

# SEVERE WEATHER: RESEARCH AND APPLICATIONS

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DEPARTMENT OF GEOGRAPHIC AND ATMOSPHERIC SCIENCES


NORTHERN ILLINOIS UNIVERSITY

13 SEPTEMBER 2018



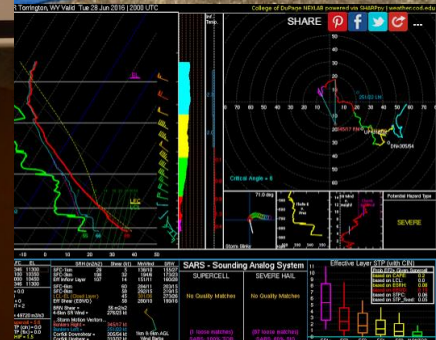
PRESENTATION FOR

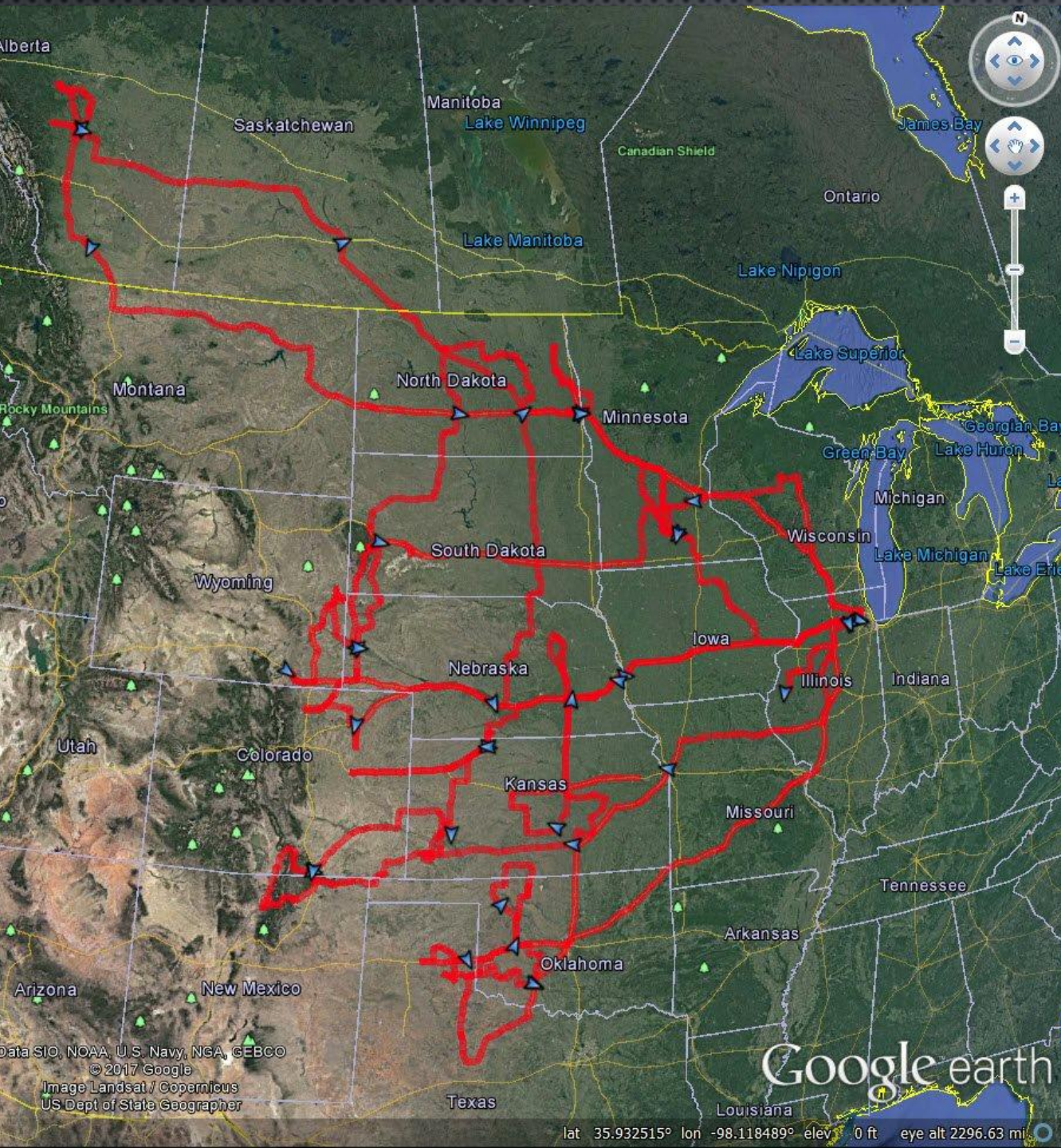


 Northern Illinois University  
**Vittorio (Victor) A. Gensini, Ph.D.**  
Assistant Professor  
Department of Geographic and Atmospheric Sciences  
Northern Illinois University



**WX GEEKS** DR. VICTOR GENISINI  
Professor - College of DuPage, NIU



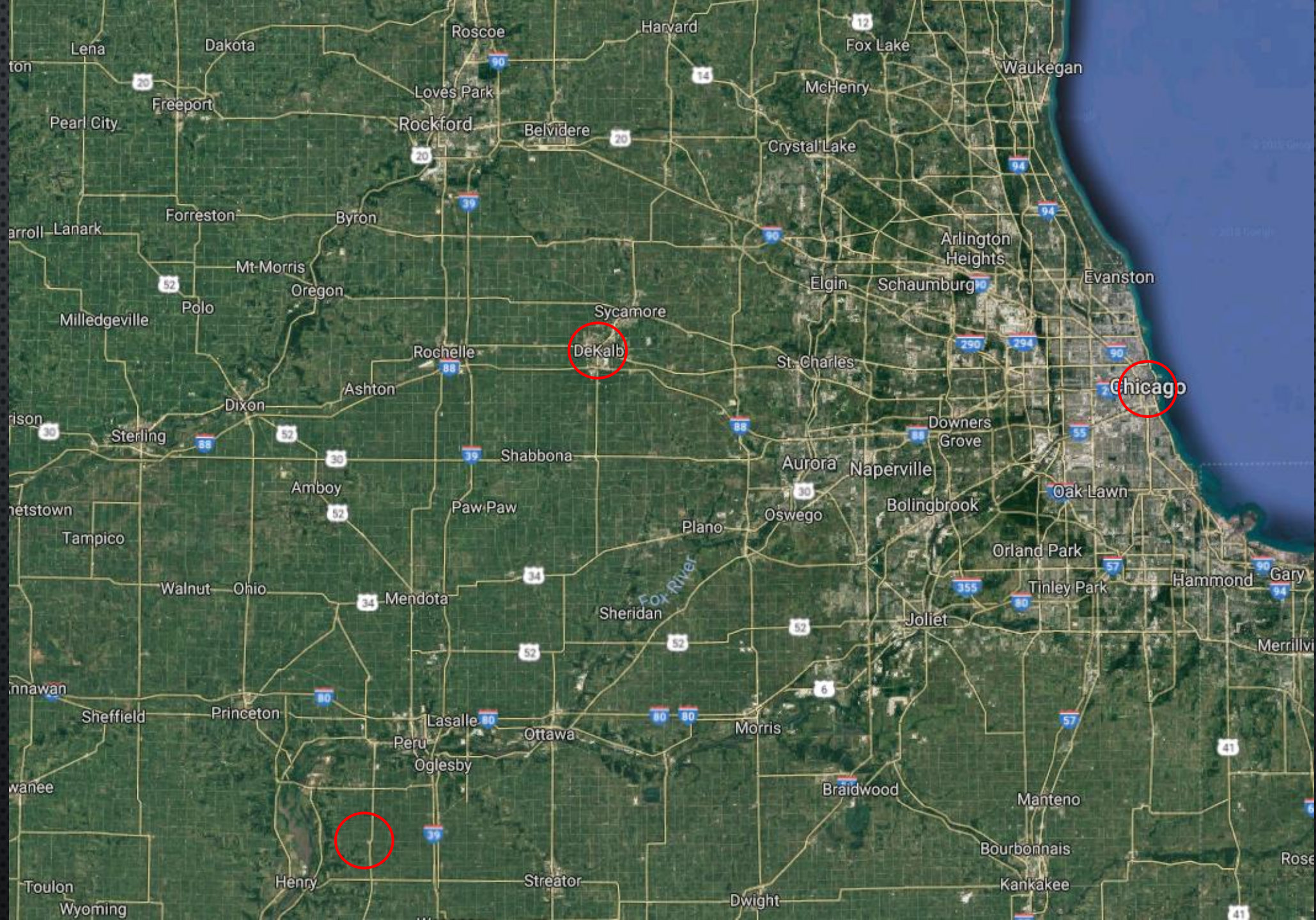


22,500 MI

GENSINIWX.COM

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DeKalb

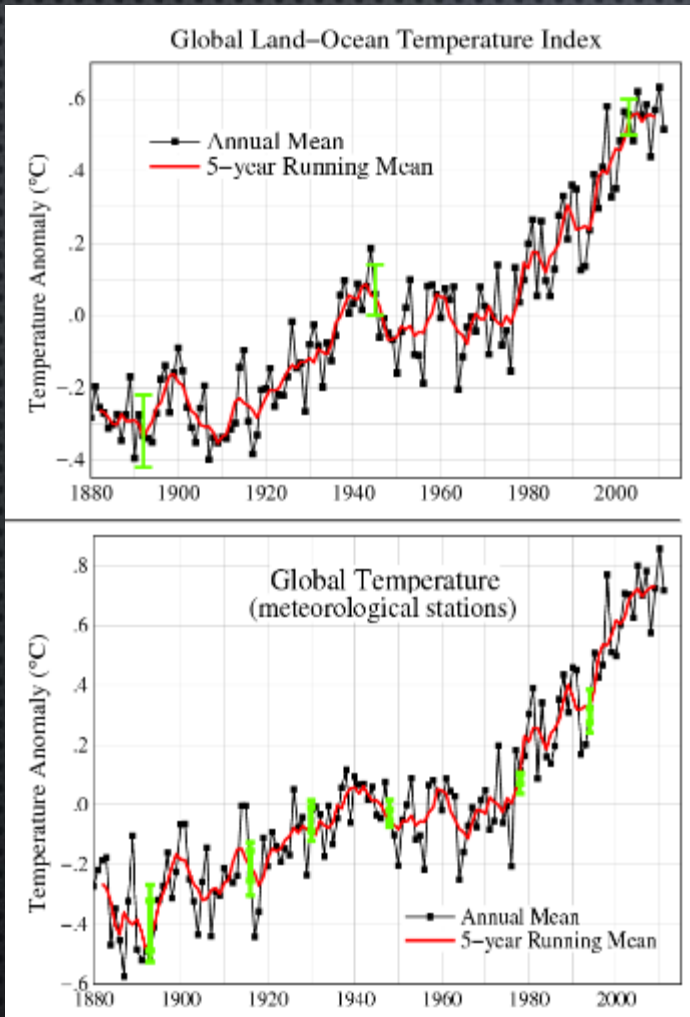
Chicago

# April 20, 2004 Granville to Utica, IL F3 Tornado Path



Photo courtesy of Jerry Funfsinn





*Hansen et al. (2001)*



*Image courtesy of Dr. Walker Ashley*

PAST

**The Palm Sunday Outbreak  
1965**

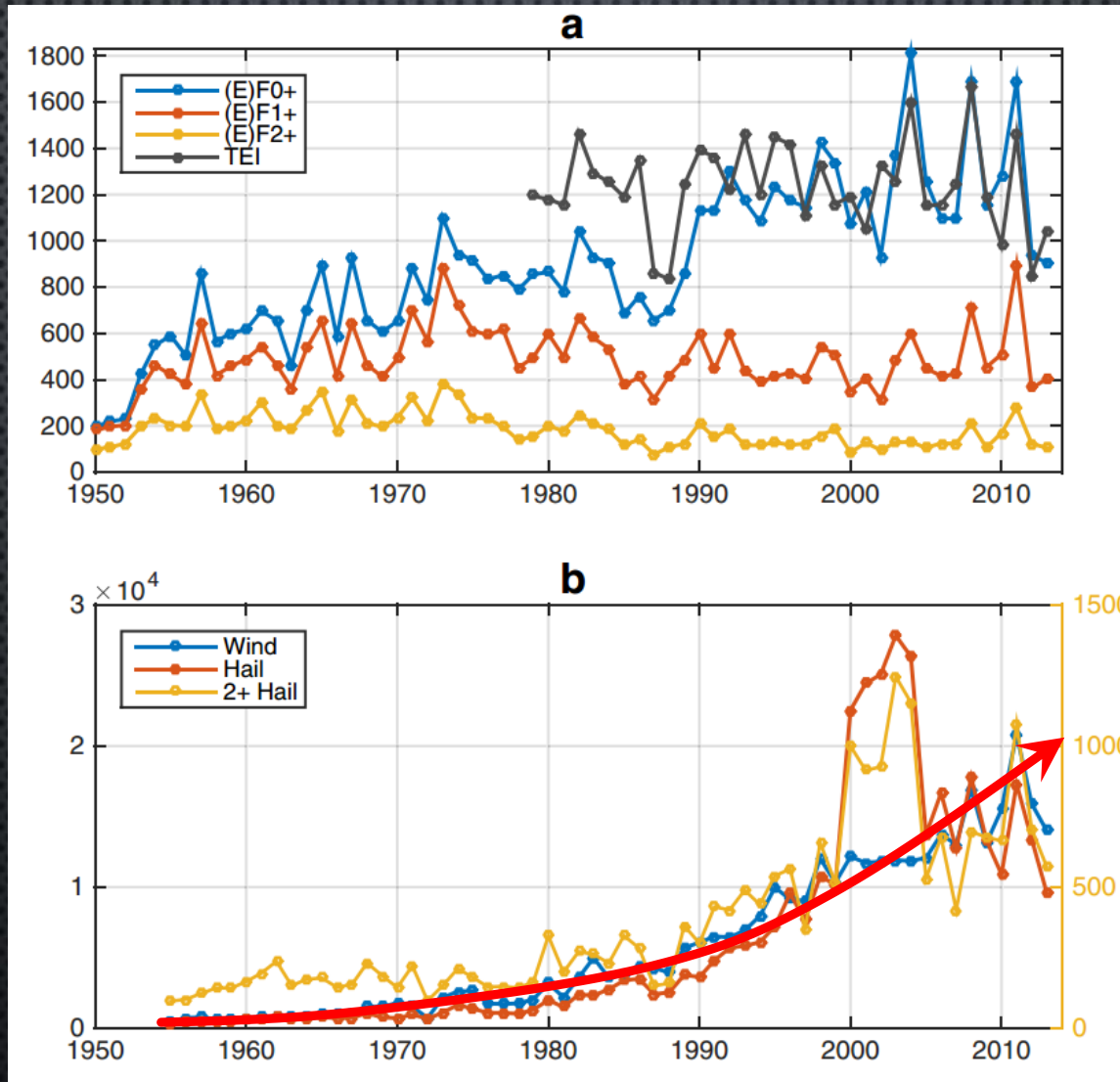


# REPORTS HAVE CAVEATS...

**Currently**

- More specific
- Increased clarity
- Supports new dissemination technology

Storm-Based Tornado Warnings  
70% less area covered  
~600,000 fewer people warned



Tippett, M. K., J. T. Allen, V. A. Gensini, and H. E. Brooks, 2015: Climate and hazardous convective weather. *Cur. Climate Change Rep.* DOI: 10.1007/s40641-015-0006-6

# INGREDIENTS BASED APPROACH



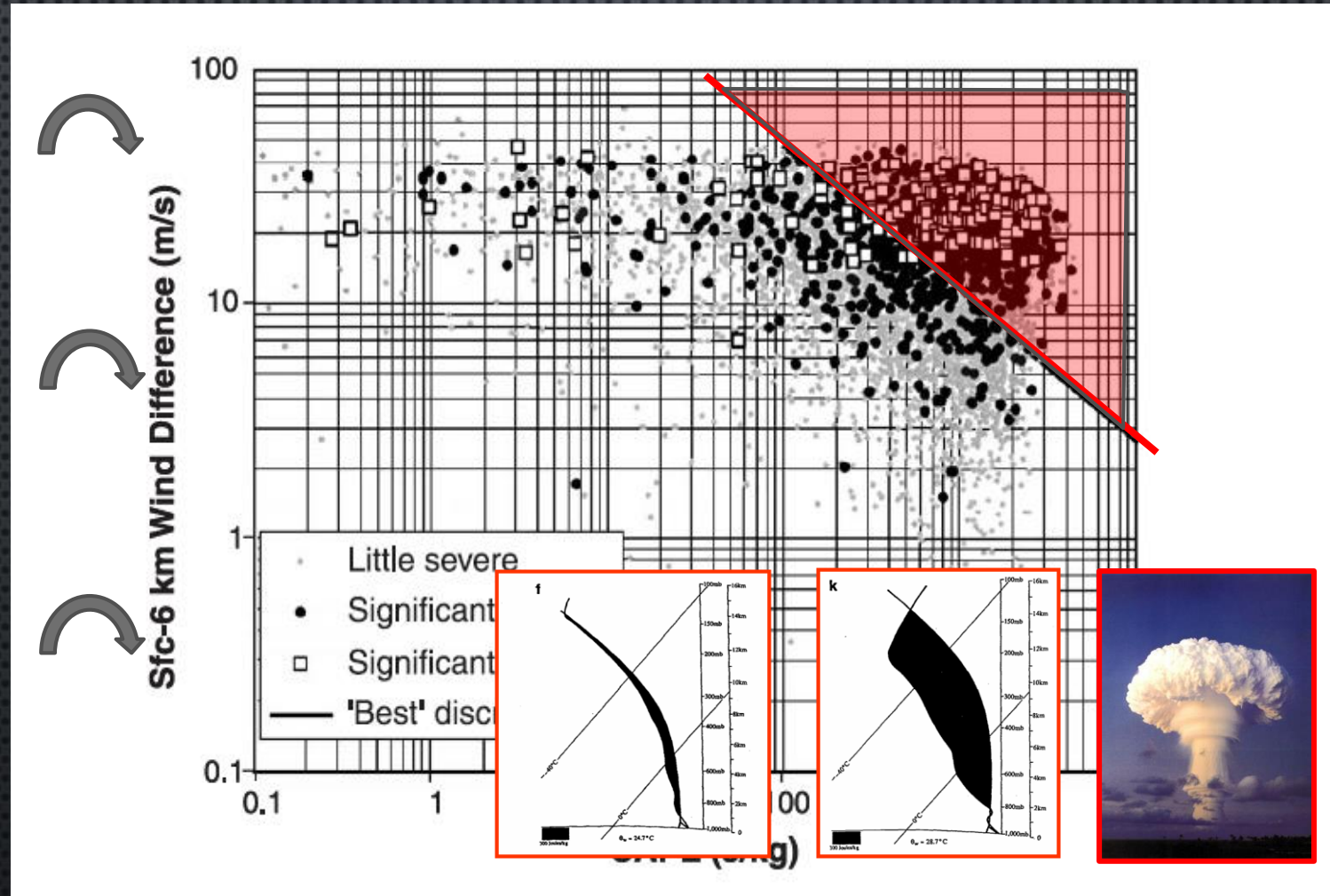
Apples  
Sugar  
Flour  
Egg



Shear of the vertical wind  
Lift  
Instability  
Moisture

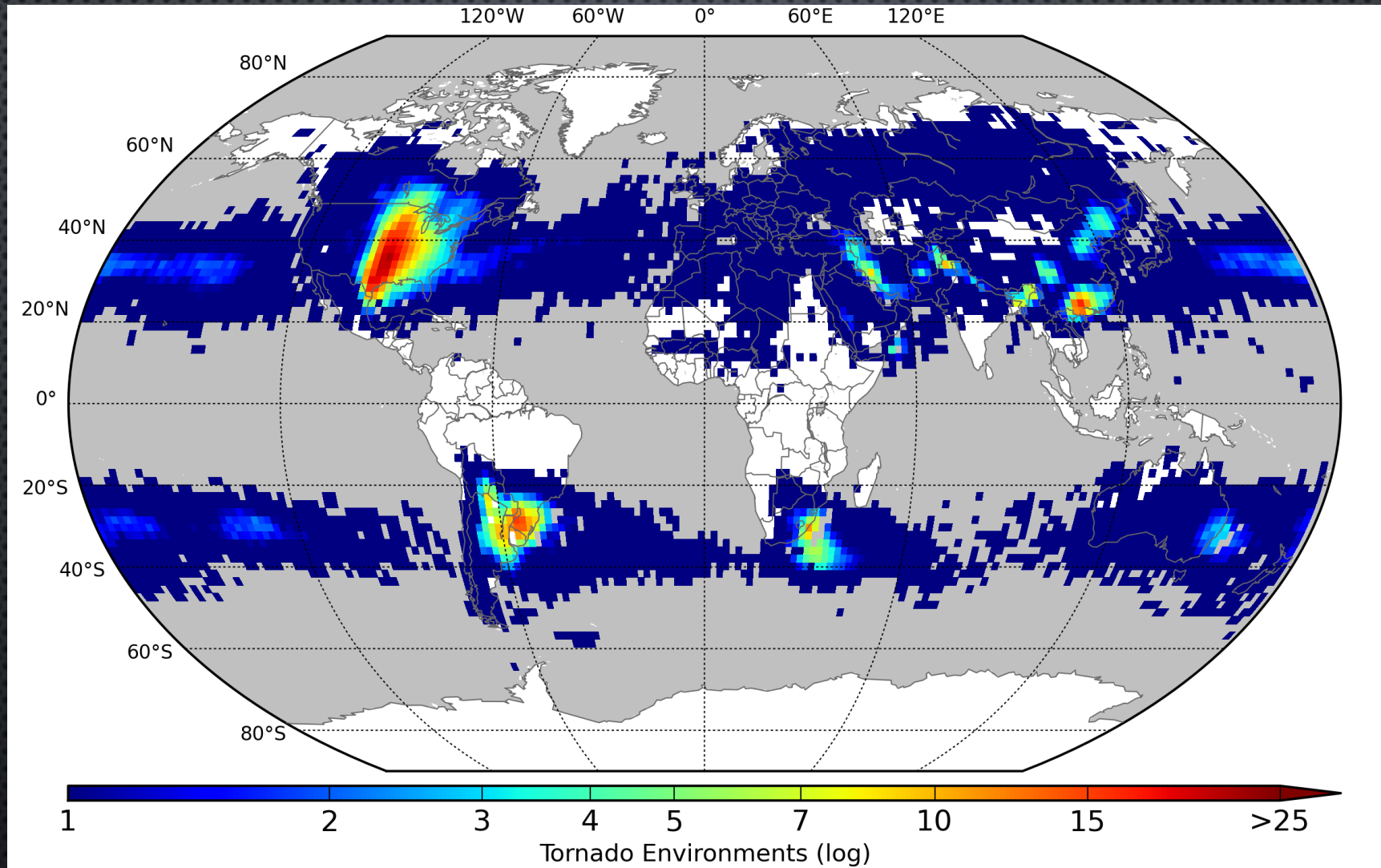
Doswell, C.A. III, H.E. Brooks and R.A. Maddox (1996): Flash flood forecasting: An ingredients-based methodology. *Wea. Forecasting*, **11**, 560-581.

