Diurnal Pulsing of Lightning in Strong Tropical Cyclones

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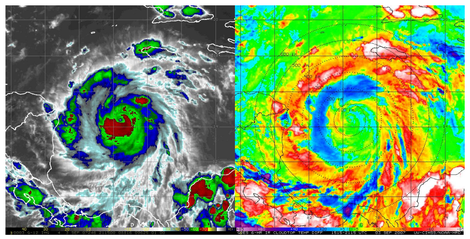
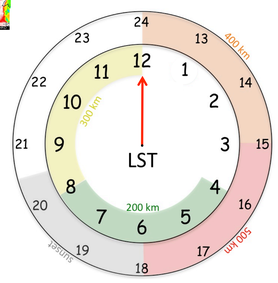
Background

- TC diurnal pulsing has been observed in 6-h infrared (IR) brightness temperature differencing (Dunion et al. 2014). The pulses appear as "cool rings" in this identification technique.



The IR image of Hurricane Felix on 3 Sep 2007 at 2115 UTC (left) and the 6-h (1515-2115 UTC) IR brightness temperature difference (right). The red ring around the TC on the right is the "cool ring" or diurnal pulse.

- These pulses begin forming near the core after sunset & move radially outward to a radius of about 500 km by the late afternoon
  - Radial location of the pulse seems to be predictable in Local Standard Time (LST)
- Changes to the TC are evident following the pulse:
  - The TC expands in size, both at upper levels (as revealed by IR imagery) and below (37 GHz microwave imagery)
  - Behind "cool ring", brightness temperatures warm – unfavorable for TC

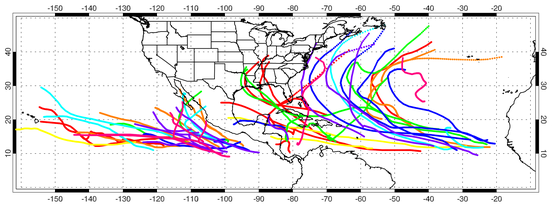


Local Standard Clock displaying the approximate location of the diurnal pulse throughout the day.

Purpose of this study: Can we see these diurnal pulses in the lightning field?

Data and Methods

- 56 major hurricanes from 2005–2012 in the North Atlantic (NATL) and East Pacific (EPAC) basins



Interpolated hourly NHC Best Track positions for the 56 major hurricanes from 2005-2012. The colors represent different years.

- World Wide Lightning Location Network (WWLLN) lightning strike locations
- National Hurricane Center (NHC) Best Track TC track positions
- Felix vs. Ike comparison:
  - Global Forecast System (GFS) 0.5° analyses for environmental CAPE and vertical velocity
  - Geostationary Operational Environmental Satellite (GOES) for brightness temperatures
  - Special Sensor Microwave Imager (SSM/I) for 85 GHz Polarization Corrected Temperature (PCT); isolates areas of deep convection

Steps to analyze the lightning data:

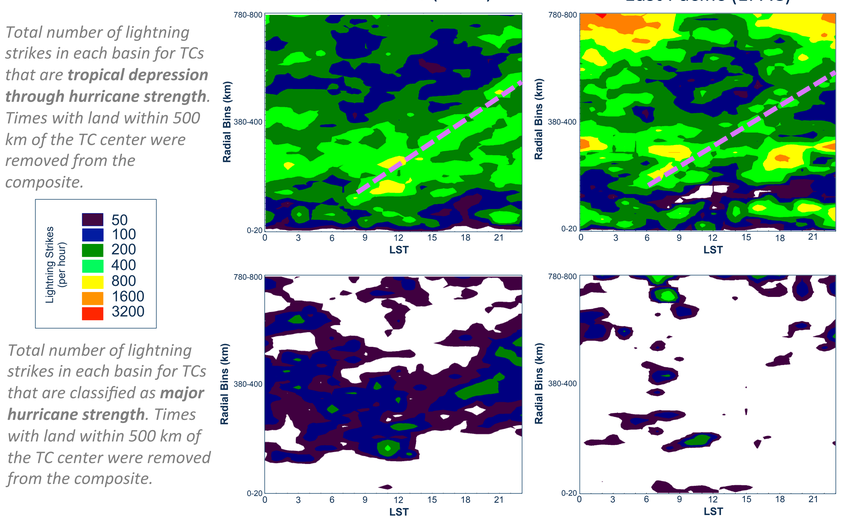
1. Track positions were linearly interpolated to 1-minute to better locate the distance of lightning strikes from the TC center.
2. The distance between each lightning strike and the TC center was calculated using a great circle.
3. The track positions and the surrounding lightning strikes for each hour were transformed from UTC to LST.

