# Overview Of Recent Developments And Results From WRF-Var

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National Center For Atmospheric Research

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**Acknowledge:**
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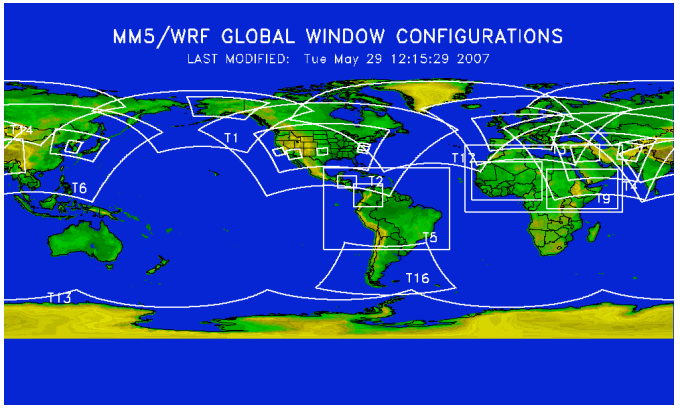
Beijing Meteorological Bureau,
Indian Met. Dept., National Center for Medium-Range Weather Prediction.

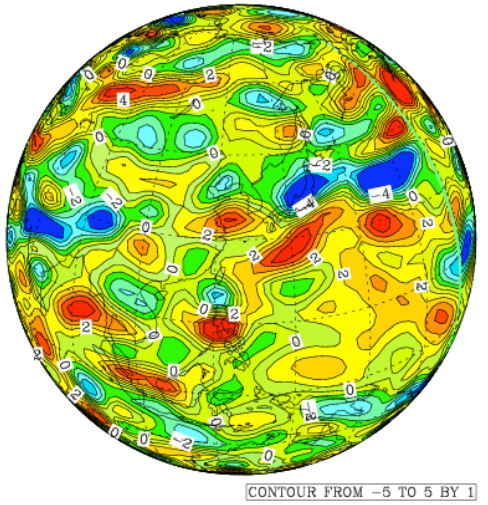
# WRF-Var Data Assimilation Overview

- **Techniques:** 3D-Var, 4D-Var (regional), Hybrid Variational/Ensemble DA.
- **Software Engineering:** WRF framework.
- **Multiple Models:** Runs with WRF, MM5, KMA global model, etc.
- **Support:** MMM Division, NCAR.
- **Applications:** Regional/global, Research/Operational, Deterministic/Ensemble,

AFWA Worldwide Theaters

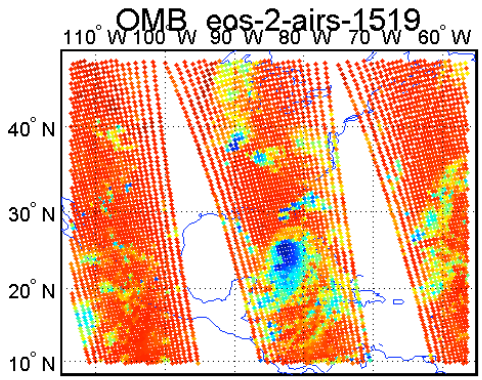


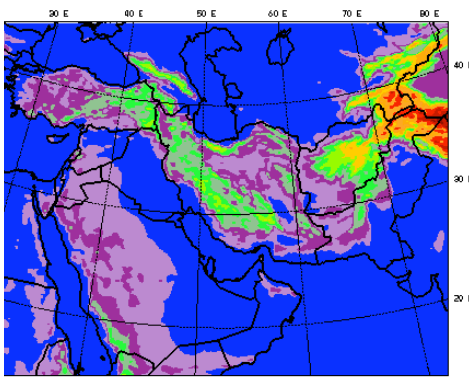

KMA T213/426 Global:

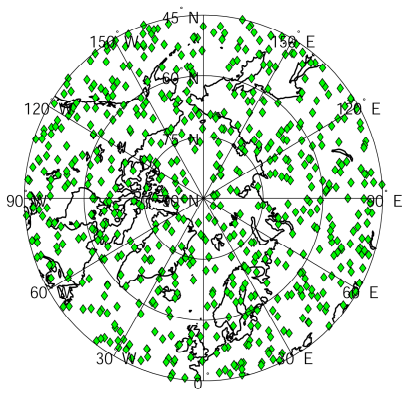


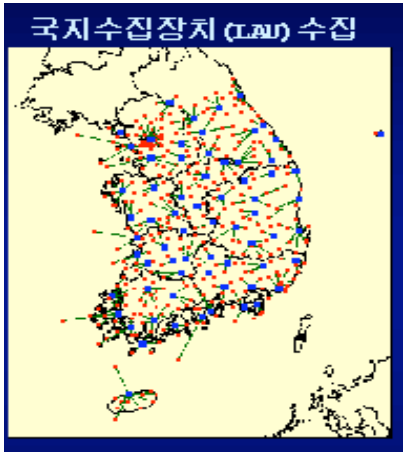
# The WRF-Var Program

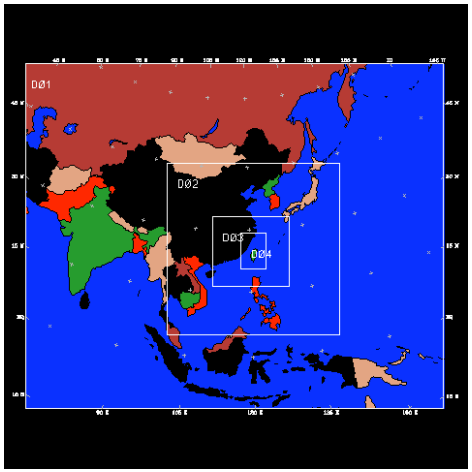
- NCAR staff: 23FTE, ~12 projects.
- Non-NCAR collaborators (AFWA, KMA, etc): ~10FTE.
- Community users: ~30 (more in 4000 general WRF downloads?).

