Lightning in Tropical Cyclones: Applications of the GOES-16 GLM

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13 March 2018
72nd Interdepartmental Hurricane Conference
Miami, FL

Astronaut Photo
ISS042-E-135015

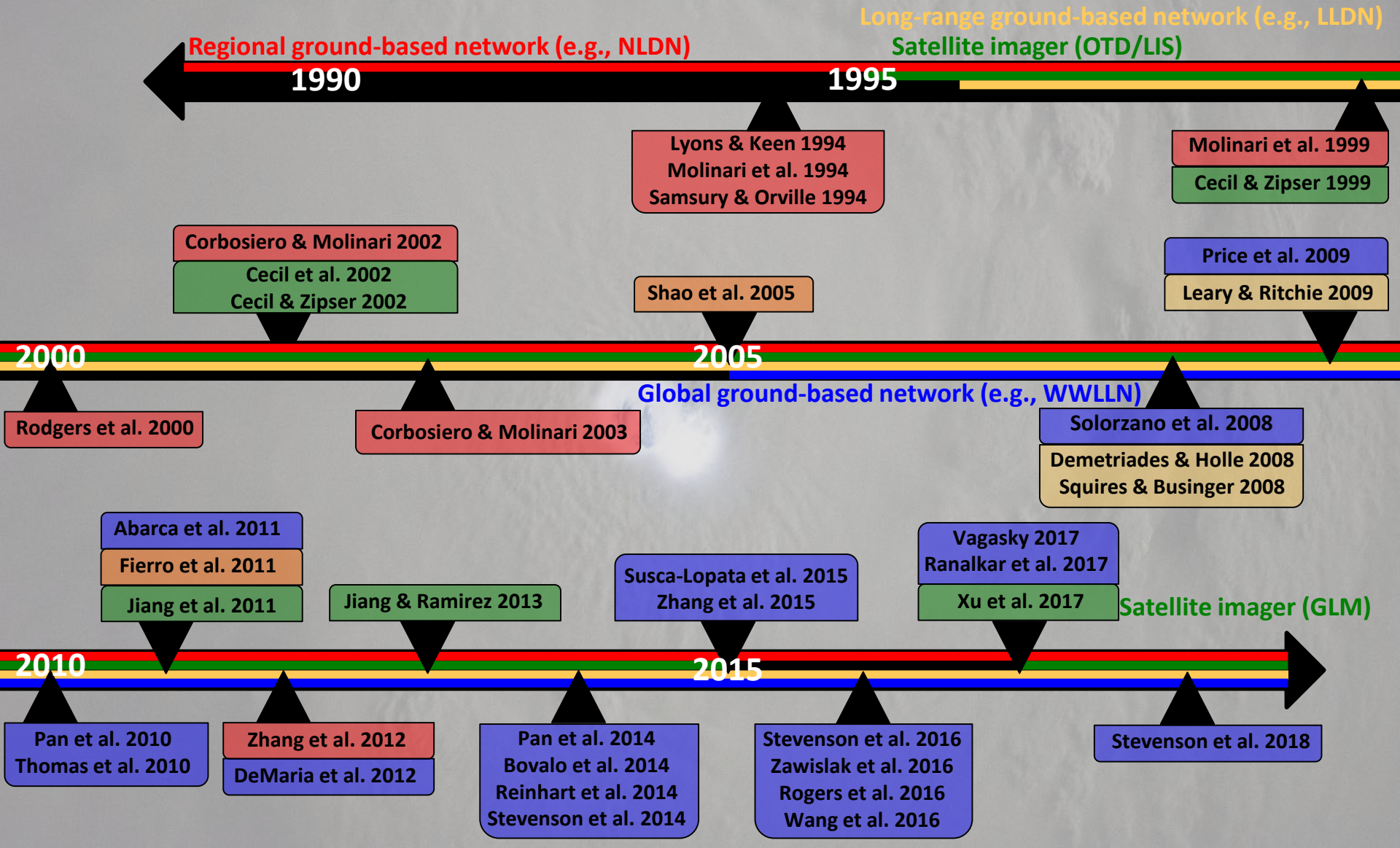
2017 Hurricane Season from GLM

Courtesy of Michael Peterson

TC lightning detection: Network pros/cons

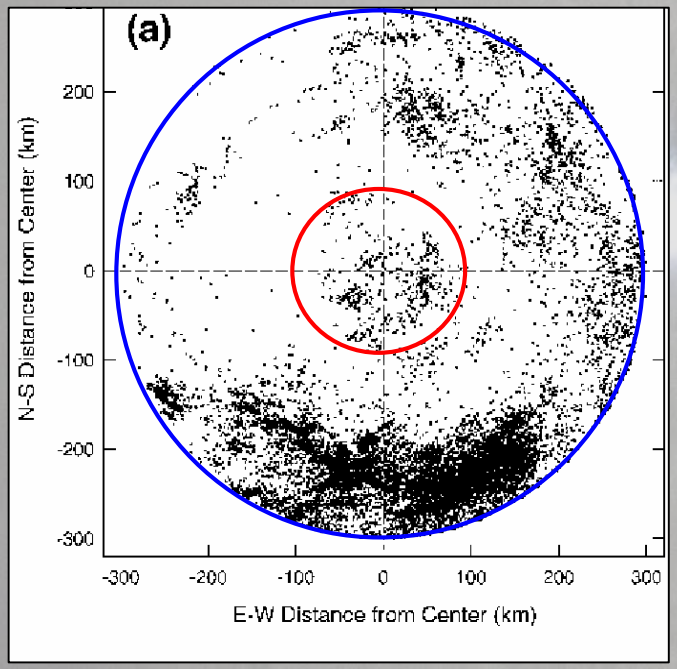
	Spatial	Temporal	Performance	Lightning Type	
	Open Ocean	Continuous	High DE	IC	CG
NLDN		✓	✓	some	✓
OTD/LIS	✓		✓	✓	✓
WWLLN	✓	✓		some	✓
GLD360	✓	✓	CG	some	✓
ENTLN	✓	✓	varies geographically	some	✓
GLM	✓	✓	✓	✓	✓