# ENVIRONMENTAL APPROACH



Brooks, H. E., J. W. Lee, and J. P. Craven, 2003: The spatial distribution of severe thunderstorm and tornado environments from global reanalysis data. *Atmos. Res.*, **67-68**, 73-94.

# GLOBAL TORNADO ENVIRONMENTS



Updated by Gensini (2014) from Brooks, H. E., J. W. Lee, and J. P. Craven, 2003: The spatial distribution of severe thunderstorm and tornado environments from global reanalysis data. *Atmos. Res.*, **67-68**, 73-94.

23 June 1998

11 April 1965



June 23, 1998

2011vortexva



## WHAT HAS THE PAST TOLD US ABOUT TORNADOES?

- PEOPLE IN NEBRASKA FILM TORNADOES WITHOUT WEARING PANTS
- TORNADO REPORTS ARE NOT A RELIABLE METRIC
- NO SIGNIFICANT TREND IN ENVIRONMENTS TO THIS POINT
- SLIGHT INCREASE IN INTERANNUAL VARIABILITY

PRESENT

# TORNADO FORECASTS



**Storm Prediction Center**  
 NOAA / National Weather Service

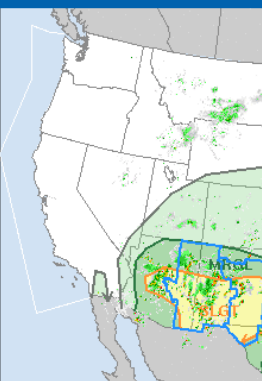
[HOME](#) | [NEWS](#) | [SPC PRODUCTS](#) | [WEATHER INFO](#) | [FORECAST TOOLS](#) | [RESEARCH](#) | [OUTREACH](#) | [NWS/NCEP](#)


**A Slight Risk of Severe Thunderstorms is Forecast Today and/or Tonight**  
 Scattered strong to severe thunderstorms are expected over much of the southwestern United States today, with the greatest threat into southern and central New Mexico.

Day 1 Outlook Probability	TORN	WIND	HAIL
2%	MRGL	Not Used	Not Used
5%	SLGT	MRGL	MRGL

Severe Thunderstorm Watch 515

[Overview](#) | [Conv. Outlook](#) | [Watch](#)

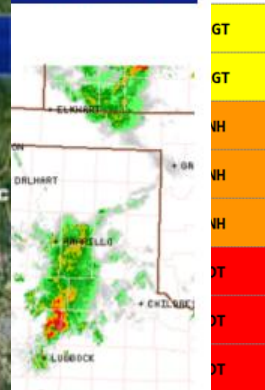


 SPC Activity Chart  
 20151020/1954

Hazard	Tue (10/20)	Wed (10/21)	Thu (10/22)
Severe	Slight	Slight	No Sev
Fire	Elevated	No Critical	No Ar



Initial RADAR



Severe Thunderstorm Watch # 515 - Valid from 110 PM until 900 PM MDT

NOAA/NWS/Storm Prediction Center Updated: 20151020/2148 UTC

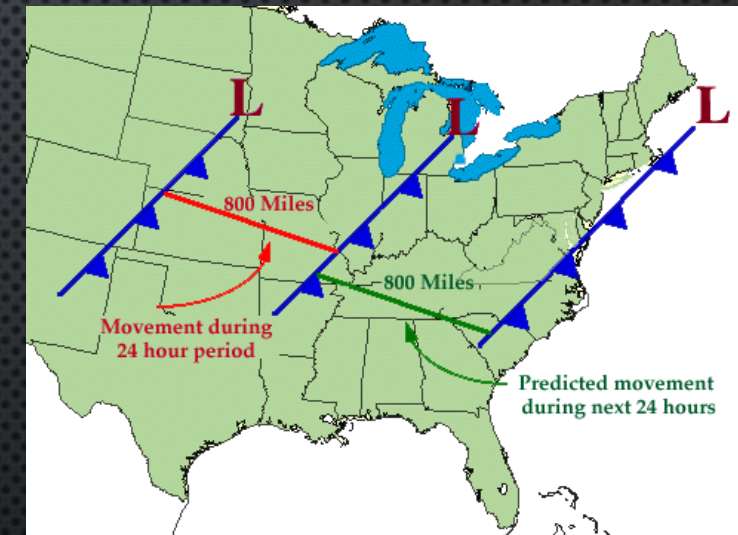
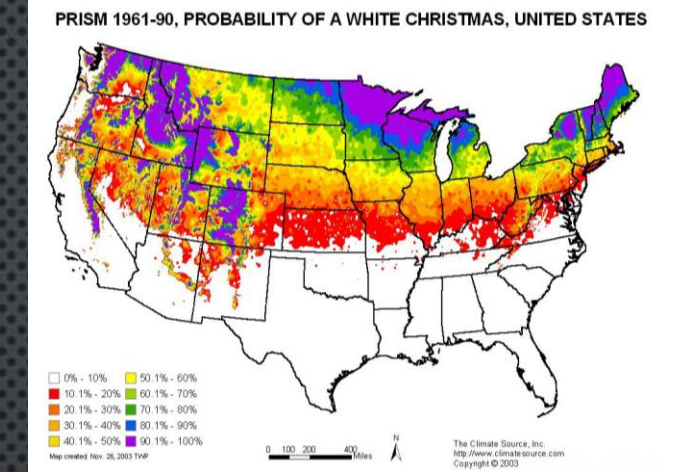
Hazard	Tornadoes	EF2+ Tornadoes	Severe Wind	65 kt+ Wind	Severe Hail	2"+ Hail
Likelihood	Low	Very Low	Moderate	Low	Moderate	Low



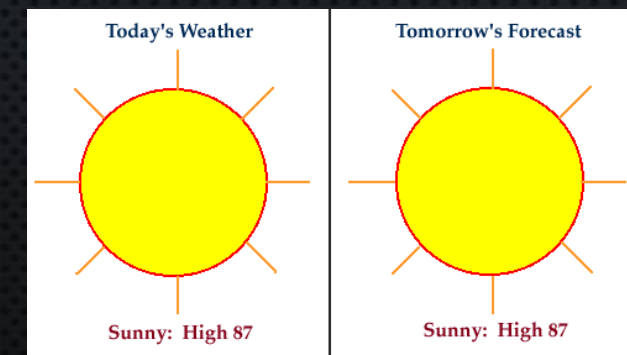
# FORECASTING METHODS

- **CLIMATOLOGICAL:** BASED ON LONG-TERM AVERAGES.
- **PERSISTENCE:** FORECASTER EXTRAPOLATES CURRENT CONDITIONS INTO THE FUTURE. (BEN FRANKLIN)
- **ANALOG METHOD:** FORECASTS THE WEATHER USING PAST SCENARIOS (ANALOG) WITH SIMILAR CONDITIONS FOR GUIDANCE.
- **NUMERICAL WEATHER PREDICTION:** USES COMPUTER PROGRAMS TO MIMIC THE BEHAVIOR OF THE ATMOSPHERE (WINDS, PRESSURE, TEMPERATURE...) OVER TIME.

Less Accurate



More Accurate



# CONSIDERATIONS...

- WHAT EXACTLY ARE YOU TRYING TO FORECAST?
- WHAT TIME SCALES ARE YOU INTERESTED IN? (I.E., INITIAL CONDITION OR FORCED BOUNDARY PROBLEM)
- HOW WILL YOU VERIFY YOUR FORECASTS?
- WHO WILL BE USING YOUR FORECASTS?
- WHAT IS THE BEST WAY TO COMMUNICATE YOUR FORECAST?
- HAVE YOU PROPERLY ASSESSED THE UNCERTAINTY IN YOUR FORECAST?

# CLIMATOLOGY

## An Objective High-Resolution Hail Climatology of the Contiguous United States

JOHN L. CINTINEO,\* TRAVIS M. SMITH, AND VALLIAPPA LAKSHMANAN

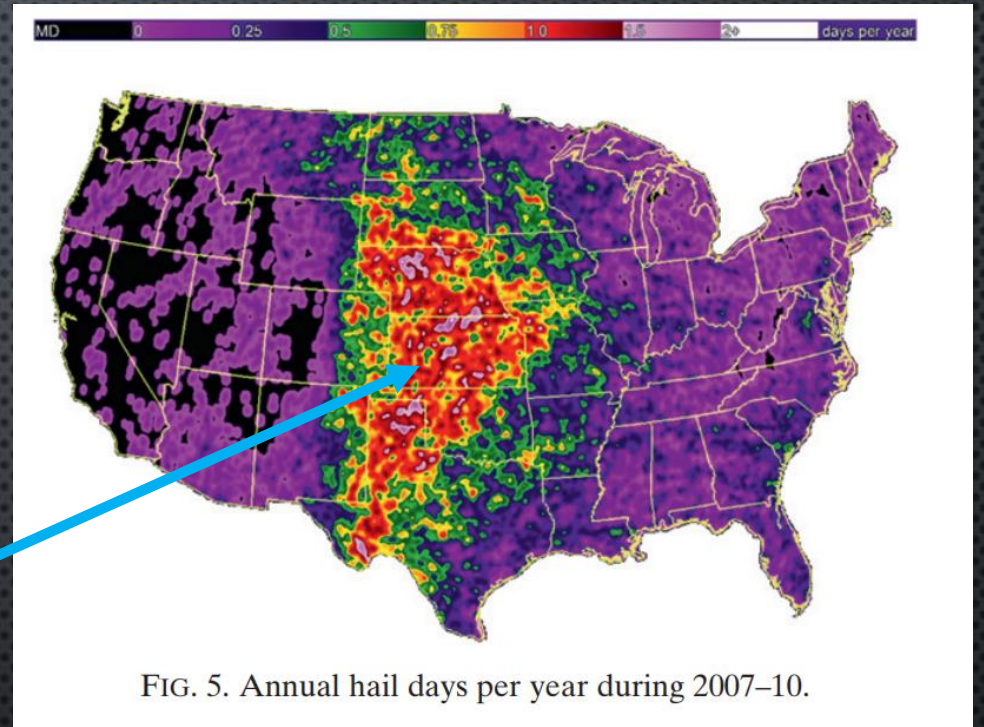
*Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, and National Severe Storms Laboratory, Norman, Oklahoma*

HAROLD E. BROOKS

*National Severe Storms Laboratory, Norman, Oklahoma*

KIEL L. ORTEGA

*Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, and National Severe Storms Laboratory, Norman, Oklahoma*



### The Scales of Hail

STANLEY A. CHANGNON, JR.

*Illinois State Water Survey, Urbana 61801*

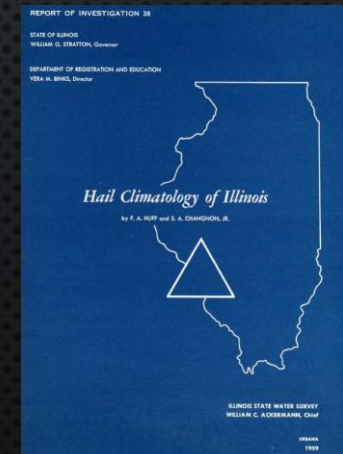
(Manuscript received 18 March 1976, in revised form 22 April 1977)

#### ABSTRACT

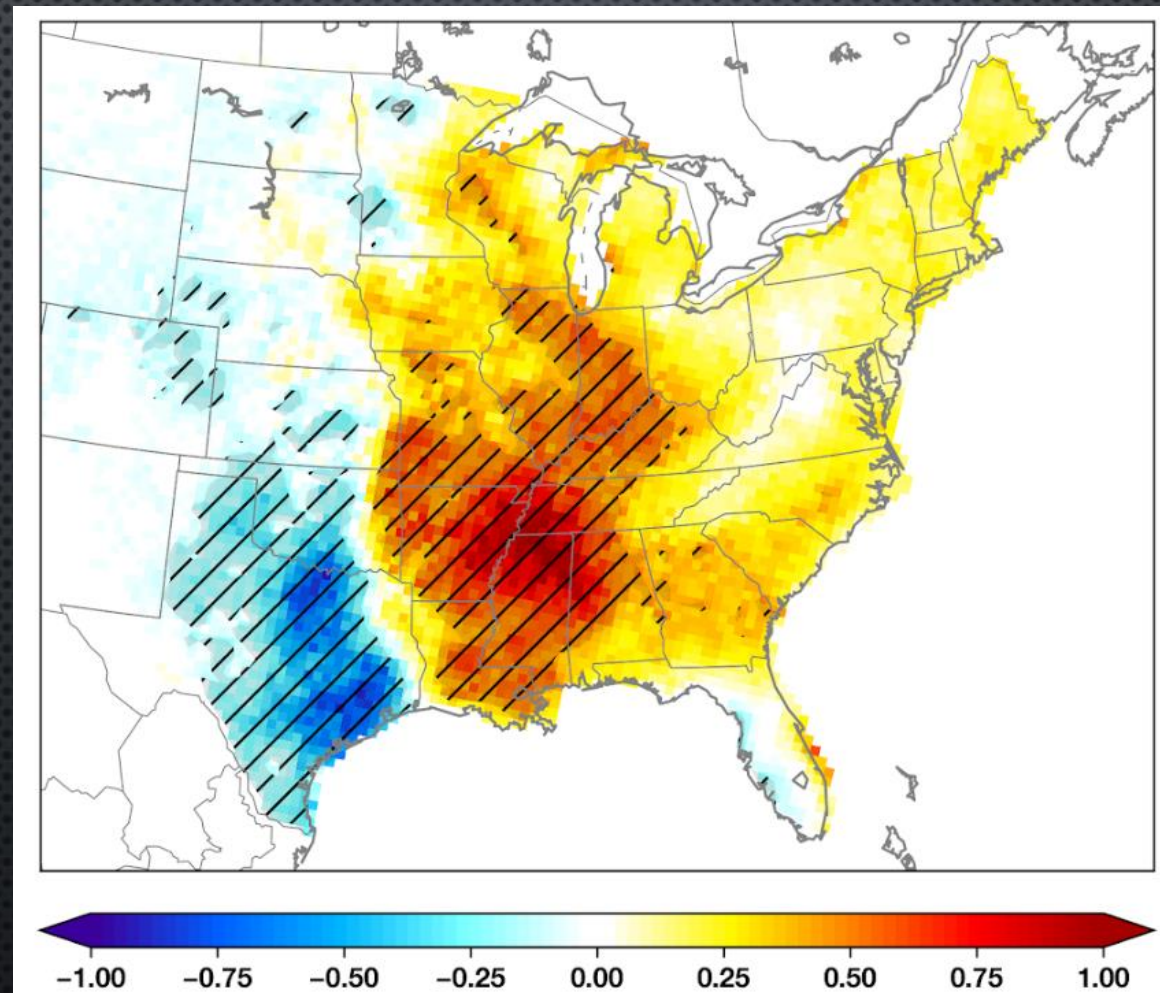
The first climatic investigations of hail in North America were by Lemons and Flora during the 1940's. These were followed by more intensive, state-scale climatic investigations in the 1960's to meet insurance concerns. Subsequent concerns with hail by the aviation industry and the weather modification community led to the first collection of mesoscale hail data from dense networks and radar studies during the 1960's and 1970's.

This paper is a review of available hail information presented in a series of time and space scales. Although the North American hail data and information are less than adequate, there is much more hail information than exists elsewhere in the world. Very extensive findings on hail are available for Alberta, Illinois and Colorado. Phenomenologically oriented studies have focused on hailstones, point hailfalls, hailbreaks, hailstorms, hailswaths and hail days over various sized areas. Results for each of these classifications are presented according to studies that focused on national, regional and small-scale areas.

The principal hail area of the continent is in and to the lee of the Rocky Mountains where hail is both frequent and intense; hence the Great Plains suffers great damages. Another high-frequency area related to spring storms extends from Texas to Michigan, but causes less crop damage since it largely precedes the crop season. Certain inexpensive data collection efforts and analyses which would greatly improve our knowledge of hail are recommended.

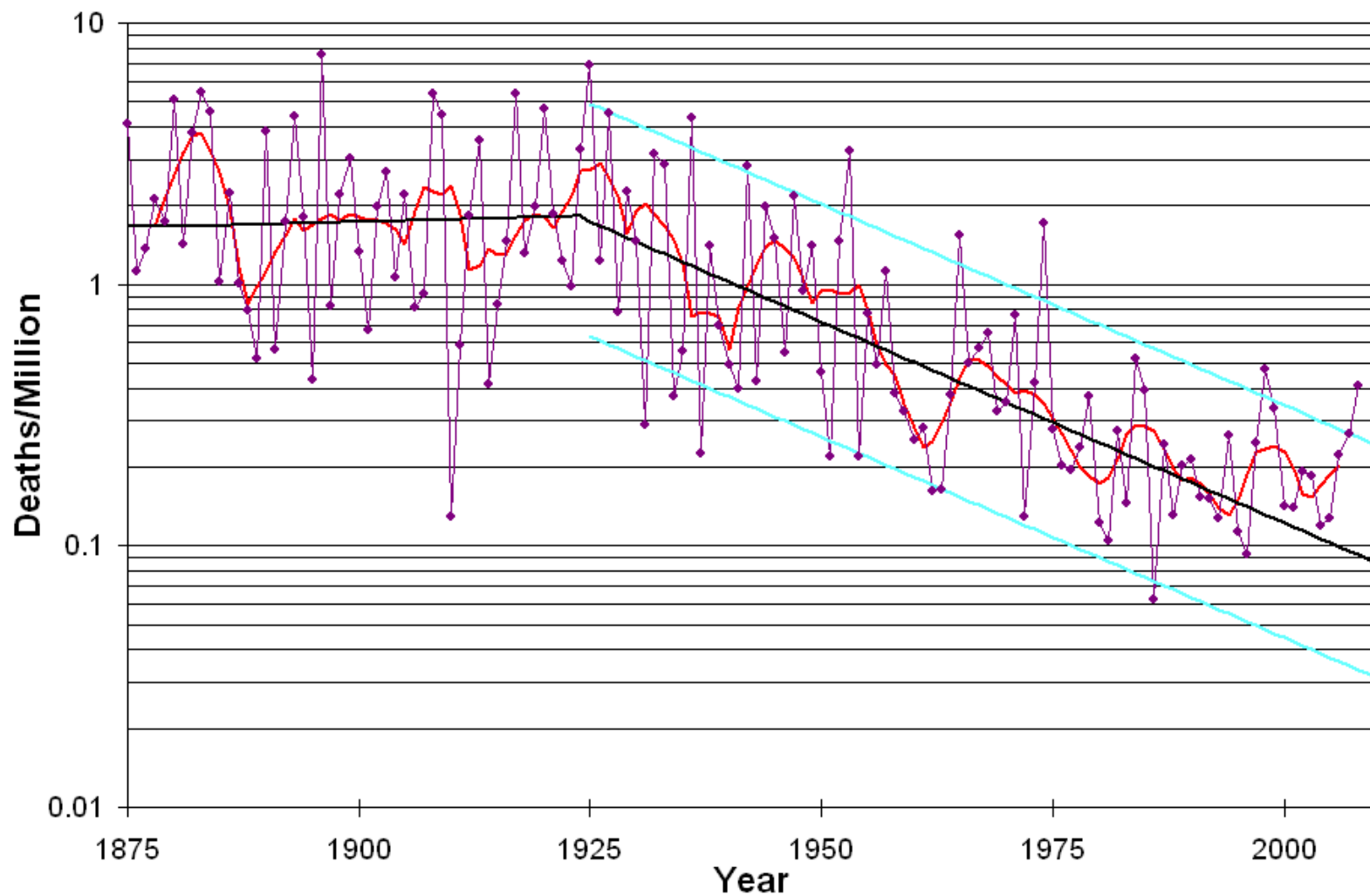


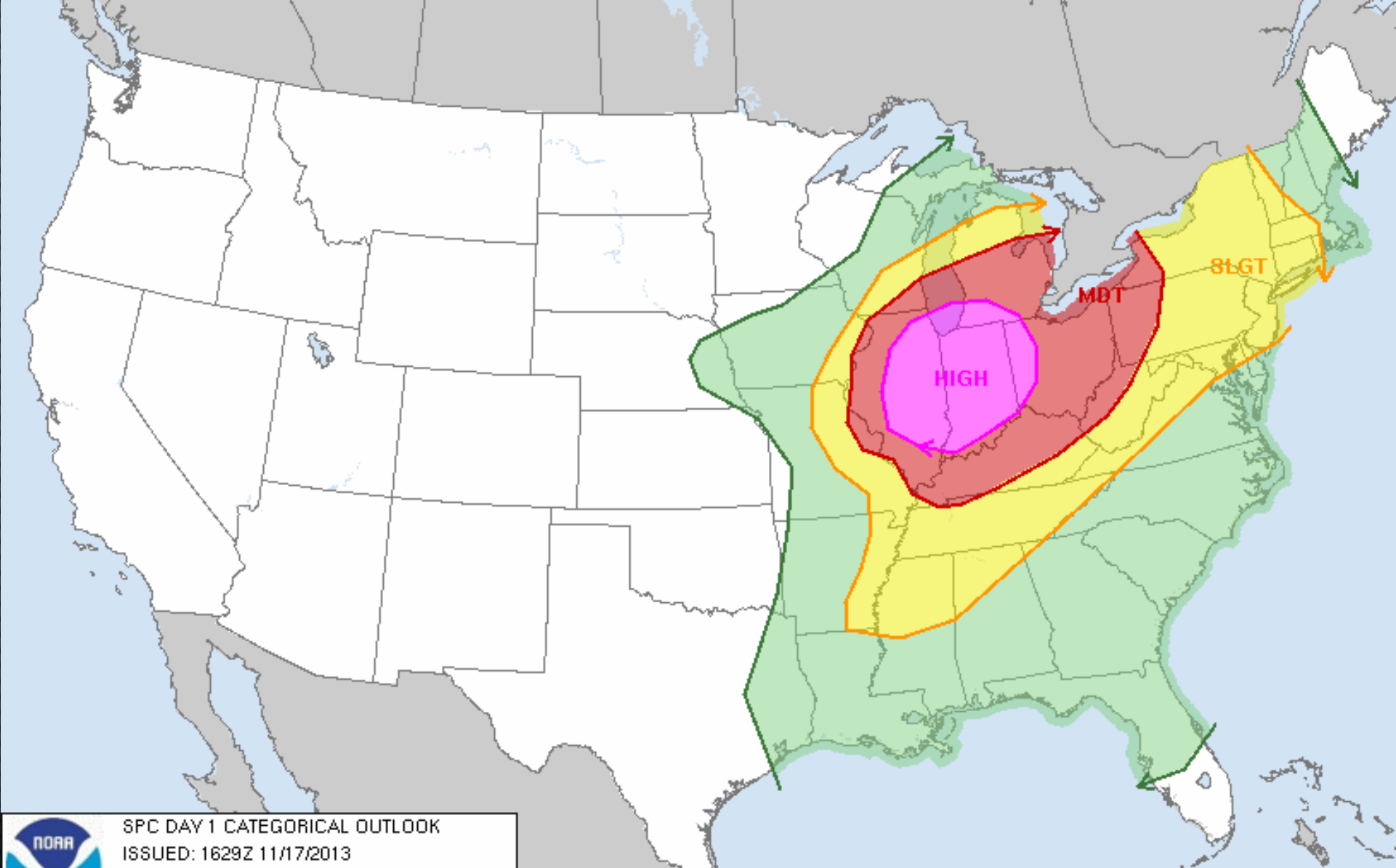
# CLIMO IS A MOVING TARGET



**Gensini, V. A.,** and H. E. Brooks, 2018: Spatial trends in United States tornado activity. *npj Climate and Atmospheric Science* [accepted]

