ATMOSPHERIC ELECTRICITY

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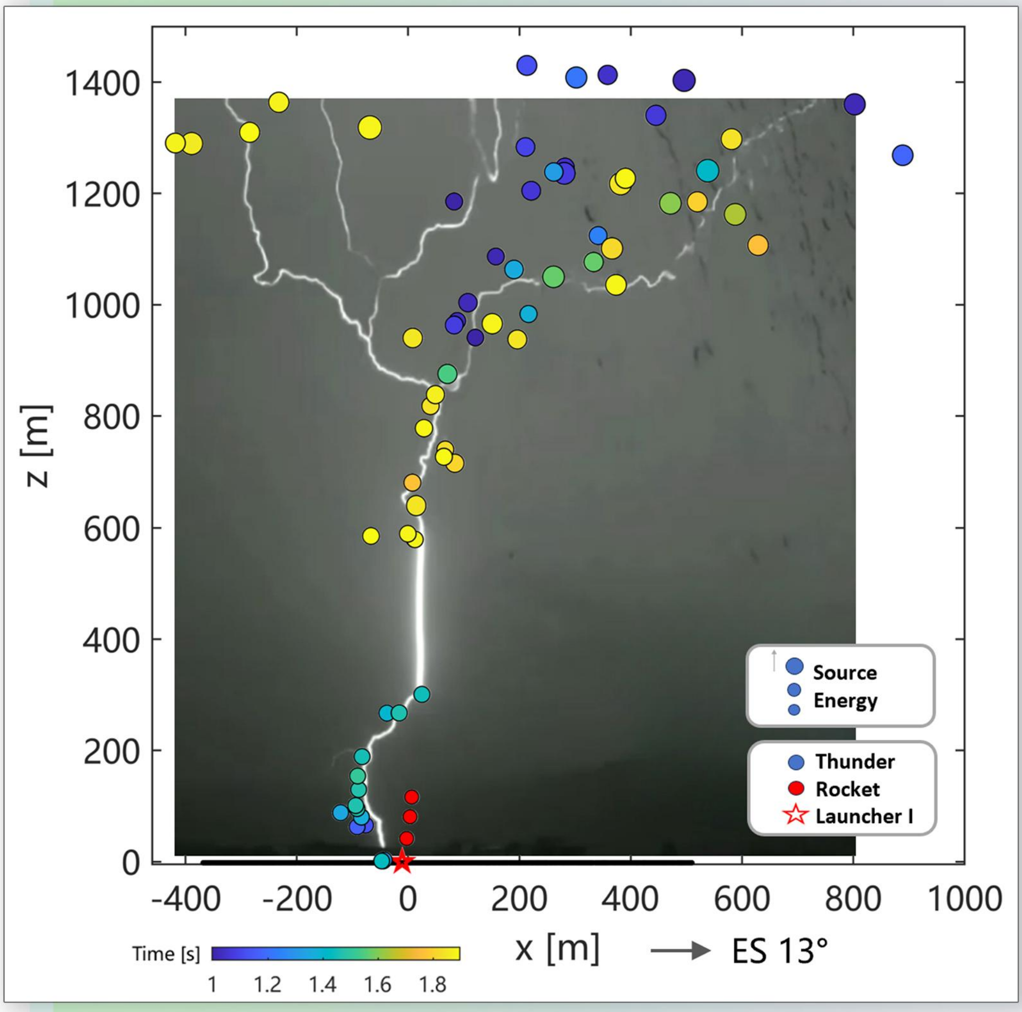

Cover Story :

Distributed acoustic sensing (DAS) was used for the first time to track acoustic sources from triggered lightning. A 4.2-km optical fiber cable was converted into 2100 acoustic sensors, which recorded two flashes with return strokes and one without. Using high-frequency DAS observations, thunder sources from three flashes were reconstructed in 3D with high precision, achieving a location accuracy of ~30 m near the ground. DAS provides an acoustic imprint of lightning polarity asymmetry and shows that thunder originates mainly from return strokes, not leaders. These results demonstrate that DAS can clearly identify and accurately locate thunder sources, offering new insights into triggered lightning.

More details refer to Hong H., Tian Y., Wang B., Lu G., Lyu W., Fan Y., and Zhang Y., (2025). Diagnostic analysis of triggered lightning with distributed acoustic sensing, *npj climate and atmospheric science*, 8: 382.

ICAE

IAMAS IUGG

https://www.iamas.org/icae/

*18*th International Conference on Atmospheric Electricity

Barcelona, July 13-17, 2026

https://icae2026.upc.edu

Dear Friends and Colleagues,

We are delighted to invite you the 18th International Conference on Atmospheric Electricity (ICAE 2026), which will be held in the colorful city of Barcelona, Spain. The International Conference on Atmospheric Electricity is the world's largest event dedicated to advancing the science of atmospheric electricity. ICAE 2026 provides an opportunity for researchers from all over the world to present the latest discoveries, exchange ideas, and the most important: learn, interact with your colleagues and make new friends.

This is the first time that ICAE 2026 lands in Spain. Our tradition in modern atmospheric electricity is dated at the beginning of XX century (1904) with measurements of atmospheric potential gradient, ions and air conductivity, and radio detection of lightning. After more than 100 years of tradition in atmospheric electricity, we are proud to host the ICAE 2026 in Spain.

The conference will be host at the Universitat Politecnica de Catalunya (Diagonal Campus) in Barcelona from July 13 to17, 2026.

Organized by:

International Commission of Atmospheric Electricity

Topics include:

- Lightning Physics
- Lightning and Meteorology
- Meteorological Applications of Lightning Data
- Energetic Radiation from Lightning and Thunderstorms
- Thunderstorm Electrification and Microphysics
- Lightning Effects on the Middle and Upper Atmosphere

- Lightning Climatology and Chemical Effects
- Lightning and Thunderstorm Detection Technologies
- Space-based Lightning Detection
- Lightning Effects, Hazards and Mitigation
- Fair Weather and Atmospheric Ions
- Global Electric Circuit
- Planetary Lightning
- Ball lightning
- Climate Change and Atmospheric Electricity
- Artificial Intelligence (including Machine Learning) in Atmospheric Electricity
- Related Topics

Notification of acceptance and oral/poster presentation: **January 31, 2026**

Contact:

icae2026@event.upc.edu

*E*GU 2026 Atmospheric Electricity Session NH1.11

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*I*nternational Conference on Grounding & Lightning Physics and Effects

GROUND2026 & 12th LPE

International Conference on Grounding & Lightning Physics and Effects

September, 13 - 18, 2026 - Foz do Iguaçu , Brazil

Visit the event website for details: **www.groundconferences.com** (active from Nov. 25th, 2025)

The event includes Lectures by experts, Round Tables addressing hottest topics on Lightning / Grounding, technical sessions with presentation of papers, exhibition, and a Workshop on Lightning Performance of Transmission Lines.

Main focus:

- *Lightning: Physics, Measurements, Parameters, Effects;*
- *Lightning Detection: Technologies and Applications;*
- *Lightning Protection of Structures, Systems and Vehicles;*
- *Grounding Electrodes: Modeling and Measurements;*
- *Grounding & Lightning Performance of Transmission / Distribution Lines , Solar Plants and Wind Farms.*

Submission deadline: March 30th, 2026

And do not miss the opportunity to visit the ***Iguaçu Falls****.*
Close to the event venue, this spot was chosen as one of the **New Natural Seven Wonders of the World**.

Additional information: lightning.grounding@gmail.com ; Phone: +55 (31) 99967 9864

*A*frican Centres for Lightning Education Network (ACLENet)

ACLENet is pleased to introduce our expanded Board of Directors who will be leading ACLENet into the new decade ahead:

President -- Ken Nixon, PhD, UWits, South Africa
Vice President – Walter Lyones, PhD, USA, past president AMS
Treasurer – Paula Galbraith, longtime ACLENet's pro bono accountant and attorney
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Richard Tushemereirwe, Ugandan co-founder, now in the USA

Daile Zhang, PhD, University of North Dakota, USA

Each brings enthusiasm as well as different talents and strengths to ACLENet.

For those of you not familiar with ACLENet's activities, please see Weatherwise Reducing Lightning Mass Casualty Incidents, How One Nonprofit is Saving Lives Across in Africa by Walter Lyons, For a free copy see our website

ACLENet has continues its activities in Uganda, expanding with:

1. National safety advocate team of volunteers eager to save lives with active social media campaigns.
2. Lightning safety clubs at many schools throughout Uganda to take lightning safety home to their families and communities.
3. Continuing to protect and repair lightning protection systems at our schools
4. Enhancing active lightning safety education across Uganda
5. Formation of a Ugandan press corps to spread report lightning incidents to build The African Lightning Injury Database as well as educate the public about lightning safety. We will be doing further training of journalists when Ken Nixon, Mary Ann Cooper and other Board members travel to Uganda in June 2026 to commemorate International Lightning Safety Day at which the First Lady Janet Museveni has been invited to be Chief Guest. Please see her Proclamation of International Lightning Safety at https://www.youtube.com/watch?v=_U_KcFjevaQ

CMA Key Laboratory of Lightning, State Key Laboratory of Severe Weather, Chinese Academy of Meteorological Sciences, Beijing, China

Structural characteristics of thunderstorms associated with negative triggered lightning flashes. This study utilizes data from a 3D lightning location system, polarimetric radar, and current measurements from channels of triggered lightning flashes (TLFs) to analyze the structural characteristics of the parent thunderstorms associated with negative TLFs in South China. The triggered-flash region (TFR) displays distinct stratiform cloud characteristics, including lower radar reflectivity heights and a predominance of ice crystals and dry snow above the 0°C layer. In contrast, the thunderstorm convection core region (CCR) tends to have more graupel particles in the mixed-phase layers and exhibits an ice-water content peak approximately 3.4 times that of the TFR. The charge regions involved in discharges in TFRs exhibit a dipolar charge structure, with the −5°C layer roughly dividing the upper positive and lower negative charge regions. Conversely, the CCRs feature a typical tripolar charge structure. The dominant dipole charge structure in the TFR results in an increase in the negative charge field below the negative charge region with height, providing a necessary condition for successfully triggering negative TLFs. Furthermore, the horizontal extent of TLFs is positively correlated with their duration and charge transfer. Regions where TLF channels with larger charge transfers propagate tend to have greater maximum radar reflectivity but lower average radar reflectivity compared to regions with TLFs with smaller charge transfer. (Liu et al., 2025AAS)

Gifu University, Japan

Typical winter TGF lightning: vertical negative leader progression features and charge structures. It has become well known that terrestrial gamma-ray flashes (TGFs) are produced by lightning discharges. However, what type of lightning discharges produce TGFs is not known. Recently, a special type of negative strokes called "energetic compact strokes" (ECSs) in winter thunderstorms have been shown to be consistently associated with downward TGFs. In this paper, we report for the first time the vertical negative leader progression features and the charge structures of 13 lightning flashes that started with ECSs and produced downward TGFs. All these TGF lightning flashes started at altitudes below 1.5 km with a downward negative leader traveling at speeds ranging from 1.3 to 4.5×10^6 m/s followed by a strong return stroke. After the return stroke, there was typically a quiet period of over 10 milliseconds without significant radio signals. Discharges then resumed, often traveling horizontally over distances greater than 10 km. In more than half of the cases, a fast upward leader appeared near the starting point of the original leader shortly after activity resumed. The upward leader moved at speeds ranging from 3.5 to 6.7 $\times10^5$ m/s. Most of these TGFs occurred beneath a main negative charge layer, located at around 2 km altitude, which was thin (less than 2 km) but extended over large horizontal distances (more than 10 km). Depending on the surrounding charge regions, the charge structure varied and could be a tripole, a positive dipole, a monopole, or an inverted dipole. This study has been published in GRL (Figure 1).