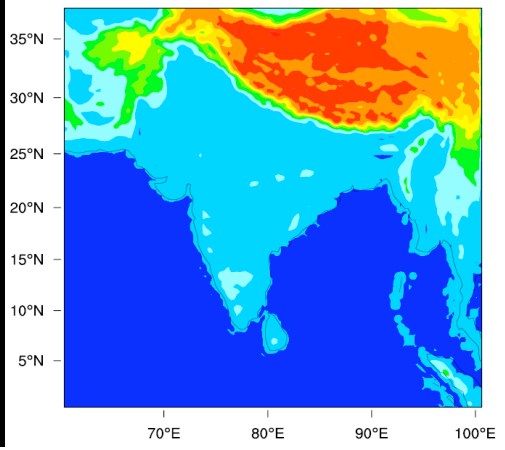


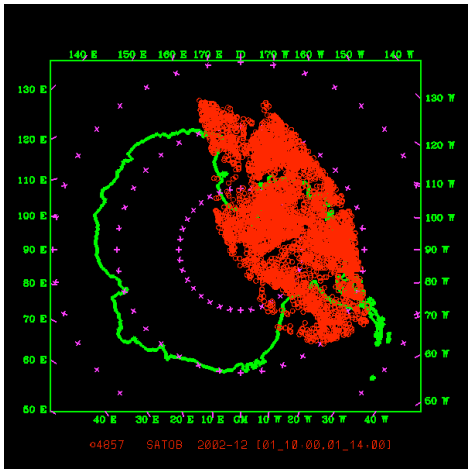



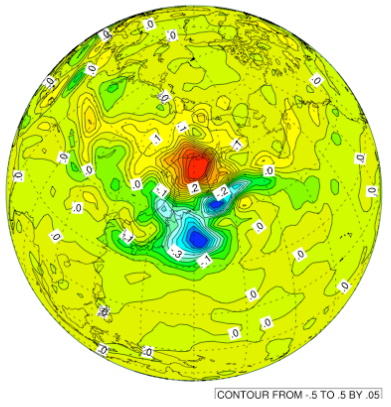




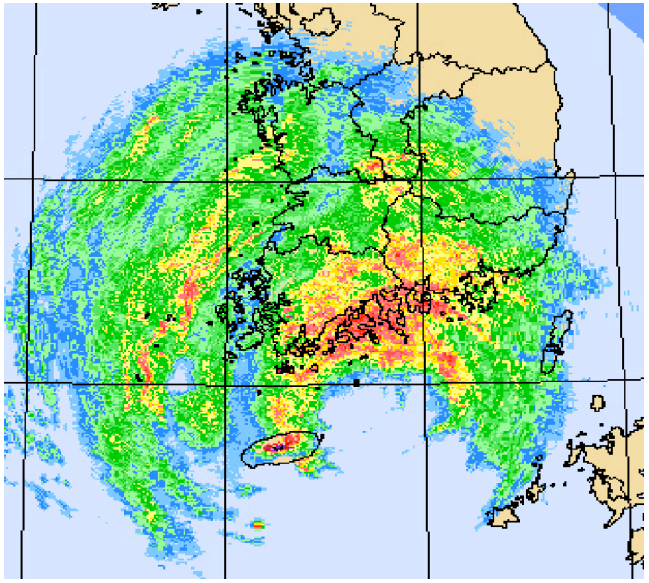



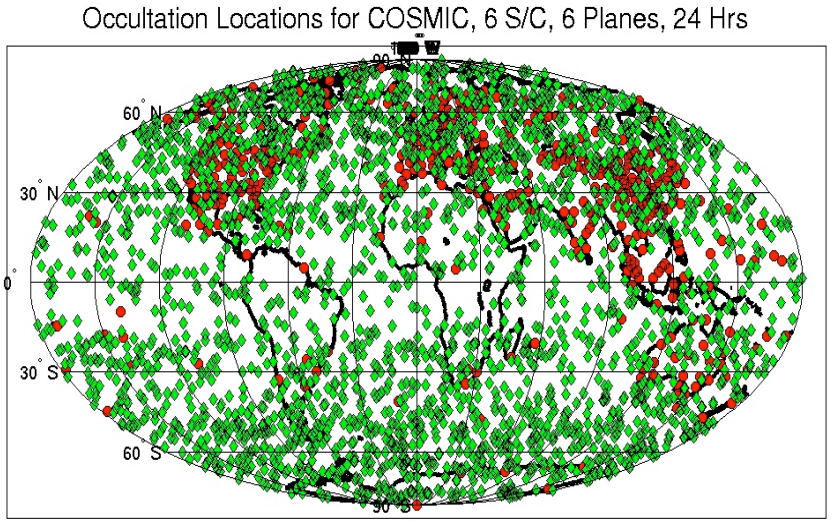



# WRF-Var Observations

- Conventional:
  - Surface (SYNOP, METAR, SHIP, BUOY).
  - Upper air (TEMP, PIBAL, AIREP, ACARS).



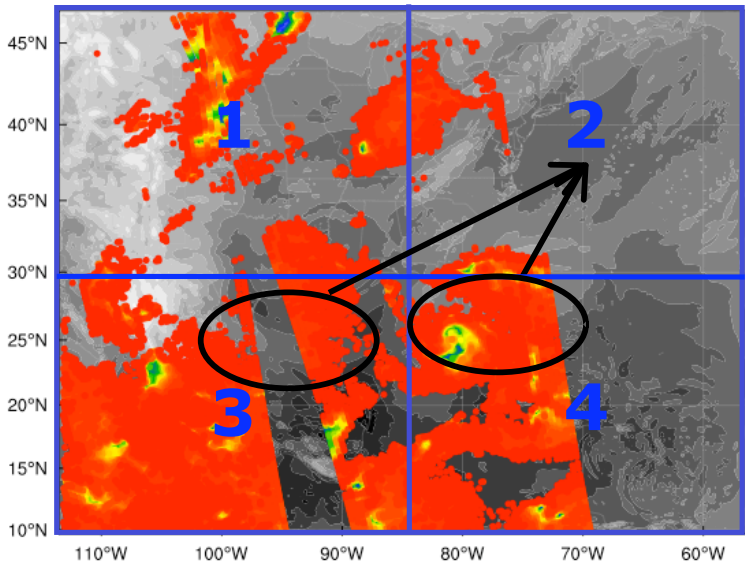
- Remotely sensed retrievals:
  - Atmospheric Motion Vectors (geo/polar).
  - Ground-based GPS Total Precipitable Water.
  - SSM/I oceanic surface wind speed and TPW.
  - Scatterometer oceanic surface winds.
  - Wind Profiler.
  - Radar (see Xiao poster).
  - Satellite temperature/humidities.
  - GPS refractivity (e.g. COSMIC).




