Analysis of Hurricanes Using Long-Range Lightning Detection Networks

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Lightning Potential

The new GOES-R satellite will be equipped with the Geostationary Lightning Mapper (GLM) that will provide unprecedented total lightning data with the potential to improve hurricane intensity forecasts. Past studies (Molinari et al. 1994, Abarca et al. 2011, and DeMaria et al. 2012) have provided conflicting interpretations of the role that lightning plays in forecasting tropical cyclone (TC) intensity changes. With the goal of improving the usefulness of total lightning, detailed case studies were conducted of five TCs that underwent rapid intensification (RI) within the domains of two unique ground-based long-range lightning detection networks.

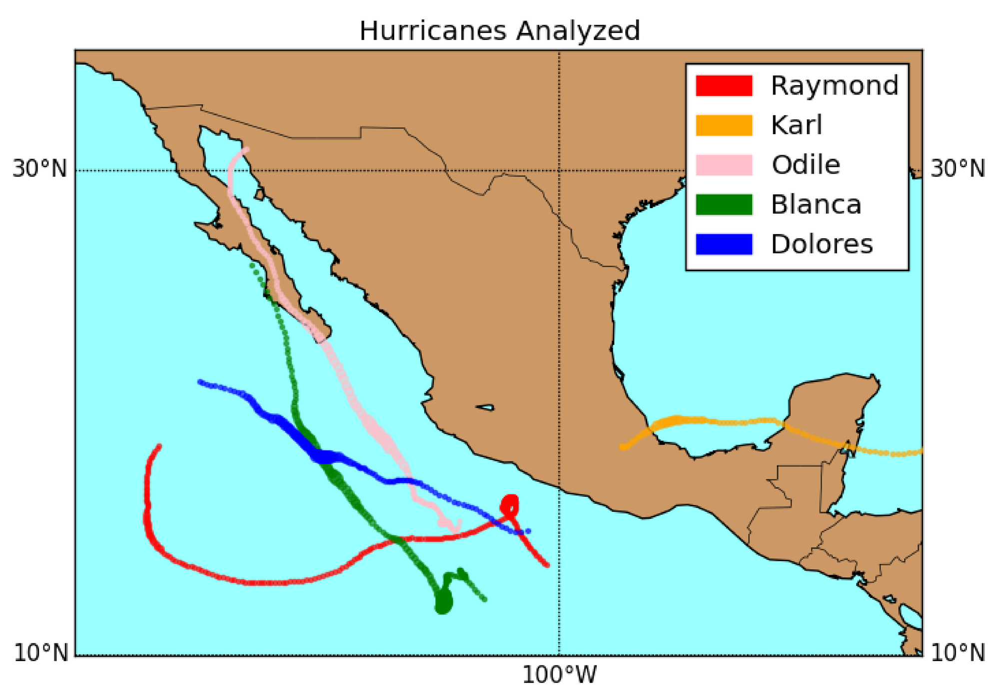

Figure 1: Tracks of the five major hurricanes examined in this study. The thickness of the line indicates strength of the storm.

Lightning Characteristics

- Three distinct regions of lightning activity are found with maxima in the eyewall and rainbands separating a minima.
- Bursts of lightning were found to exist on the order of an hour in the eyewall and several hours in the rainbands.
- Lightning tended to occur downshear-left in most but not all cases due to generally low shear.
- Lightning associated with convection never continuously persisted around an eye indicating the importance of lightning location.
- Lightning maximized in the front quadrants relative to storm motion.
- Asymmetric rainband and eyewall convection caused discontinuities in lightning features.

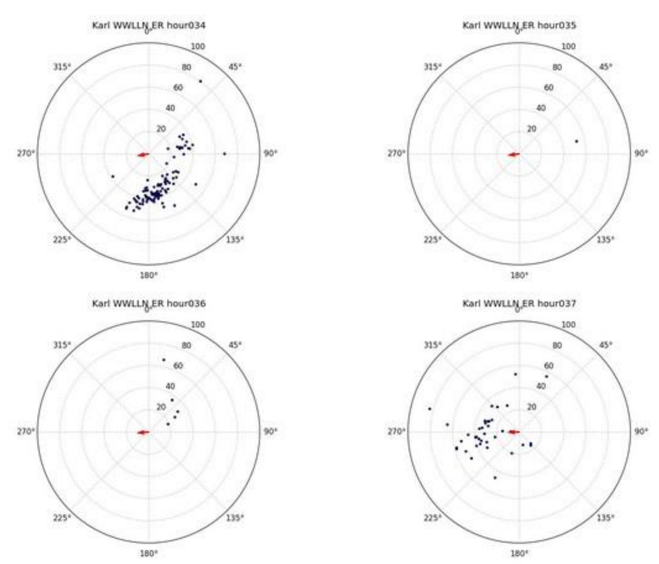

Figure 4: Hourly progressions of lightning within 100 km of Hurricane Karl's center. Bursts of lightning never persisted long enough to track around the storm center.

