Status of WRF 4D-Var

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Why 4D-Var?

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

Outline

1. WRF 4D-Var milestones
2. The current status: The basic system
3. Weak constraint for noise control: JcDFI
4. A cycling experiment
5. The ongoing work

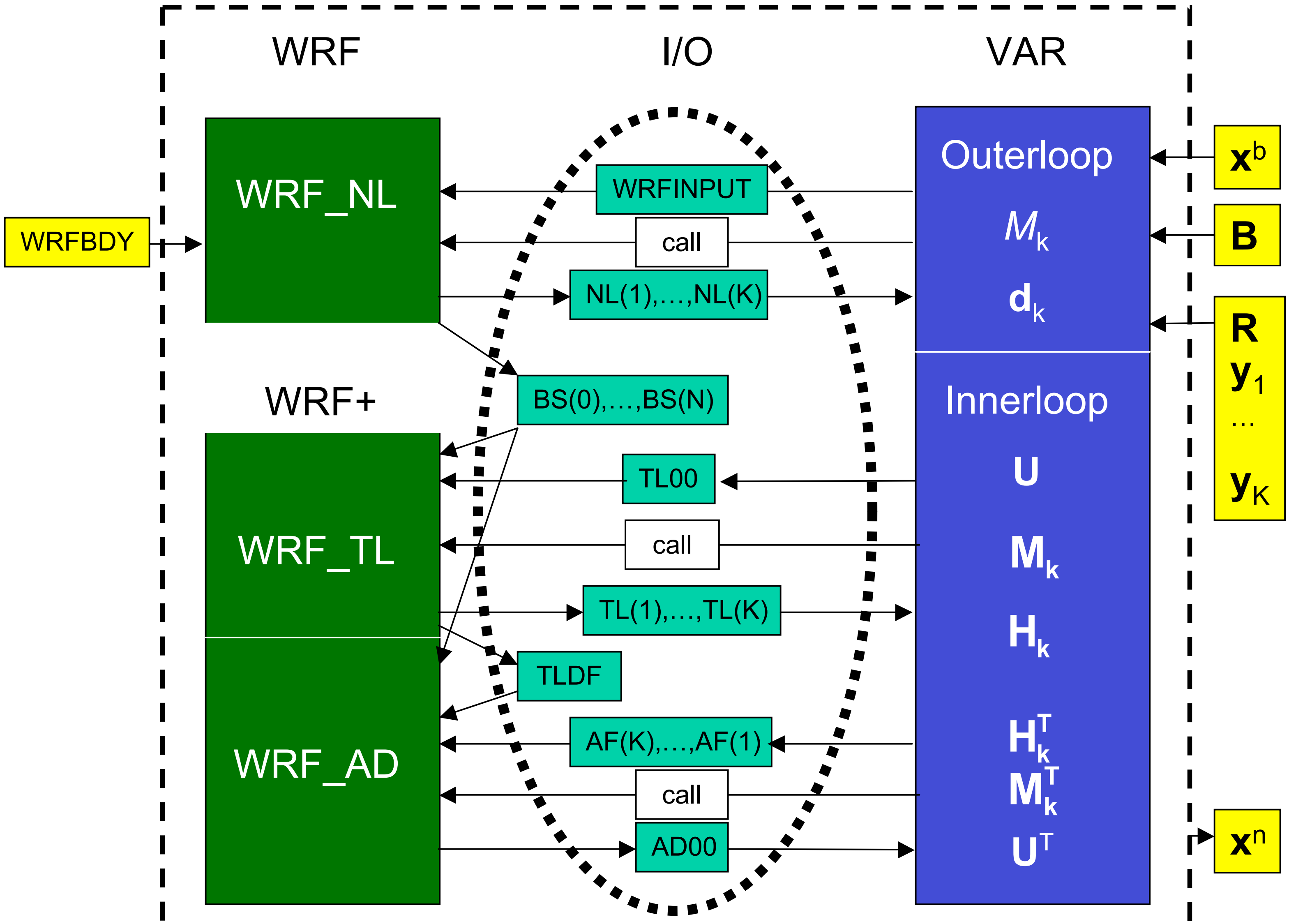
WRF 4D-Var milestones

2003: WRF 4D-Var project.	?? FTE
2004: WRF SN (simplified nonlinear model).	1.5 FTE
Modifications to WRF 3D-Var.	
2005: TL and AD of WRF dynamics.	1.5 FTE
WRF TL and AD framework.	
WRF 4D-Var framework.	
2006: The WRF 4D-Var prototype.	2.5 FTE
Single ob and real data experiments.	
Parallelization of WRF TL and AD.	
Simple physics TL and AD.	
JcDFI	
2007: The WRF 4D-Var basic system.	2.5 FTE

