TORUS supercell weather

Targeted Observations by Radar and UAS of Supercells

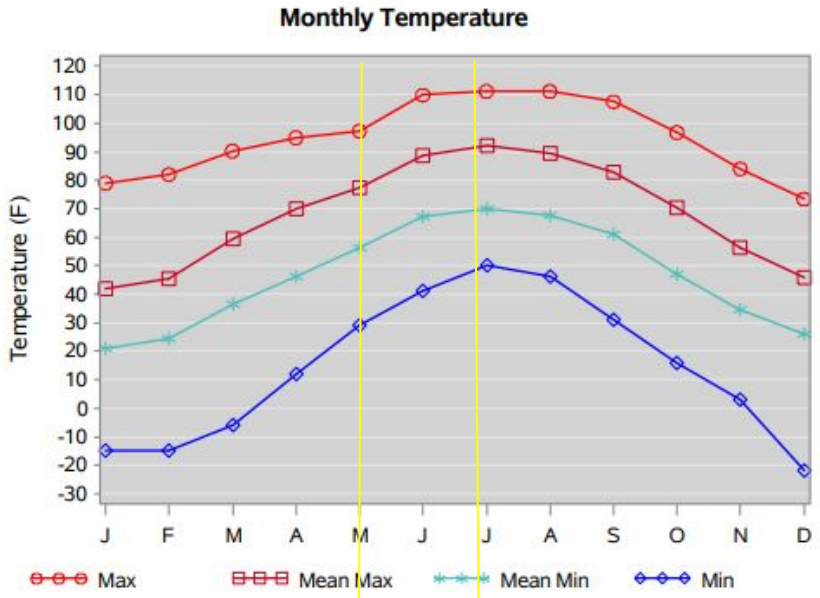
Nikki Hathaway and Mike Holmes

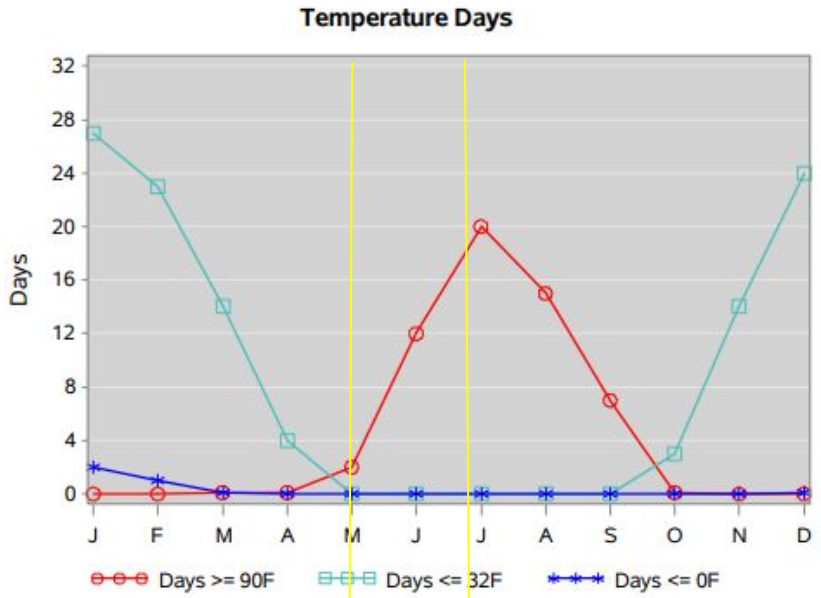
TORUS talk outline

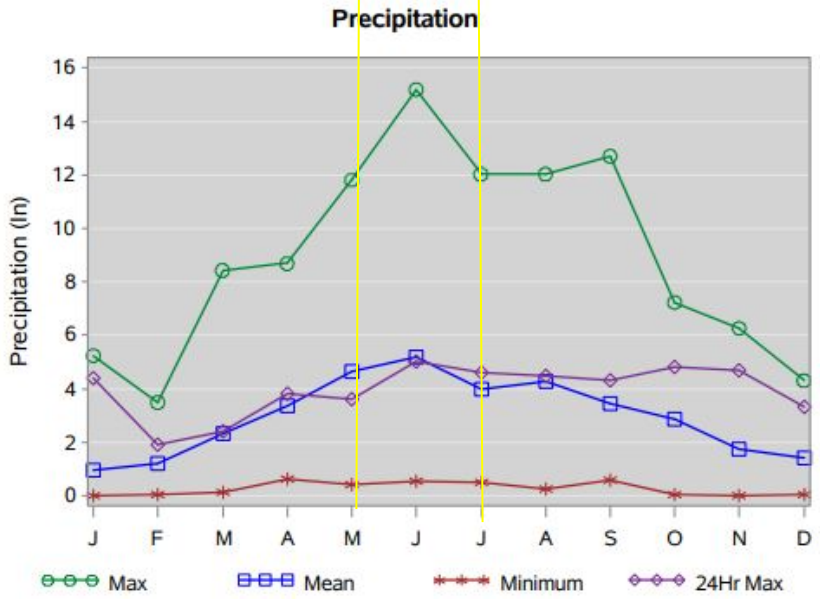
- Topeka area climatology
- Definition and description of supercells
- Weather variants
- Flight hazards
- Project notes

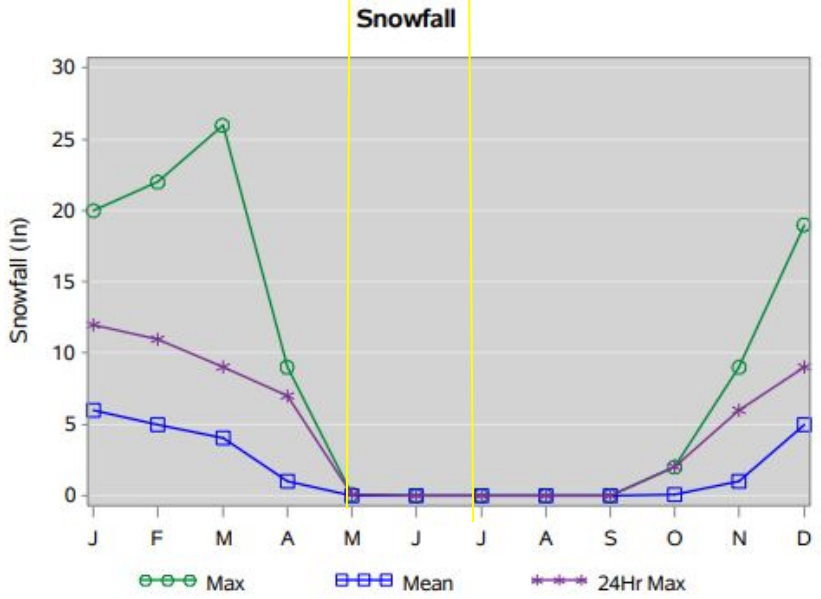
Station Name: FORBES FLD, KS Station ID: ICAO KFOE

Lat=38.951 Lon=-95.664 Elev=1078 Ft Means POR=2010-2019 Extremes POR=1942-2020









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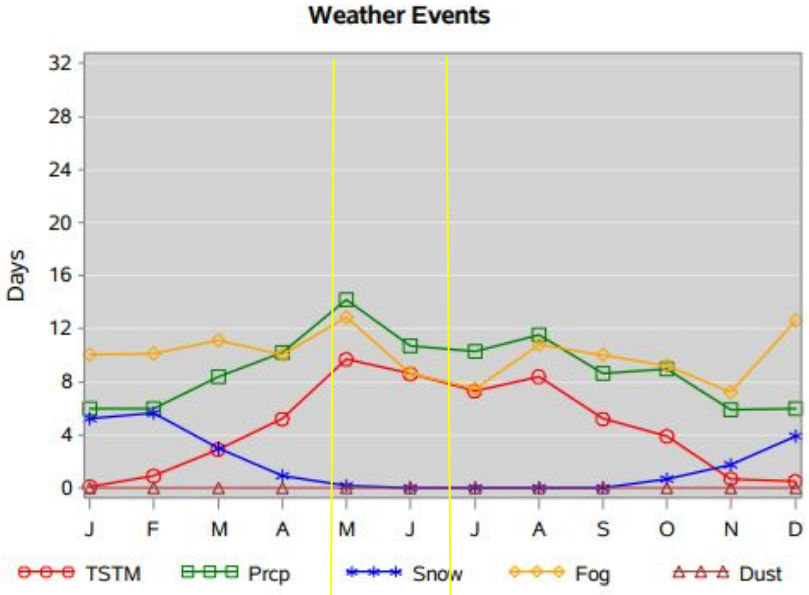