History of observational TC lightning research

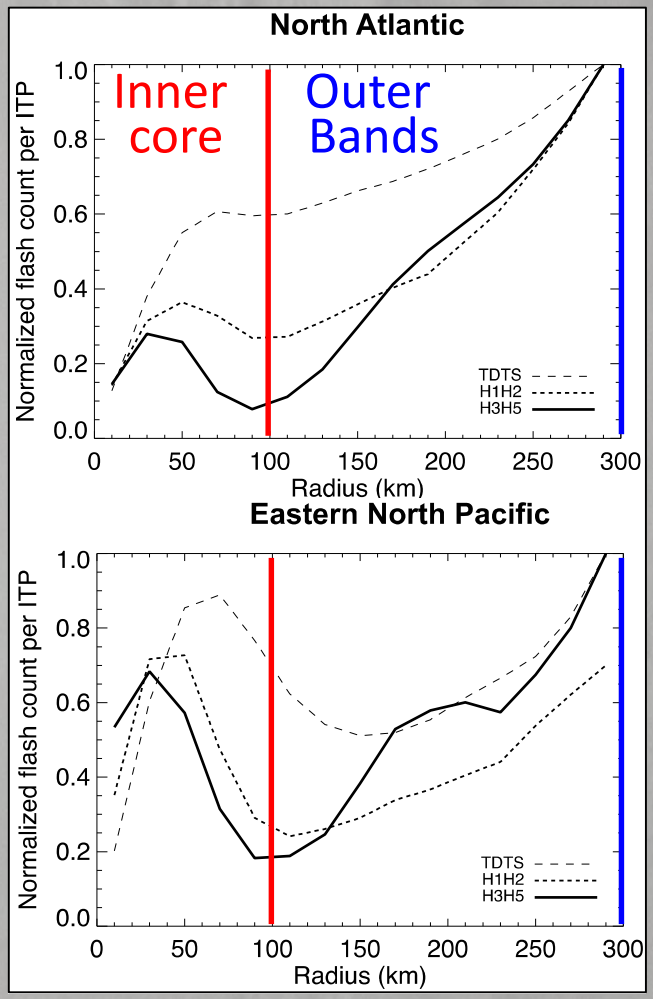


Patterns of TC lightning: Spatial

- Lightning peaks in inner core and outer rainbands, with minima in between



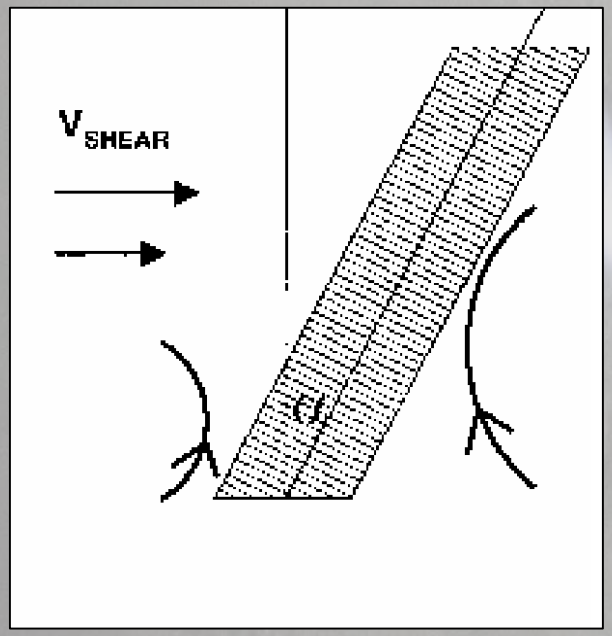
Molinari et al. 1999



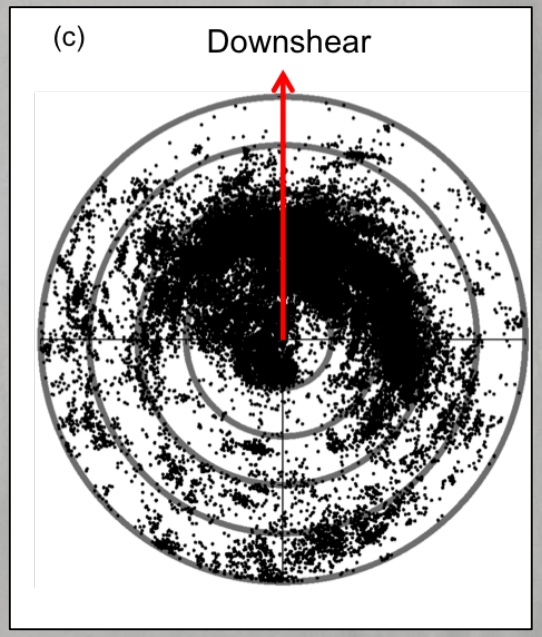
Stevenson et al. 2016

Patterns of TC lightning: Spatial

- Lightning typically occurs downshear, where there is stronger upwards motions forced by the TC vortex response



