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# LIGHTNING OBSERVATIONS FROM SPACE SHUTTLE


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| Prepared By: | William L. Boeck |
| Academic Rank: | Professor |
| University and Department: | Niagara University<br>Computer and Information Sciences |
| NASA/MSFC: | |
| Laboratory: | Space Science |
| Division: | Earth Science and Application |
| Branch: | Remote Sensing |
| MSFC Colleague: | Dr. Richard Blakeslee |
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The experimental program of the Earth Sciences and Applications Division at NASA/MSFC includes development of the Lightning Imaging Sensor (LIS) for the NOAA Earth Observing System (EOS) Polar Platform. The objective is to fly a calibrated optical lightning activity imaging sensor to acquire and investigate the global distribution and variability of total lightning. This experiment is expected to fly on a sun synchronous polar orbiting platform in 1998. The lightning detector is a staring sensor with a 10 km spatial and 1 ms temporal resolution. A real time processor will identify sudden increases in brightness caused by lightning flashes. The processor will also account for the apparent movement within the field of view. The data stream relayed to the earth will include lightning event intensity, time and pixel locations.

The research plan is to use existing lightning information to generate simulated data for the LIS experiment. Navigation algorithms were used to transform pixel locations to latitude and longitude values. The simulated data would then be used to test and develop algorithms for the analysis of LIS data.

Individual frames of video imagery obtained from Space Shuttle missions provide the raw data for the simulation. Individual video frames were digitized to get the pixel locations of lightning flashes. The pixel locations will be used to locate the geographic position of the event. Because of a lack of detailed knowledge of camera orientation with respect to Space Shuttle, video scenes that contain identifiable city lights were chosen for analysis.

This project was done in cooperation with members of the Remote Sensing Branch, in particular Dr. Richard Blakeslee of the Earth Observing Team and Mr. O. Vaughan of the Sensor Technology Team. This summer the LIS scientific team was preparing for the CDCR (Conceptual Design and Cost Review) in August. I assisted with the conceptual design of the algorithms and the descriptions of the three levels of data products. I also drafted portions of the Data Management Plan for LIS.

The majority of my time was spent working on the analysis of lightning video tapes obtained by the Mesoscale Lightning Experiment. There was a dramatic improvement in the quality of the video as operational procedures were worked out. The handheld camera video is too shaky and the camera axis too undefined to quantify the discharges seen on the video. When arrangements were made for the PI to be at the Mission Control Center and advise the ground based camera controllers of where and when there would be a target of opportunity, the video from the payload bay cameras was much more stable. A particularly good set of data was obtained on the eighteenth of January 1990 when the Mission STS-32 passed over Florida during the night.

The process of locating targets on earth is a form of navigation. In this case, the location of the spacecraft is known and the target location is desired. The direction of the camera axis when pointing at a target on earth can be determined from two angular measurements. The first angle is the tilt of the camera from a vertical nadir pointing orientation. The apparent position of the horizon can be used to find the tilt, provided the focal length of the camera is known. The second angle is the rotation of the camera axis about the vertical axis. This angle can be determined by a sighting of a known geographic location crossing the vertical center line of the image at a known time. The angle sought is then the angle between the ground trace of the orbit and the great circle path from the subsatellite point to the known location. Unfortunately there is no readout of the focal length setting of the video camera zoom lens. This value must be estimated from the contents of the image.

The lightning locations determined from satellite imagery identify the location of the illuminated cloud volume. The lightning channel is obscured by many optical thicknesses of intervening cloud. If the event is a cloud to ground stroke, the ground strike could be anywhere beneath the cloud.

The case study presented is based on two and one half minutes of video obtained on a pass over Florida. The camera is pointing toward the North West and gradually views the Southern United States from Texas to the Georgia coast. The weather analysis for that morning shows a single cold front extending from Texas to Tennessee. The GEOS imagery shows most of the South has clear skies with a line of thunderstorms in Texas, Louisiana, and Arkansas. A ground based lightning location network and a VLF radio transmission network were operational at that time.

The following analysis is based on data provided by the Mesoscale Lightning Experiment, O. H. Vaughan of NASA/MSFC, Principal Investigator, with B. Vonnegut of SUNY, M. Brook of NMIMT, and R. Blakeslee of NASA/MSFC as Co-investigators. The lightning location data was provided by EPRI and R. Henderson and R. Pyle of SUNY. The VLF transmission data were provided by U. Inan and D. Carpenter of Stanford.

The data in the table is divided into three sections. The left section of four columns is data derived from an analysis of the video. The first and second columns are the GMT for the 18th of January 1990 seven hours and twenty to twenty three minutes. The horizontal lines mark off the times when an optical flash was observed. At each of the forty times given, an optical flash corresponding to a cloud to cloud flash or a cloud to ground flash is observed.

