# 2013 realtime WRF-DART analysis and ensemble forecasts

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14th WRF User's Workshop 24-28 June 2013

## Springtime convection permitting forecasts at NCAR

10th consecutive year of realtime forecasts with the WRF model

Demonstrates WRF capabilities
Support for MMM associated field programs
Contributes to predictability studies of convection

BAMEX – **2003**

MPEX – **2013**

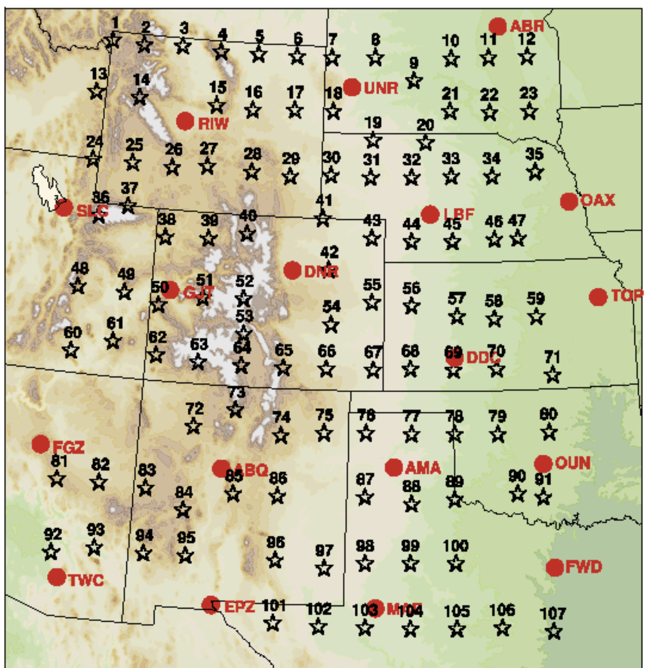
# MPEX – Mesoscale Predictability Experiment

Goals

1) Improve convection permitting forecasts by reducing initial condition uncertainty through targeted sub-synoptic observations upstream of anticipated convective events

2) Sample the near storm environment to better understand how developing convection impacts subsequent predictability

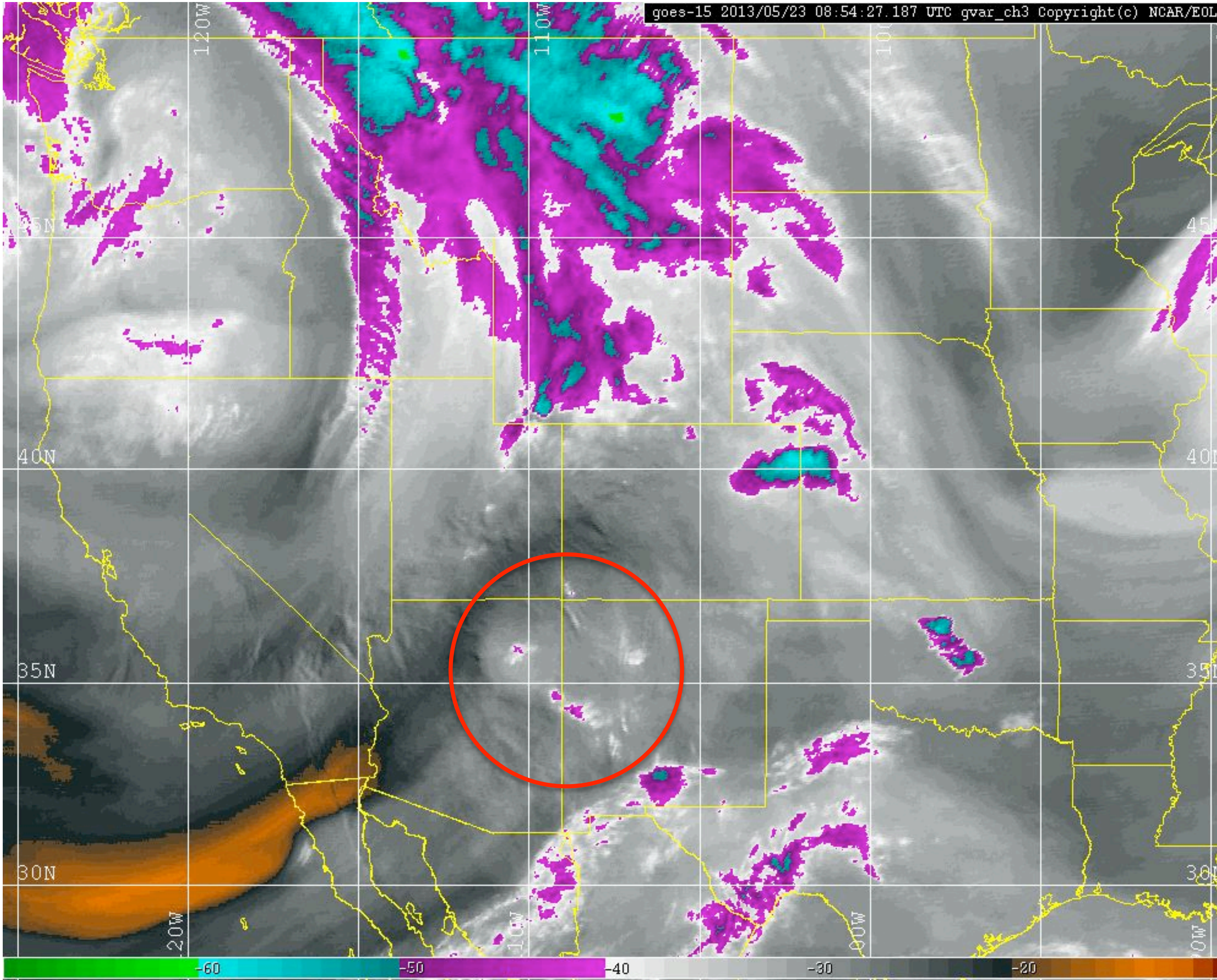
Ops from 15 May – 15 June 2013, 15 flights, 18 upsonde missions




NCAR/NSF GV

Mini-sonde

AVAPS launcher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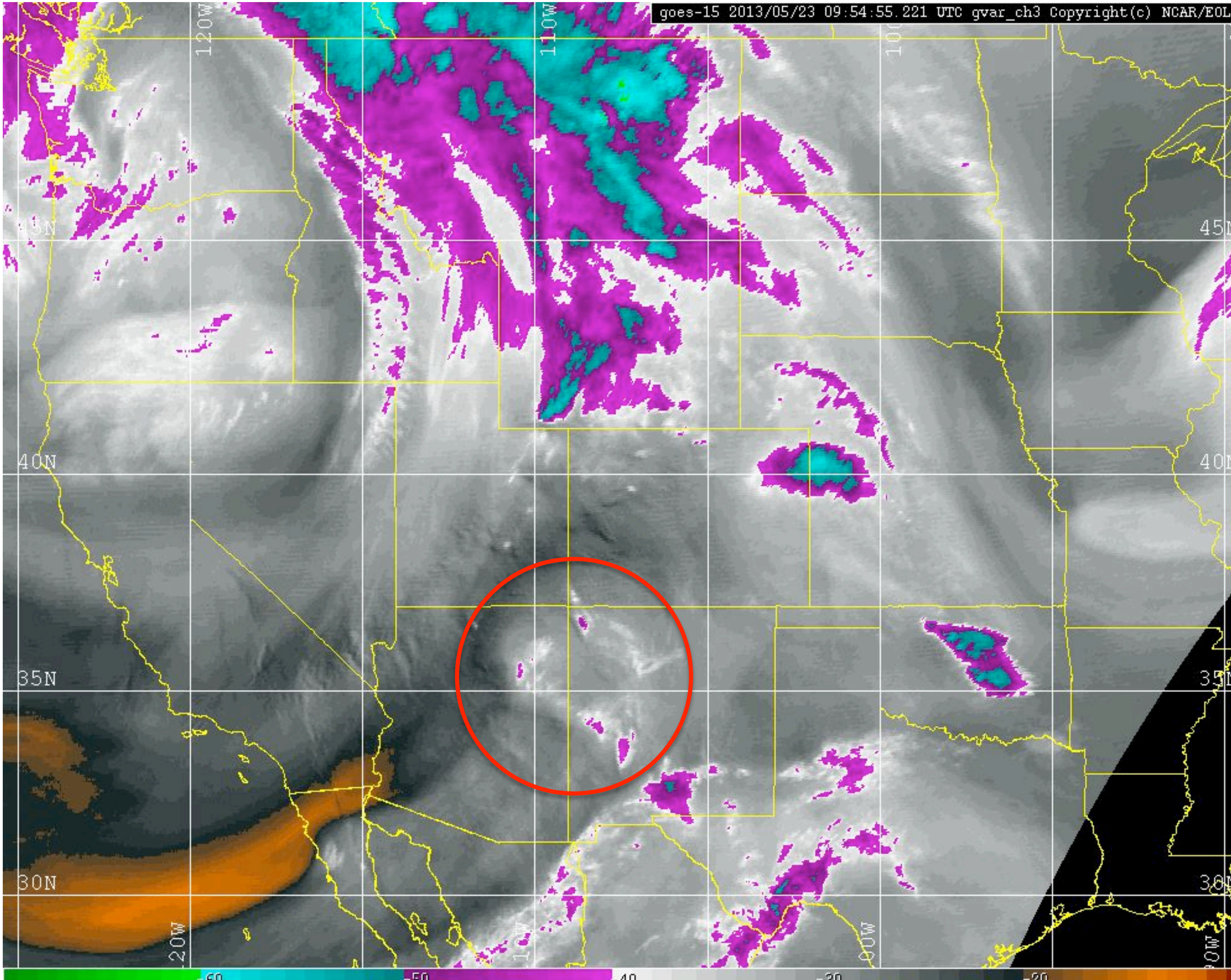
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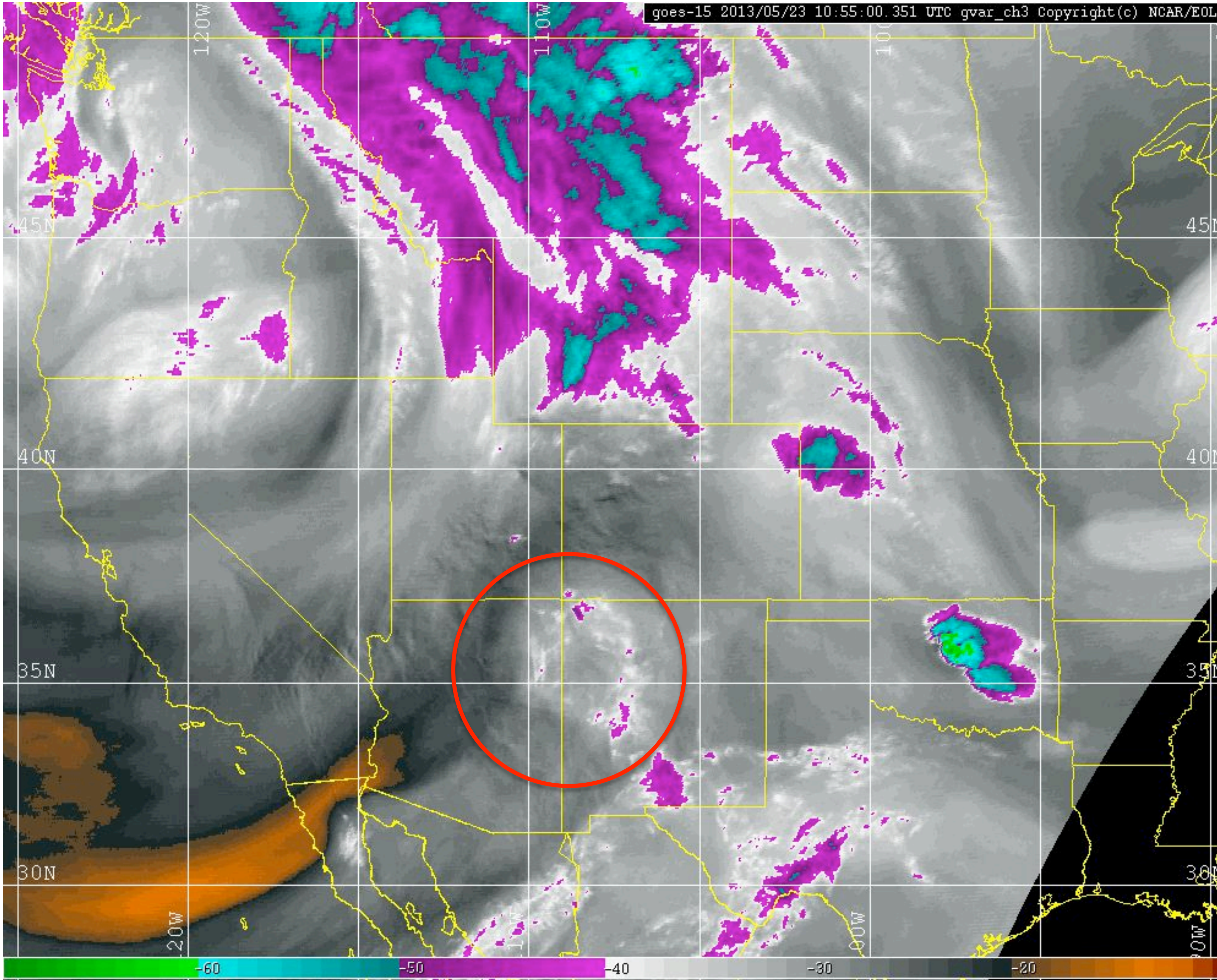

