Are Storms Changing and How Does This Effect PMP?

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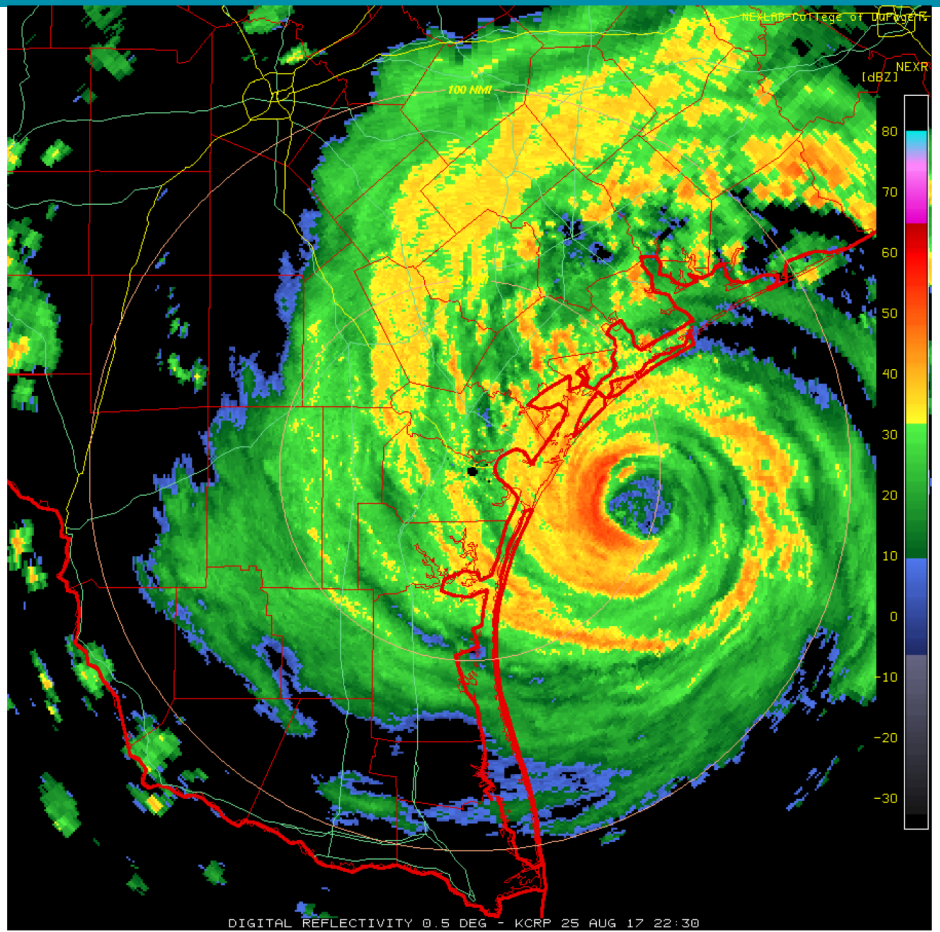
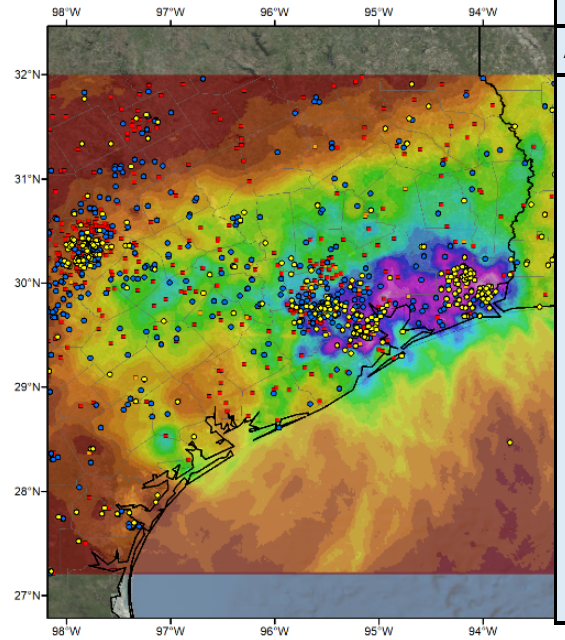
Climate Change and PMP-Background

- Climate is changing…but it always has changed and always will change
  - Are things different now?
  - What does it mean for PMP?
  - Are changes in climate already captured in PMP development?
  - No one knows for sure-different effects for different places
  - Context is important
- Clausius-Clapeyron relationship
  - Warmer air can hold more moisture than cooler air
  - If we are warmer, is this reflected in more PMP?
- Let's see what the data has to say

Radar Loop of Harvey



Harvey – Total Storm Isohyetal and DAD



Gauges
- Daily
- Hourly
- Hourly Est. Pseudo
- Hourly Pseudo
- Supplemental

Total Storm (156-hr) Precipitation (inches)
8/25/2017 0700 UTC - 8/31/2017 1800 UTC
SPAS-NEXRAD 1667

Miles: 0, 25, 50, 100
Kilometers: 0, 55, 110, 220

Precipitation (inches)

0.00 - 2.00	10.01 - 12.00	20.01 - 22.00	30.01 - 32.00	40.01 - 45.00
2.01 - 4.00	12.01 - 14.00	22.01 - 24.00	32.01 - 34.00	45.01 - 50.00
4.01 - 6.00	14.01 - 16.00	24.01 - 26.00	34.01 - 36.00	50.01 - 55.00
6.01 - 8.00	16.01 - 18.00	26.01 - 28.00	36.01 - 38.00	55.01 - 60.00
8.01 - 10.00	18.01 - 20.00	28.01 - 30.00	38.01 - 40.00	60.01 - 62.00

7/20/2018

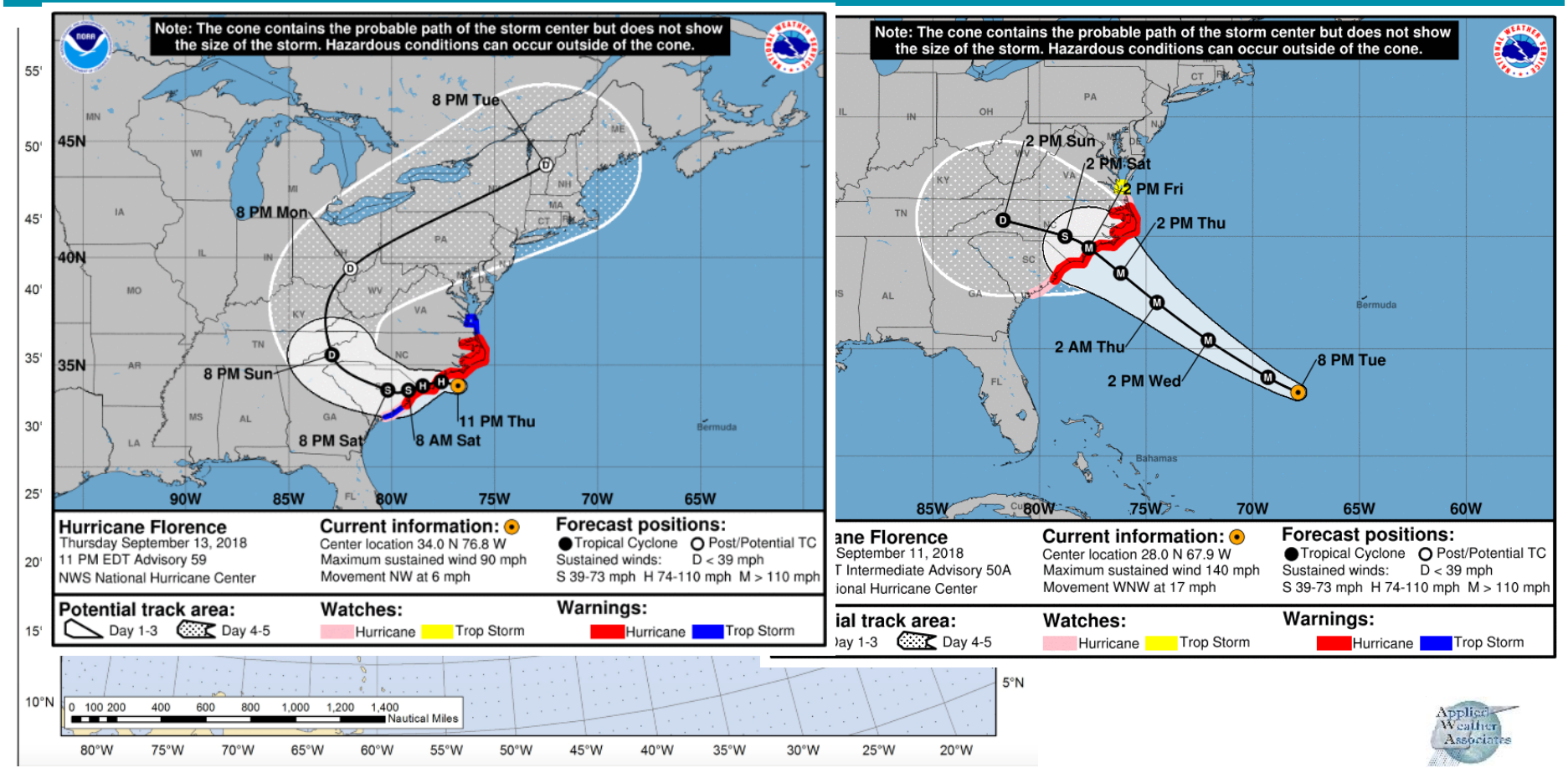
Storm 1667 - August 25 (0700 UTC) - August 31 (1800 UTC), 2017
MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

