NEWSLETTER ON ATMOSPHERIC ELECTRICITY

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AMS COMMITTEE ON ATMOSPHERIC ELECTRICITY

AGU COMMITTEE ON ATMOSPHERIC AND SPACE ELECTRICITY

INTERNATIONAL COMMISSION ON ATMOS. ELECTRICITY

Announcements

Contributions to the next edition of this Newsletter are welcome and should be submitted to Earle Williams, Secretary of the ICAE, by e-mail (preferably) (EARLEW@JULIET.LL.MIT.EDU) or by fax (617-253-6208) by October 31, 1996. Mark your calendars!

Upcoming International Conference in Osaka, Japan (June 10-14)

From Zen Kawasaki, Secretary for the Conference: Please note the following very important information regarding ground transportation to the Conference Site.

Most conference participants will arrive at the Kansai International Airport and some of them at the New Tokyo International Airport.

From Kansai International Airport

Take the public train service, Nankai Line, from the Airport to the downtown Osaka stop, called "Namba." At Namba station take the Subway, Midosuzi Line, to Yodoyabashi station, the third stop from Namba. At Yodoyabashi station we recommend you take a taxi to the Royal Hotel. The fee for the taxi from Yodoyabashi to the Royal Hotel is about ¥ 700 (Japanese Yen). (The local organizing committee never recommends taking a taxi from Kansai Airport to downtown Osaka because of the extremely expensive fee!)

From New Tokyo International Airport and/or Tokyo area

Take Shinkansen (Bullet train) to Shin-Osaka station from Tokyo station. At Shin-Osaka station take the subway, Midosuzi Line, to Yodoyabashi Station, the fourth stop from Shin-Osaka. At Yodoyabashi station we recommend you take a taxi to the Royal Hotel. The fee for the taxi from Yodoyabashi to the Royal Hotel is about ¥ 700 (Japanese Yen).

Shuttle Bus Service

Shuttle bus service is available at Yodoyabashi to Royal Hotel (exit No.4 at Yodoyabashi Station).

The local committee is now planning a one-day bus tour to Nara, the old capital, on Friday, June 14. There is no cost except for a traditional Japanese lunch box. The fee for lunch is about 20 US dollars. The local committee wants to know how many scientists will join the bus tour. If you intend to come, please let Zen Kawasaki know by Email (zen@pwr.eng.osaka-u.ac.jp) (Phone +81-6-879-7690; Fax +81-6-875-0506).

The final program for ICAE Osaka is available at the WWW address http://lightning.pwr.eng.osaka-u.ac.jp/~icae/final/program.html

Though the program will be delivered at the registration, the local committee prepared the WWW page for the participants' convenience. More than 180 scientists have now registered.

Clive Saunders, Rohan Jayaratne, and Earle Williams are planning the traditional Conference meeting on laboratory experiments and their connection with large scale thunderstorm observations. The date and time are to be announced early at the Conference.

Williams also suggests a follow-on meeting (if time allows) to the one held at the IUGG in Boulder in July 1995 to discuss intercomparisons of data sets pertaining to measurements of the global electrical circuit now underway by several investigators.

AGU CASE News (From Don MacGorman)

With the arrival of the annual AGU Spring Meeting, it is once again time for changes in AGU leadership and committee membership. I am the new chairperson for the AGU Committee on Atmospheric and Space Electricity. Thanks to ohn Willett, the retiring chairperson, for a job well done. John will remain a member of CASE for another year to help with the transition. Thanks also to retiring committee members Vince Idone, Umran Inan, Doug Mach, Nelson Maynard, and Charles Swenson for your service. New members are Monte Bateman, Richard Blakeslee, Arthur Few, Launa Maier, Vladimir Rakov, and Robert Roussel-Dupre; I appreciate your willingness to serve. The following is a list of CASE members for the coming year:

Monte Bateman, Langmuir Laboratory, Campus Station, Socorro, NM 87801. Phone: (505) 835-5102. E-mail: bateman@nmt.edu

Richard Blakeslee, ESSD, Global Hydrology & Climate Center, 977 Explorer Blvd., NASA Marshall Space Flight Center, Huntsville, AL 35806. Phone: (205) 922-5962. E-mail: rich.blakeslee@msfc.nasa.gov

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John C. Willett, Geophysics Directorate, Phillips Laboratory, Hanscom AFB, MA 01731. Phone: (617) 377-5954. E-mail: willett@plh.af.mil

Earle R. Williams, MIT Parsons Laboratory, MIT 48-211, Cambridge, MA 02139. Phone: (617) 253-2459. E-mail: earlew@juliet.ll.mit.edu

Bill Beasley deserves our thanks for agreeing to serve as guest editor for the special issue of Journal of Geophysical Research that will be dedicated to papers from the 10th International Conference on Atmospheric Electricity, Osaka, Japan. Processing and reviewing papers for the special issue is a big job, both for the editor and our community. When you are asked to review one or more of these papers, please say yes, and then return your reviews by the requested date. The special issue is a good way to bring our field of research to the attention of the rest of the AGU membership, but it cannot be completed without your help.

Although it may seem like a long time until the AGU Fall Meeting, it is time to start thinking about special sessions related to CASE. If you want to suggest a special session on a particular topic, please contact me soon. AGU will include information on special sessions in the Call for Papers this summer.

AMS / CASE News (From Bob Holzworth)

The JGR Special Section from the papers presented at IUGG Boulder 1995 is in the final stages. We expect the Section will have 8 to 10 papers and be printed this summer.

Severe Storms Monograph

Chuck Doswell at NSSL is organizing the preparation of a new monograph on Severe Storms. Earle Williams (with an Advisory Committee chaired by Steve Rutledge) is writing a chapter on lightning. He would appreciate receiving all reprints pertaining to relationships between lightning/storm electrification and all manifestations of severe weather (hail, tornadoes, damaging winds, blue jets, etc.).

"Lightning and Mountains '97"

Lucien Deschamps of the Société des électriciens et des électroniciens (Paris) announces an International Symposium entitled "Lightning and Mountains '97," to be held June 1-5, 1997, in Chamonix Mont Blanc, France. The Abstract deadline is Sept. 15, 1996. If interested, contact Dr. Deschamps at Société des électriciens et des électroniciens, 48 rue de la Procession, F-75724, Paris cedex 15, France (tel: 33-1-44-49-60-00).

