Lightning observation by the LIS aboard the TRMM satellite

Tomoo Ushio[1]

[1] Aerospace Eng., Osaka Pref. Univ.

The relationship between flash rate and storm height has been investigated to relate the lightning production with the meteorological aspects of the thunderstorm and to infer global thunderstorm characteristics from cloud observation. Williams (1985) suggests that the flash rate is a function of fifth power of the storm height, based on modification of the scaling law by Vonnegut (1963). Williams (1985) then shows the fifth power dependencies from three separate sets of field measurements in the United States during four different years.

Tropical Rainfall Measuring Mission (TRMM) satellite was launched into an orbit on 28 November 1997. The Lightning Imaging Sensor (LIS) on TRMM enable us to observe lightning on a storm scale (5 km) and to estimate the flash rate during its overpasses. On the other hand, the Precipitation Radar (PR) on TRMM observes the horizontal and vertical structure of the cloud including storm height. Since the TRMM/PR and LIS observe the same thunderstorms simultaneously from space, the instantaneous relationship between cloud height and flash rate for the same thunderstorm can be derived on a global basis.

In this study, we examine the relationship between thunderstorm height and flash rate over the globe using one month data for several different regions.

The TRMM satellite instruments used in this study are :

a. Precipitation Radar (PR), which is a space borne radar operated at 13.8 GHz. The radar has 4 km horizontal and 250 m vertical resolution over a 220 km swath. The minimum detectable Z is about 16 to 18 dBz.

b. Lightning Imaging Sensor (LIS), which is an optical sensor to detect and locate lightning. The sensor has a total Field of View (FOV) of about 600*600 km2, a nadir pixel resolution of 4 km, and a view time of at most 80 seconds. Storms which the PR observes are covered by the LIS square FOV for about 83 seconds.

In this analysis, the 2A23 (Level 2) PR product is used to define the thunderstorm height. Simply, the storm height is the maximum height of the minimum radar echo above the noise level estimated from the minimum detectable power, which is roughly 20 dBz.

Storms are identified based on areas in the LIS version 4 (V4) data sets. Areas are distinct regions of the earth that have one or more flashes in a given orbit. Physically they are roughly meant to be the thunderstorm cells generating lightning flashes. Flash rate are calculated by dividing the number of flashes composing an area by the total duration of observation time for the area.

For August, 1998, a total of 5229 LIS area are found that have coincident PR data. These LIS areas produce an average of 4.0 flashes per minute, and the mean storm radar height is 11.8 km above sea level. Only 14 % of these areas are over ocean, while 65 % occurred in summer hemisphere. Figure 1 shows flash rate versus storm height for the summer and winter hemisphere middle latitude in August, 1998. Horizontal lines near 0.7, 1.4, and 2.1 flashes/minute are due to the limited observation time (about 83 seconds) of a point on the earth overflown by the LIS.

Our results show that flash rate tends to increase as cloud height is higher albeit with large scatter. Some examples show low flash rates associated with high cloud height, but the reverse situation does not occur, which is similar to Shackford [1960]. Indeed, there appears to be a well-defined upper bound in the flash rates observed in storms at each cloud.

The relationship between flash rate and storm height is non-linear with large variance, suggesting that the fifth power scaling law is not necessarily required by the observed data. However, taller thunderstorms tend to have larger flash rate, and storm height is only one possible parameter in establishing flash rate. Other parameters which may modulate the scaling law or reexamination of their simplifying assumptions, must be considered.