

Daily Peak Activity of the African Lightning Chimney Based on Meteosat Third Generation (MTG) Lightning Imager (LI), WWLLN and Schumann Resonance (SR) Observations

K. Németh^{1,2,3,4*}, E. Williams⁵, Q. Wang⁶, A. Neska⁷, G. Sátori³, M. Herein^{8,3}, T. Haszpra^{8,3},
P. Steinbach^{1,2,9,10}, and T. Bozóki^{3,1,2}

¹Obuda University, Karman Space Research Center, Budapest, Hungary

²Obuda University, Kandó Kálmán Faculty of Electrical Engineering, Budapest, Hungary

³HUN-REN Institute of Earth Physics and Space Science, Sopron, Hungary

⁴ELTE Eötvös Loránd University, Faculty of Science, Doctoral School of Earth Sciences, Budapest, Hungary

⁵Massachusetts Institute of Technology, Parsons Laboratory, Cambridge, MA, USA

⁶Institute of Urban Meteorology, China Meteorological Administration, Beijing, China

⁷Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland

⁸HUN-REN-ELTE Theoretical Physics Research Group, Budapest, Hungary

⁹Department of Geophysics and Space Science, Eötvös Loránd University, Budapest, Hungary

¹⁰HUN-REN-ELTE Space Research Group, Budapest, Hungary

Corresponding author: Kolos Németh (nemeth.kolos@epss.hun-ren.hu)

Key Points:

- Daily lightning activity in the African lightning chimney is characterized based on the peak activity and peak time.
- Our study is one of the first to assess the performance of the MTG LI in characterizing the activity of the African lightning chimney.
- MTG flash and SR intensity show consistent daily peak activity, supporting the use of SR data during periods when MTG was not yet available.

Keywords: lightning activity, daily lightning activity, MTG LI, Schumann resonances, WWLLN, Africa

Abstract

Lightning activity is strongly concentrated in tropical continental ‘chimneys’, among which the African lightning chimney stands out as the most intense globally. However, until recently, the incomplete and spatially uneven detection efficiency of ground-based lightning networks, together with the limited spatio-temporal coverage of satellite observations, have constrained the quantitative characterization of African lightning activity, particularly on daily timescales. Since July 2024, the Lightning Imager (LI) onboard the Meteosat Third Generation (MTG) satellites has provided the first continuous, high-temporal-resolution observations of lightning activity over Africa and Europe from geostationary orbit. In this paper, we examine, based on the first year of MTG LI observations, how consistently daily peak activity in the African lightning chimney is represented in different observational datasets. For this purpose, we use MTG LI group and flash data, together with World Wide Lightning Location Network (WWLLN) stroke observations and Schumann resonance (SR) measurements, and focus on two key parameters: the daily peak activity and its timing. We find that daily peak activity derived from MTG flashes shows a strong positive correlation with SR intensity ($r = 0.749$), while WWLLN stroke observations show weaker correspondence. The timing of the daily peak is broadly consistent across the datasets, with the best agreement observed between MTG flashes and SR intensity. For all datasets, daily peak activity is strongly correlated with total daily activity. The strong correspondence between MTG flashes and SR intensity supports the use of both datasets in characterizing the daily activity of the African lightning chimney.

Plain Language Summary

Africa is one of the most lightning-active regions on Earth. Understanding how daily lightning activity varies is important for weather forecasting and for lightning protection efforts in a region where exceptionally frequent lightning poses serious safety challenges. However, reliable day-to-day monitoring of African lightning has historically been limited: ground-based detection networks tend to underestimate African lightning due to sparse receiver coverage in the region, while satellites in low Earth orbit can observe Africa only during brief overpasses. The Lightning Imager (LI) onboard the Meteosat Third Generation (MTG) satellite, operational since July 2024, provides the first continuous lightning observations over Africa and Europe from geostationary orbit. Here, we use the first year of MTG data alongside the World Wide Lightning Location Network (WWLLN) and Schumann resonance (SR) measurements to compare how different observation systems capture the daily variations in African lightning. MTG lightning flash counts and SR intensity show strong agreement in both the magnitude and timing of the daily lightning peak over Africa, while WWLLN shows much weaker correspondence with MTG. The strong agreement between MTG and SR supports the use of decades-long SR records to characterize African lightning activity for the period before MTG became operational.

1 Introduction

Lightning activity on Earth is not uniformly distributed but is strongly concentrated over tropical land regions where intense deep convection occurs (Williams, 2005). The distribution of tropical landmasses gives rise to three major regions of enhanced lightning activity, commonly referred to as tropical lightning “chimneys”, in the Americas, Africa, and Asia (Williams & Satori, 2004). Within these regions, the highest lightning activity occurs over the Amazon Basin in South America, the Congo Basin in Central Africa, and the Maritime Continent region around Indonesia and the surrounding islands. Satellite observations from the Optical Transient Detector (OTD) and the Lightning Imaging Sensor (LIS) have shown that among these three regions the African chimney exhibits the highest lightning flash densities globally (Albrecht et al., 2016; Blakeslee et al., 2020; Cecil et al., 2015; Christian et al., 2003). This dominance is not limited to optical lightning observations but is also supported by Schumann resonance measurements and by classical analyses of the global electric circuit (Williams & Satori, 2004). Ground-based lightning detection networks likewise confirm the pronounced lightning activity over Central Africa, with the most intense activity located in the Congo Basin (Kigotsi et al., 2024 and Soula et al., 2016, both using WWLLN observations). Lightning activity in Africa is of broader meteorological interest, as enhanced thunderstorm activity over eastern Africa has been shown to precede the development of African easterly waves that can later evolve into Atlantic tropical storms and hurricanes (Price et al., 2007). Understanding the spatial and temporal characteristics of lightning activity in Africa is also important from a practical perspective, as the exceptionally high lightning activity poses significant challenges for lightning protection in this region (Cooper et al., 2024; Lyons, 2025).

Despite the strong scientific interest in African lightning activity, its quantitative investigation remains limited by the capabilities of the available observation systems. Global lightning detection networks based on very low frequency (VLF, 3 - 30 kHz) electromagnetic signals, such as the World Wide Lightning Location Network (WWLLN), provide near real-time global lightning locations using distributed receiver stations. However, the detection efficiency of these networks is spatially uneven, which complicates the quantitative assessment of lightning activity on continental scales (Bozoki et al., 2023). In particular, lightning activity over Africa is often underestimated by global lightning detection networks because of the relatively sparse receiver coverage in this region (Hutchins et al., 2012; Williams & Mareev, 2014). Complementary information on global lightning activity can be obtained from extremely low frequency (ELF, 3 Hz - 3 kHz) electromagnetic observations of Schumann resonances (SRs), which are global electromagnetic resonant modes of the Earth-ionosphere cavity excited by lightning discharges (Nickolaenko & Hayakawa, 2002; Price, 2016; Schumann, 1954). Because ELF waves experience only very weak attenuation in the Earth-ionosphere waveguide (Chapman et al., 1966; Wait, 1970), global lightning activity can be monitored using SR measurements from only a small number (1–20) of receiver stations (see e.g., Satori et al., 2024; Williams et al., 2021). Every lightning flash in the atmosphere, both intracloud and cloud-to-ground, contributes to SR intensity for two key

reasons: (1) the SRs represent the transverse magnetic (TM) resonance mode of the Earth-ionosphere cavity resonator (e.g., [Galejs, 1972](#)), which is preferentially excited by a vertical electric field and (2) the physical mechanism for charge separation in thunderstorms based on ice particle collisions is gravity-driven, thereby guaranteeing a vertical component in every lightning discharge. However, while SR observations have been shown to provide robust information about the overall intensity of global lightning activity ([Bozóki et al., 2023](#)), their suitability to characterize continental-scale lightning activity has not been clearly demonstrated yet.

Satellite-based optical lightning observations provide another important tool for monitoring global lightning activity. Instruments on low-Earth orbit (LEO) satellites, such as the Optical Transient Detector (OTD) and the Lightning Imaging Sensor (LIS), have played a key role in establishing the global climatology of lightning activity ([Blakeslee et al., 2020](#); [Cecil et al., 2014](#); [Christian et al., 2003](#)). Such lightning climatologies revealed that Africa hosts a large fraction of the world's most intense lightning hotspots, with six of the ten most active hotspots worldwide located on the African continent ([Albrecht et al., 2016](#)). Recent re-evaluations of merged LEO lightning datasets, using updated detection efficiency estimates, confirm central Africa as a major year-round source of global lightning, with a broad late-afternoon lightning maximum over most continental regions, generally near 16:00 – 17:00 LST ([Cecil et al., 2026a, 2026b](#)). However, these instruments observe a given region only during relatively short overpasses, which limits their ability to continuously monitor the temporal variability of lightning activity over a specific area. Geostationary lightning imagers have recently addressed this limitation by providing continuous observations of lightning activity over large regions, for example with the Geostationary Lightning Mapper (GLM) onboard the GOES-R satellites ([Goodman et al., 2013](#); [Rudlosky & Virts, 2021](#)) and the Lightning Mapping Imager (LMI) onboard the Fengyun-4 satellites ([Cao et al., 2021](#); [Yang et al., 2017](#)). A major step forward for observations over Africa and Europe is provided by the Lightning Imager (LI) instrument onboard the Meteosat Third Generation (MTG) satellites ([Holmlund et al., 2021](#)), which provides continuous lightning observations from geostationary orbit (GEO) with high temporal resolution. However, because MTG LI has been operational only since July 2024, its performance in characterizing lightning activity in the African lightning chimney has not yet been extensively assessed.

Lightning activity in the major tropical chimney regions exhibits a pronounced diurnal cycle that is closely linked to the daily evolution of continental deep convection ([Blakeslee et al., 2014](#); [Williams et al., 2000](#)). In the African lightning chimney, this cycle is typically characterized by a strong local afternoon maximum associated with the peak of convective activity over the Congo Basin ([Blakeslee et al., 2014](#); [Soula et al., 2016](#)). While the climatological features of this diurnal cycle have been investigated in several studies (e.g., [Blakeslee et al., 2014](#)), considerably less attention has been devoted to its variability from day to day. Such variability is of particular interest because the intensity and timing of the daily maximum reflect the thermodynamic and dynamical conditions controlling convective development ([Bozóki et al., 2023](#); [Williams, 2005](#)). However, it remains unclear how well the daily lightning activity is captured by different observation systems.

In this paper, we examine how consistently the daily lightning activity in the African lightning chimney is represented in different observational datasets. To characterize daily peak behavior, we focus on two key parameters describing the daily lightning activity: the peak activity and the timing of this peak. Using these two parameters, we compare the newly available MTG LI observations with independent lightning observations provided by the WWLLN and SR measurements to assess the reliability of the MTG LI data products, while also investigating how, and to what extent, observations representing different aspects of lightning activity are correlated and connected. Evaluating these distinct datasets together provides valuable insights into their mutual relationships, such as the alignment between a spaceborne optical sensor (MTG LI) and a global ground-based VLF network (WWLLN), and the capability of SR to serve as a robust proxy for peak continental lightning activity when evaluated against continuous, high detection efficiency satellite data, while also highlighting the connection between WWLLN and SR. Additionally, we investigate the relationship between daily peak activity and total daily lightning activity. The structure of the paper is as follows. **Section 2** describes the observational datasets (MTG LI, WWLLN, SR) and the analysis methods used in this study. **Section 3** presents the results of the comparative analysis of the different datasets. The possible meteorological and observational factors that could explain the identified similarities and differences in the daily peak activities and peak times are discussed in **Section 4**, and the main conclusions of the study are summarized in **Section 5**.

2 Data and Methods

In this chapter, we first present the datasets (MTG LI, WWLLN, SR) used to characterize the African lightning chimney, then we describe how the daily peak activities and peak times are derived from them.

2.1 Lightning Data

2.1.1 MTG LI

The Meteosat Third Generation (MTG) constellation, operated by EUMETSAT, will consist of three complex and innovative geostationary meteorological satellites, of which this study is based on measurements taken by the first satellite launched in December 2022 (known as I1 or Meteosat-12). The Lightning Imager (LI) on board the MTG-I1 satellite gives the first-ever continuous coverage of Europe and Africa in terms of location and intensity of lightning flashes. The instrument has four cameras with a field of view that covers 84% of the Earth disc, including Europe, Africa, the Middle East and parts of South America (EUMETSAT, 2023). Information about MTG LI's detection efficiency is currently very limited. The official EUMETSAT LI Level 2 Operational Dissemination Validation Report (EUMETSAT, 2024) used GLD360 as the reference network in the period from 4th of July to 22nd of August 2024, and reported an overall

flash detection efficiency of 72%. [Blížňák & Sokol \(2026\)](#) found detection efficiencies above 80% when comparing MTG to ENTLN in South America.

The MTG LI instrument captures 1000 images per second, continuously observing each pixel for sudden increases in radiance that exceed a dynamically estimated background. When a pixel's signal exceeds the threshold, a lightning event is recorded. Events that occur in adjacent pixels within the same 1 ms frame are clustered together into a group. The group, as a Level-2 product, is defined by a centroid, which is the radiance-weighted average position of the underlying events. In the Level-2 group product, each group is represented as a point in time and space. A flash is defined as a collection of groups that are correlated in space and time. The temporal window used for clustering is 330 ms and the spatial criteria is 16.5 km. These criteria are the same as those used for clustering GLM group data ([Goodman et al., 2013](#)). The position of the flash is the radiance-weighted centroid of all the events (via groups) that belong to the flash ([Holzer et al., 2025](#)). Groups and flashes are thus two distinct MTG LI products, with groups having no temporal extent, whereas flashes are collections of multiple, spatially and temporally connected groups. Because both group and flash positions are computed as radiance-weighted centroids, higher-radiance events (or groups) contribute more strongly to their final location. As a result, the reported group and flash locations tend to represent the area where the optical emission was the most intense. Operational data has been released since July 2024.

The MTG LI's Level-2 data are stored and provided in netCDF-4 format in 10 s chunks ([EUMETSAT, 2021](#)). During the collection of the data, 1-hour files were created in a way that each file covers every detection (group or flash) from that given hour's start to its very end. In the original netCDF-4 files, timestamps were stored as seconds passed since 2000-01-01 00:00:00 UTC, which were converted to YYYY-MM-DD HH:MM:SS.mmmmmm format. A total of 359 days of data were collected this way from the 1st of August 2024 to the 31st of July 2025, meaning that 6 days during this period had no detection at all. After this, all detections were aggregated into 1-minute bins representing the total number of detections in that minute, and time series were created from them for each available day. These time series were used to visually filter out days where either data were missing around the peak activity or too many data were missing during the day. These shorter and longer data outages were also reported by [Enno et al. \(2026\)](#), which relate to satellite maneuvers, software updates, and optical interference. With this process 54 days were discarded, leaving 305 days of MTG LI data. To maintain a common analysis period across all datasets, one additional day was removed due to the quality of the SR measurements (see **Section 2.1.3**), resulting in a final dataset of 304 days to be used for characterizing the activity of the

African lightning chimney. All subsequent analyses were carried out using this common 304-day dataset.

2.1.2 WWLLN

Lightning stroke timestamps and locations were also collected from the World Wide Lightning Location Network's (WWLLN) lightning database. WWLLN is a global, ground-based lightning detection system designed to provide continuous, near-real-time monitoring of lightning activity. For this purpose, it utilizes a network of very low-frequency (VLF) receivers to detect sferics, which are impulsive electromagnetic signals generated by lightning discharges. Despite its lower detection efficiency relative to space-based optical measurements (Bürgesser, 2017; Rudlosky & Shea, 2013; Thompson et al., 2014), WWLLN remains a key resource as it provides long-term lightning records with temporal continuity and global coverage.

In this study, WWLLN AE data were used, which is somewhat of a newer version of the ReallocB data, which is considered to be the official WWLLN product. What differs is that in AE, the criteria applied in sferic identification and the selection of contributing stations have been revised, and a semi-heuristic estimate of lightning energy is introduced as an additional parameter. As a result, the daily text files contain information on the date, time, location, localization residual, and number of stations used, as well as on the energy, but this latter information is not used in the present study.

2.1.3 Schumann Resonances

Schumann resonance data have been processed from the Polish Polar Station in Hornsund (HRN, 77.0°N, 15.6°E), Svalbard (Neska et al., 2019), where the north-south wave propagation path corresponding to the east-west magnetic field component (EW) is primarily sensitive to the African lightning chimney, as demonstrated in Figure 1. The intensity of the first SR mode (in pT^2/Hz) was calculated as described by Bozóki et al. (2023) in 12-minute time resolution for the one-year period from August 2024 to July 2025. This dataset was also checked visually, and one day of data was omitted (14th of August 2024) due to the noisiness of the measurements. In the subsequent analysis, the first mode SR intensity of the EW magnetic field component at the HRN was compared with MTG LI group and flash, as well as with WWLLN stroke data.

