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Flash size and within-flash time evolution of cloud-top optical emissions: Implications for satellite-based lightning observations

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This full-year study spanning portions of 2017-18 quantifies GOES-16 Geostationary Lightning Mapper (GLM) flash detection efficiency (DE) in central Florida using the Kennedy Space Center Lightning Mapping Array (LMA). Findings support the expectation that about 70% of all flashes are reported when averaged over all thunderstorms and times-of-day. When quantified as a function of LMA flash parameters, GLM exhibited an average of 40% DE for small (main channel length of 5-8 km), and even lower DE for shorter-length and/or short-duration (less than 200 milliseconds) flashes. Conversely, GLM exhibited more than 95% DE for long-duration flashes with main channel lengths of 50-100 km. DE was somewhat lower during daylight and higher at night. Flash size and duration, on average are shown to be a critical parameter influencing GLM detection. Given that this behavior occurred for severe and non-severe storms, it is likely an important contributing factor to the low flash detection efficiency for storms with high flash rates (and resulting small/short flashes) associated with severe weather, thereby modulating the effects of optical scattering and absorption within cloud volumes.

These findings can be explained by the time-evolution of cloud-top optical emissions derived from observations using the Lightning Imaging Sensor (LIS) onboard the Tropical Rainfall Measuring Mission (TRMM) Satellite. Specifically, LIS group area, energy density, and cloud-top energy in intra-cloud flashes, on average, reached a local maximum value in the very first few milliseconds of a flash and fell to their minimum values at around 10-20 milliseconds into the flash. After that, all parameters gradually increased over the next 80-100 milliseconds to reach the initial values, and then continued to increase for longer-duration flashes. In addition, statistical simulations based on long-term LIS group area observations indicate that about half of the above-threshold light sources are smaller than a LIS pixel (~ 4 km x 4 km) and are the smallest during initial breakdown in IC flashes.

These observations have implications for expectations about the performance of all satellite lightning observing instruments that are based on optical observations operating in the near-IR portion of the optical spectrum. The specific values for optical source size and cloud-top energy provided by this study, as a function of time-in-flash, should help refine the expectations for the performance of the upcoming Lightning Imager on the Meteosat Third Generation geostationary satellite.