Tropical Cyclone Lightning and Rapid Intensity Change

Review of DeMaria et al (2012)

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Motivation

• Tropical cyclone intensity forecasting error is relatively high
  • Track forecast has improved faster than intensity

• Rapid intensification (RI) is particularly important, but challenging to forecast

• Inner core key to this forecast, but lack of observations here

• Lightning serves as one observation that can be measured with high spatial and temporal resolution in this region
Previous Work

- Lightning relatively rare in eyewall, only present in most vigorous updrafts
  - Could help pinpoint most convectively active regions
- Minimum in lightning found between eyewall and outer rain bands
- Evidence of positive correlation between shear and lightning
- Mixed results on correlating lightning increase with intensity increase
  - Using both LMA’s and longer range detection
- Simple argument that more lightning = more updrafts = short-term intensification may not hold
- No studies have looked at lightning as a predictive tool

Lightning Detection

• World Wide Lightning Location Network (WWLLN) used for lightning data
  • Provides lightning time and location using ground-based network of VLF detectors
• Accurate to within 15 km
• 5-10% detection efficiency
  • Primarily sees CG strokes (~3/4)
  • Should still be high enough to see lightning patterns in storms (Abarca and Corbosiero (2011))

Hurricane Ike WWLN 6hr Lightning Detection
Methods

• NHC best-track data set gathered for all storms 2005-2010
  • Atlantic and east/central Pacific Basins
  • Exclude extratropical storms and storms over land

• Add in SST and wind shear data from SHIPS dataset and GFS reanalysis, respectively

• WWLLN lightning stokes placed on to storm-relative cylindrical grid

• Divided into three regions:
  • 0-50km – Eye/Eyewall
  • 0-100km – Inner Core
  • 200-300km – Rain Bands
Temporal Variability

• Episodic patterns of increased lightning
• Inner core more variable than outer rain bands
  • 3.5x higher std. dev.
• Similar behavior in Pacific
• Consistent with previous studies

**FIG. 2.** The square root of the LD plotted as a sequential time series for all 6-h intervals for the Atlantic sample from 2005 to 2010.
Dependence on Wind Shear

• Inner core lightning density (LD) is highest with moderate shear
• Tilted PV column leads to enhanced convection through asymmetric vertical motions
• If shear is too strong, entire storm structure is disrupted
• Rain bands not tied to PV, no peak in LD with moderate shear
Intensity Change

Atlantic Eyewall

Lightning Density

-6  0  6  12  18  24

Lead Time (hr)

East Pacific Eyewall

Lightning Density

-6  0  6  12  18  24

Lead Time (hr)

Atlantic Inner Core

Lightning Density

-6  0  6  12  18  24

Lead Time (hr)

East Pacific Inner Core

Lightning Density

-6  0  6  12  18  24

Lead Time (hr)

Atlantic Rainband

Lightning Density

-6  0  6  12  18  24

Lead Time (hr)

East Pacific Rainband

Lightning Density

-6  0  6  12  18  24

Lead Time (hr)
High flash rates more often to occur before and after intensification.
High flash rates more often to occur before and after intensification

High flash rates more often to occur prior to weakening
High flash rates more often to occur before and after intensification

High flash rates more often to occur prior to weakening

Outer rain bands always have more lightning

Integrity Change
Intensity Change

• Lightning density increases during and just after intensification
• Lightning density increases 6-12 hrs before weakening
• CONCLUSION: Lightning activity increases may signal an intensification period is coming to an end, and weakening may begin

• Because lightning activity is higher in rain band region before intensification for all lead times, it may have more predictive information than inner core
Rapid Intensity Changes

• Storms that rapidly weaken in the next 24hr have a much higher LD in Atlantic
• Same pattern not evident in Pacific
  • After removing storms in cold east Pacific, trend reappears
• Rain band LD is higher for storms that undergo RI
Discussion

• Lightning in inner-core appears to occur during and just after intensification, but not necessarily ahead of it (not predictive).

• PV tilting due to shear brings on enhanced convection/lightning, but long-term effects of shear (and possibly cold pools from intense eyewall convection) are detrimental.

• Outer rain band lightning is not tied to PV-shear interactions, and LD is more just indicative of overall environmental conditions

• ERC lightning also relates to short-term intensification/long-term weakening....but most storms in this sample likely not strong enough for ERC
Use in forecasting

• Generalized Rapid Intensification Index (RII) (Kaplan et al. 2010) for addition of lightning data
  • Machine learning algorithm
  • Weight assigned to each variable indicative of how important it is

• Results show weight put on lightning data is similar to that of other variables already implemented
Conclusions

• Overall statistics appear to jive with other studies
  • Validates WWLLN data usage

• Inner core lightning appears to happen during the end of an intensification period/beginning of weakening
  • Shear $\rightarrow$ PV tilting $\rightarrow$ enhanced convection in short term
    $\rightarrow$ detrimental effects in long term
  • Eyewall replacement cycles

• Incorporation into RII adds confidence that lightning can be used as a predictive measure of intensity