Atlantic Sea Surface Temperature Anomalies and New Jersey Tropical Precipitation: 1982-2020

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Abstract

This study assesses Mid-Atlantic sea surface temperature (SST) and sea surface temperature anomalies (SSTA), with respect to the distance, strength and weighted statewide precipitation deposited by tropical storm events impacting New Jersey (e.g. Hurricane Floyd (1999) Hurricane Irene (2011), Super Storm Sandy (2012)) . It further uses those variables to evaluate a potential link between SSTA and precipitation, finding a positive relationship between the two. The analysis further finds steadily rising SSTA over the study period of 1982-2020. Future research would include a substantial dataset that could allow for modeling and a more substantial SST and SSTA reference climatology. These findings have further socio-economic implications to New Jersey residents as the frequency and intensity extreme weather events increases.

Introduction

Our understanding of storm events and their interaction with environmental systems around them is ever-changing as extreme climate anomalies continue to be observed. During recent category 5 Hurricane Harvey (2017) the system stalled for days resulting in massive amounts of precipitation being deposited in northeast Texas. Studies have linked the extreme rainfall to ocean heat content, which was the highest on record in the Gulf of Mexico as Harvey arrived (Trenberth, et al, 2018). The following year category 4 Hurricane Florence (2018) exhibited similar stalling, which in turn drove a greater storm surge and deposited record-shattering rainfall over the Carolinas (Hall and Kossin, 2019). These examples represent what appears to be an increasing trend in recent tropical events, which prompted this study to see if some pattern could be identified with regards to New Jersey tropical rainfall, in the process hoping to enhance the predictability of dangerous flooding.

- Review suggest little to no association between the North Atlantic sea surface temperature (SST) and climate variables (Chen et al. 2019; Wang et al. 2019).
- Global associations of various SST anomalies were reported if data were grouped on an inter-decadal basis.
- A connection of spring North Atlantic SST anomaly patterns with spring Eurasian surface air temperature (SAT) anomalies recorded by Chen et al. 2019.
- Similar summer northeastern China temperature anomalies was suggested by Wu et al., 2011.
- There is a growing body of research to investigate links between SSTA and frequency and intensity of extreme weather events (Enfield et al. 2001, Ting et al. 2009, Deser, et al., 2010).
- The objective of this research is to discern if there is a link between Mid-Atlantic SSTAs and precipitation deposited by tropical storm events impacting New Jersey.

Materials & Methodology

Tropical systems that at some point were within 480 Kilometers of a centroid that denotes the geographic center of New Jersey were identified during the 1982-2020 period and used in this study.

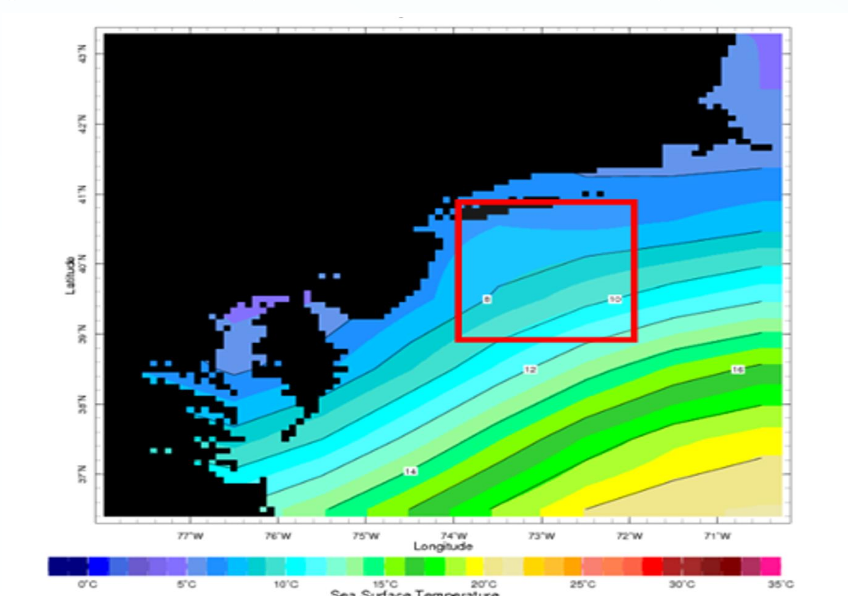

Figure 1: 2° by 2° offshore New Jersey Grid.
(SST for April 1st 2020 Depicted)

The reference point is the NJ centroid is 40.07N, -74.56W, and falls within a field just west of New Egypt (Ocean County).

