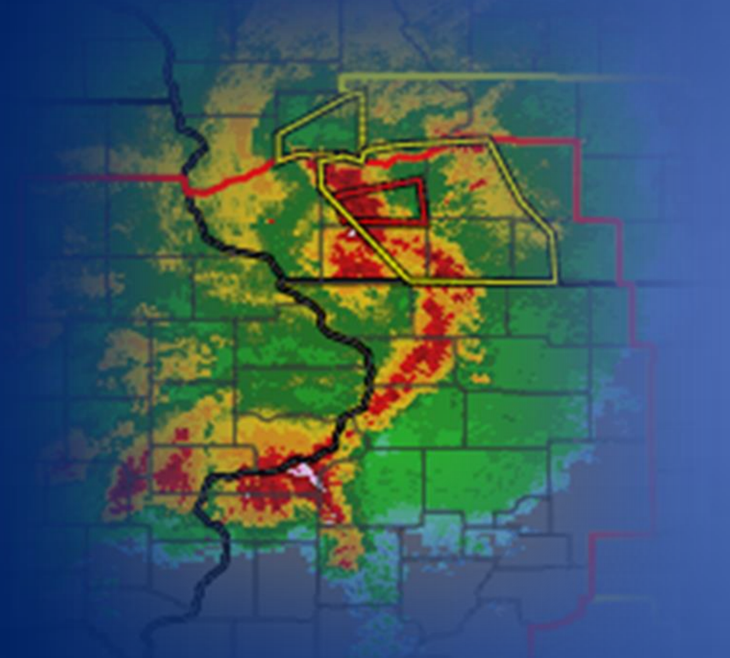
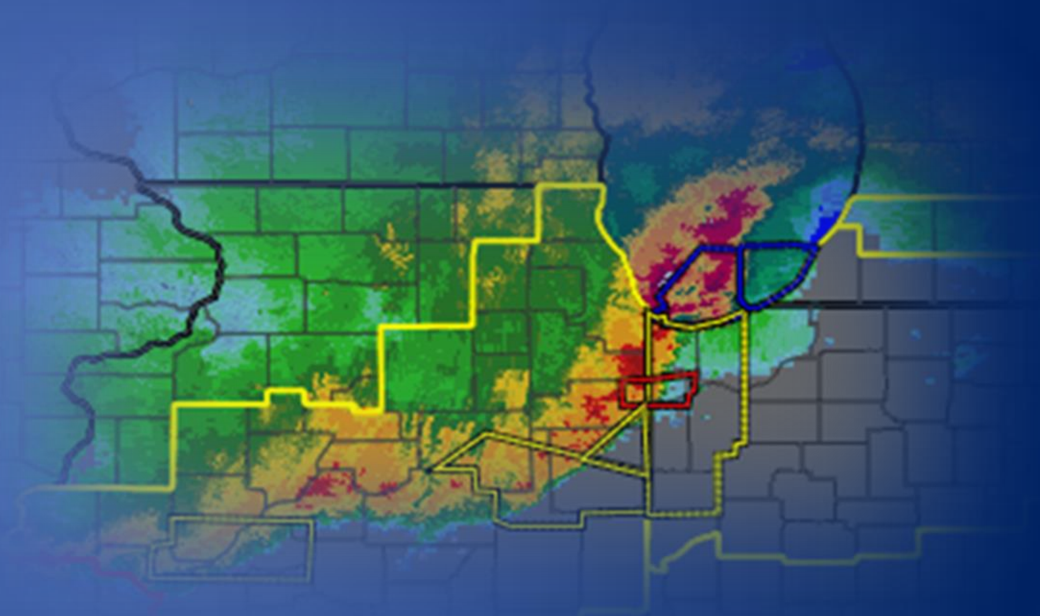
Evolution of the 30 June 2014 Double Derecho Event in Northern Illinois & Northwest Indiana





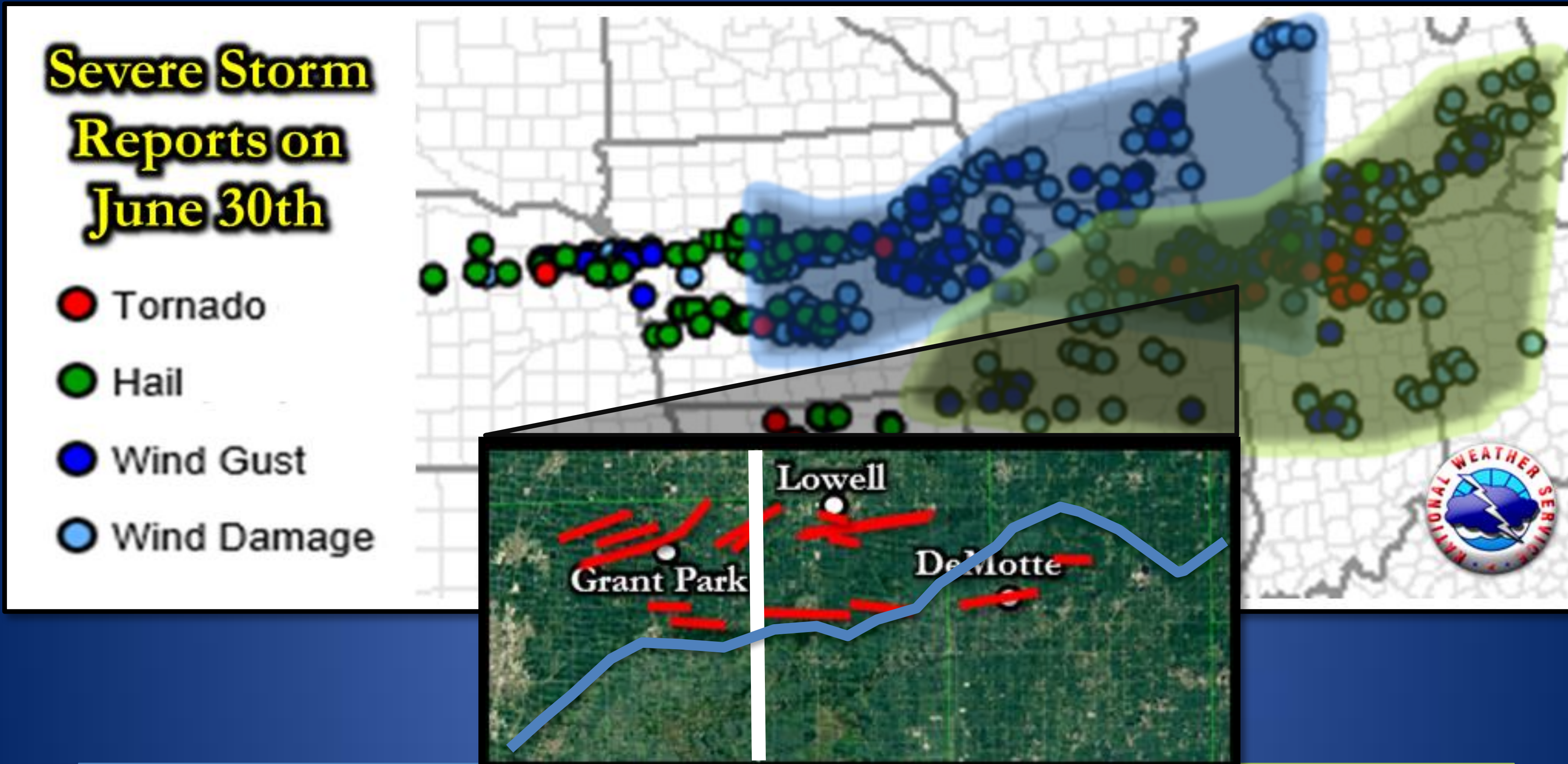
Eric Lenning, Matthew Friedlein, & Richard Castro
NOAA/National Weather Service – Chicago, IL

Anthony Lyza & Kevin Knupp
Atmospheric Sciences Department, University of Alabama in Huntsville

23rd Great Lakes Operational Meteorology Workshop: *August 24-27, 2015*

Outline & Takeaways

- *Quick* event summary
- *Brief* synoptic and mesoscale evolution
- Why was second derecho more intense, and a prolific QLCS tornado producer?
  - What from the first MCS actually helped?
  - Storm scale factors



First Derecho

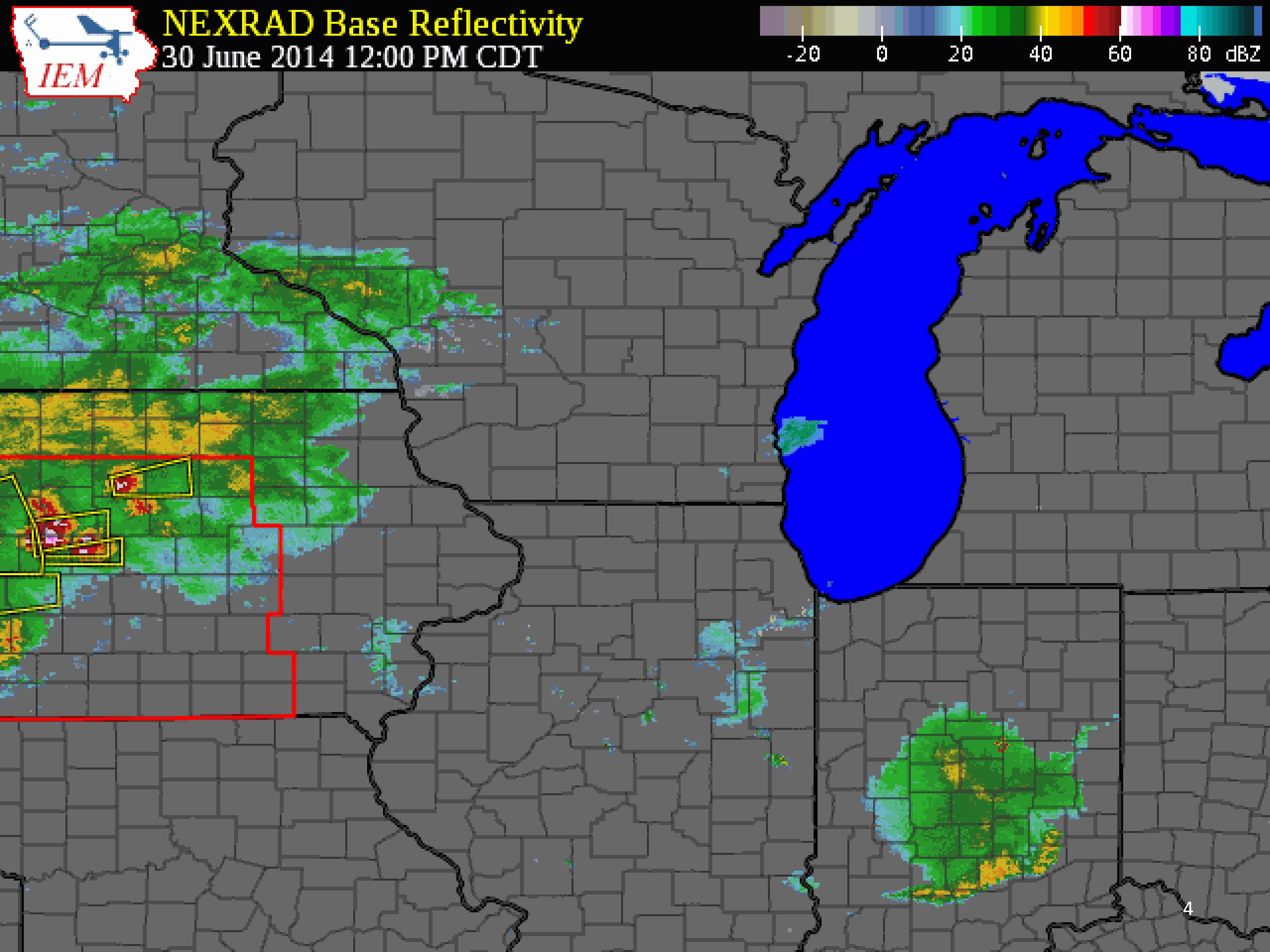
Time: 1:45 pm – 7:30 pm CDT
Wind: 112
Tornadoes: 2
Hail: 28

