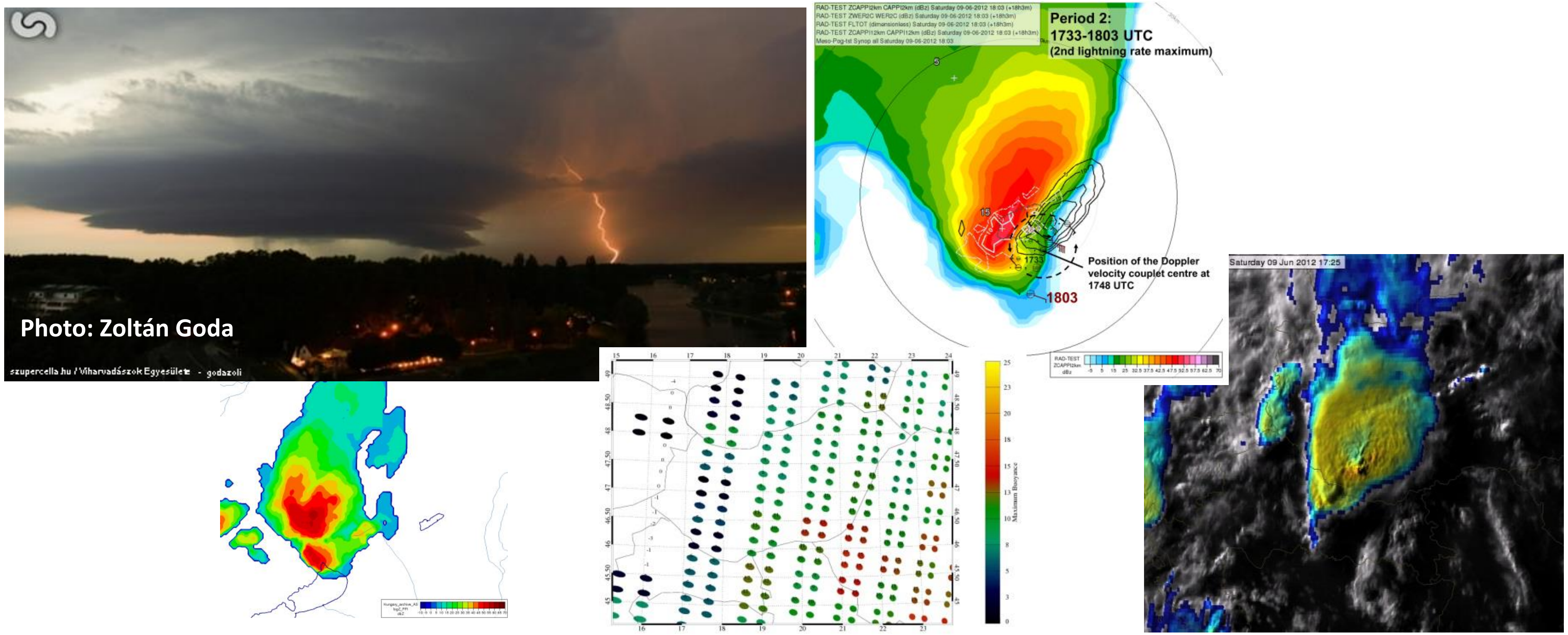
Case studies of various types of storms using satellite, radar and lightning data



André Simon, Mária Putsay and Zsófia Kocsis
Hungarian Meteorological Service

2018 Convection Working Group Workshop, Ljubljana, Slovenia, 17-19 April 2018

Outlines

Introduction
Five case studies
- Supercell, hailstorm (09 June 2012)
- Hybrid multicell-supercell storm, windstorm (08 July 2015)
- Tornadic storm (16 August 2010)
- Multicell storm and flashflood (31 July 2016)
- Single cell, short-lived local thunderstorm (23 July 2016)

Summary

Outlines

Introduction

Five case studies

- Supercell, hailstorm (09 June 2012)
- Hybrid multicell-supercell storm, windstorm (08 July 2015)
- Tornadic storm (16 August 2010)
- Multicell storm and flashflood (31 July 2016)
- Single cell, short-lived local thunderstorm (23 July 2016)

Summary

A part of a 2017 year EUMETSAT study: ‘Investigation of MSG SEVIRI and EPS IASI derived atmospheric instability in relation of other observations’

Motivation: MTG - Lightning Imager

We posed the following questions:

- **How much are the lightning characteristics related to other severe storm features on radar and satellite imagery?**
    - Is there any correlation between the radar, satellite parameters, features and lightning rate or density?

Are the observed lightning characteristics pre-cursors of severe weather?

