H8 - Cassidy

RETHINKING THE APPLICABILITY OF CURRENT FLOOD FREQUENCY ANALYSIS FOR 1 PERCENT AND 0.2 PERCENT EVENTS

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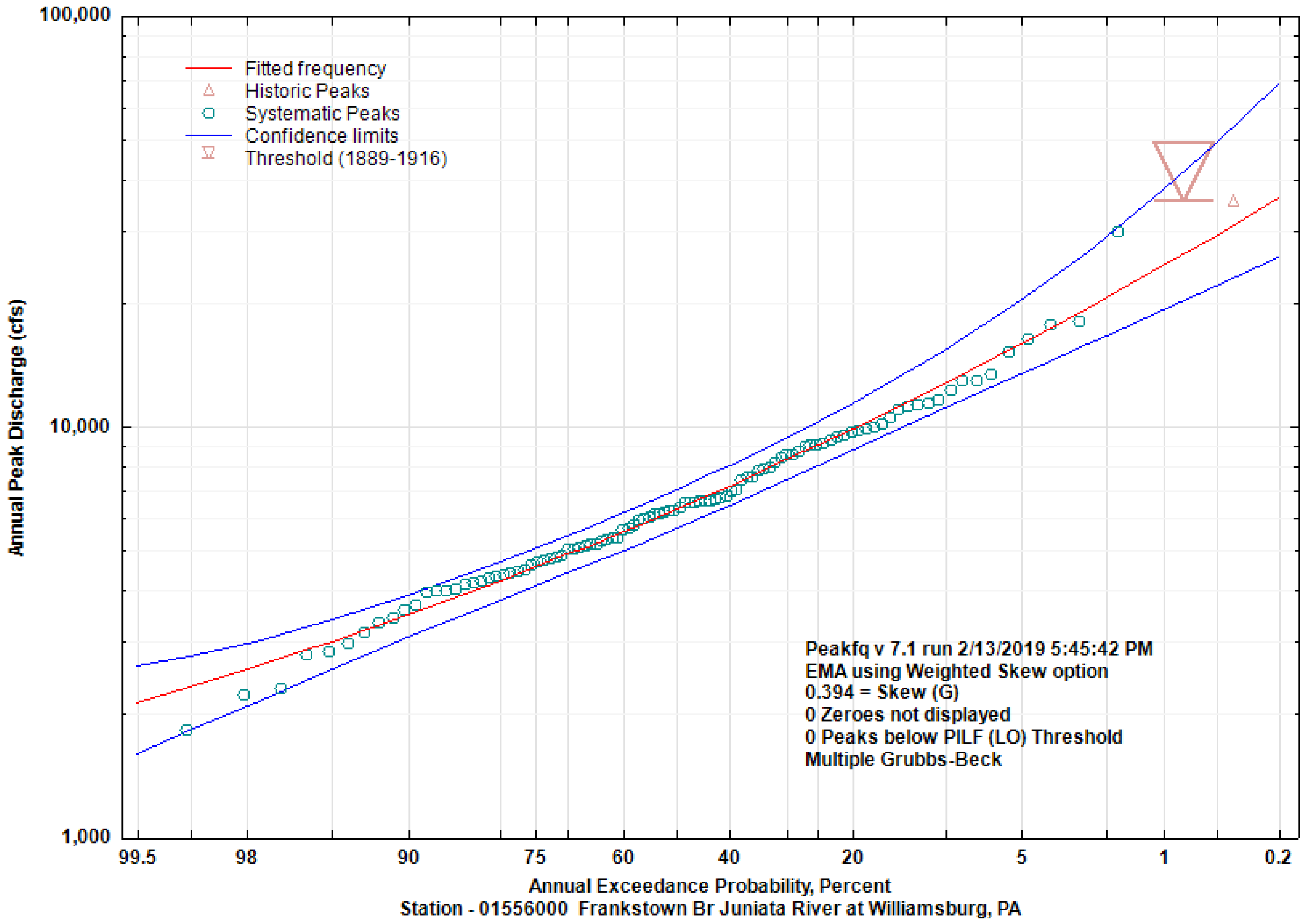
Introduction

- The Log Pearson Type III (LPIII) is the basis for the US Geological Survey (USGS) PEAFKQ and U.S. Army Corps of Engineers (USACE) Statistical Software Package, which are used to define flood intensities for desired return periods within Federal Emergency Management Agency (FEMA) Flood Insurance Studies.

Genesis

This is a typical LPIII analysis plot



Genesis 2
Journal Nature Climate Change quoted in SF Chronicle:

SCIENCE

California's deadly 1862 flood likely to repeat within 50 years, study says

Kurtis Alexander | April 23, 2018 | Updated: April 23, 2018 8:40 p.m.

Such a series of storms, involving about 40 days of punishing rain, would become more of a 50-year event — a 1-in-50 chance of happening in any given year, the authors figure.

The 1862 event was a 200-yr or larger event. (Flood of Record)

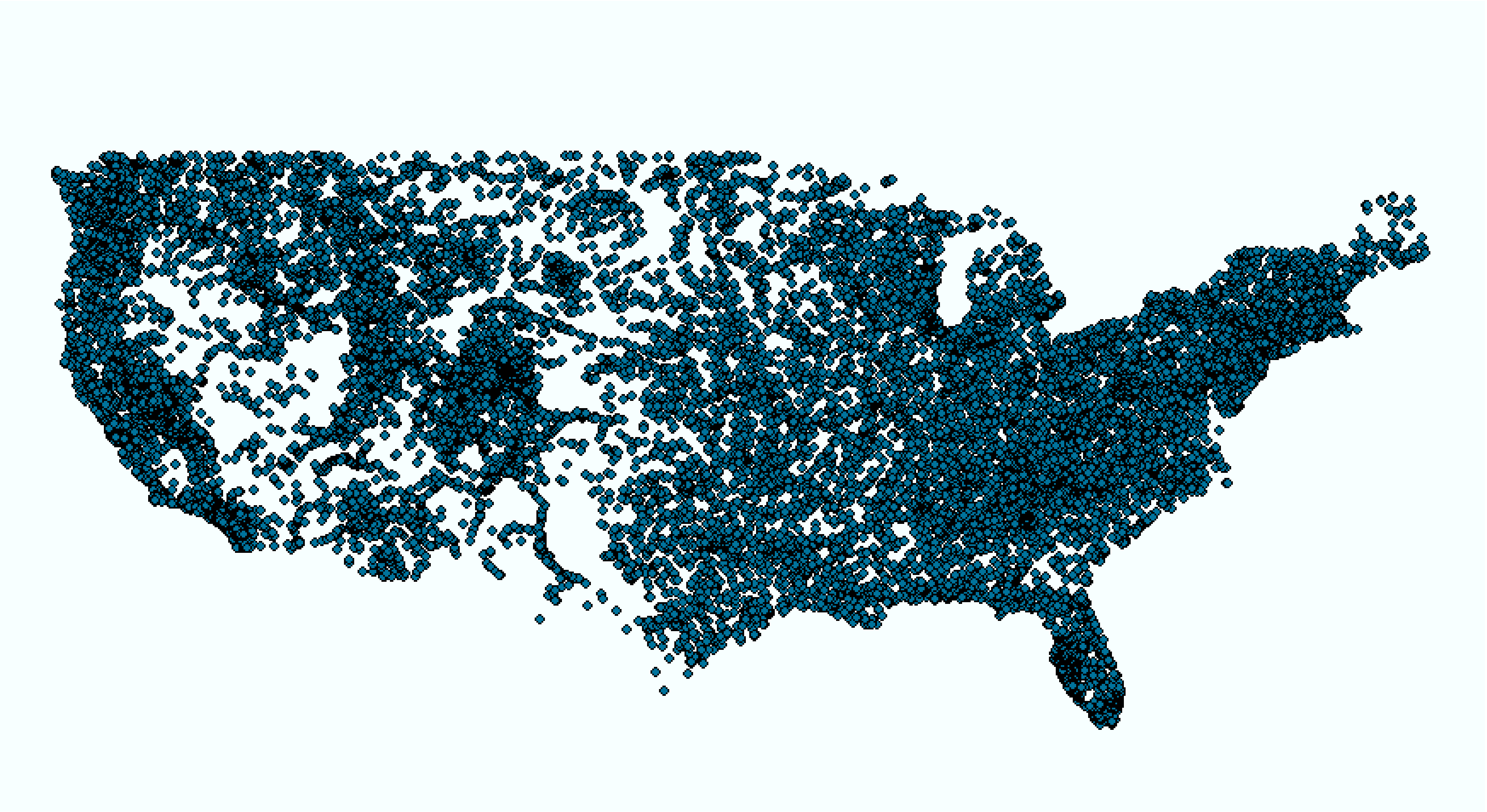
"The world is going to end in 12 years if we don't address climate change"

