NEWSLETTER ON ATOMOSPHERIC ELECTRICITY

Vol. 9 No. 2 DECEMBER 1998

AMS COMMITTEE ON ATMOSPHERIC ELECTRICITY	AGU COMMITTEE ON ATMOSPHERIC AND SPACE ELECTRICITY	INTERNATIONAL COMISSION 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@LL.MIT.EDU) or by fax (617-253-6208) any time before **April 15, 1999**. Mark your calendars!

This newsletter is now routinely provided on the World Wide Web (http://ae.atmos.uah.edu/bateman/ae-home.html). Those individuals not needing the mailed version should contact Earle Williams toward reducing distribution expenses.

***AGU / Case Meeting in San Francisco**

Following a long-established custom, AGU's Committee on Atmospheric and Space Electricity (CASE) will meet at the AGU fall meeting. The meeting will be held on Wednesday, December 9, at 5:30-7:00 pm in Room 124 of the Moscone Convention Center (where the AGU fall meeting is held).

The CASE meeting is open to all who attend the Fall AGU meeting. It will end no later than 7:00 pm, hopefully earlier.

If you have items of news or business that you would like to place on the agenda for the meeting, please notify Don MacGorman, chairperson of CASE, at the email address listed below.

Every two years, the new AGU President appoints members of CASE, with some long-standing members rotating off and some new members being appointed. Retiring members, thanks for your service to the committee.

The new CASE membership list is given below:

Monte G. Bateman
Global Hydrology & Climate Center
NASA Marshall Space Flight Center
Huntsville, AL 35806
Phone: (205) 922-5804 Fax: (205) 922-5723 email: Monte.Bateman@msfc.nasa.gov

Richard Blakeslee
Global Hydrology & Climate Center
NASA Marshall Space Flight Center
Huntsville, AL 35806
Phone: (205) 922-5962 Fax: (205) 922-5723 email: rich.blakeslee@msfc.nasa.gov

Vernon Cooray
Institute of High Voltage Research
Uppsala University
S-755 28 Uppsala, SWEDEN
Phone: +46-18-533636 Fax: +46-18-502619 email: vernon.cooray@hvi.uu.se

Prof. Richard L. Dowden
161 Pine Hill Rd.
Dunedin, NEW ZEALAND
Phone: +64-3-473-0524 Fax: +64-3-473-0521 email: dowden@otago.ac.nz

James E. Dye
MMM
NCAR
P.O. Box 3000
Boulder, CO 80307
Phone: (303) 497-8944 Fax: (303) 497-8181 email: dye@ucar.edu

Richard A. Goldberg
NASA Goddard Space Flight Center, Code 690
Greenbelt, MD 20771
Phone: (301) 286-8603 Fax: (301) 286-1648 email: goldberg@nssdca.gsfc.nasa.gov

John H. Helsdon
Institute of Atmospheric Sciences
South Dakota School of Mines & Technology
501 E. St. Joseph Street
Rapid City, SD 57701
Phone: (605) 394-2291 Fax: (605) 394-6061 e-mail: jhelsdon@msmailgw.sdsmt.edu

Donald R. MacGorman
NSSL/CIMMS
University of Oklahoma
100 E. Boyd, Rm 1110
Norman, OK 73019
Phone: (405) 325-5667 Fax: (405) 325-7614 email: don.macgorman@nssl.noaa.gov

Launa M. Maier
TE-ISD-8A
NASA Kennedy Space Center, FL 32899
Phone: (407) 867-4343 Fax: (407) 867-3658 email: launa.maier-1@pp.ksc.nasa.gov

Walter A. Petersen
Department of Atmospheric Science
Colorado State University
Ft. Collins, CO 80523-1371
Phone: (970) 491-6944 Fax: (970) 491-8449 e-mail: walt@olympic.atmos.colostate.edu

Vladimir A. Rakov
Dept. of Electrical and Computer Engineering
216 Larsen Hall
University of Florida

Gainesville, FL 32611-6200
Phone: (352) 392-4242 Fax: (352) 392-8671 email: rakov@admin.ee.ufl.edu
Arthur D. Richmond
NCAR-HAO
P.O. Box 3000
Boulder, CO 80307-3000
Phone: (303) 497-1570 Fax: (303) 497-1589 email: richmond@ucar.edu
Robert Roussel-Dupre
MS-D466
Los Alamos National Lab
Los Alamos, NM 87545
Phone: (505) 667-9228 Fax: (505) 665-7395 email: rroussel-dupre@lanl.gov

Davis D. Sentman
Geophysical Institute
University of Alaska Fairbanks
Fairbanks, AK 99775-7320,
Phone: (907) 474-6442 Fax: (907) 474-7290 email: dsentman@gi.alaska.edu
Jeffrey P. Thayer
SRI International
333 Ravenswood Avenue / MS G-275
Menlo Park, CA 94025
Phone: (650) 859-3557 Fax: (650) 322-2318 e-mail: thayer@sri.com
Brian A. Tinsley
FO22
University of Texas at Dallas
Box 830688
Richardson, TX 75083-0688
Phone: (972) 883-2838 Fax: (972) 883-2761 e-mail: tinsley@utdallas.edu
John C. Willett
Geophysics Directorate
Phillips Laboratory, PL/GPAA
29 Randolph Rd.
Hanscom AFB, MA 01731-3010
Phone: (781) 377-5954 Fax: (781) 377-2984 email: willett@plh.af.mil
Earle R. Williams
MIT Parsons Laboratory
MIT 48-211
Cambridge, MA 02139
Phone: (617) 253-2459 Fax: (617) 253-6208 email: earlew@ll.mit.edu

11th International Conference on Atmospheric Electricity

The International Commission on Atmospheric Electricity is pleased to announce the 11th International Conference on Atmospheric Electricity (ICAE 99) to be held from June 7 through 11 at the Lake Guntersville State Park, Guntersville, Alabama, 36976 USA,. The Chairman of the ICAE 99 is Dr. Hugh J. Christian of the NASA Marshall Space Flight Center.

The ICAE 99 will bring together scientists and collegues to exchange recent results and information about atmospheric electricity. The conference goal is to discuss ideas, gather information, and most importantly, create an atmosphere where scientists can pursue fruitful and stimulating discussions.

The selection of papers will be completed by early December, 1998. All papers are due no later than March 1, 1999. All deadline dates mentioned will be strictly adhered to.

ICAE'99 will be sponsored by the ICAE, NASA, the NSF and the AMS.

This conference will be truly international in participation, with over 250 abstracts submitted by contributors from 28 different countries around the world. Additional details of this conference can be found at the ICAE '99 web site at <http://icae.atmos.uah.edu>.

Now that the abstract submission deadline has passed (September 30), the abstracts are being reviewed for scientific merit. The selection process will be complete by early December, 1998, and all contributors will be notified of the decisions made by the ICAE '99 Review Panel soon afterwards. Each author whose abstract has been selected will be sent an author's kit detailing the format for the final camera-ready transcript of the short paper (3 to 4 pages) that will be printed in the conference proceedings. A bound copy of the conference proceedings will be provided to each participant at the conference.

Pre-registration for the conference will continue through March 1, 1999. A registration fee of approximately $300 will be charged to help defray the expense of the conference. All rooms at the Guntersville Lodge have been reserved for the conference and the complete facility will be at the disposal of the participants and their families.