Outlines

Introduction

Five case studies

- Supercell, hailstorm (09 June 2012)
- Hybrid multicell-supercell storm, windstorm (08 July 2015)
- Tornadic storm (16 August 2010)
- Multicell storm and flashflood (31 July 2016)
- Single cell, short-lived local thunderstorm (23 July 2016)

Summary

5 cases of different kinds of storms developed in the Carpathian Basin

Synoptic situation

Environment

Radiosonde, NWP, GII, IASI

Development of the storms

Storm tracking → temporal courses of satellite, radar, lightning parameters + features and severe weather reports

Spatial distribution of the lightning density within the storm structure (ECSS poster – Simon et al., 2017)

Satellite - METEOSAT SEVIRI RSS (5 minute data)

Lightning – data of LINET network

Hungarian radar system - **Three/four Doppler dual-polarization DWSR radars**

- **5 minute** reflectivity data
- **15 minute Doppler** wind measurement

Severe weather reports from ESWDB or from surface measurements – no hail pad data

NWP, GII, IASI

Outlines

Introduction

Five case studies

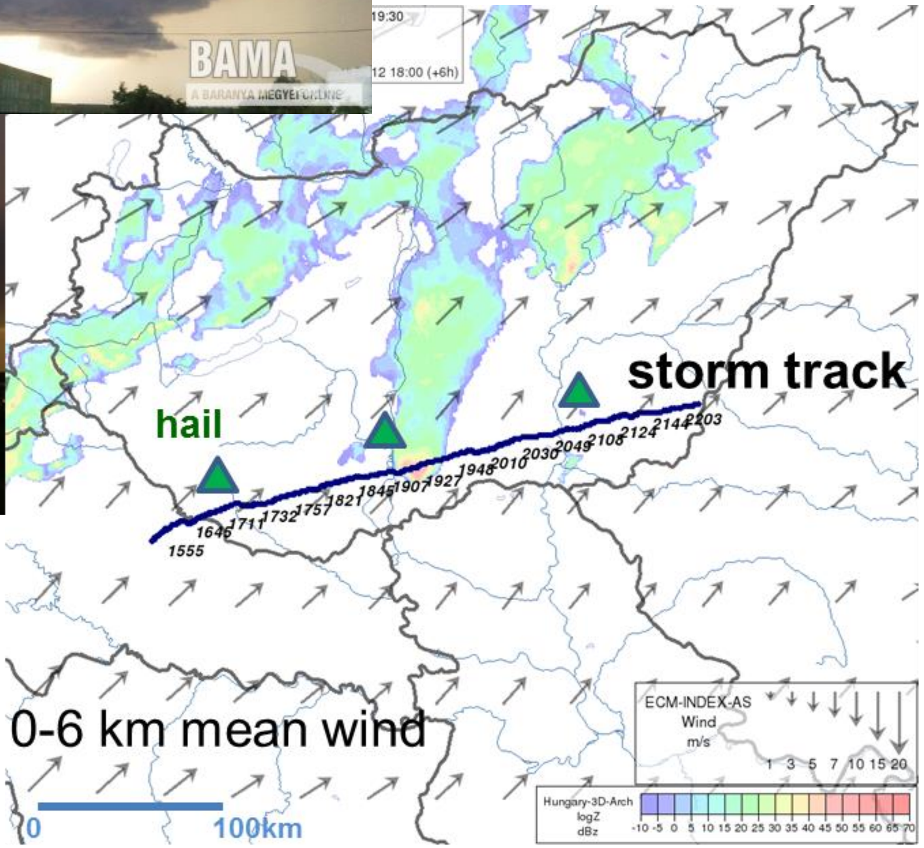
- Supercell, hailstorm (09 June 2012)
- Hybrid multicell-supercell storm, windstorm (08 July 2015)
- Tornadic storm (16 August 2010)
- Multicell storm and flashflood (31 July 2016)
- Single cell, short-lived local thunderstorm (23 July 2016)

Summary

What happened?
The storm (classic or HP supercell) passed over southern Hungary (16-21 UTC), causing large hail (3-6 cm) at many places.

Synoptic situation
The studied convective system developed at a wavy front.

View of the cell from East, at the city of Baja (~19:00 UTC)



