NEWSLETTER ON ATMOSPHERIC ELECTRICITY

Vol. 12 No. 1 MAY 2001

INTERNATIONAL COMMISSION ON ATMOSPHERIC ELECTRICITY (IAMAS/IUGG)

AMS COMMITTEE ON ATMOSPHERIC ELECTRICITY

AGU COMMITTEE ON ATMOSPHERIC AND SPACE ELECTRICITY

EUROPEAN GEOPHYSICAL SOCIETY

SOCIETY OF ATMOSPHERIC ELECTRICITY OF JAPAN

ANNOUNCEMENTS

The Newsletter on Atmospheric Electricity is now sent by e-mail. We remind all our colleagues that it is also routinely provided on the web (http://ae.atmos.uah.edu), thanks to Monte Bateman's help. Those individuals needing a mail version should contact Serge Chauzy: (chas@aero.obs-mip.fr) or Pierre Laroche: (laroche@onera.fr). They will receive the Newsletter in its paper version. Those knowing anybody who needs such a paper version are also welcome to contact us. On the other hand, the easiest way to communicate being now electronic mail, we would be grateful to all of those who can help us complete the "atmospheric electricity" list of email addresses already available.

Contributions to the next issue of this Newsletter (November 2001) will be welcome and should be submitted to Serge Chauzy or Pierre Laroche before October 31, 2001, preferably under word attached documents. A reminder will be sent to all colleagues whose e-mail addresses are presently listed.

CONFERENCES

IAMAS 2001

The next assembly of the International Association of Meteorology and Atmospheric Sciences will be held in Innsbruck, Austria, 10 - 18 July, 2001. One Symposium of special interest to Newsletter readers is planned:
7.6: The global effect of thunderstorm-produced NOx on tropospheric ozone; ICACGP, ICAE IOC-ICAE, ICCP.
Convenors: James Dye, Mesoscale and Macroscale Meteorology Division, National Center for Atmospheric Research, Boulder, CO, USA, e-mail: dye@ncar.ucar.edu. Hartmut Hoeller, Institut für Physik der Atmosphäre, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen, Germany; e-mail: hartmut.hoeller@dlr.ge. Kenneth Pickering (University of Maryland, USA).
More information is available on the web site: http://iamas.org/

ICOLSE 2001

The 2001 International Conference on Lightning and Static Electricity (ICOLSE) will take place September 11-13, 2001, in Seattle, Washington, as part of the Aerospace Congress and Exhibition (ACE). For more information visit http://www.sae.org/calendar/ico/cfp.htm.

IAGA 2001

The International Association of Geomagnetism and Aeronomy Conference will be held in Hanoi, Vietnam, August 19-31, 2001. Two sessions of special interest to Newsletter readers are planned, one treating sprites and other middle atmosphere electrical phenomena (Dave Sentman and H. Fukunishi, Co-Convenors) and one concerned with giant positive discharges (Earle Williams and Martin Fullekrug, Co-Convenors). The abstract deadline was February 1, 2001. Invited talks are also planned. Excellent opportunities here for direct interaction with tropical thunderstorms in Southeast Asia!
Web site: www.ngdc.noaa.gov/IAGA/
Two Special Sessions are of interest for our community:
GAII 1: Transient Effects of Lightning on the Middle and Upper Atmosphere: Sprites and Other Effects. Convenor: D.D. Sentman (Physics Department and Geophysical Institute, University of Alaska, Fairbanks, AK 99775, U.S.A.; Tel: +1-907-474-6442; Fax: +1-907-474-7290, E-mail: dsentman@gi.alaska.edu. Co-Convenor: H. Fukunishi.
GAII 2: Physics and Global Behavior of Giant Lightning Discharges. Convenors: E.R. Williams (Parsons Laboratory, Massachusetts Institute of Technology, Cambridge, MA 02139 USA; Tel: +1-617-253-2459, Fax:+1-781-981-0632, E-mail: earlew@ll.mit.edu. Co-Convenor: M. Fullekrug.

IWPL'2001

The 5th International Workshop on Physics of Lightning will take place September 10-13, 2001, in Nagoya-Japan. The main subjects of interest are:

1. Thunderstorm Electrification and Atmospheric Electricity
2. Lightning phenomenology and meteorology
3. Lightning discharge physics
4. Lightning detection and protection
5. Lightning and Human Beings
6. Lightning and Atmospheric Environment

The deadline for abstracts submission was December 1st, 2000. More details on the web site: http://eism.elcom.nitech.ac.jp/~iwpl/index.html

VII. INTERNATIONAL SYMPOSIUM ON BALL LIGHTNING (ISBL2001)

This conference will be held July 26-29, 2001 on the Campus of the University of Missouri in St. Louis, MO, USA. Prof. Peter H. Handel is organizing this Symposium and can be reached for information at this address: Peter H. Handel Dept. of Physics and Astronomy University of Missouri St. Louis, MO 63121 USA
Phone: 314-516-5021, FAX: 314-516-6152
e-mail: handel@umsl.edu
The deadline for the Submission of abstracts was March 5, 2001.

AGU 2001 SPRING MEETING

The 2001 Spring Meeting of the American Geophysical Union takes place in Boston, USA, May 29 – June 2, 2001. More information on the web site: www.agu.org/meetings.

AGU 2001 FALL MEETING

The 2001 Fall AGU Meeting will be held on December 10-14, 2001 in San Francisco. The AGU Committee on Atmospheric and Space Electricity (CASE) is soliciting proposals for special sessions for this meeting. Special session proposals are due to Vlad Rakov, 2001 Fall AGU program committee member from CASE, before May 25, 2001. Proposals should include a special session title, descriptive paragraph about the proposed session, convener name(s), and convener contact information. As of today, two special sessions have been proposed:
Electrical effects of thunderstorms on the middle and upper atmosphere (co-conveners D. Sentman and V. Pasko).
Lightning and storm electrification (co-conveners V. Rakov and D. MacGorman).
The deadline for receipt of electronic abstracts is September 6, 2001, 1400 UTC. For more information about the 2001 Fall AGU meeting, please visit:
http://www.agu.org/meetings/fm01call.html

AGU Committee on Atmospheric and Space Electricity (CASE)

The AGU Committee on Atmospheric and Space Electricity (CASE) is soliciting proposals for special sessions for this meeting. Special session proposals are due to Vlad Rakov, 2001 Fall AGU program committee member from CASE, before **May 25, 2001**. Proposals should include a special session title, descriptive paragraph about the proposed session, convener name(s), and convener contact information. As of today, two special sessions have been proposed:

1. Electrical effects of thunderstorms on the middle and upper atmosphere (co-conveners D. Sentman and V. Pasko).
2. Lightning and storm electrification (co-conveners V. Rakov and D. MacGorman).