- Alexandria Ocasio-Cortez

Goals

- Test the legitimacy of using the LPIII distribution
- Determine if another distributions produces better results.
- Are floods really getting more frequent or have we always under-estimated the frequency of rare events?
- Are there more rare events occurring than the analysis method predicts?
- If so,
- Parse data by geographic regions to detect potential mixed population regions
- Determine if any trends in flood frequency or intensity are due to urbanization or climate change
- What decade had the most Maximum Peaks? Are there more in this century than last?
- Are the number of floods per decade cyclical of is there a trend?

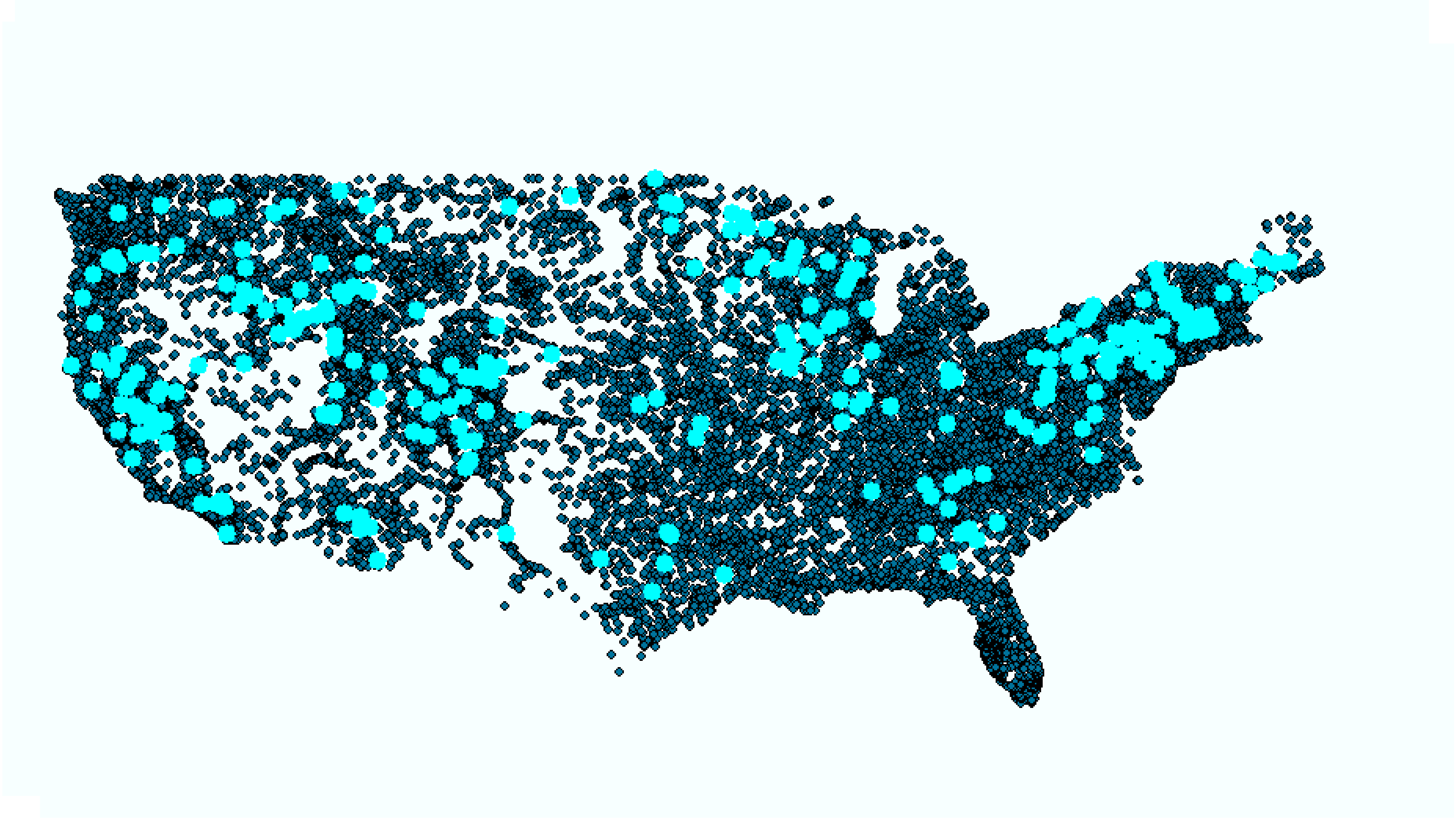
Active and Inactive USGS Streamgages



Sampling

>90 years data
> 1 and <2000 square miles
This gives 622 station
Eliminate all gages with reservoirs (Regulation)
Cuts total to 312 gages
DID NOT ELIMINATE URBANIZED WATERSHEDS

Streamgages with 90 or more years of record and unregulated– 312 STATIONS
Geographical Bias



Analysis

- LPIII analysis of all 312 sites by two independent people using slightly different methods

