Atmospheric and Space Electricity

AE21A MCC: Level 2 Tuesday 0830h

The Physics of Lightning and Storm Electrification I Posters *(joint with A, NG)*

Presiding: **A R Jacobson,** Space and Atmospheric Sciences Group, Los Alamos National Laboratory**; L D Carey,** Texas A&M University

AE21A-1090 0830h POSTER

Lightning Location Relative to Storm Structure in Mesoscale Convective Systems

Lawrence D Carey[1] (979-847-9090; carey@ariel.met.tamu.edu)

Tracy L McCormick[2] (ma_stormy@yahoo.com)

Martin J Murphy[3] (martin.murphy@vaisala.com)

Nicholas W. S. Demetriades[3] (nick.demetriades@vaisala.com)

[1] Texas A&M University, Department of Atmospheric Science 1204 Eller O&M Building 3150 TAMU, College Station, TX 77843

[2] North Carolina State University, MEAS Campus Box 8208, Raleigh, NC 27695

[3] Vaisala Inc, 2705 E. Medina Rd, Tucson, AZ 85706

Line normal composites of Dallas-Fort Worth Lightning Detection and Ranging (LDAR II) VHF radiation sources and WSR-88D reflectivity provide a unique perspective on lightning pathways and inferred charge structure within two leading-line, trailing-stratiform (LLTS) mesoscale convective systems (MCSs) during April and June of 2002. The overwhelming majority of VHF lightning sources occurred within the leading convective line in a vertical dipole pattern with upper and lower maxima centered at 9 - 9.5 km and 4.5 - 5 km AGL, respectively. A persistent, primary lightning pathway sloped rearward (by 40-50 km) and downward (by 4-5 km) from the upper VHF source maximum in the convective line, through the transition zone and into the stratiform region just above the radar bright band. A secondary and more transient lightning zone occurred 60-110 km rearward of the convective line in a spatially distinct layer (20-30 km long and 3 km deep) centered over the stratiform bright band from about 8.5 to 9.5 km AGL. Ongoing work includes a detailed comparison of individual sub-second LDAR II and NLDN detected stratiform-region ground flashes for the purpose of locating their origins. Preliminary results from these comparisons will be shown.

AE21A-1091 0830h POSTER

Comparison of in-situ Electric Field and Radar Derived Parameters for Stratiform Clouds in Central Florida

Monte Bateman[1] (256-961-7804; monte.bateman@msfc.nasa.gov); Douglas Mach[2] (doug.mach@msfc.nasa.gov); Sharon Lewis[3] (sharon@ucar.edu); James Dye[3] (dye@ncar.ucar.edu); Eric Defer[3] (defer@ncar.ucar.edu); Cedric Grainger[4] (grainger@aero.und.edu); Paul Willis[5] (willis@aoml.noaa.gov); Hugh Christian[6] (hugh.christian@nasa.gov); Francis Merceret[7] (francis.j.merceret@nasa.gov)

[1] Universities Space Research Association, 320 Sparkman Dr., Huntsville, AL 35805, United States

[2] The University of Alabama in Huntsville, 320 Sparkman Dr., Huntsville, AL 35805, United States

[3] NCAR, P.O.Box 3000, Boulder, CO 80307, United States

[4] Atmospheric Sciences Department The University of North Dakota, P.O. Box 9006, Grand Forks, ND 58202, United States

[5] NOAA/Hurricane Research Division, 4301 Rickenbacker Causeway, Miami, FL 33149, United States

[6] NASA/MSFC, 320 Sparkman Dr., Huntsville, AL 35805, United States

[7] NASA/KSC, NASA/YA-D, Kennedy Space Center, FL 32899, United States

Airborne measurements of electric fields and particle microphysics were made during a field program at NASA's Kennedy Space Center. The aircraft, a Cessna Citation II jet operated by the University of North Dakota, carried six rotating-vane style electric field mills, several microphysics instruments, and thermodynamic instruments. In addition to the aircraft measurements, we also have data from both the Eastern Test Range WSR-74C (Patrick AFB) and the U.S. National Weather Service WSR-88D radars (primarily Melbourne, FL). One specific goal of this program was to try to develop a radar-based rule for estimating the hazard that an in-cloud electric field would present to a vehicle launched into the cloud. Based on past experience, and our desire to quantify the mixed-phase region of the cloud in question, we have assessed several algorithms for integrating radar reflectivity data in and above the mixed-phase region as a proxy for electric field. A successful radar proxy is one that can accurately predict the presence or absence of significant electric fields. We have compared various proxies with the measured in-cloud electric field strength in an attempt to develop a radar rule for assessing launch hazard. Assessment of the best proxy is presented.

