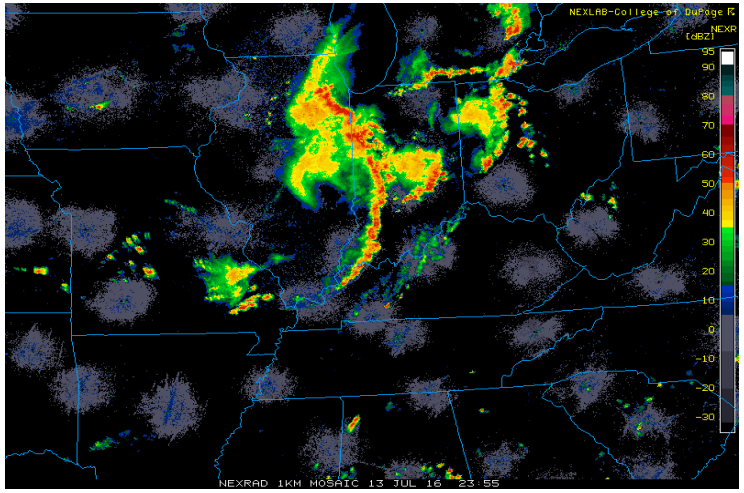
13.4 Impact of Soil Moisture Active Passive Data Assimilation on Short-Term Numerical Weather Prediction during Warm Seasons



Jonathan L. Case *(ENSCO, Inc.)*

Clay B. Blankenship *(USRA)*

William L. Crosson *(USRA)*

Christopher R. Hain & Bradley T. Zavodsky *(NASA MSFC)*

SPORT

USRA NASA

Overview of Project

Assimilate Soil Moisture Active Passive (SMAP) Level 2 (L2) retrievals of soil moisture into the Noah LSM within NASA's Land Information System (LIS)

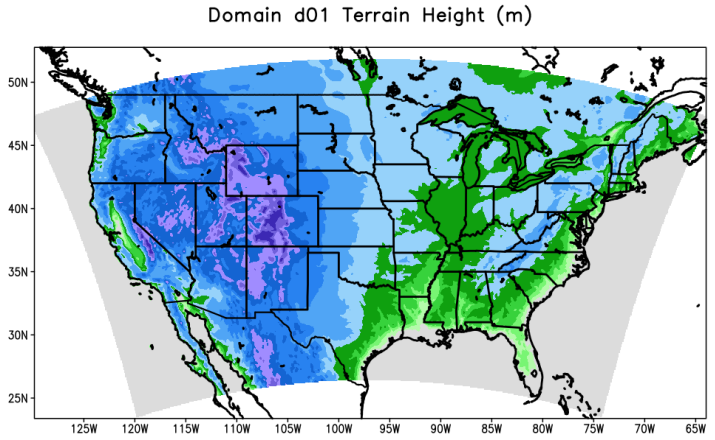
- *Data assimilation via Ensemble Kalman Filter*
- *Baseline is existing SPoRT-LIS run in CONUS [and East Africa]*
- *Builds on experience assimilating Soil Moisture Ocean Salinity (SMOS) soil moisture retrievals*
- *Assess impact of SMAP on modeled soil moisture (previous talk 13.3 in this session)*

Initialize NWP Forecasts with SPoRT-LIS and SMAP-LIS (this talk)

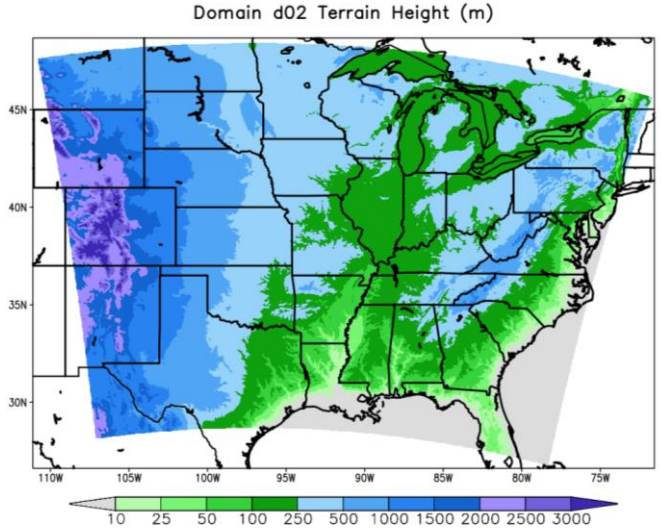
- *Investigate impact of SMAP DA on NWP forecasts*
- *Case studies and statistical verification*

NASA Unified-WRF (NU-WRF) model runs:
Model configuration and experiment details

- Domain/grid set up (images at right)
  - *Contiguous U.S. at 9-km horizontal grid spacing*
  - *Convection-allowing 3-km mesh nested grid*
- Two-day forecasts
  - *Initial/boundary conditions from NCEP Global Forecast System model*
- Model physics parameterization choices
  - *Noah land surface model (same as in LIS runs)*
  - *Convection: Scale-aware Kain-Fritsch (9-km grid only)*
  - *Planetary Boundary Layer: Yonsei University scheme*
  - *Microphysics: NASA/Goddard 4-ice parameterization*
  - *Radiation: NASA/Goddard short- and long-wave radiation schemes*
- Two land surface initialization simulations
  - ***"sportlis":** 0-h land surface fields from SPoRT's "operational" LIS run; no DA*
  - ***"smapenhda":** 0-h land surface fields from SMAP-Enhanced DA LIS run*



9-km primary grid



3-km nested grid

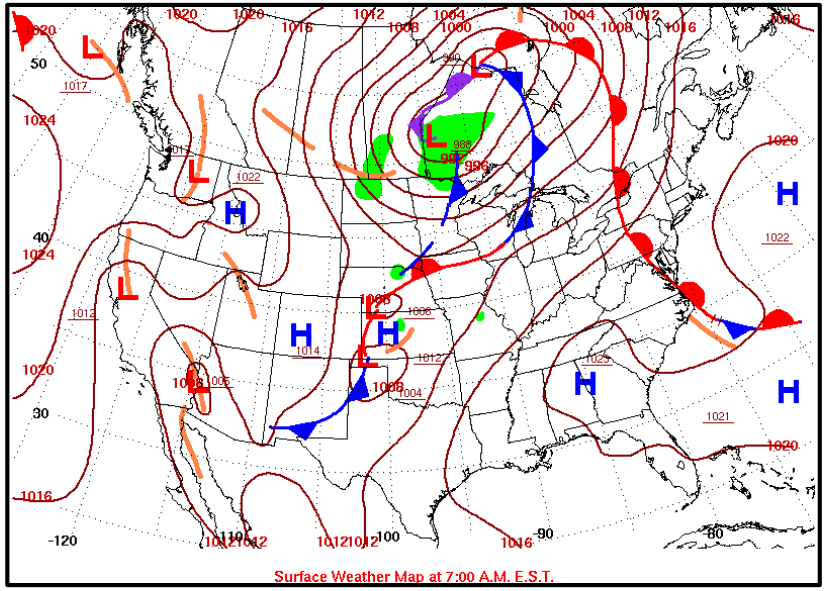
NWP Initialization Results

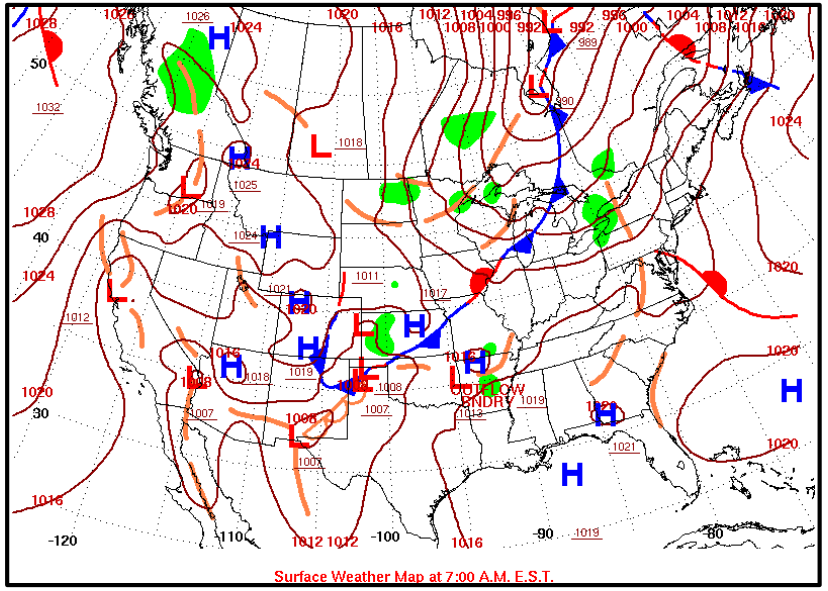
NWP model case over NE U.S. using flavor of Weather Research and Forecasting (WRF) model

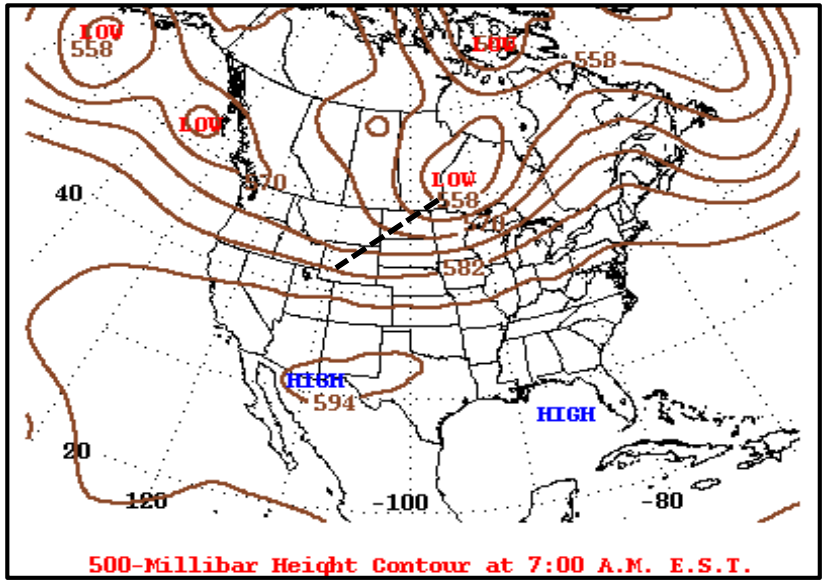
SPoRT-LIS vs. SMAP-Enh DA initialized runs

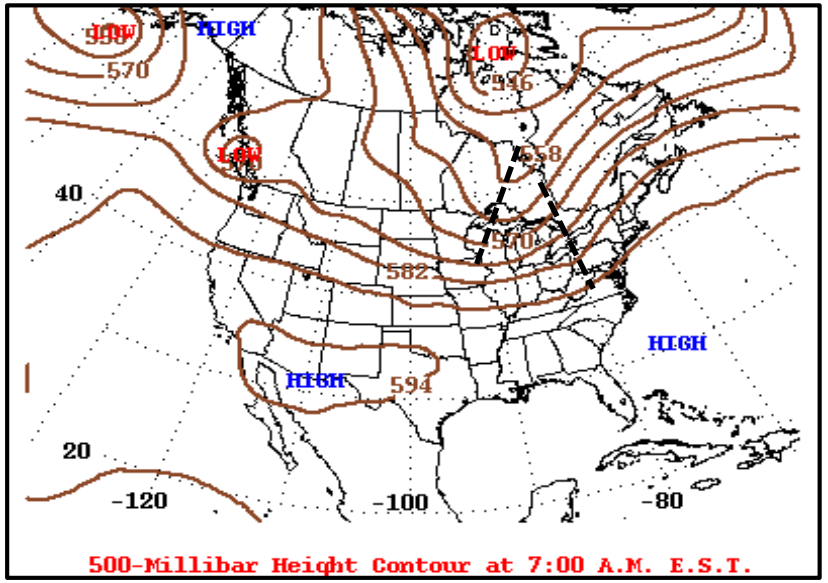
[13-14 July 2016 severe squall line event]

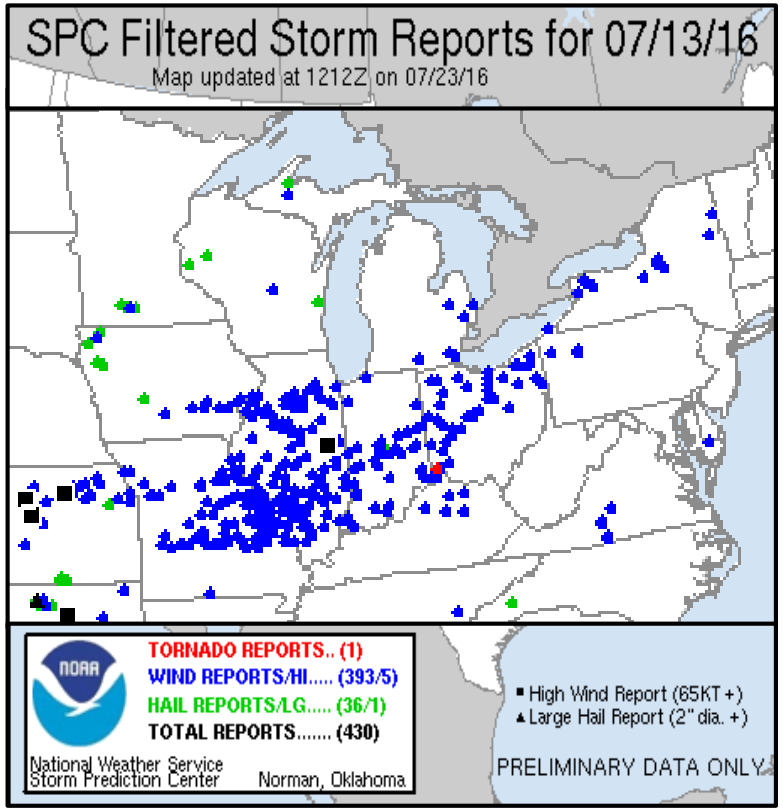
13-14 July 2016 severe squall line





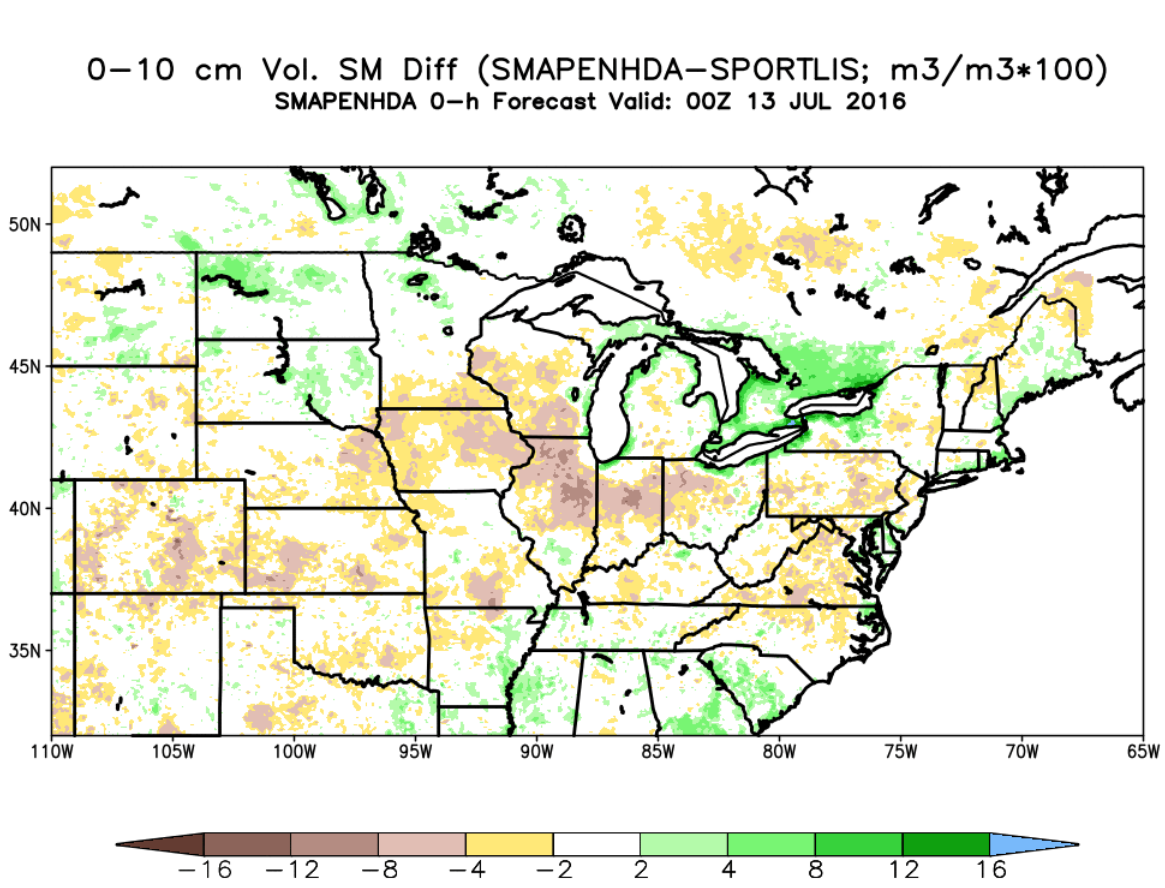


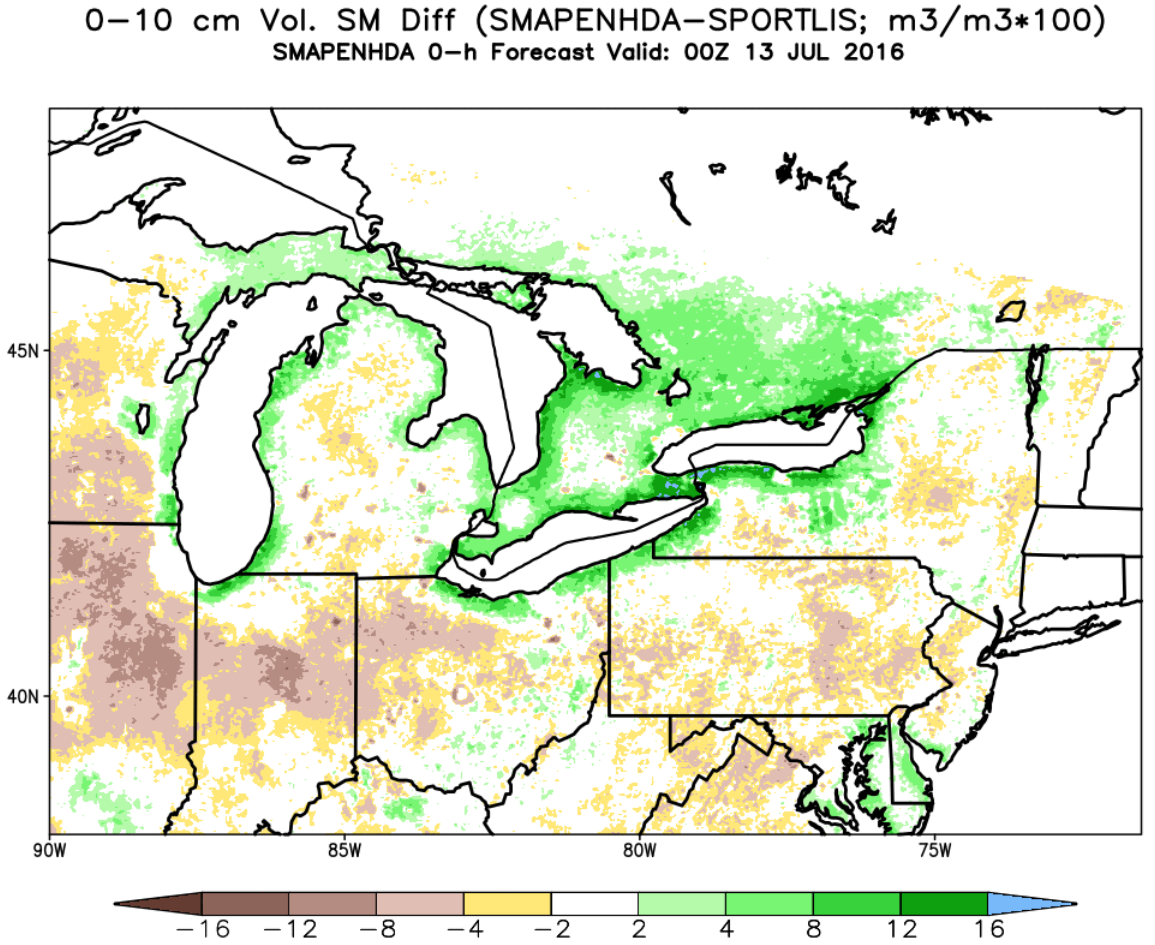




00z 13 July Soil Moisture Initialization Differences:

