Tropical Cyclone Lightning Characteristics as Revealed by the World Wide Lightning Location Network (WWLLN)

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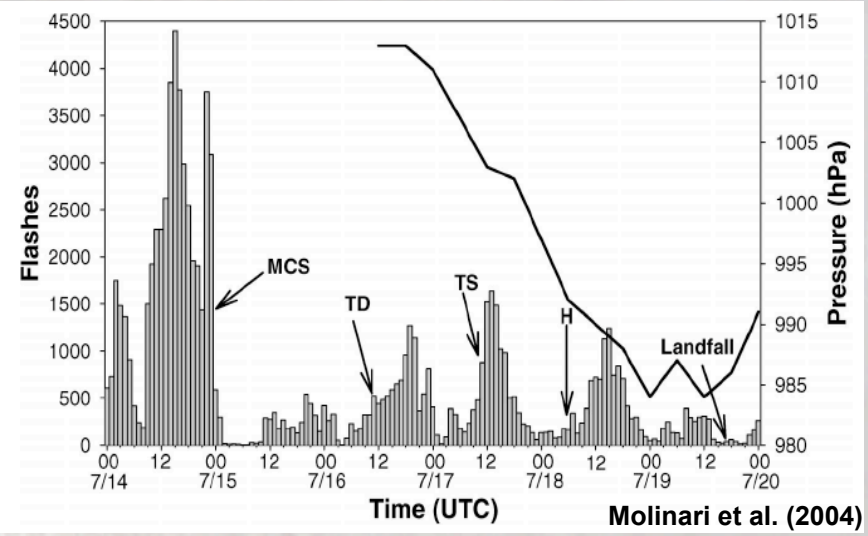
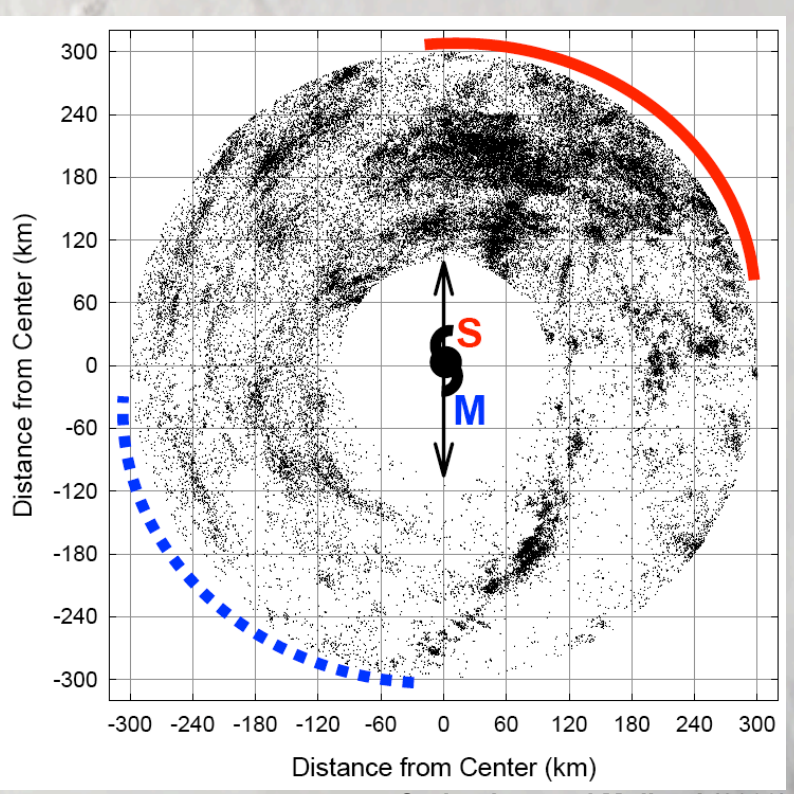
Introduction & Motivation

- Until fairly recently, the lightning characteristics of tropical cyclones (TCs) could only be observed when storms approached land.

- These studies found:
  - ~ Strong relationship between vertical wind shear and the azimuthal distribution of lightning
  - ~ Inconclusive relationship between flash frequency and intensity change
  - ~ Common radial distribution of lightning



Molinari et al. (2004)

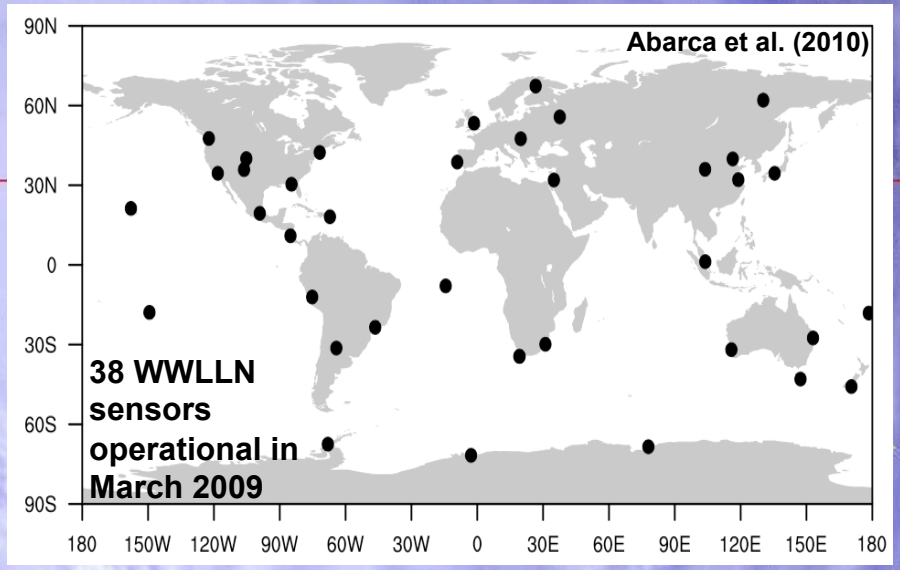


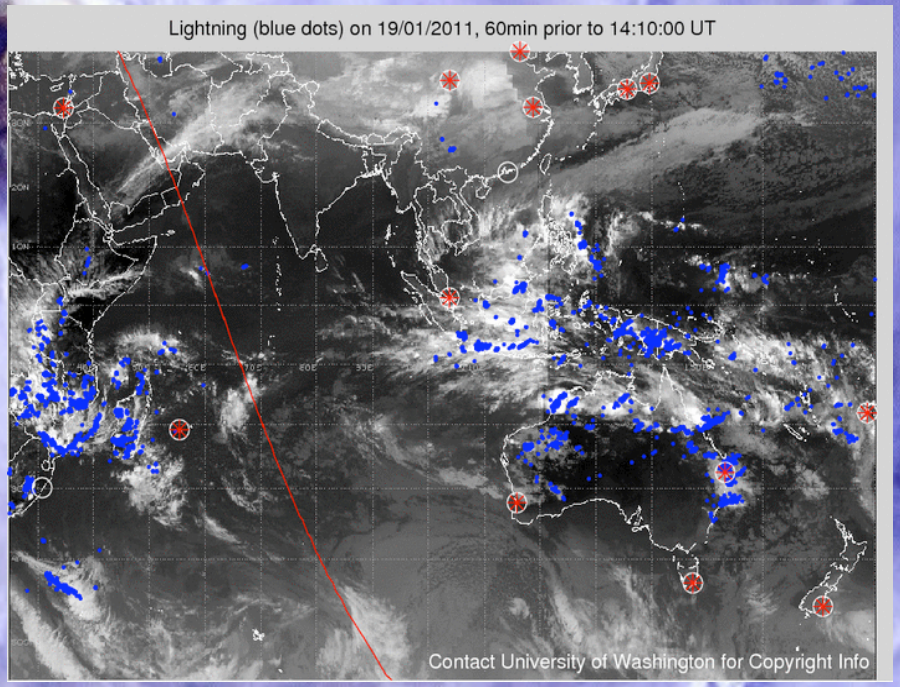
Corbosiero and Molinari (2003)

Introduction & Motivation

- With the introduction and expansion of long range lightning detection networks, the continuous monitoring of TCs over the open oceans became possible.