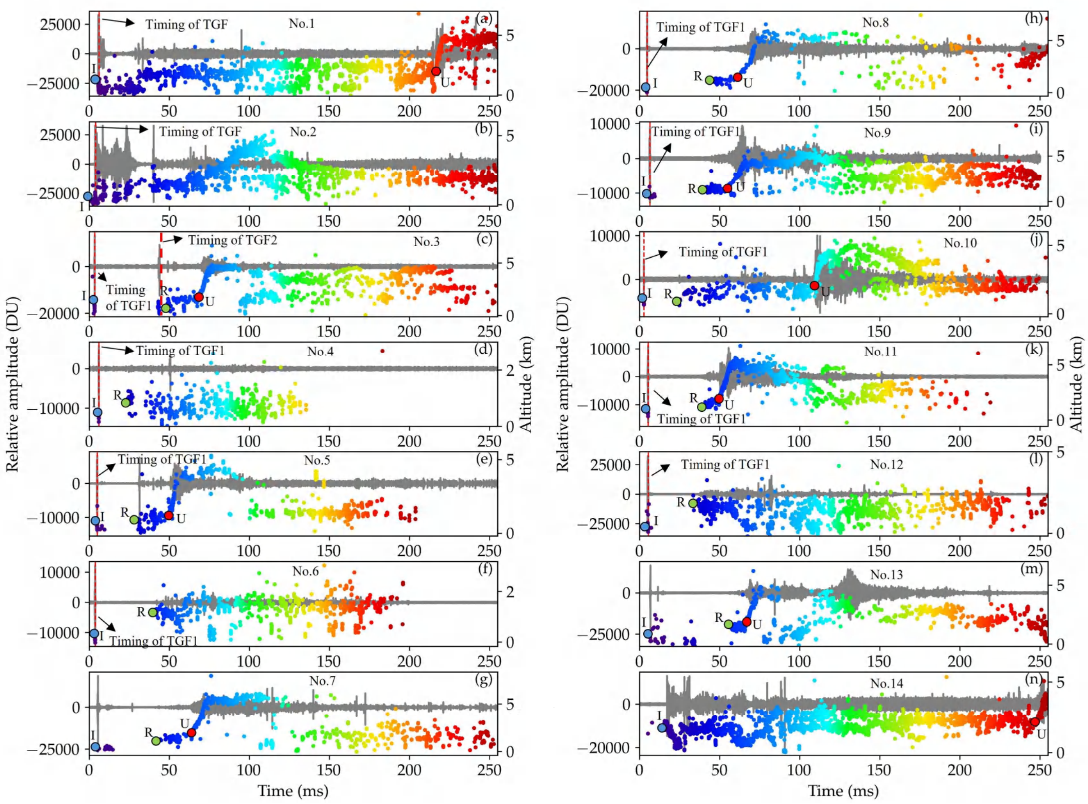

Figure 1. Altitude of lightning radiation sources versus time along with the electromagnetic MF-HF waveforms. Blue point I, green point R and red point U denote the lightning initiation point, the beginning points of the resumed discharge and the upward leader, respectively. In the No.3 event, two TGFs, denoted as TGF1 and TGF2, respectively, occurred.

HUN-REN Institute of Earth Physics and Space Science (HUN-REN EPSS), Hungary

Contributors: József Bór, Tamás Bozóki, Gabriella Sátori

Long-term Schumann resonance (SR) observations for the period 2013–2021 were used for the first time to constrain an atmospheric chemical transport model in order to quantify the contribution of lightning to long-term trends and interannual variability in global atmospheric chemistry. SR intensity data from Eskdalemuir (UK) were used for this purpose. The data was cleaned manually and was corrected for solar cycle-related variations. The SR-based parametrization of the atmospheric chemical transport model has been compared to parametrizations based on more commonly used lightning datasets (WWLLN, TRMM LIS, ISS LIS). In some cases, the former parametrization was more consistent with independent observations of the tropospheric gases studied (NOx, ozone (O3), and hydroxyl radicals (OH)), highlighting the value of SR observations in characterizing global lightning activity, thereby enhancing our understanding of lightning's role in atmospheric chemistry.

G. Sátori contributed to A. P. Nickolaenko's work who developed a heuristic model combining the standard (reference) diurnal-seasonal pattern of resonance frequency for a median year based on Schumann resonance frequency observations of the vertical electric field component in the Széchenyi István Geophysical Observatory at Nagycenk, Hungary. The model fits the observation data and accurately predicts the frequency variations using the known level of solar activity.

In Axiom Space's Ax-4 mission, 25 June - 15 July, 2025, astronauts observed intense lightning and transient luminous events (TLEs) from the Cupola window of the International Space Station in the framework of the UHU experiment (uhu.epss.hu). This experiment differed from the previous similar observation attempts in that the crew used a Nikon Z9 camera, and the space station flew in high Sun beta angle conditions for several days. During these days, the Cupola was exposed to direct sunlight continuously, which limited the possibilities for observation. Still, 26 targets, forecasted in cooperation with Yoav Yair, Reichman University, Israel, were attempted by the crew. Seven of those observations yielded imagery that has been proven to contain events of our interest. The initial review of the observation files revealed 8

ELVES (Figure 1), a sprite halo-like event, several blue events (blues), and 1 red sprite in the recorded footage. Particularly intense lightning activity was observed in central and east Africa in the tropical zone, over the coast of South-Carolina, USA, over central China, and above the maritime continent over Indonesia and the Philippines. The space mission was also supported by a ground-based data recording campaign in which a large community of citizen scientists participated from different parts of the globe by optical observations.

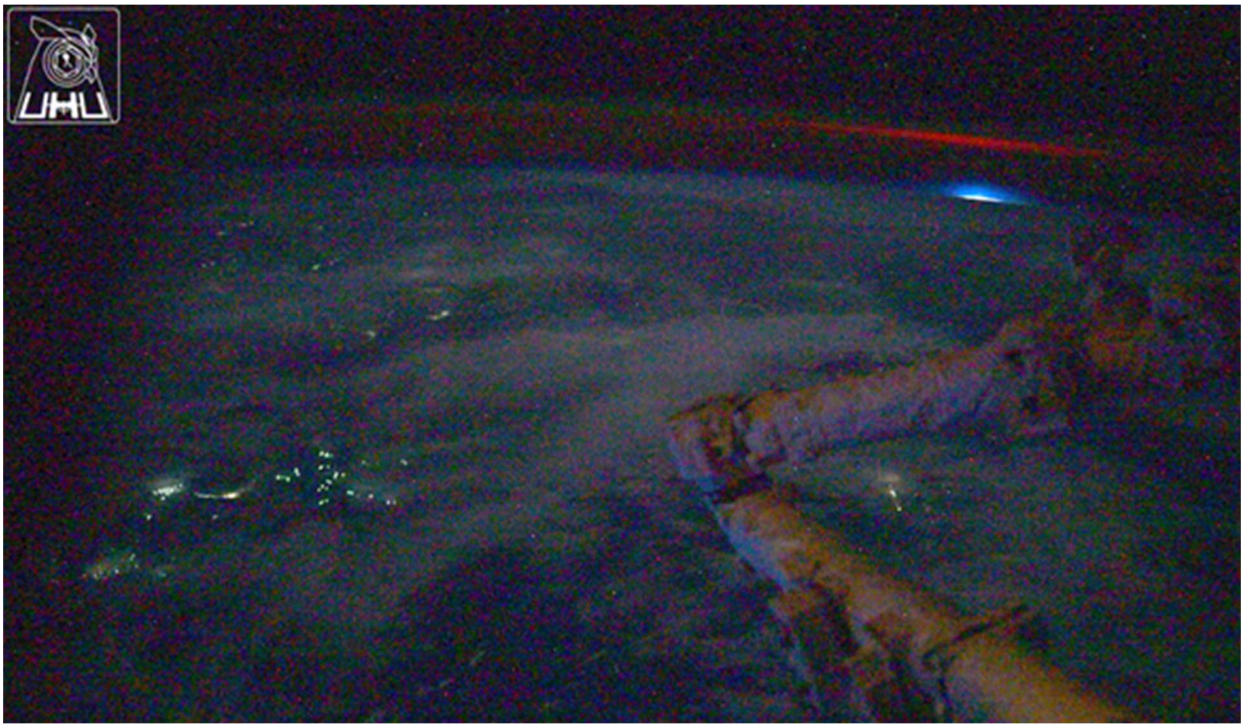

Figure 1. ELVES (red glow beneath the green airglow) and the initiating lightning flash near the horizon on July 3, 2025. Video frame (with enhanced coloring) recorded by Hungarian astronaut Tibor Kapu from the International Space Station as it was passing over Malaysia and the Philippines during Axion Space's Ax-4 mission. The station's robotic arm is visible in the foreground.

INPE, National Institute for Space Research, Brazil

With the aim of deepening the understanding of the physical processes related to lightning flashes, the research group at the National Institute for Space Research (INPE) in Brazil, led by Dr. Marcelo Magarães Fares Saba, conducts investigations integrating multiple observational techniques. These include high-speed cameras, Lightning Location Systems (LLS), electric field sensors, Lightning Mapping Array (LMA), interferometers, and scintillation sensors.

The group is currently composed of three undergraduate and two master's students, three PhD students, a postdoctoral researcher, and an external collaborator who completed her PhD within the research group. Below is a summary of the main activities carried out by the members of the INPE research group.

Pre-trained neural network. In his final undergraduate project, Hentony dos S. Barbosa (master's student) evaluated the use of pre-trained neural networks for classifying the polarity of lightning flashes from high-speed camera. During his master's studies, he will continue this line of research, applying artificial intelligence techniques to investigate the physical characteristics of lightning flashes and to improve automatic methods for lightning identification and characterization.

Upward lightning flashes. João C. M. Alves (master's student) is analyzing the evolution of positive upward leaders in towers in Johannesburg, South Africa, intrinsic characteristics of the leader are being verified through high-speed camera images: occurrence of recoil leaders and branching; behavior of vertical and average speed and channel luminosity; as well as the search for brightness between luminosity and average speed.

Lightning flashes on wind turbine. Msc. Tagianne P. da Silva (PhD student) is analyzing the behavior that upward flashes from wind turbines present in contrast with upward flashes from telecommunication towers, in partnership with Tom Warner from ZT Research in South Dakota. Additionally, she is using a high-sensitivity camera to try to capture corona discharges from wind turbines during nearby thunderstorms. She also characterized intracloud flashes using high-speed cameras, analyzing the statistics and recoil leader propagation modes through the channel, as well as estimating the current behavior based on luminosity analysis (Silva et al., 2025).

High-speed camera lightning monitoring and positive cloud-to-ground lightning analyses. Msc. Diego R. R. da Silva (PhD student) is working on monitoring and recording lightning using two high-speed cameras in Lorena-SP. He is also developing analyses of all lightning positive cloud-to-ground lightning flashes (+CG) videos taken with high-speed cameras between 2003 and 2025, which are in the database of the group at INPE. In addition, he is expanding the database, maintained by PRETS (http://prevots.org/prets/), of severe weather events that occurred in Brazil.

Negative leader propagation and terrestrial gamma-ray flashes associated with lightning. Msc. Ivan T. Cruz (PhD student) developed three studies over the past year. First, he investigated the speed of stepped leaders and showed a strong relationship between final speed of the stepped leader and the return-stroke peak current (Cruz et al., 2025a). He also used speed of the stepped leader to characterize lightning flashes associated with TGFs, showing that TGF-producing leaders are, on average, five times faster (Cruz et al., 2025b). Additionally, he identified secondary recoil leaders in upward lightning, which inject current into preceding recoil leaders and enhance the development of dart leaders toward the ground (Cruz et al., 2025c) (Figure 1).

