Severe thunderstorms and climate change

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Whatever may be the progress of science, NEVER will observers who are trustworthy, and careful of their reputation, venture to foretell the state of the weather.

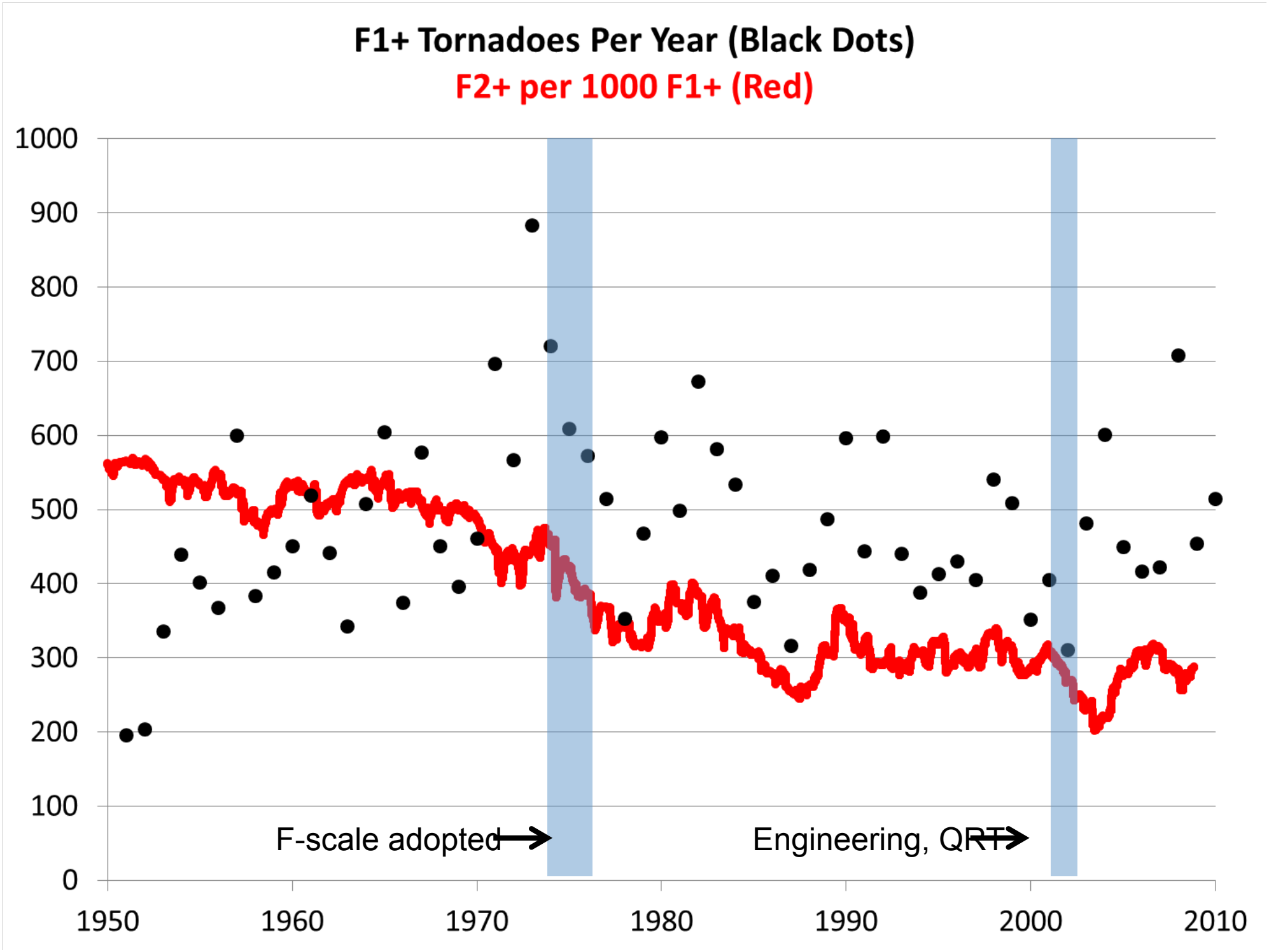
1846

2011 Tornadoes

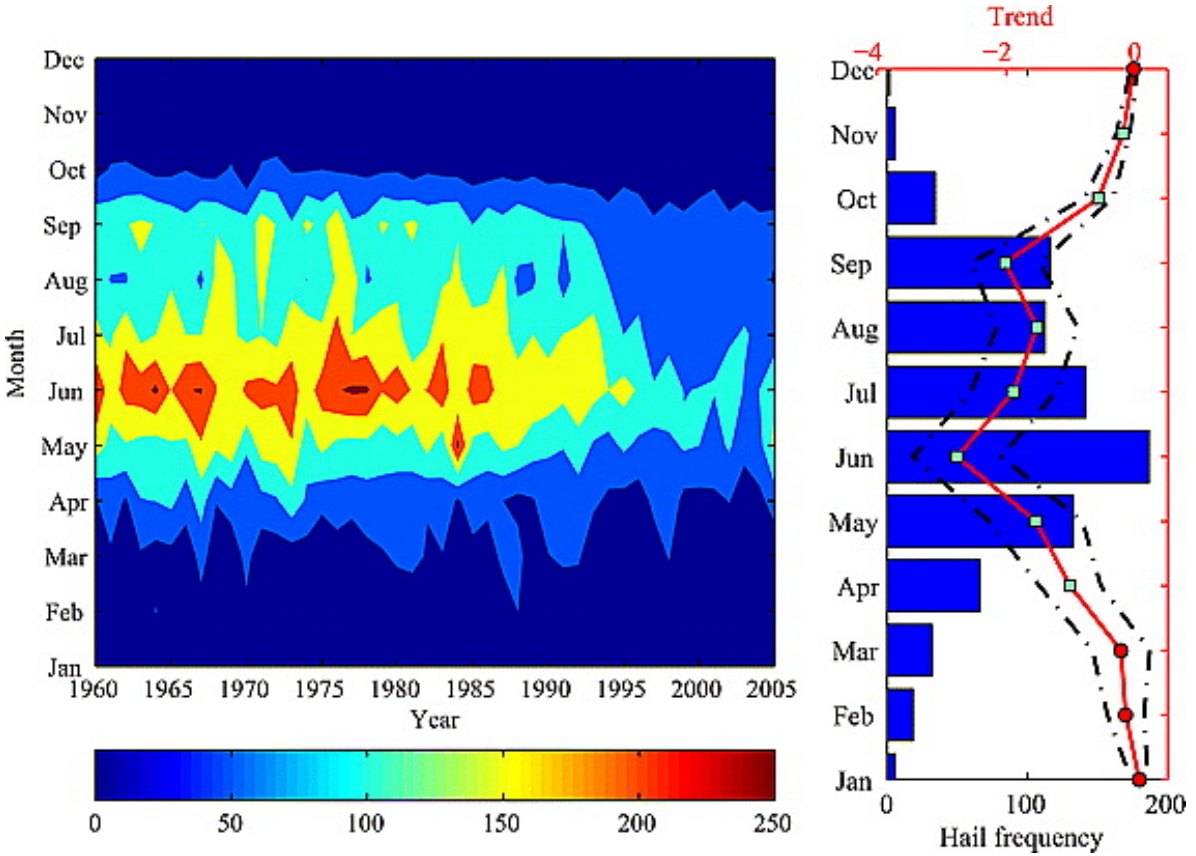
- April was biggest calendar month ever
- One of ~6 biggest days (1974, 1932, 1920, 1908, 1884)
- One of smallest first three weeks of May ever (1987)
- Joplin
- Trends on really rare events?

A logical place to start

- Reports
  - In US and ESWD, target of opportunity
  - Changes in *de jure* and *de facto* standards
- Hail in other countries
  - China-yes/no reports available at >500 sites with some size data
  - Italy, France, and Spain-hailpad networks


F1+ Tornadoes Per Year (Black Dots)
F2+ per 1000 F1+ (Red)
1000
900
800
700
600
500
400
300
200
100
0
1950
1960
1970
1980
1990
2000
2010
F-scale adopted
Engineering, QRT

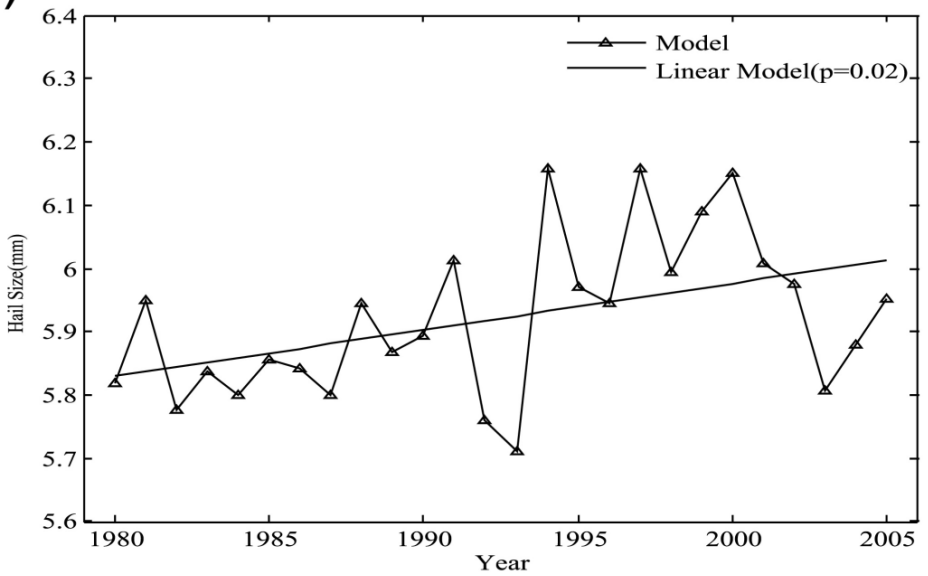
China-Hail Frequency



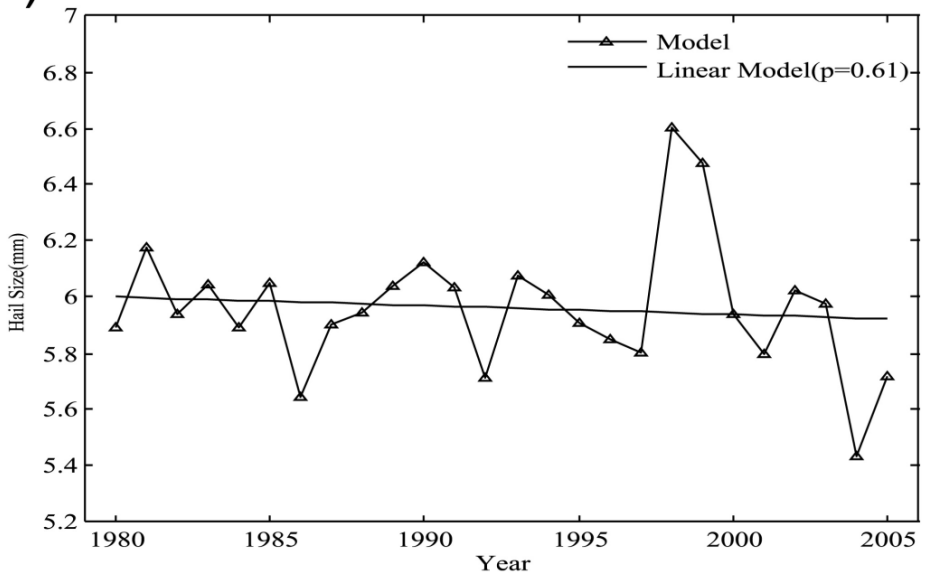
Xie et al. 2008 (*GRL*)

