NEWSLETTER ON ATMOSPHERIC ELECTRICITY

Vol. 10 No. 1 MAY 1999

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 the lucky individual to be selected at the ICAE conference in June to assume editorship. This selection will be widely announced shortly after the meeting.

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.

***ICAE '99 Conference**

The 11th International Conference on Atmospheric Electricity (ICAE '99) will be held from June 7 through 11, 1999 at the Lake Guntersville State Park, in Guntersville, Alabama, USA. Over 175 scientists from around the world have already pre-registered for this conference, and 200 papers are expected to be presented during the eight scheduled sessions.

The format for the 11th ICAE is somewhat different from recent Atmospheric Electricity conferences. In an attempt to encourage the exchange of ideas on a more personal level, all authors are required to present their work in poster form during their assigned sessions. In addition, the spacious facilities at Lake Guntersville will allow all the posters to remain displayed during the entire week of the conference, thus giving the authors several days to discuss their work with their colleagues. The combination of the presentation format and the "resort atmosphere" of the Guntersville Lodge will grant participants the opportunity to engage in fruitful and stimulating discussions.

Just as a reminder: Those who plan to attend the conference, but have not yet requested accommodations, should contact the Conference Coordinator IMMEDIATELY, as nearly all the rooms at the Guntersville Lodge are full.

For more information on accommodations and conference registration, contact the ICAE '99 Conference Coordinator (Kim Kerr) at +1-256-922-5742 or visit the ICAE '99 web site at <http://icae.atmos.uah.edu> .

***AGU / CASE Meeting in Huntsville, AL**

The AGU Committee on Atmospheric and Space Electricity (CASE) plans to meet at the International Conference on Atmospheric Electricity in Huntsville, Alabama this June. All interested participants of the ICAE are invited to attend. We are trying to arrange a time and date for the meeting and will announce this information at the conference.

CASE is considering topics for special sessions at the annual fall meeting of the AGU in San Francisco next December. If you would like to convene a special session on a topic relevant to CASE or simply would like to see a particular session convened, please send a suggested title and description of the session to Don MacGorman at don.macgorman@nssl.noaa.gov as soon as possible. AGU does not require that you involve CASE in a special session, but it avoids duplication and simplifies program planning to consolidate, or at least coordinate, our request to the program committee for the fall meeting. For AGU to publicize the special sessions in its call for papers, requests for special sessions will have to be submitted to AGU shortly after the ICAE.

***International Conference on Lightning and Static Electricity, Toulouse, France**
Centre de Congres Pierre Baudis 22-24 June, 1999. Conference Chairman: Jean-Louis Boulay

***IUGG Meeting 18-30 July 1999, Birmingham, England**

Sessions have been organized on Middle Atmosphere Electrodynamics (S.Kirkwood), Electrodynamic Discharges in the Middle Atmosphere and Lower Thermosphere (R.Goldberg), and Thunderstorm Electrification (C.Saunders).

***26th General Assembly of the International Union of Radio Science (IURS) August 13-21, 1999, Toronto, Canada**

Sessions have been organized on: (1) VLF Emission from Thunderclouds (Z.Kawaski) and M.Hayakawa), (2) Terrestrial EM Environment (D.Jones and M.Hayakawa), and (3) Lightning Ionosphere Interaction (U.Inan and D.Nunn).

RESEARCH ACTIVITY BY ORGANIZATION

***UNIVERSITY OF ALASKA (Fairbanks, AK)**

The EXL98 summer sprites campaign (http://sprite.gi.alaska.edu/EXL98/default.htm) produced some new and exciting data. The participants in the campaign included:

- University of Alaska Fairbanks: D.Sentman, E.Wescott, M.Heavner, D.Osborne, D.Moudry, J. Desrochers, H.Nielsen, L.Peticolas, and V.Besser
- Naval Research Laboratory: C.Siefring, J.Morrill, E.Bucsela and P.Bernhard
- Air Force Research Laboratory: J.Winnick, J.Kristil and T.Hudson

The campaign comprised of multiple instruments on an aircraft, and two ground stations at Wyoming Infrared Observatory (WIRO) on Jelm Mountain in Wyoming and Womble Observatory on Mt Evans in Colorado. The primary focus of the ground stations was to provide data for triangulation calculations, thus broadband cameras were deployed in those locations in addition to several developmental systems.

The aircraft instruments studied energetics within sprites. The instruments included 1) a wide- and narrow-field broadband (white-light) cameras and a color TV camera for sprite identification; 2) a 427.8 nm filtered camera for studying the emission from ionized nitrogen N_2^+ 1N emission; 3) a Near IR system for studying the influence of hydroxyl (OH) structures on sprites; 4) a middle UV system for studying CO2 emissions and 5) a Near UV N2 2P system and spectrograph.

Several times during the campaing blue starters (and a blue jet) were captured in addition to the sprites. Their strong emission in the 427.8 nm filter provides further evidence of their ionization. From the sprites captured, evidence is emerging that there is an interaction between the cloud top and the sprite, namely, the two might not be completely disconnected as previously believed.

In the upcoming summer, two ground stations will be set up in August 1999 at WIRO, and at the Atmospheric Sciences Observatory on Elk Mnt, Wyoming in conjunction with the instrumented balloon campaign of Gar Bering of Univ. of Houston, launched from Ottumwa, Iowa.

***UNIVERSITY OF ARIZONA (Tuscon, AZ)**

E. P. Krider and his group are comparing the locations and magnitudes of intracloud (IC) and cloud-to-ground (CG) lightning, as detected by the Lightning Detection and Ranging (LDAR) and field mill systems and a network of gated, wideband direction-finders (the CGLSS system), at the NASA Kennedy Space Center (KSC) and the Air Force Eastern Range (ER). Each lightning detection system locates a different physical parameter, but the results are surprisingly consistent. One interesting result is that most CG flashes seem to begin on the lower side of the negative charge region with an initial discharge that propagates downward toward a lower positive charge center (LPCC) near the melting level. Currently, we are investigating the causes of the LPCC that appear to include both IC discharges and a cloud charging mechanism wherein the LPCC appears first during the onset of electrification.

The Lightning Imaging Sensor (LIS) was launched on the TRMM satellite in December, 1997. E. P. Krider and W. J. Koshak are currently attempting to validate the performance of LIS by examining its response when lightning flashes occur over or near the KSC-ER and are within the LIS field of view. An effort is also being made to determine if the total light produced by CG and IC flashes, as detected both on the ground and on LIS, is proportional to the total charge deposited by the flash. Bruce Gungle is examining the relationship between IC and CG lightning and surface rainfall at the KSC-ER. Scott Handel is studying the behavior of the surface electric field just as storms are beginning and also the field just before large, horizontal flashes propagate into the KSC-ER area from distant storms. W. J. Koshak and E. P. Krider have developed a new method for analyzing lightning field changes at the KSC-ER that is based on a multipole expansion of the lightning-caused changes in the cloud charge distribution. Preliminary tests on both simulated and natural lightning show that this method offers advantages over previous approaches.

***COLORADO STATE UNIVERSITY (Fort Collins, CO)**

Under support from NASA/TRMM and the National Science Foundation, a major field campaign, known as TRMM-LBA, was carried out in southwestern Amazonia from 10 January 1999 through 28 February. Steven Rutledge served as the Project Scientist for this field campaign. Besides Rutledge, Radar Meteorology group members Dave Ahijevych, Bob Bowie, Larry Carey, Timothy Lang, Walt Petersen, and Jesse Ryan all participated in the field effort. Participation from several institutes in Brazil was also a major component of this highly successful field campaign. This program focused on the dynamical, microphysical, and electrical characteristics of Amazonian convection. Data collected in the program will be used in part to validate products from the TRMM satellite and to validate TRMM cloud models.

