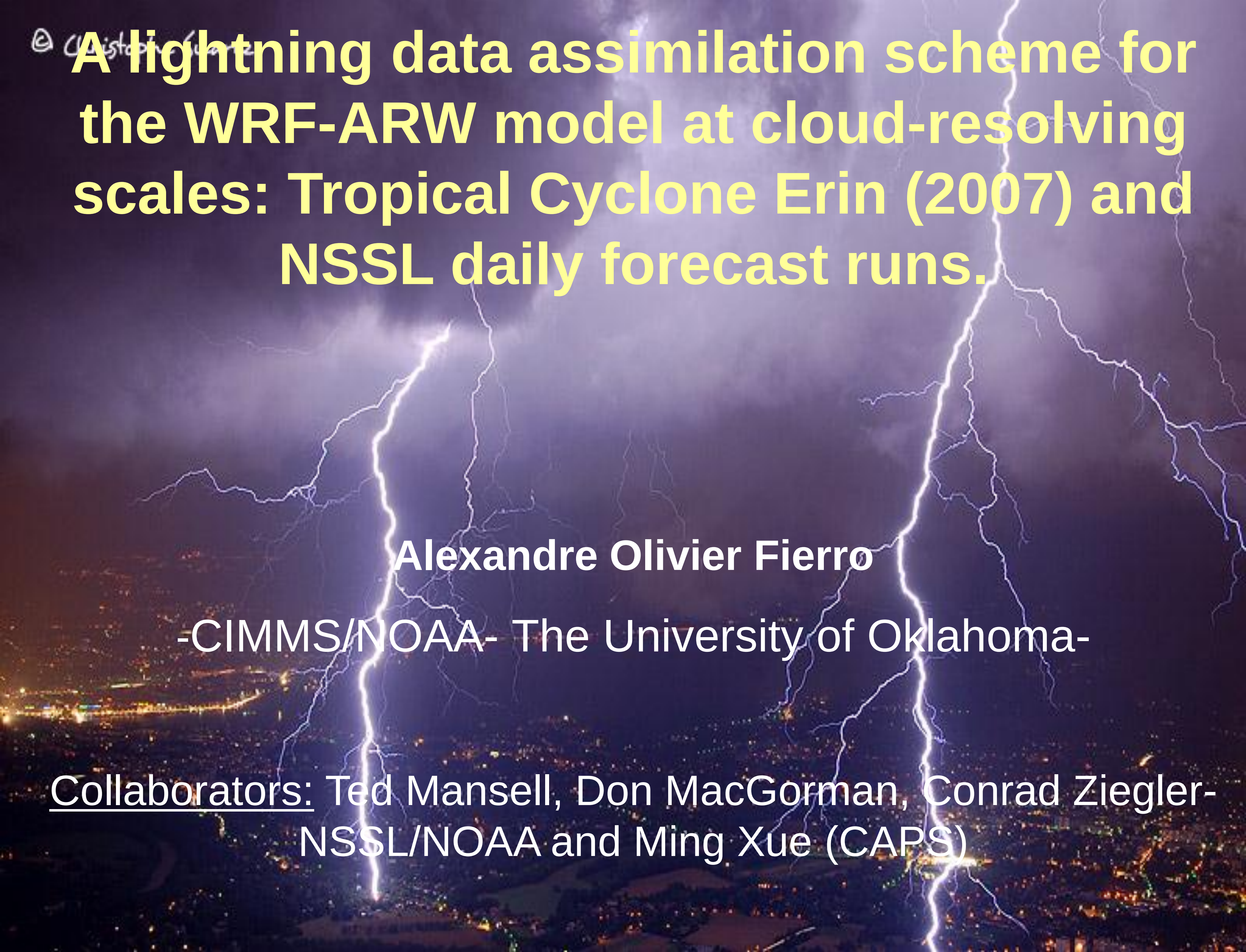

A lightning data assimilation scheme for the WRF-ARW model at cloud-resolving scales: Tropical Cyclone Erin (2007) and NSSL daily forecast runs.

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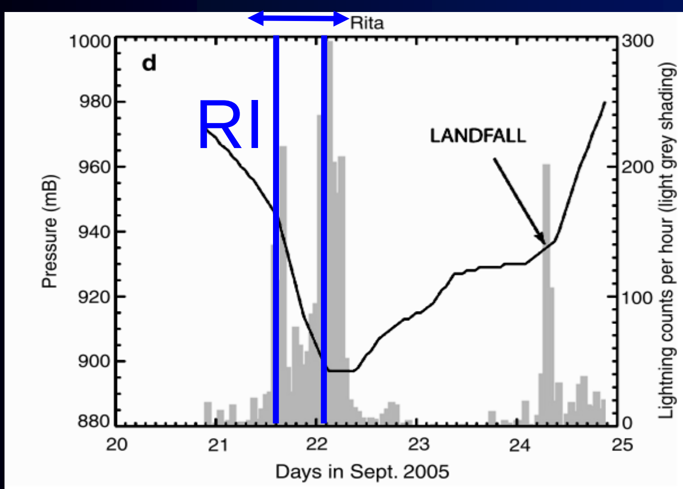
-CIMMS/NOAA- The University of Oklahoma-

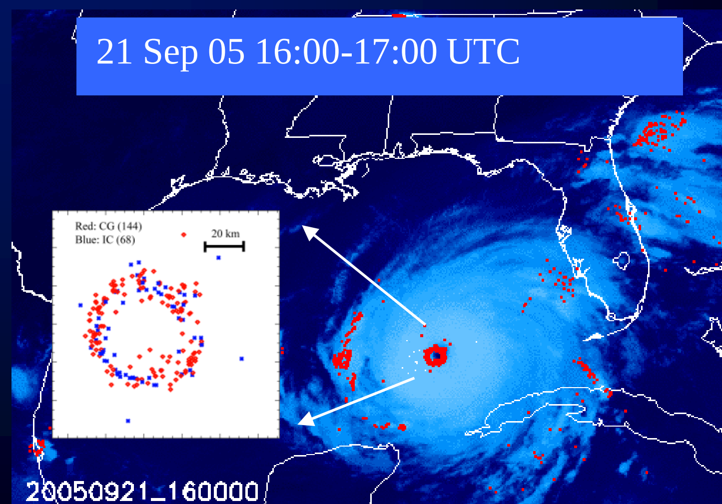
<u>Collaborators:</u> Ted Mansell, Don MacGorman, Conrad Ziegler- NSSL/NOAA and Ming Xue (CAPS)

Why using lightning data for NWP application?

- Occurrence of lightning in convection is correlated to basic quantities that are often diagnosed in dynamical model.
- Such quantities are: graupel mixing ratio, w, supercooled water supersaturation over ice and/or water among others
- Moreover, for tropical applications; observations suggest that hurricane eyewall total lightning flash rate is often accompanied by intensity fluctuations of the system (e.g., Molinari's, Fierro et als.).



Rita



Shao et al. (2006)

Scientific goals:

- Therefore a natural question to ask is:

Can total lightning data (IC+CG) be used as a forecast tool within NWP models to better predict convection in real time at cloud resolving scales (dx <= 5km)?

- The above idea is not new (Pessi and Businger; Mansell et al.) and has been tested with promise at CPS scheme scales (dx~10km).

- In this work; as a first step, the lightning data from the WTLN or LMA+NLDN were assimilated or nudged into the WRF-ARW model and tested for several cases at cloud resolving scales (here, 2 km). The following 2 will be shown in this talk:

- *23 April 2011 Great Plains severe weather event.*

- *Intensifying TS Erin (August 2007) over OK.*

23 April 2011 case

Setup in a 'flash':

- Domain covers portion of S. Plains (500x600 grid zones)
- Dx=dy=2 km with 35 vertical levels
- WSM 6 microphysics
- NAM 40 km data used as initial conditions.
- Run started at 00Z
- WTLN total lightning data interpolated onto WRF grid in 10 min intervals in the following set of 4 experiments

(i)By directly interpolating the lat/lon WTLN data onto the 2 km domain grid (G2)