Those who plan to attend the conference are requested to send completed registration and accommodations forms to the ICAE '99 Conference Chairman before March 1, 1999. These forms can be obtained from the ICAE web site, or upon request from: Dr. Hugh Christian, ICAE '99 Conference Chairman, Global Hydrology & Climate Center (GHCC), 977 Explorer Blvd, Huntsville, AL 35806 USA. Email: <icae_chairman@breakdown.msfc.nasa.gov.> Phone: +1 (256)-922-5742 FAX: +1 (256)-922-5979.

Sources for travel grants are currently being investigated. A few travel grants are expected to be made available to students (US Citizens) who will be attending this conference. First priority will be given to students who will be presenting material at the conference. Information on how to apply for these travel grants will soon be provided on the ICAE '99 web page <http://icae.atmos.uah.edu>.

Additionally, a small amount of funds are expected to be made available to scientists for international travel to the conference. Since the amount of these funds are expected to be limited, all participants are encouraged to investigate other sources of funds for travel. Information on international travel grants provided through the ICAE will be distributed by e-mail as well as listed on the ICAE web site.

4th International Workshop on the Physics of Lightning

The 4th International Workshop on the Physics of Lightning 20-23 September, 1999 will be held in Fontevraud L'Abbaye, France. Abstract deadline is February 28, 1999. For further information please contact Gerard Berger (berger@lpd.supelec.fr) or Nicolas Floret (nfloret@altern.org)

IUGG MEETING in Birmingham, England

The IUGG meeting will be held July 18-30, 1999 in Birmingham, England. Individual sessions include Electrical Discharges in the Middle Atmosphere (Convenor: Dick Goldberg (richard.a.goldberg.2@gsfc.nasa.gov)), Middle Atmosphere Electrodynamics: Influences and Processes (Convenor: Sheila Kirkwood (sheila@irf.se), and Thunderstorm Charge and Discharge Processes (Convenor: Clive Saunders (clive.saunders@umist.ac.uk)). Abstract deadline is January 15, 1999.

URSI General Assembly, Toronto, Canada

The URSI General Assembly date is August 13-21, 1999 in Toronto, Canada. Convenors: David L. Jones (david.jones@kcl.ac.uk) and Masashi Hayakawa Session E6--Terrestrial EM Environment is scheduled for August 21. Abstracts in required format are due by January 15, 1999.

International Conference on Lightning and Static Electricity

The ICOLSE Conference will be held June 22-24, 1999 at Centre des Congres Pierre Baudis in Toulouse, France. This conference will provide an opportunity for those involved in the technical aspects of lightning and other electrical and electromagnetic phenomena to share information across the broad spectrum of research, development, design, testing, and certification of all manner of aerospace vehicles, systems, and support facilities.

For more information you can contact Jim Brahney at SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001 USA, or fax 724-776-1830.

International Schumann Resonances Workshop

An International Workshop on Schumann Resonances was held in Sopron, Hungary in September, 1998. It was sponsored by the Geodetic and Geophysical Institute of the Hungarian Academy of Sciences, and hosted by Dr. Gabriella Satori. Papers and discussions focused on: wave propagation, waveguide asymmetry, ionospheric changes, global triangulation on sources, sprites and elves and associated waveguide excitation, intensity variations on numerous time scales, secular variations in intensity and frequency, El Nino related variations in lightning centers, connections with global temperature and water vapor, and coordinated global measurements.

International Conference on Electrical Injury & Safety

The International Conference on Electrical Injury & Safety was held in Shanghai, P.R. China, at the Equatorial Hotel, on October 26-28, 1998.

The conference was co-organized by the University of Chicago and Shanghai Electric Power Hospital. It brought together physicians, scientists, psychologists, engineers and safety officers to discuss advances and unsolved problems in evaluation, treatment and rehabilitation after electrical trauma. More information on the conference agenda can be obtained from our web site: http://bio-3.bsd.uchicago.edu/btc/etrp.

Please don't hesitate to contact Tatiana Tkachenko, Electrical Trauma Research Program, University of Chicago, if questions arise.

All-Russia Conference on "Atmosphere and Human Health"

The conference held in St. Petersburg, Russia 24 - 26 November 1998 was for the purpose of coordinating the efforts of the international community in evaluating the atmospheric influence on the health of humans

The participants were representatives of the Russian Academy of Sciences, Federal Service of Russia for Hydrometeorology and Environmental Monitoring, the North-West Board of Rosgidromet Hydrometeorological Service, the Health Ministry, Ministry of General and Vocational Education, Ministry of Science and Technologies, and the International Academy of Ecology, Human Safety and Nature.

IN MEMORIAM

Byron Blake Phillips. May 6, 1923 - March 28, 1998

Byron Blake Phillips died Saturday, March 28, 1998, in Longmont, Colorado. He was 74 years old.

He attended Kansas State University where he received a B.S. degree in mathematics in 1947 and a master's degree in physics in 1949. He received a Master of Science degree in meteorology from the California Institute of Technology during his WWII military service.

In 1949 he joined the United States Weather Bureau as an observer briefer.

In 1951 he was appointed physicist in Washington, DC and from 1957 to 1972 was assistant director of the Atmospheric Physics and Chemistry Laboratory, heading up the cloud physics and atmospheric electricity division. It was during this period of time that his contributions to cloud physics and atmospheric electricity were published. The laboratory was moved from Washington, D. C. to Boulder, Colorado in 1996, and the mission of the laboratory was changed. He then went to work for the National Oceanic and Atmospheric Administration, in 1973, retiring in 1977. He was then employed by the National Center for Atmospheric Research, retiring from there in the mid 1980's.

Throughout his lifetime atmospheric electricity continued to be a subject of interest and speculation. In the 1990's, with a fellow physicist co-worker from the earlier days, he set up a home laboratory to test by experiments and hypothesis the process in the atmosphere that results in lightning. He died before all of the envisioned experiments were completed.

He is survived by his wife, the former Peggy Roth; two daughters, Meg Casey of Littleton and Amy Lucas of Aurora; one brother William K. Phillips of Virginia; and three grandchildren.

Byron's most significant contributions to the theory of atmospheric electricity are contained in the Gunn Memorial Issue of the Monthly Weather Review, December 1967, Volume 95, No 12.

Special Issue in Honor of Bernard Vonnegut

Guest Editor Haflidi Jonsen reports as of November 20 that all papers are now complete for the Special Issue of Atmospheric Research.

RESEARCH ACTIVITY BY ORGANIZATION

***UNIVERSITY OF FLORIDA (Gainsville, FL)**

In spite of the drought and ban on lightning triggering because of forest fires at the beginning of the summer in Florida, the 1998 triggered lightning campaign at Camp Blanding was a success. A total of 34 lightning discharges were initiated using the "classical" (grounded wire) triggering technique, with 27 of them containing return strokes. The acquired data are presently being analyzed.

