Recent Extreme Rainfall in the Southeastern US and the Importance for Dam Safety

Bill Kappel, President/Chief Meteorologist, AWA

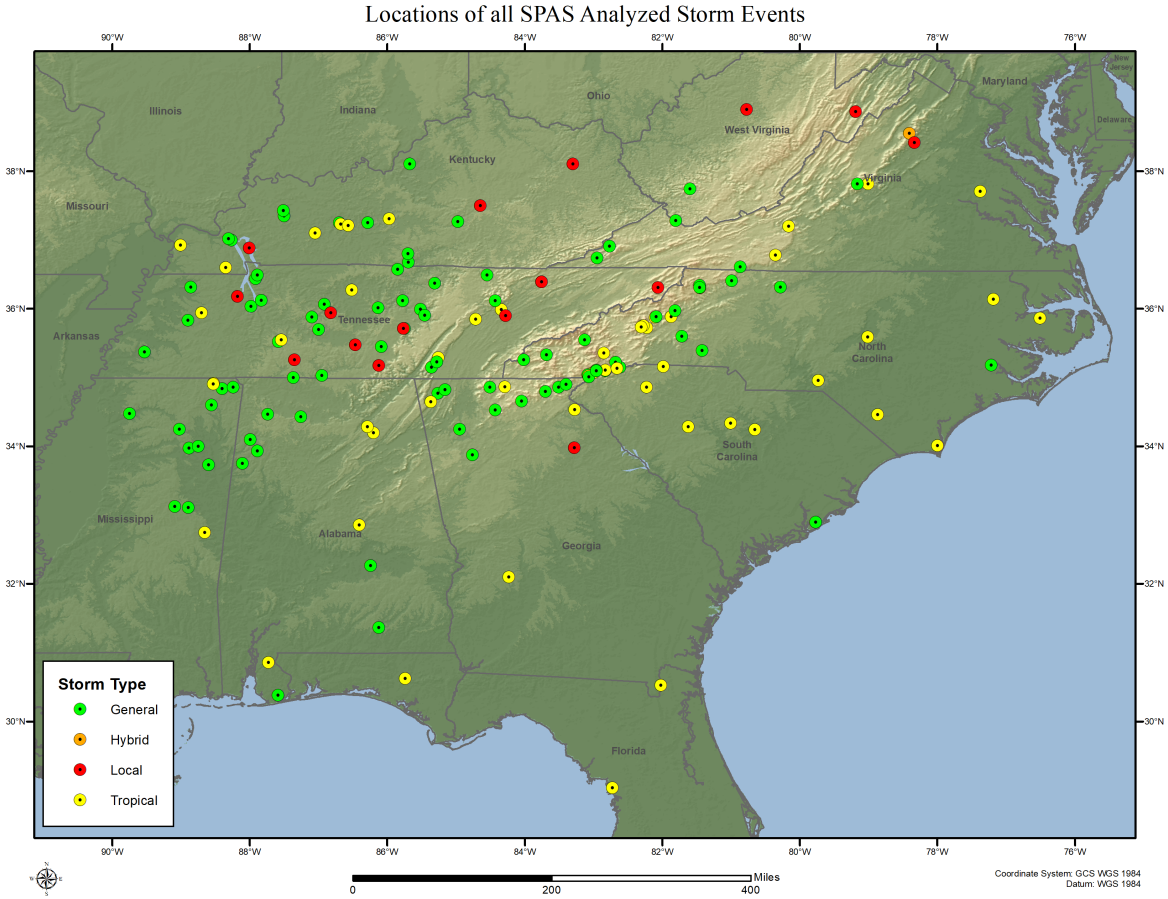
www.appliedweatherassociates.com

November 30, 2021 ● ASDSO Southeast Regional Conference

Background

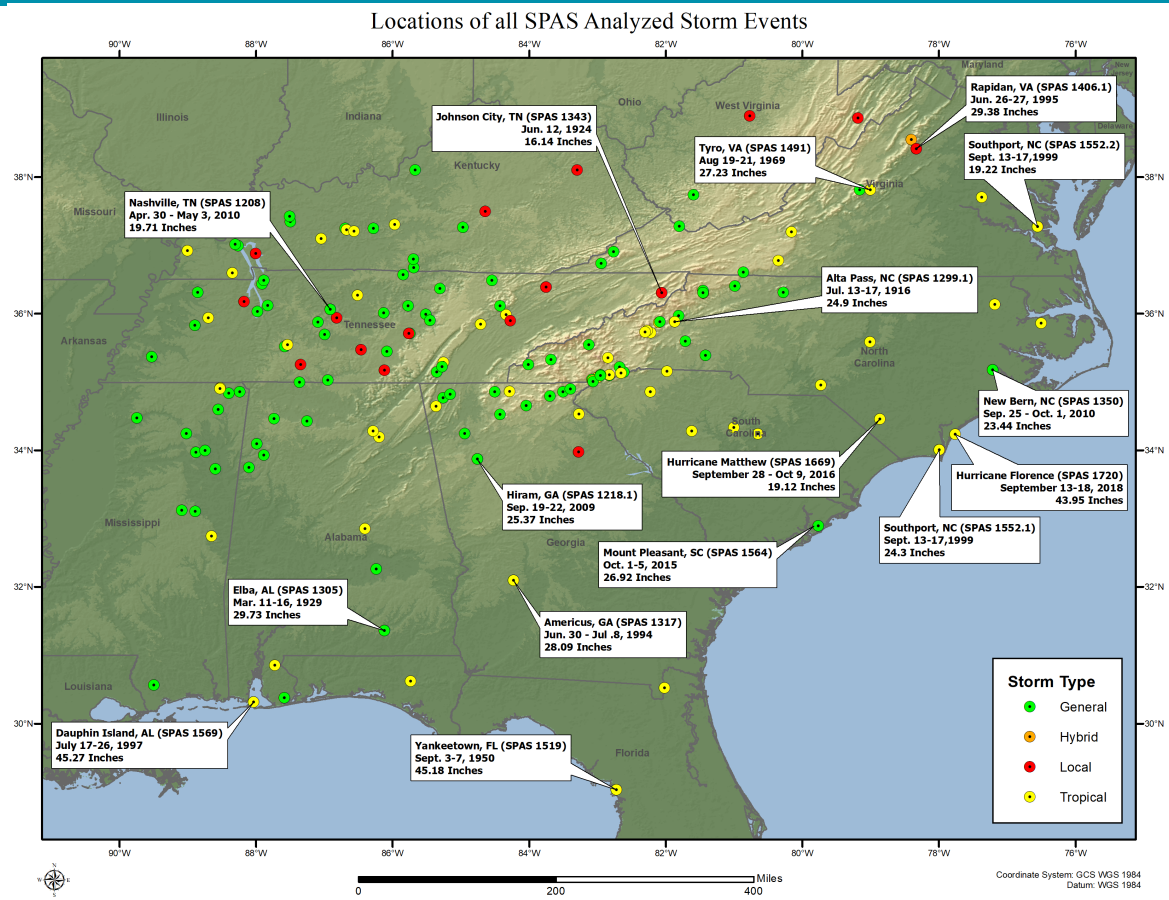
- Heavy rainfall a common occurrence in the region
  - Long history of extreme rainfall in the region
  - Happened before, it will happen again
- Two “recent” storm in focus today
  - October 2015
    - Combination of tropical and synoptic
  - Hurricane Florence September 2018
    - Purely tropical