Results

Basin Total Tropical Cyclones

*Total number of lightning strikes in each basin for TCs that are **tropical depression through hurricane strength**. Times with land within 500 km of the TC center were removed from the composite.*

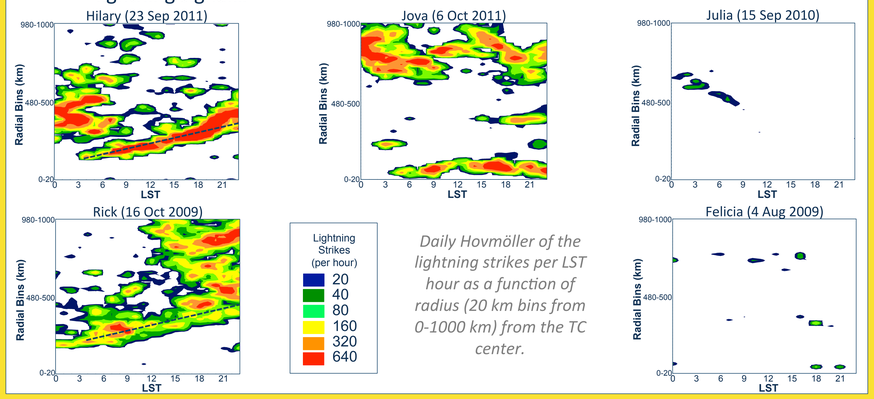
*Total number of lightning strikes in each basin for TCs that are classified as **major hurricane strength**. Times with land within 500 km of the TC center were removed from the composite.*



Individual Tropical Cyclones

Some TCs exhibit a diurnal lightning signal…

…and others do not.



Daily Hovmöller of the lightning strikes per LST hour as a function of radius (20 km bins from 0-1000 km) from the TC center.

Felix (2007) vs. Ike (2008) Comparison

Felix (2007)

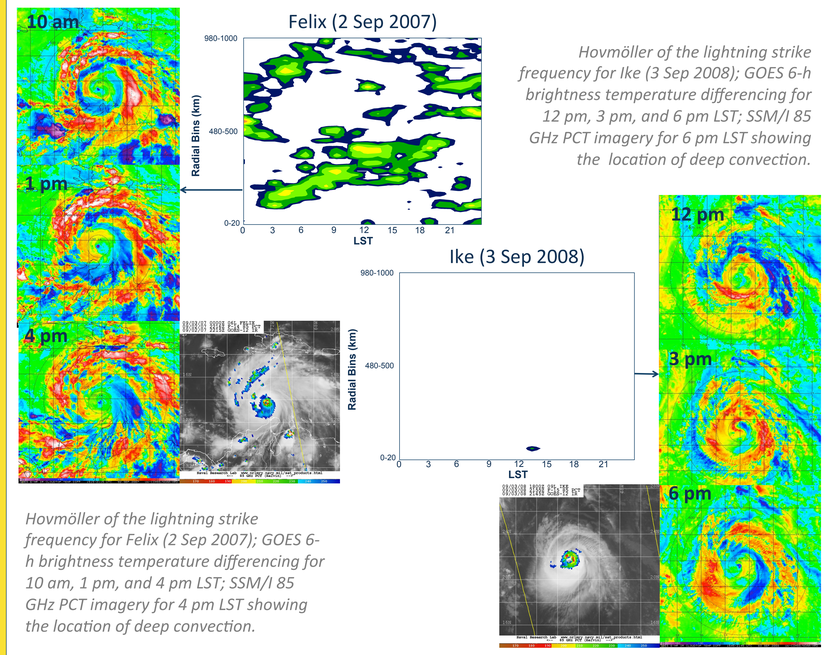
- Diurnal lightning signal
- Brightness temperatures near **-70°C** in pulse
- **Stronger** mean upward motion (500 hPa; < 500 km radii):
  - 1200 UTC: -0.18 Pa/s
  - 1800 UTC: -0.17 Pa/s
- **Increasing** mean CAPE (< 500 km radii):
  - 1200 UTC: 843 J/kg
  - 1800 UTC: 1229 J/kg
- **More** ice scattering in pulse

Both

- Diurnal pulse in IR brightness temperature differences
- Rapidly intensifying into major hurricanes on this day

Ike (2008)

- **No** diurnal lightning signal
- Brightness temperatures near **-60°C** in pulse
- **Weaker** mean upward motion (500 hPa; < 500 km radii):
  - 1200 UTC: -0.09 Pa/s
  - 1800 UTC: -0.08 Pa/s
- **Decreasing** mean CAPE (< 500 km radii):
  - 1200 UTC: 1220 J/kg
  - 1800 UTC: 1135 J/kg
- **Less** ice scattering in pulse



Hovmöller of the lightning strike frequency for Ike (3 Sep 2008); GOES 6-h brightness temperature differencing for 12 pm, 3 pm, and 6 pm LST; SSM/I 85 GHz PCT imagery for 6 pm LST showing the location of deep convection.

Hovmöller of the lightning strike frequency for Felix (2 Sep 2007); GOES 6-h brightness temperature differencing for 10 am, 1 pm, and 4 pm LST; SSM/I 85 GHz PCT imagery for 4 pm LST showing the location of deep convection.

Summary

- The radially outward propagating **diurnal cycle**, which has previously been shown using 6-h IR brightness temperature differencing, is **present in the lightning** as well.
  - Suggests diurnal pulses are associated with *deep convective* processes
- The diurnal lightning signal appears in basin-wide composites of the NATL and EPAC
  - The diurnal pulsing dominates the lightning signal in the NATL for major hurricanes
- Individual **TCs do not always have a diurnal lightning signal**, even though a diurnal cycle is present in the IR brightness temperature differencing
  - A case study of Felix (2007) and Ike (2008) showed these differences may arise from the environment's ability to support deep convection, and thus lightning. The TC with a diurnal lightning signature had:
    - Colder cloud tops in the pulse
    - Stronger vertical velocities
    - Increasing CAPE
    - More ice scattering in the pulse

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References

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