formed through conventional breakdown, runaway breakdown, or a combination of both depending on conditions? In this paper, we describe the calculation of optical emissions associated with two different simulations performed with a 2-d fully electromagnetic discharge model (UNIMAX). Optical emissions driven by primary electrons (runaway breakdown) are calculated using measured fluorescence efficiencies and quenching rates for each wavelength of interest. For the secondary electrons (conventional breakdown and secondary electrons sustained in an electric field that lies below the conventional breakdown threshold), the emissivity of nitrogen bands as a function of electric field are used to estimate the optical emissions for the N_2 1P, 2P, and N_2^+ 1N bands. We developed a methodology to split the band results into individual transitions. In addition, we include absorption from the source to an observer at a specified height. We present simulated camera images, line ratios, and spectra for a typical sprite and a carrot-type sprite. We compare our model results in detail to measurements to identify more precisely what diagnostic information about the discharge plasma can be deduced from such observations. The differences between conventional breakdown models and those based on the simultaneous occurrence of both processes are delineated.

AE21A-1101 0830h POSTER

Measurements of Continuing Currents in Lightning using ULF Magnetic Fields

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Because they are difficult to measure, relatively little is known about the long duration continuing currents that are present in some lightning flashes despite their being one of the most damaging lightning processes. We use a combination of the Ultra Low Frequency (ULF) magnetic fields recorded at three stations (Santa Cruz, California, Socorro, New Mexico, and Saskatoon, Canada) and NLDN from 11 July to 12 August 1998 to detect and measure the amplitude and duration of the continuing currents which occur after some lightning flashes. Continuing currents of up to 450 milliseconds duration and peak amplitudes of up to 200 kA-km have been detected by our analysis. We report the frequency of occurrence of these continuing currents, largest and longest recorded continuing currents, the total charge moment of the continuing currents and the storm to storm variability of these currents. We will also address whether these continuing currents occur during the day or night, whether few storms produce almost all the lightning currents, and how the current strength is related to other lightning flash parameters so that we can have a better understanding of the basic meteorological conditions under which these continuing currents occur.

AE21A-1102 0830h POSTER

Attenuation Of Current Wave Propagating Along A Perfectly Conducting Wire: Application To Lightning

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In this study, using the finite-difference time-domain (FDTD) method for solving Maxwell's equations, we demonstrate that a vertical phased array of current sources above perfectly conducting ground, activated as prescribed by the transmission line (TL) model with return-stroke speed equal to the speed of light (v = c), produces a spherical TEM wave, identical to that analytically derived for the TL model with v = c by Thottappillil et al. [2001]. (This can be viewed as a proof of validity of the FDTD method used here.) Then, we apply the same approach to the case of a lumped current source at the bottom of a vertical perfectly conducting wire above perfectly conducting ground and show that the current wave launched by the current source propagates upward with attenuation and that the resultant field structure is non-TEM, as also follows from other lightning return stroke models based on solving Maxwell's equations. The attenuation is stronger for shorter current pulses and for current sources of smaller length. Thus, it appears that the basic assumption of the TL model (no current attenuation with height) is inconsistent with Maxwell's equations, unless the lightning channel is viewed as a phased array of current sources. It is inconsistent with the transmission line theory either, since a vertical wire above ground constitutes a non-uniform transmission line, whose characteristic impedance varies with height. We will try to explain the mechanism of current attenuation on a vertical perfectly conducting wire above perfectly conducting ground, usually attributed to radiation losses, on the basis of the electromagnetic field theory. In particular, we will discuss the interaction of the electromagnetic field produced by the source with the vertical conductor and ground and the direction of resultant Poynting vector. Thottappillil, R., J. Schoene, and M. A. Uman, Return stroke transmission line model for stroke speed near and equal that of light, Geophys. Res. Lett, 28(18), 3593-3596, 2001.

AE21A-1103 0830h POSTER

Propagation Speeds of Lightning Leaders Throughout an Entire Flash Using 10 μs Time Resolution 3D Mapping Data.