Dave Crawford defended his Masters Thesis titled "Multiple-Station Measurements of Triggered Lightning Electric and Magnetic Fields". Data presented in the Thesis include fields at seven distances ranging from 5 to 500 m with simultaneously measured currents for dart-leader/return-stroke sequences, M components, and initial-stage processes in seven flashes triggered at Camp Blanding in 1997. The leader electric field change tends to decrease inversely with distance from the channel. This finding implies a more or less uniform distribution of charge along the bottom portion of the fully-formed leader channel. The return-stroke peak magnetic field amplitude is seen to vary also inversely with distance from the channel. Magnetic fields are seen to exhibit a pronounced, relatively slow ramp prior to the onset of the return stroke at the relatively large distances of 110 and 500 m from the channel. A stronger linear correlation is observed between return stroke peak current and the electric field change of the associated leader. M-component electric fields are seen to diminish with distance much more slowly than inversely beyond 30 m or so from the channel (five events); at closer distances, a marked increase in electric field amplitude is observed toward the channel (two events). Electric and magnetic field waveforms were obtained for the initial current variation occurring at the beginning of the triggered-lightning initial stage. A relatively slow electric field ramp is observed, of generally uniform amplitude over all measuring antennas, on which a sharp V-shaped waveform of tens of microseconds duration is superimposed. Simultaneous with the V-shaped pulse onset, the magnetic field is seen to rapidly decrease to nearly zero, followed by a fast rise to a peak. The latter observation is believed to reflect the interruption and subsequent resumption of current as the triggering-wire is destroyed. Dave presently continues lightning studies at Camp Blanding toward a Ph.D.

Vlad Rakov and Martin Uman authored a paper titled "Review and Evaluation of Lightning Return Stroke Models Including Some Aspects of Their application". In this paper, four classes of models of the lightning return stroke are reviewed. These four classes are: 1) the gas dynamic models; 2) the electromagnetic models; 3) the distributed-circuit models; and 4) the "engineering" models. Validation of the reviewed models is discussed. For the gas dynamic models, validation is based on observations of the optical power and spectral output from natural lightning. The electromagnetic, distributed-circuit, and "engineering" models are most conveniently validated using measured electric and magnetic fields from natural and triggered lightning. Based on the entirety of the validation results and on mathematical simplicity, the 'engineering" models are ranked in the following descending order: MTLL, DU, MTLE, BG, and TL. When only the initial peak values of the channel-base current and remote electric or magnetic field are concerned, the TL model is preferred. Additionally discussed are several issues in lightning return-stroke modeling that either have been ignored to keep the modeling straightforward or have not been recognized, such as the treatment of the upper, in-cloud portion of the lightning channel, the boundary conditions at the ground, including the presence of a vertically extended strike object, the return-stroke speed at early times, the initial bi-directional extension of the return-stroke channel, and the relation between leader and return-stroke models. Various aspects of the calculation of lightning electric and magnetic fields in which return-stroke models are used to specify the source are considered, including equations for fields, channel-base current and propagation effects as well as a discussion of channel tortuosity and branches. The paper is published in the IEEE Transactions on Electromagnetic Compatibility, Vol. 40, No 4, November 1998, Special Issue on Lightning.

Vlad Rakov and Martin Uman, in collaboration with Daohong Wang (principal author), Nobuyuki Takagi and Teiji Watanabe of Gifu University, Japan, authored a paper submitted to the JGR on the luminosity propagation characteristics of two leader/return stroke sequences in the bottom 400 m of the channel in two flashes triggered using the rocket-and-wire technique. The measurements were performed, using a high speed digital optical system (ALPS), in 1997 at Camp Blanding, Florida. One sequence involved a dart leader and the other a dart-stepped leader. The time resolution of the measuring system was 100 ns, and the spatial resolution about 30 m. The leaders exhibit an increasing speed in propagating downward over the bottom some hundred meters, while the return strokes show a decreasing speed when propagating upward over the same distance. Twelve dart-stepped leader pulses observed in the bottom 200 m of the channel have been analyzed in detail. The optical pulses associated with steps have a 10-90% rise time ranging from 0.3 ps to 0.9 ps with a mean value of 0.5 ps and a half-peak width ranging from 0.9 ps to 1.9 ps with a mean of 1.3 ps. The interpulse interval ranges from 1.7 ps to 7.2 ps with a mean value of 4.6 ps. The optical step pulses apparently originate at the leader “tip” in a process of step formation (unresolved with the spatial resolution of 30 m) and propagate upward over a distance from several tens of meters to more than 200 m (undetectable beyond that distance). This finding represents the first experimental evidence that the propagation direction of individual lightning-leader step luminosity pulses is upward rather than downward. The upward propagation speeds of the step pulses range from 1.9×10^7 m/s to 1.0×10^8 m/s with a mean value of 6.7×10^7 m/s, comparable to the return-stroke speed. An inspection of four selected pulses shows that the pulses attenuate significantly during propagation, to about 10% of the original value within the first 50 m. The return-stroke speeds within the bottom 60 m of the channel are 1.3×10^8 m/s and 1.5×10^8 m/s an in the two events analyzed.

Doug Jordan (University of West Florida) used, as part of a joint 1998 UWF/UF project, a vertical array of photodiodes to measure optical output of the lightning channel at four heights within 50 m of the lightning attachment point. Successful measurements were obtained for one triggered-lightning stroke at a distance of 140 m. At this distance, each photodiode imaged approximately 0.5 m of lightning channel. Initial analysis of the data indicates that the speed of the return-stroke optical front was approximately one-third of the speed of light between heights of 24 and 36 m above the lightning attachment point.

Carlos Mata, Mark Fernadez, Vlad Rakov, Martin Uman, Keith Rambo, Mike Stapleton, and Mirela Bejleri completed two reports summarizing studies of the lightning interaction with a test power distribution system at Camp Blanding, Florida from 1993 to 1998. These reports are prepared for EPRI (Project Manager Ralph Bernstein).

***FMA RESEARCH. (Fort Collins, CO)**

SPRITES'98 was conducted at the Yucca Ridge Field Station near FortCollins, CO from mid-May through August 1998. In addition to the FMA staff (Walt Lyons, Tom Nelson), in attendance were personnel from LANL (Dave Suszcynsky, Bob Roussell-Dupre, Bob Strabley, Eugene Symbolisty, Hal DeHaven), Utah State (Mike Taylor, Larry Gardener), Tohoku University (H. Fukunishi, Y. Takahashi), MIT (Earle Williams) and Mission Research (Russ Armstrong). Using a suite of remote sensing technologies, multiple coordinated measurements of individual sprite and elve events were obtained. Both red and blue low-light imagers (LLTVs) and multi-color broad-and narrow-band photometers monitored optical emissions. The evidence of ionization within sprites obtained in previous programs was confirmed from simultaneous 4278 and 4709 nm emissions. Additional imagery of "blue" sprite structures was obtained using blue-filtered LLTVs. High speed (1000 fps) images of sprites reveal new details of the temporal sequence of events. In addition, numerous high speed videos of the entire CG lightning event for both positive and negative polarity strokes provided new insights on the continuing currents and horizontal dendrite discharges. These videos were coordinated with optical measurements made with a photodiode array plus VLF and ELF transients (Q-bursts) made at MIT's Rhode Island Schumann resonance observatory. Sprites again were typically associated with storms with radar echoes larger than 10,000 sq. km., but some exceptions were noted, especially bursts of sprites in the dying phases of some supercell class thunderstorms. An unusual interaction between a meteor and a sprite was recorded. A meteor appears to have been the trigger for a large carrot-type sprite (not associated with a CG flash). Moreover a jet-like feature was seen retracting the lower portion of the meteor's apparent trajectory after the cessation of the sprite. Monitoring was also coordinated with scientists from Arizona State, New Mexico Tech, Stanford, and the University of Alaska. A climatology of large peak current CGs (greater than 75 kA) from the NLDN was published by Lyons, Uliasz and Nelson in the Monthly Weather Review. It revealed that the centers of large peak current CGs were distinctly geographically separated, with the large +CGs being concentrated in a broad band from New Mexico northeastwards to Minnesota. By contrast the large peak current -CGs were found primarily over water along the southeastern Atlantic and Gulf Coasts.

