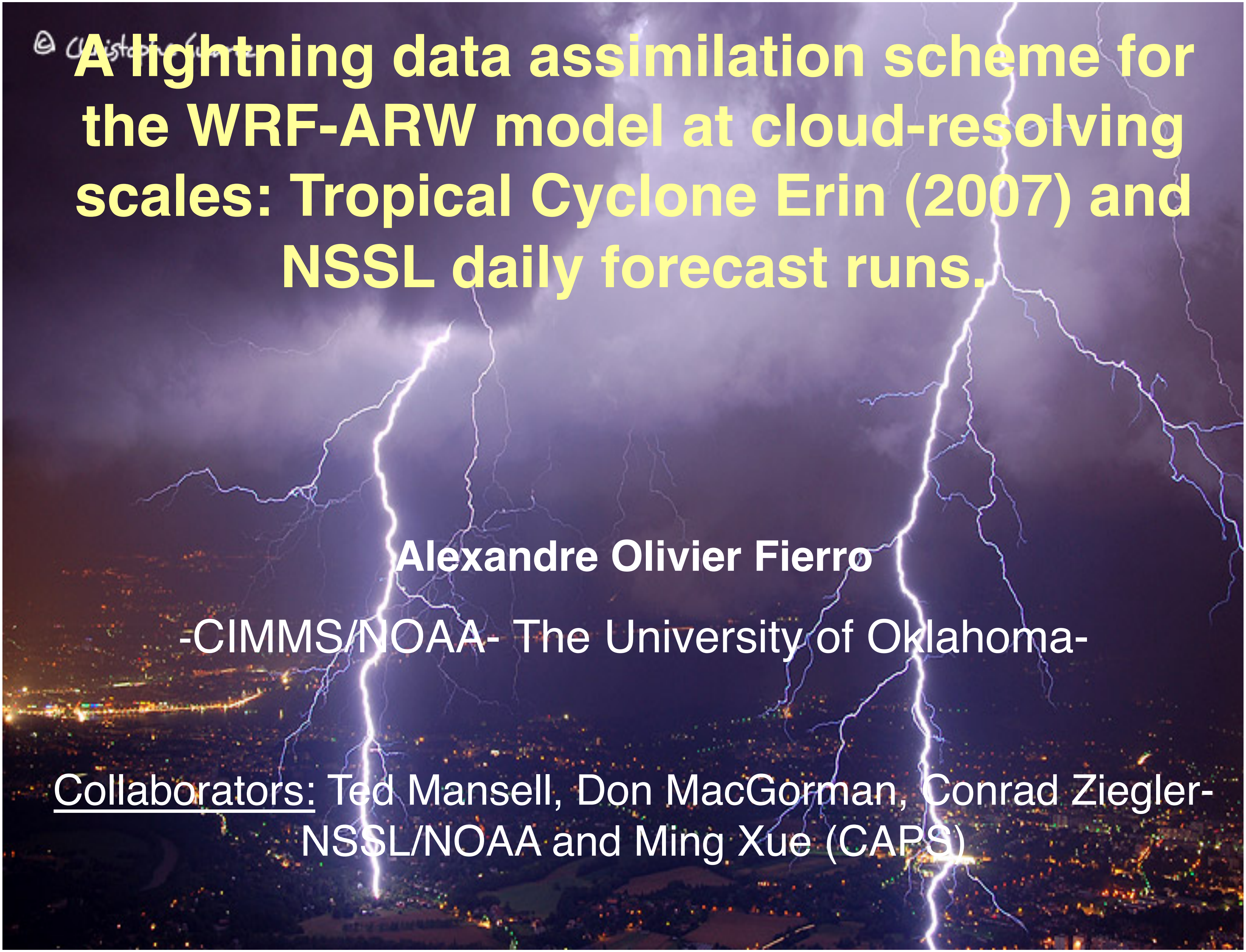

# A lightning data assimilation scheme for the WRF-ARW model at cloud-resolving scales: Tropical Cyclone Erin (2007) and NSSL daily forecast runs.


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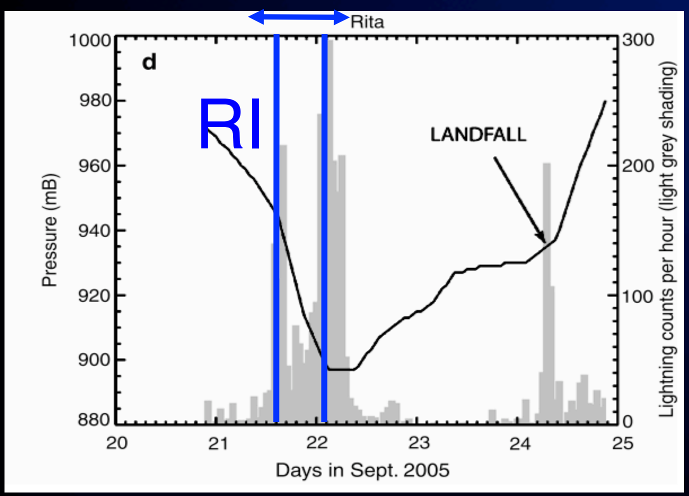
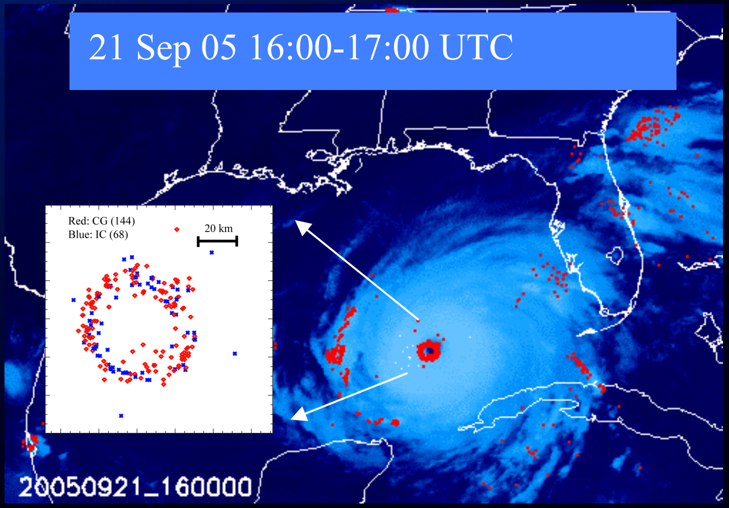
# Why using lightning data for NWP application?

- 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 rapid intensification (RI) of the system (e.g., Molinari's, Fierro et al.).




