

*What environments do
severe thunderstorms form in?*



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Currently, ~\$10B damage in US annually

Severe thunderstorms (US)

- Definition
 - Hail at least $\frac{3}{4}$ in. diameter, 50 kt (25.5 m/s) winds, or tornado
- Significant severe
 - 2 inch diameter hail, 65 kt winds, F2 tornado
 - 10% of US severe weather

Four foci

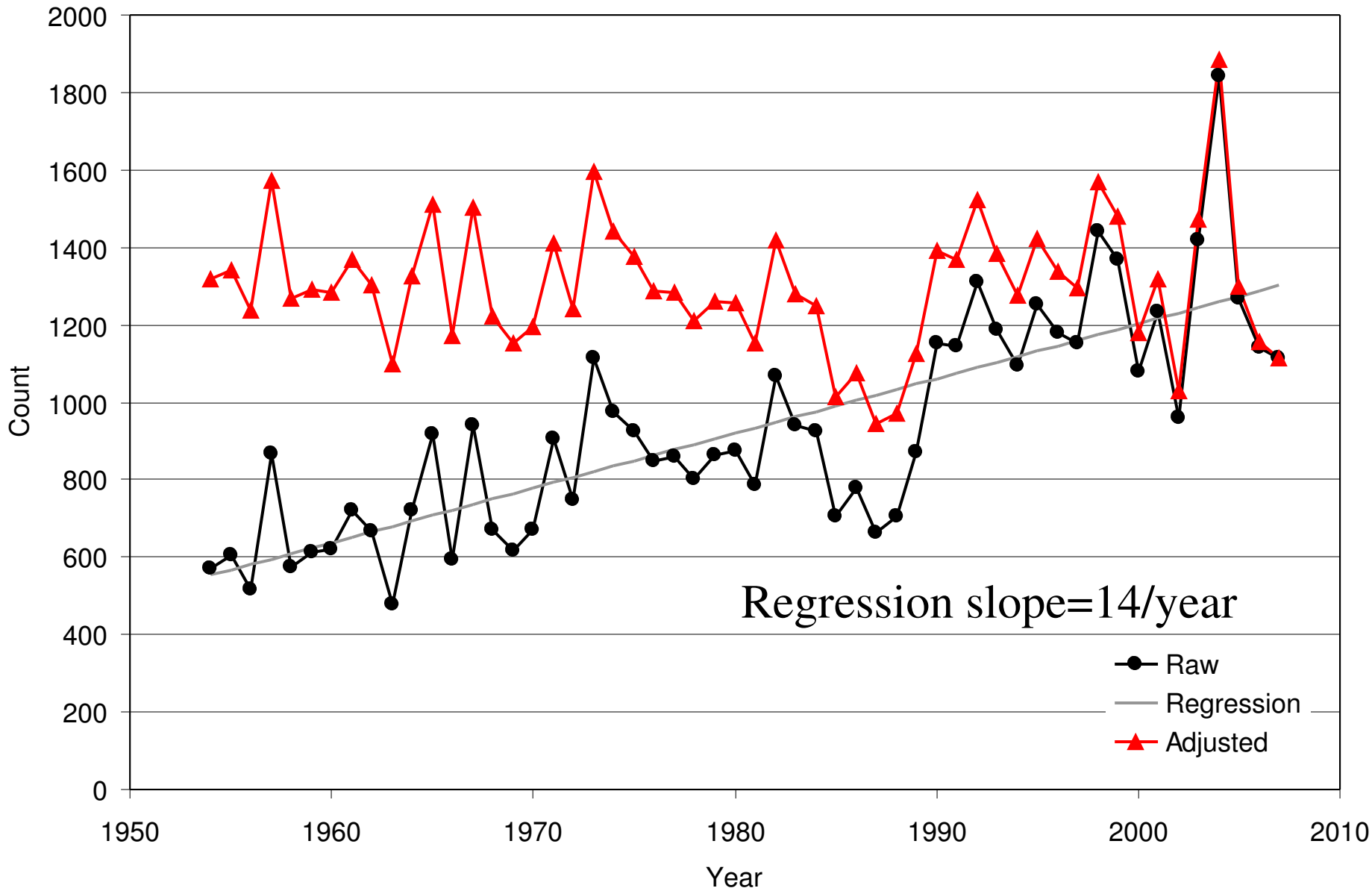
1. Reported severe weather in US
2. How do storms form?
3. Storms as a function of environment
4. How will environments change?

Two hats-forecasting, climate change

Reports

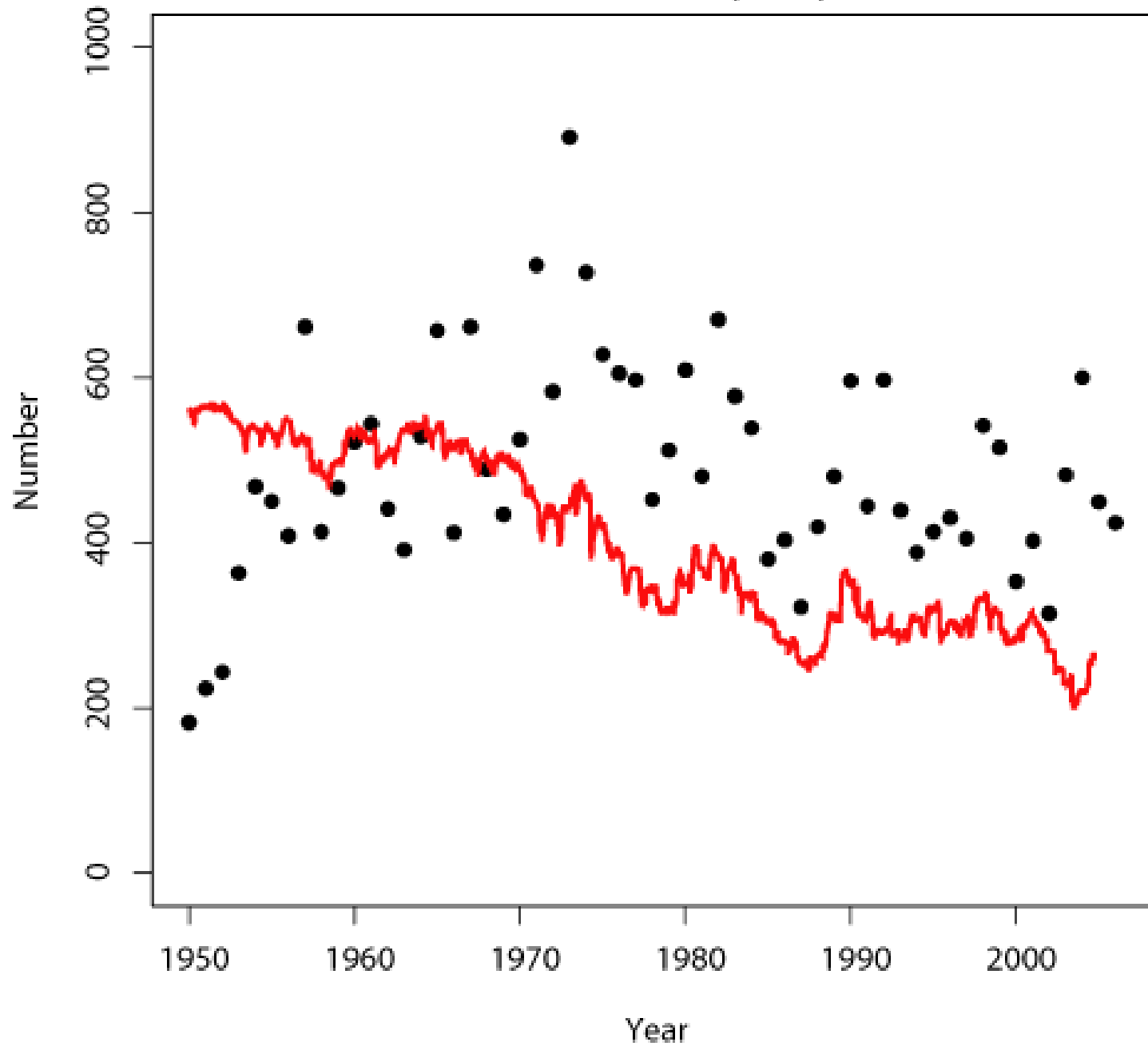
- Targets of opportunity
- US
 - Tornadoes on F-scale (0-5), largest hail diameter, wind speed/damage

US Annual Tornadoes



F1+ Tornadoes Per Year (Dots)

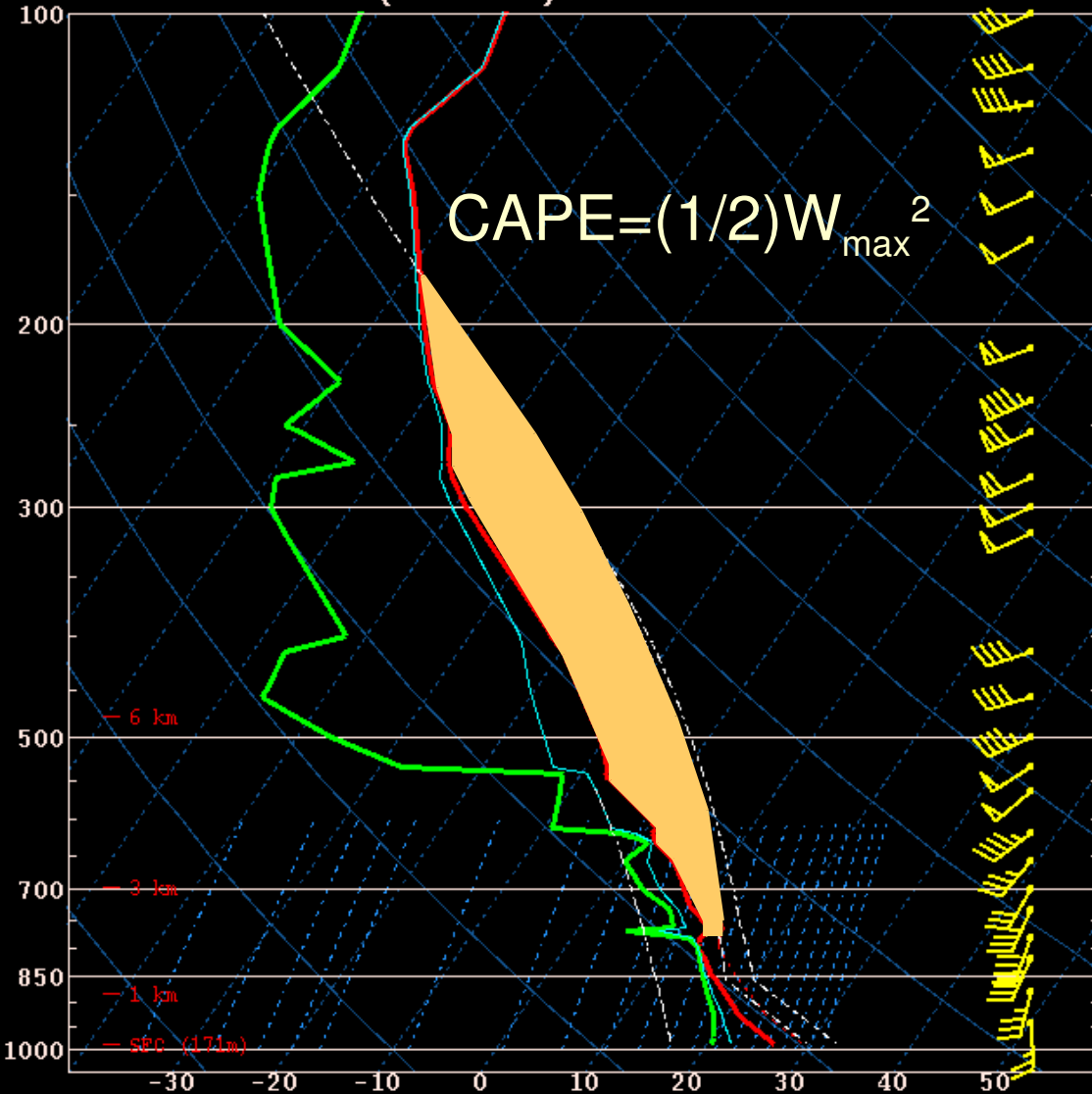
F2+ Per 1000 F1+ (Line)



Environmental “ingredients” for severe thunderstorms

- Strong updraft (theoretical estimate)
 - Moist air at low levels
 - Cold, dry air aloft
- Organization (change of winds with height)
 - Winds that increase with height
 - From equator at surface, west aloft
- Storm initiation (not seen in environment)

