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# 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 GEOSCIENCES UNION

SOCIETY OF ATMOSPHERIC ELECTRICITY OF JAPAN

***Comment on the photo above:*** **This is the negative upward connecting leader of a downward positive CG lightning discharge that caused severe damage to the blade of a windmill. The picture was one frame of the high-speed video taken at Uchinada, Japan by using Photron camera operated at 300000 fps. If you watch the video through ICAE official website http://www.icae.jp/, you will be able to see how leader steps dance along different branches. The detailed description of the lightning flash can be found in the ICLP2016 paper titled "A positive lightning discharge that caused severe damage to the blade of a windmill" by Daohong Wang, Norio Sawamura and Nobuyuki Takagi of Gifu University, Japan.**

# ANNOUNCEMENTS

## AWARDS

At the 33rd International Conference on Lightning Protection (Sep. 25-30, 2016, Estoril, Portugal) Karl Berger Award was awarded to: Prof. Farhad Rachidi and Prof. Silverio Visacro; Rudolf Heinrich Golde Award was awarded to: Prof. Akihiro Ametani and Prof. Jinliang He.

## CONFERENCES

### 4th International Symposium on Winter Lightning (ISWL2017)

This symposium will be held in Niigata-ken, Japan during April 12-14, 2017, which is a good season to enjoy Japanese cherry blossoms.
Abstract submission deadline: October 31, 2016.
Full Paper Submission deadline: January 9, 2017.
For detail, please visit http://www.iswl2017.jp/index.html.

### European Geosciences Union General Assembly 2017 (EGU 2017)

This assembly will be held in Vienna during April 23-28, 2017. The following two sessions are for our community.

**Atmospheric Electricity, Thunderstorms, Lightning and their effects (NH1.4/AS1.6/SSS0.29)**
**Convened by Yoav Yair, Serge Soula, Yukihiro Takahashi, Giles Harrison, Colin Price, Hans-Dieter Betz**

Topics:
Atmospheric electricity in fair weather and the global electrical circuit
Atmospheric chemical effects of lightning and the contribution of LtNOx
Middle atmospheric Transient Luminous Events - new observations
Global lightning and climate change
Thunderstorms, flash floods and severe weather
Modeling of thunderstorms and lightning
Now-casting and forecasting of thunderstorms

# ANNOUNCEMENTS

Planetary Lightning and related electrical phenomena
Lightning detection networks
New space, airborne and ground-based observation platforms

**High Energy Radiation from Thunderstorms and Lightning (AS4.1)**
**Convened by Sebastien Celestin, Thomas Gjesteland, and Martino Marisaldi.**

High energy radiation from thunderstorms has been measured from space, aircraft, and ground-based detectors. Thunderclouds produce bursts of gamma rays, electrons, and positrons into space. They also produce continuous energetic radiation events, which have been measured at ground level and on board aircraft. High energy radiation has also been detected in association with lightning leaders and laboratory sparks.

The physical processes associated with the production of these phenomena are not fully established yet, neither are the effects of this radiation on the upper atmosphere and the near-Earth environment.

In this session, we welcome contributions about experimental, observational, and theoretical studies related to the production of energetic particles in the atmosphere. In particular, phenomena such as terrestrial gamma ray flashes (TGFs), terrestrial electron beams, gamma ray glows, thunderstorm ground enhancements, and X-ray observations from lightning and laboratory discharges, as well as their relationships to one another are of great interest.

DEADLINE for Receipt of Abstracts is 11 January 2017, 13:00 CET.

Abstract submission is at: http://meetingorganizer.copernicus.org/EGU2017/abstractsubmission/23037.

The Early Career Scientist's Travel Support (ECSTS) (deadline: 1 December 2016).
For more information please visit http://egu2017.eu/financial_support.html.

More information about the EGU General Assembly 2017 can be found at: http://www.egu2017.eu/.

## The Tenth Asia-Pacific International Conference on Lightning (APL 2017)

This conference will be held during May 16-19, 2017 in Krabi, THAILAND.
The full paper submission deadline is November 30, 2016.
For detail, please visit http://apl2017.org/.

# ANNOUNCEMENTS

## Joint Assembly 2017 hosted by IAPSO, IAMAS and IAGA

This assembly will be held from 27 August to 1 September, 2017 in Cape Town, South Africa.
For this assembly, the following four sessions are either convened or co-convened by ICAE.

### I. Lightning discharges and Transient Luminous Events: Characteristics, Physics and applications

**Conveners: Maribeth Stolzenburg, Marcelo Saba, Joan Montanyà**

Various forms of lightning discharges initiate within clouds in the troposphere, while Transient Luminous Events (TLEs) propagate in the stratosphere and mesosphere above thunderclouds. Although these phenomena have widely varying scales, lightning and TLEs share some physical characteristics that can be investigated with similar optical, radio-wave, and electromagnetic techniques. This session invites papers related to the character of electrical discharge phenomena within the lower and middle atmosphere, including lightning, Narrow Bipolar Events, Terrestrial Gamma-ray Flashes, and TLEs.

Initiation and propagation of electrical discharges and their relation to the underlying thunderstorm charges will be discussed. Additionally, papers describing lightning chemistry, including NOx production and its variation with lightning and thunderstorm parameters, are of interest. We also encourage contributions describing the physical mechanisms and applications of lightning attachment to ground.

### II. Recent development of lightning and thunderstorm detection networks and their applications in meteorology

**Conveners: Ushio Tomoo, Eric Defer, Stan Heckman**

Lightning is a very long discharge in atmosphere and is produced in an electrified thunderstorm. Under the thunderstorm, heavy rain, strong winds, and tornadoes are also produced and become threats to our lives.

Knowing where lightning occurs in thunderstorm is essential to understand storm electrification, and lightning physics, and observing thunderstorm structure is important to investigate relationship between lightning and thunderstorm environment and thunderstorm characteristics.

In this session, recent development of lightning and thunderstorm detection network and their applications in meteorology including 1) Lightning Location System from Ground and Space, 2) Radar Observation, 3) New Technology to detect Lightning and New Radar Technology, 4) Now-casting and forecasting of thunderstorm, flash flood, and severe weather are discussed.

### III. Thunderstorm coupling to the upper atmosphere

**Conveners: Colin Price, Steven Cummer, Paula Fagundes, Andrew Collier**

While thunderstorms occur in the troposphere, sensitive to conditions at the Earth's surface, their impact can expand through the stratosphere, mesosphere, ionosphere and into the magnetosphere.

This session focuses on this coupling between thunderstorms and the upper layers of the atmosphere. This coupling could be dynamical (gravity and acoustic waves), electromagnetic (ELF/VLF waves, EMPs), electrostatic (sprites), chemical (NOx production, airglow emissions), or a combination (heating of the lower ionosphere). Furthermore, the EM energy couples through the lower ionosphere and into the upper ionosphere and magnetosphere. These topics are related to present and future satellite and ISS experiments.

We welcome papers on all aspects of the coupling between thunderstorms and the upper atmospheric layers.

**IV. Space weather throughout the solar system: bringing data and models together**
**Conveners: Sarah Gibson, Enrico Camporeale, Kyung-Suk Cho, Giuseppe Consolini, Christina Plainaki, Earle Williams**

The science behind Space Weather is becoming increasingly multidisciplinary.

From solar eruptions, to solar-wind /magnetosphere/ionosphere interactions, to complex couplings of the Earth's global electrical circuit and Schumann resonances, to space-weather impacts on other planetary environments, the scientific puzzles to solve are complex and require advances in modeling. Nowadays, forecasting models range from completely empirical, such as the prediction of geomagnetic indexes based on statistical regression analysis, to physics-based, for example, state-of-the-art MHD simulations of Coronal Mass Ejection propagation. The paradigm of 'grey-box modeling' lives between these two extrema: data-driven reduced models that on one hand stem from a physics description, and on the other hand rely on data analysis to fit the free parameters. This approach is highly effective for interpreting space-weather-related data. It can also be a useful tool in support of space missions throughout the solar system, as seen for example in global radiation modeling that includes the parameterization of space weather conditions in plasma- interaction scenarios. All of these modeling approaches benefit from mathematical techniques that have been typically studied in contexts outside that of space weather. This topic is thus a fertile ground for a broad range of interdisciplinary collaborations.

We encourage contributions pertaining to recent progress in the effective incorporation of data into space weather modeling and prediction at any point along the chain from sun to planets. Moreover, we welcome approaches that are less traditional in the space weather community but possess potential for significant progress in forecasting and understanding space weather, and that draw upon ""lessons learned"" or ""best practices"" from applications to non-space-weather problems."

CALL for abstracts: 14 Nov, 2016.
Deadline for submission of abstracts with grant application: 17 Feb. Dead line for submission of abstracts without grant application: 3 March. Notification of acceptance of abstracts: 7 April. Notification of program allocation: 21 April. Early bird registration deadline: 5 May.
For detail, please check http://iapso-iamas-iaga2017.com/.

# ANNOUNCEMENTS

## The International Conference on Lightning & Static Electricity 2017 (ICOLSE 2017)

This conference will be held in Nagoya, Japan during Sept. 13-15, 2017.
The deadline for abstract submission is Jan. 20, 2017.
For detail, please visit http://icolse2017.org/index.html.

## XIV International Symposium on Lightning Protection (SIPDA 2017)

This symposium will be held in Natal, Brazil, from 2-6 October, 2017. It is organised by the Institute of Energy and Environment of the University of São Paulo with the technical sponsorship of the Institute of Electrical and Electronics Engineers - IEEE.

The aim of the Symposium is to present and discuss recent developments concerning lightning modelling and measurement techniques, as well as grounding and lightning protection. Prospective authors are invited to submit full papers on the following topics:

1) Lightning Physics, Characteristics and Measurements
2) Lightning Detection and Location Systems
3) Lightning Protection of Substations and Transmission Lines
4) Lightning Protection of Medium and Low-Voltage Distribution Networks
5) Lightning Protection of Structures and Installations
6) Lightning Protection of Electronics and Telecommunication Systems
7) Grounding
8) Lightning Electromagnetic Fields and Electromagnetic Compatibility
9) Equipment Testing and Standardisation
10) Lightning-caused Accidents and Injuries

Deadlines:
Full paper submission: 15 May 2017.
Notification of final acceptance: 1 July 2017.
For more information, please contact sipda@iee.usp.br or visit the symposium website at http://www.usp.br/sipda.

# CONFERENCE REPORT

## Thunderstorms and Elementary Particle Acceleration (TEPA-2016) Nor Amberd, Armenia, 3–7 October 2016

The problem of the thundercloud electrification and how particle fluxes and lightning are initiated inside thunderclouds are among the biggest unsolved problems in atmospheric sciences. The relationship between thundercloud electrification, lightning initiation, and particle fluxes from the clouds has not been yet unambiguously established. *Cosmic Ray Division of Yerevan Physics Institute (YerPhI), Armenia and Skobeltsyn Institute of Nuclear Physics of Moscow State University (SINP), Russia* already 6th year are organizing Thunderstorms and Elementary Particle Acceleration (TEPA) annual meeting, creating environment for leading scientists and students to meet each other and discuss last discoveries in these fields (see reports of previous TEPA symposia in Fishman and Chilingarian, 2010, Chilingarian, 2013, 2014, 2016).

The CRD have an impressing profile of the investigations in the new emerging field of high-energy physics in the atmosphere. New designed particle detector networks and unique geographical location of Aragats station allows to observe in last 7 years near 500 intensive particle fluxes from the thunderclouds, which were called TGEs – Thunderstorm ground enhancements. Aragats physicists enlarge the TGE research by coherent detection of the electrical and geomagnetic fields, temperature, relative humidity and other meteorological parameters, as well as by detection of the lightning. Adopted multivariate approach allows relate different fluxes, fields and lightning occurrences and finally come to a theory of the TGE. One of most intriguing opportunities opening by observation of the high-energy processes in the atmosphere is their relation to lightning initiation. C.T.R. Wilson postulated acceleration of electrons in the strong electric fields inside thunderclouds in 1924. In 1992 Gurevich et al. developed the theory of the runaway breakdown (RB), now mostly referred to as relativistic runaway electron avalanches - RREA. The separation of positive and negative charges in thundercloud and existence of a stable ambient population of the cosmic ray MeV electrons enables acceleration of the electrons in direction of the Earth's surface and to open space (Terrestrial gamma flashes, TGFs). Thus both TGEs and TGFs precede the lightning activity and can be used for the research of poorly understood lightning initiation processes providing key research instrument – fluxes of electrons, neutrons and gamma rays originated in the thunderclouds. Information acquired from the time series of TGEs and TGFs along with widely used information on the temporal patterns of the radio waveforms will help to develop both reliable model of lightning initiation and detailed mechanism of electron acceleration in thunderclouds.

### TOPICS OF THE SYMPOSIUM:

30 participants from Russia, USA, Germany, Israel and Armenia present 20 plenary talks and 10 posters in 5 sessions:

- Research of the Thunderstorm ground enhancements (TGEs) observed by particle detectors located on earth’s surface;

- Research of the Terrestrial gamma-ray flashes (TGFs) observed by the orbiting gamma-ray observatories;
- Relation of Lightning to the TGE and TGF;
- Monitoring of TLEs and thunderstorms from the orbit;
- Cloud electrification and atmospheric discharges: measurements and applications.

Two discussions were hold:

- Data bases in high-energy atmospheric physics description and way ways to establish cooperation;
- Do lightning discharges produce relativistic particles?

Visit to Aragats research station 18 km from Nor Amberd conference center near south summit of Aragats Mountain coincide with installation of new detectors measuring UV and IR radiation from lightning bolt (collaboration YerPhI- SINP).

Among the most important results reported and discussed at symposia was the relation of TGEs to lightning.