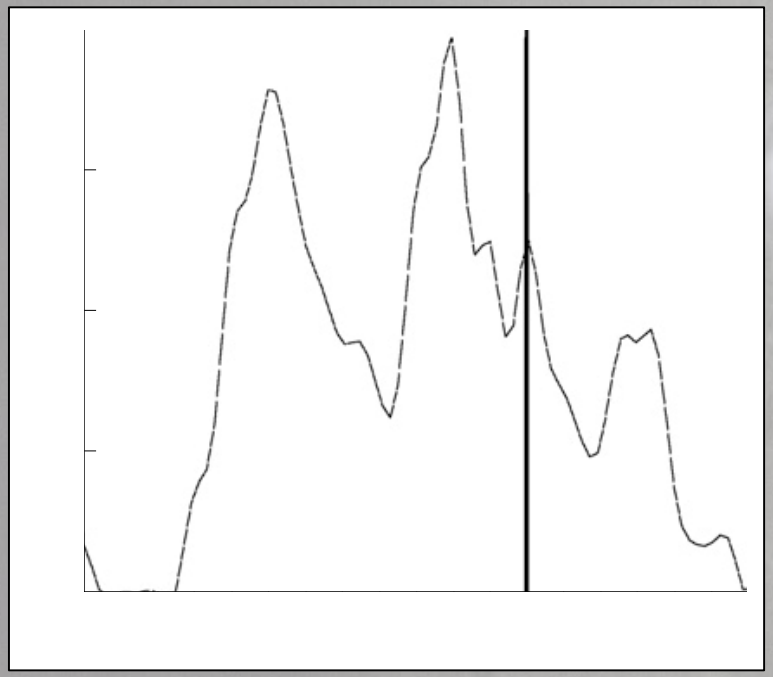
Reasor et al. 2004



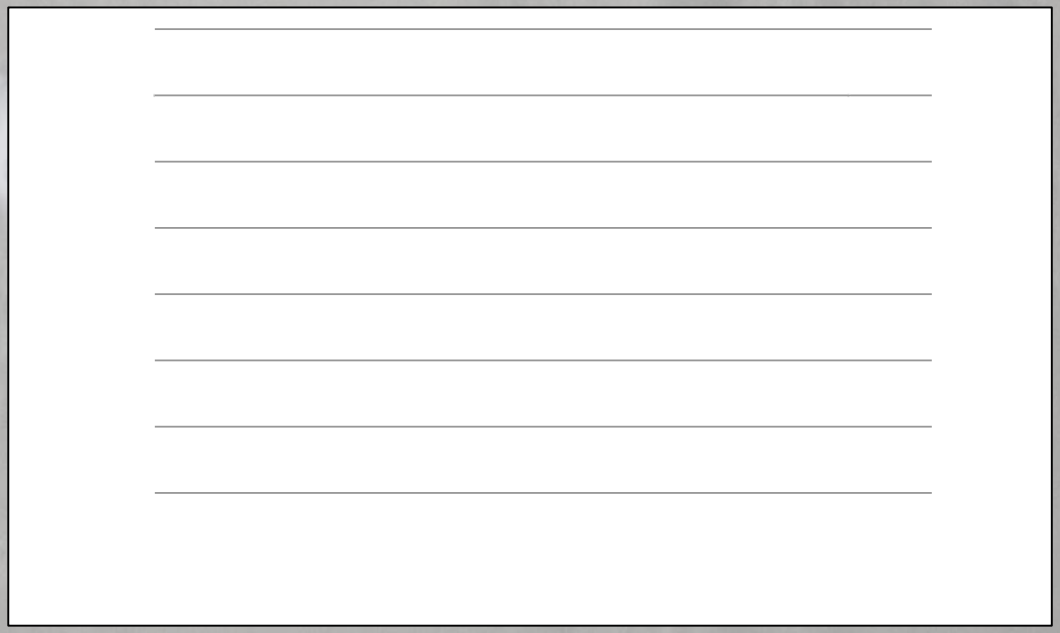
Stevenson et al. 2014

Patterns of TC lightning: Temporal

- Many recent studies link increased lightning to TC intensity change, showing promise for including lightning in intensity forecasting