- One of these networks is the World Wide Lightning Location Network (WWLLN), a series of more than 50 VLF (3-30 kHz) TOGA sensors, operated by the University of Washington.





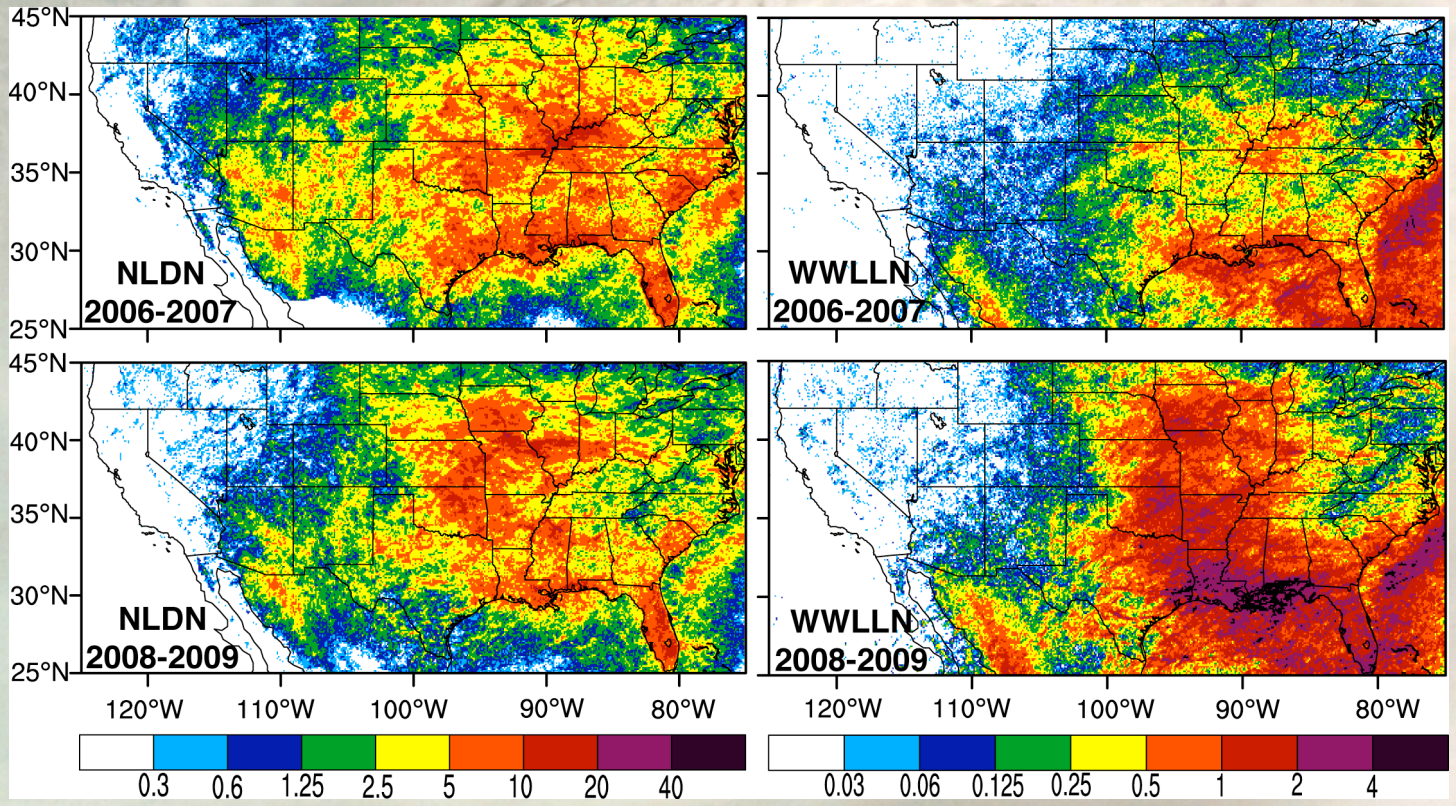
WWLLN Evaluation Using the NLDN

- **Before using the WWLLN to study TCs, we performed an evaluation of the WWLLN using the NLDN as ground truth on unprecedented time and spatial scales.**

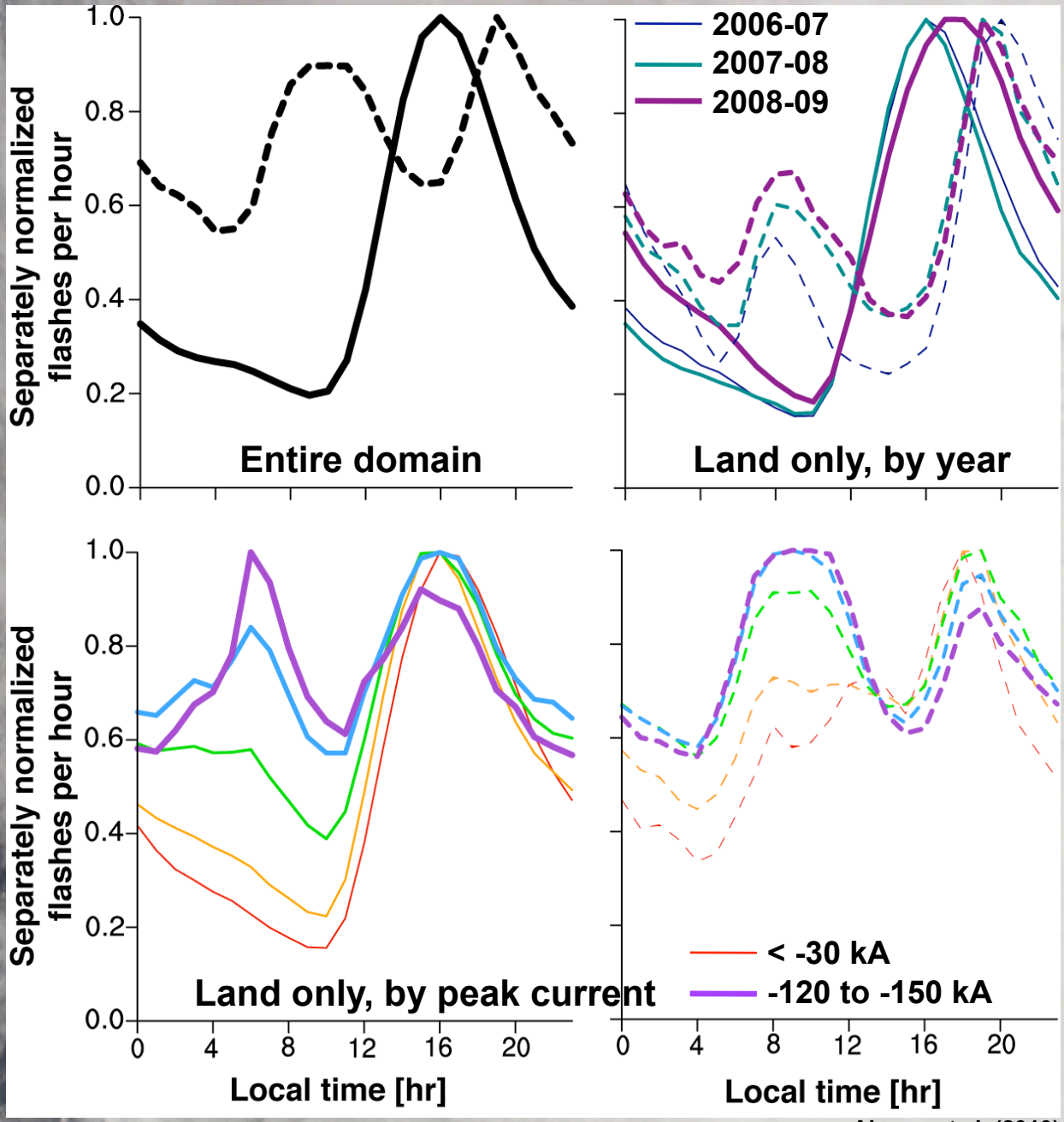
Table 2. Number of Flashes Reported by the WWLLN and the NLDN, by Year, Between 25°N–45°N and 125°W–75°[a]

