AE12A-0091 1330h POSTER

Leader Studies with the Los Alamos Sferic Array

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The Los Alamos Sferic Array records the transient electrical activity associated with lightning discharges between 1 - 500 kHz. The multi-station array has been operated since 1998, routinely geolocating lightning based on the differential times of arrival at the stations. The fast electric field change records are predominantly 8 ms record lengths but are occasionally collected with longer record lengths (up to 1 s) to provide overall lightning discharge context (including leader activity). The stations are operated in a threshold-triggered mode and predominantly trigger on initial return stroke activity. However, individual stations mayFor a small number of leader events, the FORTE satellite recorded VHF emissions from individual leaders steps. The FORTE observations allowed source altitude determination for multiple steps and therefore vertical propagation velocity determination. One type of leader provides large amplitude signatures in both the LF/VLF of the sferic array and the VHF of FORTE. For this class of event, a velocity of 10^6 m/s has been determined. This speed is approximately an order of magnitude greater velocity than the typical stepped-leader associated with an intial return stroke.

include leader radiation in the record or may even trigger on leader activity. The large number (> 2,000,000) of lightning events recorded provide a database for statistically significant studies of leader waveform parameters. We present initial results of studies of the leader activity in the sferic array database.

URL: http://edot.lanl.gov/

AE12A-0092 1330h POSTER

VHF Radiation Beam Pattern of Return Strokes Observed by the FORTE Satellite

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The FORTE satellite is in a circular orbit about 800 km above the Earths surface. The field of view (FOV) of the satellite is about 126° between the opposite limbs of the Earth. The satellite carries a broadband, log-periodic dipole array (LPA) antenna that points in the nadir direction. When the antenna operates at its low-band mode (with a 22 MHz bandwidth centered at 38 MHz) its main lobe overlaps with the satellites FOV. The large FOV offers an opportunity of viewing lightning-produced RF radiation from different angles. For return strokes, if the lowest section of the channel can be assumed vertical, the FORTE RF observations will, for the first time, enable us to investigate the radiation beam pattern within the upper half space. However, this study can only be done if the locations of the strokes, relative to the satellite, are known.

During the summers of 1998 and 1999, a campaign of joint lightning observations was conducted between the FORTE satellite and the National Lightning Detection Network (NLDN) over the North America. This campaign yielded 23546 coincident return stroke events. Among these, 3489 strokes produced very narrow (50-500 ns) RF pulses. By investigating the probability of FORTE detection as a function of the zenith angle (as viewed from the stroke), the strokes that produced the narrow pulses appear to have a radiation pattern beaming upward. If the concept of Kriders [1992] VLF radiation model can be borrowed, the propagation speed of the corresponding current front will be about 0.6c. In a clear contrast, the probability of detection for the rest of the wider-pulse strokes indicates they have a statistically isotropic beam pattern.

Krider, E. P., On the electromagnetic fields, Poynting vector, and peak power radiated by lightning return strokes, *J. Geophy., Res.*, *97*, D14, 15,913-15,917, 1992.

AE12A-0093 1330h POSTER

Effect of the Injected Space Charge on Lightning

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Abstract.

This work investigates the development of the lightning discharge between tall grounded objects and a thunderstorm cloud in the presence of local space charges. Corona currents from the objects initiated under the influence of the electric field of a thundercloud cell produce these space charges. Starting from the object, the local space charge expands toward the opposite charge in the thundercloud cell. Within seconds, the radius of the space charge (tens of meters) exceeds many times the radius of the electrode (usually one-two meters), where the space charge began.

The presence of the local space charge near the object changes qualitatively the process of lightning discharge between a thundercloud cell and an object on the earth. The air gap between them consists now of two characteristic regions: the region free of space charge and the region filled with space charge. The analytical results of the electric field and potential distribution along the air gap in the presence of a space charge indicate the significant difference from the well-known distribution of these properties in the laboratory air gaps without a space charge. The injected space charge smoothes the radial potential distribution along the charged region of the air gap. Most of the applied voltage drops along the charge-free portion of the air gap.

One of the phases of the process of lightning discharge is developing a counter leader, which will complete the discharge path between a thundercloud cell and the object on the earth. It was found theoretically and experimentally that the initiation of the leader in the long air gap (including an upward connecting leader in the downward lightning and an upward leader in the upward lightning) requires that the voltage drop near the stressed electrode must be not less than 400 kV along one meter of length. Redistribution of the voltage along the air gap influenced by the presence of the local charge can lead to a situation where that requirement will not be met, and the leader will not be initiated. Therefore, there will be no lightning discharge in the absence of the upward leader.