31st COSPAR Scientific Assembly, Birmingham, United Kingdom, 14-21 July 1996

One day meeting on 18 July: Electrodynamics of the low and sub-auroral middle atmosphere
The results will concern the electrodynamics of the low latitude middle atmosphere, i.e. conductivity and electric field. Effect of tropical lightning on middle atmospheric electrodynamics. However, sub-auroral latitude middle atmosphere phenomenon will also be considered (to include long duration balloon flight results) and some balloon and rocket results. Lightning effects on ionosphere and middle atmosphere and lightning above thunder clouds. The sprites and jets phenomena will be discussed. Ionisation in stratosphere and mesosphere due to lightning. Main Scientific Organizer: Dr. S.P. Gupta, Physical Research Laboratory, Ohmedabad 380 009, India; fax no.: 91-79-460502.

For further details contact: Cospar Secretariat, 51 Bd de Montmorency, 75016 Paris, France; fax no.: 331-405-09287

13th International Wroclaw Symposium

A Lightning Session is planned for the 13th International Wroclaw Symposium and Exhibition on Electromagnetic Compatibility, June 25-28, 1996. Interested persons should contact Prof. Michel Ianoz, LREPDE, EPFL, Lausanne, CHP1015, Switzerland, email: michel.iaonz@pre.de.epfl.ch.

National Commission on Atmospheric Electricity, Subsection "Electromagnetic Fields of the Atmosphere"

The NCAE has distributed the first announcement to the ICAE concerning the 10th International Conference on Atmospheric Electricity among Russian scientists who are active in the field of atmospheric electricity. Russian scientists submitted more than thirty abstracts of papers to the 10th International Conference. NCAE and Subsection EFA plan to conduct a seminar on the problem of remote measurement of lightning discharge characteristics during the XIV All-Russia Symposium "Radar investigation of natural media," which will be held in the Spring of 1996 in St. Petersburg. Address of NCAE: Prof. Vladimir

D. Stepanenko, Dr. Yakov M. Shvarts, A.I. Voeikov Main Geophysical Observatory, 7 Karbyshev Str., 194018, St. Petersburg, Russia.

Research Activity by Organization

Airborne Research Associates (Weston, MA)

Work continues on a project to utilize variation of ionospheric potential (Vi) as a measure of the temporal variation of global temperature An atmospheric electrical radiosonde capable of measuring the vertical electric field and conductivity, by a new technique which is particularly sensitive in the lower atmosphere, has been developed. Coordinated simultaneous measurements over two diurnal cycles were conducted between Darwin, Australia and Weston (Boston), Massachusetts in order to demonstrate that a single reliable Vi measurement can be globally representative. These were the first such comparisons between locations on opposite sides of the globe and between hemispheres. Analysis of these Vi data shows general agreement, however some comparisons did not agree during times when there was a low conductivity air near the ground at Weston. Now that the proper atmospheric conditions have been identified the program will continue with over 50 soundings planned for the next 12 months. This project is being conducted by Ralph Markson, Lothar Ruhnke and others at ARA with help from Earle Williams at MIT.

In a separate study (Ralph Markson and Colin Price) utilizing aircraft measurements of Vi obtained during the period 1970-1990, it was found that Vi is positively correlated with satellite and ground measurements of global temperature. This analysis suggests that a 1% increase in global temperature results in a 20% increase in Vi. Such results are consistent with the idea that global tropical temperature controls the development of thunderstorms and other current generating shower clouds and thus the current flow in the global circuit. They are also in agreement with reports and discussions by Williams, Price and their co-investigators on the control of global lightning by global temperature.

The results of the globe spanning simultaneous Vi measurements and correlation studies of Vi with global temperature will be reported at the 10th International Conference on Atmospheric Electricity in Osaka, June 1996.

State University of New York at Albany (Albany, NY)

Dan Davis has completed his Master's degree in physics and will spend the summer coordinating the triggered lightning operation at Camp Blanding that is devoted to John Willett's sounding rocket experiments. Vince Idone will participate by providing highly time-resolved photography of the triggered events. In addition, Vince is in the process of writing up the results of the last two seasons of local video-based verification of NLDN performance in the Albany area.

ASTeR Inc. / Mission Research Corp. (Ft. Collins, CO)

Elements of the SPRITES'96 program will be coordinated from the Yucca Ridge Field Station near Ft. Collins, CO during (tentatively) the late June through early August period. With primary sponsorship from the Air Force Office of Scientific Research, SPRITES'96 goal will be to make a series of coordinated optical and RF measurements focused on individual

lighting-induced transient luminous events in the ionosphere and mesosphere. Previous programs established operational strategies and measurement protocols. Now attention is turned on determining the detailed optical spectra of sprites, their relationship to cloud electrical discharges, their potential impacts on upper atmospheric chemical and physical processes, and the spatial and temporal evolution of sprites, elves and blue jets. ASTeR, Inc. (Walt Lyons, Tom Nelson) will continue the optical sprite imaging and VLF /ELF monitoring begun during the prior NASA-KSC funded programs (1993-1995). A number of cooperative efforts are anticipated during the 1996 program. These will include spectrometer and low-light images (for triangulation) from the Geophysical Institute of the University of Alaska (Dave Sentman, Gene Wescott), VLF and optical measurements by STAR Lab at Stanford University (Umran Inan, Bill Trabucco, Steve Reising), high speed photometers from Tohoku University (H. Fukunishi, Y. Takahashi, M. Kubota and K. Sakanoi), narrow band photometer from Mission Research Corporation (Russ Armstrong), VLF sprites detection network of the University of Otago (Dick Dowden, Jim Brundell), and various optical measurements from the Space Dynamics Laboratory of Utah State University (Mike Taylor, Peter Mace). In addition, ASTeR will continue its ongoing cooperation with MIT (Earle Williams, Bob Boldi, Charles Wong) in obtaining coordinated ELF Schumann resonance transient measurements from both Colorado and Rhode Island. Other teams are expected to join the cooperative effort. The Yucca Ridge facility will provide logistical support for the various science teams, including operational forecasting of sprite/elve-generating mesoscale convective systems. ASTeR will archive radar, satellite, ELF transient and lightning data for case studies and analyses. Other investigators interested in coordinating measurements related to transient luminous events in the ionosphere/mesosphere over the High Plains (roughly a 1000 km semicircle east from Yucca Ridge) should contact Walt Lyons (970-568-7664; lyonsccm@csn.org).