- During numerous thunderstorms on Aragats there were no particles fluxes registered simultaneously with lightning;
- In 2015-2016 23 events were detected when lightning abruptly terminates particle flux from clouds;
- Investigations of pulses shape from particle detectors and atmospheric discharges prove that all pulses from detectors are electromagnetic interferences (EMI) because:
    - ♦ only some of particle detectors show pulses, for instanced in stacked detectors upper scintillators don't count any peaks and the third bottom detector demonstrate huge peak;
    - ♦ all peaks consist from bipolar pulses, pulses from genuine particles have unipolar shape;
    - ♦ large EASs hitting neutron monitor generate genuine multiple peaks without any relation to lightning.

Observed on Aragats fluxes of electrons, gamma rays and neutrons can be explained with standard RREA + MOS theory with CR electron seeds (Chilingarian, Mailyan and Vanyan, 2012, Chilingarian 2014). Lightning does not generate high-energy particles!
Large TGEs open conductive channel for lightning and usually lightning occurred at LARGE TGEs and stop them! TGE is essential for the lightning initiation!

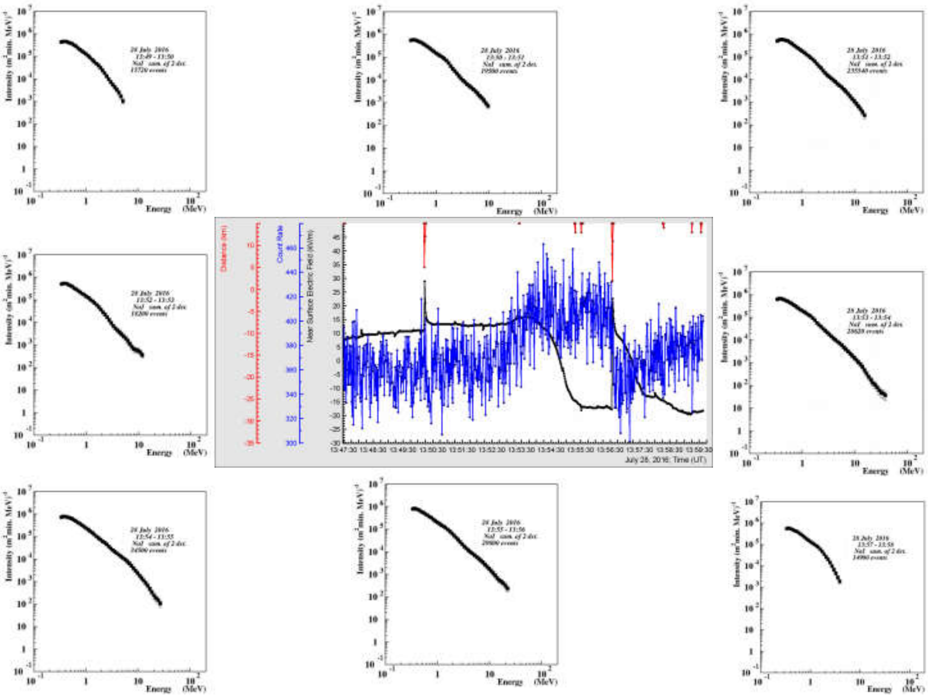

Figure 1 TGE observed on July 28 2016 with lightnings 2 time terminated particle flux. At biginning of TGE (13:49) the energy spectra prolonged up to 10 MeV, reaching 40 MeV at maximal perticle flux at 11:53.

Symposia participants agree that the topic of High-Energy Physics in Atmosphere (HEPA) is well progressing:

- There is big activity in several countries to establish surface particle detectors for research in TGE physics;
- RB/RREA model with CR seeds well explain TGE measurements worldwide;
- Planned research of TLE and TGF from orbit can be coupled with surface measurements;
- The established links with meteorology, atmospheric electricity, Atmospheric Cherenkov Telescopes (ACT) experiments, are very promising;
- Lightning mapping arrays will be very important addition to Aragats facilities;
- New fast electronics will reveal origin of TGEs and TGE-lightning relations;
- Broad collaboration with Space and Lightning physics experiments will significantly improve research and understanding in the new emerging HEPA field.

# RECRUITMENT

## Faculty Position in Lightning Physics, Department of Physics and Space Sciences - Florida Institute of Technology

The Department of Physics and Space Sciences at Florida Institute of Technology invites applications for a permanent faculty position in the electrical properties of thunderstorms, lightning, and the effects of thunderstorms in the near-earth space environment. This position is at the rank of assistant or associate professor, but higher ranks may be considered for senior or well-established candidates. Outstanding applicants from all research fields of atmospheric and space electricity will be considered, and candidates with prior experience in modeling, algorithm development, lightning and atmospheric data analysis, hardware development, instrumentation, field measurements, and optical and X-ray imaging are particularly encouraged to apply. Candidates with a background in atmospheric sciences, radio science, remote sensing, or laboratory transient electrical discharges are also encouraged to apply. While we are particularly interested in candidates who can strengthen and develop our world-class research program, a strong commitment to teaching at the undergraduate and graduate levels is also required.

Florida Tech hosts one of the largest physics and space sciences programs in the U.S. The Department of Physics and Space Sciences has 130 undergraduates and 35 graduate students. Being founded to support NASA, and being only a few miles from the Kennedy Space Center, we are tightly integrated into the federal and private space industry. Information about the department and its current research activities can be found at http://cos.fit.edu/pss/. For more information, interested candidates should contact Dr. Daniel Batcheldor and/or Dr Amitabh Nag. To apply email searchpss@fit.edu with the subject "Position # PSS706". In a single PDF provide a cover letter, CV, statements of research and teaching experience and interests, and the names and contact information of at least three references. Review of applications will begin immediately, but applications will be accepted until the position is filled. Florida Tech is an equal opportunity employer.

## Post-doctoral Position in Lightning Physics, Department of Physics and Space Sciences - Florida Institute of Technology

The Department of Physics and Space Sciences at Florida Institute of Technology invites applications for a post-doctoral research associate in the area of lightning and atmospheric electricity. Outstanding applicants from all research fields of atmospheric and space electricity will be considered, and candidates with prior experience in electromagnetic measurement systems, instrumentation development, field experiments, data analysis and modeling are particularly encouraged to apply.

Florida Tech hosts one of the largest physics and space sciences programs in the U.S. The Department of Physics and Space Sciences has 130 undergraduates and 35 graduate students. Being founded to support NASA, and being only a few miles from the Kennedy Space Center, we are tightly integrated into the federal and private space industry. Information about the department and its current research activities can be found at http://cos.fit.edu/pss/. For more information, interested candidates should contact Dr. Amitabh Nag. To apply email anag@fit.edu with the subject “Lightning Postdoctoral Position”. In a single PDF provide a cover letter, CV, and the names and contact information of at least three references. Review of applications will begin immediately, but applications will be accepted until the position is filled. Florida Tech is an equal opportunity employer.

## Atmospheric and Oceanic Sciences (AOS) at Princeton University, and Centro de Modelado Científico (CMC) at Universidad del Zulia

**Ángel G. Muñoz, Marling Juárez, David Sierra-Porta, Xandre Chourio, Joaquín Díaz-Lobatón (for the CatEx Team)**

Earlier this year, our team showed [Muñoz *et al.* 2016] that it is now possible to provide skillful forecasts of lightning at *seasonal* scale up to a few months in advance, due to long-enough records (almost 20 years) from the NASA Lightning Imaging Sensor-Optical Transient Detector missions, and the identification of robust sources of predictability associated with both large- and regional-scale climate drivers (this claim was soon after corroborated by an independent study [Dowdy, 2016] using a similar statistical methodology). These results are now becoming part of an early warning system for lightning and other extreme events in the Lake Maracaibo basin, called SIVIGILA (details here: http://cmc.org.ve/portal/proyectos.php?proyecto=35, in Spanish). As it is well known, Lake Maracaibo is the place in the world with the highest density of lightning [Albrecht *et al.*, 2016], impacting human lives and socio-economic activities in a highly vulnerable country like Venezuela.

The first phase of SIVIGILA was launched on June 30th this year, and consists of a set of products aimed at providing context information (historical behavior), and continuous monitoring of intra-cloud and cloud-to-ground lightning activity in the basin. Two commercial (Boltek) lightning detectors are used for the system, and a new World Wide Lightning Location Network (WWLLN) detector --built by our team-- is being installed at the moment, and will provide quasi-real-time cross-validation of the detected events.

These services are available to the public in the Latin American Observatory [Muñoz *et al.,* 2010, 2012] Datoteca, a local version of the International Research Institute for Climate and Society (IRI) Data Library: http://datoteca.ole2.org/maproom/Sala_de_Sivigila/#tabs-2 (see Fig. 1).

The second phase of SIVIGILA, which is expected to start in early 2017, involves the provision of both short-term and seasonal-scale lightning forecasts using a combination of dynamical and statistical models, following IRI's 'Ready-Set-Go' approach as explained in Muñoz *et al.* [2016]. Sub-seasonal forecasts are also expected to be provided at a later time, so a full cross-timescale set of products can be available to de decision-makers.

A variety of research activities, all under the name of the "Catatumbo Experiments", or *CatEx*, continue to be performed by our team in collaboration with the Venezuelan Air Force and the Venezuelan Virtual Center for Meteorology (CvM), involving the analysis of physical mechanisms associated with lightning and its predictability, using statistical and high-resolution dynamical models (Fig. 2A), reanalysis, satellite data and local field campaigns (Fig. 2B).

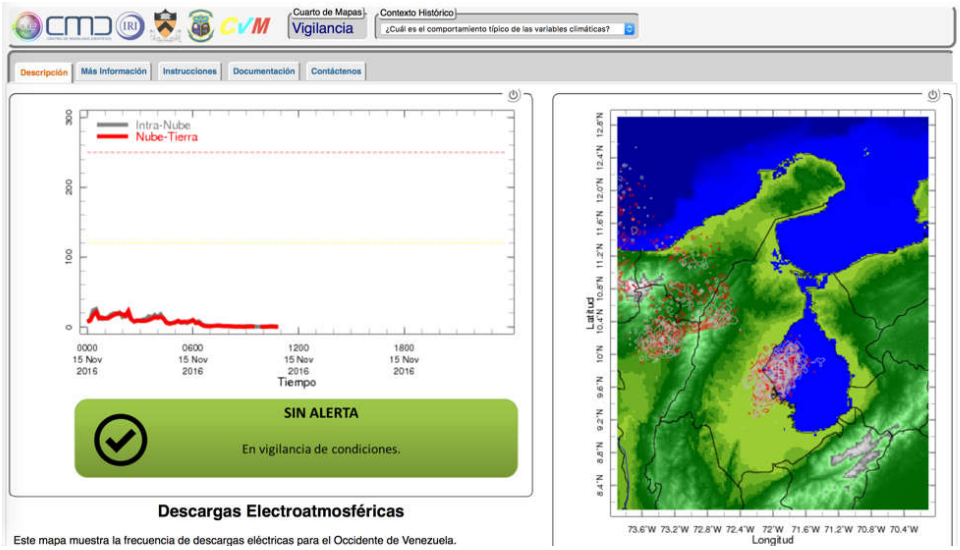


**Fig. 1** One of the products of SIVIGILA available in the Latin American Observatory Datoteca (see main text). The time series on the left shows the temporal evolution of intra-cloud (in grey) and cloud-to-ground (red) lightning in the Lake Maracaibo basin, shown in the right panel. For this day (Nov 15th, 2016) no warnings have been issued until noon: “Sin Alerta”.

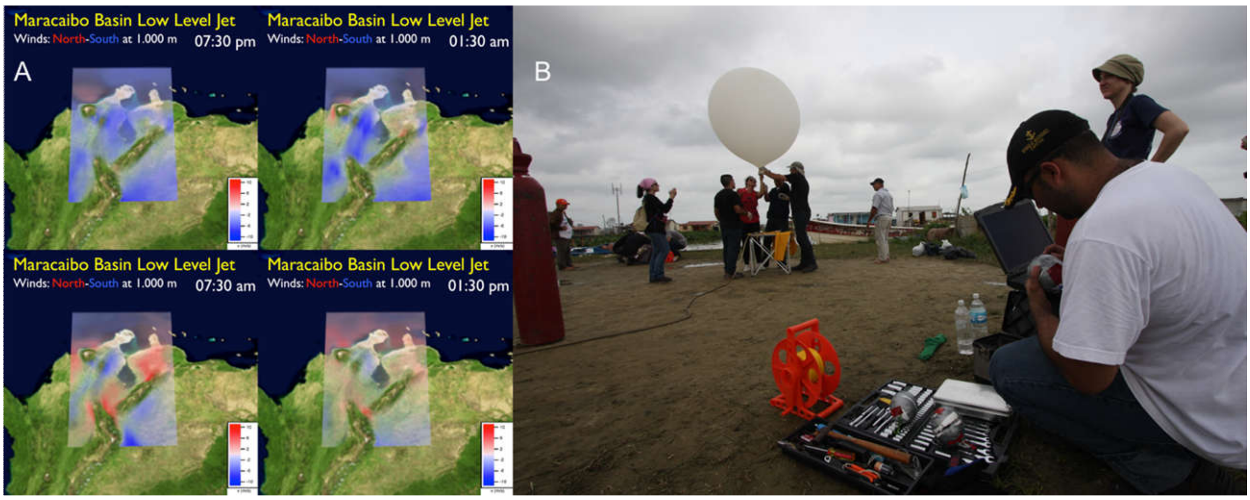


**Fig. 2** (A) Diurnal cycle of meridional winds at 1 km above sea-level, showing the evolution of the Maracaibo Basin Low Level Jet, a key driver of lightning in the zone of interest; climatology based on a 13-year simulation using the Weather and Research Forecasting -WRF- model. (B) A typical *CatEx* field campaign (picture is for May 2015): micro-sensors are tied along the lines of tethered balloons, acquiring meteorological variables every 10-30 minutes from surface to approximately 1.2 km above sea-level.

## Atmospheric electricity group of Lanzhou, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China

We have observed lightning in Datong, Qinghai Province, China by using a 3D lightning radiation source locating system (LLR for short), based on the TOA technique, for 8 years. Based on part of the data, Wu et al. (2016) recently published a JGR paper on the initial preliminary breakdown pulses and their correlation with thunderstorm charge structures. The results can be summarized as follows.

