Variational Assimilation of Total Lightning at Cloud Resolving Scales

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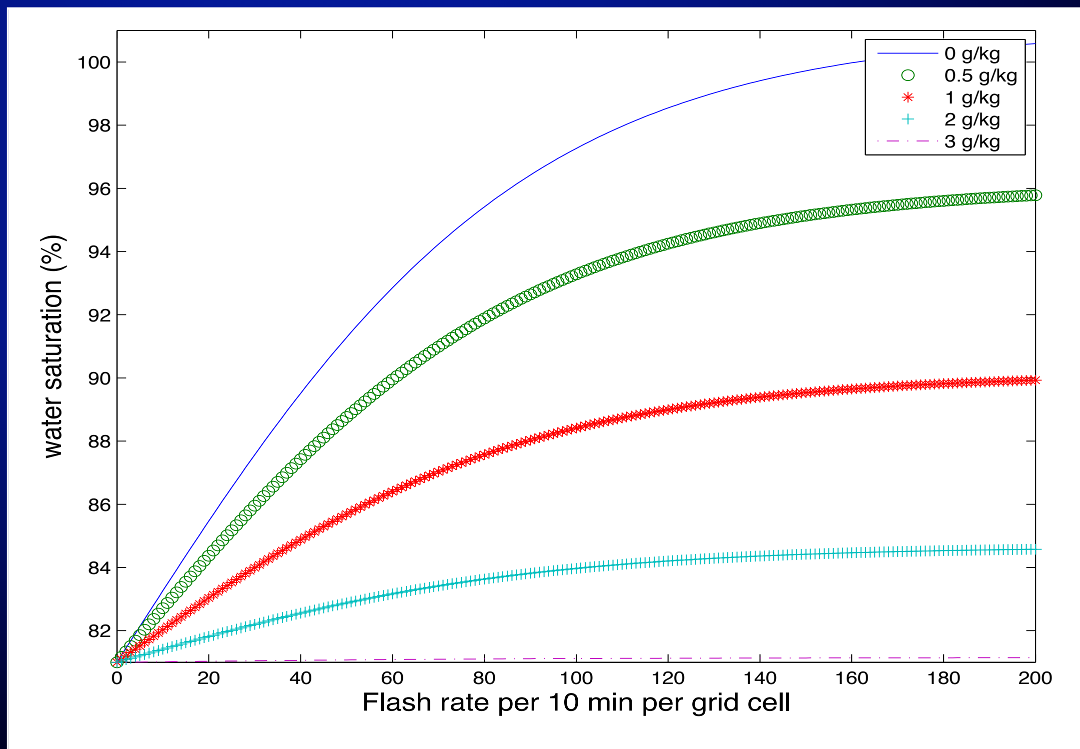
Photo: J. LaDue

Background

Q_v within a layer above cloud base is adjusted (increased) as a function flash rate (X) and simulated Q_g and $Q_{satwater}$. Increasing Q_v at constant T boosts thermal buoyancy (via θ_v) and ultimately generates an updraft.

$$Q_v = AQ_{sat} + BQ_{sat}\tanh(CX)\left[1 - \tanh(DQ_g^{\alpha})\right]$$

-Only applied whenever simulated RH and Qg < fixed thresholds: i.e., if the model already is in the right direction don't adjust Qv.



Fierro et al. (2012, 1014, 2016, 2018)

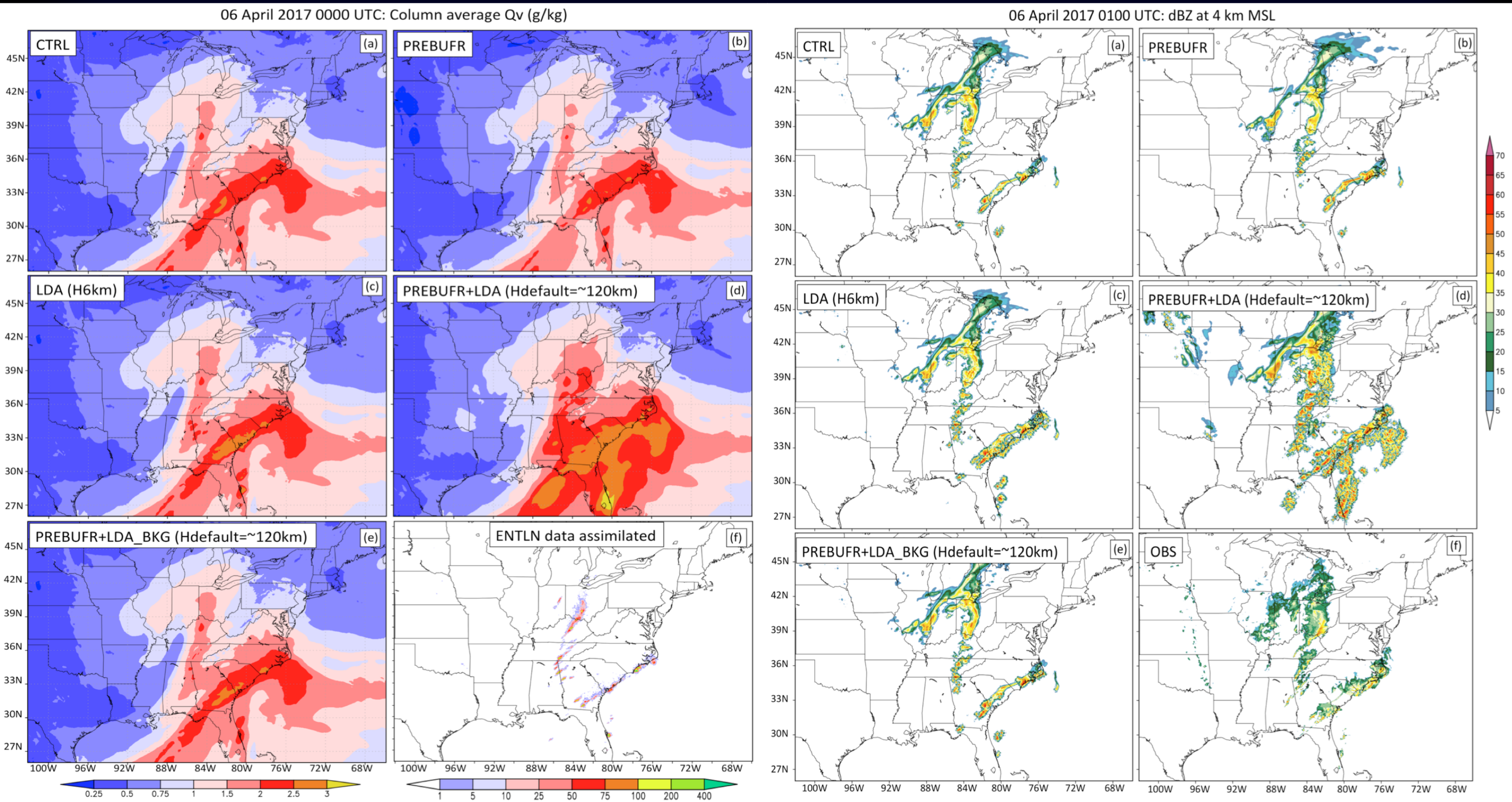
GSI Experiments

-Logical follow-on: apply this philosophy to GSI in quasi-realtime

Experiments	Description	Data assimilated	Model variables impacted
CTRL	Control run	None	None
LDA (H=6km)	Lightning DA run. horizontal length scale of 6 km.	ENTLN flash extent density rates.	q_v (LCL-15 km)
PREBUFR	PREPBUFR DA run	NCEP PREPBUFR data bundle	*
PEBUFR+LDA (H_default)	Lightning+PREPBUFR DA run. GSI default horizontal length scale ~100km.	NCEP PREPBUFR data bundle ENTLN flash extent density rates. ***No lightning=missing obs.***	q_v (LCL-15 km) + *
PEBUFR+LDA_ BKG (H_default)	Lightning+PREPBUFR DA run GSI default horizontal length scale ~100km.	NCEP PREPBUFR data bundle ENTLN flash extent density rates. ***No lightning=valid obs (zero innovation).***	q_v (LCL-15 km) + *

*NCEP ADP Global Upper Air and Surface Weather Observations (PREPBUFR format) are composed of a global set of surface and upper air reports: land surface, marine surface, radiosonde, pibal and aircraft reports from the Global Telecommunications System (GTS), profiler and US radar derived winds, SSM/I oceanic winds and TCW retrievals, and satellite wind data from the National Environmental Satellite Data and Information Service (NESDIS). The reports can include pressure, geopotential height, temperature, dewpoint temperature, wind direction and speed. Report time intervals range from hourly to 12 hourly. Source: https://gcmd.nasa.gov

GSI: representative case



-Strongly forced case -> good performance for CTRL. LDA still improves short term forecast when H <= 10km.