2.2 Quantifying Daily Peak Activity and Peak Time

As the integration window for the SR measurements has a length of 12 minutes (see Section 2.1.3), the MTG and WWLLN observations were also aggregated in 12-minute bins. To achieve this, the first step was to identify missing segments in the measurements, which was done by checking the filtered datasets described in Section 2.1.1 and looking for whole minutes passed without any

detection. As the rate of the MTG's flash, group, and WLLN's stroke detection greatly surpasses the 1 detection/minute value, it is evident that any minute that has no detection at all is not natural and is tied to artificial reasons. A list of all the minutes with no detection has been created for the two MTG and the one WLLN product. The next step was to split each day into 12-minute segments, iterate through the time-organized datasets and count observations in each segment within the latitude and longitude boundaries of 40°S to 35°N and 20°W to 55°E (presented as a red rectangle in [Figure 1](#)). This box is used in this study to represent the activity of the African lightning chimney. The list of minutes without detections was used to exclude any 12-minute segment from the final output that had at least one missing minute. This step did not affect the quantification of the peak activity, since days with missing data around the peak time had already been filtered out manually, as described in [Section 2.1.1](#). As peak activity was expected between 11 and 19 UT, the 12-minute segment with the highest count within this interval was selected for each day as the daily peak activity, and the start of that segment was defined as the daily peak time. Similarly, the highest intensity value between 11 and 19 UT and the start time of the corresponding segment were extracted from the SR data. For the MTG and WLLN data, the total count in each segment was divided by 720 to obtain rates in s^{-1} .

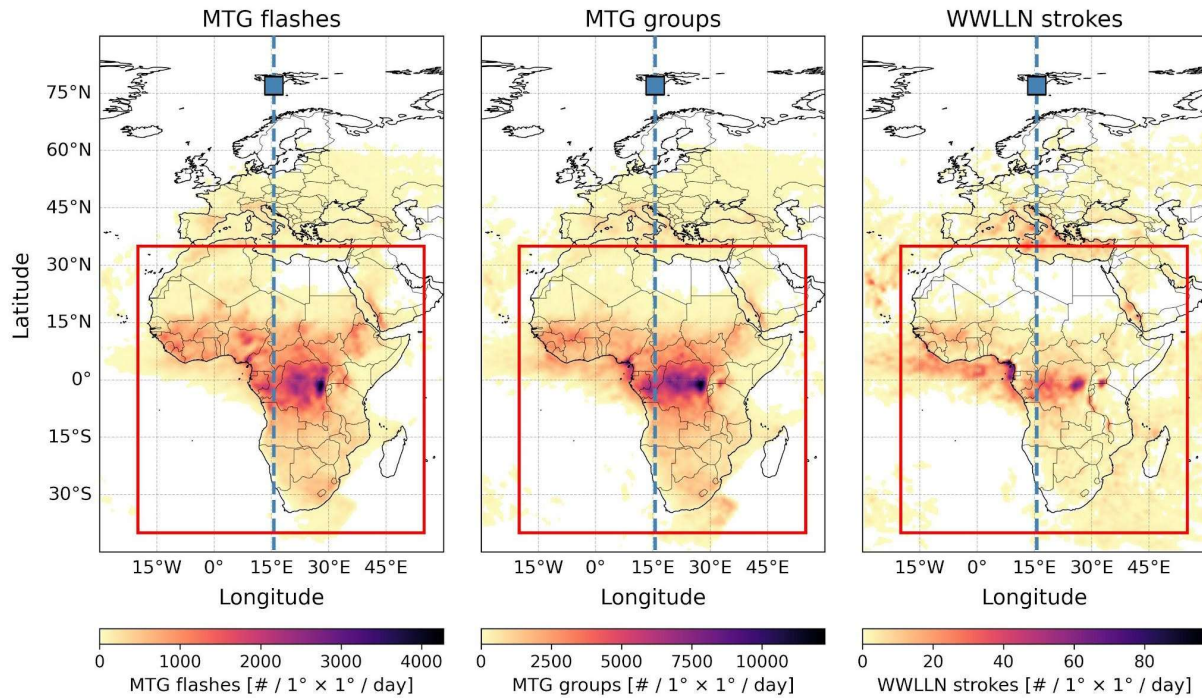


Figure 1. Lightning activity in Africa and Europe between the 1st of August 2024 and 31st of July 2025 based on MTG flash (left), MTG group (middle) and WLLN stroke (right) observations. The red rectangle indicates the box used in this study to represent the activity of the African lightning chimney. The blue square and the blue dashed line mark the location of the SR station in Hornsund, Svalbard and the wave propagation direction for which the EW coil is the most

sensitive. Note that WWLLN's stroke detection rate is significantly lower than either of MTG's products.

3. Results

The average daily lightning activity obtained from the 3 different lightning observations (MTG flash, MTG group and WWLLN stroke) are presented in [Figure 1](#) for Europe and Africa. In all three cases, 304 days of data were used to create these lightning activity maps from the 1st of August 2024 to the 31st of July 2025 (see [Section 2.1.1](#)). The large red rectangle on the figure marks the area of interest in this study, which falls between the geographical limits 40°S to 35°N and 20°W to 55°E. Lightning rates were summarized in this box to obtain the time series characterizing the activity of the African lightning chimney (see [Figure 2](#)). A blue square marks the SR station located in Hornsund, while a blue dashed meridional line drawn across the map indicates the wave propagation direction for which the EW coil of the HRN station is the most sensitive. By moving away from this line the coils' sensitivity decreases in proportion to $\cos^2(\theta)$, where θ represents the deviation angle from the meridional direction. The SR intensity of this field component primarily reflects the activity of the African lightning chimney ([Williams et al., 2021](#)).

As the color bars below [Figure 1](#) indicate, the highest detection rate is achieved by MTG's group product. As the flash product is created using multiple groups, it is evident that the detection rate is lower in the case of the MTG flashes. The lowest detection rate is observed in WWLLN's stroke data, which has a maximum daily stroke rate more than 2 orders of magnitude lower than the MTG group rate. In all cases, the region with the highest daily activity is located just south of the equator, in the Congo Basin, in the close vicinity of the wave propagation path corresponding to the EW component at HRN. MTG's products also highlight a broad, approximately 25° latitude-wide stripe from around 10°S to 15°N, where the daily lightning activity in Africa is the highest. This spatial distribution, particularly the strong maximum over the Congo Basin, is consistent with the updated LEO lightning climatologies derived from the OTD and LIS observations ([Cecil et al., 2026a, 2026b](#)). In the case of the WWLLN strokes, this stripe is thinner and appears to be just as prominent over the Gulf of Guinea as over the land. All three maps clearly show that in Africa, the Sahara Desert has the lowest lightning rates, with the northern part of the Libyan Desert having no lightning at all. WWLLN data show better coverage over the oceanic regions surrounding Madagascar, which is consistent with the fact that this area is located at the edge of the MTG LI's field of view ([Holmlund et al., 2021; Holzer et al., 2025](#)). Interestingly, the mainland of Madagascar is characterised by rather low lightning rates in the WWLLN data (~5 strokes per 1° × 1° grid cell per day), while this area is known as an active region in different lightning climatologies ([Virts et al., 2013](#)). This may indicate that the number of receiver stations in the region has changed.

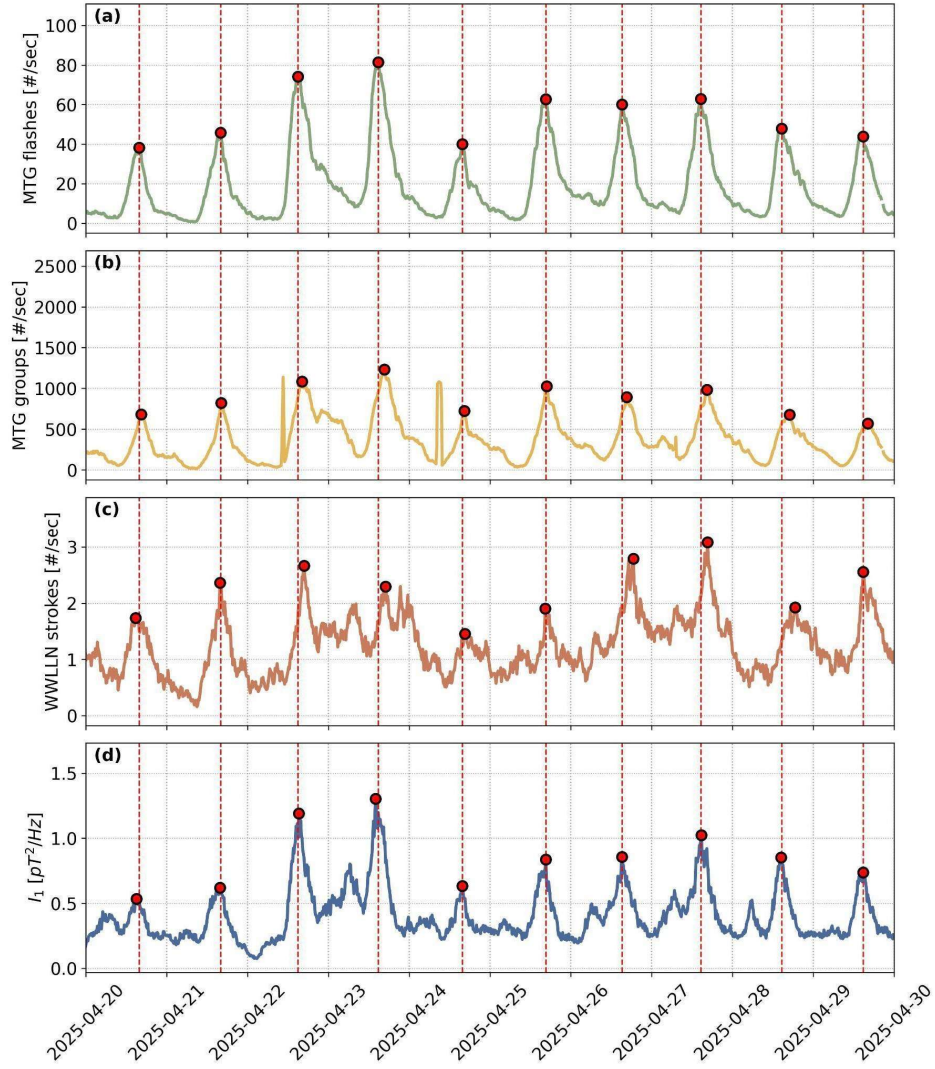


Figure 2. Comparison of African lightning activity in aggregated 12-minute segments using three different lightning products (MTG flash (a), MTG group (b), WLLN stroke (c)) and SR intensity (d), in a continuous 10-day period from the 20th to the 30th of April 2025. Only MTG and WLLN detections within the geographical coordinates of the large red rectangle, shown in Figure 1, were used to create these time series. Red dots indicate the daily peak activities between 11 and 19 UT, while the vertical dashed lines mark the peak times of MTG flash for visual comparison between the different datasets.

Figure 2 showcases a comparison of four time series characterizing African lightning activity, out of which two are made from MTG's flash (a) and group (b) products, one from WLLN's stroke data (c), and one created from the SR magnetic (EW) measurements on Hornsund, Svalbard (d). The figure depicts a continuous 10-day period from the 20th to the 30th of April 2025. To create the figure, the 12-minute segments described in Section 2.2 were used. Each day, the 12-minute

segment with the highest count between 11 and 19 UT was marked with a red dot, and similarly for the SR data, the segment with the highest intensity. Vertical dashed red lines indicate the peak times of MTG flash for visual comparison between the subfigures.

By looking at the vertical red lines in [Figure 2](#), it can be ascertained that the determination of the daily peak times is quite consistent across the 4 different datasets. During this 10-day period, the highest peaks in the SR measurements occur on the 22nd and 23rd of April, which is consistent with both MTG products. However, WLLN strokes happen to have the largest peaks on the 26th and 27th day of the month. By examining the three lightning detection products, it can be observed that the MTG curves are much smoother than the WLLN curve. The SR intensity curve also appears to be quite smooth. The peaks picked between 11 and 19 UT in the case of the MTG flash data are clearly the most prominent peaks each day, but for the MTG groups, in two cases (22nd and 24th of April), larger peaks can be observed in the earlier hours of the given days. The uprise of these curves has a very short time extent and appears as a vertical line, similar to their decline. There are multiple examples of this phenomenon in the 1-year-long dataset, but all occur outside the 11 and 19 UT range, thus having no interfering effect on the results on peak activities and peak times. This phenomenon - which is likely related to an instrumental or data processing error - is not observable in the flash data. Another interesting observation is the occurrence of a secondary peak in the SR intensity data on multiple days in the morning hours, especially from the 26th to the 28th of April. These cases are best matched by WLLN's stroke rates (although with much less prominence) and are also discoverable in the MTG products.

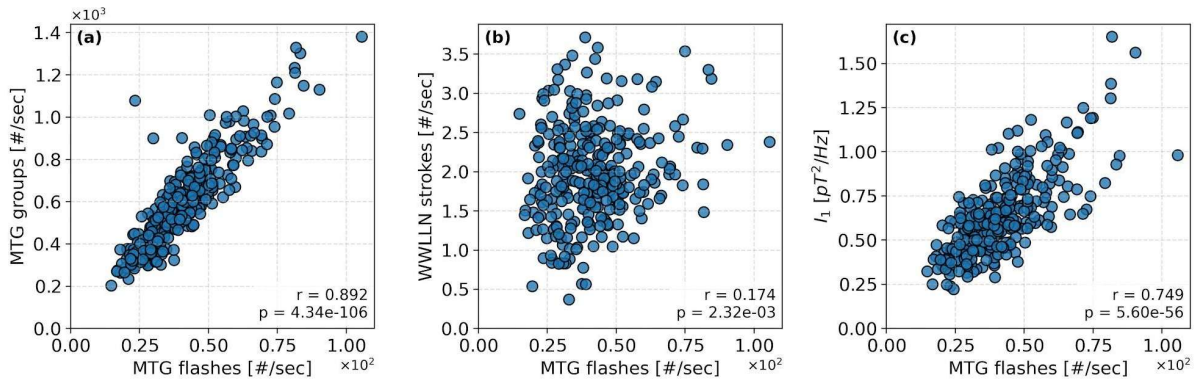


Figure 3. Scatter plots showcasing the connection of daily peak activity between MTG flashes and MTG groups (a), WLLN strokes (b), and SR intensity (c). For each day, the 12-minute segment with the highest value has been selected from between 11 and 19 UT in every dataset. In the bottom right corner, the linear Pearson correlation coefficient (r) and p-value are given. Note the significant positive correlation between the MTG flashes and the SR intensity.

[Figure 3](#) presents a collection of scatter plots where peak activities are matched, namely MTG flashes to MTG groups (a), to WLLN strokes (b), and to SR intensity (c). As described earlier, out of the 365 days there were 6 days with no MTG data, 54 were filtered out due to inadequate

MTG data quality, and 1 additional day was removed because of the lack of SR data. For the remaining days, peak activities were defined as described in **Section 2.2**. The linear Pearson correlation coefficients, marked with r , are indicated on the bottom right corners of the subplots, alongside the p -values. The MTG flash data was considered as the reference; scatter plots depicting information about the connections between MTG groups, WLLN strokes, and SR intensity are provided in the Supporting Information (**Figure S1**). It is important to emphasize that, since the peak activity of each day was determined independently for the four datasets, the matched datapoints making up the scatterplots do not necessarily belong to the same time segment.

Figure 3a shows a strong positive correlation ($r = 0.892$, Spearman correlation = 0.884) between the two MTG products, flashes and groups. The p -value, which measures whether this relationship is statistically significant, is 4.34×10^{-106} , confirming the statistical significance of the linear relationship. This is an expected result, as flashes are made of multiple groups; it is thus evident that more groups mean more flashes and vice versa. There is a finite width of the line along which the scatter points align, as the number of groups in flashes is not a fixed value. This number can range from a few groups in a flash to tens of groups, in rare cases reaching more than a hundred, resulting in a mostly well-aligned arrangement with some outlier scatter points.

Figure 3b displays the correlation between MTG flashes and WLLN strokes. The $r = 0.174$ correlation coefficient with the $p = 2.32 \times 10^{-3}$ value (Spearman correlation = 0.132) marks a weak, positive correlation. This suggests that the observations from the two different lighting detection systems are not equivalent, and measurements from one system do not clearly indicate those from the other, in line with the time series shown in **Figure 2**. This may be explained by the fact that there are orders of magnitude more MTG flashes than WLLN strokes, and that MTG detects both cloud-to-ground and intracloud/cloud-to-cloud lightnings, while WLLN mainly detects strong cloud-to-ground discharges. The limited detection efficiency of WLLN in Africa (**Williams & Mareev, 2014**) could be another important factor. **Figure S1b** presents a comparison between MTG groups and WLLN strokes created in the same manner, which further supports these results, with a slightly higher – but still weak – positive correlation of $r = 0.209$.

