

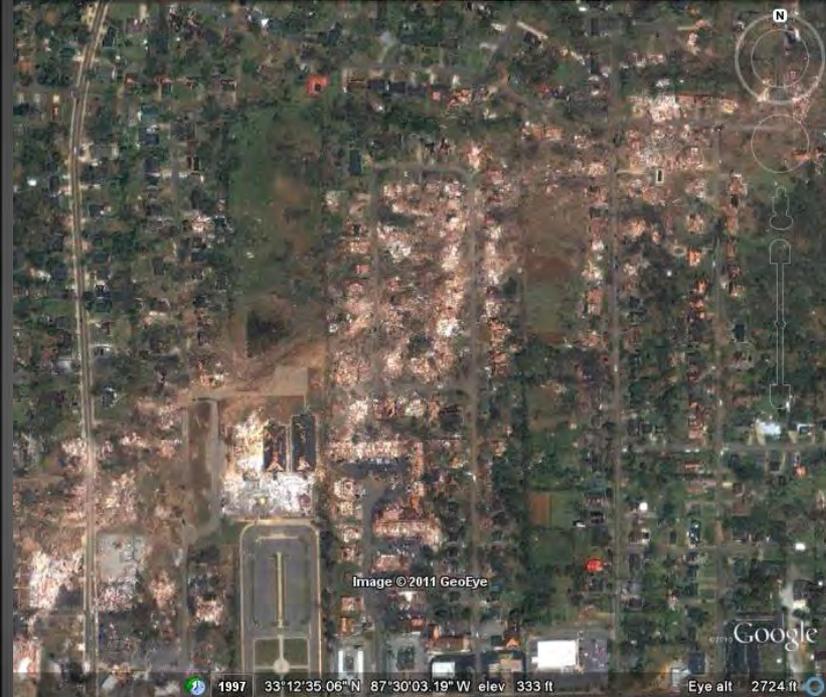
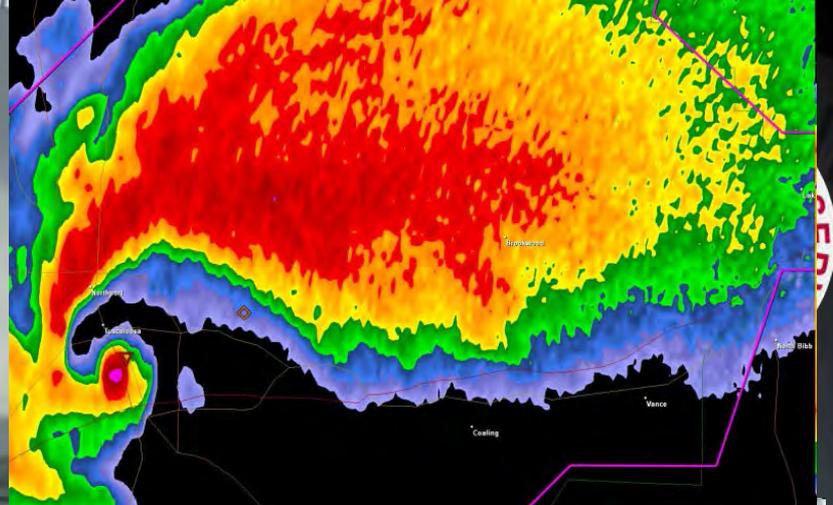


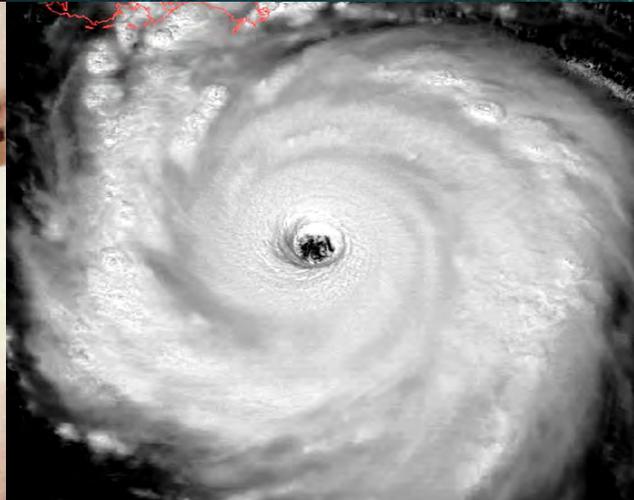
Forecasting the Ferocious: *The Predictive Science Behind NWS Forecasts for Tornadoes and Floods*

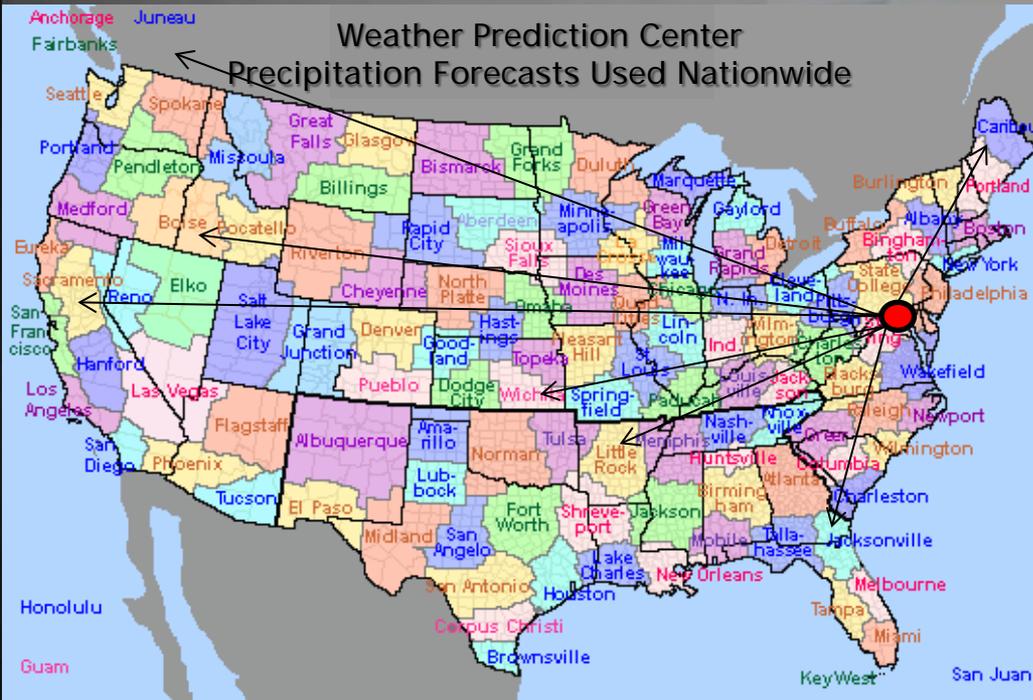
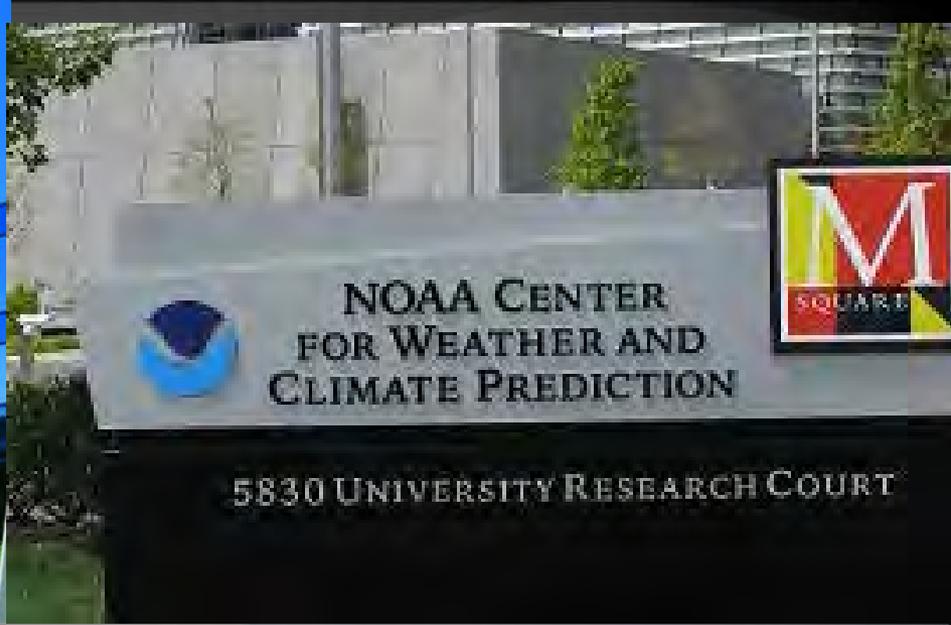
Greg Carbin

**National Centers for Environmental Prediction
Weather Prediction Center**

NCCWP, College Park, Maryland







The forecast process =

CONCEPTUAL MODELS + DIAGNOSIS + EXPERIENCE
+
TREND

- **CONCEPTUAL MODELS** help simplify the atmosphere
- **DIAGNOSIS** requires analysis and attention to detail
- **EXPERIENCE** comes with time, dedication, climatology
- **TREND** – Bringing it all together and using extrapolation, ingredients evaluation and modification, numerical model guidance, including statistical techniques to enhance model output.

CONCEPTUAL MODELS

Severe convective weather is a product of
thunderstorms...

...or, more accurately, “sustained deep moist convection”

The forecast task reduces to :

(1) ASSESS THE POTENTIAL
FOR THUNDERSTORMS



(2) DETERMINE WHETHER STORMS
WILL BECOME SEVERE OR NOT



CONCEPTUAL MODELS

Storms require a combination of three Ingredients



- **INSTABILITY**
- **LIFT**
- **MOISTURE**

Instability: tendency for air parcels to move up or down when displaced from rest; determined by rate of temperature change with height

Lift: mechanism(s) to initiate, maintain or augment vertical air motions (updrafts)

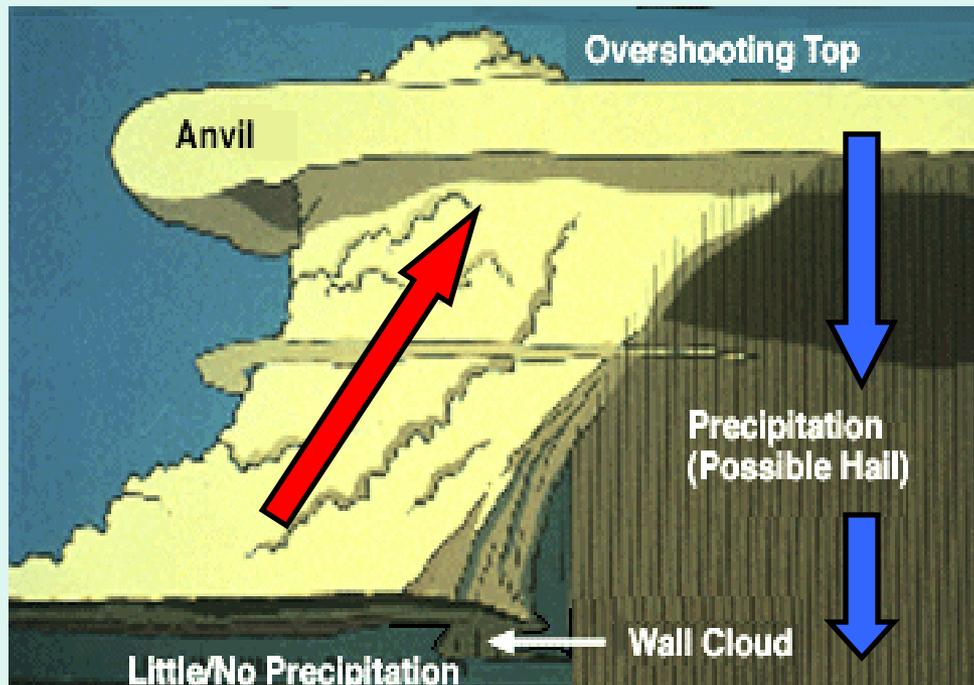
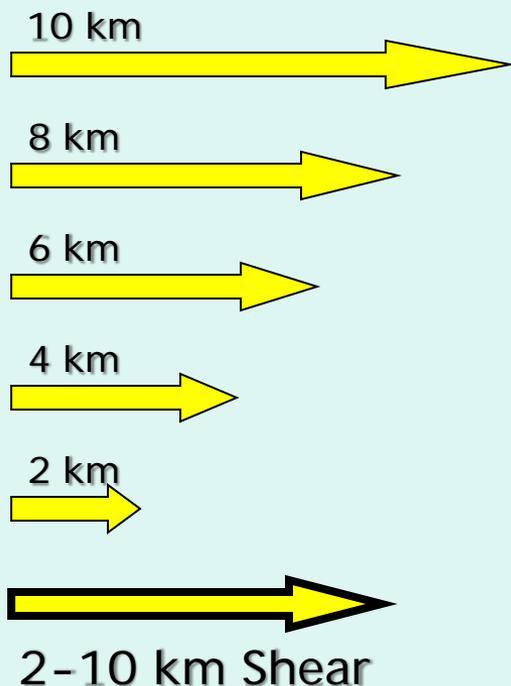
Moisture: Fuel in the form of the latent heat of condensation (2.5×10^6 J/kg)

CONCEPTUAL MODELS

Sustained convection requires another ingredient:

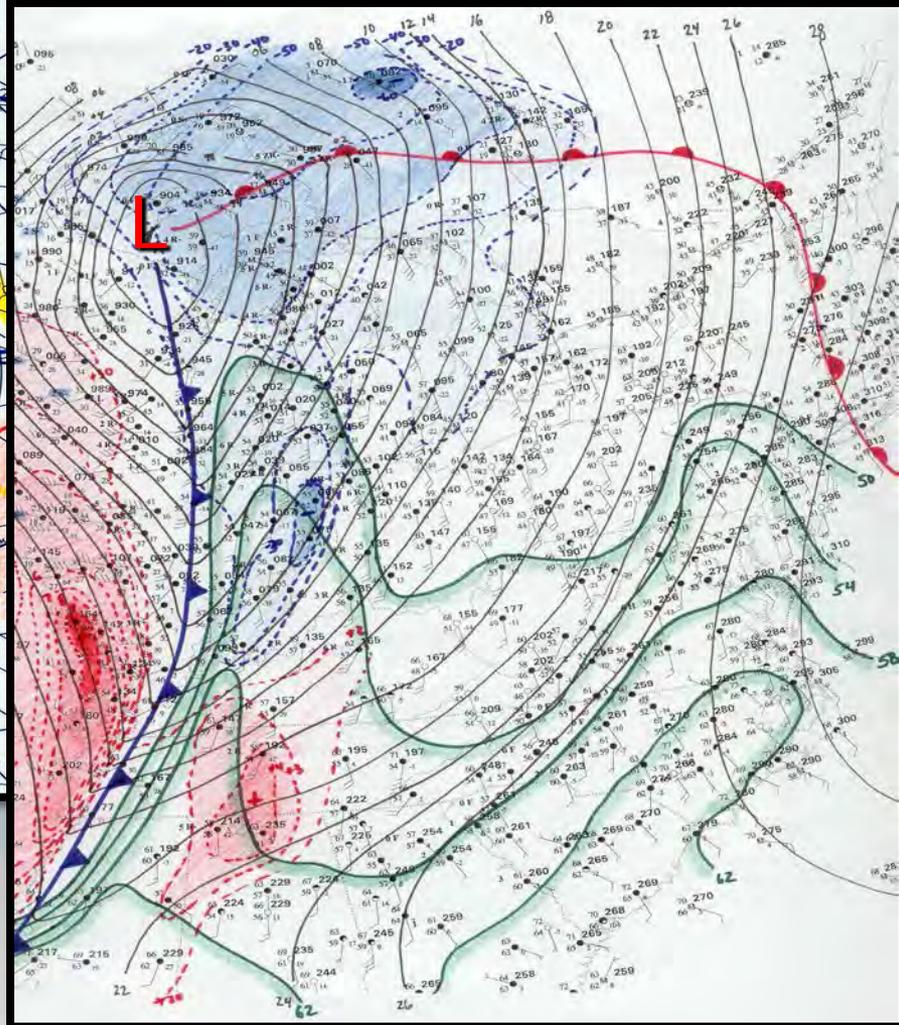
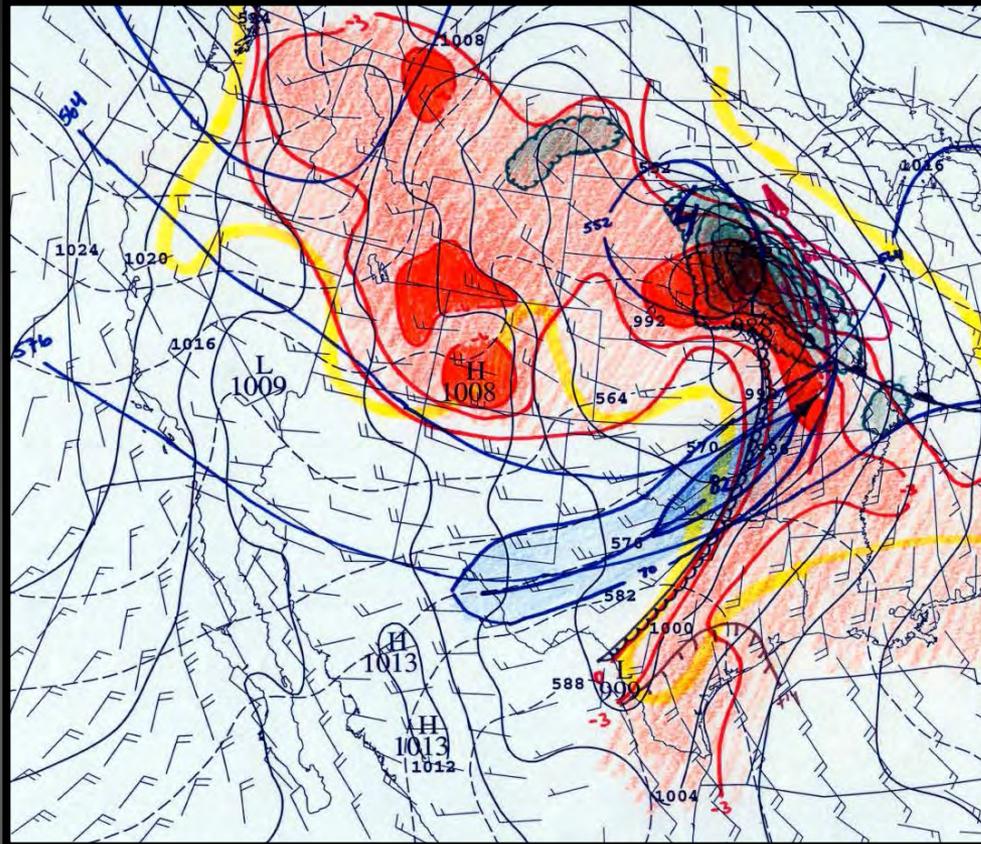
- **VERTICAL SHEAR**

The change in wind speed or direction with height...



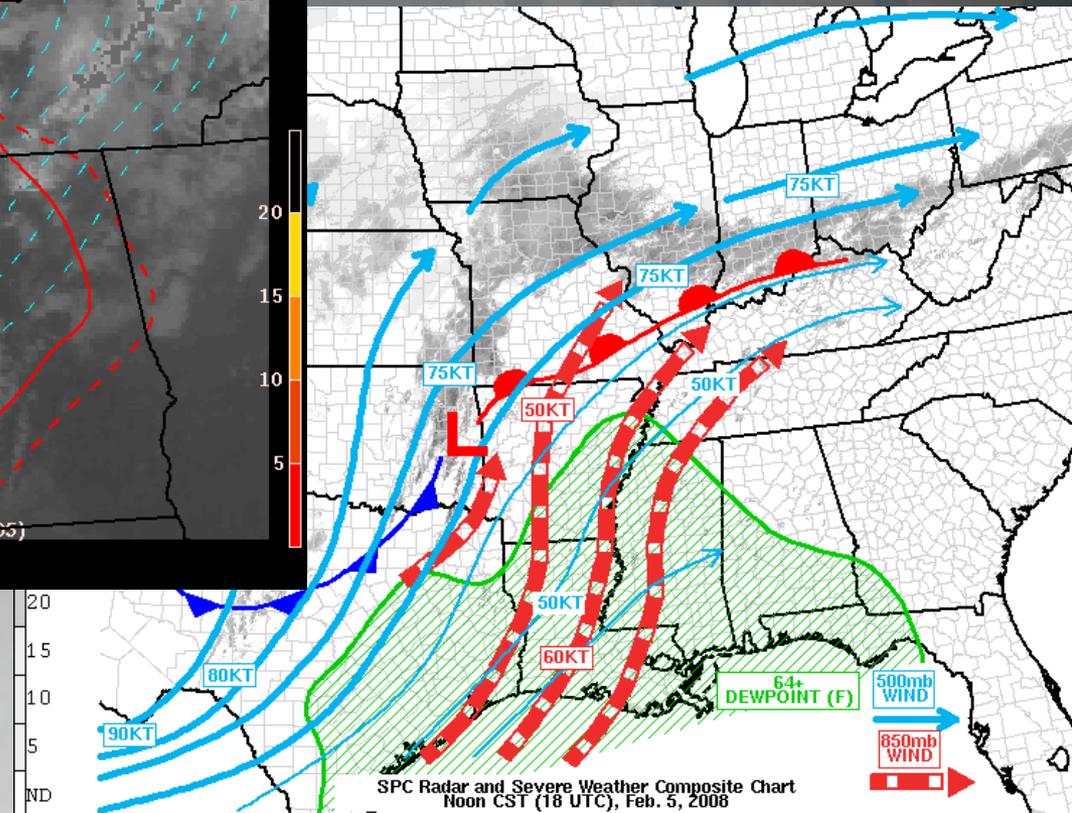
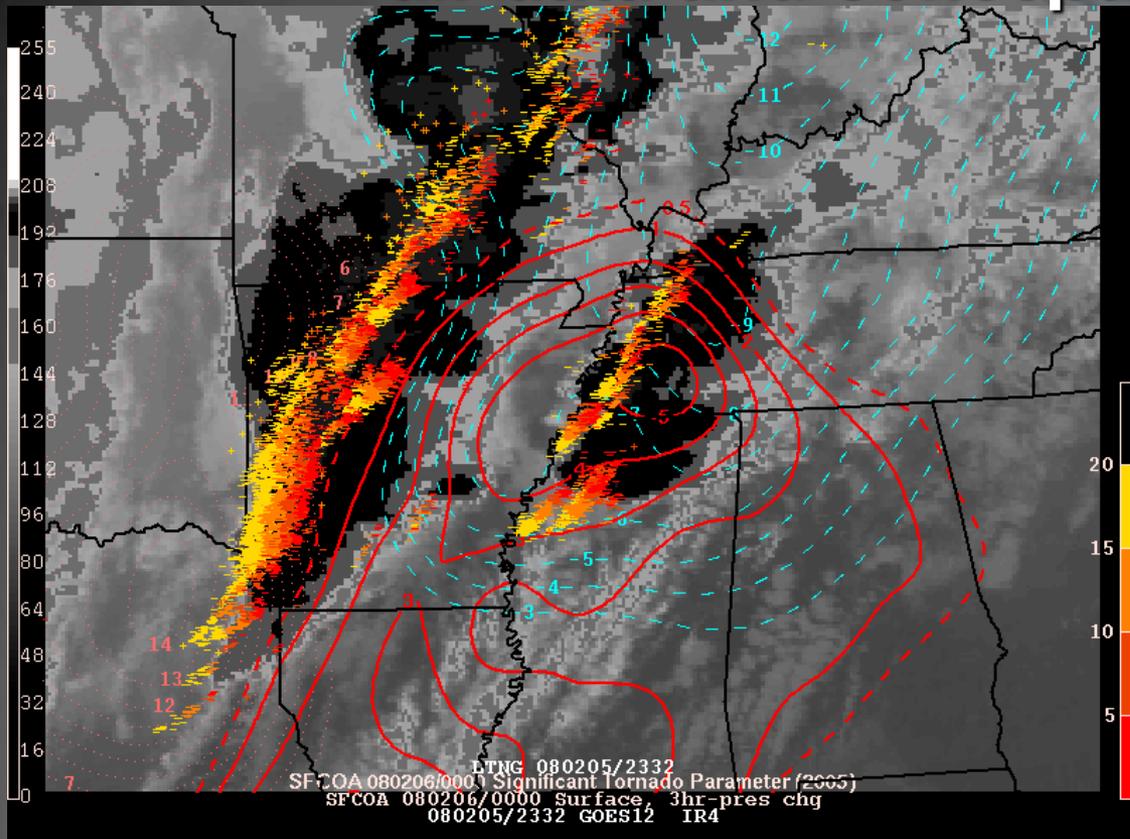
DIAGNOSIS

Combining surface observations/analysis with upper air data and conceptual models



DIAGNOSIS

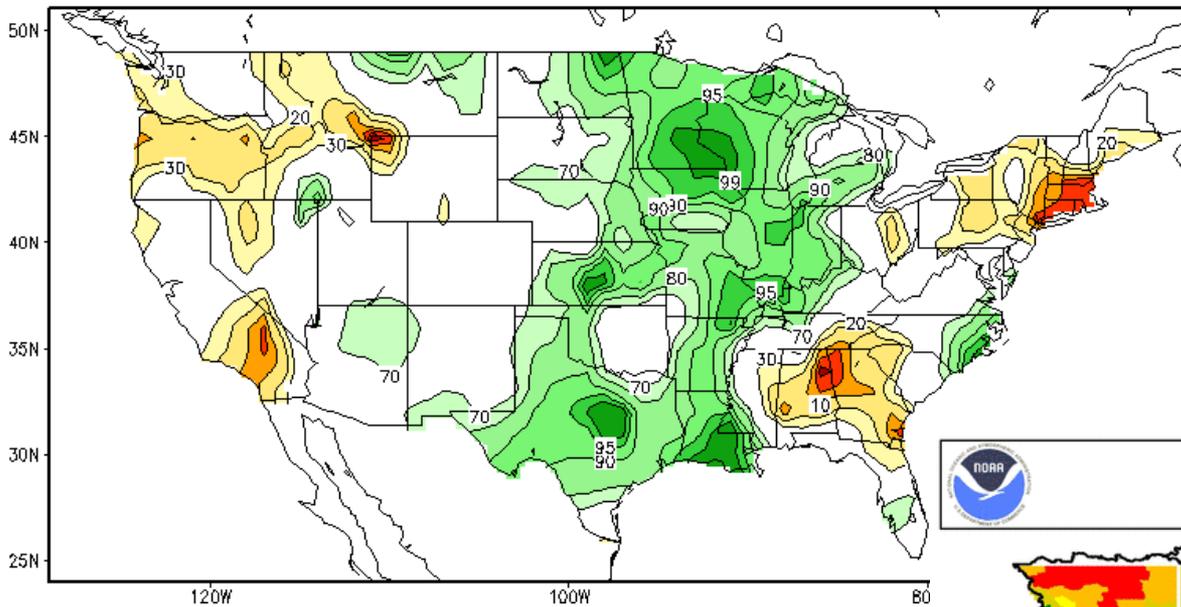
Combining surface observations/analysis with upper air data and conceptual models