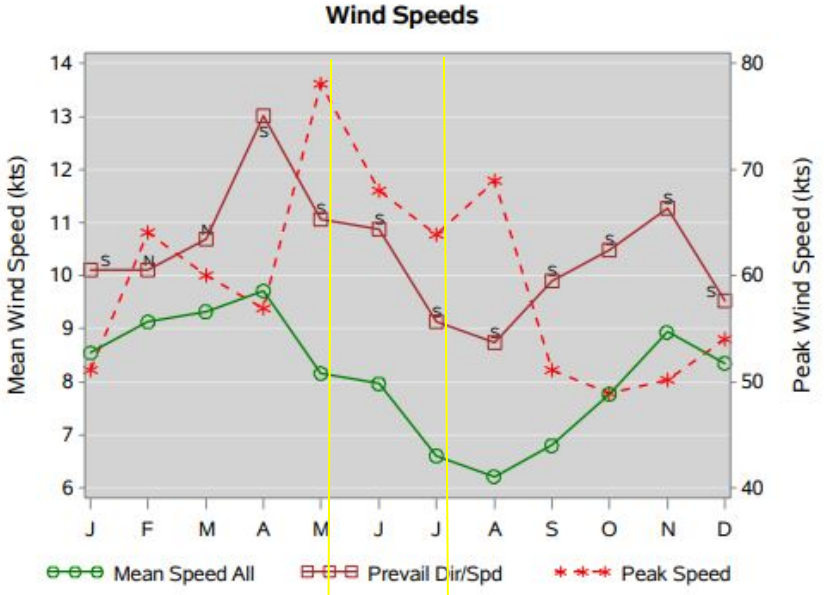

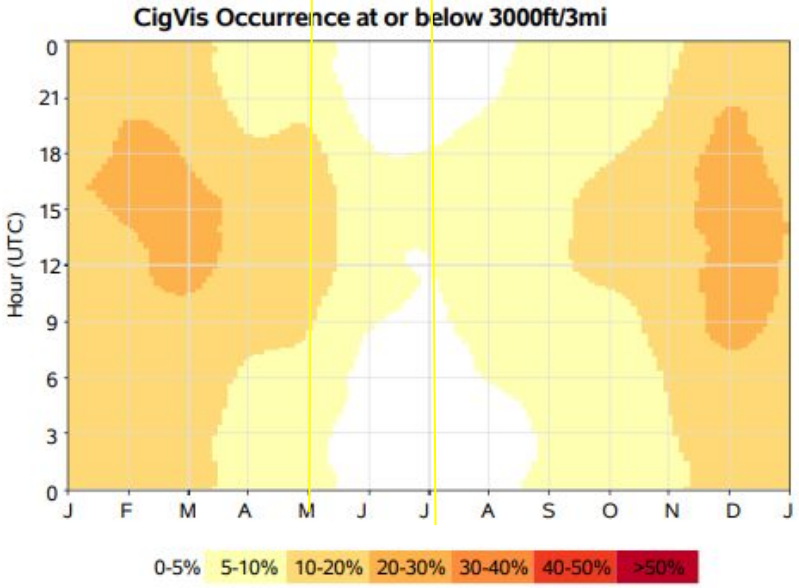

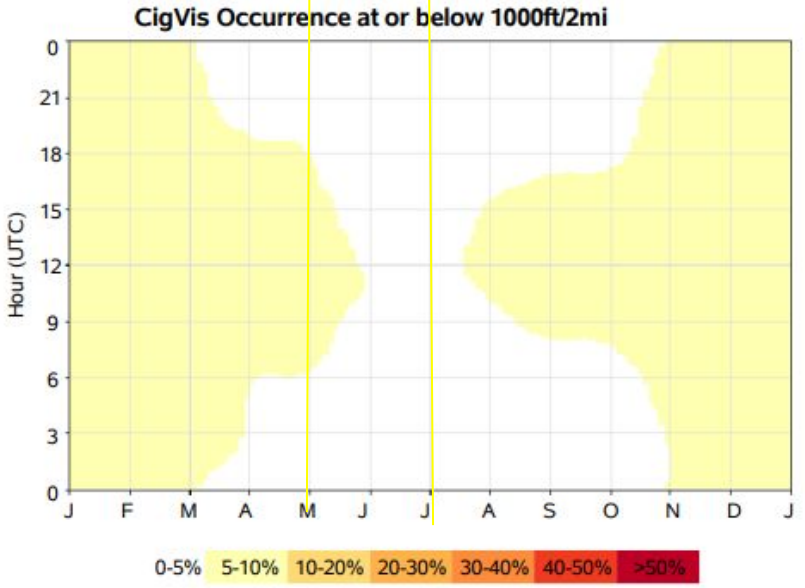

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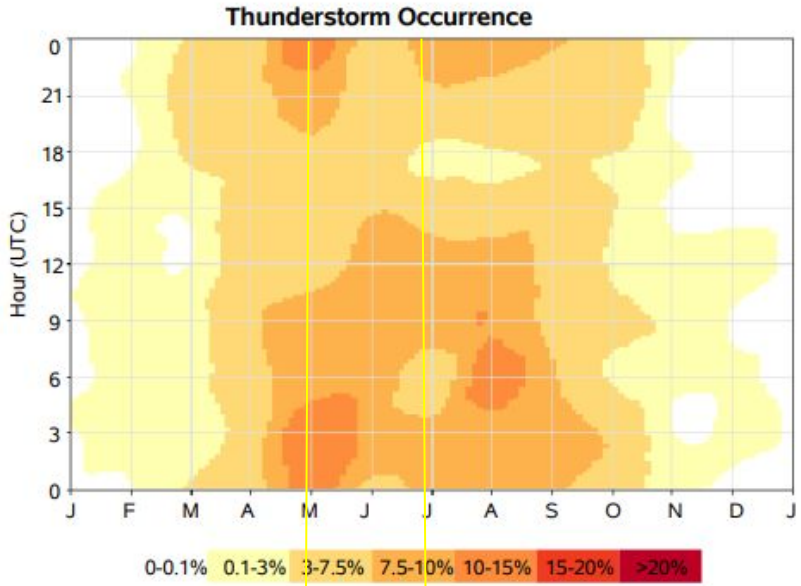
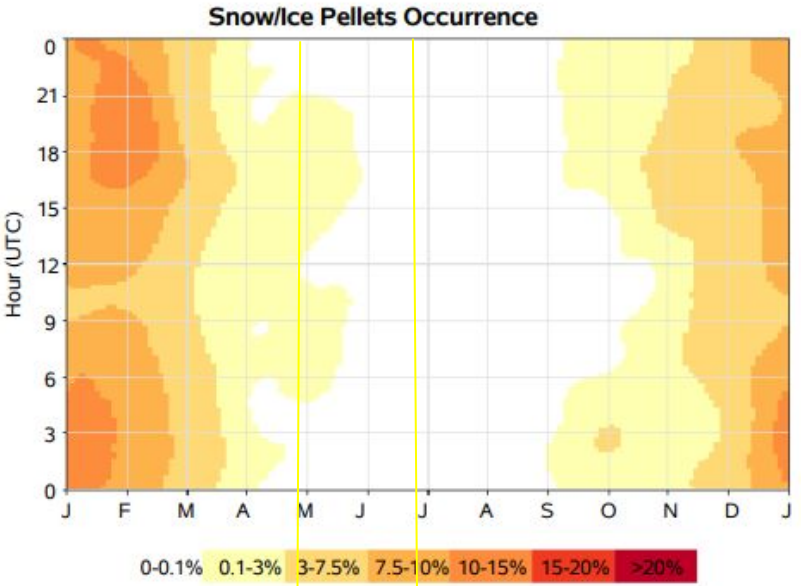
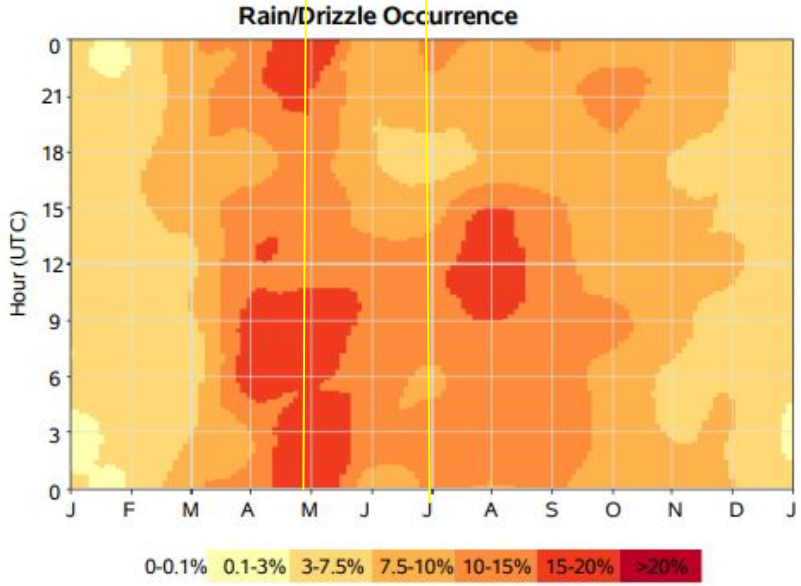
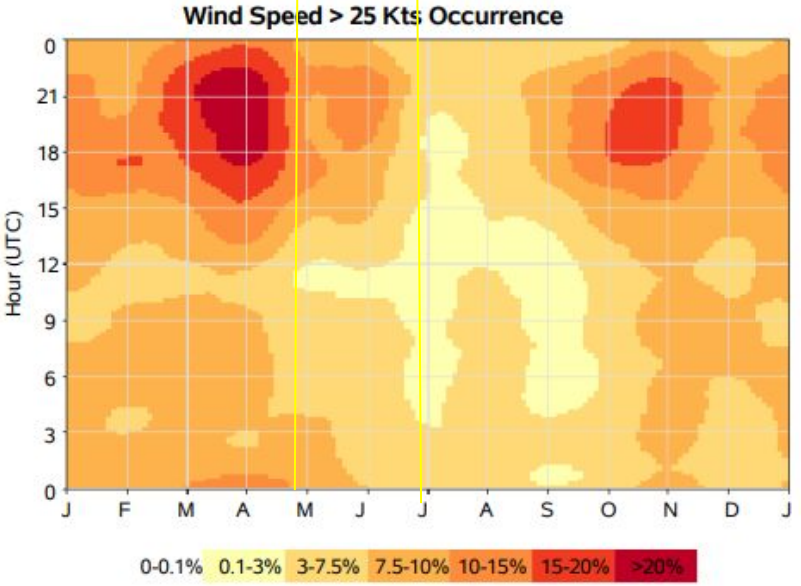
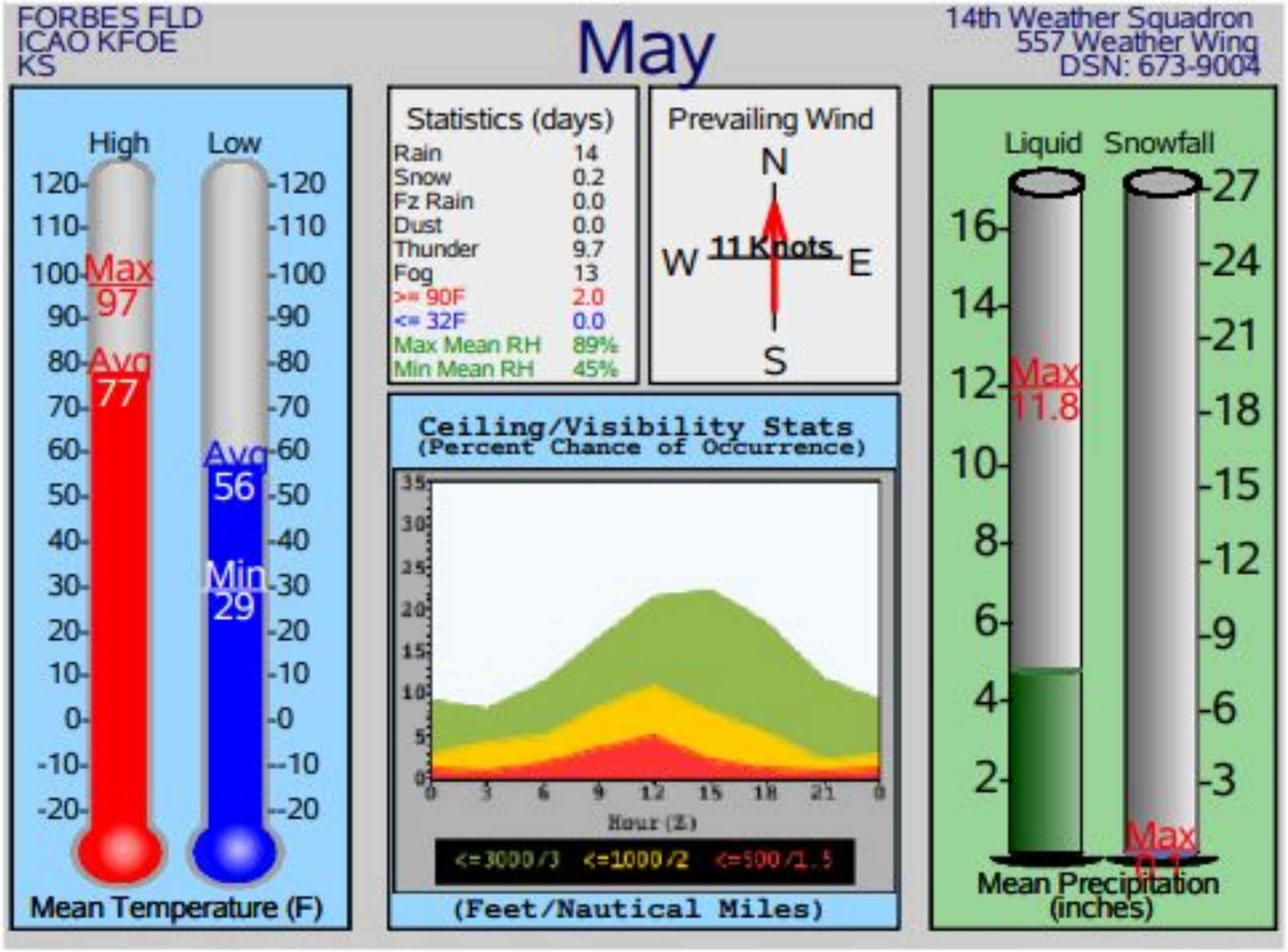
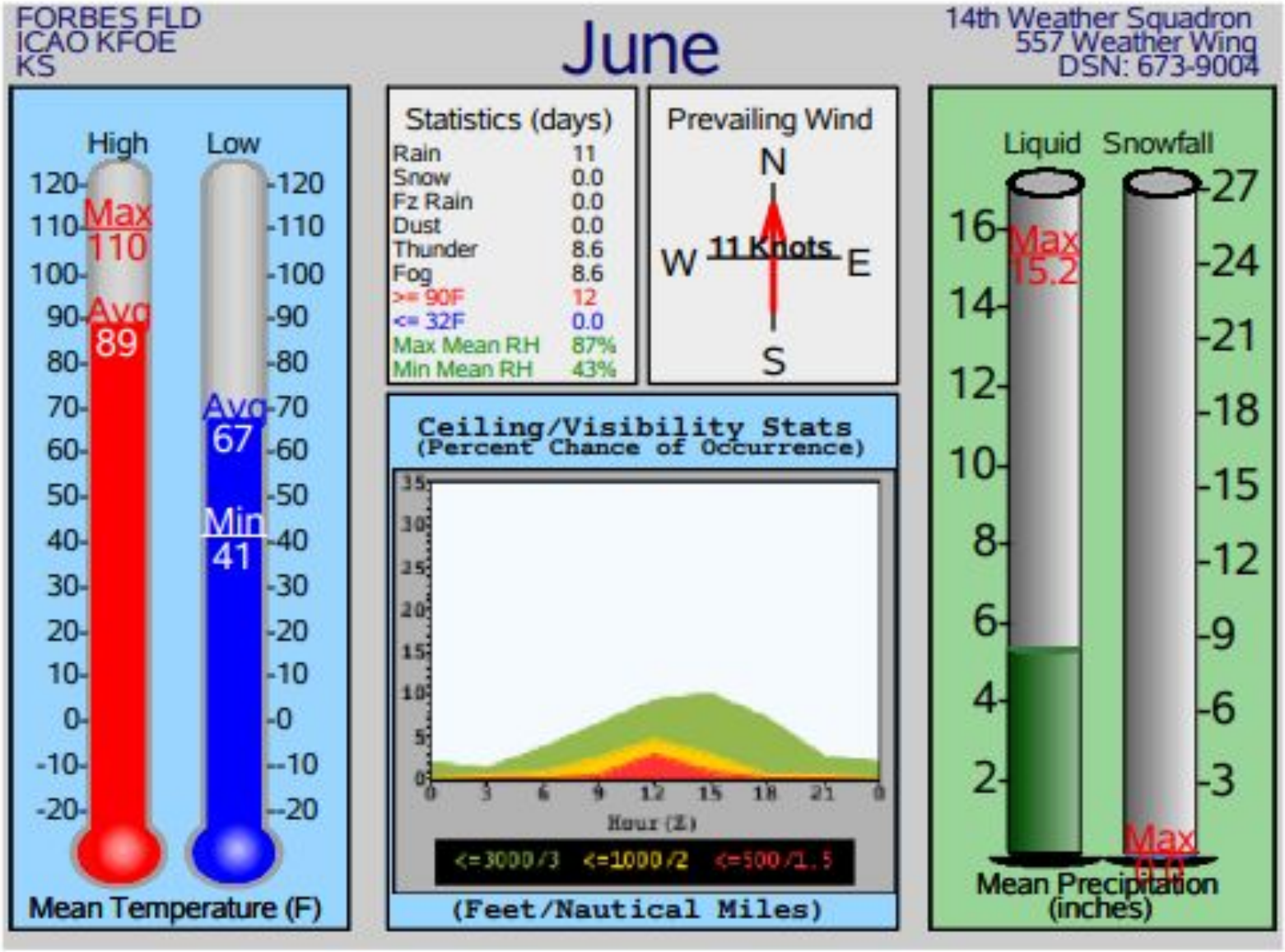









FORBES FLD
ICAO KFOE
KS
May
14th Weather Squadron
557 Weather Wing
DSN: 673-9004
High
Low
Max
97
Avg
77
Avg
56
Min
29
Mean Temperature (F)
Statistics (days)
Rain 14
Snow 0.2
Fz Rain 0.0
Dust 0.0
Thunder 9.7
Fog 13
>= 90F 2.0
<= 32F 0.0
Max Mean RH 89%
Min Mean RH 45%
Prevailing Wind
N
W
11 Knots
E
S
Ceiling/Visibility Stats
(Percent Chance of Occurrence)
Hour (Z)
<=3000/3 <=1000/2 <=500/1.5
(Feet/Nautical Miles)
Liquid
Snowfall
Max
11.8
Max
Mean Precipitation
(inches)


FORBES FLD
ICAO KFOE
KS
June
14th Weather Squadron
557 Weather Wing
DSN: 673-9004
High
Low
Max
110
Avg
89
Avg
67
Min
41
Mean Temperature (F)
Statistics (days)
Rain 11
Snow 0.0
Fz Rain 0.0
Dust 0.0
Thunder 8.6
Fog 8.6
>= 90F 12
<= 32F 0.0
Max Mean RH 87%
Min Mean RH 43%
Prevailing Wind
N
W
11 Knots
E
S
Ceiling/Visibility Stats
(Percent Chance of Occurrence)
Hour (Z)
<=3000/3
<=1000/2
<=500/1.5
(Feet/Nautical Miles)
Liquid
Snowfall
Max
15.2
Max
Mean Precipitation
(inches)

TORUS talk outline

- Salina area climatology

- Definition and description of supercells

Definitions:

- **TORUS**: Targeted Observation by Radar and UAS of Supercells
- **Supercell**: thunderstorm characterized by the presence of a mesovortex, a deep, persistently rotating updraft.
- **Mesovortex (meso)**: A storm-scale region of rotation, typically around 2-6 miles in diameter and often found in the right rear flank of a supercell (or often on the eastern, or front, flank of an HP storm). The circulation of a mesocyclone covers an area much larger than the tornado that may develop within it.

Definitions:

- **Tornado**: A violently rotating column of air, usually pendant to a cumulonimbus, with circulation reaching the ground. It nearly always starts as a funnel cloud and may be accompanied by a loud roaring noise. On a local scale, it is the most destructive of all atmospheric phenomena.
- **Funnel Cloud**: A condensation funnel extending from the base of a towering cumulus or Cb, associated with a rotating column of air that is not in contact with the ground (and hence different from a tornado).

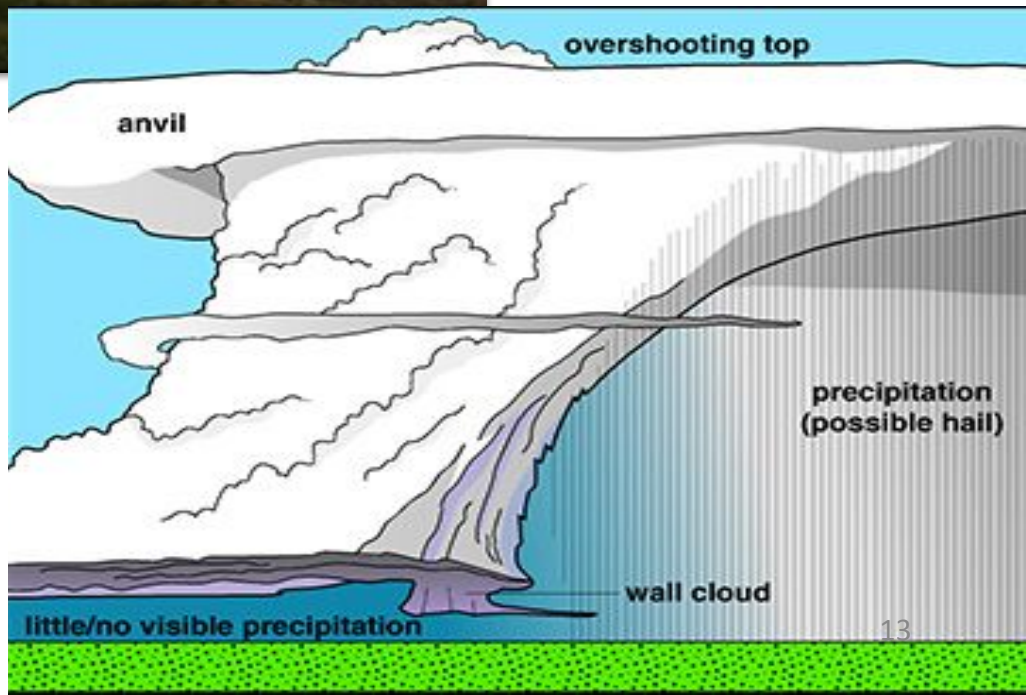
NSSL supercell acronyms

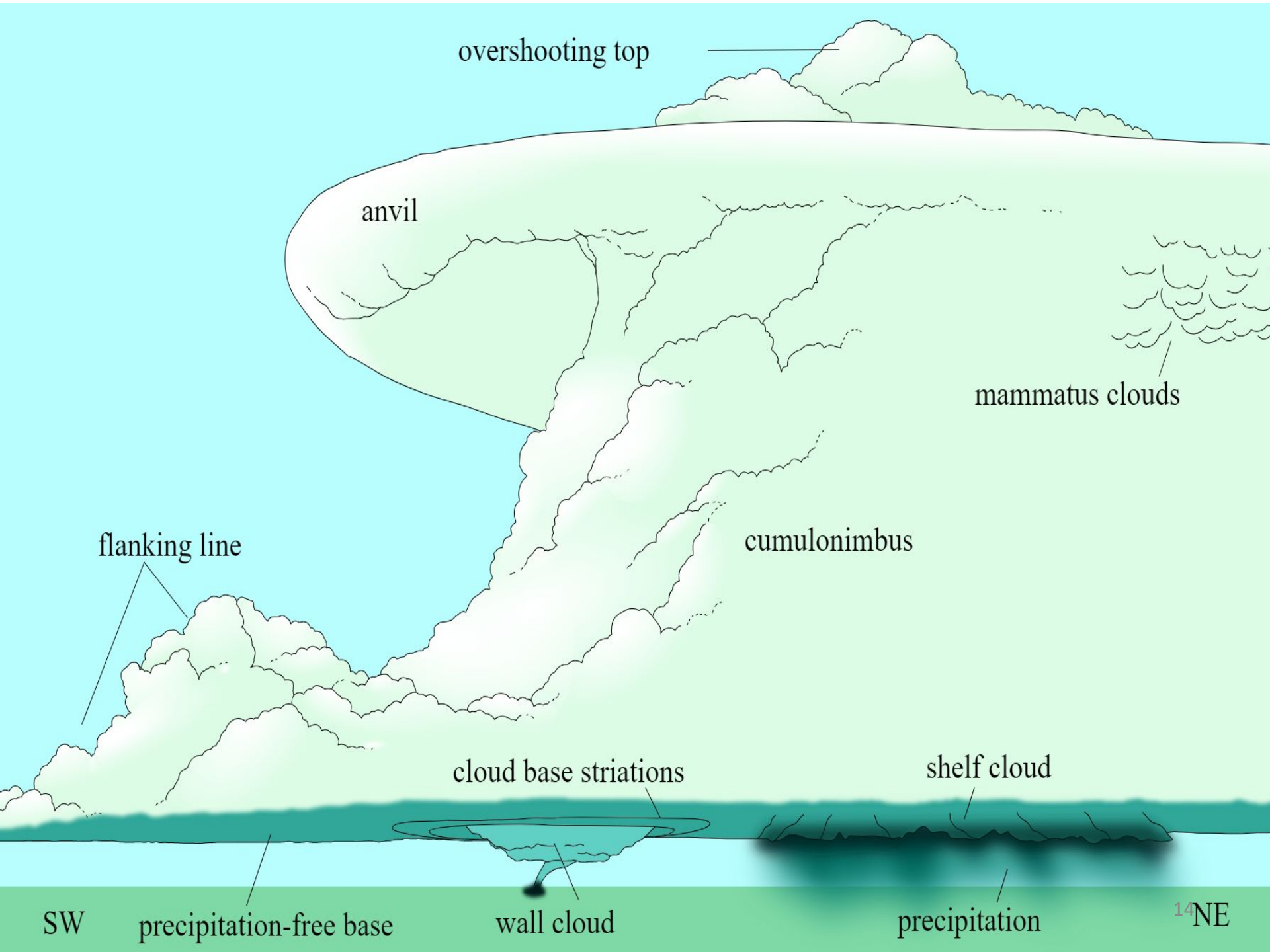
Please don't commit to memory!

MCS: Mesoscale Convective Systems
QLCS: Quasi-Linear Convective Systems
CL: Convective Line
PBL: Planetary Boundary Layer
RFGF: the leading edge of the rear-flank downdraft [**RFD**] outflow gust front
FFGF: the leading edge of the forward-flank downdraft [**FFD**] outflow gust front
RFIS: rear-flank internal surge
RFISB: rear-flank outflow (**RFO**) leading boundary
RFO: rear-flank outflow
LLS: low-level shear
VPPGF: vertical perturbation pressure gradient force
DRC: descending reflectivity cores
SVC: streamwise vorticity currents
LFVVS: left-flank vertical vorticity sheet
LFCB: left-flank convergence boundary

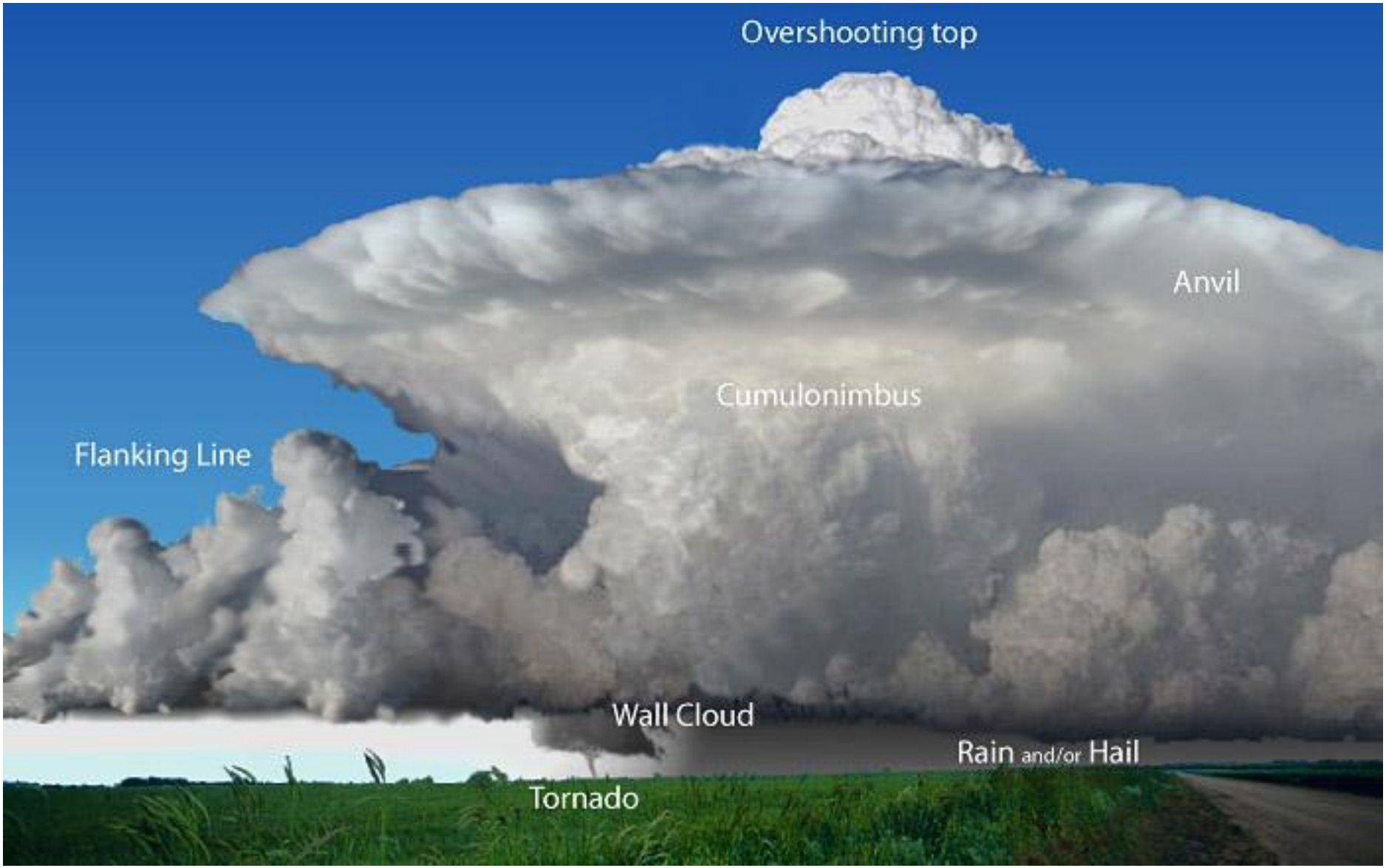
Supercell Descriptors

- 10-30 miles wide
- Tops 55,000-70,000 feet (occasionally overshooting tops even higher)
- Bases 2000-6000 ft AGL
- Overground speed 10-60 knots
- Lifespan 1-10 hours
- Updraft strength – Up to 50 m/s
- Reflectivity > 70 DBZ (when wet hail is sensed)
- Profound rotation, anvil, usually flanking line.