On subplot (c) of **Figure 3**, it can be seen how well the MTG flash data correlates with the SR data. There is a strong positive correlation with an $r = 0.749$ coefficient (Spearman correlation = 0.729), supported by a p -value of 5.6×10^{-56} , which demonstrates its statistical significance. SR intensity seems to be a good indicator of MTG's flashes, better than that of MTG groups, as it can be seen in **Figure S1c**. **Figure 3c** also shows that the scatter points are not aligned perfectly alongside a straight line but seem to split in two parts at higher flash rates; however, the number of samples in this range is rather limited, so this pattern should be interpreted with caution. Interestingly, this

phenomenon is only observed in the comparison of the SR data with the MTG products and is absent when SR data are compared with WLLN (Figure S1a).

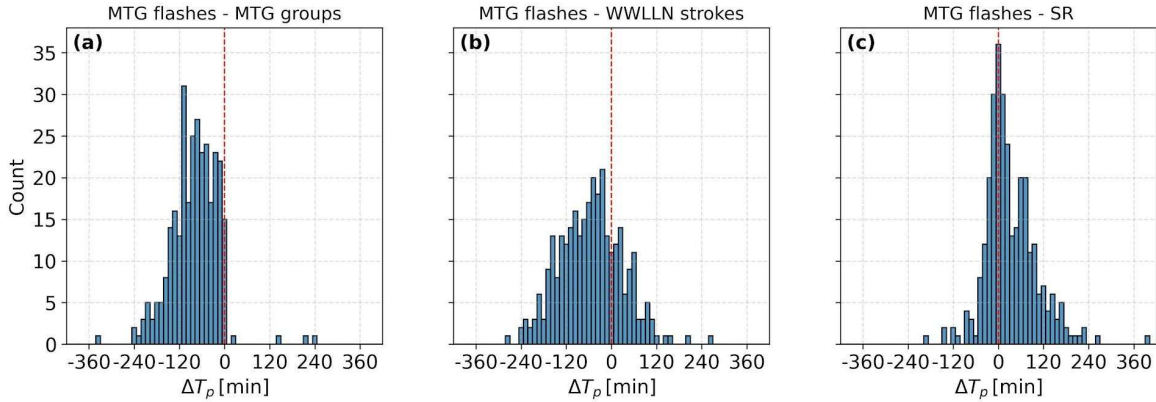


Figure 4. Histograms created from the time differences between the daily peak times for MTG flashes and MTG groups (a), MTG flashes and WLLN strokes (b), and MTG flashes and SR intensity (c). The horizontal axis shows the time difference in minutes with a bin size of 12 minutes, while the vertical axis shows the number of cases in each bin. The red dashed line indicates the 0-minute time difference. Note that on subplot (a), there is a systematic time difference between MTG’s flash and group peaks, while subplot (c) shows how well the MTG flash and SR intensity peak times coincide.

Figure 4 shows three histograms that represent the time differences between the daily peak times of MTG flashes and MTG groups (a), MTG flashes and WLLN strokes (b), and MTG flashes and SR intensity (c). To create the histograms, the daily peak times of the different datasets were subtracted from each other. The bin size of the histograms is 12 minutes in accordance with the time resolution of the original datasets. Additional histograms with information about the peak time differences of MTG groups, WLLN strokes, and SR intensity are provided in the Supporting Information (Figure S2). A complementary figure showing the distribution of the peak times for each of the four datasets is also provided in the Supporting Information (Figure S3).

When comparing the daily peak times of the two MTG products (Figure 4a), we can see a substantial displacement on the histogram, as the majority of the time differences are distributed in a circa 2-hour range that is not centered around the 0-time offset (marked with a vertical red dashed line). The fact that the peak times do not coincide, and the MTG groups consistently peak later in time, suggests that the number of groups composing a flash has a characteristic diurnal variation (see Figure 6). WLLN strokes show a better match with MTG flashes in the case of daily peak times (Figure 4b), with a roughly 0-centered distribution. However, most of the time differences still fall to the left of the plot, meaning that MTG flashes peak slightly earlier than

WWLLN strokes, and the width of the distribution is the largest in this case. The comparison of the MTG flash and SR intensity daily peak times shows that most of the time differences are close to zero, suggesting that the highest SR intensities on Hornsund (in the EW component) are typically measured when the MTG flash rates are peaking in Africa. However, the distribution is clearly skewed to the right, which means that SR intensity often peaks earlier than MTG flashes.

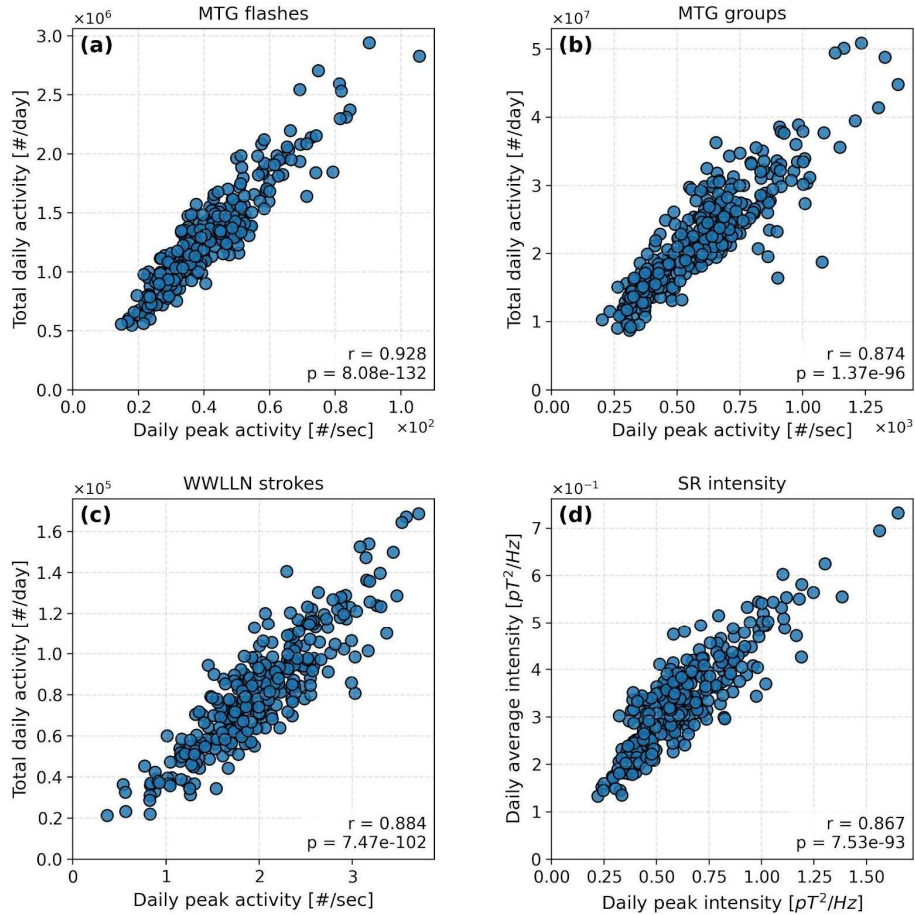


Figure 5. Scatter plots showcasing the correlation between the daily peak activity and the total number of detections each day for MTG flashes (a), MTG groups (b), and WWLLN strokes (c), as well as the correlation between daily peak and daily average SR intensity (d). In the bottom right-hand corner of each plot, the linear Pearson correlation coefficient (r) and p -value are presented.

It is also interesting to see to what extent daily peak activity reflects total daily activity. Therefore Figure 5 shows a set of scatter plots presenting the strong correlations between the daily peak

activity and the daily total number of detections in the case of the MTG flashes (a), MTG groups (b), and WWLLN strokes (c), as well as between the daily peak and daily average SR intensity (d). The scatter plots and Pearson correlation coefficients show the strong correlation between daily peak activities and total daily characteristics. The correlation is highest for MTG flashes ($r = 0.928$), which is in line with [Figure 2](#), showing that the daily peak is most prominent in this dataset. There is also a strong correlation in the case of MTG groups ($r = 0.874$), as well as WWLLN strokes ($r = 0.884$). The anomalous peaks in the case of MTG groups, described earlier, were either outside the 11–19 UT range and thus had no interfering effects on the peak activity determination, or the whole day was filtered out, as described in [Section 2.1.1](#). However, these artifacts may affect the total activity values and thus potentially reduce the correlation. The result of the analysis made on the SR data also shows a strong correlation, but it is the lowest among the four datasets. This is probably related to the secondary intensity peaks appearing in the morning hours (see [Figure 2d](#)). The low p-values indicate a statistically significant relationship in all cases. This result suggests that daily activity is primarily determined by the lightning activity during the most active period and also means that the daily peak activity represents total daily activity with good approximation and can be a suitable indicator of day-to-day variability.

4 Discussion

In this section, we will discuss the relationships between the MTG flashes and MTG groups, MTG flashes and WWLLN strokes, and MTG flashes and SR intensity, considering the possible meteorological and observational factors that could explain the identified similarities and differences in the daily peak activities and peak times. We then compare the MTG LI results with long-term lightning climatologies derived from LEO OTD and LIS observations.

4.1 Relationship Between MTG Flashes and MTG Groups

The MTG group time series frequently displays short, intense bursts of activity that are absent in the MTG flash product (e.g., vertical, spike-like excursions evident in [Figure 2b](#) but missing from [Figure 2a](#)). This discrepancy arises because the flash-clustering algorithm effectively excludes some of the anomalous peaks in the group detections in a way that larger numbers of groups are aggregated into flashes during the anomalous periods, and the group-level variability is thus smoothed out. Restricting the peak analysis to the 11–19 UT interval mitigates the influence of these anomalous group peaks and thus reduces the impact of instrumental or processing artifacts on the determination of daily peak activity. The daily total activity may still be affected by these anomalies ([Figure 5b](#)), which supports the use of daily peak activity instead of daily total activity in the quantification of daily lightning activity in the African lightning chimney in the case of the MTG group product. It is important to note that when mesoscale convective systems (MCSs) occur outside the 11–19 UT time window, they may also produce very intense lightning activity,

sometimes comparable to the total lightning count from local afternoon thunderstorms. In such a case, the representativeness of the afternoon peak in lightning activity for the entire day will become weaker. Despite this, the correlations between daily peak and daily total activity are very strong (Figure 5a and b), and upon inspecting the daily time series, it can be said that this phenomenon affects groups more than flashes.

Although the daily peak activities of MTG flashes and groups exhibit a strong positive relationship (Figure 3a; $r \approx 0.89$), the peak timing of the two products often differs (Figure 4a). This offset can be largely explained by the diurnal variation of the number of groups per flash: the composition of flashes varies systematically through the day, which tends to shift group-based peaks relative to flash-based peaks. Figure 6 illustrates this phenomenon by showing the diurnal variation of the average flash rate, group rate, and groups per flash, computed from 12-minute bins and averaged over valid days. Because the peak time is determined independently for each dataset, the peak values in Figure 3a may come from different 12-minute segments, contributing to the scatter in the correlation.

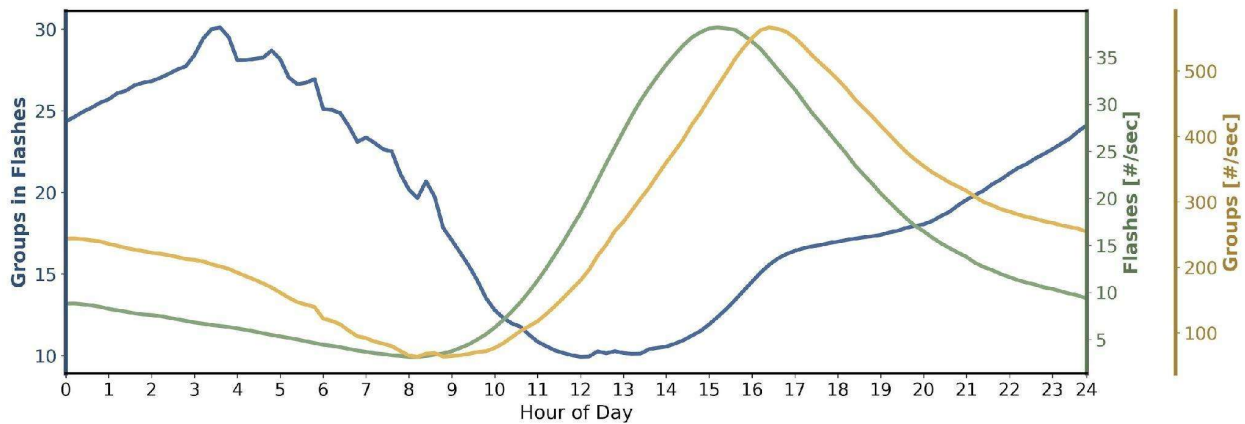


Figure 6. Diurnal variation of the average flash rate (green), group rate (golden), and number of groups per flash (blue) based on MTG observations during the study period, restricted for the study area. Note that the number of groups per flash exhibits a pronounced diurnal variation, which explains the time shift that is observable between the peaks of the flash and group rate curves.

The systematic tendency for MTG group peaks to lag flash peaks can be attributed to a combination of instrumental detection effects and meteorological factors. The MTG LI's detection efficiency exhibits a pronounced diurnal variability (Holzer et al., 2025): daytime solar background raises the noise floor and can bury faint, low-energy pulses, causing some groups (and in some cases entire faint flashes) to be missed or to be represented only by the most energetic groups. In addition, as afternoon convection develops toward its decaying stage, thunderstorm expansion creates more favorable conditions for larger-scale flashes, so the number of groups contained within a flash increases. MCSs, which dominate much of the African lightning chimney's nocturnal activity

(Schumacher & Houze, 2006), typically produce more complex, longer-lasting stratiform/anvil lightning and distribute charge over larger areas (Peterson & Liu, 2011). Such environments naturally produce flashes composed of many groups, and they are also the primary setting for giant lightning phenomena (such as spider lightning), which is reflected in Figure 6 as elevated group/flash ratios during nighttime. The combination of reduced daytime sensitivity and a nocturnally enhanced groups-per-flash regime could explain both the increase in groups per flash at certain times of day and the observed shift of group peaks toward later hours.

4.2 Relationship Between MTG Flashes and WLLN Strokes

MTG flashes and WLLN strokes sample fundamentally different subsets of lightning activity: MTG's optical flash product captures both intracloud and cloud-to-ground activity and therefore yields orders-of-magnitude higher detection rates (Figure 1), while WLLN preferentially reports high-peak current cloud-to-ground strokes (Abarca et al., 2010). This contrast is evident in the two datasets' time series (Figures 2a and 2c) and is quantified by the weak correspondence between their daily peaks ($r = 0.174$ in Figure 3b) and by the broad distribution of peak-time differences (Figure 4b). Figure 4b suggests that MTG flashes peak slightly earlier on average, consistent with cloud-to-ground strokes often occurring later than intracloud activity (MacGorman et al., 2011). This comparison could also have been made between WLLN flashes (determined from the WLLN strokes) and the MTG flashes, but the result would likely be very similar, since the WLLN typically detects only a single (the strongest) stroke in a flash (Virts et al., 2013). Together these diagnostics demonstrate that WLLN and MTG are observing different facets of the lightning population and should be treated as complementary, rather than interchangeable, observational views of convective electrical activity in the African lightning chimney. Accurately quantifying the detection efficiency of the WLLN relative to MTG flashes (and vice versa) is an important task for the future.

4.3 Relationship Between MTG Flashes and SR Intensity

Using the EW magnetic field component of a European SR station to characterize African lightning activity is a widely used method (Dydra et al., 2014; Nieckarz et al., 2009). However, the incomplete and spatially uneven detection efficiency of ground-based global lightning detection networks in Africa and the restricted spatio-temporal coverage of satellite observations has hindered the quantitative validation of this approach so far, especially on the day-to-day timescale (Bozóki et al., 2023). This claim is clearly supported by the low correlation observed between SR

intensity peaks and WWLLN strokes peak activities ([Figure S1a](#)). In this regard, the MTG satellite represents a major step forward.