Area (mi²)	Duration (hours)														
	1	2	3	4	5	6	12	18	24	36	48	72	96	120	Total
0.4	5.80	11.47	14.56	17.08	18.76	19.93	23.92	28.16	34.52	37.39	40.95	51.84	58.62	60.25	61.11
1	5.64	11.18	14.38	16.94	18.63	19.76	23.67	27.88	34.19	37.04	40.61	51.48	58.23	59.78	60.62
10	5.40	10.04	13.25	16.48	18.28	18.98	22.68	26.86	32.72	35.34	39.07	49.43	55.91	57.53	58.36
25	5.07	9.37	12.68	15.99	18.03	18.85	22.11	26.19	31.60	34.18	37.64	47.20	53.09	55.15	56.06
50	4.90	8.84	12.27	15.46	17.68	18.47	21.37	25.35	30.62	33.17	36.49	45.49	51.16	53.37	54.31
100	4.65	8.25	11.71	14.64	17.01	17.79	20.29	24.09	28.98	31.40	35.93	43.68	49.29	51.66	52.67
150	4.45	7.92	11.20	13.98	16.34	17.13	19.64	23.56	27.45	29.59	35.19	42.85	48.01	50.68	51.73
200	4.28	7.67	10.77	13.46	15.73	16.58	19.12	23.06	26.81	28.97	34.57	42.27	47.04	49.83	51.01
300	4.03	7.24	10.09	12.64	14.74	15.67	18.35	22.22	25.81	28.13	33.54	41.28	45.90	48.66	49.86
400	3.81	6.95	9.54	11.94	13.99	14.91	17.71	21.52	24.98	27.55	32.75	40.47	45.10	47.75	49.06
500	3.63	6.61	9.08	11.39	13.27	14.22	17.14	20.88	24.18	27.07	32.15	39.80	44.50	47.01	48.34
1000	2.96	5.40	7.36	9.23	10.76	11.88	15.42	18.81	21.34	25.41	30.24	37.57	42.27	44.73	46.03
2000	2.30	4.00	5.87	7.24	8.55	9.57	13.40	16.53	18.70	23.35	27.98	34.95	39.66	42.23	43.44
3500	1.84	3.25	4.73	5.87	6.89	7.81	11.57	14.43	16.90	21.31	25.92	32.49	37.11	39.84	40.82
5000	1.57	2.82	4.03	5.06	5.98	6.82	10.33	13.10	15.65	19.87	24.52	30.54	35.04	37.73	38.71
7500	1.30	2.33	3.34	4.22	5.02	5.76	9.10	11.62	14.17	18.23	22.77	28.04	32.38	35.09	35.94
10000	1.14	2.04	2.92	3.71	4.43	5.08	8.23	10.59	13.06	17.01	21.37	26.28	30.36	32.83	33.77
15000	0.88	1.67	2.39	3.10	3.73	4.26	7.04	9.18	11.45	15.26	19.19	23.53	27.29	29.79	30.56
20000	0.73	1.37	1.99	2.59	3.15	3.63	6.13	8.16	10.29	13.90	17.59	21.62	25.09	27.36	28.23
35000	0.51	0.93	1.37	1.80	2.21	2.56	4.57	6.21	7.76	10.76	13.74	17.48	20.44	22.59	23.54
50000	0.39	0.70	1.03	1.37	1.68	1.96	3.52	4.94	6.28	8.93	11.31	14.62	17.14	19.33	20.46
75000	0.26	0.52	0.74	1.02	1.28	1.45	2.65	3.65	4.60	6.68	8.58	11.65	13.75	15.53	16.60
100000	0.20	0.40	0.59	0.81	0.99	1.17	2.17	2.95	3.70	5.36	6.85	9.34	11.03	12.43	13.44
120162	0.17	0.34	0.51	0.67	0.83	0.99	1.86	2.56	3.19	4.64	5.94	8.08	9.56	10.77	11.65

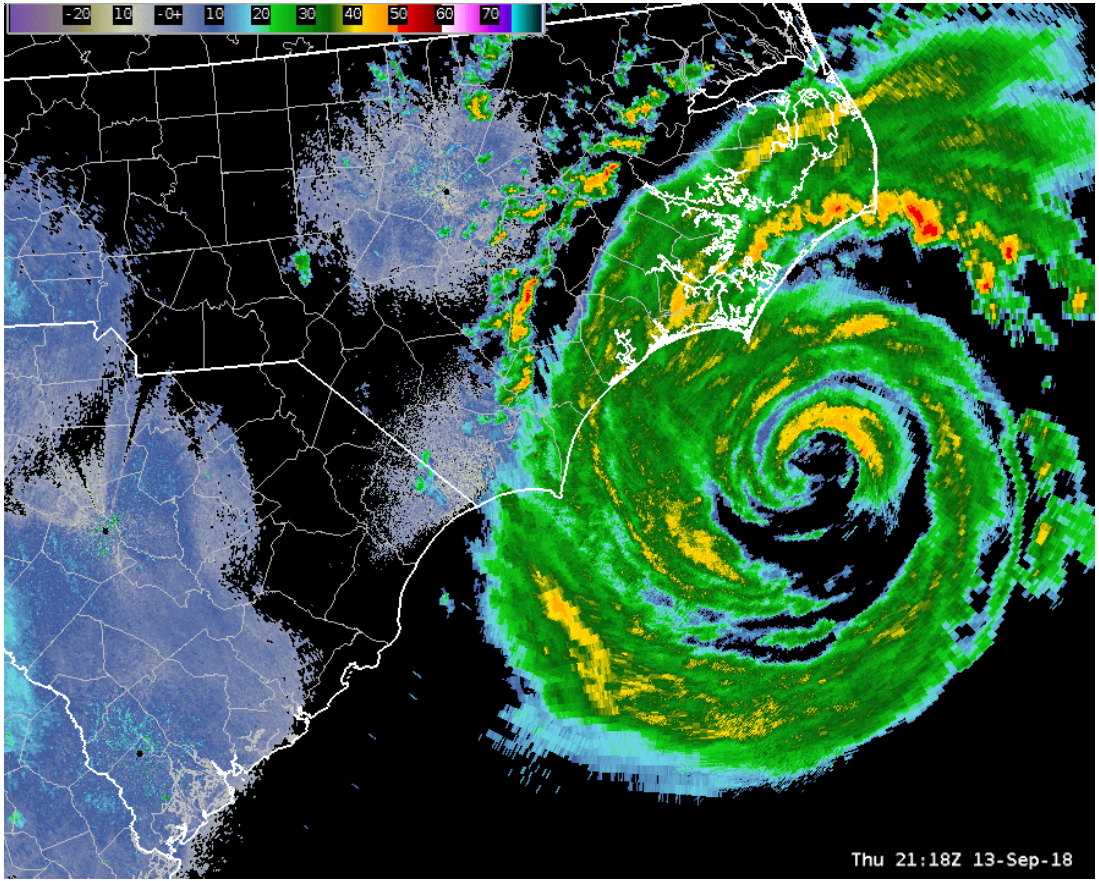
Harvey Comparison to Previous PMP

	Average Tropical PMP (post-Harvey)	Average PMP (pre-Harvey)	Average % Change of PMP	Average HMR 51 PMP	Average % Increase from HMR 51
5,000-sqmi 72-hour	30.1"	35.3"	No Increase	31.1"	No Increase
10,000-sqmi 48-hour	22.0"	24.7"	No Increase	22.9"	No Increase
10,000-sqmi 72-hour	25.9"	29.1"	No Increase	26.8"	No Increase
10,000-sqmi 96-hour	27.3"	28.2"	No Increase	N/A	N/A
10,000-sqmi 120-hour	29.5"	28.4"	No Increase	N/A	N/A
20,000-sqmi 48-hour	17.4"	20.6"	No Increase	22.8"	No Increase
20,000-sqmi 72-hour	20.8"	22.0"	No Increase	26.8"	No Increase
20,000-sqmi 96-hour	23.4"	23.1"	**1.5%**	N/A	N/A
20,000-sqmi 120-hour	24.7"	22.8"	**8.4%**	N/A	N/A

