Sensitivities of 1km Forecasts of 24 May 2011 Tornadic Supercells to Microphysics Parameterizations

Derek R. Stratman, Keith A. Brewster (2017 MWR)

OBJECTIVES

- Understand the impact of different microphysical bulk schemes on storm-scale forecasting
- Microphysics scheme used: LIN3 (Lin et al. 1983), WSM6 (Hong and Lim 2006), MYSM (Milbrandt and Yau 2005a,b).
- Two extra simulations with 2-m MY (predicts q, N) and 3-m MY (q, N, Reflectivity)
- Object-based verification technique is used to determine timing, location error of the simulations

$$N_x(D) = N_{0x} D^{\alpha_x} e^{-\lambda_x D}$$

1M scheme

- alpha=0, N_0x constant, lambda_x varies with mixing ratio
- Predicted moments: q_v, q_c, q_r, q_s, q_i, q_h (LIN3, MYSM), q_g (WSM6, MYSM)

2M scheme

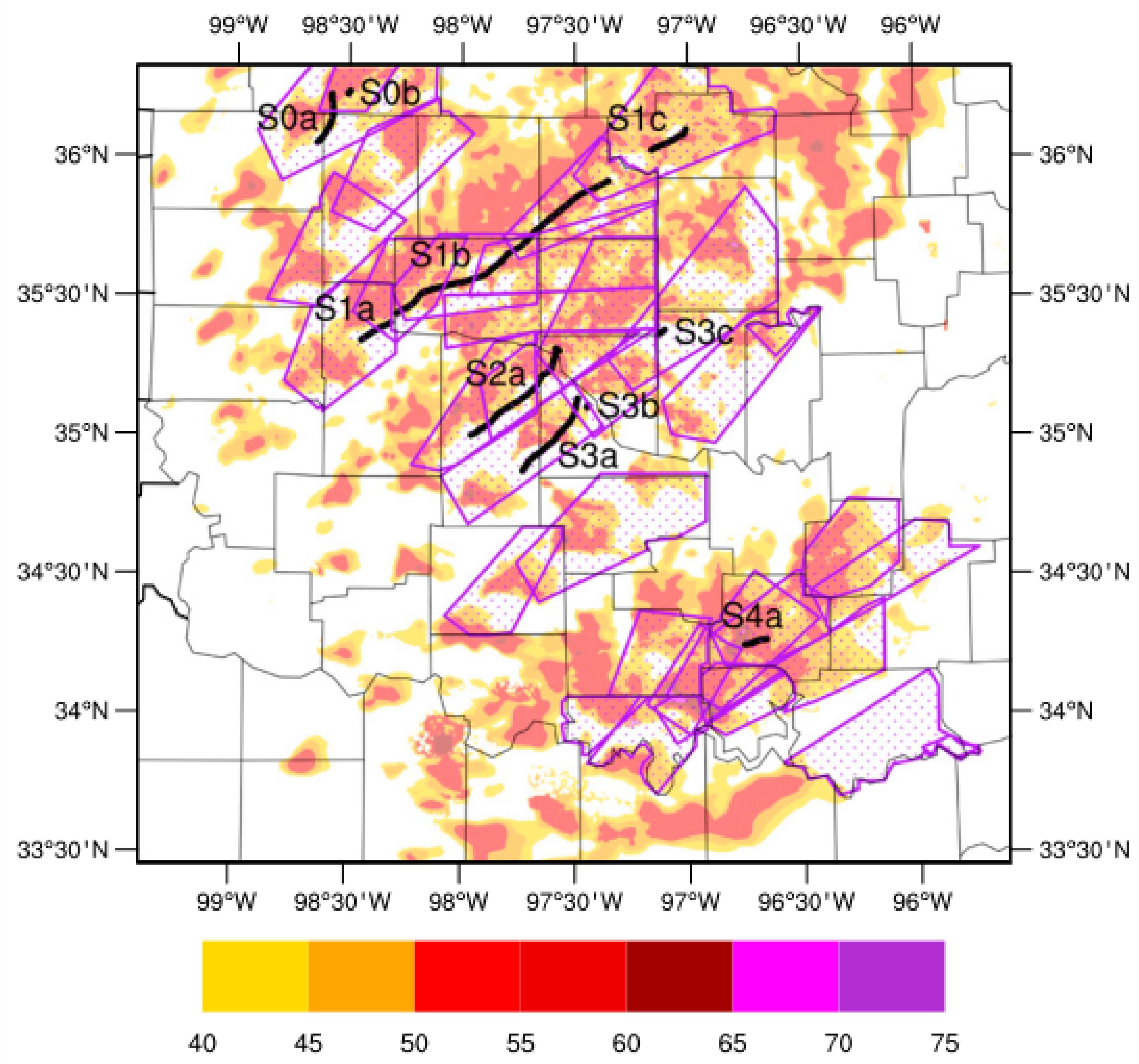
- alpha=0, N_0x and lambda_x varies with mixing ratio and number concentration (N_x)

3M scheme

- alpha can vary independently of N_0x and lambda_x

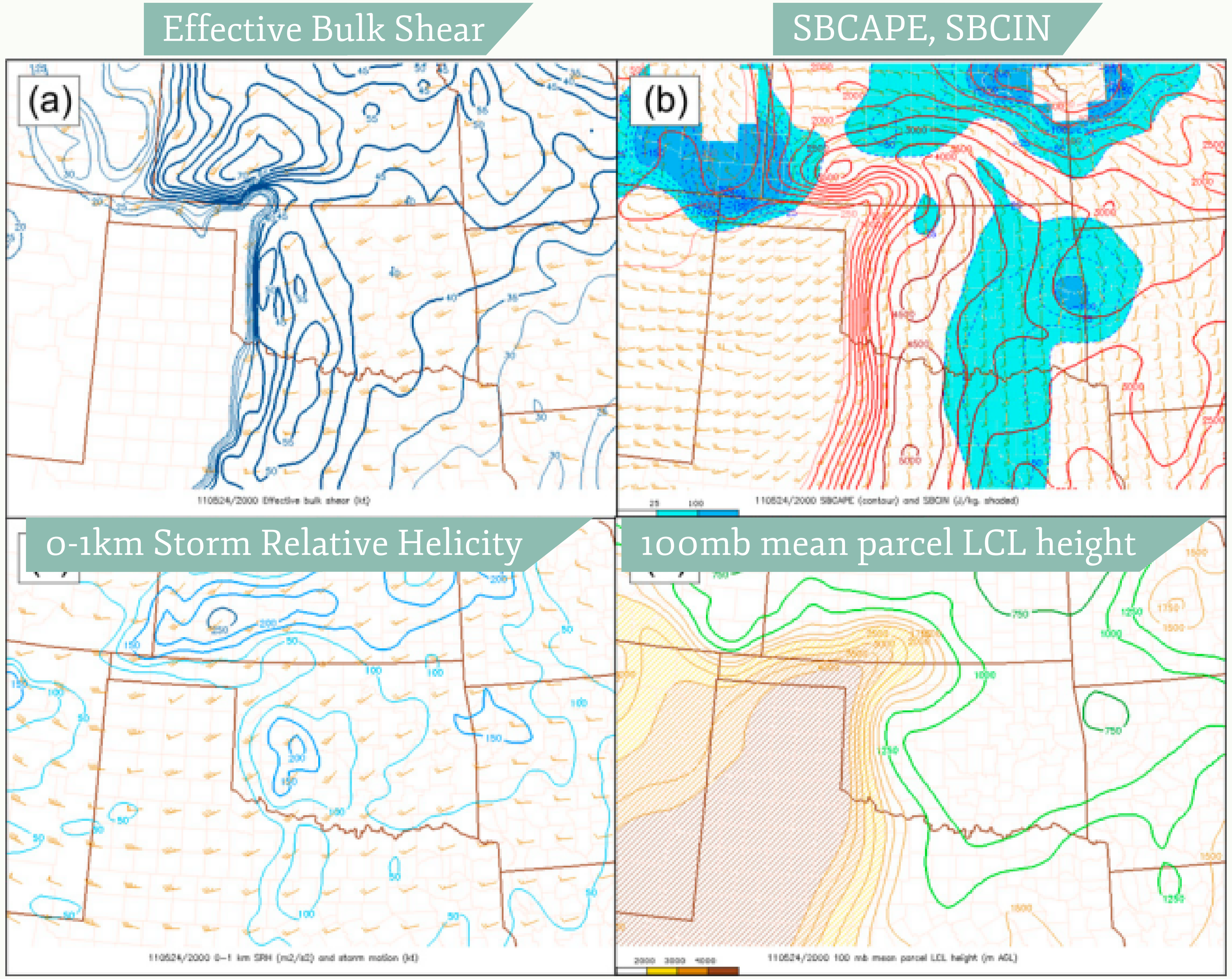
	LIN3	WSM6	MYSM
N_{0r} ($\times 10^6$ m^{-4})	8.0	8.0	8.0
N_{0i} ($\times 10^6$ m^{-4})	MD	MD	$f(T)$
N_{0s} ($\times 10^6$ m^{-4})	3.0	$f(T)$	3.0
N_{0g} ($\times 10^6$ m^{-4})	—	4.0	0.4
N_{0h} ($\times 10^6$ m^{-4})	0.04	—	0.04

Event Overview



0.5-degree Reflectivity

1 EF5 (S1b), 2 EF4 (S2a,S3a), 2 EF3 (S0a,S1a),2 EF2 (S1c,S3c), 2 EF1 (S3b,S4a), 3 EF0



SPC Mesoanalysis

Verification Methodology

Compare with Oklahoma Mesonet (1.5m T / Td, 10m u,v)

Verification

N=1,3,5,9,17 ,33,65,129

Point-based

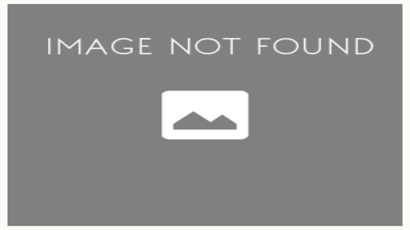
- RMSE

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{k=1}^{n}(f_k - o_k)^2}$$

- Linear-Regression Slope

$$m = \frac{\sum_{k=1}^{n}[(o_k - \bar{o})(f_k - \bar{f})]}{\sum_{k=1}^{n}(o_k - \bar{o})^2}$$

- Coefficient of Determination



- PDFs

Neighbourhood-based

How much a forecast needs to be smoothed to exhibit "useful" skill?