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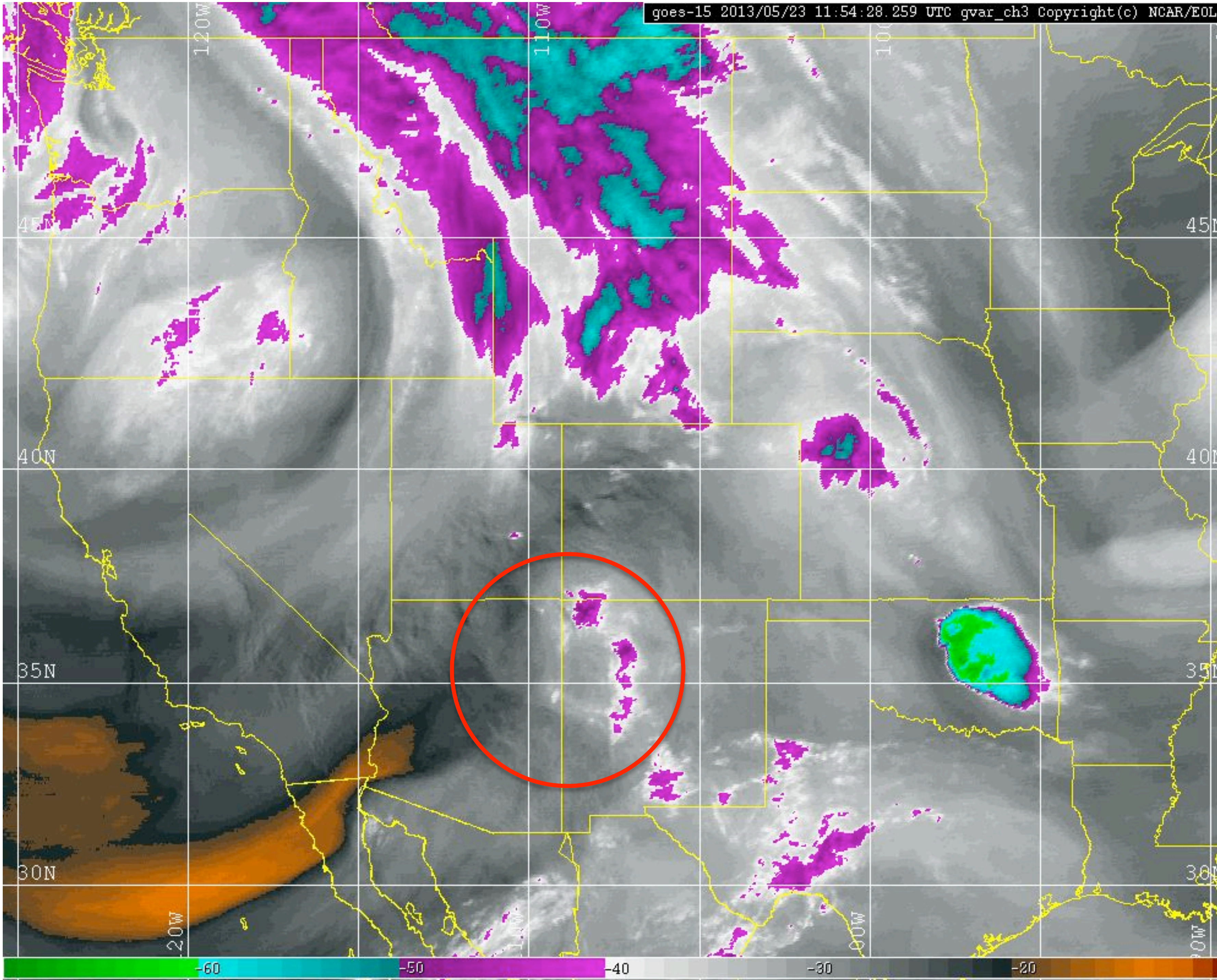

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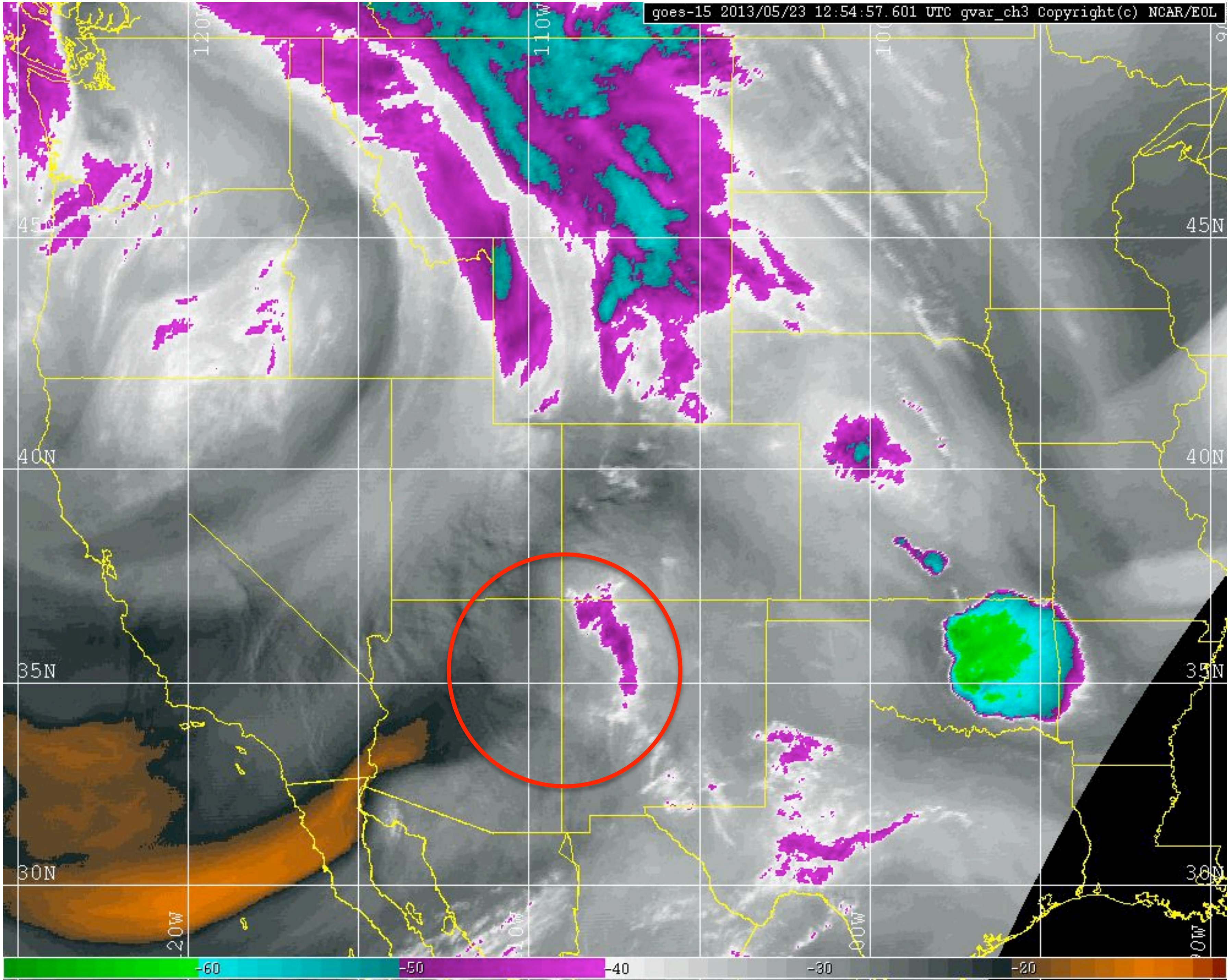
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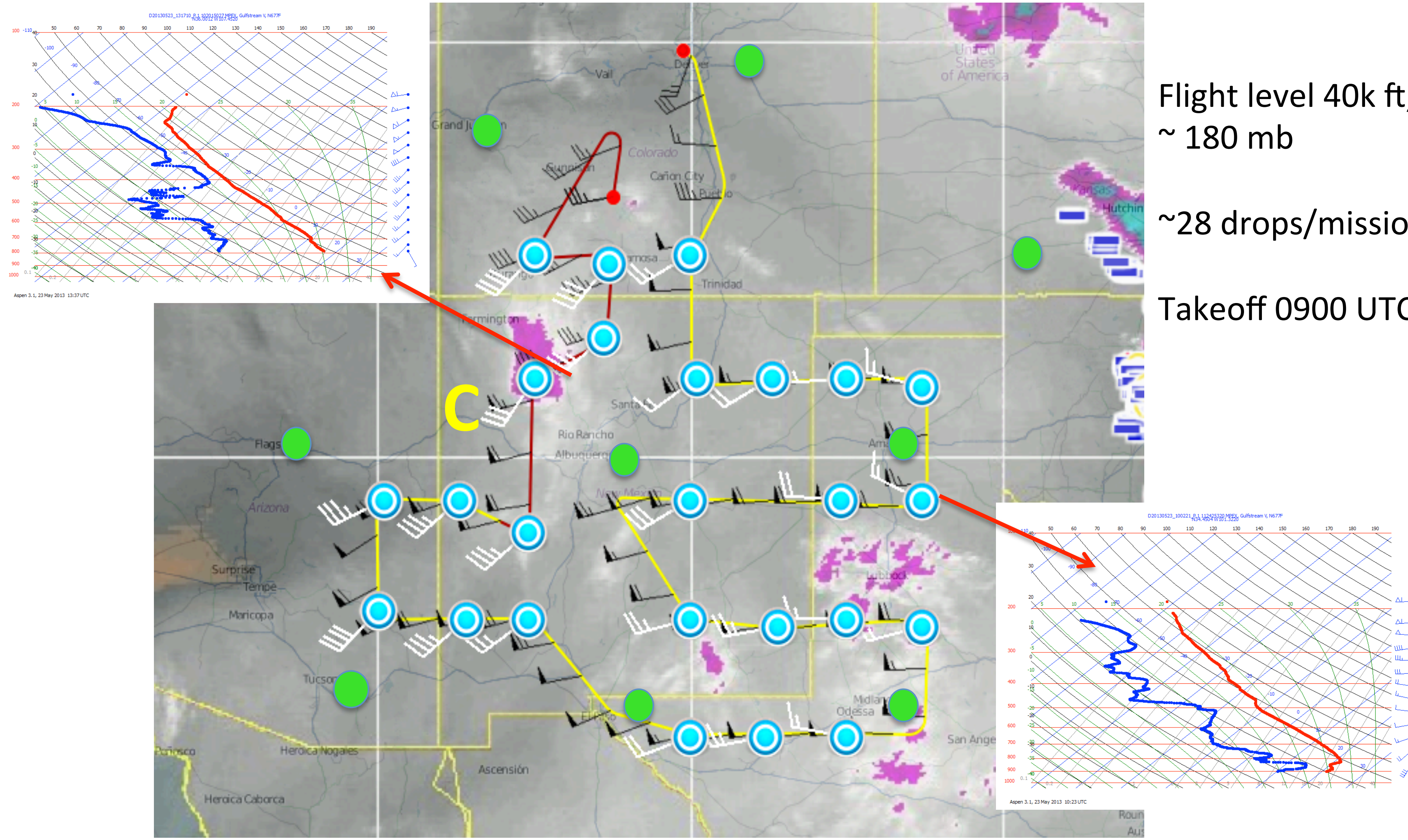
# MPEX flight operations example – 05/23/13 Water Vapor @ 14 UTC

