Observing Cloud-to-Ground Lightning In the Act: Prospects for Systematic Imaging of Lightning-Strike Contact Points

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In recent decades, tremendous progress has been made in remote-sensing systems for both cloud-to-ground (CG) lightning and intracloud lightning. Beginning in the 1970s, many countries installed lightning-detection networks of ELF receivers which coordinate direction and time-of-arrival data to locate cloud-to-ground flashes, often with a median accuracy on the order of 250 m or less. More recently, cloud-to-cloud flashes have been systematically located by means of regional networks of VHF receivers constituting Lightning Mapping Arrays (LMAs) operated by NASA and other research entities, and the GOES-16 satellite includes the Geostationary Lightning Mapper (GLM), a near-IR imaging sensor which can observe thousands of square km for lightning flashes (Stano, 2014). These large-scale systems can provide the type of macroscopic data useful to forecasters interested in severe weather accompanied by lightning. But none of them provide microscopic-scale data about the exact meter-scale location where cloud-to-ground flashes contact the earth, nor any details about subsequent events such as fires or other phenomena such as ball lightning that occasionally accompany CG lightning strikes.

While amateur and professional photographers as well as unmanned security cameras fortuitously capture close-range lightning strikes fairly frequently, the actual point of contact is rarely in view, and most such images are not useful scientifically. In order for the point of contact to be visible, the imaging system must be elevated above ground level, but obviously no higher than the typical height of a thundercloud base, on the order of 500 to 1000 m.

Until recently, any proposal to image the location of CG lightning-flash ground termination points with meter-scale precision would be defeated by prohibitive expense and practical difficulties. But the recent development of sophisticated and increasingly cost-effective unmanned aerial vehicles (UAVs) promises to change this picture.

While UAVs must operate within limits imposed by the Federal Aviation Administration, specifically a general elevation limit of 120 m, exceptions can be obtained for research-related activities. Commercial hover-style UAVs are available which can reach a height above ground of 1 km and stay on station for as long as 30 min or more. Video cameras are available for these systems which provide a pixel-level resolution on the order of 15 cm at that height, which proportionally improves at smaller distances. A network of 10 UAVs, each covering an area of 2 km^2 and deployed for 10-30 min at a location and time where CG lightning flashes were occurring at the rate of 5 km^{-2}, could reasonably be expected to produce records of 20-50 or more ground-contact points, especially in view of the fact that many flashes contact the ground at more than one point. An analysis of actual lightning data obtained in conjunction with a sighting of ball lightning in upstate New York (Stephan, 2016) shows that for certain locations in a 10-km-by-10-km area, a single drone at 1 km altitude could capture up to 5 flashes in a 10-minute interval. Such a high flash intensity is likely to be fairly localized, so the actual number could be less. Nevertheless, if each UAV is equipped with timestamp and GPS capability, post-event GIS analysis can produce extremely high-resolution location data and other useful information about any events surrounding each contact point of lightning with the ground or objects on the ground.

Many interests such as the insurance industry, electric, cable, and telecomm utilities, public safety agencies, and news media can be expected to benefit from data produced by CG contact-point video photography. Even if the activity is carried out on only an occasional research basis, the information about exactly which structures are hit, what the effects were if any, and the ability to correlate specific ground-contact events in time and space with the existing larger-scale lightning data-collection networks will provide a very useful complement to the macro-scale data currently available.

In addition, such data could form the basis of the first systematic observational study of ball lightning. While many anecdotal accounts of ball lightning are associated with nearby thunderstorms (Stenhoff, 1999), the haphazard nature of eyewitness accounts has so far frustrated any attempt to correlate the occurrence of this phenomenon with known variables such as thunderstorm intensity, location, flash intensity, or other quantitative data. Even if no likely ball-lightning events are captured, the effect of the research program described herein would be to set an upper bound on the likelihood that an average CG lightning flash will produce ball lightning nearby. The prevalence of continued eyewitness accounts of ball lighting implies that many more such incidents occur without eyewitnesses. A systematic effort to record the ground contact points and vicinities of CG flashes would stand a chance of providing useful quantitative data on an atmospheric-physics phenomenon which has so far defeated all attempts at a generally satisfactory scientific explanation.

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