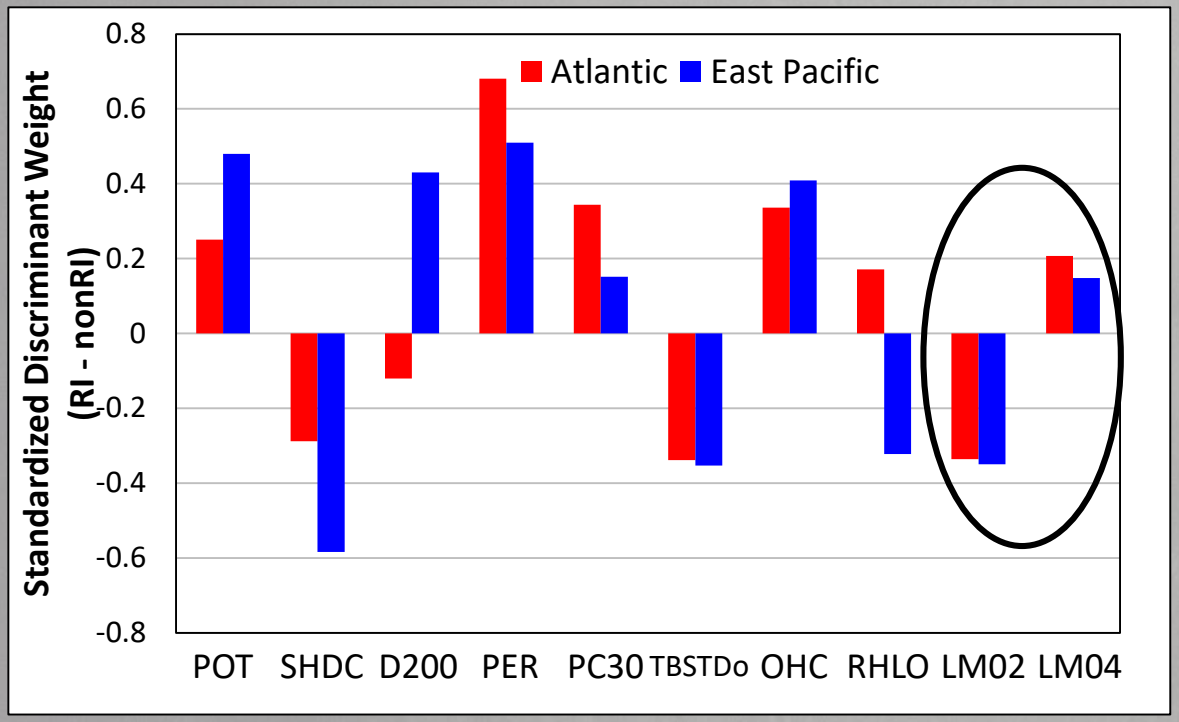
Price et al. 2009



Stevenson et al. 2014

Patterns of TC lightning: Temporal

- Lightning has significant weight when input as a predictor in the Rapid Intensification Index
  - Especially inner core lightning



Predictors:
POT: SST Potential
SHDC: Shear
D200: Divergence
PER: Persistence
PC30: % IR pixels < -30°C
