AE11A-0073 0830h POSTER

Long-term Observations of Electric Field, Temperature, Pressure, Humidity, Wind Speed, Wind Direction, Rainfall Rate and Solar Insolation at a Remote Meteorological Observing Station

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For nearly two years we observed the electric field at the surface continually and simultaneously with observations of temperature, pressure, humidity, wind speed and direction, rainfall rate and solar insolation at a remote automated meteorological observing station in Norman, OK. The electric-field observations were made with electric-field mills that were cycled on every few minutes for a period of about 20 seconds, 24 hours a day, seven days a week for the entire period of time. We observed a number of interesting patterns in the observations, some familiar and some not. For example, monthly averages of the observations often yield Carnegie curves, but not always. We noted what appears to be a sunrise effect on some days. We present a representative sample of the observations.

AE11A-0074 0830h POSTER

Simulations of Spatial and Temporal Variations of Electric Field at the Surface Beneath Thunderstorms

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In order to begin to understand how to deal with data streams from large networks of closely spaced electric-field meters, we have simulated the growth and decay of electrified storms over such a network, and consequently, the spatial and temporal variations of contours of electric field at the surface. We assumed realistic locations and spacing for approximately 50 sensors based on an existing network of remote meteorological observing stations. We assumed simple thunderstorm charge distributions with linear growth and decay of the amounts of charge. We simulated stationary charge distributions overhead, distributions that moved horizontally as if advected by a mean wind, and vertically oriented as well as tilted charge distributions. We also included the effects of CG and IC lightning discharges. We calculated the electric field at the sensor locations and then interpolated contours of constant value of the field for each time step. We present some representative simulations that suggest directions for future research.

AE12A MC: Hall D Monday 1330h

Lightning and Storm Electrification II

Presiding: **P Krider,** Atmospheric Physics, University of Arizona**; R Orville,** Dept. of Atmos. Sci., Texas AM University

AE12A-0075 1330h POSTER

VHF Global Lightning and Severe Storm Monitoring From Space: Storm-level characterization of VHF lightning emissions

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Over the last few decades, there has been a growing interest to develop and deploy an automated and continuously operating satellite-based global lightning monitor. The resulting unprecedented data set would be applicable to the commercial and military aviation communities, and to the regional/global meteorology and climatology communities. To date, efforts to develop such a system have focussed on the deployment of optical sensors which can provide cost-effective single-platform geolocation of lightning events. Recently, we have presented a proposal to develop a GPS satellite-based global lightning and severe storm monitor based on the detection of VHF emissions from lightning. This presentation concentrates on characterizing the storm-level climatology of the VHF lightning emissions that would be detected by such a monitor. Analysis of existing data sets such as those from the Fast On-Orbit Recording of Transient Events (FORTE) satellite are used to show that a GPS-based VHF lightning monitor would primarily detect narrow ($\sim 1\mu s$) impulsive signatures that are associated with narrow bipolar events (NBEs). These signatures are ubiquitous and are commonly associated with strong convective activity.

AE12A-0076 1330h POSTER

Determination of Ice Precipitation Rates and Thunderstorm Anvil Ice Contents from Satellite Observations of Lightning

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Simple calculations and modelling predict that the lightning frequency f is proportional to the product of the downward flux of solid precipitation through the body of the thundercloud and the upward flux of ice crystals into its anvil.

Calculations indicate that the separation of charge and associated field development in thunderclouds are not significantly limited by charge saturation of the interacting hydrometeors: and that the mutual interactions of graupel pellets in the charging zones of thunderstorms can significantly enhance electric field development, culminating in lightning.

An examination of data from the satellite-borne Lightning Imaging Sensor and TRMM Microwave Imager indicates that thunderstorms with the highest frequency of total lightning also possess the most pronounced microwave scattering signatures at 37 and 85 GHz. These findings are consistent throughout the seasons in a variety of regimes (12 sites encompassing 5 continents, as well as oceanic measurements), suggesting that global relationships may exist between lightning activity and cloud ice contents and/or fluxes.