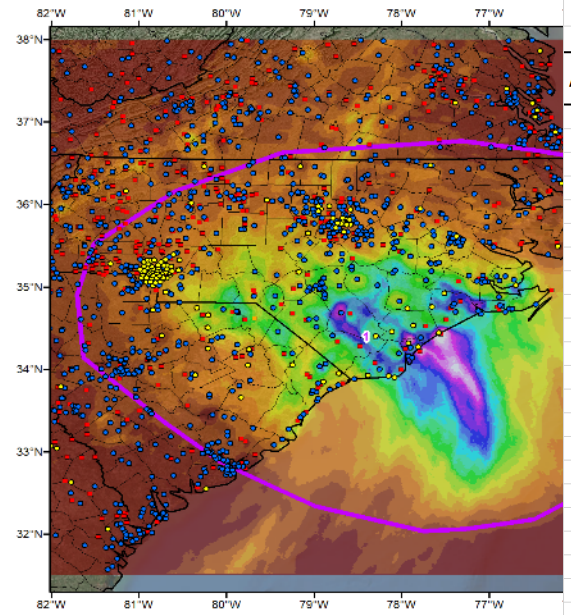
Hurricane Florence Track



Hurricane Florence Radar Loop



Hurricane Florence DAD and Total Storm Isohyetal

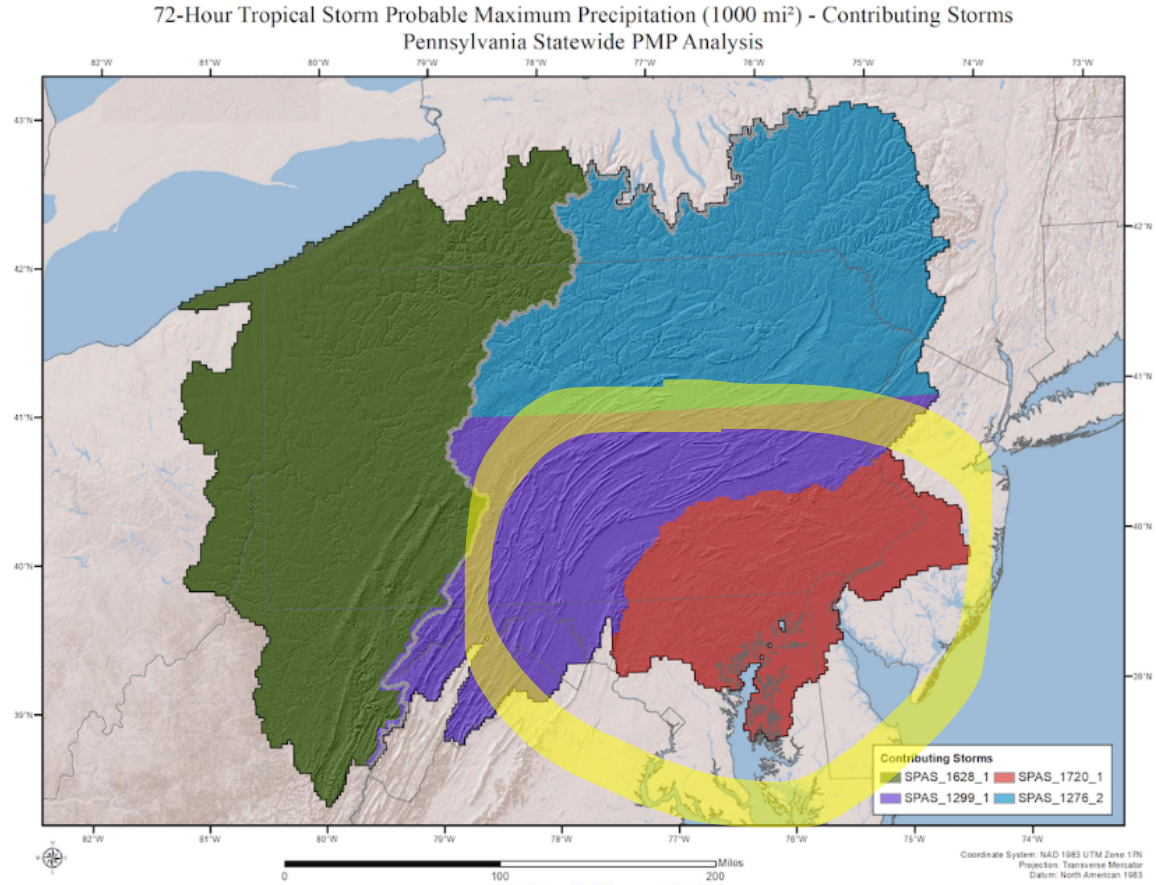


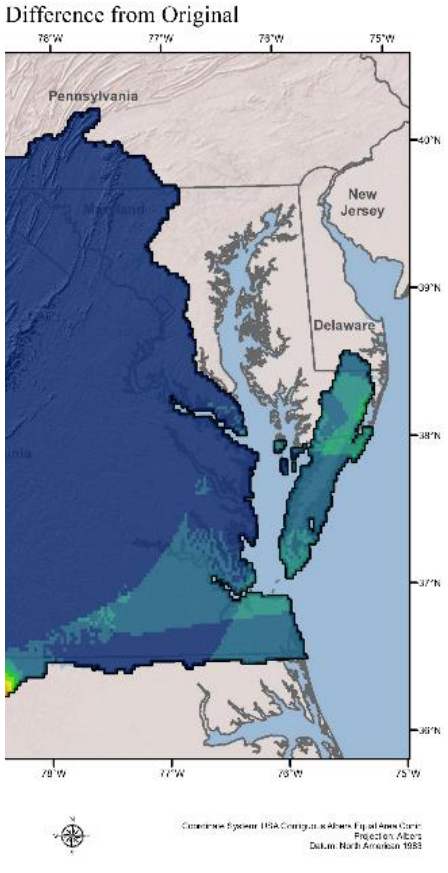
Storm 1720 - September 13 (1200 UTC) - September 18 (1100 UTC), 2018

MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

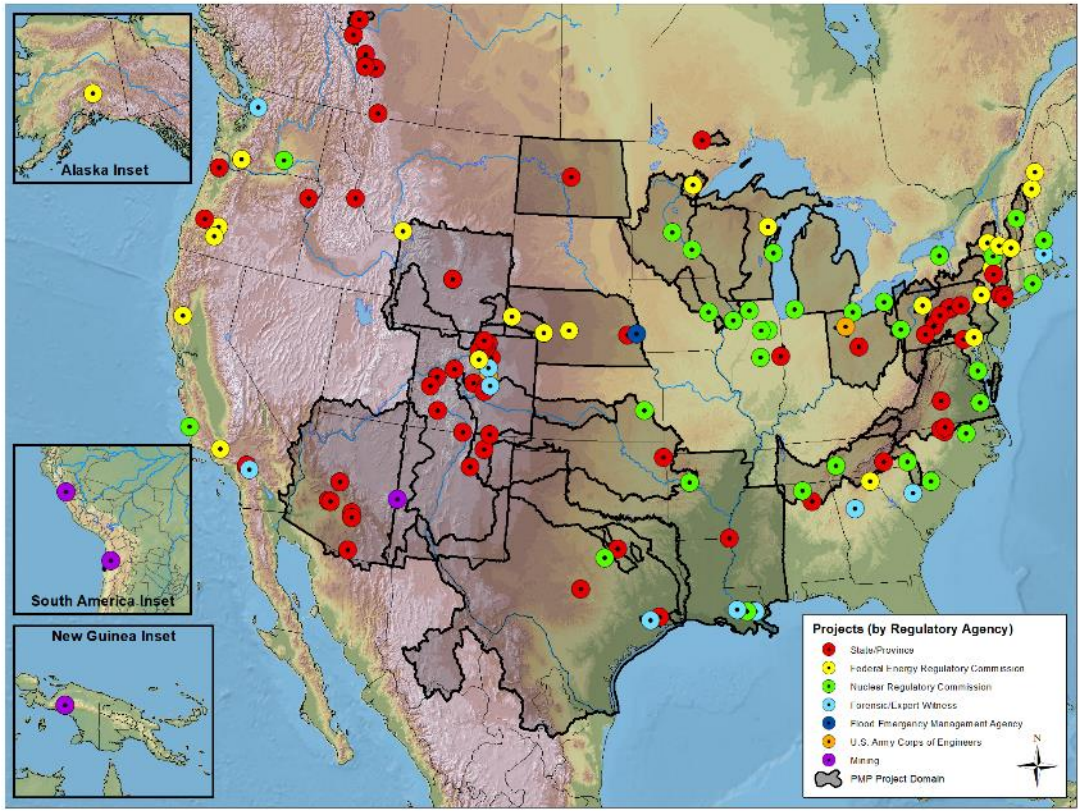
Area (mi^2)	Duration (hours)														
	1	2	3	4	5	6	12	18	24	36	48	72	96	120	Total
0.4	6.88	10.04	11.60	12.65	13.33	13.81	16.94	20.86	25.12	29.06	37.42	43.10	43.88	43.95	43.95
1	6.82	9.94	11.51	12.51	13.17	13.63	16.79	20.74	24.97	28.88	37.20	42.81	43.61	43.72	43.72
10	6.56	9.51	11.15	11.97	12.24	12.65	16.23	20.42	24.60	28.44	36.66	42.11	42.99	43.14	43.14
25	5.85	8.41	10.07	10.80	11.09	11.57	15.84	20.20	24.35	28.27	36.45	41.87	42.75	42.92	42.92
50	4.90	6.97	8.63	9.23	9.86	11.05	15.31	19.75	23.80	28.00	36.03	41.69	42.57	42.74	42.74
100	3.97	5.71	7.15	7.78	9.16	10.35	14.37	18.62	22.80	27.34	35.17	41.09	42.38	42.57	42.57
150	3.50	5.03	6.36	7.33	8.66	9.85	13.67	17.72	22.12	26.88	34.48	40.68	41.96	42.16	42.16
200	3.20	4.61	5.86	6.98	8.24	9.37	13.14	17.03	21.58	26.53	34.00	40.39	41.66	41.85	41.85
300	2.82	4.14	5.22	6.44	7.48	8.53	12.74	16.18	20.79	26.03	33.30	39.98	41.25	41.42	41.42
400	2.59	3.86	4.81	6.00	6.99	7.93	12.38	15.83	20.16	25.50	32.76	39.51	40.91	41.10	41.10
500	2.43	3.59	4.54	5.62	6.58	7.65	12.06	15.60	19.62	25.03	32.35	39.12	40.49	40.67	40.67
1,000	1.99	3.02	3.85	4.83	5.89	6.86	10.89	14.52	17.67	23.41	30.42	37.41	38.85	39.01	39.01
2,000	1.62	2.55	3.43	4.22	5.07	5.88	9.79	12.95	15.82	21.45	27.87	34.59	36.27	36.40	36.40
3,500	1.39	2.28	3.09	3.79	4.56	5.14	8.63	11.53	14.45	19.64	25.55	31.95	33.84	33.99	33.99
5,000	1.26	2.10	2.86	3.53	4.21	4.77	7.91	10.64	13.52	18.37	23.87	30.30	32.11	32.28	32.28
7,500	1.10	1.86	2.60	3.18	3.84	4.35	7.28	9.90	12.53	16.96	21.93	28.10	29.84	30.06	30.06
10,000	0.98	1.71	2.37	2.94	3.51	4.02	6.79	9.36	11.72	15.89	20.56	26.35	28.22	28.46	28.46
15,000	0.82	1.44	2.05	2.55	3.08	3.50	6.05	8.43	10.57	14.25	18.35	23.62	25.46	25.72	25.72
20,000	0.72	1.26	1.79	2.26	2.70	3.11	5.52	7.72	9.62	12.97	16.59	21.38	23.29	23.54	23.54
35,000	0.50	0.90	1.30	1.68	2.00	2.36	4.29	6.06	7.56	10.05	12.84	16.93	18.78	19.01	19.01
50,000	0.39	0.70	1.00	1.25	1.54	1.77	3.29	4.77	5.97	8.25	10.43	13.80	15.64	15.89	15.89
75,000	0.26	0.49	0.71	0.91	1.13	1.29	2.37	3.41	4.25	5.99	7.67	10.57	12.25	12.57	12.57
96,675	0.21	0.38	0.55	0.71	0.88	1.03	1.87	2.73	3.43	4.89	6.29	8.75	10.16	10.44	10.44

Where Does Florence Control PMP?

