Newsletter on Atmospheric Electricity

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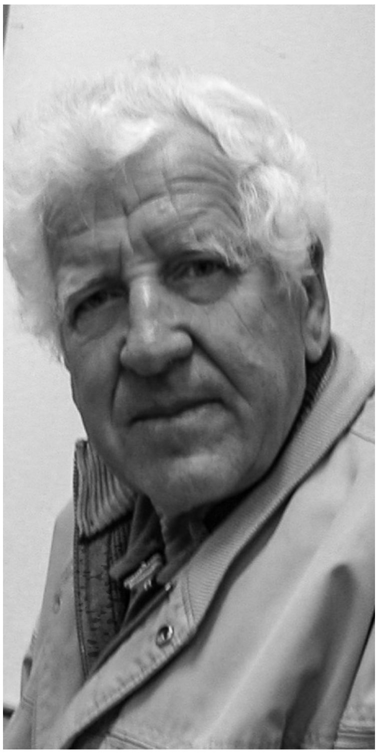
International Commission on Atmospheric Electricity (IAMAS/IUGG)
AMS Committee on Atmospheric Electricity
AGU Committee on Atmospheric and Space Electricity
European Geoscience Union
Society of Atmospheric Electricity of Japan

Dedication

Lothar H. Ruhnke (1931-2019)



Lothar Ruhnke was a gentle, soft-spoken, and self-confident man and scientist. He was born in March 2, 1931 in East Prussia, Germany to Fritz and Frieda Ruhnke. His father was a cabinetmaker, his mother a homemaker who, with modest means, took care of the family of four boys. Lothar's childhood was spent in the historical Prussian city of Tilsit, during Nazi rule in Germany and the horrors of World War II. Escaping the advancing Russian Army, the evacuated family, led by his mother, experienced the horrific bombing of Dresden by Allied aircraft, and after many struggles on the road as refugees, the family finally settled in Bavaria.

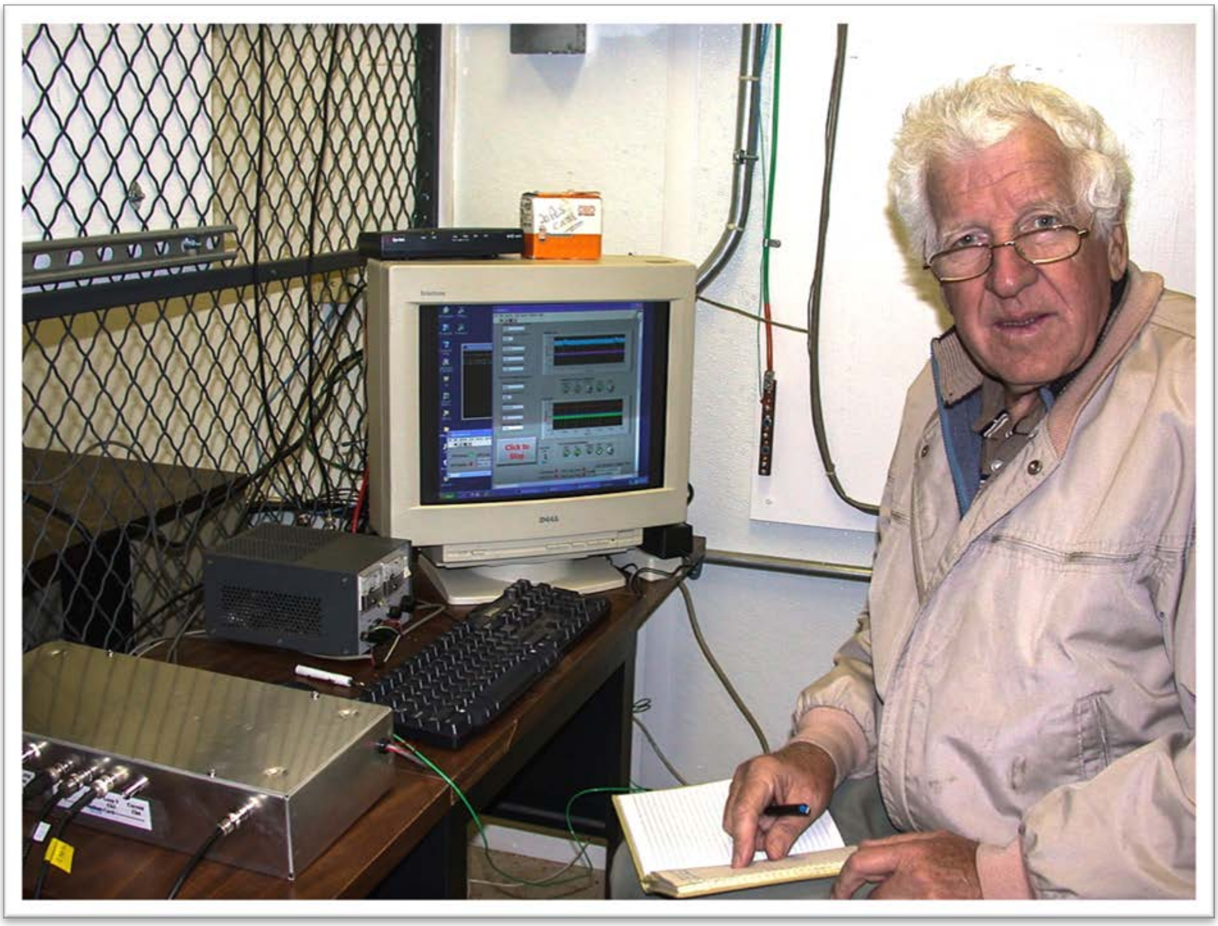
In 1954 Lothar graduated with the German equivalent of a Master's degree from Technical University in Munich, where he studied Electrical Engineering. Immediately after graduation, he was offered a job as Research Assistant to Professor W. O. Schuman (see "Schuman resonances," named after their discoverer) in the Institute of Electro-Physics at the Technical University of Munich. Lothar was put in charge of establishing an experimental research program in wave propagation of waves in the 10 kHz to 20 kHz range. After three years of work with Prof Schuman, Lothar was persuaded to accept an invitation to work in the United States. He left Germany for the United States in October 1957.

Lothar's first job in the United States was as a Research Physicist in the U.S. Army Research Laboratory in Fort Monmouth, N.J., where he met Dr. Heinz Kasemir who had been working there since his immigration to the U. S. in 1954. Both Lothar and Heinz Kasemir had come from the same town, Tilsit, in East Prussia. Together with similar scientific interests, this fact certainly helped to cement their lifelong friendship and interaction.

Lothar continued to maintain close contact with Kasemir after he left government service. In 1961, he joined Litton Systems Inc. in Minneapolis as Senior Scientist. From 1966 to 1968, he worked as Director of the Mauna Loa Geophysical Observatory in Hawaii. Lothar obtained his PhD in Geosciences-Meteorology from the University of Hawaii, in Honolulu, in 1969.

That same year Lothar moved to Boulder, Colorado, and re-united with Heinz Kasemir in the NOAA Laboratory of Atmospheric Physics and Chemistry. The Apollo 12 incident in 1969, when the Saturn rocket triggered a lightning strike during launch, brought significant attention and funding to lightning research, leading to the design of the lightning warning system at the Kennedy Space Center, using a network of electric field mills. The Boulder NOAA laboratory was a major contributor to this effort.

From 1972 until his retirement in 1992, Lothar was Head of the Atmospheric Physics Branch of the Naval Research Laboratory (NRL) in Washington, DC.



I met Lothar in the early 1980s, during my involvement in the NASA Storm Hazards Program that investigated lightning-aircraft interactions using an instrumented aircraft (NASA F-106B) for storm penetrations. At the 7th International Conference on Atmospheric Electricity in Albany, NY, I presented a paper with clear evidence of an aircraft actually triggering lightning strikes, rather than merely intercepting naturally-occurring lightning flashes. This was indirect confirmation of Heinz Kasemir's concept of lightning formation. This confirmation made Kasemir, who was attending the conference, very happy, indeed. My friendship with Kasemir began at this conference, and grew to embrace Lothar, who was Kasemir's close friend.

My collaboration with Lothar started with a 1987 JGR paper about optimizing the locations of E-field sensors on a research aircraft. In Lothar, I discovered a similarity in our scientific philosophies and a happy working chemistry - - - attributes essential for a long-term productive collaboration. We maintained close contact and had many long-distance discussions while Lothar was still at the NRL. After his retirement in 1992, I offered Lothar an opportunity to work together with me on my lightning research projects.

He accepted, and was appointed as a Visiting Research Scientist at the Cooperative Institute of Mesoscale Meteorological Studies of the University of Oklahoma.

In our collaborations, Lothar contributed his tremendous experience and the expertise he had accumulated from his previous work in the laboratory and in the field. He enjoyed challenges, especially those related to experimental work. He never tired of data search and data analysis. Lothar's defining characteristic was his confidence, which was based on his solid educational background in physics and electrical engineering.

I suppose it was the good chemistry between us that allowed us to work closely together for more than 25 years, producing thirteen published papers and several book contributions. Separated geographically, except when we were involved in field programs, we constantly interacted by phone, e-mail and Skype. Our main interest was in unveiling the mysteries of the physics of lightning discharges, and their various features and manifestations.

