Using Total Lightning Data to Improve Real-Time Tropical Cyclone Intensity Forecasts

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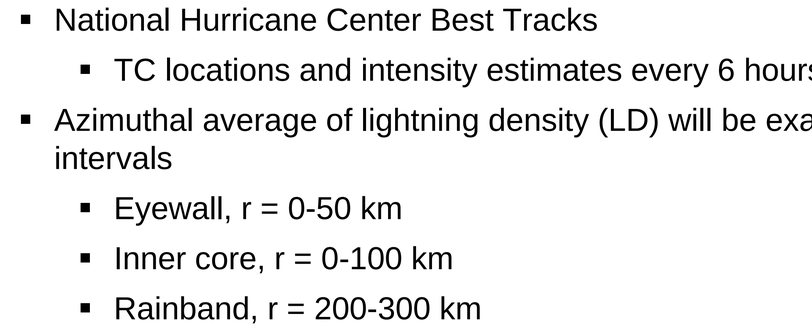
Motivation and Background

- The relationship between lightning activity and tropical cyclone (TC) intensity change is still unclear
  - Some studies show inner core lightning bursts precede TC intensification
  - Other studies show inner core lightning activity may indicate intensification is coming to an end and subsequent weakening (e.g., DeMaria et al. 2012)
  - Most studies suggest other environmental factors (e.g., vertical shear, sea surface temperature) influence both lightning activity and TC intensity change
- Limitations of current lightning data for TC research
  - Ground-based networks have low flash detection efficiency away from land
  - Low earth orbiting sensors (e.g., TRMM LIS) have low temporal frequency
- ***GOES-R Geostationary Lightning Mapper (GLM) will provide continuous lightning flash data with high (est. 75%) total lightning detection efficiency***
- In preparation for the GLM, the goal of this work to further examine relationship between *total* lightning activity and TC intensity change
  - Total lightning has been found to be better correlated with convective strength than cloud-to-ground, hence is hypothesized to be better indicator of TC intensity change
  - Past TC-lightning studies have used the World Wide Lightning Location Network (WWLLN), but we will use Earth Networks Total Lightning Network (ENTLN) because it's higher total lightning detection efficiency (Rudlosky 2015) may be a better proxy for the GLM

Data and Methodology

- World Wide Lightning Location Network (WWLLN)
  - Global flashes, 2005-2013
  - Provided by B. Callahan and S. Prinzivalli, Earth Networks Inc.
- Earth Networks Total Lightning Network (ENTLN)
  - Global flashes, 2010-2013
  - Provided by the University of Washington
- National Hurricane Center Best Tracks
  - TC locations and intensity estimates every 6 hours
- Azimuthal average of lightning density (LD) will be examined at various radial intervals
  - Eyewall, r = 0-50 km
  - Inner core, r = 0-100 km
  - Rainband, r = 200-300 km

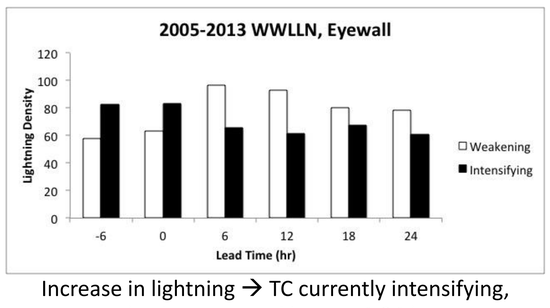
WWLLN vs. ENTLN, 2010-2013 Atlantic TCs



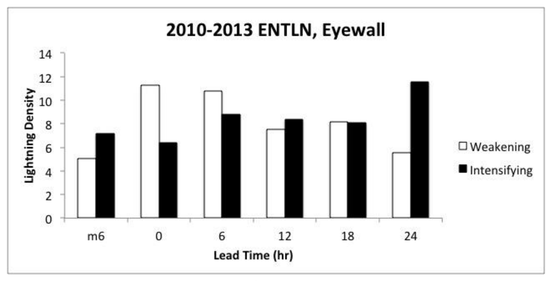
- Correlation between inner core and rainband LD, by network
  - r_{WWLLN} = 0.3
  - r_{ENTLN} = 0.5
- Correlation between WWLLN & ENTLN in different radial intervals
  - r_{IC} = 0.5
  - r_{RB} = 0.6
- Low r_{WWLLN} and r_{ENTLN} suggest lightning in inner and outer parts of TC may provide independent information
- Low r_{IC} and r_{RB} suggest different networks are providing different data (i.e., ENTLN may be providing more IC lightning flashes than WWLLN)

Lightning and TC Intensity Change

Eyewall (r = 0-50 km) - WWLLN and ENTLN provide conflicting signals

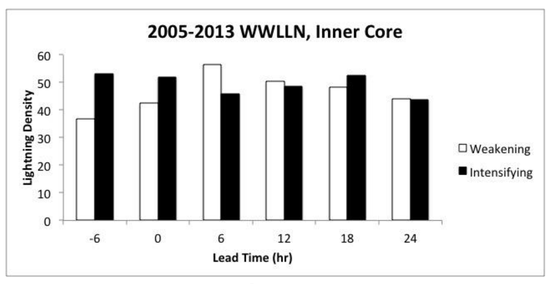


Increase in lightning → TC currently intensifying, weakening expected in next 4-24 hours

