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Impact of Assimilating CASA X-Band Radar Data for 24 May 2011 Tornadic Storms Using Various Microphysics Schemes at 1-km Grid Spacing

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Introduction

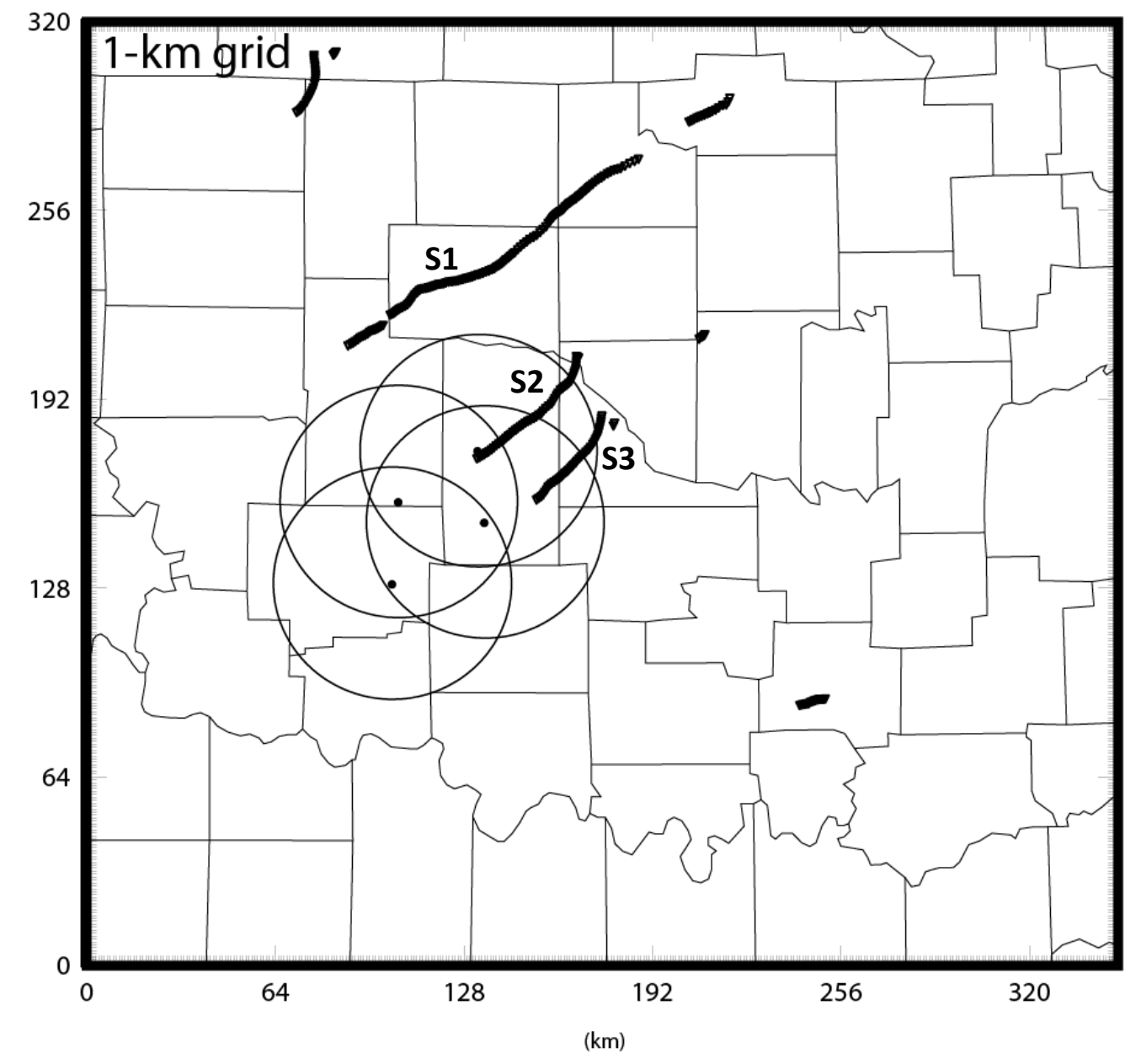
- On 24 May 2011, Western and Central Oklahoma experienced an outbreak of tornadoes, including one rated EF-5 (S1) and two rated EF-4 (S2 and S3).
- The extensive observation network across Oklahoma during the 2011 Spring makes this an ideal case to explore model forecast capabilities applicable to the Warn-on-Forecast (WoF) concept (Stensrud et al. 2009, 2013).
- The Center for Analysis and Prediction of Storms (CAPS) real-time forecasting system had good success in simulating these storms, but the impact of assimilating CASA X-band radar data on various microphysics schemes' abilities to simulate the storms and their structure has not previously been examined.
- This study's aim is to examine the effect of assimilating CASA radar data using five different microphysics parameterization schemes on the genesis and evolution of simulated mesocyclones via the updraft helicity (UH) field as compared to each other and reality (i.e., estimated tornado point locations).
- Similar to hurricane track errors (e.g., Xue et al. 2013), UH center distance and timing errors are computed to assess model performance.

