Lightning Space Observations for Nowcasting

H. Christian

Earth System Science Center
University of Alabama in Huntsville
Huntsville, Alabama USA

The remote sensing of lightning from space has proven to be a valued capability for the monitoring of convective storms. Specifically, lightning is one of the few space-based observables that provide information on physical processes that are occurring in the heart of clouds as opposed to information from just the top boundary of the cloud. For geostationary satellites, lightning sensors are the only currently available technology capable of acquiring information from deep in the cloud. This discussion addresses the physics of how cloud electrification processes are linked to the energetic processes in the cloud (hydrometeor development) and the consequences of this tight linkage.

It is widely accepted that thunderstorms electrification is powered by the ice-ice non-inductive mechanism. In this process, charge is exchanged when two ice hydrometers (usually an ice crystal and a grauple particle) collide. Typically, these rebounding collisions leave the grauple particle with a net negative charge and the ice crystal with a net positive charge. Since this charging generally occurres at or near the main updraft, the lighter ice crystal tends to be carried to higher altitudes by the updraft while the heavy grauple fall relative to the ice crystal thus providing the separation needed to produce electric fields. This charging process is tightly controlled by the quantity of ice being produced at a given time in the thundercloud with both ice crystal and grauple production critical to electrical energy generation. In a strongly convective cloud, ice production is controlled by the total quantity of water that is processed which is the energy source of the thundercloud. Hence, the amount of electrical energy generated in a thundercloud is a function of the total energy generation.

Lightning dissipates most of the electrical energy generated in the cloud. Hence, the lightning flash rate tends to be linearly related to the ice production and the energy generation of the storm. Since techniques are now available to readily detect lightning from space, lightning observations can play an important role in monitoring storm development, evolution and intensity. Electrical energy tends to only be generated during the updraft phase of a storm with subsequently more energy generated as the storm intensifies. Consequently, lightning rates also maps the storm development. The first lightning flash generally occurs within minutes of the initial ice production and the flash rate increases a the updraft and storm intensity increases. When the updraft weakens and a downdraft forms, the flash rate rapidly decreases. It is this powerful, quantitative coupling that potentially makes space based lightning observations a powerful capability for monitoring strongly convective storms.

The most powerful application of space-based lightning observations is severe weather nowcasting. Severe weather is defined as a storm that produces tornadoes, strong straight-line winds and / or hail. Basically severe storms are very intense thunderstorms. The relationships between severe storms and lightning are basically the as between regular thunderstorms and lightning with the most important difference being that serve storms tend to produce much higher flash rates than standard airmass storms. They also tend to produce a preponderance of intercloud flashes.

When a convective clouds starts to go severe it tends to intensify in a rapid manner. The updraft velocity jumps, increase water ingestion fuels large energy releases. The typical response of lightning is a rapid jump in the flash rate. This "jump signature" is very discernable and has been used with ground based lightning networks to monitor severe weather development with a primary focus on tornadic storms. Currently in the US, using Dobbler radars, tornado warning times are on the order of 10 minutes, with a probability of detection of 73% and a false alarm rate of 56%. Extensive studies of lightning "jumps" and severe weather show lightning can provide lead times in excess of 20 minutes with probability of detection of 79% and false alarm rates of 36%.

These results suggest that geostationary-based total lightning observations have the potential for providing significant value for severe weather nowcasting. Other applications include quantitative ice-phase precipitation estimates, input data assimilation systems, "pseudo-radar" data in regions of poor radar coverage and long term climate sets of lightning variability.