FINAL REPORT

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Partners Project:
Forecasting Tropical Cyclone Intensity Change:
Assessing the Impact of Inner Core Lightning Bursts
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Section 1. Summary of Project Objectives

The main objective of this project was to reconcile the discrepancies among previous studies on the intensity changes observed in tropical cyclones with an inner core lightning burst. The GOES-R Geostationary Lightning Mapper (GLM) will provide unprecedented, continuous coverage of lightning over the open oceans; thus, investigating inner core lightning could increase the utility of the GOES-R GLM data in tropical cyclone intensity forecasting. We hypothesized that the trend in intensity prior to the inner core lightning burst and/or the relative location of the inner core lightning burst play a key role in determining whether a tropical cyclone will intensify or weaken. Specifically, the research objectives of this project were to:

1. Create a database of inner core lightning bursts in Atlantic and eastern Pacific Ocean basin tropical cyclones
2. Analyze intensity changes 24 hours prior to, and following, each identified burst
3. Determine if each burst is located radially inside, or outside, the radius of maximum wind
4. Examine the location of each burst relative to the direction of environmental vertical wind shear
5. Develop guidelines and operational forecast tools that may be incorporated into NHC's guidance suite to aid in forecasts of tropical cyclone intensity change

Section 2. Project Accomplishments and Findings

A database of inner core lightning bursts (research objective 1) was created for Atlantic and eastern Pacific Ocean basin tropical cyclones from 2005–2014 using the World Wide Lightning Location Network (WWLLN). Inner core lightning bursts were identified if the following criteria were met: (1) maximum hourly lightning flash density on an 8 km x 8 km grid (i.e., the expected nadir resolution of the GOES-R GLM) within the specified inner core annulus must exceed the upper quartile of all tropical cyclone hours with at least one flash, and (2) average hourly lightning flash density within the specified inner core annulus must fall in the upper quartile of all tropical cyclone hours with at least one flash. The inner core annulus was defined as 0–150 km for tropical depressions, tropical storms, and minor hurricanes, and 0–100 km for major hurricanes.

These criteria resulted in a database of 719 (524) inner core lightning bursts (Figure 1) in the Atlantic (eastern Pacific) basin on which to evaluate research objectives (2)–(4).

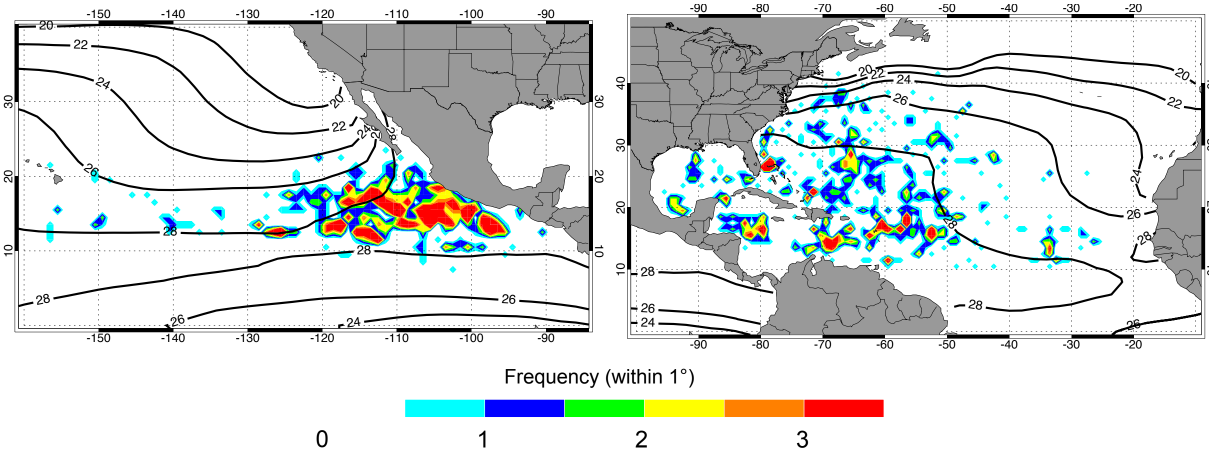

Figure 1. *The density of inner core lightning bursts (shaded) and the mean September sea surface temperature for each basin (°C; contours) in the eastern Pacific (left) and Atlantic (right) basins.*

