Sea Surface Temperature and Snowfall: How Warming Waters Can Contribute to Larger Snow Storms

Claudia I. Mazur[1,2], Andra Reed[2]

[1]Mount Holyoke College, South Hadley, MA (mazur22c@mtholyoke.edu); [2]Pennsylvania State University, State College, PA

Motivation

Major cities on the northeast coast of the United States have seen a number of historic snowfall events in recent years. For example, the large snowstorm that impacted the mid-Atlantic in early 2016 hitting New York City (NYC) and Washington DC, in addition to the extreme amount of snowfall that occurred in the Boston area in 2015. These large snowfall events have often occurred in conjunction with unusually warm sea surface temperatures (SSTs) in the Atlantic basin. However, there is very limited research attempting to address this question.

Photos courtesy of: http://www.accuweather.com/en/weather-news/recap-blizzard-2016-washington-dc-new-york-city-philadelphia-baltimore-northeast/54977271

Figures 1 & 2: The impact of the January 23, 2016 snowstorm on NYC and DC.

Objectives

- Perform a statistical analysis of mid-Atlantic SST data and snowfall amounts in Boston, NYC and DC
- Analyze how this relationship has evolved over the course of the observational record
- To predict how snowfall in the northeast will be affected by increase in SSTs

Methods and Data

Snowfall

Monthly snowfall amounts were collected for stations in and near Boston, NYC, and DC. Top snowfall 25 snowfall events were collected for NYC and DC.

SST

Mean SSTs for Boston, NYC and DC were averaged for December, January, February and March.

Type	Source	Data Set
Snowfall	National Climate Data Center (NCDC)	Monthly summaries[1]
	Weather 2000	Top 25 NYC snowstorms[2]
	Capital Weather Gang	Top 25 DC snowstorms[3]
Sea Surface Temperature (SST)	National Climate Data Center (NCDC)	Extended Reconstructed Sea Surface Temperature (ERSST) v4[4]
Oceanic Niño Index (ONI)	National Weather Service (NWS)	• Bimonthly MEI index[5] • ERSST v4

Table 1: These datasets were uploaded into R Studio for analysis. A comprehensive data set of top 25 snowfall events in Boston was not found.

Locations

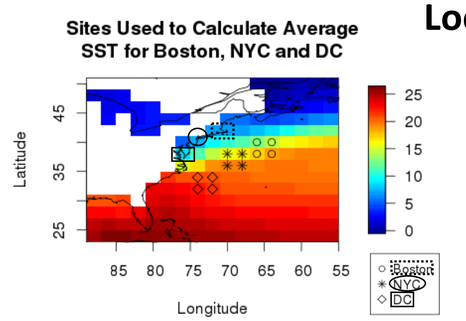


Figure 3: Mean SSTs were calculated individually for each location.

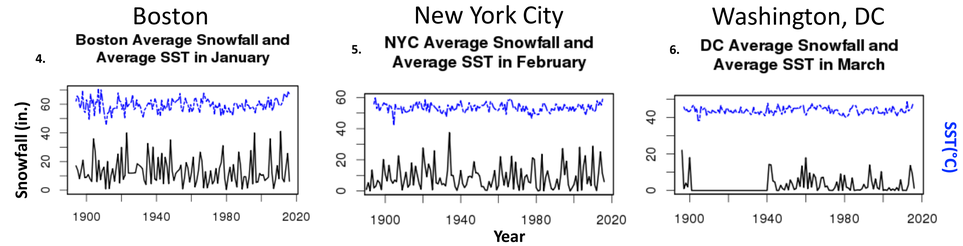
Station Names

Boston	NYC	DC
Boston Logan International Airport, MA Hartford Bradley International Airport, CT Providence T F Green State Airport, RI Worcester, MA	Bridgeport, CT Islip 0.2 NW, NY New York Central Park Obs Belvedere Tower, NY New York J F Kennedy International Airport, NY New York LaGuardia Airport, NY Newark International Airport, NJ	Baltimore Washington International Airport, MD Charlottesville 5.5 SSE, VA Hagerstown, MD Martinsburg 4.3 E, WV Maryland Science Center Baltimore, MD Washington DC Dulles International Airport, VA Washington Reagan National Airport, VA

