Meteorological characteristics of red sprite producing thunderstorms above Hungary

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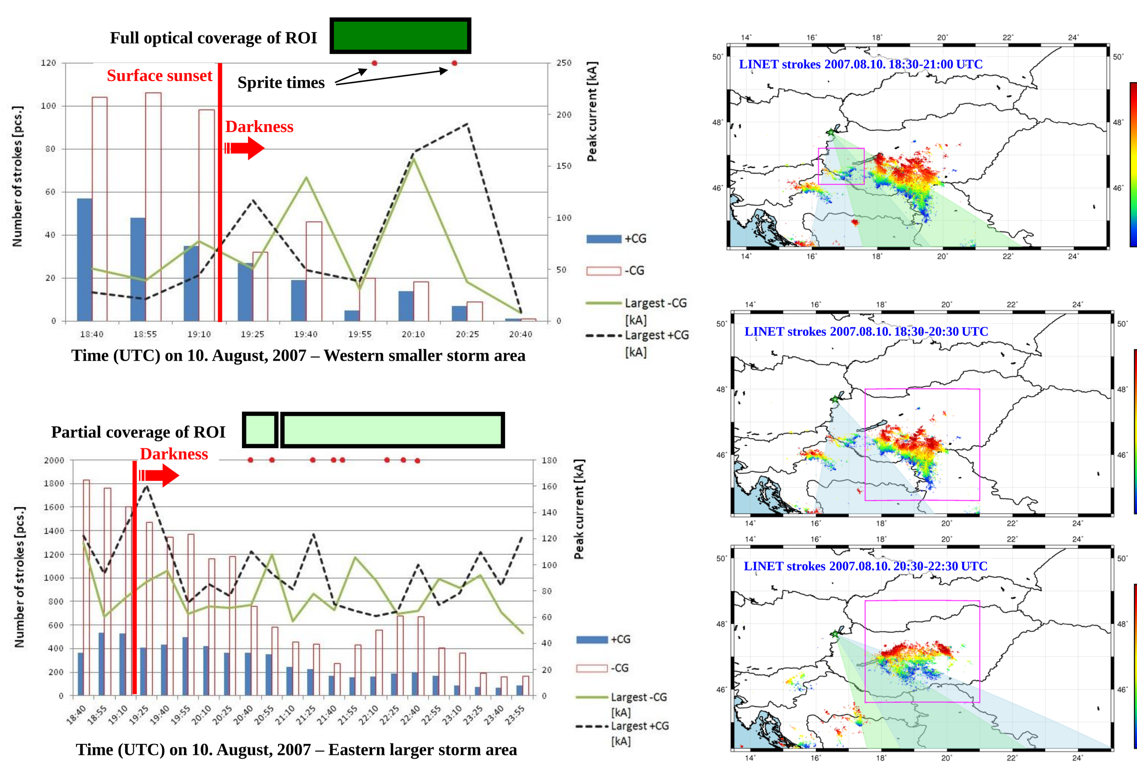
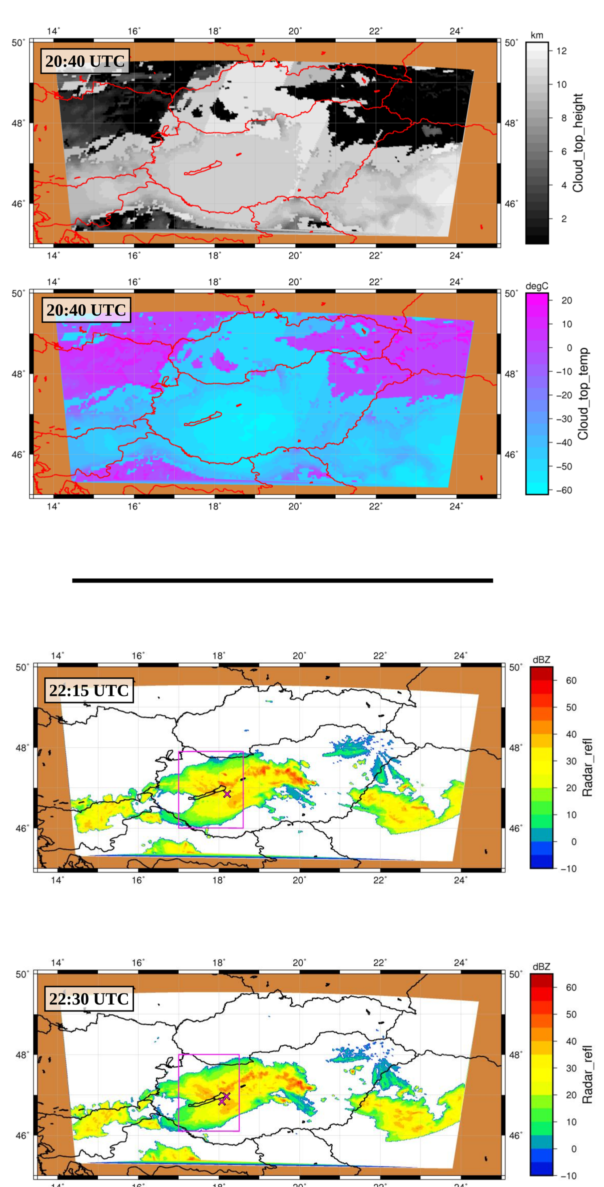
Case#1: Thunderstorm in 2007

