Weathering the Storm: Severe Thunderstorm's "New Normal" Just Met Its Match

September 2014

Prepared by Aon Benfield & Impact Forecasting

Aon
Empower Results®

Agenda

Section 1	Severe Weather 101
Section 2	Severe Weather Frequency
Section 3	Why Is Severe Weather Data So Hard To Capture Accurately?
Section 4	Help! What do we do now?

Section 1: Severe Weather 101

Severe Weather Definition In The U.S.

- Convectively-induced winds of 57 mph or greater

- Hail of 1.00” in diameter or greater
  – (changed in 2009)

- Any tornadoes

My favorite form of entertainment…

Tornado Intensity – Original vs. Enhanced

Original Fujita Scale (1971-2007)

Scale	Estimated wind speed*		Relative frequency
	mph	km/h	
F0	40–72	64–116	38.9%
F1	73–112	117–180	35.6%
F2	113–157	181–253	19.4%
F3	158–206	254–332	4.9%
F4	207–260	333–418	1.1%
F5	261–318	419–512	Less than 0.1%

Enhanced Fujita Scale (2007-Present)

scale	Wind speed		Relative frequency
	mph	km/h	
EF0	65–85	105–137	53.5%
EF1	86–110	138–178	31.6%
EF2	111–135	179–218	10.7%
EF3	136–165	219–266	3.4%
EF4	166–200	267–322	0.7%
EF5	>200	>322	Less than 0.1%

Tornado Intensity – The ENHANCED Fujita Scale

28 Damage Indicators (DI), Varying Degrees of Damage (DoD)

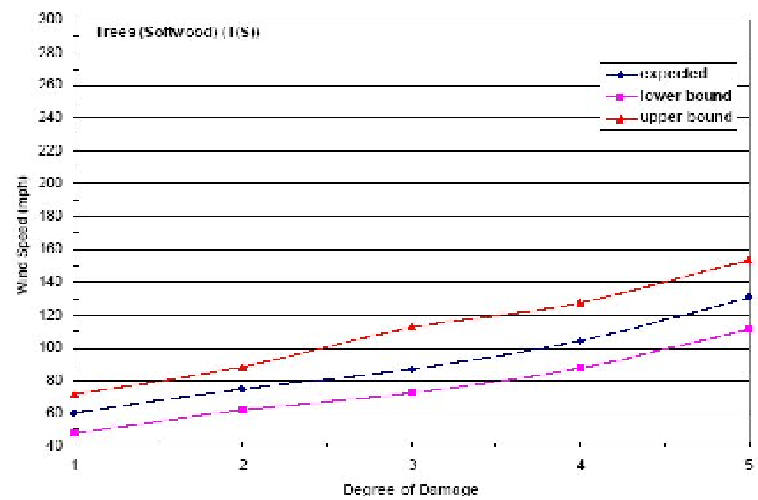
DI #	DI Description	DoD
1	Small Barns or Farm Outbuildings (SBO)	8
2	One- or Two-Family Residences (FR12)	10
3	Manufactured Home – Single Wide (MHSW)	9
4	Manufactured Home – Double Wide (MHDW)	12
5	Apartments, Condos, Townhouses [3 stories or less] (ACT)	6
6	Motel (M)	10
7	Masonry Apartment or Motel Building (MAM)	7
8	Small Retail Building [Fast Food Restaurants] (SRB)	8
9	Small Professional Building [Doctor's Office, Branch Banks] (SPB)	9
10	Strip Mall (SM)	9
11	Large Shopping Mall (LSM)	9
12	Large, Isolated Retail Building [K-Mart, Wal-Mart] (LIRB)	7
13	Automobile Showroom (ASR)	8
14	Automobile Service Building (ASB)	8
15	Elementary School [Single Story; Interior or Exterior Hallways] (ES)	10
16	Junior or Senior High School (JHSH)	11
17	Low-Rise Building [1–4 Stories] (LRB)	7
18	Mid-Rise Building [5–20 Stories] (MRB)	10
19	High-Rise Building [More than 20 Stories] (HRB)	10
20	Institutional Building [Hospital, Government or University Building] (IB)	11
21	Metal Building System (MBS)	8
22	Service Station Canopy (SSC)	6
23	Warehouse Building [Tilt-up Walls or Heavy-Timber Construction] (WHB)	7
24	Electrical Transmission Lines (ETL)	6
25	Free-Standing Towers (FST)	3
26	Free-Standing Light Poles, Luminary Poles, Flag Poles (FSP)	3
27	Trees: Hardwood (TH)	5
28	Trees: Softwood (TS)	5

28. TREES (SOFTWOOD)

Typical Construction
- Softwood: Pine, Spruce, Fir, Hemlock, Cedar, Redwood, Cypress

DOD	Damage description	EXP	LB	UB
1	Small limbs broken (up to 1" diameter)	60	48	72
2	Large branches broken (1" – 3" diameter)	75	62	88
3	Trees uprooted	87	73	113
4	Trunks snapped	104	88	128
5	Trees debarked with only stubs of largest branches remaining	131	112	153

* Degree of Damage



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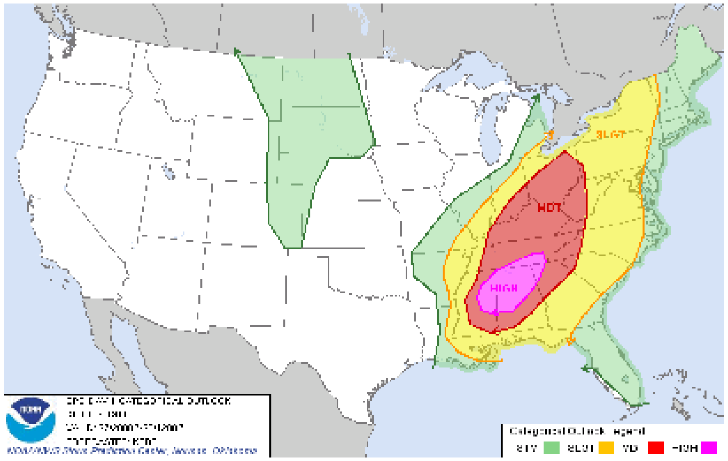
Severe Weather Forecasting: SPC

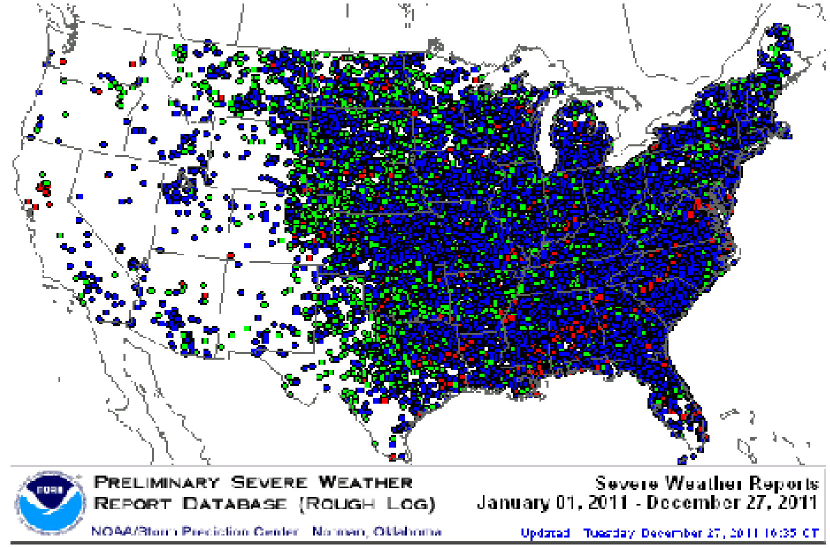
- 43 governmental employees that issue forecasts and watches for severe weather, also issues forecasts for fire weather and other hazardous weather conditions such as winter storms
  - 1952: **SE**vere **L**ocal **S**torms Unit (SELS), Washington D.C
    - 1954: 1955: Convective Outlooks
  - 1966: **N**ational **S**evere **S**torms **F**orecast **C**enter (NSSFC)
    - 1982: First **P**articularly **D**angerous **S**ituation (PDS) watch
    - 1986: Day 2 Convective Outlooks & Mesoscale Discussions
  - 1995: **S**torm **P**rediction **C**enter (SPC), Norman, Oklahoma
    - 1998: National Fire Weather Outlooks
    - 2001: Day 3 Convective Outlooks

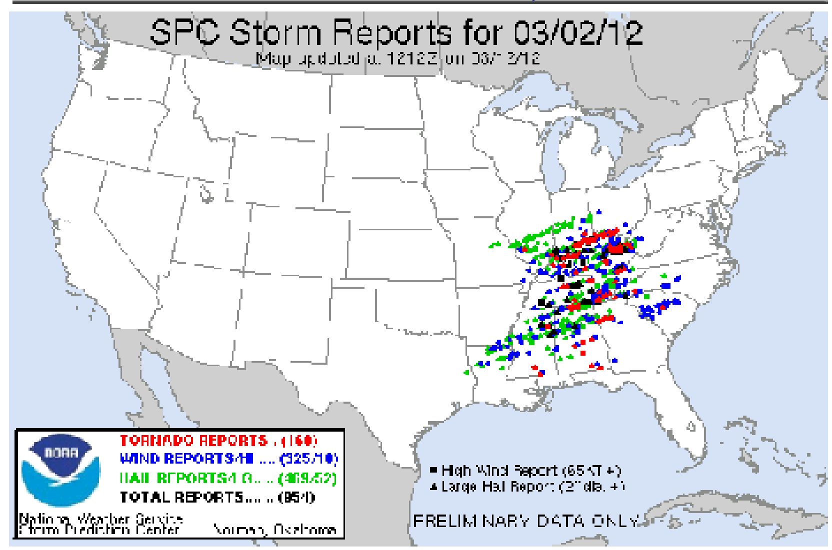
Storm Prediction Center
Norman, Oklahoma



Local Storm Reports (LSRs)

- Daily reports from National Weather Service offices of tornado, hail and damaging wind reports
- Available LSR data
  - Tornadoes: 1950
  - Hail and damaging winds: 1955
- Contains information on:
  - Date
  - Time
  - Coordinates (latitude, longitude)
  - Severe weather type
  - Severity
  - County
  - State





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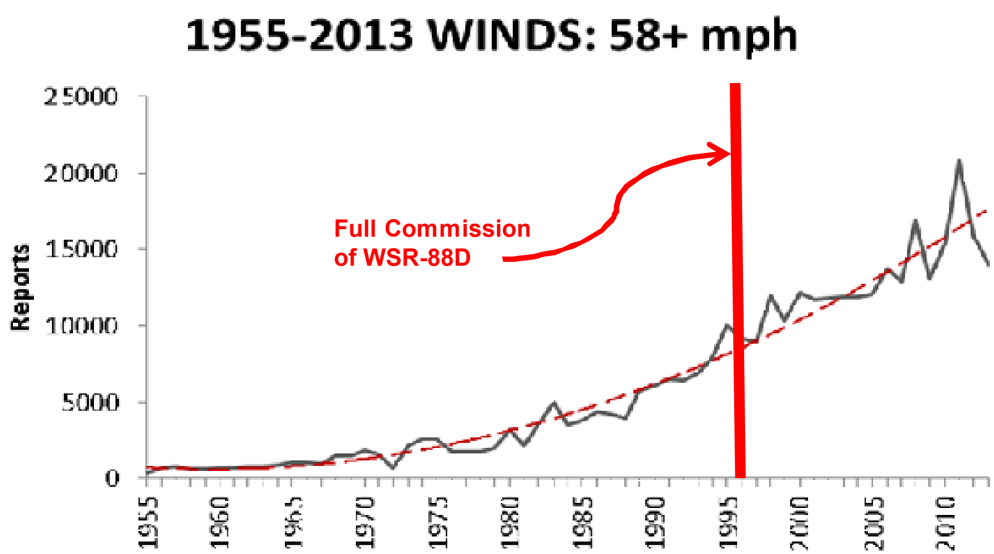
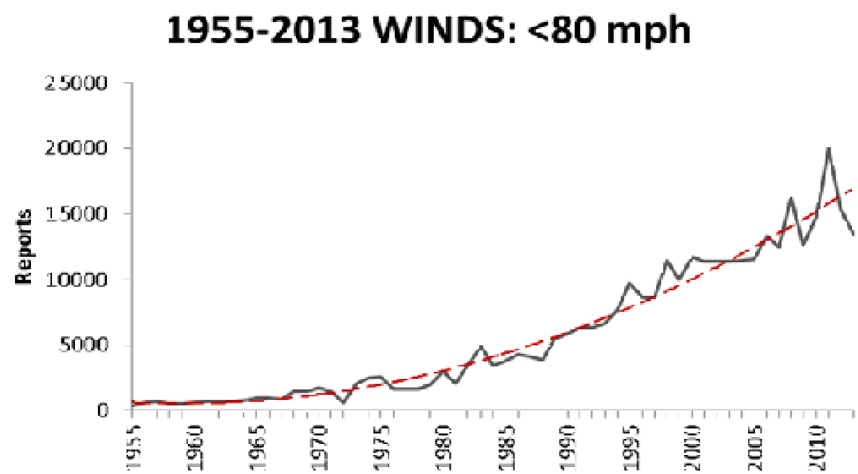
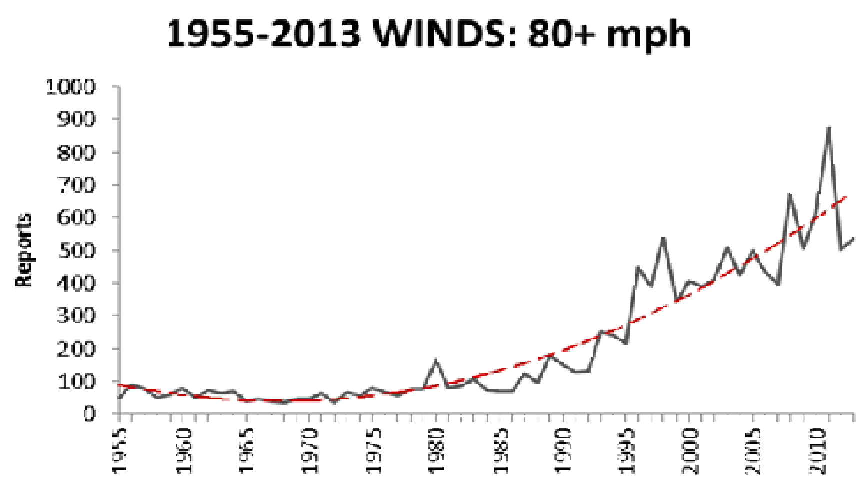
Section 2: Severe Weather Frequency

