Meteorology of thunderstorms

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For most researchers, meteorologists and official organizations, lightning and thunderstorms are completely interdependent. Lightning can be described as the result of a series of processes that occur in a typical thundercloud called "cumulonimbus". This cloud is the result of air convection combined with substantial humidity. The convection can initiate when conditional instability is released, i.e. according the parcel theory, when a parcel of air moves in an upward vertical direction, it reduces its temperature at a rate lower than that of the ambient air. Several mechanisms can enhance the rise of air, as for example saturation because its temperature decreases more slowly ('moist convection'), atmospheric circulations which can adiabatically cool down (by lifting) mid-level layers and force parcels from lower levels to ascend. The atmosphere capability to produce 'buoyancy' can be expressed thanks to criteria, for example, the Convective Available Potential Energy (CAPE), which is a potential energy in J kg-1: Thus, thunderstorm activity may last longer in areas with steeper lapse rates and higher CAPE. The thundercell, the basic organizational structure of all thunderstorms, lives for about 15-60 minutes and includes three stages: growth stage as towering cumulus, mature stage with both updraft and downdraft, and dissipation as cool outflow cuts off the base of the updraft from its supply of warm air. The interaction of vertical wind shear with buoyant bubbles is responsible for enhancing updraft and downdraft velocities, which has a consequence on the longevity of the convective cell. According to the environmental conditions of wind and CAPE values, several types of storm organizations can be found: "supercellular" when a strong vertical shear is present (>15 m/s shear vector between 0-6km altitude), "multicellular" when the thunderstorm cluster is composed of multiple cells, each at a different stage of their life cycle, systems organized linearly including mesoscale convective systems (MCSs) and squall lines.

To explain the thundercloud charge structure often observed as a positive dipole (positive charge above negative) but also sometimes as an inverted dipole, tripole, or more complex organizations with multiple layers, several mechanisms can take part in the cloud electrification, either as a process to initiate and sustain it, or as complementary processes to reinforce it. Of all charging mechanisms proposed up to now, the non-inductive ice-ice charging mechanism which stages collisions between ice crystals and graupel pellets is the best able to start the electrification within the cloud and to reproduce the vertical charge layering and the amount of charge observed. Laboratory experiments empirically show the result of the mechanism strongly depends on several parameters (ambient temperature and liquid water content). The accumulation of charge of both polarities in different regions of the thundercloud produces strong ambient electrostatic fields within the cloud (commonly observed up to about 100 kV/m) and the breakdown threshold of the air may be locally reached to initiate a discharge between two regions of opposite charge. The lightning discharge can also propagate out of the cloud and sometimes stroke the ground. Actually a wide variety of discharge can occur, according to the thunderstorm structure, its development, its severity and its environment. The lightning flash produces radiations in a very wide range of frequencies, which allows its detection and localization with specific systems. Thus, the lightning monitoring and analysis may inform about several physical characteristics of the thunderstorm.