AE21A-1092 0830h POSTER

One Dimensional Simulations of Lightning Activity in New Mexico Thunderstorms

Lee Stolzenburg Coleman[1] (662-915-7928; leonidas@phy.olemiss.edu)

Maribeth Stolzenburg[1] (662-915-5252; mstolzen@phy.olemiss.edu)

Thomas C Marshall[1] (662-915-7046; marshall@olemiss.edu)

Paul R Krehbiel[2] (505-835-5328; krehbiel@ibis.nmt.edu)

[1] University of Mississippi, Department of Physics and Astronomy, University, MS 38677, United States

[2] New Mexico Institute of Mining and Technology, Physics Department, 333 Workman Center 801 Leroy Place, Socorro, NM 87801, United States

One dimensional models of cloud charge structures based on electric field soundings, are used to simulate lightning activity by placing layers of opposing charge into the clouds so that the energy contained in the electric field is minimized. For intracloud flashes (IC's) equal amounts of negative charge are placed above positive charge, and for cloud-to-ground flashes (CG's) positive charge is placed above negative charge with a net positive charge added to the cloud. The idea that flashes should minimize the energy in a cloud is inspired by several other situations in nature for which the most likely physical solution is that which minimizes the energy. For example, Thomson's Theorem states that the solution for the electrostatic charge distribution on a conductor is that which minimizes the free field energy. Similarly, systems which obey a canonical distribution in statistical mechanics are most likely to be found in states which have the least energy. Preliminary results with the model show features similar to those seen in LMA data acquired simultaneously with the E soundings. For example, the simulated "storms" have three layers of lightning activity: two layers of deposited negative charge with a layer of deposited positive charge in between. The upper layer of deposited negative charge is associated with IC activity, while the lower layer is associated with CG activity. A close inspection of the layer of deposited positive charge indicates that the portion deposited by IC's is placed above the portion deposited by CG's, similar to the behavior revealed in real storms by the LMA data. In addition, preliminary results show IC flashes with charge moments on the order of 100 C km, and field changes at ground caused by CG flashes on the order of 15 kV/m.

AE21A-1093 0830h POSTER

Short Duration Discharges Located by NMIMT's Lightning Mapping Array

Jeremiah D Harlin[1] (505-835-3981; jharlin@nmt.edu)

Tim Hamlin[1] (thamlin@nmt.edu)

Paul Krehbiel[1] (krehbiel@ibis.nmt.edu)

Ronald Thomas[1] (thomas@nmt.edu)

William Rison[1] (rision@arctic.nmt.edu)

[1] New Mexico Institute of Mining and Technology, 801 Leroy Pl., Socorro, NM 87801, United States

While analyzing the LMA data, a distinct subset of lightning discharges has been observed. These events are short in duration, lasting less than 80 microseconds and often the LMA only records a single point. Actual source points are difficult to distinguish from random system noise; however, three categories of short duration discharges have been identified as real lightning events. The first category is the isolated event, where single point discharges are occurring in a region of the storm where other lightning has occurred. They do not appear to be associated with any of the larger, more substantial discharges within the storm. These short duration events are often localized, and in some instances are the only discharge in given area for several seconds. A preliminary comparison of these isolated discharges in one storm on June 29th, 2000, to the wind-field data from the radar synthesis, shows that most of them are occurring on the edges of the updrafts. These are also the same type of discharges that have been seen in the convective surges higher up in the storm that indicate severe weather. Another type of short duration discharge is the precursor event, which can occur up to half a second before an intra-cloud discharge. They are located in the same area as the initial points of the following discharge. This is different from the isolated events which are scattered spatially. The last category of short duration discharges is the high source power event, which have powers ranging from 100 kW to 52MW in the 60-66 MHz passband. These high power events have been seen as both isolated and precursor events. What makes them different is that they are significantly higher in power than 99% of the other located LMA sources, which range from 1W to 10 kW. Some of these events have been recorded by fast antenna and from the sferic waveform they have been identified as positive bi-polars. Analysis of these short duration flashes is an ongoing attempt to better understand the total lightning picture.

