the embryonic lightning discharge, proceeding to develop in a bipolar fashion up to the scale of typically observed lightning flashes. This paper presents results of the laboratory investigations.

AE31A-04 0900h INVITED

The Severe Thunderstorm Electrification and Precipitation Study (STEPS)

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During May-July 2000, the Severe Thunderstorm Electrification and Precipitation Study (STEPS) was conducted in the High Plains, near the Colorado-Kansas border, in order to achieve a better understanding of the interactions between kinematics, precipitation, and electrification in severe thunderstorms. Specific scientific objectives included: 1) understanding the apparent major differences in precipitation output from supercells that have led to them being classified as low-precipitation (LP), classic or medium-precipitation, and high-precipitation; 2) understanding lightning formation and behavior in storms, and how lightning differs among storm types, particularly to better understand the mechanisms by which storms produce predominantly positive cloud-to-ground (CG) lightning; and 3) to verify and improve microphysical interpretations from polarimetric radar. The project involved the use of a multiple-Doppler and polarimetric radar network, as well as a time-of-arrival VHF lightning mapping system, the T-28 armored research aircraft, electric field meters carried on balloons, mobile mesonet vehicles, instruments to detect and classify transient luminous events over thunderstorms (TLEs; e.g., sprites and blue jets), and mobile atmospheric sounding equipment. The project was a major success, gathering unprecedented data on a wealth of diverse cases, including LP storms, supercells, and mesoscale convective systems, among others. Many of the storms produced mostly positive CG lightning during their lifetimes, and also exhibited unusual electrical structures such as a possibly inverted dipole. The 29 June supercell case has received considerable study to date including the analysis of polarimetric radar data to demonstrate couplings between storm dynamics and the formation of hail and graupel, which lead to formation of significant positive charge in the mid-levels and copious amounts of positive cloud-to-ground lightning. The charge structure in the 29 June case, along with several other STEPS cases, contained charge structures that deviated from the standard tripole charge arrangement. Work is also under way to analyze the MCS event on 11 June, in particular, to better understand the mechanisms leading to positive CG lightning in the trailing stratiform region.

AE31A-05 0930h

Positive cloud-to-ground and other horizontally propagating lightning in the convective line and stratiform rain regions of a MCS observed during STEPS

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We report on an asymmetric mesoscale convective system (MCS) that occurred on 11 June 2000 during the Severe Thunderstorm Electrification and Precipitation Study (STEPS), which took place along the Colorado-Kansas border. This system passed through both dual-Doppler lobes of the CSU-CHILL and S-POL polarimetric radars, and produced a large number of lightning flashes (up to 1 flash per second), which were observed by the New Mexico Tech Lightning Mapping Array (LMA) and the National Lightning Detection Network (NLDN). Many of these were positive cloud-to-ground lightning flashes (+CGs) that came to ground in both the leading convective line and trailing stratiform rain region of the MCS. A significant percentage of these +CGs propagated over large horizontal distances (10s of km) within the stratiform region. However, great variety was observed within this subset, including +CGs that came to ground in the stratiform after initiating in the convective line, +CGs that initiated and came to ground in the convective line but tapped large charge reservoirs in the stratiform, and +CGs that initiated and came to ground within the stratiform region alone. There also were a number of intracloud flashes that propagated over long distances within the stratiform region. Polarimetric and dual-Doppler data from the two radars are used to characterize the kinematic and microphysical structure of the MCS, including the charge reservoirs tapped by these horizontally propagating lightning flashes. Results are compared to present MCS electrification theory.