Annual Severe Weather Frequency: Wind

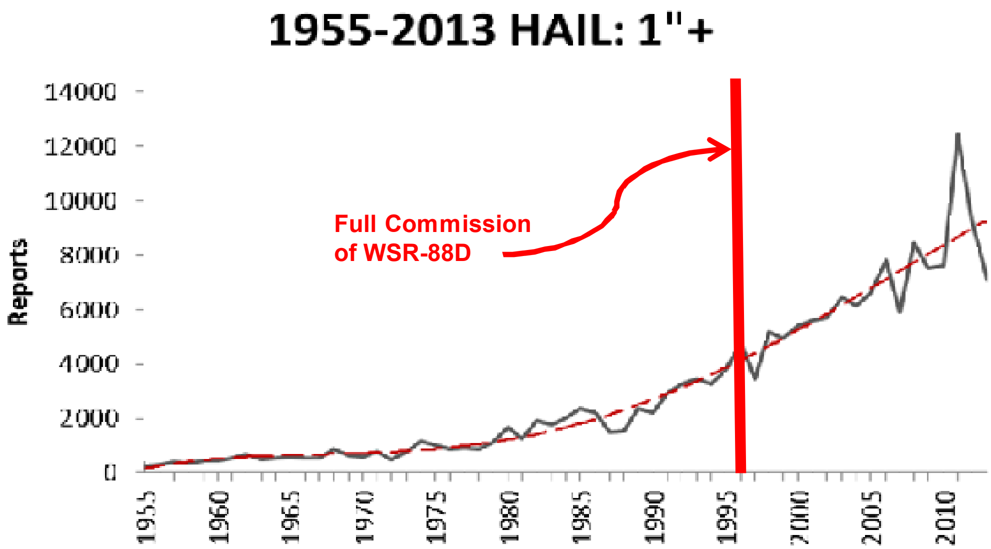




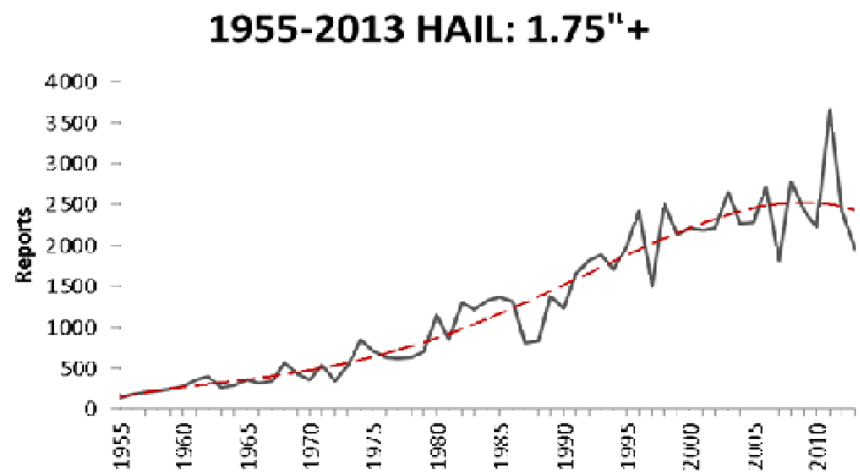
Both weaker AND stronger thunderstorm-produced winds show frequency increases



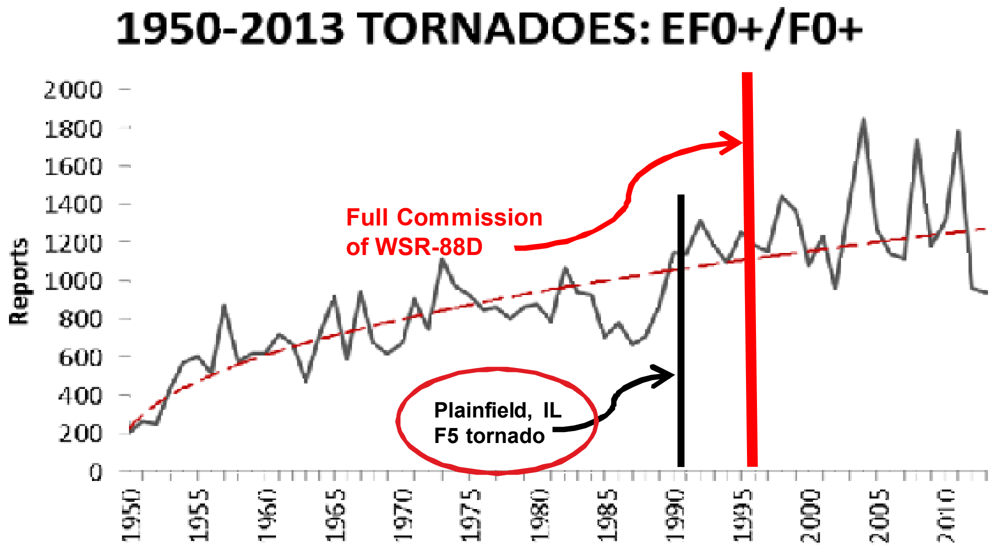
Annual Severe Weather Frequency: Hail

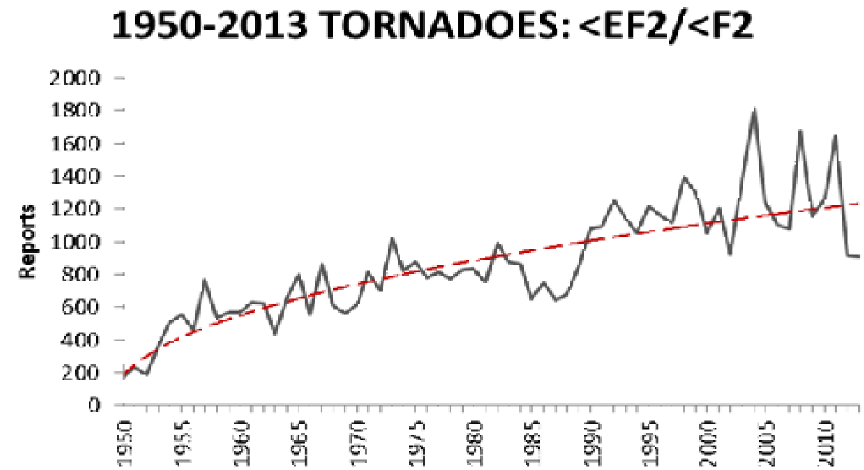


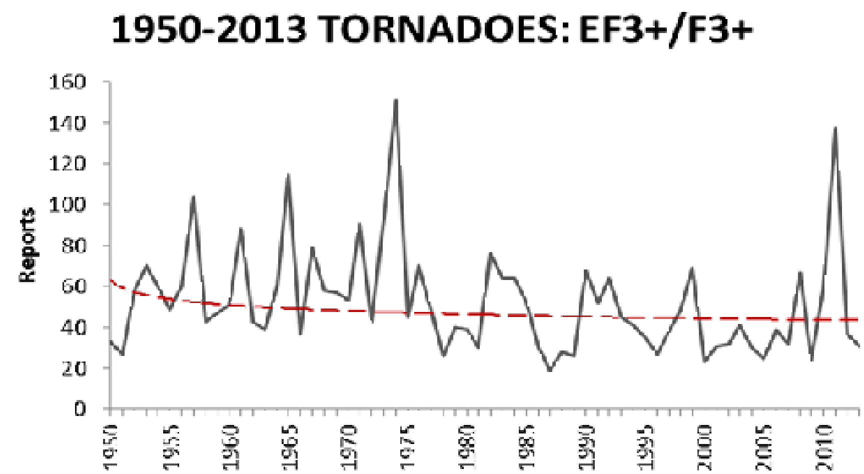
The vast majority of hail frequency increase stems from smaller hail occurrences



Annual Severe Weather Frequency: Tornadoes







The vast majority of tornado frequency increase stems from weaker tornado occurrences

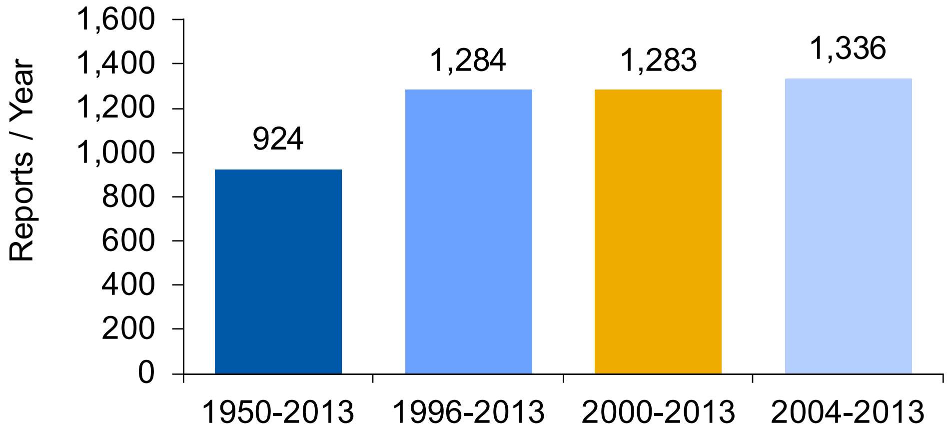
Importance Of The 08/28/90 Plainfield F5 Tornado

- Only F5/EF5 tornado to have occurred in August
- Wide rain-wrapped tornado (couldn’t see it!)
- Occurred during the end of school and work day
  - Struck Plainfield High School directly
- Moved northwest to southeast
- Only F5/EF5 to hit the Chicagoland area to this day
- **NO TORNADO WARNING UNTIL AFTER TORNADO LIFTED!**

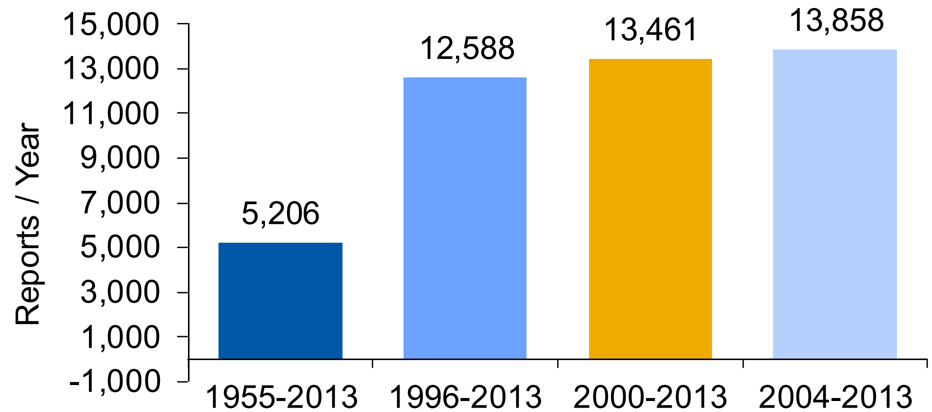
- Duration: 30 minutes
- Fatalities: 29
- Injuries: 353
- Damages (2014 USD): $195 million

Severe Thunderstorm Sub-Peril Frequency

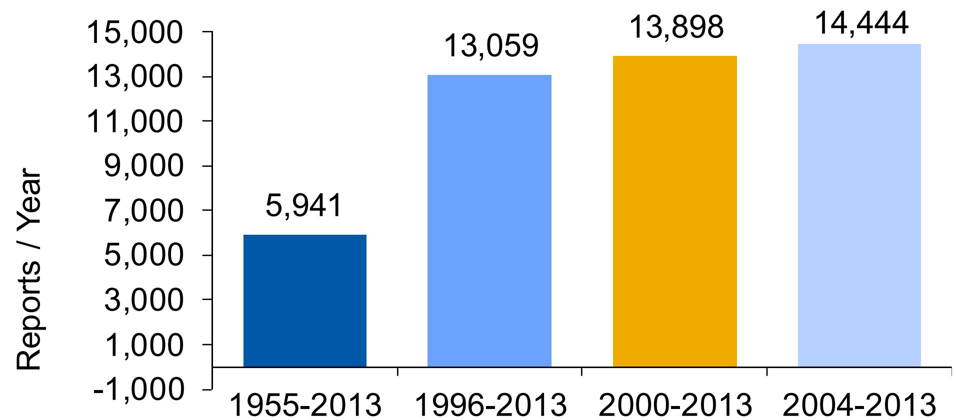
Average Annual SPC Reports: All Tornadoes