FWD 011010/0000 (Observed)



CURSOR

798mb 2052m θ=322.1K
 28.8C 6730ft θw=309.0K
 83.9F 32.7g/kg θe=429.4K

SOUNDING

798mb 2051m
 12.8C
 12.8C 201/42 kt kt

PARCEL DATA

*** FCST SFC PARCEL ***

LPL: 989mb 29C / 20C 85F / 68F
 CAPE = 3010 J/Kg LI (500mb) = -9 C
 Cape3km = 141 J/Kg LImin = -11C / 300mb
 CINH = -26 J/Kg Cap = 0C / 850mb

LEVEL	PRES	HGT (AGL)	TEMP
LCL	856mb	4208ft	
LFC	856mb	4208ft	17C
EL	166mb	43424ft	-61C
MPL	85mb	56727ft	

THERMODYNAMIC DATA

----- AVAILABLE MOISTURE -----

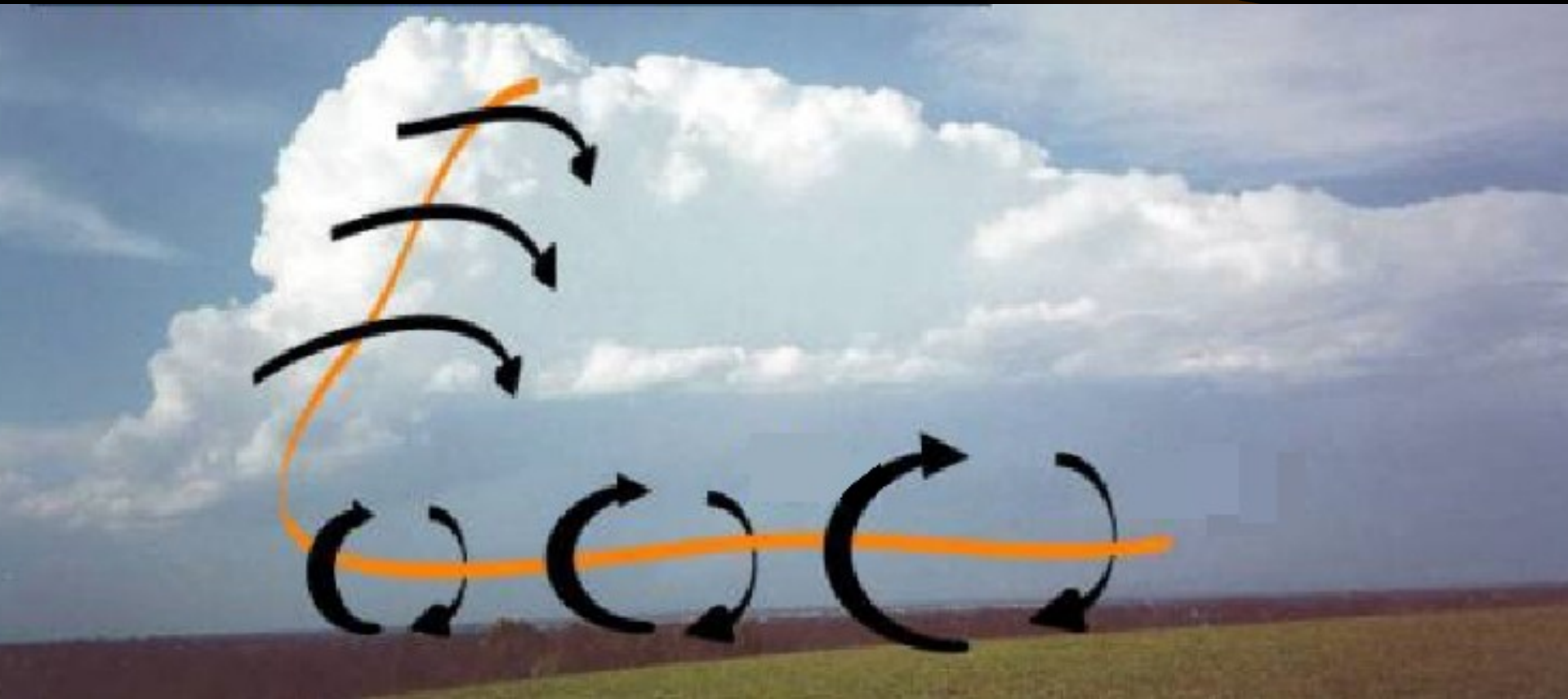
P. Water = 1.76 in Mean RH = 24 %
 Mean W = 15.0 g/Kg Mean LRH = 85 %
 Top of Moist Lyr = 781 mb / 6760 ft

----- CONDITIONAL INSTABILITY -----

700-500mb Lapse Rate = 18 C / 7.2 C/km
 850-500mb Lapse Rate = 29 C / 6.7 C/km

----- MISC PARAMETERS -----

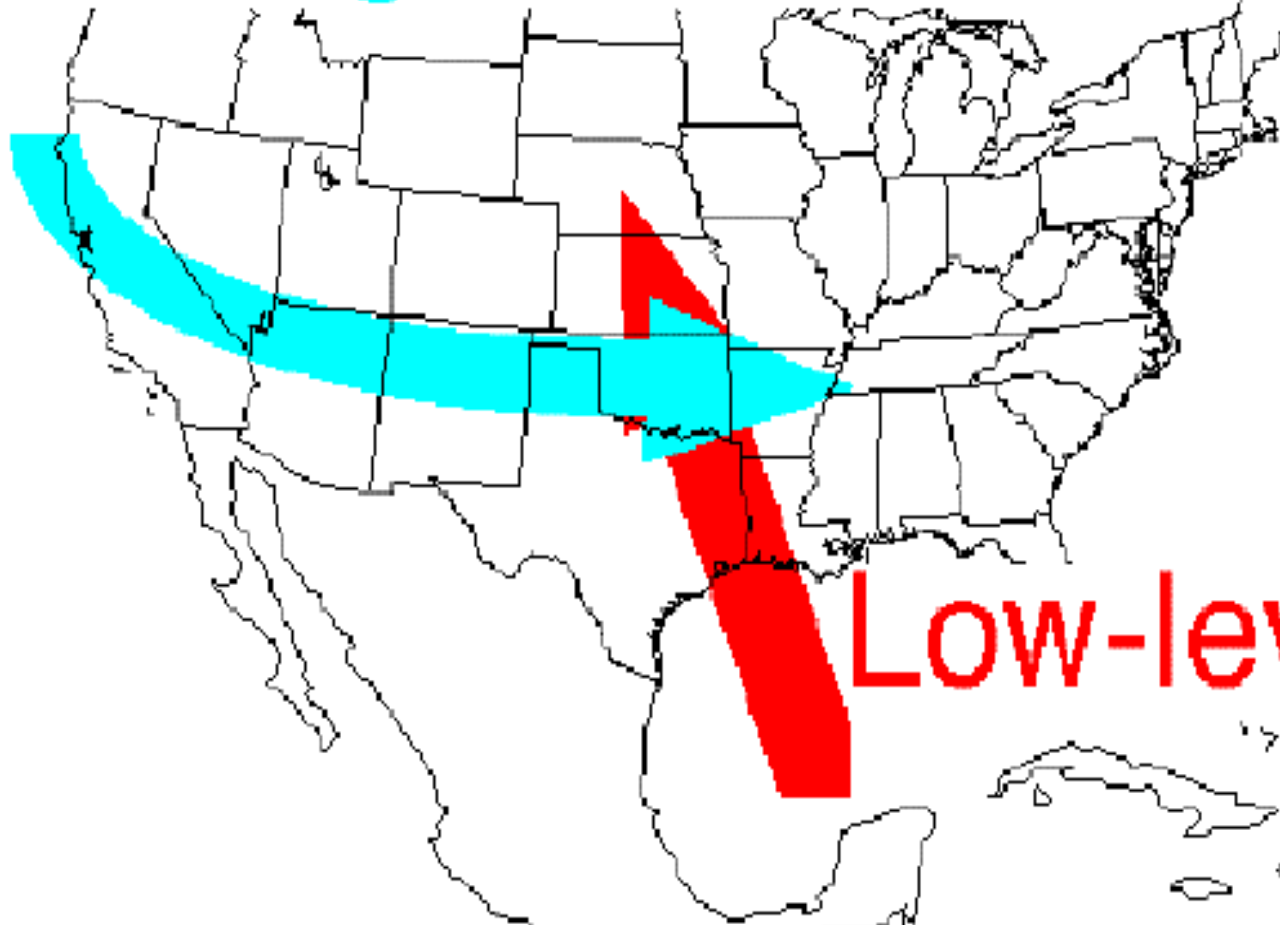
CB SigTor = 0.70 K-Index = 38
 SigTorn = 2.2 Max Temp = 86F
 Supercell = 3.8 Conv Temp = M
 WBZ level = 12844ft FGZ level = 13691ft



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Mid-to-high level flow



Low-level flow

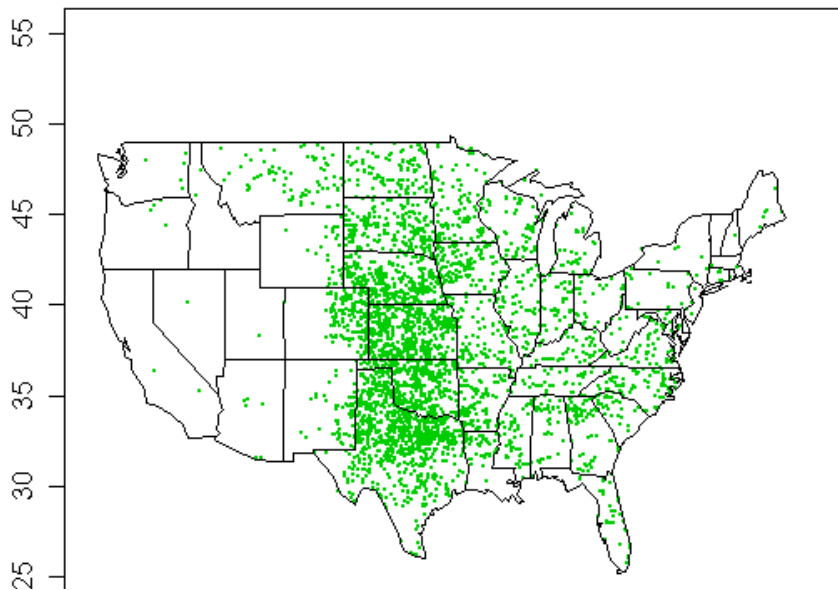
Environment-Event Relationships

- Ingredients based
 - Define events in terms of environmental conditions
 - Storm “strength”-CAPE or W_{max}
 - Organization-0-6 km wind shear
 - Initiation?