Impact of environment changes on hail size

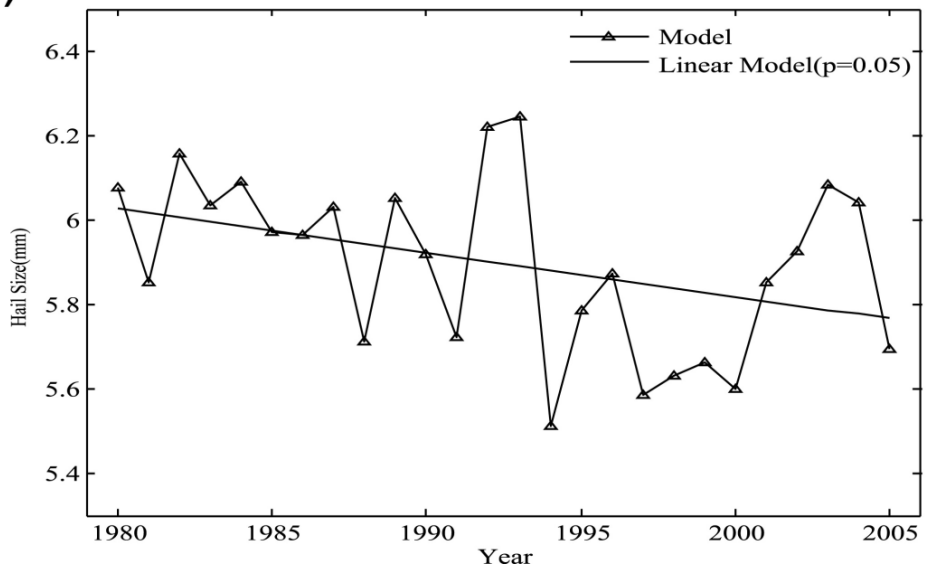
(a)



(b)



(c)



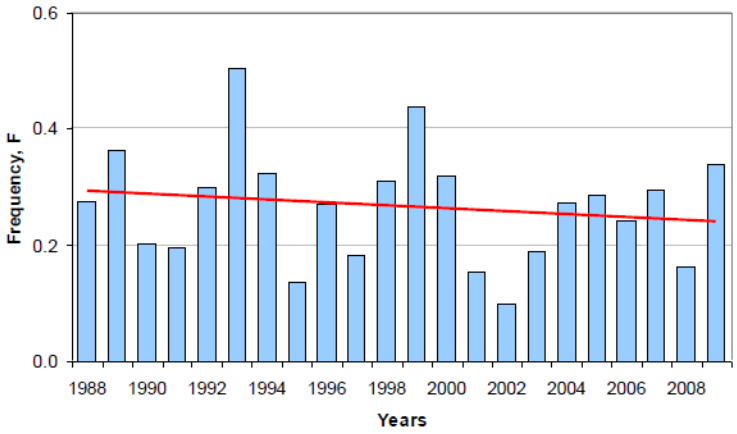
CAPE (UL)

Precipitable Water (UR)

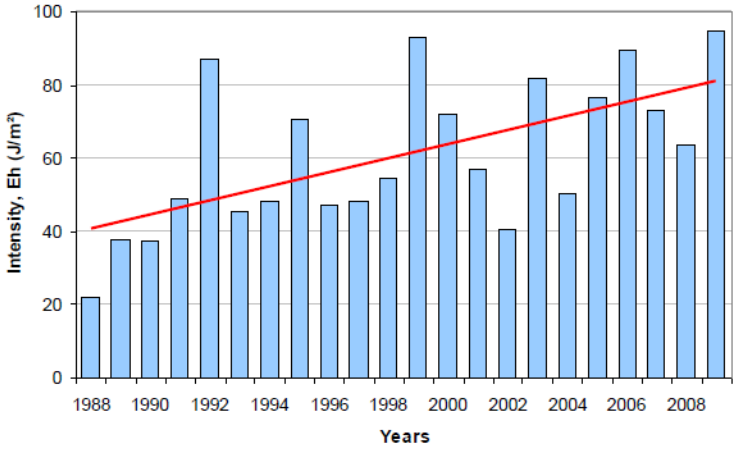
FLH (LL)

Xie et al. 2010 (*J. Clim.)*

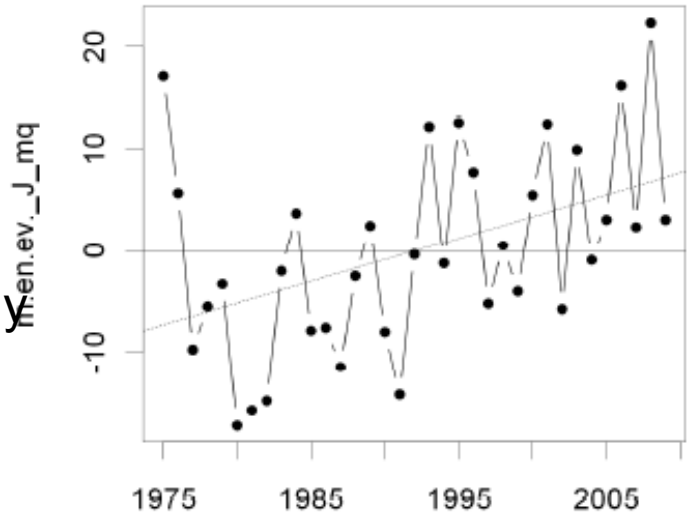
France/Italy Hailpad Data



Occurrence



Kinetic Energy



Berthet et al. (ECSS 2009)

Eccel et al. (2011)

Hail Obs Summary

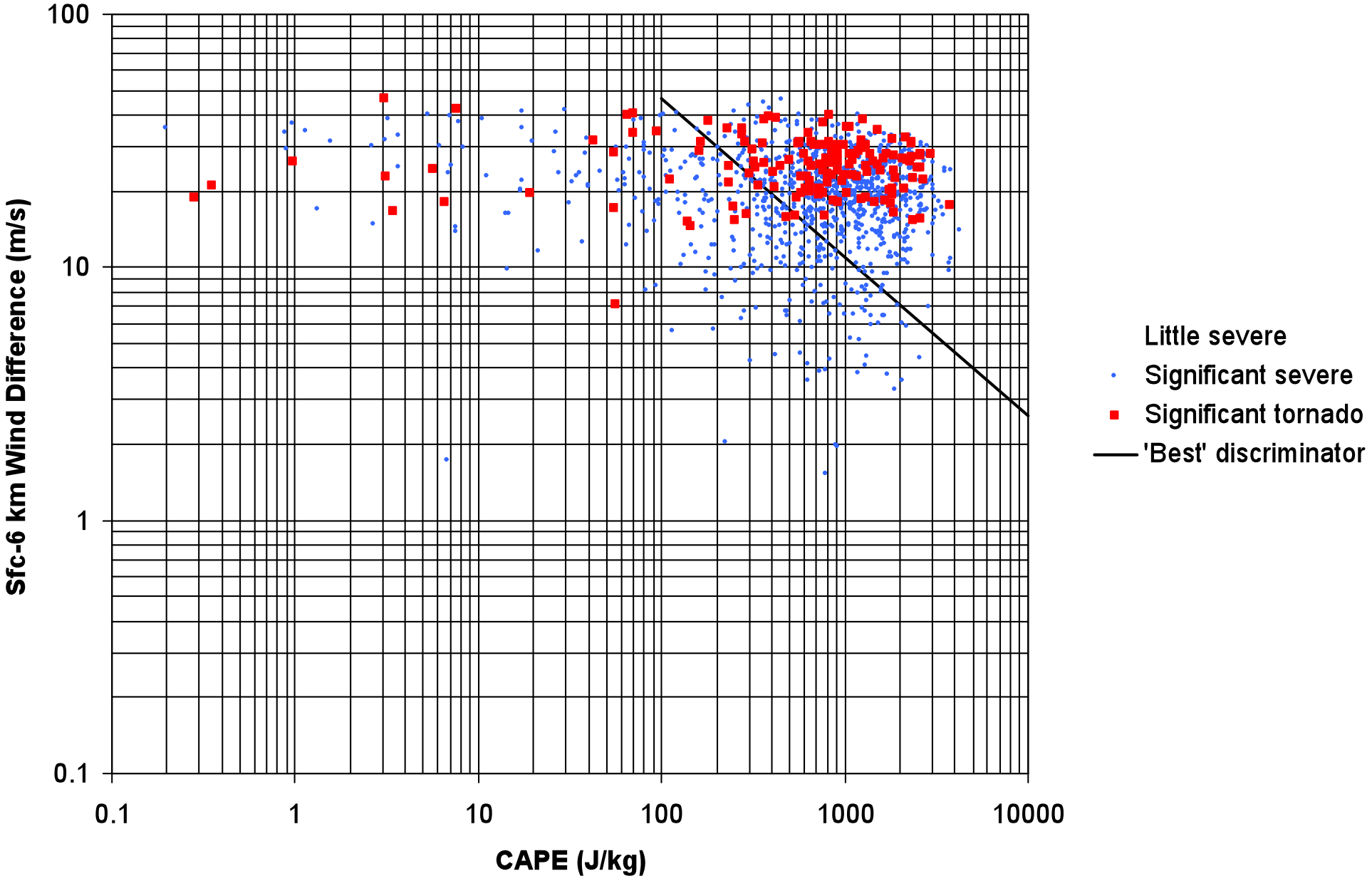
- Little change to slight decrease in occurrence
- Small decrease in mean size, but increase in kinetic energy of hailfalls
  - Start with slightly larger hail at beginning of fall
  - Melt more because of higher FLH, particularly impacting small
  - Leaves distribution shifted to larger stones
- Does it extend to larger sizes?

Using large-scale conditions

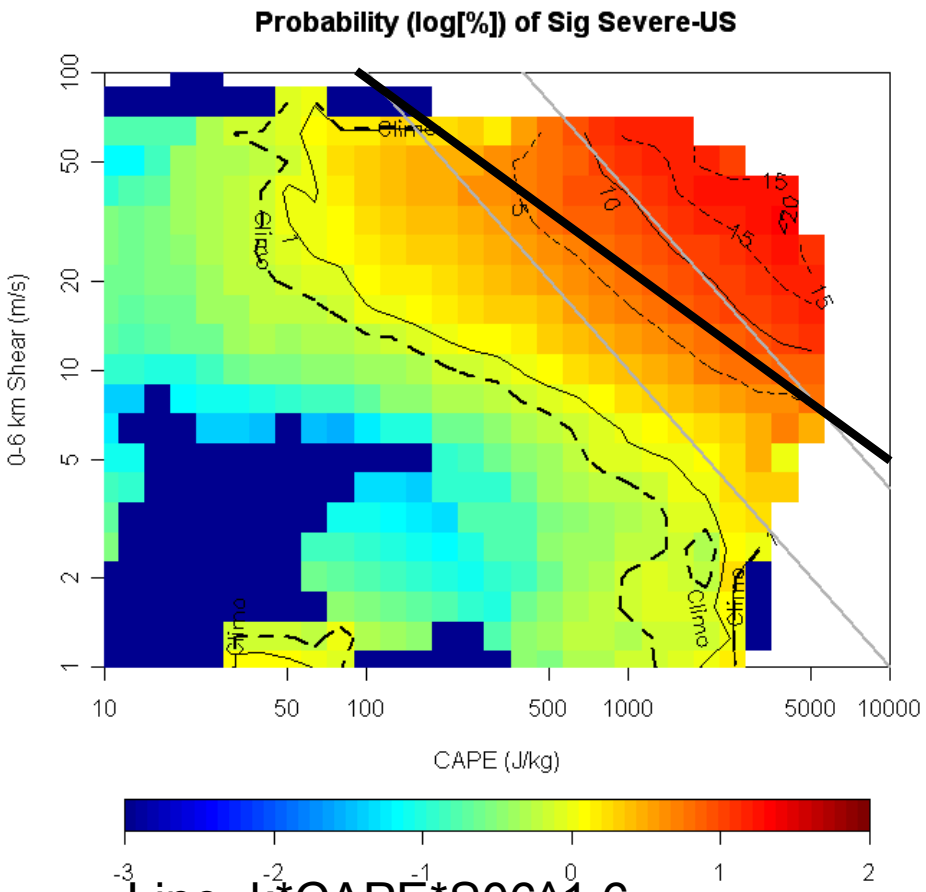
- Downscaling
  - Statistical (look at favorable conditions, ingredients-based)
  - Dynamical (nested models-Robinson et al-NEXT TALK)
- Applicable to past observations, climate models
- Define events in terms of environmental conditions
  - Storm “strength”-CAPE or Wmax
  - Organization-0-6 km wind shear
  - Initiation?