Atmospheric Environment Service (Toronto, Ontario, Canada)

The work done in collaboration with Dr. Earle Williams (MIT) is continuing. Radar data, especially CAPPI data, is being compared in detail to overlaid CG flashes. Three days of southern Ontario data, including 28 August 1990, have been studied so far. We have found something of potential value to forecasters: when the pattern of flashes increases or moves very rapidly in time, there is likely to be a tornado, mesocyclone, or strong shear zone nearby. Positive and negative CG flashes are being compared; strong storm development is usually needed to initiate positive flashes in the convective regionQthis has implications for charge separation theory. Also we continue to find negative flash concentrations well away from the radar center.

University of Arizona (Tucson, AZ)

M. J. Murphy and E. P. Krider have continued to analyze thunderstorm electric fields and lightning field changes at the NASA Kennedy Space Center (KSC). During the summer of 1995, thunderstorm data were obtained in conjunction with the NCAR CP-2 dual-polarization, dual wavelength radar. We are examining how the location and magnitude of the lightning charges and the cloud charging current relate to the cloud microphysics and if and how the cloud current is altered by lightning.

D.W. Schiber, L.M. Maier, and E.P. Krider have compared the locations and magnitudes of intracloud and cloud-to-ground lightning that were obtained using the LDAR and field mill systems at KSC and a network of gated, wideband direction-finders. Each lightning

detection system locates a different physical parameter, but the results are surprisingly consistent. W.J. Koshak and E. P. Krider are developing a new method for analyzing lightning field changes that is based on a multipole expansion of the cloud charge distribution that is altered by lightning. Preliminary tests on simulated lightning show that this method offers significant advantages over previous approaches.

During 1995, the Arizona group began investigating the causes of anomalously high electric fields (>1000 V/m) that sometimes occur at KSC under fair-weather conditions. High fields cause delays in launch and ground operations unless the causes are understood and are known to be benign. Hopefully, this study will help NASA and the USAF keep the cost impact of these false alarms to a minimum.

University of Botswana (Gaborone)

Rohan Jayaratne continues his laboratory work on thunderstorm electrification. Recently, he has been investigating possible effects of rime density and graupel surface temperatures on the charge separation during ice crystal interactions. Preliminary results show that the charge sign reversal temperature, and thereby presumably the location of charge centres in thunderclouds, is strongly affected by the surface temperature of graupel only at low cloud water contents. Details will be presented at the Osaka conference.

Together with V. Ramachandran, he has now accumulated a five-year lightning occurrence data set with a CGR3 LFC. One of the aims at present is to verify the accuracy of the instrument in detecting intracloud flashes.

University of Florida (Gainesville, FL)

Triggered-lightning experiments will continue in Summer 1996 at Camp Blanding, Florida. Researchers interested in participating in the program should contact Martin Uman (muman@admin.ee.ufl.edu).

Rajeev Thottappillil (University of Uppsala), Vlad Rakov, and Martin Uman derived exact expressions for remote electric and magnetic fields as a function of the time- and height-varying charge density on the lightning channel for both leader and return-stroke processes. They also determined the charge density distributions as a function of time and height for six return-stroke models. The charge density during the return-stroke process is expressed as the sum of two components, one component being associated with the return-stroke charge transferred through a given channel section and the other component with the charge deposited by the return stroke on this channel section. After the return-stroke process has been completed, the total charge density on the channel is equal to the deposited charge density component. The charge density distribution along the channel corresponding to the original transmission line (TL) model has only a transferred charge density component so that the charge density is everywhere zero after the wave has traversed the channel. For the Bruce-Golde (BG) model there is no transferred, only a deposited, charge density component. The total charge density distribution for the version of the modified transmission line model that is characterized by an exponential current decay with height (MTLE) is unrealistically skewed toward the bottom of the channel, as evidenced by field calculations using this distribution that yield (1) a large electric field ramp at ranges of the order of some tens of meters not observed in the measured electric fields from triggered-lightning return strokes and (2) a ratio of leader-to-return-stroke

electric field at far distances that is about three times larger than typically observed. The BG model, the traveling current source (TCS) model, the version of the modified transmission line model that is characterized by a linear current decay with height (MTLL), and the Diendorfer-Uman (DU) model appear to be consistent with the available experimental data on very close electric fields from triggered-lightning return strokes and predict a distant leader-to-return-stroke electric field ratio not far from unity, in keeping with the observations. In the TCS and DU models, the distribution of total charge density along the channel during the return-stroke process is influenced by the inherent assumption that the current reflection coefficient at ground is equal to zero, the latter condition being invalid for the case of a lightning strike to a well-grounded object where an appreciable reflection is expected from ground.

Recently, *Rakov et al.* (1995), based on the results of the 1993 triggered-lightning experiment at Camp Blanding, Florida, proposed a "two-wave" mechanism of the lightning M component. According to this mechanism, an M component involves a downward-progressing incident wave (the analog of a leader) and an upward-progressing reflected wave (the analog of a return stroke). Ground is sensed by the incident M wave as a short circuit, so that the reflection coefficient for current at ground is close to +1, and the reflection coefficient for the associated charge density is close to -1. Results of the 1995 triggered lightning experiment at Camp Blanding are in support of the "two-wave" M component mechanism indicating that:

- M components produce electric field changes at close ranges which appear as the time derivatives of the channel-base current waveforms and which are relatively insensitive to distance from the lightning channel (the two charge density waves subtract from each other).

- M components produce magnetic fields at close ranges whose waveshapes are similar to those of the channel-base currents and whose magnitudes vary as the inverse distance from the lightning channel (the two current waves add).

Vlad Rakov, Martin Uman, Glen Hoffman, Michael Masters, and Marx Brook (NMIMT) wrote a paper titled "*Bursts of Pulses in Lightning Electromagnetic Radiation: Observations and Implications for Lightning Test Standards*". The paper is scheduled for publication in the May, 1996 issue of the IEEE Transactions on EMC.