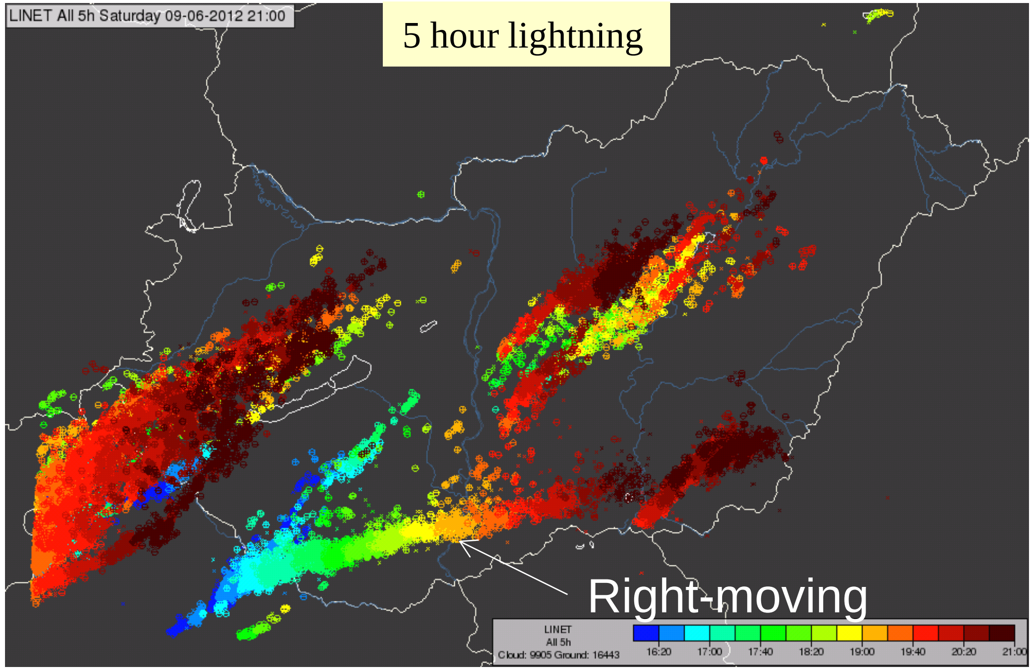
Storm track

Environment at the southern part of Hungary
Moist atmosphere, Moderate instability
Strong 0-6 km wind shear

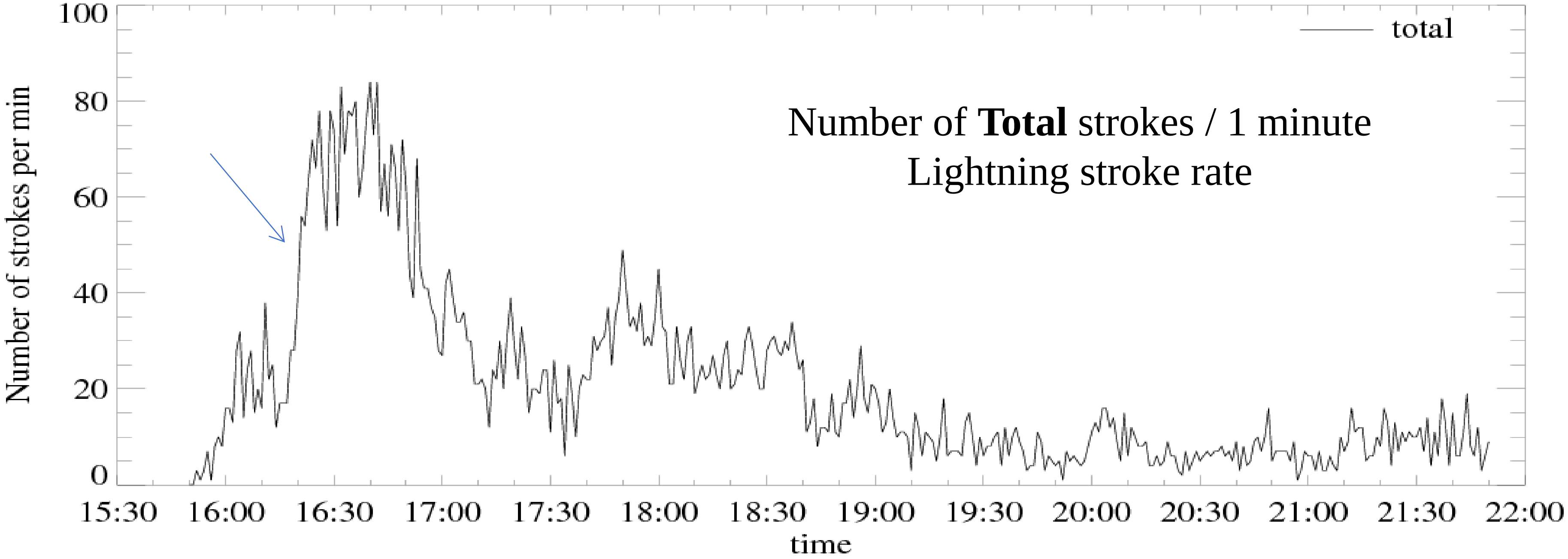
Storm development
Severe storm features

<u>Lightning features indicating possible severity:</u>

- **'Lightning jump' - sudden increase of the number of strokes**
- High stroke frequency (up to 80 strokes/minute)
- **Right mover**



