Detecting and Forecasting Tornadoes

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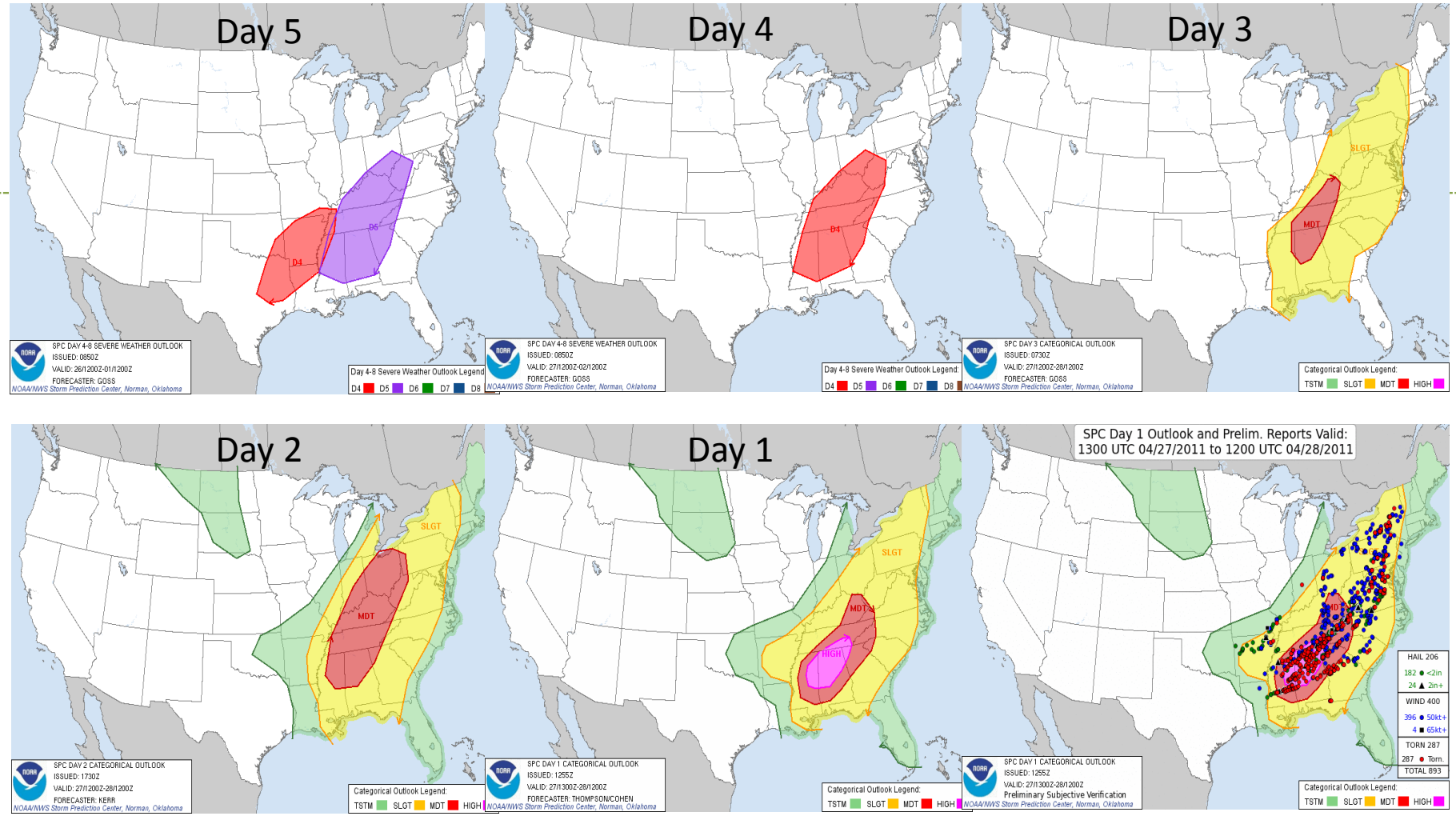
The US approach

- Forecasting on two scales (National Weather Service)
  - National-Storm Prediction Center (few hours to a week)
    - Convective outlooks (probability of severe storms, tornadoes)
    - Watches (conditions favorable for tornadoes)-~50,000 km^2, 6 hours
  - Local-Forecast Offices-122 covering small areas
    - Warnings (event happening or imminent)-~500 km^2, 45 minutes
- Research-National Severe Storms Lab (and academia)
  - Help improve forecasts and warnings
  - Long history of radar development

Deep South Super Outbreak

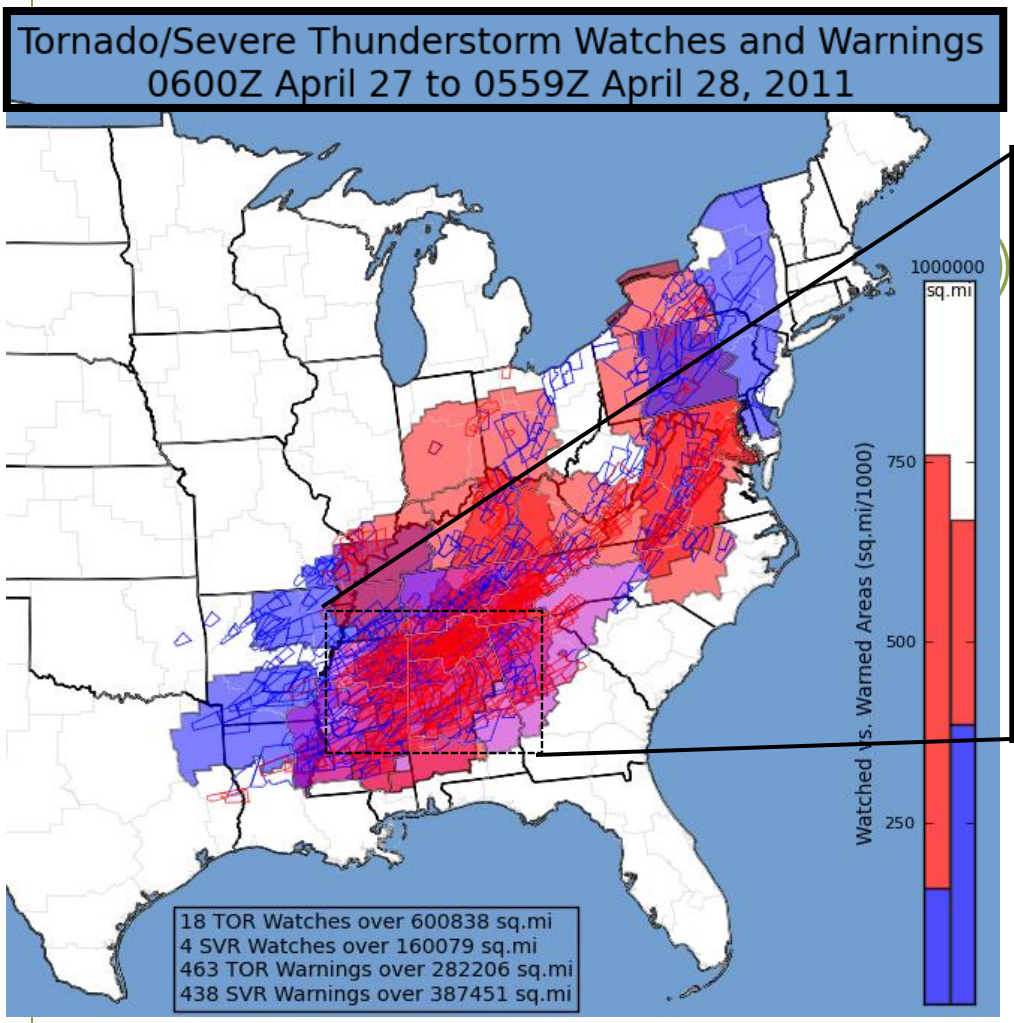
National Weather Service Outlooks – 23-27 April 2011

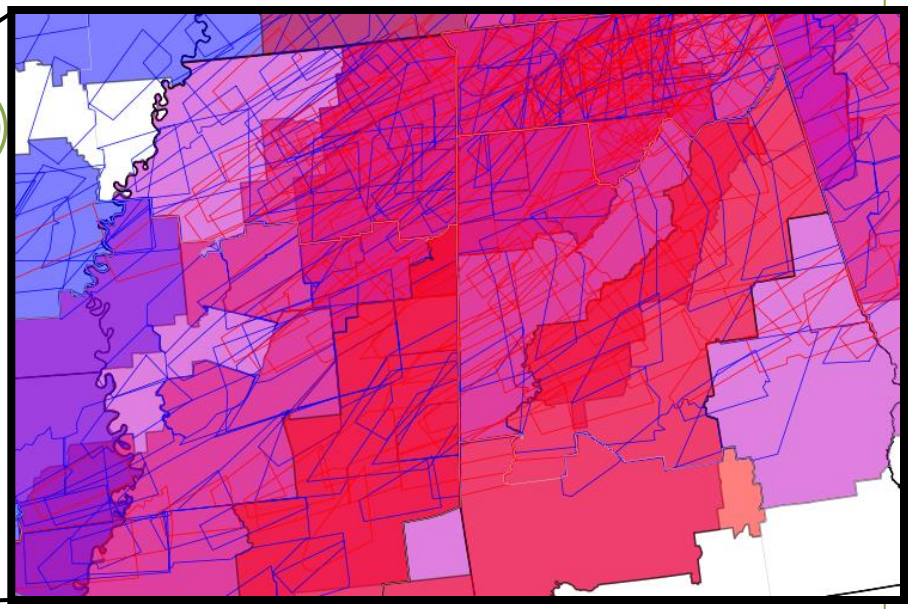


Wording used in SPC forecasts becomes more specific and threatening with time…

Deep South Super Outbreak

NWS/SPC Watches, Warnings





Watch and Warning Fatigue?