Second Derecho

Time: 8 pm – 2 am CDT
Wind: 119
Tornadoes: 29
Hail: 3

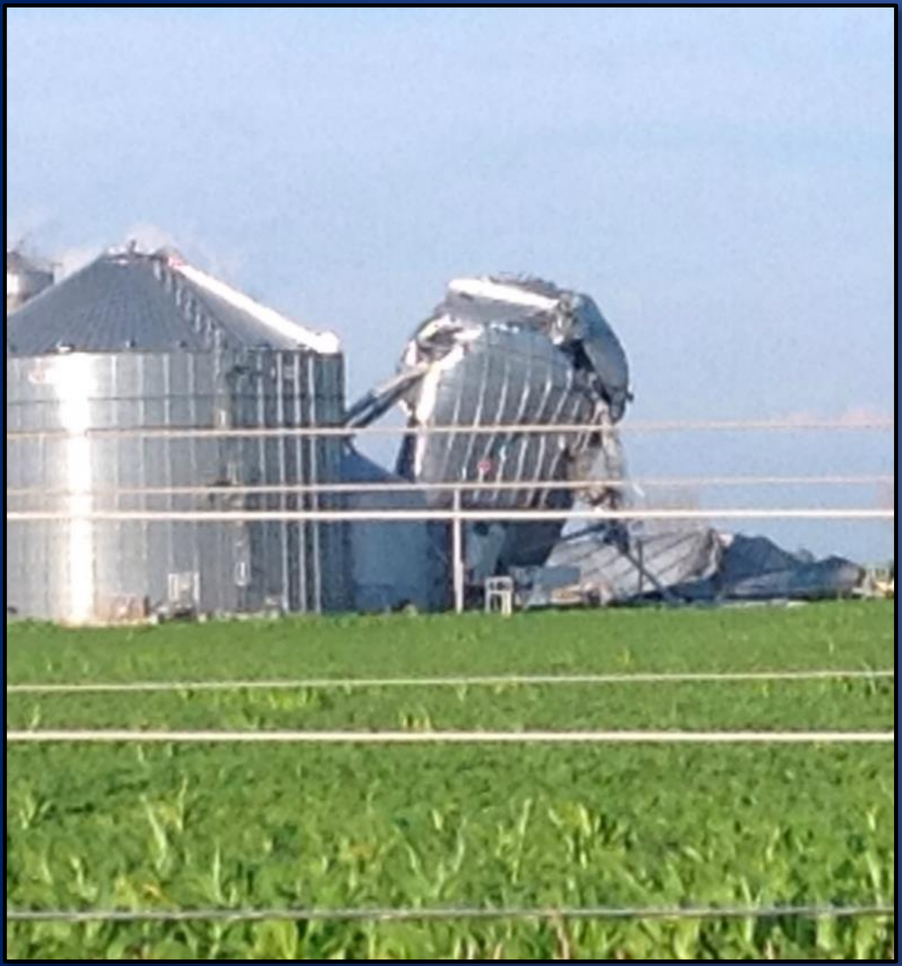
Timeline across Chicago CWA

21-02 UTC and 02-04 UTC



IEM
NEXRAD Base Reflectivity
30 June 2014 12:00 PM CDT
-20
0
20
40
60
80 dBZ

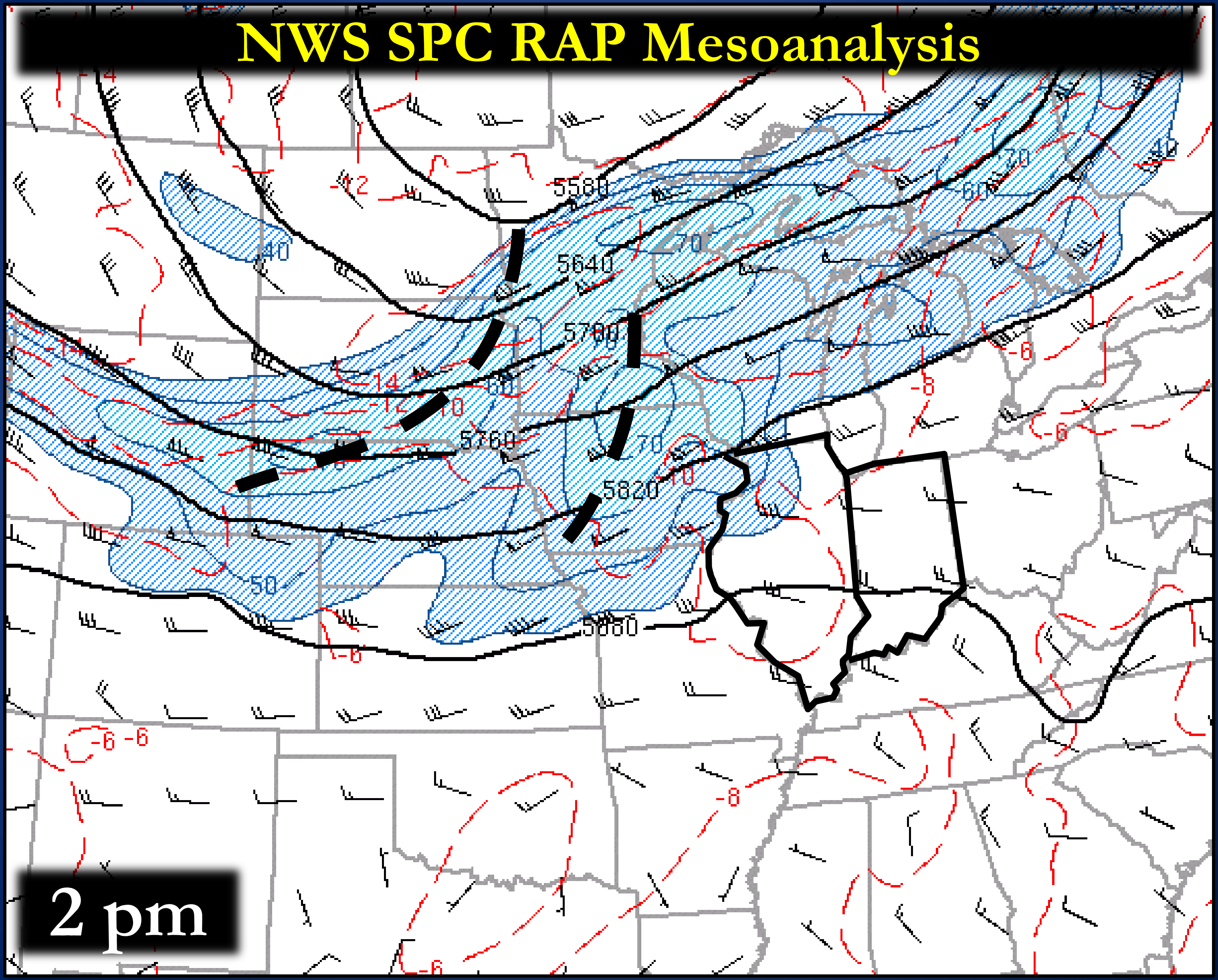

513



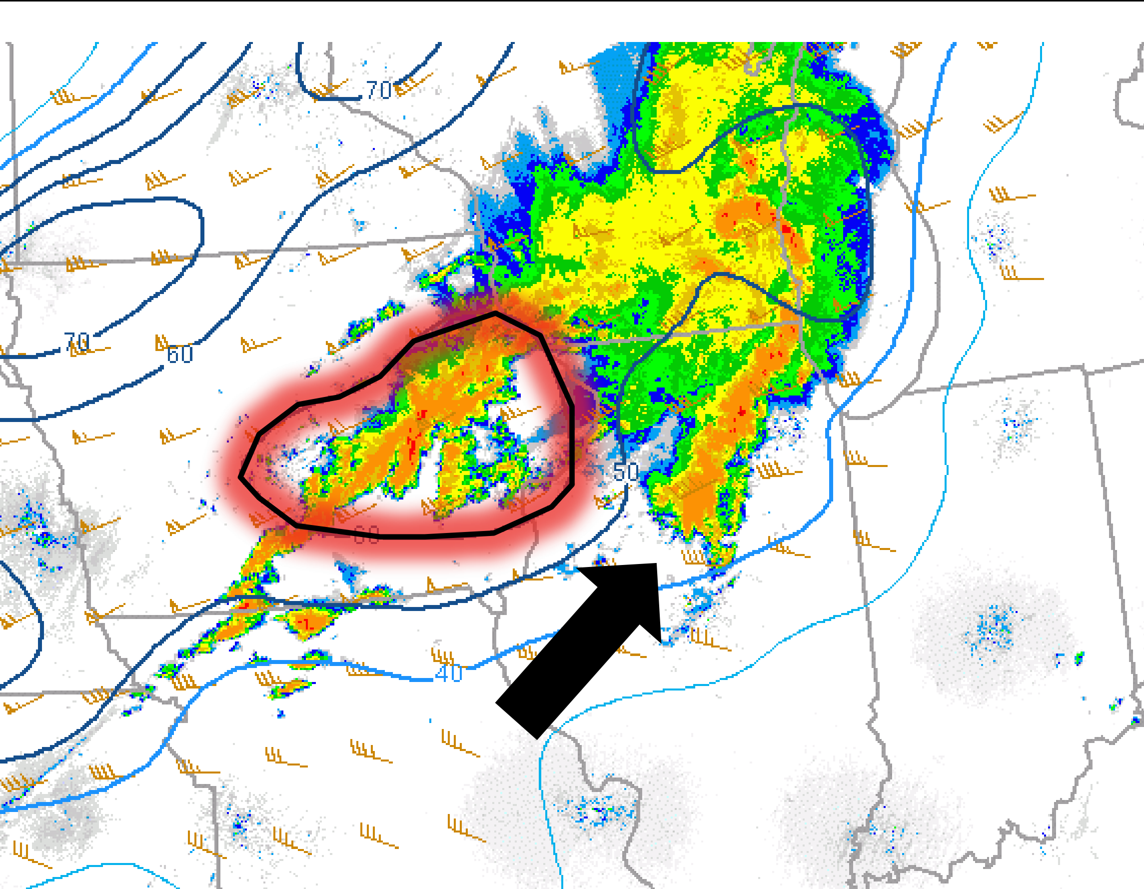

© Windy Acres Photography


Courtesy of ABC7 Chicago
Earlville, IL
First Tornado of Second Derecho

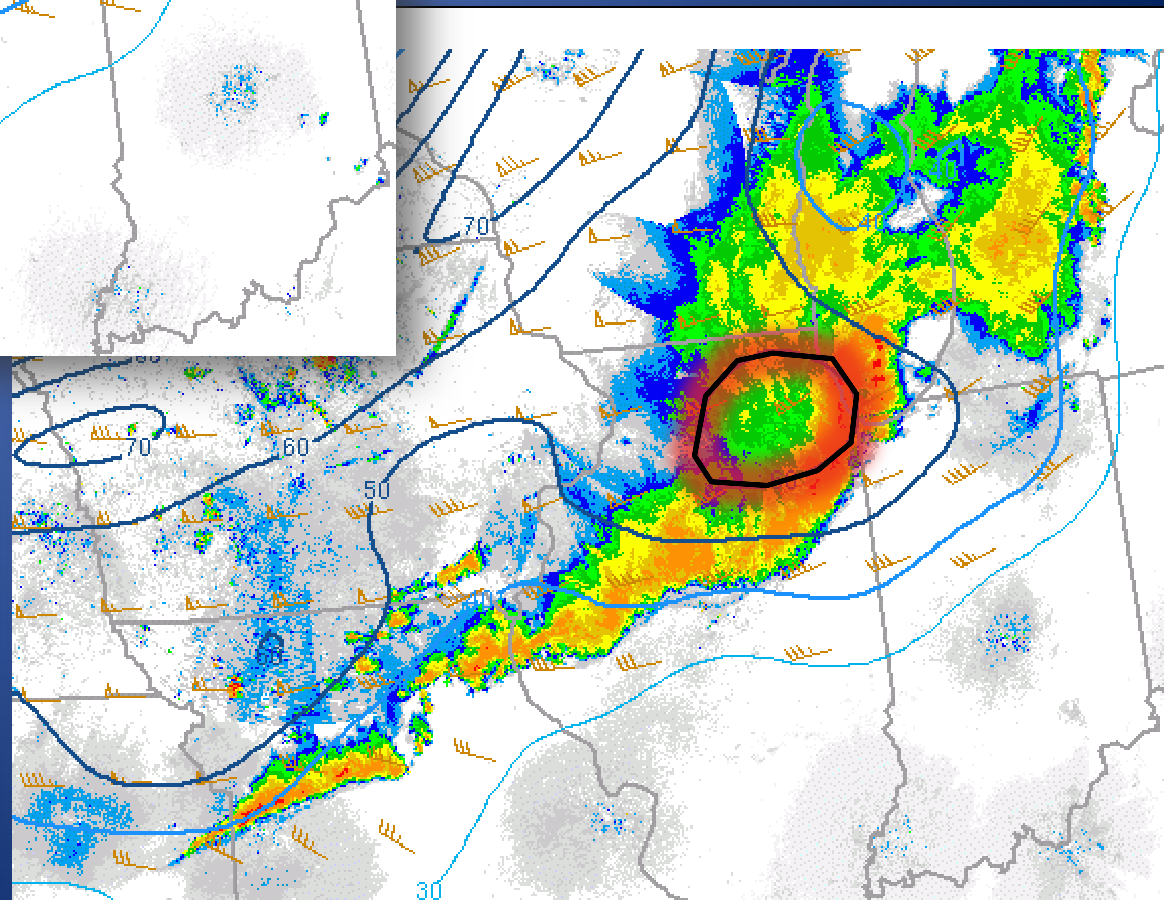
The Synoptic Environment of 30 June 2014: 500 mb



http://www.spc.noaa.gov/exper/mesoanalysis/

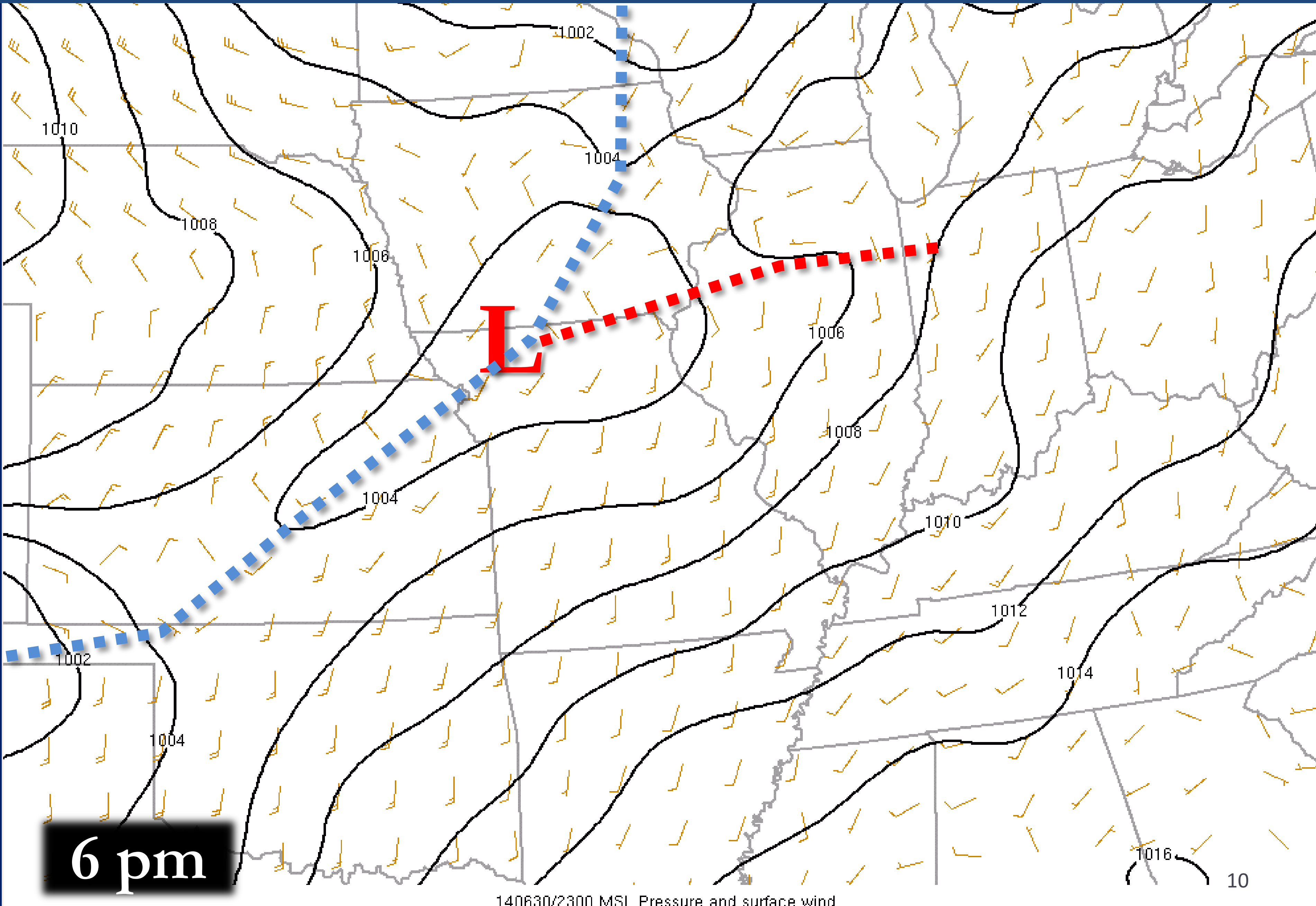


SECOND LINE
03Z 0-6km SHEAR:
25-30 m/s

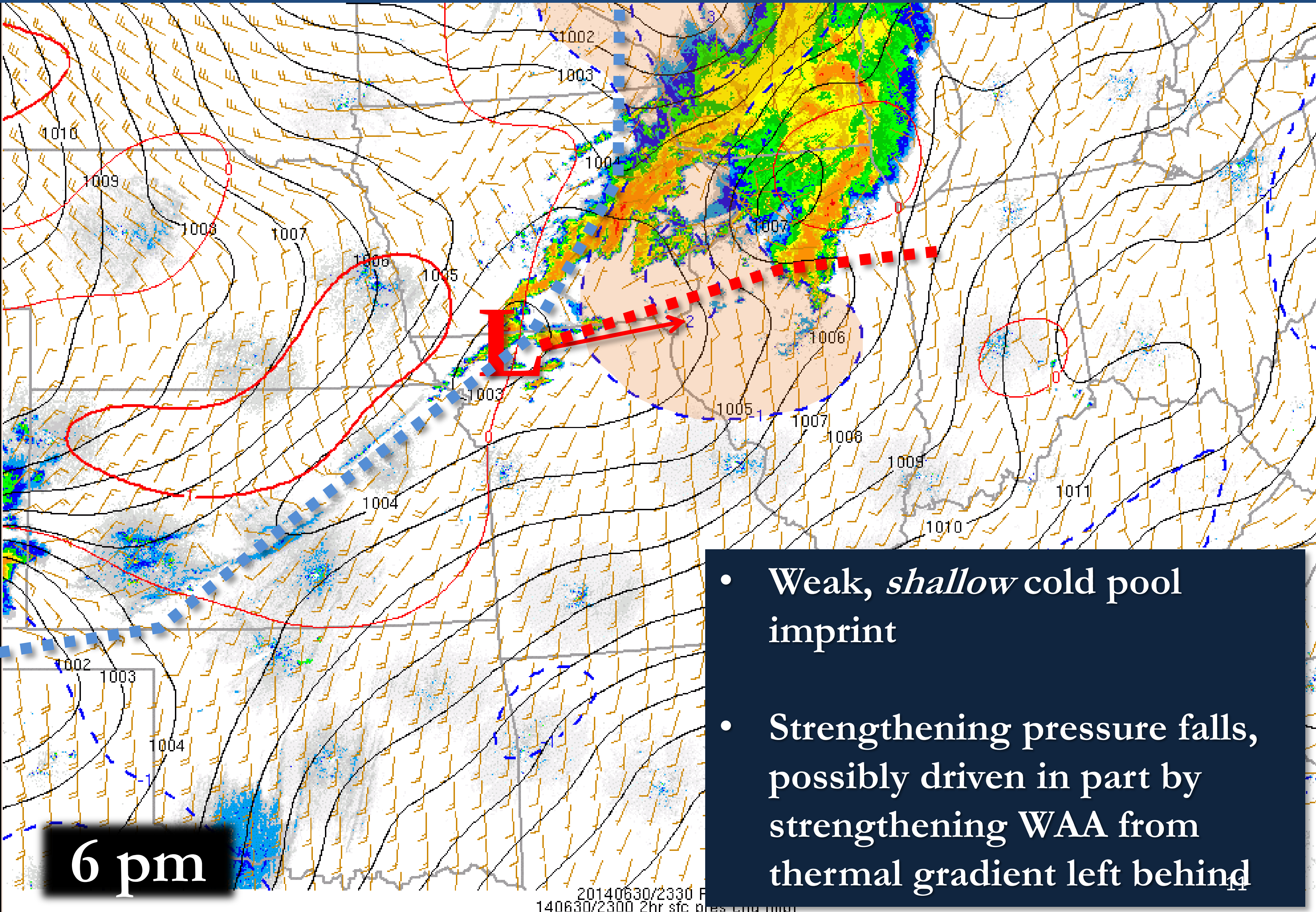


FIRST LINE
23Z 0-6km SHEAR:
20-25 m/s

The Synoptic Environment of 30 June 2014: MSLP

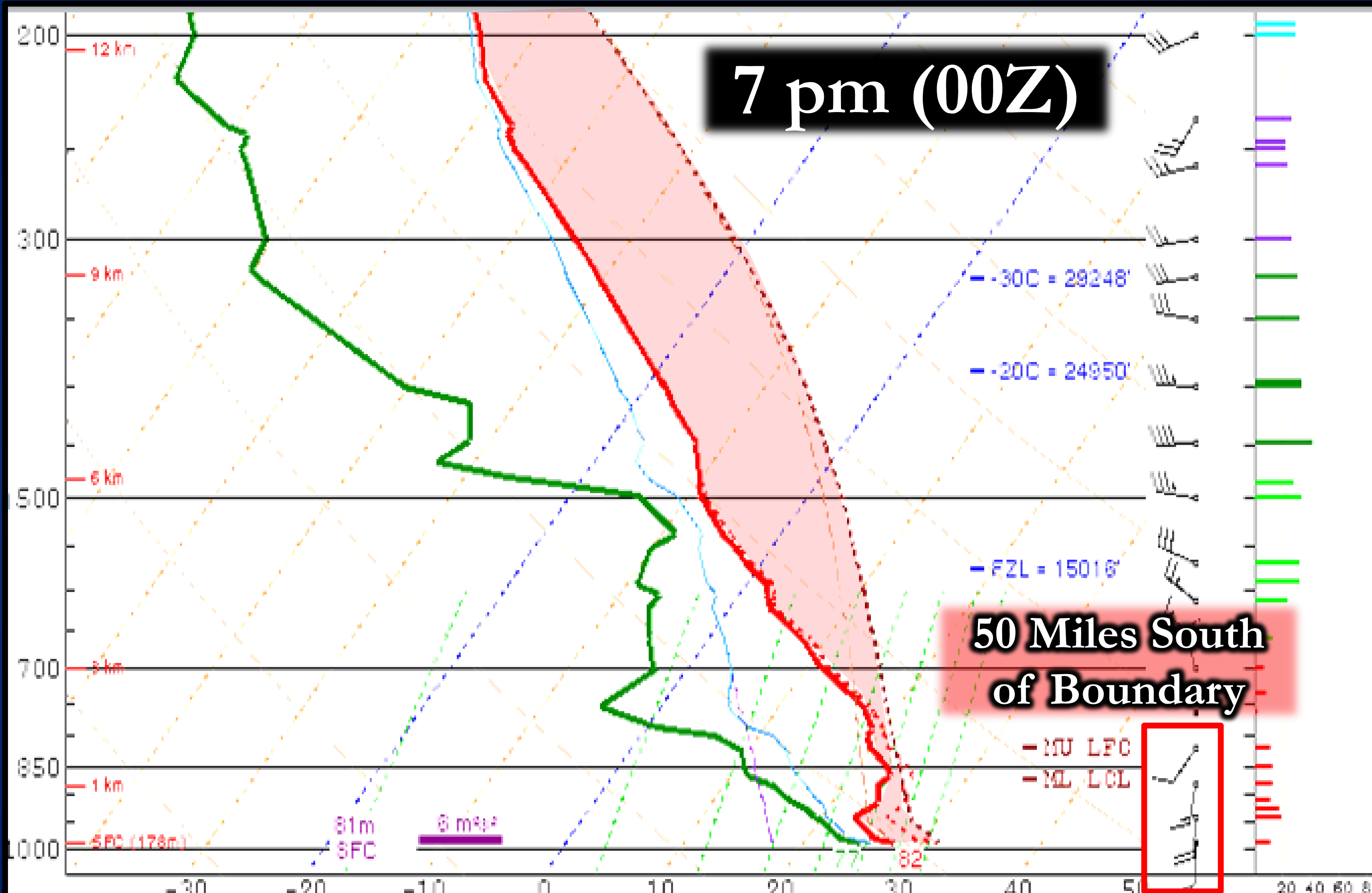


The Synoptic Environment of 30 June 2014: MSLP & 2h Change



- Weak, *shallow* cold pool imprint
- Strengthening pressure falls, possibly driven in part by strengthening WAA from thermal gradient left behind