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The Lightning Mapping Array normally records lightning radiation sources in each 80 μs time interval but can be operated in a high time resolution mode where sources can be located as often as every 10 μs. The 10 μs data can show very detailed structure and development of the breakdown channels. Using the 10 μs data, we have performed a detailed analysis of several flashes, including intracloud, cloud-to-ground, and bolt-from-the-blue type discharges, in which we isolated most of the branches and made cubic spline fits to the x, y, and z values versus time. From the analyses, we have characterized the evolution of both the individual branches and of the overall flash. For an individual branch, we often see the speed of the branch decreasing with time, reaching some minimum speed, usually between 4 - 8 $\times 10^4$ m/s, at which the branch expires. Overall, we have found that typical branch speeds range between 4×10^4 and 2×10^5 m/s.

AE21A-1104 0830h POSTER

Lightning Current Parameters of Upward Lightning Flashes Observed at the 200-m Fukui Chimney in Winter

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For over twenty years we have been observing the lightning flashes at the 200-m-tall chimney in the Fukui thermal power plant in winter in Japan. The local IKL (thunderstorm days) is about 40 in this area and the lightning flashes at the chimney are recorded about 40 times in a winter season. When the lightning strikes the 5-m lightning rod on top of the chimney, lightning currents are measured by using coaxial shunt-resistors installed at the base of the lightning rod. Lightning progressing features was measured by the 40X40 pin photodiode array system. The system records luminosity changes in the lightning channel by measuring the differences between signals from different photodiodes. At a distance of 630 m from the chimney, a vertical lightning channel of 1000 m is divided by using 40 diode elements. Electromagnetic field changes that accompany lightning flashes are also measured by using several types of antennas. These simultaneous measurements classified the behavior of winter lightning flashes. All recorded lightning flash was the lightning discharge initiated by the upward leader from the chimney. Most lightning (about 90 percent) was the lightning discharge initiated by the upward-moving positively charged leader. The lightning initiated by the upward-moving negatively charged leader was only about 10 percent. Some of the lightning produced the subsequent discharge processes following the upward leader development. There are many differences between the lightning current parameters of upward lightning flashes and the downward lightning flashes. Interestingly, the upward leader currents observed at the chimney are big compared to the downward leader currents estimated by the several methods. We will report the properties of lightning current parameters based on the data collected at the 200-m-tall chimney in winter. These statistical data of lightning current parameters are classified especially from the point of view of lightning discharge types.

AE22A MCC: Level 2 Tuesday 1330h

Advances in Lightning and Atmospheric Electricity Remote Sensing Systems and Algorithms I Posters *(joint with A)*

Presiding: **M Murphy,** Vaisala, Inc.**;** **D J Boccippio,** NASA Marshall Space Flight Center

AE22A-1105 1330h POSTER

Lightning Initiation Locations as a Remote Sensing Tool of Large Thunderstorm Electric Fields

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In this presentation we compare lightning data recorded with a three-dimensional lightning mapping array (LMA) with a flat plate antenna operated both as a 'slow' antenna and as a 'fast' antenna. The goal of these comparisons is to quantify any time delay that may exist between the initial responses of the instruments to a lightning flash. The data consists of 74 flashes from a single New Mexico thunderstorm. We find that the initial radiation source detected by the LMA usually leads the initiation response of both the slow and fast antennas. In a small number of cases, the flat plate antenna response leads the initial LMA source, but by no more than 2 milliseconds. Our observations of such close time coincidence suggest that the first LMA radiation source of each flash was located at or very near the flash initiation point. Thus, the first LMA radiation source detected from a lightning flash could be used as a remote sensing tool to find the locations of large electric fields within lightning producing clouds.

AE22A-1106 1330h POSTER

Identifying Thunderstorm Cells With LDAR Flash Initiation Points and Difficulties of Associating Lightning With Radar Cells