- Radiances:
  - SSM/I brightness temperatures.
  - Direct radiance assimilation (see Z Liu's talk).

# Tracing Example: Radiance Load Balancing

Example: Spread AMSU-B Obs Over 4 processors:




John Bray, MMM

## Original Code

| | Calls | Elapsed Time (seconds) | | | |
|---|---|---|---|---|---|
| | per PE | Average per PE | % | Minimum | Maximum |
| wrfvar | 1.0 | 349.94 | 97.8 | 347.4 on 14 | 354.1 on 27 |
| da_wrfvar_run | 1.0 | 268.65 | 75.1 | 265.8 on 4 | 273.1 on 27 |
| da_wrfvar_interface | 1.0 | 268.65 | 75.1 | 265.8 on 4 | 273.1 on 27 |
| da_solve | 1.0 | 268.62 | 75.1 | 265.7 on 4 | 273.1 on 27 |
| da_minimise_cg | 1.0 | 217.33 | 60.7 | 216.2 on 12 | 218.6 on 31 |

## Optimized Code

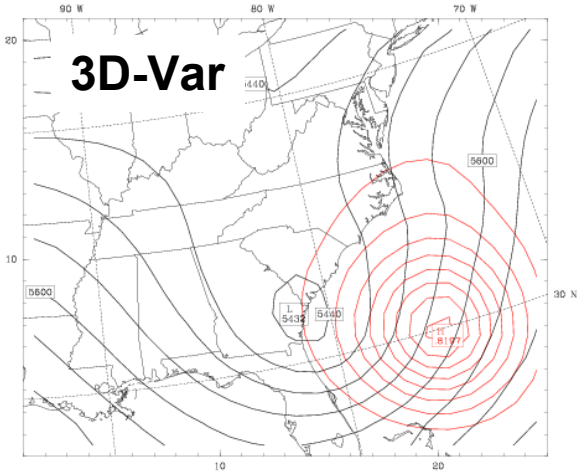
| | Calls | Elapsed Time (seconds) | | | |
|---|---|---|---|---|---|
| | per PE | Average per PE | % | Minimum | Maximum |
| wrfvar | 1.0 | 137.31 | 96.4 | 0.0 on 0 | 142.0 on 25 |
| da_wrfvar_run | 1.0 | 109.49 | 76.9 | 0.0 on 0 | 113.4 on 25 |
| da_wrfvar_interface | 1.0 | 109.49 | 76.9 | 0.0 on 0 | 113.4 on 25 |
| da_solve | 1.0 | 109.49 | 76.9 | 0.0 on 0 | 113.4 on 25 |
| da_minimise_cg | 1.0 | 88.72 | 62.3 | 88.4 on 11 | 89.1 on 0 |

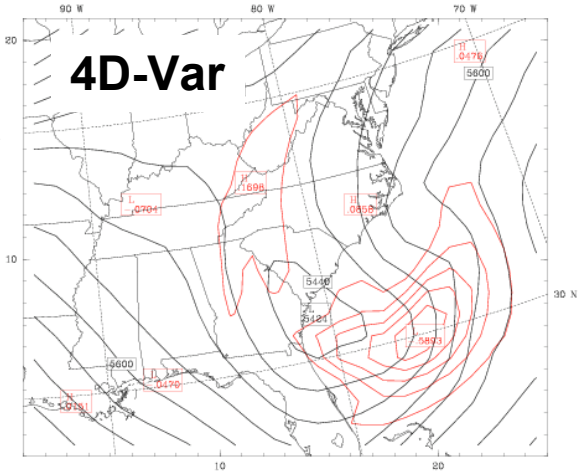
# WRF-(4D)Var Summary (see Huang's talk)