Vlad Rakov was invited to organize and chair a Special Session on Lightning and Its Effects at the 12th International Zurich Symposium on Electromagnetic Compatibility scheduled for February 18-20, 1997. The planned scope of the session includes:

1. Properties of the lightning discharge important for EMC.
2. Lightning return-stroke models.
3. Lightning EMP.
4. Coupling of lightning electromagnetic fields to overhead and buried conductors.
5. Lightning locating systems.
6. Atmospherics.
7. Lightning effects in the middle and upper atmosphere.
8. Lightning protection.
9. Lightning testing standards.

Deadline for submission of preliminary manuscripts (up to 3600 words) is July 1, 1996. Further information can be requested from Vlad (rakov@admin.ee.ufl.edu).

Global Atmospherics (Formerly LLP) (Tucson, AZ)

Global Atmospherics is in a period of investment in system analysis and in the development of basic sensing technologies.

The upgrade of the NLDN to a combined MDF/TOA network technology which processes both stroke and flash data has resulted in three significant changes to the accumulating dataset. Because these changes may impact ongoing research, they are summarized below. First, the anticipated location accuracy improvement (from 2-4 km to 500 meter median accuracy) has been verified in New York through detailed multi-camera studies carried out by Vince Idone and others at SUNY/Albany, and in other areas by many of our electric utility users. Studies carried out last spring at KSC by Mike Maier did not demonstrate the improved accuracy. This was probably due to the fact that NLDN sensor calibrations were still underway in Florida at that time. The Florida study will be repeated this summer.

Second, as part of the NLDN upgrade, the method for estimating flash multiplicity was changed to be consistent with timing-based location methods. In the past, the original angle-based method produced average multiplicities of 2.4 to 2.7 in the U.S., when averaged over long periods of time. The accuracy of this estimate is affected by numerous factors related to sensor spacing, sensor detection efficiency (DE), spatial separation of subsequent strokes, and overall flash rate. It is generally thought that the "true" average multiplicity is 3-4. The new method produces inherently lower multiplicity values because it is determined by stroke positions, and is therefore affected by the stroke detection efficiency of the network. In preliminary evaluations involving about 40,000 strokes in the NLDN, the average multiplicity ranged between 1.9 and 2.1. This result is consistent with a subsequent stroke DE of about 60 percent. Due to the fact that subsequent strokes typically have smaller peak currents than first strokes, this finding is not inconsistent with our projected overall flash DE of 80-90 percent. A more quantitative analysis of the stroke/flash relationship is currently in progress.

The third change in the NLDN data is the inclusion of a previously undetected population of small positive discharges. Following changes to the sensitivity and discrimination criteria in the NLDN sensors, the percentage of positive flashes has approximately doubled beginning late summer, 1995. The newly-detected events are low-current (5-15 kA estimated peak current) discharges which exhibit flash multiplicities that seem identical to those found for larger positive flashes. At this time, it is not known if these events are long vertical cloud discharges (since they can be seen at distances of up to 500 km) or if they are a population of previously un-detected positive cloud-to-ground discharges. Global Atmospherics is seeking precisely time-stamped video and electric field data from the research community which could help address this open issue.

Global Atmospherics has initiated two major new product development efforts that will significantly expand its line of commercial lightning detection systems. In a recent agreement with NASA, Global Atmospherics has begun a project aimed at producing a commercial version of the LDAR 3D lightning mapping system developed at NASA/KSC over the last decade. A number of enhancements to the basic LDAR signal processing will be implemented and evaluated, focusing on improved location accuracy, better detection

of small signals, and improved system flexibility and reliability. As part of this project, we will also be quantifying the 2D cloud discharge detection capabilities of our recently developed LPATS IV sensors, as compared to the LDAR system. Global Atmospherics' second area of development is in the detection and location of long-range (distant) lightning. Over the last year, we have carried out experiments focused on the detection and location of lightning discharges which occur several thousand kilometers from the detection sensors. In recent experiments we have expanded our studies to include the detection of cloud-to-ground lightning over the Eastern Pacific Ocean, Mexico/Central America, and the Atlantic Ocean, 2000-4000 km beyond the U.S. borders. In addition to the benefits for long-range severe storm forecasting, this dataset has the potential to provide the first detailed views of lightning patterns associated with such features as the southwest area monsoons over Mexico/Arizona, tropical wave activity in the windward islands, and lightning activity along the maritime provinces and the northern segment of the Gulf Stream.

For further details, please contact Ken Cummins or Burt Pifer.

Langmuir Laboratory (Socorro, NM)

The ballooning program at Langmuir Lab this summer is being conducted to further our understanding of storm electrification. During some flights we will be measuring precipitation charge and electric field inside the storms; other flights will measure X-ray production and electric field. Participants will be: Monte Bateman (Langmuir Lab), Ken Eack (U. of Oklahoma), Tom Marshall (U. of Mississippi), and Dave Rust (NSSL).

Other programs this summer will involve rocket-triggered lightning, tests of our newly-Dopplerized radar, and tests of new instruments aboard our research aircraft, SPTVAR.

MINTS Radiotechnical Institute and Radiometeorological Center (Moscow, Russia)

In some articles (JGR, 100, 1487, 1995) and reports, Prof. Edward Dubovoy et al. published the point and results of a new remote method for determination of energy and current in a lightning channel by means of radar and synchronous measurements of electric field pulses. This method doesn't depend on the spatial orientation of lightning. E.I. Dubovoy is searching for people who desire to use this method in scientific investigations or for practical aims. He may be contacted at: 2/11 Chertanovskaja, ap.2, 113208, Moscow, Russia.

M.I.T. Lincoln Laboratory (Lexington, MA)

Bob Boldi, Anne Matlin, and Earle Williams are using ASR-9 rapid-update (30 sec) radar data and events from the National Lightning Detector Network to assess the value of ground flashes in characterizing storm growth and decay for the Integrated Terminal Weather System (ITWS). Typical Level 3 (41 dBz) contour areas at the time of first ground flash in developing cells are 70-100 km2. The time of peak ground flash rate is frequently coincident with the time of maximum Level 3 contour area. Lately we have been interested in the small amplitude (2-10 kA) positive ground flashes that are identified in small radar cells in Orlando storms that are mixed in with larger amplitude negative flashes.

M.I.T. Parsons Laboratory (Cambridge, MA)

Charles Wong has completed a Master's thesis concerned with the analysis of large amplitude transients of the Schumann cavity based on measurements in West Greenwich, Rhode Island. Algorithms have been extended by Bob Boldi (Lincoln Laboratory) to produce global maps of large positives and negatives. The diurnal variations of these extraordinary events in the three major zones are lagged by 5-8 hours relative to the classical maxima in thunderstorm activity, consistent with an origin in nocturnal mesoscale convective systems.