Lightning strokes (total) belonging to the studied radar cell



Satellite cloud top features indicating possible severity of the storm SEVIRI (RSS)

High cooling rate

(seen only when it overrun the anvil **–3,9 K/5** minute in the first 5 minute period)

Right mover

Extreme cold overshooting tops (OT) (down to -66.3 °C)

After ~16:20 UTC **big elevated dome** with complex structure – **with long life time**

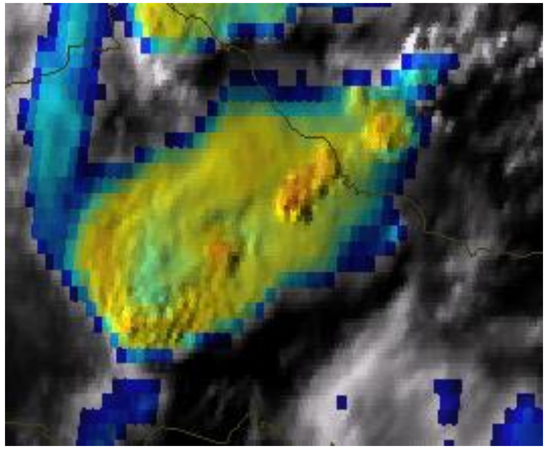
Long-lived Cold ring (more than 8 hours)

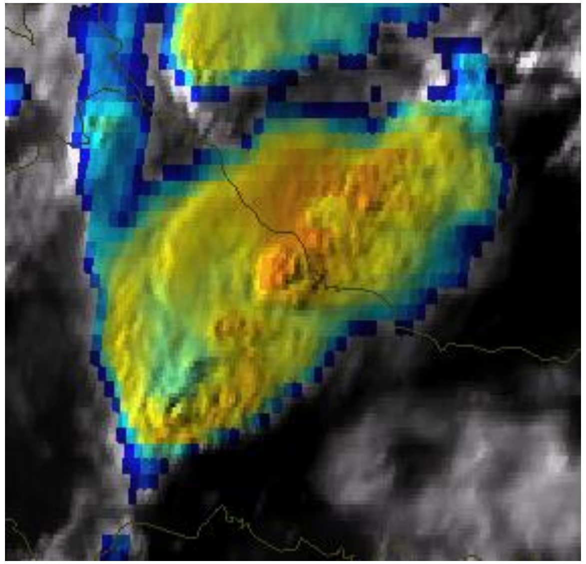
High difference between the coldest BT10.8 of the ring and the warmest BT10.8 of the warm spot

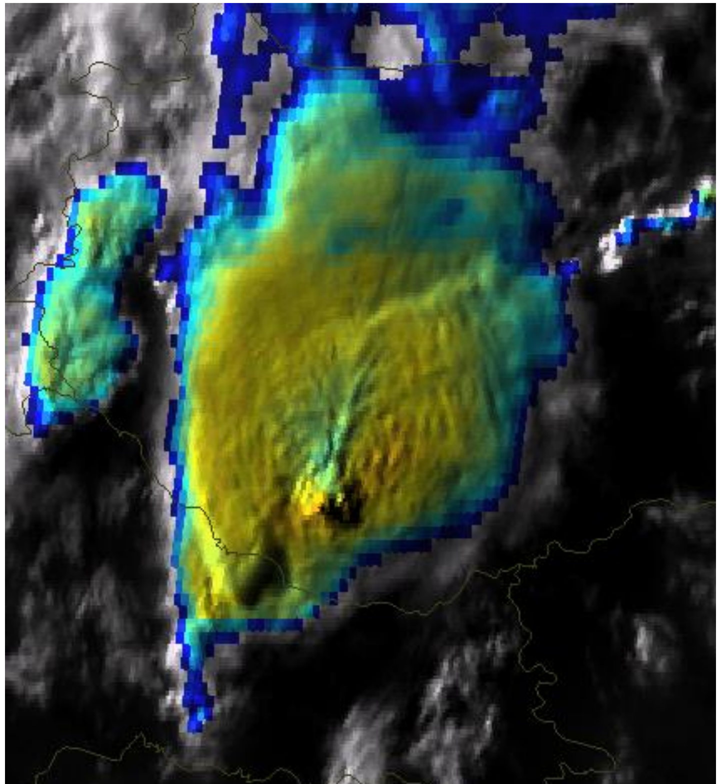
Over anvil **ice-plume**

Small ice crystals on the cloud top (Day Microphysics and Severe Storms RGBs, Re)