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 2 scenarios:

•*NSSL daily CONUS 4 km fcst run for severe wx days.*

•*The case of TS Erin (August 2007) over OK.*

# Results: Daily 4 km NSSL runs

*Setup in a flash*

•Domain covers CONUS (1200x800 grid zones)

•Dx=dy=4 km with 35 vertical levels

•WSM 6 microphysics

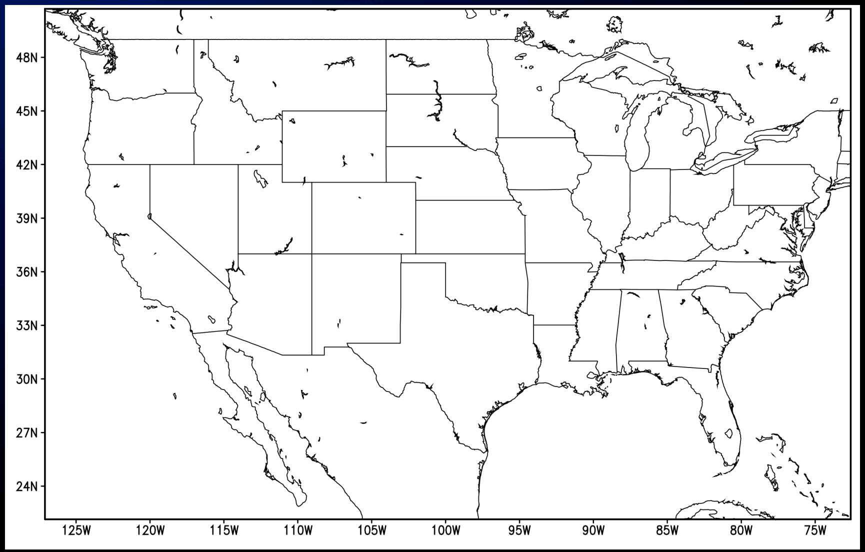
•NAM 40 km data used as initial conditions.

•Run started at 00Z for four severe weather cases characterized by different convective regimes (supercell, MCS, squall line).

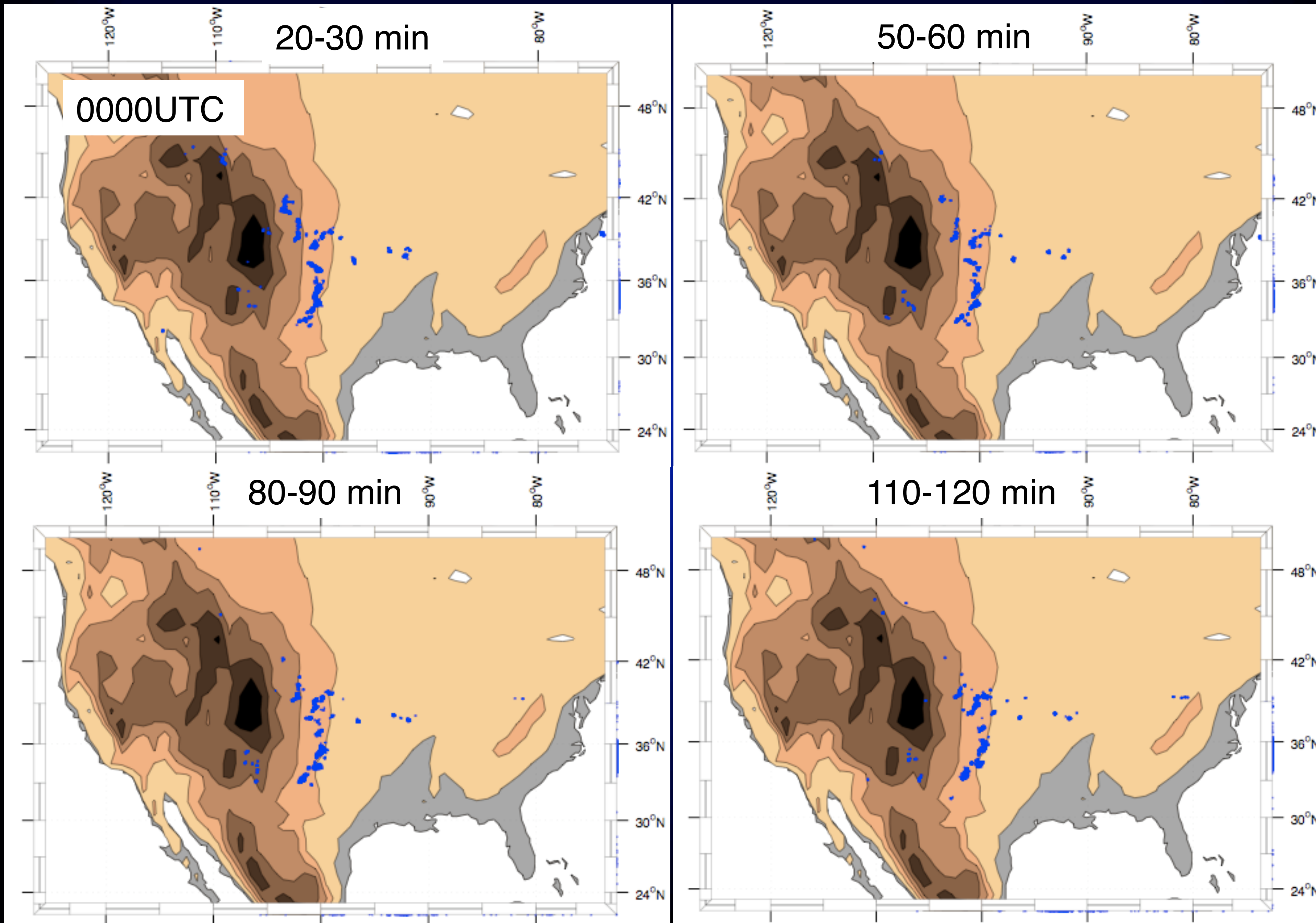
•WTLN total lightning data interpolated to WRF grid and then nudged in the model every 10 min for the first 1 or 2 h in several ways:

(i) Supersaturating 0-30°C layer wrt water by 0.5-1% and/or…

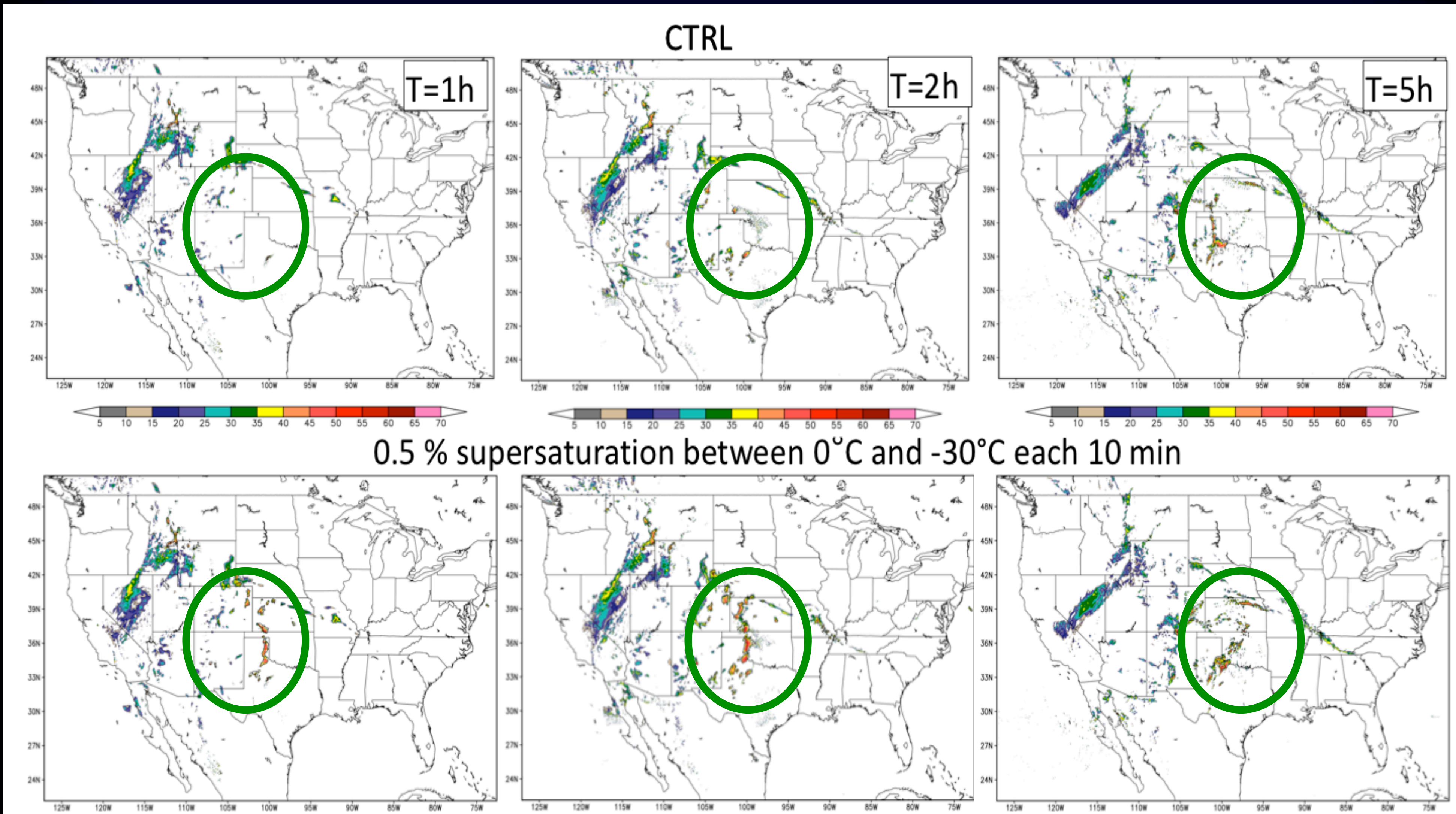
(ii) Nudged in a constant graupel mixing ratio value every 10 min