TBSTDo: GOES IR brightness temperature standard deviation
OHC: Ocean heat content
RHLO: relative humidity

LM02: Average 0–200 km lightning flash density (inner core)
LM24: Average 200–400 km lightning flash density (outer bands)

Patterns of TC lightning: Spatial and temporal

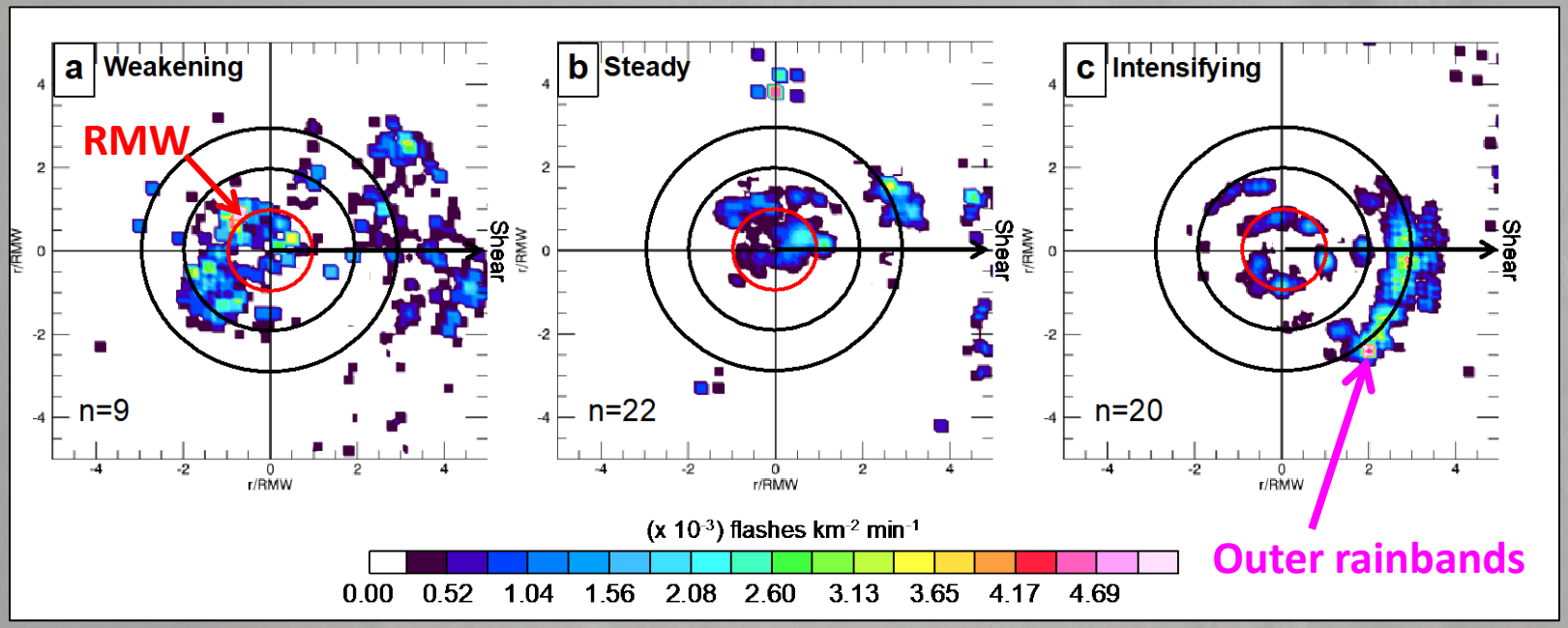
Short-term intensity change (< 24 h) associated with lightning outbreaks