# US Tornado Deaths/Million People



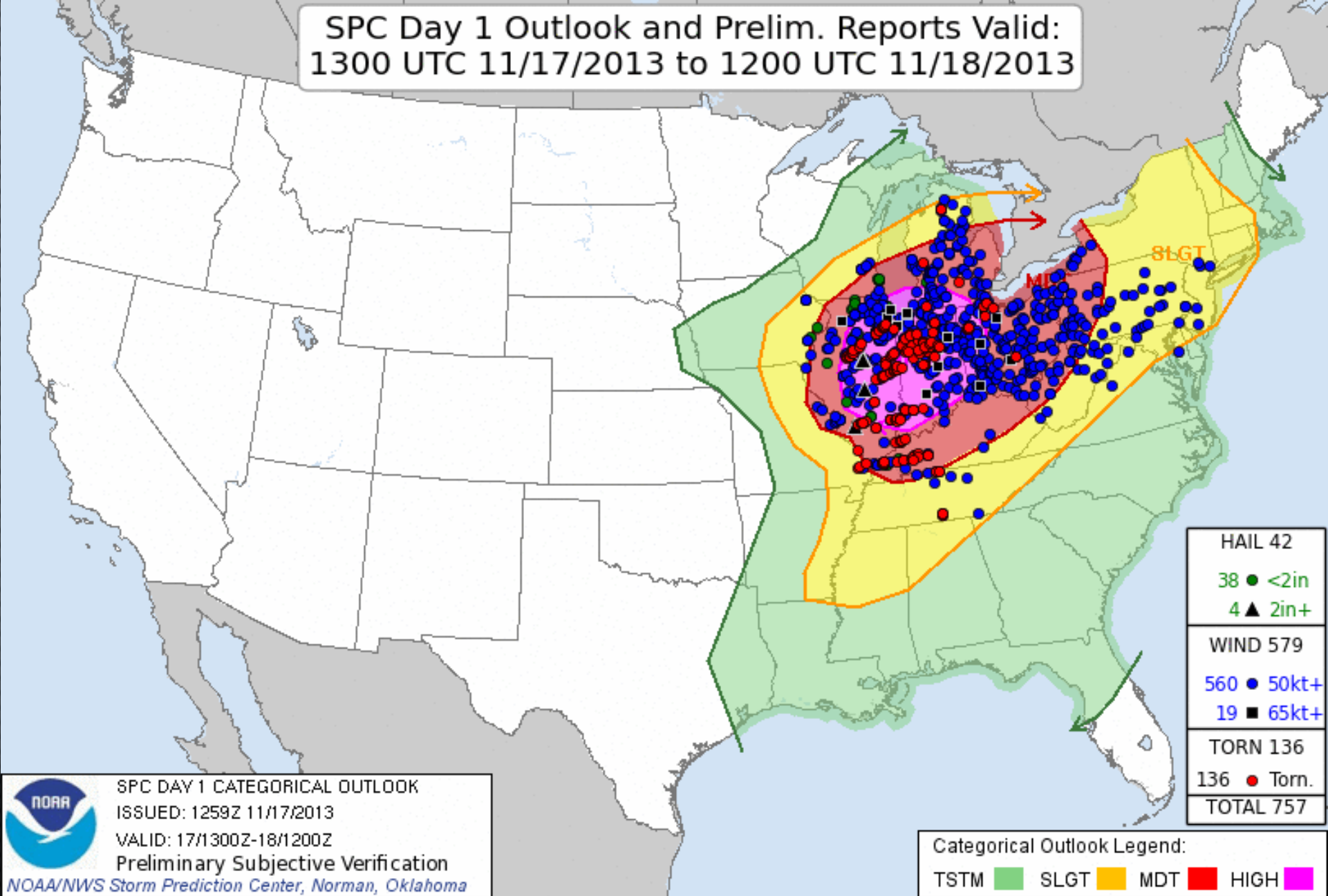


SPC DAY 1 CATEGORICAL OUTLOOK  
ISSUED: 1629Z 11/17/2013  
VALID: 17/1630Z-18/1200Z  
FORECASTER: KERR/COHEN

NOAA/NWS Storm Prediction Center, Norman, Oklahoma

Categorical Outlook Legend:  
TSTM ■ SLGT ■ MDT ■ HIGH ■

SPC Day 1 Outlook and Prelim. Reports Valid:  
1300 UTC 11/17/2013 to 1200 UTC 11/18/2013



HAIL 42	
38 ●	<2in
4 ▲	2in+
WIND 579	
560 ●	50kt+
19 ■	65kt+
TORN 136	
136 ●	Torn.
TOTAL 757	



SPC DAY 1 CATEGORICAL OUTLOOK  
ISSUED: 1259Z 11/17/2013  
VALID: 17/1300Z-18/1200Z  
Preliminary Subjective Verification

NOAA/NWS Storm Prediction Center, Norman, Oklahoma

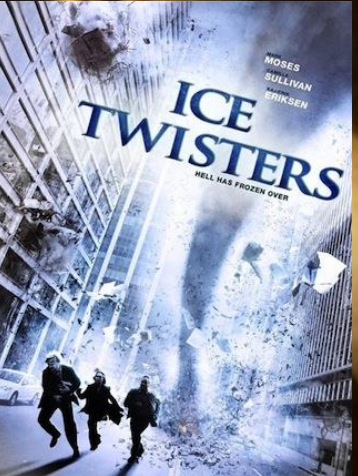
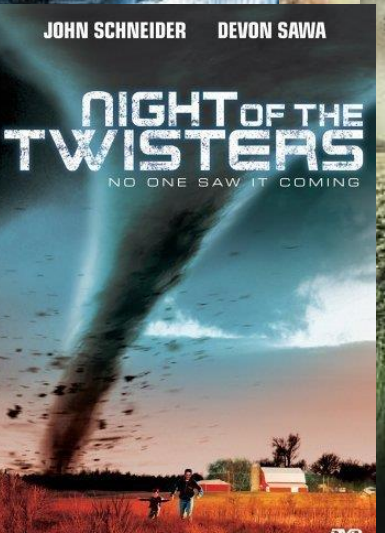
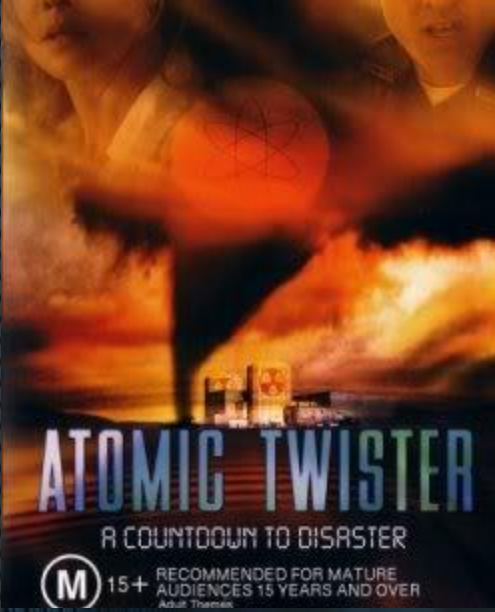
Categorical Outlook Legend:  
TSTM ■ SLGT ■ MDT ■ HIGH ■







# TORNADO SENSATIONALISM





# May 20, 2013 – Moore, OK

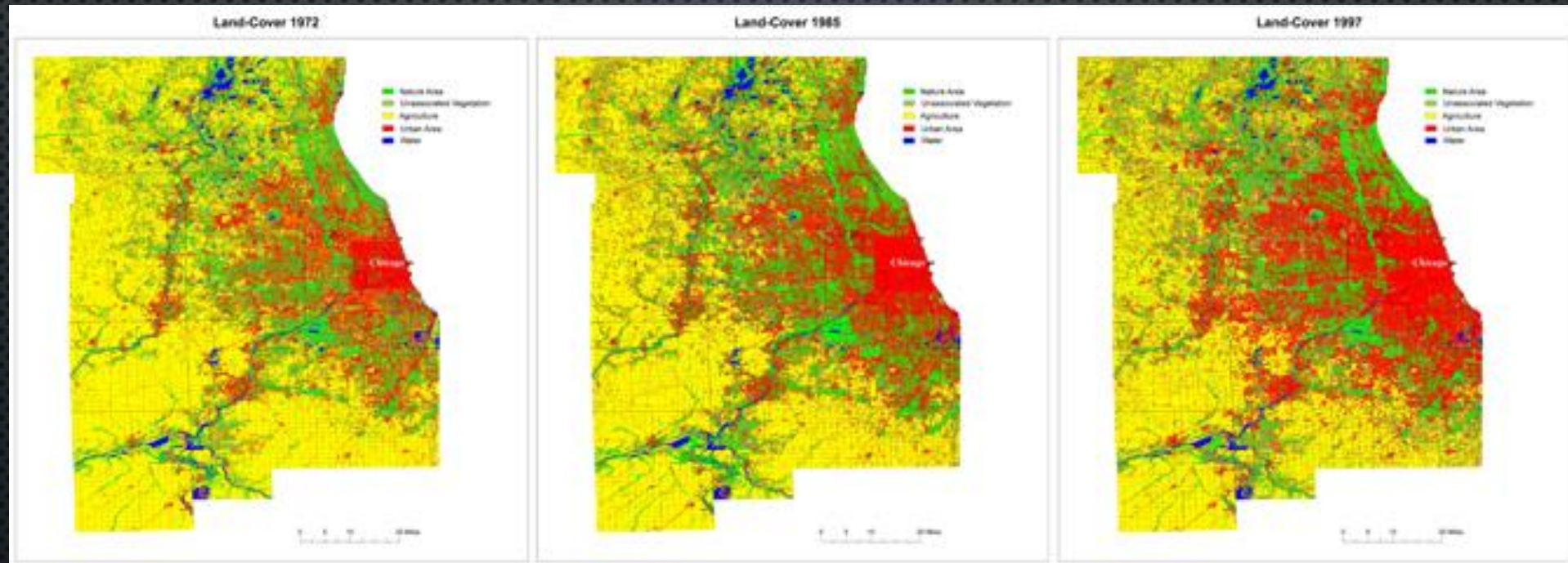


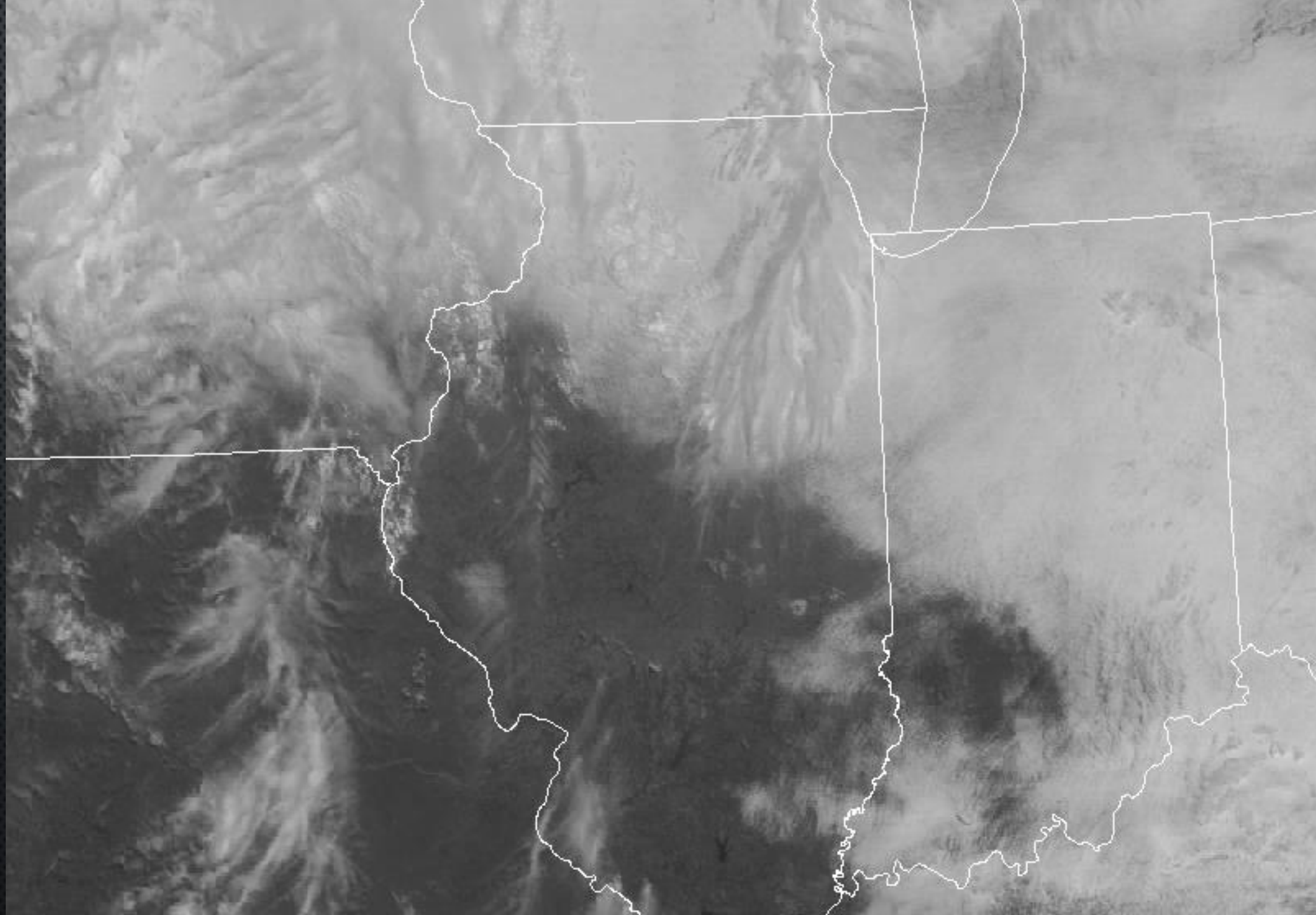
EF5, 24 fatalities, 246 injuries



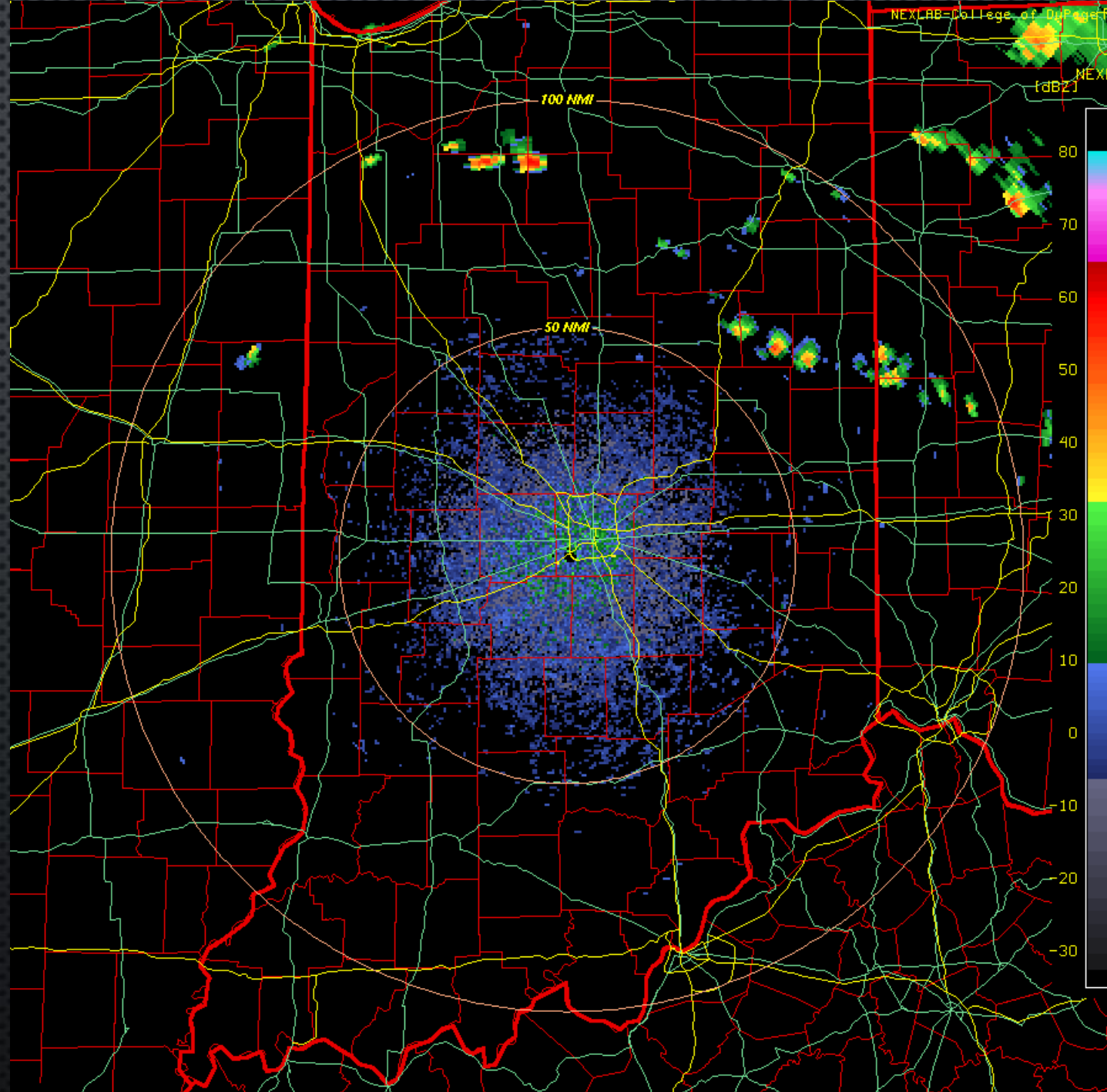
Humans modify the local environment!

More so now than *\*ever\** before!