- Fractions Skill Score

$$\text{FSS} = 1 - \frac{\frac{1}{N}\sum_{N}(P_f - P_o)^2}{\frac{1}{N}\left(\sum_{N}P_f^2 + \sum_{N}P_o^2\right)}$$

0 (no skill)
1 (perfect skill)

- A "Useful" forecast

$$\text{FSS}_{\text{useful}} = 0.5 + f_o/2$$

fo = (no. grid points > threshold / total number of grid points)

Object-based

Object-based Verification Algorithm

Updraft Helicity

$$UH = \int_{z_1}^{z_2} w\zeta \, dz.$$

Define objects

- Isolate 1–6km (0–1km) UH maxima > 300 (15) within search radius = 4km
- 4/8 (1/8) adjacent grid points >150 (10) -> UH center

Filter out non-tornadic objects

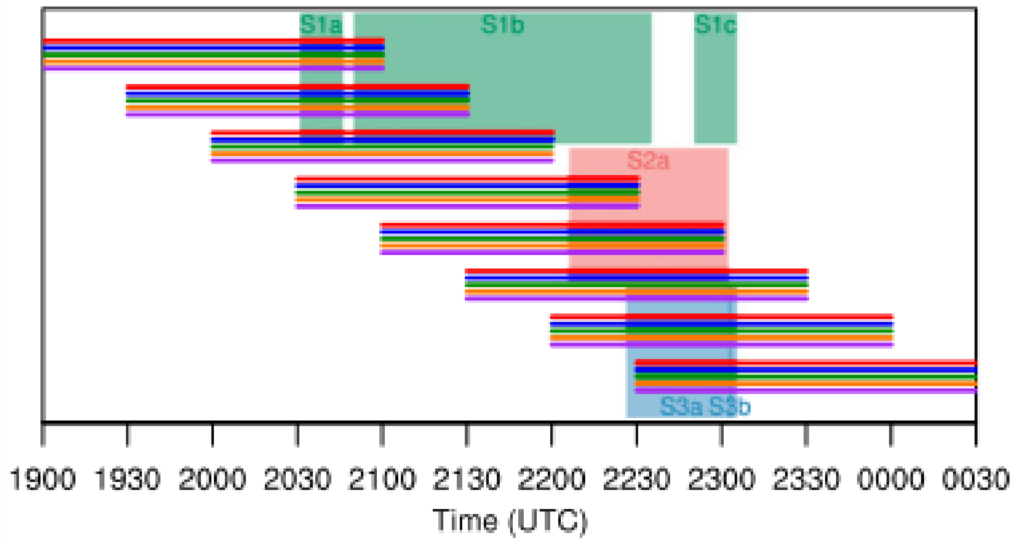
- UH-weighted centre: Radius of 3km (2km) from grid points with maximum UH
- Filter 0–1km UH centre by requiring 1–6km UH centre to concurrently exist within 5km range

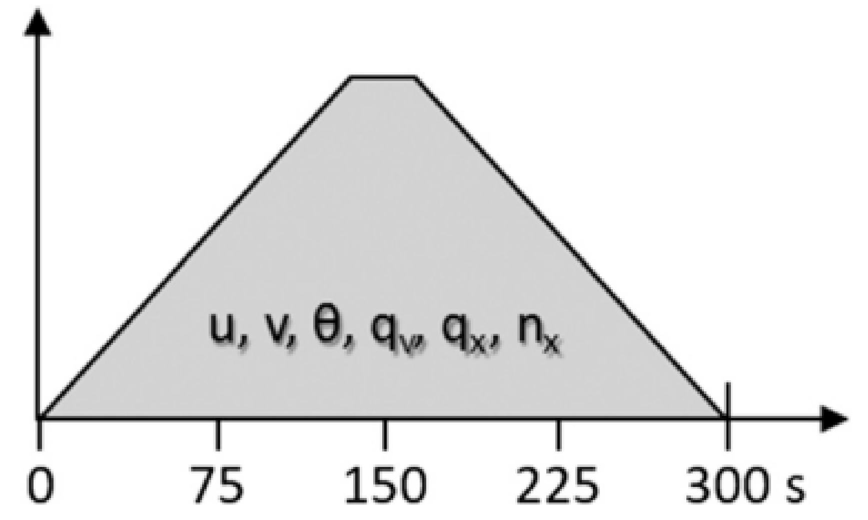
Quantify errors

- Same Time (ST): Model 0–1km UH centre and nearest tornado location at coincident time
- Anytime (AT): 0–1km UH centre and nearest tornado location at any time

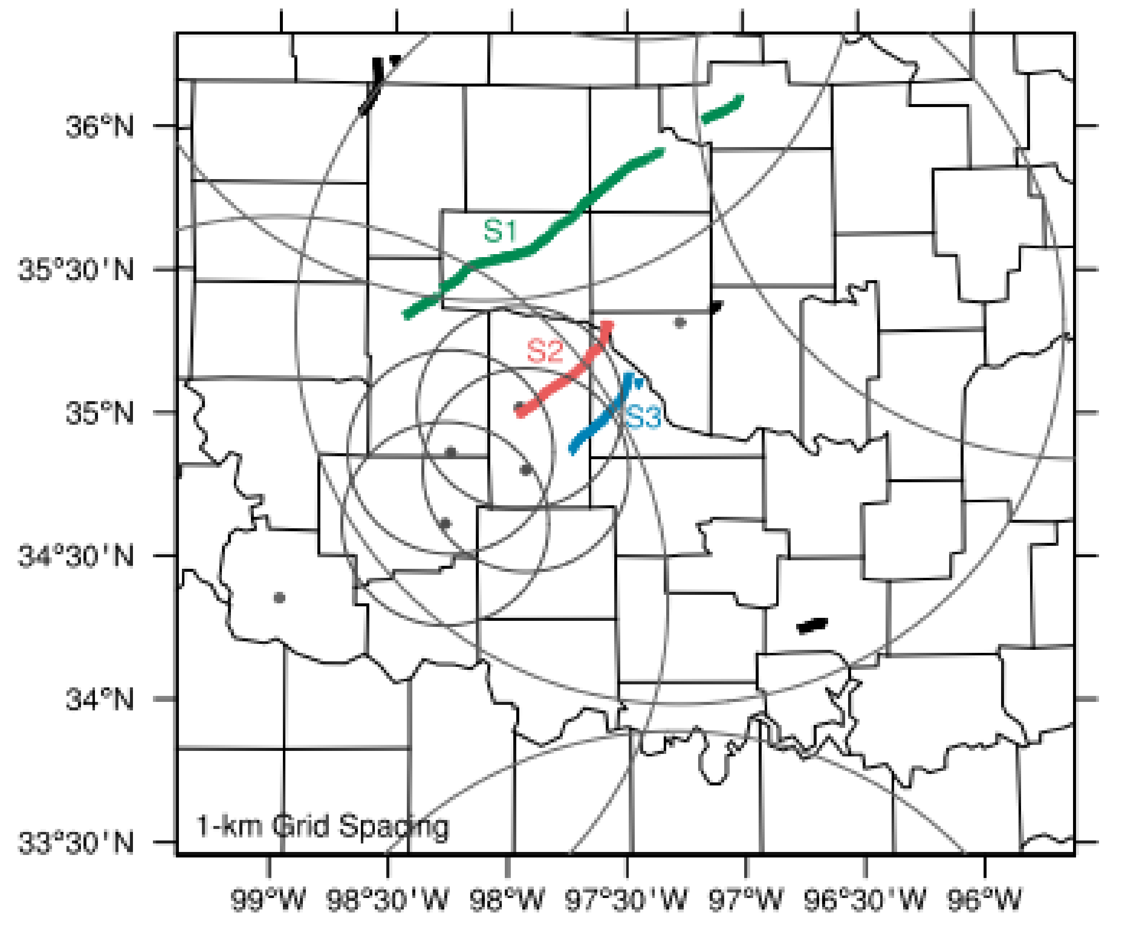
Experiment Design

- 8 sets of simulations are done, simulations are initialized every 30 min from 1855-2225UTC.
- Simulations spun up during 5min assimilation window, then integrated out to 120min
- ARPS model (Xue et al. 2003) is used to simulate this event.
- B.C. -> 1800UTC 12km NAM interpolated to model starting time
- The initial analyses (1km grid spacing, 53 vertical levels) are enhanced by assimilating observational data with ADAS Data Assimilation System (Hu et al. 2006a,b)
- ADAS assimilates (a) NWS & FAA METARs, Oklahoma Mesonets (b) NEXRAD WSR-88Ds (KFWS,KDDC,KFDR,KINX,KTLX,KVNX,KICT), CASA IP-1 X-band radars [radial wind+reflectivity]
- Incremental Analysis Updating (IAU; Bloom et al. 1996) is performed in the 5 min window.

