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Analysis of sprite events during small-scale winter thunderstorms in northern Europe

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Lightning occurrence throughout Europe is at a minimum in winter and mostly confined around the coastlines of the Mediterranean. Limited extent winter thunderstorms at higher latitudes are nevertheless found to produce intense CG strokes that may result in short-lived optical phenomena above thunderstorms in the region between the stratosphere and the lower ionosphere that are collectively referred to as transient luminous events (TLEs). Recent examples of sprite observations have been reported in northern Europe, at latitudes larger than about 49N, during very low flash-rate and small-scale winter storms. This study focuses on the characteristics of the sprite-producing strokes and the context in which they occurred. The sprite parent strokes are identified through the Météorage lightning detection network, providing additional information on the polarity and the peak current. A further characterization of the electromagnetic signal associated with these events is performed combining data from a series of quasi-electrostatic lightning sensors deployed in UK, a wideband ELF-VLF-LF radio receiver at the University of Bath (UK) and an ELF station in Poland, used for the calculations of the related current moment waveform (CMW) and charge moment change (CMC). The characteristics of the thunderstorm, as the cloud top temperature (CTT), the size and the meteorological context, are considered in order to better understand the conditions leading to the observed events.