Extreme Rainfall in the Region



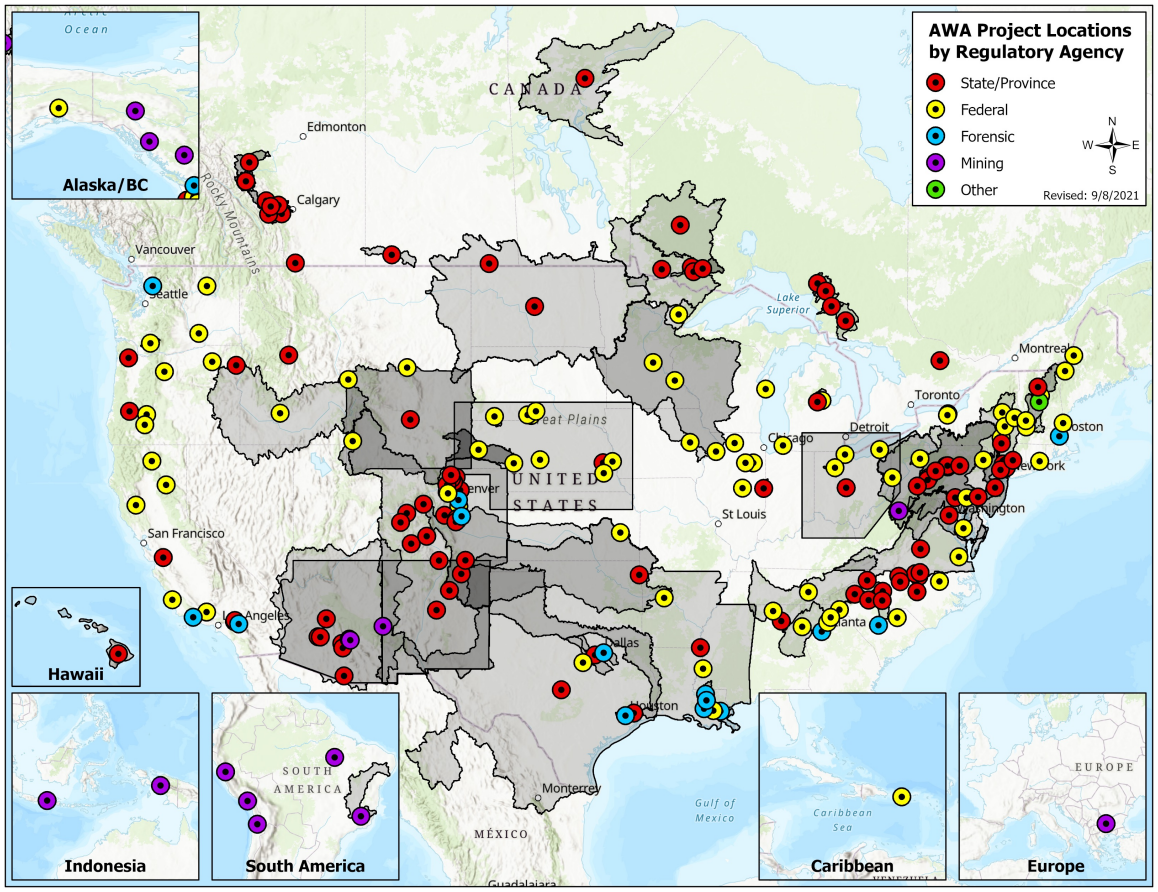
Extreme Rainfall in the Region

- July 1916
- June 1923
- March 1929
- September 1950
- August 1969
- July 1994
- June 1995
- September 1999
- May 2010
- September 2008
- September 2010
- October 2016
- September 2018



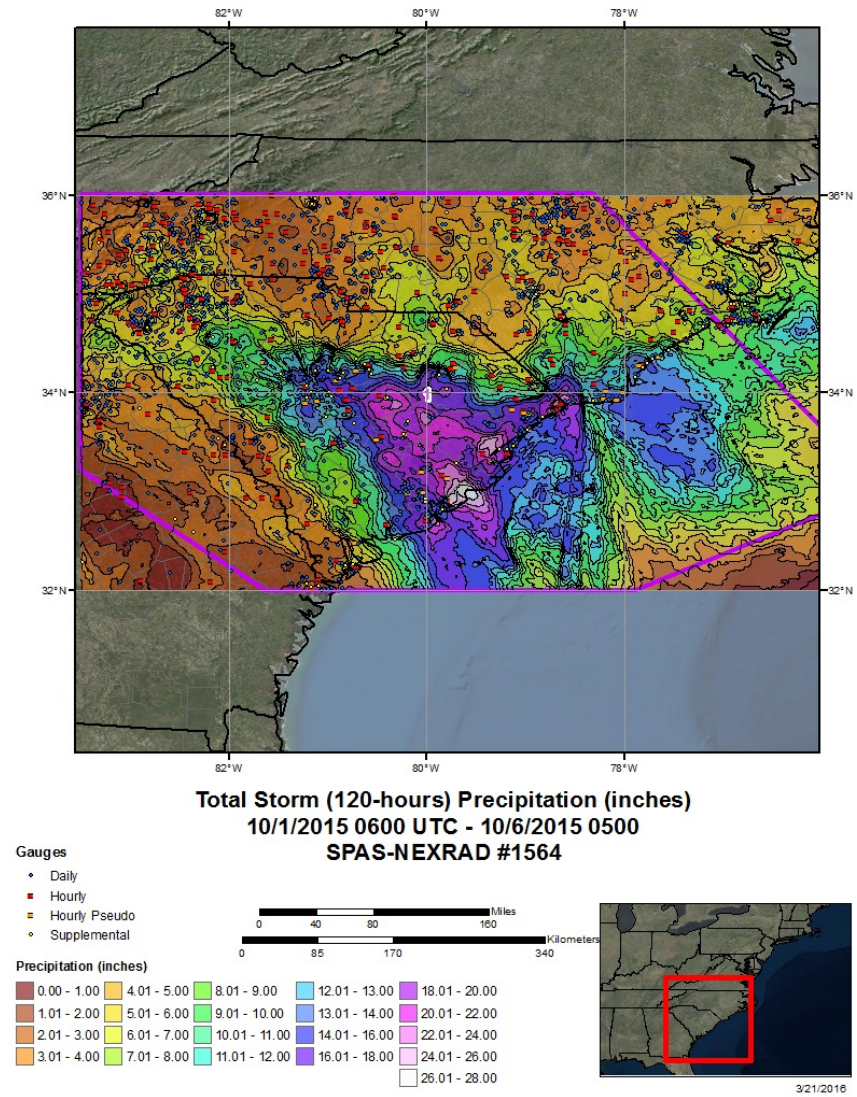
How is Extreme Rainfall Information Utilized?

- PMP/PMF development
  - Spillway evaluations
- Model calibration/validation
- Mining Operations/TSF
- Nuclear Safety
- Forensic investigations
- Climate Change assessments
- Research
- Fun…..