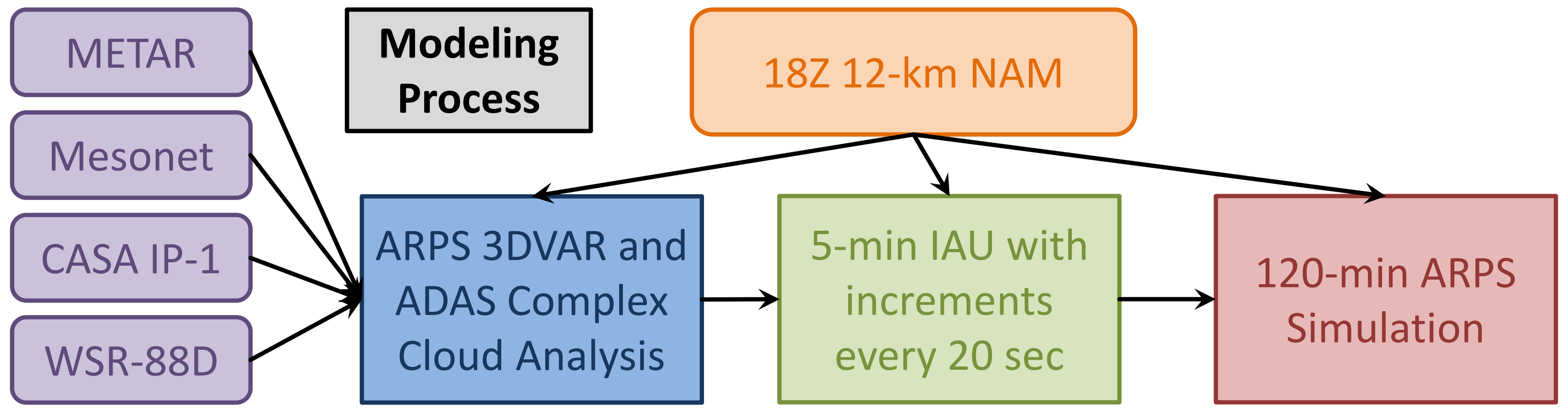
Observational Data

- NWS METAR and Oklahoma Mesonet data
- WSR-88D radar data (KTLX, KFDR, KVNX, KICT, KDDC, KFWS, and KINX)
- Collaborative Adaptive Sensing of the Atmosphere (CASA) IP-1 radar data (KCYR, KSAO, KWE, and KRSP)
- Tornado tracks estimated from National Weather Service damage surveys

Model Details

- Advanced Regional Prediction System (ARPS) with IAU assimilation, developed at CAPS
- 323x353-km domain with 53 vertical levels
- 1-km horizontal grid spacing
- Minimum vertical grid spacing of 20 m
- dt_{big} = 2.0 s and dt_{sml} = 0.5 s
- 4th order momentum advection
- 12-km North American Mesoscale (NAM) model output used for background fields and lateral boundary conditions