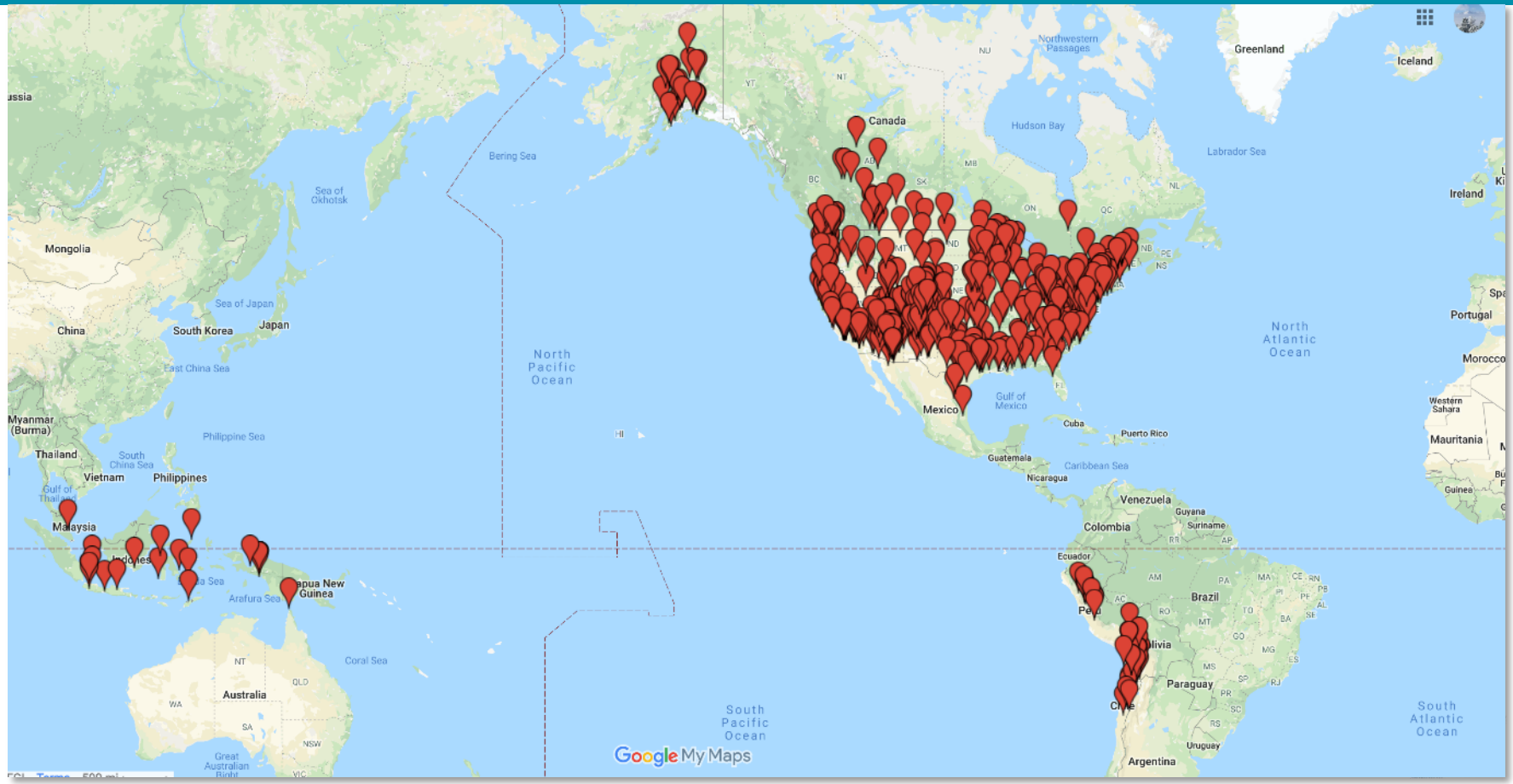




AWA Probable Maximum Precipitation Projects



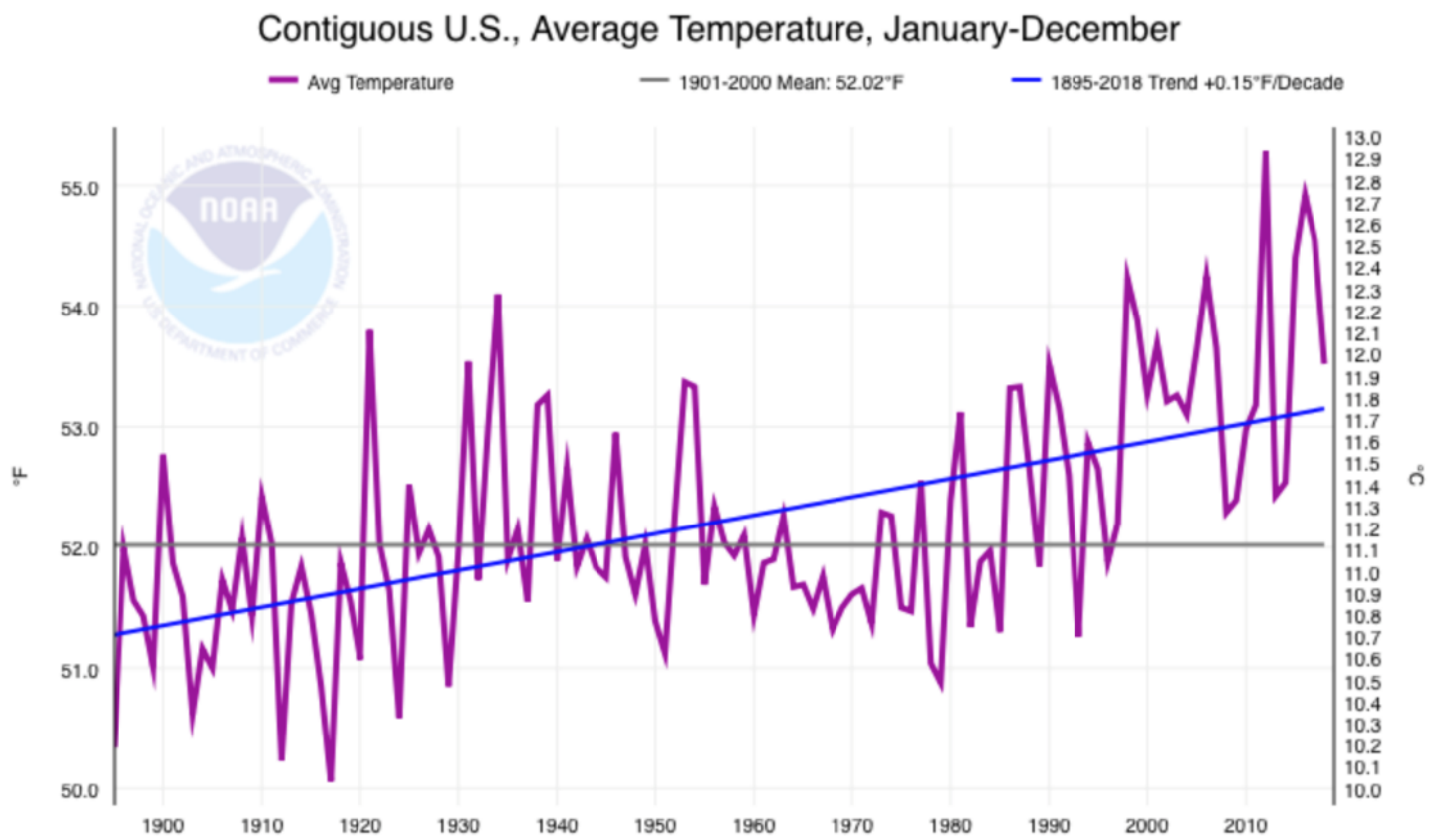
AWA Storm Analysis Locations



Are Storm Changing? Is PMP More Frequent/Intense?