DIAGNOSIS

Most flood events have antecedent conditions too

Calculated Soil Moisture Ranking Percentile
SEP, 2016

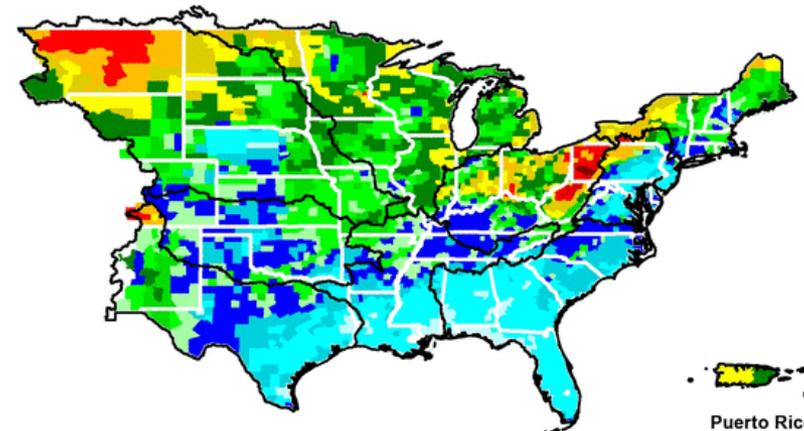


National Weather Service

Regional Map

3 Hour Flash Flood Guidance

Updated October 21, 2016 11:45 AM CDT

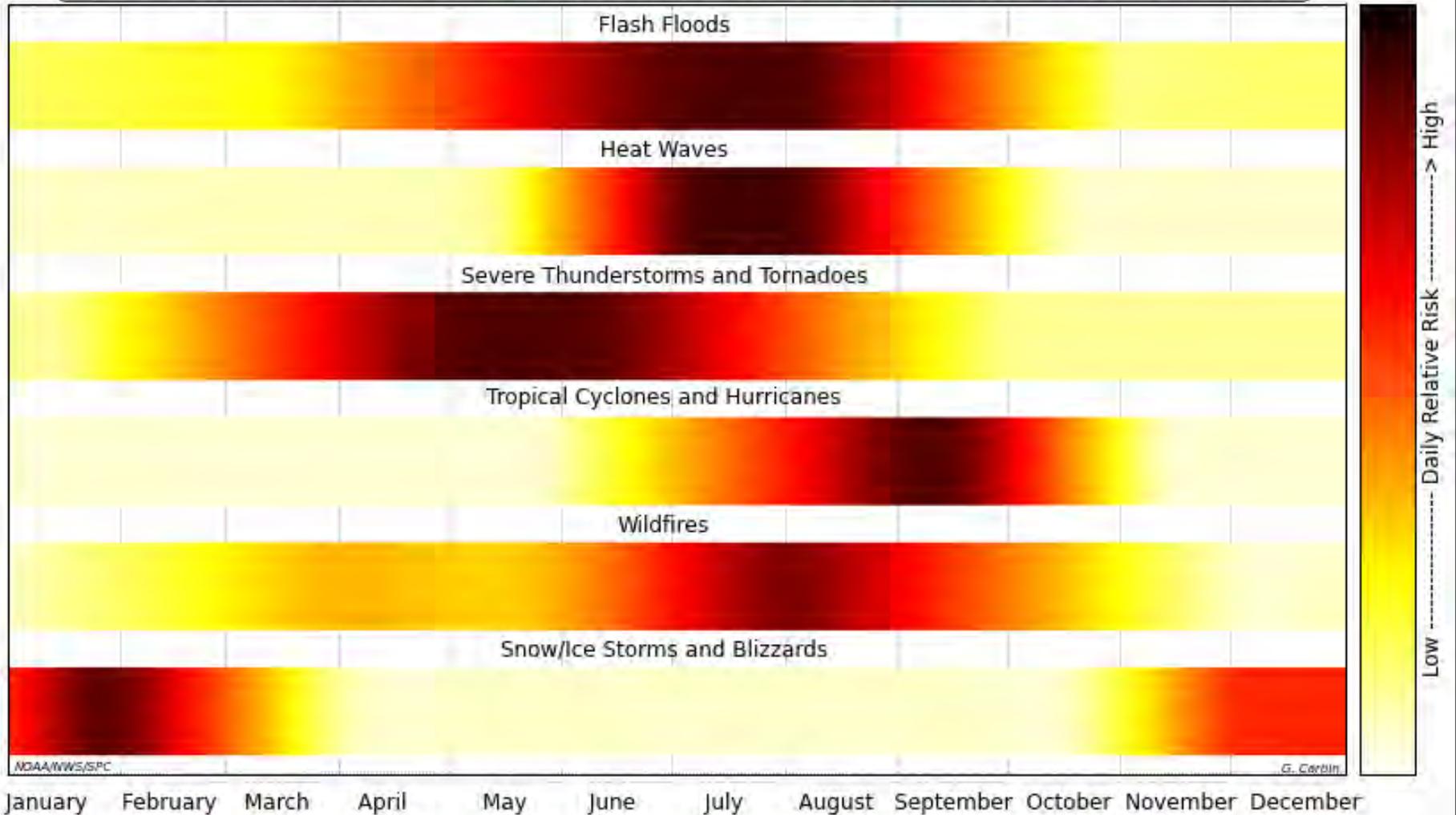


<0.6" 0.6" 0.8" 1.0" 1.2" 1.4" 1.6" 1.8" 2.0" 2.25" 2.5" 2.75" 3.0" 3.5" 4.0" >5.0" No Data

EXPERIENCE

Climatology of Hazards

U.S. Daily Average Relative Weather Risk Based on NOAA/NWS Data, 2008-2012

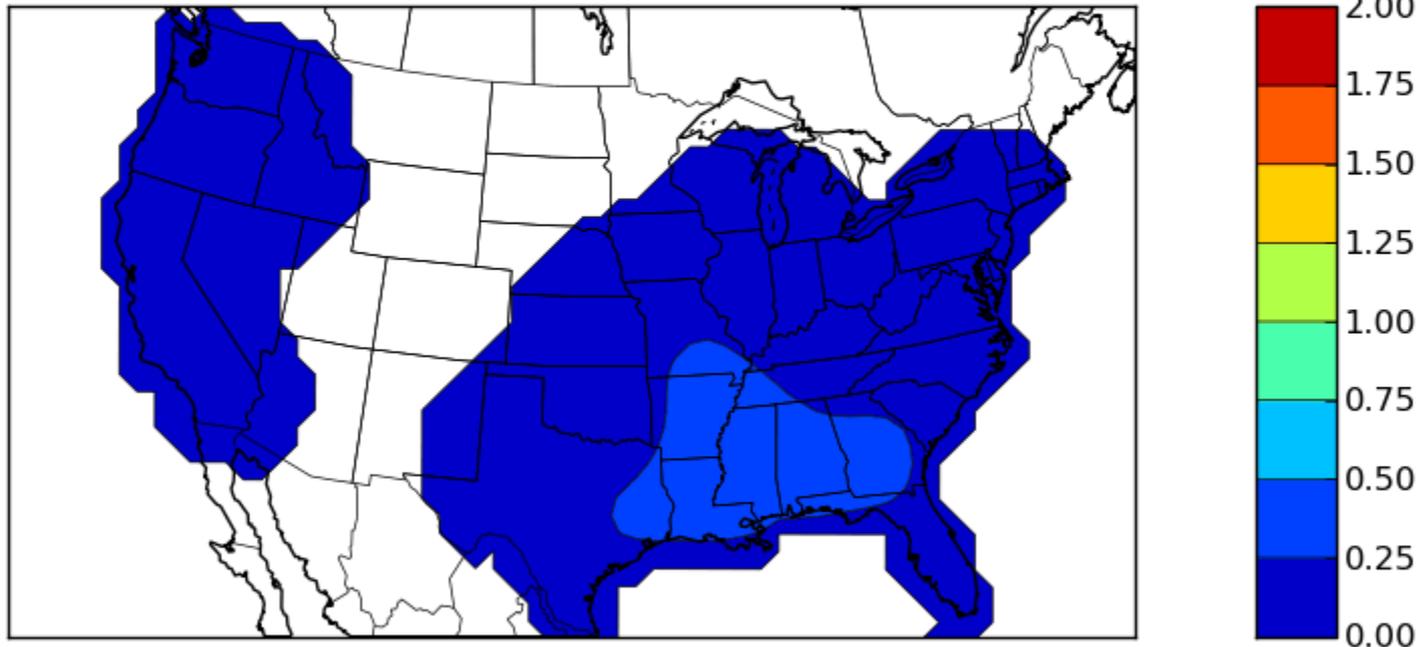


EXPERIENCE

Tornadoes are rare and unusual!

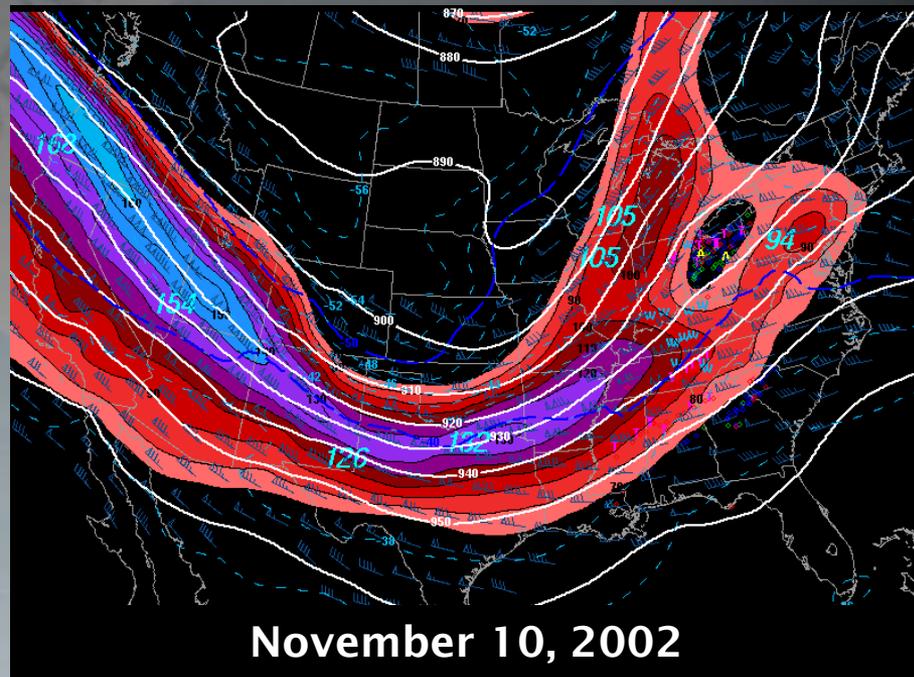
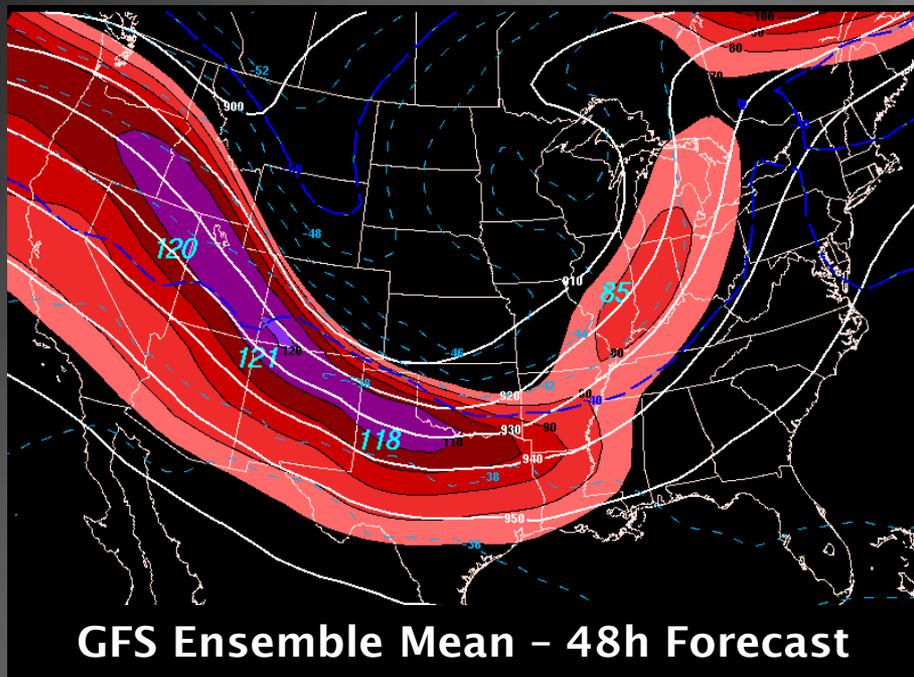
The daily probability of a tornado within 25 miles of a point (20 years of data).

