Tropical Cyclone Lightning Characteristics as Revealed by the World Wide Lightning Location Network

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Introduction and Motivation

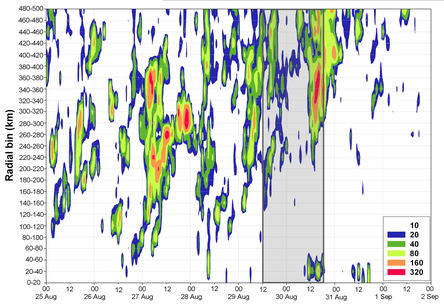


Figure 1: Hovmöller of WWLLN flashes in Hurricane Gustav (2008). The gray area denotes the time period of rapid intensification.

While lightning occurrences have been successfully used as a proxy for convective activity within tropical cyclones (TCs; see the review in Abarca et al. 2011), robust conclusions have been elusive due to the relatively rare and episodic nature of lightning in TCs.

The World Wide Lightning Location Network (WWLLN) is a long-range, ground-based network that locates flashes across the globe. Our previous research has shown an increasing detection efficiency of the WWLLN, which holds a strong statistical proportionality with more established lightning detection systems (Abarca et al. 2010).

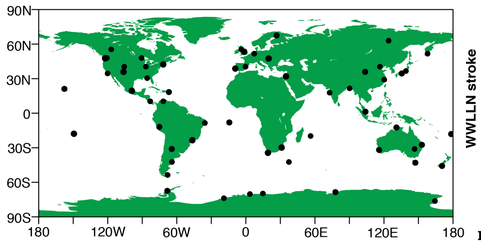


Figure 2: Locations of the over 50 sensors that make up the WWLLN.

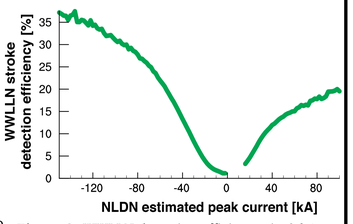


Figure 3: WWLLN detection efficiency, in 2 kA bins, using the NLDN as ground truth.

Data and Methodology

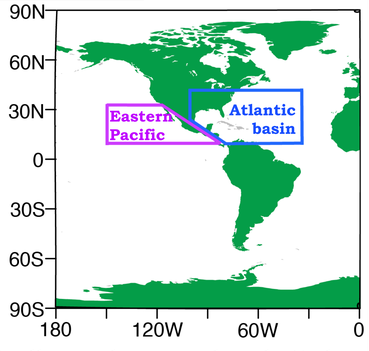
With confidence in the WWLLN's detection abilities, we have studied:

74 **Atlantic basin** TCs, 2004-2007

99 **Eastern Pacific** TCs, 2004-2009

867, six hour individual time periods (ITPs) with WWLLN flashes within 300 km of the TC center in two radial ranges:

inner core and **outer bands**



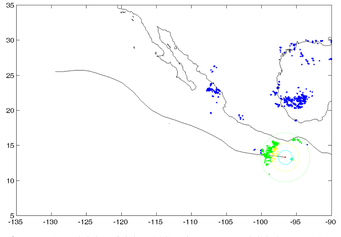


Figure 4: 1200-1800 UTC 19 August 2005 WWLLN flashes. The track (black), and the inner core (<100 km; yellow) and outer band (100-300 km; green) regions, of Hurricane Hilary are noted.

Specifically, we have explored: 1) the relationship between TC intensity, intensity change and lightning, 2) the radial and azimuthal distribution of flashes in the two basins, 3) the diurnal cycle of lightning flashes, and 4) the modulation of lightning flashes by sea surface temperature (SST).

