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ANALYSIS OF HURRICANES USING LONG-RANGE LIGHTNING DETECTION NETWORKS

Benjamin C. Trabing[1] and John A. Knaff[2]
[1]*University of Oklahoma/NSSL, Norman, OK*
[2]*NOAA Center for Satellite Applications and Research, Fort Collins, CO*

1. Introduction

Since tropical cyclones (TCs) are not easily accessible to make in situ measurements, lightning, which is fundamentally related to moist convection and can be detected remotely, could be a valuable tool in decreasing forecast errors. Molinari et al. (1994) found that in Hurricane Andrew, an outbreak of lightning occurred in the eyewall prior to each and every intensification period. DeMaria et al. (2012) found contradictory results using six-hourly lightning density from the World Wide Lightning Location Network (WWLLN; Rodger et al. 2006) to analyze rapid intensity changes in TCs from 2005 to 2010 in both the Atlantic and East Pacific basins. The study found that storms with eyewall lightning tended to decrease in intensity during the following 24 hours while those same TCs with rainband lightning tended to increase in intensity.

In 2016, the next generation (R-series) Geostationary Orbiting Environmental Satellite (GOES-R) will be launched. This satellite will be equipped with the Geostationary Lightning Mapper (GLM; Goodman et al. 2013) that will provide continuous total lightning measurements with nearly uniform spatial resolution. In preparation for this new forecasting and research tool, this study analyzes hourly lightning activity of several TC cases, exploring the use of this new data for TC intensity change forecasts by using ground-based long-range lightning detection networks as a proxy.

2. Methodology

The WWLLN and Earth Networks Total Lightning Network (ENTLN) were used to analyze five tropical cyclones that traversed both long-range lightning network's domains. The storms were selected for this study based on the conditions that rapid intensification (RI), an increase of 25 knots in 24 hours, occurred while in range of both networks. These storms were then analyzed in conjuncture with infrared (IR) and microwave (MI) satellite imagery, and deep layer (850 hPa to 200 hPa) vertical wind shear vectors from the Statistical Hurricane Intensity Prediction Scheme (SHIPS; DeMaria et al. 2005) diagnostic files (SHIPS, cited 2015). Storm center location and intensity was taken from the National Hurricane Center (NHC) Best Track dataset when available. For the 2015 storms, preliminary center and intensity measurements from the NHC were used. The storm track, intensity, and shear was linearly interpolated hourly to better co-locate the storm center and lightning data.

This study will examine the location of hourly binned lightning relative to storm motion and shear. A spatial analysis of lightning within each TC will be conducted by overlaying the lightning with enhanced (grayscale) digital IR. Azimuthal averages of lightning within the predefined storm regions will give a better understanding of the changing lightning patterns over the desired time periods. The eyewall, with a radius extending 50 km, was examined in depth because its dynamical importance to intensification processes (Rogers et al. 2013).

3. Results

The temporal evolution in hourly intervals of the five cases can be seen in the entirety of Figure 1. During the examined time periods of each of the five storms, eyewall lightning was primarily found just prior to, during, and at the conclusion of RI in each and every TC. This lightning in the eyewall tended to pulse, so there are often breaks in lightning followed by a subsequent burst. During RI, eyewall lightning pulsated frequently with only 1-2 hour breaks in between compared to an average between 6-8 hour breaks between pulses after RI had concluded. There was also a noticeable decline of eyewall lightning during the period of weakening in each TC.

* *Corresponding author address*: Benjamin C. Trabing, Univ. of Oklahoma, 120 David L. Boren Blvd., Suite 5900, Norman, OK 73072; email: Benjamin.C.Trabing-1@ou.edu