Data Analysis & Results

The database, available through the Office of the NJ State Climatologist (ONJSC) was utilized for the present analysis. Seventy-three storms qualified for this study based on the chosen distance and time criteria. Data tables were compiled to corroborate data and U.S. daily weather maps from the National Oceanic and Atmospheric Administration (NOAA) library were reviewed for each storm to determine the dates that the event likely began influencing precipitation in New Jersey. During this review they were reclassified to reflect categorization based on when they began impacting New Jersey.

Table 1: List of station groupings for top extreme rain events determination

Group Name	Location(s) and Time
A	Newton (1893-1995), Sussex 3 NW (1996-present)
B	Charlotteburg (1893-present) (used Canister RSVR for Irene)
C	Long Valley (1944-2004), Pottersville (2005-present)
D	Belvidere(1893-1981), Belvidere Bridge (1982-present), (use Phillipsburg Easton/Long Valley when neither station available)
E	Little Falls (1974-2008), Canoe Brook (2009-present)
F	Newark Airport (1932-present)
G	New Brunswick (1893-present)
H	Flemington (1899-present)
I	Hightstown (1893-present)
J	Indian Mills (1901-present), Surrogate: Pemberton (1902-2002)
K	Seabrook Farms (1949-present) (use Bridgeton 1 NE for events where station is unavailable)
L	Atlantic City Marina (1874-present), Surrogate: Tuckerton (1898-2009)
M	Long Branch (1907-2006), (use Toms River for events where station is unavailable)
N	Cape May (1894-present) Surrogate station: Belleplain (1922-2006).

Figure 2: Dataset of NJ tropical systems from 1982-2020 with color-coded classification, dates, and climate variables used in the study (distance from centroid, singular statewide precipitation, SST and SSTA)

Classification Key

Extra-TS//Sub-TS

Post-Tropical Cyclone

Tropical Depression

Tropical Storm

Hurricane Cat.1

Hurricane Cat.2

Hurricane Cat.3

Table 2: List of Storm affecting New Jersey between 1982- 2020
(List not complete due to space limitation)

Storm Name	Dates Affecting NJ	Distance (Km)	Weighted Avg (mm)	Sea Surface Temperature (ºC)	SST Anomalies (ºC)
Fay	July 10-11 2020	0	57	22.4	1.9
Hanna	Sept 6-7 2008	10	78	22.6	0.4
Bertha	July 12-15 1996	14	92	19.8	-1.0
Irene	Aug 27-29 2011	47	185	23.9	1.1
Gordon	Sept 19-20 2000	48	24	21.1	-0.3
Sandy	Oct 28-31 2012	64	71	17.7	0.9
Twenty-Two	Oct 8-10 2005	84	155	21.0	2.0
Andrea	June 7-8 2013	84	86	14.7	0.1
Charley	Aug 15-17 2004	108	21	22.4	-0.5
Floyd	Sept 15-17 1999	108	190	22.4	0.6
Cindy	July 8-10 2005	109	43	20.3	0.1

Precipitation: National Weather Service Cooperative Observing station daily precipitation reports were used from selected stations to generate regional group and statewide precipitation totals for each of the 73 systems. These stations and groupings were determined in previous studies conducted by the ONJSC. There are 14 total groupings falling within one of three NJ divisions (as designated by the National Centers for Environmental Information), with 7 in the north, 4 south, and 3 coastal.
Precipitation data was gathered using the SCACIS2 website (http://scacis.rcc-acis.org/).

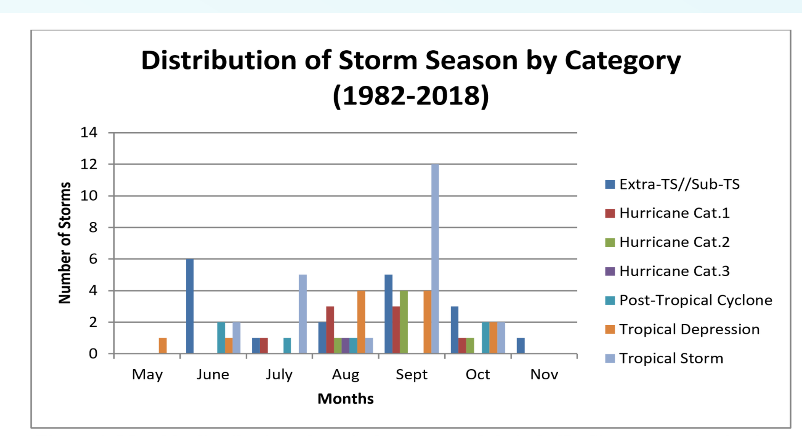

Figure 4: Monthly distribution of tropical systems and their Saffir-Simpson categorization that have come within 480 Kilometers of the New Jersey centroid from 1982-2020.