Blue (green) dots dropsonde (operational sounding) locations

Black (white) flight level (500 mb) wind vectors




Flight level 40k ft, ~ 180 mb

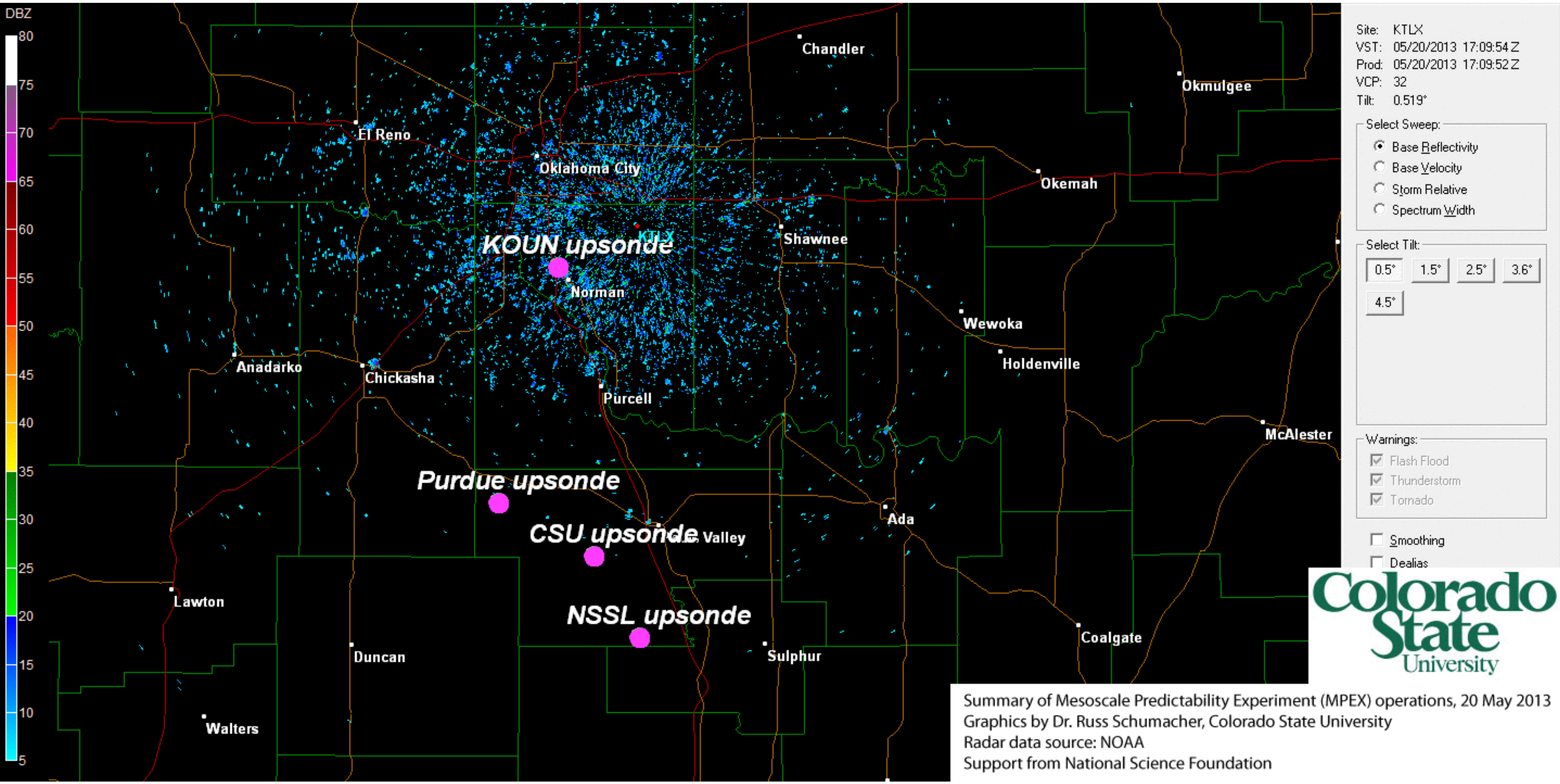
~28 drops/mission

Takeoff 0900 UTC

# MPEX upsonde operations example

– 20 May 2013 (Moore, OK tornado event)

NESL




Purdue, NSSL, CSU and Texas A&M participated in upsonde mission. ~ 20 upsondes per event.



Courtesy Russ Schumacher CSU

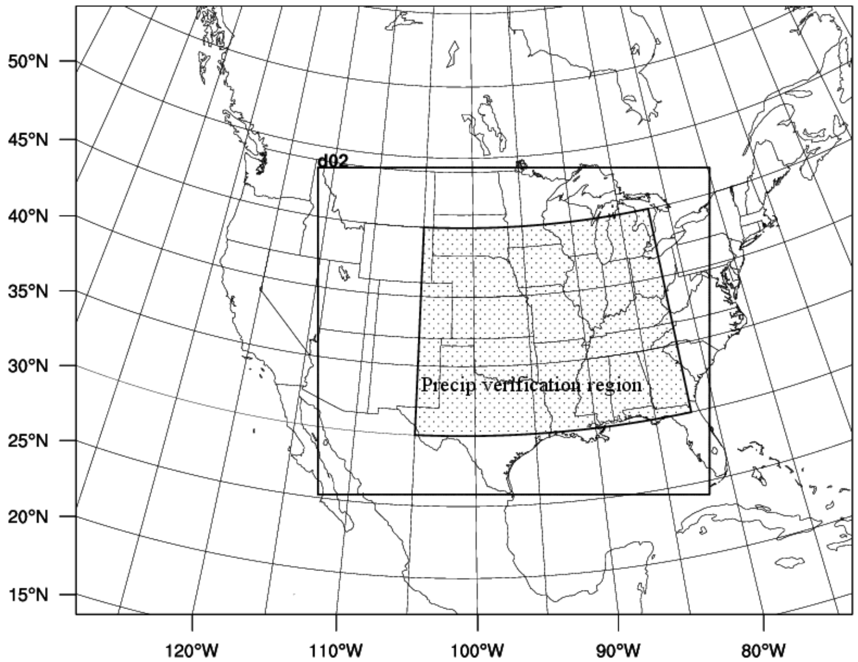
# WRF and DART configuration options

## WRF V3.3.1

- 415x325x40 (E-W)x(N-S)x(B-T), model top 50 mb
- 15 km grid spacing
- Key physics options: Tiedtke, RRTMG, Thompson, MYJ, NOAH
- Ensemble forecasts – 10 (30) member from 00 (12) UTC, 3 km grid spacing nest

## DART development branch (approx. Kodiak release)

- 50 member ensemble
- 6 hourly continuous cycling assimilation
- adaptive prior inflation, sampling error correction, adaptive localization
- conventional obs (ACARS, METAR, Radiosondes, Marine, Profiler, CIMMS motion vectors), ~180k obs/day



# Ensemble Sensitivity

$$\frac{\partial J_e}{\partial x_j} \equiv cov(\delta J, \delta \mathbf{x}_{o,j})\mathbf{D}_j^{-1} = \frac{cov(\mathbf{J}, \mathbf{X}_j)}{var(\mathbf{X}_j)}$$

Covariance between forecast metric and state divided by state variance

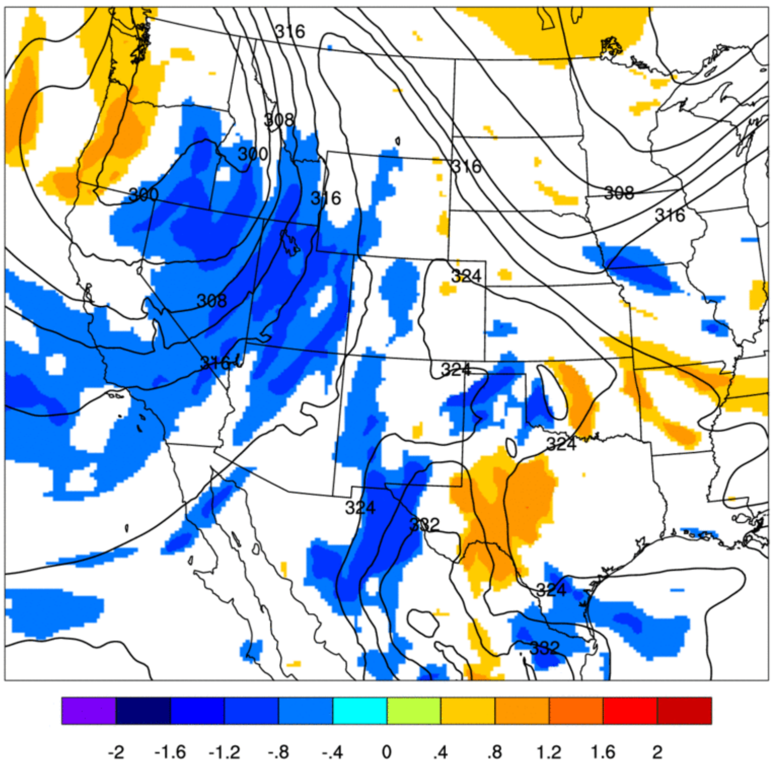
Ancell and Hakim 2007, Torn and Hakim 2008

- Ensemble-based method of computing the sensitivity to the initial conditions (or prior forecast states)
- Above equation is linear regression based on ensemble:
  - Dependent variable is ensemble estimate forecast metric (e.g. average accumulated precipitation over an area)
  - Independent variable is ensemble estimate of state variable (e.g. mid-tropospheric humidity)
- Works best when the forecast metric is more continuous
- Can also compare subset of members that have particular metric properties (e.g. max – min metric groups)

# Sample ensemble sensitivity:

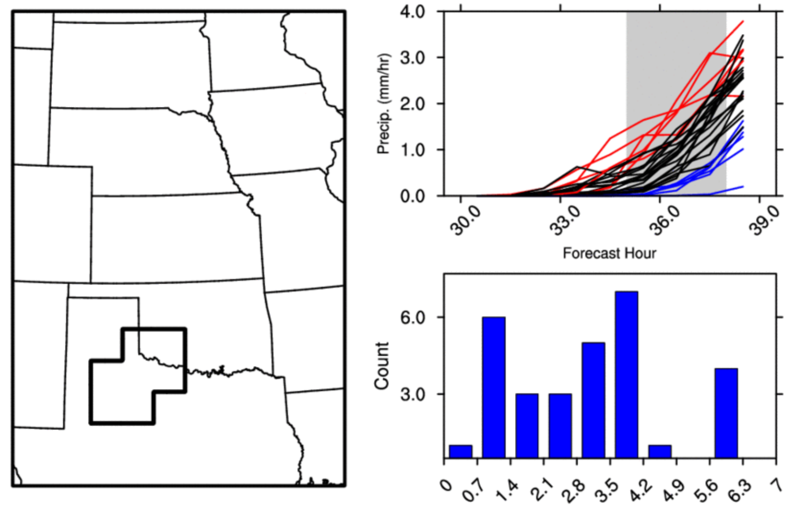
Warm (cool) colors – increase (decrease) in field at 12 UTC associated with more precip in area at right from Fhr 35-38

2-6 km theta-e valid 2013052312 (F024)

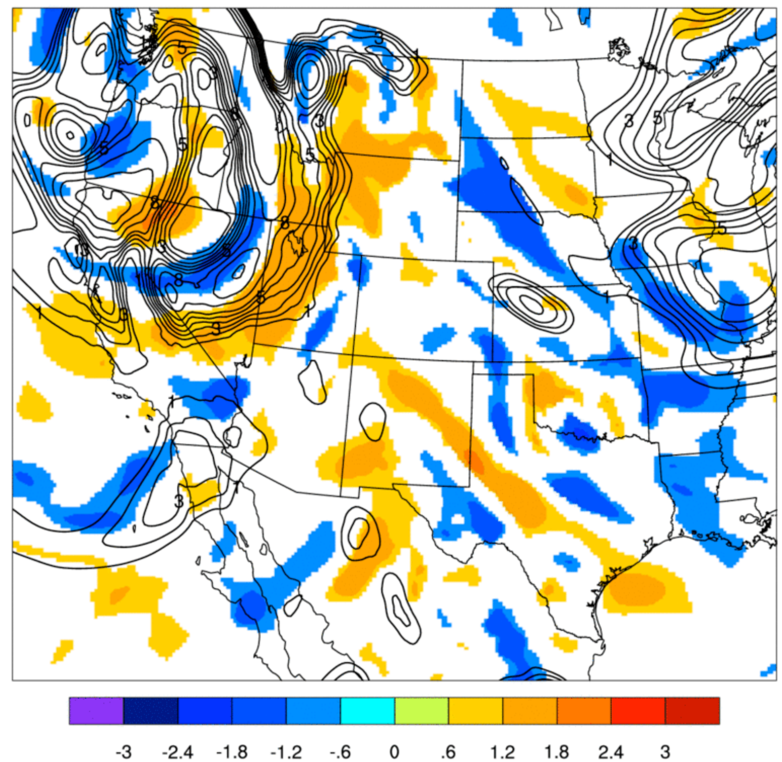



Theta-e tongue further east, trough further east leads to more precipitation in box