✓Ted - Weighted the Station skew with General Skew, Jason did not

✓Ted – Used Historical Flows to calculate the 1% and 0.2% flows, Jason did not

Results

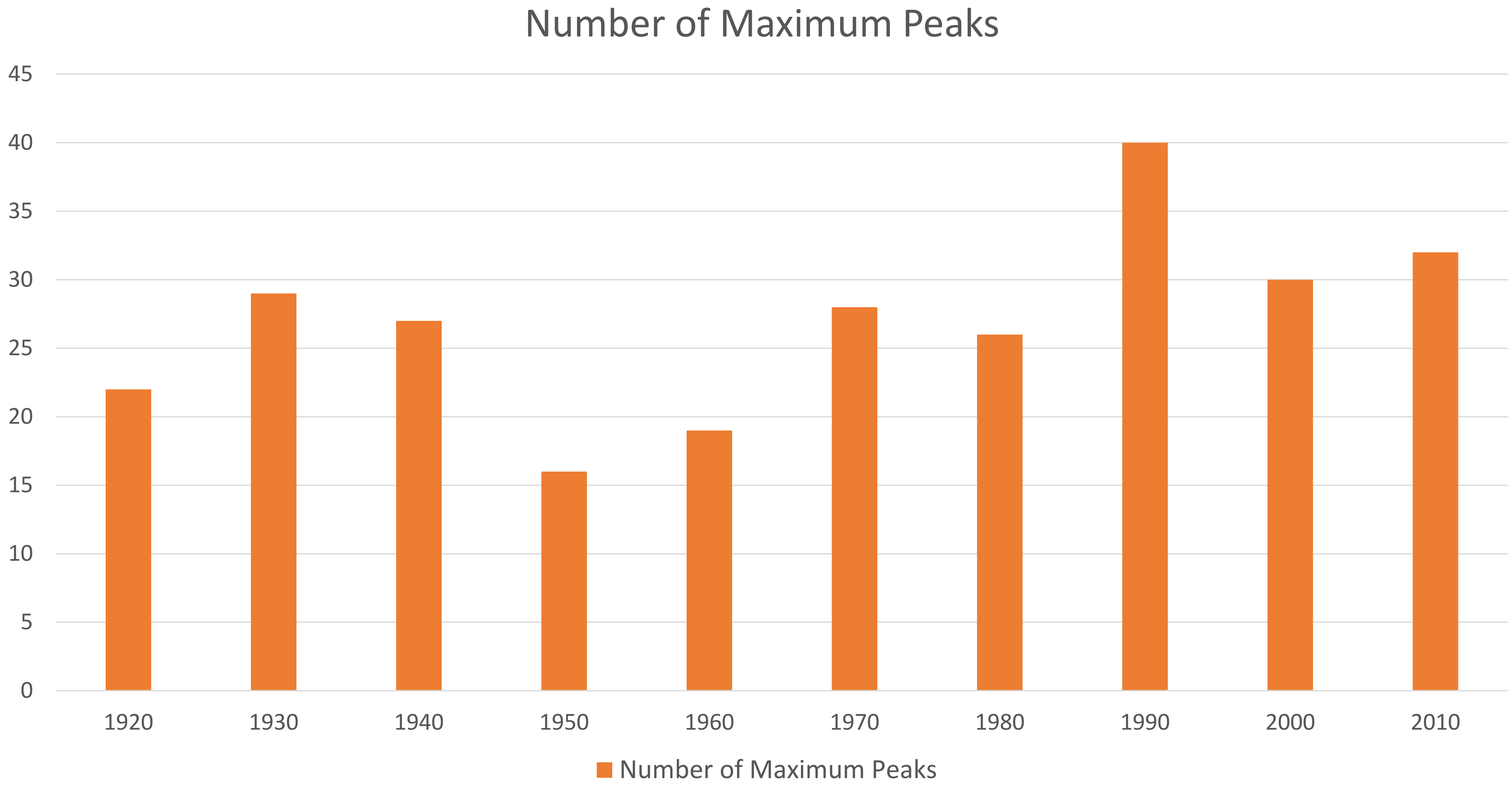
- Using Historical Peaks results in higher flow estimates so LPIII looks better
- Analysis excludes Partial Duration Peaks (in years when more than one flood occurs, only one flood is kept.)

	# of annual Pks greater than	Cummulative	Excluding Pre-1908 Events	Cummulative	Expected Value	Percent of Expected
500-yr	61	61	57	57	61	93.4
500+5%	31	92	29	86		
200 yr	87	179	84	170	152	111.8
200 yr +5%	54	233	53	223		
100 yr	116	349	109	332	304	109.2
100 yr +5%	74	423	72	404		

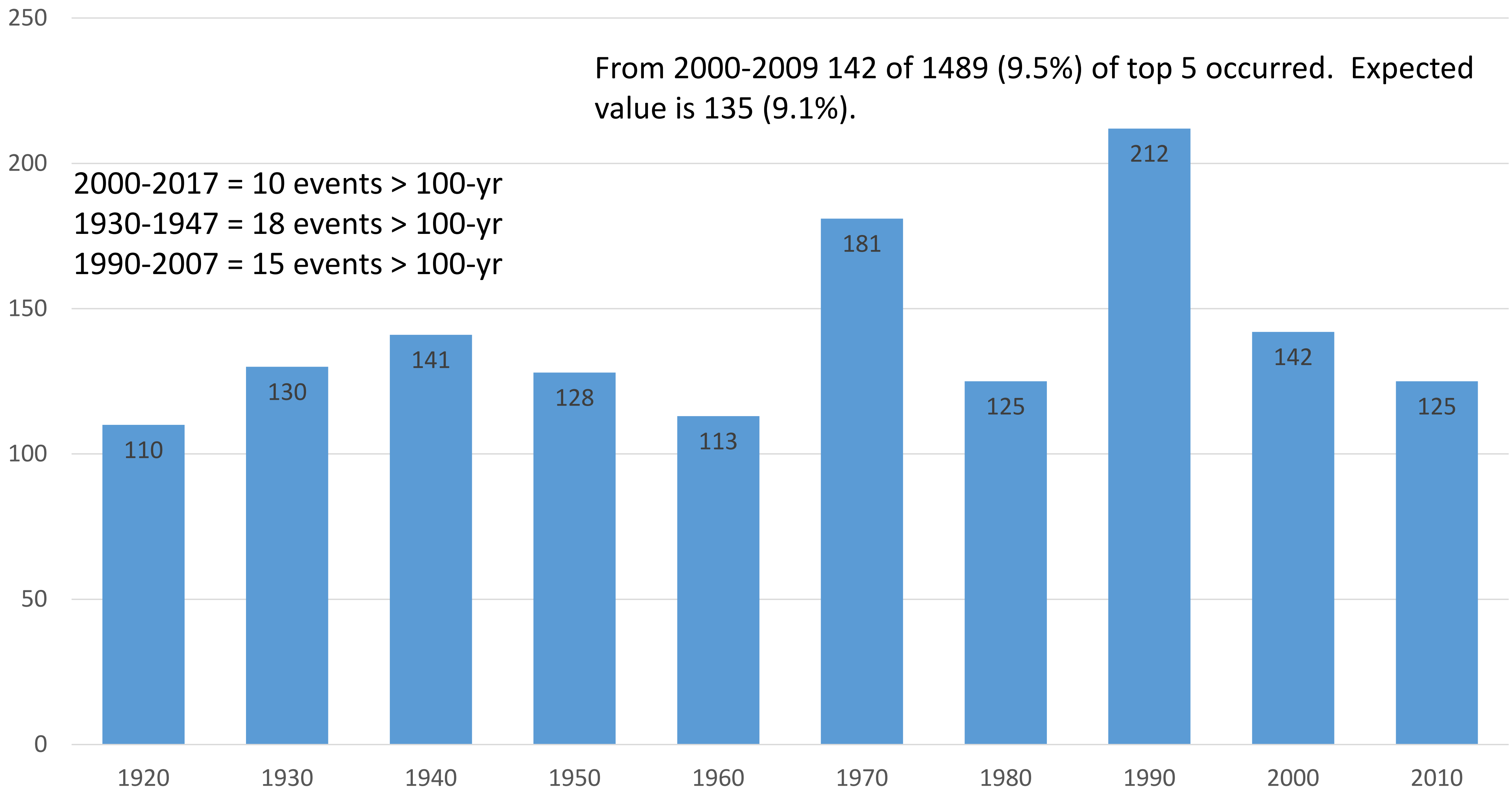
Results

However, the average largest flow at each station is 29% larger than the 1% AEP flow for a data set with an average period of record of 97.4 years.