URL: http://lightning.nmt.edu/

AE21A-1094 0830h POSTER

Further evidence for unconventional electrical discharges in thunderstorms

Abram R Jacobson ((505)667-9656; ajacobson@lanl.gov)

Space and Atmospheric Sciences Group, Los Alamos National Laboratory, Mail Stop D466, LANL, Los Alamos, NM 87545

We present a statistical analysis of thunderstorm radiofrequency and optical data from the FORTE satellite to examine the relationship of strong radiofrequency pulsed emissions to more conventional signals from lightning. The study is built on a FORTE database of intracloud, pulsed radio signals from storms whose geolocation is provided either by coincidence with the FORTE optical imager or by coincidence with ground-based lightning-detection arrays. Intracloud radio emissions with peak power >40 kW in the FORTE low band (26-48 MHz) have unique characteristics compared to weaker emissions, including: Occurring either in isolation or at the start of leader progression, but never within a progressing leader; occurring without light emission detectable with FORTE; occurring in frequent association with a rapid (10 microsec) relaxation of the electric charge; and followed by an upward-progressing leader, in the cases where a leader is initiated. These strong intracloud radio pulses appear to be associated with an intracloud discharge process that is physically distinct from conventional leader progression.

AE21A-1095 0830h POSTER

A Distinct Class of Negative Cloud-to-ground Flashes Observed by a Broadband Interferometer

Takeshi Morimoto[1] (81-6-6879-7700; morimoto@comf5.comm.eng.osaka-u.ac.jp)

Ryota Kawabe[1] (kawabe@comf5.comm.eng.osaka-u.ac.jp)

Yoichi Sonoda[1] (sonoda@comf5.comm.eng.osaka-u.ac.jp)

Zen Kawasaki[1] (zen@comm.eng.osaka-u.ac.jp)

Tomoo USHIO[2] (ushio@aero.osakafu-u.ac.jp)

[1] Department of Communications Engineering Graduate School of Engineering, Osaka University, Yamada-Oka 2-1, Suita 565-0871, Japan

[2] Department of Aerospace Engineering Graduate School of Engineering, Osaka Prefecture University, 1-1 Gakuencho, Sakai 599-7531, Japan

Two-dimensional and three-dimensional VHF source mapping systems of electromagnetic (EM) waves emitted by lightning discharge progression have been established by a unique technique based on the broadband digital interferometry. Lightning Research Group of Osaka University (LRGOU) has been conducting lightning observations in Darwin during summer thunderstorm seasons. The main objective of the Darwin campaign is the investigation of thunderstorm activity in inter tropical convection zone (ITCZ) from the aspect of VHF observations. Through these observations real time monitoring in terms of two-dimensional are realized and three-dimensional images of lightning channels by the post processing are obtained. We pay our attention to leader propagation channels of negative cloud-to-ground (CG) flashes especially their initiations, and 2 categories are identified. One is characterized that negative leaders begin at an altitude of around 8 kilometers and go down to the ground for several tens milliseconds. The other, in contrast, has some intermittent VHF radiations at 10 kilometers agl about 1 millisecond before continuous leader development which one has. Narrow bipolar pulses (NBPs) are clearly noticed in the electrical field changes in synchronization with VHF radiations at high altitude. The observations with cross-polarized radar show that the main precipitation particles are wet graupel at an altitude of 8 kilometers and the dray snow is dominant above 10 kilometers high. Assuming the tri-pole electric charge structure based on the riming electrification mechanism, it is considered that the former is triggered at lower positively charged region or between lower positive and dominant negative charge region, and the latter is triggered at higher positively charged region or between higher positive and dominant negative charge region. Additionally, the ignitions at high altitude could be powerful events. We speculate that VHF radiations at high altitude relate to transionospheric pulse pairs (TIPPs) and/or compact intracloud discharges (CIDs). This work was supported by grant of Tropical Rainfall Measuring Mission (TRMM) 3rd Research Announcement of NASDA, Japan, and the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research (A), 14254001, 2002. The authors thank them for their support.

