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Mapping of thunderstorm charge structures by automated lightning leader speed analysis of Lightning Mapping Array data: applications and statistics

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Since 2011 a 12-station 3D Lightning Mapping Array (LMA) has been operational in the Ebro Valley region in the south of Catalonia, covering an area over 200 km wide along the east coast of Spain. Since 2015 it has been split in two, with six stations active in the Santa Marta region of northern Colombia. These arrays map very high frequency pulses (60-66 MHz) emitted mainly by negative leader steps and recoil leader processes during lightning flashes.

It is well-established that lightning flashes initiate in the high-field regions between two oppositely charged sections of the thundercloud and then branch out bidirectionally into positive and negative charge volumes. A classic thunderstorm develops a "tripole" charge structure. However, how the thunderstorm environment (and climate) affects the details of the charge structure has been little investigated so far, as well as its evolution, because objective and automated ways to analyze large volumes of data in active storms have been unavailable in the past.

At the previous European Conference on Severe Storms (2015) we presented possible ways of automating the analysis of leader polarity. Now we have developed a 4D grid-based algorithm that performs much better. In each grid box, leader speed is determined by applying a robust t-x/y/z slope fitting method (Theil–Sen) to the sources in that box and surrounding boxes within dual time intervals (on the order of 5-10 ms for fast leaders and 20-40 ms for slow leaders). In each grid box the median x, y, and z component of the vector of all flashes result in a 3D vector grid which can be compared to vectors in numerical models of leader propagation in response to cloud charge structure.

The method also counts how often leaders from a lighting flash initiate in or pass through each grid box. This "local flash rate" in the storm may be used in severe weather studies and is expected to be a more meaningful tool than LMA source density which is biased by the detection efficiency for different leaders.

Among the first objectives is a statistical study of the properties of charge regions, leader speed and flash rates based on six years of LMA data, in relation to meteorological background conditions (temperature, humidity, convective available potential energy and vertical wind shear). The charge analysis can also improve the understanding of the emission of rare phenomena as Gigantic Jets and Terrestrial Gamma-Ray Flashes (TGF).