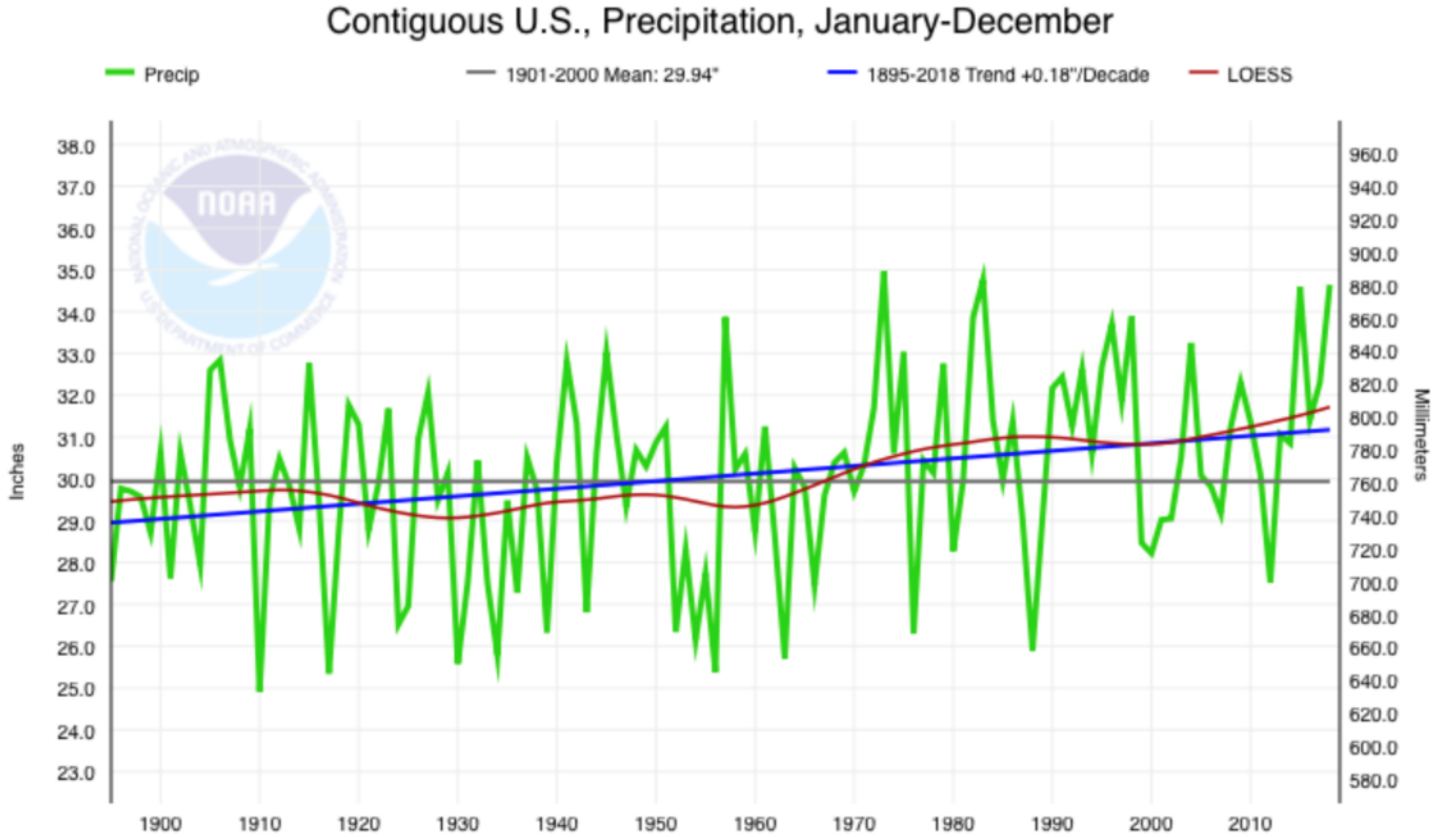
- What are the controlling storms through time
  - Harvey and Florence important
  - However, many ”old” storm still control
  - Varies by area size, duration, location, and storm type
- “Old” PMP storms examples
  - Hearne, TX September 1899
  - Thrall, TX September 1921
  - Cherry Creek, CO May 1935
  - Smethport, PA July 1942
  - Gibson Dam, MT June 1964
  - Hurricane Agnes, June 1972

US Temperature Trend 1895-2019



NOAA National Centers for Environmental information, Climate at a Glance: National Time Series, published August 2019, retrieved on August 27, 2019 from https://www.ncdc.noaa.gov/cag/

US Precipitation Trend 1895-2019



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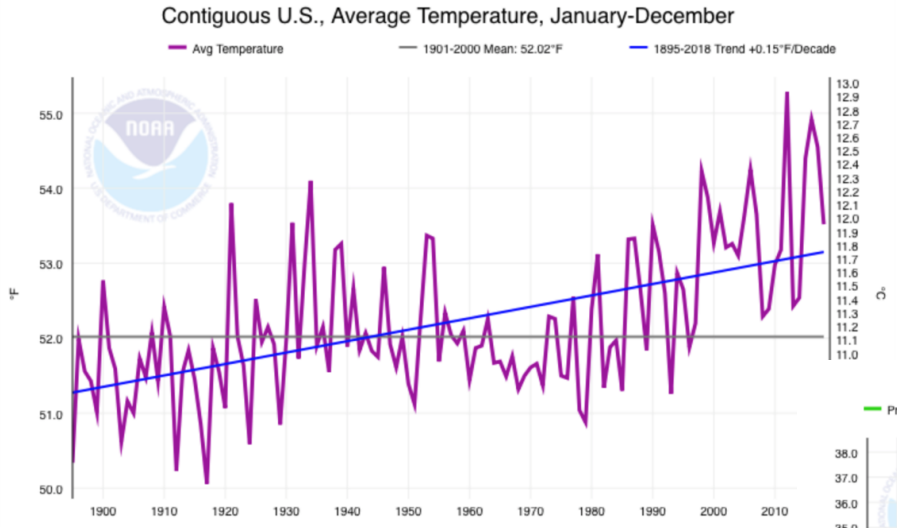
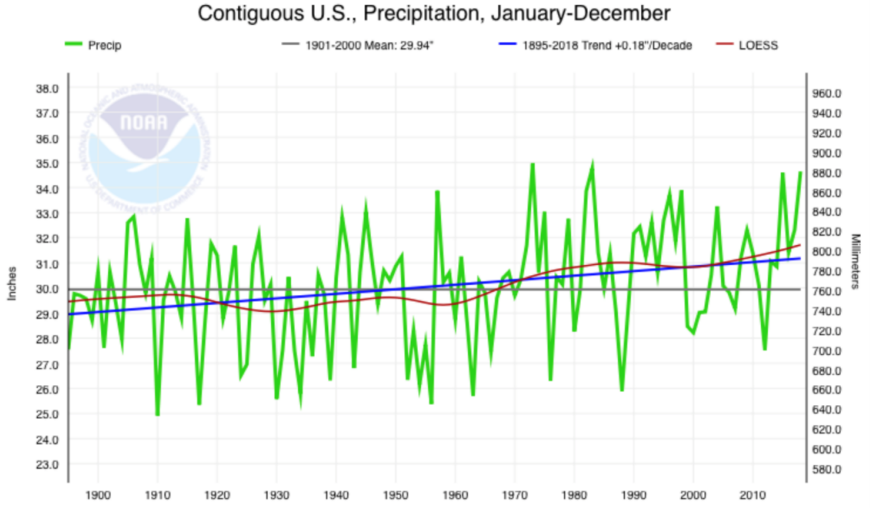
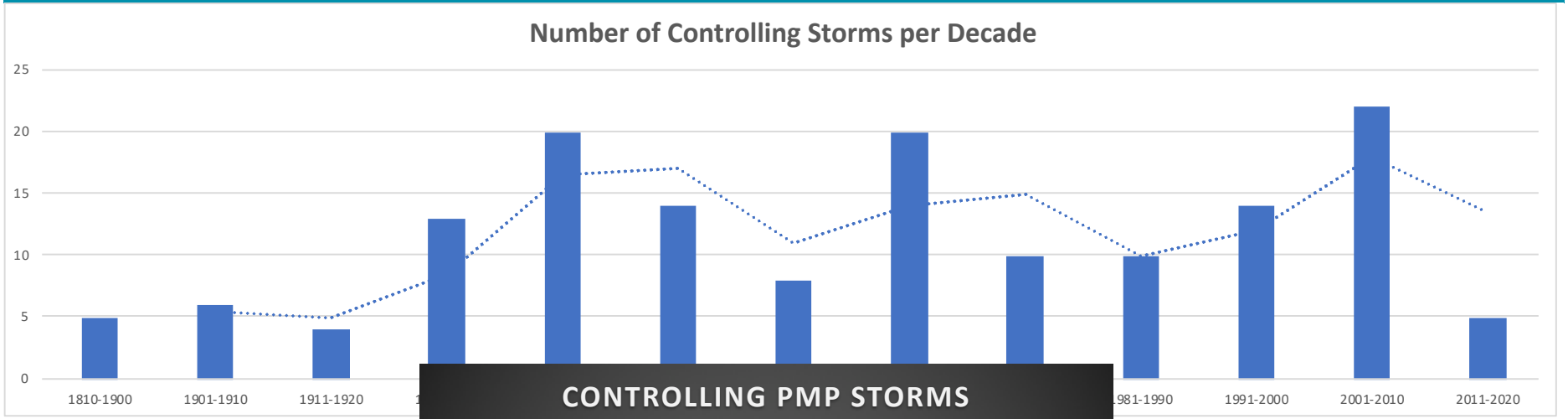
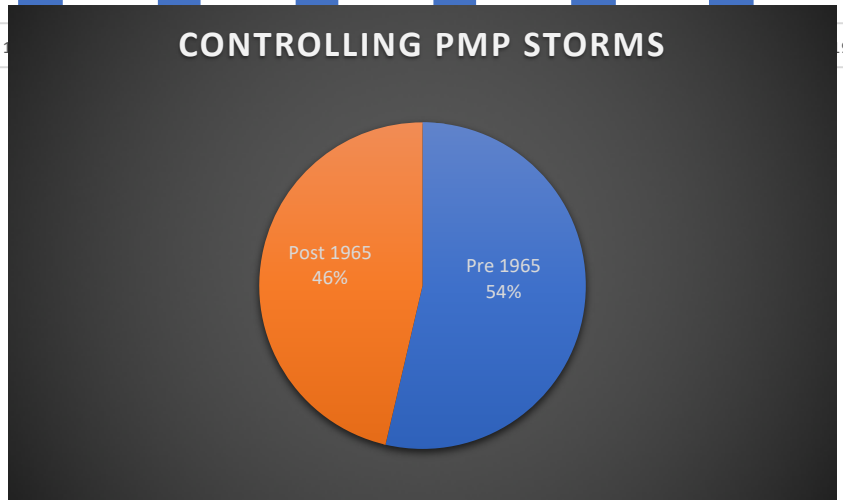
US Temperature and Precip Trends 1895-2019