AE12A-0077 1330h POSTER

A Model Study of Anvil-top Plume Formation in the 20 July 2000 Denver Thunderstorm

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A supercell convective storm northeast of Denver, Colorado on 20 July 2000 was observed by team members of STEP2000 project to have a trailing cirrus plume formation above the anvil. Since the formation of plumes above thunderstorm anvils may represent a transport of water vapor (and possibly other chemical species) from the troposphere to the stratosphere, the mechanism responsible for this phenomenon deserves a detailed examination. In this paper, we will report a numerical model simulation study utilizing a 3-D non-hydrostatic, quasi-compressible cloud model with detailed cloud microphysics to simulate the evolution of this storm. We will perform analyses of the dynamic and microphysical structures of the simulated storm to identify the mechanism responsible for the plume formation above the anvil. Preliminary results indicate that the breaking of gravity waves at and above the anvil level is a strong candidate mechanism for this phenomenon. The shell of the overshooting dome seems to be the main source of water vapor for the plume, especially in the mature stages of the storm. The details of the results will be presented at the time of the conference.

AE12A-0078 1330h POSTER

Observations of Hydrometeor Electric Charge in Thunderstorms

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Despite general acceptance of the hypothesis that charge separation in thunderstorms is largely due the non-inductive ice-ice collision charging mechanism, it has been difficult to interpret observations of hydrometeor charges in storms in terms of this hypothesis. In particular, most observations of hydrometeor charge show no clear trend for larger charges to be found on larger particles, which presumably have undergone more collisions. It quite often is observed that the largest charges are found on smaller particles. Interpretation of the observations is made difficult by chaotic hydrometeor trajectories in typical thunderstorms, the presence of lightning, and other complicating factors. During the Severe Thunderstorm Electrification and Precipitation Study (STEPS), in the summer of 2000, observations of several storms were obtained using multiple Doppler and dual-polarization meteorological radars, a lightning-leader mapping array, the National Lightning Detection Network (NLDN) cloud-to-ground lightning mapper, instrumented balloons and aircraft, and a mobile mesonet. A special instrument on the aircraft provided hydrometeor shadow imagery and charge observations. Using the coordinated observations, it is possible to isolate regions along the aircraft storm penetration tracks where the developmental history of the particles observed can be inferred with some certainty. These regions include updraft, updraft/downdraft transition, downdraft, trailing stratiform, and below-cloud base precipitation shafts. Comparisons of the observed hydrometeor charge distributions are made to those expected from collision charging. In some regions, observations conform to expected distributions, and in other regions, interpretation is less clear.

AE12A-0079 1330h POSTER

Electrical Charge Structure and Cloud-to-Ground Lightning in Thunderstorms during STEPS.

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Three-dimensional mapping observations of lightning discharges can be used to infer the basic charge structure of the parent thunderstorm and indicate how the charge structure evolved with time in storms. In this paper we discuss the electrical evolution of several storms and correlate this with the occurrence of cloud-to-ground (CG) lightning from the storm. Many storms during STEPS were multicellular systems whose electrical structure often differed between cells, from normal to inverted polarity. Storms which produced -CG discharges usually had negative charge at mid-levels (7-9 km altitude MSL) and a normal tripole structure, consisting of positive charge above and below the mid-level negative charge. Storms that produced +CG discharges, including supercell storms, had positive charge at mid-levels accompanied by upper negative and lower negative charge, and were therefore inverted in polarity. In the normal-polarity storm of July 10, 2000, the altitudes of the negative and upper positive charge regions gradually decreased with time as the storm dissipated, which caused the CG lightning to switch polarity from (-) to (+). In two supercell storms on July 22, the CG flash rate was highly episodic, with 20-30 minute lulls in the flash rate being followed by 10-15 minutes of enhanced CG activity, either of positive or negative polarity. In these and other supercell storms, episodes of +CG activity were immediately preceded by strong convective surges in the storm, as evidenced by the occurrence of high-altitude lightning in overshooting convective tops. The +CG discharges occurred immediately downwind of lightning holes associated with the convective surges. -CG discharge episodes in the July 22 storms occurred further downwind at the base of the anvil, where the upper negative and mid-level positive charges had subsided to mid- and low-levels. Inverted-polarity storms often produced no CG activity for extended time periods during their initial stages, and several such storms produced no CG discharges over their entire lifetime. Such storms also did not produce strong convective surges. Several supercell storms, including the tornadic storm of June 29, began with intracloud (IC) discharges between lower positive and mid-level negative charge, followed within 10-15 minutes by intense IC lightning between the mid-level negative and upper positive charge. The storms therefore appeared to be of normal polarity, but did not produce CG discharges until they became inverted in polarity. The mechanisms for many of the above observations remain to be determined.