TRMM-LBA had an appreciable electrical component including observations by the NCAR S-pol polarimetric radar providing remote sensing of cloud and precipitation processes; in-situ data collected by the University of North Dakota Citation II aircraft; overflights from the NASA ER-2 carrying the Lightning Information Package (LIP), EDOP (ER-2 Doppler radar) and other instrumentation; flat plate antennas; a surface mounted electric field mill (operated by E. Williams of MIT); and a four station ALDF network (deployed and operated by NASA/Marshall Space Flight Center under the direction of R. Blakeslee). NASA also operated the NOAA TOGA radar in a dual-Doppler configuration with the S-pol radar, providing information on the 3-D kinematics. Together these observations will allow for studying the relationships between cloud dynamics, microphysics and electrification in tropical convection. Markedly variable lightning flash rates were observed in the program, with generally low lightning flash rates (and heavy rainfall) during monsoonal periods. Much higher flash rates accompanied convection in the break periods, where deeper, isolated convection was dominant. Other observations made in the campaign included the NOAA/Aeronomy Lab's dual-wavelength profiler, a surface raingauge and disdrometer network, and a radiosonde network.

Recently, Walt Petersen has focused his attention on the coupled modeling of hydrometeor, electrical, and multiparameter radar characteristics of tropical convection. The goals of this effort are to a) constrain both modeled microphysics and multiparameter radar-based hydrometeor identification techniques through combined use of both the observations (e.g., inferred microphysical profiles via dual-polarized radar), and numerically modeled microphysics; and b) relate observed microphysical profiles and perturbations to those profiles (through the model), to cloud physical processes, including electrification and rainfall production. Recent tests of the coupled model have focused on simulating weakly electrified convection associated with the Fort Collins flash flood (due to its tropical character and a robust set of multiparameter radar observations from the CSU-CHILL).

Observations and modeling simulations of the Fort Collins event suggest that a warm-rain process coupled with accretional growth of ice (frozen drops in particular) near the freezing level in a riming accumulation zone led to efficient precipitation production in the convection. Though the most intense observed and modeled convection electrified to the point of producing lightning, model results coupled with CSU-CHILL multiparameter radar observations suggest that the precipitation process may have "short-circuited" electrical charge production in the clouds. More specifically, the model simulations suggest that this process was related to the removal of precipitation ice mass and cloud water from the warmer regions of the convection either prior to, or just after, extension of the precipitation mass into the mixed phase region of the cloud.

Interestingly, the modeled precipitation process and multiparameter radar structure of the Fort Collins case resembles that observed in convection over the Maritime Continent Region of northern Australia (e.g., Carey and Rutledge, 1999) and over western Amazonia during the TRMM-LBA field program (Jan-Mar. 1999).

Timothy Lang and Steven Rutledge are working on developing a multi-dimensional storm matrix to test different theories about thunderstorm lightning behavior. They will incorporate multiparameter radar and dual-Doppler data from the CSU-CHILL and PAWNEE radars in northeastern Colorado, as well as from the SPOL and TOGA radars which were involved in

TRMM/LBA-Brazil. Also incorporated into the matrix will be data from field change meters, CG lightning detection networks (such as the NLDN), and where possible thermodynamic data from soundings. Lang and Rutledge will look at a variety of thunderstorms that span the spectra from ordinary to severe and from mid-latitude to tropical.

By examining how lightning observations, such as flash rate and IC/CG ratio, vary as functions of such variables as hail production, updraft intensity, CAPE, etc. over a variety of storm types, Lang and Rutledge will further test the elevated charge mechanism to explain high IC/CG ratios in intense thunderstorms, as well as various hypotheses to explain high positive CG production in some severe storms.

David Ahijevych's recently completed masters thesis addressed the electrification process in tropical convection of the Maritime Continent. Across the myriad islands that define this region, thunderstorms develop with the aid of low-level forcing caused by sea breeze fronts. During the Maritime Continent Thunderstorm Experiment (MCTEX), the complete lifecycle of tropical island thunderstorms was studied with 5-cm C-band polarimetric Doppler radar and a suite of lightning sensors (Keenan et al., 1996). Regional coverage provided by the MSFC lightning direction finder network provided information on the temporal and spatial distribution of cloud-to-ground lightning with these storms, and an electric field change meter measured field excursions associated with all types of lightning discharges within about 45 km of the radar site.

Special emphasis was placed on testing the non-inductive graupel-ice particle charging theory. This theory is based on laboratory studies which have shown that a riming ice target (i.e. graupel) becomes significantly charged after colliding with and separating from ice crystals (e.g. Takahashi, 1978). To test this theory, the lightning flash rates were compared to the evolution of graupel mass above the freezing level for two case study days. The 3-D storm precipitation fields were constructed from polarimetric radar volumes. Cloud-to-ground lightning flash rates and the total graupel mass in the mixed phase region were well correlated. The rain water content above the freezing level also paralleled the estimated graupel mass aloft, suggesting a large component of the total graupel mass was due to the freezing of supercooled raindrops lofted above the freezing level. In addition, there was no evidence of lightning discharges within warm-rain clouds. These observations were all consistent with the non-inductive graupel-ice particle charging theory, illustrating its viability as an electrification mechanism and highlighting the importance of ice processes in tropical lightning.

Keenan, T. D., R. E. Carbone, S. A. Rutledge, J. Wilson, G. J. Holland, and P. May, 1996: The Maritime Continent Thunderstorm Experiment (MCTEX): Overview and initial results. Preprints, 7 th Conf. on Mesoscale Processes, Sept. 9-13, Reading, UK, Amer. Meteor. Soc., 326-328.

Takahashi, T., 1978: Riming electrification as a charge generation mechanism in thunderstorms. J. Atmos. Sci., 35, 1536-1548.

Jesse Ryan's master's thesis examined the relationships between lightning flash rates and radar observations for two regions: northeastern Colorado, and Darwin, Australia. Five case studies from Colorado were analyzed using observational data from: the CSU-CHILL multiparameter radar, the ONERA VHF lightning interferometer, a field change meter and the National Lightning Detection Network. Three case studies from tropical Australia were analyzed using data from: the C-POL BMRC/NCAR multiparameter radar, a field change meter and an Advanced Lightning Detection Finder network. For each case, parameters such as peak echo height, storm area, and storm volume were computed using different radar reflectivity and temperature thresholds. Storm areas and volumes were computed above the altitude of various temperature thresholds. Cloud echo-top height was defined as the peak height using the 0 dBZ reflectivity threshold.

Stronger correlations existed between 1) total flash rate and peak echo height raised to the fifth power for reflectivity thresholds > 20 dBZ and 2) total flash rate and the product of storm area and storm volume than 3) total flash rate and cloud top height raised to the fifth power. An increased correlation between total flash rate and radar variables was noted when higher reflectivity (> 20 dBZ) thresholds were used for storms that contained broad areas of stratiform precipitation. Those radar variables that correspond more closely with the mass of the mixed phase region also correspond more closely to the total flash rate.

The ratio of intracloud (IC) to cloud-to-ground (CG) lightning was also analyzed for each case. This ratio was subsequently compared to cold cloud thickness (CCTh), defined as the distance between cloud top and the environmental freezing level. The relationships between IC/CG ratio and CCTh were similar to prior research, except for storms with high (> 40) IC/CG ratios.

Captain Mike Gauthier (USAF), a second year Air Force Institute of Technology (AFIT) student (MS), is examining the co-evolving kinematic, microphysical, and electrical characteristics of significant lightning producing storms in northeastern Colorado using the CSU-CHILL multi-parameter radar and cloud-to-ground (CG) lightning data obtained from the NLDN. The storms of interest were selected because at some point in their lifetime they were observed to have been dominated by greater than 50% positive CG fraction, coupled with significant positive flash densities.