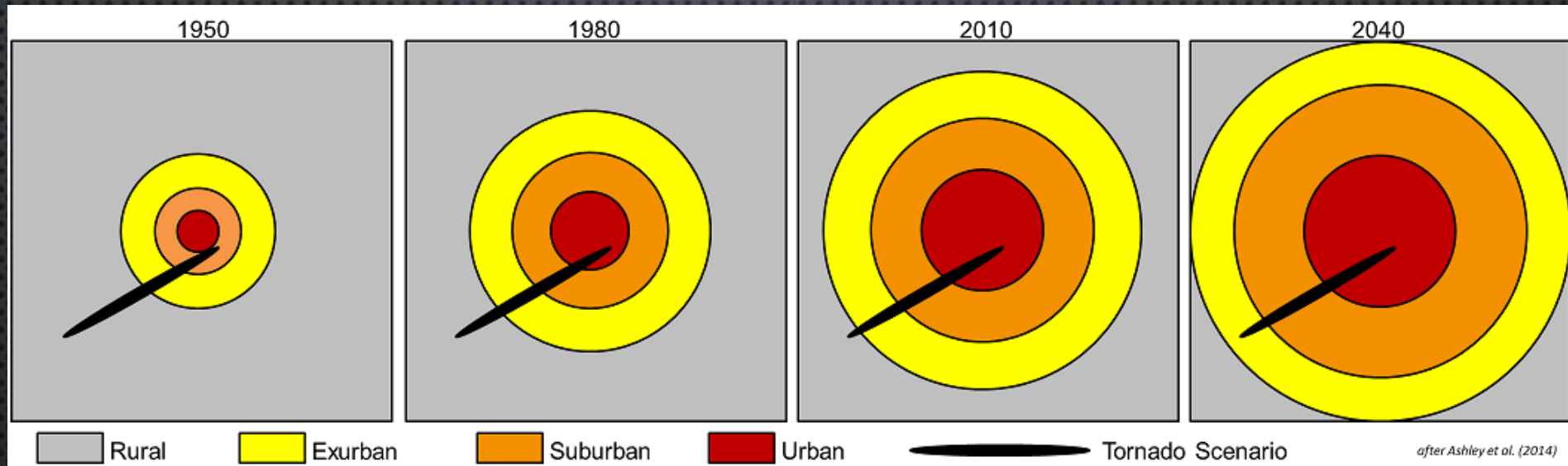








# The Expanding Bull's-eye Effect



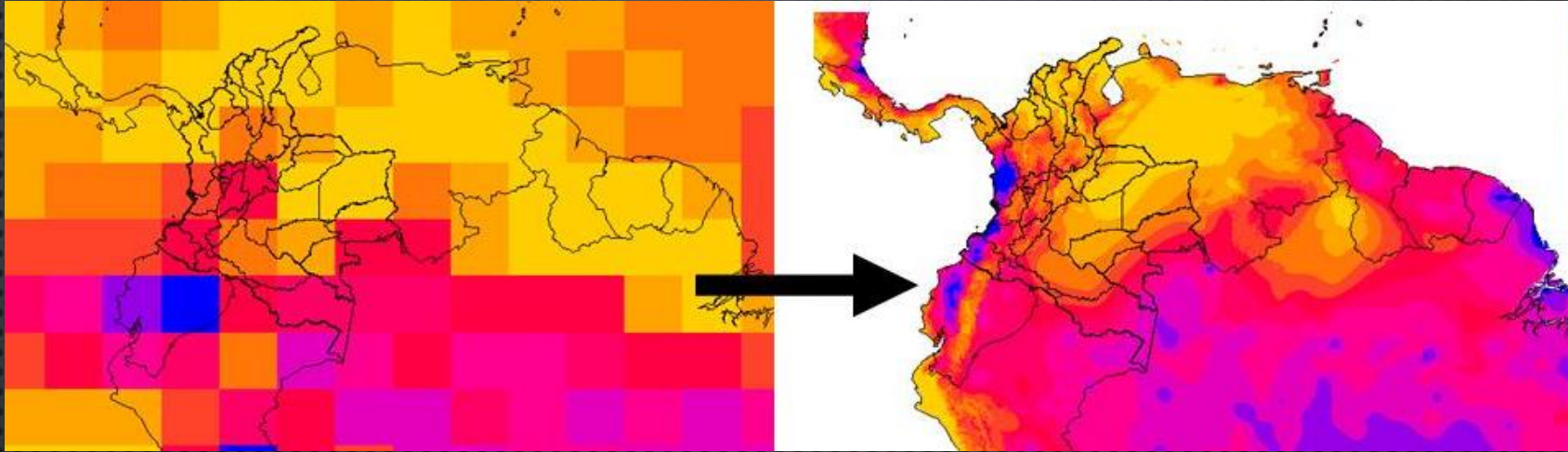
Ashley, W. S., S. Strader, T. Rosenkrantz, and A. J. Kremenec, 2014: Spatiotemporal changes in tornado hazard exposure: The case of the expanding bull's eye effect in Chicago, IL. *Weather, Climate, and Society*, 6, 175-193.

## WHAT HAS THE PRESENT TOLD US ABOUT TORNADOES?

- OUR FORECASTS ARE GETTING BETTER
- ...BUT, HAVE WE HIT A CRITICAL POINT?
- EXPOSURE & VULNERABILITY ARE KEY
- JUST WHEN YOU THINK...

FUTURE

# DYNAMICAL DOWNSCALING



- Work in this area for purposes of severe weather is relatively new.

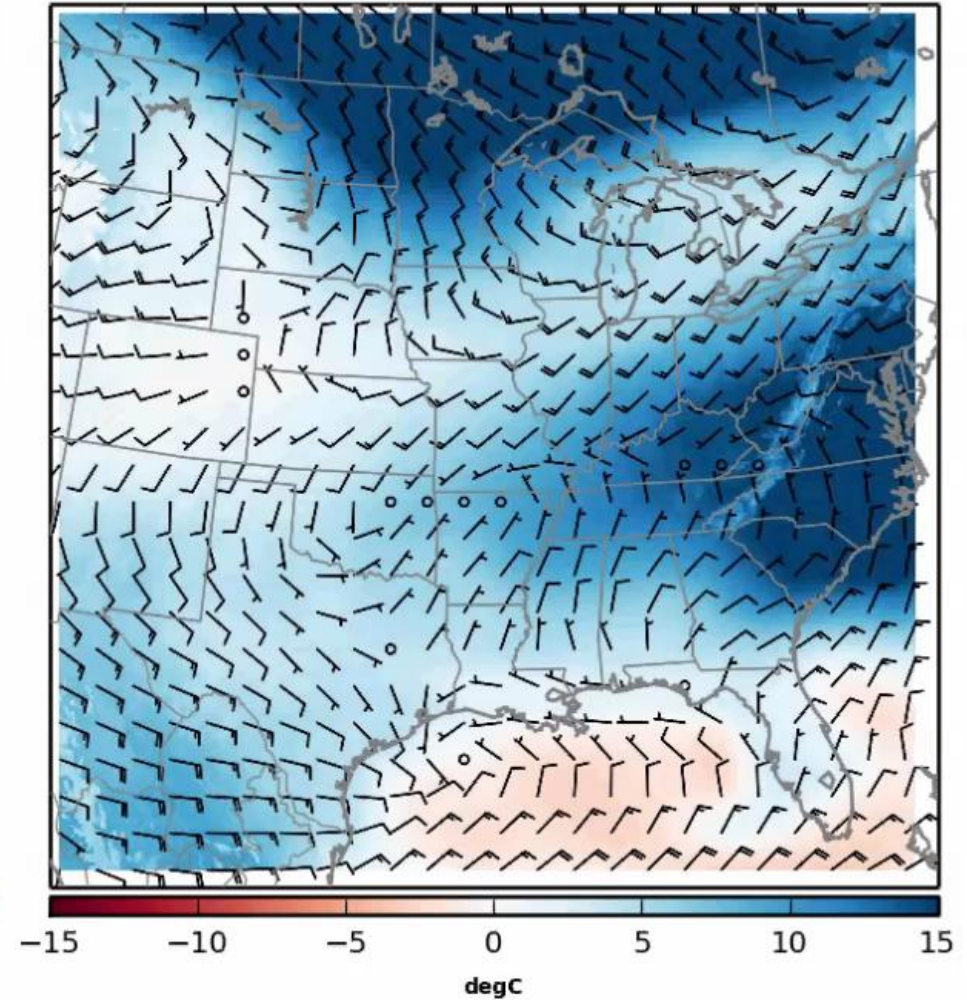
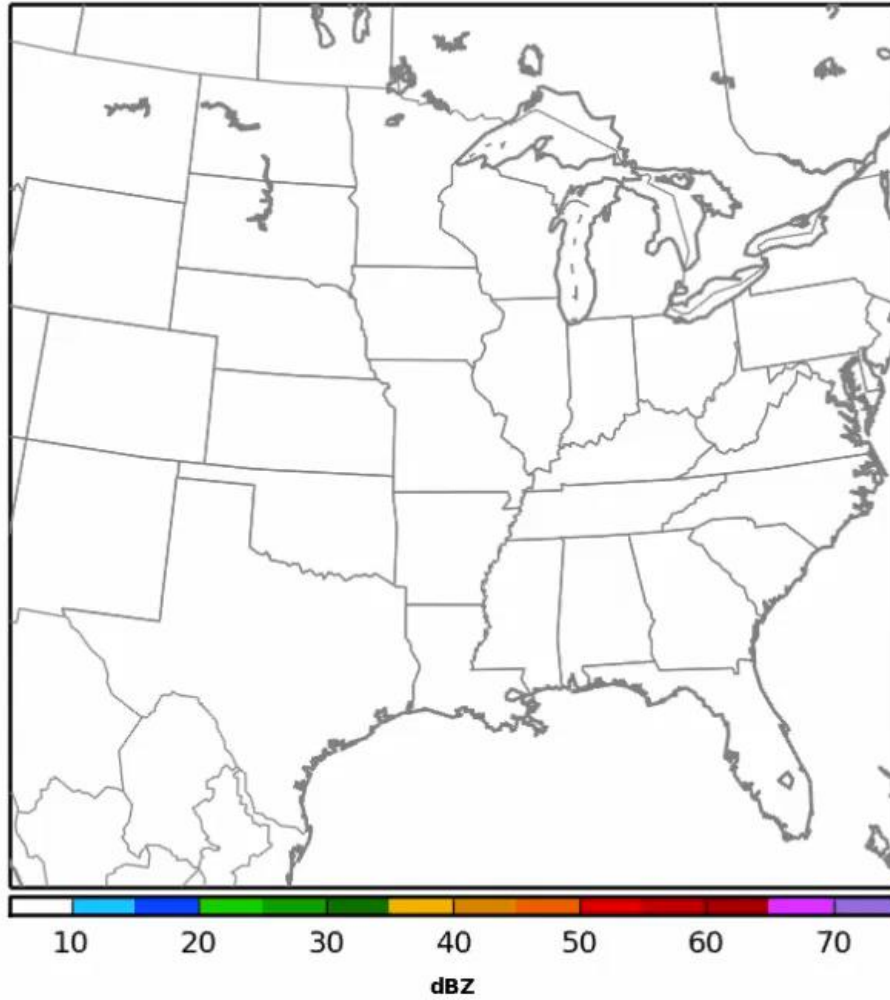
Gensini, V. A., and T. L. Mote, 2015: Downscaled estimates of late 21st century severe weather from CCSM3. *Climatic Change*, **129**, 307-321.

Gensini, V. A., and T. L. Mote, 2014: Estimations of hazardous convective weather in the United States using dynamical downscaling. *J. Climate*, **27**, 6581-6598.

Trapp, R. J., E. Robinson, M. Baldwin, N. Diffenbaugh, and B. Schwedler, 2011: Regional climate of hazardous convective weather through high-resolution dynamical downscaling. *Climate Dyn.*, **37**, 677-688.

# March – May 2009

Composite Reflectivity valid 03 01 2090 00Z





## WHAT MAY THE FUTURE HOLD FOR TORNADOES?

- GREATER NUMBER OF ENVIRONMENTS
- ALSO AN INCREASE IN VARIABILITY
- EXPOSURE & VULNERABILITY ARE STILL KEY
- JUST WHEN YOU THINK...



# CURRENT RESEARCH



SECTIONS



SEARCH

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WEDNESDAY MAR. 30, 2016

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A funnel cloud in Foss Lake, Okla. in March of 2010. (John W. Cannon / Associated Press)



# Researchers find pathway to give advanced notice for hailstorms

January 29, 2018

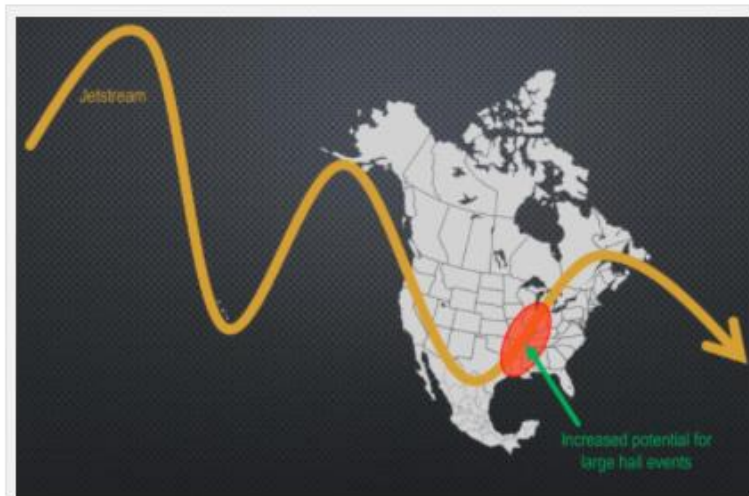
A new study led by Northern Illinois University meteorologist **Victor Gensini** identifies a method for predicting the likelihood of damaging hailstorms in the United States—up to three weeks in advance.

Hail is easily the most economically destructive hazard posed by severe thunderstorms, producing on average billions of dollars in U.S. losses each year, including damage to roofs, homes and especially crops.

“We found a really strong relationship between jet stream patterns over the Pacific Ocean and U.S. hail frequency,” Gensini said. “In simple terms, when the jet stream is really wavy, the likelihood of experiencing hail greatly increases.”

The study by Gensini and co-author **John Allen** of Central Michigan University was accepted for publication in the journal, **Geophysical Research Letters**.

Two years ago, Gensini led research on a method to predict the likelihood of U.S. tornado ice. Last year, of 26 long-range (two to three weeks) forecasts for



New research finds a strong relationship between a wavy jet-stream pattern over the Pacific Ocean and severe U.S. hailstorms. Credit: Victor Gensini, NIU

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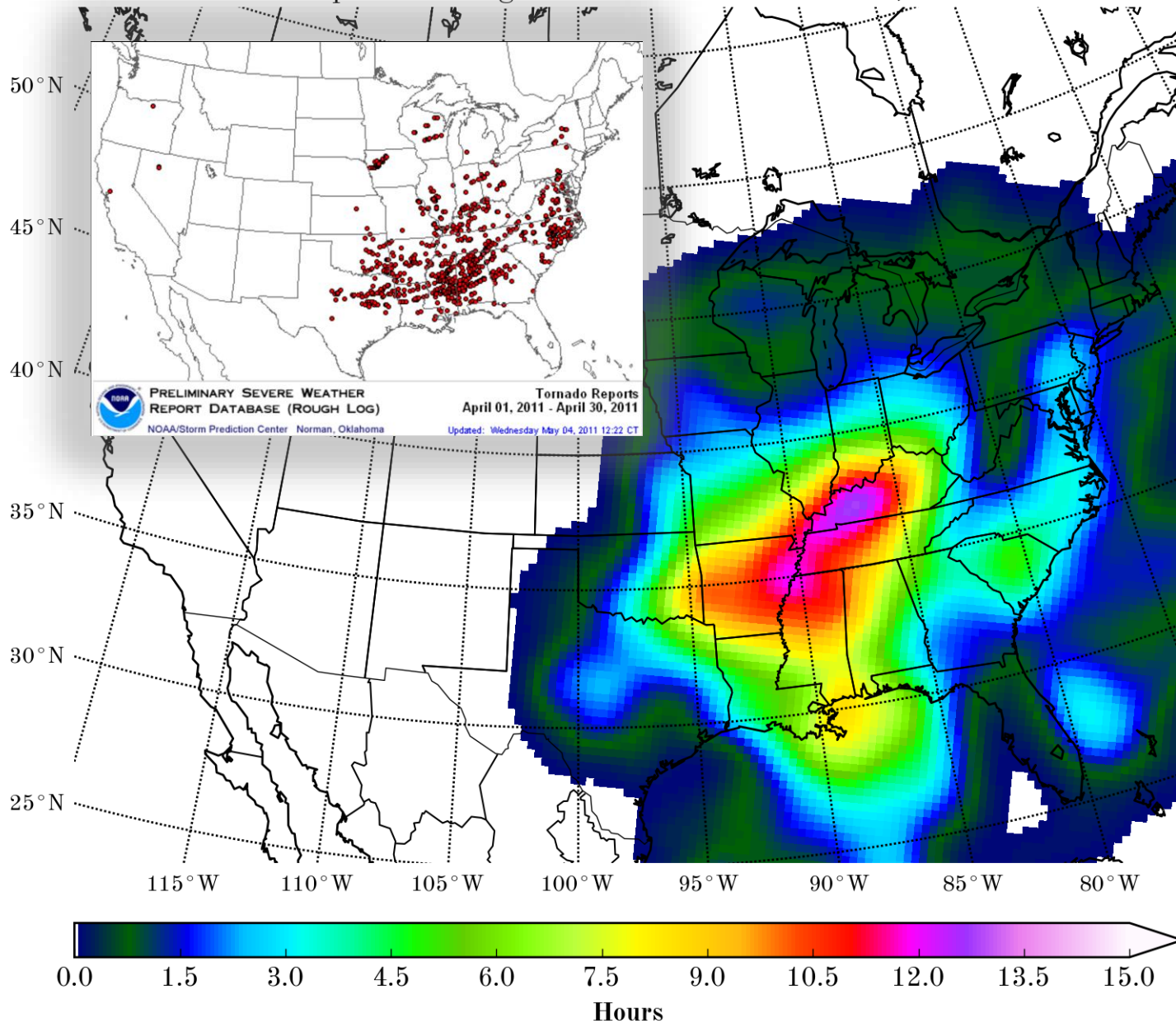
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TOPICS

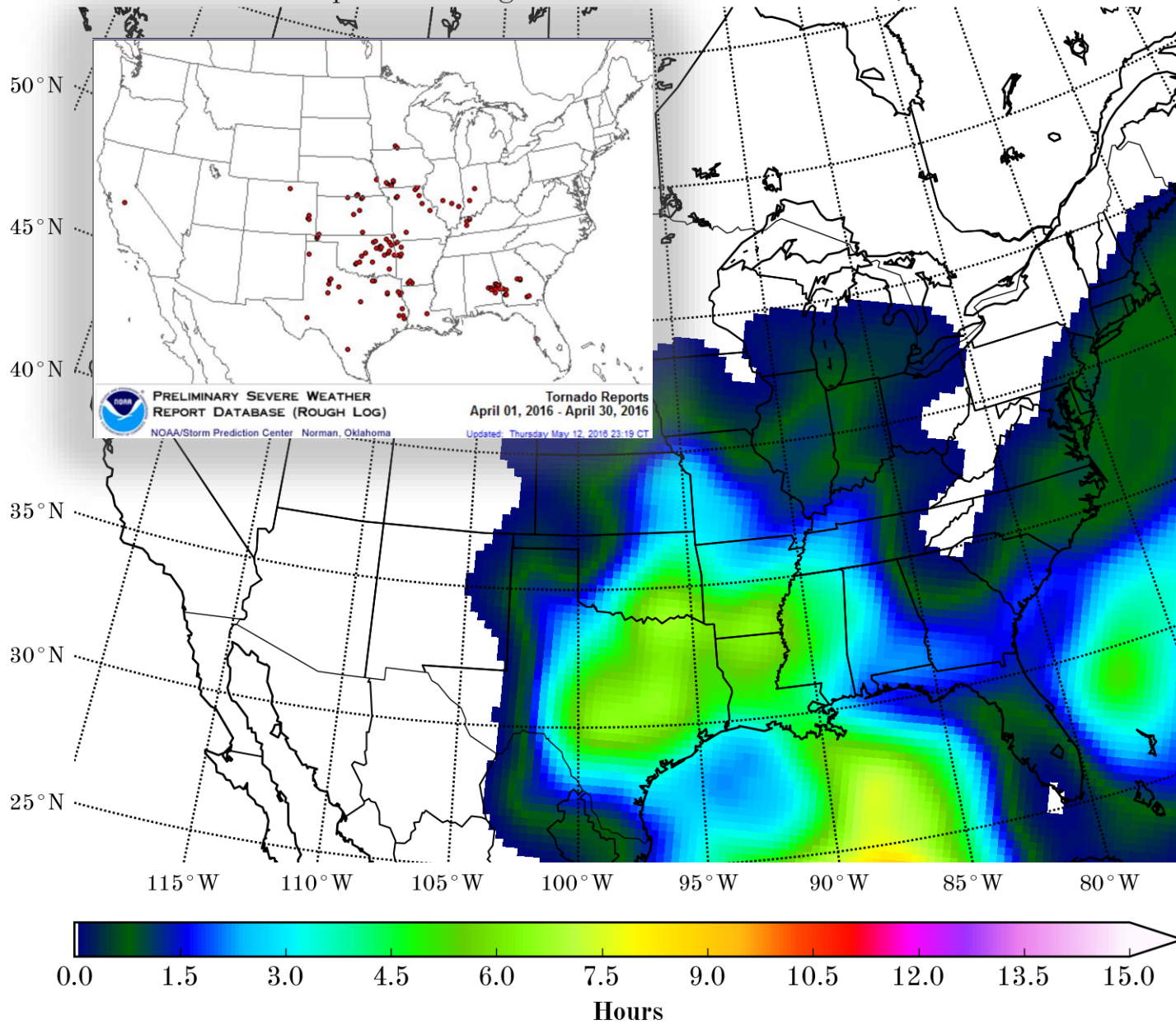
Arts, Music & Culture (38)

Business, Law & Politics (35)