The key concept of lightning physics, proposed by Heinz Kasemir in 1950, considered natural lightning as a bidirectional, bipolar leader with a zero net-charge. This concept was confirmed by my analyses of lightning-aircraft interaction in the field programs of the 1980s. Our research verified that the bidirectional bipolar leader concept serves as the magic key that unlocks the mysteries of multiple manifestations of lightning phenomena.

Lothar and I became tireless promoters of this Kasemir's physically-sound concept in the lightning research community, which, at that time, had been under the strong influence of so-called "source charge" leader model by Schonland, suggested in 1938. Changing the minds of your colleagues is often a prolonged process full of frustrating efforts. Regardless of the issue, whether a scientific discussion or in a regular conversation, Lothar was always ready to patiently explain his understanding of complex lightning physics issues to anybody who wished to learn from him. This ability made him many friends among several younger colleagues in the research community, and also with students in Brazil, where for many years we collaborated with the Lightning Research Center of the University of Minas Gerais. Lothar was highly respected by many prominent researchers who also became his friends, among whom were Nikolay Aleksandrov, Evgeny Mareev, and Professor Silverio Visacro.

Our close friendship and association with Heinz Kasemir, as well as the influence of Kasemir's work on our research, were the major factors in our desire to assemble and preserve Kasemir's scientific work in a book for both current and future researchers. We were able to get support for this project from the National Science Foundation, and completed two years' work on Heinz-Wolfram Kasemir: His Collected Works (V. Mazur and L.H. Ruhnke, Editors) in 2012. Lothar provided an Editor's Remark to each included article, and also supervised the translation from German to English of all Kasemir's essential papers published in German.

Dr. Lothar Ruhnke with students and staff members of the Lightning Research Center in the University of Minas Gerais, Brazil.

There are three U.S. patents with Lothar's name.

Lothar served the Atmospheric Electricity community as Chairman of the AGU Committee on Atmospheric and Space Electricity (1974-1976), as Secretary of the International Commission on Atmospheric Electricity (1974-1981), and as President of the International Commission on Atmospheric Electricity (1988-1992).

Lothar Ruhnke passed away after a long illness on February 17, 2019 at his home in Virginia. He is survived by his beloved children, son Volko H. Ruhnke and daughter Corina L. Regrut, daughter in law Jill Ruhnke, son in law Peter Regrut, and by two grandsons Daniel and Andrew Ruhnke.

V. Mazur

NOAA/National Severe Storms Laboratory, Norman OK 73072, U.S.A. (retired)

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Dr. Lothar Ruhnke memorial from IGFPAS

The late Dr Lothar Ruhnke is widely known for his large contributions to the development of the research field of atmospheric electricity. His great enagagement in the broad range of atmospheric electricity research topics was especially influential at the time of his Presidency of the International Committee - now the Commission on Atmospheric Electricity (ICAE).

He also inspired and supported the activities of the research group at the Institute of Geophysics, Polish Academy of Sciences. Among many useful actions he helped us to initiate simultaneous measurements of the fair-weather atmospheric vertical current using a long-wire antenna at the Polish Polar Station in Hornsund, Spitsbergen, and in Józefosław near Warsaw.

It was also the initiative of Lothar Ruhnke that a workshop meeting in Mądralin in Poland was organized in 1989 by the Institute of Geophysics PAS and ICAE. This meeting has brought important and still valid summary of contemporary observations and further development of ground-based measurements of the atmospheric electric field carried out by the whole community.

Lothar Rhunke has continued his personal engagement in the development of research on atmospheric electricity long after his ICAE presidency terminated, for example in thunderstorm and lightning research. We express our deep gratitude for his friendly attitude and his help to the atmospheric electricity group in Poland.

Stanisław Michnowski and Anna Odzimek

Announcement

New election on the International Commission on Atmospheric Electricity (ICAE)

At the International Conference on Atmospheric Electricity (ICAE) in Nara last year, new president and committee member of ICAE were elected, and the next term started from the IUGG general assembly 2019 in this July. Here is the list of the new committee members.

President	Dr. Xiushu Qie (China)
Secretary	Dr. Weitao Lyu (China)

Members of the commission

Dr. E. Avila (Argentina)	Dr. V. Cooray (Sweden)
Dr. E. Defer (France)	Dr. D. R. MacGorman (USA)
Dr. E. Mareev (Rusia)	Dr. J. Montanya (Spain)
Dr. C. Price (Israel)	Dr. V.A. Rakov (USA)
Dr. M. Saba (Brazil)	Dr. D. Smith (USA)
Dr. M. Stolzenburg (USA)	Dr. T. Ushio (Japan)
Dr. D. Wang (China)	Dr. Ute Ebert (Netherland)
Dr. G. Harrison (UK)	Dr. S. Cummer (US)
Dr. W. Lyu (China)	

Honorary Members

Dr. H. Christian (USA)	Dr. E.P. Krider (USA)
Dr. P. Laroche (France)	Dr. J. Latham (UK)
Dr. Paul Krehbiel (USA)	Dr. Jim Dye (USA)
Dr. Serge Soula (France)	Dr. Z-I. Kawasaki (Japan)
Dr. Sergei Anisimov (Russia)	Dr. S. Michnowski (Poland)
Dr. H. Tammet (Estonia)	Dr. E. Williams (USA)

Vaisala

You are invited to attend the 2020 International Lightning Detection and International Lightning Meteorology Conferences

The 26th International Lightning Detection Conference and 8th International

Lightning Meteorology Conference (ILDC/ILMC) is a biennial scientific meeting focused on lightning detection topics and meteorological applications for lightning data. The next meeting will be held from April 27-30, 2020 in Broomfield, Colorado, USA. The conference brings together global participants and lightning experts to present new detection technologies, research findings, and applications. The theme of the 2020 conference is **Connecting Lightning Research & Applications**, and the agenda will include presentations, poster sessions, and roundtable discussions. Abstract submission is now open and registration will open soon. For full conference details, visit www.vaisala.com/ildc.

Research Activity by Institution

UF Contribution to the August 2019 Issue of the Newsletter on Atmospheric Electricity

M.D. Tran and V.A. Rakov authored a paper titled "An Advanced Model of Lightning M-Component". A nonlinear and nonuniform distributed circuit (*RLCG*) model of lightning M-component has been developed. The model accounts for the variation of the series resistance *R* of M-component channel due to its heating by the transient current and its subsequent cooling, longitudinal voltage drop along the channel due to the background continuing current, ohmic losses in the channel corona sheath (represented by shunt conductance *G*), and variation of series inductance *L* and shunt capacitance *C* of the channel with height above ground. The model was tested against the channel-base current and corresponding close electric fields measured for seven M-components in negative lightning triggered using the rocket-and-wire technique. Detailed sensitivity analysis was performed for one M-component. The influences of height-varying series inductance and shunt capacitance and the length of in-cloud channel (representing the excitation source) on the computed current and field waveforms were found to be relatively insignificant, while the influences of ohmic losses in the channel corona sheath and voltage drop along the grounded channel were significant. The effects of background continuing current level and grounding resistance were significant for M-field, but not for M-current. Model-predicted overall power and current profiles below the cloud base are consistent with the observed M-component luminosity profiles and are drastically different from the observed downward leader/upward return stroke profiles. The characteristic feature of M-components, the time shift between the current onset and close electric field peak (essentially absent for leader/return stroke sequences), was well reproduced by the model. The paper is published in the Journal of Geophysical Research - Atmospheres.

D. A. Kotovsky, M. A. Uman, R. A. Wilkes, and D. M. Jordan authored a paper titled "High-Speed Video and Lightning Mapping Array Observations of In-Cloud Lightning Leaders and an M Component to Ground". High-speed video (46,000 frames per second) and lightning-mapping-array (LMA) data are correlated to determine three-dimensional properties of in-cloud lightning leaders (altitudes ranging from 2.78 to 3.81 km) observed in a rocket-and-wire triggered lightning flash. Three positive leaders were observed with speeds ranging from 6.1×10^4 to 1.0×10^5 m/s, one of which branched within the camera frame. The upper branch was then traversed twice by attempted negative leaders propagating toward the main channel to ground (speeds of 2.4×10^6 and 1.1×10^7 m/s). Both attempted negative leaders terminated abruptly at the branch point of the remnant channel. In the remnants of a separate positive leader channel, a bidirectional leader initiated, which resulted in an *M* component whose luminosity and current were measured at ground. Analysis shows that the luminosity wave associated with the entire *M* component process (propagating 8.8 km from initiation to ground) is highly dispersive, with calculated group velocities ranging from 1×10^7 to 5×10^7 m/s over the dominant signal bandwidth of DC (0 Hz) to 2 kHz. High-speed footage of the *M* component shows that multiple waves of light traverse the lightning channel in both directions. The paper is published in the Journal of Geophysical Research - Atmospheres.