AE21A-1096 0830h POSTER

COSMIC RAYS AND RUNAWAY ELECTRONS: EVIDENCE FOR ACCELERATION OF ELECTRONS DURING THUNDERSTORMS

Aleksandr S. Lidvansky[1] (7 095 1358560; lidvansk@sci.lebedev.ru)

Nail S. Khaerdinov[1] (7 866 3878607; khaerdinovs@yandex.ru)

Valery B. Petkov[1] (7 866 3878607; vpetkov@yandex.ru)

[1] Institute for Nuclear Research, 60th October Anniversary pr. 7a, Moscow 117312, Russian Federation

We present the data on correlations of the intensity of the soft component (10 -30 MeV) of cosmic rays with the local electric field of the near-earth atmosphere during thunderstorm periods at the Baksan Valley (North Caucasus, 1700 m a. s. l.). The large-area array for studying the extensive air showers of cosmic rays is used as a particle detector. An electric field meter of the electric mill' type is mounted on the roof of the building in the center of this array. The data were obtained in the summer seasons of 2000–2002. We have observed strong enhancements of the soft component intensity before some lightning strokes [1]. The largest enhancement detected in the first season demonstrated an exponential growth of intensity before lightning and was interpreted as a confirmation of runaway electron breakdown mechanism [2]. However, this event is apparently very rare (a single event for three seasons of observation). The enhancements of a different pattern (slow events several minutes long) turned out to be much more numerous. Recently, a special experiment was made to estimate the minimum distance to lightning events [3], and the distances were found to be fairly large (2-5 km). At the same time, the analysis of the regression curve intensity versus field' [4] discovers a bump at the field sign that is opposite to the field sign corresponding to acceleration of electrons (see Fig. 1). It is interpreted as a precipitation of runaway electrons from the region of the strong field (with the opposite sign) overhead. If this interpretation is true, one can conclude from these data that (i) Wilson's runaway electrons do exist, (ii) their energy can be pretty high (more than ten MeV), and (iii) they are not necessarily directly related to lightning events. Fig. 1. Deviation of the soft component intensity from its mean value versus the near-earth electric field during thunderstorms. The left-hand side of the plot corresponds to acceleration of electrons near the ground. The bump in the right-hand side is interpreted as a signature of runaway electrons accelerated and multiplied in the stronger field of opposite sign at the cloud layer. REFERENCES 1. Alexeenko, V.V., Khaerdinov, N.S., Lidvansky, A.S., and Petkov, V.B., Transient Variations of Secondary Cosmic Rays due to Atmospheric Electric Field and Evidence for Pre-Lightning Particle Acceleration, Phys. Lett., A301, 299-306, 2002. 2. Roussel-Dupre, R.A., Gurevich, A.V., Tunnell, T., and Milikh G.M., Kinetic theory of runaway air breakdown, Phys. Rev. E, 49, 2257-2271, 1993. 3. N.S. Khaerdinov, A.S. Lidvansky, V.B. Petkov, Yu.P. Surovetsky, and A.F. Yanin, Estimate of Distance to Lightning Events Associated with Cosmic Ray Enhancements during Thunderstorms, Proc. 28th ICRC, Tsukuba, Japan, July 31-August 7, 2003, 4165-4168. 4. N.S. Khaerdinov, A.S. Lidvansky, V.B. Petkov, and Yu.P. Surovetsky, Effect of the Disturbed Electric Field of the Atmosphere on Cosmic Rays: 1. Soft Component, Proc. 28th ICRC, Tsukuba, Japan, July 31- August 7, 2003, pp. 4169-4172.

AE21A-1097 0830h POSTER

Cosmic-ray Ionization Current to Ground And Its Impact on The Global Circuit

Jonah J Colman[1] (505-667-3409; jonah@lanl.gov)

Robert A Roussel-Dupre[1] (505-667-9228; bobrd@lanl.gov)

[1] Los Alamos National Laboratory, Atmospheric, Climate, and Environmental Dynamics (EES-2), Mail Stop D401, Los Alamos, nm 87545, United States

The constant current that sustains the earth's global electrical circuit has a magnitude ranging from ~ 750A - 2000A and is believed to originate from a thousand or so thunderstorms distributed across the globe. Based on a very limited set of measurements each thunderstorm is believed to carry approximately 0.5A - 1A of net positive current to the ionosphere over extended periods of time (hours) and in this way maintain the circuit and the associated earth-ionosphere potential of ~ 300 kV. The difficulties faced in verifying this paradigm have prompted us to search for a simpler alternative. In this presentation we examine the role played by the ionization produced by cosmic rays and radioactivity in driving a net electron current into the ground in a process generally referred to as the probe effect. A detailed calculation of the steady state electron distribution function from zero energy to relativistic energies is presented. Both the cosmic ray flux and the amount of radioactivity due to various radioactive gases are varied. The effects of attachment and detachment are included and the water vapor content is varied. The net flux of electrons into the ground is calculated. The impact of the results on our understanding of the global circuit will be discussed.