# April 2011 Sig-Tornado Parameter Hours > 1



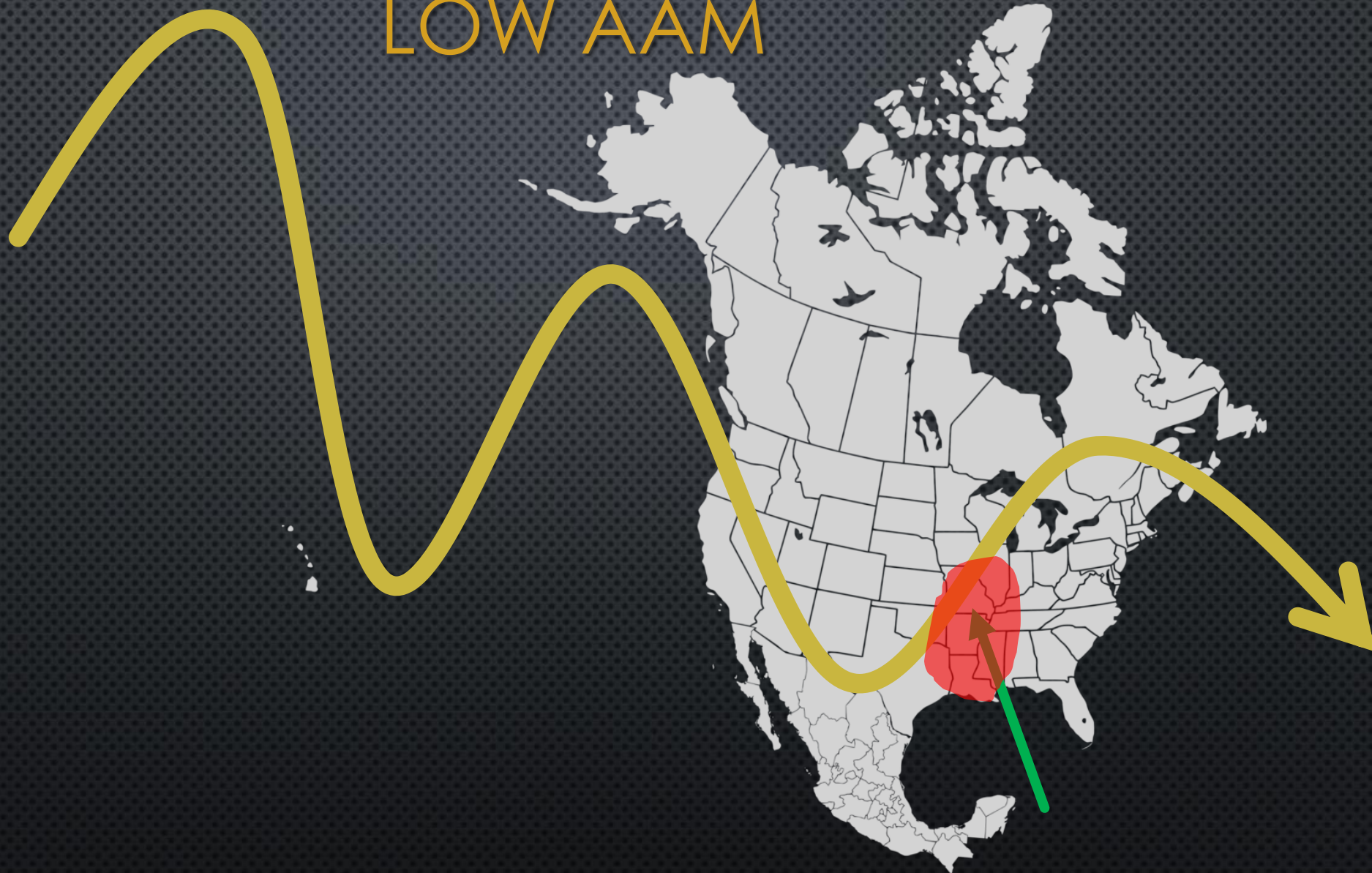
# April 2016 Sig-Tornado Parameter Hours > 1



# HIGH AAM



LOW AAM



$$M_R = \frac{a^3}{g} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \cos^2 \varphi d\varphi \int_0^{2\pi} d\lambda \int_0^{P_{sfc}} u dp$$

### Yearly Relative Atmospheric Angular Momentum Standard Anomalies

Inputs: aam\_anoms.csv (created using the AAM.ipynb found in this repository)

Created by: Dr. Victor Gensini (Fall 2016) | <http://weather.cod.edu/~vgensini>

More information can be found here: [http://nbviewer.jupyter.org/github/vgensini/aam/blob/master/notebooks/AAM\\_climo.ipynb](http://nbviewer.jupyter.org/github/vgensini/aam/blob/master/notebooks/AAM_climo.ipynb)

Relative AAM is calculated following:

$$M_R = \frac{a^3}{g} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \int_0^{2\pi} \int_1^{1000} \cos^2 \varphi d\varphi d\lambda du$$

```
In [67]: #Import necessary Python Libraries (this example uses Python 2.7)
import numpy as np
import plotly.plotly as py
import plotly.graph_objs as go
import datetime
```

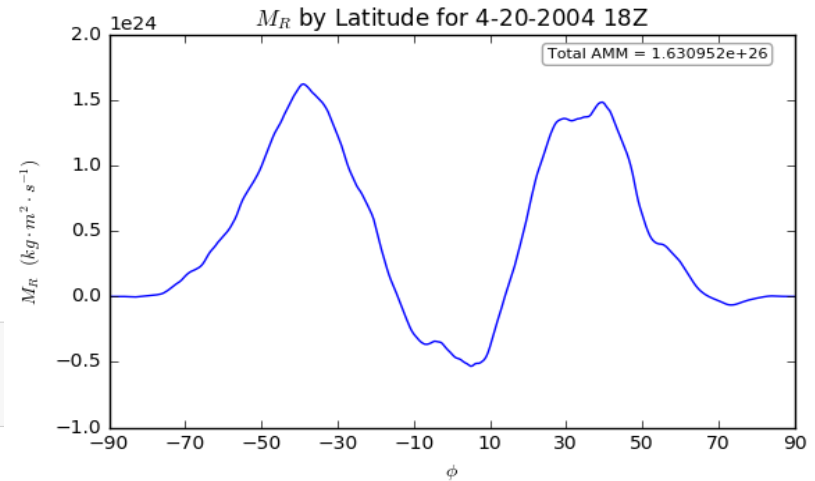
Read in relative AAM anomaly file

6-hourly climatology file (aam\_anoms.csv) which can be found in this repository: <https://github.com/vgensini/aam>

csv headers = mn,dy,hr,1979,1980,1981,1982,1983,1984,1985,1986,1987,1988,1989,1990,1991,1992,1993,1994,1995,1996,1997,1998,1999,2000,2001

```
In [68]: data=np.genfromtxt('/home/scripts/aam/aam_code/aam_anoms.csv', delimiter=',',names=True,dtype=None)
begdate = datetime.datetime.strptime("010100","%m%d%H")
enddate = datetime.datetime.strptime("123118","%m%d%H")
dates = []
while begdate <= enddate:
    dates.append(begdate)
    begdate+=datetime.timedelta(hours=6)

aamdata=[]
for year in data.dtype.names[3:]:
    aam = go.Scatter(x=dates, y=data[year],name=year)
    aamdata.append(aam)
layout = go.Layout(title='CFSR Relative AAM Standardized Anomalies by Year',xaxis=dict(showticklabels=False))
fig = go.Figure(data=aamdata, layout=layout)
py.iplot(fig)
```



More info on github:  
<https://github.com/vgensini/>





↑ Meridional momentum transport

AAM sink through - frictional & mountain torque

AAM source through + frictional torque

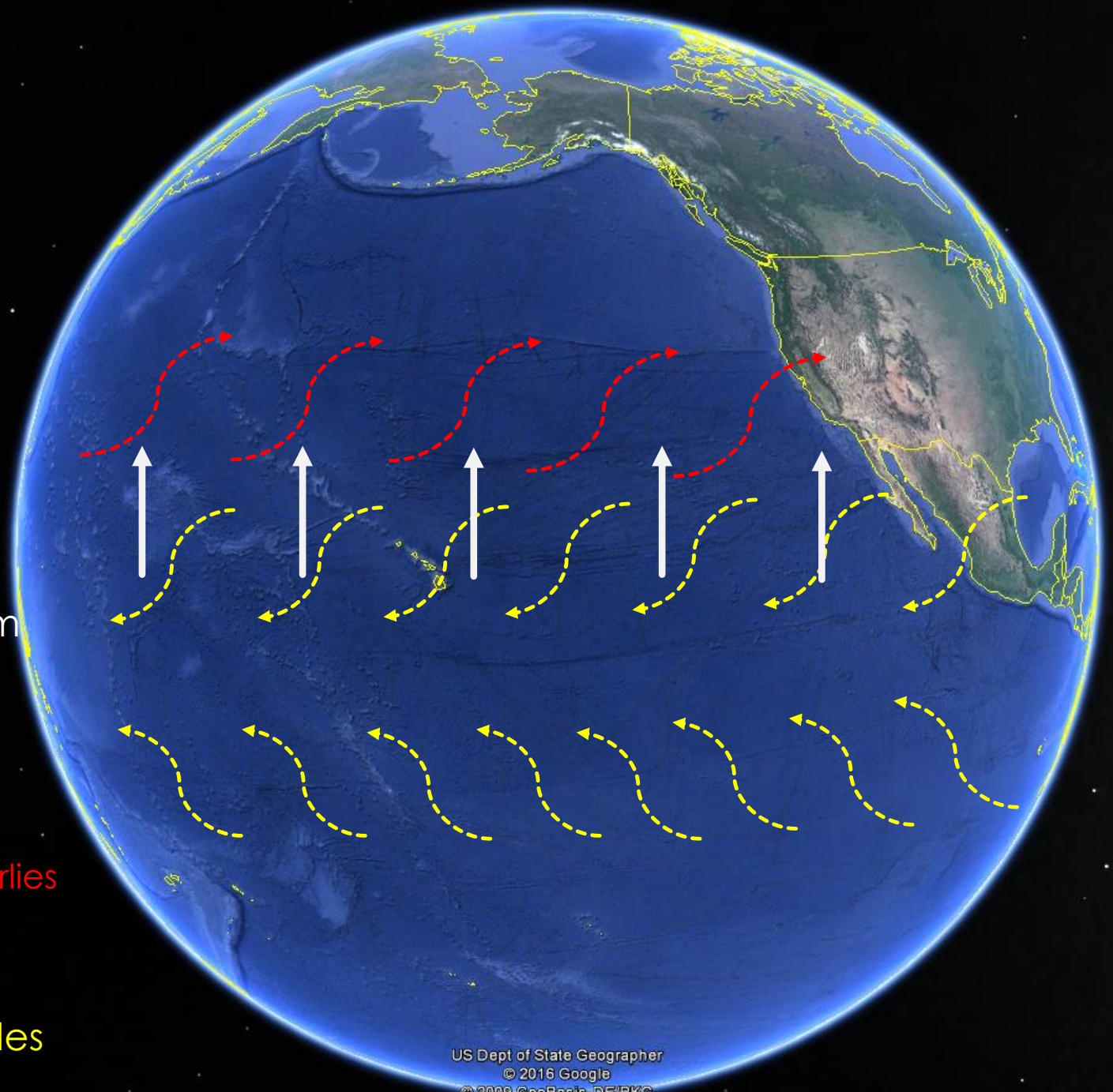
Westerlies

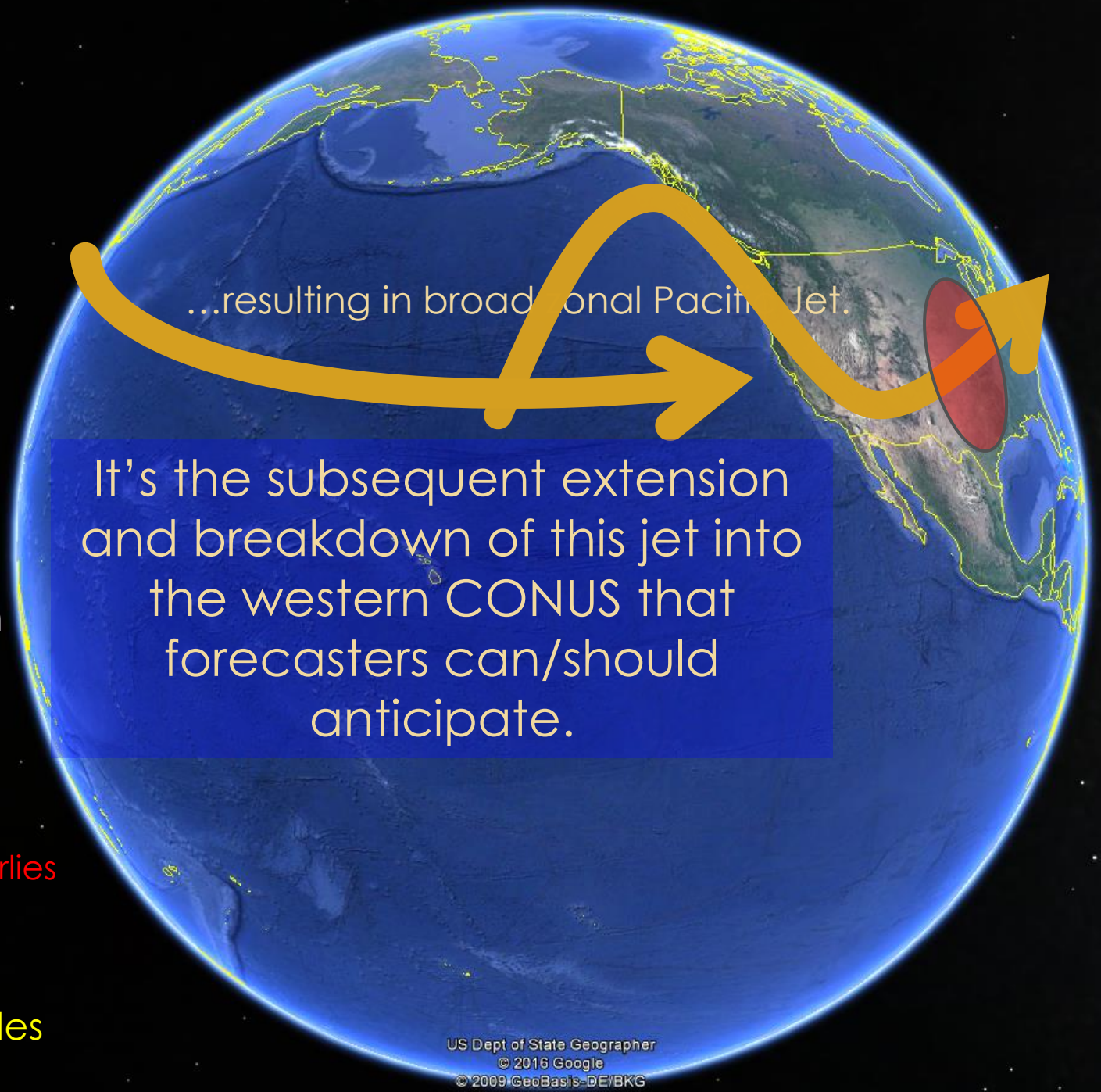
Trades

↑ Meridional momentum transport

Westerlies

Trades





...resulting in broad zonal Pacific Jet.

It's the subsequent extension and breakdown of this jet into the western CONUS that forecasters can/should anticipate.

↑ Meridional momentum transport

Westerlies

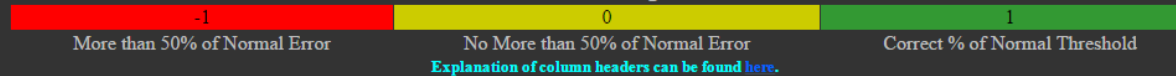
Trades

# Extended Range Tornado Activity Forecasts (ERTAF)

												ACT3C	FCST2	FCST3	VERF2	VERF3
3/1/2015	3/8/2015	3/14/2015	3/15/2015	3/21/2015	16.4	12.2	0	0	0%	0%	BA	BA	BA	BA	1	1
3/8/2015	3/15/2015	3/21/2015	3/22/2015	3/28/2015	12.2	20	0	11	0%	55%	BA	BA	BA	BA	1	1
3/15/2015	3/22/2015	3/28/2015	3/29/2015	4/4/2015	20	24.7	11	23	55%	93%	BA	A	BA	BA	1	0
3/22/2015	3/29/2015	4/4/2015	4/5/2015	4/11/2015	24.7	32.3	23	42	93%	130%	A	AA	A	AA	1	1
3/29/2015	4/5/2015	4/11/2015	4/12/2015	4/18/2015	32.3	32.1	42	32	130%	100%	AA	A	AA	A	1	1
		4/18/2015	4/19/2015	4/25/2015	32.1	42.9	32	51	100%	119%	A	A	A	A	1	1
		4/25/2015	4/26/2015	5/2/2015	42.9	52	51	28	119%	54%	A	BA	A	BA	1	1
		5/2/2015	5/3/2015	5/9/2015	52	60.4	28	123	54%	203%	BA	AA	A	A	0	0
		5/9/2015	5/10/2015	5/16/2015	60.4	56	123	101	203%	180%	AA	AA	A	AA	0	1
		5/16/2015	5/17/2015	5/23/2015	56	46.8	101	53	180%	113%	AA	A	A	AA	0	0
		5/23/2015	5/24/2015	5/30/2015	46.8	52.7	53	115	113%	218%	A	AA	AA	A	0	0
		5/30/2015	5/31/2015	6/6/2015	52.7	62.4	115	37	218%	59%	AA	BA	A	A	0	0
		6/6/2015	6/7/2015	6/13/2015	62.4	62	37	21	59%	34%	BA	BA	BA	A	1	1
		6/13/2015	6/14/2015	6/20/2015	62	46	21	42	34%	91%	BA	A	BA	A	1	1
		6/20/2015	6/21/2015	6/27/2015	46	45.1	42	60	91%	133%	A	AA	AA	AA	0	1
		6/27/2015	N/A	N/A	45.1	N/A	60	N/A	133%	N/A	AA	N/A	AA	N/A	1	N/A

All tornado report data is from the Storm Prediction Center and should be considered preliminary pending final review.