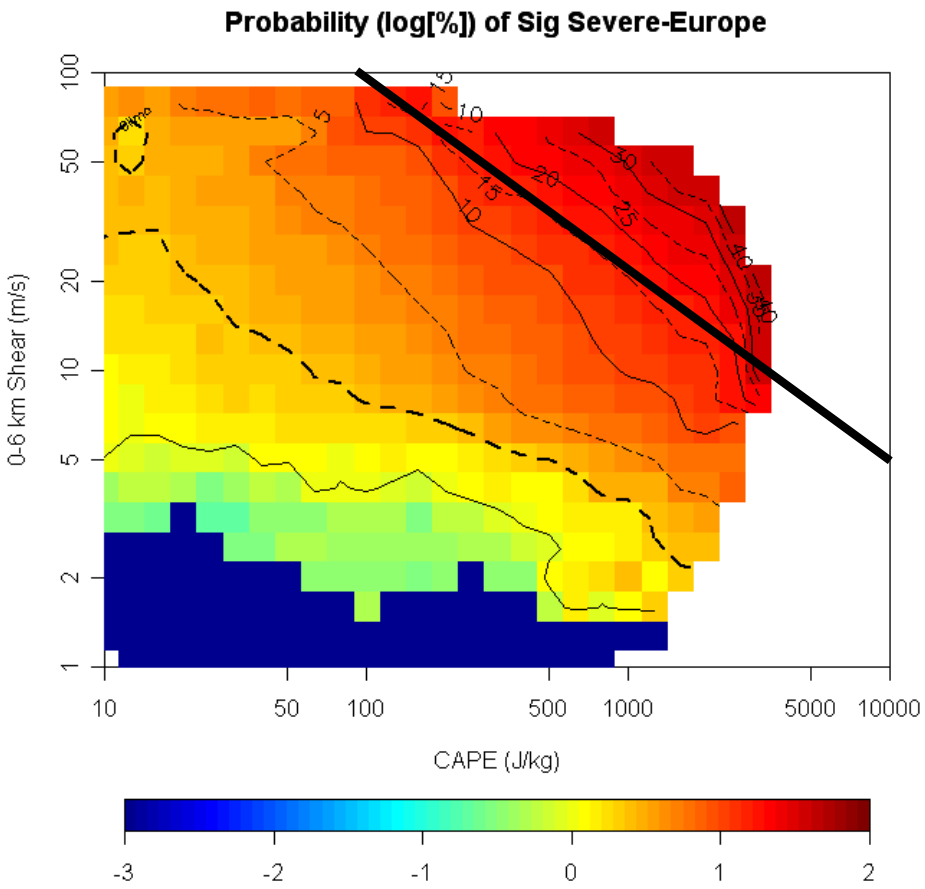
Reanalysis Proximity Soundings (1997-9)

From Brooks et al (ECSS 2002)



