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

WRF 4DVAR 91x73x17 Blueice

(IBM power 5+)

![Bar chart showing performance of WRF 4DVAR on Blueice with different numbers of processors. The chart compares adjoint, tangent, and nonlinear operations in terms of wall clock time.](image)
JcDF in WRF 4D-Var
Weak constraint for noise control

Before: \( J = J_o + J_b \)

\[
J_b(x_0) = \frac{1}{2} \left[ (x_0 - x_b)^T B^{-1} (x_0 - x_b) \right]
\]

\[
J_o(x_0) = \frac{1}{2} \sum_{k=1}^{K} \left[ (H_k x_k - y_k)^T R^{-1} (H_k x_k - y_k) \right]
\]

After: \( J = J_o + J_b + J_c \)

\[
J_c(x_0) = \frac{\gamma_{df}}{2} \left[ (\delta x_{N/2} - \delta x_{df})^T C^{-1} (\delta x_{N/2} - \delta x_{df}) \right]
\]

\[
= \frac{\gamma_{df}}{2} \left[ \left( \delta x_{N/2} - \sum_{i=0}^{N} f_i \delta x_i \right)^T C^{-1} \left( \delta x_{N/2} - \sum_{i=0}^{N} f_i \delta x_i \right) \right]
\]

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

where:

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

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Observations Verification
Precipitation Verification

0.1 mm Precipitation

5mm Precipitation

15 mm Precipitation

25 mm Precipitation
Work plan for 2007

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