# Results-23 April supercells case:

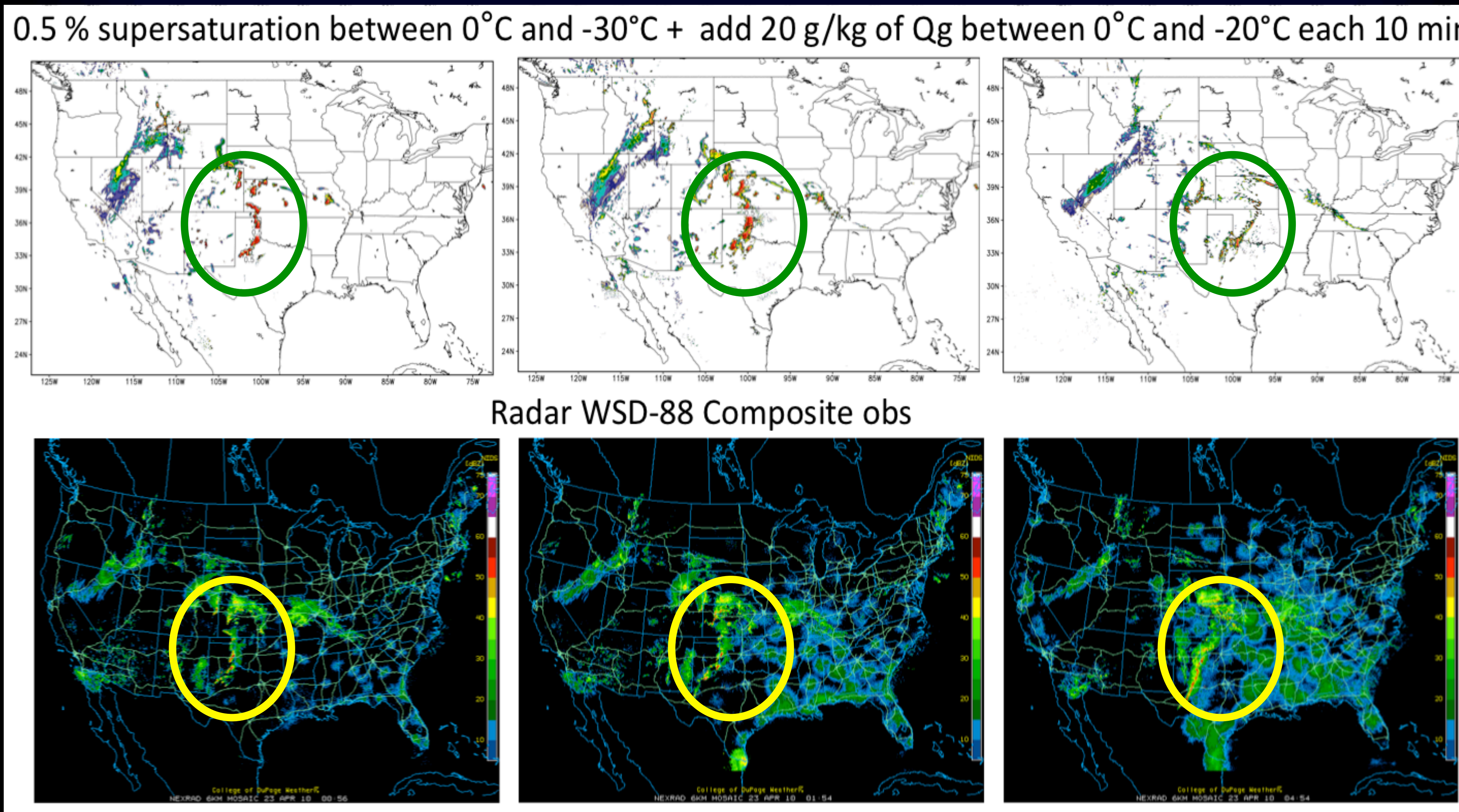


# 23 April: dBZ at 1 km AGL



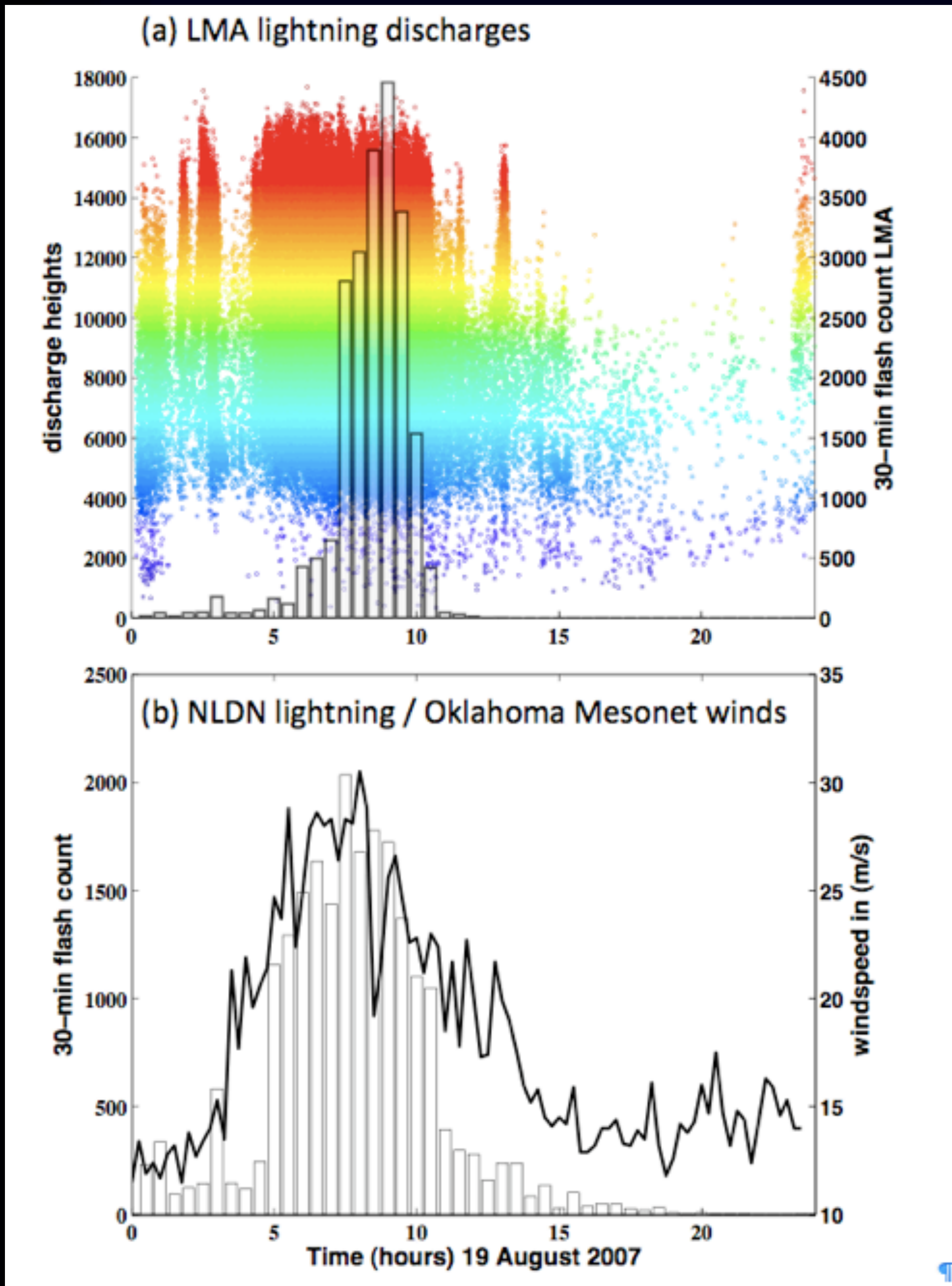

Supersaturating lightning locations results here in the convection on the OK/TX border to be displaced further East in better agreement with obs.

# 23 April: dBZ at 1 km AGL

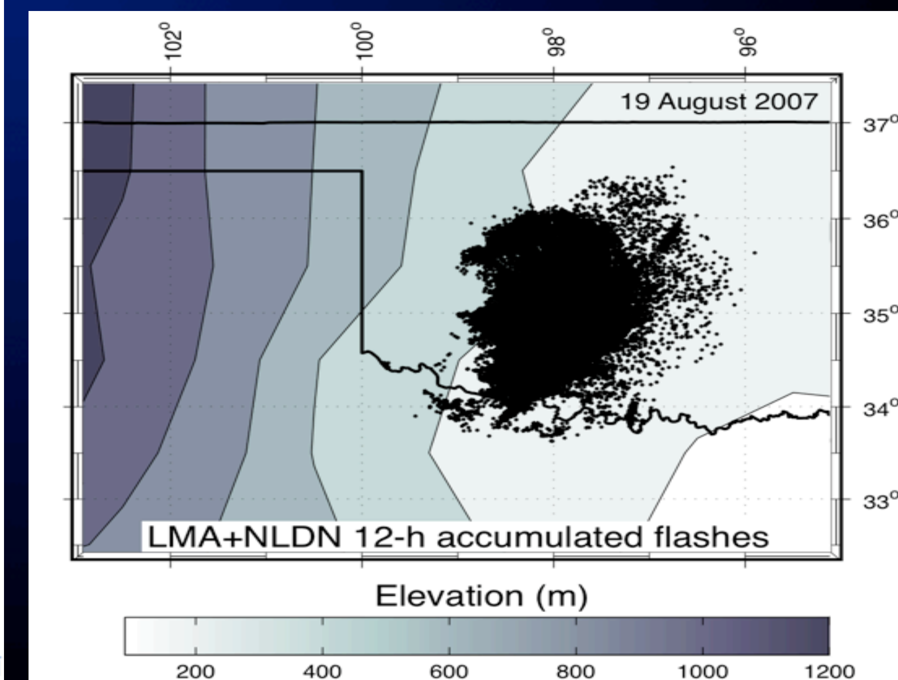



Similar results are seen when adding graupel-Note that none of the cases were able to reproduce the convection in SW TX.