overshooting top
anvil
precipitation
(possible hail)
wall cloud
little/no visible precipitation


overshooting top
anvil
mammatus clouds
flanking line
cumulonimbus
cloud base striations
shelf cloud
SW
precipitation-free base
wall cloud
precipitation
NE


A
B
C
D
E
F
Photo courtesy Brian & Steve Koch
May 31, 2013 El Reno, Oklahoma


Overshooting top
Anvil
Cumulonimbus
Flanking Line
Wall Cloud
Rain and/or Hail
Tornado

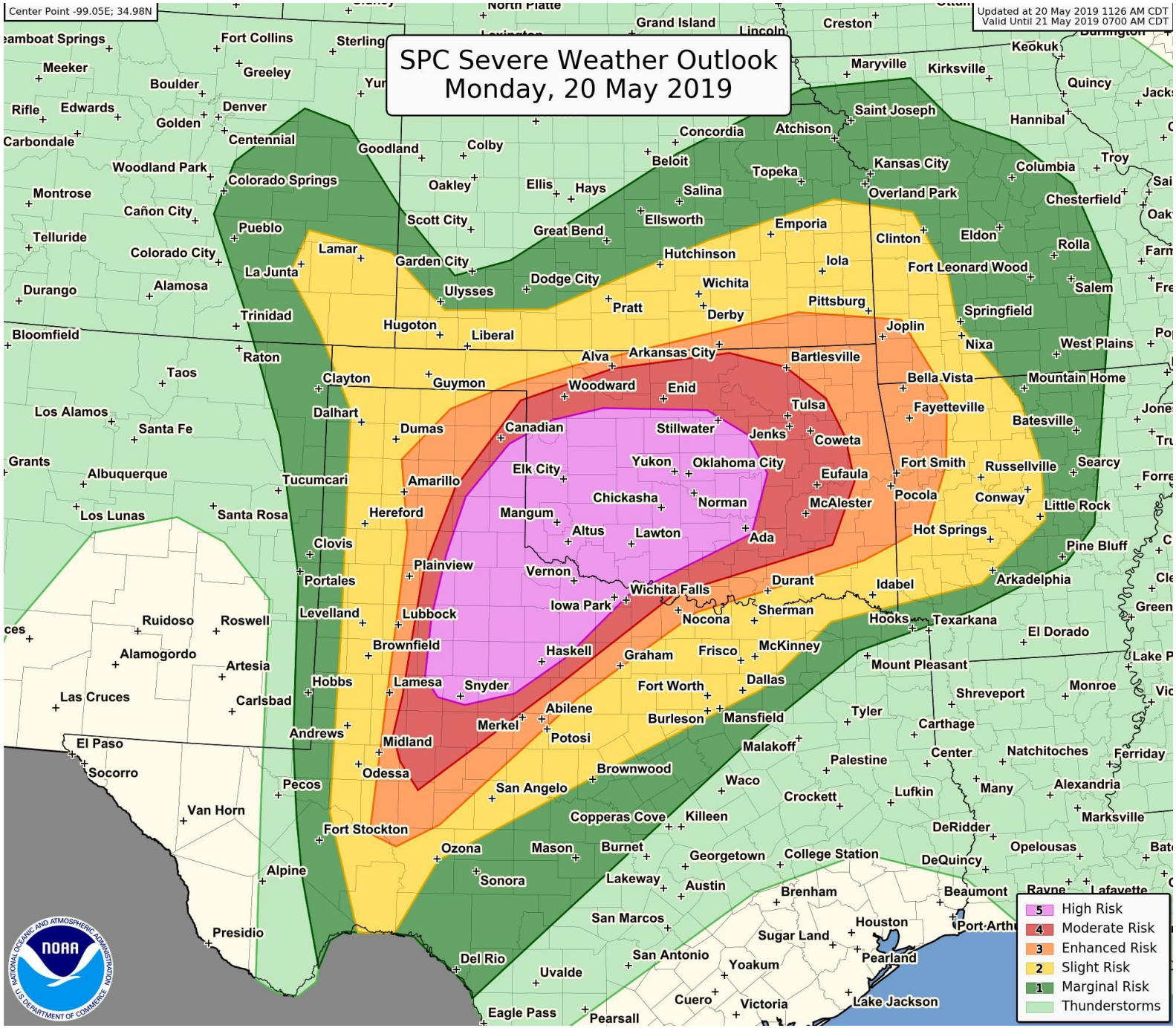
Understanding Severe Thunderstorm Risk Categories

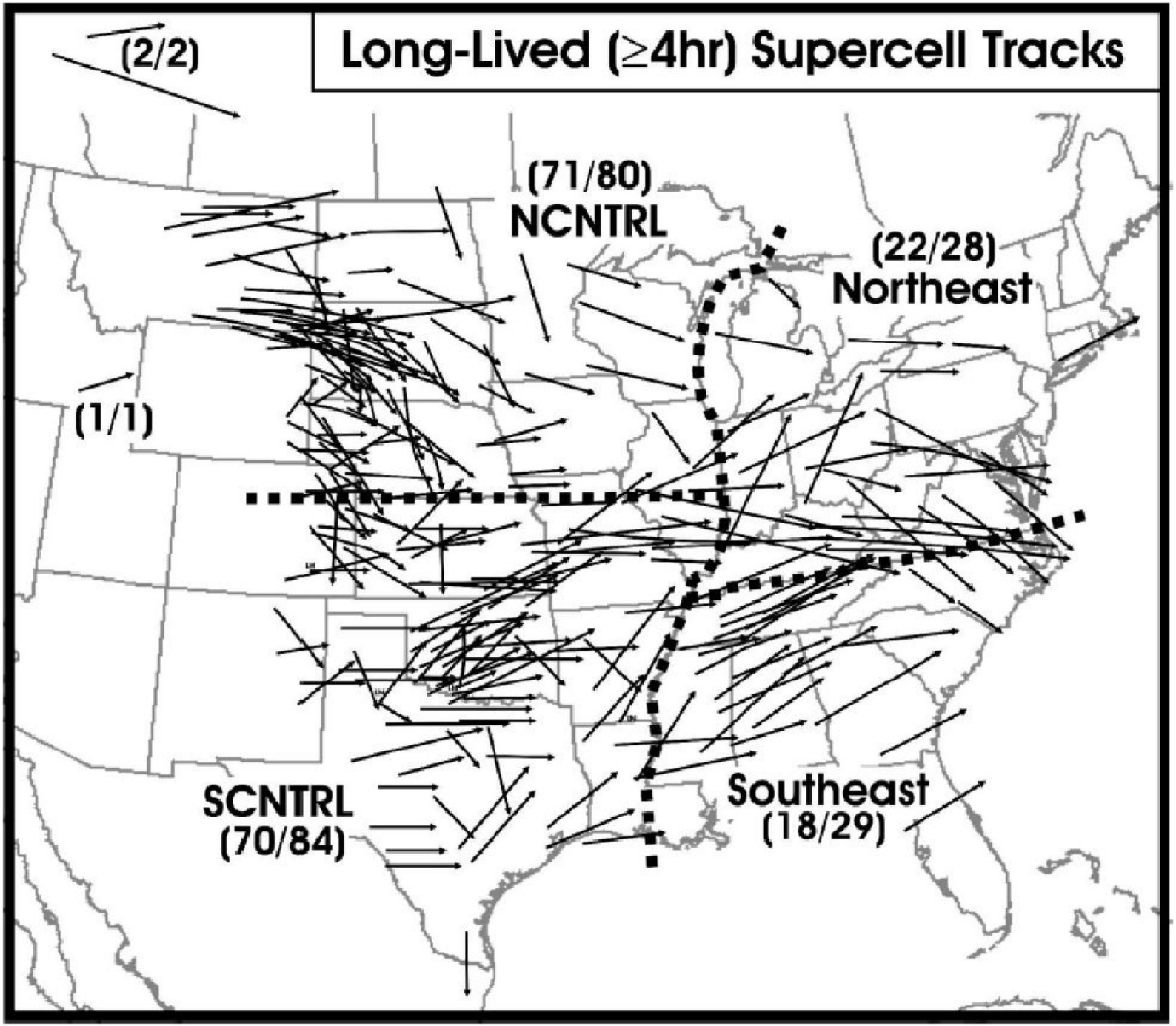
THUNDERSTORMS (no label)	1 - MARGINAL (MRGL)	2 - SLIGHT (SLGT)	3 - ENHANCED (ENH)	4 - MODERATE (MDT)	5 - HIGH (HIGH)
No severe* thunderstorms expected	**Isolated severe thunderstorms possible**	**Scattered severe storms possible**	**Numerous severe storms possible**	**Widespread severe storms likely**	**Widespread severe storms expected**
Lightning/flooding threats exist with all thunderstorms	Limited in duration and/or coverage and/or intensity	Short-lived and/or not widespread, isolated intense storms possible	More persistent and/or widespread, a few intense	Long-lived, widespread and intense	Long-lived, very widespread and particularly intense
					

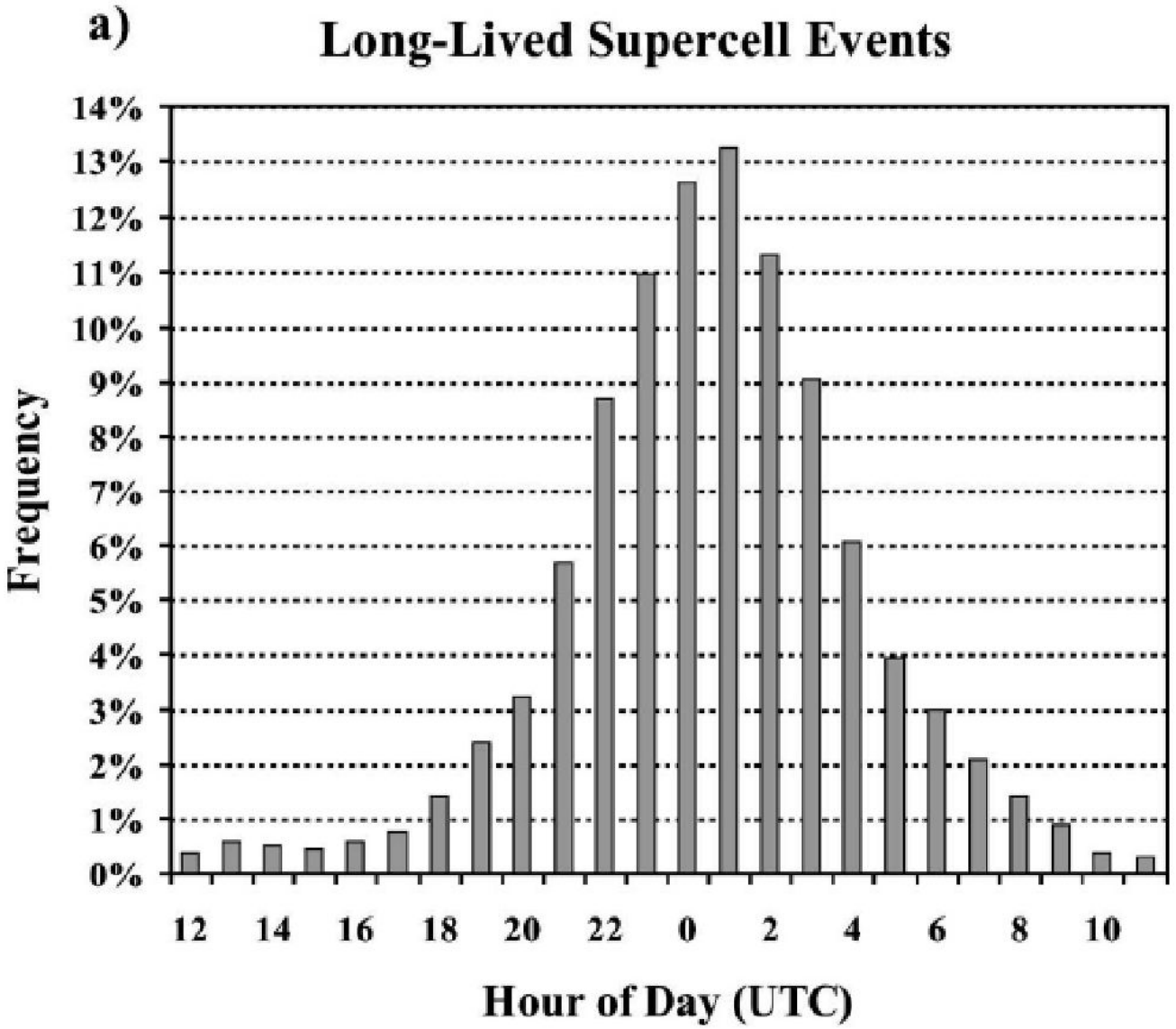
* NWS defines a severe thunderstorm as measured wind gusts to at least 58 mph, and/or hail to at least one inch in diameter, and/or a tornado. All thunderstorm categories imply lightning and the potential for flooding. Categories are also tied to the probability of a severe weather event within 25 miles of your location.