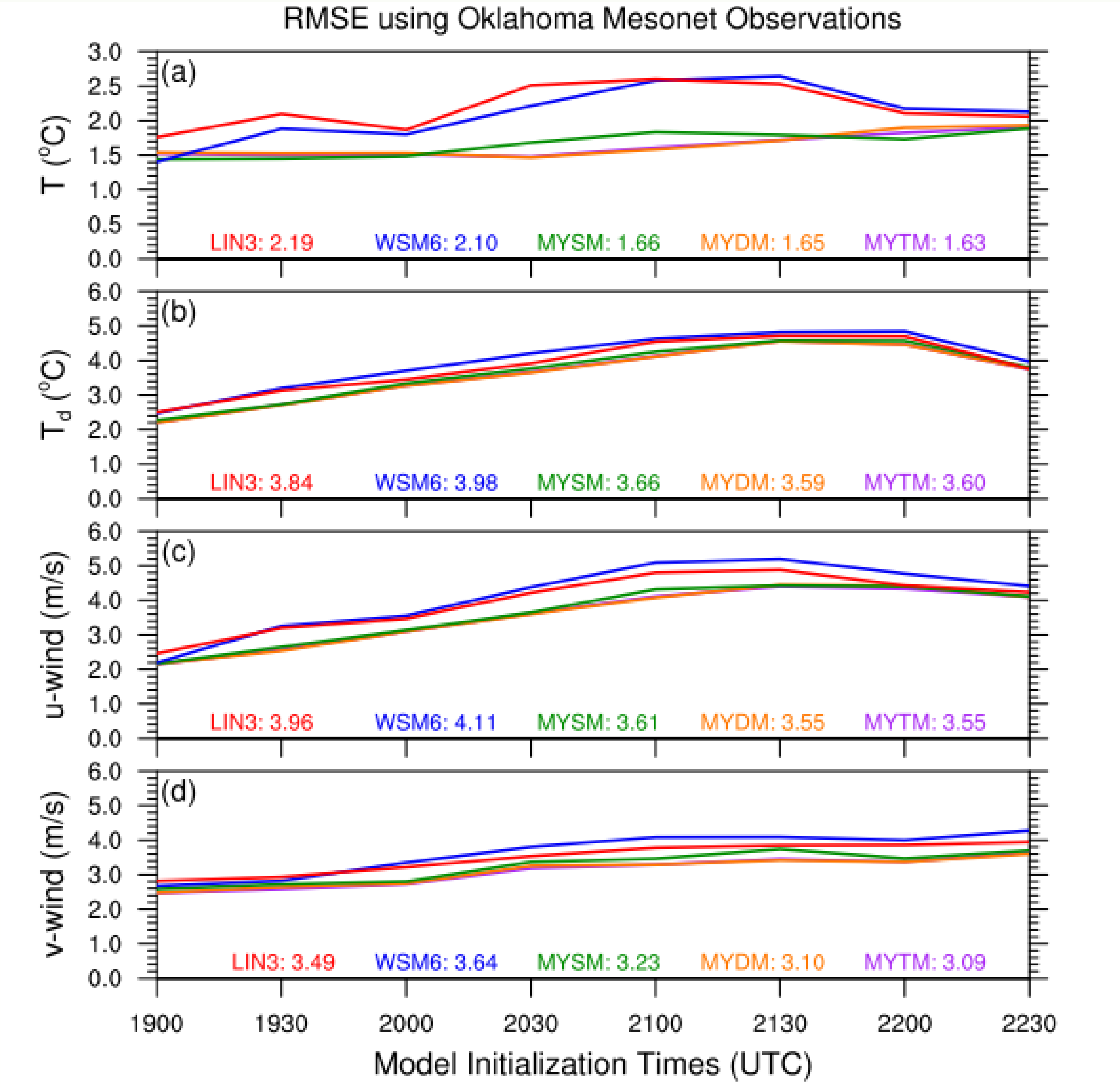


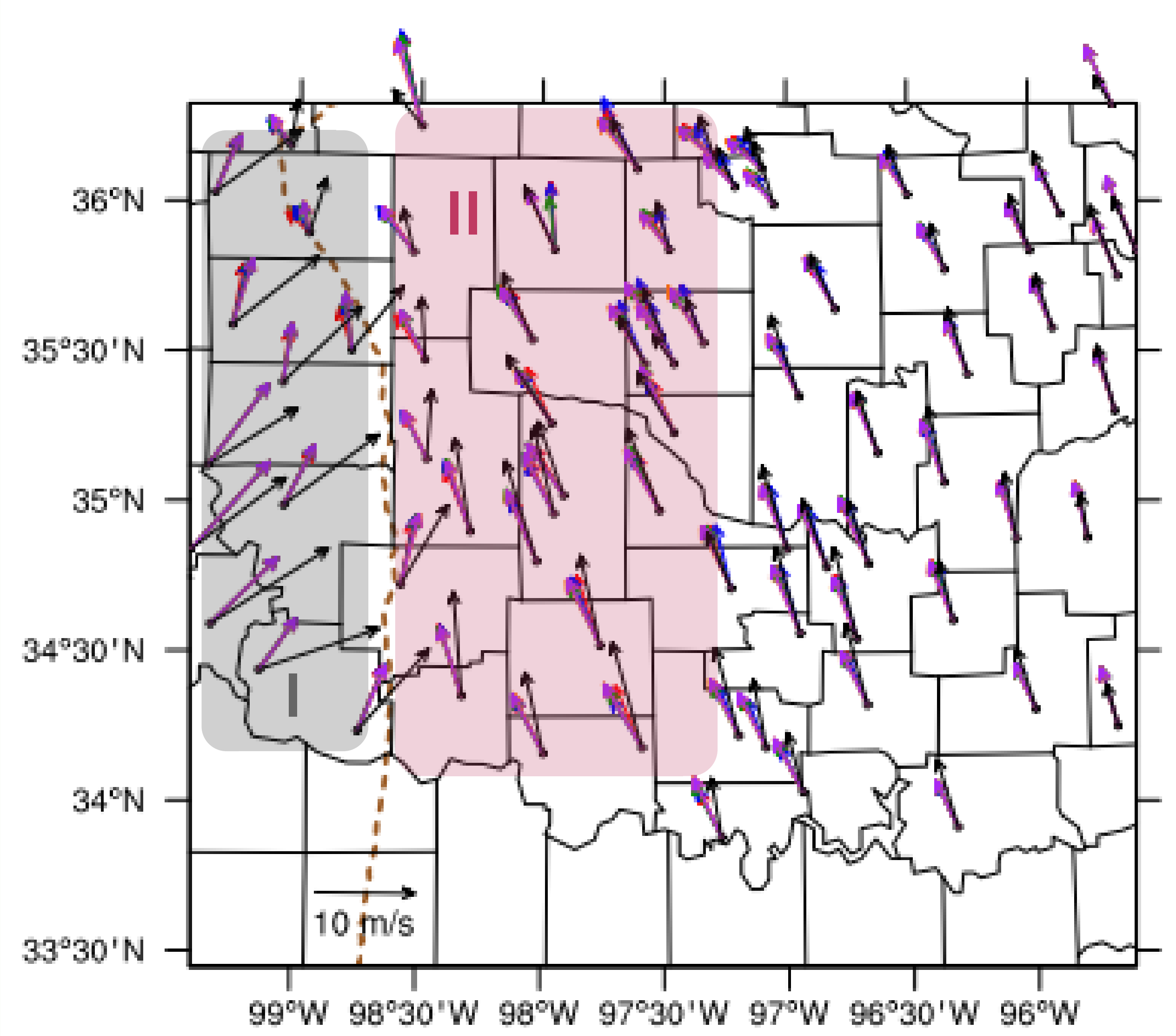


LEAPFROG FORMULATION	4TH ORDER MOMENTUM ADVECTION
1.5-order TKE closure	4th order computational mixing
Rayleigh damping beginning at 12km AGL	GSFC LW/SW Parameteri-zation
Surface flux based on predicted T/water content	2-layer force-store soil model

