# TRMM-based Lightning Climatology

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**ABSTRACT:** Gridded climatologies of total lightning flash rates seen by the spaceborne Optical Transient Detector (OTD) and Lightning Imaging Sensor (LIS) have been updated. OTD collected data from May 1995 to March 2000. LIS data (equatorward of about 38°) has been added for 1998-2010. Flash counts from each instrument are scaled by the best available estimates of detection efficiency. The long LIS record makes the merged climatology most robust in the tropics and subtropics, while the high latitude data is entirely from OTD. The mean global flash rate from the merged climatology is 46 flashes per second. The peak annual flash rate at 0.5° scale is 160 fl $km^{-2}$ $yr^{-1}$ in eastern Congo. The peak monthly average flash rate at 2.5° scale is 18 fl $km^{-2}$ $mo^{-1}$, from early April to early May in the Brahmaputra Valley of far eastern India. Lightning decreases in this region during the monsoon season, but increases further north and west. A monthly average peak from early August to early September in northern Pakistan also exceeds any monthly averages from Africa, despite central Africa having the greatest yearly average.

Most continental regions away from the equator have an annual cycle with lightning flash rates peaking in late spring or summer. The main exceptions are India and southeast Asia, with springtime peaks in April and May. For landmasses near the equator, flash rates peak near the equinoxes. For many oceanic regions, the peak flash rates occur in autumn. This is particularly noticeable for the Mediterranean and North Atlantic. Landmasses have a strong diurnal cycle of lightning, with flash rates generally peaking between 3-5 pm local solar time. The central United States flash rates peak later, in late evening or early night. Flash rates peak after midnight in northern Argentina. These regions are known for large, intense, long-lived mesoscale convective systems.

## 1. INTRODUCTION

The spaceborne optical sensors Optical Transient Detector (OTD) on the MicroLab-1 satellite and Lightning Imaging Sensor (LIS) on the Tropical Rainfall Measuring Mission (TRMM) satellite have detected lightning for nearly sixteen years (1995 - present) total. Christian et al. [2003] summarized the global lightning climatology based on OTD's five years of data (May 1995 - March 2000). The lightning team associated with NASA Marshall Space Flight Center (MSFC) extended this to include a LIS-based gridded climatology and a merged LIS-OTD gridded climatology through 2005 (available from http://thunder.nsstc.nasa.gov). The LIS and LIS-OTD gridded climatologies are here extended with LIS data from Jan. 1998 - Dec. 2010. Results are similar to those found from the earlier climatologies, although the length of the current data record allows more detailed analyses with less spatial or temporal smoothing.

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## 2. DATA AND METHODS

Details on the lightning sensors are provided by Christian et al. [2003] and Boccippio et al. [2002]. Both sensors monitor the 777.4 nm atomic oxygen multiplet, detecting pulses of illumination (produced by lightning) above background levels. Both are (were) on satellites in low earth orbit, viewing an earth location for about 3 minutes as OTD passed overhead or 1.5 minutes as LIS passed overhead.

Total viewtimes (the duration that a location is within the field of view, with the instrument operating properly) are approximated on 0.5° x 0.5° grid boxes. For each grid box, the total viewtime and flash count is accumulated over all orbits, and sorted by time of day and day of year. Flash counts are scaled by each instrument's detection efficiency [Boccippio et al. 2002 and Christian et al. 2003], which varies with time of day and also varies with geographic location for the OTD. Following Boccippio et al. [2002], the LIS detection efficiency ranges from about 69% near local noon to 88% near local overnight. The OTD detection efficiency ranges between 41-54%, except it is reduced roughly in half in the South Atlantic Anomaly.