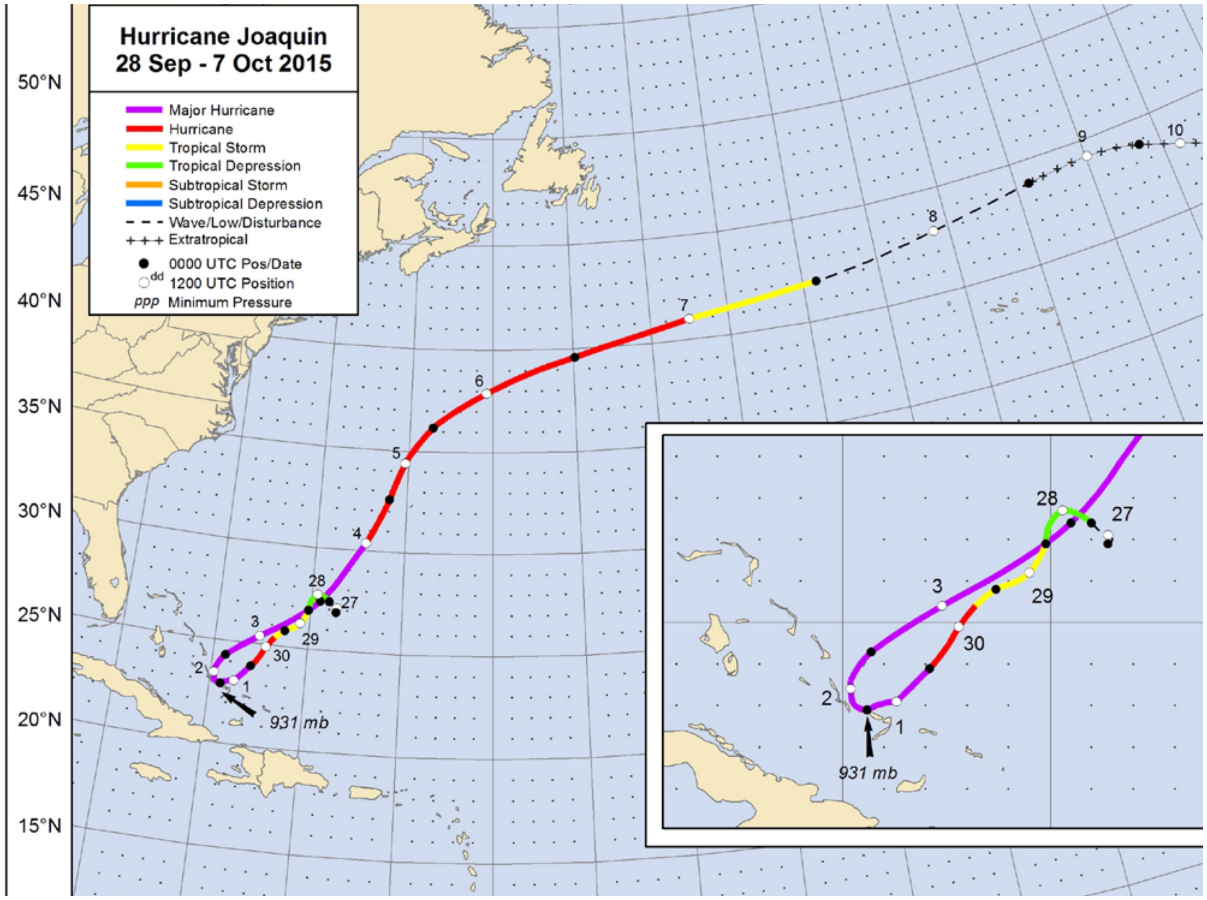


October 2015 Rainfall

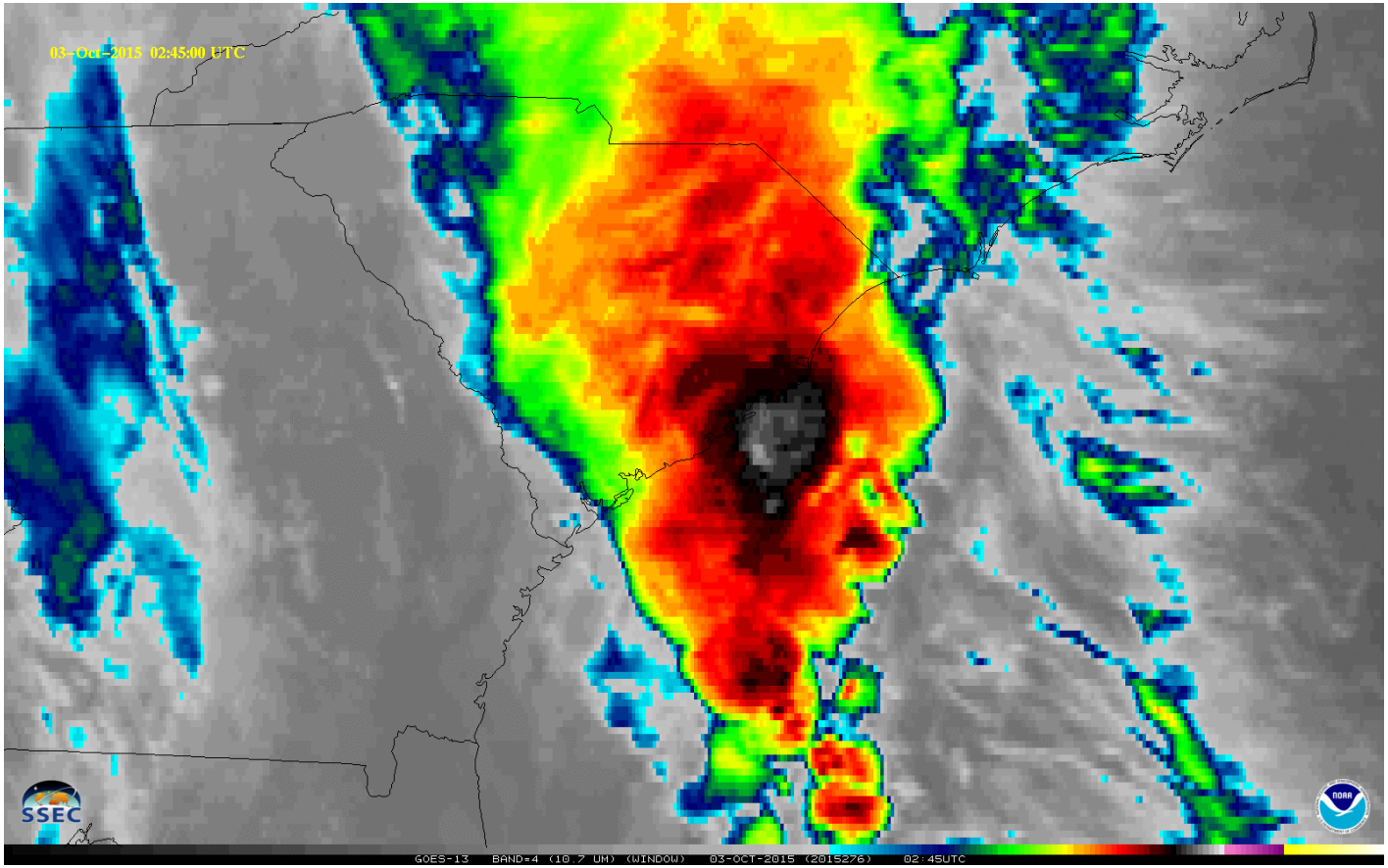
- Concentrated flow of moisture into the region
  - Hurricane Joaquin well offshore
  - Sustained moisture inflow from the SE
  - Low pressure west front off SC
- Heavy rainfall for several days in same area
- 20+ inches widespread along the main axis
  - Most rare at 3 days, >1000-year
  - Short warning time and fast rising water