Year	2006–2007	2007–2008	2008–2009
All WWLLN flashes	2,732,366	3,228,444	6,154,394
All (CG) NLDN flashes	29,614,920	27,567,606	24,839,997
Coincidences	1,147,815	1,346,692	2,558,809
CG DE (%)	3.88	4.89	10.30
IC DE (%)	1.78	2.28	4.82
CG + IC DE (%)	2.31	2.93	6.19

Abarca et al. (2010)



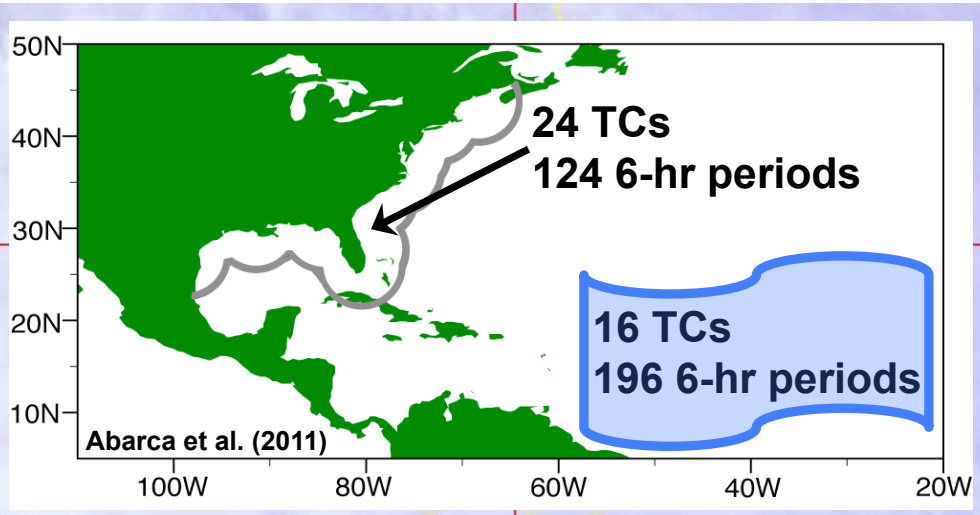
Diurnal Cycle of Lightning



Abarca et al. (2010)

WWLLN (dashed)
NLDN (solid)

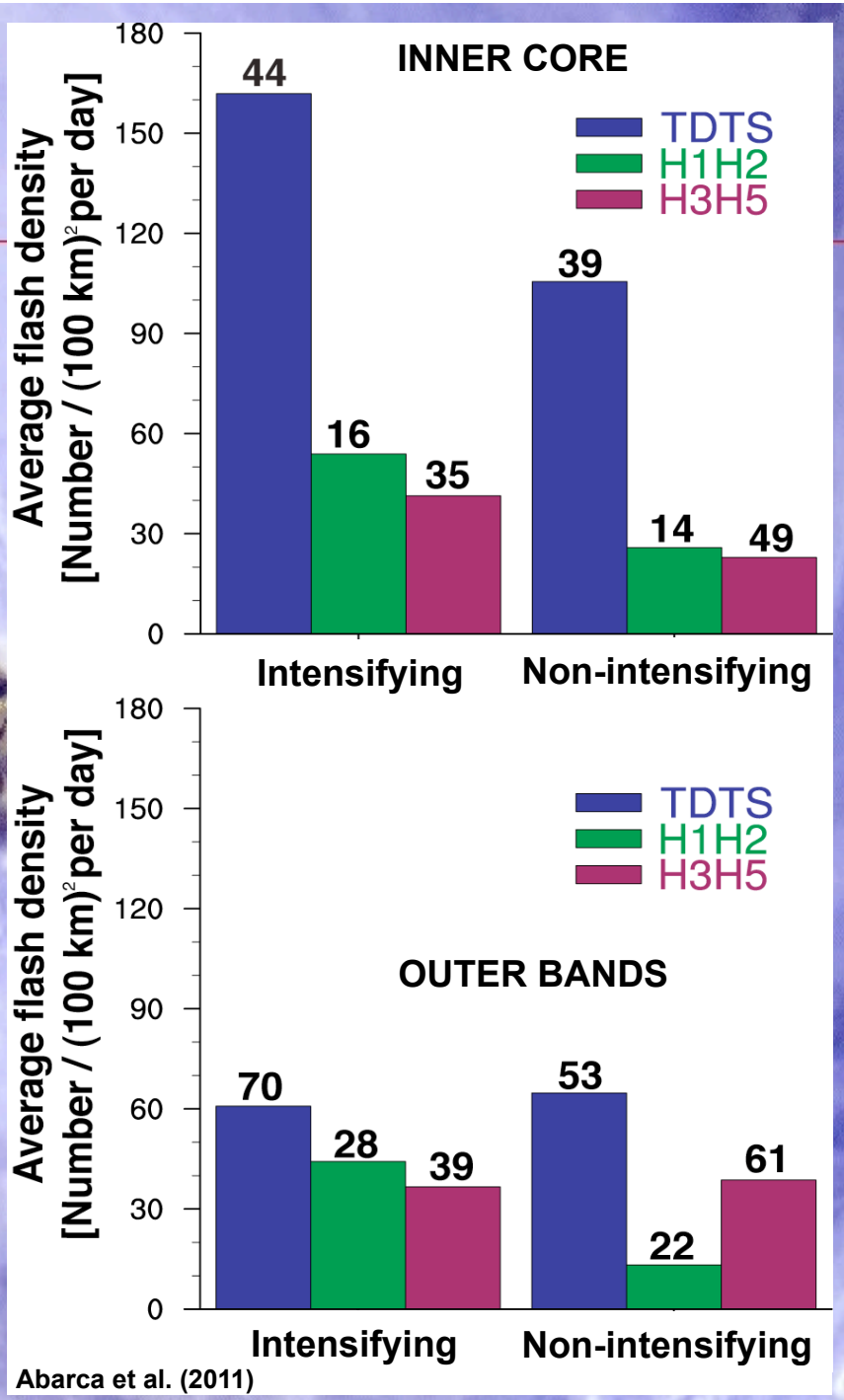
The double peak in the WWLLN is reduced when only land and the weakest flashes are considered, but the issue appears to be growing with time.