Simulating relativistic runaway electron avalanches for high-energy gamma-ray emissions. Understanding Relativistic Runaway Electron Avalanches (RREAs) is fundamental to unraveling atmospheric electrical phenomena and their high-energy emissions. Thus, Dr. Gabriel de S. Diniz (postdoctoral researcher) use Monte Carlo GEANT4 simulations to investigate the RREA behavior under simulated thunderstorm environments. He details the ambient conditions to produce gamma-ray glows in the recently published paper "Simulated characteristics of on-ground gamma-ray glows" (Diniz et al., 2025). He is deepening our research into the RREA environmental requirements for entering a self-sustaining regime through the feedback mechanism. The investigation is the result of a multi-institute collaboration and uses the supercomputer system of the Academic Center for Computing and Media Studies of Kyoto University.

Characterizing long continuing currents in cloud-to-ground lightning flashes. Dr. Paola B. Lauria (collaborating researcher) analyzed long continuing currents (LCC) in both positive and negative cloud-to-ground lightning flashes as part of your PhD research. The analyses are conducted using various instruments: high-speed and conventional cameras (1000 fps), LMA data, and slow electric field data. The camera images serve as a reference to evaluate the information recorded by the slow electric field sensors. The LMA data help in understanding the production of LCC inside the thundercloud before and during the connection of the discharge to the ground.

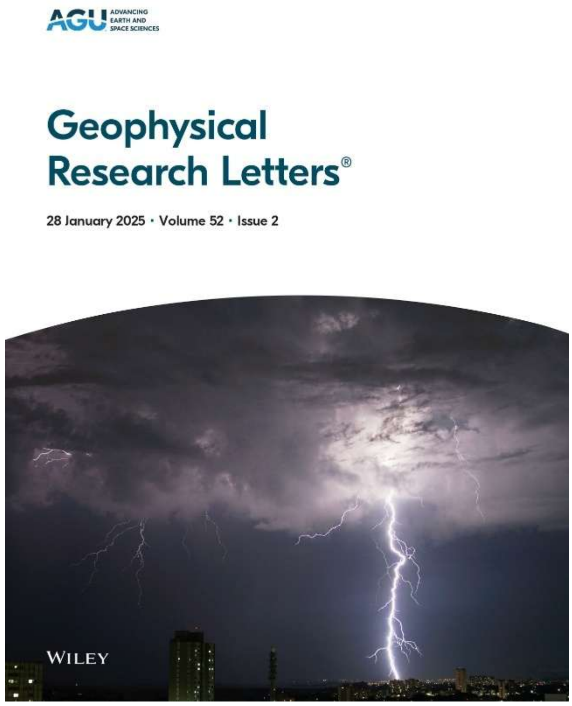

Figure 1. Cover of GRL journal, highlighting one of the papers carried out by the group in the year 2025 (from Cruz et al., 2025a).

Institute of Atmospheric Physics, Chinese Academy of Sciences (IAP, CAS), Beijing, China

The impact of intracloud negative branches on continuing current in negative cloud-to-ground lightning. A compelling observational study is conducted that links the duration of continuing current (CC) in negative cloud-to-ground lightning to the post-return-stroke behavior of intracloud negative leaders. Using high-speed video (31,000 fps) synchronized with fast electric field measurements from Beijing and Lhasa, the authors analyzed six negative CG flashes and discovered a consistent anti-correlation: long continuing currents (LCC, >40 ms) occur when intracloud negative branches show little or no development after the return stroke, whereas very short continuing currents (VSCC, <10 ms) coincide with vigorous proliferation of such negative branches. The study proposes a novel "current competition" mechanism—where active intracloud negative leaders divert charge away from the grounded channel, truncating CC—while the absence of such branches allows more charge to flow through the strike channel, sustaining LCC. This challenges the traditional focus solely on intracloud positive leaders (which remain optically obscured) and offers a practical observational proxy for predicting CC duration, a key factor in lightning-induced wildfire ignition. The findings are robust across multiple events and consistent with the known statistical tendency for LCC to follow subsequent strokes. Figure 1 integrates cumulative channel growth, negative leader count, velocity, and conceptual charge diagrams to illustrate the contrasting negative leader dynamics before and after strokes with VSCC versus LCC. (Feng et al., 2025)

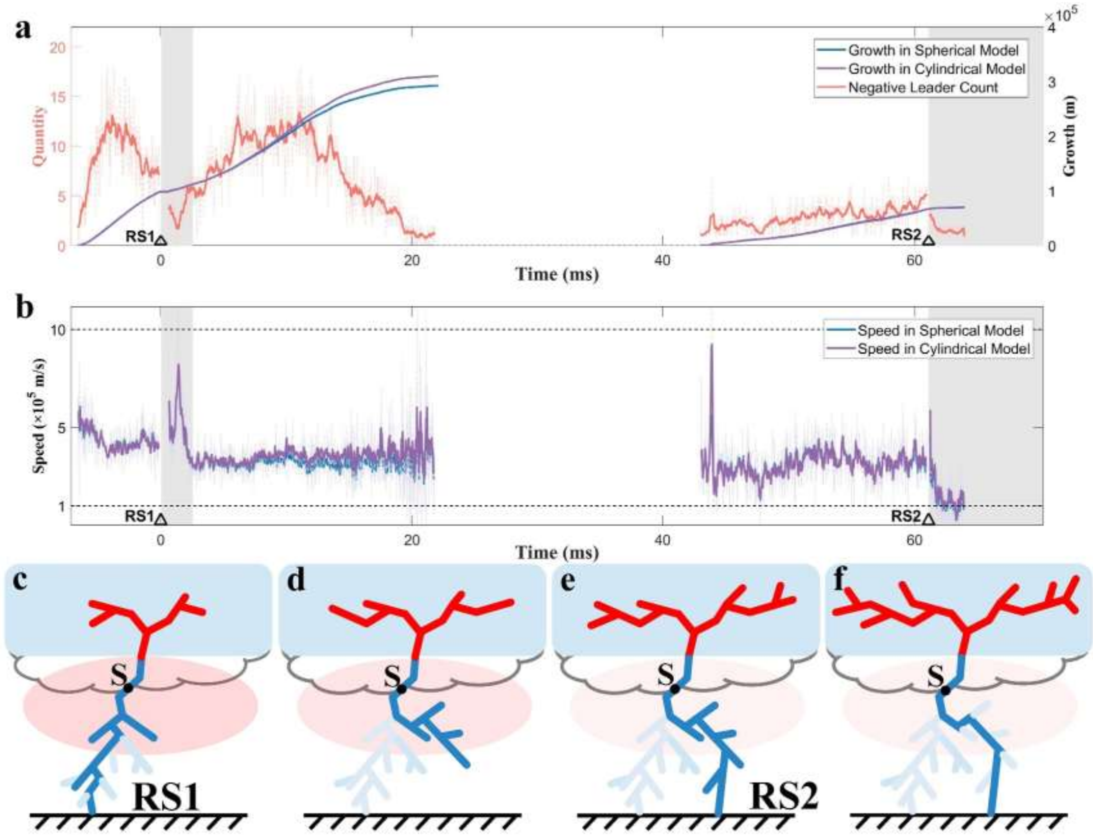

Figure 1. (a) Cumulative growth of lightning channels in the sphere model (blue curve) and cylindrical model (purple curve), and variations in the number of negative leaders over time (red curve, with bold line showing the sliding average). (b) Variations in negative leader velocity over time. The CC duration is shaded in gray, with the RS marked by "△." (c–f) Negative leader development pre- and post- RS. The blue rectangle in the diagram represents the intracloud negative charge regions, while the red ellipses depict the sub-cloud positive charge zones, with its brightness indicating the magnitude of charge density. The connection point between the positive and negative channels corresponds to the initiation point, while the S-point designates the cloud exit location.

An efficient lightning classifier using a self-supervised learning neural network. This study introduces a highly efficient lightning discharge classifier based on a self-supervised masked autoencoder (MAE) framework, significantly reducing reliance on large labeled datasets—a major bottleneck in current AI-driven lightning research. The model first pretrains on 100,000 unlabeled broadband electric field waveforms from the Beijing Lightning Network (BLNET) by reconstructing randomly masked signal segments, thereby learning robust, generalizable temporal features. It then fine-tunes on only 3,000 labeled samples across five lightning types—negative/positive cloud-to-ground (NCG/PCG), intracloud (IC), narrow bipolar events (NBE), and preliminary breakdown (PB)—achieving an impressive 98.30% classification accuracy. When evaluated on two independent public datasets, the same model attains 98.29% and 97.94% accuracy, matching or exceeding prior supervised methods (e.g., SVM, CNN) while using far fewer labels. Crucially, ablation experiments show that models without pretraining suffer from overfitting and lag ~6–7% in accuracy, underscoring the value of self-supervised pretraining. T-SNE visualizations further reveal that only the combination of pretraining and fine-tuning yields well-separated, compact clusters for each lightning class. The approach also demonstrates computational efficiency—each training epoch takes just 11 seconds on a single GPU—and offers flexibility for future expansion to new discharge categories. Figure 2 shows the framework of lightning masked autoencoder model. (Lu et al., 2025)

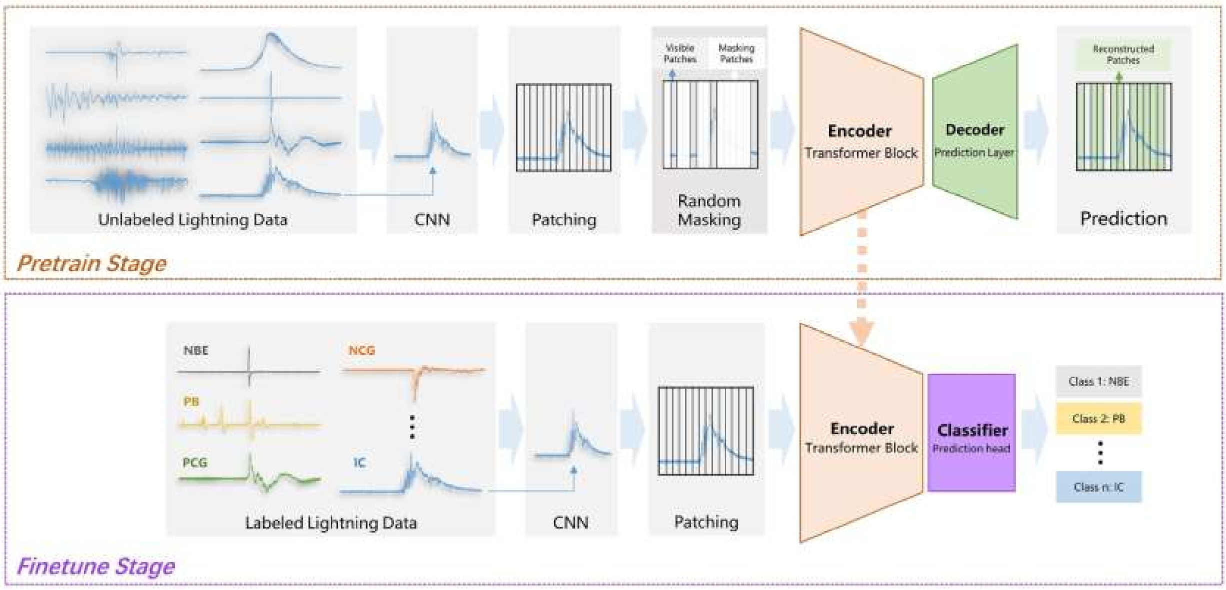

Figure 2. The lightning masked autoencoder model framework.