Our results confirm that SR intensity is closely related to lightning flashes detected by MTG: flash peak activities align closely with SR intensity peaks, and peak times are generally consistent between the two datasets ([Figures 2a, 2d, 3c and 4c](#)). Although Schumann resonances are excited by individual lightning strokes rather than clustered lightning flashes ([Boldi et al., 2018](#)), SR intensity shows a stronger relationship with MTG flashes than with MTG groups ([Figures S1c and S2c](#)). This suggests that MTG groups cannot be considered to represent lightning strokes, which is also supported by the low correlation between MTG groups and WWLLN strokes ([Figure S1b](#)). The fact that SR intensity sometimes shows a distinct secondary peak in its diurnal cycle ([Figure 2d](#)) (likely associated with the day-night asymmetry of the Earth-ionosphere cavity) that could bias daily mean values ([Figure 5d](#)), argues for using peak-activity metrics (rather than full-day integrals) in quantifying daily changes in African lightning activity. We speculate that the fact that the SR intensity sometimes peaks earlier than MTG flashes ([Figure 4c](#)) could be related to the occurrence of numerous intracloud flashes in the early stage of thunderstorm development which contribute to the SR intensity, but the MTG does not detect all of them because their radiance is below the detection threshold.

As discussed in the Introduction, intracloud lightning also contributes to the SR intensity through its vertical component. Since the WWLLN records only a fraction of vertical discharges in worldwide cloud-to-ground activity, while excluding large numbers of vertical discharges in intracloud lighting, it is not surprising that the relationship between total optical lightning (MTG) and the SR intensity is much stronger than the correlation with WWLLN lightning.

The strong link between MTG flashes and SR intensity suggests that SR intensity could be a suitable indicator for the actual flash rate in the African chimney region, and could provide a possible measure for the activity of nocturnal MCSs, which should be discernible in the SR records if their collective flash rates reach about 10-20 flashes/second (see the lower end of the relevant range in [Figure 3c](#)). Note, however, that the relationship between MTG flashes and SR intensity shown in [Figure 3c](#) pertains to the local afternoon hours and may not necessarily be applicable during the nighttime hours. This aspect deserves further investigation in the future.

At higher flash rates, we observe a divergence between MTG flashes and SR intensity ([Figure 3c](#)): the relationship that holds at low-to-moderate activity splits once flash rates exceed a higher rate (~ 70 flash/sec). We examined the seasonality of this effect and found this split to be apparent during Northern Hemisphere spring. Comparison of WWLLN stroke and SR intensity does not show an analogous split ([Figure S1a](#)), but its scatter is large, and the daily peaks are noisy, so the absence of the split cannot be taken as definitive evidence, and it remains unclear whether it is more closely associated with MTG or with SR data. One possible factor that could weaken the relationship between MTG flashes and SR intensity at higher flash rates is that when thunderstorms

deepen considerably to reach their highest flash rates, the cloud cover above the mixed-phase region may block the outgoing light from the lightning and reduce the detection efficiency of the MTG LI (Yoshida et al., 2009). Further years of parallel observation are needed to clarify this issue.

According to the SR theory (Boldi et al., 2018; Prácser et al., 2019; Shvets et al., 2010), in the case of a single (dominant) lightning source region, the magnetic intensity (I in pT^2/Hz) is related to the flash rate (F in $1/\text{sec}$) as:

$$I(f, \theta) = G^2(f, \theta) \cdot M^2 \cdot F, \quad (1)$$

where f is the frequency (in Hz), θ is the angular distance between the source and the observer (in radians), M is the mean charge moment of the lightning discharges (in C m), and G is the frequency response of the uniform Earth-ionosphere cavity (in pT/A/m). The quantity $M^2 \cdot F$ represent the usual “background” source term in SR theory in the units of $\text{C}^2 \text{ km}^2 / \text{sec}$ (Dyrda et al., 2014; Heckman et al., 1998). The G value can be determined using an analytical formula, which is described in the Supporting Information. Assuming that the African lightning chimney is located on average at the equator (so $\theta \approx 77^\circ$), the value of $3.005 \cdot 10^{-12} \text{ pT}^2/\text{A}^2/\text{m}^2$ can be obtained for G^2 at 8 Hz. Since the intensity of the 1st SR mode depends only weakly on the source-observer distance around $\theta = 90^\circ$ (see Figure S4), the choice of θ is not expected to significantly affect this value. Now the mean charge moment of the lightning discharges can be determined from the slope (m) of the linear fit to the F vs I_1 scatter plot shown in Figure 3c as follows:

$$M = \sqrt{m/G^2} = \sqrt{0.01116/(3.005 \cdot 10^{-12})} \approx 62135 \text{ C m} = 62.14 \text{ C km}. \quad (2)$$

This value shows good agreement with the global average charge moment of 56.89 C km obtained by Boldi et al. (2018) for the first SR mode.

4.4 Comparison with LEO Lightning Climatologies

LEO-based lightning climatologies, constructed from OTD and LIS observations (Cecil et al., 2026a, 2026b; Blakeslee et al., 2014), are the best long-term references when characterizing the daily lightning activity in Africa. The MTG LI results presented in this study are broadly consistent with these LEO climatological findings. The spatial distribution of mean daily lightning activity, with a pronounced maximum over the Congo Basin (Figure 1), agrees with the updated LIS/OTD climatologies, which identify central Africa as one of the dominant large-scale lightning regions and report prominent late afternoon/evening maxima over southeastern Nigeria and eastern Democratic Republic of the Congo (DRC) (Cecil et al., 2026b). The mean diurnal variation of flash rate derived from MTG LI (Figure 6) also exhibits the same late-afternoon maximum reported in the LEO observations. Cecil et al. (2026b) identified prominent central African maxima occurring at 17–19 local solar time (LST) in parts of southeastern Nigeria and eastern DRC. Using the longitude-dependent conversion between LST and UT, these correspond approximately to 15–19 UT across the two regions. Cecil et al. (2026b) also expressed their results in UT, and found that the continental-scale African lightning peaks near 17 UT. This is more closely matched by the diurnal curve of the MTG groups than the MTG flashes (Figure 6).

The main difference between the LEO-based climatologies and the present analysis is in the characterization of variability, due to their difference in temporal sampling. The LEO datasets are composed from thousands of short satellite overpasses collected over a 27-year period between 1995 and 2023. A LIS overpass typically observes a location for approximately 90–100 s, while an OTD overpass lasts approximately 200–300 s (Cecil et al., 2026b). In the tropics, the accumulated observation time is approximately 230 h for the combined record (Cecil et al., 2026a, 2026b). This sampling is sufficient to construct long-term mean diurnal cycles but does not provide a continuous observation of individual days. In contrast, the continuous geostationary coverage of MTG LI enables the daily peak activity and its timing to be determined independently for each day. Our results show that these daily values exhibit considerable scatter: the peak time differences between datasets span several hours (Figure 4), and the daily peak activities can vary substantially from day to day (Figure 3). The substantial spread of these daily values therefore represents information that is not contained in the LEO climatological mean.

5 Conclusions

In this study, we aimed to characterize daily lightning activity in the African lightning chimney, using the daily peak activity and its timing as the primary indicators of variability. For this purpose, we used MTG flash, MTG group, WLLN stroke and SR intensity data. The most important conclusion is that MTG flash and SR intensity data provide a very consistent picture of daily peak activity and peak time, which supports the more established use of both datasets in characterizing the daily activity of the African lightning chimney. This fact enables a well-founded characterization of daily lightning activity in Africa for periods when MTG data were not yet available, through the use of SR intensity data spanning several decades. We showed that WLLN observations provide a rather different picture of lightning activity in Africa; therefore, they should be regarded as complementary rather than equivalent information. Our results provide a foundation for future studies of the day-to-day variation of African lightning activity across different timescales (e.g., seasonal, ENSO), as well as for exploring its relationships with other meteorological and geophysical parameters.

Acknowledgments

This work was supported by the National Research, Development, and Innovation Office, Hungary-NKFIH, project numbers K138824 (TB, GS) and PD146019 (TB). The contribution of TB was also supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences (BO/00352/24). The contribution of E. Williams was supported by a grant from the US National Science Foundation (Grant # AGS-1945871 (“The GlobalCircuits Paradox”)). The authors wish to thank Michael Peterson, Ken Cummins, and Sven-Erik Enno for valuable discussions regarding MTG lightning observations. The authors wish to thank the World Wide

Lightning Location Network (<http://wwlln.net>), a collaboration among over 50 universities and institutions, for providing the lightning location data used in this study. The authors gratefully acknowledge EUMETSAT for providing Meteosat Third Generation Lightning Imager data used in this study.

Open Research

Daily peak activity and peak timing data for SR intensity, MTG flashes, MTG groups, and WWLLN strokes between August 2024 to July 2025 are available at a data repository (Németh et al., 2026; <https://doi.org/10.5281/zenodo.20330408>). MTG LI data can be downloaded from EUMETSAT's MTG Data store (<https://user.eumetsat.int/resources/user-guides/mtg-data-access-guide>).

Conflict of Interest Disclosure

The authors declare there are no conflicts of interest for this manuscript.

References

- Abarca, S. F., Corbosiero, K. L., & Galarneau, T. J. Jr. (2010). An evaluation of the Worldwide Lightning Location Network (WWLLN) using the National Lightning Detection Network (NLDN) as ground truth. *Journal of Geophysical Research*, 15, D18206. <https://doi.org/10.1029/2009JD013411>
- Albrecht, R. I., Goodman, S. J., Buechler, D. E., Blakeslee, R. J., & Christian, H. J. (2016). Where are the lightning hotspots on Earth? *Bull. Am. Meteorol. Soc.*, 97(11), 2051–2068. <https://doi.org/10.1175/BAMS-D-14-00193.1>
- Blakeslee, R. J., Lang, T. J., Koshak, W. J., Buechler, D., Gatlin, P., Mach, D. M., et al. (2020). Three years of the lightning imaging sensor onboard the international space station: Expanded global coverage and enhanced applications. *J. Geophys. Res.: Atmos.*, 125(16), e2020JD032918. <https://doi.org/10.1029/2020JD032918>
- Blakeslee, R. J., Mach, D. M., Bateman, M. G., & Bailey, J. C. (2014). Seasonal variations in the lightning diurnal cycle and implications for the global electric circuit. *Atmos. Res.*, 135–136, 228–243. <https://doi.org/10.1016/j.atmosres.2012.09.023>
- Bliznák, V., & Z. Sokol (2026). First validation of the Lightning Imager aboard Meteosat Third Generation satellite with Earth Networks Total Lightning Network. *Int. J. Appl. Earth Obs. Geoinf.*, 147, 105205, <https://doi.org/10.1016/j.jag.2026.105205>

- 677 Boldi, R., Williams, E., & Guha, A. (2018). Determination of the global-average charge moment
678 of a lightning flash using Schumann resonances and the LIS/OTD lightning data. *Journal of*
679 *Geophysical Research: Atmospheres*, 123(1), 108–123. <https://doi.org/10.1002/2017JD027050>
- 680 Bozóki, T., Prácer, E., Satori, G., Dálya, G., Kapás, K., & Takátsy, J. (2019). Modeling
681 Schumann resonances with schupy. *Journal of Atmospheric and Solar-Terrestrial Physics*, 196,
682 105144. <https://doi.org/10.1016/j.jastp.2019.105144>
- 683 Bozóki, T., Satori, G., Williams, E., Guha, A., Liu, Y., Steinbach, P., et al. (2023). Day-to-day
684 quantification of changes in global lightning activity based on Schumann resonances. *J.*
685 *Geophys. Res.: Atmos.*, 128(11), e2023JD038557. <https://doi.org/10.1029/2023JD038557>
- 686 Bürgesser, R. E. (2017). Assessment of the World Wide Lightning Location Network (WWLLN)
687 detection efficiency by comparison to the lightning imaging sensor (LIS). *Q. J. R. Meteorolog.*
688 *Soc.*, 143(708), 2809–2817. <https://doi.org/10.1002/qj.3129>
- 689 Cao, D., Lu, F., Zhang, X., & Yang, J. (2021). Lightning activity observed by the FengYun-4A
690 lightning mapping imager. *Remote Sens.*, 13(15), 3013. <https://doi.org/10.3390/rs13153013>
- 691 Cecil, D. J., Buechler, D. E., & Blakeslee, R. J. (2014). Gridded lightning climatology from
692 TRMM-LIS and OTD: Dataset description. *Atmos. Res.*, 135–136, 404–414.
693 <https://doi.org/10.1016/j.atmosres.2012.06.028>
- 694 Cecil, D. J., Buechler, D. E., & Blakeslee, R. J. (2015). TRMM LIS climatology of thunderstorm
695 occurrence and conditional lightning flash rates. *J. Clim.*, 28(16), 6536–6547.
696 <https://doi.org/10.1175/JCLI-D-15-0124.1>
- 697 Cecil, D. J., Buechler, D. E., Lang, T. J., Virts, K. S., & Mach, D. M. (2026a). Lightning
698 climatology datasets from TRMM LIS, ISS LIS, and OTD. *J. Appl. Meteor. Climatol.*, 65, 51–
699 72. <https://doi.org/10.1175/JAMC-D-25-0110.1>
- 700 Cecil, D. J., Buechler, D. E., Lang, T. J., Virts, K. S., & Mach, D. M. (2026b). Lightning
701 Imaging Sensor (LIS) and Optical Transient Detector (OTD) missions, 1995–2023. *Bull. Amer.*
702 *Meteor. Soc.*, E404–E418. <https://doi.org/10.1175/BAMS-D-24-0268.1>
- 703 Chapman, F. W., Llanwyn Jones, D., Todd, J. D. W., & Challinor, R. A. (1966). Observation on
704 the propagation constant of the Earth-ionosphere waveguide in the frequency band 8 kc/s to 16
705 kc/s. *Radio Sci.*, 1(11), 1273–1282. <https://doi.org/10.1002/rds1966111273>
- 706 Christian, H. J., Blakeslee, R. J., Boccippio, D. J., Boeck, W. L., Buechler, D. E., Driscoll, K. T.,
707 et al. (2003). Global frequency and distribution of lightning as observed from space by the
708 optical transient detector. *J. Geophys. Res.*, 108(D1), ACL4-1–ACL4-15.
709 <https://doi.org/10.1029/2002JD002347>
- 710 Cooper, M. A., Tushemereirwe, R., Gomes, C., Holle, R. L., Lusambu, C. T. M., Akantambira,
711 B., & Zhang, D. (2024, September). The African Centres for Lightning and Electromagnetics

- Network (ACLENet)–Ten Years of Service. What Do the Next Ten Years Hold?. In *ICLP 2024; 37th International Conference on Lightning Protection* (pp. 1123–1128). VDE.
- Dyrda, M., Kulak, A., Mlynarczyk, J., Ostrowski, M., Kubisz, J., Michalec, A., & Nieckarz, Z. (2014). Application of the Schumann resonance spectral decomposition in characterizing the main African thunderstorm center. *Journal of Geophysical Research: Atmospheres*, 119(23), 13338–13349. <https://doi.org/10.1002/2014JD022613>
- Enno, S.-E., Viticchié, B., Navia, D., & Grandell, J. (2026). First year of Meteosat Third Generation Lightning Imager observations. *EGUsphere* [Preprint]. <https://doi.org/10.5194/egusphere-2026-3386>
- EUMETSAT (2023), MTG LI Level 2 data guide, v1, 17 November 2023, EUMETSAT User Portal. Available from: <https://user.eumetsat.int/resources/user-guides/mtg-li-level-2-data-guide> (Accessed 6 March 2026).
- EUMETSAT (2024), *LI Level 2 Data Operational Dissemination Validation Report*, EUM/RSP/REP/24/1431135, v1G, 30 Oct 2024, EUMETSAT, Darmstadt, Germany.
- EUMETSAT. (2021, July 9). MTG LI Level 2 Format Specification (Doc. No. EUM/MTG/SPE/10/0452; Issue v5C) [Technical report]. EUMETSAT.
- Galejs, J. (1972). *Terrestrial propagation of long electromagnetic waves*. Pergamon.
- Goodman, S. J., Blakeslee, R. J., Koshak, W. J., Mach, D., Bailey, J., Buechler, D., et al. (2013). The GOES-R Geostationary Lightning Mapper (GLM). *Atmospheric Research*, 125–126, 34–49. <https://doi.org/10.1016/j.atmosres.2013.01.006>
- Heckman, S. J., Williams, E., & Boldi, B. (1998). Total global lightning inferred from Schumann resonance measurements. *Journal of Geophysical Research*, 103(D24), 31,775–31,779. <https://doi.org/10.1029/98JD02648>
- Holmlund, K., Grandell, J., Schmetz, J., Stuhlmann, R., Bojkov, B., Munro, R., et al. (2021). Meteosat third generation (MTG): Continuation and innovation of observations from geostationary orbit. *Bull. Am. Meteorol. Soc.*, 102(5), E990–E1015. <https://doi.org/10.1175/BAMS-D-19-0304.1>
- Holzer, A. M., et. al.: EUMETSAT-ESSL Application Guide on the Use of MTG LI in Severe Convective Storms Nowcasting, ESSL Report 2025-01, <https://www.essl.org/cms/essl-testbed>, 2025.
- Hutchins, M. L., Holzworth, R. H., Brundell, J. B., & Rodger, C. J. (2012a). Relative detection efficiency of the world wide lightning location network. *Radio Science*, 47(6), RS6005. <https://doi.org/10.1029/2012RS005049>