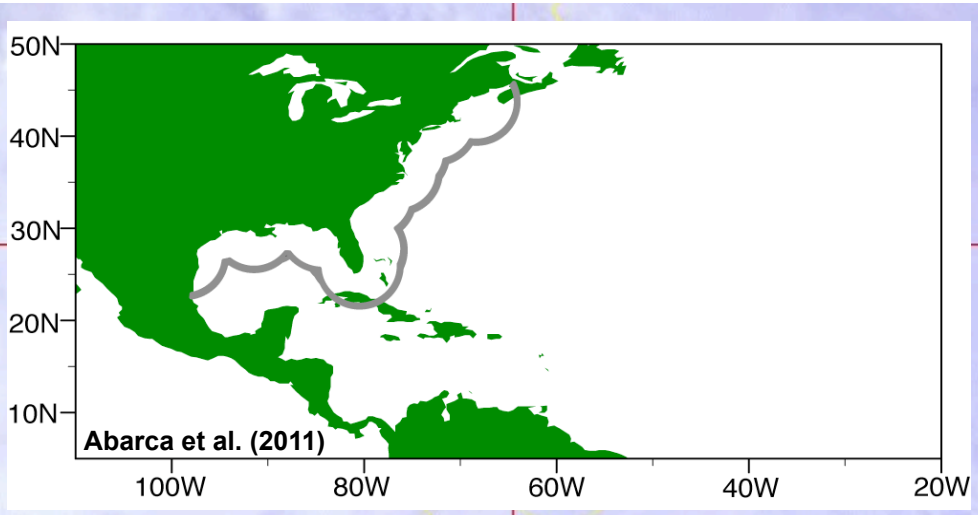


Atlantic Basin TCs 2004 – 2007

- WWLLN-NLDN evaluation (scalloped) and WWLLN open ocean (box) domains

- Intensifying vs. non-intensifying flash densities for the inner 100 km (core; top) and 100-300 km ring (outer bands; bottom) over the open ocean

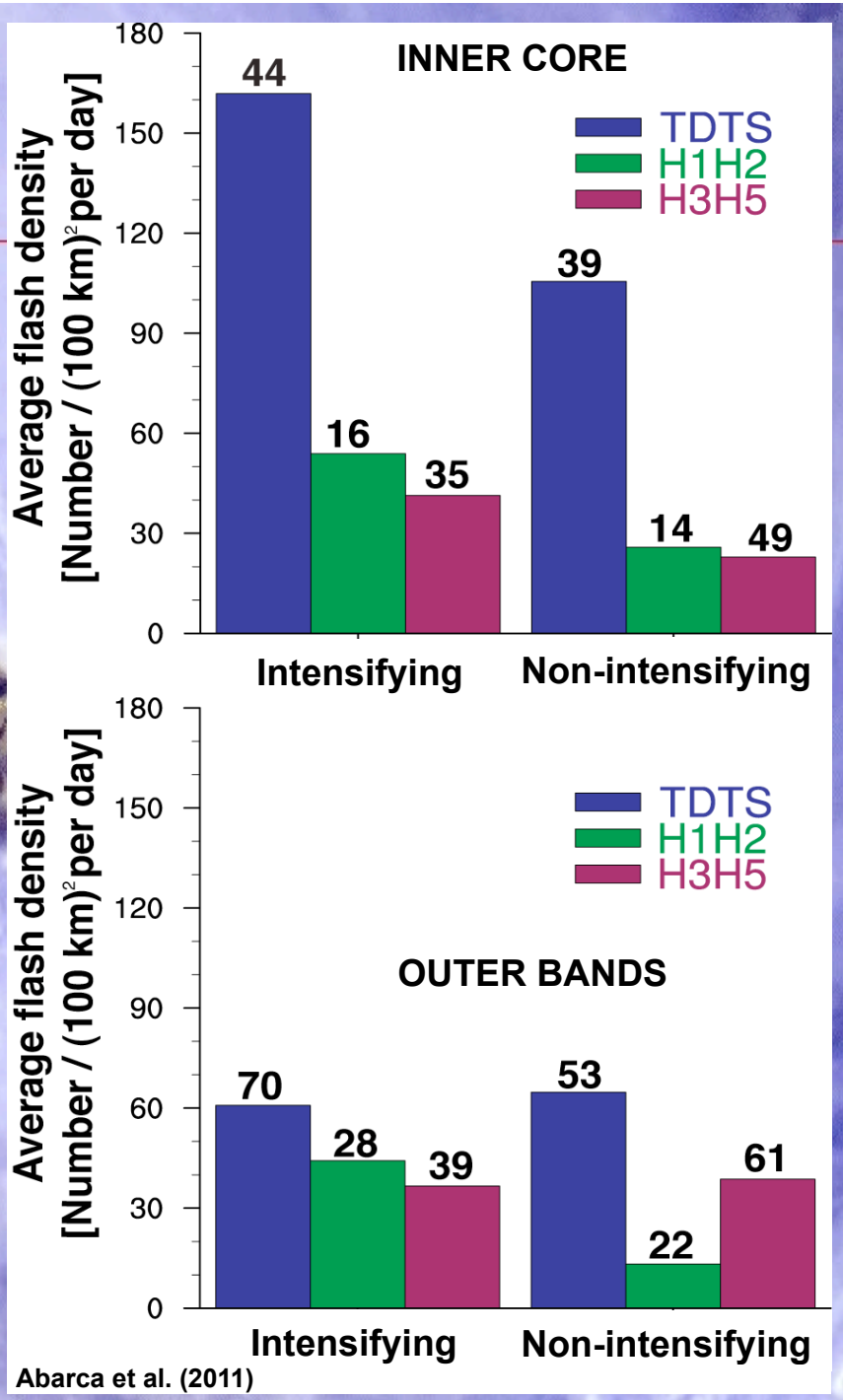




Atlantic Basin TCs 2004 – 2007

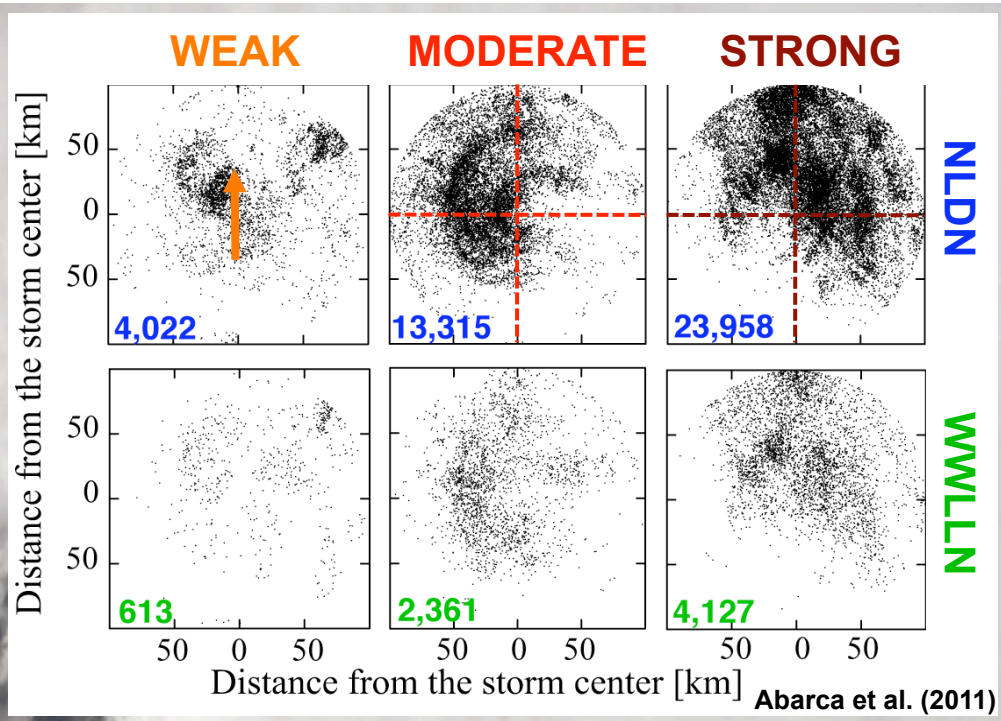
~ The inner core is more electrically active than the outer bands, especially in weaker TCs.