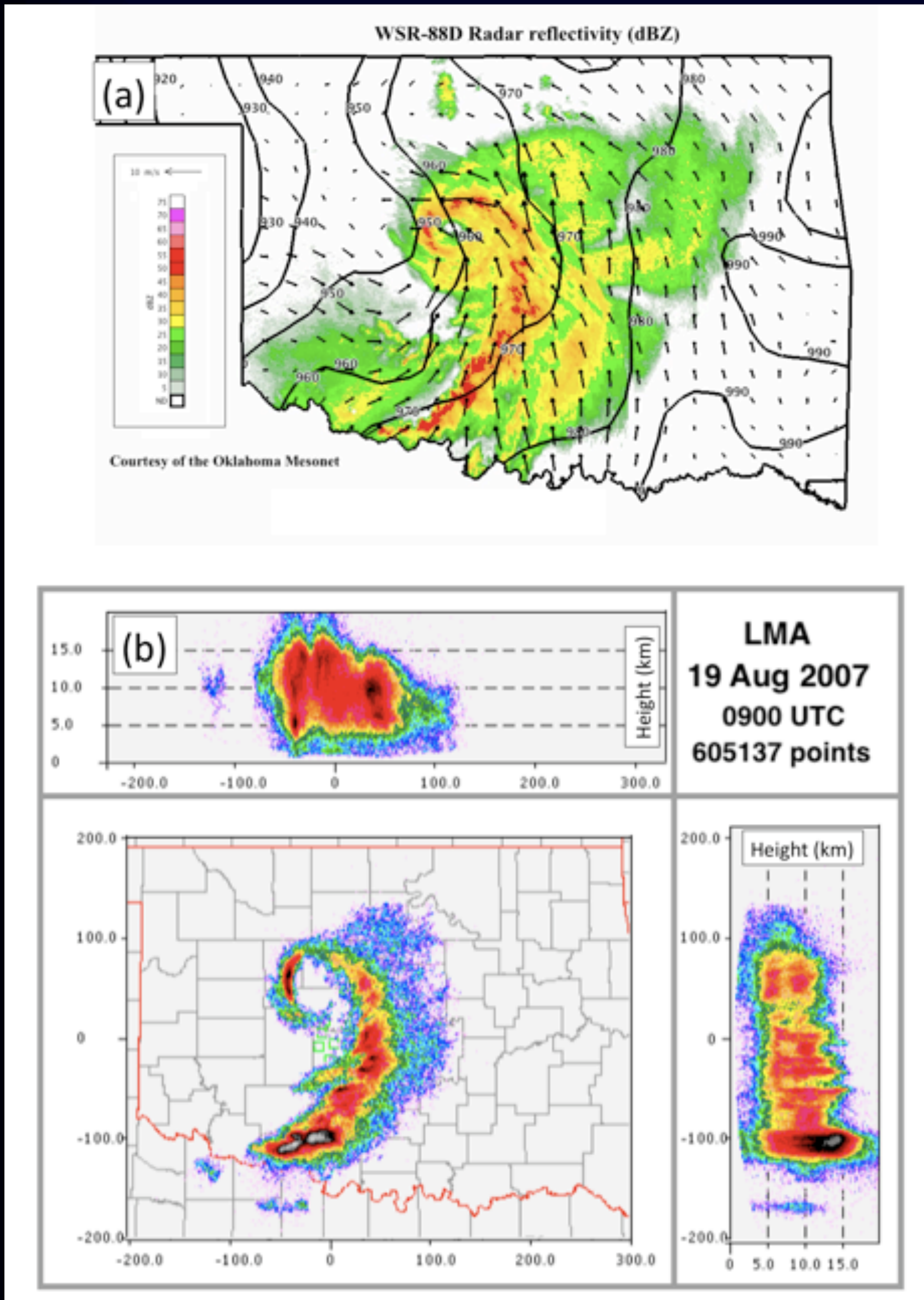
# TC Erin: 1) Observations




- 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…



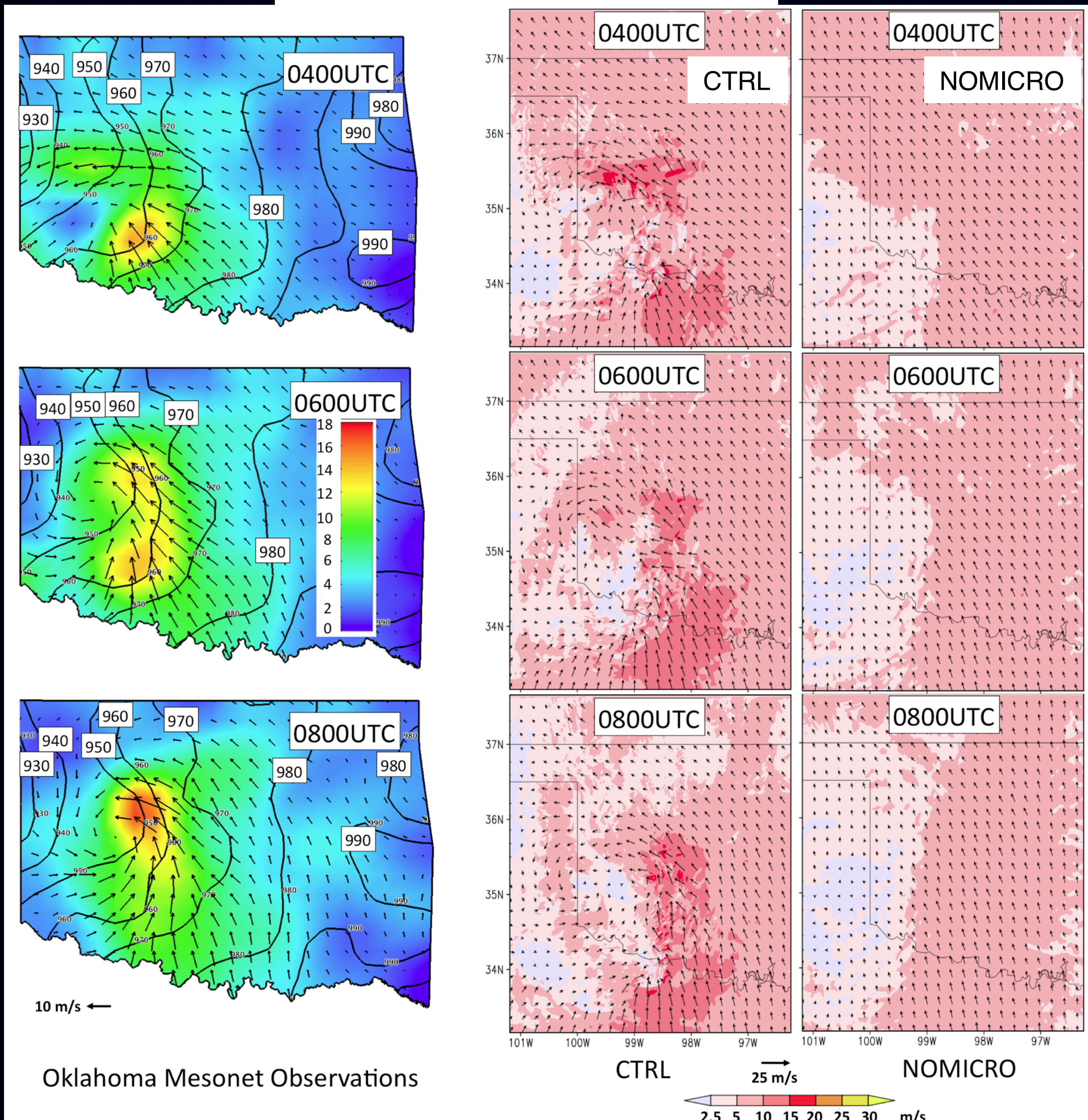

- Erin showed a well-defined closed circulation with an eye-like feature at 0900UTC, which was depicted by the LMA sources.
- Source heights were seen as high as 18 km indicative of deep convection.
- Reminiscent of convective heat axisymmetrization by hot towers in TC eyewalls.