Computer modeling of the lightning discharge in long air gaps demonstrated that by optimizing the design of the electrodes emitting corona current it is possible to redistribute the electric field in such a way that will prevent in many cases the initiation of the counter- and upward leaders from the tall grounded objects.

AE12A-0094 1330h POSTER

A Sensitivity Study of the Importance of the Assumed Vertical Distribution Of Lightning NO_x

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A series of sensitivity runs aimed at studying the vertical distribution of lightning-produced NO_x and its effects on atmospheric chemistry have been carried out using the Model for Atmospheric Transport and Chemistry (MATCH). The model uses the Prince and Rind (1992, 1994) parameterization for lightning and the Zhang/McFarlane/Hack convection scheme. We consider two classes of runs, one with a simplified lightning-NO_x tracer which is released like normal lightning NOx, but has a constant exponential decay loss with a decay lifetime of two days, and another set involving the full non-methane hydrocarbon version of the model. The vertical distribution of lightning NO_x generation, as treated in previous versions of the model, rests on three basic assumptions: 1) Intracloud flashes outnumber cloud-to-ground flashes; 2) Cloud-to-ground flashes, on the other hand, are about 2-10 times more energetic than intracloud flashes; and 3) Lightning-NO_x production depends linearly on the ambient pressure, as well as being proportional to the energy of the flash. The first two assumptions will tend to cancel each other out to an extent in the model. Thus, due to the pressure weighting, NO_x is assumed to be released as an even mixing ratio throughout the convective column. The sensitivity runs examine other possible scenarios regarding the placement of lightning-NO_x within the convective events; e.g., lightning-NO_x only in the uppermost layers of the convective column. The results with the simplified NO_x tracer show substantial differences for the various runs. The NMHC-chemistry runs are currently underway and will also be reported on.

AE12A-0095 1330h POSTER

The impacts of NOx production by lightning on tropspheric chemistry

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The production of NOx by lightning over the contiguous United States has been evaluated by using combined ground-based and satellite lightning measurements. The lightning data from the National Lightning Detection Network (NLDN) over the period of 1995-1999, along with a ratio of intracloud (IC) to cloud-to-ground (CG) flashes derived in conjunction with satellite lightning measurements from the Optical Transient Detector (OTD), are analyzed to obtain the CG and IC flashes. In addition we use a global three-dimensional chemical transport model to investigate the impact of lightning on the chemistry of the troposphere, specifically NOx and O3 levels. We compare the effects of major surface emission sources (anthropogenic activity, biomass burning, and soil release) to those of lightning-produced NOx estimated from the ground- and satellite-based data. We find lightning to be a dominant source in controlling NOx concentrations in the upper troposphere, and to have a significant impact on O3 as well. Furthermore, this effect can be propagated over large distances due to the atmospheric circulation.

AE21A MC: 123 Tuesday 0830h

Lightning and Storm Electrification III

Presiding: **V A Rakov,** University of Florida**; D R MacGorman,** National Severe Storms Laboratory/CIMMS

AE21A-01 0830h INVITED

Global Frequency and Distribution of Lightning as Observed From Space

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We now have over six years of near continuous lightning observations from space. Two space-based instruments, the Optical Transient Detector (OTD) and the Lightning Imaging Sensor (LIS), have provided the measurements. The OTD was launched into a 750 km high, 70 degree inclination near polar orbit in April of 1995 while the LIS, one of the Tropical Rainfall Measuring Mission (TRMM) instruments, was launched into a 350 km high, 30 degree inclination orbit in November of 1997. The OTD views most regions of the earth more than 400 hundred times during a one-year period, with an average observational duration of 2 minutes. Because of its low inclination orbit, LIS observations are restricted to more Tropical regions (+/-35 degrees), and the low orbital altitude restricts viewing time to 83 seconds. Both instruments optically detect lightning flashes within their field-of-view (1300x1300 km2 for the OTD, 650x650 km2 for the LIS). A statistical examination of the lightning data reveals that nearly 1.4 billion flashes occur annually over the entire earth. This annual flash count translates to an average of 44 +/-5 lightning flashes (total lightning) occurring around the globe every second, which is well below the traditional estimate of 100 flashes per second that was derived in 1925 from world thunder-day records.