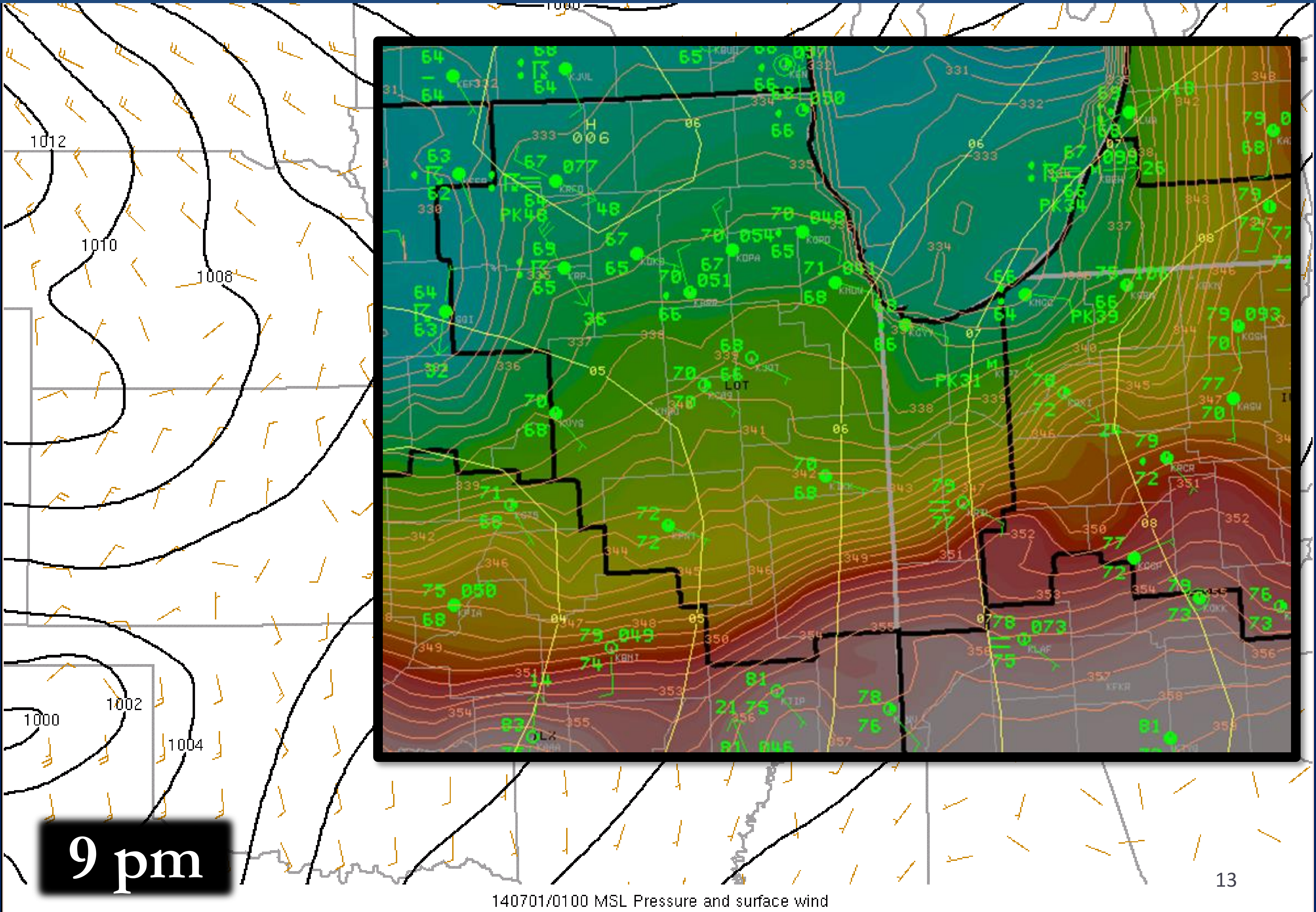
The Synoptic Environment of 30 June 2014: ILX Sounding

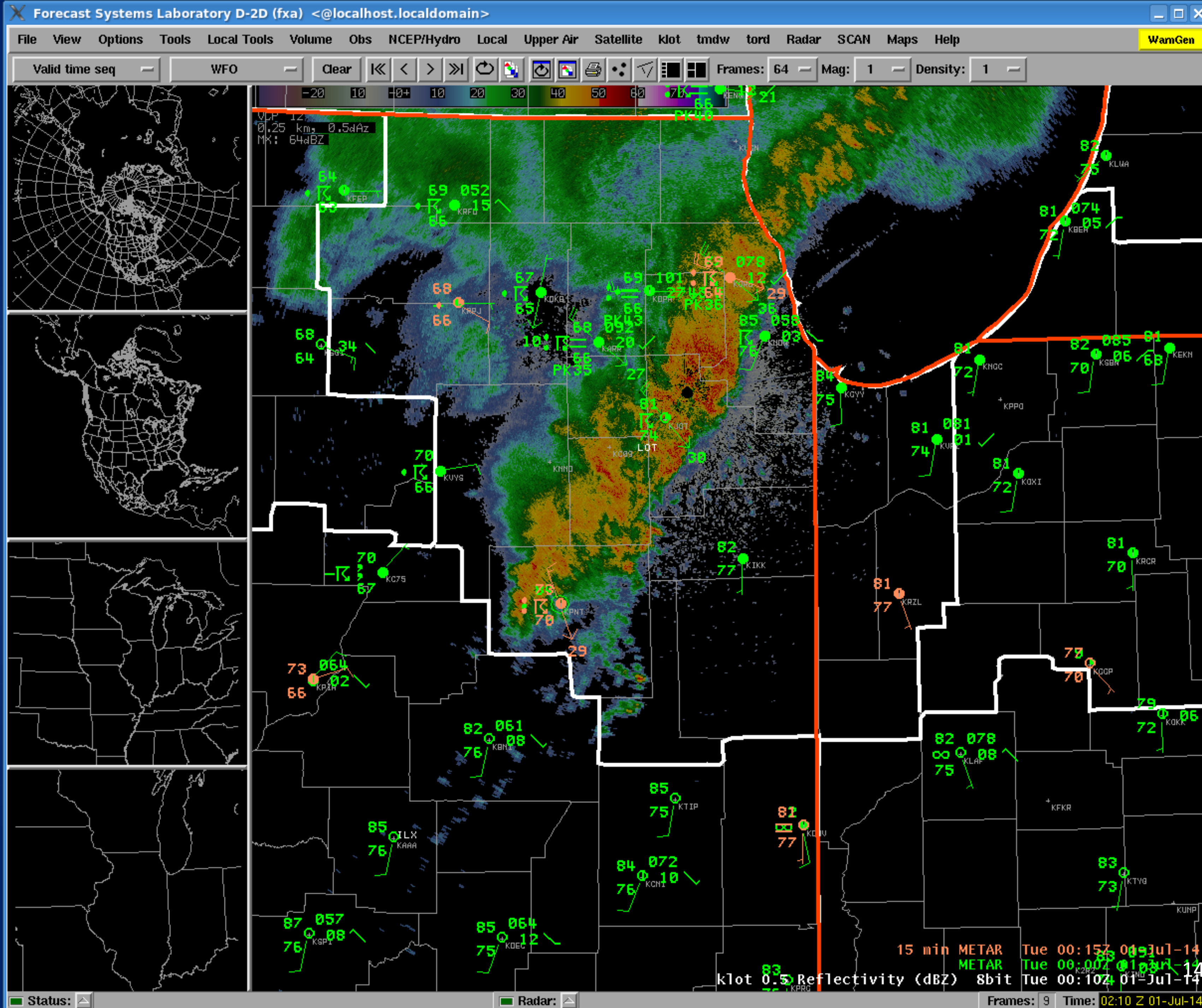


PARCEL	CAPE	CINH	LCL	LI	LFC	EL
SURFACE	4880	-8	358m	-11	1627m	48060'
MIXED LAYER	1837	-215	1112m	-6	2997m	41913'
FCST SURFACE	3163	-33	1792m	-9	2565m	46500'
MU (989 mb)	4880	-8	358m	-11	1627m	48060'

	SRH(m2/s2)	Shear(kt)	MnWind	SRW
SFC - 1 km	27	3	186/16	166/29
SFC - 3 km	-16	22	195/8	162/22
Eff Inflow Layer	6	2	181/14	162/27
SFC - 6 km		34	258/9	178/14

The Synoptic Environment of 30 June 2014: MSLP & Theta-E

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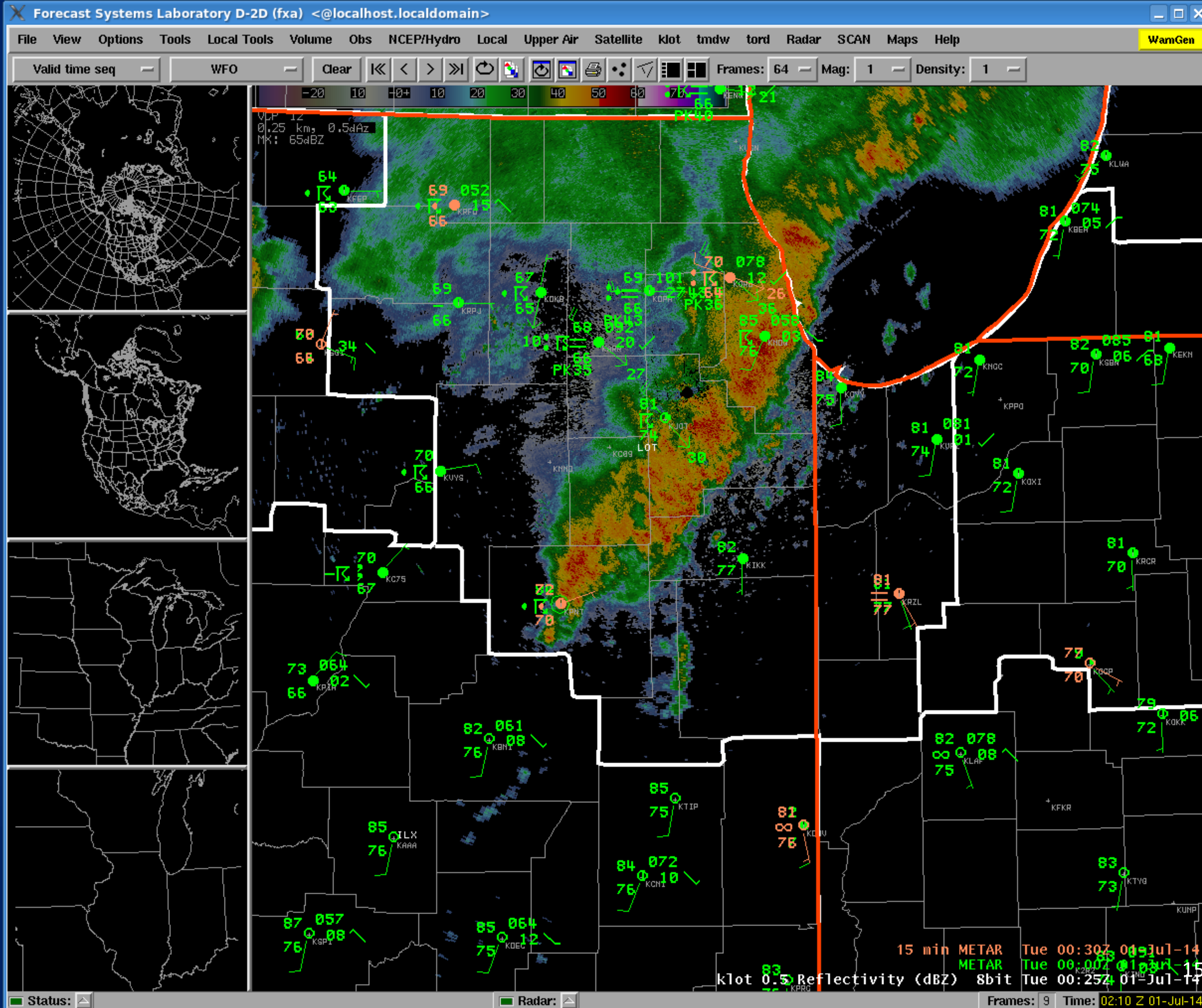
File View Options Tools Local Tools Volume Obs NCEP/Hydro Local Upper Air Satellite klot tmdw tord Radar SCAN Maps Help
WarnGen
Valid time seq
WFO
Clear
Frames: 64
Mag: 1
Density: 1
VCP 12
0.25 km, 0.5dAz
MX: 64dBZ
LOT
ILX
15 min METAR Tue 00:15Z 01-Jul-14
METAR Tue 00:00Z 01-Jul-14
klot 0.5 Reflectivity (dBZ) 8bit Tue 00:10Z 01-Jul-14
Status:
Radar:
Frames: 9
Time: 02:10 Z 01-Jul-14