HRV/IR10.8 blended images 16:03,16:25, 17:33 UTC

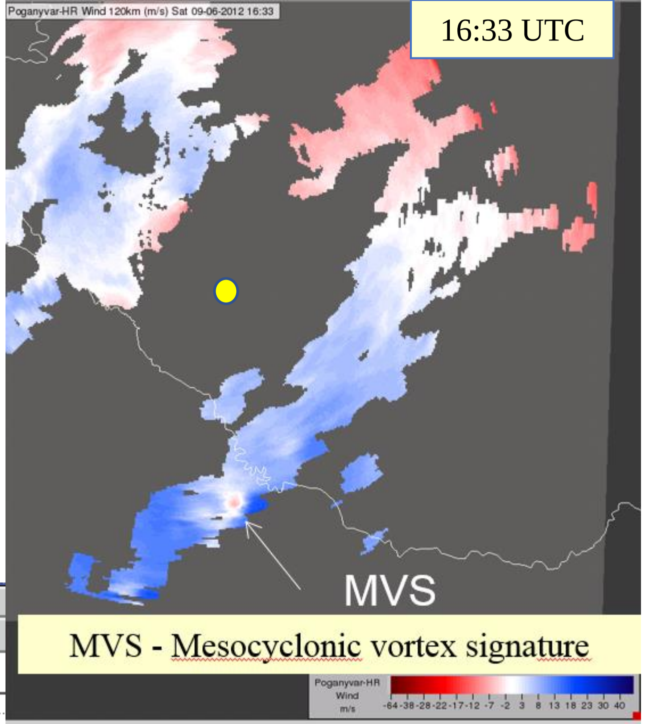






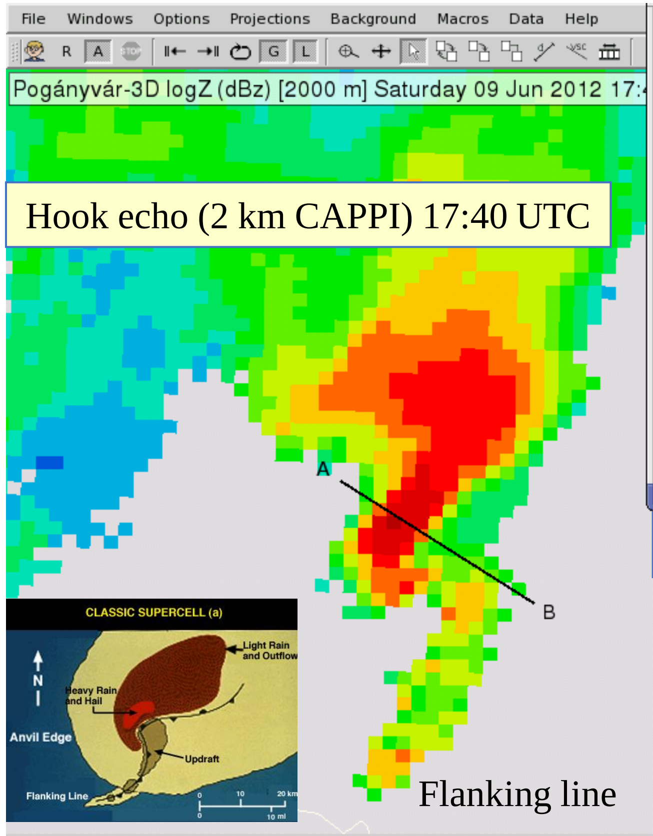
Radar features indicating possible severity of the storm

- Doppler wind feature - **MVS** – indicating **rotation** (next slide)
- **Right mover**
- **Long-lived intense** radar cell (more than 8 hours)
  - **High reflectivity values (up to 61.5 dBz)**
  - **High VIL values (up to 76 kg/m²)**
- **Hook, bow and WER/BWER echoes**