The OTD and LIS measurements have been used to construct lightning climatology maps that demonstrate the seasonal distribution of lightning activity for the globe. An analysis of this annual lightning distribution confirms that lightning occurs mainly over land areas (88% over the continents, 12% over the oceans).

An average of 78% of the global lightning activity occurs between 30 degrees South and 30 degrees North. A dominant Northern Hemisphere summer peak occurs in the annual cycle and evidence is found for a tropically driven semiannual cycle. A comprehensive review of LIS and OTD data will be presented.

AE21A-02 0855h

The Effects of Charge and Electrostatic Potential on Lightning Propagation

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In this presentation we will compare three-dimensional maps of lightning paths in storms to the locations of cloud charge regions inferred from balloon soundings of electric field in the storms. We will present data showing that the horizontal channels of bilevel intracloud (IC) flashes travel through preexisting charge in the cloud. Typically, these bilevel flashes had an upper level of negative polarity breakdown through the cloud's upper positive charge region and a lower level of positive polarity breakdown through the main negative charge region. We will also present comparison data from cloud-to-ground (CG) flashes. In particular we will focus on two types of CG flashes: those in which the descending negative leader comes straight to ground with little or no horizontal branching and those in which the negative leader travels horizontally through the lower positive charge before coming to ground. We have two main goals for these comparisons. First, we want to show how closely lightning paths overlap with the preexisting charge in a cloud. Second, we will attempt to show how horizontal lightning paths are influenced by the preexisting charge and electric field in a cloud.

AE21A-03 0910h INVITED

Electrical Evolution of Thunderstorms and Lightning

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This presentation uses data collected during the 1999 Study of Electrical Evolution of Thunderstorms (SEET) to investigate two types of interactions between lightning flashes and the evolving electrical structure of a thunderstorm. The first type of interaction involves the effects of lightning on the evolution of the charge structure. The SEET data suggest that lightning charge deposition tends to make the overall charge distribution inside a storm more complicated. This finding helps explain the complicated charge distributions commonly observed with balloon-borne instruments. In the second type of interaction the evolving charge structure influences the lightning activity. It is known that the lightning flashes at the beginning of many thunderstorms are exclusively intracloud flashes. The SEET data suggest that the lack of cloud-to-ground (CG) flashes at the beginning of a storm is due to a relatively weak electric field in the lower part of the storm: the field below the main negative charge region is not strong enough to initiate a lightning flash. As the storm's electrical structure evolves and a sufficiently large region of lower positive charge develops, then initiation of CG flashes can occur. Storms that develop a substantial lower positive charge region early in their life-cycle have CG flashes early, too. Examples of these two types of interactions between electrical evolution and lightning will be presented.

AE21A-04 0935h

Observations of the Decay of Electric Fields in anvils over Kennedy Space Center

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In-situ observations of electric fields and associated microphysics have been made in anvils of active and decaying thunderstorms over or near Kennedy Space Center from the Univ. of No. Dakota Citation II jet aircraft. Simultaneous observations of lightning were made using the KSC Lightning Detection and Ranging (LDAR) and CG Lightning Detection Systems. Thus we know when and where lightning was occurring in the storms or decaying anvils being investigated by the Citation. Storm structure and evolution was determined from radar reflectivity measured with the 5 cm Patrick Air Force Base 74-C radar. Different cases will be presented to illustrate: 1) the presence of thunderstorm strength electric fields near and somewhat downwind of the storm cores; 2) the decrease of electric field with distance from cores still producing lightning; 3) after the last lightning, the temporal decay of electric fields in anvil debris; 4) and that 2 1/2 to 3 hours after the last lightning, electric fields in the decaying anvils can be quite weak.

AE21A-05 0950h

Lightning Relative to Graupel Occurrence in a Tornadic Supercell Storm during MEaPRS