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Frames: 64
Mag: 1
Density: 1
VCP 12
0.25 km, 0.5dAz
MX: 65dBZ
LOT
ILX
15 min METAR Tue 00:30Z 01-Jul-14
METAR Tue 00:00Z 01-Jul-14
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Radar:
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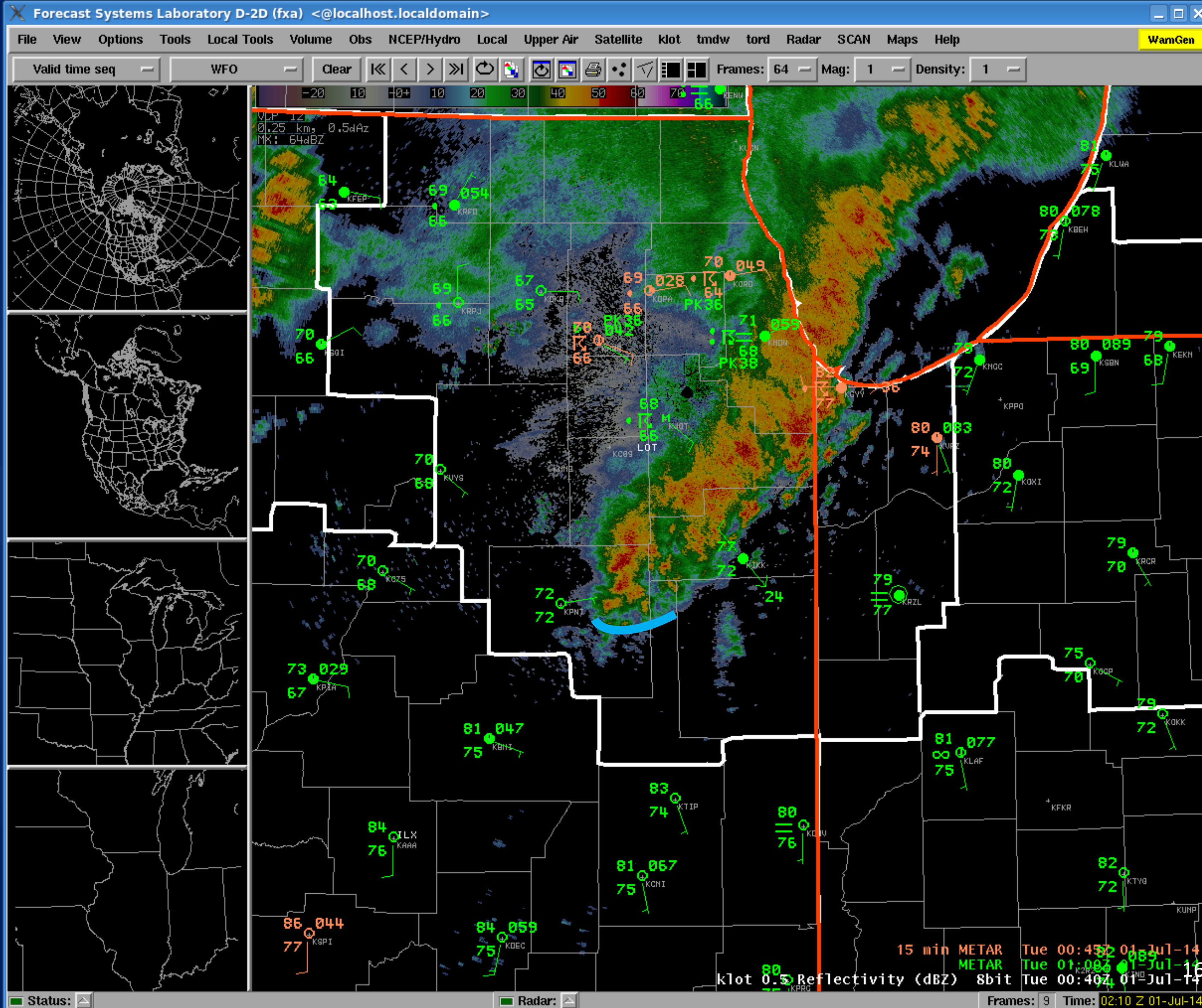
Forecast Systems Laboratory D-2D (fxa) <@localhost.localdomain>
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Frames: 64 Mag: 1 Density: 1
LOT
15 min METAR
METAR
klot 0.5 Reflectivity (dBZ) 8bit Tue 00:40Z 01-Jul-14
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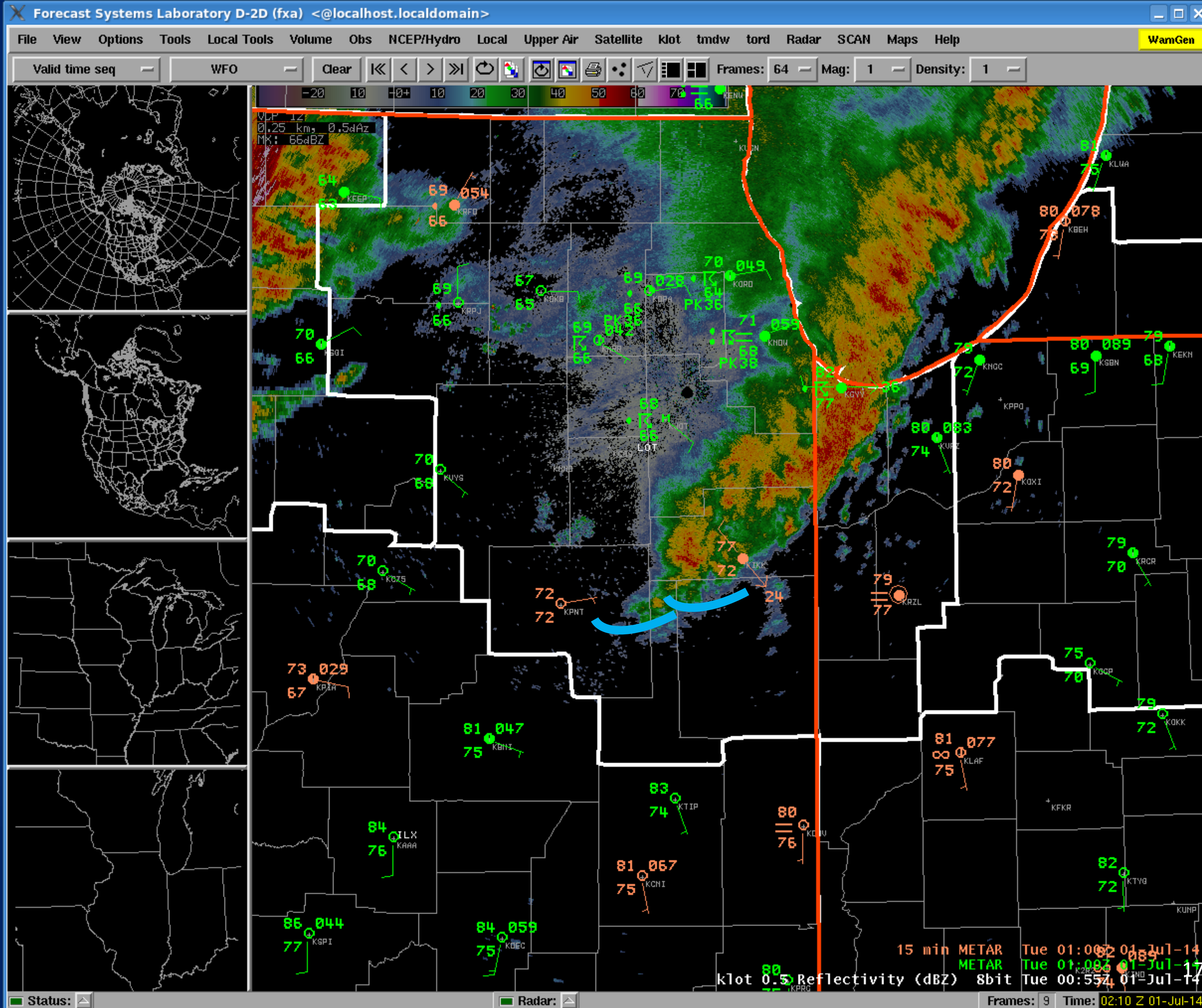
Radar:
Frames: 9
Time: 02:10 Z 01-Jul-14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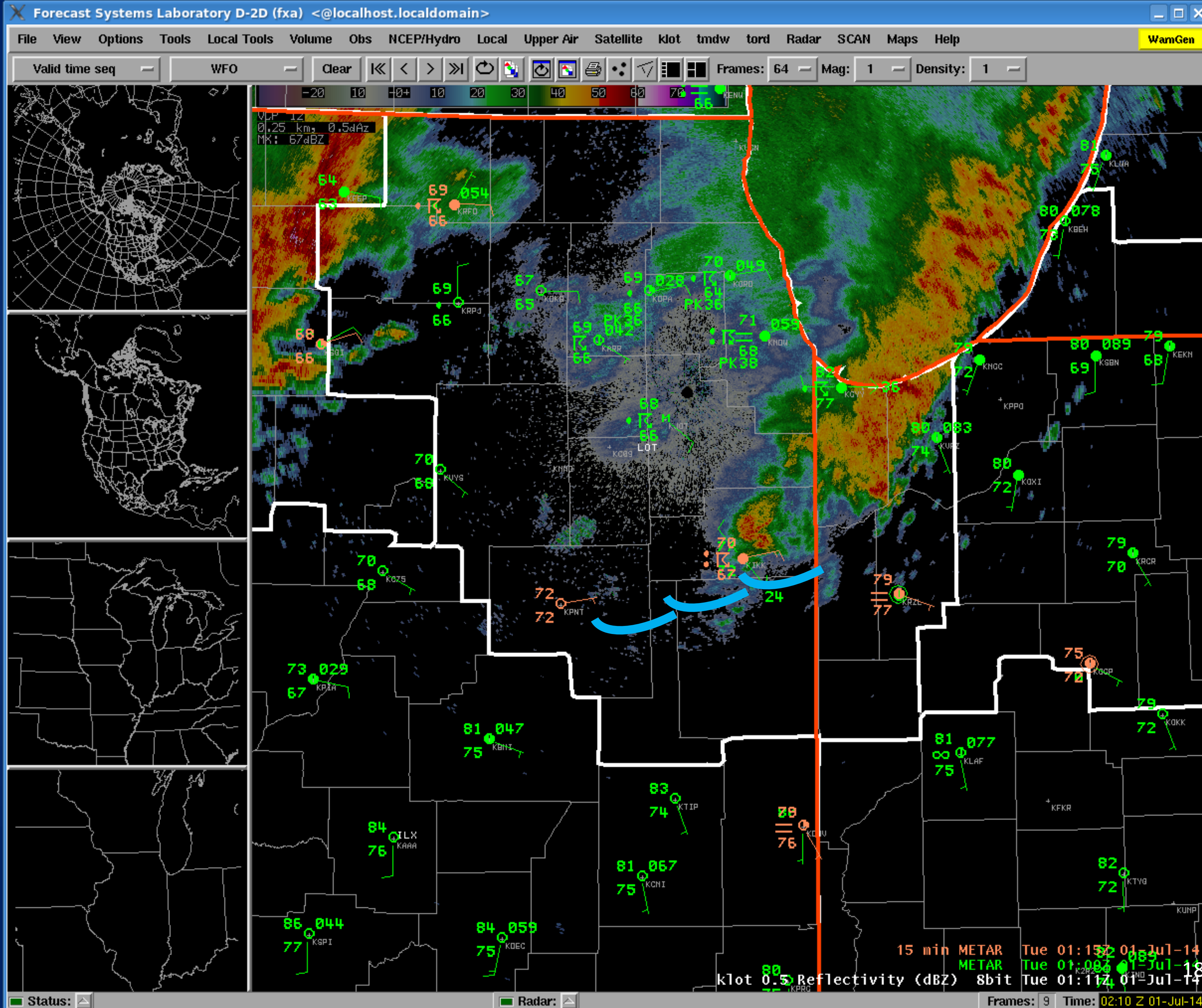
WarnGen
Valid time seq
WFO
Clear
Frames: 64 Mag: 1 Density: 1
0.25 km, 0.5dAz
MX: 66dBZ
LOT
15 min METAR Tue 01:00Z 01-Jul-14
METAR Tue 01:00Z 01-Jul-14
klot 0.5 Reflectivity (dBZ) 8bit Tue 00:55Z 01-Jul-14
Status:
Radar:
Frames: 9 Time: 02:10 Z 01-Jul-14


Forecast Systems Laboratory D-2D (fxa) <@localhost.localdomain>
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WarnGen
Valid time seq
WFO
Clear
Frames: 64
Mag: 1
Density: 1
VCP 12
0.25 km, 0.5dAz
MX: 67dBZ
LOT
ILX
15 min METAR
METAR
klot 0.5 Reflectivity (dBZ) 8bit Tue 01:11Z 01-Jul-14
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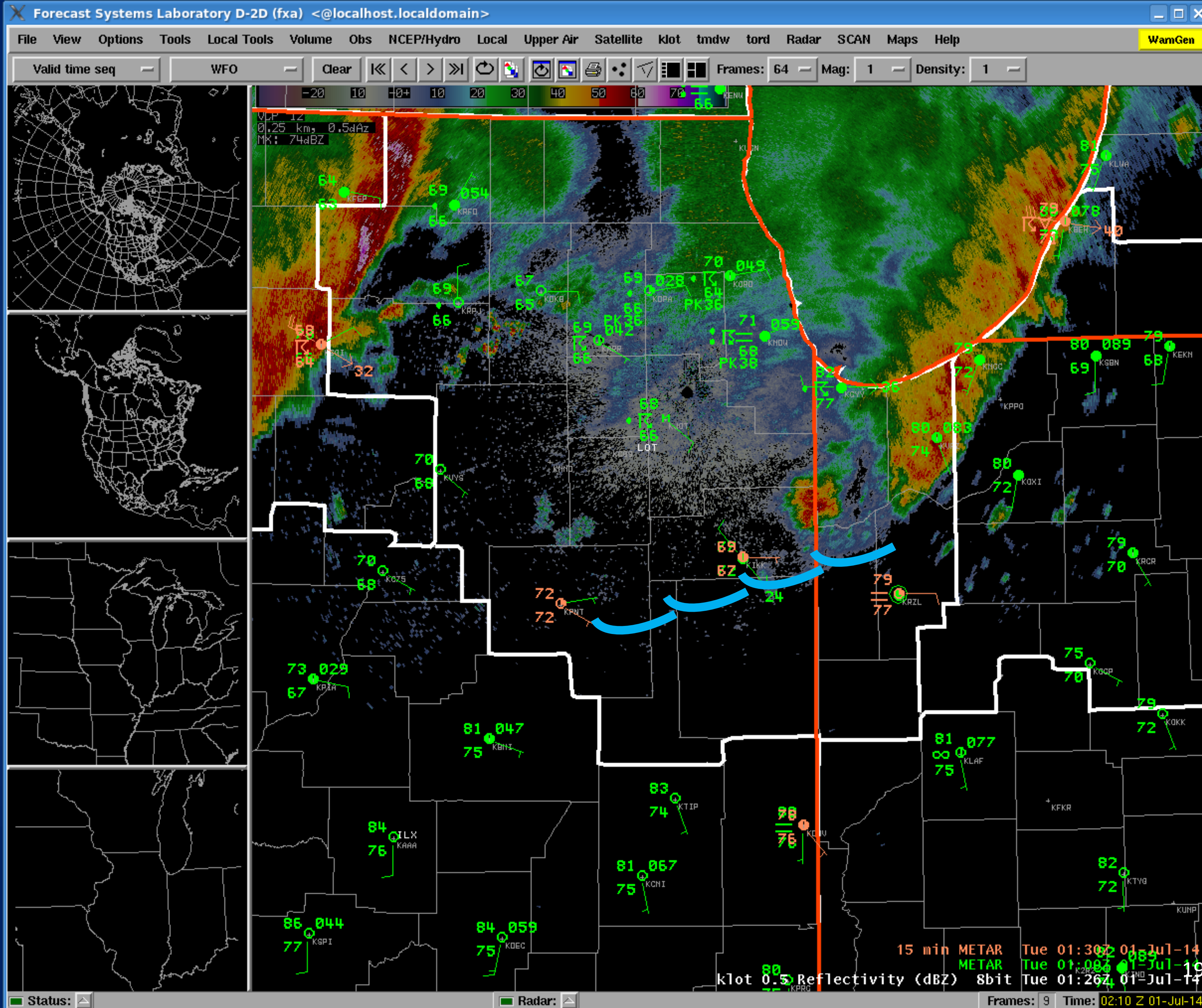
Radar:
Frames: 9
Time: 02:10 Z 01-Jul-14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Valid time seq
WFO
Clear
Frames: 64
Mag: 1
Density: 1
VCP 12
0.25 km, 0.5dAz
MX: 74dBZ
LOT
ILX
15 min METAR Tue 01:30Z 01-Jul-14
METAR Tue 01:00Z 01-Jul-14
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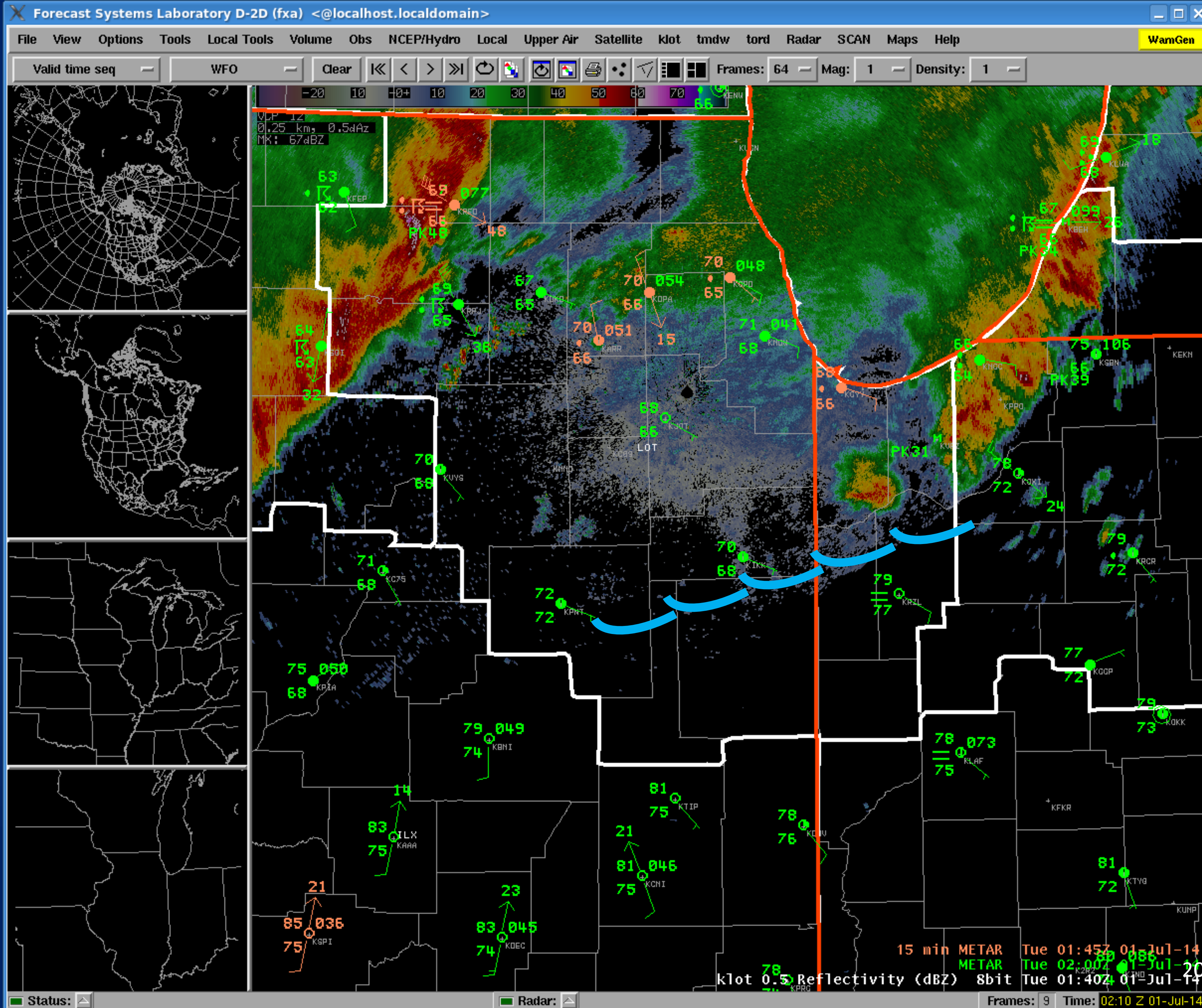