### Verification Legend



## Week 2 Outlook Graphic

### Week 2 Tornado Outlook

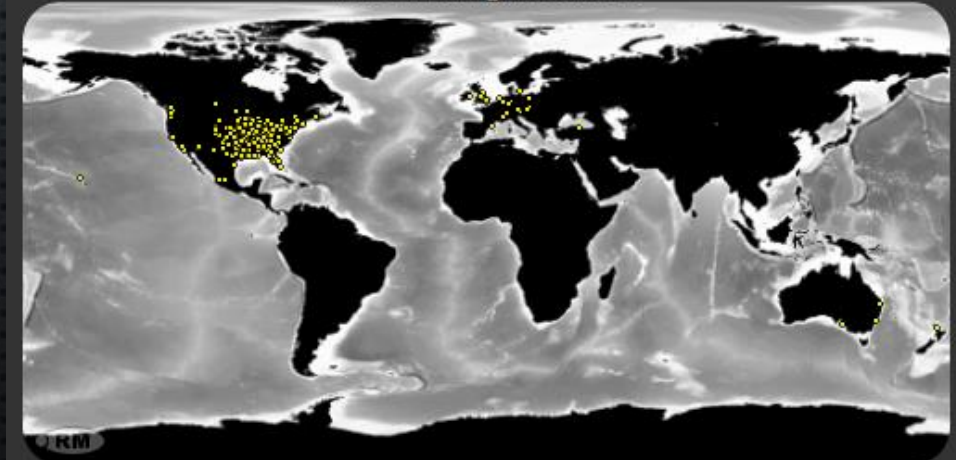
Valid: 18 March - 24 March 2015

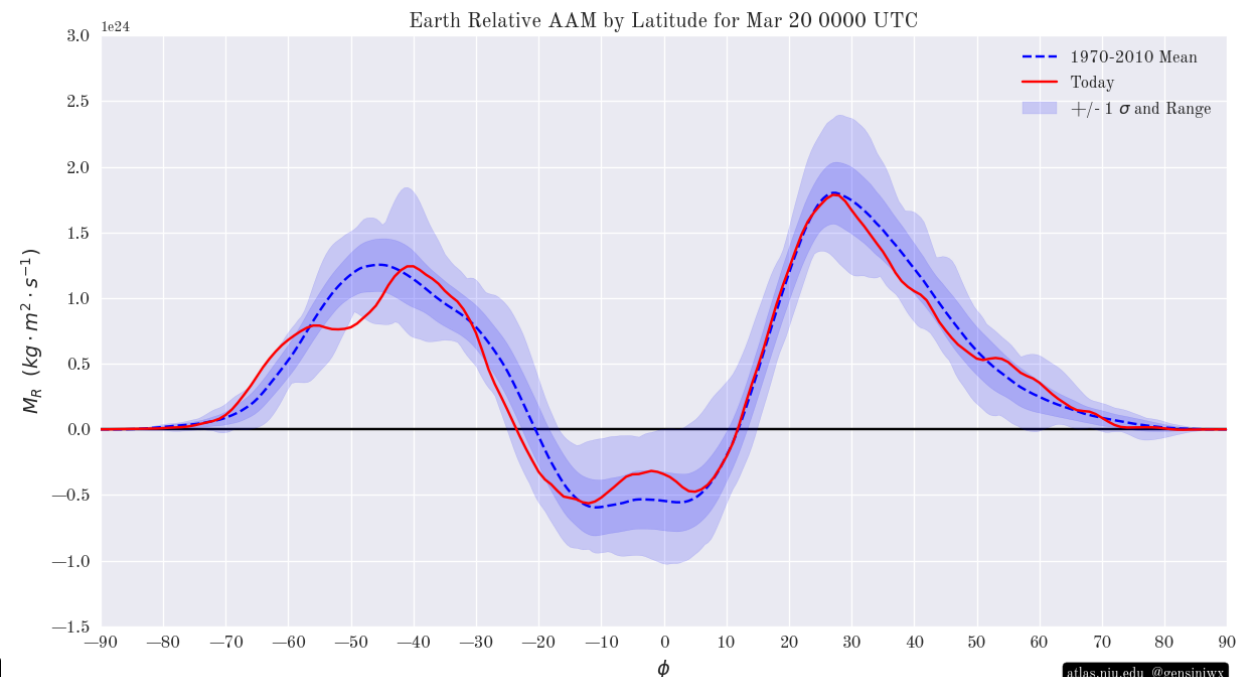
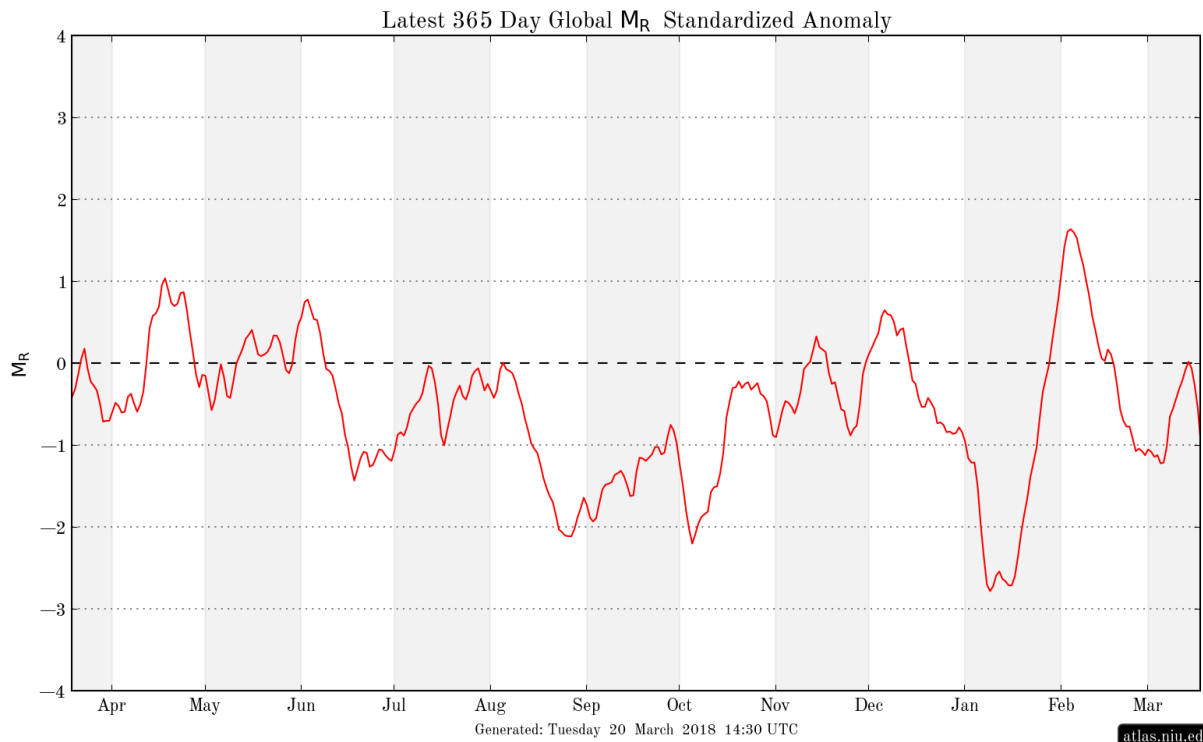
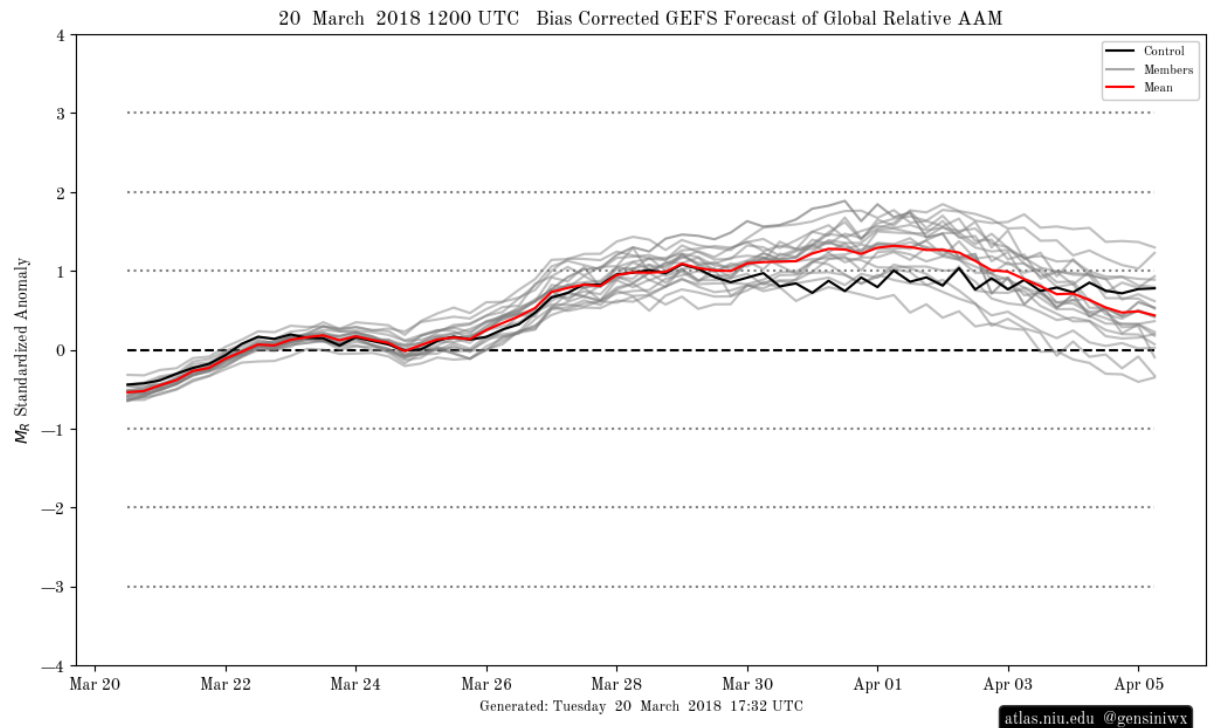
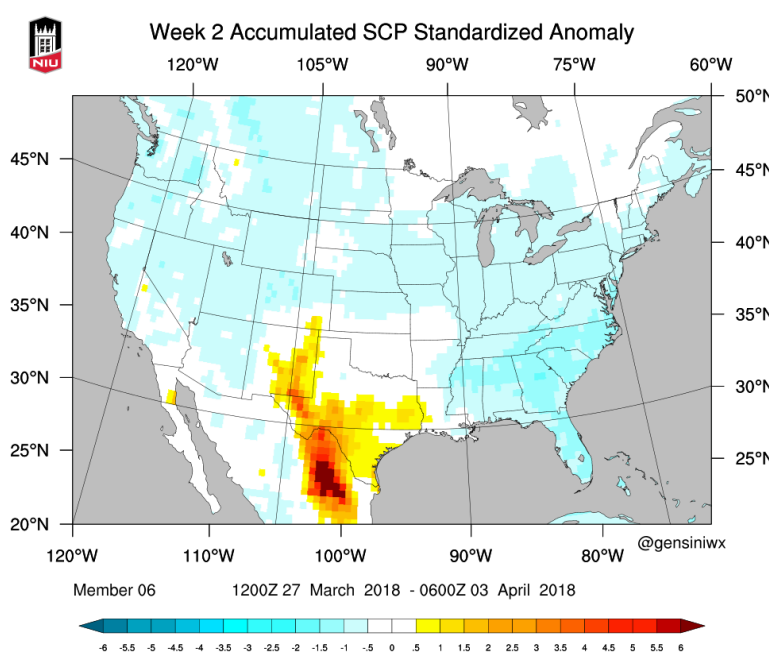
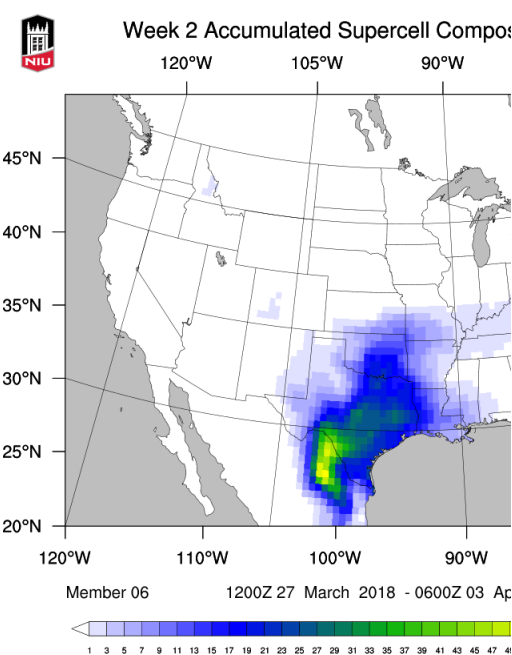


<http://atlas.niu.edu/ertaf/>

Forecasts issued on Sunday evening for Weeks 2 and 3 tornado/hail activity

### Who's looking at ERTAF?



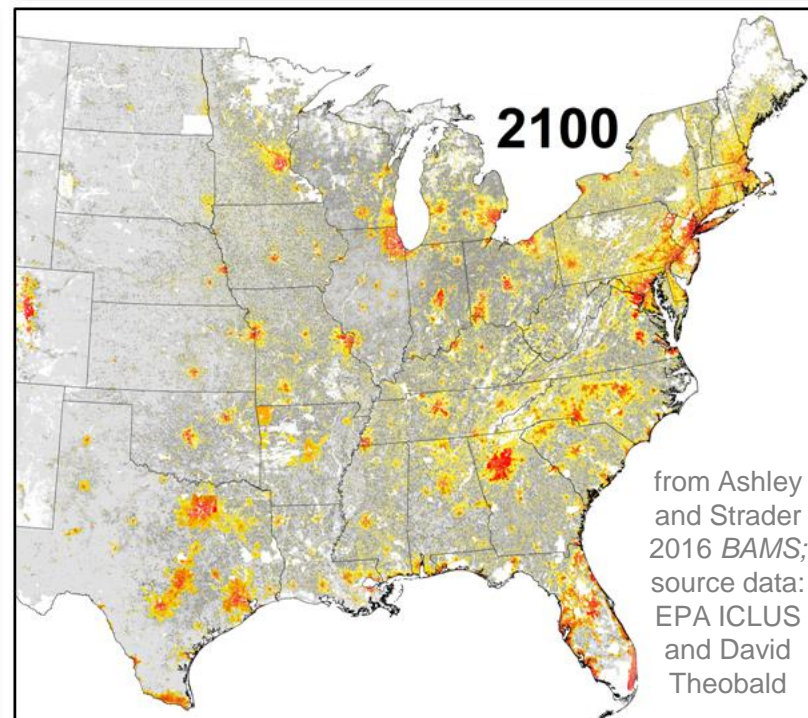
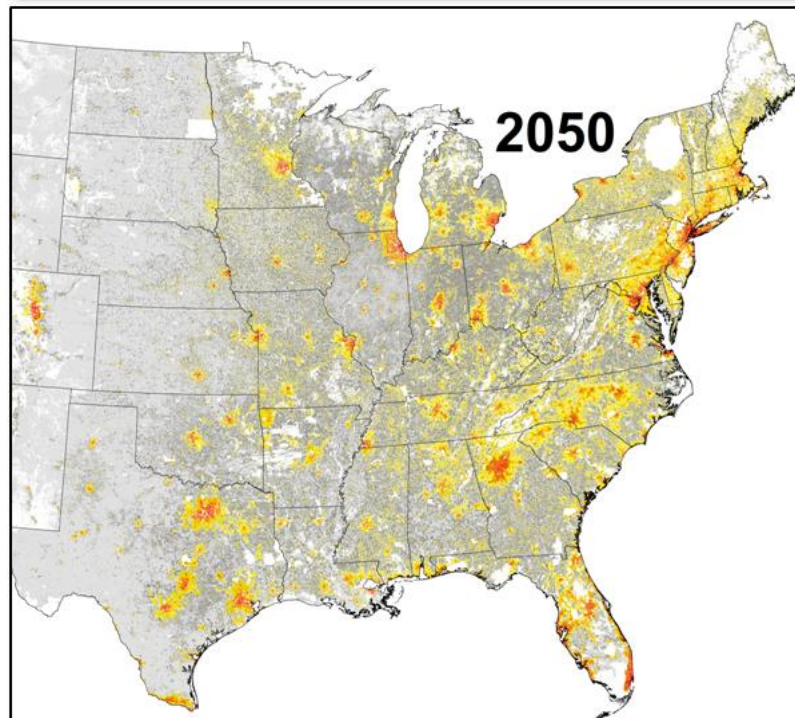
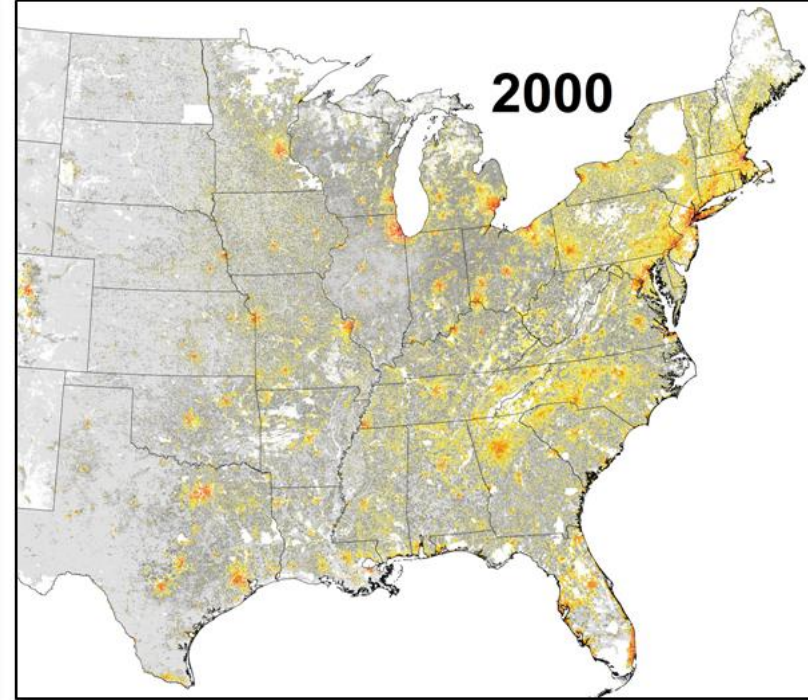
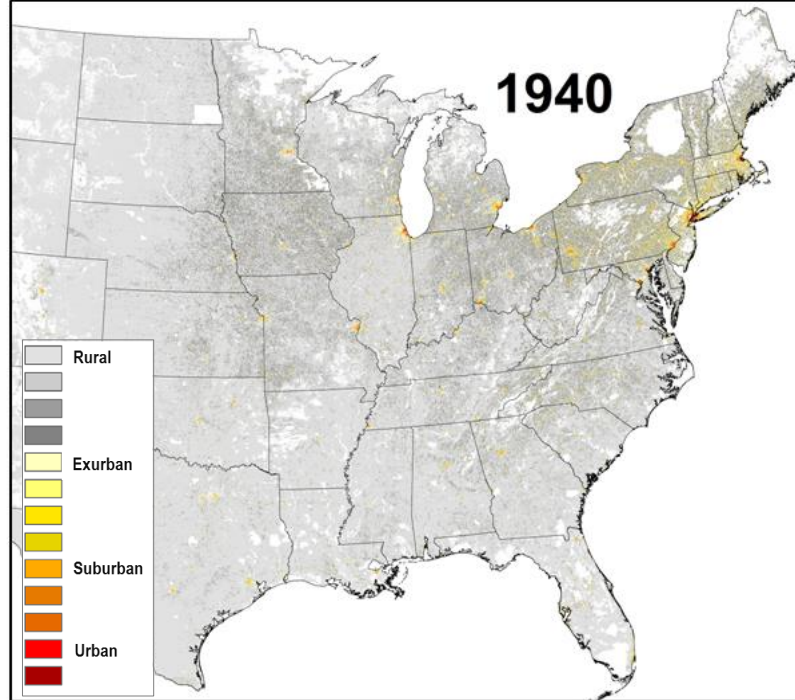




Population more than **doubled** the past 80 years

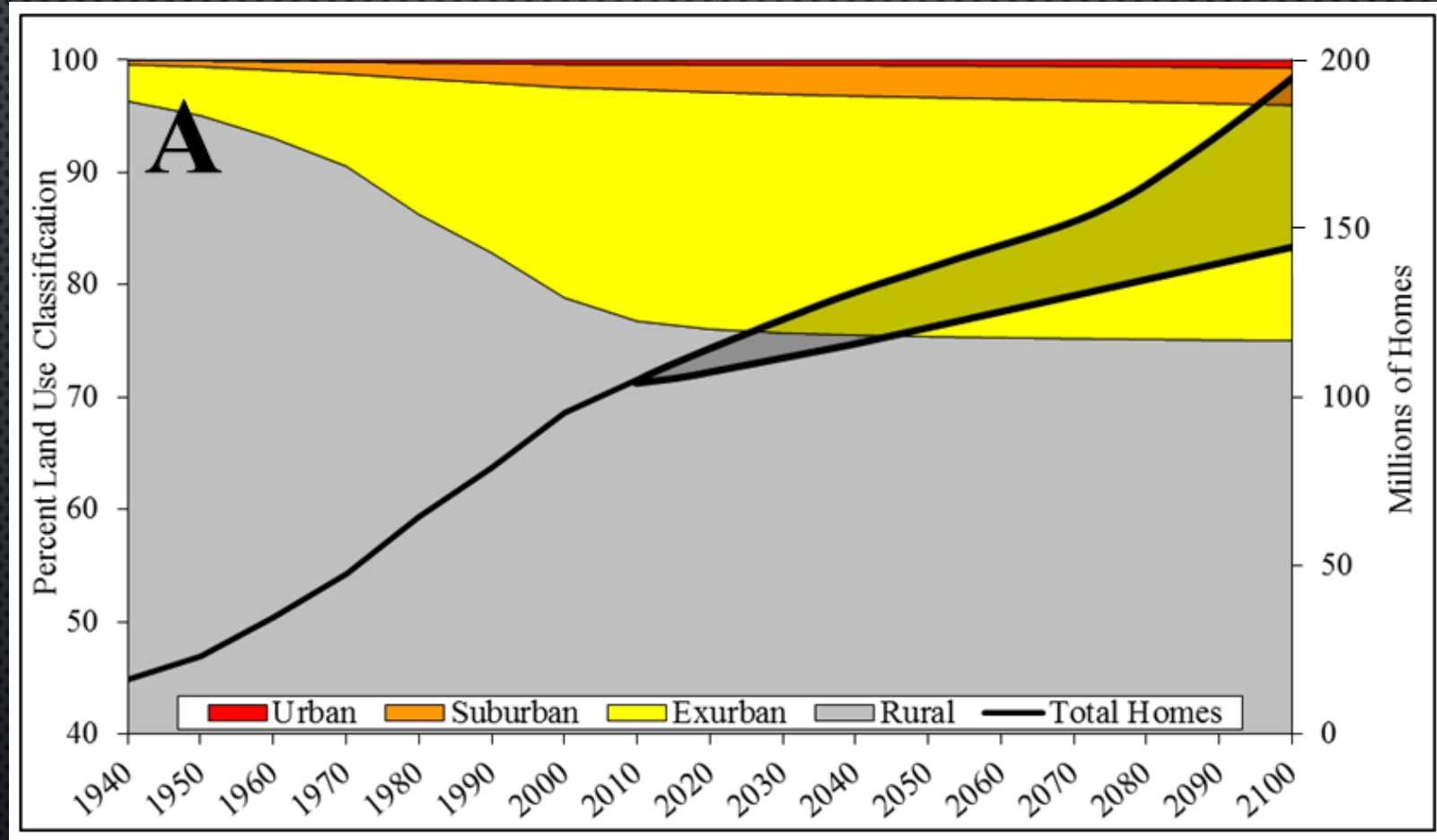
Transitioned from a rural to urban to suburban development character

Escalated exposure of population and built environment to hazards



# % urban, suburban, exurban, and rural land use, 1940-2100 (A2)

East of the Continental Divide



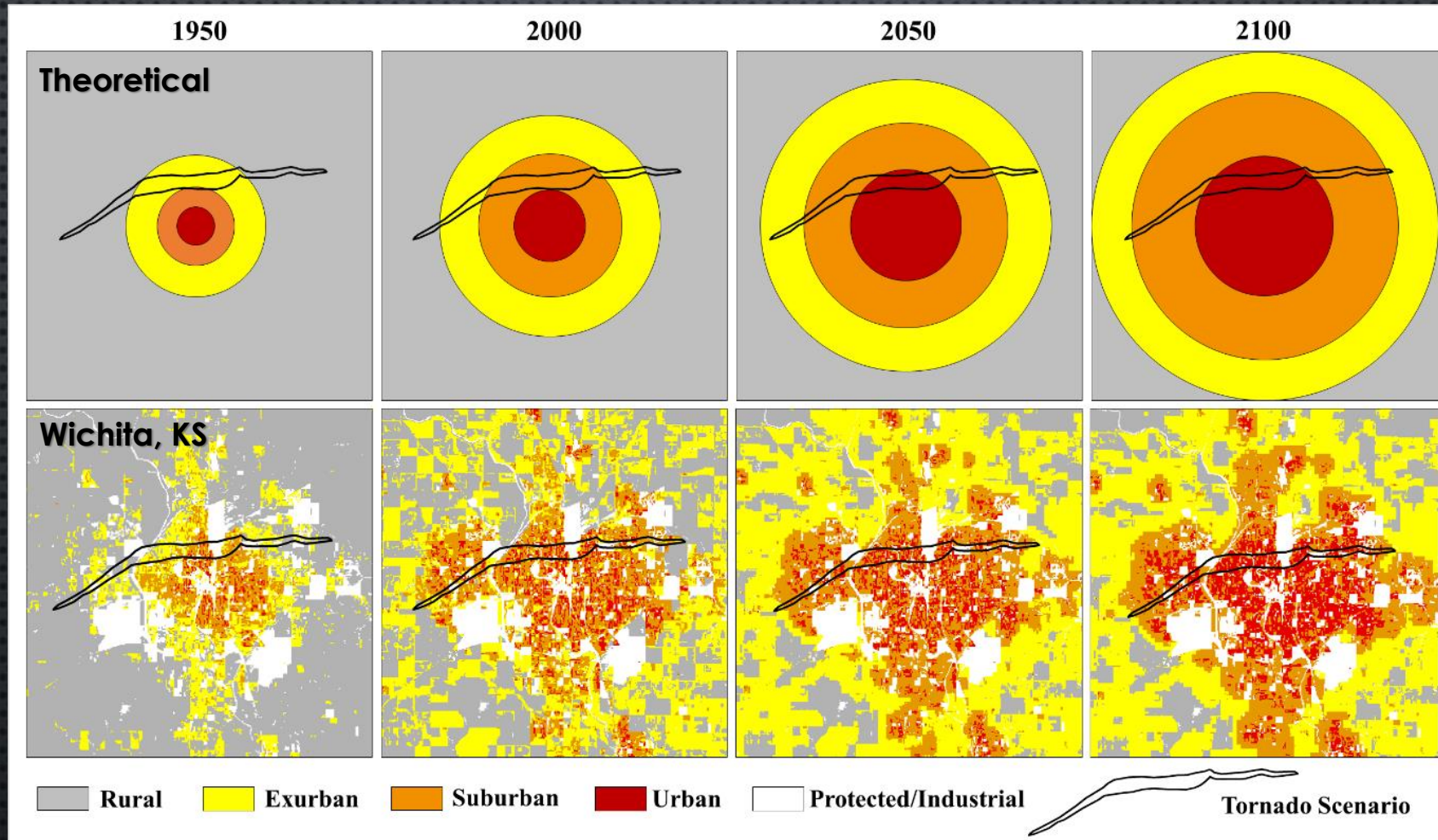
black line: total number of homes (millions)

shaded: the potential number of homes in 21<sup>st</sup> century based on climate/societal scenarios

