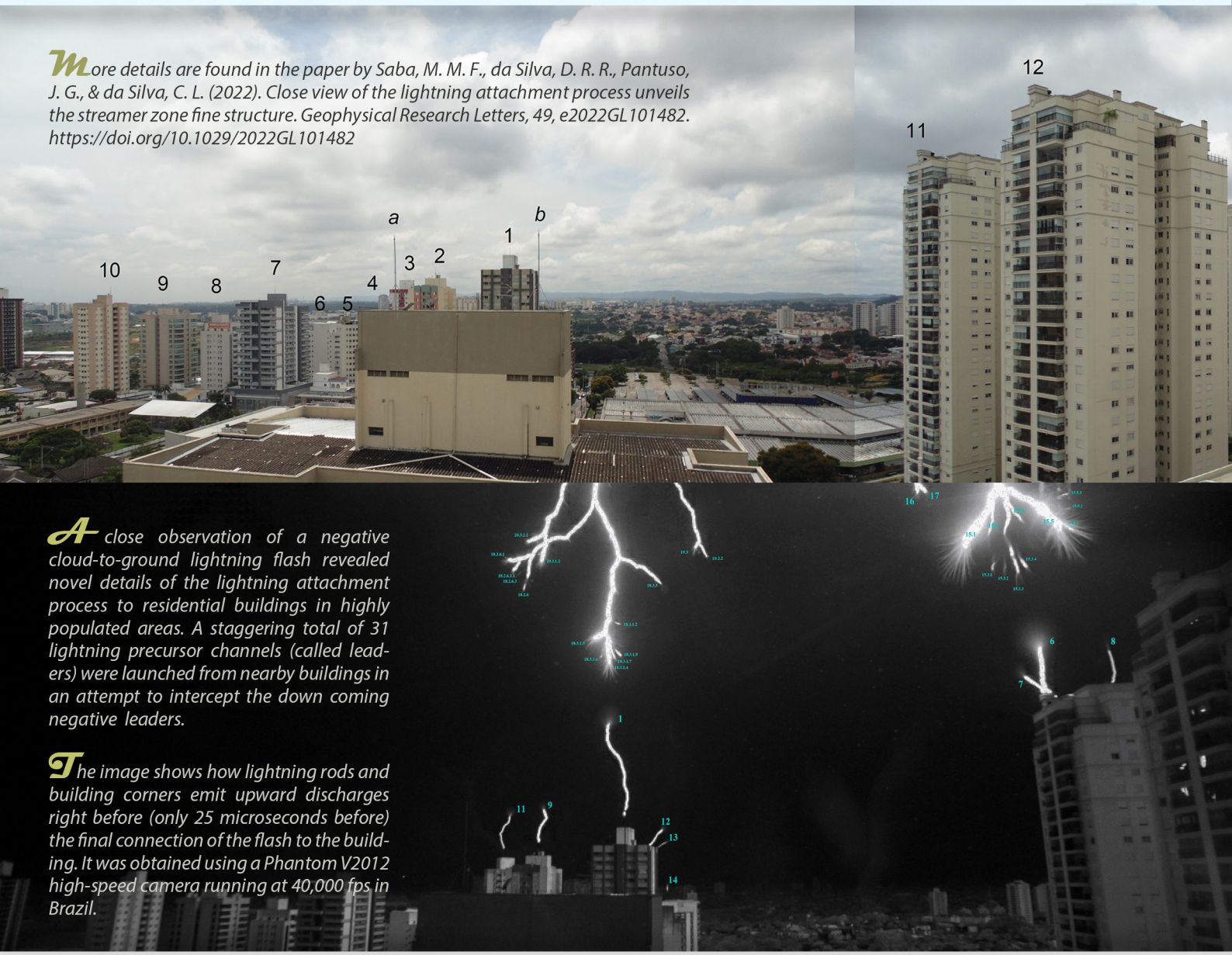
# Atmospheric Electricity

https://www.iamas.org/icae/
NEWSLETTER
Vol.34 NO.1 May 2023




*More details are found in the paper by Saba, M. M. F., da Silva, D. R. R., Pantuso, J. G., & da Silva, C. L. (2022). Close view of the lightning attachment process unveils the streamer zone fine structure. Geophysical Research Letters, 49, e2022GL101482. https://doi.org/10.1029/2022GL101482*

*A close observation of a negative cloud-to-ground lightning flash revealed novel details of the lightning attachment process to residential buildings in highly populated areas. A staggering total of 31 lightning precursor channels (called leaders) were launched from nearby buildings in an attempt to intercept the down coming negative leaders.*

*The image shows how lightning rods and building corners emit upward discharges right before (only 25 microseconds before) the final connection of the flash to the building. It was obtained using a Phantom V2012 high-speed camera running at 40,000 fps in Brazil.*

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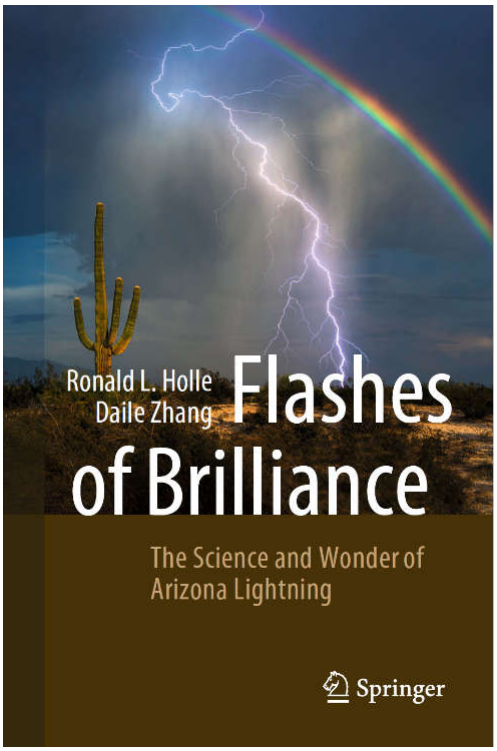
# New Book

Below is a link to the book just published with the title "Flashes of brilliance: The science and wonder of Arizona lightning": https://link.springer.com/book/10.1007/978-3-031-19879-3.

This book is intended for a broad audience comprised of visitors, interested lay public, a variety of scientific disciplines, media, medicine, lightning safety, and fire weather. It is the first resource book on the full range of lightning topics in Arizona. It is written by Ronald Holle of Oro Valley, Arizona, and Dr. Daile Zhang of the University of Maryland. The bibliographical description is as follows:

ISBN 978-3-031-19878-6, published on 05 April 2023 by Springer Nature Switzerland AG.



# *A*frican Centres for Lightning and Electromagnetics Network (ACLENet)

ACLENet wishes to thank all those worldwide who support our mission to decrease deaths, injuries, and property damage from lightning across Africa. We have been submitting updates to this newsletter since 2017, letting supporters and donors know about our work and how their contributions are utilized.

With this update, it is a pleasure to announce that the work of lightning safety has spread to many other continents as colleagues interested in applying their lightning expertise to saving lives have taken the lead. In addition to many individual countries, two multinational lightning safety advocacy groups have formed:

**South Asian Lightning Network (SALNet)**, spearheaded by Dr Shriram Sharma <salnetnep@gmail.com> in Nepal, has been active for nearly three years, producing phenomenal webinars and conferences. SALNet, in association with Atmospheric and Material Science Research Center is set to organize an 'International conference on Lightning Electromagnets and Applications of Semiconducting Materials (ICLEASM) 2023, scheduled for October 4-6, 2023 (https://icleasm23.salnet.asia/).

**Latin American Lightning Education Network (LALENet)** is just beginning, spearheaded by Lizardo Lopez thelizar@gmail.com from Peru and Daniel Esteban Villamil Sierra devillamils@gmail.com of Colombia.

'Spreading the lightning safety message to all people must become the ethical duty among lightning researchers.'

~ Daniel Esteban Villamil Sierra, SIPDA 2019

I pray that the international lightning community will offer these organizations their support as they have to ACLENet.

Blessings and Peace to all –

Mary Ann Cooper, MD, Managing Director
African Centres for Lightning and Electromagnetics Network
Professor Emerita, University of Illinois @ Chicago

ACLENet
Lightning and Electromagnetics Network

Lightning Kills! Save a Life in Africa
https://ACLENet.org

## *A*tmospheric and Space Electricity Research Team of University of Science and Technology of China (Hefei, China)

**Impact of urbanization in the Beijing area on the lightning phenomenology.** Previous studies on the climatic characteristics of lightning activity in Beijing are sparse due to the lack of long-term, continuous and stable lightning location data. In this paper, the long series of lightning location data during 2009–2018 were applied to reveal the spatiotemporal distribution of cloud-to-ground (CG) lightning in Beijing. The spatial characteristics were low west and high east, and the temporal characteristics were frequent in summer. In the complex terrain areas of northeast Beijing, there was a positive relationship between CG density and altitude, with the correlation coefficient higher than 0.8. The northeastern trumpet-shaped terrain had the forced lifting effect on thunderstorms, forming lightning-intensive areas of 500 $km^2$. In addition, urban heat island (UHI) effect provided the necessary thermal conditions for the development of thunderstorms, forming lightning-intensive areas in the built-up areas, with the highest value of CG flash density exceeding 6 $fl/km^2$. Note that the lightning-

sparse areas in the urban center exhibited a distinct barrier effect on the spatial patterns of summertime CG lightning in the built-up areas, which was mainly modulated by the type of synoptic background. The results from this study has been published in *Urban Climate.*

In specific, Analysis of one typical thunderstorm on 13 July 2017 revealed that the barrier effect might result in a bifurcation of low-level airflow and splitting of the convergence line. A more important finding was the modulation of the barrier effect by the scale and density of the built-up area, and the numerical simulation experiments further confirmed this potential association. This study has been published in *Geophysical Research Letters* (Figure 1).