The deadline for receipt of electronic abstracts is **September 6, 2001, 1400 UTC**. For more information about the 2001 Fall AGU meeting, please visit http://www.agu.org/meetings/fm01call.html.

Below is a list of CASE members appointed by AGU President for the term from July 1, 2000 to June 30, 2002.

Chair:
Vladimir A. Rakov, Department of Electrical and Computer Engineering, University of Florida.
Members:
Dennis J. Boccippio, Global Hydrology & Climate Center, NASA Marshall Space Flight Center.
Vernon Cooray, Institute of High Voltage Research Uppsala University.
James E. Dye, National Center for Atmospheric Research.
Kennneth Eack, Langmuir Laboratory, New Mexico Institute of Mining and Technology.
John Hallett, 1316 Muir Drive Reno, NV 89503.
John H. Helsdon, Institute of Atmospheric Sciences, South Dakota School of Mines & Technology.
Robert H. Holzworth, Department of Geophysics, University of Washington.
Umran S. Inan, STAR Laboratory, Stanford University.
Pierre Laroche, Office National d'Etudes et de Recherches Aerospatiales, Paris.
Donald R. MacGorman, National Severe Storms Laboratory, University of Oklahoma.
Launa M. Maier, TE-ISD-8A
NASA/Kenney Space Flight Center, Kennedy Space Center.
Arthur D. Richmond, High Altitude Observatory, National Center for Atmospheric Research.
David A. Smith, Space & Atmospheric Sciences, Los Alamos National Laboratory
Jeffrey P. Thayer, SRI International, Menlo Park, CA 94025..
Brian A. Tinsley, University of Texas, Dallas.
Daohong Wang, Department of Electronics & Computer Engineering, Gifu University, JAPAN.
John C. Willett, Geophysics Directorate, Phillips Laboratory.
Earle R. Williams, Parsons Laboratory, Massachusetts Institute of Technology

30th CONFERENCE ON RADAR METEOROLOGY

This AMS Conference will be held 19-24 July 2001, in Munich, Germany. Deadline for abstract has passed. More information is available on the web site: http://www.ametsoc.org/AMS/meet/fainst/30radar_hp.html

AWARD

JOHN ADAM FLEMING MEDAL

Our colleague Martin A. Uman, Professor at the University of Florida, has been awarded the 2001 John Adam Fleming Medal by the American Geophysical Union. The medal recognizes original research and technical leadership in geomagnetism, atmospheric electricity, aeronomy, space physics, and related sciences. The "Citation" will be given by E. Philip Krider at the AGU Spring Meeting in Boston on May 31, 2001.

RESEARCH ACTIVITY BY ORGANIZATION

*AIRBORNE RESEARCH ASSOCIATES (Weston, MA)

During the summer and fall of 2000 Ralph Markson continued development of the ATLAS single sensor total lightning mapping system using the ARA TurboBaron aircraft to study storms in Florida and with ground based ATLAS systems. A newly developed wave visualization system with 10 ns sampling showed details of the initial breakdown which had not been observed previously. Initial results with the new system supports the concept of using the initial breakdown amplitude as an invariant strength signal which will allow the first accurate range estimation from a single sensor. Additional work is required including acquiring more data and automation of the system.

The second project done at ARA was full time-lag analysis of the ionospheric potential variation, obtained from balloon soundings, compared to temperature variation over Africa and South America. In agreement with earlier preliminary reports (e.g., ICAE/AE Conference, Guntersville, 1999) it was found that there was a positive correlation using morning temperature but shielding of solar radiation by cloudiness created by the initial thunderstorms in late morning and early afternoon decreases temperature in the mid and late afternoon causing an inverse correlation. A paper discussing the relationship of the global circuit to global warming is being prepared for publication.

* THE UNIVERSITY OF ARIZONA (Tucson, Arizona, USA)

Natalie Murray and E. P. Krider are collaborating with John Willett on a re-examination of the submicrosecond structure of dE/dt and E waveforms radiated during the onset of first return strokes in cloud-to-ground lightning. We have found that most strokes produce multiple pulses in dE/dt during the onset of the slow front and/or the fast transition in E, and that there are very narrow peaks and considerable structure in the associated E signatures. Natalie is also measuring the spatial and temporal coherence of space charge generated within or near the surf zone at the NASA Kennedy Space Center (KSC). This summer Natalie will measure the surface electric field over water and over land using a mobile sensor to support an aircraft campaign being conducted by Hugh Christian and Jim Dye at KSC.

Nathan Parker is extending William Valine's work on the luminous development of lightning and the multiplicity of attachment points in cloud-to-ground discharges. Nicole Kempf is continuing Bruce Gungle's study of the relationships between lightning and convective rainfall. William Koshak and E. P. Krider are studying the response of the NASA Lightning Imaging Sensor (LIS) when lightning occurs over or near the KSC and is within the LIS field of view. An effort is also being made to determine if the total light output from lightning flashes, as recorded by LIS, is proportional to the total charge in the flash or any other electrical parameter. Charles Weidman is developing and testing optical sensors that elementary, high school, and college students can use to help validate the performance of satellite lightning sensors. Charles is being assisted in this work by Gary Wallace and Peter Lewis.

* COLORADO STATE UNIVERSITY (Fort Collins, Colorado, USA)

1. RADAR METEOROLOGY GROUP

Severe Thunderstorm, Electrification and Precipitation Study (STEPS)

Preliminary activities include attempts to quantify the climatological difference between positive and negative lightning-producing storms. Comparisons are made based on polarity, percent positive, flash density, and geography. In addition to better understanding the physics of these storms, these measurements may provide insight into whether operational forecasters will be able to "nowcast" severe weather formation through the use of lightning data.

1) 11-12 June, 2000-0200 UTC: Bow-echo MCS with predominately positive CG lightning-producing convection, and a trailing region of stratiform precipitation that also produced a few positive CG's. Interestingly, convection on the south side of the MCS produced predominately negative CG lightning (coincident with positive CG lightning on the north end of the system) during initial stages of the lifecycle. This storm was classified as severe based on reports of 3/4 inch hail, but was apparently non-tornadic. The LMA noted horizontally propagating lightning into the trailing stratiform region. We are at the initial stage of analysis for this case and will focus on dual-Doppler derived kinematics and polarimetric retrieval of relevant microphysics. These results will subsequently be compared to EFM (balloon), LMA, and aircraft data, all of which gathered robust data samples in the convective and stratiform regions of the MCS.