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In 1998, the MCS Electrification and Polarimetric Radar Studies (MEaPRS) field program acquired data from a 10-cm polarimetric radar operated by the National Severe Storms Laboratory and from the lightning mapping array operated by New Mexico Institute of Mining and Technology. One of the storms observed by MEaPRS was a supercell storm that produced weak to strong tornadoes in the Oklahoma City area on June 13. This storm was positioned well for data collection by both the lightning mapping array and the polarimetric radar for roughly one hour, during which it produced tornadoes and large hail. This is the period analyzed by this paper. The majority of cloud-to-ground flashes that occurred during this period were the anomalous flashes that lower positive charge to ground. Also, many of the cloud flashes that occurred in the upper part of the storm during this period appeared to discharge negative charge above positive charge, a polarity which is inverted from what is normally observed. Shortly after the storm moved beyond the range of three-dimensional lightning mapping data, it weakened and dissipated. The data show that trends in the number of VHF radiation sources near and within the mixed phase region of the storm were similar to trends for the mass and volume of graupel in this region. Graupel mass at still higher altitudes appeared unrelated to lightning. Severe weather was not preceded by rapid jumps in flash rates, as has been reported for Florida severe storms by other investigators, possibly because flash rates were very large in the Oklahoma City storm throughout most of the period. However, the rate of VHF emissions tended to increase at middle levels of the storm prior to tornadoes. Furthermore, the maximum height of VHF sources tended to increase shortly before or coincident with severe weather, in a pattern suggestive of updrafts and cloud turrets penetrating above the equilibrium level.

AE21A-06 1025h INVITED

Lightning Mapping Observations: What we are learning.

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The use of radio frequency time-of-arrival techniques for accurately mapping lightning discharges is revolutionizing our ability to study lightning discharge processes and to investigate thunderstorms. Different types of discharges are being observed that we have not been able to study before or knew existed. Included are a variety of inverted and normal polarity intracloud and cloud-to-ground discharges, frequent short-duration discharges at high altitude in storms and in overshooting convective tops, highly energetic impulsive discharge events, and horizontally extensive 'spider' lightning discharges in large mesoscale convective systems. High time resolution measurements valuably complement interferometric observations and are starting to exceed the ability of interferometers to provide detailed pictures of flash development. Mapping observations can be used to infer the polarity of the breakdown channels and hence the location and sign of charge regions in the storm. The lightning activity in large, severe storms is found to be essentially continuous and volume-filling, with substantially more lightning inside the storm than between the cloud and ground. Spectacular dendritic structures are observed in many flashes.

The lightning observations can be used to infer the electrical structure of a storm and therefore to study the electrification processes. The results are raising fundamental questions about how storms become electrified and how the electrification evolves with time. Supercell storms are commonly observed to electrify in an inverted or anomalous manner, raising questions about how these storms are different from normal storms, and even what is 'normal'. The high lightning rates in severe storms raises the distinct possibility that the discharges themselves might be sustaining or enhancing the electrification. Correlated observations with radar, instrumented balloons and aircraft, and ground-based measurements are leading to greatly improved understanding of the electrical processes in storms.

The mapping observations also provide possible diagnostics of storm type and severity. Lightning 'holes' are observed as storms intensify and are robust indicators of strong updrafts and precursors of tornadic activity. Lightning in overshooting convective tops provides another indicator of strong convective surges and a valuable precursor of severity. The lightning observations show the locations of convective cores in storms and can be obtained in real time to monitor and track convective activity, much like meteorological radar. Mapping systems are able to passively detect and track aircraft flying through ice crystal clouds, as well as airborne or ground-based instruments or vehicles carrying active transmitters. Finally, the mapping techniques could readily be adapted to monitor noise and detect faults on power transmission lines.

AE21A-07 1050h

Cloud and Cloud-to-ground Lightning Detection at LF and VHF: Early Results from Global Atmospherics Dallas-Fort Worth LDAR-II and IMPACT/ESP Research Networks

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Global Atmospherics, Inc. (GAI) recently installed a regional Lightning Detection and Ranging (LDAR-II) network and a regional VLFLF lightning detection network of IMPACTESP and LPATS IV sensors (configured to detect both cloud-to-ground lightning and cloud discharges) for research purposes in the vicinity of Dallas-Fort Worth (DFW) International Airport. The LDAR-II and VLF/LF networks became fully operational on 1 March 2001 and 10 June 2001, respectively. The DFW LDAR-II network is made up of 7 sensors, with 20 to 30 km baselines, that can detect pulses of radiation produced by the electrical breakdown processes of lightning in a 5-MHz band within a subset of the VHF (50-120 MHz) band. This regional LDAR-II network can map lightning flashes in 3-dimensions within approximately 150 km of the center of the network, degrading in performance with increasing range. Expected lightning flash detection efficiency is greater than 99% within the interior of the DFW LDAR-II network (a range of 30 km from DFW International Airport) and greater than 90% out to a range of 150 km from DFW International Airport. Expected three-dimensional location accuracy for individual pulses of radiation is better than 100 m within the interior of the network and better than 2 km to a range of 150 km from the network center.