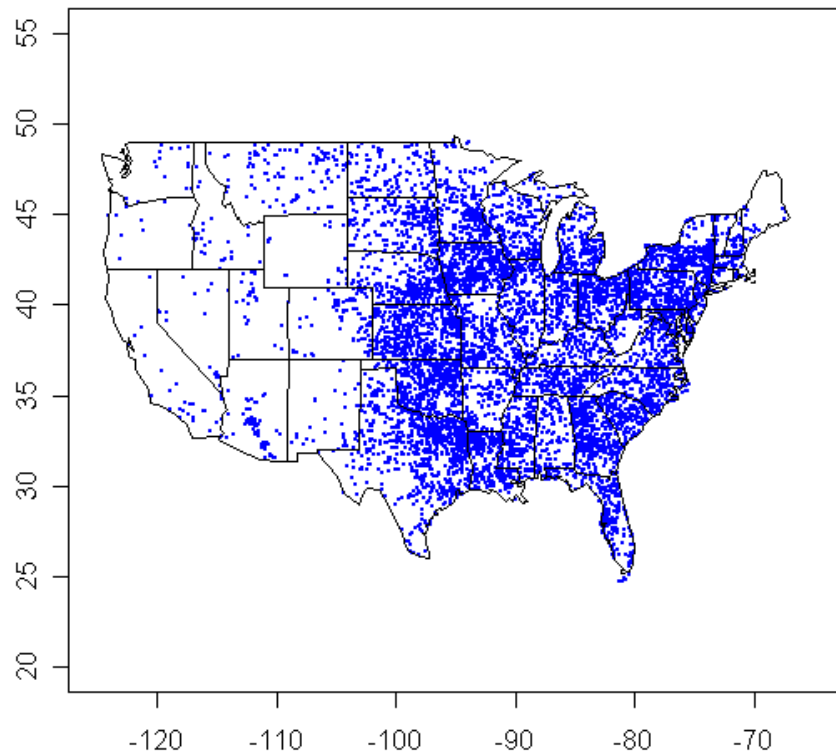
Datasets

- Storm Prediction Center severe weather reports (1991-9)
- Environmental conditions from “reanalysis”
 - 1.9x1.9 lat/lon spacing, every 6 hours
 - 3.75 million soundings
- Focus on significant severe thunderstorms

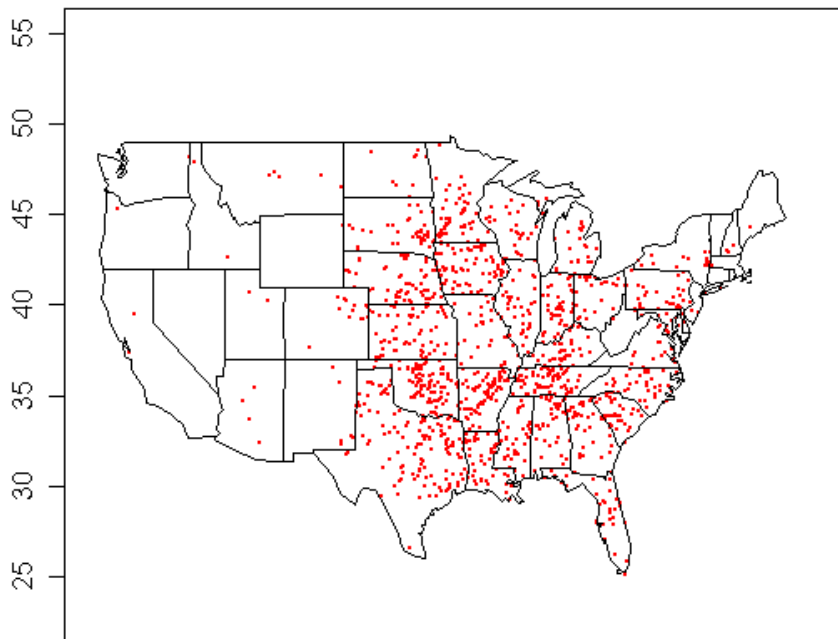
Sig Hail 1991-9



Sig Wind 1991-9

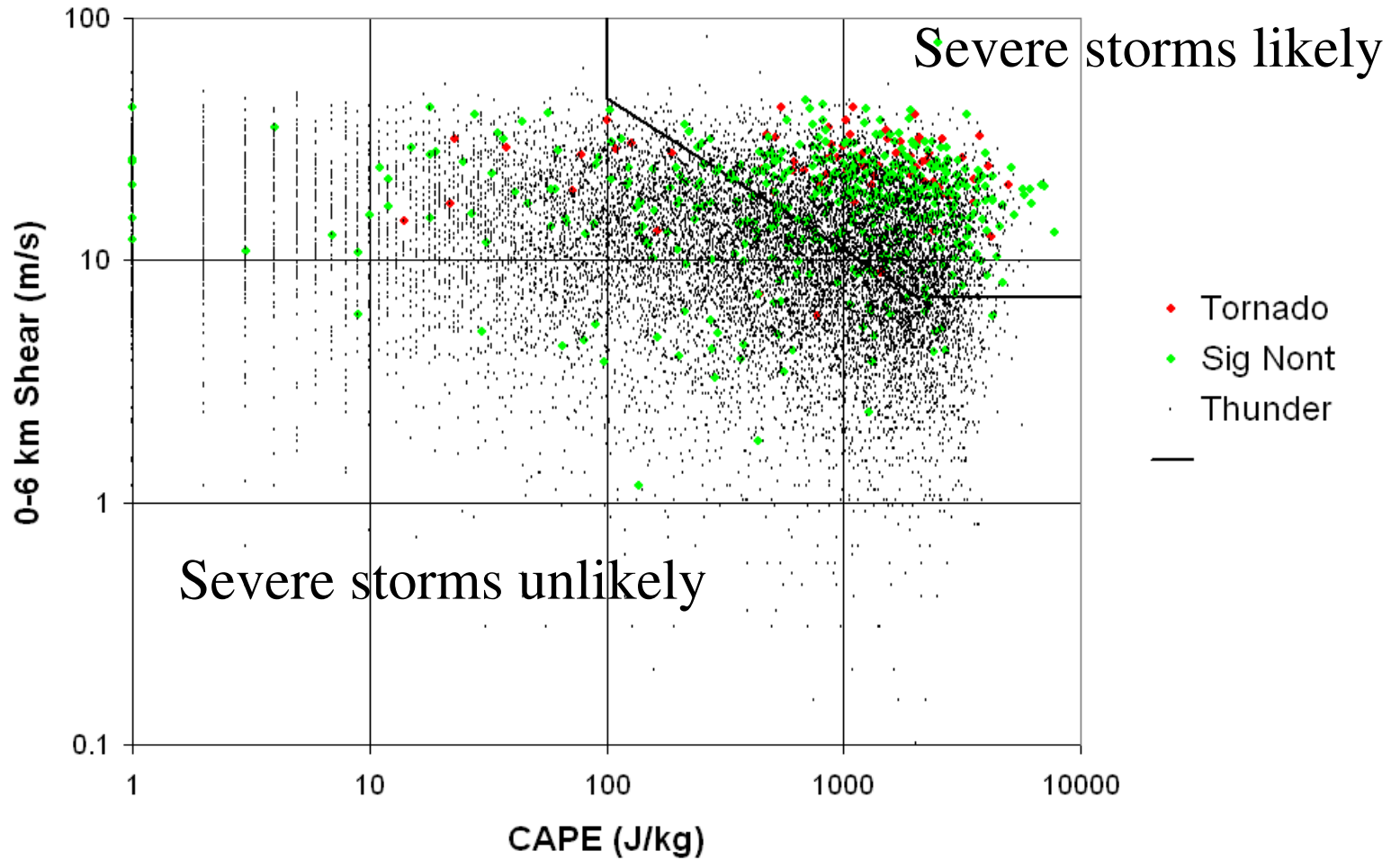


Sig Tornado 1991-9

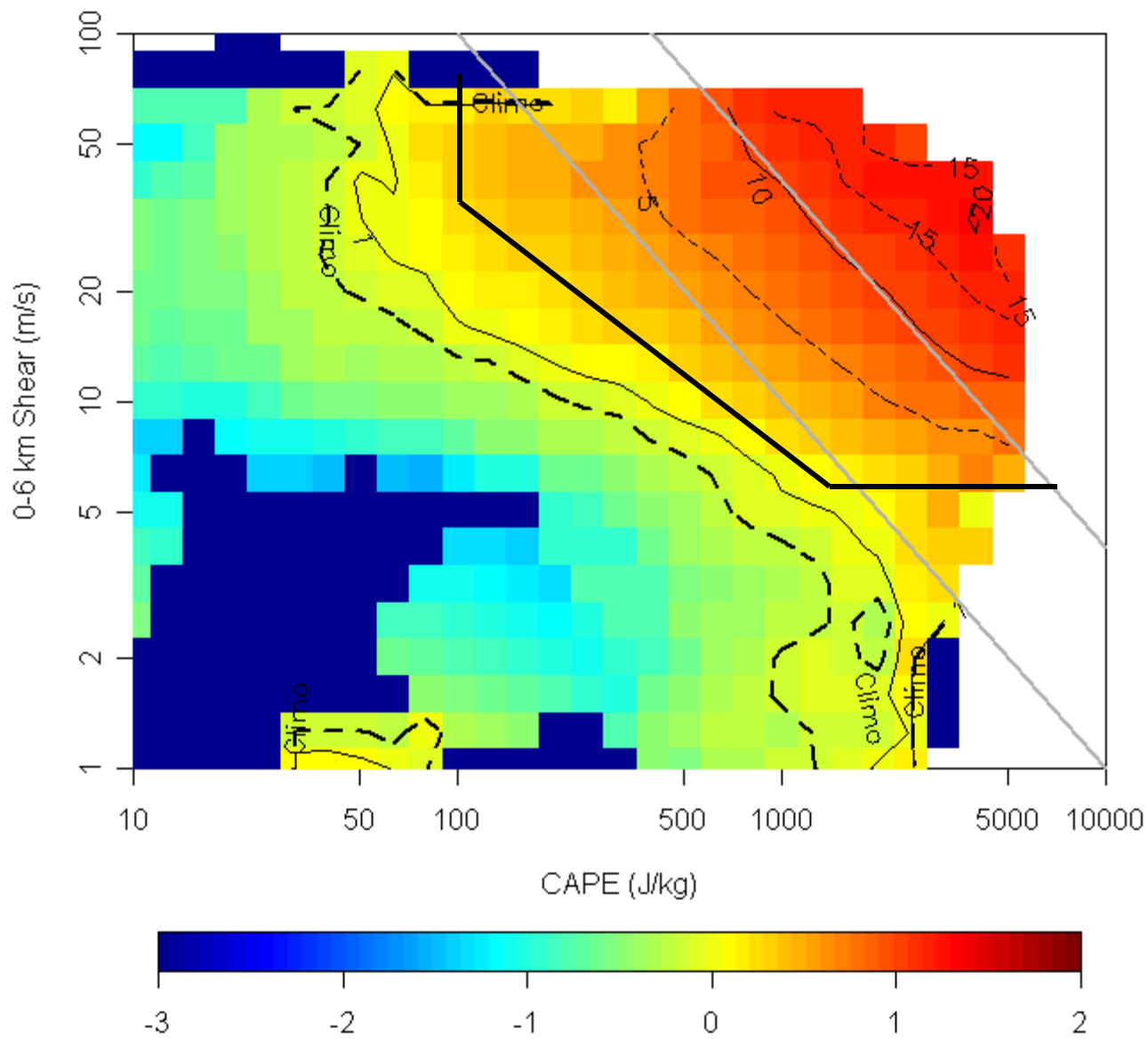


**Significant Severe Weather
Locations (1991-1999)**

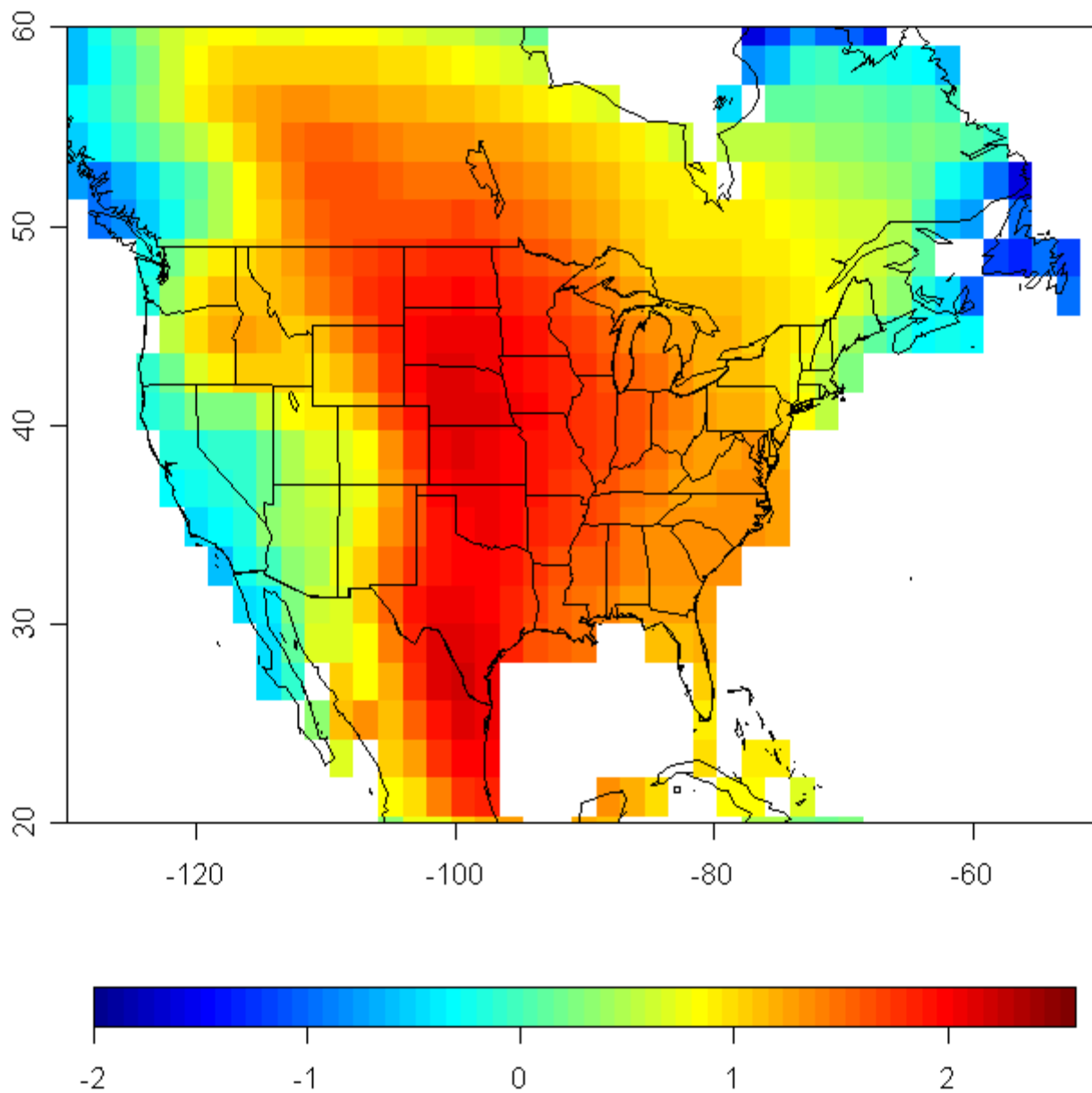
Observed Environmental Proximity Parameters