Anomalous vertical structure of tropospheric ozone due to stratospheric intrusions and convective transport. This study reveals an anomalous "bottom-heavy" vertical structure of tropospheric ozone (O_3) over northern China during a cut-off low (COL) event in summer 2024. Using temporally dense ozonesonde measurements from the SHATLE field campaign in Binzhou, the authors observed pronounced O_3 enhancements (exceeding the 90th percentile of the climatological baseline) in the middle-to-lower troposphere, coexisting with significant O_3 depletion (33–48% below normal) in the upper troposphere–lower stratosphere (UTLS). Combining trajectory modeling, reanalysis data, and satellite observations, they attribute this dual-layer anomaly to two concurrent processes: (1) stratospheric intrusions of dry, O_3-rich air driven by the approaching COL, and (2) convective uplift of low-O_3, moist boundary layer air from the Tibetan Plateau into the UTLS. The stratospheric airmasses descended slowly (~0.6 km/day) but were blocked from reaching the planetary boundary layer by a stable atmospheric layer associated with the western Pacific subtropical high. Multi-year AIRS satellite data further show that such stratospheric influence occurs on ~13% of summer days, causing short-term O_3 enhancements up to 35% above normal at 500 hPa. These findings highlight the non-negligible role of synoptic-scale dynamics—particularly COLs—in modulating tropospheric O_3 budgets through vertical transport. The results display the anomalous O_3, relative humidity, and static stability profiles from four successive ozonesonde launches, clearly illustrating the "bottom-heavy" structure and its evolution against the climatological baseline. (Chen et al., 2025)

Lateral negative re-discharges on the negative leader in a positive cloud-to-ground lightning flash. This study reports the first direct evidence of lateral negative re-discharges occurring along pre-ionized negative leader channels during a positive cloud-to-ground (+CG) lightning flash over the Tibetan Plateau. Using high-resolution very high frequency (VHF) interferometric measurements, the authors captured two distinct phases of these re-discharges. Prior to the return stroke (RS), small-scale, needle-like negative re-discharges repeatedly flickered along nearly the entire horizontal extent of the weakening negative leader—unlike classic "needles" that cluster only near positive leader tips. These pre-RS events propagated toward the negative leader tip at an average 2D speed of ~8.0×10^4 m/s and appeared linked to gradual potential changes induced by the steadily advancing positive leader. Following the RS, abrupt potential shifts triggered more intense discharges: fast axial reactivations along existing channels and new lateral breakdowns into virgin air, forming brush-like branches that extended the negative channel up to ~30 km and sustained a prolonged continuing current. The study reveals a clear polarity-dependent asymmetry in lightning leader behavior and demonstrates that channel potential dynamics—not just corona sheath effects—govern re-discharge initiation. These findings significantly refine our understanding of bidirectional leader evolution and the microphysical processes governing lightning propagation in +CG flashes. Figure 3 visually contrasts the spatial and temporal behaviors of positive leader needles and negative leader lateral re-discharges, clearly illustrating their distinct distributions—localized near PL tips versus spread across the entire NL channel. (Sun et al., 2025)

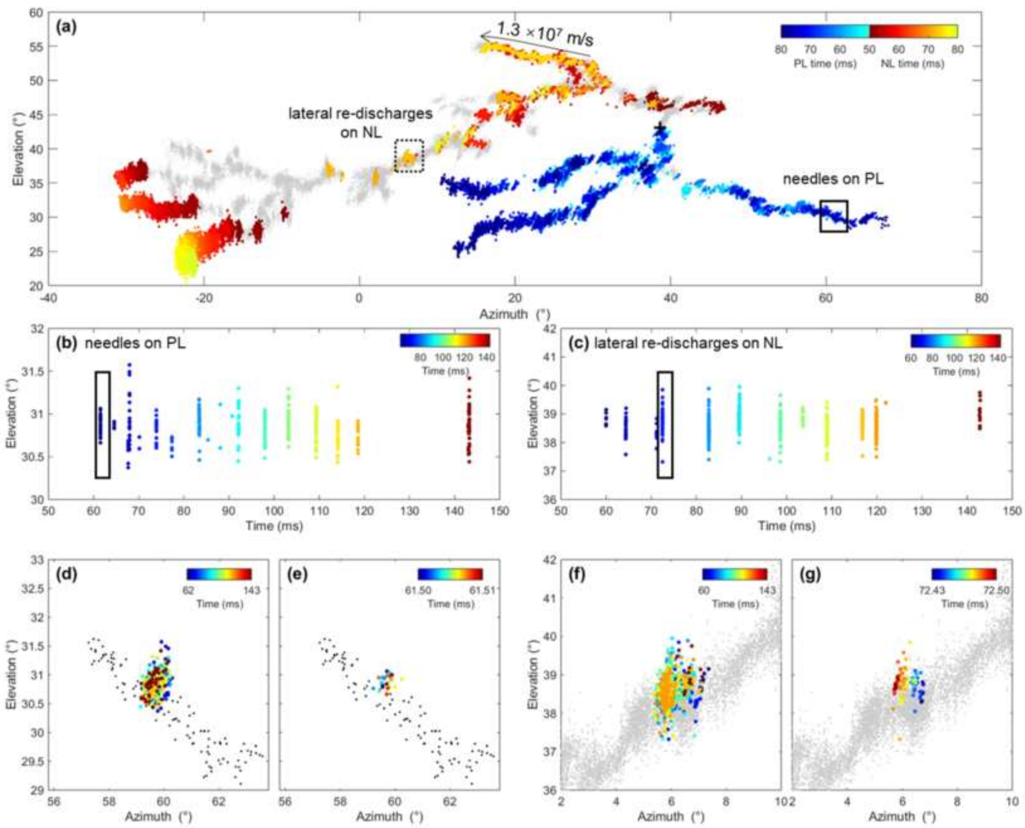

Figure 3. Spatiotemporal evolution of very high frequency (VHF) radiation sources before the +RS. (a) Azimuth-elevation distribution during 50–80 ms. (b) Temporal evolution of positive leader (PL) needle flickers, corresponding to the solid black rectangle region in panel (a). (c) Temporal evolution of negative leader (NL) lateral re-discharges, corresponding to the dashed black rectangle region in panel (a). (d) Spatial development of PL needles (50–145.8 ms) of panel (b). (e) Instantaneous PL needle at ~61 ms of panel (b). (f) Spatial development of NL lateral re-discharges (50–145.8 ms) of panel (c). (g) Instantaneous NL lateral discharge structure at ~72 ms of panel (c). All VHF sources are colored with time. Gray points indicate initial NL activity, while black points represent recoil leader sources occurring after +RS.

Inverted charge structure in a Tibetan Plateau thunderstorm. This study reports the first-ever observation of an inverted tripole charge structure in a thunderstorm over the central Tibetan Plateau (TP)—the world's highest plateau—using high-precision lightning Very High Frequency (VHF) interferometry and C-band Doppler radar data collected in Lhasa on 8 July 2020. Unlike typical TP thunderstorms, which are generally weak and exhibit lower positive charge centers, this storm displayed a rare negative–positive–negative vertical charge configuration: a lower negative region near 0°C, a main positive layer between −30°C and −5°C, and an upper negative region below −20°C. As the storm evolved, the lower negative charge dissipated, transitioning the structure to an inverted dipole.

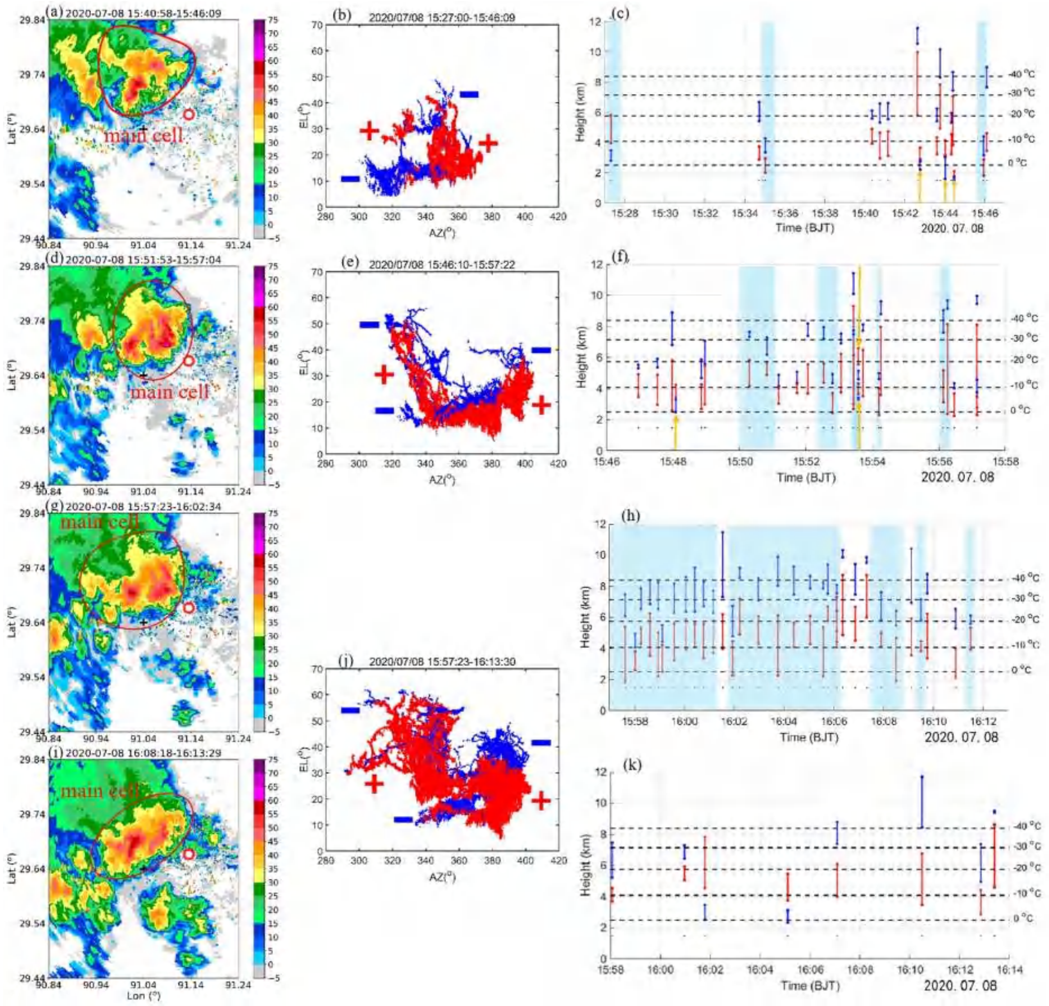

Figure 4. The composited radar reflectivity (a, d, g, i), the superimposed lightning very high frequency channels (b, e, j) and the estimated charge structure involved in discharge (c, f, h, k) from 15:30 to 16:14 for the main cell in this thunderstorm. Symbol conventions in (a, d, g, i) are consistent with those in Figures 1c–1f. The red (blue) dots in (b, e, j) represent the lightning radiations in positive (negative) charge regions. Blue "– " and red "+" stand for the negative and positive charge regions,

respectively. Red (blue) lines in (c, f, h, k) represent the positive (negative) charge regions, respectively. Yellow arrows mark positive polarity flashes; black dashed lines show environmental temperatures. Blue shadings in (c) highlight flashes occurred in the rear portion. Those in (f, h) point to flashes in the left flank of the cell's motion direction. (h, k) Both indicate the charge distribution from 15:57 to 16:14, corresponding to (g, i, j), but for flashes occurred in the peripheral and central parts of the main cell, respectively.

Remarkably, no positive cloud-to-ground (+CG) flashes were detected throughout the storm's life, contrasting with inverted-tripole storms at lower elevations that often produce abundant +CGs. Instead, five negative CG flashes and 109 intracloud (IC) flashes—90% within the upper inverted dipole—were recorded. The storm's intensity, reflected by a peak flash rate of 6 fl/min and radar reflectivity exceeding 60 dBZ, surpassed typical TP convection but remained weaker than plain-region inverted-tripole supercells. These findings highlight how unique thermodynamic and microphysical conditions over the TP (e.g., low liquid water path and moderate CAPE) can foster anomalous electrification structures, reshaping our understanding of high-altitude thunderstorm physics. Figure 4 comprehensively illustrates the spatial evolution of the charge structure, radar reflectivity, and lightning channels, clearly showing the coexistence and transition from inverted tripole to inverted dipole. (Wei et al., 2025)

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

Contributor: Jose Tacza

Forbush decreases, magnetopause compression and potential gradient response. Our recent work revisits how Forbush decreases (FDs) influence the global electric circuit (GEC). Using primary galactic cosmic-ray measurements from AMS-02 together with potential-gradient (PG) data from the CASLEO observatory (Argentinian Andes Mountain), we examined a set of FD events where earlier studies had shown that only the largest FDs produce a clear increase in the fair-weather PG. By combining solar-wind observations with both empirical and MHD models of the magnetosphere, we quantified the subsolar magnetopause standoff distance and the associated solar-wind turbulence level during each FD. Our analysis reveals that PG-effective FDs form a distinct family of events. Only when the magnetosphere is strongly compressed, with an effective subsolar standoff distance below about 7 Earth radii, and the solar-wind turbulence is high, do FDs reach amplitudes larger than ~10 % in AMS-02 data and produce a robust increase in PG. In contrast, smaller FDs – particularly those driven by corotating interaction regions – occur with a more weakly compressed magnetosphere and do not generate a measurable PG response. This two-population behaviour suggests that, in addition to modulation by CME structures in interplanetary space, enhanced turbulence inside a compressed magnetosphere can further suppress cosmic-ray fluxes and strengthen the electrical response of the global circuit at the ground (Li et al., 2025).