Storms ingesting smoke from Mexican fires produced unprecedentedly high percentages of +CGs, which in turn had twice the normal peak currents. A record number of sprites (nearly 400 in 208 minutes) were imaged above one such smoke-influenced storm. As well documented by both satellite imagery and surface aerosol concentration measurements, smoke from the vast 1998 El-Nino drought-related forest fires in Mexico and Central America frequently advected into the United States. Specifically, from about the 7th of April until the 8th of June, most air masses over the southern plains of the U.S. were influenced by the smoke. A strong frontal zone crossing the region, between the 14th - 18th of May, resulted in smoke being advected as far north as Ontario and eastward to New England. As documented by the National Lightning Detection Network (NLDN), thunderstorms developing within these contaminated air masses had extraordinary changes in their electrical characteristics. Specifically, large thunderstorm systems exhibited very high percentages of cloud-to-ground (CG) lightning flashes with positive polarity (+Cgs). While +CGs are typically less than 10% of the total, many affected storms, such as those with the mid-May frontal system, sustained +CG percentages of 50 to 90% during their lifetime. Moreover, the peak currents within these +Cgs were much higher than normal. Throughout a two month period, storms in the southern plains averaged three times the normal frequency of +CGs and twice the average peak current. Prior research suggests +CGs have far greater potential for starting fires, disrupting electrical systems, and possibly producing larger amounts of NOx. The initial observations were published by Lyons, Nelson, Williams, Cramer and

Turner in the 2 October 1998 issue of Science. Similar though less pronounced +CG enhancements may have been observed in Florida sea breeze thunderstorms during that state's siege of summer wildfires. Possible mechanisms which might explain these unexpected changes are currently being evaluated. Plans are being made for SPRITES'99 activities at Yucca Ridge. The primary focus will be the supported planned stratospheric balloon sprite missions of Gar Bering of the University of Houston.

***GLOBAL ATMOSPHERICS, INC. (Tuscon, AZ)**

Global Atmospherics (GAI) is currently involved in a number of product development and applied research projects. We have formally established a "Directed Research" group comprised of four scientists. One of the mandates for this group is to collaborate with and support research organizations that carry out lightning-related research. A brief overview of ongoing and recently completed projects is provided below.

The Dual-use development project with NASA to commercialize the 3D "total lightning" LDAR technology developed at Kennedy Space Center is in its third and final year. A prototype Time-Interval Unit (TIU) developed by GAI is operating in parallel with the NASA system, and is collecting data for use in GAI research. The new TIU is designed to locate significantly more sources per flash than the current LDAR system. As part of this Dual-use project, GAI has utilized waveform and source location data from the NASA LDAR system to help characterize the cloud discharge detection capabilities of GAI's LPATS IV Time-of-Arrival lightning sensors, located throughout central Florida. Using these systems, GAI has characterized the LF vertical electric field source strength distribution for events occurring during cloud flashes. A summary of this work was presented at GAI's semi-annual International Lightning Detection Conference (ILDC), held in Tucson, Arizona, November 17-18, 1998.

Numerous studies have illustrated the limitations in location accuracy and peak current estimates produced by lightning detection networks, resulting from propagation effects. Martin Murphy and Burt Pifer have developed parametric methods to partially compensate for these effects. These methods provide propagation corrections as a function of azimuth and range from each sensor in a network. Preliminary results show a 15% reduction in propagation-related "disagreement" among sensors used in peak current estimates. standard deviations in sensor timing were reduced by 5-30%. Work to date was described in a paper at the ILDC.

Since 1995, GAI has been delivering a real-time "long range" lightning data set to the NWS Aviation Weather Center for maritime applications. This service, developed in cooperation with Fred Mosher and John Jalickee (NWS), is produced exclusively using VLF sferics signals detected by sensors on the North American continent. In an effort to explore the possibility of including sensors on other continents, John Cramer and Ken Cummins have carried out a detailed analysis of storms in the central U.S. at ranges of 1500-2000 km from the sensors on both coasts. In this study, cloud-to-ground lightning detection efficiency peaked at 15-20 percent during the nighttime hours, but fell off to a few percent during mid-day. Most located discharges had peak currents in excess of 30 kA. Median location error was less than 5 km. The performance of this "test" configuration should set a lower bound on what can be expected for the national-scale network at distances of about 2000 km off shore. These results were presented in more detail at the ILDC. An "extended" version of this dataset, which also includes located events with no redundant information for verification, is being used in the FORTE project by Abe Jacobson and collaborators at Los Alamos National Labs.

GAI has completed the installation and commissioning of the 81-sensor Canadian Lightning Detection Network (CLDN), owned by Environment Canada. The CLDN integrates seamlessly with the NLDN, creating a "North American Lightning Detection Network" which covers the coast-to-coast land mass from the northern border of Mexico up to 60: North Latitude. This 187-sensor network is the largest lightning detection network ever deployed, and can provide previously unavailable information for research on regional climatology, lightning, and severe weather. Data from these sensors also significantly improves the performance of the NLDN in the northern states. It also contributes to the long-range Maritime Lightning data set that is used by the NWS Aviation Weather Center and is available to Environment Canada.

Recent publications co-authored by GAI researchers are summarized below. Electric utility applications of lightning detection networks are summarized in an upcoming special issue of the IEEE Transactions on Electromagnetic Compatibility (Ken Cummins, E. P. Krider, and Mark Malone). This paper also discusses the instrumentation limitations that can affect these applications. Recent observations of thunderstorms in the Texas/Oklahoma area with 50-90 percent positive discharges is reported in the October 2, 1998 issue of Science (Walt Lyons et al.), contributed to by John Cramer and Tommy Turner. Unlike previous reported cases involving individual storms, this condition persisted over several weeks. The peak current median for these positive discharges was in excess of 45 kA. These storms were spatially and temporally correlated with smoke from fires in Mexico. The April 1998 issue of the JGR Atmospheres contains a paper authored by GAI staff (Cummins et al.) that describes the NLDN and discusses the lightning parameters provided by the NLDN. Two companion papers by Vince Idone and coworkers at the State University of New York at Albany are in the same issue. These papers describe the detection efficiency and location accuracy of the NLDN based on multi-camera studies in the Albany area over a two-year period. This collection of JGR papers should provide sufficient information to allow the research community to understand and properly employ lightning data provided by the NLDN.

***INDIA INSTITUTE OF TROPICAL METEOROLOGY (Pune, India)**

"Seasonal Thunderstorm Frequencies and Sea Surface Temperatures at Port Blair and Minicoy Island Stations and along the East and West coasts of India" G.K. Manohar, S.S. Kandalgaonkar and M.I.R. Tinmaker.

Summary - Monthly data on the number of thunderstorm days and mean sea surface temperature (SST) for a period of 11 years, over one island station, each in the Bay of Bengal and Arabian Sea; and for several stations along the east and west coasts of the Indian Peninsula have been used in this study. For the two data sets, at each of these locations, we present the results of their monthly mean variation and compare the thunderstorm days activity with the SST. This comparison has revealed that both the parameters show clear semiannual variations which are in phase with each other. This comparison confirms the intuitive feeling one has about the convection over the oceans. The central focus, therefore, of this study was the issue of the sensitivity of the occurrence of thunderstorms to SST variation. This issue is similar to the numerous sensitivity studies of lightning and the occurrence of the thunderstorms with that of the wet-bulb temperature on the land regions in the tropics. This information is an exceedingly important result towards documenting the response of tropical convection to modest changes in the surface thermodynamics over the oceans. Our analysis has shown that the occurrence of the thunderstorms over the Bay of Bengal sea regions for 1˚C change in SST was twice more than

that over the Arabian sea regions. SST analysis has suggested that the higher frequency of thunderstorms over the Bay of Bengal may be attributed to the warmer (0.4 to 1.2˚C) temperature conditions of the Bay of Bengal and partly due to the higher concentration of Aitken Nuclei than over the Arabian sea. The other result of this analysis has shown that the warmest period of the SST usually precedes the occurrence of the ensuing monsoon by about 30 days.