Probability (log[%]) of Sig Severe-US



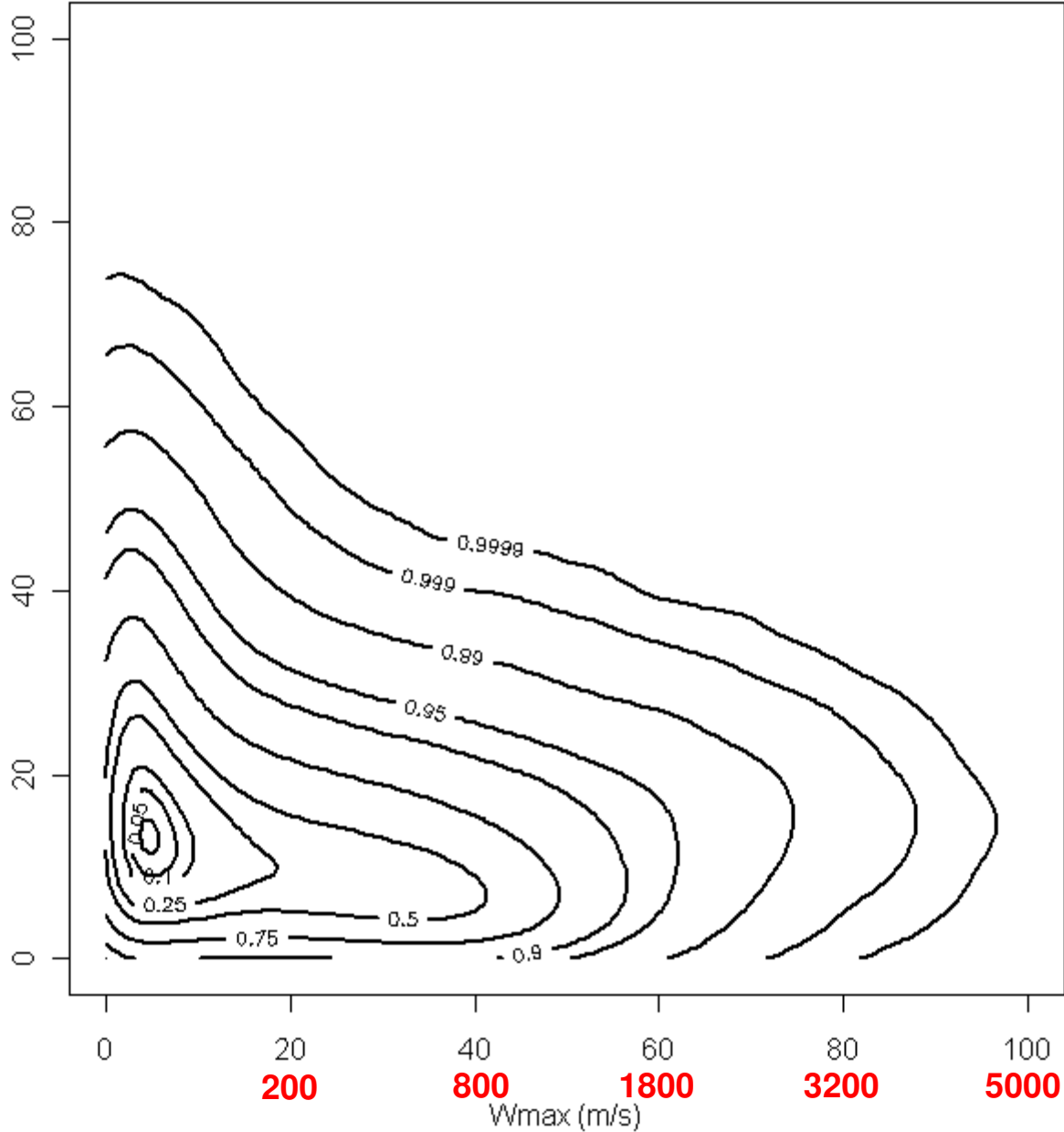
Severe Environment Periods (log) 1958-1999



US Sounding Distribution

Organization

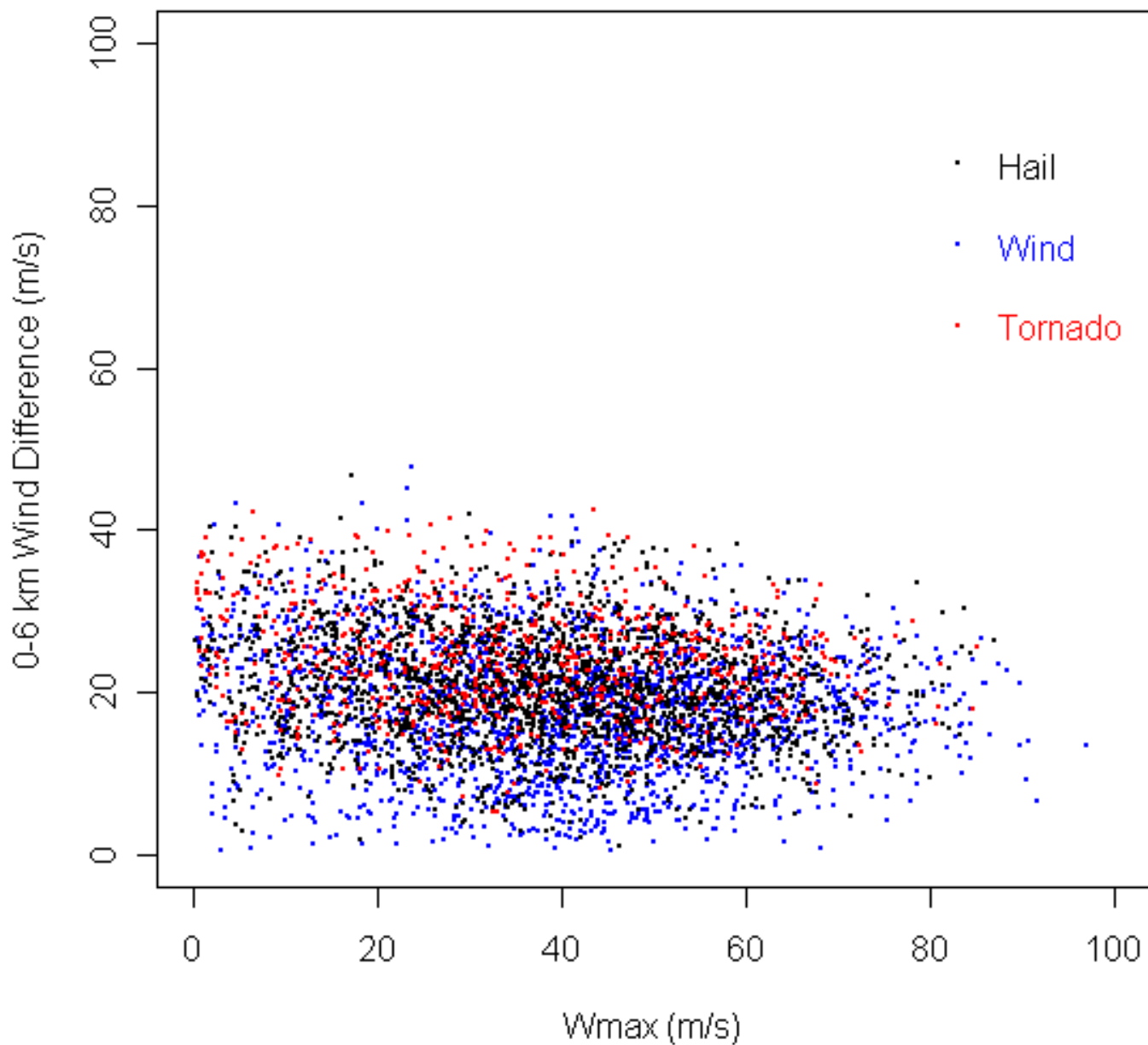
0-6 km Wind Difference (m/s)



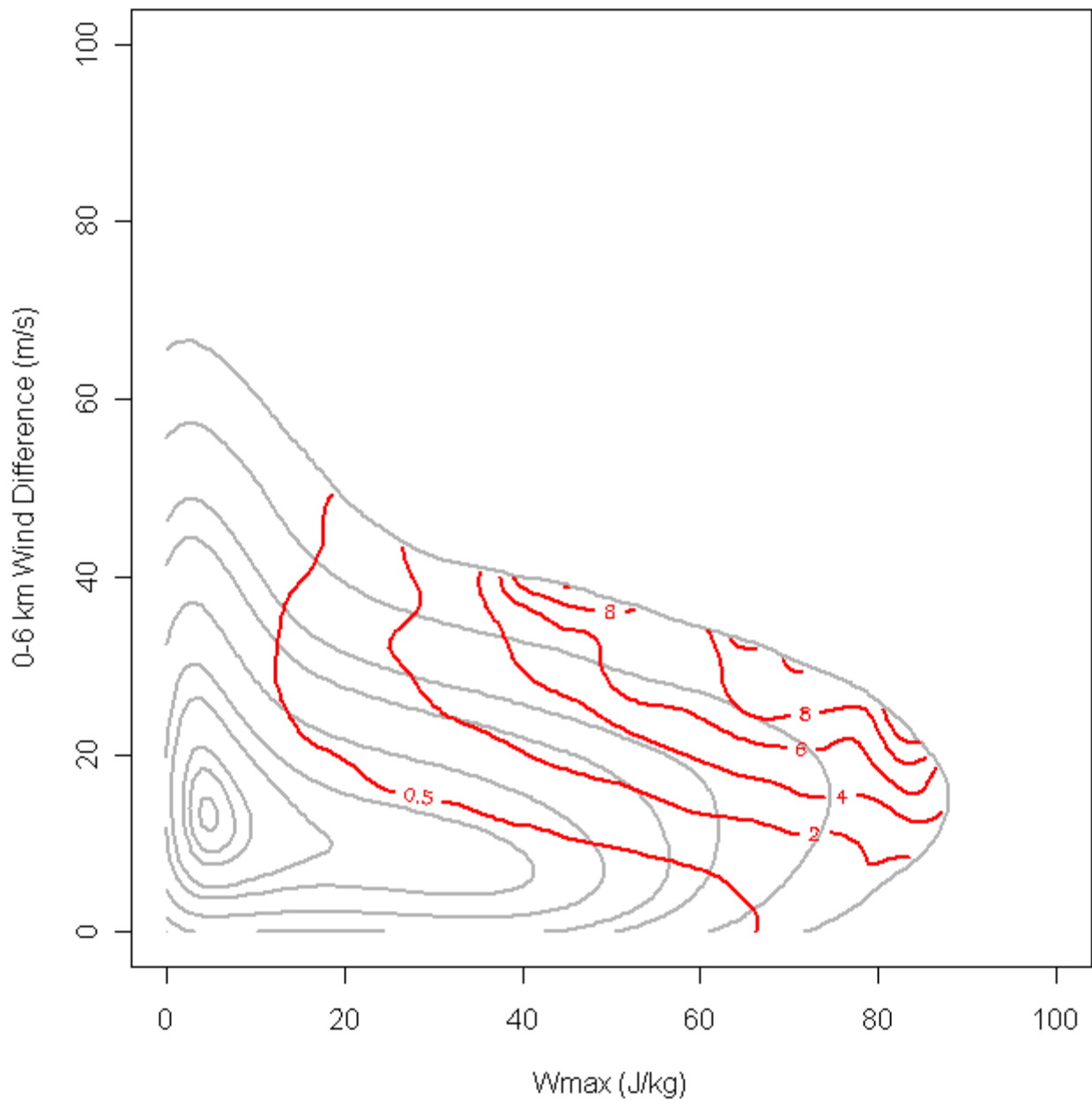
Wmax

CAPE

Significant Severe Soundings (US-1991-1999)