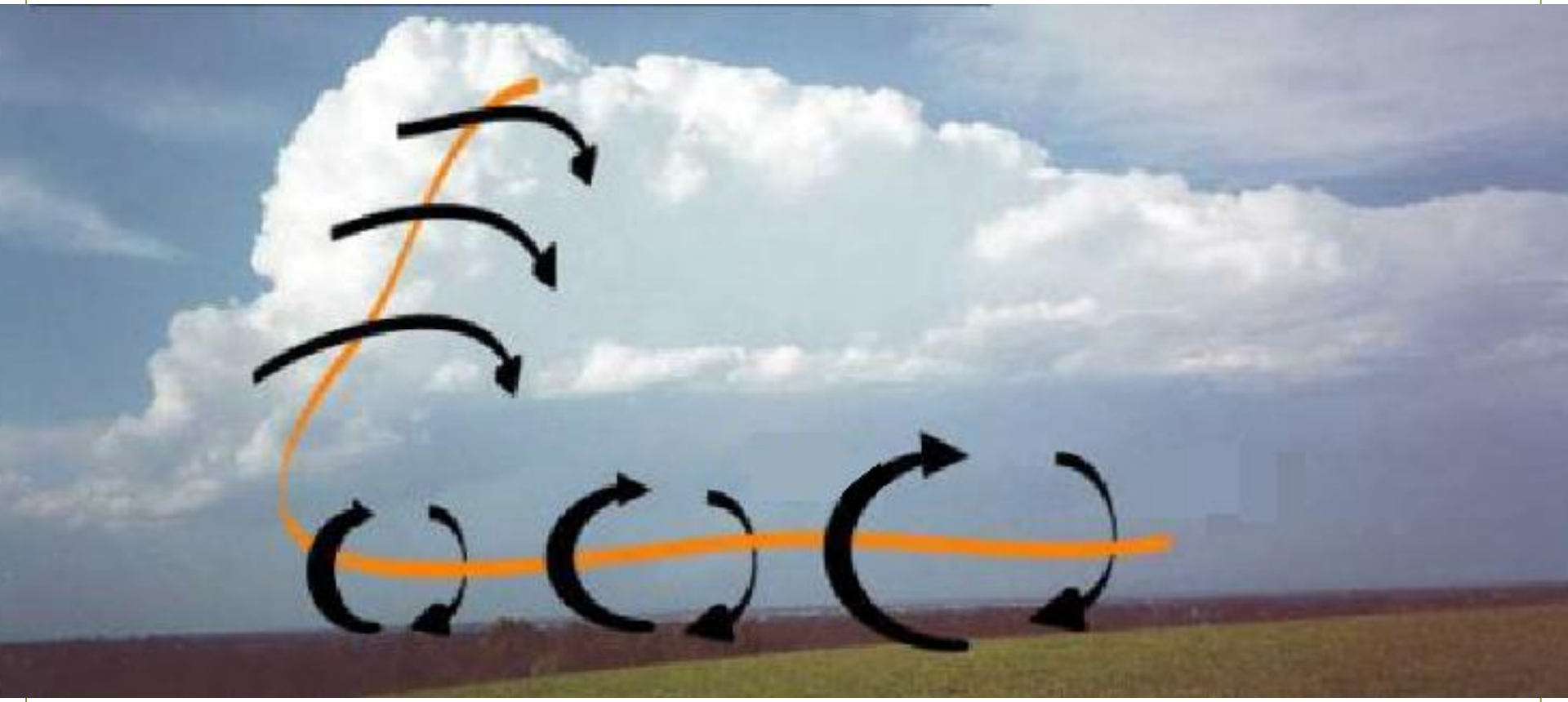
What is a tornado?

- "A violently rotating column of air in contact with the ground associated with a thunderstorm or a developing thunderstorm."
  - *Glossary of Meteorology*
- Observed on every continent except Antarctica
  - Only have "good" records in a few countries
- Damage described on Fujita scale
  - Goes from 0-5
  - Describes maximum damage

The importance of supercells

Rotation in storms-a three stage process

- Rotation aloft comes from changes of the wind with height at low levels



Rotation in storms-a three stage process

- Rotation aloft comes from changes of the wind with height at low levels
- Rotation near the ground comes from processes inside the storm
  - Rotation of storm
  - Precipitation falls and evaporates


NSSL archive photo

Courtesy of Dave Blanchard

Courtesy of Dave Blanchard

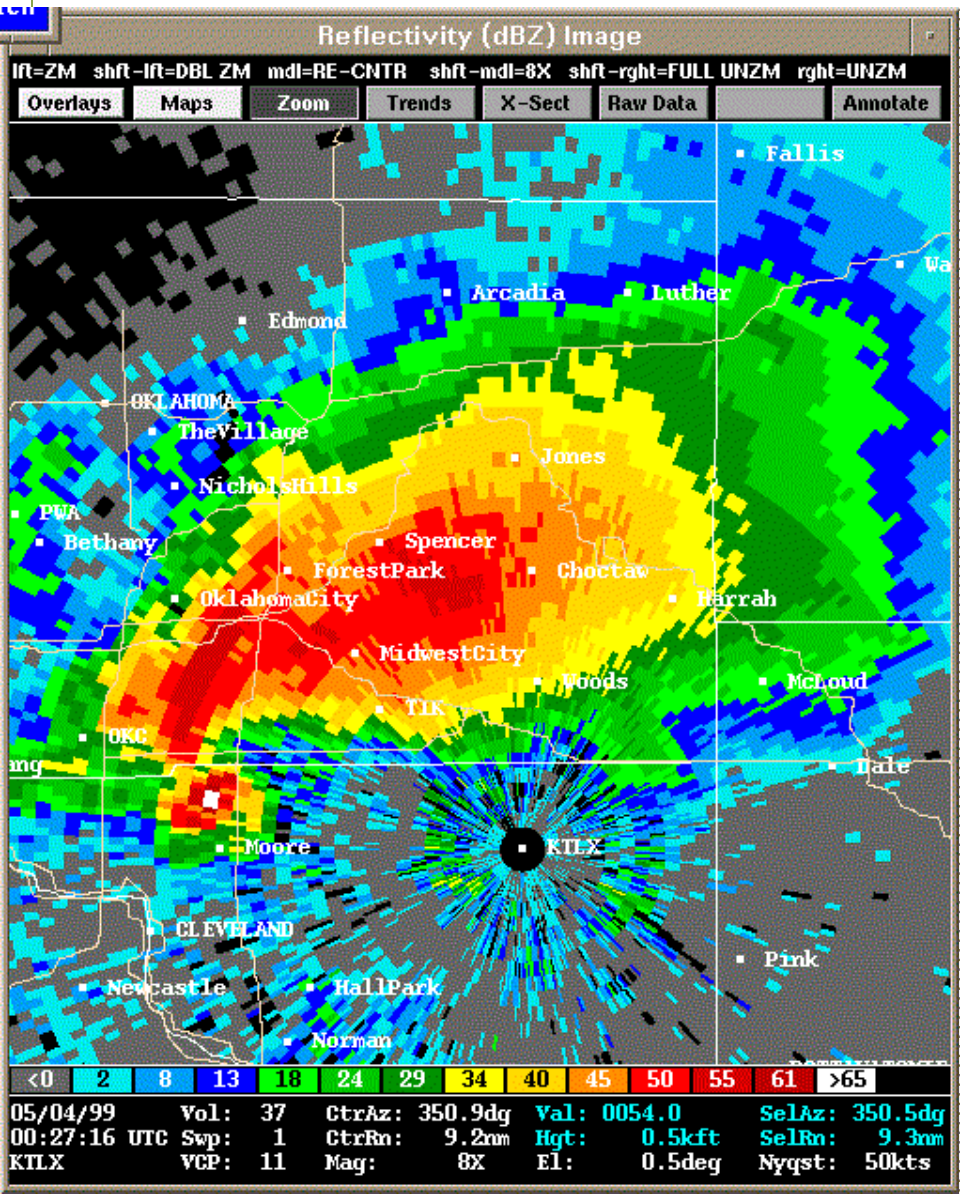
Rotation in storms-a three stage process

- Rotation aloft comes from changes of the wind with height at low levels
- Rotation near the ground comes from processes inside the storm
  - Rotation of storm
  - Precipitation falls and evaporates
- Rotation strengthens at ground because of low-level processes

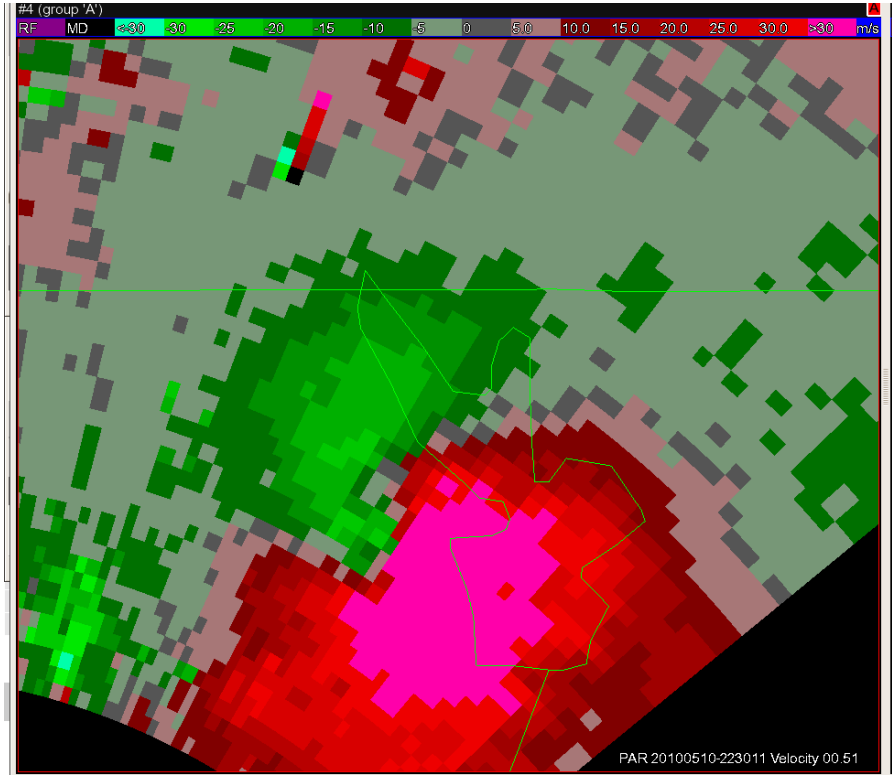
Observing storms

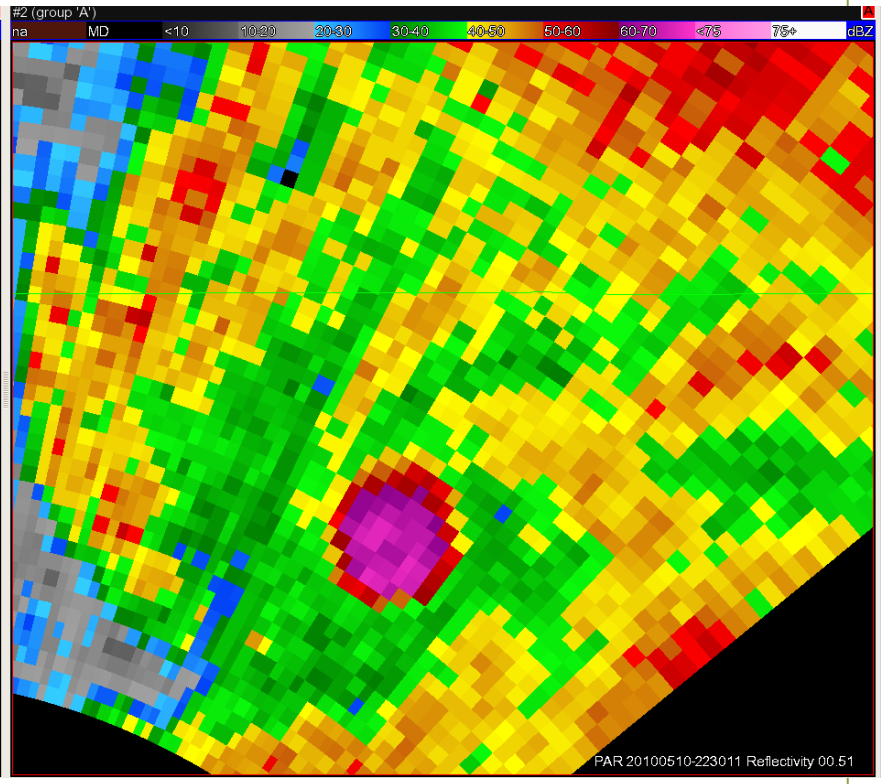
- Collect environmental conditions around storms
- Human observers report
- Radar to see what's going on inside of storms
  - Limitations-curvature of earth, geometry of beams

