NEWSLETTER ON ATMOSPHERIC ELECTRICITY

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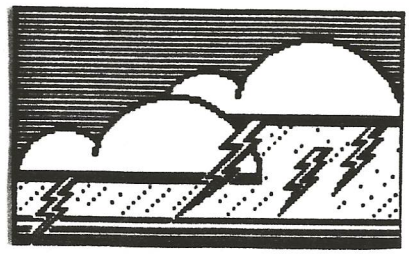

AMS COMMITTEE ON
ATMOSPHERIC ELECTRICITY

ANNOUNCEMENTS

John Willett and Arnold Barnes of the Air Force Geophysics Laboratory are planning to meet with members of ONERA in France in January, 1991 concerning the conduct of future collaborative lightning experiments in the U.S. They are soliciting specific suggestions from the atmospheric electricity community on the design of these experiments and on a specific data exchange formalism. This topic will be discussed at the evening meeting (probably Tuesday, December 4) during the San Francisco AGU meeting.

Other topics for discussion at the latter meeting should be communicated to members of the AMS Committee on Atmospheric Electricity.

Roger Wakimoto is calling for a **CaPE Workshop at NCAR** (Room 650 at RL-3) for **November 8-9, 1990.** If you cannot attend this meeting but are interested in the proposed field experiment at KSC for Summer 1991, please provide Roger with your input. An additional CaPE document was released in August.

The **20th General Assembly of IUGG** will take place in **Vienna, Austria August 11-24, 1991.** The International Commission on Atmospheric Electricity (ICAE) is co-organizing two symposia, 'Global Lightning and its Applications to Nowcasting' and 'Electrical Properties of Thunderstorms'. For further information contact Anthony Illingworth.

The **San Francisco AGU Meeting (December 2-7, 1990)** will contain two regular sessions on Atmospheric Electricity with 13 papers each (Tuesday) and a poster session on Wednesday.

The **European Geophysical Union** will hold its annual meeting in **Wiesbaden, Germany on April 22-26, 1991.** Prof. John Latham plans to organize within that meeting a special Atmospheric Electricity Conference. His phone number is 44 061 200-3932.

The deadline for abstracts for the **Radar Meteorology Conference in Paris (June 1991) is October 15, 1990.** Contact Dave Jorgensen at NSSL in Boulder, CO.

The contributions to this Newsletter are increasingly voluntary, though many were coerced. If you want a Newsletter, please contribute to it. Additions and modifications to the mailing list (currently 220 recipients) are always welcome.

RESEARCH ACTIVITIES BY ORGANIZATION

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (Bolling AFB, D.C.)

Jim Stobie reports that the AFOSR $600,000/year atmospheric electricity initiative begins in FY91 and lists below the tentative selections for FY91 funding:

Colorado State Univ. (Bringi); Multiparameter Radar and Aircraft Based Studies of the Microphysical, Kinematic and Electrical structure of convective clouds during CaPE.

Univ. of Florida (Thomson); Location and characterization of In-cloud lightning currents by multiple station VHF and electric field measurements.

New Mexico Tech. (Krehbiel); Remote sensing of precipitation and electrification with a dual-polarization, coherent, wideband radar system.

NCAR; Support for the Convective and Precipitation/Electrification experiment (CaPE).

Univ. of Washington (Baker); A numerical study of thunderstorm electrification.

Because of budget uncertainties at press time, these selections must still be considered "tentative".

AIRBORNE RESEARCH ASSOCIATES (Weston, MA)

Ralph Markson's recent work in atmospheric electricity falls in two main areas: 1) The production of a new combined optical/electric field change instrument for detection of lightning. It works in either optical or field change mode, or in coincidence, to eliminate false alarms. It is battery operated, handheld, weighs 1 lb. and detects intracloud and cloud-to-ground strokes within flashes. It has a detection range greater

than 100 miles in the electric field change (flat plate antenna mode; 2) The measurement of several electric field profiles from the surface to as high as 24 km in Hawaii (including one from Mauna Loa). The results showed an exponential increase in conductivity with height from close to the ground due to the clean air near the surface of the earth (right to the ground at Mauna Loa). These measurements were made in preparation for continued ionospheric potential measurements successfully conducted in September at Christmas Island in the equatorial Pacific Ocean in conjunction with initial tests of a kite-borne system for continuous monitoring of ionospheric potential under development by Ben Balsley at the NOAA Aeronomy Lab in Boulder, CO.

UNIVERSITY OF ARIZONA (Tucson, AZ)

Phil Krider writes that L.E. Deaver has completed a M.S. paper on the temporal behavior of the displacement (and Maxwell) current densities under small Florida thunderstorms. W.J. Koshak is completing a Ph.D. dissertation on linear methods for inverting multi-station measurements of lightning field changes. These methods allow constraints to be added to the error function to reduce solution ambiguities, a procedure that may eventually lead to improved methods for analyzing airborne electric field measurements. Capt. T. D. Oram is now comparing lightning locations inferred from field changes measured by the USAF-NASA network of field mills with LLP lightning locations at the NASA Kennedy Space Center and USAF Eastern Space and Missile Center.