	TC intensifies		TC Weakens
Inner Core	Lyons and Keen 1994 *	Molinari et al. 1999	DeMaria et al. 2012
	Molinari et al. 1994 *	Wang et al. 2016 *	Jiang and Ramirez 2013
	Squires & Businger 2008 *		Stevenson et al. 2016
	Pan et al. 2010		Xu et al. 2017
	Stevenson et al. 2014 *		
	Zhang et al. 2015		
	Ranalkar et al. 2017		
Outer Rainbands	DeMaria et al. 2012		
	Jiang and Ramirez 2013		
	Bovalo et al. 2014		
	Stevenson et al. 2016		
	Xu et al. 2017		

* case studies

Patterns of TC lightning: Spatial and temporal

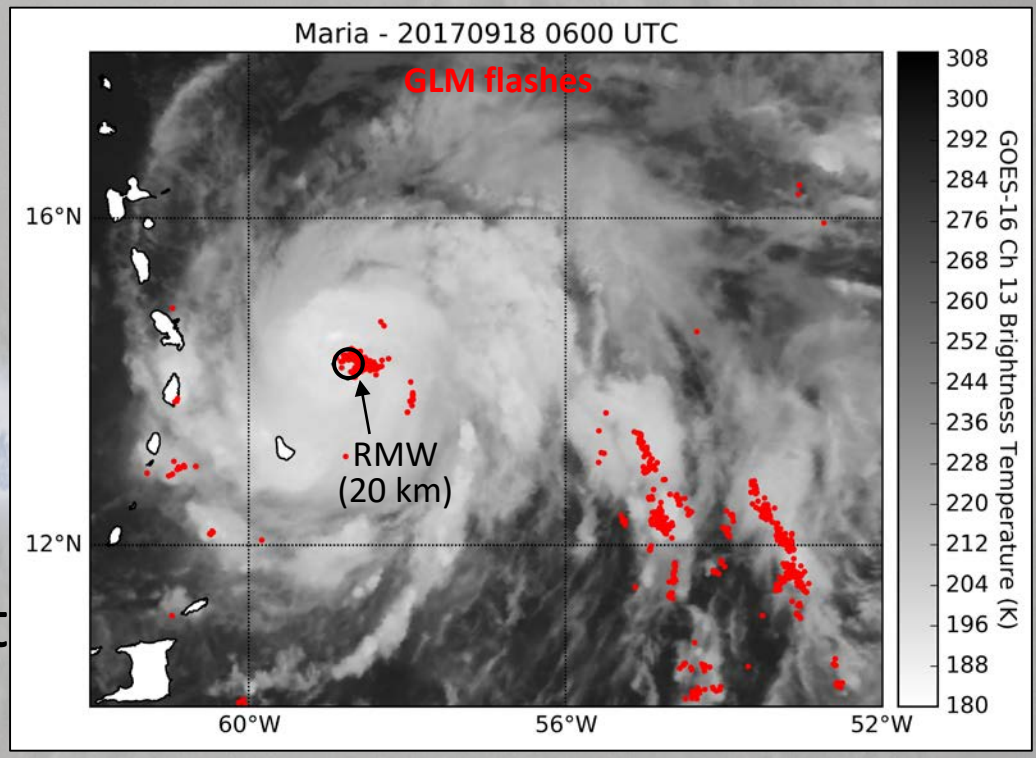
- An in-depth look at inner core lightning bursts found those inside radius of maximum wind (RMW) were associated with intensifying TCs