The central section of four columns is obtained from a lightning location network. The columns are the GMT second for a cloud to ground flash, the latitude and longitude of the ground stroke and the magnitude of the current. Seven events are identified as the times of cloud to ground flashes. The remainder of the optically detected flashes are identified as cloud to cloud. In four cases the video image has been analyzed to estimate the position. The estimated locations are in satisfactory agreement with the LLP locations. In each case the optical locations of city lights were computed. The city location errors were less than 100 km. The optical locations are near the center of the illuminated cloud which may or may not be near the ground stroke. The last flash observed is a positive flash which is located very near to the horizon. The large longitude error is due to the lack of perspective at the limb of the earth. This flash has a vertical illuminated column arising from the cloud top. Further work is being done to resolve the apparent time jitter between the two sets of measurements.

The right section of the table reports a summary of VLF propagation measurements on a path from Nebraska to Puerto Rico. There is a one to one correspondence between negative cloud to ground flashes and transmission decreases at 48.5 kHz. There is an apparent exception a 7:21:25. This is the smallest of the flashes and the decrease may be obscured by noise. A optical location will be determined on the nearest event in time to determine whether it is the same event or if this flash was not detected optically. Most of the cloud to cloud flashes did not produce a signal on this transmission path. Note that the large positive flash did not cause a VLF transmission change.

Conclusions

A method for locating the payload bay camera axis has been developed and tested. Two measurements are need, the pixel location of the apparent horizon and a timed siting of a known location passing the principal line of the image.

Individual video frames have been navigated and lightning illuminated clouds have been located on the map. Satisfactory agreement in location has been achieved for cities and LLP lightning locations.

Ground truth measurements have been compared to satellite observations.

A vertical lightning event has been identified on the horizon.

VLF transmission on this particular occasion shows a strong response to negative cloud to cloud flashes.

GMT: January 18 seven hours

| MIN | SEC | LAT | LONG | SEC | LAT | LONG | MAG kA | SEC | COMMENT |
|---|---|---|---|---|---|---|---|---|---|
| | | OPTICAL LOCATION | | | LLP LOCATIONS | | | | |
| | | | | 51 | 32.20 | -93.14 | -135.60 | | |
| | | | | 6 | 31.38 | -92.05 | -76 | 6 | NEB 2% DECREASE |
| | | | | 25 | 31.62 | -92.36 | -92.70 | 25 | NEB 2% DECREASE |
| 20 | 54 | | | | | | | | |
| 20 | 55 | | | | | | | | |
| 20 | 56 | 32.15 | -95.29 | | | | | | |
| 21 | 0 | 31.61 | -94.22 | | | | | | |
| 21 | 10 | | | | | | | | |
| 21 | 11 | 32.17 | -92.13 | 11 | 32.36 | -92.40 | -116 | 11 | NEB 2% DECREASE |
| 21 | 15 | 31.55 | -92.92 | 15 | 31.96 | -92.71 | -170.10 | 15 | NLK 15% PULSE |
| 21 | 16 | 31.54 | -91.50 | 15 | 31.66 | -92.53 | -170.10 | 15 | NEB 6% DECREASE |
| 21 | 20 | | | | | | | | |
| 21 | 21 | | | | | | | | |
| 21 | 24 | | | 25 | 32.07 | -95.36 | -36.10 | 25 | NLK 10% PULSE |
| 21 | 27 | | | | | | | | |
| 21 | 28 | | | | | | | | |
| 21 | 29 | | | 29 | 32.62 | -93.59 | -98.30 | 29 | NLK 8% PULSE |
| 21 | 30 | | | 30 | 32.25 | -93.11 | -118.10 | 29 | NEB 2% DECREASE |
| 21 | 34 | | | | | | | 34 | NEB 4% PULSE |
| 21 | 40 | | | | | | | 41 | NEB 2% PULSE |
| 21 | 41 | | | | | | | | |
| 21 | 45 | | | | | | | | |
| 21 | 49 | | | | | | | | |
| 21 | 53 | | | | | | | | |
| 21 | 55 | | | | | | | | |
| 21 | 58 | | | | | | | | |
| 22 | 2 | | | | | | | | |
| 22 | 3 | | | | | | | | |
| 22 | 6 | | | | | | | | |
| 22 | 9 | | | | | | | | |
| 22 | 14 | | | | | | | | |
| 22 | 19 | | | | | | | | |
| 22 | 20 | | | | | | | | |
| 22 | 23 | | | | | | | | |
| 22 | 33 | | | | | | | | |
| 22 | 38 | | | | | | | | |
| 22 | 43 | | | | | | | | |
| 22 | 49 | | | | | | | | |
| 22 | 51 | | | 51 | 31.87 | -92.77 | -71.50 | 51 | NLK PULSE |
| 22 | 51 | | | 51 | 31.98 | -92.36 | -91.80 | 51 | NEB 13% DECREAS |
| 23 | 1 | | | | | | | | |
| 23 | 13 | | | | | | | | |
| 23 | 25 | | | | | | | | |
| 23 | 27 | | | 28 | 32.03 | -91.81 | 42.50 | 28 | NLK 10% PULSE |
| 23 | 27 | 32.09 | -88.20 | 28 | 32.13 | -91.10 | 108.50 | | |
| | | | | 31 | 32.13 | -94.32 | -263.60 | 31 | NEB 10% DECREAS |
| | | | | 48 | 32.06 | -95.39 | -162.30 | 48 | NEB 6% DECREASE |