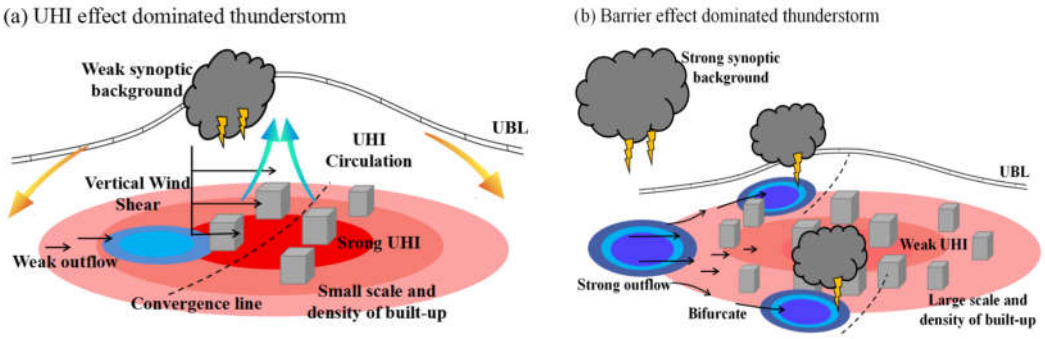



**Figure 1.** Effect of urbanization on the development of thunderstorms might depend on the meteorological background, as well as the size of urbanization. Based on the results from Shi et al. (2022GRL) and Shi et al. (2023UC).

**Application of machine learning to obtain the sprite distribution of different polarities from ISUAL observations.** The morphological features of sprites are closely related to the polarity of their causative lightning strokes. Using the machine learning method, we develop a model with an accuracy of 93.8% to identify the polarity of sprite-producing CG lightning strokes for events recorded during the Imager of Sprites and Upper Atmospheric Lightning (ISUAL) mission. Approximately 17% of the sprites are identified to be produced by negative CG lightning strokes. The global distribution of the polarity of sprite-producing CG lightning strokes suggests that the ratio of sprites produced by negative CG lightning strokes relative to sprites produced by positive ones varies with latitude and sea-land distribution. Sprites produced by negative CG lightning strokes appear to be generated in the tropical regions below 20° latitudes and the oceanic area. Moreover, the proportion of sprites produced by negative CG lightning strokes over Africa and North America are much smaller

than that over the rest of the continents and the sea. This study has been published in *JGR-Atmosphere* (Figure 2).

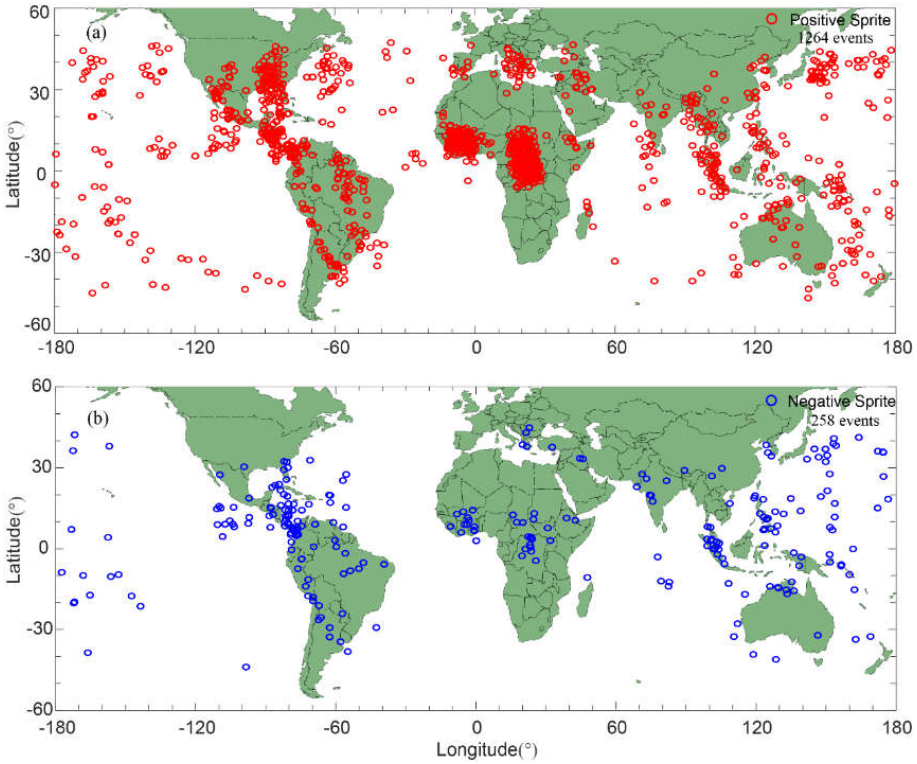
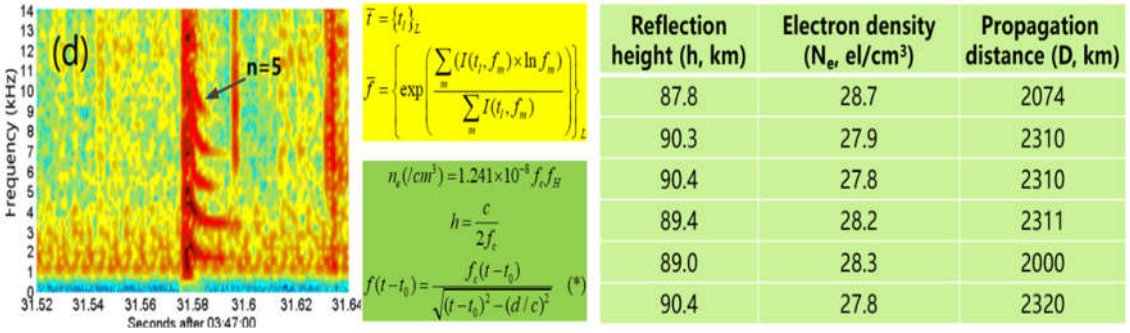



**Figure 2.** Global distribution of sprites produced by intense lightning strokes of different polarities as determined by the machine learning method.

**Automatic recognition of tweek atmospherics and plasma diagnostics in the lower ionosphere with the machine learning method.** Tweek atmospherics are extremely low frequency and very low frequency pulse signals with frequency dispersion characteristics that originate from lightning discharges and that propagate in the Earth–ionosphere waveguide over long distances. In this study, we developed an automatic method to recognize tweek atmospherics and diagnose the lower ionosphere based on the machine learning method. The differences (automatic−manual) in each ionosphere parameter between the automatic method and the manual method were −0.07 ± 2.73 km, 0.03 ± 0.92 $cm^{-3}$, and 91 ± 1,068 km for the ionospheric reflection height ($h$), equivalent electron densities at reflection heights ($Ne$), and propagation distance ($d$), respectively. Moreover, the automatic method is capable of recognizing higher harmonic tweek sferics. The evaluation results of the model suggest that the automatic method is a powerful tool for investigating the long-term variations in the lower ionosphere (Figure 3).




| Reflection height (h, km) | Electron density ($N_e$, el/cm³) | Propagation distance (D, km) |
|---|---|---|
| 87.8 | 28.7 | 2074 |
| 90.3 | 27.9 | 2310 |
| 90.4 | 27.8 | 2310 |
| 89.4 | 28.2 | 2311 |
| 89.0 | 28.3 | 2000 |
| 90.4 | 27.8 | 2320 |

**Figure 3.** Determination of ionospheric parameters from the radio frequency lightning signals based on the machine learning method.

## *D*epartment of Physics, Space Physics, Institute of Atmospheric Physics of the Czech Academy of Sciences

***Contributed by Ivana Kolmasova***

The Institute of Atmospheric Physics of the Czech Academy of Sciences and the LOFAR group has been cooperating on the data analysis from the broadband magnetic loop antennas SLAVIA (Shielded Loop Antenna with a Versatile Integrated Amplifier, Figure 1) and the array of LOFAR antennas from 2020. These efforts led already to four joint papers published in 2021-2022 (doi:10.1029/2020JD033126, doi:10.1038/s41598-021-95433-5, doi:10.1103/PhysRevD.105.062007, doi:10.1029/2022GL098073). All these papers gained from the complementary information acquired by both antenna types, which allowed us to identify the evolution stage of incloud discharges using the magnetic field recordings sampled at 200 MHz and to image these incloud phenomena in very high resolution thanks LOFAR imaging procedures. The fifth paper, which was just accepted for publishing in Geophysical Research Letters (doi: 10.1029/2023GL103864), reports new observations of relatively rarely occurring trains of regular microsecond-scale pulses, which were found to be produced by propagating in-cloud negative dart-stepped leaders close to the to the boundary between the thundercloud charge centers, where high ambient electric fields could be expected. The data for the study on pulse trains were recorded during the measuring campaign in 2021, when the mutual triggering of both antenna systems was installed. The broadband antenna stopped working in winter 2022, and one of the reasons for the silence of

our broadband measuring system were mice (Figure 2). Now it is repaired and fully operational waiting for the Dutch thunderstorm season.

**Figure 1**. Broadband shielded magnetic loop with an integrated preamplifier installed close to Ter Wisch, Netherlands.

**Figure 2** Cable interconnecting the antenna and the acquisition unit, two coaxial cables are used to transmit the analog signals from the antenna, the UTP cable secures the power for the integrated preamplifier and gain control.

## *Gifu University, Gifu, Japan*

**A 3D interferometer-type lightning mapping array for observation of winter lightning in Japan.** We have developed and deployed a 3D Interferometer-type Lightning Mapping Array (InLMA) for observing winter lightning in Japan. InLMA consists of three broadband interferometers installed at three stations with a distance from 3 to 5 km as shown in Figure 1. At each interferometer station, three discone antennas were installed forming a right triangle with a separation of 75 m along their two orthogonal baselines. The output of each InLMA antenna is passed through a 400 MHz low-pass filter and then recorded at 1GS/s with 16-bit accuracy. A new method has been proposed for finding 3D solutions of a lightning mapping system which consists of multiple interferometers. Using the InLMA we have succeeded to record many flashes in winter. In this research, we focus on a positive CG lightning flash, particularly its preliminary breakdown (PB) process. A study on individual PB pulse processes allows us to infer that each PB pulse process contains many small-scale discharges scattering in a height range of about 150 meters. These small-scale discharges in a series of PB pulses appear to be continuous in space, though discontinuous in time. Our results may indicate that a PB process may involve both fast positive breakdown (backward progression here) and fast negative breakdown. And we have also examined the positive return stroke in the CG flash and found a 3D average return stroke speed of $7.5\times10^7$ m/s. This study has been published in *Remote Sensing*.

