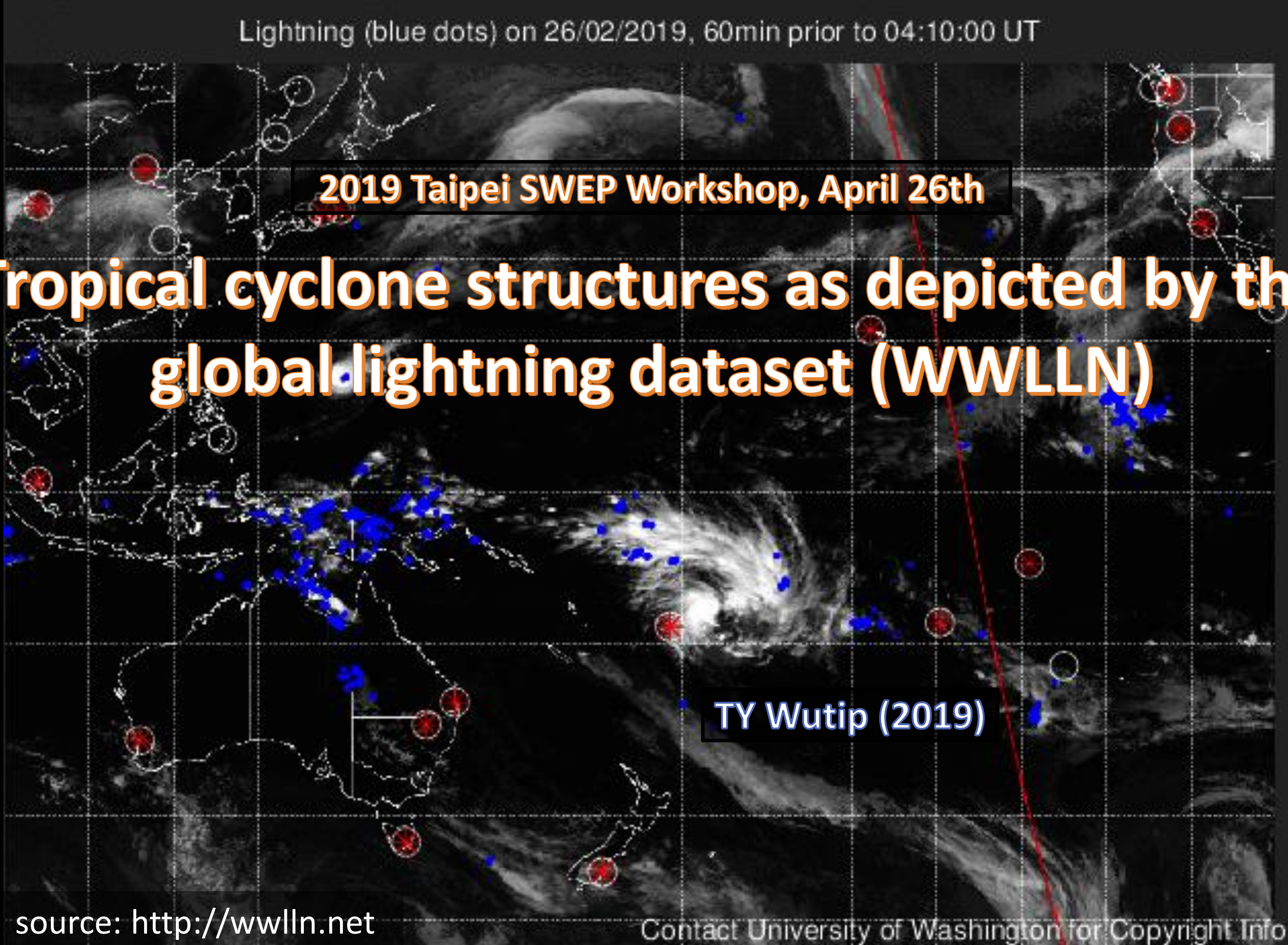
2019 Taipei SWEP Workshop, April 26th

Tropical cyclone structures as depicted by the global lightning dataset (WWLLN)



Shu-Jeng Lin, and Kun-Hsuan Chou
Department of Atmospheric Sciences, Chinese Culture University, Taipei, Taiwan.

Lightning related studies on TC

- Lightning frequency and location

  Cecil et al. (2002), Cecil and Zipser (2002), Fitzpatrick (2006), Nagele (2010), Zhang et al. (2012, 2015), Fierro et al. (2018a)

- Rapid intensification

  Molinari et al. (1999), Cecil and Zipser (2002), Fitzpatrick (2006), Stevenson et al. (2018), Fierro et al. (2018a)

- Lightning modeling

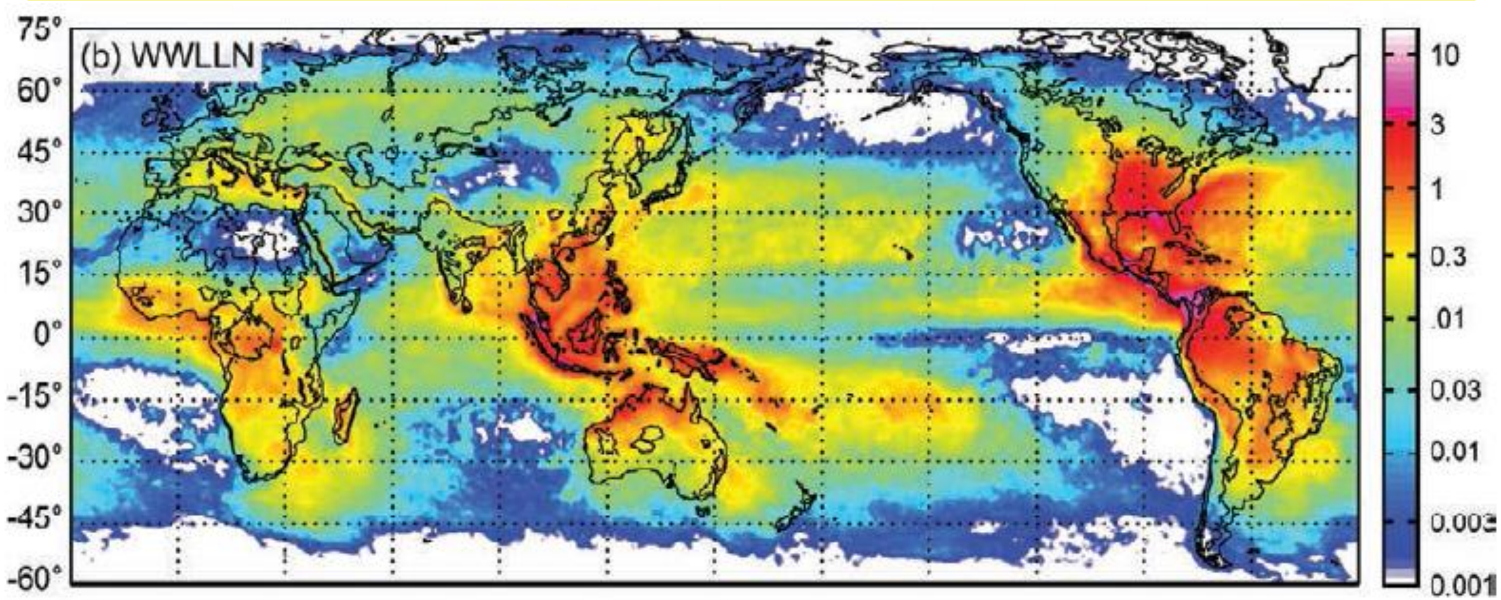
  Fierro and Mansell (2017), Fierro et al. (2018b)

Virts et al. (2012)

HIGHLIGHTS OF A NEW GROUND-BASED, HOURLY GLOBAL LIGHTNING CLIMATOLOGY

BY KATRINA S. VIRTS, JOHN M. WALLACE, MICHAEL L. HUTCHINS, AND ROBERT H. HOLZWORTH

The ground-based World Wide Lightning Location Network (WWLLN) provides unprecedented sampling of lightning frequency, providing a basis for climatologies that resolve diurnal as well as seasonal variations.



WWLLN (strokes km^{-2} yr^{-1})

Zhang et al. (2015)

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE
10.1002/2014JD022334

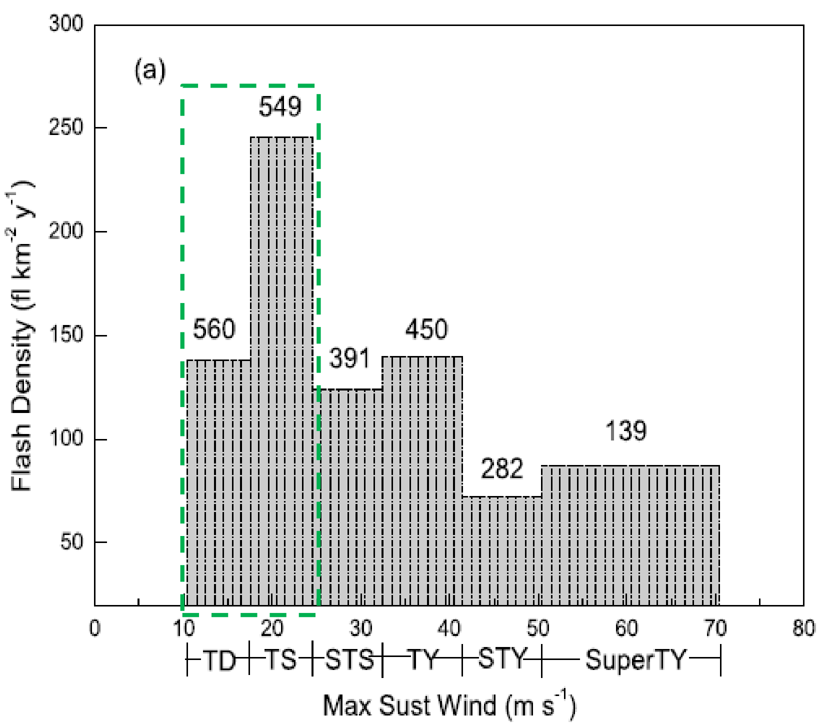
Relationship between lightning activity and tropical cyclone intensity over the northwest Pacific