May 2024 geospace superstorm: impact on the potential gradient. In a companion study, we reported the response of the GEC to the May 2024 geospace superstorm, using near-surface vertical PG measurements at the high-altitude Gar station on the Qinghai–Tibet Plateau. The storm, driven by a sequence of fast coronal mass ejections from active region 13664, produced the most intense geomagnetic disturbance in two decades, accompanied by a large FD and the ground-level enhancement GLE74. After applying strict fair-weather criteria and constructing a reference diurnal curve from 30 nearby fair days, we isolated the disturbance-related deviation of the PG. We found a clear sequence in the PG response. At the time of the FD minimum, the deviation at Gar is slightly positive, consistent with reduced galactic cosmic-ray ionization decreasing atmospheric conductivity near the surface. During the GLE74 phase a few hours later, the deviation turns negative, indicating that enhanced solar-energetic-particle ionization locally increases conductivity and reduces the near-surface PG. Thereafter, as the solar wind remains above 700 km/s and the magnetopause is compressed to about 5 Earth radii, the PG enters a long-lasting positive phase that persists for more than three days, closely tracking the elevated geomagnetic activity. These observations show that extreme space-weather events can imprint a complex but physically interpretable signature in the PG, linking cosmic-ray modulation and magnetospheric compression to measurable changes in the GEC over the Tibetan Plateau (Fu et al., 2025).

Institute of High Energy Physics, Chinese Academy of Sciences

Contributor: Qibin Yi, Shaolin Xiong on behalf of Insight-HXMT team
Chenwei Wang, Shaolin Xiong on behalf of GECAM team

Unveil the TGF-lightning relation with a large sample of TGFs detected by Insight-HXMT. Terrestrial Gamma-ray Flashes (TGFs) are brief (typically 0.1 ms), intense bursts of gamma rays originating from Earth's atmosphere, with photon energies reaching tens or even over a hundred MeV. Insight-HXMT—launched on June 15, 2017—is China's first X-ray astronomy satellite, capable of broadband gamma-ray (0.2–5 MeV) monitor with excellent timing resolution, making it particularly suitable for detecting short-duration, high-energy transients like TGFs (Yi, Zhao, et al. 2025). From June 22, 2017 to July 30, 2024, we identified 4,279 TGF events from Insight-HXMT data, among which 1,327 were associated with lightning discharges, providing a large observational sample for studying TGF-lightning connections (Figure 1, Yi, Guo, et al. 2025).

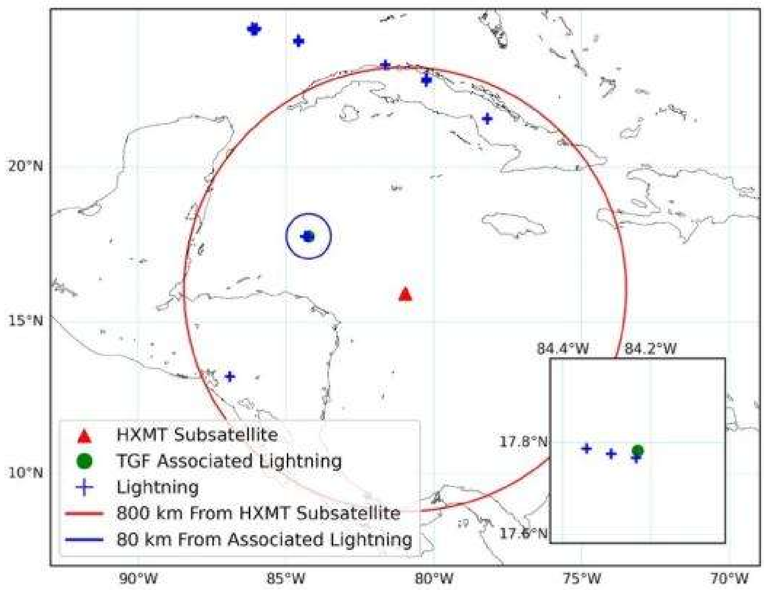

Figure 1. Example of TGF and associated lightning (Yi, Guo, et al. 2025).

To explore the relationship between TGFs and lightning, we developed a novel two-step association method (which was originally proposed in 2014): Step 1: Expand spatial search range while narrowing temporal window to identify candidate lightning near the TGF time. Step 2: Refine spatial localization while extending the time window to capture more lightning components associated with TGF. This approach overcomes limitations of conventional methods that rely strictly on narrow time coincidence, enabling more comprehensive identification of lightning activity related to TGFs.

Using this method and the large TGF sample from Insight-HXMT, we conducted a systematic analysis and obtained the following key results from Insight-HXMT: (1) We find that TGFs consistently occur during the initial phase of lightning development, suggesting they are triggered by the early establishment of strong electric fields before full lightning channel formation. (2) Three distinct lightning components are associated with TGFs. Each TGF is linked to a complex sequence of lightning activity within approximately 800 ms, comprising: Simultaneous sferics ($|\delta T| \leqq 0.2$ ms), Adjacent sferics (0.2 ms $< |\delta T| \leqq 5$ ms), Follow-up sferics (5 ms $< \delta T \leqq 800$ ms). All three originate from nearly the same geographic location as the TGF, confirming their physical connection within the same thunderstorm system. (3) Simultaneous sferics exhibits significantly higher energy compared to adjacent and follow up components, with its median energy increasing as TGF duration decreases (Figure 2).

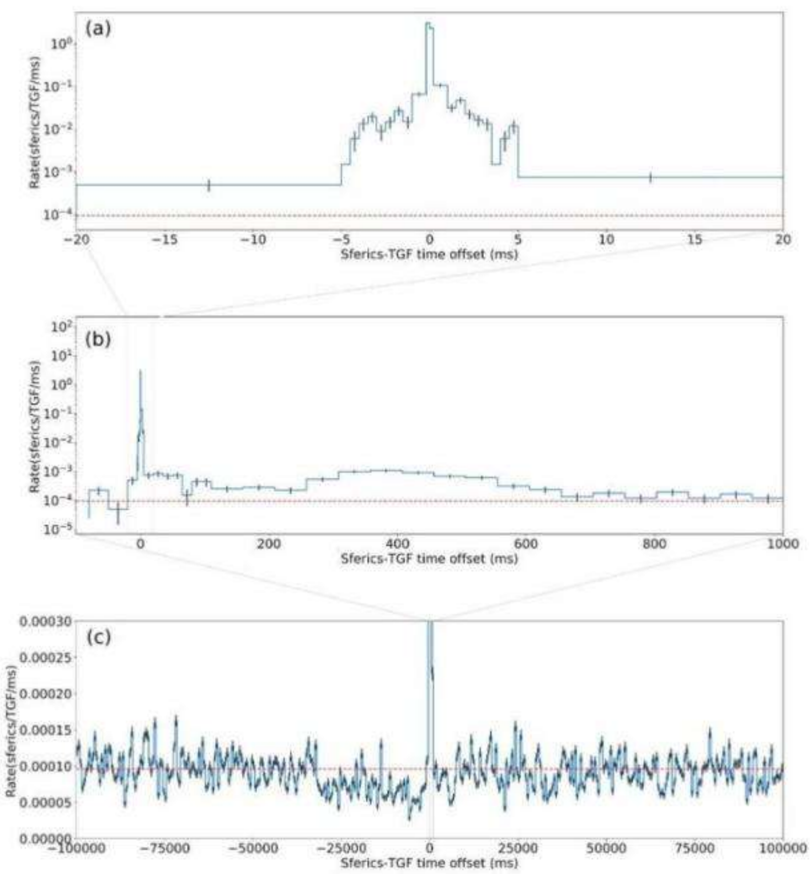

Figure 2. TGF and three associated lightning components.

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GECAM discovery of peculiar oscillating particle precipitation events. Charged particle precipitation, which plays an important role in the space weather, typically manifests as a gradual increase and decrease of flux observed by space detectors in Low Earth Orbit (LEO). Therefore, the observation and study of particle precipitation events is a crucial aspect of space physics research. However, for a long time, high-resolution detection of particle precipitation events with rapid changes on a short time scale has been sparse due to limitations of instruments, such as time resolution of detectors.

The Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor (GECAM) is a space gamma-ray astronomical satellite designed for time-domain astronomy, with a time resolution as high as 0.1 μs. The joint observation of gamma-ray detectors (GRDs) and charged particle detectors (CPDs) onboard GECAM give it the ability to detect and identify particle precipitation events.

Thanks to the delicate and innovative designs of detectors and electronics, GECAM has detected many space-charged particle events with fast variability. Notably, on March 21, 2024, GECAM-B fortunately detected three interesting particle precipitation events (denoted as tn240321a, tn240321b, and tn240321c), two of which (tn240321b and tn240321c) exhibited significant periodicity (Figure 3). Through comprehensive analysis, we have excluded instrumental effect origins for the periodic signals and conclusively identified these phenomena as local space charged particle events with intrinsic oscillatory characteristics. In light of these interesting and rare features, we propose to name this kind of phenomena as oscillating particle precipitation (OPP) events. Moreover, several interesting temporal and spectral features of these particle precipitation events are revealed for the first time: (1) The oscillations, as depicted by base frequency, of two OPP events are different (i.e., ~5 Hz for tn240321b and ~6 Hz for tn240321c), and the frequency does not show obvious evolution over time for each event. (2) The amplitude of the oscillations varies among energy ranges, resulting in the same modulation in the hardness ratio. (3) The oscillations in different energy ranges also exhibit significant spectral lag, including the spectral lag of narrow pulses and the profile of the overall envelope.

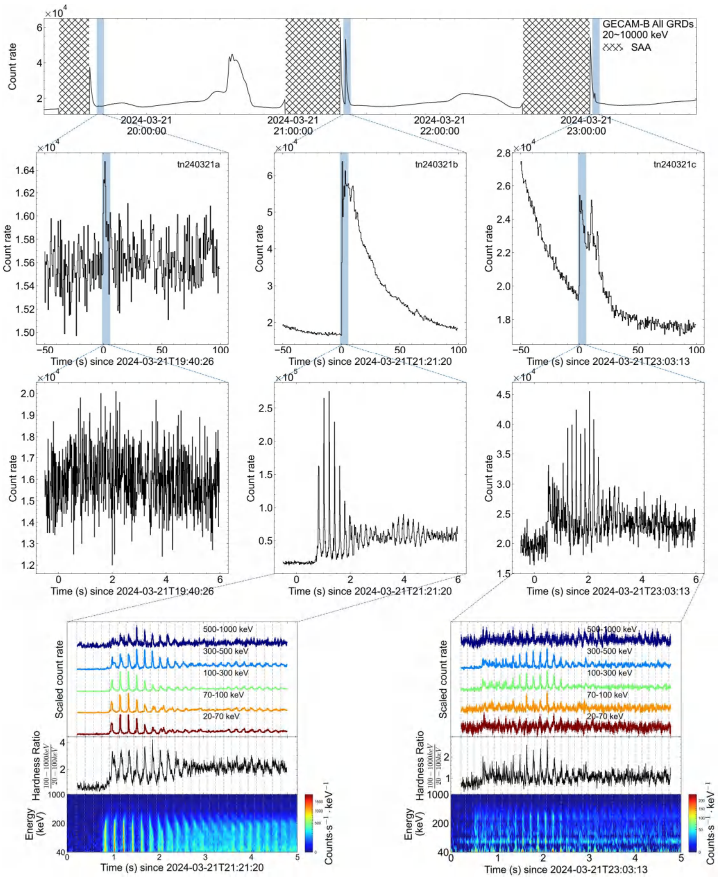

Figure 3. The count rate curves of OPP events detected by GECAM-B on March 21, 2024, with different time resolution. The significant oscillation can be clearly seen in high time resolution data. (Wang et al. 2026).