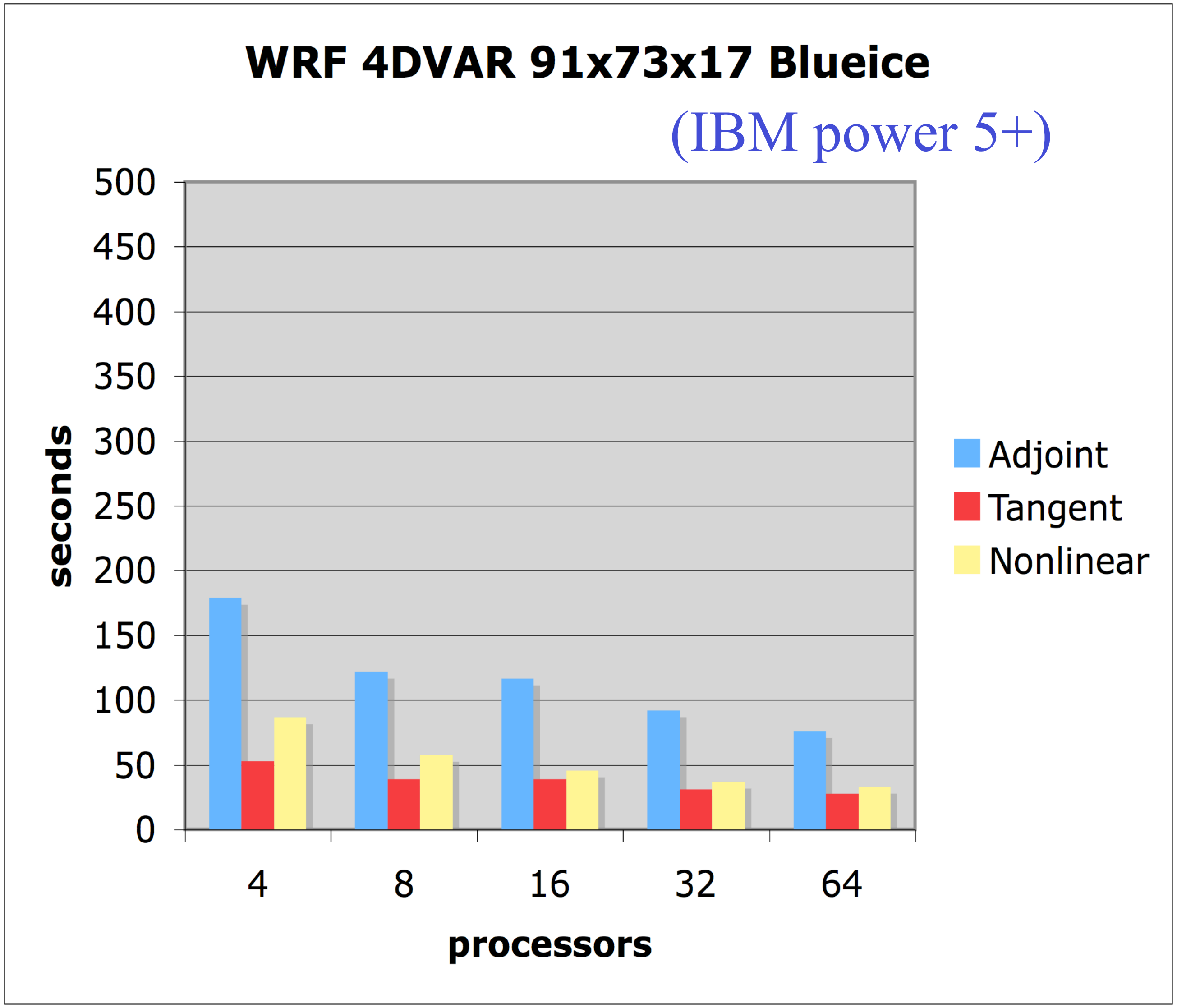
The WRF 4D-Var basic system

- WRF, VAR and WRF+ parallelized in WRF Software Framework
  - WRF TL/AD (dyn + vdiff + lsc) produced using TAF (www.fastopt.com)
  - Parallel versions from hand-parallelized TAF output
- MPMD execution on processors sets under IBM load-leveler/LSF
- Coupling (coordination and exchange) among WRF, VAR and WRF+ through files