NEXRAD-3 May 1999

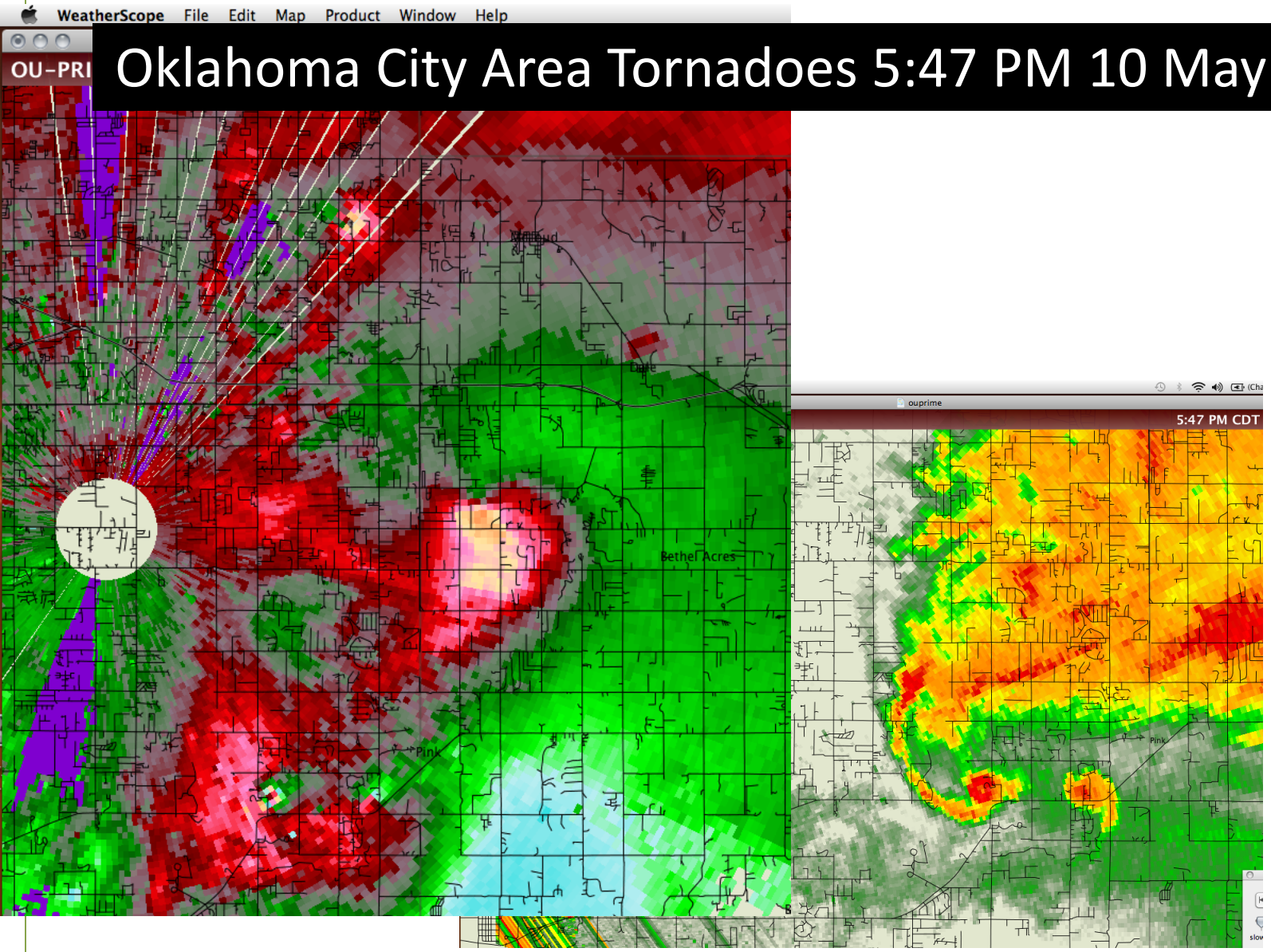


Phased Array Radar (10 May 2010) Lake Stanley Draper Tornado



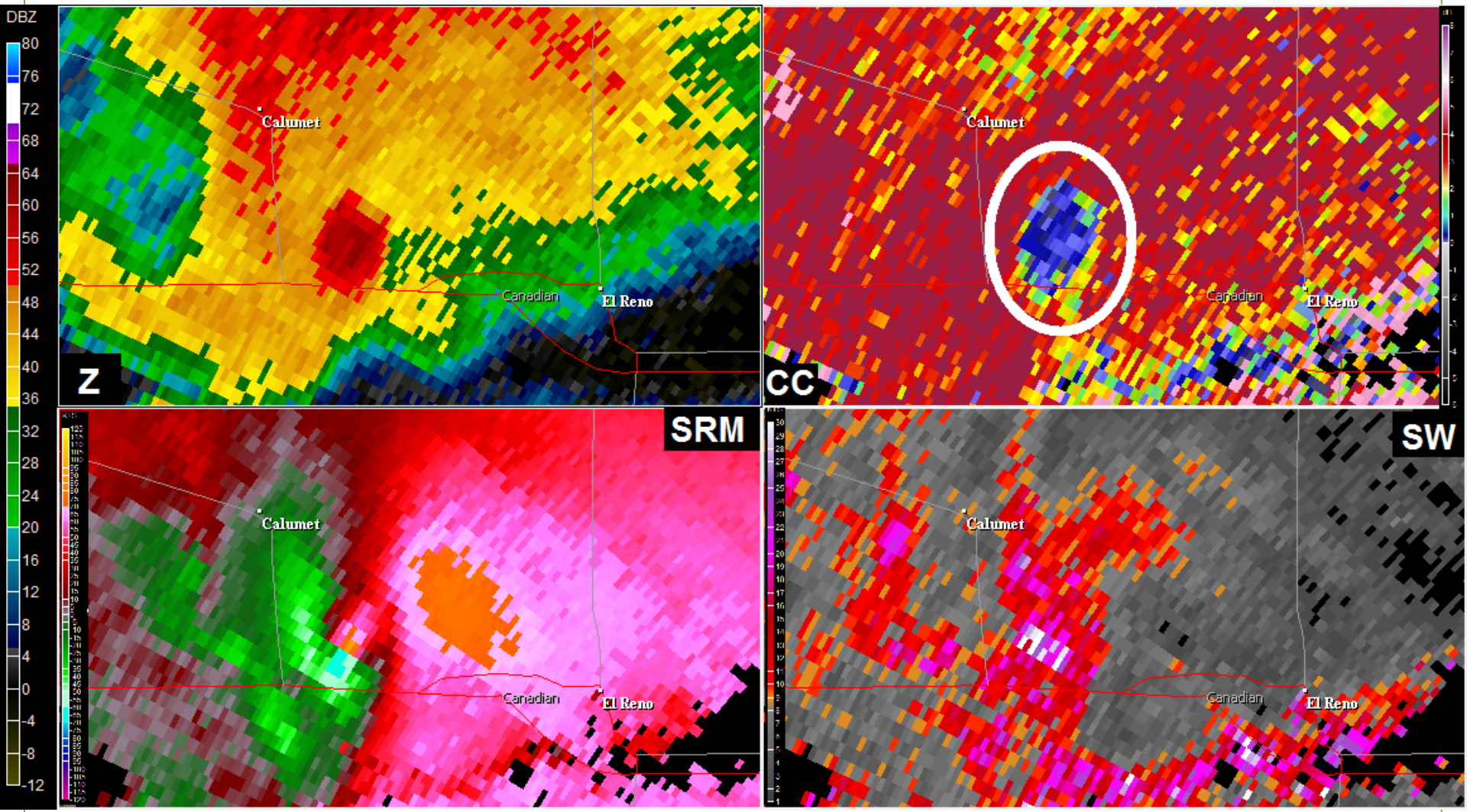


Oklahoma City Area Tornadoes 5:47 PM 10 May 2010



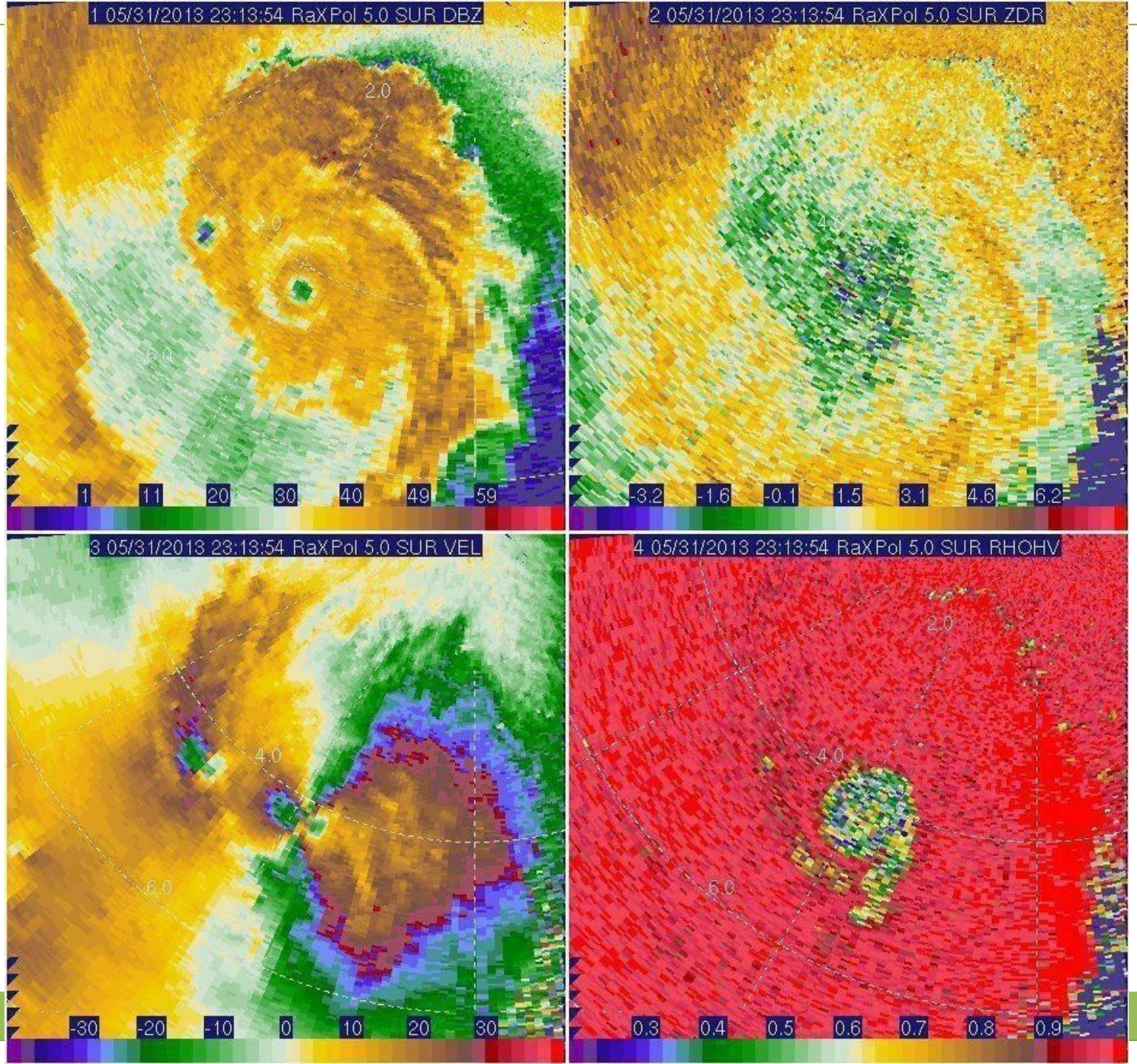
Dual-polarimetric radar

- Sends out two beams
- Differentiates between large drops of rain (flat) and hail (looks rounder)
- Can see debris


