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APPLICATIONS OF LONG-RANGE LIGHTNING DATA TO HURRICANE FORMATION AND INTENSIFICATION

by

John Molinari[1]*, Nick Demetriades[2], Ron Holle[2], and David Vollaro[1]
[1]Department of Earth and Atmospheric Sciences
The University at Albany/SUNY
Albany, New York
[2]Vaisala, Inc., Tucson, AZ

1. INTRODUCTION

Lightning locations from the National Lightning Detection Network have proven to be a useful indicator of convective outbreaks in incipient and mature hurricanes that are within 400-500 km of the U.S. coast. Such outbreaks often signal substantial deepening of the storms (Molinari et al. 1994, 2004; Demetriades and Holle 2006). Lightning distribution in tropical cyclones also gives insight into their evolving thermodynamic structure. Because major questions still remain about how tropical cyclones form, lightning information is potentially of significant value, both for prediction and understanding of storms, during the early stages of development.

Molinari et al. (2004) investigated the development of Hurricane Danny (1997) from a tropical depression in the Gulf of Mexico using data from the NLDN. They calculated vertical wind shear between 850 and 200 hPa, and found an intense lightning outbreak downshear from the center. "Downshear" indicates the half of the circulation opposite the vertical shear vector; if vertical shear is from the west, downshear represents the eastern half of the storm, and "downshear left" the northeast quadrant. They provided evidence that this burst of lightning brought about a downshear re-formation of the storm. This new center ultimately intensified to a hurricane.

Most hurricane formation and early intensification occurs outside the range of the traditional NLDN. A long-range detection network is now part of the NLDN (Murphy et al., 2006) that detects ground flashes 2000 km or more from the U.S. coast. The nighttime detection efficiency exceeds 10% even at the far reaches of the eastern Caribbean. This dataset will be used to examine the lightning evolution during the unprecedented behavior of Hurricane Claudette (2003). Between 0600 and 1200 UTC 10 July this storm unexpectedly developed from a disorganized tropical storm to a hurricane. Then it weakened just as quickly, returning to marginal tropical storm intensity by 1800 UTC the same day. Claudette did not achieve hurricane intensity again until several days later, even though it remained over warm water. This writeup will focus on the period that Claudette suddenly gained, then lost, hurricane intensity. Of interest is whether long range lightning data provide some insight into the behavior of the storm.

2. RESULTS

Vertical wind shear represents a key variable in tropical cyclone intensity change. Shelton (2005) showed that vertical wind shear was strong from the southwest and west-southwest during most of the lifetime of TS/Hurricane Claudette. The distribution of lightning flashes with respect to the storm center and to the vertical wind shear was calculated in this study for an eight-day period as Claudette moved from the Caribbean to the Texas coast. The goal was to confirm that the long-range data show results comparable to those of Corbosiero and Molinari (2003) using the NLDN. Within 100 km of the center, 92% of flashes were downshear, with a downshear-left maximum. Between the 100 and 200 km radii, almost 97% of flashes were downshear, with a downshear-right maximum. These results closely match those of Corbosiero and Molinari (2003; their Figure 7) for strong-shear cases like Claudette. This provides evidence that the long-range data contain information as useful as that provided by the NLDN, but with the obvious advantage of a much greater range.

Figure 1 shows a time series of the number of flashes indicated by the long-range network within 100 km of the center. Only 8-12 July 2003 is shown, centered on the time that hurricane intensity was achieved. Also shown is the time variation of minimum central pressure in the storm. During the first two days of study (8-9 July), fewer than 60 total flashes per hour occurred within 100 km of the center. The storm did not substantially change intensity during this time. Early on 10 July, a substantial outbreak produced more than 150 flashes in one hour, and the storm began to deepen. Between 0700 and 1000 UTC on the 10th, a second large outbreak occurred. The storm rapidly deepened during this time and reached hurricane intensity at 1200 UTC. The lightning thus provided some advanced and coincident indication of the development.