0-10 cm volumetric soil moisture

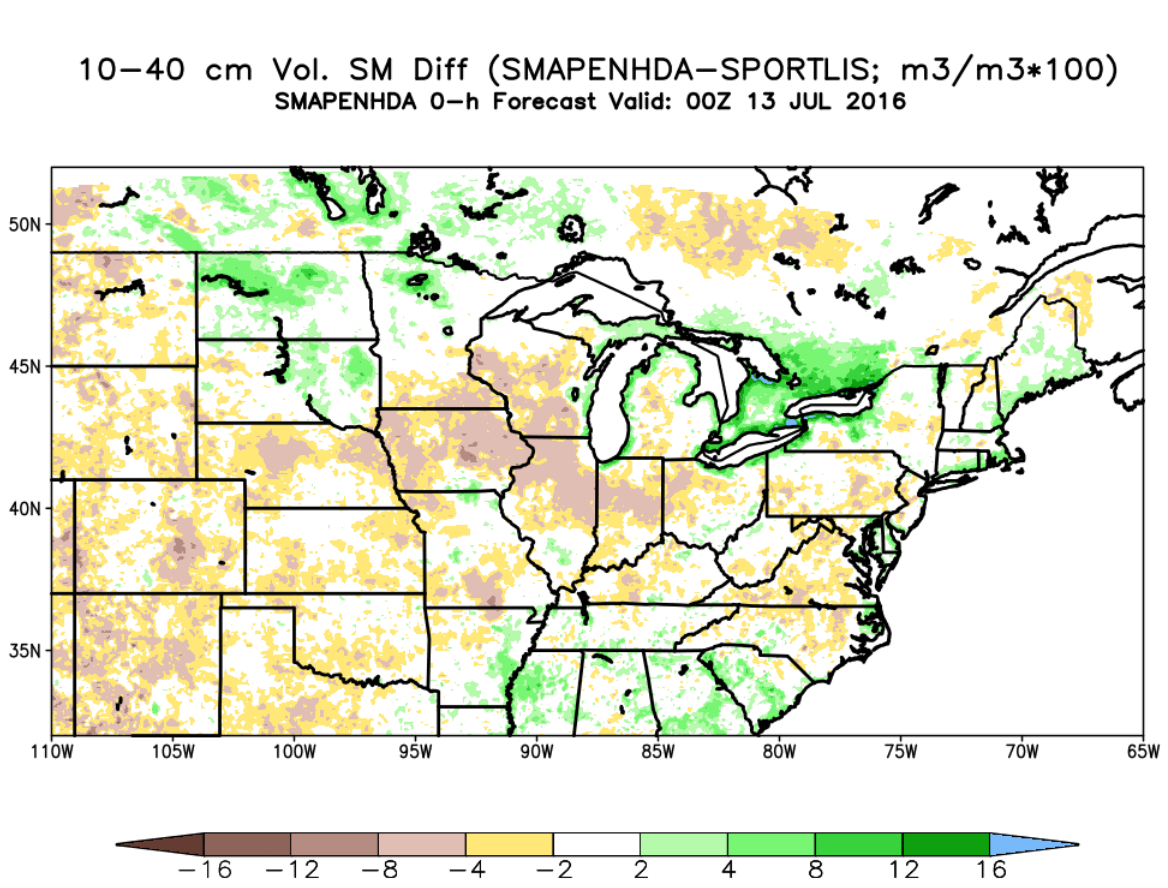


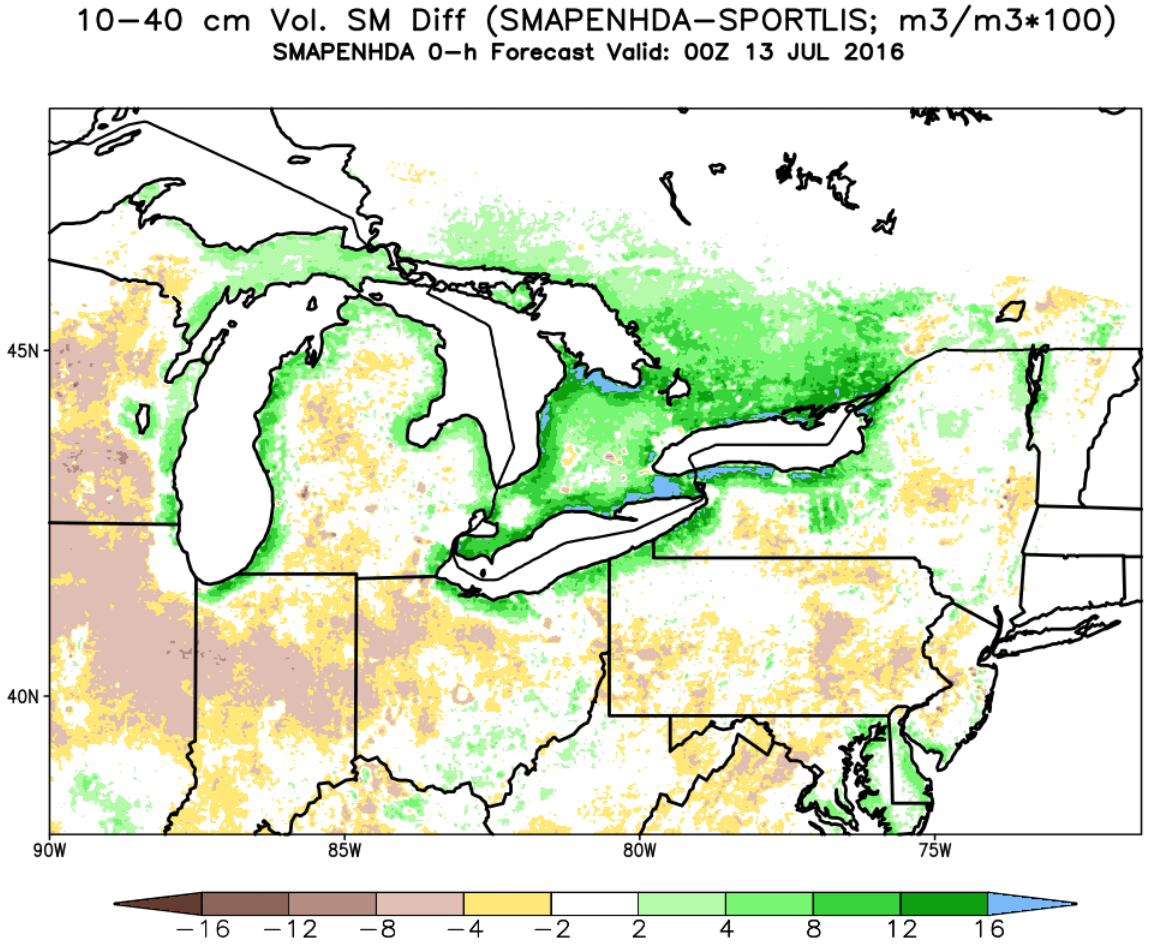


- Drier signal in Midwest/Cornbelt;
- More moist in SE Canada (corrected dry artifact in SPoRT-LIS soils)

00z 13 July Soil Moisture Initialization Differences:

10-40 cm volumetric soil moisture

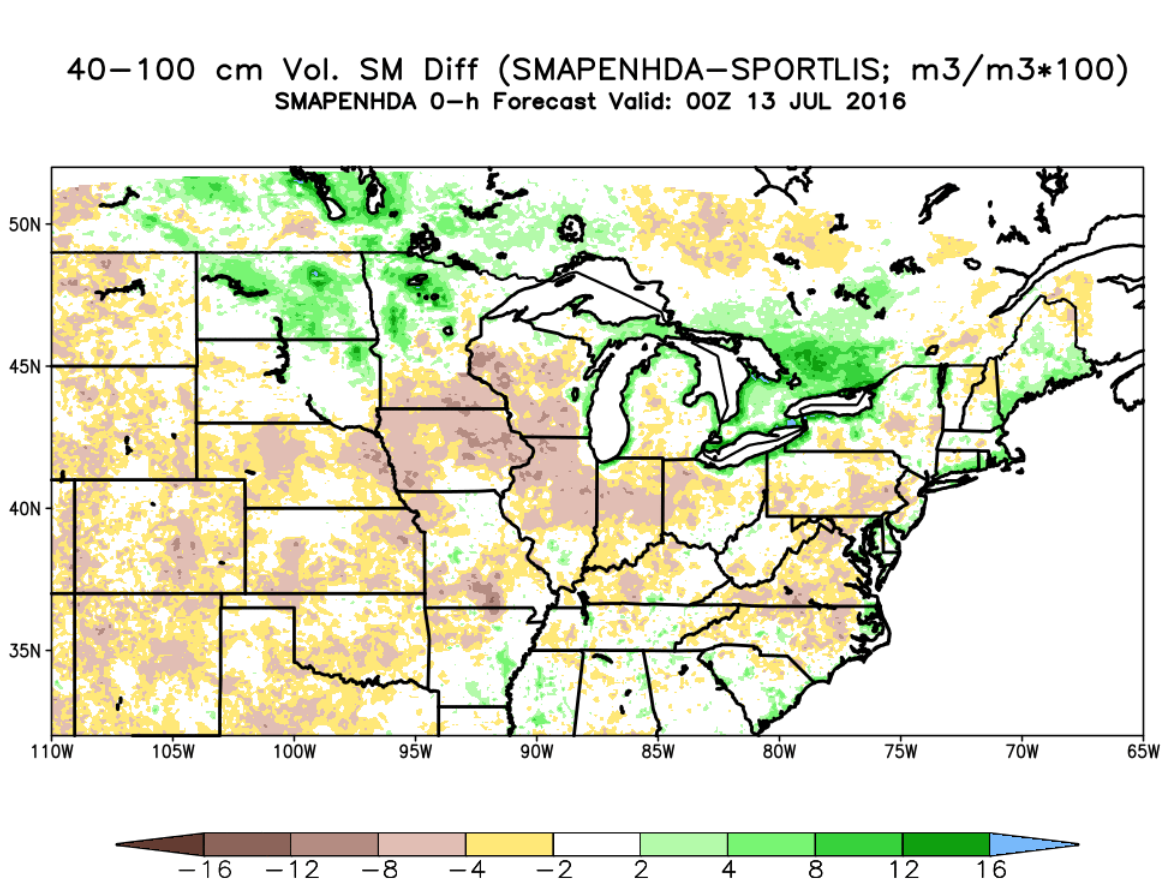


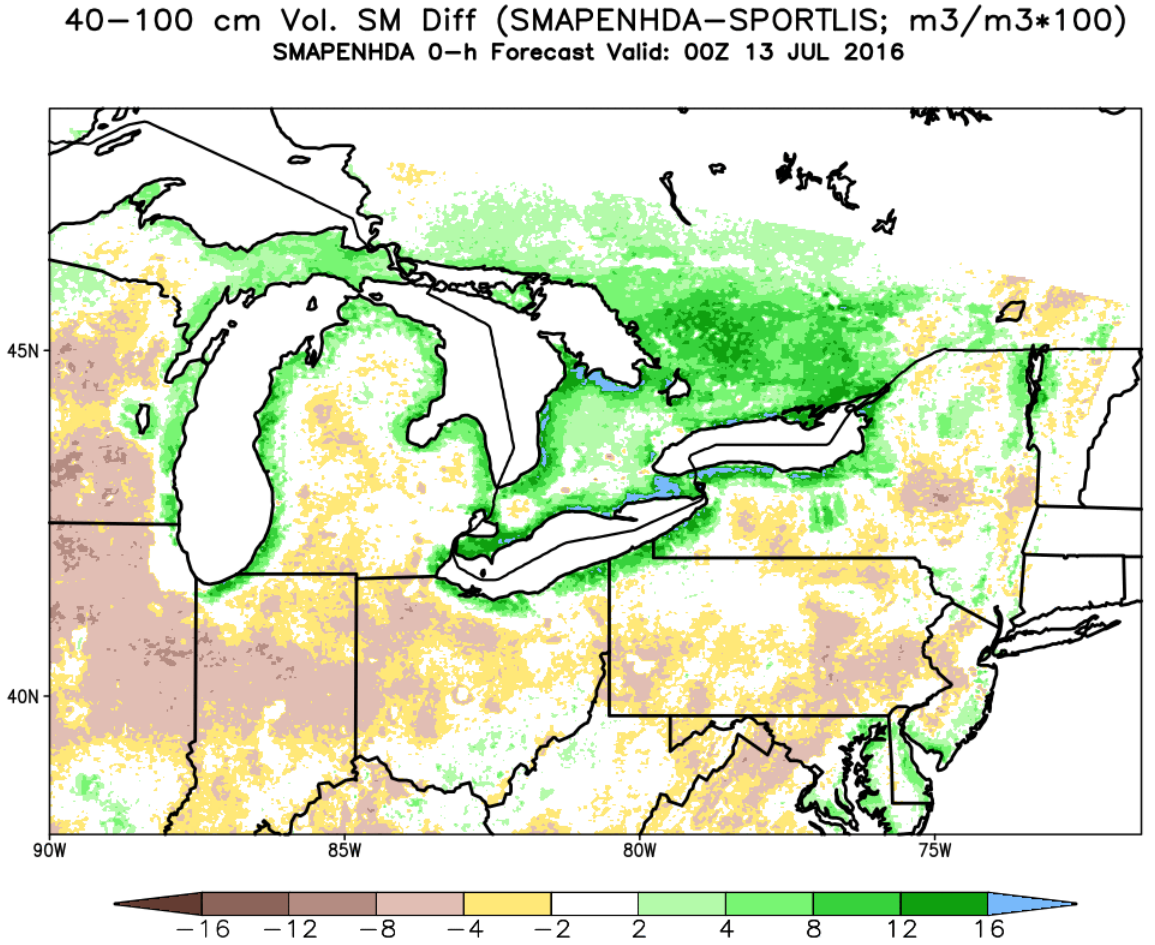


- Drier signal in Midwest/Cornbelt;
- More moist in SE Canada (corrected dry artifact in SPoRT-LIS soils)

00z 13 July Soil Moisture Initialization Differences:

40-100 cm volumetric soil moisture

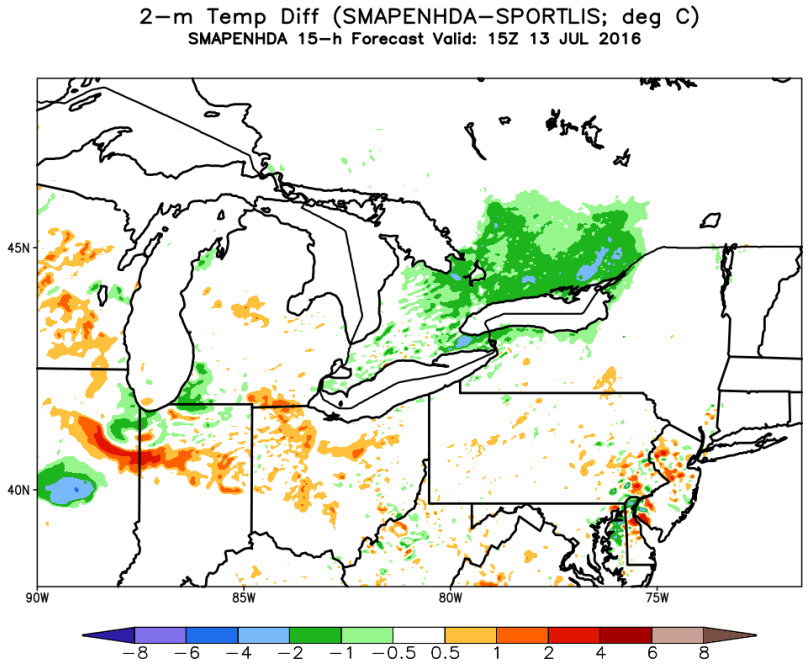




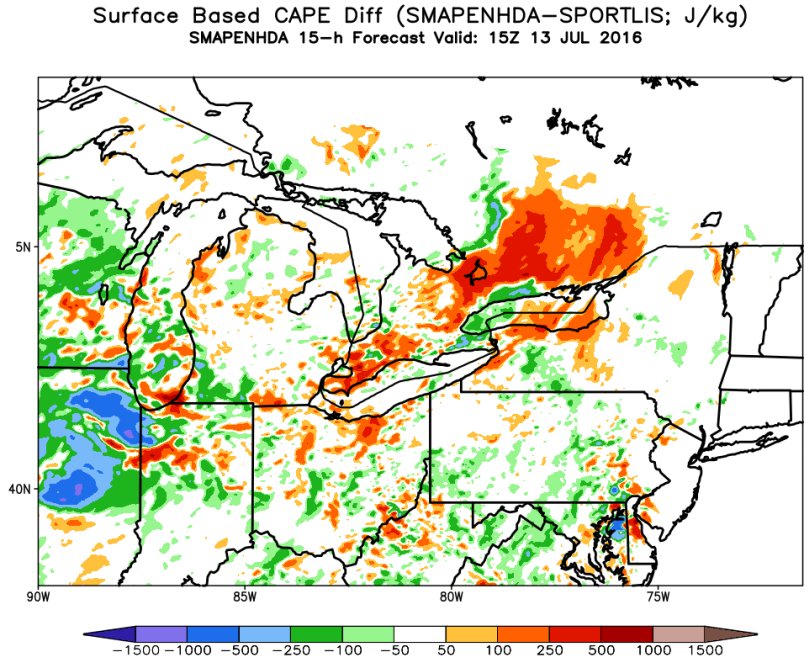
- Drier signal in Midwest/Cornbelt;
- More moist in SE Canada (corrected dry artifact in SPoRT-LIS soils)

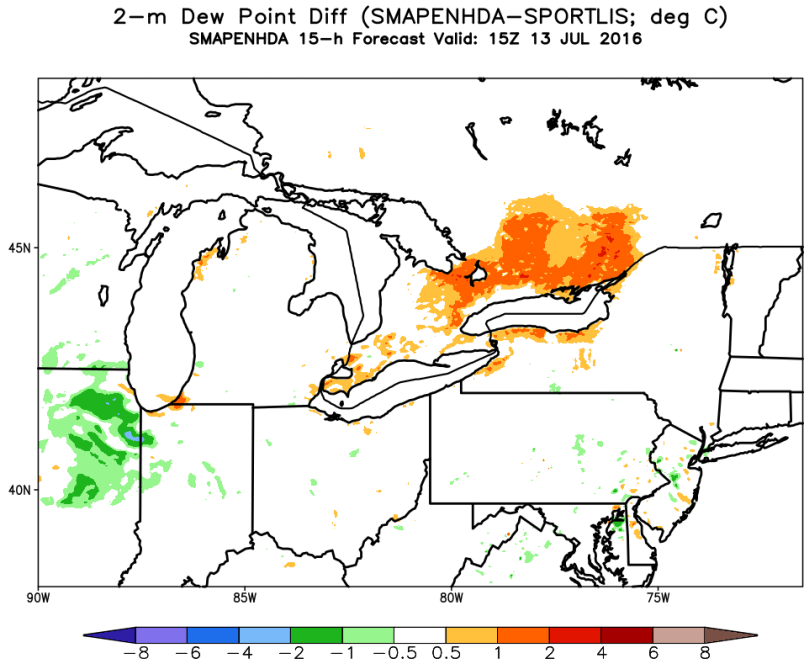
13 July 2-m Temp/Dewp/SBCAPE Differences:

15-h forecast valid 15z 13 July



~9am local time

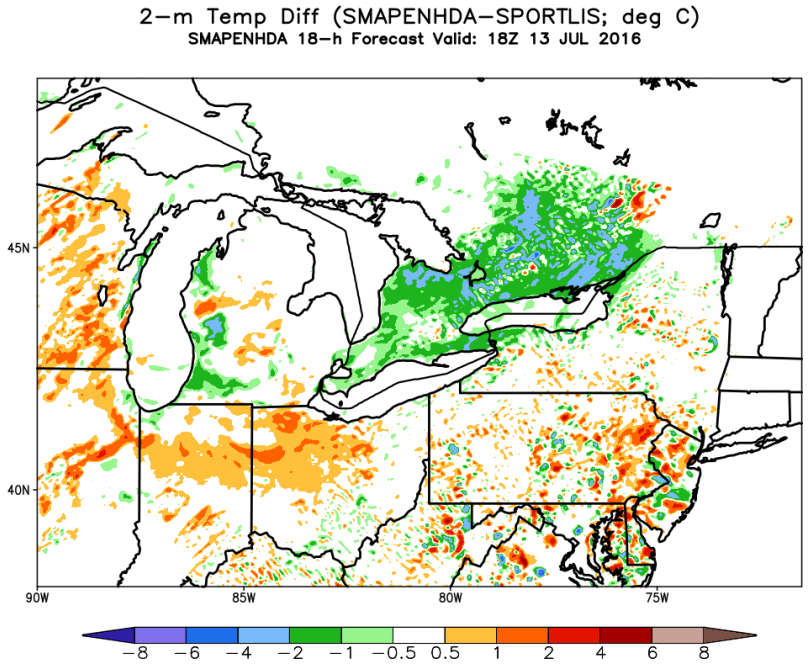




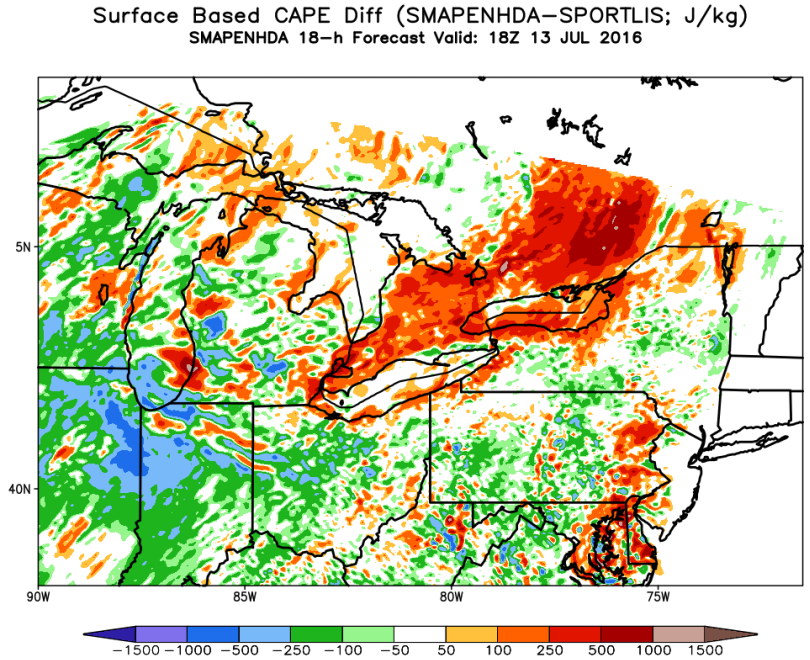
- smapenhda run is warmer/drier/less unstable in Midwest/Cornbelt;
- smapenhda run is cooler/more moist/more unstable in SE Canada

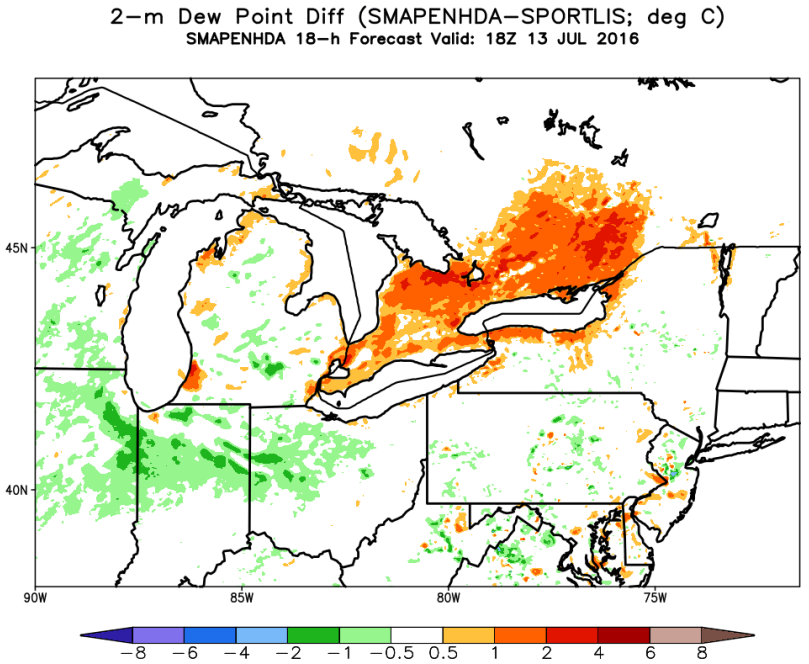
13 July 2-m Temp/Dewp/SBCAPE Differences:

