4A.2 RECURVATURE AND LANDFALL OF ATLANTIC HURRICANES AND THEIR RELATIONSHIP TO THE NORTH ATLANTIC OSCILLATION

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1. INTRODUCTION

To date, much of the research relating to seasonal North Atlantic tropical cyclone forecasts has focused on their frequency and severity. Little research has been done on hurricane tracks, although this situation is changing (Gray 2000). A hurricane's greatest impacts are felt when it makes landfall, which is directly the result of its track. Seasons may be characterized by a high number of recurving systems with little impact on land, e.g., the active 2000 season, or by activity that is well below normal but in which a single landfall by a hurricane that did not recurve early enough (or at all) has catastrophic consequences, e.g., Hurricane Andrew in 1992.

Recent research has linked the North Atlantic Oscillation (NAO) index, defined as the normalized difference between the mean sea-level pressure (SLP) in the Azores, and the mean SLP in south-western Iceland, to the tracks taken by major Atlantic hurricanes (Elsner et al. 2000). In this analysis, the NAO index was calculated using the data from the Climate Research Unit at the University of East Anglia, and was examined in relation to hurricane recurvature and landfall as a possible track-predicting candidate variable to be incorporated into future seasonal forecasting models. Particular interest was focused on the NAO index in August, September and October (ASO), during which most Atlantic hurricanes occur (Landsea 1993, Neumann et al. 1999).

2. METHODOLOGY

The best-track hurricane dataset (HURDAT) (Jarvinen et al. 1984), was examined to identify each tropical cyclone that formed south of 23.5ºN and east of 65.0ºW between 1944 and 1997 during ASO and which reached at least minimal hurricane strength during its lifetime. This region of interest (ROI) forms the approximate boundary within which Cape Verde hurricanes originate. Hurricanes were classed according to whether they: (i) recurved (82%), (ii) maintained a straight-line track until decaying at landfall (10%), or (iii) died out over water before recurving (7%). Approximately 1% were not classed.

A recurving hurricane was defined to be one that transitioned from having a generally westward velocity component to a generally eastward velocity component at some point during its lifetime. The longitude at which the hurricane recurved was its westernmost position before transition occurred. For hurricanes continuing in a westerly or west north-westerly track until decaying at landfall, the longitude at which it dissipated after landfall was recorded.

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The average longitude of recurvature (LOR) for all ASO recurving and straight-line hurricanes each year was calculated, i.e., an index expressing the westernmost longitude of these hurricanes, weighted according to their frequency in a given year.

HURDAT was also examined to identify tropical cyclones classified as hurricanes at landfall or that impacted the U.S. coastline with hurricane force winds in ASO from 1901 – 1997. These hurricanes were further classified into minor and major hurricanes. Three landfall regions were defined: (i) the Gulf Coast (GC), (ii) Florida only (FL), and (iii) the East Coast (EC), and a count of landfalls in each region by the selected hurricanes was calculated.

Using data from the National Centers for Environmental Prediction (NCEP) and the National Center for Atmospheric Research (NCAR) reanalysis project from 1958 – 1998, the deep layer tropospheric steering flow during ASO was examined.

3. RESULTS

The results of the analysis of the relationship between the NAO and LOR indices in ASO are outlined in Tables 1A and 1B, in which composites of years of very high and low values of each index are compared. No significant statistical relationship was uncovered. There appears to be little ability to predict the ASO NAO index from observations of the index earlier in the year. At most 5% of the NAO index variance was explained (results not shown).

TABLE 1A. For the years 1944-1997, (a) compares the mean values of the LOR index for the ten highest and lowest LOR index years, and (b) compares the mean values of the ASO NAO index for the same years.

All Hurricanes[c]	(a) LOR Index	(b) NAO Index
High LOR Yrs.	83.4	0.19
Low LOR Yrs.	61.8	0.18
Z-value[d]	8.83[b]	0.01

TABLE 1B. For the years 1944-1997, (a) compares the mean values of the ASO NAO index for the ten highest and lowest ASO NAO index years, and (b) compares the mean values of the LOR index for the same years.

All Hurricanes[c]	(a) NAO Index	(b) LOR Index
High NAO Yrs.	1.44	71.2
Low NAO Yrs.	-1.32	70.9
Z-value[d]	12.28[b]	0.06

With respect to the effect of the NAO in ASO on landfalling hurricanes (see Table 2 for results of this analysis), a statistically significant relationship exists for the case of major hurricanes striking Florida only.

The results suggest that when the ASO NAO index is high, more major hurricanes make landfall in Florida. However, no impact on landfalling hurricanes (minor or major) on the U.S. Gulf Coast was apparent.