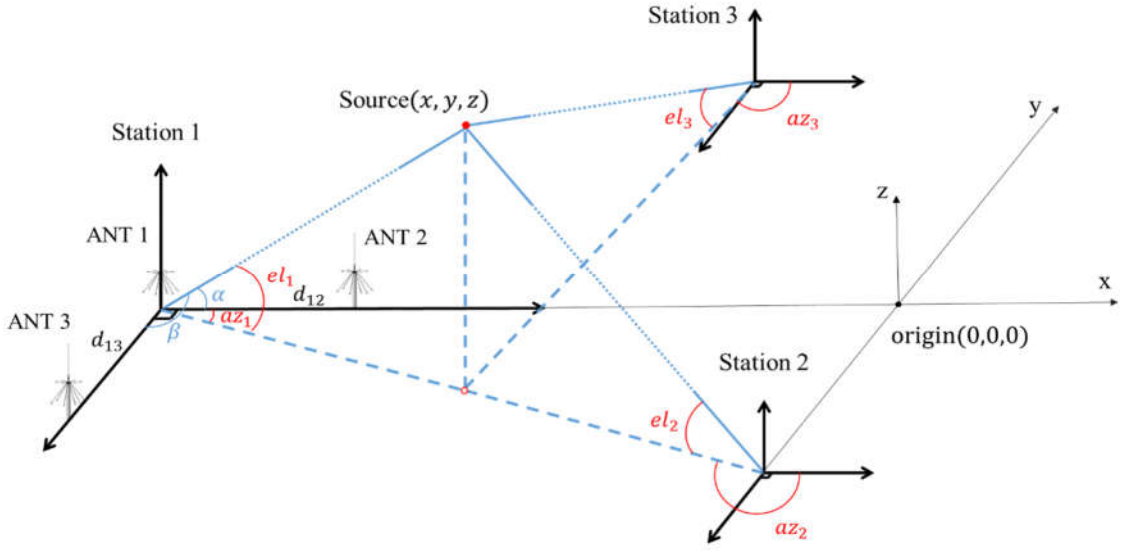



**Figure 1.** Illustration of three station InLMA with an assumed point discharge source$(x, y, z)$ which radiates electromagnetic waves to the three stations.

# INPE, National Institute for Space Research, Brazil

**First lightning jump documented during an unseasonable tornadic event in Brazil.** Favorable synoptic conditions at the beginning of June 2016 led to the formation of several supercell storms during late afternoon of 4 June, traversing the eastern half of the state of São Paulo until early next morning. This is exceptional, since it occurred during the dry austral winter season. Shortly after midnight (local time), one of them spawned an F2-3 tornado (Fujita scale) at 00:22 LT (03:22 UT), causing considerable damage in several suburbs of the city of Campinas along its 20-minute track. At 23:59 LT, the reflectivity and VIL (Vertical Integrated Liquid water content) had reached a peak as the lightning frequency dropped to a marked low, followed by a sudden increase in lightning activity, representing a *lightning jump*. Figure 1 shows the peak of 238 strokes per minute of total lightning at 03:14 UT (00:14 LT), 7 min prior to the tornado touch down.

Tornados are actually rare events in this region: Between 1991 and 2016 (26 years) only 13 severe tornados had been confirmed, of which only 8 occurred within range of the S-band Doppler radars and could thus be studied in detail. This was also the first time that a severe tornado was recorded during the winter months and at night, while the majority occurred during the atmospheric transition months (May and September).

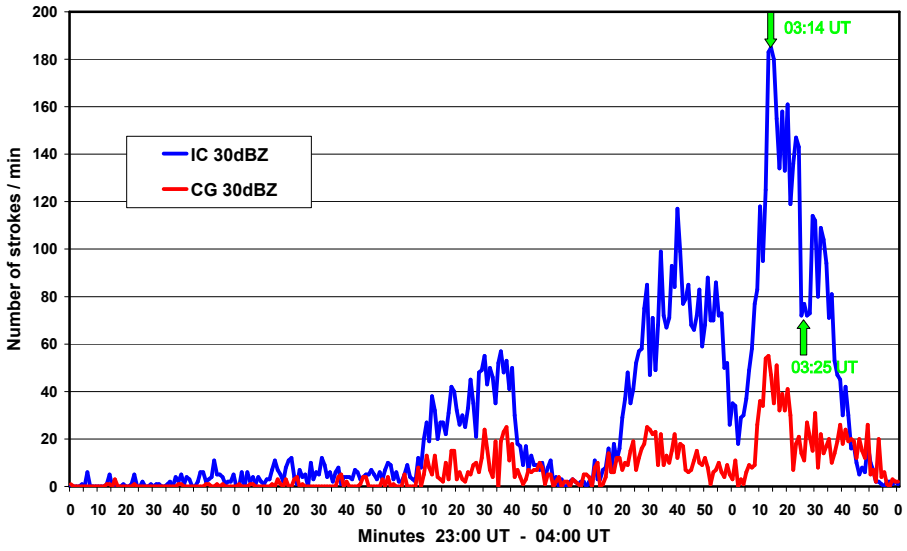



**Figure 1.** Number of CG-neg strokes and IC pulses per minute within the 30 dBZ reflectivity contour of the tornadic supercell on 04/05 June 2016, 23:00 to 04:00 UT, while tracked by the S-band Doppler radar in Bauru. It continued outside the quantitative radar range for another 3,5 hours, but no further damage was reported.

This relation of the electrical activity with the severe weather occurrence can be explained by the interaction between strong updrafts within the cloud and the electrification of hydrometeors. The updrafts, together with gravitational forces distribute hydrometeors within the cloud according to their size, which are then quickly electrified by non-inductive electrification processes. The result is a rapid formation of positive and negative charge centers within the cloud that leads to an enhancement of the lightning production. In general, the speed by which the *lightning jump* phenomena (curve slope) intensifies is directly related to the increase of the updrafts (or convection invigoration), which produces much more ice within the cloud, but with smaller size and density, leading to a higher number of collisions, higher charge transfers and consequently more intense and larger charge centers. The detailed case study has been presented at the forthcoming International Conference "GROUND-2023 & 10$^{th}$ LPE" in Belo Horizonte, Brazil. (Held G., Naccarato K.P. & Gomes A.M.: "Case Study of an Unseasonal Tornadic Supercell in the State of São Paulo: Radar Characteristics and Lightning Observations").

## *I*nstitute of Earth Physics and Space Science (ELKH EPSS), Sopron, Hungary

***Contributors: József Bór, Tamás Bozóki, Attila Buzás, Ernő Prácser, Gabriella Sátori, Karolina Szabóné André, José Tacza***

Bór et al (2023) discussed the response of the AC and DC parts of the Global Electric Circuit (GEC) to the large eruption of the Hunga Tonga - Hunga Ha'apai (HT-HH) volcano on the 15th of January 2022. The AC-related investigation was based on Schumann resonance (SR) measurements from the Nagycenk Geophysical Observatory (NCK), Hungary as well as from distant stations on the globe belonging to the HeartMath Institute (https://www.heartmath.org/gci/). The DC-related investigation was based on atmospheric electric potential gradient measurements (PG) from six recording stations in Europe and in the USA. The GLD360 and WWLLN lightning detection networks were used to characterize lightning activity in the vicinity of the HT-HH island on the investigated day. The performances of the two networks over this not well covered area were comparatively analyzed. The GLD360 network detected about an order of magnitude more lightning strokes than WWLLN, so most

results in the study are based on GLD360 data.

Lightning stroke rates in the volcanic cloud were comparable to all other lightning activity on Earth at the peak of the electric activity of the eruption. The peak lightning stroke rate was 83/second (5000/minute). Lightning occurred in symmetric rings of changing diameter around the vent of the volcano. The radial distributions of positive and negative lightning locations and intensities (in terms of the peak current) varied differently around the vent in the main phase of the eruption. The dominant polarity of the lightning strokes within the whole volcanic cloud alternated in the examined time period, but negative polarity lightning occurred almost all the time in the „vent region", i.e. within a range of ~20-30 km around the vent. The dynamics of lightning activity in connection with the explosions during the eruption is also discussed.

A global intensification of SR is apparent in connection with the enhanced lightning activity caused by the eruption. The SR data together with the global network observations indicate that the lightning activity in the eruption dominates the naturally occurring global activity for a period of at least one hour. The highly localized increase in lightning activity over HT-HH provides a unique point source of excitation for the SR.

In contrast to the dramatic response of the AC global circuit, the response of the DC GEC to this exceptional eruption is not readily obvious in the PG measurements (Figure 1). Multi-station PG observations were combined using a new method to amplify the global signal in the records. The results suggest that impulse-like charging of the GEC with an overall enhancement of ~15% in the atmospheric electric field happened during two episodes when negative polarity lightning strokes dominated the total lightning activity of the volcanic cloud. It is hypothesized that these enhancements occurred mostly due to charging of the Earth negatively by -CG lightning strokes from the volcanic cloud. Information on the IC/CG type of the volcanic lightning strokes was not reported by the lightning detection networks, so the realization of this scenario could not be confirmed. Nevertheless, the total lightning currents estimated from the peak currents allowed for this to happen even if only a fraction of the detected lightning strokes was of type CG.

A time delay of 7-8 minutes has been inferred for near-surface electric field changes from these enhancements. This could be the first direct measurement of the time constant of the DC GEC near the Earth's surface, as well as the first observation of the direct charging of the GEC by a single atmospheric electrified source, provided the discussed hypothesis is valid.