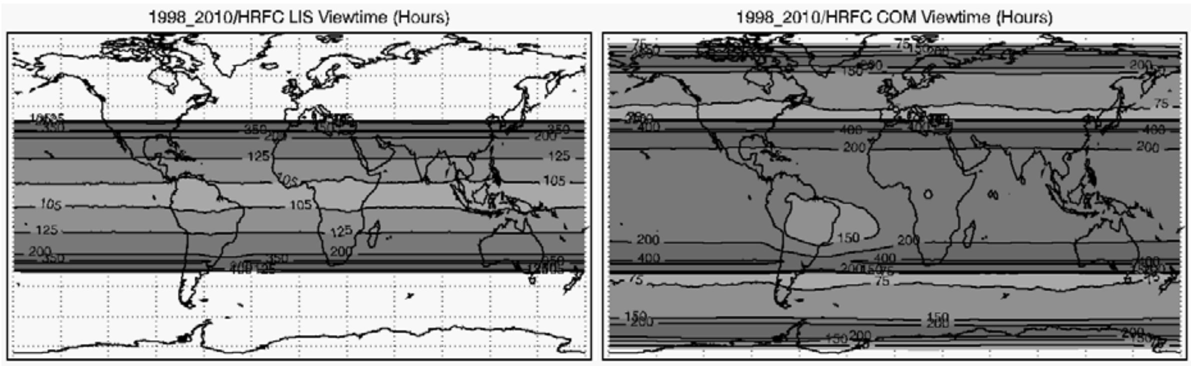


Figure 1. Accumulated viewtime in hours for (a) LIS from 1998-2010 and (b) OTD plus LIS from 1995-2010. Viewtime from OTD alone is the same as shown in Fig. 1 of Christian et al. [2003].

The TRMM satellite carrying LIS orbits between 35° N and S, so its sampling is maximized near those latitudes. LIS has observed equatorial regions for a little over 100 h, and a band between 30-38° N and S for between 200-400 h (Fig. 1a). With a typical sampling duration of ~90 s at a time, this equates to around 4000 separate observations of any point on the equator, and 8000-16000 observations of each location in the subtropics. Adding the five years of OTD yields a combined viewtime grid (Fig. 1b) with just over 150 h recorded at the equator, around 65 h immediately poleward of the edge of LIS's field of view (~38° N and S), and 240 h near 75° N and S. High rates of noise from the South Atlantic Anomaly reduce the effective viewtime from OTD near Brazil, but LIS is only marginally affected due to its higher orbit.

Flash rates are computed using the flash counts scaled by detection efficiency and the total viewtimes. Boxcar averages in space (2.5°) or time (31 days) are used to smooth some fields, depending on the type of analyses.

## 3. RESULTS

### *3.1 Annual flash rates*

The mean annual flash rate from LIS-OTD is mapped in Fig. 2. The peak annual flash rate at 0.5° scale is 160 fl km$^{-2}$ yr$^{-1}$ in eastern Congo. A broad region of central Africa exceeds 30 fl km$^{-2}$ yr$^{-1}$, and most land regions in the tropics and subtropics - except for arid regions - exceed 10 fl km$^{-2}$ yr$^{-1}$. For more details on local extrema, see Albrecht [2011]. The global average from this dataset is 46.1 fl s$^{-1}$ (very similar to that reported by Christian et al. [2003] from the OTD climatology by itself), 2.9 fl km$^{-2}$ yr$^{-1}$, 1.46 billion flashes per year.

About 90% of that comes from within the LIS domain (+/-38°). Without merging the LIS and OTD data, the 1998-2010 LIS climatology has 2% more flashes in the +/-38° domain than does the 1995-2000 OTD.