Tornado Probability on Day 001



EXPERIENCE

Pattern recognition and past events



EXPERIENCE

Pattern recognition and past events

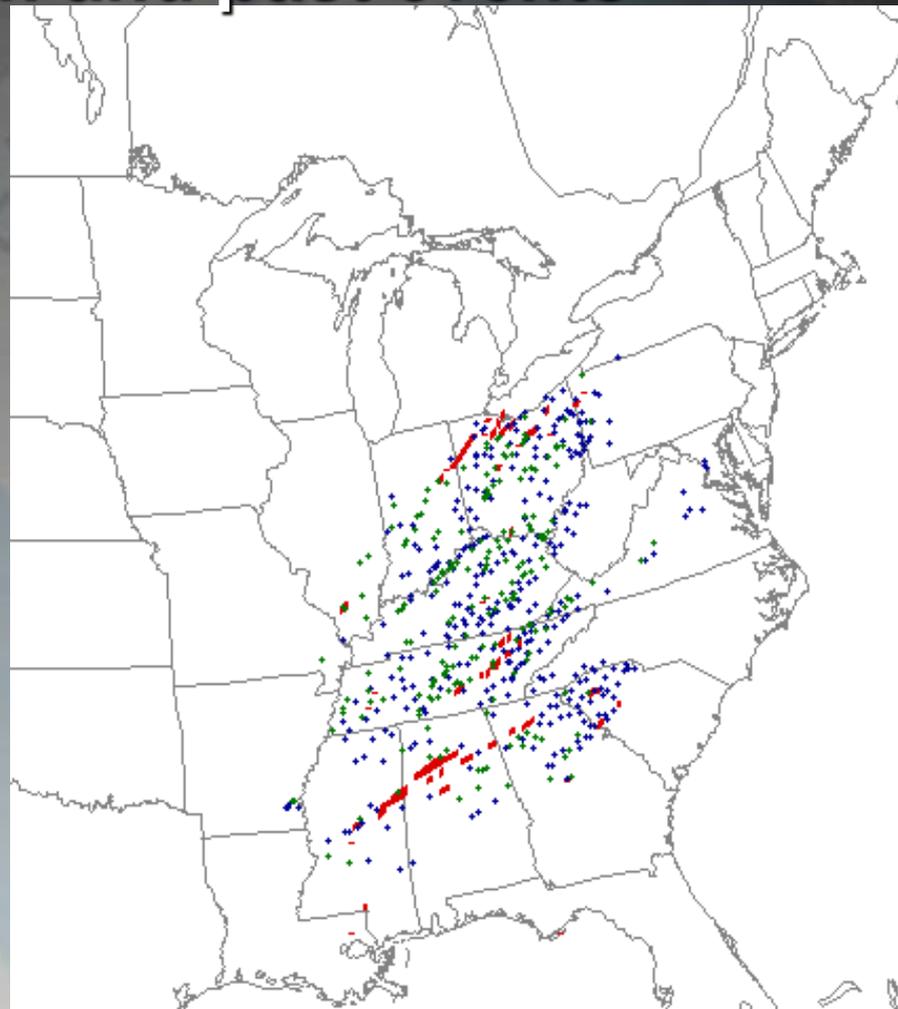


Service Assessment

Veterans Day Weekend Tornado Outbreak of November 9-11, 2002



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Silver Spring, Maryland



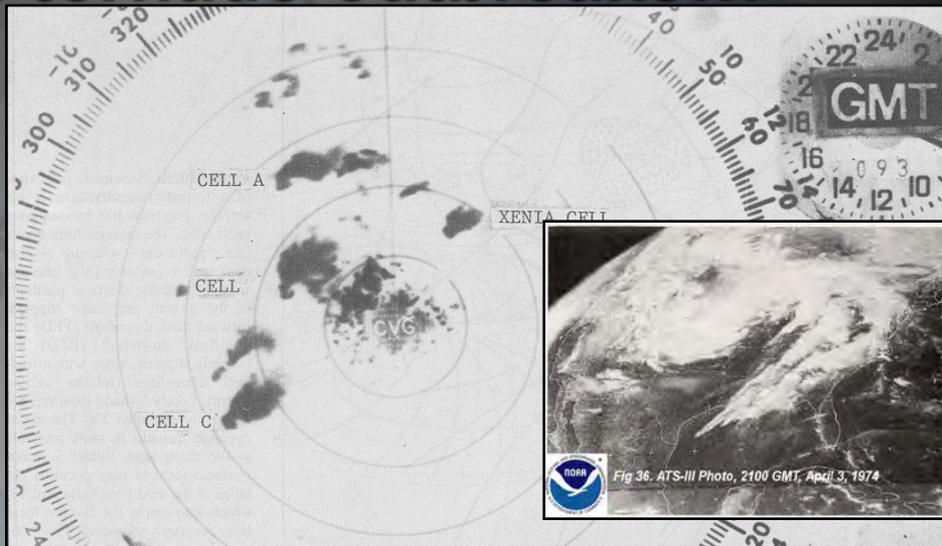
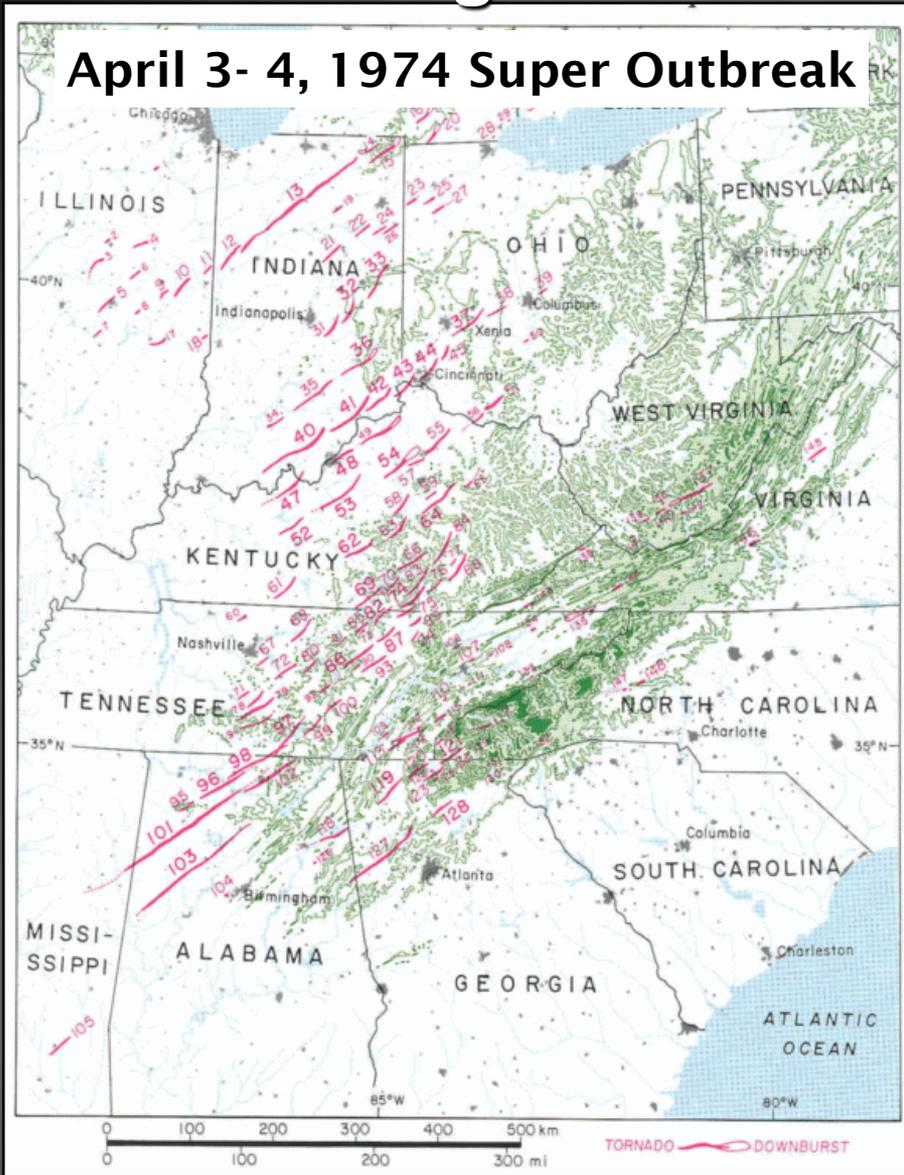
Tornadoes: 83 (1 F4, 2 F3 in AL)

States: 13

Fatalities: 36 (11 AL)

EXPERIENCE

Other significant U.S. tornado outbreaks...



EXPERIENCE

Historical flash floods

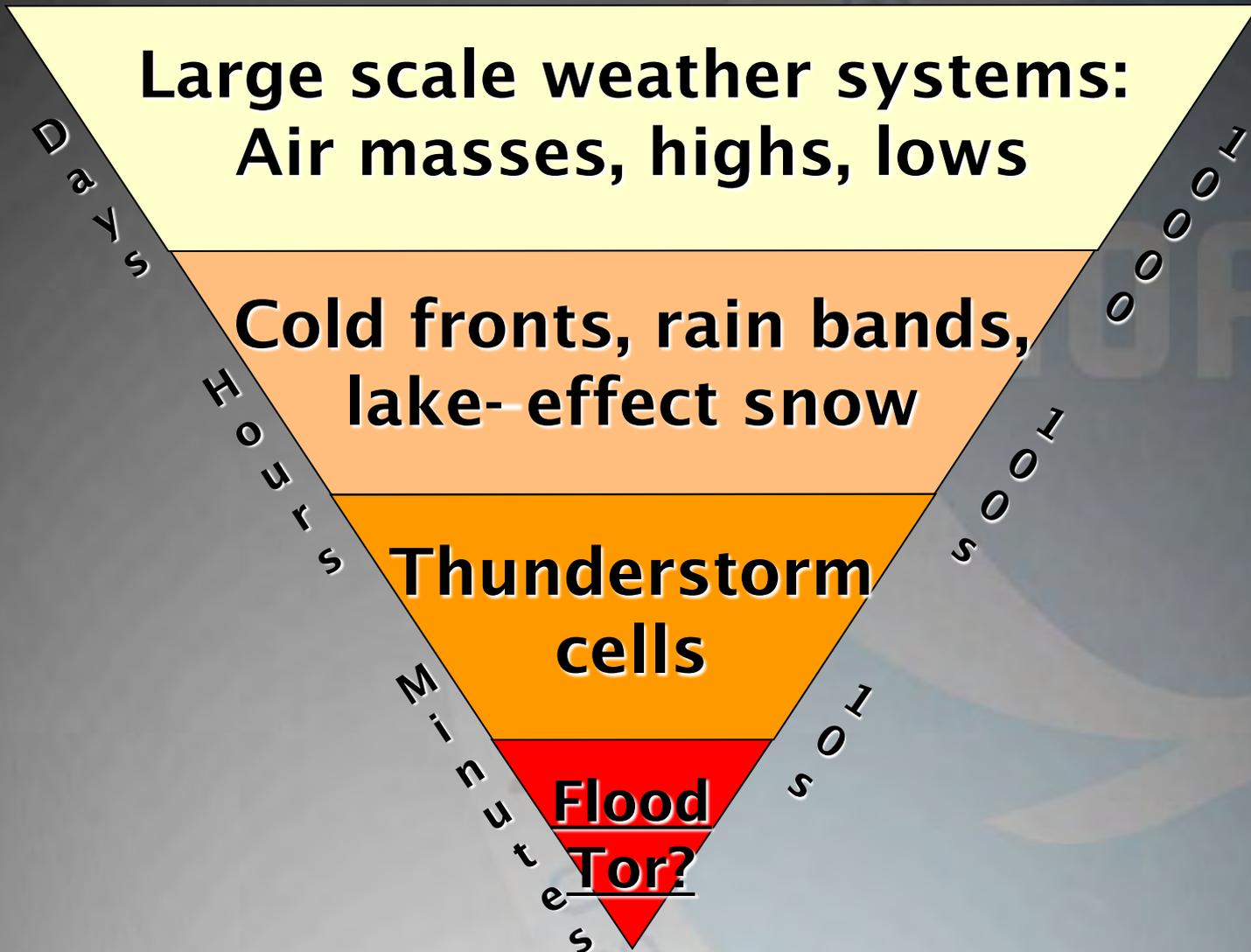


May 1889

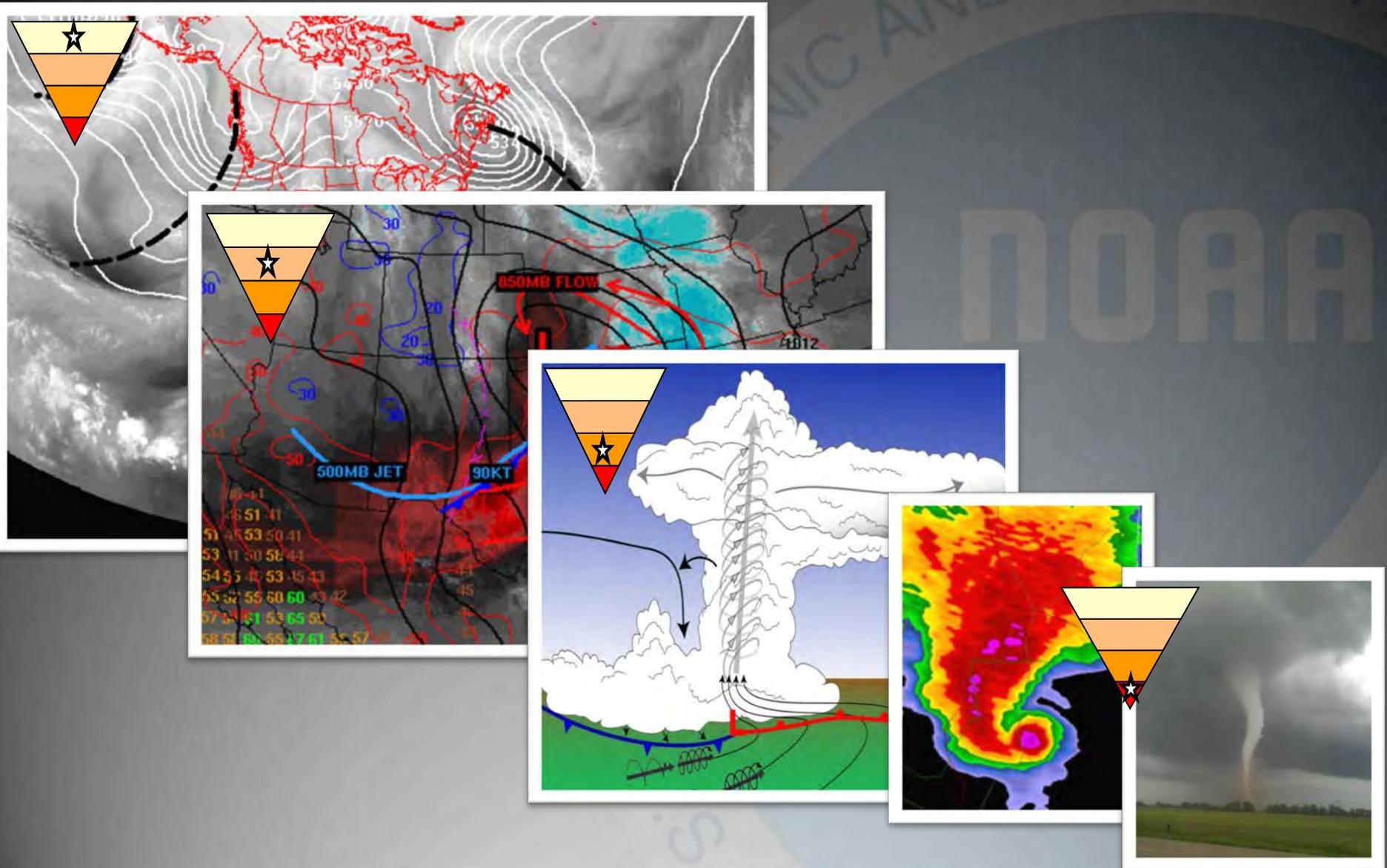


July 2016

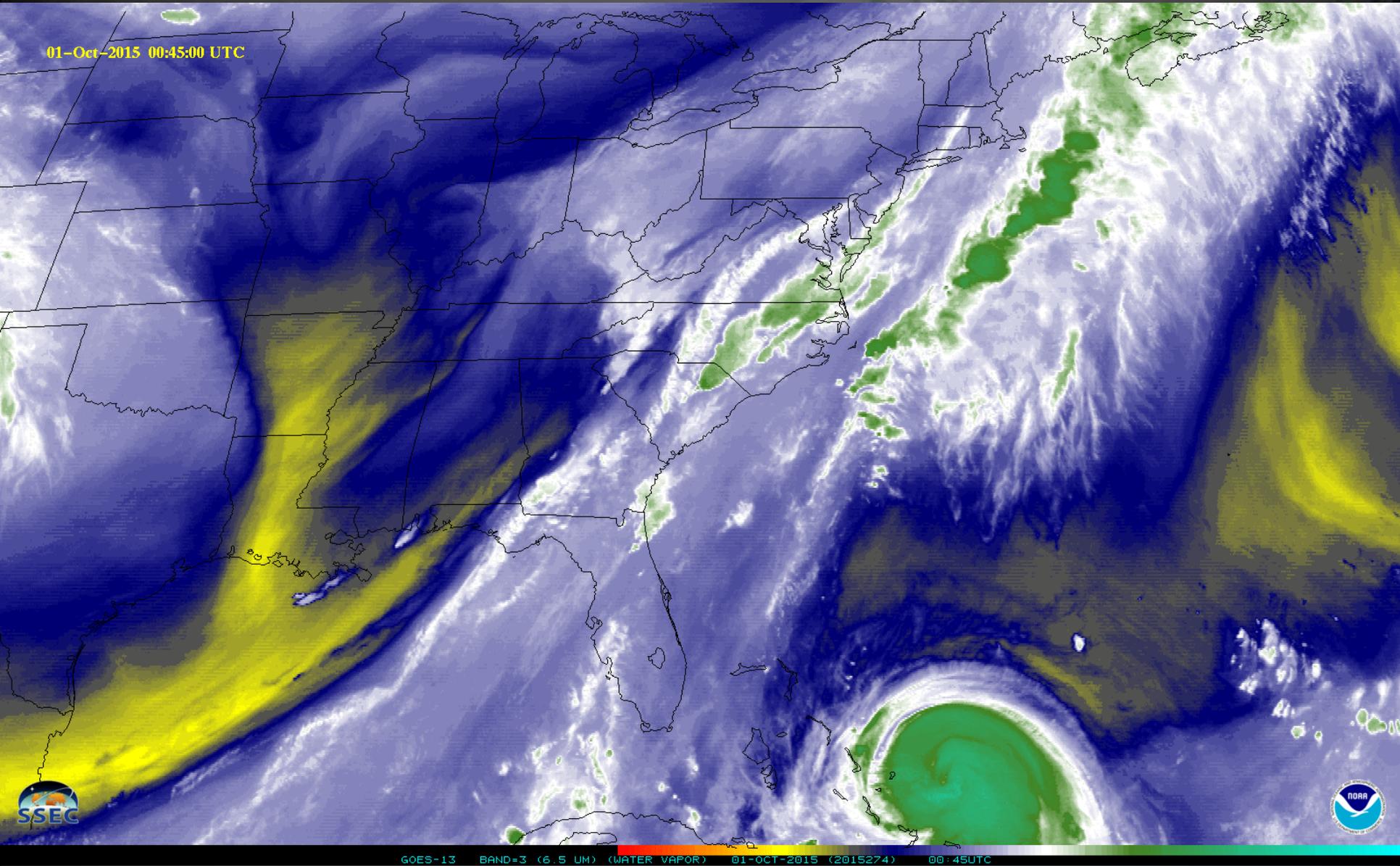
Bringing it all together: Forecast Funnel