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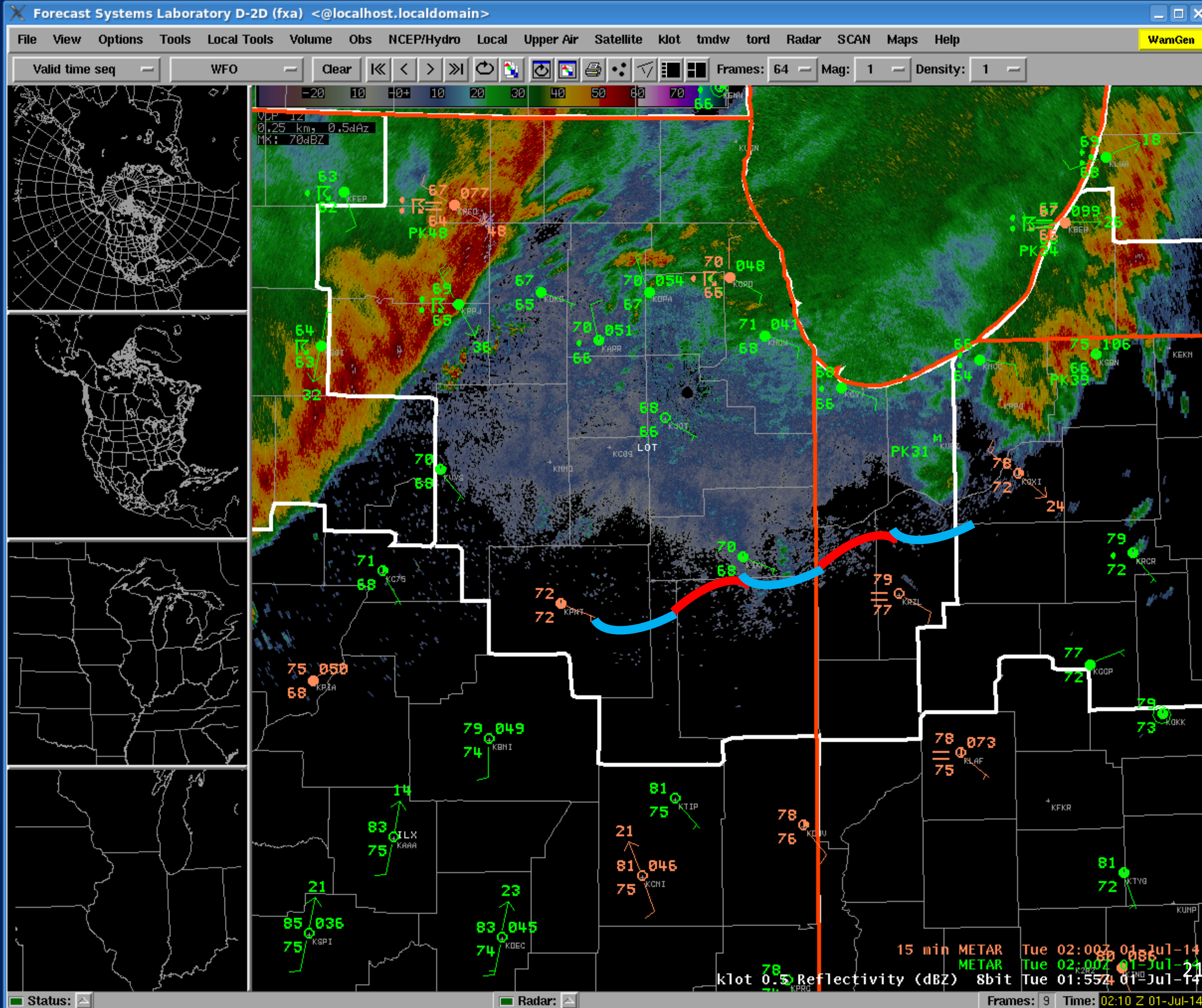
WarnGen
Valid time seq
WFO
Clear
Frames: 64 Mag: 1 Density: 1
LOT
ILX
15 min METAR Tue 01:45Z 01-Jul-14
METAR Tue 02:00Z 01-Jul-14
klot 0.5 Reflectivity (dBZ) 8bit Tue 01:40Z 01-Jul-14
Status:
Radar:
Frames: 9
Time: 02:10 Z 01-Jul-14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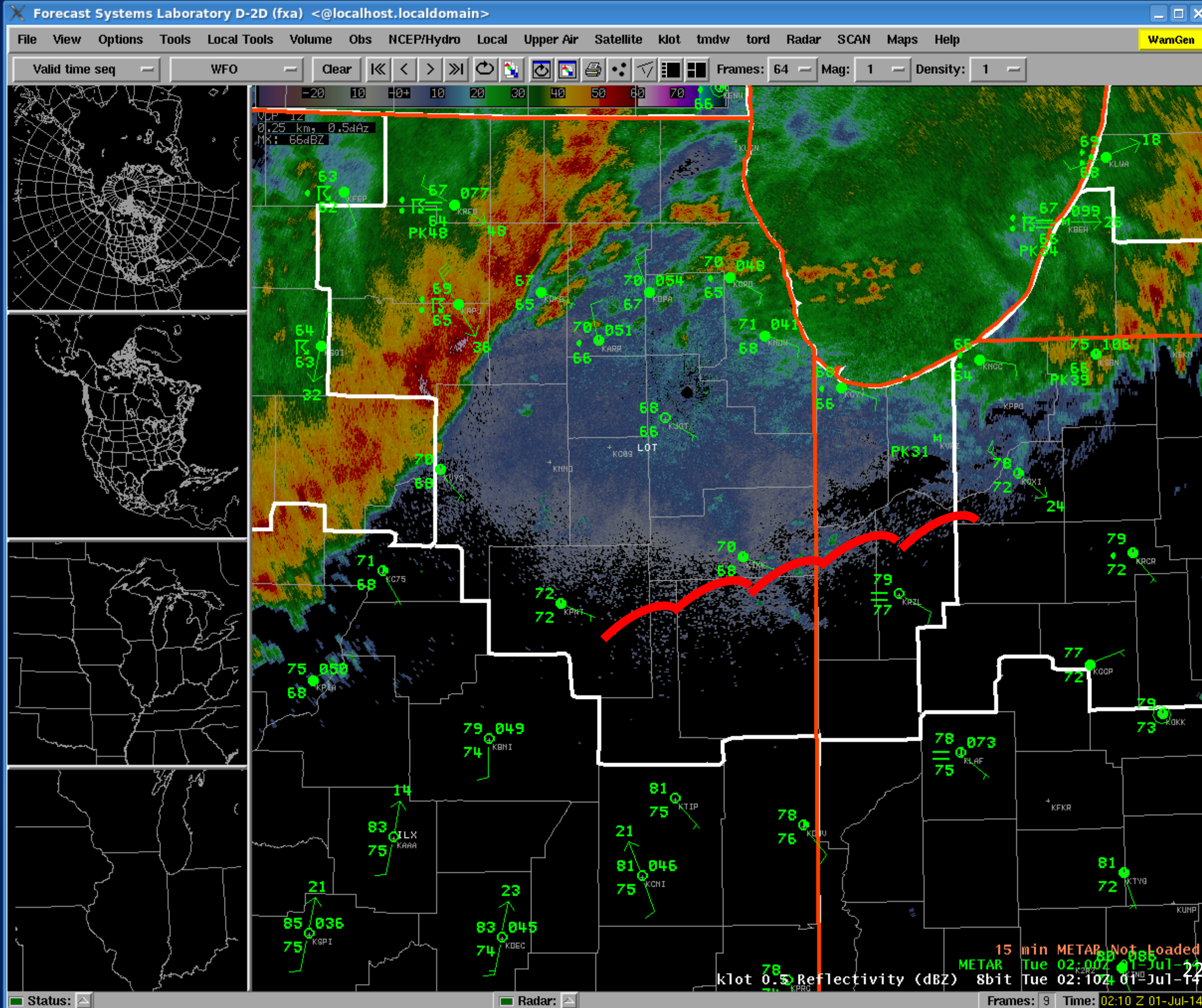
File View Options Tools Local Tools Volume Obs NCEP/Hydro Local Upper Air Satellite klot tmdw tord Radar SCAN Maps Help
WarnGen
Valid time seq
WFO
Clear
Frames: 64
Mag: 1
Density: 1
VCP 12
0.25 km, 0.5dAz
MX: 70dBZ
LOT
ILX
15 min METAR Tue 02:00Z 01-Jul-14
METAR Tue 02:00Z 01-Jul-14
klot 0.5 Reflectivity (dBZ) 8bit Tue 01:55Z 01-Jul-14
Status:
Radar:
Frames: 9
Time: 02:10 Z 01-Jul-14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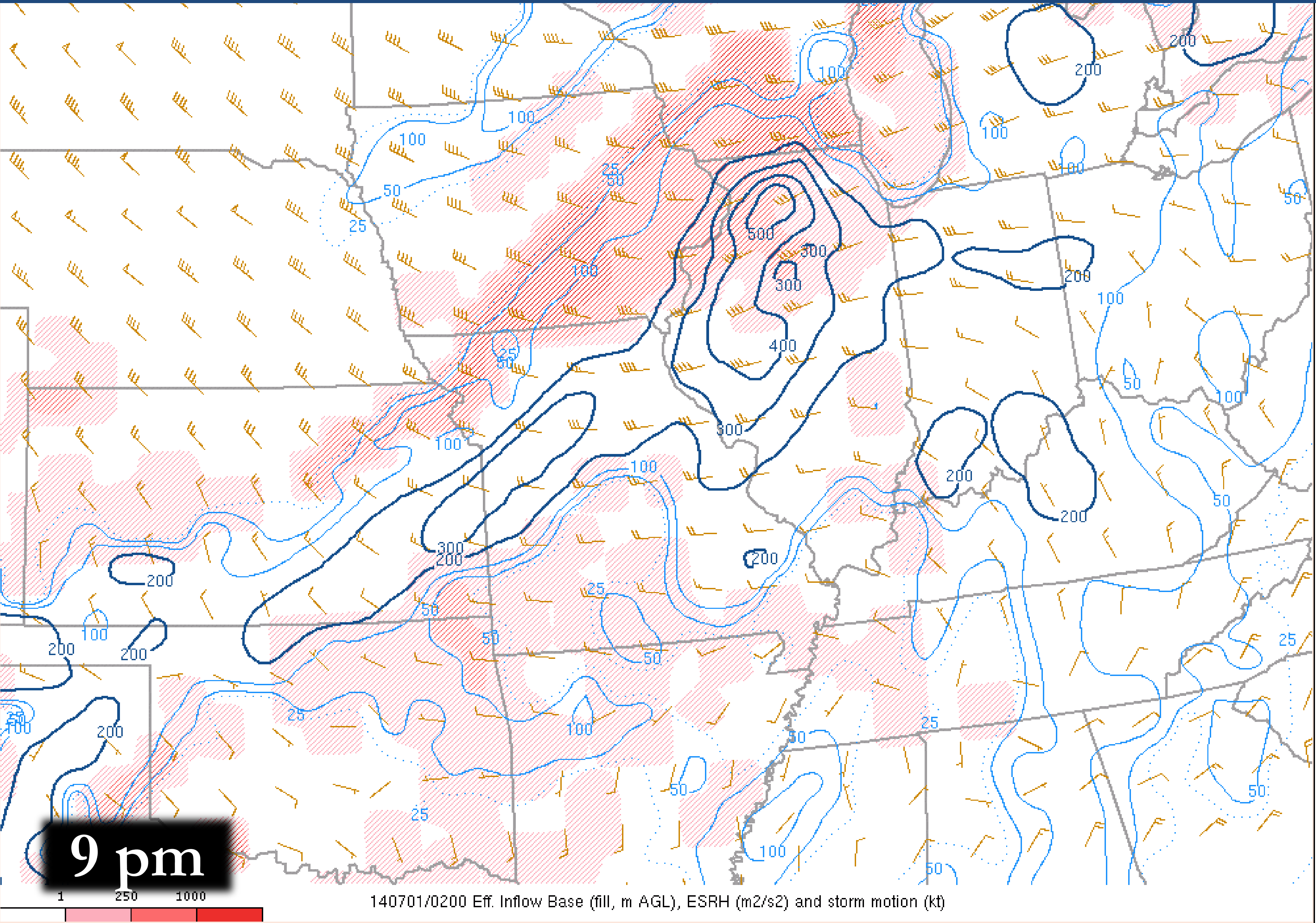
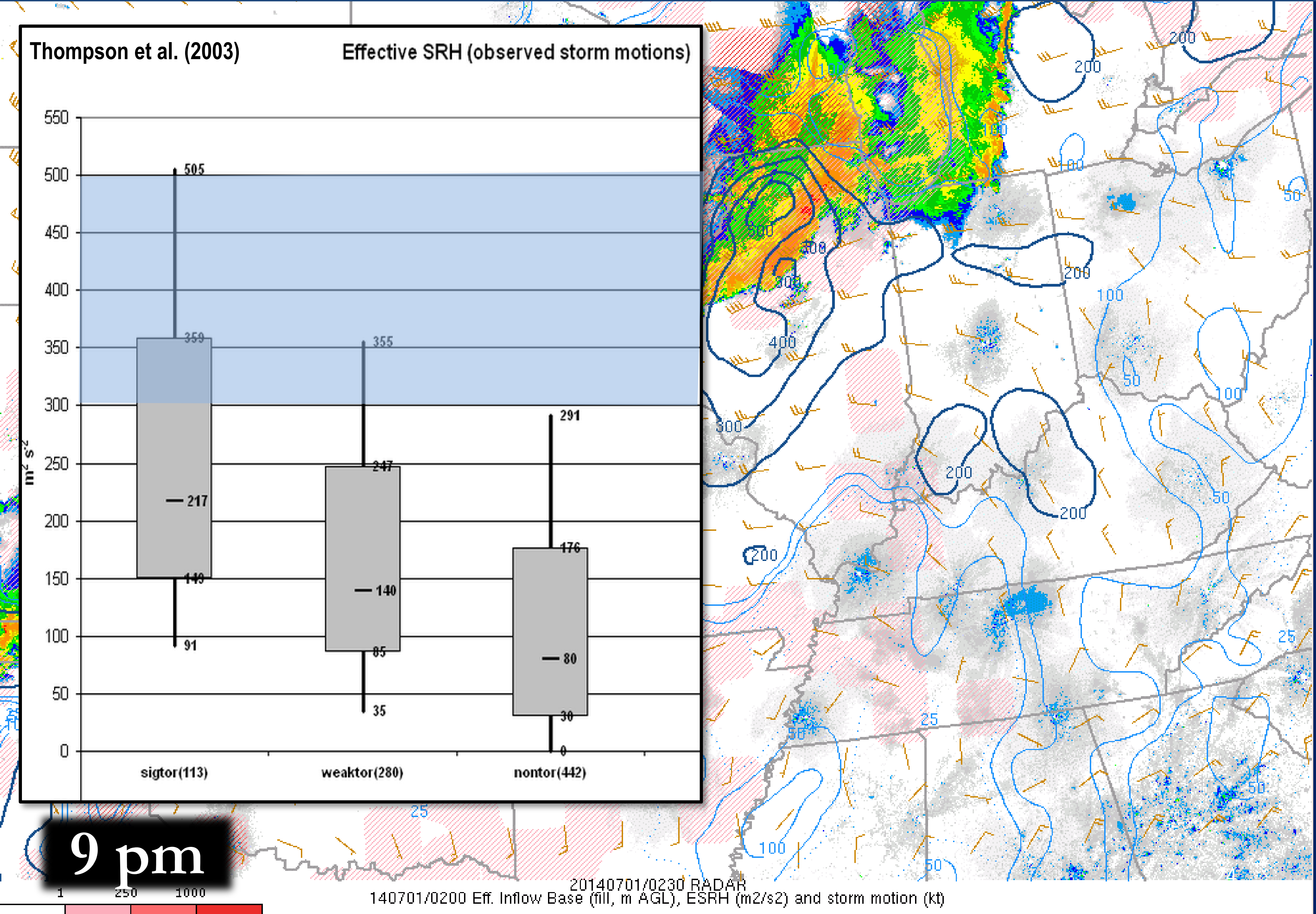
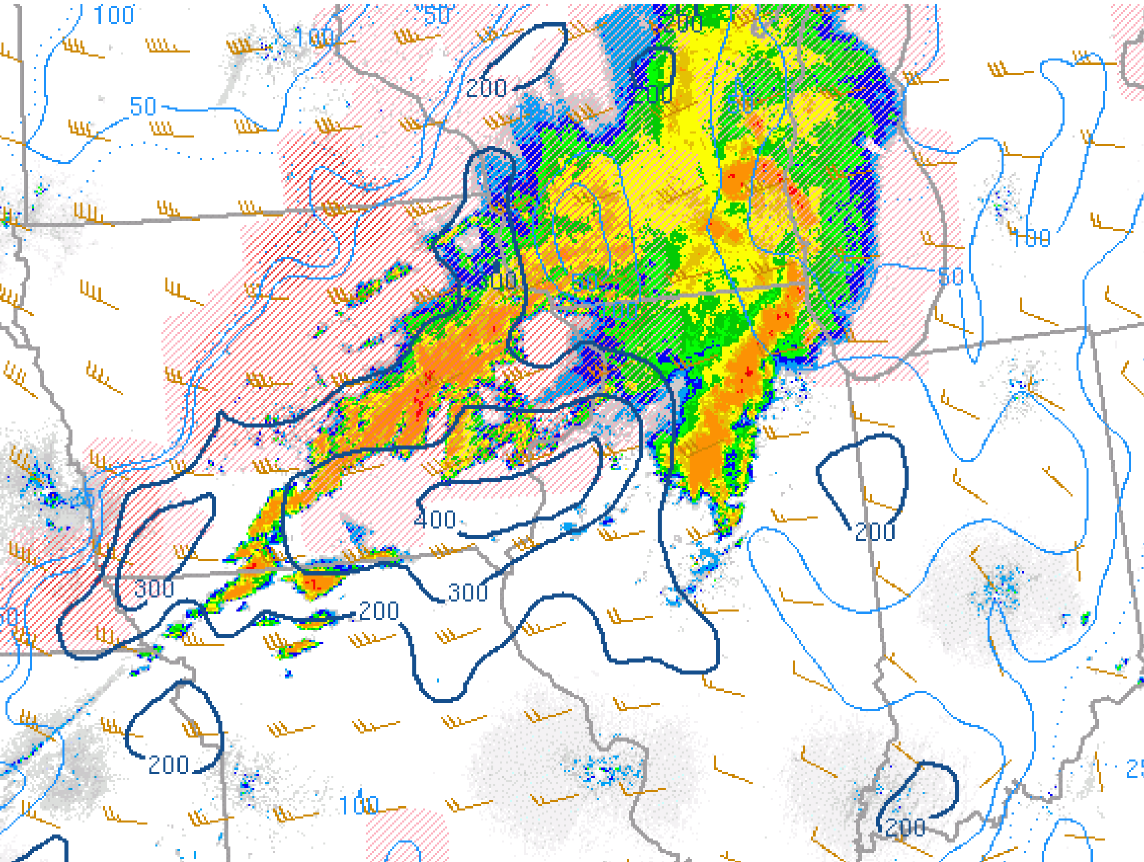
WarnGen
Valid time seq
WFO
Clear
Frames: 64
Mag: 1
Density: 1
0.25 km, 0.5dAz
MX: 66dBZ
LOT
15 min METAR Not Loaded
klot 0.5 Reflectivity (dBZ) 8bit Tue 02:10Z 01-Jul-14
Status:
Radar:
Frames: 9
Time: 02:10 Z 01-Jul-14