Evaluating research objective 2, 24 h after an inner core lightning burst, more tropical cyclones intensify ($\Delta v > 10$ kt) than weaken ($\Delta v < -10$ kt), though most remain steady (-10 kt $\leq \Delta v \leq 10$ kt). No relationship was found between the prior and future intensity change (Figure 2). Persistence was the strongest signal, though tropical cyclones that intensified after an inner core lightning burst were more likely to be steady or intensifying prior to the burst onset.

Examining the location of the burst relative to the direction of the environmental vertical wind shear (research objective 4), no clear relationship was found (Figure 3). While more tropical cyclones intensified with a downshear burst, there were still a number of tropical cyclones that weakened. Furthermore, the hypothesis that upshear inner core lightning bursts may be more beneficial for intensification was proven to be untrue for all tropical cyclones.

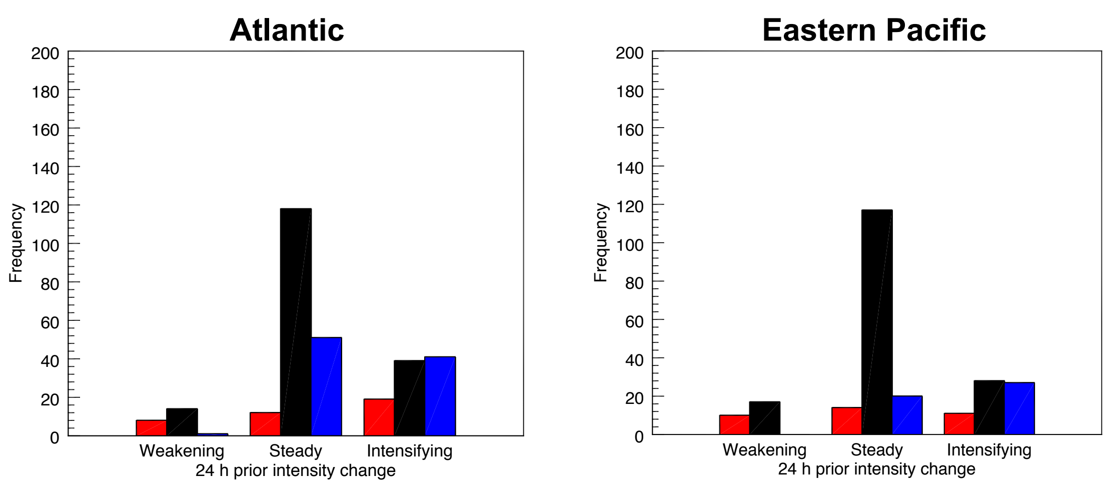

Figure 2. *The frequency of inner core lightning bursts in the Atlantic (left) and eastern Pacific (right) that weakened (red), remained steady (black), and intensified (blue) 24 h after an inner core lightning burst for the given 24 h prior intensity changes.*