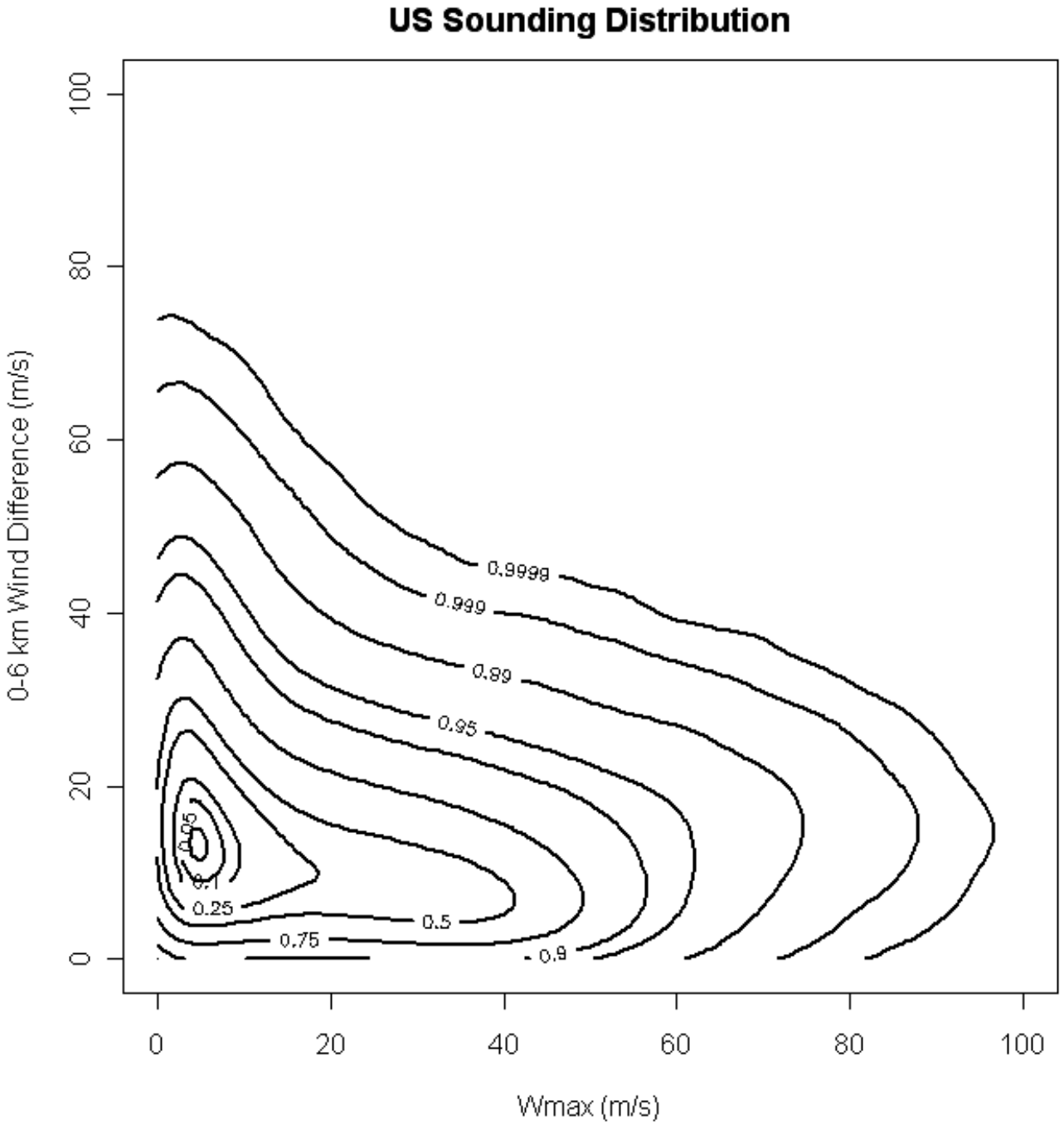
Probability of Sig Severe

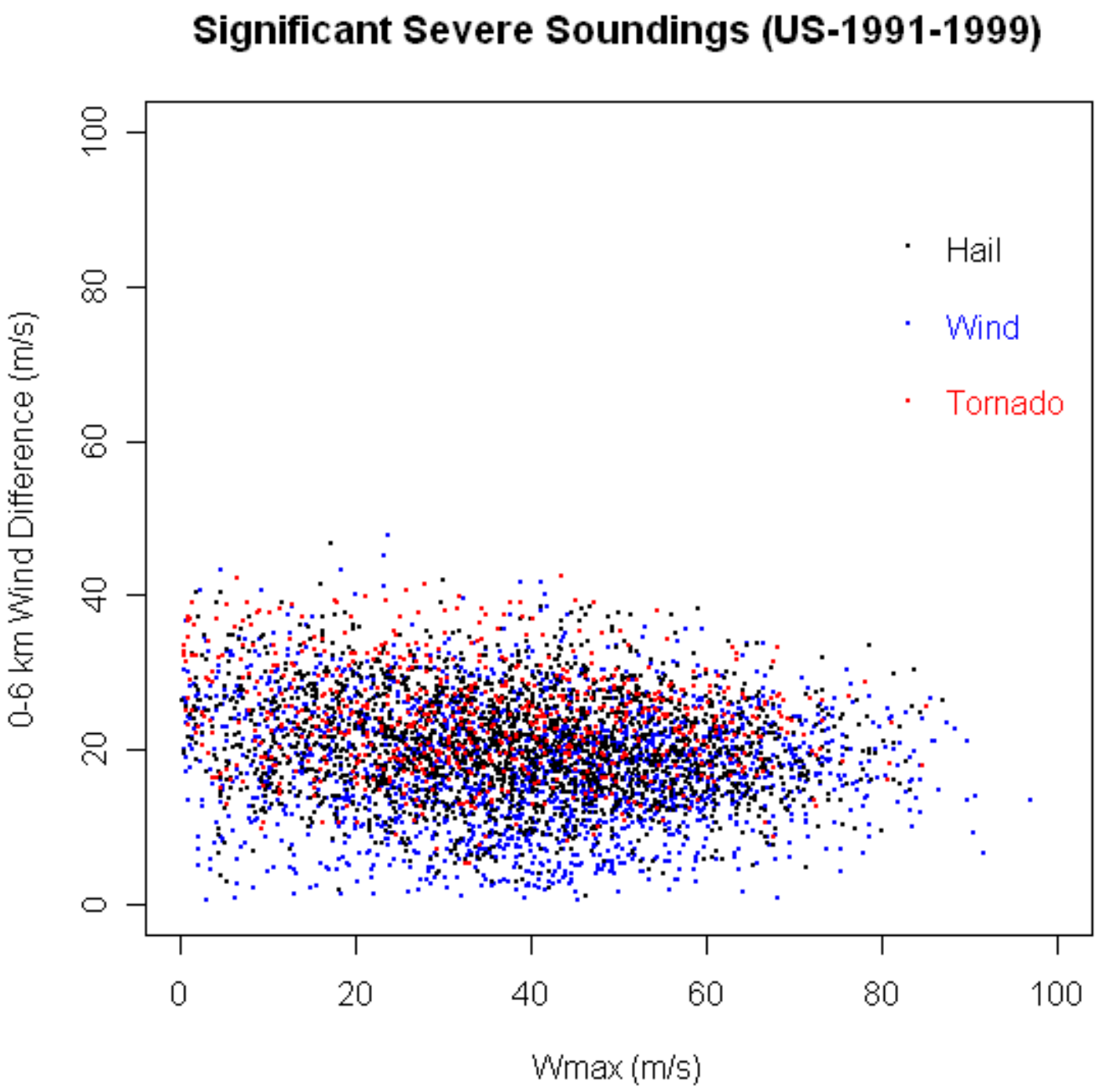


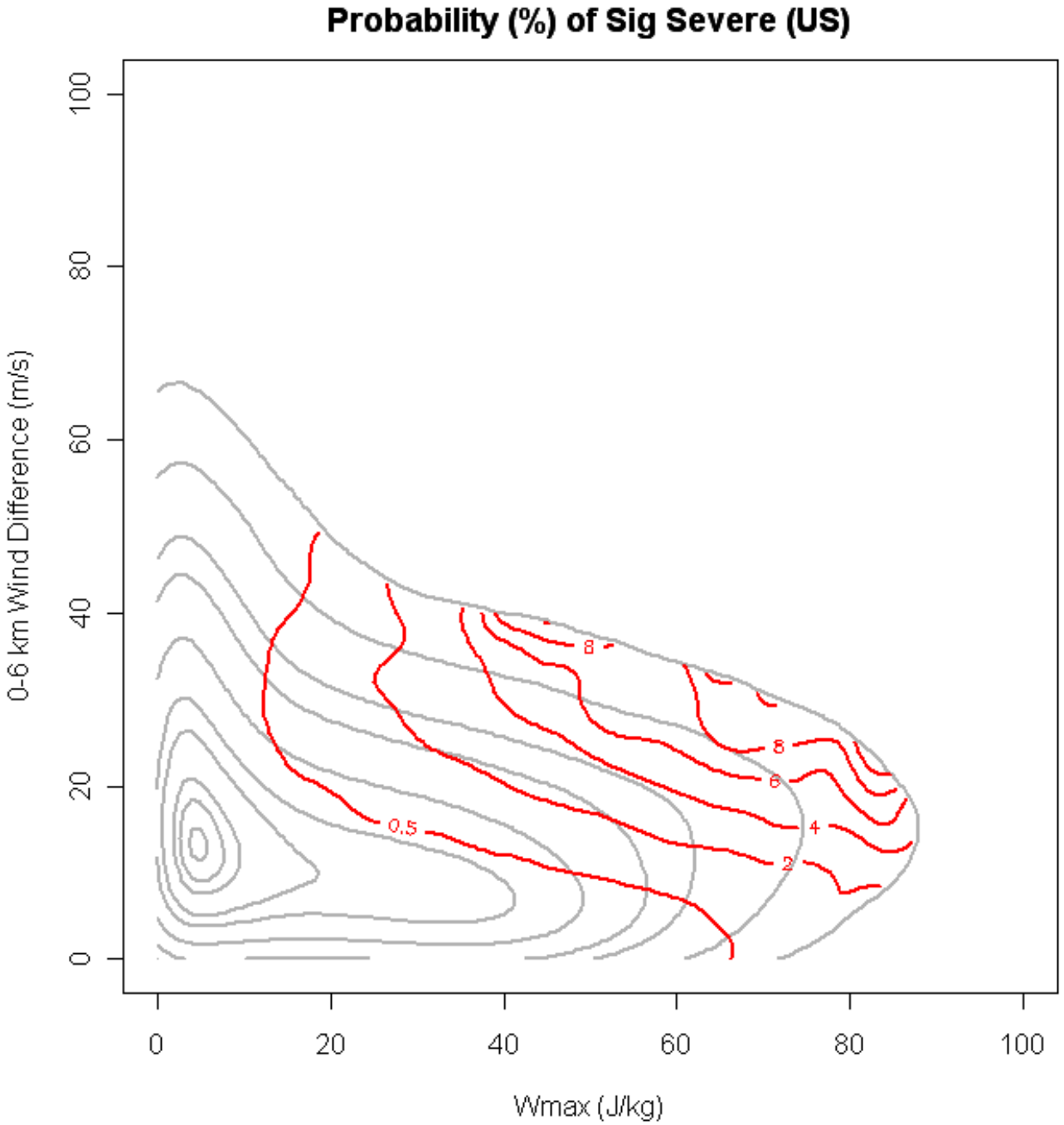


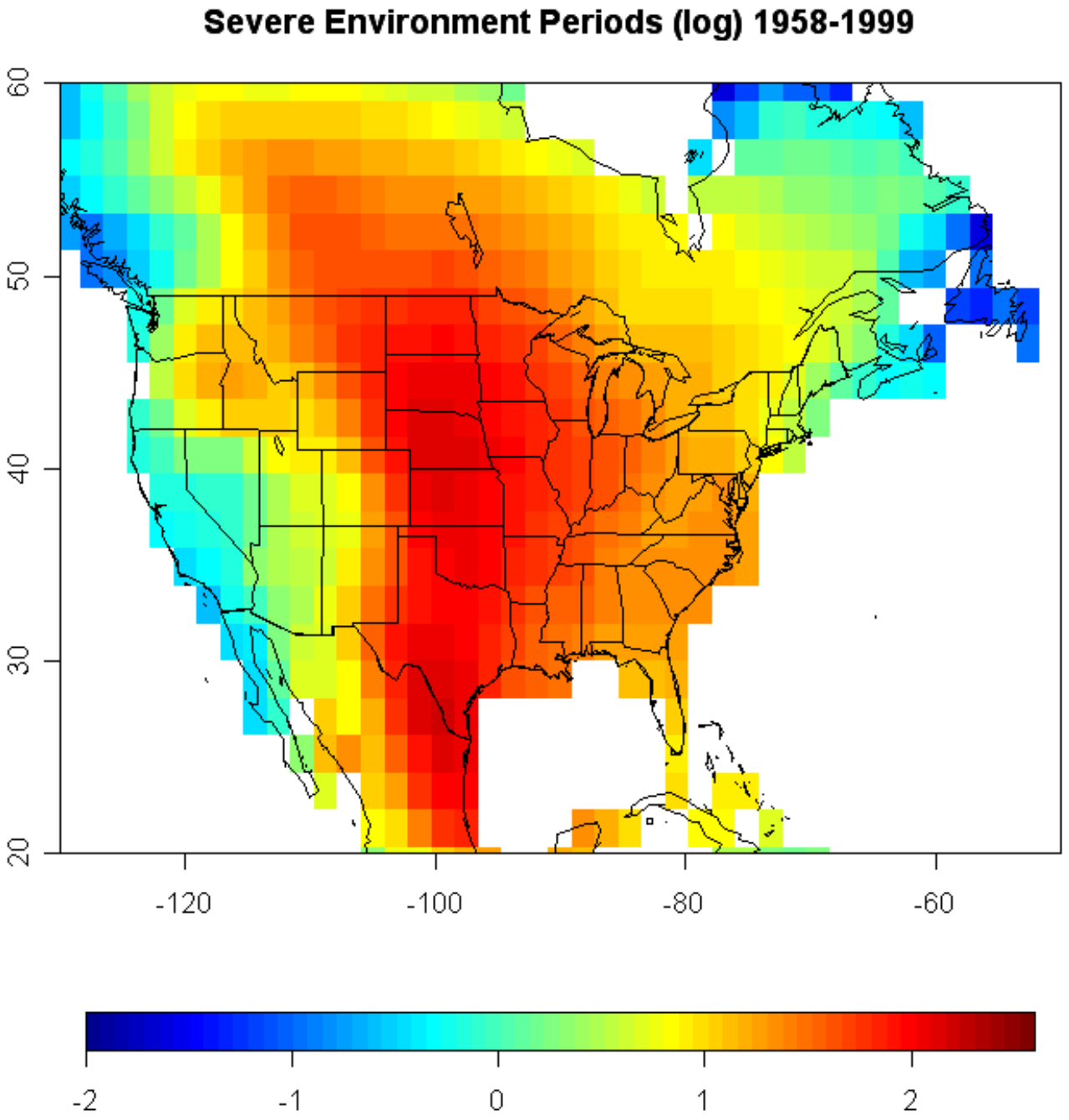
Line~k*CAPE*S06^1.6
(Allen et al.-10:45)

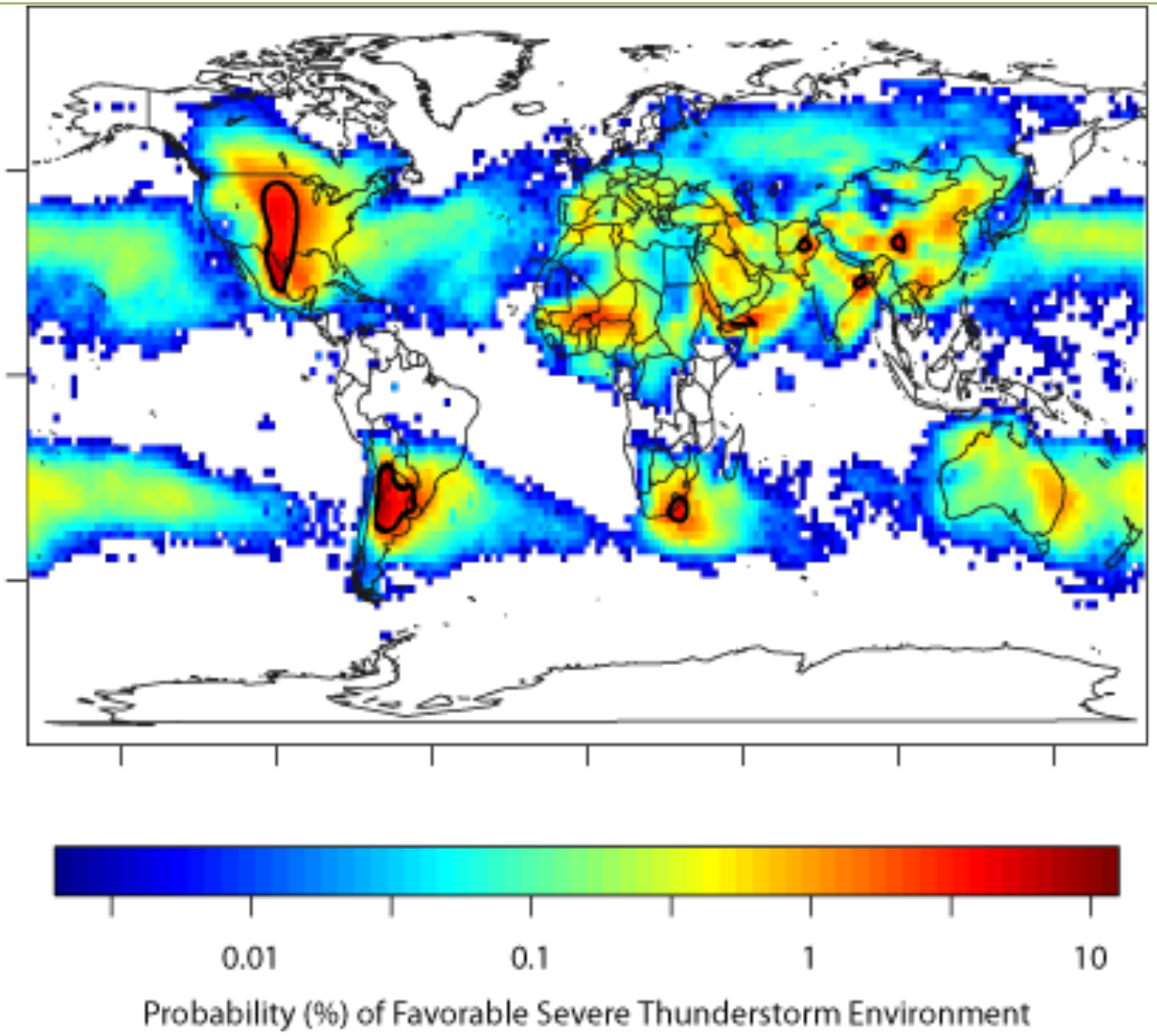
From Brooks et al (ECSS 2007)


US Sounding Distribution
0-6 km Wind Difference (m/s)
Vmax (m/s)
0
20
40
60
80
100
0.9999
0.999
0.99
0.95
0.9
0.75
0.5
0.25
0.1
0.05


Significant Severe Soundings (US-1991-1999)
0-6 km Wind Difference (m/s)
0
20
40
60
80
100
Wmax (m/s)
Hail
Wind
Tornado