-GSI, however <u>does not</u> allow for multiscale VAR passes and assumes a large default H (~100 km) for all variables !

→ Not mature enough for assimilating convective scale information together with mesoscale data.

-> use of NSSL 3DVAR. (cf Fierro et al. 2018 JCSDA Quarterly Newsletter for details).

NEWS3DVAR Experiments

-Use a similar approach than for GSI but combine LDA with level II radar data instead of PREPBUFR (follow Fierro et al. 2016).

Experiments	Description	Data assimilated	Model variables impacted
CTRL	Control run	None	None
GLM	Lightning assimilation run.	GLM flash density rates.	q_v (LCL-15 km)
RAD	Radar assimilation run	Vr and dBZ	q_r, q_g, q_i, q_s, q_h, u, v, w, θ
RAD+GLM	Lightning+radar assimilation run	GLM flash density rates, Vr and dBZ	q_v (LCL-15 km), q_r, q_g, q_i, q_s, q_h, u, v, w, θ

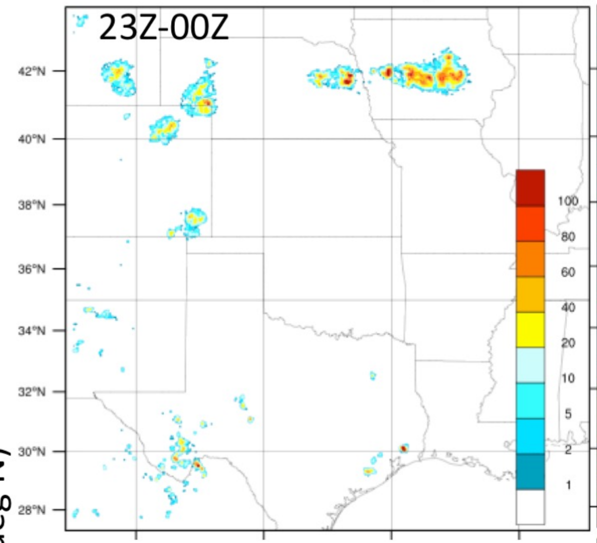
NB: level II data from ~70 radars were assimilated
Forecasts use NSSL 2-mom microphysics.

NEWS3DVAR: Quasi-realtime tests with GLM data

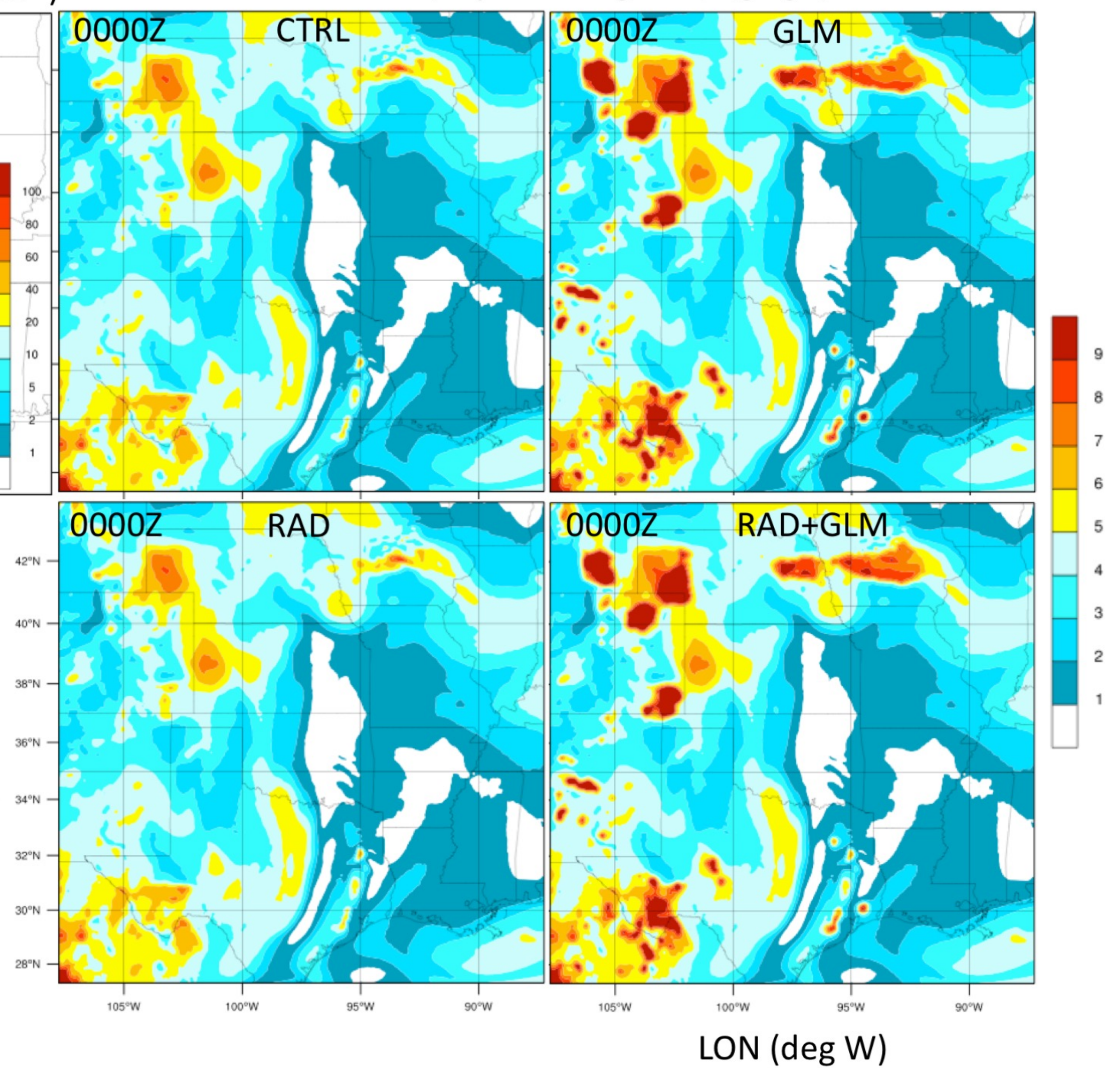
GLM densities and Qv fields

7 June 2018, 0000Z forecast (t=0h)

GLM Flash Densities (h^{-1} 9 km^{-2})