AE21A-1098 0830h POSTER

The Runaway Electron Avalanche as a Radio Emitter in Thunderstorms

Heidi E Tierney[1] ((505)665-8018; htierney@lanl.gov)

Robert A Roussel-Dupre[1] (rroussel-dupre@lanl.gov)

Eugene MD Symbalisty[2] (esymbalistycfl.rr.com@aftac.gov)

William H Beasley[3] (whb@ou.edu)

[1] Los Alamos National Laboratory, PO Box 1663, MS F665, Los Alamos, NM 87544, United States

[2] AFTAC TTAD, 1030 S. Highway A1A, Patrick AFB, FL 32925-3002, United States

[3] School of Meteorology, University of Oklahoma, Norman, OK 73019, United States

Previous simulations of runaway electron avalanches in the atmosphere, which solve the modified relativistic Boltzmann equation for various values of ambient electric field, have yielded the equilibrium ionization rates and energy distribution functions for the runaway electrons. The mean runaway electron energies and associated rates are employed here in two macroscopic treatments in order to set bounds on the expected radio emissions from runaway electron avalanches occurring in thunderstorms. The ambient electric field is that calculated from two disks of charge with sinusoidally varying charge density in altitude and peak charge density of ± 10 nC/m^3. An analytic expression for the radiatied electric field from a point-charge avalanche, including high-energy and low-energy electrons is shown to be highly dependent upon the ambient electric field strength and profile. For comparison, a one-dimensional numerical model of a runaway electron avalanche and the resulting radio emissions are presented. For the numerical case the runaway avalanche is dominated by production of high and low-energy electrons, relaxation, electron attachment, and high-energy electron loss. The radius of the 1-D electron avalanche is treated as an independent parameter and the resulting rise in the channel conductivity can limit the amplitude of the radio emissions, even in strong ambient electric fields. The peak electric-field amplitude and HF and VHF spectral amplitudes are compared with narrow bipolar pulse observations.

AE21A-1099 0830h POSTER

New instruments for measuring x-rays from rocket-triggered lightning

Maher Al Dayeh[1] (maldayeh@fit.edu); Joseph R Dwyer[1] (321-674-7208; dwyer@pss.fit.edu); Martin A Uman[2] (uman@ece.ufl.edu); Hamid K Rassoul[1] (rassoul@pss.fit.edu); Vladimir A Rakov[2] (rakov@ece.ufl.edu); Lee Caraway[1] (caraway78@yahoo.com); Brian Wright[1] (bwright@fit.edu); Andrew Chrest[1] (achrest@fit.edu); Keith J Rambo[2] (rambo@tec.ufl.edu); Douglas M Jordan[2] (jordan@ece.ufl.edu); Jason Jerauld[2] (jjerauld@ufl.edu); Chuck Smyth[2] (cadet003@hotmail.com)

[1] Florida Institute of Technology, Department of Physics and Space Sciences, Melbourne, FL 32901, United States

[2] University of Florida, Department of Electrical and Computer Engineering, Gainesville, FL 32611, United States

We have previously reported the observations of energetic radiation from rocket-triggered lightning made in the summer of 2002. These observations used one 12.7 cm diameter NaI(Tl)/PMT detector and one identical control detector (with no scintillator), housed in a container designed to operate in the electromagnetically noisy environment near lightning. Since then, we have constructed four new instruments, using seven 7.6 cm diameter NaI(Tl)/PMT detectors plus one control detector. The instruments were each housed in a heavy aluminum box. The sides of the boxes were 1.27 cm thick, except for a 0.32 cm thick Al window on the top that allowed x-rays with energies down to 30 keV to enter. The boxes were welded and RF gaskets and O-rings were used on all access doors to prevent RF noise, moisture and light from entering. The instruments were battery powered, and controlled on and off through fiber optic signals. In addition, the data were transmitted through fiber optic cables to a receiver in a shielded metal trailer and saved on the hard drives of three PCs. Data acquisition was initiated by an external trigger derived from the lightning current, signaling the time of the leading edge of the return strokes or other large current pulses. The entire waveforms from seven of the PMT detectors were then digitized with 0.2 microsecond resolution for 220 msec with 20 msec of pre-trigger sampling. For three detectors the waveforms were digitized with 10 nanosecond resolution for 10 msec with 1 msec of pre-trigger sampling. Measurements were made using these instruments at the International Center for Lightning Research and Testing (ICLRT) at Camp Blanding, FL during the summer of 2003, and 10 flashes were observed with a total of 28 dart leader/return strokes sequences and two initial continuous current intervals. For the first five lightning flashes, 1.7 cm thick bronze collimators were placed around and in front of the detectors in order to study the intensity and arrival time of the x-rays as a function of height above the ground. The collimators had an opening angle of about plus or minus 15 degrees and were pointed in the direction of the lightning channel at 0, 15, 30 and 45 degrees from vertical. For the remaining five flashes, the collimators were replaced with bronze attenuators to study the energy spectra and electron and photon components of the energetic radiation. In a final experiment, the spacing and distance of the instruments were varied to study the spatial extent of the x-rays. In this report we shall describe the x-ray instruments, the observations made, and give a brief overview of the results.