Publications

Kotovsky, D., Uman, M. A., Wilkes, R. A., & Jordan, D. M. (2019). High-speed video and lightning mapping array observations of in-cloud lightning leaders and an M component to ground. Journal of Geophysical Research: Atmospheres, 124, 1496–1513. https://doi.org/10.1029/2018JD029506

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"Synchronized two-station optical and electric field observations of multiple upward lightning flashes triggered by a 310-kA +CG flash", J. Geophys. Res. Atmos., 124, 1050-1063, 2019, DOI: 10.1029/2018JD029378, B. Wu, W Lyu, Q. Qi, Y. Ma, L. Chen, Y. Zhang, Y. Zhu, and V.A. Rakov

Lightning Research Group of Gifu University (Gifu, Japan)

A statistical study on the velocity of positive leaders in IC and negative CG lightning flashes

We have performed a statistical study on velocities of positive leaders in 553 intracloud (IC) and 220 negative cloud-to-ground (-CG) flashes observed by the Fast Antenna Lightning Mapping Array (FALMA). It is found that velocities of positive leaders in IC and -CG flashes have very similar distributions, with the vast majority in the range of 1 to 3×10^4 m/s. Average velocities are 1.64 and 1.55×10^4 m/s, respectively, for positive leaders in IC and -CG flashes. Velocities of positive leaders in IC flashes show a clear negative correlation with initiation altitudes and leader propagation altitudes as shown in Figures 1a and 1b. The negative correlation also exists for positive leaders in -CG flashes but is relatively weak as shown in Figures 1c and 1d. We also found that positive leaders in both IC and -CG flashes propagate with a stable velocity, contrary to downward positive leaders in +CG flashes and upward positive leaders in negative upward and triggered flashes, which were usually found to accelerate during propagations. These results suggest that positive leaders in IC and -CG flashes and those in +CG, upward and triggered flashes propagate with essentially different velocities.

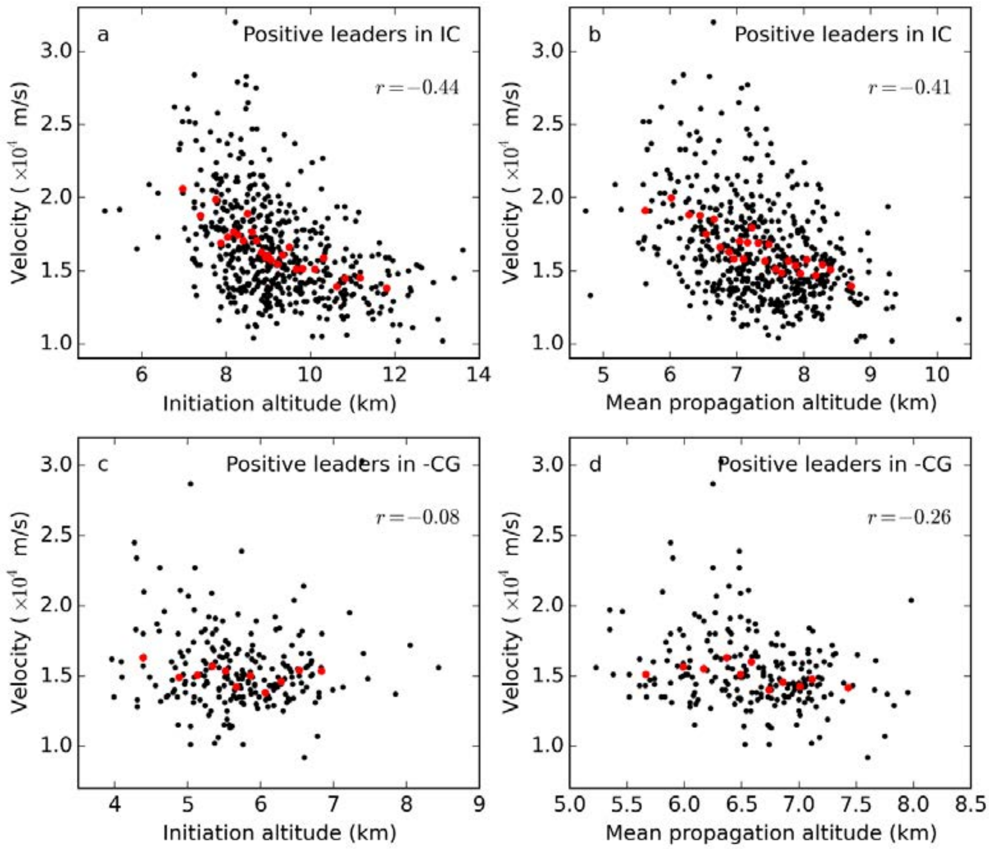

Figure 1. Relationships between positive leader velocities and initiation altitudes and mean propagation altitudes for (a and b) IC flashes and (c and d) -CG flashes. Red dots represent average velocities for every 20 consecutive black dots. Values of *r* represent correlation coefficients.

Correlation between the first return stroke of negative CG lightning and its preceding discharge processes

Using the negative cloud-to-ground (CG) lightning cases well located by the Fast Antenna Lightning Mapping Array (FALMA), we have studied the correlation between the first return stroke (RS_{1st}) intensity and its preceding discharge process which consists of preliminary breakdown (PB) and stepped leader (SL). The RS_{1st} intensity is measured from the range-normalized radiation field. The parameters used to characterize PB/SL include PB altitude, PB/SL vertical speed, PB/SL pulse rate and SL duration. Figure 2 exhibits the scatterplots of the parameters in the PB/SL process and the RS_{1st} intensity. We can see that the scatterplots in Figure 2 hardly exhibit meaningful correlations between the PB process and the RS_{1st} intensity, as reflected by extremely low Spearman's correlation coefficients if the raw data are used. However, on average, the PB processes with lower initiation altitude, faster vertical speed and higher pulse rate tend to be followed by stronger RS_{1st}. Compared to the PB process, the correlation between the SL process and the RS_{1st} intensity is significantly larger, no matter using the raw or averaged data. It indicates that a stronger RS_{1st} tends to follow a SL with a shorter duration, a faster vertical speed and a higher pulse rate. According to the above correlations, we speculate that the combination of a middle negative charge region (MNCR) with a uniform and wide horizontal distribution, and a small lower positive charge region (LPCR), is a favorable condition for an intense RS_{1st}.

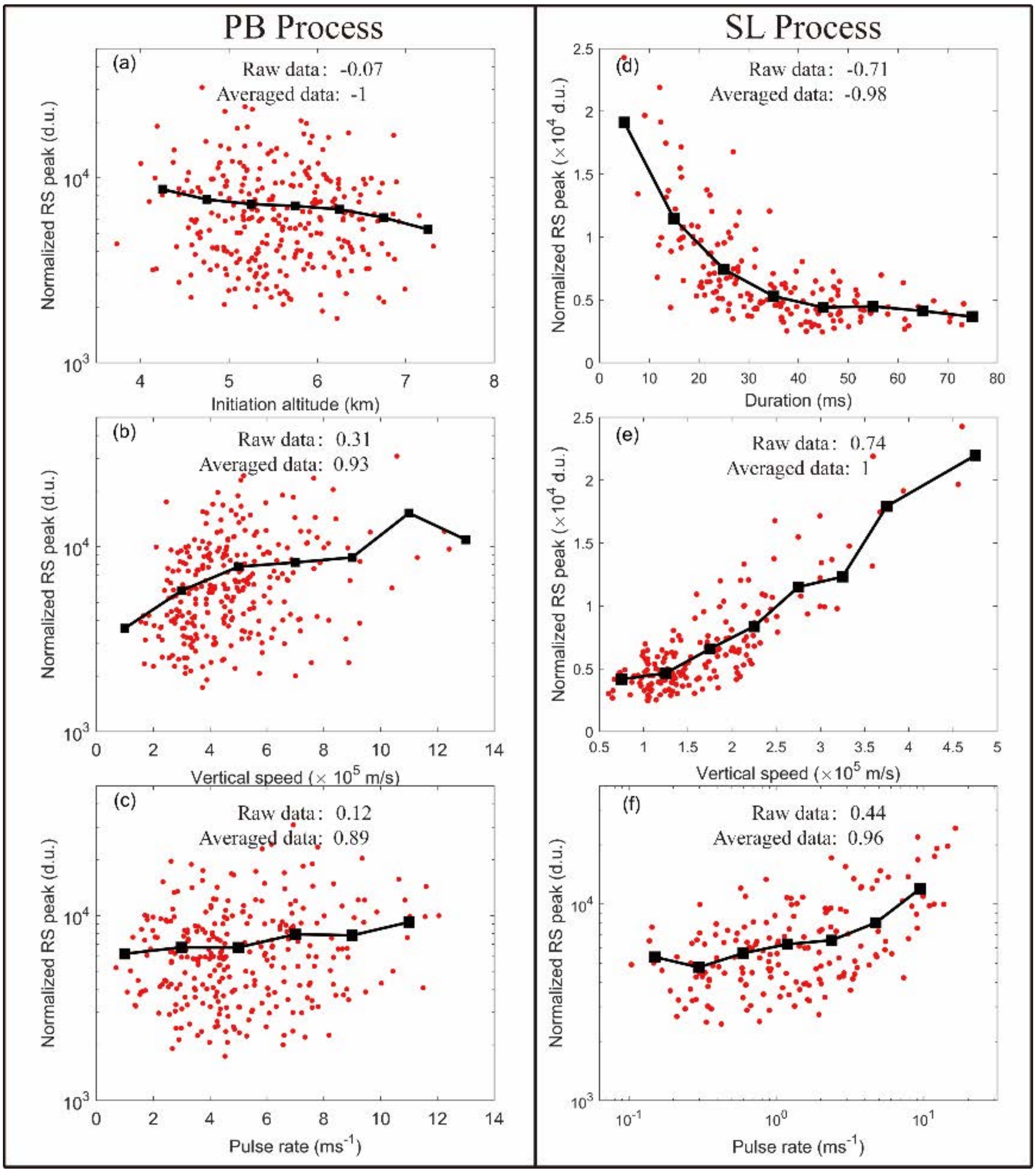

Figure 2. Scatterplots of the parameters in the PB/SL process and the normalized RS_{1st}

peak radiation field. The abbreviation d.u. stands for digital unit. Black squares indicate the averaged data. The Spearman's correlation coefficients for the raw and averaged data are given in each subplot.