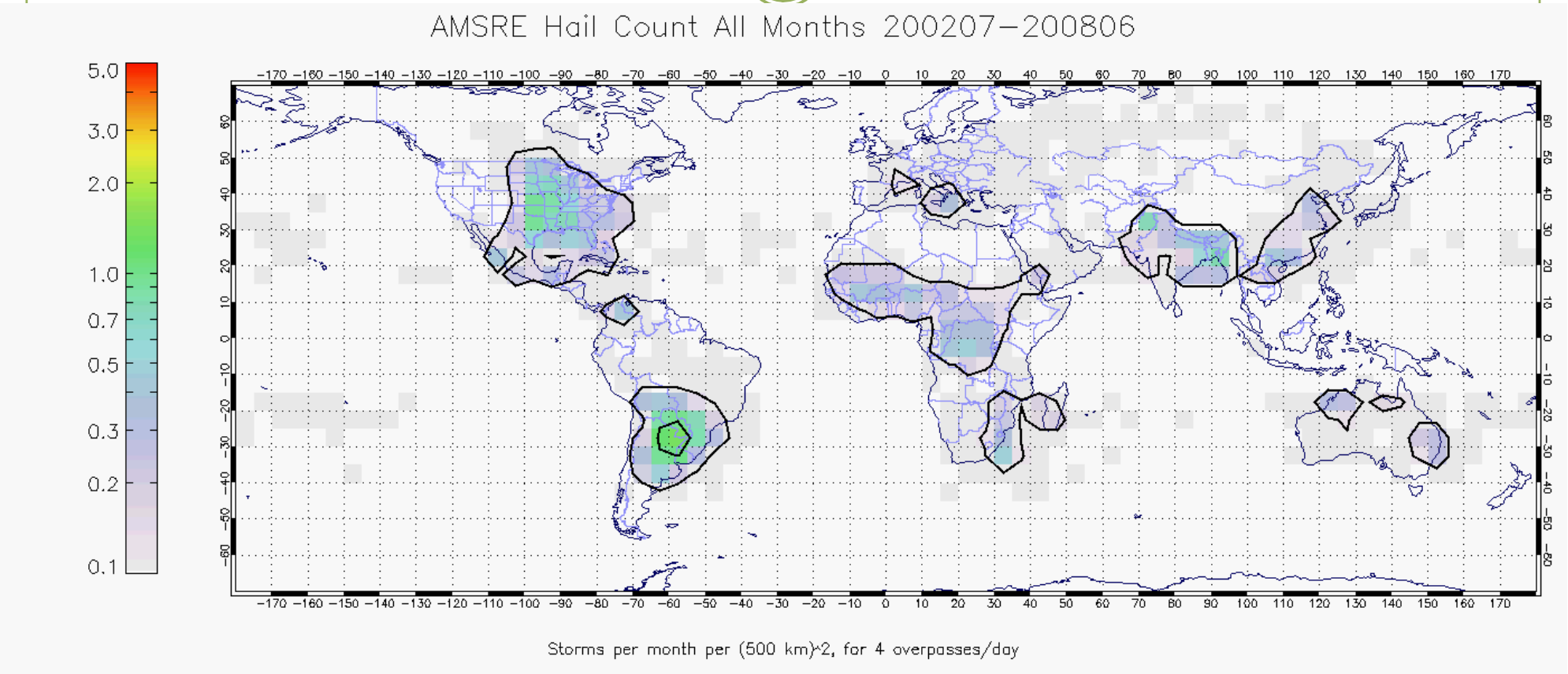

Probability (%) of Sig Severe (US)
0-6 km Wind Difference (m/s)
0
20
40
60
80
100
Wmax (J/kg)
0
20
40
60
80
100
0.5
2
4
6
8
8


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



Updated from Brooks et al (ECSS 2002)

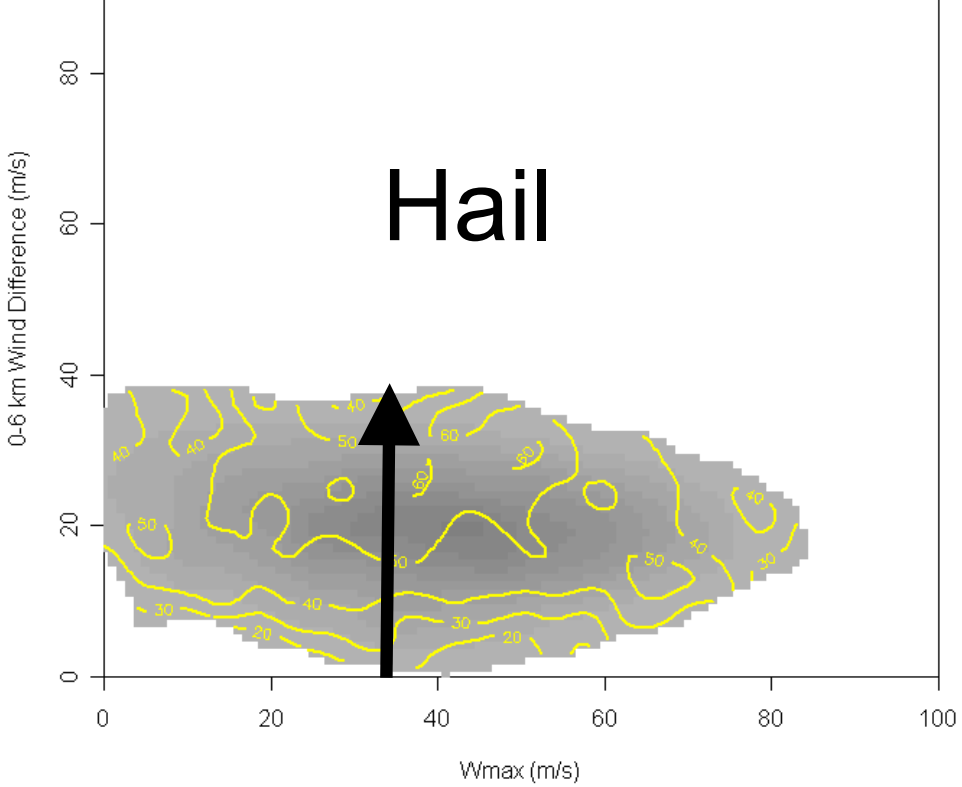
Satellite Estimate of Hail

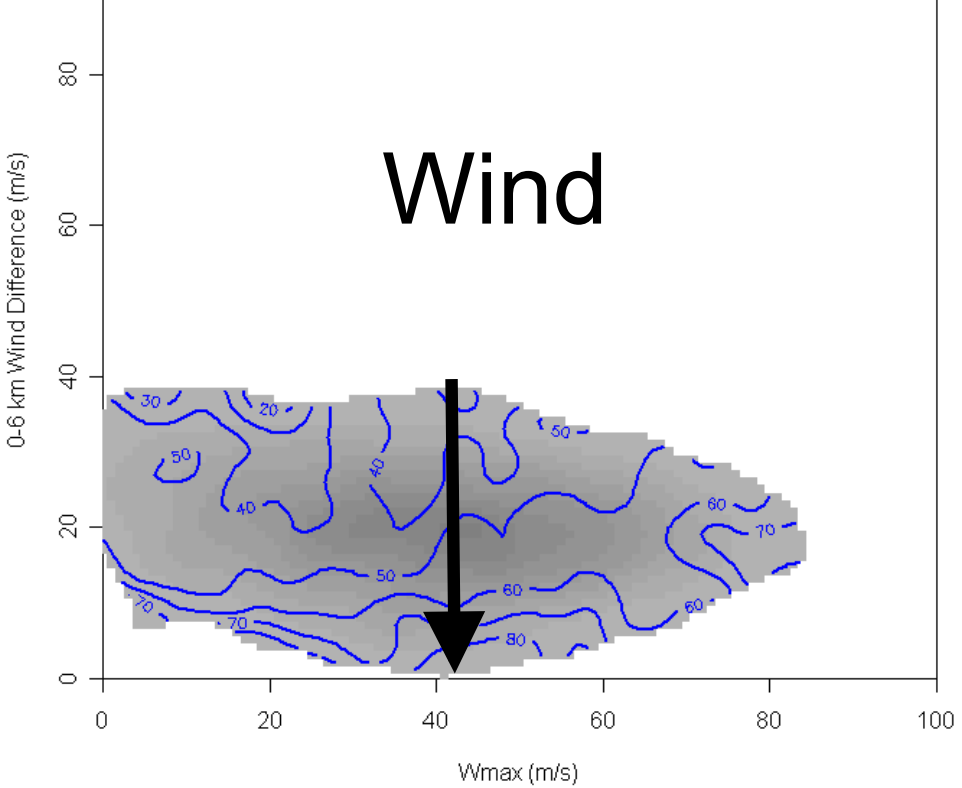


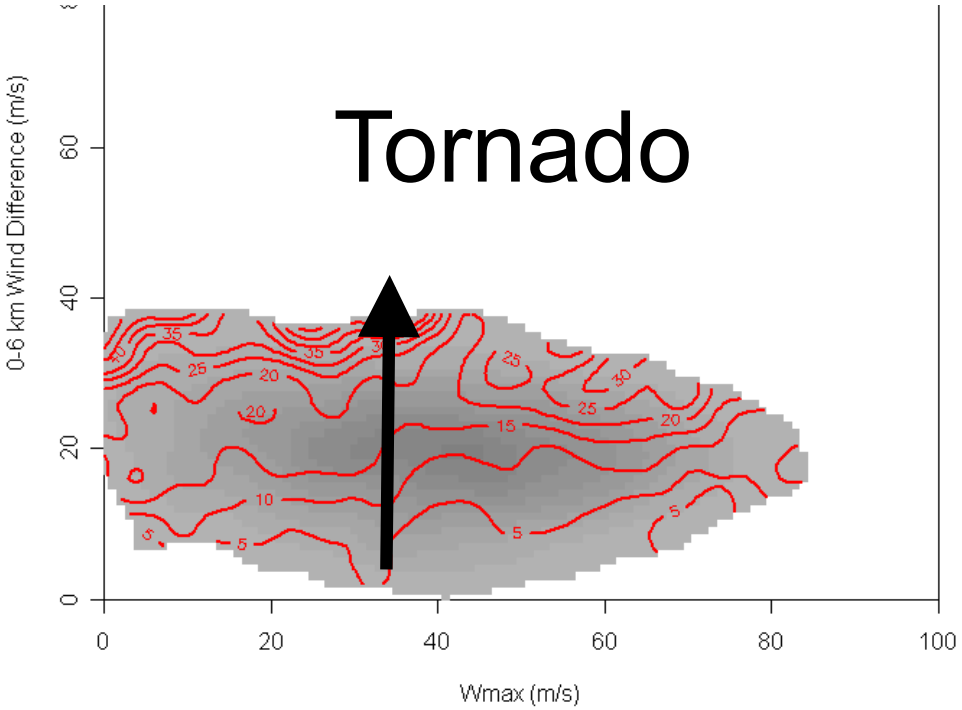
(Cecil et al., in press)

Individual threats

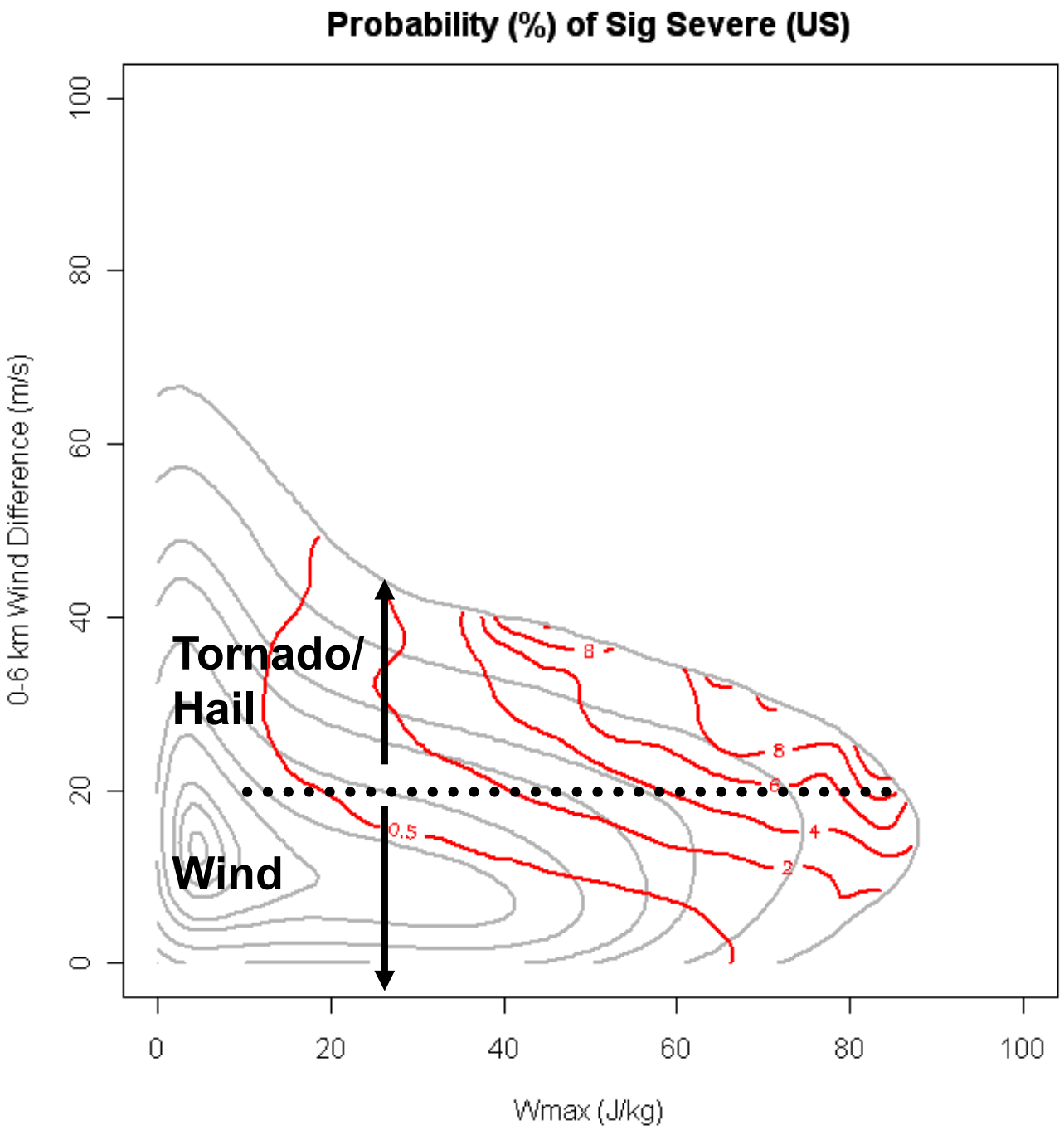
- Consider probability of different threats, given significant severe
- Probability of big event given any event
- Focus on patterns