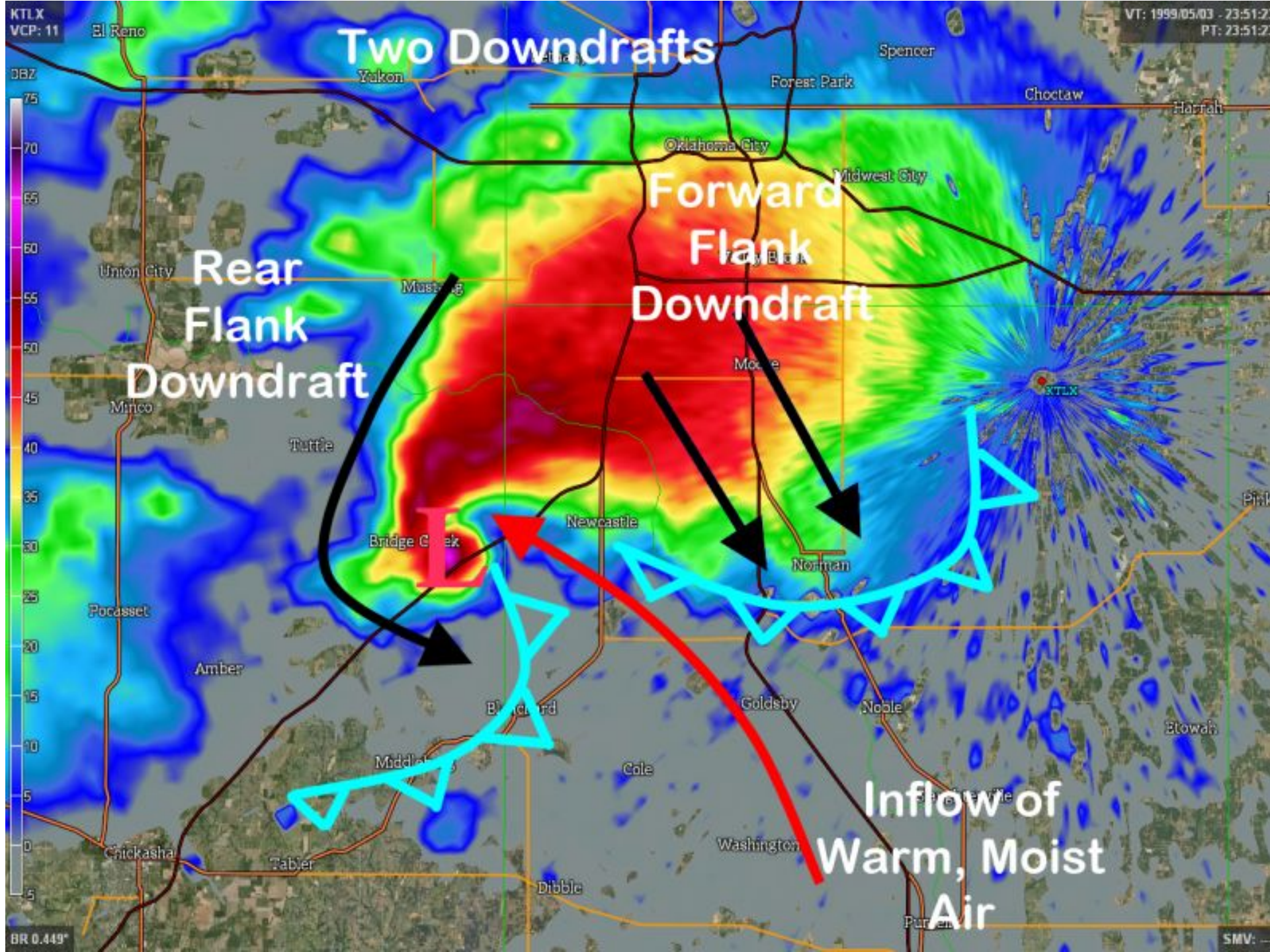
National Weather Service

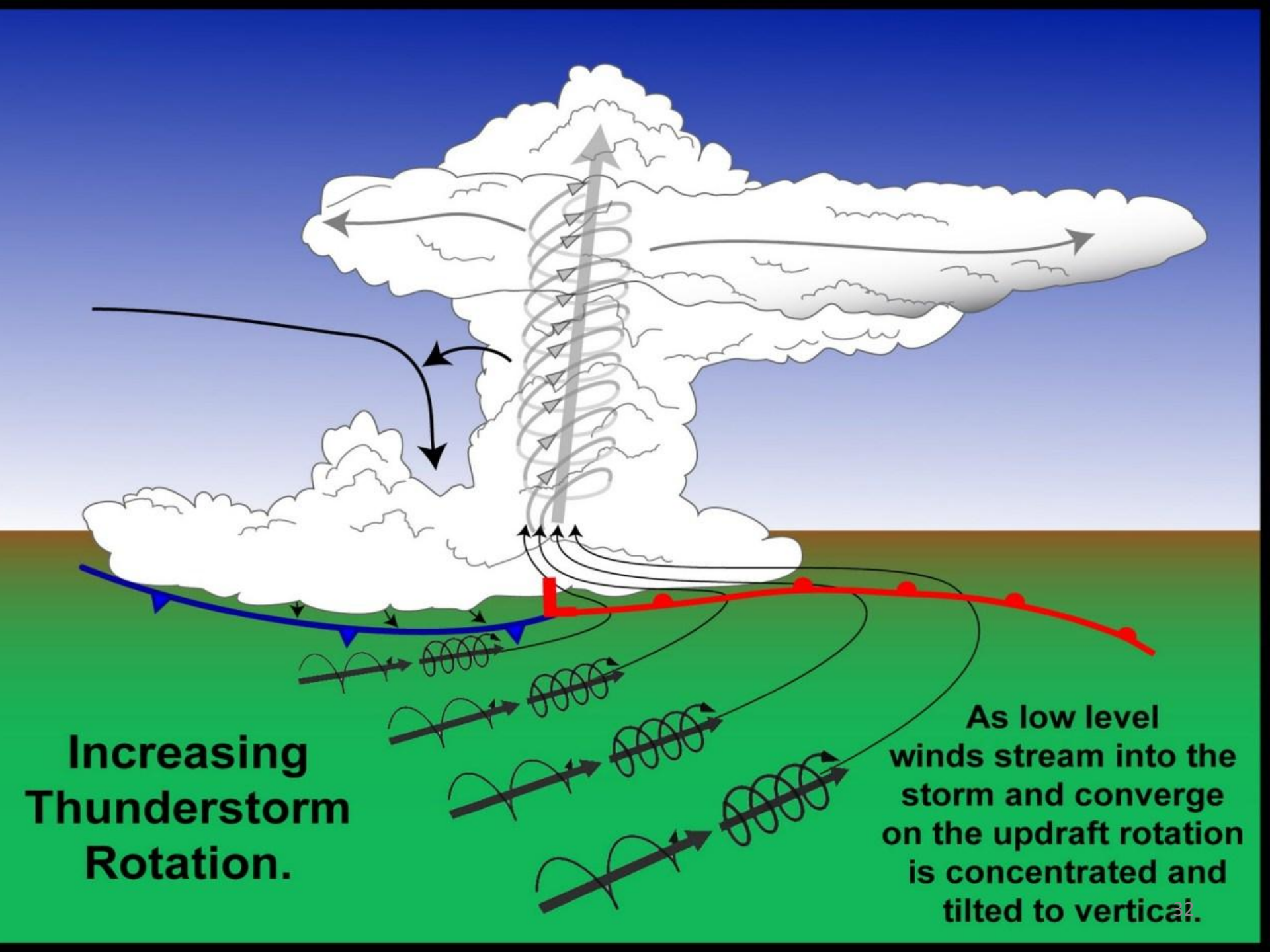
www.spc.noaa.gov

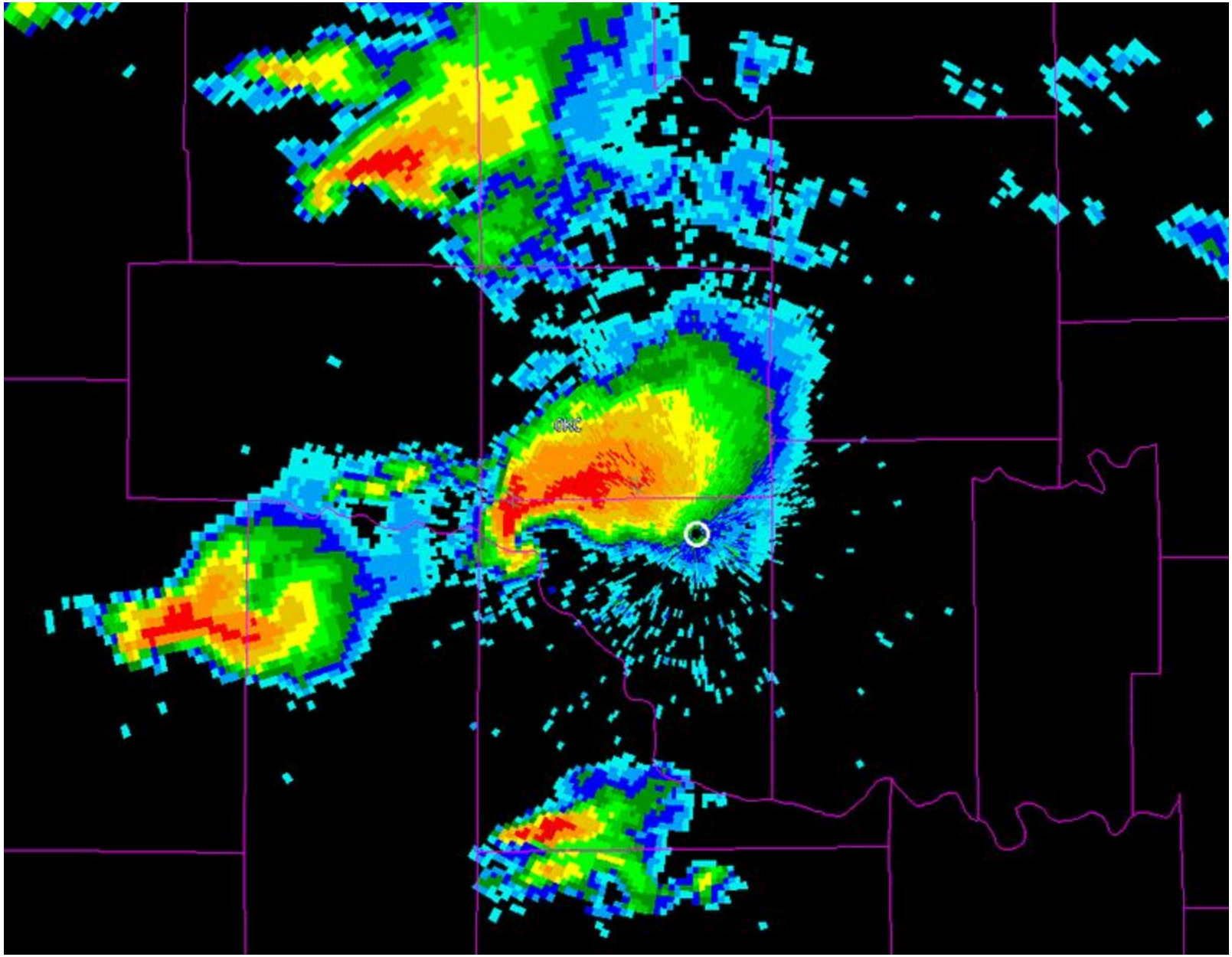

Center Point -99.05E; 34.98N
Updated at 20 May 2019 1126 AM CDT
Valid Until 21 May 2019 0700 AM CDT
SPC Severe Weather Outlook
Monday, 20 May 2019
5 High Risk
4 Moderate Risk
3 Enhanced Risk
2 Slight Risk
1 Marginal Risk
Thunderstorms
NOAA

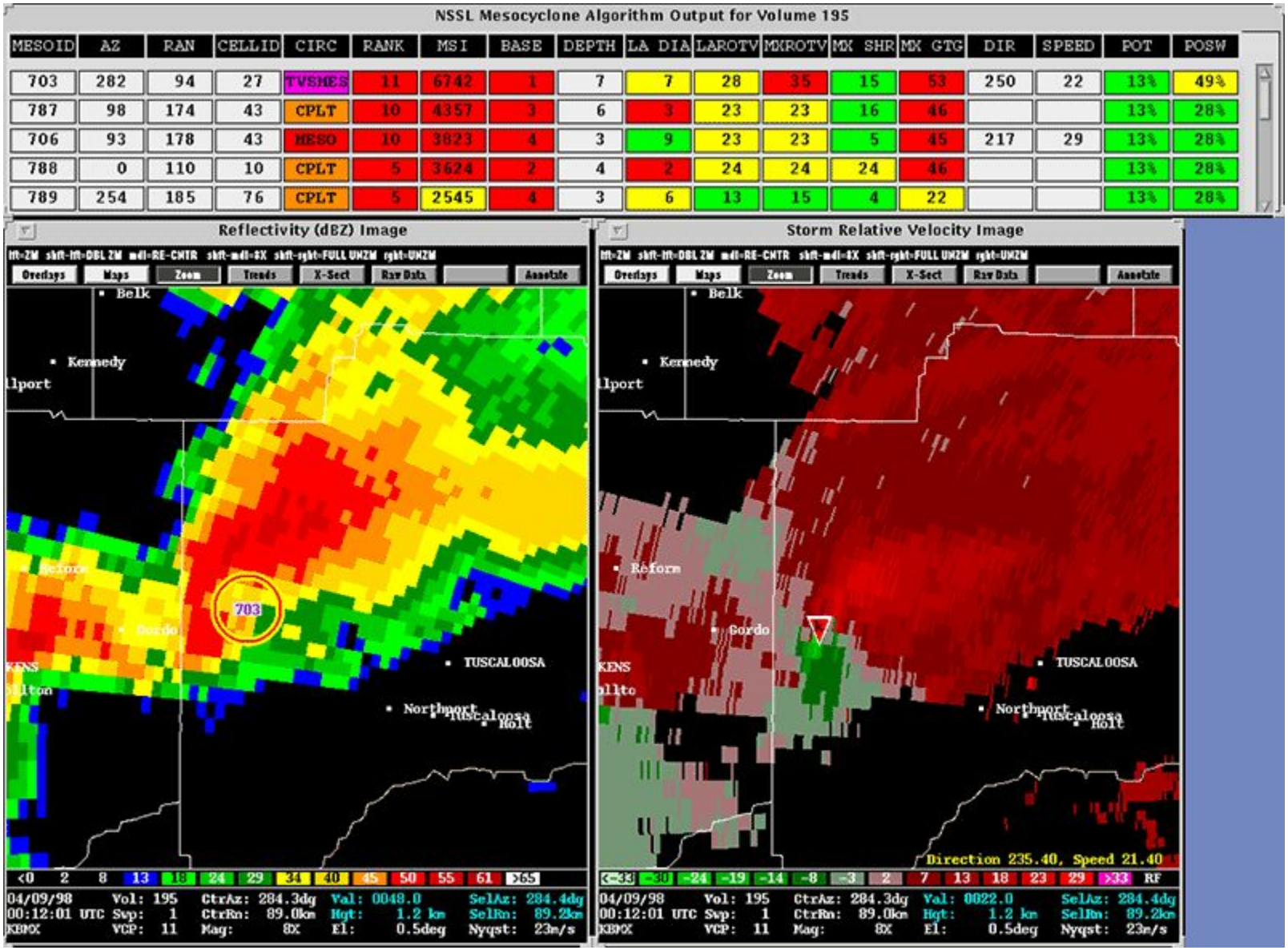

Long-Lived (≥4hr) Supercell Tracks
(2/2)
(71/80)
NCNTRL
(22/28)
Northeast
(1/1)
SCNTRL
(70/84)
Southeast
(18/29)

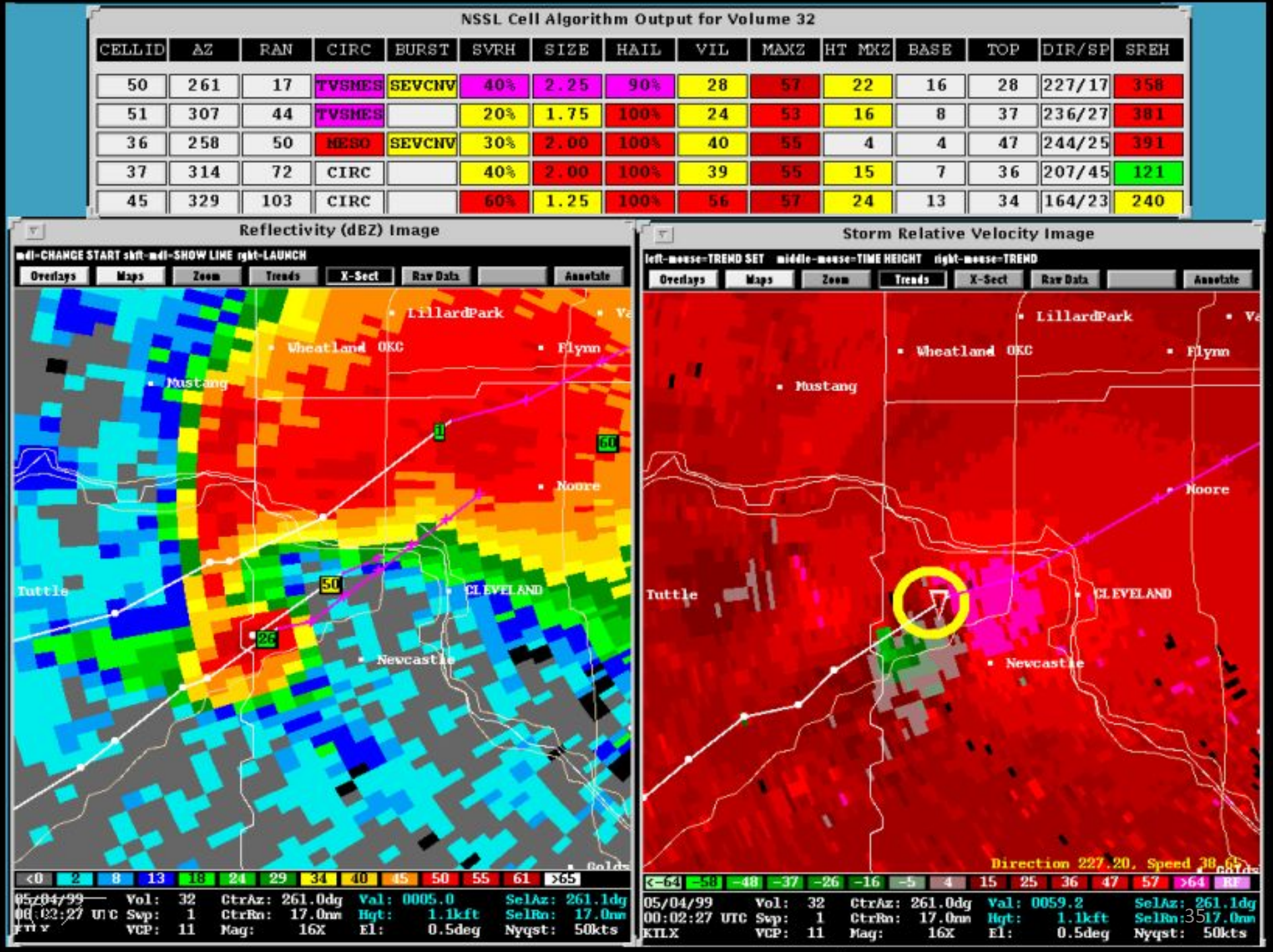

a)
Long-Lived Supercell Events
14%
13%
12%
11%
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
Frequency
12
14
16
18
20
22
0
2
4
6
8
10
Hour of Day (UTC)

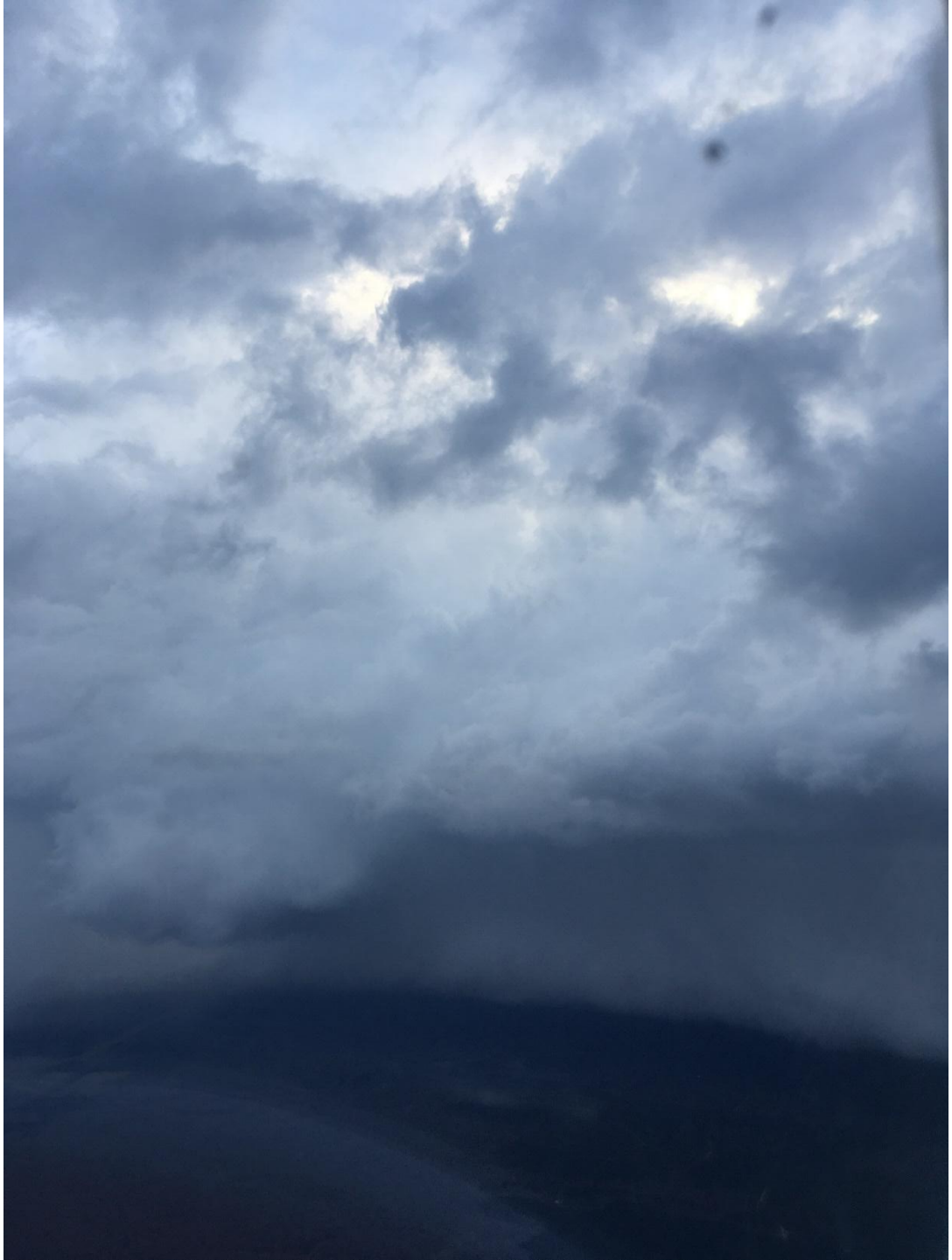

KTLX
VCP: 11
VT: 1999/05/03 - 23:51:2
PT: 23:51:2
DBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
Two Downdrafts
Rear Flank Downdraft
Forward Flank Downdraft
Inflow of Warm, Moist Air
L
El Reno
Yukon
Spencer
Forest Park
Choctaw
Harrah
Oklahoma City
Midwest City
Union City
Mustang
Moore
KTLX
Minco
Tuttle
Newcastle
Bridge Creek
Norman
Pocasset
Amber
Blanchard
Goldsby
Noble
Etowah
Middleberg
Cole
Washington
Chickasha
Tabler
Dibble
BR 0.449°
SMV:


Increasing Thunderstorm Rotation.
As low level winds stream into the storm and converge on the updraft rotation is concentrated and tilted to vertical.