Progression features of dart leaders in natural negative Cloud-to-Ground lightning flashes

We have analyzed the propagation process of nine dart leaders in four natural negative lightning flashes observed by a high speed optical system LAPOS 5. The propagation speeds range from 0.6 to 3.7×10^{7} ms^{-1} with an average value of 1.5×10^{7} ms^{-1}. The leader luminosity peaks at the front part of the leader head and decreases gradually backward within the head. The leader channel behind the leader head has a relatively low and constant luminosity. The average luminosity of the leader head is about 1.3 times brighter than that of the leader channel behind. The head lengths of 7 dart leaders were estimated to range from 21 to 88 m. Our results show that as the ground is approached, the dart leader propagates faster with its leader head growing brighter and longer. For different strokes within an individual lightning flash, it was found that the larger change ratio of leader head brightness relates with the larger change ratio of propagation speed and the larger change ratio of leader head length.

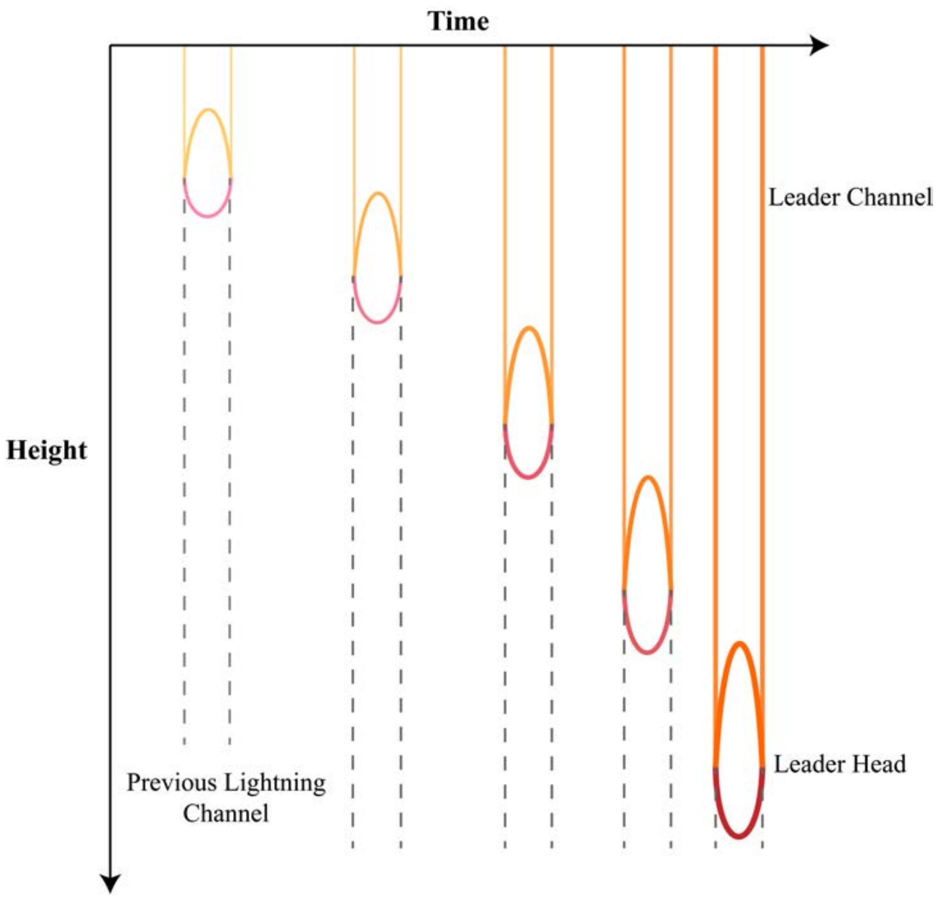

Figure. 3. A sketch to illustrate the propagation process of the dart leader. The dart leader tends to propagate faster with a brighter and longer leader head while the ground is approached.

Charge regions indicated by LMA lightning flashes in Hokuriku's winter thunderstorms

The charge distribution of some cells in three winter thunderstorms in the Hokuriku region of Japan is investigated based on Lightning Mapping Array (LMA) flash data. The vertical arrangements of charge regions involved in the discharges suggested diverse charge patterns, including quad-polar, tripole, positive dipole, inverted dipole, and inverted tripole. The riming electrification between graupel and ice crystals or their aggregations are thought to be responsible for the electrification of most cells. The charging process between snow/aggregates and ice crystals may be responsible for some inverted charge structure that occurred above 0°C isotherm and accompanied with weak radar echoes. Convection indicated by the vertical development of radar reflectivity appears crucial to shaping the diverse charge distribution patterns by determining which charging mechanisms occur and where; it also influences changes in height or even the disappearance of the charge regions. The charge cores are distributed from 0.7 to 5.3 km heights or from 2 to −31°C temperature, while the distances between adjacent charge cores with opposite polarities change between 0.2 and 3.4 km, with a mean of 1.3 km. The mean flash duration and horizontal distance are 425.0 ms and 19.8 km, respectively. The average height, temperature, and power of flash initiations are 2.8 km, −11.9°C and 15.6 dBW, respectively.

Publications:

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Wu, T., Wang, D., & Takagi, N. (2019). Intracloud lightning flashes initiated at high altitudes and dominated by downward positive leaders. Journal of Geophysical Research: Atmospheres, https://doi.org/10.1029/2018JD029907

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

Dongfang Wang completed his PhD thesis intitled “Three-Dimensional Lightning Location System Based on Fast Electric Field Change and Temporal-Spatial Distribution of Lightning Flash Over Beijing” and defended his PhD degree. He continues to serve as a stuff in IAP, CAS, mainly engaging in lightning detection technology, focusing on operation and upgrading of the Beijing Lightning NETwork.

Shanfeng Yuan completed his PhD thesis intitled “Study on Physical Characteristics and Initiation Mechanism of Tower-initiated Upward Lightning” and defended his PhD degree. He continues his postdoctoral research in IAP, CAS, mainly concerning tower-initiated upward lightning and the relevant physical and meteorological issues.

Our group continues research interests on the following topics: (1) Lightning Detection and Lightning Physics, observing rocket-triggered lightning and natural lightning based on VHF interferometry, LF/VLF lightning location network, channel-base current measurement, high-speed camera observation, and conventional meteorological observation. (2) Lightning Meteorology and Lightning Data Assimilation, revealing characteristics of electrification, lightning activity and their relationship with dynamics and microphysics in severe thunderstorm, and improving numerical weather forecast by using lightning data. (3) Transient Luminous Events in Middle and Upper Atmosphere, containing sprits, halo, gigantic jets and their occurrence mechanism.

Lightning Detection and Lightning Physics

Some new insights into the positive leader branching have been revealed. During the propagation of upward positive leader, we captured the nearby bidirectional leaders with clear asymmetrical channel extensions at opposite ends. They became new branches of positive leader by making connection with the lateral side of the progressing main positive channel. This kind of side discharge, together with the head-splitting, are considered as two important branching mechanisms of positive leader. Sometime the head splitting processes are invisible and can be revealed by subsequent recoil leader events (Yuan et al., 2019).

Regarding the propagation characteristics of positive, negative and recoil leaders, Qie et al. (2019) gave a detailed comparison based on our recent years' observation by high-speed camera, current measurement and electromagnetic field detections. The rare positive recoil leaders through pre-conditioned channels in both tower lightning and rocket-triggered lightning were summarized. Observational facts of intermittent propagation of positive leader during the initial and sustained development of positive leader were clarified. Additional analysis (submitted to JGR) on leaders' propagation before attachment of a flash striking a 325-m tower showed that downward negative leader stepping does not influence the hop-forward and restrike of positive leader.

Employing the comprehensive measurements in rocket triggered lightning, the subsequent CPT leaders with intensive chaotic pulse trains were analyzed in detail and compared with normal dart leaders and dart-stepped leaders occurring in a same flash. The CPT leader emitted much more intensive radiation at LF- MF, VHF and visible light band, accompanied by energetic radiation. We eventually determined that the large product of return stroke charge to 1 ms and the velocity of the leader (QV) could be a reliable proxy/indicator for CPT. (Pu et al., 2019). We also examined the underground magnetic field near the triggered lightning channel. By Comparing the microsecond-scale magnetic pulses during the upward leader as simultaneously detected in the subsurface space and at the 2-m depth soil, the magnetic signal was found to be modified by the soil medium, with typical attenuation of more than 55% and pulse peak delay of about 0.6 μs. The component with relatively high frequency is subject to more attenuation than is the component with relatively low frequency (Li et al., 2019).