		0.01 AEP	Yr	#1 Flow	Max Flow / 0.01% AEP
4077400	WOLF RIVER NEAR SHAWANO, WI	5112	1973	5200	1.02
5496000	Wyaconda River above Canton, MO	20370	1933	17700	0.87
9239500	YAMPA RIVER AT STEAMBOAT SPRINGS, CO	6636	1921	6820	1.03
6186500	Yellowstone River at Yellowstone Lk Outlet YNP	10260	1997	9950	0.97
5374000	ZUMBRO RIVER AT ZUMBRO FALLS, MN	38360	2010	53000	1.38
					1.29


Number of Maximum Peaks
45
40
35
30
25
20
15
10
5
0
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Number of Maximum Peaks

Top 5 Storms


From 2000-2009 142 of 1489 (9.5%) of top 5 occurred. Expected value is 135 (9.1%).
2000-2017 = 10 events > 100-yr
1930-1947 = 18 events > 100-yr
1990-2007 = 15 events > 100-yr
250
200
150
100
50
0
110
130
141
128
113
181
125
212
142
125
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Number of Gages that have experienced 1% and 0.2% Events

- Number of Stations with 1% events – 245
- Expected Number of Gages that have experienced a 1% Events –
- 100*(1-(1-.01)^98) = 62.6% of 312 = 195
- 245/195 = 126% of expected
- Number of Stations with 0.2% events – 62
- Expected Number of 0.2% Events - 100*(1-(1-.002)^98) = 17.8% of 312 = 56
- 62/56 = 111% of expected

Results with

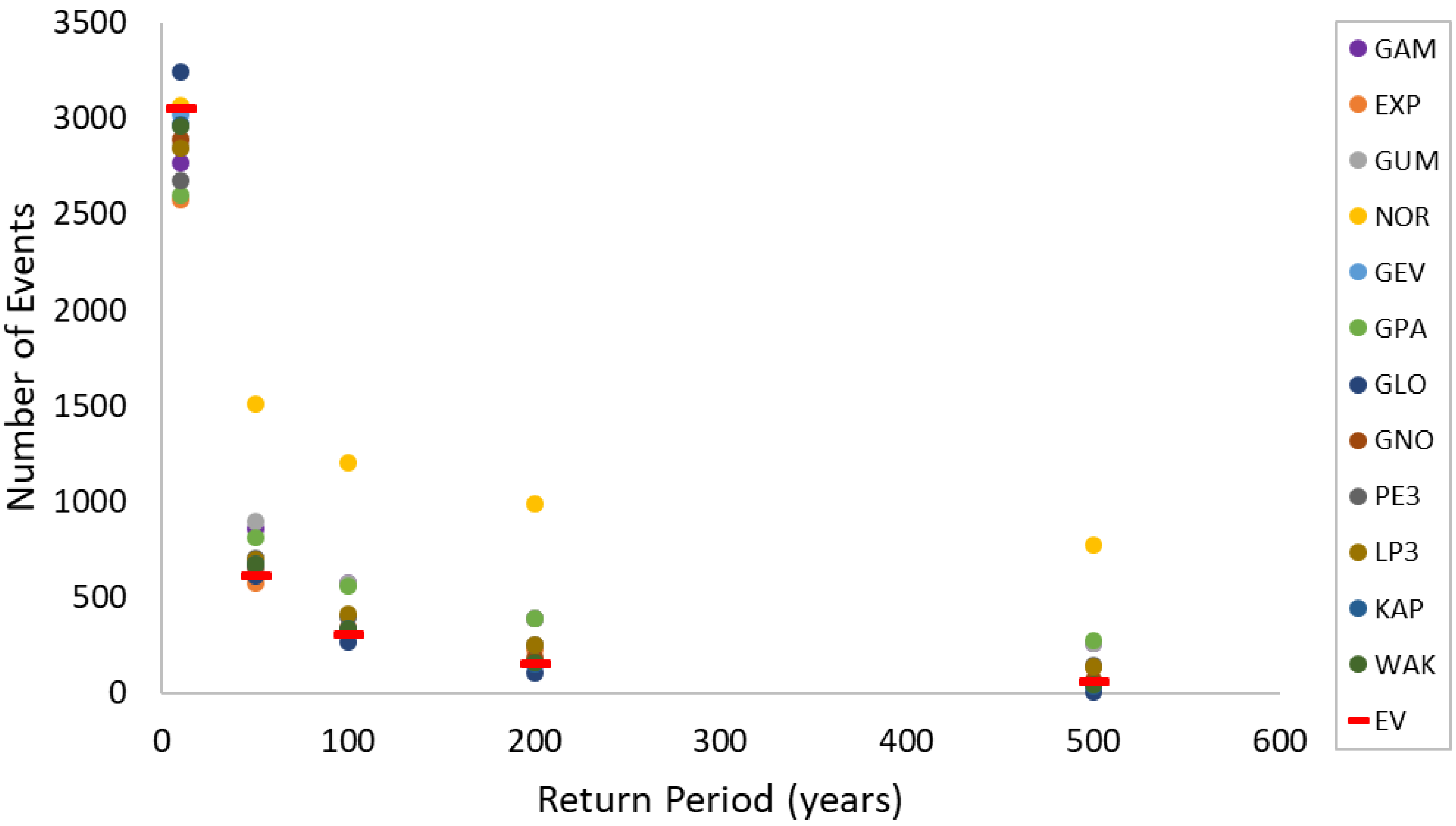
- Station Skew only
- No Historical Floods used to calculate Flows

Comparison of Distribution Performance

- Number of events exceeding each return period (yrs) event was computed for each distribution.
- GEV out-performed Log-Pearson Type III for all return periods.
- Log-Normal performed best for the most extreme events.
- Underlined value represents best performer compared to expected value.

Distribution	500	200	100	50	10
Gamma	259	388	573	858	2768
Exponential	139	228	347	574	2577
Gumbel	260	393	578	895	2854
Normal	776	988	1204	1513	**3065**
Gen. Extreme Value	43	**153**	**316**	657	3021
Gen. Pareto	278	393	557	815	2599
Gen. Logistic	10	107	267	**617**	3247
Log-Normal	**68**	180	329	663	2891
Pearson III	144	251	400	702	2677
Log Pearson III	141	251	413	700	2848
Kappa	36	156	334	673	2970
Wakeby	43	161	339	675	2962
Expected Value	61	153	305	611	3054

Comparison of Distribution Results



Distribution Overall Performance

- Average error for all return periods was computed for each distribution.
- GEV performed the best overall.
- Log Pearson Type III was outperformed by 6 distributions tested in this study.