DBZ
80
76
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
-4
-8
-12
Z
Calumet
Canadian
El Reno
CC
Calumet
Canadian
El Reno
SRM
Calumet
Canadian
El Reno
SW
Calumet
Canadian
El Reno

Up close with research radars

- Sends out two beams
- Differentiates between large drops of rain (flat) and hail (looks rounder)
- Can see debris


1 05/31/2013 23:13:54 RaXPol 5.0 SUR DBZ
2.0
4.0
6.0
1
11
20
30
40
49
59
2 05/31/2013 23:13:54 RaXPol 5.0 SUR ZDR
4.0
-3.2
-1.6
-0.1
1.5
3.1
4.6
6.2
3 05/31/2013 23:13:54 RaXPol 5.0 SUR VEL
4.0
6.0
-30
-20
-10
0
10
20
30
4 05/31/2013 23:13:54 RaXPol 5.0 SUR RHOHV
2.0
4.0
6.0
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Ingredients-based forecasting

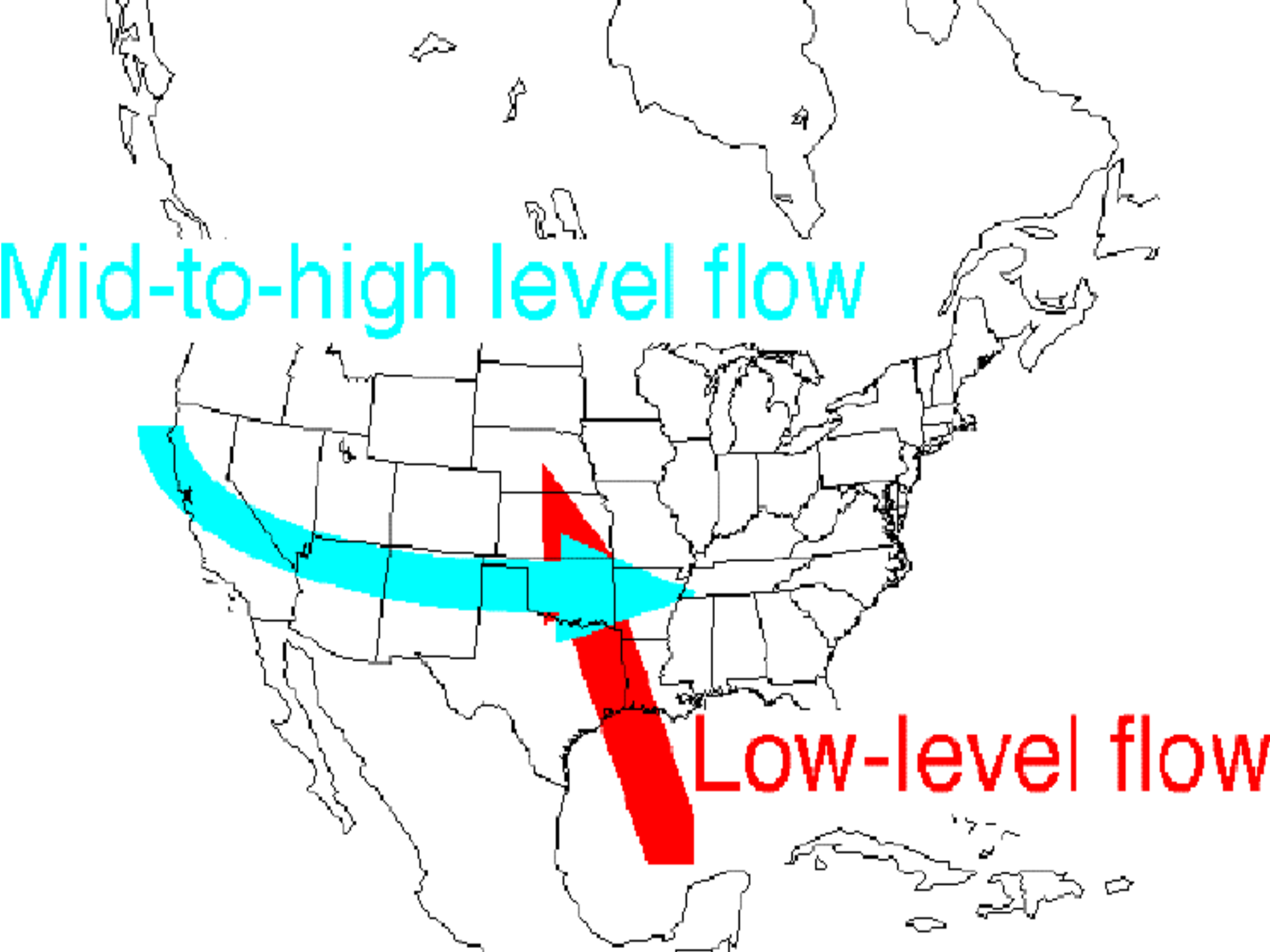
- Based on physical understanding, what do you need to have the “thing” occur?
- Are they present now?
- Is there a process to bring a missing ingredient?

Ingredients for supercells

- Making a thunderstorm (Energy)
  - Low-level warm, moist air
  - Mid-level (~2-10 km) relatively dry air (cools off rapidly with height)
  - Something to lift the warm, moist air
- Organization (Shear)
  - Winds that increase and change direction with height over lowest few km
  - From equator at surface, west aloft