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Previous research has shown that cloud and cloud-to-ground (CG) lightning flashes most often occur within or slightly displaced from reflectivity cores (> 40-50 dBZ). Observations from the Dallas-Fort Worth (DFW) Lightning Detection and Ranging (LDAR II) network confirm that the majority of VHF lightning sources are detected within or slightly displaced from the reflectivity cores of air mass, multicell and supercell storms and mesoscale convective systems (MCS). A statistical study using Fort Worth WSR-88D reflectivity data and LDAR II sources will be presented to summarize our observations. Since many lightning flashes extend over horizontal distances larger than a single thunderstorm cell and sometimes over 100 km (e.g. Proctor, 1983), using all VHF sources within a flash can present difficulties for identifying cells. Further research from the DFW LDAR II network has shown that the majority of lightning flashes for all storm types initiate within or close to reflectivity cores, regardless of their length of propagation. For this reason, we use the initial VHF sources within flashes to identify thunderstorm cells. The results obtained from using this method will be shown for several thunderstorm environments. In addition, comparisons will be made with the Storm Cell Identification and Tracking (SCIT) algorithm, which is based on reflectivities. The next step in this process is to associate lightning cells with their parent radar cells properly. For many thunderstorm environments this process can be extremely complex. We will illustrate some of the difficulties involved when lightning and radar identify different numbers of cells. Proctor, D.E., Lightning and precipitation in a small multicellular thunderstorm. *J. Geophys. Res.*, *88*, 5421-5440, 1983.

AE22A-1107 1330h POSTER

On the Development of Lightning Hazard-Warning Decision-Support Criteria

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Among natural hazards that lead to high-risk situations for outdoor activities, lightning is arguably the most problematic to predict on the basis of currently available meteorological products. Decision makers responsible for the safety of outdoor personnel and reliable operation of vulnerable systems during thunderstorms need as much information as they can get, as far in advance as they can get it, to decide when to warn for lightning in a specific area or to switch to auxiliary power, and when to sound the "all clear". The Lightning Decision Support System©(LDSS©) a model-based forecast product developed by Weather Decision Technologies, Inc., uses data from the National Lightning Detection Network and the national network of WSR-88D radars to predict, on time scales of 30 minutes, the movement and intensity of lightning in storms approaching or leaving a region of interest. However, there are no widely available tools to predict when and where the first lightning strike to ground (CG) from a particular storm is likely to occur or to determine whether a storm remains sufficiently electrified to produce additional ground flashes late in its lifetime. To be able to make such predictions, it is necessary to have knowledge of the electric field at the ground within the area of concern. Preliminary results based on output from an advanced storm-scale numerical model with parameterized electrification and lightning suggest that at least under some circumstances it ought to be possible to predict the occurrence of first CG flashes within an area of a few km2, a few minutes in advance. The challenge is to determine the circumstances under which such predictions can be made reliably. This paper describes the model output for two storms, the analysis of the electric field at the ground, and possible deployments of field meters that could provide support for real-time decisions on the probability of first and last lightning strikes in a storm. The LDSS, with this added local field assessment capability, can provide comprehensive support for lightning hazard-warning decisions.

AE22A-1108 1330h POSTER

New Mexico Tech Lightning Mapping Array: Real-Time System Monitoring and Data Display

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The New Mexico Tech Lightning Mapping Array (LMA) is a VHF time-of-arrival (TOA) lightning mapping system. In a typical deployment it consists of ten to fifteen VHF receivers distributed over a geographical area of about 90 km in diameter. It was designed to be relatively inexpensive by recording TOA data locally at the remote stations, using GPS timing to determining the time of arrival of impulsive VHF radiation from lightning with about 40 ns accuracy. The TOA data is collected after storms by driving to the remote stations and collecting the data on magnetic media for post-processing. During its design phase cost-effective communications links with a high enough bandwidth for real-time processing and display were not available. We initially used low-speed (9600 baud) wireless links to the remote stations for system monitoring and control. With recent advances in wireless communications, it is now cost-effective to implement real-time data processing and display. Each LMA station typically determines the time of the strongest source of VHF radiation in an 80 μs window, for up to 12,500 TOA sources per second. At its full data rate it can take tens of minutes to process a minute of LMA data. Using software to decrease the data rate so that the TOA data is windowed over a longer interval (say, 400 μs), it is possible to process this decimated data in real time using an inexpensive PC. While the images generated using this decimated data are not as detailed as post-processed images generated using the full TOA data, they are sufficiently detailed for most operational uses. Using relatively inexpensive IEEE 802.11b wireless Ethernet cards, we can achieve data rates sufficiently high so that we can transmit this decimated data from remote stations to a central location. During the summer of 2003 we have developed a real-time monitoring and data processing/display system, somewhat similar to the monitoring and display system for the North Alabama LMA[1]. We use software developed in-house for data transmission and processing, and use the NCAR Command Language (NCL[2]) for generating graphical images. Over the next few months we plan to install this monitoring/display software on the NMT LMA in central New Mexico, and the NSSL LMA in central Oklahoma.