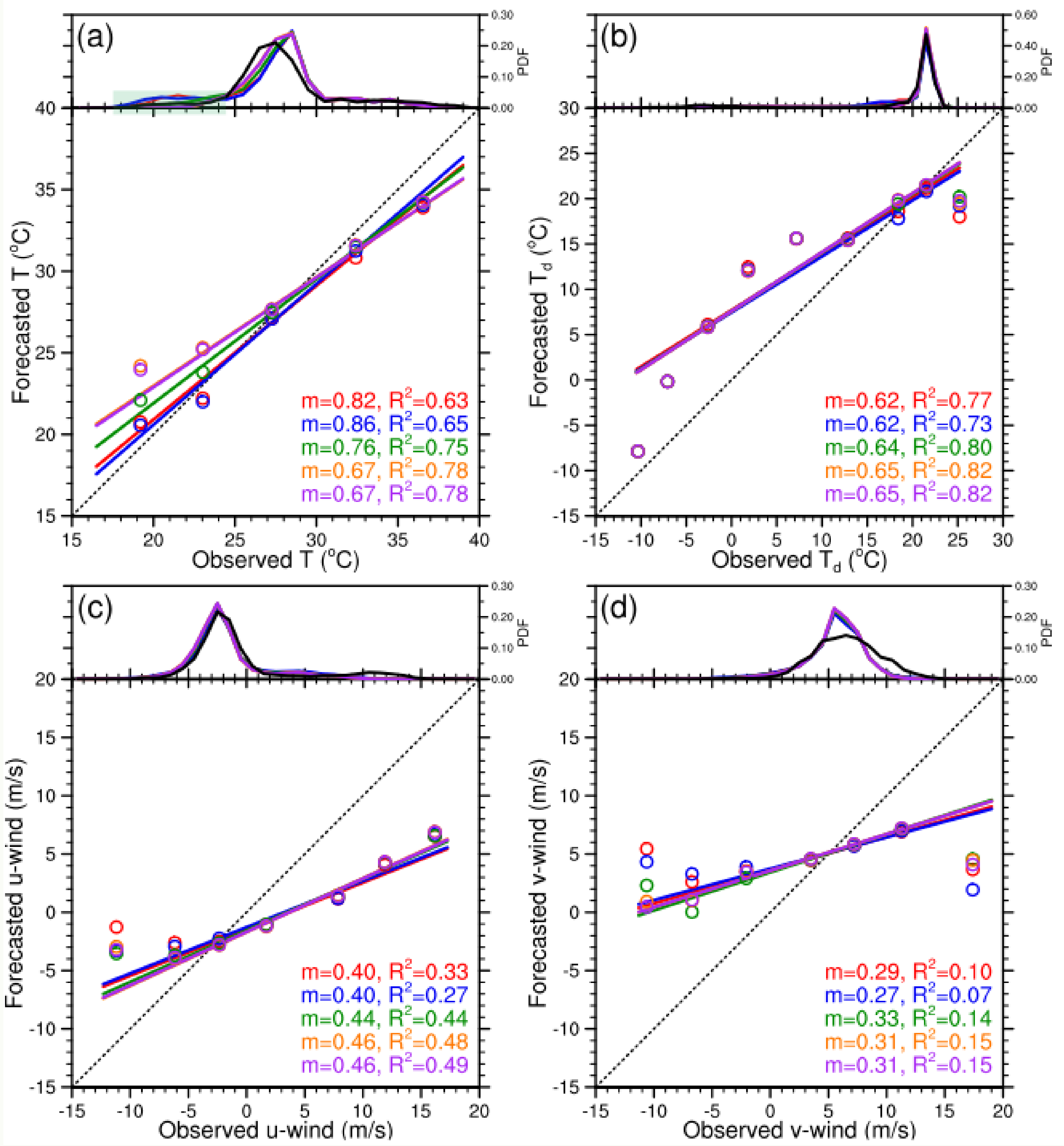


Point results

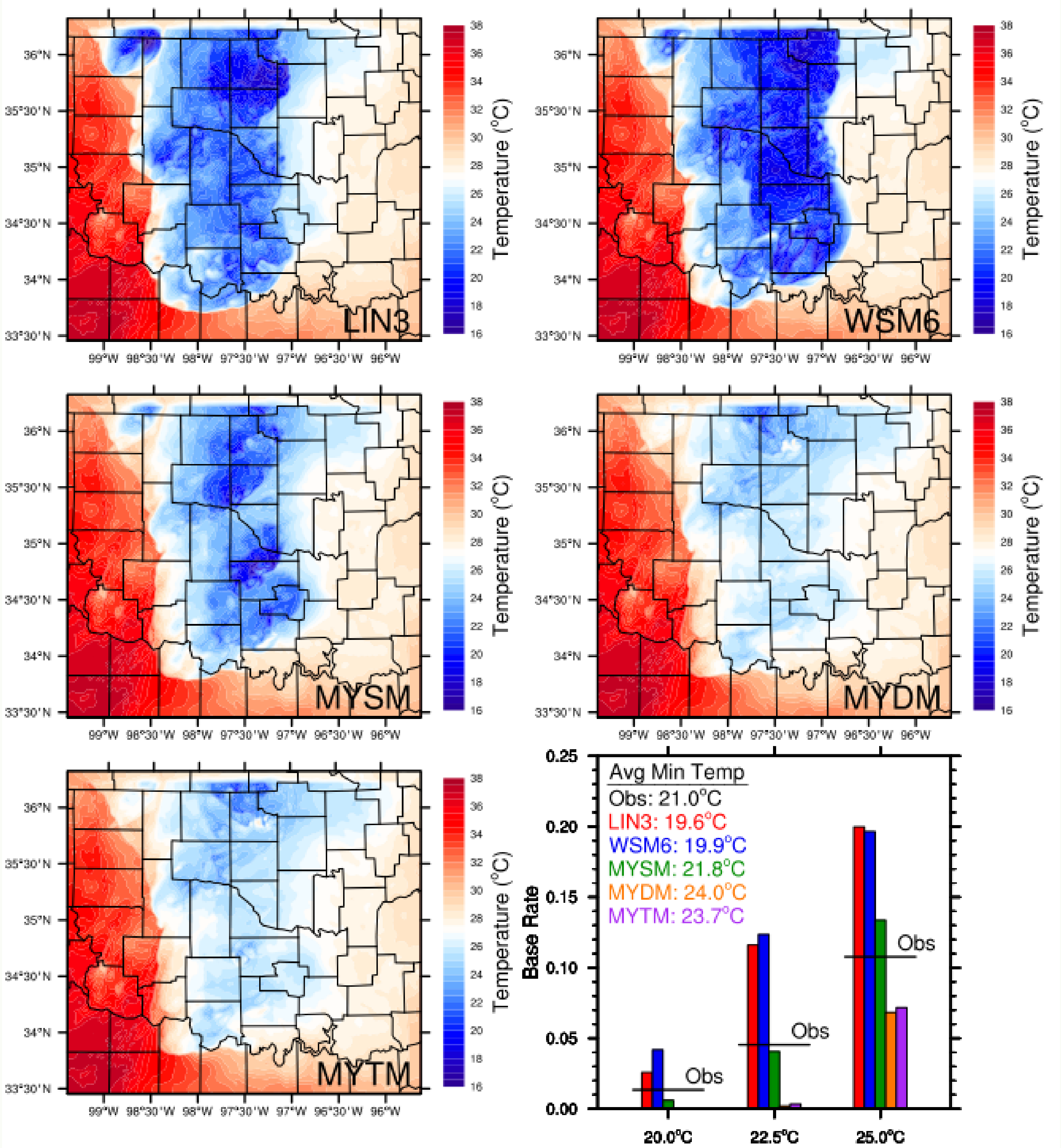




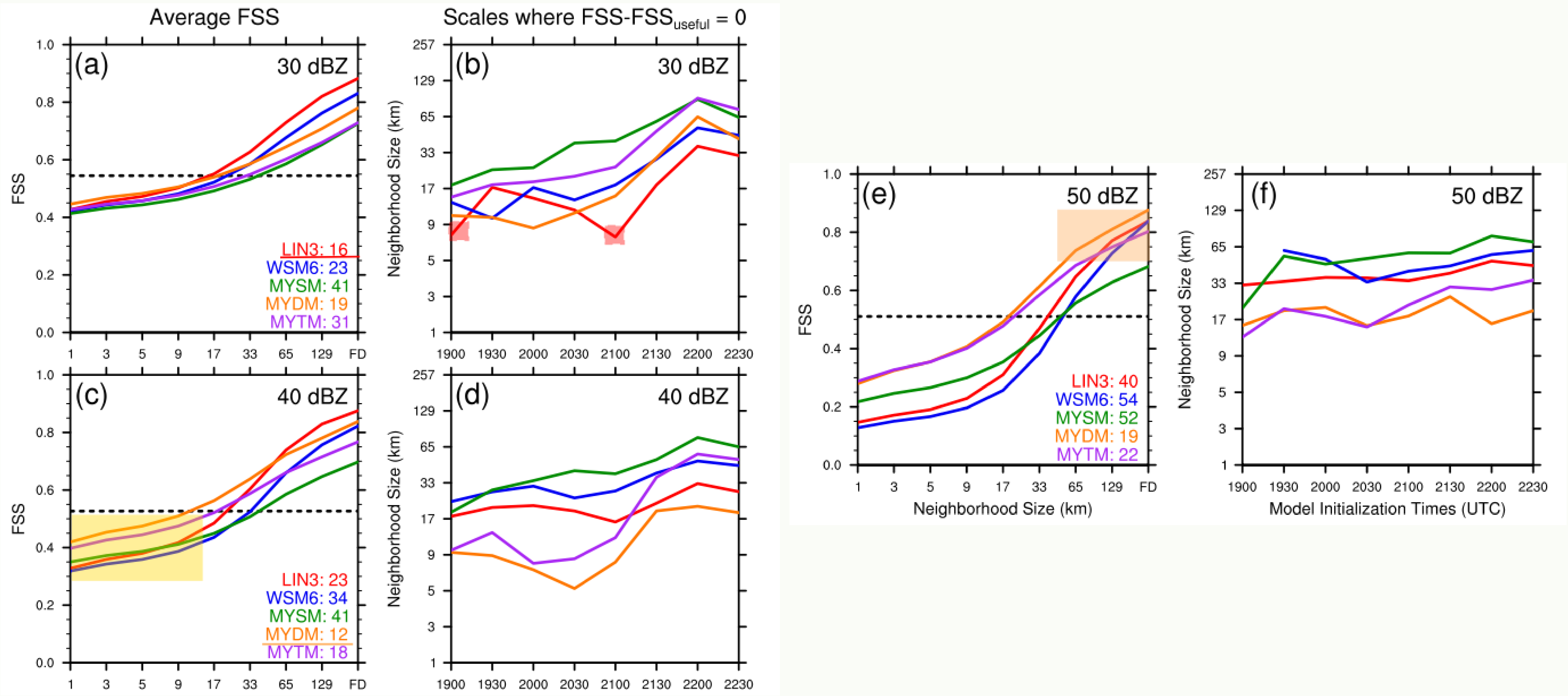
Point results

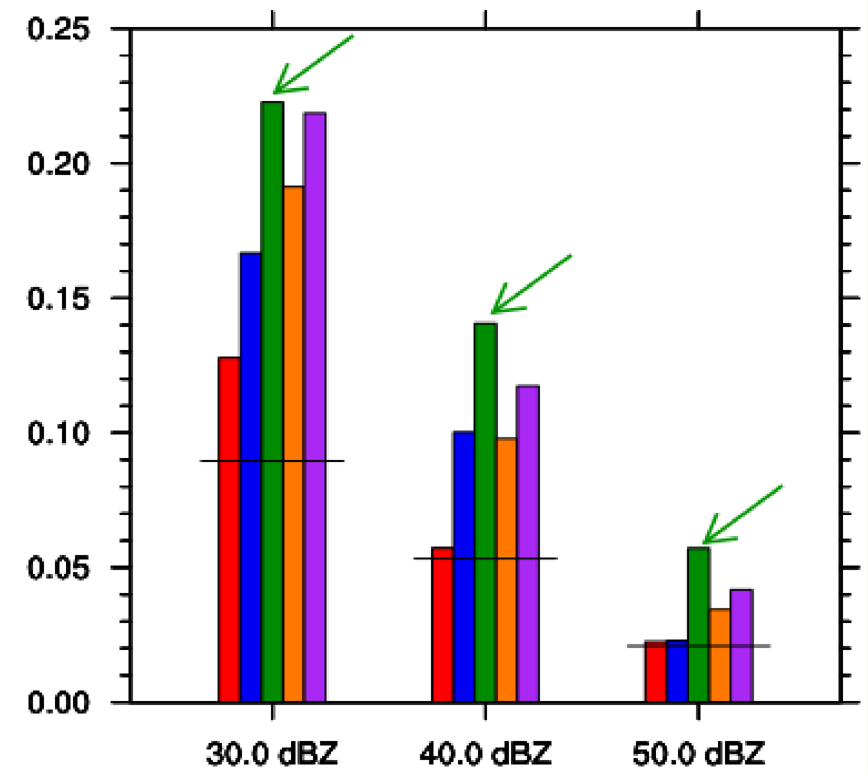


90-min forecasts of T from 2130 simulation

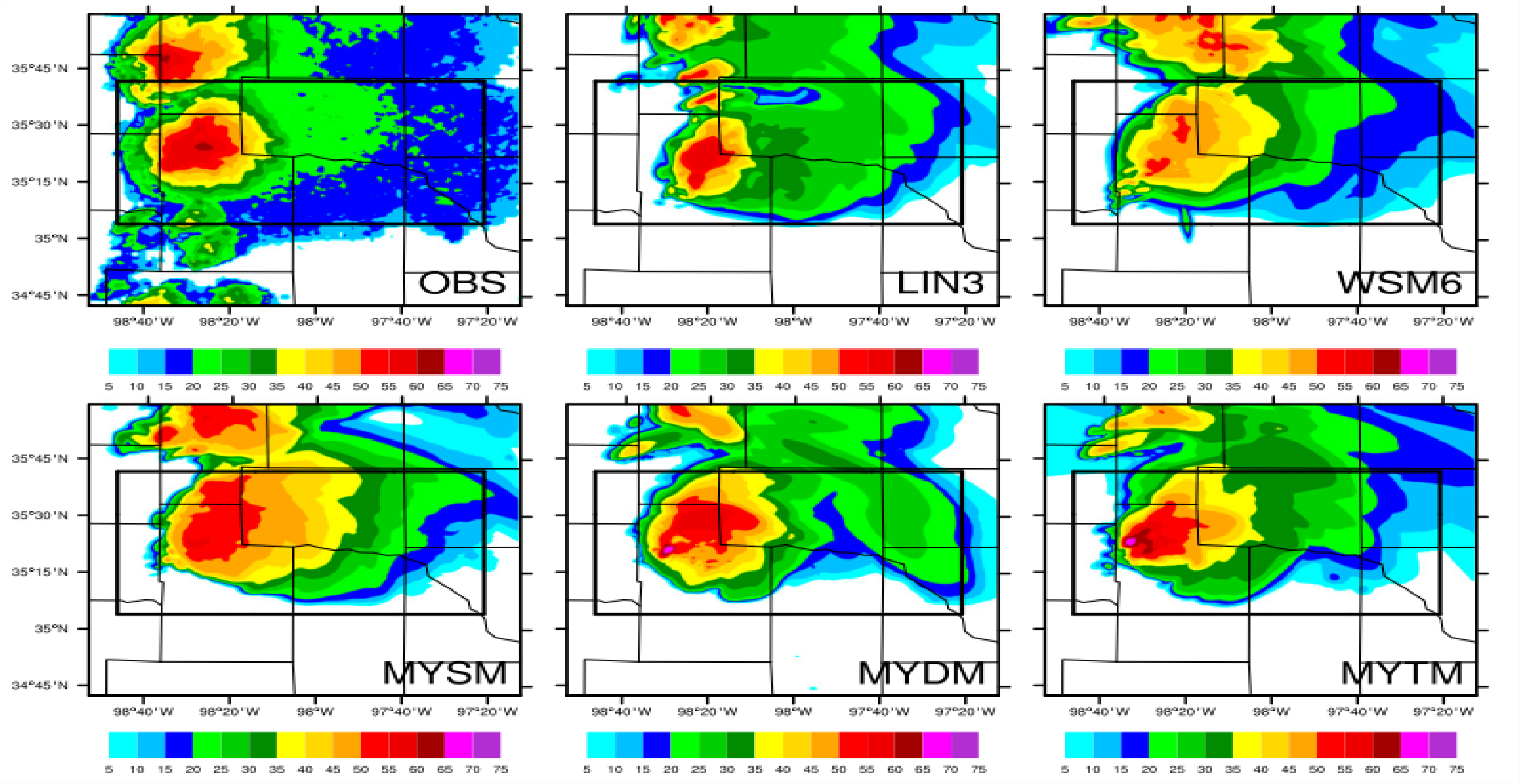