Early analysis of the DFW LDAR-II and VLF/LF networks has involved comparisons with the U.S. National Lightning Detection Network (NLDN) and radar base reflectivity images from the DFW National Weather Service (NWS) radar. The results of these comparisons will be summarized for representative thunderstorm cases. In addition, a specific case involving an extensive spider lightning discharge will

be presented. This discharge originated at a distance of more than 50 km from DFW airport, traveled a total path of approximately 150 km, and initiated four isolated cloud-to-ground discharges one of which resulted in a safety-related incident at DFW airport.

AE21A-08 1105h

Comparison of New Mexico Tech VHF Interferometer and Arecibo radar data of lightning

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The New Mexico Tech InterferometerSferic (NMT INTF) system records both broadband electric field data and narrowband VHF phase and amplitude information at 274 MHz. Previous studies have shown that the NMT INTF system can identify and map most forms of slow and fast negative breakdown processes, but generally has difficulty detecting slow positive breakdown processes.

The Arecibo Observatory UHF radar (430 MHz) was used between August 25 and September 10, 2001, to detect the backscatter from lightning leaders. When lightning was over or near the observatory, the radar was operated in a special "leader mode" with an interpulse period (IPP) of 1 ms and a pulse width of 2 μs. The radar beam had a width of about 300 m and could detect a conducting object with a cross section of as little as 10^-10 m^-2 at a distance of 100 km. The NMT INTF system was situated about 8 km north of Arecibo Observatory, an ideal location for mapping lightning both in the main beam of the radar as well as (more typically) in the sidelobes. Data obtained by the interferometer will be compared with that of the radar and some preliminary results of this comparison will be presented.

AE21A-09 1120h

Combined Lightning Observations Using the TRMM and FORTE Satellites

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The Tropical Rainfall Measuring Mission (TRMM) and Fast On-Orbit Recording of Transient Events (FORTE) missions have lightning sensing experiments. On occasion, both sets of instruments measure the properties of the same flash. This paper presents several examples of how the data sets are combined to detect, locate, map, classify and analyze a lightning flash in a remote storm location. The Lightning Imaging Sensor (LIS) on TRMM has the sensitivity to detect, locate, organize and map the spatial and temporal development of a flash. Because of the higher orbit, the FORTE instruments trigger their recordings on the largest events during a flash. Within the context of the LIS data, the high time resolution FORTE Photo Diode Detector and FORTE VHF data confirm the LIS detections and provide additional diagnostic information to classify strokes within a flash. The combined analysis, in some cases, can include altitude information about the VHF source to produce a two and a half-dimensional analysis of a flash. The remote locations of these oceanic storms illustrate how space based lightning observations can complement those made by fixed, ground based lightning detection networks.

AE21A-10 1135h

Characterization of the Initial Stage of Object-Initiated and Rocket-Triggered Lightning

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Upward discharges are initiated by a leader that originates from the object and propagates upward toward the charged cloud overhead. Upward discharges involve an initial stage that is characterized by a continuous current with a duration of some hundred milliseconds and an amplitude of some tens to some hundreds of amperes, often followed by one or more downward leader/upward return stroke sequences. Since direct current measurements are usually performed on towers that experience primarily upward discharges, there has been considerable interest lately in characterizing upward lightning flashes. Specifically, there is the question of whether current pulses occurring during the initial stage, that is, pulses superimposed on the long-lasting, low-level continuous current, are due to return strokes or due to an M-component-type lightning process.

The phenomenology of upward lightning is similar to that of rocket-triggered lightning. Wang et al. (1999b) have studied the characteristics of the current pulses in the initial stage (IS) of rocket-triggered lightning. In most cases the IS contained current pulses (initial continuous current (ICC) pulses) superimposed on the slowly varying continuous current. A statistical comparison between these pulses and the M-component pulses following return strokes in triggered lightning indicates that both types of pulses are due to similar physical processes.