Basic system: 3 exes, disk I/O, parallel, simple phys, JcDF



Wall clock of 6 hours integration



JcDF in WRF 4D-Var

Weak constraint for noise control

Before: $J = J_o + J_b$

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

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

After: $J = J_o + J_b + J_c$

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

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

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

where:

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

Performance of JcDF

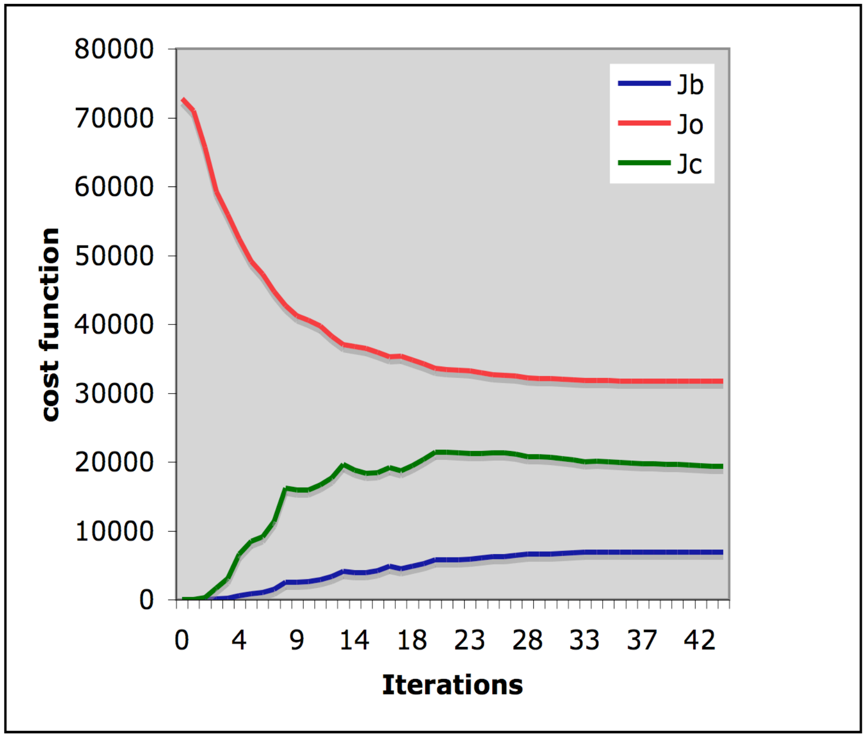


Figure 3 Cost functions without JcDF (gama=0.1)