***NASA / MARSHAL SPACE FLIGHT CENTER (Huntsville, AL)**

The Lightning Imaging Sensor (LIS) which was successfully launched on 28November 1997 as a scientific payload on the Tropical Rainfall MeasuringMission (TRMM) has now completed 1 year of successful operation. The LIS isa calibrated optical sensor operating at 0.7774 microns that detects, locates, and measures the radiant energy produced by lightning (intracloudand cloud-to-ground flashes, day and night) from its 350 km altitude, 35˚inclination orbit with high detection efficiency (>90%), total field of viewof 600 km x 600 km, storm scale (5-10 km) spatial and 2 ms temporalresolution. The LIS mission will provide a three to four year survey of the distribution and variability of total lightning occurring over the Earth in the tropics and subtropics. Another satellite, the Optical TransientDetector (OTD), developed in-house at MSFC and launched in April 1995 as a prototype for the LIS, continues to provide measurements of global lightning activity from its 735 km altitude, 70˚ inclination orbit. More information about both LIS and OTD can be found on the web page athttp://thunder.msfc.nasa.gov. The LIS and OTD daily browse images are available there. Data from LIS and OTD is available to the general scientific community and can be ordered on line at this web site.

We continue to have an interest in lightning data sets that could contributeto a global lightning climatology and to on-going ground truth activitiesfor OTD (e.g. regional lightning detection networks, etc.) and LIS. Anyindividual or group interested in such a collaboration is encouraged to contact S. Goodman (e-mail: steven.goodman@msfc.nasa.gov), H. Christian(hugh.christian@msfc.nasa.gov). An extremely successful series of field programs have been completed in 1998 in support of validation of the TRMM sensors, data products, and retrieval (e.g., multi-sensor precipitation retrieval) algorithms. We began in thespring with the Texas phase of the TExas FLorida UNderflight (TEFLUN-A) experiment. Then in the summer, we participated in the concurrently conducted Convection and Moisture Experiment (CAMEX-3), TEFLUN-B (with afocus on Florida), and USWRP Hurricanes at Landfall (HAL) which, inadditional to TRMM validation noted above, supported the study of lightning relationships in Hurricanes and tropical cyclones. The NASA ER-2 and DC8 aircrafts, equipped electrical measurement packages (R. Blakeslee, M. Bateman, J. Bailey, D. Mach and M. Stewart) and other complementarymeasurement systems were flown as key components of these experiments. InDecember (J. Bailey, R. Blakeslee, S. Goodman, C. Weidman, N. Renno, O. Pinto, A. Athayde) a four station ALDF network will be installed in the Rondonia region of western Brazil to support the Tropical “Land” FieldCampaign in January/February 1999, as well as provide long term ground basedlightning measurements for LIS and OTD validation. In addition, efforts toexpand the range of the lightning network at Kwajalein continue to be pursued with Aeromet to support the Tropical "Ocean" Field Campaign to be conducted in the summer of 1999.

***MIT LINCOLN LABORATORY (Lexington, MA)**

Bob Boldi and Earle Williams joined Steve Goodman (NASA MSFC) and Steve Hodanish and Dave Sharp (NWS Melbourne) to present a series of papers on the Florida LISDAD

(Lightning Imaging Sensor Demonstration and Display) system at the AMS Severe Storms Conference in Minneapolis. These papers focussed on pronounced 'jumps' in intracloud lightning activity prior to large hail, strong surface wind, and tornadoes. A collaborative paper on this topic has also been submitted to the Special Issue of Atmospheric Research honoring Bernard Vonnegut. The extraordinary flash rates (>100 flashes per minute) based on the LDAR (Lightning Detection and Ranging) system have raised questions of validity. Further comparisons with the Kennedy Space Center field mill network observations for the February 23, 1998 tornadic mesocyclones are underway with Bill Koshak and Steve Goodman.

Following Walt Lyons' recent observations of changes in positive ground flash activity in midwestern storms ingesting smoke from fires and Danny Rosenfeld's interest in the possible role of aerosol in invigorating the convection, LISDAD surveillance was directed (by Steve Goodman and Earle Williams) at the Florida wildfires in June, 1998. The isolated storm on June 25 growing over fire near Daytona produced a majority of positive ground flashes from the very beginning of its ground flash activity. It also produced golf ball size hail. Both characteristics are highly unusual for Florida thunderstorms.

***MIT PARSONS LABORATORY (Cambridge, MA)**

Sunnia Lin completed a Master's thesis in June concerned with the analysis of radar and lightning data (Lightning Imaging Sensor) from the NASA TRMM satellite. By integrating information from multiple satellite orbits, radar CAPPI's were constructed and compared with the optical lightning activity on a global tropical basis. Radar reflectivity at 7km altitude was found to be 10-15 dB stronger in continental than in oceanic convection, consistent with the order-of-magnitude land/ocean contrast in lightning activity. No dramatic differences were noted in the radar cloud top heights over land and in the ITCZ in the Pacific Ocean. Graduate student Carlos Labrada is now working with these data sets to establish regime—dependent lightning/rainfall relationships.

The use of Schumann resonance measurements from Rhode Island to infer vertical charge moments has been used to test predictions made by C.T.R. Wilson (1925) for dielectric breakdown (as a mechanism for sprites) in the mesosphere. Values for charge moment associated with sprite positive CG's range from a few hundred C-km to a few thousand C-km, and are generally not sufficiently large to cause conventional air breakdown at 60 km altitude, but are adequate to account for electron runaway breakdown. The existence of negative ground flashes with comparable (large) charge moments casts doubt on this physical property as an explanation for the exclusive association of sprites with positive lightning. Rather, an avalanche length associated with electron runaway greater than density scale height at sprite initiation altitude will strongly favor upward electron runaway that requires a positive ground flash. These results have recently been submitted for publication in the Journal of Geophysical Research by Everest Huang, Earle Williams, Bob Boldi, Stan Heckman, Walt Lyons, Tom Nelson, Mike Taylor and Charles Wong.

Comparisons have been made between the background Schumann resonance intensities in Sopron, Hungary (with Gabriella Satori) and in Rhode Island for a 4-5 year period. The annual variation with maximum in Northern Hemisphere summer is the dominant signal in both records. The semiannual signal is strong in Hungary and very weak in Rhode Island—an effect attributed to Hungary's proximity to Africa (where the semiannual signal is strong) and Rhode Island's proximity to South America (where the semiannual signal is relatively weak). Interannual intensity variations are correlated between the two stations, but the positive correlation with the tropical temperature anomaly found in the analysis of an earlier epoch (Williams, 1992) is not apparent. The explanation for this different behavior during two strong but distinct El Nino episodes is presently unknown. These results will be discussed further at the ICAE Conference in Alabama. The quantitative analysis of the global lightning activity from single station Rhode Island observations by Stan Heckman, Earle Williams and Bob Boldi will be published in the December issue of the Journal of Geophysical Research.