Mesoscale Environment of 30 June 2014: Effective SRH



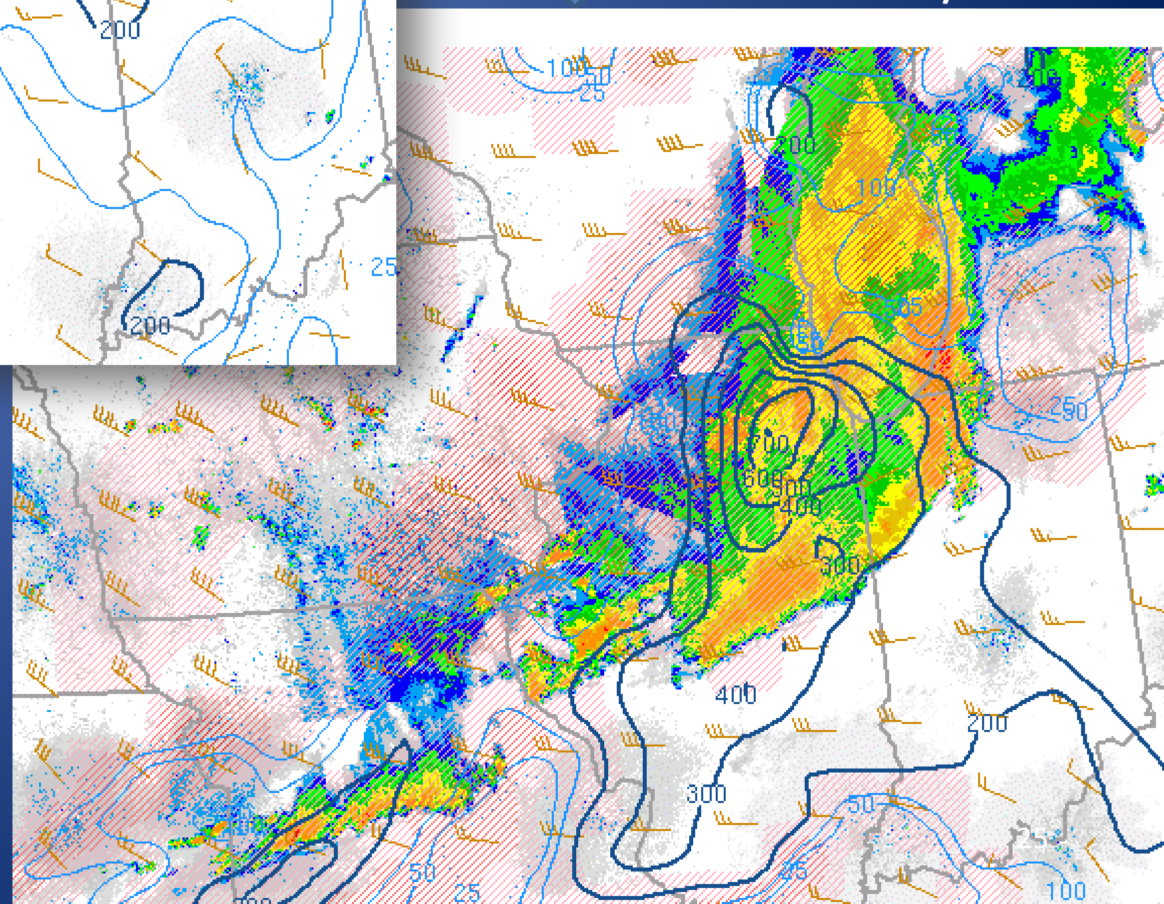
The Synoptic Environment of 30 June 2014: Effective SRH



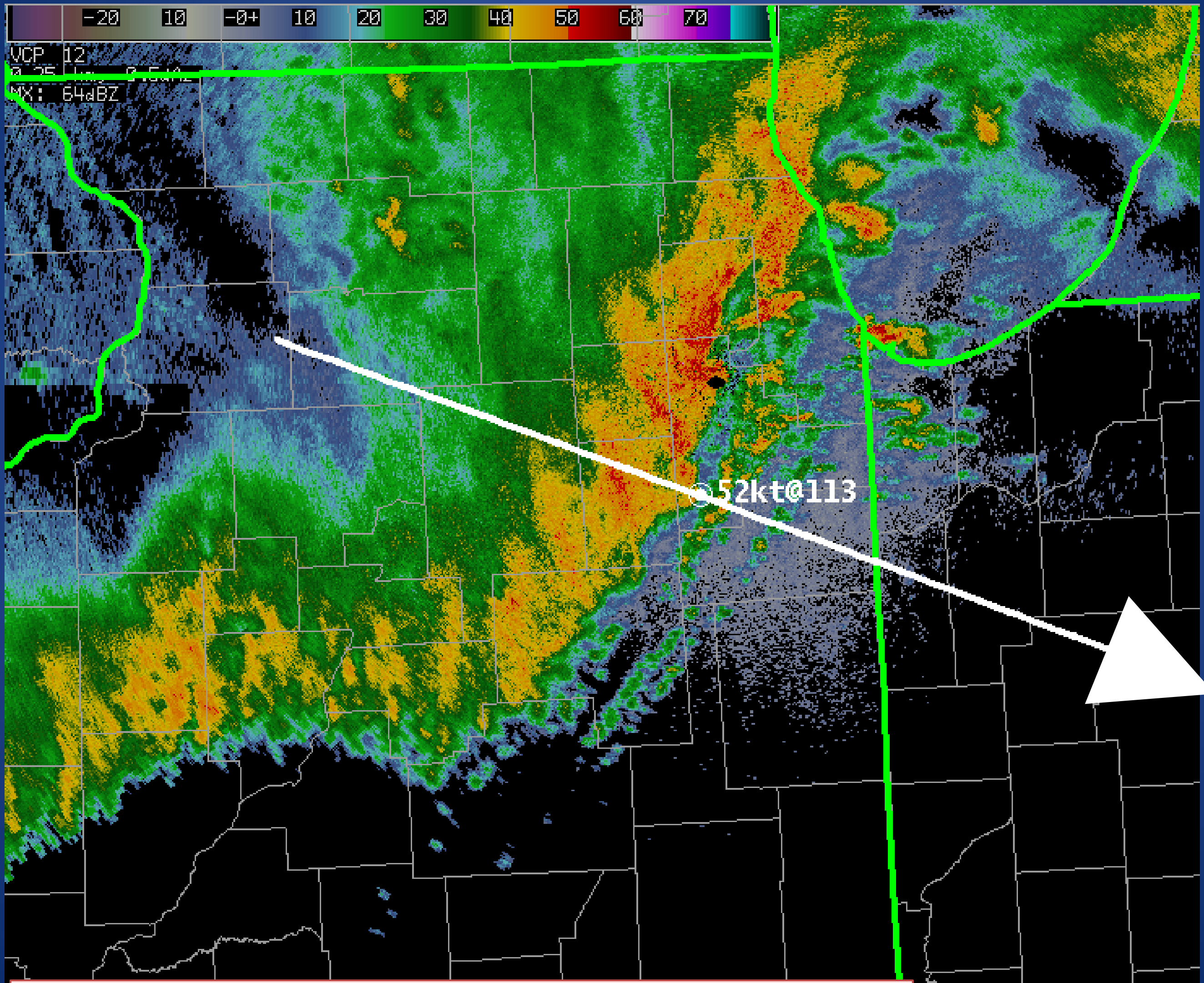


FIRST LINE
23Z Effective SRH:
100-200 m^2/s^2

SECOND LINE
04Z Effective SRH:
300-700 m^2/s^2



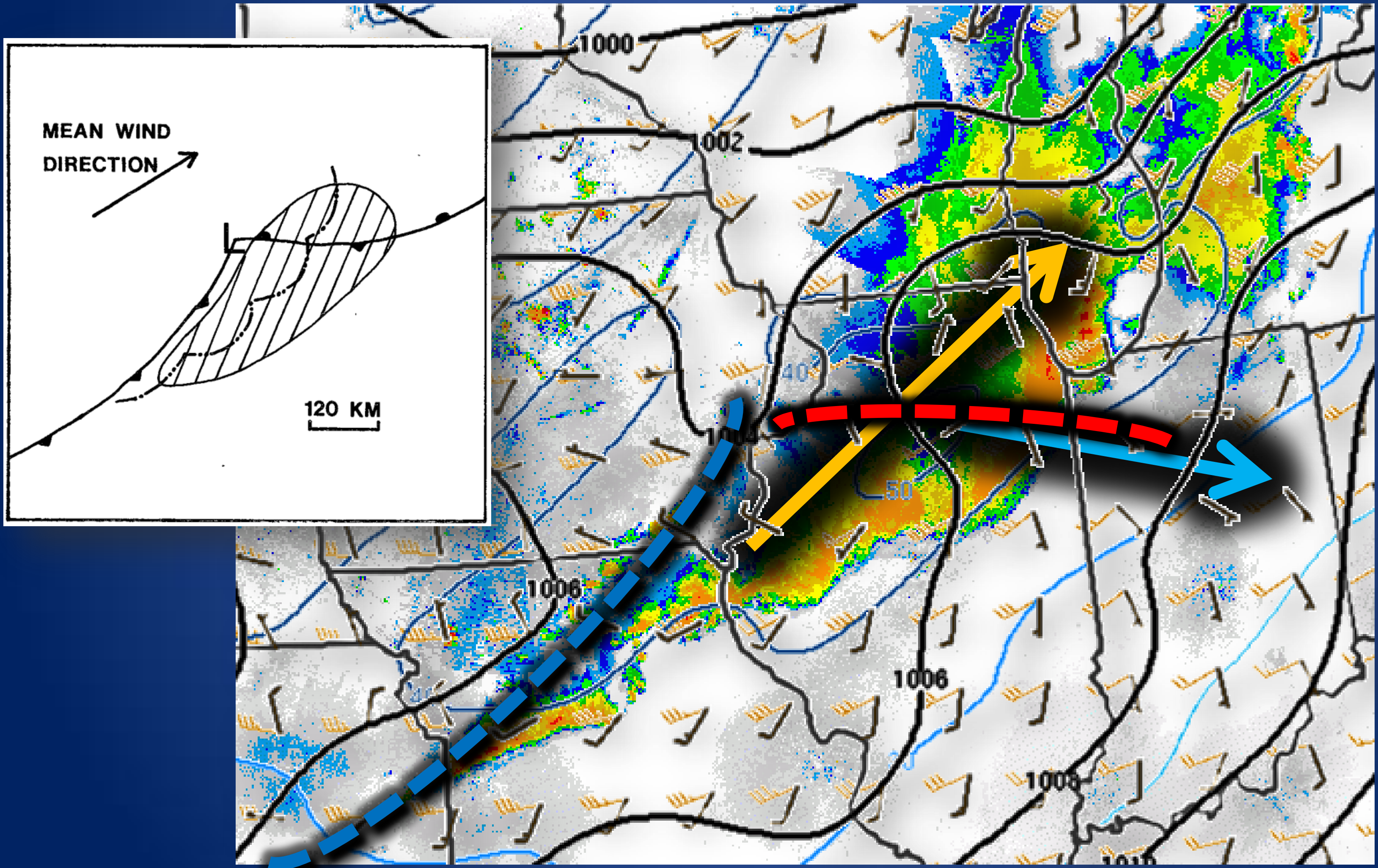
Motion of Tornadic Section of 2nd QLCS



03Z – 1 July 2014

Estimated Motion (27 m/s or 52kt)

850-300mb Mean Wind vs Storm Motion



T rise continues as rapid P rise occurs

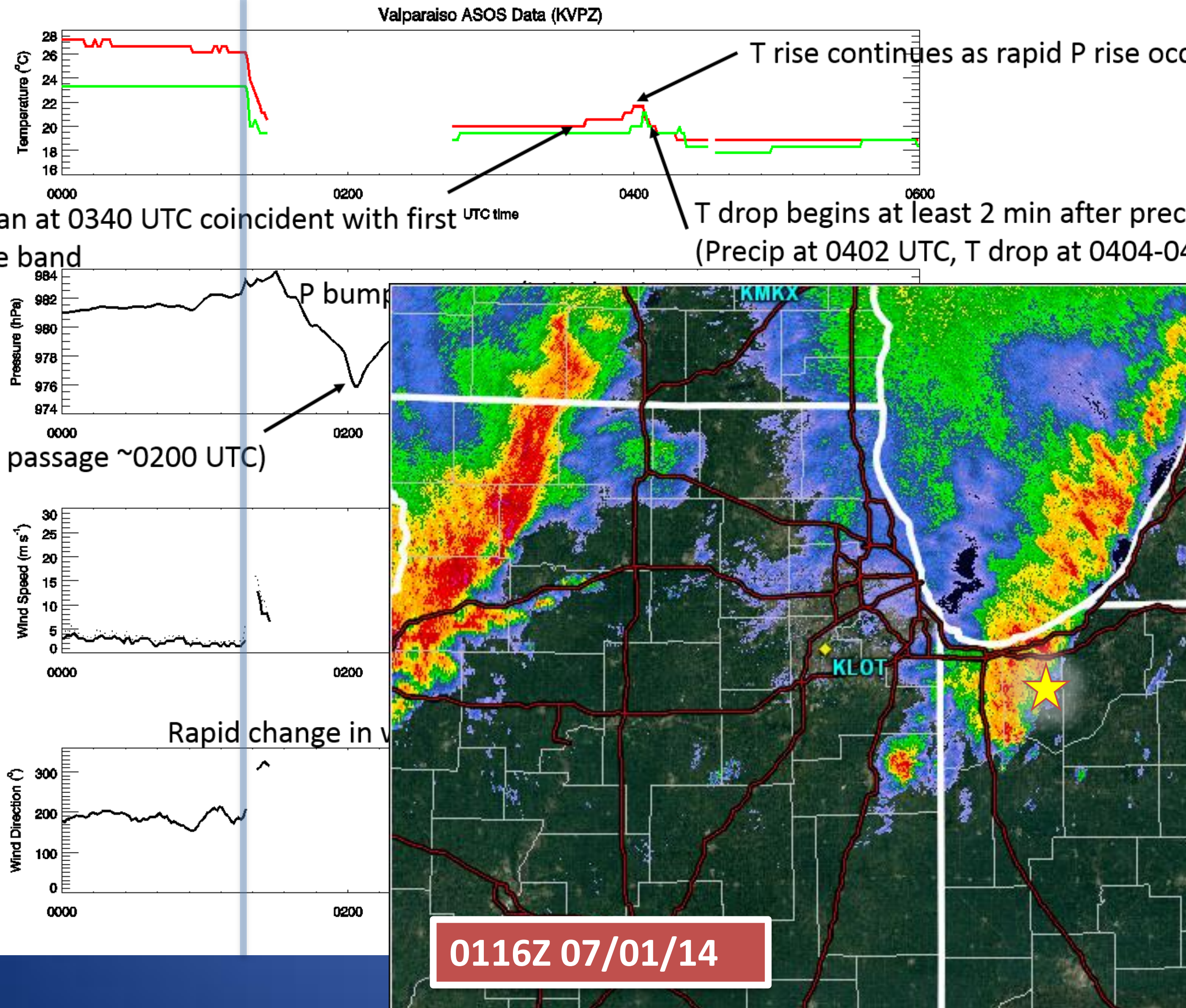
T rise began at 0340 UTC coincident with first convective band

T drop begins at least 2 min after precip begins (Precip at 0402 UTC, T drop at 0404-0405 UTC)

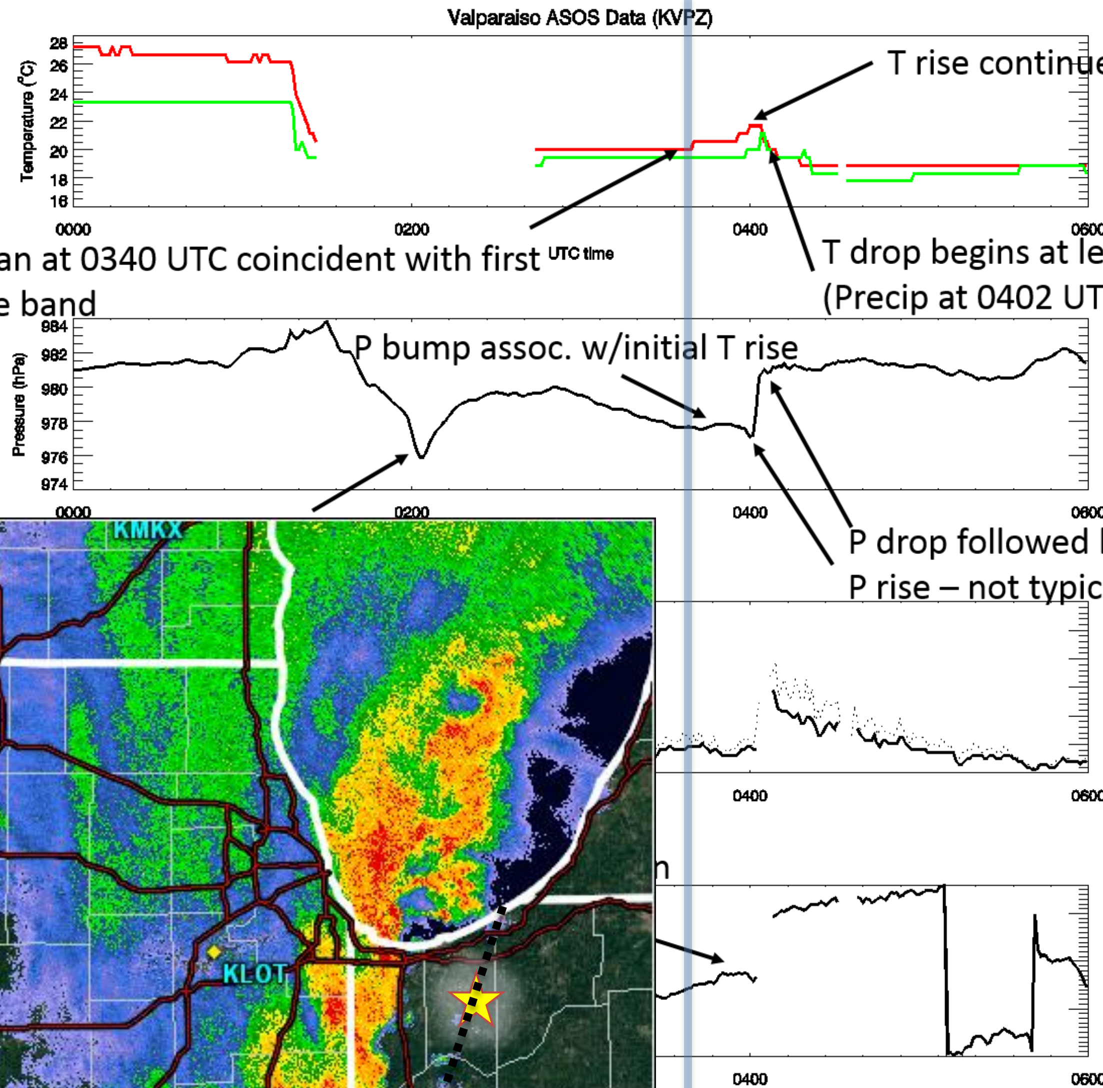
P bump

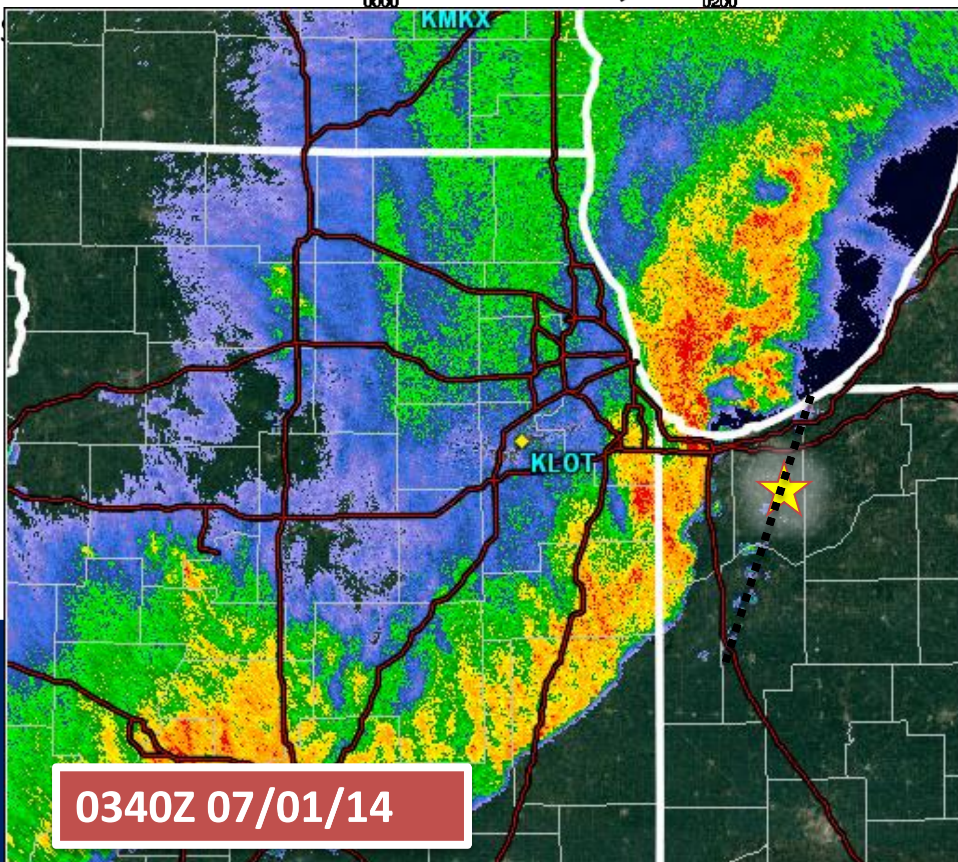
(Side note: wake low passage ~0200 UTC)

