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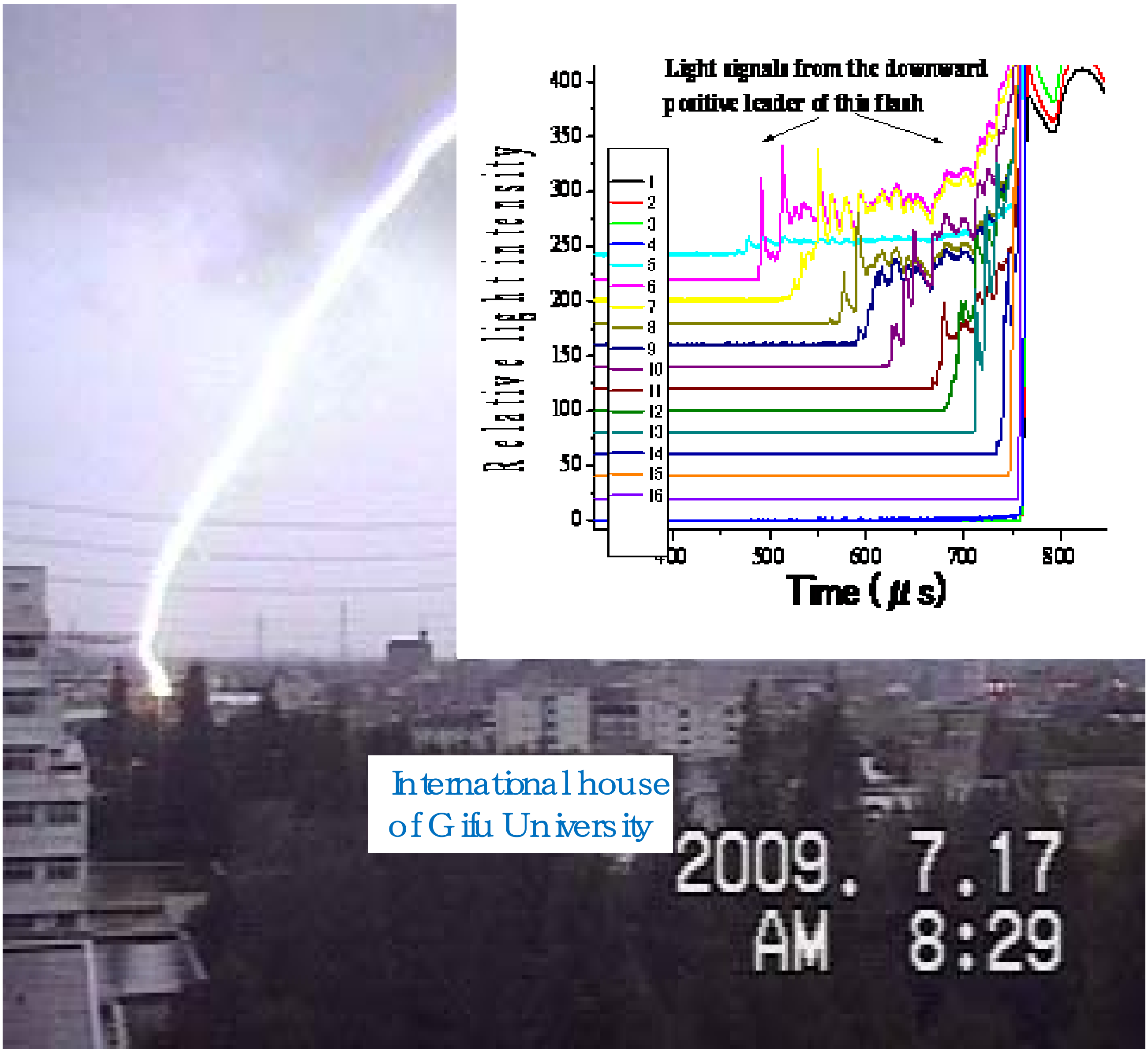

***Comment on the photo above*: This lightning flash is a positive cloud-to-ground discharge whose downward positive leader has emitted light pulses similar to a negative downward leader as shown in the inset figure. The photo was taken by the lightning research group of Gifu University of Japan from a building within their campus on July 17th, 2009. The light signals emitted from the positive leader of the flash, as seen in the inset figure, were recorded with a high speed digital optical system (ALPS) at a time resolution of 100 nanoseconds.**

History of the Lightning Mapping Array

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To commemorate the 20th Anniversary of the ICAE Newsletter, I have been asked to write up the history of the Lightning Mapping Array, or LMA. What follows is an informal recollection of the events leading up to and through the development of the LMA.

The LMA was conceived by myself, Bill Rison, and Ron Thomas during a late-evening return flight to New Mexico from the 1994 Fall AGU Meeting in San Francisco. We were flying on Southwest Airlines, whose airplanes at the time had a seating arrangement in which the front two rows of seats in the economy section faced each other, similar to a train compartment. I was facing backward and Bill and Ron were on the other side facing forward. The flight was mostly empty and we had the seats to ourselves. The three of us were discussing the AGU presentations and thinking out loud about our lightning studies in general, when the idea for the LMA suddenly popped into my head. By the time we landed in Albuquerque, we had worked out all the basic details of the system. The history prior and subsequent to this point is related below.

I started working with Marx Brook in 1966 as a research engineer to help out with his studies of lightning and thunderstorms. Together we built several research radars and developed several techniques for remotely sensing lightning inside storms. Bill Rison came to Tech in 1984 to work in the Langmuir Laboratory group with Charlie Moore. Following Marx and Charlie's retirements in the mid 1980s, Bill and I teamed up to continue our various studies. The two of us were joined by Ron Thomas in 1989, whom we had hired as one of the first faculty of the new Electrical Engineering program Bill and I were setting up at Tech. My main research projects at the time were one of Marx's many brainchilds, the wideband dual-polarization radar, and the VHF lightning interferometer. Bill and Ron brought valuable expertise and new ideas to both of these projects.[1]

By the fall of 1994 we had just been through a whirlwind four years of intense field studies, beginning with the large, multi-investigator Convective and Precipitation Electrification (CaPE) experiment at Kennedy Space Center, Florida. I had extensive experience working at KSC in the mid-1970s during the Thunderstorm Research International Program (TRIP 76-78). For the TRIP studies, Marx and I and a small band of dedicated students spent three non-stop summers making 12-station electric field change measurements for determining lightning charge centers and also operating our fast-scanning 'Red Ball' radar. It was hard work but we were tough back then.

TRIP resulted from a unanimous recommendation for such a study that came out of the Fifth ICAE Conference held in 1974 in Garmisch-Partenkirchen. The conference was highlighted by lively and

1) The lightning interferometer was brought to Tech in 1980 by Craig Hayenga, who began its development as a Ph.D. student at the University of Colorado under radio astronomer Jim Warwick. Craig was recruited to Tech as a post-doctoral researcher by Marx, who by then had become Director of Tech's Research and Development Division. Craig and graduate student Charley Rhodes focused on developing the interferometer and using it in field studies of lightning. This paralleled similar work being conducted by Pierre Laroche and Philippe Richard of the ONERA group in France. Craig left Tech in 1987, after which I became directly involved in the interferometer's further development.

forthright discussions of thunderstorm electrification issues, documented for posterity in the published Conference Proceedings. A number of groups participated in TRIP, which was sponsored by the National Science Foundation (NSF) and by NASA. Included were Roger Lhermitte of the University of Miami, who, along with the NCAR facilities group, operated a triple-Doppler radar network centered around KSC, and NASA's Carl Lennon, who developed the Lightning Detection and Ranging (LDAR) system at KSC. In addition, Bill Taylor of the NOAA Wave Propagation Laboratory operated a two-station network of his short-baseline, broadband time-of-arrival lightning mapping system.

CaPE was also an NSF- and NASA-supported study and was as multi-faceted as TRIP but held for one summer rather than three. We participated in CaPE with the dual-polarization radar and our lightning interferometer. Just the sheer logistics of getting everything transported, set up, and working in Florida was pretty daunting. With the radar we obtained real-time observations of electrically aligned ice crystals in thunderstorms, following up on the pioneering early studies of electrical alignment by McCormick and Hendry in Canada. With the interferometer, Ph.D. student Xuan-Min Shao and I experimented with a new baseline configuration that provided a key advance in using the interferometer for studying lightning. We were so wrapped up in the two efforts that we stayed at KSC into the fall season, well beyond the official end of CaPE.

The following year, during the summer of 1992, we returned to Florida and operated the interferometer for several months in a study of lightning at Orlando International Airport. We worked side-by-side with Vlad Mazur, who operated an all-sky high-speed video camera, while Xuan-Min and I operated the interferometer. The new baseline configuration from the CaPE studies solved a major problem of resolving the fringe ambiguities of the interferometer and enabled us to process the data automatically. For the Orlando studies, we undertook a quick effort to process and display the interferometer data in real time. This was done using the newly available PC-based digital signal processing technology that Bill Rison had introduced to our dual-polarization radar studies. Xuan-Min was tasked with writing the processing code while I wandered off to the Ninth International Conference in St. Petersburg.

The real-time processing was as successful for the interferometer studies as it had been for the radar. For the first time we were able to watch images of lightning channels as they occurred inside storms, on the color screen of a PC monitor. Among other things we were fascinated by the common occurrence of bilevel intracloud (IC) discharges in the Florida storms. Subsequent analyses of the Orlando and CaPE observations formed the basis for Xuan-Min's Ph.D. dissertation and for several papers on the development of cloud-to-ground and IC discharges inside storms.

During the summers of 1993 and 1994 we continued to operate the interferometer and radar at Tech's Langmuir Laboratory in central New Mexico. Bill Rison and Mark Stanley further developed the processing and recording system for the interferometer, and returning Ph.D. student Richard ('Chip') Scott was bringing his microwave industry experience and polarization ideas to bear on the radar. Among other things, we wanted to start putting the VHF lightning observations into the context of the storm provided by the multiparameter radar data. We also obtained observations of triggered lightning and experimented with adding a set of vertical baselines to the interferometer.

The Langmuir studies produced several examples of bilevel IC flashes overlaid on the radar data. The overlays were made by intersecting the azimuth and elevation values of the 2-dimensional VHF data with vertical radar scans through the center of the storm. The geometry of the measurements was such that overlays having a reasonable degree of confidence could be obtained only for flashes that developed in the scan plane of the radar and were properly located relative to the interferometer. Only a few flashes wound up satisfying the criteria, which highlighted the need for 3-dimensional lightning data. In addition, although we were still in the process of publishing the Florida results, we had gone about as far as we could in using the 2-D interferometer measurements to study in-cloud discharge processes. By the time of the 1994 AGU meeting it was clear that what we needed next were 3-dimensional lightning measurements.

We resisted pursuing a 3-D interferometer because we had enough experience with the interferometer technique to see that a 3-D system involving two or more spaced 2-D stations would be difficult to implement and likely would not work very well. The interferometer was not only expensive and hard to construct, but was a fundamentally myopic instrument. It worked well for determining the azimuth and elevation angles of nearby lightning, but discharges at intermediate and greater distances had their elevation angles progressively poorly determined. Our attempts to alleviate the elevation problem using vertical baselines had not worked well due to ground reflections and antenna interaction effects. While individual interferometer stations obtain their measurements coherently, the only practical way of combining the data from multiple stations would be by triangulation - an incoherent process that would degrade the spatial accuracy of the results.2

Re-enter the LDAR system. I had worked closely with data from Lennon's original system during and after TRIP, both with Roger Lhermitte and as part of my Ph.D. studies. LDAR was patterned after the long-baseline time-of-arrival (TOA) technique developed by Dave Proctor in his pioneering lightning studies in South Africa. Lennon's version of Proctor's system took advantage of the newly available 'Biomation' transient digitizers (20 MHz, 8 bit - cutting edge technology at the time) to determine the TOA values automatically in real time. The LDAR network consisted of six outlying stations in an approximately circular array about 20 km in diameter around a seventh, central measurement station. Similar to Proctor's system, wideband microwave telemetry links were used to transmit the fast lightning signals from each station to the central processing site, where they could be digitized and recorded with accurate time synchronization.

