The Influence of the North Atlantic Oscillation on Hurricane Landfalls from Virginia to Maine

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Abstract

Hurricane activity along the northeast coast from Virginia to Maine was examined from 1950-2009. Historically, major hurricanes having tremendous impacts have made landfall in this geographical area. Given that hurricane activity occurs much less frequently poleward of 35°, not much research has been done to analyze the link between climate factors and hurricane activity from Virginia to Maine. This study analyzes climate factors such as the North Atlantic Oscillation (NAO), sea surface temperature (SST) profiles, and El Nino Southern Oscillation (ENSO) as well as large-scale synoptic weather conditions, with the goal of improving understanding of hurricane activity in the northeastern U.S. Hurricanes involve small scale mesoscale motions and physical processes, but the mechanisms that steer these storms occur on the synoptic scale. The results suggest that the NAO and general synoptic flow have a significant correlation to landfalling hurricanes along the northeast coast. Ascertaining a better understanding of climate factors that affect hurricane activity from Virginia to Maine could have a significant impact on preventive measures and improving methods for modeling, thus decreasing the loss of life and property.

Introduction

Why study hurricane activity along the northeast coast?

•Although much more infrequent, tropical activity occurs all along the northeast coast of the United States.

•These areas are particularly vulnerable because they are densely populated and prone to storm surge and flash flooding.

•Even weak hurricanes can have a significant impact on these areas.

30 Costliest Mainland Unites States Tropical Cyclones 1900-2006

Rank	Hurricane	Year	Category	Damage (Millions)
1*	Hurricane Katrina (Gulf Coast)	2005	3	584,645
2*	Andrew (Florida/ Louisiana)	1992	5	48, 058
6*	Hugo (South Carolina)	1989	4	13,480
7	Agnes (FI/ Ne coast)	1972	1	12,424
12	Diane (NE Coast)	1955	1	7,770
15	The New England Hurricane	1938	3	6,571
17	Hurricane Floyd (Mid-Atlantic)	1999	2	6,342
18	Hurricane #7 (NJ to ME)	1944	3	5,927
22	Carol (NE Coast)	1954	3	4,345
25	Donna (FI/ NE Coast)	1960	4/2	3,345
27	Bob (NC/ NE Coast)	1991	2	2,853

*Again note that of the top 30 costliest storms 8 affected the northeast coast

The North Atlantic Oscillation (NAO)

•It is determined by fluctuations in the atmospheric pressure at sea level between the Icelandic low and the Azores high.

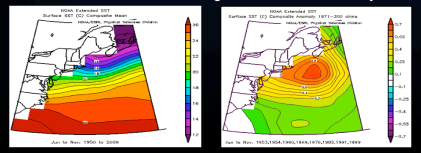
•Most studies link the NAO to winter weather, but few have linked it to hurricane activity.

•This climate phenomenon is important because it directly influences the direction and magnitude of westerly winds and thus storm tracks across the North Atlantic including areas from VA to ME.

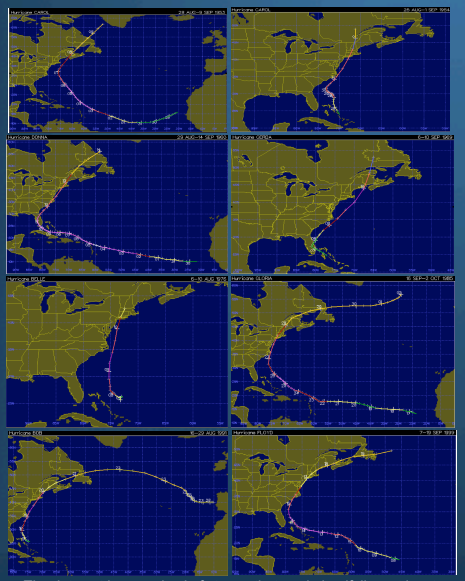
Sea Surface Temperatures (SST)

•Sufficiently warm SST and minimal wind shear are necessary for tropical cyclone genesis.

•Baroclinic enhancement often plays a role in maintaining intensity as cooler waters are encountered, but even small increases in SST can lead to heightened hurricane activity.



Data Set



The data set is comprised of storms that made landfall as at least a category 1 hurricane from VA to ME between 1950 and 2009. Hurricane tracks were retrieved from The Tropical Prediction Center via Unisys.