Utilizing the measured polarimetric variables, emphasis has been placed on determining the three-dimensional distribution of various hydrometeor types within these storms (especially during periods of electrical transition from one CG polarity to another), as well as estimating mass fluxes associated with the descent of rain and hail from the storm. Overall, this research will contribute to the understanding of thunderstorm electrification mechanisms, and explore the plausibility of various hypotheses offered to explain the occurrence of positive CGs (dominating over negative CGs) within severe thunderstorms.

His research will also lead to the development of a regional climatology of cloud-to-ground lightning based on data obtained from the NLDN. This regional climatology will enable us to better describe how CG lightning characteristics (multiplicity and peak current) for each polarity (positive and negative) change as a function of the percentage of positive CG lightning that is occurring.

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

Triggered-lightning experiments will continue in Summer 1999 (for the seventh year) at Camp Blanding, Florida. A number of experiments are planned including (1) continued multiple-station measurements of electric and magnetic fields (close natural lightning discharges are also recorded), (2) studies of the interaction of lightning with power distribution lines of different design, (3) continued lightning testing of an airport lightning system, and (4) initiation of the positive lightning discharge using the rocket-and-wire technique. Two negative flashes were triggered at Camp Blanding on January 23, 1999. These two are the first lightning discharges triggered from winter thunderstorms in Florida.

Mark Fernandez, Vlad Rakov, and Martin Uman authored a paper titled "Transient Currents and Voltages in a Power Distribution System Due to Natural Lightning." The paper has been presented at the IEEE Power Engineering Society Conference in New Orleans, Louisiana (April 11-17, 1999).

Vlad Rakov has been invited to give the Dominick Labino Lecture at the 29th Annual Glass Art Society Conference (Tampa, Florida, April 29 May 2, 1999; for further information visit GAS website: www.glassart.org) entitled "Lightning Makes Glass." The lecture concerns various properties of fulgurites produced by natural lightning, triggered lightning, and by laboratory discharges. Materials on laboratory-made fulgurites were provided by Friedhelm Noack of Technische Universitat Ilmenau, Germany, and by of Technische Universitat Wien, Austria. A number of fulgurites created at the International Center for Lightning Research and Testing (ICLRT) at Camp Blanding, Florida, will be discussed. These include (1) fulgurites produced by lightning striking underground power cables, (2) the world-record 17-foot fulgurite, and (3) the fulgurite that became the centerpiece of an artistic installation entitled "Petrified Lightning from Camp Blanding" by internationally recognized artist Allan McCollum. The fulgurite studies at the ICLRT have been conducted by a team composed of Dan Cordier, Martin Uman, Keith Rambo, Mike Stapleton, and Vlad Rakov. The Lecture will be published in the 1999 Glass Art Society Journal.

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

Planning is underway at the Yucca Ridge Field Station for the SPRITES'99 field program. The core program for this upcoming summer will be to provide ground support for up to six stratospheric balloon missions near sprite producing convective systems launched with NASA support by Gar Bering of the University of Houston. The primary activities will occur during August 1999. Sensors to be deployed at YRFS will include those from FMA Research, MRC, Los Alamos, and Tohoku University. MIT will provide ELF coverage from the Rhode Island Schumann Resonance observatory (Earle Williams).

A paper summarizing the climatology of sprite-producing thunderstorms and lightning flashes over the U.S. High Plains was prepared by Lyons and co-authors for the upcoming ICAE meeting in Alabama. Among the highlights are that the number of sprites per storm is only marginally correlated with radar echo size above a minimum threshold in the 7,500-10,000 km2 range. The probability that a +CG will induce a sprite or elve is a strong function of peak current. Less than 3% of the +CGs with peak currents <50 kA were associated with sprites or elves, versus greater than 75% for those +CGs with peak currents >125 kA.

During April, a two-day workshop reviewing recent results was conducted by MRC/FMA at Yucca Ridge. In attendance were Russ Armstrong (MRC) Dick Spaulding (DoE), Earle Williams (MIT), Dave Suszcynsky, Eugene Symbalisty, Slava Yukimuk (Los Alamos), Mike Taylor (Utah State), Mark Stanley (New Mexico Tech), Tom Nelson and Walt Lyons (FMA Research).

Planning is also underway for submission of coordinated proposals to NSF for the summer 2000 CESAR Program (Cloud Electrification Studies Using Aircraft and Radar). The plan is to have a 2-3 month intensive observations of High Plains convective systems producing large peak current lightning flashes. In addition to aircraft and multi-parameter radar, 3-D in-cloud measurements are anticipated to be provided by the New Mexico Tech Lightning Mapping System [LMS]. For more details on CESAR contact Andy Detwiler (adetwiler@taz.sdmst.edu).

CESAR may provide an unequaled opportunity to investigate tropospheric electrical connections to the
middle and upper atmosphere.

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

A brief account of the research work that was pursued during recent months.

Title**:** Robust Diurnal variation of Point Discharge Current at a Tropical inland Station Pune

Authors: G.K.Manohar, S.S. Kandalgaonkar and M.I.R.Tinmaker Indian Institute of Tropical Meteorology, Pune-411008, India

Summary: The most significant and well established result of numerous studies on point discharge current (PDC) measurements have shown that the surface of the earth receives a net negative charge through the parameter of PDC. It appears that the issue of the diurnal variation of this important parameter has, however, received little attention in the literature. Data on PDC measurements, during a total of 65 thunderstorm days at Pune (18.32 N, 73.51 E; 559 m ASL), covering the major period of the annual thunderstorm activity, from April-October, and spread over six years from 1972-1977, were analysed to investigate the robust diurnal variation of PDC and the factors related with this current. The diurnal variation of PDC, and the charge brought down to the earth, of both polarities, was analysed on quarter hour time scales. Our analysis of these quantities showed an afternoon maximum between 1730-1930 hours IST and early morning minimum between 0000-0230 hours IST. Our results have shown that the net charge received by the earth was negative although the measurements in a storm did show a good mix of the charges of both polarities. The mean of the quarter hourly charge ratios of negative to positive charge was 1.4, with maximum, minimum and median values 5.4, 0.27, and 1.13 respectively. The ratio values greater than 1.0 occurred nearly consistently during 1630-2045 hrs IST, while the values lower than 1.0 also occurred quite consistently during the late night-early morning hours at the end of the storm day. This observation was intriguing and was separately examined by segragating the diurnal period into three different time intervals: 1400-2100 hrs, 2100-0800 hrs and 0800-1400 hrs IST. The observed transition in the polarity of the charge transfer from negative to positive, referred above, was more obvious from this analysis. A probable explanation for this observed behavior may be sought in the difference between the afternoon and night-time thermodynamic conditions of the cloud environment such as strong convection and absence of convection etc. Seasonal comparison of the average values of the currents, drawn over April-October, months showed a predominance of negative current values over the positive ones. Both current values showed a maximum in the months of April-May and a minimum during July-August. Some comparison between the present results and those obtained elsewhere is also made.

***LOS ALAMOS NATIONAL LABORATORY (Los Alamos, NM)**

FORTE Ground Support

Dave Smith reports:

For the 1999 thunderstorm season, the FORTE Science Team will conduct a major ground support campaign to learn more about lightning discharges recorded by the FORTE satellite over the continental United States. Two five-station arrays of electric field change meters will be operated, each providing lightning locations and multi-station sferic waveforms.

One or two additional stations will also be operated to enhance long-distance lightning ranging accuracy.

The first array builds upon last year's efforts in New Mexico and features stations in Los Alamos (LANL), Socorro (NM Tech), Tucumcari (Mesa Technical College), and Roswell (Eastern NM University). The fifth station has yet to be installed, but will probably reside in Lubbock. Last year the New Mexico array located and recorded nearly 130,000 lightning flashes in New Mexico and the neighboring states. This year we plan on supplementing the NM field change array with ground-based optical and broadband RF instrumentation that will support both FORTE studies and ground-based lightning phenomenology studies. We'll also work closely with NM Tech and their Lightning Mapping System (LMS).