2) 29-30 June: 20:30-03:00 UTC: Kyle Wiens is conducting initial analyses of NEXRAD and LMA data that show two distinct cells which developed near the KS-CO-NE border with nearly identical electrical characteristics in their early stages. Both cells appeared to be inverted electrically, with negative charge overlying positive and IC lightning between the two. One cell weakened and moved off while the other underwent a dramatic change in a matter minutes. This second cell showed explosive vertical development and drastic changes in its electrical activity; it became a supercell and later produced a tornado. There was excellent coverage by nearly all STEPS instrumentation during this time. There are plans to include more data sets to try to determine why these two cells exhibited such drastically different behavior. Review is underway to find similar cases that occurred during the STEPS campaign.

3) Manuscript preparation has begun for two STEPS related studies. The first study is a ten-year climatological comparison between severe storm reports and cloud-to-ground lightning

characteristics that was used in the scientific and logistical planning for STEPS. (Carey, L. D., S. A. Rutledge, and W. A Petersen, 2001: The Relationship between Severe Storm Reports and Predominate Positive Cloud-to-ground Lightning in the Contiguous United States from 1989 - 1998. Mon. Wea. Rev., to be submitted.).

The second is a case study of the Spencer F4 tornadic supercell on 30 May 1998 that produced predominately positive polarity cloud-to-ground lightning for most of its lifecycle. The results from this case study will help direct further investigation in more detailed case studies from the unique STEPS data set. (Carey, L. D., W. A. Petersen, and S. A. Rutledge, 2001: Radar and Cloud-to-ground Lightning Characteristics of the Spencer F4 Tornadic Supercell of 30 May 1998. Mon. Wea. Rev., to be submitted.)

Electrification and Lightning

Jesse Ryan is tying electrification and lightning to the microphysics of the Goddard Cumulus Ensemble model. He will be using the model to investigate the relationship between latent heating profiles and lightning flash rates.

2. COOPERATIVE INSTITUTE FOR RESEARCH IN THE ATMOSPHERE (CIRA)

The Virtual Institute for Satellite Integration Training (VISIT) is offering training on remote sensing topics such as lightning to National Weather Service forecasters. Training is delivered using a distance-learning application called VISITview and a conference phone call. VISITview allows a slide show to be viewed by multiple users using Java-Applet scripts and an Internet connection. Capabilities of VISITview include animation, annotation, overlays, etc. VISIT training sessions on lightning are described below.

"Lightning Meteorology I: Electrification and Lightning Activity by Storm Scale" is the training session currently offered. It examines thunderstorm electrification and cloud-to-ground (CG) lightning activity in isolated storms and mesoscale convective systems (MCSs). The session balances theory and application by first introducing theoretical concepts and then presenting four case studies that demonstrate consistency between theory and observation.

"Lightning Meteorology II: Advanced Electrification and Anomalous Lightning Behaviors" is planned for release in early summer 2001. It examines electrification at a more detailed level than Lightning Meteorology I in order to offer explanations for anomalous lightning behaviors found in a small fraction of severe storms and in many winter storms.

"CONUS CG Lightning Activity" was presented from July 1999–January 2000. It describes the operation and performance of the National Lightning Detection Network and examines the spatial and temporal (annual and diurnal) distributions of CG lightning over the contiguous United States.

The VISIT web site is located at: www.cira.colostate.edu/visit. The point-of-contact for VISIT lightning training is Bard Zajac at: zajac@cira.colostate.edu.

* COMMUNICATION AND SPACE SCIENCE LABORATORY, PENN STATE UNIVERSITY (University Park, Pennsylvania, USA)

Les Hale (LesW3LH@aol.com) reports:

I have previously reported on slow tail measurements, but this is about a clearly coded "mystery" signal that I am trying to identify and could use some help. Slow tail measurements have been frequently unsatisfactory, usually because of high ELF noise levels, inadequate preamp impedance or bandwidth, or all of these. Perhaps one of the best efforts was one of the earliest, when Lee Tepley of UCLA went to a quiet location away from power lines in Hawaii

(JGR, 1959). Subsequent high quality measurements were made in Hawaii by Hughes (but only of earth currents), David Llanwyn Jones on occasional trips to rural Wales, and Lee Marshall from the woods of Pennsylvania. The consensus confirms Tepley, that most lightning launches relatively uniform "millisecond" slow tails which propagate many thousands of km before substantial dispersion (not to be confuseed with the generally longer, less uniform, and weaker "continuing currents").

There is nothing mysterious about these phenomena: the slow tails are required to satisfy the post lightning stroke boundary conditions, as demonstrated by Mike Baginski (Nature 329,614, 1987). Just to have some nice slides I took a two meter whip on top of my minivan to Aguirre Springs State Park, NM, which turned out to be very quiet. Using an op-amp follower and a Fluke 123 digitizing voltmeter, I was able to make some nice pictures. They confirmed the "millisecond" slow tail concept.

But I observed something else which I would like help in understanding. I see sequences of coded groups, obviously man made, whether they are in blue (Navy), in black (spooks), or little green men. The "default" pulse group is ten pulses spaced by precisely one millisecond, and of about one quarter millisecond duration. Variable amplitude and some fading indicate that it is not a local source. Pulses are omitted and some have reversed polarity, with a potential of 59,049 different codes.

Some of the data I took is shown in a Figure, which I wikll FAX to anyone who is interested. The lower right panel shows lightning flashes followed by unipolar millisecond "slow tails," as expected from Tepley's data (later confirmed by David Llanwyn Jones of England). The other data shows samples of the coded groups.

I cannot find anyone who knows the source of these coded signals, which I admit are probably not of extra-terrestrial origin, unless another source cannot be identified. The top panel appears to be a "default" code with ten pulses spaced by precisely one millisecond. Pulses can be omitted or of opposite polarity, giving 59.049 different messages, counting a flat line, according to my son Trevor. The variable amplitude indicates the source is not local. Check it out yourself. Very easy to do.

I would suspect that this signal is not of extraterrestrail origin. For one thing, precisely one millisecond-spaced pulses would be quite coincidental. But it got me to thinking, that because of the extremely effective penetrating capabilities of longitudinal electrostatic waves, ELF and below just might be a good place to look for LGM.

* UNIVERSITY OF FLORIDA (Gainesville, Florida, USA)

Triggered-lightning experiments will continue in Summer 2000 (for the ninth year) at the International Center for Lightning Research and Testing (ICLRT) at Camp Blanding, Florida. A number of experiments are planned including (1) continued multiple-station measurements of electric and magnetic fields due to both natural and triggered lightning, (2) continued studies of the interaction of lightning with power distribution lines (both direct and induced effects), and (3) measurement of electric fields in the immediate vicinity of the lightning channel using Pockels sensors (jointly with CRIEPI, Japan).

Carlos Mata defended his Ph.D. dissertation titled “Interaction of Lightning with Power Distribution Lines”. He is presently with the NASA Kennedy Space Center.