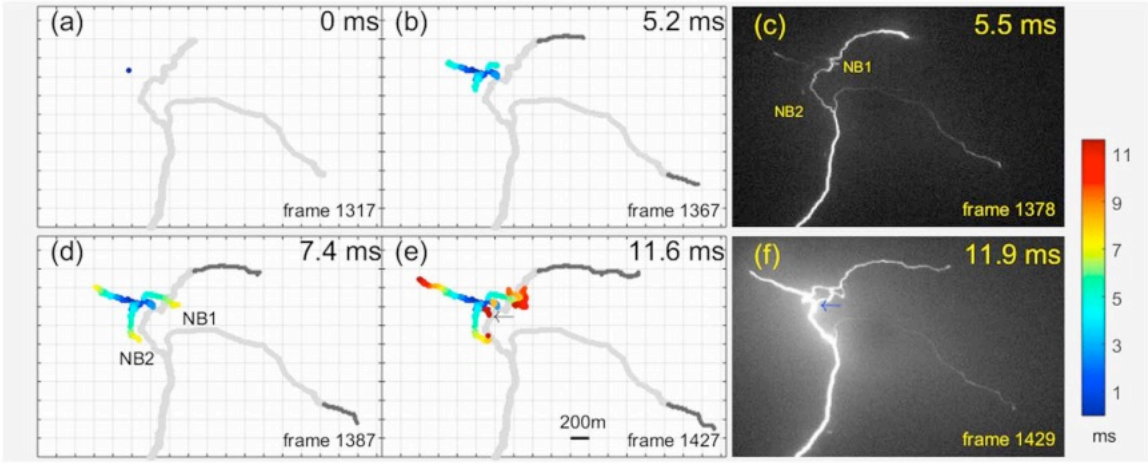

Figure1. Branching of the main positive progressing channel by the initiation, extension and junction of a bidirectional leader nearby.

Lightning Meteorology and Lightning Data Assimilation

A new lightning data assimilation (LDA) scheme comprehensively nudging water contents in the WRF model was developed at cloud-resolving scale. It took the dynamical and thermodynamic conditions into consideration and nudged the low-level water vapor and graupel mass in the mixed-phase region according to the detected total lightning flash rate and model environments. Benefiting from assimilation of lightning data, the simulated storm structure and surface cold pool are improved and closer to the observations. (Chen et al, 2019).

Characteristics of severe thunderstorms in plain area of Beijing, as came from the upstream mountains under weakly forced conditions were investigated, with 18 squall lines (SL) and 15 convective clusters (CC) compared in detail. Distinct features of the SL and CC storms are revealed in terms of their convective environments and mesoscale structures, such as cold pool, horizontal wind convergence, and humidity distribution. Low convective inhibition and high low level wind speed on the plains are common to both SL and CC, whereas higher vertical shear over the plains and stronger wind speed on both mountains and plains distinguishes SL from CC. Stronger wind and vertical shear in SL generate stronger and more organized downdrafts, producing a deeper cold pool, strong outflow and convergence. The cold pool produced in CC is shallower and weaker, resulting in weaker outflow and convergence and convective activities. (Xiao X. et al., 2019)

Transient Luminous Events in Middle and Upper Atmosphere

The parent CGs of the positive and negative sprites were found located in distinct thunderstorm regions with different lightning activity and thunderstorm structure, suggesting different conditions needed for inducing sprites in different polarities. The negative sprites are associated with intense, deep convection, and positive sprites are mostly associated with stratiform region without strong convection (Yang et al., 2018a).

Our study confirmed that positive halos are always accompanied by sprites, and negative sprites are usually associated with halos. The majority (353, or 71%) of ISUAL-observed halos are pure events without discernible streamer development. Due to the dependence on the timescale of impulse charge transfer for streamer development, many negative cloud-to-ground strokes with iCMCs exceeding the threshold for sprite production actually produce halos instead (Lu et al., 2018).

Gigantic jets (GJs) are mostly observed over summer tropical or tropical-like thunderstorms and are usually associated with convective surges or overshooting tops. Different from most of previous observations showing GJ-producing summer thunderstorms only produced GJ type of transient luminous events during their life cycles, our analysis indicates that the MCS provides favorable conditions not only for the GJ but also for the sprites (Yang et al., 2018b).

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UPC Lightning Research Group, Terrassa, Spain

After a successful campaign in August 2017, with results of 2 gigantic jets recorded at 900 frames per second presented at the ICAE 2018 in Nara, Japan, a second campaign for the observation of gigantic jets with a faster intensified camera system has been conducted by Oscar van der Velde in October and November of 2018, mainly from Barranquilla and Cartagena. Although there were many cloudy nights, this time 8 gigantic jets were detected with 3 events successfully recorded by the high-speed camera. One of them launched 3 separate branches to the ionosphere, another was a bright carrot-like event, which we could precisely study in time against ELF waveforms from our Cape Verde station and Duke University (Steve Cummer). The Geostationary Lightning Mapper luminosity was compared against jet luminosity and its cloud flash. The analysis paper was accepted with final revisions at Nature Communications. We noted also a significant number of sprites triggered by negative cloud-to-ground flashes in Colombia, which tend to be rare at mid-latitudes.

Jesús López, who assisted the campaigns and installed the Lightning Mapping Array in Colombia, obtained his Ph.D. in Barcelona, June 21st 2019. He published about the charge structures of two thunderstorms in Colombia in Journal of Geophysical Research – Atmospheres.

The group is now involved in the analysis of optical and TGF events detected by the Atmosphere-Space Interactions Monitor over Colombia. In relation to TGFs, Ferran Fabró published a paper (in journal) about the climatological differences across tropical regions producing different lightning to TGF activity ratios.

Gigantic jet captured from Cartagena, November 19th 2018.

University of Texas at Dallas

At UT Dallas Brian Tinsley worked with the late John Frederick in a series of papers in which they showed that stratus-type clouds in the Arctic (Alert, Canada) and Antarctic (South Pole) show thickening (measured as changes in longwave infrared thermal radiation) in response to changes in downward ionosphere-earth current density, Jz. The day-to-day Jz changes can be produced by day-to-day changes in the current output of thunderstorms and electrified showers, acting on the ionization produced throughout the atmosphere by the cosmic ray flux. Such changes can also be produced by solar wind – induced changes in polar ionospheric potential and in atmospheric column resistance. Together with Liang Zhang and Limin Zhou of East China Normal University a series of papers have been published that model electro-anti-scavenging (applicable to CN and small CCN) and electro-scavenging (applicable to large CCN and IN) that modify cloud microphysics and can produce these and other effects of atmospheric electricity on clouds.

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Frederick, J. E., Tinsley, B. A., Zhou, L., 2019. Relationships between the solar wind magnetic field and ground-level longwave irradiance at high northern latitudes. Journal of Atmospheric and Solar-Terrestrial Physics, 193, 105063. doi .org/10.1016/j.jastp.2019.105063

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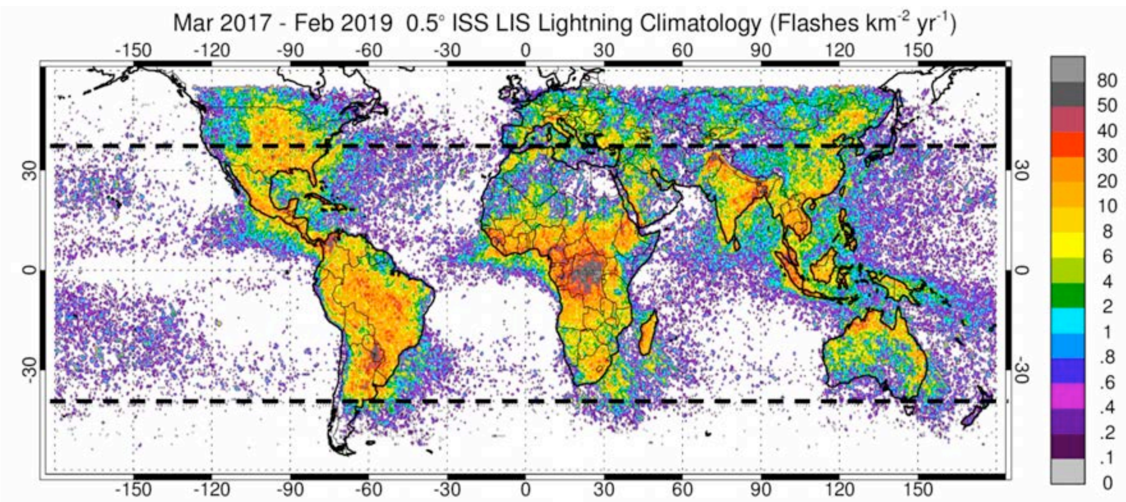
ICAE Newsletter contribution for 2019 No.1 issue - Contribution from the National Space Science and Technology Center with NASA Marshall Space Flight Center and University of Alabama in Huntsville

The on-going Lightning Imaging Sensor on International Space Station (LIS on ISS) mission continues to perform well. Although the prime mission concluded at the end of February 2019 (two years after launch), the excellent health of LIS and the great science benefit of continuing operations resulted in a decision by NASA Headquarters to a extend the mission through at least September 2020. For the first time since its predecessor mission, the Optical Transient Detector (OTD), ended in 2000, LIS is gathering lightning observations for important mid-latitude storms, as well as providing coverage of the continental U.S. and middle and southern Europe. Prior to LIS on ISS, OTD provided only five years of space-based observations north and south of 38^0 latitude, so there is great value in extending the time series observations of these climatically sensitive mid-latitudes. Other activities that benefit from the mission extension are operational applications of real-time LIS data by several NOAA (National Oceanic and Atmospheric Administration) agencies, which are only now ramping up. In addition, LIS on ISS now contributes important synergistic observations to those of the European Space

Agency (ESA) sponsored Atmosphere-Space Interaction Monitor (ASIM) to help unravel the causes and mechanisms leading to terrestrial gamma-ray flashes (TGFs).