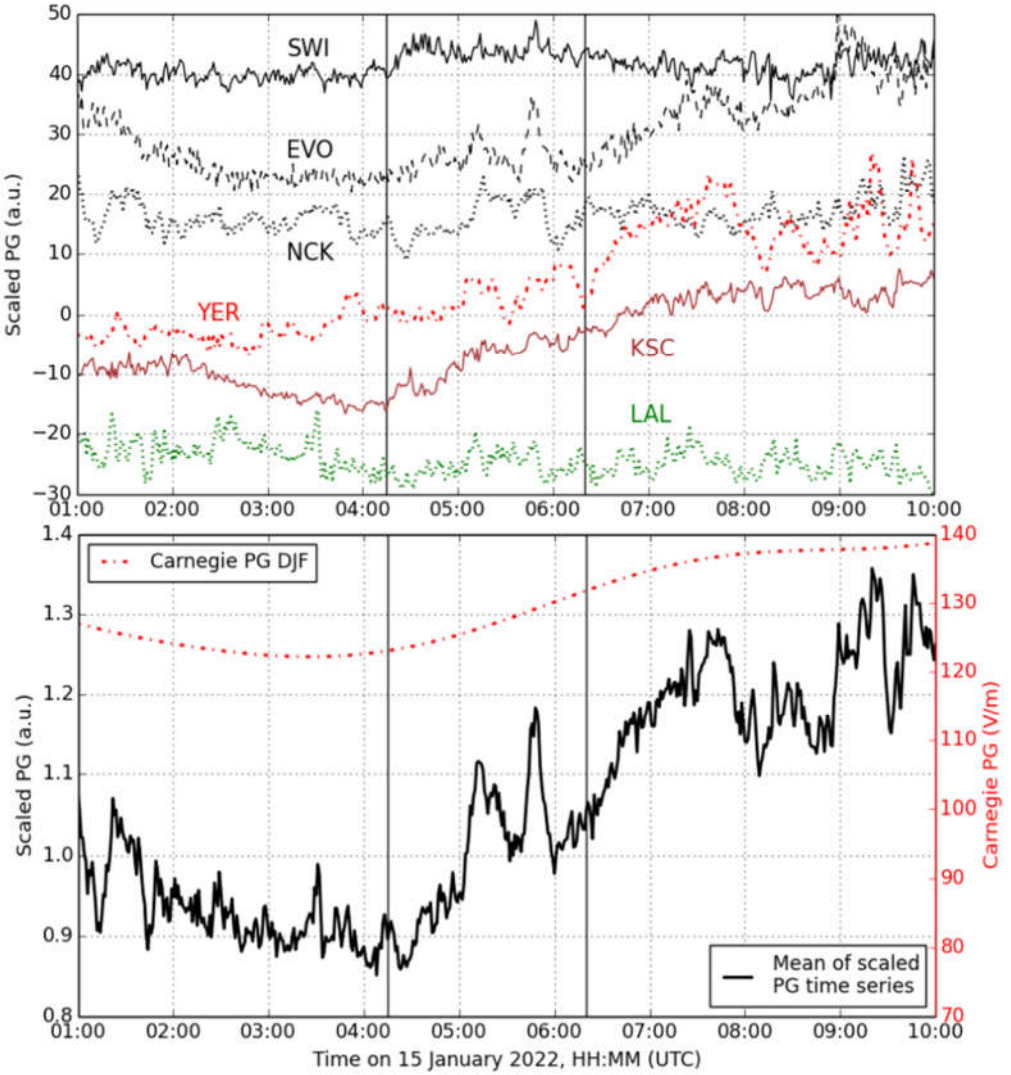



**Figure 1.** Upper panel: PG time series from recording stations, Swider (SWI), Evora (EVO), Nagycenk (NCK), Yerevan (YER), the Kennedy Space Center (KSC), and the Los Alamos National Laboratory (LAL); scaled and shifted for better view. Vertical lines mark the 4:15-6:20 UTC time interval in which the lightning activity in the volcanic cloud was the strongest. Lower panel: Sum of normalized PG time series from the upper panel. Each time series was normalized by its mean value calculated in the marked time interval. The red curve is the variation of the Carnegie curve in the months December, January, and February. Adapted from Figure 7 in Bór et al. (2023).

Professor Earle Williams from MIT will visit our research group for three months in 2023, thanks to the generous support provided by the Distinguished Guest Scientist Fellowship Programme of the Hungarian Academy of Sciences. The joint scientific research planned for this visit will primarily, but not exclusively, cover the comparative study of the two global electrical circuits (DC and AC) on individual days, further investigation of the global

electrical circuits' response to volcanic electrical activity associated with the major eruption of the HT-HH volcano, as well as the study of the signatures of distant, large-scale, migrating thunderstorms in SR frequencies.

Dr. Jose Tacza Anaya from Peru has joined our team as a postdoc for one year from September 2022. His work mainly focuses on the analysis of long-term PG records from the Széchenyi István Geophysical Observatory (also known as the Nagycenk Geophysical Observatory) in Hungary, the study of "electromagnetic" seasons identified from long-term SR measurements from Nagycenk, as well as the investigation of the main periodicities in long-term SR records from multiple stations around the globe.

Tamás Bozóki has defended his PhD dissertation entitled "Monitoring Global Lightning and the Lower Ionosphere with Schumann Resonances" in December 2022 and his dissertation is freely available in the dissertation repository of the University of Szeged (Bozóki, 2022).

Two datasets of PG Nagycenk data have become freely available. PG hourly values recorded in the Széchenyi István Geophysical Observatory (NCK, 47.632°N, 16.718°E), Hungary are available from 1962, when the regular measurements were started, up to 2009. Throughout this time period, data were collected using practically the same instrument at the same location (Buzás et al., 2022). Additionally, PG data with a temporal resolution of approximately 42 seconds are available from 1999 up to 2009 (Magos et al., 2022).

## *I*nternational Lightning Physics Group – ILPG

The ILPG is an international group for lightning research cooperation between several institutions from different countries. We report here some recent activities on some topics that are studied by ILPG.

**Lightning associated with high-energy radiation detection**. During April 2023, Dr. Rasha Abbasi from Loyola University in Chicago, Dr. Marcelo Saba, Ivan T. Cruz from INPE – National Institute for Space Research, Brazil, and Dr. Listz Araújo and Dr. Miguel Guimarães from CEFET, BH, Brazil have installed 4 electric-field mills and three photometers to operate in conjunction with high-speed video cameras and the Telescope Array (TA) surface detector.

**Figure 1.** High-speed cameras, photometers, electric-field mill, and the gamma ray detector in Utah.

**Current measurements of upward flashes from towers and attachment processes of downward flashes.** A research cooperation project between Dr. Carina Schumann and Dr. Hugh Hunt from the University of Witwatersrand in Johannesburg, South Africa, Dr. Marcelo Saba from INPE – National Institute for Space Research, Brazil, and Dr. Listz Araújo and Dr. Miguel Guimarães from CEFET, BH, Brazil, is developing current sensors are already installed, and under installation in another tower and on top of buildings.

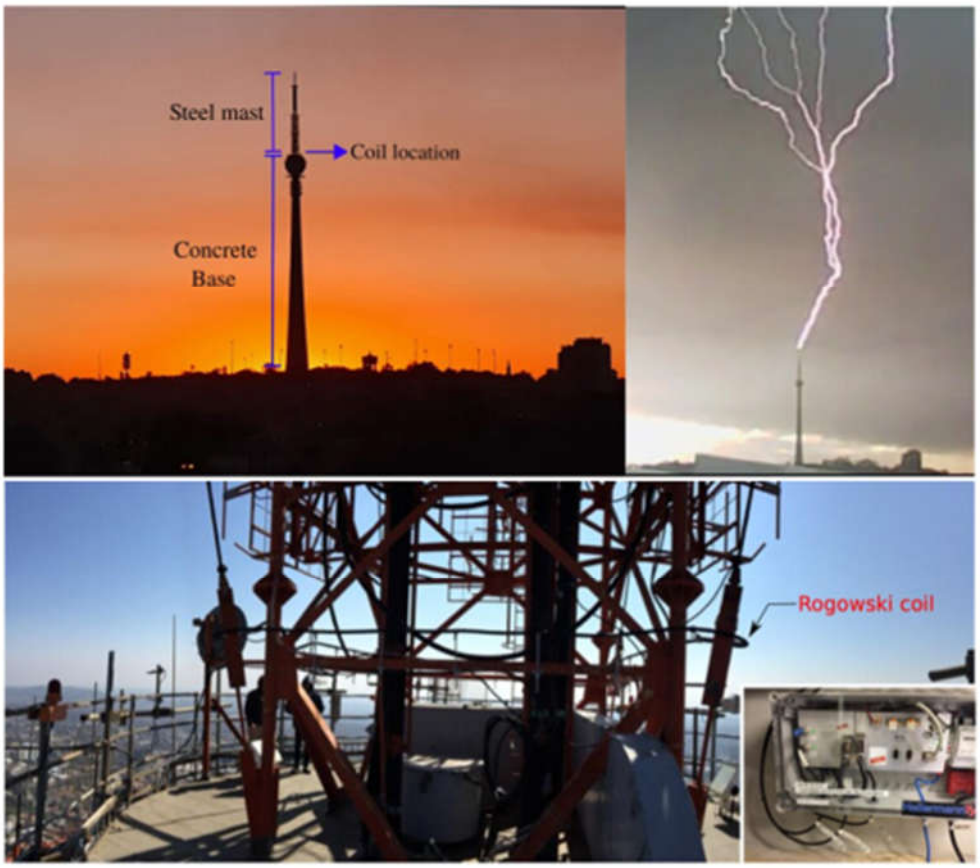



**Figure 2.** One instrumented tower in Johannesburg and details of the current sensor installation.

## *L*aboratory of Lightning Physics and Protection Engineering, State Key Laboratory of Severe Weather, Chinese Academy of Meteorological Sciences, Beijing, China

**Can lightning indicate genesis frequency of tropical cyclones over the South China Sea?** The present study identifies a significant negative correlation of the South China Sea (SCS) summer–fall (JJASON) tropical cyclone (TC) genesis with the previous boreal spring (MAM) total lightning flash rate east of the Philippines during 1996–2013 (Figure 1a-b). The increased lightning flash rate east of the Philippines signifies an enhancement in deep convection, which induces cyclonic wind anomalies to the west via a Gill-type atmospheric response (Figure 1c) and results in an increase in convection and cloud cover over the SCS during spring. The atmospheric changes lead to a decrease in sea surface temperature

(SST) and ocean heat content (OHC) in the SCS by reducing downward short-wave radiation and enhancing oceanic upwelling. The negative SST and OHC anomalies persist from spring to summer–fall and induce unfavorable thermodynamic anomalies, suppressing the SCS TC genesis during JJASON. Thus, the spring total lightning flash rate east of the Philippines, as an indicator of deep convection, may serve as a precursor of the SCS TC genesis.