We analyzed the initial spatiotemporal development direction and propagation path of lightning for 591 flashes and divided preliminary breakdown process of lightning into two processes (IPBP and SPBP) based on the different development direction of the streamer where the initial radiation sources developed upward or downward, which occurred before the initial streamer became approximately horizontal, as the “initial preliminary breakdown process” of the lightning （shown in Figs. 1 and 2）. We found there are two different categories of the subsequent preliminary breakdown process (SPBP) for IC flashes and redefined preliminary breakdown process of IC flashes. For the first category, shown in Fig. 3, where the IPBP first ends at the moment of the channel changing to a horizontal propagation (i.e., when the SPBP begins): At this point, the horizontal channel develops continuously for some distance before converting to an upward or downward propagation, and the feature of pulses produced by the process of upward or downward propagation shows clustering (i.e., when the SPBP ends). As with the first category, the IPBP in the second category ends when the channel changes to a horizontal propagation (i.e., when the SPBP begins). However, for this category of SPBP, the horizontal channel develops continuously and does not stop until the appearance of the first K events, shown in Fig. 4.

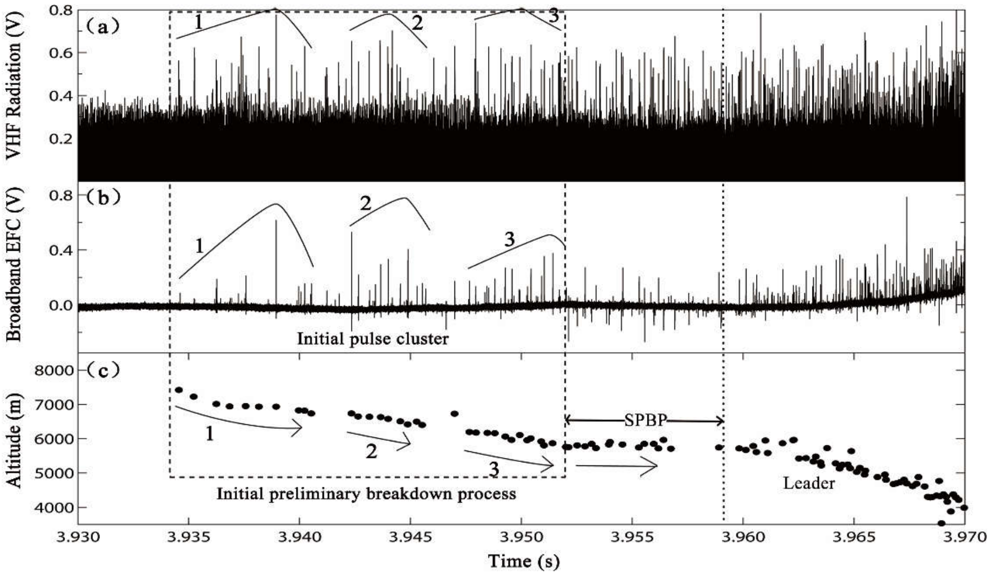


**Fig. 1** The initial preliminary breakdown process of negative CG flash 201503: (a) VHF radiation (relative value), (b) broadband electric field change (relative value), and (c) mapping altitude of the radiation sources.

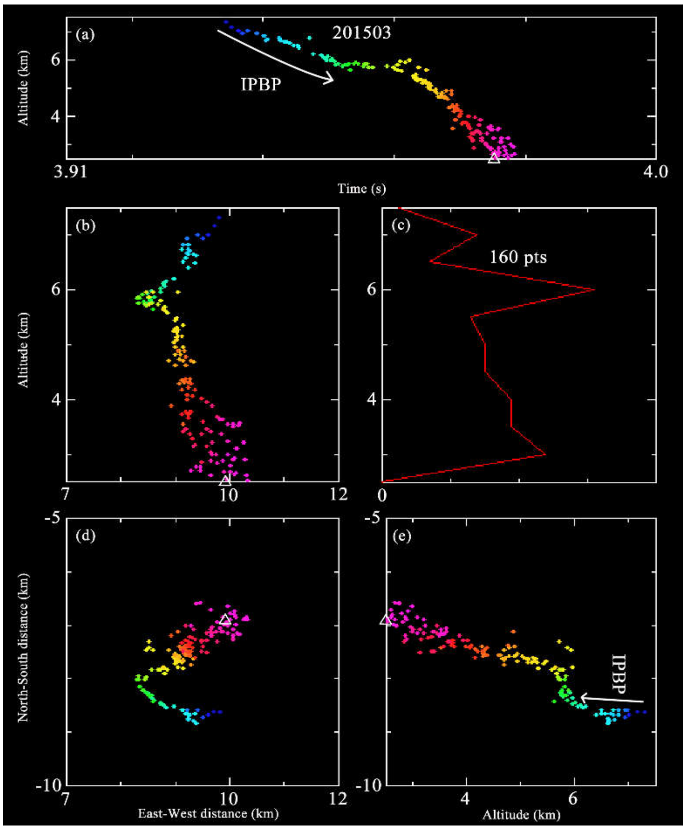


**Fig. 2** Radiation sources of the negative CG flash 201503 discharge: (a) height-time plot, (b) north-south vertical projection, (c) height distribution of the number of radiation events, (d) plan view, and (e) east-west vertical projection of the lightning radiation sources.

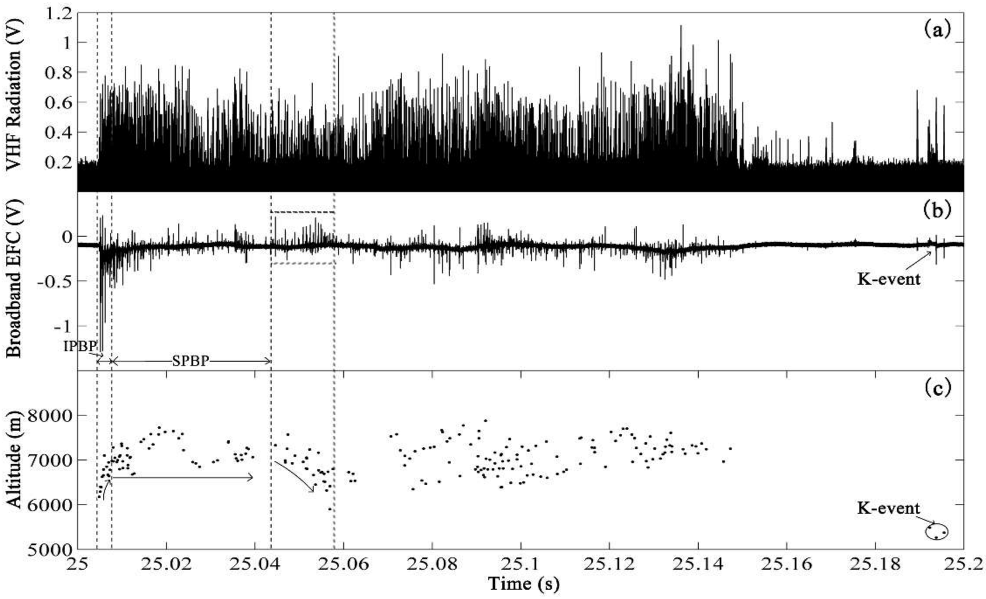


**Fig. 3** The preliminary breakdown process of the first category of IC flashes, showing the synchronized charge for the radiation sources in flash 205725 (25.00–25.20 s): (a) the VHF radiation (relative value); (b) the broadband electric field change (relative value); and (c) the altitude.

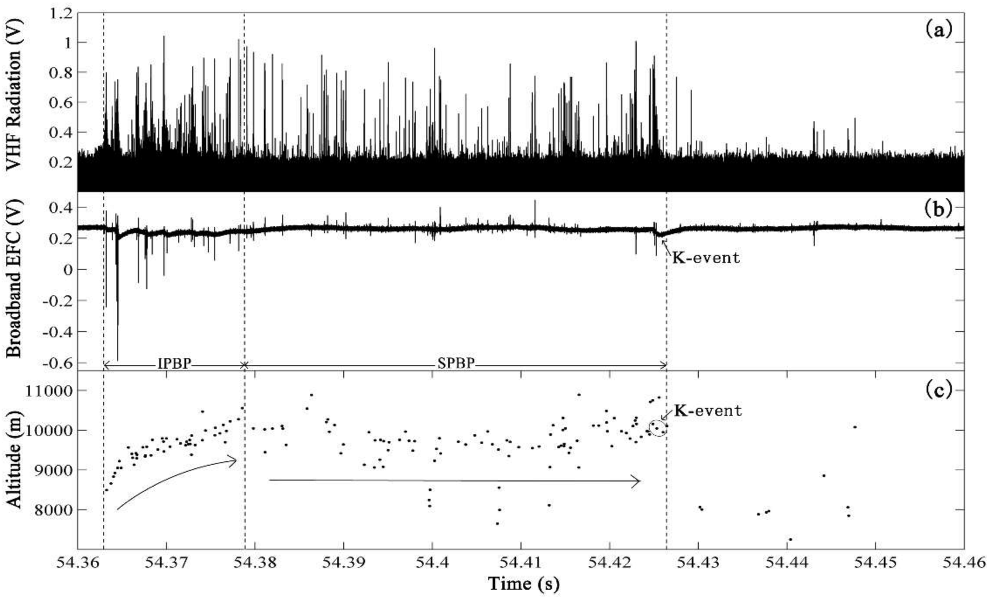


**Fig. 4** The preliminary breakdown process of the second category of IC flashes, showing the synchronized charge for the radiation sources in flash 210954 (54.36–54.46 s): (a) the VHF radiation (relative value), (b) the broadband electric field change (relative value), and (c) the altitude.

We also analyzed the correlation between the propagation direction of the initial streamer and the polarity of the initial pulse cluster, as well as the correlation between the propagation path of the initial streamer and the thunderstorm charge structure before the lightning occurred. The statistical analysis shows that the streamer propagation distance of the initial preliminary breakdown process maintained good consistency with the number of the initial pulse clusters generated in the initial preliminary breakdown process. When the initial preliminary breakdown process included multiple pulse clusters, the initial streamer exhibited a discontinuous discharge channel through a stepped development traveling upward or downward. Each step corresponded to a pulse cluster. The polarity of the initial pulse cluster was consistent with the propagation direction of the initial streamer in the initial preliminary breakdown process, and the propagation direction of the initial streamer was consistent with the charge structure of the thunderstorms. When the polarity of the initial pulse cluster was negative, the IC and negative cloud-to-ground flash occurred in the positive dipole structure of the normal-polarity tripolar charge structure. When the polarity of the initial pulse cluster was positive, the IC flash occurred in the inverted-dipole charge structure or the negative dipole structure of the normal-polarity tripolar charge structure.

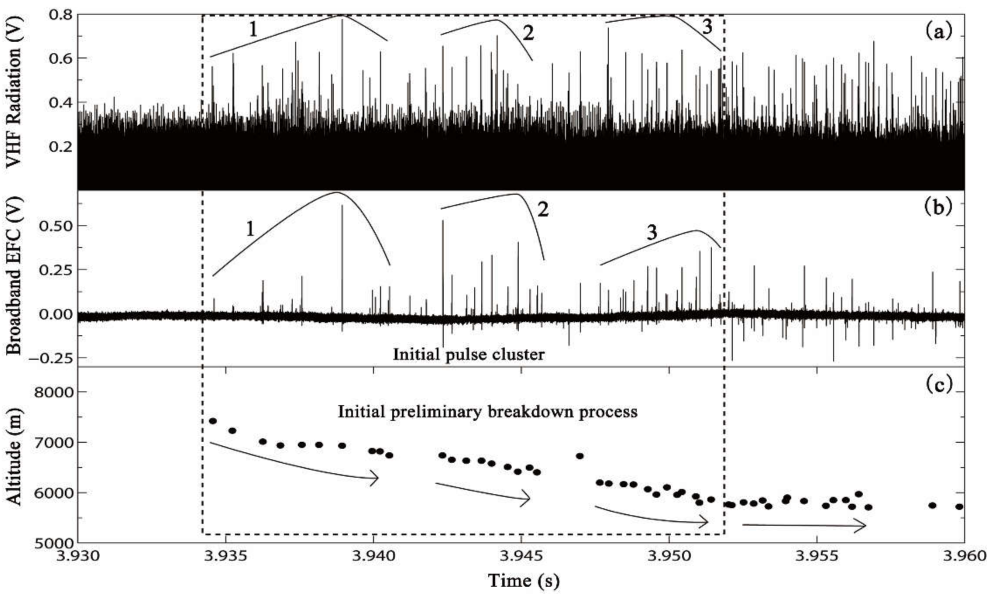


**Fig. 5** The synchronized charge of (a) the VHF radiation (relative value), (b) the broadband electric field change (relative value), and (c) the altitude of the radiation sources in negative CG flash 201503.

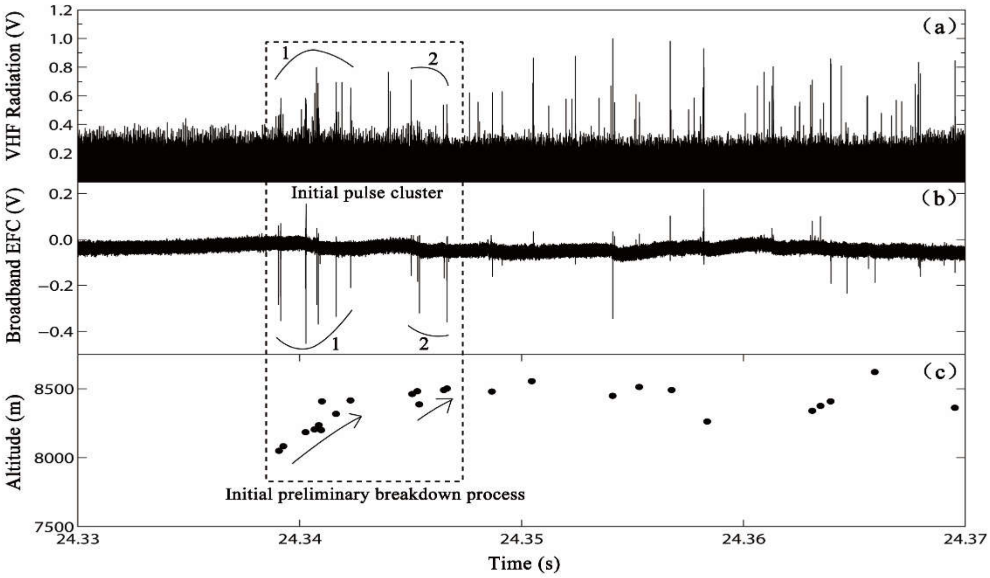


**Fig. 6** Negative CG flash 201124: (a) VHF radiation (relative value), (b) broadband electric field change (relative value), and (c) mapping altitude of the radiation sources.

