Radar data assimilation in NCAR/RAL RTFDDA:

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

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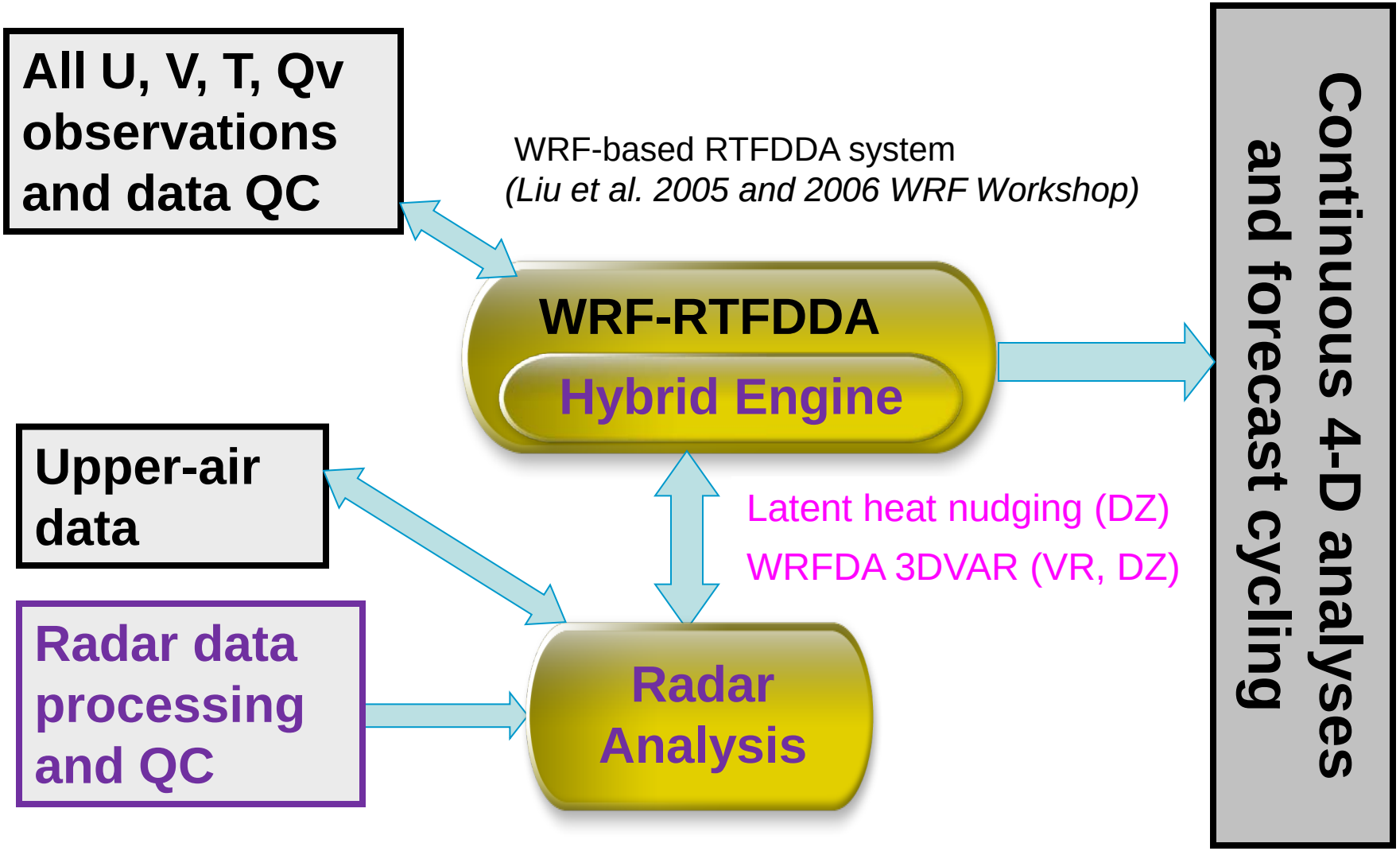
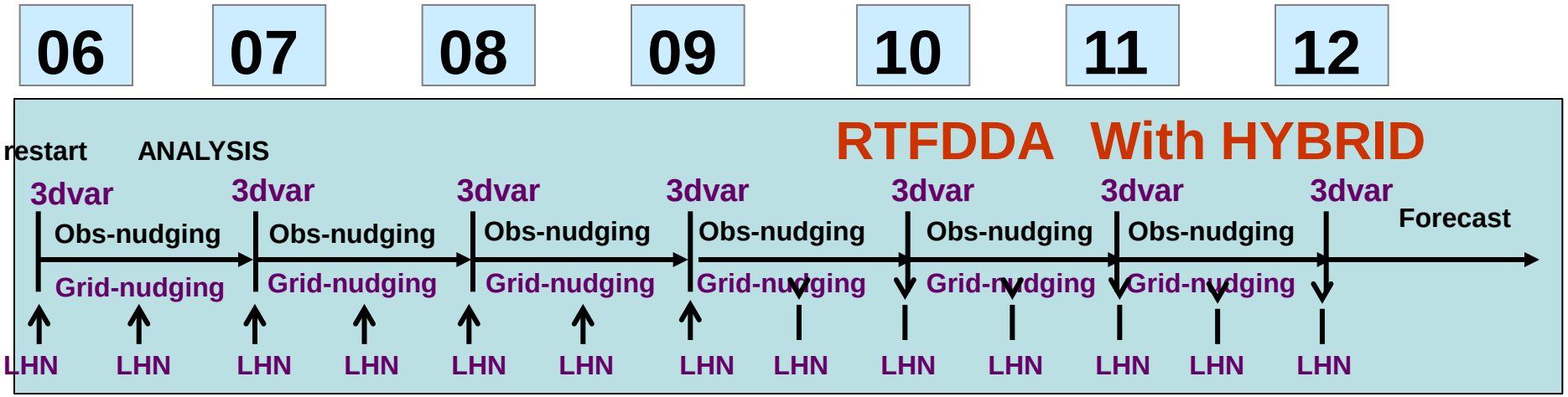
Components of the hybrid system