Average Annual SPC Reports: All Hail



Average Annual SPC Reports: All T-Storm Winds (Non-Tornadic)



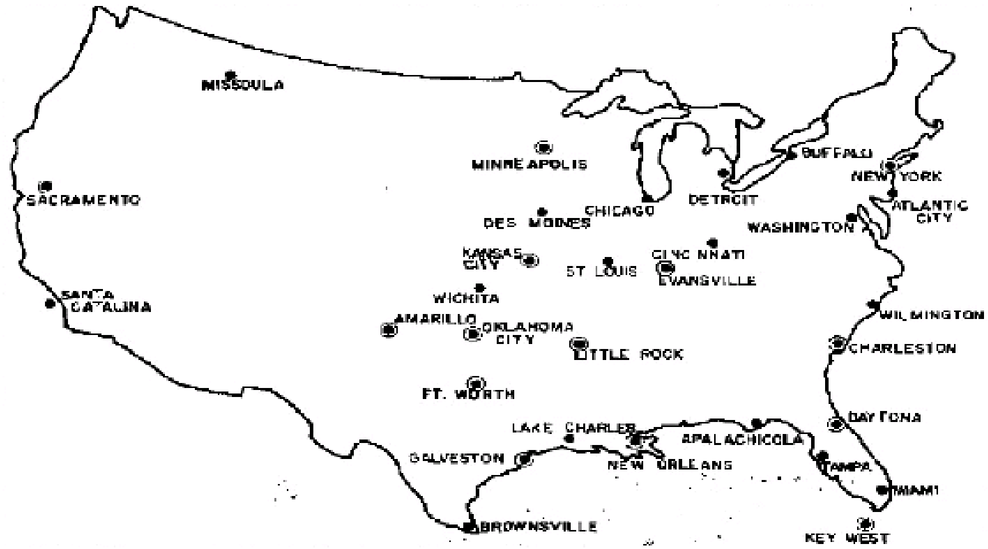
- 1950-2013: Entire SPC historical database
- 1996-2013: U.S. Doppler Radar deployment
- 2000-2013: 21st century
- 2004-2013: Last 10 years

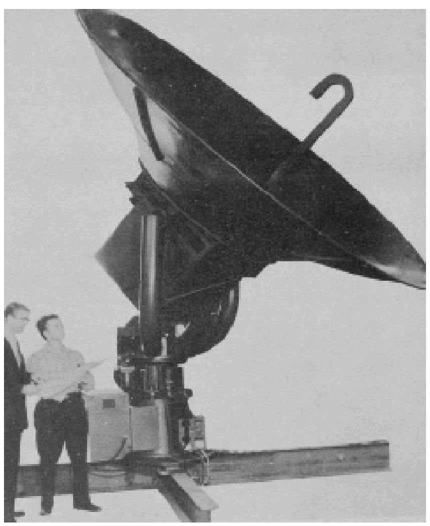
WHY THE DRAMATIC FREQUENCY CHANGES?

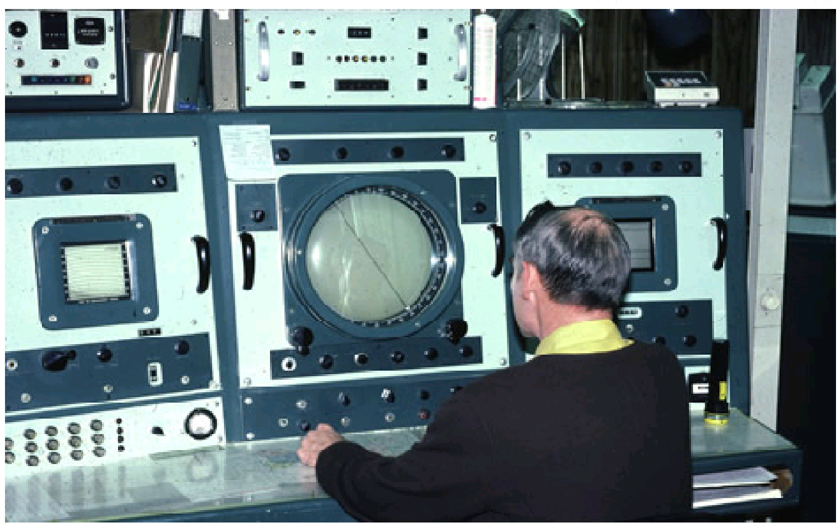
Meteorological Advances: Technology

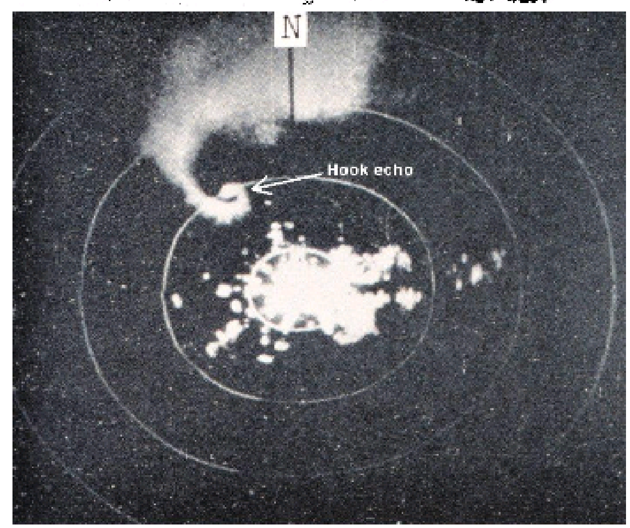
1950s – early 1990s: WSR-57

- 66 radars
- vacuum tubes
- max range: 494 nautical miles
- max power: 410,000 watts





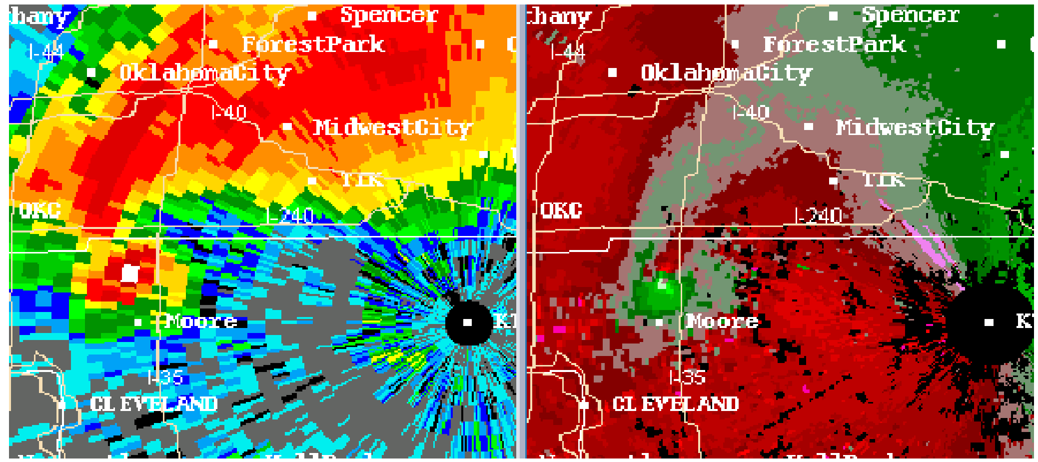


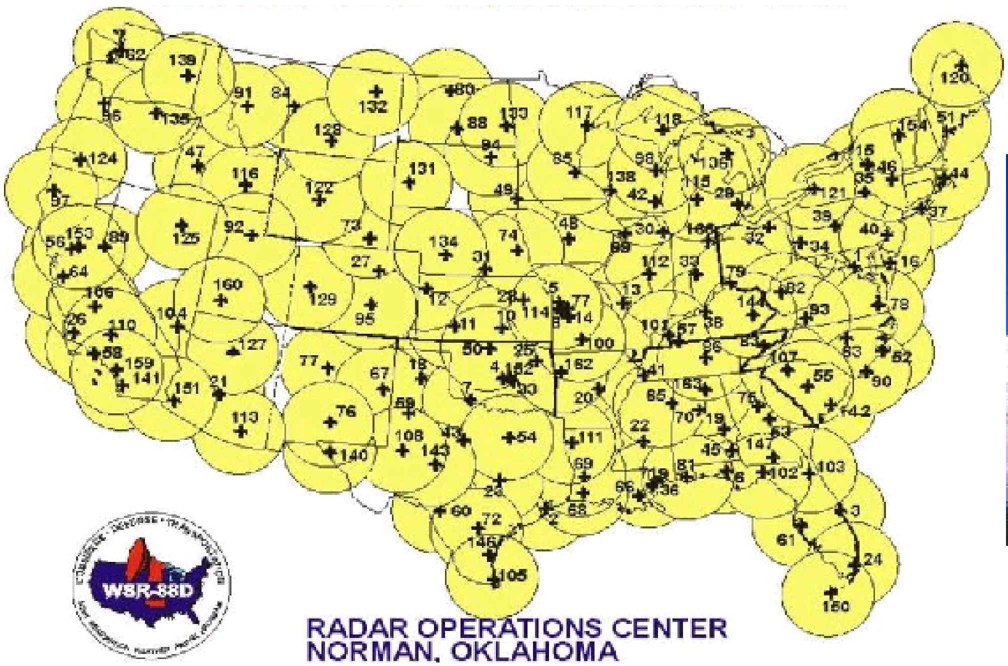


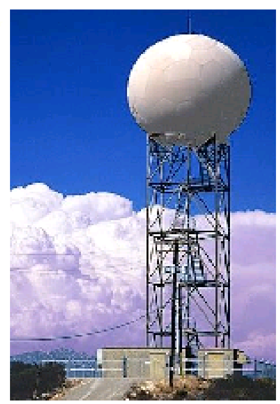
Meteorological Advances: Weather Technology

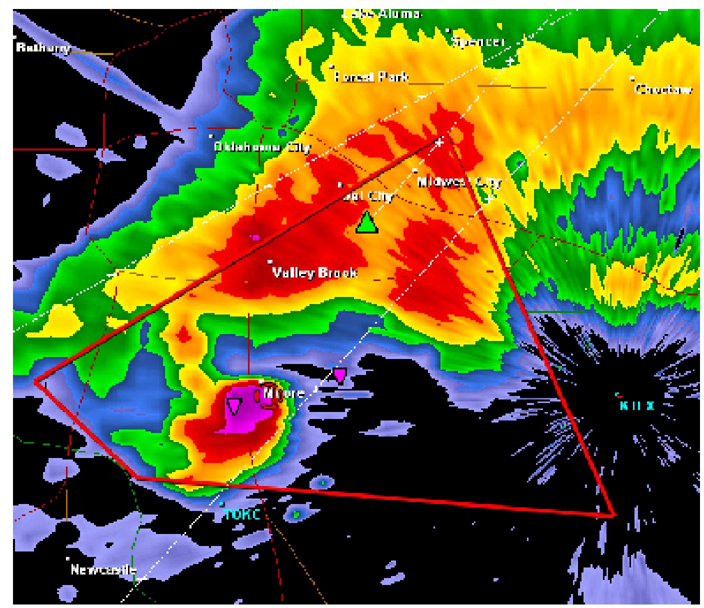
1990s – current: WSR-88D

- 158 radars
- max range: 254 nautical miles
- max power: 750,000 watts



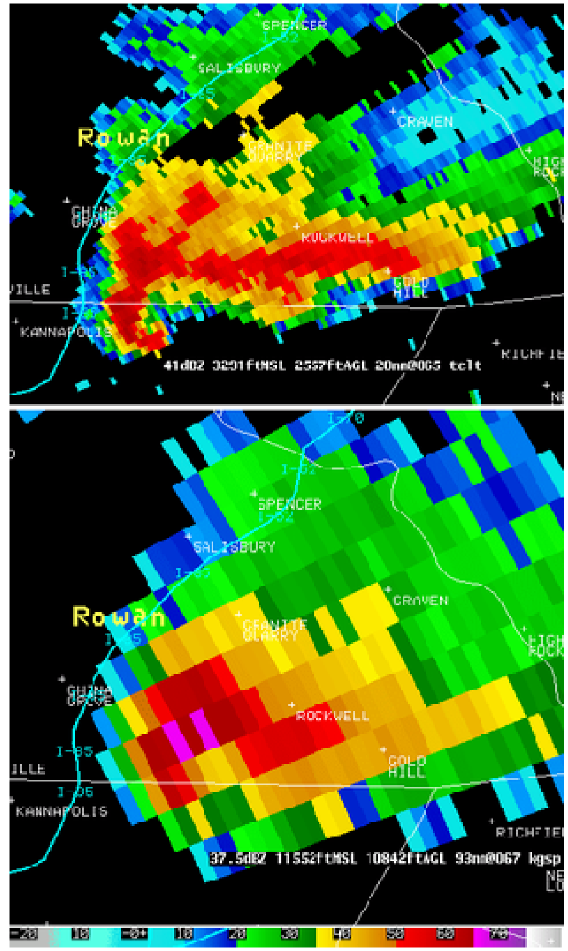


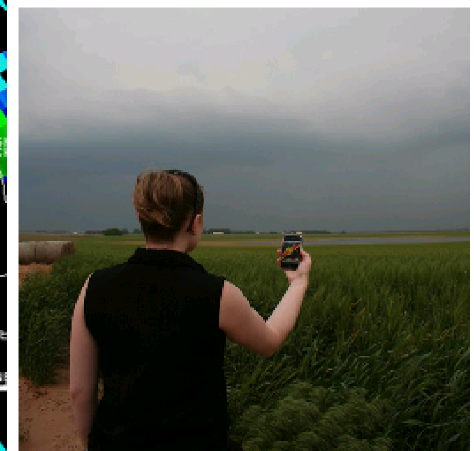




Meteorological Advances: Reporting Technology

- SKYWARN (1971)
  - Currently 290,000 professionally trained storm spotters across the United States that are activated by region when severe weather is forecast
- **A**utomated **S**urface **O**bserving **S**ystem (ASOS)
  - 900+ ASOS stations
- **T**erminal **D**oppler **W**eather **R**adar (TDWR)
  - 48 active radars
- Severe weather reporting methods
  - Smartphones, websites, social media
    - Facebook, Twitter, mPING





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Section 3: Why Is Severe Weather Data So Hard To Capture Accurately?