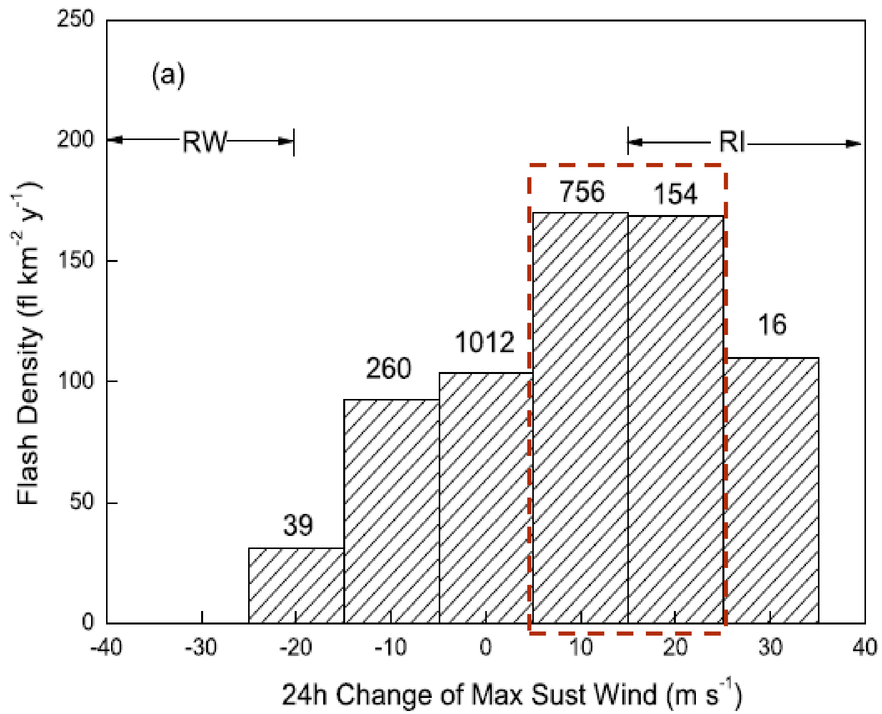
Wenjuan Zhang[1,2], Yijun Zhang[1,2], Dong Zheng[1,2], Fei Wang[1,2], and Liangtao Xu[1,2,3]

[1]State Key Laboratory of Severe Weather, Chinese Academy of Meteorological Sciences, Beijing, China, [2]Laboratory of Lightning Physics and Protection Engineering, Chinese Academy of Meteorological Sciences, Beijing, China, [3]College of Earth Science, University of Chinese Academy of Sciences, Beijing, China

Key Points:

- Lightning in TCs over NP is more likely to occur in TD and TS intensity level
- Lightning in the inner core may be a better indicator for NP RI prediction
- A different pattern of lightning and TC intensity change exists among basins

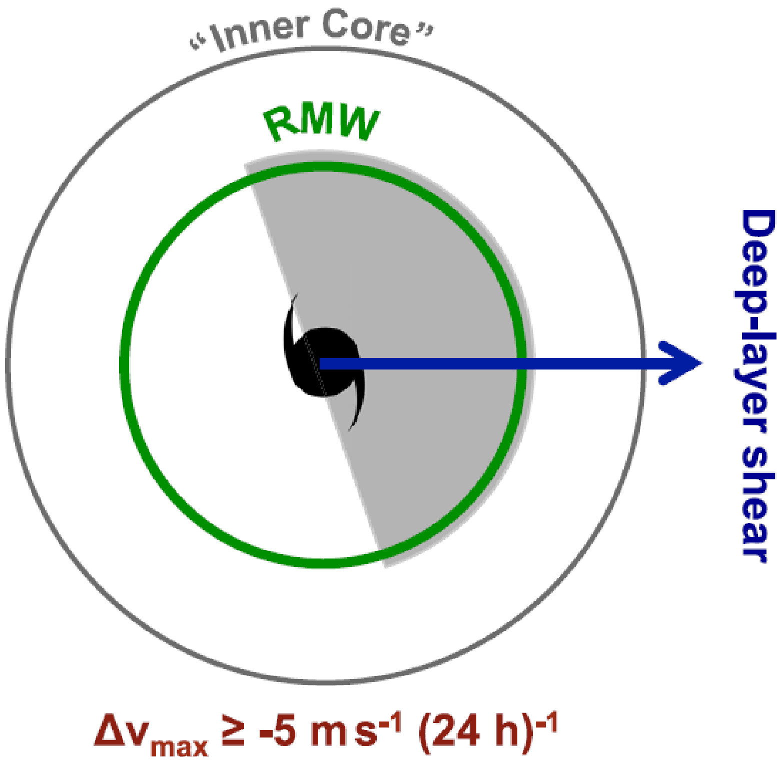


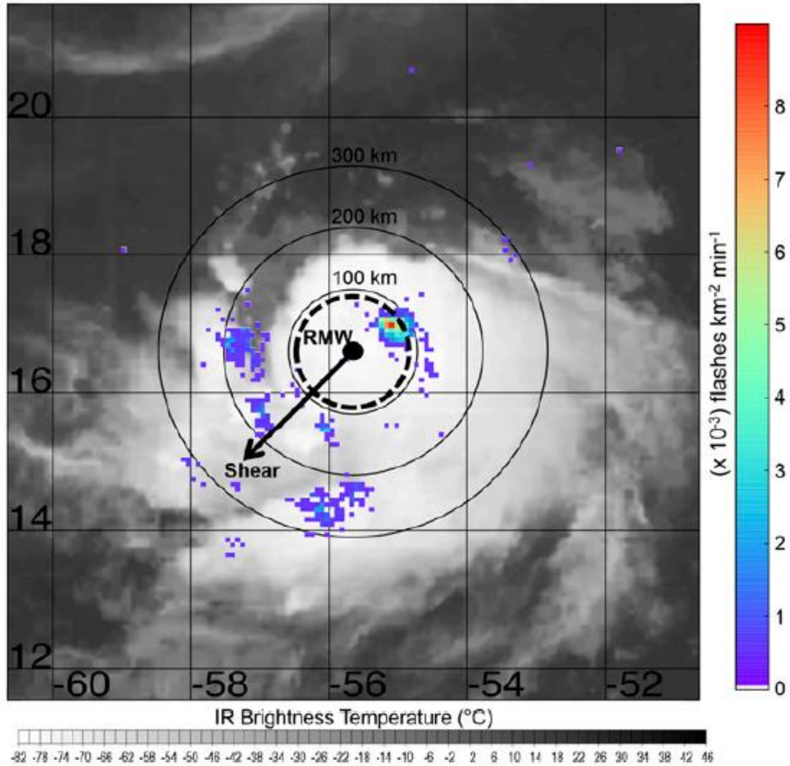


Stevenson et al. (2018)

A 10-Year Survey of Tropical Cyclone Inner-Core Lightning Bursts and Their Relationship to Intensity Change

1) A steady or intensifying TC 24 h prior to the ICLB onset,
2) An ICLB initiating in the downshear- or upshear-left quadrants, and
3) An ICLB located near or inside the RMW.





A schematic summary highlighting the scenarios when an ICLB is most likely to be associated with TC Intensification.

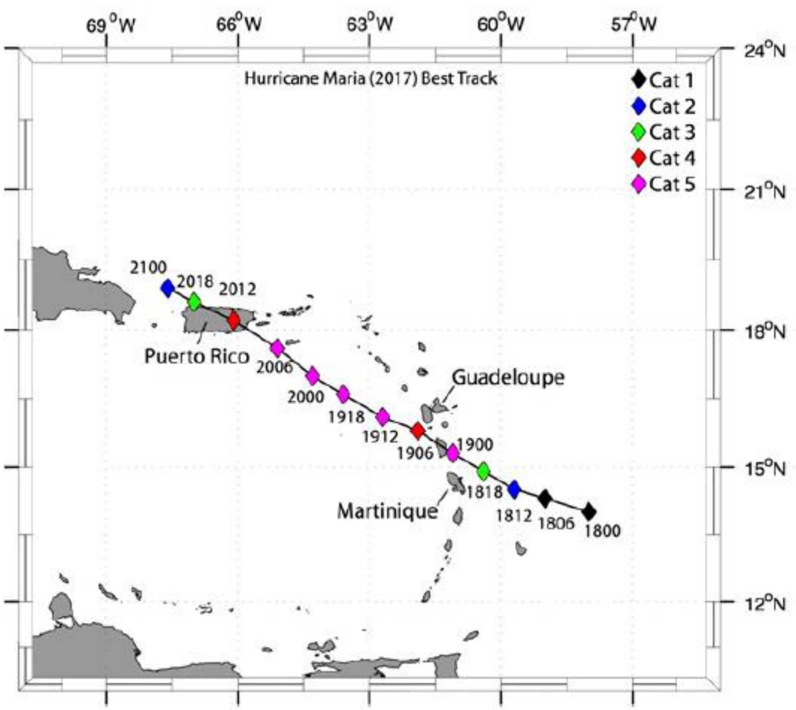
A sample graphic that would aid forecasters in using lightning to forecast TC intensity change.

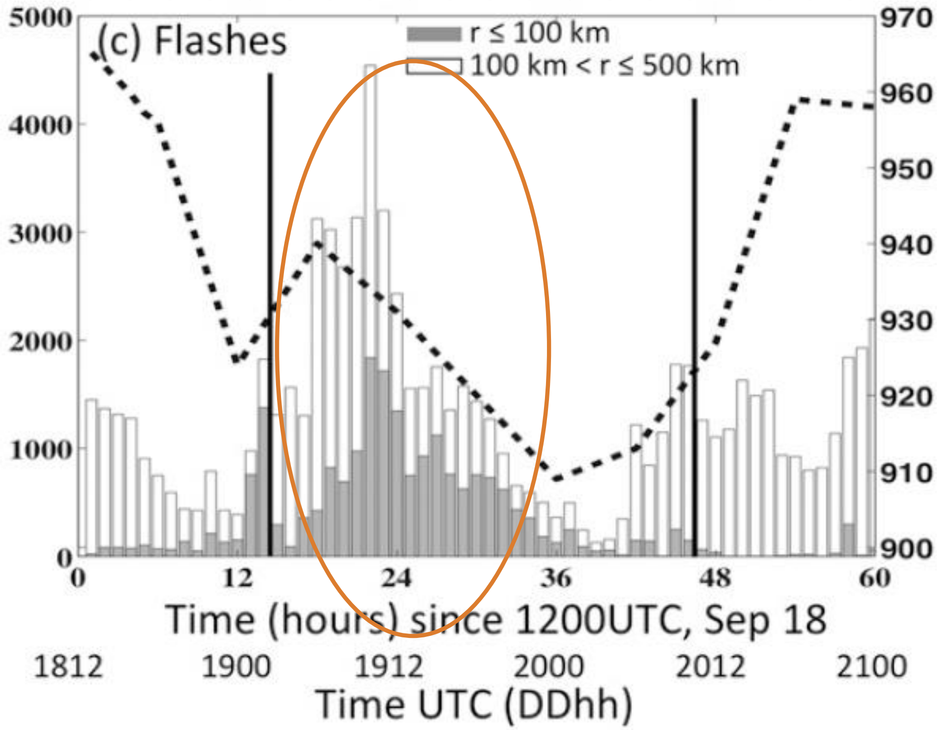
Fierro et al. (2018)