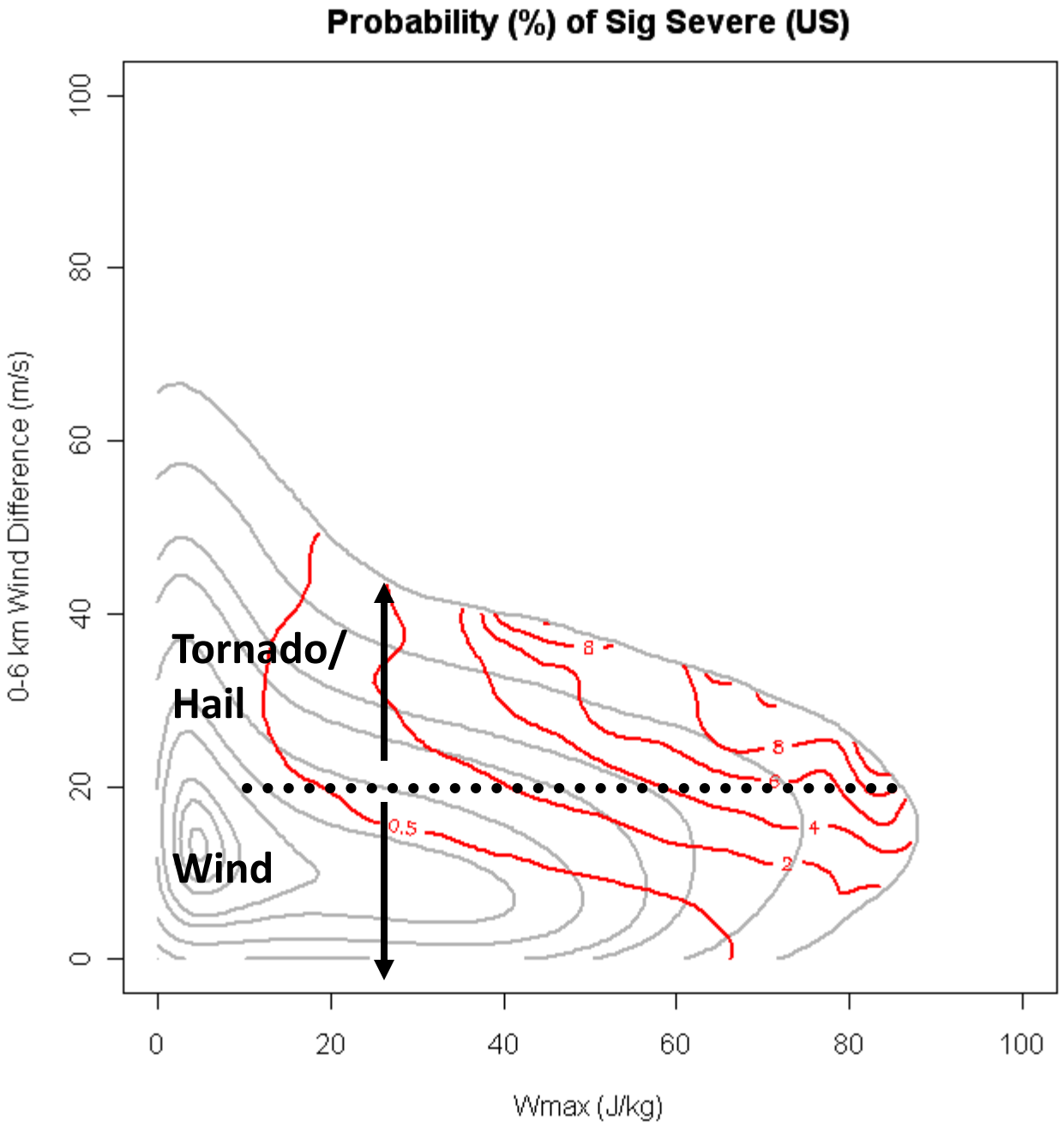
Increasing chances for tornadoes

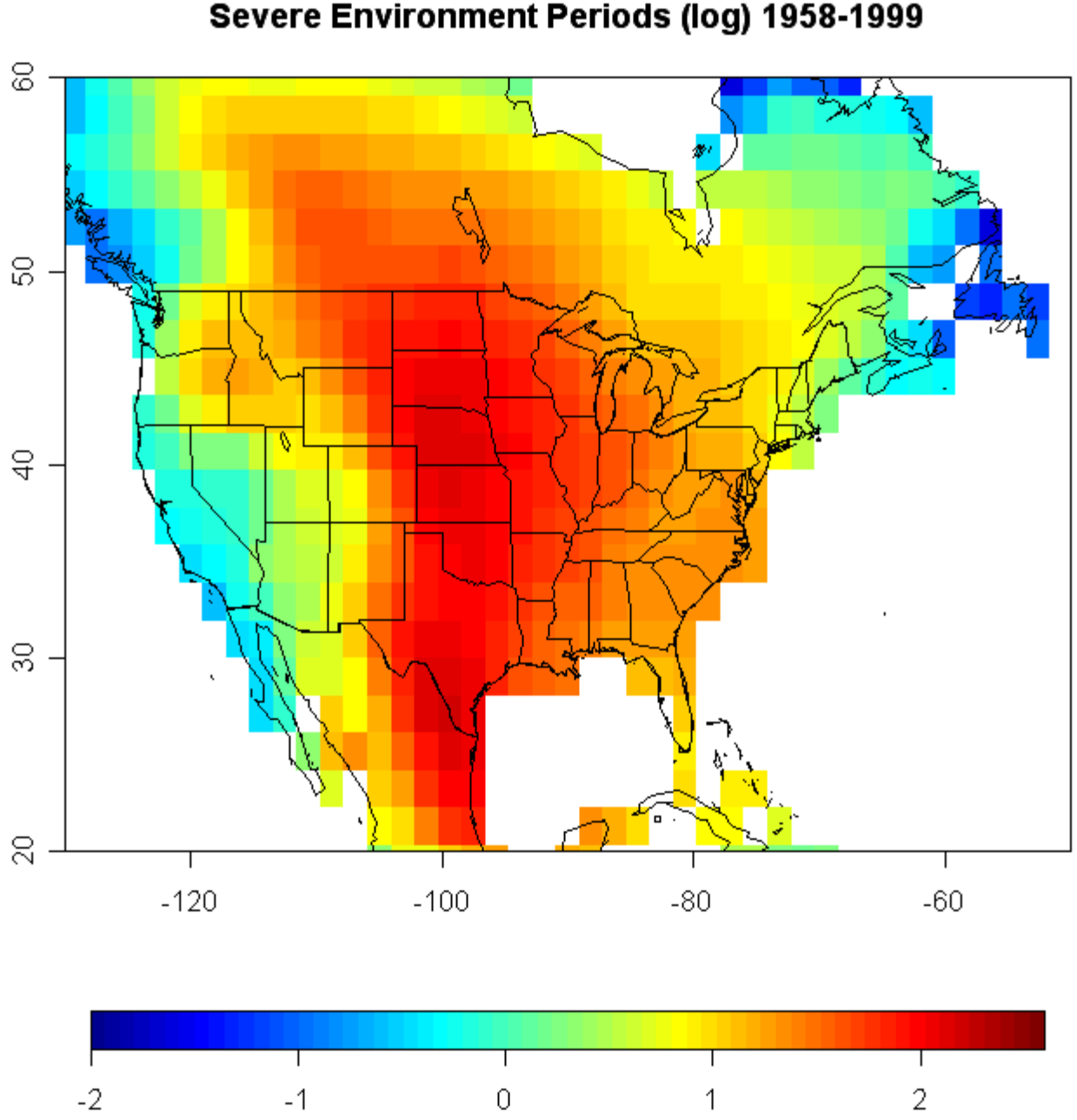
- Not too dry at the ground
  - Evaporation makes air too cold
- Strong shear in lowest ~1 km

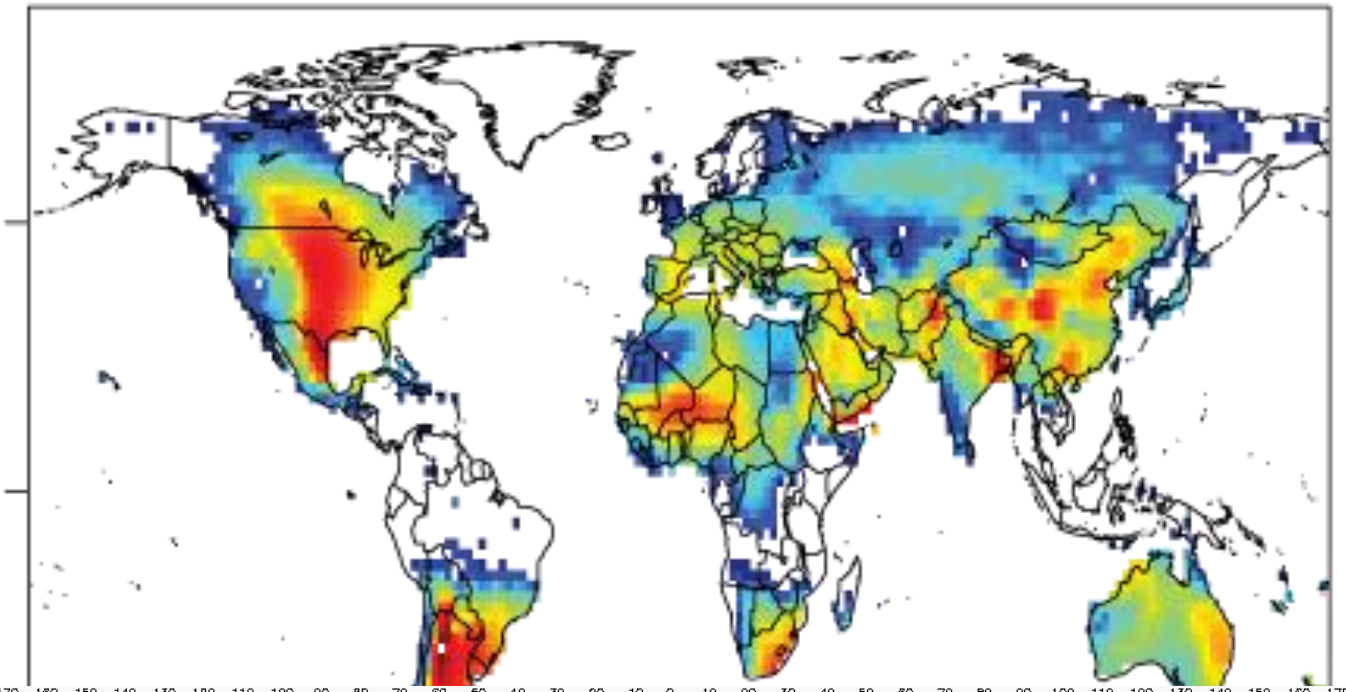

Mid-to-high level flow
Low-level flow

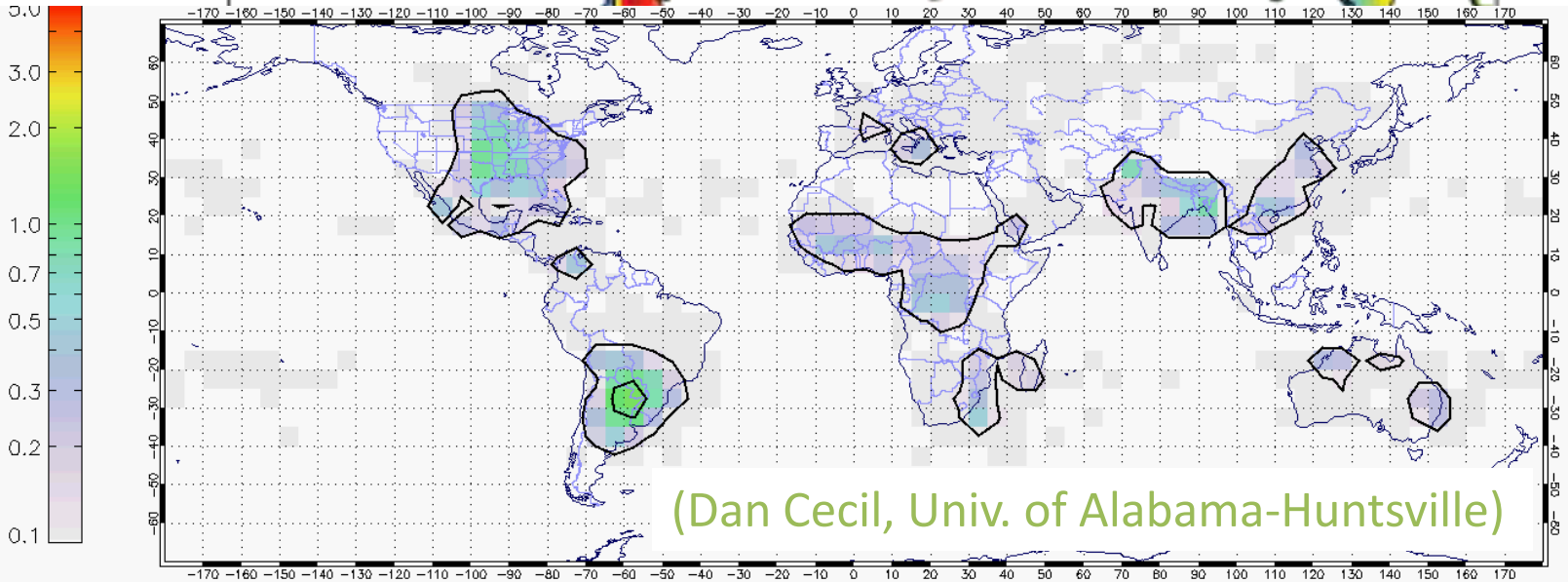
Using environments to estimate storms

- Start of forecasting process
- Environmental information collected more systematically
- If the ingredients in observations associated with storms are present, call it a “yes.” If not, “no”
- Difficult to see initiation in large-scale conditions

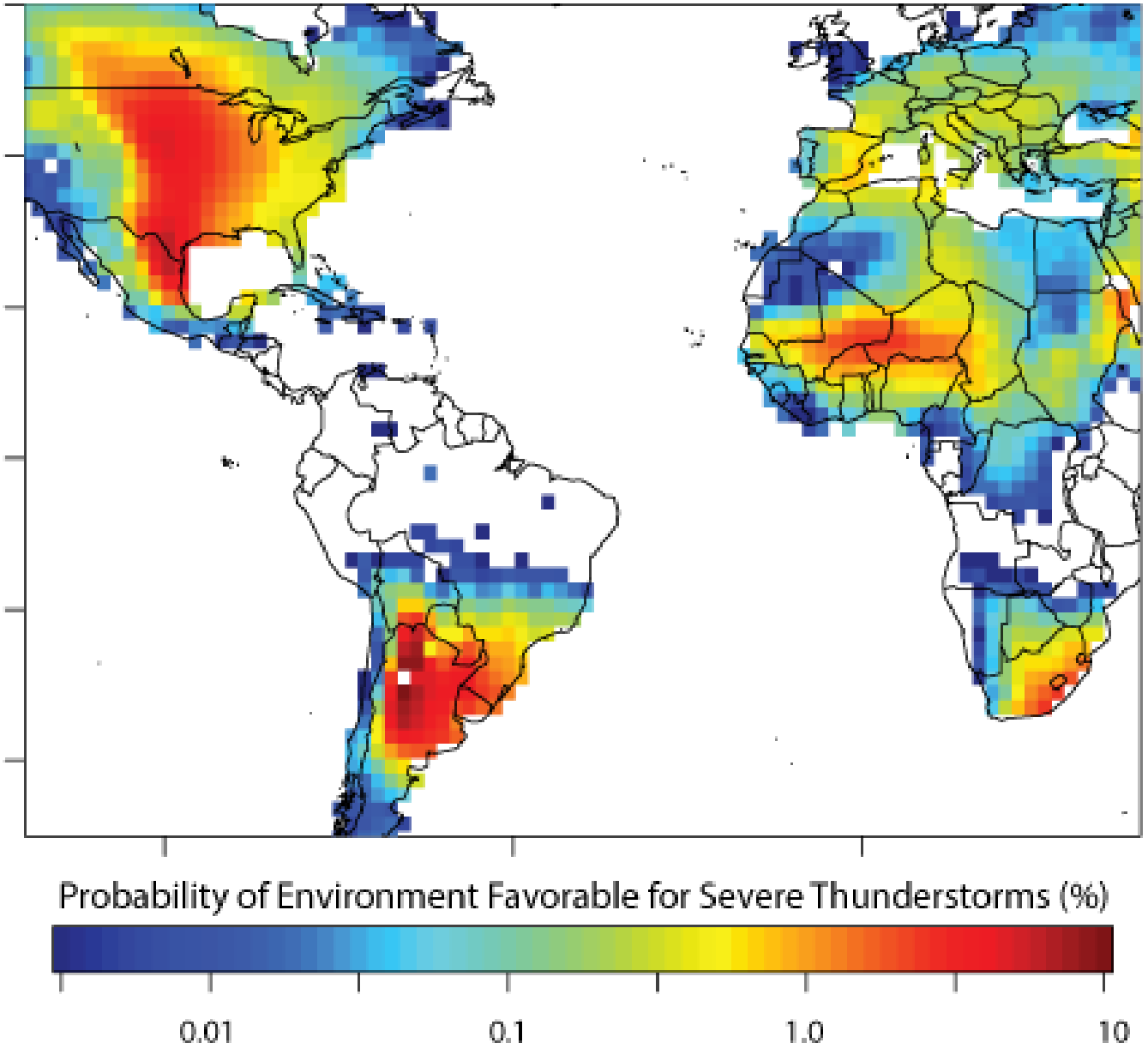

Probability (%) of Sig Severe (US)
0-6 km Wind Difference (m/s)
0
20
40
60
80
100
Wmax (J/kg)
0
20
40
60
80
100
Tornado/
Hail
Wind
8
8
6
4
2
0.5