## Atmospheric electricity research group in Bulgaria

<u>**Analyses of lightning data**</u>: ATDnet lightning data over the territory of Bulgaria for the period 2012-2016 were analyzed to determine the temporal and territorial lightning distribution. Some results confirmed those obtained for other regions in Europe, such as the relationship between lightning activity and terrain topography, the clear annual (with a maximum during the warm half of the year) and diurnal cycles (with a maximum between 1200 and 1500 UTC) of lightning activity. It was also established that the number of flashes and the number of days with thunderstorm increase with the increasing of the average height up to 1200m. Above this height, no trend between detected flashes and average height was found. This work will be submitted for publication soon (B. Tsenova, National Institute of Meteorology and Hydrology, boryana.tsenova@meteo.bg).

Relationship between lightning (flash rate, multiplicity and polarity) and radar (maximum radar reflectivity, radar cloud top, radar reflectivity, VIL,etc) parameters of different types of thunderstorms developed over Bulgaria was studied (R. Mitzeva, Sofia University, rumypm@phys.uni-sofia.bg, B. Markova, National Institute of Meteorology and Hydrology, boryana.markova@meteo.bg, Ts. Dimitrova, Hail suppression agency, dimitrova_tsvetelina@abv.bg, S. Petrova, Sofia University, asavita@phys.uni-sofia.bg). Results show that in most of the analyzed thunderstorms 1) the first flashes are detected when echo-height of 40 dBZ is above 6-7 km AGL (temperatures lower than -15°C) and radar cloud top is above 10 km AGL (temperatures lower than -35°C); 2) there is an increase in flash rate after a sharp increase of height of 40 dBZ above isotherm -20°C, and

height of 15 dBZ above -40°C; 3) A logarithmic correlation is established between flash rate averaged in 1 km bin, and heights of different radar reflectivity only for thunderstorms with high average flash rate (FR>2/min). The analyses reveal that there is a difference in lightning behavior in different type of hail producing thunderstorms. The main results are: 1) there is a positive time lag between the jumps of both multiplicity and flash rate and the registration of large hail on the ground; 2) significant numbers of positive total strokes are detected in both supercell and multicell which evolved into supercell storms, especially during the period of large hail falls on the ground; 3) in the supercell storm an "lightning hole" in flash density occurred, associated with an existence of bounded weak-echo region of the cell.
Analyses on thermodynamic characteristics at the development of thunderstorms over Bulgaria (land) and Black sea are performed (B. Markova, R. Mitzeva, S. Petrova, Ts. Dimitrova). Results support the traditional thermal hypothesis that the difference in temperature and humidity over land and sea may explain the difference in lightning activity.

Since 2011 at the National Institute of Meteorology and Hydrology a scheme for forecasting the lightning activity over Bulgaria was developed based on some instability indices calculated using ALADIN output (B. Tsenova). Studies are carried out with the aim to improve this scheme. It was established for example that the additional consideration of some forecasted by ALADIN parameters (such as integrated solid and liquid water mixing ratios between 3 and 6 km) could improve additionally the lightning probability forecast.

**Numerical simulations:** The non-hydrostatic model MesoNH was used to evaluate the effects of charging at low effective water content (parametrization based on the theoretical assumptions of the "Relative Growth Rate Hypothesis") and low cloud temperature (parametrization based on laboratory results obtained in Avila et al., 2011) on two simulated cloud charge structure and lightning activity (B. Tsenova, D. Barakova, National Institute of Meteorology and Hydrology, denitsa.barakova@meteo.bg, R. Mitzeva). Results showed that the inclusion of the charge separation at very low effective water content influences more the simulated cloud charge structure than does the inclusion of the charge separated at low temperatures. Also, the effect of the charge separated at very low effective water content is more pronounced when the original parameterization for non-inductive charging is based on the effective water content rather than on the rime accretion rate.

The thunderstorm research groups in Bulgaria work in collaboration with colleagues from Laboratoire d'aerologie, Toulouse, France, from NOA, Athens, Greece and from the Nowcast GmbH, Munich, Germany.

## Department of Meteorology, University of Reading

Keri Nicoll and Giles Harrison are leading a new effort to enable atmospheric electricity researchers worldwide to share data easily. The GLOCAEM (GLObal Coordination of Atmospheric Electricity Measurements) project is a UK NERC funded project to set up an online near real time data repository, hosted by CEDA – the Centre for Environmental Data Analysis. The project will focus on Potential Gradient (PG), air-Earth current (Jc) and conductivity measurements and the seven project partners are currently working on producing a standard data format for files to allow ease of interpretation. As well as providing access to near real time data, archiving of historical datasets is also planned within the project lifetime. GLOCAEM is happy to incorporate new partners so anyone who has a dataset of at least one of the above mentioned electrical variables, which they are willing to share, is encouraged to contact the PI Keri Nicoll at k.a.nicoll@reading.ac.uk.

## Laboratory of Lightning Physics and Protection Engineering (LiP&P), Chinese Academy of Meteorological Sciences (CAMS), Beijing, China

**Model study of relationship between updraft core and graupel non-inductive charging regions.** Using a 3-D charging-discharging cloud resolution model, an isolated thunderstorm was simulated based on the sounding data in Beijing for investigating the spatial relationship between the updraft core (where the updraft speed >5 m/s) and the graupel non-inductive charging region (GNCR). The characteristics of updraft in GNCR were also analyzed. The results showed that the GNCR mainly distributed in and around the updraft core. The non-inductive charging processes in the GNCR always had a relatively high charging efficiency (RHCE) with the absolute value greater than 0.1 nC/m$^3$. In the region of updraft speed center, graupel can still obtain charges through the non-inductive charging processes. But too strong updraft speed was disadvantageous for appearance of more efficient non-inductive charging efficiency (MENCE), which absolute value was greater than 0.5 nC/m$^3$. In this simulation case, the RHCE almost appeared only when the maximum updraft speed was higher than 5 m/s. The regions with RHCE were usually distributed in the regions with the updraft speed range from -4 to 28 m/s. Although the area with MENCE would extend wider and its position would be closer to the updraft center while the maximum updraft speed became stronger, the center of the area with MENCE never overlapped with the updraft center, and always appeared in the region with the updraft speed less than 20 m/s. Additionally, the height of the updraft speed center was approximately coincident with the height of inverted temperature. It could be used to separate the regions where graupels obtained negative and positive charges respectively through the non-inductive charging processes in operation in the future: during most of the time the updraft core existing, graupel in the regions near or above this height will obtain negative charge dominantly; graupel in the regions beneath this height will be charged by positive charge.

**Characteristics of cloud-to-ground lightning strikes in the stratiform regions of mesoscale convective systems.** To better understand the characteristics of cloud-to-ground lightning (CG) strikes in the stratiform regions of mesoscale convective systems (MCSs), radar and CG data from 10 MCS cases in China are comprehensively analyzed. Results show that stratiform CGs have characteristics distinct from those of convective CGs. A significant polarity bias appears in convective CGs, but the polarity bias in stratiform CGs is either undetectable or opposite that of the bias of convective CGs. The medians of the first return stroke current for positive and negative stratiform CGs have mean values of 59.7 kA and -37.3 kA, respectively; these values are 26% and 24% higher than the corresponding mean values for positive and negative convective CGs, respectively. In contrast to stratiform CGs, the first return strokes of convective CGs have polarized currents. Most convective CGs have relatively low currents, but most CGs with maximum currents in MCSs also fall within convective CGs. In the 10 MCSs studied, most stratiform CGs strike the ground at or near the edge of a region whose maximum reflectivity (≥30 dBZ) occurs at 3–6 km height (e.g., Fig. 1). The characteristics of reflectivity across this region are consistent with the reflectivity characteristics of the brightband; thus, this study provides important evidence for the relationship between the brightband and stratiform CGs. A charging mechanism based on melting of ice particles is speculated to be the key to initiating stratiform lightning. This mechanism could induce the propagation of lightning from the convective region to the stratiform region, thereby explaining the observed strikes on the ground nearby.

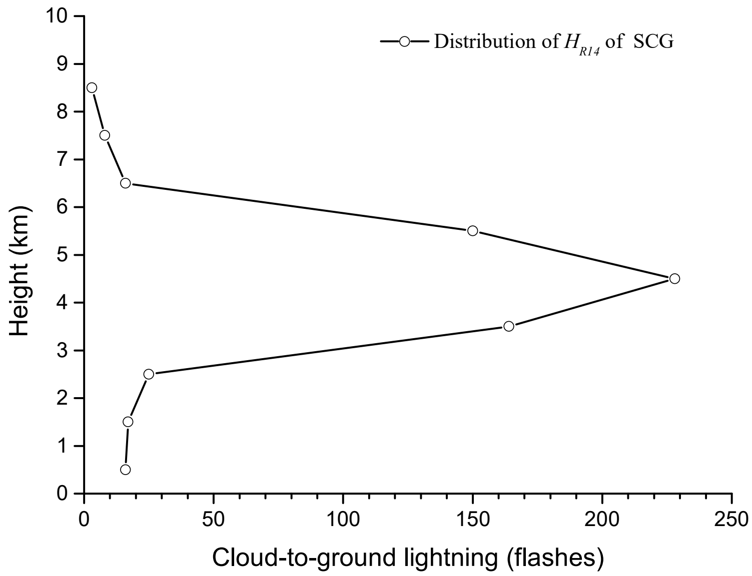


**Fig. 1** Height distribution of $R_{14}$ (the maximum reflectivity within a 14 km radius of the stroke point of an SCG)

**The role of dynamic transport in the formation of the inverted charge structure in a simulated hailstorm.** The inverted charge structure formation of a hailstorm was investigated using the Advanced Weather Research and Forecasting (WRF-ARW) model coupled with electrification and discharge schemes. Different processes may be responsible for inverted charge structure in different storms and regions. A dynamical-derived mechanism of inverted charge structure formation was confirmed by the numerical model: the inverted structure was formed by strong updraft and downdraft under normal-polarity charging conditions such that the graupel charged negatively in the main charging region in the middle-upper level of the cloud. The simulation results showed the storm presenting a normal charge structure before (Fig. 2a) and after hail-fall (Fig. 2d); while during the hail-fall stage, it showed an inverted charge structure—negative charge region in the upper level of the cloud and a positive charge region in the middle level of the cloud—appearing at the front edge near the strong updraft in the hailstorm (Figs. 2b and 2c). The charging processes between the two particles mainly occurred at the top of the cloud where the graupel charged negatively and ice crystals positively due to the strong updraft. When the updraft air reached the top of the storm, it would spread to the rear and front. The light ice crystals were transported backward and forward more easily. Meanwhile, the positively charged ice crystals were transported downward by the frontal subsidence, and then a positive charge region formed between the 10 and 25°C levels. Subsequently, a negative charge region materialized in the upper level of the cloud, and the inverted charge structure formed.

Figure 3 illustrates a conceptual model of the normal and inverted charge structure formation in the hailstorm. In the non-hail-fall stage (Fig. 3a1), the mixed region of graupel and ice crystals is situated in the middle of the cloud. The charge separation taking place among the different particles involve normal-polarity processes. The graupel charges negatively and ice crystals positively in the colder regions of the cloud. When the two types of particles collide, the light positive ice crystals are transported to the upper level, and then the normal charge structure forms (Fig. 3a2). During the hail-fall stage (Fig. 3b1), strong and wide updraft exists in the storm, which makes the mixed region of graupel and ice crystals appear at the top of the cloud. The charging process mainly occurs in the mixed regions where the graupel also charges negatively and ice crystals positively. Subsequently (Fig. 3b2), the negatively charged graupel appears at the top of the cloud. The ice crystals are lighter than the graupel, and so are more easily transported by the flow. The strong updraft spreads to the rear and front after reaching the top of the storm. Ice crystals, which carry positive charge at the cloud top, are also transported by the front and rear outflow. The downdraft also plays an important role in the transportation of particles. The ice crystals are forced downward by the descending air in the upper level of the front. As a result, the heights of negative charge regions are situated in the upper level, while the positive charge regions are lowered at the front of the storm. The positive charge region is also enhanced by the presence of snow. Therefore, the inverted charge structure tends to occur at the front of the storm, near the strong updraft. In the upper level of the rear of the storm, the ice crystals and graupel are carried rearward into the stratiform cloud region. The downdraft inflow in the rear is largely made up of the air that ascended in the updraft, so some ice crystals are also carried to a relatively low position. However, the source of the charge is complex in the stratiform region far from the updraft.

