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Space Shuttle Video Images: An Example of Warm Cloud Lightning

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ABSTRACT

Warm cloud lightning has been reported in several tropical locations. We have been using the intensified monochrome TV cameras at night during a number of shuttle flights to observe large active thunderstorms and their associated lightning. During a nighttime orbital pass of the STS-70 mission on 17 July 1995 at 07:57: 42 GMT, the controllers obtained video imagery of a small cloud that was producing lightning. Data from a GOES infrared image establishes that the cloud top had a temperature of about 271 degrees Kelvin (-2 degrees Celsius). Since this cloud was electrified to the extent that a lightning discharge did occur, it may be another case of lightning in a cloud that presents little if any evidence of frozen or melting precipitation.

INTRODUCTION

Dr. Bernard Vonnegut maintained a belief that there are alternatives to cloud electrification mechanisms based on the interactions with frozen and melting precipitation. In addition to proposing an alternate mechanism, he promoted experimental demonstrations and actively sought counter examples. One group of counter examples contains reports of lightning discharges in small cumulus clouds that do not contain frozen precipitation, so called warm clouds. Although the reporters of warm cloud lightning are trained weather observers or lightning scientists, their reports have not persuaded the majority of persons interested in storm electrification mechanisms. In situ measurements of cloud microphysics during a lightning discharge could convincely establish the absence of frozen precipitation. Because warm cloud lightning is certainly not a common phenomena, the probability of a successful direct measurement is extremely low. All reports to date rely on proxy measurements to establish the cloud microphysics. These proxy measurements are based on estimates of the environmental temperature at the level of the warm cloud top. The argument asserts that when the top of the cloud does not extend above the 0 degree C isotherm, the cloud will not contain frozen precipitation. An alternate statement of the same argument is that lightning sometimes occurs before frozen falling precipitation forms in the cloud.

PREVIOUS OBSERVATIONS

Warm cloud lightning has been reported in several tropical locations by scientists and military weather observers. Foster [1950] flew directly over one of two clouds that were observed producing lightning. The location was about 200 miles north of Guam in the

Pacific Ocean. The radar altimeter read 8100 feet MSL while the dry bulb temperature was 6 degrees Celsius as they flew about 100 feet over the cloud. Pietrowski [1960] observed lightning in four small clouds located about 19 miles off the eastern coast of Florida. His aircraft flew directly over one of the clouds at an altitude of 10,000 ft. The measured air temperature was + 2 degrees Celsius which agrees with a simultaneous sounding measurement of 2.5 degrees Celsius above Cape Canaveral (38 miles away) at the same altitude.

The report of lightning scientists consist of ground based observations. Lightning in a small cloud was reported in a 1960 paper by Moore, Vonnegut, Stein, and Survilas [1960]. They presented photographic evidence and radar data from a storm near Grand Bahama Island. " We were never lucky enough to be over a warm cloud when it gave lightning". They combined photographs of the cloud internally illuminated by lightning with radar measurements of the range to conclude that all parts of the cloud were well below the zero degree isotherm. Another report by Michnowski [1963] also observed that small cloud was producing multiple flashes of lightning in Northern Vietnam on June 29, 1959. He estimated that the cloud top height was 2000 meters when he saw the first flash and the top was at 4000 meters when he saw the second flash, about 3 minutes after the first flash was noted. There was no nearby temperature sounding to establish the height of the zero degree isotherm. The estimated height for the conditions of that evening was about 4000 meters. African observations were added by Lane-Smith [1971]. He reported observing a small cloud that produced lightning in the evening at 17:15. He observed this from his home in Freetown, Sierra Leon, Africa on 17 September, 1965. He estimated the cloud base to be at 300 meters which is normal for that area. He assumed the saturated lapse rate within the cloud, in order to estimate the cloud top height at 53000 +/-700 meters. The normal freezing level is about 5600 meters. The storm produced one intra-cloud flash. Lane-Smith did not find another example of warm cloud lightning during an additional year of observations in Africa. Rossby [1966] observed warm cloud lightning on two moonlight nights near Key West. The aircraft was making ULF measurements of the cloud discharges which were below the altitude of the aircraft and therefore below the freezing level.