METAR

Mesonet

CASA IP-1

WSR-88D

Modeling Process

18Z 12-km NAM

ARPS 3DVAR and ADAS Complex Cloud Analysis

5-min IAU with increments every 20 sec

120-min ARPS Simulation

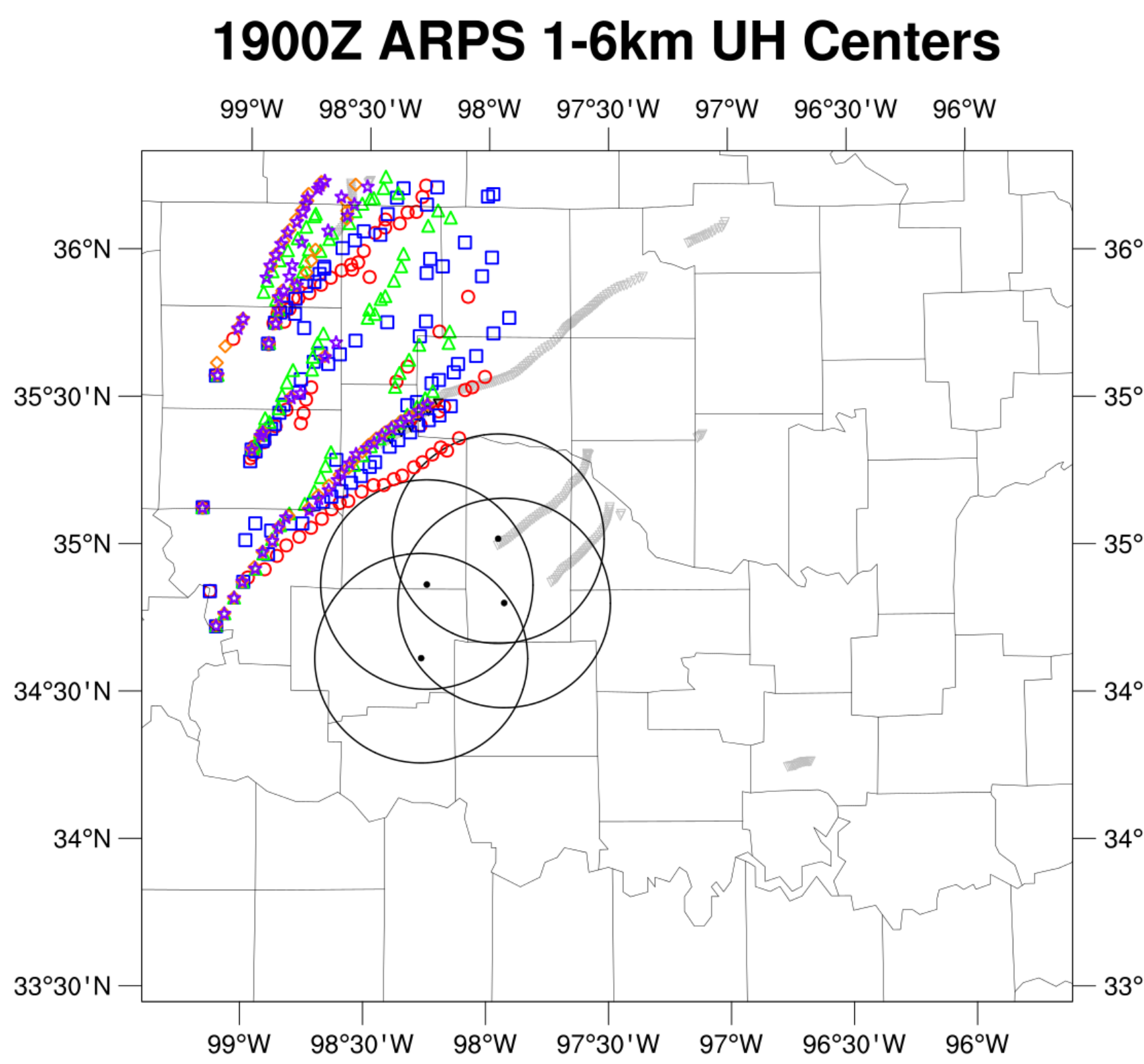
ID	Microphysics Scheme
LIN3	Lin 3-ice microphysics
WSM6	Weather Research and Forecasting single-moment 6-class microphysics
MYSM	Milbrandt and Yau (MY) single-moment bulk microphysics
MYDM	MY double-moment bulk microphysics
MYTM	MY triple-moment bulk microphysics