[1]http://branch.nsstc.nasa.gov/cgi-bin/LMA.pl
[2]http://ngwww.ucar.edu/ncl/index.html

AE22A-1109 1330h POSTER

Accuracy of the Lightning Mapping Array

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We have conducted a detailed study of the accuracy of the Lightning Mapping Array in which experimentally determined values of the location uncertainties are compared with simple geometric formulations of the errors and with linear covariance estimates of the uncertainties from the least-square solution procedure. Observations of a sounding balloon that carried a GPS receiver and pulsed VHF transmitter show that the mapping system is able to locate sources inside the periphery of the network with a horizontal accuracy of about 10 m rms and, when the sources are higher than 1-2 km above ground, with a vertical accuracy of 30-50 m rms. The vertical accuracy is determined primarily by the nearest station contributing to the solution; the accuracy approaches that of the horizontal locations when the source is directly above the close station and the uncertainty increases by a factor of 2-3 or more for sources located between stations or at low altitude. For sources outside the network, the locations and their uncertainties are best described in a network-centered spherical coordinate frame. The radial distance R of the source is determined primarily by stations transverse to the arrival direction, which measure the radius of curvature of the incoming wavefront. A simple geometric model shows that the radial location error increases as $(R/D)^2$, where D is the network diameter. The vertical location error is dominated by the uncertainty of the source's elevation angle, which is determined primarily by stations along the arrival direction, and increases as $R^2/(zD)$ where z is the source height above the network tangent plane. The azimuthal or transverse position of the source is most accurately determined, with the uncertainties increasing only as (R/D). The location uncertainties are all proportional to $c\Delta t$, where Δt is the rms uncertainty of the time-of-arrival measurements. Δt can be accurately determined from the statistics of the reduced chi-squared values of the solutions; the effective value of Δt was 50 ns rms for the LMA network operated during STEPS 2000. Most of the lightning sources (typically 80%) are located by only 6 or 7 stations of the network (6 being the minimum number required by the processing) and therefore have somewhat greater uncertainties than if they were located by the full complement of measurement stations. The uncertainties of the system were also investigated by determining the scatter of airplane tracks detected by the LMA when the airplanes were flying through ice crystal clouds (anvils or cirrus). For both the aircraft and sounding balloon data, the measured uncertainties agreed well with those predicted by the simple geometric models and by the covariance error estimates. When zoomed in on, the aircraft and balloon tracks exhibited characteristic 'sawtooth' patterns that we believe are caused by the gradual accumulation and successive correction of systematic timing errors at each measurement station. The effect of these errors is comparable to the other timing uncertainties and are included in the overall error determinations. We should be able to reduce this contribution to the timing errors with small improvements to the system.

AE22A-1110 1330h POSTER

Effects of a Longer Detection Window in VHF Time-of-Arrival Lightning Detection Systems

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Lightning detection systems that operate by measuring the times of arrival (TOA) of short bursts of radiation at VHF can produce huge volumes of data. The first automated system of this kind, the NASA Kennedy Space Center LDAR network, is capable of producing one detection every 100 usec from each of seven sensors (Lennon and Maier, 1991), where each detection consists of the time and amplitude of the highest-amplitude peak observed within the 100 usec window. More modern systems have been shown to produce very detailed information with one detection every 10 usec (Rison *et al.*, 2001). Operating such systems in real time, however, can become expensive because of the large data communications rates required. One solution to this problem is to use a longer detection window, say 500 usec. In principle, this has little or no effect on the flash detection efficiency because each flash typically produces a very large number of these VHF bursts (known as sources). By simply taking the largest-amplitude peak from every 500-usec interval instead of every 100-usec interval, we should detect the largest 20% of the sources that would have been detected using the 100-usec window. However, questions remain about the exact effect of a longer detection window on the source detection efficiency with distance from the network, its effects on how well flashes are represented in space, and how well the reduced information represents the parent thunderstorm. The latter issue is relevant for automated location and tracking of thunderstorm cells using data from VHF TOA lightning detection networks, as well as for understanding relationships between lightning and severe weather. References Lennon, C.L. and L.M. Maier, Lightning mapping system. *Proceedings, Intl. Aerospace and Ground Conf. on Lightning and Static Elec.*, Cocoa Beach, Fla., NASA Conf. Pub. 3106, vol. II, pp. 89-1 - 89-10, 1991. Rison, W., P. Krehbiel, R. Thomas, T. Hamlin, J. Harlin, High time resolution lightning mapping observations of a small thunderstorm during STEPS. *Eos Trans. AGU*, *82* (47), Fall Meet. Suppl., Abstract AE12A-83, 2001.