LIS was successfully launched to ISS on February 19, 2017 as on a hosted payload on the Department of Defense Space Test Program - Houston 5 (STP-H5) mission. LIS on ISS has been continuously acquiring science data since its activation on February 27, 2017. It records the time, energy, and locations of lightning within its field-of-view. Since lightning relates to both thunderstorm and other atmospheric processes, NASA, other agencies, and the science community are using these data for weather, climate, air quality, and other studies. During its prime mission, LIS measurements helped calibrate and validate the new Geostationary Lightning Mapper (GLM) instruments that fly on the Geostationary Operational Environmental Satellite (GOES)-16 and -17.

The LIS Science Team now anticipates making a public announcement for the release of the Validated Level 2 data in August. Gridded data products will follow soon afterward. The LIS data is accessible through the Global Hydrology Resource Center (GHRC), one of NASA's Distributed Active Archive Centers (DAACs) at https://ghrc.nsstc.nasa.gov/lightning/ . As noted in previous newsletters, LIS on ISS data users should see little or no change from Tropical Rainfall Measuring Mission (TRMM) LIS in terms of data products, formats, software or access. However, in addition to maintaining the legacy data format, products cast in more modern netCDF format are now also available (and the earlier TRMM LIS data sets are now available in this format as well).



The map shows annual global lightning flash rate density (Flashes/km2 yr) from LIS on ISS during two years on orbit with view time and efficiency corrections applied. For the first time since the end of the Optical Transient Detector (OTD) mission in 2000, lightning can be observed over the entire continental U.S. and middle and southern Europe using LIS on ISS. This climatology agrees with results obtained from OTD and TRMM LIS. To emphasize the expanded mid-latitude coverage offered by LIS on ISS, the northern and southern limits of TRMM LIS are shown as dashed lines for comparison. Image credit: NASA's Marshall Space Flight Center.

Massachusetts Institute of Technology (Cambridge, MA)

Research organizations from 23 countries have generously contributed most of their ELF time series data to the MIT Super Cloud Site (with much assistance from Yakun Liu) for purposes of multi-station inversion calculations for the worldwide lightning activity in absolute units. Key contributors include Mike Atkinson, Jozsef Bor, Ciaren Beggan, Vasilis Christofilakis, Steve Cummer, Alexander Koloskov, Andrzej Kulak, Marc Lessard, Mariusz Neska, Rollin McCraty, Blanca Mendoza, Joan Montanya, Robb Moore, Masahito Nose, Janusz Mlynarczyk, Adriena Ondraskova, Pascal Ortega, Marni Pazos, Colin Price, Tero Raita, Rahul Rawat, Alfonso Salinas, Mitsutero Sato, Gabriella Satori, Sebastian Sevcik, Ashwini Sinha, Giorgos Tatsis, Yuri Yampolski, Xinyan Ouyang, and Xuemin Zhang.

Based on lightning stroke observations from both Earth Networks and Vaisala (GLD360), one day has been selected (January 28, 2019) when the African (chimney) source is clearly predominant. Anirban Guha has undertaken forward model calculations to check on the accuracy of the waveguide propagation conditions. In most cases, the agreement mode-by-mode is excellent, but some problem cases have also been identified. Inversion calculations based on the good-agreement cases, show indications of nonuniqueness linked with the diametrically-opposite Asian and American chimneys. We are working on that.

A scanning S-band radar 22 km from extensively documented "glows" on Mt Aragats in Armenia has proven valuable in diagnosing the phase of thunderstorm convection linked with specific kinds of Thunderstorm Ground Enhancements (TGEs). Negative TGEs are most prevalent during the End of Storm Oscillation (EOSO) when dominant negative charge is overhead, and when the reflectivity core of the storm is offset from the event. In contrast, the most energetic cases involve positive TGEs that are found in the "bulls-eye" of the low-level reflectivity, during microburst outflows and linked with field excursions associated with precipitation when the electrical axis of the storm is centered on the observation location. Presentations at the AGU Meeting on this topic are planned with Ashot Chilingarian, Hripsime Mkrtchyan and Suren Hovakimyan. Based on renewed discussion with Tamas Bozoki and Irina Mironova at the recent IUGG meeting in Montreal, we and others (Gabriella Satori, Alexander Koloskov, Yuri Yampolski, Mitsu Sato, Mariusz Neska, Ashwini Sinha and Anirban Guha) have committed to return to the problem of the pronounced deformation of the high-latitude Schumann cavity over the 11-year solar cycle. As suggested initially by Satori et al. (2016), the favored mechanism is based on energetic electrons (>30 keV) from the radiation belt, whose flux varies by more than three orders of magnitude. Since the flux of these electrons is quite variable on shorter time scales, a major endeavor at present is to look for correlated variations in Schumann resonance intensity in high-latitude station data (Vernadsky, Syowa, Hornsund and Maitri).

Earle Williams and Rohan Jayaratne gave an invited review talk at the IUGG meeting on the mysteries of charge separation in thunderstorms. A focal point of the talk was the reminder that both water and ice are exceptionally electropositive—they are prone to take on positive charge in contact with nearly everything else. This finding is consistent with experimental evidence that liquid water and ice surfaces (the latter presumed to be undergoing vapor deposition in typical laboratory scenarios) are negatively charged (OH^-) with compensating positive charge (H^+) inside the medium. These configurations are also consistent with the exceptional mobility of H^+ ions in water and ice, in comparison with all other ions. A remaining puzzle pertains to the rimed and often sublimating graupel particles that unlike almost everything else, take on negative charge when contacting ice crystals. Rime ice deserves attention!

Vaisala

Vaisala's U.S. National Lightning Detection Network (NLDN) underwent a complete sensor upgrade in 2013 followed by a central processor upgrade in 2015. Among the results of these upgrades were a major improvement in the detection efficiency of cloud lightning flashes as well as a substantial increase in the number of cloud pulses geo-located in each flash. However, these upgrades also re-aggravated a historical problem with the tendency to misclassify a population of low-current positive discharges as cloud-to-ground strokes when, in fact, most are probably cloud pulses. We have also identified some poorly geo-located events in which the contributing sensor data was either improperly associated or simply under-utilized by the geo-location algorithm. We have developed additional improvements to the central processing system in order to address these issues. In this presentation, we show the results of these improvements in comparison to the 2015 central processor version. The new central processor became operational on 07 November 2018 in North America. The upgrade was first reported at the 9th Conference on the Meteorological Application of Lightning Data of the 99th Annual Meeting of the American Meteorological Society in January 2019. It is available at https://ams.confex.com/ams/2019Annual/meetingapp.cgi/Paper/353551. A detailed follow-up paper describing the evolution of the NLDN since 2013 is currently in preparation

Vaisala has developed a new product that identifies when a cloud-to-ground (CG) lightning stroke involves continuing current. This data product leverages the complementary capabilities from Vaisala's ground-based NLDN and GLD360 lightning networks and data from NOAA's Geostationary Lightning Mapper (GLM) on the recently launched GOES-16 and GOES-17 satellites. The ground-based networks can identify and precisely locate CG strokes. While the GLM instrument cannot provide the same level of precision, it can identify sustained optical signatures that correlate with continuing current. The new data product tags those CG strokes reported by NLDN and GLD360 that match a suspected continuing current identified by the GLM. The small percentage of CG strokes that contain continuing current represent an important risk due to sustained heating. For the first time ever, maintenance and fire crews will be able to use an operational lightning data feed to target CG lightning events most likely to cause asset damage due to heating or start a wildfire. Vaisala plans to release a beta version to select customers by the end of the year.

ICAE Fall 2019 Newsletter announcement - ACLENet

African Centres for Lightning and Electromagnetics (ACLENet)

In October 2018, the African Centres for Lightning and Electromagnetics Network (ACLENet, https://ACLENet.org) was awarded a grant by the Ludwick Family Foundation that has enabled ACLENet to:

1. Form a Lightning Protection Working Group (LPWG) of volunteer LP specialists from the US Lightning Protection Institute and from the South African firm Lightning Protection Concepts to design and install LP on projects in Uganda. Our thanks to these volunteers!
2. Protect three more schools in Uganda (see map)
3. Publish newspaper inserts for general public education about lightning (available at https://aclenet.org/news-publications/publications/newspaper-

inserts.html) Newspaper inserts have been successful in fighting the HIV epidemic and teenage pregnancy in Uganda and teachers often use the inserts as posters or for help with lesson plans. Newspaper inserts #2 (lightning science and prevalence) and #3 (mechanisms of injury and safety) are scheduled for September and October 2019.