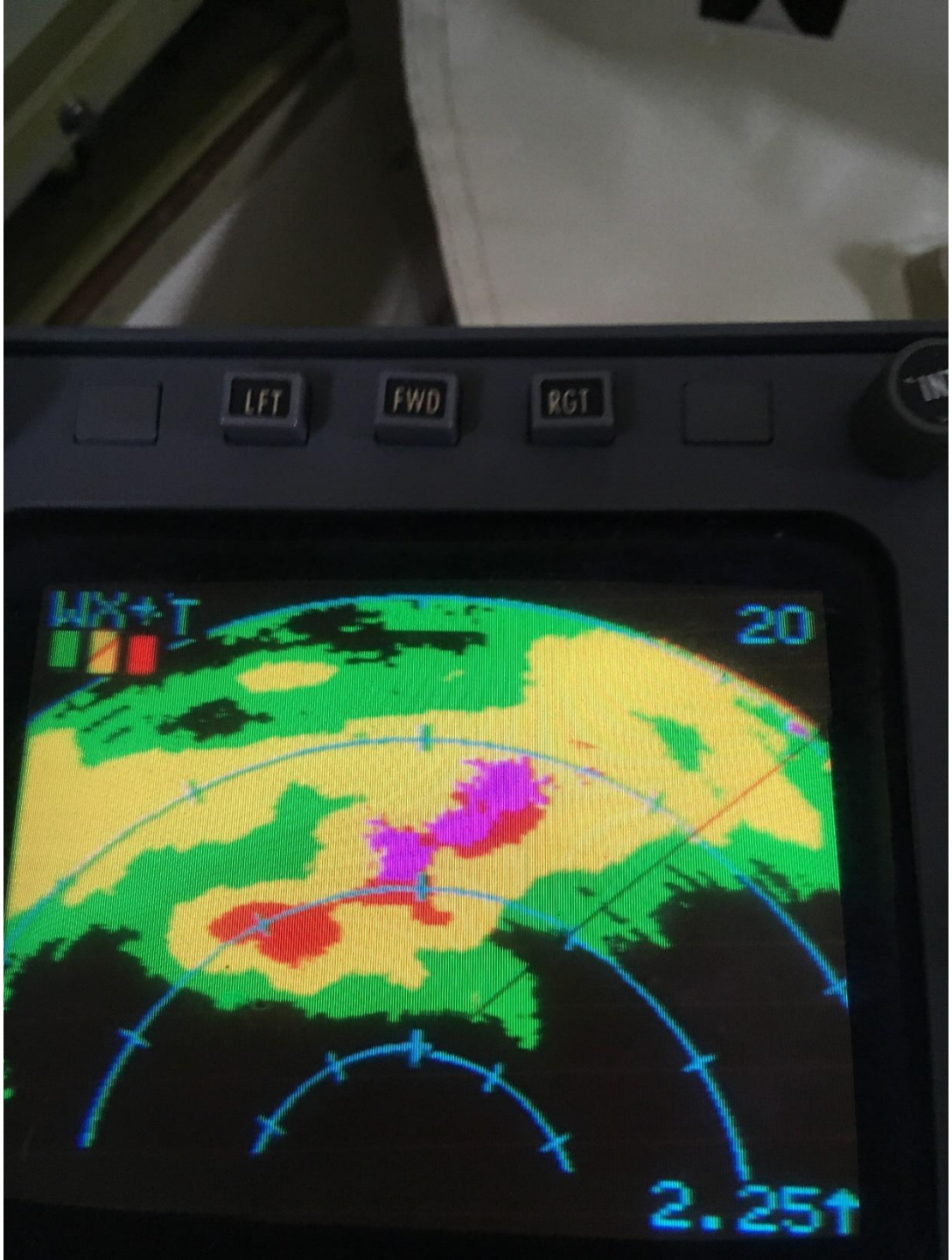


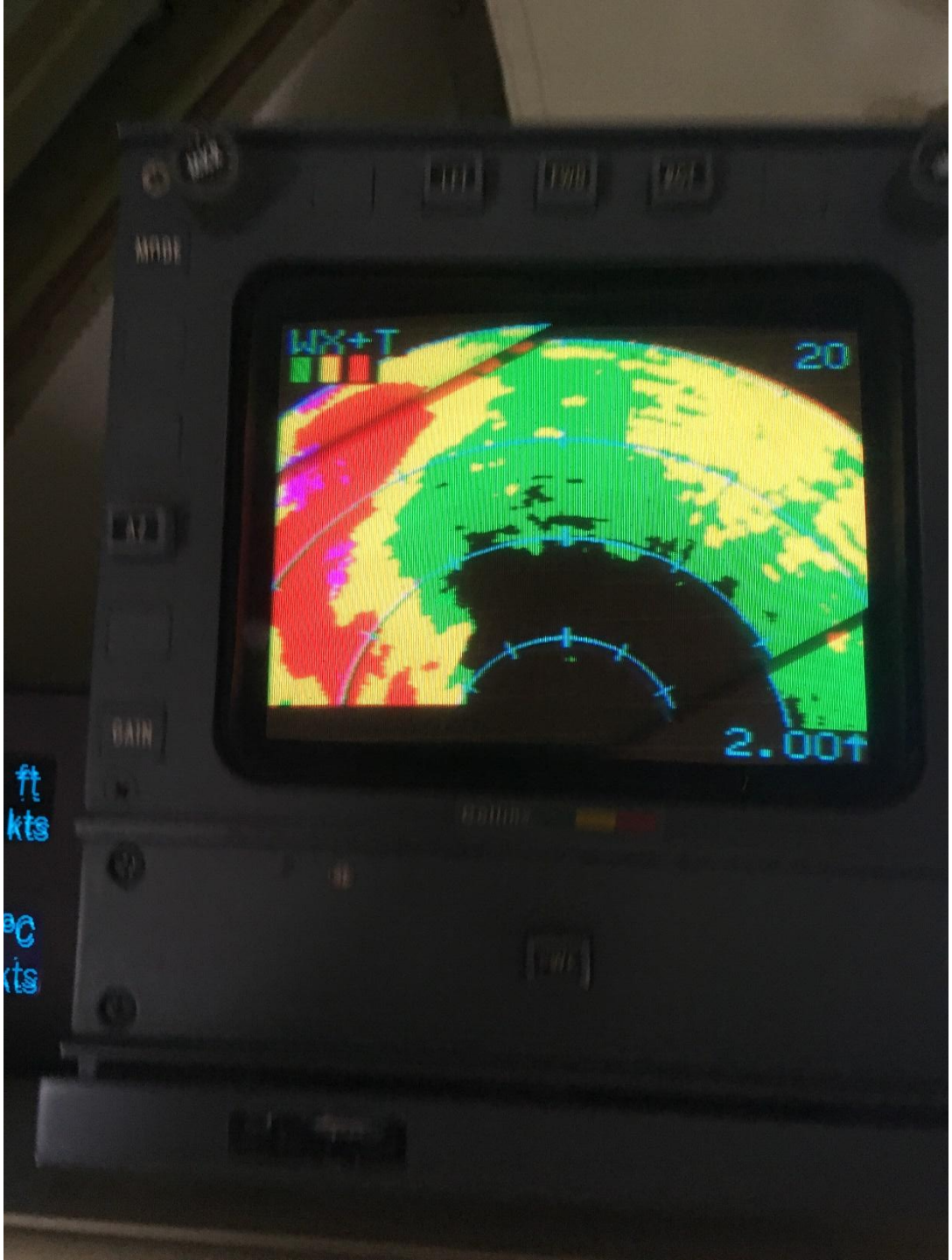

NSSL Mesocyclone Algorithm Output for Volume 195
MESOID AZ RAN CELLID CIRC RANK MSI BASE DEPTH LA DIA LAROTV MXROTV MX SHR MX GTG DIR SPEED POT POSW
703 282 94 27 TVSMES 11 6742 1 7 7 28 35 15 53 250 22 13% 49%
787 98 174 43 CPLT 10 4357 3 6 3 23 23 16 46 13% 28%
706 93 178 43 MESO 10 3823 4 3 9 23 23 5 45 217 29 13% 28%
788 0 110 10 CPLT 5 3624 2 4 2 24 24 24 46 13% 28%
789 254 185 76 CPLT 5 2545 4 3 6 13 15 4 22 13% 28%
Reflectivity (dBZ) Image
Storm Relative Velocity Image
Overlays Maps Zoom Trends X-Sect Raw Data Annotate
Belk
Kennedy
Reform
Gordo
TUSCALOOSA
Northport
Tuscaloosa
Holt
703
<0 2 8 13 18 24 29 34 40 45 50 55 61 >65
<-33 -30 -24 -19 -14 -8 -3 2 7 13 18 23 29 >33 RF
Direction 235.40, Speed 21.40
04/09/98 00:12:01 UTC KBMX
Vol: 195 Swp: 1 VCP: 11
CtrAz: 284.3dg CtrRn: 89.0km Mag: 8X
Val: 0048.0 Hgt: 1.2 km El: 0.5deg
SelAz: 284.4dg SelRn: 89.2km Nyqst: 23m/s
Val: 0022.0 Hgt: 1.2 km El: 0.5deg
SelAz: 284.4dg SelRn: 89.2km Nyqst: 23m/s

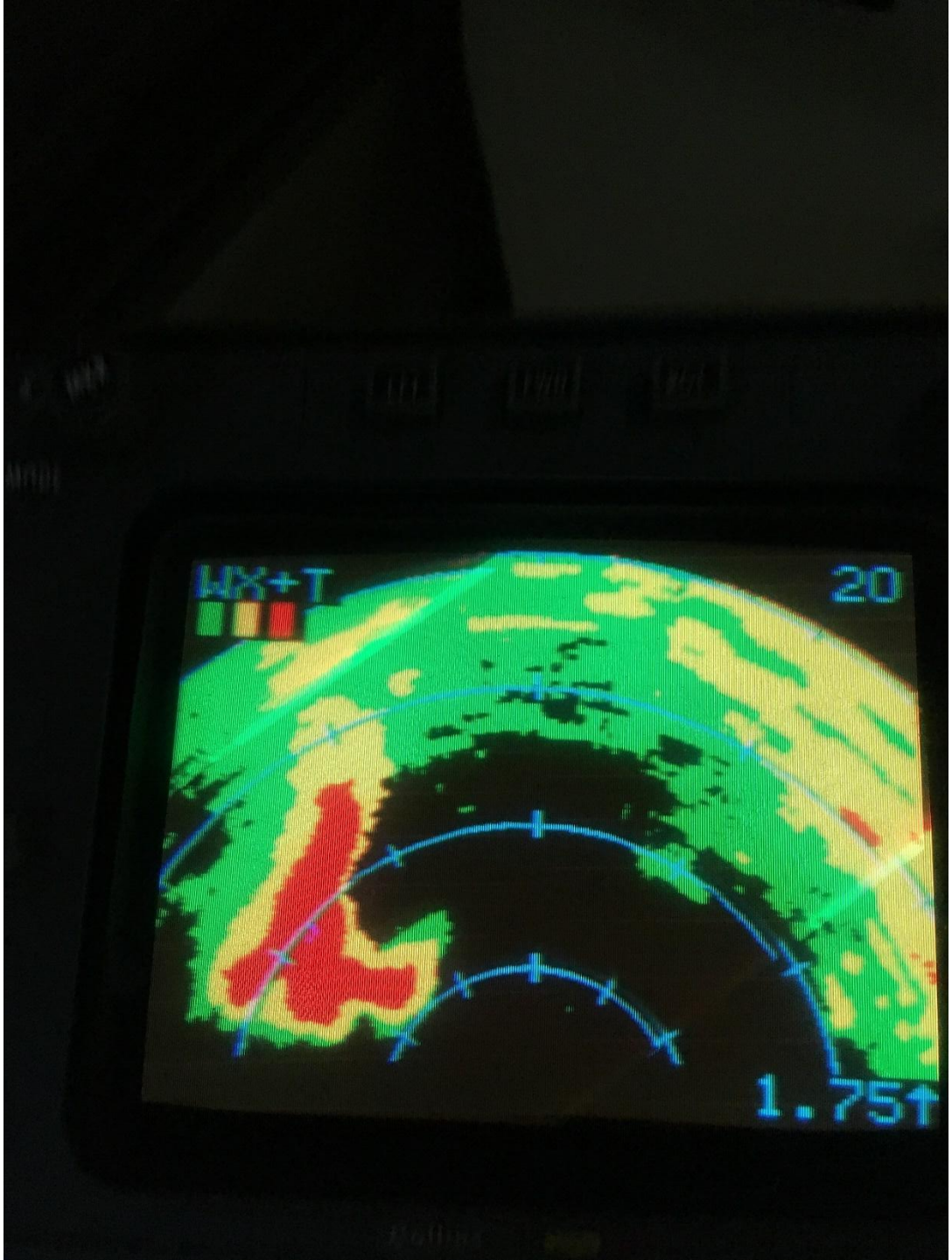

NSSL Cell Algorithm Output for Volume 32
CELLID AZ RAN CIRC BURST SVRH SIZE HAIL VIL MAXZ HT MXZ BASE TOP DIR/SP SREH
50 261 17 TVSMES SEVCNV 40% 2.25 90% 28 57 22 16 28 227/17 358
51 307 44 TVSMES 20% 1.75 100% 24 53 16 8 37 236/27 381
36 258 50 MESO SEVCNV 30% 2.00 100% 40 55 4 4 47 244/25 391
37 314 72 CIRC 40% 2.00 100% 39 55 15 7 36 207/45 121
45 329 103 CIRC 60% 1.25 100% 56 57 24 13 34 164/23 240
Reflectivity (dBZ) Image
mdi-CHANGE START shft-mdi-SHOW LINE rght-LAUNCH
Overlays Maps Zoom Trends X-Sect Raw Data Annotate
LillardPark
Wheatland OKC
Flynn
Mustang
Noore
Tuttle
CLEVELAND
Newcastle
<0 2 8 13 18 24 29 34 40 45 50 55 61 >65
05/04/99 Vol: 32 CtrAz: 261.0dg Val: 0005.0 SelAz: 261.1dg
00:02:27 UTC Swp: 1 CtrRn: 17.0nm Hgt: 1.1kft SelRn: 17.0nm
KTLX VCP: 11 Mag: 16X El: 0.5deg Nyqst: 50kts
Storm Relative Velocity Image
left-mouse=TREND SET middle-mouse=TIME HEIGHT right-mouse=TREND
Overlays Maps Zoom Trends X-Sect Raw Data Annotate
LillardPark
Wheatland OKC
Flynn
Mustang
Noore
Tuttle
CLEVELAND
Newcastle
Direction 227.20, Speed 38.65
<-64 -58 -48 -37 -26 -16 -5 4 15 25 36 47 57 >64 RF
05/04/99 Vol: 32 CtrAz: 261.0dg Val: 0059.2 SelAz: 261.1dg
00:02:27 UTC Swp: 1 CtrRn: 17.0nm Hgt: 1.1kft SelRn: 17.0nm
KTLX VCP: 11 Mag: 16X El: 0.5deg Nyqst: 50kts