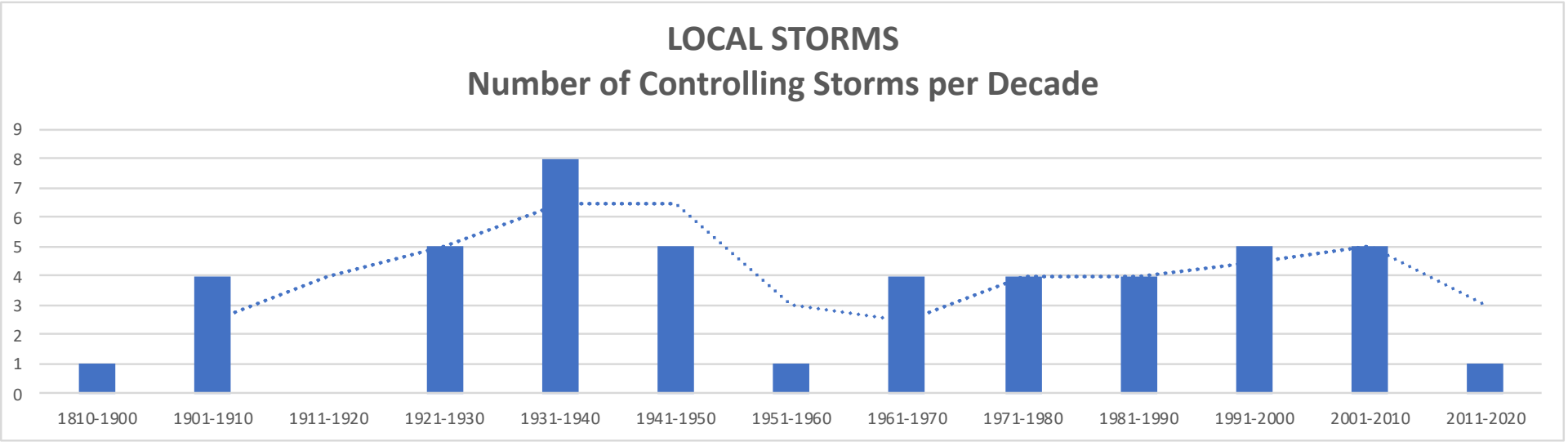


Controlling Storms Per Decade





Controlling Storms Per Decade-Local Storms



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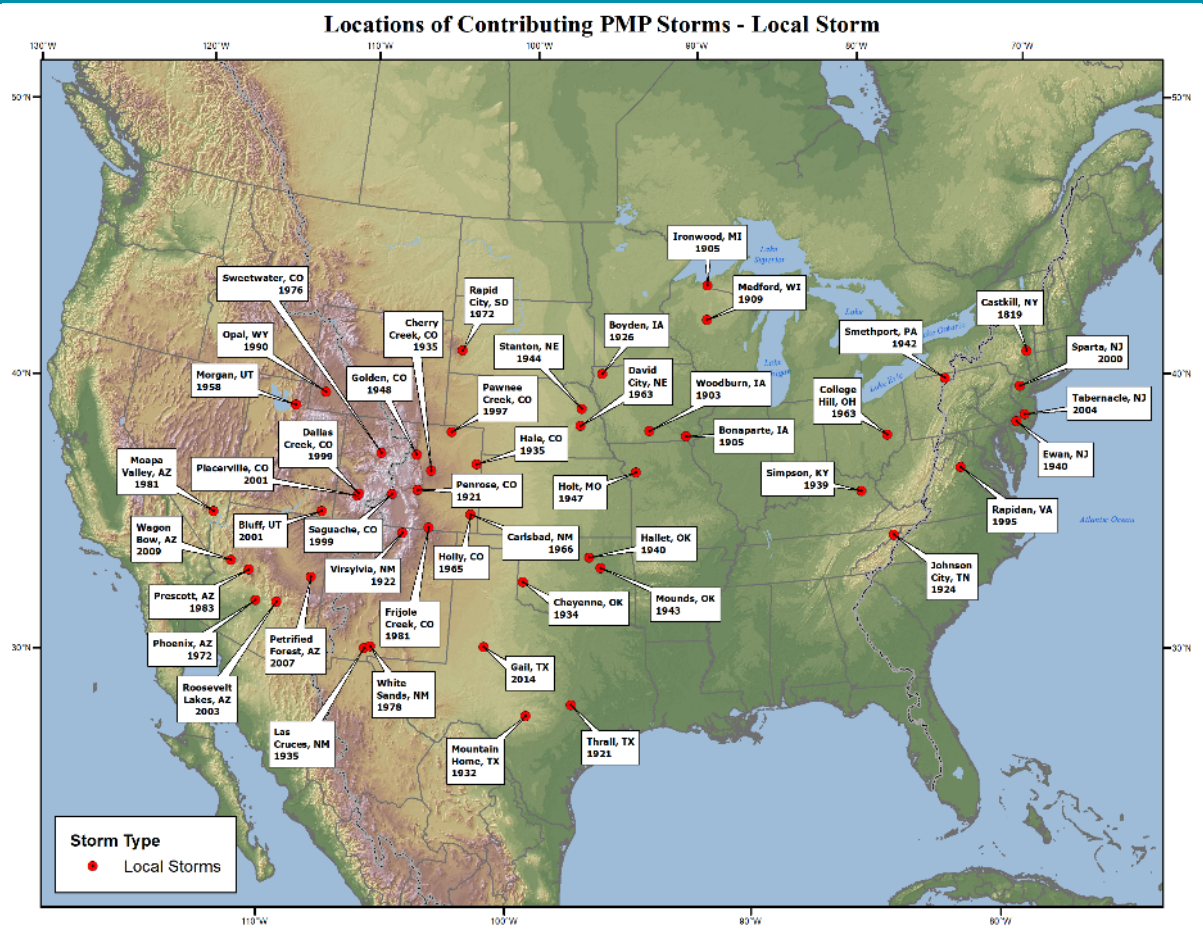
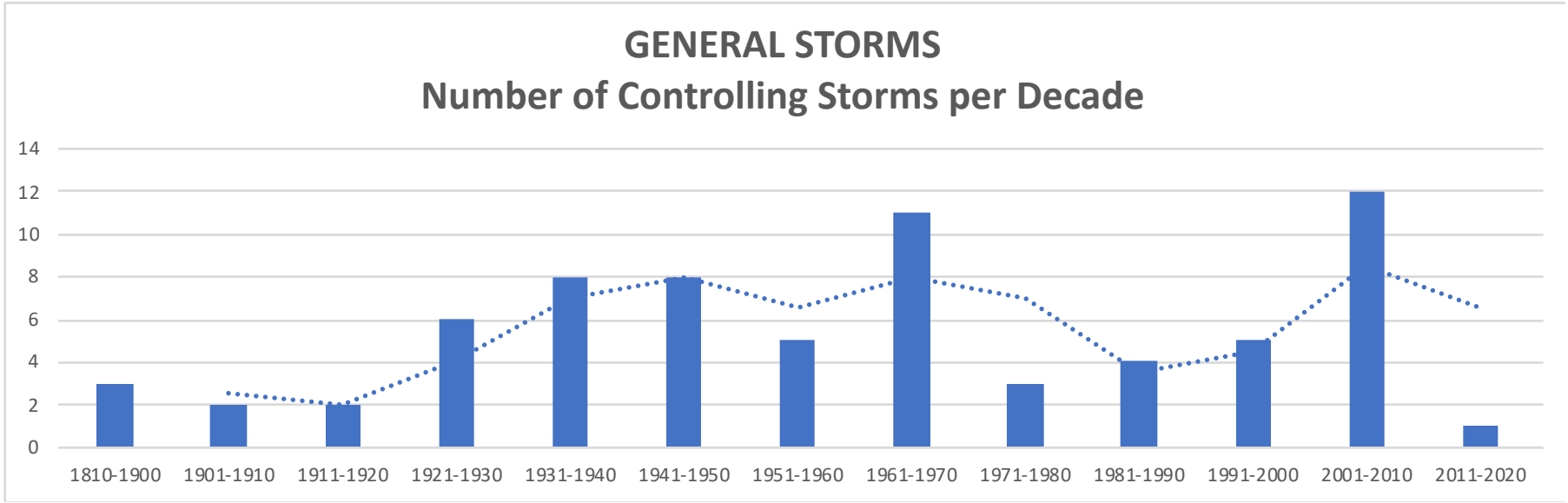
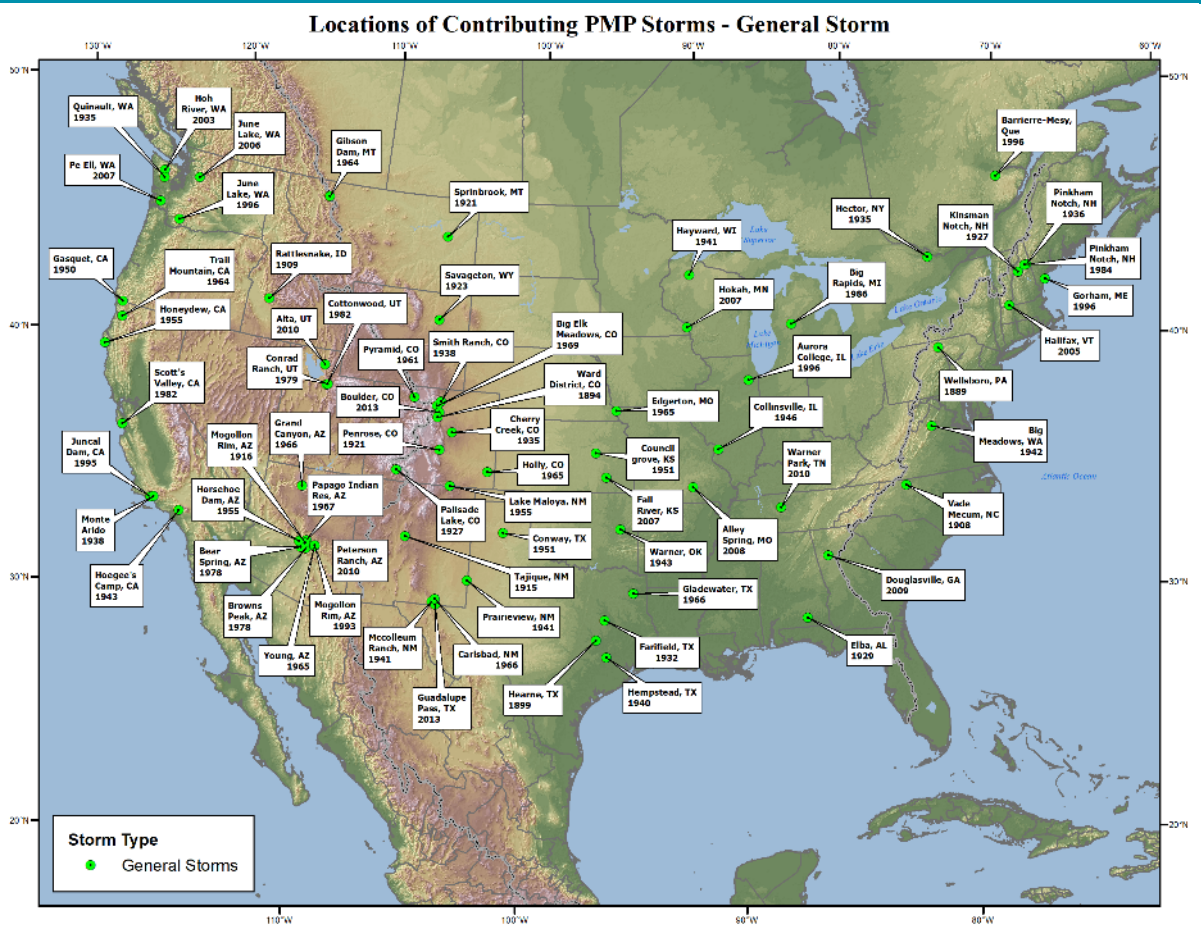