Considering that lightning can generate signals of charged particles with a short time scale, such as terrestrial electron beam (TEB) and lightning-induced electron precipitation (LEP), we also explore the possibility of lightning origins of these OPP events. But the association with lightning is not favored as there is no supporting evidence by analyses of time coincidence and localization coincidence between OPP events and lightning activity with WWLLN data (Figure 4). Therefore, we conclude that these GECAM-detected OPP events may represent a new type of particle precipitation event or a peculiar lightning-induced electron precipitation.

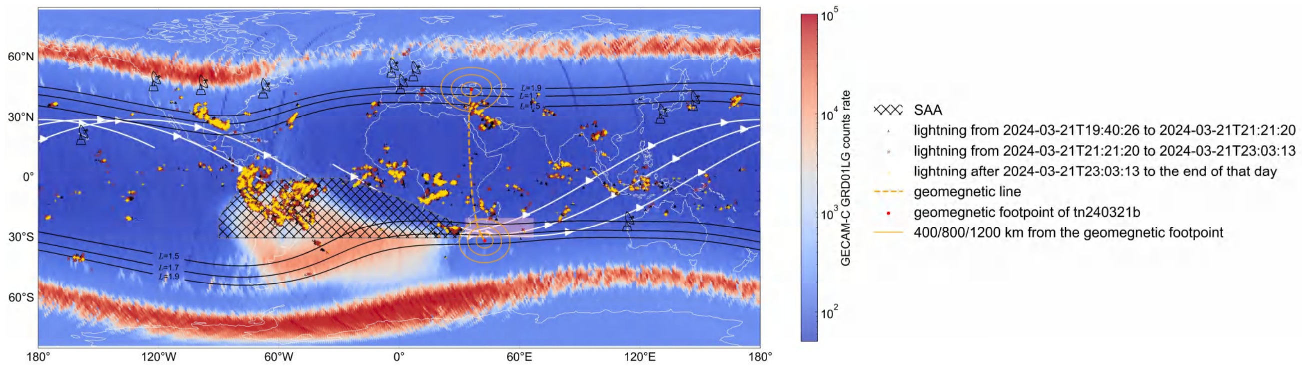

Figure 4. The OPP events detected by GECAM-B on March 21, 2024. The orbit of GECAM-B is depicted as white lines.

Israel Atmospheric Electricity Group

Reichman University and Hebrew University of Jerusalem

Prof. Yoav Yair had recently won an Israeli Science Foundation (ISF) grant to study lightning and sprites in planetary atmospheres, starting with the Gas Giants of the solar system, and beyond. He is collaborating with Prof. Carynelisa Haspel and Dr. Assaf Hochman from the Hebrew University of Jerusalem, and with graduate student Jonathan Bar-Zeev have been simulating the potential regions for sprite inception in Jupiter's atmosphere. The model developed by Haspel et al. (2022) was adapted to Jovian conditions and can account for two charged clouds – a deep H_20 cloud at the 5-bar pressure region and a NH_3 cloud above it. Different cloud sizes and charge configurations are being tested, to account for the complexity of lightning activity observed by the Juno spacecraft.

Prof. Yoav Yair, together with Dr. Roy Yaniv and Dr. Assaf Hochman from the Hebrew University of Jerusalem, will deploy an Ez field-mill on-board the Mediterranean Explorer vessel (MEDEX) and conduct regular measurements in the Herzliya marina just north of Tel-Aviv, where the ship is anchored. The ship will also conduct several cruises in the eastern Mediterranean, and the plan is to obtain, for the first time, continuous daily patterns of the Ez within the maritime boundary layer under various conditions (fair weather, dust intrusion, cloudiness). There are only few measurements of the electric field above the open sea, and the planned research has the potential to obtain important new results.

On-going analysis of data obtained from the ILAN-ES campaign, conducted during Axiom-Space AX-3 mission to the International Space Station in January 2024, yielded an observation of the longest-ever delayed sprite event on record - almost a full second (916.6 ±16.6 ms) from the visible onset of the parent flash. Based on meteorological, satellite, and ground-based ELF data, we reconstruct a realistic charge configuration for the parent thunderstorm. This charge configuration was input to a 3D quasi-electrostatic model (Haspel and Yair, 2025) to simulate regions of possible sprite inception as a function of time corresponding to this sprite event. It was demonstrated how the observed delayed sprite could have been incepted by a prolonged piecewise pattern of the current in the parent flash. The paper is now in review for *Geophysical Research Letters*.

Yoav Yair collaborated with Jozsef Bór (HUN-REN Institute of Earth Physics and Space Science, Hungary) in executing the UHU experiment on-board Axiom Space's 4th private mission to the International Space Station. The AX-4 mission lasted from June 25th to July 15th, 2025, and during this period observations of thunderstorms and TLEs were conducted by the astronauts from the Cupola window. Forecasting sessions for global thunderstorms were conducted daily, as in previous ILAN-ES campaigns on-board the ISS (Yair et al., *Acta Astronautica*, 2023). The results are being analyzed and evaluated by the UHU team and will be reported in upcoming conferences.

<u>Tel Aviv University</u>

Prof. Colin Price together with postdoc Dr. Vlad Landa and Prof. Yuval Reuveni (Ariel University) is developing a nowcasting scheme using AI and lightning data (whether ground-based or satellite-based). The algorithm uses a particle-filter scheme to estimate the motion vector and clustering of thunderstorm cells, with nowcasts out to 6 hours in the future (Figure 1). The lightning-only scheme is comparable with more complicated schemes that require data from different sources, and often even models. The project is partially funded by Google for nowcasting thunderstorms over Africa.

Prof. Price together with graduate students Hadar Reshef and Noam Tishler are analyzing the new lightning data from the European MTG geostationary satellite with the first lightning imager (LI) onboard. We plan to study the lightning in African easterly waves (AEWs) and the impact of biomass burning in Africa on lightning activity in thunderstorms.

Prof. Price together with Prof. Yair and Prof. Reuveni are part of the Science Team of the Israeli-French CIEL project that will have two microsatellites with lightning sensors onboard to study thunderstorms and lightning simultaneously from two different angles. This joint mission with Dr. Eric Defer (France) will be launched in 2028 and will provide the highest spatial resolution images of lightning from space, and for the first time sample lightning in 3 dimensions from space.

Prof. Price has recently been funded by the Israel Science Foundation to study the impact of the global electric circuit on plants! Both the DC and AC fields will be investigated together with scientists in the Plant Sciences department at Tel Aviv University. The research will include lab experiments and outdoor experiments in the Botanical Gardens of the university.

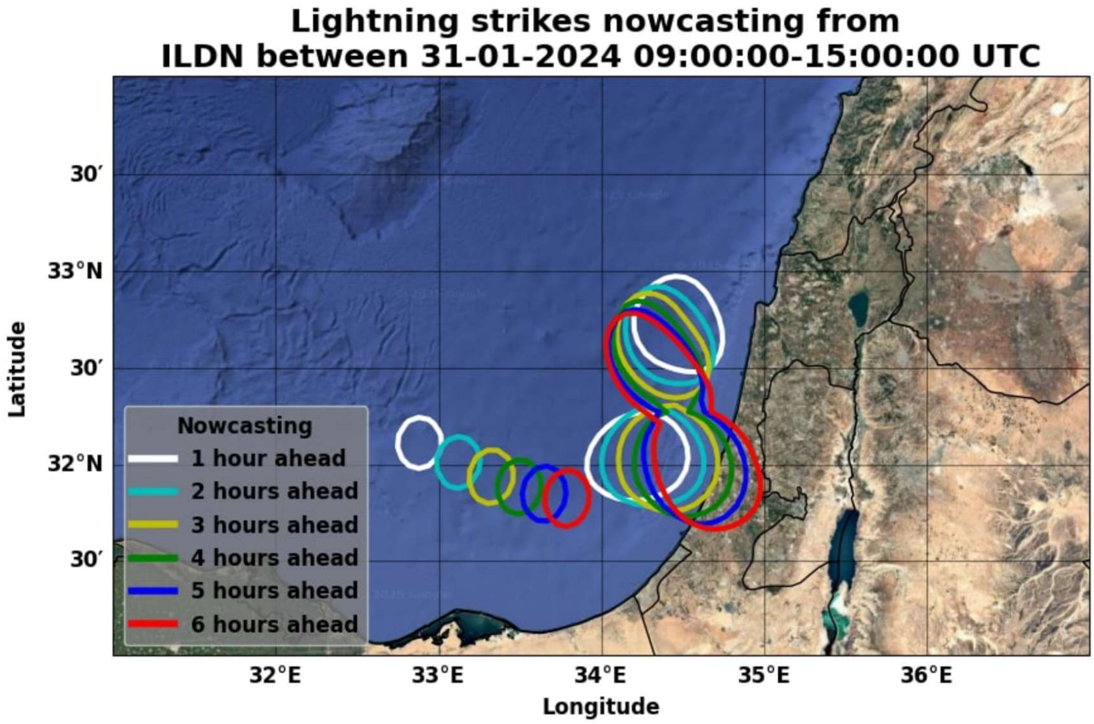

Figure 1. Lightning strikes nowcasting from ILDN.

<u>Ariel University</u>

Prof. Yuval Reuveni, together with his graduate student Nadav Mauda and Prof. Yoav Yair (Reichman University), has recently published a study in *Science of the Total Environment* presenting a comprehensive multi-parametric analysis of thunderstorm ground enhancements (TGE) and associated gamma-ray emissions observed on Mount Hermon, Israel. In parallel, Prof. Reuveni, jointly with graduate students Muyiwa P. Ajakaiye and Ben Romano, published in *Journal of Geophysical Research: Space Physics* their investigation of the signatures imposed by intense geomagnetic storms on Very Low Frequency (VLF) radio-wave propagation across the Mediterranean region.

Ongoing research efforts continue to advance these themes. Prof. Reuveni and graduate student Muyiwa P. Ajakaiye are completing an in-depth investigation of D-region ionospheric responses to X-class solar flares during the ascending phase of Solar Cycle 25, integrating VLF measurements with GOES X-ray observations. A full manuscript is expected to be submitted to *Journal of Geophysical Research: Space Physics* in the near term.

In parallel, Prof. Reuveni and graduate student Ben Romano are pursuing continued work on characterizing D-layer properties using VLF observations, numerical modeling frameworks, and deep-learning–based assessments of ground-wave conductivity. This study is also nearing submission to *Journal of Geophysical Research: Space Physics*.

Additionally, under a collaborative research program funded by the Israeli Ministry of Science, Technology, and Space, Prof. Reuveni and Prof. Morris Cohen (Georgia Institute of Technology, USA) are progressing in the development of an operational nowcasting capability for HF communication disruptions induced by space-weather events. This effort leverages real-time VLF observations to monitor D-region electron density variations and aims to enhance forecasting reliability for ionospheric disturbances affecting communication systems.