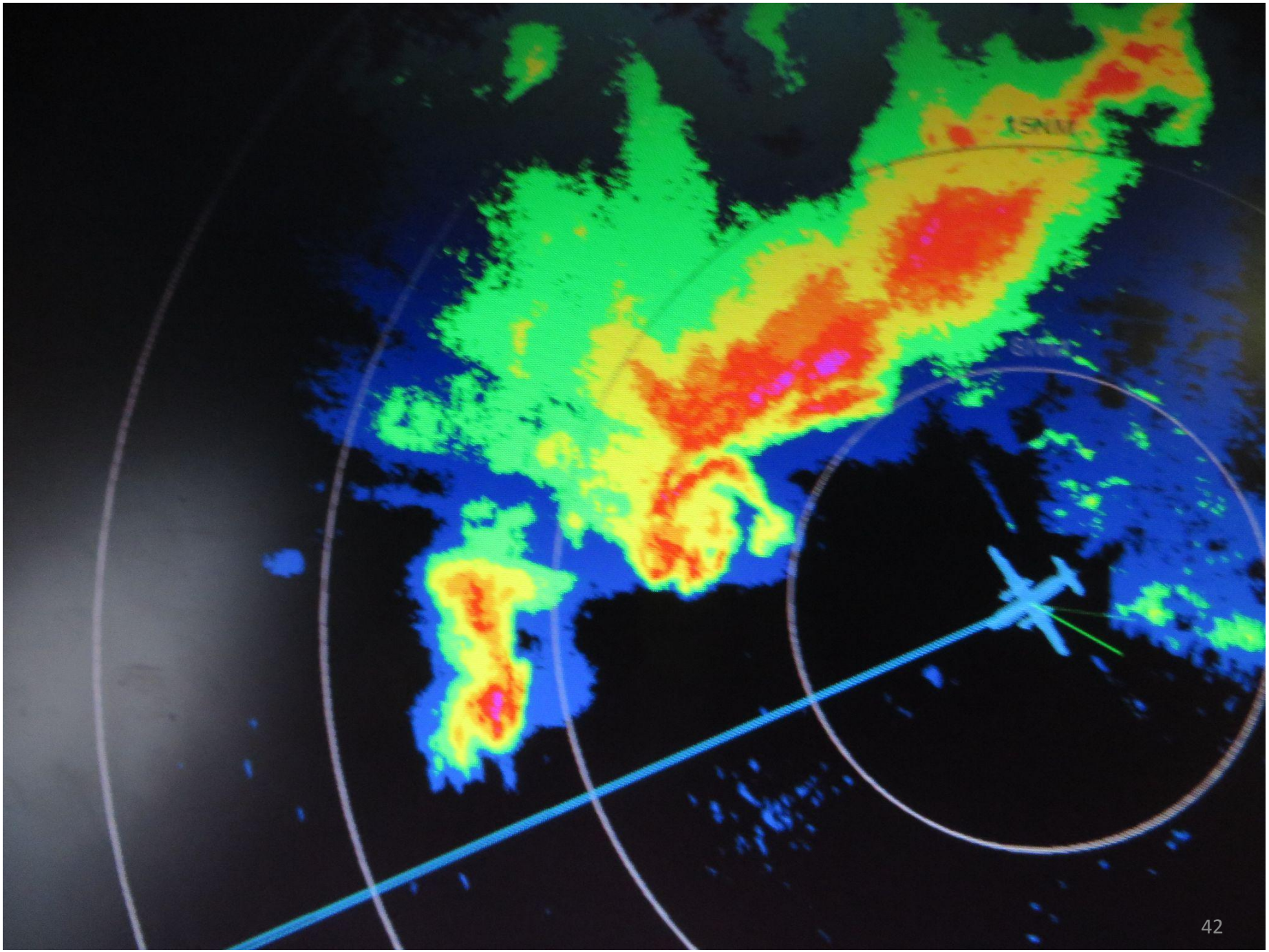


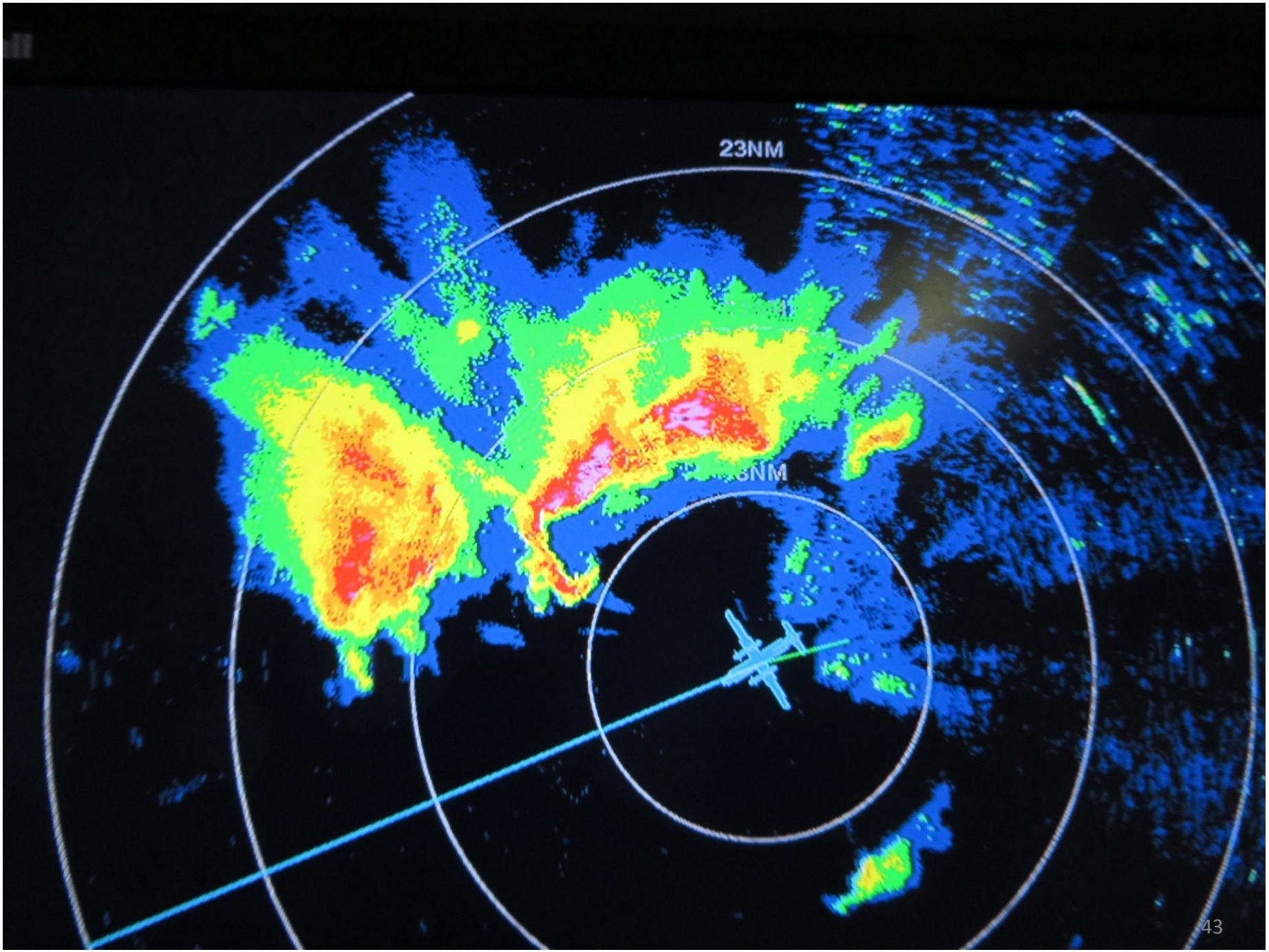

LFT
FWD
RGT
INT
RNG
HOLD
TILT
WX+T
10
2.25
Collins
PWR


LFT
FWD
RGT
WX+T
20
2.25↑


MODE
GAIN
WX+T
20
2.00↑
ft
kts


WX+T
20
1.75↑


15NM


23NM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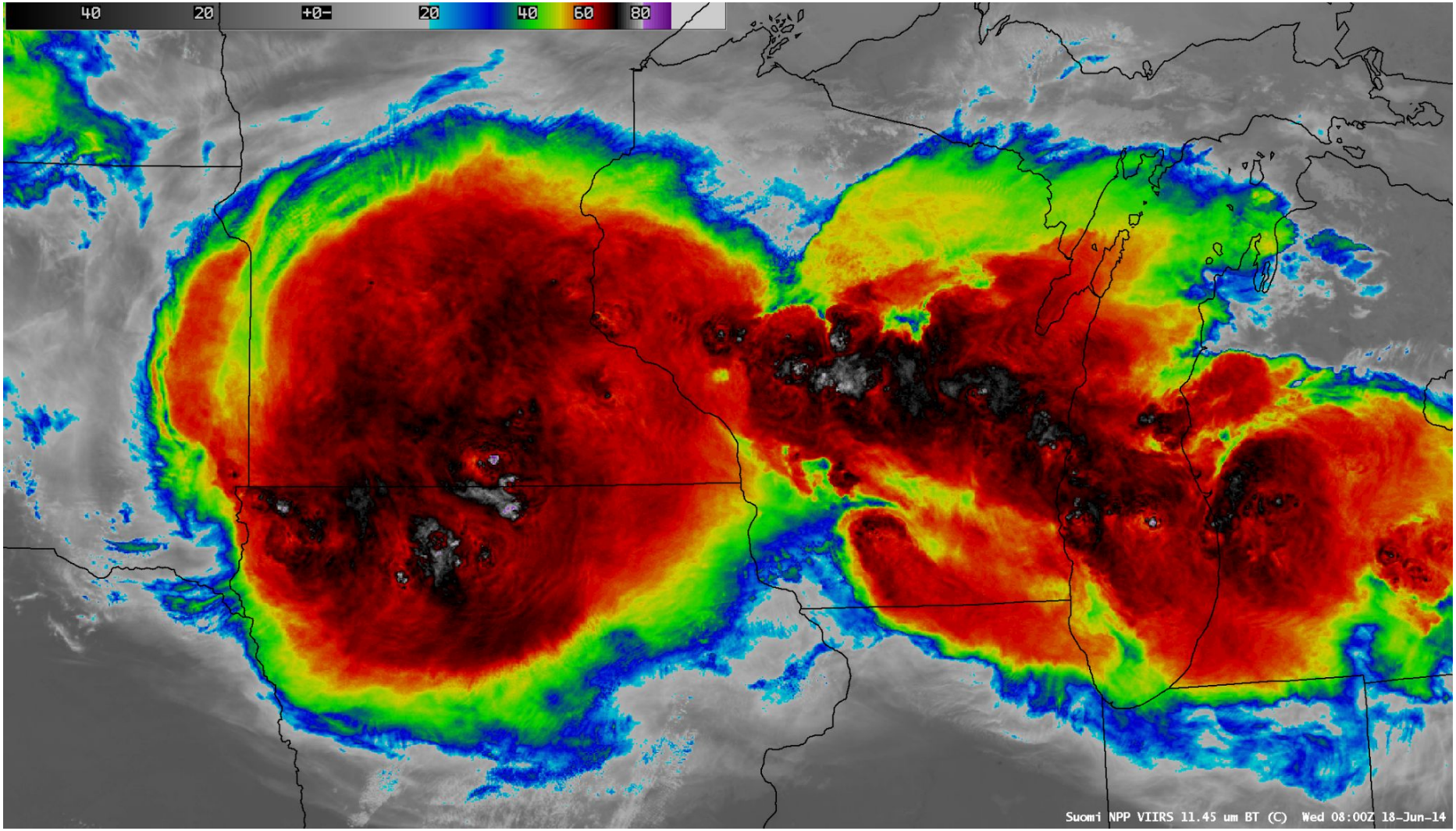
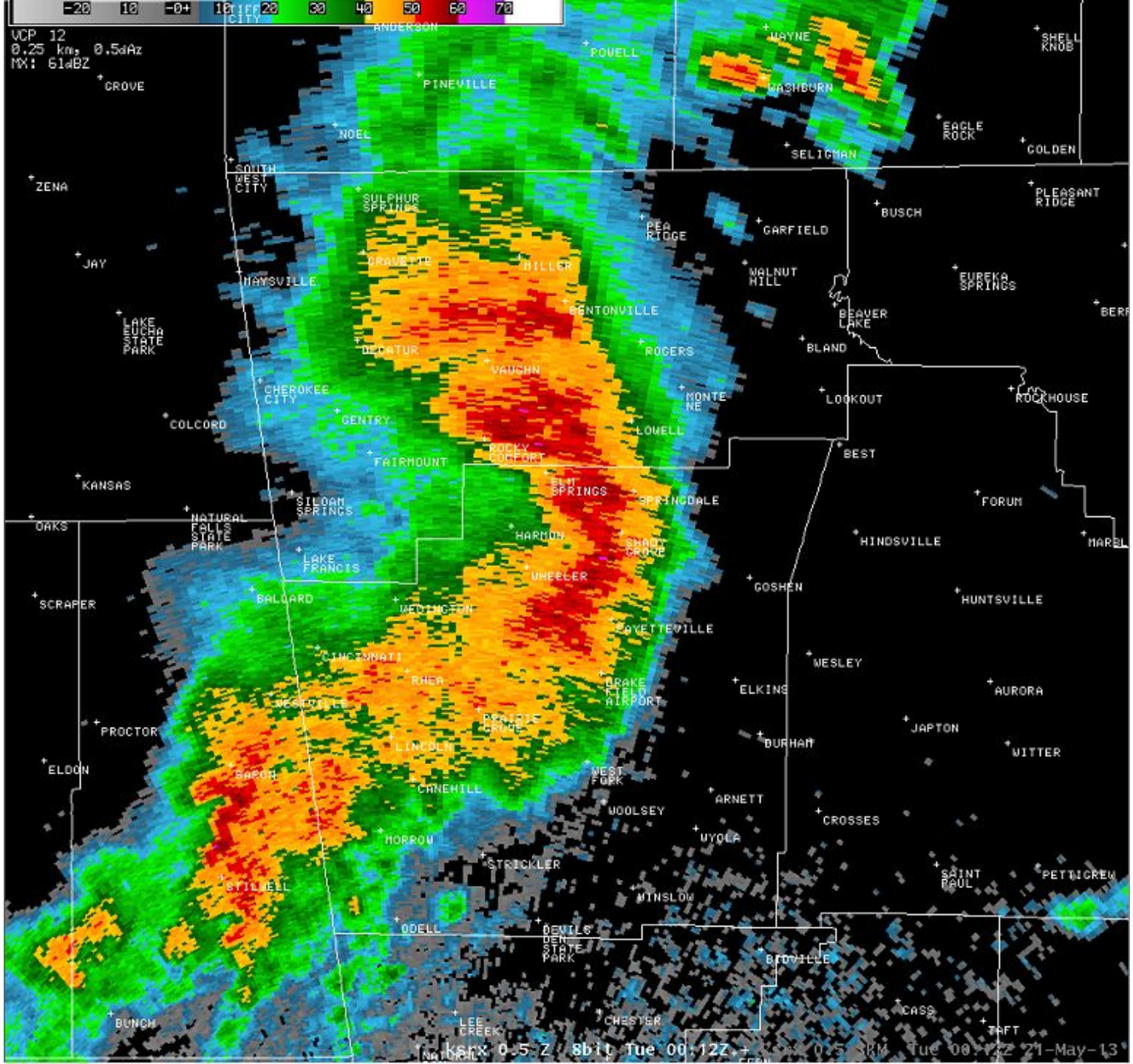
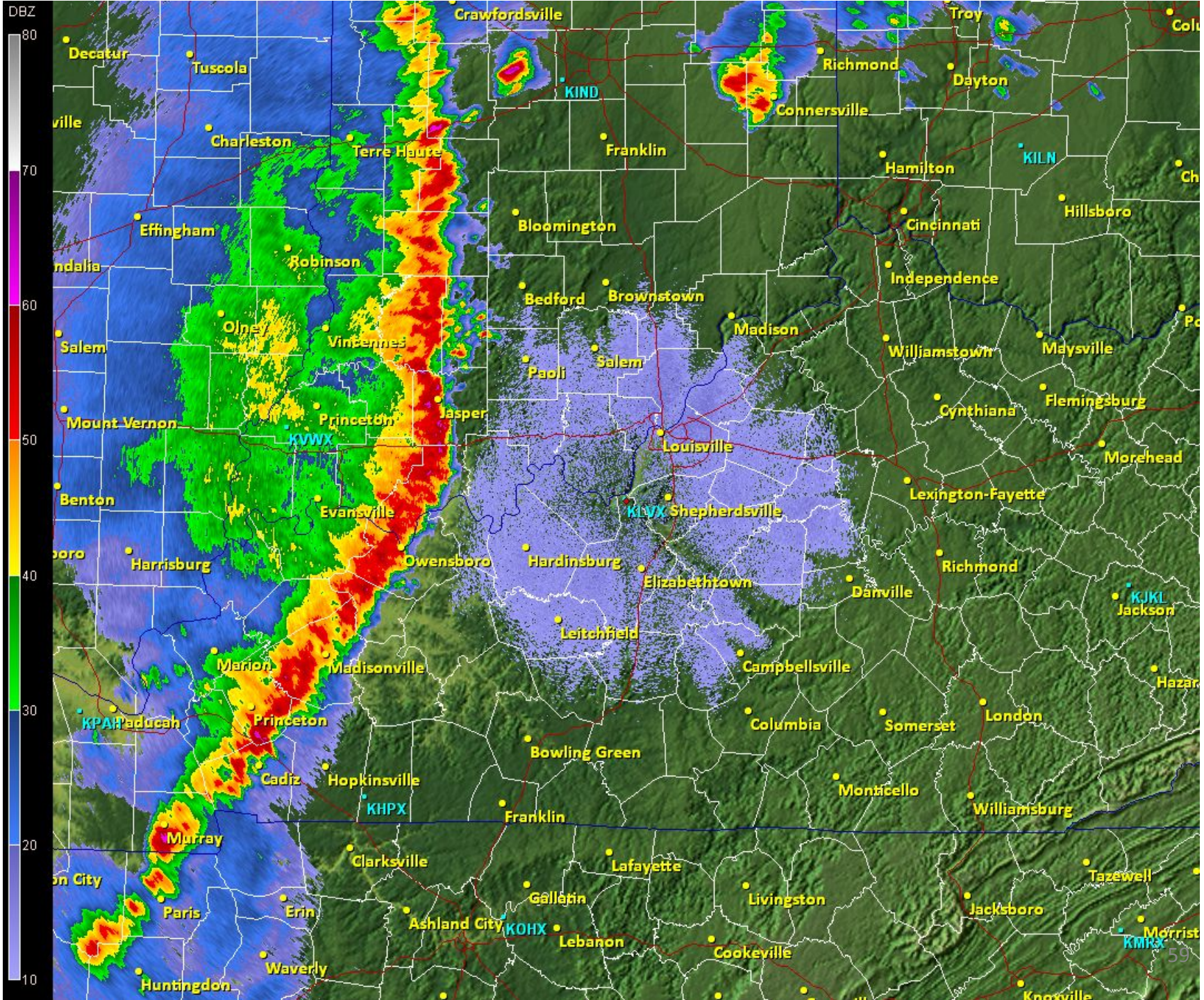
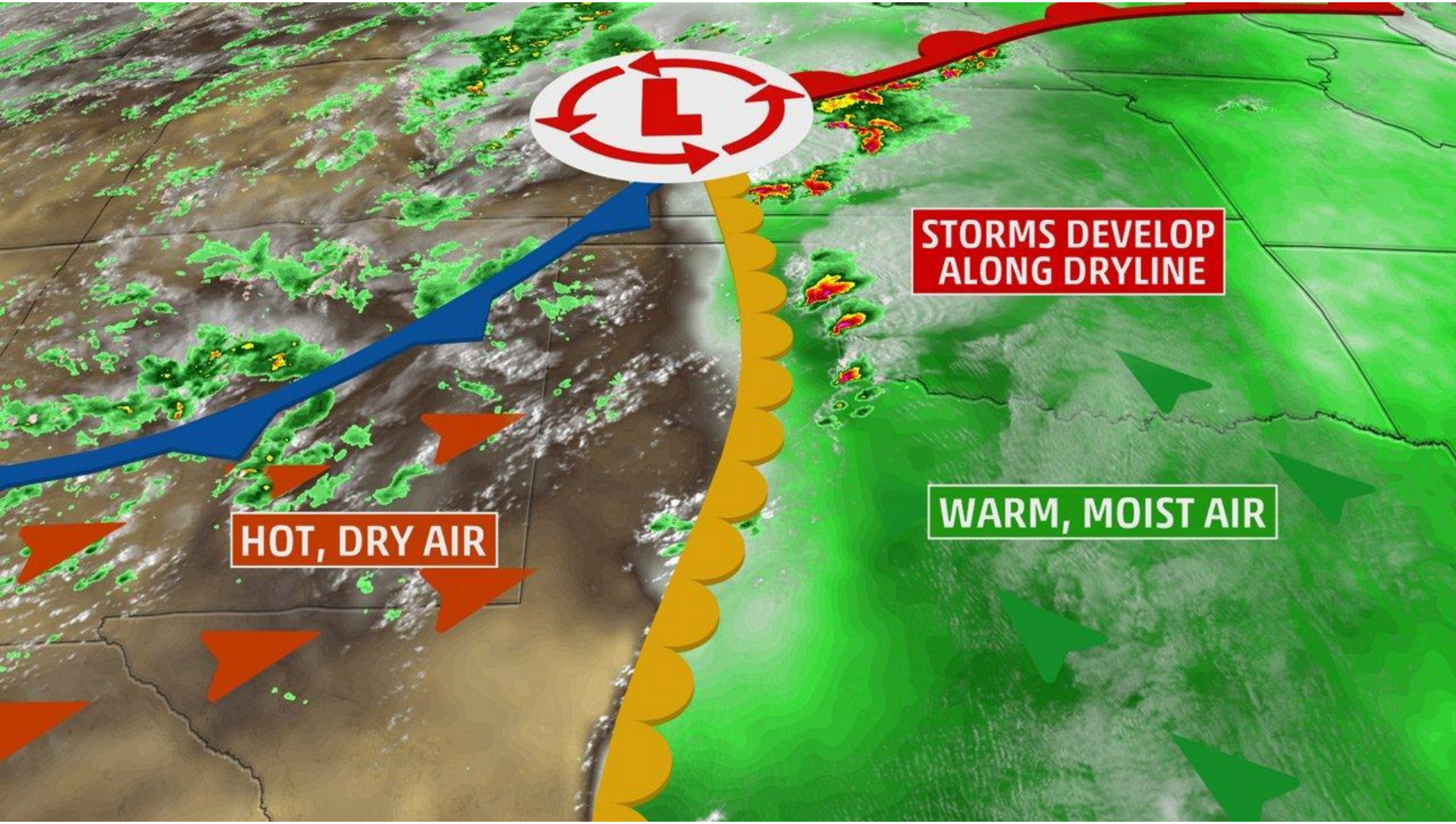
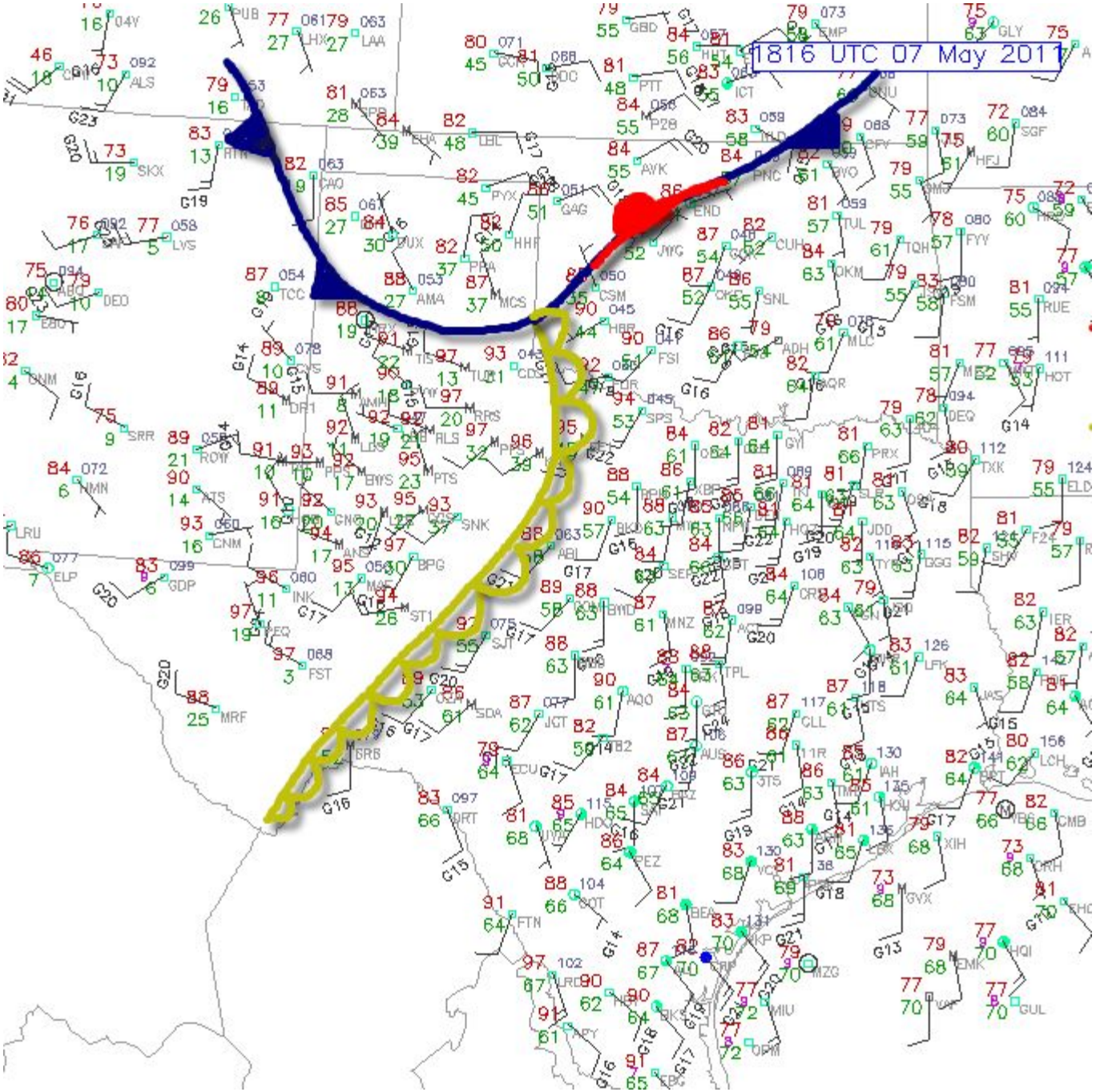
- Definition and description of supercells
- Weather variants