Bringing it all together: Forecast Funnel

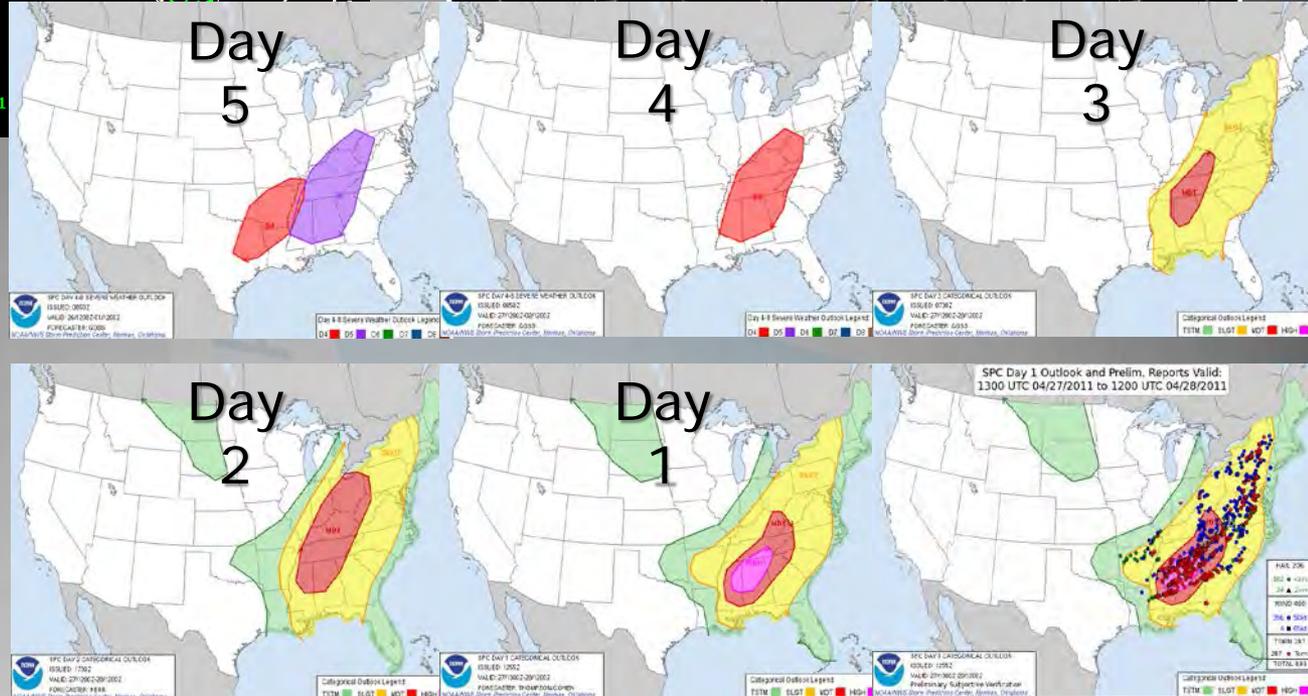
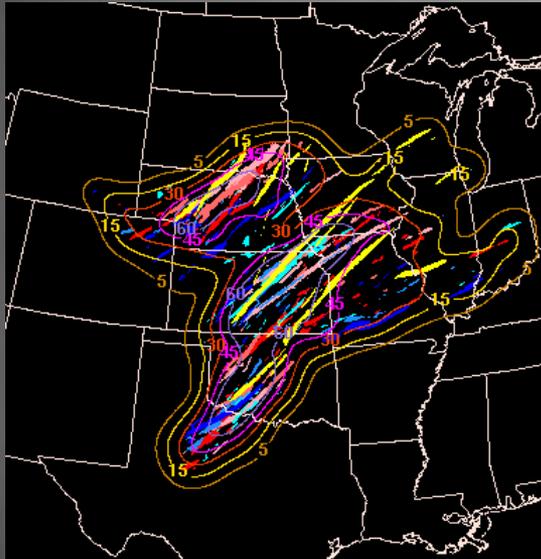
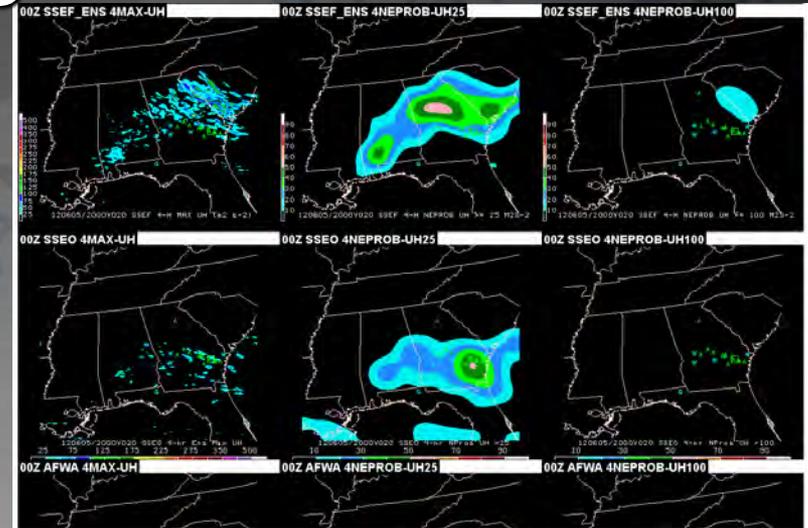
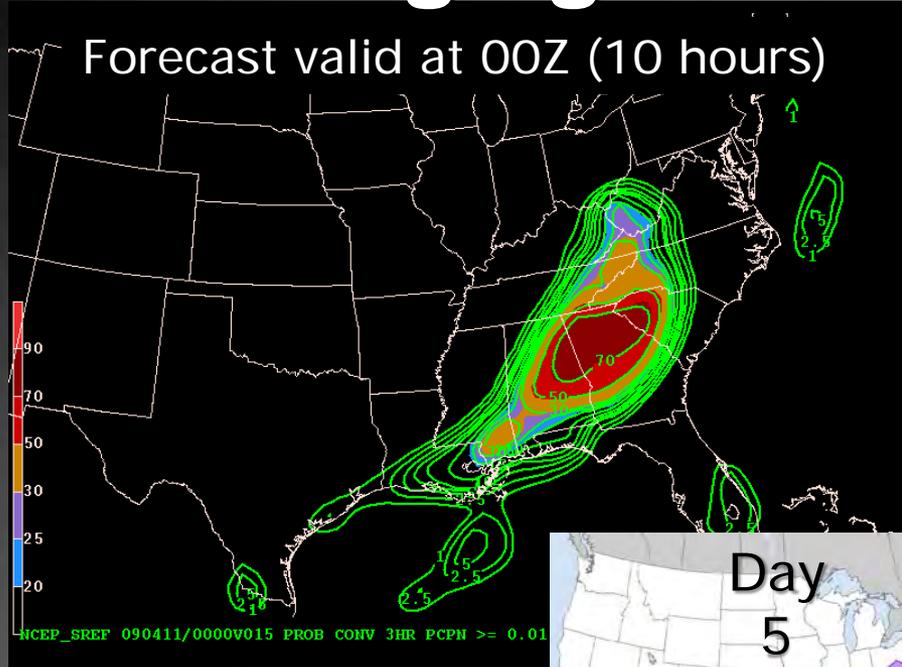


Bringing it all together: Scale Interaction

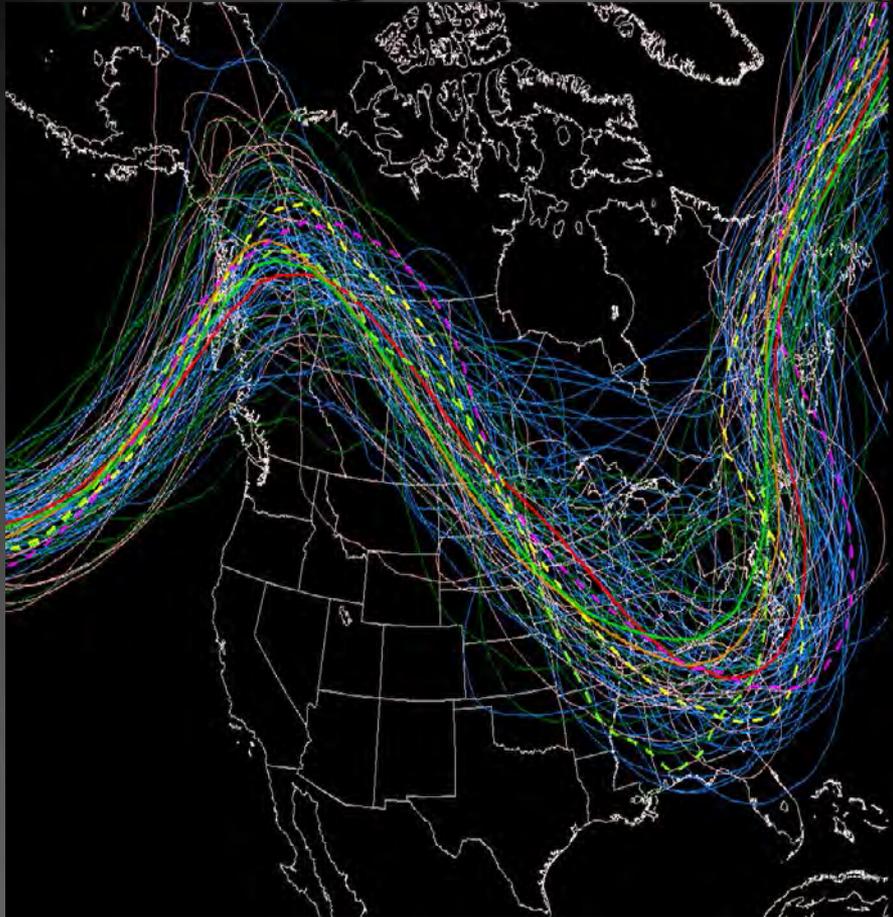


Bringing it all together: Models

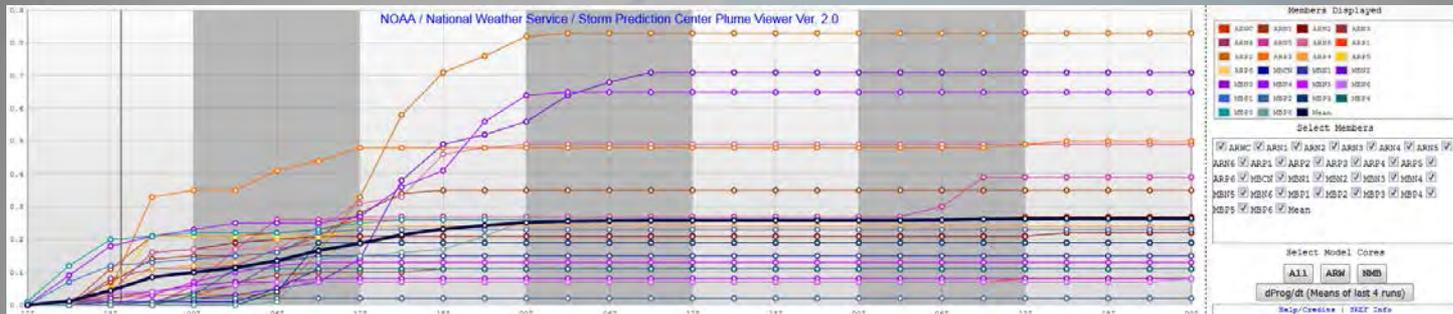
Forecast valid at 00Z (10 hours)



Bringing it all together: Ensembles



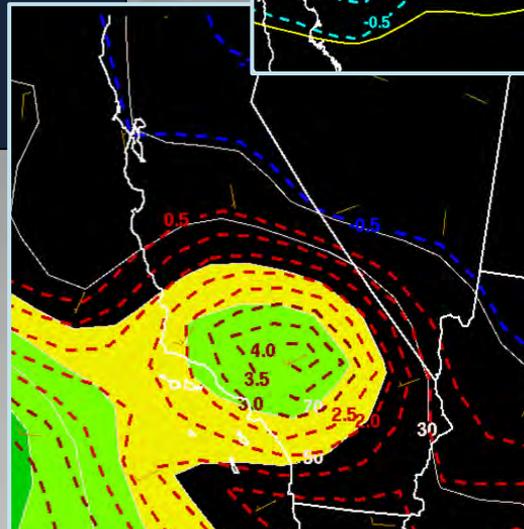
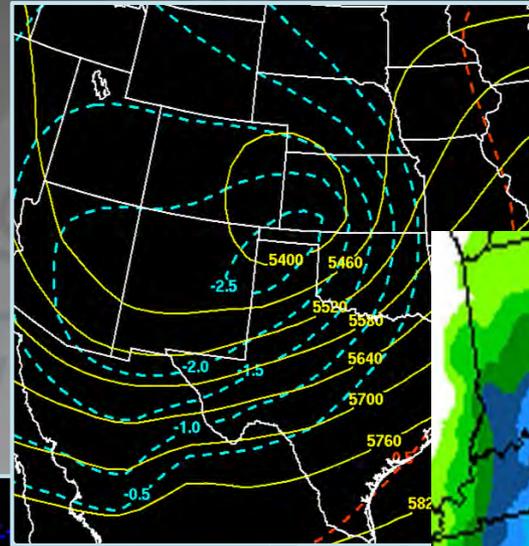
91-member spaghetti plot (left)
ECMWF ensemble 1" QPF (right)
SREF plume chart (bottom)



