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Radar Reflectivity Associated with the Enveloped Eyewall Lightning Signature of Hurricane Irma (2017)

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***Abstract*—A recent publication [Vagasky, 2017a] defined a newly seen phenomenon of Enveloped Eyewall Lightning (EEL) signatures. EEL signatures are defined as an area of detected lightning that completely surrounds the eyewall of a tropical cyclone for a period of six hours or longer. Most of these signatures have been seen over the open oceans at long distances from land or out of reach of aircraft reconnaissance, making the study of the EEL signature somewhat difficult. In September 2017, Hurricane Irma passed near Puerto Rico during its period of maximum intensity, while exhibiting the EEL signature. This close pass to Puerto Rico allowed for the storm to be sampled by the San Juan NEXRAD WSR-88D Doppler Radar, enabling the comparison of lightning and radar reflectivity within the eyewall.**

***Keywords*—Tropical Cyclone Lightning; Enveloped Eyewall Lightning; Radar; Tropical Cyclones**

I. Introduction

Tropical cyclone (TC) lightning is still a relatively poorly understood phenomenon, with questions remaining about how its location and time trend may impact the intensity or track of the system [Molinari et al. 1999; Squires and Businger 2008]. Recent technological developments such as the Worldwide Lightning Location Network [Lay et al. 2004] and the Global Lightning Dataset [GLD360; Said et al. 2010] have allowed ground-based lightning location systems to detect lightning at long ranges, including over the oceans away from landmasses. Satellite advances, including the Lightning Imaging Sensor on the Tropical Rainfall Measuring Mission [Christian et al. 1992] and the Geostationary Lightning Mapper [Goodman et al. 2013] also allow lightning to be detected over oceans. These new capabilities for lightning detection have provided tropical meteorologists with new tools for monitoring and understanding tropical convection.

Using GLD360, Vagasky [2017a] examined all global TCs with a maximum intensity of 113 knots or greater between 2012 and 2016 for lightning in the eyewall. Of the 82 TCs examined, 32 exhibited the Enveloped Eyewall Lightning (EEL) signature. As defined in Vagasky [2017a], an EEL signature is an area of detected lightning that completely surrounds the eyewall of a TC for a period of six hours or longer. Most of the EEL signature TCs (18) occurred in the West Pacific, where there is limited aircraft reconnaissance and poor radar coverage.

Hurricane Irma (Fig. 1) developed on 30 August 2017 in the Eastern Atlantic Ocean, and progressed west across the basin, making multiple landfalls and eventually dissipating over Georgia on 12 September 2017. Hurricane Irma reached a maximum intensity of 160 knots, becoming the strongest hurricane in the open Atlantic on record. On 6-7 September 2017, Hurricane Irma passed over the British Virgin Islands and near Puerto Rico. This close path to Puerto Rico enabled sampling of Hurricane Irma by the San Juan NEXRAD Doppler radar.

Weather radar has been critical for studying TCs since its development in the 1940s. Weather radar has been used to study the structure of TCs, monitor track and intensity changes, and forecast severe weather at landfall, among other uses [Marks and sources within 2003]. Vagasky [2017b] performed a cursory examination of radar reflectivity and lightning within Super Typhoon Meranti (2016) and found that eyewall lightning ceased when the eyewall was disrupted by southern Taiwan.

This paper compares eyewall lightning detected by GLD360 and radar reflectivity measured by the San Juan NEXRAD Doppler radar at two points of Hurricane Irma's lifecycle. First, at Hurricane Irma's peak intensity as it passed over the British Virgin Islands, and second, during an eyewall replacement cycle (ERC) approximately 4 hours later.

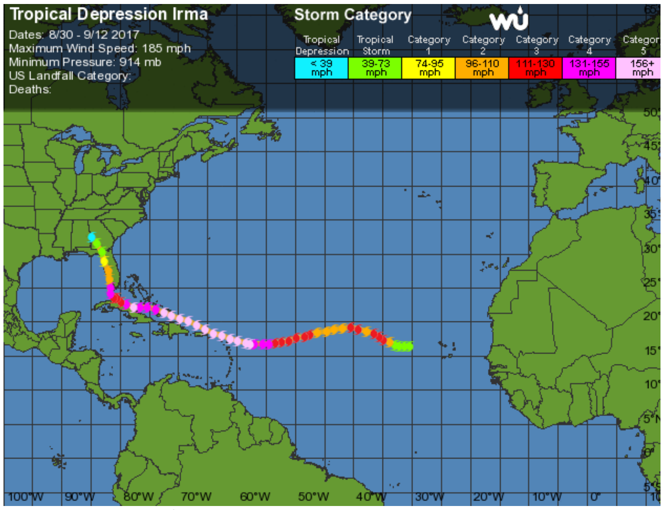

Fig. 1. Track map of Hurricane Irma (2017). Position is color-coded by intensity. Available at: https://www.wunderground.com/tropical/tracking/at201711.html

II. Lightning and Radar in Hurricane Irma (2017)

A. At peak intensity

We first examine Hurricane Irma shortly after making landfall on the US and British Virgin Islands on 6 September 2017, during the 30 hour period of Irma's peak intensity of 160 knots. Fig. 2 shows the radar reflectivity of Hurricane Irma at 1809 UTC with GLD360 detected lightning strokes from the previous 5 minutes overlaid.