Evolution of GLM-Observed Total Lightning in Hurricane Maria (2017) during the Period of Maximum Intensity

ALEXANDRE O. FIERRO

Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, and NOAA/OAR/National Severe Storms Laboratory, Norman, Oklahoma





Fierro and Mansell (2017)

Electrification and Lightning in Idealized Simulations of a Hurricane-Like Vortex Subject to Wind Shear and Sea Surface Temperature Cooling

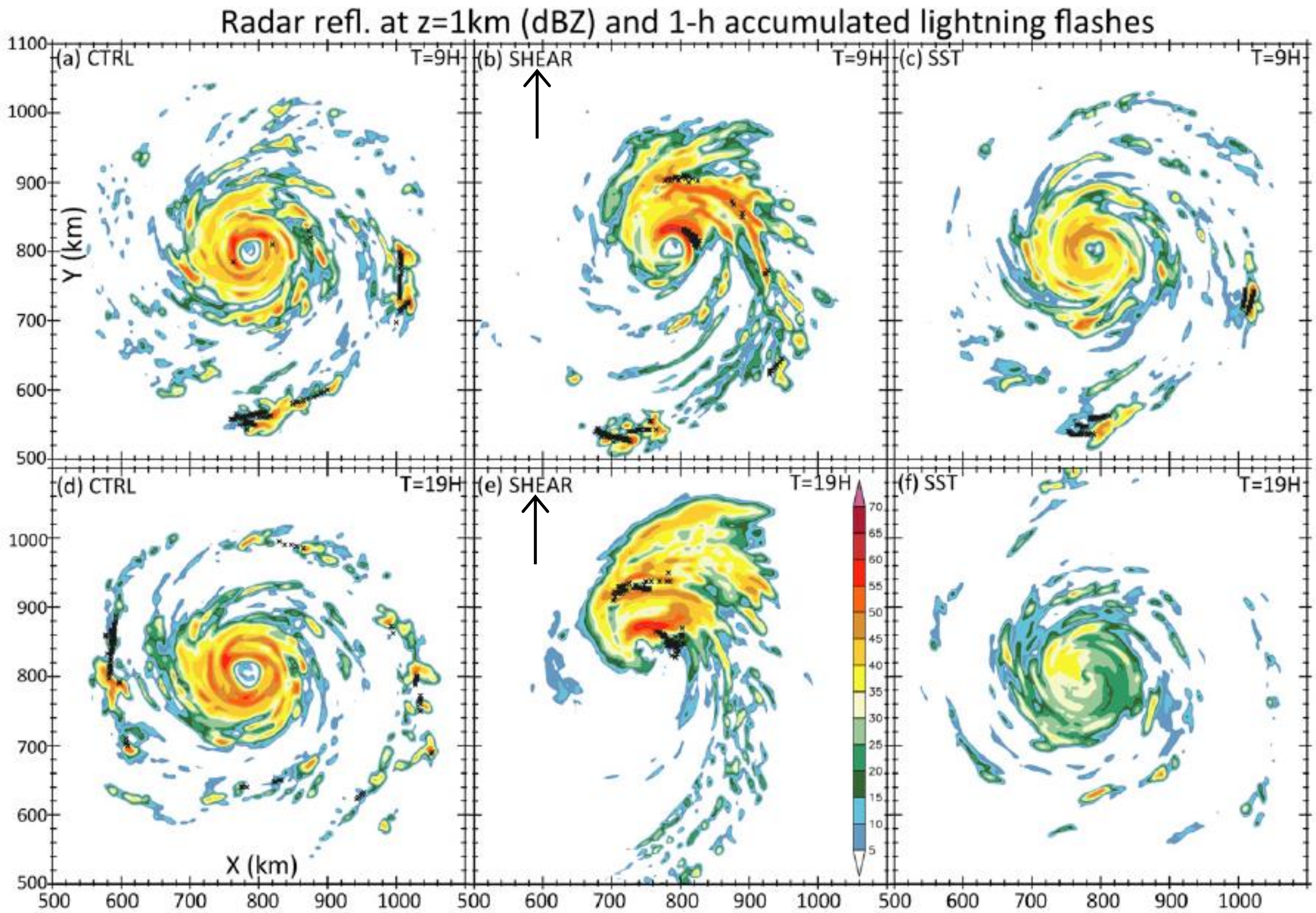
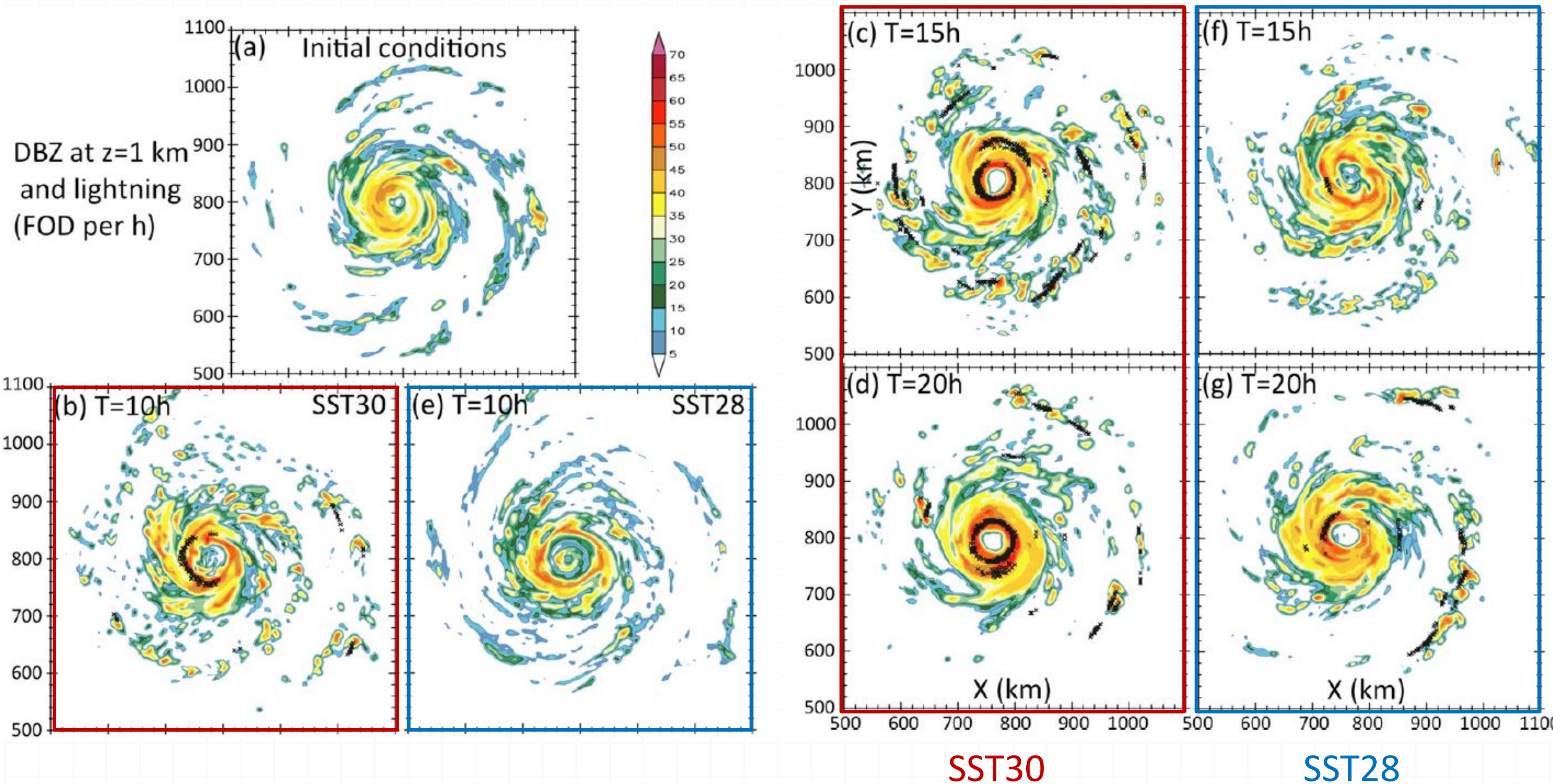


FIG. 4. Horizontal cross sections of simulated radar reflectivity fields at $z = 1$ km MSL overlaid with lightning initiation locations (black crosses) for (a) CTRL, (b) SHEAR, and (c) SST at 9 h into the simulation. (d)–(f) As in (a)–(c), respectively, but at 19 h.

Fierro et al. (2018)

Relationships between Electrification and Storm-Scale Properties Based on Idealized Simulations of an Intensifying Hurricane-Like Vortex



Motivation

- The lightning signal is a proxy to represent the deep convection in the cloud, thus its distribution over the storm could be applied to determine the convective structure of TC.
- There are a lot of studies on TC lightning in the North Atlantic, but such research is rare in the western North Pacific (WNP).
- This study will attempt to investigate TC lightning in the WNP through the **World Wide Lightning Location Network (WWLLN)** in 2005-2017.
  - Convection asymmetry
  - Rapid intensification
  - Terrain-induced eyewall evolution

