Assessment of Sprite Initiating Electric Fields Using Streamer Modeling and Experimental Observations

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Sprites are large air discharges appearing above thunderclouds typically following intense positive cloud-to-ground lightning discharges [e.g., Sentman et al., GRL, 22, 1205, 1995]. Streamer discharge theory has been applied to explain the filamentary structures observed in sprites [e.g., Pasko et al., GRL, 25, 2123, 1998; Gerken et al., GRL, 27, 2637, 2000; Liu and Pasko, JGR, 109, A04301, 2004; GRL, 32, L05104, 2005; Pasko, PSST, 16, S13, 2007]. Modeling results of sprite streamers indicate streamers propagate with expansion and acceleration in external electric fields greater than the minimum field required for their stable propagation. An enhancement of electric field is also found in the heads of streamers, which leads to production of relatively energetic electrons and localization of optical emissions in the same region.

Recent submillisecond video observations of sprites [e.g., Cummer et al., GRL, 33, L04104, 2006; McHarg et al., GRL, L06804, 2007; Stenbaek-Nielsen et al., GRL, L11105, 2007] have confirmed the features of sprites observed in previous high-speed videos [e.g., Stanley et al., GRL, 26, 3201, 1999; Moudry et al., JASTP, 65, 509, 2003; Marshall and Inan, GRL, 32, L05804, 2005]. Sprites normally initiate in the form of downward propagating positive streamers and the speed of the streamers can reach a fraction of the speed of light. In addition, it has been observed that sprite streamers expand and accelerate during the propagation and their emissions are mostly confined to the heads [McHarg et al., 2007; Stenbaek-Nielsen et al., 2007], which is consistent with streamer modeling results.

Multiwavelength observations of sprites from space are provided by the ISUAL scientific payload on the FORMOSAT-2 satellite [Chern et al., JASTP, 65, 647, 2003]. The ISUAL payload is able to simultaneously record emissions from the band systems of N_2 and N_2^+, which allows the derivation of the energetics of electrons in sprites and the driving field [e.g., Kuo et al., GRL, 32, L19103, 2005; Liu et al., GRL, 33, L01101, 2006] by comparing the recorded data with theoretical results.

In this talk, we will present our recent work on streamer modeling and compare the corresponding results with the high-speed video observations [McHarg et al., 2007; Stenbaek-Nielsen et al., 2007] and the multiwavelength recordings provided by the ISUAL instrument. The results support the sprite theory proposing that sprites are caused by conventional breakdown of air when the lightning field in the upper atmosphere exceeds the local breakdown threshold field [Pasko et al., JGR, 102, 4529, 1997], which has also been supported by a recent study comparing modeled lightning fields obtained using measured current moments of causative lightning discharges and video observations of sprites [Hu et al., JGR, 112, D13115, 2007].