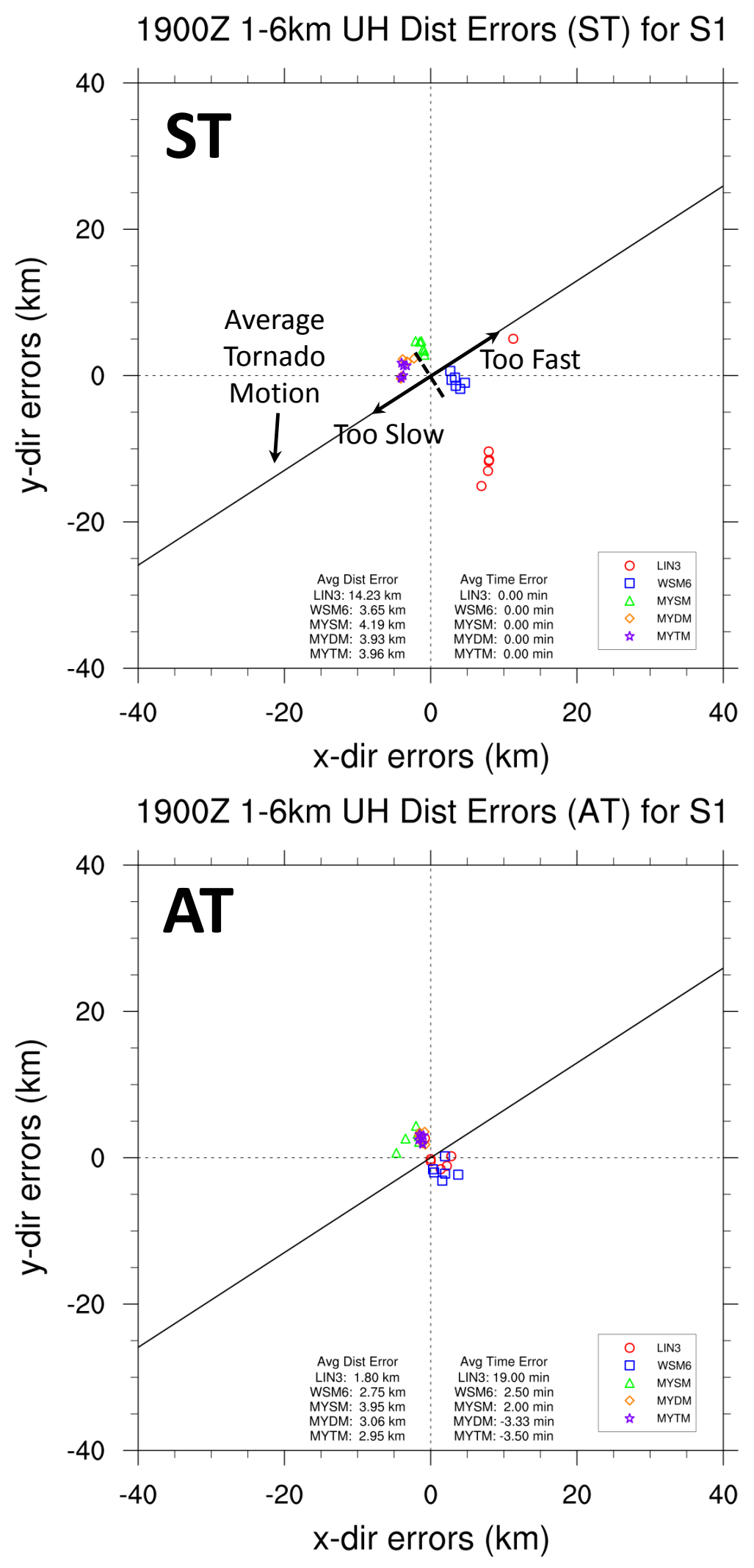
ARPS Begin – End	S1 2031 Z - 2046 Z 2050 Z - 2235 Z 2250 Z - 2305 Z	S2 2206 Z - 2301 Z	S3 2226 Z - 2305 Z 2302 Z - 2303 Z
1900 Z – 2100 Z	+1:31		
1930 Z – 2130 Z	+1:01		
2000 Z – 2200 Z	+0:31		
2030 Z – 2230 Z	+0:01	+1:36	+1:56
2100 Z – 2300 Z	-0:29	+1:06	+1:26
2130 Z – 2330 Z	-0:59	+0:36	+0:56
2200 Z – 0000 Z	-1:29	+0:06	+0:26
2230 Z – 0030 Z	-1:59	-0:24	-0:04

Verification Technique

- A search radius of 10 km is used to isolate 1–6-km (0–1-km) UH maxima that are greater than or equal to 400 $m^2 s^{-2}$ (20 $m^2 s^{-2}$) and their surrounding grid point values.
- A max UH value is considered a UH-center candidate if 4 out of 8 (3 out of 8) of the adjacent grid point values equals or exceeds 200 $m^2 s^{-2}$ (10 $m^2 s^{-2}$).
- Once the UH-center candidates are determined, the UH-weighted center is computed using a radius of 5 km extending from the grid point with the max UH value.