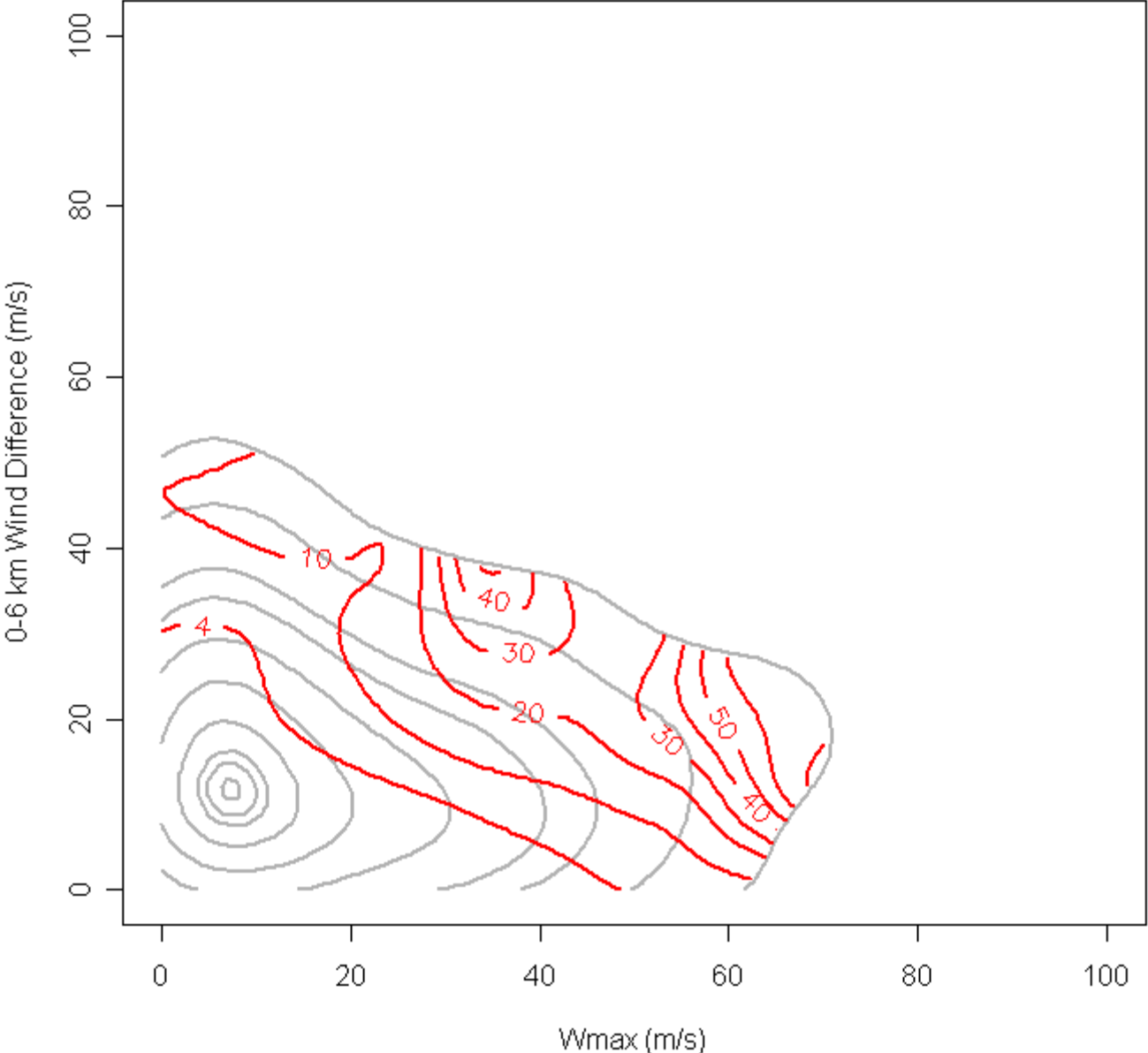
Probability (%) of Sig Severe (US)



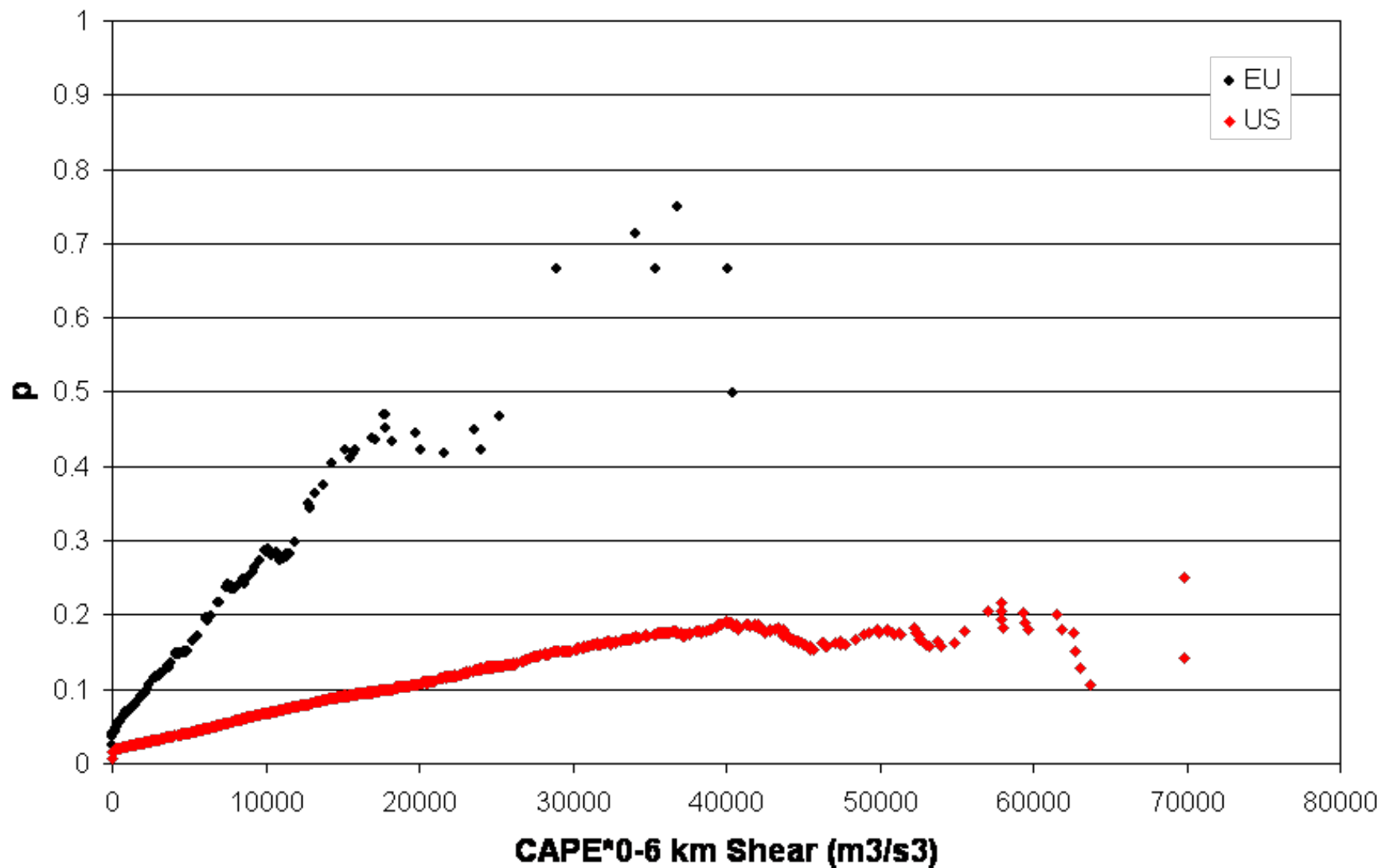
European Data

- European Severe Weather Database
 - Growing with time
 - Biased towards tornadoes and Germany

Sounding Distribution Europe



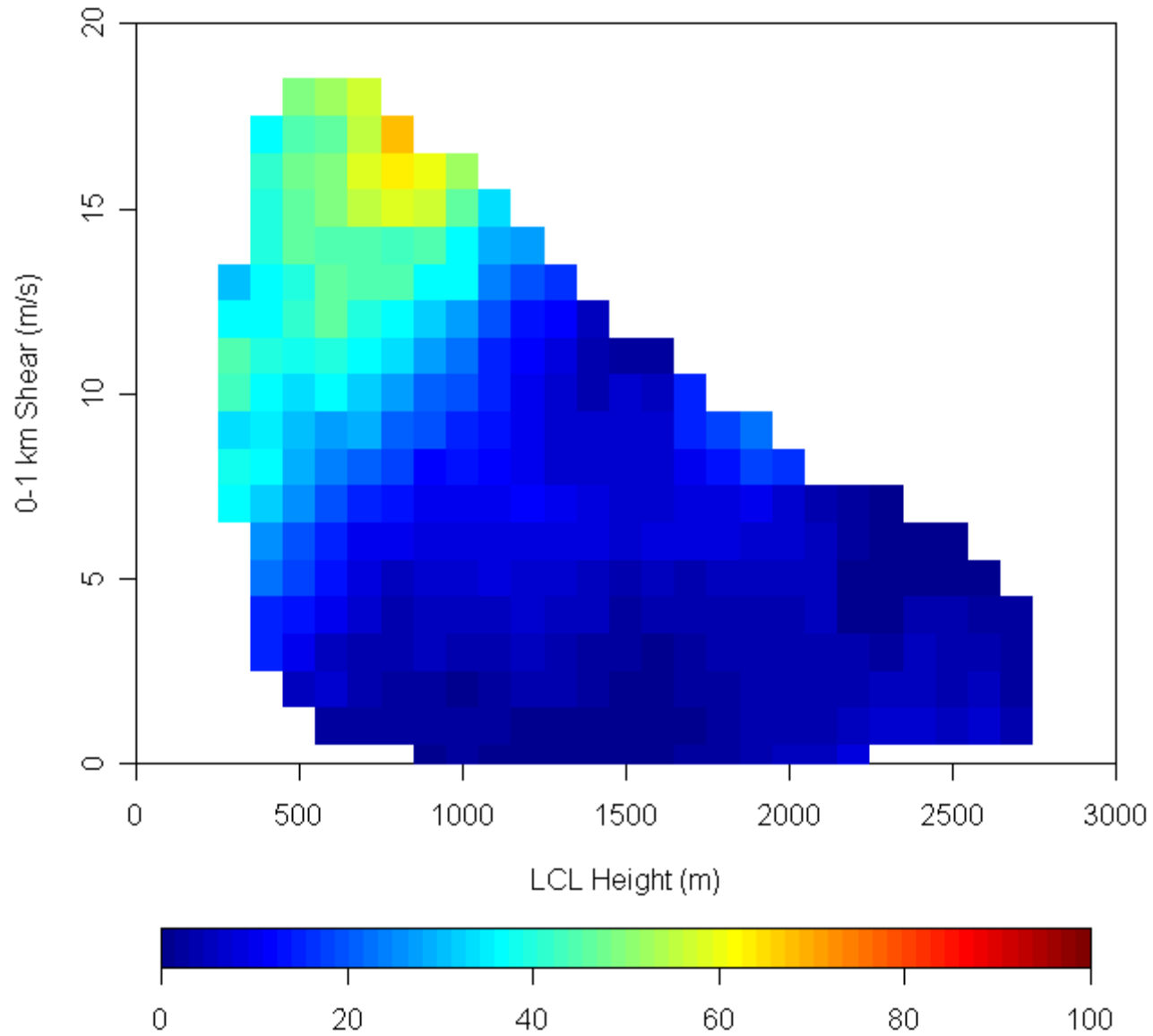
Probability of Significant Severe if CAPE*Shear Exceeds X



Tornadic/Nontornadic Discrimination

- Low-level (0-1 km) wind shear
- Cloud-base height (low is good)