The Cycling Scheme

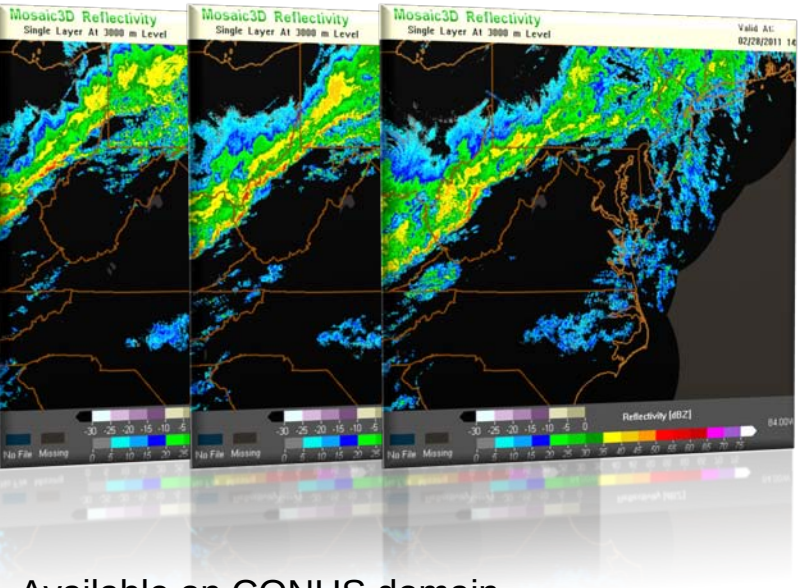
Schematic (for 6-h forecast cycles)



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

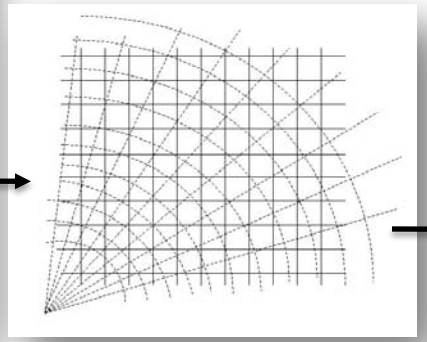
Latent Heat Nudging

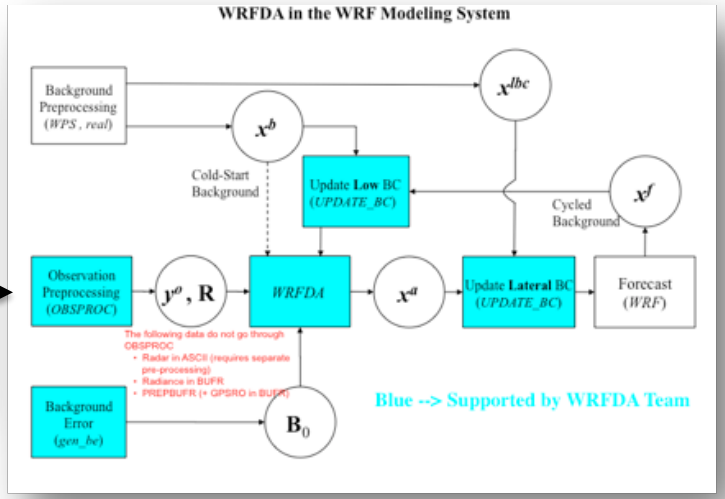


Available on CONUS domain with resolution of 1x1x0.25 km^3 from NSSL.