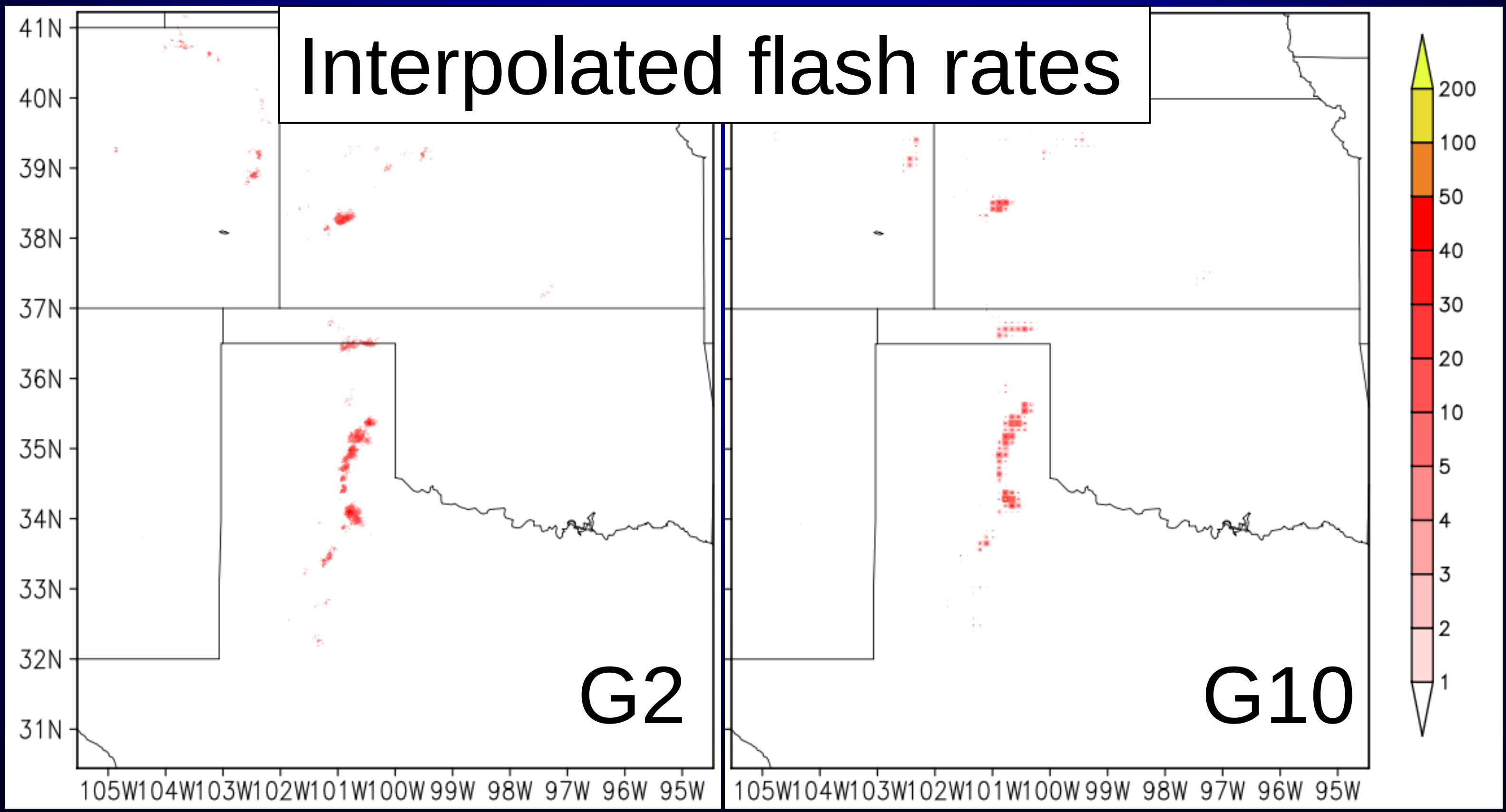
(ii)By first interpolating the WTLN data onto the domain using an hypothetical GEOS-R resolution of 10 km and then extrapolate that 10 km data onto the 2 km domain (G10).

(iii)Then, in separate experiments, for G2 and G10, the lightning data was nudged in during either the first 1 hour or during the first 2 h of simulation after 00Z.

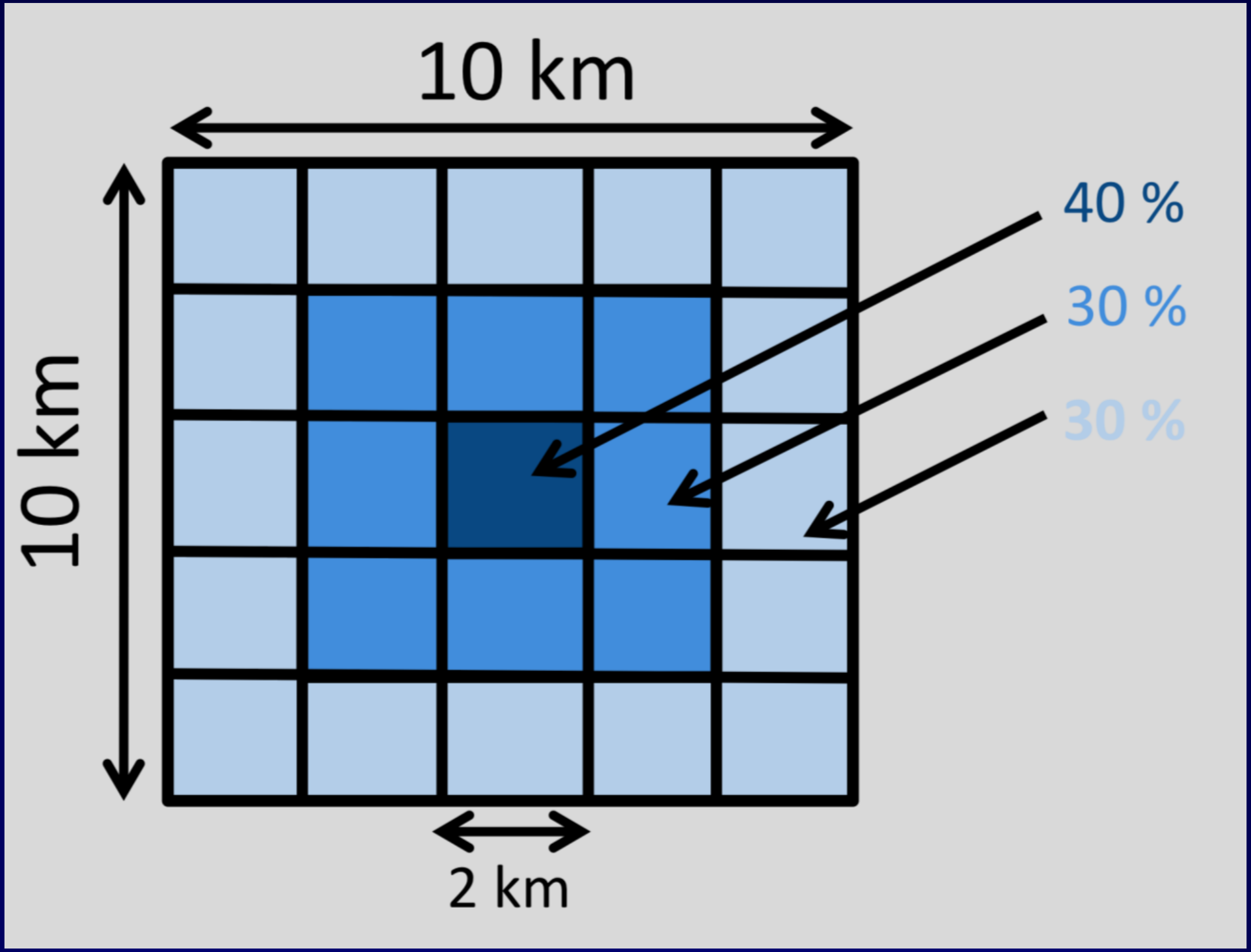
How is the lightning nudged into WRF?

Because lightning flashes are generally associated with the presence of updrafts, whenever a flash (gridlight) was present in a I,J location, the layer between 0 and -30° C (representative of the mixed-phase graupel rich region of storms) was supersaturated w.r.t water as a function of flash rate as follows:

$$q_{vapor} = q_{sat} + 0.05 * q_{sat} * \tanh(gridlight/30)$$

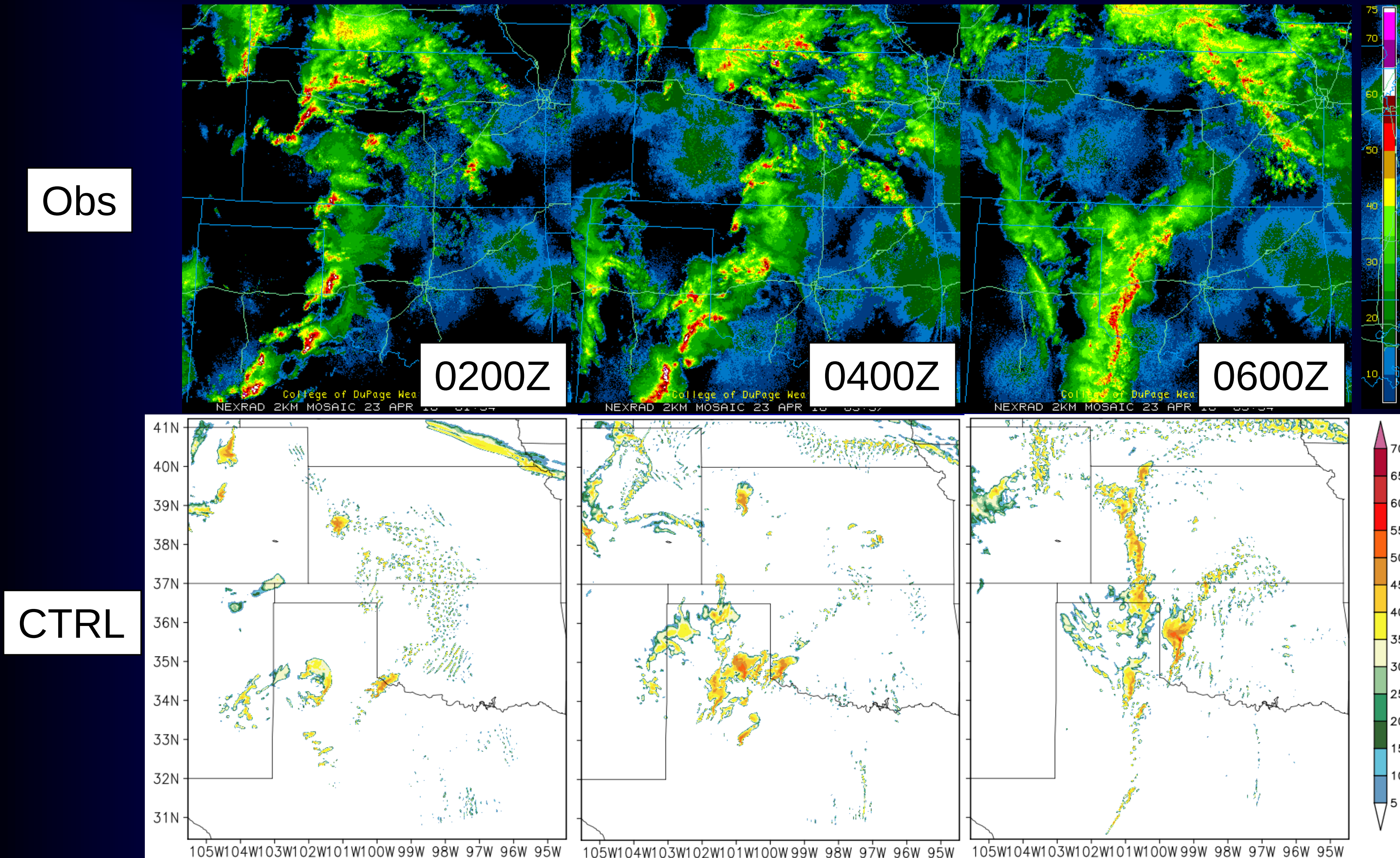


How are the WTLN flashes extrapolated from 10 km to 2 km grid?



Flash count is assumed conserved and maximized at the center of the grid cell.

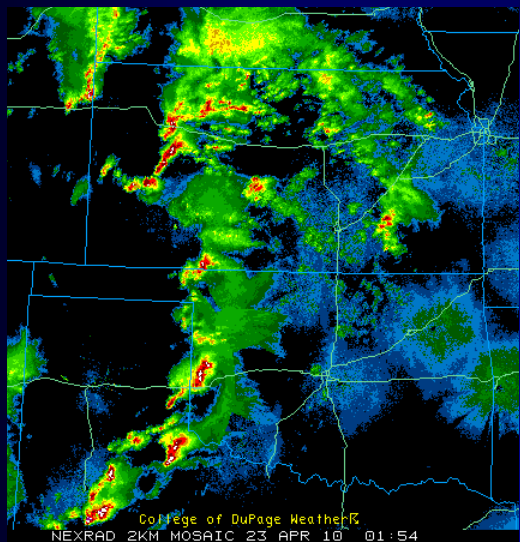
23 April: dBZ at 1 km AGL



CTRL run does not reproduce supercells at 02Z in the TX panhandle as well as the convection over the warm front in KS. Simulated squall line is also ill defined and located too far to the W.

