Lightning Detection from Satellites

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With 2 figures

Abstract

The detection of lightning by the Defense Meteorological Satellite Program (DMSP) of the United States is reported and two cases are analyzed for lightning flash density. The first is a squall line to the west of Florida on 14 November 1972 (06:27 UT), which has a flash density of $2{,}4 \times 10^{-5}$ flashes/(sec km^2). The second is the severe storm system of 3–4 April 1974 recorded on 4 April 1974 (05:54 UT), which has a flash density of 1.5×10^{-4} flashes/(sec km^2), or six times higher than the first case. We suggest that lightning flash density determined from satellites may be one of several indicators of the presence of a severe storm system.

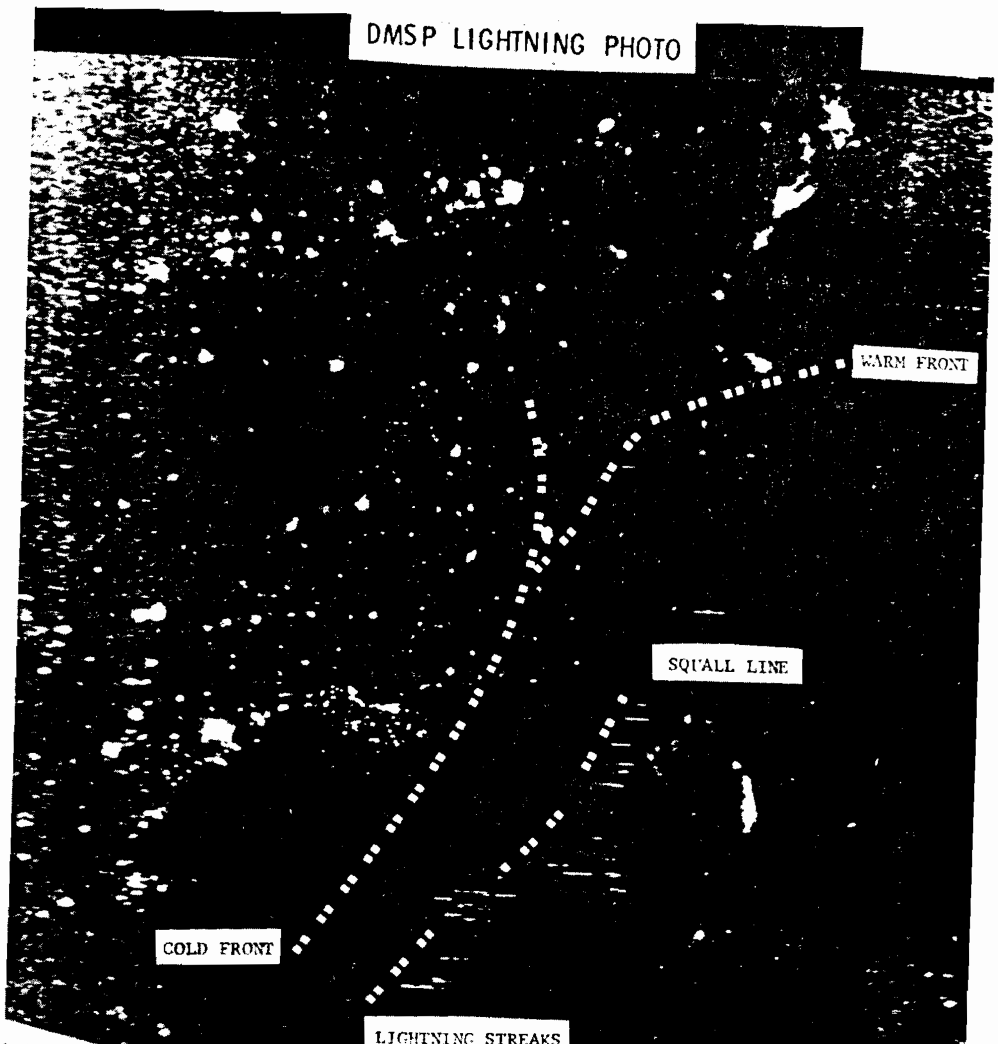

Fig. 1. A DMSP satellite photograph of the midwest and eastern U.S. recorded on 14 November 1972 with superimposed synoptic features (courtesy *Sizoo* and *Whalen*, 1974)

EXCERPT from: ELECTRICAL PROCESSES IN ATMOSPHERES (Proceedings of the Fifth International Conference on Atmospheric Electricity held at Garmisch-Partenkirchen [Germany], 2-7 September 1974.) Edited by Hans Dolezalek and Reinhold Reiter. Darmstadt: Steinkopff, 1977. Pages 750-753.