- 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

WRFDA 3DVAR

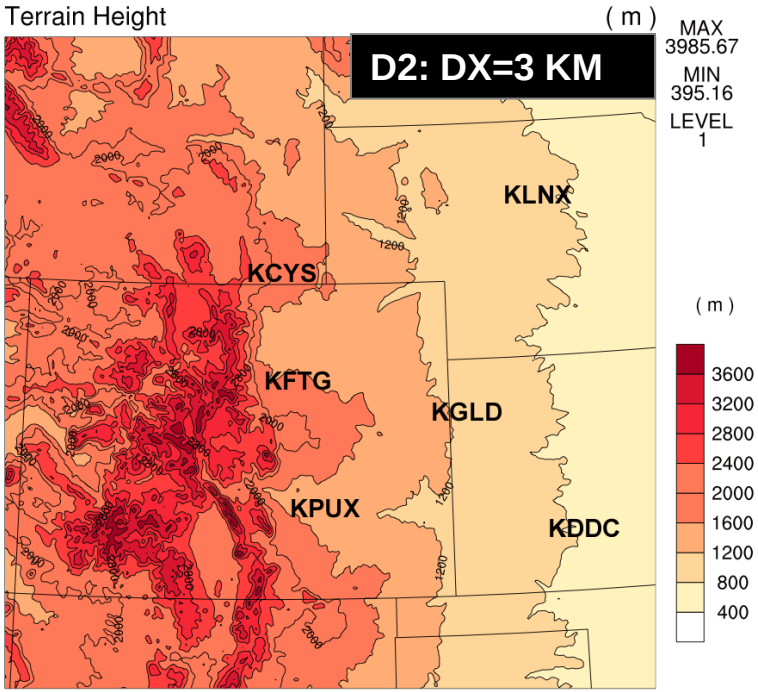




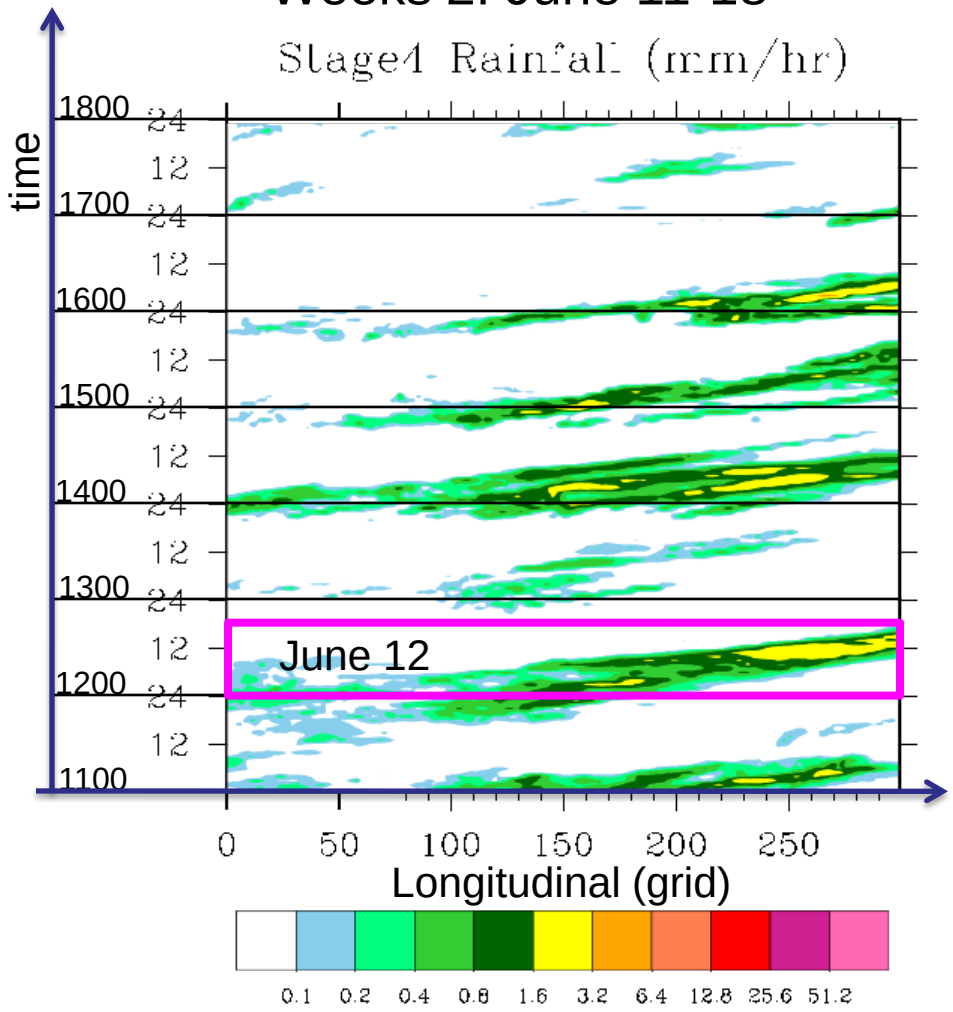
- Ingest Level 2 radial wind and reflectivity from individual radars
- Result in increments in all model variables
- May strongly depend on the background field and error correlations
- Tunable parameters: factors for background error covariance, scale length, number of iterations

Front Range Convection

Retrospective period
June 4-17, 2009



Weeks 2: June 11-18

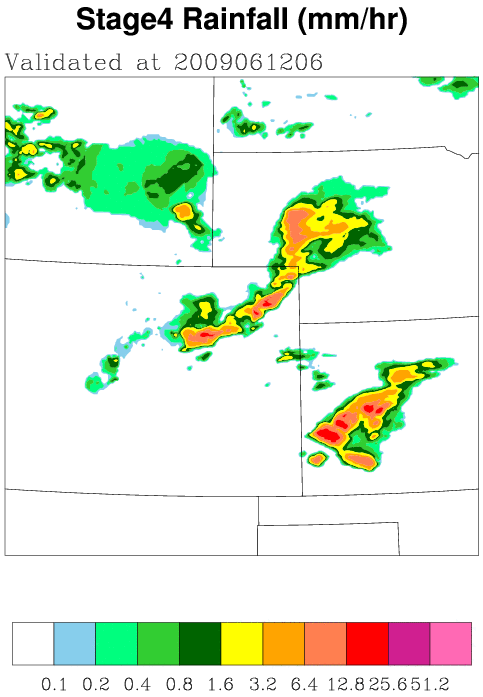


Stage4 hourly rainfall rate: averaged over latitudes

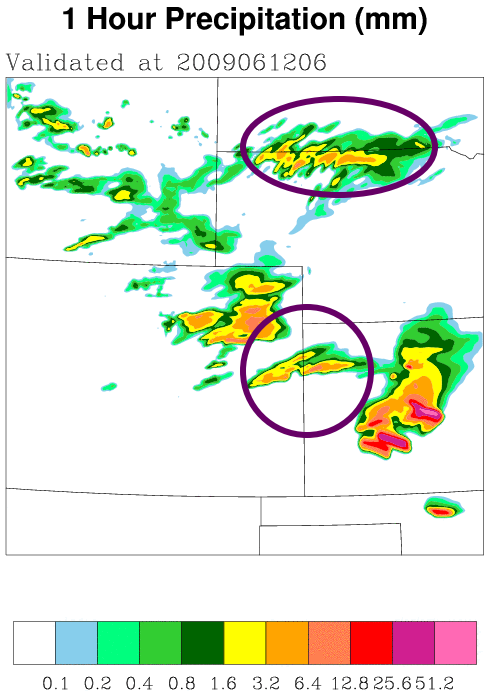
Impact of radar data LHN on cyc200906 1206