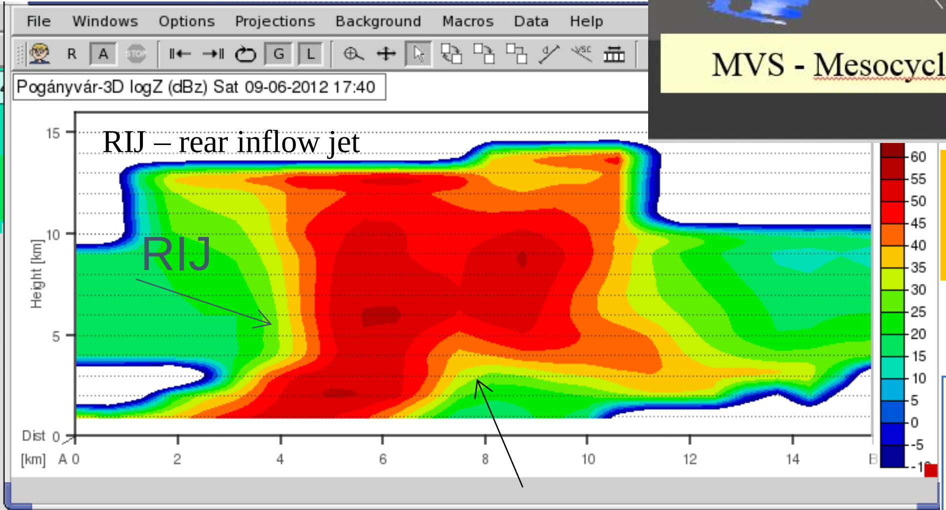
MVS - Mesocyclonic vortex signature

Persistent mesocyclone



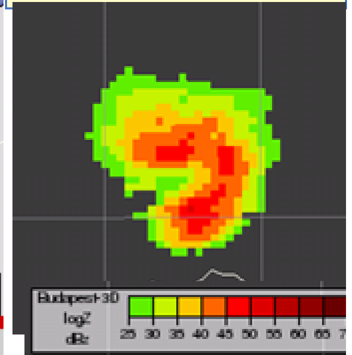
Hook echo (2 km CAPPI) 17:40 UTC

Flanking line



WER+BWER echo (vertical cross section) 17:40 UTC

Bow echo
in 9 km CAPPI
20:15 UTC



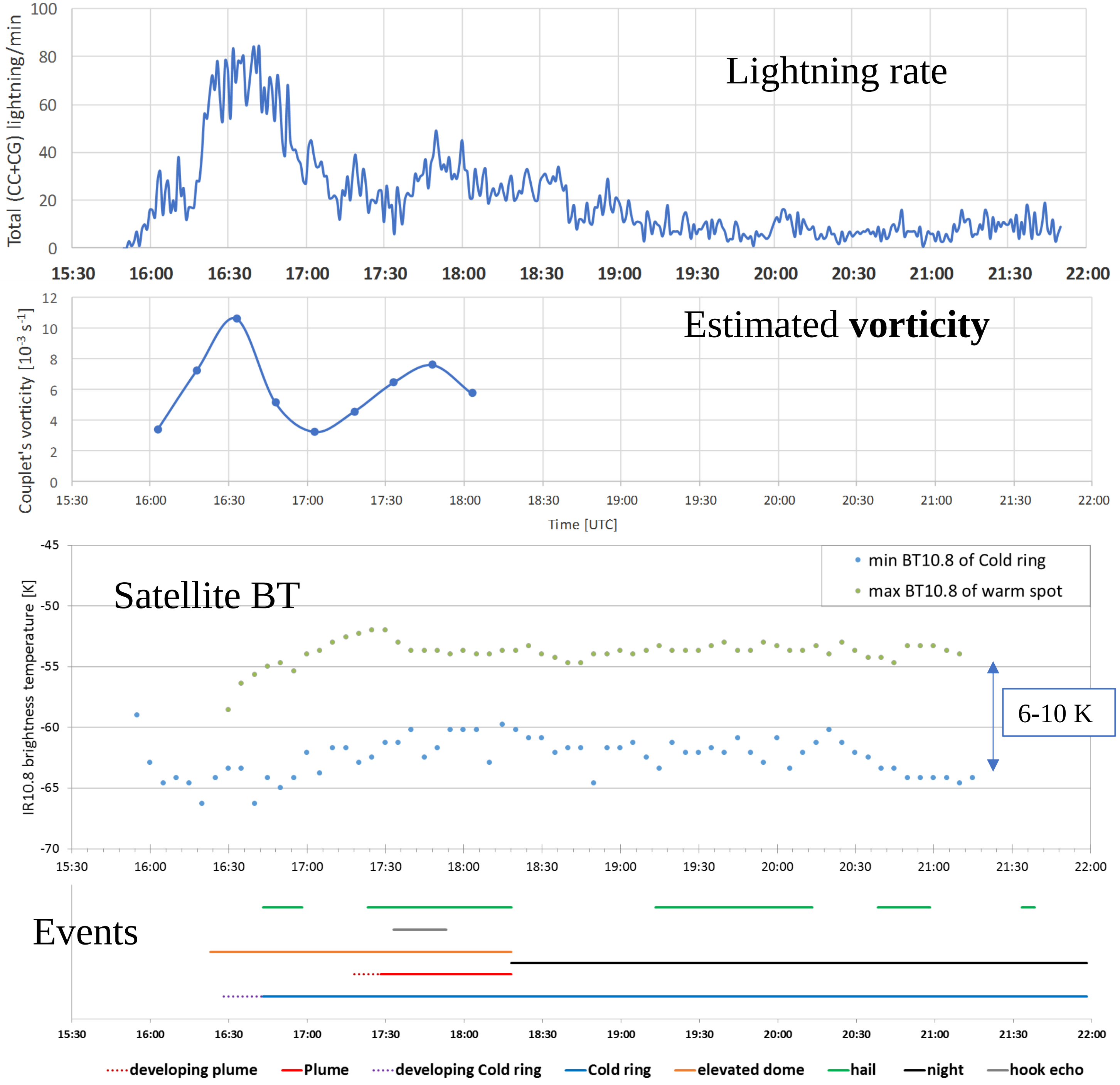
Temporal courses of the satellite, radar and lightning characteristics and features of the storm (system)