Doppler Radar Coverage Issue

- Tornadoes develop and occur in the lowest one kilometer of the atmosphere (3,300 feet)
  - If rotation in this level, most likely to produce a tornado
- Mid-level rotation can extend past 10,000 feet
  - Not as likely to produce a tornado at the surface (many thunderstorms produce mid-level rotation)
- Note the gaps of Doppler Radar coverage, even in Tornado Alley and the Plains!

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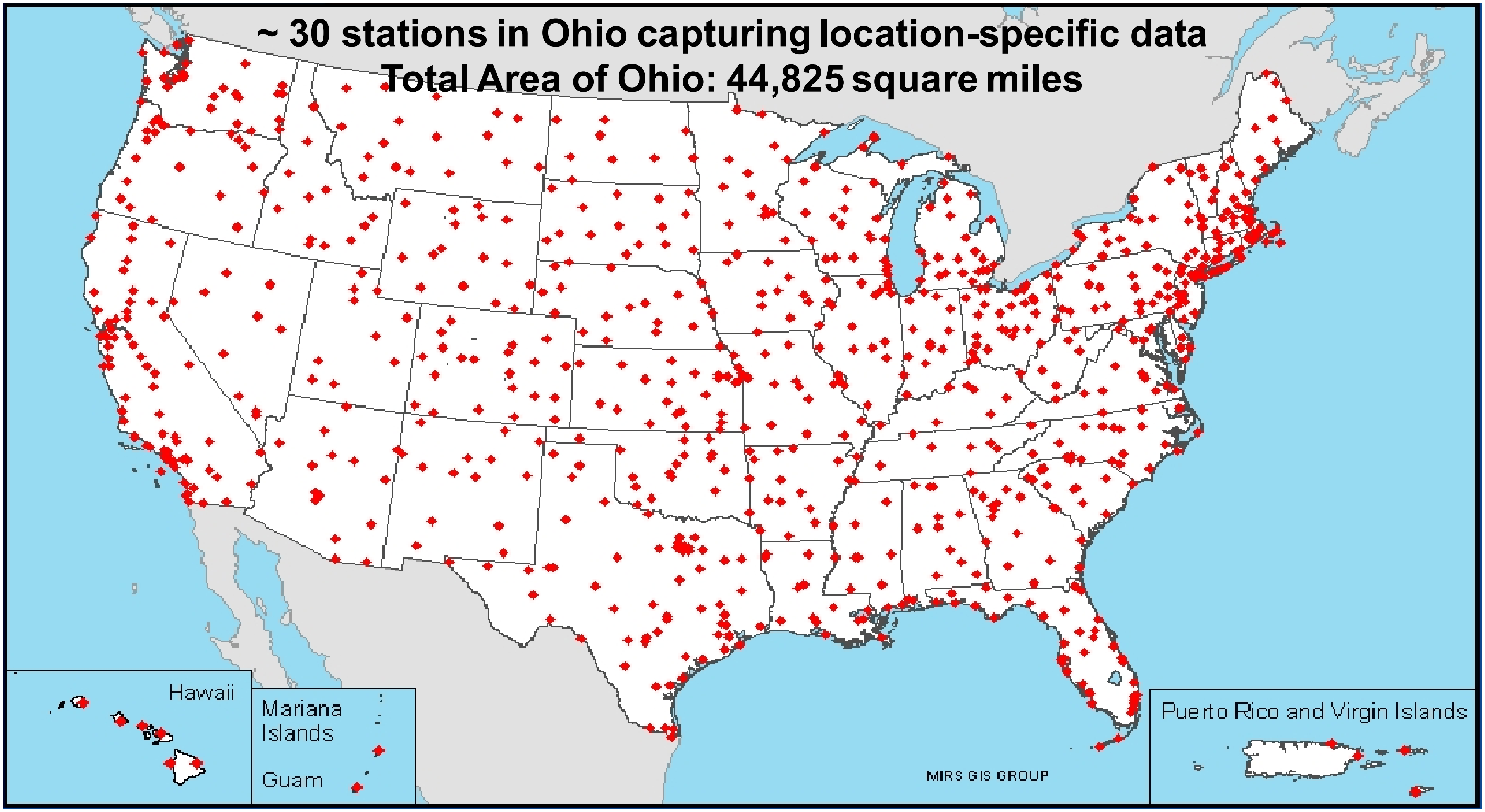
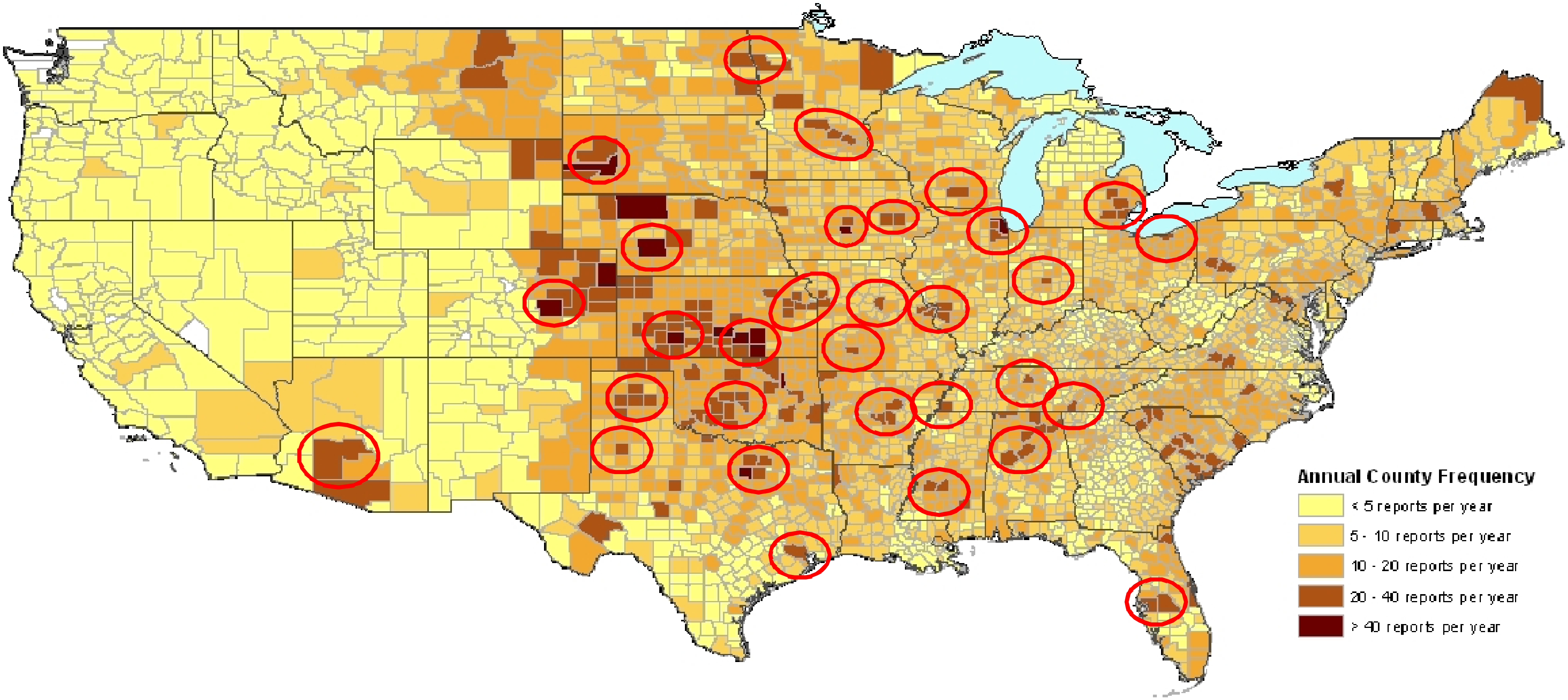
ASOS Density Issue

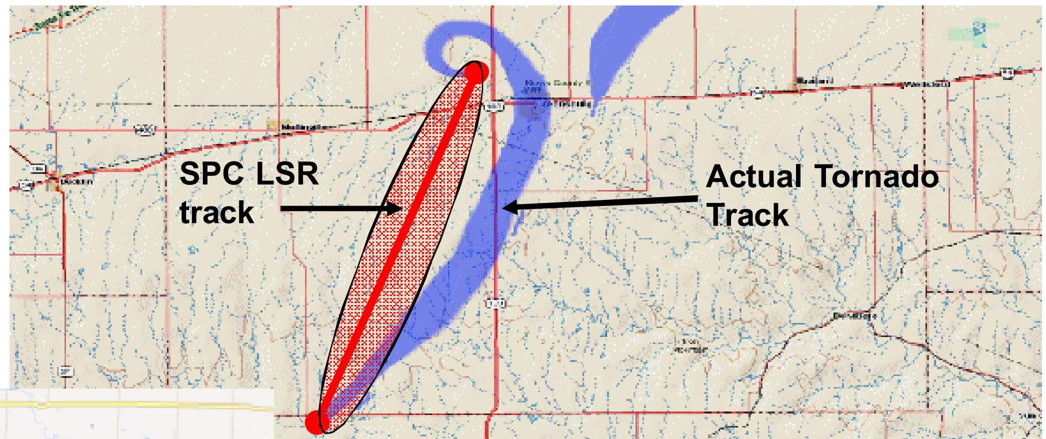


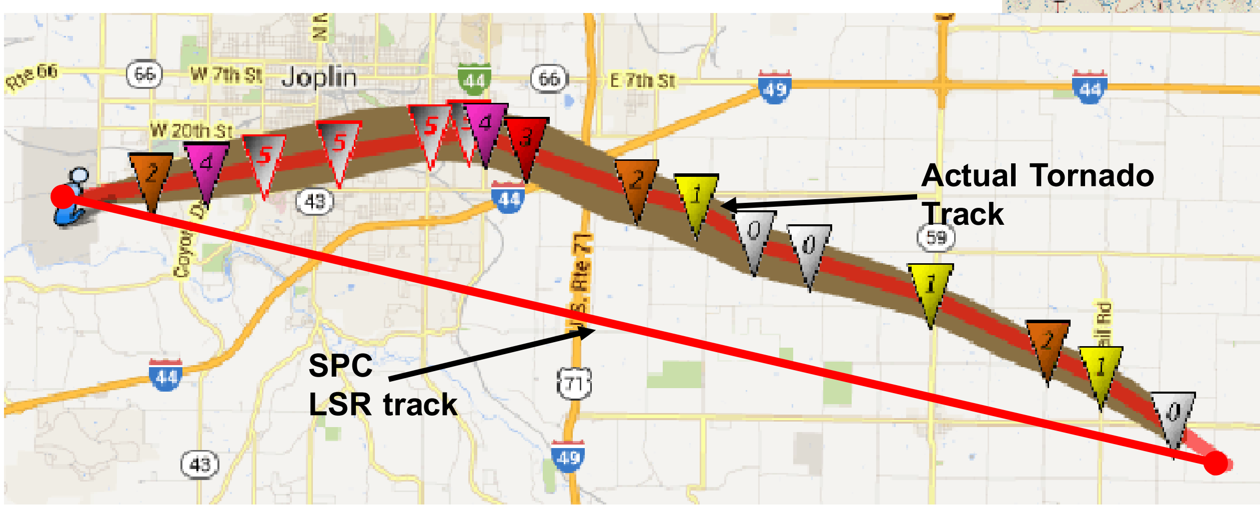
Urban Bias Issue



SPC's Tornado LSR Issue

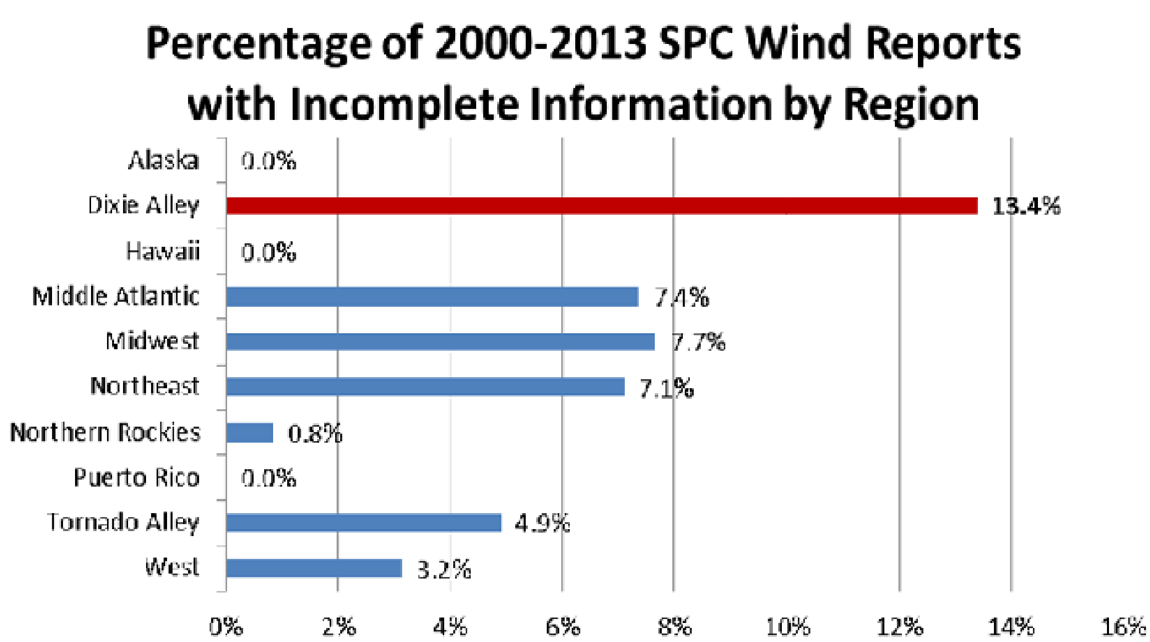
Tornado paths don't include fine resolution of intensity and directionality





