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Mixed Mode of Charge Transfer During an Upward Positive Flash at Säntis Tower

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The term “mixed mode of charge transfer to ground for initial continuous current (ICC) pulses” in the context of upward lightning flashes was first proposed by Zhou *et al*. 2011 [1] to describe fast pulses, distinct from the classical M-component mode of charge transfer, superposed on the slowly varying initial-stage current of upward negative flashes they observed at the Gaisberg Tower in Austria. The pulses in question were associated with leader/return-stroke processes occurring in decayed or newly created branches of the plasma channel connecting to the grounded, current-carrying channel, with junction points below the cloud base (height < 1 km) [1,2].

Herein, we report, to the best of our knowledge, the first observation of a mixed-mode-type pulse during the initial stage of an upward *positive* flash that was initiated from the Säntis Tower in Switzerland. The Mt. Säntis Lightning Research Facility, which recorded the flash, consists of a current measurement system installed in the mountaintop tower (2.5 km ASL), slow and fast electric field sensors and X-ray detectors 20 m from the tower base, an additional fast E-field sensor 15 km away, as well as full HD cameras and a high-speed camera (HSC) at various distances, among other systems (see Šunjerga *et al*. 2021 for details [3]).

The observed flash, categorized as a Type 1 from its current waveform (see Romero *et al*. 2013 for definition [4]), occurred at 16:24:03 UTC on July 24th, 2021, during the Laser Lightning Rod project [5]. Its “return stroke”-like main pulse was confirmed from HSC footage to have been triggered by a downward-connecting leader with a junction height of approximately 369±5 m AGL, well below the defined cut-off of 1 km. Interestingly, though the 12 kA peak current is reasonable for a mixed-mode pulse, the current and E-field risetimes were both >10 μs, more characteristic of a M-component-type ICC pulse [2].

These observations are important to improving our understanding of the charge transfer mechanisms in upward lightning flashes, which regularly damage wind turbines, telecommunications towers, and airplanes during take-off and landing.

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