Earle Williams and students will travel to Ji Parana, Rondonia, Brazil in December to investigate Tropical Continental Convection, the NASA LBA experiment. The equipment generously loaned by Marx Brook and Dave Rust will be used to investigate positive ground flashes that are simultaneously recorded from the Schumann resonance station in Rhode Island.

*NATIONAL LIGHTNING SAFETY INSTITUTE (NLSI) (LOUISVILLE, CO)

1. *NLSI Meetings*. NLSI will conduct a two day intensive lightning safety workshop at Louisville Colorado October 22-23. This Certified Workshop is designed for ìsubject matter expertsî to become informed about lightning safety issues. NLSI will conduct a one day class at Rocky Flats Environmental Test Site, Denver Colorado, Oct. 9. This Certified Class is designed for technicians to understand lightning safety issues and to perform inspections upon standard Lightning Protection Systems. Full descriptions, course outlines, registration forms, etc. are available on the WWW at: http://www.lightningsafety.com

2. *Other Meetings*. An ad hoc group of organizations concerned with lightning safety has adopted and will promulgate recommendations for personal lightning safety. These guidelines are posted on the Global Atmospherics Inc. WWW site at: HYPERLINK http://www.glatmos.com/
recommendations. Group participants include : NLSI (Kithil), NSSC (Holle, Howard, Lopez), Global Atmospherics (Cummins, Lawry, Zimmerrman), Univ. Illinois (Cooper), College of William & Mary (Bennett), St. Paul Insurance (Lunning), NASA (Madura), QPS (McGee), Patrick AFB (Roeder), Secondary School Science Teachers (Vavrek), Univ. Arizona (Krider), and LPT (Byerley).

NLSI attended the Department of Defense Explosive Safety Board meeting in Orlando, Florida August 18-20, 1998. The United Nations Conference on Early Warning Systems for the Reduction of Natural Disasters invited NLSI to present a paper on Lightning Detection Systems at the Potsdam, Germany meeting Sept 7-11, 1998. This and other recent paper presentations can be found on the NLSI WWW site, listed above.

3. *Lightning Safety Video*. A sixty minute video presenting lightning safety issues is available from NLSI. Subjects covered include: Atmospheric Physics 101; Basis for Lightning Behavior; Effects of Lightning on People; Personal Lightning Safety ñ Indoor and Outdoor Situations; Lightning Safety Tips. The video is a teaching and training tool for government and private organizations.

4. *Annual USA Lightning Costs and Losses*.

*NATIONAL SEVERE STORMS LABORATORY, NOAA (Norman, OK)

The paper by Vlad Mazur, Shao Min and Paul Krehbiel, "Spider" lightning in intracloud and positive cloud-to-ground flashes", *JGR*, 103, 19,822-19,822, August 1998, clarifies the nature of the "spider" lightning as a different manifestation of the negative leaders occurring in both IC and +CG flashes in late stages of the storm. The paper also sheds some light on the detectability of positive leaders in positive CG flashes and on the capabililty of the interferometric system to "see" all radiating components of lightning flashes.

The paper by Vlad Mazur and Lothar Ruhnke, "Model of electric charges in thunderstorms and associated lightning", JGR, 103, 23,299-23,308, September 1998, demonstrates the physical and quantitative relationships among cloud charges, potentials, and electric fields, and the induced charges, currents, and electric field changes of the lightning leaders in both IC and CG cases. Of course, leaders are bidirectional and with zero net charge.

The MCS Electrification and Polarimetric Radar Study (MEaPRS) was sponsored and hosted by the National Severe Storms Laboratory in Norman, Oklahoma. The following is a brief summary of the field phase of the project. Since the list of participants is lengthy, we have listed none in this summary. See the web addresses at the end for links to detailed information. The goal of the project was to expand our observational data set of midlatitude Mesoscale Convective Systems (MCSs), with emphasis on the electrical structure of the MCS and parameters observable with a polarimetric radar. Significant and often flood-producing rainfall, frequent lightning, and strong straight winds are common weather hazards of MCSs.

This project ran from May 15-June 15, 1998. A NOAA P-3 aircraft obtained radar measurements of 3-dimensional airflow and reflectivity, with local sensing of winds, temperature, humidity, and cloud and precipitation particle sizes, and hydrometeor charge. Despite the dearth of MCSs in the target region, the P-3 operated a total of 45 hours and produced data on seven case days. The data have several new aspects. Foremost for the P-3 is an improved airborne Doppler radar observational capability, permitting much higher maximum unambiguous velocity measurements that improve accuracy and reliability of 3-D wind syntheses while dramatically reducing total analysis time. Use of microphysical sensors of hydrometeor concentration, size, and shape, coupled with an expanded analysis capability for the P-3 probes, promises new insights into MCS structure and processes through synergistic application of radar and in-situ data. We operated the P-3 in close coordination with ground-based mobile laboratories launching balloon-borne instrument trains of a radiosonde, an electric field meter, and sometimes other specialized particle charge or lighting field change sensors. The full observational suite of the P-3 will be used to define the immediate environment sampled by balloon soundings. Polarization radar and coincident ground-based disdrometer data were obtained to compare polarimetric signals with rainfall. For the first time ever, a prototype mesoscale-coverage, fully three-dimensional total lightning mapping system was deployed and obtained data needed to document the progression of very large, long lightning flashes that are typical of MCS stratiform regions. (Lightning was also mapped in tornadic storms.)

The next step is the follow-on analyses by the collaborating team of research scientists from several NOAA and other federal laboratories and universities. The MEaPRS homepage with operations plans and participating organizations is at http://www.nssl.noaa.gov/projects/meaprs/. The field catalog is at http://spider.nssl.noaa.gov/meaprs/. The data catalog is at http://mrd3.nssl. ucar.edu/MEaPRS/MEaPRS.HTML.

***PENN STATE UNIVERSITY (Univ. Park, PA)**

Les Hale ON MESOSPHERIC AEROSOL

The recent interest in middle atmospheric electrodynamics has sparked interest in the region, and a number of gas phase models have appeared, using available electron-ion-molecule reaction rates. This seems very logical, but is doomed to failure in the mesosphere below about 80 km. because of neglect of the well documented importance of "invisible" mesospheric aerosol.

In 1958 the writer was at Los Alamos, when a great deal of concern was generated by the loss of communication related to high electron densities in the ionospheric D-region following high altitude nuclear tests. (This was found later to be mainly due to "radioactive debris.") A massive mainly DoD funded program was undertaken to understand D-region phenomena involving theory, laboratory, and in-situ experimentation. "Complete" computer models were generated, involving hundreds of reaction rates. In November 1966 these models were put to the test during a total solar eclipse in Brazil. Instruments to follow the electron density, particularly during the totality of the eclipse, were launched on several rockets by two groups, the U. of Illinois with NASA sponsorship and my Penn State group with DoD support. The models had converged on a drop in electron density of about 30% during the few minutes of totality. However, by the time of the first rocket, tens of seconds into totality, there was no detectable electron density (down orders of magnitude), a result confirmed by both groups on subsequent rockets (and later in subsequent eclipses).

It was found to be impossible to reconcile the data with the gas-phase reaction rate models. It was suggested that the data might be explained by large changes in particular rates, but these rates were extensively rechecked in the laboratory and found to be correct.