AE12A-0080 1330h POSTER

Lightning Observations by the Broadband Interferometer to Consider Possible Charge Distribution in Thunderclouds

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It is known that VHF impulses are mainly emitted at the tip of breakdown, something like at the leader tip and especially in case of a negative breakdown. From this aspect it is noticed that the VHF impulse source location during leader developing phase is equivalent to the imaging of the lightning progression. Moreover, the source location after the occurrence of return strokes or during the continuing current in case of a negative breakdown gives the positive charge distribution inside the thundercloud. In other words we are able to get images of positive charge distributions by VHF observations. Lightning Research Group of Osaka University (LRGOU) has been conducting campaigns in Darwin, Australia and at Hokuriku Coast, Japan. The main objective for Darwin Campaign is the investigation of thunderstorm activity in inter tropical convection zone (ITCZ) in terms of VHF observations. The main target for Hokuriku Campaign is further understanding of positive cloud-to-ground lightning discharges during winter thunderstorms. Through the observations two-dimensional and three-dimensional imaging of lightning channels are obtained respectively. The VHF source mapping in azimuth and elevation format for cloud discharges are obtained, and several branches are noticeable. If we compare the progression of branches with their electric field changes, it is found that the terminations of branch progressions correspond to the small but abrupt electric filed changes. The termination of negative breakdown progression means its arrival at a positive charge region and immediate K change due to a recoil streamer occurrence, and this is understandable phenomenologically. The three-dimensional lightning leader images for multiple strokes from the aspects of traditional definition are also given. However multi-point strikes are noticeable by VHF observations, and it is concluded that these flashes should be the multi-point lightning flash instead of traditional multiple strokes. High time-resolution by the broadband interferometer can present us the occasion to reconsider the definition multiple flash, and the understanding on the cause of multi-point and multiple flashes still remains.

AE12A-0081 1330h POSTER

Thunderstorm Charge Structure and the Spatial Distribution of Radiation Sources Located by LMA

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The Lightning Mapping Array (LMA) typically locates between 100 and several thousand radiation sources in each lightning flash. The location is found by measuring the time-of-arrival of the radio frequency pulse at 6 to 13 ground stations. In the past we have described the sources in either a single flash or an entire storm; in this presentation we will look at the distribution of sources in a series of a few flashes to find clues of the process of charge separation and redistribution. Typically in the NM storms IC flashes are found to occur between the main negative charge region and the upper positive charge region, while CG flashes occur between the main negative region and both the ground and the lower positive region. In the main negative region radiation sources from the ICs are on the average higher in altitude than those from CGs. The radiation sources from the upper branches of ICs associated with the upper positive charge often follow the highest altitude radar echos. Examination of successive flashes in the same storm, shows that the paths of the branches that a flash follows avoids the regions traversed by the previous few flashes; in this manner a series of flashes completely fill in the main regions in the storm.