Rapid change in w

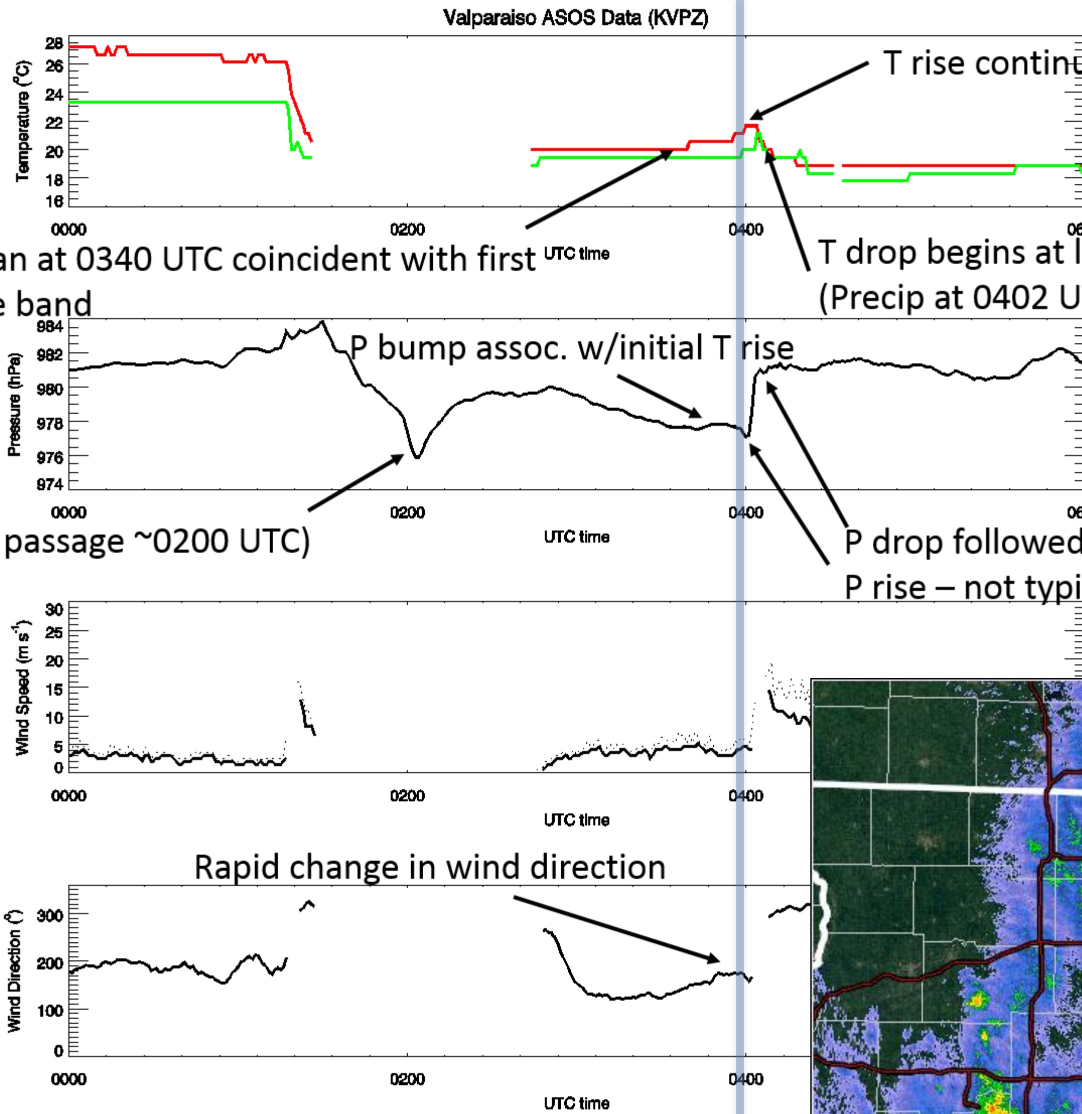


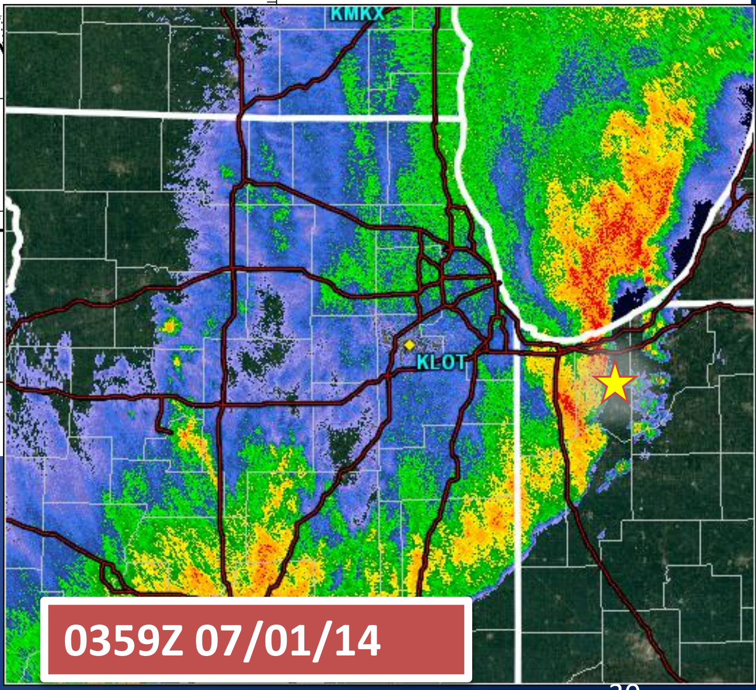
VPZ Time Series


Valparaiso ASOS Data (KVPZ)
Temperature (°C)
28
26
24
22
20
18
16
0000
0200
0400
0600
UTC time
T rise continues as rapid P rise occurs
T rise began at 0340 UTC coincident with first convective band
T drop begins at least 2 min after precip begins
(Precip at 0402 UTC, T drop at 0404-0405 UTC)
Pressure (hPa)
984
982
980
978
976
974
P bump assoc. w/initial T rise
P drop followed by extremely sharp P rise – not typical of a cold pool

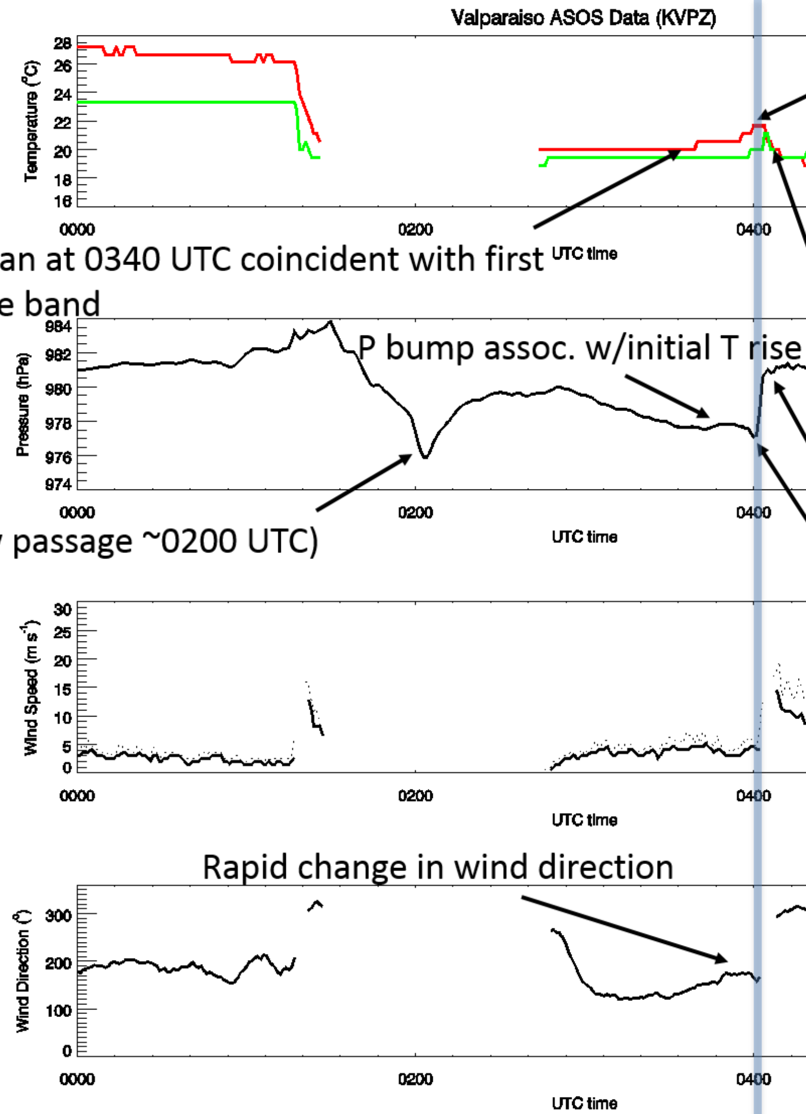

KMKX
KLOT
0340Z 07/01/14

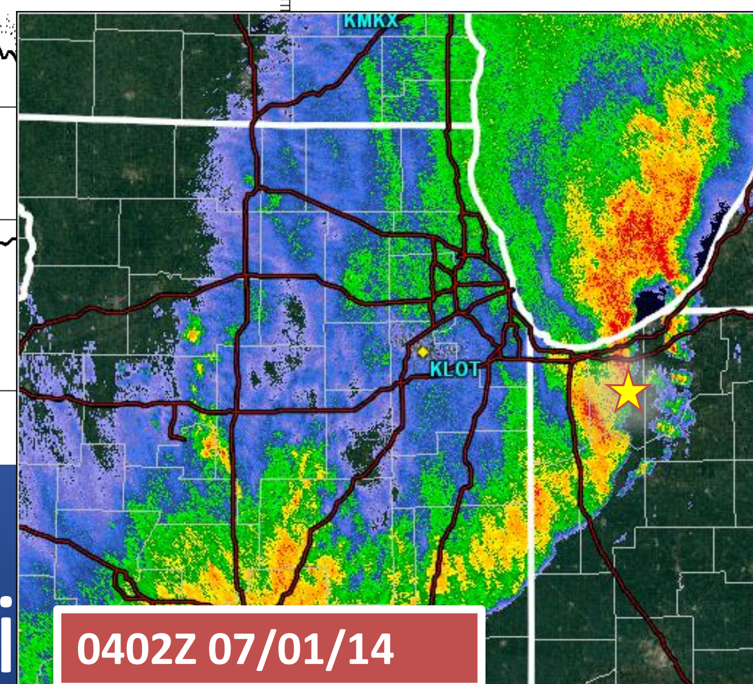
Series





VPZ Time Seri





VPZ Time Seri

Bore Observations & Dynamics

- TEMPERATURE: Steady or rising
- MIXING RATIO: Steady or decreasing
- PRESSURE: Rapid rise

Destabilization of Boundary Layer

- Common consequence of bores
- Raise inversion height
- Mix warmer, drier air to surface

Temperature rise just ahead of QLCS arrival

Speed of Density Current (shallow, with drag)

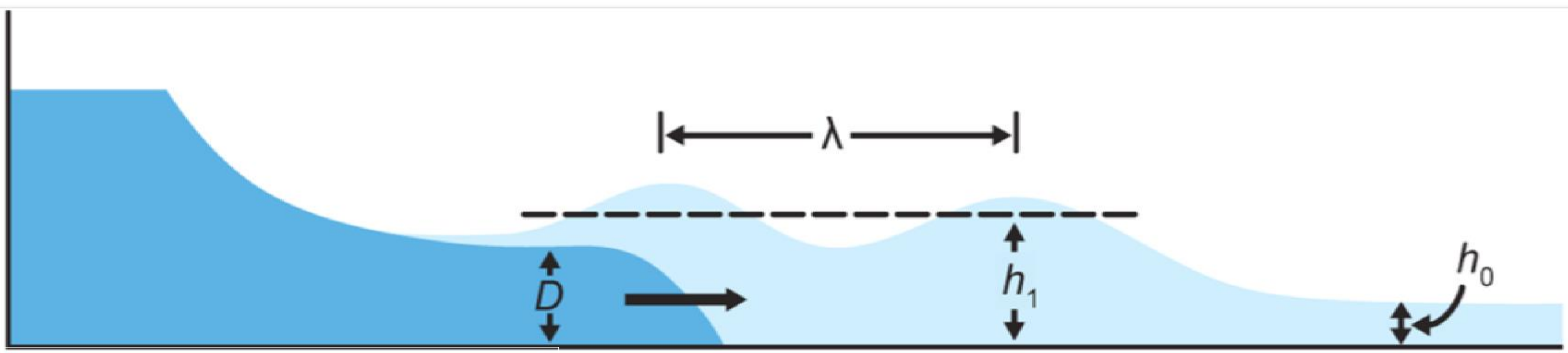
$$c = k\left[gh\frac{\rho 1 - \rho 0}{\rho 0}\right]^{\frac{1}{2}}$$

Speed of Gravity Wave

$$C_{gw} = \left[g\left(\frac{\Delta\theta v}{\theta v}\right)h_0\right]^{\frac{1}{2}}$$

Speed of Bore

$$C_{bore} = C_{gw}\left[\frac{1}{2}\frac{h_1}{h_0}\left(1 + \frac{h_1}{h_0}\right)\right]^{\frac{1}{2}}$$



Markowski and Richardson 2010

Figure 6.12

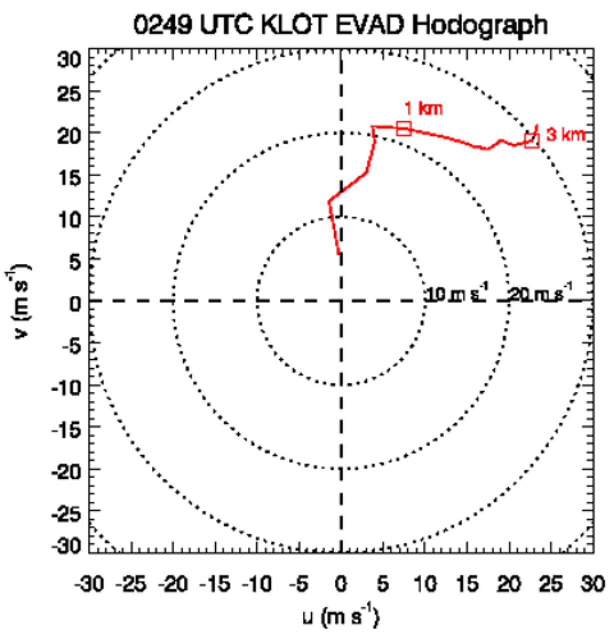
Generation of a bore of depth h_1, by an advancing density current of depth D, intruding into a stable layer of depth h_0. Shading indicates the density of the fluid, with darker shading indicating denser fluid. (Adapted from Rottman and Simpson [1989].)

