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

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

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

WRF AD

WRF TL

ARW WRF

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

Scientific Performance of WRF 4D-Var

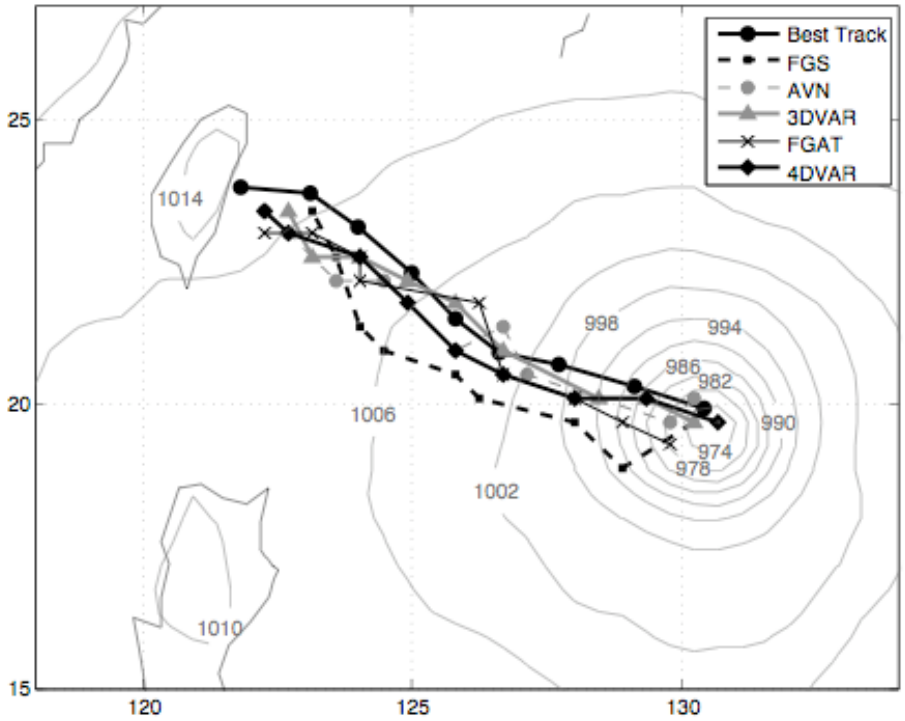
Typhoon Haitang experiments:

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

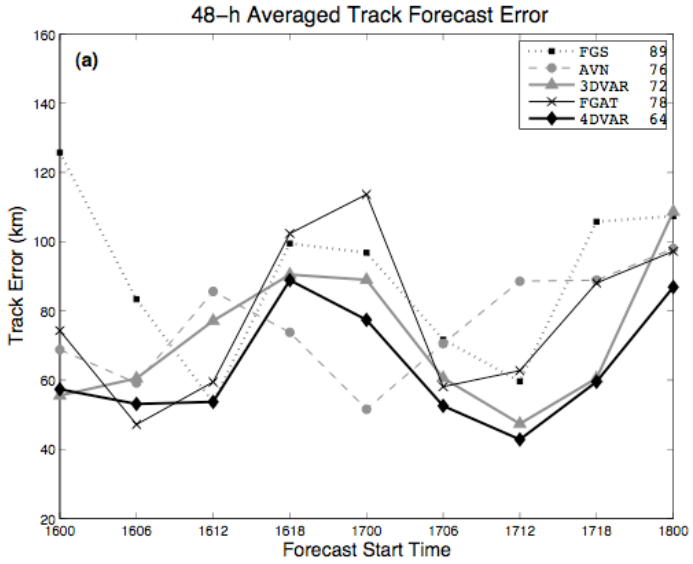
1. FGS – forecast from the background [The background fields are 6-h WRF forecasts from NCEP GFS analysis.]
2. AVN – forecast from the NCEP GFS analysis
3. 3DVAR – forecast from WRF 3D-Var
4. FGAT – first guess at appropriate time (A option of WRF-3DVAR)
5. 4DVAR – forecast from WRF 4D-Var

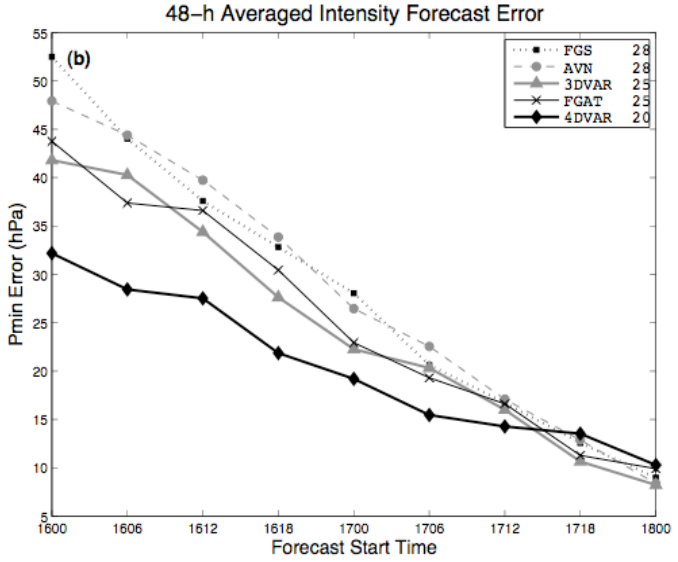
Domain size: 91x73x17
Resolution: 45 km
Time Window: 6 Hours,
Observations: GTS conventional observations, bogus data from CWB