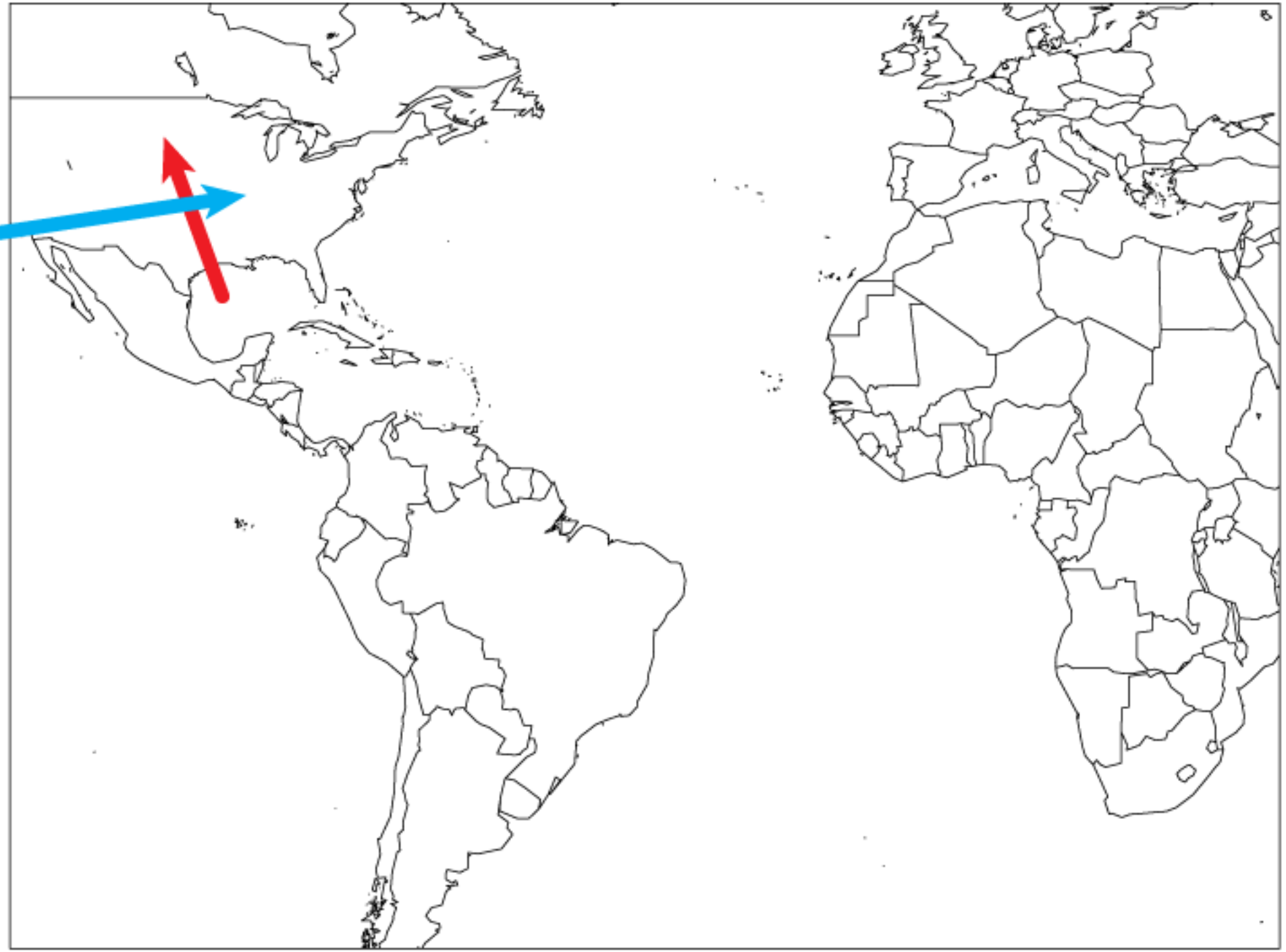

Severe Environment Periods (log) 1958-1999
60
50
40
30
20
-120
-100
-80
-60
-2
-1
0
1
2