2013052212 Precipitation Metric




500 hPa vorticity valid 2013052312 (F024)



# Hypothetical observation impact

- Ensemble-based method allows for estimate of observation impact
  - Can get change in metric value if you know observation properties, ensemble metric values and observation value itself
  - Can get reduction in variance knowing first two above (no need for observation)

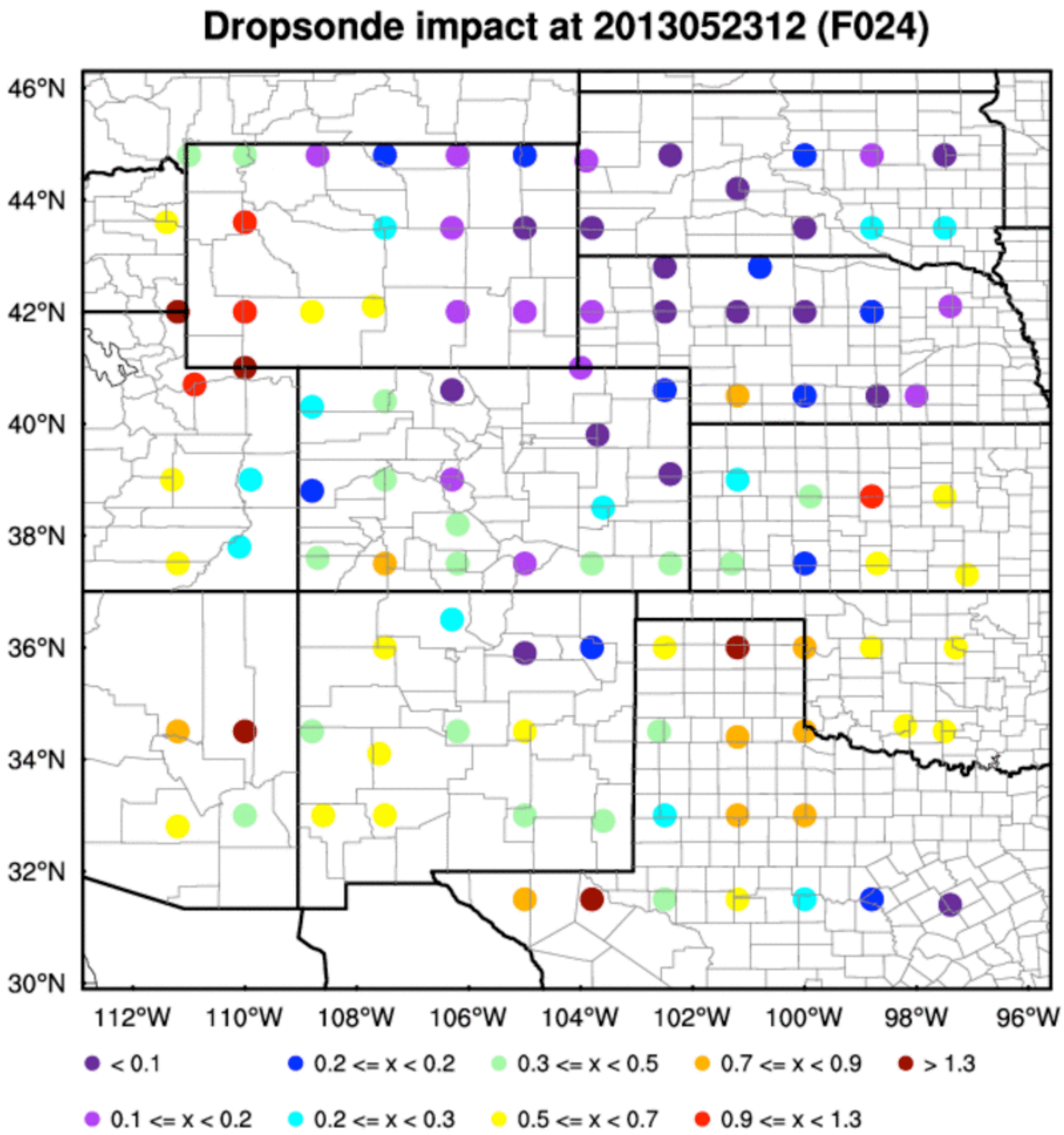
$$\delta J = \mathbf{J}(\mathbf{H}\mathbf{X}^b)^{\mathrm{T}}(\mathbf{H}\mathbf{P}^b\mathbf{H}^{\mathrm{T}} + \mathbf{R})^{-1}[\mathbf{y} - \mathcal{H}(\mathbf{x}^b)]$$

Change in Forecast metric — slope — innovation covariance — innovation

$$\delta\sigma = -\mathbf{J}(\mathbf{H}\mathbf{X}^b)^{\mathrm{T}}(\mathbf{H}\mathbf{P}^b\mathbf{H}^{\mathrm{T}} + \mathbf{R})^{-1}\mathbf{H}\mathbf{X}^b\mathbf{J}^{\mathrm{T}}$$

Change in forecast metric variance — Forecast metric observation covariance x inverse innovation covariance

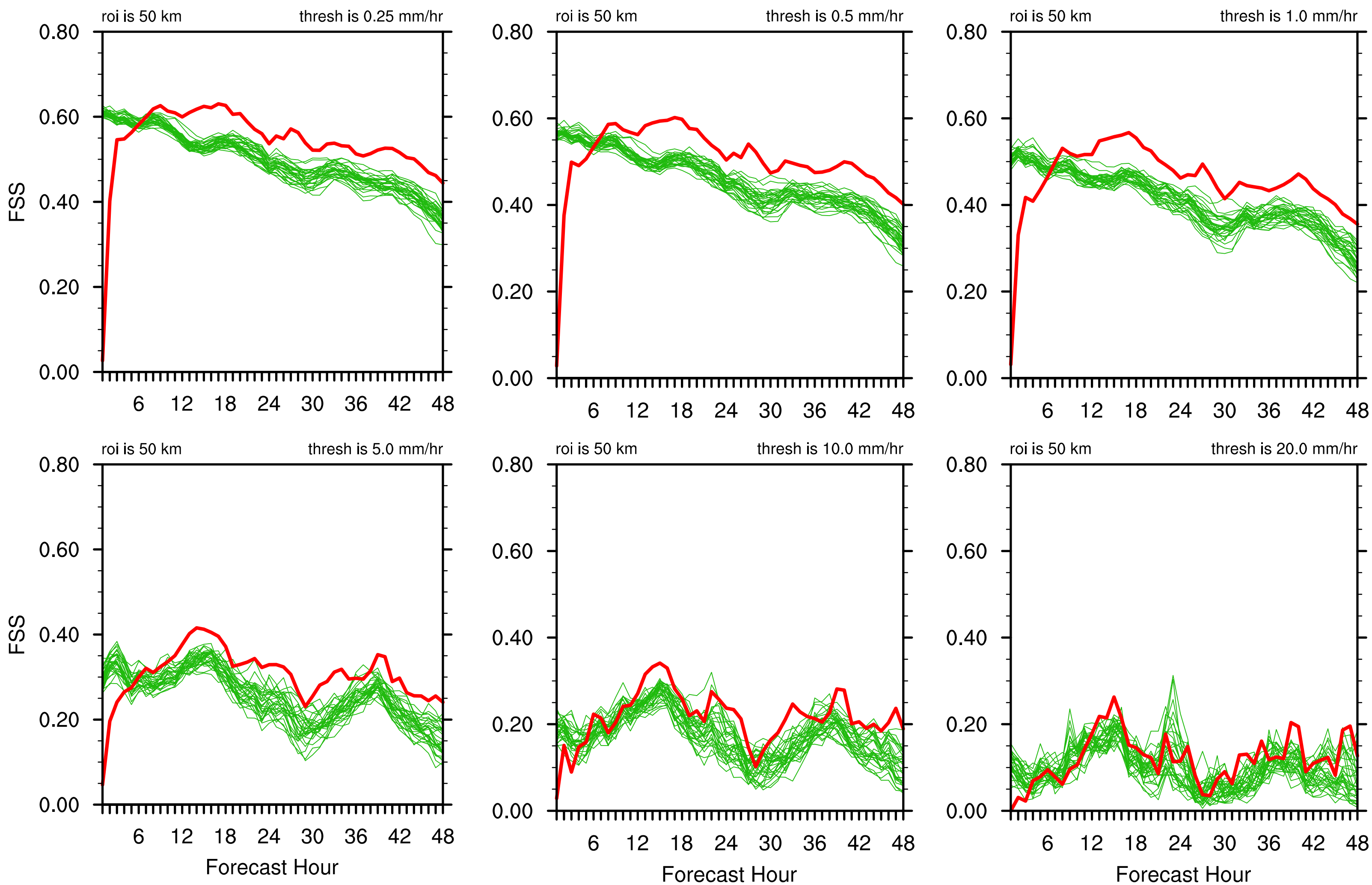
See Torn and Hakim 2008, MWR




Highest impact associated with synoptic features, mid-troposphere theta-e, surface theta-e, and the sampled mid-troposphere disturbance in NM/AZ