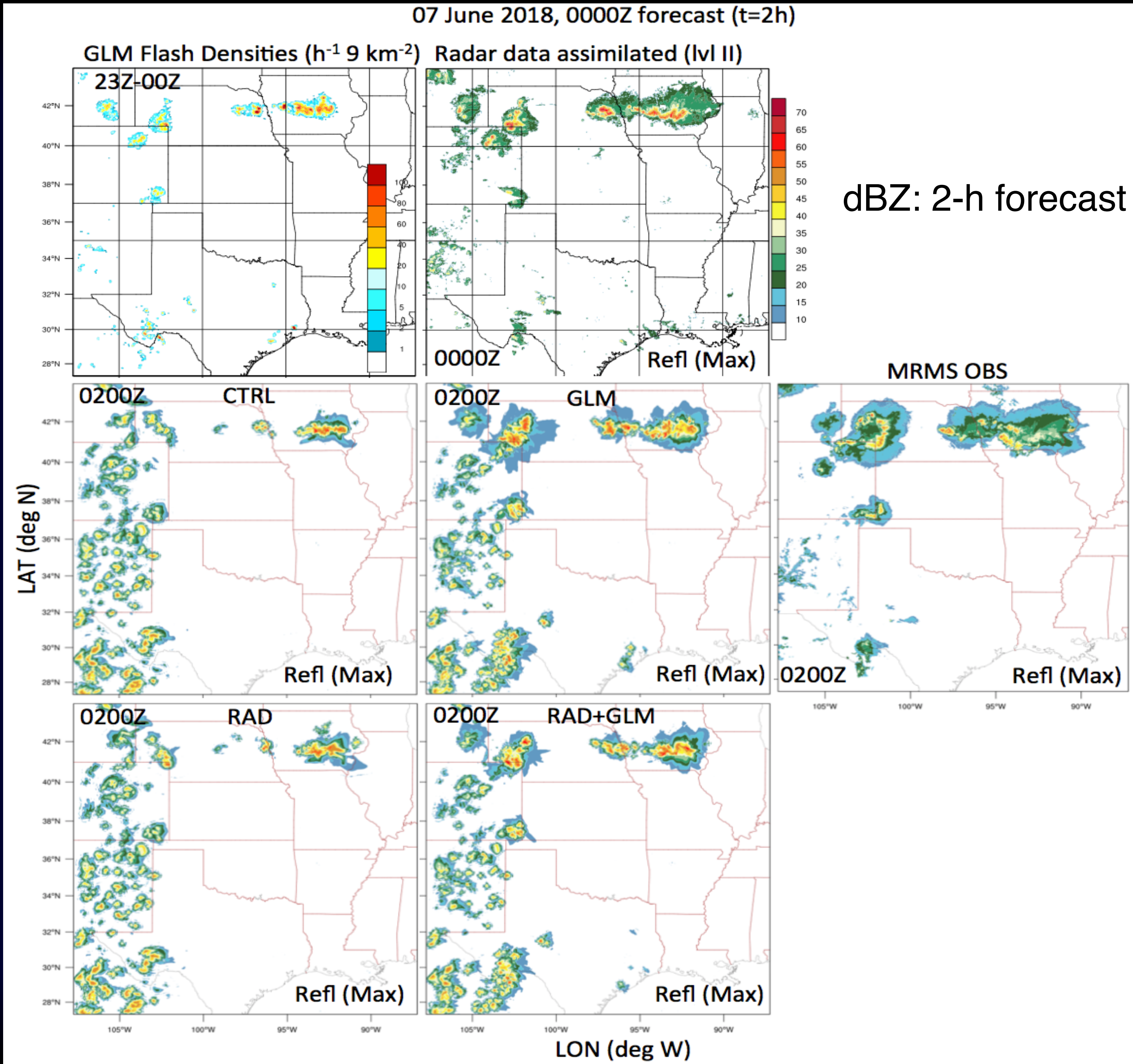


Z=3-7km, layer-averaged Qv (g kg^{-1})

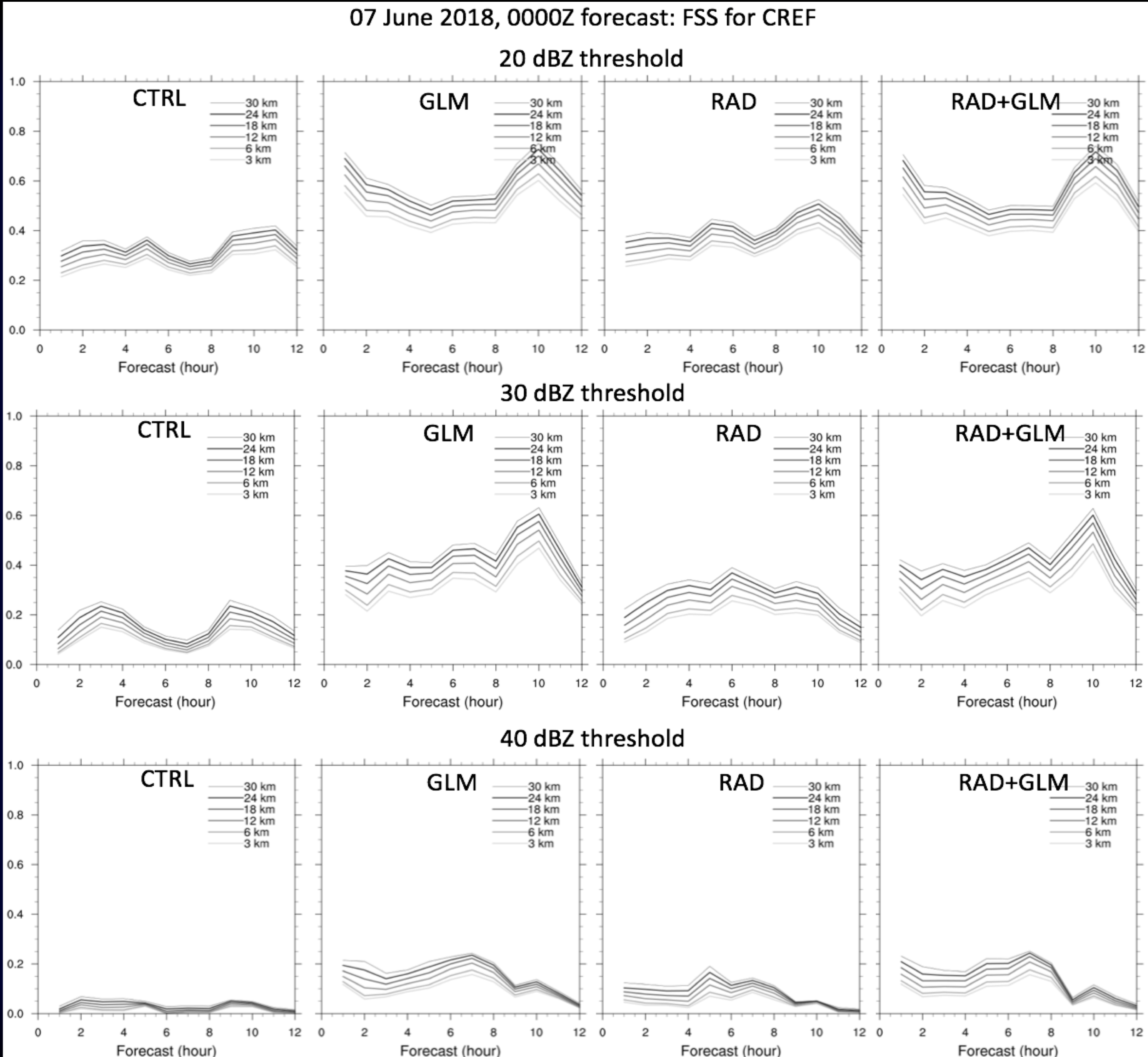


<u>Lightning VAR DA params:</u>
RH=95%, z=LCL-15km.
0 density pts=missing obs
<u>Radar VAR DA params:</u>
-Vr (missing obs <= 25 dBZ)
-Hydrometeors (R=4km)