A number of other workers using D-region data found the need for a rapid "2-body" electron loss process not to be found in gas phase processes. These were accumulated in a PhD thesis by E.T. Chesworth and summarized in a paper "Ice Crystals in the Mesosphere" (E.T. Chesworth and L.C. Hale, GRL 1, 347, 1974), in which it was concluded that a wide range of phenomena were best explained by a substantial density of ~10nm "invisible" aerosol particles, probably ice or ice-coated.

Recently, in his PhD research, Lee Marshall of Penn State has observed VHF emissions coincident with "millisecond" ELF pulses which accompany "red sprites." A difficulty was found in creating enough free electrons to be accelerated by the electromagnetic pulses to explain these data, as breakdown processes were insufficiently rapid and did not work over the entire region from 50 to80 km. A solution appears to be in the photo-detachment of electrons trapped in the lattice of the ice crystals by light from the parent lightning stroke, which has a threshold of about 0.5 eV.

This may also lead to an explanation for the observed "cooking time" for the appearance of red sprites after lightning conditions are suitable. This could be due to the growth of the ice crystals to much larger sizes, and are much more likely to be due to cooling rather than cooking. This may occur throughout the night, possibly aided by dynamic processes which occur in the "lee" of the mountain ranges, such as the Rockies. Evidence may have been provided for this in a pre-dawn rocket measurement by J.D. Mitchell at White Sands, which showed exceptionally low ionic electrical conductivity in the mesosphere.

*STANFORD UNIVERSITY: STARLAB (Stanford, California)

The VLF Group at STAR Laboratory of Stanford University is actively involved in experimental and theoretical work targeted on understanding of upward electrodynamic coupling of tropospheric thunderstorms to the mesospheric and lower ionospheric regions and associated optical, VLF and ELF effects.

This summer the Stanford group returned to the Langmuir Laboratory for Atmospheric Research near Socorro, New Mexico to take part in the Sprites '98 campaign. Throughout July and August, Elizabeth Gerken and Chris Barrington-Leigh of Stanford and Mark Stanley of New Mexico Tech fielded widedband VLF receivers, intensified CCD cameras, the Fly's Eye photometer array, and a novel telescopic imager. The imager, named the Dobsonian Sprite Experiment, includes of a 40 cm - aperture Newtonian telescope affording a 1-degree-wide field of view across an intensified CCD array. New high-resolution imagery from this experiment has recorded remarkable fine-structure in sprites, with complex filamentary structure on the scale of 10 m occurring at 60 km altitude. Fast photometry from the Fly's Eye has revealed, based on 1997 data, the ubiquitous nature of fast transient heating of the lower ionosphere by the electromagnetic pulse from cloud-to-ground lightning, optically identified as "elves." These results, reported by Chris Barrington-Leigh and Umran Inan, are currently in review at GRL. Also at Langmuir, Rick Rairden of Lockheed Palo Alto Research Laboratory made the first observations of sprites with an intensified CID camera, and a group led by Martin Fullekrug from Frankfurt University made measurements as part of an ultra-low-frequency network to correlate with sprite events.

During the summer of 1998, the Holographic Array for Ionospheric Lightning research (HAIL) team lead by Mike Johnson deployed an additional five VLF receivers along the Front Range in Colorado. A total of ten receivers operated from Cheyenne, Wyoming to Socorro, New Mexico. Nine of these receivers are self running (at seven high schools and two colleges), while the one deployed in Socorro was temporarily installed and run by Elizabeth Gerken, a PhD student operating our optical experiments at Langmuir Labs. The HAIL software was improved before the campaign by Andy Gray, a computer science student working in our group, and is now more robust in a remote environment and has improved phase measurement capabilities. The data continues to be transferred daily from the stations, and this year all 10 of the stations were connected to the Internet. The station status was confirmed every day and any problem was quickly corrected. As a result, we were able to obtain more than 95% of the data from all of the stations

throughout the summer. Scott Mease, and undergraduate student researcher, improved our online data browser which is available (with help files) at: http://hail.stanford.edu. With the improved receiver location density, preliminary data analysis confirms our forward scattering model and continues to suggest that some ionospheric disturbances may be caused by more than one mechanism, each with its own recovery time constant. VLF perturbations from Sprites and mesospheric gravity wave disturbances were recorded. A Gamma Ray Flare from a Magnetar 23,000 light years away from earth created measurable ionospheric disturbances on three separate occasions and in one case evidence indicates that the nighttime ionospheric conductivity profile briefly returned to daytime levels and was modulated with the 5.16 s Magnetar periodicity. Please visit http://hail.stanford.edu/gammaray.html

Tim Bell, Steve Reising and Umran Inan reported results of analysis of broadband ELF/VLF mesurements of the magnetic field radiated by positive cloud-to-ground discharges associated with sprites (GRL, Vol. 25, Page 1285, 1998). Total current and charge moments associated with sprites were deduced, and it was found that in every case, intense continuing currents of ~1 ms duration are responsible for most of the positive charge transfer to ground that precedes the appearance of the sprite. The time delay between the causative positive discharge and the video field in which the sprite first appeared varied from 0 to 15 ms for the larger events to as much as 100 ms for the smaller events. It was suggested that in the smaller events the removal of significant positive charge during this delay interval is acomplished through a horizontal intracloud discharge

Steve Cummer (now at Goddard Space Flight Center), Umran Inan, Tim Bell and Chris Barrington-Leigh reported measurements of ELF-radiating currents associated with sprite-producing lightning discharges which exhibit a second current peak simultaneous in time with sprite luminosity, suggesting that the observed ELF radiation is produced by intense electrical currents flowing in the body of the sprite (GRL, Vol. 25, Page 1281, 1998).

Victor Pasko, Umran Inan and Timothy Bell developed a theory of the streamer electrical breakdown above thunderstorms which explains recent observations of fine spatial structures and bursts of blue optical emissions associated with sprites (GRL, Vol. 25, Page 2123, 1998).

Victor Pasko, Umran Inan, Tim Bell, and Steve Reising investigated charge and current systems associated with sprites as part of the large scale atmospheric circuit (GRL, Vol. 25, Page 3493, 1998) in order to understand physical mechanism of experimentally reported ELF radiation originating from currents flowing within the body of sprites. It is shown that the impulse of the electric current driven in the conducting body of the sprite by lightning generated transient quasi-electrostatic fileds produces significant electromagnetic radiation in the ELF range of frequencies,
comparable to that radiated by the causative lightning discharge.

Victor Pasko, Umran Inan and Timothy Bell demonstrated (J. Atm. Solar-Terr. Phys., Vol. 60, Page 863, 1998) that electrostatic thundercloud fields may heat lower ionsopheric electrons significantly under night time conditions. The lower ionospheric conductivity can be modified as a result of the heating by up to one order of magnitude in regions with a characteristic lateral extent of ~150 to 350 km. The vertical extent of the heated region is ~10 km, at altitudes of ~70-80 km, reaching above 85 km in some cases, depending on the ambient night-time conductivity profile. The electron heating can potentially alter the chemical balance in the D-region, modify the ambient levels of optical emissions and the magnitude of electrostatic thundercloud fields which map to higher ionospheric altitudes.