analysis

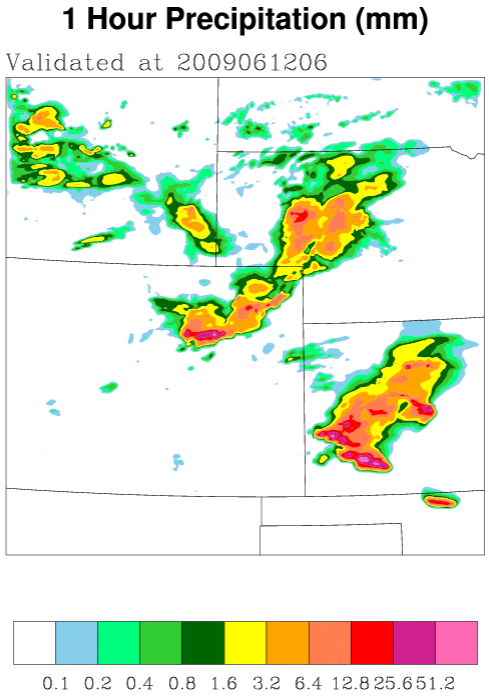
Restart from 00 UTC



observation



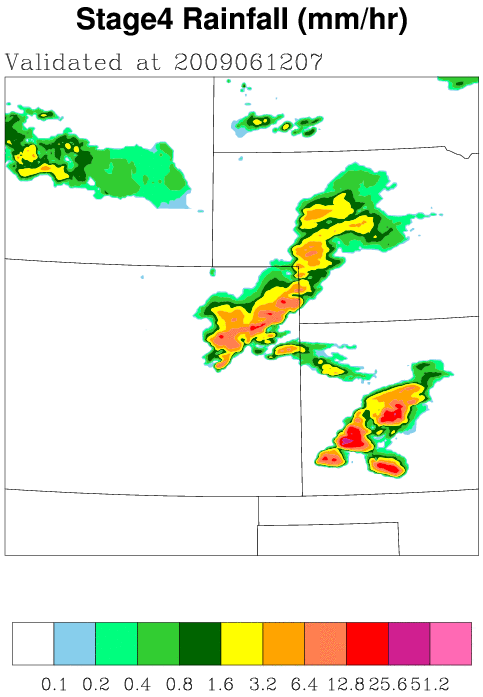
RTFDDA - no radar



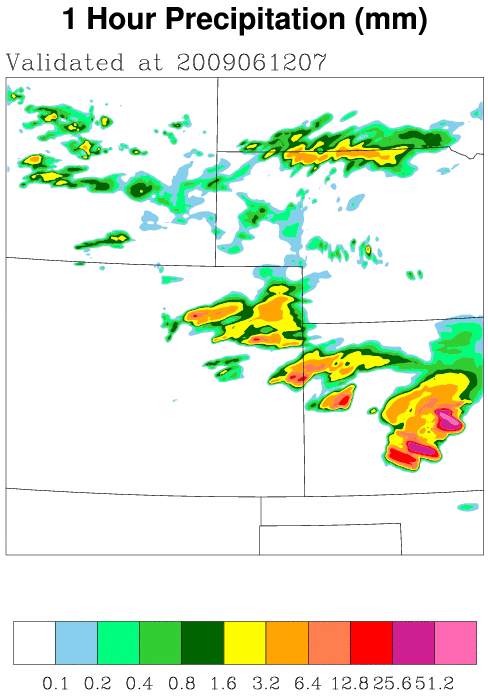
RTFDDA with radar LHN

Impact of radar data LHN on cyc200906 1206

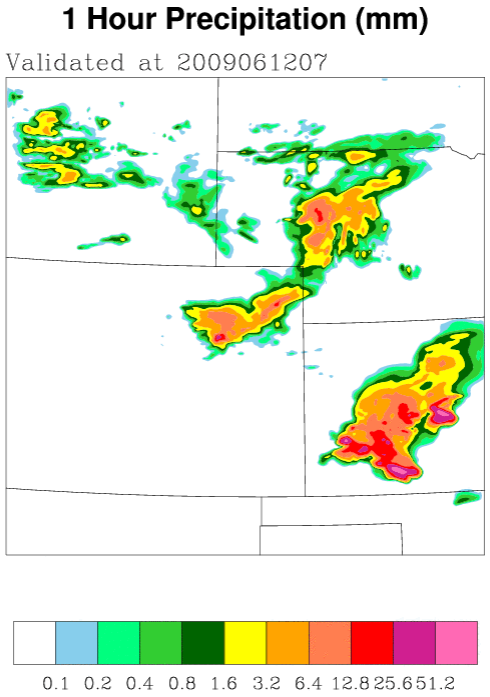
1 h forecast



observation



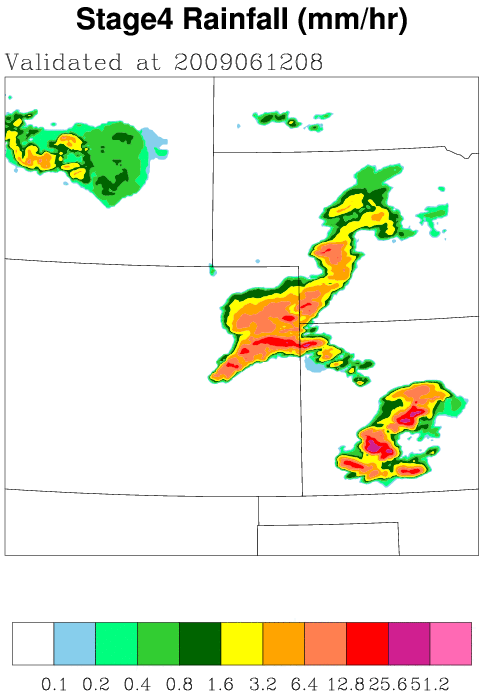
RTFDDA - no radar



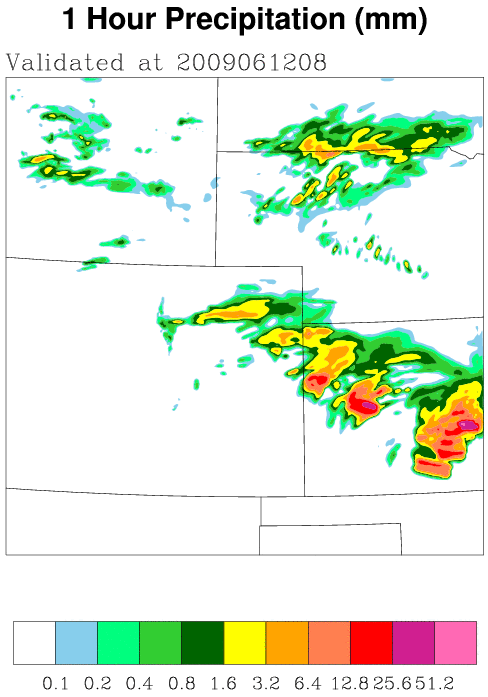
RTFDDA with radar LHN

