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

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("Four-Dimensional Variational Data Assimilation for WRF: Formulation and Preliminary Results”, 2008: Submitted to M.W.R., Xiang-Yu Huang, Qingnong Xiao, et al.)
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Current Status of WRF 4D-Var

\[ J'_{vn} = v^n + \sum_{i=1}^{n-1} v^i + \sum_{k=1}^{K} M_k S_{V-W}^T H_k^T R^{-1} [H_k S_{W-V} M_k S_{V-W} U^{-1} v^n + H_k (M_k (x^{n-1}) - y_k)] \]

- **Black** – WRF-3DVar \([B, R, U=B^{1/2}, v^n=U^{-1}(x^n-x^{n-1})]\)
- **Green** – modification required
- **Blue** – existing (for 4DVar)--WRF
- **Red** – new development

*(Huang, et.al. 2006: Preliminary results of WRF 4D-Var. WRF users’ workshop, Boulder, Colorado.)*
Scientific Performance of WRF 4D-Var

Typhoon Haitang experiments:

5 experiments, every 6 h, 00Z 16 July - 00 Z 18 July, 2005.
Typhoon Haitang hit Taiwan 00Z 18 July 2005

1. FGS – forecast from the background [The background fields are 6-h WRF forecasts from NCEP GFS analysis.]
2. AVN – forecast from the NCEP GFS analysis
3. 3DVAR – forecast from WRF 3D-Var
4. FGAT – first guess at appropriate time (A option of WRF-3DVAR)
5. 4DVAR – forecast from WRF 4D-Var

Domain size: 91x73x17
Resolution: 45 km
Time Window: 6 Hours,
Observations: GTS conventional observations, bogus data from CWB
Typhoon Haitang Verification

48-h forecast typhoon tracks from FGS, AVN, 3DVAR, FGAT, 4DVAR, together with the observed best track. Forecasts are all started from 0000 UTC 16 July 2005.
KMA Heavy Rain Case

- **Period**: 12 UTC 4 May - 00 UTC 9 May, 2006
- **Grid**: (60,54,31)
- **Resolution**: 30km
- **Domain size**: the same as the operational 10km domain.
- **Assimilation window**: 6 hours
- **Warm started cycling run**
Precipitation Verification

- 0.1 mm Precipitation
- 5mm Precipitation
- 15 mm Precipitation
- 25 mm Precipitation
• For general cases, the performance of WRF 4D-Var is comparable with WRF 3D-Var.

• For some fast developing, fine scale cases such as squall line, tropical cyclone, heavy rainfall case, WRF 4D-Var does a much better job than 3D-Var.
Software Engineering Performance of WRF 4D-Var

• Ability to assimilation all kinds of observation as 3D-Var (Radiance and Radar).

• Both serial and parallel runs are supported.

• Tested Platforms: IBM with XLF, Linux with PGI & G95, Mac G5 with G95 & XLF.

• Multi-incremental 4D-Var.
Timing of a Radar Assimilation Case on IBM blueice

**Domain size:** 151x118x31  
**Resolution:** 4km  
**Time-step:** 25s  
**Time window:** 15m  
**# of iterations:** 60  
**Obs.:** OSSE radar wind  
**# of obs.:** 262517  
**Obs Freq:** 5m

( P5.6 ASSIMILATION OF DOPPLER RADAR DATA WITH WRF 4DVAR FOR A CONVECTIVE CASE. Yong-Run Guo et al. 9th Annual WRF Users’ Workshop)

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On-going Works

- Remove Disk IO which is used as communication among WRF 4D-Var components, ESMF is a candidate. (~50% wall-clock time reduction, improve parallel scalability)
- Cleanup WRF Adjont model (~90% cost), trade re-computation with memory (another ~50% wall-clock time reduction).