COLORADO STATE UNIVERSITY (Ft. Collins, CO)

Steve Rutledge and his colleagues report continued efforts to develop a 2-D cloud electricity model that can be used to address the development of charge (and subsequent cloud-to-ground lightning) in stratiform regions of Mesoscale Convective Systems. They have reviewed the laboratory work of Saunders et al. in an effort to develop an expression for the charge separated per collision between graupel and cloud ice, both in the presence and in the absence of supercooled water. They are also looking at the results of Takahashi to see how they compare to the laboratory studies of Saunders et al., and what the differences mean in terms of the model-predicted charge distribution in clouds. The model is now being used to examine the amount of charging by the mesoscale vertical motion field, and associated microphysics internal to these widespread regions of stratiform precipitation. Data obtained from COPS 89 (Cooperative Oklahoma P-3 Studies) carried out with NSSL are being

used to initialize and validate the model. Model-predicted incloud charge distributions and electric fields will be compared to measurements of these quantities obtained in COPS 89 by Dave Rust and Tom Marshall.

An effort to model the one-dimensional dynamics and microphysics of deep tropical convective storms observed in our DUNDEE experiment in Australia (in collaboration with Earle Williams) is underway. This work involves moving the electrical parameterizations developed in the work described above into an existing 1-D time dependent, Eulerian cumulus model in order to investigate the differences in the dynamical, hydrometeor, and charge profiles between tropical continential and oceanic convection (i.e. high CAPE and low to moderate CAPE environments). Their field observations showed a strong dependence of total lightning rates on CAPE, which was evident as higher radar reflectivities in the mixed-phase region of continental storms compared to oceanic storms.

They also have started to analyze the four station LLP data obtained in DUNDEE. A plan to overlay plots of radar reflectivity and cloud-to-ground lightning locations and polarities is being developed to determine if lightning bipolar patterns appear in the rather low-shear tropical environments.

COLUTRON RESEARCH (Boulder, CO)

Lars Wahlin reports that Colutron Research has continuously monitored electric field, Wilson current, positive and negative ion concentrations, humidity, temperature, wind velocity and barometric pressure for three years on strip recorders. This summer they have developed a simple analog/digital system which records up to 8 channels per 3 - 60 seconds and stores the data on a 5" floppy disk. At present they are running the same 8 channels and taking readings every 30 seconds (one byte per channel per reading) which fills one disk every 14 days. The set-up consists of a modified multifunction card to which an ADC 0808 A/D chip has been added.

Work on a theoretical model which involves ionic and electric parameters in the atmosphere has been completed this summer.

DEPARTMENT OF TRANSPORTATION (Cambridge, MA)

John Caniff and his colleagues at the DOT/Volpe National Transporation Systems Center (VNTSC) have been evaluating lightning detection technology for over two years. The sponsoring agency for this work is the FAA Automated Weather Observing System (AWOS) Program. The AWOS system is designed as a set of weather sensors installed at

non-towered airports, with computer-generated voice broadcasts of local weather data (ceiling, visibility, wind, temperature, dewpoint, altimeter) available to pilots. FAA wants to enhance the AWOS reports with thunderstorm information.

VNTSC has been evaluating the SUNYA lightning data network since July 1988. This network reports only cloud-to-ground strikes, and is based on direction finding technology. The coverage, accuracy, and reliability of the SUNY network has proven sufficient for AWOS requirements. VNTSC has demonstrated the concept for accessing the SUNY network data, processing that data in real-time to determine thunderstorms within 30 miles of any AWOS, and transmitting a thunderstorm warning to particular AWOS sites every minute.

More recently, VTNSC has evaluated data from the LLP single-site-sensor, for direct input into individual AWOS's. VNTSC is currently evaluating data from the ARSI lightning network, which is based on time-of-arrival technology. In August-September 1990 at the Lincoln Laboratory's FL-2 radar site near the Orlando airport, VNTSC participated in a joint evaluation of Terminal Doppler Weather Radar (TDRW) and the SAFIR lightning detection system, the French interferometer-based system which detects intracloud lightning as well as cloud-to-ground. Results from the Orlando evaluation will be available after several months of processing and analysis.

DESERT RESEARCH INSTITUTE (Reno, NV)

A collaborative project between the Hurricane Research Division of NOAA, Univ. of Miami (R. Black, P. Willis), Desert Research Institute (John Hallett) and University of Manchester Institute of Science and Technology (Clive Saunders) is investigating electrification and cloud physics processes in oceanic convection off Florida and in the eyewall region of hurricanes.