Distribution	Average Error
GAM	123.1%
EXP	42.4%
GUM	125.1%
NOR	431.9%
GEV	8.4%
GPA	128.6%
GLO	26.7%
GNO	10.2%
PE3	51.7%
LP3	50.4%
KAP	13.1%
WAK	11.9%

Conclusions

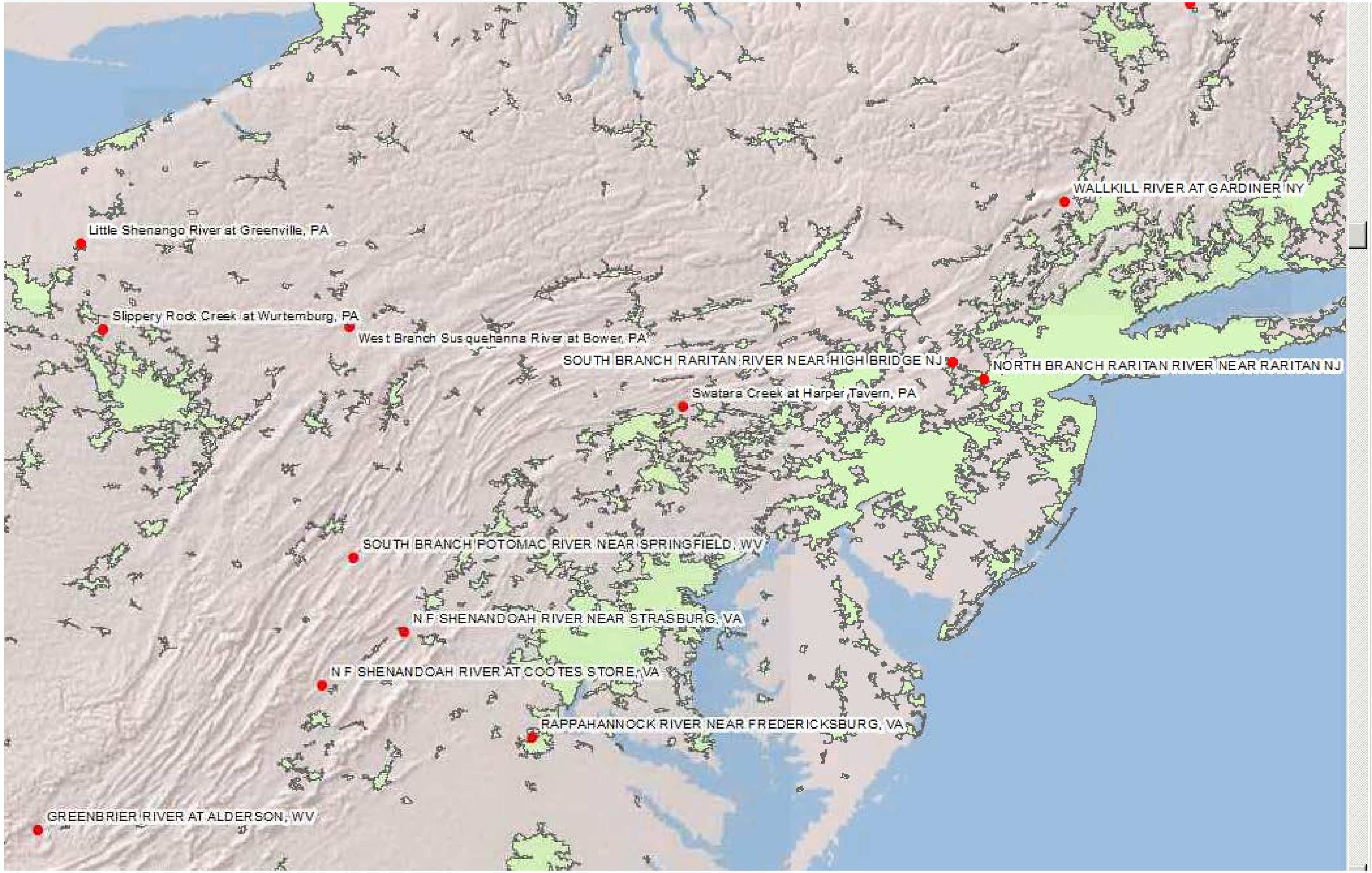
- **Log-normal** performed best at the 500-year return period.
- **GEV** performed best at the 200- and 100-year return periods.
- **Gen. Logistic** performed best at the 50-year return period.
- **Normal** performed best at the 10-year return period.
- **Log-Pearson Type III** substantially under-predicted the flows for all return periods.
- **Gen. Logistic** was the only distribution to under-predict the number of 200- and 100-year events.
- <u>**GEV** performed best overall.</u>

Results

Number of Sites with 2 or more of the top five annual peaks with the last 20 years = 72
Number of Sites with 3 or more of the top five annual peaks with the last 20 years = 21

6817000	Nodaway River at Clarinda, IA	2008	2014	2016	1947	2012	urbanizing????
3465500	NOLICHUCKY RIVER AT EMBREEVILLE, TN	1901	1978	1940	2004	1995	
1467000	North Branch Rancocas Creek at Pemberton NJ	2011	2004	1939	1971	1938	
1398500	North Branch Raritan River near Far Hills NJ	1919	1971	2011	1999	1997	

Only a Few in Urbanizing Areas



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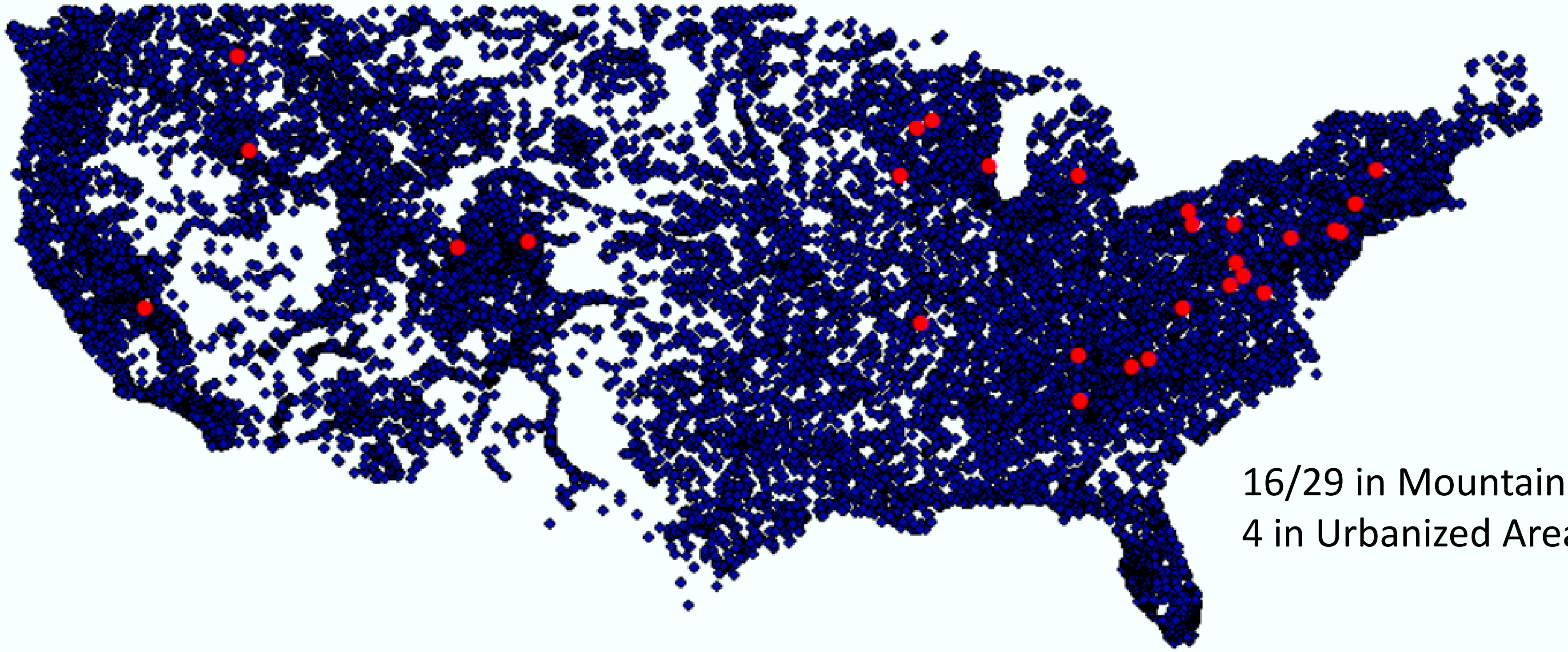
Gages with 3 or More Major Floods (> 100-yr events)