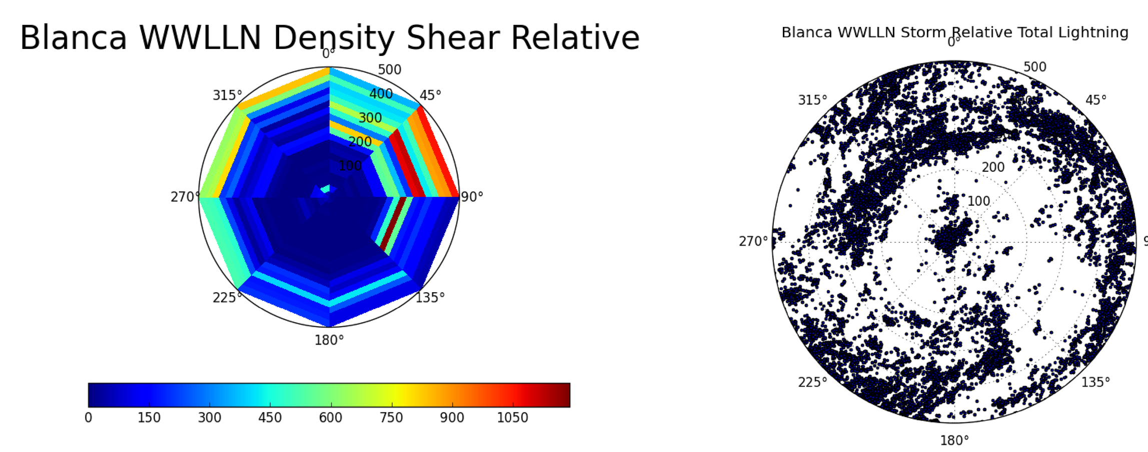

Figure 5: At left, lightning totals binned in 20 km bands relative to a northward shear relative vector. At right, storm motion relative lightning totals for Hurricane Blanca showing lightning regions.