Typhoon Haitang Verification

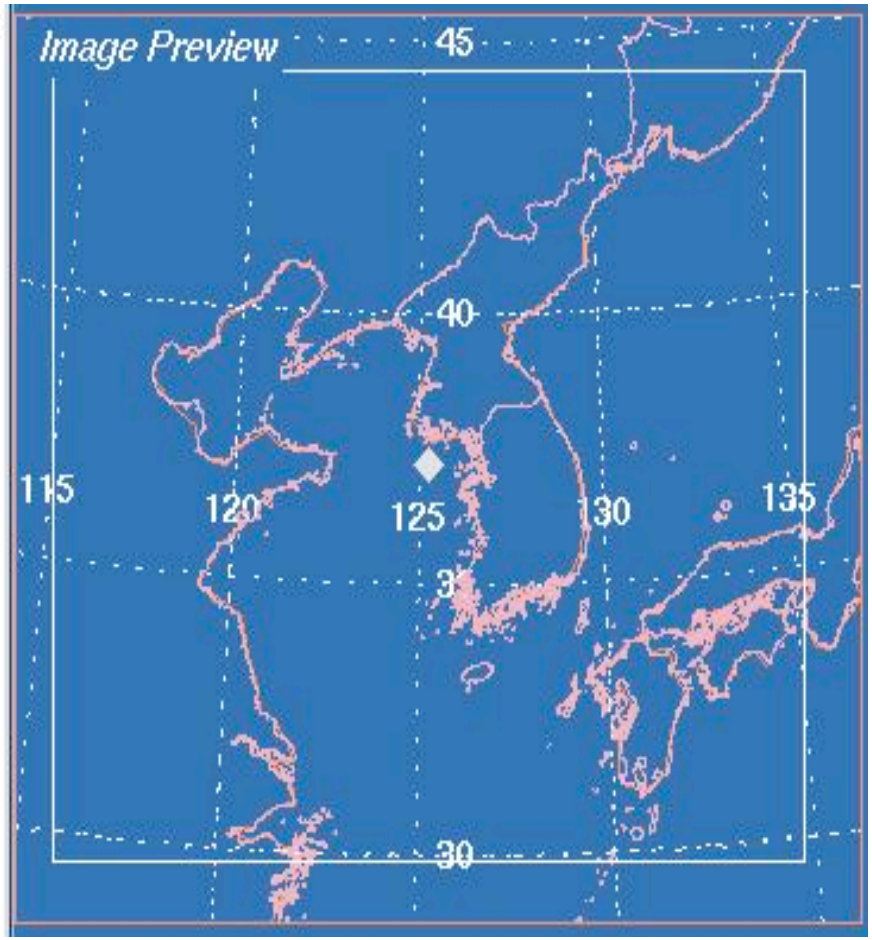


48-h forecast typhoon tracks from FGS, AVN, 3DVAR, FGAT, 4DVAR, together with the observed best track. Forecasts are all started from 0000 UTC 16 July 2005.