URL: http://radarmet.atmos.colostate.edu/~tlang/11jun00/

AE31A-06 0945h

Lightning Modes in Thunderstorms

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The Lightning Mapping Array (LMA) shows the complete sequence of lightning discharges in convective storms and has expanded our understanding of the types of lightning discharges that can occur in the storms. In addition to the intracloud (IC) and cloud-to-ground (CG) discharges of normal-polarity storms, which occur between the mid-level negative and upper positive charge regions, and between the negative charge and ground, the LMA data show with surprising clarity the presence of lower positive charge in the storm, with some CG flashes discharging lower positive charge on their way to ground and others going straight to ground. In addition, the data also show the occurrence of 'low-altitude' ICs between the mid-level negative and lower positive charges, that do not go to ground. Finally, the observations delineate the mechanism of 'bolt from the blue' type flashes, which begin as normal-polarity upward-developing IC discharges in which the upper positive charge appears to be weak in comparison to the mid-level negative charge, resulting in the negative breakdown exiting the side of the cloud (through apparent positive screening charge along the radar cloud boundary) and going to ground as a -CG up to 5 or 10 km away from the storm center. Such discharges are surprisingly common and are even sometimes the dominant CG lightning type of a storm. The above behaviors of the lightning can be explained in terms of the relative amounts of the positive and negative charges in the different parts of the storm. The question as to what types of discharges will be occurring can be explained in terms of the energy of the storm charge distribution and how the energy would be changed by the different types of discharges, with the discharge types tending to be the most energetically preferred ones as time progresses. In addition to the above 'normal-polarity' lightning types, the LMA observations show where positive CG (+CG) discharges originate and how they develop inside a storm. They have also revealed the surprising occurrence of inverted-polarity IC discharges between main mid-level positive charge and upper negative charge. Inverted polarity ICs are the dominant lightning type in anomalously electrified storms and provide a good indicator of the anomalous electrification. The anomalous storms tend to be supercell or severe storms, but not all such storms are anomalously electrified. The discharges sometimes indicate a complex, rapidly evolving, multilayer charge structure but often indicate simple, inverted-type dipolar structures in which relatively shallow negative charge is above a dominant, deeper positive charge. The anomalous storms can go for long periods of time (or for their entire lifetime) without producing CG discharges, something that does not occur in normally electrified storms. The inverted polarity ICs can be bi-level in nature or can propagate large vertical distances downward through the storm precipitation, something never seen in normal-polarity ICs. Finally, the LMA has provided greatly expanded observations of short-duration (sub-ms) discharges in storms. The short duration discharges are temporally isolated and can occur as precursor events to full-fledged lightning or as spatially limited or attempted breakdown events. They occur much more commonly in anomalous than in normally electrified storms, and are associated with the upper negative charge region and convective surges in the anomalous storms. A more complete understanding of the short-duration discharges should provide important clues about the processes by which lightning is initiated in storms.

AE31B MCC: 3020 Wednesday 1020h

Advances in Lightning and Atmospheric Electricity Remote Sensing Systems and Algorithms II

(joint with A)

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

AE31B-01 1020h INVITED

Overview of Current Lightning Detection Systems

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We give an overview of the techniques that are currently used in both ground-based (e.g. NLDN, LDAR/LMA, SAFIR) and satellite-based (e.g. OTD, LIS, FORTE) lightning detection systems, the key performance parameters (e.g. Detection-Efficiency, Location-Accuracy, and False Reports), and the algorithms that each system uses to time-tag lightning "events" and count "flashes" and "strokes."

AE31B-02 1040h INVITED

Improving Regional and National Weather Operations with New Lightning Mapping Technologies

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Technology now provides several options for mapping lightning over large regions. The present U.S. National Lightning Detection Network (NLDN) maps lightning ground strike points over continental distance scales, including substantial distances over oceans, and its capabilities are being expanded to map some cloud flashes. VHF time-of-arrival or interferometer networks map all lightning in considerable detail to a range of roughly two few hundred kilometers and are capable of countrywide coverage. VLF networks have demonstrated ability to map lightning globally, including over all oceans. And the demonstrated capability of satellite lightning mappers also could provide global coverage. A major application of these systems at present is thunderstorm detection to help mitigate effects of the lightning hazard itself and of other storm hazards. Thunderstorm detection is particularly valuable in the large regions where radar coverage is poor and not feasible, such as over oceanic and mountainous regions and in impoverished or sparsely populated countries. Though some mapping technologies, such as VLF systems and the present NLDN, are capable of detecting only one or a few points per flash and have a strong bias toward cloud-to-ground flashes, all mapping systems detect thunderstorms adequately for many purposes, including simple data assimilation into numerical weather forecast models. However, storms can be delineated much more quickly, reliably, and clearly by technologies that map all types of lightning and map several pixels or many points per flash. Such mapping systems reveal storm structure comparable in many ways to the structure provided by conventional radars. Depending on the storm and on the technology used, it is possible to map storm features such as overshooting storm tops, rising concentrations of lightning activity apparently reflecting rising updrafts, v-structures at storm top caused by flow around the obstacle presented by strong storm updrafts, sparse-lightning holes in the updraft cores of supercell storms, cores of large lightning density resembling the reflectivity cores of cells, and the maturation of the stratiform precipitation region of mesoscale convective systems, which produce much of the rainfall and flooding in the central United States. However, it is relatively difficult for weather forecasters to incorporate much information from lightning data into their forecasts when using only raw, real-time lightning locations. More research is needed to help extract or summarize information from the lightning data and present it in a form easier for forecasters to digest. Another area in which lightning data can contribute is data assimilation into numerical weather models to improve their forecasts. Research has demonstrated that lightning data can be assimilated into forecast models in much the same way as radar data are, but lightning data could readily be available over large regions of the globe where obtaining radar data is not feasible. Besides improving the initialization of the model by improving the location and extent of storms when the model begins its forecast cycle, a process that itself still can be improved, lightning data could be