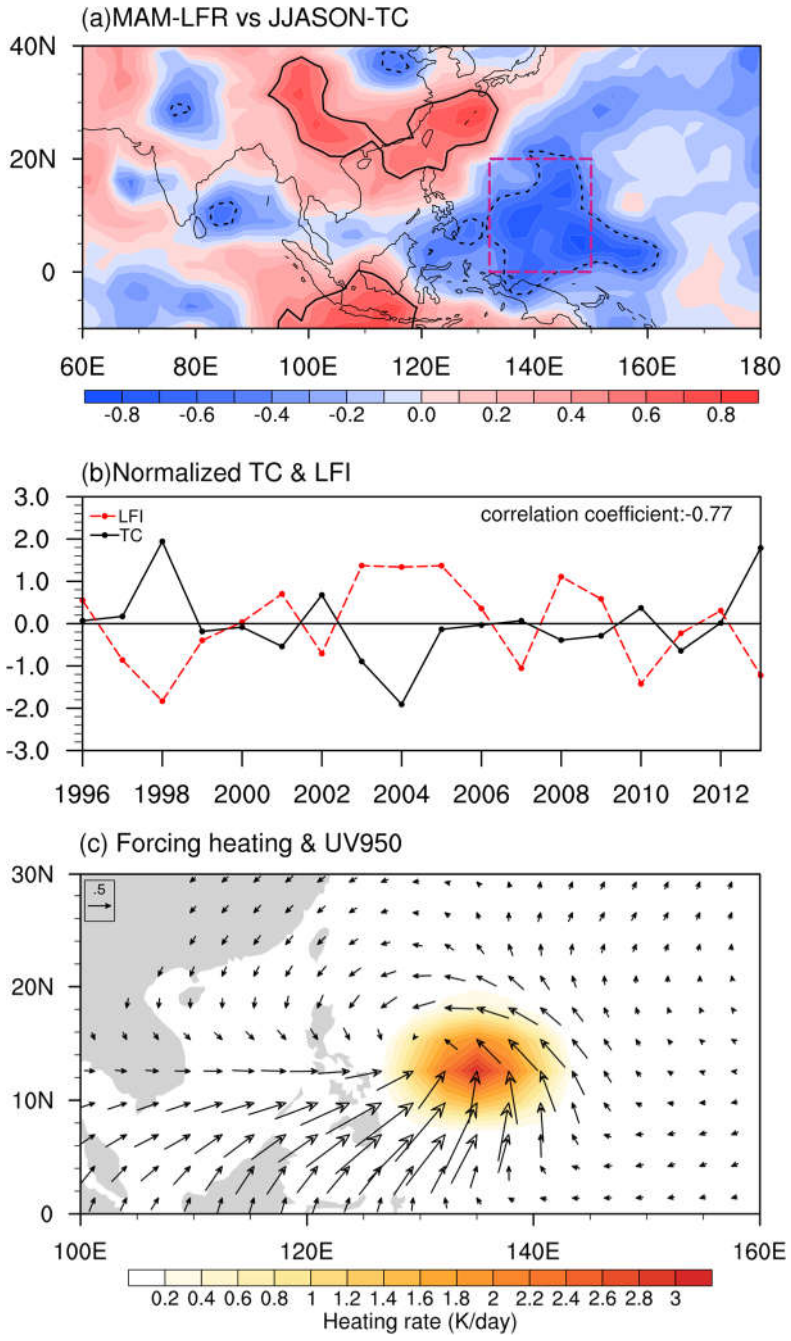



**Figure 1.** (a) The correlation coefficient of total lightning flash rate (LFR) in MAM with TC genesis number over the whole SCS during JJASON of the period 1996–2013. The solid and dashed line

indicates that the correlation coefficients are significant at the 95% confidence level. The violet red boxes denote the domains with obvious negative correlation coefficients, which are located in east of the Philippines. (b) The normalized time series of the MAM lightning frequency index east of the Philippines (LFI, red dashed line) and the following JJASON SCS TC genesis frequency index (black solid line) with the linear trend removed. (c) The spatial distribution of the heating forcing for the numerical experiments (shaded) and the model response of horizontal winds at 950 hPa (m $s^{-1}$, vectors) averaged over days 21–50.

## *L*ightning Research Group of Institute of Atmospheric Physics, Chinese Academy of Sciences (IAP, CAS), Beijing, China

**Three-dimensional mapping on lightning discharge processes using two VHF broadband interferometers.** We report an approach to mapping lightning channels in three dimensions (3D) using two simultaneous interferometers separated by about 10 km. A 3D mapping algorithm was developed based on the triangular intersection method considering the location accuracy of both interferometers and the arrival time of lightning VHF radiation. Simulation results reveal that the horizontal and vertical location errors within 10 km of the center of the two stations are less than 500 m and 700 m, respectively. The 3D development of an intra-cloud (IC) lightning flash and a -CG lightning flash with two different ground terminations in the same thunderstorm are reconstructed, and the extension direction and speed of lightning channels are estimated consequently. Both IC and CG flash discharges showed a two-layer structure in the cloud with discharges occurring in the upper positive charge region and the lower negative charge region, and two horizontally separated positive charge regions were involved in the two flashes. The average distance of the CG ground terminations between the interferometer results and the CG location system was about 448 m. Interferometry with two or more stations has the advantage of lower station number and is feasible in regions with poor installation conditions, such as heavy-radio-frequency-noise regions or regions that are difficult for the long-baseline location system. (Figure 1, Sun Z. et al.,2022, Remote Sens.)

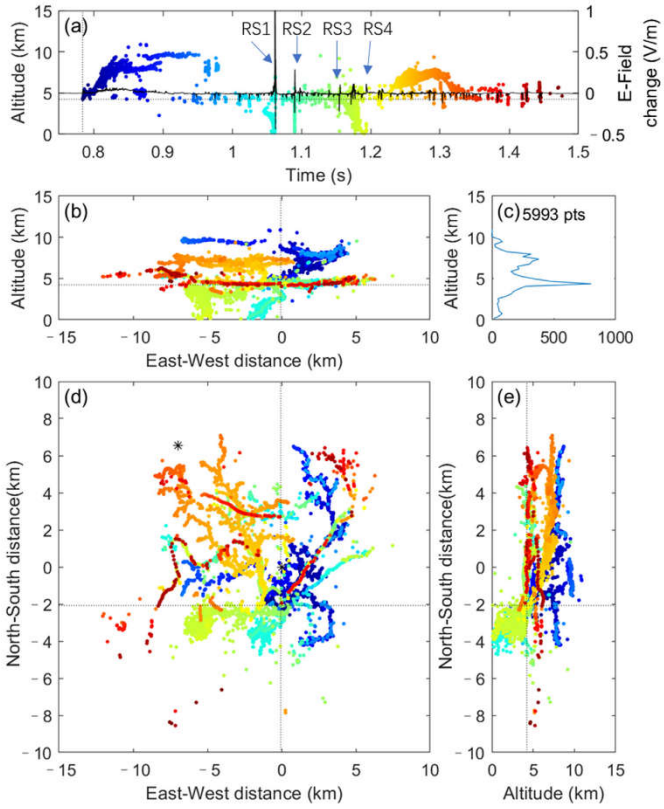



**Figure 1**. Three-dimensional location results of the CG lightning flash. (a) height with time, (b) north– south vertical projection, (c) height distribution of the number of radiation sources, (d) plane projection, and (e) east–west vertical projection of the three-dimensional location result. Asterisks are positions of the interferometer. Dashed lines intersect at the initiation point of the flash.

**Ionospheric perturbations due to large thunderstorms and the resulting mechanical and acoustic signatures.** Perturbations from thunderstorms can play a notable role in the dynamics of the ionosphere. In this work, ionospheric perturbation effects due to thunderstorms were extracted and studied. Thunderstorm-associated lightning activities and their locations were detected by WWLLN. The mechanical components of ionospheric perturbations due to thunderstorms were extracted from the total electron content (TEC), which was measured at selected thunderstorm locations using the polynomial filtering method. Further analyses were conducted using wavelet analysis and Discrete Fourier Transform (DFT) to study the frequency modes and periodicities of TEC deviation. It was revealed that the highest magnitudes of TEC deviations could reach up to ~2.2 TECUs, with dominant modes of frequency in the range of ~0.2 mHz to ~1.2 mHz, falling within the gravity wave range and the second dominant mode in the acoustic range of >1 mHz to <7.5 mHz. Additionally, a 20–60

min time delay was observed between the sprite events, the other high-energy electrical discharges, and the time of occurrence at the highest peak of acoustic-gravity wave perturbations extracted from TEC deviations. The possible mechanism responsible for this phenomenon is further proposed and discussed. (Ogunsua et al.,2022, Remote Sens.)

**Distribution of lightning spatial modes and climatic causes in China.** We investigate the distribution of spatial modes of CG lightning activity across China's land areas during the period 2010–20 and their possible causes based on the CG lightning dataset of the China National Lightning Detection Network. It is found that the first empirical orthogonal function mode (EOF1) occupies 32.86% of the total variance of the summer CG lightning anomaly variation. Also, it exhibits a negative–positive–negative meridional seesaw pattern from north to south. When the SST of the East Pacific and Indian Ocean warms abnormally and the SST of the Northwest Pacific becomes abnormally cold, a cyclonic circulation is stimulated in the Yellow Sea, East China Sea, and tropical West Pacific region of China. As the water vapor continues to move southwards, it converges with the water vapor deriving from the Bay of Bengal in South China, and ascending motion strengthens here, thus enhancing the CG lightning activity of this area. Affected by the abnormal high pressure, the corresponding CG lightning activities in North China and Northeast China are relatively weak. The ENSO phenomenon is the climate driver for the CG lightning activity occurring in land areas of China. (Xu., 2023, AOSL)