Lightning and Intensity Change

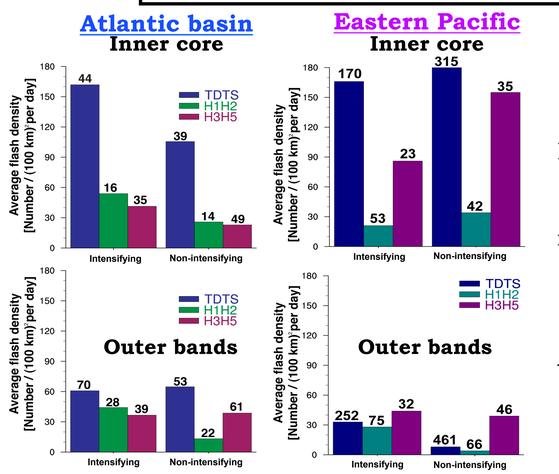


Figure 5: Average flash density for intensifying and non-intensifying TCs, in the core (top row) and outer bands (bottom row) in the Atlantic (left) and Eastern Pacific (right). The number on each bar is the number of ITPs used to calculate the average.

In both basins, the inner core is more active than the outer rainbands.

In the **Atlantic**, the flash density in the core is larger in intensifying periods for all TC strengths.

In the **Eastern Pacific**, however, the flash rate in the core is larger for non-intensifying time periods, especially for the strongest TCs.

Lightning and SSTs

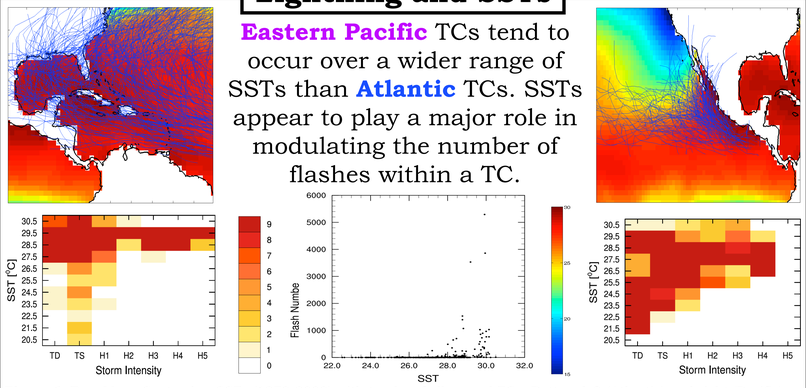


Figure 6: Top: Mean September SSTs (1970-2009) with tracks of all named TCs. Bottom left (Atlantic) and right (Pacific): Distribution of all ITPs as a function of SST and intensity. Bottom center: Number of flashes per ITP as a function of SST.

Eastern Pacific TCs tend to occur over a wider range of SSTs than **Atlantic** TCs. SSTs appear to play a major role in modulating the number of flashes within a TC.

Azimuthal Distribution of Lightning

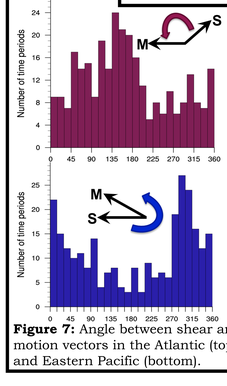


Figure 7: Angle between shear and motion vectors in the Atlantic (top) and Eastern Pacific (bottom).

Corbosiero & Molinari (2003) showed that the lightning asymmetry attributed to storm motion is largely an artifact of the shear signature, and depends on the relative directions of the shear and motion vectors.

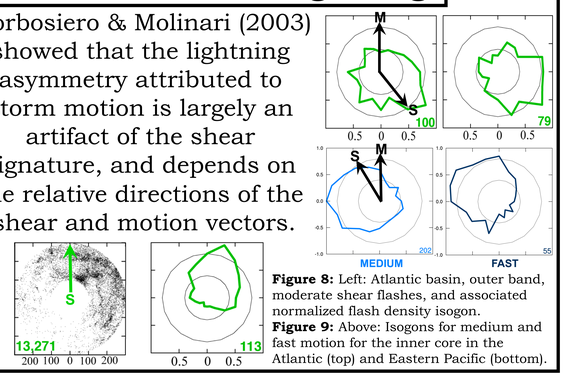


Figure 8: Left: Atlantic basin, outer band, moderate shear flashes, and associated normalized flash density isogon.