Charles Wong and Earle Williams have exchanged transient ELF records from large lightning events with Sasha Nickolaenko in the Ukraine for comparative processing. Agreement on event location is excellent, save for small differences associated with the selection of waveguide propagation parameters.

Stan Heckman (Phillips Laboratory) has refined a single-station inversion method for treatment of Schumann resonance background measurements. Estimates of the global lightning in absolute units, combined with moment change estimates from Bill Koshak, show a global flash rate of 20-40 flash/sec. These numbers are consistent with recent estimates from the Optical Transient Detector by NASA MSFC. Preliminary inversions for individual days for an entire year reveal a semiannual and annual variation in global lightning, consistent with recent published results by Satori and Zieger in Hungary and with the variation of land surface air temperature for the tropics and for the globe.

Dennis Boccippio has compared the locations of 40 events of large luminous area seen by the Optical Transient Detector with ELF events recorded in Rhode Island, using algorithms developed by Charles Wong and Bob Boldi. Great circle bearings show excellent agreement with the OTD determinations. The single station range estimates based on the impedance method of D.L. Jones show agreement at the 1 Mm level. In general, these comparisons substantiate the idea that the lightnings that single-handedly excite the Earth-ionosphere cavity have large lateral extents in the cloud coupled to a channel to ground.

Earle Williams met with Martin Fullekrug, Dave Sentman, and Frank Morrison at Berkeley, California in April to explore collaborative use of ELF/VLF observations in interpreting the behavior of the Earth-ionosphere cavity. Methods to improve on absolute calibration of measurements were also identified.

Earle Williams has been working with Fatih Eltahir and students on the variations in discharge from large tropical rivers on the El Ni□o time scale. These results indicate that the warm El Ni□o regime is associated with reduced total rainfall, a result reminiscent of the monsoon-break period comparisons on rainfall and lightning with Steve Rutledge and colleagues in Darwin, Australia.

Masaru Ishii has collaborated with the MIT group by supplying times of large amplitude ground flashes from LLP networks in Japan and Indonesia to identify at ELF from Rhode Island. Such events provide important additional tests of the normal mode equations as an approximation for the real Earth-ionospheric cavity. We would appreciate getting well-timed large amplitude events from other parts of the world.

NASA / Marshall Space Flight Center (Huntsville, AL)

The Optical Transient Detector (OTD) has now completed one year of observations of global lightning from space after being launched on April 1995 into a 750 km, 70°

inclination orbit. The sensor detects lightning events during both day and night with a time resolution of 2 ms to within 8 km over a 1300 x 1300 km region. OTD is the engineering flight model of the NASA Lightning Imaging Sensor (LIS) which is included on the Tropical Rainfall Measurement Mission (TRMM) planned for launch in 1997. Significant progress has been made by the LIS science team (H. Christian, K. Driscoll, D. Boccippio, D. Mach, J. Hall, W. Boeck, D. Buechler, W. Koshak, S. Goodman, R. Blakeslee) in the processing, analysis and validation of the OTD data. Preliminary results indicate a global flash rate of 40 to 50 flashes/second. Additional results will be presented at the International Conference on Atmospheric Electricity in Osaka.

A WWW OTD home page is located at URL http://wwwghcc.msfc.nasa.gov/otd.html. This home page includes the OTD global lightning distributions for April 1995 to March 1996. OTD observations of several recent hurricanes are also on the home page. This home page will be updated regularly to keep the science community abreast of our progress. Other information about the MSFC electricity program can be found at this site.

The LIS for the TRMM satellite completed laboratory calibration (H. Christian, W. Koshak, J. Bergtrom, M. Stewart, J. Hall) in January and has been delivered to Goddard Space Flight Center for integration onto the TRMM satellite (TRMM launch is scheduled for Fall 1997). In addition, the LIS data processing software has also been delivered.

We successfully participated in the international Maritime Continent Thunderstorm Experiment (MCTEX) field campaign which was conducted in the Tiwi Islands of Northern Australia during November and December 1995 (R. Blakeslee, H. Christian, J. Bailey, S. Goodman, M. Stewart). A four station Advanced Lightning Direction Finder (ALDF) network was installed in October (includes one island and three mainland sites). In addition, a field mill and a wideband E-field sensor was operated during MCTEX in collaboration with CSU (S. Rutledge). The ALDF sites will now remain deployed for several years to support TRMM ground truth. New algorithms (i.e., generalized linear inversion for 2 or more sites, and 3 site analytic TOA) have been developed/tested for processing the ALDF data (W. Koshak, R. Blakeslee, J. Bailey).

Preparations are underway for participation in the STERAO field campaign this summer in Colorado in collaboration with J. Dye. In support of this program MSFC will provide optical pulse sensors, an electric field change meter, and a transient waveform recorder for integration on the NCAR high altitude aircraft WB-57 aircraft (H. Christian, R. Blakeslee, M. Stewart).

We continue to have an interest in lightning data sets that could contribute to a global lightning climatology and/or to our ground truth activities for OTD (e.g., regional lightning detection networks, etc). Any individual or group interested in such a collaboration is encouraged to contact S. Goodman (steven.goodman@msfc.nasa.gov) or H. Christian (hugh.christian@msfc.nasa.gov).

The MSFC Atmospheric Electricity group is located at the Global Hydrology and Climate Center in Huntsville, Alabama. The mailing address is: 977 Explorer Blvd., Huntsville, AL 35806. The fax number is 205-922-5723.

National Lightning Safety Institute (NLSI) (Louisville, CO)

The following is the Periodic Activity Report from Richard Kithil at NLSI:

1. NLSI delivered the standard Lightning Safety Training Course to:
a. Arvada/North Jeffco Parks & Rec. Dept. (Colorado), 65 attendees.
b. Metro Denver Arson Investigators, 15 attendees.
c. National Safety council, Tampa, FL, 65 attendees.
d. Florida Phosphate Council (US Agri-Chemicals), Bartow FL, 25 attendees.
e. Lake County Emergency Services, Lake County FL, 60 attendees.
f. State of Florida, Dept. of Labor, Div. of Safety, Safety Executives Advisory Panel, 35 attendees.
g. Denver Federal Center Professional Engineers, 30 attendees.
h. Panamax Corporation, San Rafael, CA, 125 attendees.