16/29 in Mountainous Regions
4 in Urbanized Areas

Tropical Events in Pennsylvania

3015500	Brokenstraw Creek at Youngsville, PA	108	0	1913	2017	2007	1947	1948
1439500	Bush Kill at Shoemakers, PA	109	0	1955	1969	2005	2011	2006
1552000	Loyalsock Creek at Loyalsockville, PA	92	0	2011	1996	1972	1975	2004
1550000	Lycoming Creek near Trout Run, PA	104	0	1996	2011	1972	1946	2018
3020500	Oil Creek at Rouseville, PA	107	0	1959	2003	1955	1964	2004
1573000	Swatara Creek at Harper Tavern, PA	99	1	1889	2011	1972	2006	1933
1534000	Tunkhannock Creek near Tunkhannock, PA	104	0	2006	2004	1996	1940	1951
1538000	Wapwallopen Creek near Wapwallopen, PA	98	0	1972	1996	2011	2006	2004

September 1, 2011	LEE
June 23, 1972	AGNES
October 15, 1954	HAZEL
September 9, 2004	FRANCES
September 18, 2004	IVAN
June 28, 2006	Trop Low

“Life on the Mississippi” by Mark Twain

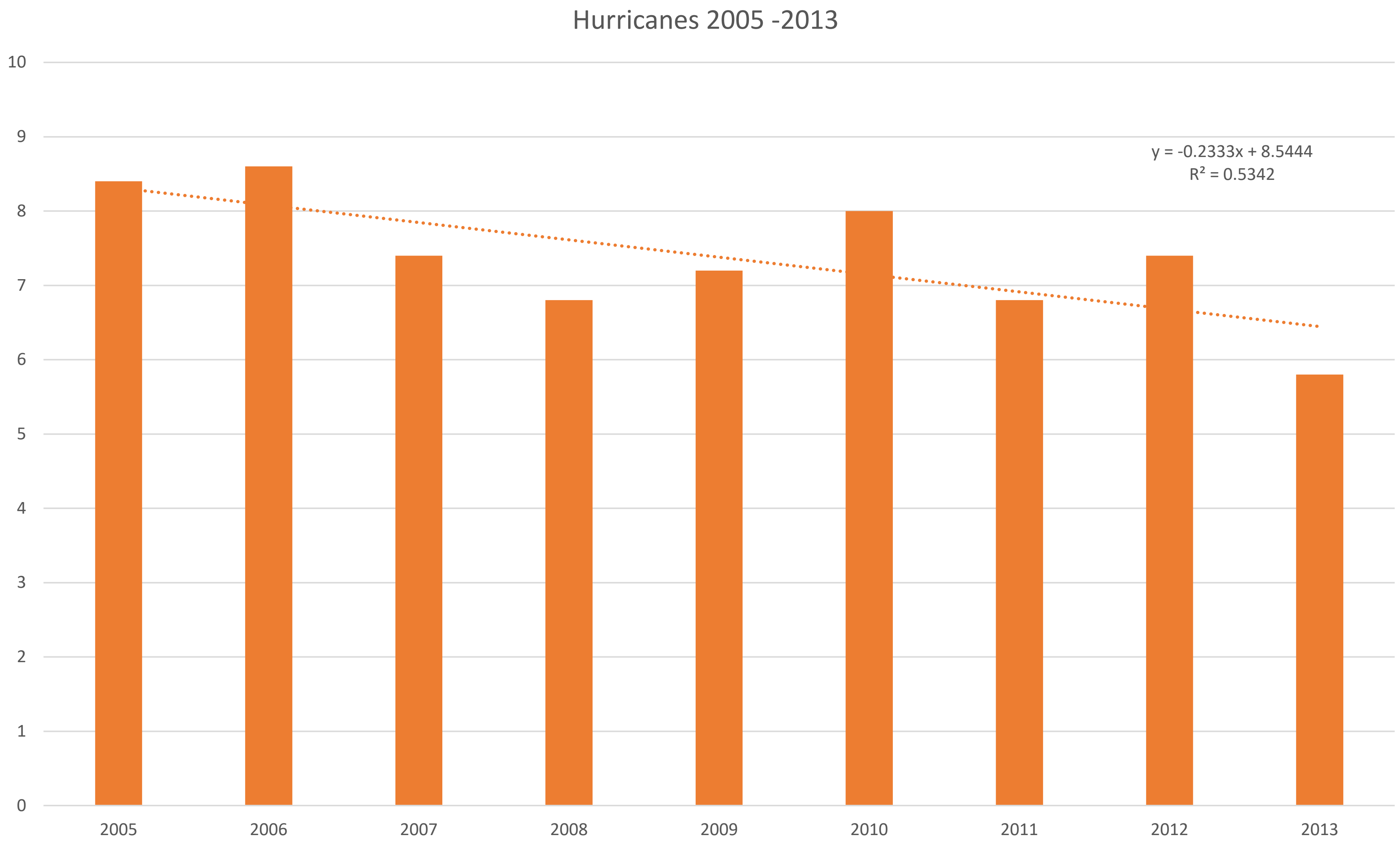
- "In the space of one hundred and seventy-six years the Lower Mississippi has shortened itself two hundred and forty-two miles. That is an average of a trifle over one mile and a third per year. Therefore, any calm person, who is not blind or idiotic, can see that in the Old Oölitic Silurian Period, just a million years ago next November, the Lower Mississippi River was upwards of one million three hundred thousand miles long, and stuck out over the Gulf of Mexico like a fishing rod. And by the same token any person can see that seven hundred and forty-two years from now the Lower Mississippi will be only a mile and three quarters long, and Cairo and New Orleans will have joined their streets together, and be plodding comfortably along under a single mayor and a mutual board of aldermen. There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact."

How many years of record are enough?

Analysis Range	Years of Record	100-yr Flow Estimate
Full records	60	20,300
1950 - 1964	15	23,300
1957-1971	15	37,650
1962-1976	15	8,329

- If we had only 15 years of record, the estimate would potentially be less than half of the 60 year estimate!