4. Fund two television broadcasts in Uganda on lightning science and safety.

Shipping of LP materials, import fees, and airport storage while these fees are being assessed, can be excessive. ACLENet, with help from LPWG, wants to see if we can decrease the cost of LP by using locally sourced materials instead of expensive imports and to design templates for typical school buildings that can be used throughout Africa.

There is more news as well as links to injury reports across Africa in The African Flash, ACLENet's monthly newsletter (past issues at https://aclenet.org/news-publications/newsletters/). To subscribe, contact Dr. Mary Ann Cooper at macooper@uic.edu or sign up at https://aclenet.org/news-publications/mailing-list.html.

Contributions from the Chinese Academy of Meteorological Sciences

A Method of three-dimensional location for LFEDA combining the time of arrival method and the time reversal technique

Based on fast electric field waveforms of the Low-frequency E-field Detection Array (LFEDA), we introduced the time reversal technique into lightning three-dimensional location for the first time and propose a new algorithm for the three-dimensional location of lightning low-frequency discharges. Without using complex filtering algorithms to remove higher-frequency component, this method obtains similar results to the newly reported LFEDA refinement algorithm. The new algorithm can obtain finer, more continuous, and richer positioning results with a minimum of four stations, 5-dB signal-to-noise ratio, and 500-ns time error compared with the low-frequency signal time of arrival three-dimensional positioning method. These results indicate that the new algorithm has the advantages of low requirements on the number of stations, certain anti-interference ability, and low requirements on time accuracy. The standard deviations in the X and Y directions for return strokes of triggered lightning flashes are both approximately 90 m. The comparison between the new method and conventional method can be shown in Fig. 1.

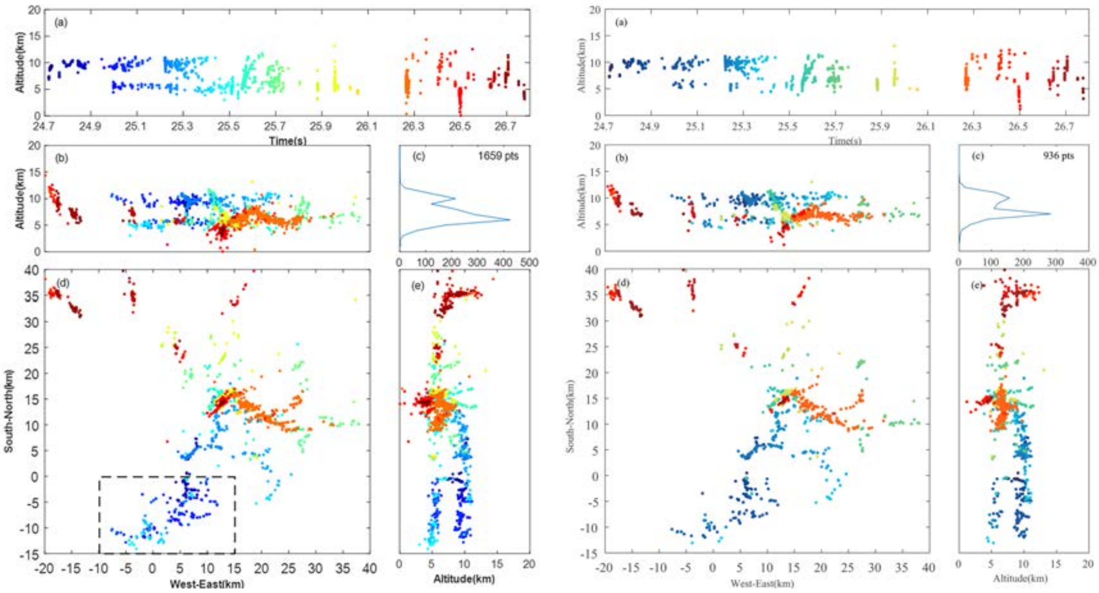


Fig.1 Positioning results of a lightning process at 16:26 on 15 August 2015 by the New algorithm (left) and a conventional TOA method (right).

Duration, spatial size and radiance of lightning flashes over the Asia-Pacific region based on TRMM/LIS observations

The geographical distributions of flash duration, length, footprint and radiance, as well as their correspondence with thunderstorm structures, are investigated for the first time in the Asia-Pacific region ranging from 70°E to 160°E and from 18°N to 36°N and in six specially chosen regions by employing flash data collected by the Lightning Imaging Sensor (LIS) aboard the Tropical Rainfall Measuring Mission (TRMM) satellite and TRMM based radar precipitation feature (RPF) data from 2002 to 2014. The flash length, footprint and radiance values are, on average, the largest over the deep ocean, followed by offshore waters and land. Flash duration is the longest over the offshore waters near the east coast of China, followed by the deep ocean and land. The Tibet Plateau and the northern part of the Indian Peninsula have the weakest flash properties in the study region. Furthermore, the geographic distributions of the flash properties exhibit evident seasonal changes. The monotonic relationship between flash spatial size and radiance is stronger than the monotonic relationships between flash duration and spatial size or radiance. Based on a comparison of the seasonal and regional changes in flash properties with RPF properties, convective intensity is proposed to play a crucial role in characterizing the flash spatial size and radiance, according to their inverse correlation in most regions. However, the climatological correspondence between flash duration and thunderstorm structures remains poorly constrained. We have launched a discussion of the possible association between thunderstorm structures and flash properties.

Initial results of a dual band 3-D lightning locating system

A newly designed dual-band lightning locating system that works in VHF and VLF/LF bands is used to locate lightning discharges by using Differential Time of Arrival method. The system currently consists of 14 dual-band sensors deployed over an area of 100 km in diameter in Chongqing, China, synchronized by GPS device with an accuracy better than 50 ns. Each of the sensor includes two parts: receiving and processing. The bandwidth of VHF receiver is 6 MHz, the center frequency of which can change from 30 to 300 MHz with a step size of 1 MHz. The center frequency used in Chongqing is 266 MHz to decrease electromagnetic interference. The output center frequency of the VHF receiver is 15 MHz. The VLF/LF receiver is similar to the circuit used in a fast electric field change meter with a decay time constant of 1 ms, is design to measure the electric field change caused by lightning. The processing module is made up of a high-speed A/D card with 14 bits resolution, a GPS receiver and a computer, which is responsible for real time parameter extraction and data storage. The VHF and VLF/LF signals are digitized continuously and independently at a sample rate of 20 MHz and 5 MHz respectively. The record lengths of the two channels are 25000 and 5000 samples respectively. The data recorded in each site include two categories, original waveforms and detected waveform parameters. The waveform data are comprised of the waveforms and the time information of the two bands. When the system is working, the parameter data will be saved and transferred back to the center station via the Internet at first, then the waveform data are saved to local storage as much as possible to keep the system running properly. The parameter extractions of VHF and VLF/LF waveforms are also independent. The parameters extracted from VHF waveform are peak value of pulse and time information. In addition to time and amplitude, the parameters extracted from VLF/LF signal also include some pulse feature used to identify the type of lightning such as polarity, rise time, fall time and pulse width. The widths of the extracting windows applied to VHF and VLF/LF signals are 100 μs and 1 ms respectively. Hence, the time resolutions of the VHF and VLF/LF location results are 100 μs and 1ms respectively too. The system can locate lightning discharges continuously, image the structure of lightning discharges in 3D and record the waveforms of lightning radiations. The location accuracy can be better than 200 m within the coverage of the sensors according to a Monte Carlo simulation. Most of the VLF/LF sources overlapped with VHF sources (Fig. 2). The combined observations are helpful to describe lightning more integrally and can be used to clarify the link between the sources of different frequency bands.

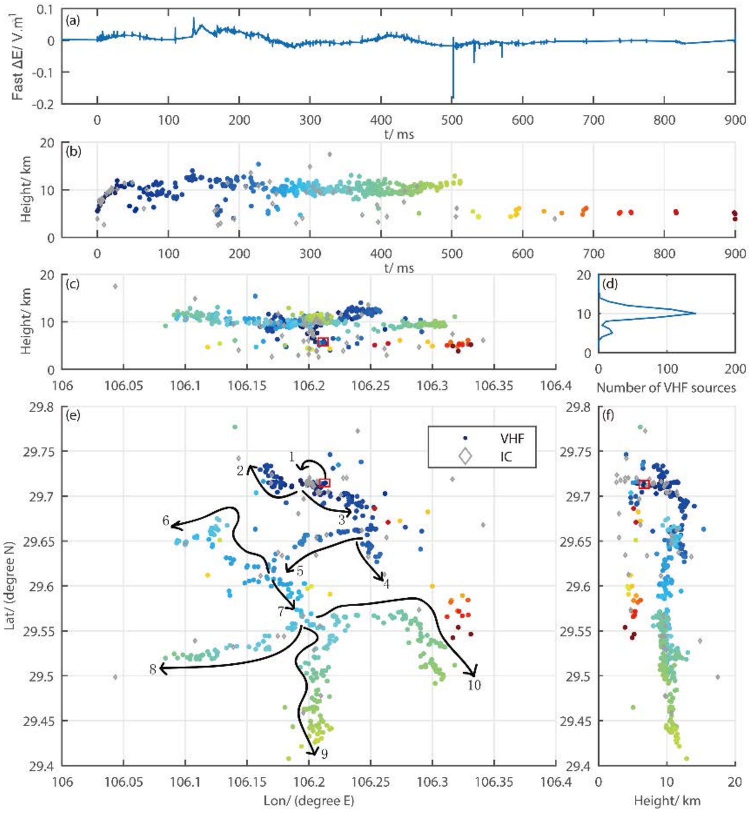


Fig. 2 An IC flash located by the system (a) Fast electric field change waveform, (b) VHF and VLF/LF sources altitude versus time, (c) east-west vertical view of the sources, (d) VHF source number distribution along height, (e) plan view, (f) north-south vertical view.