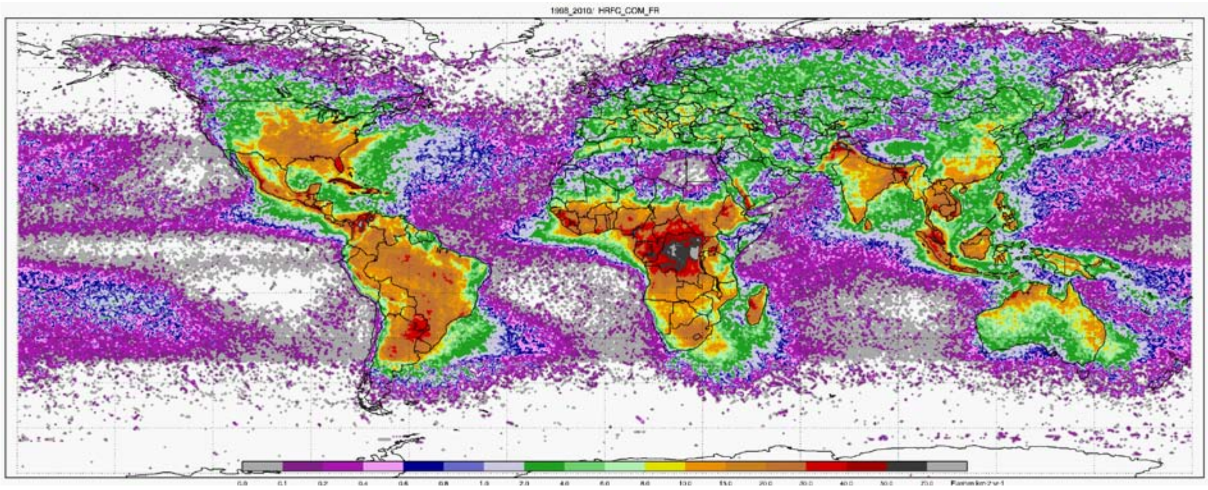

Figure 2. Mean annual flash rate from merged LIS and OTD, 0.5° grid.

### *3.2 Seasonality*

Most continental regions away from the equator have an annual cycle with lightning flash rates peaking in late spring or summer (Fig. 3). The main exceptions are India and southeast Asia, with springtime peaks in April and May. The greatest monthly average flash rate at 2.5° scale (Fig. 4) is 18 fl $km^{-2}$ $mo^{-1}$, from early April to early May in the Brahmaputra Valley of far eastern India (between Bangladesh and the Himalayas). Lightning decreases in this region during the monsoon season, but increases further north and west. A monthly average greater than 13 fl $km^{-2}$ $mo^{-1}$ from early August to early September in northern Pakistan also exceeds any monthly averages from Africa, despite central Africa having the greatest yearly average.

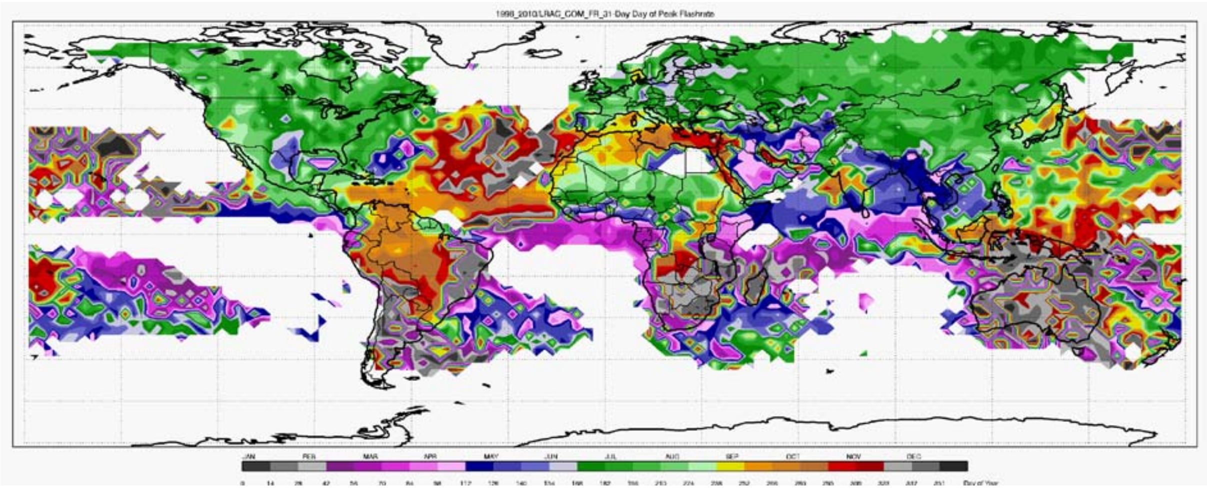

Figure 3. Day of year having the highest monthly flash rate, using a 31-day moving boxcar average.

For landmasses near the equator, flash rates peak near the equinoxes. For many oceanic regions, the peak flash rates occur in autumn. This is particularly noticeable for the Mediterranean and North Atlantic. Recall that the sampling is greatly reduced poleward of 38°, and inadequate for high resolution analysis of the type shown in Figs. 3-4. Low flash rate regions of the ocean also appear noisy at this scale, but coherent larger scale features can be noticed (e.g., peaks for southern hemisphere autumn over large portions of the south central Pacific, southwest Atlantic, and southwest Indian Ocean).