**Most growth in exurban and suburban morphologies, largely at expense of rural land**  
**From 1950-2010: 1) housing units increased by 79 million, or 346%; 2) urban footprint increased more than fivefold**

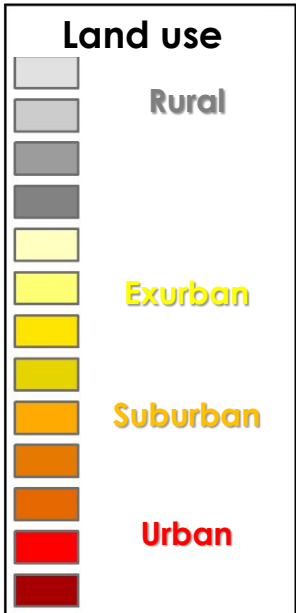
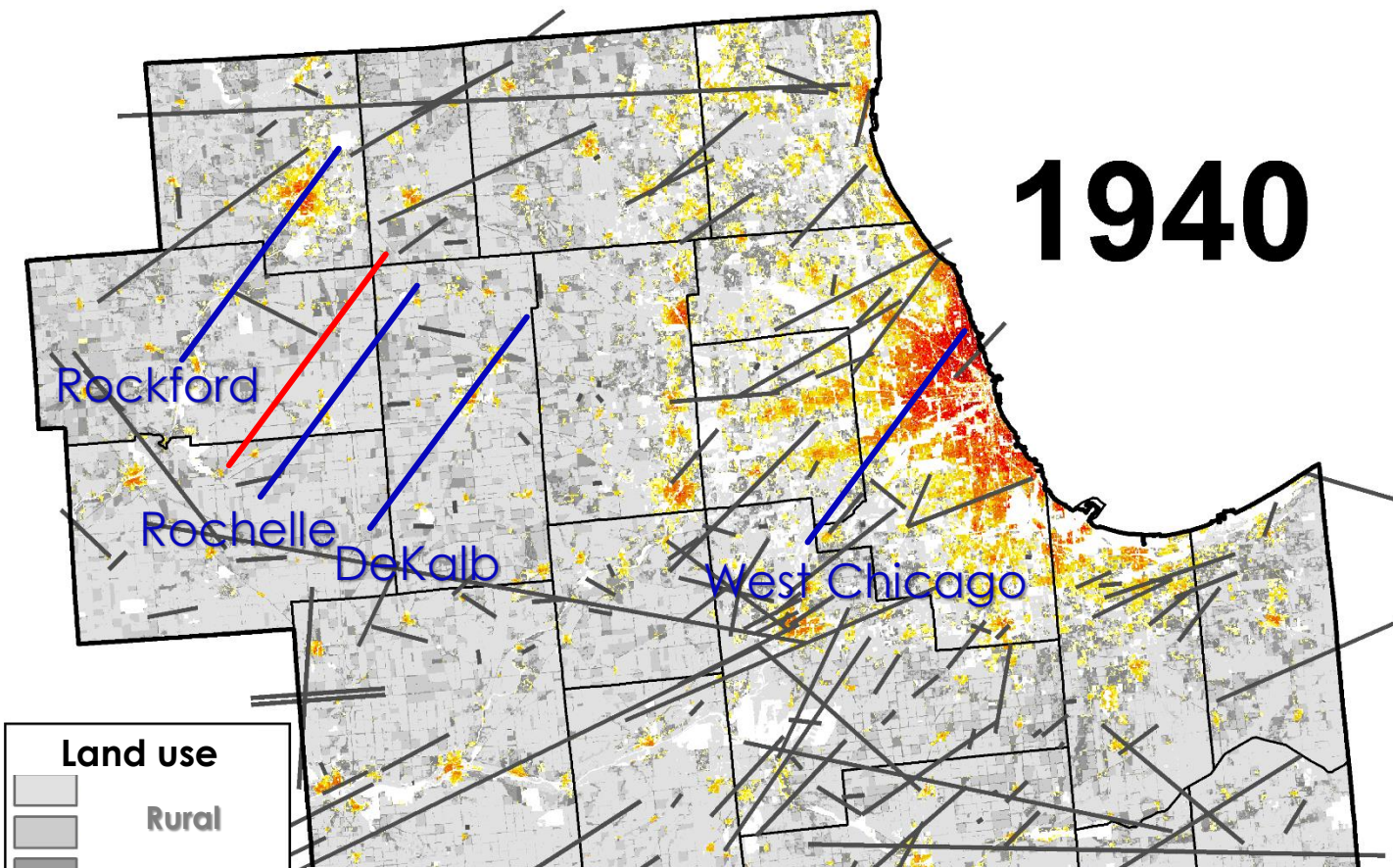


# Expanding Bull's Eye Effect



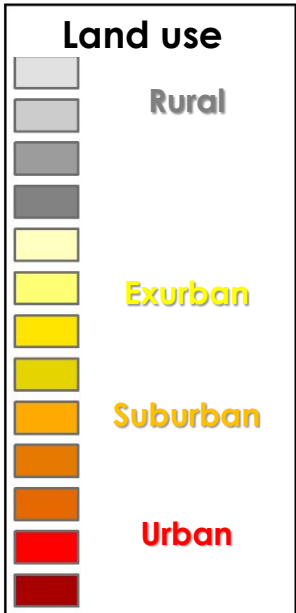
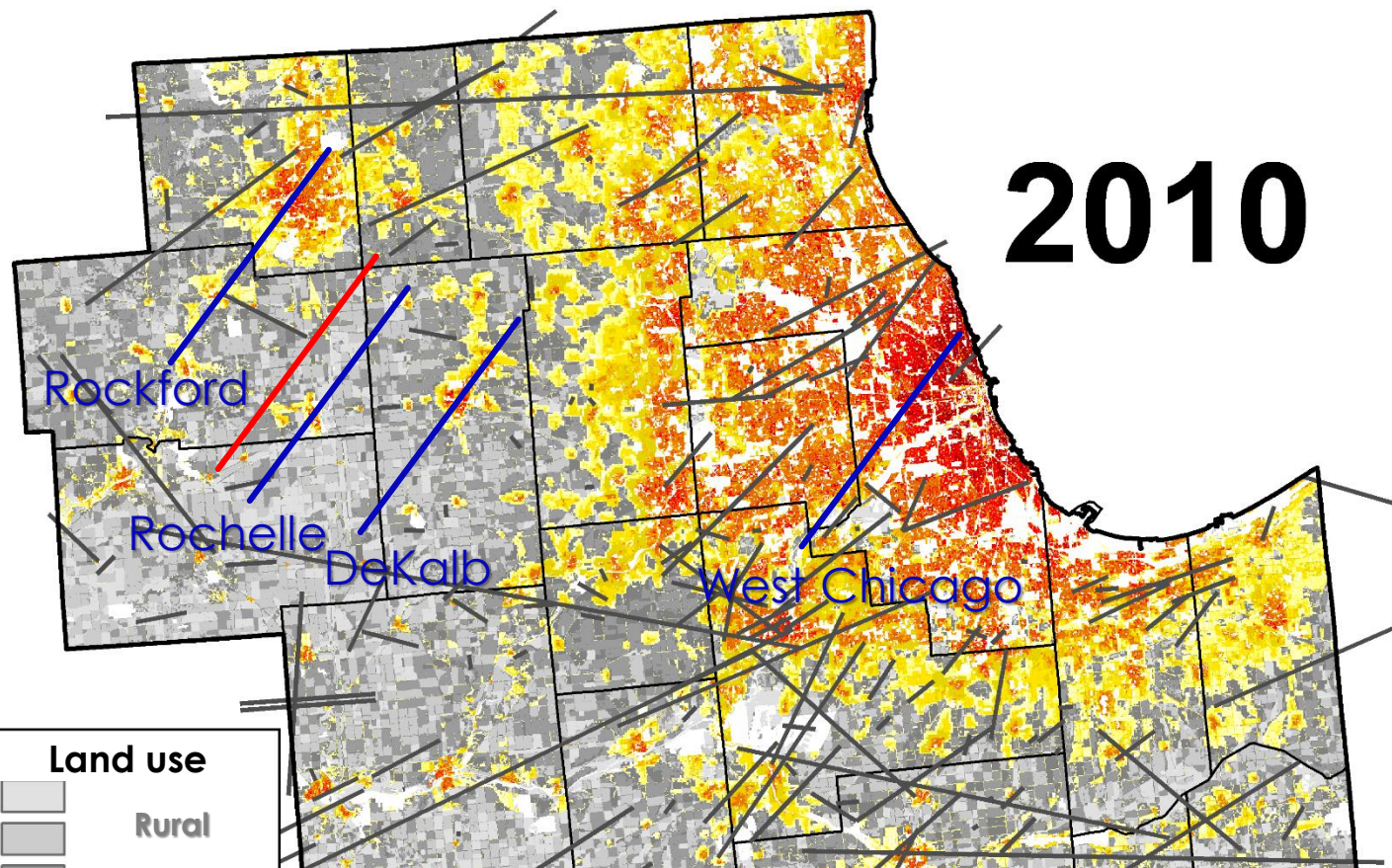
*Argues that “targets”—i.e., humans and their possessions—of hazards are increasing as populations grow ... and spread*

# 1940



Scenario	1940 Homes	2010 Homes	Change	% Change
Observed Event	25	75	+50	+200%
Byron-Rockford	925	3,500	+2,575	+248%
Rochelle	270	940	+670	+278%
DeKalb-Sycamore	325	2,000	+1,675	+515%
West Chicago	9,500	20,000	+10,500	+111%

# 2010



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# Contemporary Tornado Disaster Cases

Path	Year	Deaths	HUs							1950–2010 absolute change	Percent change 1950–2010
			1950	1960	1970	1980	1990	2000	2010		
Moore	2013	24	45	83	354	1,327	2,545	3,448	3,829	3,784	8,354
Plainfield	1990	29	109	242	516	804	907	1,670	2,173	2,064	1,892
Tuscaloosa	2011	65	1,549	3,061	4,507	6,420	6,420	8,549	8,809	7,260	469
	Length (km)	Max width (m)	Percentage of path developed								
Moore	22.5	1,737	5.8	10.4	21.6	37.1	57.6	75.9	88.4	82.6	
Plainfield	26.4	548	11.6	26.9	33.7	36.7	37.8	45.0	69.0	57.4	
Tuscaloosa	80.7	2,377	18.0	22.7	25.6	28.9	33.2	40.2	42.5	24.5	

Ashley and Strader 2016 *BAMS*



Moore 2013

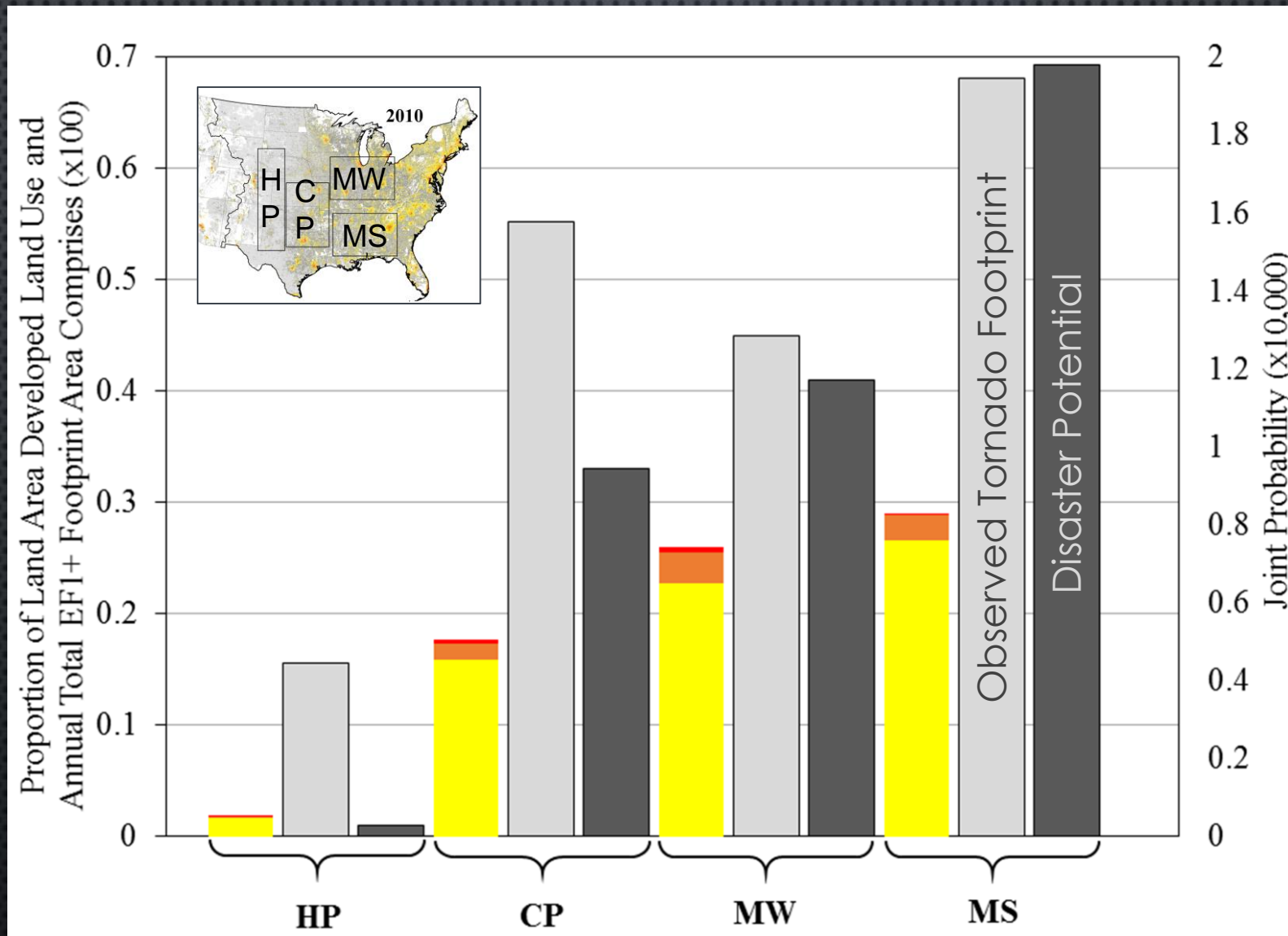


Plainfield 1990

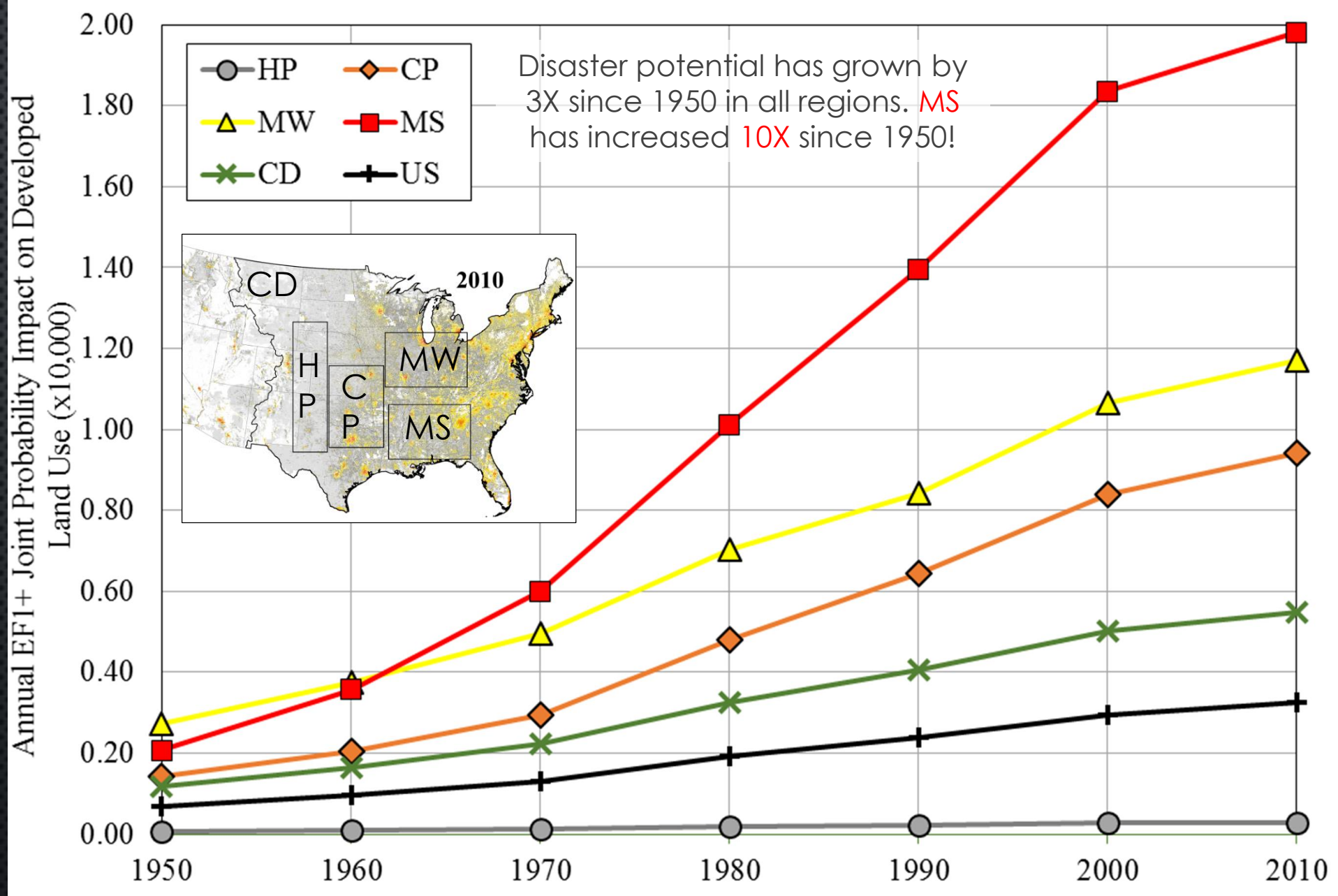


Tuscaloosa 2011

Probability an EF1+ path intersects development (**urban**, **suburban**, **exurban**) in 2010.