AE21A-1100 0830h POSTER

Modeling of Sprite Optical Emissions From Runaway and Conventional Breakdown and Comparison to Measurements

Laurie A. Triplett[1] ((505) 665-3328; ltriplett@lanl.gov)

Robert A. Roussel-Dupre[1] ((505) 667-9228; rroussel-dupre@lanl.gov)

Eugene M. D. Symbalisty[2] ((321) 494-8455; emds@aftac.gov)

David M. Suszcynsky[3] ((505) 665-3119; dsuszcynsky@lanl.gov)

Hiedi E. Tierney[1] ((505) 665-8018; htierney@lanl.gov)

[1] Los Alamos National Laboratory, EES-2, MS F665, Los Alamos, NM 87545, United States

[2] AFTAC/TTAD, 1030 S. Highway A1A, Patrick AFB, FL 32925-3002, United States

[3] Los Alamos National Laboratory, NIS-1, MS D466, Los Alamos, NM 87545, United States

There has been much scientific interest in understanding the physical processes that lead to high-altitude optical transients (i.e. sprites). Are sprites formed through conventional breakdown, runaway breakdown, or a combination of both depending on conditions? In this paper, we describe the calculation of optical emissions associated with two different simulations performed with a 2-d fully electromagnetic discharge model (UNIMAX). Optical emissions driven by primary electrons (runaway breakdown) are calculated using measured fluorescence efficiencies and quenching rates for each wavelength of interest. For the secondary electrons (conventional breakdown and secondary electrons sustained in an electric field that lies below the conventional breakdown threshold), the emissivity of nitrogen bands as a function of electric field are used to estimate the optical emissions for the N_2 1P, 2P, and N_2^+ 1N bands. We developed a methodology to split the band results into individual transitions. In addition, we include absorption from the source to an observer at a specified height. We present simulated camera images, line ratios, and spectra for a typical sprite and a carrot-type sprite. We compare our model results in detail to measurements to identify more precisely what diagnostic information about the discharge plasma can be deduced from such observations. The differences between conventional breakdown models and those based on the simultaneous occurrence of both processes are delineated.

AE21A-1101 0830h POSTER

Measurements of Continuing Currents in Lightning using ULF Magnetic Fields

Arthi Swaminathan[1] (9196605232; as75@ee.duke.edu)

Steven Andrew Cummer[1] (9196605256; cummer@ee.duke.edu)

Martin Fuellekrug[2] (+49 69 798-23959; fuellekr@geophysik.uni-frankfurt.de)

Walter Lyons[3] (1-800-854-7219; walyons@mail.frii.com)

[1] Duke University, 130 Hudson Hall, Dept. of Electrical and Computer Engineering, Durham, NC 27708, United States

[2] University of Frankfurt Am Main, Institute for Meteorology and Geophysics,, Frankfurt 60323, Germany

[3] FMA Inc., Forensic Meteorology and Geophysics Associates, Inc., Fort Collins, CO 80524, United States

Because they are difficult to measure, relatively little is known about the long duration continuing currents that are present in some lightning flashes despite their being one of the most damaging lightning processes. We use a combination of the Ultra Low Frequency (ULF) magnetic fields recorded at three stations (Santa Cruz, California, Socorro, New Mexico, and Saskatoon, Canada) and NLDN from 11 July to 12 August 1998 to detect and measure the amplitude and duration of the continuing currents which occur after some lightning flashes. Continuing currents of up to 450 milliseconds duration and peak amplitudes of up to 200 kA-km have been detected by our analysis. We report the frequency of occurrence of these continuing currents, largest and longest recorded continuing currents, the total charge moment of the continuing currents and the storm to storm variability of these currents. We will also address whether these continuing currents occur during the day or night, whether few storms produce almost all the lightning currents, and how the current strength is related to other lightning flash parameters so that we can have a better understanding of the basic meteorological conditions under which these continuing currents occur.