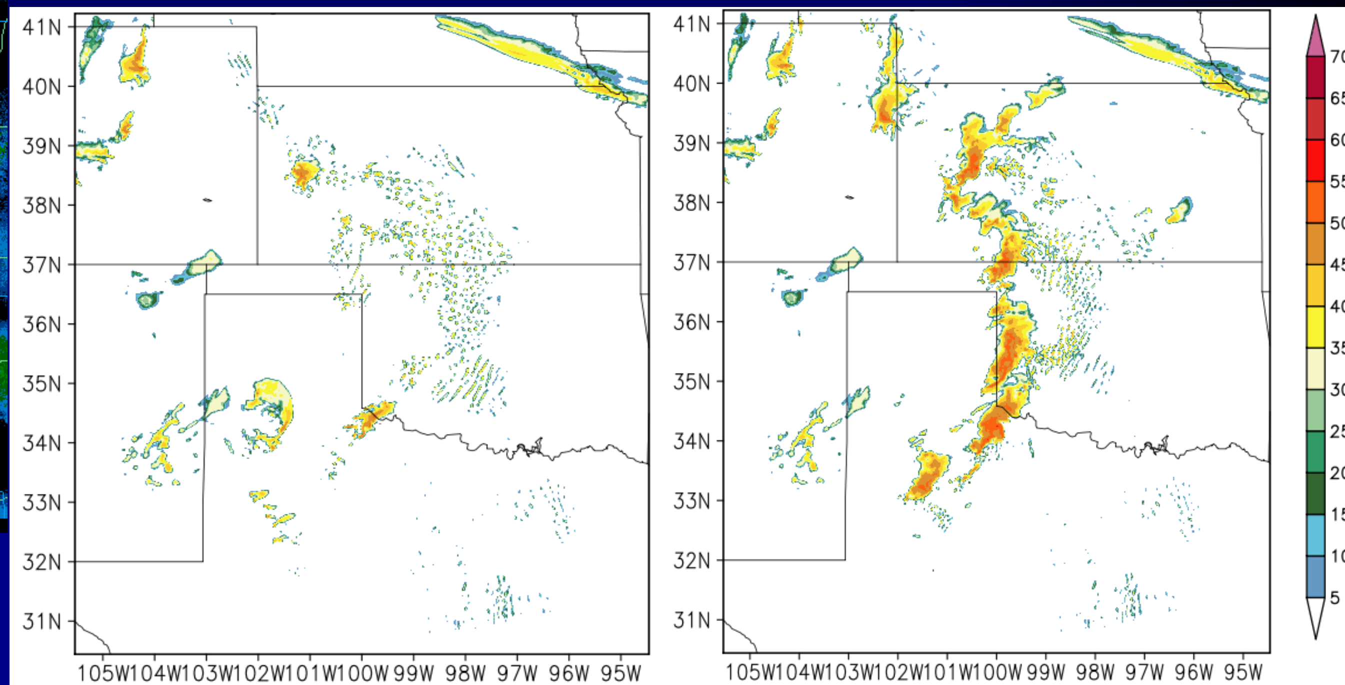
23 April: 2 h assimilation

Obs



CTRL

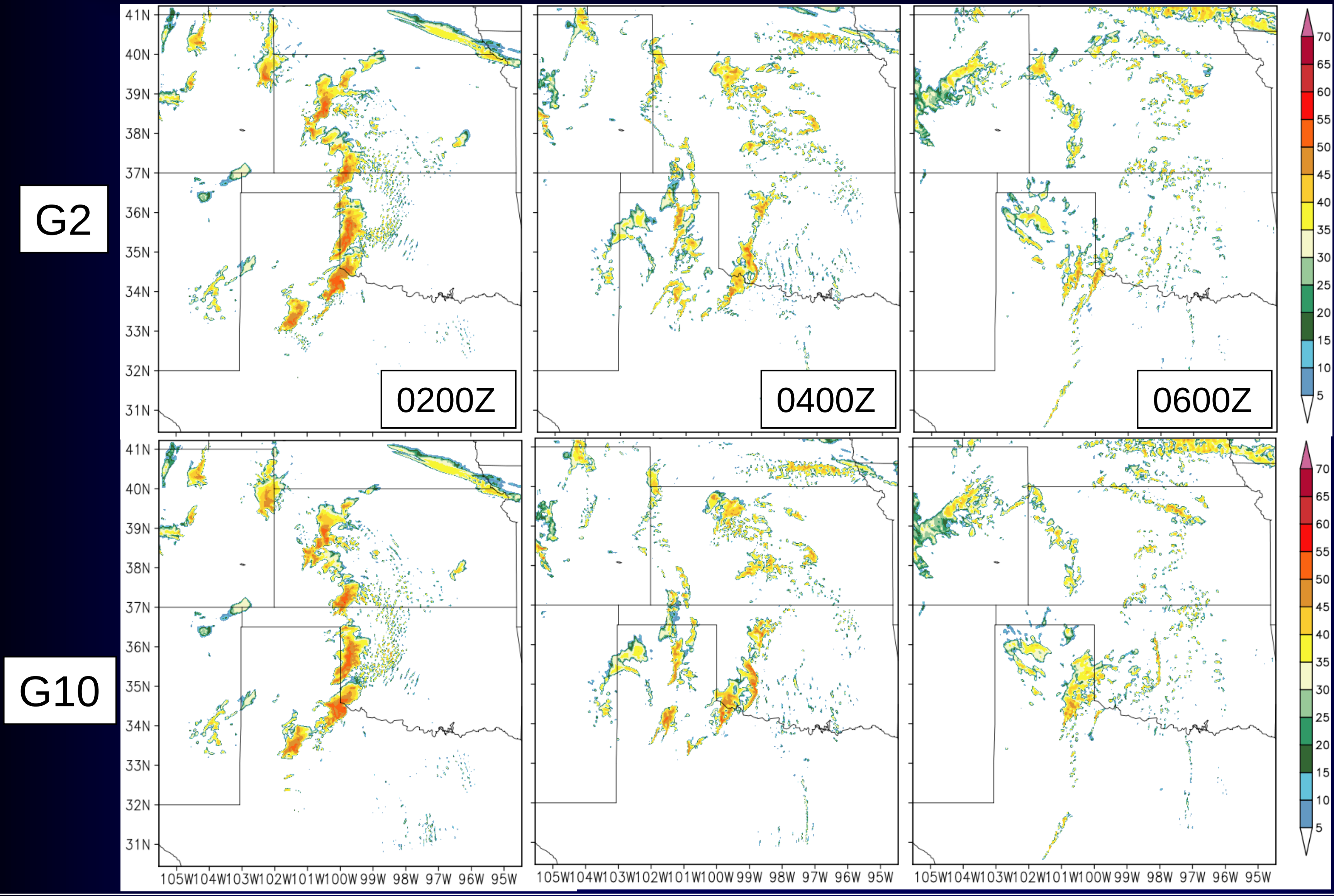
G2



0200Z

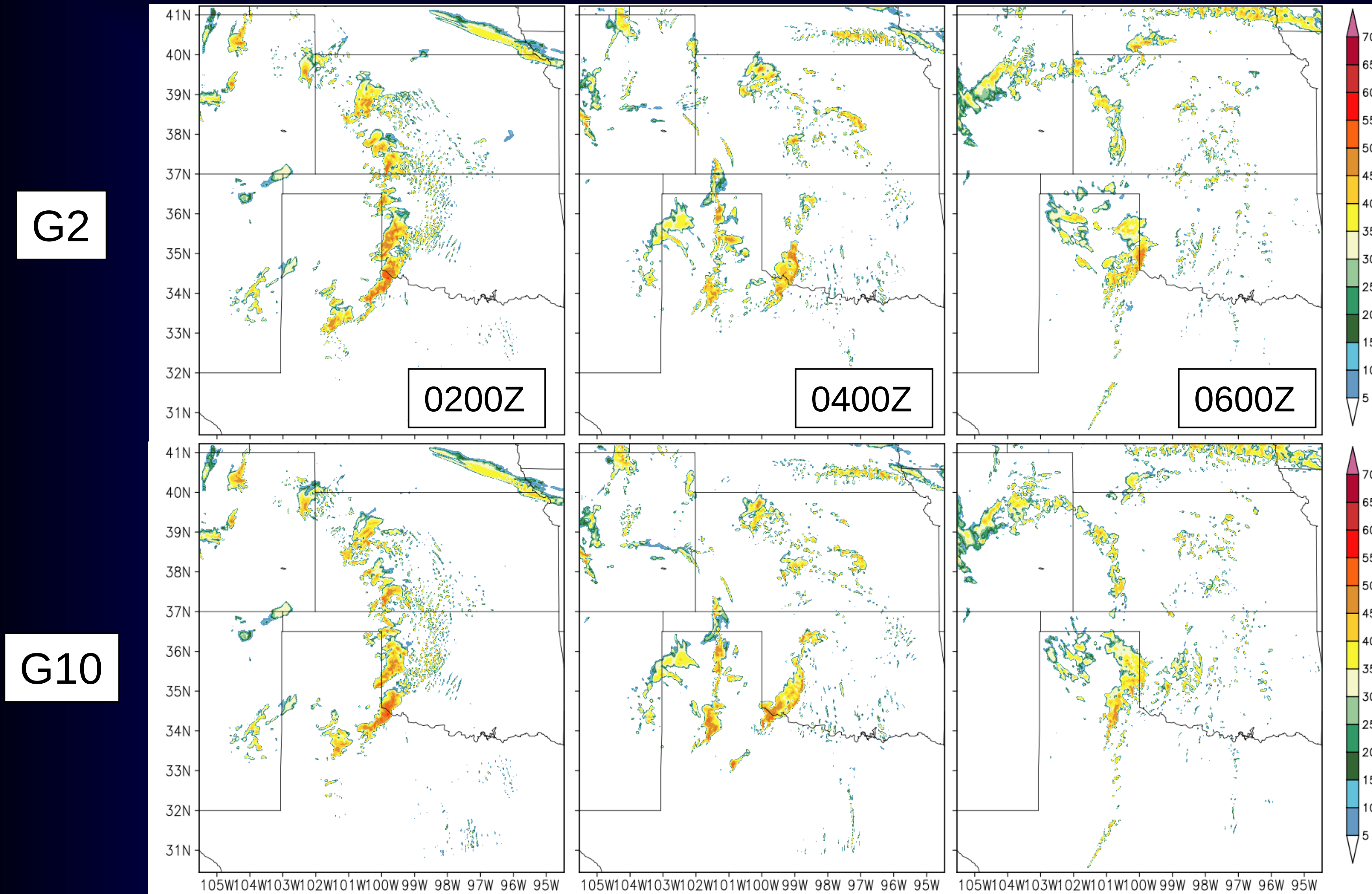
As expected, early supercellular activity is more correctly resolved using lightning.

23 April: 2 h assimilation



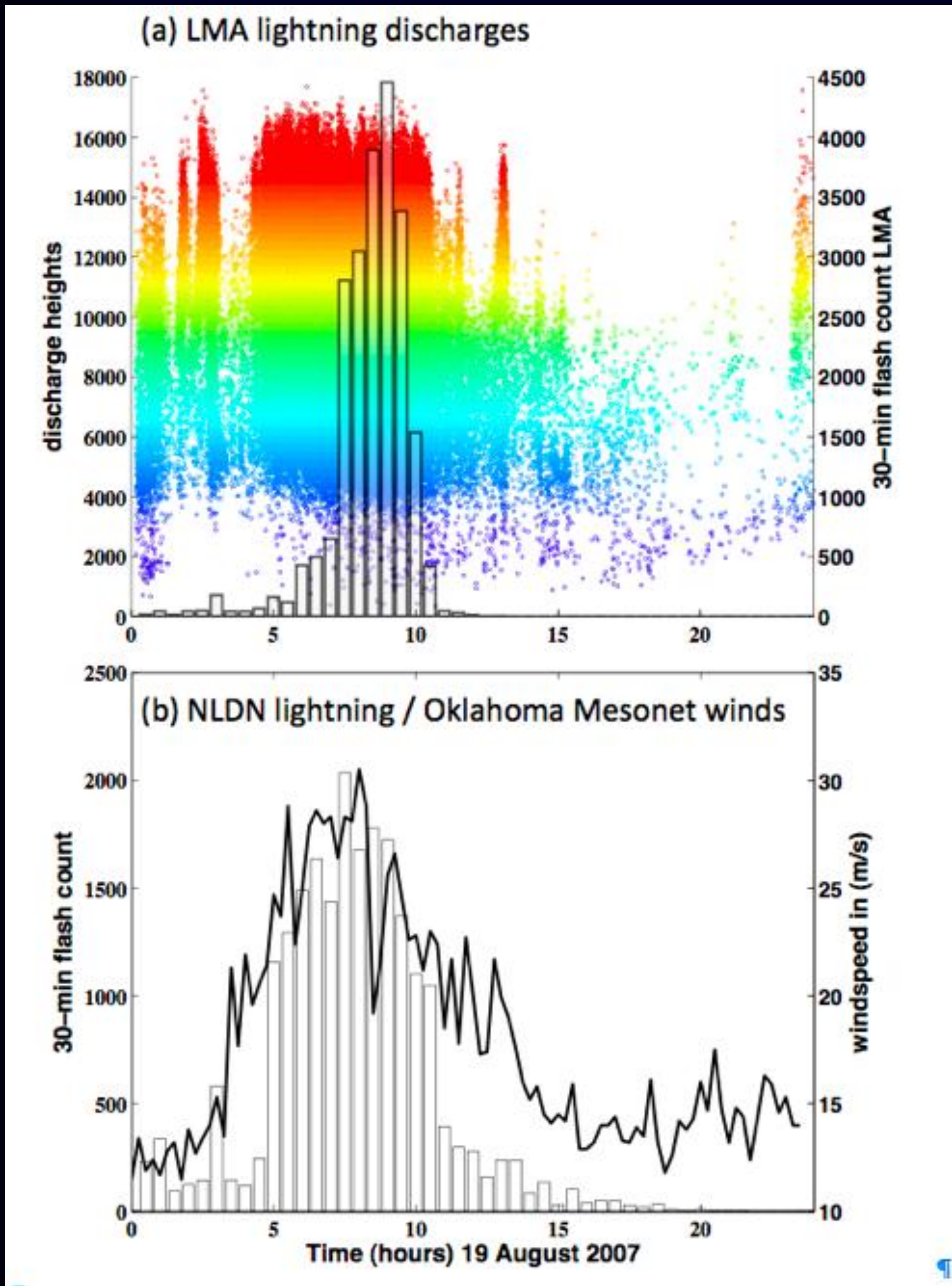
For both again, early supercellular activity is more correctly resolved using lightning. Warm frontal convection in KS is also better represented. However, the squall line in W OK is per say inexistent and worst that in CTRL. Note also that both cases show a high degree of similarity → Would GEOS-R resolution flash data (vs lat/lon) be sufficient for assimilation?