18-h forecast valid 18z 13 July



~noon local time

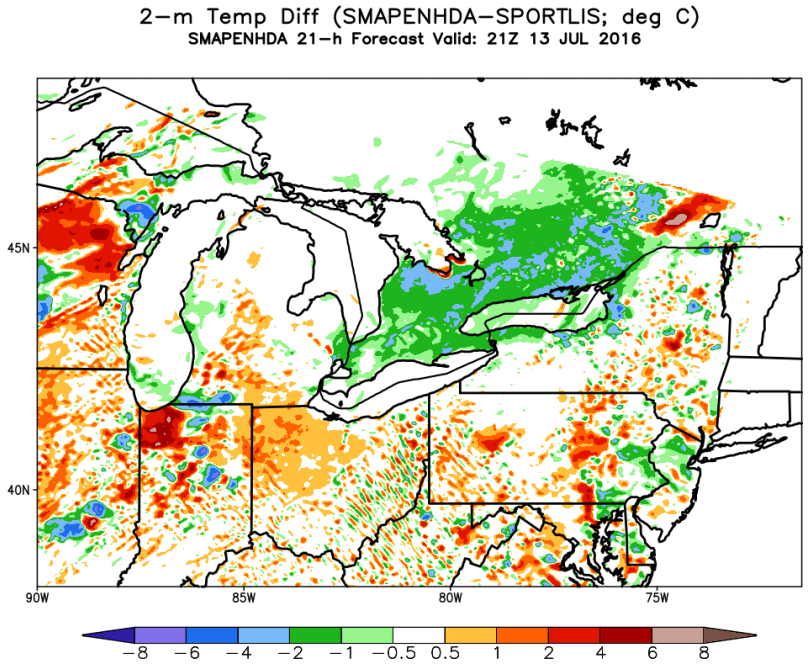




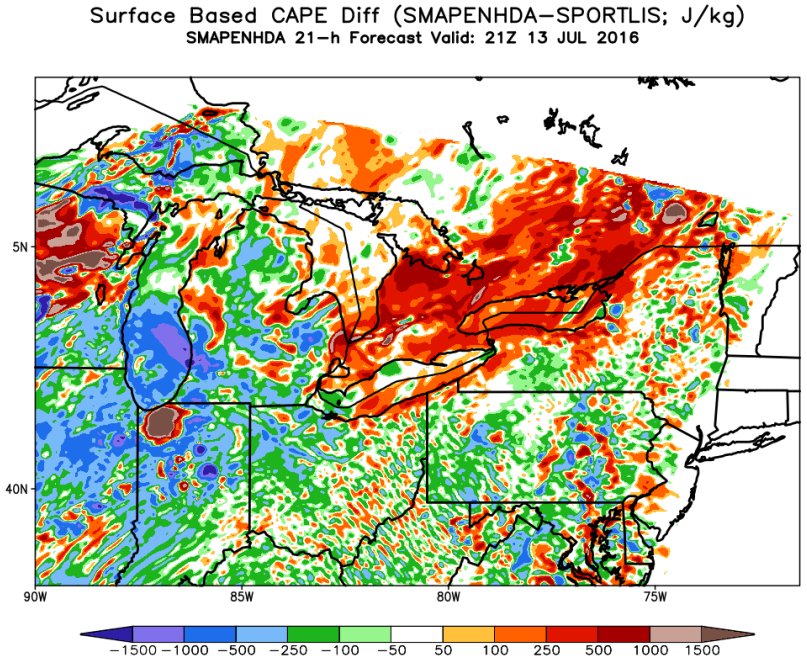
- smapenhda run is warmer/drier/less unstable in Midwest/Cornbelt;
- smapenhda run is cooler/more moist/more unstable in SE Canada

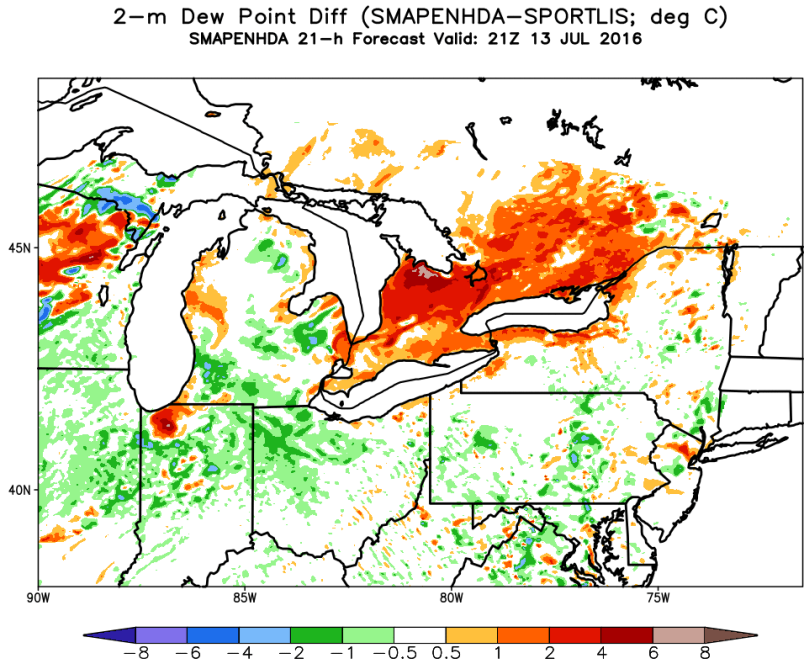
13 July 2-m Temp/Dewp/SBCAPE Differences:

21-h forecast valid 21z 13 July



~3pm local time

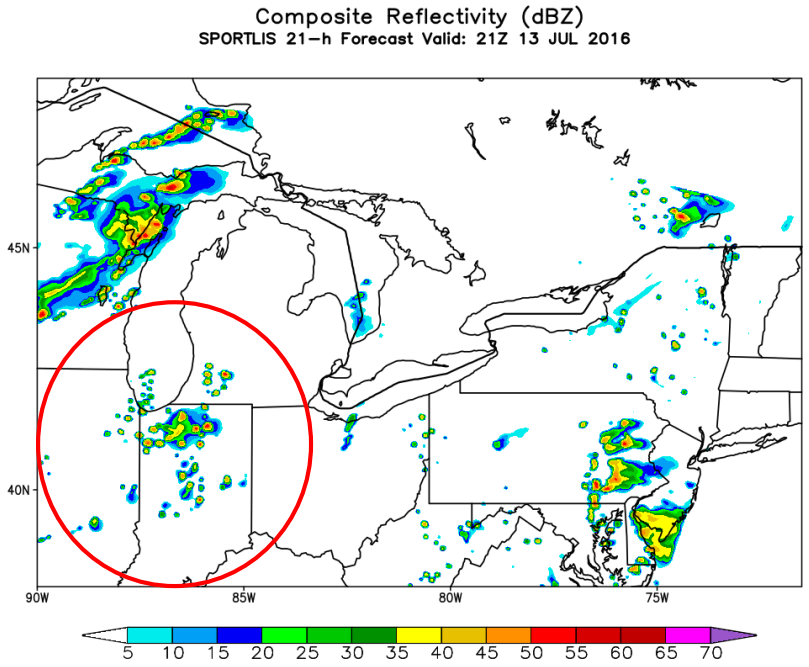




- smapenhda run is warmer/drier/less unstable in Midwest/Cornbelt;
- smapenhda run is cooler/more moist/more unstable in SE Canada

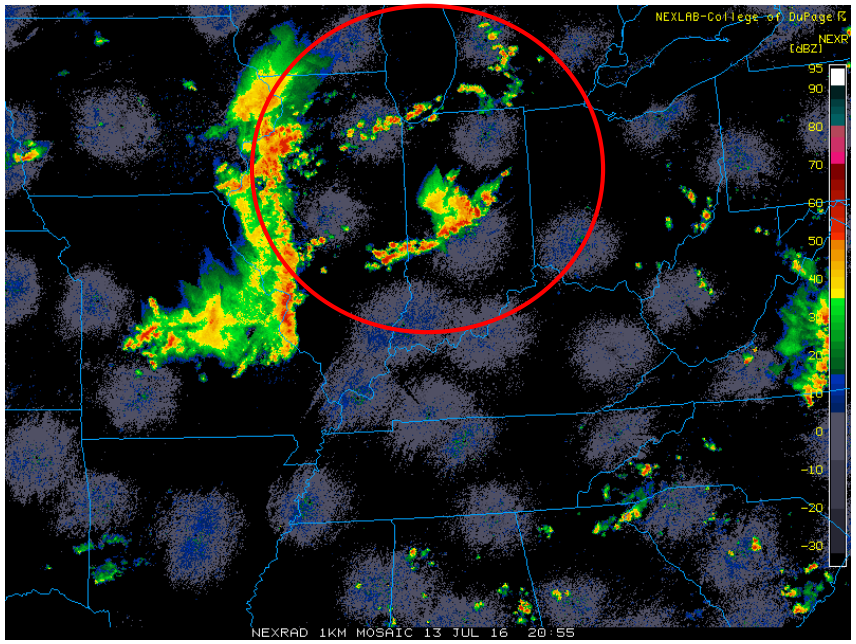
13-14 July Convection Evolution Differences:

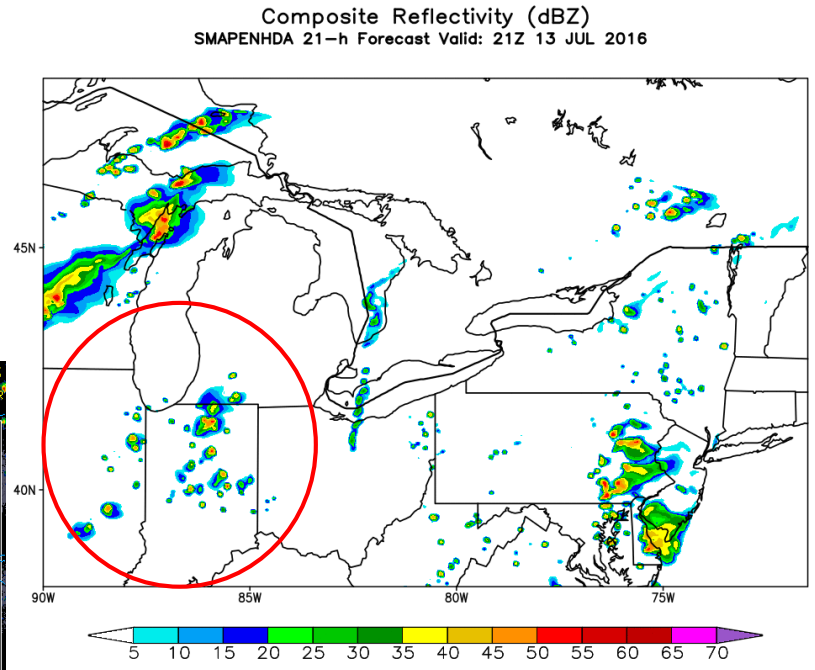
21-h forecast valid 21z 13 July



SPoRT-LIS (Control)

Observed Radar Composite



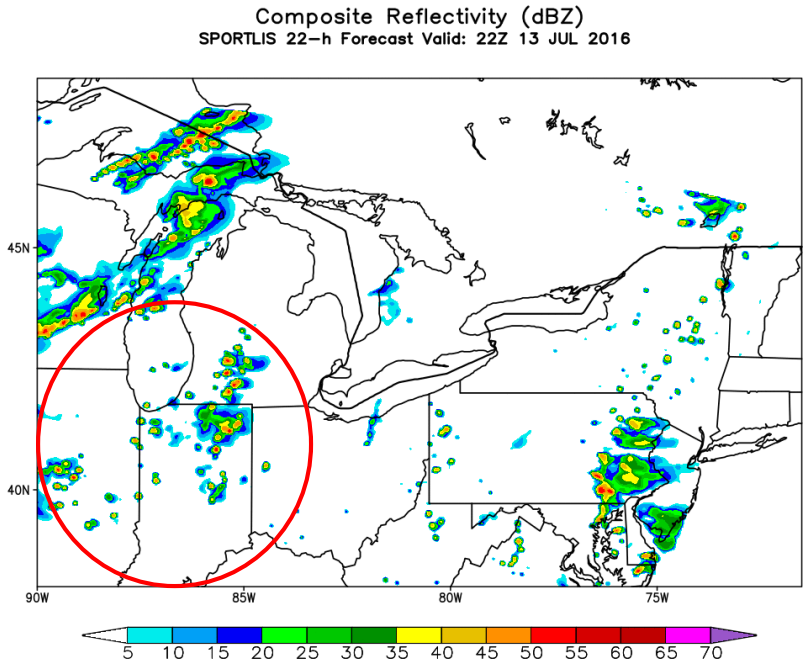


SMAP-Enh Data Assimilation

- sportlis-initialized run (left) squall line too slow, esp. earlier in late aft/early eve.
- smapenhda-initialized run (right) more correctly has faster propagation, but still too slow, esp. late eve.

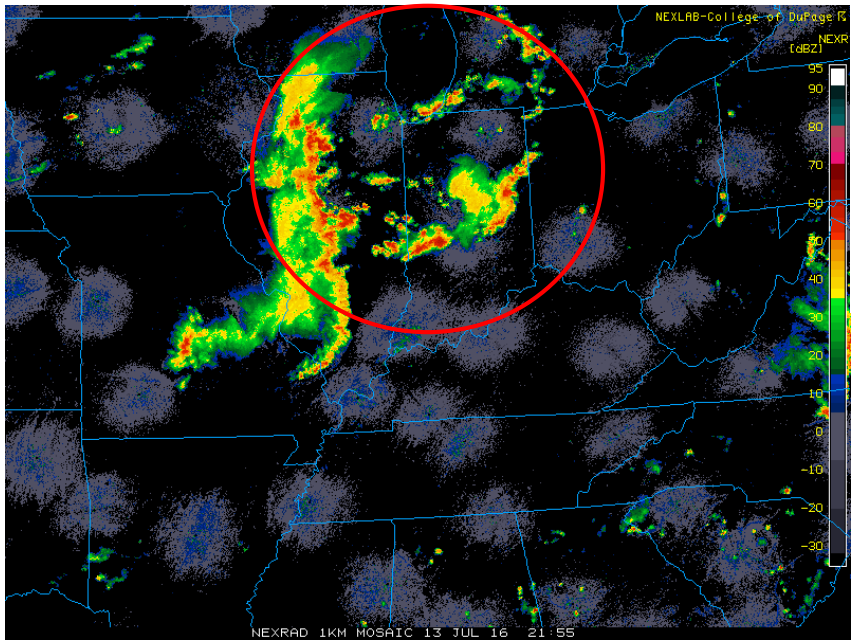
13-14 July Convection Evolution Differences:

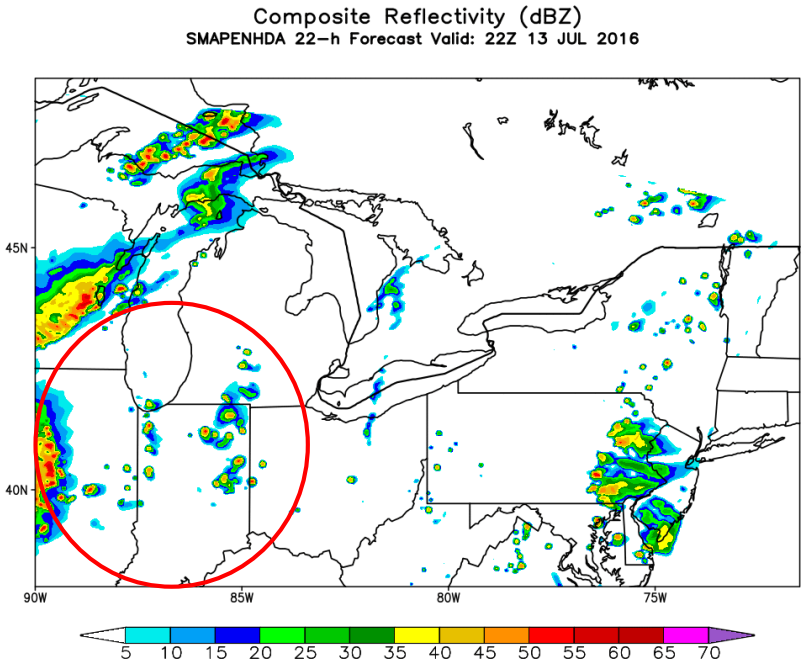
22-h forecast valid 22z 13 July



SPoRT-LIS (Control)

Observed Radar Composite



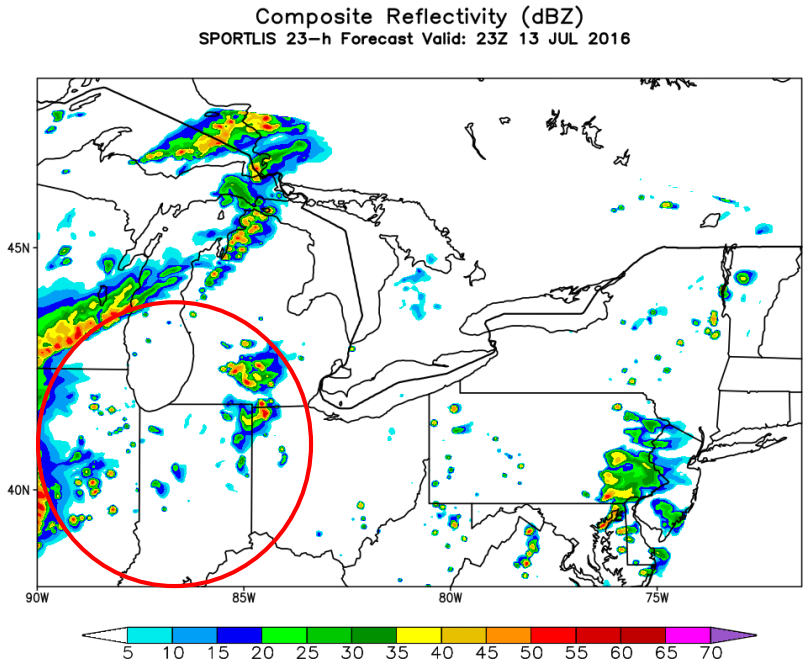


SMAP-Enh Data Assimilation

- sportlis-initialized run (left) squall line too slow, esp. earlier in late aft/early eve.
- smapenhda-initialized run (right) more correctly has faster propagation, but still too slow, esp. late eve.

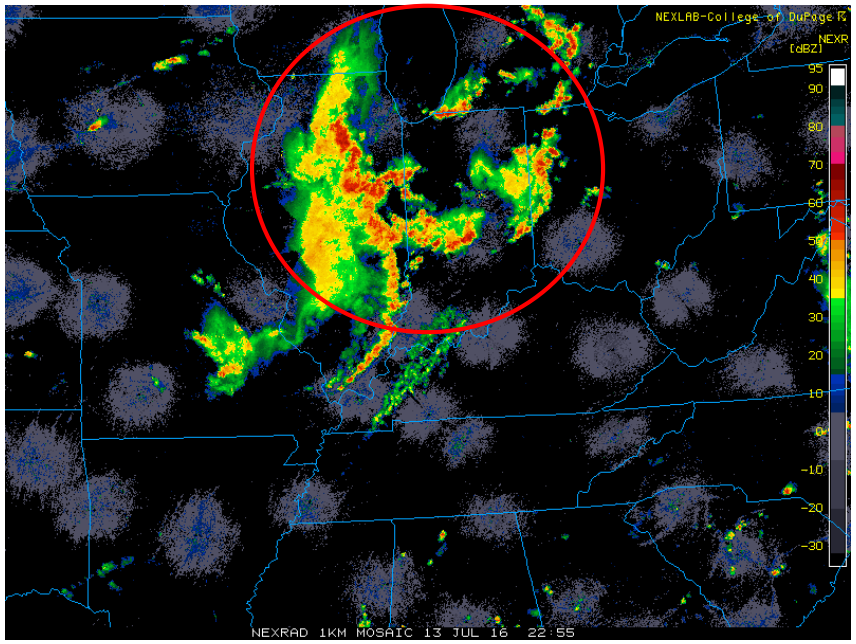
13-14 July Convection Evolution Differences:

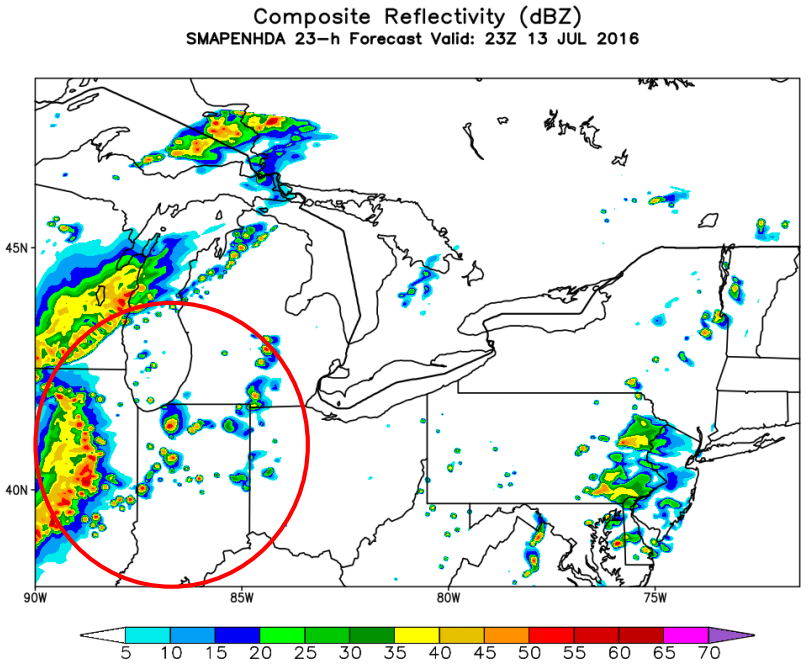
23-h forecast valid 23z 13 July



SPoRT-LIS (Control)

Observed Radar Composite



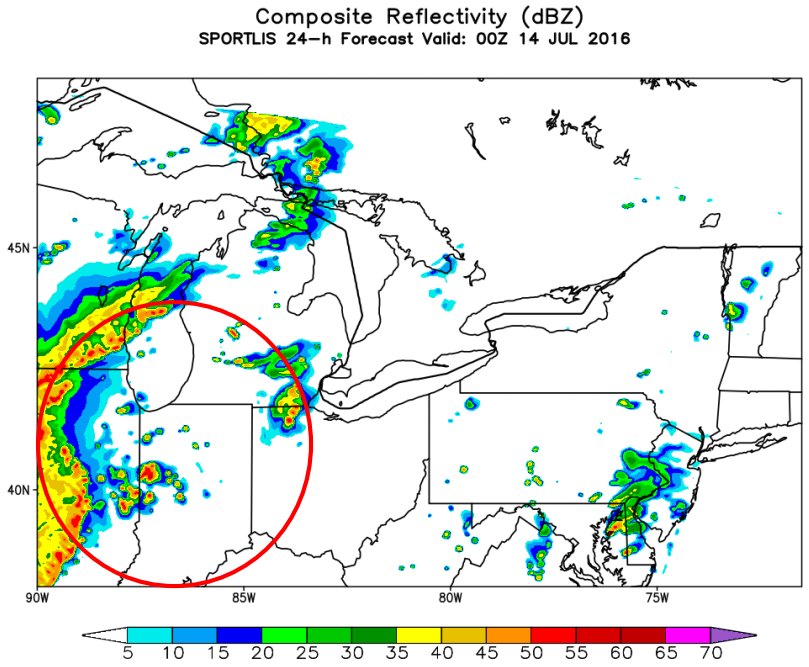


SMAP-Enh Data Assimilation

- sportlis-initialized run (left) squall line too slow, esp. earlier in late aft/early eve.
- smapenhda-initialized run (right) more correctly has faster propagation, but still too slow, esp. late eve.