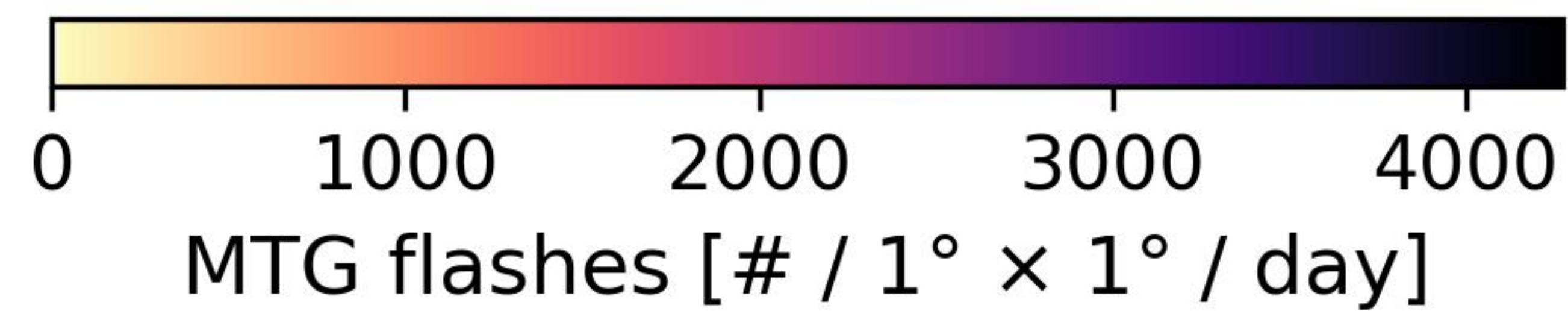
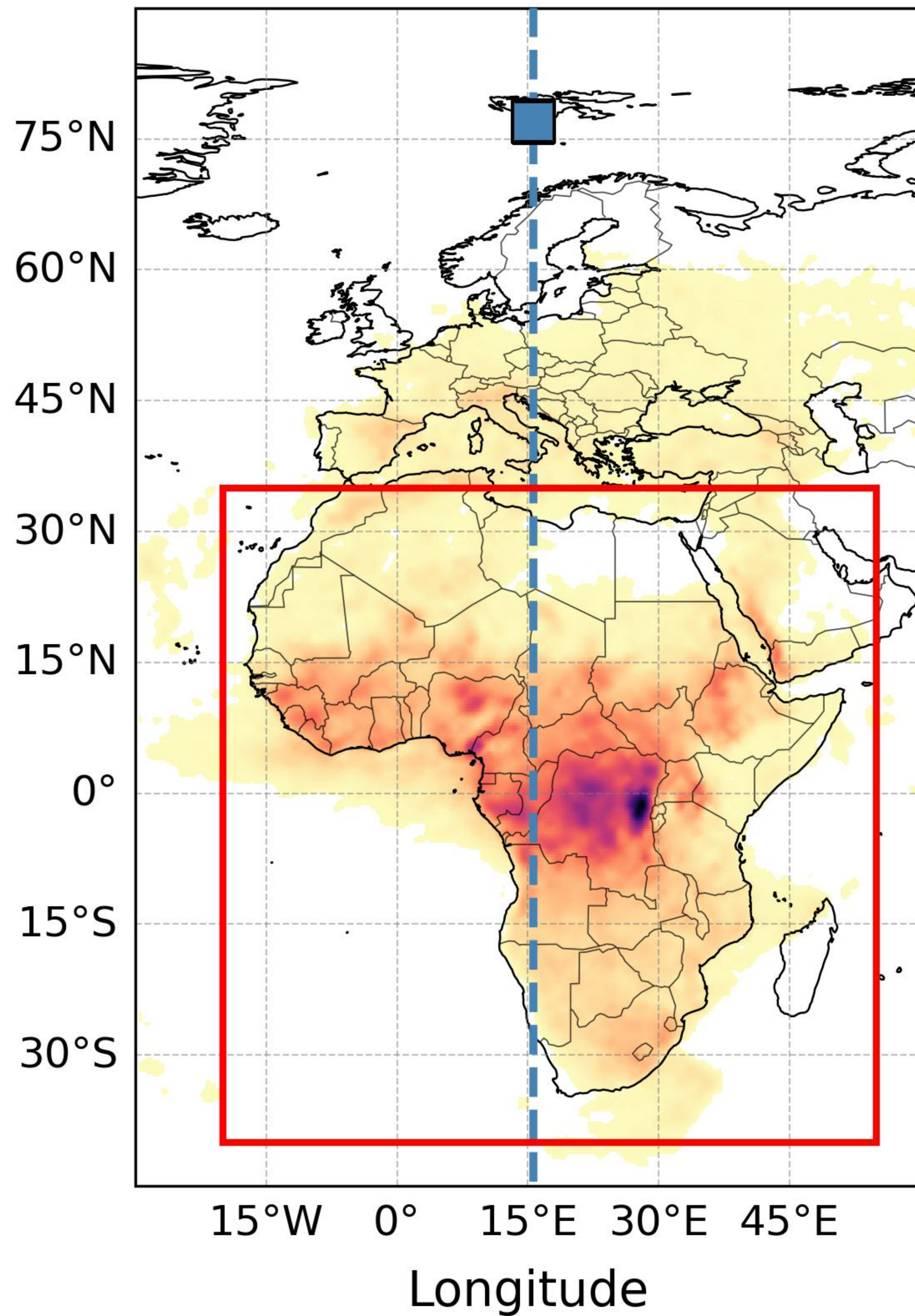
- Kigotsi, J. K., Soula, S., Athier, G., Lisika, L. K., & Lee, K. O. (2024). Analysis of the lightning activity during 18 years in the Congo Basin. *Atmos. Res.*, 309, 107577. <https://doi.org/10.1016/j.atmosres.2024.107577>
- Lyons, W. (2025). *Reducing Lightning Mass Casualty Incidents: How One Non-Profit is Saving Lives in Africa Using Lessons from the U.S. Experience*. Taylor & Francis. <https://doi.org/10.1080/00431672.2025.2563459>
- MacGorman, D. R., Apostolakopoulos, I. R., Lund, N. R., Demetriades, N. W. S., Murphy, M. J., & Krehbiel, P. R. (2011). The timing of cloud-to-ground lightning relative to total lightning activity. *Monthly Weather Review*, 139(12), 3871–3886. <https://doi.org/10.1175/MWR-D-11-00047.1>
- Mushtak, V. C., & Williams, E. R. (2002). ELF propagation parameters for uniform models of the Earth-ionosphere waveguide. *Journal of Atmospheric and Solar-Terrestrial Physics*, 64(18), 1989–2001. [https://doi.org/10.1016/S1364-6826\(02\)00222-5](https://doi.org/10.1016/S1364-6826(02)00222-5)
- Neska, M., Czubak, P., & Reda, J. (2019). Schumann resonance monitoring in Hornsund (Spitsbergen) and Suwałki (Poland). *Publications of the Institute of Geophysics, Polish Academy of Sciences*, 425, 41–45. https://doi.org/10.25171/InstGeoph_PAS_Publs-2019-008
- Németh, K., Herein, M., Haszpra, T., Steinbach, P., Sători, G., Williams, E., Wang, Q., Neska, A., & Bozoki, T. (2026). Daily peak activity and peak timing data for SR intensity, MTG flashes, MTG groups, and WWLLN strokes between August 2024 to July 2025 [Data set]. Zenodo. <https://doi.org/10.5281/zenodo.20330408>
- Nickolaenko, A. P., & Hayakawa, M. (2002). *Resonances in the Earth-ionosphere cavity*. Kluwer
- Nieckarz, Z., Kułak, A., Zięba, S., Kubicki, M., Michnowski, S., & Barański, P. (2009). Comparison of global storm activity rate calculated from Schumann resonance background components to electric field intensity E0Z. *Atmospheric Research*, 91(2–4), 184–187. <https://doi.org/10.1016/j.atmosres.2008.06.006>
- Peterson, M., & Liu, C. (2011). Global statistics of lightning in anvil and stratiform regions over tropics and subtropics observed by TRMM. *Journal of Geophysical Research*, 116, D23201. <https://doi.org/10.1029/2011JD015908>
- Prácsér, E., Bozoki, T., Sători, G., Williams, E., Guha, A., & Yu, H. (2019). Reconstruction of global lightning activity based on Schumann resonance measurements: Model description and synthetic tests. *Radio Science*, 54(3), 254–267. <https://doi.org/10.1029/2018RS006772>
- Price, C. (2016). ELF electromagnetic waves from lightning: The Schumann resonances. *Atmosphere*, 7(9), 116. <https://doi.org/10.3390/atmos7090116>
- Price, C., Yair, Y., & Asfur, M. (2007). East African lightning as a precursor of Atlantic hurricane activity. *Geophys. Res. Lett.*, 34, L09805. <https://doi.org/10.1029/2006GL028884>

- Rudlosky, S. D., & Virts, K. S. (2021). Dual geostationary lightning mapper observations. *Mon. Weather Rev.*, 149(4), 979–998. <https://doi.org/10.1175/MWR-D-20-0242.1>
- Rudlosky, S., & Shea, D. (2013). Evaluating WWLLN performance relative to TRMM/LIS. *Geophys. Res. Lett.*, 40(10), 2344–2348. <https://doi.org/10.1002/grl.50428>
- Sátori, G., Bozóki, T., Williams, E., Prácsér, E., Herein, M., Albrecht, R. I., & Beltran, R. P. (2024). How do Schumann resonance frequency changes in the vertical electric field component reflect global lightning dynamics at different time scales? *J. Geophys. Res.: Atmos.*, 129(19). <https://doi.org/10.1029/2024jd041455>
- Schumacher, C., & Houze, R. A., Jr. (2006). Stratiform precipitation production over sub-Saharan Africa and the tropical East Atlantic as observed by TRMM. *Quarterly Journal of the Royal Meteorological Society*, 132, 2235–2255. <https://doi.org/10.1256/qj.05.121>
- Schumann, W. O. (1952). Über die strahlungslosen Eigenschwingungen einer leitenden Kugel, die von einer Luftschicht und einer Ionosphärenhülle umgeben ist. *Zeitschrift für Naturforschung*, 7(2), 149–154. <https://doi.org/10.1515/zna-1952-0202>
- Shvets, A. V., Hobara, Y., & Hayakawa, M. (2010). Variations of the global lightning distribution revealed from three-station Schumann resonance measurements. *Journal of Geophysical Research*, 115, A12316. <https://doi.org/10.1029/2010JA015851>
- Soula, S., Kasereka, J. K., Georgis, J. F., & Barthe, C. (2016). Lightning climatology in the Congo Basin. *Atmos. Res.*, 178–179, 304–319. <https://doi.org/10.1016/j.atmosres.2016.04.006>
- Thompson, K. B., Bateman, M. G., & Carey, L. D. (2014). A Comparison of two ground-based lightning detection networks against the satellite-based Lightning Imaging Sensor (LIS). *J. Atmos. Oceanic Technol.*, 31(10), 2191–2205. <https://doi.org/10.1175/JTECH-D-13-00186.1>
- Virts, K. S., Wallace, J. M., Hutchins, M. L., & Holzworth, R. H. (2013). Highlights of a new ground-based, hourly global lightning climatology. *Bull. Am. Meteorol. Soc.*, 94(9), 1381–1391. <https://doi.org/10.1175/BAMS-D-12-00082.1>
- Wait, J. R. (1970). *Electromagnetic wave in stratified media*. The Institute of Electrical and Electronics Engineers Inc. New York: Oxford University Press.
- Williams, E. R. (2005). Lightning and climate: A review. *Atmos. Res.*, 76(1–4), 272–287. <https://doi.org/10.1016/j.atmosres.2004.11.014>
- Williams, E. R., & Mareev, E. A. (2014). Recent progress on the global electrical circuit. *Atmos. Res.*, 135–136, 208–227. <https://doi.org/10.1016/j.atmosres.2013.05.015>
- Williams, E. R., & Sátori, G. (2004). Lightning, thermodynamic and hydrological comparison of two tropical continental chimneys. *J. Atmos. Sol. Terr. Phys.*, 66(13–14), 1213–1231. <https://doi.org/10.1016/j.jastp.2004.05.015>

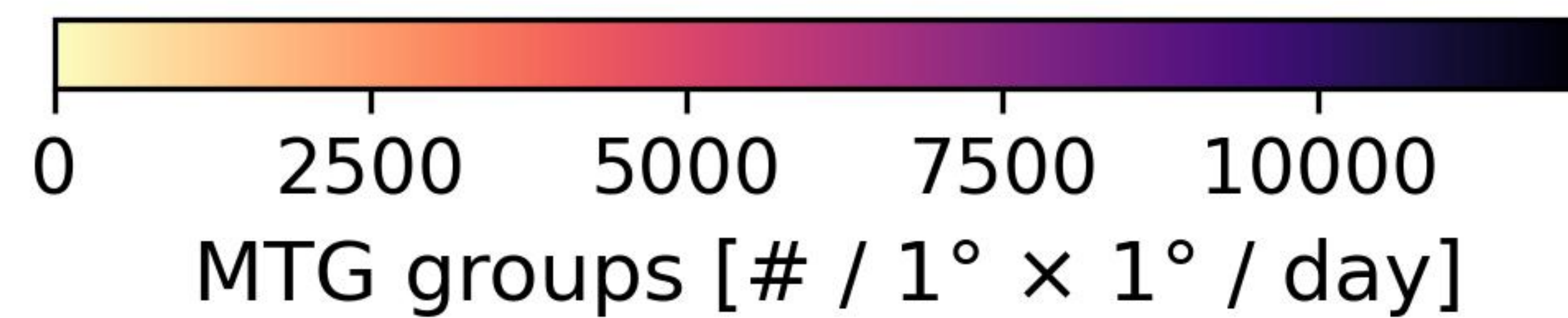
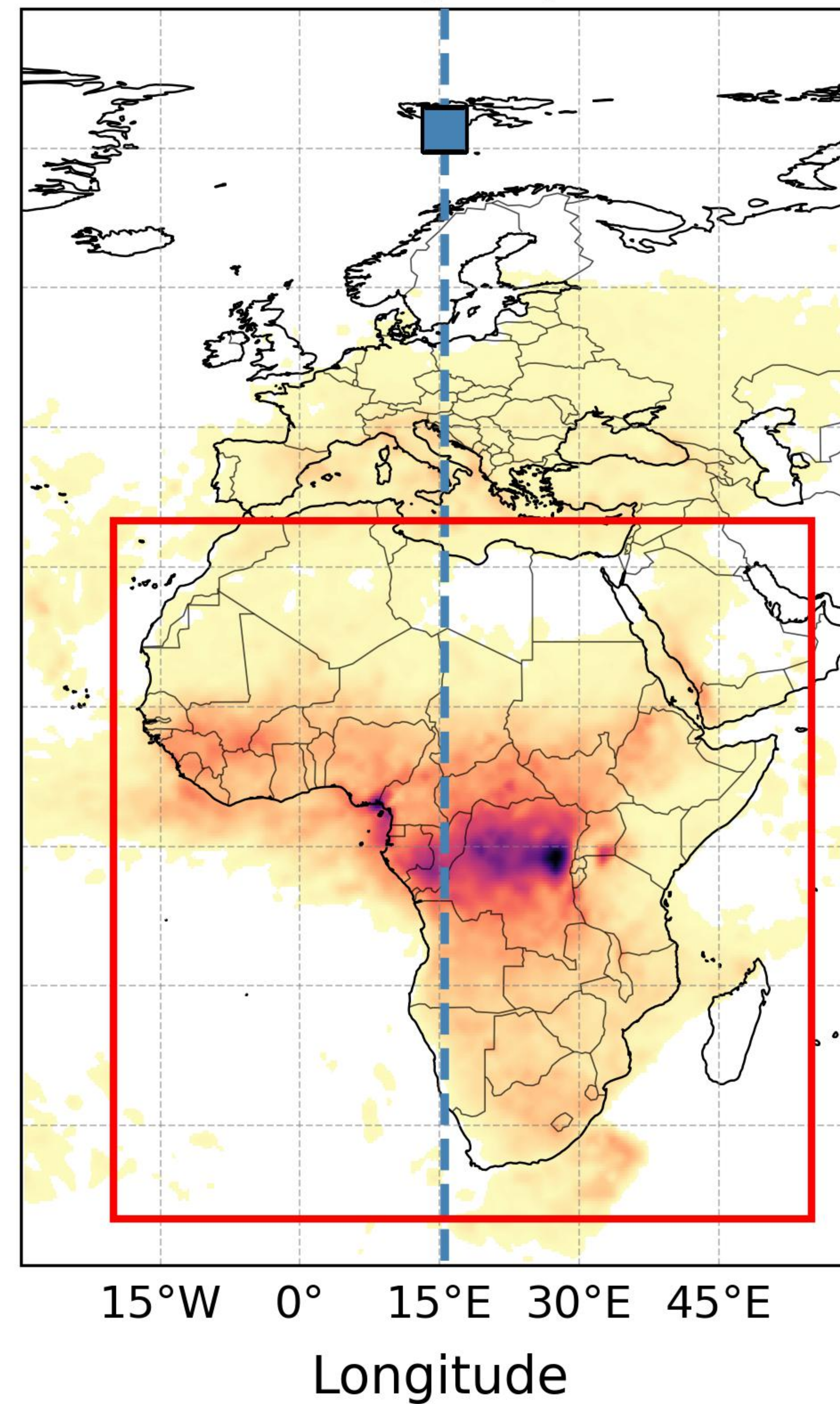
- 814 Williams, E., Bozóki, T., Sători, G., Price, C., Steinbach, P., Guha, A., et al. (2021). Evolution of
815 global lightning in the transition from cold to warm phase preceding two super El Niño events. *J.*
816 *Geophys. Res.: Atmos.*, 126(3), e2020JD033526. <https://doi.org/10.1029/2020JD033526>
- 817 Williams, E., Rothkin, K., Stevenson, D., & Boccippio, D. (2000). Global lightning variations
818 caused by changes in thunderstorm flash rate and by changes in the number of thunderstorms. *J.*
819 *Appl. Meteorol. Climatol.*, 39(12), 2223–2230. [https://doi.org/10.1175/1520-](https://doi.org/10.1175/1520-0450(2001)040%3C2223:GLVCBC%3E2.0.CO;2)
820 [0450\(2001\)040%3C2223:GLVCBC%3E2.0.CO;2](https://doi.org/10.1175/1520-0450(2001)040%3C2223:GLVCBC%3E2.0.CO;2)
- 821 Yang, J., Zhang, Z., Wei, C., Lu, F., & Guo, Q. (2017). Introducing the new generation of
822 Chinese geostationary weather satellites, Fengyun-4. *Bull. Am. Meteorol. Soc.*, 98(8), 1637–
823 1658. <https://doi.org/10.1175/BAMS-D-16-0065.1>
- 824 Yoshida, S., Morimoto, T., Ushio, T., & Kawasaki, Z. (2009). A fifth-power relationship for
825 lightning activity from Tropical Rainfall Measuring Mission satellite observations. *Journal of*
826 *Geophysical Research: Atmospheres*, 114, D09104. <https://doi.org/10.1029/2008JD010370>