# WRF test runs for Erin

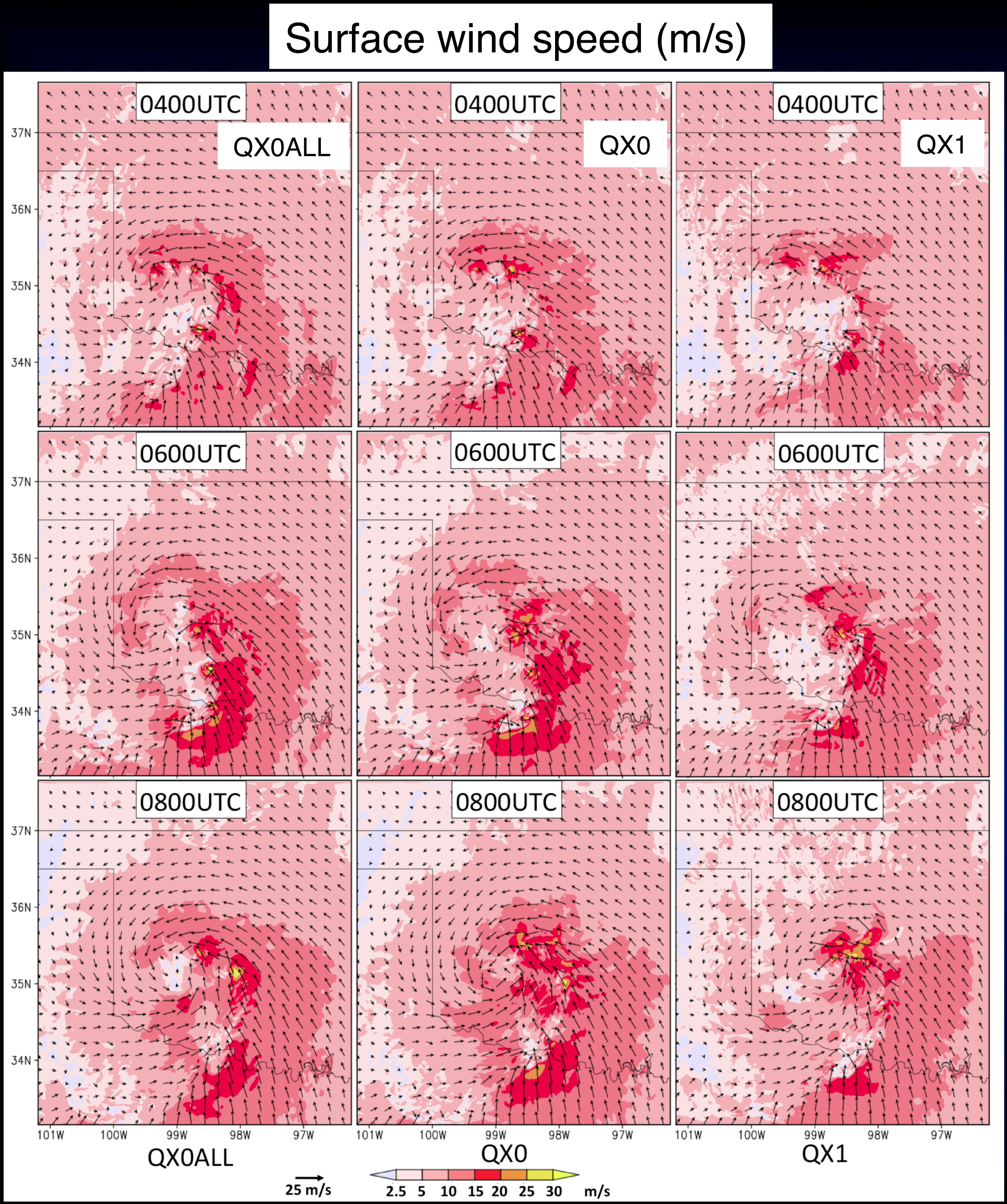
| *Experiments* | *Description* |
| --- | --- |
| CTRL | Control run-Model run in free mode with microphysics |
| NOMICRO | As in CTRL but with microphysics turned off |
| QX0 | Hydrometeor mixing ratios nudged to 0 g $kg^{-1}$ except within regions of lightning occurrence as shown in Fig. 1 |
| QX0ALL | As in Qx0 but hydrometeor mixing ratios nudged to 0 everywhere |
| QX1 | As in Qx0 except mixing ratios nudged to 1 g $kg^{-1}$ |