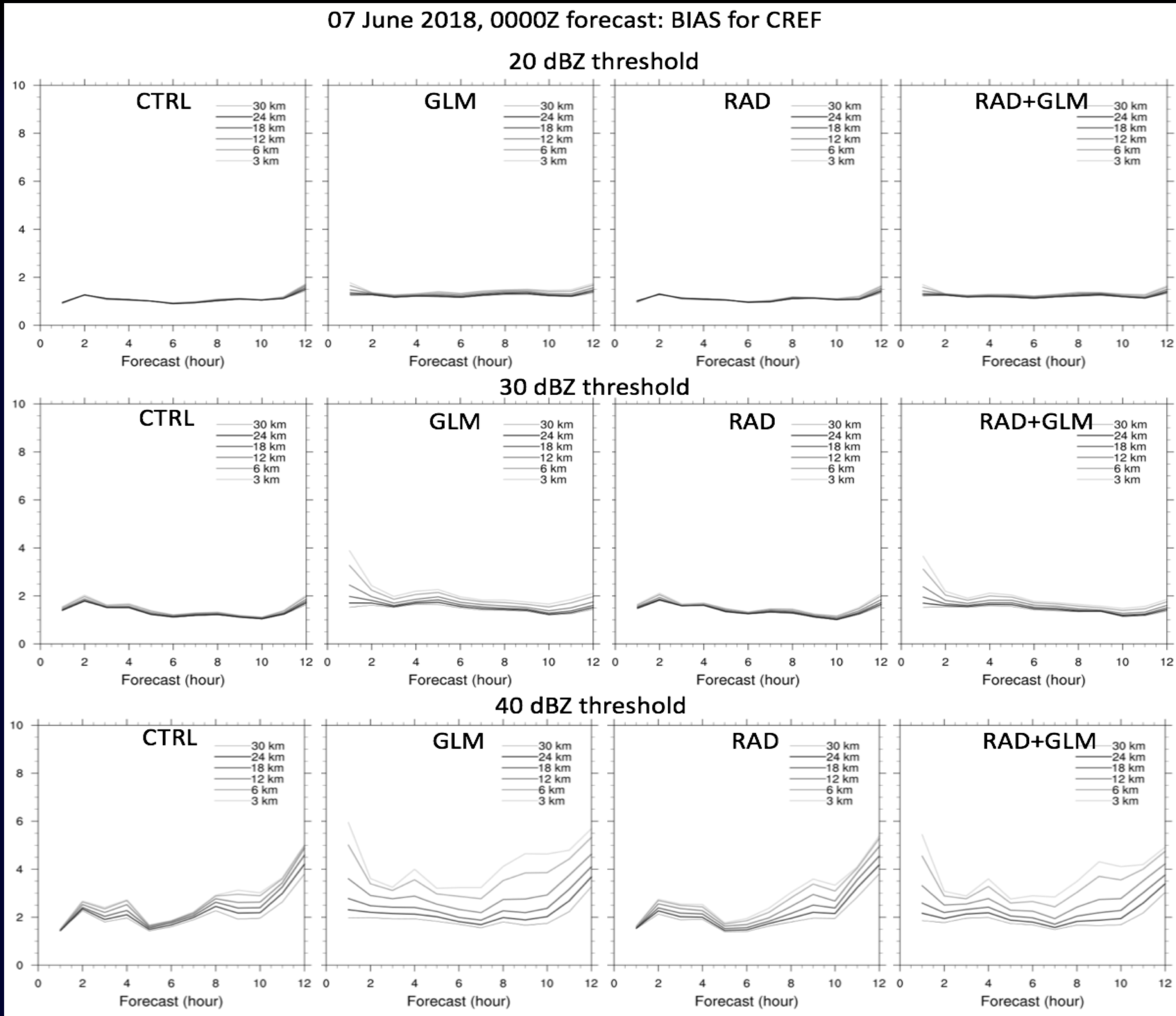
-H=24, 12 km: multi-scale:
24km, 12km: Vr
12km: lightning
-V=2 grid points for all vars
-One cycle (0000Z)



07 June 2018, 0000Z forecast (t=2h)
GLM Flash Densities (h-1 9 km-2)
Radar data assimilated (lvl II)
23Z-00Z
0000Z
Refl (Max)
dBZ: 2-h forecast
MRMS OBS
0200Z
CTRL
GLM
RAD
RAD+GLM
LAT (deg N)
LON (deg W)