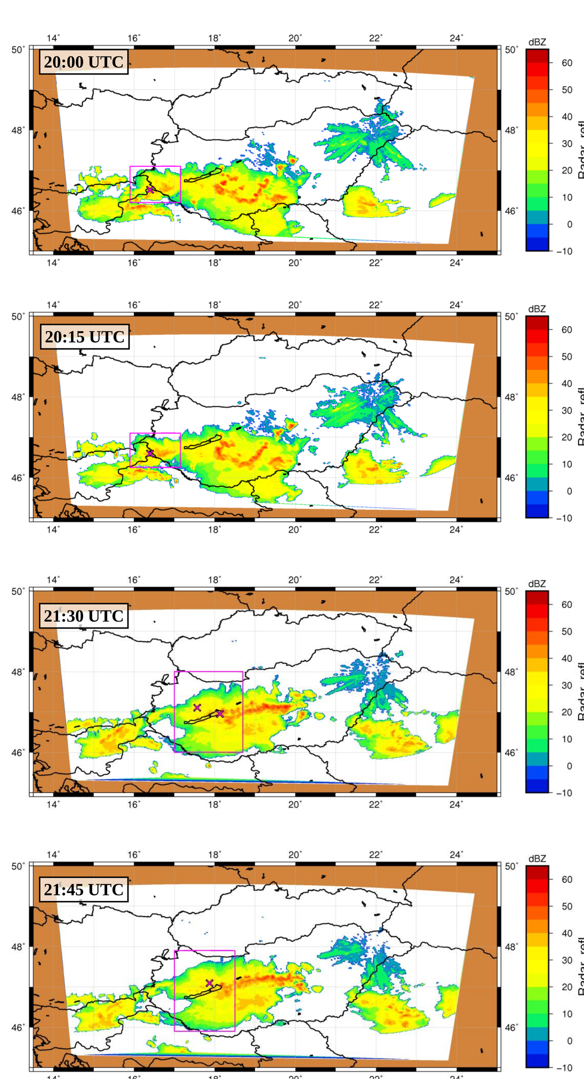
A mesoscale convective system embedded in squall line came from south-west bringing moist, unstable air. A cold, not strong vortex formed at higher levels, and warm, moist air advected at lower levels. The vorticity advection in the pre-frontal zone of the cold vortex possesses high thunderstorm triggering capability since it is strongly unstable.

Sprite observations were in 3 periods during the night
from Sopron (16.58 E, 47.68N, 234 m MSL) in Hungary:
2007.08.10. 19:44:27 - 20:19:55 UTC (0h. 35 m. 28 s.), western small area, 2 sprites
2007.08.10. 20:44:29 - 20:58:04 UTC (0h. 13 m. 35 s.), eastern large area, 2 sprites
2007.08.10. 20:58:18 - 23:35:18 UTC (2h. 37 m. 00 s.), eastern large area, 6 sprites