Vladimir Rakov, David Crawford (presently with the NASA Kennedy Space Center), Keith Rambo, George Schnetzer, Martin Uman, and Rajeev Thottappillil (University of Uppsala, Sweden) authored a paper submitted to JGR, titled “M-Component Mode of Charge Transfer to Ground in Lightning Discharges”. The M-component mode of charge transfer to ground is examined using multiple-station measurements of electric and magnetic fields at distances ranging from 5 to about 500 m from the triggered-lightning channel. The corresponding currents at the channel base were also measured. Data have been obtained in 1997, 1999, and 2000 at the International Center for Lightning Research and Testing at Camp Blanding, Florida for (1) "classical" M-components that occur during continuing currents following return strokes and (2) impulsive processes that occur during the initial stage of rocket-triggered lightning and are similar to the "classical" M components. All lightning events considered in the paper effectively transported negative charge to ground. For one triggered-lightning event, in addition to the current and close fields, the electric field 45 km from the lightning channel was measured. The measured close electric and magnetic fields are generally consistent with the guided-wave mechanism of the lightning M-component. Specifically, the M-component electric field peaks exhibited a logarithmic distance dependence, $\ln(kr^{-1})$, which is indicative of a line charge density that is zero at ground and increases with height. Such a charge density distribution is distinctly different from the more or less uniform charge density distribution inferred from close electric field measurements to be characteristic of subsequent leaders in triggered lightning. The M-component magnetic field peaks exhibited a distance dependence close to an inverse proportionality (r^{-1}), consistent with a more or less uniform distribution of current within the lowest kilometer or so of the channel. The M-component electric field at 45 km appeared as a bipolar microsecond-scale pulse that began prior to the onset of the M-component current waveform at the channel base. The microsecond-scale pulse is probably associated with establishing the contact between an in-cloud leader and the current-carrying channel to ground. This contact results in the launching of the initial, downward-moving M-wave, which subsequently reflects off ground. M-component-type processes can produce acoustic shock waves with peak pressure values of the same order of magnitude as those for leader/return stroke sequences in triggered lightning.

Martin Uman, Jens Schoene, Vladimir Rakov, Keith Rambo, and George Schnetzer authored a paper, submitted to the JGR, titled "Correlated Time Derivatives of Current, Electric Field Intensity, and Magnetic Flux Density for Triggered Lighting at 15 m". The authors present measured current and its time derivative correlated with the corresponding electric field intensity and magnetic flux density and their time derivatives measured at 15 m for two lightning return strokes triggered in 1999 at Camp Blanding, Florida. Lightning was triggered to a vertical 2 m rod mounted at the center of a 70 m x 70 m buried metallic grid. The rocket launching system was located underground at the center of the grid. The experiment was designed to minimize any influence of either the strike object or a finite-conducting Earth (propagation effects) on the fields and field derivatives. The measured current derivative, magnetic field derivative, and electric field derivative waveforms associated with return strokes are observed to be unipolar pulses that have similar wave shapes for the first 150 ns or so, including the initial rising portion, the peak, and about 50 ns after the peak. The current and magnetic field derivative waveshapes are essentially identical for their total duration and both decay to near zero about 200 ns after the peak derivative is reached. The electric field derivative decays more slowly than the current derivative after about 150 ns, taking about 500 ns to decay to near zero. The transmission-line model is used to calculate the return-stroke field derivatives given the measured current derivative as a model input with the return stroke speed as an adjustable parameter. A reasonable match between calculated and measured fields for stroke S9934-6 is achieved for an assumed return stroke speed of 1.7×10^8 m s^{-1}, and for stroke S9934-7 for a speed of 1.5×10^8 m s^{-1}, but there are clearly aspects of the physics of the return stroke of which the relatively simple transmission-line model does not take adequate account. Although the field derivatives and the current derivative have similar waveshapes for about 150 ns, which might appear to be consistent with the hypothesis that the peak is dominated by the radiation field component, transmission line model calculations show that at the electric field derivative peak of both strokes about 40 percent of the total derivative is electrostatic field, about 40 percent induction field, and about 20 percent radiation field; while for the magnetic field derivative peak of S9934-6 about 60 percent is induction field and about 40 percent is radiation field and for S9934-7 about 70 percent is induction field and 30 percent is radiation field. If one assumes that the measured electric field derivatives are purely radiation field, which apparently is not the case, and applies the transmission line formula for a radiation field source near ground level, a return stroke speed near the speed of light is calculated, consistent with the results of previous close measurements and similar theory. Measured electric field derivative waveshapes at 15 m and at 30 m are observed to be similar, which also might appear to be consistent with the hypothesis that the derivatives are dominated by the radiation field component, but, according to transmission line model calculations, while the calculated total field derivative waveshapes are similar at 15 and 30 m, the mix of field components at these two distances is quite different.

Rajeev Thottappillil (University of Uppsala, Sweden) and Vladimir Rakov authored a JGR paper titled "On Different Approaches to Calculating Lightning Electric Fields". Three different approaches to the computation of lightning electric and magnetic fields are compared and discussed. These approaches are the traditional dipole (Lorentz condition) technique and two versions of the monopole (continuity equation) technique. The latter two techniques are based on two different formulations of the continuity equation, one used by Thottappillil et al. (1997) and the other by Thomson (1999), the difference between the formulations being related to different treatments of retardation effects. The three approaches involve the same expression for the vector potential but different expressions for the scalar potential. It is analytically shown that the three different expressions for the scalar potential are equivalent and satisfy the Lorentz condition. Further, the three approaches yield the same total fields and the same Poynting vectors. However, expressions for the individual electric field components in the time domain in the three approaches, traditionally identified by their distance dependence as electrostatic, induction, and radiation terms, are different, suggesting that explicit distance dependence is not an adequate identifier. It is shown that the so identified individual field components in the electric field equation in terms of charge density derived by Thottappillil et al. (1997) are equivalent to the corresponding field components in the traditional equation for electric field in terms of current based on the dipole technique. However, the individual field components in the electric field equation based on Thomson's (1999) approach are not equivalent to their counterparts in the traditional dipole-technique equation. Further, in Thottappillil et al.'s (1997) technique and in the traditional dipole technique, the gradient of scalar potential contributes to all three electric field components, while in Thomson's (1999) technique only to the electrostatic and induction components (the radiation component is determined by the time derivative of vector potential only). Calculations of electric fields at different distances from the lightning channel show that the differences between the corresponding field components identified by their distance dependence in different techniques are considerable at close ranges (tens of meters from the channel), but become negligible at far ranges (of the order of 100 km). Expressions for the individual magnetic field components in the three techniques are the same since they are derived from the same expression for the vector potential.