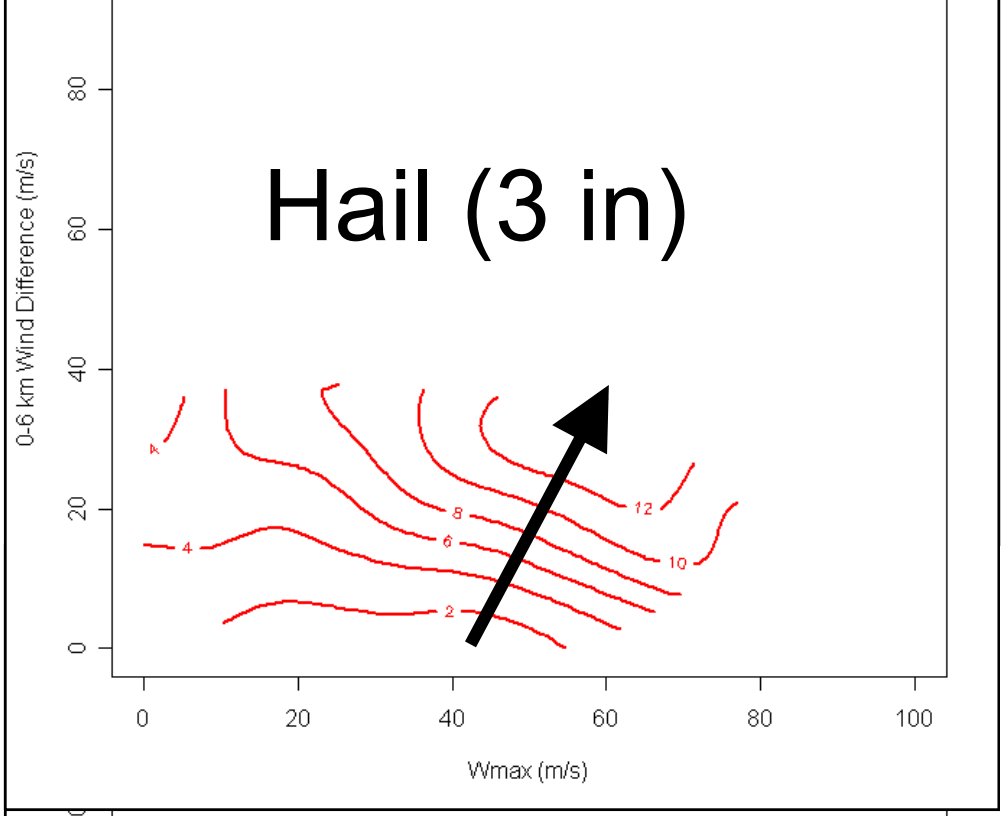


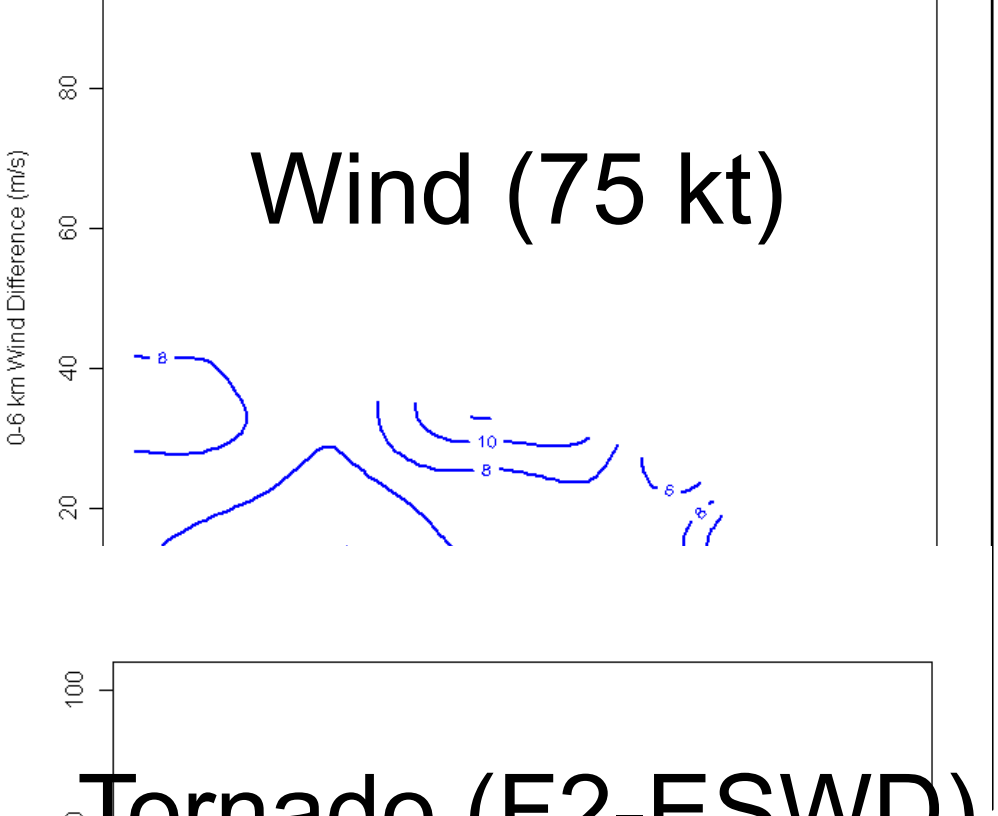


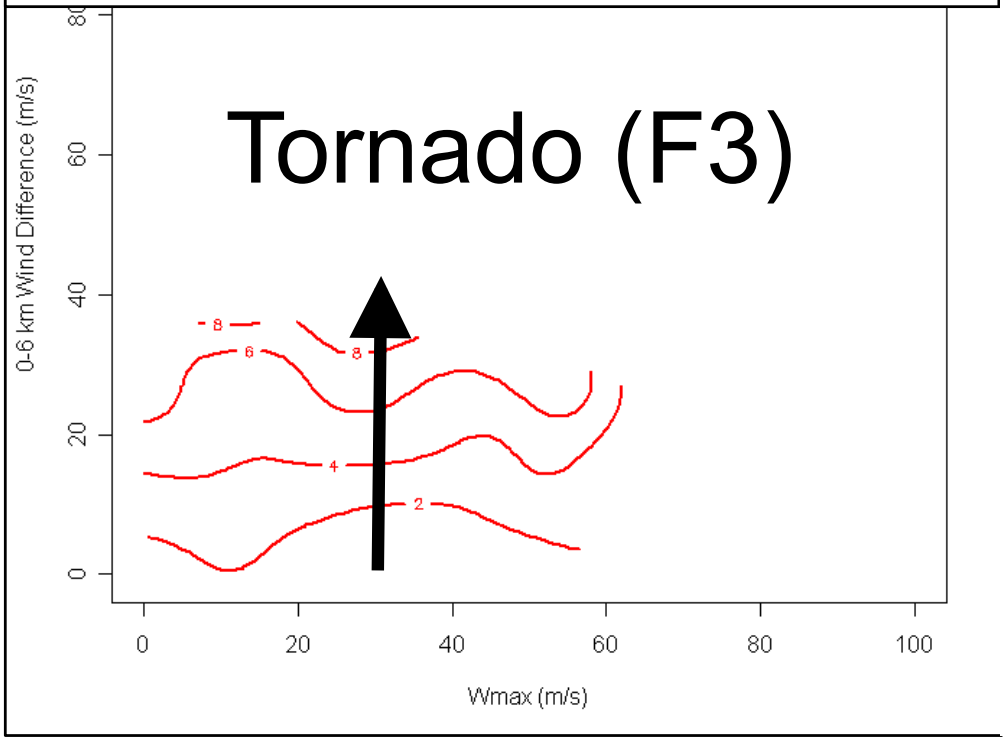


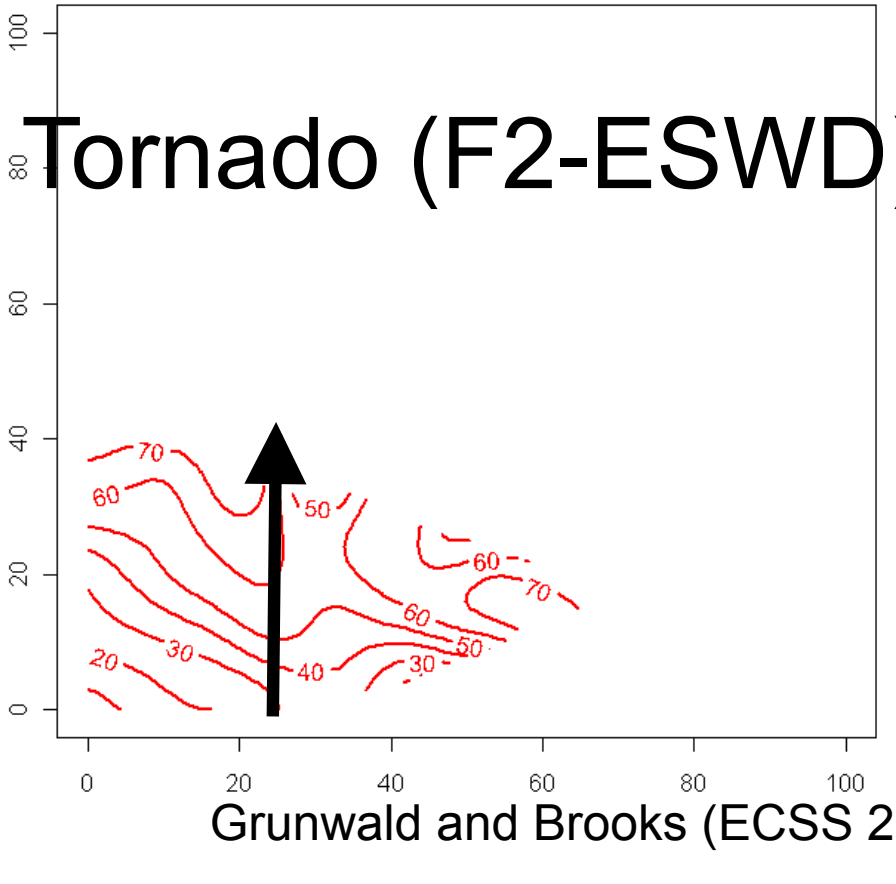
Conditional Probability of Events Given Any Significant Event