AE22A-1111 1330h POSTER

WWLL Global Lightning Detection System Regional Validation Study in Brazil

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The World Wide Lightning Location network (WWLL) is an experimental lightning detection network, which will eventually provide real time global coverage with 10 km location accuracy and at least 50% detection efficiency. This paper provides an analysis of the WWLL in a region of Brazil where the VLF lightning receivers are very distant (>7000 km) to estimate the worst case scenario of location accuracy. The detection accuracy in Brazil is analyzed by comparison to a local Brazilian lightning detection network with respect to time, location, and peak current of the lightning strokes. We find that in Brazil, WWLL detection has a high threshold on the peak return stroke current, resulting in detection of only about 0.8% of the total lightning strokes. However, the detected strokes have a location accuracy of 20 ± 13 km and a temporal accuracy of 0.0641 ± 0.1935 ms, providing a good overview of regions of local lightning activity in real time.

AE22A-1112 1330h POSTER

GPS Radiosonde with Spread-Spectrum Transmitter for Aerial dE/dt Studies

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Inexpensive, low-power and reliable telemetry is a continuous struggle for those engaged in developing balloon-borne instruments for atmospheric electric studies. Several custom designs, by NCAR and others, have enabled much useful work in radiosondes. Also, packet radio technology has been used with great success. Easily obtainable packet radios are currently limited to 9600 baud. In search of higher baud rates that integrate well with microprocessor-based data acquisition systems, we have tested a new commercial off-the-shelf spread-spectrum transmitter. The transmitter operates in the 900 MHz industrial, scientific and medical (ISM) band with a transmit power of 100 mW. The transmitter (a Maxstream XC09-019NST) is used with a dedicated receiver, such that the data to be transmitted is fed via RS-232C protocols to the transmitter, and received as a text string via a serial port on the receiver. We did tests at raw baud rates of 9600 and 19200 (roughly 1000-2000 characters/second). Initial range tests required integrating the transmitter with a GPS and sending the NMEA-position-string (National Marine Electronics Assoc.) to a ground-based receiver. In ground-based tests, we repeatedly saw that a clear line-of-sight between transmitter and receiver was required for successful telemetry. The maximum range obtained during ground tests was 15.3 km at 9600 baud. Initial balloon tests results were, as hoped, more encouraging than ground-based tests. The maximum range (ground distance and altitude) of any balloon transmission was 58.0 km in fair-weather with excellent line-of-sight visibility. Our highest altitude transmission was 28.6 km absolute altitude (25.3 km altitude relative to launch point). These numbers were determined from the GPS coordinates transmitted. Antenna alignment and acceptance angle effects were observed in our received data. For these reasons, the full data rate of 19200 baud was only obtained out to 10 km, and then again around 45-58 km. Performance of the system could be improved by spreading packets over a wider range of spectrum, improving the transmit antenna geometry, increasing power, using a more directional receive antenna; or all of the above.