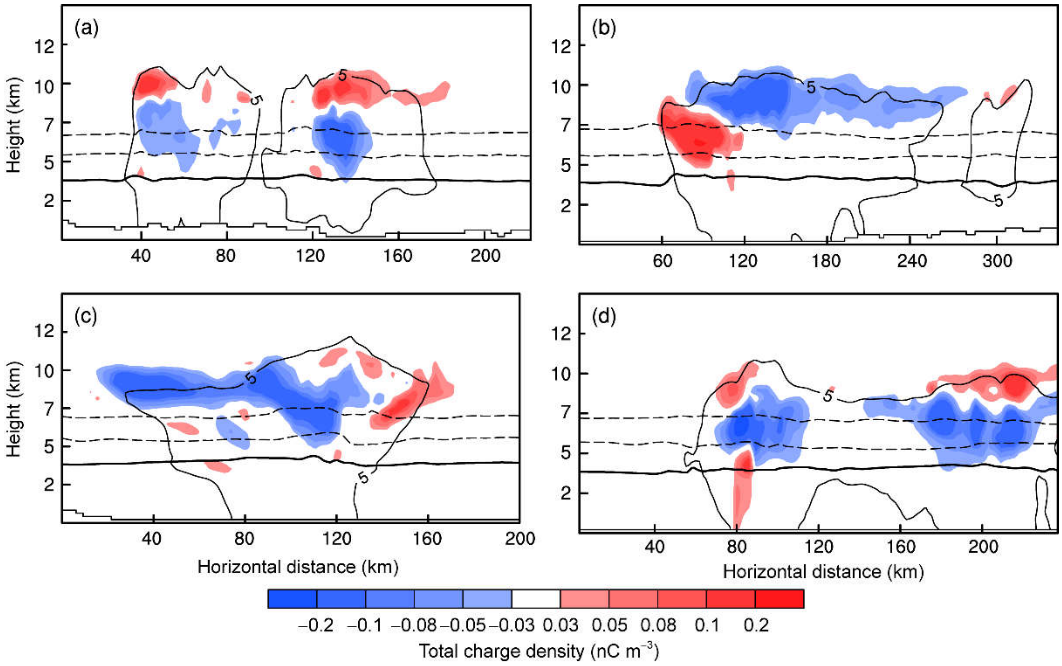


**Fig. 2** Vertical cross-sections of total charge density (nC $m^{-3}$; shaded). The horizontal lines represent the isotherm lines of 20, 10 (dashed line), and 0°C (solid line). The solid line labeled "5" represents the contour line of 5 dBZ.

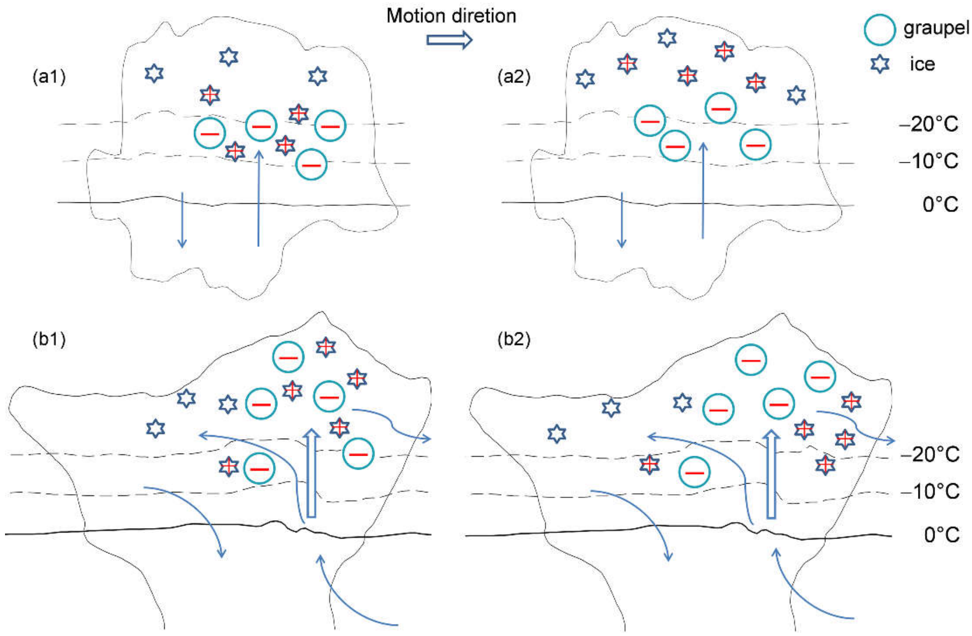


**Fig. 3** Conceptual model of the (a) normal and (b) inverted charge structure formation in the hailstorm.

**Advances in lightning observations during the past decade in Guangdong, China.** During the decade-long series of lightning field experiments conducted in Guangdong, China, the technology of rocket-wire artificially triggered lightning has been improved. A total of 94 flashes were successfully triggered during the 10-yr period, in which the maximum and average peak current of the return stroke (RS) was 42 and 16 kA, respectively. The phenomenon that the downward leader connects to the lateral surface of the upward leader in the attachment process was discovered, and the speed of the upward leader during the connection process being significantly greater than that of the downward leader was revealed. The characteristics of several RSs in could-to-ground (CG) lighting have also been revealed, and the mechanism causing damage to lightning protection devices (i.e., ground potential rise within the rated current) was established. Quantitative assessments of the performance of three lightning monitoring systems in Guangdong Province have been conducted.

Findings show that the length of the upward connecting leader initiated from tall structures can be several hundred meters and even more than 1 km, and the speed of the upward connecting leader can reach a magnitude of $10^6$ m $s^{-1}$. Considerable diversity has been found in the connection scenario during the attachment of the downward leader and upward connecting leader. Tests of lightning protection technologies show that the voltage on the overhead lines induced by close-distance electromagnetic wave coupling from artificially triggered lightning can reach a magnitude of kilovolts. Multiple return strokes, continuing current, and ground potential rise are the main factors that cause damage to surge protective devices. Results regarding the performance of the Guangdong–Hong Kong–Macau Lightning Location System show that the detection efficiency of flashes and strokes is 96% and 89%, respectively. Meanwhile, the arithmetic mean value of location error is 532 m, and the estimated value of the return stroke current intensity is around 63% of the true value.

A 360-m tall meteorological observation tower, designed to directly measure lightning current at its top, has been constructed in Shenzhen recently. Such structures, capable of directly observing the current of a natural lightning flash, will be an important complement to triggered lightning experiments in future research on the physics of lightning discharge and its effects. They will also further improve our understanding of thunderstorm electricity, likely elucidating the mechanisms underpinning the origins of lightning in cloud, which has remained unsolved at present.

Optical and electrical observations in Guangdong in recent years have revealed some new phenomena during the initial process of lightning, thus deepening our understanding of this process. The occurrence of lightning is accompanied by strong convective processes. As such, lightning information is of great significance to the monitoring and prediction (i.e., early warning systems) of hazardous weather.

Lightning field observing experiments need to be improved in the following aspects in the future: (i) Testing the combined lightning detection systems with multiple parameters of radar observations with the aim to reveal the relationships between lightning activity of convective weather and the electrical structure of developing thunderstorms; (ii) Applying lightning information to monitoring and early warning systems for disastrous weather, especially through the correlation between lightning activity and disastrous weather processes; (iii) Exploring the response mechanisms of lightning activity to climate change, with a focus on observations of lightning-generated NO*x* and the impact of aerosols on lightning activity.

# RESEARCH ACTIVITY BY INSTITUTIONS

## MIT Parsons Laboratory (Cambridge, MA, USA)

In a recent paper in GRL (Williams, Mattos and Machado, 2016), stroke multiplicity of initial ground flashes has been studied in incipient thunderstorms in Brazil with exceptionally small diameters, as observed with an X-band polarimetric radar. 87% of 46 initial negative ground flashes are characterized by single strokes. The notable suppression of multi-stroke behavior is attributed to the short horizontal distance available for positive leader extension aloft following the initial stroke.

Laboratory studies of long (~1 meter) DC arcs in air with current (~1 ampere) have been underway with Joan Montanya, Robert Golka, Mike Valente, Jim Bales and Yakun Liu, using a large +/-65 kV source powered with a diesel generator. A conspicuous instability, documented in high-speed video in the writhing, tortuous unconfined arcs, is for an abrupt straightening of the channel when 'oxbow' bends in the arc are cutoff and abandoned. The arc channel voltage drops and the current surges during such events. The same process in river channels is called 'avulsion'. In earlier work on rocket-triggered lightning, Idone (1995) documented a similar straightening of channel tortuosity in continuing current. Applications of avulsion to M-components in lightning are under consideration.

Earle Williams participated in the PhD defense of Yen-Jung Wu with the ISUAL team at the National Cheng Kung University in Taiwan in September. This doctoral work focused on an inter- comparison of the heights of many well-known features of the mesosphere: elves, OH airglow, the nighttime ledge in electron density, and the boundary for the global VLF waveguide. Puzzlements remain about the low detection efficiency for elve-producing lightning by a variety of lightning networks.

The inversion of multi-station background Schumann resonance observations for the global lightning activity has been reprised. Anirban Guha is now back at MIT on a Raman Fellowship to lead this effort. The coordination with Gabriella Satori and Erno Pracser in Hungary continues. More than 20 international collaborators have generously contributed new ELF data sets for this study. The total ELF station numbers are now sufficiently numerous that two independent inversions can be carried out to inter-compare results on the global lightning source.

## National Cheng Kung University (Taiwan)

**Yen-Jung Wu**

The Imager of Sprite and Upper Atmospheric Lightning (ISUAL) on board the Taiwanese satellite Formosat-2 has been terminated in July 2016 but has accomplished a decade of operation in orbit. Elve occurrence has been studied during El Niño and La Nina in Wu et al. (2012) (Occurrence of elves and lightning during El Niño and La Niña, *Geophys. Res. Lett.*, 39, L03106, doi:10.1029/2011GL049831) with 5 years of ISUAL satellite observations. Given the historical El Niño in the period 2015 to 2016 and now receiving wide attention, it is timely to revisit this issue with a 10-year data set. Three regions with significant sea surface temperature anomaly (SSTA) in ENSO episodes are discussed, the percentage of area with enhanced anomaly of elve occurrence density(AEOD) follows the change of SSTA in the SSTA-horseshoe, SSTA-Pacific and SSTA-Indian Ocean, whereas the variation in the anomaly of the lightning flash rate (ALFR) with ENSO phase is rather ambiguous (Fig. 1). Compared with the results in Wu et al. (2012), the correlation of the predominant pairs remains close to 0.6, while the most ENSO-responsive region over the 10-year time frame is found to be the east Australia-central Pacific pair where the correlation coefficient with Southern Oscillation Index (SOI) is 0.71 (Fig. 2). The elve response is stronger in the west Indian Ocean where the synoptic circulation is affected, particularly during the period between a strong El Niño and the following strong La Nina. From the result above, the weaker CAPE in the upwelling region of the synoptic circulation provides the environment to develop elve-producing thunderstorms, such that the elves show better agreement than lightning with the variation of the synoptic circulation and ENSO. This work substantiates the findings in Wu et al. (2012), now with data in a longer10-year time frame, that elves are more sensitive than lightning to ENSO and the variation of the synoptic circulation. This work has been accepted by *Terrestrial, Atmospheric and Oceanic Sciences.*

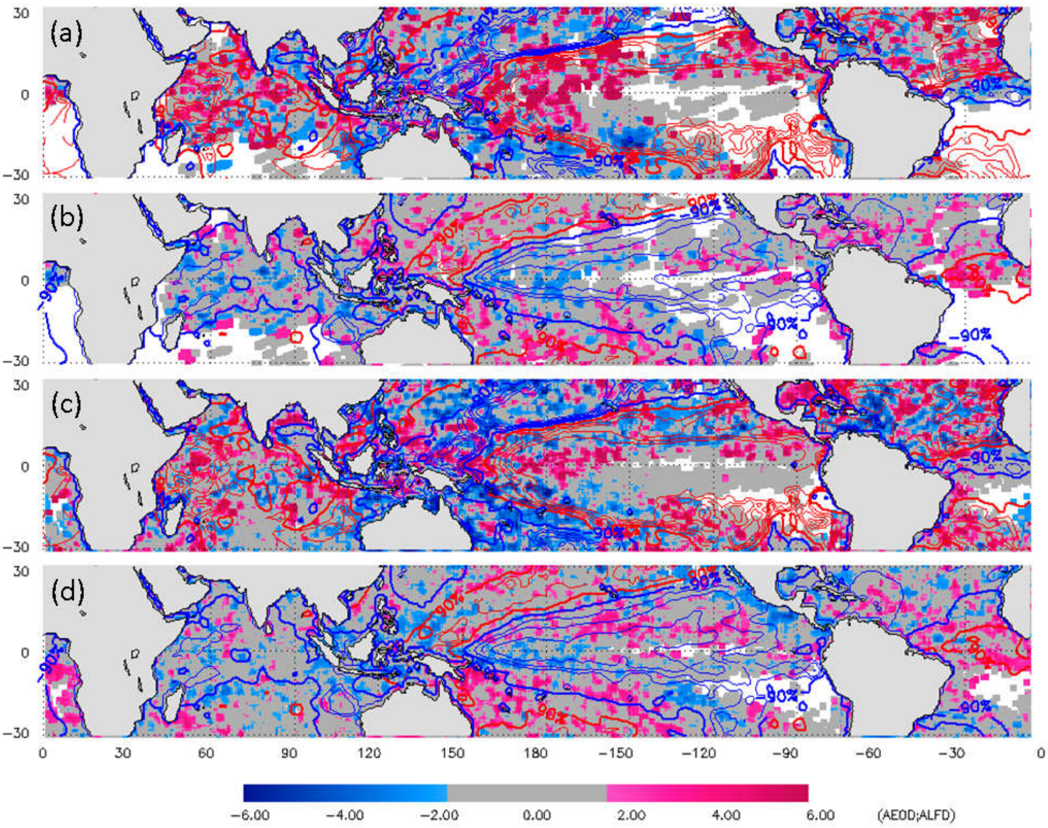


**Fig. 1** The AEOD (top two panels) and ALFD (bottom two panels) during ENSO for the warm phase (a and c) and the cold phase (b and d). Color codes: red shaded, area with significant occurrence increase over 90th percentile of confidence interval; blue shaded, area with significant occurrence decrease over 90th percentile of confidence interval; gray shaded, area with no statistically significant changes. The red (blue) thick isopleths indicate where SSTA enhancement (reduction) reaches the 90% confidence interval.