The second array is located in Florida and features stations in Gainesville (University of Florida), Cape Canaveral (Kennedy Space Center), Boca Raton (Florida Atlantic University), Ft. Myers (Cyberstreet), and Tampa (University of Southern Florida). By operating an array in Florida, we hope to greatly increase the number of waveforms recorded in coincidence with FORTE triggers, as well as use the opportunity to study tropical coastal thunderstorms. We hope to collaborate with the University of Florida and support some of their work at Camp Blanding. We also hope to make some comparisons with the KSC Lightning Detection and Ranging (LDAR) system. An additional field change meter is currently operating in Omaha at Creighton University. Events recorded by this station as well as one (or both) of the arrays will be useful in reducing and evaluating ranging errors.

Ken Eack (LANL Postdoc), Jeremiah Harlin (NM Tech Grad. Student), and Dave Smith (LANL Postdoc) are currently running the FORTE ground support effort. Anyone interested in collaborating is encouraged to contact one of these people.

FORTE Optical Sensors Continue to Observe Lightning

Matt Kirkland reports:

The optical payload on FORTE has yielded considerable information which mostly corroborates previous satellite-based observations of terrestrial lightning, but also gives us some new insight. The optical payload on FORTE consists of two instruments. The first is a fast, silicon photodiode detector (PDD) that provides a two millisecond time-power history of transient optical signals, with microsecond precision in the trigger time and 15 microsecond sampling. The second instrument is a planar array of charge-coupled devices that serves as the Lightning Location Sensor (LLS). The LLS is essentially the same instrument as the Optical Transient Detector (OTD) flown by NASA. Each LLS pixel maps to a 10 km x 10 km region on the Earth's surface for lightning location.

Observations made with the PDD (700,000 events attributed to lightning as of mid-April 1999) have shown that optical lightning events generally occur over continental land masses, as reported by previous investigators. A comparison with data from the National Lightning Detection Network has shown that, at the stroke level, the PDD detects about 5% of all NLDN-reported cloud-to-ground strokes. At the flash level, the PDD/NLDN overlap increases to approximately 40%. A detailed analysis suggests that the PDD preferentially detects optical signals originating from within clouds, as opposed to signals originating below clouds. This is consistent with modeling work reported by Thomason and Krider [1982].

Optical signals observed by the PDD have a mean peak power of one gigawatt and less than a megajoule of energy at the assumed isotropic source. The effective pulse width of optical pulses are typically several hundred microseconds and imply tens of kilometers of cloud delay path for NLDN-reported cloud-to-ground strokes, or intracloud events having relatively large spatial extents.

We continue to analyze FORTE-detected VHF/optical waveform pairs from lightning events. This data set is being used to develop satellite-based lightning discrimination capabilities and is also providing insight into cloud scattering processes. VHF/optical waveform pairs are routinely collected both as individual lightning pulses and as sequences of pulses associated with CG and IC flashes. CG pulses can be distinguished from IC pulses based on the properties of the VHF and optical waveforms, but mostly based on the associated VHF spectrograms. The VHF spectrograms are very similar to previous ground-based HF and VHF observations of lightning and show unique signatures that allow us to identify/discriminate initial and subsequent return strokes, stepped and dart leaders, attachment processes, and intra-cloud activity. The VHF signatures are observed to precede the arrival of the optical signatures at the satellite by a mean value of 240 microsecs for CGs. This lag is consistent with a mean scattering delay of about 140 microsecs (40 km additional path length) for CG light as it propagates through the clouds. This inferred delay is consistent with the observed effective pulse widths discussed earlier.

A review of optical events exceeding 100 gigawatts at the assumed isotropically radiating source reveals that bright optical events are ubiquitous. When correlated with data from the NLDN, these bright optical events are found to be associated with both positive and negative cloud-to-ground strokes, with the negative/positive ratio being equivalent to that found for weak optical lightning signals. The preponderance of evidence suggests that bright optical events are simply occupants in a single, peak-power distribution of lightning, and are likely events for which a relatively unobscured line-of-sight to the satellite exists. The VHF emissions associated with bright optical events are unremarkable.

The FORTE/Lightning Location System (LLS) continues to provide location information for detected lighting events. The current analysis algorithms allow for location accuracies of better than 20 km and are being used to study storm-level processes such as the time and spatial evolution of optical lightning events with respect to radar data.

FORTE VHF correlations with NLDN: Results of a six-month campaign

Abe Jacobson reports:

FORTE and NLDN have been used in a campaign to provide contemporaneous observations of lightning from two highly complementary systems. FORTE is a low-Earth-orbit satellite carrying radio-wave and optical instruments for the study of lightning. The radio receivers aboard FORTE observe very-high-frequency (VHF) emissions from the air-breakdown process preceding and (sometimes) accompanying large-scale current flow. Only VHF (and higher) emissions from lightning can reliably penetrate the ionosphere to a satellite, especially along grazing-incidence paths.

The National Lightning Detection Network (NLDN) is a ground-based array of sensors in the continental United States (CONUS) observing the low-frequency (LF) and very-low-frequency (VLF) radiation from large-scale vertical currents. Prior to the launch of FORTE in

1997, essentially no work had been done on the statistical correlations between (a) ground-based LF/VLF and (b) spaced-based VHF remote sensing of lightning. During April - September 1998, FORTE was tasked with taking maximum triggered VHF data over and near the CONUS, and NLDN data were specially post-processed in a loosened-criterion mode providing enhanced detection range beyond the CONUS. The time history of reported events from the two systems was compared, and event pairs (each pair containing one event from FORTE, the other from NLDN) that were candidate correlations (closer than 200 millisec from each other) were scrutinized to determine if there was a statistically meaningful timing relationship. We have found that there is a statistically significant correlation, consisting of a prompt coincidence between a subset of NLDN events and a subset of FORTE events. This coincidence is most likely to occur for intracloud, and less likely to occur for cloud-to-ground discharges. The prompt coincidences mostly are within 150 microsec, after correction for the propagation of the VHF signal to FORTE from the NLDN-geolocated discharge. The NLDN-furnished geolocation of the prompt-coincident, FORTE-observed VHF pulses allows the pulses to be better interpreted. In particular, we can deduce, from the lag of the VHF ground-reflection echo, the height of the VHF emission region in the storm.

Our study has been submitted for publication. We reach several conclusions: (a) NLDN-FORTE coincidences which rise above the accidental coincidence level are prompt within ~30 microsec, except for the NLDN strokes which are further than 600 km from the nearest participating NLDN sensor. (b) FORTE-observed VHF emissions in the North America sector are often as strong as, or stronger than, Blackbeard-observed TIPPs. (c) Satellite-observed VHF emissions are much more likely to be associated with intracloud discharges than with cloud-to-ground discharges. Satellite-observed VHF emissions are more likely to be associated with positive- than with negative-cloud-to-ground discharges. (d) Satellite-observed VHF emissions associated with intracloud discharges tend to be narrower in pulsewidth than are VHF emissions associated with either polarity of cloud-to-ground discharges. (e) TIPPs that are associated with NLDN discharges are even more likely to be associated with intracloud discharges. (f) TIPPs that are associated with NLDN discharges display a region-dependent emission-height distribution, suggestive of the height-versus-latitude of key isotherms, e.g. -20 C, in the troposphere. Over the CONUS/Canadian interior above 45 deg N, the half-points of the distribution are at roughly 6 and 9 km, and the peak is at 7-8 km. Over the southern maritime region, the peak is at >13 km, and the distribution is broader. We have no statistically significant evidence, amongst the TIPPs that are associated with NLDN discharges, for TIPP-emission heights above 15 km.