Due in part to relatively long readout times, the original LDAR system located a relatively small number of sources per flash - from less than 10 up to 50 or so total events.[3] While the LDAR data constituted a major advance in remotely sensing lightning, the LDAR sources tended to be randomly located in space and time and, for IC discharges, appeared to be biased toward the upper part of the storm. The significance of the altitude bias was not at all understood at the time but is now known to have

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2) Time-of-arrival systems also have primarily horizontal baselines and therefore similar elevation problems, but this is substantially alleviated by the fact that the arrival times are coherent measurements over long baselines, providing much greater areal coverage before the elevation errors start becoming important. In addition, the uncertainties of timing measurements have less effect on the location results than those of the phase measurements required by interferometry.

3) As continues to be the case in modern TOA systems, the LDAR system operated in discrete time epochs, or 'windows', each 100 microseconds long. Unlike present systems, the windows were not adjacent in time but occurred intermittently as the digitizers could be re-armed and were re-triggered. To accommodate lightning in all directions, the time windows for each station were synchronized to all be centered on the trigger time, and wide enough (+/- 50 microseconds) in relation to the size of the network to ensure that the triggering event would be captured at all stations. The network radius R was therefore restricted to have transit times less than 50 microseconds, so that R < 15 km. Modern TOA systems have time windows of comparable or shorter length but record their data continuously, so that the overall size of the network (typically 50-60 km diameter) is not restricted by the window width.

resulted from the fact that negative breakdown is impulsive in nature and illuminates positive charge regions more strongly at VHF than positive breakdown illuminates negative charge regions.

The original LDAR system obtained the source locations by analyzing two independent sets of 4-station measurements, corresponding to alternate sets of three outlying stations and the central station. To be accepted as legitimate the independent solutions had to agree within a specified 3-dimensional distance, typically two hundred meters or so. The relatively strict acceptance criteria eliminated spurious events and ensured that the reported events were correctly identified and located. Despite this, the upward altitude bias (and the source locations sometimes being above the radar-detected cloud top) led Marx to conclude that the LDAR system had some unknown systematic error. As a result, he insisted that the altitude values needed to be adjusted downward by some arbitrary amount, about a kilometer or so. Lennon and Lhermitte vigorously objected to this, and the altitudes were not adjusted. I have blissfully forgotten what my role or complicity was in this entire issue, but it was probably equally embarrassing. As confirmed by subsequent networks, the LDAR sources were accurately located.

The seemingly random nature of the LDAR source locations was additionally misleading and not understood. One interpretation was that it was an inherent feature of the impulsive lightning activity, suggesting that TOA measurements would not be that useful in delineating lightning channels or revealing the discharge structure. This turned out not to be true, as shown by the subsequent LDAR and LMA systems (not to mention Proctor's early studies). Instead, the early LDAR data were simply just undersampled, probably aggravated by being focused primarily on the strongest radiation events.

Following TRIP, NASA effectively decommissioned the LDAR system by redeploying it to Wallops Island, where it languished. More than ten years later, in preparation for CaPE, a rejuvenated and upgraded LDAR system was started by Carl Lennon and his colleagues Tom Britt and Launa Maier. But the high speed digitizing rate (100 MHz, 8 bit) and custom digital processing circuitry proved too difficult to implement in time for CaPE. The new LDAR system became operational in 1994. Observations from the system were first presented at a one-day lightning workshop hosted by Los Alamos National Laboratory (LANL) in Albuquerque during November 1994, a couple of weeks before the AGU meeting. At the workshop, we presented examples of our bilevel IC discharge results, and Launa Maier followed with even better lightning images from the rejuvenated LDAR. While the interferometer gave detailed pictures of leaders and flash development, the LDAR data provided almost the same amount of information and were 3-dimensional.

Such was the status of things at the time of the 1994 AGU meeting. The LDAR system was producing 3-dimensional results but had the major disadvantage of requiring wideband microwave links for the needed time synchronization. The communication links were difficult and expensive to set up and maintain, making the LDAR system equally or more complicated to get working than a 3-D interferometer. And, once set up, the network would be essentially impossible to move to another location. This is what we were discussing on the plane flight back to New Mexico.

The inspirational moment during the flight stemmed from two technological developments that were becoming available at the time. The first was the gradual emergence of GPS and, in particular, of relatively inexpensive GPS receivers that were starting to show up on the market. The second was the new capability of wireless digital communications and ethernet. What suddenly popped into my mind was that one could put a GPS receiver at each site to make the arrival time measurements independently at each station, and wireless links to send the relatively low-rate TOA values back to the central site. A simple enough idea in hindsight, but a major breakthrough at the time. Bill and Ron knew exactly what to do with the idea, and by the time we landed in Albuquerque we had the system well figured out. We were so absorbed in this that I forgot I was facing backward on the plane and at one point became totally disoriented.

The mapping system was first operated in Oklahoma during June 1998 as part of the Mesoscale Electrification and Precipitation Radar Study (MEaPRS). We didn't have a particular name for the system at the time, but just referred to it as the lightning mapping system. The Oklahoma network was comprised of ten stations spread out over an area 50 km in diameter, in open wheat and cattle country northwest of Oklahoma City. Each station was housed in a large, heavy-gauge steel 'Greenlee' construction-site box, containing a minitower PC AT running Linux, a UPS, and two large car batteries for the UPS. The GPS and VHF receiver components were mounted on a plywood sheet lining the inside back of the box. The stations received the lightning signals in a locally unused broadcast television channel (Channel 3, 60-66 MHz) and detected the strongest radiation event above an adjustable noise threshold in successive 100 microsecond time windows. The mast and VHF receiving antenna were initially anchored to the Greenlee boxes but were moved 50 to 100 feet away from the boxes when we discovered that radio frequency noise from the PC circuitry was being picked up by the antenna. The data stream at each station was recorded by the PC on 2 GB digital audio (DAT) tapes, which were collected every few days as the tapes filled up with local noise and lightning triggers. Three students, Ron, and I set the network up in about a week, but without communications links. Rather, the network was operated by 'pick-up' truck, visiting the stations every couple of days to check their operation.

Development of the mapping stations was funded in 1995-96 by the Air Force Office of Scientific Research (AFOSR), and in 1996-99 by an NSF Academic Research Infrastructure (ARI) grant. Ron Taylor of NSF was instrumental in our being awarded the ARI grant, against stiff competition. The stations were designed to utilize low-cost, off-the-shelf components and to be simple in their overall implementation. The central component of each station was an application-specific printed circuit card, subsequently called the 'LMA card', that interfaced the output of a 12-bit 20-MHz digitizer to an Altera field programmable gate array (FPGA). Housekeeping information and control operations were provided by a Motorola 68HC11 microcontroller, and the resulting data stream was output to the host computer over the PC-AT bus. An accurate 20 MHz clock was obtained by phase locking the output of a voltage-controlled crystal oscillator to the one pulse-per-second (1 PPS) signal of the GPS receiver. Initial work on the design of the PC card was done in 1995-96 by three Electrical Engineering students for their senior design project, under Bill Rison's tutelage. The firmware was completed in subsequent years by EE students Michael Davis, Tamara Barber, and John Sinnott. Construction of the mapping stations and printed circuit cards was done by then-undergraduate physics student Jeremiah Harlin and by Mike Jones. Tim Hamlin joined the project as a graduate student in August 1997 and along with Jeremiah went on to play a major role in the subsequent development of the LMA.

All of us squeezed in the mapping system development with classwork and teaching, with the result that we were unable to field-test the stations prior to being deployed in Oklahoma -- much less the operation of the network as a whole. Ron Thomas had developed IDL software for processing the TOA data and thoroughly tested the code with simulated data, and Bill and I set up two stations side by side in the lab to determine the relative accuracy of independently measured signal times. Good agreement was obtained, and Bill was confident that everything would work just fine. But I remained apprehensive that the timing accuracy would somehow be degraded for widely spaced stations in the field. As we finished setting up the Oklahoma network, I got cold feet and changed the location of the final station to be closer in on the western edge of the network than originally planned. This turned out to be totally unnecessary, but the new site turned out to be a better location, at least.

We lucked out in Oklahoma and had an amazing sequence and variety of storms during the 3-4 weeks of operations. But our attempts to process the data for the source locations were a complete failure - all we got out of the processing were occasional noise points due to random correlations in the data. Individual flashes were well-correlated in overall data plots for the different stations, but the processing yielded no correlations on a fine time scale. At an evening gathering of investigators toward the end of MEaPRS I took a set of plots to show everyone, including plots showing the non-solutions. Despite not having any actual source locations, some of my colleagues politely congratulated me on the success of the project! I had to politely decline the congratulations back.

I returned to New Mexico about a week before the end of MEaPRS to accompany my wife Kay to a library conference in Utah. Tim and Jeremiah had been the mainstays of the operations and stayed behind to complete the field program and bring the stations back to New Mexico. Before leaving for Utah, I got together with Ron in his office to see if we could figure out why the processing was not working. A couple of hours before needing to depart I spotted something funny in plots of the station locations. The aspect ratio of the network appeared to be different than on the topographic maps we had marked up during the field operations. In the tried and true ways of old, we made a hard copy of the station location plot and used a ruler to measure the north-south and east-west distances in comparison to the values from the topo maps. Sure enough, the E-W distances were elongated relative to the N-S distances. From that we quickly determined that the latitudinal dependence had been left out of the lat/long to Cartesian coordinate transformations - a basic freshman physics error.

The cosine(lat) term was added to the transformations and bingo!, out came incredibly beautiful pictures of IC flashes. Kay and I left for Utah shortly afterward, with me in a highly euphoric and unusually talkative state, all the way to Utah. Ron got started on the weeks- and months-long effort of processing the Oklahoma data. His code continually displayed the results as the processing proceeded, and we watched with great interest as the data continually unfolded. A particularly striking feature of the Oklahoma results was the essentially continuous and volume-filling nature of the discharges inside the large storms. Regions where there was not lightning stood out like sore thumbs, and quickly became called lightning ‘holes’.

After MEaPRS, Tim and Jeremiah brought the stations back to New Mexico and set them up around Langmuir Laboratory, this time with 900 MHz high speed modem links from each station up to the mountain-top laboratory. Soon afterwards, the stations could be monitored and controlled remotely from our offices and homes in Socorro. The network was operated at Langmuir for the remainder of the 1998 season and through the summer of 1999, and continued to produce beautiful data. In addition to seeing myriads of CG and bilevel IC flashes we immediately began seeing bolt-from-the-blue discharges and to understand how they were produced. Working in conjunction with our Los Alamos colleagues, we found that energetic narrow bipolar events (NBEs) often occurred at the beginning of IC flashes.

Another new and unexpected result was that the mapping data nicely illuminated the lower positive charge regions of storms.

Steve Hunyady and Graydon Aulich working on an original LMA station during the 1999 field program at LangmuirLaboratory

We presented initial results of the Oklahoma and New Mexico observations at the 1998 December AGU meeting, and subsequently at the 11th International ICAE Conference in Guntersville in early June 1999. During questions at the end of my Guntersville talk Hugh Christian revealed that he and John Latham had engaged in a wager about the existence of inverted polarity IC flashes. Hugh was humorously inquiring about what the outcome of the bet would be. As I recall, the wager was for a bottle of Scotch whiskey, with Hugh betting that inverted ICs didn't occur and John betting that they did. Although we didn't understand their significance yet, we had seen clear examples of inverted IC discharges in the Oklahoma data. I cheerfully assured Hugh that he had lost the bet, but he didn't accept the answer. The existence of inverted IC flashes was shown beyond a shadow of a doubt during STEPS, where they were by far the most prevalent type of discharge.

Another sidelight of the Guntersville conference was a last-minute hallway discussion between the NM Tech group and the NASA folks, prior to everyone leaving the conference facility to return to Huntsville. We had started using 'Lightning Mapping System' and 'LMS' as the official name and acronym for the mapper. NASA being the highly acronym-oriented organization that it is, Steve Goodman and Hugh Christian were informing us that they had first priority to the LMS acronym for their proposed geosynchronous optical mapper, in their case standing for 'Lightning Mapping Sensor'. Our position was that the satellite sensor was primarily a concept at that point, whereas we had a working system, but they didn't buy that. Nevertheless, on the drive back to Huntsville with Bill and Ron I wound up concluding that we should change the name after all, and suggested 'Lightning Mapping Array' after the Very Large Array (VLA) radio telescope based in Socorro. Bill and Ron agreed, and upon arriving in Huntsville we informed Steve and Hugh of the change. The irony of the story, of course, is that they subsequently changed the name of the satellite sensor to the more flashy 'Geostationary Lightning Mapper', or GLM. For our part, we have been very happy with LMA - it has a nicer 'ring' to it!