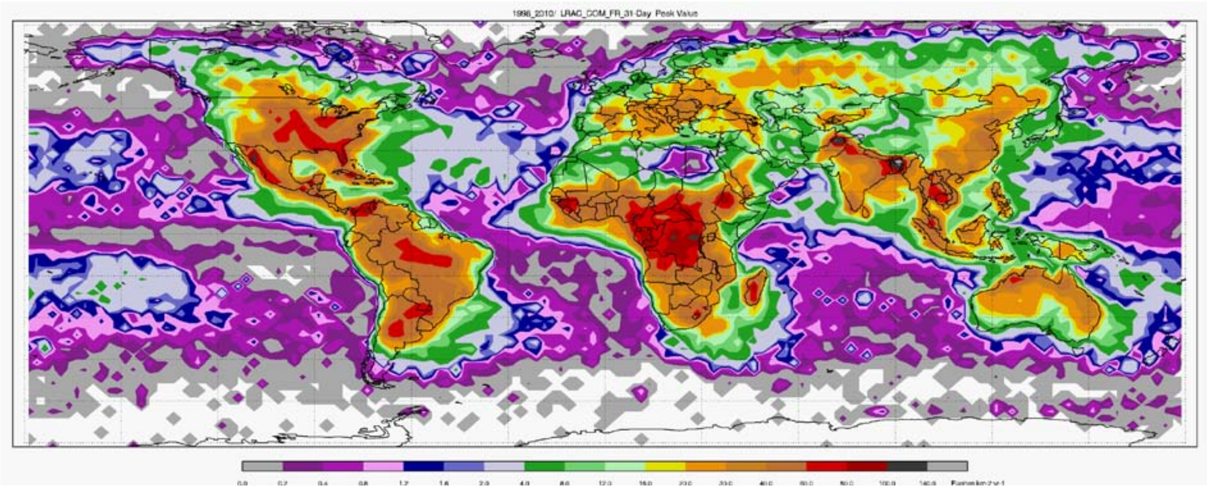

Figure 4. Highest monthly average flash rate at each location, using a 31-day moving average computed daily. Note that the flash rate scale is double that in Fig. 2, and the grid size is 2.5°.

### *3.3 Diurnal maxima*

Landmasses have a strong diurnal cycle of lightning, with flash rates generally peaking between 3-5 pm local solar time. The central United States flash rates peak later, in late evening or early night. Flash rates peak after midnight in northern Argentina. These regions are known for large, intense, long-lived mesoscale convective systems.

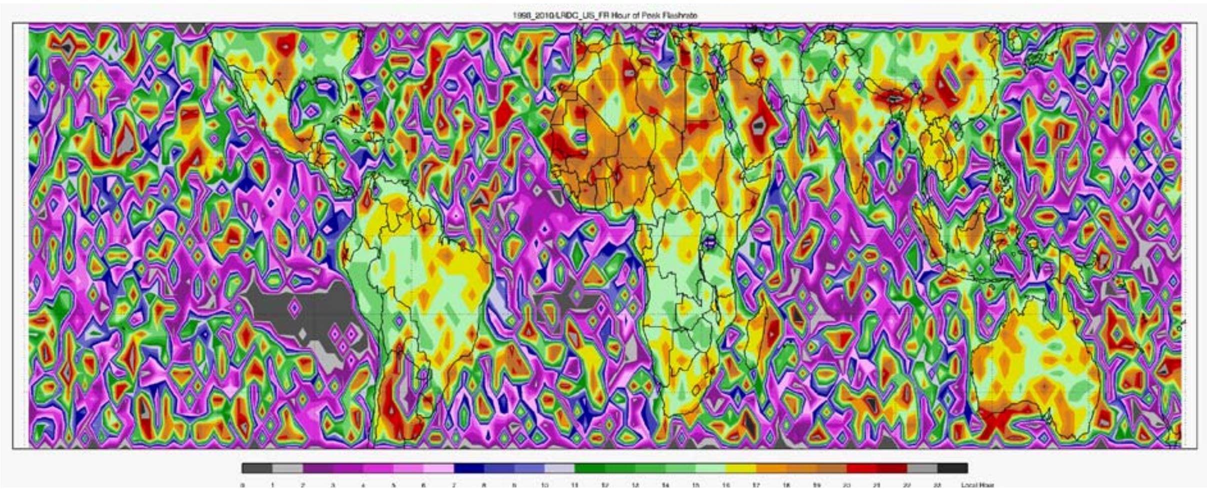

Figure 5. Time of day (local solar time) with greatest LIS flash rates.

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