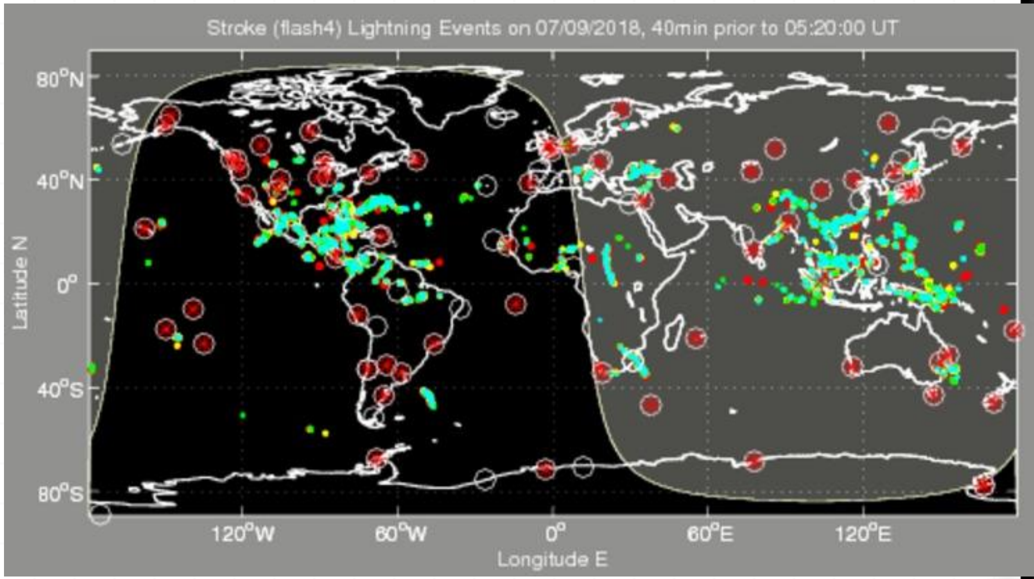
Data

- Lightning data – WWLLN (the ground-based World Wide Lightning Location Network)
  - Localization accuracy ~15 km.
  - Only detects strokes with peak currents ≥30 kA. (primarily CG)
  - Higher detection efficiency over the ocean (Roberts et al. 2017).
  - Nearly 80 WWLLN sensors are installed worldwide. (11 sensors in 2003, **> 70 sensors in 2008**)
- JTWC best track

  TC information (location, intensity, and radius of maximum wind speed)
- NCEP FNL Analysis

  Vertical wind shear

  (850-200 hPa, deep shear)



source: http://wwlln.net

Results

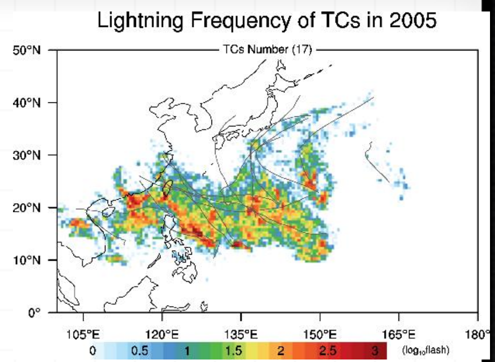
- The yearly lightning distribution of TCs over WNP
- The convection asymmetry associated with TC lightning.
- The lightning distribution of different intensity change types (ICT)

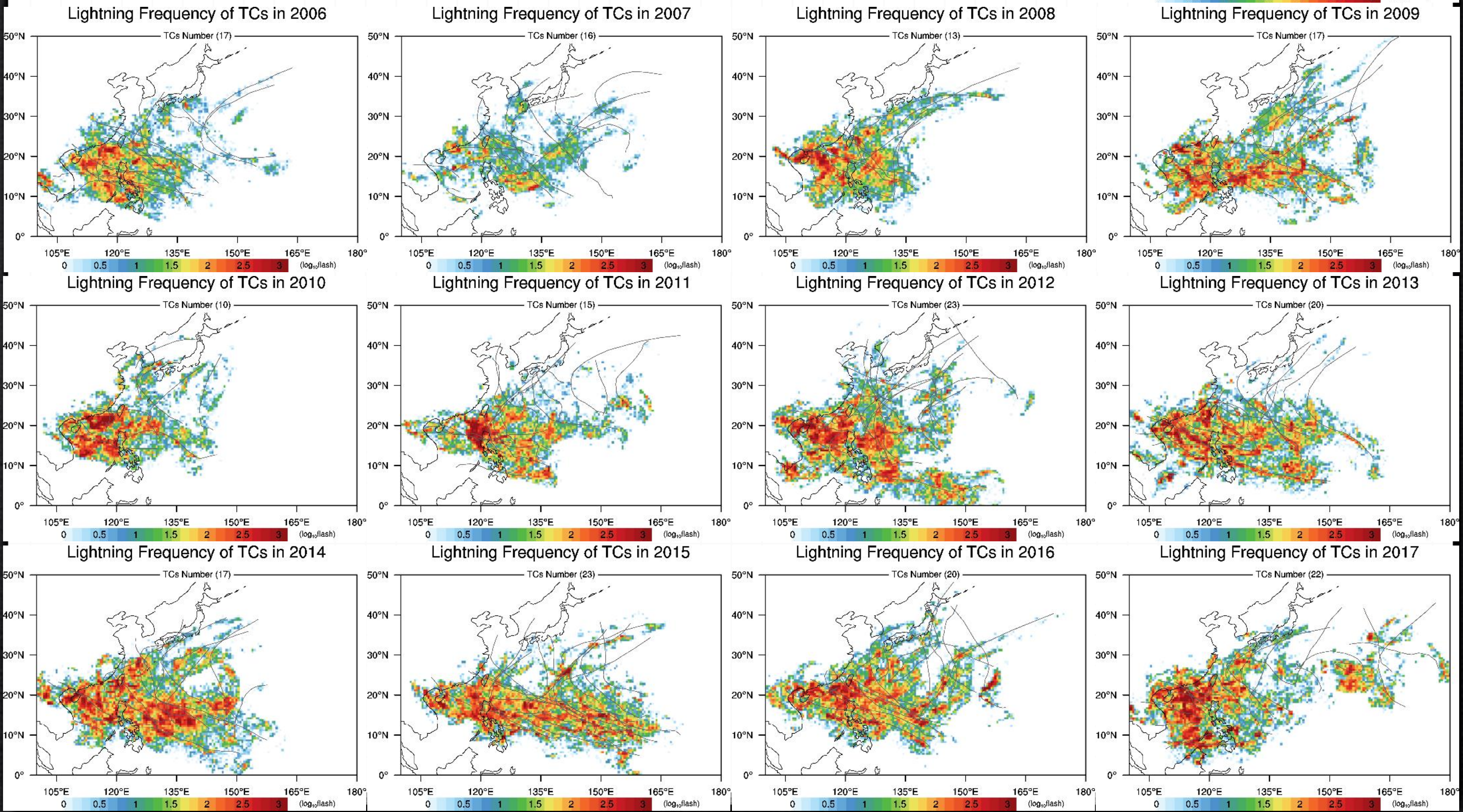
Result I:
The yearly lightning distribution of TCs over WNP

The **yearly lightning frequency** of TCs and **detection rate correction** in 2005-2017

Yearly lightning frequency of TC over WNP

- ➢ The intensity of the selected TCs must reach 34 kt and remain at least 24 h. (totally 230 cases)
- ➢ WWLLN lightning (shaded) displays on a 0.5 x 0.5 degree within 5 latitudes for each TC.



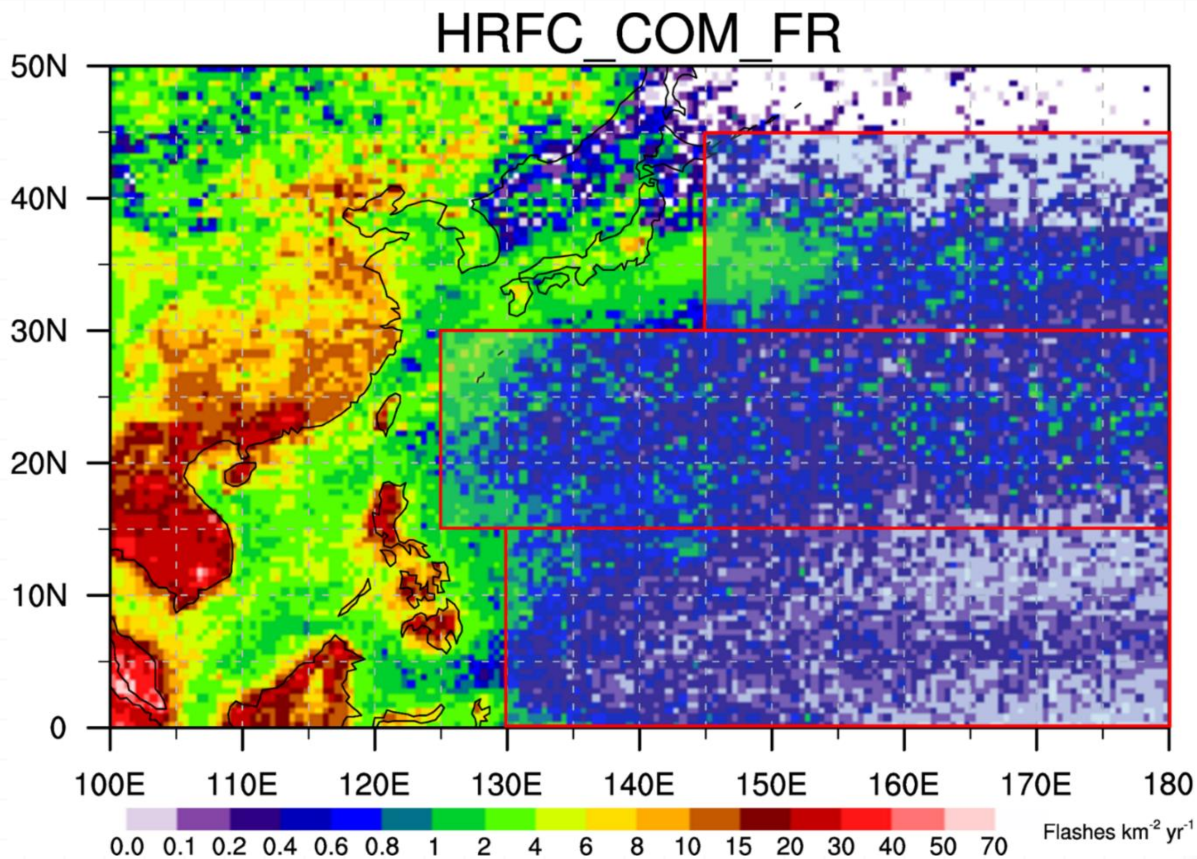


Detection rate correction

- Adjustment factors are determined by the ratio of mean lightning density each year from WWLLN to annual mean lightning density climatology (1998-2014) from TRMM LIS/OTD. (similar to Pan et al. 2014)

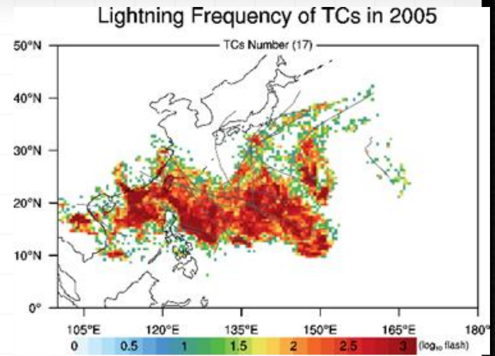
WNP (0-15N, 130-180E); (15-30N, 125-180E): (30-45N, 145-180E)

