LIGHTNING IN HURRICANES

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1. INTRODUCTION

Although much research has been done on the structure and nature of hurricanes, very few studies have focused on the electrification of tropical storms. In recent years, with the advent and subsequent upgrade of the National Lightning Detection Network (NLDN), the work of Lyons and Keen (1994), Samsury and Orville (1994) and Molinari et al. (1994) has investigated the questions of lightning frequency, temporal and radial flash distribution and flash polarity in Atlantic basin tropical storms.

Through analysis of cloud-to-ground lightning flash locations for nine Atlantic hurricanes, Molinari et al. (1998) found a distinct radial distribution of flash density: a maximum in the eye wall, a minimum between 100 and 180 km from the eye and a strong maximum located outward of 200 km associated with the outer rain bands. In addition, flash counts were often lowest in the northwest quadrant of the storm, even though this was the area closest to the coast and thus to the NLDN sensors. This result gave credence to the use of the NLDN for detecting flashes in hurricanes over water but also raised many questions as to why this distribution was observed.

One of the explanations proposed by Molinari et al. (1998) for this distribution of flashes was vertical wind shear. The purpose of the present study is to examine the relationship between the azimuthal distribution of lightning and vertical wind shear in five Atlantic basin tropical storms.

2. DATA AND METHODOLOGY

The lightning data were obtained from archived observations of the NLDN that provide the date, time, latitude, longitude, polarity, multiplicity and signal strength of the first stroke. Data were used only when the storms were within 400 km of at least one NLDN sensor, the nominal limit of the NLDN (Molinari et al., 1994). With the exception of Bob 1985, all lightning data were gathered after the 1995 upgrade of the NLDN with its current configuration of magnetic direction finders and time of arrival sensors (Cummins et al., 1995; Idone et al., 1998). The flash locations for Bob 1985 were recalculated using the updated 1993 site corrections curves obtained from GeoMet Data Services that maintains the network.

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This study also employs gridded analyses from the European Centre for Medium Range Weather Forecasts (ECMWF). The grids are uninitialized and contain 12 vertical pressure levels and 1.125° latitude-longitude horizontal resolution. The grids are interpolated bilinearly in the horizontal to yield cylindrical grids as in Molinari and Vollaro (1989) with dr=100 km and $d\lambda=5°$. Following Molinari (1993), the mean wind components are calculated as an area weighted average. This calculation removes the axisymmetric vortex component of the wind so that the resulting winds measure the basic current across the storm at each level. The average vertical wind shear is then calculated in the 850-200 mb layer over a 500 km radius.

The National Hurricane Center "best track" dataset was used to determine time intervals when the storm centers were within 400 km of at least one NLDN sensor and to partition data into pre-and post-landfall sections.

The NLDN latitude-longitude data were converted to distance from the center (r) and azimuthal direction (λ) with respect to the storm center using great circle transforms. The number of flashes occurring in the twelve hour period centered on the available 00 and 12 UTC shear data were totaled and plotted with respect to the storm center. The flashes were then rotated such that the shear vector for each 12 hour period was now pointing due north. This rotation was performed so that comparisons could be made between different time periods in the same storm and between storms. Total pre- and post-landfall times were then compiled to produce 2 datasets for each storm, using only 12 hour time periods when the shear exceeded 7 m/s. Average positions were separately computed for land, water and total storm flashes.

3. RESULTS

Figure 1 shows the storm relative positions of all flashes recorded by the NLDN from 18 UTC 10 October to 00 UTC 13 October associated with Bertha 1996 before landfall. The flashes are rotated around the storm center with respect to the shear vector, such that the shear is directed due north. The clear downshear azimuthal distribution of both the inner (eyewall) and outer (rainband) flashes can be seen.

Figure 2 shows the average positions of all recorded lightning flashes for both land and water time periods for the five storms studied. Although storm strength, direction of motion and the amount of lightning produced vary considerably from storm to storm, all exhibit a common down shear distribution of lightning. A comparison between the land and water averages shows that the average flash positions tend to move outward and be more scattered around the storm center after landfall, not exhibiting the more direct downshear signal that the water averages do. This could be attributed to the dying off of eyewall lightning and probable synoptic and environmental influences on the outer bands after landfall.

The storms, in general, also exhibit a downshear left azimuthal distribution of lightning (Figure 2). A proposed explanation is that cyclonic radial winds carry the updraft around the storm so that the lightning flashes appear cyclonically shifted from the downshear location where the updrafts originate.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

Cummins, K.L., E.A. Bardo, W.L. Hiscox, R.B. Pyle, and A.E. Pifer, 1995: NLDN '95: A combined TOA/MDF technology upgrade of the U.S National Lightning Detection Network. *Intern. Aerospace and Ground Conf. on Lightning and Static Electricity*, Williamsburg, VA, 26-28 September, Paper 72, 1-15.

