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ATLANTIC SEA SURFACE TEMPERATURES AND EASTERN UNITED STATES CLIMATE, 1950-1992

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1. INTRODUCTION

Although sea surface temperature anomalies (SSTAs) in tropical oceans can have far-reaching effects on climate, as is the case with the El Nino-Southern Oscillation (ENSO) phenomenon, the effects of mid-latitude SSTAs are less clear. Mid-latitude SSTAs in the Pacific Ocean have been linked to atmospheric circulation anomalies over the North Pacific and North America (e.g. Namias *et al.*, 1988; Rogers, 1976; Namias, 1974), but observations suggest that SSTAs are initially forced by atmospheric circulation anomalies (e.g., Davis, 1976; Palmer and Sun, 1985). However, GCM experiments suggest that feedback between ocean and atmosphere may maintain atmospheric anomaly patterns (e.g. Palmer and Sun, 1985; Lau and Nath, 1990). Where GCM experiments indicate an atmospheric response to mid-latitude SSTAs, the response appears to be strongly dependent on the background circulation (Kushnir and Held, 1996; Peng *et al.*, 1997).

One might assume then, that mid-latitude SSTAs are of little utility in the diagnosis and prediction of regional climate anomalies. However, SSTAs along the Atlantic coast have been linked with precipitation anomalies along parts of the east coast of the United States (Namias, 1966; Colucci, 1976) and with snowfall variations in southern New England (Hartley, 1996). A temperature response to SSTAs along the coast of the Netherlands was identified by van den Dool (1984) and attempts to predict summer temperatures in England from preceding winter North Atlantic SSTAs showed some promise (Colman, 1997).

In this paper, we present some preliminary results of an ongoing investigation of possible linkages between climate anomalies and SSTAs along the east coast of the United States.

2. DATA

Seasonal values of temperature and precipitation were compiled from the National Climatic Data Center (NCDC) Monthly Divisional Data Set. Winter snowfall totals were computed from daily values for stations from NCDC's TD3200 and Summary of the Day data sets. Gridded monthly 700 mb analyses by the National Center for Environmental Prediction (NCEP) were obtained from the Data Support Section of the National Center for Atmospheric Research (NCAR). Monthly SSTs for a region of the western Atlantic Ocean were extracted from the reconstructed global analysis of the Climate Prediction Center (Smith *et al.*, 1996). For each calendar season, a rotated (Varimax) principal component analysis identified several regions of coherent SST variability for which seasonal standardized anomaly indices were computed. Figure 1 shows regions for the winter season. The two regions that are referenced in this paper (CARIB and NE) have a similar areal extent in all four seasons. It is important to note, however, that no physical interpretation is to necessarily be made of the regions identified. At this stage they primarily serve as convenient points of reference from which to explore possible linkages between SSTAs and climate anomalies.

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3. METHODS

Seasonal indices of SSTAs were correlated against divisional values of temperature and precipitation, station snowfall totals, and gridpoint anomalies of 700 mb heights. Composite anomaly maps of climate variables and 700mb heights were also computed based on extreme values of regional SSTA indices. Both contemporaneous and lagged associations (with SSTAs leading) were considered.

4. RESULTS

Strong contemporaneous associations were evident in all seasons, many of which can probably be explained by the coincident forcing of both the climate anomalies and SSTAs by atmospheric circulation. However, some lag associations were found, and a few examples are presented and discussed in the remainder of the paper.

4.1. *Spring Precipitation*

Spring precipitation is correlated with winter SSTs in the NE region over much of the northeastern US (Figure 2). Correlations are greatest in the southern Hudson Valley, northern New Jersey, and eastern Pennsylvania (Figure 3). The exact nature of this association is currently under investigation .

4.2. *Winter Snowfall*

Lagged correlations between winter snowfall and NE SSTAs of the preceding fall are shown in Figure 4.

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Winters following negative SSTAs in the NE region tend to be relatively snowy from the central Appalachians to the east coast (Figure 5). Figure 6 shows the composite difference of the 700 mb height field comparing winter patterns following the 7 coldest NE falls with the 7 warmest. Following cold NE falls, the winter circulation tends to be more meridional over the eastern US and western Atlantic, a pattern that favors a more southerly storm track and thus an increased likelihood of precipitation as snow rather than rain. SSTAs in the NE region are very persistent from fall to winter. However, it can not be determined at this stage to what extent, if any, fall SSTAs in the NE region influence the subsequent winter atmospheric circulation.