1998 was the first of three major field programs and hectic summers with the LMA. After Guntersville we spent the rest of the '99 season at Langmuir working with Tom Marshall and Maribeth Stolzenburg. They had come to Langmuir along with Ph.D. student Lee Coleman to make balloon-borne electric field soundings for studying the electric evolution of thunderstorms (acronym: SEET). Dave Rust and OU student Aaron Bansemer joined in to help out with the ballooning operations, Tim Hamlin operated the LMA, and I ran the dual-polarization radar from the airport in Socorro, 27 km to the east of Langmuir.

The 1999 Langmuir program was highly successful, with many storms and good sets of balloon flights. We obtained a veritable gold mine of data that is still being looked at today. Tom and Maribeth's balloon packages carried a modified version of the NCAR's newly developed GPS dropsondes. For the first time, the trajectory of the soundings through the storm was accurately known and could be compared in detail with the LMA and radar data. Among other things, we could see how lightning was related to the charge structure of the parent storm, and the effect of lightning in complicating the structure. The LMA data showed the occurrence of low-altitude IC discharges and, combined with the sounding measurements, explained a number of features of ground-based electric field mill records (field excursions associated with precipitation, lightning-induced field 'lockovers', and end-of-storm oscillations) that had long been seen but were not well understood.

The 1999 results reinforced the idea that lightning reflects the charge structure of the parent storm. This, coupled with the fact that the polarity of the discharge channels could be determined from the LMA data, led us to develop the 'charge identification' approach for analyzing the LMA data, in which the storm charge regions are inferred from the lightning mapping observations.

An even bigger field program, the Severe Thunderstorm Electrification and Precipitation Study (STEPS), loomed large on the horizon for the summer of 2000. In the meantime, Bill Rison and Graydon Aulich were busy developing a second generation version of the LMA electronics. Instead of minitower PCs, the new electronics utilized a smaller, PC-104 computer and an improved design and revised form factor of the LMA card. The digitizer rate was increased to 25 MHz to give improved time resolution (40 ns) and reduced window size (80 microseconds). The changes made the electronics package considerably more compact and allowed stations of later networks to be housed in successively smaller and lighter enclosures. The version 2 design was the basis for a set of stations to be supplied to the NASA/Huntsville group for deployment in north Alabama.

In preparation for STEPS and for the North Alabama LMA, I began a sort of second career of hunting down and selecting sites for the mapping stations. This included testing potential sites for locally-generated VHF background noise, which had become an important issue in site selection. During week-long breaks between classes and semesters, I made two reconnaissance trips to the upcoming STEPS project area in northwestern Kansas and eastern Colorado, and a somewhat longer wintertime trip with Graydon to north Alabama.

Having pre-arranged the STEPS sites, and with a well-experienced crew, we set up the 13-station STEPS network in record time of about two weeks during May 2000. The network was 60-80 km in diameter and had daisy-chained wireless ethernet links all the way back to our central operations trailer in Goodland, Kansas. The communications links were a major accomplishment in themselves and were greatly facilitated by the relatively flat and open terrain of the STEPS project area. This was our first experience using wireless ethernet for anything, much less long distances. It was probably one of the first long distance applications of wireless ethernet in the U.S. The LMA network itself was a hybrid of the original Oklahoma/Langmuir stations and five of the newer stations being constructed for the Alabama network. Just driving around to all the STEPS stations was a several hundred mile journey requiring a full day. The station boxes were packed with computer gear and immediately began overheating in the hot sun, resulting in a marathon day-long trip by Ron and Jeremiah to modify the Greenlee boxes for vents and install cooling fans. In addition to the LMA network, Kyle Wiens had developed a set of electric field change instruments and set them up at five of the LMA sites, and Mark Stanley set up and operated the lightning interferometer and slow/fast antenna recording system in the center of the network.

It was not easy keeping the LMA working, but with the expert abilities of Tim, Jeremiah, Bill, and Ron, it produced amazing results throughout STEPS. The communications links enabled us to download sample data files from storms and process them in a timely manner for the morning meetings of the STEPS investigators.

STEPS was a huge success, both in terms of the overall project and for the LMA. A primary goal of the program was to study storms that produced predominantly positive cloud-to-ground (PPCG) flashes. With the mapping data we quickly found that this was due to the storms having an inverted polarity electrical structure from that seen in normally electrified storms. The IC discharges were invariably ‘upside down’ and revealed a deep mid-level positive charge capped by an upper negative charge. This basic structure was confirmed by balloon-borne electric field soundings through the storms by the University of Oklahoma/National Severe Storms Laboratory (OU/NSSL) group under Dave Rust and Don MacGorman. Detailed polarimetric data were obtained on the storms by the CSU-CHILL and NCAR S-Pol radars and, along with data from the Goodland NEXRAD radar, were used by the CSU group under Steve Rutledge to generate high-quality wind fields in the storms and hydrometeor identification results. Overall, these efforts resulted in a series of published case studies of the STEPS storms and scientific results.

STEPS highlighted the need for faster, C-based software to process the voluminous data for the lightning source locations. While in the middle of the field program, Tim Hamlin came up with a key idea about how to efficiently process the multistation TOA data, and Jeremiah Harlin implemented the approach in a major first-time C programming effort. Jeremiah’s code has since been succeeded by a structured and more flexible 3rd generation C++ program developed by graduate student Harald Edens, but performed very well for a number of years.

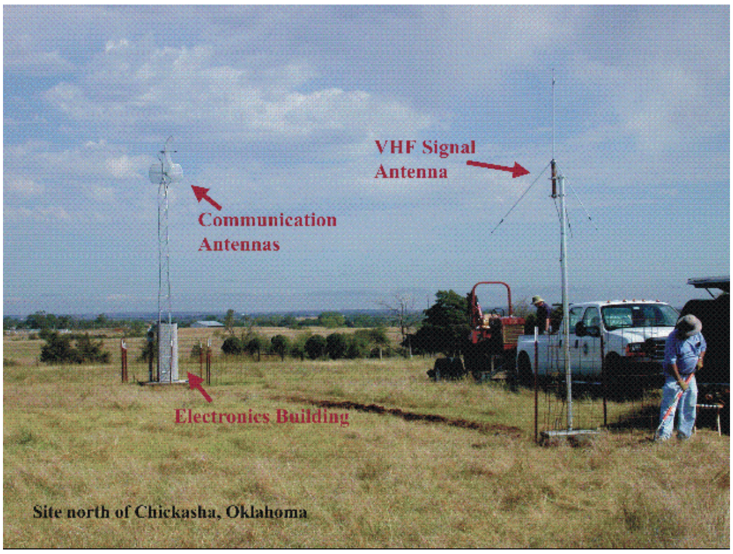
Two experiments were conducted during STEPS that were important in the LMA’s development. Bill Rison set up a two-day test in which the network was operated with short, 10 microsecond time windows, rather than the 80 or 100 microsecond windows of normal operations. While requiring much longer times to process the data, the experiment was a major success and provided substantially more detailed pictures of individual flashes. The 10 microsecond mode has subsequently become the preferred mode of operation when it is important to obtain the most complete data.

The second experiment was conducted by Bill Winn and Steven Hunyady, along with then-visiting Dutch student Harald Edens. A lightweight pulsed VHF transmitter was launched on a free balloon and tracked by the LMA as it ascended into the base of the stratosphere. The balloon package included a handheld GPS receiver, whose location versus time could be compared with the LMA data to assess the accuracy of the LMA locations. Bill Winn came up with the ingenious idea of using the time intervals between VHF pulses to communicate the 1 second serial binary GPS data stream back down to the ground. After a couple of attempts a final flight produced beautiful data. The experiment provided the basis for a detailed study of the accuracy of the LMA, published in a 2004 issue of JGR. Bill and Steve hoped to recover the balloon package by having the LMA track it all the way to the ground, similar to the Langmuir ballooning operations, but the package went too high in the atmosphere (~20 km) before balloon-burst, and the instrument failed part way into the descent.

Following STEPS, LMA networks were supplied to NASA and to the University of Oklahoma and used to set up the North Alabama and Oklahoma LMAs. Both networks had dedicated wireless ethernet links for processing the data in real time, and have been operating continuously since about 2002 and 2003, respectively. The NASA group, comprised of Steve Goodman, Rich Blakeslee, Jeff Bailey, and John Hall, developed the first real-time processing and display system for the LMA, using the Hamlin/Harlin C processing code. With this in hand, they and the staff of the Huntsville Weather Forecast Office (WFO), notably Chris Darden, played a lead role in the use of total lightning data for nowcasting operations.

The original set of Oklahoma stations was destroyed in a warehouse fire in July 2001, hours after being personally delivered to the OU group by Graydon. The fire also destroyed one of the mobile SMART radars that was being housed in the facility at the time, along with a considerable amount of equipment used in mobile ballooning and other field operations. The LMA was replaced a year later by a second system which, to put a positive light on it, incorporated the third and still-current generation electronics design and improved station housing. The Oklahoma LMA has provided support for several research studies, including the Thunderstorm Electrification and Lightning Experiment (TELEX) in 2003 and 2004, as well as forecasting studies. Current and archived data for the Alabama and Oklahoma systems can be seen at http://branch.nsstc.nasa.gov/PUBLIC/NALMA/ for the Alabama LMA and at http://lightning.nmt.edu/oklma/ for the Oklahoma LMA. The Alabama LMA has recently started to be augmented by several stations in the Atlanta area, operated by John Trostel of the Georgia Tech Research Institute. A third LMA network was installed closer to home at White Sands Missile Range in south-central New Mexico. The White Sands LMA became operational in 2004/2005 and is used by the WSMR Meteorological Office for range operations and for nowcasting studies by NCAR.

Subsequent to STEPS, Steve Hunyady and Bill Winn embarked on a multi-year effort to set up a research LMA around Langmuir Laboratory. They were joined in this by Harald Edens, who by then had returned to Tech as a Ph.D. student to work with the LMA. The basic idea of the Langmuir network was to have a concentrated array of stations along the high ridges of the mountain-top observatory for detailed observations of individual lightning discharges and to support the various other Langmuir studies. For the first time, the LMA did not function very well. In addition to often being damaged by lightning, the high-altitude (3 km msl) stations picked up signals from distant, interstate television transmitters. Whereas in 1999 only two stations were on the mountaintop, now there were eight - a sufficient number for the stations to try and locate the distant signals, in the process contaminating local lightning observations. A second problem with the network was that during overhead storms the strong electric fields at the ground caused a cacophony of corona- and point discharge-produced radio frequency radiation from the receiving antennas and nearby ground sources that further contaminated the lightning signals. The distant transmitter problems were mostly eliminated following the recent conversion to digital television in the U.S., which resulted in most TV transmitters in the lower VHF converting to higher frequencies. At the same time the number of lower elevation, outlying stations were increased to dilute and discriminate against the mountain-top corona effects. The Langmuir network currently consists of 9 outlying and 7 mountain-top stations, all operated in 10 microsecond mode, and produces impressive images of lightning over and around the Laboratory.



Oklahoma LMA station, under construction by Don MacGorman

The Langmuir network has provided a valuable test bed for further development of the LMA technology. Included in this has been development of solar-powered stations and reducing the power consumption of stations. The stations run off of 12 V DC and currently require about 10 watts of power. A totally new, fourth generation 'LMA on a chip' design is currently being developed that will decrease the consumption to a couple of watts for truly remote operation. Also, as a side-product to his studies at Langmuir, Harald Edens recently improved the speed with which data can be processed and the latency of displaying the results in real time. Called 'LiveLMA', the new software processes and broadcasts the lightning activity over the web on a second-by-second basis.

Shortly after we began developing the LMA, Global Atmospherics Incorporated of Tucson, Arizona (now Vaisala), and operators of the National Lightning Detection Network (NLDN), independently entered into a technology transfer agreement with NASA to develop a commercial version of the KSC LDAR system. Ken Cummins (then with GAI) announced the start of this project to the atmospheric electricity community at the 1995 Fall AGU CASE meeting. The system, called LDAR-II, was being designed to use the same GPS timing and digital communications approach as the LMA. In the summer of 1996, at the end of the Tenth ICAE Conference in Osaka, Ken and I discussed coordinating the development efforts of the two systems. The result was that data interfacing and formatting protocols we were developing for the LMA stations were incorporated into the LDAR-II system, and the IDL-based

XLMA format for displaying and analyzing data was made common to both systems.[4] A prototype LDAR-II station was tested alongside one of the LMA stations during STEPS, and a complete demonstration network was set up in the Dallas-Fort Worth (DFW) area in the summer of 2001. The DFW LDAR-II network continues to provide forecast and research lightning data for the metropolitan area and is being operated in conjunction with a network of Vaisala's 2- and 3-dimensional interferometric mapping stations.