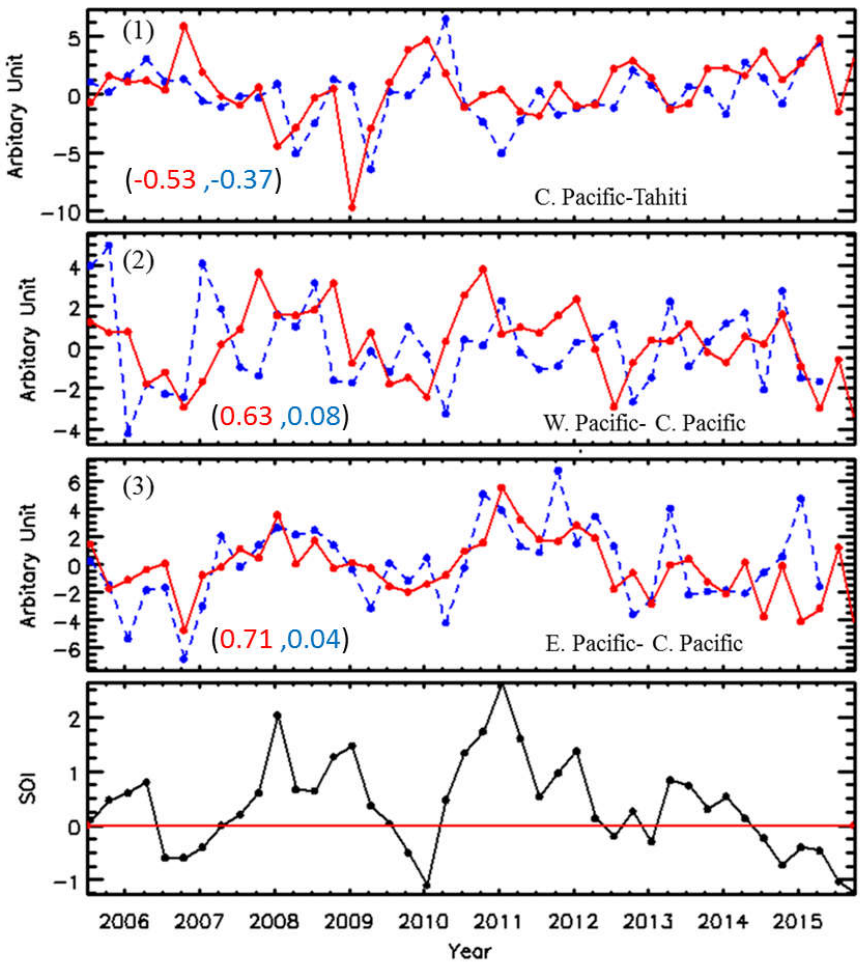


**Fig. 2** The Elve Anomaly Index (the difference of the elve anomaly in two targeted areas) and Lightning Anomaly Index (the difference of the lightning anomaly in area 1 and area 2) in three pair areas over the Pacific Ocean. The red graphs denote ISUAL elves, and the blue graphs represent LIS lightning. The numbers in the parentheses are the correlation coefficient of EAI vs. SOI (red) and LAI vs. SOI (blue). The bottom panel shows the Southern Oscillation Index (SOI).

## National Severe Storms Laboratory (NSSL), Norman, Oklahoma, USA

Sean Waugh recently defended his dissertation, entitled *A Balloon-Borne Particle Size, Imaging, and Velocity Probe for In Situ Microphysical Measurements.* His project analyzed data the NSSL Storm Electricity Team collected with this instrument (Waugh et al. 2015), in conjunction with data from polarimetric radars and a balloon-borne electric field meter, during the Deep Convective Clouds and Chemistry (DC3) Experiment. Besides beginning to put together papers for journal publication based on his dissertation work, he has recently been hired as a scientist of the Field Observing Facility at NSSL and is developing an improved version of his particle imager.

Lightning and radar observations of a supercell storm observed during DC3 are analyzed in "An overview of the 29 May 2012 Kingfisher supercell during DC3" by DiGangi et al., which has recently been accepted for publication in *Journal of Geophysical Research – Atmospheres*. She found that the timing of increases in VHF counts in the 8-10 km AGL layer, which contained the largest VHF source counts, is similar to the timing of increases in updraft mass flux, in updraft volume, and in graupel volume at approximately 5-9 km AGL. Although some increases in VHF source counts had little or no corresponding increase in one or more of the other storm parameters, at least one other parameter had an increase near the time of every VHF increase, a pattern which suggests a common dependence on updraft pulses, as expected from the noninductive graupel-ice electrification mechanism. A classic bounded weak lightning region was observed initially during storm intensification, but late in the period it appeared to be due to a wake in the flow around the updraft, rather than due to a precipitation cascade around the updraft core as is usually observed. For her Ph.D. project, Elizabeth DiGangi is continuing work on other aspects of this storm and is expanding her research to other storms observed in the three venues of DC3.

Vlad Mazur has sent his completed monograph on lightning physics to his publisher and is awaiting page proofs. Don MacGorman, Matt Elliott, and Elizabeth DiGangi have submitted a paper to *Journal of Geophysical Research - Atmospheres* analyzing the continual discharges in the overshooting top of five storms relative to radar reflectivity structure. They show that the maximum height of VHF sources in the overshooting top is well correlated with the maximum height of 18–30 dBZ radar reflectivity. The period in which lightning extended continually throughout the overshooting top tended to have a higher probability of large hail.

Alex Fierro, Ted Mansell, Conrad Ziegler, and other NSSL scientists have developed a scheme for assimilating total lightning data into weather forecast models. They have released a public module for assimilating total lightning observations in WRF-ARW by nudging water vapor in locations in which lightning is observed. Their technique has also been adapted to be used in a 3DVAR framework. Using either the initial nudging technique or the technique in the 3DVAR framework tended to improve the location and rainfall trends of forecasted storms. They recently received funding to work with University of Oklahoma scientists and the National Weather Service's National Centers for Environmental Prediction to begin testing the 3DVAR technique in a framework suitable of use by Weather Service forecast models.

Using techniques, he developed for retrieving concentrations of various types of hydrometeors from the three-dimensional wind fields derived from multiple Doppler radars, Conrad Ziegler is analyzing the 29 May 2012 supercell storm observed during DC3. He is using a numerical cloud model to study the formation of the bounded weak lightning region, also called a lightning hole, in that storm.

Alex Eddy has begun investigating the occurrence of storms that have anomalous vertical electrical structures, sometimes called inverted polarity storms. His goal is to determine the environmental conditions responsible for producing such storms in the United States of America.

## New Mexico Tech, Broadband Interferometer and LMA studies

**Paul Krehbiel**

After several years of study, analysis of observations showing how high-power narrow bipolar events (NBEs) are produced has appeared in print (Rison et al., 2016; doi: 10.1038/ncomms10721). The observations, obtained in 2013 at Langmuir Laboratory and initially reported on at the 2014 Atmospheric Electricity Conference in Norman, show that NBEs are produced by newly-recognized fast positive streamer breakdown. In addition to the NBEs initiating normal intracloud (IC) flashes, fast positive breakdown was found to occur with a wide range (50 dB or more) of VHF powers and sferic strengths, and to be the initiator of both IC and CG discharges in storms. The results support the early ideas of Loeb, Dawson and Winn in the 1960s, and of Phelps and Griffiths in the 1970s, that self-intensifying positive streamers are responsible for initiating lightning. The observations were obtained with a flash-continuous broadband VHF interferometer system (INTF) and the Langmuir Lightning Mapping Array (LMA). The INTF was developed in 2011 and 2012 in collaboration with Manabu Akita of the Osaka University group and is an upgraded version the original Osaka broadband digital interferometer (DITF), that utilizes a high speed streaming digitizer for capturing entire flashes and generalized cross-correlation for processing the observations.

Subsequent to being operated at Langmuir, in 2015 the INTF was briefly deployed near Fort Morgan, Colorado for studies with the north Colorado LMA and the CSU/CHILL radar. The operation, conducted by Bill Rison and Mark Stanley, was aimed at investigating inverted-polarity discharges in the anomalously electrified storms of the western Great Plains, initially studied during STEPS 2000. For the Colorado study the baselines were increased from 15-20m separation utilized in the Langmuir studies to 50 m, for increased angular resolution.

This past July (2016) the INTF was deployed at Kennedy Space Center (KSC) Florida for collaborative studies with Ningyu Liu and Ph.D. student Julia Tilles at Florida Tech (now at the University of New Hampshire), and Robert Brown and Jennifer Wilson at the KSC Weather Office. The purpose was two-fold: first to obtain comparative studies of Florida and New Mexico lightning, and secondly to prepare the INTF for validation studies of data from the soon to be launched Geosynchronous Lightning Mapper (GLM) on board the GOES-R satellite. The studies are being conducted in conjunction with the recently established KSC LMA and were originally planned to last two months, after which the INTF was to be re-deployed to central Oklahoma in support of the GLM validation in April-May 2017. The Florida operation has been amazingly productive, however, so much so that the INTF will continue to be operated at KSC through the GLM validation. Similar to the Langmuir and Colorado studies, at KSC the INTF utilizes three flat plate antennas arranged in an equilateral triangle, with the entire system being remotely operated, in this case over the web via cell modem communications, with the data recording being automatically triggered by the electrostatic field changes of nearby lightning. An important added capability for the KSC studies is that the recording is also triggered from the VHF power obtained from the high-speed digital data stream, allowing both close discharges and distant high-power events such as NBEs to be captured. The baseline lengths were also increased to 100 m, which has enabled discharges to be studied out to distances of 40-50 km or more from INTF.

The resulting observations have been spectacular. An example is shown on the cover. This shows the surprisingly good ability of the extended-baseline configuration to resolve the fine structure of multiple simultaneous branches, in this case during a downward negative stepped leader to ground. Another surprising result of the observations is that Florida storms are prolific producers of high-power NBEs, much more so than in NM or CO (Fig. 1). Hundreds to a thousand or more high- and lesser-power NBEs have been recorded from late summer/fall storms. Combined with simultaneously recorded high-speed fast electric field change measurements and LMA data, the observations are providing an excellent database for continued studies of NBEs, as well as discharge processes in general. Lightning flashes are routinely initiated by fast NBE-type breakdown, primarily of positive polarity, but some apparently of negative polarity. Short duration, attempted 'precursor' discharges are also observed in abundance (e.g., Fig. 1c), which are seen in detail by the INTF (Fig. 2).

All in all, tens of terabytes of time series data have been obtained so far, with more to come. Because of the unique and voluminous nature of the observations, and their high quality, KSC will be hosting an online repository of the INTF and LMA data which, along with supporting data will be available to other investigators for collaborative and independent studies.

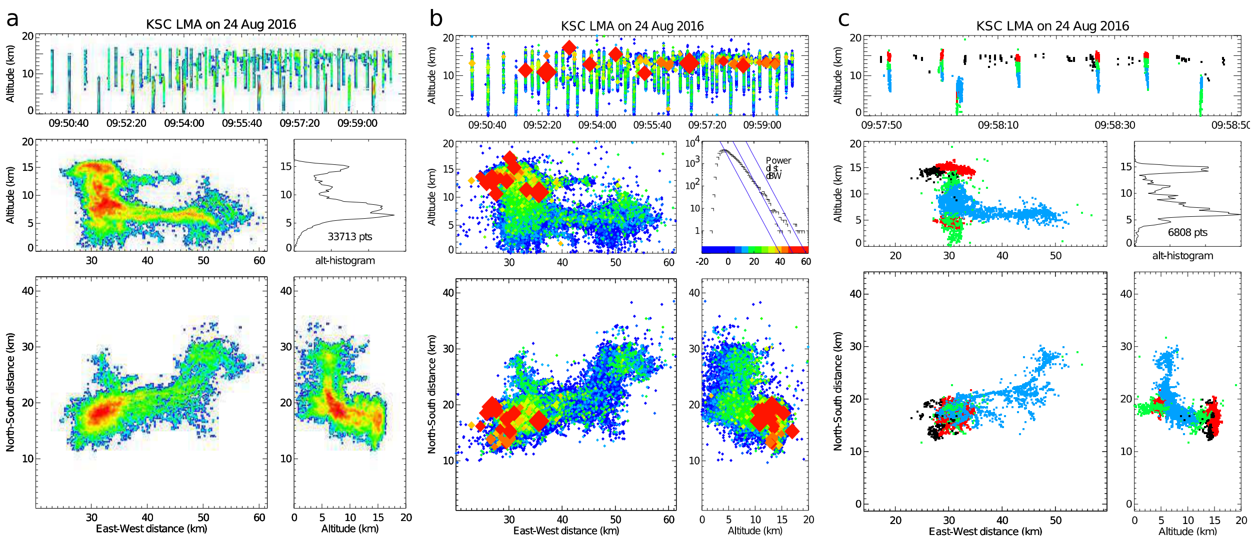


**Fig. 1** Ten minutes of data from an approaching storm 30-40 km offshore from Kennedy Space Center on 24 August, showing a) the density of VHF sources and b) the VHF source powers. Two minutes into the record, as the storm intensified, numerous short-duration precursor (PC) events started to occur at high altitude along the storm's upper leading edge. A number of PCs and IC flashes were initiated by high power, 40-50 dBW (10-100 kW) NBEs (red diamonds in panel b). The black sources in panel c) show that the PCs occurred at the base of the upper positive charge region at 14-15 km altitude (red sources), well above the storm's negative charge region (blue sources). IC discharges in the storm initiated at the same high altitude as the PCs, with the positive breakdown having to develop several km downward

before turning horizontal in the storm's negative charge region.