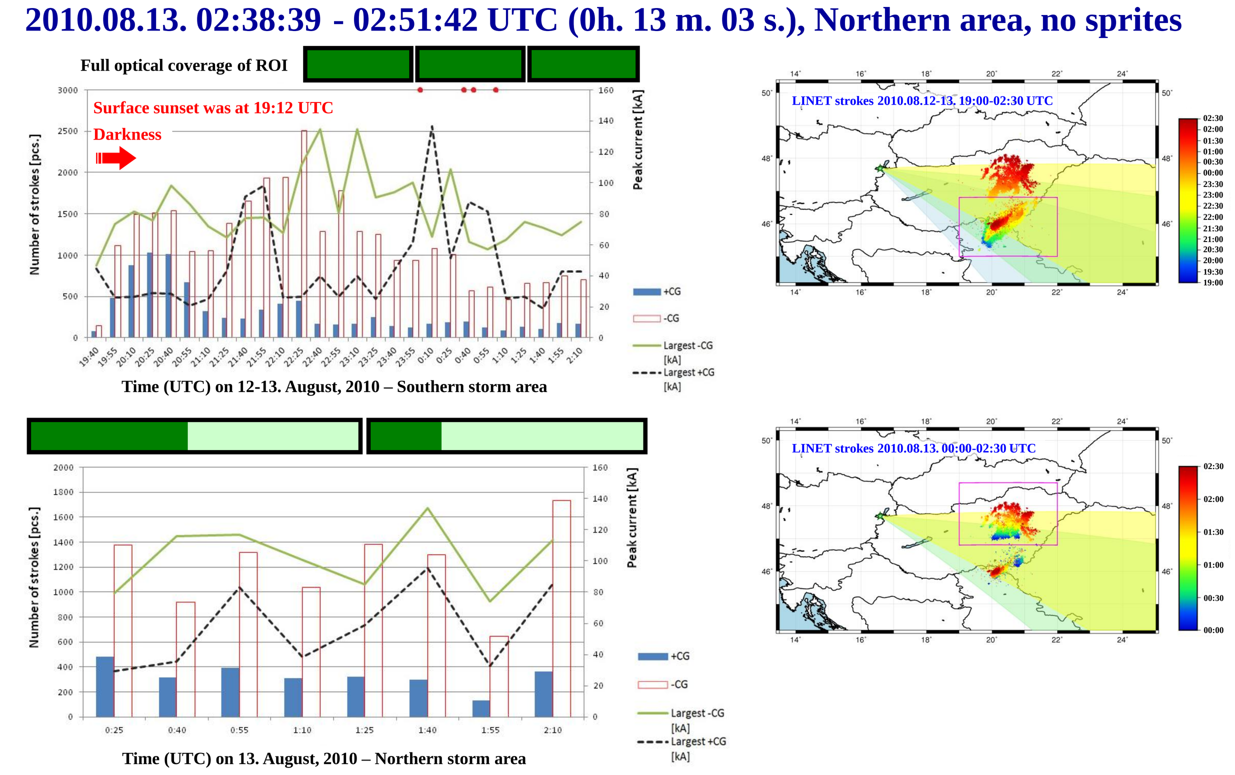
Examples of sprite parent lightning stroke locations on radar reflectivity maps