* FMA RESEARCH INC. (Fort Collins, Colorado)

Walter A. Lyons reports:

FMA Research, Inc. is preparing for the ninth consecutive summer of sprite observations from the Yucca Ridge Field Station (Walt Lyons and Tom Nelson). Since 1993, over 7500 transient luminous events (TLEs), including sprites, halos, trolls, elves, and blue starters have been imaged from Yucca Ridge. This year's activities will be scaled back somewhat from past efforts. Primary emphasis will be placed on observing TLEs above storms in Oklahoma, near the new Lightning Mapping Array (LMA), during balloon missions of Bill Beasley (OSU) and Ken Each (NM Tech).

The main focus this year will be to analyze the vast amount of data acquired during the 2000 STEPS campaign (under NSF Support). Over 160 sprites were imaged in or near the coverage area of the NM Tech 3-D LMA. In addition, ELF measurements were obtained by Earle Williams (MIT), Colin Price (Tel Aviv University), Martin Fullekrug (Germany) and Steve Cummer (Duke University). Charge moments have been computed by Williams and Cummer for several dozen sprites from the storms on 18 and 19 July 2000. Initial evidence suggests that, as expected, large charge moments (> 300 C*km) were associated with the +CG discharges that resulted in optically detected sprites. ELF/ULF signals were also obtained at the Syowa Antarctic station operated by Tohoku University (H. Fukunishi). Excellent signatures of High Plains sprites were monitored on 4 July 2000 at Syowa. Among the more interesting results from STEPS were the first known ground-level videos of what appear to be blue starters emerging from the top of an electrically active supercellular thunderstorm about 75 km from Yucca Ridge. A new GEN III blue extended imager was employed which may have aided in this observation. The same storm produce numerous (several dozen) very small (1-2 pixel), short (1 video frame) and very bright flashes of light or "dots" on the outer surface of the convective overshooting dome of the storm. These events were generally not associated with in-cloud lightning or VLF emissions. They may have represented immature "blue starters" or perhaps yet another new phenomenon.

Walt Lyons will make a presentation on the imaging and visual observations of sprites at the upcoming NCAR Workshop on Atmospheric Optics in June in Boulder, CO.

* GLOBAL ATMOSPHERICS INC.

We have recently begun full operation of a VHF time-of-arrival network using a research version of our LDAR-II sensor. The network of seven sensors located around the Dallas-Fort Worth International Airport has collected complete data sets for several storms during spring of 2001. The LDAR II system is a commercial extension of New Mexico Tech's Lightning Mapping Array. The operation of this test network is a major step in the development of the commercial LDAR-II VHF system and is also important for on-going work to understand the importance of cloud lightning information in general and the altitude information provided by VHF mapping systems in particular. The assessment of the value of altitude information is an evolution from a joint study between GAI and MIT Lincoln Laboratory (Earle Williams, Bob Boldi, Mark Weber, Anne Matlin) that involved examining altitude information in addition to discharge rate in relation to severe storms in Florida observed by the original NASA LDAR system.

Our efforts to understand further the importance of cloud discharges are also motivated by a growing interest among operational meteorologists in having cloud plus cloud-to-ground [CG] lightning information. Lightning detection networks that employ GAI's new IMPACT-ESP sensor, which can detect and report both cloud and CG discharges, have recently been installed by the Danish Meteorological Institute (DMI), the New Zealand Meteorological Service, and the Korean Meteorological Administration (KMA). The KMA has also purchased an LDAR-II VHF system that is designed to provide cloud flash information with high detection efficiency over all of South Korea to complement the high-efficiency CG detection of the IMPACT-ESP network. Finally, a recent paper by Dennis Boccippio (NASA-

MSFC), Ken Cummins, Hugh Christian (NASA-MSFC) and Steve Goodman (NASA-MSFC) describes the combination of total lightning observations by the NASA Optical Transient Detector with CG data from the U.S. National Lightning Detection Network to estimate the long-term ratio of cloud lightning to CG lightning over the continental U.S. (*Monthly Weather Review*, vol. 129, pp. 108-122).

In November, 2000, GAI hosted the 2000 International Lightning Detection Conference (ILDC) in Tucson Arizona, and was attended by more than 160 attendees from 25 countries. Forty-eight (48) papers were presented. Major topics included technologies for total lightning detection using both ground-based and space-based systems, the applications of total lightning information in meteorology, and thunderstorm forecasting and safety. A complete list of papers presented and links to the abstracts/papers can be found at www.glatmos.com/news/ildc_schedule.htm.

For further information, contact mmurphy@glatmos.com, kcummins@glatmos.com, or rholle@glatmos.com

* INDIAN INSTITUTE OF TROPICAL METEOROLOGY – PHYSICAL METEOROLOGY AND AEROLOGY DIVISION (Pune, India)

The Indian Institute of Tropical Meteorology (IITM) functions as a national centre for basic and applied research in monsoon meteorology of the tropics in general with special reference to monsoon meteorology of India and neighbourhood. Its primary functions are to promote, guide and conduct research in the field of meteorology in all its aspects. IITM has made significant contributions in the challenging areas of the Meteorology and Atmospheric Sciences like Weather Forecasting, Climatology and Global Change, Hydrometeorology, Monsoon, Climate Modelling, Cloud Physics, Weather Modification, Atmospheric Chemistry and Atmospheric Electricity.

Studies in Atmospheric Electricity is one of the projects of Physical Meteorology and Aerology Division of the IITM. Under this project the continuous observations of different electrical parameters such as electric field, point discharge current, drop charge etc. were taken since the 1970 at this station (Pune) during fair and disturbed weather conditions. From the atmospheric electricity point of view the study of thunderstorms is one of the important topic as it controls the global electrical system. With this view, in the present study the authors have examined the occurrence of nature's important phenomenon thunderstorm, by using the statistical model viz. the Markov Chain Models and present the results derived thereof.

Markov Chain Models for the pre-monsoon season thunderstorms over Pune

M. K. Kulkarni , S. S. Kandalgaonkar and M.I.R. Tinmaker

Thunderstorm is an important weather phenomenon to understand many issues relating to the atmospheric electricity and weather. The occurrence/non-occurrence of thunderstorm on a given day is a simple meteorological example and sequence of their daily observations at a particular location constitutes the time series of that variable. The time series analysis is one of the statistical method used to forecast the thunderstorm occurrence. The thunderstorms have a tendency to cluster and form a sequence of thunderstorm day or a non-thunderstorm day. Such a tendency can be well explained by Markov Chain Models of a particular order of conditional dependence of a physical process. The present study deals with the application of Markov Chain Models to the thunderstorm events during the pre-monsoon season over the Pune region (18^0 32' N ,73^0 51' E, 559 amsl).