2. NLSI assisted in preparing lightning safety information for specific clients upon request:
a. Department of Energy, Office of Nuclear and Facility Safety
b. College of William and Mary, Sports Medicine Dept., Williamsburg, VA
c. Florida Boating Association, Clearwater, FL
d. US Summer Olympic Games, Regatta Events, Savanna, GA
e. Ohio Insurance Institute, Columbus, OH
f. Time-Life Books, 1997 edition, NY, NY
g. Quantas Airways, Brisbane, Australia
h. American Family Insurance, Milwaukee, WI
i. Hewlett Packard Corp., Jakarta, Indonesia
j. Univ. of New Mexico Athletic Dept., Albuquerque, NM
k. Indiana Little League Baseball League, Indianapolis, IN
l. NASA, Washington, DC
m. DoD contractor, Albuquerque, NM
n. Denver Post, Denver, CO
o. Conoco Offshore, Lafayette, LA
p. Montana State University, EE Dept., Bozeman, MT
q. Risk Management Office, Collier County (Naples), FL
r. Lockheed Martin, Denver, CO
s. Transwestern Pipeline, Roswell, NM
t. US Navy, Miramar, CA
u. Bay Process Consultants, Tauranga, New Zealand
v. Lockheed Martin, Starke, FL
w. Scott AFB, IL

3. NLSI has revised its World Wide Web Page with new information to the current URL: http://www.lightningsafety.com This WWW page is generating 5-15 "hits" daily. "Hits" include general readership of the Web page information (length is about 15 regular pages in size), as well as inquiries on specific subjects. About half of the Guestbook sign-in information is retained for follow-up purposes. Answers to questions received usually are answered the same day.

4. NLSI held a Board of Directors meeting February 9, 1996.

5. NLSI received confirmation of non-profit status by the state of Colorado.

6. NLSI was retained as an expert witness for plaintiffs in:
a. Municipal golf course deaths/negligence case in Oklahoma City, OK with Martin Uman)
b. Property damage insurance claim in Montgomery, AL
c. Property damage claim in Lowndes County, AL

7. NLSI received and completed contracts for lightning mitigation/lightning safety studies at
a. Westinghouse Hanford Corporation for Dept. of Energy, Waste Tank Storage Sites at Hanford, WA.
b. Central and South West Services, Dallas, TX for 6600 KW Wind Turbine Farm at Fort Davis, TX.
c. ASTeR, Inc. Meteorological Laboratory, Fort Collins, CO.

National Severe Storms Laboratory (Norman, OK)

Don MacGorman of the National Severe Storms Laboratory, Jerry Straka of the Univ. of Oklahoma, and Conrad Ziegler of NSSL continue to work on developing capabilities for their three-dimensional numerical cloud model, which includes inductive and non-inductive electrification mechanisms. They recently added a new parameterization of lightning to the model. A simulation of a supercell storm with the new model produced charge and electric field distributions that were similar overall to those presented previously by *Ziegler and MacGorman* (1994) from their three-dimensional kinematic model.

Dave Rust of the National Severe Storms Laboratory plans to join collaborators at the Irving Langmuir Laboratory for Atmospheric Research in New Mexico in early August. Tom Marshall (Univ. of Mississippi), Monte Bateman (Langmuir Laboratory), Ken Eack (Univ. of Oklahoma), Bill Beasley (Univ. of Oklahoma), and Dave will make a few balloon soundings with electric field meters, particle charge-size sensors, and LORAN sondes. Some flights will include an x-ray detector and/or a GPS sonde (to be tested in thunderstorm environments and also compared with LORAN wind finding).

Conrad Ziegler of the National Severe Storms Laboratory, with collaborators John Lee (Science Applications International Corp.) and Roger Pielke (Colorado State University), employed national lightning ground strike network data from Global Atmospherics, Inc. in a study of deep, moist dryline convection as simulated by the CSU mesoscale model. Densely concentrated lightning strike areas served as proxy for heavy convective rainfall to assist the interpretation of the input soil moisture analyses and simulated convection. Horizontal soil moisture gradients are frequently present at sunrise east of the dryline in regions where persistent storms and mesoscale convective systems develop during the afternoon or early evening of the same day. Simulated afternoon dryline convection develops near areas of CG lightning from observed dryline storms.

A short paper on the national lightning network and its applications to fire weather was prepared by Brenda Graham, fire weather meteorologist at the National Weather Service in Medford, Oregon, and Ron Holle and Raul Lopez of the National Severe Storms Laboratory. The paper was published in the preprints for the Symposium on Fire & Forest Meteorology of the 22nd Conference on Agricultural and Forest Meteorology held in January by the American Meteorological Society in Atlanta.

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

Atmospheric Electricity Research Group (AERG)
Comparative analysis of the Maxwell current measured at the Polish Polar Station Hornsund, Spitsbergen and Jozefoslaw observatory in Poland has been continued (A.C.

Losakiewicz). Some of the data sets display significant values of the cross-correlation function. According to the theory of current response to ionospheric potential variations, the Jozefoslaw current precedes in phase the Hornsund current for these data sets. The phase delay (up to 90 s) indicates that changes in ionospheric potential are the origin of the observed global Maxwell current fluctuations. Hence, these fluctuations are connected with the proceses occurring in the extraterrestrial (magnetospheric, interplanetary) space.

Currents produced by charge flowing in the lower atmosphere are examined theoretically. P. Baranski is investigating the use of the electric field and current measurements near the earth surface for distinguishing the convective component of the Maxwell current density from other components. He is also studying the use of electical methods for detection of severe weather phenomena (e.g. downburst events) accompanying the observed thundercloud. Some recent results of a field experiment carried out during rainfalls and downdrafts associated with nearby thunderstorms in Warsaw have given support for such expectation.

Studies on fast electric field changes generated by lightning discharges continue. Research is within CESAR (Central European Sattellite Advanced Research) satellite experiment programme. We are still in the laboratory phase aimed at designing a satellite detector of fast changes of the electric field and the suitable digital data aquisition system. Coworkers: P. Baranski (BARANSKI@IGF.EDU.PL), T. Kuraszkiewicz (TOMEK@IGF.EDU.PL), A. Losakiewicz (ANDRZEJ@IGF.EDU.PL), M. Morawski (MORAWSKI@CBK.WAW.PL).