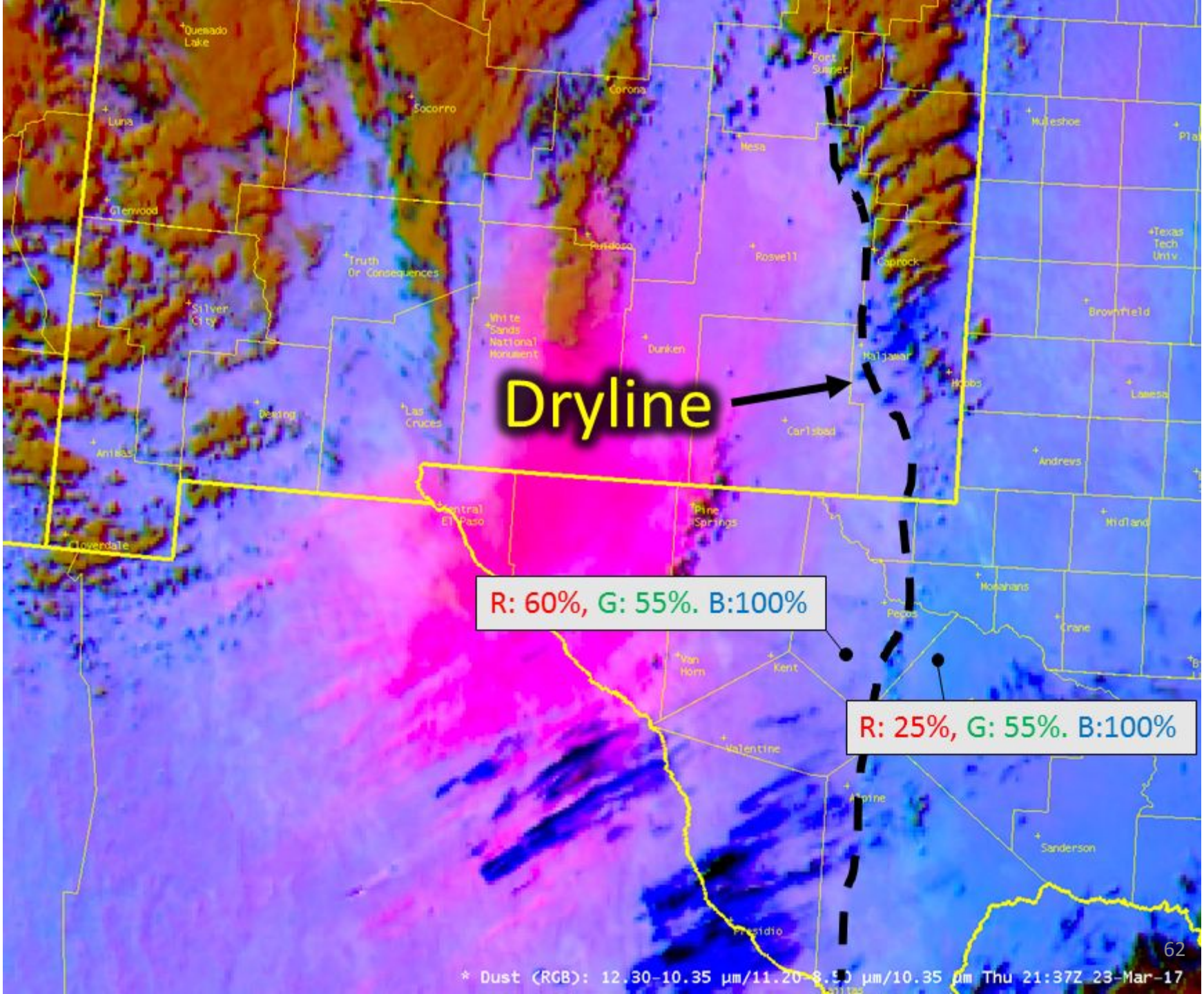

40 20 +0- 20 40 60 80
Suomi NPP VIIRS 11.45 um BT (C) Wed 08:00Z 18-Jun-14


-20 10 -0+ 10 20 30 40 50 60 70
VCP 12
0.25 km, 0.5dAz
MXI: 61dBZ
ANDERSON
POWELL
WAYNE
SHELL KNOB
CROVE
PINEVILLE
WASHBURN
NOEL
EAGLE ROCK
SELIGMAN
GOLDEN
SOUTH WEST CITY
ZENA
SULPHUR SPRINGS
PEA RIDGE
GARFIELD
BUSCH
PLEASANT RIDGE
JAY
HAYSVILLE
HILLER
WALNUT HILL
EUREKA SPRINGS
LAKE EUCHA STATE PARK
BENTONVILLE
BEAVER LAKE
DECATUR
ROGERS
BLAND
VAUGHN
CHEROKEE CITY
MONTE NE
LOOKOUT
ROCKHOUSE
COLCORD
GENTRY
LOWELL
ROCKY COMFORT
BEST
FAIRMOUNT
KANSAS
ELM SPRINGS
SPRINGDALE
FORUM
SILOAM SPRINGS
OAKS
NATURAL FALLS STATE PARK
HARMON
SHADY GROVE
HINDSVILLE
LAKE FRANCIS
WHEELER
GOSHEN
SCRAPER
BALLARD
HUNTSVILLE
WEDINGTON
FAYETTEVILLE
CINCINNATI
WESLEY
RHEA
DRAKE FIELD AIRPORT
ELKINS
AURORA
PROCTOR
JAPTON
LINCOLN
BURHAM
WITTER
ELDON
SAPOA
WEST FORK
CANEHILL
ARNETT
WOOLSEY
CROSSES
MORROW
UYOLA
STRICKLER
SAINT PAUL
PETTIGREW
STILWELL
MINSLOW
ODELL
DEVILS DEN STATE PARK
BIDVILLE
CASS
BUNCH
LEE CREEK
CHESTER
TAFT
ksrx 0.5 z 8bit Tue 00:12Z+ 0.5 KM Tue 00:12Z 21-May-13


DBZ
80
70
60
50
40
30
20
10
Crawfordsville
Troy
Decatur
Tuscola
Richmond
Dayton
KIND
Connersville
Charleston
Terre Haute
Franklin
Hamilton
KILN
Effingham
Bloomington
Cincinnati
Hillsboro
Robinson
Independence
Bedford
Brownstown
Madison
Olney
Vincennes
Salem
Williamstown
Maysville
Paoli
Salem
Cynthiana
Flemingsburg
Mount Vernon
Princeton
Jasper
KVWX
Louisville
Morehead
Benton
Evansville
Lexington-Fayette
KLVX
Shepherdsville
Harrisburg
Owensboro
Hardinsburg
Richmond
Elizabethtown
Danville
KJKL
Jackson
Leitchfield
Marion
Madisonville
Campbellsville
KPAH
Paducah
Princeton
Columbia
Somerset
London
Bowling Green
Cadiz
Hopkinsville
Monticello
KHPX
Franklin
Williamsburg
Murray
Clarksville
Lafayette
Tazewell
Paris
Erin
Gallatin
Livingston
Jacksboro
Ashland City
KOHX
Lebanon
Cookeville
KMRX
Waverly
Huntingdon


L
STORMS DEVELOP ALONG DRYLINE
HOT, DRY AIR
WARM, MOIST AIR


1816 UTC 07 May 2011


Dryline
R: 60%, G: 55%. B:100%
R: 25%, G: 55%. B:100%
* Dust (RGB): 12.30-10.35 µm/11.20-8.50 µm/10.35 µm Thu 21:37Z 23-Mar-17

TORUS talk outline

- Salina area climatology
- Definition and description of supercells
- Weather variants
- Flight hazards

Meteorological Hazards

Inflow side of thunderstorms/supercells

- Very turbulent boundary layer - strong inflow/outflow - shear
- Isolated new-growing thunderstorms on flanking line
- Merges
- Rapid supercell motion

Mitigation Measures

- SA – Best use of all P-3 radars for positioning, orientation and planning the path ahead
- SA – Good use of near real-time WX products (but know their latency)
- Direction of turn to safer environment. Avoid notches.
- Awareness and caution to new-growing cells in the flanking line
- Line crossing approaches. Awareness of hazards at line ends, gaps
- Coordination with ATC challenges with fast supercell motion

Meteorological Hazards

Miscellaneous

- Nighttime missions (visibility, crew rest)
- Terminal Operations (afternoon and evening severe weather, lightning on the ramp, return to base)
- Mobile unit balloon launches

Mitigating Measures

- Maximum use of system radars
- Adjustment of circadian cycle, don't exceed crew duty limits
- SA about daily forecast, fly or no-fly
- Monitor any severe WX approach from generally west quadrants
- RTB - Nav, FD coordination and SA
- Good ground unit/aircraft/operation center communication
- Consider hangaring aircraft if severe weather is forecasted or approaches the airfield

Not-Meteorological Hazards

- UAV's in flight – Follow the ORM document

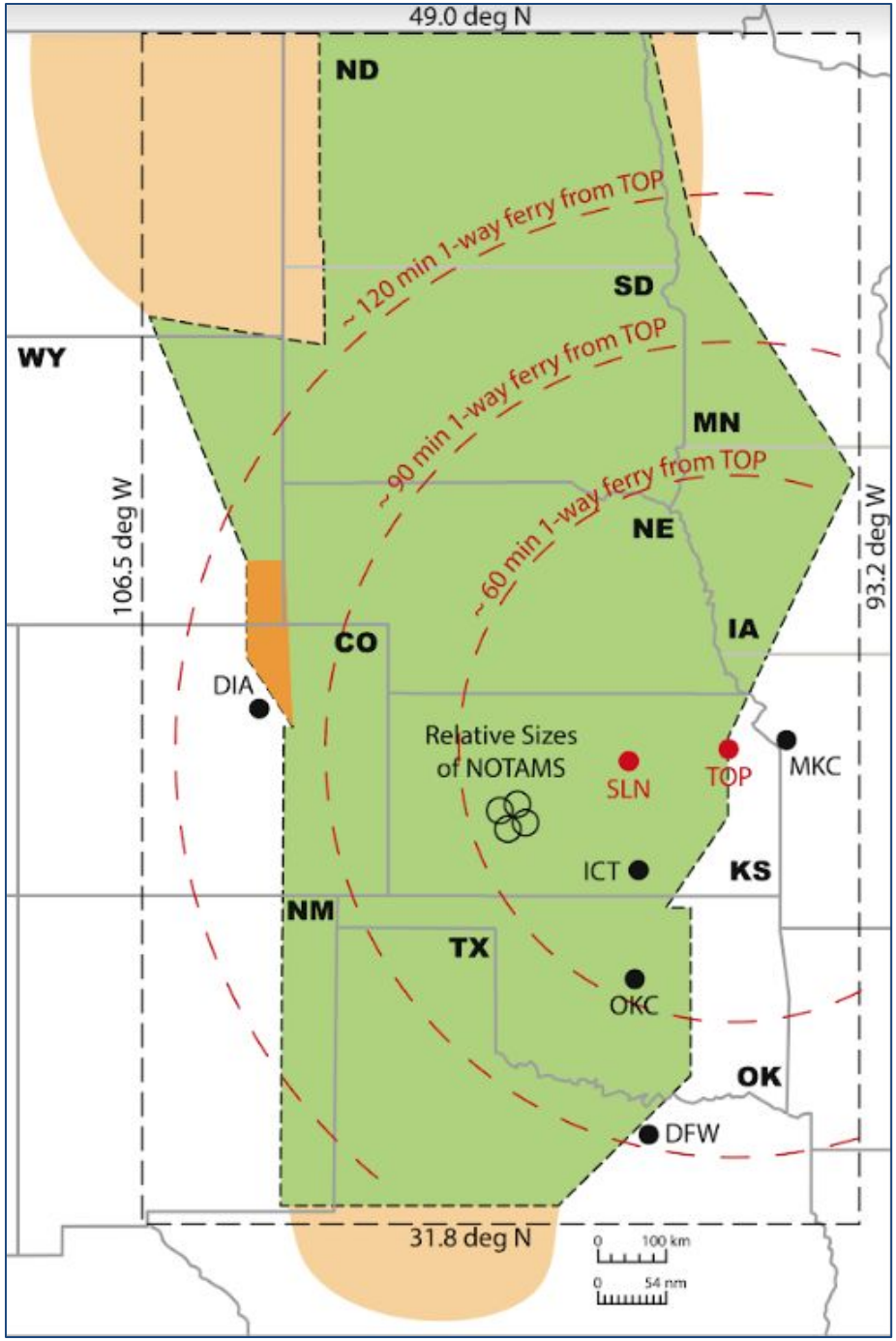
- Balloon launches – from more distant mobile team