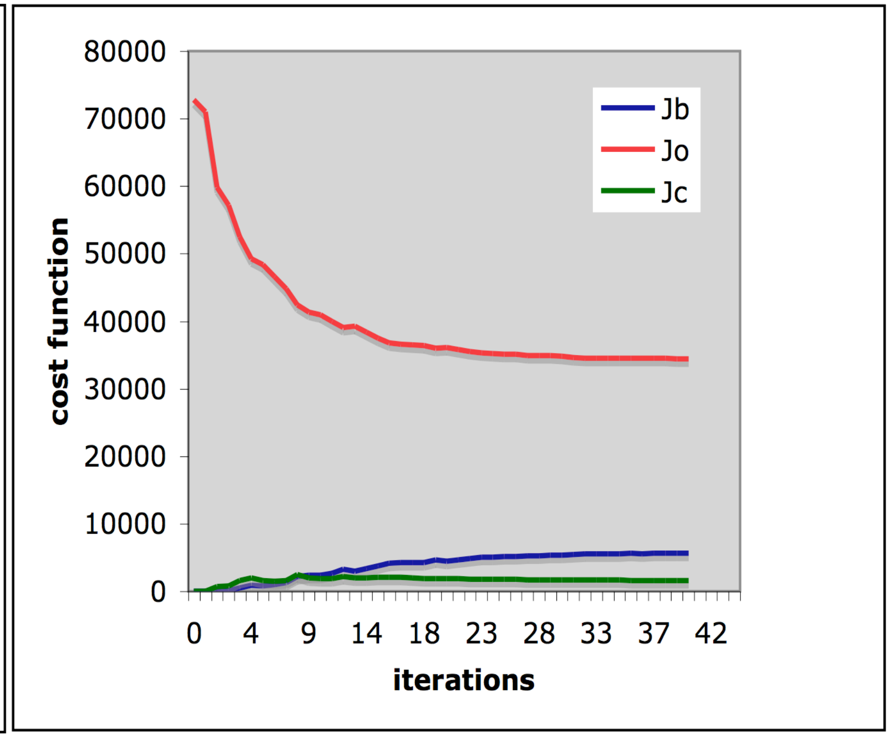
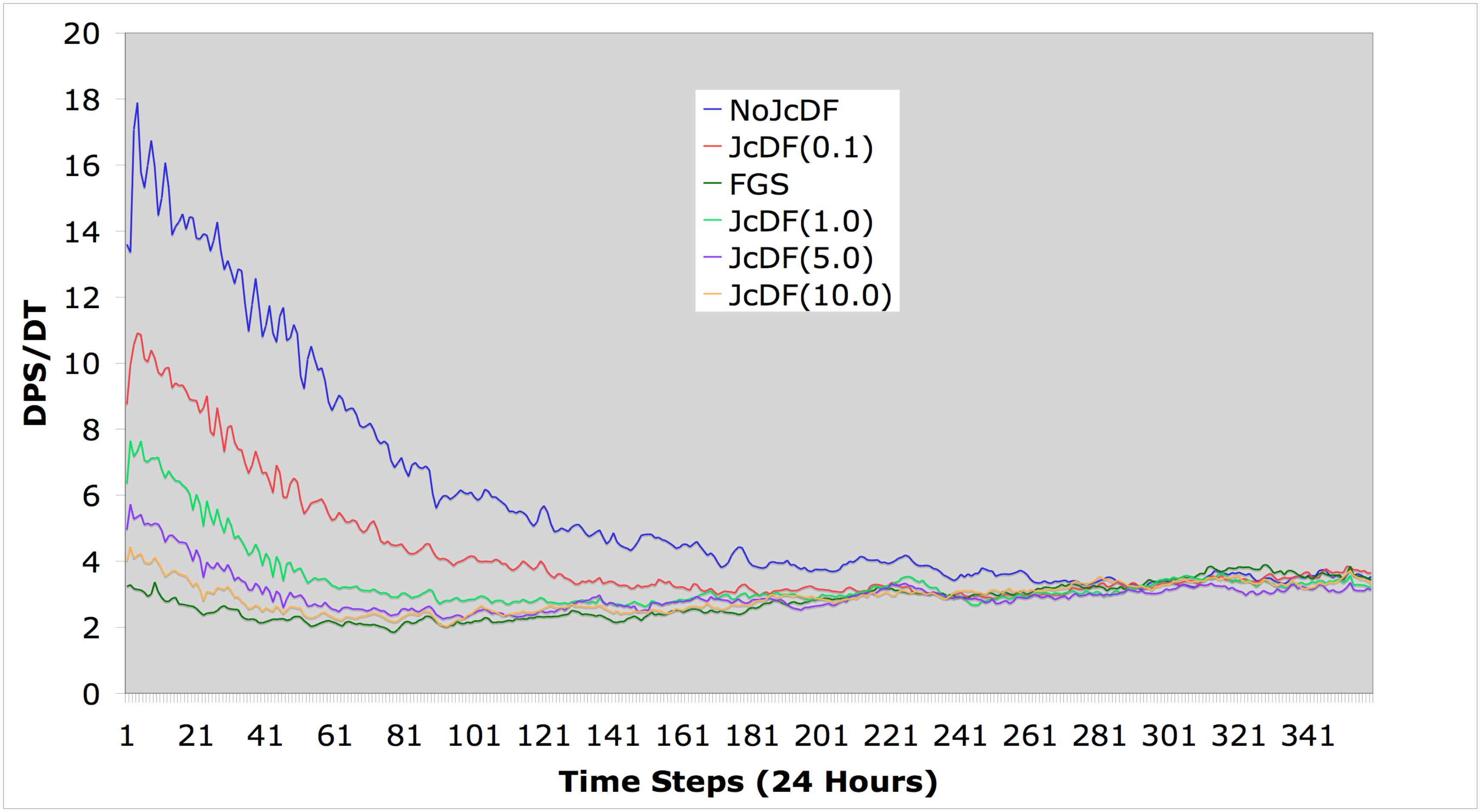