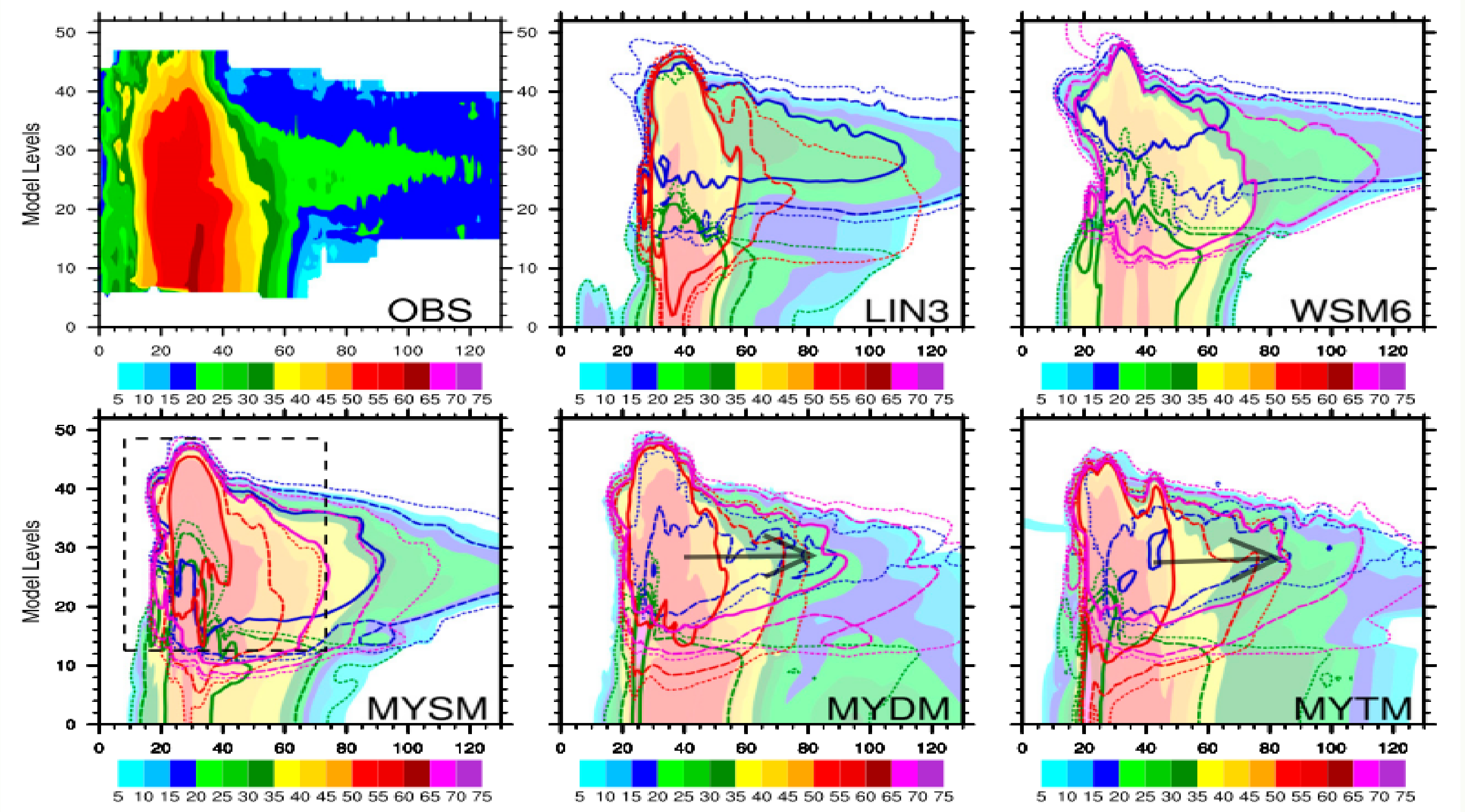
Neighbourhood-based results





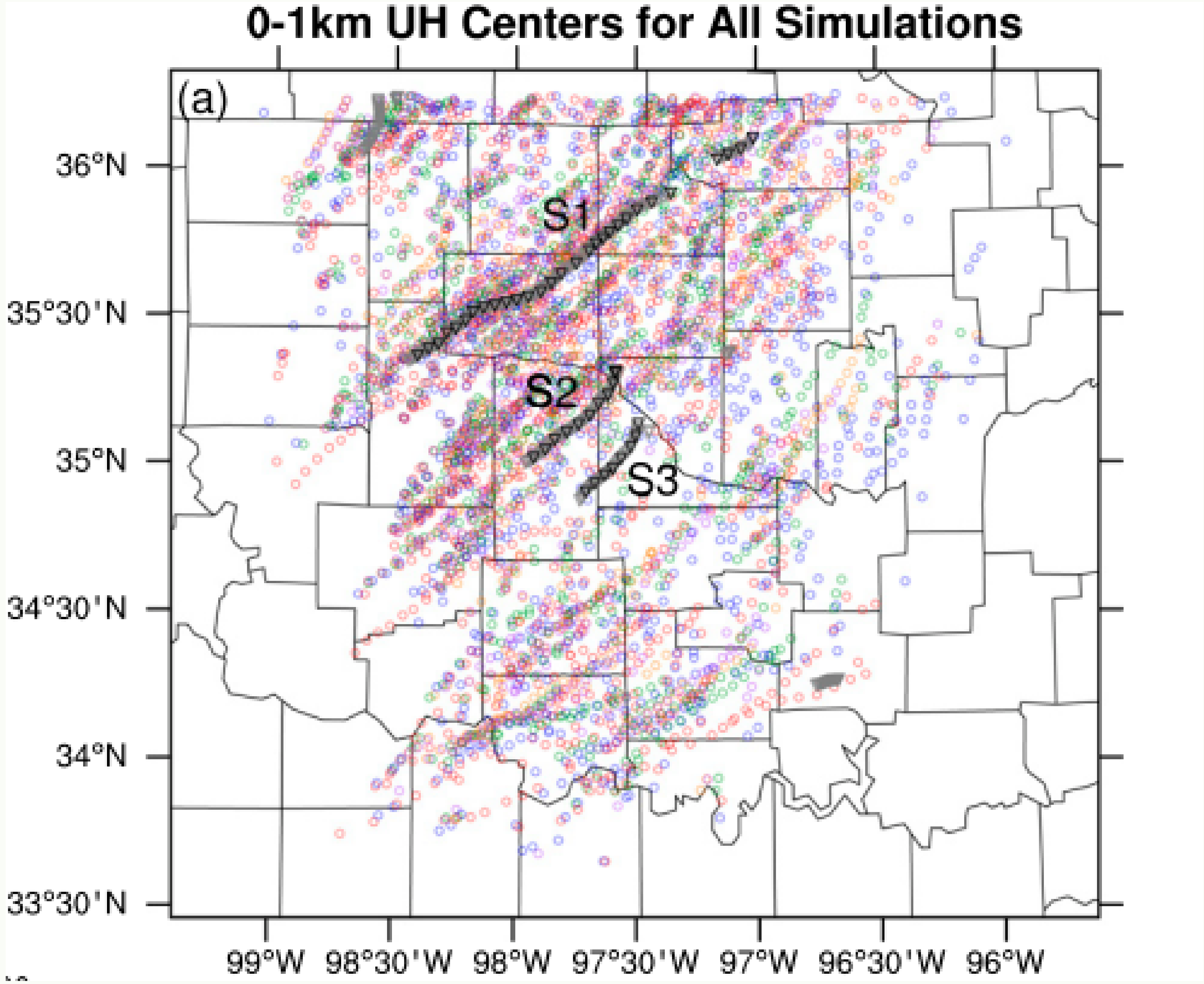
Base rate (f0) comparison
for different thresholds

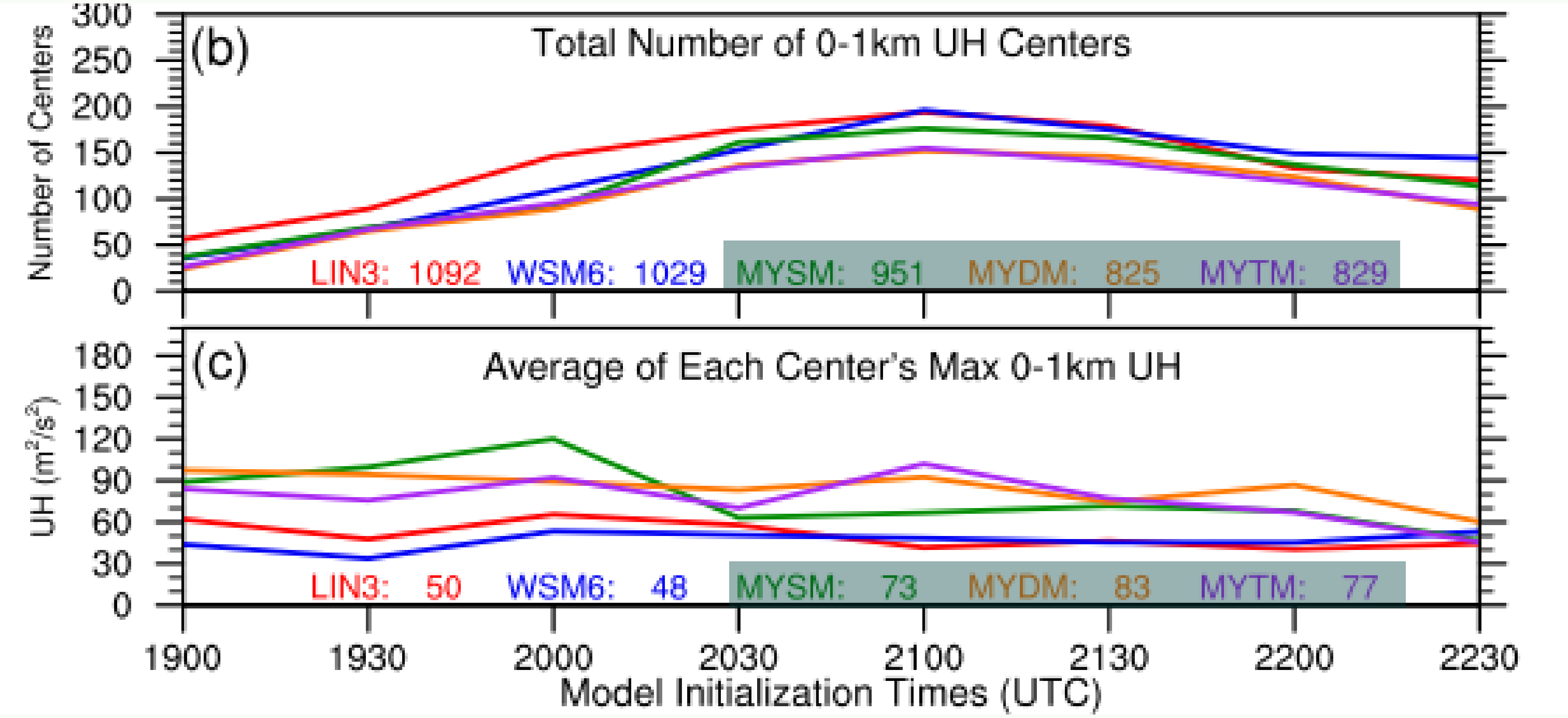




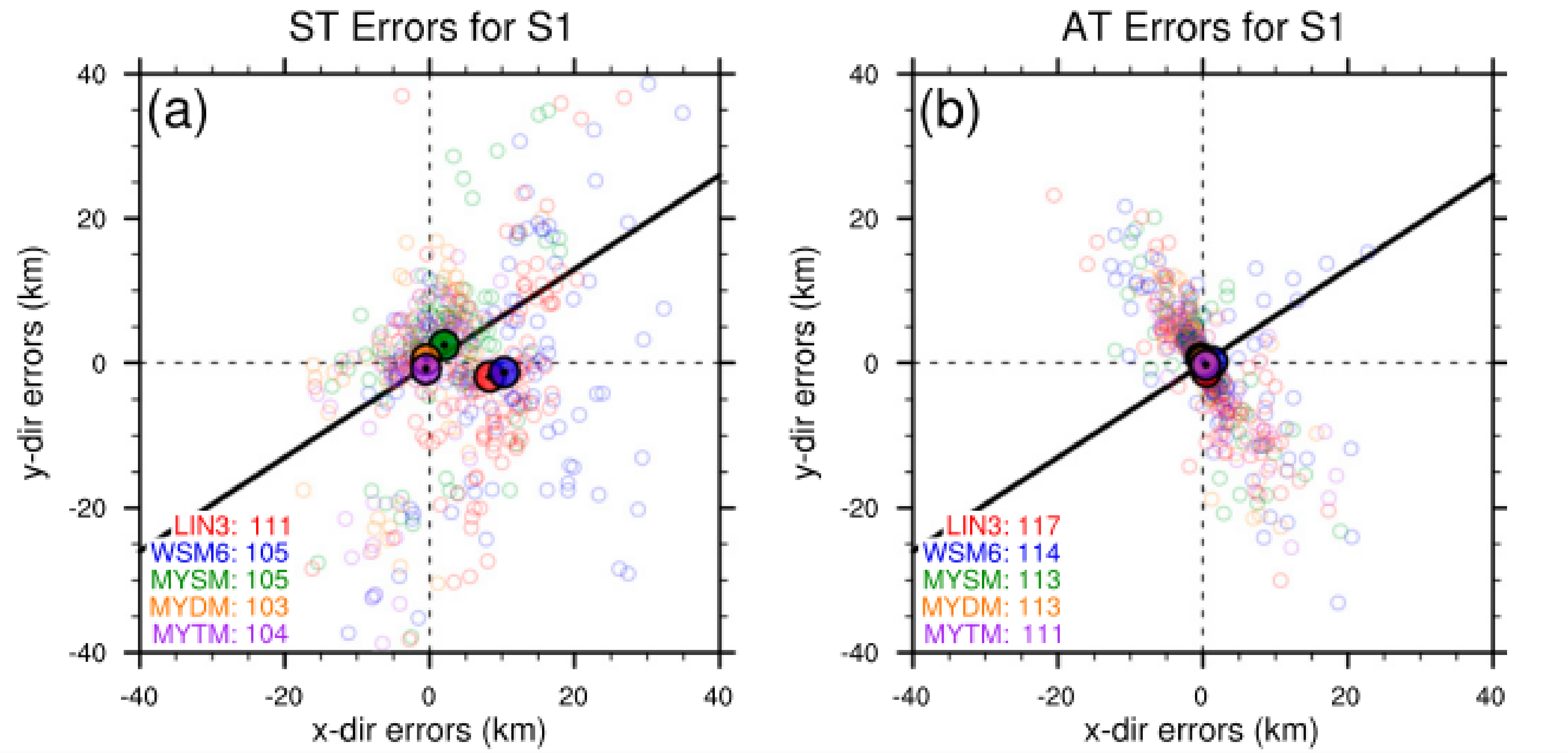
rain (green), snow (blue), hail (red), and graupel (magenta)