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









Grunwald and Brooks (ECSS 2009)

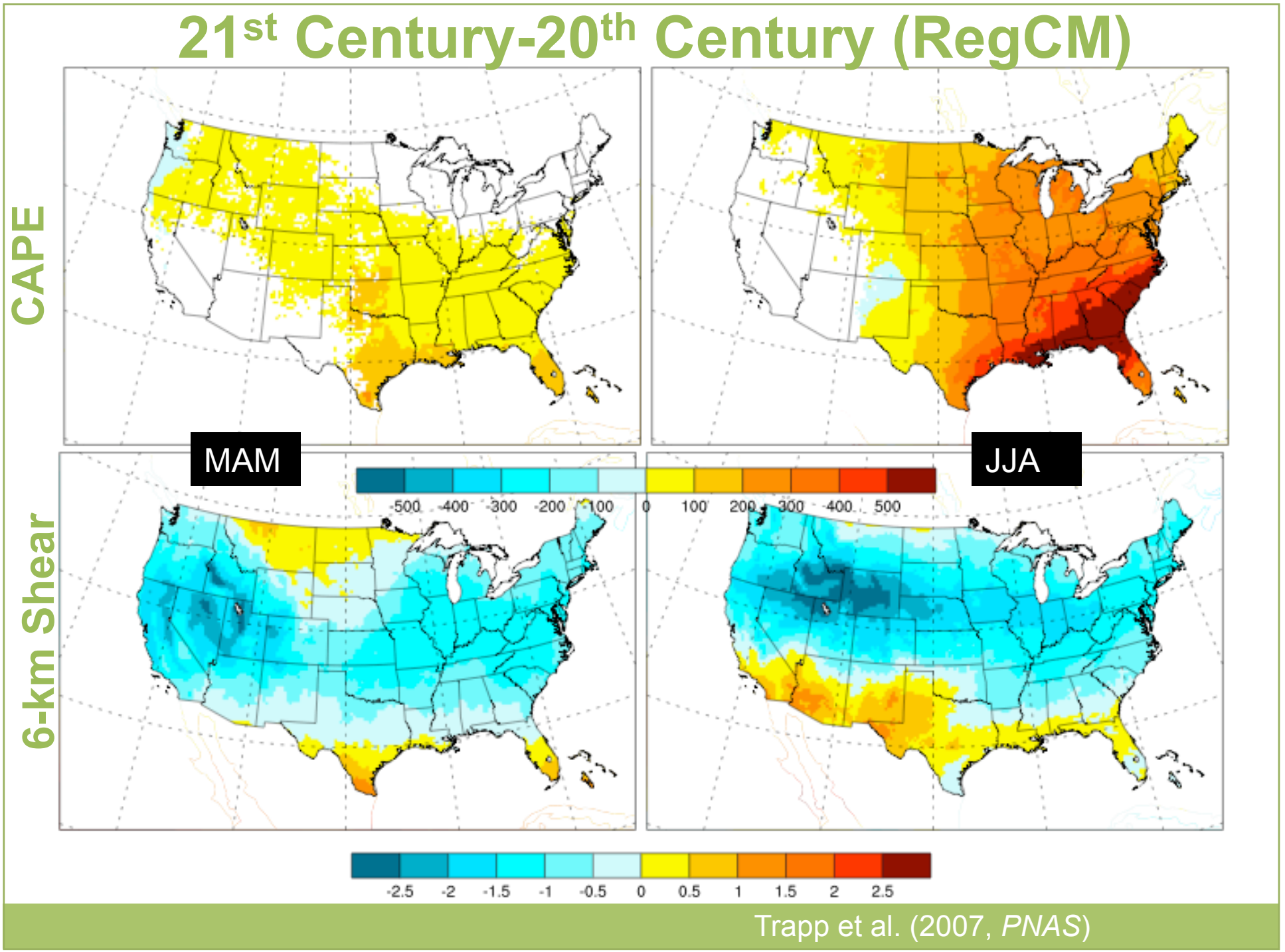
Importance of shear

- Big tornado years typically have hail as dominant non-tornadic event
  - Predominantly shear
- Intensity of tornado/hail increases with increasing shear

What will happen in the future

- Mean expected changes
  - CAPE goes up (related to moisture increase)
  - Shear goes down (decrease in equator-to-pole gradient)
- Climate model simulations
  - Three main groups (so far)
    - GISS (parameterized updraft)
    - Oklahoma/Melbourne
    - Purdue
  - Look at favorable conditions (statistical modelling)
    - Concentrate on changes in model world

21st Century-20th Century (RegCM)



Trapp et al. (2007, *PNAS*)

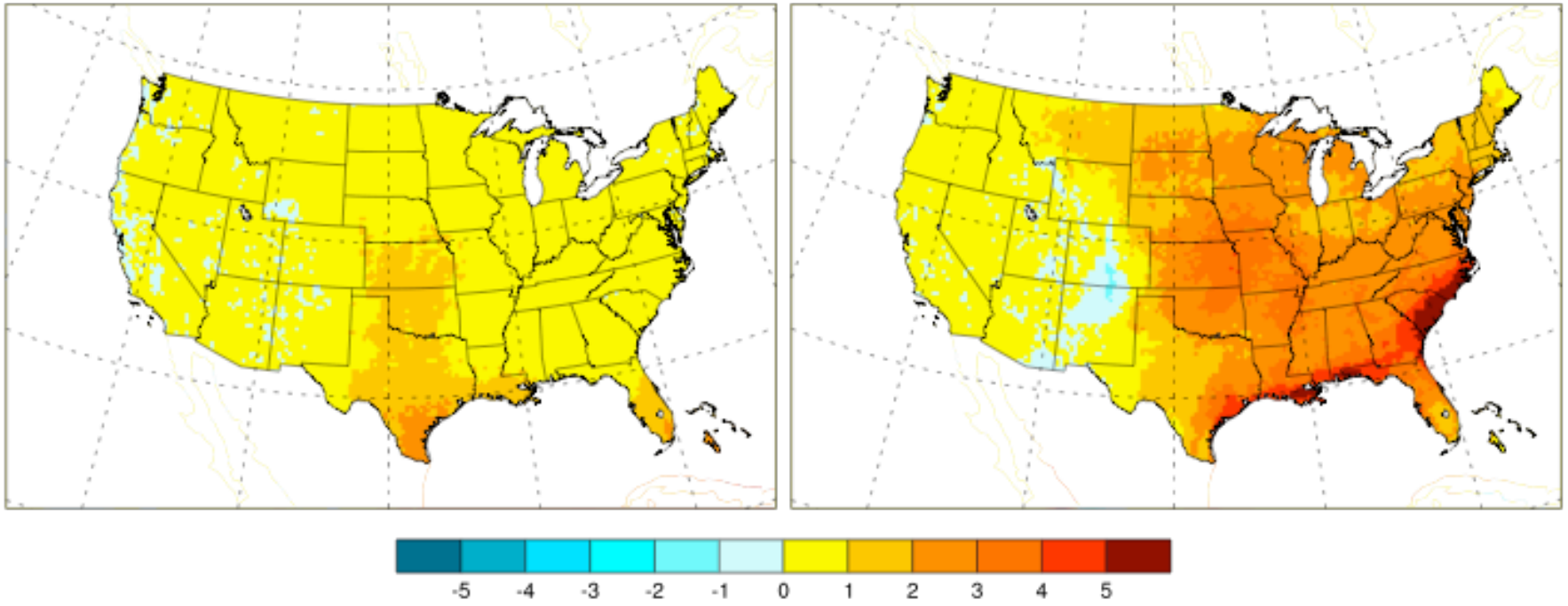
Regional Climate Model simulations (RegCM)