**The electrical activity of a thunderstorm under high dust circumstances over Beijing metropolis region.** A rare dust-thunderstorm affected the Beijing area on April 15, 2021, generating frequent lightning, dirt precipitation, and gusting. Based on comprehensive data from satellite retrieval, in-situ observation, weather radar, and reanalysis data, this study investigated the electrical activity of this dust-thunderstorm. The results showed that dust aerosols from Mongolia were involved in the growth process of the thunderstorm. During the evolution of the thunderstorm, the ground electrical field always changed positively with the highest value of 9 kV, and PM2.5 and PM10 increased rapidly with the highest values of 1500 $\mu g/m^3$ and 250 $\mu g/m^3$. The +CG lightning accounted for a high percentage with an average ratio of >50%. The dust aerosols acting as effective ice nuclei (IN) and cloud condensation nuclei (CCN) invading the thunderstorm were likely to increase the content of ice-phase particles and supercooled water, resulting in a high proportion of +CG lightning. It is deduced that the dust-thunderstorm possibly presented an inverted charge structure. (Figure 2, Sun C. et al., 2023, AR)

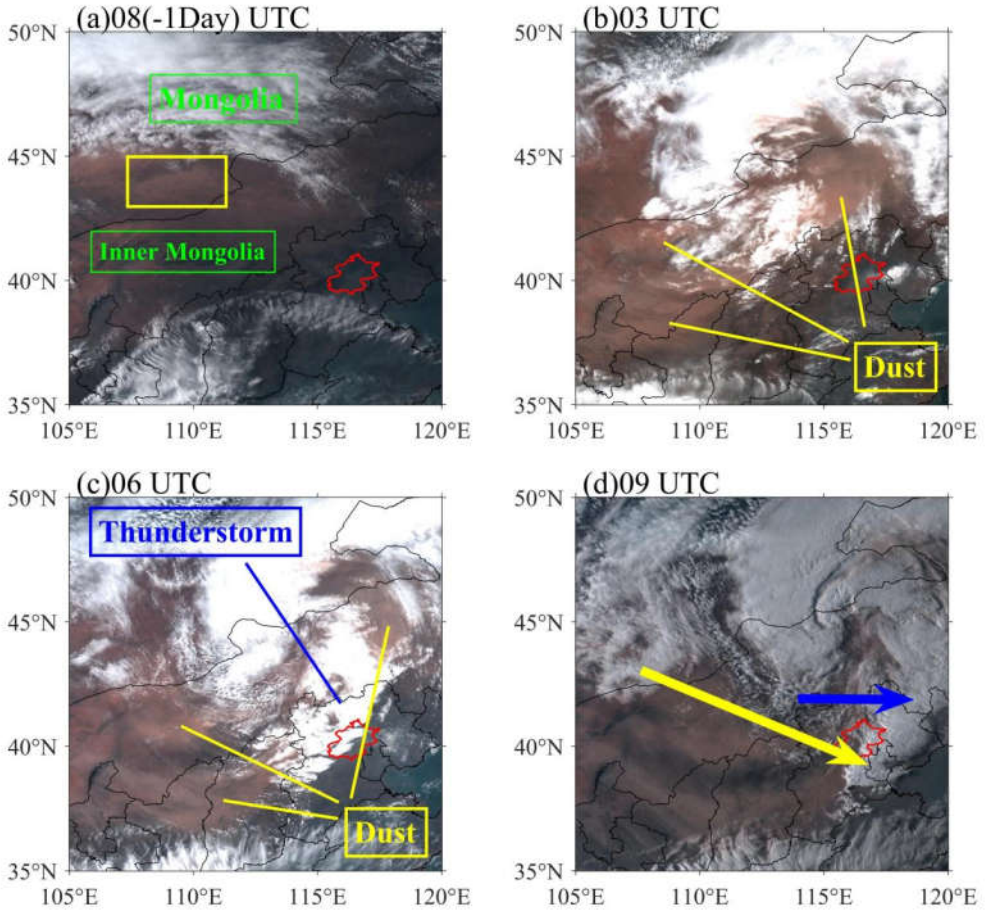



**Figure 2**. RGB composite images from Himawari-8 satellite at (a) 08 UTC, April 14, 2021, (b) 03 UTC, (c) 06 UTC and (d) 09 UTC, April 15, 2021. The yellow box in (a) is the source of the dust storm. The yellow arrow indicates the dust movement. The blue arrow indicates the thunderstorm movement. The boundary of Beijing is shown by the red polygon. Part of the dust was covered by clouds.

**First triggering lightning experiment in Hainan island, China.** In order to study the physical parameters and the development process of lightning in tropical thunderstorm, the artificial triggering lightning experiment was first carried out in Chengmai, Hainan Province from September 2021, and till now eleven lightning were successfully triggered. For the one positive triggering lightning and two negative ones in 2021, the comprehensive measurements of channel-base current, electromagnetic field at close distance, ground atmospheric electric field (*E*-field) and weather radar data indicated that the peak current of the

positive triggering lightning is +6.48 kA, which is the strongest among the reported ones, and its duration and transferred charge were 114.6 ms and +78.6 C respectively. The mean peak current of two negative lightning was -1.21 kA, while their durations were longer (about 475.7 ms and 217.4 ms), and thus the transferred charge reach -87.3C and -23.1C. Both positive and negative leader propagated upward in step. For the negative leader, its average current intensity is one time bigger than the positive one with smaller pulse interval and higher initiation height (390 m); The subsequent ripple pulses are obvious, and the intensity is about 2 times bigger than that of upward positive leader. Abundant precursor pulses occurred before the leader process in three triggering lightning, and their duration reached about 1508, 793 and 414 ms, respectively. However, the precursor process of positive lightning has longer duration and higher onset height. Meanwhile, it presents different waveform characteristics. During the thunderstorm lifetime, the ground *E*-field usually varies within ±2 kV/m. When the rocket launched, the *E*-Fields were -0.9, +0.6 and +1.3 kV/m respectively, which were significantly smaller than the results of triggering lightning in Shandong Province (about 5 kV/m measured by the same instrument). It reflects that the thunderstorms dominated by warm cloud precipitation in the tropical area may have different electrical characteristics compared to those in other higher latitude regions. More experiments will be conducted in the near future.

**Distribution and trends of lightning activity over the Sichuan-Tibet railway, China.** The lightning distributions over the Sichuan-Tibet Railway section are investigated using data from the WWLLN during 2010-2019, considering the relative detective efficiency. The findings indicate significant differences in the temporal and spatial distributions between sections below (from Chengdu west to Ya'an station) and above the 3 km contours (from Ya'an to Lhasa station). The mean flash rates exhibit a higher spatial distribution over the eastern section (50 flashes/100 $km^2$/annual) compared to the western section (10 flashes/100 $km^2$/annual). In addition, lightning activity occurs earlier (May) and lasts longer (until November) over sections above the 3 km contours, while over sections below 3 km, it occurs from June to October. Moreover, diurnal lightning activity peaks in the afternoon (4:00 pm to 8:00 pm) for sections above 3 km contours, whereas it peaks in the early morning (between 0:00 am and 6:00 am) for sections below 3 km contours. Regarding long-term trends, the increase in lightning density over the Sichuan-Tibet Railway is greater than the decrease. Sections above 3 km contours mostly present an upward trend, with lightning density exceeding 14 flashes/100 $km^2$/annual and increasing by more than 70%. Particularly around Lhasa station, the lightning density increases by up to 150%. However, stations below 3 km contours

(Chengdu west to Ya'an station), show a significant decreasing trend of ~ -10 flashes/100 $km^2$/annual and a decrease of -60%.

## *M*assachusetts Institute of Technology

Sustained interest in Schumann resonances is focused on possible two-channel ELF measurements of global lightning activity from the South Pole, one of two meteorological symmetry points for the three lightning chimneys (America, Africa and the Maritime Continent) at low latitude. The fortuitous longitudinal separations of chimney sources by ~90 degrees, ~90 degrees and ~180 degrees allow for the ELF detection of Africa with one induction coil and the detection of America and the Maritime Continent/SE Asia with a perpendicular coil, but roughly 12 hours out of phase in time. This measurement geometry keeps the source-receiver distance fixed (near 10 Mm) for all three sources, avoiding the (non-linear) distance dependence in the Legendre function equations linking magnetic intensity and lightning source strength in absolute units ($coul^2km^2$/sec). The South Pole is also remote from local lightning activity. Two operational ELF stations that approximate the expected two-coil response at the South Pole are the Indian station Maitri (Manu et al., 2015) in Antarctica (71S, 12 E) and the Polish Hornsund station (Satori et al., 2007) in Spitsbergen (77 N, 15 E). At both locations, the Africa source is prominent in the EW-oriented coils and the Maritime Continent and America sources are prominent in the NS-oriented coils. Efforts are underway to compare the chimney source strengths on individual days from these two stations in opposite hemispheres. The proposed South Pole measurements at 8 Hz (fundamental SR mode) will provide for a "Carnegie Curve" for lightning on any given day.

It is widely recognized that air-earth current is a more globally representative measure of the DC global circuit than the potential gradient at any given single location. However, with small collection areas (square meters to thousands of square meters), the published measurements of air-earth current are still quite noisy because of the dominating local effects (in conductivity and local space charge). To improve on this situation, unused and unenergized power lines are being sought in Brazil, China, Hungary, India, Poland, Switzerland and the United States for the possible continuous measurement of the air-earth current. Such lines are not plentiful these days because of the high demand for power lines linking new renewable energy sources with energy consumers. But sufficiently long lines

(kms to 100 kms) can boost current collection areas by orders of magnitude in comparison with earlier measurements, and should then serve to integrate out local effects. Persons interested in testing available lines and making comparative measurements please contact Earle Williams (earlerw@mit.edu).

An inexpensive instrument for the measurement of the fair-weather field, intended for the measurement of the ionospheric potential, is now in final development at Quasar Federal Systems in San Diego. Initial testing in the atmosphere is now planned for this coming June in San Diego, California.

## *N*anjing University of Information Science and Technology (NUIST), Nanjing, China

**A self-sustained charge neutrality intracloud lightning parameterization containing channel decay and reactivation.** Lightning parameterization schemes are essential for the simulation of thunderstorm electrical evolution, and in particular, the parameterization scheme with explicit channels has developed into one of the most important tools for exploring the relationship between the thunderstorm electrical environment and lightning discharge characteristics. In this study, we present a new lightning parameterization scheme with explicit channels. The most significant improvement of this scheme over previous schemes is the addition of channel state variations including channel decay and reactivation. To enable the simulation of channel decay and reactivation, the new scheme replaces the fixed potential setting in the stochastic lightning model with time-varying nonlinear electrical parameters, and preserves the charge neutrality of the entire discharge channel at any simulation moment. Moreover, the new scheme also takes the polarity asymmetry of the positive and negative leader into account and allows the simultaneous development of multiple branches. Implanting this scheme into the classical tripole charge structure, we perform the simulation of IC flashes. The simulation results reproduce the morphological characteristics of IC flashes, the evolution of nonlinear electrical parameters, and the channel decay and reactivation process, which are in good agreement with the existing knowledge on the lightning discharges (Figure 1).