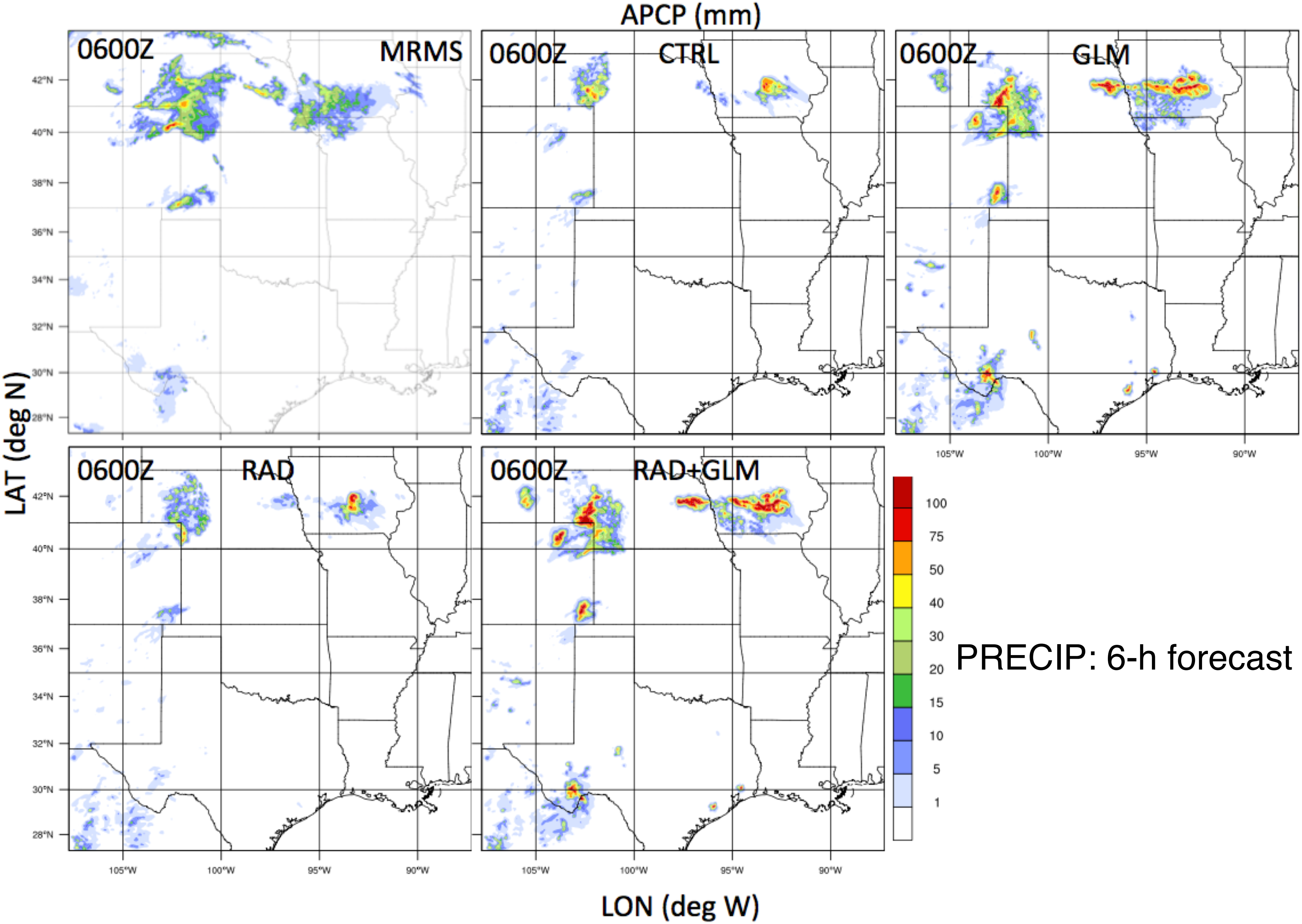


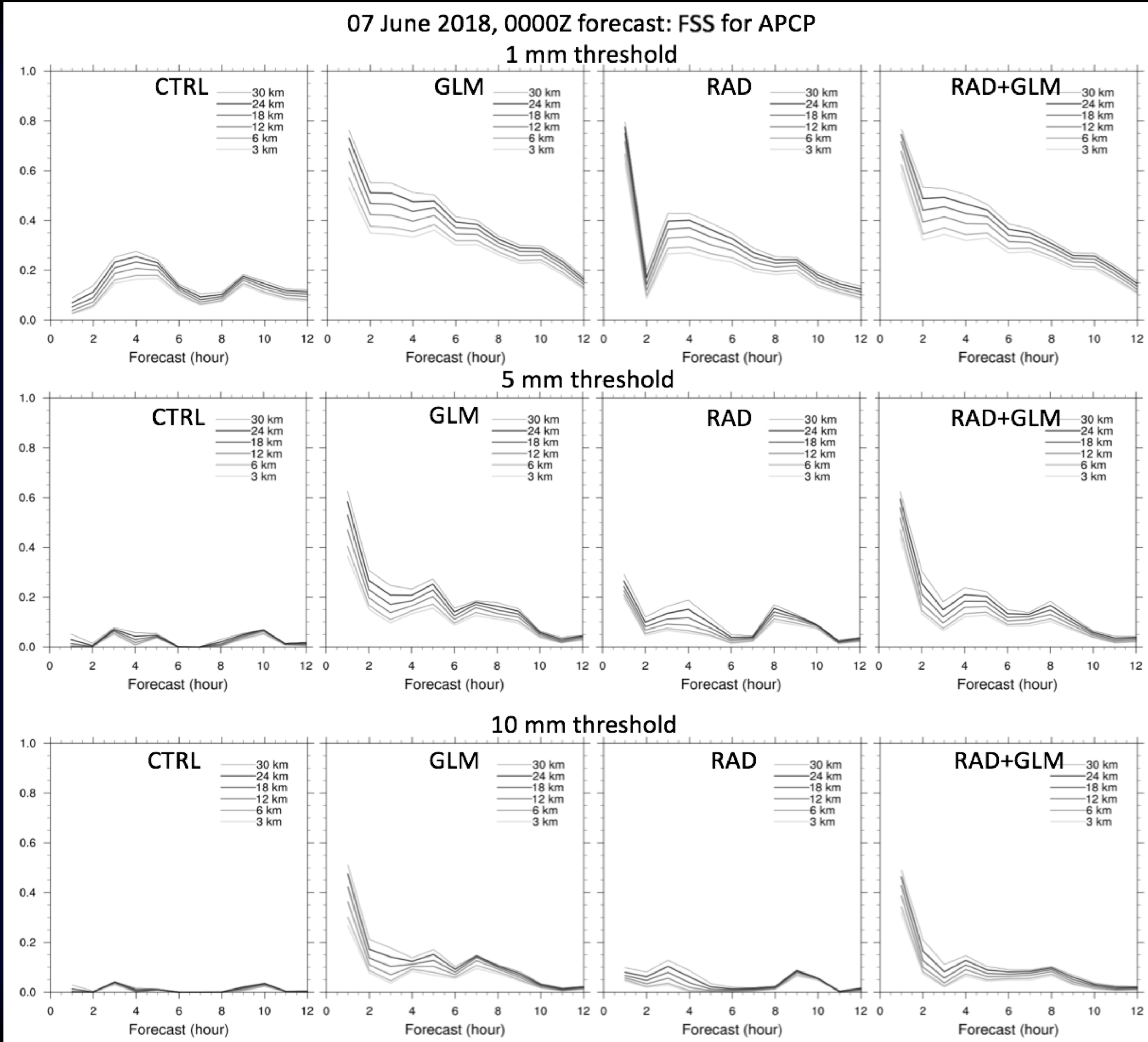
07 June 2018, 0000Z forecast: FSS for CREF
20 dBZ threshold
30 dBZ threshold
40 dBZ threshold
CTRL
GLM
RAD
RAD+GLM
30 km
24 km
18 km
12 km
6 km
3 km
Forecast (hour)



NB: Bias already present in CTRL, is exacerbated in DA runs due to increase in storm coverage. Not caused by DA but inherent to microphysics. Other schemes tested had similar or higher bias.

7 June 2018, 0000Z forecast (t=6h)



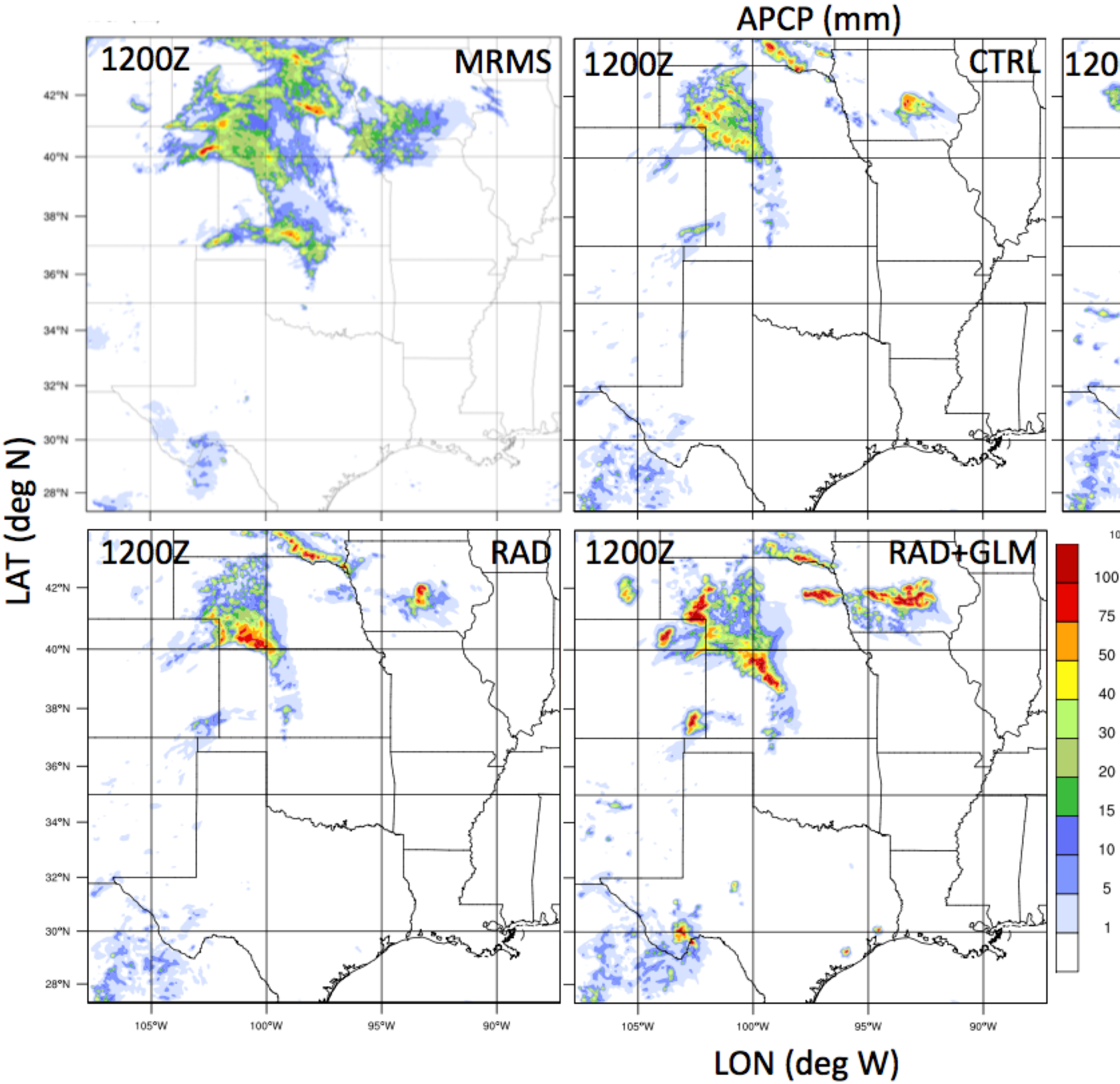


07 June 2018, 0000Z forecast: FSS for APCP
1 mm threshold
5 mm threshold
10 mm threshold
CTRL
GLM
RAD
RAD+GLM
30 km
24 km
18 km
12 km
6 km
3 km
Forecast (hour)