Probability (%) of Sig Tornado Given Severe-US

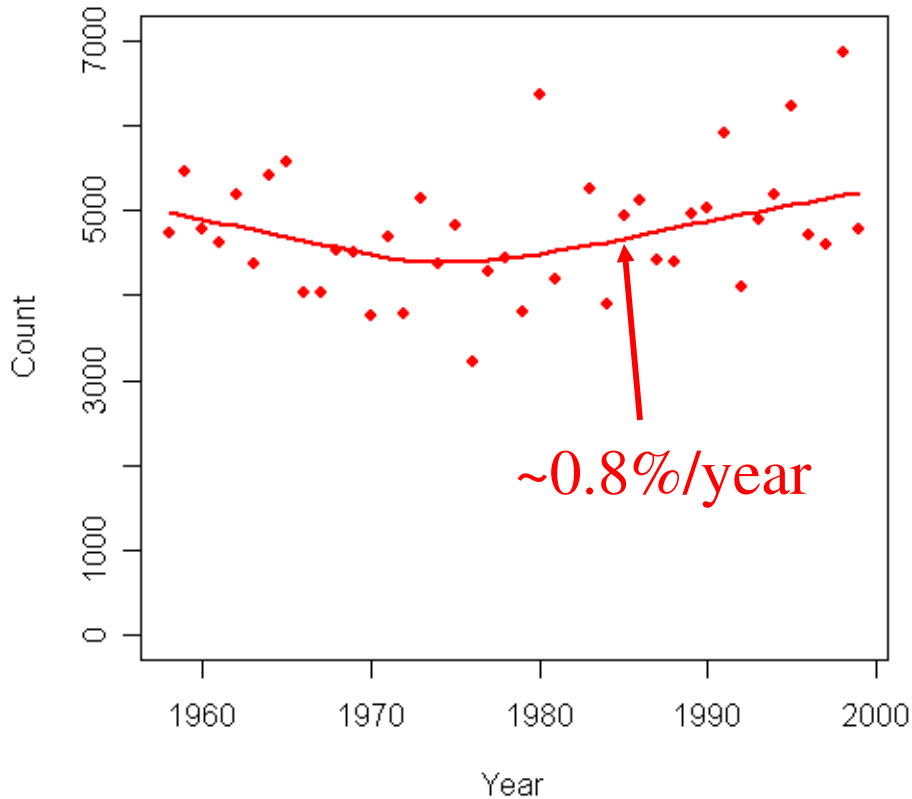


How do estimated trends compare to reports?

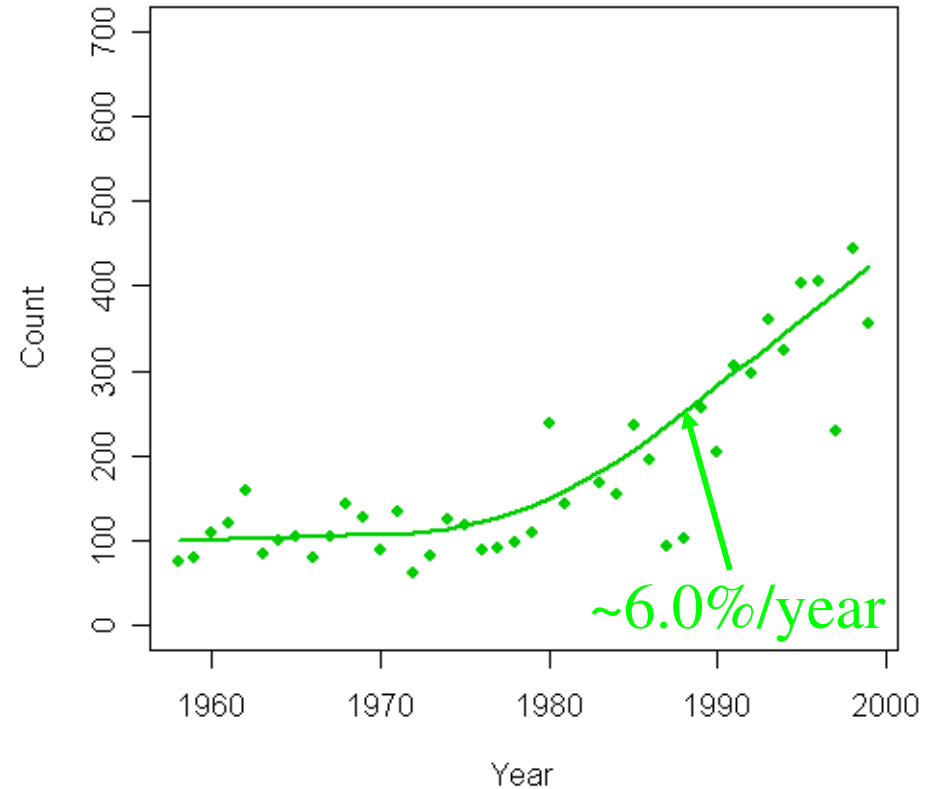
- Focus on really big hail (2.5 in or 7 cm)
- Count favorable environments in US

Comparing Reanalysis Environment Estimates to Reports

Favorable Severe Environment Points-US

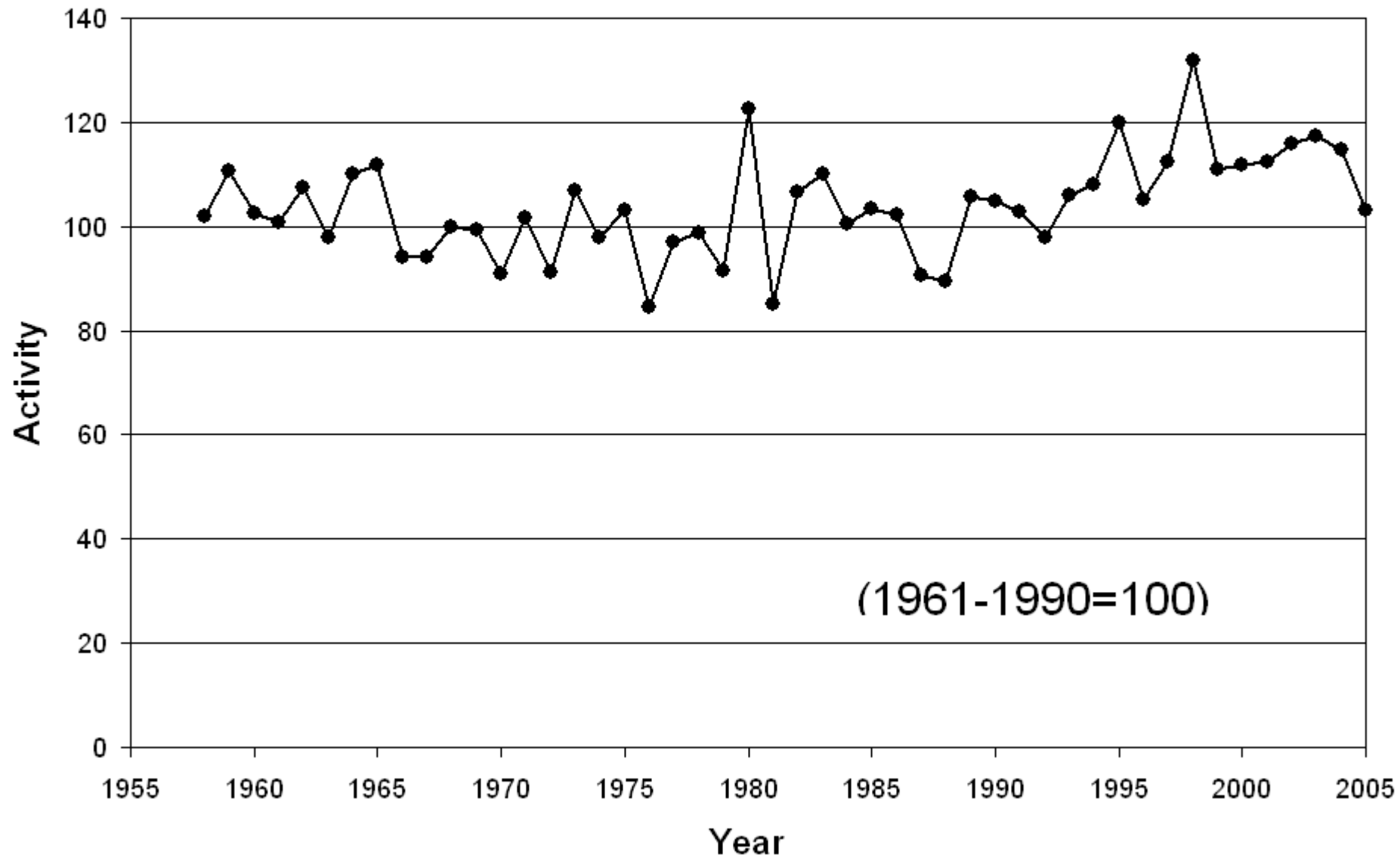


2.5 in. and Larger Hail Reports



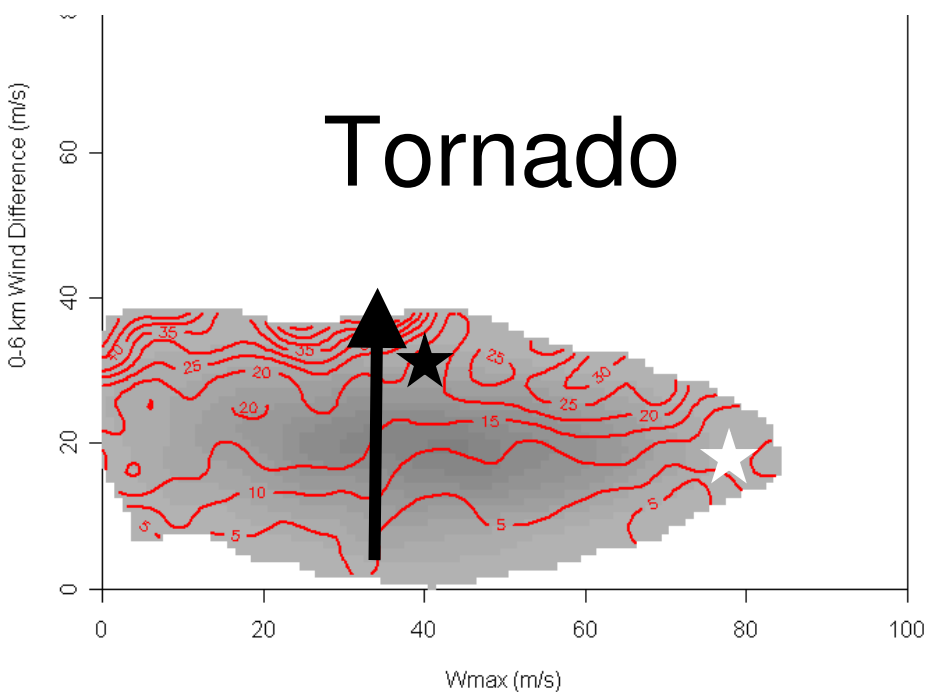
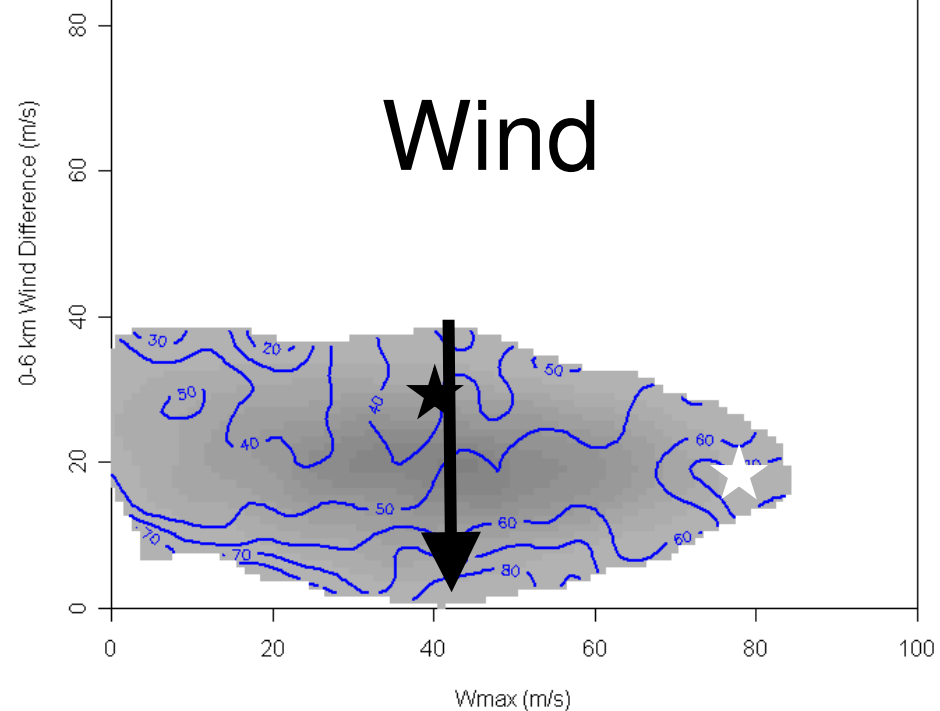
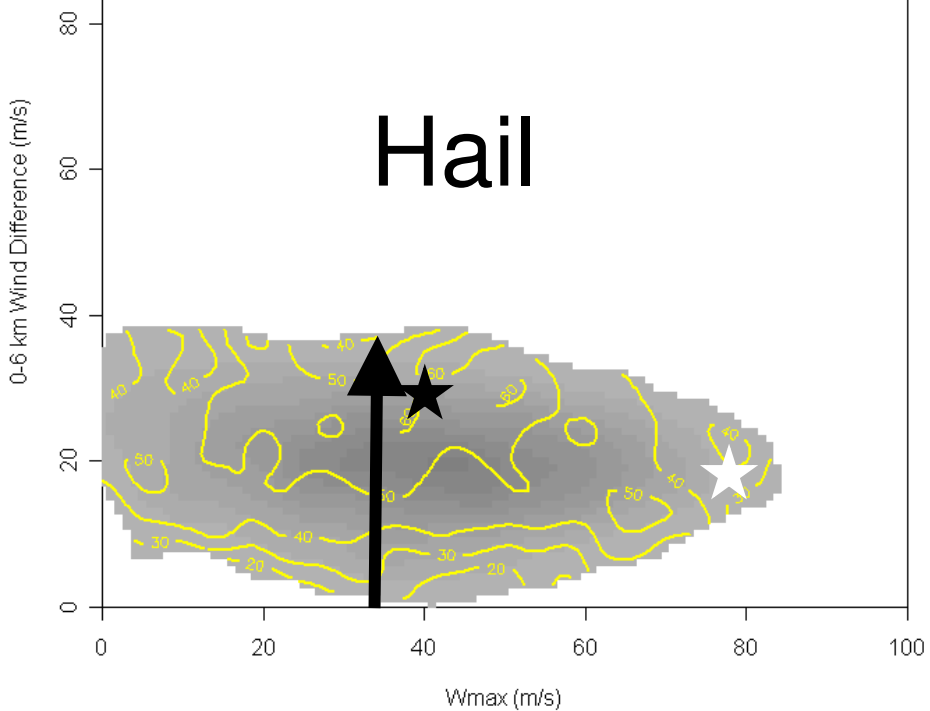
Environments account for $\sim 7\%$ of increase in reports