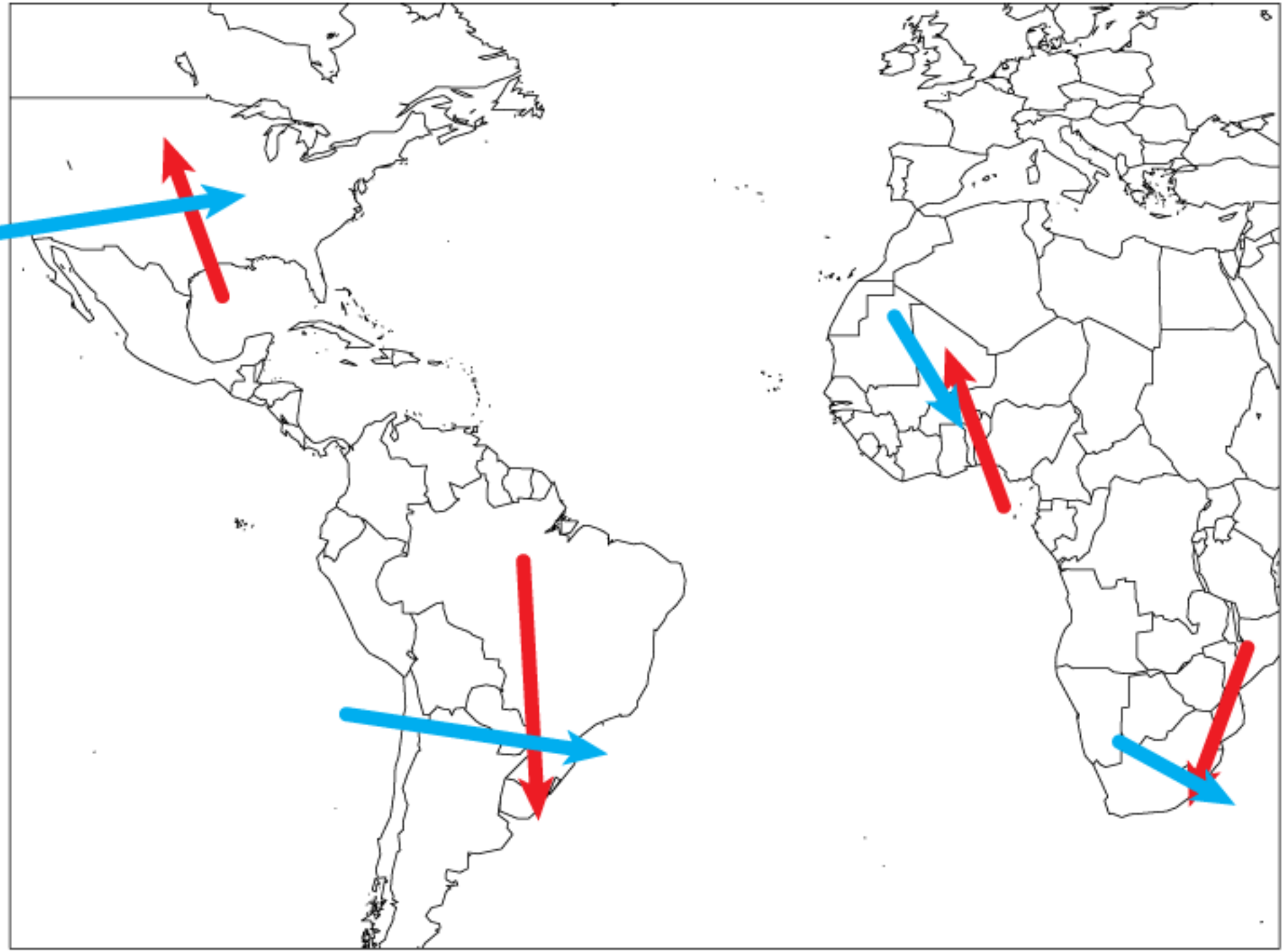


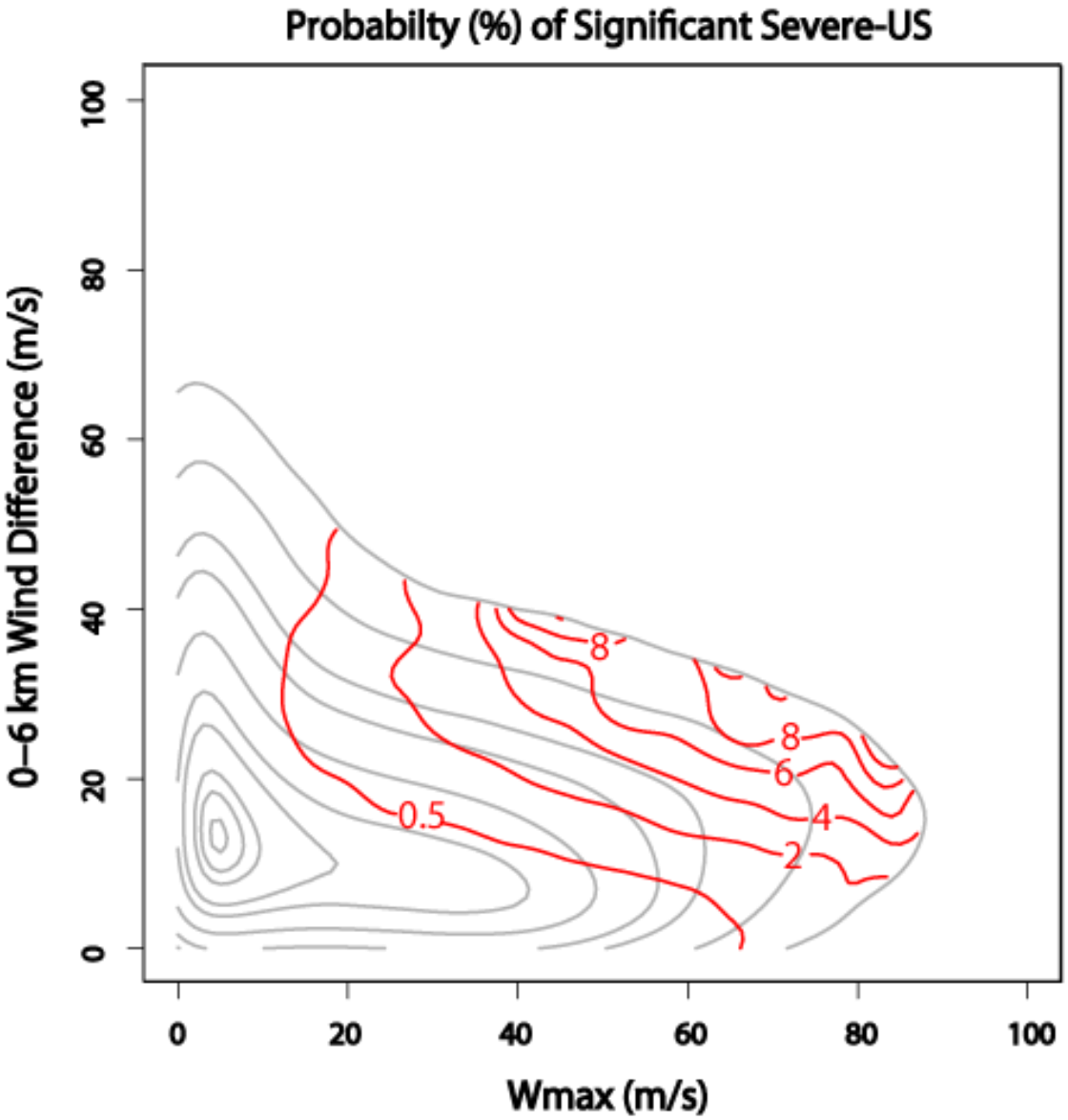


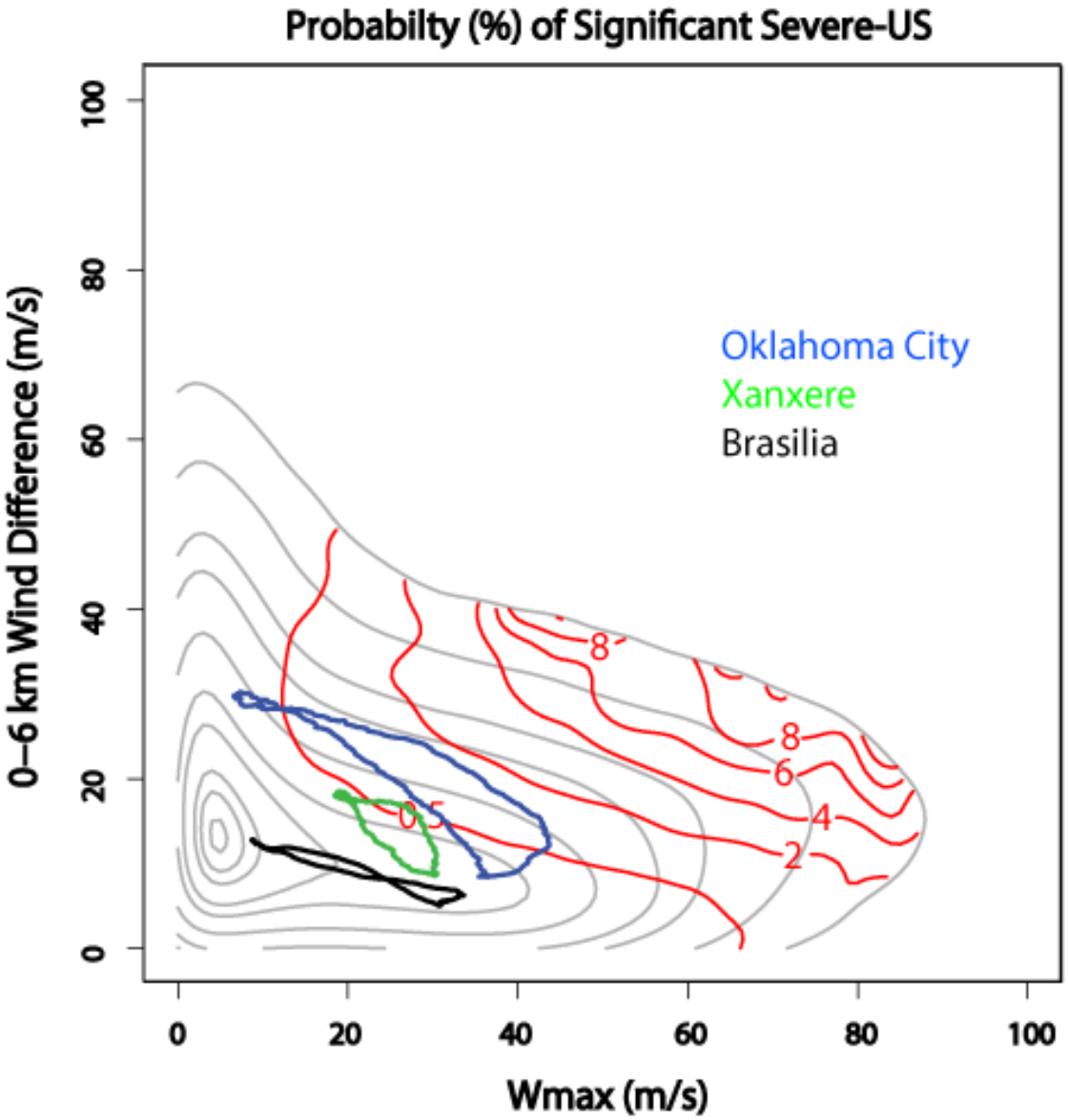
(Dan Cecil, Univ. of Alabama-Huntsville)


Probability of Environment Favorable for Severe Thunderstorms (%)
0.01
0.1
1.0
10