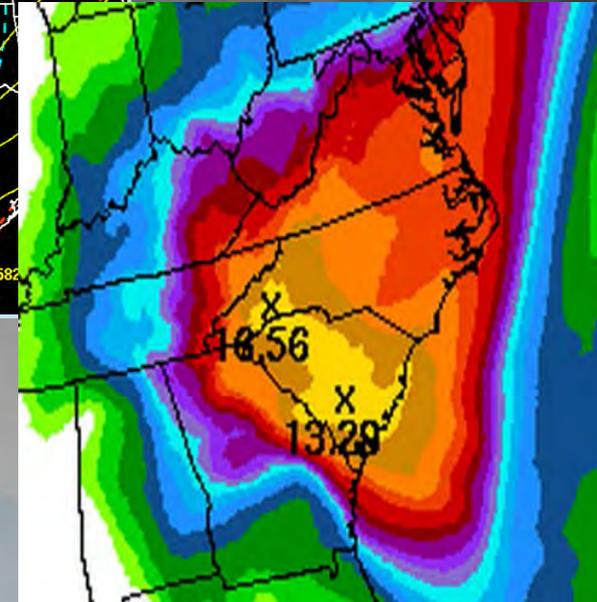
Bringing it all together: Anomalies

Ingredients-based approach

- PW and flux anomalies
- Anomaly persistence
- Warm-rain processes
- Model trends

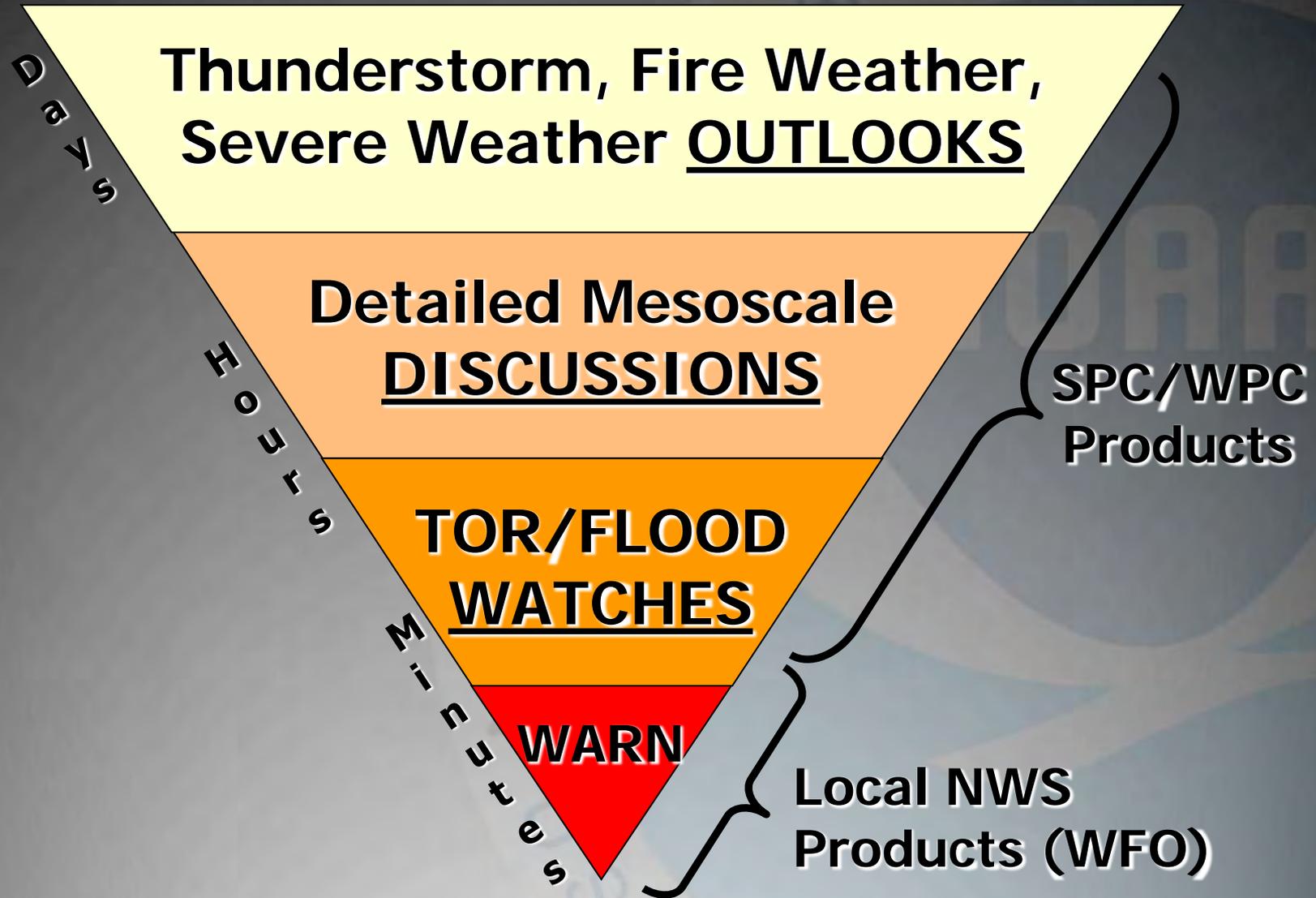


Standard deviations
from climatology



Lead confidence in
forecast of occurrence of
rare events

Bringing it all together: Products



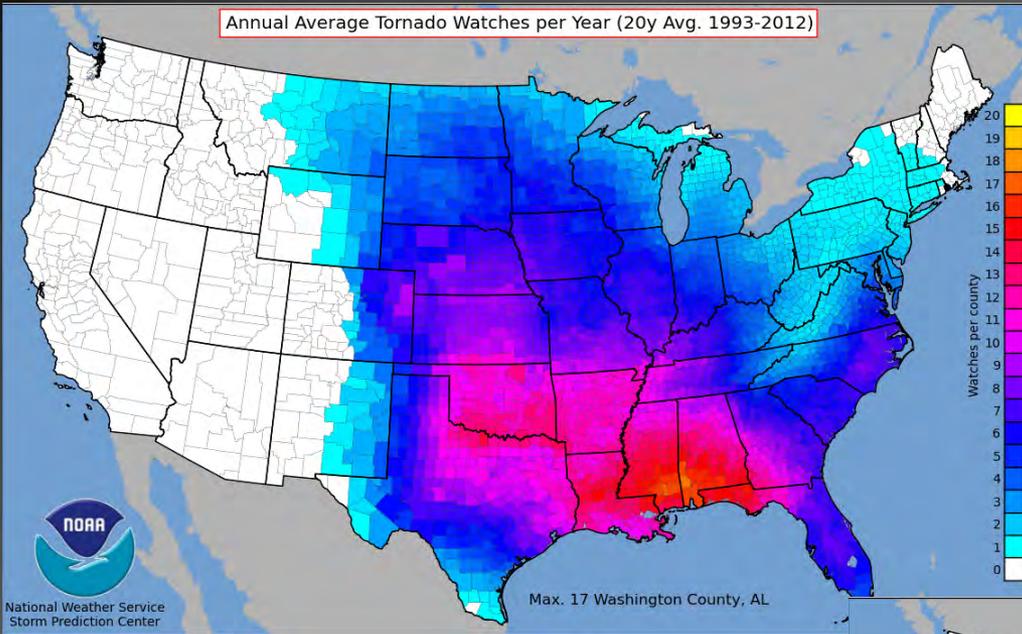
Severe Weather/Flood **Watches**

Tornado and Severe Thunderstorm

- ☁ Monitor Conditions in Your Area. Watch!
- ☁ Environment Becoming More “Favorable”
- ☁ Issued Based on Forecasts & Observations

Severe Weather Watches

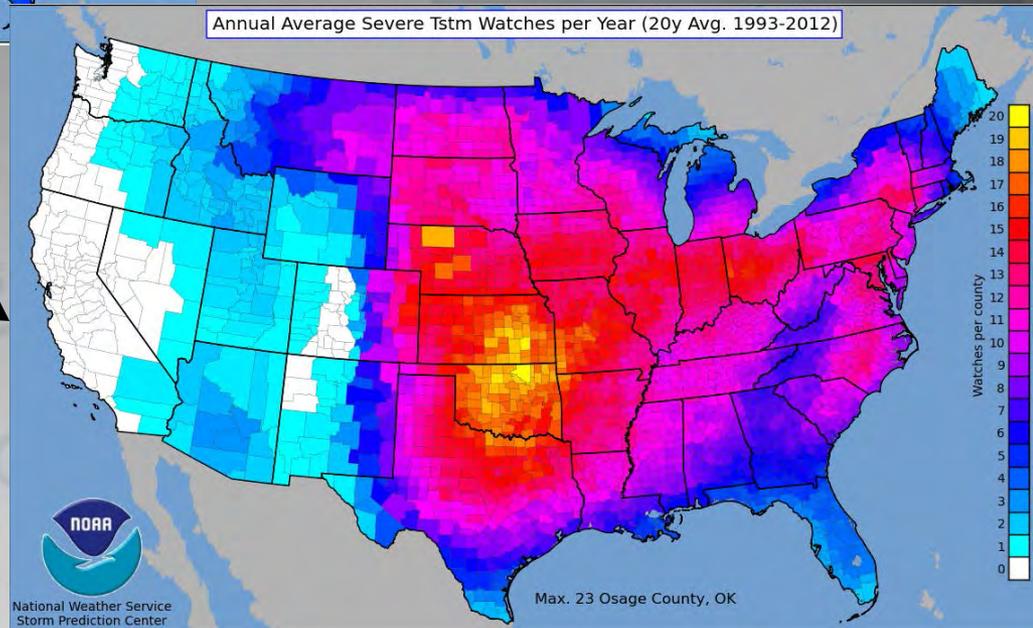
Annual Average Tornado Watches per Year (20y Avg. 1993-2012)



Tornado Watches
per year



Annual Average Severe Tstm Watches per Year (20y Avg. 1993-2012)



Severe Thunderstorm Watches
per year

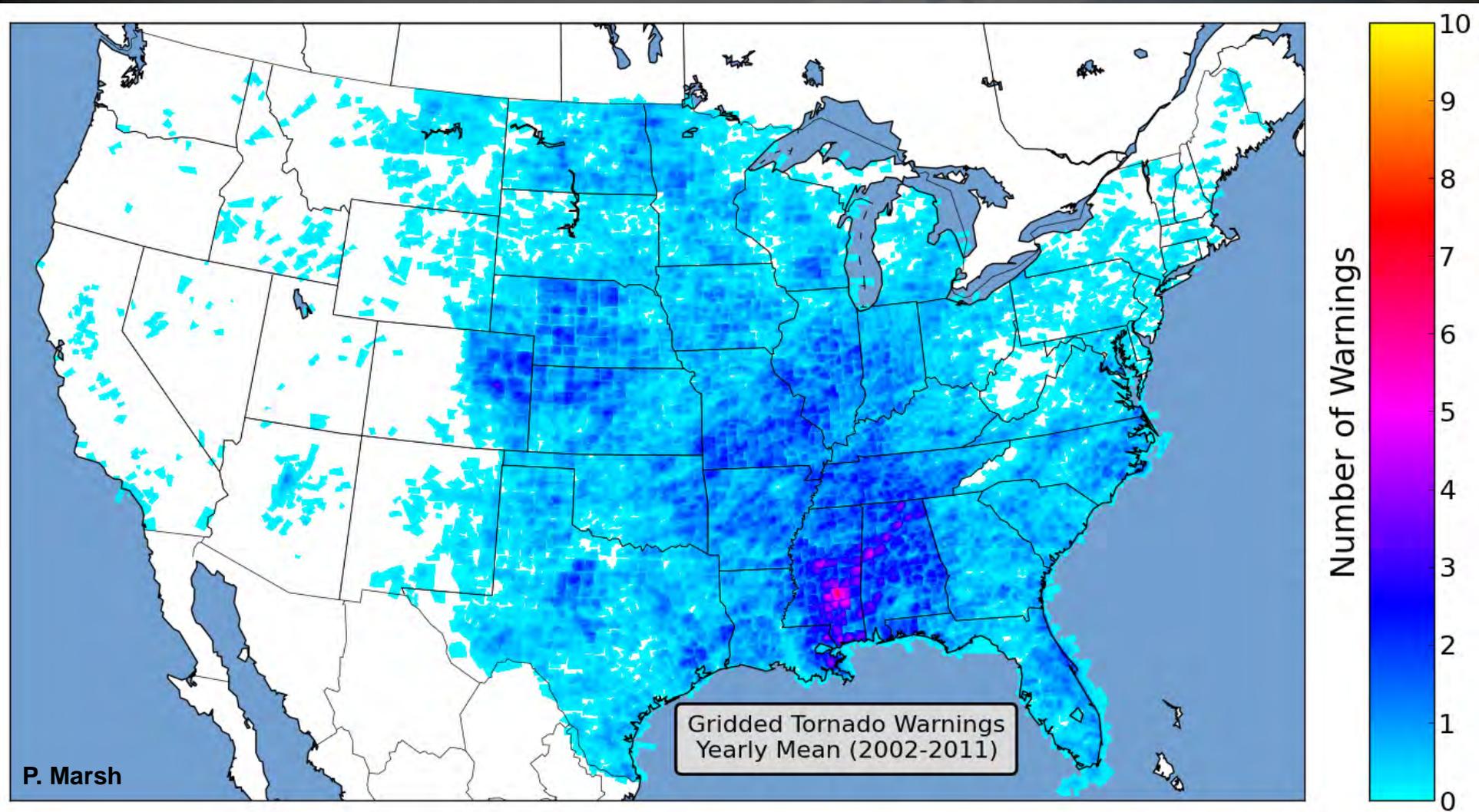


Severe Weather/Flood **Warnings**

Tornado and Severe Thunderstorm

- ☁ Take Cover Now! (Put your plan into ACTION)
- ☁ Danger is Immediate / Certainty is High
- ☁ Issued Based on Observations (radar/reports)