John Hallett (DRI) has equipped the P-3 Aircraft with vertically pointing field mills, with horizontal mills being added later in the season. The P3 (along with similar type aircraft) is subject to some self charge which needs to be allowed for in estimating ambient field; this turns out to be small compared with enhanced thunderstorm fields, but interferes with fine weather field measurements. An experimental system for measurement of individual precipitation particle charges to 10^{-13}C is also being installed on the P3 with Clive Saunders (UMIST). This is a standard induction ring probe, and rejects electrified splashes by analyzing pulse shape. The electrical data are being synthesized with particle phase/size from PMS data supplemented by formvar replica; cloud motions are obtained by the rapid scan radar to give the horizontal flow

field from the P3 aircraft outside the cloud. The vertical cloud structure and vertical velocity profile is obtained directly from the penetrating aircraft. Measurements were made in hurricane Hugo last year, and have been supplemented this year by measurements made within individual clouds near the Bahamas, with the aircraft ascending with the cloud as it grows. The combination of these data is providing evidence of the buildup of electrical activity as the cloud grows through the 0 C level and the precipitation mechanism transforms from a coalescence-induced process to an ice process at lower temperatures.

UNIVERSITY OF FLORIDA (Tallahassee, FL)

Ewen Thomson and Pedro Medelius are continuing to measure wideband electric fields (3 Hz to 150 MHz) over a salt marsh next to the Indian River at the Kennedy Space Center. The aim of this project is to investigate the origins of VHF radiation by comparing the wideband measurements with simultaneous signals from a narrowband (10 MHz) VHF receiver centered at 50 MHz.

A second project involves the measurement of 10 MHz-bandwidth electric fields and VHF radiation at six remote sites at KSC. This project is still in the development stage with a view to being operational for CaPE 91. Thomson, Medelius, and NASA personnel are presently building ground planes, testing microwave links, establishing fiber optic links, and acquiring high-speed digitizers.

LAWRENCE LIVERMORE NATIONAL LABORATORY (Livermore, CA)

Richard Hasbrouck reports that the Interagency Lightning Threat Warning Working Group (ILTWWG) has been dormant for some time and may disappear, but that he has been working with Robert Olsen of White Sands Missile Range, who is chairman of the (DOD) Range Commanders Council/Meteorology Group (RCC/MG). Last February they held a one-day seminar at White Sands; proceedings will be available in the Spring of 1991. The RCC/MG has just added a "Lightning Prediction and Detection" committee of which Richard Hasbrouck is the chairman.

The committee's draft charter is to "identify mutual problems and share knowledge and techniques associated with (the) prediction and detection of lightning." The preliminary objectives are:

1. Reduce down time for activities.
2. Improve launch availability.
3. Achieve cost savings through shared knowledge and purchases.
4. Provide timely and credible information to duty weather forecasters.

5. Coordinate common range problems and solutions.
6. Periodically conduct lightning prediction and detection workshops.
7. Develop methods to facilitate technology transfer from the scientific community to the operational environment.
8. Identify where new technology is required.
9. Identify and standardize criteria for selection, siting and maintenance of instrumentation.

The next RCC/MG meeting will be held at Vandenberg AFB in late February/March 1991.

LIGHTNING LOCATION AND PROTECTION, INC. (Tucson, AZ)

LLP is carrying out a research program related to improving lightning detection efficiency and location accuracy in lightning networks. The detection efficiency work involves the acquisition, cataloging, and complete analysis of lightning waveforms from sensors imbedded in a detection network. Efforts related to locational accuracy are focused on improved location algorithms and flash timing. This work is performed using an LLP-owned network in the Tucson area, as well as several stand-alone direction finders. Contact Patrick Zumbusch or Kenneth Cummins for additional information regarding LLP activities.

LOS ALAMOS NATIONAL LABORATORY (Los Alamos, NM)

Charley Rhodes reports they are currently developing a 3-dimensional (two-station) triggered interferometer system for lightning location. The system is a half-wavelength operating at 130MHZ with 1 microsecond time resolution. Currently, they are operating a single station in hopes of obtaining some 2-D data. They expect to present results at AGU in San Francisco.

UNIVERSITY OF MANCHESTER INSTITUTE OF SCIENCE AND TECHNOLOGY (UMIST) (Manchester, UK)

Anthony Illingworth reports that the XXth General Assembly of the International Union of Geodesy and Geophysics (IUGG) will take place in Vienna, August 11-24, 1991. The ICAE (International Commission on Atmospheric Electricity) is co-organizing two symposia: 'Global Lightning and its applications to Nowcasting' and 'Electric properties of thunderstorms. This should be an excellent opportunity to meet scientists from all countries and especially Eastern Europe. Call for papers in third circular this Fall; Available from IUGG 91 Organizing Committee

(Fax 43-222-369-1233) or contact Anthony Illingworth, UMIST, (Fax 44-61-200-3941).