Figure 4 Cost functions with JcDF (gama=0.1)

Domain-averaged absolute surface pressure tendency (hPa/3h)



A KMA Heavy Rain Case

Period: 12 UTC 4 May - 00 UTC 7 May, 2006

Assimilation window: 6 hours

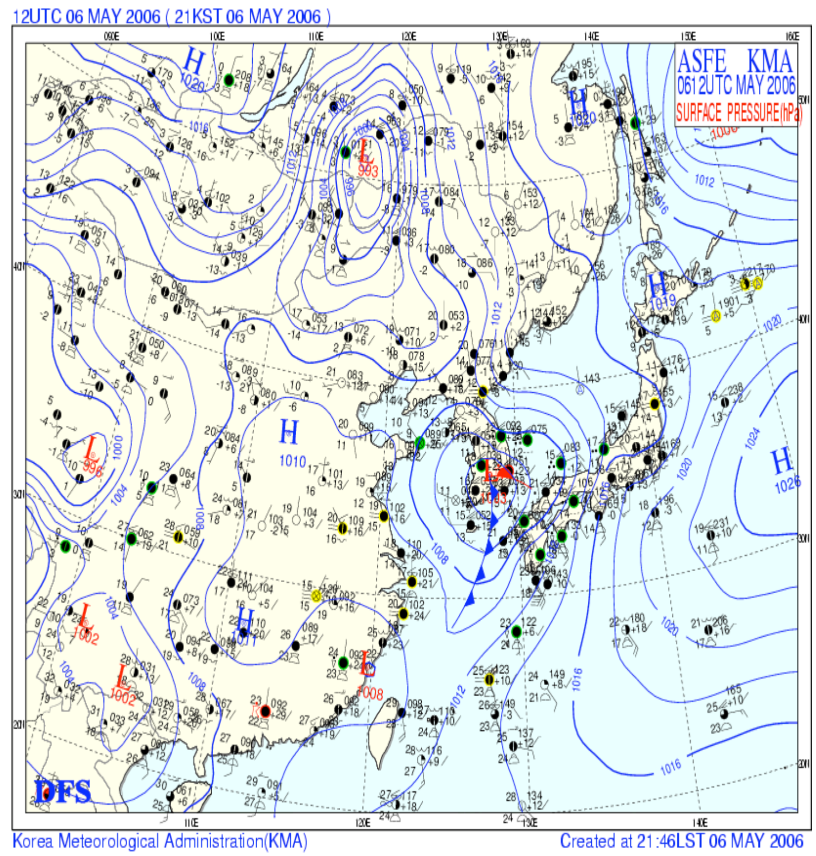
Cycling

All KMA operational data

Grid : 60x54x31

Resolution : 30km

Domain size: the same as the KMA operational 10km domain.



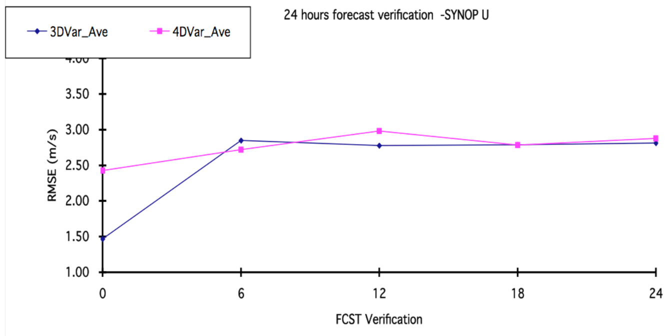
Observations used in 3D-Var

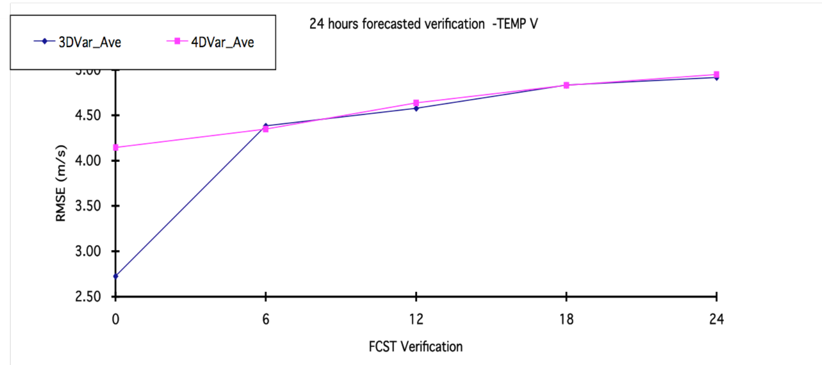
	U wind	V wind	Temperature	Pressure	Water vapor
SOUND	459	464	519	-	385
SONDE_SFC	14	15	15	15	15
SYNOP	67	59	73	71	72
GEOAMV	74	76	-	-	-
PILOT	182	195	-	-	-
METAR	559	551	614	33	36
SHIP	1	1	2	2	1