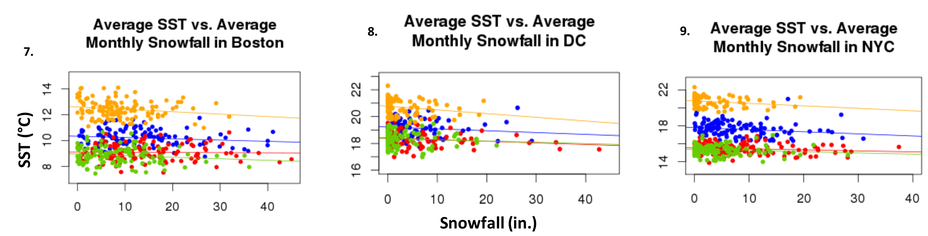
Table 2: Stations for each location were chosen based off the National Weather Service observed weather reports.

Results: Monthly Data

Overall, snowfall amounts are decreasing over time with increase in SSTs



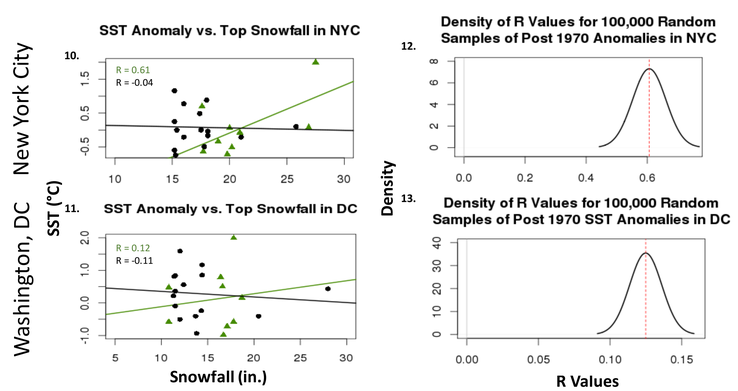
Figures 4, 5 & 6: Plots of average total snowfall and SST from 1894 to 2016. Mean snowfall was calculated by averaging observed values at each station. Time series plots were made for January, February, March and December for each location.



Figures 7, 8 & 9: Increasing SSTs have a negative relationship with increasing snowfall. These trends are seen in all the winter months throughout the three locations. January is highlighted in **blue**, February in **red**, March in **green** and December in **orange**.

Results: Top Snowstorms

Top snowfall events are shown to be more frequent post 1970



Figures 10 & 11: Top snowstorms post 1970 (**green**) have a positive relationship between the increase in SST anomalies and observed snowfall in NYC and DC unlike pre 1970 (**black**) which have a negative relationship.

Figures 12 & 13: In order to test the significance of the post 1970 results, a test of 100,000 random samples was conducted on both locations. Both results show a significant positive relationship.

Results: El Niño and Snowfall

Most snowstorms occur during stronger El Niño years

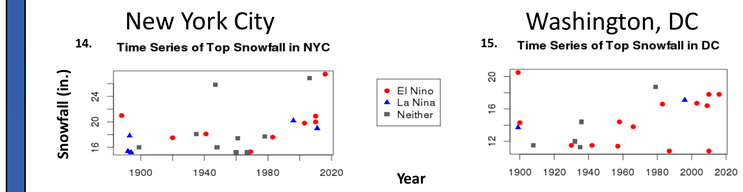
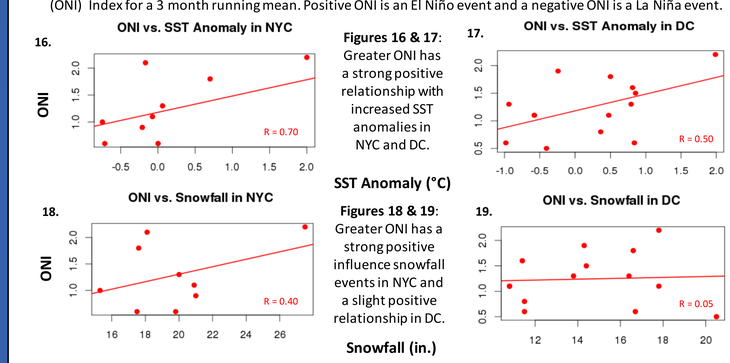