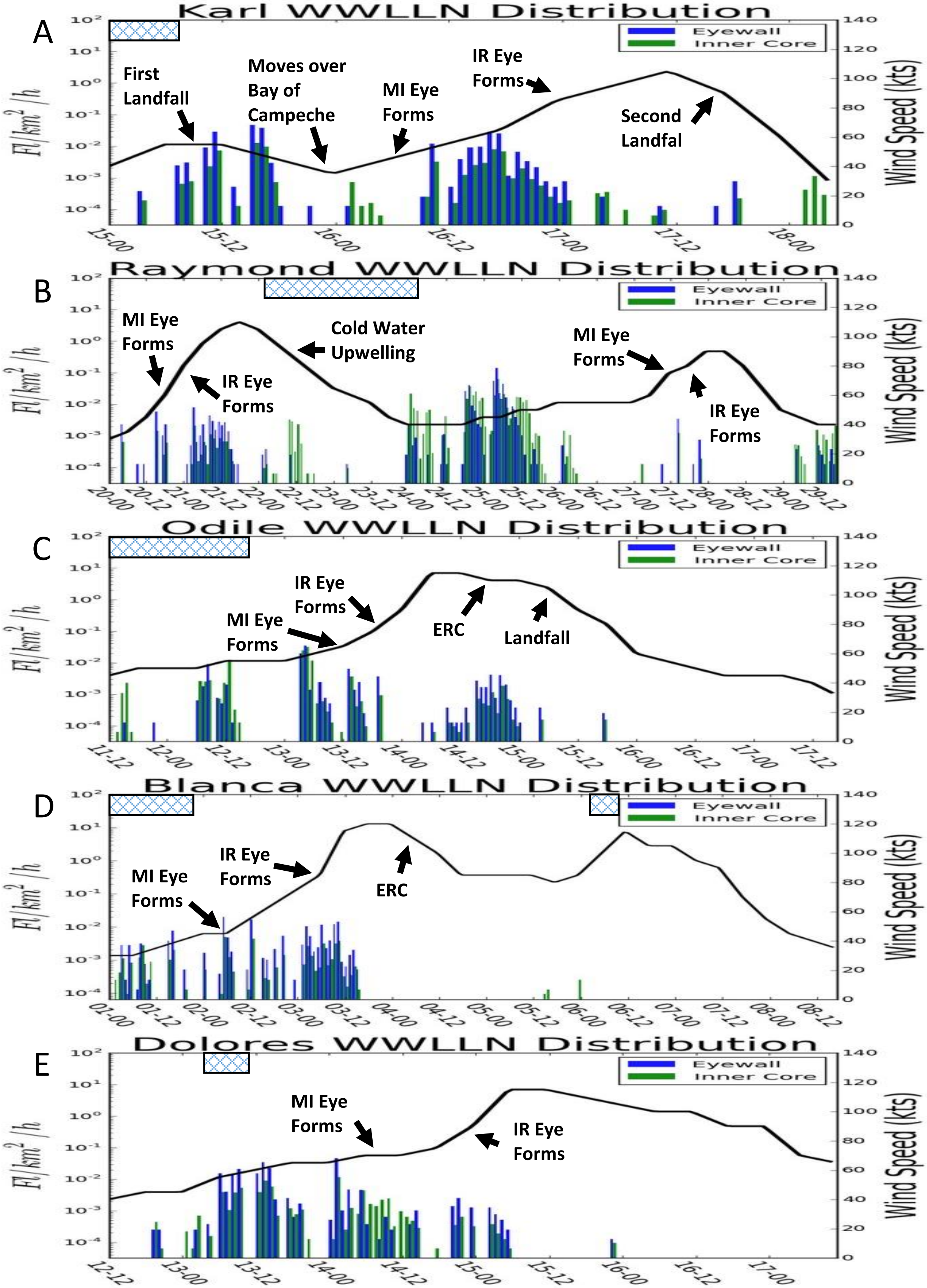

Figure 1 Temporal lightning distribution showing eyewall (blue) and inner core (green) lightning in Hurricanes Karl (A), Raymond (B), Odile (C), Blanca (D), and Dolores (E) in relation to wind speed. The blue hatched area at the top of each graph shows the time period where shear is >15 kts.

Bursts of eyewall lightning occurred prior to the development of the eye in both the MI and IR satellite imagery. Hurricane Karl was the only storm that did not have this occurrence in the MI. Lightning prior to the IR eye formation in Hurricane Odile can be seen in Figure 2. Subsequently, bursts of eyewall lightning appear to be related to rapid changes in eyewall structure. The location of lightning in each storm tended to be in the front-right quadrant relative to storm motion in the area of expected maximum wind speeds (Uhlhorn et al. 2014). It is important to note that since the networks detect primarily cloud-to-ground flashes, intracloud lightning could be going undetected.

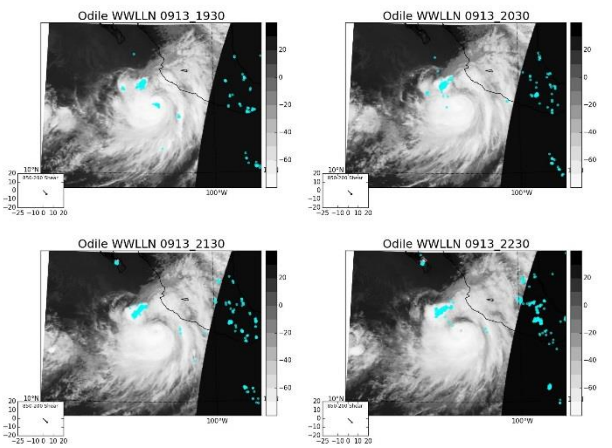

Figure 2 Hourly lightning progression with deep layer shear of Hurricane Odile showing a burst of eyewall lightning prior to eye formation in IR imagery. The top left image begins at 13 Sep 1930 UTC ending with the bottom right at 13 Sep 2230 UTC.

By examining the shear vectors of each TC, we found that when a decrease in shear occurred, subsequent bursts of lightning in the eyewall corresponded to intensification. Stronger shear persisted over several time periods in the hurricanes examined and eyewall lightning still occurred (Figure 1). This eyewall lightning could have been a product of higher shear instead of convective updrafts. In a low shear environment, lightning is indicative of updraft strengths, in contrast to lightning being enhanced by strong shear. This implies that accurate shear estimates may need to be examined along with lightning data to get the correct signal.

4. Summary

For the cases examined, results show that RI follows a burst of lightning in the eyewall when coinciding with a period of little environmental vertical shear. Eyewall lightning is associated with deep convection and strong updrafts in low shear environments (< 15 kt) that promote intensification of TCs. Lightning was found to pulse prior to, during, and at the conclusion of RI with the time between pulses decreasing as RI was occurring and increasing after. Findings also show that a burst in lightning observed in the eyewall could be used to signal eye formation in both the IR and MI, indicating structural changes in the inner core. Eyewall lightning tends to form in the front-right quadrant with respect to motion and then rotate to the storm's rear, mimicking observations and modeled mesovorticies, which may mix eye and eyewall air masses promoting further intensification.

As an indicator for intense eyewall convection and upward motion, lightning could be an important factor that could aid in the prediction of TC intensity changes. The launch of GOES-R equipped with the GLM will allow for these results to be reexamined and improved upon in the near future.

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