Clive Saunders is continuing the charge transfer experiments with ice crystals bouncing off graupel pellets in the presence of super-cooled water droplets. The aim is to provide a set of data linking charge transfer values obtained under realistic thunderstorm conditions with the impact speed, temperature, ice crystal size and the cloud liquid water content. Such data can be incorporated into numerical models of the electrical development of thunderstorms.

The search for the elusive primary charge transfer mechanism continues, with X-ray topographic studies of crystals and rime-ice. The aim is to determine the charges on dislocations--if the interacting crystals and graupel have different concentrations of dislocations, then charge will be transferred during contact. However, other theories have not been ruled out!

MIT LINCOLN LABORATORY (Lexington, MA)

MIT and the French Government Laboratory ONERA conducted a coordinated measurement program in Orlando, Florida this summer for comparison of thunderstorm morphology and dynamics and lightning-induced VHF radiation. Three Doppler weather radars were deployed around the Orlando International Airport to support operational demonstrations of low-altitude wind shear detection with the Federal Aviation Administration's Terminal Doppler Weather Radar and Airport Surveillance Radar wind shear detection systems. As a complement to these experiments, ONERA deployed an interferometric VHF direction finding system to detect and localize radio-frequency noise sources generated by cloud-to-ground and intracloud lightning processes. Data from the radar and lightning locating systems will be compared to understand relationships between thunderstorm dynamic processes relative to aviation safety (updrafts/downdrafts, microburst outflows, turbulence) and lightning activity.

Good quality coordinated measurements from the radar and lightning detection systems were obtained on 21 days during the time period 10 August to 12 September 1990. An initial set of 6 storms has been identified for detailed analysis, based on quality of radar and lightning data, and the criterion that a significant portion of these thunderstorms' life cycle occur within the area of accurate multiple-Doppler and lightning measurements.

Principal investigators for this effort from MIT are Mark Weber, Cynthia Engholm, Valerie Coel (Lincoln Laboratory) and Earle Williams (Department of Earth, Atmospheric and Planetary Sciences). From ONERA,

principals are Pierre LaRoche, Claire Malherbe, [illegible]ne Bondiou, and Jean Boulay. Phillipe Richard (Dimensions, Inc.) designed and constructed the interferometric VHF localization system deployed by ONERA.

MIT WEATHER RADAR LABORATORY (Cambridge, MA)

The MIT C-band Doppler, now back from NSF-sponsored field studies in Darwin, Australia (with Steve Rutledge of Colorado State University and the Australian Bureau of Meteorology) was installed northwest of Orlando, FL airport in August under the auspices of MIT Lincoln Laboratory, as part of a triple Doppler network with Lincoln's FL-2 radar and the University of North Dakota (UND) C-band. The network will continue operation into the Fall with Speed Geotis and Josh Wurman to document the evolution of isolated microburst-producing storms from early stages and to overlap with thunderstorm overflights planned for October by Rich Blakeslee and Hugh Christian of Marshall Space Flight Center. Radar and electric measurements are expected to continue during Spring and Summer 1991 with MIT's collaboration with both Lincoln Laboratory and ONERA.

The analysis of 4-station LLP ground flash data and radar measurements of precipitation in Darwin continue to show order-of-magnitude differences in the total precipitation yields per ground flash between the synoptically-forced monsoon and the continental 'hot tower' convection. These comparisons suggest a rather loose coupling between the global electrical current and the strength of the equatorial Hadley cell. Other comparisons support a tight coupling between 'hot tower' convection and the global circuit, with a four to five-fold increase in lightning activity per degree centigrade of surface wet bulb temperature in monthly means. Earle Williams is seeking additional long term data on lightning activity (i.e. lightning counters, LLP systems, etc.) at tropical stations in Africa, South America and Southeast Asia to evaluate the usefulness of ionospheric potential as a diagnostic for global temperature change. Any offers out there?

Stan Heckman returned to Kennedy Space Center this Summer for further radar and optical measurements of rocket triggered lightning. The measured radar cross-sections are an order of magnitude greater than calculations assuming a long thin tortuous target. UV photography at 2900 A is underway to investigate the possible role of overdense corona envelopes in enhancing the radar cross-section. William Jafferis has provided valuable logistical support for these studies.

NASA-MARSHALL SPACE FLIGHT CENTER (MSFC) (Huntsville, AL)

Recent activities of the Marshall group known locally as the ASTAG (Atmospheric electricity: Science, Technology, and Applications Group) as reported by Hugh Christian include:

The preliminary design of the Lightning Mapper Sensor (LMS) which we hope to fly in geostationary orbit on a GOES satellite is essentially complete. TRW has done an excellent job. We are presently working with NOAA in order to get a commitment to fly LMS on GOES. If an agreement can be worked out, NASA will be in a position to proceed with the final LMS development.