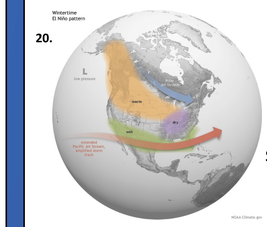
Figure 14 & 15: Warm (red) and cold (blue) periods are based on a threshold of +/- 0.5°C for the Oceanic Niño (ONI) Index for a 3 month running mean. Positive ONI is an El Niño event and a negative ONI is a La Niña event.



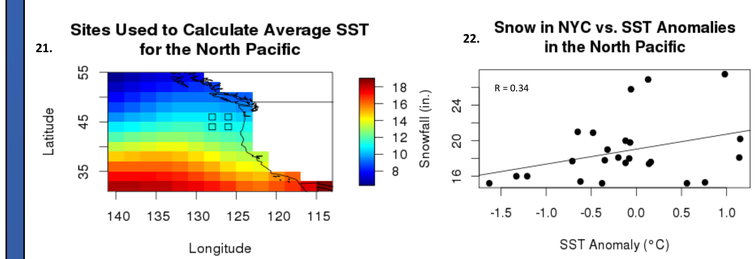
Figures 16 & 17: Greater ONI has a strong positive relationship with increased SST anomalies in NYC and DC.

Figures 18 & 19: Greater ONI has a strong positive influence snowfall events in NYC and a slight positive relationship in DC.

Discussion



Warmer SSTs in the Pacific are associated with higher snowfall in the northeast. El Niño events force the jet stream to dip down more frequently, sending cool air to combine with warm SSTs in the mid-Atlantic, which contribute to larger snowfall events (Figures 20, 21 & 22).



Conclusions

- Over time, increasing SSTs in the mid-Atlantic result in overall less monthly snowfall in the northeast
- Larger, individual snowfall events can occur in conjunction with increased SSTs and stronger El Niño events

Acknowledgements

I would like to thank Dr. Andra Reed for all her guidance with this research project, Dr. Patrick Applegate for his help with R, Katerina Kostadinova and my fellow 2016 SCRiM Summer Scholars. This work was supported by the National Science Foundation through the Network for Sustainable Climate Risk Management (SCRiM) under NSF cooperative agreement GEO-1240507.

References

[1]NCDC monthly snowfall data obtained from: https://www.ncdc.noaa.gov/cdo-web/
[2]Top 25 NYC Snowstorms data obtained from: http://www.weather2000.com/NY_Snowstorms.html
[3]Top 25 DC Snowstorms data obtained from: https://www.washingtonpost.com/news/capital-weather-gang/wp/2016/01/12/ev ery thing-y ou-need-to-k now-about-snow-in-washington-d-c/
[4]Huang, B., V. F. Banzon, E. Freeman, J. Lawrimore, W. Liu, T.C. Peterson, T.M. Smith, P.W. Thorne, S.D. Woodruff, and H.-M. Zhang, 2014: Extended Reconstructed Sea Surface Temperature version 4 (ERSST.v4): Part I. Upgrades and intercompansions. *Journal of Climate*, in press, doi:10.1175/JCLI-D-14-00006.1[link is external]
[5]Quinn, W.H., and V.T. Neal, 1992: The historical record of El Niño events. In *Climate since A.D. 1500*, Bradley, R.S., and P.D. Jones (eds). Routledge: London; 623-648.