used in variational schemes to diagnose and compensate for errors often present in the atmosphere at the beginning of a model's forecast cycle. Otherwise, these errors in the model atmosphere often cause the forecast to return close to the state it would have had in 6-12 h without even simple data assimilation.

AE31B-03 1100h INVITED

The Integration of Total Lightning Information Into National Weather Service Operations

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The collocation of a National Weather Service (NWS) Forecast Office with atmospheric scientists from NASA/Marshall Space Flight Center (MSFC) and the University of Alabama in Huntsville (UAH) has afforded a unique opportunity for science sharing and technology transfer. One such technology transfer is the utilization of the North Alabama Lightning Mapping Array (LMA) in daily forecast and warning operations. The LMA consists of ten VHF receivers deployed across northern Alabama and a base station located at the National Space Science and Technology Center (NSSTC) on the UAH campus. Preliminary investigations have shown a strong correlation between the time rate-of-change (trending) of total lightning and changes in intensity/severity of the parent convective cell. It is hoped that through the use of near real-time total lightning information, in conjunction with other remote sensing datasets (radar, satellite, observations), that the forecaster can achieve an even greater level of situational awareness. The primary mission of the NWS is to protect life and property. The utilization of the LMA data may prove to be a vital contributor to this mission by enhancing severe weather warning and decision-making, improving warning lead times, and increasing the probability of detection of severe and hazardous weather. To maximize the use of total lightning information, the LMA data is being ingested in real-time into the NWS Advanced Weather Interactive Processing System (AWIPS) decision support system. The presentation will focus on the collaborative process, technology transfer methodologies and a look to the future. In addition, a brief review of recent LMA case studies will be provided.

URL: http://wwwghcc.msfc.nasa.gov/sport/

AE31B-04 1120h INVITED

Developing Oceanic Convective Products to Mitigate the Impact of Weather Hazards on Transoceanic Flights

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Transoceanic flights will increase significantly in the next decade. To manage this increased demand for capacity, while maintaining safety, the Federal Aviation Administration (FAA) is exploring whether the separation minima normally used between aircraft crossing oceanic regions can be reduced both horizontally and vertically. However, before reducing separation standards, the increased hazard of encountering convective weather over oceanic routes must be considered. New evidence has shown that roughly half of the turbulence encounters over oceanic regions were likely associated with convective activity. This phenomenon, Convectively-Induced Turbulence (CIT), can occur several kilometers from convective cores. Operational decision-makers need to detect turbulence associated with oceanic convective activity to route or reroute aircraft safely. However, the only weather data consistently available is from satellite imagery, which can reveal potential areas of convection, but can't unambiguously isolate the hazardous regions from the benign regions. Being able to do this would improve routing and rerouting decisions. The FAA and other agencies are collaborating to develop oceanic convective products. The National Weather Service's Aviation Weather Center created a product that identifies thunderstorms by using the output from different satellite imagers. The technique exploits the difference between the 11-micron infrared (IR) channel and the 6.7-micron water vapor channel. The National Center for Atmospheric Research has developed a new product that maps cloud top temperatures drawn from IR satellite imagery and converts them to aircraft flight levels. In addition, the Naval Research Lab in Monterey, CA is developing cloud classification algorithms that will distinguish between cirrus and convective clouds. We have compared these new convective diagnostic techniques to long-range ground base lightning data and lightning data from the National Aeronautics and Space Administration (NASA) Tropical Rainfall Measuring Mission (TRMM) satellite. We will present the results of the comparison at the meeting. Developing oceanic convective and turbulence nowcasting and short-term forecasting products would have a significant positive impact on flight operations since they would show possible locations of turbulence and wind shear associated with convection. These products would also increase airspace capacity by enabling the FAA to decrease oceanic aircraft separation standards while preserving safety. We wish to reduce the incidence of noncoordinated deviations (because of unexpected encounters with turbulence associated with convection), through greater situational awareness and more time for coordination. By helping pilots avoid areas of convective activity and associated turbulence over oceanic regions, these products have the potential to improve safety of flight and increase efficiency (e.g., facilitate routing and rerouting resulting in smaller flight track deviations and reduced fuel costs).