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

An opportunity arose in the TRMM Brazil experiment (December 1998-March 1999) to explore electrification and convection in one of the three tropical "chimneys". Earle Williams and Nadia Madden measured cloud condensation nuclei, initial radar echo heights and total lightning activity from the TOGA radar site on Abracos Hill, near Ouro Preto, Rondonia. These measurements were designed to test ideas of Daniel Rosenfeld about the role of dirty continental air in influencing instability and the enrichment of the mixed phase region with supercooled water. The observation that first echo heights were systematically higher (by 2 km in the mean) in the break period than in the monsoon is consistent with these ideas. The distinction between break period and monsoon in Brazil was as clear as in earlier studies in Darwin, Australia, also with Steve Rutledge and his colleagues at roughly the same latitude.

Calibrated field change measurements on spider lightning linked with positive ground flashes were also carried out in Brazil with instrumentation generously loaned by Marx Brook and Dave Rust. These measurements are to be used to estimate electrostatic vertical moment changes for comparison with electromagnetic inferences of the same quantity based on Schumann resonance measurements of these exceptional lightning flashes from Rhode Island. Energetic positive ground flashes from Brazil and other locations worldwide have previously been recorded both in Rhode Island and in Hungary in collaboration with Bob Boldi and Gabriella Satori. Vadim Mushtak is examining these simultaneous events to establish physical parameters in his asymmetric model for the Earth-ionosphere cavity.

Danny Castro has been comparing background and transient Schumann resonance observations in the Rhode Island data archive. These results show a proportionality between the maximum background intensity in the local afternoon and the total number of large positive transients recorded from the same zone on the same day (but which often lag the background maximum). These findings are consistent with mesoscale comparisons with Walt Lyons, Tom Nelson and Tom Chang relating total lightning, sprites, and positive ground flashes. These results taken together suggest that variations in the 'tail' of the global lightning distribution are indicative of variations in ordinary afternoon lightning. This is good news because the lightning events in the 'tail' may be mapped on a global basis whereas the inversion of background data from one station is a more difficult problem, as discussed in a recent paper in JGR by Stan Heckman, Earle Williams and Bob Boldi.

Karen Rothkin has analyzed a large batch of observations from NASA's Optical Transient Detector to examine variations in flash rate and the number of storms on the diurnal and the annual time scale. Her results indicate that on the diurnal time scale, variations in both flash rate and number of storms contribute substantially to the variations in total lightning activity. On the annual time scale, by way of contrast, the variation in the number of storms is the dominant source of overall variability. Dennis Boccippio and Stan Heckman at NASA MSFC made important contributions to this study.

Carlos Labrada has developed methods for examining precipitation mass flux and simultaneous lightning flash rates as observed from the NASA TRMM Satellite. The lightning/rainfall relationship appears to be a highly variable one. The occurrance of 40 dBZ echos at 7 km altitude is largely confined to continental zones, consistant with observations in earlier ground-based field campaigns. The lightning yield per unit of rainfall was notably higher in Darwin, Australia than in Rondonia, Brazil in the January 1998 TRMM observations. Carlos also participated in the recent Brazil field experiment.

Gabriella Satori's long term record of Schumann resonance intensity has been compared with simultaneous measurements at the Rhode Island station. The dominant common signal is the annual one which greatly dominates over the interannual variability, despite the occurrance of significant El Nino activity. The semiannual signal is strong in Hungary and weak in Rhode Island, and this appears to mirror indications of the intrinsic local semiannual variations in Africa (close to Hungary) and in S. America (close to Rhode Island). Details of these comparisons are to be presented at the ICAE conference in June.

The paper entitled "Criteria for Sprites and Elves Based on Schumann Resonance Observations" by Everest Huang, Earle Williams, Bob Boldi, Stan Heckman, Mike Taylor, Walt

Lyons, Tom Nelson and Charles Wong will appear shortly in The Journal of Geophysical Research.

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

Bob Boldi, Anne Matlin and Earle Williams in collaboration with Steve Goodman at NASA MSFC have turned from NEXRAD to TDWR radar data to examine the evolution of the Sanford tornado supercell on February 23, 1998. This Orlando-based radar was located 40-50 km from the tornado and provides improved resolution of the low level features, most notably the surface convergence that is observed to precede the mesoscyclone intensification and lightning 'jump' aloft, more than 15 minutes prior to tornado touchdown.

Bob Boldi is exploring algorithms for grouping LDAR radiation sources into flashes in severe Florida storms with very active lightning. An earlier algorithm developed by Launa Maier is one of these.

A paper concerned with the behavior of total lightning in severe Florida storms by Earle Williams, Bob Boldi, Anne Matlin, Mark Weber. Steve Goodman, Ravi Raghavan, Dennis Buechler, Steve Hodanish and Dave Sharp will appear in the Special Issue of Atmospheric Research in honor of the late Bernard Vonnegut.

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

Both the Lightning Imaging Sensor (LIS), which was successfully launched in November 1997 as a scientific payload on the Tropical Rainfall Measuring Mission (TRMM), and the Optical Transient Detector (OTD), which was launched in April 1995 as a prototype for the LIS, continue to provide measurements of global lightning activity. More information about both LIS and OTD can be found on the web page at <http://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 remain interested in lightning data sets that could contribute to a global lightning climatology and to on-going ground truth activities for OTD (regional lightning detection networks, etc.) and LIS. 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).

In December 1999 (J. Bailey, R. Blakeslee, A. Athayde, O. Pinto, N. Renno, S. Goodman, C. Weidman, and E. Ferraz), installation of a four station, real-time ALDF network was begun in the Rondonia region of western Brazil. The ALDF network was installed to support the Brazilian Tropical "Land" Field Campaign in January/February 1999, as well as to provide long term ground-based lightning measurements for LIS and OTD validation. The primary installation of the ALDF sites and associated Vsat communication links were completed by March, although some additional effort remains to bring the network into full operational status. The data from the network are now being archived at the Global Hydrology Resource Center. Once quality assurance (Q/A) and processing algorithm issues have been addressed/implemented, the network data including browse products will be made available to researchers. Data from the network will also be archived and processed in Brazil. For more information about these data during this interim period please contact R. Blakeslee (rich.blakeslee@msfc.nasa.gov). Plans are to maintain the ALDF network in Brazil at least through the life of the TRMM mission (~2001). Also, the TOGA radar (J Gerlach, E. Williams) operated during the Tropical "Land" Field Campaign will remain in Rondonia for one additional year.

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

During the MEaPRS field program in the central United States in Spring 1998, an adjunct experiment obtained data from storms having periods in which the majority of cloud-to-ground flashes lowered positive charge to ground, instead of the usual negative charge. Instrumentation included balloon-borne electric field meters, the new deployable lightning mapping system by New Mexico Institute of Mining and Technology (NMIMT), WSR-88D Doppler radars, NSSL's S-band polarimetric radar, and the National Lightning Detection Network (NLDN). Severe storms with positive ground flashes occurred on seven days during the experiment. Complete or partial balloon soundings were obtained from eight of these storms on four days. Lightning mapping data were obtained on two days with soundings, as well as on three other days.

An analysis of WSR-88D radar data and NLDN data from three of the days with soundings is nearing completion. Lightning mapping data have been processed and some plots of the lightning location data have been made by NMIMT for all days having suitable storms. Processing to produce preliminary electric field profiles has been done at the University of Mississippi for all available cases. Selected data from these cases will be presented in a poster at the ICAE '99 in June.

***NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY, (Socorro, NM)**

The New Mexico Tech Lightning Mapping System (NMT LMS) is currently deployed and operational in New Mexico with the central station situated at Langmuir Laboratory. Tim Hamlin, an NMT graduate student under the supervision of William Rison, is actively involved in upgrading the system to a real-time data display capability through the radio modems which are currently used to communicate with the stations and configure their threshold criteria. Other graduate students are constructing slow antennas which will be used to obtain multi-station measurements of electric field changes in conjunction with the highly successful 3D-mapping of the lightning discharges at radio frequencies. Ron Thomas, Paul Krehbiel, and William Rison have analyzed various data sets from the first year of NMT LMS operations in 1998 and have numerous significant findings which will be reported at the ICAE conference in June. The homepage for the NMT LMS is at "http://ibis.nmt.edu/nmt_lms/".

Mark Stanley, an NMT doctoral candidate under the supervision of Paul Krehbiel, submitted in late March a paper to GRL which summarized some key parameters of initial sprite development as observed by a light-intensified high speed video camera. Mark is also collaborating with Steve Cummer, a postdoc at the Goddard Space Flight Center, who is using an ELF waveguide propagation model to determine the parent discharge charge moment at the time of sprite initiation as indicated on high speed video. Steve will summarize these results in a paper which will be submitted to GRL very soon. Steve is also assisting in the analysis of 3 separate day-time positive CG discharges which were each followed by a delayed and isolated slow field change indicative of a sprite. Mark Stanley will submit the day-time sprite results to GRL shortly. The homepage for NMT sprite research is at "http://ibis.nmt.edu/sprites/".

***UNIVERSITY OF OKLAHOMA SCHOOL OF METEOROLOGY, (Norman, OK)**

Lightning Protection Technology (Leon Byerley), the OU School of Meteorology and the Oklahoma Mesonet (Bill Beasley and Aaron Bansemer), are cooperating in the development of a very low-power, low-cost, low-maintenance electric field meter suitable for deployment in the Mesonet. The objectives are to study the electrification of Southern Great Plains thunderstorms and possibly to develop ways to improve electrical storm hazard notification using a network of electric field meters. A prototype field mill has been running continuously at the Norman site of the Oklahoma Mesonet since Nov. 1998. The field mill is designed to operate in a variety of modes in conjunction with data loggers used in the Mesonet. The mill consumes less than 60 mW and provides either analog or 12 bit serial digital data on twisted pair or fiber. The continuous time series of electric-field data since November, in conjunction with a suite of other meteorological observations made regularly at Mesonet stations, is being analyzed by Aaron Bansemer as part of his MS degree program.

***ONERA (Meudon, France)**

Anne Bondiou (bondiou@onera.fr) at ONERA is carrying on the development of a project named ORAGES, a space experiment aimed at realizing a space survey of lightning activity in the tropical area. The project involves in implementing a VHF interferometer on a microsatellite that would be launched in the future years. A balloon borne prototype of the space interferometer will fly at the end of 2000. Franck Roux (rouf@aero.obs-mip.fr) and Serge Chauzy (chas@aero.obs-mip.fr) of the Laboratoire Meteorology in Toulouse, are involved in this project.

ONERA and DLR are analyzing the data collected during the EULINOX campaign. During the summer of 1998 the Onera 3D VHF interferometer (thery@onera.fr), DLRs Doppler multipolarimetric weather radar POLDIRAD (harmut.hoeller@dlr.de) and DLRs instrumented aircraft Falcon20 and Dornier 228 were operated simultaneously to analyze the behavior of storms occuring around the DLR site at Oberpfafenhofen (South of Munich, Germany). The aim of the experiment was to detect and evaluate the production and transport of NOx by storms. EULINOX is a European scientific program involving also KNMI (Netherlands National Weather Research Center) and NILU (Norvegian Institute for Air Research).

ONERA and CEAT (Centre d' Essais Aeronautique de Toulouse) are conducting some basic experiments on interaction between electrical discharges and dielectrics with the objective to improve the understanding of lightning strikes to aircraft radomes. Regarding the study of lightning channel sweeping on aircraft, Anders Larsson from Upsalla University is undertaking Post Doc work at ONERA on the modeling of that phenomenon. Anne Bondiou, Philippe Lalande (lalande@onera.fr) and Pierre Laroche (laroche@onera.fr) are collaborating with John Willett (willett@plh.af.mil) at the Air Force Research Laboratory and Dan Davis (davis@atmos.albany. edu) at SUNYA on the analyses of results of the triggered lightning experiment conducted at Camp Blanding in 1996. Monique Petitdidier (mpe@cetp.ipsl.fr) from CETP(Centre d' Environnement Terrestre et Plan Etaire) with the help of Pierre Laroche conducted ground-based electric field measurements at the National Astronomy and Ionospheric Center (NAIC) in Arecibo (Puerto Rico) during Hurricane Georges in September 1998. She is currently analyzing the VHF and UHF radar data from Arecibo, and the electric field data and disdrometer measurements performed simultaneously at the same place by C. W. Ulbrich of Clemson University.

***OSAKA UNIVERSITY (Osaka, Japan)**

The Lightning Research Group of Osaka University (LRGOU) has conducted two main field campaigns. One is a project of thunderstorm observations in Darwin, Australia during the developing stage of its monsoon. Objectives of this project are the investigation of the mechanism and features of thunderstorm activity in the Inter Tropical Convection Zone, and the understanding of the characteristics of lightning discharges by means of VHF Broadband Interferometers. LRGOU has designed and manufactured a VHF Broadband antenna with logarithmic amplifier to capture the lightning flash data which occurred within a radius of several tens of kilometers, and has realized 3D imaging of lightning discharges. The time sequence of VHF radiation sources due to discharge development can be given as a three dimensional picture. Broadband Interferometers were equipped at two sites with a base line of 23.1 km and a GPS was operated to synchronize two interferometers with a time accuracy of 1 microsecond. A preliminary paper on the broadband interferometer observations was presented at the international EMC Conference in Zurich in February 1999 and will be published in a Japanese scientific journal in July 1999. The captured data in this field campaign have been analyzed, and related papers will be presented coming ICAE, ICOLSE and IWPL. The other campaign is a project of winter storm observations on the Hokuriku Coast in Japan where a relatively higher ratio of positive to negative cloud-to-ground (CG) flashes is observed than during summer storms. LRGOU operated the narrow band interferometers, slow antenna, and ALPS. The main target of these observations is the upward initiating lightning discharges. LRGOU succeeded in observing both upward positive leaders and negative leaders by means of interferometers. The lightning currents were measured with a shunt resistance and the leader polarity can be confirmed. Time sequence of progression of upward positive leaders is presented in terms of UHF radiation sources and is compared with cross sections obtained with a C-band radar. The leader is observed topropagate toward the region of highest reflectivity (40 dBz) and the temperature of the area is -10 degrees Centigrade. In other words the direction of leader progression is coincident with the negatively charged area.

***POLISH ACADEMY OF SCIENCES (Warsaw, Poland)**

The atmospheric electricity research group at the Institute of Geophysics reports:

Atmospheric electricity recordings accompanied by meteorological, aerosol, radioactive pollution, and other observations have been carried out at Swider Geophysical Observatory in Poland since 1956. The results are being published (year-books) and exchanged systematically (M.Kubicki). The electric field and vertical air-earth current recordings together with meteorological, geomagnetic field and other geophysical measurements are continued at the polar atmospheric electricity station at Hornsund, Spitsbergen, (M.Kubicki).

Correlations between the simultaneous variations of vertical air-earth current density at the high latitude station (Spitsbergen) and middle latitude (Poland) are being analysed (J.Drzewiecki, S.Michnowski). The response of the atmospheric electricity variations at the ground in polar regions to the interplanetary magnetic field, IMF, embedded in the solar wind is examined. Examples were found of a very distinct influence of IMF on the measured values obtained under certain conditions. They are now being examined (S.Michnowski, N.Kleimenova, S.Israelsson, N.Nikiforova, J.Drzewiecki, M.Kubicki).

New solutions of instruments for the ground based recording of the electric field were designed and constructed (J.Berlinski, S.Warzecha).