Two other LDAR-II networks are being operated in the U.S.; the first being in the Houston Metropolitan area and the other at Kennedy Space Center. The 12-station Houston LDAR-II network was set up by Dick Orville of the University of Texas at Austin and became operational in 2005 (see http://www.met.tamu.edu/ciams/ldar/). The 9-station network at KSC replaced the earlier LDAR system and became operational in 2007; data from it can be seen at:
http://branch.nsstc.nasa.gov/PUBLIC/LDARII/.

In July 2005 a workshop was held in Fort Worth for users of LMA and LDAR total lightning data. The meeting was hosted by Vaisala and by the local Weather Forecast Office, and followed an initial workshop held two years earlier in Huntsville. The ad hoc group named itself 'Southern Thunder' and has continued to remain active, holding a well-attended workshop in Cocoa Beach in July 2009. One outcome of the Fort Worth workshop was a recommendation to set up a demonstration LMA network in the Washington D.C. metropolitan area. We were in the process of developing a portable version of the LMA stations and volunteered to loan a set of stations to the project. The 'DC Demonstration LMA', as it was called, was to be a cooperative project between the NASA and NM Tech groups working in coordination with the National Weather Service. The NASA/NM Tech proposal to the NWS was accepted by them, and we proceeded to set up an 8-station network in the DC/Maryland/Virginia area in the late spring and summer of 2006. The DC LMA was experimental in that it was the first system to be set up in an RF-noisy urban environment and to use the internet as a means of communicating with the stations. Modern buildings are a source of substantial noise in the lower VHF and this necessitated operating the DC LMA in the upper VHF, in this case television Channel 10 (192-198 MHz). The network is administered by the NASA/Huntsville group and was expanded to ten stations in May 2009. Decimated data are processed in real time and communicated to the Sterling Virginia WFO for their nowcasting operations, overseen by Steve Zubrick (see http://branch.nsstc.nasa.gov/PUBLIC/DCLMA/).

In addition to thunderstorm studies, the LMA stations and networks are being increasingly used for other applications. The portable stations were designed with the specific purpose of enabling networks to be simply and rapidly set up, either on a short-term battery-powered basis or for quick deployment, longer term studies. Their development was supported by an NSF Small Grant for Experimental Research, with a particular application being the study of volcanic lightning. The initial complement of portable stations was completed in December 2005. The stations consist of a light-weight styrofoam picnic cooler placed inside a 'Rubbermaid' storage container, and are sufficiently weatherproof to be operated outdoors for extended periods of time. The containers can also be checked as luggage on

4) XLMA is the extensive IDL-based software package that has been continuously developed over the years by Ron Thomas, computer science student Nate Campbell and a number of other Tech students. It is widely used for interactively analyzing the processed LMA data and implements a large number of analysis features, including flash algorithms, charge identification, animations, and diagnostic functions.

airplane flights, along with associated station equipment, for rapid deployment in distant locations. Within a month of the stations being ready, Mount St. Augustine erupted in Alaska's Cook Inlet. Working in conjunction with Steve McNutt, Guy Tytgat, and Ed Clark of the Alaska Volcano Observatory (AVO), we quickly deployed two stations along the Kenai Peninsula coast, just in time to capture the next set of eruptions beginning on January 27, 2006. The first of the eruptions was very active electrically, both during the explosion itself and subsequently in the plume above and downwind of the volcano.

Setting up portable mapping stations on Kenai Peninsula coast overlooking Cook Inlet, used to study Redoubt Volcano eruptions. Above: Paul Krehbiel working on station electronics. Right: Ron Thomas setting up VHF receiving antenna. Redoubt is in background obscured by ever-present clouds.

Since Augustine, and with additional NSF support, the portable stations have been deployed above the lava lake on top of Mt. Erebus in Alaska, around the Pavlof volcano in the Aleutian Islands, and offshore from the 2008 Chaiten eruption in southern Chile. The deployments produced minimal results due to missing the initial explosive sequences, but this changed with the recent eruption of the Redoubt volcano on the west side of Alaska's Cook Inlet. As with other major Alaskan volcanoes in the southern Alaska chain, Redoubt was being closely monitored by AVO. It became seismically active sufficiently in advance of erupting for us to set up a 4-station network along the Kenai coast on the opposite side of Cook Inlet. A few weeks later, between March 22 and April 4, Redoubt erupted more than 20 times, with many of the eruptions being quite strong. Cloudy weather prevented most of the eruptions from being observed visually, but all were recorded at VHF by the mapping stations. The lightning activity in many of the eruptions was spectacular, being as strong or stronger than that observed in large great plains storms. The observations are the subject of several presentations at the upcoming Fall AGU meeting and are posted online at http://lightning.nmt.edu/redoubt/.

In closing, it is important to note that the LMA has been very much a team effort. The system could not have been developed without the highly capable support and participation by Graydon Aulich, Sandy Kieft, and Steve Hunyady of the Langmuir Lab staff, and by the dedicated efforts of talented graduate and undergraduate students, notably Ph.D. students Tim Hamlin, Jeremiah Harlin, Harald Edens, and Sonja Behnke, and undergraduate and Master's students Charles Stanhope, John Sinnott, Mike Davis, Tamara Barber, Mike Jones, Demian Shown, Nate Campbell, Kyle Wiens, Sean Gorman, Nick O'Connor, and Dan Rodeheffer.

ANNOUNCEMENTS

New Books

A monograph "Electromagnetic Phenomena Associated with Earthquakes"

Edited by M. Hayakawa, has just appeared. It contains ten chapters by leading scientists in the field of seismo-electromagnetics (total 279 pages).

Chapter 1: The ultralow-frequency magnetic fields associated with and preceding earthquakes.
A. C. Fraser-Smith.

Chapter 2: Study of local anomalies of ULF magnetic disturbances before strong earthquakes and magnetic fields induced by tsunami.
Yu. A. Kopytenko, V. S. Ismagilov and L. V. Nikitina.

Chapter 3: Stress-activated positive hole charge carriers in rocks and the generation of pre-earthquake signals.
F. Freund

Chapter 4: Pre and post seismic disturbances revealed on the geochemical data collected in Kamchatka (Russia) during the last 30 years.
P. F. Biagi.

Chapter 5: Seismogenic perturbation in the atmosphere.
M. Hayakawa.

Chapter 6: Lower ionospheric perturbations associated with earthquakes, as detected by subionospheric VLF/LF radio signals.
M. Hayakawa.

Chapter 7: Earthquake precursors observed in the ionospheric F-region.
Tiger J. Y. Liu

Chapter 8: Anomalous seismic phenomena: View from space.
M. Parrot.

Chapter 9: Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) model.
S. Pulinets.

Chapter 10: Lithosphere-Atmosphere-Ionosphere Coupling due to Seismicity.
O. A. Molchanov.

Publisher: Transworld Research Network (India), and please visit the site of the publisher on further details. http://www.ressign.com/UserBookDetail.aspx?bkid=894&catid=207

A special issue ***"Electromagnetic phenomena associated with earthquakes and volcanoes"*** has just appeared in Physics and Chemistry of the Earth (vol.34, issues 6-7, p.341-515, 2009). Guest editors are M. Hayakawa, J. Y. Liu, K. Hattori, and L. Telesca, and it contains preface and 22 scientific papers selected by the peer-review process. You can enjoy the present situation of seismo-electromagnetic studies.

CONFERENCES

2009 AGU Fall Meeting

The fall meeting of AGU will be held on 14-18 December 2009, at the Moscone Center West, 800 Howard Street, San Francisco. For detail, please visit http://www.agu.org/meetings/fm09/.

2010 Asia-Pacific EMC Symposium

The 2010 Asia-Pacific Electromagnetic Compatibility Symposium and Technical Exhibition will be held in Beijing International Conference Center, Beijing China, Monday, April 12 through Friday, April 16, 2010.

After the resounding success of the **2008 APEMC in Singapore** jointly organized with the **19th EMC Zurich Symposium**, it was decided to hold the **2010 Asia-Pacific EMC Symposium in Beijing**. This event will continue in the spirit of APEMC and at the same time address the EMC community of the Asian-Pacific region and its link to the world. Beijing has been selected to host the 2010 APEMC because of its fabulous facilities and excellent business climate with the great success of the 2008 Beijing Olympic Game, and also because it is the world most vibrant city both in economic and technology development with rich cultures, modern & historical landmarks.

Following the tradition of APEMC, we are planning a full week of EMC-related events. The symposium will cover the entire scope of electromagnetic compatibility as EMC measurement techniques, EM environment, lightning protection, power system EMC and high power EMC, IEMI, transportation EMC, system-level and chip-level EMC and protection, antenna and wave propagation, computational electromagnetics, semiconductor device and IC EMC, wireless communication EMC, bio-medical electromagnetics, and nanotechnology for EMC. On the other hand, 18 special sessions, several industrial forum, two topical meeting, and about 20 workshops and tutorials will be organized, all will be presented by famous EMC experts.

Now the paper submission was closed, 540 high quality papers from 41 countries and regions were submitted, and other more than 30 invited papers are being submitted, most of the top EMC experts will attend this event.

By the way, a topical meeting on lightning protection will be held in APEMC2010, the chairs of this topical meeting is Prof. Vladimir Rakov, Dr. Shigeru Yokoyama, and Prof. Farhad Rachidi, a Technical Committee was organized for this topical meeting, members include A. Ametani, Y. Baba, A. Borghetti, M. Bouquegneau, J. H. Chen, W. J. Chen, J. V. Coller, V. Cooray, F. Heidler, S. Grzybowski, Z. A. Hartono, M. Ishii, Zen Kawasaki, B. H. Lee, Korea, G. Maslowski, C. Mata, M. Loboda, C. Mazzetti, M. Paolone, A. Piantini, X. S. Qie, M. Rubinstein, R. Thottappillil, and S. Visacro. Now 80 papers were submitted for this topical meeting.

So come and join the EMC-ASIA-PACIFIC WEEK in Beijing in 2010! We will offer a rich scientific program of highest quality with invited speakers from all over the world and provide a broad forum of exchange both for academia and industry alike. On the other hand, a technical exhibition on EMC RF/Microwave Measurement and Instrumentation will be organized. For exhibition, please contact the Exhibition Chair of APEMC2010, Dr. Jun Hu, by email hjun@tsinghua.edu.cn.

For more information please browse the website **http://www.apemc2010.org, www.emc-zurich.org**, or contact with the conference president, Prof. Jinliang He by email hejl@tsinghua.edu.cn.

2010 EGU GENERAL ASSEMBLY

The General Assembly 2009 of the European Geosciences Union (EGU) will be held in **Vienna**, Austria, on **2 – 7 May 2010.** The EGU General Assembly covers all disciplines of the Earth, Planetary and Space Sciences. Especially for young scientists the EGU appeals to provide a forum to present their work and discuss their ideas with experts in all fields of geosciences.
The website address of the assembly is: http://meetings.copernicus.org/egu2010/index.html

30th International Conference on Lightning Protection (ICLP)

On behalf of the organizing committee we invite you to attend the 30th International Conference on Lightning Protection, ICLP 2010, to be held in Cagliari, in the beautiful island of Sardinia in Italy.

The ICLP 2010 conference continues the tradition of the preceding ICLP conferences, the last ones being held in Uppsala, Kanazawa, and Avignon. The ICLP offers a unique platform for the exchange of scientific and technical information on lightning physics and protection.

Topics of interest include: lightning discharge, lightning occurrence characteristics, lightning electromagnetic impulse (LEMP) and lightning-induced effects, lightning attachment, lightning protection (buildings, power systems, electronic systems, wind turbines), lightning deleterious effects, lightning testing and standards.

CONFERENCES

Important Dates:

15 January 2010	→	Extended summary submission
16 April 2010	→	Notification of acceptance
04 June 2010	→	Full paper submission

For more information, visit the conference web site: http://www.diee.unica.it/iclp2010/index.htm

14th International Conference on Atmospheric Electricity

As announced in the last issue of ICAE newsletter, 14th International Conference on Atmospheric Electricity (14th ICAE) will be held in Rio de Janeiro (the city to host 2016 summer Olympic Games), Brazil on August 08-12, 2011. Abstract submission will start on **March 1st, 2010.** The overall information on the conference will be available on the website of the conference (http://www.icae2011.net) and on the website of the International Commission on Atmospheric Electricity (http://icae.jp) in December 2009.