Figure 1.

MTG flashes



MTG groups



WWLLN strokes

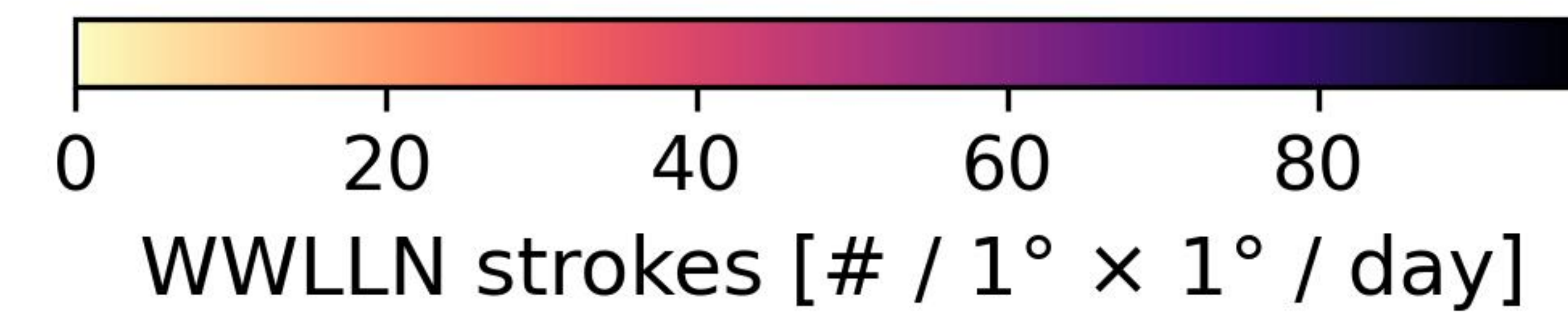
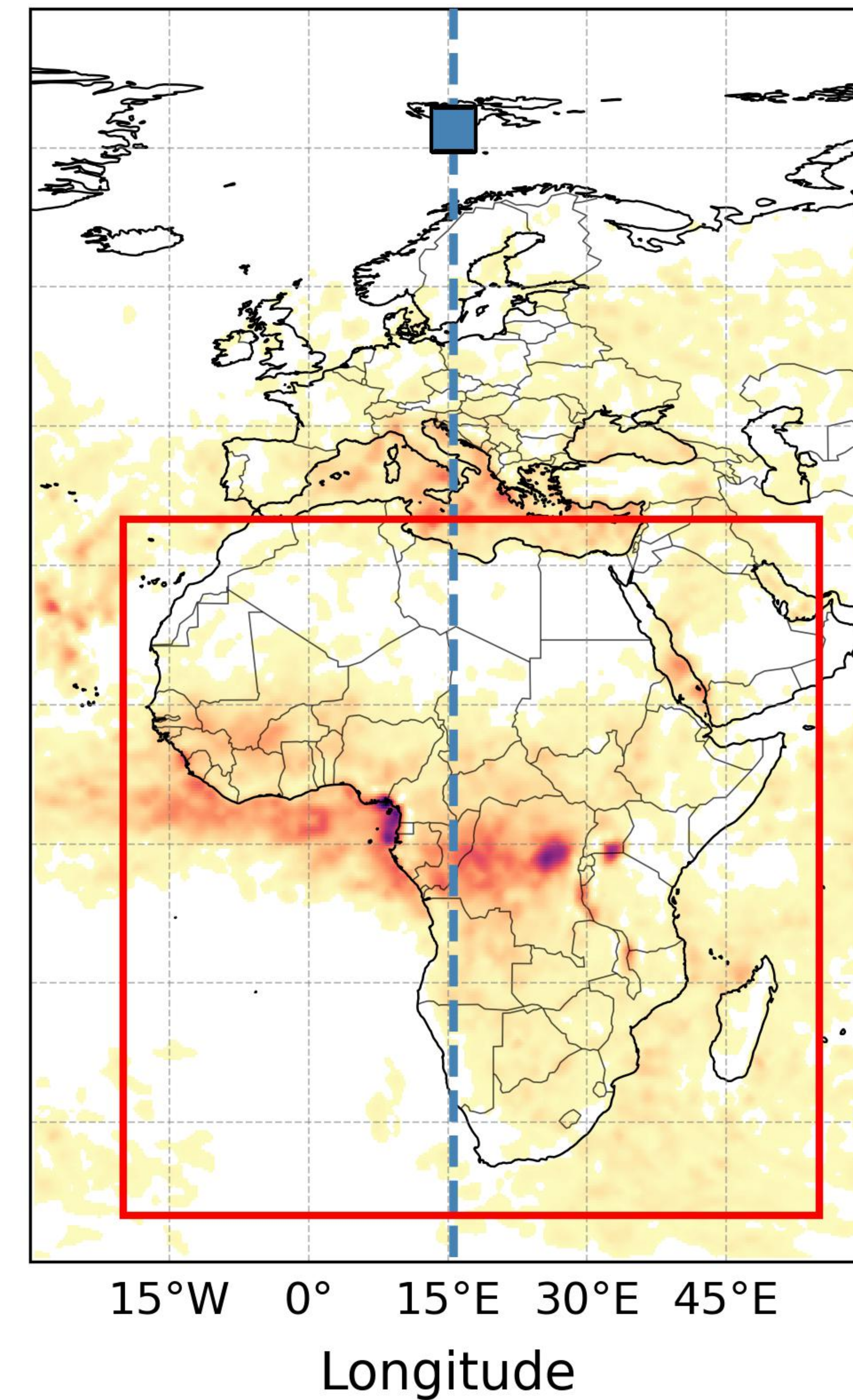


Figure 2.

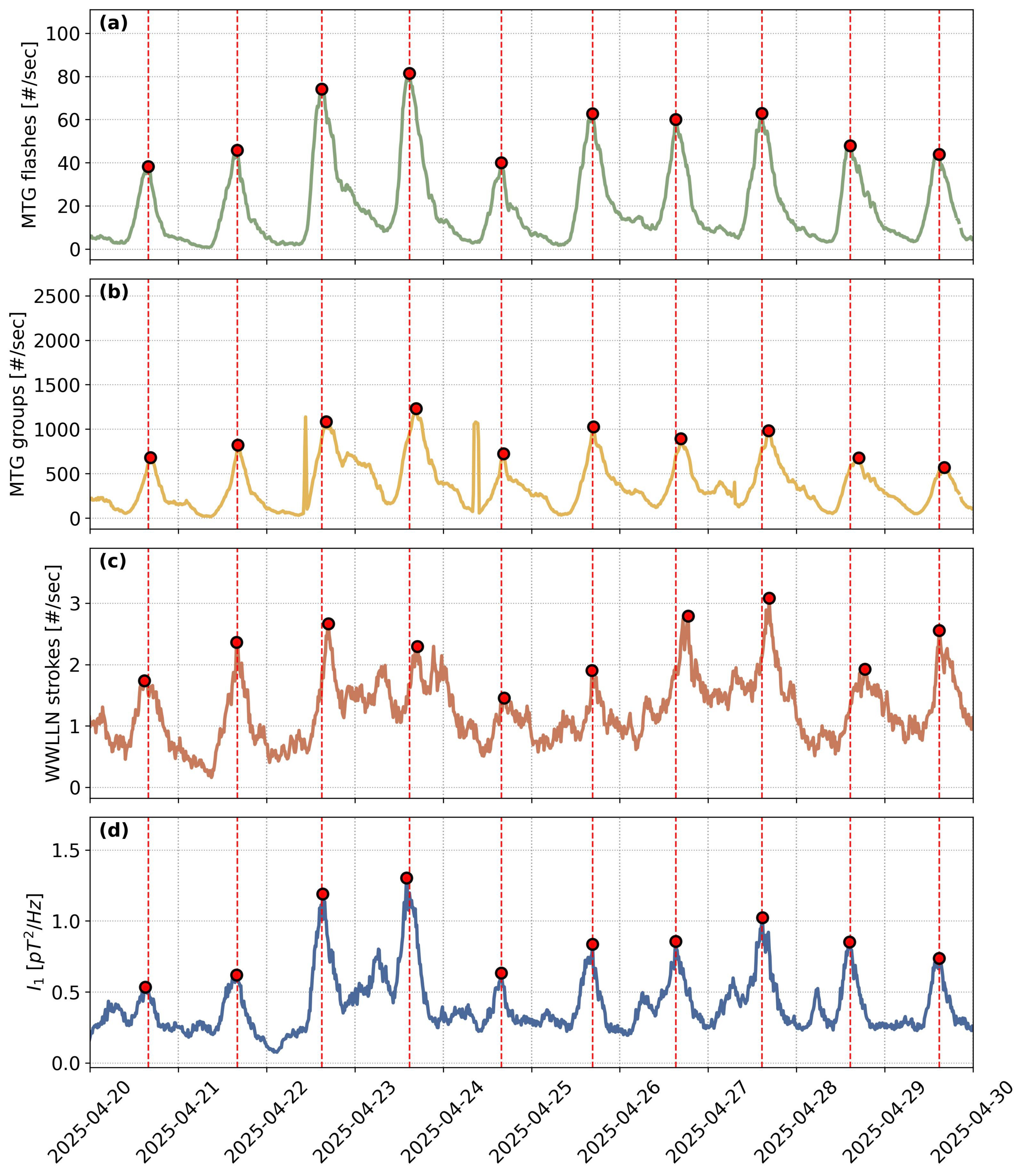


Figure 3.

