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Lightning discharge

There is disagreement amongst authors regarding the frequency of lightning discharges globally. According to Malavika and Vishal[1], lightning occurs approximately 40–50 times per second worldwide, resulting in almost 1.4 billion flashes per year. According to Blumenthal et al.[2], at any given time, around 2000 thunderstorms occur around the world, generating about 100 lightning strikes per second or 8 million strikes per day (resulting in 2.9 billion strikes per year). Dwyer and Uman[3] indicate that there are 30–100 cloud and cloud-to-ground lightning discharges per second worldwide, which is about 9 million discharges per day worldwide. Despite lightning being a particularly complex phenomenon to study due to its spontaneous nature, over the years much effort has been invested in lightning-related research. This much-researched natural phenomenon is often defined as being a spontaneous, momentary, high-current electrical discharge/spark accompanied by sound, produced by a thunderstorm and occurring in the atmosphere, stretching over kilometres in length.[3,4] The discharge is therefore the final stage of an extremely complex process. Despite centuries of research into lightning initiation, there still is currently ongoing research on the physics and formation of lightning flashes. Tilles et al.[5] discovered that lightning initiation within thunderclouds might be bidirectional rather than the original concept of a fast positive breakdown of air being the cause of lightning initiation.

Existing lightning detection techniques and systems

Because lightning flashes produce electromagnetic radiation that disseminates across the globe, lightning can be detected over several distances and in real-time.[6] Before the development of weather radars, narrowband very low frequency ‘sferics’ detection systems employing two or more spatially separated magnetic-direction finding (MDF) receivers were the primary means of identifying and tracking thunderstorms at medium and long ranges with a location accuracy of several kilometres.[7] In direction finding techniques, the direction of the incident wave is determined at the antenna stations. The intersection of these directions gives the source location.[8]

In the 1930s and 1940s, time-of-arrival (TOA) geolocation techniques were developed for marine navigation purposes and were first employed in the geolocation of lightning in the late 1950s as described by Lewis et al.[9] In this technique, the exact time of the signal’s arrival at the antenna stations is compared for the different locations.[8] The position of the signal source is given by the intersection of the hyperbolas for equal time differences.[7,8,10,11] TOA methods can provide accurate locations at long ranges, and if the antennae are properly sited, the systematic errors are minimal.[10] A major challenge associated with the early TOA systems was the need for precise time-synchronisation of multiple remote sensors.[7] However, modern techniques address the limitations in early direction finding and TOA methods such as Lightning Mapping Arrays (LMA).[7]

More recently, the majority of lightning location systems that detect electromagnetic radiation utilise a combination of the MDF and TOA methods[6,12], minimising the geometric uncertainty in location accuracy.[8]

Lightning or total lightning sensors detect pulses in the VHF spectrum and are capable of detecting both cloud-to-ground and cloud-to-itself lightning with great accuracy but over smaller spatial scales.[6] Examples of these sensors include the Vaisala (Helsinki, Finland) total lightning sensor (which uses combined MDF and TOA techniques) and LMA.[13] LMAs are capable of detecting lightning in both two and three dimensions, consisting of sensors that are grouped closely together.[6,14] This is typically achieved by using TOA or direction finding location methods.[7,10,14] The Lightning Detection and Ranging System is also an example of a TOA method operating at a very high frequency.[10]

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