4.3. *Summer Temperature*

Over much of the southeastern US, summer temperatures are significantly correlated with spring SSTAs in the CARIB region (Figures 7 and 8). Figure 9 shows gridpoint correlations of the spring 700 mb field vs. the spring SSTA index for the CARIB region. The pattern suggests that positive SSTAs in the CARIB region are associated with a relatively weak Bermuda high and correspondingly weak trade winds. In spring, anomalously warm surface waters in the CARIB region tend to be accompanied by anomalously cool water in the Gulf of Mexico and around Florida (not shown). However, with progression from spring into summer, the 700 mb pattern breaks down and the SSTAs appear to drift westward into the Gulf and northward to the southeastern US (Figure 10). The apparent drift of the SSTAs may be due to the relaxation of the forcing pattern of the spring, or may simply involve advection around the Atlantic sub-tropical gyre.

5. DISCUSSION AND CONCLUSIONS

In this paper we have presented a few examples of regional climate variations that are statistically related with preceding season SSTAs in a certain sector of the western Atlantic. As yet, the physical processes (if any) involved in these associations have not been determined. In the case of summer temperatures in the Southeast, there may be a direct response involving ocean-to-atmosphere transfers of sensible and latent heat. On the other hand, winter snowfall variations in the central Appalachians are more likely to involve changes in storm tracks, which may be influenced by SST gradients off the northeast coast, or may be merely coincidental with the SSTA pattern. It is also possible that the coupled atmosphere-ocean system has modes of season-to-season transition characterized by distinct patterns of SSTAs that become established at an early stage.

Although statistically significant, the explained variance in each case is not large and the predictive skill of these associations has not yet been assessed. A more rigorous analysis for a longer period of record will be conducted as data become available. However, the existence of lag associations with SSTs leading the atmosphere/climate suggests the role of SSTs in contemporaneous associations may not be insignificant.

ACKNOWLEDGEMENTS

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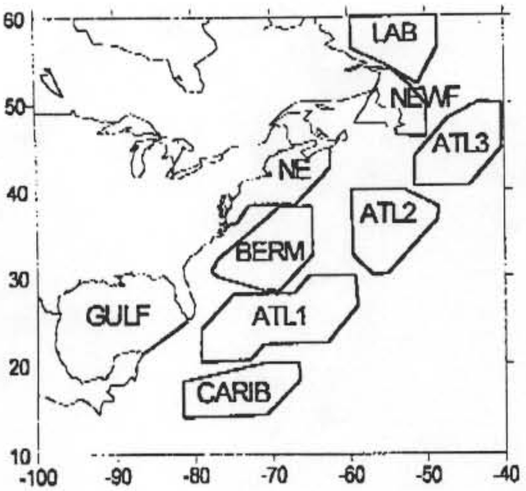

Figure 1. Regions of coherent SST variability obtained by rotated PCA for the winter season

Figure 2. Climate divisions for which spring precipitation is significantly correlated with preceding winter SSTs in the NE region. Light shading = 0.05 sig.; dark shading = 0.01 sig.

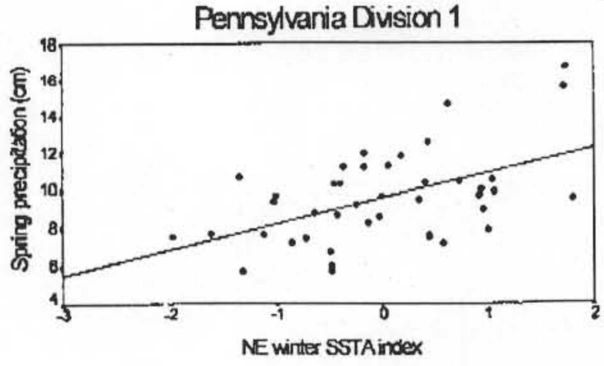

Figure 3. Example scatterplot of spring precipitation vs. winter NE SSTA. R = 0.43.

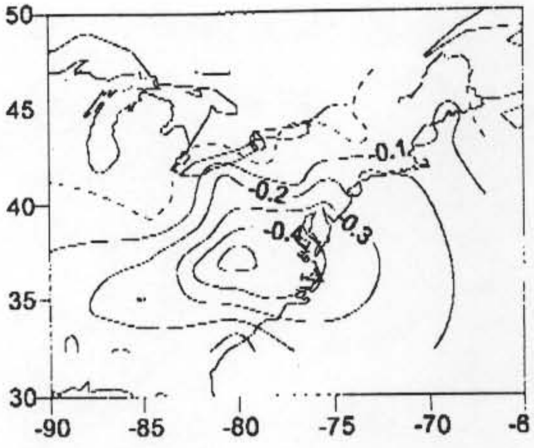

Figure 4. Lag correlations between winter snowfall and preceding fall SSTAs in the NE region. The critical value for 0.05 significance is 0.32.