URL: http://lightning.nmt.edu

AE12A-0082 1330h POSTER

STEPS 2000: Relationships Between Thunderstorm Charge Structure, Lightning Behavior, and Storm Severity.

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We infer the charge structure of thunderstorms from New Mexico Tech Lightning Mapping Array (LMA) and ground-based electric field data. Using polarimetric radar scans of these storms, we investigate the relationships between their dynamical, microphysical, and electrical characteristics. Based on these analyses, we find that severe storms and non-severe storms have differing charge structures and lightning behavior during their initial development.

A non-severe storm on June 23 had a "typical" charge structure: a negative charge "layer" near 7 km MSL with overlying positive charge near 9 km. Initial intra-cloud (IC) lightning in this storm discharged the negative charge into the overlying positive charge. Cloud to ground (CG) lightning began within 10 minutes of the first lightning and removed charge from the negative "layer". All CGs were negative CGs. IC lightning in the later stages of the storm discharged the negative layer both upward to the overlying positive and downward through a presumed lower positive layer near 5 km MSL. This storm's total flash rate was less than 5 flashes/min.

A moderately severe storm on June 3 initiated with an elevated negative charge layer near 9 km MSL, a closely overlying positive charge layer, and an underlying positive charge layer near 6.5 km. Both positive charge layers participated in IC flashes for the duration of the storm. The IC flash rate peaked at 80 flashes/min. There was no cloud to ground lightning from this storm.

A severe storm on June 29 initiated with negative charge near 7 km MSL along with a lower positive charge near 5 km. The first 20 minutes of lightning in this storm was composed entirely of low frequency (less than 5 flashes/min) IC flashes between the negative and lower positive layers. After developing explosively into a tornadic supercell, flash rates exceeded 100 flashes/min. The vast majority of flashes were IC, with only 3 or 4 CGs during the first two hours. The flash rates then surged again to more than 300 flashes/min. This surge was closely followed by onset of frequent positive CGs and a tornado. The source charge for the +CG's appeared to be at mid-levels (6-7 km), not in the anvil.

AE12A-0083 1330h POSTER

High Time Resolution Lightning Mapping Lightning Mapping Observations of a Small Thunderstorm during STEPS

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During the 2000 STEPS (Severe Thunderstorm Electrification and Precipitation Study) program, the New Mexico Tech Lightning Mapping Array (LMA) was operated in high time resolution mode [Rison *et al.*, 2000] for several days. On July 11 a small thunderstorm formed over the northern part of the LMA network while the LMA was in this mode. The lightning mapping observations show that the electrical structure of the thunderstorm changed significantly during its lifetime. The electrical development of the storm as inferred from the lightning mapping observations will be presented.

In high time resolution mode the LMA records the time of the strongest VHF radiation received in 10 μs windows (compared to 100 μs windows in normal time resolution mode). In high time resolution mode the LMA can produce significantly more detailed images of continuous radiation processes (such as stepped leaders, dart leaders and K-changes). Cloud-to-ground discharges examined in the July 11 storm show significant branching in stepped leaders, and there is sufficient detail in stepped and dart leaders and K-changes that good velocities for relatively fast leader processes (10^7 m/s) can be determined.

Rison, W., P. Krehbiel, R. Thomas, T. Hamlin, and J. Harlin, A Time-of-Arrival Lightning Mapping System with High Time Resolution, Abstract A52C-01, Fall Ann. Mtg. Amer. Geophys. Union, **EOS, 81**, p. F47, 2000.

AE12A-0084 1330h POSTER

Reflectivity and airborne measurement of the electric field recorded in Florida thunderstorms during the ABFM project

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The Airborne Field Mill (ABFM) project was conducted in Central Florida during June 2000, February 2001 and May-June 2001. The University of North Dakota (UND) Citation performed in situ measurements of microphysics and electric field in anvils. The WSR74C radar located at Patrick Air Force Base documented the structure of the sampled clouds. For some cases the measurement of the vertical electric field will be related to the radar reflectivity at the flight level and also above and below the flight track. We will present and summarize the results of the analysis.