SPC's Convective Wind LSR Issue

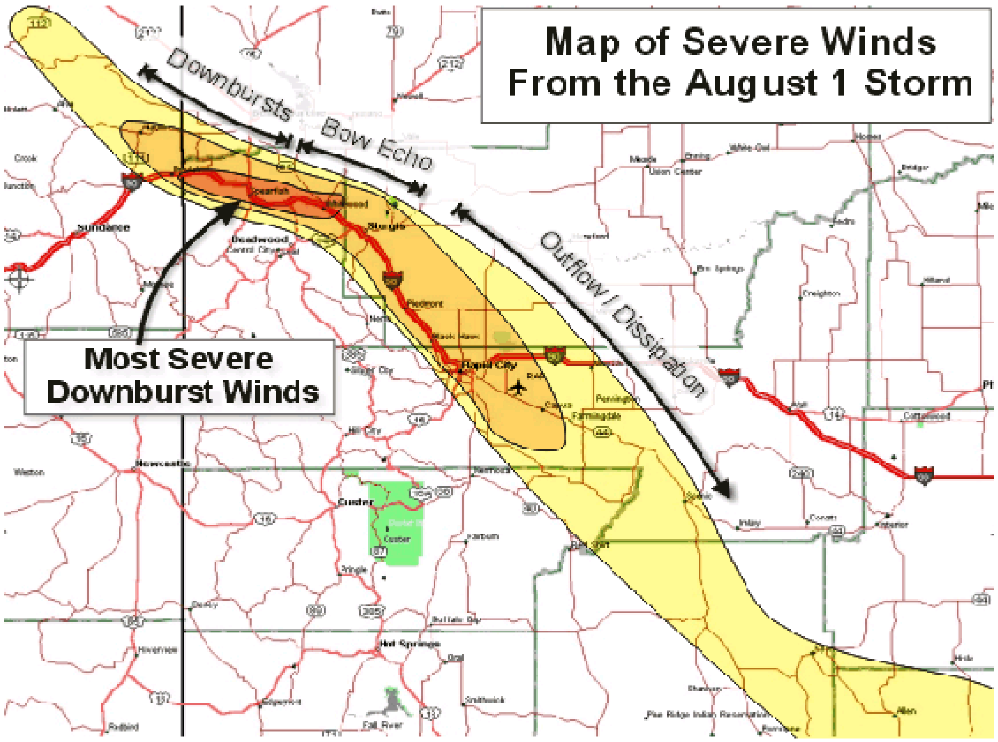
- Convective wind storm reports can be reported in two ways:
  - Actual gust wind speed (57 mph or greater)
  - Damage caused by severe thunderstorm wind gust
- Some regions more prone to reporting wind DAMAGE vs. actual wind speed

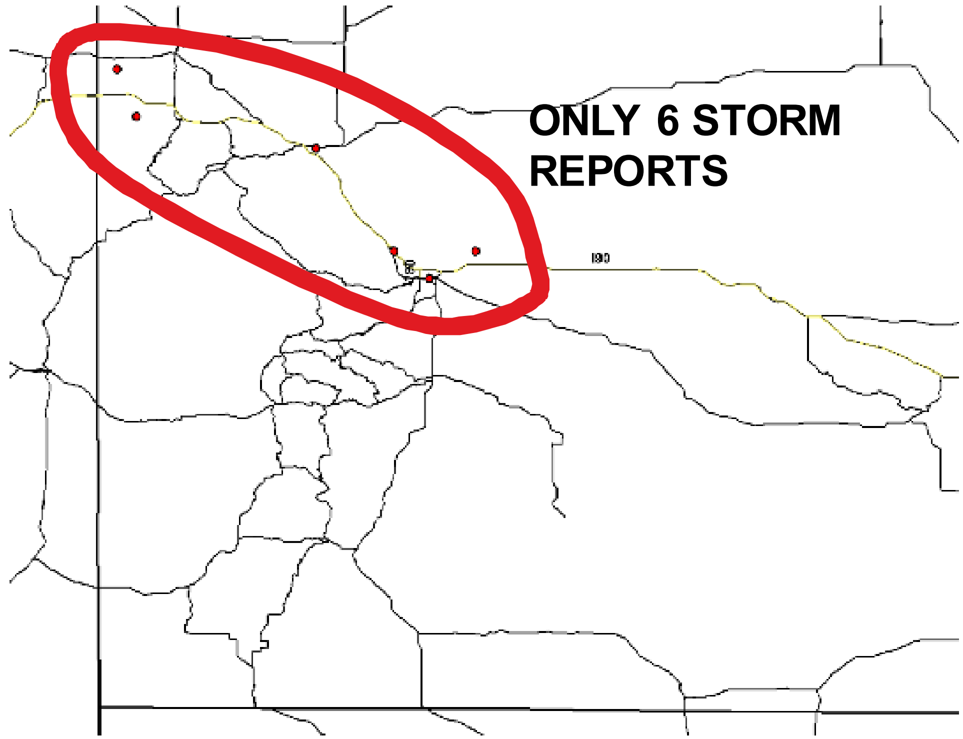


[illegible]	UNK	[illegible]	BLOUNT	AL	[illegible] 8647	SEVERAL TREES DOWN AND POSSIBLE STRUCUTRE DAMAGE IN THE AREA. (BMX)
1122	UNK	ALEXANDRIA	DE KALB	TN	3608 8603	TREES WERE BLOWN DOWN. A SPOTTER MEASURED AN 52 MPH GUST BEFORE HIS HOME WIND EQUIPMENT WAS DESTROYED. (OHX)
1122	UNK	FAYETTEVILLE	TALLADEGA	AL	3315 8641	TREES AND POWER LINES DOWN ON CEDAR CREEK ROAD. (BMX)
1125	UNK	ARAB	MARSHALL	AL	3432 8650	TREES DOWN ON HOMES ALONG HIGHWAY 231 SOUTH OF ARAB. POSSIBLE TORNADO. (HUN)
1126	UNK	LINCOLN	TALLADEGA	AL	3360 8614	STRUCTURAL DAMAGE ON EVERY [illegible] ROAD IN LINCOLN. (BMX)
1126	UNK	WALNUT GROVE	ETOWAH	AL	3406 8629	TREES DOWN ON HOUSE. (BMX)
1126	UNK	3 E AKERSVILLE	MONROE	KY	3665 8533	TREES DOWN NEAR STATE LINE. (LMK)
1130	UNK	ODENVILLE	ST. CLAIR	AL	3369 8640	ROOFS OFF, TREES DOWN, 18 WHEELER ROLLED. (BMX)
[illegible]	UNK	RAGLAND	ST. CLAIR	AL	[illegible]	TREES DOWN AND ROOF DAMAGE TO NUMEROUS HOMES. (BMX)
[illegible]	UNK	ARAB	MARSHALL	AL	[illegible]	CHICKEN HOUSES WERE DESTROYED. POSSIBLE TORNADO DAMAGE. (HUN)
[illegible]	UNK	[illegible] ARAB	MARSHALL	AL	[illegible]	SEVERAL TREES DOWN ALONG HIGHWAY 69 BETWEEN ARAB AND GUNTERSVILLE. POSSIBLE TORNADO. (HUN)
1130	UNK	8 NE MANCHESTER	COFFEE	TN	3555 8599	TREES DOWN ALONG BOTH ROCK ROAD AND NEW HOPE ROAD OFF OF HIGHWAY 55 IN SUMMITVILLE AREA. (OHX)
1130	UNK	2 N MOUNT JULIET	WILSON	TN	3624 8652	HOUSE OFF FOUNDATION [illegible] HALL SUBDIVISION. (OHX)
1131	UNK	TALLADEGA	TALLADEGA	AL	[illegible]	NUMEROUS TREES DOWN ACROSS CITY. (BMX)
[illegible]	70	CARTHAGE	SMITH	TN	3626 8594	SPOTTER ESTIMATED A 70 MPH WIND GUST. (OHX)

SPC's Hail and Convective Wind LSR Issue

Hail and wind occurrences are reported as "points", not "swaths"





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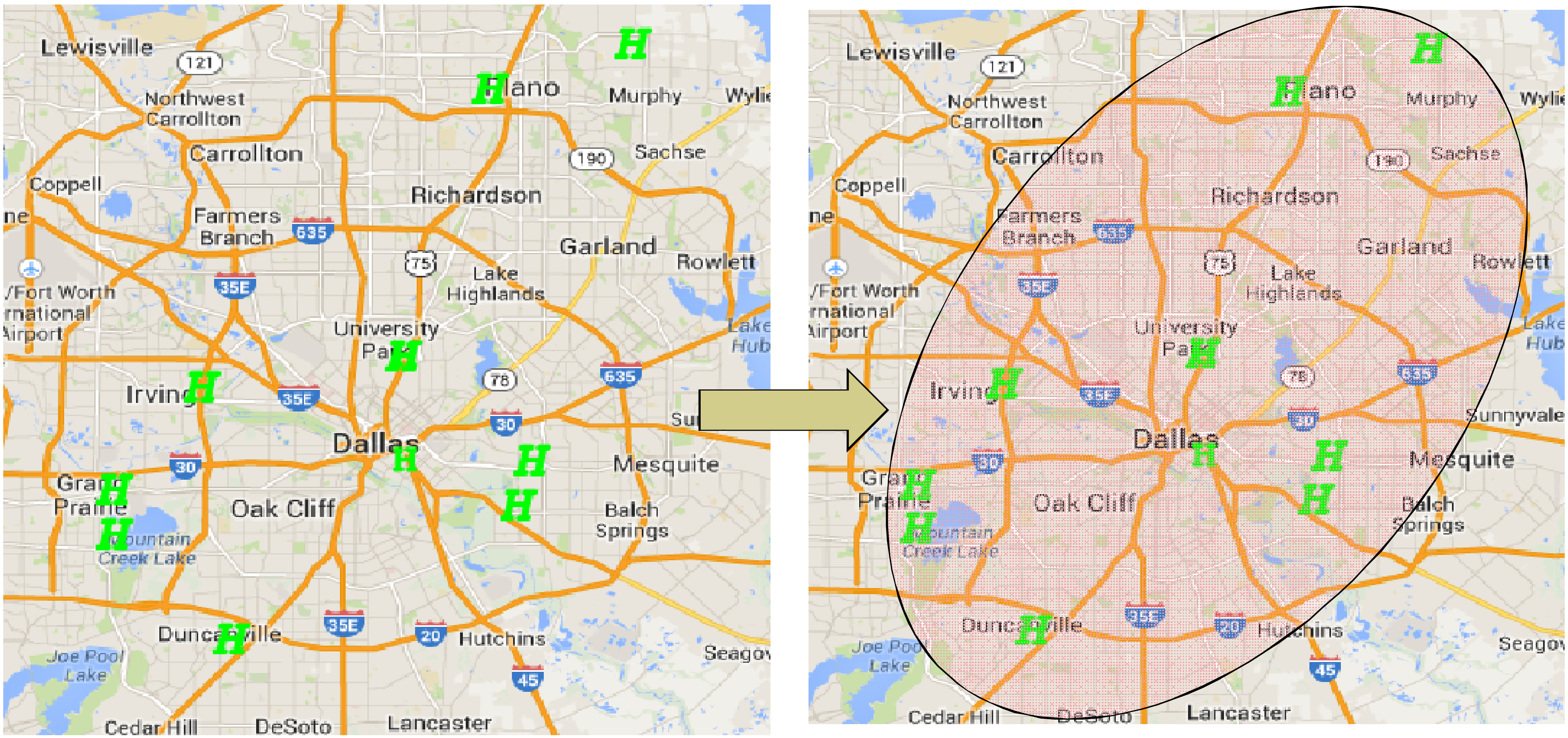
SPC's Hail and Convective Wind LSR Issue

Multiple reports can be tied to the same hail or wind event



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Storm Chaser Observational Issue

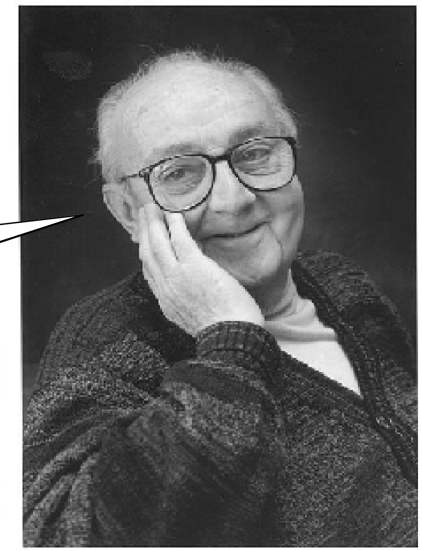
Who wants to get up close to a tornado to measure its wind speed?