Severe Weather Warnings



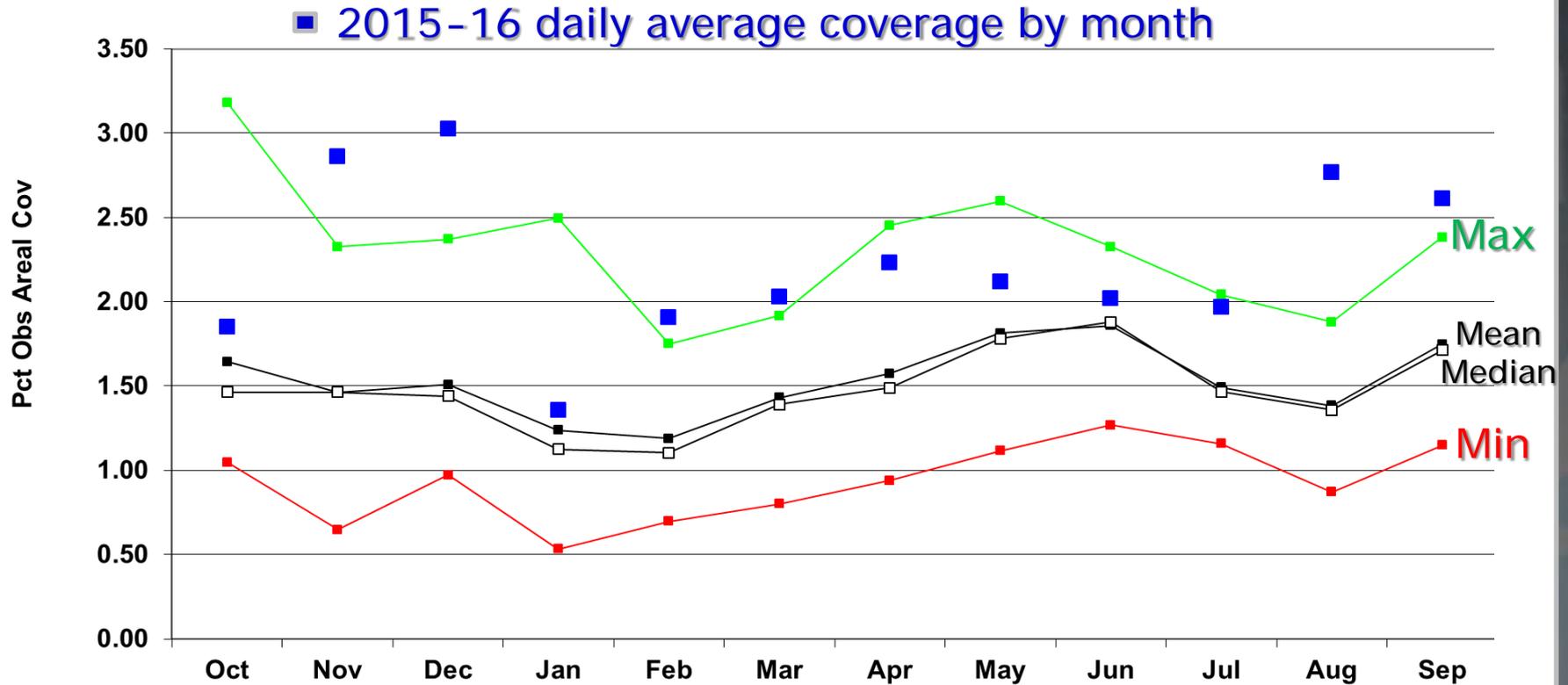
More info on weather watches

The image shows a YouTube video player interface. At the top left is the YouTube logo. To its right is a search bar and a 'Browse' button. Below the search bar is the video title 'FAQ: What's a Watch?'. Under the title, there is a channel name 'NOAAAWP', a 'Subscribe' button with a plus icon, and a dropdown menu showing '40 videos'. The video player itself features a large white speech bubble with a blue outline against a background of a sunset sky. Inside the speech bubble, a brown circle contains the text 'Frequently Asked Questions', and the main text reads 'What's a Watch?'. Below the video frame is a playback control bar showing a play button, a volume icon, and a progress indicator at '0:05 / 2:44'. At the bottom of the player are buttons for 'Like', 'Add to', 'Share', and a print icon. On the right side of the bottom bar, it shows '1,858' views and a thumbnail icon.

<http://www.youtube.com/watch?v=x3V3HZBs1Y4>

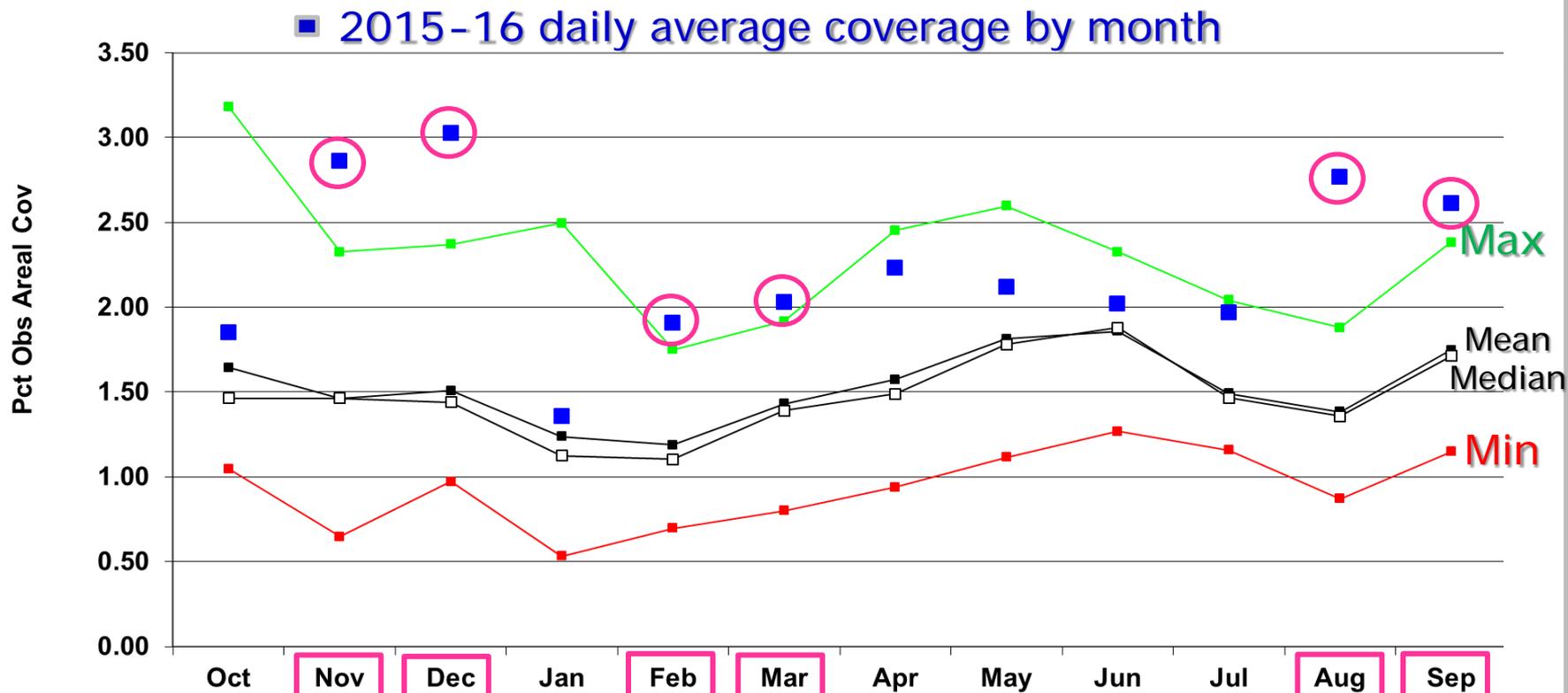
Increasingly Heavy Rainfall

17-years daily average 1" rainfall coverage over U.S by month



Increasingly Heavy Rainfall

17-years daily average 1" rainfall coverage over U.S by month



- Every one of the past 12 months has been above normal
- 6 of the past 12 months set new records for 1" coverage!

Increasingly Heavy Rainfall



Six Separate Billion Dollar Flooding Disasters in FY16
\$17.5 Billion in losses 124 Fatalities