1. WRF-(4D)Var AFWA project: 2004-2007.

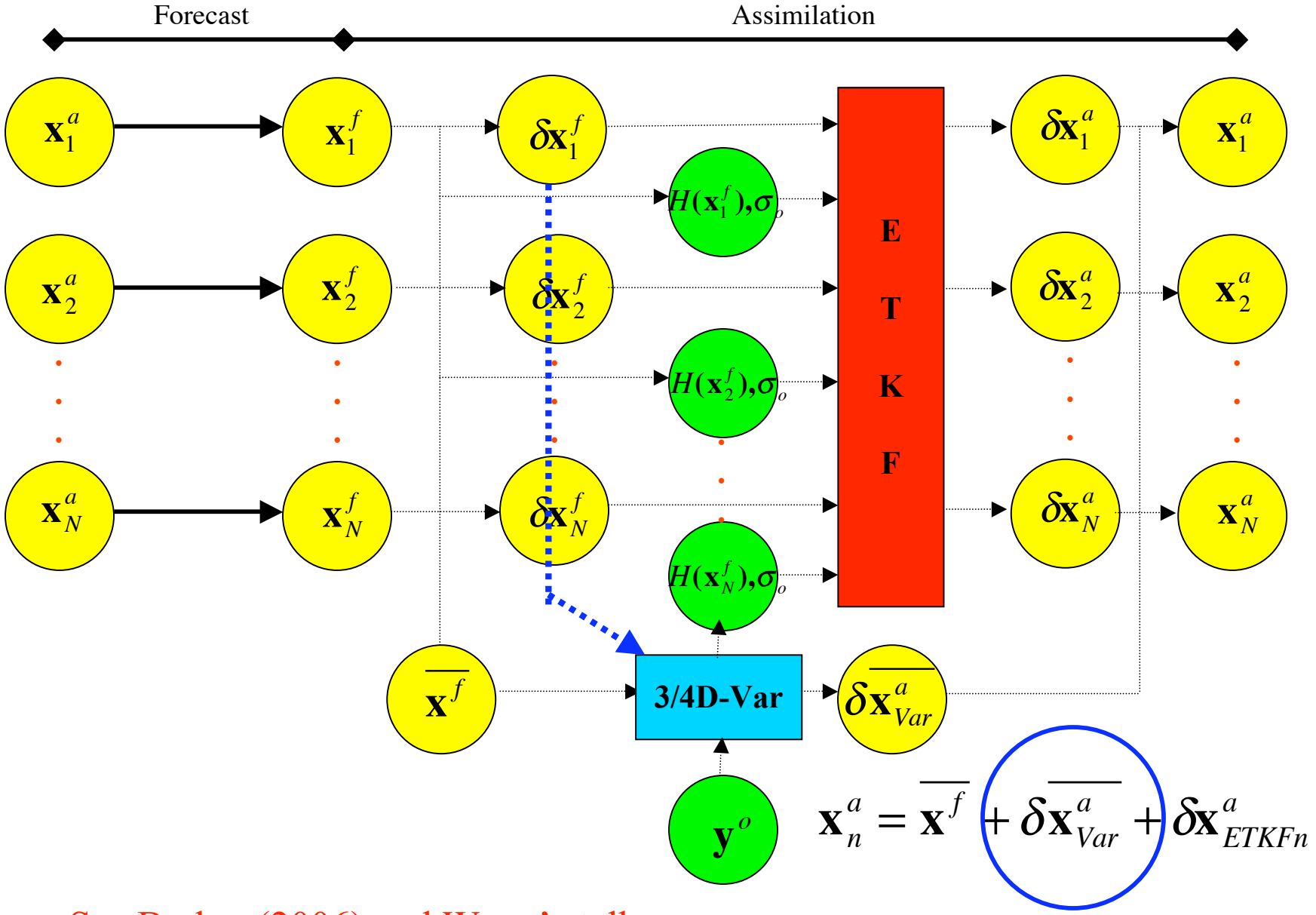
2. Formulation: Built within WRF-Var, using ARW dynamic core.

3. Status:
   - Prototype built (parallel, JcDFI, limited physics).
   - Prototypes delivered to AFWA in 2006 and 2007.
   - Current focus: Testing, more physics, optimization.



# Cycling WRF/WRF-Var/ETKF System (Hybrid DA)

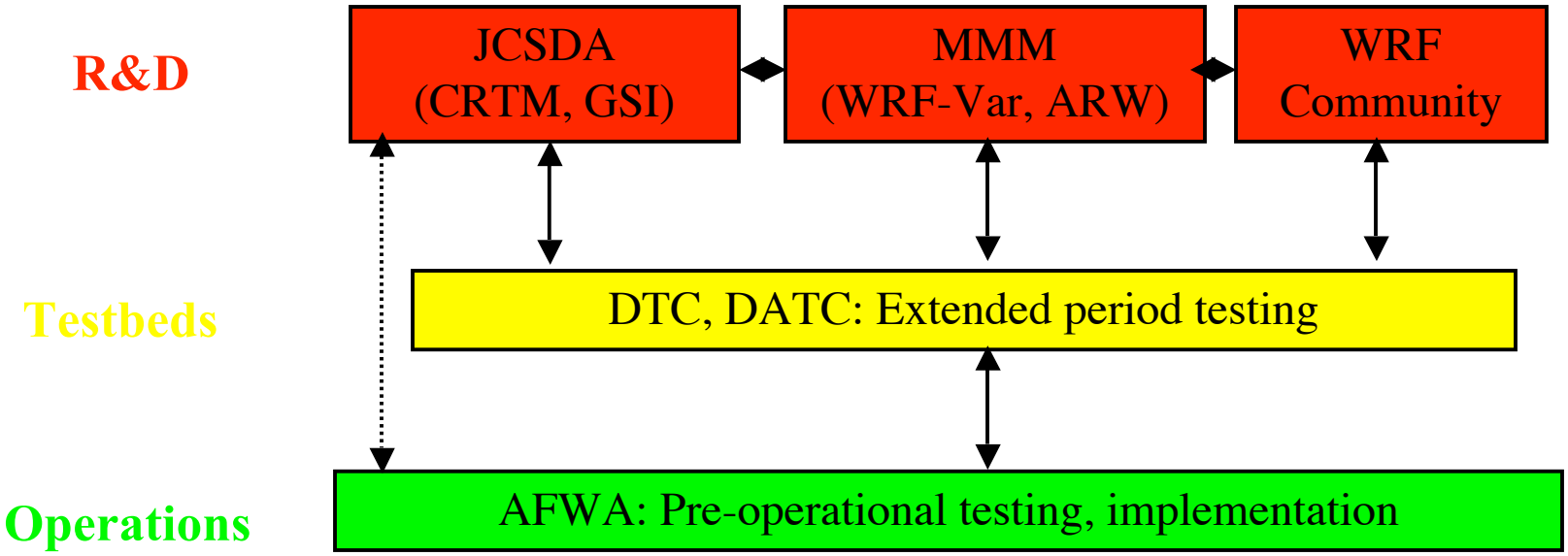



See Barker (2006) and Wang's talk

# WRF-Var/WRF Version 3.0 (March 2008)

- Major new features/improvements (provisional):
  - Radiance data assimilation via CRTM/RTTOV.
  - Hybrid variational/ensemble DA.
  - Ensemble Transform Kalman Filter (ETKF).
  - Enhanced gen_be utility (EPS-based stats., efficiency).
  - Major software engineering reorganization.
  - Option to use [PREP]BUFR for observation ingest.
  - Remove obsolete features (e.g. MM5/GFS-based errors).
- Unify code management (process, regression testing, SE framework) for WRF/WRF-Var.
- NOT included: 4D-Var.