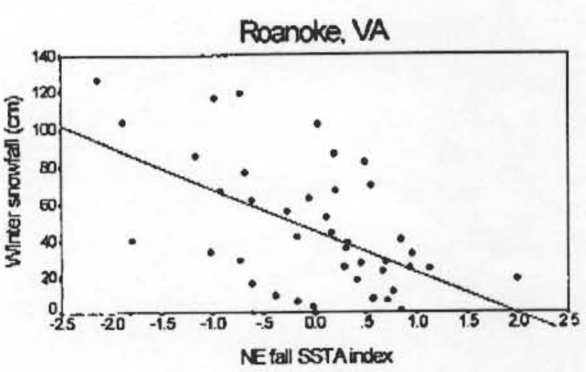

Figure 5. Example scatterplot of winter snowfall vs. SSTAs of preceding fall in NE region. R = -0.56

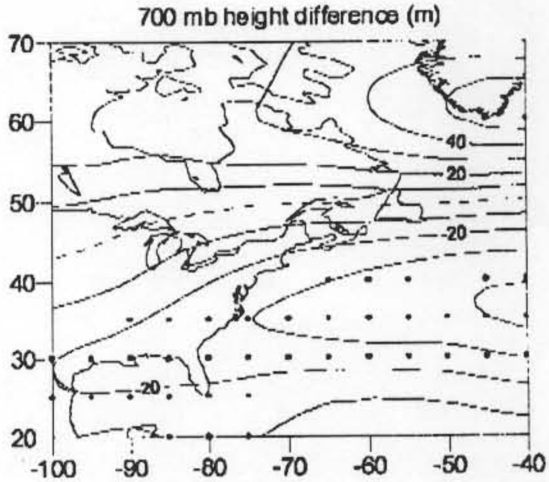

Figure 6. Composite difference of winter 700 mb height fields - 7 coldest NE falls vs. 7 warmest NE falls. Dots show gridpoints at which height difference is significant at 0.05 level as indicated by a bootstrap procedure.

Figure 7. Climate divisions for which mean summer temperature is signficantly correlated with preceding spring SSTAs in the CARIB region. Light shading = 0.05 sig.; dark shading = 0.01 sig.

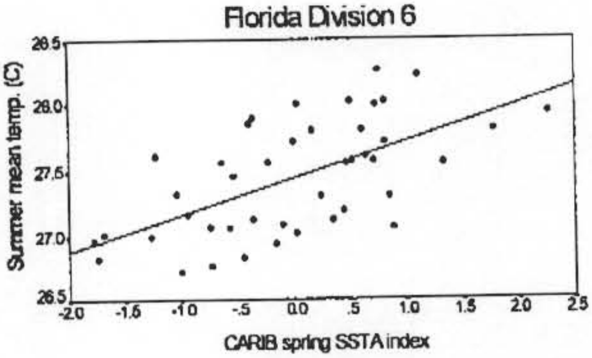

Figure 8. Example scatterplot of summer temperature vs. spring CARIB SSTA. R = 0.60

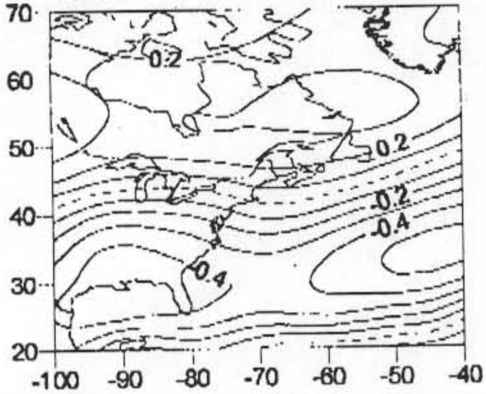

Figure 9. Contemporaneous gridpoint correlations of 700 mb heights with the spring SSTA index for the CARIB region.

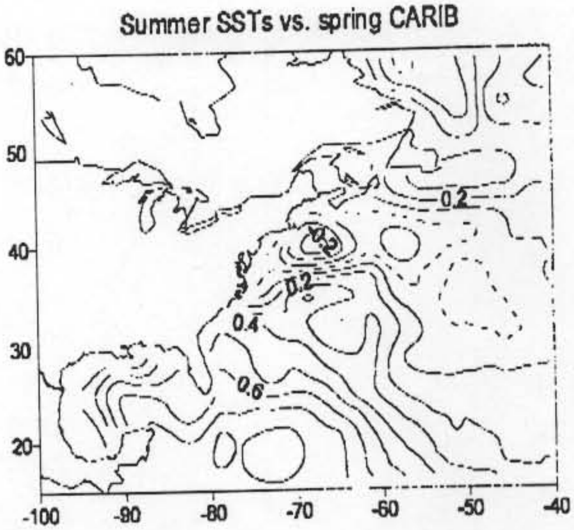

Figure 10. Lagged gridpoint correlations of summer SSTs vs. the spring SSTA index for the CARIB region.