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Title: ER-2 Investigations of Lightning and Thunderstorms

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Background of the Investigation: The primary objective of the ER-2 lightning program is to investigate relationships between lightning and storm electrification and a number of underlying and interrelated phenomena including the structure, dynamics, and evolution of thunderstorms and thunderstorm systems, precipitation distribution and amounts, atmospheric chemistry processes, and the global electric circuit. This research is motivated by the desire to develop an understanding needed for the effective utilization and interpretation of data from the Lightning Imaging Sensor (LIS), the Lightning Mapper Sensor (LMS), and other satellite-based lightning detectors planned for the late 1990's and early 2000's. These satellite lightning detection systems will be characterized by high detection efficiencies (i.e., 90%) and the capability to detect both intracloud and cloud-to-ground discharges during day and night. The Lightning Imaging Sensor (LIS) is being developed by NASA for the Tropical Rainfall Measuring Mission (TRMM) satellite. In the ER-2 and related investigations, the emphasis is on establishing quantitative relationships and developing practical algorithms that employ lightning data, such as could be derived from satellite observations of optical lightning emissions, as the independent variable.

Presently, the ER-2 aircraft provides the best means to fly above thunderstorms since the ER-2 can be vectored over regions of interest. The ER-2 platform also provides a cloud top perspective similar to that viewed by a space sensor, albeit much closer. The proposed ER-2 lightning instrumentation will detect total storm lightning and differentiate between intracloud and cloud-to-ground discharges. It should be noted that the ER-2 lightning instrument package will generally be flown with other sensor systems (e.g., infrared, passive microwave, EDOP Dopplar radar, etc.) that will provide new understanding of thunderstorms and precipitation and support detailed satellite simulations of storm measurements through the acquisition and analysis of multiparameter data sets. By developing and maintaining the capability to monitor lightning and thunderstorms with the ER-2, NASA will also be able to provide important ground truth verifications and calibrations when the LIS and other lightning detectors begin operations in the late 1990's.

The emphasis, now, is to "quantify" the lightning relationships that have been determined. It is hoped that as a result of these kinds of investigations, lightning data alone and/or in conjunction with other remote sensing techniques will provide quantitative information about such storm characteristics as the occurrence and location of embedded convection, the strengths of updrafts and downdrafts, thermodynamic and electrical energy budgets, precipitation amounts and distributions, and the storm type, dimensions, and life cycle. Lightning rates, distribution, and characteristics (i.e., number of strokes per flash, ratio of intracloud to cloud-to-ground lightning, discharge energy, etc.) are all factors that may prove useful in devising quantitative algorithms, and these factors can be studied appropriately with the ER-2.

Significant Accomplishments in the Past Year: During May 1991, we integrated the Lightning Instrument Package (LIP) onto the ER-2 aircraft. This integration was required since the U-2 aircraft on which the lightning package flew in the past have been phased out of NASA's high altitude aircraft fleet and replaced by the larger ER-2 aircraft. We are now able to conduct atmospheric electrical investigations above thunderstorms for the first time since the COoperative Huntsville Meteorological EXperiment (COHMEX) in 1986. An independent subset of LIP was integrated earlier onto the ER-2. This sensor subset consists of electric field mills, conductivity probes, and an associated data system.

During July and August 1991, ER-2 science flights were conducted as part of the Convective and Precipitation/Electrification (CaPE) experiment. CaPE will provide extensive multiparameter data sets referred to above. More importantly, two of the major scientific goals of CaPE (1. the identification and investigation of the relationships among the co-evolving wind,

water, and electrification within the convective cloud and 2. rainfall estimation) coincide with primary objectives of the ER-2 investigations and NASA's overall lightning program. A large number of storm overflights were obtained during CaPE including a number of cases of multiple storm passes. In February and March 1992, the ER-2 participated in the STORM-Fronts Experiment Systems Test (STORM-FEST) experiment. STORM-FEST provided an opportunity to study wintertime thunderstorms.