Atmospheric and Space Physics Group at Bard High School Early College Queens (BHSEC Queens), Long Island City, Queens, NY, USA

Natalia N. Solorzano (nataliansolo@gmail.com)
Jeremy N. Thomas (jnt@u.washington.edu)
http://earthweb.ess.washington.edu/jnt/

Lightning in tropical cyclones globally: Solorzano and Thomas are investigating tropical cyclone lightning using the World Wide Lightning Location Network (WWLLN). Using the full temporal (better than 1 ms) and spatial capabilities of WWLLN (about 10 km), we find episodic inner core lightning outbreaks prior to and during changes in storm intensity for tropical cyclones in all global basins. A manuscript that presents case studies of North Atlantic Hurricanes Emily, Katrina, and Rita (2005) has been accepted for publication in JGR-Space Physics. A new result of our analysis indicates an increase in the relative number of positive cloud-to-ground lightning in the inner core prior to and during periods of storm weakening, which is potentially important for hurricane intensity change forecasting. Additionally, we find that the majority of inner core lightning located by WWLLN had peak currents that surpassed the threshold needed to produce optical emissions (elves) and drive electron density perturbations in the lower ionosphere (80-105 km). Figure 1 shows polarity and energetics of inner core lightning in Hurricane Emily.

Urban effects on lightning activity in Queens, NY: Thomas and Solorzano are working with their students to study of how human activities that cause pollution and temperature changes in Queens might be affecting the local weather and lightning activity. A weather station, a video camera, and WWLLN lightning station have been installed at BHSEC Queens. To see our students explain this project in their own words, please see our video at: http://www.youtube.com/watch?v=seAMK5S0yZc&feature=player_embedded .

Reexamination of magnetic precursors to earthquakes: The precursors to the 1989 Loma Prieta and 1993 Guam earthquakes have been carefully reexamined. This work has been recently published in PEPI and GRL.

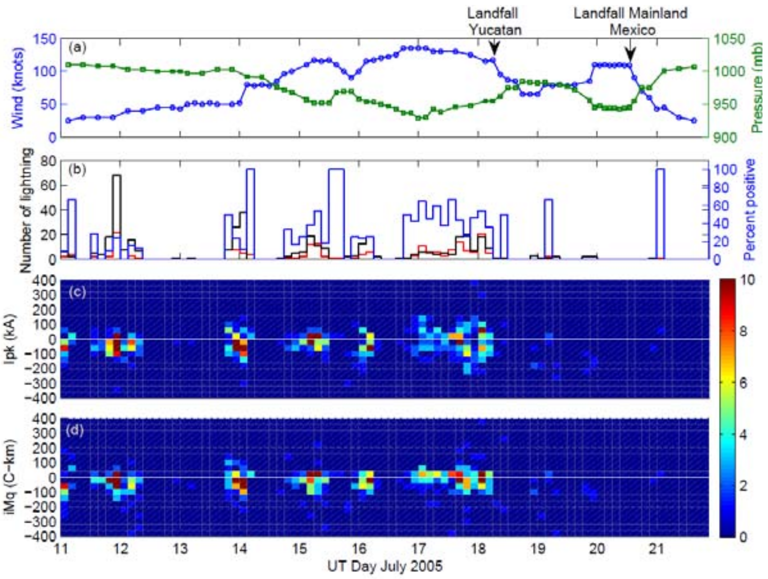
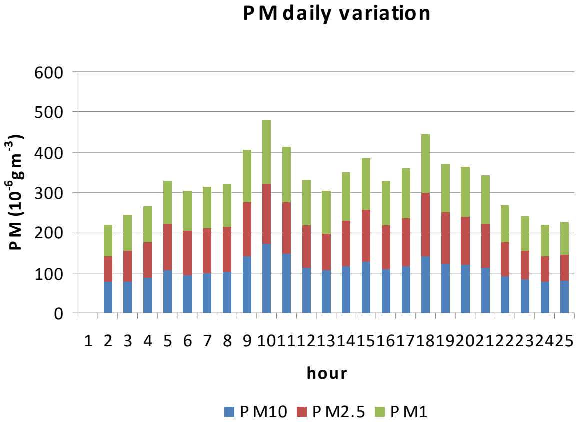


Figure 1 Temporal evolution of inner core lightning in Hurricane Emily. (a) Maximum sustained winds (1-minute averages in knots shown as blue circles) and minimum central pressure (green squares). (b) Lightning activity within 100 km of the best-track storm center binned in 3-hr intervals (black bars are negative CG lightning, red bars are CG positive lightning, and blue bars are percent positive lightning (c) A spectrogram of peak currents (I_{pk}) using 3-hr by 40 kA bins. (d) A spectrogram of vertical impulse charge moment changes (iM_q) using 3-hr by 40 C-km bins. The color bar indicates the number of lightning events in each bin, and dark red represents 10 or more events. Events with I_{pk} and iM_q magnitudes greater than 400 kA (C-km) are included in the 360-400 kA (C-km) bins. (From Thomas et al. 2009)

Atmospheric Electricity Group, Departments of Physics, University of Shkodra and Tirana, Albania

Florian Mandija; fmandija@yahoo.com

Atmospheric group in Albania is in an important phase of the restructuring of the atmospheric laboratory in University of Shkodra. Nowadays we are working to receive nano size mobility particle spectrometers, and aerosol counters. The objective is to study the nucleation process, and to evaluate aerosol-ion interaction in the nucleation mode of the aerosols. It is taken a special intention beside atmospheric ion measurements, on the aerosol monitoring. Aerosol size determinations in several regions in diverse meteorological conditions are the principal investigations. The size interval of measured aerosol particles is micrometric and sub-micrometric, including a part of the accumulation mode and all the coarse mode. During the period May-November, there are carried out several measurement campaigns and continuous monitoring of the particulate matter. The principal measurements consist on the monitoring of the variation of the PM1, PM2.5 and PM10 in the centre of the city of Shkodra, in its suburbs and in the remote areas alongside the Shkodra Lake and Tarabosh mountain (the southeast extreme of the Dinarie Alps). The measurement is realized using mobile and stationary instruments. Two principal problems are taken into the focus: the daily variation of the PM-s and the comparison of PM concentrations among urban centre, suburbs and remote areas.



The main objective in both analyses is the determination of the traffic effects on the air quality in the urban centre in the city of Shkodra. Primary traffic effects are considered motor emissions and dust resuspensions. Both these processes are analyzed using the meteorological effects, especially the reduction of the aerosol concentration by the precipitation. The averaged daily variation of PM1, PM2.5 and PM10 are presented by the attached figure.

It is important to mention that the overall results of the PM2.5 and PM10 concentration averaged over all the measurement time exceeds the international recommendations for the air quality standards.

Atmospheric Electricity Group, Physics Department at the University of Munich, Garching, Germany

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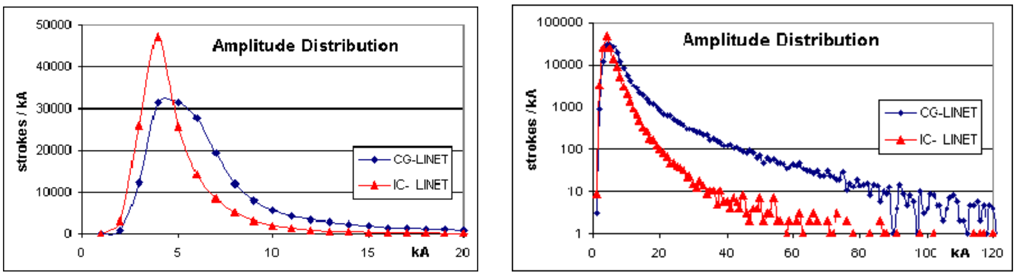
One of the topics pursued by the Munich research group concerns cloud lightning. For this purpose, the European lightning detection network LINET is used, which operates solely in the VLF/LF regime and exploits a 3D-technique for the discrimination of pulses emitted near ground (CG) and within the clouds (IC). Since this discrimination procedure relies on both geometrical effects and highly precise time-of-arrival measurements, it is independent of signal shape, strength and polarity. The network differs from others in three aspects: it has mostly small baselines (~200 km), handles all lightning pulses irrespective of shape, and employs a highly advanced combination of site-error and propagation corrections; the latter are very important for the unprecedented location accuracy of ~100 m, described in the Newsletter of May 2009. All together, a wealth of very small signals is detected and reliably located. Given these circumstances, abundant reporting of cloud events becomes feasible, which is representative for the electric activity of convective storm cells. The figures below illustrate a typical result for an amplitude distribution of an intensive storm, in both a linear and semi-log scale for CG and IC events.

For small amplitudes the IC signals dominate, while for stronger currents the CG strokes become more frequent. A certain portion of the small CG signals may not be totally typical for a return stroke, but may reflect a distinct, fast current surge during a ground flash. The IC events exhibit mostly, though not in all cases, typical features of a lightning stroke, in contrast to VHF emission of leader channels. CG and IC strokes are represented by two entirely different distributions; this may be taken as verification of the discrimination power of the employed technique. Data of this kind has been collected more extensively; a comprehensive description and analysis of lightning data compiled with one and the same network in four continents is given by Hoeller et al. (2009) *[Hoeller, H., H.-D. Betz, K. Schmidt, R. V. Calheiros, P. May, E. Houngninou, and G. Scialom, "Lightning characteristics observed by a VLF lightning detection network (LINET) in Brazil, Australia, Africa and Germany, Atmos. Chem. Phys., 9, 7795-7824, 2009.]* This paper also addresses the emission height of IC strokes in the various areas with different meteorological conditions from mid-latitudes to tropics, and discusses many other lightning parameters and derived quantities such as lightning-induced NO_x production.



Amplitude distribution from VLF/LF-based detection and location of ground strokes and cloud lightning for a strong storm in central Europe, in a linear (left) and semi-log scale (right). Polarities are not identified.

Atmospheric Electricity Research Group at the Institute of Geophysics, Pol. Acad. Sci., Warsaw, Poland

In the summer 2009 (from 16 June to 16 September) our joint research team from four institutions, i.e. the Institute of Geophysics (baranski@igf.edu.pl), Warsaw University of Technology (marek.loboda@ee.pw.edu.pl), Space Research Centre (morawski@cbk.waw.pl) and Institute of Meteorology and Water Management (zdzislaw.dziewit@imgw.pl) operated successfully, in the region of Warsaw, a small lightning detection system, the Local Lightning Detection Network (LLDN), consisting of six measuring stations. Lightning activity was also monitored in this area by the Polish SAFIR/PERUN lightning detection system. From the LLDN-detected E-field, triggered by nearby lightning discharges, we evaluated the position, time and electric charge structure of multiple cloud-to-ground strokes, using the point electric charge model (Krehbiel et al., 1979). Initial results of this campaign will be presented during the final COST P18 meeting in Stockholm (Sweden) on 23-24 November 2009. Furthermore, we also implemented and used a digital high-speed camera for the analysis of the time evolution of natural lightning channels and dynamic evolution and lightning activity associated with supercell and tornado events that occurred in Poland on 20 July 2007. These results will be published soon in the special issue of our journal, i.e. Publications of the Institute of Geophysics (Publ. Inst. Geophys. Pol. Acad. Sc.), volume D-73(412), 2009, which will shortly be available on-line at http://pub.igf.edu.pl/index.php. This special issue is published to commemorate the 90th birthday of our group leader in atmospheric electricity and lightning research Stanislaw Michnowski.

At the Geophysical Observatory in Swider, we continue measurements of the vertical electric field, vertical air-Earth current density, electrical conductivity and simultaneous meteorological observations and measurements of radioactivity and air pollution (M. Kubicki, B. Laurikainen). The data recorded in the recent period will be stored in a newly prepared database (Marek Kubicki, swider@igf.edu.pl). Also, at the Polish polar station in Hornsund, Spitsbergen, electric field recordings, magnetometer and riometer data are collected and meteorological observations and measurements of the radioactivity and air pollution are continued (M. Kubicki, S. Michnowski, B. Laurikainen). The measurements of the electric field obtained in the mid-latitude observatory in Swider and the high latitude Hornsund station, and magnetic field components from the IMAGE magnetic station network as well as satellite recordings of the interplanetary magnetic field (IMF) and solar wind data are used for the studies of the response of electric field to the variations of solar wind parameters, in collaborations with our Russian colleagues (N.G. Kleimenova: kleimen@ifz.ru, O. V. Kozyreva, M. Kubicki, S. Michnowski). Moreover, S. Michnowski is finishing now his new version of an extended paper on the ground-level electric field and current variations in polar and mid-latitude regions in relation to solar wind changes. We also collaborate with the University of Leicester, UK, and support the development of the new high-resolution model of the global atmospheric electric circuit: EGATEC. More recently, Anna Odzimek (aodzimek@igf.edu.pl) has joined our group from the University of Leicester and in collaboration with Leicester she will continue the work on EGATEC in our institute.