The storm (system) should be tracked –

Tracking is based on radar data: *The 2-7 km CAPPI radar reflectivity fields were averaged and the studied **radar cell (group)** was tracked in this field.*

For this cell along the track

- Separate the lightning strokes belonging to the studied cell (group) and count the **total lightning strokes** in 1 minute intervals.
- Collect the **radar characteristic** (Column Maximum Reflectivity (Cmax), Vertically Integrated Liquid (VIL), Constant Altitude Plan Position Indicator (CAPPI)) and **features** (bow, hook, Weak Echo Regions (WER), Bounded Weak Echo Region (BWER) echoes)
- Estimate **vorticity or convergence** from radial Doppler velocity couplets (when present).
- Collect the **satellite characteristic** (e.g. TB) and **features** (OT, ice plume, cold-ring, when present)
- Collect the **severe weather reports, surface measurements**



Correlation between lightning number and estimated vorticity. (Significant peaks in total lightning rate, when the mesocyclone strengthened, both are likely related to intensification of the storm's updraft).

Cold ring formed just after the lightning jump at around the time of the first vorticity maximum. (Cold ring forms in case of strong updraft.)

Lightning jump preceded the hail events.

Later, the number of total lightning discharges was lower, though, large hail was still reported.

Spatial distribution of the lightning density within the storm structure

How to characterize the storm structure?

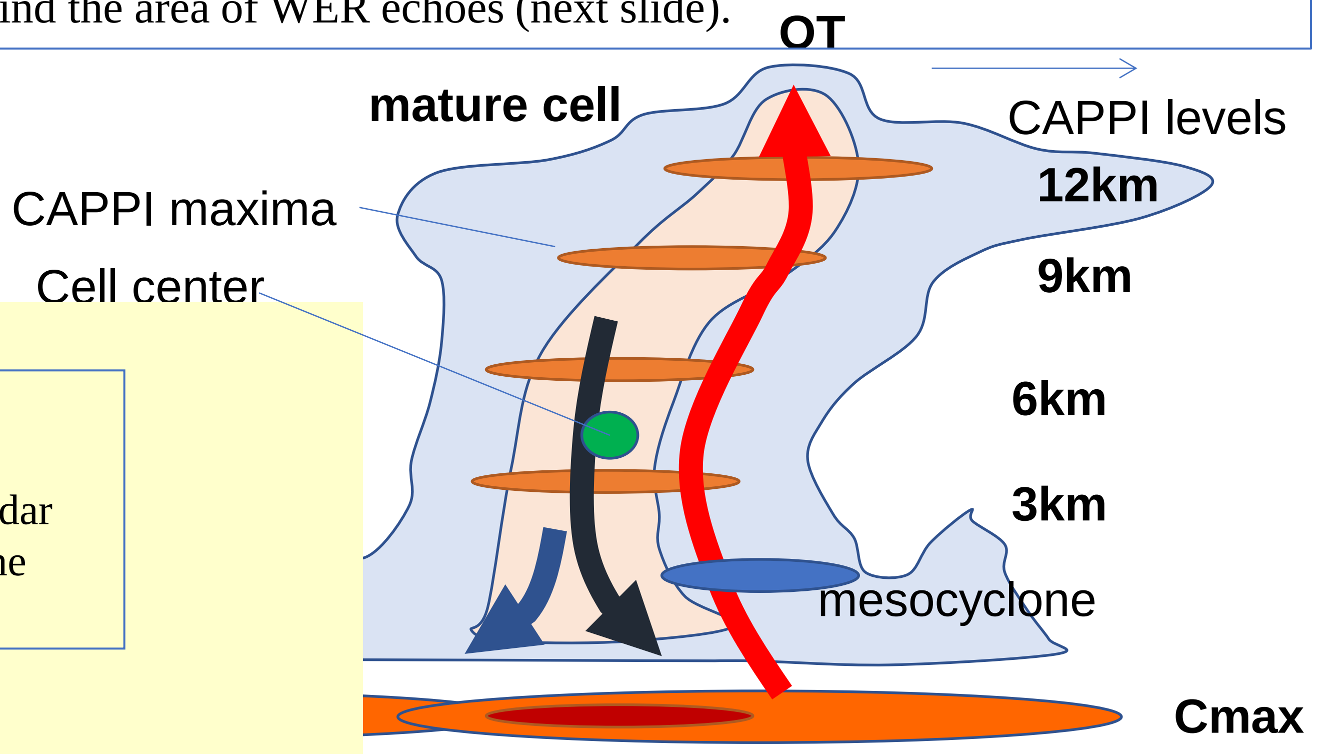
Based (mainly) on radar data

- To map the area of **precipitation** / (low/mid level downdraft**)** - 2km CAPPI field is used
- How to map the (likely) area of **updraft/mesocyclone**?