AE31B-05 1135h INVITED

The Integration of Real-Time Lightning With Other Meteorological Data to Develop Intelligent Weather-Enabled Decision Support Systems

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Meteorlogix has successfully integrated real-time Vaisala cloud-to-ground lightning flash data along with a variety of conventional weather information data, all within a Geographic Information System (GIS) to provide an intelligent automated decision support system. The spatial analysis inherent in the GIS determines the location and intensity of the lightning activity, along with consideration of other weather parameters (i.e. Doppler radar reflectivity) and then executes a comparison against geo-referenced assets at specific points, along vectors, or within areas of coverage. This unique approach introduces the capability of simultaneously monitoring multiple locations and numerous environmental parameters, and then automatically triggering location-specific alerts when conditions warrant. The distribution of the alert notifications can then be accomplished using e-mail, telephone, or immediate transmission to other wireless devices. Static assets (i.e. electrical power substation) or mobile assets (i.e. GPS-enabled devices) can be utilized in the system. This new concept of an intelligent automated weather decision support system may be capable of assisting commercial organizations improve weather related risk management, increase safety for their employees, improve operating efficiencies, and provide enhanced customer service.

URL: http://www.meteorlogix.com/pdf/EnergyWatch.pdf

AE31B-06 1150h

Dual-Satellite Observations of VHF Lightning From GPS Orbit

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Over the last several years, the remote sensing of very high frequency (VHF) lightning emissions from both low-earth orbit and Global Positioning System (GPS) orbit has been demonstrated with the Fast On-Orbit Recording of Transient Events (FORTE) satellite and with an experimental VHF receiver aboard the SVN 54 GPS satellite. Analyses have shown that these systems are most sensitive to an impulsive type of incloud lightning that appears to be a good generic indicator of thunderstorm convective activity. As a consequence, satellite-based VHF receivers are now recognized as potential candidates for global lightning monitoring missions. With the recent launch of a second experimental VHF receiver aboard the SVN 56 GPS satellite, we now have the opportunity to characterize multi-satellite detection of VHF lightning from GPS orbit. This paper presents data from and analysis of simultaneous observations of VHF lightning events by the SVN 54 and SVN 56 VHF receivers. The dual-satellite observations are used to (1) characterize the expected performance parameters of a multi-satellite VHF global lightning detection system, (2) demonstrate two-satellite thunderstorm geolocation using an intersecting isochron technique and (3) determine a detection efficiency for impulsive in-cloud lightning as a function of zenith angle (radiation pattern).

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AE31B-07 1205h

Lightning Initiation Locations as a Remote Sensing Tool of Thunderstorm Electrical Evolution

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The New Mexico Tech Lightning Mapping Array (LMA) uses time of arrival to locate impulsive radiation sources in individual lightning flashes. The close time coincidence between LMA and antenna data [Maggio et al., this conference] suggests that the initial LMA radiation source from a lightning flash is located within about 300 m of the flash's initiation point. Locations of the initial sources should indicate electrically active parts of a cloud and, particularly, regions with strong electric field (SEF). In this study we investigate the electrical evolution of a small thunderstorm in New Mexico that produced 74 lightning flashes. We compare the locations of the 74 initial radiation sources to the evolution of precipitation in the storm cells and to the evolving electrical structure derived from four balloon soundings of electric field (E). A time-altitude plot of the initial lightning sources in this storm reveals four distinct stages. These stages are based on the altitude range of strong electric fields inferred from the initial sources; balloon E soundings confirm these inferences in the first three stages. The early stage shows upward development of the SEF region and was associated with the upward growth of substantial precipitation. In the early-mature stage, the SEF region was between 7.7 and 9.2 km altitude. All the lightning in the first two stages was either intracloud or hybrid cloud-to-ground (CG). In the late-mature stage there were two SEF regions: one between 7.7 and 9.7 km altitude and the other (associated with normal CG flashes) between 4.9 and 6.1 km. In the late stage the SEF region was between 7.0 and 8.0 km altitude and was associated with the dynamical decline of the storm. Preliminary analyses indicate that the initial sources were usually located above and or to the side of the principal reflectivity core in the storm. The initial sources were located in reflectivities of 30-45 dBZ, while the cores had reflectivities of 45-60 dBZ. Implications about possible charging mechanisms will be discussed.