Idone, V.P., D.A. Davis, P.K. Moore, Y. Wang, R.W. Henderson, M. Ries, and P.F. Jamason, 1998: Performance evaluation of the U.S. National Lightning Detection Network in eastern New York, 1. Detection effinecency. *J Geophys. Res.*, **103**, 9045-9055.

Lyons, W.A., and C.S. Keen, 1994: Observations of lightning in convective supercells within tropical storms and hurricanes. *Mon. Wea. Rev.*, **122**, 1897-1917.

Molinari, J., and D.Vollaro, 1989: External influences on hurricane intensity. Part I: Outflow layer eddy momentum fluxes. *J. Atmos. Sci.*, **46**, 1093-1105.

Molinari, J., 1993: Environmental controls on eye wall cycles and intensity changes in Hurricane Allen (1980). *ICSU/WMO International Symposium on Tropical Cyclone Disasters*, Beijing, China, October 12-16.

Molinari, J., P.K. Moore, V.P. Idone, R.W. Henderson and S.B. Saljoughy, 1994: Cloud-to-ground lightning in Hurricane Andrew. *J. Geophys. Res.*, **99**, 16,665-16,676.

Molinari, J., P.K. Moore, and V.P. Idone, 1998: Convective structures of hurricanes as revealed by lightning locations. Accepted by *Mon. Wea. Rev.*.

Samsury, C.E., and Orville, R.E., 1994: Cloud-to-ground lightning in tropical cyclones: A study of Hurricanes Hugo (1989) and Jerry (1989). *Mon. Wea. Rev.*, **122**, 1887-1896.

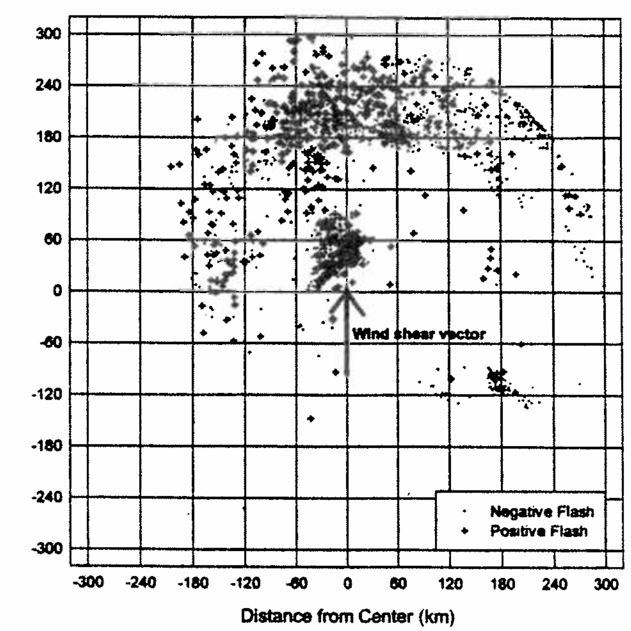

Figure 1. Total pre-landfall ground flashes in Hurricane Bertha 1996 composited with respect to the hourly center position and rotated such that the shear vector is pointing due north.

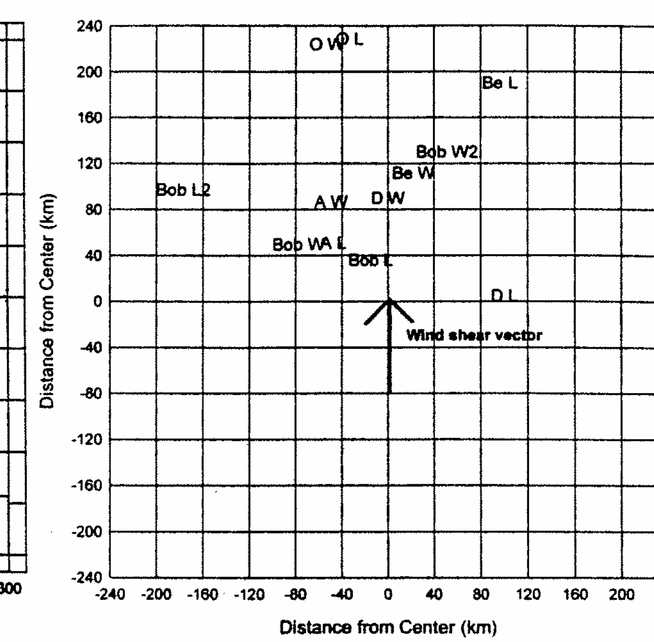

Figure 2. Total storm flashes pre- and post-landfall for 5 tropical storms composited with respect to storm center and rotated such that the shear vector is pointing due north. A is Allison 1995, Be is Bertha 1996, O is Opal 1995 and D is Danny 1997. L and W refer to land and water averages respectively. Bob 1985 W refers to time spent in the Gulf of Mexico, L is Florida, W2 the Atlantic and L2 the U.S. mainland.