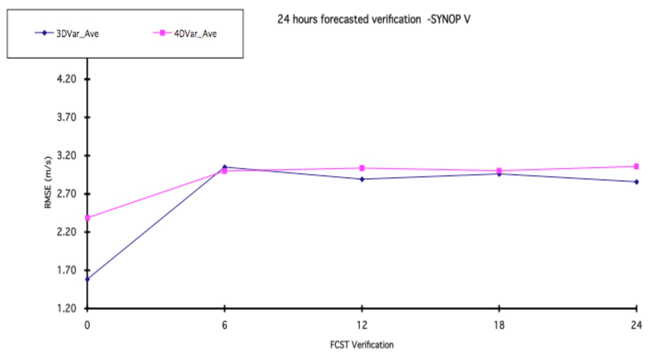
Observations used in 4D-Var

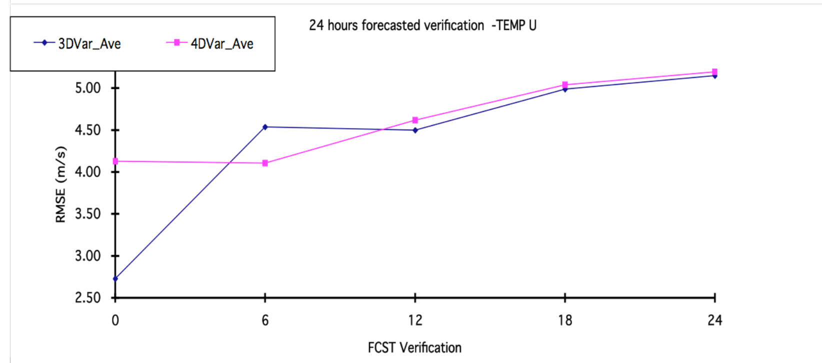
	U wind	V wind	Temperature	Pressure	Water vapor
SOUND	456	461	519	-	384
SONDE_SFC	14	14	15	14	15
SYNOP	253	212	268	191	204
GEOAMV	-	-	-	-	-
PILOT	185	194	-	-	-
METAR	2636	2402	2957	218	240
SHIP	1	1	2	2	1