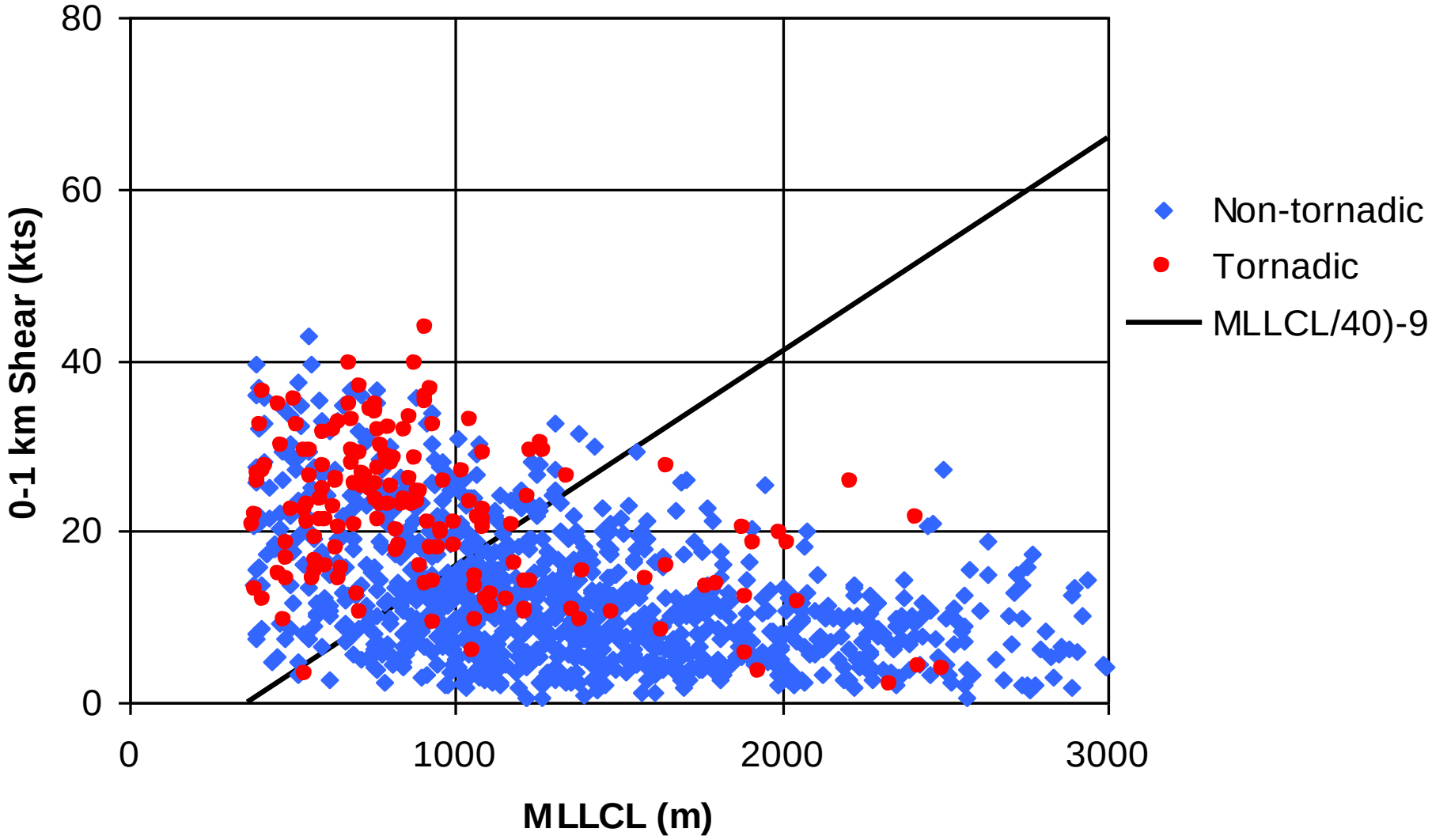


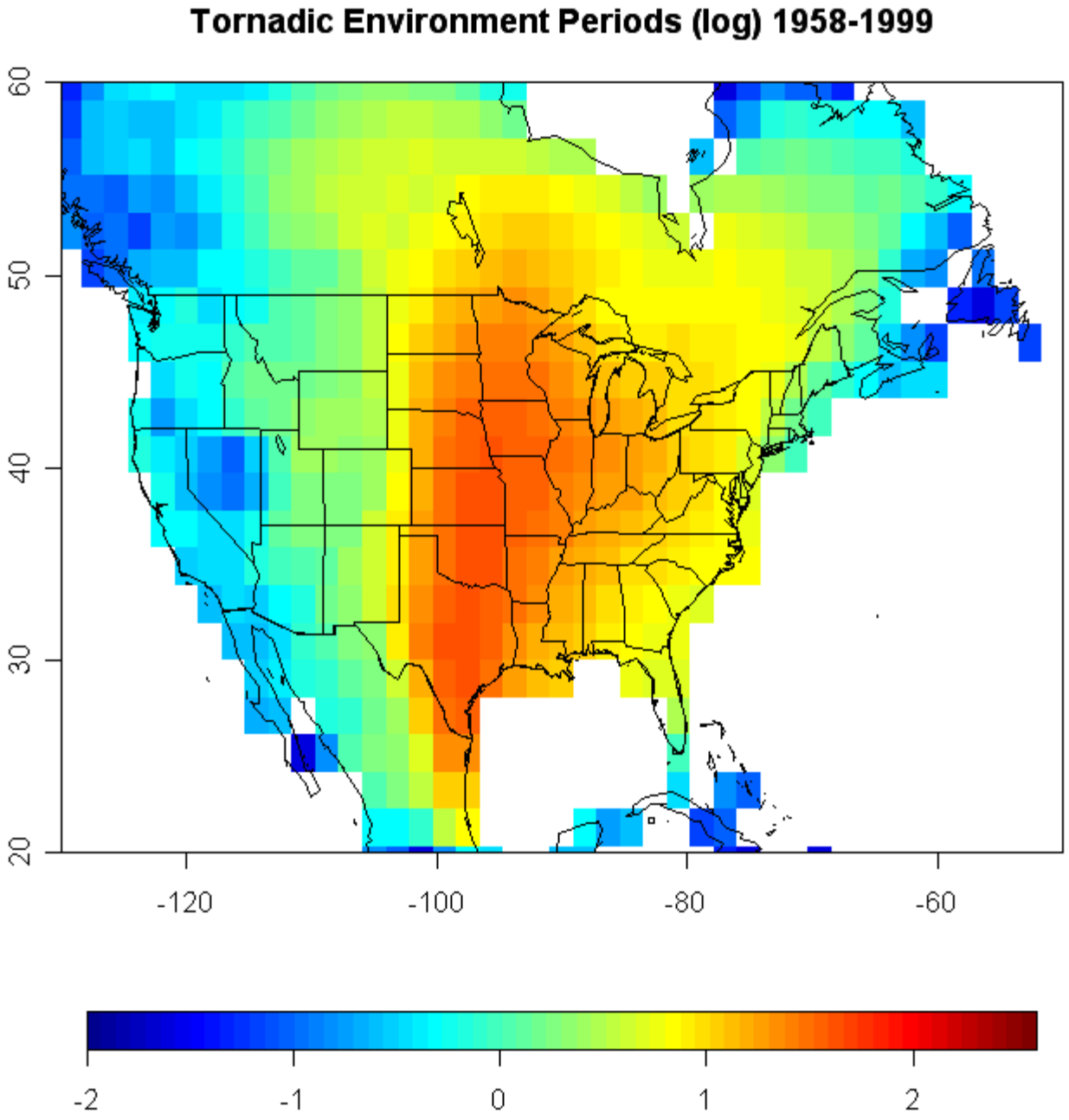


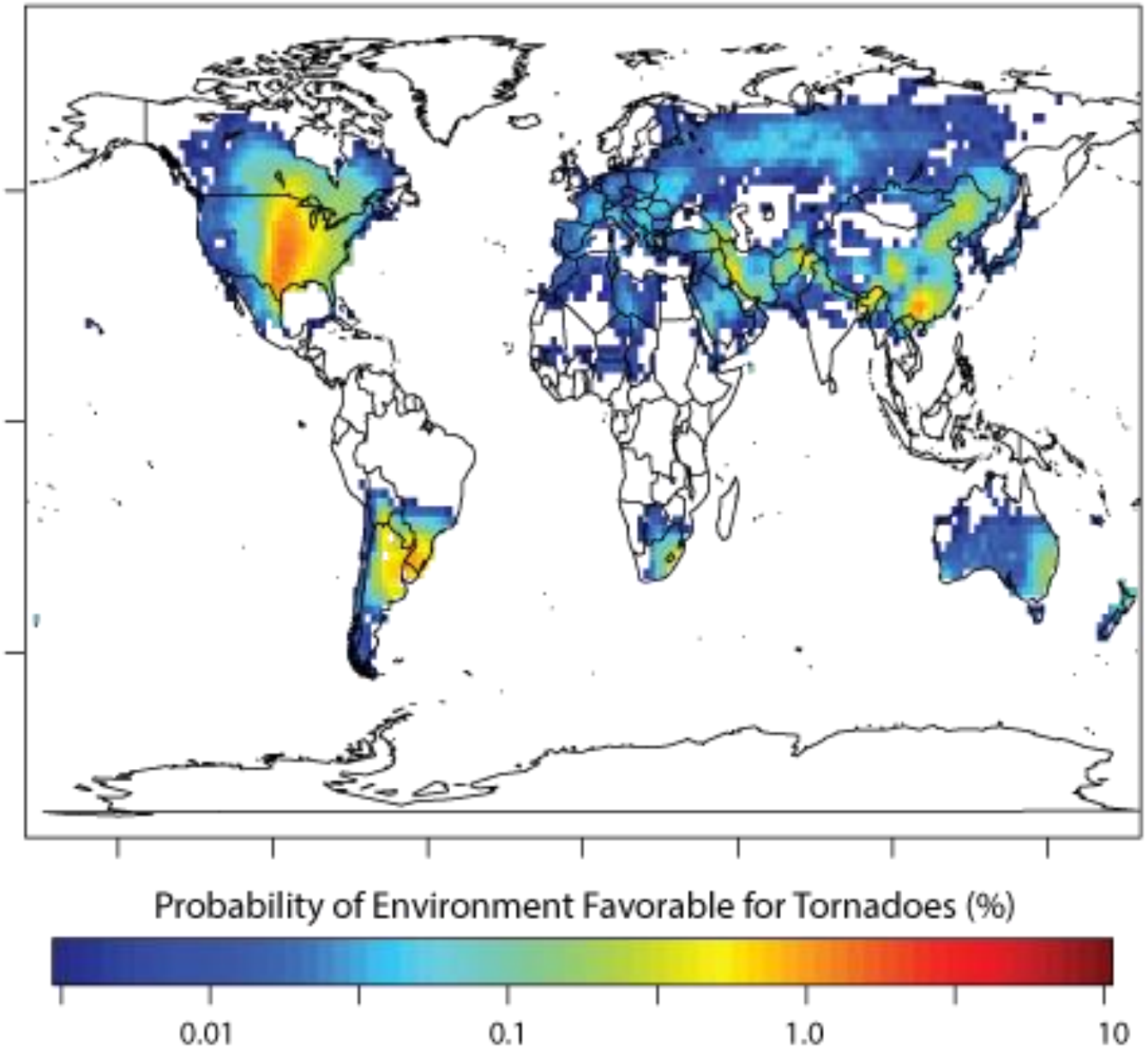

Probabilty (%) of Significant Severe-US
0–6 km Wind Difference (m/s)
0
20
40
60
80
100
Wmax (m/s)
0
20
40
60
80
100
0.5
2
4
6
8
8

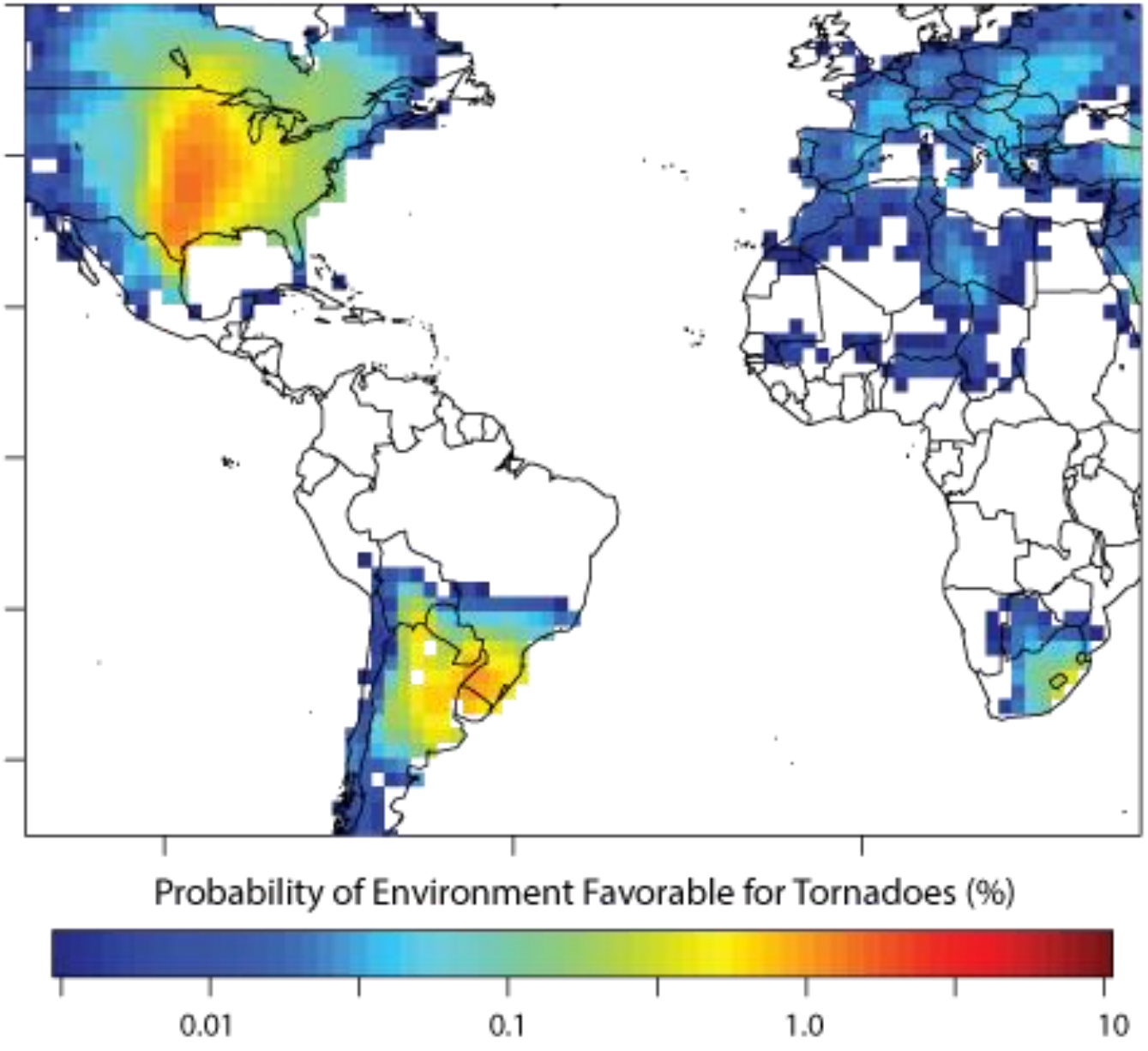

Probabilty (%) of Significant Severe-US
0–6 km Wind Difference (m/s)
Wmax (m/s)
0
20
40
60
80
100
Oklahoma City
Xanxere
Brasilia
8
8
6
4
2
0.5

Near-Storm Environmental Conditions (Reanalysis-1997-1999)




Tornadic Environment Periods (log) 1958-1999
60
50
40
30
20
-120
-100
-80
-60
-2
-1
0
1
2


Probability of Environment Favorable for Tornadoes (%)
0.01
0.1
1.0
10


Probability of Environment Favorable for Tornadoes (%)
0.01
0.1
1.0
10

Some closing thoughts

- Brazil/Uruguay/Argentina/Paraguay-probably 2nd most likely region to have tornadoes on planet
  - Possible regional focus for 24-48 hour forecasts
- Forecaster training and tools
  - Ingredients for forecasting
  - Radar use and interpretation
- Research
  - Support local researchers with severe thunderstorm/tornado expertise