Stevenson et al. 2018

Patterns of TC lightning: Spatial and temporal

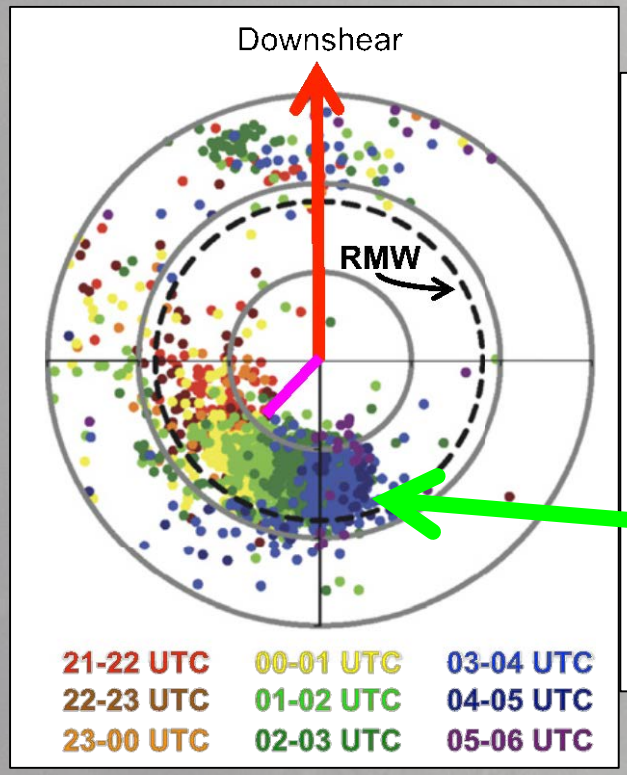
- GLM observed an inner core lightning burst inside the RMW at beginning of RI in Hurricane Maria (2017)
  - 80-kt Cat 1 to 135-kt Cat 4 in 24 h



Preliminary, non-operational data

Patterns of TC lightning: Spatial and temporal

- Also, inner core bursts that rotate *upshear* tend to be associated with intensification



Stevenson et al. 2014

Plans for use of lightning for operational TC intensity forecasts

- Assemble climatological database for statistical models
  - Relate GLM to ground-based networks
    - Preliminary results
      - Rainband region straightforward, inner core more difficult
- Combine with aircraft or satellite radius of maximum wind estimates
- Run experimental rapid intensification index (RII) with lightning input in 2019 season
- Transition to NHC operations for 2020
- Longer term – assimilate lightning in dynamical models

New opportunities for TC lightning research

- Ground-based networks used in unison with GLM can help determine intracloud (IC) vs. cloud-to-ground (CG) flash ratios in TCs
- Some early research suggests IC flashes may increase prior to CG, which may help improve intensity change forecast lead time
- Assimilation of GLM for HWRF and other dynamical models

Summary

- Lightning is observed most frequently during TC intensity change
  - **Inner core lightning** associated with TC intensification (weakening) if radially inside (outside) the RMW, or rotating upshear
  - **Outer rainband lightning** mostly associated with TC intensification
- Lightning shows promise for statistical TC intensity guidance
  - Experimental tests planned for 2019
  - Target operational transition for 2020 season