Ingredients-Based US Severe Storms Activity Estimate



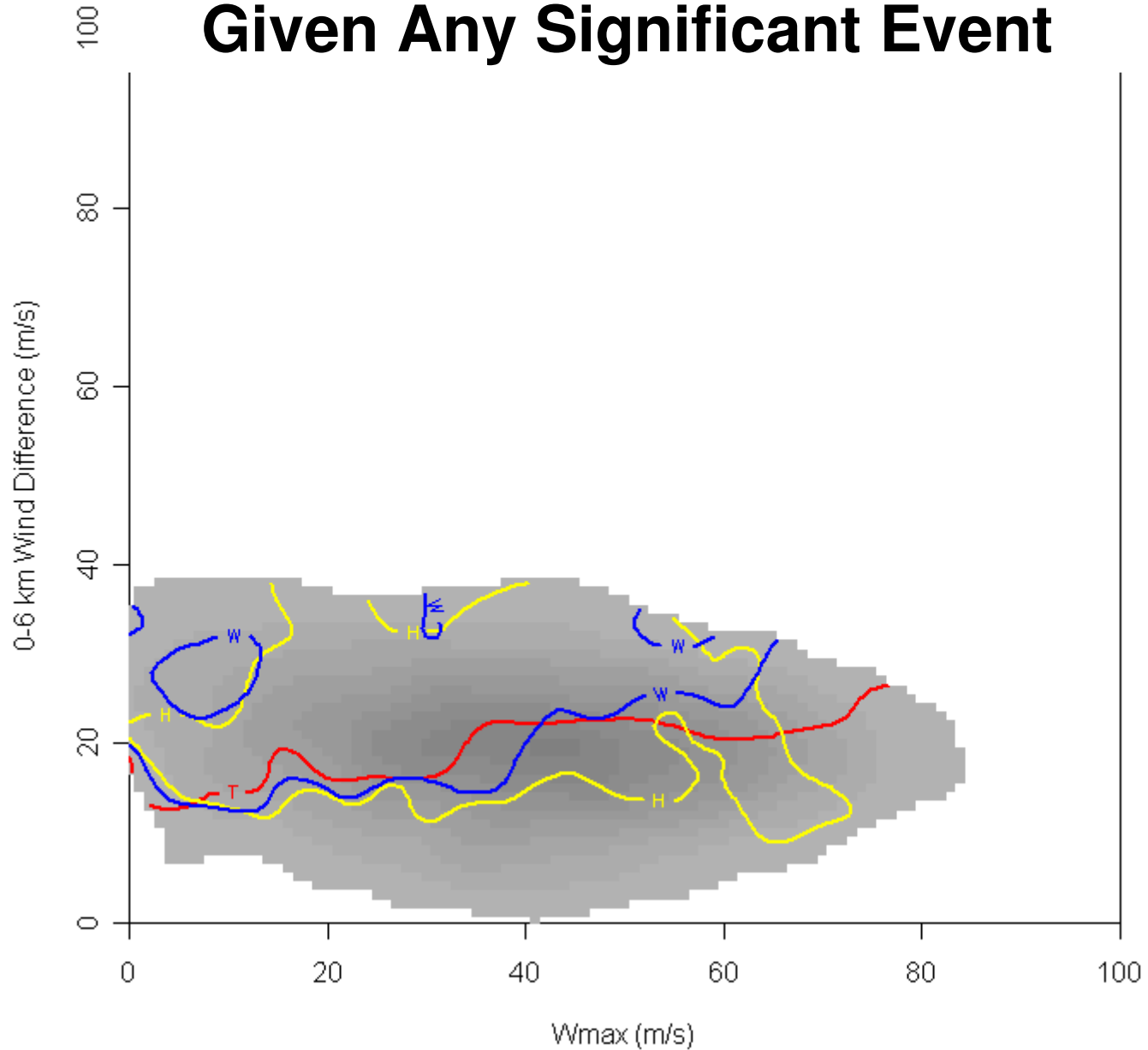
Conditional Probabilities of Hazards

- Severe is frequently easy for forecasters to identify
- Likely threat?
- Conditional probability of really big events

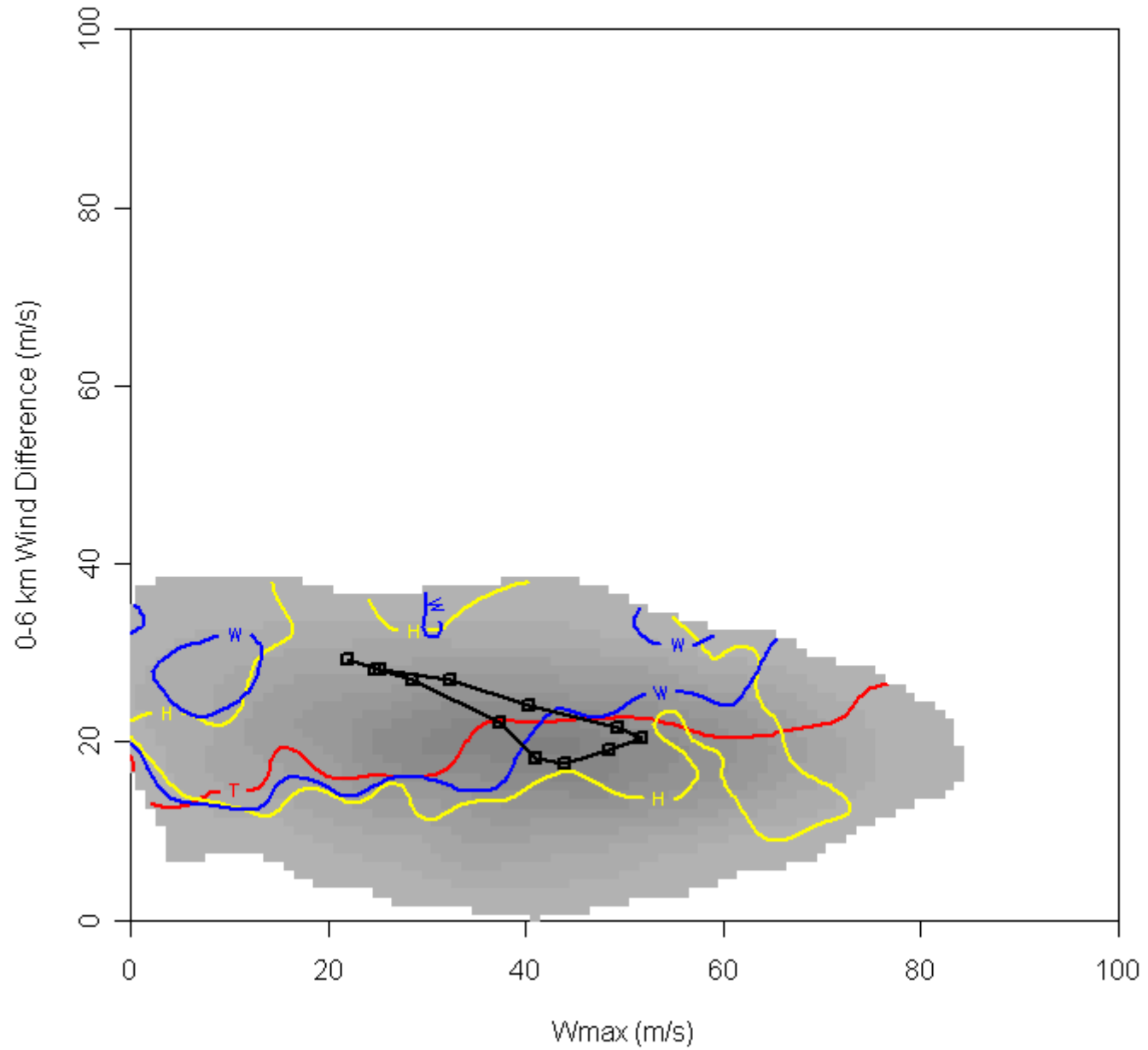


**Conditional Probability
of Events Given
Any Significant Event**

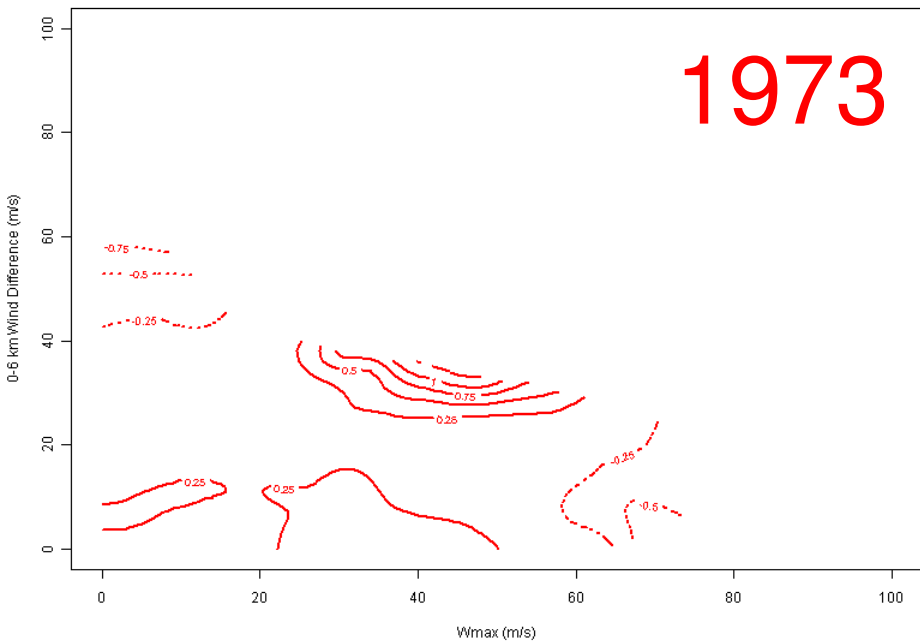
Conditional Probability of Events Given Any Significant Event