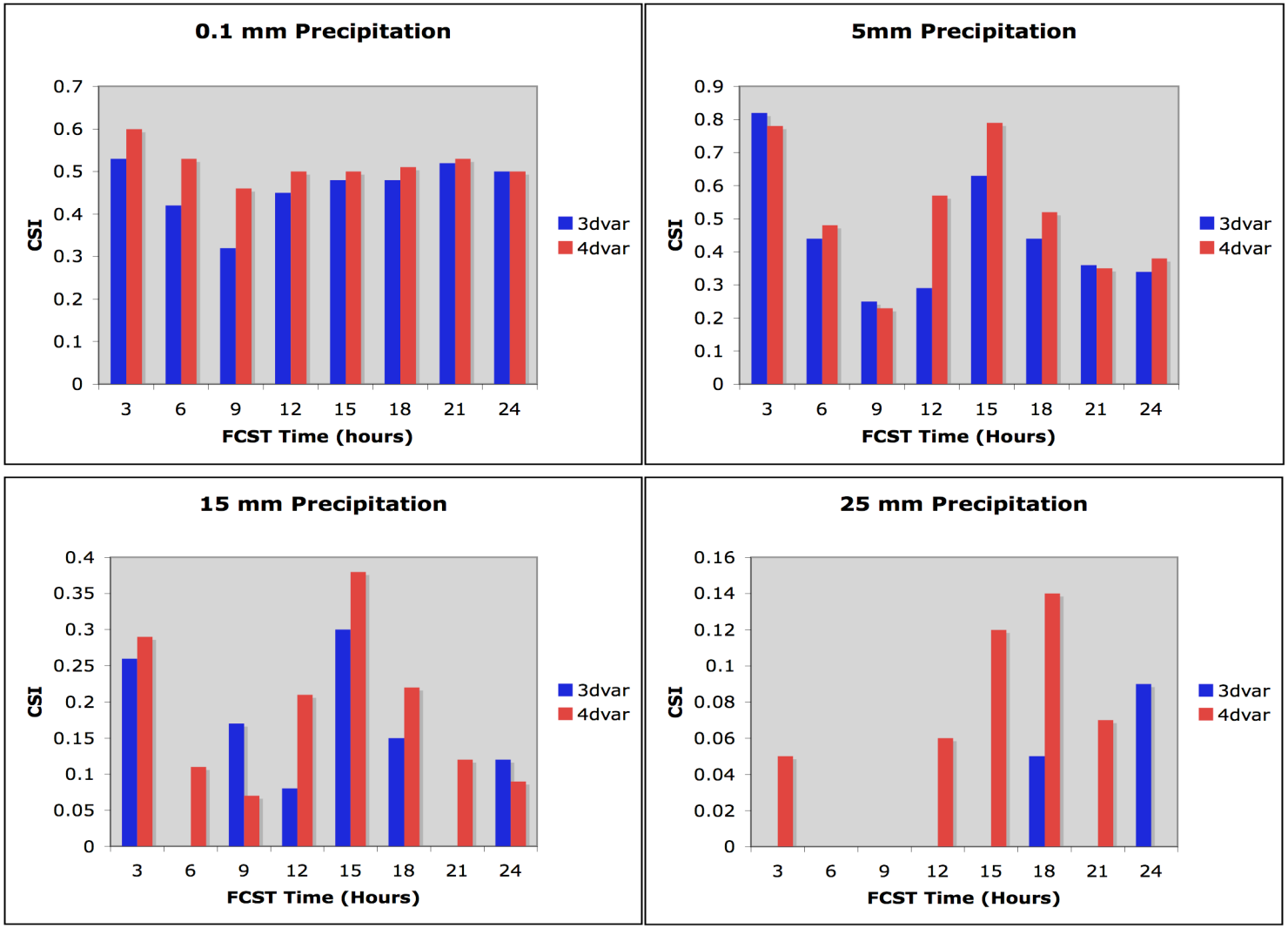


KMA Heavy Rain Case



- **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



- 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

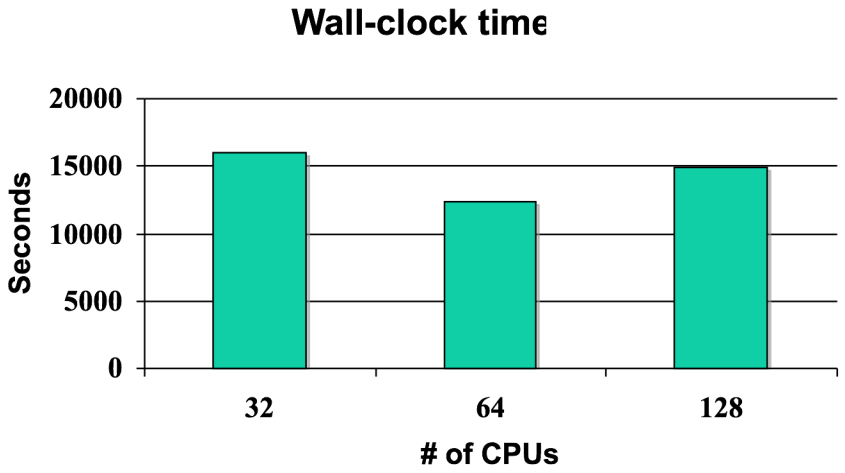
Time window:15m

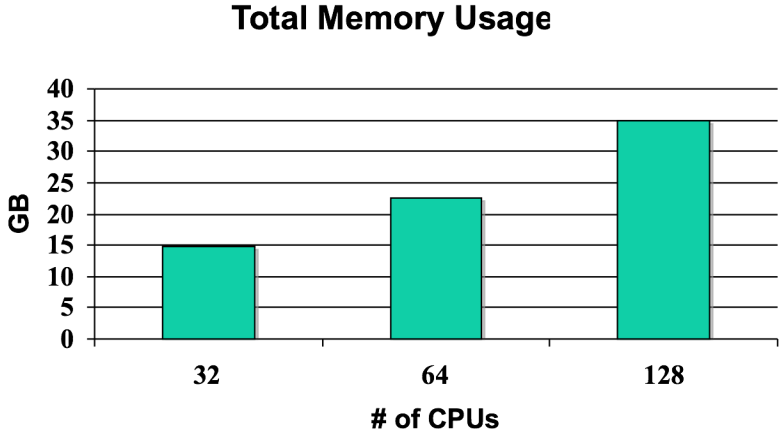
# of iterations: 60

Obs.: OSSE radar wind

# of obs.: 262517

Obs Freq: 5m





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

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).