Equatorial Geophysical Research Laboratory, Indian Institute of Geomagnetism, India

Equatorial Geophysical Research Laboratory (EGRL) has full fledged atmospheric and upper atmospheric laboratories equipped with state-of-the-art of the in-situ-Instruments spread over 42 acres of land in the southern peninsular state of India. Within a short span, a number of significant scientific findings have emerged from the experiments conducted here and now it became renowned centre for Atmospheric and Geophysical studies. This is one of the Regional Centers of Indian Institute of Geomagnetism (IIG), first started by modest means as magnetic observatory in 1992 by IIG's former Director Prof. R.G Rastogy. The EGRL research group has recently published two papers enlisted in the publication list.

IIG will be hosting a training programme for young researcher in Atmospheric Sciences during January 6-19, 2010 (Sponsor Dept. of Science and Technology, Govt of India). More details available in www.iigm.res.in.

Geodetic and Geophysical Research Institute, Sopron, Hungary

GGRI was the hosting institute of the 11th Scientific Assembly of IAGA in Sopron, Hungary between August 23 and 30. The II.01 Symposium titled "Electrodynamical coupling from the troposphere to the magnetosphere related to thunderstorm electrical activity" was held in the frame of this assembly with 20 oral (4 invited) lectures and 7 poster presentations. Conveners and co-conveners were Colin Price, Gabriella Sátori, Fernanda T. São Sabbas and Elisabeth Blanc.Veronika Barta, József Bór, Tamás Nagy and Gabriella Sátori from GGRI contributed to the

"Sprite with the Moon" photoed by József Bór

symposium with one oral and three poster presentations reporting on their studies on background and transient Schumann resonances based on SR measurements at Nagycenk Observatory, Hungary as well as observation of TLEs above Central Europe from Sopron.Developing SR data base was discussed during the IAGA Assembly for the formal inversion of the background Schumann resonance to quantify evolving global lightning activity described by Vadim Mushtak and Earle Williams, MIT.

József Bór made a study trip to Israel to the Tel Aviv University (Colin Price's group) and Open University (Yoav Yair's group) to calibrate our camera for TLE observation and to visit the SR field site in the Negev Desert at Mitzpe Ramon.

Indian Institute of Tropical Meteorology, PUNE

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A research work titled "Lightning and its association with low pressure systems over the Indian seas" has been performed. The main objective of this work is to study the lightning activity associated with Low Pressure Systems (LPS) over Indian seas: Arabian Sea (AS) and Bay of Bengal (BoB) by using Lightning Imaging Sensor (LIS) gridded (1^o*1^o) data for a 10 year period (1998-2007). The spatial variation of lightning activity is found to be maximum at 7^o-9^o N and 65-73^o E over AS, whereas over BoB the activity is maximum at 16^o-20^o N and 87^o-89^o E. The study revealed that the monthly mean variation of lightning and Sea Surface Temperature (SST) a maximum occurrence in the month of May and October. The amplitude of first maximum (May) is higher than second maximum (October). The behavior of lightning and Sea Surface Temperature (SST) for the months March-September during drought, deficient and normal monsoon years (2002, 2003 and 2004) is also examined. The analyses shows that peaks SST and lightning occurred in the month of April for 2002 and 2004 (drought and deficient monsoon years) over AS and for 2003 (normal monsoon year) the lightning and SST peak occurred in the month of May over AS and BoB. The authors have also made an effort to examine first time the influence of Low Pressure System (LPS) and interactions with change in SSTs over the Indian seas. The monthly variation of LPS over Indian seas shows that the performance of the monsoon on a seasonal and monthly basis respectively depends on the total number of lows and depressions forming in the monsoon trough and the number of days with the existence of LPS. The LPS tracks reach up to northwest India during normal years whereas they are confined to central India during drought years.

Laboratory of Lightning Physics and Protection Engineering, Chinese Academy of Meteorological Sciences, Beijing, China

Guangdong Comprehensive Observation Experiment on Lightning Discharge (GCOELD): From mid-May to the end of August 2009 collaborating with Guangdong Meteorological Bureau, Laboratory of Lightning Physics and Protection Engineering (LiP&P) continued the GCOELD in Guangdong, China. The experiment mainly includes artificially triggering lightning experiment, comprehensive observation on the characteristics of acoustic, optic, electric and magnetic signals of natural and artificially triggered lightning, observation on the effects of lightning electromagnetic pulses to electronic equipments, and lightning electromagnetic shielding effects of construction models with different constructs. Four scientific issues were addressed in the experiment: (1) channel current characteristics of different discharge processes in triggered lightning; (2) propagation characteristics of leaders in the attachment process of natural lightning; (3) characteristics of lightning induced voltage and current in different cables, same cables with different embedding conditions and different shielding ways; (4) lightning shielding effects of construction models with different structures under authentic lightning environment. In 2009 GCOELD, a total of 7 lightning were triggered. In classical triggered lightning flashes, the channel current data with high temporal resolution and precision were obtained, including that of large current processes (e.g. return stroke) and small current processes (e.g. continuing current). The synchronous multi-parameters data of considerable natural lightning events were also observed, especially that of attachment process of downward lightning which stroke on high buildings. Study of lightning electromagnetic pulse protection was deepened and refined, and the lightning induction characteristics of cables under the authentic lightning discharge conditions were analyzed systematically.

Operational Application of Lightning Nowcasting and Warning Technique: LiP&P has established a synthetical lightning warning and forecasting method and developed the Lightning Nowcasting and Warning System (CAMS_LNWS). The system proposed a lightning characteristic diagnose and nowcasting scheme for strong convective weather in typical region and adopted a multi-data, multi-parameter and multi-algorithm lightning nowcasting method. It integrated observation data from radar, satellite, lightning monitoring system, ground electric instruments and sounding instruments, with weather pattern forecasting products, charge and discharge model, and employed algorithms of region recognize, track and extrapolate, and decision tree. The system supplies products of Lightning Occurrence Probability, Moving Trend of Lightning Activity Area and Lightning Occurrence Probability of Key Area (Fig1, Fig2), automatically. Through the operational application, a technical scheme was proposed for operational development and test of lightning warning system platform. The scheme is a complementarity of the model and algorithm for regional lightning warning and forecasting, and achieves application service with lightning nowcasting and warning products. During the past two years, operational promotion and application of CAMS_LNWS have been widely conducted in China. Through the promotional and technique research, LiP&P has established a lightning monitoring and warning system platform and conducted improvement, upgrade and technical support for system users. Furthermore, the CAMS_LNWS also participated in the 2008 Olympic and Paralympics Weather Service, and played an important role in the meteorological service of lightning nowcasting and warning.

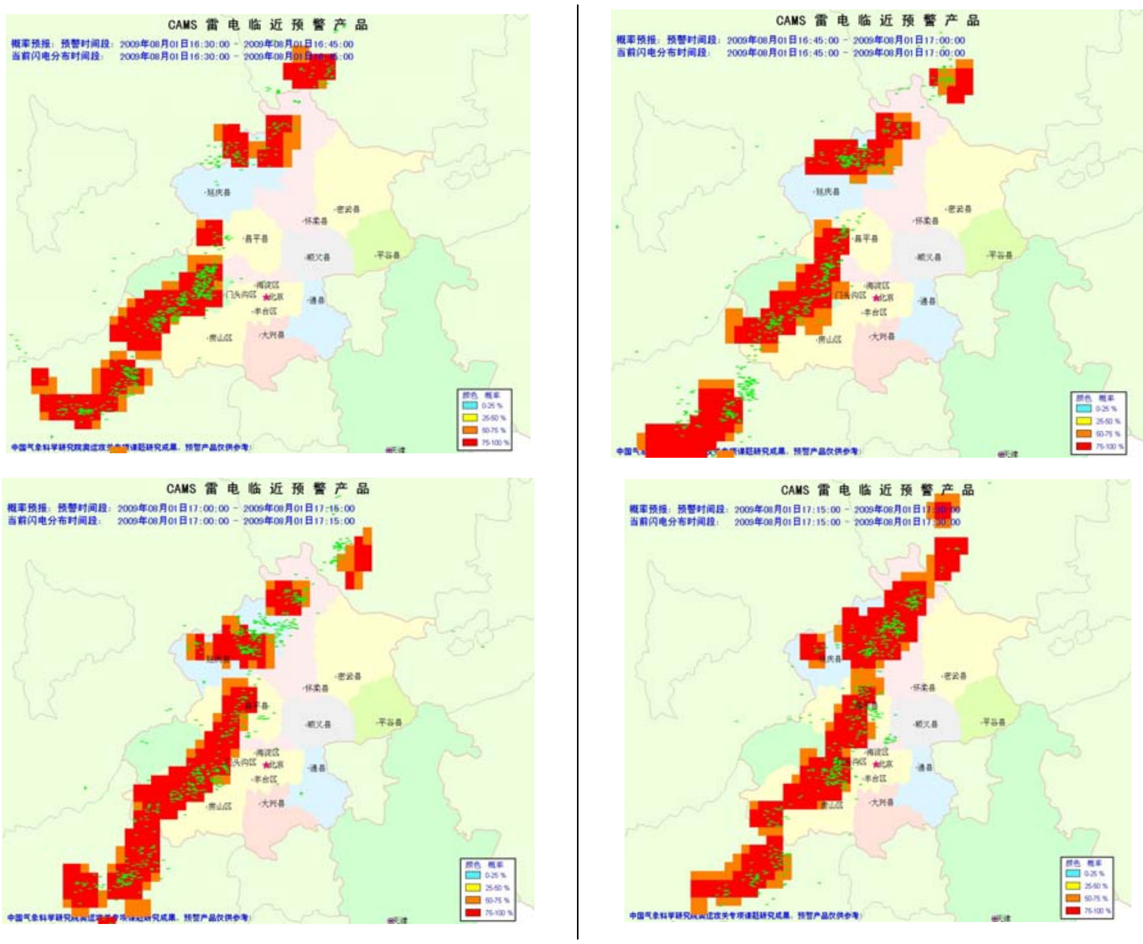

Fig. 1 Overlay of lightning occurrence probability products given by CAMS_LNWS with observed results detected by lightning locating system at 16:30~17:30, 1st August 2009 (green dots indicate lightning location results).

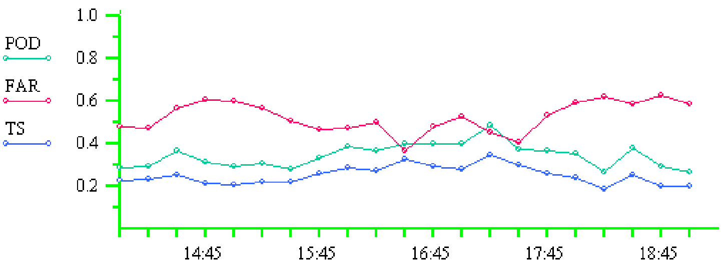

Fig. 2 Evaluation results of the CAMS_LNWS products at 14:00-19:00, 1st August 2009.

Laboratory of Middle Atmosphere and Global Environment Observation (LAGEO), Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

New model of rocket and the first triggered lightning experiment: The new-model rocket for artificially triggering lightning was developed recently in China, and the body of the rocket is made of composite material and is light in weight. The new rockets and new measurement technique of current and the corresponding electromagnetic fields were used in Shandong Artificially Triggering Lightning Experiment in the summer of 2009 (SHATLE2009), and three negative lightning discharges from cloud to ground, including 6 subsequent return strokes, were successfully triggered in the experiment. The waveforms of discharge current were documented with 0.1 μs time resolution by using the new coaxial shunt with a resistantance of 0.5 mΩ which output was transmitted to a 16-channel digital oscilloscope for recording through a broad band optical fiber. The corresponding electromagnetic fields at 30 m, 60 m, and 480 m were measured simultaneously. The peak current of 6 subsequent return strokes ranged from 11.2-16.3 kA with a geometric mean value of 12.8 kA. The half peak width ranged from 7.4-34.9 μs with a geometric mean value of 21.6 μs. The rise time from 10% to 90% peak ranged from 0.5-1.4 μs with a geometric mean value of 1.0 μs. The successful triggered lightning experiment confirmed that the rocket with wire-trailing function is reliable and safe, and the parachute assembled inside the rocket shows good performance. The new-developed rocket for triggering lightning provide a crucial tool not only for the study of lightning and its effects, but also for the data accumulation of lightning current waveforms which is essential to the lightning protection design.