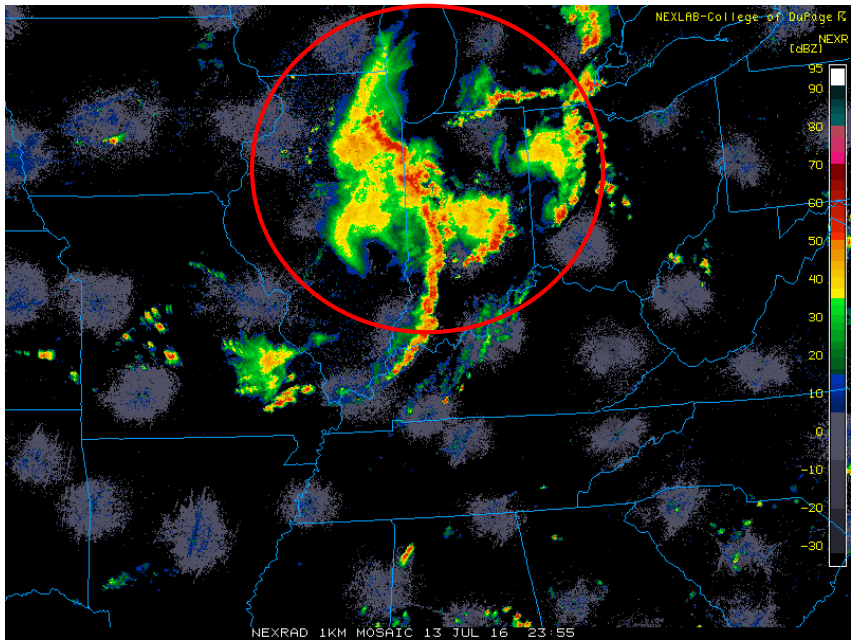
13-14 July Convection Evolution Differences:

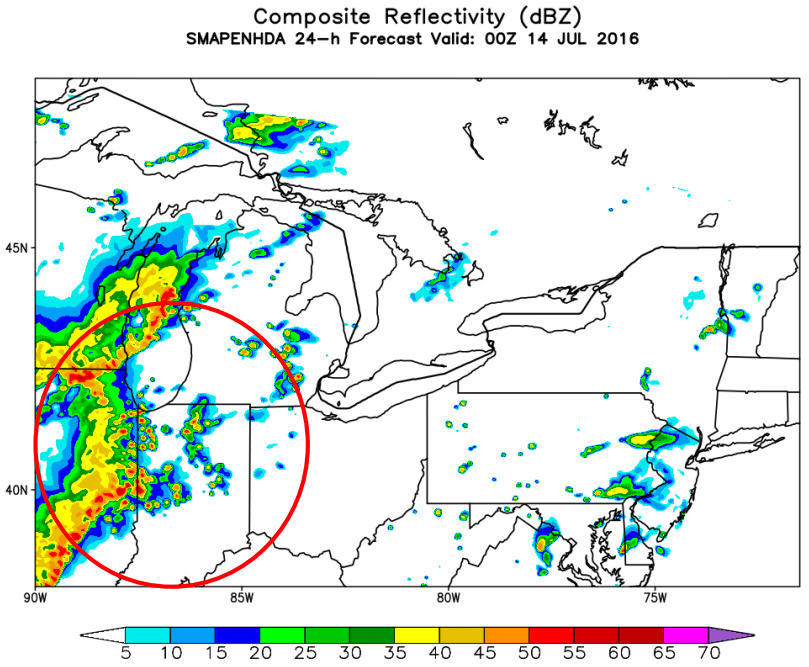
24-h forecast valid 00z 14 July



SPoRT-LIS (Control)

Observed Radar Composite



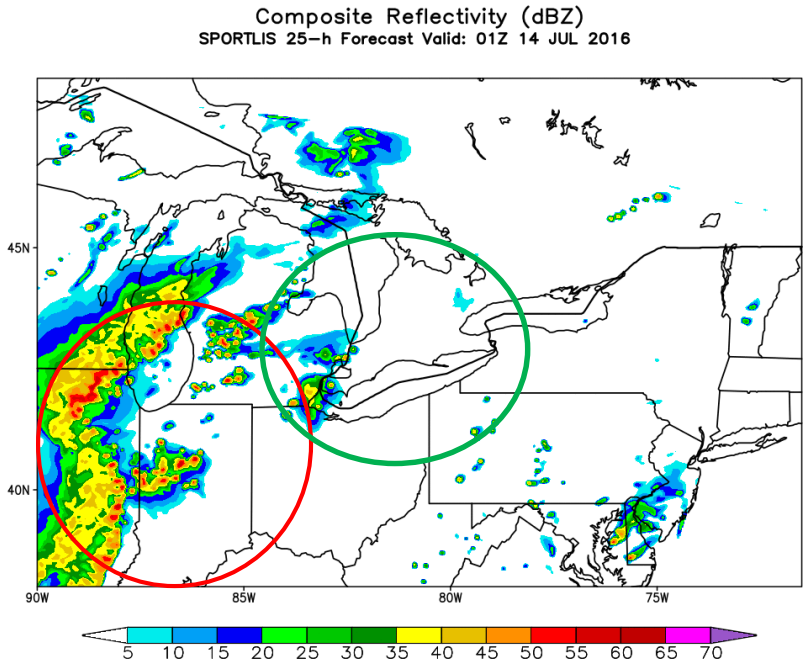


SMAP-Enh Data Assimilation

- sportlis-initialized run (left) squall line too slow, esp. earlier in late aft/early eve.
- smapenhda-initialized run (right) more correctly has faster propagation, but still too slow, esp. late eve.

13-14 July Convection Evolution Differences:

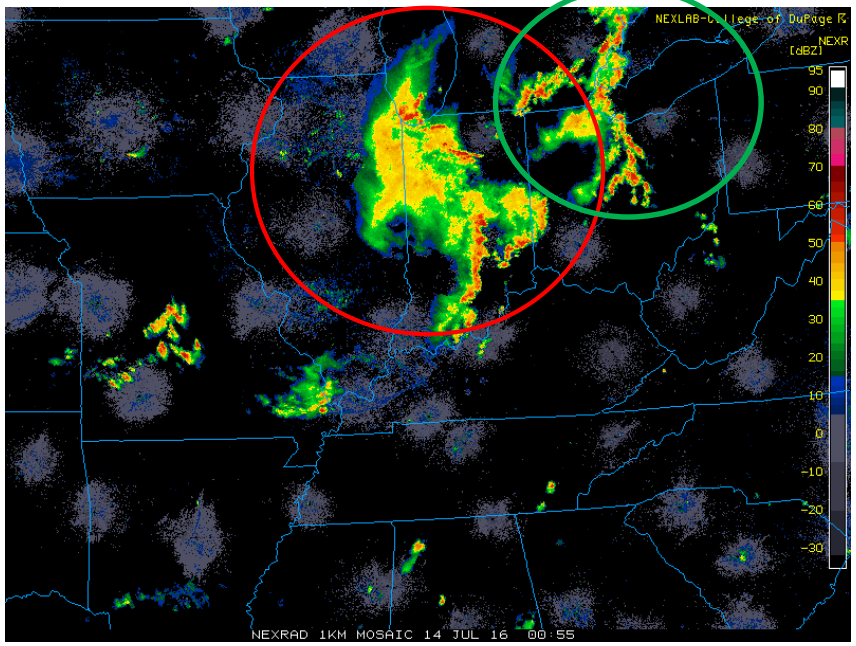
25-h forecast valid 01z 14 July

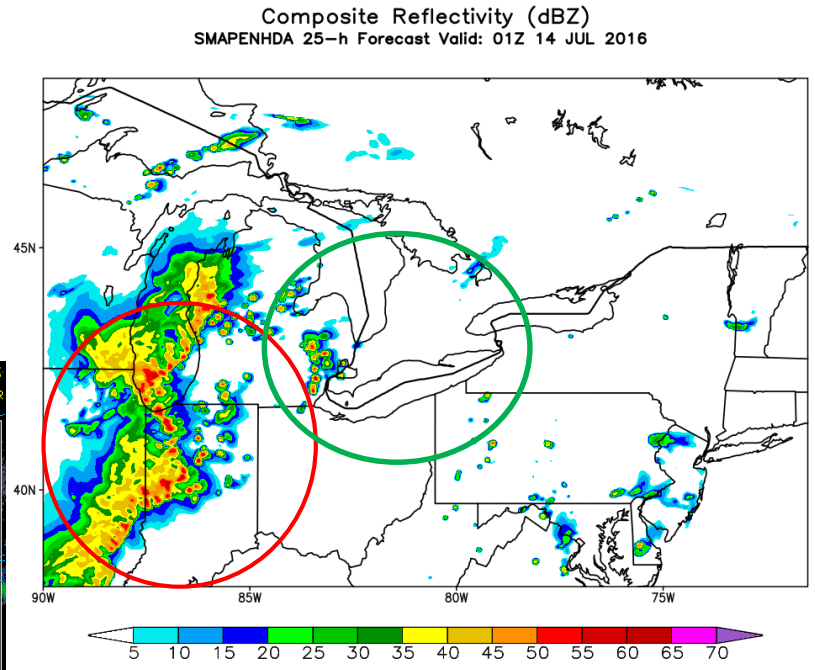


SPoRT-LIS (Control)

- **SPoRT-LIS mostly misses secondary line development in Ontario/Ohio**

Observed Radar Composite





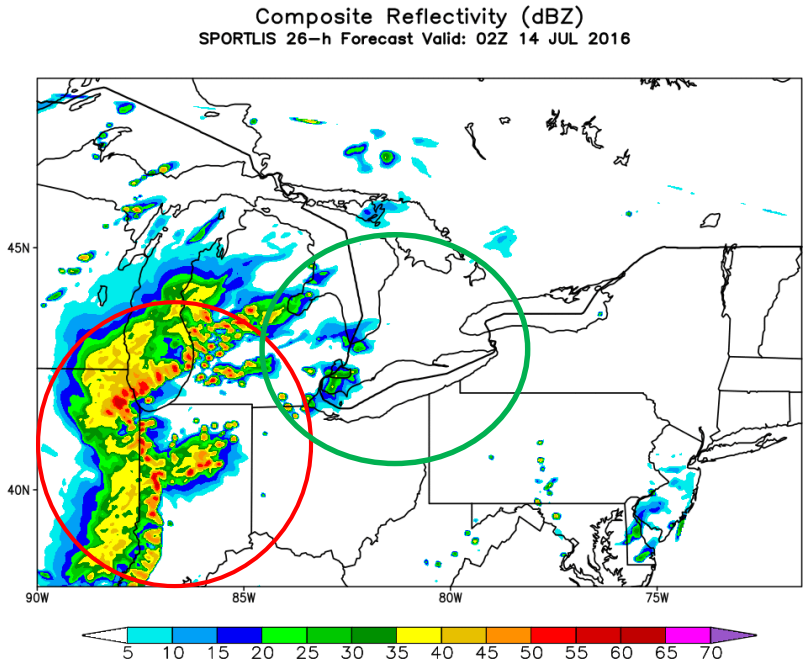
SMAP-Enh Data Assimilation

- **SMAP-Enh DA simulates secondary line, but mainly over Ontario**

- sportlis-initialized run (left) squall line too slow, esp. earlier in late aft/early eve.
- smapenhda-initialized run (right) more correctly has faster propagation, but still too slow, esp. late eve.

13-14 July Convection Evolution Differences:

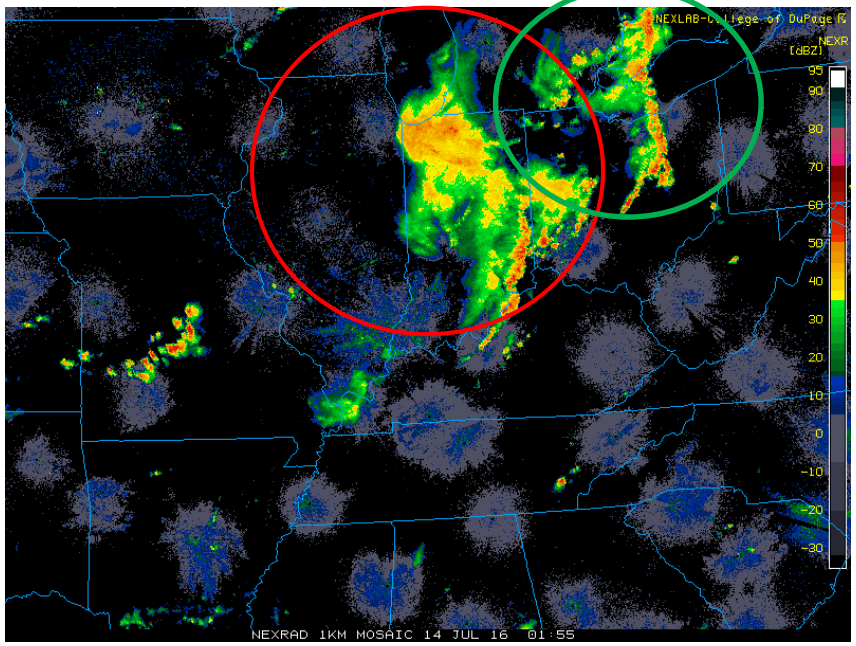
26-h forecast valid 02z 14 July

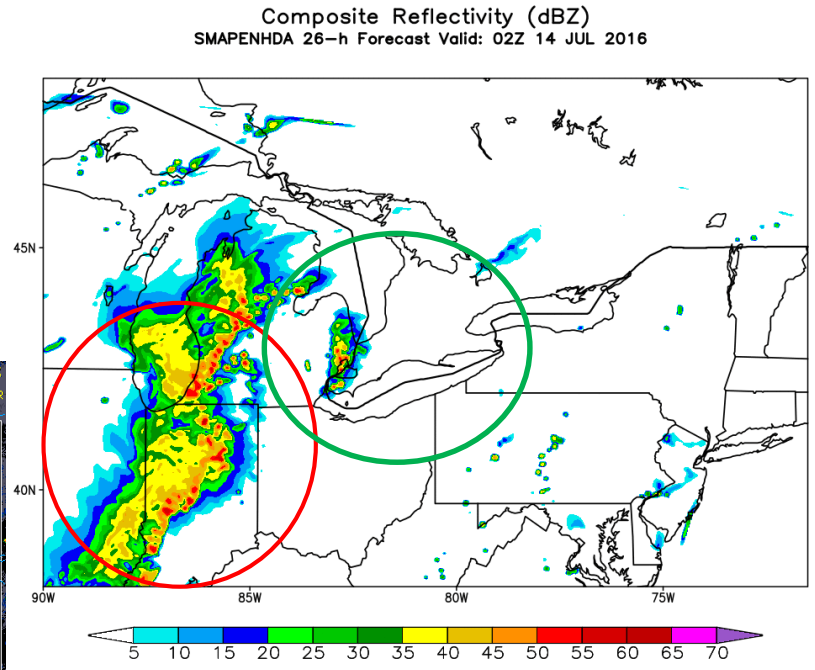


SPoRT-LIS (Control)

- **SPoRT-LIS mostly misses secondary line development in Ontario/Ohio**

Observed Radar Composite





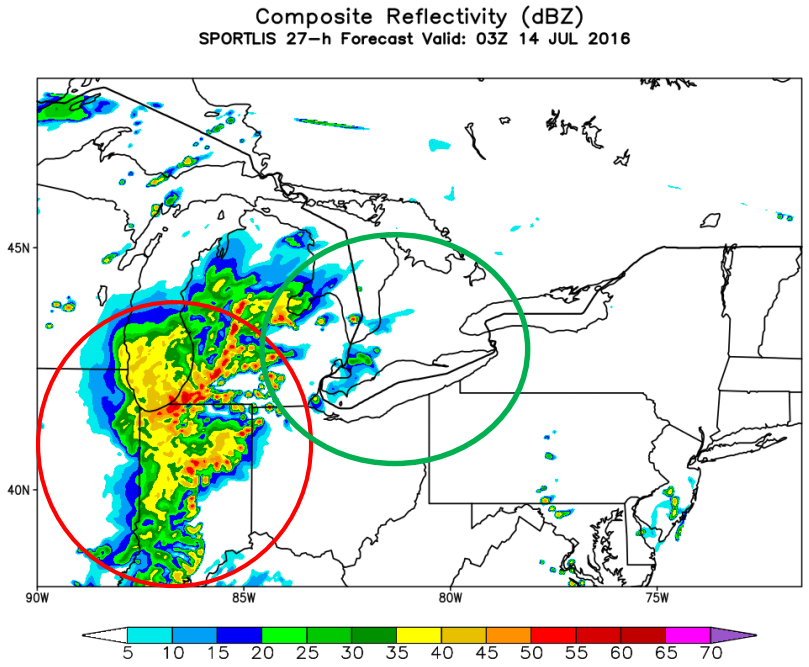
SMAP-Enh Data Assimilation

- **SMAP-Enh DA simulates secondary line, but mainly over Ontario**

- sportlis-initialized run (left) squall line too slow, esp. earlier in late aft/early eve.
- smapenhda-initialized run (right) more correctly has faster propagation, but still too slow, esp. late eve.

13-14 July Convection Evolution Differences:

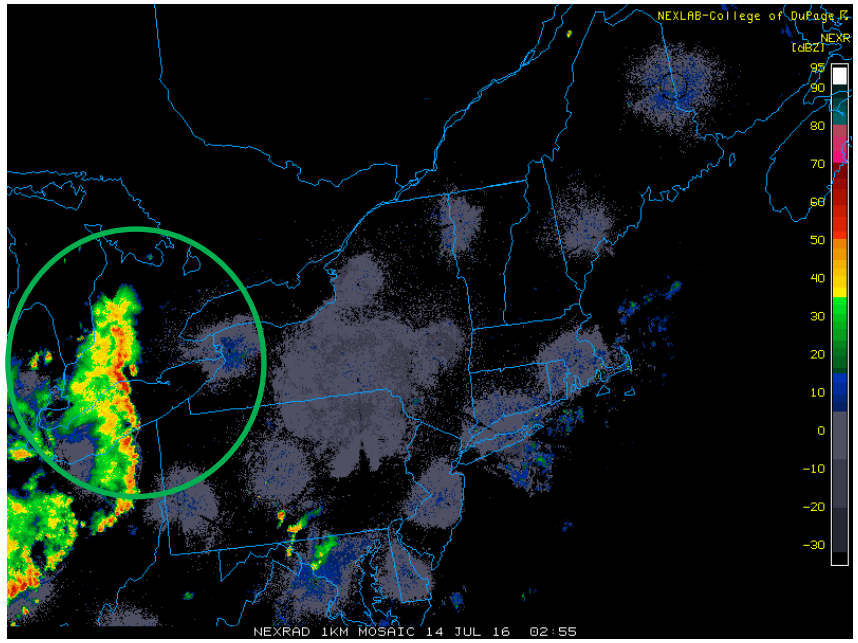
27-h forecast valid 03z 14 July

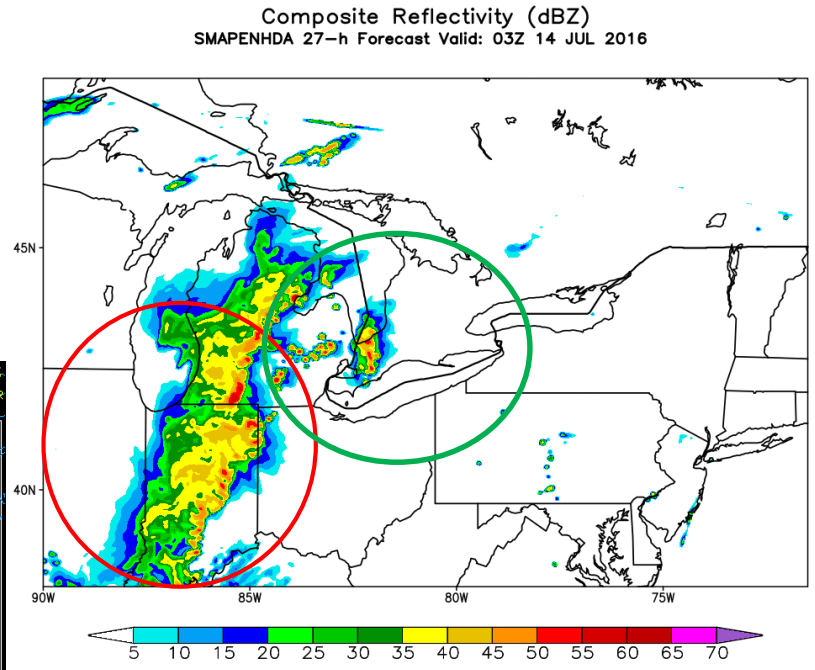


SPoRT-LIS (Control)

- **SPoRT-LIS mostly misses secondary line development in Ontario/Ohio**

Observed Radar Composite





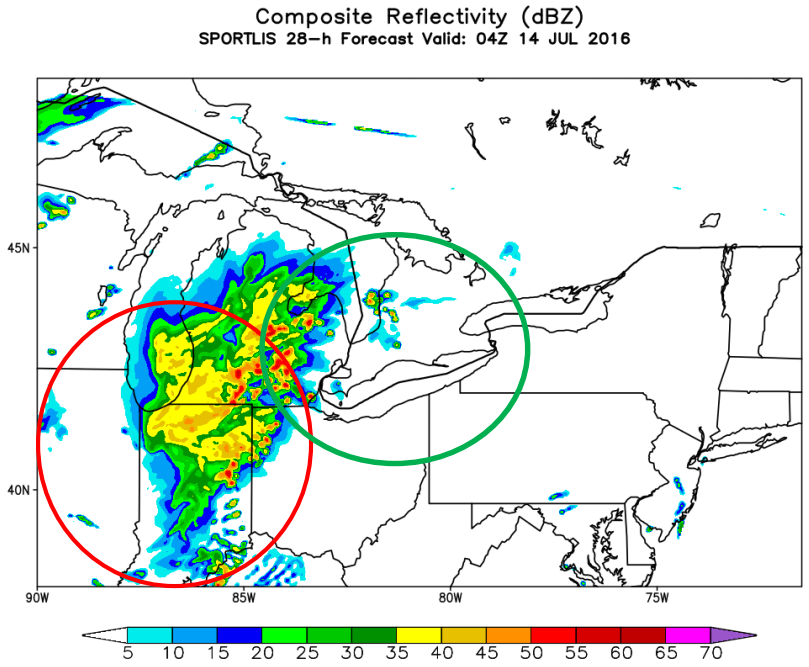
SMAP-Enh Data Assimilation

- **SMAP-Enh DA simulates secondary line, but mainly over Ontario**

- sportlis-initialized run (left) squall line too slow, esp. earlier in late aft/early eve.
- smapenhda-initialized run (right) more correctly has faster propagation, but still too slow, esp. late eve.