TABLE 2. For the years 1901-1997, (a) compares the mean values of the ASO NAO index for the 20 highest and lowest ASO NAO index years, and (b) – (d) compares the mean values of the average number of **major** hurricane landfalls in each geographical region for the same years.

Major Hurricanes	(a) NAO Index	(b) GC	(c) FL	(d) EC
High NAO Yrs.	1.62	0.40	0.30	0.50
Low NAO Yrs.	-1.26	0.40	0.05	0.20
Z-value[d]	23.68[b]	0.00	1.82[a]	1.19

The results of the analysis of the relationship between LOR and landfall are outlined in Table 3. The analysis indicates a statistically higher threat of landfall from hurricanes (minor or major), significant at the 95% level, along the U.S. East Coast during years when the LOR index is very high.

TABLE 3. For the years 1944-2000, (a) compares the mean values of the LOR index for the ten highest and lowest LOR index years, and (b) – (d) compares the mean values of the average number of **all** hurricane landfalls in each geographical region for the same years.

All Hurricanes[c]	(a) LOR Index	(b) GC	(c) FL	(d) EC
High LOR Yrs.	83.4	0.90	0.30	1.50
Low LOR Yrs.	60.5	1.00	0.30	0.50
Z-value[d]	9.69[b]	-0.26	0.00	1.98[a]

The deep layer wind patterns observed in the ROI during the highest and lowest LOR index years are clearly different from those observed during the different NAO phases, as shown in Figures 1 and 2.

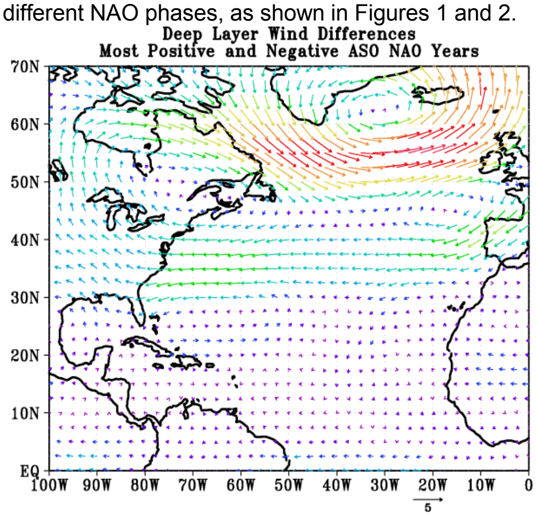

FIG. 1. Deep layer wind differences in ASO between the ten highest and lowest ASO NAO index years.

[a] Significant at the 95% level.
[b] Significant at the 99% level.
[c] For at least two hurricanes with genesis in ROI.
[d] Z-value expresses the difference between means.

In Figure 1, the deep layer wind differences in the center of the ROI are very small, suggesting that the NAO has little influence on hurricane track in the deep tropical Atlantic. Closer to the U.S., however, the winds indicate a higher threat from landfalling hurricanes along the entire East Coast during positive NAO years, suggesting that once a hurricane leaves the ROI and approaches the U.S., landfall is more likely during these years.

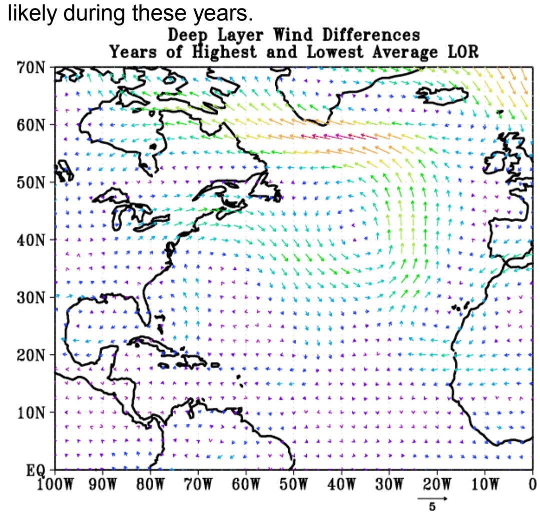

FIG. 2. Deep layer wind differences in ASO between the seven highest and lowest LOR index years.

In contrast, Figure 2 illustrates that northerly wind anomalies tend to set up in the center of the ROI during high LOR index years, a pattern consistent with late recurvature of hurricanes. During these years, the deep layer wind patterns indicate a greater likelihood of landfalls along the U.S. East Coast, but not in Florida, and no increased threat in the Gulf of Mexico. This is consistent with the statistical analysis results in Table 3.

4. REFERENCES

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