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WESTERN ATLANTIC SEA SURFACE TEMPERATURES AND NORTHEASTERN UNITED STATES PRECIPITATION, 1896-1995

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1. INTRODUCTION

Sea surface temperature anomalies (SSTAs) have been hypothesized as one possible contributor of major seasonal to interannual climate anomalies. Effects on the climate due to tropical SSTAs associated with the El Nino-Southern Oscillation (ENSO) have been shown to be far-reaching, with studies showing an extratropical atmospheric response along with pronounced temperature and precipitation anomalies (Lau, 1997; Barsugli et al, 1999).

Studies have linked atmospheric response over the North Pacific (Rogers, 1976) and North Atlantic (Namias, 1967) to mid-latitude SSTAs, and have discussed the relationship between SSTAs and North Atlantic Oscillation (NAO) signals (Hurrell, 1995). However, it is not known whether the SSTAs are driving the atmosphere or the atmosphere is initially forcing the SSTAs. SSTAs in the western North Atlantic have been linked with precipitation variability along the east coast of the United States (Namias, 1966; Colucci, 1976) and with snowfall variations in southern New England (Hartley, 1996).

Here we report on the results of our examination of potential relationships between SSTAs and northeastern United States precipitation. A century of data is used to determine if Namias had the right idea and whether SSTAs may be used to improve regional precipitation forecasts a season in advance.

2. DATA

Monthly SSTAs for the western North Atlantic Ocean were extracted from the Global Ocean Surface Temperature Atlas Plus (GOSTAplus) database obtained from the United Kingdom Meteorological Office (UKMO) for the years 1896-1995. Seasonal anomalies were computed and Varimax rotated principal component analyses (PCA) was used to determine coherent regions of SST anomalies in the western Atlantic (Figure 1). Regions were quite similar amongst all seasons, particularly between fall-winter and spring-summer. Data from 1950-92 were used in the PCA (Smith et al, 1996). We assume that these regions were coherent throughout the 20th century.

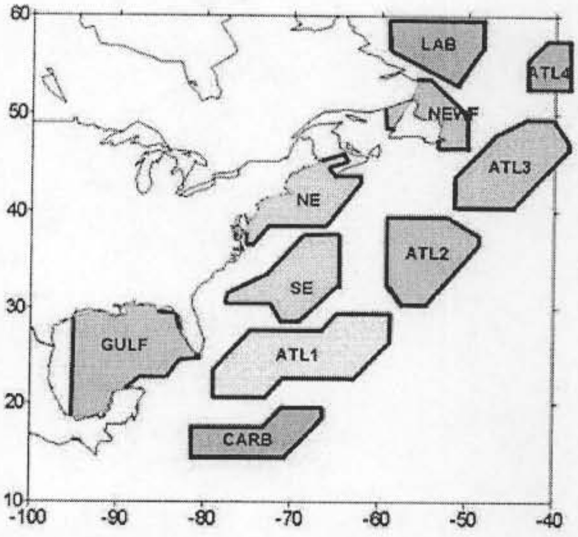

Figure 1. Regions of coherent SST variability obtained by rotated PCA for the winter season

Regional precipitation data were compiled from the National Climatic Data Center (NCDC) Monthly Divisional Data Set for selected climate divisions in Connecticut, Delaware, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. Data for selected coastal and piedmont divisions from Maryland to New Hampshire were composited and seasonal values were computed. We will refer to this region as the Northeast Corridor.

Seasonal NAO index values were compiled from the Ocean and Atmospheric Climate data section of the Climate Prediction Center (CPC), and are based on differences in air pressure between Portugal (Azores High) and Iceland (Icelandic Low). Seasonal Southern Oscillation Index (SOI) data were compiled from the Atmospheric & SST Indices data section of the CPC, and are based on differences in air pressure between Tahiti and Darwin, Australia.

3. RESULTS

Seasonal SSTA values were correlated against composited Northeast Corridor precipitation totals and against NAO and SOI index values. Correlations were

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run for both contemporaneous and lagged relationships utilizing the Northeast Corridor precipitation totals and the regional SSTAs. Regression analysis was performed on significant associations.

3.1 Contemporaneous Correlations

Upon examining 40 contemporaneous correlations of seasonal Northeast Corridor precipitation totals and SSTAs from the 10 ocean regions, 16 are found to be significant at the 0.10 level or higher (Table 1). Of these correlations, 14 are positive. Negative correlations are associated with the high latitude Labrador and Atl4 regions.

Spring (5) and fall (6) associations dominate, with winter and summer having 2 and 3 associations, respectively. Spring correlations have the greatest level of significance.

The Northeast, Newfoundland, and Atlantic2 SST regions each have 3 significant positive associations. All are significant in the spring and fall. The Northeast region is also significant in the winter and the other two regions in the summer.

	Winter		Spring		Summer		Fall	
Carb	.01		**.22**	**.03**	.10		**.18**	**.07**
Gulf	-.01		-.02		-.01		.14	
SE	.15		.00		.06		**.24**	**.02**
NE	**.18**	**.07**	**.26**	**.01**	.15		**.22**	**.03**
Newf	.07		**.20**	**.05**	**.25**	**.01**	**.17**	**.09**
Lab*	-.21		**-.19**	**.07**	-.01		.00	
Atl1	.02		.11		.09		**.31**	**.00**
Atl2	.12		**.32**	**.00**	**.22**	**.03**	**.20**	**.05**
Atl3	.05		.10		**.20**	**.05**	.16	
Atl4	**-.19**	**.10**	-.13		-.03		-.14	

Table1. 100-Year Contemporaneous Correlation R-Values. Far left column is SST region. This is followed by correlations (R-values) and levels of significance for those cases exceeding 0.10 by season. *The N for Labrador winter is less than 100, thus the R-value required for significance needs to be greater.