Eyewall Lightning Indicating RI

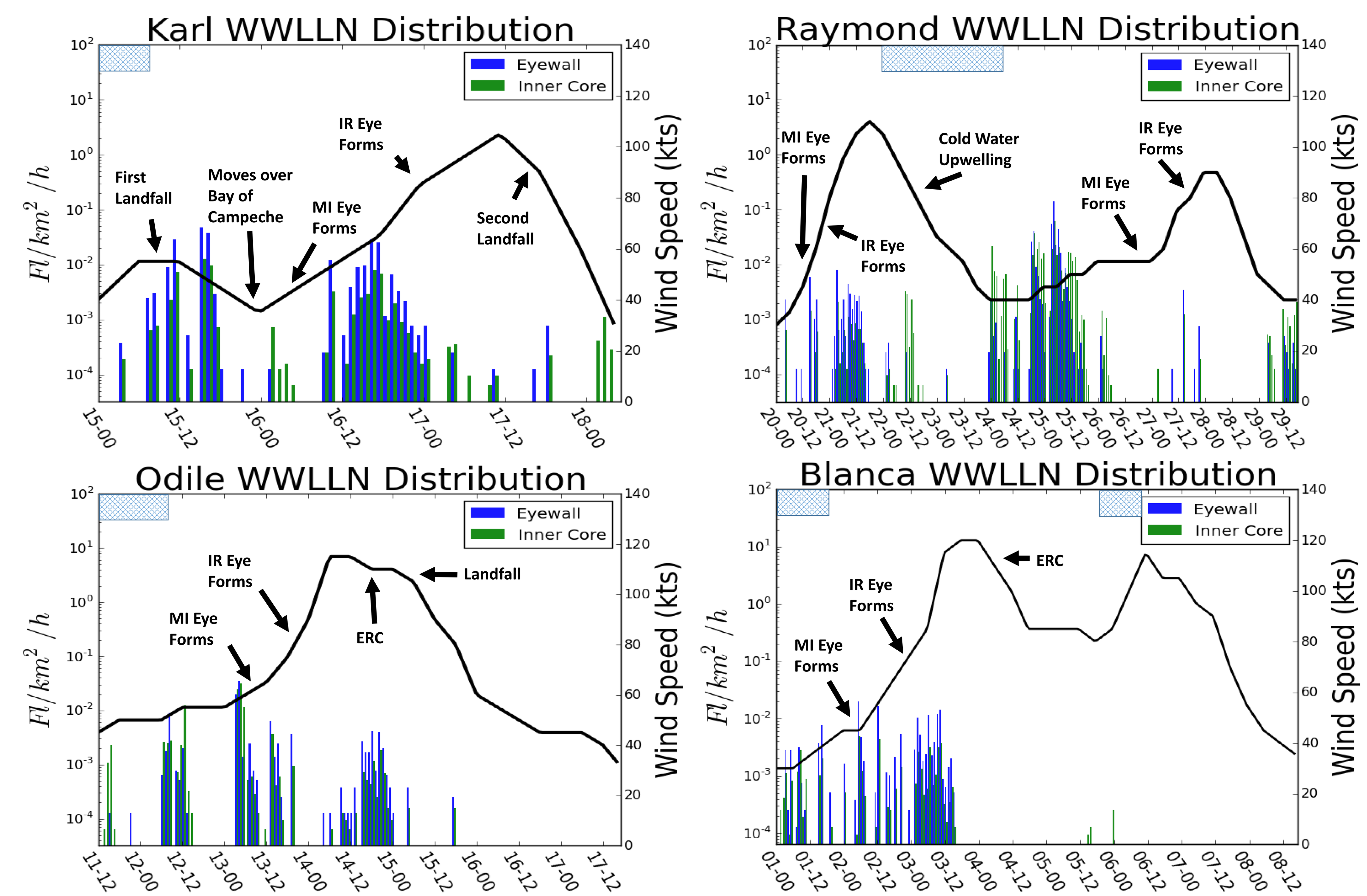

Figure 6: Temporal lightning distribution showing eyewall (blue) and inner core (green) lightning in Hurricanes Karl, Raymond, Odile, and Blanca in relation to wind speed. The blue hatched area at the top of each graph shows the time period where shear is >15 kts.

- Bursts of lightning preceded eye formation in both IR and MI imagery indicating that lightning could signal structural changes of hurricanes.
- Lightning was present in the eyewall prior to, during, and at the conclusion of RI with few eyewall flashes present in weakening stages of TCs.
- Rainband lightning had a diurnal pattern but did not show a distinct relationship to intensity change.
- Bursts of Lightning occurred prior to and during eyewall replacement cycles, but was not examined further.
- Results show the potential of the GLM to improve TC intensity forecasts.

Lightning was found to be a good indicator for intensification in low shear environments, but studies on non-intensifying cases need to be conducted.

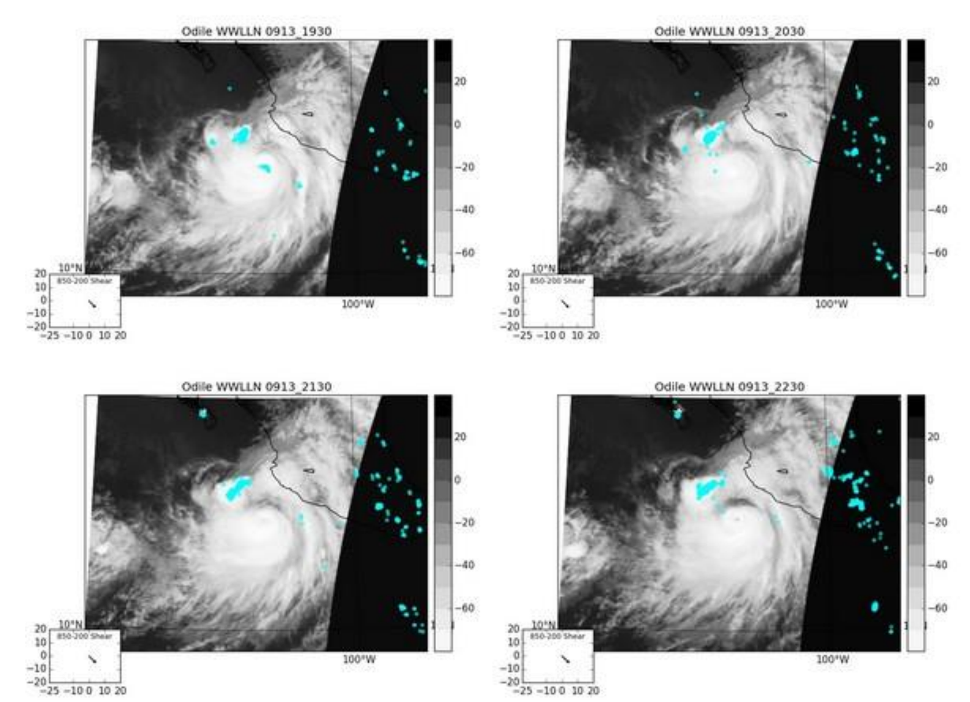

Figure 7: Hourly lightning progression of Hurricane Odile showing a burst of eyewall lightning prior to eye formation in IR imagery.