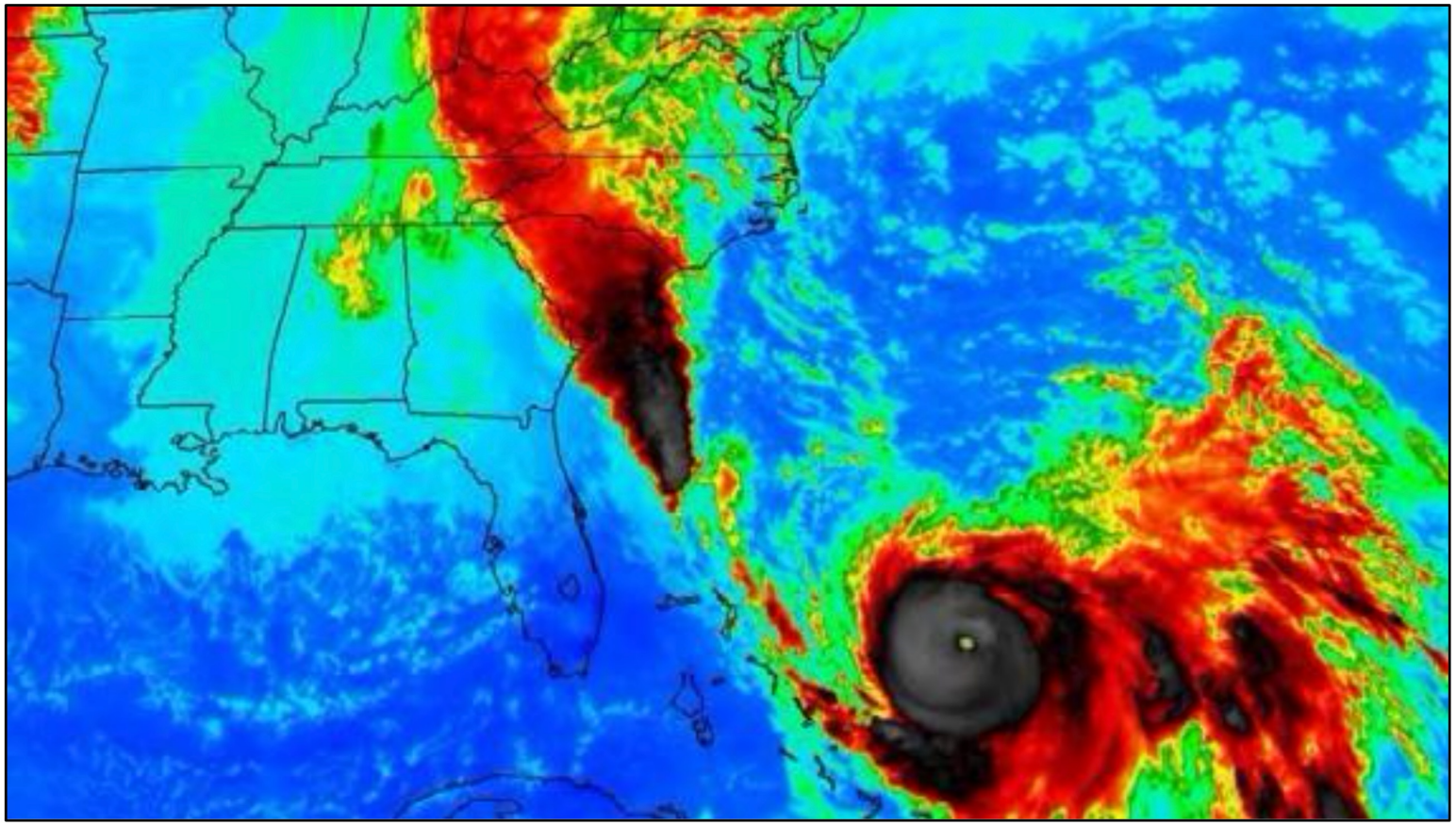
October 2015 Rainfall-Joaquin Track



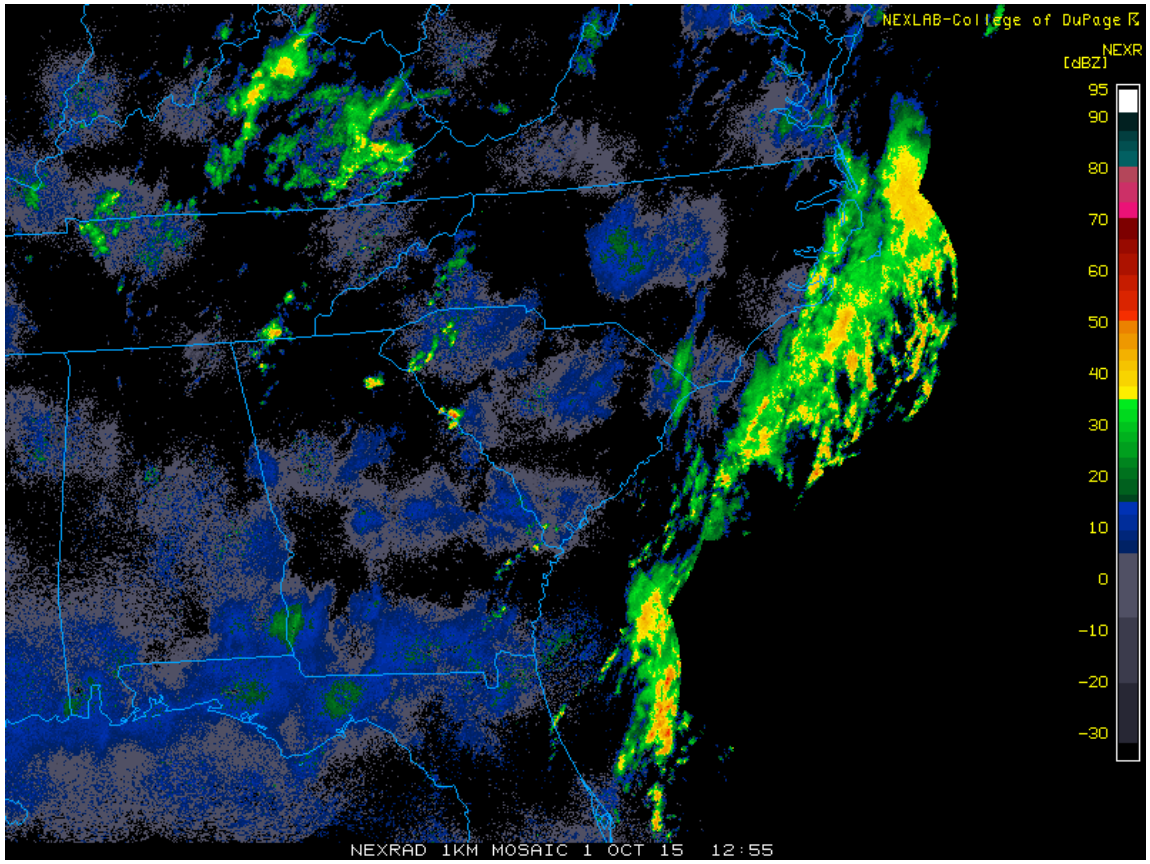
October 2015 Rainfall-IR Satellite Loop



October 2015 Rainfall-IR Image

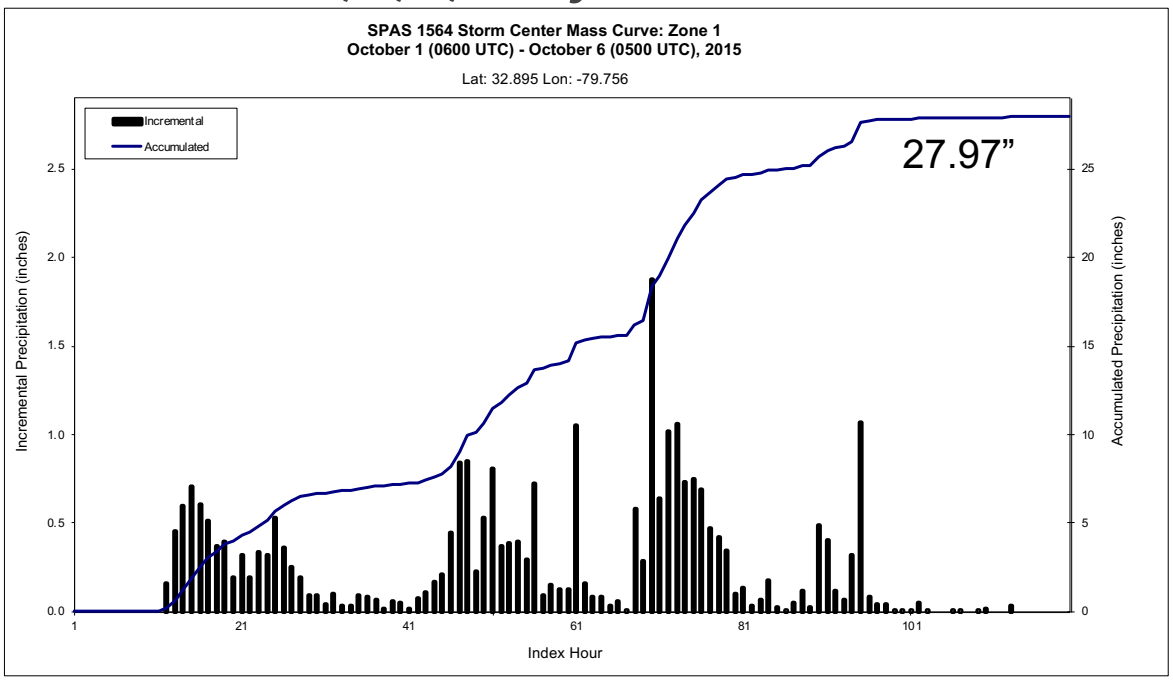


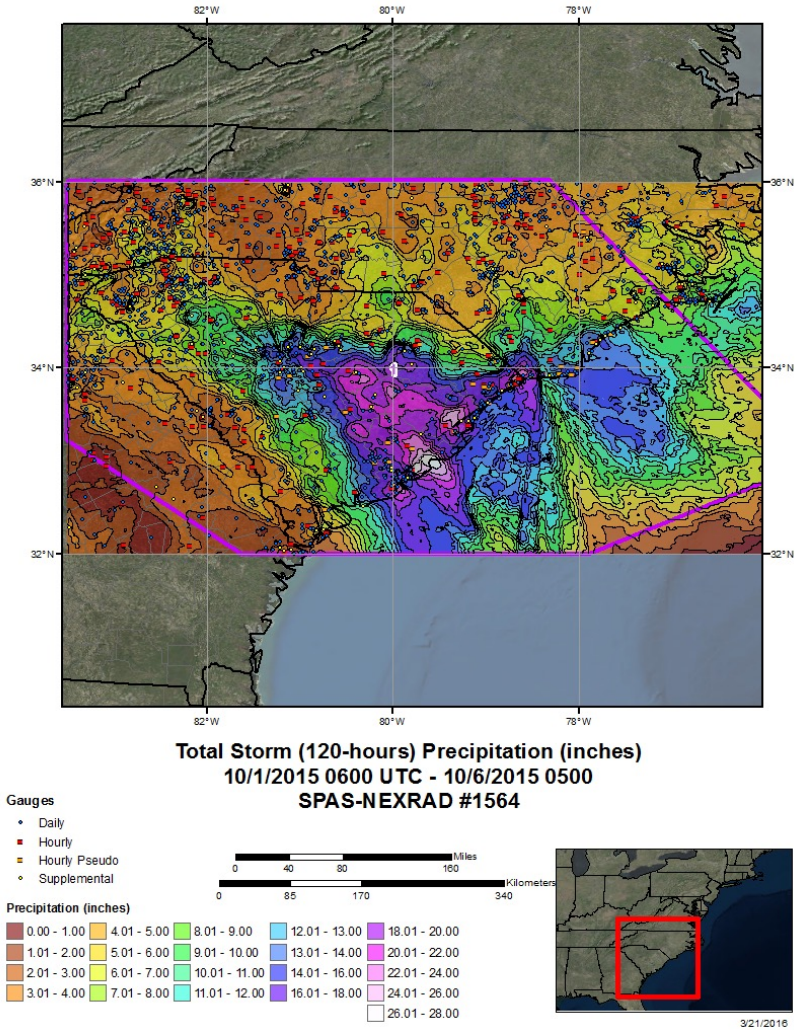
October 2015 Extreme Rainfall-Radar Loop



October 2015 SPAS Analysis

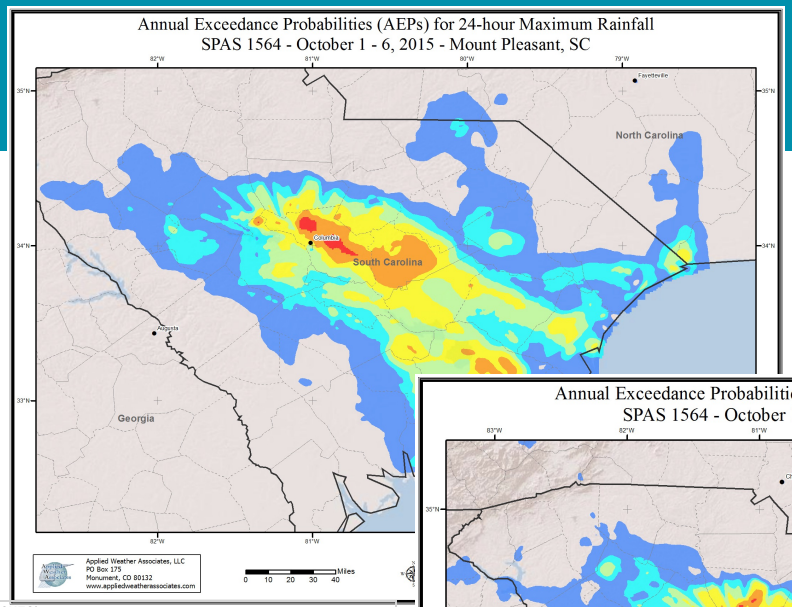
- Several days of heavy of rain
- Excellent data in and around storm center
- Greatest 1 and 2-day rainfall KCAE
- Greatest 1, 2, 3, 4 day at KCHS