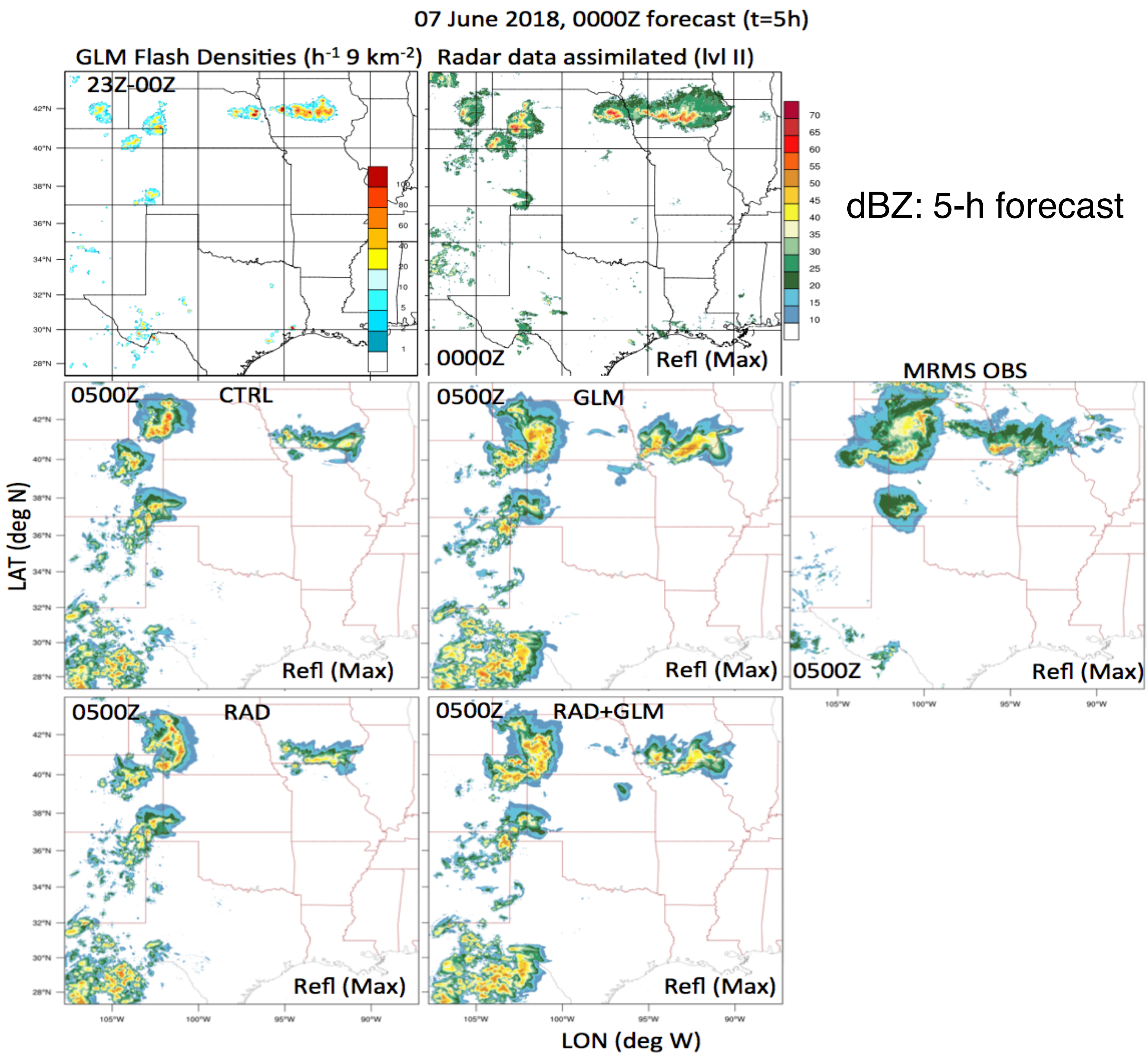
Ongoing and future work

- Experiments only employ one cycle (at 00Z): test influence of additional 3DVAR cycles with different frequencies.
- Run additional cases spanning different convective regimes.
- Increase/decrease the assimilation time window.
- Establish the significance at the 5% level of the difference between score metrics: ETS(GLM)-ETS(CTRL) etc ... using random sampling (bootstrapping).
- Develop/Implement dynamic weighting between radar and lightning during the DA.
- Continue to work on producing real-time evaluation graphics, which could be used during real time experiments (e.g., HWT).
- Start thinking about hybrid ensemble-3DVAR implementation for lightning.

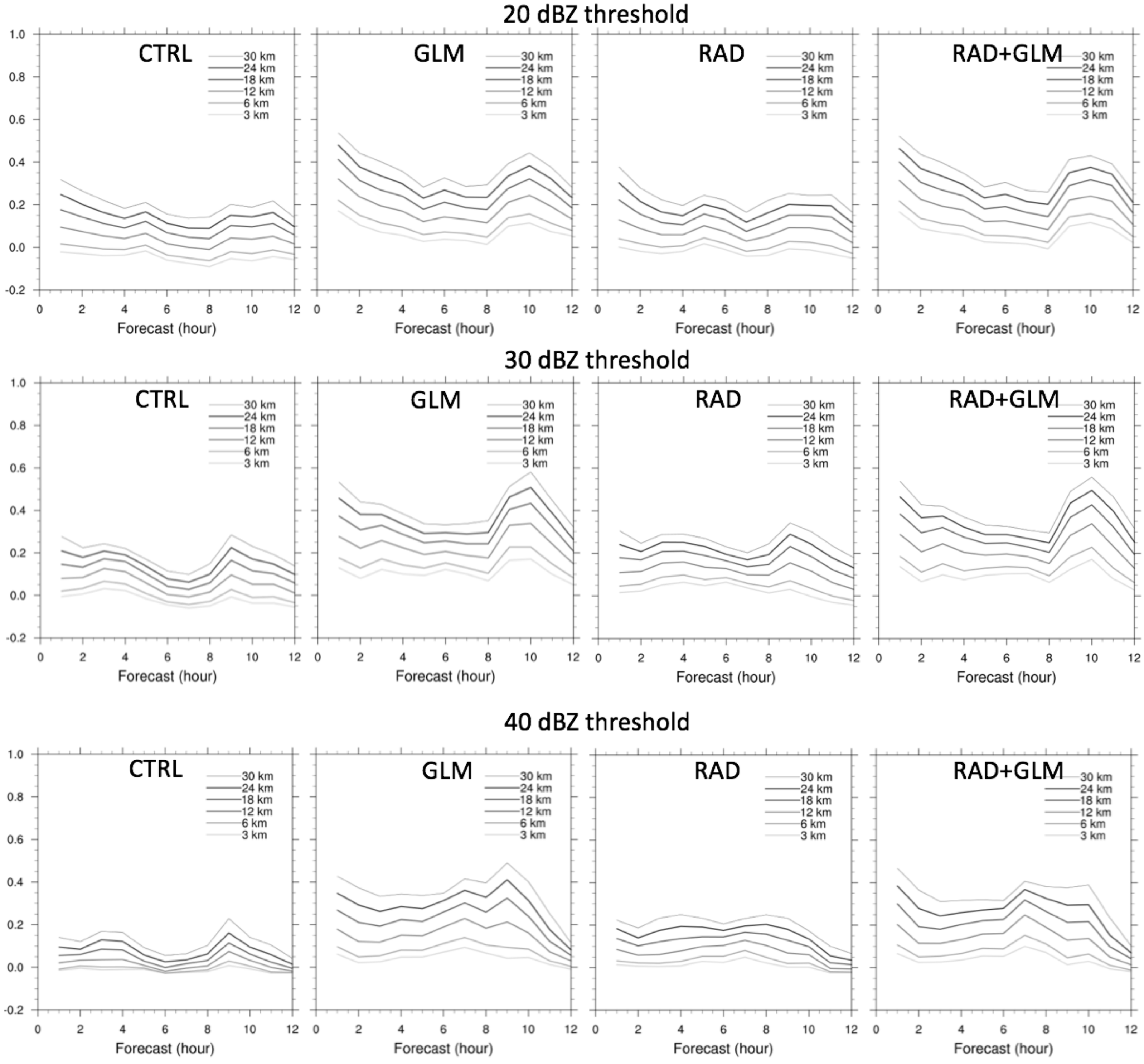
7 June 2018, 0000Z forecast (t=12h)