The Lightning Imaging Sensor (LIS) is still under consideration for flight on the EOS-A polar platform. Selection should be announced in October, 1990. If selected, LIS will be flown in a sun synchronous, 705 km orbit with 2 o'clock local crossings. LIS is essentially a scaled downed LMS (1/16th the processing power) that will provide a 15 year data base of global lightning coverage. We have also proposed to fly LIS on the Tropical Rainfall Measuring Mission (TRMM) which would enable us to acquire non-time dependent lightning data and simultaneous data with a number of rain sensing instruments including an active radar, passive microwave radiometers, and visible/infrared imagers.

A NASA Learjet instrumented with electric field mills was flown in the Cape Canaveral area for a seven week period beginning last July as part of the Airborne Field Mill Program (ABFM). This joint NASA/Air Force program is focused on studying weather conditions that impact the launch of space vehicles. The analysis effort is being headed by Doug Mach and Jeff Bailey.

A major upgrade to the field mill network at the Cape has been planned for some time. A decision has been made that MSFC will build the new sensors and the base station. Mark James will direct this effort.

Electric field mills and conductivity probes have recently been installed on a NASA ER-2 (Lightning Instrumentation Package). A three week deployment in Florida is planned beginning in October. Electric field and conductivity soundings will be obtained in addition to measurements over the tops of thunderstorms. Passive microwave and multispectral sensor measurements also will be made. Richard Blakeslee is leading the effort to provide an enhanced lightning instrumentation package for the 1991 CaPE field program.

Steve Goodman, Dennis Buechler and Pat Wright are continuing their analysis of COHMEX data and are preparing for a major effort during CaPE. In the long term we hope to expand this work into studies of tropical storms. Steve also is leading the effort to archive DMSP OLS data in a digital format beginning in January 1991 to provide global lightning data in the era prior to the launch of their space sensors.

Bill Koshak has recently joined their group and plans to get involved with continued development of his lightning field change location algorithm and the development of optical radiative transfer models of clouds.

Bill Boeck is at MSFC on sabbatical from Niagara University. He has been working with videos of lightning taken from the Shuttle. Bill and keet Vaughan are analyzing a number of images that appear to be upward propagating lightning. In addition, Bill will be generating simulated LIS data from the lightning videos which will in turn be used for generation of data analysis algorithms that will become part of the EOS data information system.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH (NCAR) (Boulder, CO)

James Dye (NCAR) in collaboration with John Hallett (DRI) flew two field mills on the NCAR Electra during the Hawaiian Rainband Project (July-August 1990) to investigate warm cloud electrification and understand more about electric field measurements from aircraft with high self-charging. Analysis is at a very early stage but underway.

Dye is also involved in planning for the CaPE program in Florida in 1991. It is likely that the NCAR sailplane will operate in this program and the NCAR and Wyoming King Airs have been requested to support the electrical, microphysical, and airflow-mapping studies.

Jim was scheduled to conduct a working group meeting on cloud physics and electrification at the October Workshop on Atmospheric Research Measurements at NCAR. This workshop has since been postponed until Spring because of travel restrictions imposed by Gramm-Rudman.

NOAA-HURRICANE RESEARCH DIVISION (Miami, FL)

Robert Black is continuing the analysis of the vertical electric field data collected in hurricanes that were reported on at the Conference on Cloud Physics, San Francisco, in collaboration with John Hallett (DRI). This work includes electric field measurements from four hurricanes (Emily ('87), Gilbert ('88), Gabrielle, and Hugo ('89)). Their plans for this season include installation on the NOAA P-3 of two more field mills and an induction ring for measuring the magnitude and sign of the charge on ice particles. The induction ring is being developed by John Hallett of DRI and Clive Saunders of UMIST.

NATIONAL SEVERE STORMS LABORATORY (NSSL) (Norman, OK)

Members of NSSL's Storm Electricity and Cloud Physics Research group are involved in or planning research in the following areas:

Don MacGorman is working with Howie Bluestein and Steve Keighton (Univ. of OK) to complete analysis of cloud-to-ground strike activity in a 1981 tornadic storm. This is the third case study of a tornadic storm using Doppler radar and our direction-finder network. Based on these three storms, our hypothesis is that storms with especially strong updrafts and a classical supercell structure tend to delay cloud-to-ground activity in the vicinity of the updraft core until the updraft and mesoscale weaken and reflectivity increases at middle-to-low altitudes. In weaker, less well-organized tornadic storms, cloud-to-ground lightning activity increased during the tornado instead of later and tended to cluster in and around the reflectivity core near the mesocyclone. Work to test this hypothesis and explore how storm kinematics and dynamics affect lightning activity is continuing in two efforts: (1) a study with Conrad Ziegler examining kinematic retrieval models of electrification in tornadic storms, and (2) a study of cloud-to-ground lightning activity relative to mesocyclone characteristics in 20-30 tornadic storms.