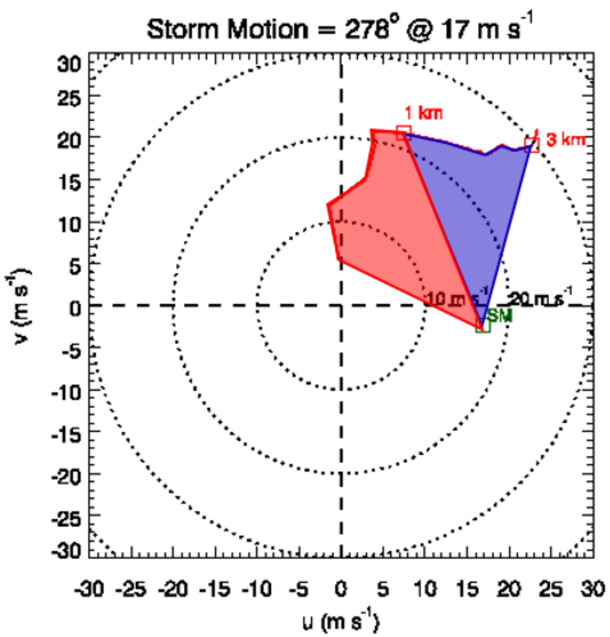
System Motions thru VPZ Area

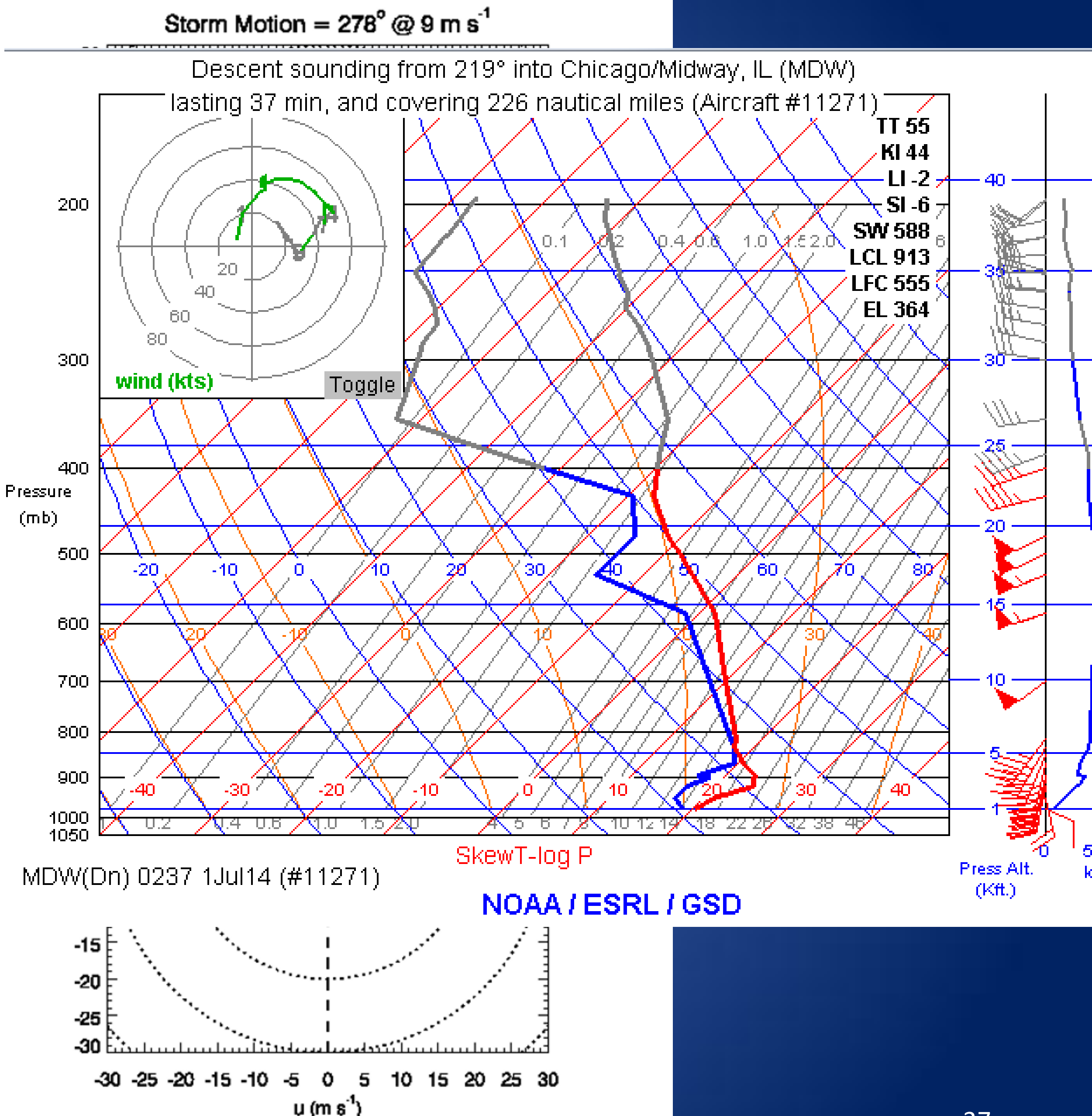
	1st QLCS	2nd QLCS
Actual Speed	17 m/s	25 m/s
Theoretical Cold Pool Speed	16-30 m/s	9-17 m/s
Theoretical Bore Speed	n/a	26 m/s

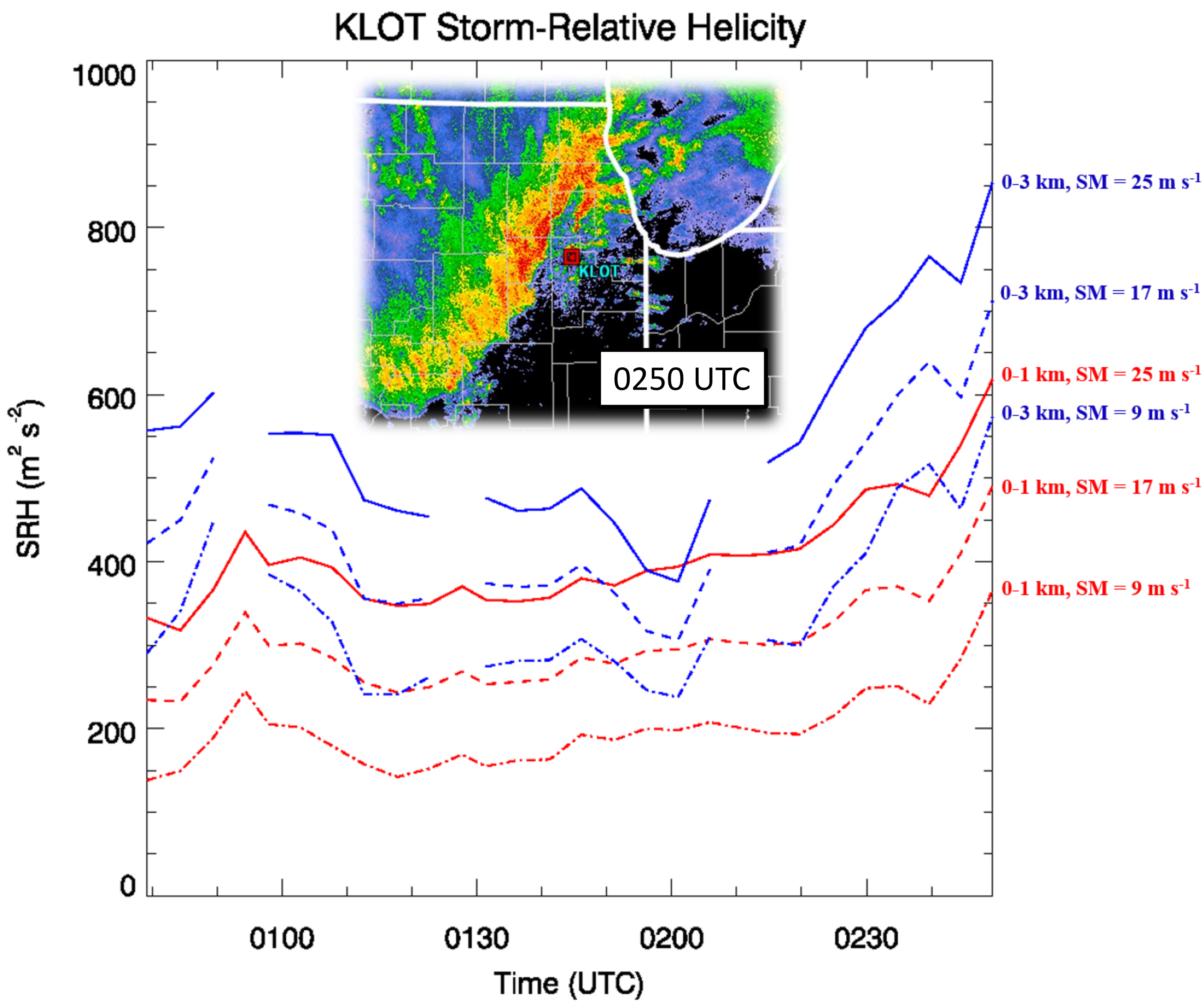
Bore-Driven Enhancement of SRH

- SRH large even with cold-pool propagation speed
- Faster bore-related movement substantially increased environmental SRH
- Result: SRH was extreme for this QLCS

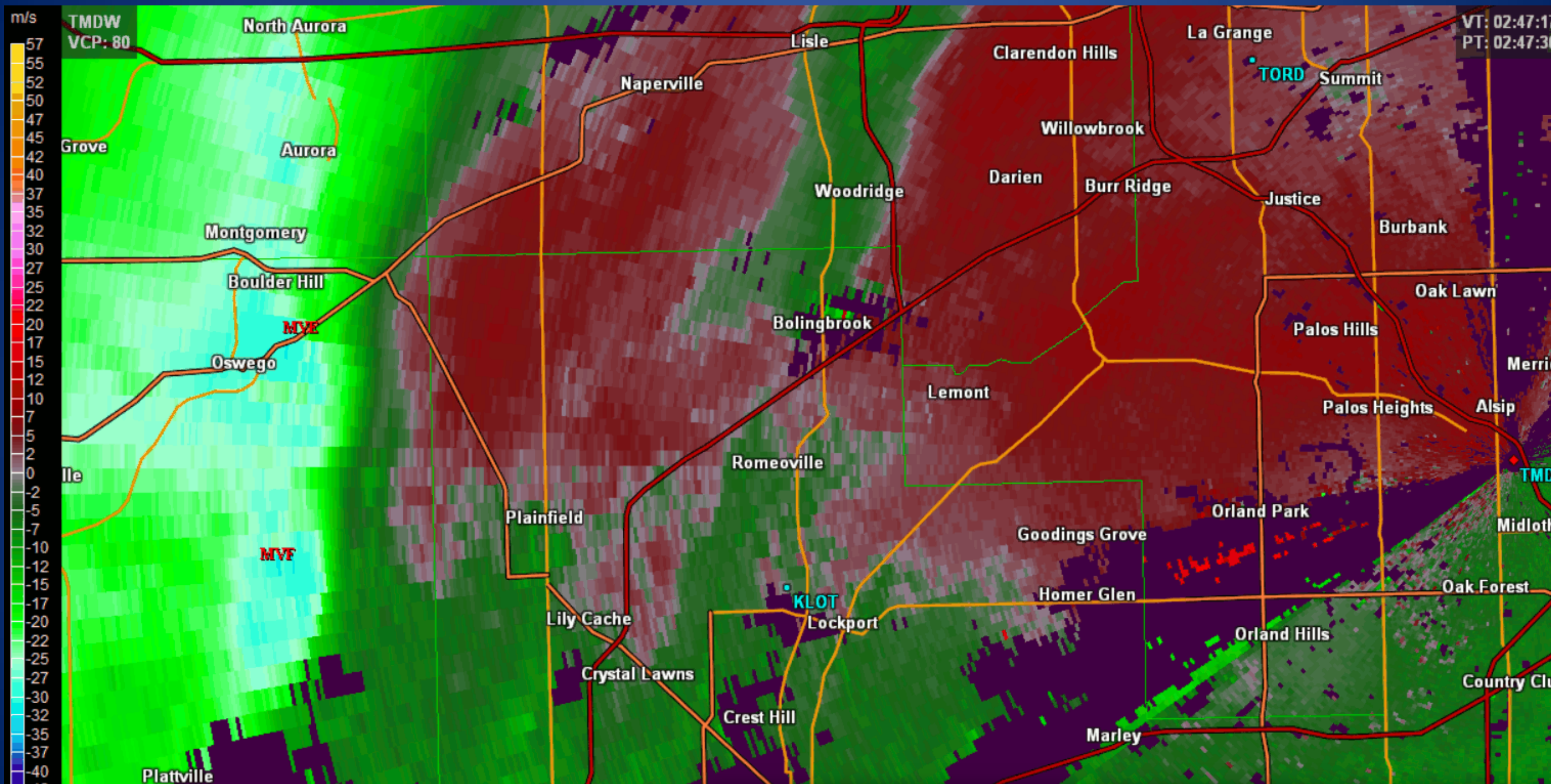

0249 UTC KLOT EVAD Hodograph
1 km
3 km
10 m s-1
20 m s-1
v (m s-1)
u (m s-1)


Storm Motion = 278° @ 17 m s-1
1 km
3 km
10 m s-1
20 m s-1
SM
v (m s-1)
u (m s-1)


Storm Motion = 278° @ 9 m s-1
Descent sounding from 219° into Chicago/Midway, IL (MDW)
lasting 37 min, and covering 226 nautical miles (Aircraft #11271)
TT 55
KI 44
LI -2
SI -6
SW 588
LCL 913
LFC 555
EL 364
wind (kts)
Toggle
Pressure (mb)
SkewT-log P
MDW(Dn) 0237 1Jul14 (#11271)
NOAA / ESRL / GSD
Press Alt. (Kft.)
u (m s-1)


KLOT Storm-Relative Helicity
SRH ($m^2 s^{-2}$)
1000
800
600
400
200
0
0100
0130
0200
0230
Time (UTC)
0250 UTC
KLOT
0-3 km, SM = 25 m s^{-1}
0-3 km, SM = 17 m s^{-1}
0-1 km, SM = 25 m s^{-1}
0-3 km, SM = 9 m s^{-1}
0-1 km, SM = 17 m s^{-1}
0-1 km, SM = 9 m s^{-1}

KLOT Close-up View of QLCS Tornado



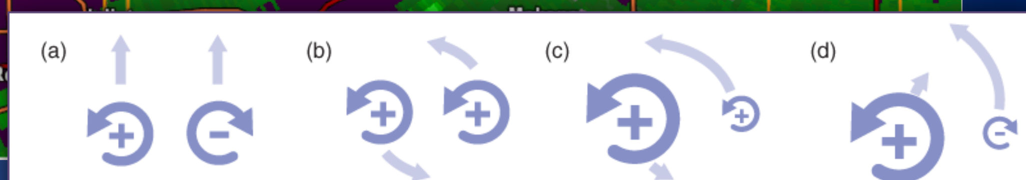


Figure 3.17

Fujiwhara Interactions?

Overall Effect of Bore-Driven Motion

- Ingest of surface or near-surface parcels via:
  - Low-level destabilization
  - Vertical motion associated with bore
- Lifting of parcels to top of stable layer
- Extreme SRH from veered/faster storm motion

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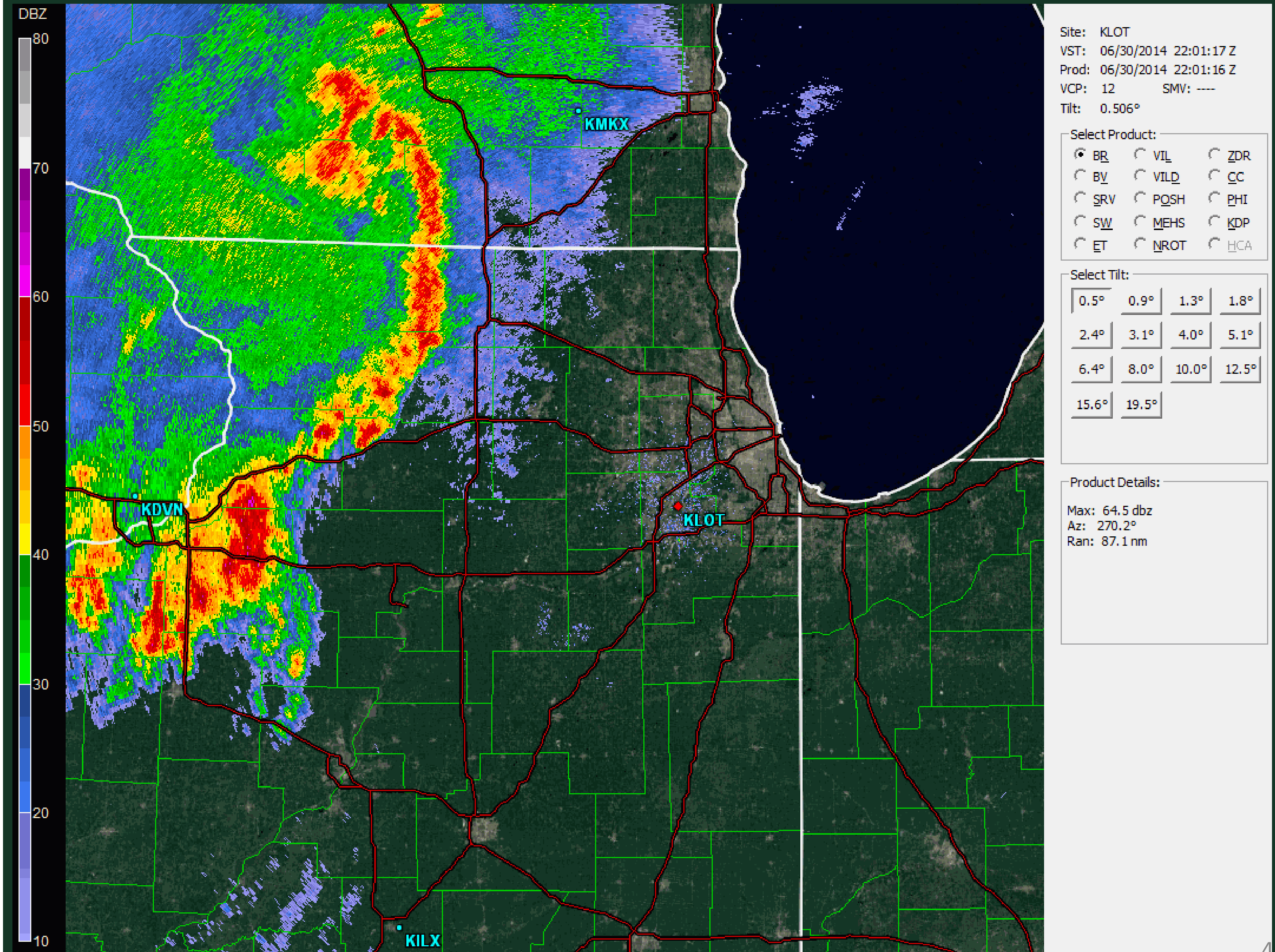
DBZ
80
70
60
50
40
30
20
10
KMKX
KDVN
KLOT
KILX
Site: KLOT
VST: 06/30/2014 22:01:17 Z
Prod: 06/30/2014 22:01:16 Z
VCP: 12 SMV: ----
Tilt: 0.506°
Select Product:
BR VIL ZDR
BV VILD CC
SRV POSH PHI
SW MEHS KDP
ET NROT HCA
Select Tilt:
0.5° 0.9° 1.3° 1.8°
2.4° 3.1° 4.0° 5.1°
6.4° 8.0° 10.0° 12.5°
15.6° 19.5°
Product Details:
Max: 64.5 dbz
Az: 270.2°
Ran: 87.1 nm