Figure 9: Above: Isogons for medium and fast motion for the inner core in the Atlantic (top) and Eastern Pacific (bottom).

Hurricane Earl (2010)

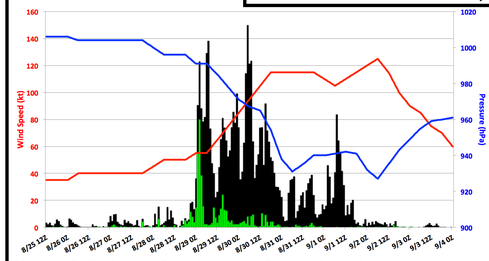


Figure 10: Evolution of maximum wind speed (kt; red), minimum central pressure (hPa; blue), and normalized r=0-500 km (black) and inner core (r < 100 km; green) flash counts in Hurricane Earl (2010).

As part of the NASA Genesis and Rapid Intensification Processes (GRIP) field campaign, the rapid intensification (RI) of Hurricane Earl (2010) was extensively sampled by multiple in situ aircraft, radars, and dropsondes.

Earl was one of the most electrically active TCs to be observed by the WWLLN, with two significant convective outbreaks in the core and extensive outer rainbands consistently oriented downshear to downshear right of the center.

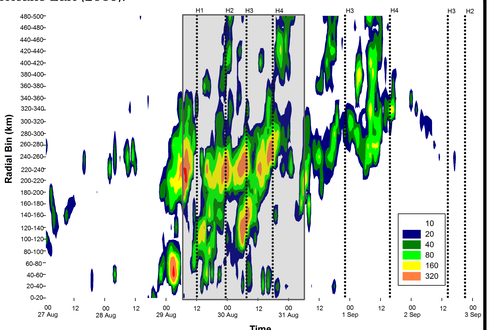


Figure 11: Hovmöller of WWLLN flashes in Hurricane Earl (2010). The gray area denotes the time period of rapid intensification.

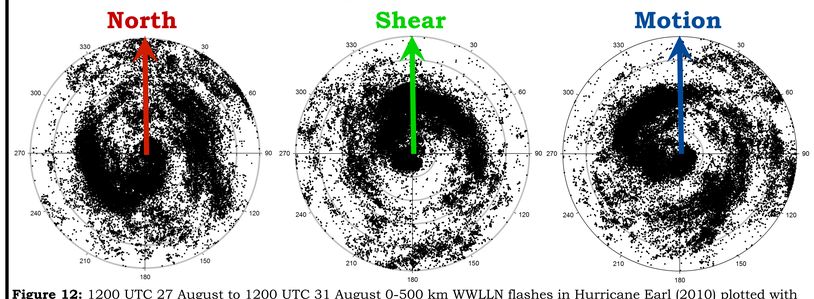


Figure 12: 1200 UTC 27 August to 1200 UTC 31 August 0-500 km WWLLN flashes in Hurricane Earl (2010) plotted with respect to geography (left), and rotated such that the shear (middle) and motion (right) vectors for each ITP point due north. Light gray range circles mark 100 km increments from the center.

The inner core convective burst that immediately preceded the RI of Earl occurred in the upshear left quadrant, contrary to the expected downshear left asymmetry in a storm embedded in 8–9 m s^{-1} of vertical wind shear.

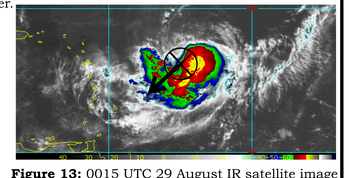


Figure 13: 0015 UTC 29 August IR satellite image of Earl. The "X" marks the NHC best track center, and the arrow is the direction of the shear.

Acknowledgements

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