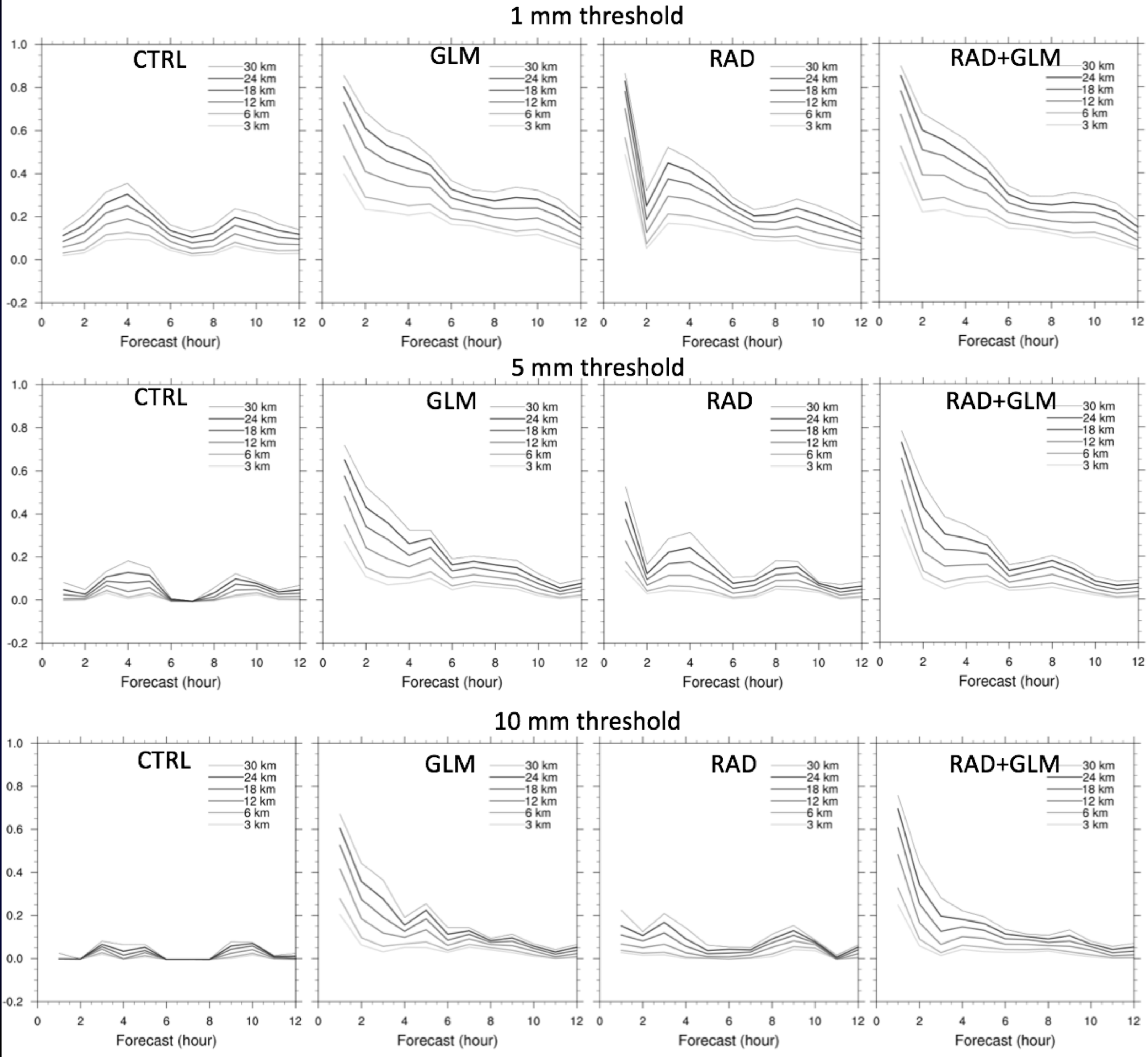
PRECIP: 12-h forecast


07 June 2018, 0000Z forecast (t=5h)
GLM Flash Densities (h⁻¹ 9 km⁻²)
23Z-00Z
Radar data assimilated (lvl II)
0000Z
Refl (Max)
dBZ: 5-h forecast
MRMS OBS
0500Z
CTRL
GLM
RAD
RAD+GLM
LAT (deg N)
LON (deg W)

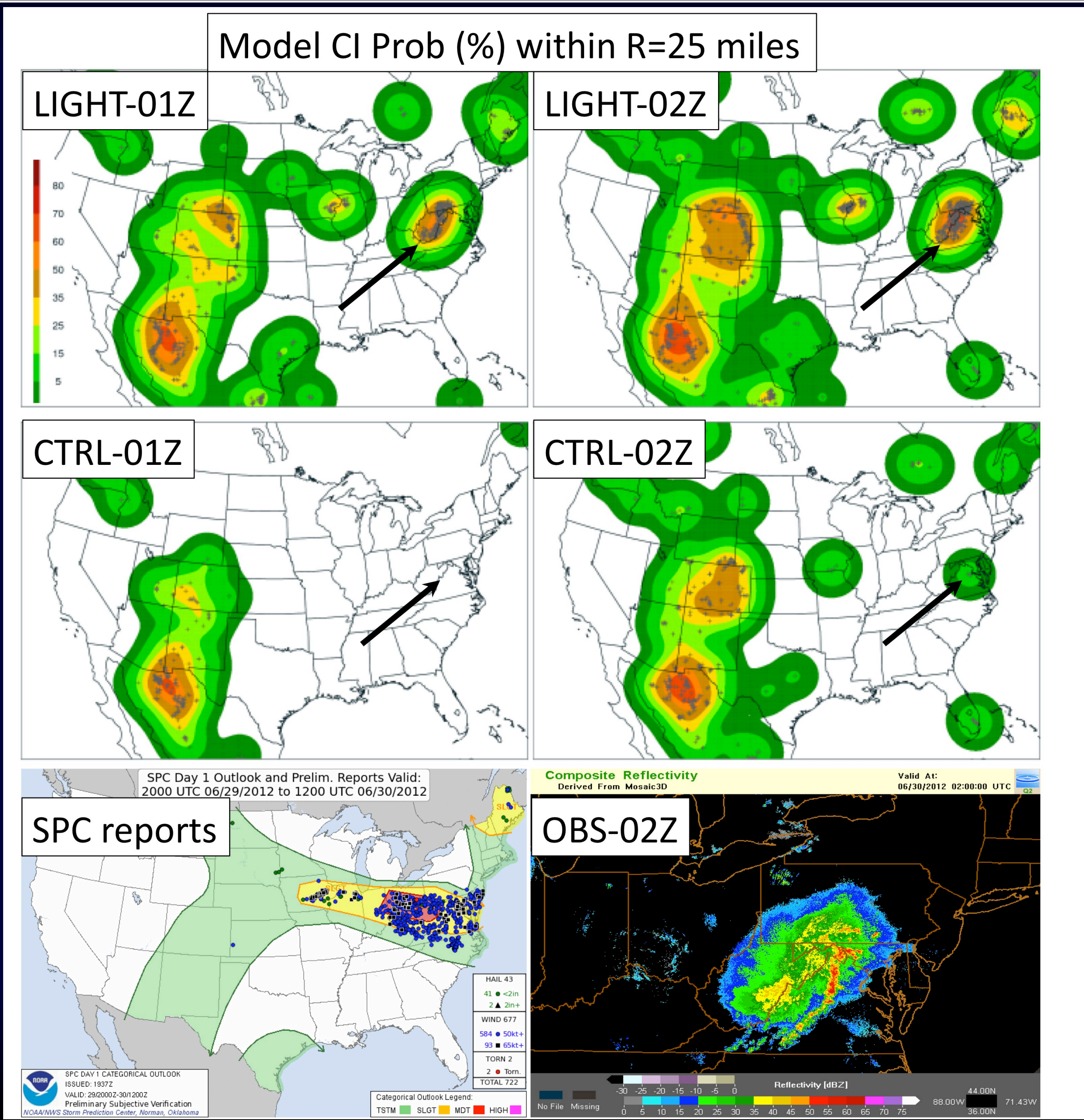
07 June 2018, 0000Z forecast: ETS for CREF