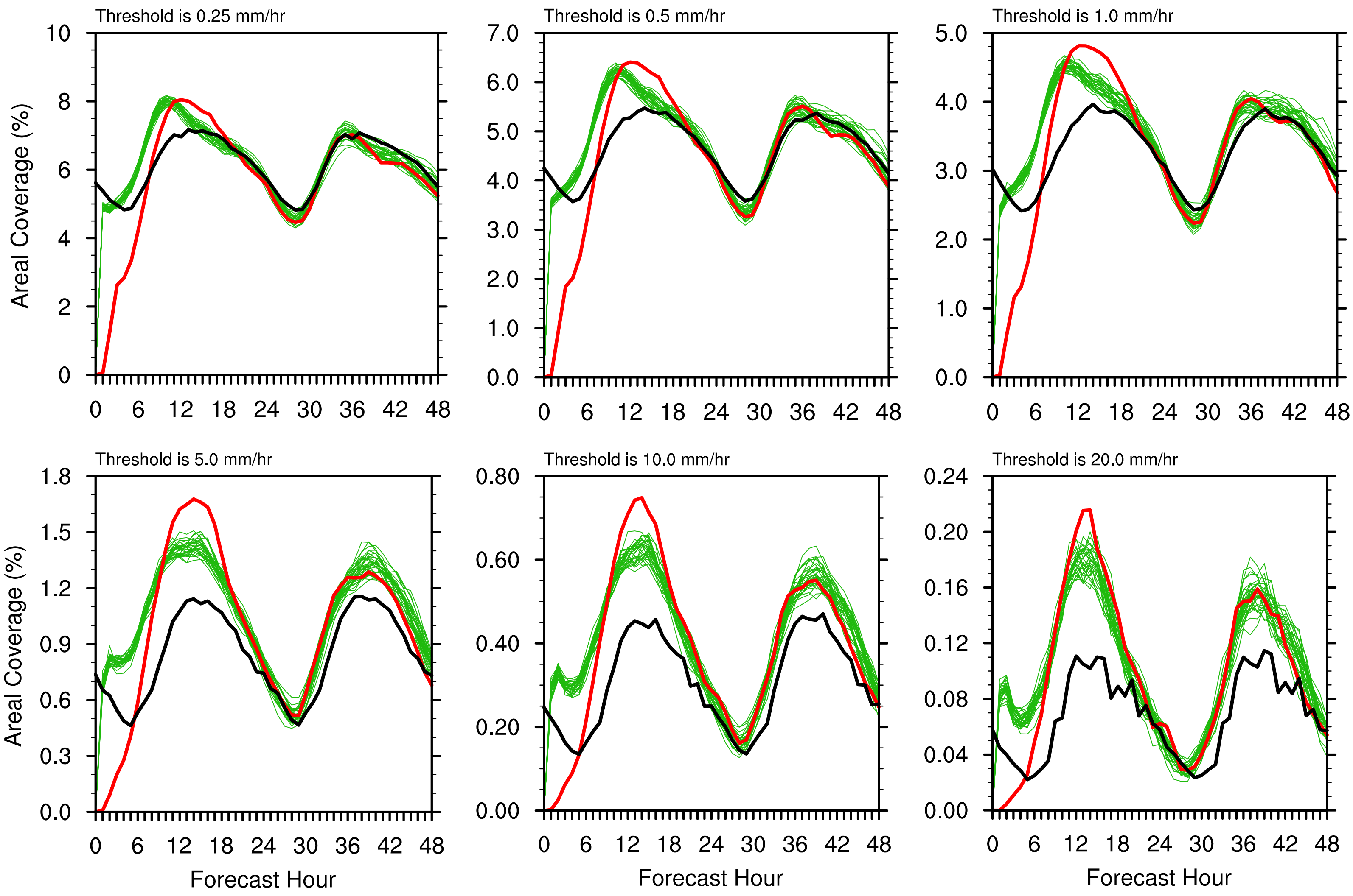
# Fractions Skill Score

50 km radius of influence, by Fhr for NCAR ensemble vs. GFS IC

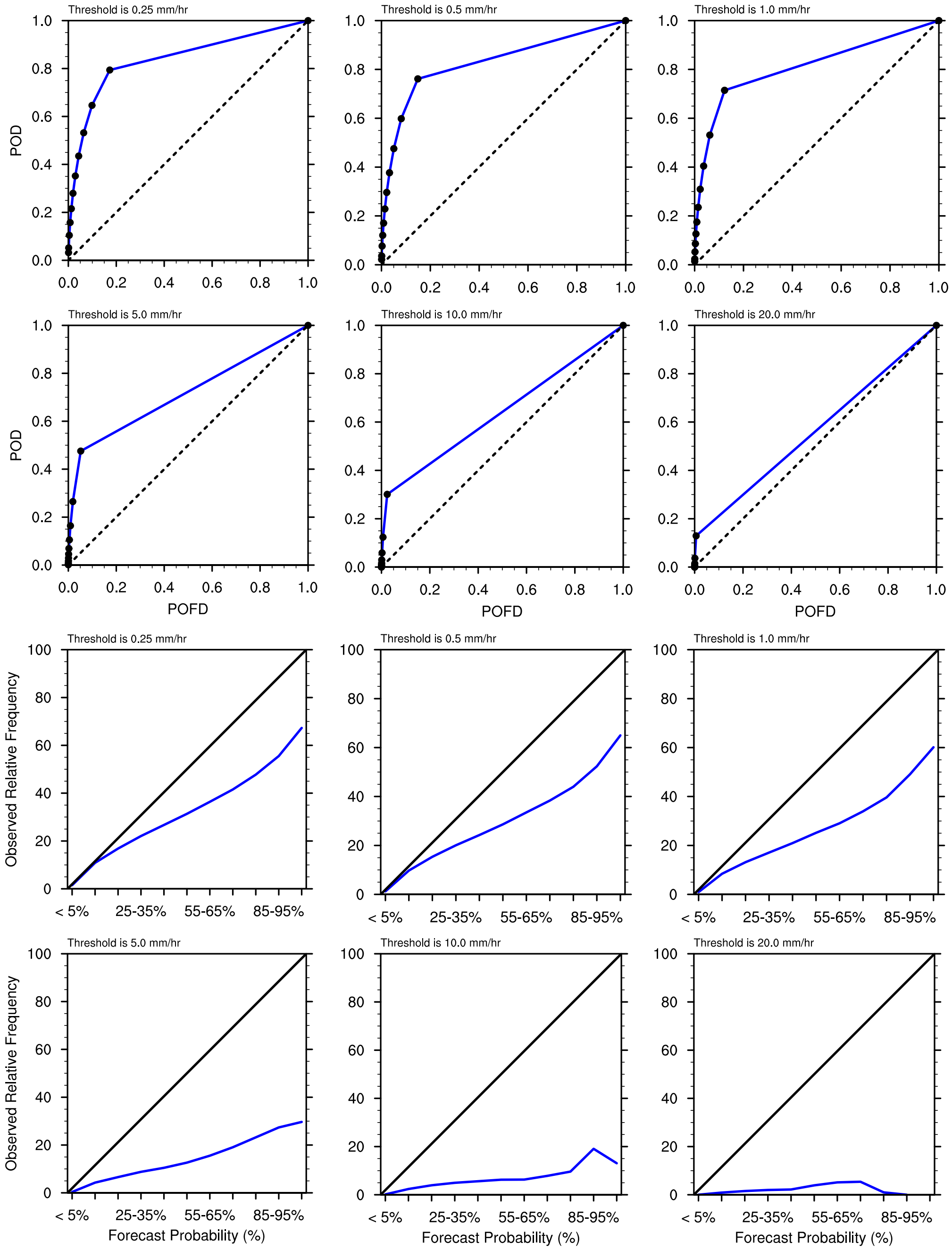



$$FBS = \frac{1}{N}\sum_{i=1}^{N}(f_i - o_i)^2, \quad FBS_{worst} = \frac{1}{N}\sum_{i=1}^{N}(f_i^2 + o_i^2) \quad FSS = 1 - \frac{FBS}{FBS_{worst}}$$

**Areal coverage by rain rate threshold**, ensemble (green), GFS (red), and ST4 observed (black). Day 1 NCAR ens early peak in diurnal, GFS especially higher bias day 1 [but both too wet day 1, better day 2].



# Gridscale ROC and reliability




## F1-12 ROC diagrams

Relative operating characteristic curves, skill when left of diagonal

## F1-12 Reliability diagrams

Over (under) dispersive left (right) of diagonal

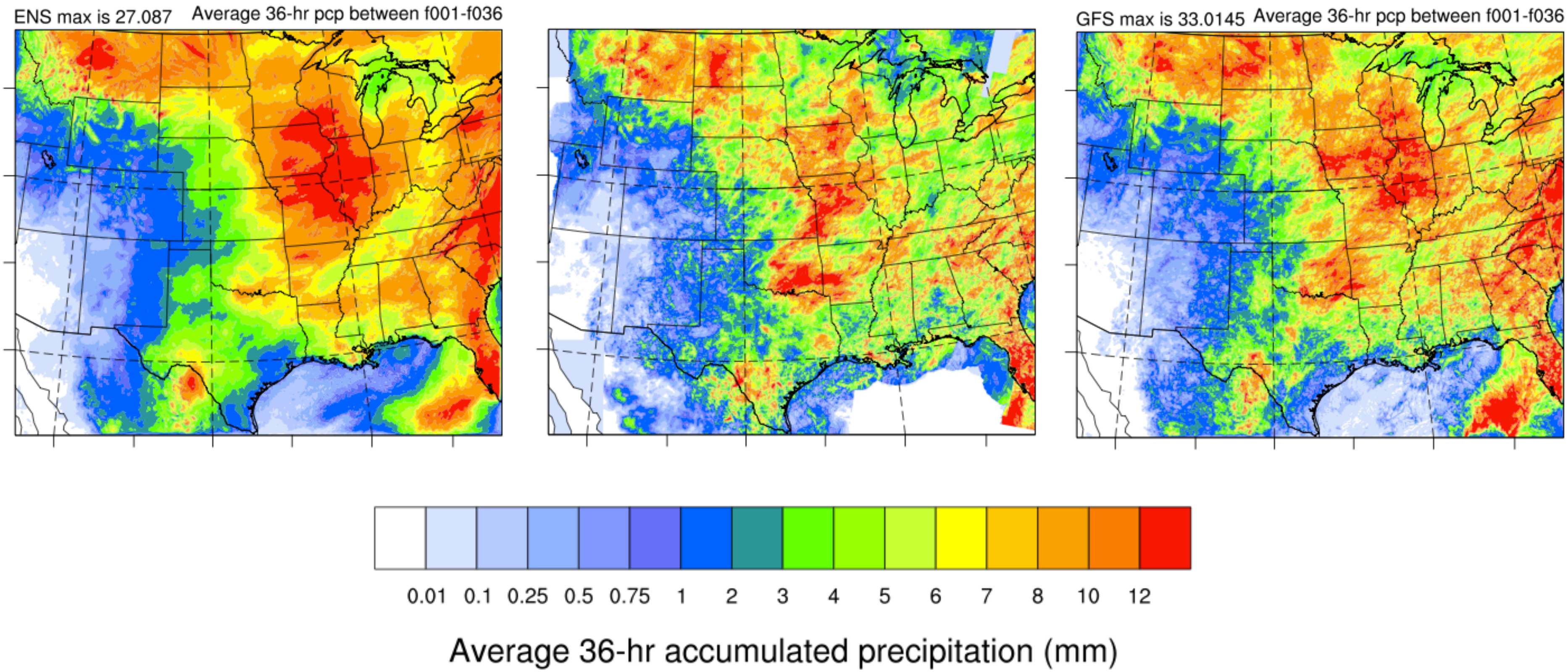
A neighborhood approach would lead to 'improved' stats

# Average accumulated precipitation from 36 h 12 UTC initialized forecasts

WRF-DART ensemble mean

Stage IV (**observations**)

GFS initial condition deterministic

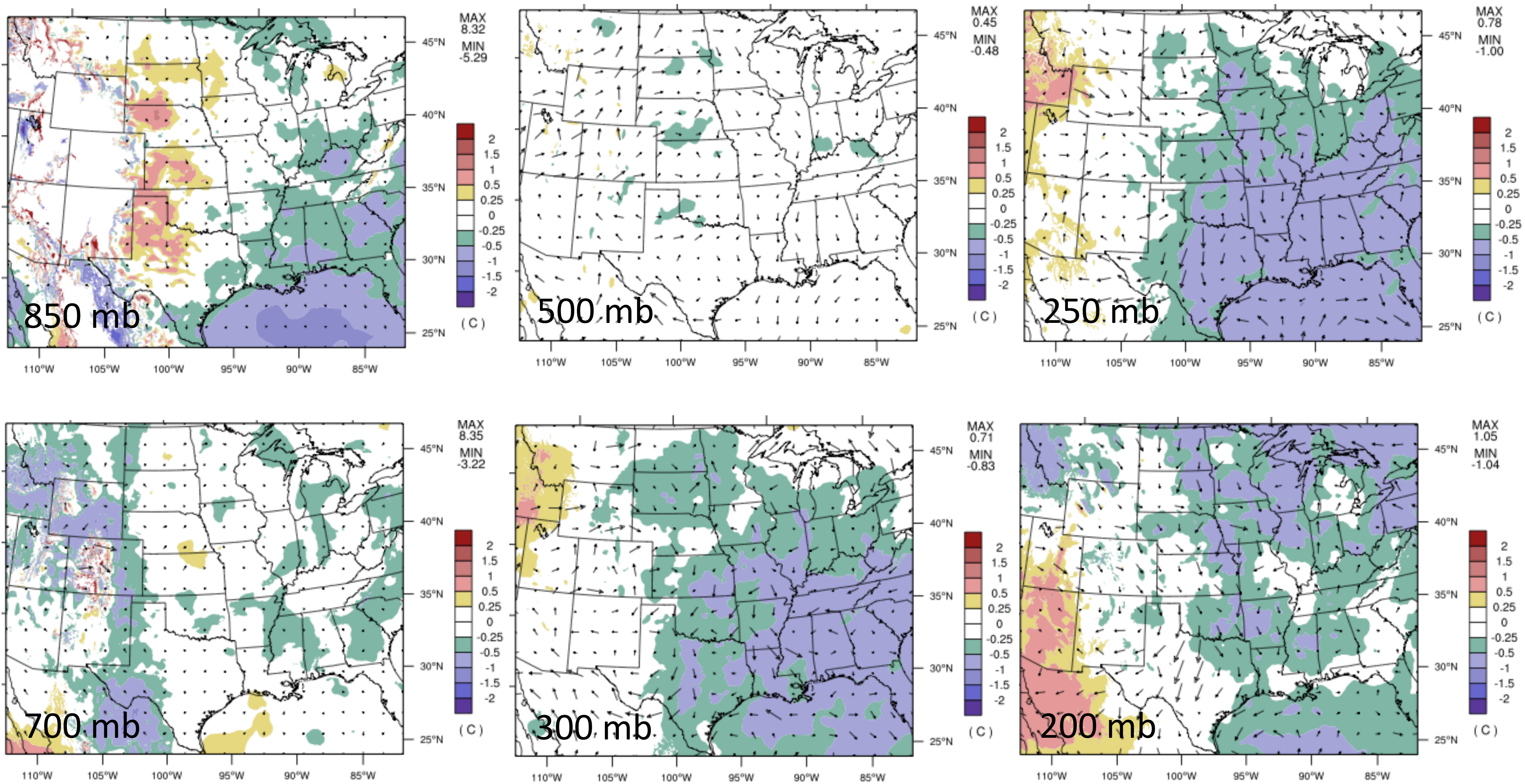



Forecast errors are more like each other than the observations, but generally both compare well.