Experiment #1 – Control Run Vs. No-CASA Run



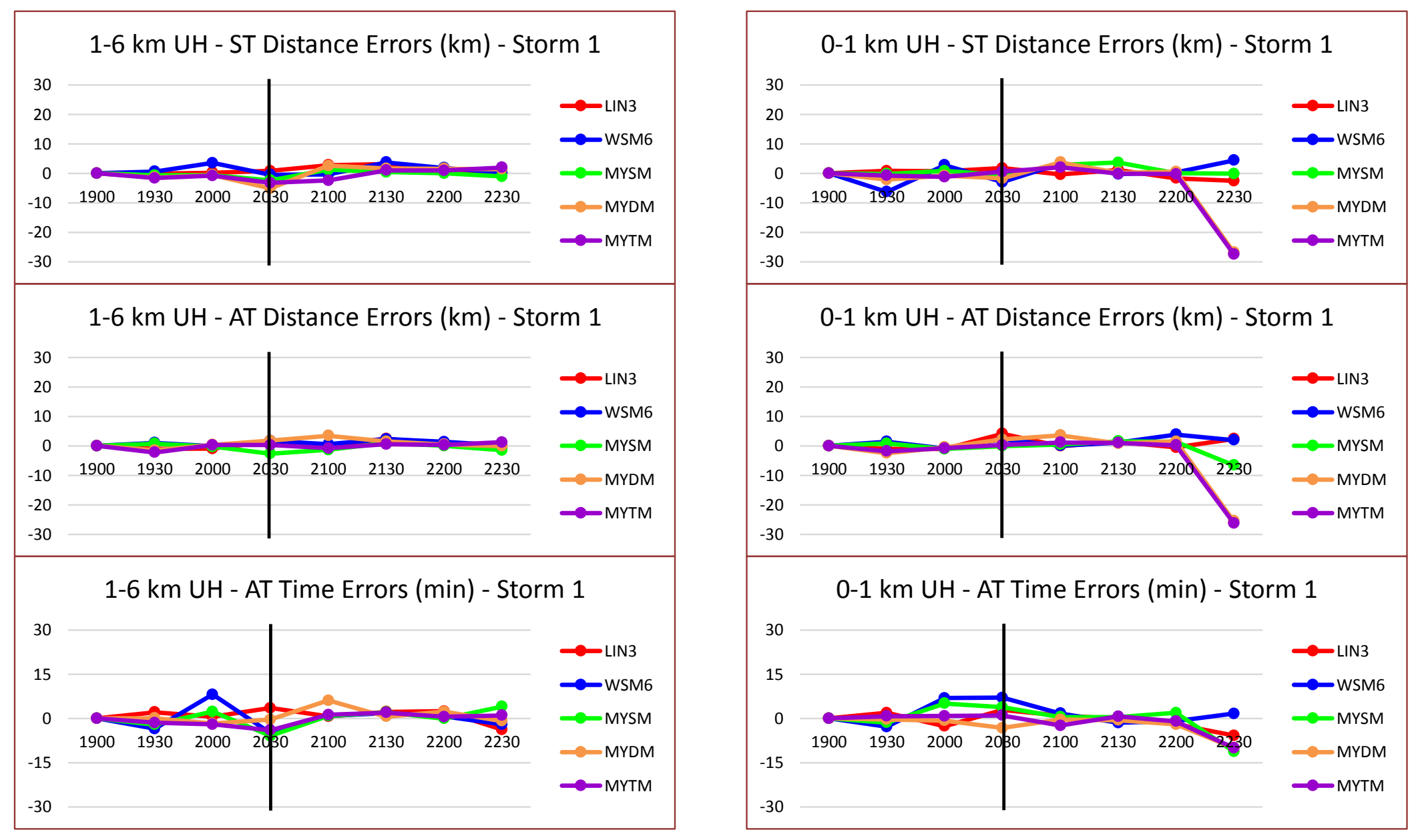


- **Same Time (ST)** - UH centers and tornado points occurring simultaneously
- **Any Time (AT)** - UH centers occurring at any time during the life of the tornado