Mean # days when CAPE x 6 km shear > 10,000

MAM

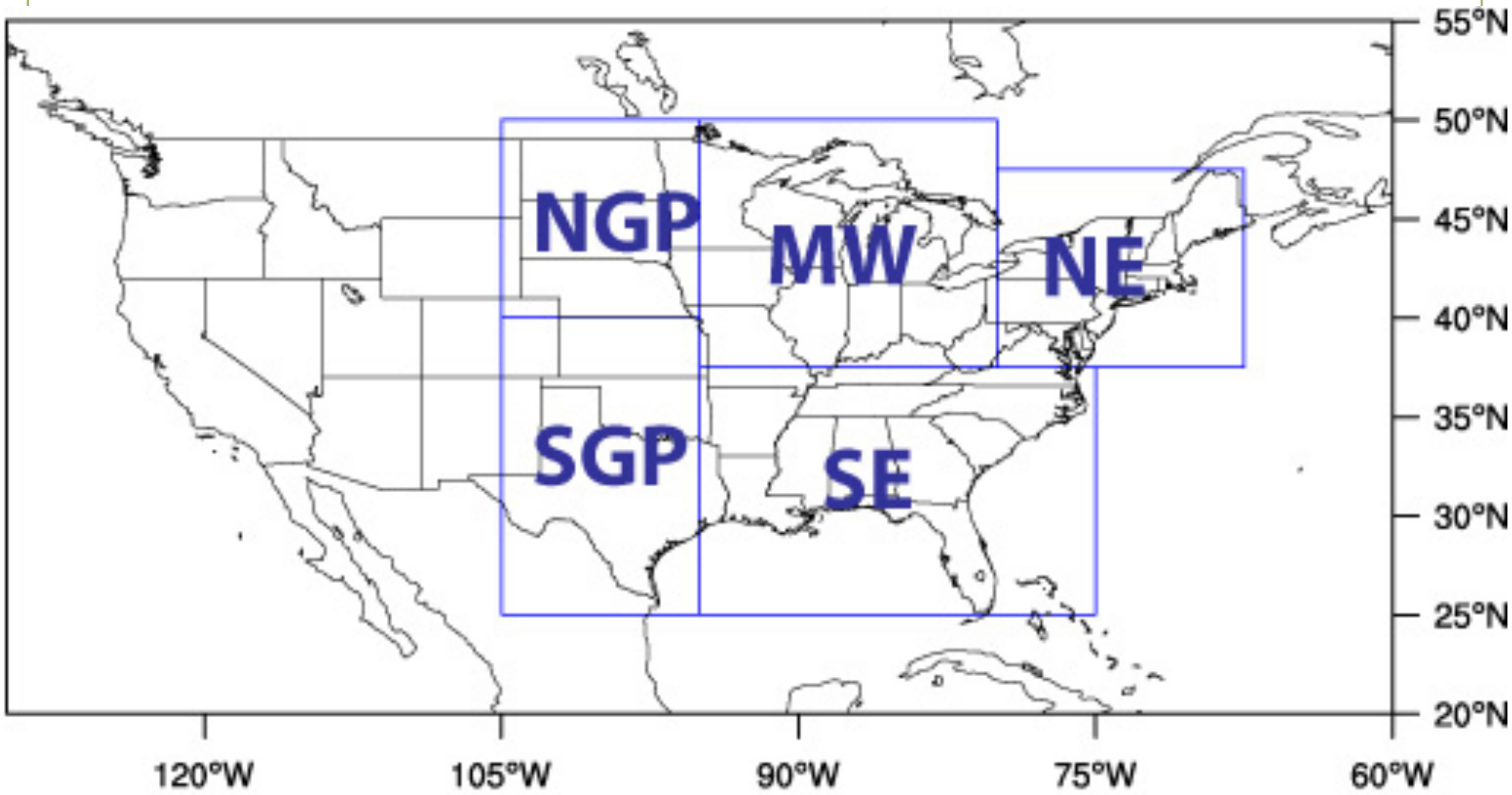
JJA

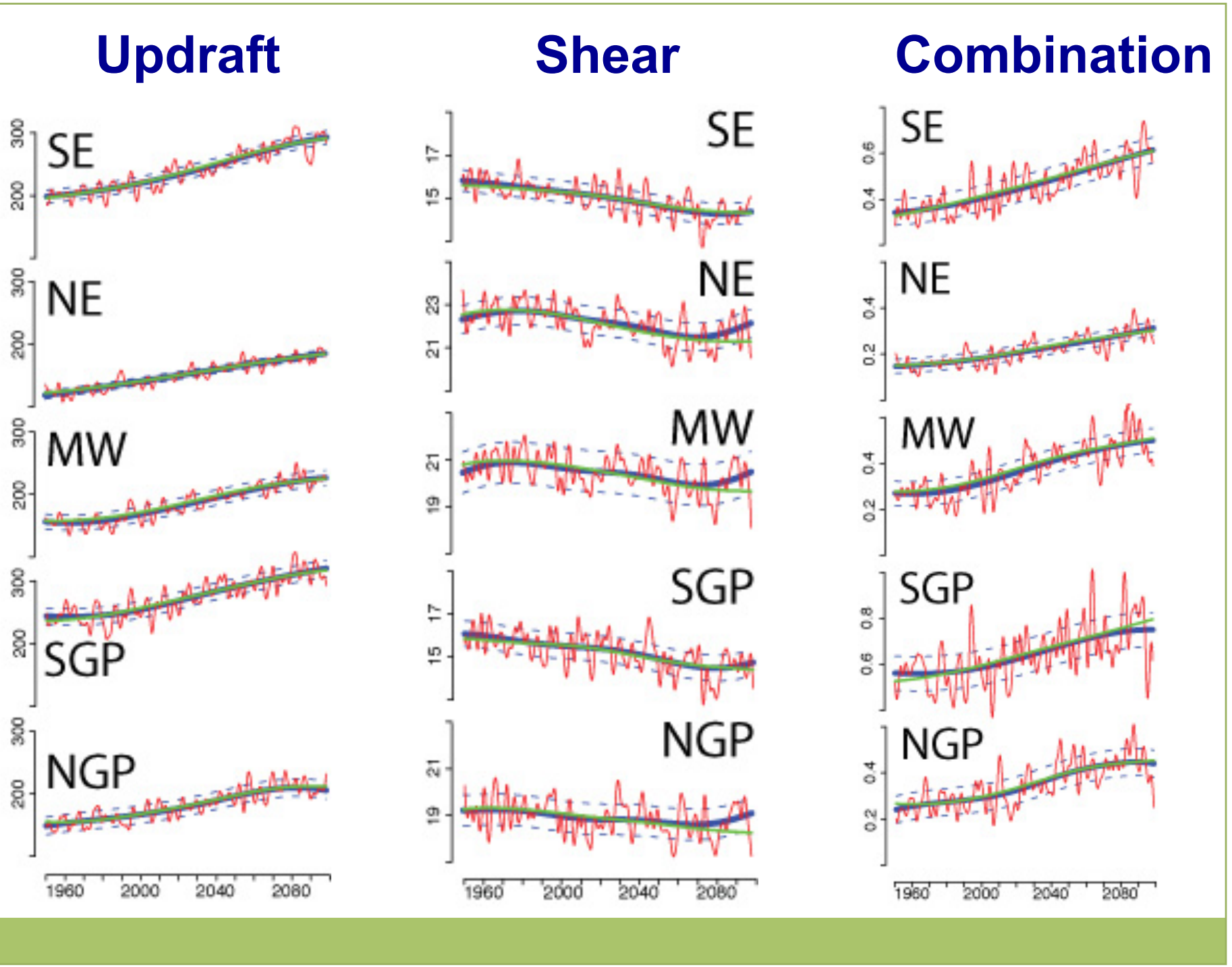
Difference (future-past)

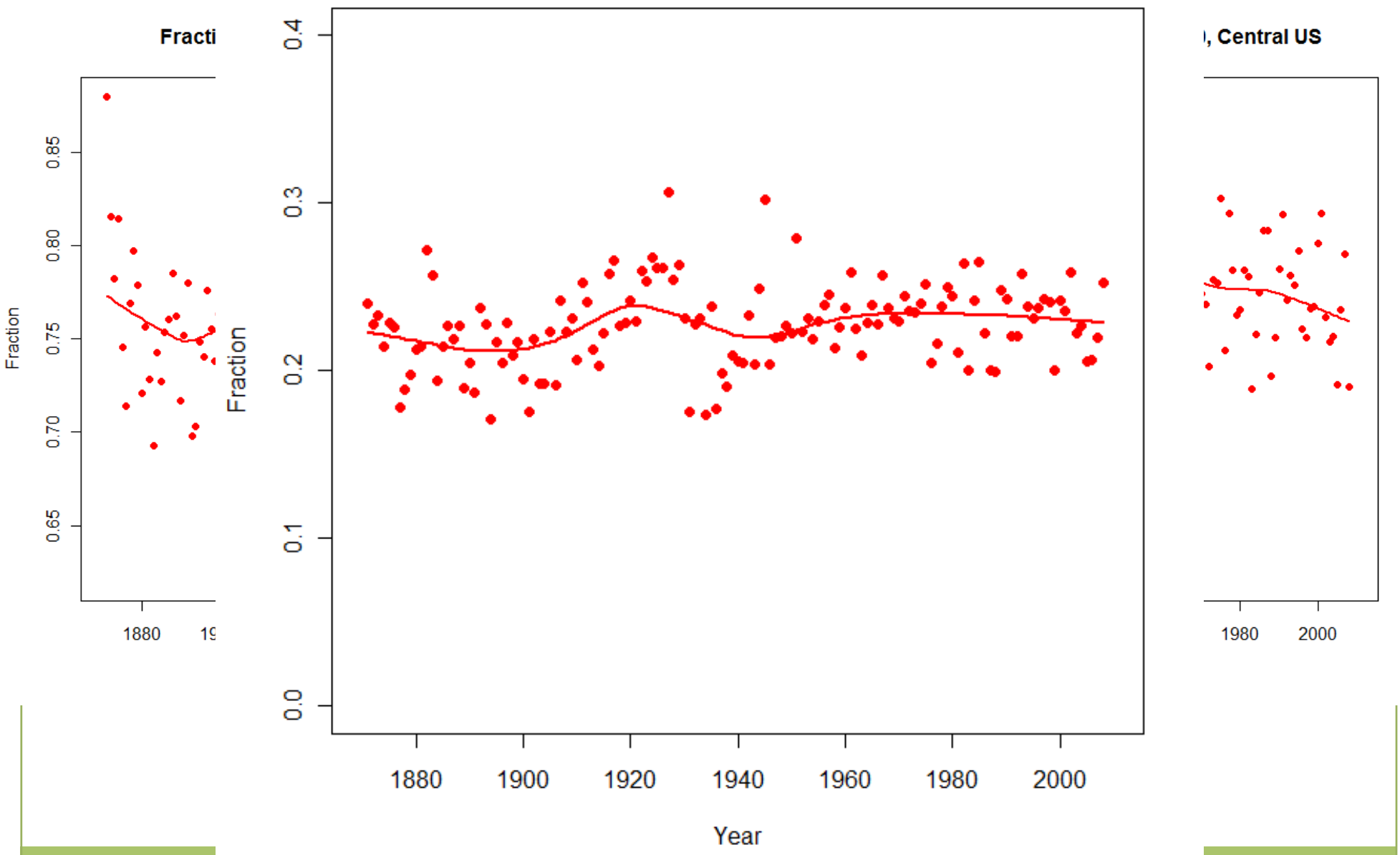


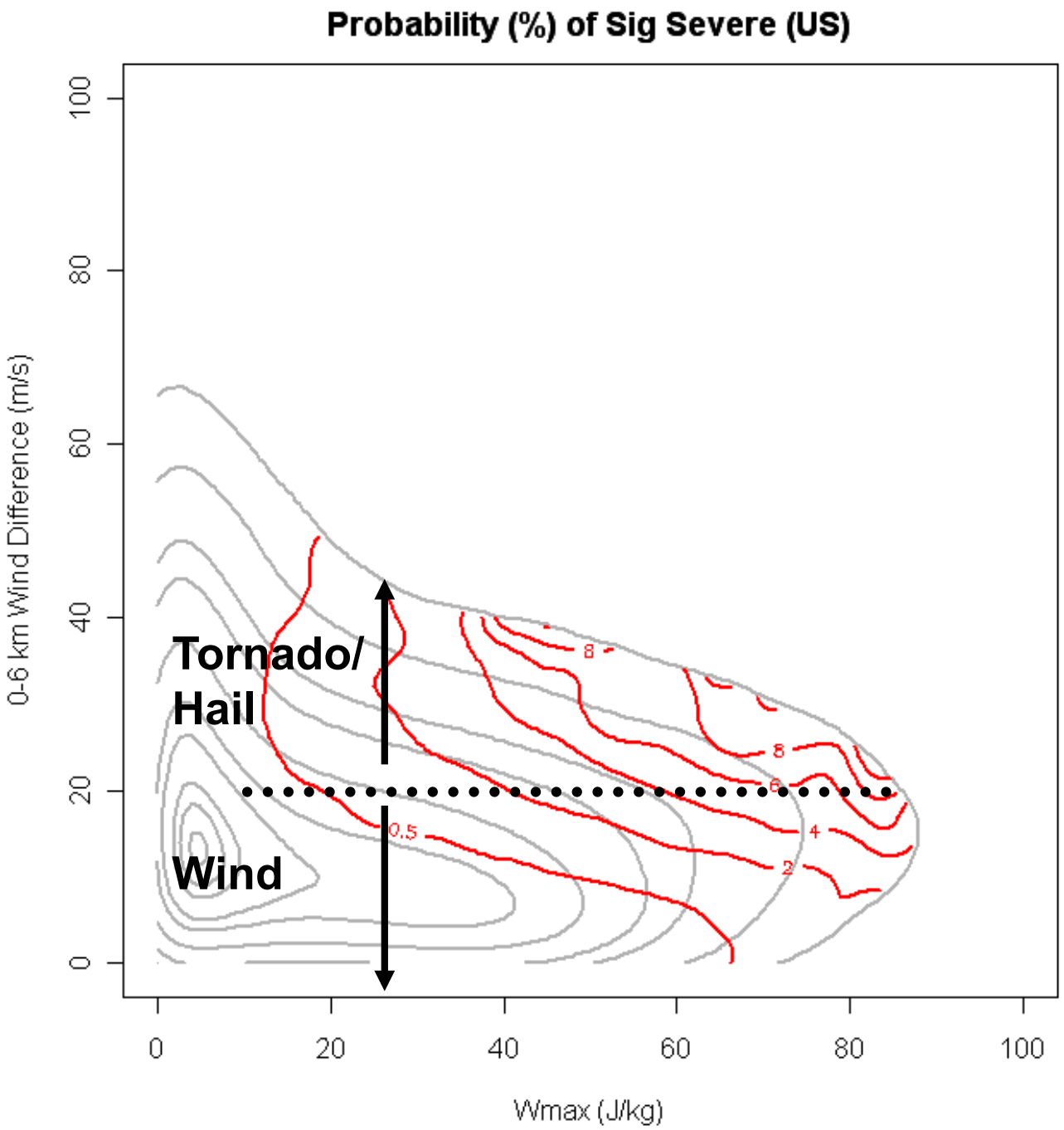
Trapp et al. (2007, *PNAS*)

Trapp et al. (2008) Regional Analyses




Updraft
Shear
Combination
SE
NE
MW
SGP
NGP
1960
2000
2040
2080


Fractional Coverage of Shr6>=20 (CAPE>0), Central US
Fracti
, Central US
Fraction
0.65
0.70
0.75
0.80
0.85
1880
19
1980
2000
Fraction
0.0
0.1
0.2
0.3
0.4
1880
1900
1920
1940
1960
1980
2000
Year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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

Closing thoughts

- Applicability of US to rest of world?
  - Thermodynamics dominated by boundary-layer moisture
  - China may follow, but other locations may not show same
- Need to improve environment-event relationships
- Higher resolution, better reanalyses
- Increased use of high-res models