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14. ABSTRACT During the Summer and Fall of 1998 five balloon-borne instruments were launched into thunderstorms to observe changes in the vertical component of electric field caused by lightning. Data from two flights have been compared with data from the National Lightning Detection Network (NLDN) for cloud-to-ground lightning flashes that were coincident in time. The field changes observed at altitude appear to have been caused by charge movements relatively nearer the instruments than the ground-strike location of coincident flashes. LF/VLF signals by which ground strikes are located by the NLDN are often accompanied by broadband VHF emissions recorded by receivers on the FORTE satellite. For the period April through September, 1998, 6131 FORTE satellite VHF data records have been assigned the median NLDN coordinates of their corresponding source storm. During the same time period, approximately 25% of the events detected by the photodiode detector (PDD) aboard the FORTE satellite over the continental United States and classified as lightning were associated with flashes detected by the NLDN. About 50-70% of PDD events with estimated peak optical source powers greater than 10 gigawatts but only about 10-25% of events with lesser source powers were associated with NLDN locations. It appears that PDD optical events with high estimated peak source power are more likely to be associated with cloud-to-ground flashes.					
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Final Technical Report
AASERT97 Student Support for Observations Relevant to Sprites and Jets
Grant No. F49620-97-1-0410

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Introduction

This AASERT award was originally intended to support a candidate for the Ph.D. in Physics, Heidi Morris, and an undergraduate assistant, to work with the principal investigator on development and field deployments of balloon-borne instruments into and above thunderstorms to record changes in electric field that might be related to the production of the transient luminous events (TLE) that often occur in the region 30 km to 100 km above thunderstorms. The student was to identify a Ph.D. research topic relating the electric-field-change observations to lightning locations and characteristics as well as storm features. The Ph.D. student participated in preparation for, and balloon launches during, the Mesoscale Electrification and Precipitation Radar Studies (MEaPRS), during summer of 1998. Observations of electric-field changes were obtained, but none of the storms were within range of the TLE observatory in Colorado.

In the fall of 1998, the student's work came to the attention of research scientists at Los Alamos National Laboratory (LANL) and she was offered the opportunity to complete her Ph.D. research at LANL on a topic related to the AFOSR support of the principal investigator and to the data taken during the summer during MEaPRS and during an overlapping time period by the FORTE satellite operated by LANL. The remaining AASERT funding was then used to support a candidate for the Ph.D. in Meteorology, Cynthia Machacek Noble, and a candidate for the MS in Meteorology, James O'Brien, to work on the project.

As a result of this support, two students will complete the Ph.D. degree and one student will complete the M.S. during the year 2001 on projects related to the original goal of understanding the conditions under which sprites and jets occur above storms.

Overview of Scientific Results Published and Presented Publicly

The research in which the students participated has resulted in several publications and conference presentations:

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1) Observations of electric-field changes in storms relevant to the mechanisms for sprites and jets were made during MEaPRS, and the results have been published in Geophysical Research Letters

2) The Physics Ph.D. candidate changed her research emphasis upon moving to Los Alamos National Laboratory, although it is still relevant to the question of what makes Transient Luminous Events. She has worked on the VHF radio emissions of lightning as observed by the FORTE satellite and on the mechanisms that may cause them, has published one paper in Radio Science, and has presented several conference papers.

3) The Meteorology Ph.D. candidate has been working with optical data from the FORTE satellite, comparing it with the ground-based data from the National Lightning Detection Network with the goal of trying to determine the storm and lightning characteristics that may be particular to the most energetic optical events as observed from over top of storms. She has presented one conference paper. One concern is to see if the events that have the most optical power are also accompanied by Transient Luminous Events as well. A paper was presented at the Fall 2000 meeting of the AGU.

Specific Findings

During the Summer and Fall of 1998 five balloon-borne instruments were launched into thunderstorms to observe changes in the vertical component of electric field caused by lightning. Four of these were for measurement of field change only. The fifth was part of a larger package that included a gamma radiation detector and a GPS receiver on board. Electric-field-change data from two of these flights have been processed and were discussed in the GRL publication. Examples of field changes observed at altitude were compared with data from the National Lightning Detection Network (NLDN) for cloud-to-ground lightning flashes that were coincident in time. Limits on time resolution and timing accuracy prevent unambiguous identification of the lightning processes that caused the field changes. It appears that they may have been caused by charge movements relatively near the instruments as compared with the ground-strike location of coincident flashes.