23 April: 1 h assimilation

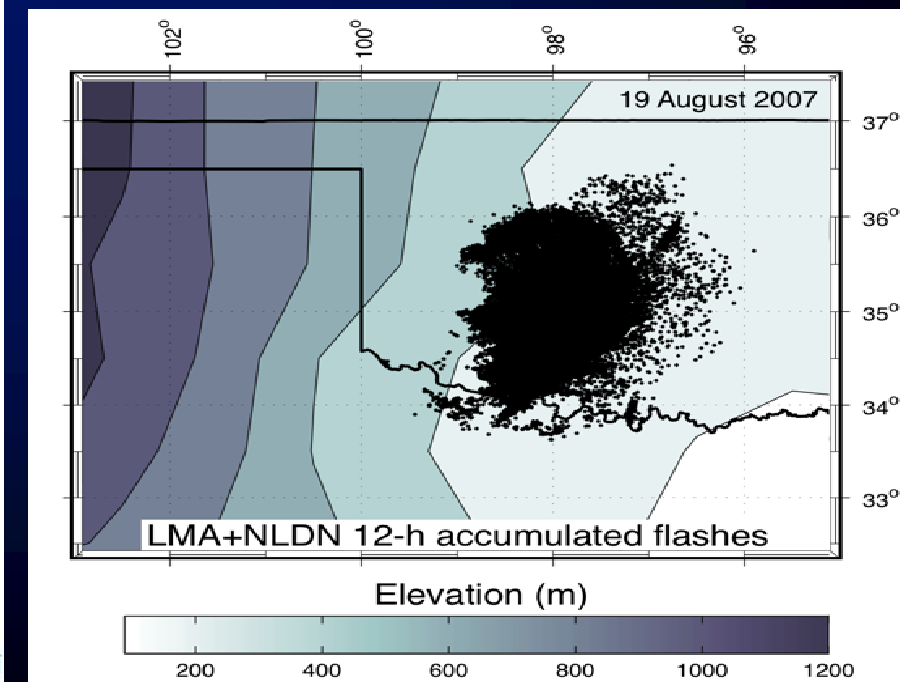


Early supercellular activity is still well depicted as well as KS convection, although slightly weaker than obs (and than 2h assimilation runs). As before, squall line in W OK produced by merging of supercells is inexistent. Rather The convection in TX panhandle in all runs developed in the TX panhandle along a boundary (dry-line and/or cold front).

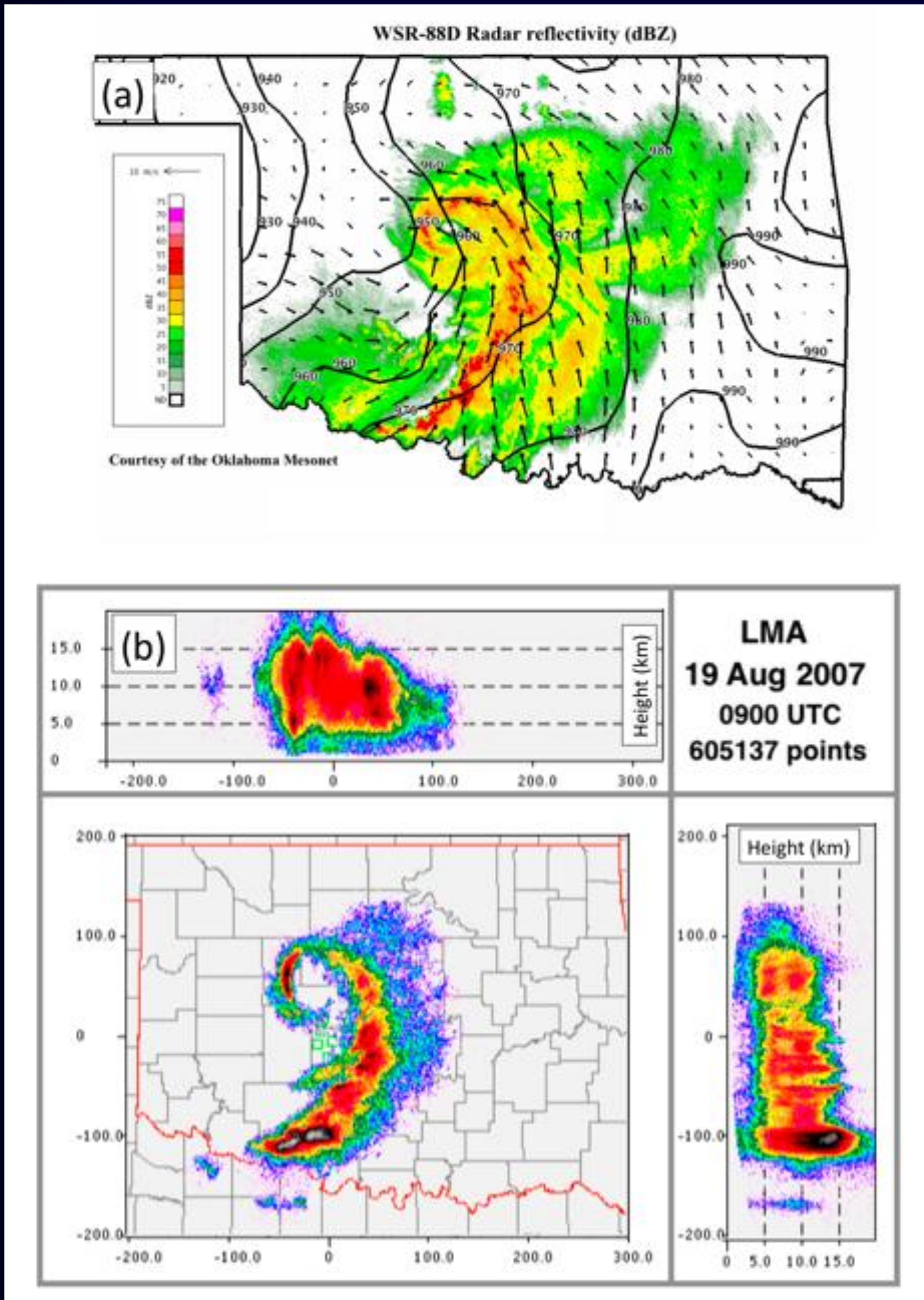
TC Erin: 1) Observations



- •Similar to Rita; TS Erin 'eyewall' was lit up with lightning flashes during its intensification period.
- •LMA detected 8 times as many flashes as NLDN-
- •Topology of accumulated 12-h LMA+NLDN flashes starting at 00Z 19 Aug used to 'control' microphysics in WRF runs



Observations ctd…



- Erin showed a well-defined closed circulation with an eye-like feature at 0900UTC, which was depicted by the LMA sources.
- Source heights were seen as high as 18 km indicative of deep convection.
- Reminiscent of convective heat axisymmetrization by hot towers in TC eyewalls.

WRF test runs

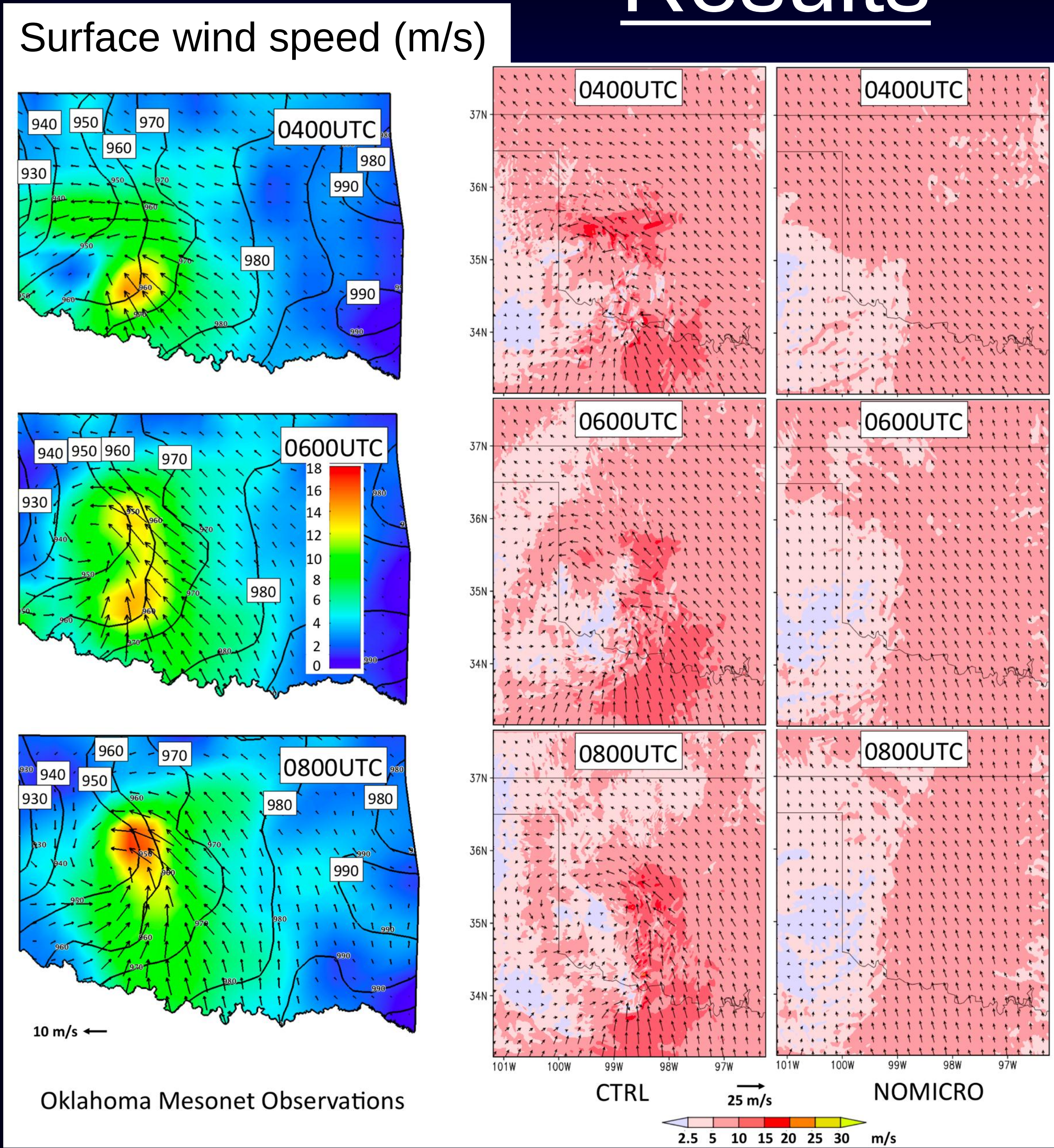
Experiments	*Description*
CTRL	Control run-Model run in free mode with microphysics
NOMICRO	As in CTRL but with microphysics turned off
QX0	All predicted hydrometeor mixing ratios (and hence, contents) of the WSM6 scheme nudged to 0 g m^{-3} except within the regions of observed 12-h accumulated lightning as shown in Fig. 4.
QX0ALL	As in QX0 but with hydrometeor contents nudged to 0 everywhere
QX1	As in QX0 except with hydrometeor contents nudged to 1 g m^{-3}