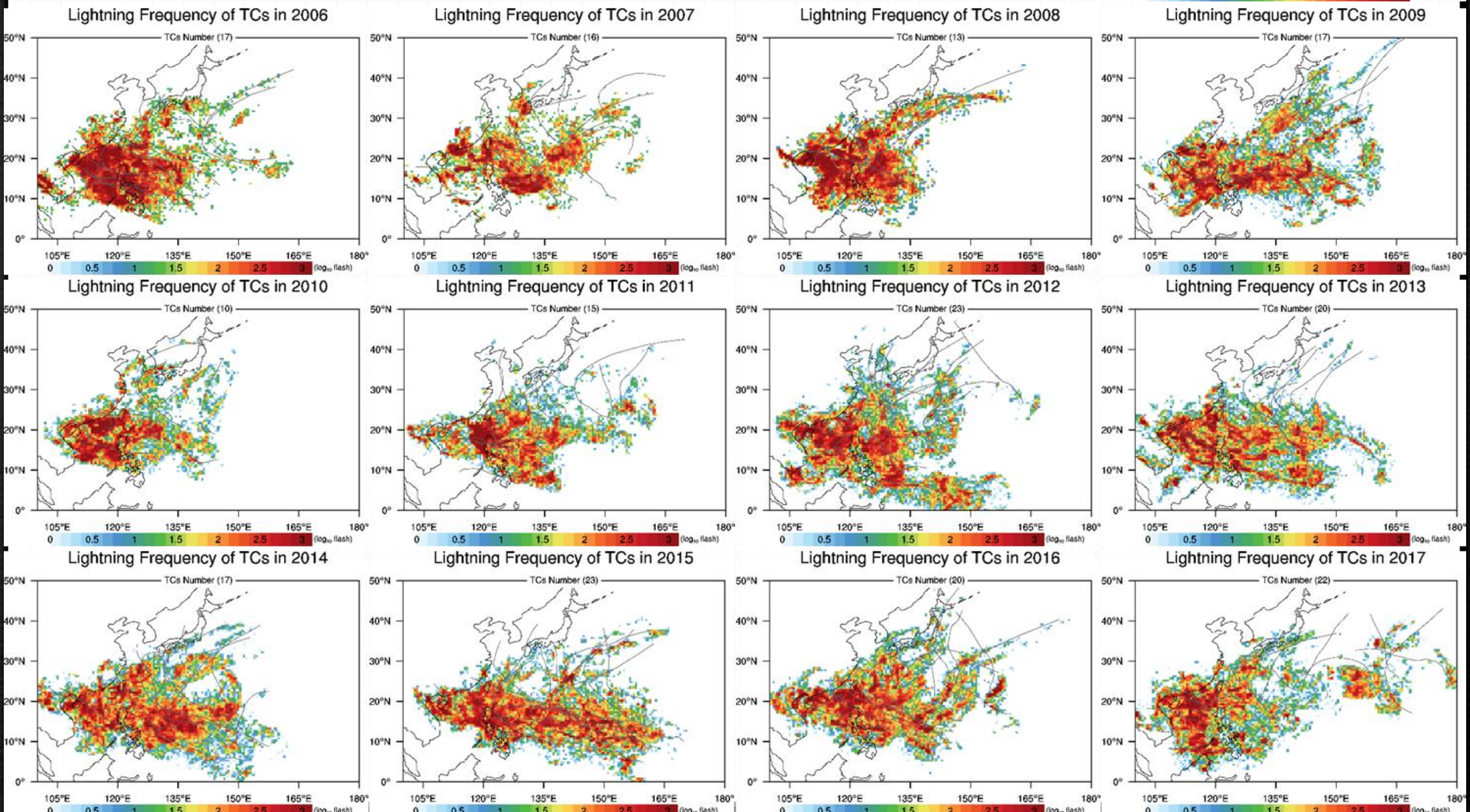
YEAR	AF
2005	10.112
2006	10.067
2007	12.406
2008	7.339
2009	2.898
2010	2.742
2011	2.760
2012	2.071
2013	2.012
2014	1.741
2015	2.562
2016	2.338
2017	1.526



Yearly lightning frequency with AF

- The order of yearly lightning frequency is more reasonable by considering the adjustment factors.

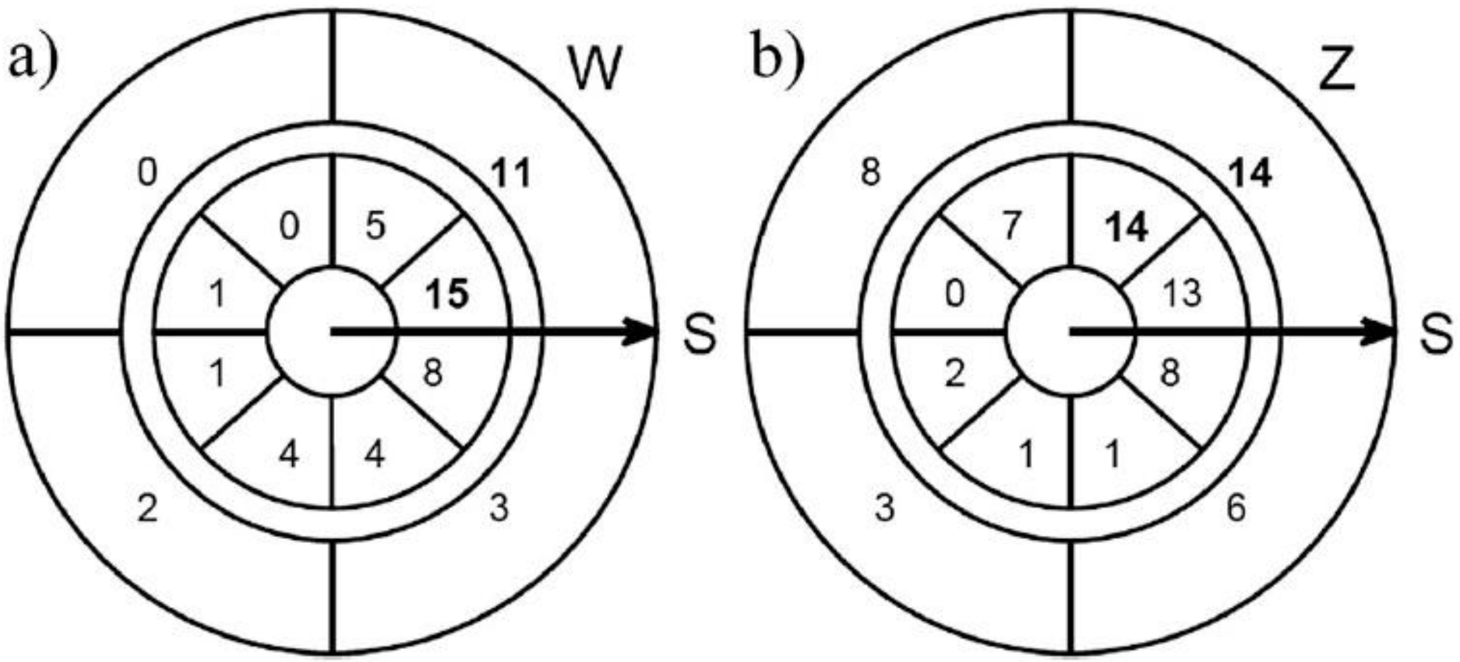




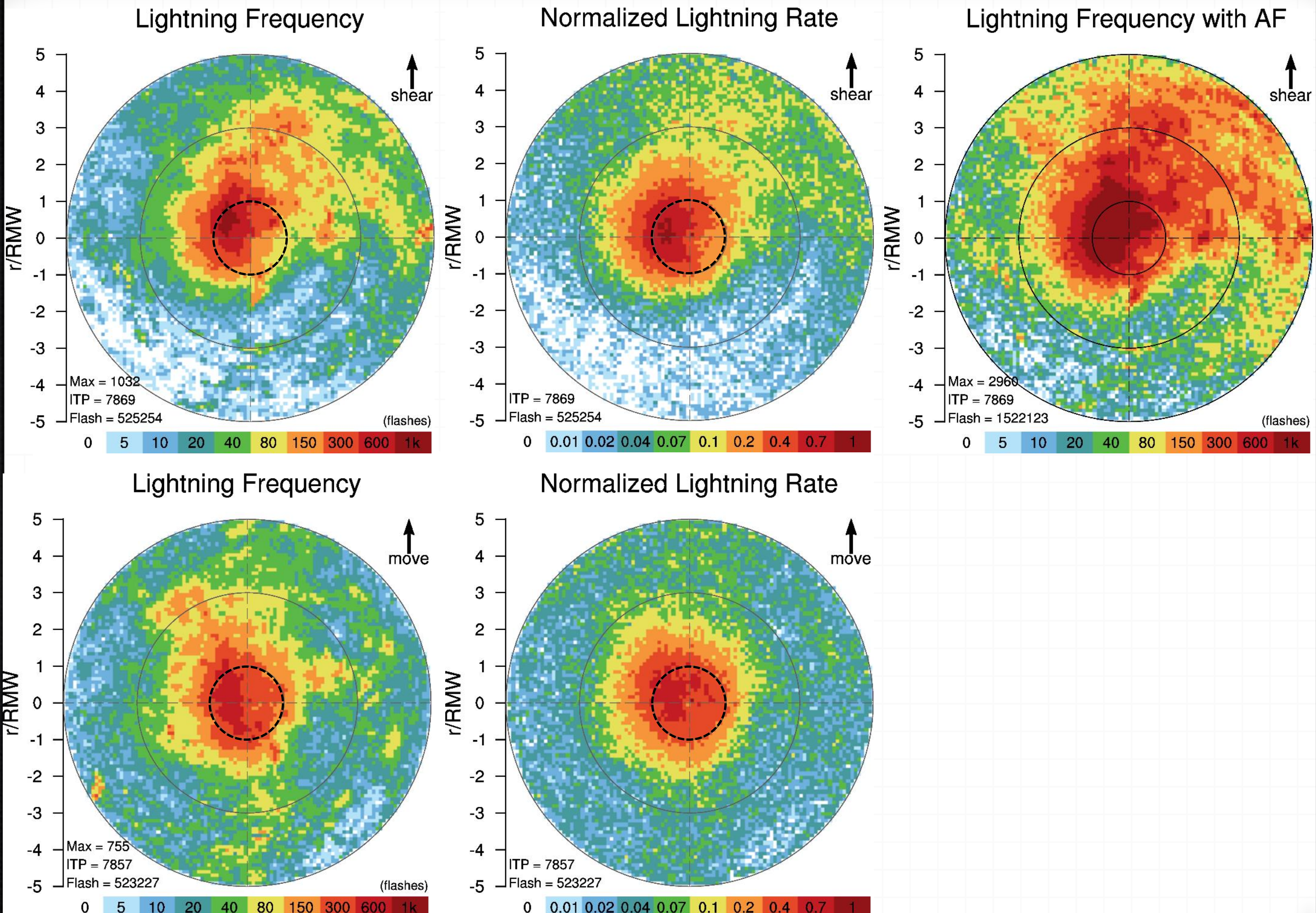
Result II:
The convection asymmetry associated with TC lightning.