Green= T.D. Yellow= T.S. Red= Cat 1 Light Red= Cat 2 Magenta= Cat 3 Light Magenta= Cat 4 White= Cat 5

Methodology

•Analysis was done from 1950-2009 for which data was available.

•Using the NCEP Reanalysis tool, it was possible to plot geopotential height at several levels, Omega, & SST.

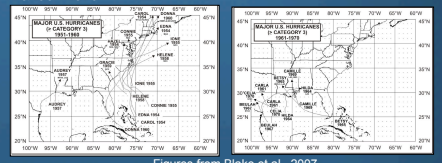
•Using NAO composites from NOAA's Climate Prediction Center and The Climatic Research Unit, NAO values and trends were able to be computed during active and inactive periods.

•Using data from various climate centers, ENSO cycle during landfalling years was examined.

•Examining all of these factors will provide a clearer understanding behind the climatology of hurricane activity along the northeast coast as well as the significance of the effect of the NAO on hurricane landfalls from VA to ME.

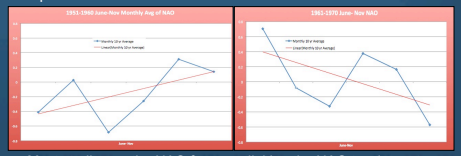
Results

• It is believed that northeast hurricane effects and landfalls occur on multi-decadal periods of activeness and inactiveness. This has been observed in analyzing the periods of 1951-1960 &1961-1970.



Figures from Blake et al., 2007

•Looking at NAO compilations during each of the periods exposes stark differences.



•Most studies on the NAO focus on linking the NAO to winter storms, but in this study it appears that a negative NAO trending positive is favorable for tropical activity on the east coast of the U.S.

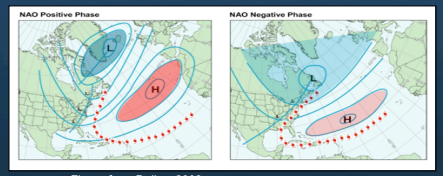
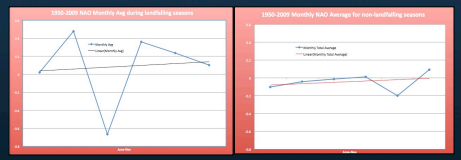


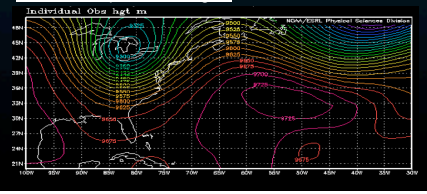
Figure from Dailey, 2009



Synoptic Reanalysis: Hurricane Carol- 8/31/54 Cat 3

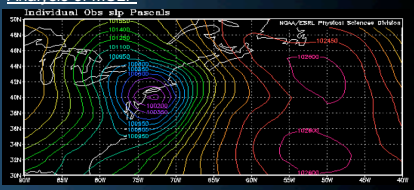
•One of the worst storms to affect New England.
•22nd Costliest Hurricane in U.S. History- $4.3 billion.
•Winds up to 135 mph & Storm Surge up to 14 feet.
•28th Deadliest Hurricane in U.S. History – 60 deaths.

500 MB Geopotential Heights

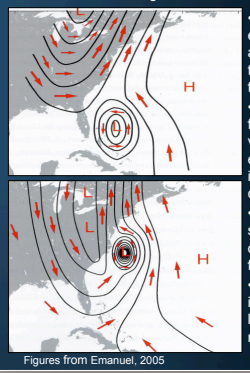


Results (continued)

Analysis of MSLP



•Reanalysis was completed for all of the data set and similar results were discovered for all the storms.
•The synoptic features were nearly identical with every hurricane. In each case there was a digging trough to the west and a massive high to the east.



•As the storm enters this environment, it is greatly accelerated and begins to be encapsulated by the trough.
•The trough continuously feeds the storm energy via baroclinic enhancement although it is moving over much cooler waters.
•For this reason, very strong hurricanes could directly impact areas as far north as Maine.
•This feature is observed in nearly all hurricane landfalls along the northeast U.S. coast.

Figures from Emanuel, 2005

Conclusions

•The NAO plays a major role in landfalling hurricanes along the northeast U.S. coast.
•Synoptic conditions allow hurricanes to remain strong as they move over cooler waters, but small increases in SST can contribute to increased hurricane activity.
•ENSO in nearly each case was very weak or neutral.
•Understanding climate factors that affect hurricane activity can have major implications on preventive measures.

References

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