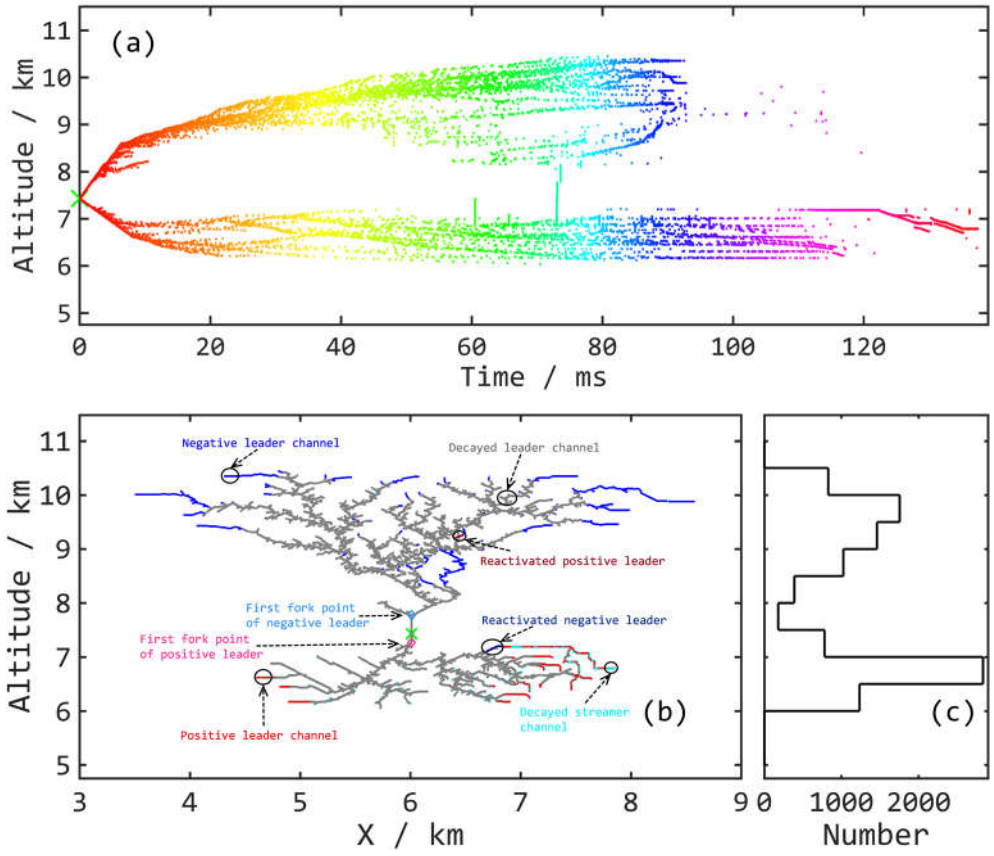



**Figure 1.** Simulation results of an intracloud lightning (IC1). (a) Variation in the altitude of each new channel point with time. The green cross denotes the initiation height of IC1. (b) Lightning channel structure for IC1. The green cross is the initiation point, blue and red lines represent negative and positive leader channels respectively, pink and light blue diamonds indicate the first fork points of positive and negative leader channels respectively, cyan lines correspond to decayed streamer channels, gray lines are decayed leader channels, dark red and deep blue lines are reactivated positive and negative leader channels respectively. (c) Distribution of channel segment number with height.

**Diurnal differences in the effect of aerosols on cloud-to-ground lightning in the Sichuan Basin.** The effect of aerosols on lightning has been examined in many studies, but its mechanisms are complex and far from understood. This study investigated the influence of aerosols on CG lightning during both afternoon (12:00–18:00 Beijing Time) and night (23:00–05:00 Beijing Time) in the Sichuan Basin by analyzing 9-year datasets of CG lightning, aerosol loading, dynamic-thermodynamic, and cloud-related data from ground-based measurements, satellite, and model reanalysis to understand the difference in the influences of aerosols under conditions with and without solar radiation. The relationship between lightning and aerosol optical depth (AOD) is nonlinear in the afternoon and at night

with a turning point at AOD ~ D 0.3. When AOD is less than 0.3, increasing AOD will lead to an increase in lightning flashes both in the afternoon and at night. When the AOD exceeds 0.3, the increase of AOD will reduce the lightning flashes in the afternoon but have no obvious effect on the lightning flashes at night. The different relationship between aerosol loading and lightning flashes in the afternoon and at night after AOD exceeds 0.3 is related to the changes in solar radiation in these two periods. In the afternoon, excessive aerosols reduce the solar radiation reaching the ground through its direct and indirect radiative effects, resulting in the decrease of the surface temperature, increasing atmospheric stability, inhibiting convection, and thus reducing lightning. At night, due to the absence of solar radiation, the influence of aerosols on surface temperature is weakened; thus, the inhibition of aerosols on lightning activity is weakened (Figure 2).

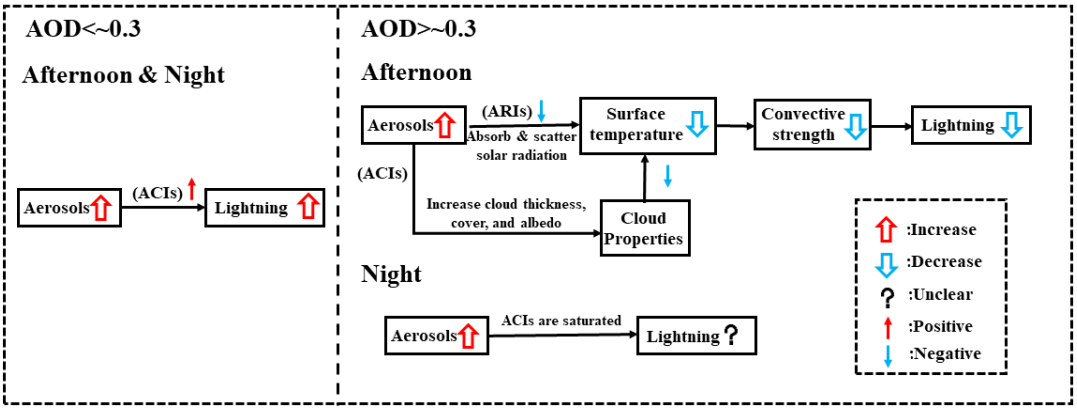



**Figure 2.** Schematic diagram illustrating the difference in effects of aerosols on lightning activity in the afternoon (12:00–18:00 BJT) and at night (23:00–05:00 BJT) over the Sichuan Basin.

**Significant influence of aerosol on cloud-to-ground lightning in the Sichuan Basin.** The effects of aerosols under special terrain on lightning activities in the Sichuan Basin (SB) are studied using the CG lightning data and AOD data from 2010 to 2018. Interesting results show that the topographic drop plays an important role in the process of aerosol affecting lightning. The great topographic drop in the western SB is conducive to the production of CG lightning. Both the CG lightning production and AOD in the northwest and southwest of the basin decrease in fluctuation during the study period. It can be inferred that the reduction of aerosol results in the decrease of lightning activity. Due to the topographic drop in the northwest of the basin being greater than that in the southwest, the correlation of 0.64 between AOD and CG lightning in the northwest of the basin is larger than that of 0.31 in the southwest. Since the

lightning activity in SB generally occurs at night, the aerosol-radiation interaction (ARI) has an insignificant influence on the occurrence of convection. Under this condition, it can be inferred that the aerosol-cloud interactions (ACI) are dominant over SB region. These could better support the reduction of lightning generation.

**First experimental verification of opacity for the lightning near-infrared spectrum.** Spectral analysis is an ideal diagnostic technique used to study the physical properties of lightning remotely. To measure the physical parameters of a lightning discharge through spectroscopic analysis of lightning plasma, the optical thickness of the lightning channel for a particular wavelength of interest must be known. Using the spectral data of a lightning continuing discharge process observed on the 600-meter-high Canton Tower, experimental verification of the optical thickness of lightning neutral nitrogen (NI) and oxygen (OI) radiation in the near-infrared spectrum is presented first by comparing the measured relative intensities of two NI multiplets with theoretical values. For the first time, the spectral evolution characteristics of the tall structure lightning continuing discharge process show that visible band singly ionized lines were apparent for approximately 320 to 400 μs. The ionized lines with higher excitation energies and the neutral lines with lower excitation energies coexist for approximately 240 to 320 μs, which means that there is a hot region radiating ionized lines in a radial direction from the lightning channel, but at the same time there is also a cold region radiating neutral lines.

**A non-time-synchronized three-dimensional lightning positioning method based on the difference of pulse interval and its preliminary application.** The time-of-arrival (TOA) method realizes the lightning location based on the time synchronization of all stations. This paper proposes the Difference of Pulse Interval (DOPI) method, which completely abandons the necessity of time synchronization of the lightning positioning network. Using the difference of the double-pulse interval of seven stations, two lightning radiation sources can be located at the same time. In this paper, the principle of DOPI method is described, and the positioning error of the method is simulated. And use the electric field data of a lightning flash to verify the positioning performance of the DOPI method. The repositioning results of the measured data show that the three-dimensional position of the lightning can be accurately located by using the DOPI method on the basis of completing the pulse matching. For the DOPI method, higher data sampling rate will bring higher precision lightning positioning results.