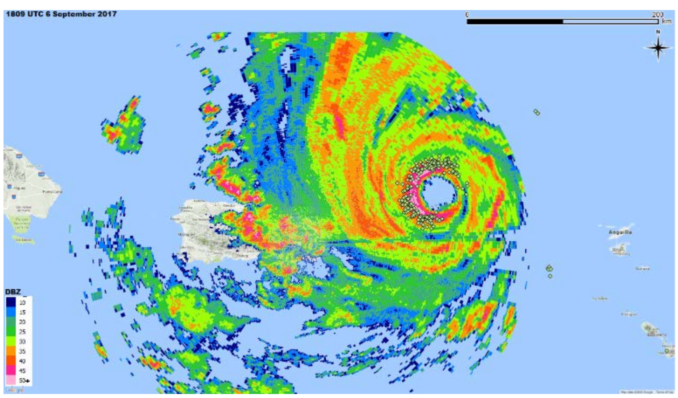

Fig. 2. GLD360 lightning strokes (small diamonds) overlaid on San Juan, Puerto Rico, NEXRAD Doppler Radar reflectivity at 1809 UTC 6 September 2017. GLD360 lightning data includes all lightning strokes detected in the 5 minutes prior to the radar image.

In Fig. 2, the eyewall lightning is concentrated in the western semicircle of the eyewall, where the highest reflectivity (greater than 50 dBZ) is located. In the eastern semicircle of the eyewall, there are fewer lightning strokes, mainly in regions greater than 40 dBZ. There is almost no lightning located in the outer rainbands of Hurricane Irma, which is consistent with other EEL signature TCs.

A closer look at the lightning stroke data appears to reveal there are two thunderstorm cells, one on the northern edge of the eyewall, and one on the southwestern quadrant. Removing the lightning data from the radar image (not shown) reveals two separate regions of enhanced (greater than 50 dBZ) reflectivity that the lightning appears to be associated with. These two cells appear to rotate around the center of circulation.

B. During an Eyewall Replacement Cycle

After 1900 UTC on 6 September 2017, a new eyewall begins to develop in Hurricane Irma, and a several hour ERC begins. For a more detailed explanation of an ERC, we refer you to Willoughby et al. [1982]. During the course of this ERC, the peak wind speed remains the same, but the central pressure fluctuates slightly.

Fig. 3 shows the radar reflectivity of Hurricane Irma at 2211 UTC on 6 September 2017 with GLD360 detected lightning strokes from the previous 5 minutes overlaid.

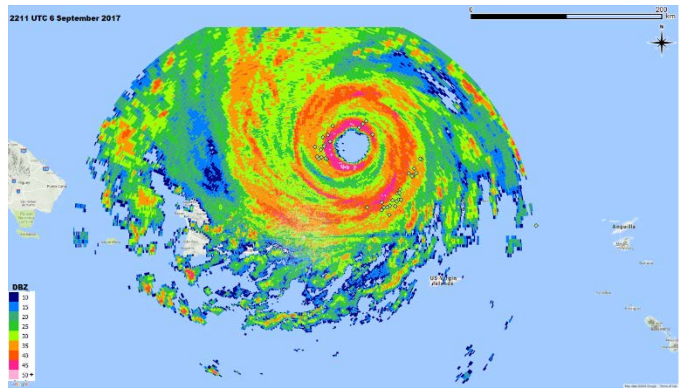

Fig. 3. As in Fig. 2, but for 2211 UTC 6 September 2017. A secondary eyewall is beginning to interact with the inner eyewall at this time.

When compared to Fig. 2, there are substantial changes. There are far fewer lightning strokes in the eyewall between 2206 and 2211 UTC, and the intensity of the convection in both the inner and outer eyewall of Hurricane Irma are reduced, with lower coverage of greater than 50 dBZ bins.

In the southeast quadrant of Hurricane Irma, the outer eyewall is beginning to interact with the inner eyewall. The inner eyewall has no lightning in this area, while the outer eyewall has lightning and is intensifying.

Overall in Hurricane Irma, there is greatly reduced lightning in the eyewalls and the storm as a whole during the ERC. This is consistent with Vagasky [2017b], which found significantly reduced lightning after the inner eyewall of Super Typhoon Meranti was disrupted.

III. Concluding Remarks

During Hurricane Irma's peak intensity, eyewall lightning was collocated with the strongest convection (highest radar reflectivity). While lightning wrapped around the entire eyewall, there were concentrated areas of greater lightning density where there was enhanced radar reflectivity. Very little lightning occurred in the outer rainbands of Irma, consistent with other TCs that exhibited the EEL signature.

As Hurricane Irma continued to the northwest after 7 September 2017, and its outer rainbands began interacting with more landmasses, lightning in the outer rainbands increased while eyewall and inner core lightning decreased (not shown). At this time, Hurricane Irma also began weakening.

TC lightning remains a topic that has a lot of potential for future study. There is potential for TC lightning to be used as a monitoring tool and a predictor for track and intensity changes. As ground based lightning location systems and satellite lightning sensors continue to improve, new opportunities to study TC lightning will continue to present themselves.

IV. Future Work

This work focused on the radar reflectivity and GLD360 detected lightning. The San Juan, Puerto Rico, NEXRAD Doppler radar was upgraded to dual polarization capability in May 2013. A more detailed examination of polarimetric radar variables and GLD360 lightning data in Hurricane Irma is planned, including comparisons of both lightning dense and non-lightning locations.

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