Working with Kevin Driscoll, an Auburn Univ. Ph.D. student participating in the NASA sponsored Graduate Students Research Program (GSRP), a finite difference numerical model that incorporates the full Maxwell equations was developed and used to investigate how thunderstorm currents and fields are related to the storm's electrical generator and associated lightning (including lightning type, rate, charge exchange, ratio of ic to cg, etc.). We have demonstrated that by using time-averaged electrical properties of a thunderstorm, including the effects of lightning, the electrical behavior of the atmosphere in the vicinity of the storm can be examined with a simple analytical formulation. Also we have had some success in using the model to simulate and investigate U-2 lightning observations obtained during COHMEX.

Focus of Current Research and Plans for Next Year: Analysis of ER-2 data from CaPE and STORM-FEST is a high priority and underway. In addition, some of the U-2 COHMEX lightning data may be reexamined as well. As noted earlier, the emphasis is on storm characterization and algorithm development (particularly precipitation algorithms) that utilize lightning measurements. Some other areas of interest include the effect of thunderstorms on the global electric circuit and the relationship of thunderstorms to atmospheric chemistry processes involving trace gases (e.g., NO_x).

Preparations for participation in the TOGA-COARE field program are well underway. These include providing an improved LIP for the ER-2 and a small lightning package for the DC-8, and deploying lightning ground stations near the Intensive Flux Array (IFA) This latter activity is being conducted in cooperation with scientist from the Univ. of Arizona (C. Weidman and P. Krider), Texas AM Univ. (R. Orville and E. Zipser), and New Mexico Tech.(M. Brook).

Although not part of the ER-2 effort, an investigation of LIS statistics using lightning direction finder data from the MSFC LLP network and TRMM orbit characteristic to simulate LIS observations has been initiated and is providing valuable insights. This research on simulated LIS statistics using direction finder lightning data will continue and it is hoped that the data sets employed for this study can be expanded (with D. Buechler). We will also explore the possibility of using shuttle video lightning images to simulate Lightning Imaging Sensor (LIS) data in the LIS algorithm development effort (with W. Boeck).

Publications:

Blakeslee, R.J., H.J. Christian, and B. Vonnegut, Electrical measurements over thunderstorms, J. Geophys. Res., 94(D11), 13135-13140, 1989.

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Boeck, W.L., O.H. Vaughan,Jr., R. Blakeslee, B. Vonnegut, and M. Brook, Lightning induced brightening in the airglow layer, Geophys. Res. Letters, 19, 99-102, January 24, 1992.

Blakeslee, R.J., and E.P. Krider, Ground level measurements of air conductivity under Florida thunderstorms, accepted for publication J. Geophys. Res. - Atmos., 1992.

Driscoll, K.T., R.J. Blakeslee, and M.L. Baginski, A modeling study of the time-averaged electric currents in the vicinity of isolated thunderstorms, accepted for publication J. Geophys. Res. - Atmos., 1992.

Vaughan, O.H., R. Blakeslee, W.L. Boeck, B. Vonnegut, M. Brook, and J. McKune, Jr., A cloud-to-space lightning as recorded by space shuttle payload bay TV cameras (picture of the month), Mon. Wea. Rev., 120, 1992.

The following papers will be presented at the St. Petersburg 9th International Conference on Atmospheric Electricity and will be included in the Preprint volume for that conference.

Driscoll, K.T. and R.J. Blakeslee, A simple analytic method to estimate a thunderstorm's contribution to the global electric circuit.

Geis, P.B., R.J. Blakeslee, A.A. Few, E.K. Stansbery, and H.J. Christian, A global model of thunderstorm electricity

Buechler, D., and R. Blakeslee, Cloud-to-ground lightning observations used to simulate observations from a low earth orbit lightning sensor.

Boeck, W.L., O.H. Vaughan, R.J. Blakeslee, B. Vonnegut, M. Brook, and J. McKune, Observations of vertical lightning in the stratosphere.