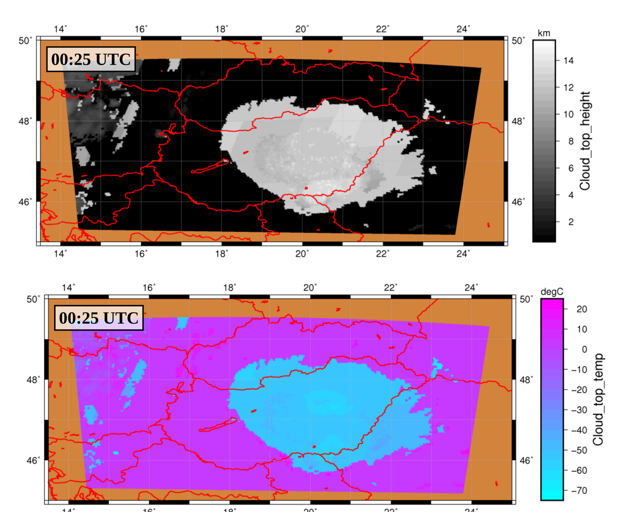


Case#2: Thunderstorm in 2010

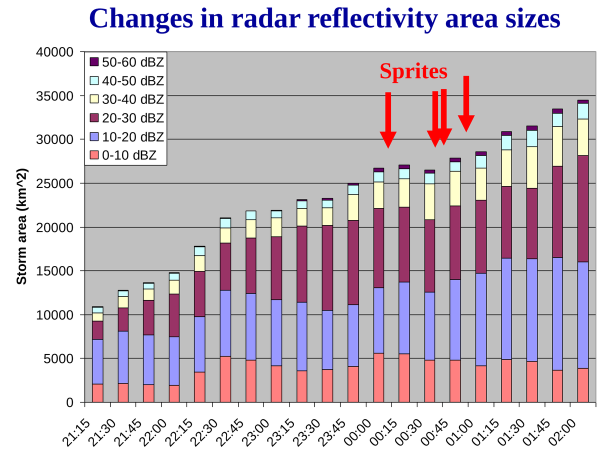
A long, stretched waving frontal zone with warm, moist, unstable air flew from the west towards Hungary. A great mesoscale convective system formed along the conveyor belt in the unstable environment in the eastern part of Hungary coming from Serbia. The convection in the region is presumably caused 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 Sopron (16.58 E, 47.68N, 234 m MSL) in Hungary:
2010.08.12. 22:20:09 - 23:57:45 UTC (1h. 37 m. 06 s.), Southern area, no sprites
2010.08.13. 00:00:05 - 01:22:29 UTC (1h. 22 m. 24 s.), S+N areas, 4 sprites
2010.08.13. 01:26:38 - 02:35:07 UTC (1h. 08 m. 29 s.), S+N areas, no sprites
2010.08.13. 02:38:39 - 02:51:42 UTC (0h. 13 m. 03 s.), Northern area, no sprites

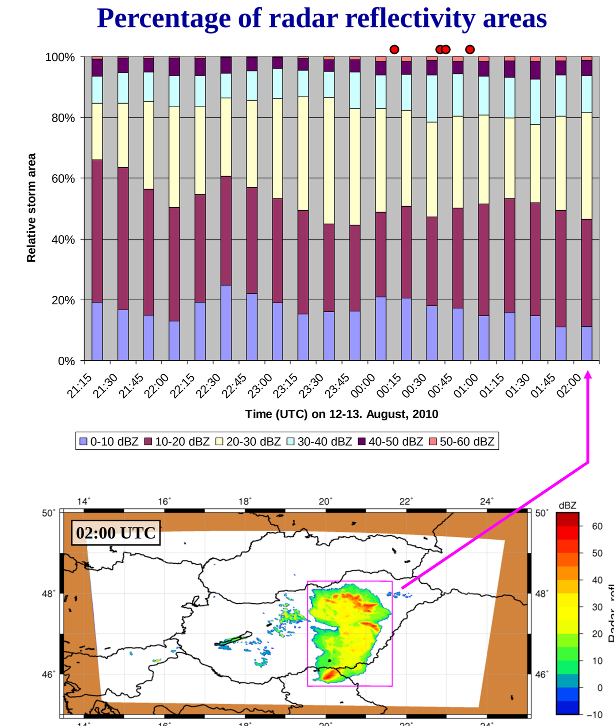




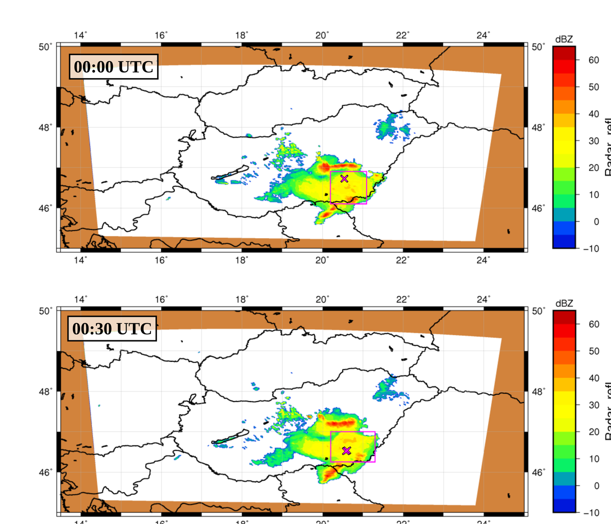
Changes in radar reflectivity area sizes