(Disclaimer: Don't ask a storm chaser this question)

Section 4: Help! What do we do now?

~~Everyone~~ Paul's Favorite Quotable Statistician

Essentially, all models are wrong, but some are useful


George E. P. Box

2011 CAS Annual Meeting: Try Freq and Severity

Severity Analysis

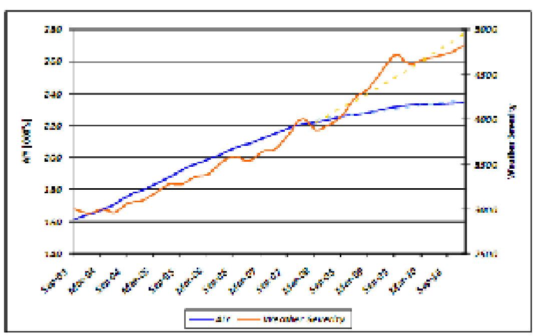
- The severity of weather claims appears to be relatively stable across different event sizes (excluding hurricanes/earthquakes/flooding)
- Ideal approach is to use as few years as possible to calculate an appropriate estimate for severity
  - Increases responsiveness to new trends in the prices of housing materials
  - Estimate will be less dependent on and leveraged by the trend selection

Frequency Analysis

- Since severity is generally stable from year to year, the main driver of the severity of weather events in total is frequency
- First step was to fit historical data to a frequency distribution
- Weather claims are **not** independent and therefore can not be fit to any of the most commonly used discrete frequency distributions
- However, if the average frequency is independent from year to year, we can fit this to a continuous distribution using each year's frequency as a sample data point

Severity Analysis

- Many non-modeled catastrophe ratemaking methodologies rely on a relationship between loss and AIY's over a long period of time
- Unless this relationship is carefully developed, it can add more distortion than accuracy into the projected catastrophe loss



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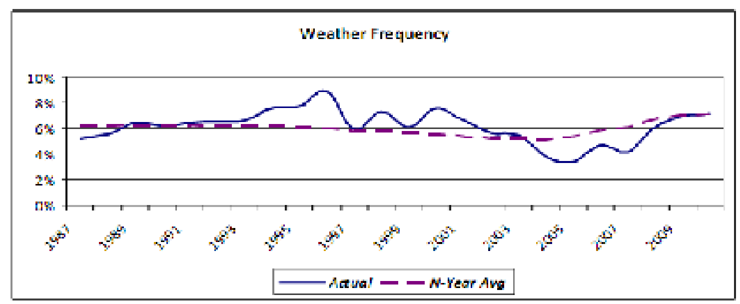
Frequency Analysis



- Based on the graph, there is no indicator of a definite trend or cyclicality, but this does help to explain the results of the correlation test
- Given the combination of results from the simulation and correlation testing, using more years of data stabilizes the estimate around the true mean

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Source: C-25: Severe Weather Ratemaking, Shantelle Thomas, Senior Actuary –Product Pricing, Allstate Insurance Company

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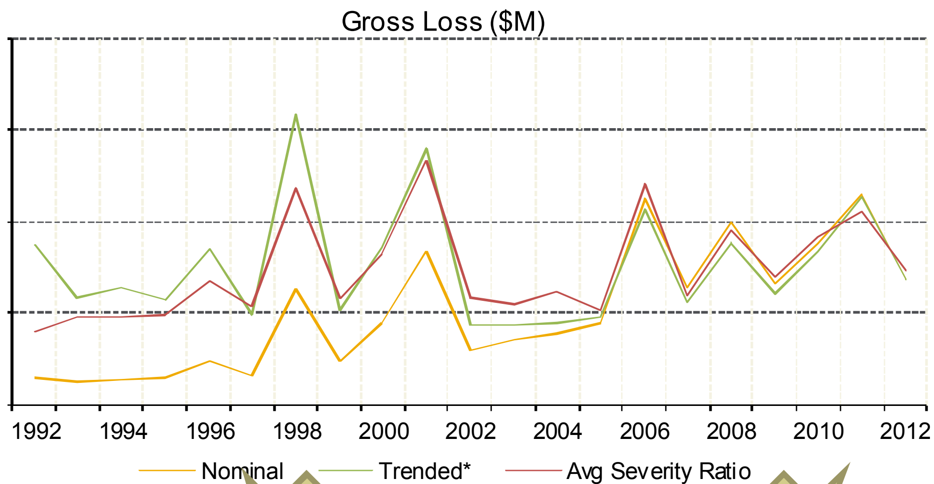
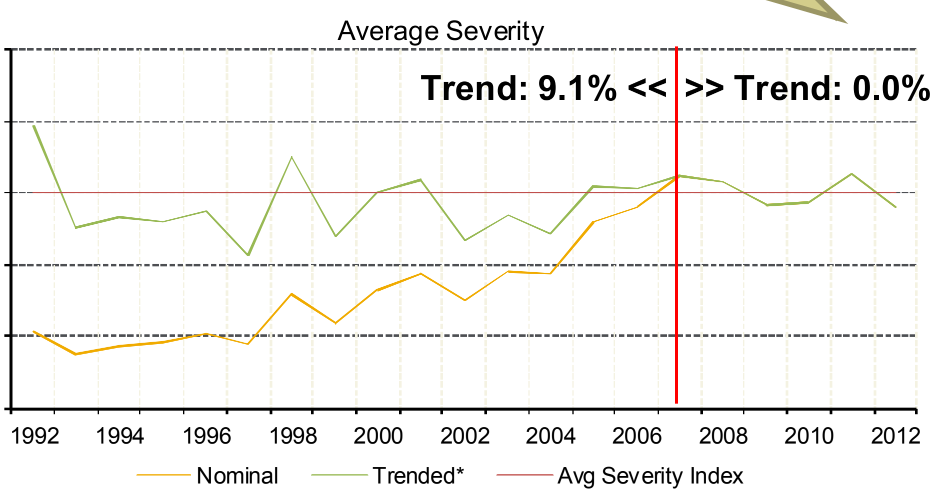
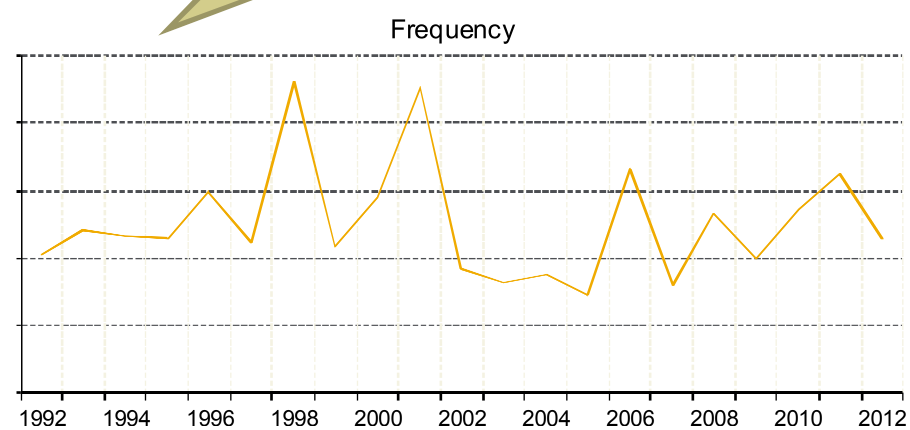
Where's the Volatility?