The measurements of electric charge on precipitation particles brought to the earth's surface during thunderstorms are carried out in Warsaw (P.Baranski). The data are analyzed together with simultaneous measurements of the Maxwell current (total and convective component) and the electric field. Some characteristic changes in the charge transport linked to rain particles connected with the different electrical polarity of the thundercloud were observed. Recent results are to be presented during the forthcoming 11th ICAE in Alabama (P.Baranski).

The complex observations of lower positive charge centers in thunderclouds are in preparation (P.Baranski, J.Parfiniewicz, M.Chrobak, S.Michnowski).

The analysis of processes of the lightning discharge initiation in clouds is beeing continued (Nguyen Manh Duc, S.Michnowski).

The antenna lightning recording system designed for a low orbiting satellite is undergoing the field tests at the ground surface(T.Kuraszkiewicz, P.Baranski, M.Morawski, S.Michnowski).

***UNIVERSITY OF ROORKEE (Roorkee, India)**

The Department of Physics, University of Roorkee, Roorkee is doing extensive studies in atmospheric sciences in general and particularly in atmospheric electricity under the leadership of Prof. Jagdish Rai. Recording of the atmospheric conductivity, aerosol and meteorological parameters were made during the total solar eclipse of 1995. Arvind K. Singh, Adarsh Kumar, Manoj Bansal and M.P. Singh were involved In this campaign. The results have been published in The Indian J. of Radio and Space Physics (Feb. 1999, Vol 28, pp 1-10). The effect of orography, air pollution and atmospheric ionization and electrical parameters have been studied theoretically by Adarsh Kumar, Arvind K. Singh, M.J. Nigam and Sri Nivas (Indian J. Radio and Space Physics, Oct. 1998, Vol. 27, pp 215-223). Dr. M.J. Nigam, Department of Electronics and Computer Engineering, and Prof. Sri Nivas, Department of Earth Sciences, are also collaborating in the studies on atmospheric electricity. Instruments have been designed and fabricated to measure the difference of electrical conductivities of ambiant and filtered air. It has been found that the difference of conductivities is proportional to the level of particulate pollution. This kind of measurements may provide an index of particulate pollution. Savi Toshniwal and A. K. Bansal were involved in this kind of study.

Space weather is a major challenge to scientists involved with studies in aeronomy. Work is being done to see the effect of thundercloud and lightning on the ionospheric ionization. For this purpose the SROSS-C2 satellite data are being obtained from the Indian Space Research Organization (ISRO) and the data connected to the lightning electric fields is being recorded in the Department of Physics, UOR, Roorkee. The problem is also being tackled theoretically. Arvind K. Singh, D.K. Sharma and Rupesh Tyagi are engaged in these studies.

Lightning discharges have been the subject of major studies by the group. Presently, instruments are being designed to recieve atmospherics in the broad band range from ELF to VLF. The main purpose of the study will be to utilize the atmospherics for geophyical exploration. As part of these research works, this group is actively involved in the exchange of information through conferences/seminar/symposia. During the last two years the group has presented their ideas in three different symposia/workshops. Jagdish Rai, Arvind K. Singh, Manoj Bansal and Adarsh Kumar have attended the National Space Science Symposium at the Physical Research Laboratory (PRL), Ahemdabad, India and presented three research papers. Recently Arvind K. Singh and Manoj Bansal presented two research papers in a seminar on Stratosphere-Troposphere Interactions, held at Cochin, India. They also attented an International

Workshop on Long Term Changes and Trends in the Atmosphere held at the Indian Institute of Tropical Meteorology (IITM), Pune, India from Feb. 16-19, 1999.

***SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY (Rapid City, SD)** Work is currently underway to combine proposed field efforts for LPEX (Low Precipitation Supercell Experiment) and CESAR (Cloud Electrification Studies using Aircraft and Radars) in the spring/summer of 2000. The project will be based in eastern Colorado/western Kansas/southwestern Nebraska. Basic facilities will be deployed from mid-May through mid-August, with intensive observing periods scheduled from mid-May through June, and late-July into early August. Field operations will include a network of 3 Doppler radars (2 of them with polarization diversity) and a lightning discharge channel mapping system developed by Bill Rison and Paul Krehbiel at NMIMT. Aircraft, balloons, storm intercept vehicles, and a mobile mesonet are also planned. A central theme of the operations will be to map storm microphysical characteristics and circulations (both in the "main" storm and the anvil regions), and to determine why LP supercells are Low Precipitation. In addition, investigators will use this information along with a range of other observations to address hypotheses concerning relationships between microphysics and various electrical phenomena, including lightning, X-ray emission, transient luminous events (sprites, elves, etc.), and charge separation within thunderstorms. Other interests include comparison between remotely-sensed and in situ measurements of microphysics, chemical production and transport within thunderstorms, and verification of ensemble mesoscale forecasts of thunderstorms.

For addition information, or to express interest in participation, contact Andy Detwiler at the South Dakota School of Mines and Technology (605-394-2291 [voice], 605-394-6061 [fax], or <andy@ias.sdsmt.edu>).
Overview documents are currently available at http://silver.sdsmt.edu/~detwiler

***STANFORD UNIVERSITY: STARLAB (Stanford, CA)**

The VLF Group continues active work directed toward further understanding of upward electrodynamic coupling of tropospheric thunderstorms to the lower ionosphere and associated optical and electromagnetic effects.

In the past few months, the involved with the Holographic Array for Ionospheric Lightning research (HAIL) lead by Mike Johnson continued to operate nine VLF receivers in Wyoming, Colorado, and New Mexico. Several papers based on the 1998 campaign are now in preparation. Results have confirmed the forward scattering nature of early/fast VLF events, and quantified the scattered beam to have a 15 dB beamwidth of 30 degrees. In addition, some Lightning induced Electron Precipitation (LEP) events observed with the HAIL array are shown to have a massive disturbance region, latitude dependent onset delay, and a poleward-displaced disturbance with respect to the causative lightning location, in accordance with the predictions of a recent quantitative model of oblique-whistler-induced precipitation. Please visit: http://www-star.stanford.edu/~hail/.

While work is ongoing in consolidating and reporting results from 1999 recordings with the Dobsonian Sprite Experiment telescopic imager and the Fly's Eye photometric array, preparations are also in progress for the coming summer's campaign. Chris Barrington-Leigh and Umran Inan recently published "Elves triggered by positive and negative lightning discharges"

(GRL, Vol. 26, Page 683, 1999), describing the ubiquity of the ionospheric heating effect caused by the electromagnetic pulses of lightning and resulting in the optical flashes known as elves. Umran Inan, Elizabeth Gerken, and Chris Barrington-Leigh are also working to publish results based on the high spatial resolution measurements of sprites from this past year.

This summer graduate students Elizabeth Gerken and Timothy Chevalier, along with undergraduate Robert Moore, will again be fielding multiple instruments at Langmuir Laboratory (New Mexico). Research will focus on fine-tuning high spatial and temporal resolution observations of sprites and on characterizing the widespread incidence of elves through fast array photometry. Campaign results will be posted as they become available at http://www.stanford.edu/~vlf. >

Steve Reising (Microwave Remote Sensing Laboratory, University of Massachusetts, Amherst), Umran Inan and Tim Bell using broadband ELF/VLF measurements of sferics near Ft. Collins, Colorado, demonstrated (GRL, Vol. 26, Page 987, 1999) that ELF sferic energy was a proxy for sprite occurrence which could be used to estimate the number of sprites produced by a thunderstorm. Ultra-long range (~12000 km) measurements at Palmer Station, Antarctica, confirm the application of this proxy to storms where no video observations of sprites are available. Comparison with high-resolution photometer measurements demonstrate the simultaneity of sprite luminosity and an ELF "second pulse" believed to be radiated by electrical currents within the sprite body [Cummer et al., 1998]. Measurements of the second ELF pulse are used to identify a quantitative relationship between the current in sprites and total sprite luminosity.