Massachusetts Institute of Technology

Qianqian Wang, Anirban Guha, Chuntao Liu, Tamas Bozoki, Gabriella Satori, Anne Neska, Rollin McCraty, Mike Atkinson, Courtney Schumacher, Aaron Funk and Earle Williams have been collaborating on Schumann resonance studies of global convection. Two special ELF datasets have enabled an investigation of the relationship between background and transient Schumann resonances (SR) at the lightning chimney scale. ELF magnetic measurements at Hornsund in the Arctic provide selective and separate access to SR background variations in three chimneys: SE Asia/Maritime Continent, Africa and America. Additional ELF measurements at six HeartMath stations (California, Canada, Lithuania, Saudi Arabia, South Africa, and New Zealand) provide for the TOA-based geolocation of Q-burst transients, also showing concentration in three chimney regions. Chimney background maxima near 9 UT, 15 UT and 21 UT, are linked with local lightning maxima near 4 pm local time in each chimney. Positive Q-bursts consistently lag the times of SR background maxima in continental chimneys Africa and America, in conditions of stratiform precipitation and confirmed by radar reflectivity profiles from the NASA GPM in space. The numbers of positive Q-bursts are correlated with the SR background magnetic intensity. Chimney conditions in the aftermath of the 4 pm convection ("End of Storm

Oscillation") are likened to conditions in the trailing stratiform regions of MCS squall lines, productive of positive CGs, megaflashes and sprites. Further discussions are planned for the ICAE in Barcelona.

Northwest Normal University, China

The influence of corona sheath conductivity distribution on the transmission characteristics of return-stroke currents. The study on transmission characteristics of lightning return-stroke currents along the channel is of great significance for deeply understanding the microphysical mechanisms of lightning discharge processes, improving theoretical models, and optimizing lightning protection systems. Based on the spectra obtained from three lightning processes and the waveforms of synchronous ground electric field changes caused by the lightning, the characteristic parameters such as channel temperature, linear charge density, and radius are calculated. Combined with the electrodynamics model of lightning, the propagation process of electromagnetic waves in the lightning channel and the surrounding corona sheath is simulated, and the dispersion curves, as well as the intensity changes of radial and axial electric fields are obtained under two conditions: with and without considering the electrical conductivity in the corona sheath. The impact of the electrical conductivity distribution in the corona sheath on the transmission characteristic of electromagnetic waves is analyzed for the first time. On this basis, the transmission law of current along the channel height at different moments for the three return-strokes is simulated. The results show that compared with the case that only the electrical conductivity of the current- carrying core channel is considered, the radial distribution of electrical conductivity in the outer corona sheath will slow down the decay rate of current transmission along the channel. The larger the radius of the high electrical conductivity channel, the smaller the decay rate of the return-stroke current along the channel. In the early stage of the return-stroke, the current intensity decays rapidly along the channel height, decaying in an exponential form. As time goes on, the current decay slows down and gradually transitions to a linear decay or a uniform distribution form. It further confirms that the decay of the return-stroke current along the channel height is mainly manifested in the early stage of the return-stroke. The radius of the current-carrying channel and the distribution of conductivity in the corona sheath are key factors affecting the transmission decay of current along the channel.

The radial distribution of temperature and electrical conductivity in lightning core current-carrying channel and its time evolution. The study of characteristic parameters of lightning current-carrying channels is crucial for a deeper understanding of the physical mechanisms underlying lightning discharge processes. The study investigated the radial distributions and temporal evolution of temperature, electron density, and conductivity in the lightning core current-carrying channel. The calculations employed a one-dimensional radial Fourier heat conduction equation, accounting for Joule heating generated by the return-stroke current and the effects of radiative energy loss. The study found that the peak temperature is positively correlated with the current but does not follow a simple functional relationship. Both the temperature and conductivity are decaying at an accelerating rate toward the channel edge, their peak values lag behind the current peak, reaching maxima near the half-peak point of the return-stroke current. With the presence of the return-stroke current, the calculated channel temperature matches well with the values diagnosed from ionic lines in experimental spectra. In the late stage of the return-stroke discharge, the channel temperature aligns with that derived from atomic lines. This finding further confirms that ionic lines originate primarily from radiation in the current-carrying core channel, providing a basis for deeper understanding of the light radiation mechanism within the channel. With the presence of the return-stroke current, the channel maintains a relatively high electron density and conductivity. The radial decay of electron density in the core channel does not exhibit orders-of-magnitude changes; it shows a slight increase at the edge during 30-100 μs. The regions of high temperature, electron density, and conductivity expand radially outward with time, resulting in a gradually rising of temperature, electron density, and conductivity around the perimeter of the core channel, this feature effectively enlarging the radius of the high-temperature, high-conductivity range, which is a critical factor influencing current transmission.

Precise determination of lightning plasma parameters based on a collisional-radiative model. Precise spectral diagnosis is vital in revealing the microscopic physical mechanism of lightning discharge process. By considering the main microphysical processes between particles, a reasonable collisional-radiative model (CRM) has been established to simulate the fine spectrum of natural lightning, and the dependency relationship between line-intensities of N II and electron temperature (T_e) and electron density (n_e) were obtained. It was found that the line-intensity proportion of 500.52 nm and 567.96 nm in the multiple spectral lines to which they belong tend to stabilize in the T_e-n_e variation space, which is an inherent physical property that can be applied in determining the experimental intensity of characteristic lines from the total intensity of overlapped lines. The line profiles at ~500.5 and ~568.0 nm were fitted by a summation algorithm, and the proportion of characteristic spectral line intensity to the total intensity of the envelope was analyzed. A feasible method was proposed, in dealing with the problem of the overlapped lines in natural lightning spectra. By accurately matching the theoretical intensity-ratio with the experimental one, two intersections of contours of line-intensity ratios in the two-dimensional plane of T_e-n_e were derived, and then the simultaneous diagnosis of T_e and n_e in the lightning channel was realized.

The radiation power density of a natural ball lightning estimated by its spectra. The energy and its source of ball lightning (BL) have long been a mystery. At present, there is no consensus on the energy source of ball lightning. Based on the unique high-time resolution spectra and video data of a natural BL, combined the theory of spectral analysis and the Stefan Boltzmann law of a black body, the radiation power density of this BL is calculated for the first time, and its evolution characteristics are investigated in this work. The results show that the radiation power density calculated by O I spectral lines is the highest, its average value is about 37.40×10^7 W/m^2. The average radiation power density calculated by Si I and Fe I spectral lines are only around 3.04×10^7 W/m^2 and 2.56×10^7 W/m^2, which remained basically steady during the stable luminescence stage. The spectral and energy feature indicated, the BL maybe exist a core with higher energy. The radiation power density shows a periodic pulse feature in the energy core and maintains basically stable in the bright periphery with lower energy. The highest energy of this BL can only excite light radiation of the near infrared band from the O I atoms in the air. The BL moved toward the nearby power line. Deduced from the energy distribution and moving direction that this BL should be associated with small gap intermittent discharge at the bottom of previous cloud-to-ground (CG) lightning channel, meanwhile, the strong atmospheric electric field during thunderstorm and its distribution should be a potential outside source that drives the discharge and moving direction of this BL. This work has important reference significance to reveal the mystery of ball lightning and the application of BL phenomenon.

Study on the electric field and current intensity in lightning discharge channel based on the Hα broadening. This study presents a method for indirectly measuring the electric field within a lightning discharge channel, utilizing the spectral line broadening of the Hα 656.3 nm line. The method is based on the relationship between spectral line broadening and electric field strength, which allows for the calculation of the radial and axial electric fields within the channel during a lightning return stroke. In the calculation, two methods are adopted for the spectral line broadening: direct measurement of spectral line profiles and inversion from the electron density calculated by the Stark broadening theory of spectral lines. The calculated radial electric fields ranged from 2.31×10^4 kV/m to 22.78×10^4 kV/m, and axial electric fields from 1.30 kV/m to 13.14 kV/m. The internal electric fields were further validated by calculating the axial current using Ohm's law, which showed a strong correlation with peak current estimates derived from electric field change waveforms. Additionally, the study found a positive correlation between the peak current and the radius of the current-carrying channel, suggesting that the channel's current-carrying capacity is strongly influenced by its radius. These results offer a new method for characterizing the electromagnetic environment within a lightning channel and provide insights into the physical mechanisms of lightning discharge. The findings are crucial for improving lightning protection systems and understanding the dynamics of lightning behavior.

Opacity of N II ion radiation in the lig htning discharge plasma channel. In this paper, based on the Boltzmann distribution of the excited state population number and the definition of the intensity of spectral lines, combined with the theory of excited radiation, a method of determining the optical thinness of the light source from the experimental spectra is explored and developed. The specific research contents and main results are as follows: The ratio of the intensities of the same ionic spectral lines with the same upper energy level in the spectrum is no longer temperature dependent. On the basis of this property, the theoretical and experimentally recorded intensity ratios of the two characteristic spectral lines of N II ions (480.3 nm and 594.2 nm) formed by radiative transitions from the same upper energy level in the spectra were compared and analyzed using the spectra of nine natural lightning return strokes recorded in field experiments in Datong County, Qinghai Province. The calculation results show that the intensity ratios of these two spectral lines in the spectra of return strokes with different temperatures agree with the theoretical values. The above calculations confirm that the ratio of the intensities of the two spectral lines N II 480.3 nm and 594.2 nm is not affected by the difference in the temperature of the specific return stroke channels, i.e., the absorption effect of these two spectral lines can be neglected, and the optically thin condition is satisfied. Combined with the calculated absorption coefficient and optical thickness of the N II 594.16 nm spectral line, it is further confirmed that the N II ionic lines in the lightning discharge plasma channel meet the optically thin condition. Furthermore, the variation of the temperature along the channel height under optically thin conditions also verified the rationality of the result.

Penn State University

The most recent results obtained at Penn State University, University Park, Pennsylvania, USA can be summarized as follows. The photoelectric feedback discharges (https://doi.org/10.1029/2025JD043897) seed streamers that produce electromagnetic radiation with frequencies spanning from UHF (0.3-3 GHz) at sea level air pressure to ULF (0.3-3 kHz) at an altitude of 80 km in Earth's atmosphere (https://doi.org/10.1029/2025GL118469). The observed electromagnetic radiation associated with gamma-ray glows, flickering gamma-ray flashes, and terrestrial gamma-ray flashes can be understood as a progression of electrical gas discharge forms - from relativistic electron avalanches to streamers and then to conventional electron avalanches - with a progressive increase in magnitude of reduced applied electric field Ea/delta, where delta=n/n0, n is altitude-dependent air number density, and n0=2.688e25 m-3 is a reference value corresponding to standard atmospheric conditions at sea level (https://doi.org/10.1029/2025GL118469).

Figure 1 illustrates (a) Reduced characteristic frequencies for relativistic electron avalanches, streamers, and electron avalanches due to conventional breakdown in air as a function of reduced applied electric field; (b) Frequency band of streamer radio emission as a function of altitude. Shaded area depicts radiation in very high frequency (https://doi.org/10.1029/2025GL118469). Additional information: https://youtu.be/P4OHXWOgMpY.