Steve Rutledge (Colorado State Univ.) and Don MacGorman are cooperating in studies of cloud-to-ground lightning in mesoscale convective systems (MCS's) that occurred during the PRE-STORM program. Don has been studying lightning strike locations and flash rates relative to the evolution of satellite IR images of MCS cloud tops. As noted earlier by Goodman and MacGorman for mesoscale convective complexes (MCC's), a subclass of MCS's, lightning ground flash rates in MCS's tended to increase rapidly when the area within -52C isotherms was also growing rapidly. Peak ground flash rates usually occurred near the time the cloud top of a system reached its coldest temperature. Positive ground strikes often were separated from negative strikes and tended to occur downshear from the coldest cloud tops.

Ph.D. candidate Monte Bateman (Univ. of OK) has successfully built and flown a particle size and charge measuring instrument on free balloons. These first flights have been into severe storms and stratiform rain region of MCS's. He is analyzing particle and electric field data from three flights. We plan a few additional flights during the fall storm season in Oklahoma. In a related work in collaboration with Tom Marshall (Univ. of MS), we are upgrading the balloon-borne electric field meter to increase its resolution from about 800 V/m to about 10 V/m. This will allow for much better determination of the horizontal components of the electric field. Tom Marshall and Dave Rust plan on continuing balloon flights into severe storms and MCS's next year.

During May and June, Vlad Mazur, Marx Brook (NMIMT), and Zen Kawasaki (Osaka Univ.) acquired data on intracloud lightning at NSSL. They used a video system operating at 200 frames/s along with optical and

field change sensors to investigate the junction stage of discharges in the cases where lightning propagated outside the cloud. Early results indicate that the video observations of lightning channels with a camera azimuthally pointed do not always provide the entire structure of the discharge. Therefore, the whole-sky method of observation was applied and tested. This experiment is planned to continue in Fall, 1990 and Spring 1991.

Kurt Nielsen has been searching for relationships between the locations of cloud-to-ground (CG) strike points of lightning and the radar observations of mesoscale convective systems. Our analysis reinforces the findings of earlier research that there appears to be a close association between the amount of rainfall in convective systems and the amount of CG lightning they produce. Although earlier research indicated that the average rain volume per flash appears to be almost independent of geographical location, it now seems evident that a unique relationship will not hold for every region. Lightning data will provide valuable information on convective systems and improve our estimation of rainfall from them should the lightning-rainfall relationships prove robust.

Using mobile ballooning and MCLASS (Mobile Cross-chain LORAN Atmospheric Sounding Sytem) to make balloon-borne measurements in severe storms, we have observed profiles of electric fields in MCS's. Steve Hunter and Terry Schuur are leading the analysis of two MCS's from 1989. The trailing stratiform regions of both had electric fields that indicate the distribution of electric charge is more complex than the long accepted dipole model for convective cells. We plan to acquire more profiles through MCS's to see if there is a typical electrical structure and to provide data for modelers.

NSSL is planning to conduct a field program next Spring to study storms that form near the dryline in western Oklahoma and the Texas panhandle and to study MCS's. Data will be collected with NSSL's multi-parameter radar, mobile laboratories, and NOAA's P3 aircraft with its Doppler radar.

NATIONAL SEVERE STORMS LABORATORY (NSSL) (Boulder, CO)

Raul Lopez, Ranjit Passi, and Lin Li have been working on improved analysis of cloud-to-ground lightning data from direction-finder networks. A meeting was held in March 1991 at LLP in Tucson with Raul and Ron Holle of NSSL (Boulder), Phil Krider (Univ. of AZ), Martin Uman (Univ. of FL), and Pat Zumbusch, Burt Pifer, Ken Cummins and Bill Hiscox of LLP. The current state of site error and location optimization methods were discussed in detail and steps were outlined to complete the work in a series of collaborative studies.

Irv Watson is extending earlier studies of low-level convergence forcing of lightning-bearing thunderstorms over KSC through the addition of recent years' data, smaller network areas, and storm-scale composites of lightning, radar and mesonet wind fields. He will be investigating the ability of the NEXRAD radar at Melbourne, Florida to track low-level convergence in combination with the surface mesonetwork, as part of the CaPE program.

Ron, Raul and Irv wrote an article for the World Meteorological Organization's Bulletin, reviewing the current state of cloud-to-ground lightning network utilization by meteorologists. Raul and Ron also have been appointed as WMO rapporteurs for the next 4 years on lightning detection for the WMO Commission for Instruments and Methods of Observation (CIMO).