13-14 July Convection Evolution Differences:

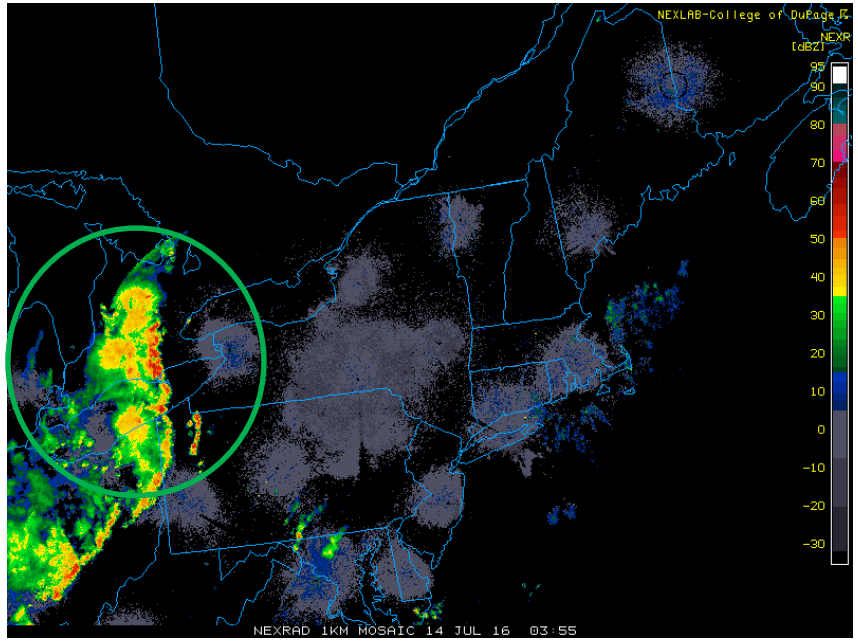
28-h forecast valid 04z 14 July

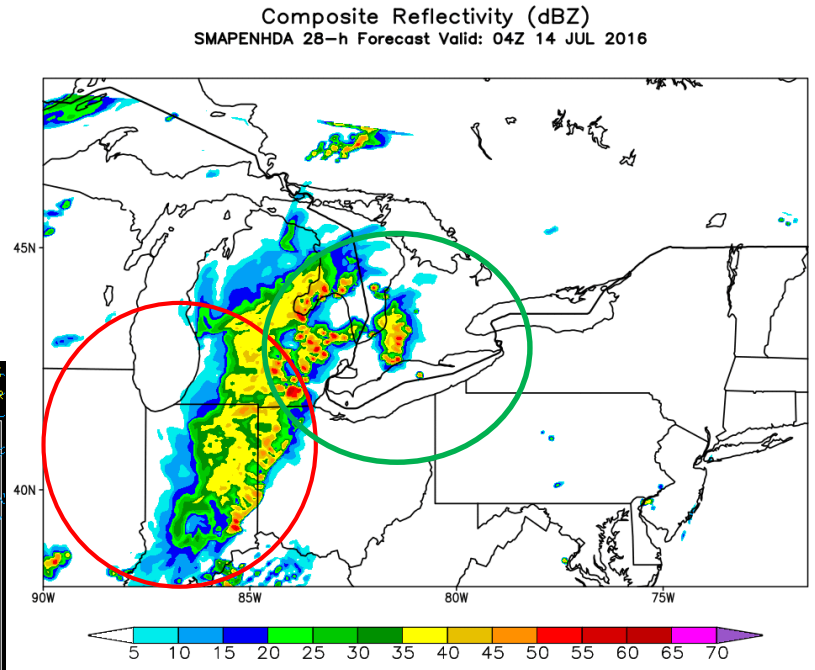


SPoRT-LIS (Control)

- **SPoRT-LIS mostly misses secondary line development in Ontario/Ohio**

Observed Radar Composite





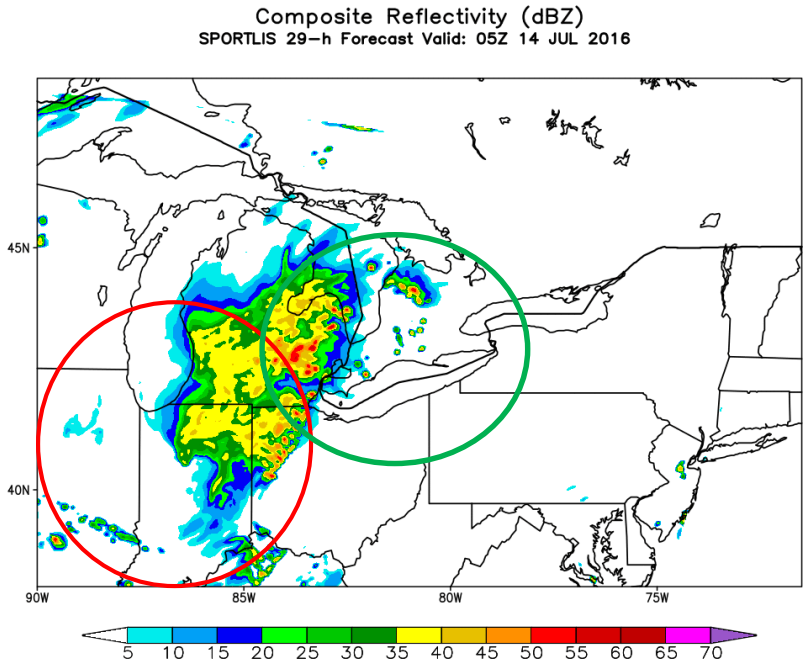
SMAP-Enh Data Assimilation

- **SMAP-Enh DA simulates secondary line, but mainly over Ontario**

- sportlis-initialized run (left) squall line too slow, esp. earlier in late aft/early eve.
- smapenhda-initialized run (right) more correctly has faster propagation, but still too slow, esp. late eve.

13-14 July Convection Evolution Differences:

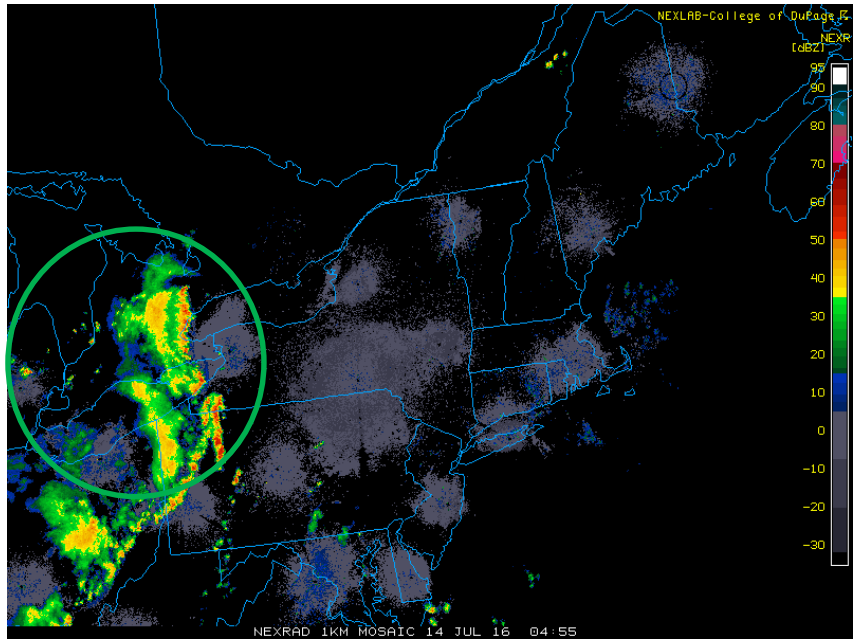
29-h forecast valid 05z 14 July

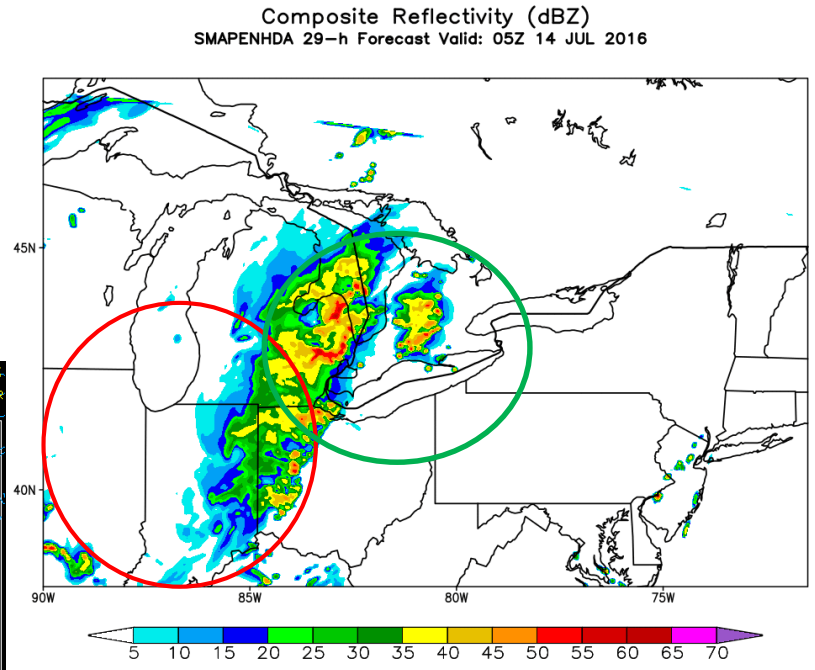


SPoRT-LIS (Control)

- **SPoRT-LIS mostly misses secondary line development in Ontario/Ohio**

Observed Radar Composite





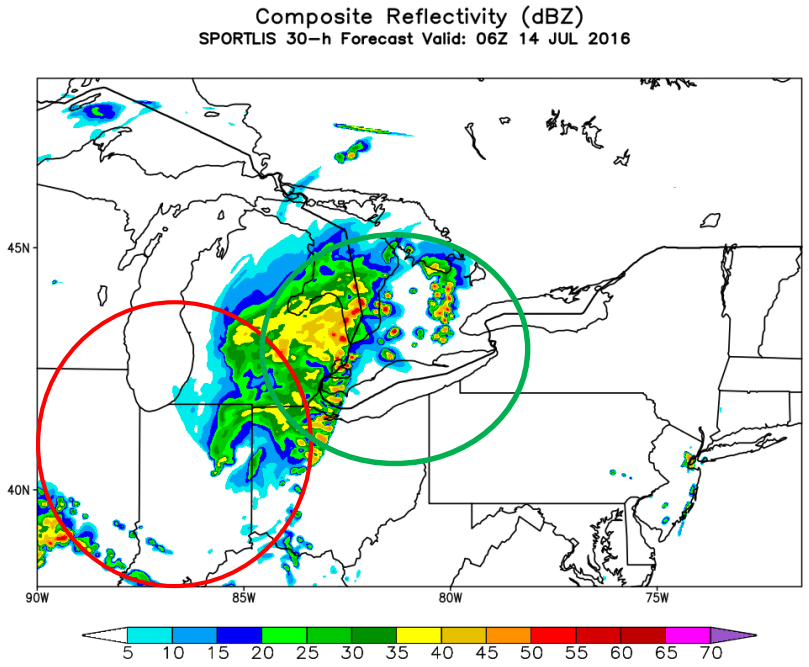
SMAP-Enh Data Assimilation

- **SMAP-Enh DA simulates secondary line, but mainly over Ontario**

- sportlis-initialized run (left) squall line too slow, esp. earlier in late aft/early eve.
- smapenhda-initialized run (right) more correctly has faster propagation, but still too slow, esp. late eve.

13-14 July Convection Evolution Differences:

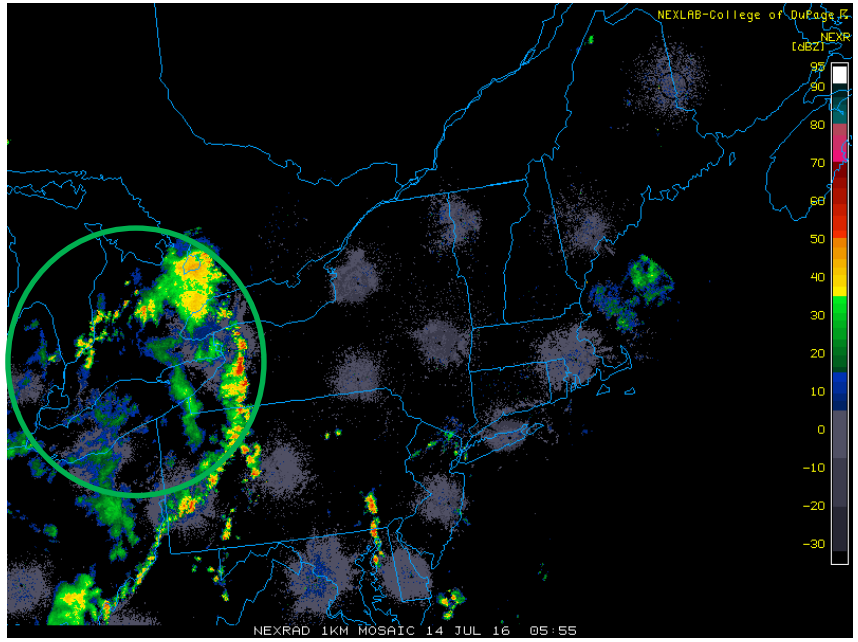
30-h forecast valid 06z 14 July

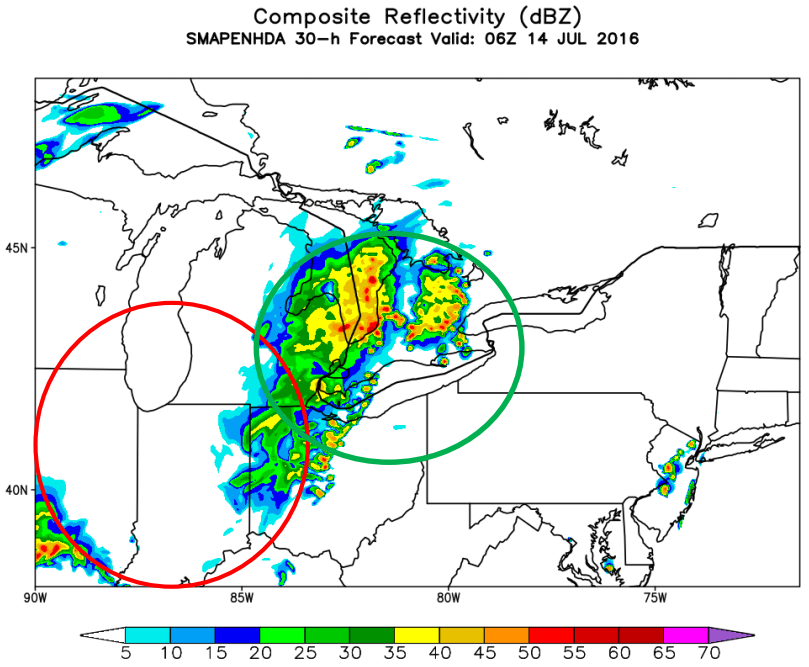


SPoRT-LIS (Control)

- **SPoRT-LIS mostly misses secondary line development in Ontario/Ohio**

Observed Radar Composite





SMAP-Enh Data Assimilation

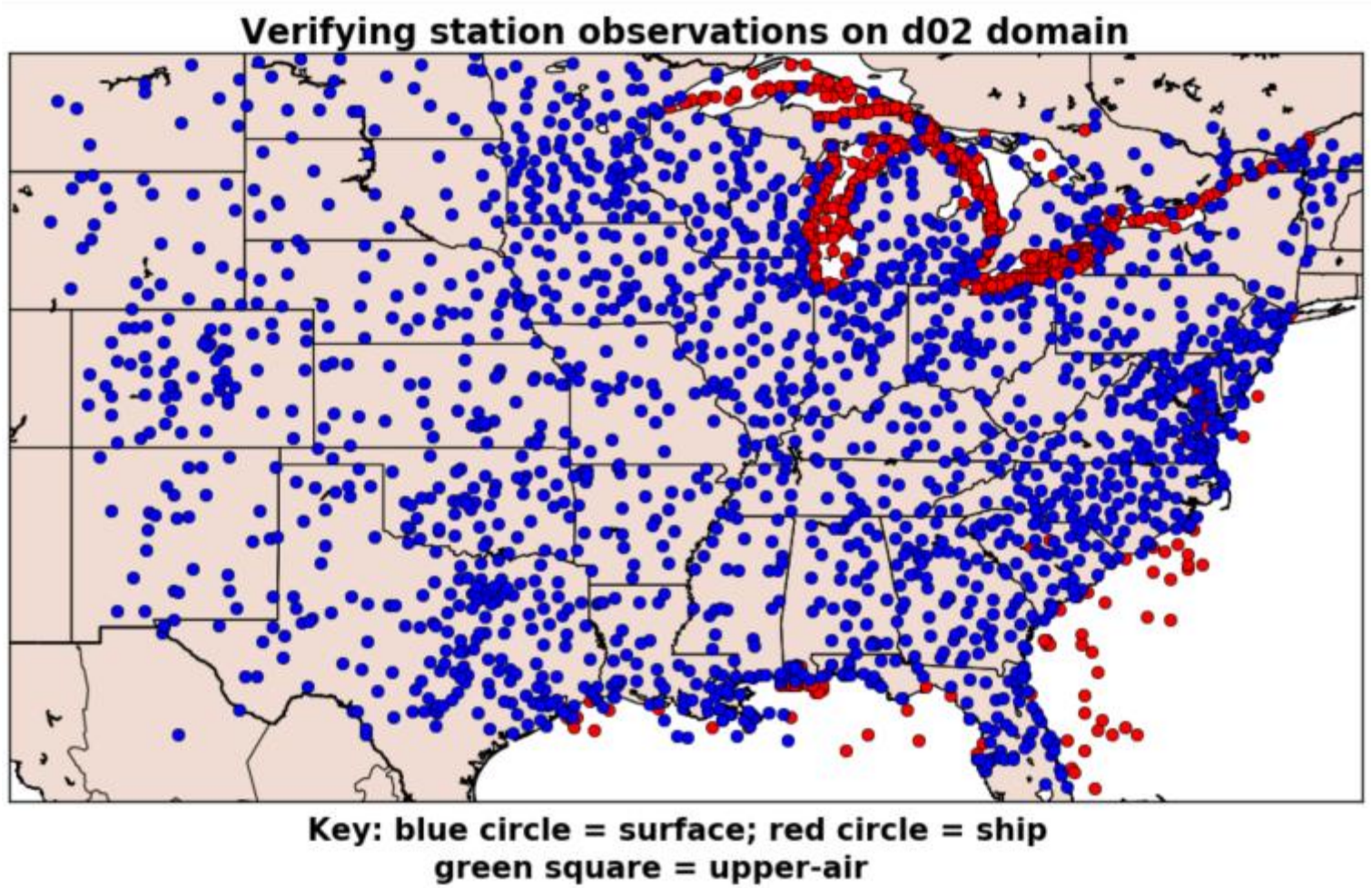
- **SMAP-Enh DA simulates secondary line, but mainly over Ontario**

- sportlis-initialized run (left) squall line too slow, esp. earlier in late aft/early eve.
- smapenhda-initialized run (right) more correctly has faster propagation, but still too slow, esp. late eve.