The Markov Chain is the most common class of the model to represent the time series of discrete variable. It consists of a system and a set of transitional states. The principle of Markov Chain is the probability of a thunderstorm on any day depends only upon whether there was a thunderstorm or not on the previous day. In this short contribution, the daily thunderstorm data for Pune station for a period of 11 years (1970-80) during pre-monsoon season is utilised and subjected to Markov Chain Models.
The data for each year is considered as a separate sample of a time series of a particular year. Using conditional frequencies, transition probabilities for the first, second and third order Markov Chain Model have been calculated. The parameter estimates of the Markov Chains of different order have been estimated separately for each sample and then overall estimates are obtained by combining suitably the estimates of all samples. Instead of conventional Chi-Square test a decision making procedure based on the extension of the maximum likelihood principle was used. The proper order of Markov Chain for modelling the time series of thunderstorm occurrence is assessed by using the Akaike's Information Criterion. The overall study suggested that the data series under investigation was best explained by the first order Markov Chain Model. The analysis of n-step probability distribution of thunderstorm activity over Pune region reveals that from 5th step onwards the thunderstorm phenomenon becomes independent irrespective of its initial state. The overall stationary or climatological probability of pre-monsoon thunderstorm recurrence activity over Pune region is very less (0.12). The observed and theoretical values of mean recurrence times for thunderstorm day and non-thunderstorm days realistically matched. The results narrated in the present study appeared to be consistent with the availability of the data. Further investigations are needed to confirm the results obtained.

* INSTITUTE OF ATMOSPHERIC SCIENCES, SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY (Rapid City, South Dakota 57701, USA)

Andy Detwiler (Andrew.Detwiler@sdsmt.edu) reports:
John Helsdon continues to work on modelling lightning discharges with student Inna Suz. He also works with PhD candidate Xingjun Zhang modelling the effects of lightning on cloud chemistry. Zhang is comparing their model results with lightning and chemical observations from the STERAO field program.
Andy Detwiler, Qixu Mo, and Donna Kliche continue to organize and analyse observations from last summer's STEPS field program. Preliminary results are posted at http://www.ias.sdsmt.edu/institute/t28/index.htm .
The SDSMT armored T-28 is being outfitted with a replacement engine. It will be flying in the Rapid City area this summer for a series of instrument development tests. Ken Eack, NMIMT, and Bill Beasley, OU, will be testing their equipment for observing X-rays, and the SDSMT group will be working on several of their own instrument projects. The aircraft has no commitments for the summer of 2002 and we are looking for researchers who are interested in incorporating in situ measurements in convective storms into their research plans. If you have such interest, please contact Andy Detwiler by email at andy@ias.sdsmt.edu, or by phone at 605-394-2291.

* INSTITUTE FOR PROBLEMS IN MECHANICS (Moscow, Russia),

KRZHIZHANOVSKY POWER ENGINEERING INSTITUTE (Moscow, Russia), LIGHTNING ELIMINATORS & CONSULTANTS, INC. (Boulder, Colorado, USA), MOSCOW INSTITUTE OF PHYSICS & TECHNOLOGY (Dolgoprudny, Russia)

Nickolay Aleksandrov (MIPT, alek@neq.mipt.ru), Edvard Bazelyan (KPEI), Roy Carpenter (LEC), Mark Drabkin (LEC) and Yuri Raizer (IPM) have recently begun a new study of the effect of corona on lightning discharge under thundercloud conditions.

The purpose of this work is to numerically simulate corona discharge near a high grounded object in an atmospheric electric field and to estimate the effect of the injected space charge on the initiation and the development of upward leader and counterleader. A simulation model of non-stationary corona near the electrodes of different geometry has been developed. This model was used to calculate the volt-ampere characteristic of the discharge, the distribution of the injected space charge in the cloud-to-ground gap and the evolution in time of the electric field near the tip of the object. A model for describing the initiation and the development of upward leader and counterleader in the cloud of space charge has been suggested. It was shown that a strong redistribution of electric field by the injected space charge can retard and even eliminate the initiation and development of upward leader in the thundercloud electric field. The effect becomes more pronounced for multi-center (with numerous needles) electrodes of large radius that have been suggested by *Lightning Eliminators & Consultants, Inc*.

The next step of this work is to analyze the development conditions for the stepped leader of downward lightning and the way a lightning chooses a point to strike. Focus will be on the study of the leader process in the completing phase when the leader tip propagates in the space charge layer close to the ground. The peculiarities of the development of downward leader under conditions of an extremely extended charged layer (~ 1 km^2 and larger) created by a large number of specially mounted grounded electrodes will also be considered.

The applied aim of this work is to develop new efficient methods to protect large-dimension engineering objects against direct lightning strokes.

*LF*EM RESEARCH (Dunedin, New Zealand)

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Richard L Dowden, James B Brundell, and Craig J Rodger report on global lightning location by VLF:

Current methods of radio location of lightning by timing, such as LPATS, measure the time of arrival (TOA) of the leading edge of the lightning impulse or "sferic". Using bandwidths extending to a few megahertz, the leading edge can be determined to within 1 microsecond or better. This in turn allows ground strike location to within a few hundred meters. To avoid reception of the skywave, receiver sites must be less than few hundred km apart.

In the VLF band (3-30 kHz) lightning sferics can be detected some 10,000 km away. The catch is that the sferics from such distant lightning are strongly dispersed. They have a duration of several milliseconds instead of tens of microseconds. More importantly, there is no sharp onset and so no definite TOA. Instead, the amplitude of the sferic waveform increases from the noise background over several tens of microseconds to a rather blunt maximum before decreasing over a few milliseconds.

One way of getting around this is to cross-correlate the sferic waveforms received at a pair of spaced receivers to find the arrival time difference. This uses the amplitude spectrum of the sferics from the discrete Fourier transform (DFT) of the data. Noting that the Omega Navigation System, using only 8 transmitteres world-wide at frequencies of ~10 -14 kHz achieved location accuracies of 1-2 km by phase measurement, we use the progression of phase versus frequency at the time of triggering. The latter can be determined from the GPS pulse-per-second (PPS) to well within 1 microsecond.

In a "perfect" (Dirac delta) pulse, all frequency components have the same phase at the pulse instant so the progression of phase versus frequency is zero. In a dispersed pulse such as a lightning sferic this is no longer true. However, by restricting our phase measurement to the frequency range 6-20 kHz, which contains most to the sferic energy and largely avoids the "tweeks" at the Earth-ionosphere cutoffs, we find the delay to the "Time Of Group Arrival" (TOGA) from the average (from a regression line) progression of phase versus frequency at the trigger time. Omega measurement of such progression of phase from 10.2 to 13.6 kHz could also have been used for location. In fact, TOGA is a sort of "inverse-Omega" where precisely located receivers are used to locate a multitude of "VLF transmitters" (lightning).