The new-model rockets

The team of SHATLE2009

Characteristics of natural lightning flashes in Daxinganling primitive forest areas in northeastern China: Aiming at the investigation of the relationships between natural lightning flash characteristics and the forest fires in northern China, a multi-station observation campaign was conducted during the summer of 2009. The campaign lasted for three months and a total of 3198 lightning flashes were recorded. Preliminary analysis showed that there were about 480 cloud-to-ground lightning flashes (CGs), and 19.5% of them were positive, and the rest of them are negative. Since the continuous currents play an important role in causing the forest fires, statistical analysis showed that about 6.88% of positive CGs with continuous currents and 24.34% of negative CGs with continuous currents. Although we have not caught the forest fire data, the campaign will be continued during the next summer.

The characteristics of lightning activity, radar reflectivity and ice scattering in tropical typhoons over the Northwest Pacific: The characteristics of lightning activities, radar reflectivity and ice scattering in 255 overpasses of 46 China-landfalling typhoons from 1998 to 2008 have been analyzed by using the data from the precipitation radar (PR), lightning imaging sensor (LIS), and passive microwave imaging (TMI) onboard the Tropical Rainfall Measuring Mission (TRMM) satellite. The results indicated that more lightning are likely to happen in the weaker period of tropical cyclones, when comparing with the stronger ones. There are different spatial distributions of lightning activity in the different periods of tropical cyclones. As a whole, the precipitation systems in tropical cyclones are dominated by stratiform rain. The radar reflectivity above the freezing level is sharply decreased and the ice scattering signature is weaker. The eyewall region has the strongest convective signatures, but has less lightning flashes than the outer rainband. With the same radar reflectivity, lightning flashes are likely to occur in typhoon and severe tropical storm, but a bigger threshold of radar reflectivity is needed in super typhoon. The electrical activity is closely related to supercooled water, graupel, ice and vertical motion, so to some extent, lightning data can give us some information about the microphysical and dynamic process in tropical cyclones.

Daxinganling forest areas and the observation team

Lightning Research Group of Gifu University, Gifu, Japan

During the last summer, we have performed an observational experiment on the lightning that took place nearby our campus. Very fortunately, we caught a positive lightning that hit on the ground just about 400 meters from our high speed camera systems. It was very interesting to note that the downward positive leader contained in that flash emitted similar light pulses as a negative downward leader (see the figure in the cover page).

We have also continued analyzing the data obtained for the lightning that hit on a windmill and its lightning protection tower during the last 4 winter seasons. Based on our analysis, we found that lightning not only tend to strike a highest point, but also a point with combination of height and horizontal size. In addition, lightning tend to strike the points which are subject to strong wind and less corona space charges. In order to efficiently to protect high grounded-structures from direct strike of lightning, we suggest considering (1) not only vertical electric field but also horizontal E-field (that is, not only the vertical size but also the horizontal size of a high structure); (2) space charge produced by corona discharge and wind effect. These results have been reported in the MOCA 2009 (or IAMAS 2009) held in Montreal, Canada in July of 2009.

For the coming winter season, we have already set up our equipments and are waiting for the lightning that might hit on the windmill and its lightning protection tower. Our experiment will last until the end of January of 2009.

RESEARCH ACTIVITY BY INSTITUTIONS

Massachusetts Institute of Technology, Cambridge, MA, USA

A meeting was held among investigators of the Earth's Schumann resonances during the IAGA Conference in Sopron, Hungary in August. Plans were laid for the exchange of station data for purposes of performing iterative inversions to infer the global lightning source. A memorandum was prepared and distributed to interested parties.

In early November, Earle Williams hand-carried two magnetic coils and electronic equipment to Siberian ELF colleagues (Yuri Bashkuev and Darima Buyanova) in Ulan Ude (on Lake Baikal) for purposes of coordinated measurements from locations separated by nearly 180 degrees in longitude. En route to Siberia from China (via the trans-Mongolian railway), Williams gave a series of lectures on lightning and meteorological applications to the China Meteorological Administration in Beijing. Important contributions to these lectures came from Hans Betz, Larry Carey, Ken Cummins, Walt Lyons, Don MacGorman, Ralph Markson, Peter Neilley, Dick Orville, Vlad Rakov an Kyle Wiens.

Further work on halos as a likely resolution of the sprite polarity paradox continues with important input from Robert Newsome, Bob Boldi, Joszef Bor, Cheng Lin Kuo, Toriu Adachi, Marcelo Saba, Gabriella Satori, Walt Lyons and Mike Taylor. Another presentation on this topic is planned for the upcoming AGU meeting.

National Lightning Safety Institute, Louisville Colorado, USA

In Tanzania, three lightning safety projects for people and facilities were completed by the National Lightning Safety Institute (NLSI) at large above-ground gold mines in September. Similar assignments in 2009 were conducted at mining operations in Dominican Republic, Canada and Nevada USA. In accord with lightning defenses described in IEC 62305, IEEE 1100, Motorola R-56 and other recognized documents, protective measures have been adopted. People safety for 1,000-3,000 outdoor workers, employed in areas ranging about 15 X 25 square kilometers, required detailed attention to the following subject areas:

1. Advanced threat warning using lightning detection equipment.
2. Notification to all personnel via radios, alarms, etc.
3. Pre-designated safe shelters for refuge.
4. Continuing monitoring of the thunderstorm activity.
5. “All Clear” resumption of work activities.
6. Education and training of the workforce.

Lightning protection for mining facilities will include process control areas, communications, security, IT administrative areas, explosives storage etc. The defenses at these locations are highly site-specific, however a generalized guideline was:

1. Air Terminals where appropriate. (Example: all-metal buildings and radio towers often are self-protected.)
2. Shielding of sensitive components.
3. Equi-potential bonding to avoid voltage rise mis-matches.
4. Earthing techniques to provide low impedance grounding.
5. Surge protection at critical electrical and electronic locations.
6. Education and training of the technical/engineering departments.

The global mining industry regularly is visited by disruptive lightning events. Worker deaths and costly suspension of operations are consequences. One example of vulnerability was a lightning-caused electric power failure at a Papua New Guinea mine. Repairs to generators took three months. Loss of production at the mine was some $700,000 per day. Cause of the incident was found to be inadequate air terminal designs and poor earthing.

National Severe Storms Laboratory, Norman, Oklahoma, USA

Dave Rust and Don MacGorman have just completed a feasibility study of a balloon-borne particle imaging videosonde to provide 'ground truth' data to compare with polarimetric radar data in addition to using particle data in cloud electrification studies. The imager utilizes a consumer-grade high definition video camera. The shutter speed of 1/8000 second produces clear images. The sample volume is illuminated by four intense light emitting diodes. Data were acquired on balloon flights of the particle imager through two storms in October, 2009, in central Oklahoma. Supporting data include an electric field profile, GPS tracking of the instruments, a radiosonde that transmitted temperature, pressure, relative humidity, winds, and GPS-derived location C band polarimetric data from the University of Oklahoma. A cursory look at the data reveals rain, graupel, ice crystals, and small hail in various places in the storms. In summary, the data appear to be of high enough quality to provide relevant storm electrification data. We plan additional analysis to assess whether the particle imager does indeed record useable data.

Tel Aviv University (TAU) and the Open University of Israel (OUI)

Yoav Yair and Colin Price and their students have started the 5th season of the ILAN winter sprite campaign (http://www.tau.ac.il/~royyaniv/ILAN_website/ILAN.html). Calibrated optical measurements led by students Na'ama Reicher and Roy Yaniv will are conducted intermittently from Tel-Aviv and Mizpe-Ramon. Additionally, long-range observations will be attempted from Mt. Hermon (1500 m above sea-level) which will enable monitoring TLE activity as far as western Turkey and over the Mediterranean Sea as well as Jordan and Iraq in the east. Simultaneous measurements will be attempted from the Hebrew University campus in Jerusalem, led by Caryn-Elissa Erlich. This ground based capacity will become an asset for future space missions such as Taranis and ASIM.

Yoav Yair is cooperating with Ute Ebert from the University of Amsterdam (NL) in laboratory simulations of planetary sprites. Following theoretical computation of the possibility for sprites in Venus and Jupiter *[Yair, Y., Y. Takahashi, R. Yaniv, U. Ebert, and Y. Goto (2009), A study of the possibility of sprites in the atmospheres of other planets, J. Geophys. Res., 114, E09002, doi:10.1029/2008JE003311.]*, PhD student Daria Dubrovin-Flaurov had completed the analysis of streamers produced in various gas compositions, together with Technical University of Eindhoven student Sander Nijdam. Results are submitted to the special issue of JGR-Space Physics dedicated to the Chapman meeting on TLE research. This research is supported by the Israeli Science Foundation (117/09).

Colin Price and Yuval Reuveni completed

analyzing VLF data obtained from the Sde-Boker station in southern Israel, and found a strong signal in the VLF emission from terrestrial lightning activity with a 27-day periodicity, related to the solar rotation. They suggest that continuous monitoring of VLF radio noise at frequencies close to the waveguide cutoff could provide a new method of continuously monitoring changes in the solar rotation rate *[Reuveni, Y., and C. Price (2009), A new approach for monitoring the 27-day solar rotation using VLF radio signals on the Earth's surface, J. Geophys. Res., 114, A10306, doi:10.1029/2009JA014364].*

Colin Price, Yoav Yair and Lev Dorman (TAU) have started a research project focused on monitoring space weather from earth's surface by measurements of various electrical parameters (electric field, conductivity, ELF and VLF emissions) in conjunction with observations of the cosmic-ray flux. The 3-year project is based on two stations, one on Mt. Hermon and the other in the Wise observatory in the Negev desert.

Orit Altaratz and Ilan Koren (Weizmann Institute of Science, Israel) collaborated with Yoav Yair and Colin Price, and used the ground-based World-Wide Lightning Location Network (WWLLN) lightning measurements together with Aqua-MODIS aerosol and cloud data to study lightning response to smoke from Amazonian fires. They found evidence for the transition between two opposing effects of aerosols on clouds: in low aerosol loading, the smoke-produced CCN concentration leads to an intensification of the cloud electrical activity, while for higher values of aerosol loading the absorption effect takes over, weakening the convection and reducing electrical activity. Results are submitted to GRL.

The UK Met Office, Observation R&D Group, VLF Arrival Time Difference Lightning Location Network (ATDnet)

Alec Bennett (alec.bennett@metoffice.gov.uk)

The UK Met Office long range lightning location network (ATDnet) has continued to show an improvement in location accuracy and detection efficiency since the algorithm update in February. This July saw a record number of strokes reported for ATDnet, with a monthly total of 12 million and several instances of five minute totals exceeding 3,000 strokes during stormy days in Europe. Widespread activity was detected during June (figure 1), especially in Eastern Europe. Progress continues on network expansion and comparison with other lightning detection networks. The effects of modal interference on waveform correlation have been investigated further during the continued ATDnet performance analysis, including visualisation of interference bands in two-dimensions by calculating spatial differences in waveform correlation across Europe. Sources of interference in the ATDnet sensing band (approx. 6-21 kHz) are being monitored and arrangements with the International Telecommunication Union are being sought to mitigate the effects of man made interference in the lower VLF band and safeguard the use of this frequency for long-range lightning detection.