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

# Surface wind speed (m/s)

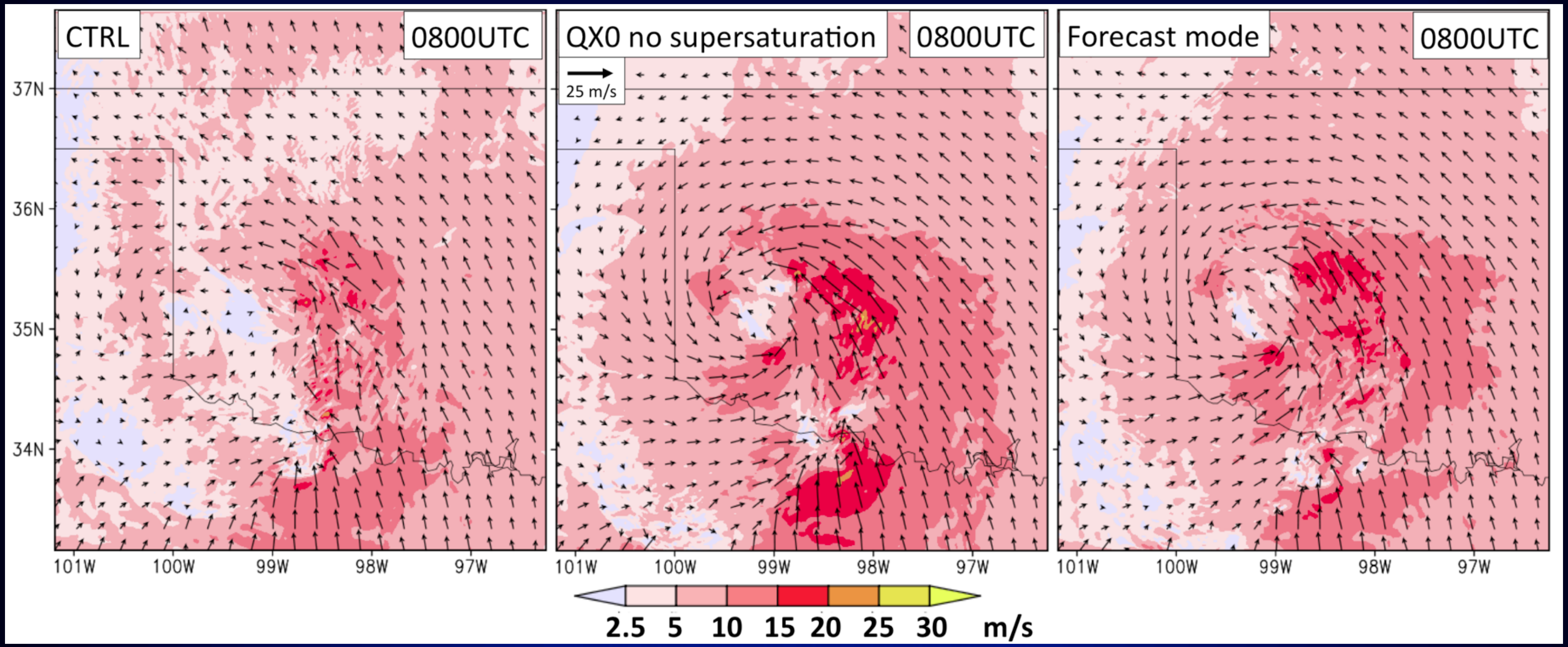



- •CTRL run produced strong squall line that eventually disrupt and 'kill' the primary circulation of the vortex via the production of strong surface cold pools
- •NOMICRO run indicates that vortex intensification must involve moist convection in the model as in real hurricanes-