$$if\,(q_x \geq b/\rho_{air})\;then\;\; q_x = \max(\alpha * q_x, b/\rho_{air})$$

where b is the mixing ratio threshold (0 for run QX0), α=0.2, q_x is the mixing ratio of hydrometeor class x

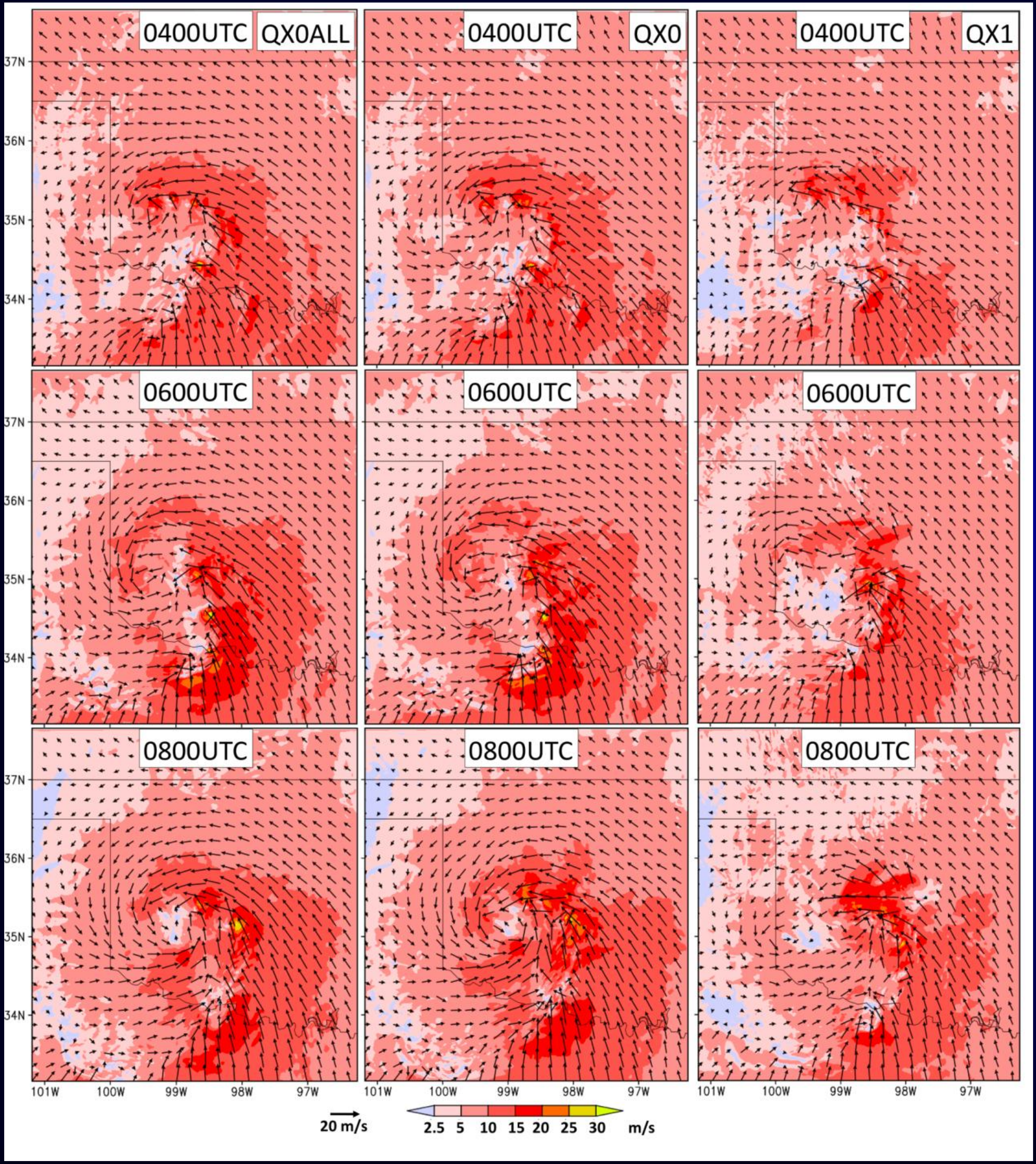
Lightning assimilated in 10 min intervals throughout the simulation for all cases → More of an analysis study rather than a forecast-

Results



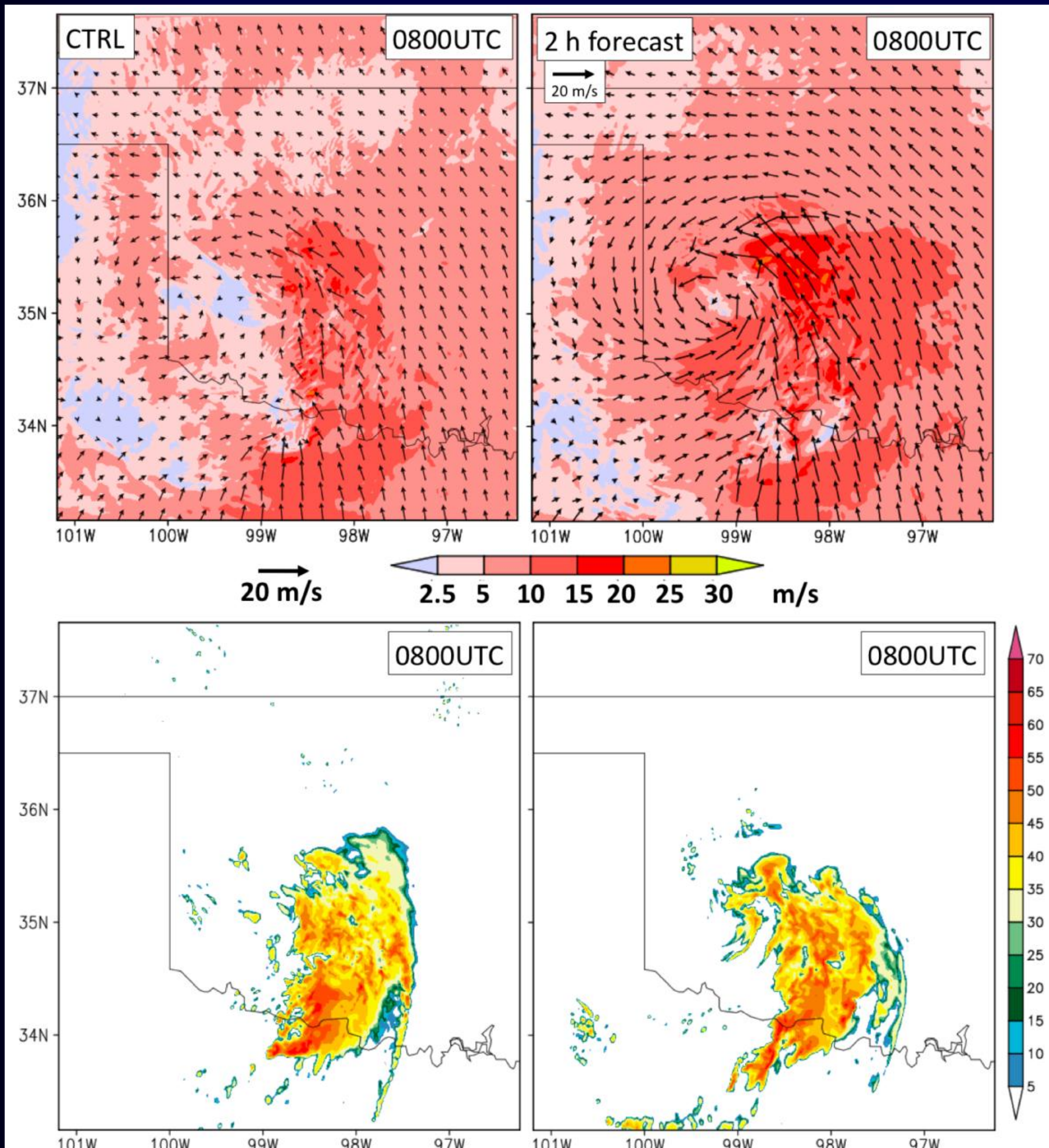
- CTRL run produced strong squall line that eventually disrupt and 'kill' the primary circulation of the vortex via the production of strong surface cold pools
- NOMICRO case indicates that vortex intensification must involve moist convection in the model as in real hurricanes-