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

An on-going study of lightning and thunderstorms in the Eastern Mediterranean, conducted by the cloud physics group, headed by Zev Levin. Orit Altaratz and Yoav Yair (presently at the Department of Natural Sciences, the Open University of Israel), emphasizes differences in lightning distributions along the Israeli coastline and the relation between meteorological conditions and the positive ground flash fraction.

Measurements in the last two winter seasons, conducted in Tel-Aviv and Haifa using LPATS and CGR3 counters, show an increase by a factor of 10 in flash density over a horizontal distance less than 90 km. An analysis of radar and satellite images of thunderclouds is being performed for chosen events.

The RAMS model will be used to model cloud evolution and the microphysical properties of clouds in these situations. An intensive analysis of TRMM/LIS data for several thunderstorms in our region showed a weak correlation between flashes registered by the LIS sensor and those recorded by the LPATS system. Further work on the LIS data base is being performed.

Colin Price continues the collection of Schumann Resonance data from his Negev Desert site. The station is now hooked up with a modem connection to transfer the data back to the University campus every few days. This has reduced the down time due to power failures which had resulted in extensive periods of dead-time previously. Some of the initial data for March 1998 has been distributed to Vadim Mushtak, Earle Williams, Sasha Nickolaenko and Sasha Shvarts. Since the raw data is saved over a 5-minute period once every hour, the data can be reanalysed by others using different methods and algorithms.

Colin Price has started analysing some of the ELF data collected during the SPRITES'98 campaign. Thanks to Tom Nelson and Walt Lyons, it was found that some of the visibly observed events in Colorado produced large ELF signals that are observed in the Negev ELF data. In addition, we were sampling during the massive 27 August, 1998, cosmic gamma-ray burst that was shown to significantly influence VLF waves in the troposphere. We saw NO effect in the ELF band and we are investigating this difference with the help of Vadim Mushtak.

Together with Umran Inan and Bill Trabucco of Stanford, Colin Price has erected a 10 meter high VLF antenna in the Negev desert, similar to the two antennas operated by Stanford in Antarctica and California. Our initial recordings indicate very distinct sferics. The sensitivity of the VLF system allows us to detect sferics from as far off as 12,000 km. We are in the process of setting up the recording system with a GPS clock to allow us to use all 3 stations simultaneously to get global lightning coverage.

***TEXAS A&M UNIVERSITY (College Station, TX)**

The lightning research at Texas A&M University can be summarized in the following way: Robert Wacker and Richard Orville have documented the "Changes in measured lightning flash counts and return stroke peak current after the 1994 US National Lightning Detection Network upgrade 1. Observations" (JGR, vol 104, no. D2, pages 2151-2157, January 27, 1999). We have documented the increase in the detection of positive flashes after 1994 and show that it is predominately limited to peak currents less than 10 kA. A similar increase is not seen in the negative flash count. In a companion paper by Wacker and Orville (JGR, vol. 104, no. D2, pages 2159-2162, January 27, 1999) we show how the change in the network efficiency for positive flashes below 10 kA can be explained by the change in the waveshape discrimination criteria. Contamination from intracloud flashes can account for the increase in positive flashes observed since 1994. Thus, researchers should be aware of this problem and ignore positive flashes below 10 kA in the NLDN.

A paper by R. Orville and G. Huffines is in press (Monthly Weather Review) that summarizes the cloud-to-ground properties of lightning in the continental United States for the years 1995-1997. The lightning maps include flash density, peak currents, polarity distributions, and multiplicity variations with a resolution of 20 km.

New thunderstorm duration maps for the continental United States are in press (G. Huffines and R. Orville, "Lightning ground flash density and thunderstorm duration in the continental United States: 1989-1996," Journal of Applied Meteorology, summer 1999). We present the mean annual flash density, thunderstorm duration, and flash rates using 121.7 million CG flashes for the period 1989-1996. We report a maximum annual flash rate of 45 flashes per hour in the Midwest, along the Florida coasts, and along the Mid Atlantic coasts. A relationship is derived between thunderstorm duration and flash density.

Research on the onset of CG lightning at the NASA Kennedy Space Center has been completed by M. Gremillion. (Gremillion and Orville, "Thunderstorm characteristics of cloud-to-ground lightning at the Kennedy Space Center, Florida: A study of lightning initiation signatures as indicated by the WSR-88D", Weather and Forecasting, In press, summer 1999) We find that the 40 dBZ echo at the minus 10 degree Celsius level is the best indicator for predicting the beginning of CG lightning activity.

N. Demetriades is completing his master's work on the "Exploration of the meteorological characteristics leading to the rapid cessation of cloud-to-ground lightning in winter cyclones along the East Coast of the United States". A detailed analysis of seven winter storms, including the Superstorm of 1993, shows an unusual and unexplained cessation of CG lightning as the systems moved north during the winter months. Part of the research is to determine if the cessation can be predicted based on the known and routine observations of the meteorological characteristics of the storms.

***UNIVERSITY OF WASHINGTON (Seattle, WA)**

Vicki Schroeder, Marcia Baker and John Latham (UMIST) recently completed a model study on the initiation of streamers from hydrometeors. The results are in good agreement with earlier laboratory studies and suggest the feasibility of a microphysical mechanism for lightning initiation. A paper on this work has been accepted by the Quarterly Journal of the Royal Meteorological Society.

In a second study funded by the NASA GEWEX program Vicki Schroeder and Marcia Baker are examining possible links between lightning production, updraft velocity and the vertical transport of water and ice. The study makes use of a combination of observed data from a variety of field projects (New Mexico, CaPE, MCTEX) and model results. The model is a 1.5 dimensional cloud model with explicit microphysics and a lightning paramaterization, developed by Robert Solomon (a recent graduate from the group). The results from this study will be used together with NASA's satellite lightning programs (LIS and OTD) to establish the spatial and temporal distributions of these hard to measure cloud properties.

In a further study involving the use of the 1.5D model mentioned above, the effects of increased aerosol concentrations and properties on lightning frequency and type will be examined. The study is motivated by observations of increased lightning flashrates in polluted areas - both urban areas, such as Mexico City, and those affected by particulate pollutants from large forest fires.

Brian Swanson, J. G. Dash, Marcia Baker and a new graduate student will continue the laboratory studies of ice-ice collisional charge transfer begun by B. Mason and J. G. Dash. R. Jayaratne will visit Seattle this summer as part of this effort. We plan to focus first on possible impurity effects on charge transfer.

***YORK UNIVERSITY (Toronto, Ontario, Canada)**

Stephen Clodman, at the Cantre for Research in Earth and Space Studies (CRESS) of York University, is studying the general problem of detection of sprites and related phenomena by satellite. This is an outgrowth of a project analyzing WINDII optical emission and wind data (from the UARS satellite) for evidence of sprites and other storm effects. Although WINDII data proved not to be well suited for this purpose, it became evident that a properly designed satellite or Space Shuttle experiment would be of value. A satellite might detect emissions anywhere on earth; it could detect information at wavelengths not usable from the earth's surface; it might detect middle atmosphere gravity waves above storms.

There are in fact several different ways of designing an optical detection experiment, each with its own advantages. A limb view is a possible approach. However, a downward view, particularly at an oblique viewing angle, would also be feasible. This could be a modification of the MESO low-cost satellite design proposed at York (originally for chemical studies). Several different wavelengths, from ultraviolet to far infrared, might be used. The design must overcome a range of obstacles, such as interference from lightning. These issues are discussed in a paper to be given at the International Conference on Atmospheric Electricity this June. CRESS, which has experience in satellite and instrument design and in related scientific issues such as aurora, is seeking ways to further advance the work.