# Mean difference (5/14-6/15) between WRFDART analysis and downscaled GFS analysis temperature on nest domain for 12 UTC initial conditions – WRF physics related drift?

**EKF-GFS**

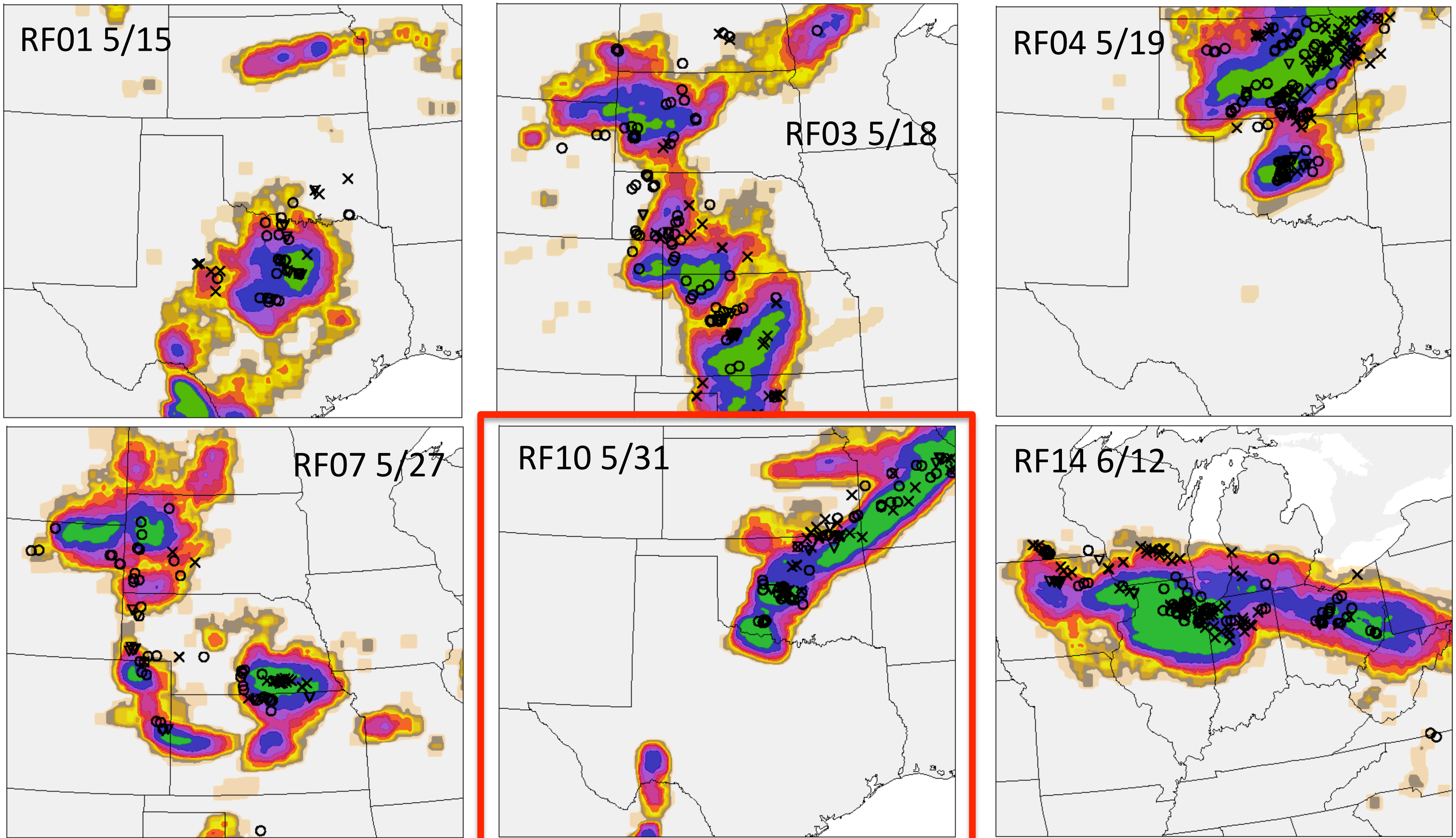
NESL




Will need to evaluate both against obs

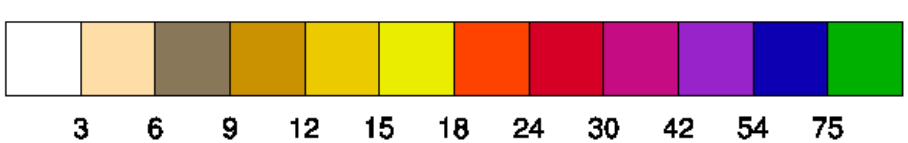
May need to include climatological covariances in continuously cycled assimilation to control drift

# Probability of organized convection from 12 Z fcsts, storm reports

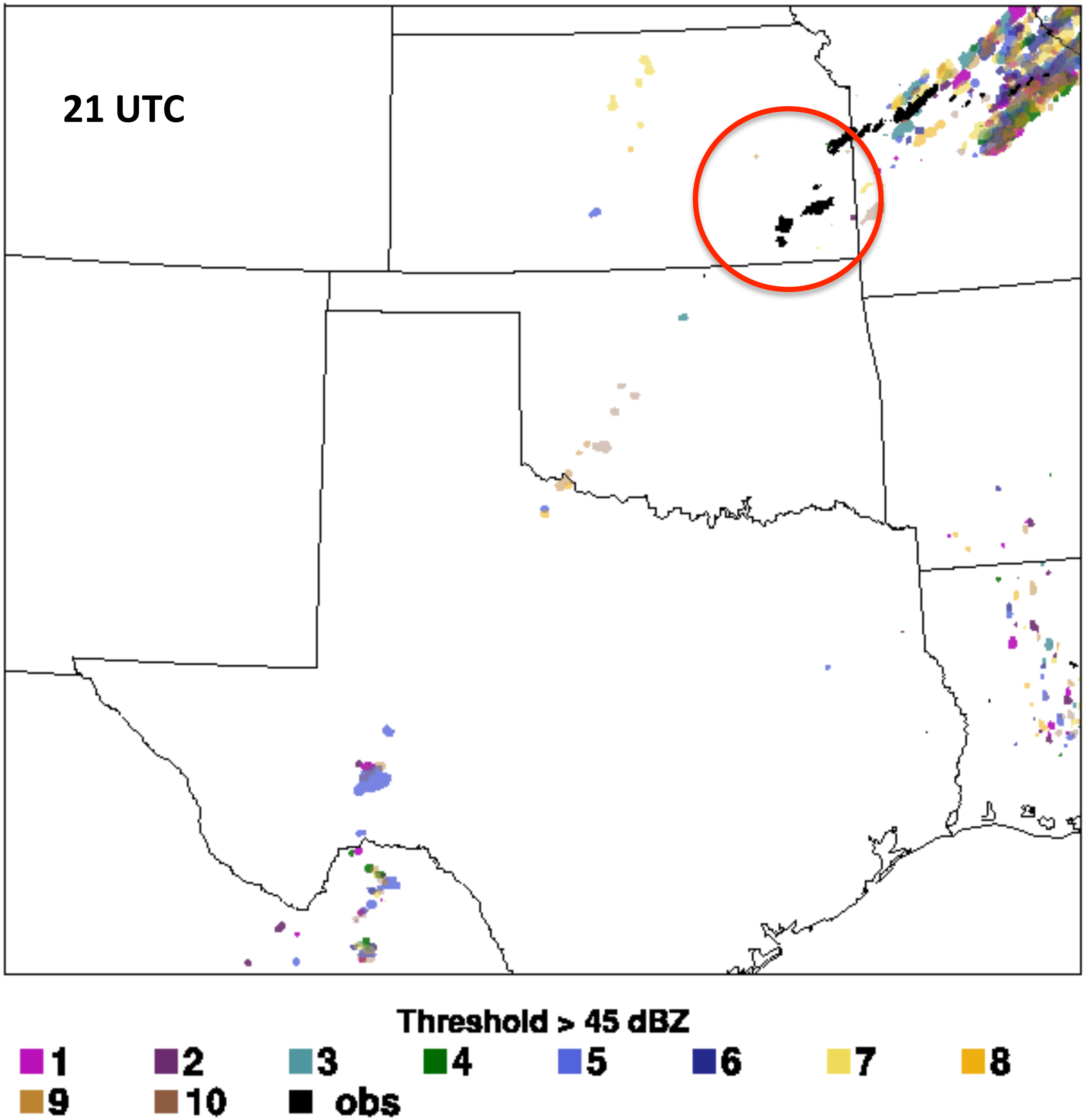



30 member, 50 km neighborhood, 6-15 Fhr

High POD but also high FAR



2013-05-31 12 Z ensemble fcst, reflectivity > 45 dBZ, mem 1-10 (color) and obs (black)



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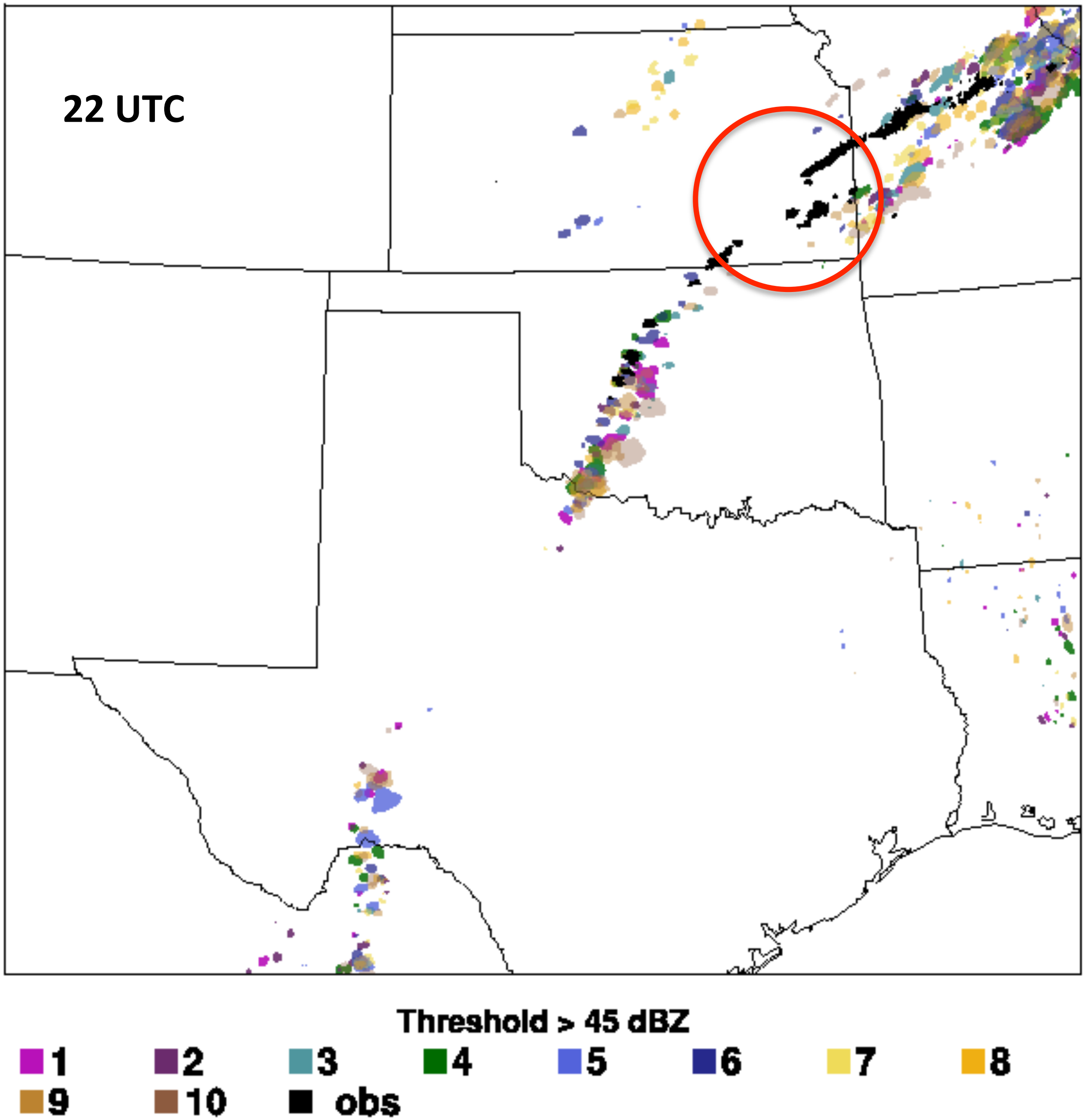