The **spatial distribution** and **average lightning rate (ALR)** in the different TC intensity and VWS strength.

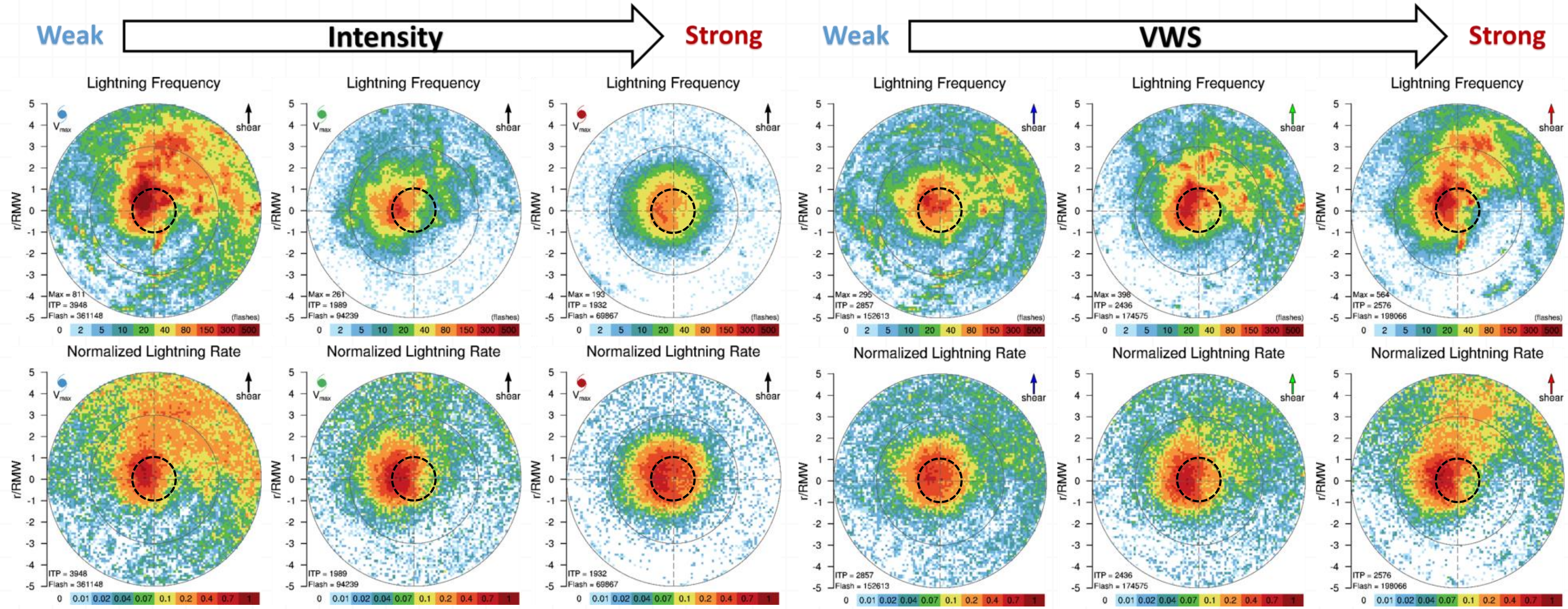
Reasor et al. (2013)



- The authors extend the analysis to the asymmetric structure using the airborne Doppler radar measurements from 75 TC flights.
- The composite analysis confirms principal features of the shear-relative TC asymmetry documented in prior numerical and observational studies (e.g., downshear tilt, downshear-right convective initiation, and a downshear-left precipitation maximum).



Lightning Frequency
Normalized Lightning Rate
Lightning Frequency with AF
shear
move
r/RMW
Max = 1032
ITP = 7869
Flash = 525254
ITP = 7869
Flash = 525254
Max = 2960
ITP = 7869
Flash = 1522123
(flashes)
0 5 10 20 40 80 150 300 600 1k
0 0.01 0.02 0.04 0.07 0.1 0.2 0.4 0.7 1
Lightning Frequency
Normalized Lightning Rate
Max = 755
ITP = 7857
Flash = 523227
ITP = 7857
Flash = 523227



	WTC (34-64 kt)	MTC (64-96 kt)	STC (above 96 kt)
ITP	3948	1989	1932
FLASH	361148	94239	69867
ALR	★ 91.476	47.380	36.163

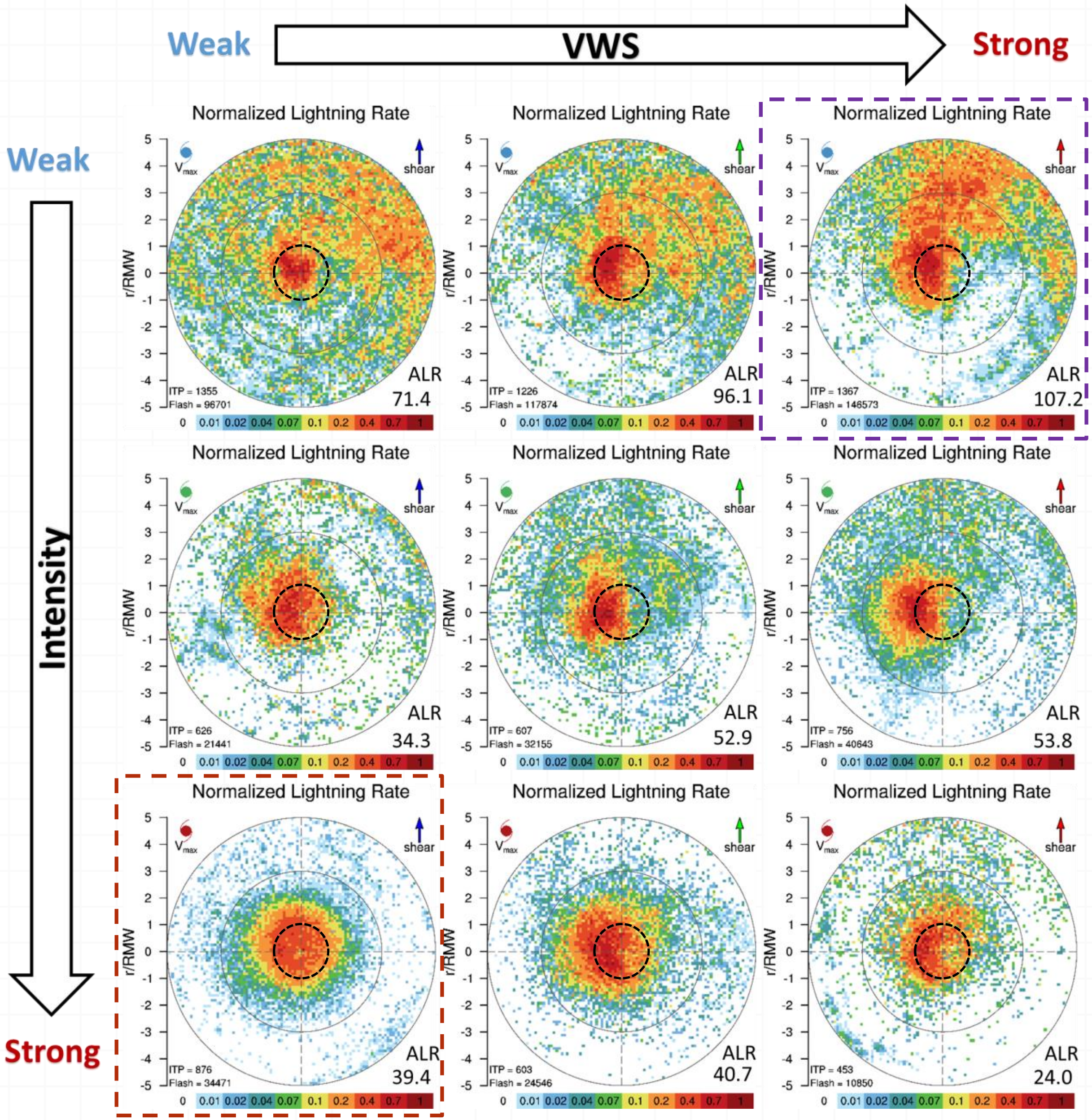
	WVS (0.1-10 kt)	MVS (10-17 kt)	SVS (above 17 kt)
ITP	2857	2436	2576
FLASH	152613	174575	198066
ALR	53.417	71.665	★ 76.889

ALR (Average Lightning Rate) = total FLASH / total ITP

The flashes are more asymmetric and higher proportion in the outer region of the downshear side with the decreasing TC intensity.

The flashes are more asymmetric and higher proportion in the outer region of the downshear side with the increasing VWS.