South Carolina
Floods
Oct 2015

Midwest Holiday
Storm
Dec 2015

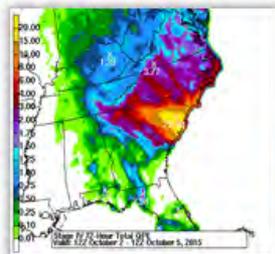
TX/Louisiana
Flood
March 2016

Houston
Flash Flood
April 2016

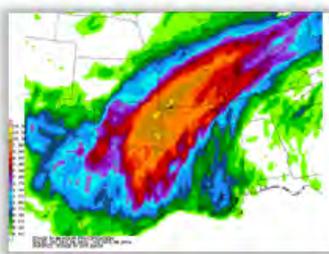
WV Flash Flood
June 2016

Louisiana
Flood
Aug 2016

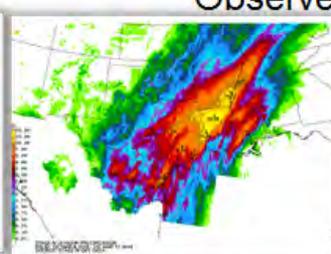
Observed Rainfall



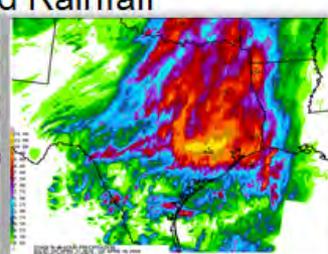
25 Fatalities



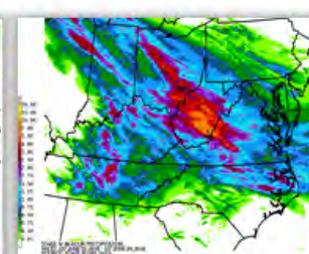
50 Fatalities



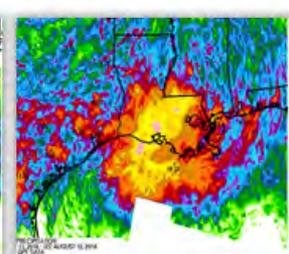
5 Fatalities



8 Fatalities



23 Fatalities

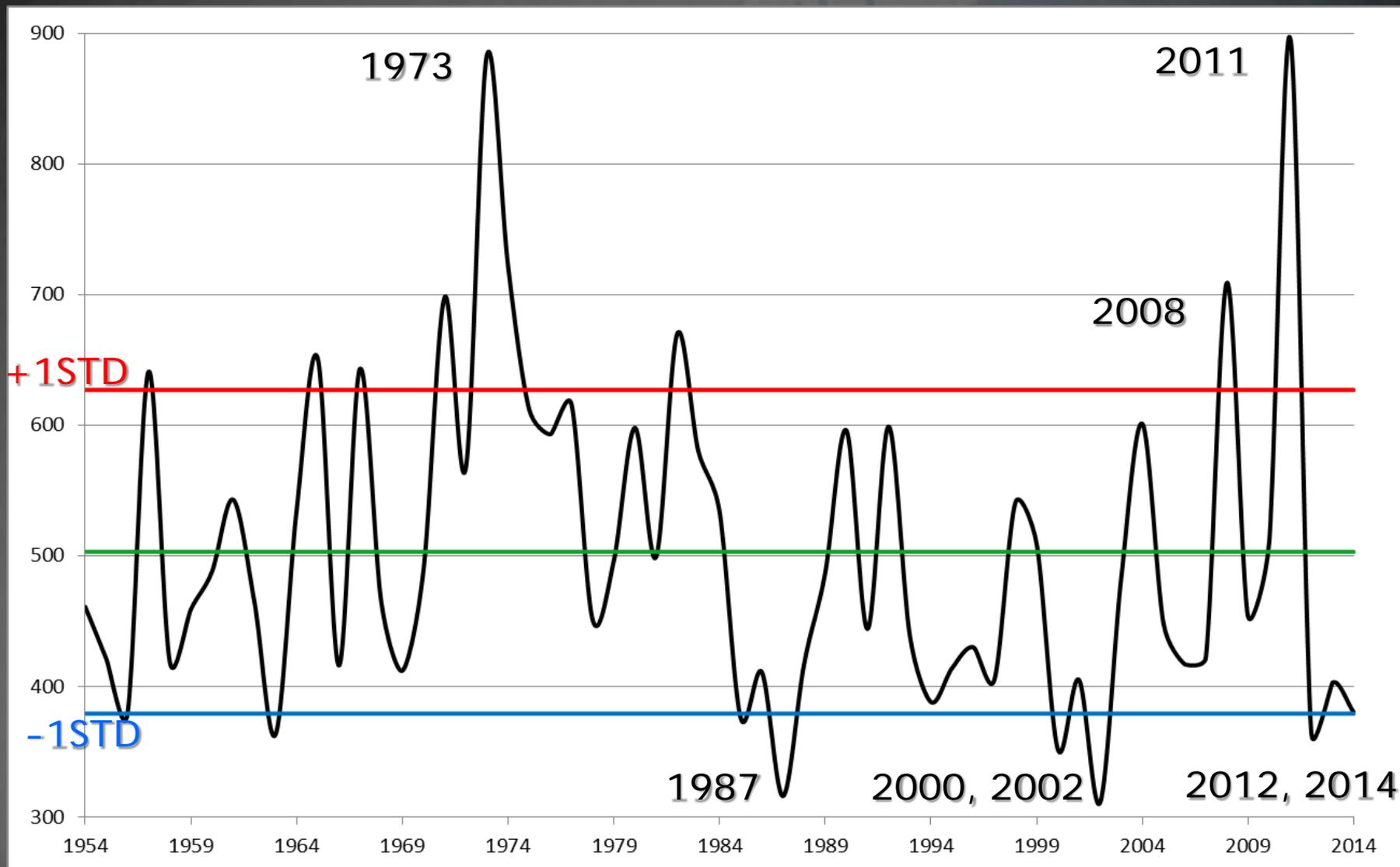


13 Fatalities

Source: NCEI

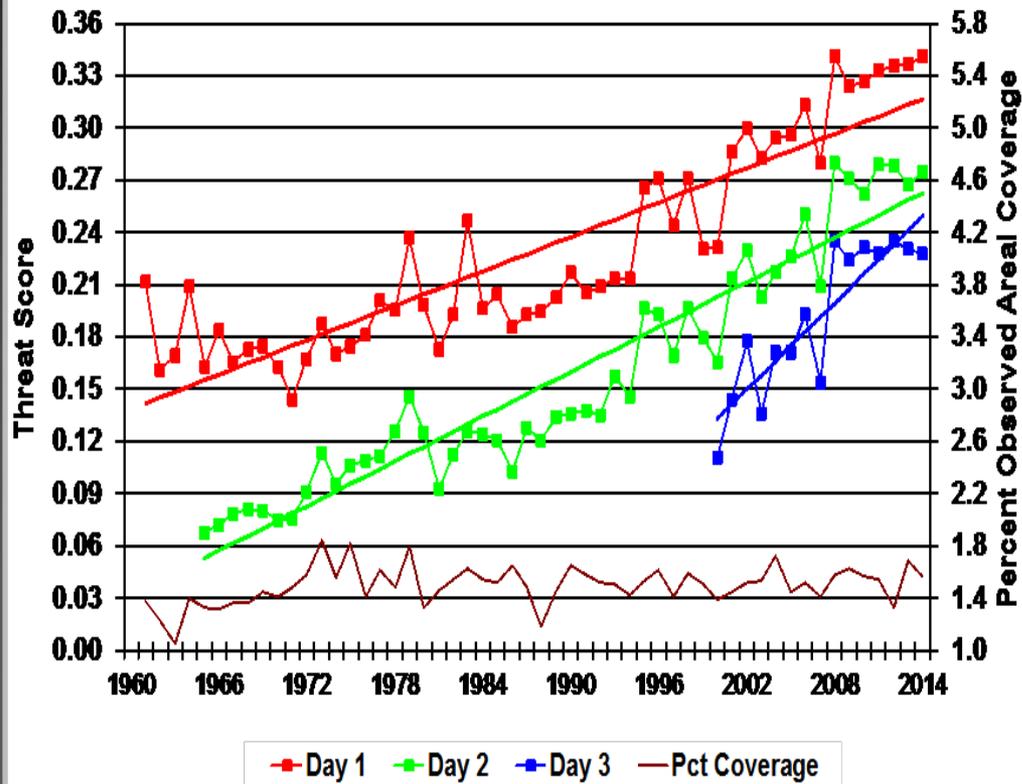
Tornado Variability in Recent Decades

60-years of Annual (E)F1 and Stronger U.S. Tornado Counts



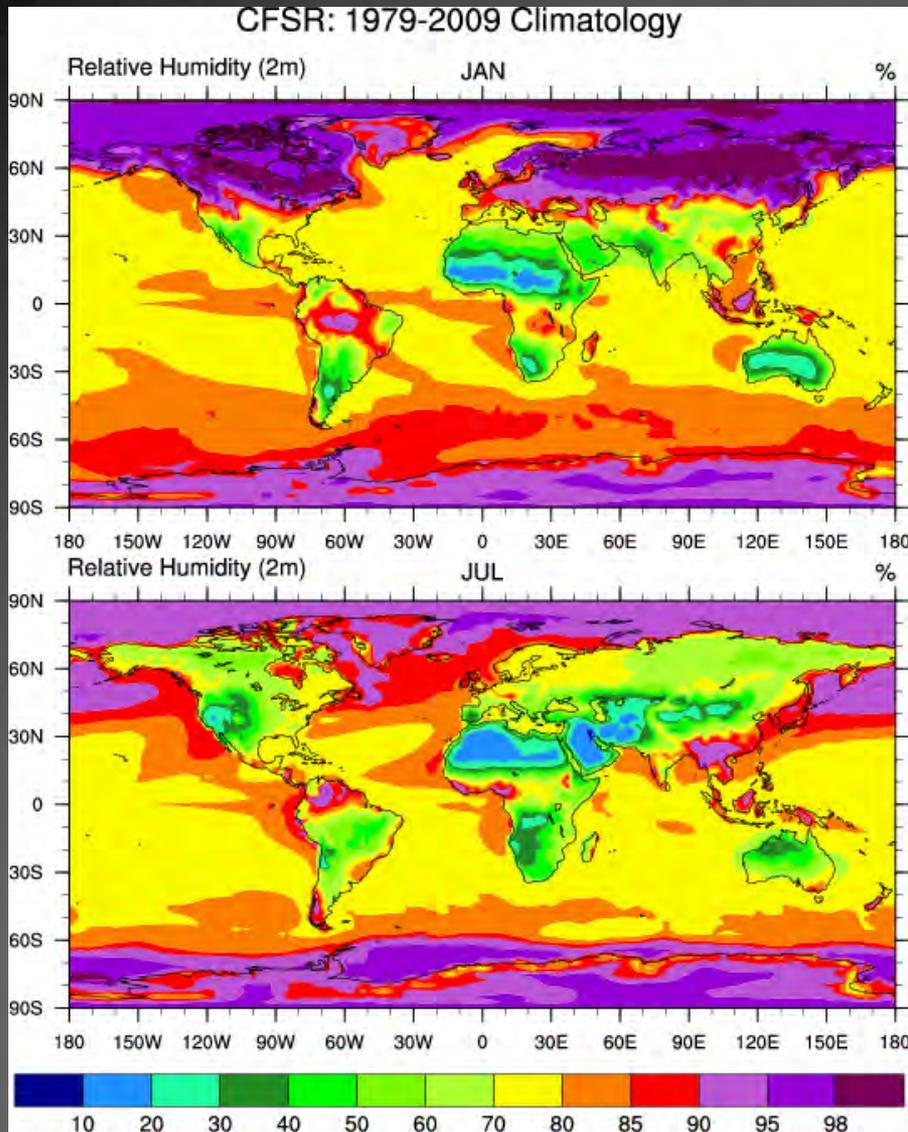
Predictions Have Steadily Improved

WPC QPF verification
1-inch threat score



- Gap between Day 1, 2, 3 threat scores is narrowing
- Upward trend began in 1970s with LFM NWP
- Abrupt jump in 1990s w/ modernization/WSR-88D
- Day 3 scores today as good as Day 1 scores in 1994

What's Next?



Climate Forecast System (CFS)

V2 Became operational in March 2011

Global model: coupled ocean-sea ice-land-atmosphere

1979-2011 CFS-reanalysis was used to calibrate and initialize the CFSv2 but CDASv2 is used to init operational CFSv2 runs

T126 horizontal resolution (~100km)
&
64 vertical sigma-pressure hybrid layers

16 CFSv2 operational runs per day
Forecasts to at least 45 days!

What's Next?

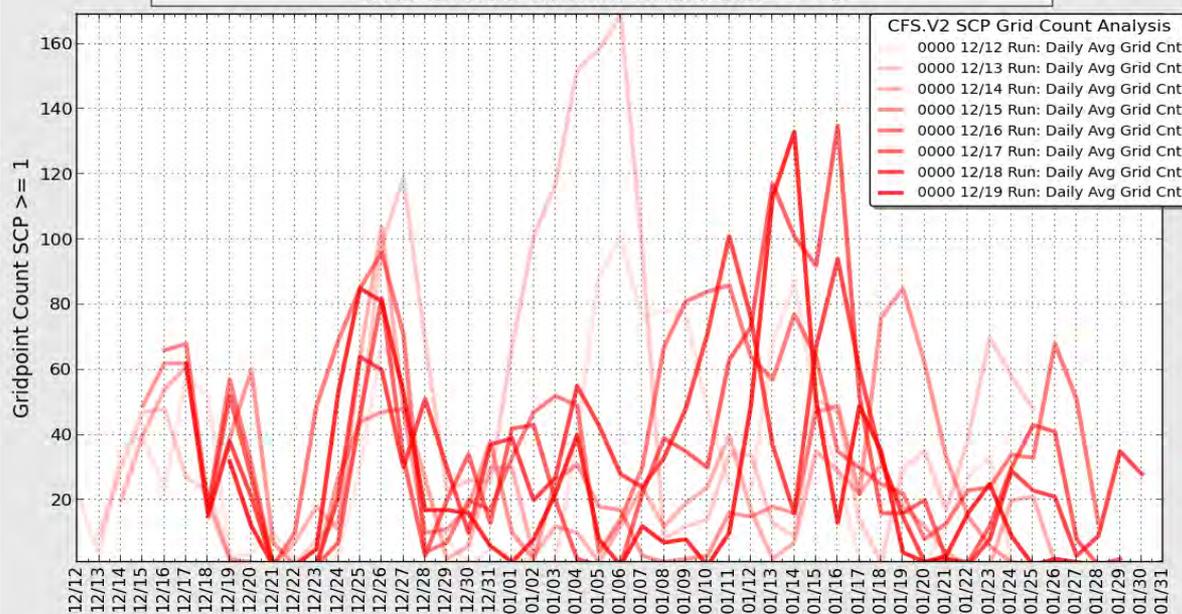


Evaluating a large ensemble of forecasts depicting the ingredients for severe thunderstorms over a limited domain.

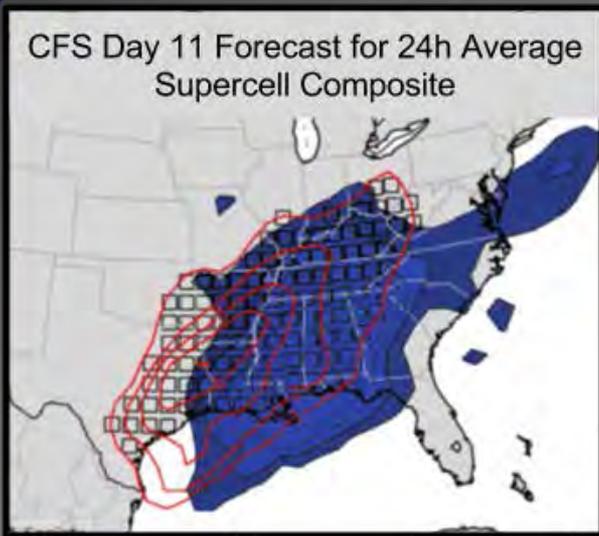
Forecast consistency provides insight into regime predictability.

R2O efforts are ongoing to extend predictions beyond 7 days.

Comparison of recent CFS.V2 runs for daily averaged gridpoint count over CONUS domain where $SCP \geq 1$



What's Next?



SPC 20 UTC Day 1 Outlook issued Saturday, Dec. 21, 2013



More information and links...

Current time (in UTC/GMT/Julia): 16:45:56

Storm Prediction Center

N O A A / National Weather Service

NOA: NWS SPC SFC/STC/STL WEA/WH/ENG FORECASTS/TOOLS/REL/BAORD/DT/WH/ACH/WB/NOB/

A Moderate Risk of Severe Thunderstorms is Forecast Today and/or Tonight
 THE NWS STORM PREDICTION CENTER IN NORMAN OK IS FORECASTING THE DEVELOPMENT OF TORNADOES, LARGE HAIL AND DAMAGING WINDS OVER PARTS OF THE SOUTHERN/CENTRAL PLAINS LATER TODAY AND TONIGHT.
 For additional details, see the current [Public Severe Weather Outlook \(PWOT\)](#).

Overview Conv. Outlook Watches MDS Storm Reports Mesoanalysis Fire Hazards

All Products Watches MDS Outlooks Fire

Enhanced Thunderstorm Outlook
 - Issued: 9 minutes ago

Day 1 Convective Outlook
 - Categorical Risk: **MODERATE**
 - Issued: 10 minutes ago

TORNADO 0114
 - Valid until: 04/18/2013 0300Z
 - States affected: KS MO
 - Issued: 32 minutes ago

Day 1 Fire Weather Outlook
 - Categorical Risk: **MODERATE**
 - Issued: 04/17/2013 at 1520Z

SEVERE THUNDERSTORM 0113
 - Valid until: 04/17/2013 2200Z
 - States affected: IA IL MO WI
 - Issued: 04/17/2013 at 1415Z

SPC Activity Chart
 201304171444

Severe Weather Climatology (1982-2011)
 Significant Hail Probabilities: 17 Apr

Today's Storm Report Trend
 report count vs report time

Did You Know?
What's a Watch?
 Find out the difference between a severe weather Watch and Warning.

Forecast Tools
 Observed Soundings

2013 Watch Summaries

Severe Weather IQ
Tornado Safety
 Tornado Safety

Latest SPC Publications

Latest SPC Case Archive
 April 11, 2013 Tornado: 25 Wind: 133 Hail: 21
 SPC Storm Reports for 04/11/13

WEATHER PREDICTION CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NCEP AWC CPC EMC NCO NHC OPC SPC SWPC WPC

HOME FORECASTS & ANALYSES ARCHIVES VERIFICATION INTERNATIONAL DEVELOPMENT ABOUT SEARCH

HAZARD DAY 1 (OCT 21) DAY 2 (OCT 22) DAY 3 (OCT 23) DAY 4-7 (OCT 24-OCT 28)

EXCESSIVE RAINFALL SLIGHT MARGINAL NO AREA
 HEAVY SNOW (≥ 4") SLIGHT HIGH MODERATE
 ICE (≥ 0.25") NO AREA NO AREA NO AREA

DAY 4-7 HAZARDS ARE CURRENTLY AVAILABLE AT THE CLIMATE PREDICTION CENTER

National Forecast Charts Legacy Page: Valid Fri Oct 21, 2016

Day 1 Day 2 Day 3

Weather Forecast for Fri, Oct 21, 2016, issued 4:47 AM EDT
 ©2016 NOAA/NWS/NCEP/Weather Prediction Center
 Prepared by McCreynolds based on WPC, SPC and NHC forecasts

WPC Top Stories:
 Mesoscale Precipitation Discussion #0750 is currently in effect

Learn about WPC's MetWatch Desk

Tweets by @NWSWPC

NOAA NWS Weather Prediction Center
 431K likes

NOAA NWS Weather Prediction Center added 2 new photos.
 20 hrs

Heavy rainfall is expected across portions of the Ohio Valley and Northeast this weekend as a strong cold front pushes through the region. Flash flooding will be a concern with several inches of rainfall expected. Cold air surging in behind the front will allow rain to change to snow across the higher elevations of upstate New York and northern New England Saturday night into Sunday. The first image shows the probability of at least 2 inches of snowfall through Sunday evening. The second image shows the precipitation forecast through Sunday evening.

LIGHTNING SAFETY FLOOD SAFETY FALL PREPAREDNESS



Acknowledgements



Russell Schneider

Harold Brooks

Steve Corfidi

Keli Pirtle

James Murnan

Mark Darrow

David Novak

Patrick Burke

Marty Rausch

Thank-you!

Gregory.Carbin@noaa.gov (@GCarbin)



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Will Campbell