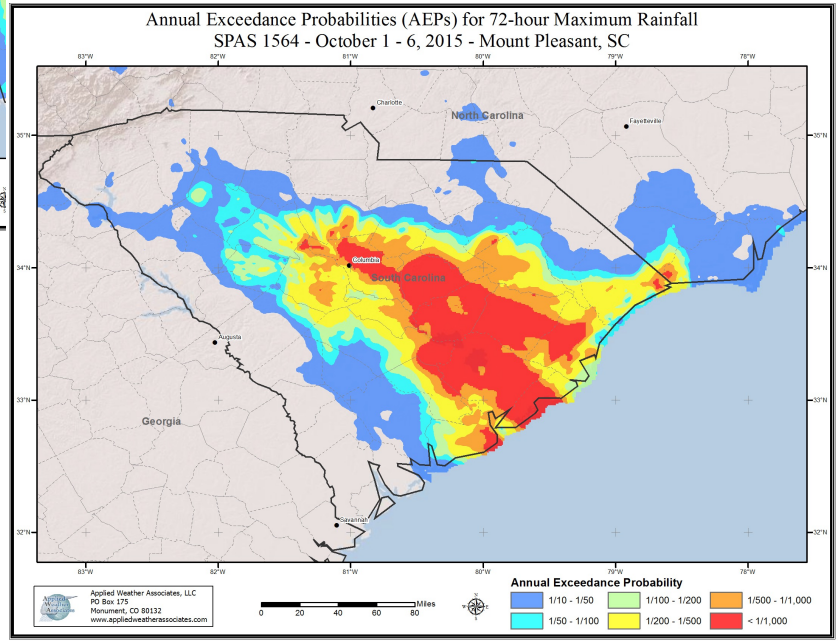




October 2015 AEP

- Similar to tropical but like an AR
- Hybrid event





MAXIMUM AVERAGE DEPTH OF PRECIPITATION (INCHES)

	Duration (hours)														
areasqmi	1	2	3	4	5	6	12	18	24	36	48	72	96	120	total
0.4	3.33	5.83	7.36	8.84	9.98	10.77	13.02	14.70	15.41	19.97	21.23	24.81	27.91	27.97	27.97
1	3.30	5.82	7.35	8.84	9.97	10.58	13.02	14.57	15.25	19.86	21.07	24.80	27.90	27.96	27.96
10	3.11	5.69	7.23	8.74	9.75	10.55	12.94	14.53	15.21	19.02	20.40	24.64	27.82	27.88	27.88
25	2.93	5.50	7.04	8.58	9.54	10.49	12.81	14.47	15.14	18.86	19.89	24.37	27.69	27.75	27.75
50	2.76	5.18	6.88	8.36	9.31	10.27	12.57	14.37	15.03	18.59	19.72	23.83	27.46	27.52	27.52
100	2.56	4.73	6.60	8.01	9.08	9.86	12.35	14.10	14.86	18.05	19.41	23.43	26.98	27.11	27.11
150	2.46	4.43	6.27	7.66	8.88	9.51	12.17	13.86	14.65	17.51	19.36	23.00	26.68	26.79	26.79
200	2.39	4.34	5.71	7.39	8.68	9.21	12.09	13.82	14.58	17.32	19.28	22.64	26.38	26.47	26.47
300	2.28	4.15	5.44	6.96	8.27	8.69	11.93	13.68	14.40	17.07	19.06	22.09	25.83	25.98	25.98
400	2.14	3.94	5.15	6.62	7.44	8.31	11.76	13.43	14.17	16.83	18.82	21.96	24.92	25.51	25.51
500	2.11	3.78	4.83	6.39	7.39	8.19	11.59	13.30	13.98	16.61	18.69	21.85	24.54	25.18	25.18
1,000	1.87	3.33	4.43	5.60	6.63	7.47	10.75	12.46	13.10	15.46	18.04	20.98	23.33	23.92	23.92
2,000	1.63	2.72	3.83	4.89	5.73	6.46	9.60	11.37	12.10	14.91	17.22	20.33	21.74	22.55	22.55
5,000	1.02	2.06	2.95	3.93	4.69	5.34	8.25	9.58	10.54	13.66	15.65	18.66	20.17	20.72	20.72
10,000	0.81	1.56	2.25	2.95	3.56	3.91	6.60	8.31	8.86	11.83	13.99	16.18	18.24	18.79	18.79
20,000	0.59	1.09	1.66	2.17	2.60	2.97	5.42	6.67	7.23	9.85	11.24	13.70	15.54	16.47	16.47
50,000	0.29	0.53	0.78	0.95	1.06	1.26	2.33	4.11	4.77	6.20	7.09	9.80	11.55	12.14	12.14
100,000	0.16	0.30	0.44	0.57	0.72	0.85	1.61	2.26	2.71	3.84	5.01	6.63	7.67	8.02	8.02
100,549	0.15	0.30	0.43	0.57	0.72	0.85	1.60	2.25	2.71	3.84	5.01	6.61	7.64	7.99	7.99

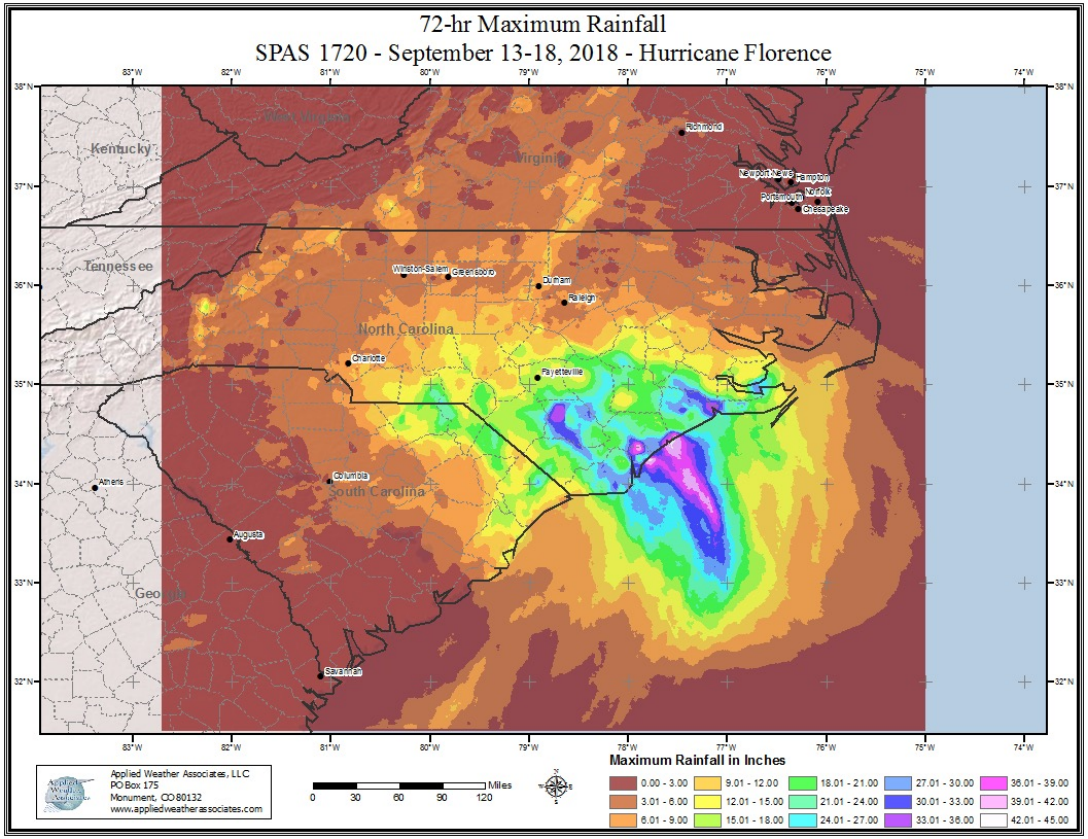
October 2015 Rainfall-Effects of the Storm

- 36 dam failures
- Damage estimates exceeded $1.5 Billion
- 19 fatalities
  - 9 in Richland County
  - Several from trapped vehicles in flooding
  - 1500 water rescues