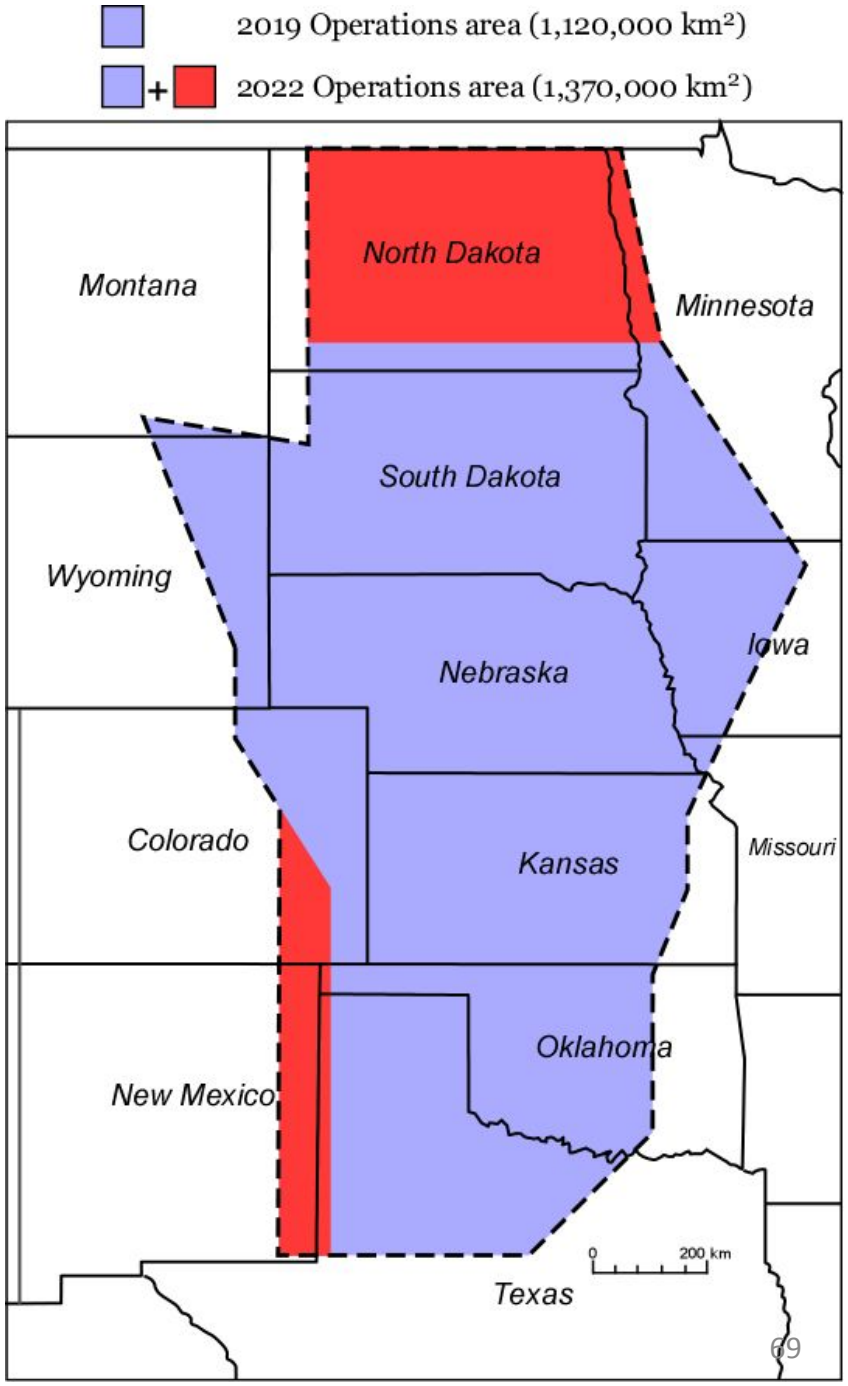
ORM Mitigation Measures

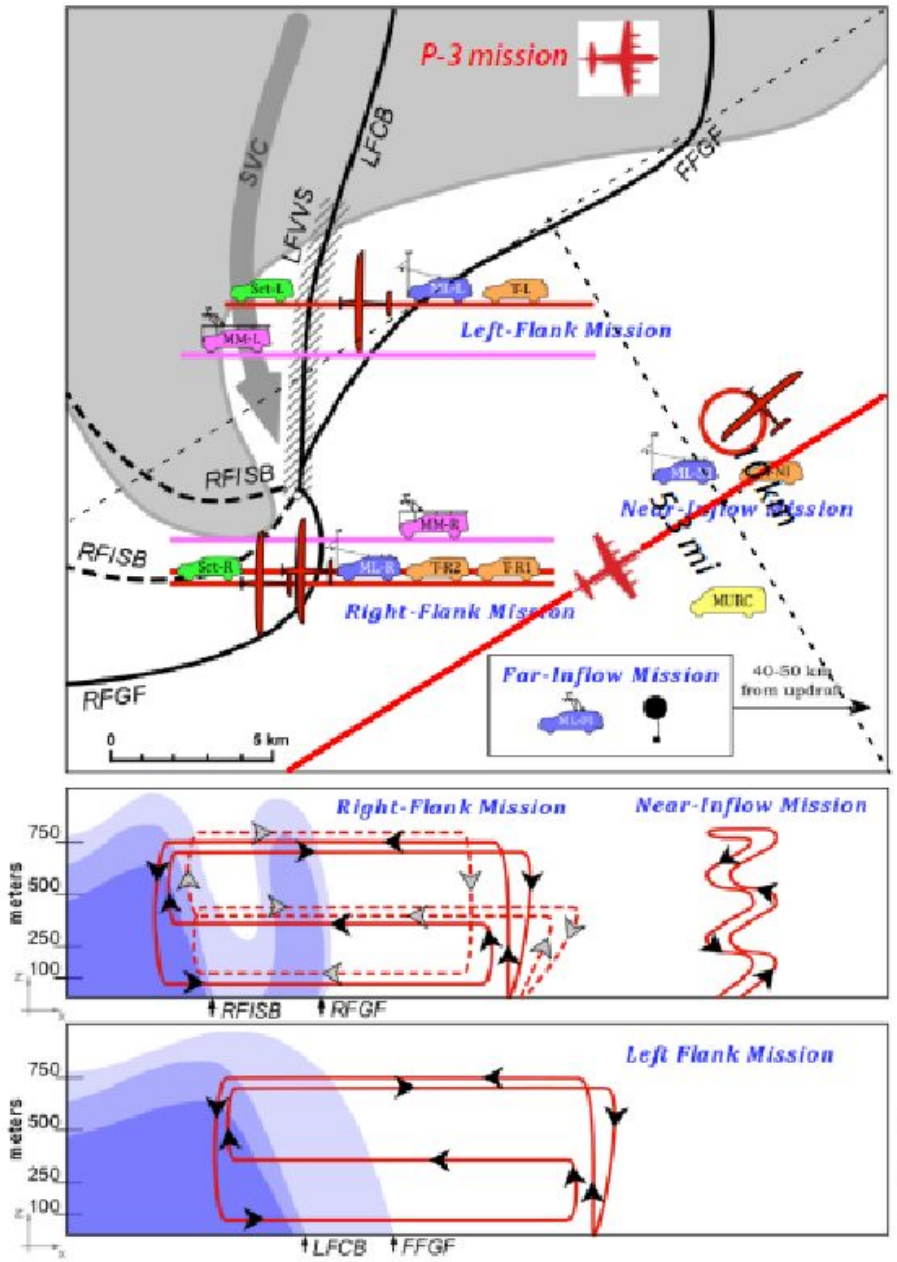
- Minimum altitude AGL 4500 feet near the convective area leading edge. Go below 4500 AGL if deemed safe between AC and FD.
- Proper standoff distance from edge of > 40 dBZ
- Pilots avoid hooks, U, V notch signatures
- Shall not intentionally fly into radar shadows
- Pilots, FD shall coordination when operating in the vicinity of > 40dBZ. Evaluate gradients, cellularity, and nose radar magenta signatures.
- Hail avoidance. Fly below freezing level. Avoid downwind areas of preferred hail trajectory.
- Minimize flight into areas of greatest expected electrification (remain > +2C in/near convective weather)
- FD brief the expected height of the melting level at planeside brief
- Internet products. Reckon with latency.
- CRL measures. Off <1000 feet AGL and <1000 feet (V) and 2 mi (H) of other aircraft
- In order to fly through > 40dBZ :
    - Area critical to research
    - Non-Cellular
    - Gradient < 10 dBZ/mile

TORUS talk outline

- Salina area climatology
- Definition and description of supercells
- Weather variants
- Flight hazards
- Project notes


49.0 deg N
ND
SD
WY
MN
NE
IA
CO
KS
NM
TX
OK
106.5 deg W
93.2 deg W
31.8 deg N
~ 120 min 1-way ferry from TOP
~ 90 min 1-way ferry from TOP
~ 60 min 1-way ferry from TOP
DIA
Relative Sizes of NOTAMS
SLN
TOP
MKC
ICT
OKC
DFW
0 100 km
0 54 nm


2019 Operations area (1,120,000 km²)
+ 2022 Operations area (1,370,000 km²)
Montana
North Dakota
Minnesota
South Dakota
Wyoming
Nebraska
Iowa
Colorado
Kansas
Missouri
Oklahoma
New Mexico
Texas
0 200 km



Left-Flank Mission

- UA-L (UCB) - Tempest/TTwistor UAV
- Mission Lead (UNL) - IMeT
- Scout (UNL) - Rented vehicle
- Mobile Mesonet (NSSL) - NSSL truck with mesonet rack
- Tracker (UCB) - Tracker

Right-Flank Mission

- UA-R1 (UCB) - Tempest/TTwistor UAV
- UA-R2 (UCB) - Tempest/TTwistor UAV
- Mission Lead (UNL) - IMeT
- Tracker (UCB) - Tracker
- Tracker (UCB) - Rented vehicle
- Scout (UNL) - Rented vehicle
- Mobile Mesonet (NSSL) - NSSL truck with mesonet rack

Near-Inflow Mission

- UA-NI (UCB) - Tempest/TTwistor UAV
- Mission Lead (UNL) - IMeT
- Tracker (UCB) - Rented vehicle

Far-Inflow Mission

- Mobile Sounding System (OU/NSSL)
- Mission Lead (OU/NSSL) - Fleet vehicle + mesonet rack
- Mobile UAS Research Collaboratory (UCB)

Radars and Associated Vehicles (not shown)

- TTU-Ka1 (TTU)
- TTU-Ka2 (TTU)
- NOXP (NSSL)
- NOXP Scout (OU/NSSL) - Fleet vehicle + mesonet rack

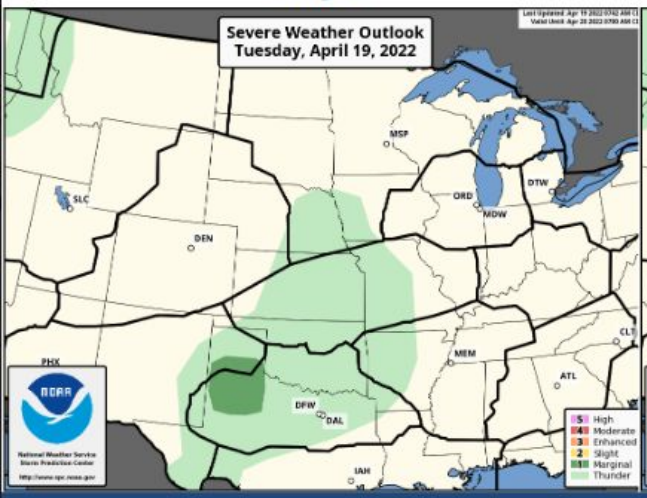
TORUS Planning Wx

Issued 04-19-2022 at 15Z by SOMEONE

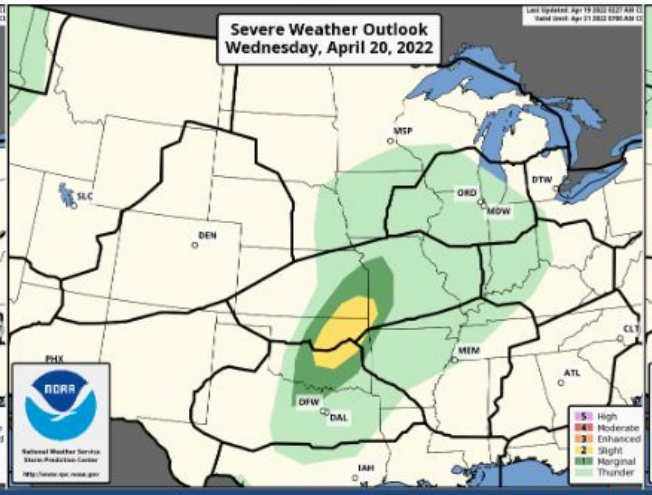
	VSBY (nm)	CIG	WIND (kt)	X-Wind (kt)
VFR	> 5	> 030	< 25	< 25
MVFR	3 - 5	010 - 030	25 - 49	≥ 25
IFR	< 3	< 010	≥ 50	≥ 30
SVR	> 5% prob. of 1+ inch hail, 50+ kt, or Tornado			
OTHER	FG=Fog, SN=Snow, RA=Rain, TS=Thunder			

Location	15-May		16-May		17-May		18-May		19-May	
	00Z	12Z	00Z	12Z	00Z	12Z	00Z	12Z	00Z	12Z
KFOE	CIG, TSRA, X-Wind						HAIL, TOR		CIG, TSRA	

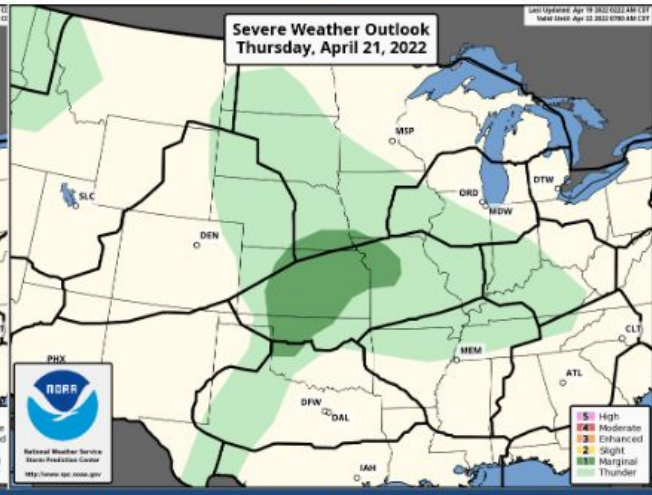
Day 1



Day 2



Day 3



U.S. Department of Commerce | National Oceanic and Atmospheric Administration | Aircraft Operations Center

top is above the aircraft's altitude (or the surface is below the aircraft's height). For example, if the echo top, h, is 10 nmi (50,000 ft) and the aircraft altitude is 5 na mi (25,000 ft) then R is 5 na mi. If h is 50,000 ft and the aircraft altitude is 1 na mi (5,000 ft) then R is 9 na mi. Thus, low level flight patterns are desired to eliminate the (as much as possible) the contamination of radial Doppler velocity by terminal fallspeed

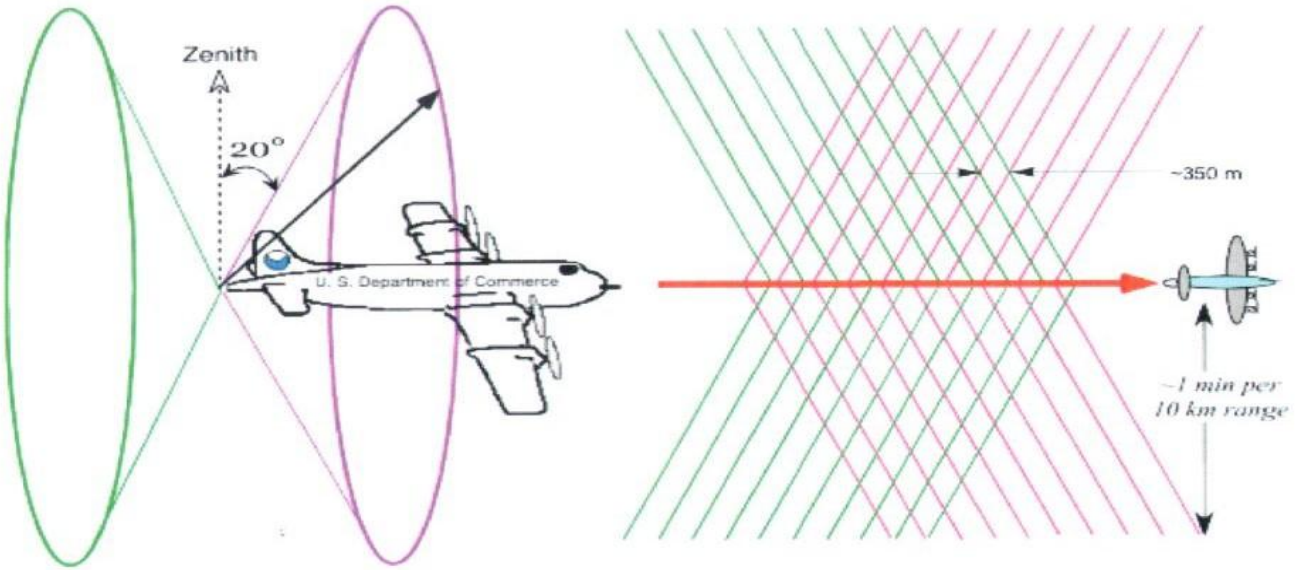


Fig. xyz. Tail radar scanning geometry. The left plot shows a schematic of the antenna scanning methodology. A horizontal projection of the beams is shown on the right.

v) Lightning Mapping Array

NASA operates the VHF-band North Alabama Lightning Mapping Array, with additional stations installed or planned in North Georgia by Georgia Tech. The LMA maps total (cloud and ground) lightning flash rates and flash extent in the cloud. Since 2016, NASA has augmented its network


MIPS

Many Thanks. See You In Topeka!

Daily weather briefings are available in the VORTEX_SE field catalog.

http://catalog.eol.ucar.edu/vortex-se_2017/report/100/499/188083/53697988

The information to access the meeting is as follows. Meeting time 12:15 CDT.

VORTEX-SE 2017 Daily Briefing

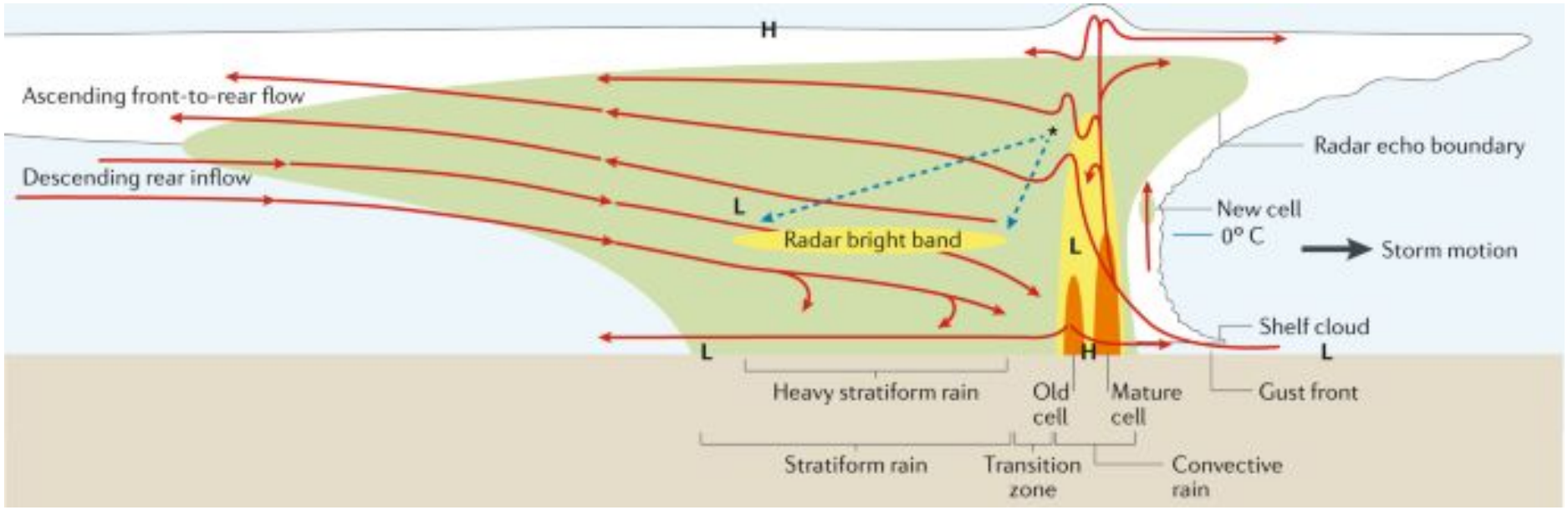
Please join my meeting from your computer, tablet or smartphone.
https://global.gotomeeting.com/join/685478629

You can also dial in using your phone.
United States +1 (571) 317-3112

Access Code: 685-478-629

Additional Slides

MCS Diagram


H
Ascending front-to-rear flow
Descending rear inflow
L
Radar bright band
L
L
H
Radar echo boundary
New cell
0° C
Storm motion
Shelf cloud
L
Gust front
Heavy stratiform rain
Old cell
Mature cell
Stratiform rain
Transition zone
Convective rain