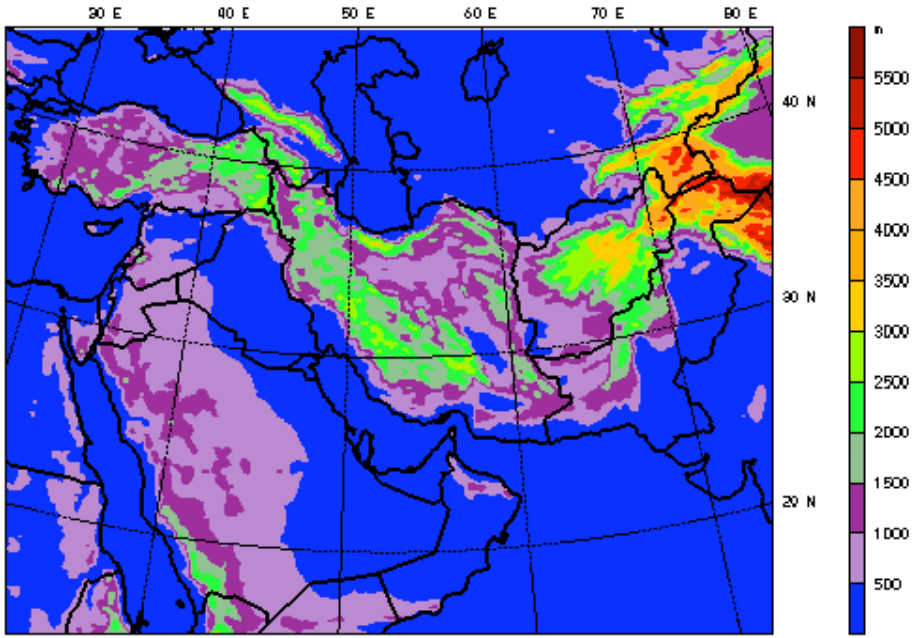
# WRF DA Research To Operations



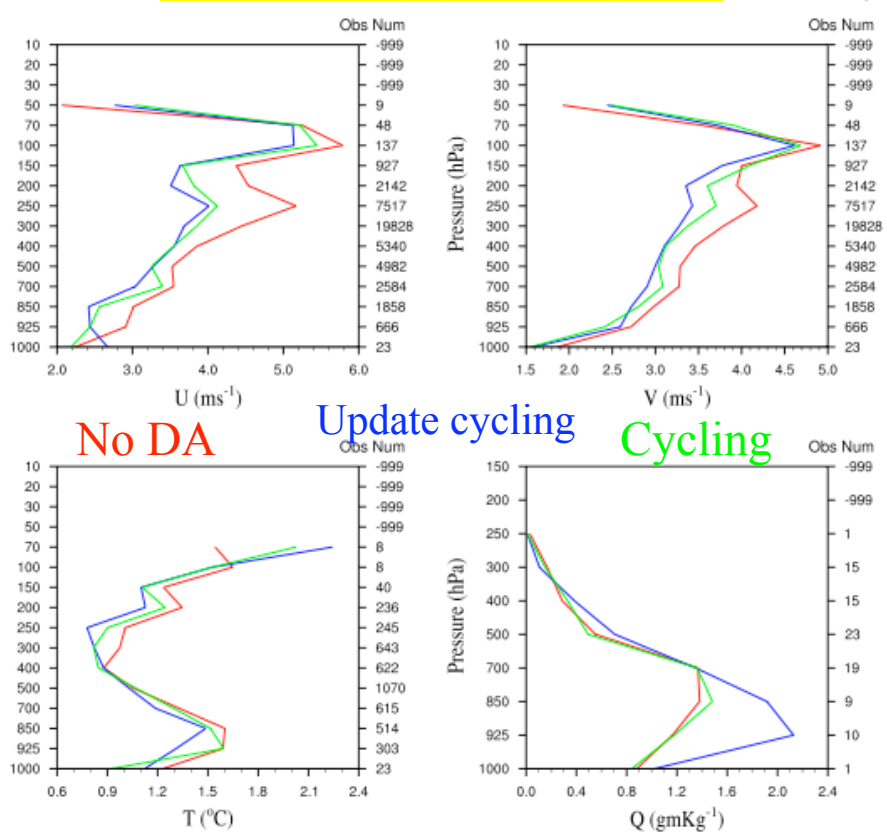

- NCAR/AFWA DA Program initiated in August 2006.
- MMM Division responsible for WRF-Var development and initial testing.
- JCSDA provides Community Radiative Transfer Model (CRTM), etc.
- WRF Community contributions include radar, radiance (RTTOVS).
- Data Assimilation Testbed Center (DATC) responsible for extended-period testing.

# DATC AFWA Testbed: S. W. Asia (T4B Theater)

- October 2006 global data archived at JCSDA (Jianjun Xu).
- 15km "T4B" S. W. Asia theater chosen.
- Test impact of 6 hourly cycling: NoDA, update/intermittent and full-cycling.