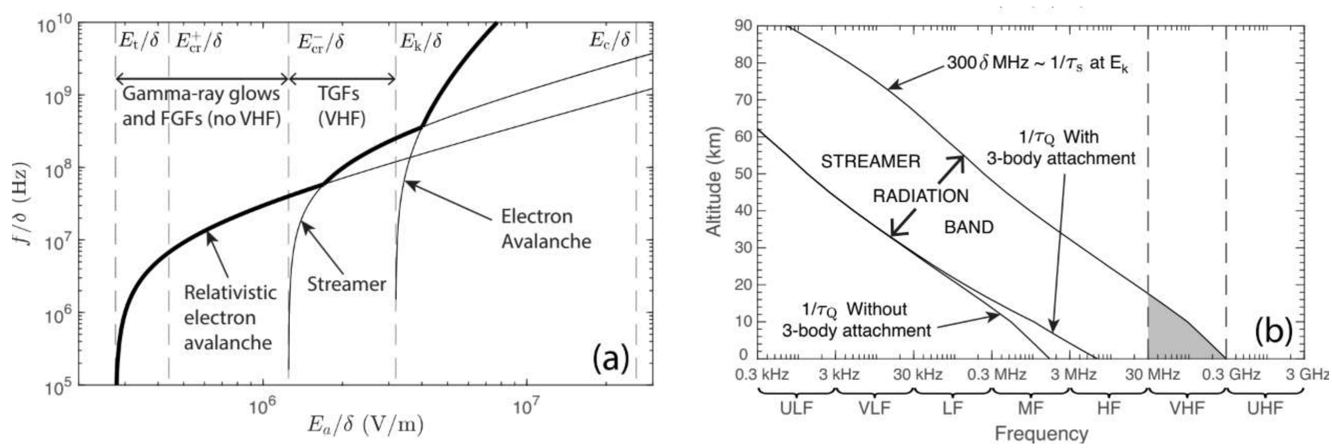

Figure 1. (a) Reduced characteristic frequencies for relativistic electron avalanches, streamers, and electron avalanches due to conventional breakdown in air as a function of reduced applied electric field; (b) Frequency band of streamer radio emission as a function of altitude. Shaded area depicts radiation in very high frequency.

University of California, Santa Cruz, USA

The high-energy atmospheric physics group at the Santa Cruz Institute for Particle Physics, UCSC, has deployed gamma-ray detectors for atmospheric electricity research (the Terrestrial High-energy Observations of Radiation, or THOR project) at 11 sites worldwide, with the generous support of collaborators at many institutions, listed at the end of this article. These systems include NaI and plastic scintillator detectors of various sizes that record both continuous photon-by-photon data and digitized photomultiplier traces at times of bright, transient events such as terrestrial gamma-ray flashes (TGFs).

As of this writing, we are about to test the latest generation of a more unusual detector, a digital dosimeter called the Intense Radiation Integration Sensor (IRIS, Figure 1). IRIS uses simple commercial photodiodes to record the radiation dose from a nearby TGF at intensities that would saturate any detector that has a significant volume or electronic gain, up to and including doses that might be of medical significance. IRIS units will be deployed to many of our current research sites, but we would also like to offer to share the design and software (or, under some circumstances, possibly a working unit) with any group interested in deploying their own; a unit costs only about US$ 200 to construct (excluding a computer to read it out). Please contact David Smith (dsmith8@ucsc.edu) for more information.

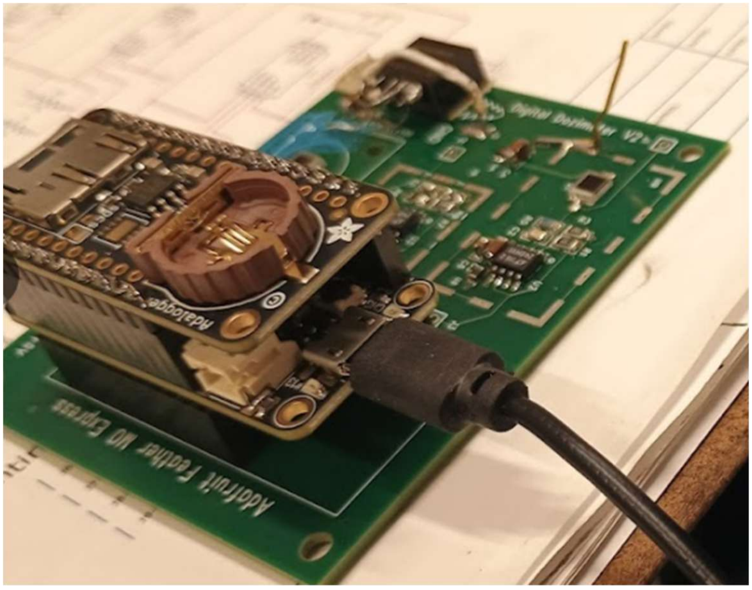

Figure 1. Prototype of the IRIS digital radiation dosimeter.

Recent results from the THOR arrays include two observations from Japan made with the support and sponsorship of Dr. Masashi Kamogawa of the University of Shizuoka.

First terrestrial gamma-ray flash associated with positive cloud-to-ground lightning. Every other kind of lightning had been previously known to be able to produce a TGF (+/- IC, natural -CG, and upward and triggered -CG lightning). A powerful +CG stroke in January 2025 at Uchinada, Japan, identified in low-frequency electric field data by collaborator Ting Wu of Gifu University, produced a bright TGF as the return stroke reached the top of the channel (Figure 2). This behavior, including the timing of the TGF, is common in a class of powerful -CG lightning strokes called Energetic Compact Strokes (ECS) by Dr. Wu and collaborators; this event appears to be a positive counterpart to this class. With this observation, TGFs have been observed to accompany every major class of lightning. This work was published in GRL by James Sanchez et al. (2025, GRL 52, e2025GL117634), and will be presented by him at the 2025 AGU meeting.

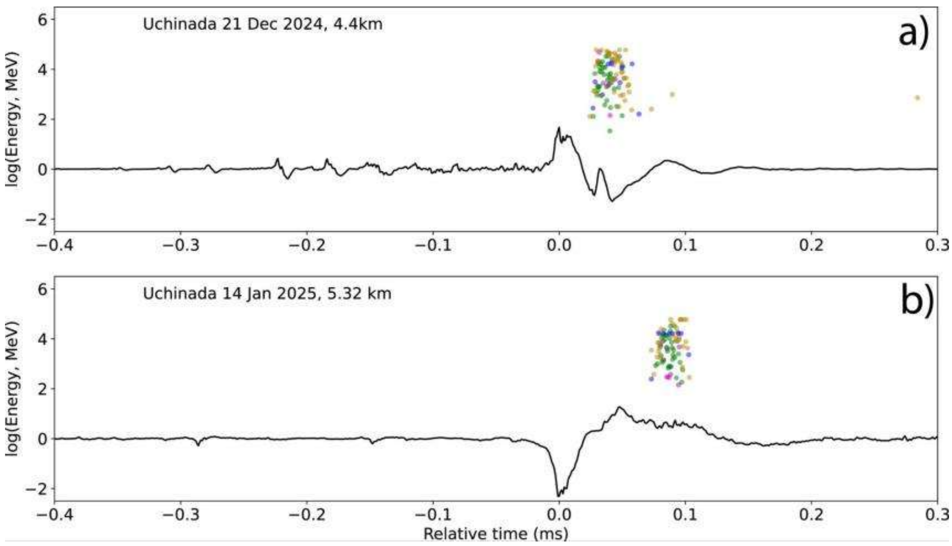

Figure 2. First TGF associated with a +CG lightning stroke (panel b). Black trace: FALMA LF electric field waveform. Colored dots: gamma-ray counts registered by the four THOR detectors. The top panel shows a TGF associated with a -CG Energetic Compact Stroke for comparison.

Measurement of the clustering of photon arrival times in a thunderstorm gamma-ray glow. A bright gamma-ray glow was observed by a THOR array placed at the summit of Mt. Fuji in summer of 2022, courtesy of Dr. Kamogawa and the Mount Fuji Research Station NPO. At the peak of the glow's count rate in THOR's large plastic scintillator, about 2000 x-ray counts/second, a statistically significant excess of clusters of 2 and 3 counts less than 1.5 microseconds apart -- relative to the expectation from random (Poisson) arrival -- was observed. For a range of realistic estimates of the glow's altitude above the site, we estimate that 10^5-10^7 gamma-rays above 1 MeV are produced in bunches by either unexpectedly large individual avalanches, or near-simultaneous bursts of smaller avalanches. Comparison to avalanche modeling by Joseph Dwyer of the University of New Hampshire is in progress. This work will be presented by Isabel Kim at the 2025 AGU meeting. These and other results will be presented by David Smith at ICAE 2026 in Barcelona.

THOR deployment hosts:

Uchinada, Japan and Mt. Fuji: Masashi Kamogawa, Tomoyuki Suzuki, Hironobu Fujiwara (University of Shizuoka)

Mt. Santis, Switzerland: Farhad Rachidi-Haeri, Toma Chaumont Behrs (EPFL), Marcos Rubinstein (HEIG-VD)

Split, Croatia: Antonio Sunjerga, Dragan Poljak, Vicko Dorić (University of Split)

Los Alamos National Laboratory, New Mexico, USA: Xuan-Min Shao, Daniel Jensen, Amitabh Nag (LANL)

Melbourne, Florida, USA: Austin Tyler Brower, Dylan Goldberg, Hamid Rassoul, (Florida Inst. of Technology)

Langmuir Laboratory, New Mexico, USA: Caitano da Silva, Richard Sonnenfeld, Adonis Leal, Luis Contreras Vidal, John Pantuso (New Mexico Tech)

Barrancabermeja, Colombia: Joan Montanya, Brandon Steven Ardila Murillo, Jesús Alberto López (Universitat Politècnica de Catalunya)

La Hague, France: Sebastien Celestin, Yanis Hazem (Université d'Orléans)

Tel Aviv, Israel: Colin Price, Arie Kopitman (Tel Aviv University), Yoav Yair (Reichman University)

Mountain Village, Colorado, USA: City of Mountain Village

Collaborators providing LF radio data essential to TGF interpretation:

Jeff Lapierre (AEM Corp., Earth Networks Division)

Ting Wu (Gifu University)

University of Florida

Ziqin Ding, Si Chen, Hanbo Yang, Kang Yang, Vladimir A. Rakov, Joel B. Harley, Yanan Zhu, and Istvan Kereszy authored a paper titled "Identification of Lightning Strikes to Towers Using Their Electric Field Signatures and a Machine Learning Approach". Lightning often strikes tall (≥200 m) objects and poses significant threat to the infrastructure. Using the characteristic electric field signatures of the tower-terminated lightning, the authors developed a machine learning approach to identify strikes to towers in large lightning datasets. The ground-truth data were acquired at the Lightning Observatory in Gainesville (LOG), Florida. The classification model used in this study is based on supervised multi-layer perceptron model, aiming to capture complex pulse patterns with the neural network architecture. The results show that tower-terminated lightning and non-tower-terminated lightning can be accurately identified. Using the Local Interpretable Model-agnostic Explanations (LIME), the authors found that their machine learning model is capable of capturing the key features of electric field signatures produced by lightning strikes to tall towers. This paper is published in the IEEE Sensors Journal.

In a collaborative Doshisha University/UF study, Shota Ueda, Yoshihiro Baba, and Vladimir A. Rakov authored a paper titled “FDTD Computation of Ground-Level Electric Fields Generated by Compact Intracloud Discharges”. Using the finite-difference time-domain (FDTD) method for solving Maxwell’s equations, the authors simulated ground-level electric fields produced by compact intracloud discharges (CIDs) represented by an elevated vertical low-conductivity cylinder. As per the previous study by the same group (Ueda et al., 2024), the cylinder was assumed to have a length of about 1000 m, a radius of 100 m, the permittivity and permeability equal to those of vacuum, and the electric conductivity of 10^{-4}–10^{-5} S/m. The cylinder was placed at altitudes of 14–21 km above ground, energized at its midpoint, and resultant vertical electric fields on the ground surface at horizontal distances of 14–38 km were computed. Different excitation voltage waveforms were tested to see if they can yield E-field waveforms matching measurements by Nag (2010). A reasonably good match was obtained for the empirically adjusted excitation voltage waveforms with a half-peak width of about 30 µs, but not for the 5 or 10 µs ramp followed by a constant value or for a Gaussian pulse with a half-peak width of 4 or 10 µs. The results indicate that representation of CIDs by a low-conductivity cylinder, in conjunction with FDTD-enabled full-wave solution, allows one to reproduce the observed electric field signatures of CIDs. This paper is published in the IEEE Transactions on Electromagnetic Compatibility.

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ATMOSPHERIC ELECTRICITY

NEWSLETTER

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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 (weitao.lyu@gmail.com) preferably by e-mail as an attached word document.

The deadline for **2026 spring issue** of the newsletter is **May 15, 2026**.

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