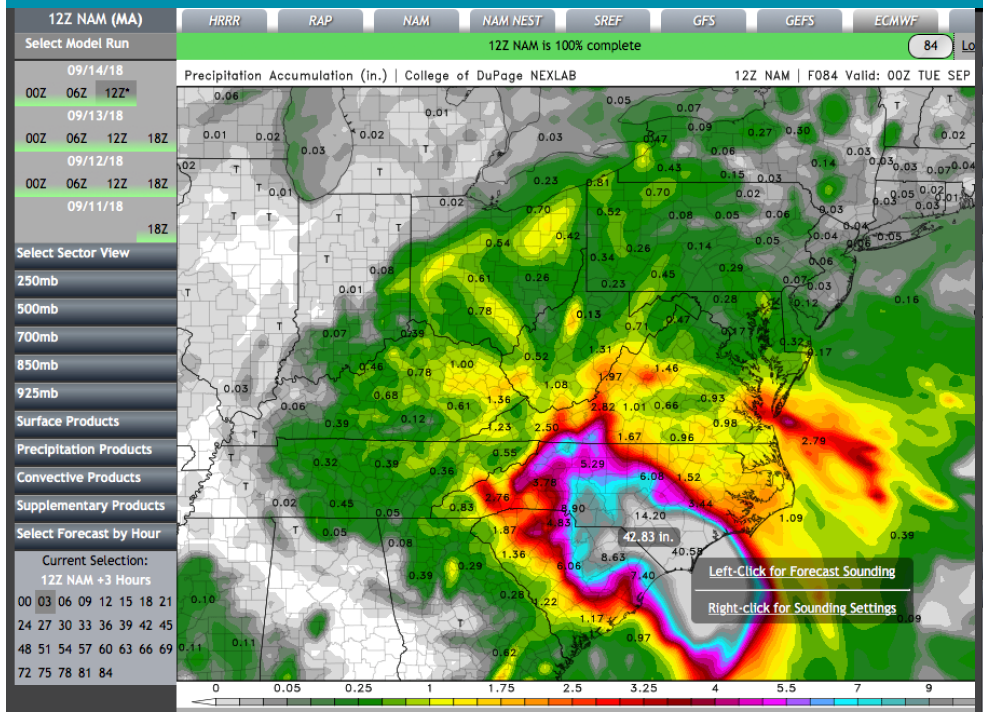
Florence Extreme Rainfall

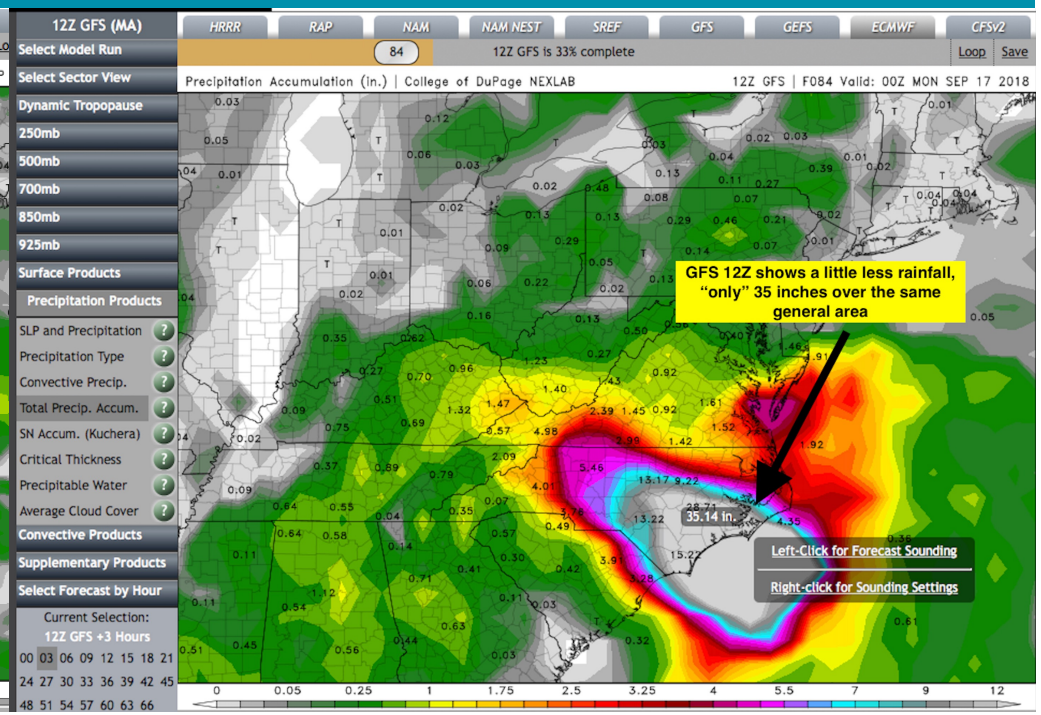
- Slow Moving Storm, well forecast
- Unprecedented rainfall
  - 40+ inches over 3 days
- Slow moving in the same area
  - Common factor
    - E.g. Harvey

Rainfall records: Five spots have preliminarily topped North Carolina's tropical cyclone rainfall record: Swansboro (33.90 inches), Hofmann Forest (29.48 inches), Sunny Point (27.44 inches), Nature Conservancy (27.12 inches) and Newport/Morehead City (25.20 inches). The previous record was 24.06 inches from Hurricane Floyd in 1999.