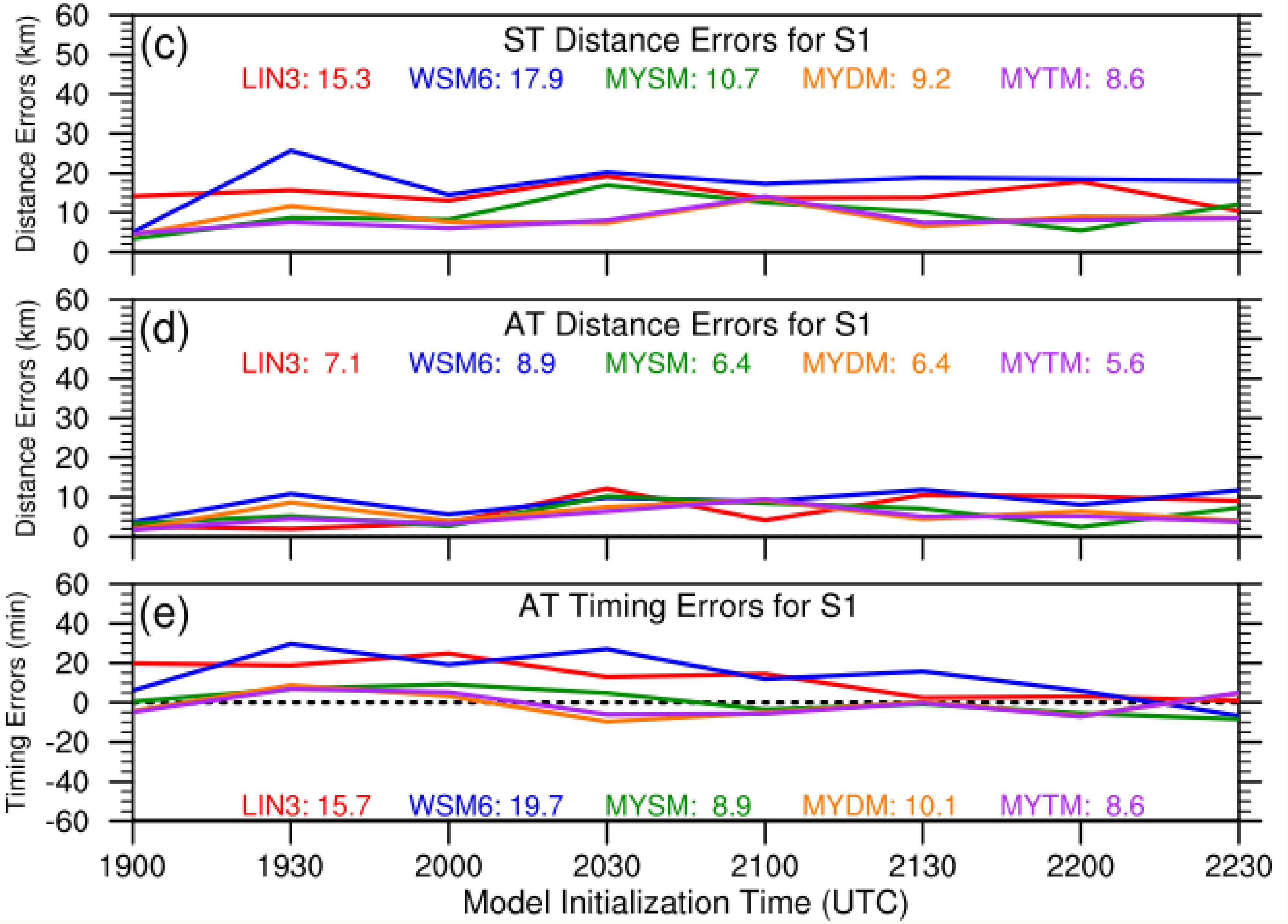
Object-based results - I. Overview

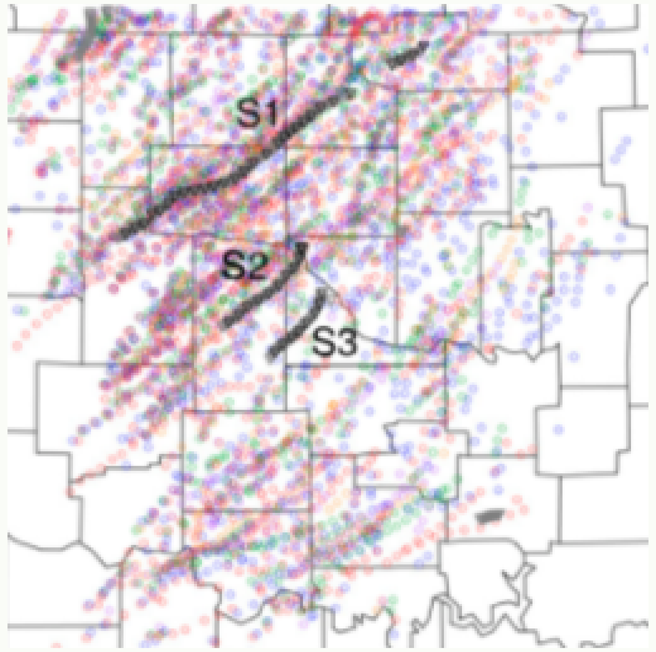




Object-based results - II. S1



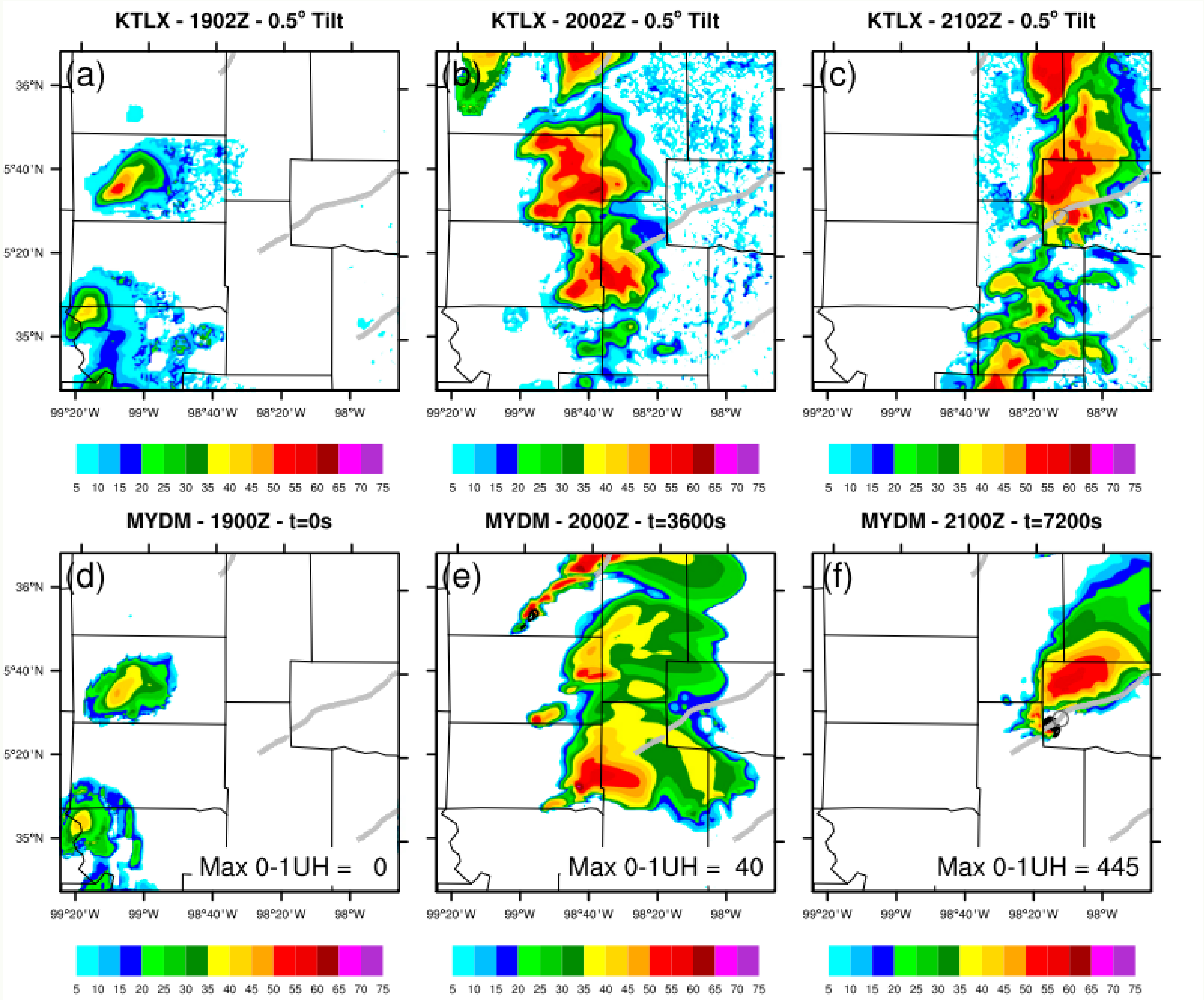




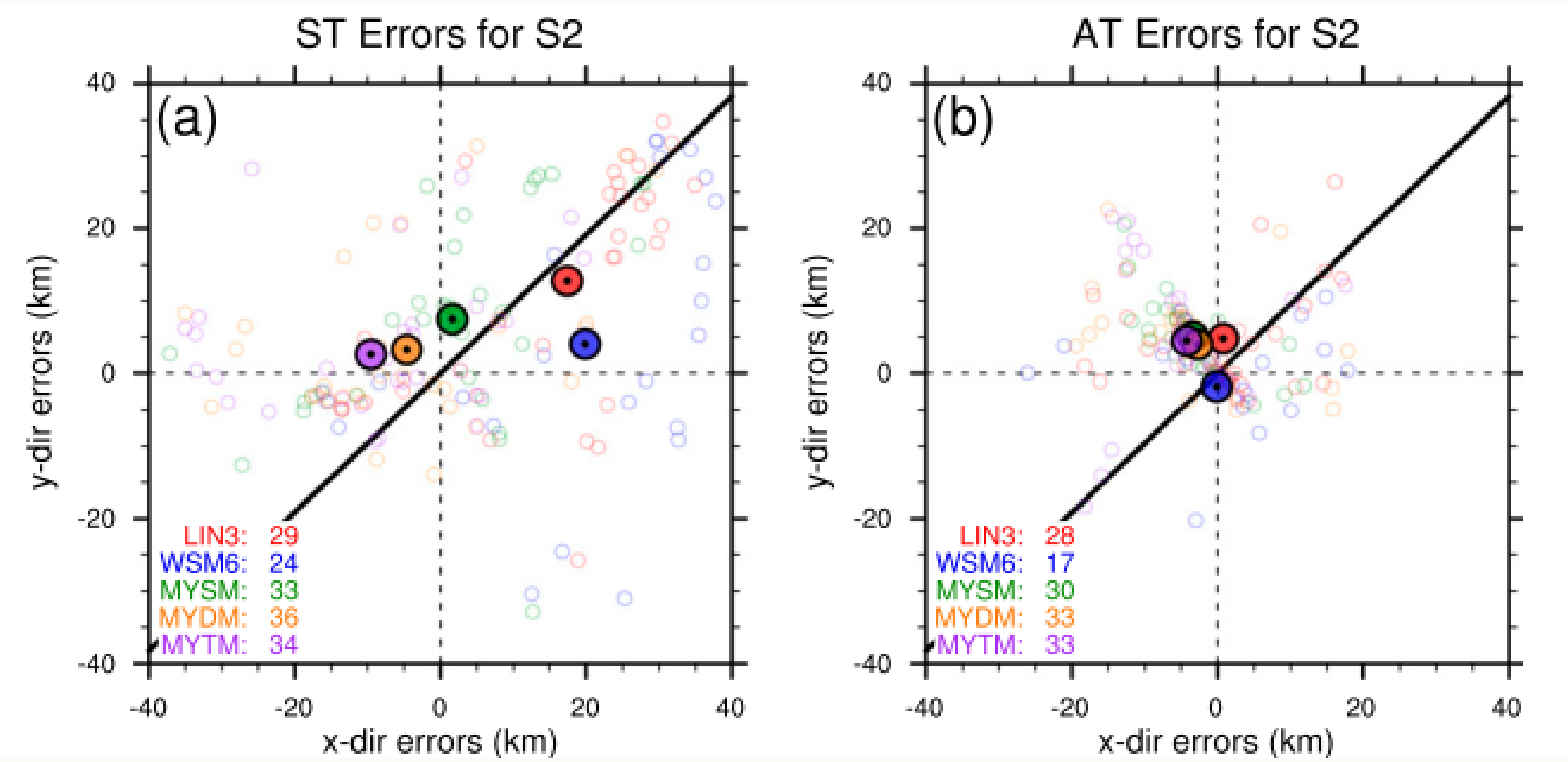
Object-based results - II. S1

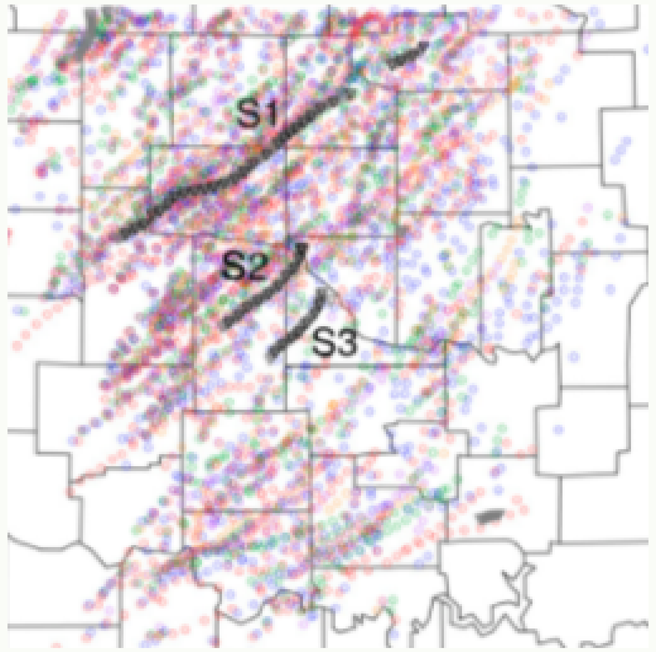
+1 hr

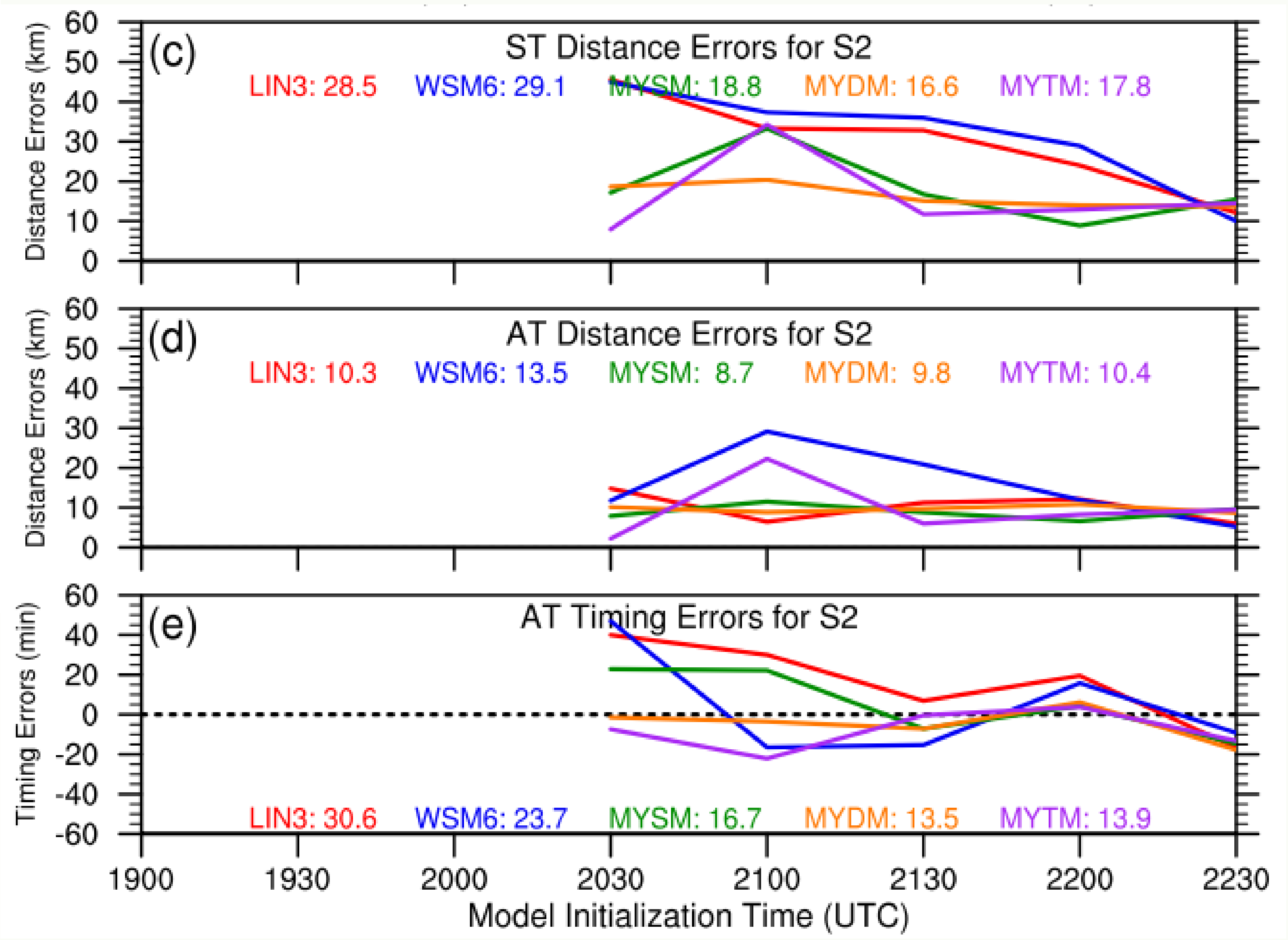
+2hr



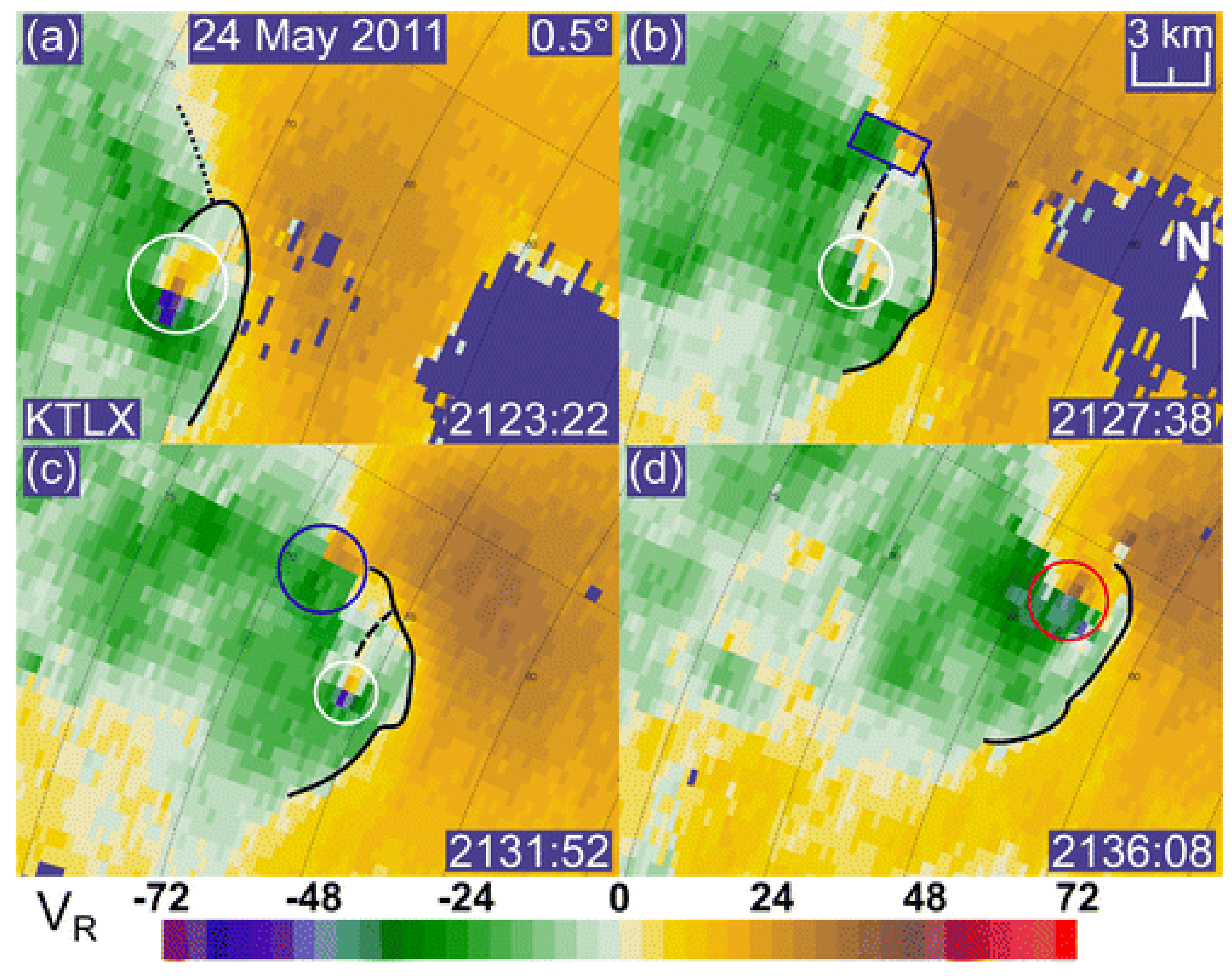
Object-based results - III. S2