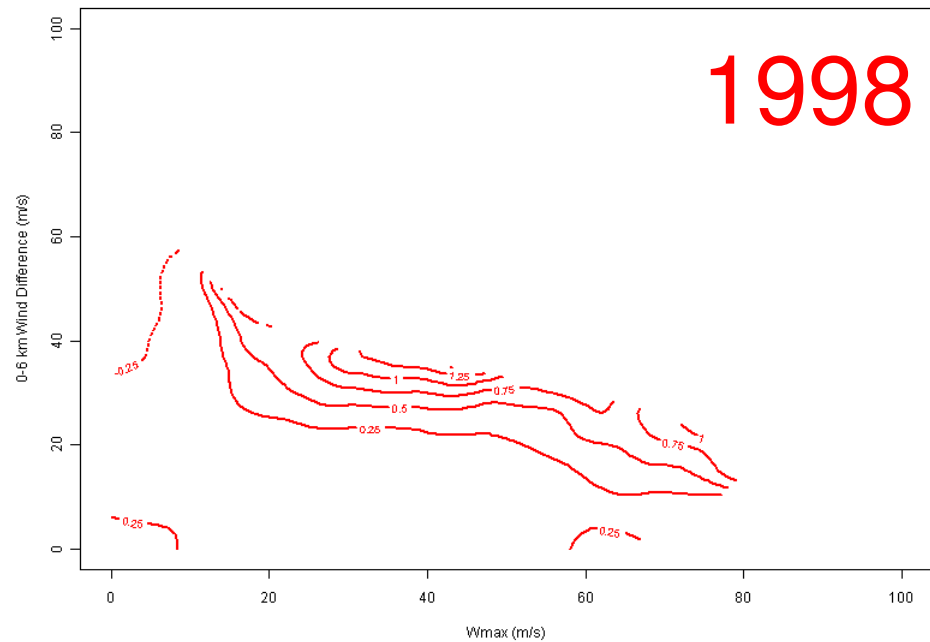
Annual Cycle of 'Big' Soundings



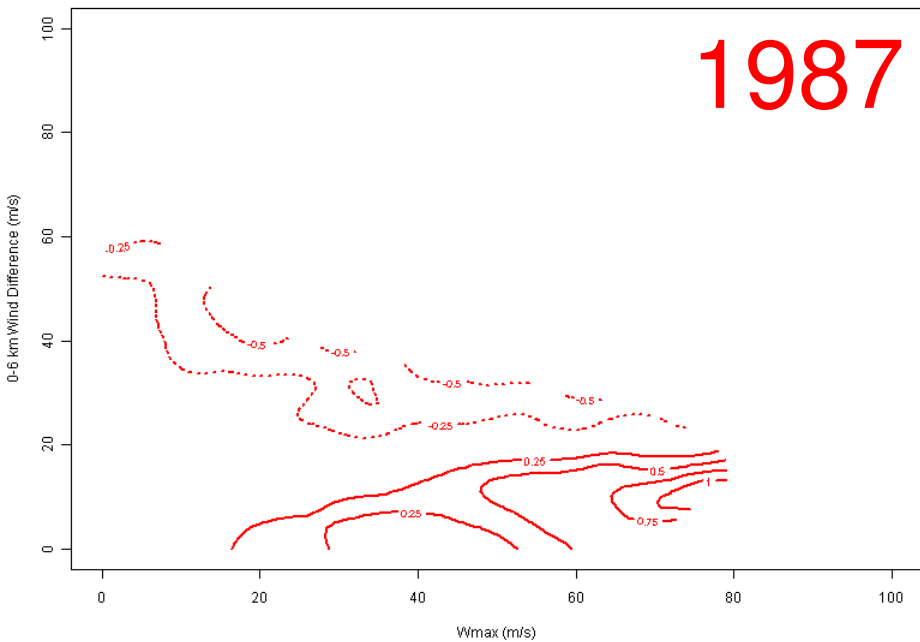
Relative Anomalies in 1973



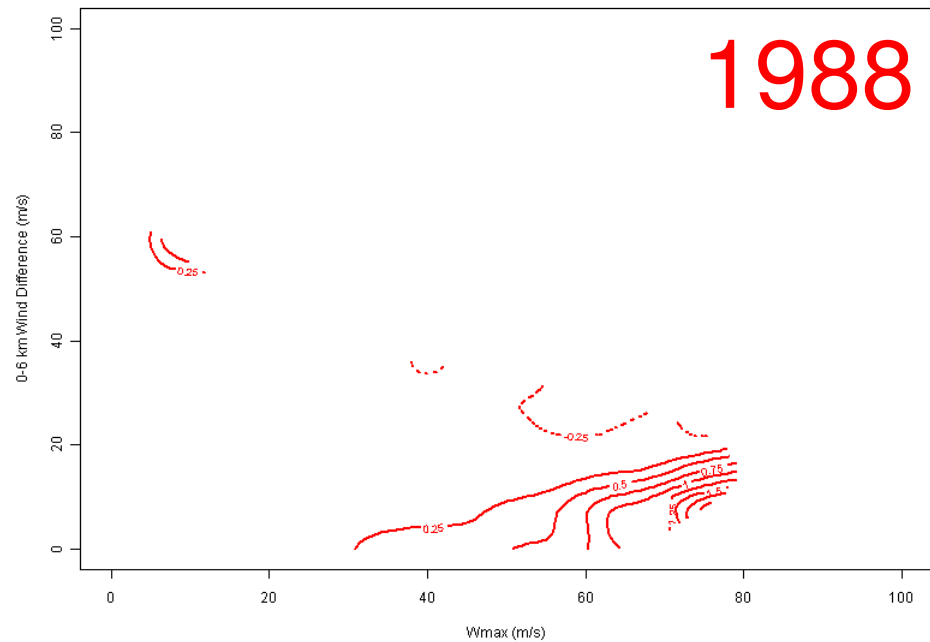
Relative Anomalies in 1998

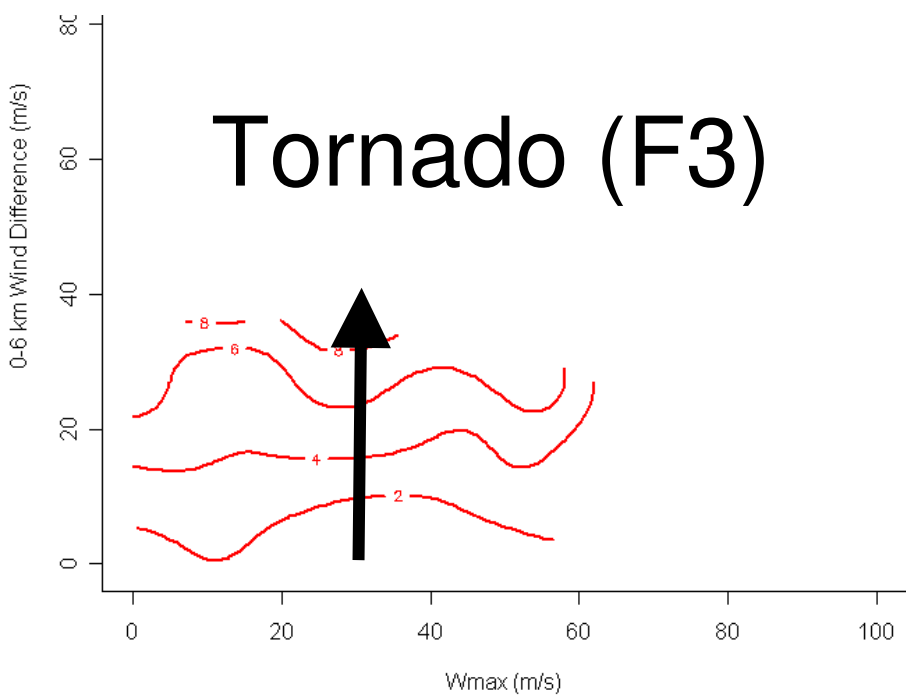
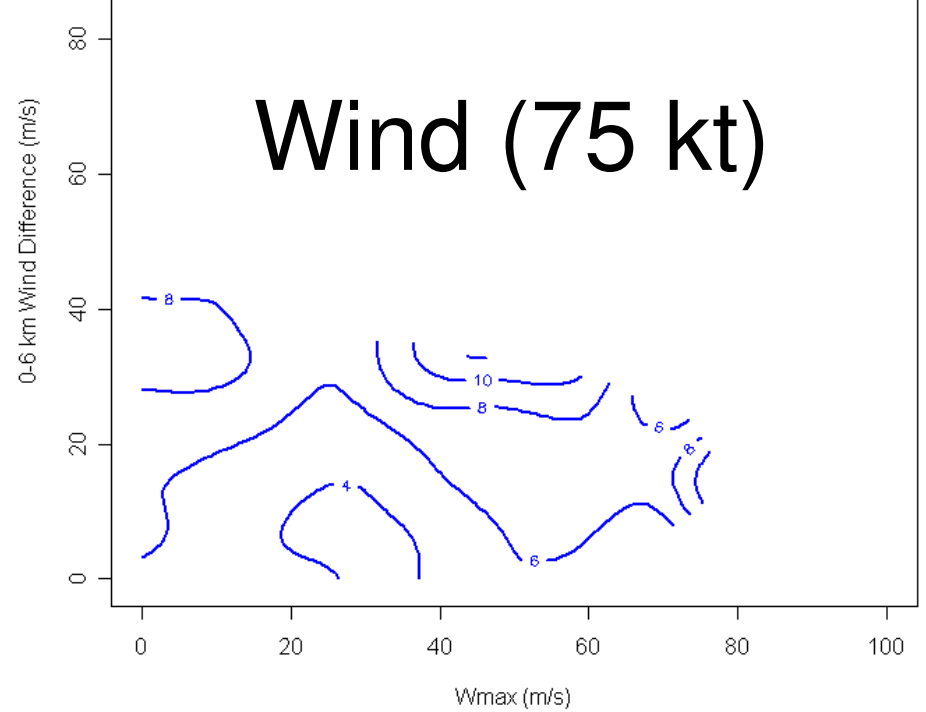
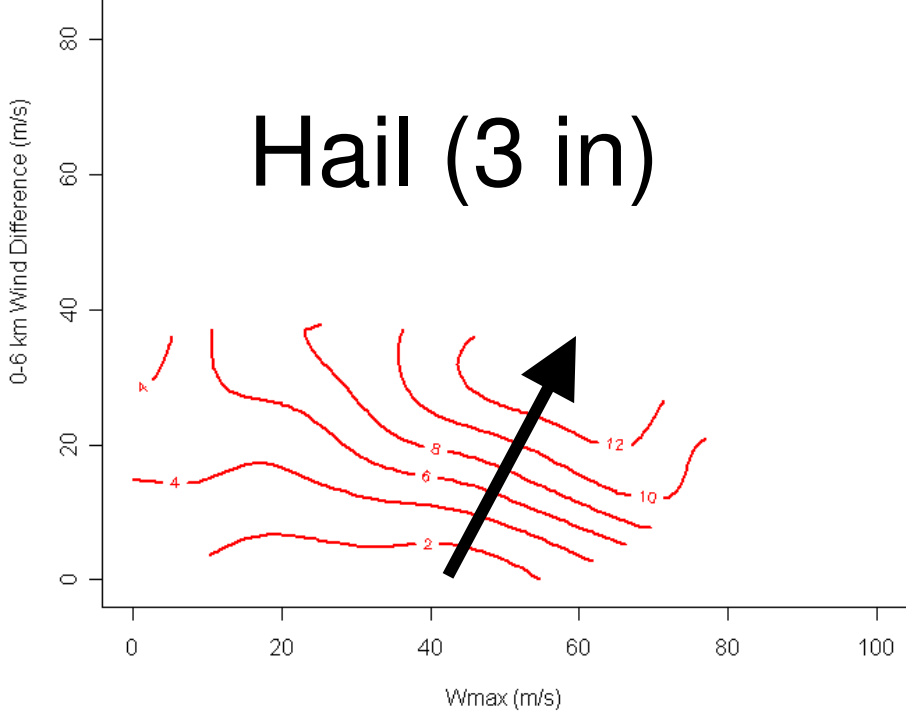


Relative Anomalies in 1987



Relative Anomalies in 1988





Conditional Probability of Really Big Events

What do we know?

- Reports aren't very reliable
- Environments
 - High shear-wmax (CAPE) good for severe
 - Given “some” wmax, mostly function of shear
 - High shear-tornado, hail
 - Low shear-wind
 - Tornado intensity-function of shear
 - Historical trends look like US surface temp