BACKGROUND FOR SPACE OBSERVATIONS

The space shuttle is an excellent platform to observe the earth and it's atmosphere during the day or at night. The nighttime observations of the earth's lightning displays appear at the top of the clouds as the shuttle orbits the earth. The astronauts compare the lightning displays to the appearance of bursting popcorn kernels against a dark background. Most examples of lightning are on the cloud tops of the large convective storm complexes that develop mainly over the land masses. Occasionally lightning is seen on the oceans where the storms do not appear to be as electrically active. The space shuttle has six TV cameras that are mounted on the forward and rear bulkheads of the shuttle's payload bay area as well as on the remote manipulator arm. We have been using the intensified monochrome TV cameras at night during a number of shuttle flights to observe large active thunderstorms and their associated lightning. These observations were made for the

Mesoscale Lighting Observational Program (MLE)[Vonnegut et al., 1985] [Vaughan and Vonnegut, 1989][Vaughan et al.,1992][Boeck et al.,1992] [Boeck et al.,1995]. During shuttle missions the cameras were operated by the Instrumentation and Communication Operations (INCO) personnel of the NASA Johnson Space Flight Center. The low light level monochrome cameras are under ground control whenever the crews are asleep or when the crews are not available to operate them due to timeline constraints.

NIGHTTIME OBSERVATION OF A SMALL TROPICAL CLOUD THAT PRODUCED LIGHTNING

During a nighttime orbital pass of the STS-70 mission on 17 July 1995 at 07:57: 42 GMT, the controllers obtained video imagery of a small cloud that was producing lightning. We found this small cloud lightning flash while replaying the mission videotapes. The cloud was located over the Caribbean Sea within a cluster of other small clouds. This particular cloud was the only one of the group that produced lightning during the 61 seconds of this video scene.. The cloud can be geolocated using the shuttle's orbital parameters and the star fields that are seen in the video images. Using a computer program, developed by John McKuen of NASA JSC, we were able to locate the cloud at 23.0 N Latitude and 86.5 W Longitude. This small cloud appeared to be a very small warm cloud based on the evidence in an GOES-8 satellite infrared image.

EVIDENCE

A sequence of video frames, Figs 1- 4, show the small cloud, illuminated by moonlight, and its internal lightning as recorded by the shuttle's video camera. Fig 5 is the GOES 8 satellite image of the cloud field near the same time. Data from this infrared image establishes that the cloud top had a temperature of about 271 degrees Kelvin (-2 degrees Celsius)[Graumann, 1995]. Since the infrared data provides a measure of the cloud top temperature it would appear that this cloud might be described as a warm cloud. It is interesting to note that this is the only cloud in the area that produced lightning during the video sequence. There are numerous other small and even larger clouds that are probably capable of producing lightning in the GOES image. Fig 6 is the same GOES 8 infrared image over which a grid has been registered and Fig 7 is a magnified section of that image to show single pixel resolution [Graumann, 1995]. The average sea surface temperature was 29.5 to 30 Celsius at this location [Legeckis, 1997]. Fig.7 shows the warm cloud and a much larger cloud, with a cloud top infrared temperature of 244 degrees Kelvin (-29 degrees Celsius). This larger and colder cloud did not produce lightning at the time the shuttle passed over this area. The average size of the warm cloud appears to be about 8 km in diameter. Since the infrared sensor's field of view is 4 km in diameter, we believe this is a valid infrared temperature for the cloud top and thus presents a strong argument for warm cloud lightning. Since this cloud was electrified to the extent that a lightning discharge did occur, it may be another case of lightning in a cloud that presents little if any evidence of frozen or melting precipitation.

CONCLUSIONS

The data from this video provides researchers with yet another example of warm cloud lightning. By adding these observations of warm cloud lightning to the existing set of data, we may move closer to accepting that various mechanisms can produce electrification in small, warm tropical clouds.

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