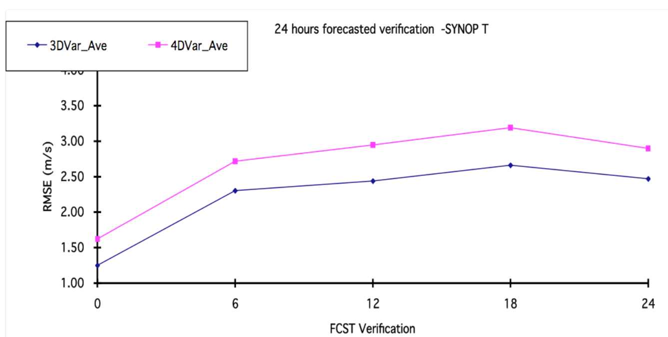
Observations Verification

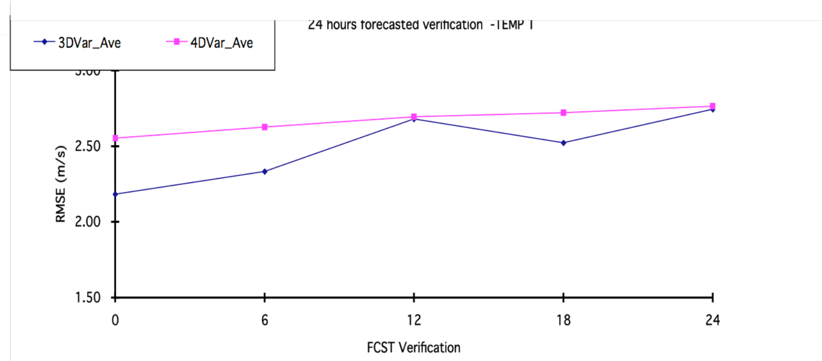




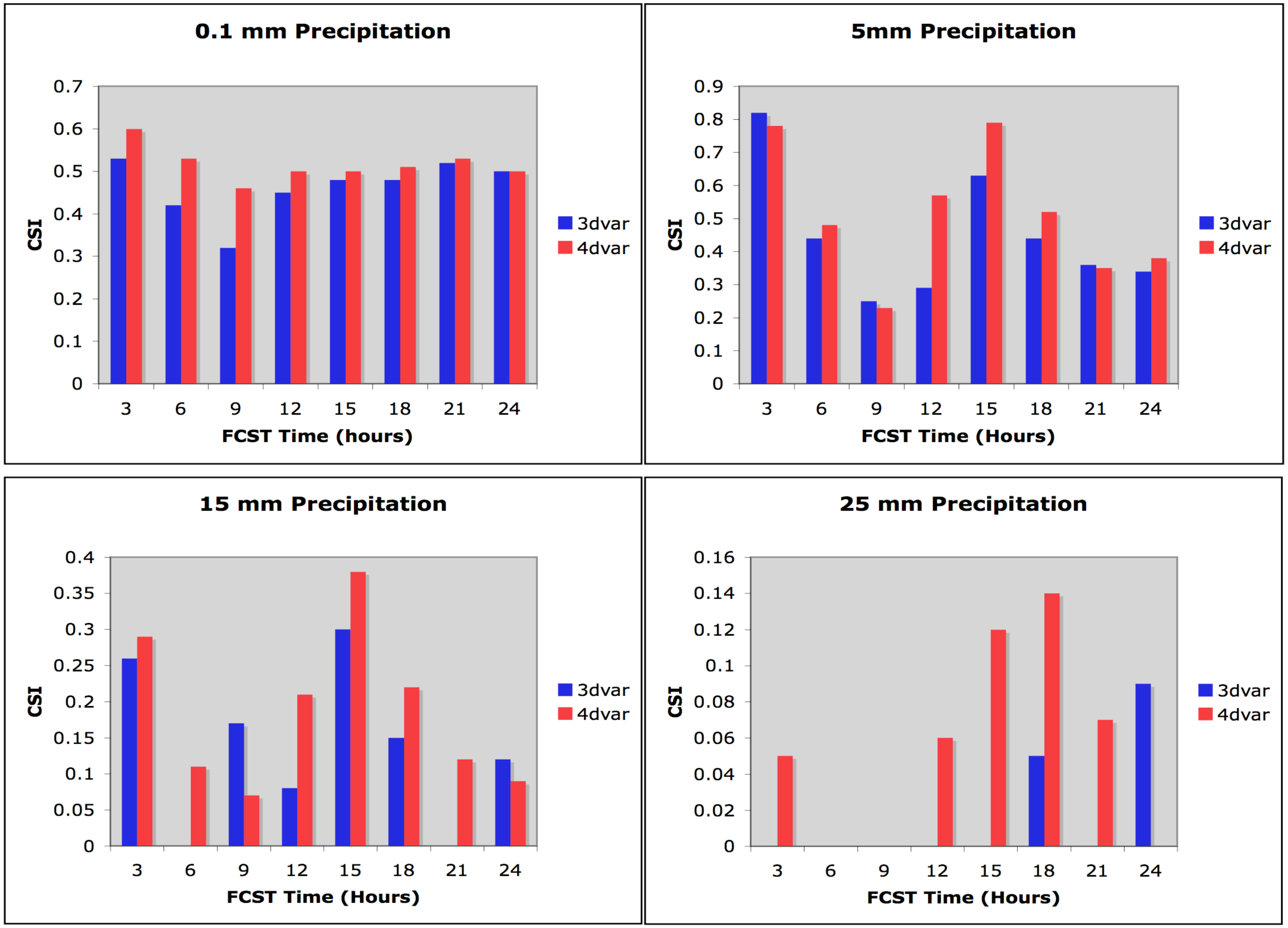








Precipitation Verification



Work plan for 2007

1. Multi-incremental formulation
2. Optimization
3. Convection
4. Meteorological tests
5. Lateral boundary control
6. Analysis on C-grid