As in any radio location of lightning by timing, only the arrival time differences at pairs of stations is relevant. However, only the TOGAs need to be compared instead of the full waveforms in the cross-correlation method. Since calculation of the TOGA is derived from the phase spectrum of the DFT of the data, we hope to get location accuracies similar to that of Omega, and eventual global coverage with a similar number (~10) of receivers.

At this stage of our research we have only 3 receivers, spaced a few thousand km apart. We need more to establish accuracy and efficiency.

* MASSACHUSETTS INSTITUTE OF TECHNOLOGY (Lincoln Laboratory, Lexington, Massachusetts, USA)

Mark Weber and Earle Williams are involved in a new project on oceanic convective weather in collaboration with NCAR, NRL and ARINC, and sponsored by the Federal Aviation Agency. NASA TRMM data (radar, visible/infrared, and the Lightning Imaging Sensor) will be used to interpret more intelligently the GOES satellite imagery for convective weather hazard to aviation. The use of DoD non-imaging satellite assets is also planned to develop a climatology for oceanic mesoscale lightning, and as a possible monitor for the Madden-Julian Oscillation which strongly modulates oceanic convective weather.

* MASSACHUSETTS INSTITUTE OF TECHNOLOGY (Parsons Laboratory, Cambridge, Massachusetts 02139, USA)

Correlated variations of rainfall and lightning over the African continent on a 4-5 day time scale are now understood in the context of a global 5-day planetary wave. The integrated mesoscale lightning activity is documented with Schumann resonance observations from Rhode Island. The daily African rainfall is provided in datasets from NOAA (John Janowiak and Pingping Xie) and NASA (Bob Adler and George Huffman). The global wave is revealed in global observations of surface air pressure that show a westward moving wavenumber-one disturbance (as in Madden and Julian (1972)), with a strongly declining pressure over Africa on days with maximum mesoscale lightning. Graduate student Akash Patel is documenting these results in a Master’s thesis to be completed this summer.

Observations carried out in the TRMM (Tropical Rainfall Measuring Mission) LBA field experiment in Rondonia, Brazil have been submitted for publication in the LBA Special Issue of the Journal of Geophysical Research with numerous coauthors from NASA and from Brazil. During the westerly wind regime in Brazil, equivalent to the monsoon regime in India and northern Australia, convection over the Amazon (disclosed with NASA TOGA radar observations) showed a distinct maritime characteristic (clean boundary layer, weakly developed mixed phase region, and low lightning activity). Accordingly, this regime over the Amazon rainforest has been named 'green ocean'. Collaboration with Daniel Rosenfeld has been very valuable in the documentation of a strong influence of aerosol in suppressing warm rain coalescence through a deep zone during the highly polluted early premonsoon regime when smoke from biomass burning is prevalent.
A review article on sprites has recently been prepared for Physics Today. Numerous images of sprites, elves and haloes were generously provided by many researchers in this field. This article emphasizes the early contributions from spectroscopy and gaseous electronics (in work by Lord Rayleigh, J.J. Thomson, C.T.R. Wilson and Irving Langmuir) to the present understanding of the phenomenon.
In part to prepare for the writing of this review article, laboratory experiments were carried out (with Bob Golka, Dave Williams, Stan Heckman and Russ Armstrong) with air-filled DC-excited glow discharge tubes of various sizes, at pressures representative of sprite altitudes in the mesosphere. Integrated spectroscopic observations of the positive column of the discharge showed, as with integrated observations in the main body of sprites, abundant evidence for (red) nitrogen first positive emission but an absence of (blue) first negative emission. These results will be discussed at the IAGA meeting in Hanoi, Vietnam in August.

* NATIONAL LIGHTNING SAFETY INSTITUTE, NLSI (Louisville, Colorado, USA)

(www.lightningsafety.com)

1. We continue our Subject Matter Expert two day intensive education seminars, primarily directed to US Department of Defense and US Department of Energy management/supervisory persons. During the past six months five such workshops were conducted at Los Alamos NM (2), Washington DC (2), and Charleston SC (1).
2. A new one day workshop, intended for field electricians and facility inspectors, is called "Inspection, Maintenance and Testing of the NFPA-780 Lightning Protection System." Graduates of this class are certified by NLSI to verify that existing NFPA-780 lightning protection systems are in as-specified working condition. Already this training has been provided for DoD, DOE, and US Navy personnel.
3. Site inspections of interest included: A) Shortwave radio transmission facility at Bella Vista, Costa Rica. Bonding and surge suppression issues were examined. B) Vestas wind turbine farm near El Paso TX.. A 8.5 ohms earth electrode subsystem was developed in dry rocky conditions where background soils were measuring 155 ohms.
4. A new Transfer Impedance Measurement Instrumentation System (TIMIS) is available to characterize the lightning response of sensitive assets and facilities. Injection of low currents into the LPS and measurement of very low conducted or induced voltages or electric fields are used to determine transfer impedances into building steel, AC power lines, signal and data wiring, copper water pipes, etc. The transfer impedances are used to determine lightning voltages and currents in critical systems or components within the facility. TIMIS is particularly useful for the very sensitive transfer impedance measurements required to characterize Faraday cage LPSs. An extensive set of

verification and validation tests on TIMIS was successfully completed recently by Sandia National Laboratories. The TIMIS is now being commercialized by BOLT, Inc. under the direction of its President, Dr. Marvin Morris, who was formerly the manager of Sandia National Laboratories Electromagnetic Analysis and Test Department. NLSI is collaborating in the effort to predict lightning behavior and effects upon high risk structures.

5. In response to continuing vacillation by NFPA regarding their “Standard for the Installation of Lightning Protection Systems NFPA-780”, both the US Dept Defense and the US Dept Energy are reviewing and updating their respecting lightning protection documents. NLSI is a contributing member to both review panels. A NLSI article in the Jan. 2001 issue of Quality Power Assurance outlines our comprehensive, systematic approach to lightning safety. This paper can be reviewed at: http://www.lightningsafety.com/nlsi_lhm/explosives.html
6. NLSI continues to broadcast the lightning safety message with written presentations and public speaking engagements, recently including: US Weather Broadcasting Meteorologists Assn.; Science Insight; Colorado State Parks Assn.; Sports Turf Mgrs. Assoc. Mtg.; International Lightning Detection Conference; Michigan Sports Turf Managers Assn.; DOE Consequence Assessment and Protective Actions Subcommittee (SCAPA); City of Westminster; Colorado Public Risk Assessment Org.; WABC Channel 7 TV – New York City; “Safety and Supervisor” magazine; “Athletic Turf” magazine; Network of the World (London), etc.
7. NOAA/NWS has declared June 18-23 “National Lightning Safety Awareness Week.” NLSI is participating in this effort.