~ The average number of flashes in the inner core is larger in intensifying periods for all strengths of TCs.



Azimuthal Distribution of Flashes: Inner Core Region (< 100 km)

WWLLN (green)
NLDN (blue)



Abarca et al. (2011)

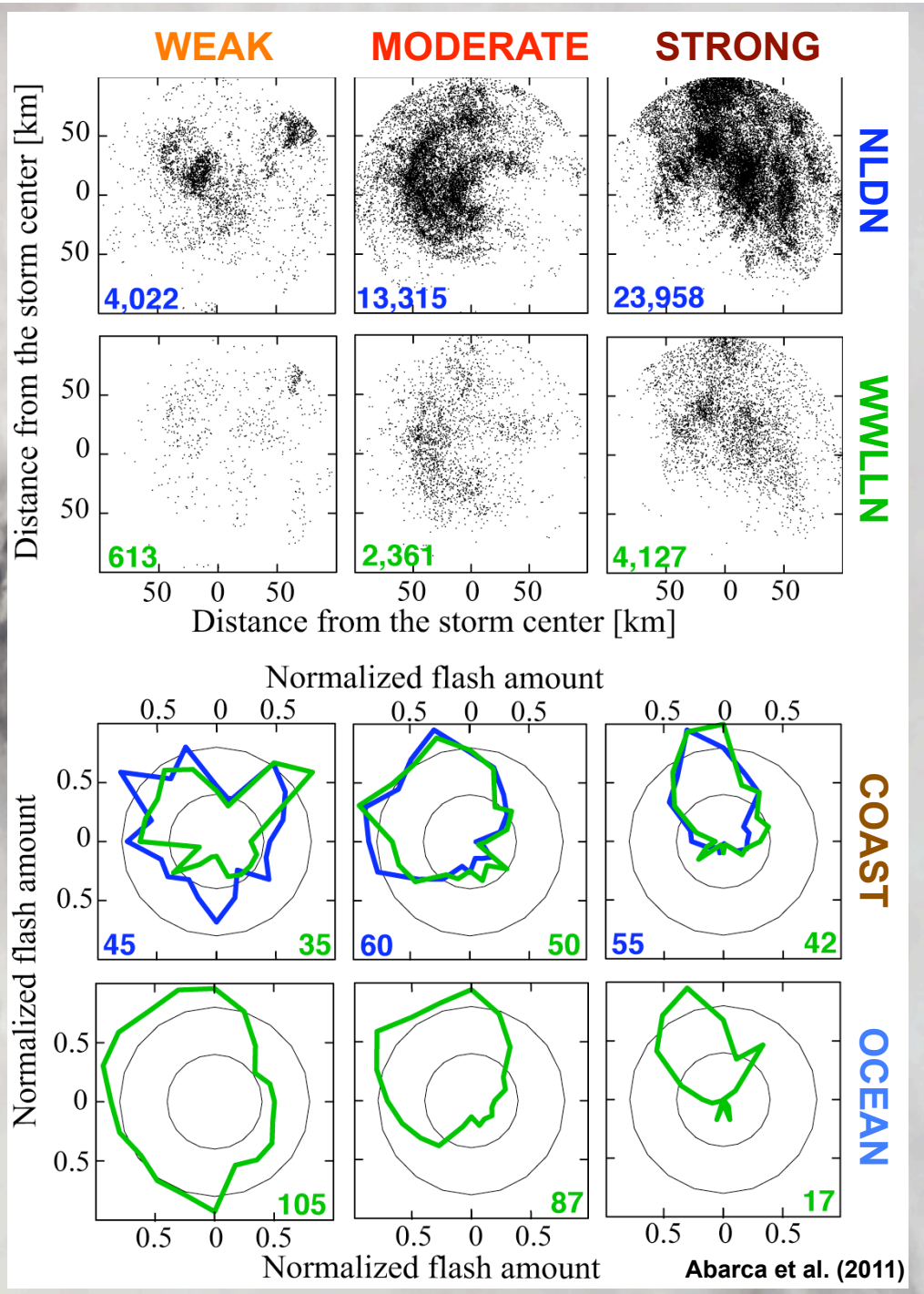
Flashes in each 6-hr period have been rotated around the center so that the shear vector is pointing due north and then composited.

Weak shear: < 5 m s^{-1}
Moderate shear: 5-10 m s^{-1}
Strong shear: > 10 m s^{-1}

Azimuthal Distribution of Flashes: Inner Core Region (< 100 km)

The flashes in 18° sectors around each 6-hr period are summed and normalized by the largest value.

The normalized sums are plotted as the vertices of 20-sided polygons and plotted at a radius proportional to the normalized sum in the direction of the sector.