The atmospheric electricity recordings are carried out at polar station Hornsund in Spitsbergen (M. Kubicki and M. Chrobak). The response of the ground electric field on magnetospheric-ionospheric influences, observed in periods coinciding with strong geomagnetic activity and fair-weather conditions is examined (S. Michnowski, N. Nikiforowa, M. Kubicki).

Atmospheric electricity recordings at Swider station have been continued (M. Kubicki). The errors of the measurements of the ion mobility spectra and electrical conductivity of the air have been analysed (J. Berlinski).

Polytechnic University (Tomsk, Russia)

An abstract to a paper by E. T. Protasevich states: Properties of the gas-discharge plasma and the possibility of its variations on account of the control of water vapor concentration in the air are dealt with. Preliminary results have shown that there is an optimal value of air humidity for each pressure value, which leads to the formation of a cool nonequilibrium plasma with a lifetime from tens of milliseconds to seconds. The understanding of the mechanisms of the physico-chemical processes in such plasma offers to develop the principles for control of atmospheric phenomena and to explain the nature of such atmospheric electricity phenomena as St. Elmo's fire, ball lightning, bead lightning and the atmosphere glowing in energy-active zones (vicinities of earthquakes, underground nuclear explosions, etc.). Causes of the initiation of natural electromagnetic background, and its effect on the atmosphere and environment are considered. The book presents a technique for recording radioactive pollution by measuring radiation in the superhigh frequency region.

South Dakota School of Mines & Technology (Rapid City, SD)

Planning continues for a Radar and Aircraft Cloud Electrification Study (RACES) for the period late May through early July, 1997, to be conducted in the vicinity of the CSU-CHILL radar near Greeley, Colorado. A main focus will be to obtain detailed measurements of the microphysical and electrical structure of hailstorms, and to test against these observations proposed mechanisms to explain the observed correlation between large hail and predominantly positive cloud-to-ground lightning activity. Collaboration is welcomed with researchers interested in hail, electricity, and other aspects of severe storms. An overview document should be out during April. Please contact Andy Detwiler (andy@nimbus.ias.sdsmt.edu) or John Helsdon (jhelsdon@lightning.ias.sdsmt.edu) for further information. Both can be reached via phone at 605/394-2291 or fax at 605/394-6061, and by regular mail at

Institute of Atmospheric Sciences
South Dakota School of Mines and Technology
Rapid City, SD 57701-3995.

Stanford University: Starlab (Stanford, California)

Theoretical and experimental work continues to be motivated by the desire to understand the mechanisms, role and effects of the luminous structures in the mesosphere known as sprites, jets and elves. These phenomena provide visible evidence of coupling between tropospheric lightning, the intervening mesosphere and the D-region ionosphere.

Several recent papers have contributed to understanding the mechanisms producing sprites, jets, elves and terrestrial gamma rays.

Victor Pasko, Umran Inan, Yuri Taranenko (now at LANL) and Tim Bell proposed (Feb. 15, 1995 GRL) a theoretical model explaining sprites as a result of heating, ionization and optical emissions produced by large quasi-electrostatic (QE) fields appearing at ionospheric altitudes following intense lightning discharges.

Tim Bell, Victor Pasko and Umran Inan published in the Aug. 15, 1995 issue of GRL the results of a new model suggesting that QE fields can also produce an upward-traveling beam of ~1 MeV runaway electrons which may contribute to the production of optical emissions associated with sprites.

Umran Inan, Wesley Sampson (now at Qualcomm, Inc.), and Yuri Taranenko (LANL) presented in the Jan. 15, 1996 issue of GRL a new two-dimensional (cylindrically symmetric) model of interaction with the ionosphere of electromagnetic pulses (EMP) radiated by lightning discharges. EMP pulses produce bright optical emissions at 80-95 km altitudes emitted in a thin cylindrical (doughnut-like) shell expanding to radial distances of up to 150 km and lasting ~400 microsec, with optical emissions in good agreement with observable features of elves.

Victor Pasko, Umran Inan and Tim Bell published (Feb. 1, 1996 GRL) the first mechanism explaining blue jets in terms of pre-discharge QE fields immediately above the thundercloud which lead to the formation and upward propagation of streamer-type ionization channels.

Victor Pasko, Umran Inan and Tim Bell (in print at GRL) proposed a mechanism explaining the formation of carrot-like vertically striated shapes of sprites as well as the significant

delay (1-20 ms) of optical emissions associated with sprites with respect to the causative lightning discharge.

Umran Inan, Victor Pasko, and Tim Bell (in print at GRL) proposed an original mechanism for the explanation of early/fast VLF events based on sustained heating of the ionosphere above thunderstorms.

A broad-based experimental campaign is planned to measure lightning, VLF perturbations and optical emissions during the summer of 1996. Bill Trabucco and Mike Johnson are updating and relocating the California coastal system of narrowband VLF receivers measuring the amplitude and phase of VLF transmitters at 100 samples per second. Changes in D-region (80-100 km at night) ionospheric conductivity due to heating and/or ionization cause transient perturbations in the subionospherically propagating VLF signals. The narrowband VLF systems will be installed in high schools in New Mexico and Colorado to accomplish a VLF hologram array sensitive to ionospheric perturbations above large thunderstorms in the midwestern U.S. The VLF data will be transmitted in real time over the Internet, allowing the students and other researchers timely access to the data. Steve Reising and Bill Trabucco are constructing two portable ELF/VLF (30 Hz to 30 kHz) broadband receivers to record radio atmospheric (sferic) waveforms of sprite-associated lightning at close range. These receivers complement the ongoing long-range (1000 - 14,000 km) ELF/VLF sferics measurements at Palmer Station, Antarctica. Chris Barrington-Leigh and Sean Hansen are developing an optical experiment to be deployed at Yucca Ridge, Colorado, to measure the morphology and time development of elves.

Recent experimental results include the first experimental evidence of the association of lightning with terrestrial gamma-ray bursts. A sferic produced by a positive cloud-to-ground flash was detected to be within +/-1.5 ms of a gamma-ray burst detected by the BATSE instrument on CGRO. The paper will appear in the April 1, 1996 GRL, by Umran Inan, Steve Reising, Jerry Fishman (NASA/MSFC) and John Horack (NASA/MSFC).