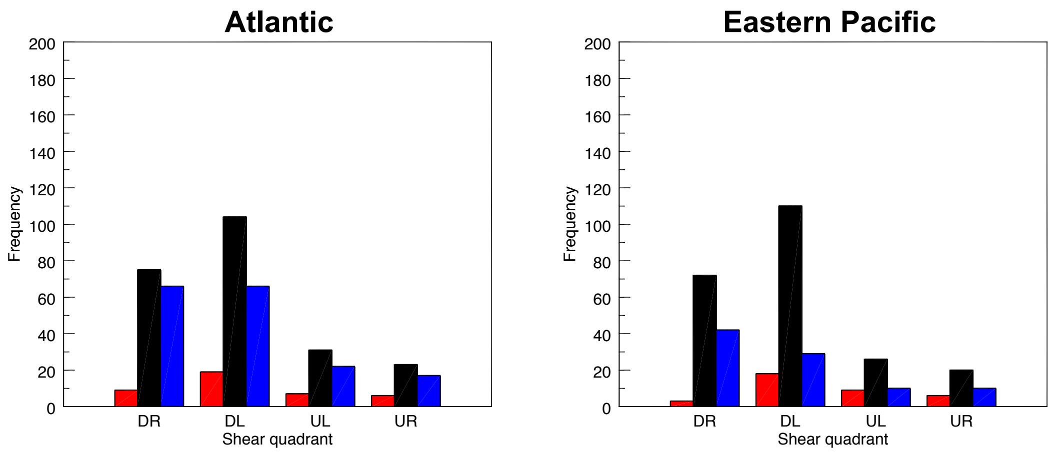

Figure 3. *The frequency of inner core lightning bursts in the Atlantic (left) and eastern Pacific (right) that weakened (red), remained steady (black), and intensified (blue) 24 h after an inner core lightning burst occurring in the given shear quadrant (DR: downshear right; DL: downshear left; UL: upshear left; UR: upshear right).*

The clearest signal from our analysis was found in the location of the inner core lightning burst with respect to the radius of maximum wind (research objective 3). While an accurate radius of maximum wind could not be determined for all inner core lightning bursts in the database, a robust number of cases were analyzed using flight level tangential wind profiles from aircraft reconnaissance flight legs identified in the Extended Flight Dataset (FLIGHT+). Tropical cyclones with the burst located near or inside the radius of maximum wind intensified, while those located near or outside the radius of maximum wind weakened (Figure 4). The number of cases in this analysis will continue to increase as slight modifications are made to the criteria to identify flight legs with a relevant radius of maximum wind.

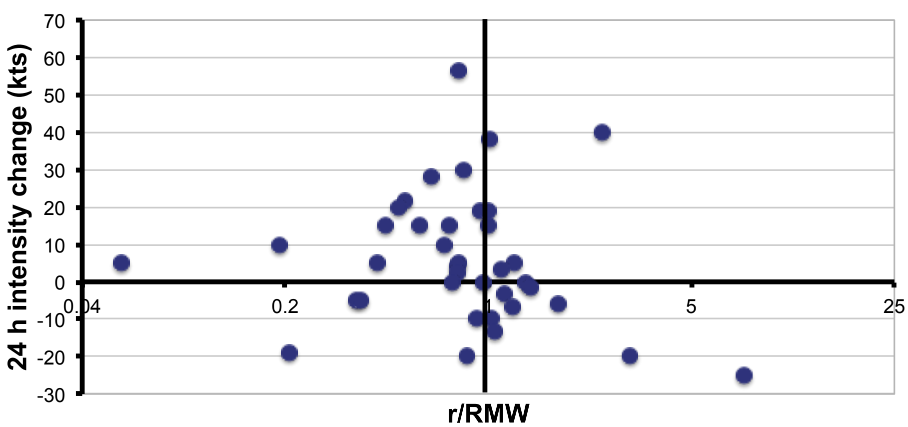

Figure 4. *Scatterplot of lightning burst locations relative to the radius of maximum wind (r/RMW) and the observed 24 h intensity change.*

The results of the inner core lightning burst analysis were shared with NHC Technology and Science Branch staff member Matt Sardi. PI Corbosiero and graduate student Stephanie Stevenson produced example products (research objective 5) that could be incorporated into the NHC forecast guidance suite, including: (1) a time series of lightning flash density in the inner core and some measure of intensity (i.e., minimum pressure or maximum wind), and (2) an IR satellite image with lightning density, the radius of maximum wind, and the shear direction overlaid. Given that a lightning density map is already available in the NHC forecast suite, the second product may be easier to annotate for further utility. Implementing these products is an ongoing part of this project.