Percentage of radar reflectivity areas



Examples of sprite parent lightning stroke locations on radar reflectivity maps



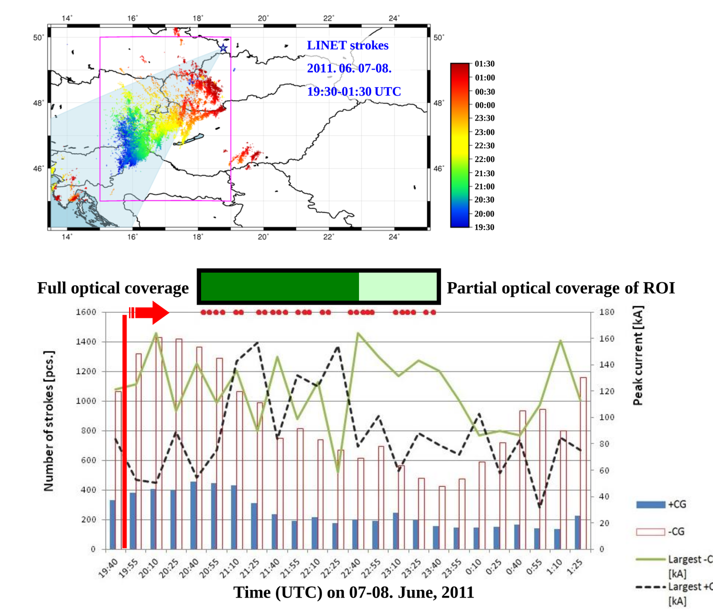
Case#3: Thunderstorm in 2011

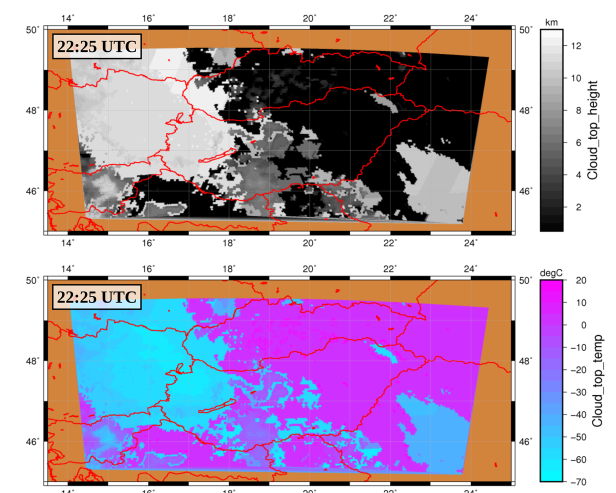
The formation of this thunderstorm was caused by a squall line built in a mesoscale convective system. Hot tropical air was transported from south-west owing to cyclone's frontal area. Strong convergence was observable at low levels. A jet caused divergence with vorticity advection. This was also observable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

Sprite observations were in 1 period during the night
from Nydek (18.77E, 49.67N, 482 m MSL)
in the Czech Republic:

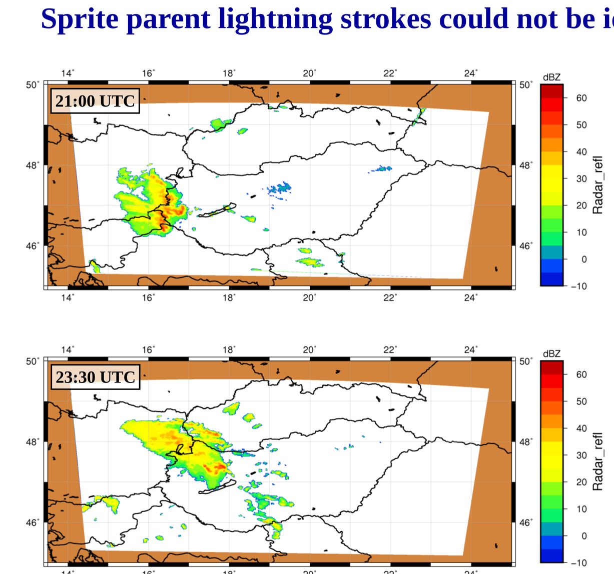
2011.06.07. 20:58 - 23:40 UTC (PC time) (2h. 42 m.)
37 sprites