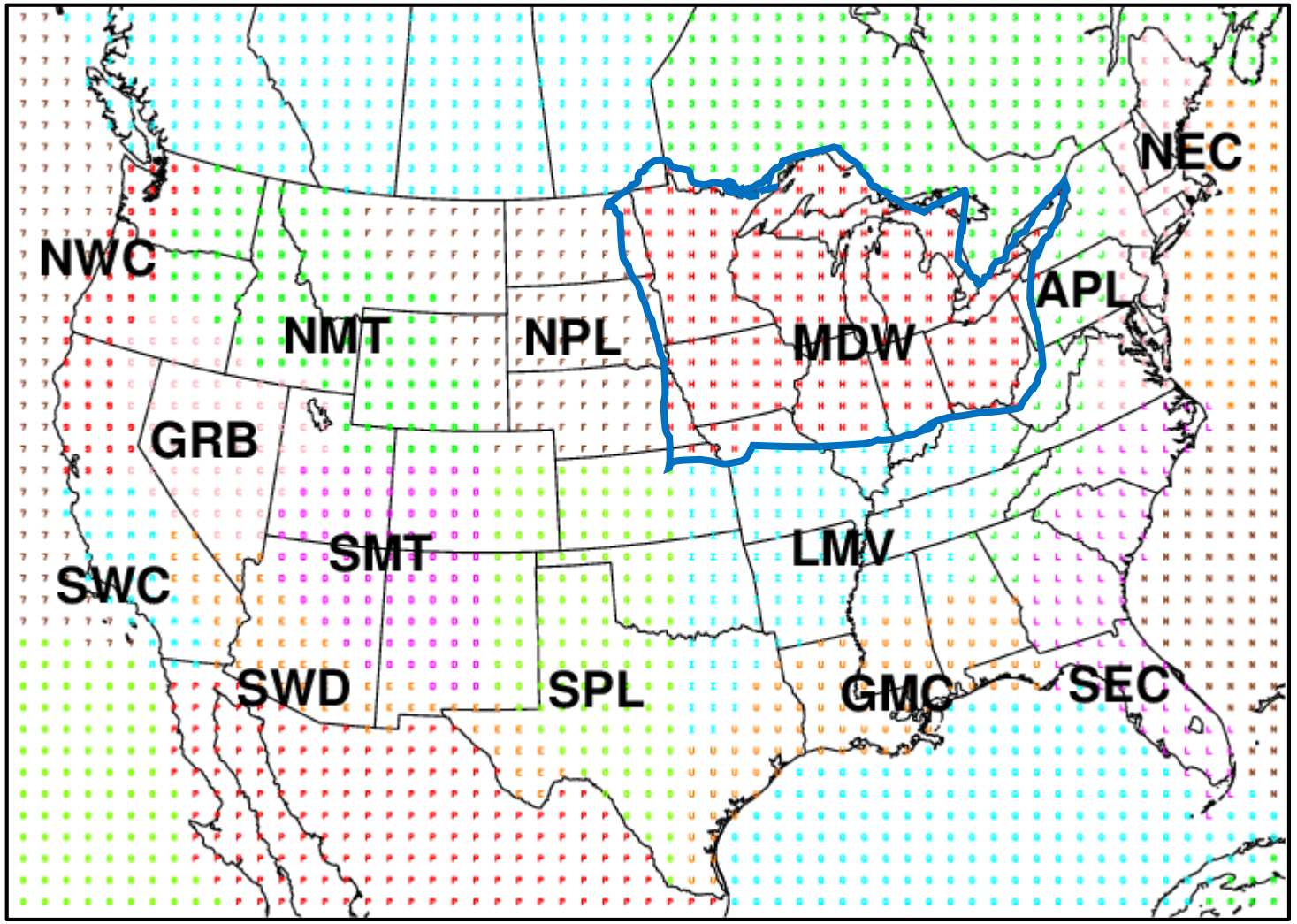
MET Verification Statistics

(Using MADIS METAR and Mesonet observations)

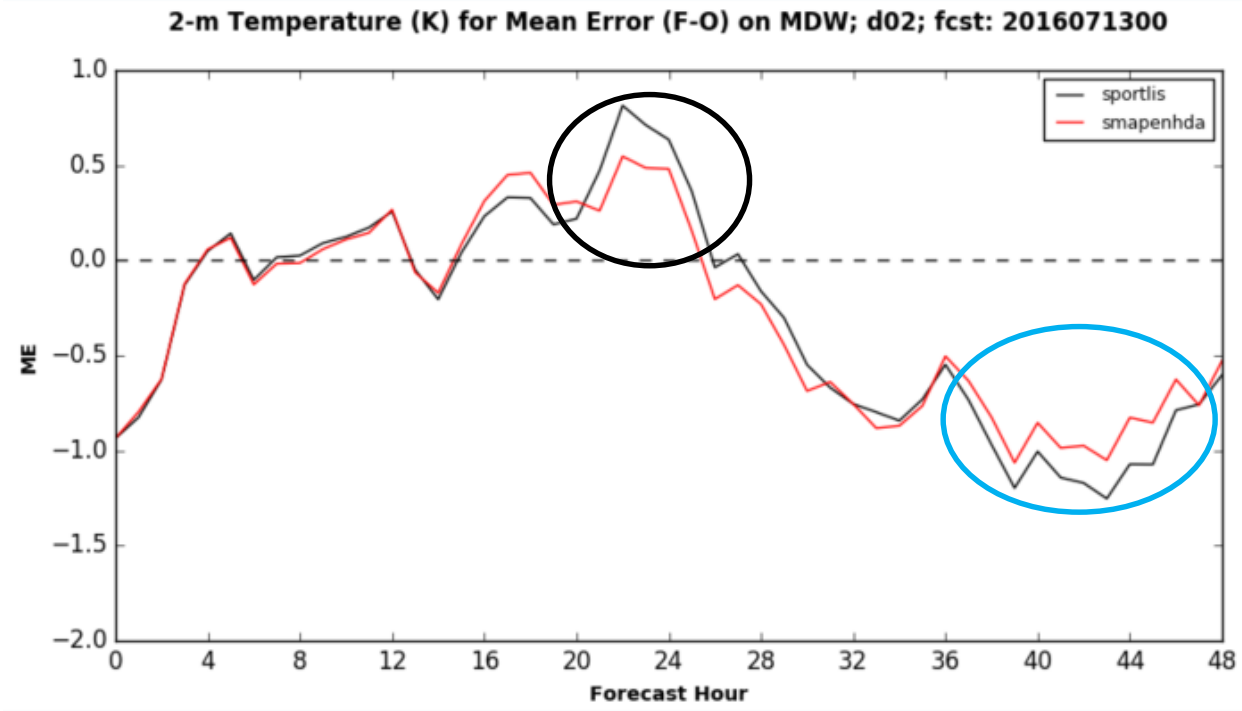
Observation Locations



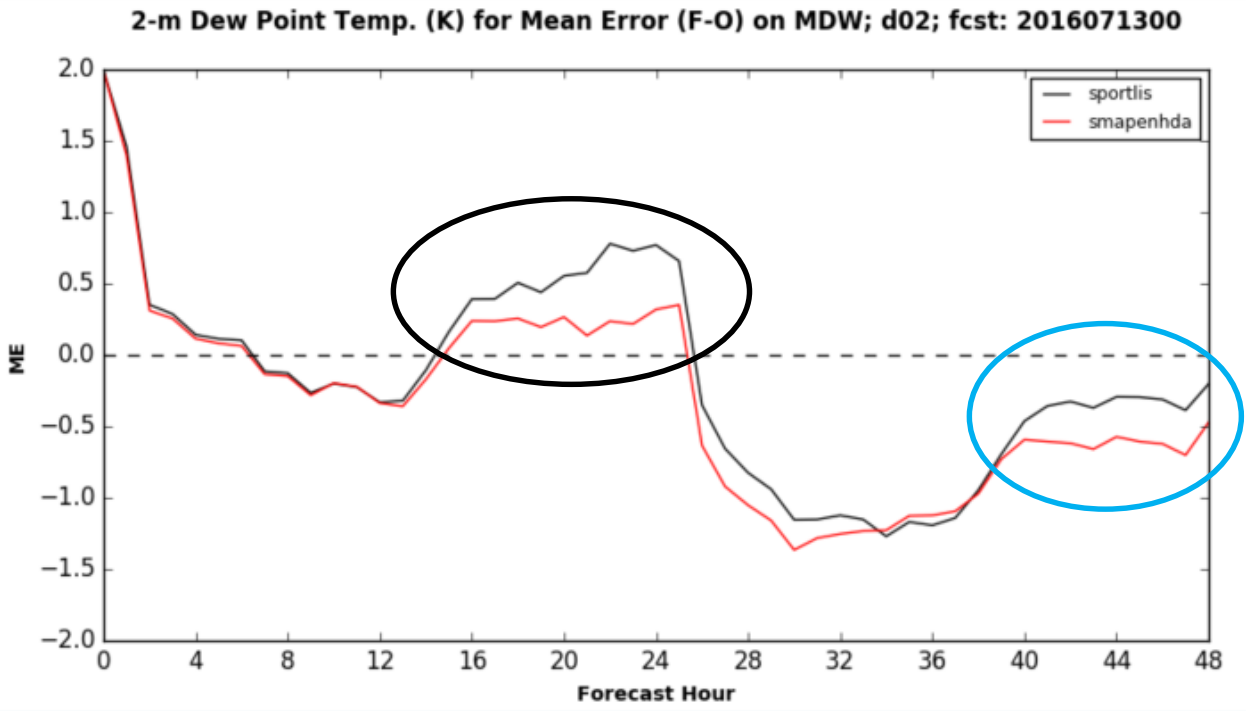
NCEP/EMC Verification Regions Applied



2-m Temp and Dewp Mean Error (3-km nest)



- The Midwest region where squall line develops and propagates eastward experiences improvement in day1 daytime 2-m Temp bias and especially Dewp. (black ovals)
- Slight improvement in day2 daytime cool bias, but some degradation in dry bias (blue ovals)



NWP Initialization Results

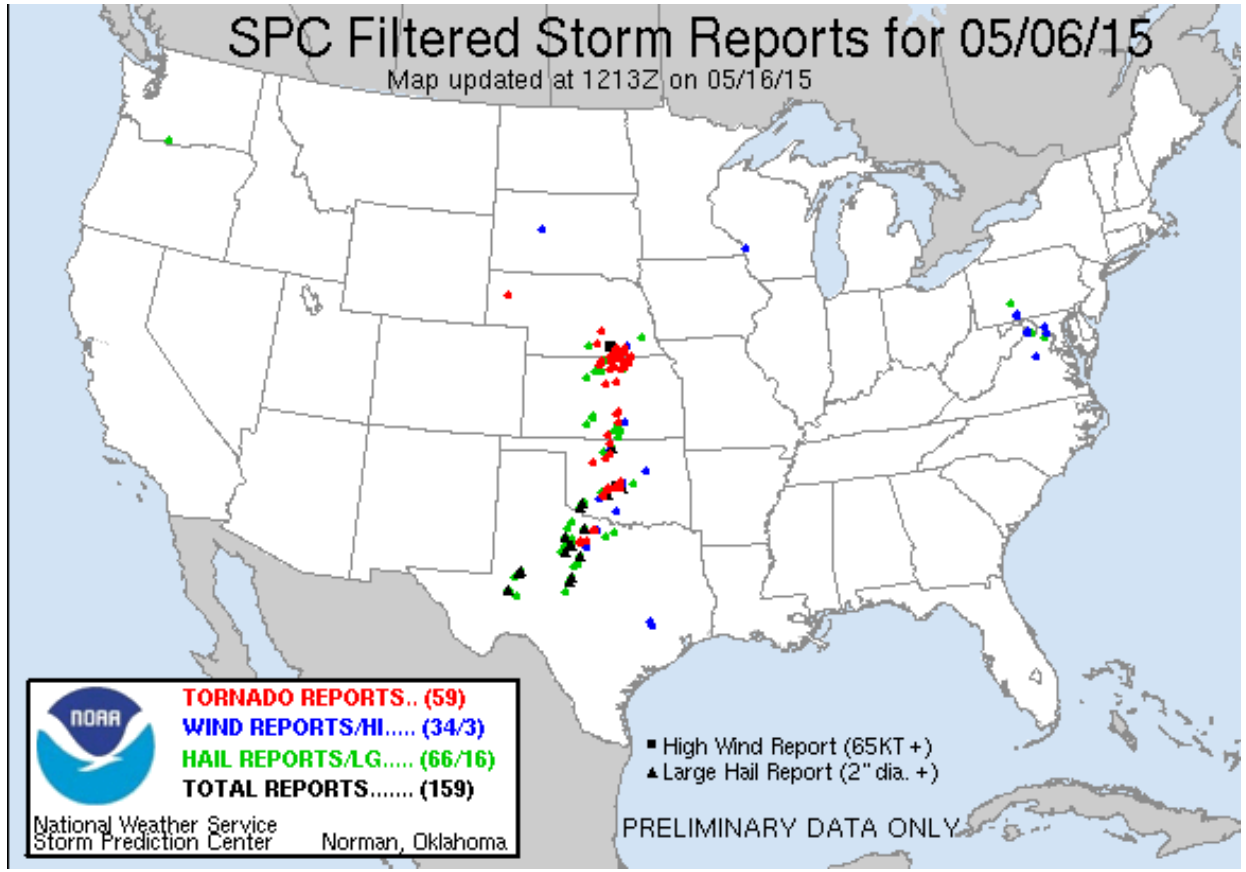
WRF case over Southern Plains

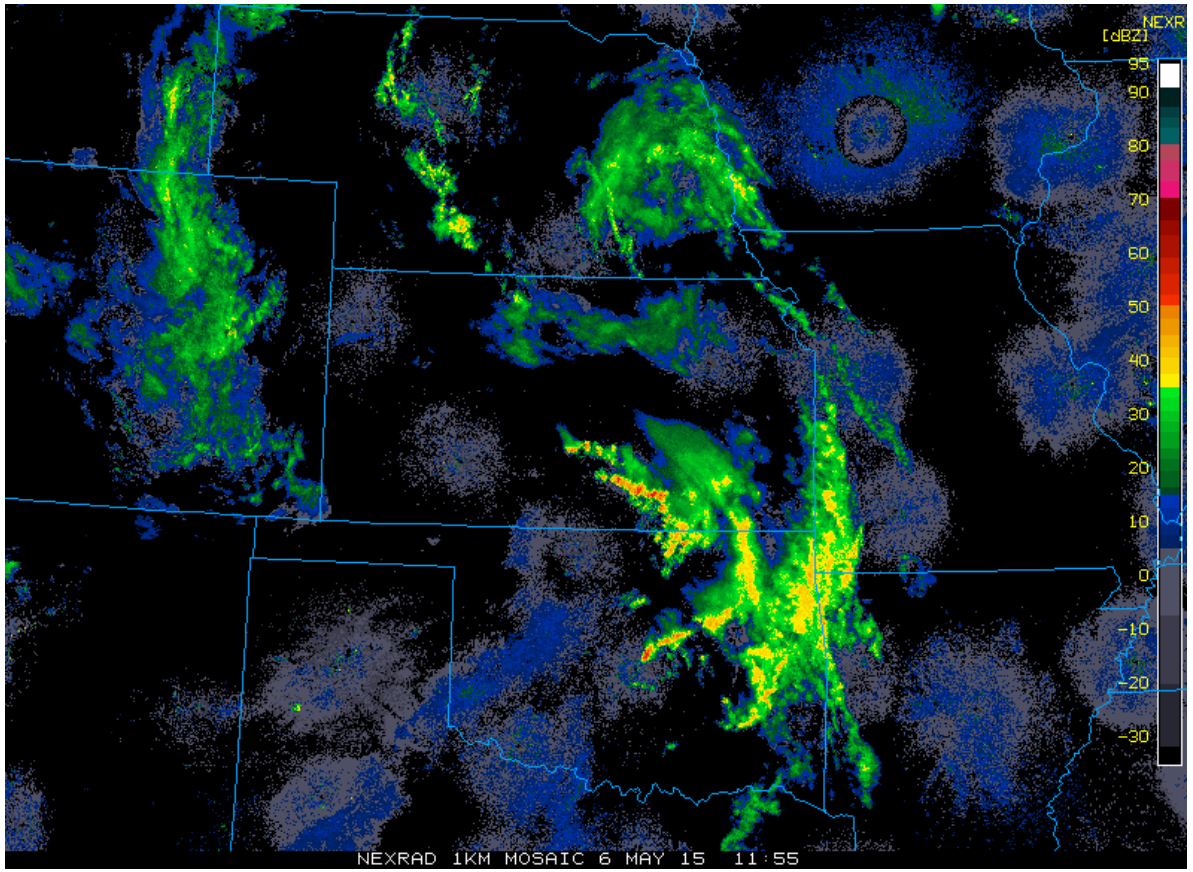
SPoRT-LIS vs. SMAP-Enh DA initialized runs

[6-7 May 2015 tornado outbreak]

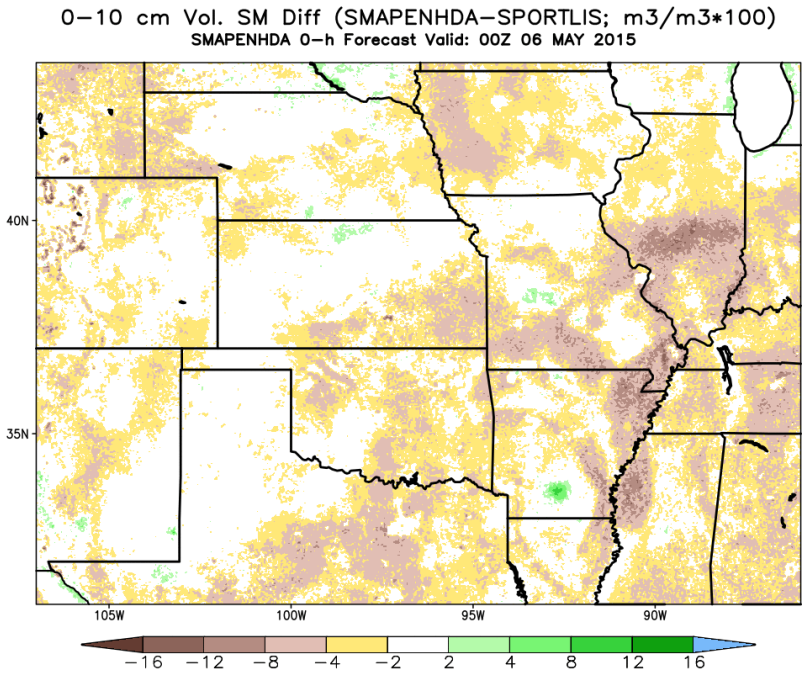
6-7 May 2015 Southern Plains tornado outbreak:

NASA Unified-WRF (NU-WRF) sensitivity simulations



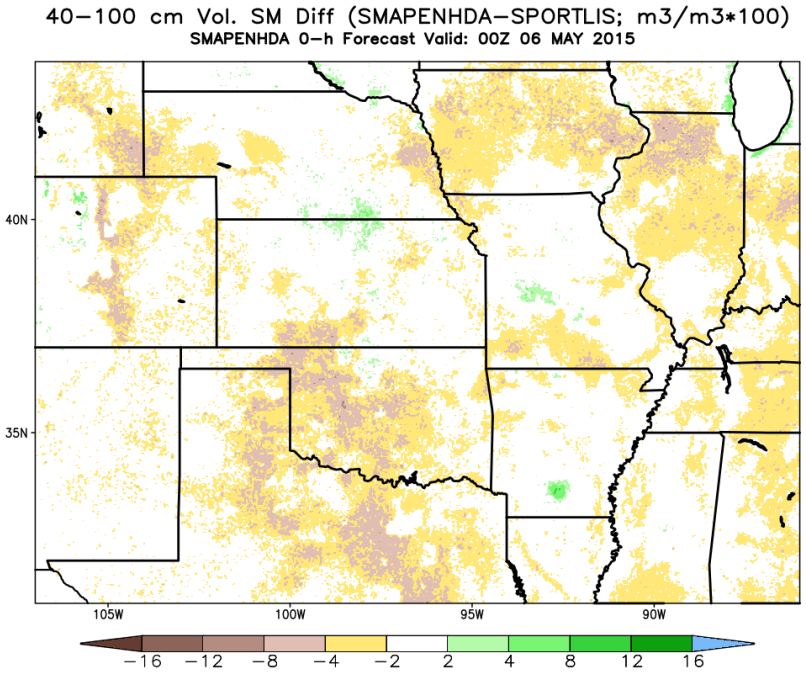


NASA Unified-WRF (NU-WRF) model runs:
Soil Moisture Initial Condition Differences on 3-km nest

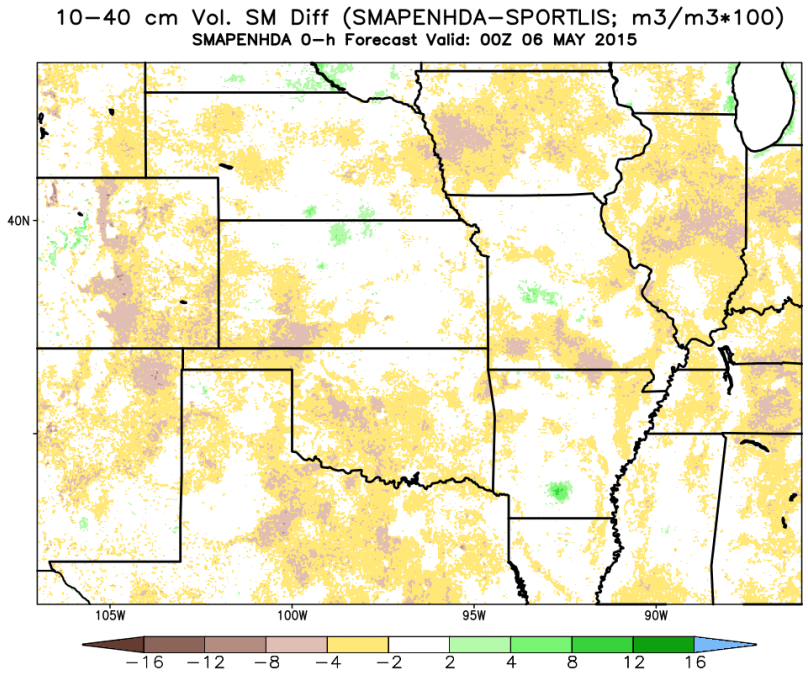


Top soil layer (0-10 cm)

SMAP-Enhanced data assimilation run generally produced drier soil moisture fields than sportlis.