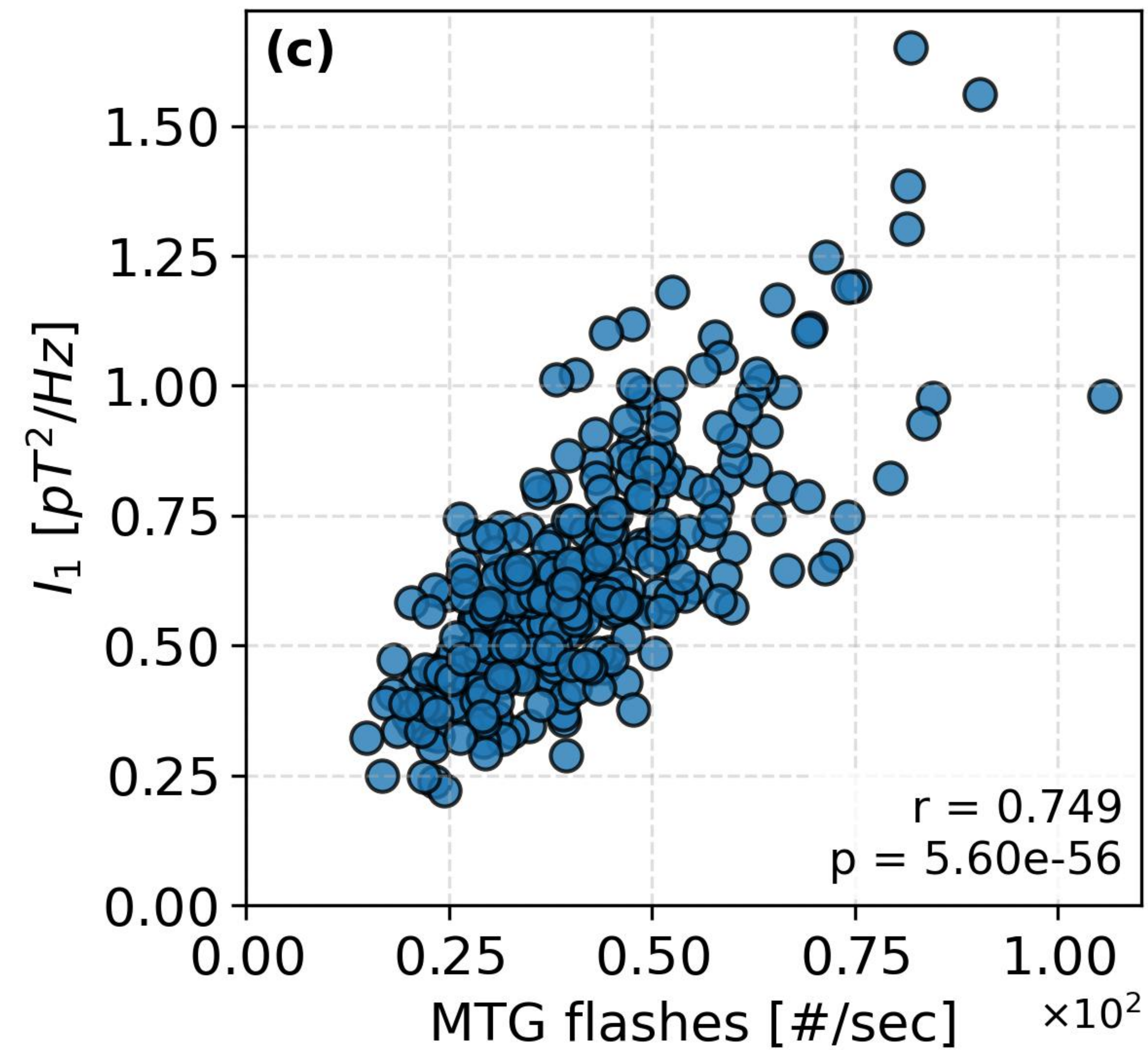
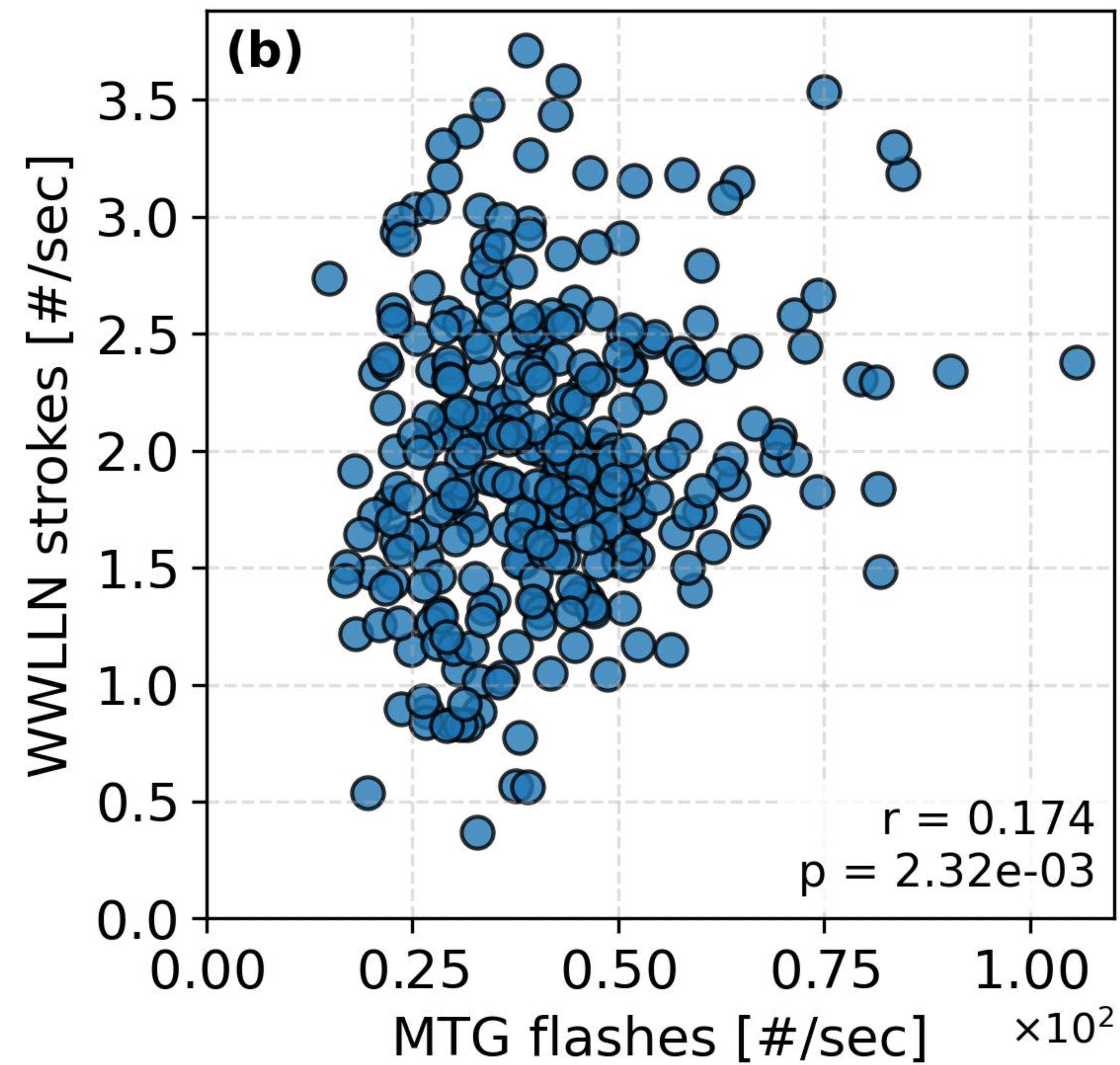
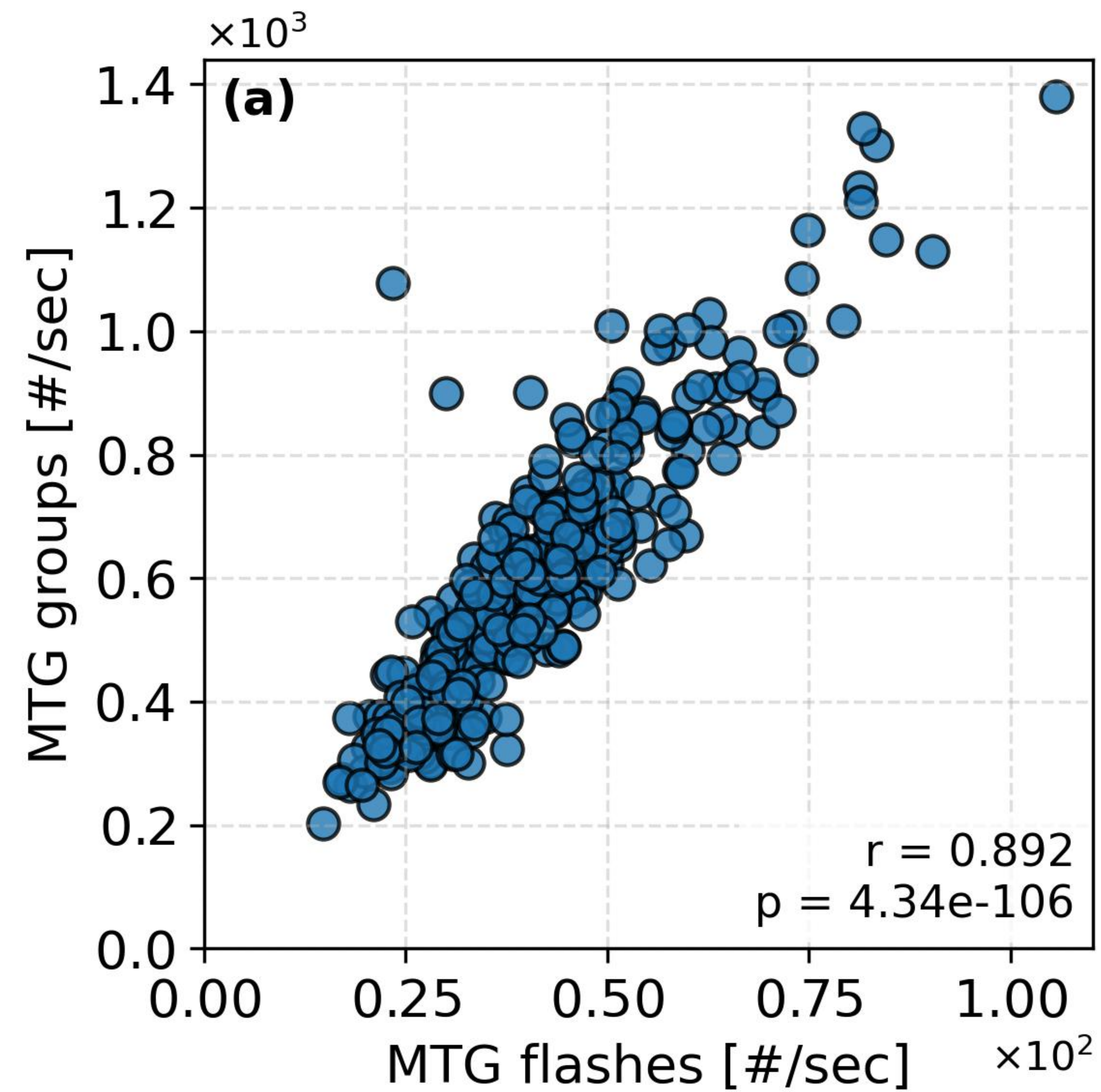
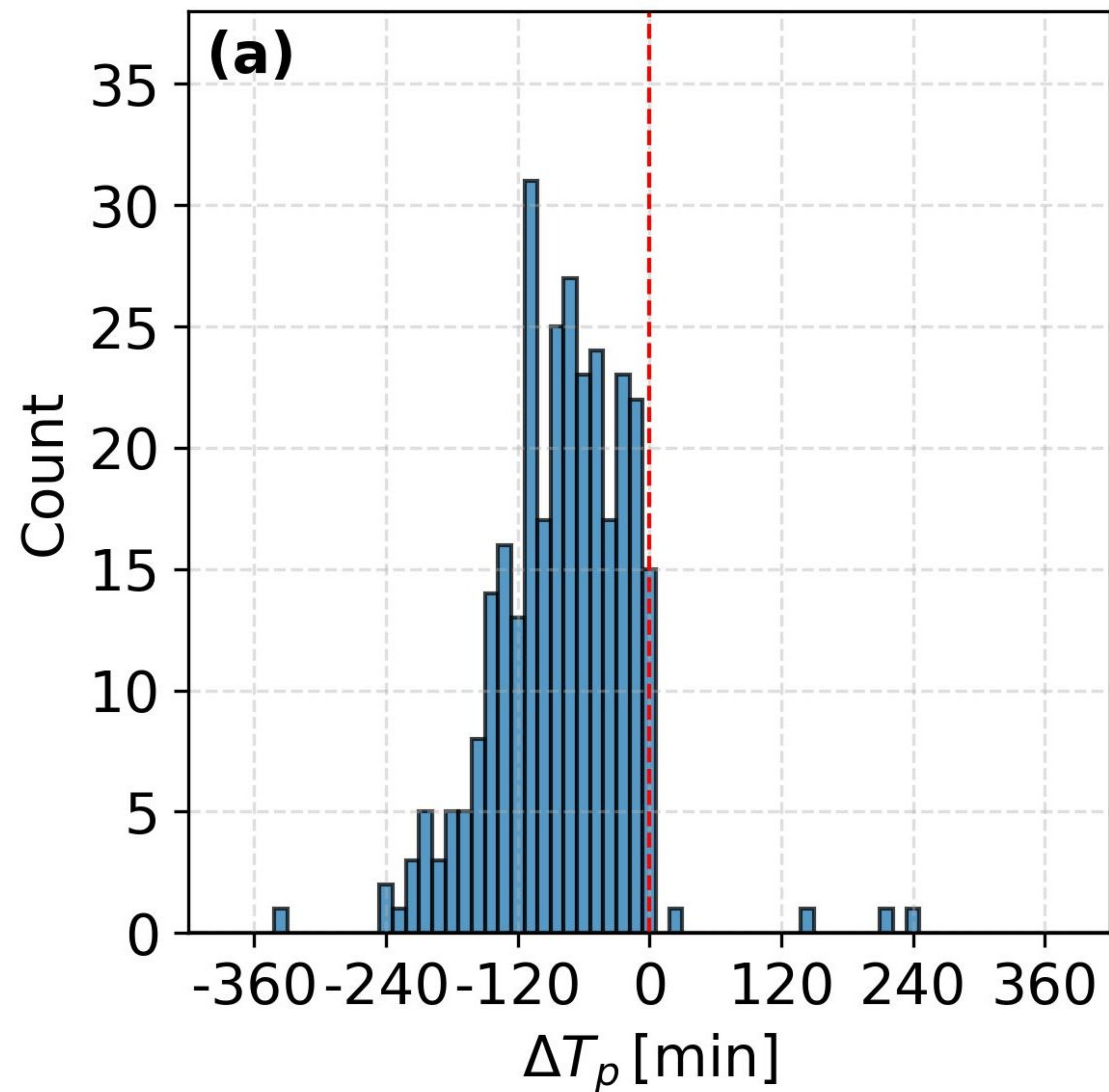
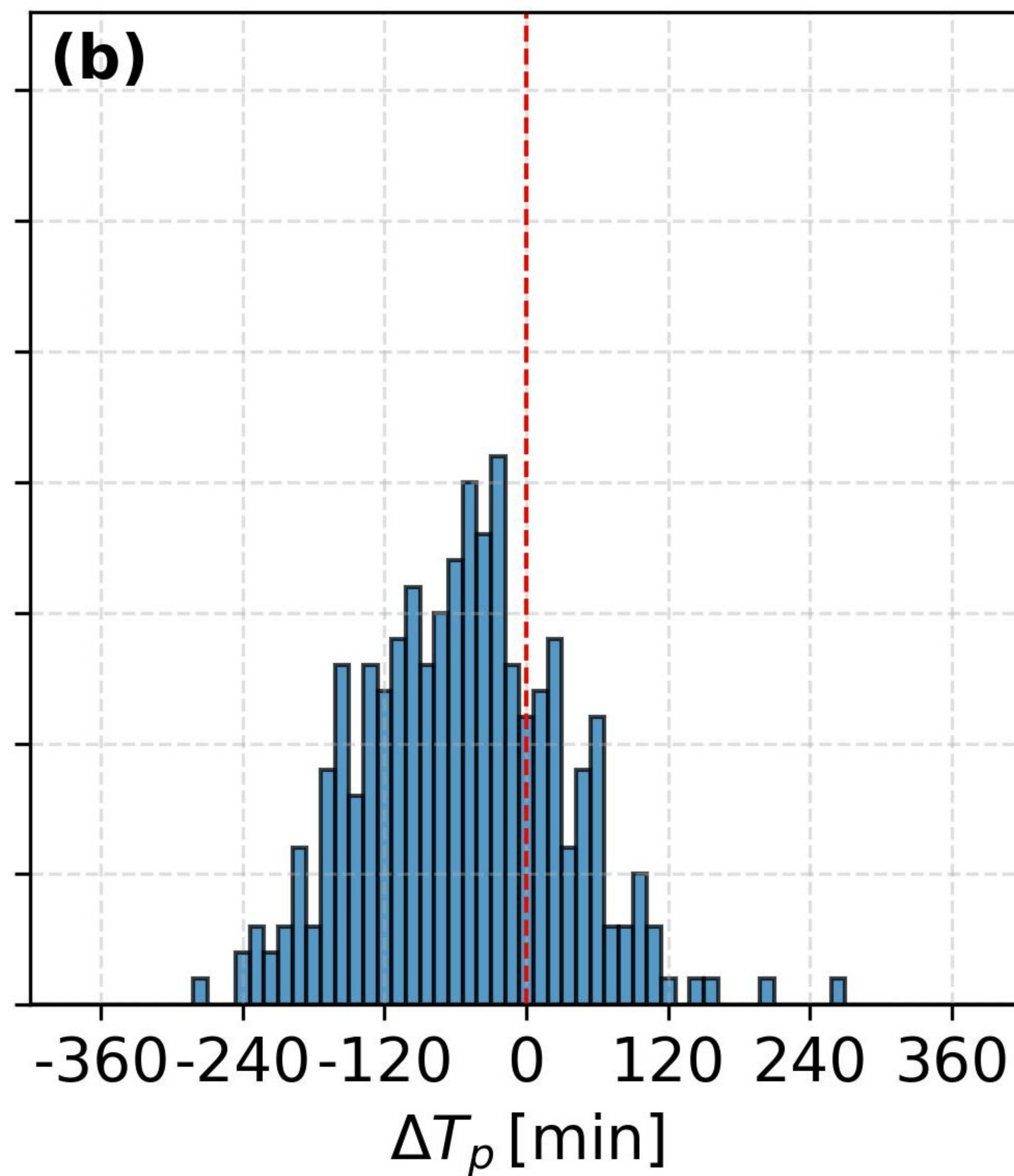


Figure 4.

MTG flashes - MTG groups



MTG flashes - WWLLN strokes



MTG flashes - SR

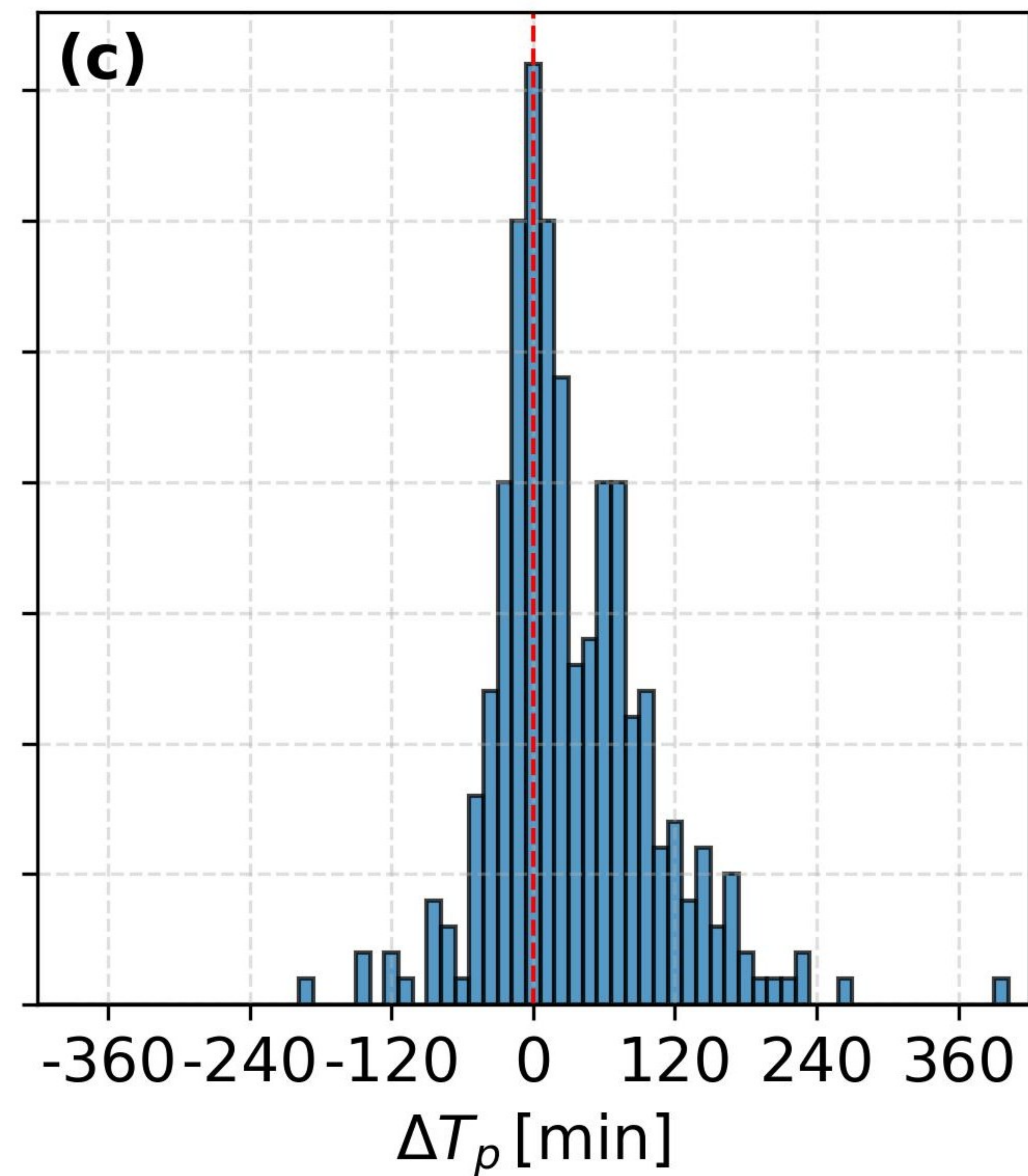


Figure 5.