Inner-core lightning outbreaks and convective evolution in Super Typhoon Haiyan (2013)

Using lightning data from the World Wide Lightning Location Network, infrared satellite imagery, and microwave observations, we investigated lightning outbreaks and convective evolution in the inner core (0–100 km) of Super Typhoon Haiyan (2013), the strongest storm on record to make landfall in the northwest Pacific. This storm was characterized by intense lightning activity with half of the strokes occurring in the inner core. Three major inner-core lightning outbreaks and convective bursts (CBs) were observed during rapid intensification (RI), maximum intensity (MI), and weakening stages. These outbreaks coincided with favourable large-scale environmental conditions for TC development with higher sea surface temperature (29–30 °C), higher relative humidity (75–80%), and weaker deep-layer vertical wind shear (3–8 m s^{-1}), compared to the climatological averages for the month of November in the northwest Pacific. The RI lightning outbreak occurred primarily in the downshear quadrants and CBs were located inside the radius of maximum wind (RMW). The MI lightning outbreak occurred just after the eyewall replacement cycle, inducing marked depression of brightness temperature at 91-GHz. The lightning outbreak during Haiyan's weakening stage preferred the upshear–left quadrant outside the RMW. In contrast, relative lack of cloud-toground lightning in the rainbands was observed during all three main outbreaks. The radial and azimuthal distributions of lightning outbreak within the inner core provided indicative information on the relationships between convective structure and intensity changes of Haiyan.

Properties of negative initial leaders and lightning flash size in a cluster of supercells

Properties of negative initial leaders (NILs) and flash size in a cluster of supercells with generally inverted charge structure in Oklahoma on 10–11 May 2010 are examined, primarily using Lightning Mapping Array data. A method to identify NILs from Lightning Mapping Array source is proposed and helps to reveal the multiple NILs properties and their distributions. The NILs in the supercell cluster have smaller speed (median 3-D displacement speed: 0.65×10^5 m/s), relative to the previous reports in normal thunderstorms. Furthermore, median NIL speeds initially decrease with increasing height but begin increasing above 12 km. The NILs tend to decelerate during the early stage. The parameters characterizing flash duration and spatial size are also investigated. It is found that they all follow lognormal distributions and the spatial flash size is relatively small on average (median horizontal distance: 5.54 km). Most flashes (83.18%) extend primarily in the horizontal direction. Flash area shows an inverse relationship with flash density at their fast changes during storm evolution. Although large flash initiation density (FID) generally occurs in regions with small flash size, the smallest flash size is nearly not collocated with large FID value. In the regions with large FID, average flash duration roughly increases with increasing FID, while average flash area changes little. We proposed that the pattern of charge pockets and variation of charge density dominated by the strong kinematics are responsible for some new findings about the properties of NIL and flash size in the supercell cluster.

Synchronized two-station optical and electric field observations of multiple upward lightning flashes triggered by a 310-kA +CG flash

A positive cloud-to-ground (+CG) lightning flash containing a single stroke with a peak current of approximately +310 kA followed by a long continuing current triggered seven upward lightning flashes from tall structures. The flashes were observed on 4 June 2016 at the Tall Object Lightning Observatory in Guangzhou, Guangdong Province, China. The optical and electric field characteristics of these flashes were analyzed using synchronized two-station data from two high-speed video cameras, one total-sky lightning channel imager, two lightning channel imagers, and two sets of slow and fast electric field measuring systems. Three upward flashes were initiated sequentially in the field of view of high-speed video cameras (Fig. 3). One of them was initiated approximately 0.35 ms after the return stroke of +CG flash from the Canton Tower (see Fig. 3②), the tallest structure within a 12-km radius of the +CG flash, while the other two upward flashes were initiated from two other (see Fig. 3④ and 1⑤), more distant tall objects, approximately 18 ms after the +CG flash stroke. The initiation of the latter two upward flashes could be caused by the combined effect of the return stroke of +CG flash, its associated continuing current (see Fig. 3①), and K process in the cloud (see Fig. 3③). Each of these three upward flashes contained multiple downward leader/upward return stroke sequences, with the first leader/return stroke sequence of the second and third flashes occurring only after the completion of the last leader/return stroke sequence of the preceding flash. The total number of strokes in the three upward flashes was 13, and they occurred over approximately 1.5 s.

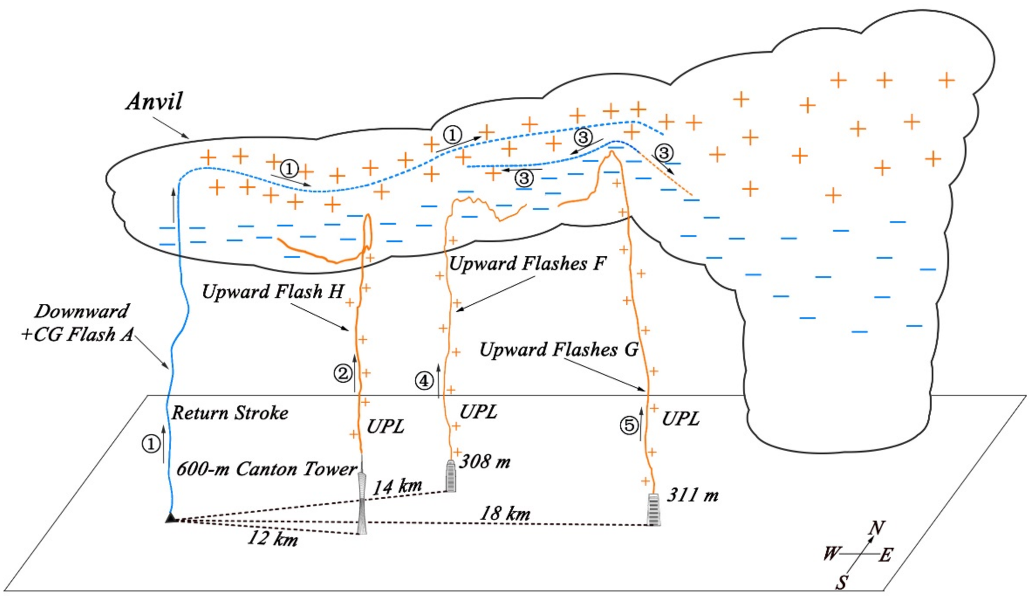


Fig. 3 The possible scenario of the sequential initiation of three upward flashes (H, F, and G) by +CG flash A. “+” refers to positive charge, and “–” refers to negative charge. The black solid triangle is the ground termination point of +CG flash A reported by the GDLLS. The arrows indicate the directions of channels extension. UPL represents upward positive leader. The dashed lines represent the inferred discharge processes in the cloud. The circled numbers refer to the sequence of the different discharge processes. CG=cloud-to-ground.

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Ball lightning as the main source of some gamma ray glows by Mikhail L. Shmatov, Ioffe Institute, St. Petersburg, Russia

The author has shown that photons of the prolonged gamma ray emission or, in other terms, gamma ray glow recorded by the GROWTH experiment on January 13, 2012 (Umemoto et al. 2016) could be emitted mainly by ball lightning, while other photons of this glow could be generated by annihilation of positrons which arose mainly due to production of the β^{+}-active isotopes by the sharp gamma ray flash (see also Enoto et al. 2017; it has been assumed that this flash accompanied the formation of ball lightning) and production of electron-positron pairs by photons from ball lightning (Shmatov 2019). The prolonged emission had a duration of about 60 s, its spectrum was a superposition of the continuum with the upper boundary of 6.5–10 MeV and a line identified with an electron-positron annihilation one (Umemoto et al. 2016). Ball lightning model proposed by the author (Shmatov 2003) was used. It is based on the assumption that ball lightning has a core consisting of clouds of electrons and almost totally ionized ions which oscillate with respect to each other.

A search for visible light from ball lightning in the GROWTH and other experiments on a search for high-energy photons of atmospheric origin was proposed and several problems related to identification of sources of prolonged gamma ray and/or X-ray emissions with ball lightning were considered (Shmatov 2019).

Termination of gamma ray glow by ordinary lightning (see e.g. Wada et al. 2018) could result, in particular, from attraction of ordinary lightning to ball lightning. The situations when ball lightning initiates ordinary lightning seem also to be possible. These assumptions correspond to observational data (Brand 1923; Imyanitov and Tikhii 1967). Both aforementioned effects can be related to ionization of air by high-energy photons from ball lightning.

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