Climate Change will Eliminate Hurricanes by 2042



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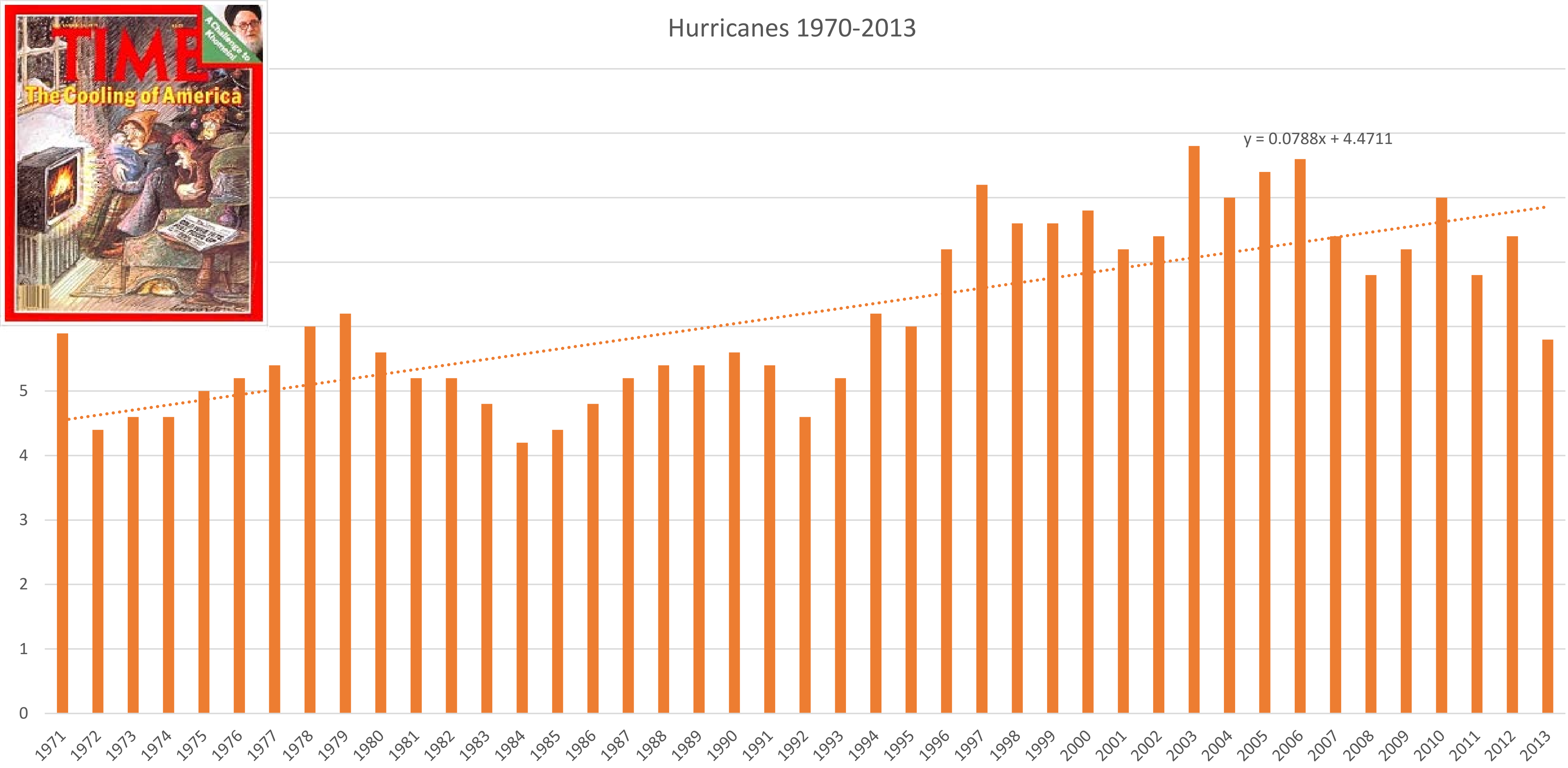
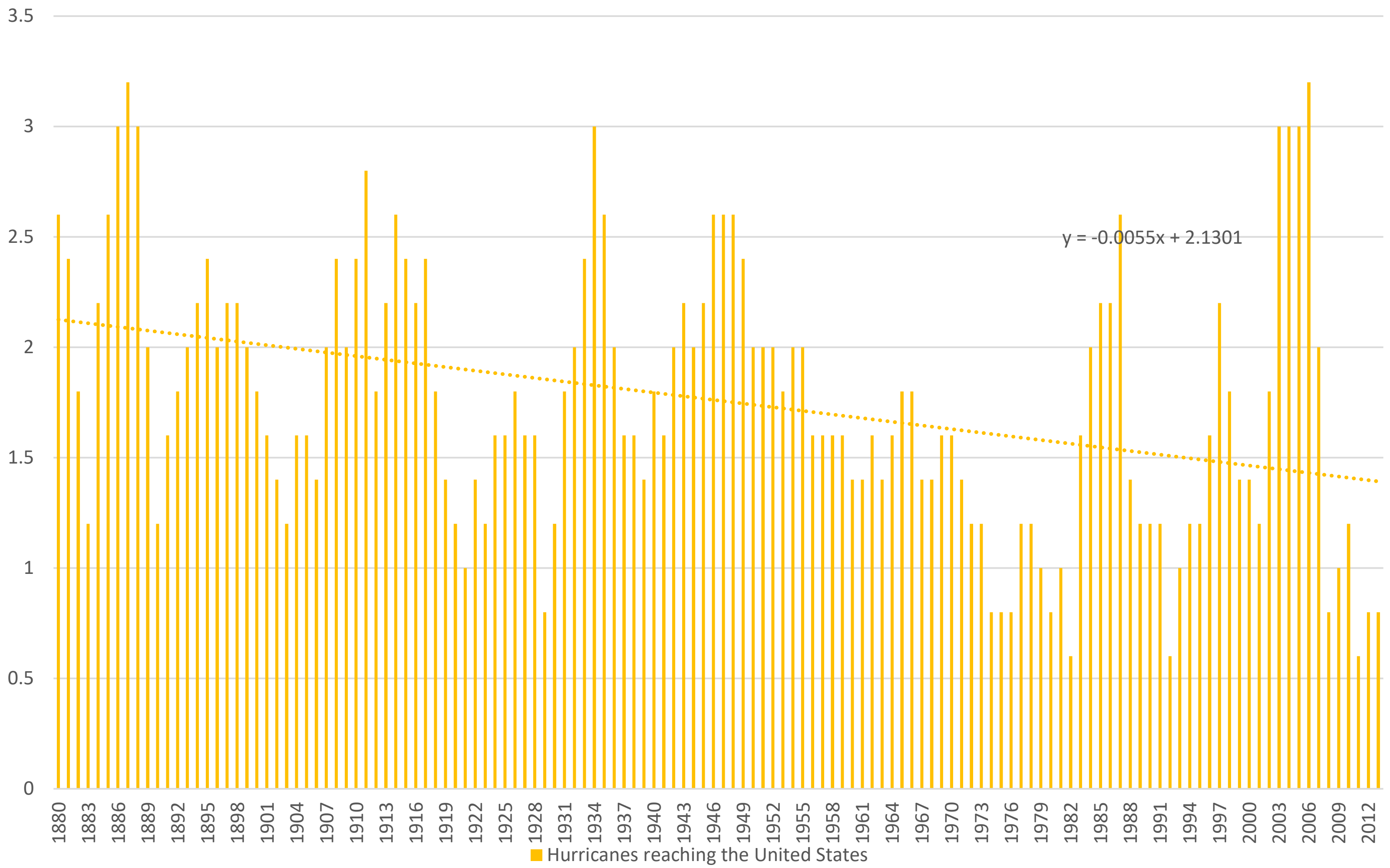
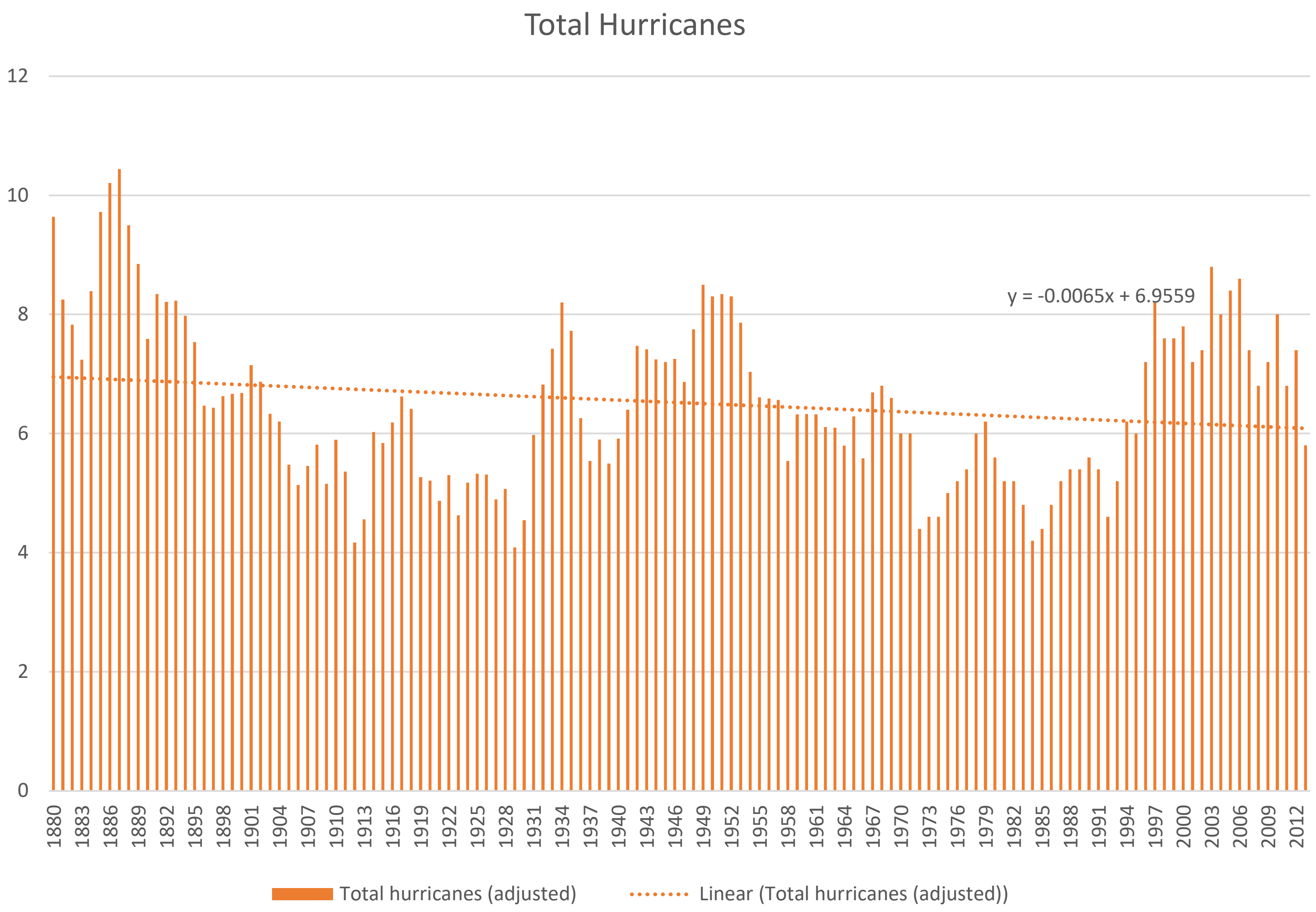
Many Climate Change Studies Begin in the 1970's