AE21A-1102 0830h POSTER

Attenuation Of Current Wave Propagating Along A Perfectly Conducting Wire: Application To Lightning

Yoshihiro Baba[1,2] (352-392-9794; ybaba@mail.doshisha.ac.jp)

Vladimir A. Rakov[1] (352-392-4242; rakov@ece.ufl.edu)

[1] Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611, United States

[2] Department of Electrical Engineering, Doshisha University, Kyotanabe, Kyoto 610-0321, Japan

In this study, using the finite-difference time-domain (FDTD) method for solving Maxwell's equations, we demonstrate that a vertical phased array of current sources above perfectly conducting ground, activated as prescribed by the transmission line (TL) model with return-stroke speed equal to the speed of light ($v = c$), produces a spherical TEM wave, identical to that analytically derived for the TL model with $v = c$ by Thottappillil et al. [2001]. (This can be viewed as a proof of validity of the FDTD method used here.) Then, we apply the same approach to the case of a lumped current source at the bottom of a vertical perfectly conducting wire above perfectly conducting ground and show that the current wave launched by the current source propagates upward with attenuation and that the resultant field structure is non-TEM, as also follows from other lightning return stroke models based on solving Maxwell's equations. The attenuation is stronger for shorter current pulses and for current sources of smaller length. Thus, it appears that the basic assumption of the TL model (no current attenuation with height) is inconsistent with Maxwell's equations, unless the lightning channel is viewed as a phased array of current sources. It is inconsistent with the transmission line theory either, since a vertical wire above ground constitutes a non-uniform transmission line, whose characteristic impedance varies with height. We will try to explain the mechanism of current attenuation on a vertical perfectly conducting wire above perfectly conducting ground, usually attributed to radiation losses, on the basis of the electromagnetic field theory. In particular, we will discuss the interaction of the electromagnetic field produced by the source with the vertical conductor and ground and the direction of resultant Poynting vector. Thottappillil, R., J. Schoene, and M. A. Uman, Return stroke transmission line model for stroke speed near and equal that of light, Geophys. Res. Lett, 28(18), 3593-3596, 2001.

AE21A-1103 0830h POSTER

Propagation Speeds of Lightning Leaders Throughout an Entire Flash Using 10 μs Time Resolution 3D Mapping Data.

Sonja A Behnke[1] (sbehnke@nmt.edu)

Ronald J Thomas[1] (thomas@nmt.edu)

Paul Krehbiel[1] (krehbiel@ibis.nmt.edu)

William Rison[1] (rison@arctic.nmt.edu)

[1] Geophysical Research Center, New Mexico Institute of Mining and Technology, Socorro, NM 87801

The Lightning Mapping Array normally records lightning radiation sources in each 80 μs time interval but can be operated in a high time resolution mode where sources can be located as often as every 10 μs. The 10 μs data can show very detailed structure and development of the breakdown channels. Using the 10 μs data, we have performed a detailed analysis of several flashes, including intracloud, cloud-to-ground, and bolt-from-the-blue type discharges, in which we isolated most of the branches and made cubic spline fits to the x, y, and z values versus time. From the analyses, we have characterized the evolution of both the individual branches and of the overall flash. For an individual branch, we often see the speed of the branch decreasing with time, reaching some minimum speed, usually between $4 - 8 \times 10^4$ m/s, at which the branch expires. Overall, we have found that typical branch speeds range between 4×10^4 and 2×10^5 m/s.