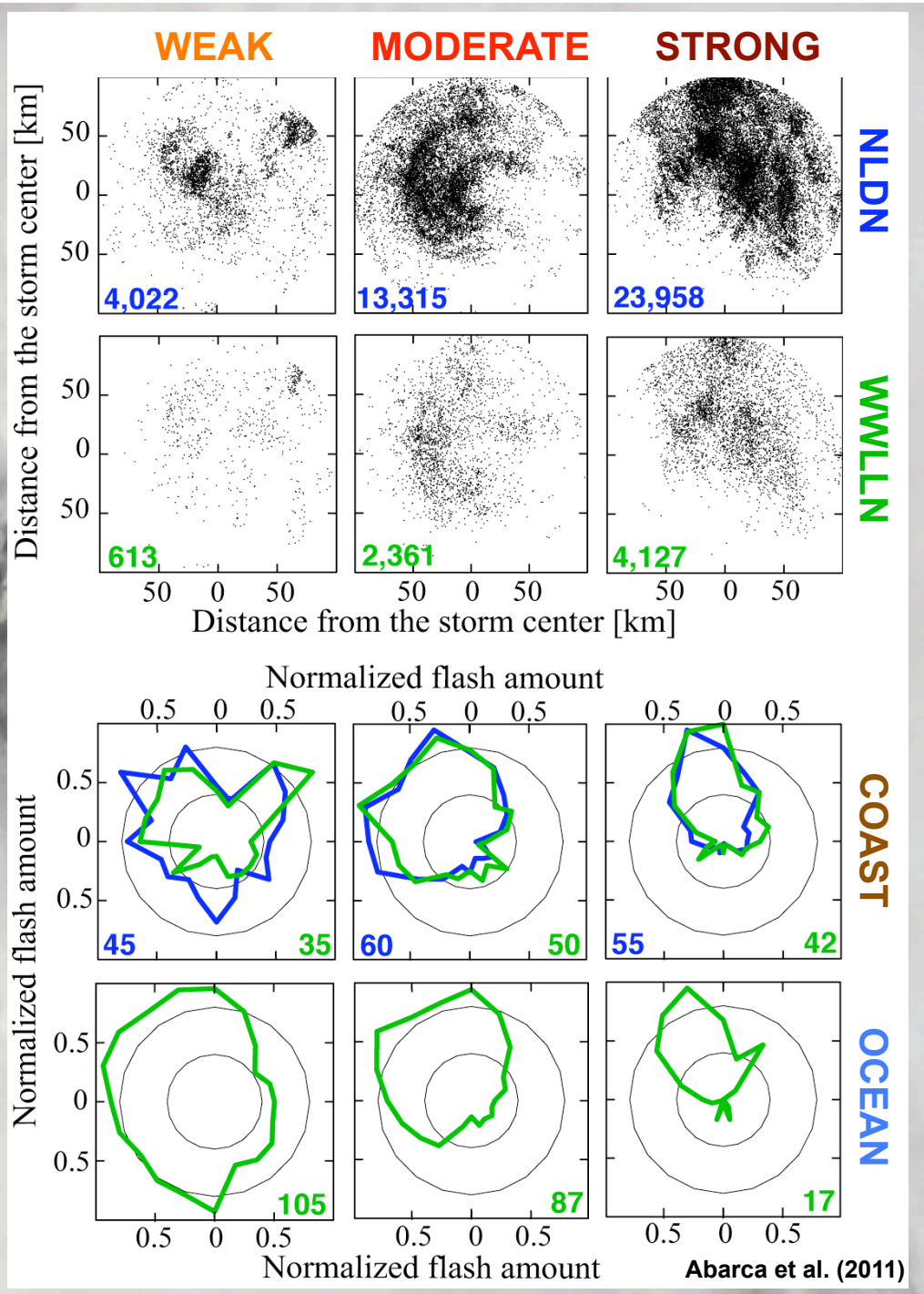


Azimuthal Distribution of Flashes: Inner Core Region (< 100 km)

WWLLN (green)
NLDN (blue)

Shear

Lightning in the inner core shows a downshear left preference for shear > 5 m s^{-1}, with the azimuthal span of the convection sharpening with larger shear values.

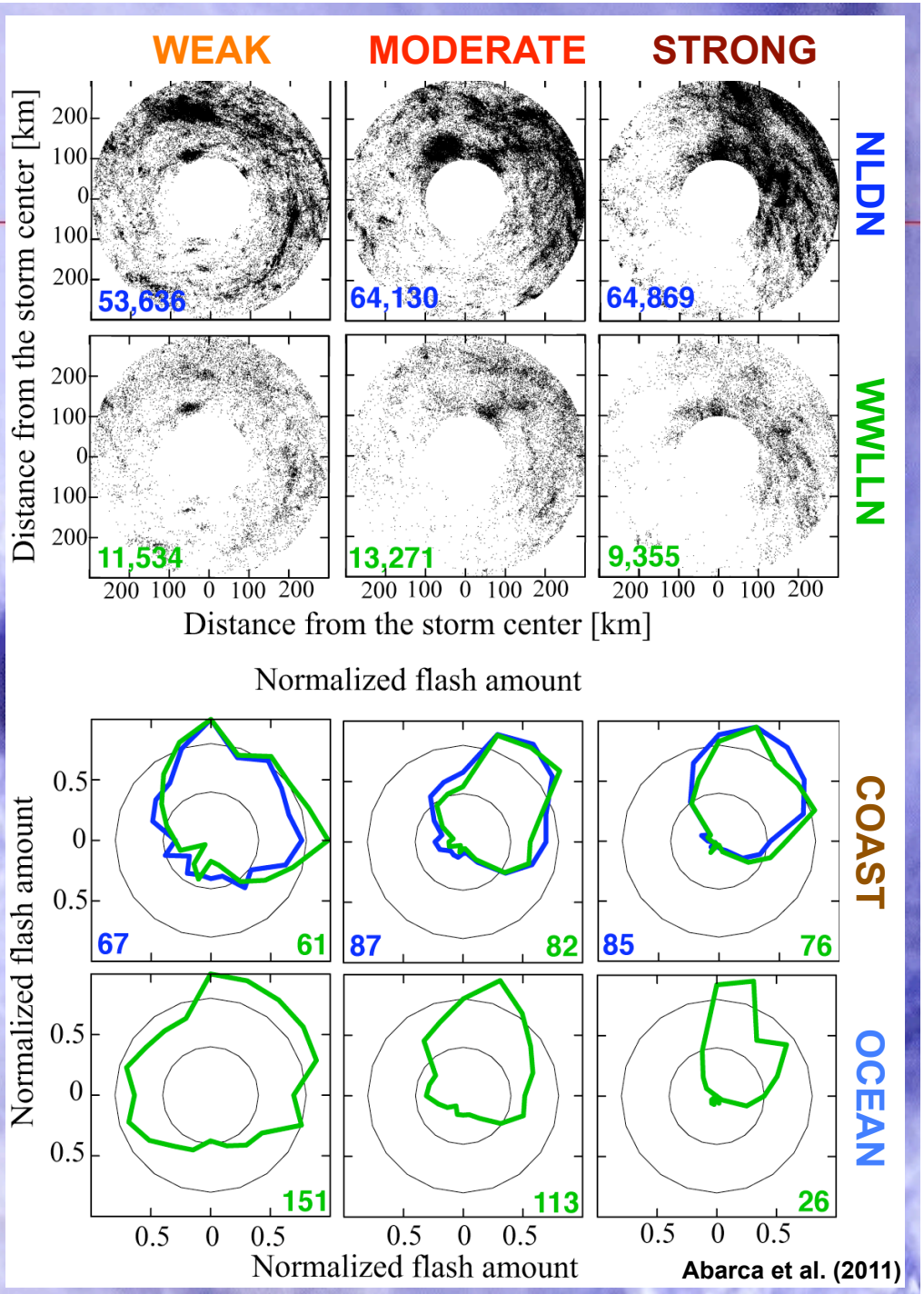


Azimuthal Distribution of Flashes: Outer Band Region (100-300 km)

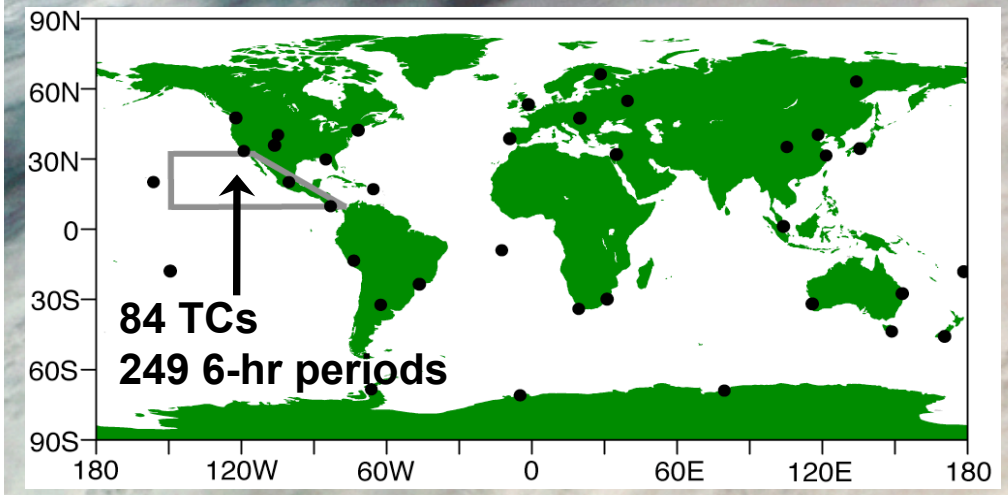
WWLLN (green)
NLDN (blue)

Shear

Lightning in the rainband region shows a distinct preference for the downshear right quadrant with a narrowing of the region with increasing shear.