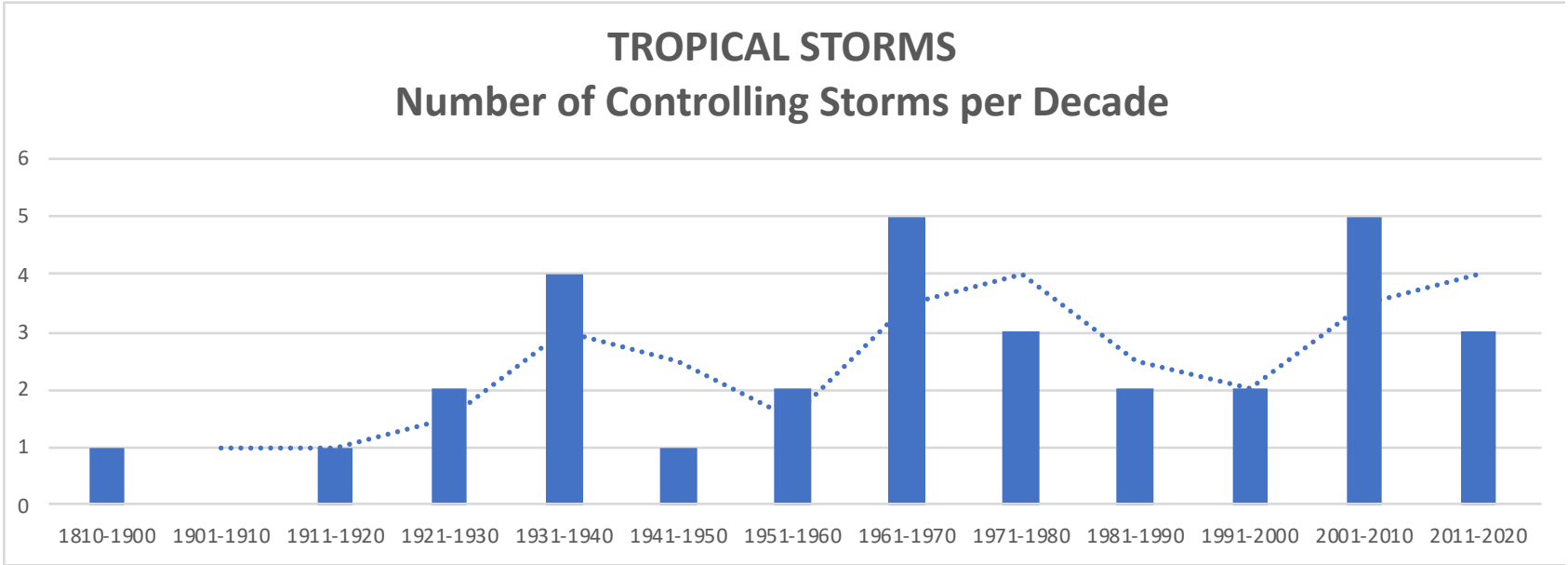
Controlling Storms Per Decade-General Storms



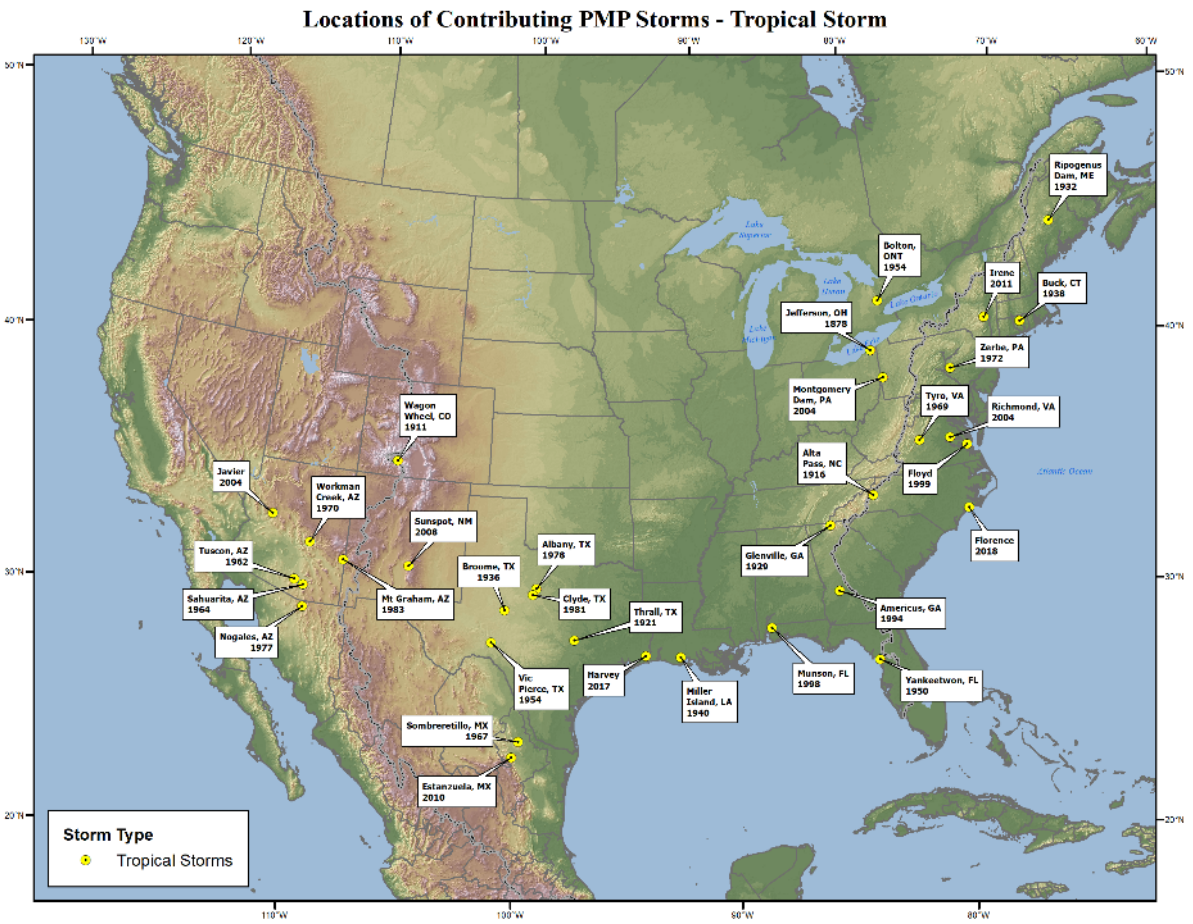
Controlling Storms-General Storms



Controlling Storms Per Decade-Tropical Storms



Controlling Storms-Tropical Storms



Summary

- Storms controlling PMP are a mix of old and new
- Climate change is involved, but it always has been involved and always will be
- PMP doesn't show a trend either way-they've happened before and will happen again
- But, given the uncertainty, it's always good to "err on the side of caution"