Impact of radar data LHN on cyc200906 1206

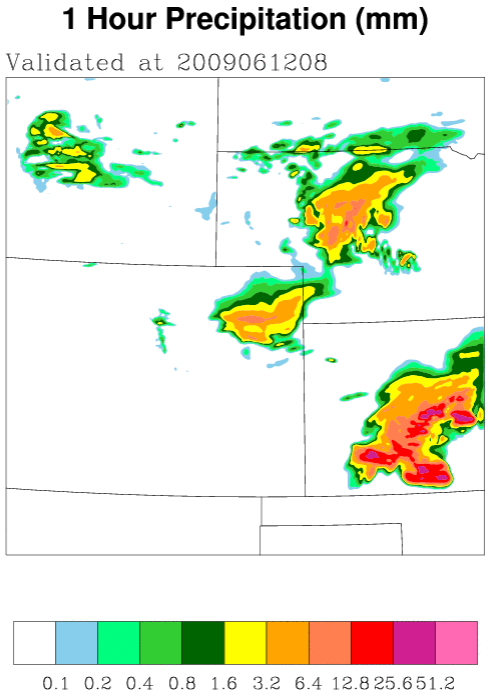
2 h forecast



observation



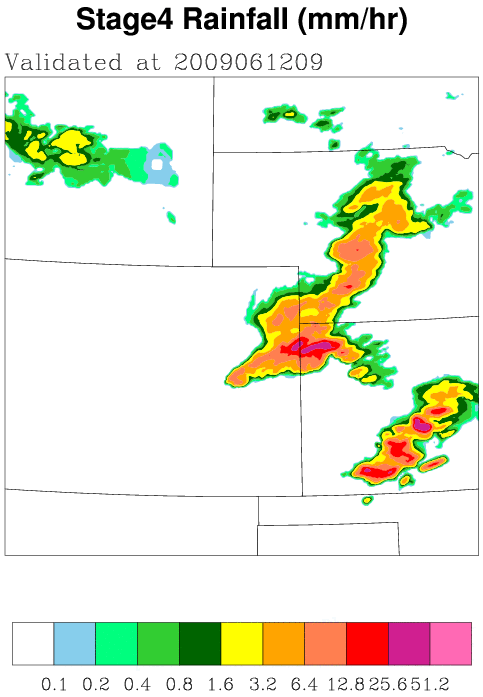
RTFDDA - no radar



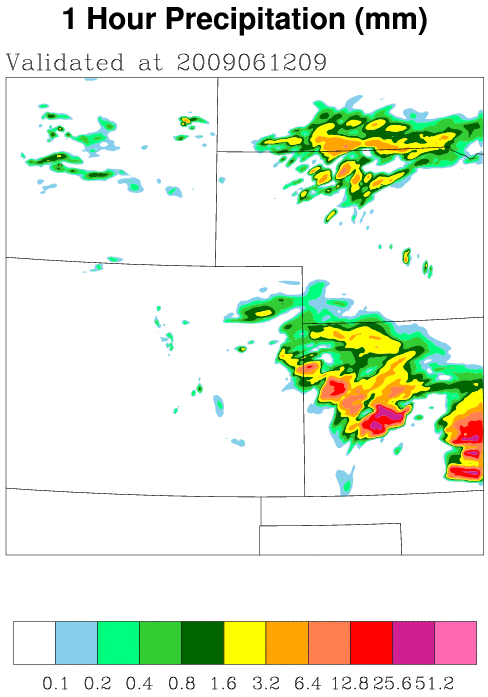
RTFDDA with radar LHN

Impact of radar data LHN on cyc200906 1206

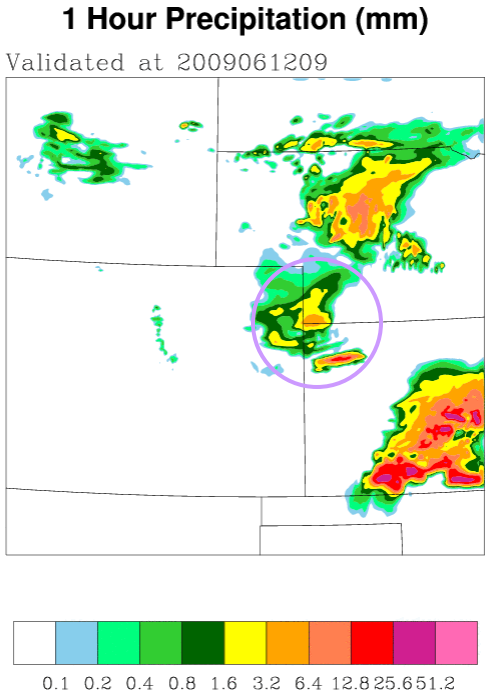
3 h forecast



observation



RTFDDA - no radar

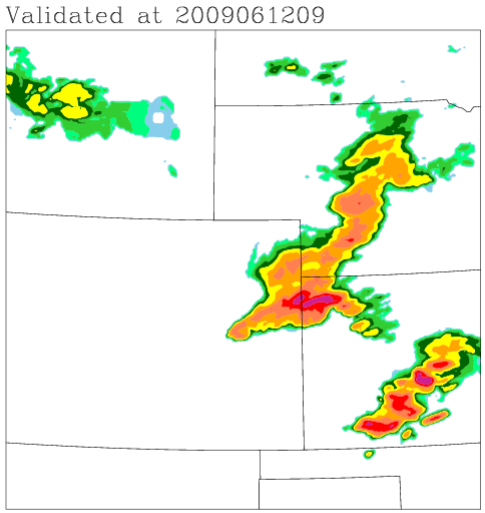


RTFDDA with radar LHN

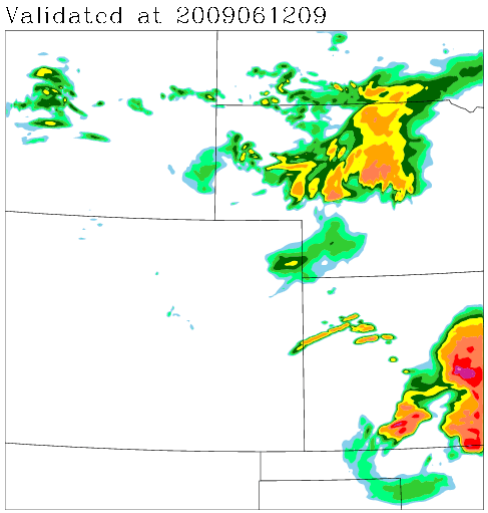
