PICTURE OF THE MONTH

A Cloud-to-Space Lightning as Recorded by the Space Shuttle Payload-Bay TV Cameras

Otha H. Vaughan, Jr., and Richard Blakeslee
NASA/ Marshall Space Flight Center, Huntsville, Alabama

William L. Boeck
Niagara University, Niagara University, New York

Bernard Vonnegut
Department of Atmospheric Science, State University of New York at Albany, Albany, New York

Marx Brook
Physics Department, New Mexico Institute of Mining and Technology, Socorro, New Mexico

John McKune, Jr.
NASA/Johnson Space Center, Houston, Texas
27 September 1991 and 1 November 1991

1. Introduction

Video images from space showing a single upward luminous discharge into the clear night air above a thunderstorm were recorded for the first time during the space shuttle STS-32 mission, and later during the STS-31 mission and other missions using the shuttle’s payload-bay TV cameras. The space shuttle closed-circuit television (CCTV) system and the shuttle’s payload-bay TV cameras (TVC) were developed under NASA Contract NAS9-15374 and monitored by engineers of the Tracking and Communications Division, Television Systems Group at NASA/Johnson Space Center, Houston, Texas. The sensor for each camera was a silicon intensified target (SIT) vidicon similar to the RCA Model 4804/H, antiblooming SIT, and was used during the earlier 1980 shuttle flights. In 1986 a new, improved camera, the Model-508 series, replaced the Model 4804H since it had more sensitivity. The use of automatic iris control (within the lens assembly) and the automatic light control circuitry, in conjunction with the SIT vidicon, provides excellent low-light-level performance and good immunity to image washout due to bright light sources within the field of view. The cameras can be configured to produce either black-and-white video or field-sequential color video solely as a function of an installed lens assembly unit. There are three types of lens assemblies: a monochrome version (MLA), a color version (CLA), and a wide-angle version (WLA). These lens assemblies have the capability to remotely operate the lens iris and zoom, and to focus the lens. The focal lengths for the MLA and CLA lens are 18–108 mm, with a 6:1 zoom ratio. The focal lengths for the WLA are 8.2–25 mm, with a 3:1 zoom ratio. Both the CLA and the WLA lens assembly have a six-segment, three-color rotating filter wheel that produces sequential red, green, and blue color fields. The wheel speed and phasing are such that each segment intercepts the video-image path for \( \frac{1}{60} \) s, or one video field, and only that light that falls within the path of the color-wheel filter will be allowed to pass on to the camera vidicon tube. These color cameras are normally used to observe the astronauts as they do EVA, and, at various times, to make observations of the earth’s atmosphere, geologic features, and oceans. The monochrome lens assembly without the color-wheel filters has increased sensitivity, thus allowing it to capture very low-light-level images. A TV camera, when configured with the MLA assembly, can see very dim images at night, including the aurora, the airglow, stars, distribution of city lights, and thunderstorms and their lightning displays. Recently, these cameras have been used to collect data for the Mesoscale Lightning Experiment (MLE). This experiment’s purpose is to obtain video images of large convective thunderstorms...
and their lightning displays as seen from space, and to provide design criteria for future earth or planetary lightning observational satellites. This atmospheric lightning research program is supported by NASA Headquarters. Dr. James C. Dodge, Earth Science and Applications Division, Washington, D.C.

2. Background

The new lightning observational program (MLE) was the first lightning observational-type experiment to be flown on shuttle STS-26—the first shuttle test flight after the Challenger accident that destroyed the shuttle STS-51L. Since an important goal of the STS-26 mission was the resuming of the shuttle program and checking out the improved shuttle, limited time was available for the crew to secure data for the MLE. Therefore, a limited amount of MLE data was collected. After this flight, it was decided that in future shuttle flights the payload-bay TV cameras would be operated by remote control from the ground whenever possible. This technique allows data to be collected even when the crews are asleep or their scheduled work load does not allow time for them to operate the cameras. The targets for MLE are targets of opportunity and are difficult to schedule. Therefore, potential targets are identified by MLE personnel in real time during each shuttle mission using weather satellite data. The coordinates of these targets can then be sent up to the crew prior to the time that they can be observed. The MLE research team consists of Otha H. Vaughan, Jr., Principal Investigator of NASA/ Marshall Space Flight Center, Huntsville, Alabama, and his co-investigators, Bernard Vonnegut, State University of New York at Albany, New York, Marx Brook, New Mexico Institute of Mining and Technology, and Richard Blakeslee, also of NASA/ Marshall.

3. Discussion

Figure 1 shows the upward luminous discharge that was seen to move out of the top of a single thunderstorm during the flight of STS-31. This video image was taken at 0335:59 UTC 28 April 1990 while the shuttle was on its 55th orbit and passing over Mauritania, northwest Africa. The payload-bay TV camera was controlled from the ground for the MLE operations by J. E. Conner of NASA/Johnson Space Center (JSC).
He was observing a few large thunderstorms to the south of the orbital track and near the limb of the earth when this discharge was recorded. The storm that had the luminous discharge was located at approximately 7.5°N, 4.0°E, and was about 2000 km from the shuttle's position. The lightning discharge was determined to be at least 31 km long using computer programs developed at MSFC and JSC. These programs, developed in-house at MSFC and JSC, use the shuttle orbital position and its attitude orientation and the orientation of the camera to calculate the length of the discharge above the top of the cloud.

The upward luminous discharge is of interest because it is probably caused by an electric-field concentration in the upper part of the thunderstorm and appears to be a discharge that was predicted by Wilson (1925). Wilson's paper pointed out that the electric field may cause ionization at great heights and thus cause a continuous or discontinuous discharge to occur between the cloud and the upper atmosphere.

A recent survey by Vaughan and Vonnegut (1989) provides a summary of observations by 15 civilian, commercial, and military pilots who observed vertical discharges out of the tops of thunderstorms. The pilots were impressed by what they saw, but were not able to photograph the phenomena. The storms were noted to be very large energetic thunderclouds; however, even small clouds with tops at 15 000 ft mean sea level (5000 m) have been observed to exhibit this unusual lightning. Estimated lengths for these discharges were on the order of 2 km, as reported by the pilots.

In a recent paper, Franz et al. (1990) presented video images of an unusual twin upward luminous discharge into the clear air above a thunderstorm. These images from the ground were obtained during the course of the Skyflash Observation Program. They estimated that the discharges extended 20 km in length above the top of the thunderstorm, which was located on the northwest side of Lake Superior and about 250 km from their observational site.

4. Conclusions

Although astronauts have reported some impressive lightning displays on Apollo, Skylab, and shuttle flights, this is the first time we have recorded a number of luminous discharges from the tops of thunderstorms. We are now trying to understand the significance in its relationship to the earth's atmosphere and the global electric circuit. In future manned or unmanned space missions, it is hoped that we will see more of this atmospheric phenomenon.

REFERENCES