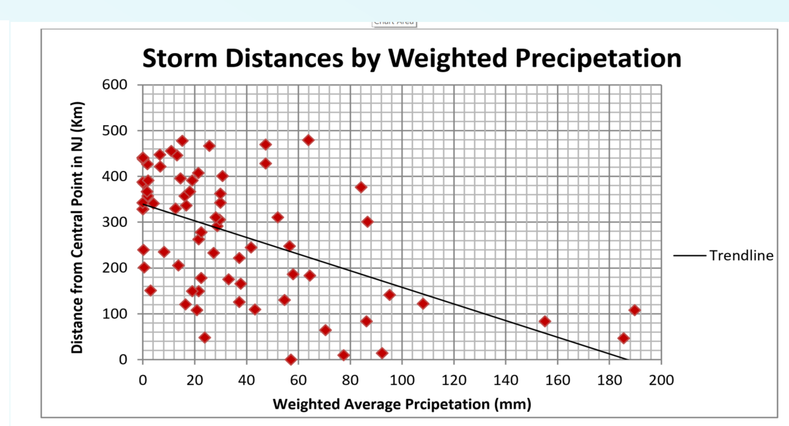

Figure 5: The average New Jersey wide precipitation from all tropical systems from 1982-2020 plotted against the distance from the NJ centroid.

Sea Surface Temperature and Anomalies: SST and SSTAs for the 1982-2020 period were compiled using a Columbia University database (https://iridl.ldeo.columbia.edu/maproom/Global/Ocean_Temp/). The database is generated using in situ and satellite observations as described in Reynolds (2002) and employs 1971-2000 climatology to establish anomalies. For this investigation, data from a coordinate grid was extracted using database tools. The grid (Figure 1) is a 2° latitude by 2 ° longitude grid offshore of New Jersey (39°N to 41° N and 72°W to 74°W).

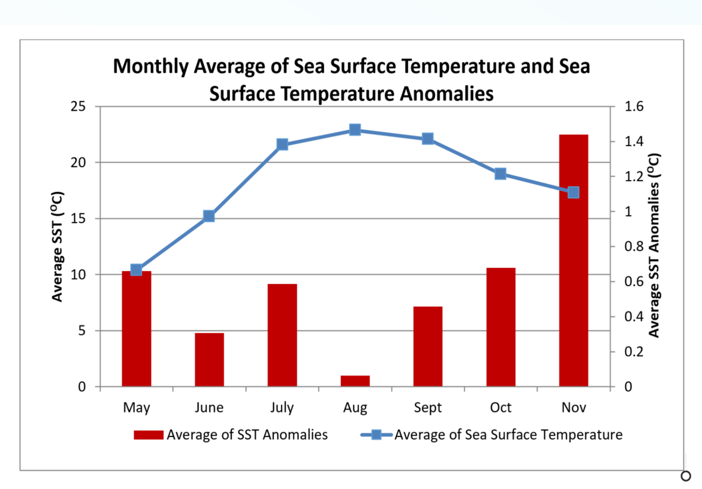

Figure 6: Monthly distribution of average sea surface temperature and sea surface temperature anomalies for select systems from 1982-2020.

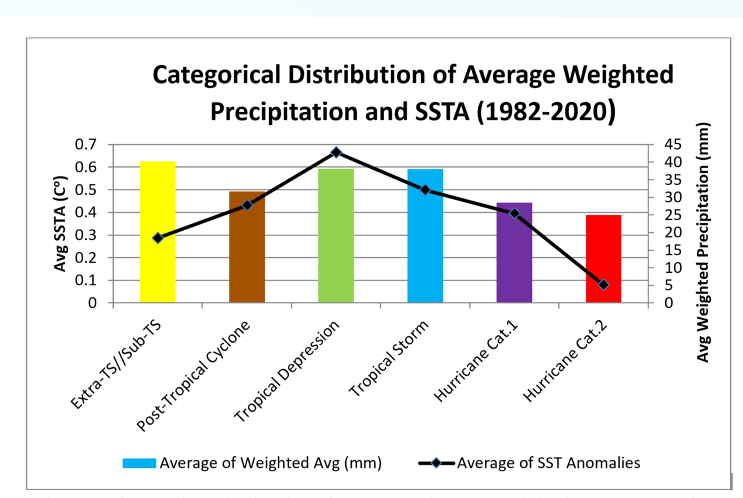

Figure 7: Categorical distribution of average weighted precipitation and sea surface temperature anomalies for select systems; 1982-2020.