* NEW MEXICO TECH – LIGHTNING MAPPING GROUP (Socorro, New Mexico, USA)

Paul Krehbiel, Bill Rison, and Ron Thomas report:

New Mexico Tech's Lightning Mapping Array (LMA) was operated in the Severe Thunderstorm Electrification and Precipitation Study (STEPS) between May 24and August 10, 2000. A network of 13 mapping stations was deployed and provided excellent observations of numerous predominantly positive CG storms and several tornadic storms. The +CG storms were commonly found to produce inverted polarity intracloud discharges, namely discharges between mid-level positive charge in the storm and upper-level negative charge, or between lower positive and mid-level negative charge. Lightning ‘holes’ were again observed in several tornadic and supercell storms, and appear to be a characteristic feature of such storms.
We are in the process of documenting and evaluating the huge dataset collected during STEPS in collaboration with the other investigators. All of the lightning mapping data have been processed in decimated form and are available on the web, at www.lightning.nmt.edu. On the website, visit ‘STEPS 2000 Observations’ for a description of the program and an initial posting of results, or ‘LMA STEPS data server’/‘Download STEPS LMA data’ to look at complete sets of data images and web animations. (Some specific animation examples are June 22 2200-2400 and June 23 0000-0400, or July 21 0000-0600.) The full, non-decimated data are currently being processed during important storm times.

* TEL AVIV UNIVERSITY, DEPARTMENT OF GEOPHYSICS AND PLANETARY SCIENCES (Tel Aviv, Israël)

The team led by Zev Levin, Colin Price and Yoav Yair will try and obtain high-resolution images of sprites from space during the MEDIEX campaign, and correlate them with ground-based ELF-VLF measurements. The present launch date for STS-107 (the space shuttle Columbia) is April 2002, for a 16-day mission at 39 degrees inclination. The payload consists of a multi-spectral Xybion IMC201 camera that will be operated by an Israeli astronaut in cooperation with a ground team located at NASA/GSFC. Images will be recorded on digital VCRs in the crew-cabin and downlinked to the ground. Observational runs would consist of continuous recording of the Earth's limb from the direction of the dusk terminator towards the night side, preferably before midnight local time at the observed area. In order to enhance the success probability, as many thunderstorms as possible would be targeted. The observation areas would cover an area that extends from 39S to 39N, along the shuttle orbit. The most (active) desired areas will be tropical South America, North-Australia and Indonesia, South-East Asia, China, Sea of Japan, Continental USA and the Gulf of Mexico. Several groups have expressed interest in the MEDIEX-Sprite campaign and will collect electromagnetic and optical data during the mission. These include Earle Williams (MIT), Umran Inan (Stanford), Walt Lyons (FMA Research Inc.), Marcelo Saba (Brazil), Zen Kawasaki (University of Osaka, Japan) and Martin Fullekrug (Frankfurt, Germany).

Orit Altaratz, Zev Levin and Yoav Yair continue the study of the properties of winter thunderstorms along the coast of Israel, with special emphasis on the differences between the areas near Tel-Aviv and Haifa. The objective is to understand the role of different parameters, such as topography, sea-land temperature difference and aerosol particles concentration in affecting the dynamical and microphysical characteristics of thunderclouds in this region. Part of this study is carried out by analyzing data from lightning detection systems (LPATS, CGR3 and LIS) and data from the Tel Aviv University radar. In addition, a numerical study is being carried out by using the RAMS model to simulate the evolution of clouds, including electrical charge separation and electric field build-up, as they move from the Mediterranean Sea toward the coast.

Colin Price, together with graduate student Mustafa Asfur, has analysed part of the Israeli ELF/VLF data collected during the STEPS2000 field campaign. Using a higher sampling frequency than previously used for the ELF (1 kHz) allowed a better estimate of the distance from our station of the positive lightning that produces sprites. Furthermore, using the VLF for direction finding, we were able to considerably improve our location of the positive lightnings that produced sprites, a distance of 11,000 km away from our observing station.

Colin Price and graduate student Moshe Blum published a paper in Earth, Moon and Planets (November, 2000) describing the VLF pulses produced by meteors entering the atmosphere. We have found a close link between the frequency of meteors during the Leonid '99 meteor shower and the frequency of VLF pulses identified with the meteors. We have found a unique spectrum related to the meteors, very different to the normal lightning discharge spectrum, hence allowing us to differentiate between the two.

Since November 2000, Martin Fullekrug from the University of Frankfurt has been working with Colin Price at Tel Aviv University on the relationship between large positive lightning discharges over African storms and the cloud characteristics of these storms. It was found that the maximum development of the African thunderstorms occurs around 1800 UT, while the maximum frequency of large positive discharges, that likely produce sprites, occurs 4 hours later. It is suggested that observations of sprites from Mt. Cameroon may provide an average of 70 sprites per night.

* THE UNIVERSITY OF UTAH (Salt Lake City, Utah 84112-0110, USA)

Ed Zipser and one or more students will participate with many colleagues in this community in the NASA and U.S. Weather Research Program supported Convection and Moisture Experiment (CAMEX-4) in August-September 2001. The program will include coordinated flights in tropical cyclones by the NASA ER-2 and DC-8, one or more NOAA WP-3Ds, and other aircraft. One of the goals will be to watch for opportunities for detailed observations of convective bursts in hurricane eyewalls, seeking clues whether lightning and other remote sensing data can help anticipate rapid intensification of the storm.

Ongoing research in the tropical convection group at the University of Utah includes systematic analysis of the 3-year TRMM (Tropical Rain Measuring Mission) database, and data from previous TRMM validation field programs. A number of papers are in press, but a sample of the database and research approach can be found in Nesbitt, S.W., E. J. Zipser, and D.J. Cecil, 2000: A census of precipitation features in the tropics using TRMM: Radar, ice scattering, and lightning observations. *J. Climate*, **13** (23), 4087-4106.

Zipser will present some recent results from the TRMM data analysis at the IAMAS meeting (Innsbruck, July) and the AMS Radar Conference in Munich the following week. The IAMAS paper will feature recent work of Nesbitt on the diurnal cycle of precipitation, demonstrating that rain from MCSs and from smaller storms peaks at different times. The Radar Conference paper by Yorty, Zipser, and Nesbitt may be of particular interest to the AE community, because it highlights the most extreme storms observed by TRMM during the 3 years. Many of these storms have correspondingly extreme lightning "flash" rates. As an exercise for the reader, where would you expect these "greatest storms on earth" to be found?