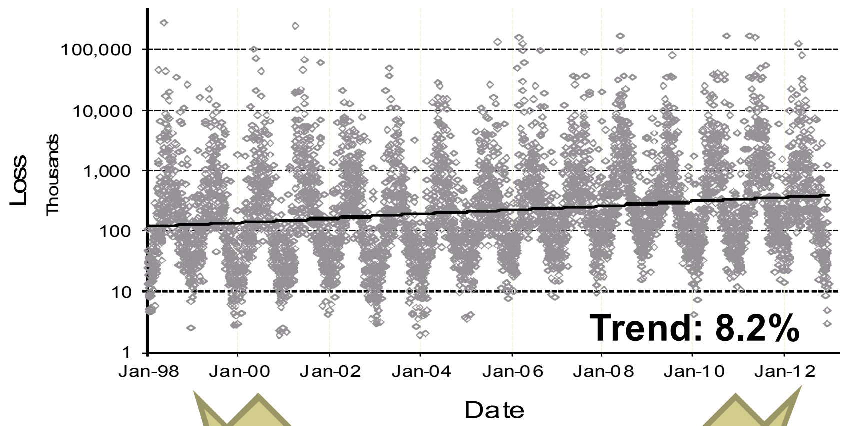


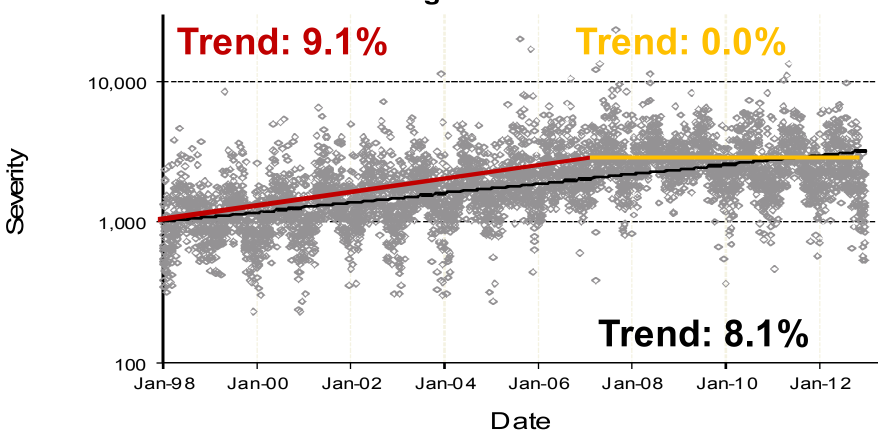


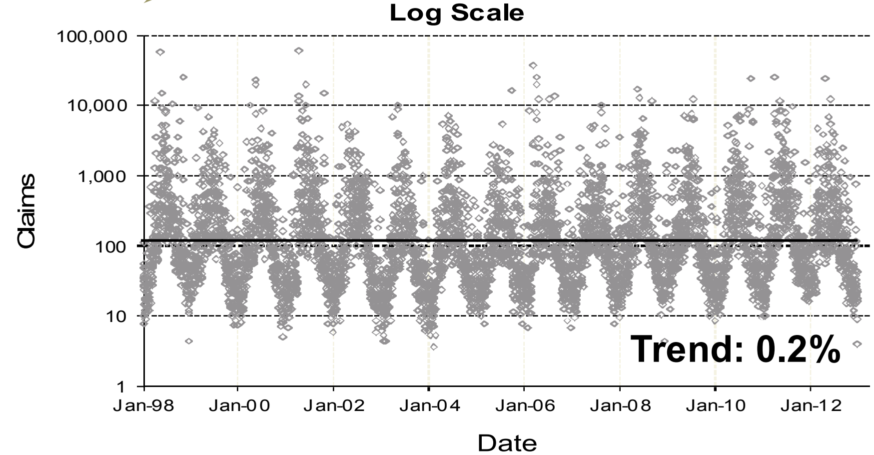


Severe Weather Experience Investigation

Analysis Of Daily Loss Data

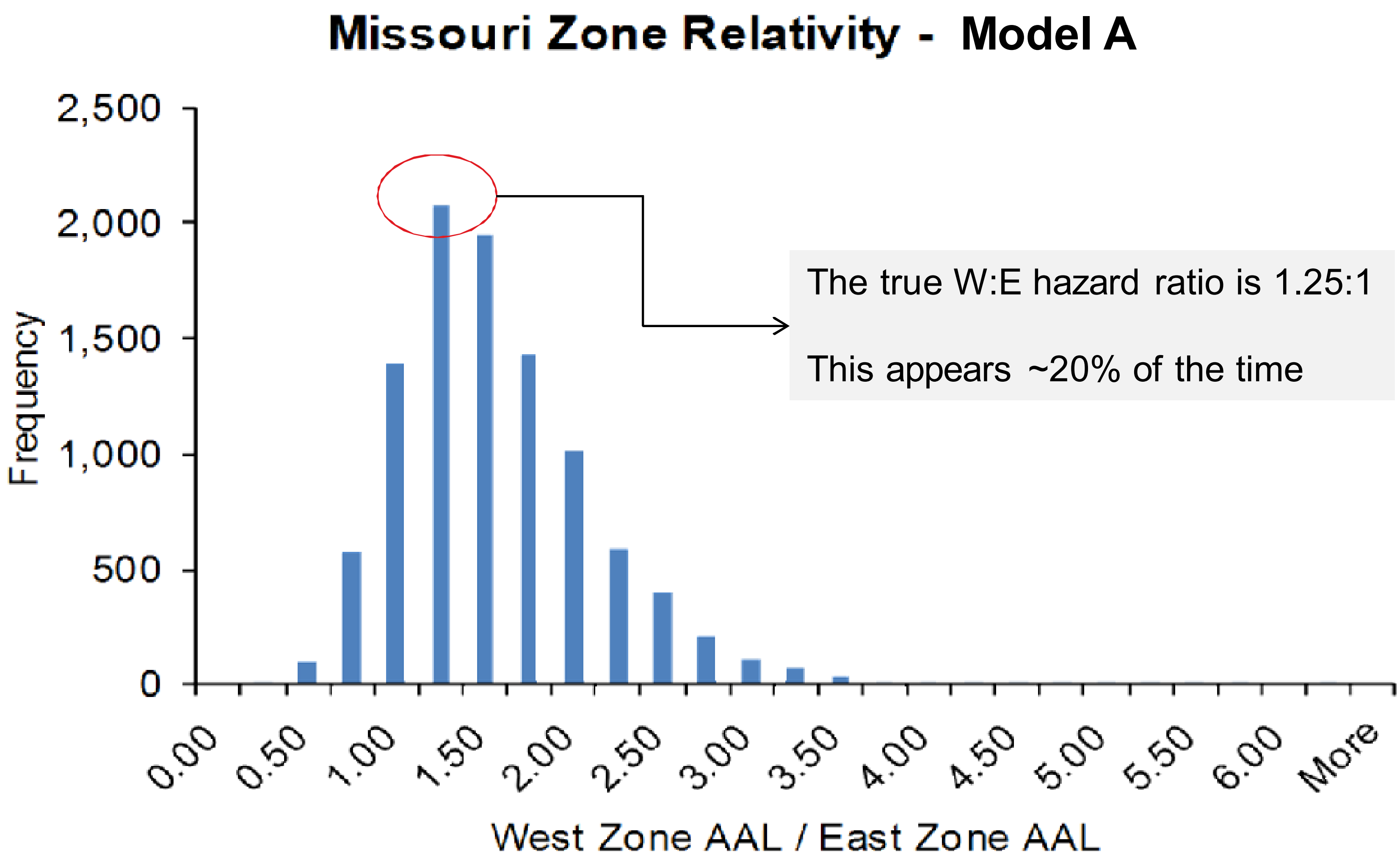






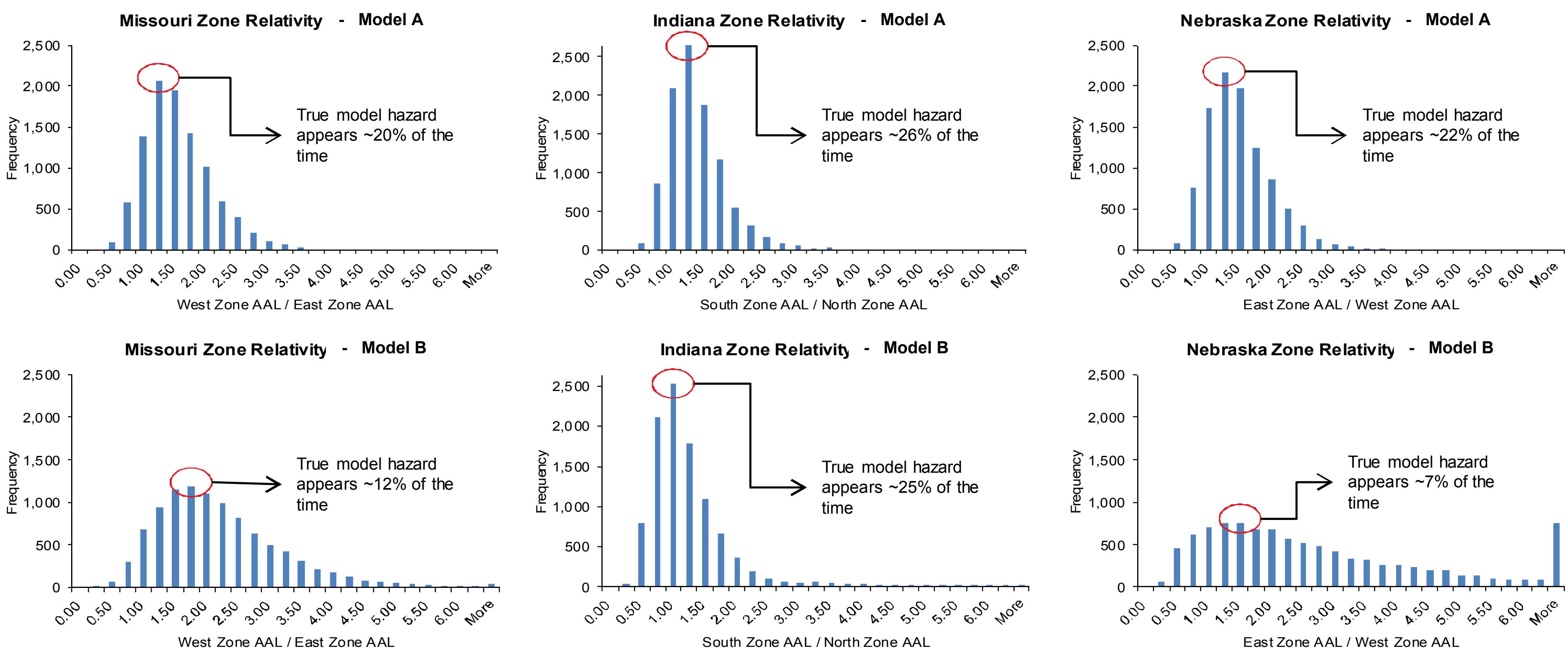
Why Experience Alone Is Not The Answer

Analysis of 10,000 22-year Simulations



Zone Relativity using Homeowners Book

Analysis of 10,000 22-year Simulations by State

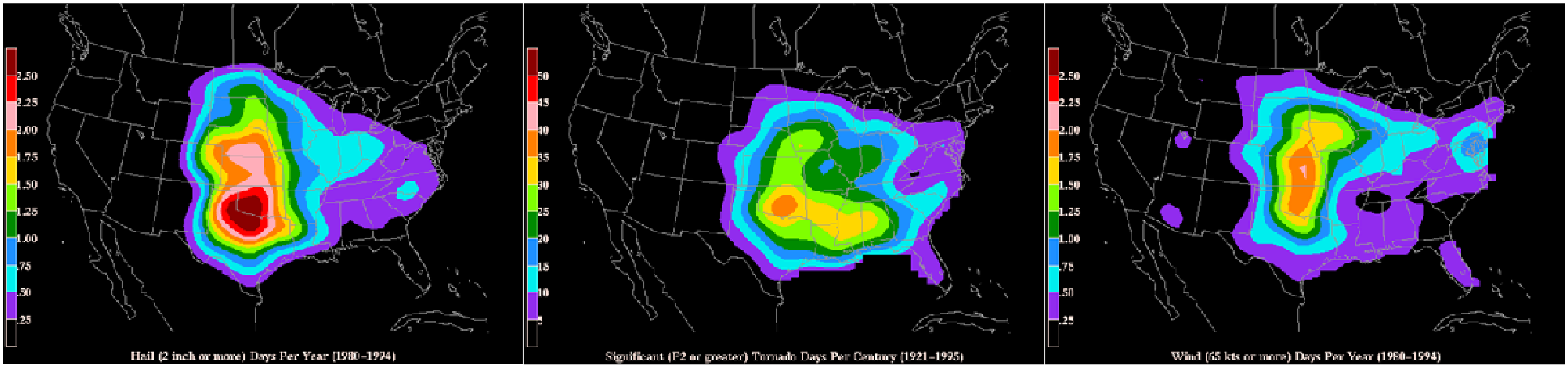


Empower Results®

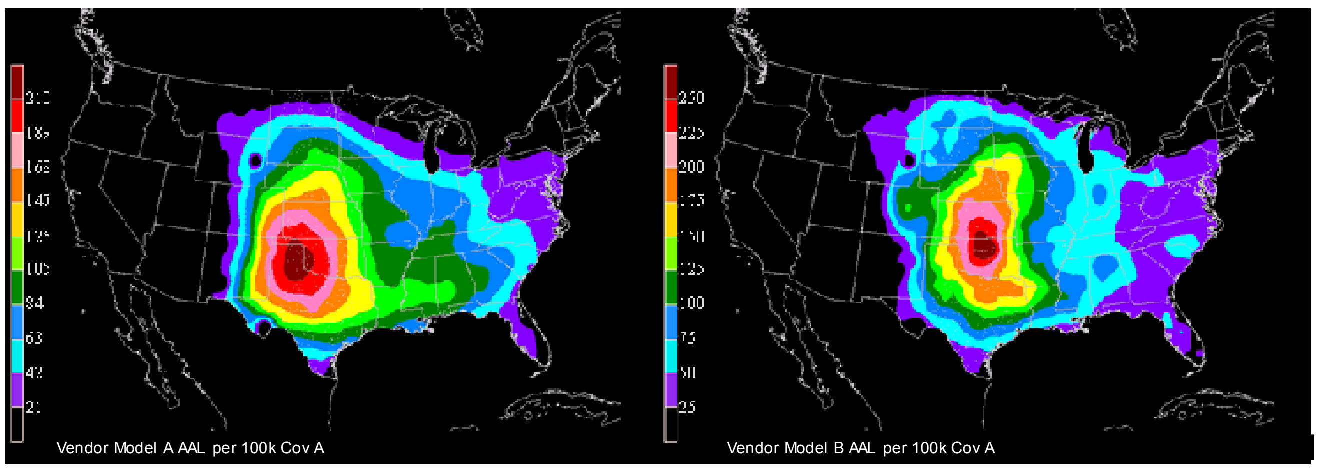
Are The Vendor Models Doing Anything Right?

http://www.nssl.noaa.gov/hazard/index.html

Vendor Model Hazard Compared to NOAA

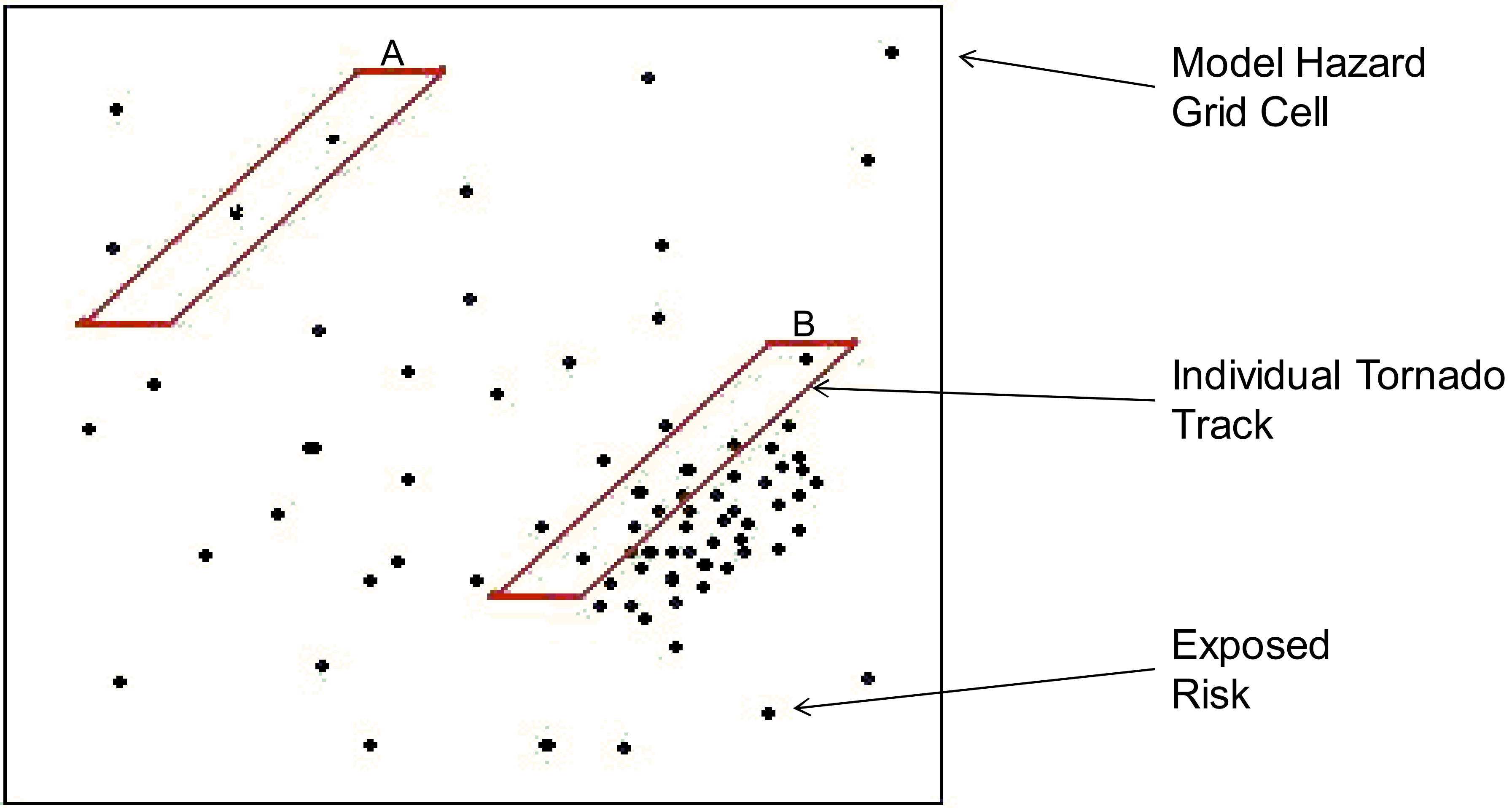


NOAA.gov Total Threat for High End Severe Weather (2in+ Hail, F2+ Tornado, 75mph+ Winds)