Surface wind speed (m/s)



- The three QX experiments, whereby the WRF convection is almost suppressed outside the lightning area result in a well-defined TS-like circulation as in obs.
- → Convection in the model had to be imposed a severe limit for the vortex to intensify.

Forecast test



•Assimilating LMA+NLDN lightning data for the first 6 h resulted in a better 2 h (=0800Z) forecast compared to CTRL.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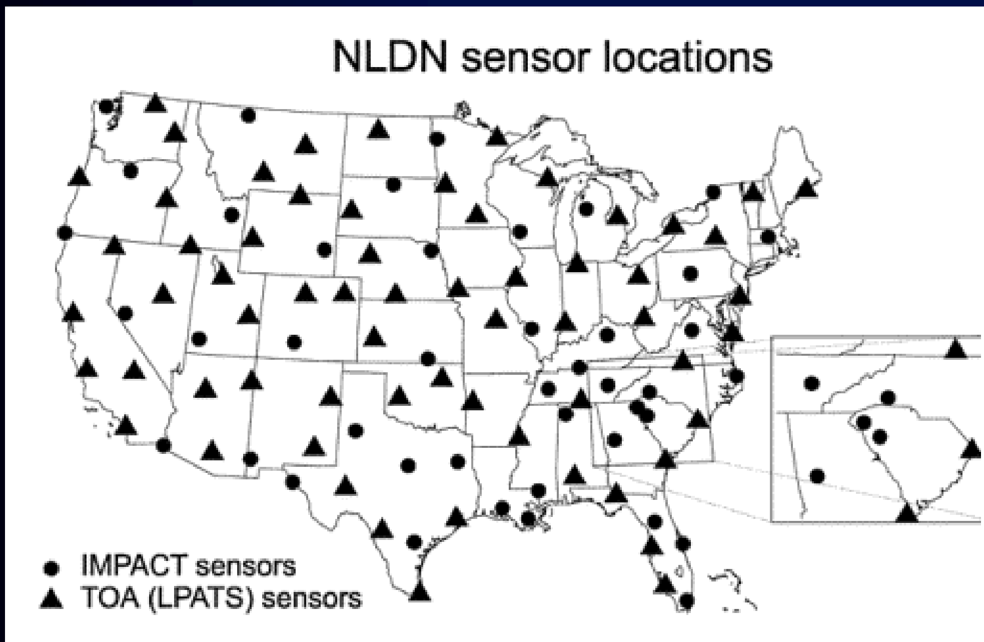
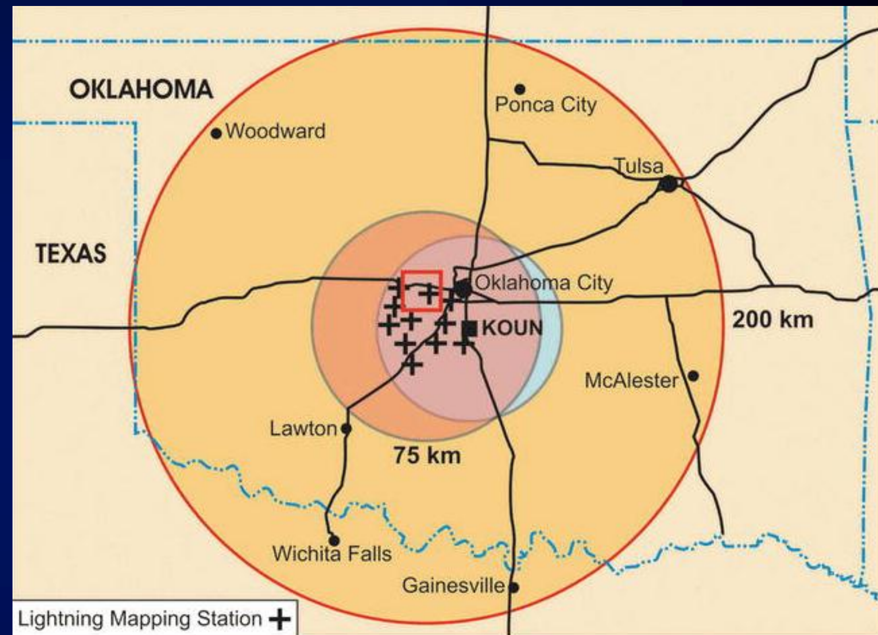
Questions?

LMA and NLDN networks in a nutshell

•The OK LMA consists of a group of stations located near the TLX radar, while NLDN covers CONUS evenly:





Map of NLDN sensor locations and type (IMPACT - Improved Performance from Combined Technology; TOA - Time Of Arrival) for CONUS.

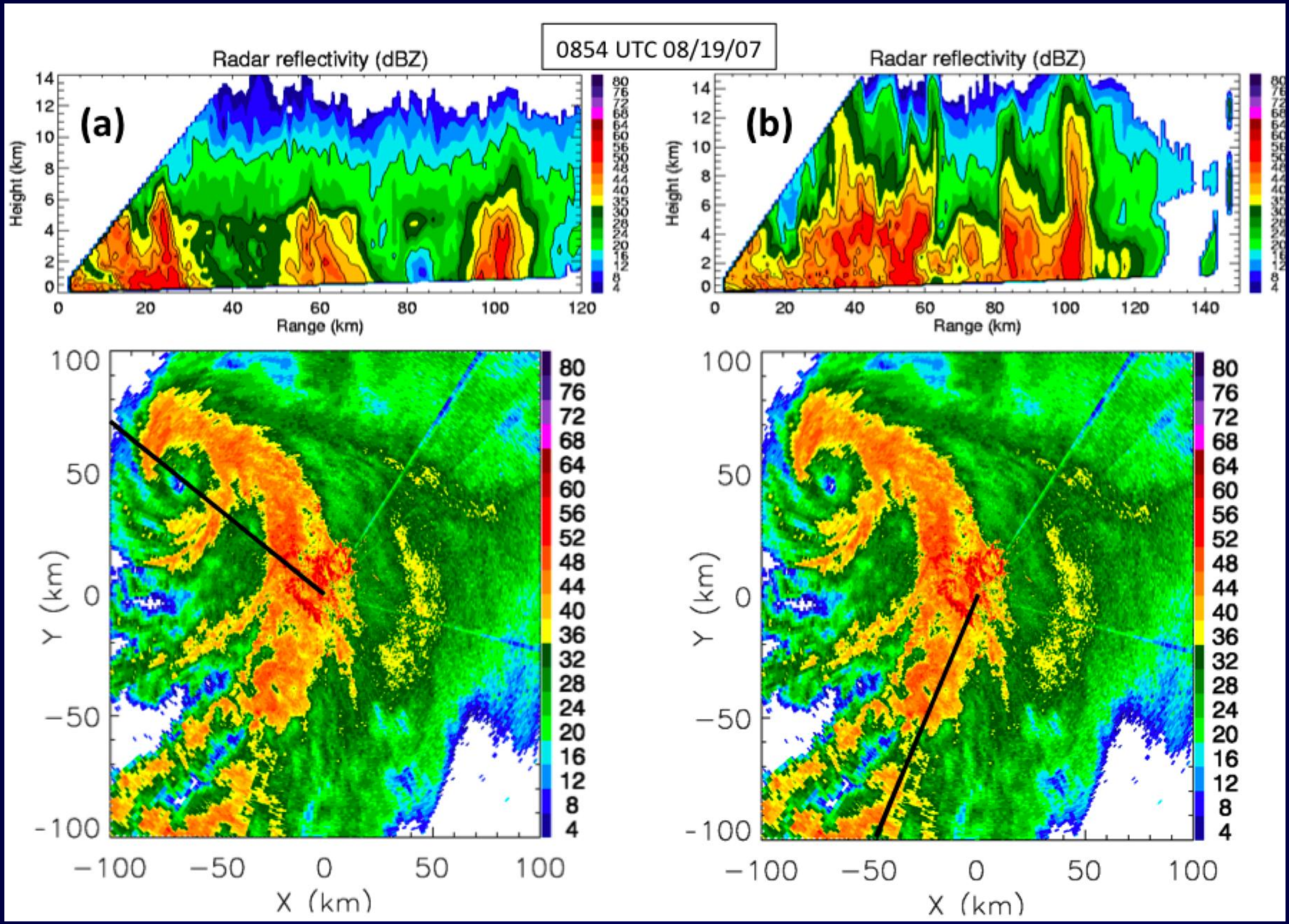
Blue circle indicates a 60-km radius from KOUN and the peach-shaded circle indicates a 75-km radius from the center of the LMA network. (Bruning et al. 07)

WTLN network

•WeatherBug Total Lightning Network is the world's largest lightning detection network with detection efficiency ranging between 25-60% over CONUS.
•Measure broadband electric field, from 1 Hz to 12 MHz
•Incorporates advanced lightning location technology
•The first network to detect both in-cloud (IC) and cloud-to-ground (CG) lightning.
•More than 360 lightning sensors from around the globe making WTLN the world's largest and fastest lightning detection network.