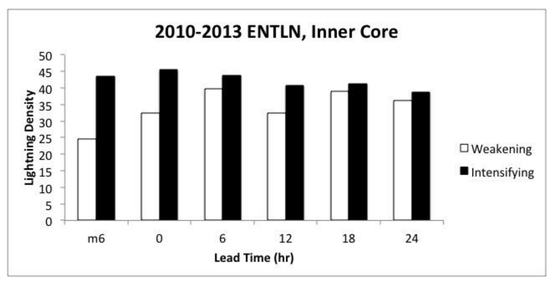


Increase in lightning → TC currently weakening, intensification expected in ~24 hours

Inner Core (r = 0-100 km) - WWLLN and ENTLN provide similar signals

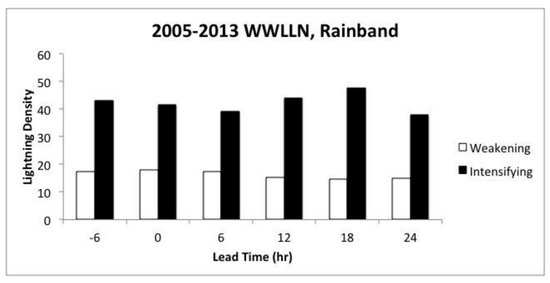


Increase in lightning → TC currently intensifying, possibly weakening in short term (next 6 hours)

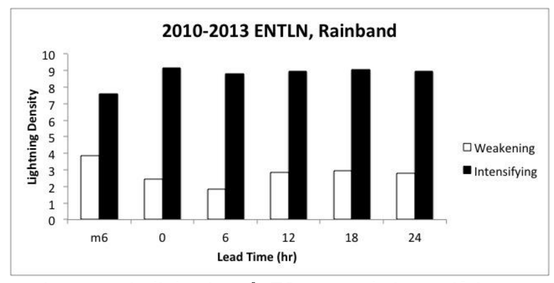


Increase in lightning → TC currently intensifying,

Rainband (r = 200-300 km) - WWLLN and ENTLN patterns very similar



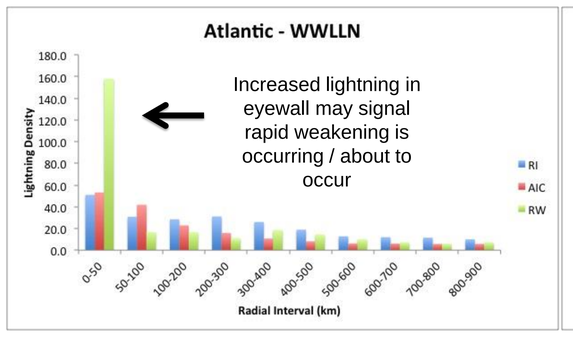
Increase in lightning → TC currently intensifying, continuing to intensify

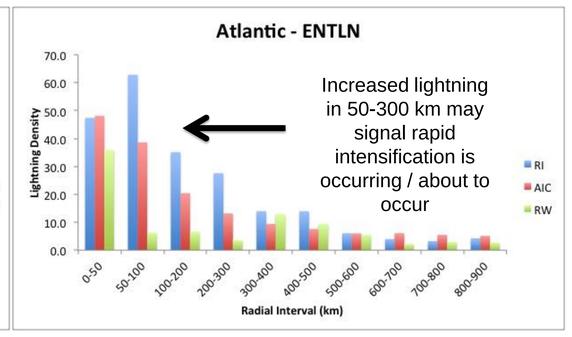


Increase in lightning → TC currently intensifying, continuing to intensify

Lightning and Rapid Intensification / Weakening

- Rapid intensification defined as $\Delta v_{max} \geq 30$ kt in 24 hours
- Rapid weakening defined as $\Delta v_{max} \leq -20$ kt in 24 hours
- Once again, the signals are mixed…





Summary and Future Work

- Similarities between WWLLN and ENTLN analyses
  - Lightning activity in TCs is episodic, more so in inner core than rainbands
  - Intensifying TCs have more lightning in rainband region than weakening TCs
- Differences between WWLLN and ENTLN analyses
  - Largest differences in eyewall region analyses
  - WWLLN suggests increase in eyewall lightning → weakening / RW
  - ENTLN suggests increase in inner core lightning → intensification / RI
- Future work
  - Examine asymmetric lightning density and relationship to TC intensity change
  - Explore relationships between LD, TC intensity change, and other environmental and storm-related conditions (shear, SST, storm motion)
  - Using variable radial intervals, based on TC size (currently fixed)
  - Incorporate ENTLN LD into the Rapid Intensification Index (RII)

- DeMaria, M., R. T. DeMaria, J. A. Knaff, and D. Molenar, 2012: Tropical Cyclone Lightning and Rapid Intensity Change, *Mon. Wea. Rev.*, **140**, 1828-1842.
- Rudlosky, S. D., 2015: Evaluating ENTLN performance relative to TRMM/LIS. *J. Operational Meteor.*, **3 (2)**, 11–20.
- Abarca, S. F., K. L. Corbosiero, and D. Vollaro, 2011: The World Wide Lightning Location Network and convective activity in tropical cyclones, *Mon. Wea. Rev.*, **139**, 175-191.