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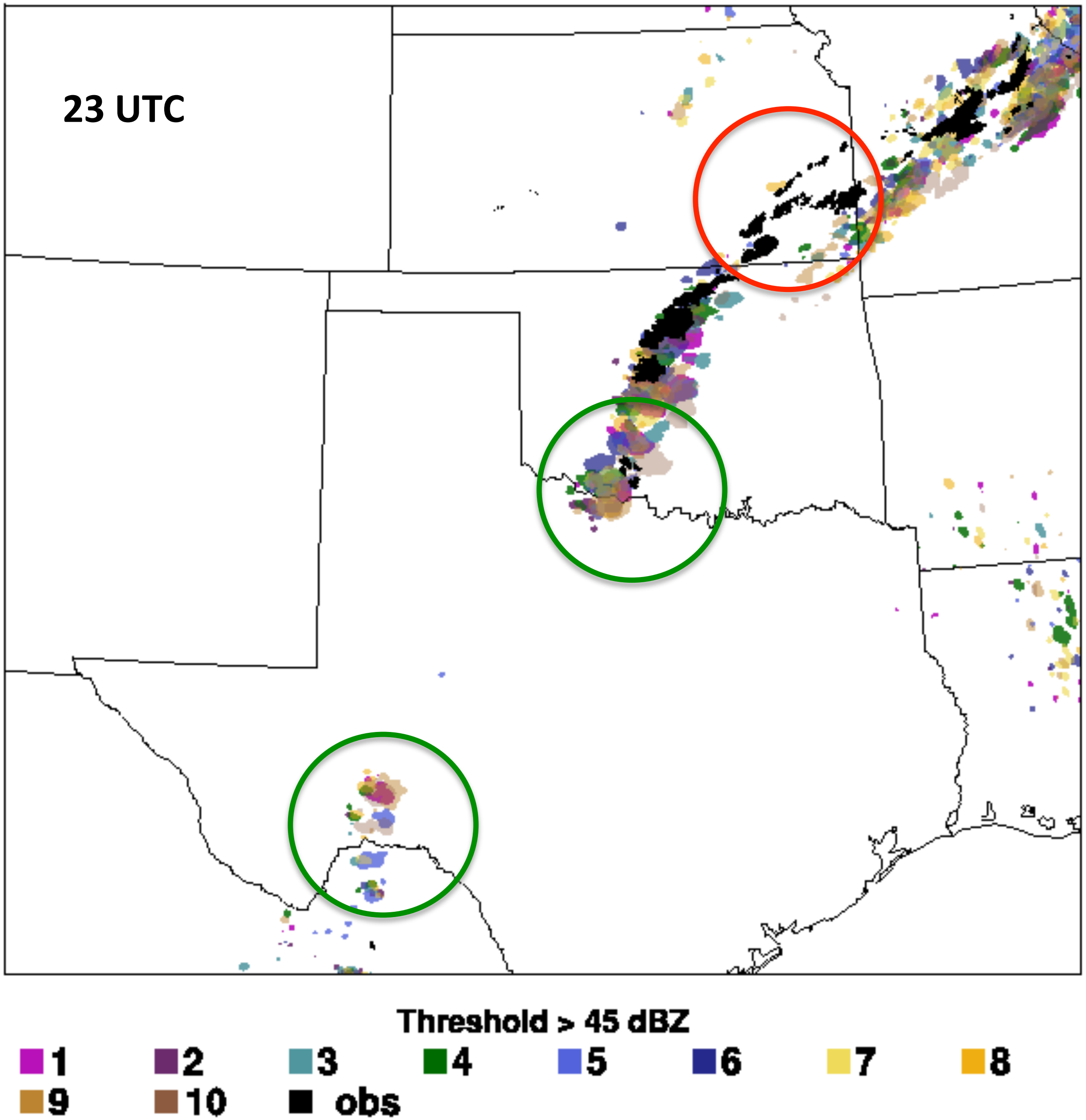

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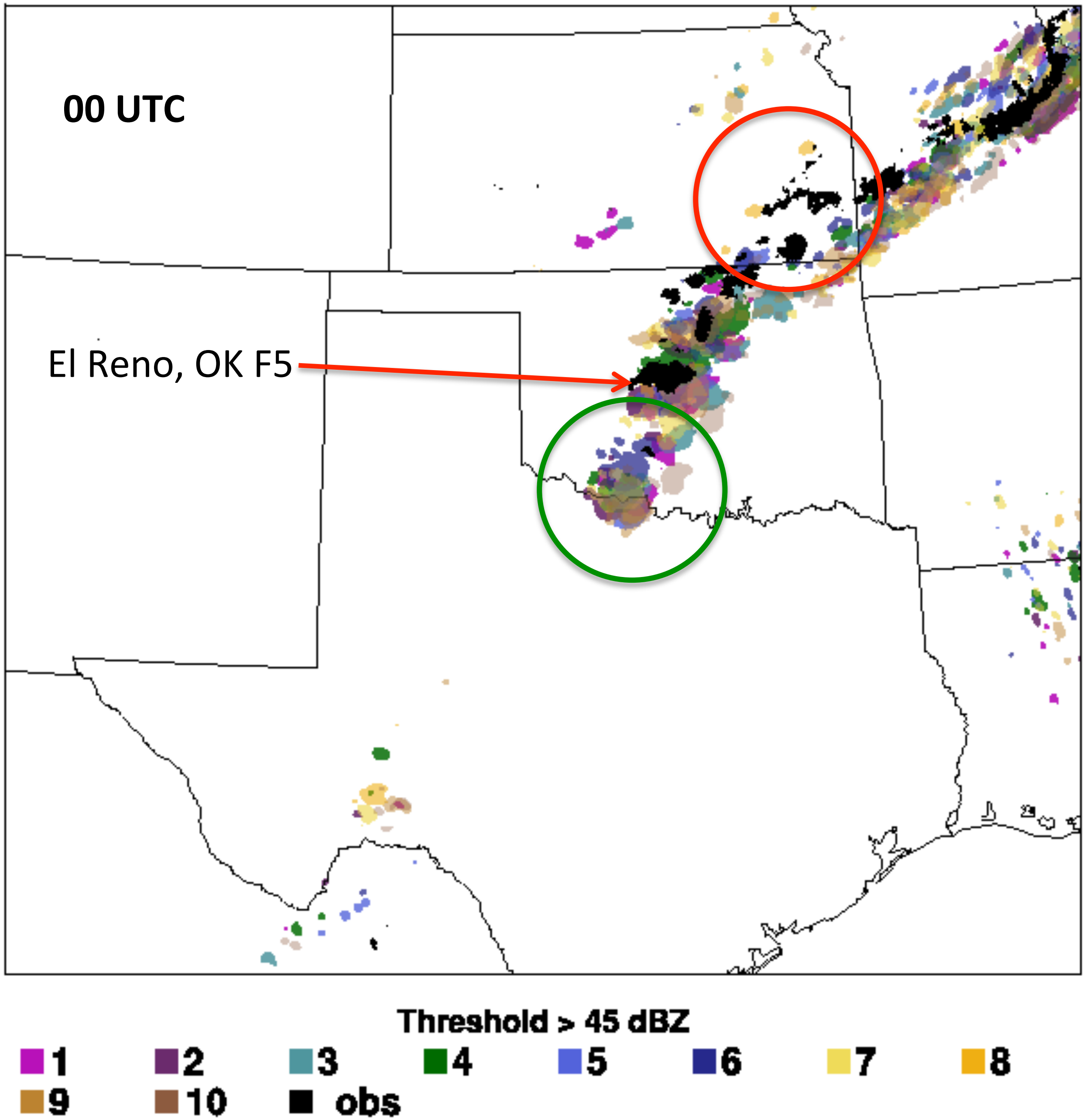

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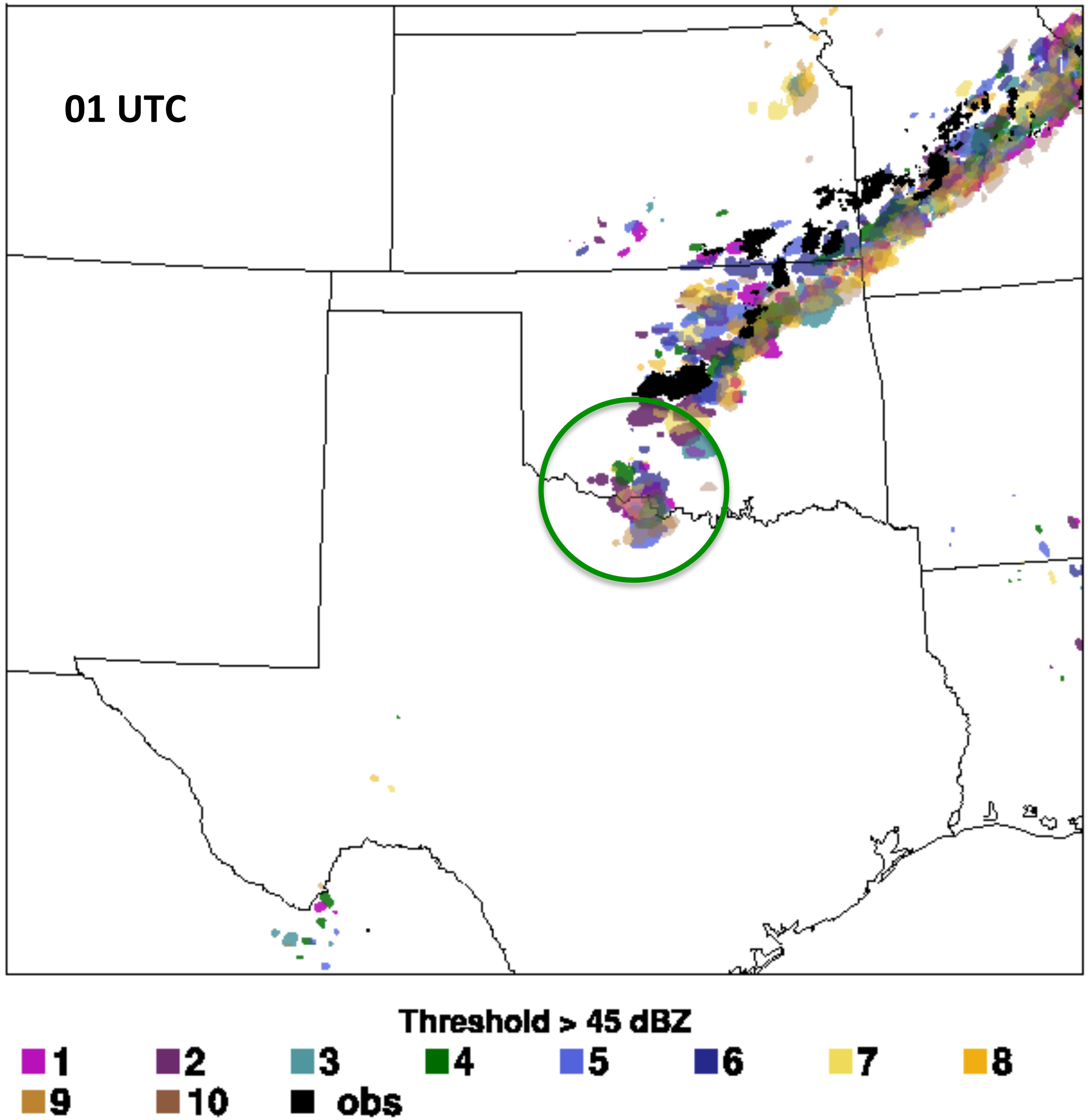