Vendor Model Convective Storm Loss Hazard

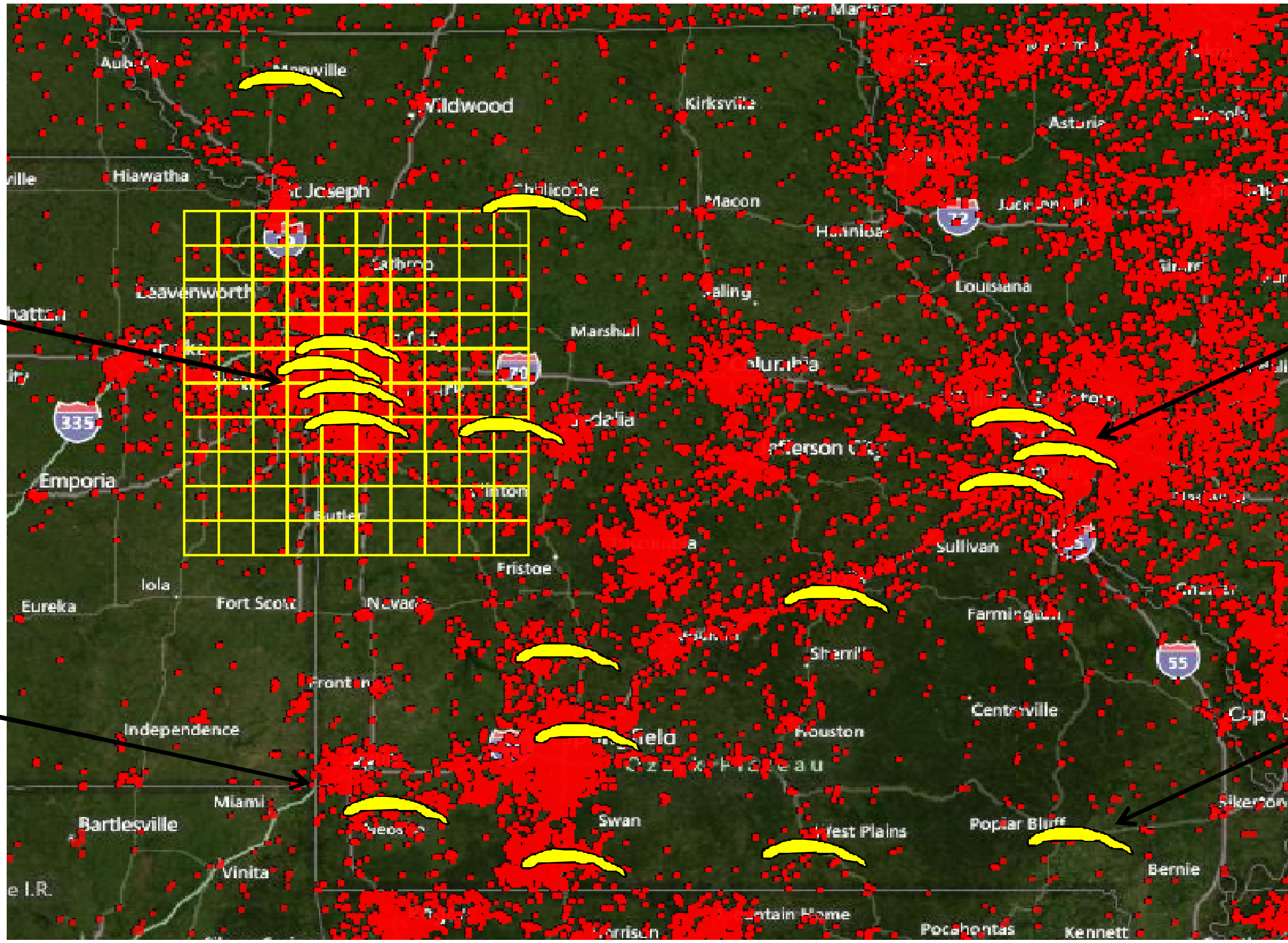
Methodology: Aggregate TIV Accurately



Risk Has a Shape

Kansas City

St. Louis



Joplin

Tornado Track

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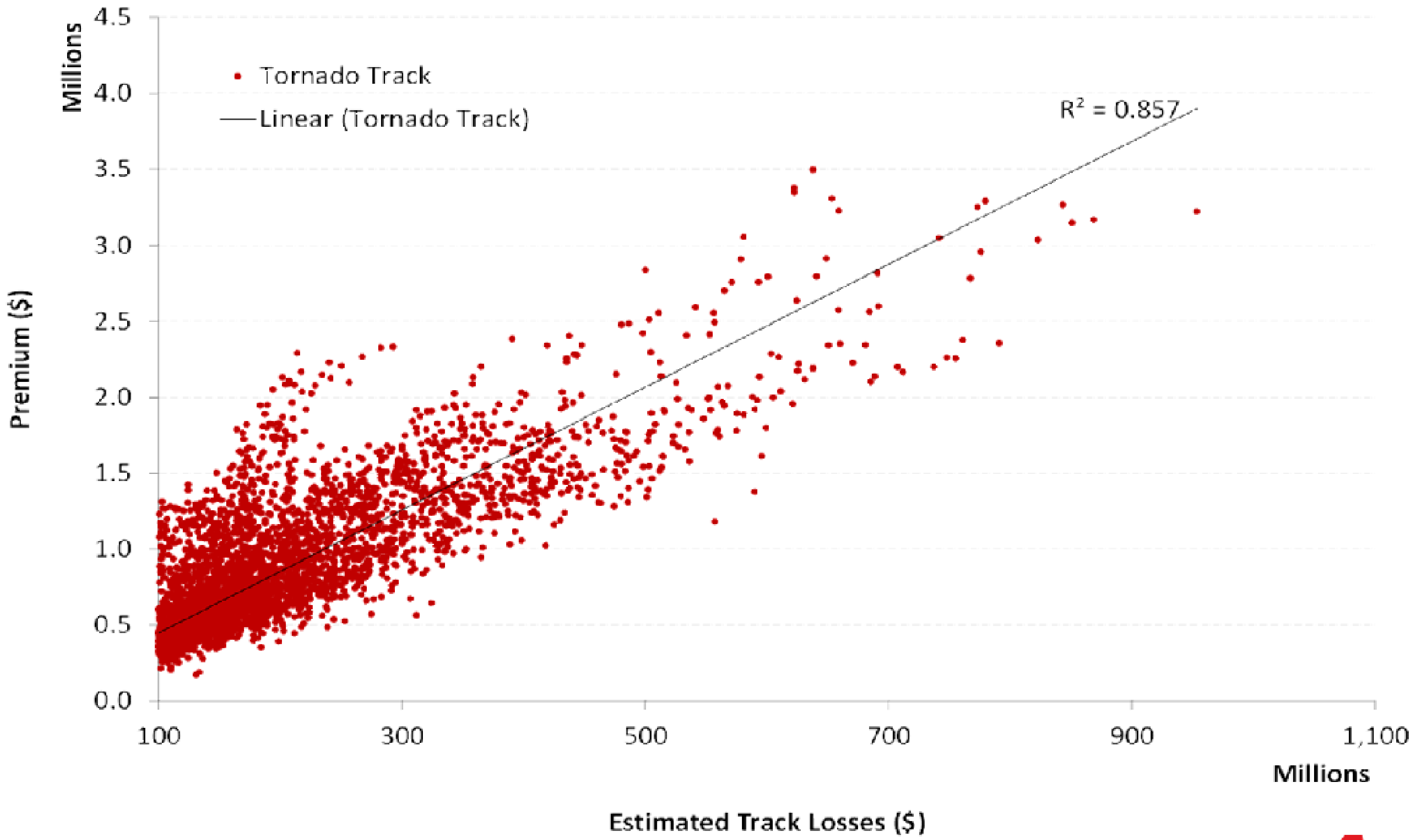
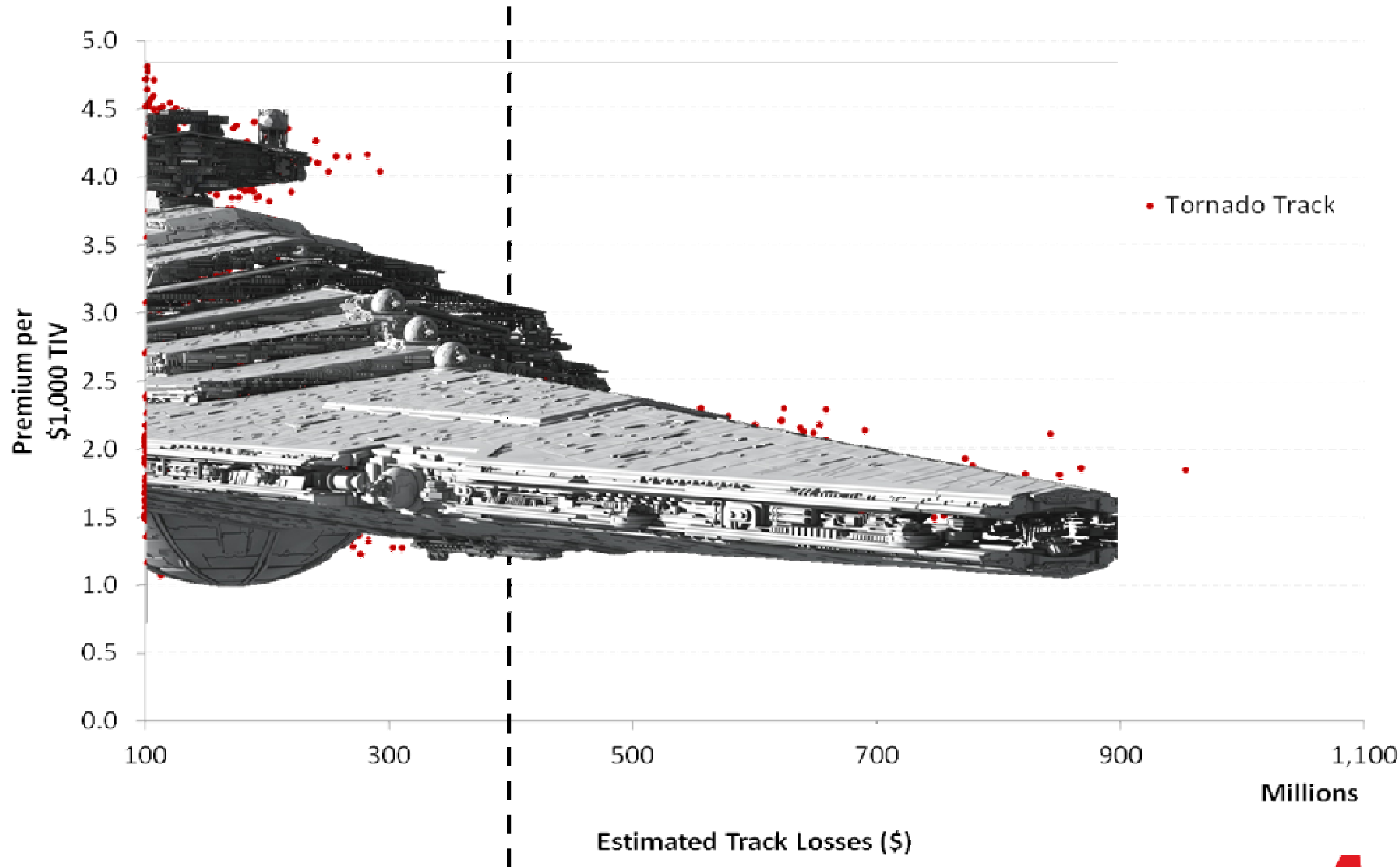
Premium Versus Estimated Loss per Tornado Track



Rate Versus Estimated Loss per Tornado Track



What if…

…there was a severe thunderstorm catastrophe model that would more accurately predict my AAL?

Aggregate Scenario Analysis: IF RePlay

Comparison of Severe Convective Storm Models To Actual Client Historical AALs

Client	Client Size*	IF STS RePlay to Actual	Stochastic Model A to Actual	Stochastic Model B to Actual	Stochastic Model C to Actual
A	Large	0.90	0.51	0.54	0.40
B	Large	1.00	0.49	0.58	0.40
C	Small	1.78	0.87	2.30	0.95
D	Small	1.33	2.06	1.54	1.16
E	Large	1.04	0.85	0.84	n/a
F	Large	0.90	0.65	0.61	n/a
Weighted Average		**0.93**	**0.54**	**0.58**	**0.41**

Biographies

Steve Drews, Associate Director & Lead Meteorologist

Steve Drews is Associate Director and Lead Meteorologist for Impact Forecasting. He currently heads the development of model customization for Impact Forecasting's catastrophe modeling suite, ELEMENTS. Over his 12 years with Aon, Steve has provided expert analysis on hurricane and tornado damage and has been a featured speaker at client, meteorological and government presentations about coastal urbanization, global climate change, tropical cyclone frequency, and severe convective weather frequency as well as provided scientific testimony on behalf of insurance and reinsurance companies in legal matters.

Paul Eaton, FCAS, Director

Paul Eaton has worked in the Aon Benfield Analytics Chicago office for seven years. Paul's current role focuses on catastrophe management including risk adjusted pricing and capacity allocation. Paul dabbled in telephony consulting, home improvement sales, and even driving an ambulance prior to joining Aon Benfield.

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