- **Negative values -> Control performed better**

Storm 1

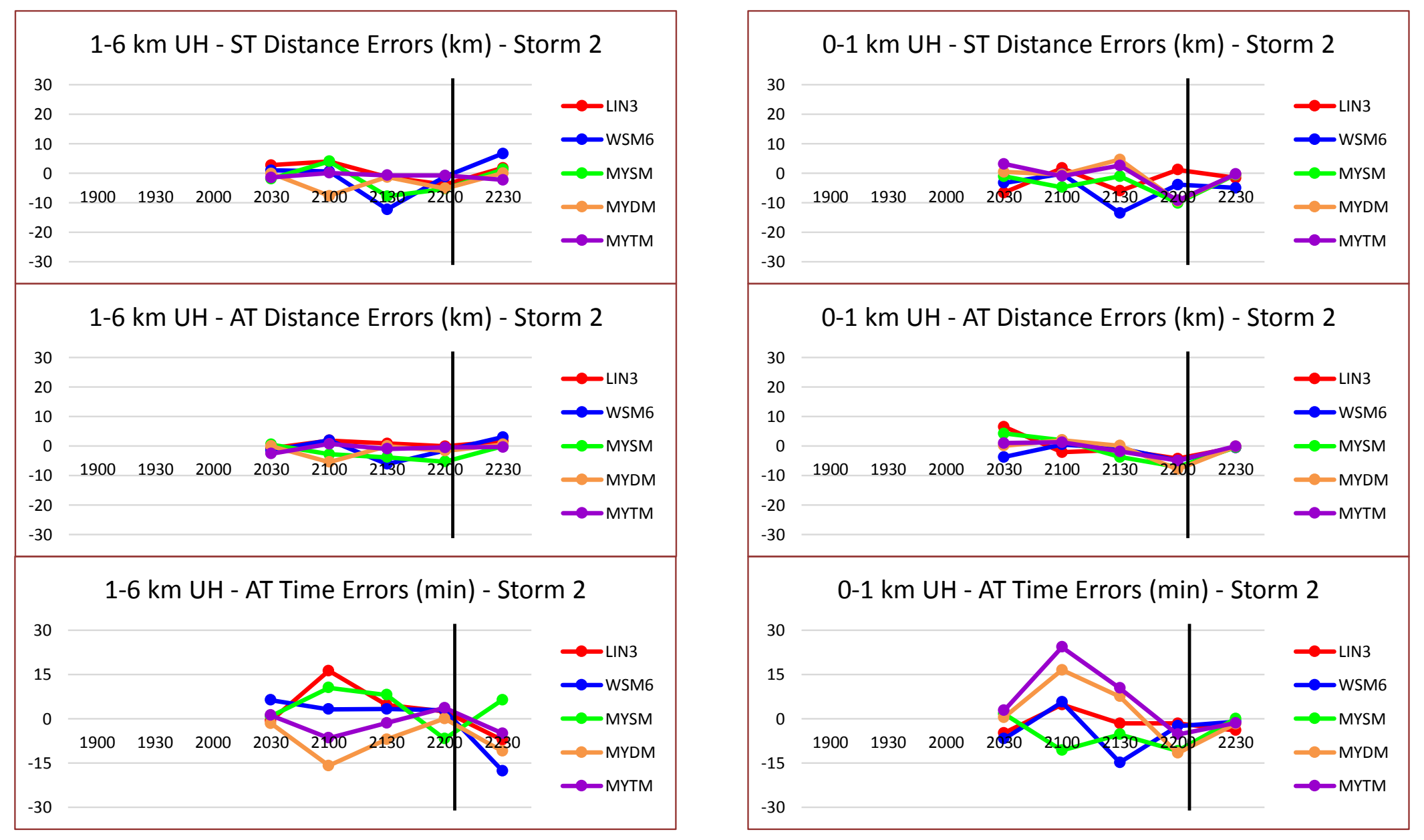
- Small differences (< 10 km) exist between ST and AT distance errors for both levels of UH.
- AT timing error differences are mostly < 10 min.
- CASA radar data has no impact on the 1900 UTC runs.