Umran Inan, Alex Slingeland (now at Qualcomm, Inc), Victor Pasko and Juan Rodriguez (now at AFPL) presented (Mar. 1, 1996 JGR) new experimental evidence of disturbances of the electrical conductivity of the nighttime mesosphere and the lower ionosphere in association with lightning discharges. They reported two distinct new categories of early/fast VLF events, namely rapidly recovering events having a post-onset peak which typically lasts 1-2 sec and short duration events which recover to pre-event levels in < 3 sec. In the Dec. 15, 1996 issue of GRL, Umran Inan, Victor Pasko, Tim Bell, Walt Lyons (ASTeR, Inc.) and Dave Sentman (U. of Alaska) reported experimental verification of the association of early/fast VLF events with sprites.

Tel Aviv University (Tel Aviv, Israel)

Orit Altaratz, an M.Sc. student under Prof. Zev Levin, is compiling a combined data set of LPATS lightning strike positions (obtained from the Israeli Electrical Company) together with radar images obtained from the Florence and Louis Ross Meteorological Radar operated from the Cloud Physics Laboratory in the Department of Geophysics and Planetary Sciences. Together with Dr. Yoav Yair, Ms. Altaratz is trying to determine the relationship between strike polarity, current magnitude, the intensity of the radar echo and the ambient meteorological variables. This is done by examining vertical cross sections of active clouds and relating the observed lightning flashes to those clouds. The work is a

continuation of earlier work on the occurrence of positive ground flashes in Tel-Aviv thunderstorms, which was carried out by Zev Levin, Yoav Yair and Baruch Ziv using the CGR3 lightning counter data. The results of that work have been accepted for publication in GRL.

Our group will participate in the advanced phase of the study of global lightning characteristics, co-ordinated by D. Mackerras and M. Darveniza from the university of St. Lucia in Queensland. A new and improved version of the CGR3 detector will be placed at the Institute for Oceanography and Limnology, near Haifa, 80 km north of Tel-Aviv. This will allow both the existing system and the new one to operate, and will enhance our coverage of northern lightning storms (which have not been covered from Tel-Aviv). Furthermore, the northern CGR3 station will enable us to compare results with those of the LPATS, which showed a local maximum of lightning activity in that area.

The Jovian cloud model, used by Dr. Yoav Yair to calculate lightning frequencies and energies in Jupiter's atmosphere, is now being adapted to the atmosphere of Saturn. The water clouds in Saturn's atmosphere are believed to reside in the 10 bar pressure level, and have a mixed liquid water / ice segment where charge can be generated and separated via the ice-graupel non-inductive mechanism. Results show that the charge separation efficiency in these clouds is similar to that of terrestrial clouds, and is lower by a factor of 2.5 compared to Jupiter.

Dr. Colin Price continues to work on the subject of lightning-produced nitrogen oxides in the troposphere. Together with Joyce Penner of Lawrence Livermore National Laboratory and Michael Prather of UC Irvine, he is participating in NASA's Atmospheric Effects of Aircraft Project (AEAP)-''Subsonic Assessment (SASS), to understand the significance of aircraft emissions on tropospheric chemistry. In order to quantify the contribution from aircraft, it is necessary to estimate the contribution from natural sources such as lightning. Two papers on this topic will soon be published in JGR-Atmospheres.

Colin Price together with Earle Williams of MIT is working on the construction of a Schumann Resonance monitoring station in the Negev Desert. A remote site has been located and the equipment will soon be transported to the site for initial tests. The site is ideal for this type of study due to it's remote location, it's dry climate and very few days with precipitation and electrical activity.

Texas A&M University (College Station, TX)

The Texas A&M Lightning Research Group is publishing several papers that are or will appear in the next six months. They include the following:

Livingston, E. R., J. W. Nielsen-Gammon, and R. E. Orville, 1996, "A Climatology, Synoptic Assessment, and Thermodynamic Evaluation for Cloud-to-Ground Lightning in Georgia: A Study for the 1996 Summer Olympics," *Bull. Amer. Meteor. Soc.,* to be published in July 1996. (We present a summary of the lightning in the Georgia-Olympic area over the last ten years. A logistic regression technique is developed to assist NWS forecasters in identifying the active lightning days during the period of the Olympics '96, July 20 to August 8.)

Orville, R. E. and A. C. Silver: 1996, "Lightning Ground Flash Density in the Contiguous United States: 1992-1995," *Monthly Weather Review,* Accepted, in revision. (We present the

lightning ground flash density maps, positive flash density contours, and percent of positive lightning for the four years, 1992-1995.)

Toracinta R., K. Devlin, E. J. Zipser, and R. E. Orville, 1996: "A Comparison of WSR-88D Reflectivities, SSM/I Brightness Temperatures, and Lightning for Mesoscale Convective Systems in Texas, Part 1: SSM/I Brightness Temperatures and Lightning," *Jour. of Applied Meteorology,* In Press, May 1996.

Devlin, K. I., E. R. Toracinta, E. J. Zipser, and R. E. Orville, 1996: "A Comparison of WSR-88D Reflectivities, SSM/I Brightness Temperatures, and Lightning for Mesoscale Convective Systems in Texas, Part 2: Radar Reflectivity and Lightning," *Jour. of Applied Meteorology,* In Press, May 1996.

Lucas, C. and R. E. Orville, 1996: "TOGA COARE: Oceanic Lightning," Accepted for publication. *Monthly Weather Review,* In Press, August 1996. (The first analysis of the TOGA COARE lightning data from Kavieng is presented. The near local midnight peak cg lightning activity is documented as well as the appearance of the MJO in the lightning data.)

Petersen, W. A., R. E. Orville, and S. A. Rutledge, 1996: "Cloud-to-Ground Lightning Observation in TOGA COARE: Lightning Location Algorithms and Selected Results,". *Monthly Weather Review,* April. (In cooperation with Walt Petersen, sample lightning data are overlaid with radar and satellite data to indicate the type of coordinated studies that can be accomplished with the TOGA lightning data set.)

University of Washington (Seattle, WA)

Bob Holzworth will be launching a rocket from Poker Flat Alaska in January 1997 with Profs. George Parks and Michael McCarthy to study pulsating aurora. His instrument will have vector electric field for dc and VLF waves and will include a state of the art high sensitivity, low noise preamplifier in each of the probes.