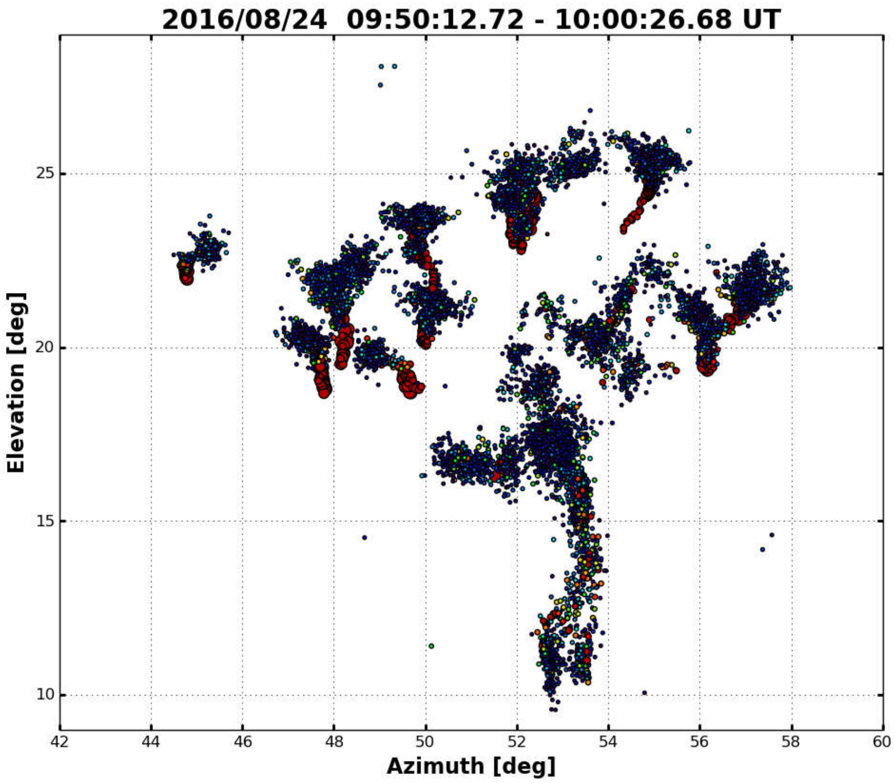


**Fig. 2** INTF observations of a number of short duration, attempted discharges initiated by high-power NBEs in the storm of Fig. 1. Most of the events consisted of two or more repeated attempts in the same location a few tens to hundreds of milliseconds apart in time -- similar to the successive cascading breakdown observed during a high-altitude screening discharge by Rison et al. (2016). Such breakdown is indicative of localized regions of strong electric field. A vertical IC discharge in the storm core (bottom center) is shown for reference. Each attempted event began with downward fast positive breakdown (red sources), followed by weaker upward negative breakdown that did not succeed in initiating a flash. All events occurred immediately below the storm's upper positive charge region at 14-15 km altitude (Fig. 1c), with the different elevation values being due to the events occurring at closer or further distances in the storm.

## Research Centre for Astronomy and Earth Sciences Geodetic and Geophysical Institute (GGI), Hungarian Academy of Sciences

**Veronika Barta, Tamás Bozóki, József Bór, Ernő Prácser, Gabriella Sátori** (in alphabetical order)

Research in GGI on atmospheric electricity (AE) is represented in the recently started ESF COST Action CA15211, "Atmospheric Electricity Network: coupling with the Earth System, climate and biological systems". This action aims at studying the interactions between different constituents of the environment, including effects on the biosphere, as mirrored by measured parameters of AE. The Action puts an emphasis on AE parameters which correspond to quasi-static and slowly varying properties of the Global Electric Circuit up to the ELF (extremely low frequency) band.

GGI contributes to the project GloCAEM, i.e., the Global Coordination of Atmospheric Electricity Measurements. GloCAEM is a project funded by Natural Environment Research Council, UK (NERC) and led by the University of Reading, UK. A network of atmospheric potential gradient measurements is being established in the framework of this project to encourage collaboration and ease of data sharing between researchers in atmospheric electricity.

In the frame of an international project for Schumann resonance (SR) inversion initiated by Earle Williams (MIT), Ernő Prácser has developed an inversion program based on Nelson (1967) work. The inversion code processes the electromagnetic spectra of the vertical electric and horizontal magnetic field components of ELF time series recorded in different SR observatories in the world. The inversion code determines those areas where the lightning activity is high, and provides the intensity values corresponding to each of these areas in absolute units. In the forward modeling algorithm, the wave equation is solved in the Earth-Ionosphere cavity. The inversion code has been successfully tested on synthetic data and the first results of the inversion based on observational data are also encouraging.

Veronika Barta has visited Earle Williams at MIT for a three-month period in the scope of Fulbright Fellowship. During her visit she studied the effects of energetic solar emissions on the lower ionosphere using ionosonde observations. The impact of two exceptional solar events - the Bastille Day event (July 14, 2000) and the Halloween event (Oct/Nov2003) on the lowest region of the ionosphere (<100 km) have recently been analyzed with global Schumann resonance measurements (Sátori et al., 2016). The aim of her present project is to extend the investigation to somewhat higher levels of the ionosphere (90-150 km) accessible with ionosonde observations. The variation of two ionospheric parameters, namely the minimum frequency of echoes (fmin) and the critical frequency of the E-layer (foE) were studied to disclose the effect of the solar flares on the lower ionosphere. The time series of the fmin and foE parameters recorded at meridionally-distributed stations in Europe were analyzed during these two intense solar events. Extreme increases of the fmin values (2-6 MHz) were observed at several European stations. This ionospheric response is more pronounced at higher latitudes. At the same time, the absence of the foE parameter was observed especially at high latitudes. These results suggest that the latitude-dependent change of the fmin and foE parameters is related to energetic solar particles penetrating to the lower ionosphere.

Gabriella Sátori and her MSc student, Tamás Bozóki, have been studying the possible effect of electron precipitation on Schumann resonance (SR) amplitudes/intensities during geomagnetic storms and geomagnetically disturbed periods. They focus on the St. Patrick event occurred in March, 2015 and use SR time series recorded in a quasi-meridional chain of SR stations from high (polar) latitude (Hornsund) to mid (Belsk, Hylaty, Nagycenk) and lower (Mitzpe Ramon) latitudes. The dynamic spectra of SR intensities indicate interesting results depending on the latitudes, field components and modes.

The first results have been published from the project which aims at studying the electromagnetic properties of the Earth-Ionosphere waveguide on the base of Q-bursts, i.e. Schumann resonance (SR transients) detected in the ELF band. It was found that ELF data-based source azimuths of Q-bursts differ systematically from true source azimuths. The error of ELF data-based azimuths could be decomposed into time dependent and static components. The largest error term at NCK station, Hungary, was found to be static but it varies with the true azimuth of the source. This variation of the source azimuth error correlates to the azimuthal variation of the horizontal conductivity gradient in the Earth's crust inferred from magnetotelluric surveys at NCK (Fig. 1) (Bór et al., 2015). These results will be presented also in the 2016 AGU Fall meeting (paper number GP43A-1236).

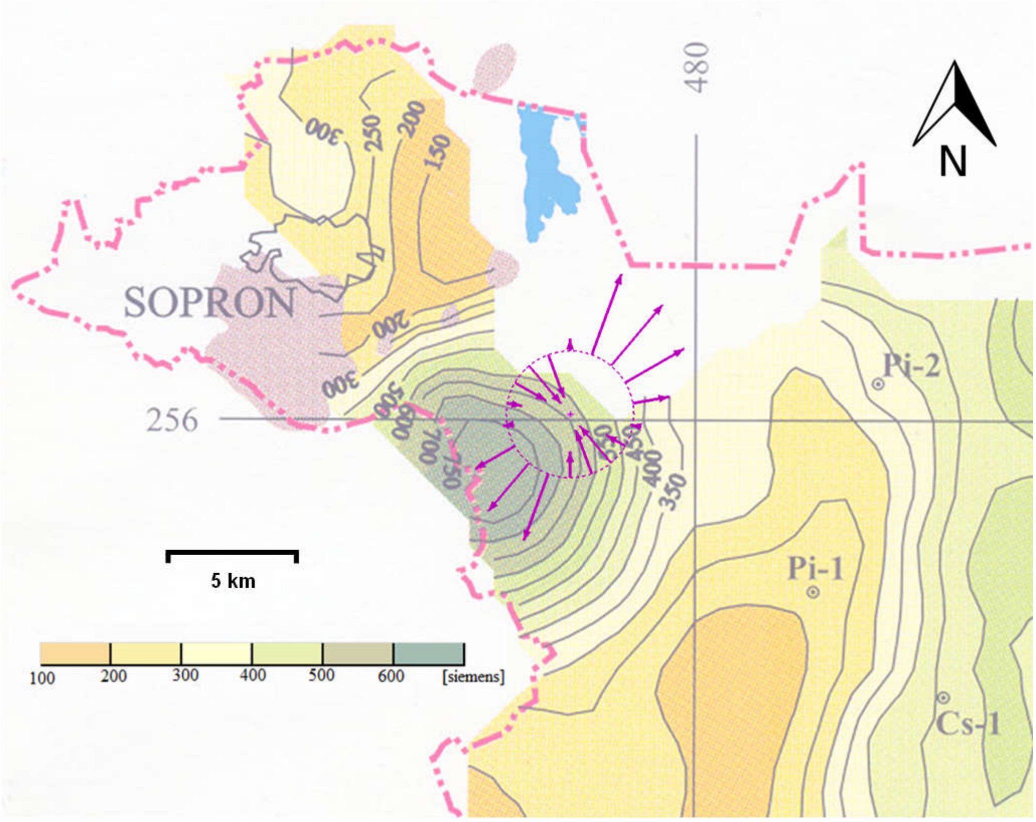


**Fig. 1** Conductance map near NCK station, Hungary. The location of NCK station is marked by a small plus sign. Shaded area on the map shows the appearances of lower east-alpine Palaeozoic crystalline rocks at the surface near the town of Sopron. The white area without conductance data to North from NCK is part of Lake Fertő which is covered by reed. Deviations of ELF data-based source directions from the true source azimuth are represented by arrows. Arrows are drawn by 20° starting at 0°. Arrows pointing inwards and outwards of the circle around NCK station correspond to negative and positive azimuth deviations, respectively. The length of the arrows is proportional to the absolute value of the ELF data-based average source direction deviation at each plotted azimuth. For example, the arrow at 20° azimuth corresponds to +18.25° azimuth deviation. (Re-plotted from Figure 5 in Bór et al., 2016.)

## The Universitat Politecnica de Catalunya (UPC, Barcelona, Spain)

The analysis of high-energy background radiation (0.1–2 MeV) enhancements during eight winter thunderstorms and five summer storms in the Ebro delta region in the northeast of Spain is presented. For the first time, high-energy radiation counts, precipitation, radar reflectivity, and very high frequency lightning detections to infer charge regions altitude have been analyzed in order to find out what produces the measured background radiation increments associated with storms. The good agreement between radar reflectivity and precipitation with increases in background radiation counts coupled with the spectrum analysis comparing rain/no rain periods suggests that radon-ion daughters play a major role in the radiation increments reported. No evidence has been found supporting that measured background radiation enhancements can be produced by storm electric fields. Finally, a single case of a high-energy radiation increase was prior to a cloud-to-ground lightning stroke, which reinforces the theory that a lower positive charge layer's existence is important for the production of Terrestrial Ground Enhancements.

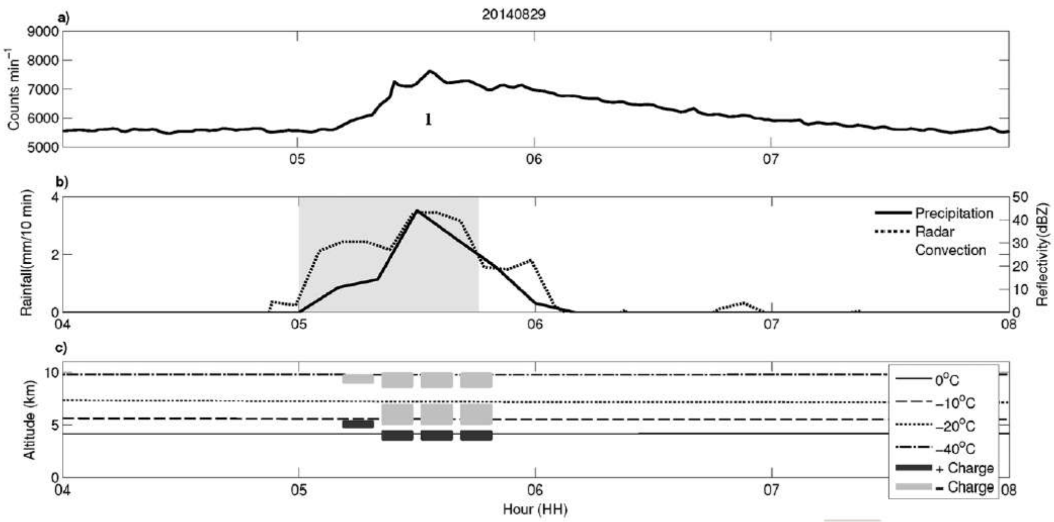


**Fig. 1** Time evolution for 29 August 2014 episode of (a) X-ray counts, (b) maximum radar reflectivity and precipitation above the scintillator, and (c) altitude of the 0ºC, −10ºC, −20ºC, and −40ºC isotherms charge regions altitudes inferred from LMA detections.

# RESEARCH ACTIVITY BY INSTITUTIONS

## University of Florida (Gainesville, FL, USA)

A total of 12 full-fledged lightning flashes were triggered in 2016 at Camp Blanding (CB), Florida. Nine flashes contained leader/return stroke sequences (a total of 25) and three were composed of the initial stage only.

Jaime Caicedo (advisor M.A. Uman) defended his Ph.D. dissertation titled “Return stroke current reflections in rocket-triggered lightning and lightning evolution characteristics of five north central Florida storms”. Brian Hare (advisor M.A. Uman) defended his Ph.D. dissertation titled “Relationship of Terrestrial Gamma Ray Flashes and Cosmic Ray Air Showers to Natural and Triggered Lightning”. Vijaya Somu (advisor V.A. Rakov) defended his Ph.D. dissertation titled “Interaction of lightning electromagnetic pulse with the ionosphere as inferred from wideband measurements and modeling”. Daniel Kotovsky (advisor R.C. Moore) defended his Ph.D. dissertation titled “Response of the nighttime upper mesosphere to electric field changes produced by lightning discharges”.

