Meteorological characteristics of red sprite producing thunderstorms above Hungary

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Summary and main findings

Red sprites are brief luminous optical emissions accompanying electric discharges in the mesosphere. Lightning discharges dominantly occur after intense +CG lightning flashes. Nevertheless, sprite producing lightning discharges don't occur in all thunderstorms.

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

Data collected in the analysis included cloud top heights and cloud top temperatures from METEOSAT IR imaging, DWD weather radar intensities (vertical composites), and information about lightning strokes provided by the LNETLN lightning network location.

- Cloud tops of the examined sprite-producing thunderstorms reached up to heights of 80-90 km. The corresponding cloud tops had temperatures between -55°C and -60°C.
- Most of the identified sprite-parent lightning strokes occurred in an area of 20-50 dBZ reflectivity, where total reflectivities in the surrounding area were 45-48 dBZ. This observation supports the important role of stratiform storm areas in sprite production.

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Some related papers

Time of sprite-parent lightning events (UTC)

[Maximum peak current values of +CG strokes raised near (and even exceeded that of -CG and the two quantities varied anti-parallel in most periods of sprite production.]

Case#1: Thunderstorm in 2007

A meso-scale convective system embedded in squall line came from south-west bringing moist, unstable air. A cold, wet, strong vortex formed at higher levels, and warm, moist air advected at lower levels. The vorticity advection in the pre-frontal zone of the cold vortex possesses high thunderstorm triggering capability since it is strongly unstable.

Sprite observations were in 3 periods during the night from Supran (18:58 E, 47:48N, 234 m MSL) in Hungary:
- 20:00-20:45 UTC (16. 35 m 28 s), western small area, 2 sprites
- 20:46-20:54 UTC (18. 13 m 35 s), eastern large area, 2 sprites
- 20:55-20:58 UTC (20. 00 m 00 s), eastern large area, 6 sprites

Case#2: Thunderstorm in 2010

A long, stretched vortical front zone with warm, moist, unstable air flew from the west towards Hungary. A great meso-scale convective system formed along the conveyor belt in the unstable environment in the eastern part of Hungary coming from Serbia. The vorticity advection in the region was presumably caused by interaction between the curved conveyor belt and the vorticity advection generated in the pre-frontal trough coming from south.

Sprite observations were in 4 periods during the night from Supran (18:58 E, 47:48N, 234 m MSL) in Hungary:
- 20:00-20:05 UTC (16. 35 m 28 s), western small area, 2 sprites
- 20:06-20:09 UTC (16. 46 m 00 s), northern large area, 2 sprites
- 20:10-20:15 UTC (18. 25 m 00 s), northern large area, 4 sprites
- 20:16-20:18 UTC (20. 19 m 00 s), northern large area, 6 sprites

Case#3: Thunderstorm in 2011

The formation of this thunderstorm was caused by a squall line built in a meso-scale convective system. Hot tropical air was transported from south-west owing to cyclonic's frontal area. Strong vorticity was observable at low levels. A jet caused convergence with vorticity advection. This was also observable at higher levels and it was presumably the main trigger of the thunderstorm.

Sprite observations were in 1 period during the night from Nyádik (18:77E, 48:07N, 462 m MSL) in the Czech Republic:
- 2011:06:07, 20:58 - 23:40 UTC (PC time) (2h 42m), 37 sprites

Case#4: Thunderstorm in 2012

A slow-moving cold front triggered the thunderstorm. The front split up several convergence lines. Warm air at low levels with the cold air at upper levels formed an unstable system. This instability together with strong wind at high levels caused wind shear - a good setup for long-lasting rotating supercells. The slow-moving front maintained convergence at ground level enabling enough heat and moisture for following thunderstorms.

Sprite observations were in 1 period during the night from Nyádik (18:77E, 48:07N, 462 m MSL) in the Czech Republic:
- 2012:06:09, 19:30 - 21:44 UTC (PC time) (1h 14m), 8 sprites

Changes in radar reflectivity area size

Percentage of radar reflectivity area

Examples of sprite parent lightning stroke locations on radar reflectivity maps

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Radar reflectivity map examples

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