- weaker TC intensity or stronger VWS → more asymmetric lightning distribution
- stronger TC intensity or weaker VWS → more compact lightning distribution

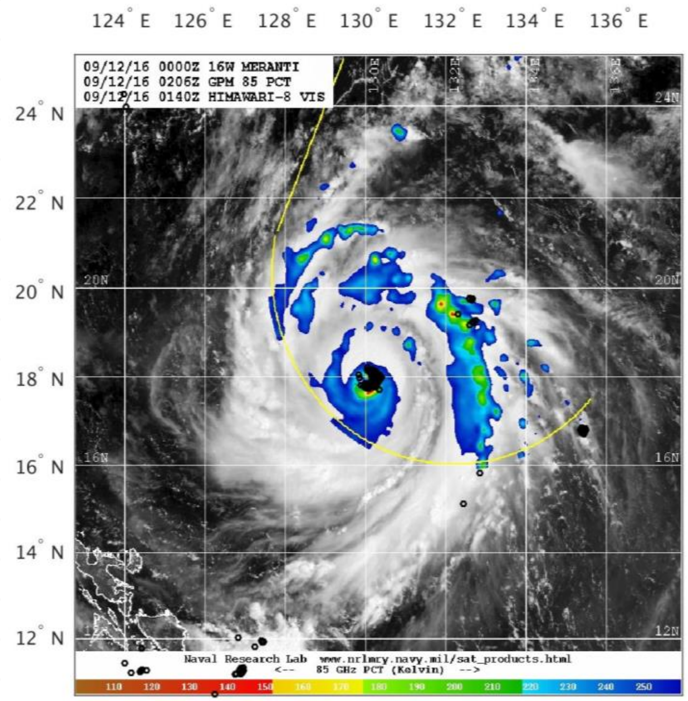


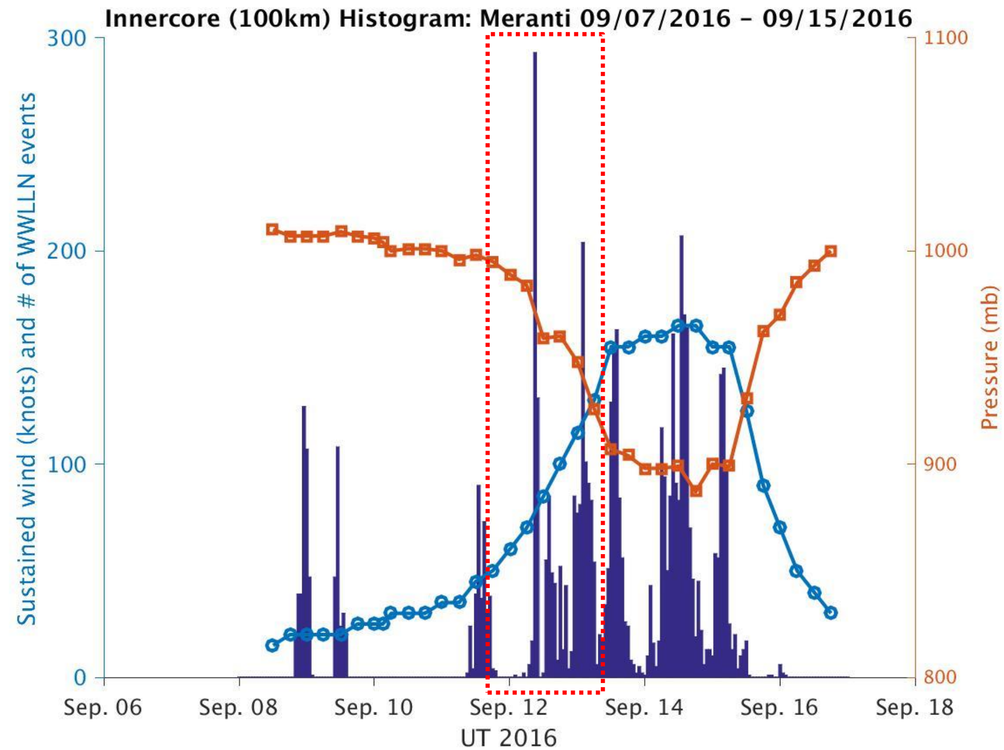
Result III:
The lightning distribution of different intensity change types (ICT)

The definitions of **5 ICTs** – RW, WE, ST, IN, and RI

Impact of **concentration** and **symmetry** of lightning distribution on intensity change

RI of Typhoon Meranti (2016)

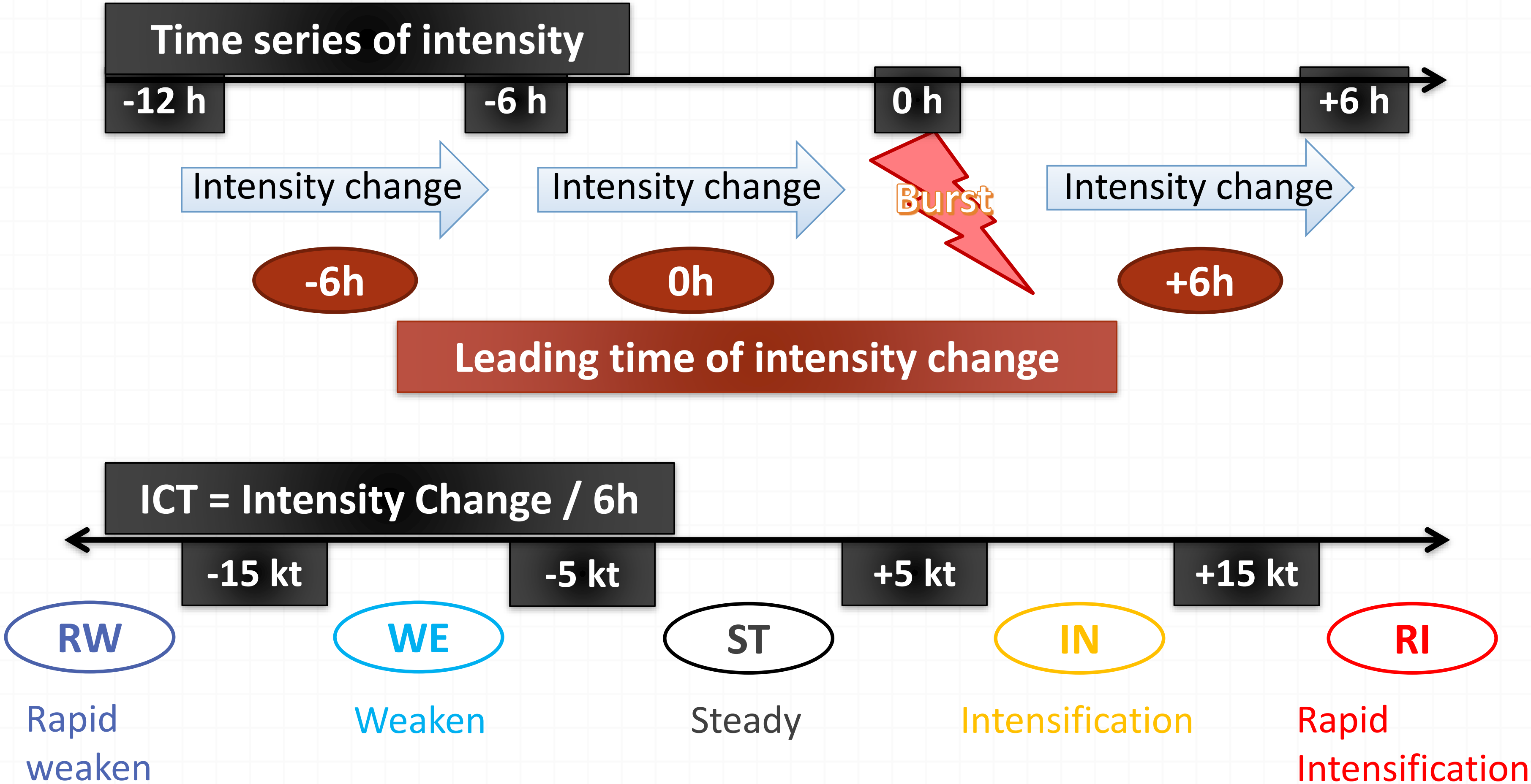




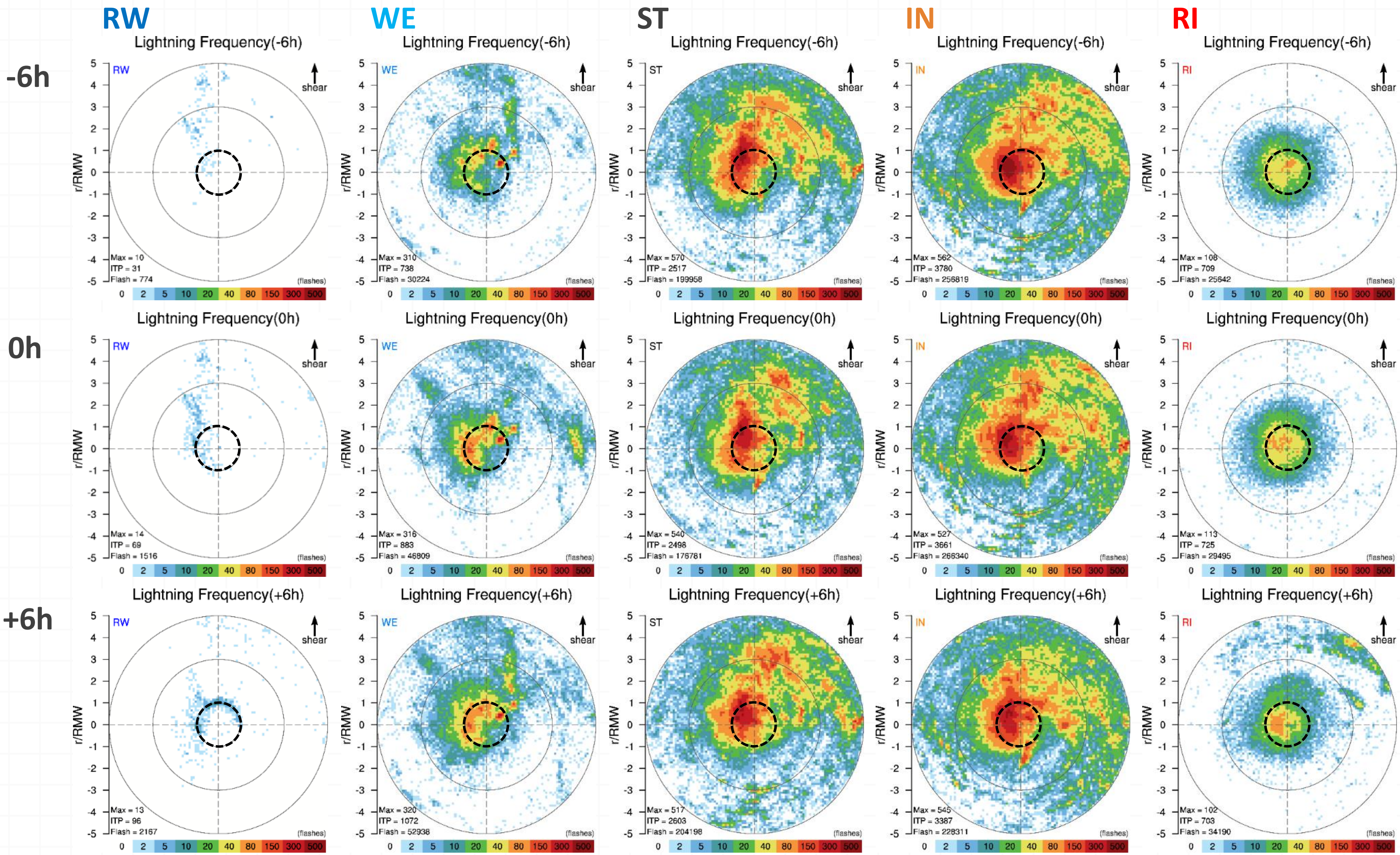
source: http://wwlln.net

Rapid Intensification: An increase in the maximum sustained winds of a tropical cyclone of at least 30 kt in a 24-h period. (NHC)