Questions

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PMP Can and Does Happen-Hawaii April 15

POSSIBLE NEW NATIONAL RECORD 24-HOUR RAINFALL FROM KAUAI
132 PM HST WED APR 25 2018

PRELIMINARY DATA DOWNLOADED FROM A REMOTE RAIN GAGE IN NORTH KAUAI INDICATE THAT RAINFALL DURING THE FLASH FLOOD EVENT ON APRIL 14-15, 2018 BROKE THE U.S. 24-HOUR RAINFALL RECORD. THE RAIN GAGE, LOCATED IN WAIPA ABOUT ONE MILE WEST OF HANALEI, RECORDED 49.69 INCHES OF RAINFALL DURING THE 24-HOUR PERIOD ENDING AT 12:45 PM HST APRIL 15. THIS TOTAL, IF CERTIFIED, WILL BREAK THE CURRENT U.S. 24-HOUR RECORD OF 43 INCHES AT ALVIN, TX ON JULY 25-26, 1979, AND THE STATE OF HAWAII RECORD OF 38 INCHES AT KILAUEA (KAUAI) ON JANUARY 24-25, 1956.

PMP Can and Does Happen

Here is a list of other top 24-hour-rainfall records, all of which were related to a tropical storm or hurricane except for Waipa:

71.85 inches — Foc-Foc, La Reunion (Jan. 7-8, 1966)

66.49 inches — Belouve, La Reunion (Feb. 27-28, 1964)

64.33 inches — Isla Mujeres, Mexico (Oct. 21-22, 2005)

62.33 inches — Aurere, La Reunion (April 7-8, 1958)

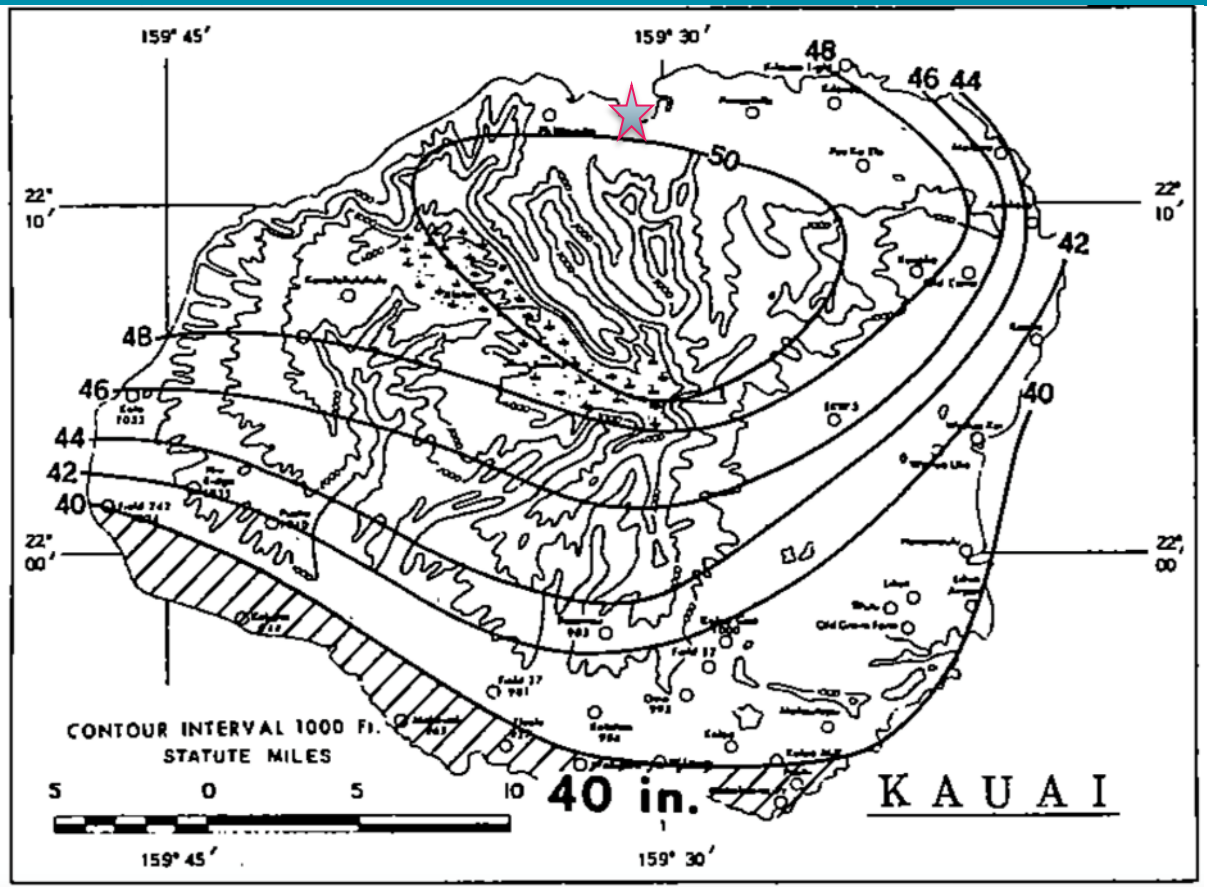
55.20 inches — Weiliaoshan, Taiwan (Aug. 8, 2009)

55.04 inches — Commerson, La Reunion (Feb. 25, 2007)

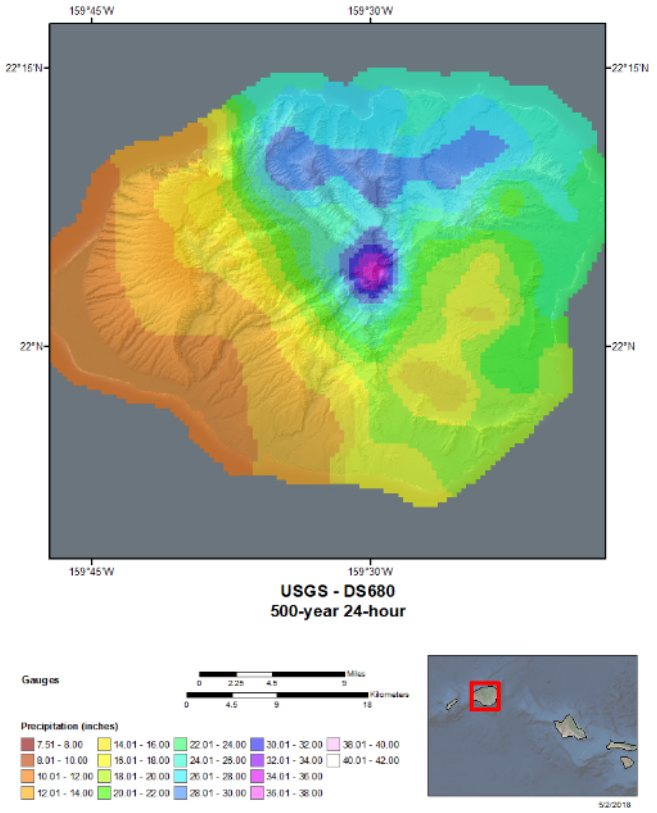
51.85 inches — Kaikawa, Tokushima, Japan (Aug. 1, 2004)

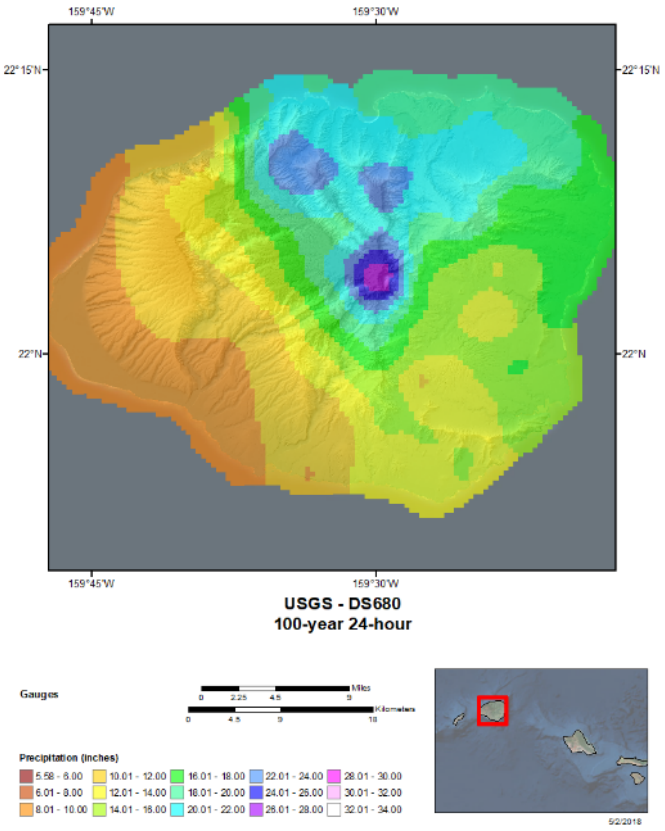
49.69 inches — Waipa, Hawaii (April 14-15, 2018)*

HMR 39 24-hour PMP Depths



Record Rainfall Location





Extra Slides