Surface sunset was at 19:49 UTC





Radar reflectivity map examples
Sprite parent lightning strokes could not be identified



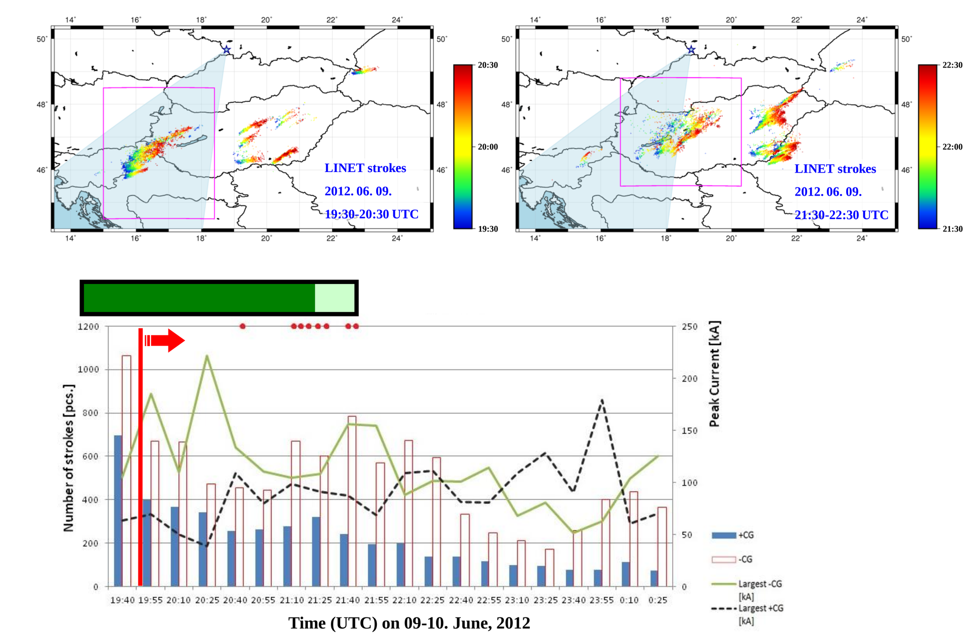
Case#4: Thunderstorm in 2012

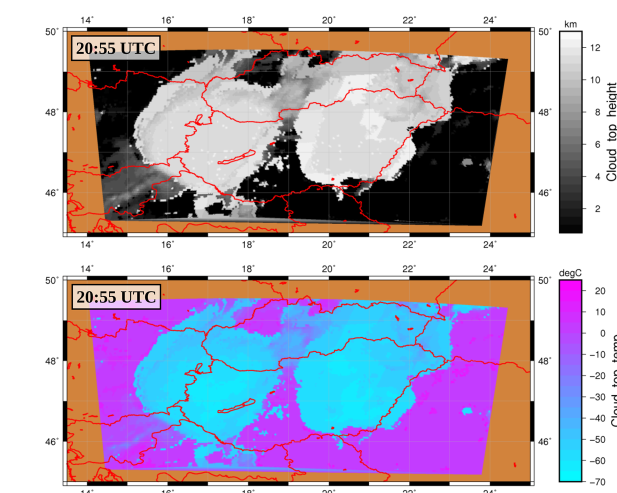
A slow-moving cold front triggered the thunderstorm. The front split up several convergence lines. Warm air at low levels with the cold air at upper levels formed an unstable system. This unstability together with strong wind at high levels caused wind shear - a good setup for long living rotating supercells.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

Sprite observations were in 1 period during the night
from Nydek (18.77E, 49.67N, 482 m MSL)
in the Czech Republic :