Hurricanes Hitting the US



The answer depends upon where you start.

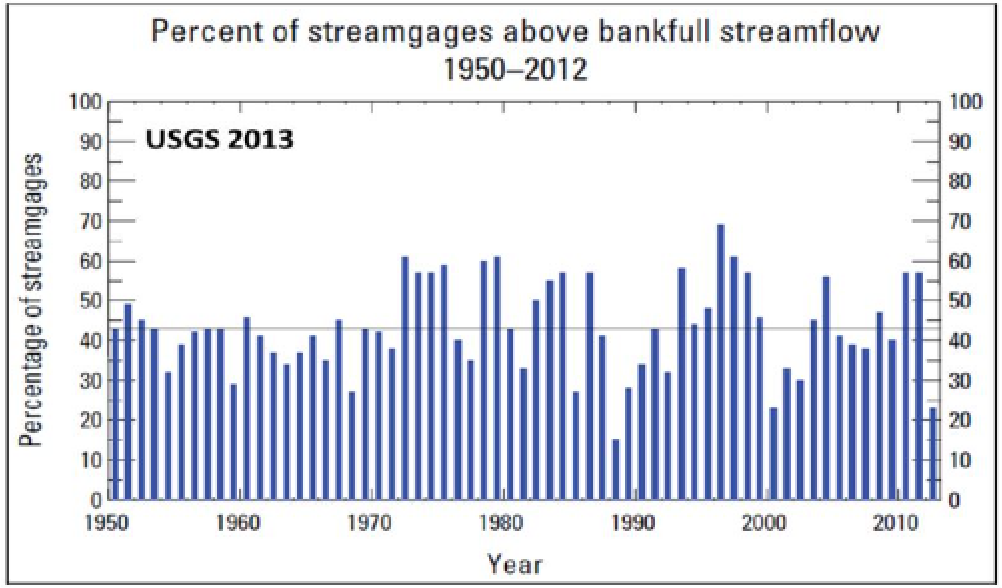


"The degree to which you believe global warming is causing major hurricanes to increase is inversely proportional to your knowledge about these storms."

Dr. William Gray

Results Similar to USGS and IPCC AR5 (2014)

Climate Change: Big Factor in Floods, Droughts?



No trend in U.S. flood magnitudes during 1950-2012 – U.S. Geological Survey

"[T]here is low confidence in detection and attribution of changes in drought over global land areas since the mid-20th century." – IPCC AR5, Ch. 10, p. 913

"There continues to be a lack of evidence and thus low confidence regarding the sign of trend in the magnitude and/or frequency of floods on a global scale." – IPCC AR5, Ch. 2, p. 214

Conclusions

- There are more 1% AEP events than expected (statistically) using LPIII (we are under-estimating the 1% AEP flows)
- The 1990’s was the decade with the greatest number of major floods
- 2000-2009 saw 9.5% of the large floods vs 9.15% expected
- Tropical Events are a MAJOR cause of rare floods in the Appalachians
- This creates a MIXED POPULATION and LPIII grossly underestimates the 1% flood
- Urbanization didn’t cause many of the multiple >1% events