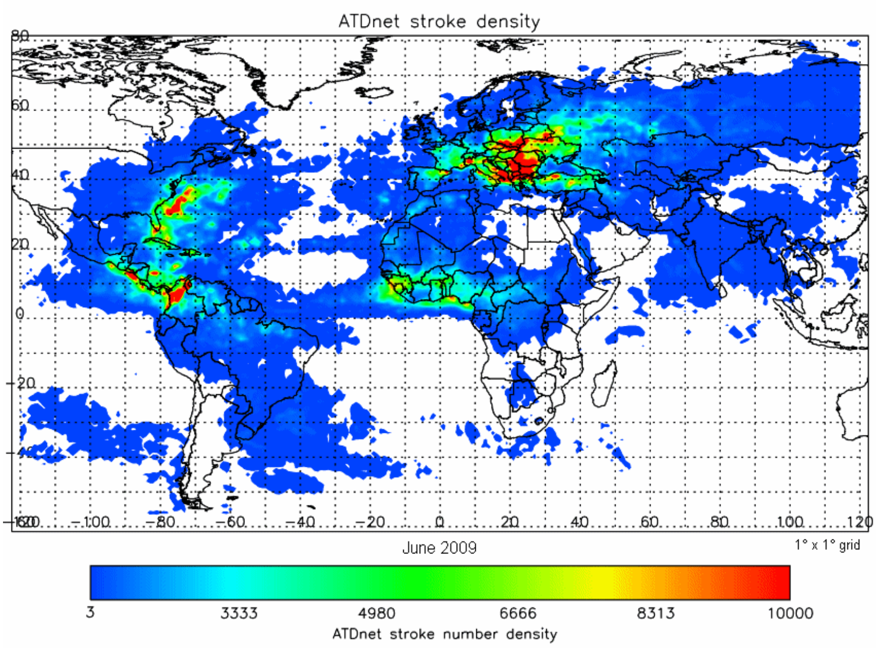

Figure 1 Lightning stroke density detected by ATDnet during June 2009, for one degree grid boxes.

University of Electro-Communications, Terrestrial Electromagnetic Environmental Studies Group, Tokyo, Japan

M. Hayakawa (hayakawa@whistler.ee.uec.ac.jp)
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Winter sprites in the Hokuriku area and parent lightning discharges: The study of winter sprites in the Hokuriku area will be continued in the coming winter by means of coordinated measurements of optical observations, ELF observation in Moshiri, lightning observation (VHF) and field-mill observations etc. The main emphasis will be elucidation of electrical and meteorological characteristics of parent lightning of winter sprites, in relation to the sprite morphology (column, carrots etc.). A highly sensitive camera is planned to be used this winter.

Summer sprites in the Maebashi area and their associated phenomena: The similar campaign as above was performed in summer in the north of Tokyo area (Maebashi area known for its high lightning activity in summer). Then, there were observed a large number of blue jets, in association with huge summer lightning, and extensive study on these blue jets and their parent lightning is going on.

Computer simulation on sprite generation: Asano et al. (2009) have indicated on the basis of EM code computer computation that the higher-frequency components (like M components) in the continuing current are playing an important role in elucidating the poorly understood issues of sprites (such as long-delay effect etc.). Simulations will be continued.

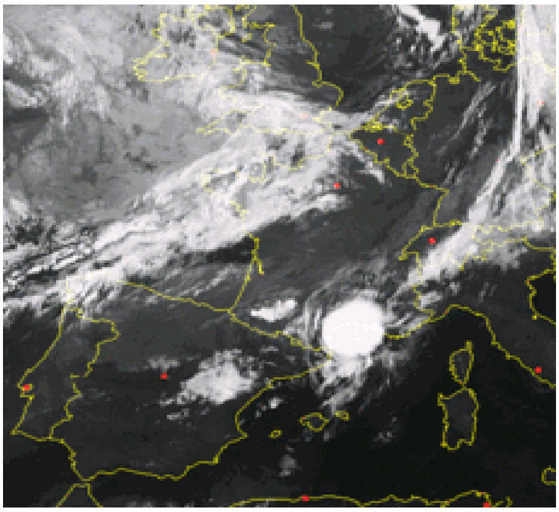
Inversion of Schumann resonance data to obtain the global lightning distribution: Shvets et al. (2009) have published a paper in which the 3-stationed SR data are used to obtain the global mapping of lightning distribution by means of the inversion. Our paper is based on the data only for a few days, so that the result by using one-year-data will be available shortly. These results on background lightning activity would be compared with those for intense lightning deduced from ELF transients (Yamashita et al., 2009)

Seismo Electromagnetic effects: Electromagnetic phenomena associated with earthquakes have been investigated extensively, with the main emphasis on the seismo-ionospheric perturbations (with the use of subionospheric VLF/LF signals) and seismogenic ULF-emissions. Two important jobs by our group are publishing of (1) a special issue in Phys. Chem. Earth (2009) and (2) a review monograph (edited by M. Hayakawa) (2009).

Universite de Toulouse, Laboratoire d'Aerologie, Toulouse, France

Large sprites observed from Pic du Midi

A new camera for TLEs observation was operated at Pic du Midi (2877 m altitude) before the summer 2009. In the frame of the Eurosprite campaign and in the frame of the UPC contribution to the Atmosphere-Space Interactions Monitor (ASIM) project (Joan Montanya, Oscar van der Velde, Serge Soula), several tens of events were recorded during the months of June, July and September. On the night of 1-2 September, a very active circular storm complex located above Lion Gulf, east of Perpignan, produced some very large sprites (see infrared meteosat image). Several events consisted of a long lasting sequence of groups of sprites. Two examples of such sprites are shown in the images which display the whole luminous emission constituting the sprite event. These sprites exhibited tendrils reaching very low altitudes measured to be 30-35 km with secondary TLE (troll?) extending below it and lasting for 40 ms. More details about these sprites are visible on the website http://eurosprite.blogspot.com/.



Infrared Meteosat Image at 02h00 UT on September 2

Sprite observed at 02h33min16s

University of Florida, Gainesville, Florida, USA

A total of 26 lightning flashes (24 negative and 2 bipolar) were triggered in 2009 at the International Center for Lightning Research and Testing (ICLRT) at Camp Blanding, Florida, operated jointly by the University of Florida and the Florida Institute of Technology. Eighteen of them contained leader/return stroke sequences and the other eight were composed of the initial stage only. Additionally, two natural negative lightning discharges that terminated on site or in its immediate vicinity were recorded by the multiple-station electric and magnetic field measuring network and/or by the Thunderstorm Energetic Radiation Array (TERA). Eleven triggered-lightning flashes were recorded both at Camp Blanding and at the Lightning Observatory in Gainesville (LOG), separated by a distance of about 45 km. Additionally, eleven flashes were recorded by a 3D broadband VHF interferometer operated at Camp Blanding by Dr. Satoru Yoshida of Osaka University, Japan, for two of which good 3D VHF images of upward positive leaders were obtained. Note that positive leaders are usually "silent" at VHF.

J.E. Jerauld, M.A. Uman, V.A. Rakov, K.J. Rambo, D.M. Jordan, and G.H. Schnetzer authored a paper titled "Measured electric and magnetic fields from an unusual cloud-to-ground lightning flash containing two positive strokes followed by four negative strokes". The authors present electric and magnetic fields measured at multiple stations between about 300 and 800 m of a cloud-to-ground "bipolar" lightning flash containing two initial positive strokes, separated in time by 53 ms and striking ground at two locations separated by about 800 m, followed by four negative strokes that traversed the same path as the second positive stroke. The leader electric field durations for the positive first, positive second, and negative third strokes were about 120 ms, 35 ms, and 1 ms, respectively. The first-stroke leader electric field changes measured at five stations ranged from about +16 to +35 kV/m, the second stroke +8 to +13 kV/m, and the third stroke -0.9 to -1.8 kV/m (atmospheric electricity sign convention). The microsecond-scale return stroke waveforms of the first and second (positive) strokes exhibited a similar "slow-front/ fast-transition" to those observed for close negative first strokes. The peak rate-of-change of the positive first stroke electric field normalized to 100 km was about 20 V/m/us, similar to the values observed for close negative first strokes. The positive second stroke was followed by a long continuing current of duration at least 400 ms, while the positive first stroke had a total current duration of only about 1 ms. All four negative strokes were followed by long continuing current, with durations ranging from about 70 ms to about 230 ms. The overall flash duration was about 1.5 s. The paper is published in JGR-Atmospheres.

A. Nag and V.A. Rakov authored a paper titled "Electromagnetic Pulses Produced by Bouncing-Wave-Type Lightning Discharges". The authors, based on experimental evidence of multiple reflections and modeling, inferred that the so-called compact intracloud lightning discharge (CID) is essentially a bouncing-wave phenomenon. Some tens of reflections may occur at both radiating channel ends. The reflections influence the magnitude of the overall CID electric field waveform (narrow bipolar pulse) and are responsible for its fine structure, as well as, by inference, for "noisiness" of dE/dt waveforms and for accompanying HF–VHF radiation bursts. The paper is published in the IEEE Transactions on EMC

RESEARCH ACTIVITY BY INSTITUTIONS

University of Texas at Dallas, USA

Modeling and data analysis work continues on variability of the global electric circuit and its effects on clouds, precipitation, and atmospheric dynamics. Our modeling has shown that the presence of aerosols in the troposphere produce about a 60% increase in global return path resistance, and clouds produce about a 10% increase, compared to an atmosphere without these constituents. Analysis of meteorological changes has shown highly significant correlations of surface pressure over the Arctic and Antarctic with changes in the downward current density Jz. The influence of Jz on clouds is due to the effects on aerosol scavenging of space charge, which accumulates in gradients of resistivity produced by gradients in droplet concentration in the clouds, in accordance with Ohm's Law and Gauss's Law. The space charge is deposited on droplets and aerosol particles, with models and measurements showing 50-100 elementary charges on droplets, and a fraction of that on the particles, depending on their size and evaporative history. Our most recent publication gives values for the electrically-induced changes in the collisional rate coefficients and lifetimes against removal for aerosols, including cloud condensation nuclei, and ice forming nuclei, in these regions of space charge.

Our work began as a search for a mechanism for the effects of solar activity on weather and climate, but this has led to a demonstration of the significance of effects of Jz on clouds that is internal to the atmosphere and climate system, and amounts to an electrical teleconnection between thunderstorm regions and clouds anywhere in the global atmosphere.

University of Washington, USA

Status of WWLLN (World Wide Lightning Location Network): The WWLLN is a collaboration among ~50 scientific organizations (primarily universities and government labs) through which we collect global VLF (very low frequency) radiation from lightning sferics, and determine the location of the parent lightning location (see http://wwlln.net). The network locates about 30 to 40% of strong lightning (peak currents above ~45 kA) and about 10% of all global lightning. The network also detects nearly 100% of all lightning-generating storms. We have deployed sensors to new stations in India, Nigeria, Brazil, Argentina, Nova Scotia and the Indian Ocean, and we have sent new or replacement gear to Davis and Maitre stations in Antarctica. So, we expect to have over 50 stations by the end of the year. New stations in Manaus, Brazil and on LaReunion Island are just now coming on line. WWLLN archival data are available from the University of Washington for just $550/year for the entire globe.

Status of the C/NOFS ionospheric satellite: The US Air Force and NASA C/NOFS (Communication/Navigation Outage Forecast System) satellite has been in near equatorial orbit (13 degree inclination, 400 to 800 km altitude) since April 2008, and is doing very well. The satellite vector electric field instrument (VEFI) includes an optical lightning sensor, which together are being used to study lightning influences in the ionosphere. The latest work, about obtaining global ionosphere TEC (Total Electron Content) data from sferic dispersion, and about discoveries of strong lightning signatures in equatorial electron density cavities is to be reported at the Fall 2009 AGU (American Geophysical Union) meeting.

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Reminder

Newsletter on Atmospheric Electricity presents twice a year (May and November) to the members of our community with the following information:

- announcements concerning people from atmospheric electricity community, especially awards, new books...,
- announcements about conferences, meetings, symposia, workshops in our field of interest,
- brief synthetic reports about the research activities conducted by the various organizations working in atmospheric electricity throughout the world, and presented by the groups where this research is performed, and
- a list of recent publications. In this last item will be listed the references of the papers published in our field of interest during the past six months by the research groups, or to be published very soon, that wish to release this information, but we do not include the contributions in the proceedings of the Conferences.

No publication of scientific paper is done in this Newsletter. We urge all the groups interested to submit a short text (one page maximum with photos eventually) on their research, their results or their projects, along with a list of references of their papers published during the past six months. This list will appear in the last item. Any information about meetings, conferences or others which we would not be aware of will be welcome.

Newsletter on Atmospheric Electricity is now routinely provided on the web site of ICAE (http://www.icae.jp), and on the web site maintained by Monte Bateman http://ae.nsstc.uah.edu/.

In order to make our news letter more attractive and informative, it will be appreciated if you could include up to two photos or figures in your contribution!

Call for contributions to the newsletter

All issues of this newsletter are open for general contributions. If you would like to contribute any science highlight or workshop report, please contact Daohong Wang (wang@gifu-u.ac.jp) preferably by e-mail as an attached word document.

The deadline for 2010 spring issue of the newsletter is **May 15, 2010**.

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