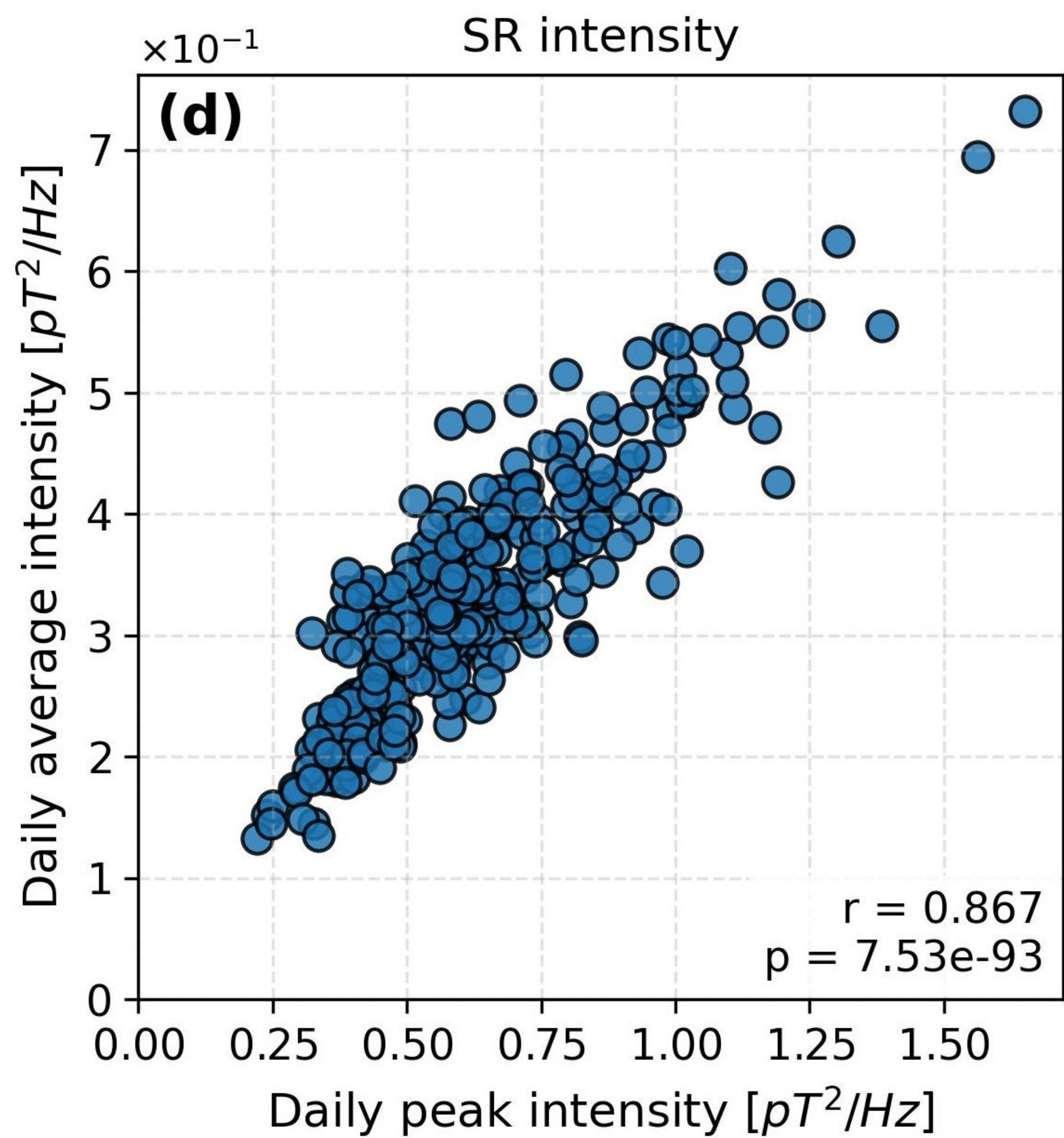
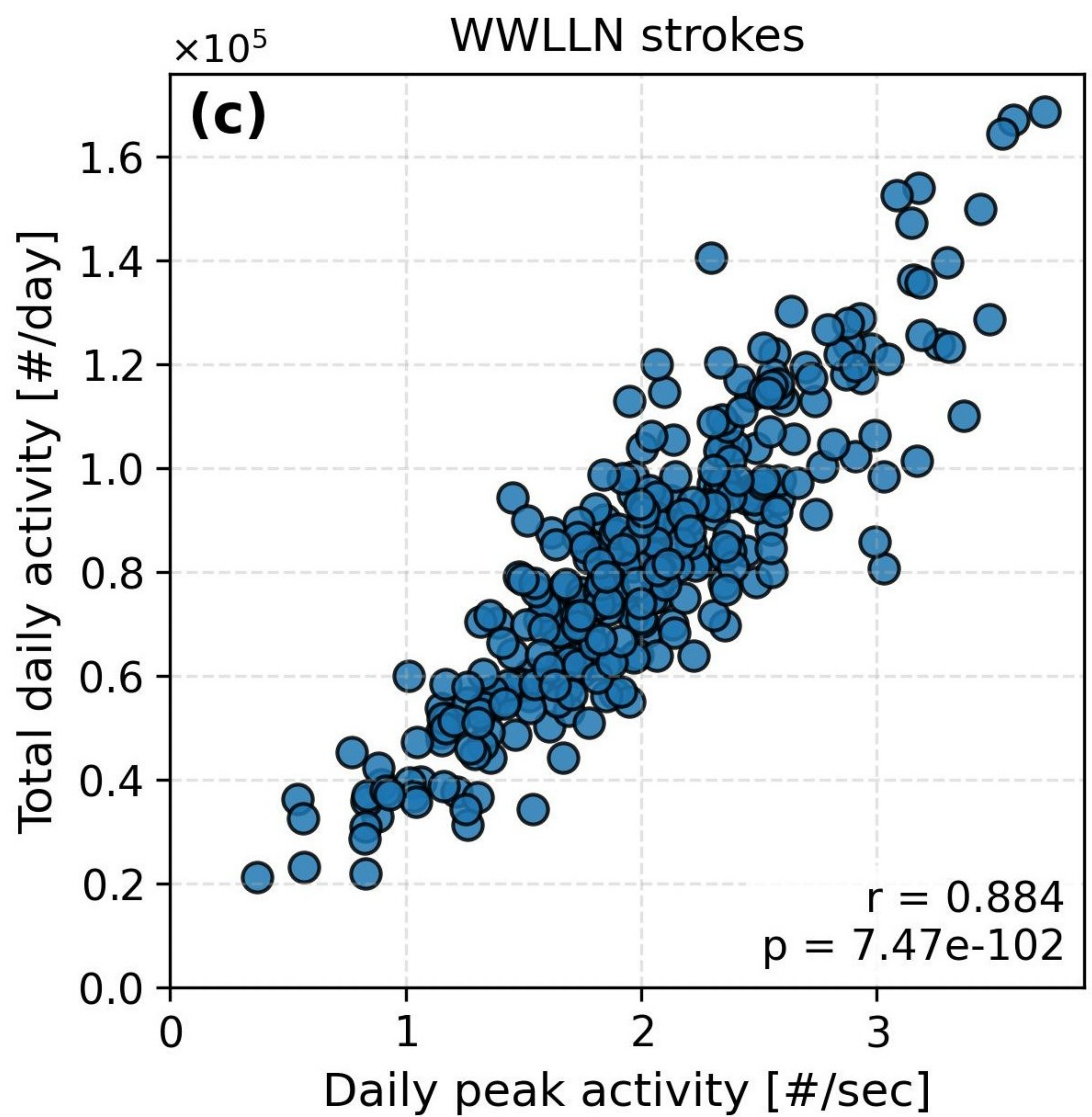
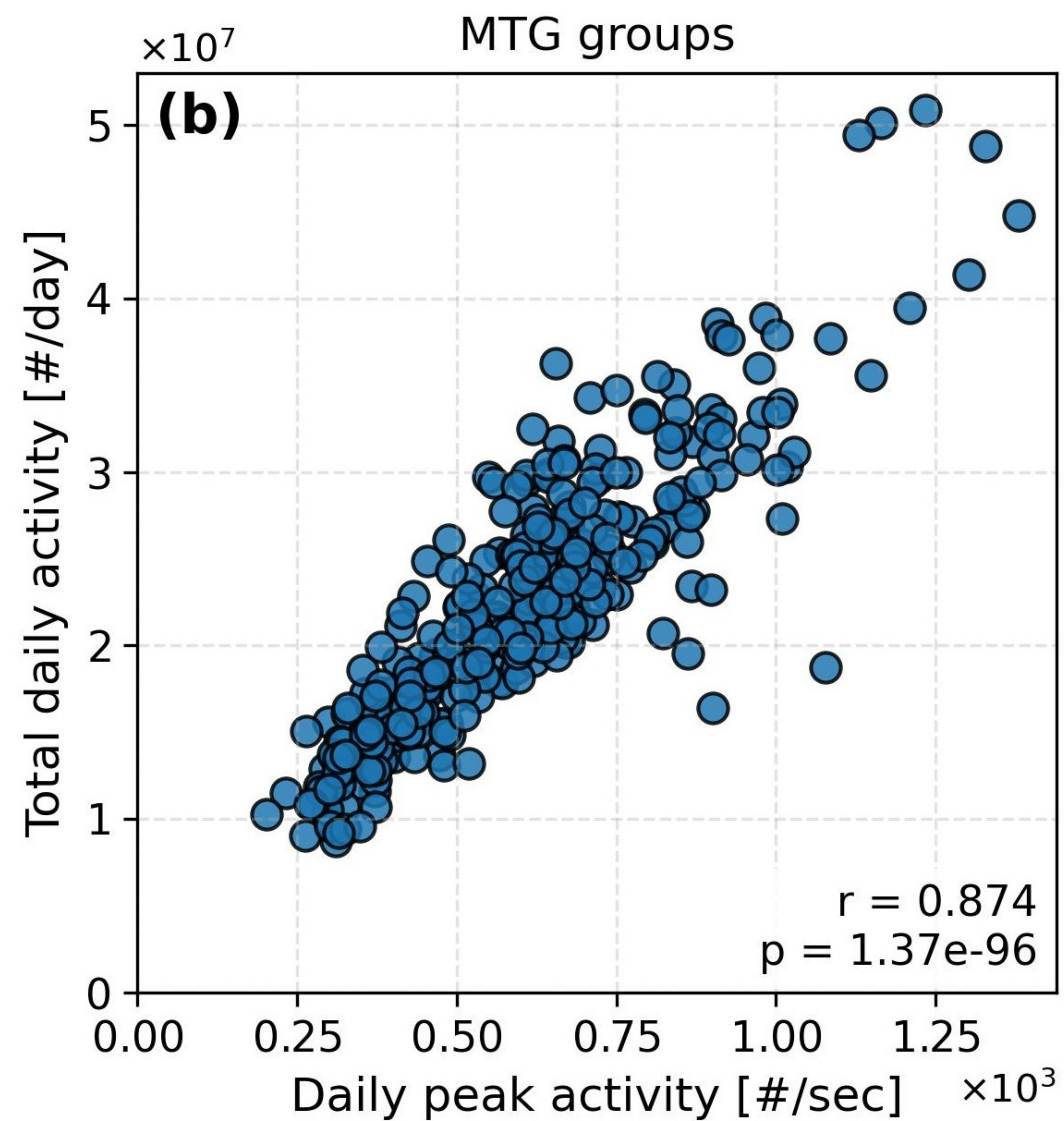
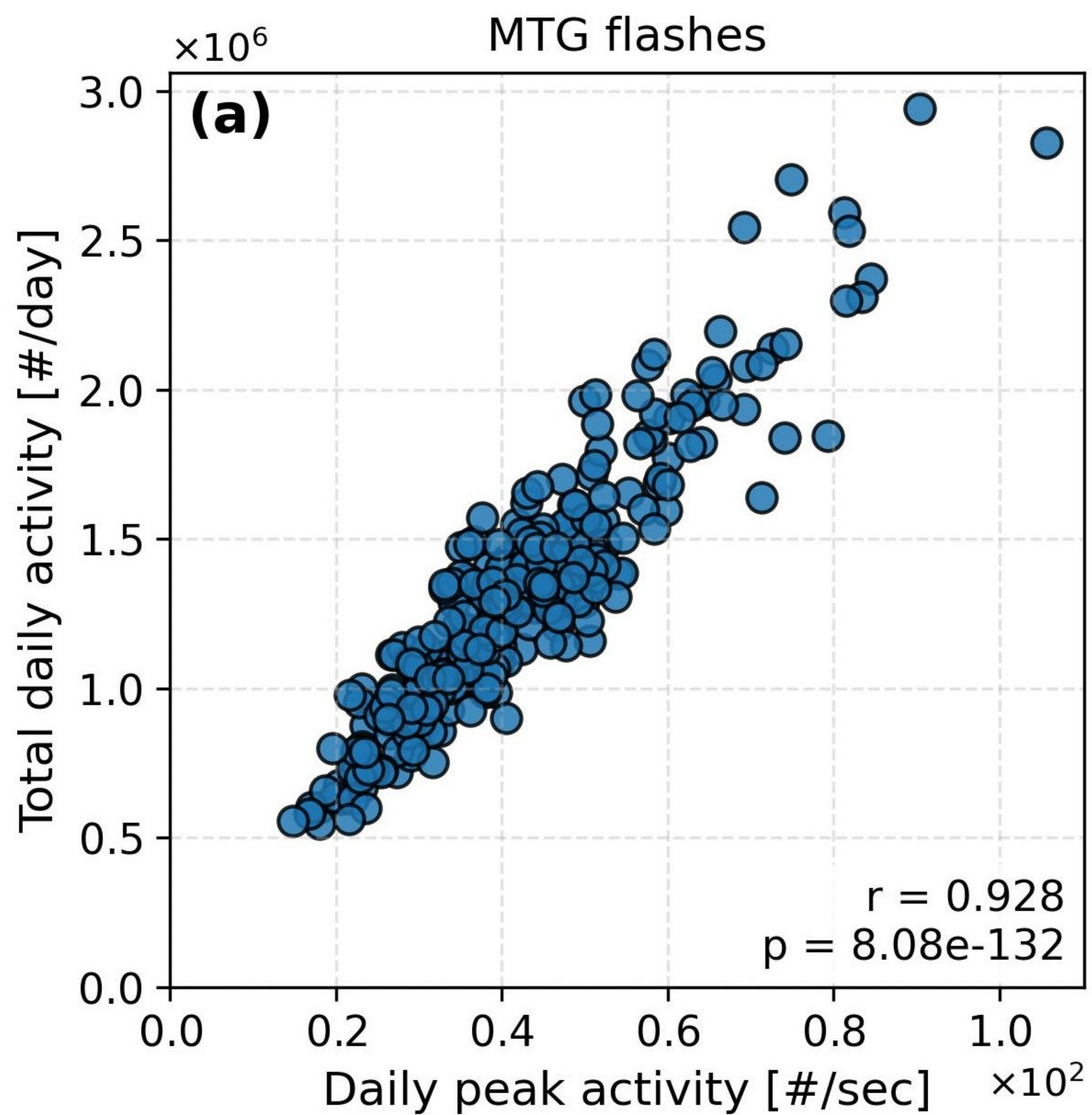


Figure 6.