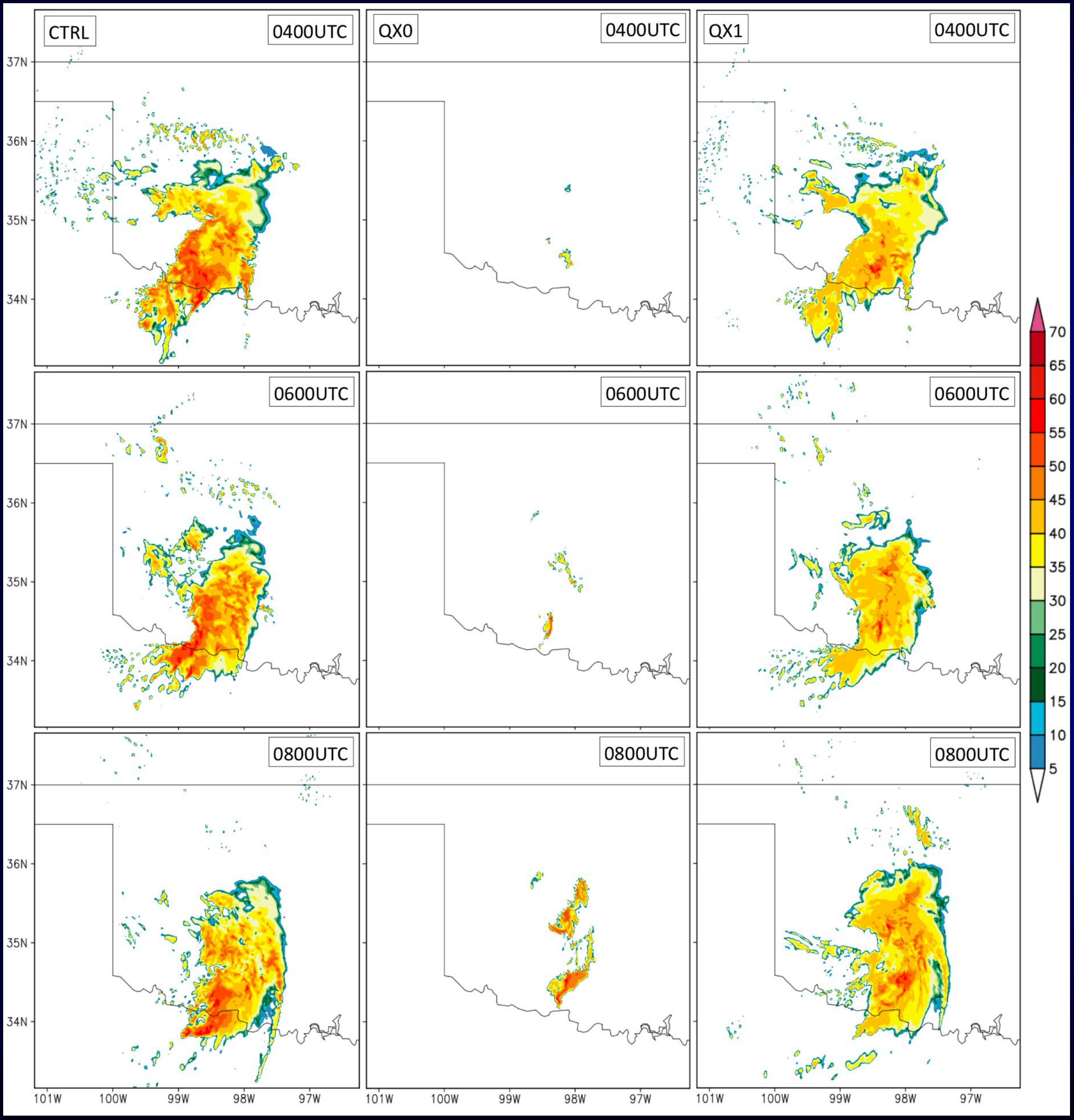
http://earthnetworks.com/OurNetworks/LightningNetwork.aspx

Observations ctd…

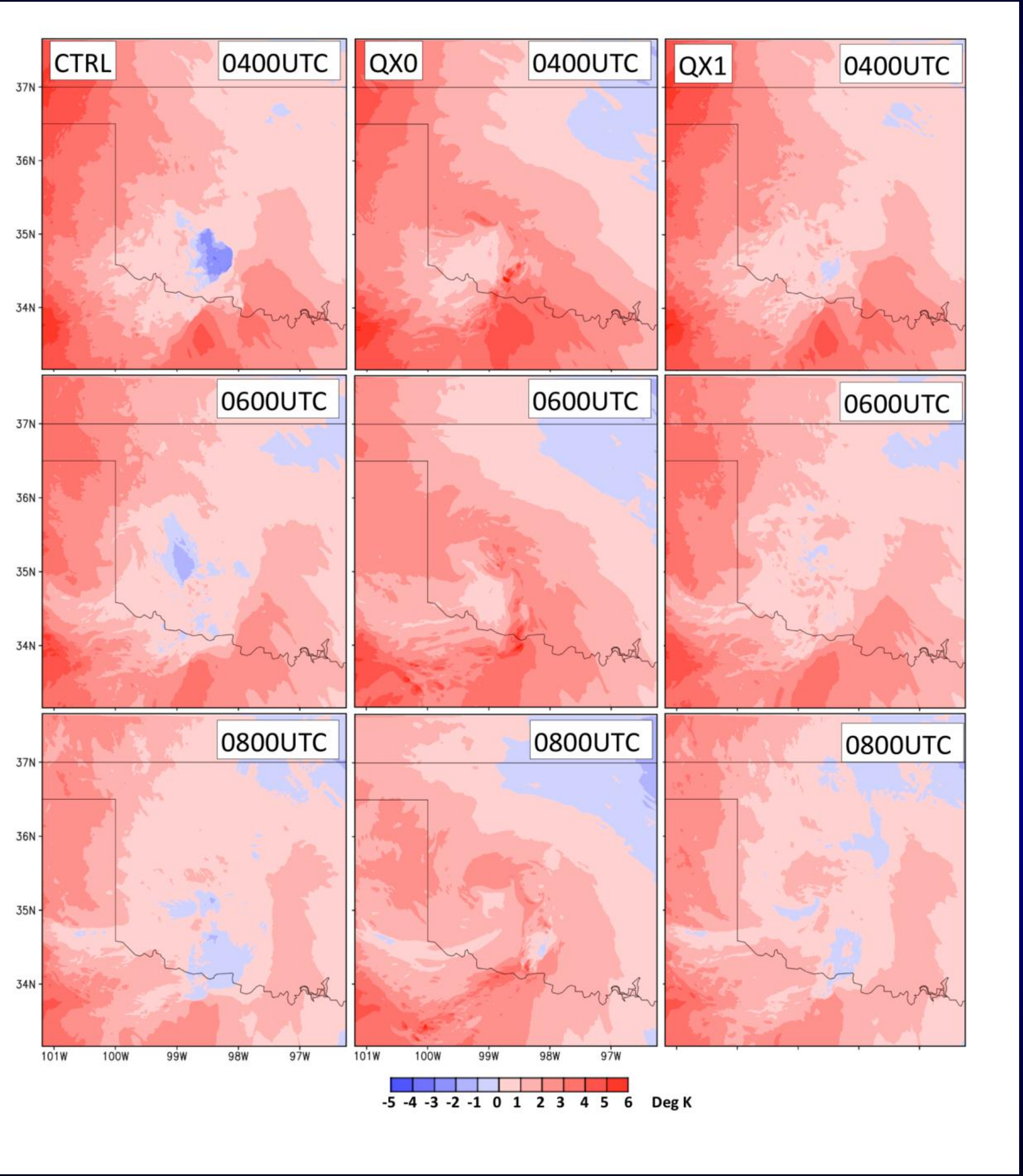


Deeper LMA sources on the SE of the center of circulation are coincident/consistent with deeper radar echoes (particularly 30-40 dBZ, KOUN OU polarimetric radar)

Erin: dBZ at 1 km AGL



Erin: theta' at the surface



- CTRL run with unconstrained model produces strong cold pools near the center of circulation of the vortex resulting in its weakening.

Erin: pre-convective sounding in SE quadrant