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

# Forecast test for Erin




•QX0 without supersaturation resulted in a weaker and more ill-defined vortex highlighting the importance of the lightning data nudging.
•Assimilating the lightning data for 6 h and then letting the model run 'freely' result in a better 2 h forecast compared to CTRL.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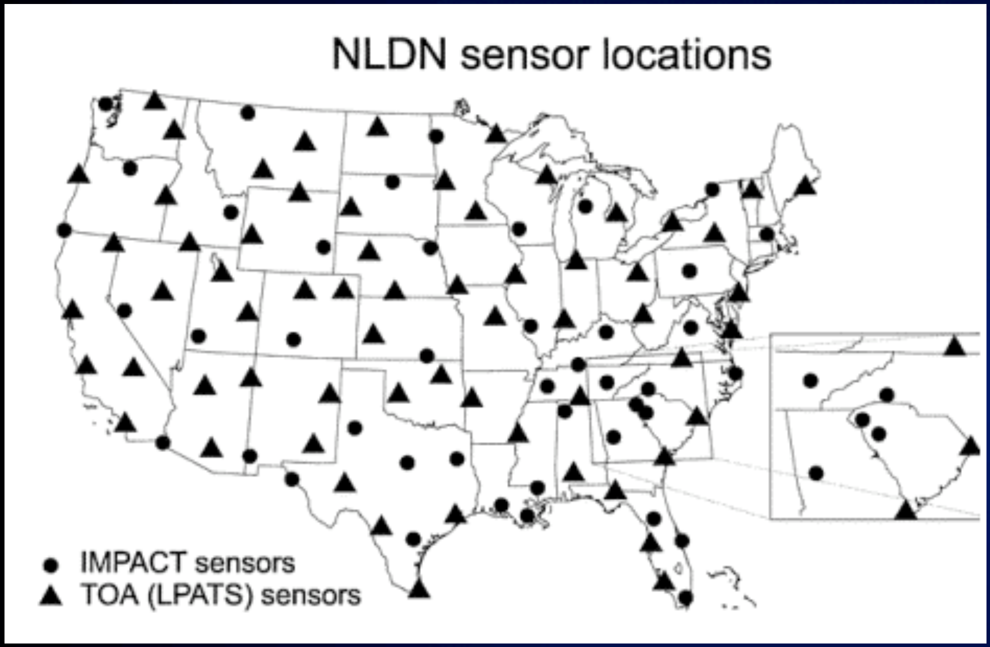
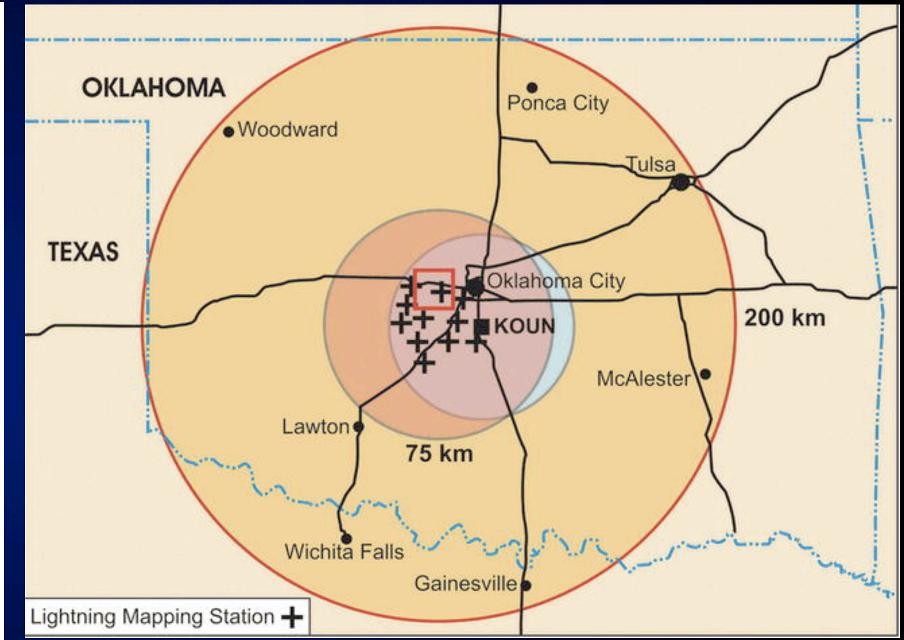
Questions?

# 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.

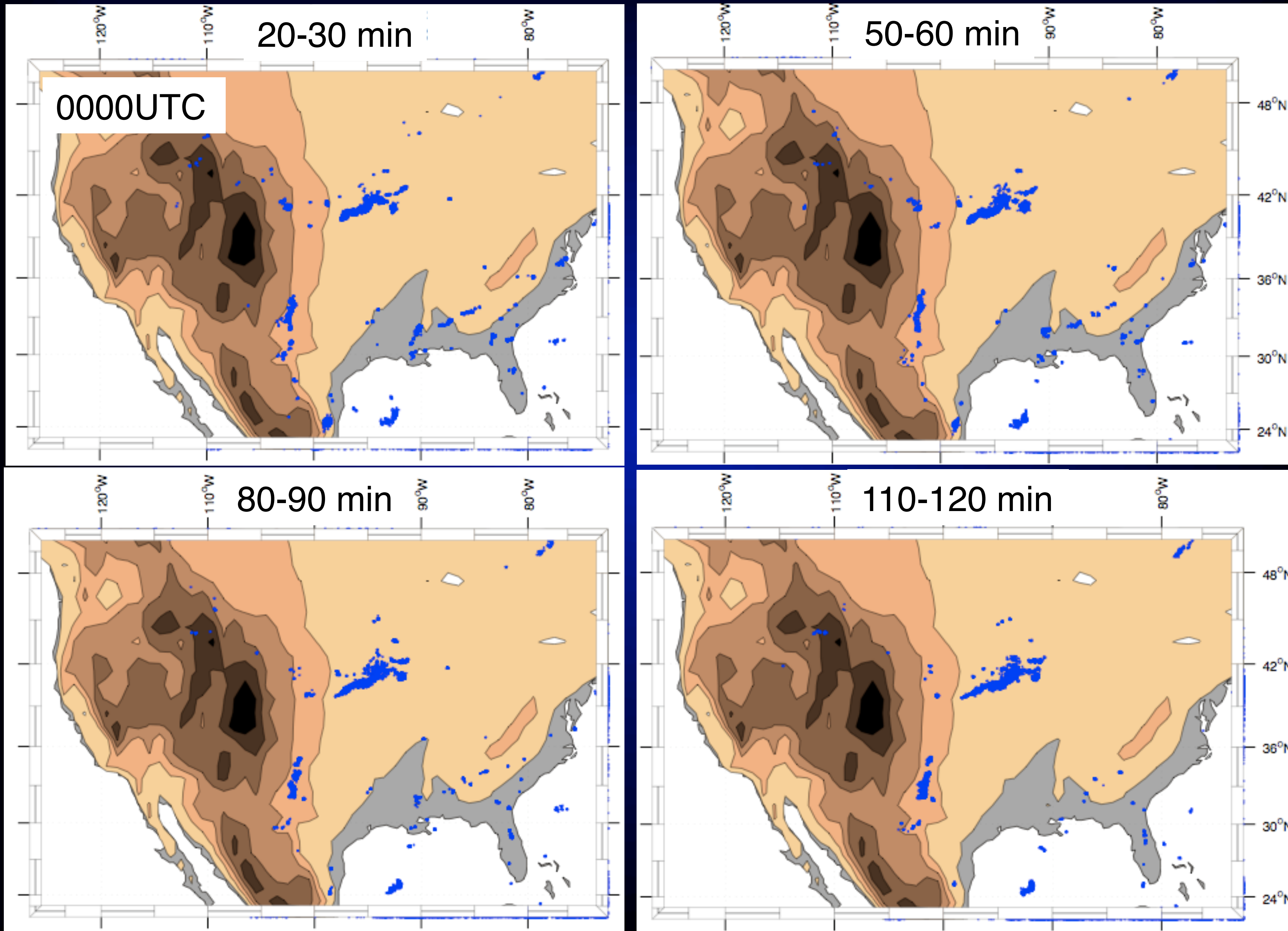
Blue circle indicates a 60-km radius from KOUN and the peach-shaded circle indicates a 75-km radius from the center of the LMA network. (Bruning et al. 07)