AE12A-0085 1330h POSTER

Analysis of 3-month lightning activity in Colorado during the STERAO-A project

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We analyzed the lightning activity recorded by the ONERA real time VHF lightning mapper during the STERAO-A project between 13th of June and 6th of September 1996 in the northeastern part of Colorado. Four-to-eight-hour periods of lightning activity were recorded in real time during sixty-five days of that summer within the 250 x 250 km2 STERAO-A domain. The ONERA real time system located over 100 VHF sources per second in two dimensions (XY) with a 100us time resolution. We applied algorithms developed by ONERA to combine VHF sources in components and components in flashes. Total flash rate, flash duration as well as total flash density will be summarized according to storm categories and environmental conditions. We will also discuss the flash detection efficiency of the ONERA real time system and uncertainties of the flash rate retrieved from the real time measurements

AE12A-0086 1330h POSTER

Lightning as a Detector of Convective Surges in Thunderstorms

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New Mexico Tech's 3-dimensional lightning mapping system (LMA) was operated in support of the Severe Thunderstorm Electrification and Precipitation Study (STEPS) from late May to early August 2000. Previous LMA studies discovered occasions where high-altitude radiation sources were frequently observed above convective thunderstorms. These observations represented a lightning phenomena which had not been observed prior to the advent of the LMA. The events consisted of frequent, localized, short-duration discharges and appeared to occur continuously and independently of other lightning activity in the lower regions of the storm. Indications were that the events happen within (or possibly above) overshooting tops associated with strong convective bursts in thunderstorms. On June 29, 2000 during STEPS, the LMA recorded a storm which produced an F1 tornado. Prior to tornado formation there were three periods where lightning sources rose above the main discharge regions of the storm. During these occasions of enhanced high-altitude activity, lightning free holes formed in the central region of the cell, indicating that the events correlate with overshooting convective tops. Several other convective bursts occurred in rapid succession after the third, and an F1 tornado formed. Following the tornado, the storm continued to show strong convective surges as well as an overall increase in height of lightning activity. In this paper we discuss case studies where a height versus time display, over the active lifetime of a storm, demonstrates similar behavior. When the data is displayed over a large time range the epochs of enhanced high-altitude discharges are very clear, and indicate an increase in storm intensity and severity.

AE12A-0087 1330h POSTER

Influences of the Local Environment on Supercell Cloud-to-Ground Lightning, Radar Characteristics, and Severe Weather on 2 June 1995

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Radar, cloud-to-ground (CG) lightning characteristics, and storm reports are documented for 20 long-lived supercell thunderstorms that occurred during a six-hour period in the west Texas Panhandle on 2-3 June 1995. These thunderstorms occurred in proximity to a pre-existing mesoscale outflow boundary.

Storms that remained on the warm side of the mesoscale outflow boundary as well as storms that formed directly on the boundary tended to produce weaker rotation, lower 40 dBZ echo top heights, and had the largest negative CG flash rates. Distinct increases in radar characteristics occurred for nine of eleven storms that crossed the boundary. There was a notable increase in mesocyclone strength, 40 dBZ echo top height, and increased radar reflectivity above the environmental freezing level. Five out of eleven storms dramatically increased their positive flash rate within 60 minutes after crossing the outflow boundary. These large positive flash rates were associated with descending reflectivity cores that were larger in magnitude and areal extent compared to other storms in the study.

The local mesoscale environment and its horizontal variations of vertical wind shear, CAPE, and boundary-layer mixing ratio appeared to greatly influence storm structure and evolution. The observed environmental variations are hypothesized to support changes in charge structure that might lead to the observed changes in flash rate and polarity.