Terry Schuur, Dave Jorgensen and Brad Smull are analyzing COPS-89 data from electric-field meters, airborne and surface Doppler radars, in situ microphysical sensors, and cloud-to-ground lightning networks to examine the electrification of stratiform clouds in mesoscale convective systems. Plans are underway to collect more of the type of data in COPS-91.

NATIONAL WEATHER SERVICE (NOAA-NWS) (Silver Spring, MD)

Henry Newhouse reports that the experimental system for composite national lightning data is continuing to be used by various federal agencies. The National Weather Service has expanded its use and evaluation of the data in field forecast operations. The NWS also plans a competitive procurement for operational lightning data.

Ron Reap of TDL is currently analyzing lightning location data for Alaska to determine some of the climatological characteristics of convection over high-latitude mountainous terrain. Forecast equations will also be developed from the lightning data and numerical model forecasts for use by operational forecasters in predicting general thunderstorm activity over Alaska.

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

Marx Brook spent a few weeks in Norman, OK taking data on the severe storms that came through in June 1990. Vlad Mazur took high speed video of lightning while Marx recorded electric field change data at a rate of 2 Msamples/s for a period of 0.66 seconds/flash. He notes the remarkably sudden transition from negative strokes to positive and the need for more data memory for these large storms.

Marx also plans to deliver a paper on ratios of radiation amplitude

to electrostatic field change in multiple stroke lightning flashes at the AGU meeting in San Francisco. He has found that wideband recordings of lightning flashes (duration 0.5 s) viewed with high time resolution show both radiation and electrostatic field changes in excellent detail, but are difficult to present in condensed form. An interesting presentation results from a compaction method which avoids averaging (and the attendant loss of short duration transients) by selecting maximum and minimum values from a set of intervals of the original data array. The interval length is chosen to produce a given number of points (in this case 32K points) from the original 2.66 Mbyte array. As a result of the compaction, the ratio of the radiation peak amplitude which falls off as 1/R, to the electrostatic field change, which falls off as $1/R^3$, is simple to discern and measure. Results of these ratios for a number of multiple stroke flashes have been studied and some conclusions drawn as to the constancy of the ratio within a flash as a function of distance.

Paul Krehbiel reports that new software has been developed for analyzing the lightning interferometer data using the Interactive Data Language (IDL) package running on a Sun workstation. It greatly improves their ability to analyze the microsecond time-resolution lightning data. The software has been developed by Ron Thomas of their new Electrical Engineering Dept. and graduate student Xuan-Min Shao, in consultation with Charley Rhodes, who is now at Los Alamos National Lab working with Dan Holden on continued interferometric studies of lightning and other radiation.

This group is currently refining the analysis of a complex, 5-stroke flash. The flash had a long period of in-cloud preliminary breakdown whose transition to the initial leader to ground was well-marked by the onset of localized and slowly-moving radiation at the beginning point of the leader. The second stroke of the flash was initiated by a sequence of two dart-type leaders along two main branches connecting into the vertical channel to ground. The leader for the third stroke followed another path into the channel to ground and initiated a continuing current that was sustained by the re-activation and coupling of the earlier channels into the continuing current path. In general, the discharge channels were extended by negative streamers which were initiated at a distance from the ends of previous channels and subsequently propagated into the previous channels.

Observations of thunderstorms with NMIMT's dual-polarization radar have shown that lightning echoes are readily detectable at 3 cm wavelength in the cross-polar channel of the radar, and have a somewhat greater volume reflectivity than at longer wavelengths. In addition, changes have been observed in the cross-polar return from some precipitation echoes at the time of lightning discharges. The changes are

explained as being due to the presence of aligned particles whose degree or direction of alignment changes when lightning causes the local electric field to change. Such changes were first detected in a localized region in the upper part of an active thunderstorm, but are extensive and easily detected above the brightband in decaying storms. Ice crystals that could be aligned by the electric field are expected to be present in both situations.

STATE UNIVERSITY OF NEW YORK AT ALBANY (Albany, NY)

Since January 1990, the National Lightning Detection Network (NLDN) (now administered by Kenneth L. Demerjian) has been collecting lightning return stroke data for all flashes detected. The geographical area for stroke collection is from the East Coast to the Rocky Mountains. For each stroke detected the absolute time (with an accuracy and resolution of 100 microseconds), azimuth, polarity, peak magnetic signal strength, and peak electric field signal strength are recorded. Ronald Henderson, a research associate, reports a few interesting observations from running the NLDN this year: 1) the flash rate in July exceeded 22,000 flashes/hour on 4 consecutive days throughout the country, 2) given that a flash contains multiple strokes, on average, 30 to 40 percent of those flashes have a subsequent stroke that has a higher peak current than the first stroke, and 3) during the Ohio flash flood in June, the peak flash rate for that area reached 2 flashes/second.

