Initial Breakdown Pulses in Intracloud Lightning Flashes and Their Relation to Terrestrial Gamma Ray Flashes

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The initial breakdown stages of 10 intracloud (IC) lightning flashes that may have produced terrestrial gamma-ray flashes (TGFs) have been studied with a 10-sensor array of wideband electric field change (E-change), multi-band magnetic field change (B-change), and VHF lightning mapping data. The flashes were chosen because their initial breakdown stages (approximately the first 5 – 15 ms of each flash) met the following published criteria known to be associated with TGFs: (1) had a slow ULF pulse in the B-change data with a duration of 2 – 6 ms and a charge moment change > 10 C km and (2) had one or more VLF/LF pulses roughly coincident with the slow ULF pulse. Previous lightning studies have shown that the largest amplitude fast pulses in IC flashes occur during the initial breakdown stage; these initial breakdown pulses (IBPs) have bipolar waveforms, durations of 10 – 100 μs, and one or more fast-rising sub-pulses superimposed on the initial half cycle. Using data from the E-change sensor array, the (x, y, z, t) locations of IBPs were determined with a time-of-arrival technique called PBFA (Position By Fast Antenna). Previous research has also shown that a typical intracloud flash initiates just above the main negative cloud charge (MNCC), then an initial negative leader propagates upward in 1 – 20 ms to the bottom of the upper positive cloud charge (UPCC), thereby establishing a conducting path between the MNCC and UPCC. As will be shown in this presentation, the PBFA locations indicate that initial breakdown pulses are directly related to the initial negative leader. The initial breakdown pulses primarily occur in short (< 750 μs) bursts of 2 – 5 IBPs, and each burst of IBPs is accompanied by a slow (2 – 4 ms), monotonic E-change. Typically 1 – 3 bursts of IBPs are needed to span the vertical gap from the MNCC to the UPCC, with successive bursts separated by 1 – 5 ms. Each burst of IBPs has an associated ULF pulse in the B-change data that is apparently caused by the same physical event that produced the slow, monotonic E-change of the burst. Similarly, each burst of IBPs has several associated LF pulses in the B-change data that are apparently caused by the same physical events that produce the fast-rising sub-pulses of the IBPs. As will be shown, we speculate, based on similarities with known TGF-associated signals and on estimates of the electric field strength associated with the charge moment change before an IBP, that a relativistic electron avalanche causes each LF pulse/IBP sub-pulse pair; thus each pair has the potential to cause a TGF.