**Estimation of lightning-generated $NO_x$ in the mainland of China based on cloud-to-ground lightning location data.** Lightning-generated nitrogen oxides ($LNO_x$) have a major influence on the atmosphere and global climate

change. Therefore, it is of great importance to obtain a more accurate estimation of $LNO_x$. The aim of this study is to provide a reference for the accurate estimation of the total $LNO_x$ in the mainland of China based on CG location data from 2014 to 2018. The energy of each CG flash was based on the number of return strokes per CG flash, the peak current of each return stroke, and the assumed CG breakdown voltage. The energy of intracloud lightning (IC) was based on the estimated frequencies of IC and the assumed energy of each IC flash. Combining the energy of lightning and the number of nitric oxide (NO) molecules produced by unit energy ($\rho_{no}$), the total $LNO_x$ production in the mainland of China was determined. The $LNO_x$ in the mainland of China estimated in this study is in the range (0.157–0.321) × $10^9$ kg per year [Tg(N) $yr^{-1}$], which is on the high end of other scholars' works. Negative CG (NCG) flashes produce the most moles of $NO_x$, while positive CG (PCG) flashes produce the least total moles of $NO_x$. The breakdown voltage of PCG is greater than that of IC or NCG, while the latter has a greater output of $LNO_x$.

**A simple method for predicting intensity change using the peak time lag between lightning and wind in tropical cyclones.** Using lightning data from the WWLLN and tracking data for Tropical Cyclones (TCs) from the China Meteorological Administration (CMA), the relationship between the peak time lag ($T_{lag}$) and the wind intensity change in severe and super typhoons was investigated. The $T_{lag}$ between the maximum peaks of the inner-core lightning and the TC intensity ranged from −132 to 198 h, while that of the entire TC lightning ranged from −174 to 198 h. The median $T_{lag}$ values for strengthening and weakening storms were 54 and −21 h, respectively, while those for the entire TCs were 59 and −64 h, respectively. Lightning Frequency Peaks (LFPs) occurred more often with Average Intensity Changes (AICs) than intense intensity changes. Boundary equations were established based on the previous wind intensity change versus $T_{lag}$, and $T_{lag}$ was simplified as a potential forecasting parameter of TC intensity change.

# *South Asian Lightning Network (SALNet)*

South Asian Lightning Network (SALNet) was funded in September 2019 during a Roundtable Meeting on Lightning and Thunderstorms, held in Tripura, Agartala, India. Currently, SALNet's secretariat is in Kathmandu, Nepal and its member countries are Bangladesh, Bhutan,

India, Nepal and Sri Lanka. Pakistan, Maldives and Afghanistan are yet to join the Network. The regional network was founded with the objectives of mitigating loss of human lives and property damage from lightning and electrical hazards in the south Asan countries while working with global community. Since its establishment, SALNet has organized dozens of trainings and awareness raising program, both on virtual platform and on in-person platform. It has been supporting the government institutions of the respective countries by providing them technical support, assisting in drafting the standards, in adoption of international standards such as IEC.

The Nepal chapter of SALNet has been extremely active and has been playing a significant role in formulating the adoption of international standards in the national standards. SALNet Nepal has conducted dozens of trainings dedicated to electrical engineers and sub-engineers joining hands with various governmental and non-governmental institutions namely: Nepal Army, Provincial Center for Good Governance (PCGG), under the Ministry of Federal Affairs and General Administration, Karnali Province, Nepal, Lalitpur Municipality, Nepal, Kathekhola, rural municipality, Gandaki province, United Nations Development Programme, Asian Disaster Preparedness Center, Nepal Engineers Association, Society of Electrical Engineers etc.

**Figure 1.** a) and b): Photographs taken during the training program held at Nepal Army premise targeted to electrical engineers.


**Figure 2.** a) and b): Photographs of awareness programs organized in association with Lalitpur metropolitan city a) Marking the electrical safety day b) During electrical fire safety campaign.

SALNet is also trying its best to denounce the fraudulent products marketed with false claims in Nepal. In some of the buildings the fraudulent products have been replaced by the components as complying with IEC 62305. SALNet is also providing electrical safety audit services and had assisted Department of Urban Development and Building Construction in upgrading the electrical code to be adopted by the concerned ministry.

## *Tel* Aviv University (TAU) and Reichman University (RU), Israel

In the winter of 2019, many sea turtles were washed ashore along the Israeli coastline and were diagnosed with burst lungs. An investigation into the cause of this event led to possibly acoustic pressure waves from lightning. While this was ruled out as the cause of death of the turtles, it opened funding to investing the impact of lightning (and thunder) on sea life. As a result, Colin Price (TAU) and Yoav Yair (RU) are working with marine researchers Mustafa Asfur and Jack Silverman on the impact of lightning on commercial fish farms off the coast of Israel. The fish cages were fitted with acoustic sensors, cameras, and chemical sensors, while the lightning data over the past winters has been analyzed from the Earth Networks ENTLN lightning network in our region. While we have noticed changes in the behaviour of the fish during and after lightning strikes, the impacts do not appear to be fatal.

Colin Price (TAU) and Yoav Yair (RU), together with TAU graduate student Yanai Namia Cohen have been studying the local maxima in superbolts detected by the WWLLN network in the Eastern Mediterranean Sea. We are trying to understand what storms produce these superbolts. The intermediate surprising result is that superbolts appear to be produced in very weak storms with low CAPE, shallow cloud depth, and low lightning flash rates.

Colin Price (TAU) and graduate student Judi Lax continue working on laboratory experiments related to the charging of metals from high humidity environments. In the past it was shown (Lax et al., 2020) that metals (in particular zinc) spontaneously gain charge when the relative humidity rises above 60%, whether in the lab or outdoors. We are continuing our experiments with different configurations to further our understanding of the processes involved in the spontaneous charging.

Colin Price (TAU) together with undergraduate student Einat Sandovski have been working on flash floods in the Negev and Arava deserts in Israel. We have hooked up with researchers from the Dead Sea & Arava Research Center to obtain river discharge data related to flash floods. Using the ENTLN lightning data we are looking for spatial and temporal patterns between lightning and the streamflow gauges.

Yoav Yair (RU) is expecting to conduct sprite and lightning observations in the ILAN-ES experiment, to be flown on the AX-2 private mission to the ISS, scheduled for launch in May 2023. The American/Saudi crew of 4 will receive daily targets for optical observations through the Cupola window, in the same manner used successfully during AX-1 in April 2022. The results from that mission were submitted for publication in *Acta Astronautica* and are available on Arxiv (https://arxiv.org/abs/2305.01565).

## *U*niversity of Florida

Z. Ding, V. A. Rakov, Y. Zhu, M. D. Tran, and I. Kereszy authored a paper titled “Transient phenomena in positive cloud-to-ground lightning discharges”. The paper is devoted to positive lightning discharges to ground (+CGs) that are relatively rare and considerably less studied than negative ones (-CGs). The authors presented observations of unusual transient phenomena occurring in +CGs and discussed their mechanisms. One of them is a brief electric coupling to a concurrent -CG initiated from a 257-m tall tower located 11 km from the +CG

channel. A transient process (stroke) in the -CG flash appears to cause a transient luminosity enhancement (M-component) in the +CG channel. In the course of these essentially simultaneous transients, positive charge is in effect taken from the ground at the position of the tower and injected into the ground at the position of the +CG channel. The newly acquired data and previous observations of lightning strikes to the same tower are consistent with a hypothetical scenario in which the coupling was facilitated by collision of (1) the positive end of a bidirectional leader above the tower preceding the first return stroke of the –CG and (2) the in-cloud (negative) end of the grounded channel carrying continuing current of the +CG. Further, recoil leaders reactivating decayed +CG branches near the cloud base were each observed to cause a transient luminosity decrease (dip), as opposed to the expected luminosity increase (M-component), in the +CG main channel. It appears that a recoil leader channel near the cloud base and the grounded main channel competed for the access to the cloud charge source, and that the recoil leader was temporarily winning the competition. The paper is published in Communications Physics (2022) 5:313, doi:10.1038/s42005-022-01087-8.

S. Koike, Y. Baba, T. Tsuboi, and V.A. Rakov authored a collaborative paper titled "Lightning Current Waveforms Inferred from Far Field Waveforms for the Case of Strikes to Tall Objects", in which a procedure for inferring source currents from measured fields is developed. Electric and magnetic fields at far distances produced by lightning strikes to tall objects are different from those associated with lightning strikes to flat ground. Specifically, in the case of strikes to tall objects, the waveforms are oscillatory because of current reflections at the top and bottom of the tall object. The authors have developed a procedure to reconstruct the waveform of far electric field due to the lightning strike to flat ground from the corresponding waveform of far electric field due to a lightning strike to a tall object. Once the effect of tall strike object is removed from the measured field waveform, the channel-base current for the strike to flat ground is estimated using the procedure proposed by Fukuyama et al. (2021). Further, the channel-base current waveform is used to find the waveform of current at any altitude along both the strike object and the lightning channel using the expressions proposed by Baba and Rakov (2005). Computations of far electric fields due to lightning strikes to tall objects are carried out using the finite-difference time-domain (FDTD) method in the 2D cylindrical coordinate system. The lightning return stroke is represented by the transmission-line (TL) model, the modified TL model with linear current decay with height (MTLL), or the modified TL model with exponential current decay with height (MTLE). The paper is published in the IEEE Transactions on EMC, doi: 10.1109/TEMC.2023.3261422.

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# Atmospheric Electricity

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NEWSLETTER

Vol.34 NO.1 May 2023

Edited by: Wenjuan Zhang (CAMS) and Haiyang Gao (NUIST)


## REMINDER

Newsletter on Atmospheric Electricity presents twice a year (May and November) to the members of our community with the following information:

- ✧ announcements concerning people from atmospheric electricity community, especially awards, new books...,
- ✧ announcements about conferences, meetings, symposia, workshops in our field of interest,
- ✧ brief synthetic reports about the research activities conducted by the various organizations working in atmospheric electricity throughout the world, and presented by the groups where this research is performed, and
- ✧ a list of recent publications. In this last item will be listed the references of the papers published in our field of interest during the past six months by the research groups, or to be published very soon, that wish to release this information, but we do not include the contributions in the proceedings of the Conferences.

No publication of scientific paper is done in this Newsletter. We urge all the groups interested to submit a short text (one page maximum with photos eventually) on their research, their results or their projects, along with a list of references of their papers published during the past six months. This list will appear in the last item. Any information about meetings, conferences or others which we would not be aware of will be welcome.

## Call for contributions to the newsletter

All issues of this newsletter are open for general contributions. If you would like to contribute any science highlight or workshop report, please contact Weitao Lyu (wtlu@ustc.edu) preferably by e-mail as an attached word document.

The deadline for **2023 winter issue** of the newsletter is **Nov 15, 2023**.


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