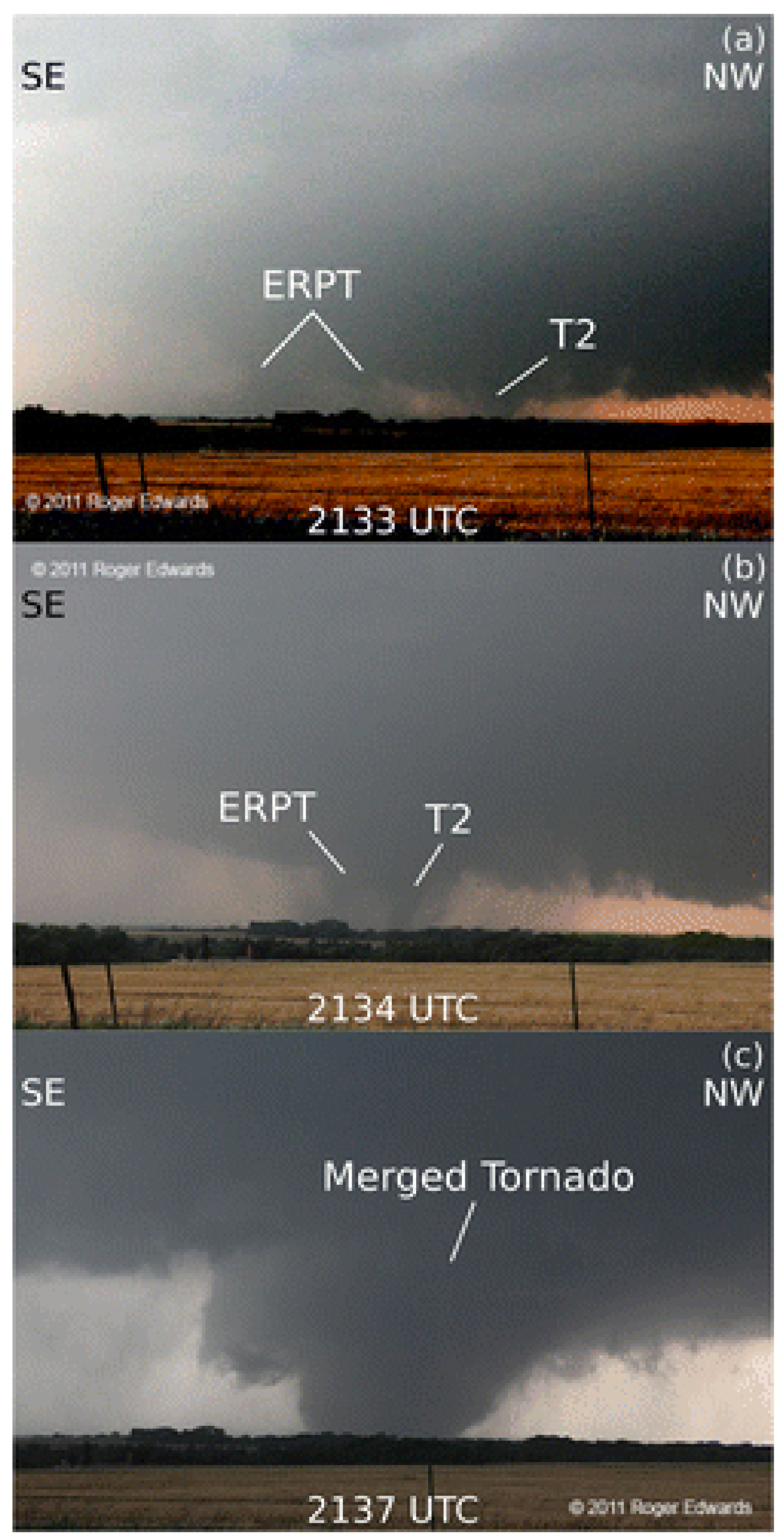




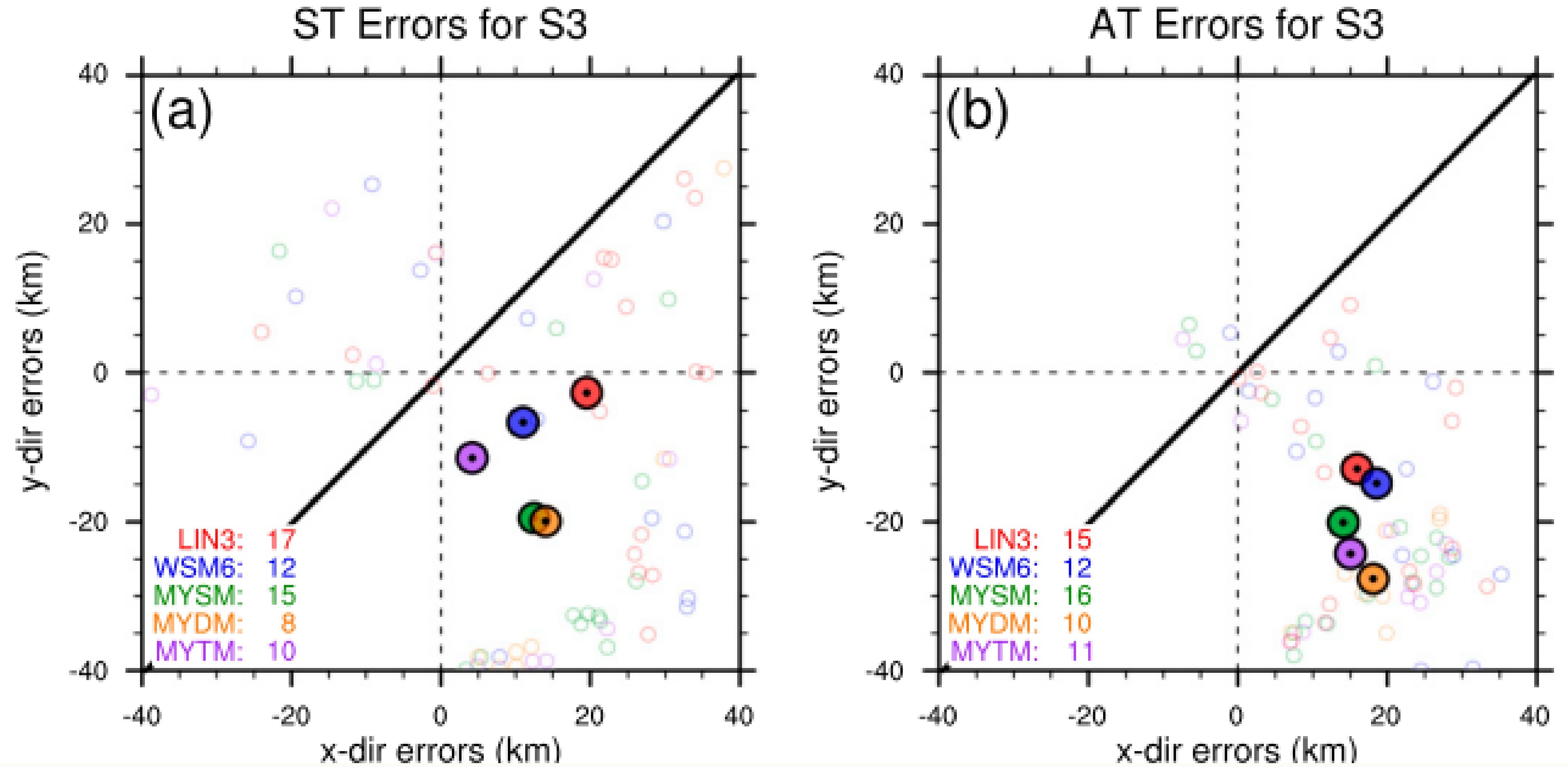


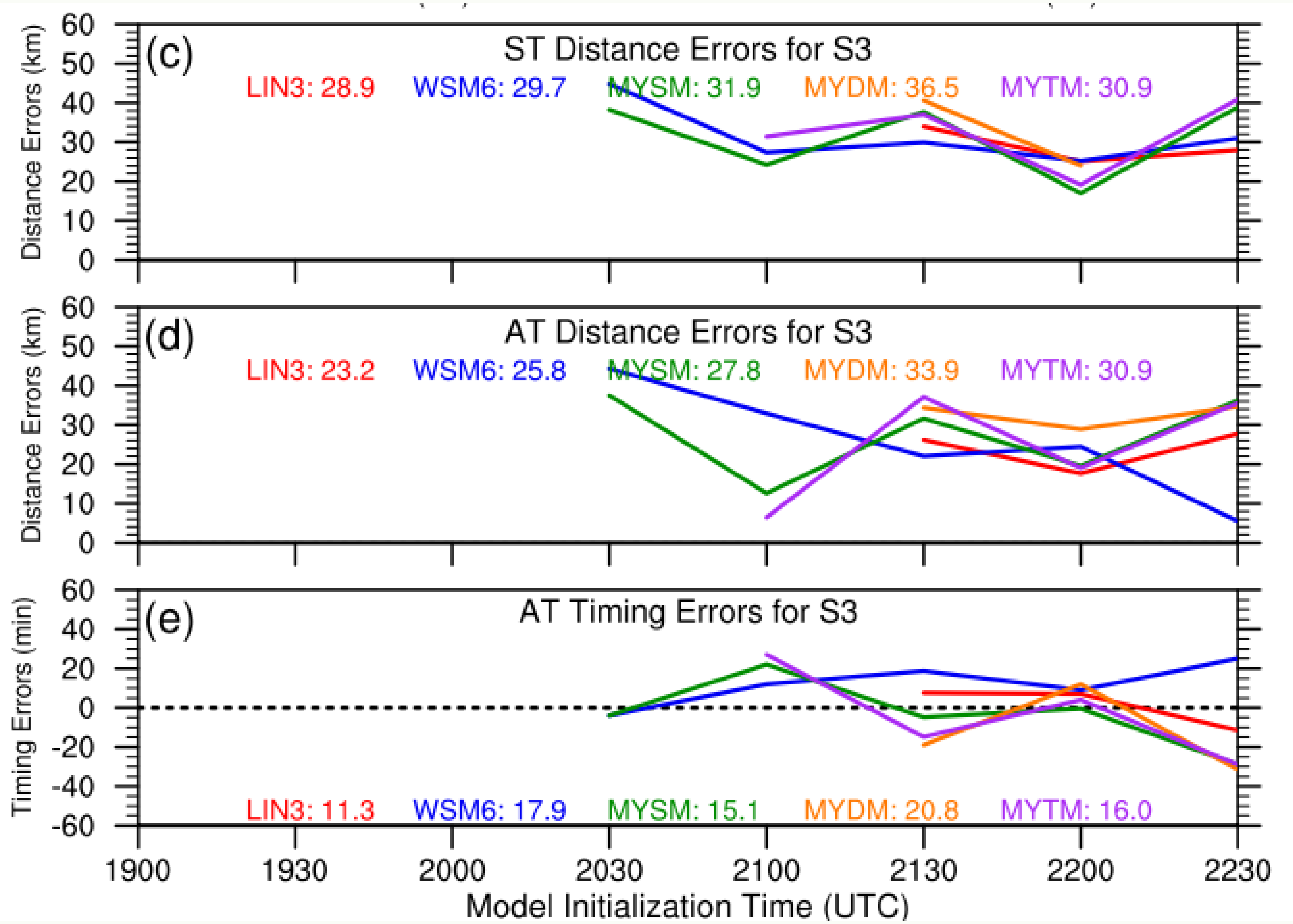
A rare tornado merger case (French et al. 2015)

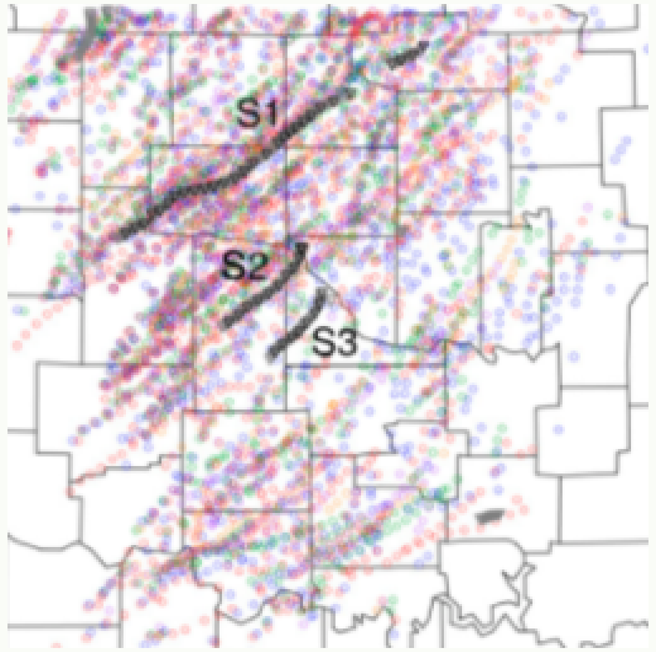




Object-based results - IV. S3



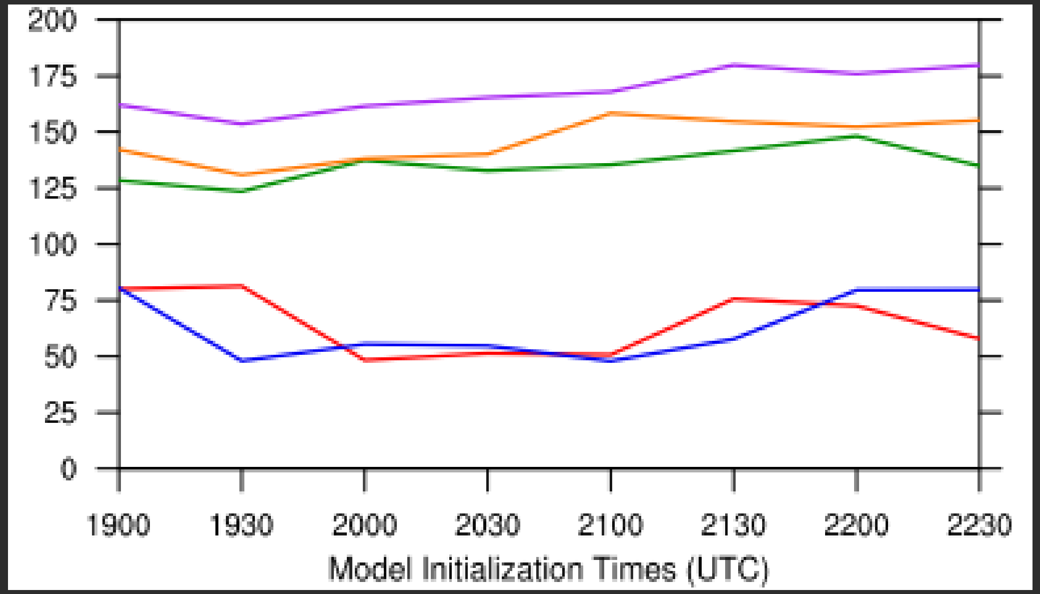




Key Findings

Single or multimoment?

- Inconclusive
- Computational cost an inescapable issue
- More schemes needed?



Novel verification technique

- Deficiencies in point-observation comparison
- Object-based technique is effective and can be used to solve multiple problems
- All models overforecast reflectivity field (perhaps precip rate is preferable?)

Bias identified

- Most of the single-multi moment scheme difference can be expressed as "highly related to cold pool"
- Single-moment schemes generate stronger cold pool due to more hydrometeor evaporation.

THE END

Thank you for listening