Data and Methodology

- Environmental data from SHIPS diagnostic files and storm center locations taken from the National Hurricane Center Best Track dataset when available.
- Lightning binned hourly and analyzed in relation to linearly interpolated track data and predefined storm features.
- Analyzed spatial and temporal aspects of lightning with microwave (MI) and infrared (IR) satellite imagery.

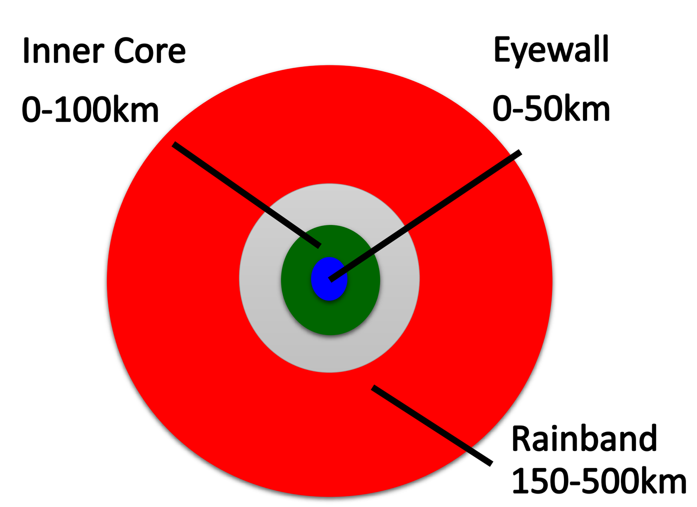

Figure 2: Predefined storm features used in the analysis. Static features used to easily incorporate results into operations.

Lightning Detection Networks

World Wide Lightning Location Network (WWLLN)

- Detects mostly cloud-to-ground discharges at VLF wavelengths
- Detection efficiency is low but consistent over oceans

Earth Networks Total Lightning Network (ENTLN)

- Detects both cloud-to-ground and intracloud flashes
- Detection efficiency limited off the coast of landmasses away from sensors

Both networks showed similar results in a spatial and temporal analysis validating the use of either network in the domain.

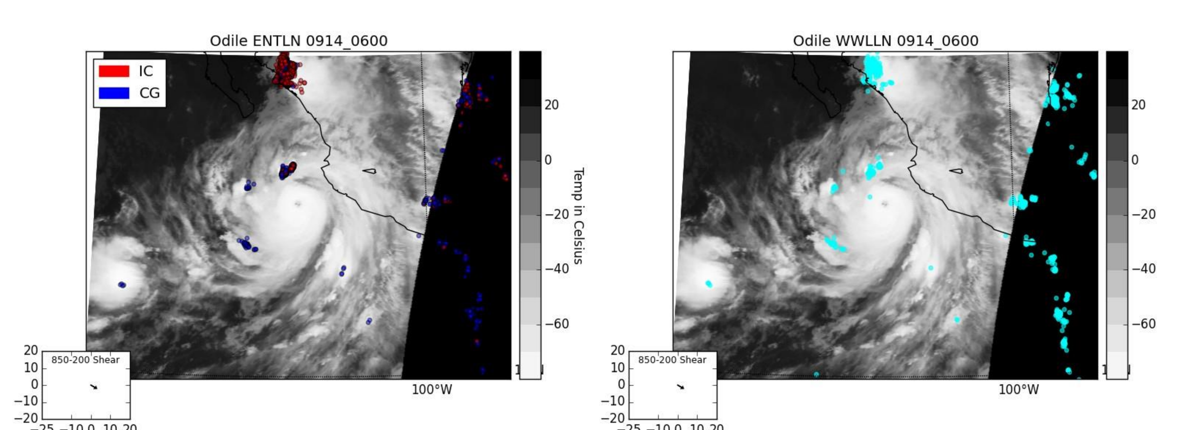

Figure 3: Similar spatial comparison of lightning in Hurricane Odile by ENTLN (left) and WWLLN (right).

References

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Molinari, J., P.K. Moore, V.P. Idone, R.W. Henderson, and A.B. Saljoughy, 1994: Cloud-to-ground lightning in hurricane Andrew. J. of Geophys. Res., 99, 16665-16676.

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