07 June 2018, 0000Z forecast: ETS for APCP

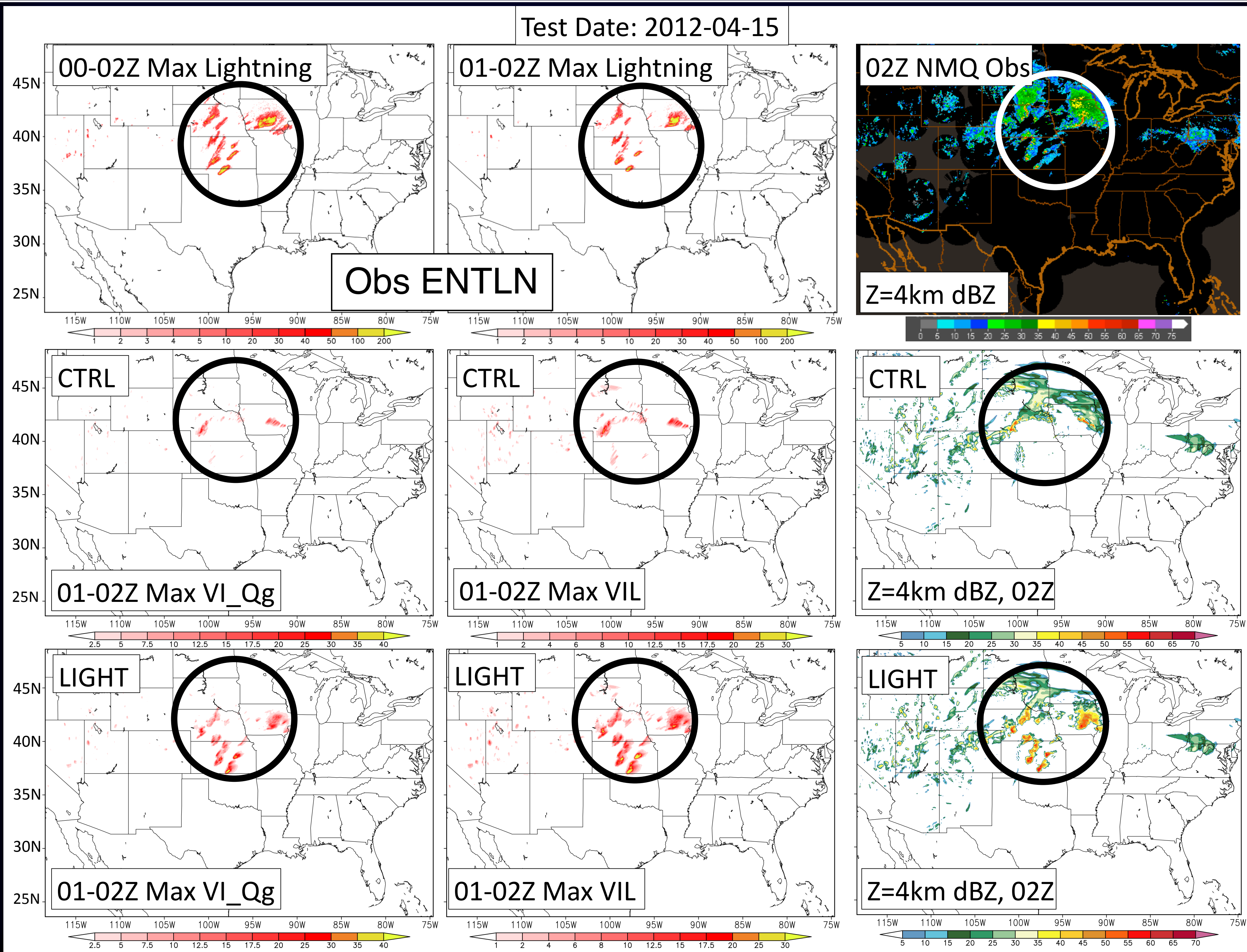


Real -time implementation into WRF-NSSL 4-km CONUS runs

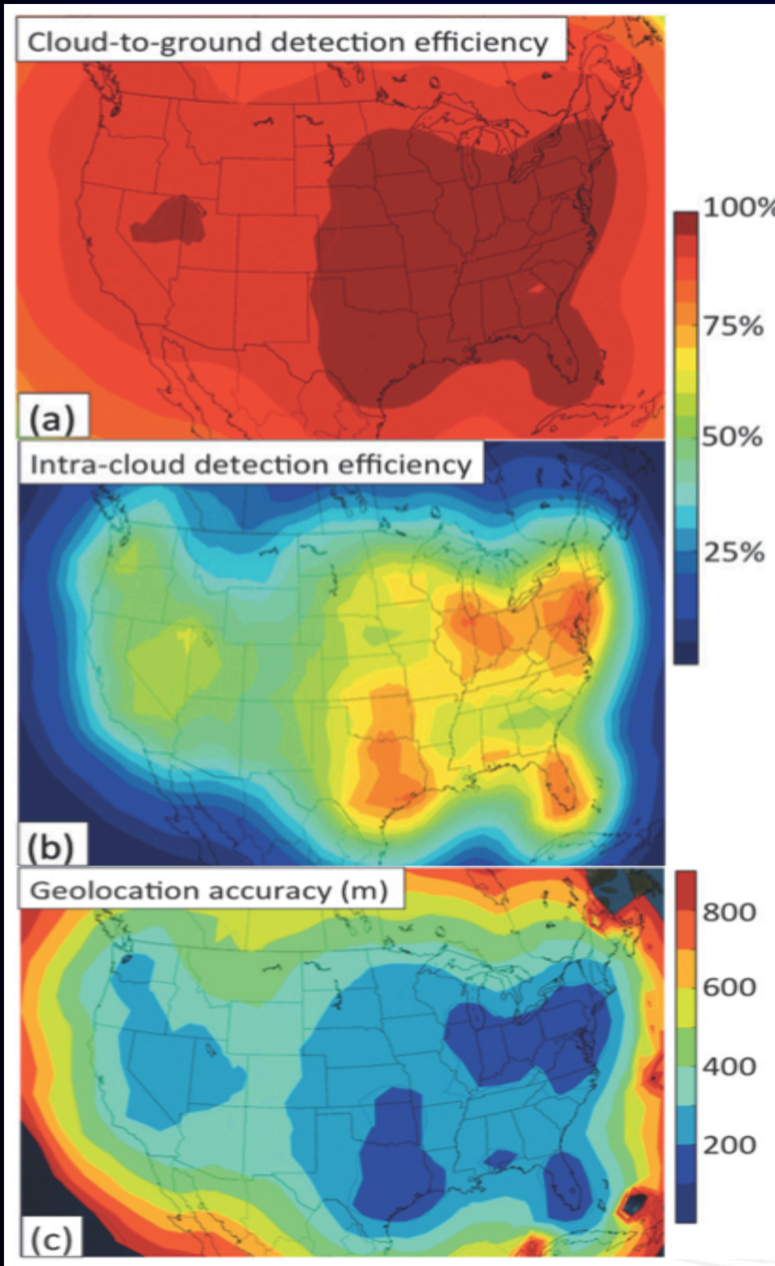


cf Fierro et al. (2014, MWR)

Real -time implementation into WRF-NSSL 4-km CONUS runs



ENTLN network



http://earthnetworks.com/OurNetworks/LightningNetwork.aspx

- Measure broadband electric field, from 1 Hz to 12 MHz.
- Effective proxy for GOES-R total lightning measurements.
- Remarkable detection efficiency for CG return strokes over CONUS (98%) and IC with efficiencies > 70% over OK.
- High network density results in overall small geo-location error generally (< 300 m over OK).

Graphics courtesy of Jim Anderson, Stan Heckman and Steve Prinzivalli from EarthNetworks®-Used with Permission.