0000 UTC Tue 25 Jan 00
 Fcst: 0.00 h Valid: 0000 UTC Tue 25 Jan 00 (1700 MST Mon 24 Jan 00)
 PETURBATION perturbation potential θ at pressure = 500 hPa
 Geopotential height at pressure = 500 hPa

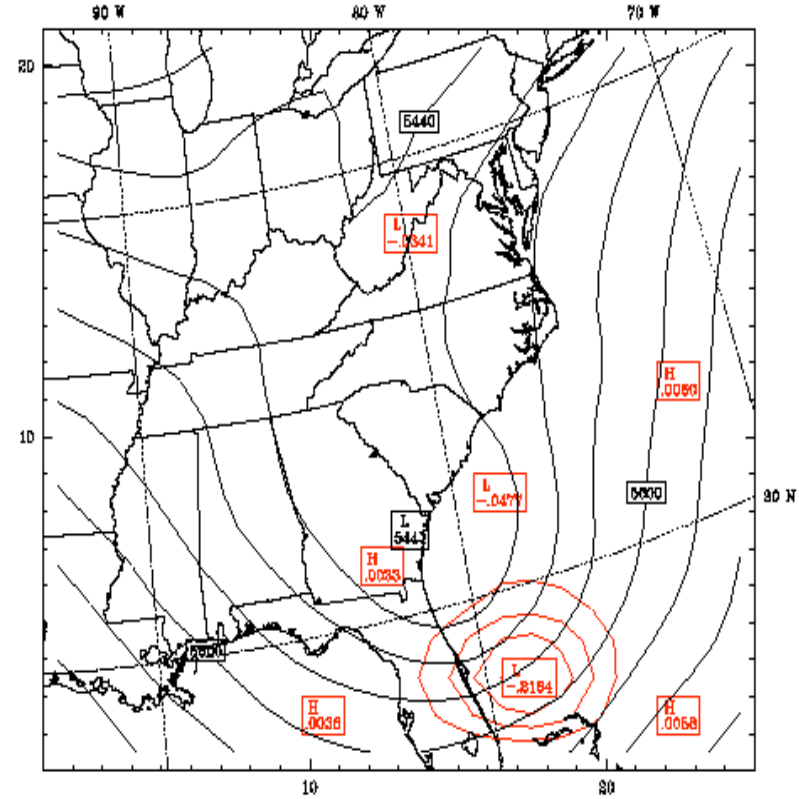
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 PETURBATION perturbation potential θ at pressure = 500 hPa
 Geopotential height at pressure = 500 hPa



CONTOURS: UNITS=m LOW= 5400.0 HIGH= 5720.0 INTERVAL= 40.000
 CONTOURS: UNITS=k LOW= -1.0000 HIGH=-0.5000E-01 INTERVAL= 0.5000E-01
 Model Info: V2.0.3.1 No Cu No PBL No microph No SFC 90 km, 18 levels, 900 sec
 LW: none SW: none DIFF: none

3DVAR

WRF-(4D)Var



CONTOURS: UNITS=m LOW= 5400.0 HIGH= 5720.0 INTERVAL= 40.000
 CONTOURS: UNITS=k LOW=-0.80000 HIGH= 0.0000 INTERVAL= 0.5000E-01
 Model Info: V2.0.3.1 No Cu No PBL No microph No SFC 90 km, 18 levels, 900 sec
 LW: none SW: none DIFF: none

4DVAR

NCAR-CSU DA workshop 9/19/2005

Summary

1. WRF-(4D)Var project: 2004-2006.
2. WRF-(4D)Var formulation:
 - Based on the existing WRF 3D-Var and WRF model
 - Multi-incremental
 - Simplified tangent linear and adjoint models
3. Current status of WRF-(4D)Var:
 - Necessary modifications to WRF-3DVar have been completed.
 - WRF-(4D)Var framework has been done.
 - The prototype has been put together and “can run”.
4. Near future plan
 - Evaluate the performance through single observation experiments and case studies
 - Prepare for the Stage III (I/O to memory) and Stage IV (more physics, MPP, etc) work.

500mb θ increments at 00h to a 500mb T observation at 03h