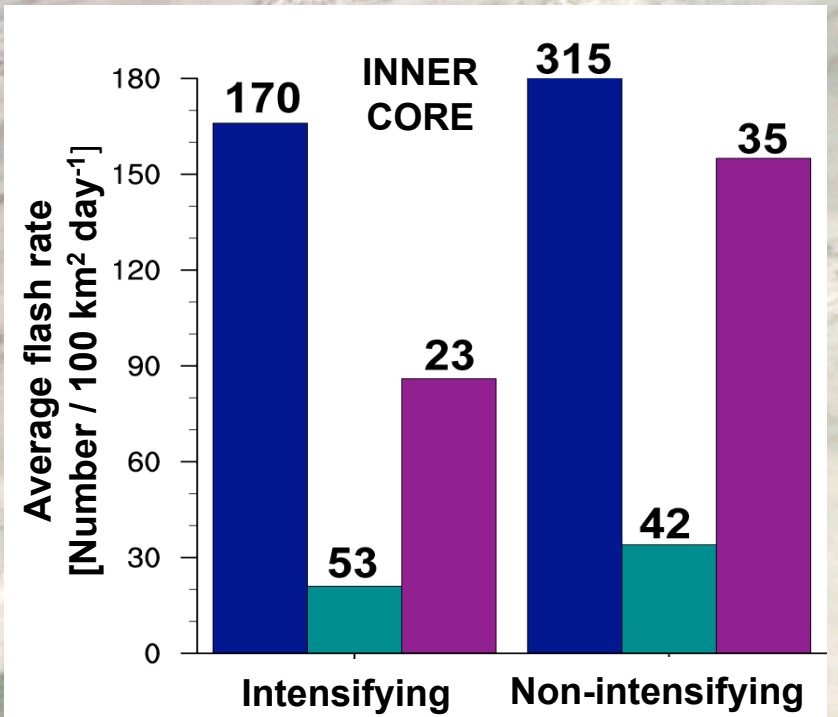
Abarca et al. (2011)

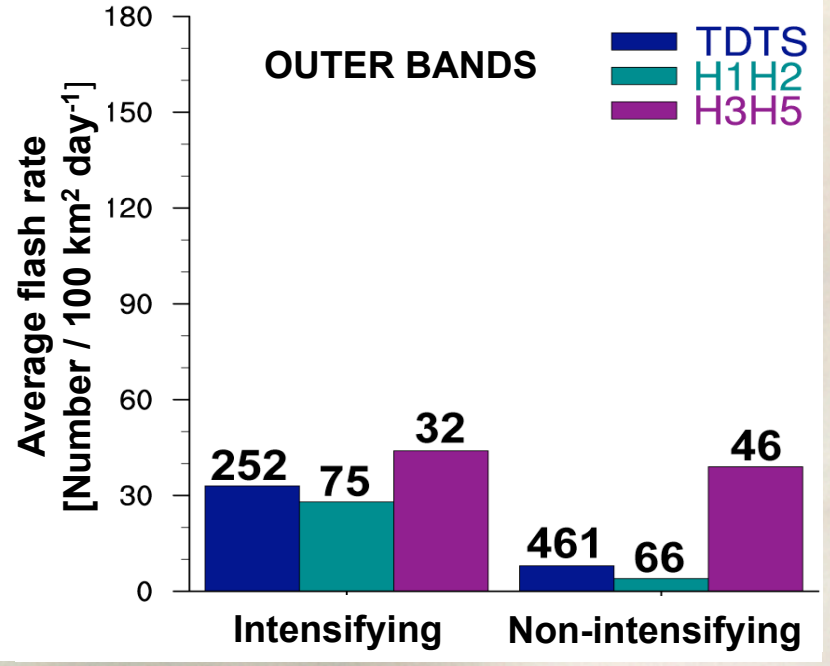


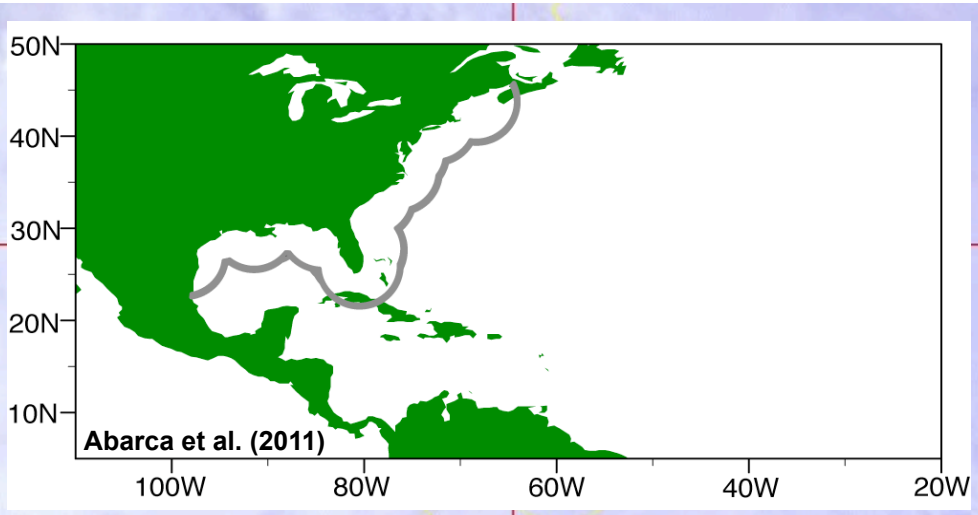
Eastern Pacific TCs 2004 – 2009

~ Like the Atlantic, the inner core is more electrically active than the outer bands.

~ However, the average flash rate in the inner core is larger in non-intensifying periods, especially for the strongest TCs.