Impact of 3DVAR

dependence on background

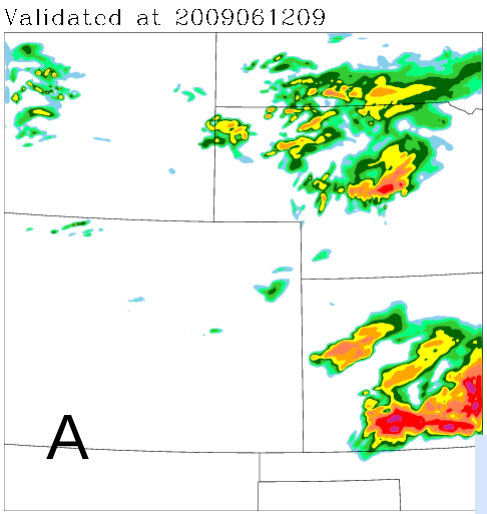
observation

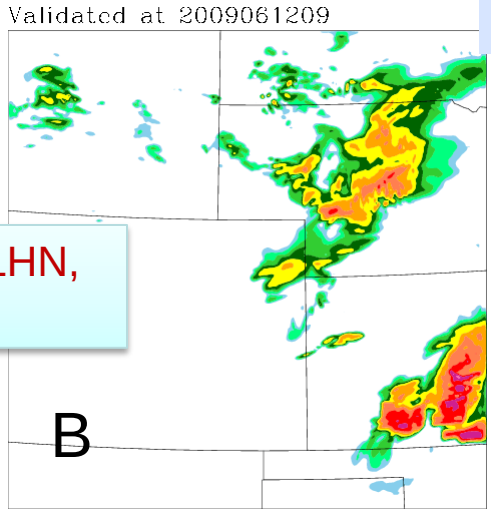


RTFDDA + LHN



3-hour forecast





RTFDDA+LHN
+3DVAR

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*

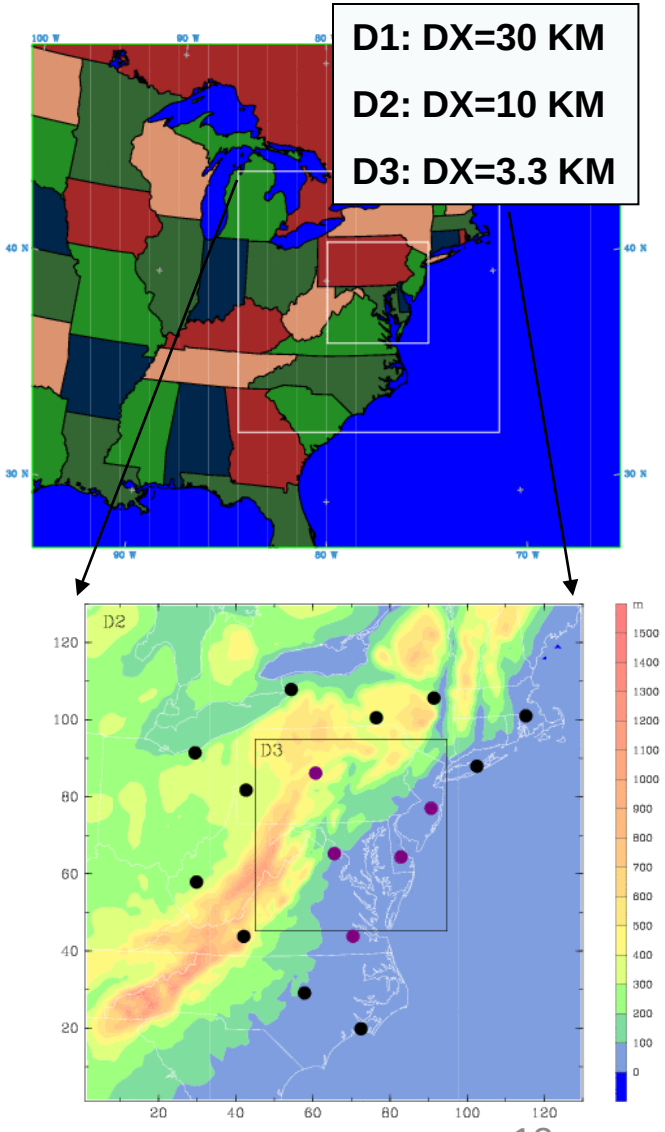
✓*Ingest NSSL Mosaic and Level2 data from 16 radars*

✓*Do hourly radar analysis on D2 & 3*

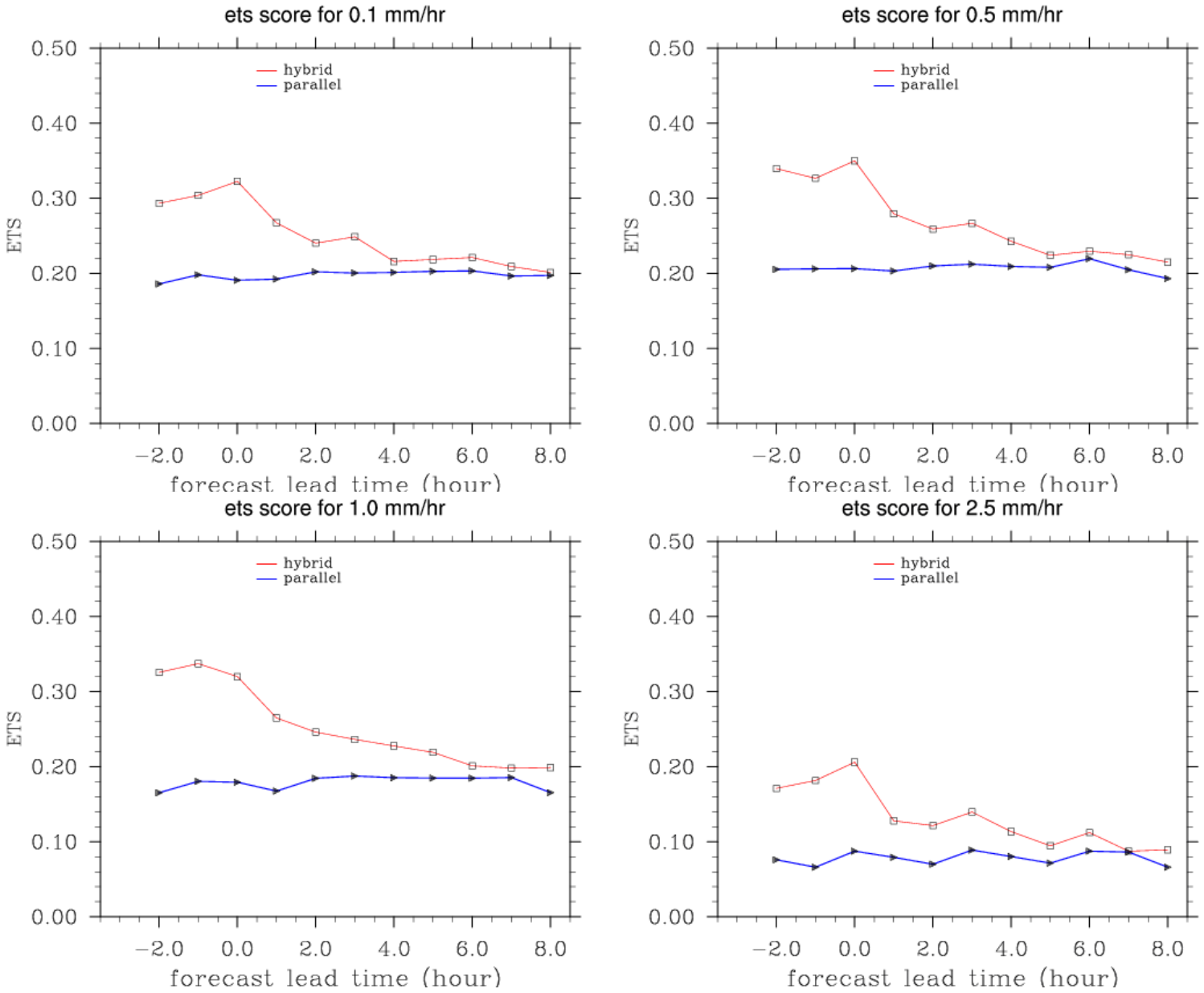
✓ *Grid nudging radar analyses in RTFDDA*