AE21A-1104 0830h POSTER

Lightning Current Parameters of Upward Lightning Flashes Observed at the 200-m Fukui Chimney in Winter

Atsushi Wada[1] (+81 3-3480-2111; jun@criepi.denken.or.jp)

Akira Asakawa[1]

Megumu Miki[1]

Takatoshi Shindo[1]

[1] Central Research Institute of Electric Power Industry, 2-11-1, Iwado Kita, Komae-shi, Tokyo 201-8511, Japan

For over twenty years we have been observing the lightning flashes at the 200-m-tall chimney in the Fukui thermal power plant in winter in Japan. The local IKL (thunderstorm days) is about 40 in this area and the lightning flashes at the chimney are recorded about 40 times in a winter season. When the lightning strikes the 5-m lightning rod on top of the chimney, lightning currents are measured by using coaxial shunt-resistors installed at the base of the lightning rod. Lightning progressing features was measured by the 40X40 pin photodiode array system. The system records luminosity changes in the lightning channel by measuring the differences between signals from different photodiodes. At a distance of 630 m from the chimney, a vertical lightning channel of 1000 m is divided by using 40 diode elements. Electromagnetic field changes that accompany lightning flashes are also measured by using several types of antennas. These simultaneous measurements classified the behavior of winter lightning flashes. All recorded lightning flash was the lightning discharge initiated by the upward leader from the chimney. Most lightning (about 90 percent) was the lightning discharge initiated by the upward-moving positively charged leader. The lightning initiated by the upward-moving negatively charged leader was only about 10 percent. Some of the lightning produced the subsequent discharge processes following the upward leader development. There are many differences between the lightning current parameters of upward lightning flashes and the downward lightning flashes. Interestingly, the upward leader currents observed at the chimney are big compared to the downward leader currents estimated by the several methods. We will report the properties of lightning current parameters based on the data collected at the 200-m-tall chimney in winter. These statistical data of lightning current parameters are classified especially from the point of view of lightning discharge types.

AE22A MCC: Level 2 Tuesday 1330h

Advances in Lightning and Atmospheric Electricity Remote Sensing Systems and Algorithms I Posters *(joint with A)*

Presiding: **M Murphy,** Vaisala, Inc.**;** **D J Boccippio,** NASA Marshall Space Flight Center

AE22A-1105 1330h POSTER

Lightning Initiation Locations as a Remote Sensing Tool of Large Thunderstorm Electric Fields

Christopher R Maggio[1] (662-915-1544; crmaggio@olemiss.edu); Leonidas M Coleman[1] (662-915-7928; leonidas@phy.olemiss.edu); Thomas C Marshall[1] (662-915-5325; marshall@olemiss.edu); Maribeth Stolzenburg[1] (662-915-5252; mstolzen@phy.olemiss.edu); Mark A Stanley[3] (505-667-8353; stanleym@lanl.gov); Timothy Hamlin[2] (505-835-5137; thamlin@nmt.edu); Paul R Krehbiel[2] (505-835-5215; krehbiel@ibis.nmt.edu); William Rison[2] (505-835-5486; rison@ee.nmt.edu); Ronald J Thomas[2] (505-835-5683; thomas@nmt.edu)

[1] University of Mississippi , Department of Physics and Astronomy, University, MS 38677, United States

[2] New Mexico Institute of Mining and Technology, Geophysical Research Center , Socorro, NM 87801, United States

[3] Los Alamos National Laboratory, Space and Atmospheric Sciences, NIS-1, MS D466, Los Alamos, NM 87545, United States

In this presentation we compare lightning data recorded with a three-dimensional lightning mapping array (LMA) with a flat plate antenna operated both as a 'slow' antenna and as a 'fast' antenna. The goal of these comparisons is to quantify any time delay that may exist between the initial responses of the instruments to a lightning flash. The data consists of 74 flashes from a single New Mexico thunderstorm. We find that the initial radiation source detected by the LMA usually leads the initiation response of both the slow and fast antennas. In a small number of cases, the flat plate antenna response leads the initial LMA source, but by no more than 2 milliseconds. Our observations of such close time coincidence suggest that the first LMA radiation source of each flash was located at or very near the flash initiation point. Thus, the first LMA radiation source detected from a lightning flash could be used as a remote sensing tool to find the locations of large electric fields within lightning producing clouds.

AE22A-1106 1330h POSTER

Identifying Thunderstorm Cells With LDAR Flash Initiation Points and Difficulties of Associating Lightning With Radar Cells

Nicholas Demetriades[1] (520 806 7523; nick.demetriades@vaisala.com)

Ronald Holle[1] (ron.holle@vaisala.com)

Martin Murphy[1] (martin.murphy@vaisala.com)

[1] Vaisala Inc., 2705 E. Medina Rd., Tucson, AZ 85706, United States