24hr Fcst Verif. Vs. Obs



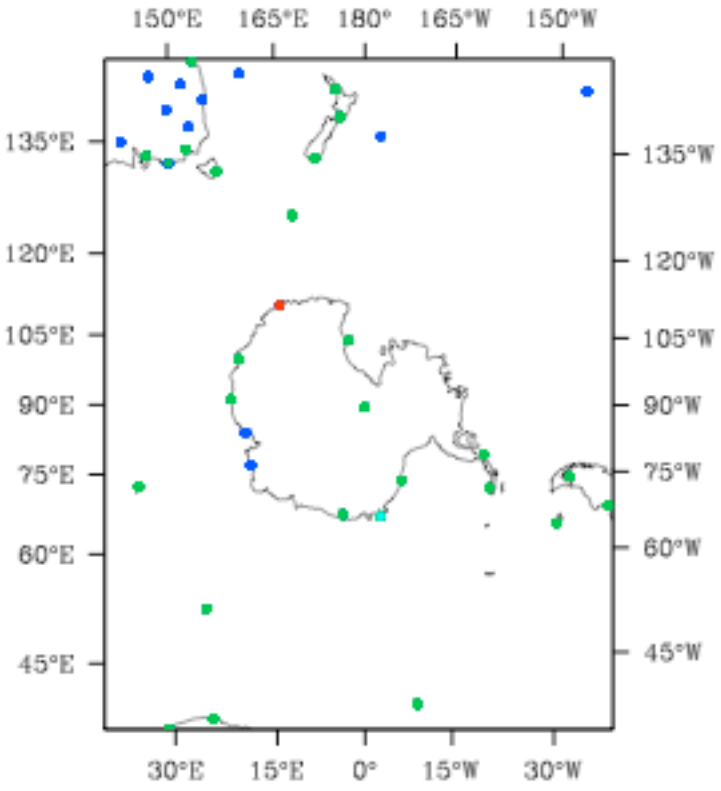

Conclusion: Update-cycling best, but full-cycling results encouraging. Next test: radiance assimilation, COSMIC.

Meral Demirtas, DATC

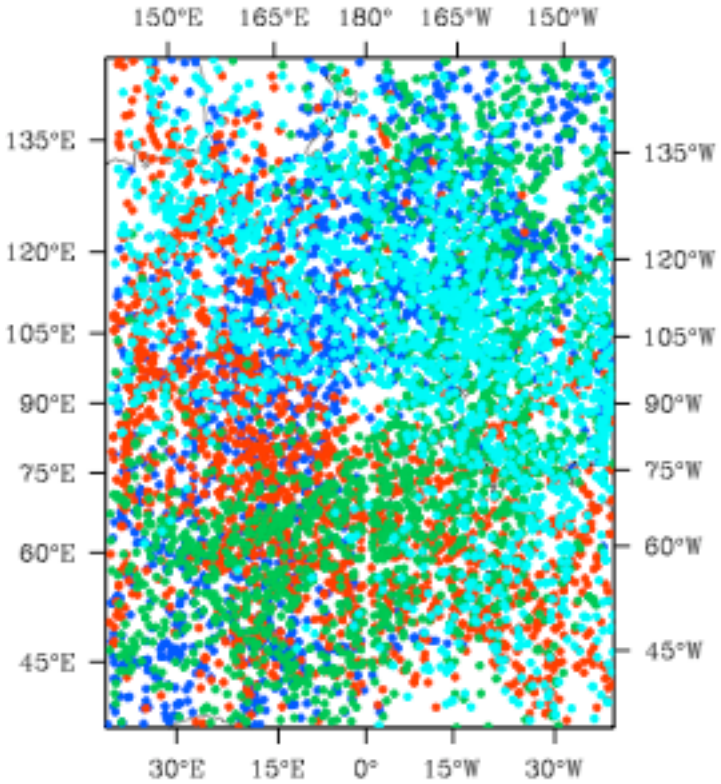
# DATC Antarctica Testbed

- Use Antarctic Mesoscale Prediction System (AMPS)' 60km domain.
- 1 - 31st October 2006 test period. 6 hourly cycling.
- Initial studies: Tuned polar error covariances, COSMIC impact.

