Case studies of red sprite producing thunderstorms in Hungary

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Red sprites are streamer-based natural air discharges which develop on millisecond timescales in the mesosphere. Red sprites usually appear after positive polarity lightning discharges of high vertical charge moment change. In this work, large-scale meteorological parameters of sprite producing Central European summer thunderstorms were examined in order to shed some light on conditions which may characterize the periods of occurrences of such lightning flashes which can trigger red sprites. Maps of lightning activity, cloud top heights and temperatures, and radar reflectivities were analyzed for 4 thunderstorm systems which traversed the area of Hungary in 2007, 2010, 2011, and 2012. Occurrences of red sprites above these storms were observed optically from Hungary and from the Czech Republic. The results support the importance of the formation of a stratiform cloud region in thunderstorms from the point of view of sprite production.

1. Introduction

Red sprites, a form of transient luminous events (TLEs), are brief emissions with optical lifetimes of at most a few hundreds of seconds [1]. Sprite emissions are produced in streamer discharge fronts which are known to initiate and propagate in the mesosphere in a background quasi-static electric field. A background *E* field between the thundercloud and the lower ionosphere sufficiently strong to support sprite streamers can be built up after intense lightning discharges of high vertical charge moment change (CMC). The asymmetry of sufficient conditions for the initiation and propagation of streamers of different polarity causes that the majority of sprites are triggered by +CG lightning strokes of high CMC [2].

Such lightning discharges don't occur in all thunderstorms. The parent storm must be capable of intense charge separation and it needs to support the accumulation of a large amount of charge before the sprite triggering +CG breakdown occur. The existence of these conditions is supposed to be mirrored by gross meteorological parameters of thunderstorms, too.

Characterization of sprite producing thunderstorms on the US high plains [3] as well as in Western Europe [4,5] in summer, and in the Eastern Mediterranean region [6] as well as around Japan [7] in winter can be found in the literature. Also the general sprite producing potential of different thunderstorm types (single/multi cell storm, mesoscale convective system, squall line, etc.) has been considered [8]. According to the reports, sprite-active thunderstorms possess considerable area of cloud coverage including a stratiform region, high convection, relatively low cloud top temperatures and correspondingly high cloud tops (note the higher and lower values of this parameter found in summer and winter sprite-active storms, respectively), and generally intense lightning activity. Additionally, a decrease in the radar reflectivity values has been noted by more authors before the main period of sprite production [4,8].

In this work, sprite-producing thunderstorms are analyzed in Central Europe in order to characterize the meteorological properties of sprite-active storms in this region, and to find such large-scale meteorological properties which may indicate periods when sprite production probably occur.

2. Studied thunderstorms and datasets

Four thunderstorms have been considered in this study. The storms were crossing the area of Hungary in the summer months of 2007, 2010, 2011, and 2012. Appearances of red sprites were monitored from Sopron (16.58°E, 47.68°N, 234 m MSL), Hungary and from Nydek (18.77°E, 49.67°N, 482 m MSL), Czech Republic with optical detections systems.

The following meteorological parameters have been examined for each storm: cloud top height and cloud top temperature data from METEOSAT IR

observations (time resolution is 15 min., spatial resolution is 2 km), radar reflectivity intensities (vertical composites) from DWSR weather radar measurements (in the same resolution as the METEOSAT data), and rate of lightning strokes of different type (CG/IC) and polarity from the dataset provided by the LINET lightning detection network.

3. Summary of main results

Cloud tops of the examined sprite producing thunderstorms reached up to heights of 10-12 km. The corresponding coldest cloud tops had temperatures between (-55)°C and (-65)°C.

Sprite producing lightning strokes were selected from the lightning database via matching the time points of sprite observations with the occurrence time of such +CG strokes of relatively high peak current, which occurred aligned with the direction of the observed sprites. More of the identified sprite parent lightning strokes occurred in regions of the storms where the radar reflectivity was between ~25 dBZ and ~35 dBZ. The maximum reflectivity value, however, was 48.5 dBZ, so these events were not in the regions of the highest reflectivities (Figure 1).

The distribution of radar reflectivity values suggests formation of a trailing stratiform region in those extended thunderstorms which produce sprites.

Variations of the examined meteorological parameters did not show characteristic tendencies which was commonly and unambiguously present in all cases and according to which sprite producing periods and periods without sprites could be clearly separated in the examined thunderstorms. A worth noting observation is, however, that the level of maximum peak current values of +CG strokes raised near (and even exceeded that of) the –CGs in the period of sprite production and the two quantities varied anti-parallelly. A characteristic example for this is shown in Figure 2.

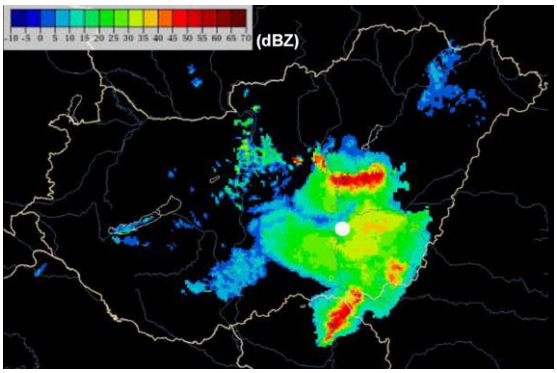

Figure 1. Radar reflectivities at 00:30 UTC on 13. August, 2010. The white circle shows the location of a sprite-parent +CG as detected by LINET Europe.

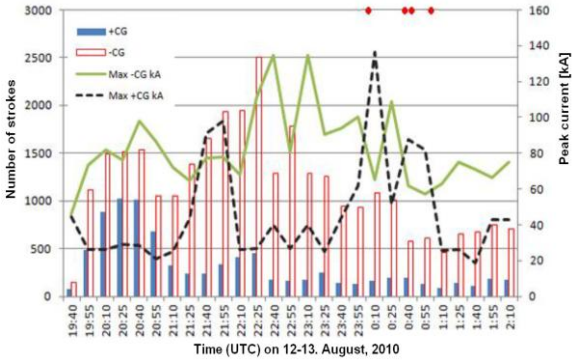

Figure 2. Numbers and peak current values of +/- CG strokes from LINET Europe in a sprite producing thunderstorm in Central Europe. Red dots show the time points of observed sprite events.

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