AE22A-1113 1330h POSTER

Analytic Solution to the Problem of Aircraft Electric Field Mill Calibration

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It is by no means a simple task to retrieve storm electric fields from an aircraft instrumented with electric field mill sensors. The presence of the aircraft distorts the ambient field in a complicated way. Before retrievals of the storm field can be made, the field mill measurement system must be "calibrated". In other words, a relationship between impressed (i.e., ambient) electric field and mill output must be established. If this relationship can be determined, it is mathematically inverted so that ambient field can be inferred from the mill outputs. Previous studies have primarily focused on linear theories where the "relationship" between ambient field and mill output is described by a "calibration matrix" M. Each element of the matrix describes how a particular component of the ambient field is enhanced by the aircraft. For example the product MixEx is the contribution of the Ex field to the ith mill output. Similarly, net aircraft charge (described by a "charge field component" Eq) contributes an amount MiqEq to the output of the ith sensor. The central difficulty in obtaining M stems from the fact that the impressed field (Ex , Ey , Ez , Eq) is not known but is instead estimated. Typically, the aircraft is flown through a series of roll and pitch maneuvers in fair weather, and the values of the fair weather field and aircraft charge are estimated at each point along the aircraft trajectory. These initial estimates are often highly inadequate, but several investigators have improved the estimates by implementing various (ad hoc) iterative methods. Though numerical tests show that some of the iterative methods do improve the initial estimates, none of the iterative methods guarantee absolute convergence to the true values, or even to values reasonably close to the true values when measurement errors are present. In this work, the mathematical problem is solved directly by analytic means. For m mills installed on an arbitrary aircraft, it is shown that it is possible to solve for a single 2m-vector b that provides all other needed variables (i.e., the unknown fair weather field, the unknown aircraft charge, and the unknown matrix M). To avoid retrieving the trivial solution b = 0, appropriate external constraints are applied. Numerical tests of the solution, effects of measurement errors, and studies of solution non-uniqueness are ongoing as of this writing.

AE22A-1114 1330h POSTER

On The Design and Implementation of a New Electric-Field Meter with Reciprocating Shutter and Field-Change-Antenna Option

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The atmospheric electric field is a unique indicator of locally disturbed weather, local thunderstorms and local atmospheric electrical hazards. Yet, surprisingly, routine observations of ambient electric field have never been included in the canonical suite of measured meteorological variables. This notable omission may be a result of the historically high costs to acquire, install, and maintain conventional electric-field mills. To reduce costs and overcome limitations of traditional field meters, Campbell Scientific, Inc. has developed an electric-field meter (patent pending) with a reciprocating shutter that eliminates the problem of making electrical contact with a rotating shaft. The reciprocating action is under microprocessor control, so the sample rate can be varied in response to measured conditions. Between samples of electric field, the shutter can even be left open indefinitely, allowing the instrument to function as a field-change antenna. Since the shutter is closed before and after each measurement in field-meter mode, it is relatively easy to account for drift and offsets automatically, so that measurements can be made even if the electrode insulator becomes degraded by conductive deposits of the types likely to be encountered in severe outdoor environments. Because the motor is energized for only a small fraction of each measurement cycle, average power consumption is exceptionally low, making the new field meter especially suitable for solar-powered applications such as automated remote meteorological stations. Some preliminary observations demonstrate the capabilities of the instrument.

AE22A-1115 1330h POSTER

An Electric-Field Meter With Reciprocating Shuter, Used as a Lightning Flash Counter

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Cloud-to-ground (CG) lightning flashes result in transfers of charge from cloud to ground. Consequently, there are relatively large and abrupt changes in the electrostatic field in the region near the ground-strike point. Although cloud (IC) discharges can also result in changes in the electrostatic field at the ground, the changes tend to be smaller. In both cases there will be abrupt step changes in the electric-field record, followed by a characteristic relaxation period. Thus electric-field meters normally used to measure the ambient electrostatic field can also be used to count flashes by counting the abrupt changes. The Campbell Scientific CS110 electric-field meter is especially well suited to the task of monitoring and counting local lightning field changes because of its unique design and special features, including built-in data-processing capability. Because it has a reciprocating shutter under microprocessor control, rather than a spinning rotor, the CS110 has several advantages over traditional field mills, including greater reliability, lower noise, continuous adjustment for drift, and, not least, the option of leaving the shutter open so that the instrument can be operated as a field-change meter sensitive to distant lightning. In this paper we discuss use of the CS110 in field-meter mode to count nearby lightning flashes and in field-change-meter mode to count distant lightning flashes. To test the use of the CS110 as a flash counter for nearby lightning, we calculated the time derivative of the field at each sample; a moving median, M, of the derivatives; a moving standard deviation, s and moving Low and High limits, LH = M + ns, and LL = M - ns, (where n is chosen empirically). Events that exceed the limits are counted as nearby lightning flashes, where the meaning of "nearby" depends on the choice of n. To test the use of the CS110 as a flash counter for distant lightning, we operated it with the shutter open and recorded the output of the charge amplifier directly. We compare the resulting waveforms with those of a standard flat-plate type of field-change antenna.