The FORTE satellite is in a circular orbit at an altitude of about 800 km. This orbit has a 70 degree inclination with respect to the Earth's equator. It covers equatorial regions and midlatitudes, the most important lightning-producing regions of the globe. FORTE observes VHF emissions from lightning, or other sources, that originate within a circle of greater than 3000-km arc radius centered at satellite nadir. LF/VLF signals recorded and located by the National Lightning Detection Network (NLDN) are often accompanied by broadband VHF emissions of sufficient intensity to trigger satellite-based RF receivers. It has previously been shown that events recorded by the FORTE satellite and the NLDN, which have occurrence-time differences of 0.3 ms or less, can be assumed to originate at the same approximate geolocation with 97.5% reliability. For such event pairs, the VHF events recorded by FORTE were assigned the NLDN locations. For the time period of April through September of 1998 a total of 6131

satellite data records, which were not previously located, have been assigned the median NLDN coordinates of their corresponding storm. These results were published in Radio Science.

For the period of April 1998 through September 1998, approximately 37,000 events classified as lightning were detected over the continental United States (CONUS) by the photodiode detector (PDD) aboard the Fast On-orbit Recording of Transient Events (FORTE) satellite. Approximately 9,000 of these (25%) are associated with lightning events detected by the National Lightning Detection Network (NLDN). It has been found that about 50-70% of PDD events with estimated peak source powers greater than 10 gigawatts were associated with NLDN events, compared with a NLDN association for only about 10-25% of PDD events with source powers on the order of 0.1 to 1 gigawatts. This trend, for a higher percentage of "brighter" PDD events to be associated with NLDN-detected events, also holds true when events are categorized on a monthly basis. The average source power for PDD lightning events is about 1 gigawatt. Though events "brighter" than 10 gigawatts account for only 16% of the total CONUS PDD events for the time period considered, these brighter events represent about 30% of the NLDN associated CONUS events. Since 99% of the NLDN events considered were cloud-to-ground flashes, it appears that PDD events with estimated peak source power greater than 10 gigawatts are more likely to be associated with cloud-to-ground flashes than events with estimated source powers less than about 10 gigawatts.

Publications (AASERT Students underlined)

Beasley, W.H., K.B. Eack, H.E. Morris, W.D. Rust, and D.R. MacGorman, Electric-field changes of lightning observed in and above thunderstorms, *Geophys. Res. Lett.*, 27, 2, 189-193, January 15, 2000

Tierney (ne Morris), Heidi E., Jacobson, Abram R., Beasley, William H., Argo, Paul E. Determination of source thunderstorms for VHF emissions observed by the FORTE satellite, *Radio Sci.* Vol. 36, No. 1, p. 79, January, 2001

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Noble, C.M., W.H. Beasley, M.W. Kirkland, T.E. Light, D.M. Suszcynsky, K. Cummins, Coincidence of FORTE PDD Optical Lightning Events and NLDN Lightning Locations: Dependence on Estimated PDD Peak Optical Source Power, Fall Meeting, AGU, December, 2000

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Morris, H.E., R.A. Roussel-Dupre, K.B. Eack, D.A. Smith, Phenomenology of Multiple VHF Pulses Observed by the FORTE Satellite, Fall Meeting, AGU, December, 1999

Pongratz, M.B., H.E. Morris, A.R. Jacobson, W.H. Beasley, P.E. Argo, Determination of Source Thunderstorms for VHF Emissions Observed by the FORTE Satellite, Fall Meeting, AGU, December, 1999

Morris, H.E., K.B. Eack, W.H. Beasley, Electric-Field Changes of Cloud-to-Ground Lightning at Various Altitudes and Distances from the Ground Strike Point, Fall Meeting, AGU, December, 1997