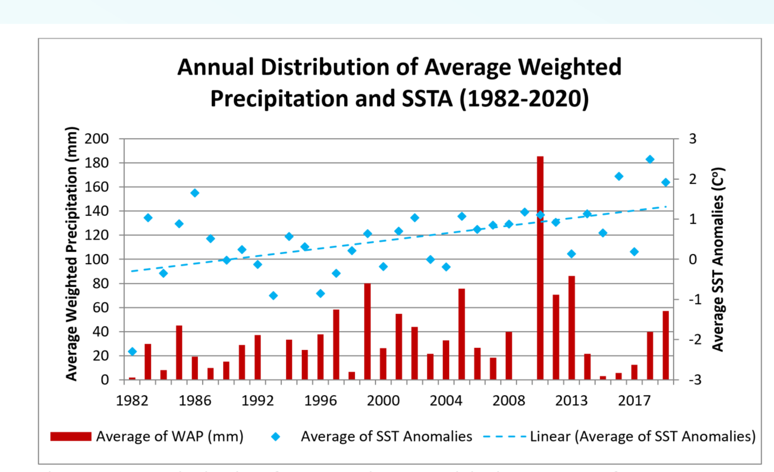

Figure 8: Yearly distribution of average weighted precipitation and sea surface temperature anomalies for 1982-2020.
(Note: Three years 2009, 1989, 1987, and 2019 are not plotted here as there was no recorded event.)

Sea surface temperature and anomalies are both important variables impacting storm strength and timing. They may play a role in predicting event sustenance and force. It is known they have a major impact on global events when an El Niño–Southern Oscillation episode occurs over the tropical eastern Pacific Ocean, including the generation (or not) of tropical storms in the Atlantic Basin. Questions remain on SST impacts from tropical events in local regions such as the Mid-Atlantic.

Discussion & Conclusion

The present analysis of 73 storm systems that fell within a 480-Kilometer radius of New Jersey during the 1982-2020 period suggest that a relationship with increased precipitation and positive anomalies of SST exists within the Mid-Atlantic region.

The slight upward trajectory indicates an overall ocean warming within the region (Figure 8). Although there is a significant correlation between WAP and SSTA (r=0.87), the trend is weak for the last five years of data (Figure 9). This may reflect the weakening of the circulation response to SSTA which is closely tied to the increased atmospheric stability under global warming. Study results tend to agree with a global review that suggests the changes in planetary circulation regimes are linked to global sea surface temperature anomalies (Mo 2000). It further suggests that the general weakening of the atmospheric circulation will offset some of the enhancement of the tropical rainfall response to these SST models as a result of global-warming (Huang et al. 2017).

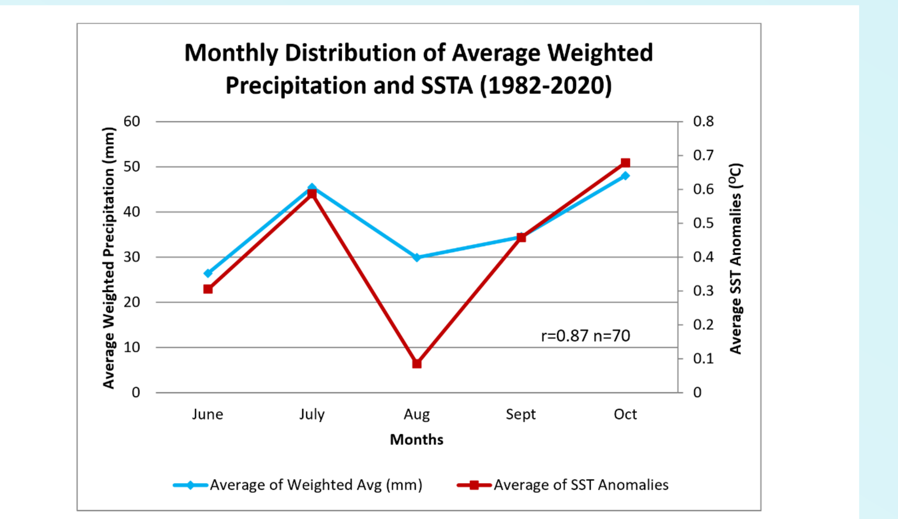

Figure 9: Monthly distribution of average weighted precipitation and sea surface temperature anomalies for select systems; 1982-2020.

Future Directions: The application of forecasting models such as Weather Research and Forecasting (WRF) and General Circulation Model (GCM) would provide a more robust analysis. Examination of other storm systems such as the western Pacific Ocean, north Indian Ocean, and the US Atlantic Coast and Gulf and in the Caribbean help understand SST and SSTAs in relation to precipitation.

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Contact

This study was part of my undergraduate thesis submitted to the School of Arts and Sciences, Rutgers University. I am currently pursuing my Masters in Climate and Society, Columbia Climate School, Columbia University, New York, USA.

SCAN ME

I am a geographer who is excited about aiding coastal cites in their disaster response as well as helping them mitigate and adapt to the oncoming climate crisis!

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