AE22A-1116 1330h POSTER

Operational VHF Broadband Digital Interferometry and Observation of Thunderstorm

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Chubu Electric Power Corporation (CEPCO) and Lightning Research Group of Osaka University (LGOU) have been conducting a cooperative project of thunderstorm observations during a couple of summer seasons. The main objective of the project is to realize an operational VHF broadband interferometer as a lightning monitoring system. The VHF broadband interferometer has been proposed by the group of New Mexico Tech and LRGOU independently and simultaneously. LRGOU has been working for developing the system, and accomplished the experimental system of the VHF broadband interferometers. Following this, CEPCO and LRGOU has designed a special A/D converter and broadband VHF antenna for interferometry.

The A/D converter owns three channels, and can capture at most 2048 VHF pulses for one lightning flash with 200MHz sampling frequency. The time window for one VHF pulse is 2.5 microseconds, and it is sufficient to record VHF pulses radiated from lightning. They carried out field campaigns during summer thunderstorm seasons, and captured a lot of data. The location of 3D VHF radiation sources has been accomplished. Basically one VHF pulse in one time window gives us the continuous development image of lightning discharge. Two or three VHF pulses are eventually noticed in a 2.5 microseconds-window. Though we speculate it may be the evidence of the bi-directional leader concept, the interpretation in terms of the data analysis is not completed yet. They intend to compare VHF broadband interferometer observations with a Doppler radar data to confirm the performance of the system. They conclude tentatively that the function of the system is working well, and the VHF broadband interferometer for lightning monitoring is accomplished with high accuracy from the aspects of time and space.

AE22A-1117 1330h POSTER

Los Alamos Sferic Array 1998-2003: Results, Array Status, Data Processing and Calibration

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The Los Alamos Sferic Array (LASA) network of fast electric-field-change meters has operated in several configurations during the past five years. This presentation describes the array operations including calibration issues and methods. We will include a summary of 'lessons learned' from the array operations. The routine processing algorithms will be described in detail. Comparison of LASA lightning observations with other detection systems will be updated to cover the entire 5 years of data. The changes in the array operations which have been possible due to improvements in technology will be noted, and directions for future array improvements will be presented.

URL: http://edot.lanl.gov

AE22A-1118 1330h POSTER

Comparison Study of LIS and EDOT Lightning Detection

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LIS is a NASA space borne sensor that identifies the optical emissions of lightning emerging from the top of thunderstorm clouds. LIS data is organized into pulses and then into flashes to produce a product that measures total lightning. EDOT is a ground-based network of "fast antennas" that detect electric field changes. This network is owned and operated by Los Alamos National Lab and currently deployed primarily in Florida. EDOT uses time-of-flight measurements to calculate the source location, time, peak current, event-type classification and, in some cases, emission height. LIS and EDOT lightning parameters complement each other. The calculated instantaneous footprint of LIS defines a subset of EDOT events for Florida and the surrounding seas. Subsets of other available lightning data were also created for the LIS field of view. The subsets are cross-linked to match EDOT events to a specific LIS flash. EDOT events classified as cloud to ground lightning and narrow bipolar events are of particular interest. Both spatial-temporal correlations and anti-correlations will be presented.

AE22A-1119 1330h POSTER

Full Wave Analysis and Observation of Spherics Generated by Lightning

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We have developed a simple and cheap system with just a single VLF electromagnetic (EM) receiver to locate lightning discharges, which can determine both the direction and range of each lightning return stroke. With this system, we observe wave forms of two horizontal magnetic fields and of one vertical electric field of VLF spherics. The wave form of each VLF spheric usually consists of a couple of sequential pulses. The first pulse comes directly from a lightning return stroke, and is used for the direction finding of the stroke. The second and later pulses represent the multiple reflections of the first pulse between the ionosphere and the ground. The difference in the time-of-arrival of each set of adjacent pulses is determined by the difference in their multi-hop propagation path lengths in the Earth-ionosphere waveguide. By using the time-of-arrival differences between two or more pulses, we can inversely estimate both the reflection height of the ionosphere and the range of the lightning stroke. In this study, in order to quantitatively evaluate the observed spheric wave forms, we compute the propagation of the electromagnetic pulses (EMP) radiated by lightning current strokes by using the full wave method including the ionosphere and the ground, and compare their characteristics with the actual observations.