The detection of lightning by satellites was first reported by *Sparrow* and *Ney* (1968) using the solar observatory satellite (OSO-B) equipped with four photomultipliers. More recently, *Sizoo* and *Whalen* (1974) have analyzed high-resolution nighttime photographs obtained with the Defense Meteorological Satellite Program (DMSP) and identified lightning associated with squall lines. The purpose of this note is to bring these recent data to the attention of the conference and report on the satellite detection of high lightning flash frequency associated with the 3–4 April, 1974, tornado outbreak in the United States.

A summary of the DMSP satellite characteristics is available in the *Sizoo* and *Whalen* (1974) paper. These satellites are at an altitude of 815 to 850 km and are kept in noon-midnight and in dawn-dusk

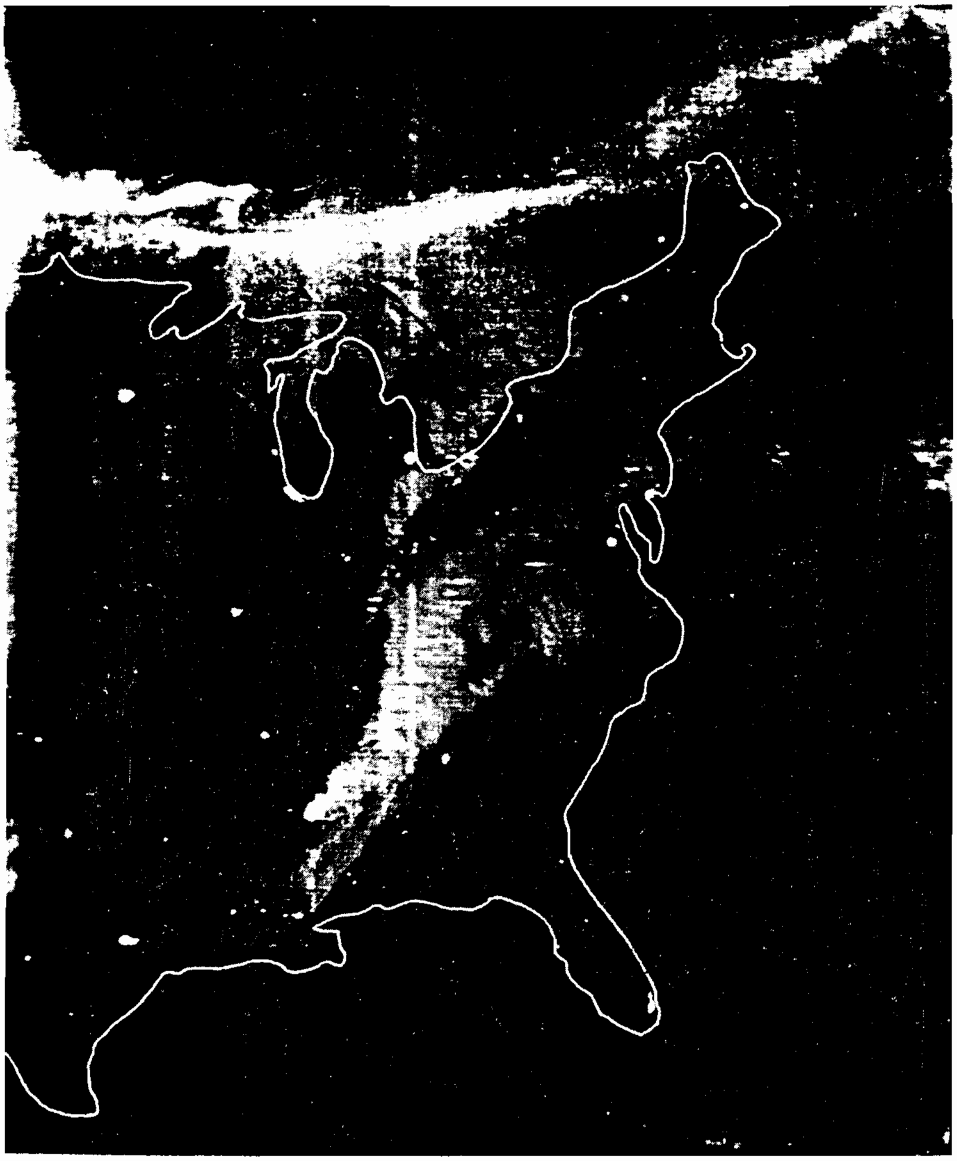

Fig. 2. A DMSP satellite photograph recorded on 4 April 1974, 05:54 UT. Note the high density of horizontal streaks in the central portion, which are believed to be the result of lightning flashes in the storm system

planes. Photographic data are obtained by a scanning radiometer that sweeps repeatedly across the earth in a line perpendicular to the path of the satellite and through the subsatellite point. The rotating mirror has a period of 562 msec and views the earth for 180 msec. Adjacent lines in the image have a separation of 3.7 km at the earth's surface and an approximate horizontal extent of 3000 km. The spectral range of the detector is 0.45 to 1.1 micrometer.