1-6 km UH **0-1 km UH**



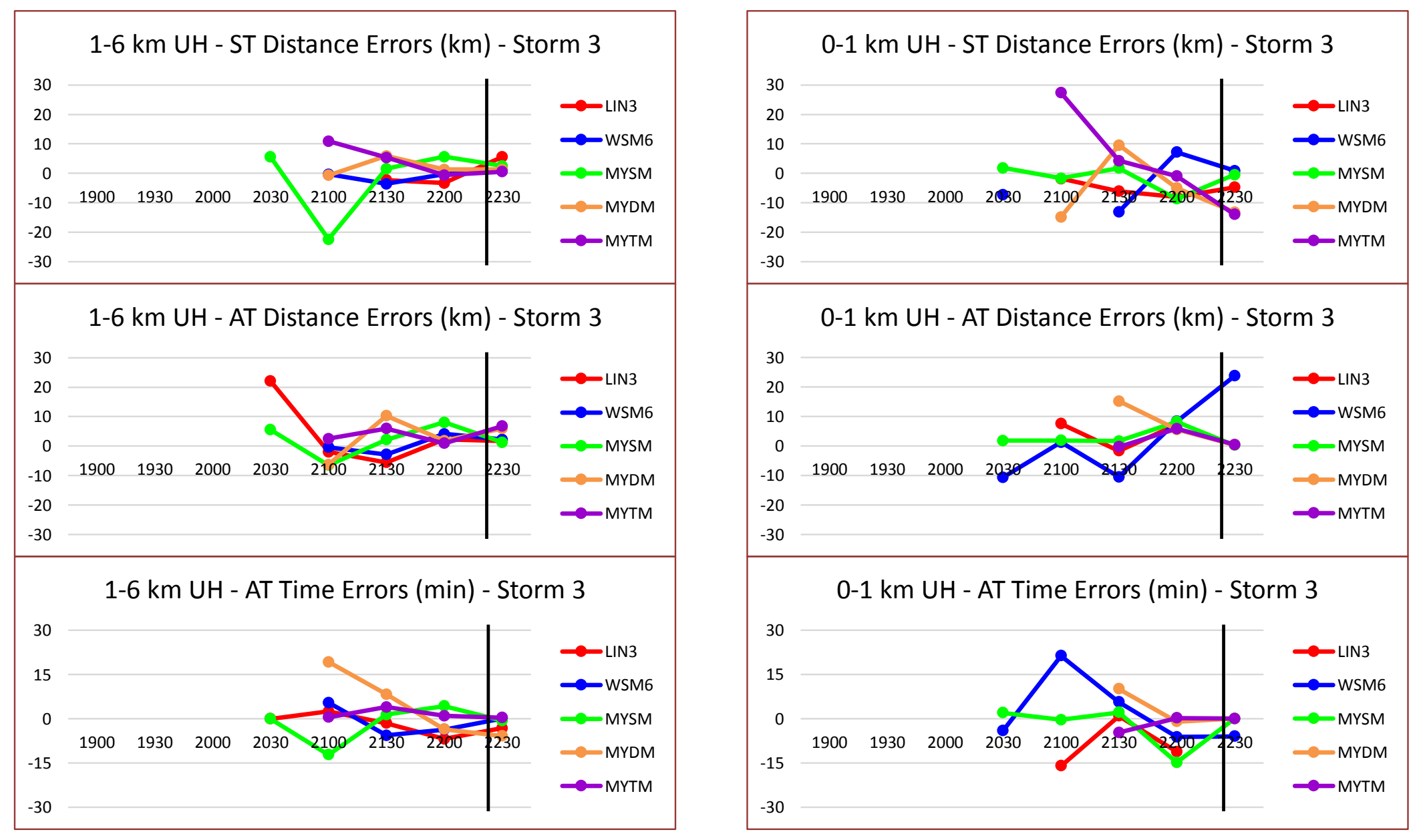
Storm 2

- Control runs generally have smaller ST distance errors.
- While small (< 10 km), AT distance errors reveal the positive impact of assimilating CASA radar data.
- Timing differences are highly variable.



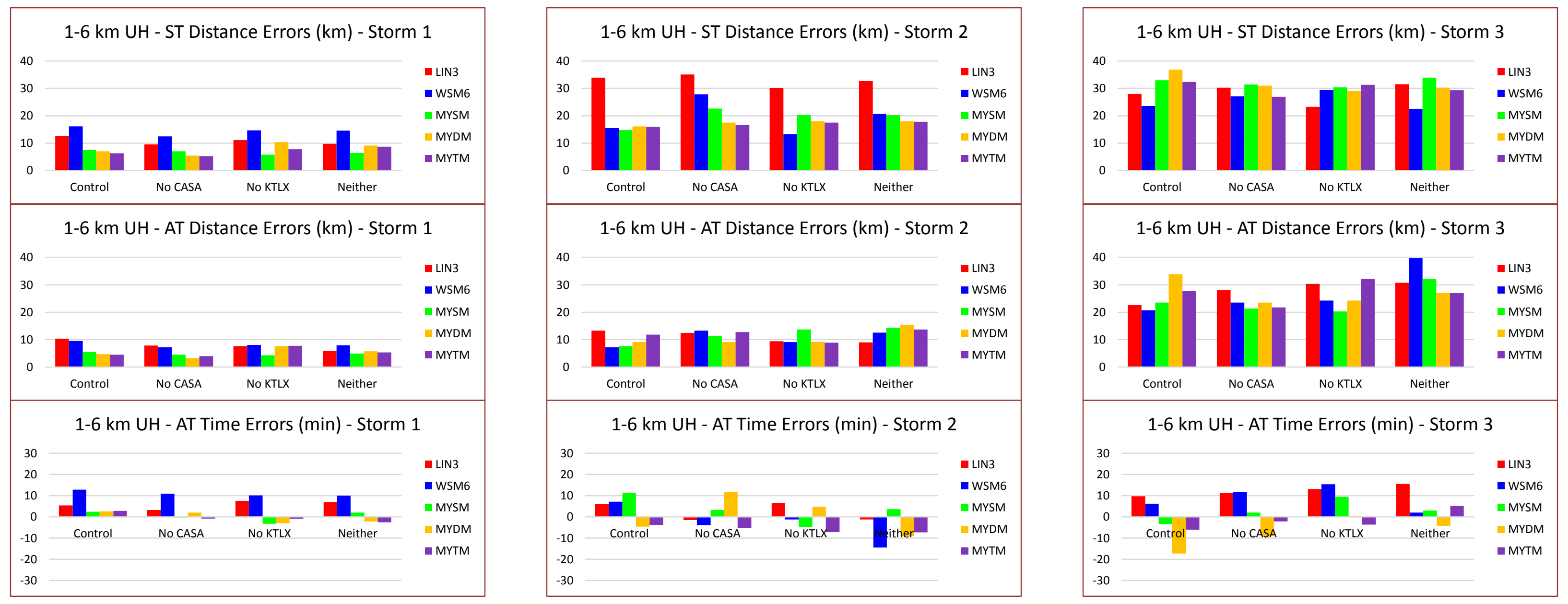
Storm 3

- Few UH centers = higher run-to-run variability
- No-CASA 2200 and 2230 UTC runs mostly have smaller distance errors for 1–6-km UH, but larger timing errors.
- 0–1-km UH ST distance errors and AT timing errors favor Control runs



Experiment #2 – What if the KTLX radar goes down for 2130 UTC initiation?

