Radar data assimilation in NCAR/RAL RTFDDA:

a hybrid approach of 3DVAR, latent heat adjustment and grid-nudging

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Components of the hybrid system

- All U, V, T, Qv observations and data QC
- Upper-air data
- Radar data processing and QC
- WRF-based RTFDDA system (Liu et al. 2005 and 2006 WRF Workshop)
- Continuous 4-D analyses and forecast cycling
- Hybrid Engine
  - Latent heat nudging (DZ)
  - WRFDA 3DVAR (VR, DZ)

Diagram:
- WRF-RTFDDA
- Radar Analysis
With HYBRID RTFDDA

3dvar 3dvar 3dvar 3dvar 3dvar 3dvar 3dvar
Forecast Obs-nudging Obs-nudging
Grid-nudging Grid-nudging

Latent heat is derived based on radar measured rain water and snow

WRF-3DVAR is used to assimilate radar radial wind and reflectivity

Grid-nudging is used to assimilate radar measured hydrometers, latent heat and 3DVAR wind analysis

Adding radar data into RTFDDA

- Radar reflectivity is processed to derive rain water and snow
- Latent heat is derived based on radar measured rain water and snow
- WRF-3DVAR is used to assimilate radar radial wind and reflectivity
- Grid-nudging is used to assimilate radar measured hydrometers, latent heat and 3DVAR wind analysis
Latent Heat Nudging

- Ingest NSSL 3D gridded mosaic reflectivity
- Map radar data to model grid, convert DZ to observation of QR/QS
- Adjust the thermodynamic and microphysical fields based on the differences between model and observations
- Challenges: location and amount of heating
- Tunable parameter: nudging coefficient or heating amount
- Limitations: using reflectivity data only

Available on CONUS domain with resolution of 1x1x0.25 km³ from NSSL.
WRFDA 3DVAR

- Ingest Level 2 radial wind and reflectivity from individual radars
- Result in increments in all model variables
- May strongly depend on the background field and error correlations
- Tunable parameters: factors for background error covariance, scale length, number of iterations
Front Range Convection

Retrospective period
June 4-17, 2009

Weeks 2: June 11-18
Stage4 Rainfall (mm/hr)

Stage4 hourly rainfall rate: averaged over latitudes
Impact of radar data LHN on cyc200906 1206

analysis

Restart from 00 UTC

Stage4 Rainfall (mm/hr) Validated at 2009061206

1 Hour Precipitation (mm) Validated at 2009061206

1 Hour Precipitation (mm) Validated at 2009061206

observation RTFDDA - no radar RTFDDA with radar LHN
Impact of radar data LHN on cyc200906 1206

1 h forecast

Stage4 Rainfall (mm/hr)
Validated at 2009061207

1 Hour Precipitation (mm)
Validated at 2009061207

1 Hour Precipitation (mm)
Validated at 2009061207

observation
RTFDDA - no radar
RTFDDA with radar LHN
Impact of radar data LHN on cyc200906 1206

2 h forecast

Stage4 Rainfall (mm/hr)
Validated at 2009061208

1 Hour Precipitation (mm)
Validated at 2009061208

1 Hour Precipitation (mm)
Validated at 2009061208

observation

RTFDDA - no radar

RTFDDA with radar LHN
Impact of radar data LHN on cyc200906 1206

3 h forecast

Stage4 Rainfall (mm/hr)

1 Hour Precipitation (mm)

1 Hour Precipitation (mm)

observation

RTFDDA - no radar

RTFDDA with radar LHN

Validated at 2009061209

Validated at 2009061209

Validated at 2009061209
Impact of 3DVAR

dependence on background

observation

RTFDDA + LHN

3-hour forecast

Nudging 3DVAR analysis B adds value to RTFDDA+LHN, while nudging analysis A does not.

A: previous cycle forecast as background in 3DVAR
B: pre-3DVAR conditioning of background
Real-time System for an Army Test Range

Aberdeen Test Center, MD

✓ Run 3-domain WRF-based RTFDDA
✓ Ingest NSSL Mosaic and Level2 data from 16 radars
✓ Do hourly radar analysis on D2 & 3
✓ Grid nudging radar analyses in RTFDDA
✓ parallel runs for two weeks
  (110 forecasts; Feb. 20 – March 6, 2011)
ATC 0220-0306 verification of 1-h rainfall Domain 3
Cycle from 14 UTC, Feb. 28, 2011 (Restart at 11 UTC)

**Stage4 Rainfall (mm/hr)**

- Observation
- RTFDDA - no radar
- Hybrid

Validated at 2011022814
Cycle from 14 UTC, Feb. 28, 2011 (Restart at 11 UTC)

3 h forecast

Stage4 Rainfall (mm/hr)
Validated at 2011022817

observation

RTFDDA - no radar

Hybrid
Cycle from 14 UTC, Feb. 28, 2011 (Restart at 11 UTC)

Surface temperature verification (model-obs)

Stage4 Rainfall (mm/hr)

Validated at 2011022817

Bias = 2.920
RMS = 4.585

RTFDDA - no radar

Bias = 0.396
RMS = 2.903

With hybrid

3 h forecasts
Summary of Findings

1) LHN generally can improve very short-term precipitation forecasts. The effects are more lasting for some storm types and short-lived for some others.

2) WRF-3DVAR often has problems when the background has existing offset small-scale structures. Improvements can be obtained when pre-3DVAR conditioning of the background is used.

3) The hybrid system of RTFDDA and LHN improves (upon RTFDDA) 0-6 h precipitation forecasts statistically at both Front Range and ATC in the retrospective studies.

4) The hybrid system of RTFDDA, LHN and 3DVAR produces improvement (over RTFDDA+LHN) in 0-6 h forecasts in two case studies. The statistical effect is yet to be tested.