3.2 Lagged Correlations

Upon examining 40 lagged correlations of SSTAs (season 1) and Northeast Corridor precipitation (season 2), 7 are found to be significant at the 0.10 level or higher (Table 2). Of these correlations, 6 are positive. As with the contemporaneous associations, the negative correlation is associated with the high latitude Atlantic4 region. A winter SSTA to spring precipitation relationship dominates, accounting for 5 of the 7 significant associations and having the highest levels of significance.

There is no dominant SST region, the 7 significant correlations are spread amongst 7 regions. Three high latitude SST regions do not have any significant lagged relationships; Newfoundland, Labrador, and Atlantic3.

The strongest correlation discovered is a lagged association between winter SSTAs in the Northeast SST region and spring precipitation totals (Figure 2). The regression indicates that a change in SST of 1°C leads to a change in precipitation of 40 mm.

	Winter		Spring		Summer		Fall	
Carb	.05		.09		.05		**.19**	**.06**
Gulf	.12		**.20**	**.05**	-.07		.12	
SE	.16		**.24**	**.02**	-.01		.09	
NE	.09		**.38**	**.00**	.05		.16	
Newf	-.05		.01		.08		.12	
Lab*	-.06		-.19		-.05		.08	
Atl1	.04		.14		.04		**.17**	**.10**
Atl2	-.09		**.24**	**.02**	-.02		.05	
Atl3	-.05		.08		-.03		.04	
Atl4	-.05		**-.30**	**.01**	-.06		.14	

Table 2. 100-Year Lagged Correlation R-Values. Far left column is SST region. This is followed by correlations (R-values) and levels of significance for those cases exceeding 0.10 by season. The SST anomalies utilized are for the preceding season. *The N value for Labrador winter is less than 100, thus the R-value required for significance needs to be greater.

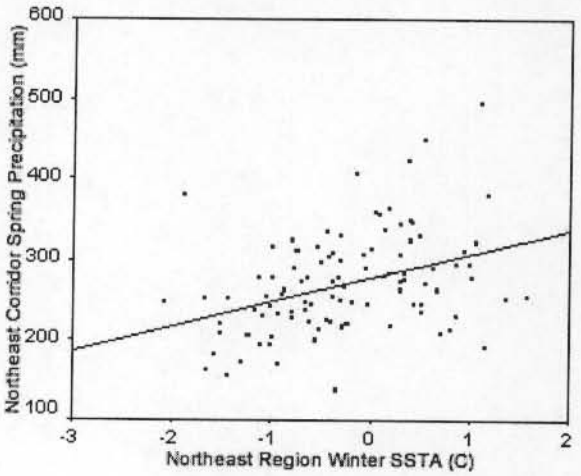

Figure 2. 100-Year Scatter Plot of Northeast region winter SSTAs vs. Northeast Corridor spring precipitation (R = +0.38).

3.3 Trends

Contemporaneous correlations of fall and spring associations are strongest in the first half of the century. It is interesting to note that SSTs were cooler during this time than in the latter half of the century. This overall pattern of cooler SSTs during the first half of the century is also evident for the other two seasons. However, there is no tendency for one half of the century to drive the correlations.

4. DISCUSSION

A significant positive relationship between Northeast region winter SSTAs and the winter North Atlantic Oscillation (NAO) exists over the century (R=+0.21). It is most pronounced in the last half of the century. This was a period with a higher NAO index and warmer SSTs in the Northeast region. This period also coincided with greater winter and spring precipitation. A positive winter NAO is indicative of a zonal jet stream and positive height anomalies centered on 40°N latitude over the midlatitude study region. This reduces the flow of Arctic air into the Northeast Corridor and offshore waters. A negative winter SOI, associated with an El-Nino event, also tends to set up a more zonal atmospheric circulation. A weak relationship between winter SOI and spring precipitation is observed in the Northeast Corridor. So both a positive NAO and an active ENSO result in warmer than average winter SSTs in coastal Atlantic Ocean waters. One can speculate that as spring sets in, positive SSTAs may influence development of stronger, likely wetter storms affecting the Northeast Corridor. A relatively weaker relationship between spring SSTAs and spring precipitation (R=+0.26), than the lagged winter SSTA and spring precipitation relationship, is possibly due to extensive spring cloud cover and greater storminess. This might establish a negative feedback, reducing positive SSTAs.

5. CONCLUSIONS

Contemporaneous and lagged relationships between western Atlantic Ocean SSTAs and precipitation in the Northeast Corridor of the U.S. were found to be statistically significant in all seasons. Relationships were strongest for regions closest to the Northeast Corridor. The most significant relationship being a positive one between Northeast region winter SSTAs and spring precipitation in the Northeast Corridor.

While the relationships are significant, they do not explain a large portion of the variance. However, they provide useful guidance toward understanding contemporaneous precipitation conditions and toward predicting upcoming season precipitation anomalies.

Relationships uncovered and speculations regarding feedback mechanisms that may be in operation within and between seasons, require further empirical study. They also call for investigations using coupled atmosphere-land-ocean models.

6. ACKNOWLEDGEMENTS

This work is funded by the National Science Foundation under grant contract number ATM-9714762.

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