Fig. 1 shows a DMSP image obtained on 14 November 1972, between 06:26 UT and 06:29 UT (*Sizoo and Whalen*, 1974). The eastern half of the United States is recorded, and the lights of the cities and suburbs are clearly visible (the Miami area shows clearly in the lower right quadrant). *Sizoo* and *Whalen* have identified the horizontal streaks as caused by lightning and indicated the existing synoptic weather features at the approximate time the image was obtained.

If one assumes that the lightning frequency remained constant during the time taken for the satellite to scan the squall line system in Fig. 1, it is possible to calculate the frequency of flashes in the system. We estimate that the satellite took 145 seconds to scan the latitudinal section containing the squall line. Only a small fraction of this time, however, was used to record the area associated with the squall line. This area is 2×10^5 km^2, and the time taken to scan it is 3.3 sec. There are approximately 22 streaks, and consequently we estimate a flash frequency of 7 lightning flashes per second. Dividing by the area producing these flashes, we obtain a flash frequency of 2.4×10^{-5} flashes/(sec km^2). There is no way to determine the fraction of these flashes that are intracloud or cloud-to-ground.

The analysis of Fig. 1 provides a reference for the interpretation of Fig. 2, a DMSP satellite image obtained on 4 April 1974 at approximately 05:54 UT. The significance of this image is that it was obtained during the final hours of one of the most devastating tornado outbreaks in the history of the United States (*Purdom*, 1974). In the 18-hour period beginning at 19:00 UT on 3 April the total path length of tornadoes exceeded 2000 miles, or more than half of the U.S. yearly average (*Fujita*, 1974). More than one half of the average yearly U.S. deaths and damages due to tornadoes occurred during this same period.

In Fig. 2 a high density of lightning streaks is immediately apparent. The area in which the lightning flashes occur is approximately 1.3×10^5 km^2, and the time to scan this area is estimated to be 2.1 sec. There are approximately 45 streaks in this area, so that we estimate a flash frequency in the system of approximately 21 per sec. Dividing by the area we obtain a flash density of 1.5×10^{-4} flashes/(sec km^2) or a rate that is 6 times higher than the value obtained for the squall line in Fig. 1.

Insufficient data exist to determine if high lightning flash densities are characteristic of storm systems producing severe tornadoes. In the absence of these data, we suggest that the detection of a high flash density by satellites may be one of several indicators of the severity of a storm system.

Acknowledgments

We thank *Edmond Dewan* and *James Whalen* for generously making available Figs. 1 and 2. The preprint by *Sizoo* and *Whalen* (1974) has stimulated our interest in this problem, and we are extremely grateful to these authors for making us aware of their research in advance of publication.

This research was supported by the Atmospheric Sciences Section of the National Science Foundation under grant A 0-35395 X and the Office of Naval Research under contract number N 00014-71-C-0156.

References

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Discussion

Albrecht, Wachtberg-Werthhoven, West-Germany:

Did you supplement these observations by simultaneous directional measurements of electromagnetic noise on, perhaps, VHF or UHF?

Orville, Albany, New York, USA:

No.

Winn, Socorro, New Mexico, USA:

In reference to the last question, *William Taylor* at NOAA in Boulder may have such information from one of his tornado direction finding stations.

R. V. Anderson, Washington D.C., USA:

We have been looking at the same tornadoes to see whether the VLF analyser that we operate showed any indication, and qualitatively yes, there was a very strong indication. I have also been talking with the NASA people about their satellites, and yes, they have data; but it's going to take them months to get it processed. The question I would wish to raise is: is it possible to obtain any warning from satellites, or is the time lag in data processing so great that no good would be done? Some sort of ground-based spheric system, if it works, could conceivably give a warning. I question whether satellites could.

Orville:

Of course, we cannot answer that. I have wondered about this myself. One may have a severe tornado outbreak which would be over an area which is not heavily populated and a high flash density is detected. If it moved in a known direction one could obtain some predictive value.

R. B. Anderson, Pretoria, South Africa:

I should just like to ask whether tornadoes are particularly productive of lightning during the nighttime only. Our observations in southern Africa show that the majority of the thunderstorms perhaps start about 2 o'clock or 3 o'clock in the afternoon and end round about 8 o'clock in the evening. So is this not, perhaps, a difficulty regarding satellite pictures of tornadoes?

Vonnegut, Albany, New York, USA:

I think that there is little question that optical detectors could be arranged to work in the daytime as well as at night. As we have heard during this meeting, the New Mexico group has been using optical detectors successfully during the day. I see no reason why similar equipment could not be used with satellites. It is worth emphasizing that this satellite was built to study aurora and that the lightning observation was serendipitous.

Few, Houston, Texas, USA:

In one of the figures there appeared to be a cloud system illuminated by the internal flashes. Is this so or not?

Orville:

This is correct. It was an extensive cloud system in the south-eastern part of the U.S.

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