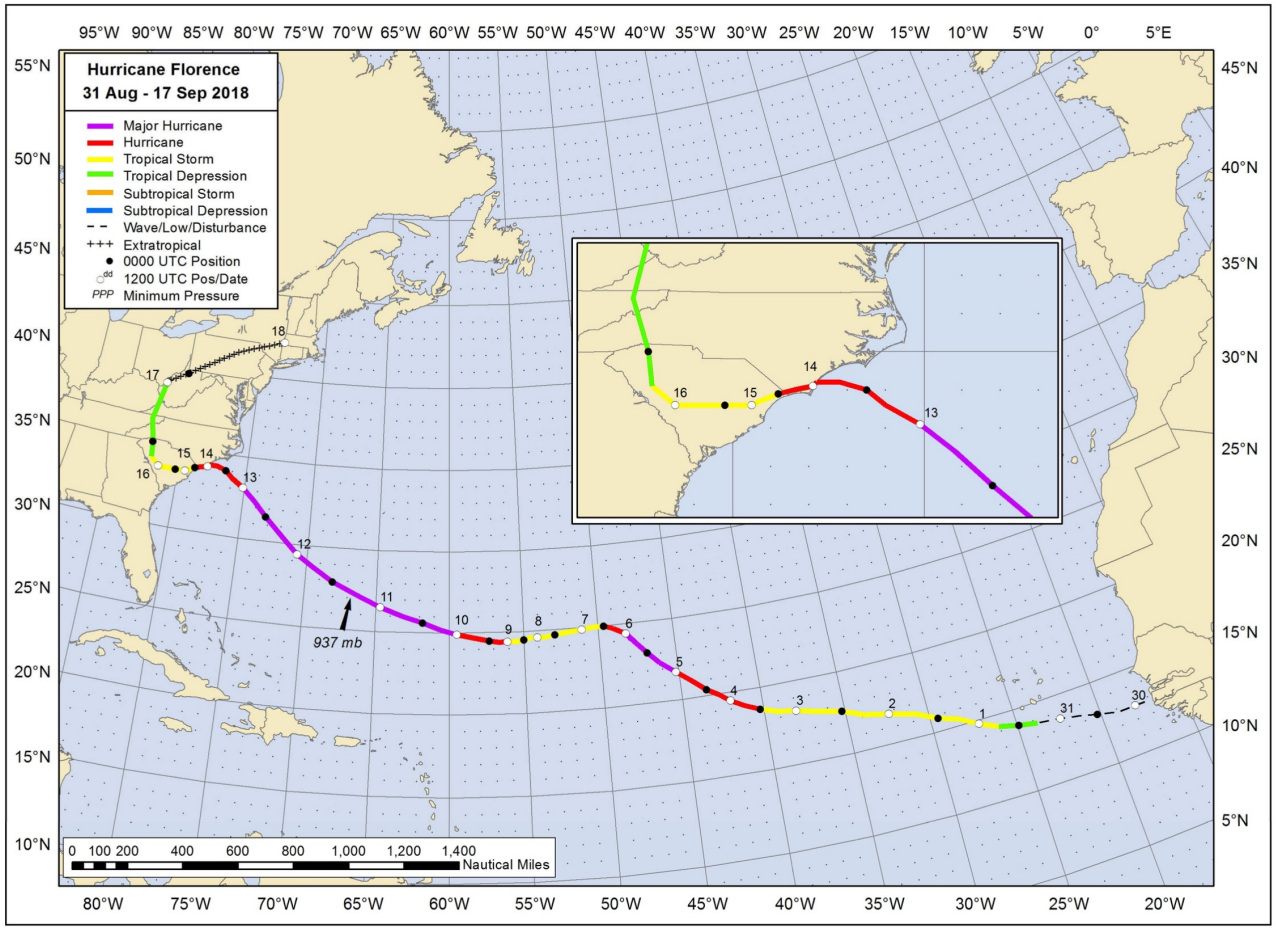


Florence Hurricane Track

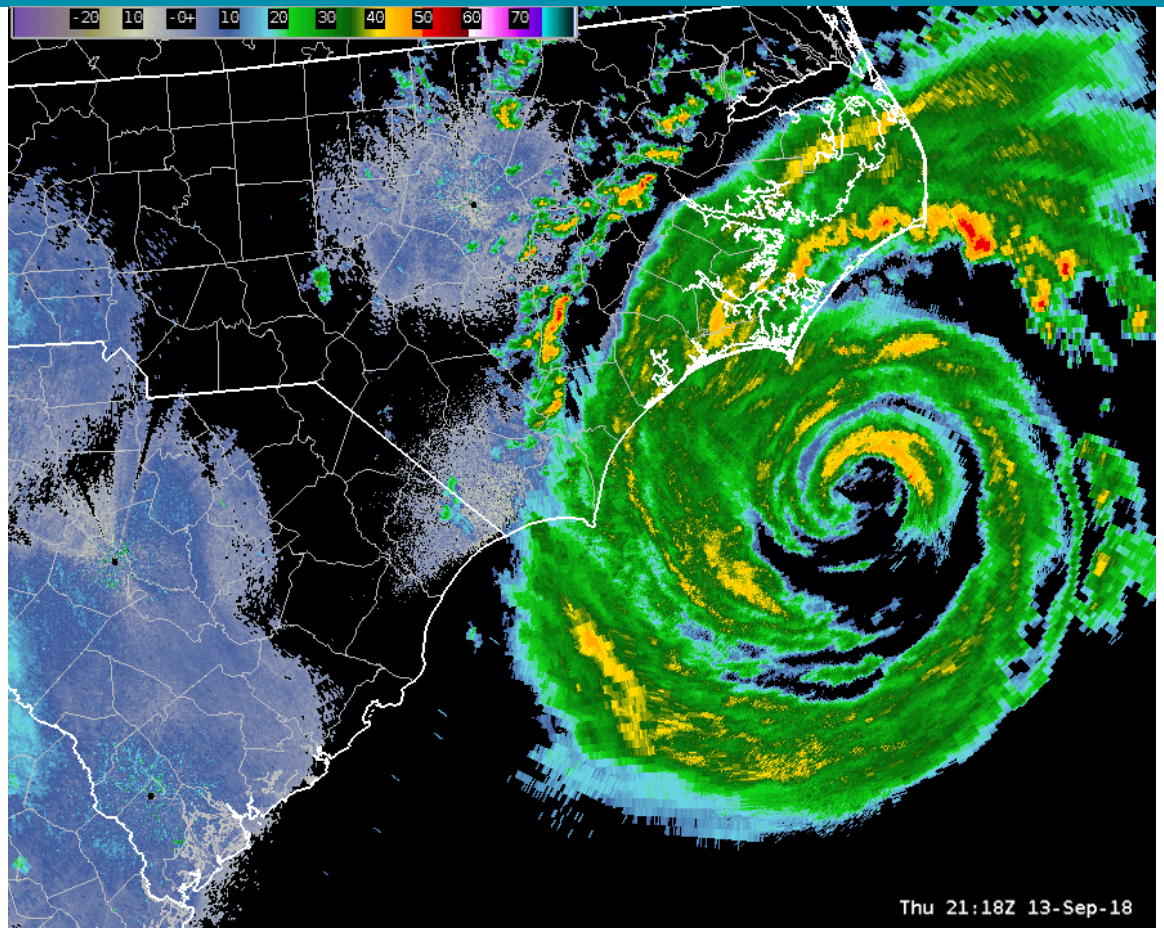




Florence Hurricane Track

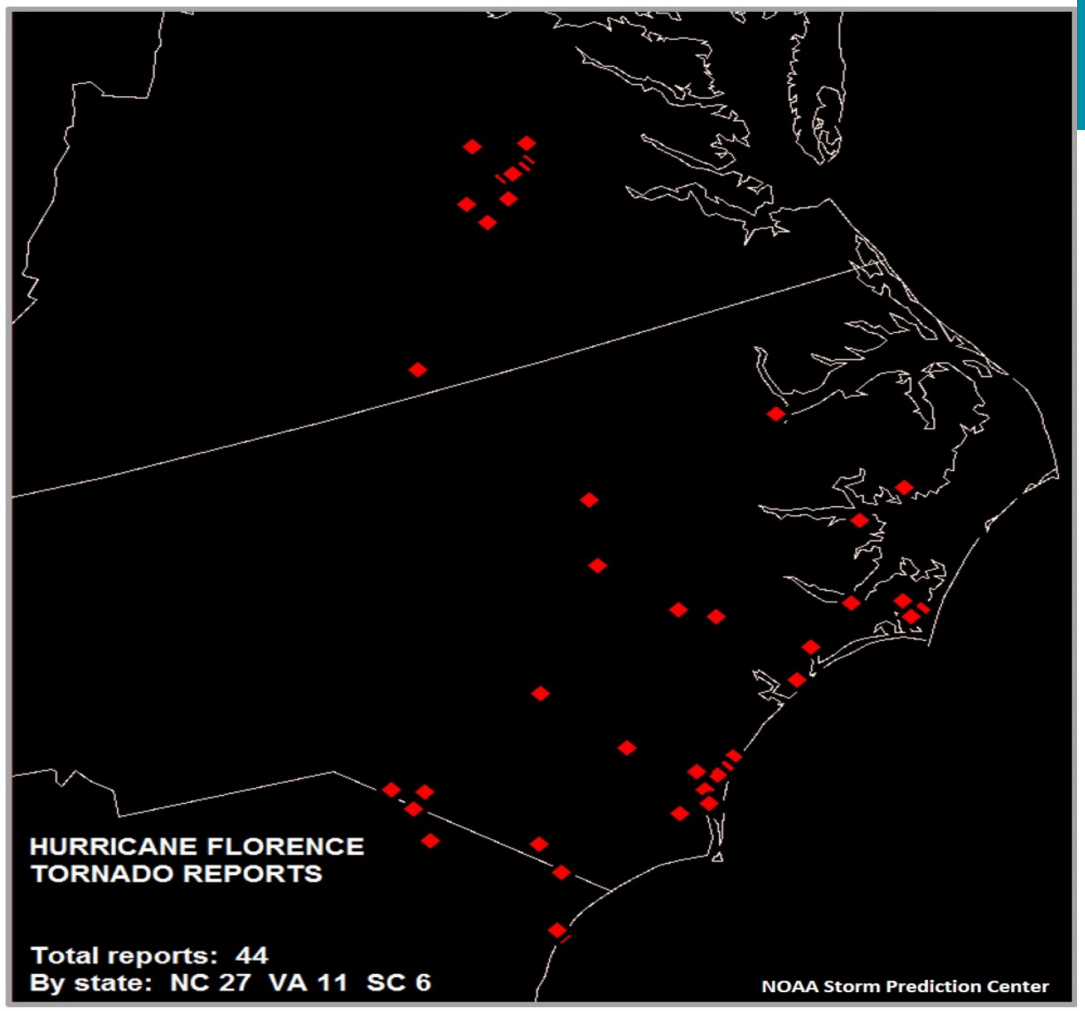


Florence Rainfall



Florence Tornadoes

- Hurricanes produce lots of hazards
  - Surge
  - Wind
  - Rain
  - Flood
  - And Tornadoes



Florence Rainfall

Excessive rains resulted in extensive low-land and river flooding North Carolina and northeastern South Carolina

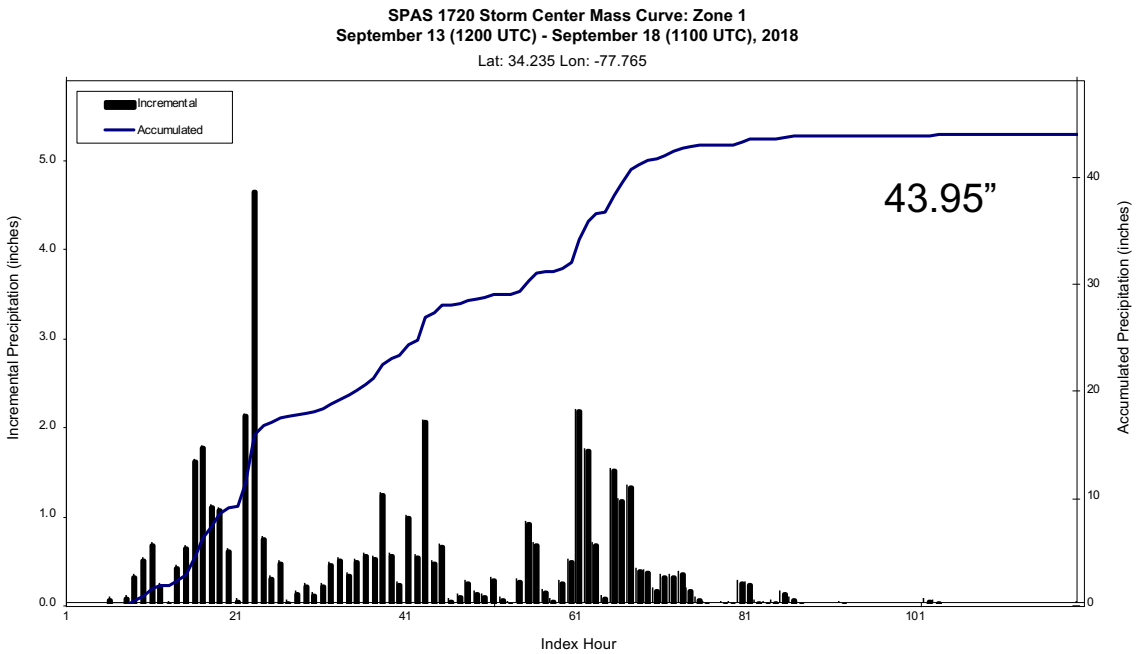
- Many rivers exceeding records set during Hurricane Matthew in 2016 (which broke records previously set during Hurricane Floyd in 1999)
- 22 USGS gages in North Carolina/11 in South Carolina measured record setting peak stages