URL: http://mrd3.nssl.ucar.edu/˜gilmore/www/mwrnew/GilmoreWicker.pdf

AE12A-0088 1330h POSTER

Lightning Flash Rate and CG Polarity Relationships in Simulated Storms

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Possible relationships between lightning characteristics and storm quantities have been investigated with a three-dimensional thunderstorm simulation model. Lightning flash rate has been compared with updraft mass flux, graupel volume, rain mass, ice crystal mass, and upward ice crystal mass flux, among others.

For a short-lived single-cell storm, one of the best correlations is between graupel volume (or mass) and total lightning flash rate. This result is consistent with observations that the onset of strong electrification is coincident with the appearance of graupel and that graupel volume and flash rate increase and decrease together. Trends in updraft mass flux, however, typically precede similar trends in flash rate. Initial updraft growth precedes graupel formation, and after the updraft decays, lightning activity continues as the charged graupel descends away from and unmasks oppositely charged ice crystals. Updraft mass flux appears to be better time-correlated to microscopic charge separation than with flash rate.

The polarity of simulated cloud-to-ground (CG) lightning appears to be related to the net charge carried by the modeled storm, as has been speculated previously by others. A preliminary model result is that the polarity of a CG flash is usually the same as the polarity of net charge carried by the storm. Screening layer development and the fallout of charged precipitation are the two main processes responsible for the development of net charge on storms prior to the onset of CG flashes.

The cloud model used for the simulations has a sophisticated microphysics package with 12 hydrometeor categories. The model includes parameterizations for noninductive ice-ice collisional charge separation, inductive charge separation for rebounding graupel-droplet collisions, and electrical screening layer formation. Lightning is simulated by a stochastic breakdown model which propagates flashes bidirectionally in a step-by-step manner, resulting in fractal-like branch structures.

URL: http://www.nssl.noaa.gov/∼mansell/agu2001/

AE12A-0089 1330h POSTER

A Non-Grid-Point-Dependent Lightning Scheme for Multi-Dimensional Storm Models

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A lightning discharge propagation model has been developed that approximates the tortuous path of a lightning channel. After initiation in the region of highest electric field, the discharge channel propagates bidirectionally in 50 m segments that are independent of the model grid configuration. Cosmic-ray-generated random free (avalanche) electrons in the vicinity of the channel tip are used in conjunction with the charge-density gradient to determine the direction of the next channel segment. The ambient electric field and the field due to the two previous channel segments are used to determine which random free electron is chosen. An angle criterion, based on the work of Hill [1968], is also used in choosing the electron. If more than one free electron satisfies these criteria, a branch channel is generated. Results from a two-dimensional implementation of this scheme will be presented using both a model-generated charge distribution and several idealized charge distributions.

AE12A-0090 1330h POSTER

Using the LMA to Study Flash Initiation

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In support of the Severe Thunderstorm Electrification and Precipitation Study (STEPS 2000), New Mexico Tech's Lightning Mapping Array (LMA) was dispersed over an 80 km wide area of eastern Colorado and western Kansas from early May to mid August of 2000. Operating 13 stations, with real time communications, enabled us to locate and record all lightning activity within 200 km of the array. Because of the LMA's unique 3-D resolution, it is possible to observe individual lightning flashes and compare the initial radiation sources of both intra-cloud and cloud to ground discharges. Comparing the localization, timing, and power of the initial sources can reveal specific traits within a storm, enabling us to categorize storms. Differences in flash initiation could be indicative of the differences in the local environment. Some of the physical characteristics of the storm can be determined by comparing the LMA points to radar scans, electric field measurements, and other observations.

Of particular interest are bi-polar pulses, which emit very powerful radiation compared to other sources. Some of these pulses have been observed to be the first source in a lightning discharge, while others have been found to be isolated both spatially and temporally. Only certain storms produce these energetic events, most storms do not. A small selection of these bi-polar events have been confirmed using electric field data, but were misidentified as positive cloud to grounds by the NLDN.

URL: http://lightning.nmt.edu/

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).