Y. Zhu, V.A. Rakov, and M.D. Tran, in collaboration with W. Lu (Chinese Academy of Meteorological Sciences), authored a paper titled “A subsequent positive stroke developing in the channel of preceding negative stroke and containing bipolar continuing current”. A bipolar cloud-to-ground lightning flash was observed to exhibit two types of polarity reversal associated with the first two strokes separated by a not unduly long time interval of 70 ms. The first stroke was negative and had a peak current of -101 kA. The second stroke was positive, had a peak current of 16 kA and was followed by a 122 ms long bipolar continuing current. The first two strokes, including the bipolar continuing current, occurred in the same channel to ground, whose imaged 2-D length was 4.2 km. The occurrence of positive stroke in the negative-stroke channel is highly unusual. The 2-D speed versus height profiles for the negative stepped leader of the first stroke and, for the first time, for the positive leader in the previously conditioned, first-stroke channel was examined and the average speeds were found to be $4.7 \times 10^5$ m/s and $7.2 \times 10^5$ m/s, respectively. The paper is published in the Geophysical Research Letters.

Hare, B.M., M.A. Uman, J.R. Dwyer, D.M. Jordan, M.I. Biggerstaff, J.A. Caicedo, F.L. Carvalho, R.A. Wilkes, D.A. Kotovsky,W.R. Gamerota, J.T. Pilkey, T.K. Ngin, R.C. Moore, H.K. Rassoul, S.A. Cummer, J.E. Grove, A. Nag, D.P. Betten, and A. Bozarth authored a paper titled “Ground-level observation of a terrestrial gamma ray flash initiated by a triggered lightning”. They reported on a terrestrial gamma ray flash (TGF) that occurred on 15 August 2014 coincident with an altitude-triggered lightning at the International Center for Lightning Research and Testing (ICLRT) in North Central Florida. The TGF was observed by a ground-level network of gamma ray, close electric field, distant magnetic field, Lightning Mapping Array (LMA), optical, and radar measurements. Simultaneous gamma ray and LMA data indicate that the upward positive leader of the triggered lightning flash induced relativistic runaway electron avalanches when the leader tip was at about 3.5 km altitude, resulting in the observed TGF. Channel luminosity and electric field data show that there was an initial continuous current (ICC) pulse in the lightning channel to ground during the time of the TGF. Modeling of the observed ICC pulse electric fields measured at close range (100–200 m) indicates that the ICC pulse current had both a slow and fast component (full widths at half maximum of 235 µs and 59 µs) and that the fast component was more or less coincident with the TGF, suggesting a physical association between the relativistic runaway electron avalanches and the ICC pulse observed at ground. Our ICC pulse model reproduces moderately well the measured close electric fields at the ICLRT as well as three independent magnetic field measurements made about 250 km away. Radar and LMA data suggest that there was negative charge near the region in which the TGF was initiated. The paper is published in the Journal of Geophysical Research - Atmospheres.

## University of Mississippi, Oxford, MS USA

Our group recently completed the data collection phase (June to October, 2016) of a project to study lightning initiation in North Mississippi thunderstorms. A 50 km x 40 km array of seven sensor sites was installed and operated, each acquiring slow and fast electric field change, dE/dt, and logRF VHF data at 5-10 MegaSamples/s. Despite increasing drought conditions in this region through the summer season, we obtained seven-sensor data for at least 28 storm days. Data analyses are underway, and initial results will be presented by Tom Marshall and physics graduate student Sampath Bandara at the Fall Meeting of the AGU.

We also are continuing to examine multi-sensor electromagnetic and high-speed video data collected around NASA Kennedy Space Center in Florida during the summers of 2010 and 2011. Recent results from these analyses include the following, as reported in JGR-Atmospheres:

*Stolzenburg et al.* [2016] used high-speed video data for four hybrid lightning flashes to show that luminosity bursts at visible wavelengths are time-correlated with large, intracloud flash (IC) initial breakdown (IB) pulses in electric field change (E-change) data. The candidate IC-type IB pulses were large in range-normalized E-change amplitude and peak current (2.2-3.4 V/m range-normalized to 100 km, 2.9-11.1 kA) and had slow (0.3-2.2 ms duration) field changes corresponding to charge moment changes of 0.5-15 C-km. Such large amplitude IB pulses have been associated with production of terrestrial gamma-ray flashes in prior work. No gamma-ray observations were available for these events. In each flash, a luminosity increase was evident in the video data at the time of the largest IC-type IB pulses, when VHF sources and E-change data indicated that the IC initial leader was at 6.1 - 9.4 km altitude and rapidly developing upward. Luminosity started increasing within -10 µs to +20 µs of the main IC-type IB pulse peak, i.e., within the same 20-µs video frame as that in which the E-change peak occurs. Delay time between the beginning of the E-change pulse and beginning of the luminosity increase was 40 to 110 µs. Video intensities increased sharply for 80 to 220 µs to their maximum value, then decreased over a longer time period, with entire burst durations of 300 to 800 µs in the examples described. The time lag between IB pulse peak and maximum luminosity is consistent with these IC-type IB pulses starting a large current that peaks and becomes bright at the time of the main pulse peak, and lasts for several hundred microseconds.

*Karunarathne et al.* [2016] described electric field change measurements of 35 positive narrow bipolar events (NBEs) that were obtained at close range (within 10 km) with an array of 10 sensors. At the closest sensor, all 35 NBEs had a net electrostatic change ($\Delta E_{fast}$) associated with the main bipolar pulse, with amplitudes ranging from 0.4 to 16.3 V/m (not range-normalized). At the closest sensor the bipolar pulse of each NBE was followed by a relatively long, slow electrostatic change ($\Delta E_{slow}$) with amplitude ranging from 0.1 to 43.4 V/m and duration of 0.7 to 33.7 ms. For $\Delta E_{fast}$ the estimated 3-D charge moments for 10 NBEs ranged from 0.46 C km to 1.81 C km with an average and standard deviation of (1.09 ± 0.36) C km. Seven 3-D charge moments were essentially vertically oriented, and the other three 3-D charge moments were tilted at 10° to 20° from vertical. These 3-D charge moments were overlaid on vertical radar cross sections; it was found that 6 NBEs occurred in weak reflectivity near the upper reflectivity boundary, while the other 4 occurred near the top of the high-reflectivity core of the thunderclouds. For $\Delta E_{slow}$, we estimated 3-D charge moments for only three NBEs, which ranged from 1.11 C-km to 2.69 C-km (with standard deviation of ±0.80 C-km). A two-current transmission line model was developed that matched the bipolar pulse and the following slow change ($\Delta E_{slow}$) of one NBE reasonably well. The slow change mechanism may be different from the NBE mechanism and perhaps is similar to the mechanism of the initial E-change found before typical lightning flashes.

## Vaisala

**Seasonal, monthly, and weekly distributions of NLDN and GLD360 cloud-to-ground lightning.** Annual maps of cloud-to-ground lightning flash density have been produced since the deployment of the National Lightning Detection Network (NLDN). However, a comprehensive national summary of seasonal, monthly, and weekly lightning across the contiguous United States has not been developed. Cloud-to-ground lightning is not uniformly distributed in time, space, or frequency. Knowledge of these variations is useful for understanding meteorological processes responsible for lightning occurrence, planning outdoor events, anticipating impacts of lightning on power reliability, and relating to severe weather. To address this gap in documentation of lightning occurrence, the variability on seasonal, monthly, and weekly scales is first addressed with NLDN flash data from 2005 to 2014 for the 48 states and adjacent regions (Fig. 1). Flash density and the percentage of each season's portion of the annual total are compiled. In spring, thunderstorms occur most often over southeastern states. Lightning spreads north and west until by June, most areas have lightning. New England, the northern Rockies, most of Canada, and the Florida Peninsula have a small percentage of lightning outside of summer. Arizona and portions of adjacent states have the highest incidence in July and August. Flash densities reduce in September in most regions. This seasonal, monthly, and weekly overview complements a recent study of diurnal variations of flashes to document when and where lightning occurs over the United States. NLDN seasonal maps indicate a summer lightning dominance in the northern and western United States that extends into Canada using data compiled from GLD360 network observations. GLD360 also extends NLDN seasonal maps and percentages into Mexico, the Caribbean, and offshore regions.

**Objective airport warnings over small areas using NLDN cloud and cloud-to-ground lightning data.** Lightning can have a significant impact on ground-crew and other operations at airports, resulting in a cascade of delays beyond the immediate locations. Measures of these impacts have not been presented previously in a comprehensive approach for a variety of factors. Prior approaches typically used lightning data within outer observation radii of varying sizes to anticipate cloud-to-ground (CG) flashes in a smaller inner warning area such as an airport. The goal of this paper is to address issues related to the balance between safety and the efficiency of lightning warnings for such situations. The first of two topics addressed in this study is to examine the value of adding cloud pulses to CG strokes. The detection efficiency of the U.S. NLDN for cloud pulses increased to about 50% by late summer 2013, so NLDN data during the entire 2014 summer are considered at 10 locations. Verification is performed for the occurrence of NLDN-detected CG strokes at the airports. Cloud pulses were found to improve the 2-min probability of detection by 13% compared with CG strokes only. The second topic of the study is the reduction of the inner warning area from the size of an entire airport to a small section of the airport, from a radius of 4.8 to 0.5 km. The probability of detection with a2-min lead time increases to over 0.90 for the smaller area, while the false alarm ratio also increases substantially when CGs plus cloud pulses are included.

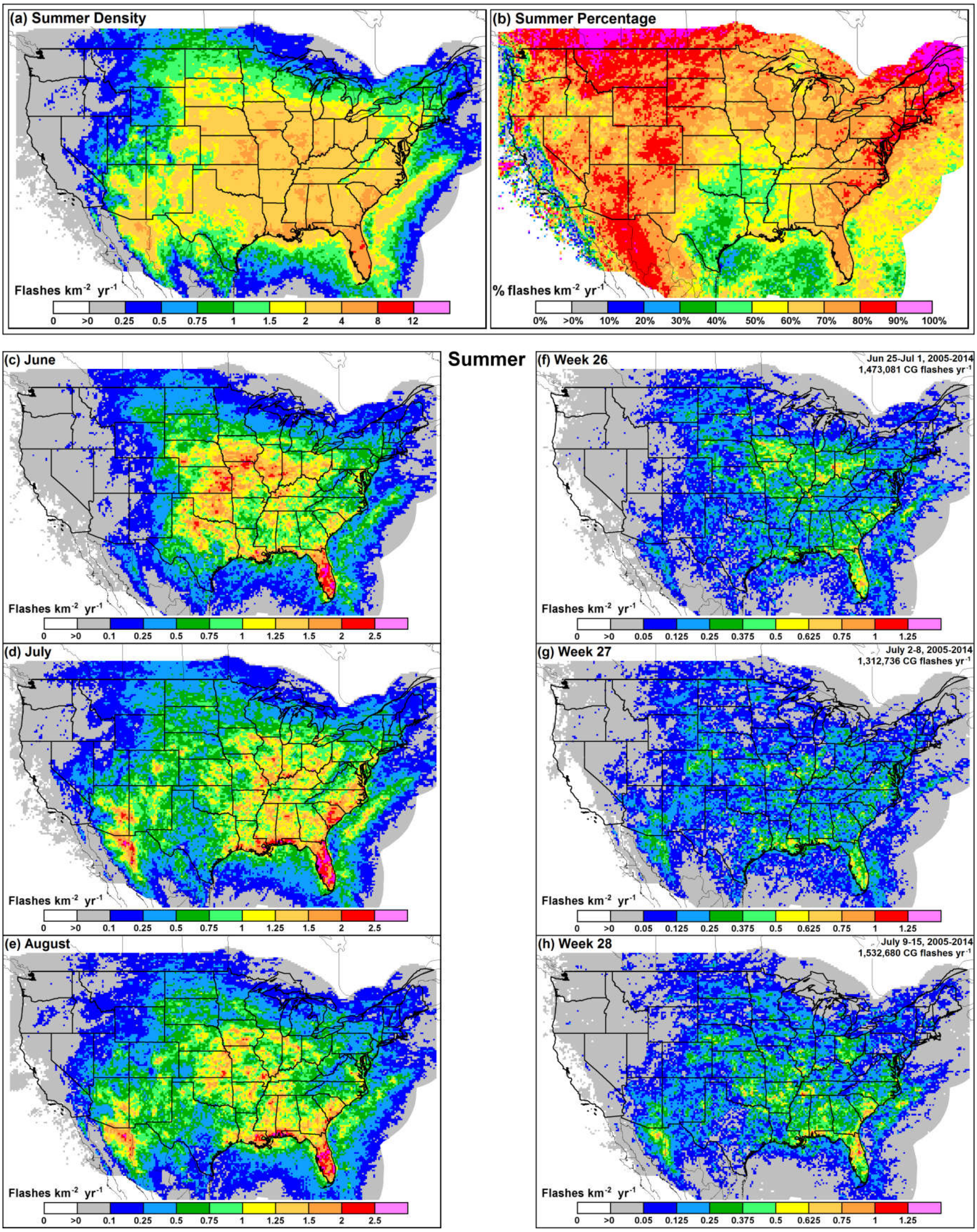


**Fig. 1** Cloud-to-ground flash data from the National Lightning Detection Network: (a) summer flash density, (b) summer flash percentage of annual total, and flash densities for (c) June, (d) July, (e) August, (f) week 26, (g) week 27, and (h) week 28. Scales are across the bottom of the maps. Flashes and strokes with weak positive estimated peak currents (i.e., <15 kA) are omitted from these maps.

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# 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.

Newsletter on Atmospheric Electricity is now routinely provided on the web site of ICAE (http://www.icae.jp), and on the web site maintained by Monte Bateman http://ae.nsstc.uah.edu/.

**In order to make our news letter more attractive and informative, it will be appreciated if you could include up to two photos or figures in your contribution!**

## 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 Dr. Daohong Wang (wang@gifu-u.ac.jp) preferably by e-mail as an attached word document.

The deadline for **2017 spring** issue of the newsletter is **May 15, 2017**.

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