Lightning distribution on TC intensity change types (ICT)

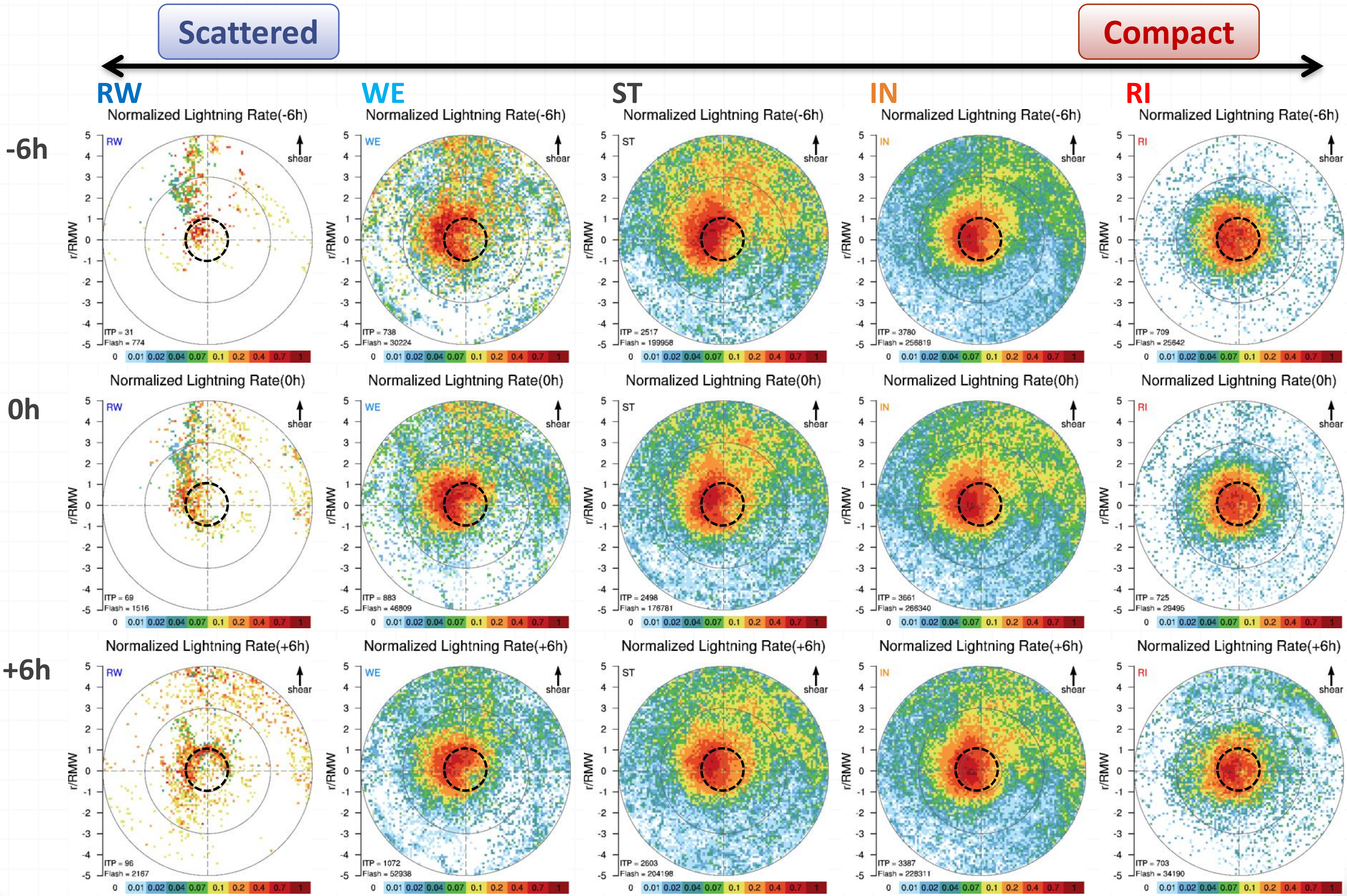


Lightning frequency on ICT



ALR (6h) = 22.6 | 49.4 | 78.4 | 67.4 | 48.6

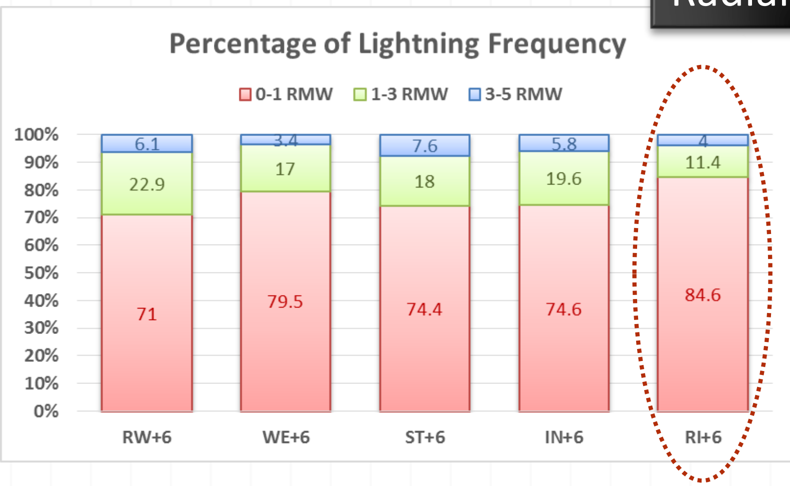
Normalized lightning rate on ICT

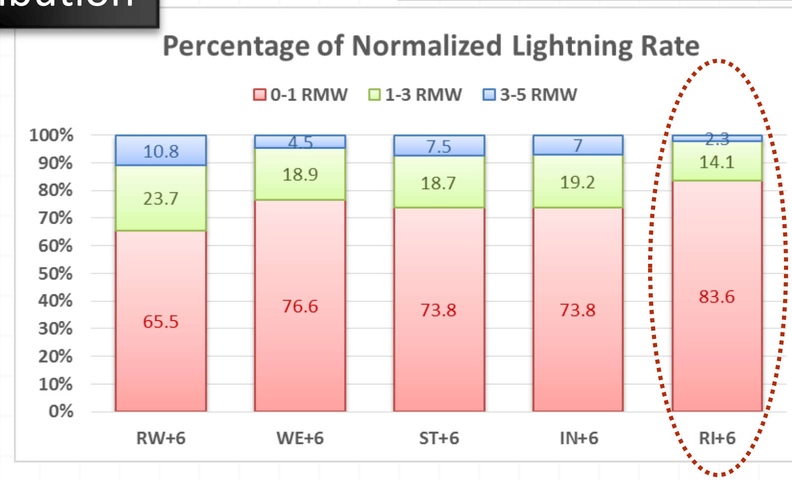


Impact of concentration and symmetry of lightning distribution on intensity change

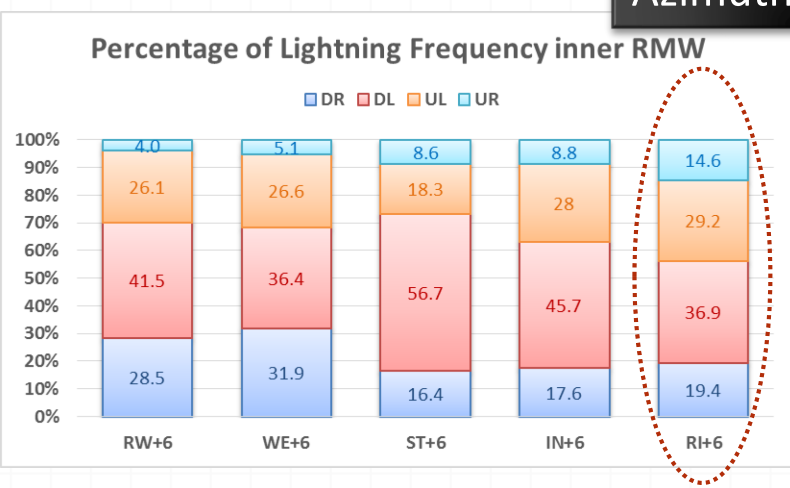
Leading time +6h

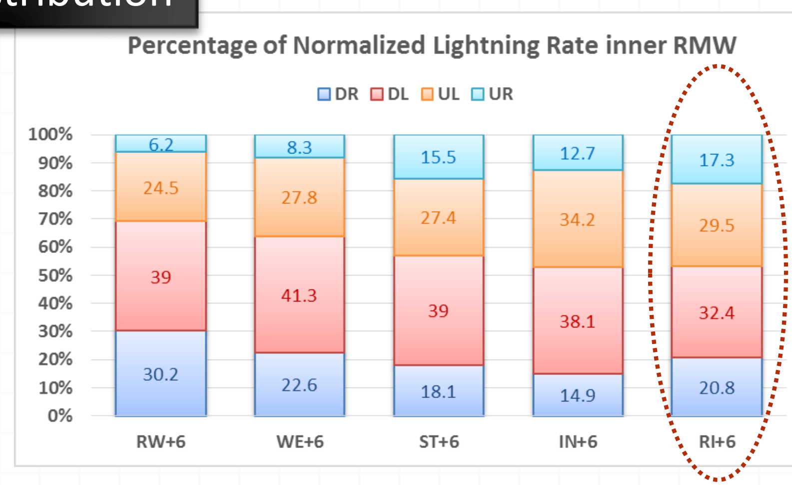
Radial distribution





Azimuthal distribution





The RI type of inner-core (<1 RMW) lightning distribution is the most compact and symmetric.

Conclusions

- This study examines the lightning activity of TC over the western North Pacific through the WWLLN, JTWC best track, and NCEP FNL data for 230 TCs between 2005 and 2017.
- The flashes are **active in the downshear-left of the inner core**, and that in the **downshear-right of the outer region**.
- The flashes of lightning are **more asymmetric and higher proportion in the outer region of the downshear side with the increasing VWS** (**decreasing TC intensity**).
- The **average lightning rate in the weak TC** (**strong VWS**) **is higher** than that in the strong TC (weak VWS).
- The lightning distribution of the **RI type is the most compact and symmetric**.

Thanks for listening

END~