✓parallel runs for two weeks

(110 forecasts; Feb. 20 – March 6, 2011)

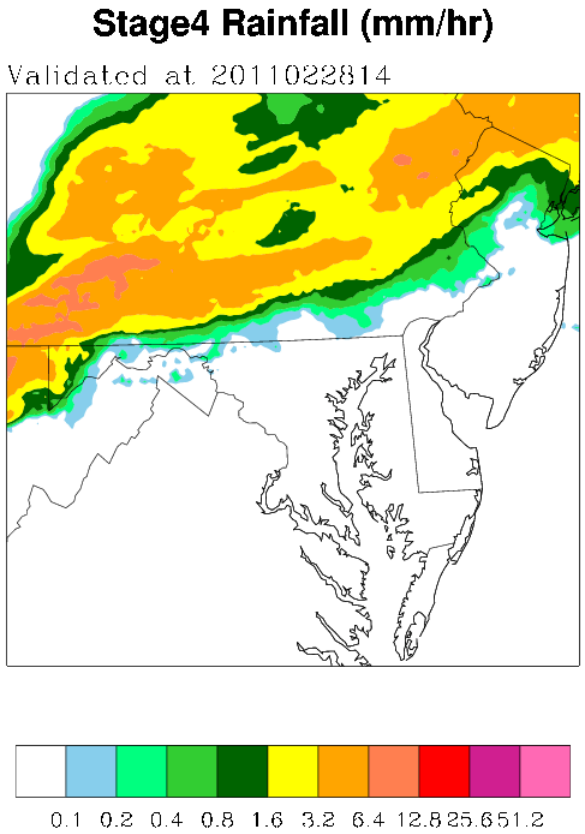


ATC 0220-0306 verification of 1-h rainfall Domain 3

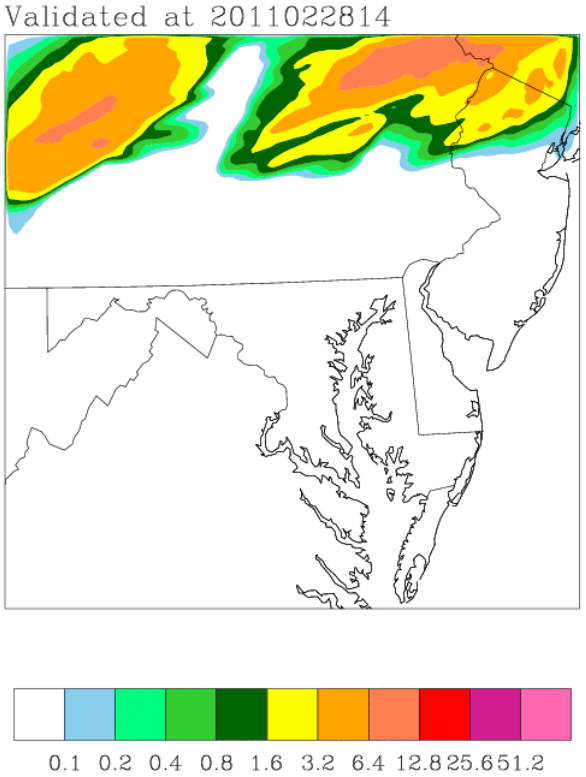


Cycle from 14 UTC, Feb. 28, 2011 (Restart at 11 UTC)

