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Key Points:
- The sprite-producing lightning flashes have a long propagation within the stratiform region
- The CMC of the stroke is confirmed as a good predictor of the sprite production
- Long-delayed sprites are associated with current moment waveforms of low amplitude and long duration

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Time and space correlation between sprites and their parent lightning flashes for a thunderstorm observed during the HyMeX campaign

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Abstract During the night of 22–23 October 2012, together with the Hydrology cycle in the Mediterranean eXperiment (HyMeX) Special Observation Period 1 campaign, optical observations of sprite events were performed above a leading stratiform Mesoscale Convective System in southeastern France. The total lightning activity of the storm was monitored in three dimensions with the HyMeX Lightning Mapping Array. Broadband Extremely Low Frequency/Very Low Frequency records and radar observations allowed characterizing the flashes and the regions of the cloud where they propagated. Twelve sprite events occurred over the stratiform region, during the last third of the lightning activity period, and well after the coldest satellite-based cloud top temperature (−62°C) and the maximum total lightning flash rate (11 min^{-1}). The sprite-producing positive cloud-to-ground (SP + CG) strokes exhibit peak current from 14 to 247 kA, Charge Moment Changes (CMC) from 625 to 3086 C km, and Impulsive CMC (iCMC) between 242 and 1525 C km. The +CG flashes that do not trigger sprites are initiated outside the main convective core, have much lower CMC values, and in average, shorter durations, lower peak currents, and shorter distances of propagation. The CMC appears to be the best sprite predictor. The delay between the parent stroke and the sprite allows classifying the events as short delayed (<20 ms) and long delayed (>20 ms). All long-delayed sprites, i.e., most of the time carrot sprites, are produced by SP + CG strokes with low iCMC values. All SP + CG flashes initiate close to the convective core and generate leaders in opposite directions. Negative leaders finally propagate toward lower altitudes, within the stratiform region that coincides with the projected location of the sprite elements.

1. Introduction

Sprites constitute a type of Transient Luminous Events (TLEs) that are commonly observed from ground. They consist of streamer discharges, in response to a strong transient electrostatic field that exceeds the threshold for dielectric breakdown in the mesosphere [*Pasko et al.*, 1997], either rapidly (a few milliseconds) after the lightning stroke [*Bell et al.*, 1998; *Cummer and Lyons*, 2005] or a few tens of milliseconds after a long lightning continuing current following the stroke [*Cummer and Füllekrug*, 2001]. The sprite discharge can cover an altitude range from 40 to 90 km [*Sentman and Wescott*, 1993; *McHarg et al.*, 2002] and appear as various vertically structured shapes, individual or multiple column or/and carrot-shaped luminous elements [*Neubert et al.*, 2008; *van der Velde et al.*, 2006]. Sprites can also horizontally extend over several tens of kilometers in the form of sprite clusters [*Sentman et al.*, 1995; *Füllekrug et al.*, 2001; *Soula et al.*, 2014] and even over more than 100 km in the form of sequential luminous emissions that are called "dancing sprites" [*Winckler et al.*, 1996; *Füllekrug et al.*, 2013a].

Sprites are generally observed above the stratiform region of a Mesoscale Convective System (MCS) after positive polarity cloud-to-ground (SP + CG) strokes that lower a large amount of charge to the ground [*Boccippio et al.*, 1995; *Lyons*, 1996; *São Sabbas et al.*, 2003; *Cummer and Lyons*, 2005; *Soula et al.*, 2009]. Sprites are produced when the lightning activity associated with the convective regions of the storm decreases and when the stratiform region is well developed [*Soula et al.*, 2009; *Lang et al.*, 2010]. Most of the time, the SP + CG flashes start close to the convective cores and horizontally extend across the stratiform region with layers of alternating charge polarity at different altitudes. The flashes often extend from higher