Steve Reising completed his Ph.D. dissertation entitled "Remote sensing of the electrodynamic coupling between thunderstorm systems and the mesosphere/lower ionosphere" which demonstrated that the ELF sferic energy can be used as a proxy indicator to estimate the number of sprites produced by a thunderstorm with an accuracy of +/-25%. The use of this proxy indicator is achieved at a range of ~12,000 km from the source lightning, suggesting that a few appropriately placed ELF/VLF sferics receivers may be sufficient for estimation of global sprite occurrence rates [Reising et al., 1996]. Simultaneous ELF/VLF and video observations of sprites reveal variable delays of up to 100 milliseconds between the positive cloud-to-ground flash and sprite onset. Comparison with high-resolution photometer measurements demonstrate the simultaneity of sprite luminosity and an ELF "second pulse", radiated by electrical currents within the sprite body [Cummer et al., 1998]. Measurements of the second pulse are used to identify a quantitative relationship between the current in sprites and total sprite luminosity.

***TEL AVIV UNIVERSITY (Tel Aviv, Israel)**

Colin Price continues his work on setting up a Schumann Resonance monitoring station in the Negev Desert. In the last six months we have managed to finish the construction and testing of our vertical electric field detector. The first spectra collected using this new electrode look excellent. As part of this project Earle Williams from MIT and Sasha Nickolaenko from the Ukraine visited the new site in September. Some of the initial results from this new field site were presented at the Symposium on Schumann Resonance held in Sopron, Hungary, in September.

During the summer Colin Pice spent time at NASA Goddard Institute of Space Studies working with Drew Shidell and David Rind on modeling global lightning distributions in the latest version of the GISS global climate model. In addition to modeling lightning in the very simplest way, we are attempting to calculate the amount of NOx and ozone produced in the troposphere as a result of lightning activity. We also wish to perform climate change simulations to understand the potential importance of lightning to changes in atmospheric chemistry in the future.

In collaboration with Umran Inan of Stanford, Colin Price, together with Zev Levin and Yoav Yair are constructing a VLF antenna in the Negev desert for research into regional and global lightning characteristics. The antenna being build is of the International Geophysical Year (IGY) type, made of two orthogonal triangles, each 9 meters high and 18 meters across the base. The large size will allow great sensitivity, with lightning detection up to 12,000 km away. This antenna will be identical to the one at Palmer Station, Antarctica, and the antenna used by Stanford University in California. Given the 3 stations, our wish is to be able to continuously monitor sferics from around the globe.

***UNIVERSITY OF TORONTO, (Toronto, Canada)**

Canadian National Tower Lightning Studies Group

During 1997 and 1998 seasons the Lightning Studies Group at the University of Toronto (U of T) continued its activities under the direction of Professor W. Janischewskyj (E-mail janisch@ecf.utoronto.ca), and in cooperation with Professor A.M. Hussein of the Ryerson Polytechnic University in Toronto and Professor J.-S. Chang of McMaster University in Hamilton, Ontario. In addition to the regular monitoring of lightning at the Canadian National Tower and in its surroundings, the Group has analyzed lightning data collected so far from several standpoints and presented its findings at appropriate meetings of experts.

At the end of 1996 a digital high speed camera (1000 frames per second) was incorporated into the program. Results collected during the 1997 lightning season were compared with observations made by the VHS video camera and reported to the ICLP (24th International Conference on Lightning Protection) in Birmingham, England in the paper "Details of Canadian National Tower Flashes Utilizing a Digital High-speed Camera" by W. Janischewskyj, A.M. Hussein, M. Wiacek, and J.-S. Chang.

During the 1997 lightning season Dr. Farhad Rachidi, from the Ecole Polytechnique Federale de Lausanne in Switzerland, has participated in the work of the group. As part of his efforts, a comparison was made between our and the Swiss field measurement systems. Both systems indicated qualitatively similar responses to lightning stimuli, but a need was discovered to perform their additional scaling calibration. As one of the results of his stay in Toronto, a paper was prepared for the ICLP by F. Rachidi, W. Janischewskyj, A.M. Hussein, C.A. Nucci, S. Guerrieri and J.-S. Chang under the title "Electromagnetic Fields Radiated by Lightning Return Strokes to High Towers".

In September of 1997, the paper entitled "Characteristics of CN Tower Multistroke Flashes", authored by W. Janischewskyj, A.M. Hussein and J.-S. Chang, was presented to the 10th International Symposium on High Voltage Engineering (ISH). The paper finds an interdependence between peak value of the current in a subsequent stroke and the duration of the preceding interstroke interval. At the September 1997 meeting of the CIGRE Study 33 (Power System Overvoltages) in Toronto, details on the effects of the CN Tower structure upon the current waveform were reported in the paper entitled "Propagation of Lightning Current within the CN Tower" co-authored by W. Janischewskyj, A.M. Hussein and V. Shostak. Also in September 1997, W. Janischewskyj has delivered, at the XII International Conference on Gas Discharges and their Applications, in Greifswald, Germany, an invited lecture entitled "Lightning Discharges and Tall Structures".

Students have also participated in activities of the Studies Group. In January 1998 Mohamed Abdel-Rahman defended successfully his MASc. Thesis "Currents and Fields of CN Tower Multistroke Lightning Flashes". Findings of the thesis were presented at the ICLP in the contribution entitled "Statistical Analysis of Magnetic-Fields Due to CN Tower Multistroke Flashes" by M. Abdel-Rahman, W. Janischewskyj, A.M. Hussein, F. Rachidi and J.-S. Chang.

In April 1998 two BASc. Theses were submitted at U of T. One by Helen Li "Analysis of Currents in CN Tower Multistroke Lightning Flashes -Distinction between the Characteristics of 2nd Stroke and Higher Subsequent Strokes", the other by Filipp Chekmazov "Current and Electric Field Characteristics of a Lightning Flash with Multiple Strokes".

During the lightning season of 1998, Dr. Volodymyr Shostak from the Kyiv Polytechnic Institute (Ukraine) was the Visiting Scientist. His duties included: analysis of instrumentation and of processed data, preparation of technical proposals and of contributions for publications, overall supervision of the personnel and of the day-to-day operation of the program. Marcin Wiacek, Satha Arulsingam, Daisy Tam, Viliam Sivaninec, Irfan Cehajic, participated in the activities of the Group as summer students. Results of their work were presented at the Cage Club Student Conference on High Voltage Engineering and Applied Electrostatics (July, 1998, University of Western Ontario, London, Canada).

In the ICLP paper "Comparison of Lightning Electromagnetic Field Characteristics of First and Subsequent Return Strokes to a Tall Tower Magnetic Field" by W. Janischewskyj, V. Shostak, A.M. Hussein, in addition to current reflections within the tower, the effect of reflections from the front of the continuously progressing return stroke channel was introduced as a further development of the MTL model. The second part of this paper will deal with the electric field and is planned to be presented at the forthcoming ISH in London, UK.

During the 1998 lightning season, further extension to the measurement system has taken place:

- A second Rogowski coil was installed on the 553 m tall CN Tower. There are three important advantages to the new installation: (1) In contrast to the old coil (which enclosed only 1/5 of the steel structure), the new coil encompasses the whole CN Tower. This ensures registration of the total lightning current. (2) The new coil is located at a different level (509 m) than the old coil (474m). This permits a comparison between di/dt records of same events observed at two different levels, and provides a means for verification of CN Tower models. (3) Finally, sharp reduction of noise is achieved by the fiber-optic connection between the new coil and the recording digitizer.

• The acquisition systems at the CN Tower (to record di/dt) and at the University of Toronto (to record E and H fields) were upgraded using Pentium computers, and new programs.

• The use of the high-speed camera was continued and recordings were made with different camera settings.

• Work was initiated to prepare a Data Base (on CDs) of all records collected during the last 20 years of Lightning Studies at the University of Toronto.