Vince Idone continues to analyze the photographic data obtained from the triggered lightning campaigns of the last few years at the Rocket Triggered Lightning site at Kennedy Space Center. A paper has just been accepted for publication in JGR on the subject of the inference of length bounds for connecting discharges in subsequent strokes of triggered lightning. Also, Vince has recently submitted a proposal to NSF for the continued study of triggered flashes using time-resolved photography, particularly in cooperation with C. Weidman (Univ. of Arizona). The photographic analyses also are expected to involve collaborations with Pierre Laroche (ONERA), John Willett (AFGL) and Marx Brook (NMIMT). In the immediate future, Vince will be more involved in various research aspects of the NLDN.

Scott Jacobs is continuing his studies of the occasional isolated storms seen on the NLDN that are sometimes observed to produce exclusively positive cloud to ground discharges for periods of two hours or more.

Bernard Vonnegut and Hugh Christian (MSFC) are hoping to arrange for an instrumented Lear jet airplane to make measurements of the polarity of the electric field above thunderstorms that are producing

positive cloud-to-ground flashes as indicated by the NLDN. Vonnegut also is continuing to urge tracer experiments to determine how the air motions in a thundercloud might be expected to transport the electric charge being deposited on the upper surfaces of the cloud by C.T.R. Wilson conduction current. He has submitted an article to Annales Geophysicae drawing attention to this long-standing question.

Haflidi Jonsson has recently completed a series of laboratory measurements on the conductance of various plastic filaments used in the investigation of thundercloud electricity by means of balloon-borne instrumentation to permit the estimation of the electric currents that might flow under the influence of thunderstorm electric fields. He also has been making measurements of the electrical conductivity of rain falling from local thunderstorms with equipment he has developed for making these measurements with a time resolution of a few seconds. It has been of interest to determine whether rain formed in the near vicinity of a lightning flash exhibits an anomalously high conductivity.

Mike Brock is collecting and analyzing the various theories that have been proposed to explain why cloud to ground lightning flashes sometimes lower positive instead of negative charge.

Christine Breslawski-Skubis's Master's thesis on lightning observations from the Space Shuttle will soon be made generally available to the communicty as a NASA technical report.

Ernesto Barreto continues his involvement with the interaction of aircraft and rockets with lightning. He believes a satisfactory treatment must consider the development of a hot thermalized channel with a leading streamer fan that reaches or originates from the vehicle being considered. In both cases discharges at the surface of the vehicle must change from a weak incipient glow to a hot thermalized channel. The transition is a necessary but not sufficient condition for actual damage that may lead to a fire or explosion. It involves the problem of gas heating in electrical discharges that has never been clarified. Even the nomenclature is confusing because different processes are called by the same name in lightning and in the laboratory (e.g. streamers, arcs and sparks).

ONERA (Meudon, FR)

Jean-Louis Boulay reports that ONERA is planning to participate in two experiments next year: 1) to continue their cooperation with Lincoln Laboratory and MIT in order to predetect microburst occurrance by using a 3D electromagnetic interferometer at the Orlando, FL airport, and 2) to investigate intracloud lightning discharges and altitude triggered lightning phenomena in cooperation with AFGL, NASA, MIT, NSSL and SUNY at Albany.

RICHARD E. ORVILLE (Schenectady, NY)

Dick Orville is examing LLP lightning data to determine the variation of cloud-to-ground flash characteristics over large geographical regions as a function of season. As you may recall, the variation of first stroke peak current with latitude was reported in a January 1991 Nature letter.

PENNSYLVANIA STATE UNIVERSITY (University Park, PA)

Les Hale of Penn State contends that many approaches neglect most of the lightning-related energy deposited externally in conductors, specifically that caused by the deposit and decay of Wilson monopoles. A paradigmatic problem is the total current pulse in the earth and ionosphere due to the instantaneous deposition of a unit of charge at one scale height altitude in an atmosphere with exponentially varying conductivity. An approximate analytical approach resulted in the compact form $I(t)=d/dt\ (\ln T/t)^{-1}$, where T is the relaxation time of air at the surface. Les is interested in other solutions which confirm or dispute this one, and suggests collecting them for comparison. Interested parties please respond. For further information see Nature 329, 814 (1987).

THE SOUTH DAKOTA SCHOOL OF MINES (Rapid City, SD)

Andy Detwiler reports that the South Dakota School of Mines T-28 journeyed to Socorro, NM in July and carried out three intercomparison flights with the NMIMT SPTVAR. The primary goal of obtaining electric field measurments around thunderstorms while in close formation flight was achieved. Detailed intercomparison of the two sets of field measurements will be carried out this fall.