Section 3. Benefits and Lessons Learned: Operational Partner Perspective

This project was very beneficial to NHC. It provided guidance on new methods for displaying lightning data on NHC's operational N-AWIPS and AWIPS systems. The importance of the radial location of the inner core lightning is motivating new lightning density display products that will include flight level wind data and radius of maximum wind estimates when available. This product will help forecasters determine when inner core lightning might be an indicator of tropical cyclone intensification, rather than weakening. This work will also help to guide the quantitative use of GLM data in NHC's statistical intensity forecast models. The results of this project indicate that the predictor development should concentrate on the radial distribution of lightning, and that the azimuthal distribution is of lesser importance. Results from other GOES-R projects suggest that it may be possible to estimate the RMW from IR satellite imagery for storms with eyes. Those estimates from the ABI can be used when aircraft observations are not available.

Section 4. Benefits and Lessons Learned: University Partner Perspective

This collaboration was beneficial for PI Corbosiero and graduate student Stevenson. Both attended the NHC GOES-R/JPSS Proving Ground meeting in January 2016 and met with NHC Technical and Science Branch Support Staff member Sardi in September 2016. These meetings allowed both to gain an understanding of the forecast suite available to forecasters at NHC and how lightning is currently used in the forecast process. PI Corbosiero and graduate student Stevenson were also exposed to several satellite products, some of which are in development, that have useful applications to tropical cyclone observations and research. Both were able to meet with forecasters at NHC, as well, and learned that the radius of maximum wind is often estimated with various methods by different forecasters when reconnaissance aircraft data is not available. This collaboration resulted in PI Corbosiero and graduate student Stevenson accepting an invitation to attend the GOES-R launch in November 2016, as well as attend a science meeting just prior to the launch.

While no major problems were encountered during this project, there was a delay in gaining access to the Extended Flight Dataset (FLIGHT+) from Jonathan Vigh that slowed progress on research objective (3). Additionally, several methodologies to define an inner core lightning burst were tested over the course of this research project.

Section 5. Publications and Presentations

5.1 Publications

Stevenson, S. N., K. L. Corbosiero, and M. DeMaria, 2017: A 10-year survey of tropical cyclone inner core lightning bursts and their relationship to intensity changes. *Wea. and Forecasting*, in preparation.

5.2 Presentations

Stevenson, S. N., and K. L. Corbosiero, 2016: Understanding the relationship between lightning activity and intensity change in tropical cyclones. *32nd Conference on Hurricanes and Tropical Meteorology*, 19 April, San Juan, PR.

Stevenson, S. N., K. L. Corbosiero, and M. DeMaria, 2016: Lightning and TC intensity change. *Review of 2015 NHC GOES-R/JPSS Proving Ground*, 27 January, Miami, FL.

Stevenson, S. N., and K. L. Corbosiero, 2016: Lightning observations in Atlantic and East Pacific TCs. *Hurricane Research Division Seminar*, 28 January, Miami, FL.

Stevenson, S. N., and K. L. Corbosiero, 2015: The relationship between lightning activity and intensity changes in tropical cyclones. *17th Cyclone Workshop*, 28 October, Pacific Grove, CA.

Section 6. Summary of University/Operational Partner Interactions and Roles

UAlbany PI Corbosiero and graduate student Stevenson accomplished research objectives (1)–(4), with input on task (3) from NHC Partner DeMaria. Progress on the project and suggestions for improvements in the analysis were discussed between PIs Corbosiero and DeMaria, and graduate student Stevenson, at the NHC GOES-R/JPSS Proving Ground meeting in January 2016 and at the 32nd Conference on Hurricanes and Tropical Meteorology in April 2016. Additionally, PI Corbosiero and graduate student Stevenson met with NHC Technology and Science Branch Support Staff member Sardi in September 2016 to discuss the results and ways to implement the findings in the display systems utilized by NHC forecasters.