**Corresponding author address:* John E. Molinari, University at Albany/SUNY, Department of Earth and Atmospheric Sciences, 1400 Washington Avenue, Albany, New York 12222 USA; email: molinari@atmos.albany.edu

Conversely, after the storm began to weaken, additional outbreaks occurred late on 10 July and on 11 July that clearly did not relate to deepening. In order to investigate this further, we examine only the lightning occurring left of the vertical wind shear vector in Figure 2. The rationale for this choice is as follows: Reasor et al. (2004) showed that tropical cyclones can successfully resist the negative effects of vertical wind shear by tilting to the left of the shear vector. This produces maximum upward displacement of a circulating air parcel, and thus deep convection and lightning, at the same location. We hypothesize the following: a tropical cyclone with lightning mostly left of the vertical wind shear shows the storm is successfully resisting shear and more likely to deepen; in contrast, a storm with lightning mostly to the right of shear is less able to resist shear and more likely to weaken. Figure 2 provides support for this hypothesis: outbreaks occur left of shear during deepening, but the large outbreaks in Figure 1 during non-deepening periods are predominantly right of shear.

It is thus proposed that not just the frequency of lightning, but also its distribution, provide information as to whether a storm is about to deepen. This hypothesis will be tested with additional long-range data in tropical cyclones.

3. ACKNOWLEDGEMENT

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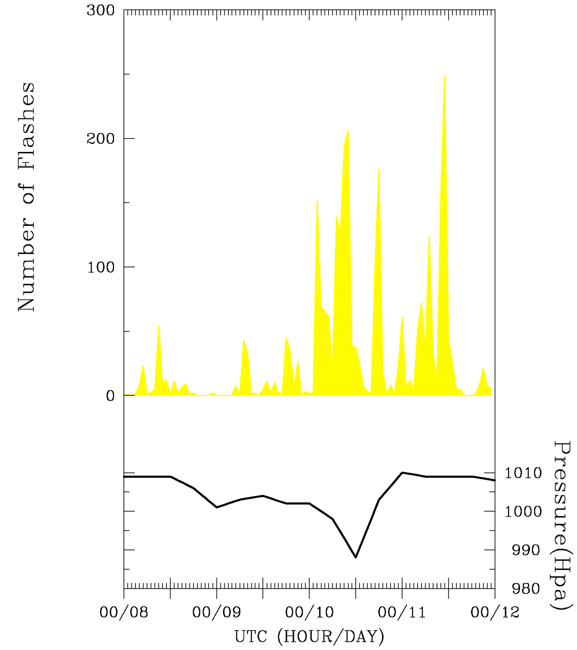

Figure 1. Hourly flash count (shaded) from the long range lightning network within 100 km of the center of Tropical Storm/Hurricane Claudette during 8-12 July 2003. Also shown is the time variation of minimum central pressure (hPa; solid line).

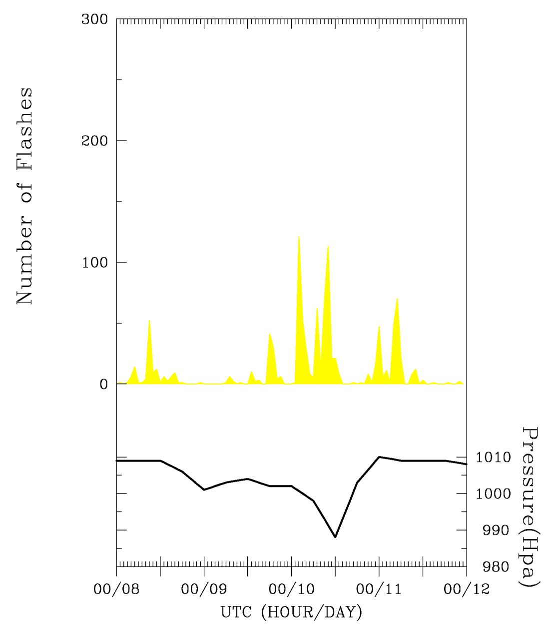

Figure 2. As in Figure 1, but only for the number of flashes occurring to the left of the vertical wind shear vector.