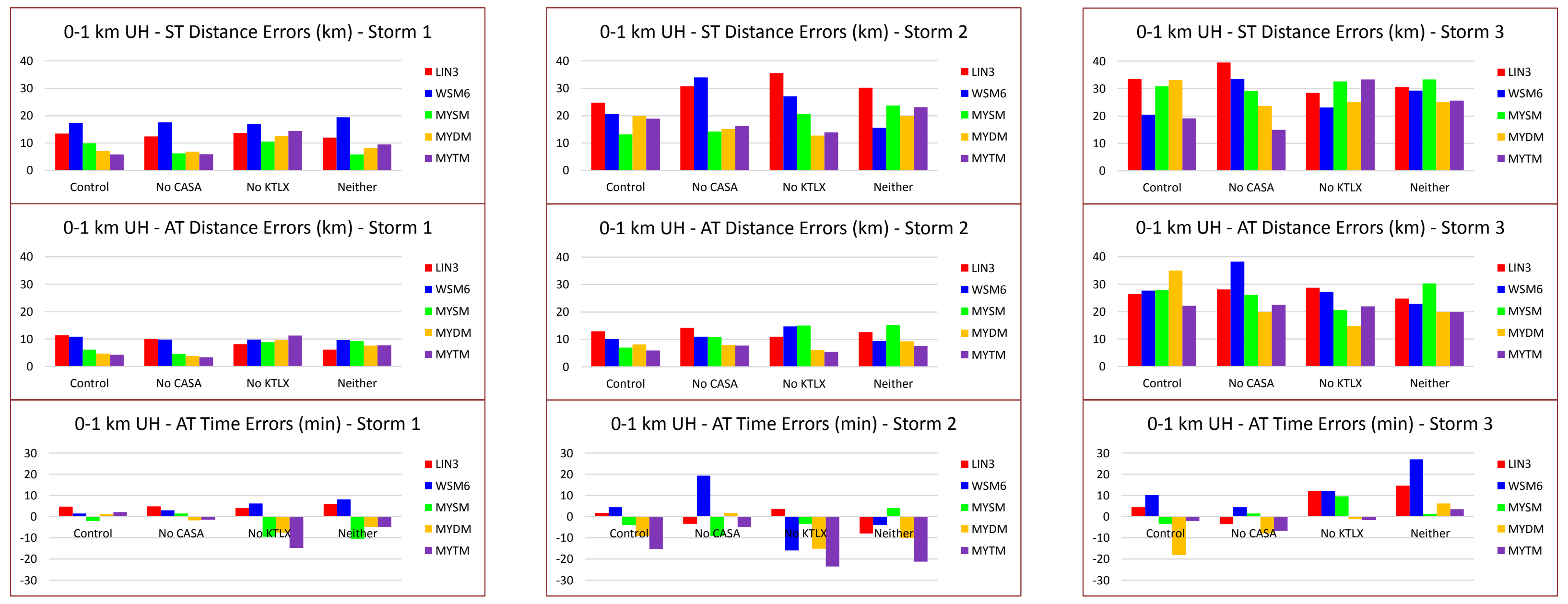
Storm 1 **Storm 2** **Storm 3**



1–6-km UH Results

- Very small differences between the four runs for Storm 1, but MYDM and MYTM have slightly larger ST and AT distance errors for the No-KTLX and Neither runs. In addition, their UH centers go from being slightly too fast to being slightly too slow.
- Except for MYSM and MYDM, the No-CASA run performed worse than the No-KTLX run with respect to the AT distance errors. This result indicates that the assimilation of CASA radar data may have more of an impact on the forecast of UH centers than the assimilation of KTLX radar data when a storm is initialized within the CASA radar network.
- No meaningful conclusions can be drawn for Storm 3.

Storm 1 **Storm 2** **Storm 3**



0–1-km UH Results

- Generally, the No-KTLX and Neither runs have larger ST and AT distance and timing errors for Storm 1. This indicates that the removal of CASA radar data from the assimilation process has a smaller impact on the low levels than the removal of KTLX radar data due to Storm 1 existing outside the CASA radar network.
- Except for Lin3, the largest differences in AT timing errors for Storm 2 occurs between the No-CASA and Control runs.
- Once again, the failure to properly forecast Storm 3 yields little/no meaningful results.

Conclusions and Future Work

- The impact of assimilating CASA X-band radar data proved to be largely variable run-to-run and between microphysics schemes, especially for Storm 2 and Storm 3.
- Not surprisingly, the impacts likely were small for Storm 1 due to the storm being located well to the north of the CASA radar network.
- The low-levels (< 2 km AGL) of storms within the CASA radar network initially exhibit stronger horizontal and vertical circulations with the inclusion of CASA radar data (not shown), but this seemingly-important benefit has less impact on forecasts than anticipated.
- Future: Look at the differences between the Control, No-CASA, No-KTLX, and Neither simulations for the other simulation times and additional case studies.

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