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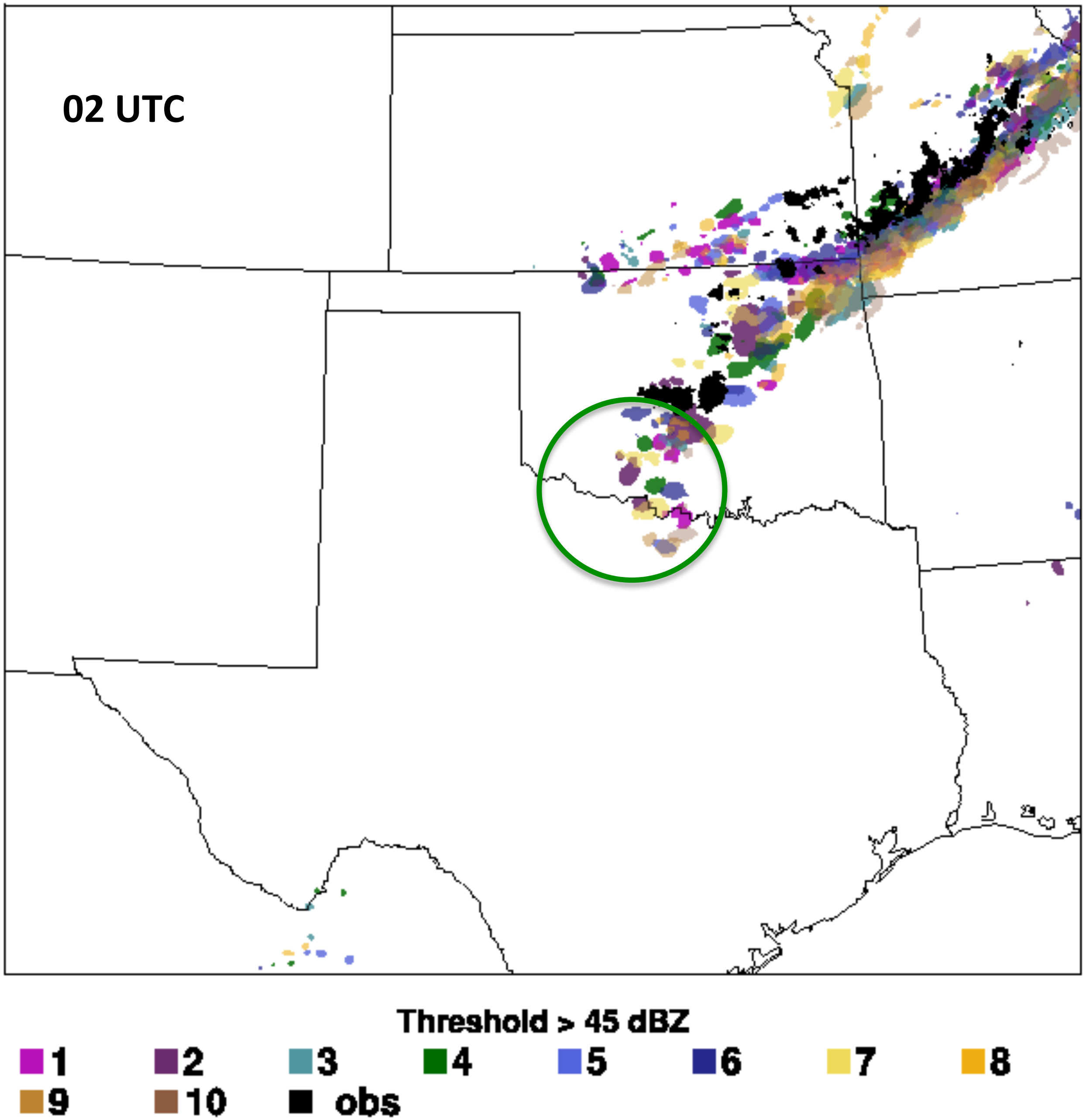

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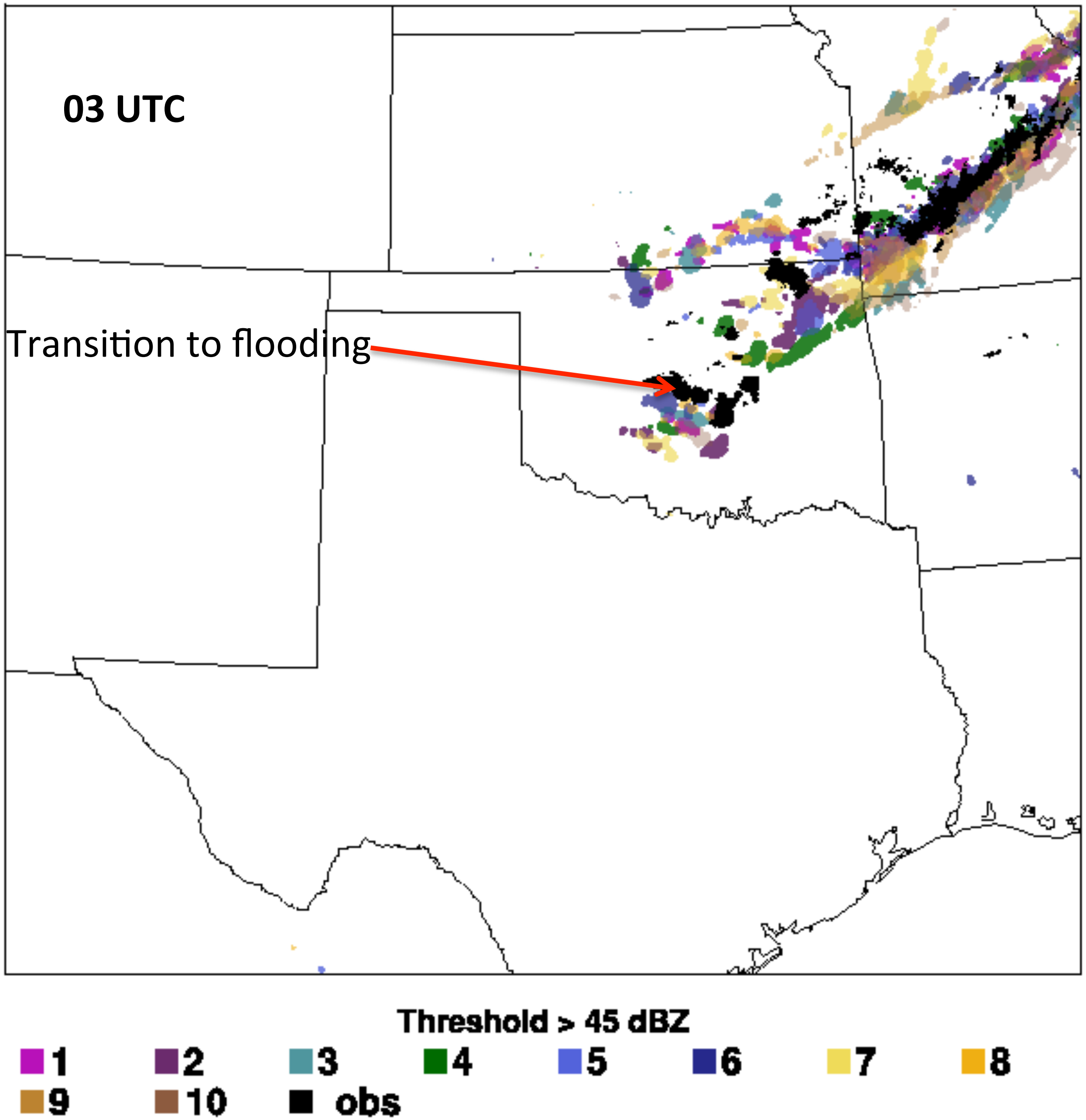

# Summary, future work

- 2013 marked 10th consecutive season of NCAR realtime spring convection permitting (CP) forecasts – first season with ensembles, 3rd with WRF-DART initial conditions

- Ensemble forecasts during MPEX provided useful guidance of significant severe weather hazards during day 1 of the forecast (many strongly forced events)

- Further evidence of 'drift' in continuously cycled WRF model forecasts – unique manifestation this season, will compare both analyses to obs

- Ensemble sensitivity application to targeted observing strategies will be further explored

- We will be assimilating MPEX sondes in retrospective studies with WRF-DART with subsequent CP ensemble forecasts (data denial obs impact experiments)

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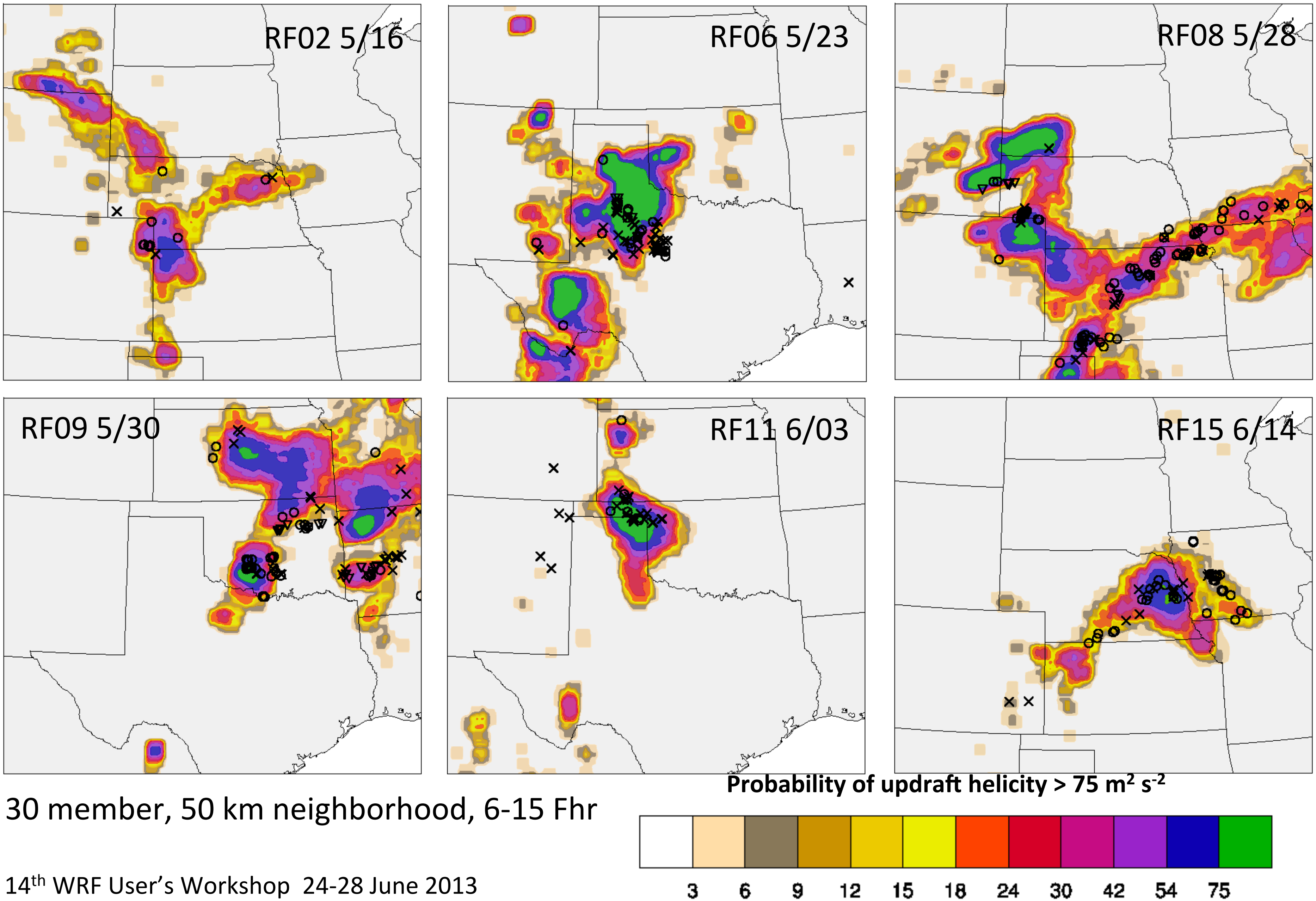


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