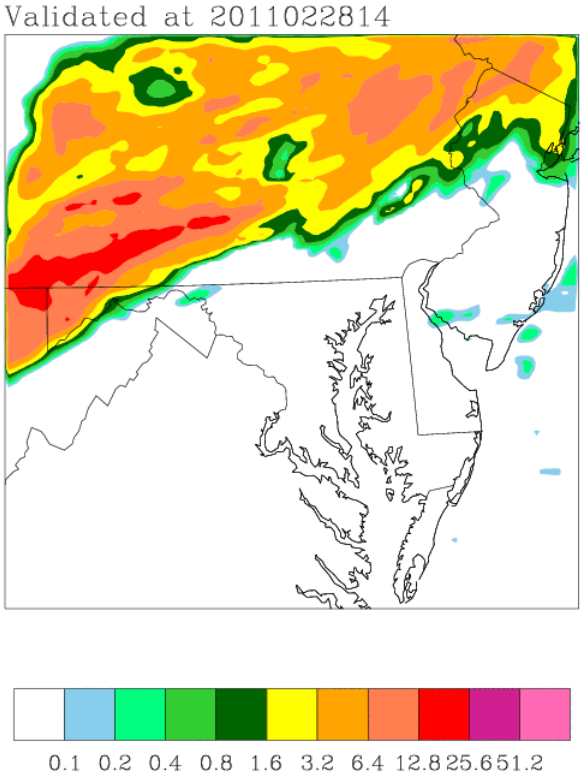
analysis



observation



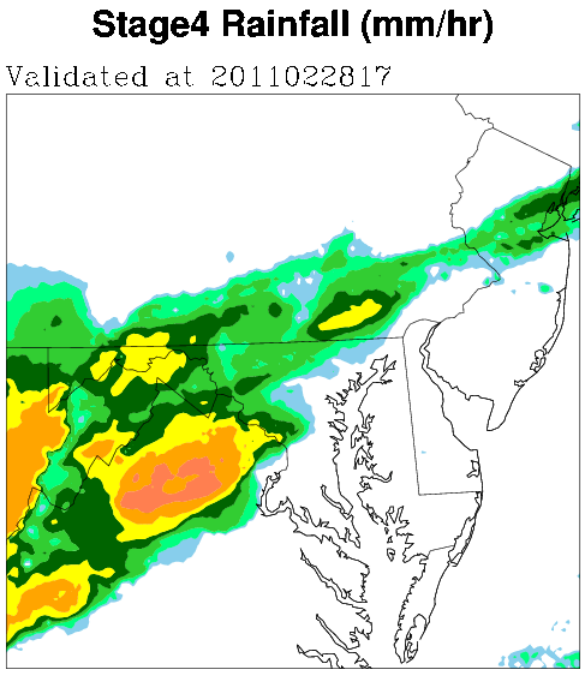
RTFDDA - no radar



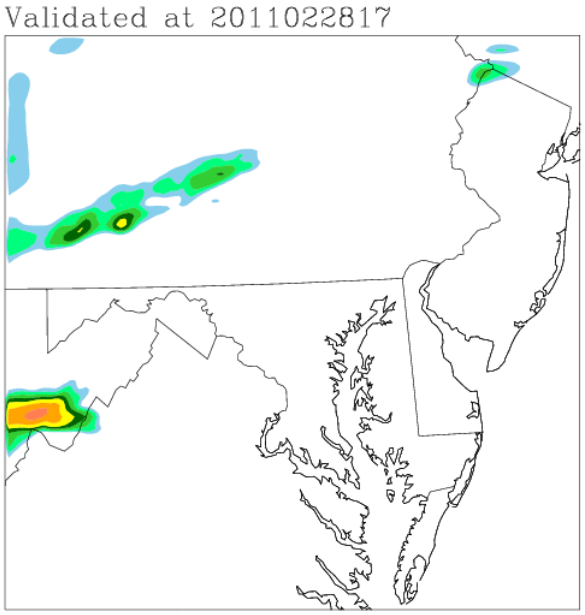
Hybrid

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

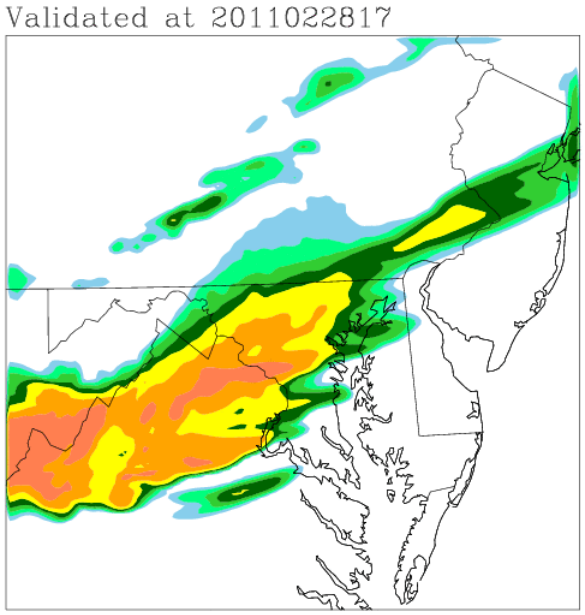
3 h forecast



observation



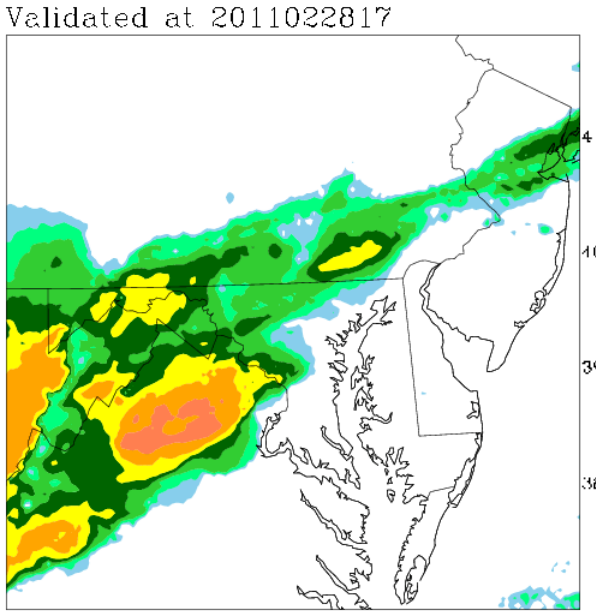
RTFDDA - no radar



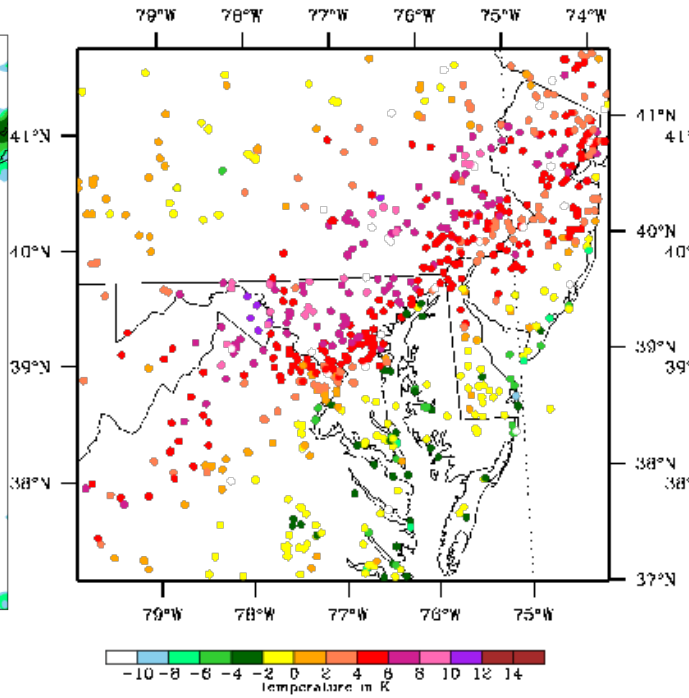
Hybrid

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

Surface temperature verification (model-obs)

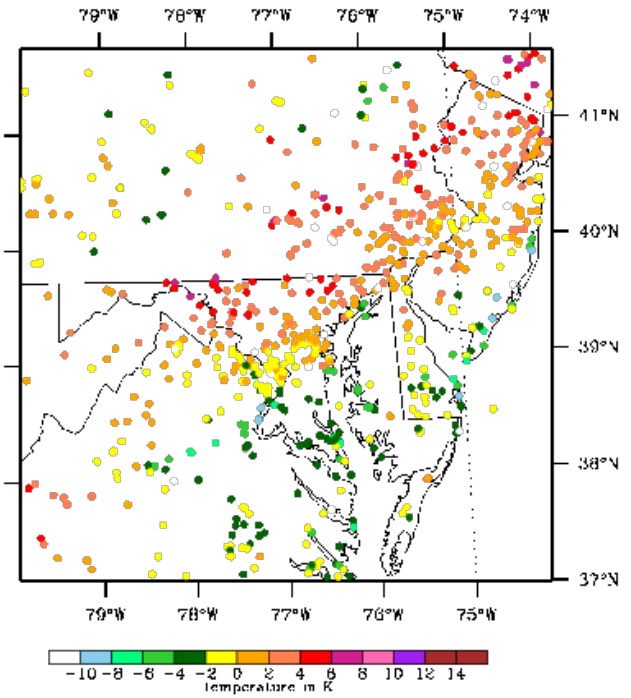


Bias =2.920
RMS=4.585



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.