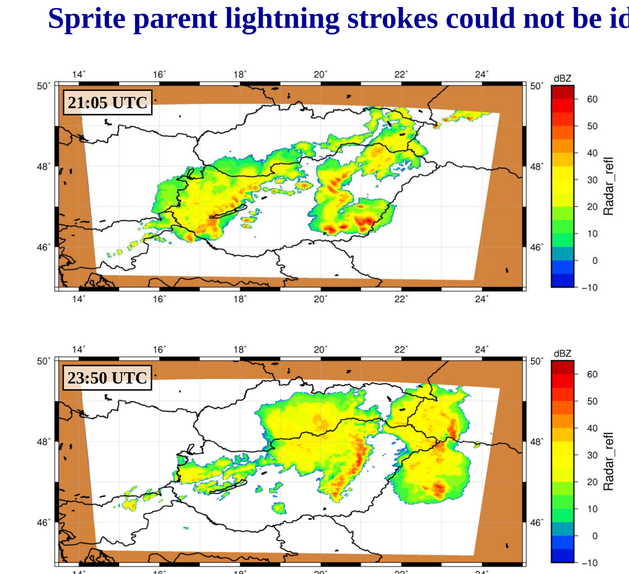
2012.06.09. 19:30 - 21:44 UTC (PC time) (1h. 14 m.), 8 sprites

Surface sunset was at 19:51 UTC





Radar reflectivity map examples
Sprite parent lightning strokes could not be identified



Summary and main findings

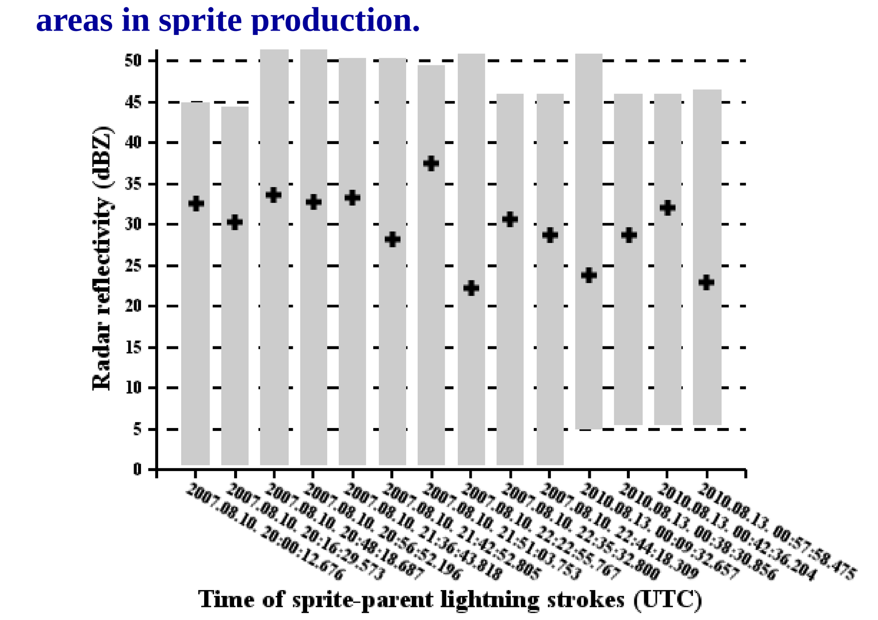
Red sprites are brief luminous optical emissions accompanying electric discharges in the mesosphere. Such discharges dominantly occur after intense +CG lightning flashes. Nevertheless, sprite producing lightning discharges don't occur in all thunderstorms.

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 occur in a thunderstorm.

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

- 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.

- Most of the identified sprite-parent lightning strokes occurred in an area of 25-35 dBZ reflectivity, while top reflectivities in the surrounding area were 45-50 dBZ. This observation supports the important role of stratiform storm areas in sprite production.



- Maximum peak current values of +CG strokes raised near (and even exceeded that of) the –CGs and the two quantities varied anti-parallelly in most periods of sprite production.

Acknowledgements

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Some related papers

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[2] S. Soula et al., Atmos. Res., 135–136 (2014) 415–431, doi: 10.1016/j.atmosres.2012.10.004
[3] W.A. Lyons et al., Chapter 17 in H.D. Betz et al. (eds.), Lightning: Principles, Instruments and Applications, (2009), doi:10.1007/978-1-4020-9079-0_17
[4] A. Savtchenko et al., J. Atm. Solar–Terrestrial Phys. 71 (2009) 1277–1286, doi: 10.1016/j.jastp.2009.04.010
[5] M. Ganot et al., Geophys. Res. Lett., 34 (2007) L12801, doi:10.1029/2007GL029258
[6] T. Adachi et al., J. Geophys. Res. D: Atmospheres, 110(11) (2005) 1-11, doi:10.1029/2004JD005012