**Sonde Coverage**

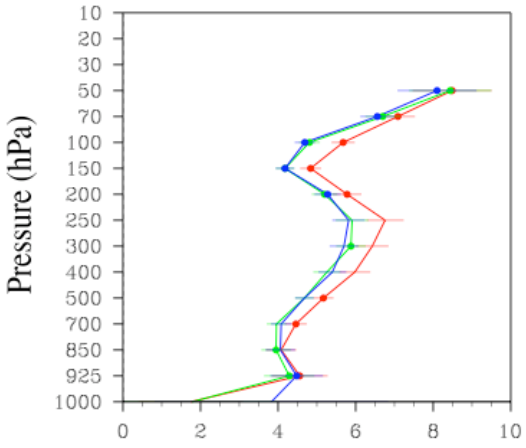



**COSMIC Coverage**




Hui Shao, DATC

# Antarctica Testbed: 36hr Forecast Verification Against Obs

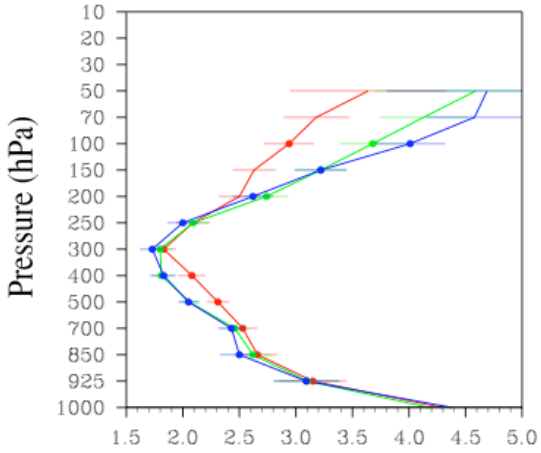



**U RMSE (m/s)**

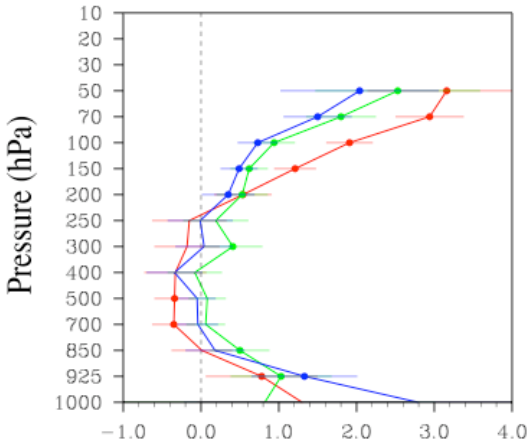
Conventional Obs

Conv. + COSMIC

Conv. + COSMIC + Tuned BE

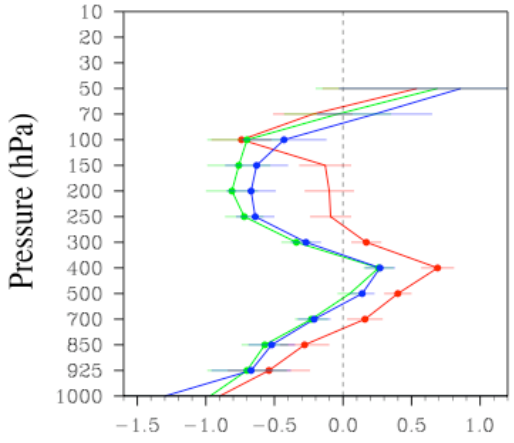



**T RMSE (degK)**




**U Bias (m/s)**

- COSMIC improves polar wind forecasts.
- COSMIC improves tropospheric temperatures.
- COSMIC degrades stratospheric temperatures.
- "2nd generation" tuned BE has small impact.




**T Bias (degK)**

# Future Plans

**General Goals:**

- Research: Focus on high-resolution (1-10km).
- Development: Unified DA system (3/4D-Var, EnKF).
- Community Model: Retain flexibility for research.
- Leverage international WRF community efforts.
- Work to eliminate **unnecessary** diversity.

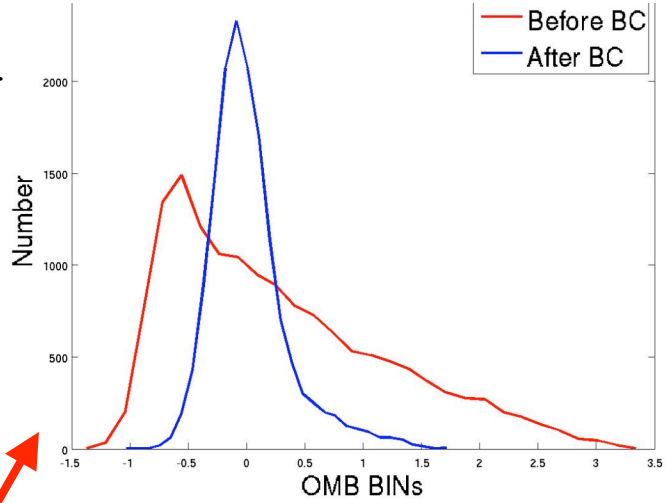
**WRF-Var Development (MMM Division):**

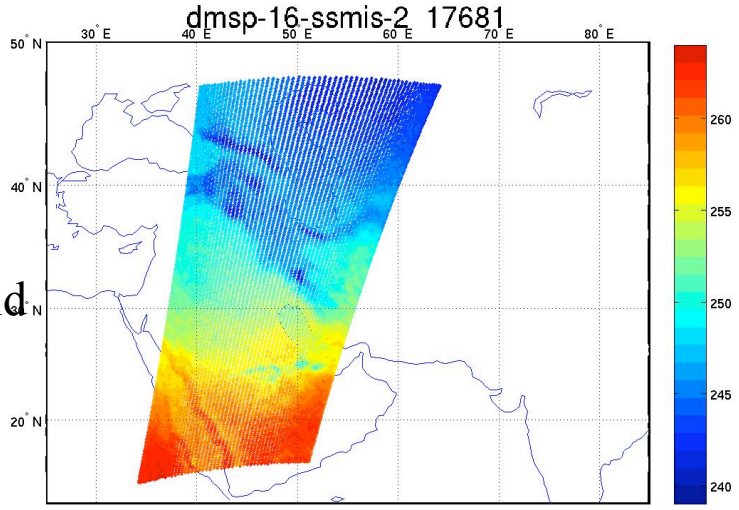
- 4D-Var (physics, optimization).
- Adjoint Sensitivities.
- EnKF within WRF-Var.
- Instrument-specific radiance QC, bias correction.

**Data Assimilation Extended-Period Testing (DATC):**

- Technique intercomparison: 3/4D-Var, EnKF, Hybrid
- System studies: WRF-Var, GSI, DART.
- Obs. impact: AMSU, AIRS, COSMIC, SSMI/S.
- New Regional testbeds: Korea, India, CONUS.