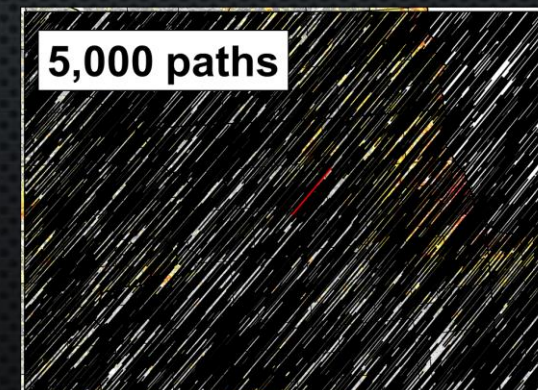
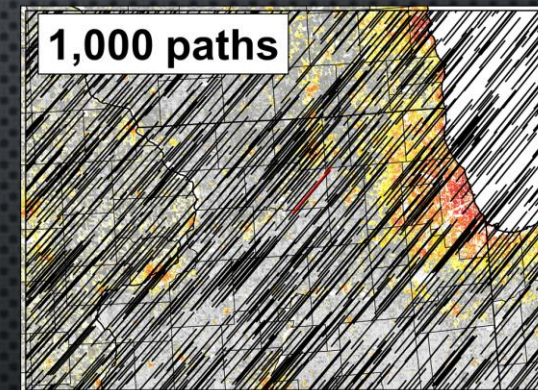
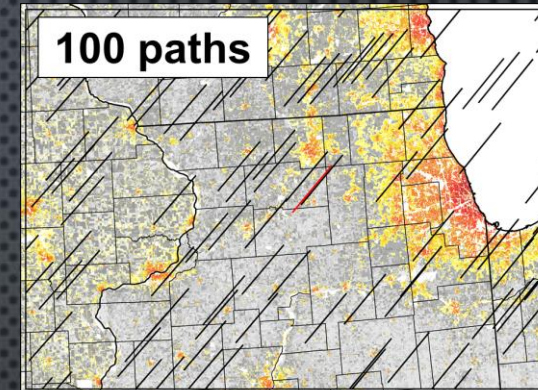
Left axis: proportion of land area that is **developed** and EF1+ total footprint (light grey).  
 Right axis: probability an EF1+ tornado path traverses a developed grid cell (dark grey).



joint probability that an EF1+ tornado path is juxtaposed with a developed land use grid cell by analysis region

# TORNADO IMPACT MONTE CARLO (TORMC) MODEL

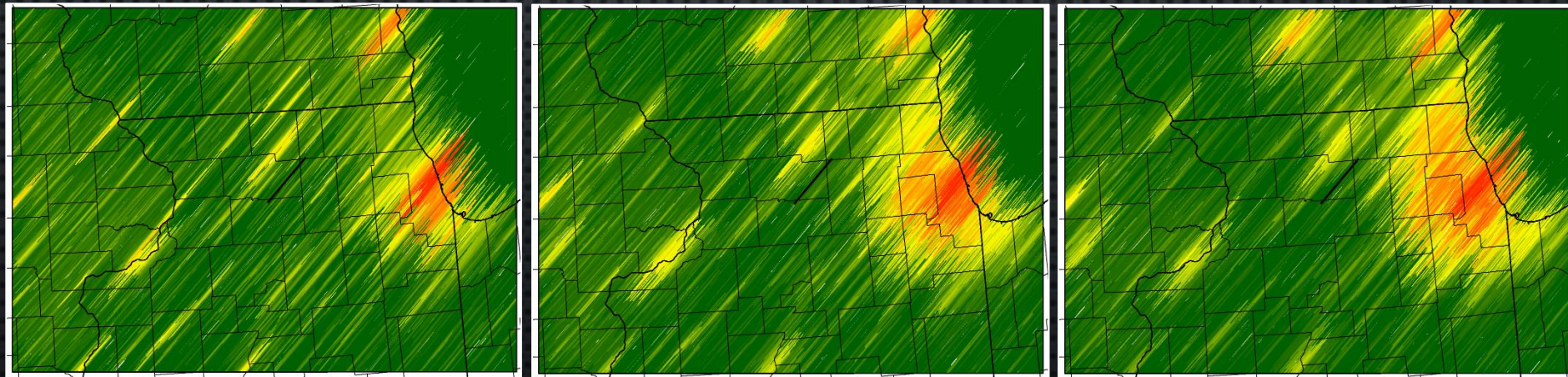
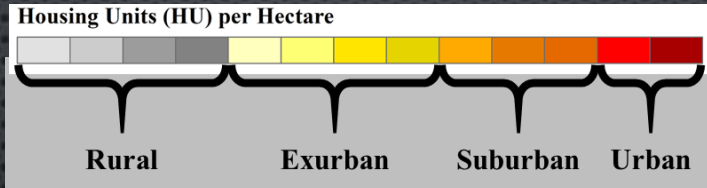
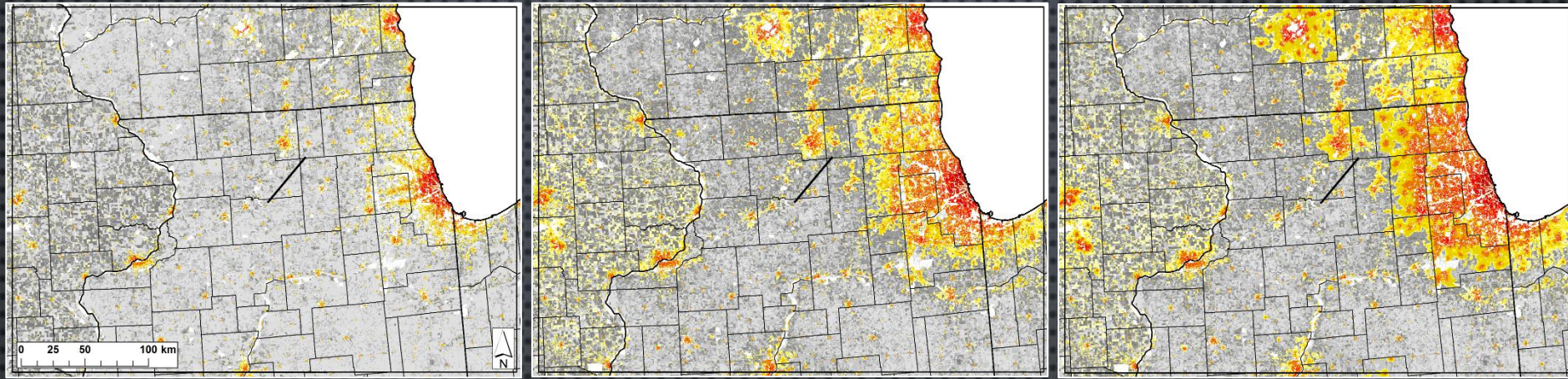
1. RECREATE THE ROCHELLE, IL TORNADO 10,000 TIMES ACROSS NORTHERN IL
  2. TAKE HISTORICALLY OBSERVED **REGIONAL** TORNADO ATTRIBUTES (I.E., LENGTH, WIDTH, AZIMUTH, MAGNITUDE, COUNTS, ETC.) AND GENERATES NEW EVENTS BASED ON THESE ATTRIBUTES
    - 10,000 YEARS OF MIDWEST EVENTS
- INTERSECT PATHS WITH UNDERLYING COST SURFACE (HOUSING UNITS, POPULATION) TO ESTIMATE IMPACTS
  - PROBABILITY OF EXCEEDANCE CURVES  $\approx$  IMPACT MAGNITUDE PROBABILITIES



1950

2010

2070

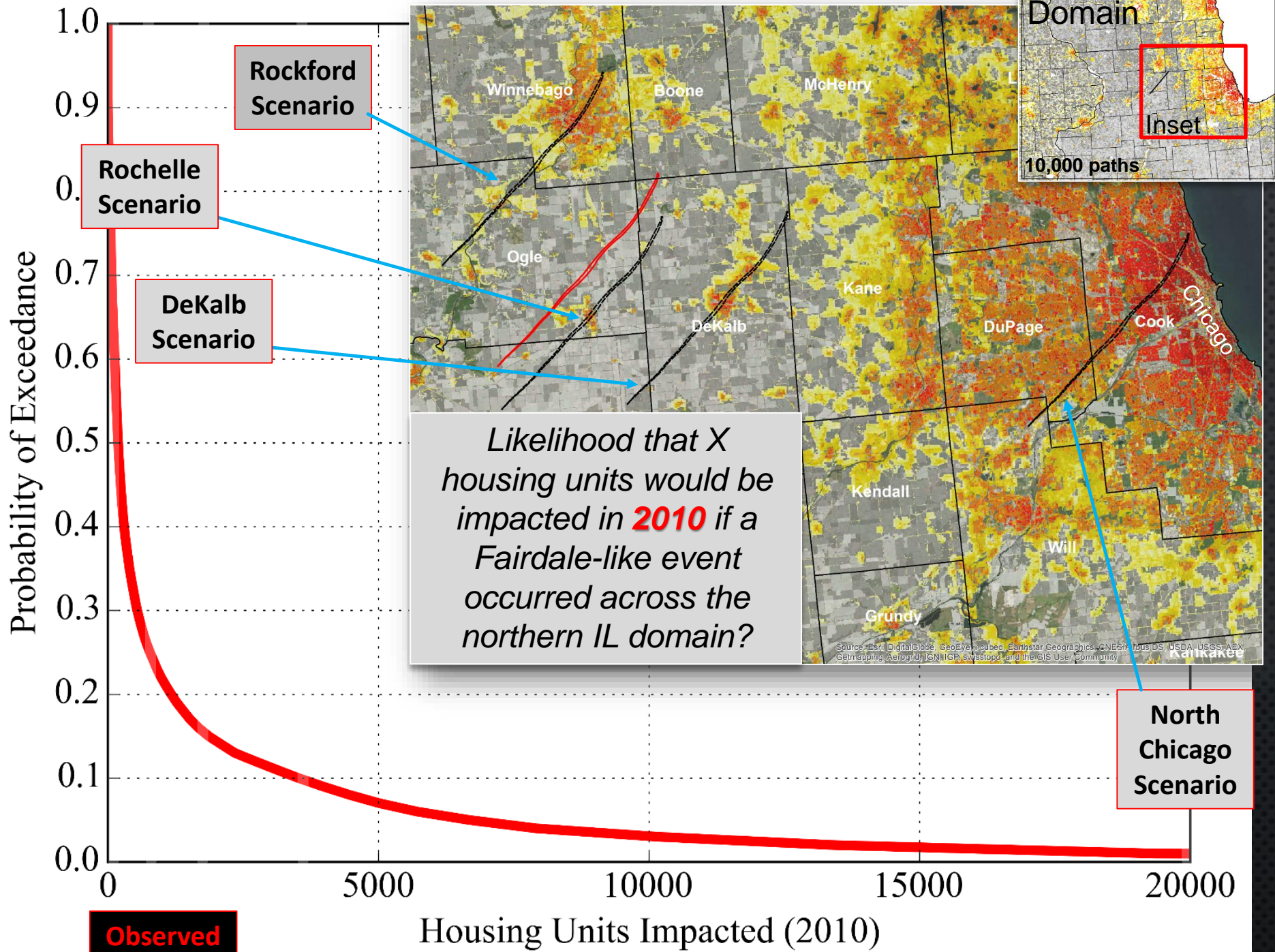


10,000 Rochelle tornado simulations

Tornado Impact Magnitude



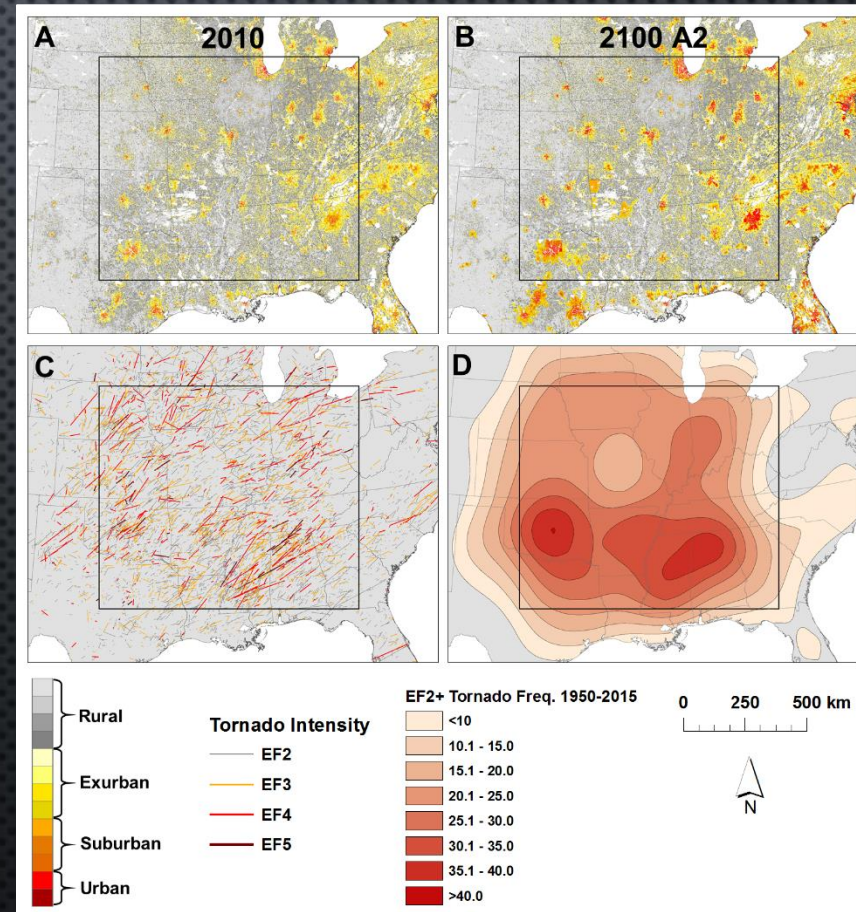




# 21<sup>ST</sup> CENTURY $\Delta$ IN RISK, EXPOSURE, AND DISASTER POTENTIAL

Four-step experimental control methodology with selected exposure and risk simulation scenario combinations.

Simulation scenario	Exposure variable	Risk variable
Baseline control	2010	Observed EF2+ risk
Changing exposure; constant risk	2100 (A2)	Observed EF2+ risk
Changing risk; constant exposure	2010	50% <b>increase</b> in EF2+ frequency and annual variability
Changing risk and exposure	2100 (A2)	50% <b>increase</b> in EF2+ frequency and annual variability



- Impacts are expected to increase between 6 and 36 times from 1940-2100

**Δ exposure; constant risk**

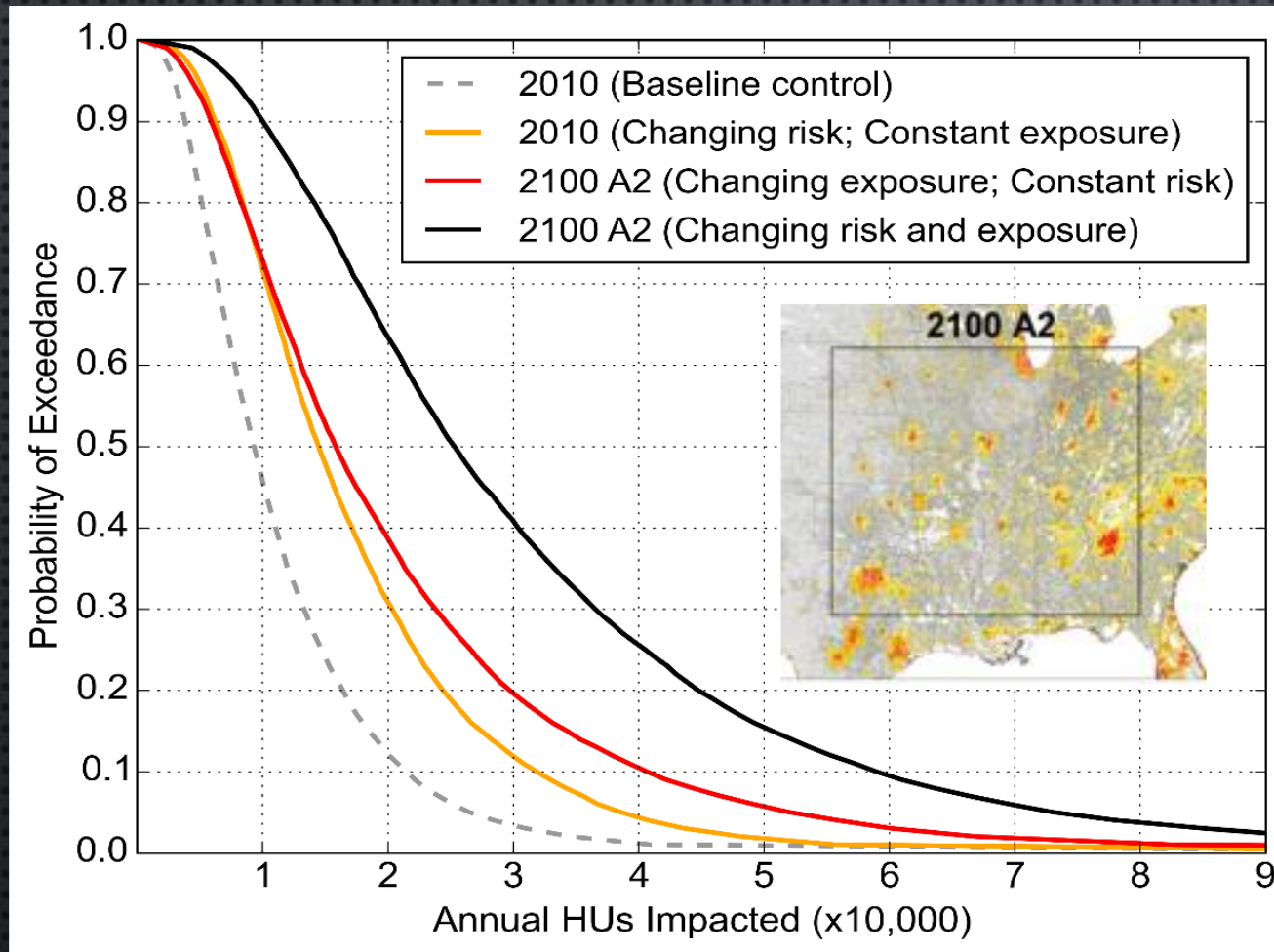
*doubling* of high-end tornado impact potential by 2100

**Δ risk; constant exposure**

median annual tornado impact potential **1.5 times** greater by 2100

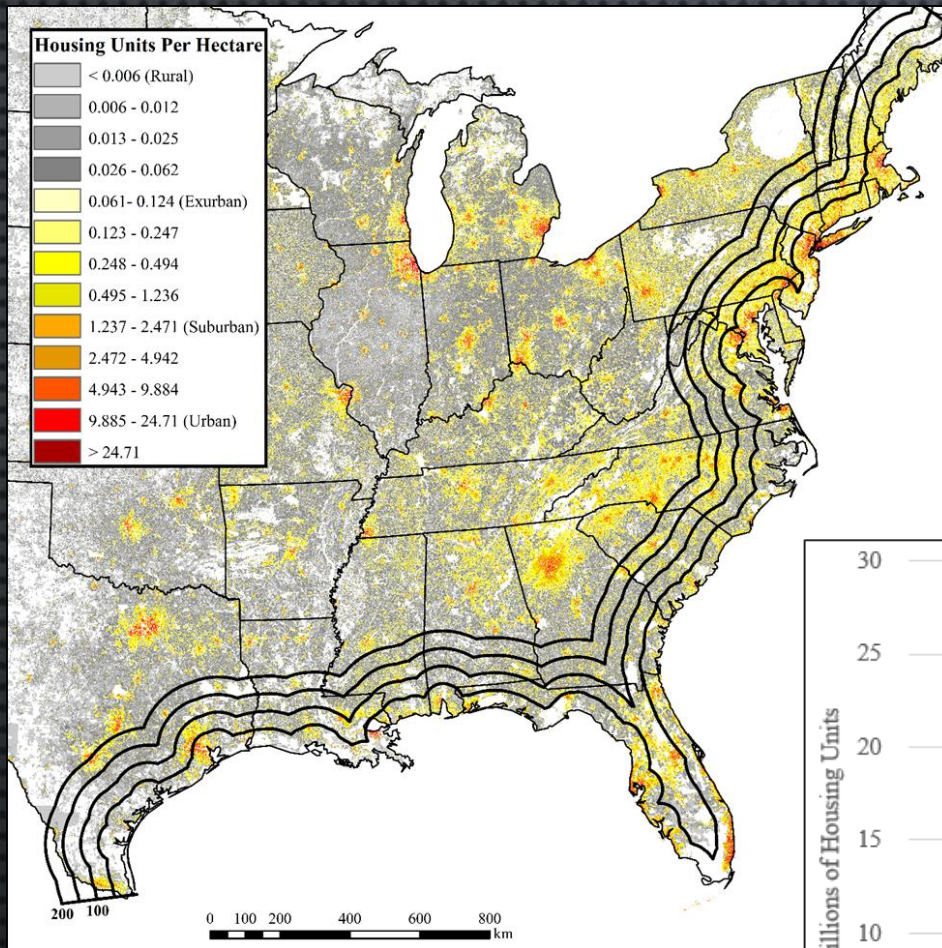
**Δ risk and Δ exposure**

**threefold** ↑ in median annual tornado impacts and disaster potential from 2010>2100



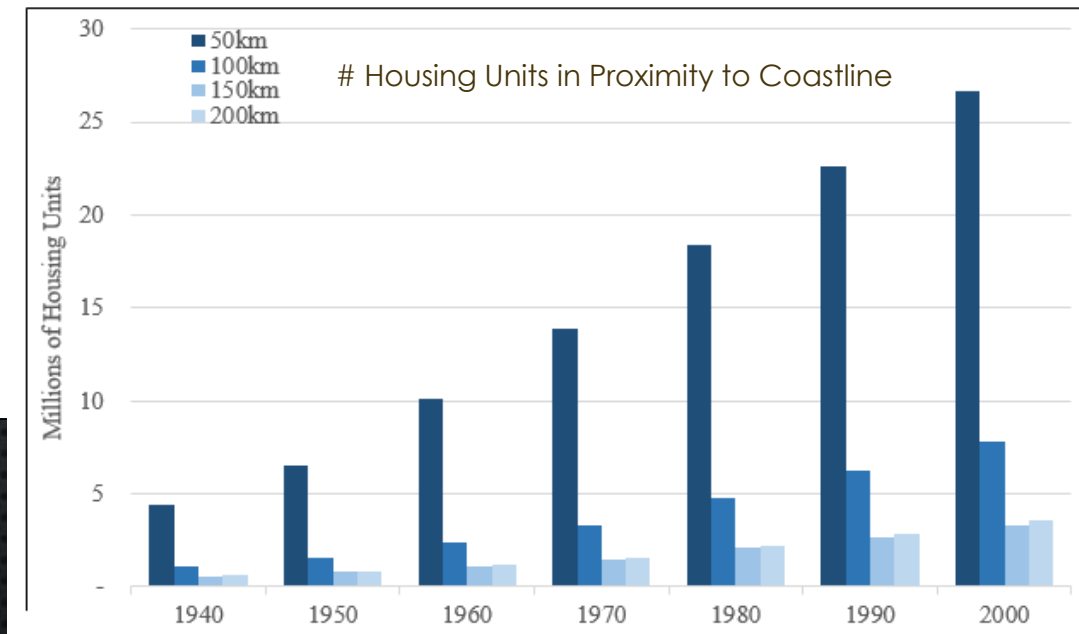
Impacts are expected to ↑ between 6 and 36 X from 1940-2100

Largest ↑ will be in Southeast and Mid-South, which has highest disaster potential.



Not just a tornado problem.

An EVERY hazard problem!



40% of population lives in coastal counties, which is only 10% of land area of lower 48.

# BOTTOM LINE

- HCW WILL CONTINUE TO BE A \$10B PERIL ANNUALLY IN THE US
- INCREASE IN VARIABILITY
- EXPOSURE & VULNERABILITY ARE KEY
- FORECASTS ARE GETTING BETTER (NEED MORE R&D)
- JUST WHEN YOU THINK...



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**Thanks!**

**Questions / Discussion?**