# WTLN network

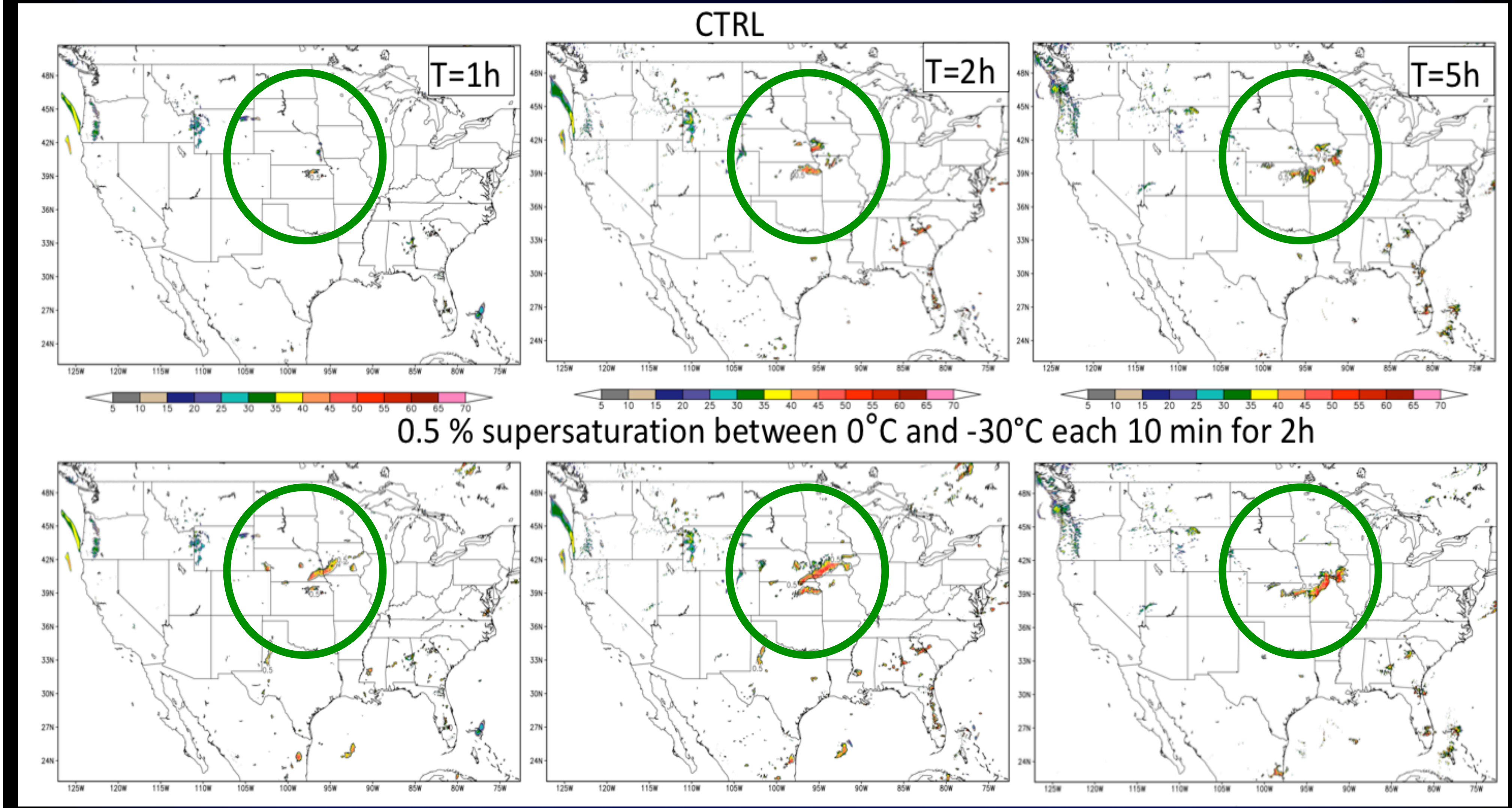
- WeatherBug Total Lightning Network is the world's largest lightning detection network with detection efficiency ranging between 25-60% over CONUS.
- Measure broadband electric field, from 1 Hz to 12 MHz
- Incorporates advanced lightning location technology
- The first network to detect both in-cloud (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

# WTLN - 02 June MCS case:

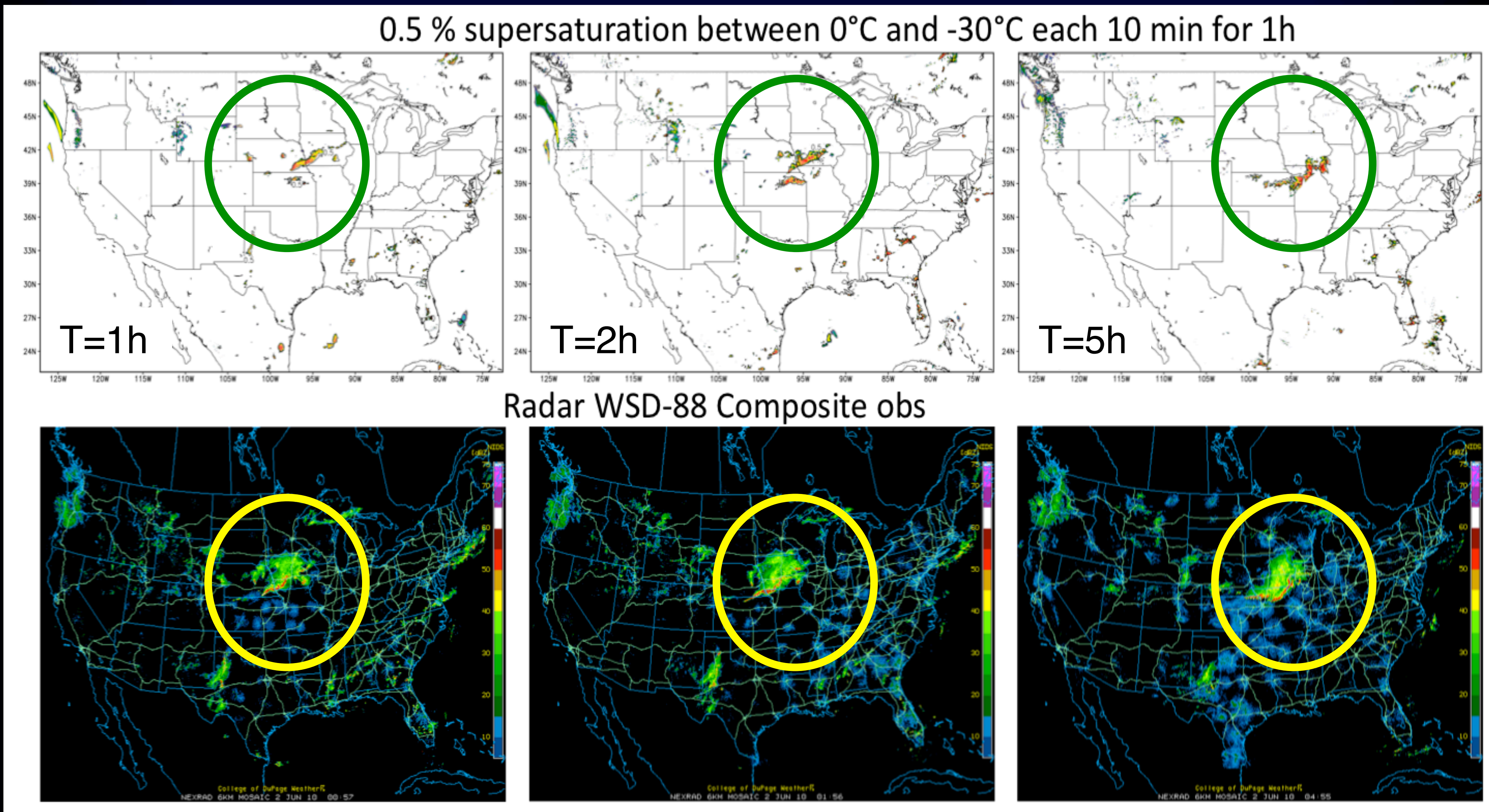


# Results: 02 June; dBZ at 1 km AGL




Using 0.5% of water supersaturation results in a more linear system than the CTRL run and in better agreement with observations (for this case).

# 02 June: dBZ at 1 km AGL




Adding graupel has for primary effect to strengthen cold pools and in this case results in a faster-moving system.