**Air Mass Bias Correction: AMSU-A**

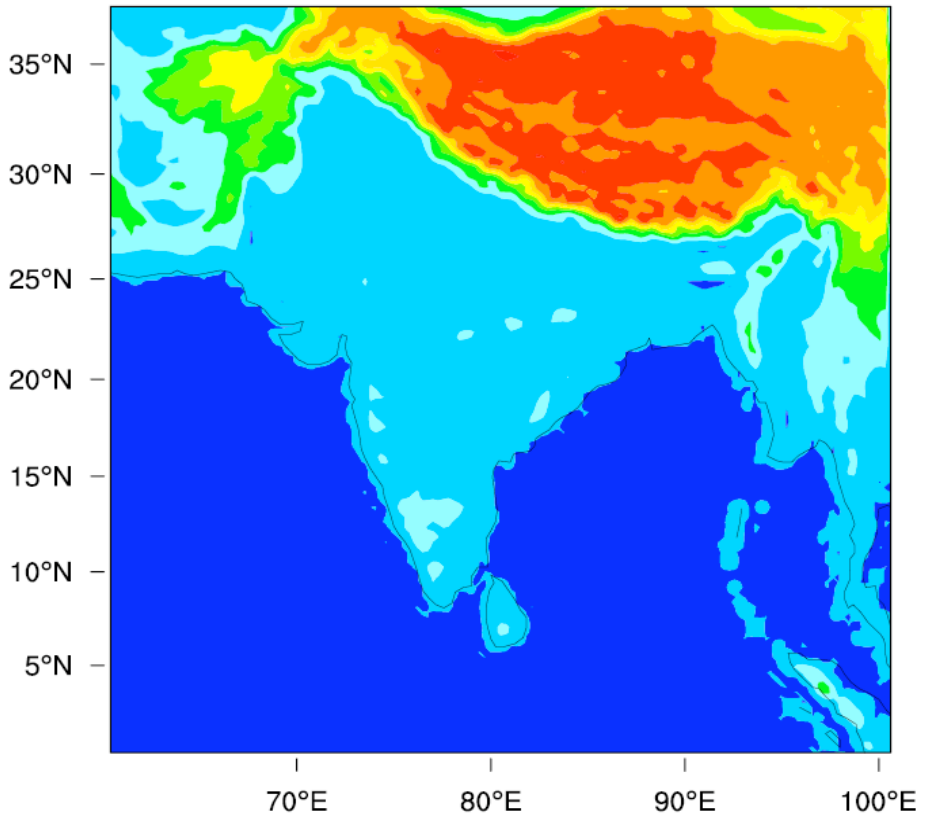


# Indian WRF Data Assimilation Studies

Ananda Das (IMD), Ashish Routray (IIT/Delhi)

- Advanced Research WRF
- WRF-Var V2.2 (3D-Var)
- 30km resolution domain
- August 2005 test period
- Control - ARW Forecasts from NCEP global analysis
- Test - Cycle ARW/WRF-Var



# India Testbed: 24hr Forecast Verification (August 2005)

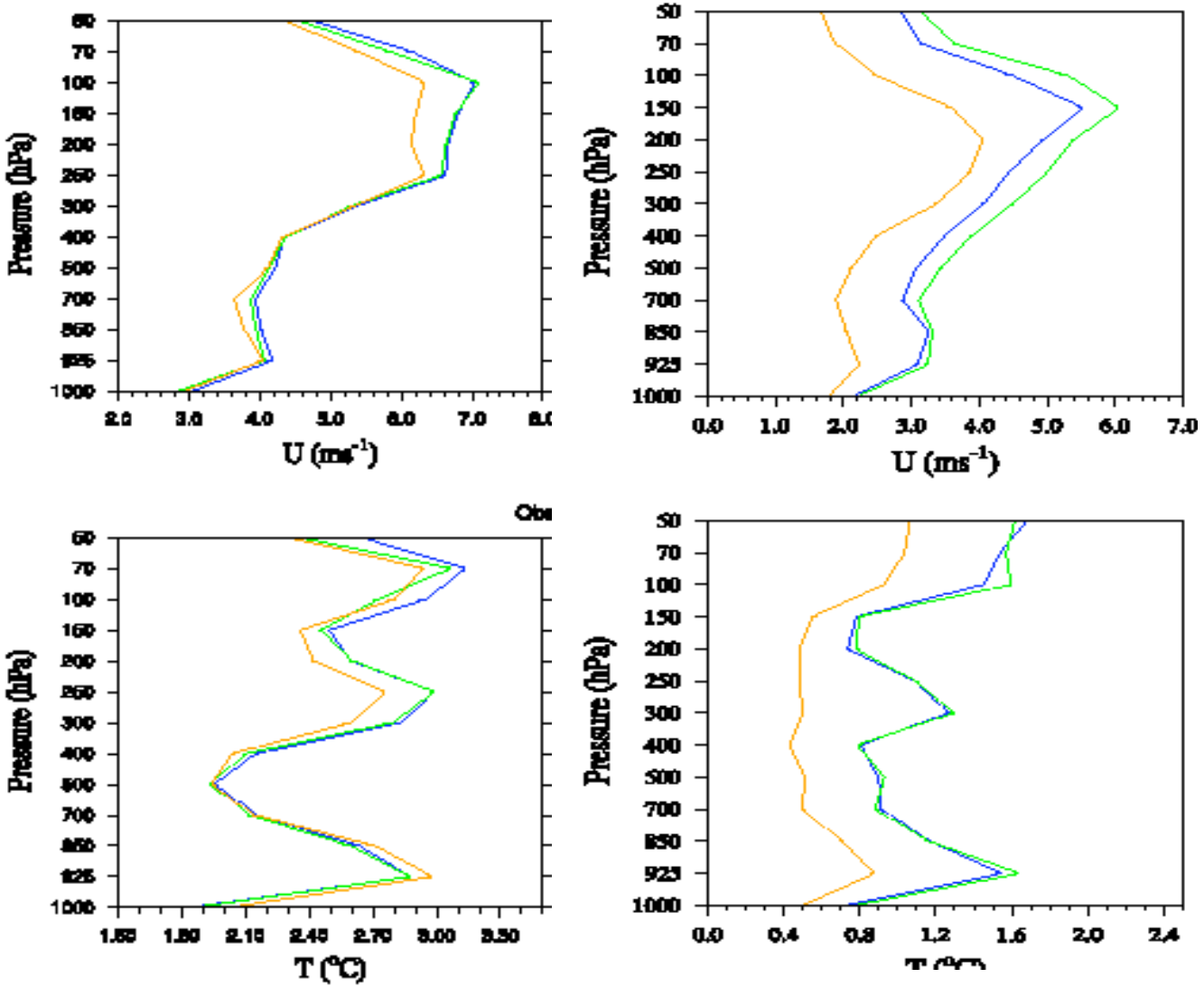
Verif. Vs. Observations

Verif. Vs. Analyses

NoDA

Cold-Start

Cycling




- Conclusion: Full-cycling generally verifies better against obs. and analyses.