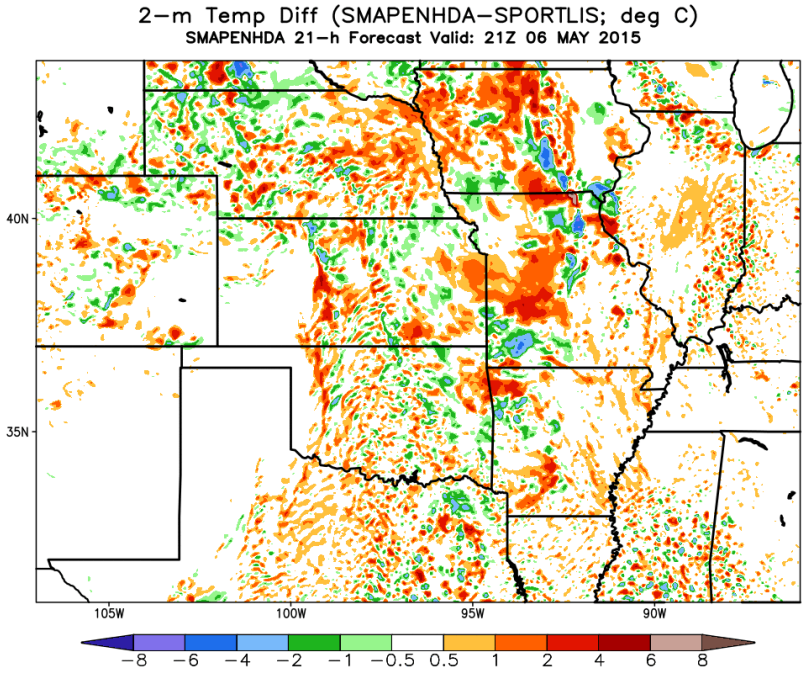


Soil layer 3 (40-100 cm)



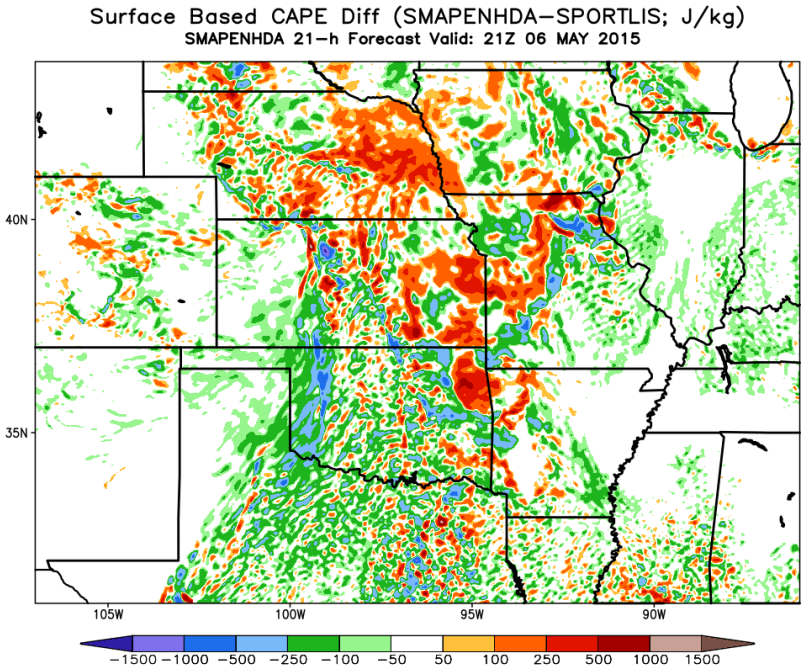
Soil layer 2 (10-40 cm)

NASA Unified-WRF (NU-WRF) model runs:
Slight improvement in simulated convective evolution

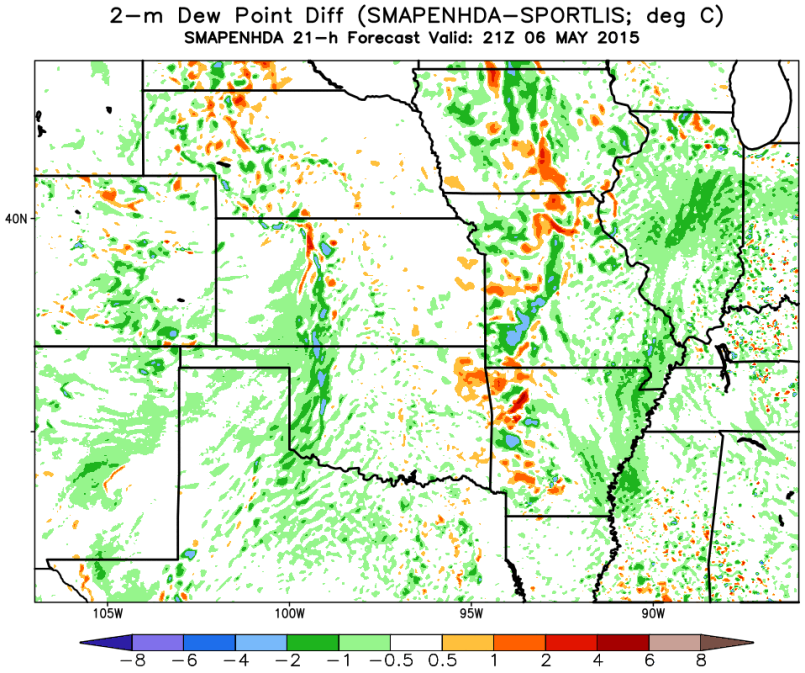


2-m Temperature

smapenhda-initialized NU-WRF runs generally simulated warmer/drier daytime temperatures/dewpoints, with slightly lower instability where convection/supercells developed.



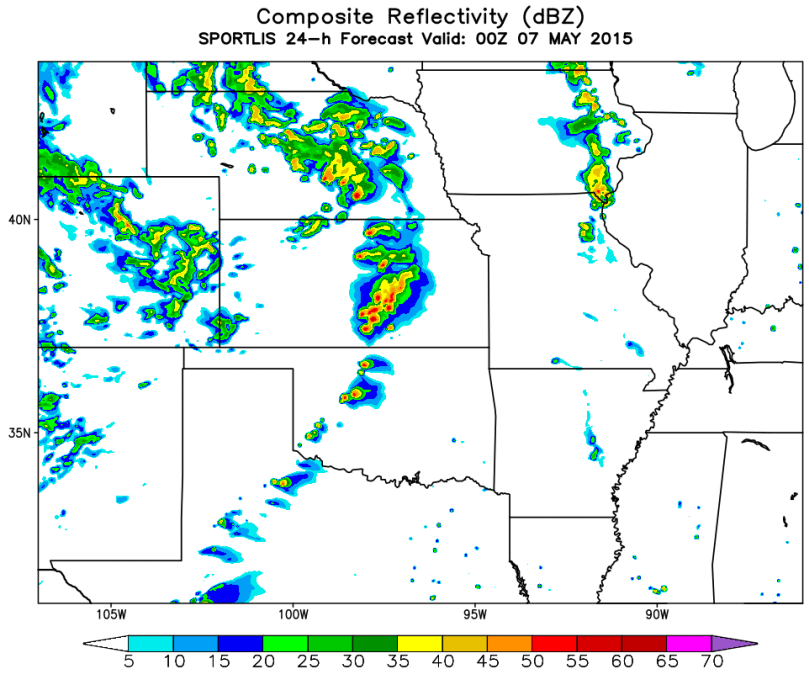
Sfc-based Convective Available Potential Energy



2-m Dewpoint Temperature

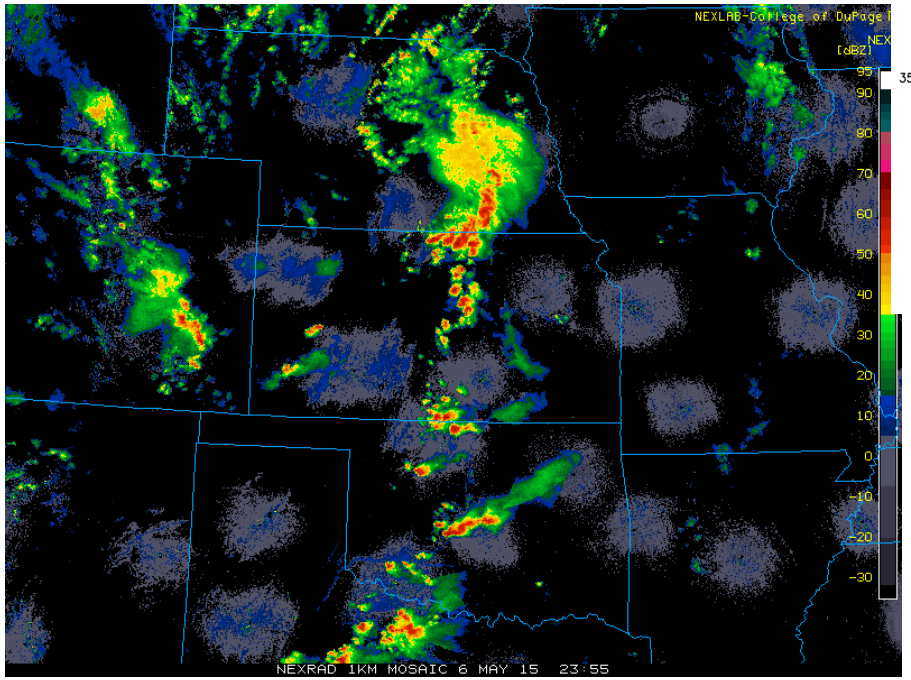
*****All simulated fields shown are from the 21-hour NU-WRF forecast, valid on 2100 UTC 6 May 2017***

NASA Unified-WRF (NU-WRF) model runs:
Slight improvement in simulated convective evolution

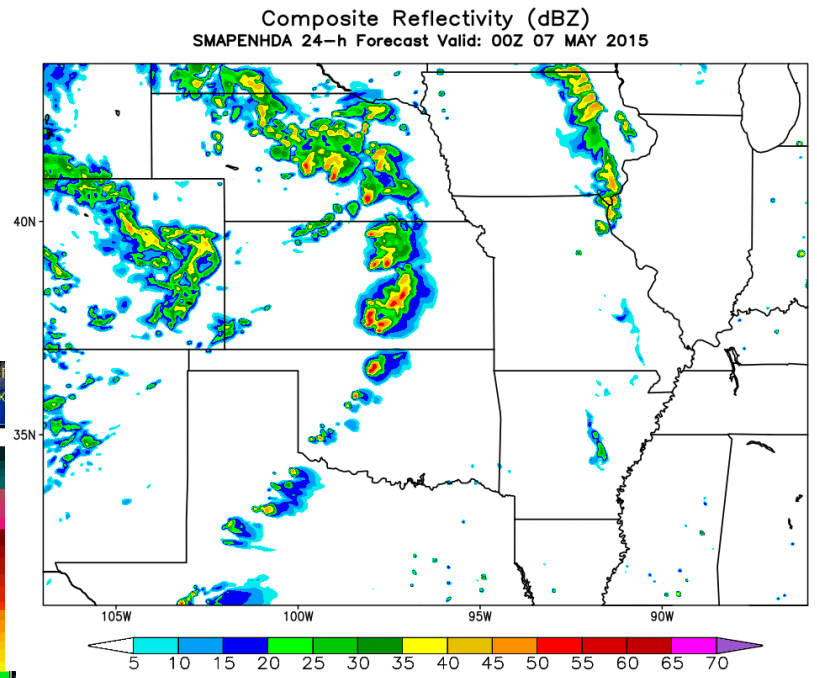


sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



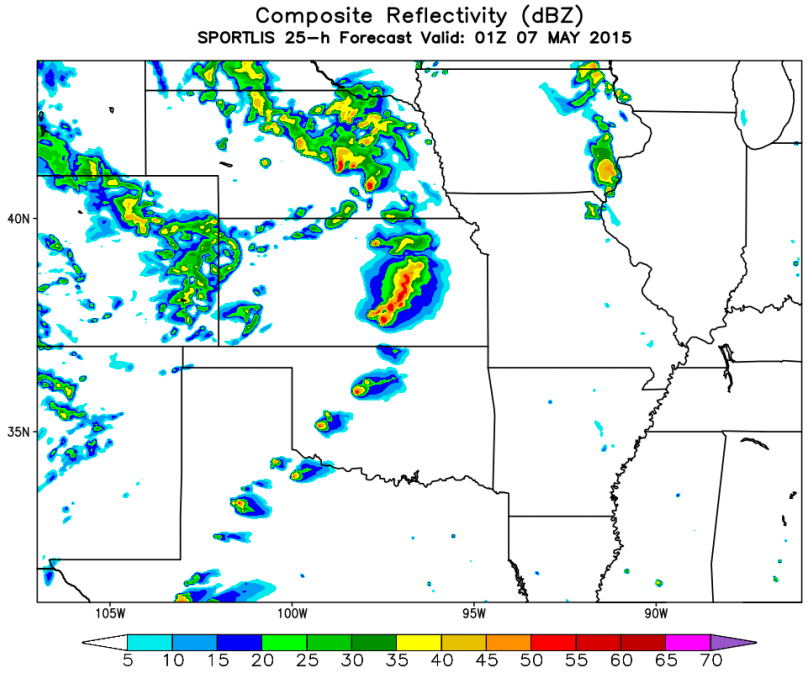
Observed regional radar reflectivity (dBZ)



smapenhda-initialized NU-WRF run

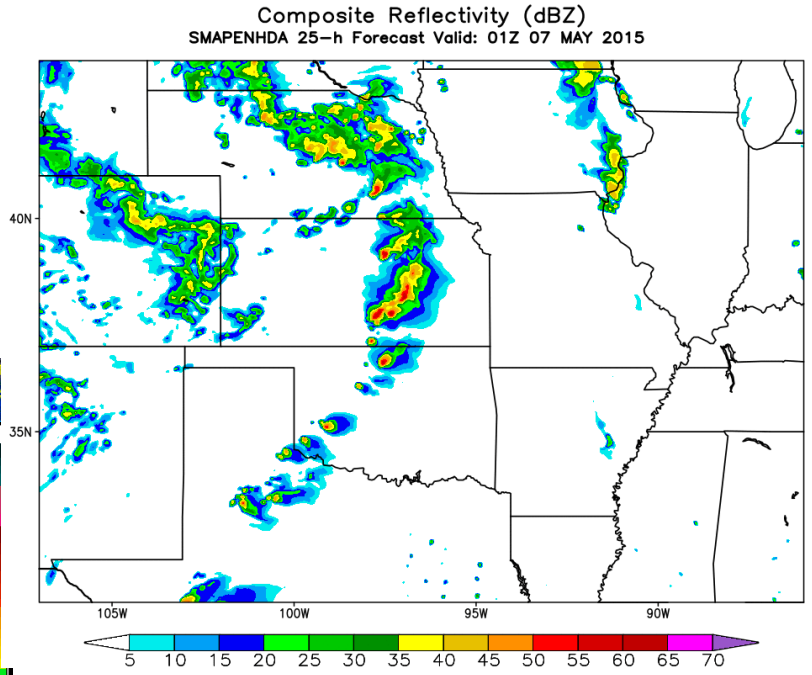
24-hour NU-WRF forecasts and observed radar imagery valid at 0000 UTC 7 May 2015

NASA Unified-WRF (NU-WRF) model runs:
Slight improvement in simulated convective evolution



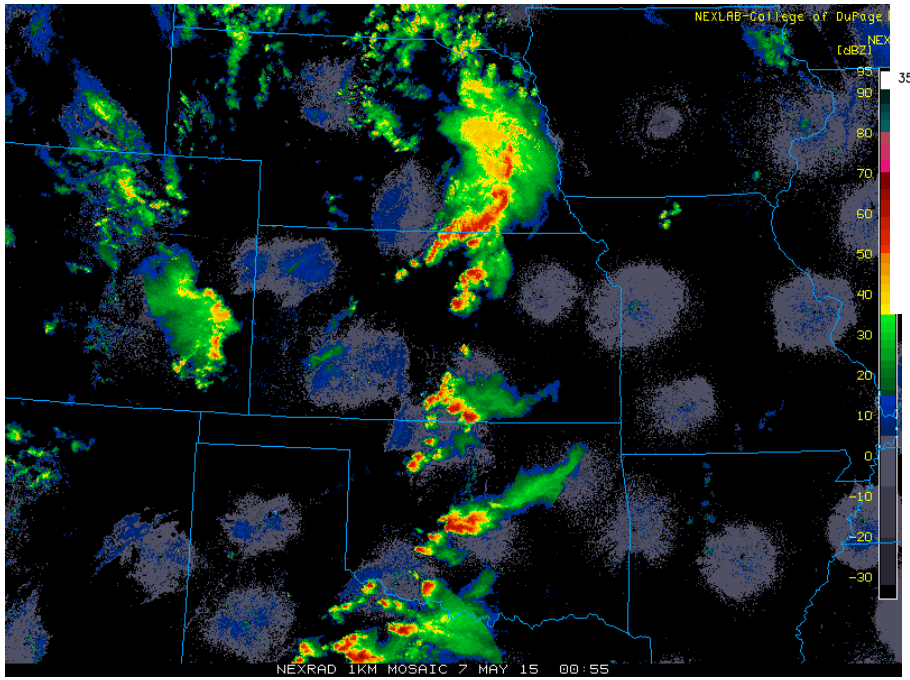
sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



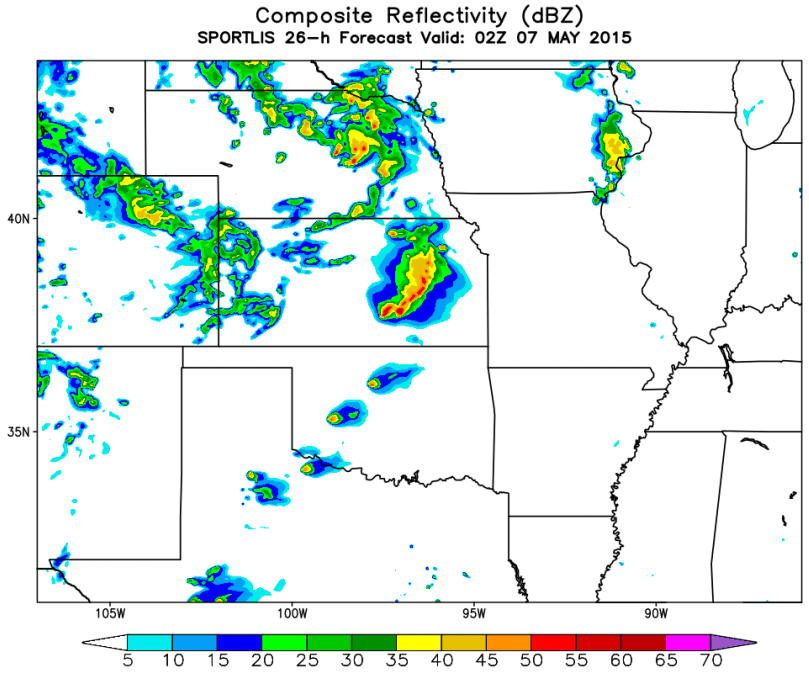
smapenhda-initialized NU-WRF run

25-hour NU-WRF forecasts and observed radar imagery valid at 0100 UTC 7 May 2015



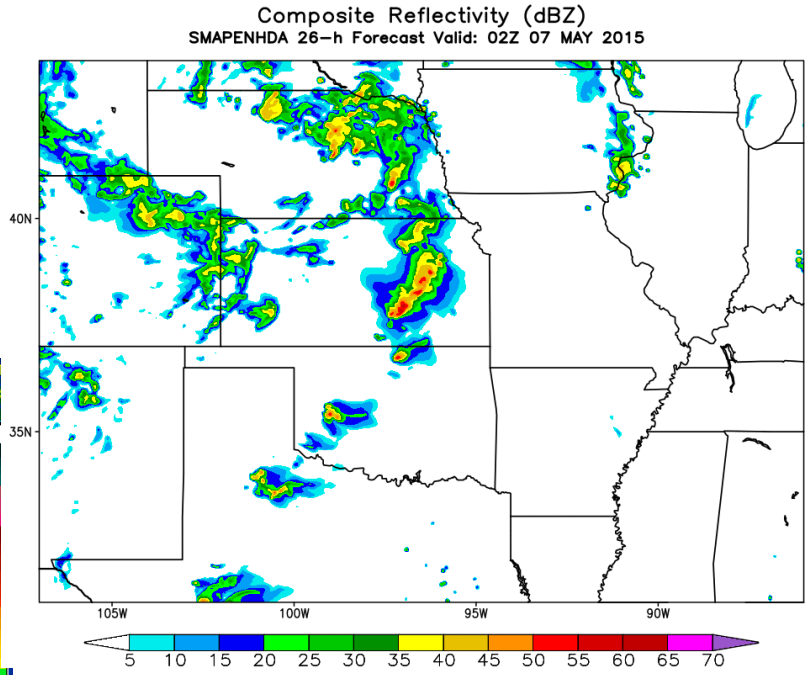
Observed regional radar reflectivity (dBZ)

NASA Unified-WRF (NU-WRF) model runs:
Slight improvement in simulated convective evolution



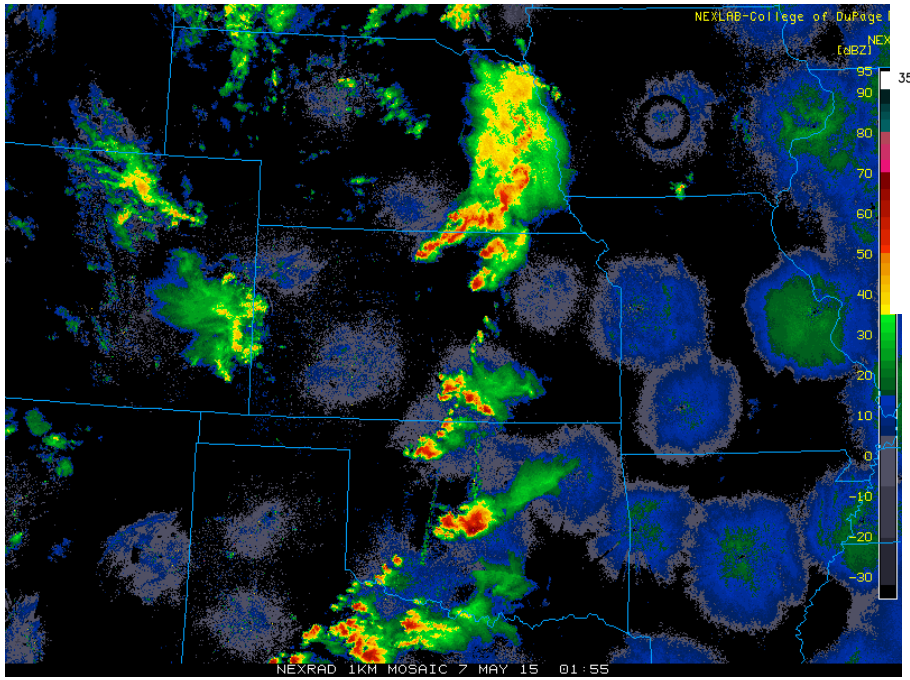
sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



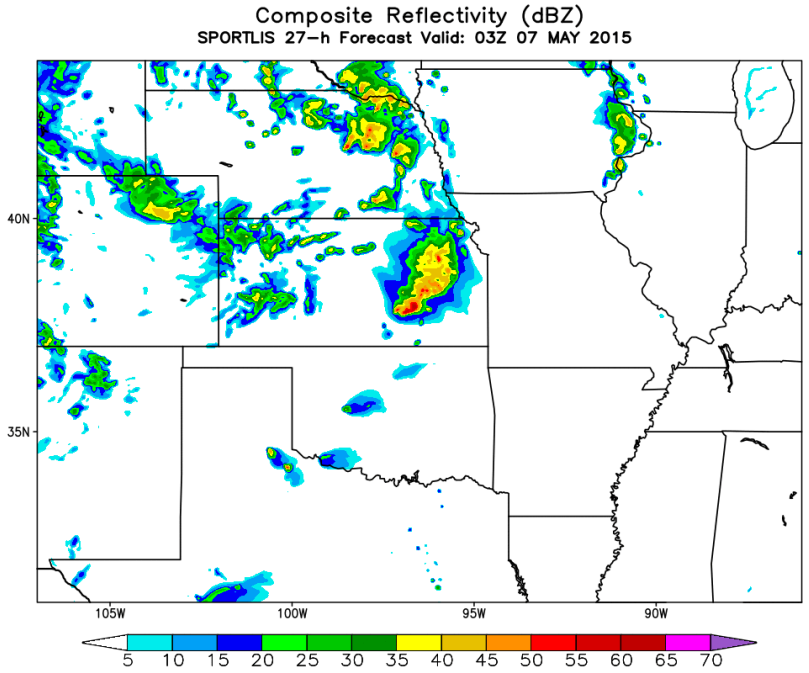
smapenhda-initialized NU-WRF run

26-hour NU-WRF forecasts and observed radar imagery valid at 0200 UTC 7 May 2015



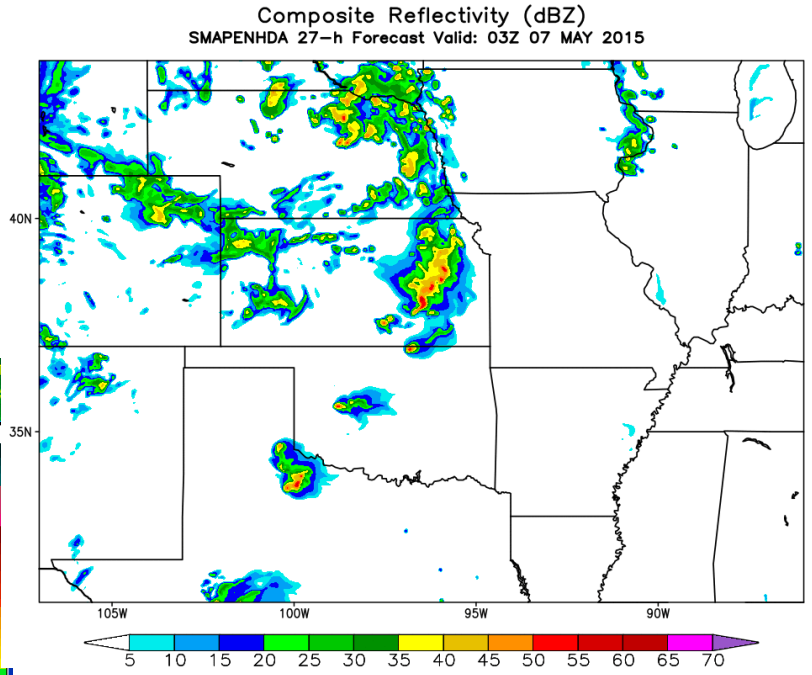
Observed regional radar reflectivity (dBZ)