AE31A MCC: 3020 Wednesday 0800h

The Physics of Lightning and Storm Electrification II *(joint with A, NG)*

Presiding: **A R Jacobson,** Space and Atmospheric Sciences Group, Los Alamos National Laboratory**; L D Carey,** Texas A&M University

AE31A-01 0800h INVITED

Lightning Initiation by Runaway Air Breakdown

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The maximum macroscopic electric fields measured in thunderstorms are generally found to exceed the threshold for runaway breakdown and lie below the threshold for initiating conventional breakdown. In order for the conventional process that has been studied extensively in the laboratory to initiate lightning discharges it is necessary therefore to invoke the existence of field enhancements (e.g. around water droplets) in the thunderstorm electrical environment. On the other hand, the recent measurements of penetrating radiation in association with the leader activity that precedes a return stroke in natural lightning and triggered lightning have confirmed the importance of runaway breakdown in lightning discharge physics as a whole. In this talk we examine the potential role of runaway breakdown in initiating lightning. Several mechanisms are proposed including the initiation of an intra-cloud lightning discharge by an extensive energetic ($>10^{15}$ eV) cosmic ray shower (CRS). The results of first principles, fully electromagnetic, 2-D simulations of these various initiation mechanisms are presented. Conventional breakdown is found to develop in the field enhancement that occurs at the tip of a propagating positive streamer initiated by the combination of runaway breakdown and a CRS. The radio frequency emissions calculated for these discharges resemble the narrow bipolar pulses that have been associated with lightning initiation. The theory of runaway breakdown will be contrasted against conventional breakdown and the implications of our results for lightning initiation will be discussed.

AE31A-02 0830h

Observations of Runaway Breakdown in Thunderstorms: Where We've Been, Where We Are and Where We Need to Go

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The search for energetic electrons associated with thunderstorms began with C.T.R Wilson's original hypothesis in 1925. With varying degrees of success, numerous investigators have attempted to verify this hypothesis through ground-based measurements as well as *in-situ* measurements using balloons and aircraft. Over the past two decades, more advanced theories for energetic electron avalanches (Runaway Breakdown) have been proposed. Also during this time, more advanced measurement techniques have been applied in the effort to confirm or refute the presence of runaway breakdown in thunderstorms. These recent measurements indicate that energetic electrons indicative of runaway breakdown are present in lightning (step-leaders and dart-leaders) as well as near charge centers of thunderstorms. Since we have so few observations, additional measurements of energetic electron processes inside thunderstorms are certainly needed. However, this area of observational research appears to be ready to move beyond pure phenomenology and can begin to shape the next generation of runaway breakdown models. Conversely, we need to use current models to improve the next generations of observations.

AE31A-03 0845h

Laboratory Investigation of Positive Streamer Discharges From Simulated Ice Hydrometeors and Possible Relevance to the Problem of Lightning Initiation

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Observations have demonstrated that lightning can begin at very high altitudes at which environmental temperatures are well below -18°C, yet previous laboratory studies of positive streamer discharges from ice hydrometeors have been taken as evidence that ice hydrometeors at these cold temperatures likely do not contribute significantly to lightning initiation. The results of a new laboratory investigation indicate that simulated ice hydrometeors at temperatures as low as -38°C can initiate positive streamer discharges; however, relatively strong electric fields are required. Among many hypotheses for lightning initiation, we are concerned with two possibilities: 1) the hydrometeor-initiated intensifying positive streamer system, whereby a relatively weak (but still stronger than observed) background electric field can be locally intensified to levels believed sufficient for lightning leader formation, and 2) runaway breakdown, an alternative means of local electric-field enhancement that requires background electric-field strengths comparable with observational evidence. During the course of the laboratory investigation, a third possibility came to mind: perhaps reality is better explained by a combination of these two hypothesized processes. Perhaps an initial runaway electron avalanche need only result in a local electric-field enhancement sufficient to support initiation of positive streamer discharges from nearby hydrometeors. If so, any initial positive streamers should intensify rapidly and branch, resulting in significant electric-field enhancement at their origin. The positive feedback on the electric field should cause a succession of intensifying positive streamer systems, further enhancing the local electric field to strengths sufficient for the formation of a bipolar leader in a manner similar to that of the negative stepped-leader 'step'. Then perhaps this small bipolar leader could serve as