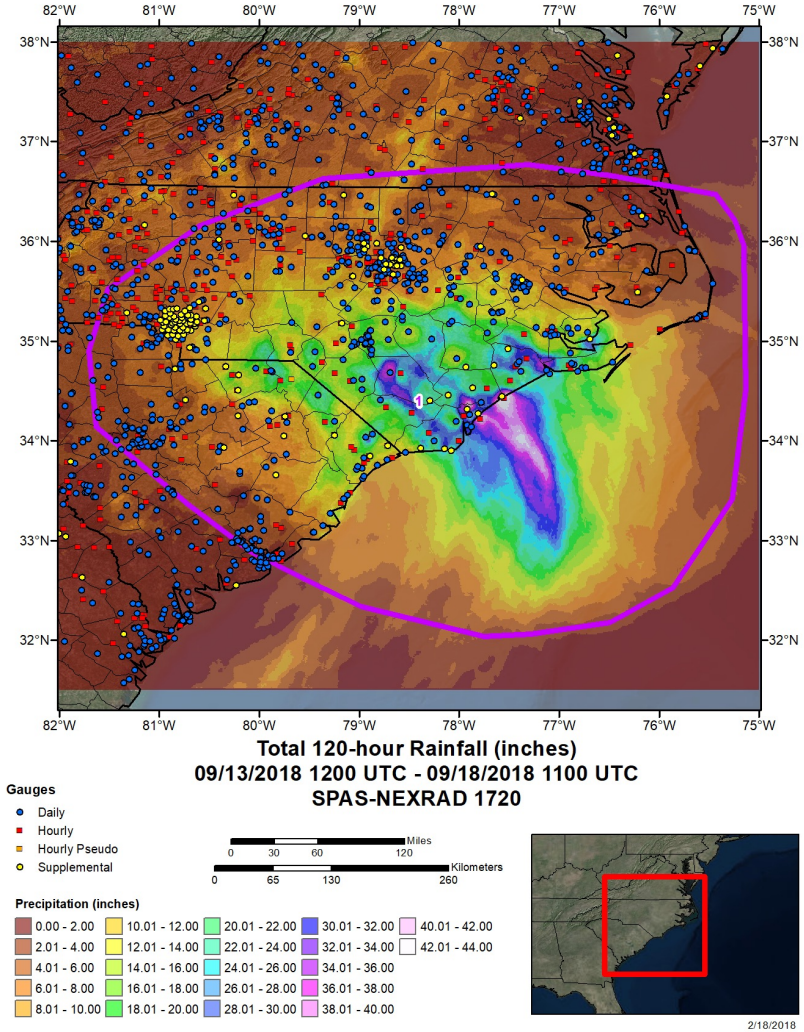
Florence caused 22 direct deaths

- 17 were due to flooding, 4 due to wind, 1 due to tornado
- 15 in North Carolina
- 4 in South Carolina
- 3 in Virginia. Of the direct deaths,

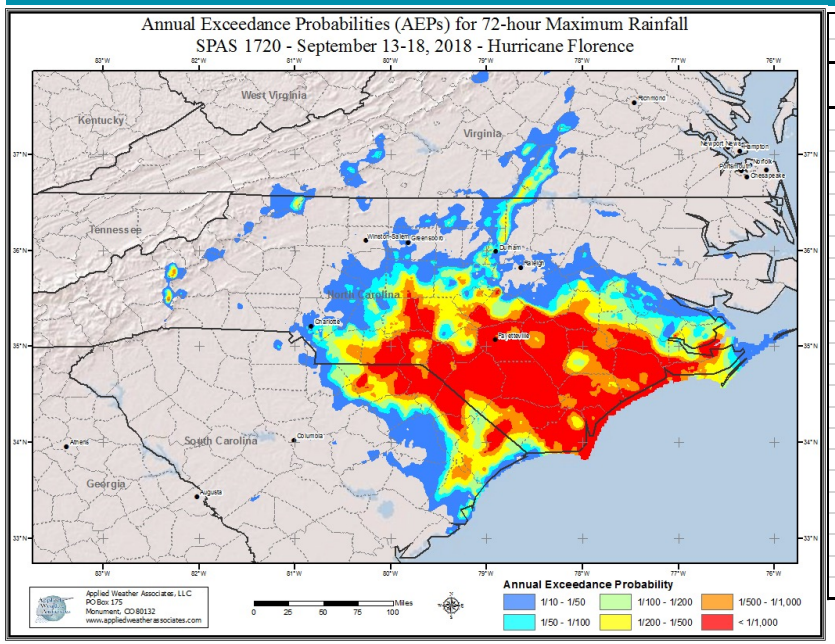
Florence SPAS Analysis

- Record breaking rainfall
  - Slow moving
  - Consistent access to moisture





Florence AEP and DAD



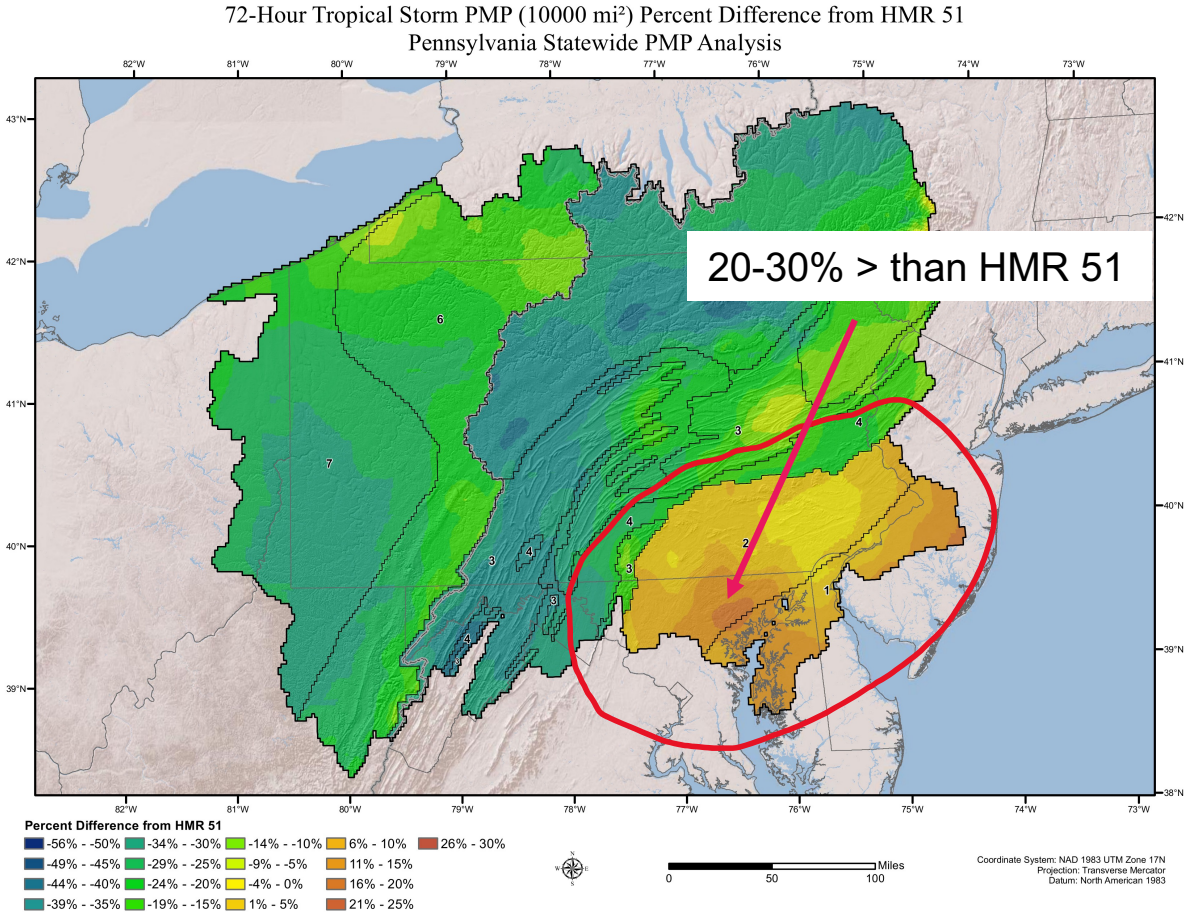
Storm 1720 - September 13 (1200 UTC) - September 18 (1100 UTC), 2018

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

Florence Rainfall-Compared to PMP

- Controls PMP
  - 1000 to 10000-sqmi
  - 24 to 72-hrs
- Where to move it?



What Do We Know, What Should We Do?

- Each event produced extreme rainfall with similar mechanisms
- Storm Types
- Transposition limits?
- Resulting in significant loss of live and damages
- Storms of these magnitudes have happened before and will happen again
- What does this say about our infrastructure readiness?

THANK YOU

Bill Kappel
President/Chief Meteorologist
billkappel@appliedweatherassociates.com
719-964-3395
www.appliedweatherassociates.com