In this international collaborative study, we compare the characteristics of the IS in rocket-triggered lightning in Florida with their counterparts in natural upward lightning as observed on (1) the Gaisberg tower (100 m, Austria), (2) the Peissenberg tower (160 m, Germany), and (3) the Fukui stack (200 m, Japan). All current records in Japan and some of the current records in Germany and Austria were obtained in winter, whereas all triggered-lightning data were obtained in summer. All lightning events effectively transported negative charge to ground. The geometric mean (GM) values of the overall characteristics of the IS, duration (T), charge transfer (Q), and average current (I), for rocket-triggered lightning (T = 305 ms, Q = 30.4 C, I = 99.6 A) are similar to their counterparts for Gaisberg-tower flashes (T = 235 ms, Q = 29.6 C, I = 126 A) and Peissenberg-tower flashes (T = 290 ms, Q = 38.5 C, I = 133 A), while the Fukui-stack flashes are characterized by a somewhat shorter GM initial-stage duration (T = 88.4 ms) and a larger average current (I = 496 A). The GM initial-stage charge transfer for the Fukui-stack flashes is 48.8 C. The observed differences in the IS duration and the average current are probably related to the differences in the lower current measurement limits: about 200 A for the Fukui data set vs. 15 to 20 A for the other three data sets. The characteristics of the ICC pulses in object-initiated (Gaisberg, Peissenberg, and Fukui) lightning are similar within a factor of two to three, but differ more significantly from their counterparts in rocket-triggered lightning. Specifically, the ICC pulses in object-initiated lightning exhibit larger peaks, shorter risetimes, and shorter half-peak widths than do the ICC pulses in rocket-triggered lightning. Possible reasons for the observed dissimilarities will be discussed.

AE21A-11 1150h

Submicrosecond Structure of the Electric Field Derivative During the Onset of First Return Strokes in Cloud-to-Ground Lightning

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Typically, the radiation field that is produced by the first return stroke in cloud-to-ground lightning begins with a slow front that lasts about four microseconds and that is followed by a fast transition to peak in tens to hundreds of nanoseconds. We have analyzed 132 digitized records of the dE/dt (100 MHz) and E (10MHz) fields that were radiated by first strokes in strikes to sea water under conditions where the lightning locations were known and there was minimal distortion of these fields due to propagation. A large fraction (64%) of the dE/dt signatures contained significant multiple peaks within a 5 μs interval near (4 μs before to 1 μs after) the dominant peak, and 38% had multiple peaks within 1 μs of the dominant peak. When the integral of dE/dt was computed and compared with E, the integrated waveforms exhibited considerable fine-structure that was not resolved by the 10 MHz digitizer. This structure includes fast pulses near the beginning of the slow front, large peaks and shoulders within the slow front and during the fast transition, and very narrow peaks in E. Examples of the dE/dt and E waveforms will be given together with statistics that suggest the lightning attachment process is more complex than is commonly assumed in the literature.

AE22A MC: 123 Tuesday 1330h

Thunderstorm Electrical Effects on the Middle and Upper Atmosphere and Ionosphere I

Presiding: **D D Sentman,** University of Alaska**; V P Pasko,** The Pennsylvania State University

AE22A-01 1330h INVITED

The Search for Upward Lightning

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Some of the reports about 'upward lightning' are over one hundred years old. Eyewitness reports became more numerous with the advent of night aviation operations. Early photographs of lightning, Nighttime-Daytime Optical Survey of Lightning Experiment (NOSL), in November 1981 produced interesting images of lightning as seen from Space Shuttle. Both civilian and military pilots had observed luminous phenomena occurring above thunderstorms, although they were reluctant to report them in official channels. Vaughan and Vonnegut collected and published some of these eye witness reports in 1982 and 1989. From 1985 into the 1990's the Mesoscale Lightning Experiment (MLE) gathered video images of lightning from the Space Shuttle platform. By 1989, the remotely operated low light video camera in the payload bay yielded many hours of lightning images. The breakthrough came in 1989 with the video evidence obtained by Franz, Nemzek and Winckler. This video clip provided hard evidence of the existence and duration of upward lightning. MLE investigators received a copy of the video for study. Many hours of Shuttle video were then reexamined to find these brief events that extended beyond the horizon as seen from space. The high oblique view provided a simultaneous view of the lightning in a storm cell and the sprite above. Within a few years investigators were in the field using a variety of sensors to measure and analyze sprite phenomena. The name 'sprite' replaced earlier names for upward lightning. Dr. Davis Sentman suggested it after he had observed them during the summer of 1994 from jet aircraft. The search for upward lightning led to the study of sprites, jets, elves and starters. Because sprites, jets and elves have appeared for millennia, their eventual discovery was inevitable. The Winckler contribution was the catalyst for major progress in this science.

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Electrical Discharges into the Stratosphere from the Tops of Intense Thunderstorms

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