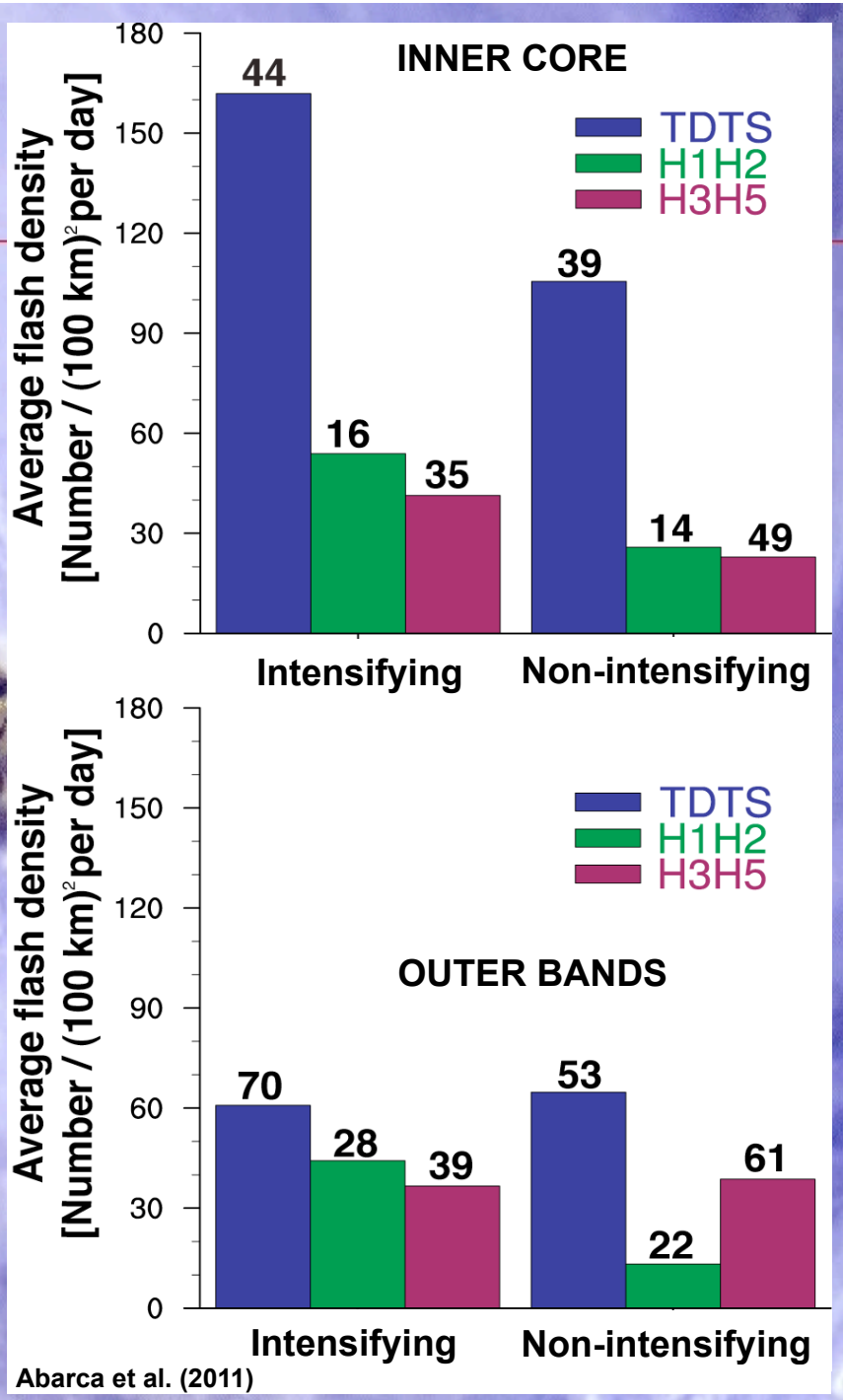




Atlantic Basin TCs 2004 – 2007

~ The inner core is more electrically active than the outer bands, especially in weaker TCs.

~ The average number of flashes in the inner core is larger in intensifying periods for all strengths of TCs.

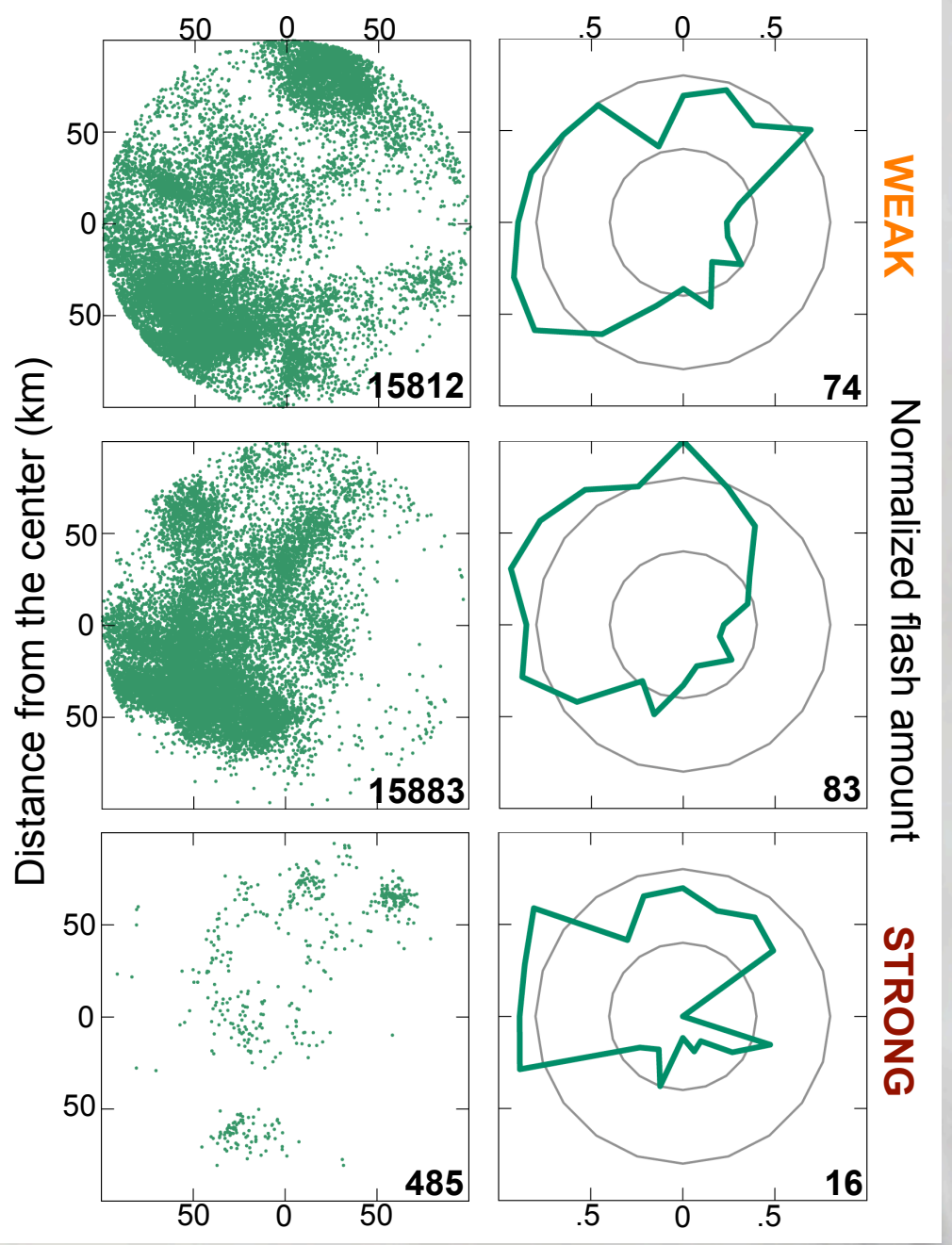


Azimuthal Distribution of Flashes: Inner Core Region (< 100 km)

Only WWLLN flashes

Shear

Similar to the Atlantic, the inner core flashes in the eastern Pacific show a strong downshear left preference, but without the narrowing of the main region of convective activity.



Summary & Future Work

- In the Atlantic and eastern Pacific basins, convective activity is maximized in the downshear left quadrant in the core, and downshear right in the rainbands
- Flash density in the inner core may have potential for distinguishing between intensifying and non-intensifying TCs in the Atlantic, while in the Pacific the strongest, non-intensifying TCs have the highest flash rates
- Continue to investigate the flash densities and distributions in the eastern Pacific and other basins where aircraft reconnaissance is not routine