NASA Unified-WRF (NU-WRF) model runs:
Slight improvement in simulated convective evolution



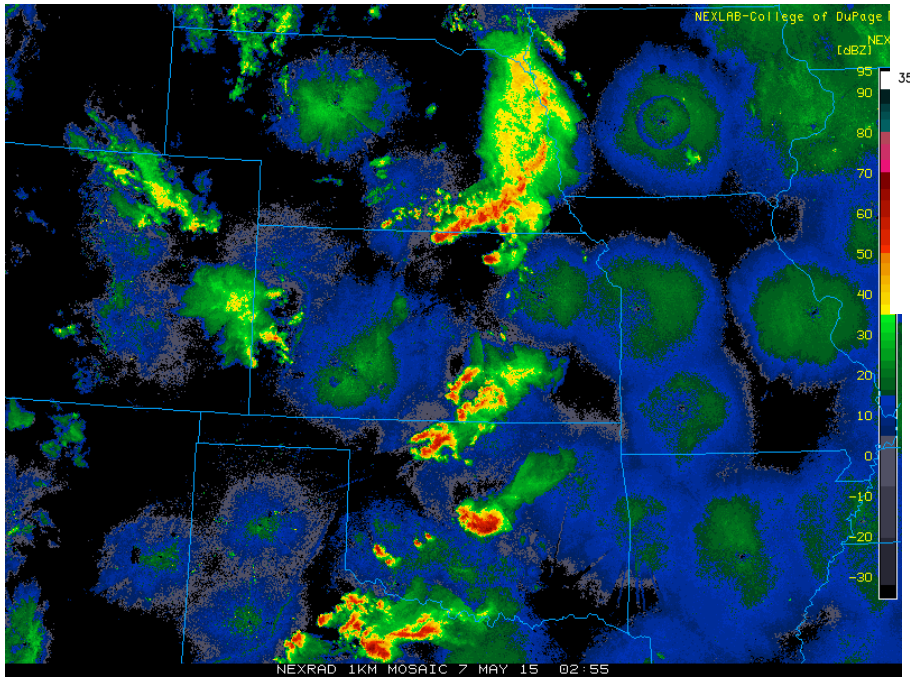
sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



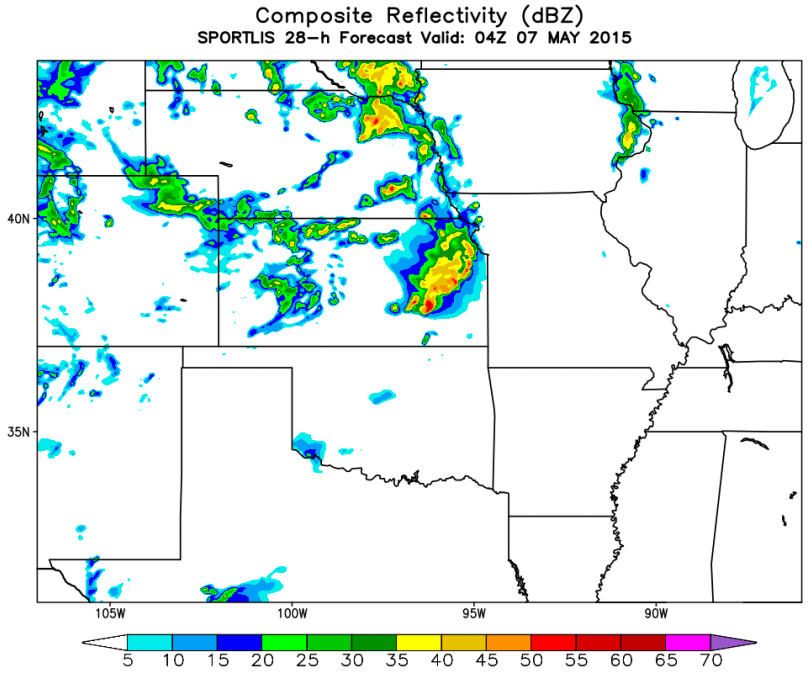
smapenhda-initialized NU-WRF run

27-hour NU-WRF forecasts and observed radar imagery valid at 0300 UTC 7 May 2015



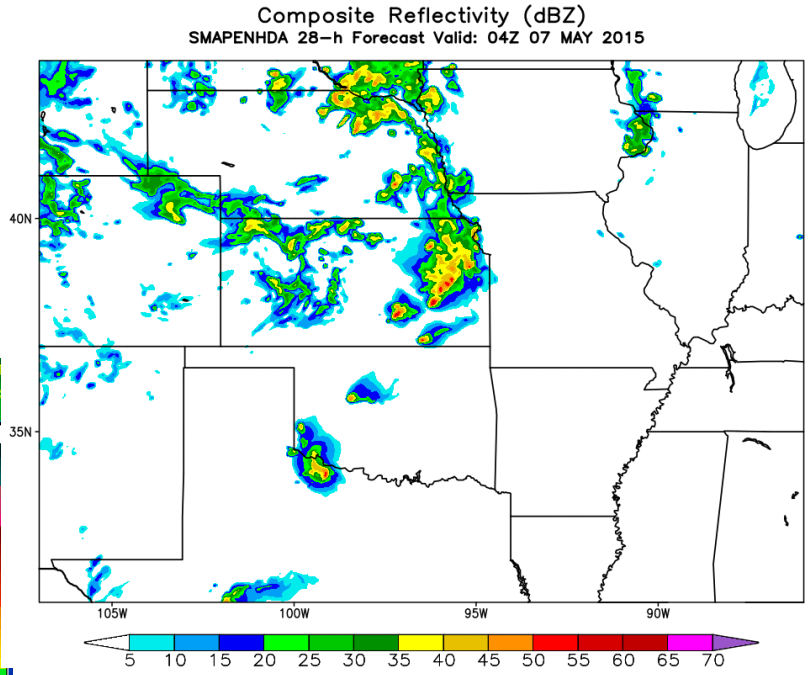
Observed regional radar reflectivity (dBZ)

NASA Unified-WRF (NU-WRF) model runs:
Slight improvement in simulated convective evolution



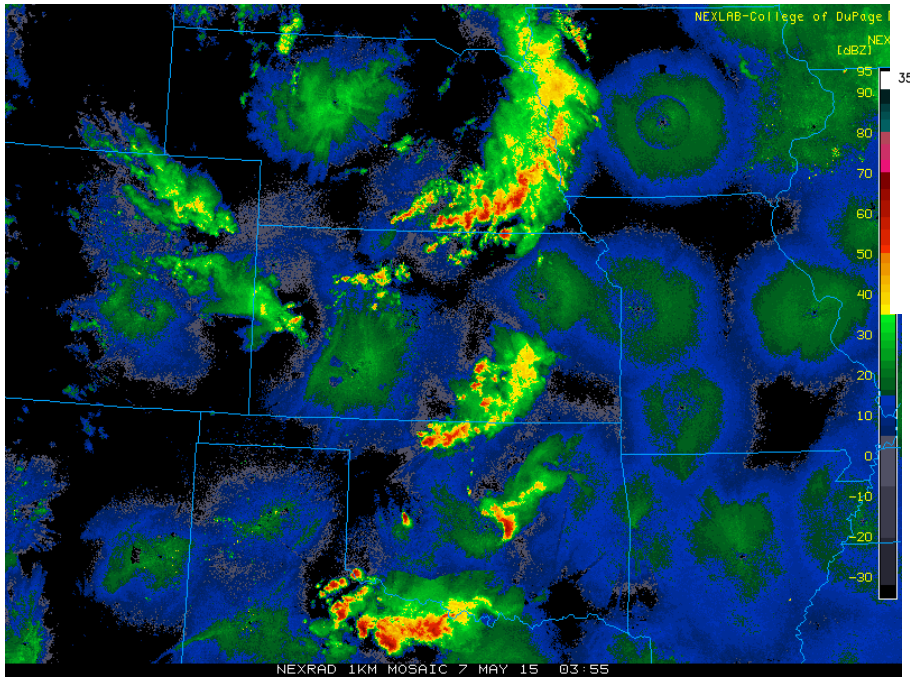
sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



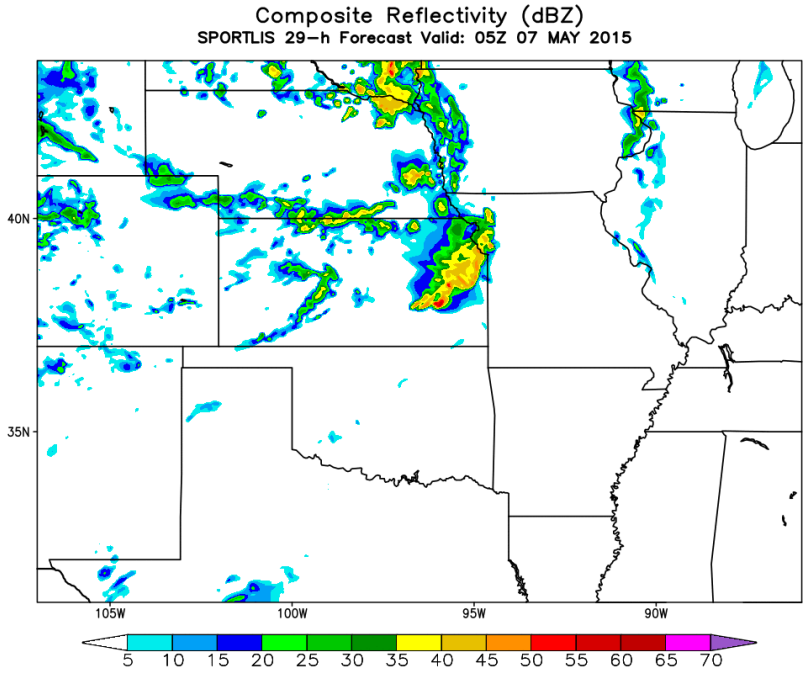
smapenhda-initialized NU-WRF run

28-hour NU-WRF forecasts and observed radar imagery valid at 0400 UTC 7 May 2015



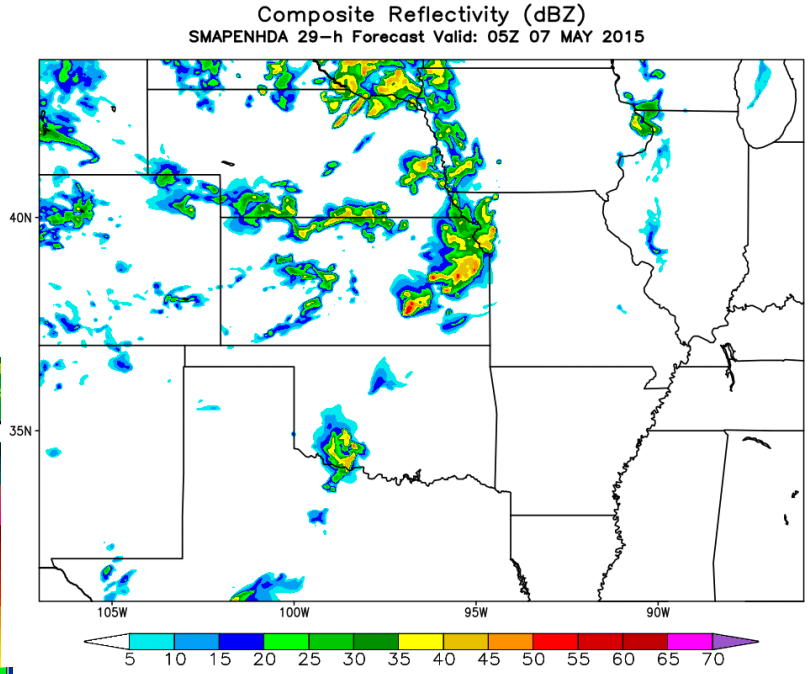
Observed regional radar reflectivity (dBZ)

NASA Unified-WRF (NU-WRF) model runs:
Slight improvement in simulated convective evolution



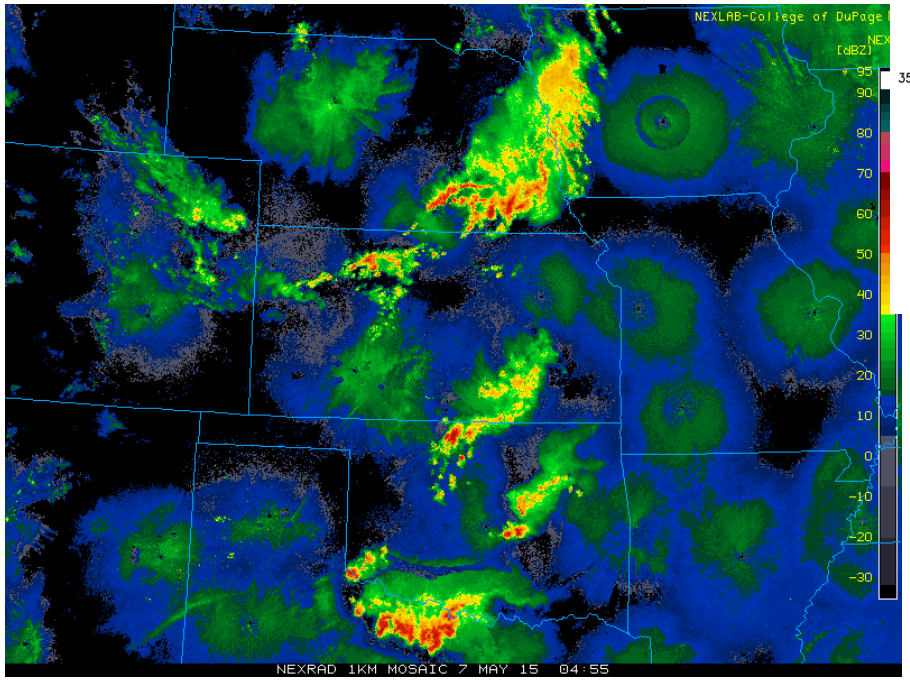
sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



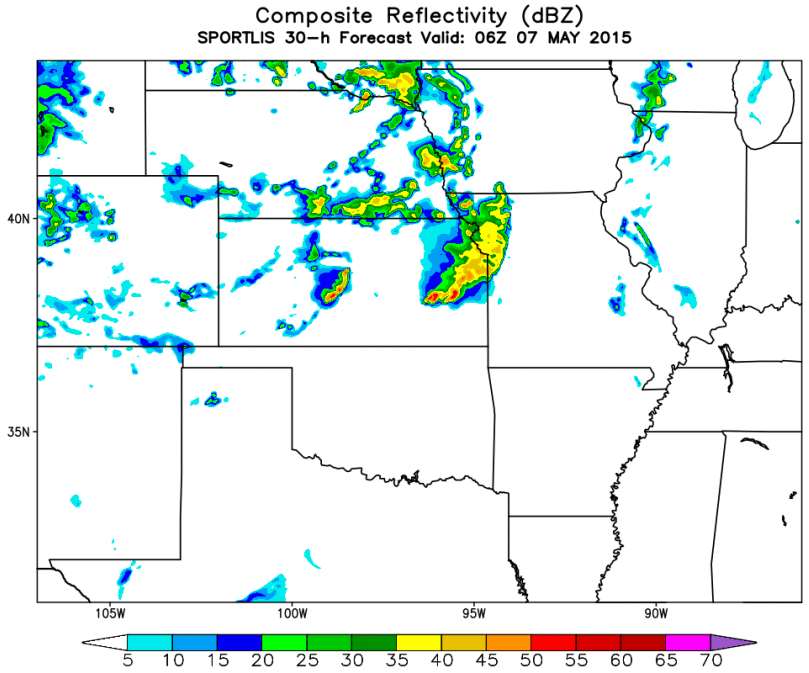
smapenhda-initialized NU-WRF run

29-hour NU-WRF forecasts and observed radar imagery valid at 0500 UTC 7 May 2015



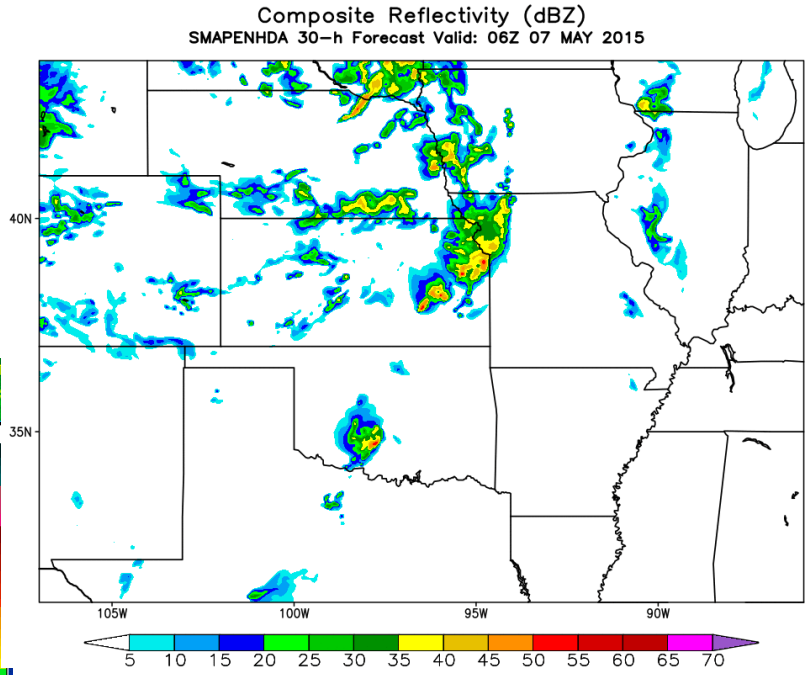
Observed regional radar reflectivity (dBZ)

NASA Unified-WRF (NU-WRF) model runs:
Slight improvement in simulated convective evolution



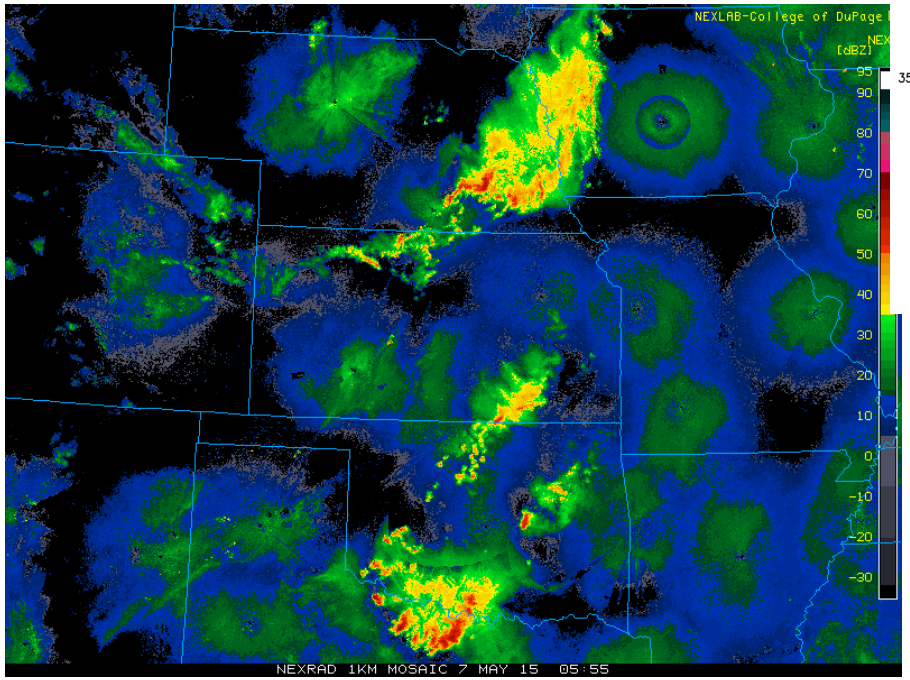
sportlis-initialized NU-WRF run

smapenhda-initialized NU-WRF runs more correctly retained convection in southern OK and northern TX into the overnight hours of 7 May 2015.



smapenhda-initialized NU-WRF run

30-hour NU-WRF forecasts and observed radar imagery valid at 0600 UTC 7 May 2015



Observed regional radar reflectivity (dBZ)

Ongoing and Future Efforts

- Finalize SMAP data assimilation methodology for optimized smapenhda-initialized short-term NWP experiments
- Run entire 2015 and 2016 warm seasons of sportlis- and smapenhda-initialized NU-WRF daily simulation
  - Continue examining other high-impact case studies
  - Produce bulk verification statistics against MADIS point observations (T, Td, etc.)
  - Produce precip verification statistics against MRMS hourly QPE (gridded ~1-km)
- East Africa domain: Run dry/wet season transition periods
  - Produce bulk verification against global PREPBUFR observations
  - Produce precip verification statistics against GPM/IMERG-Final product

Acknowledgments

- Land Information System Team (NASA-GSFC)
- SMAP Science Team and Early Adopters Team
- Funding: NASA Earth Science Division
  (ROSES 2015 Science Utilization of SMAP Mission Program)

Questions and Comments?

clay.blankenship@nasa.gov ; jonathan.case-1@nasa.gov

http://weather.msfc.nasa.gov/sport/

Facebook: NASA.SPoRT

Twitter: @NASA_SPoRT

SPORT

NASA USRA ENSCO