  From satellite images – locations of *overshooting tops* (OT) – upper part of the updraft (at the cloud top level)

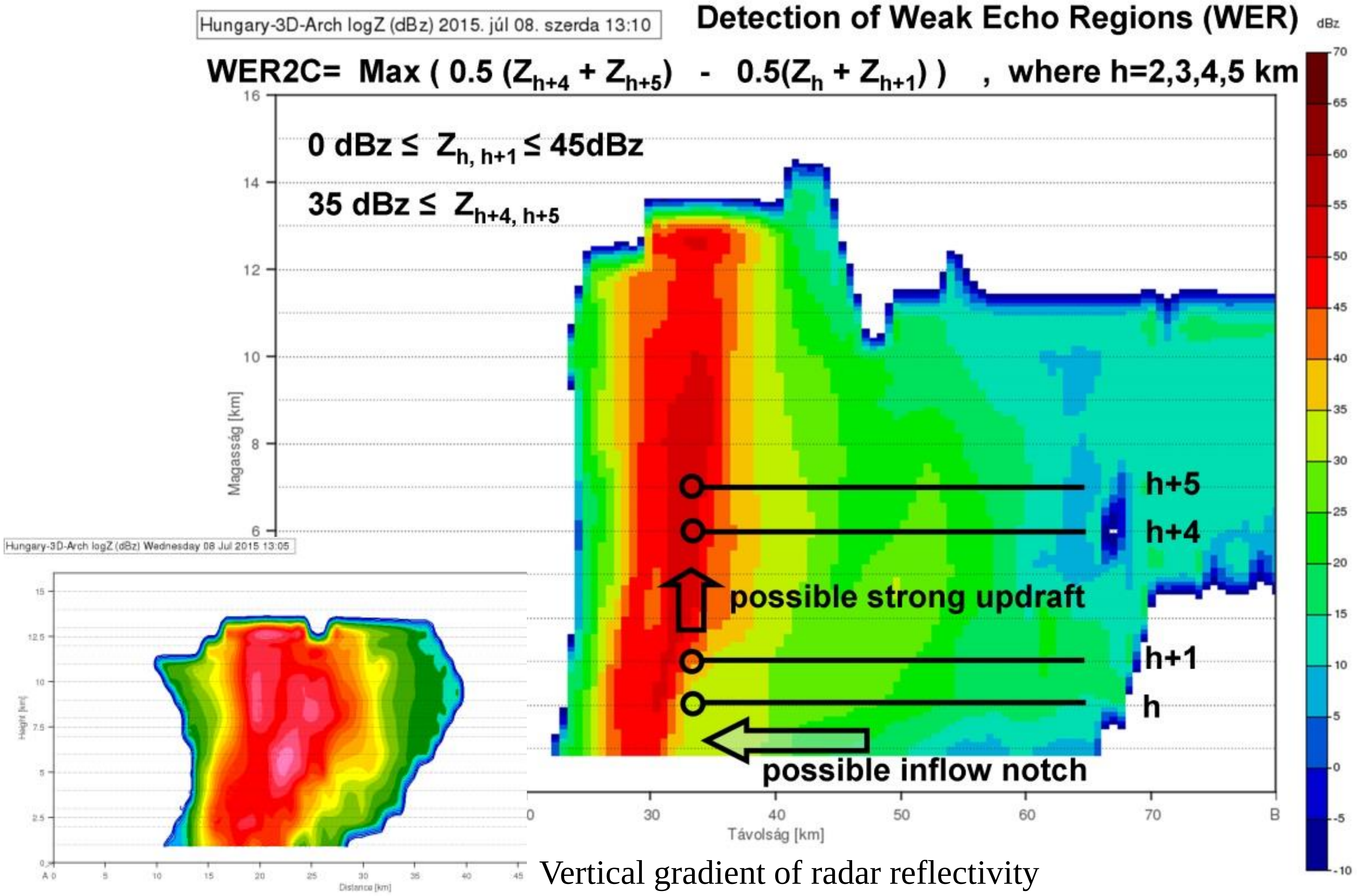
  From radar data –

  - *High (convective echo) at ~12 km CAPPI area*
  - '*Mesocyclonic Vortex Signature*' in the Doppler velocity measurement, if present (*mid-level info*)
  - *WER/BWER echo region* – likely location of *mid-level updraft/mesocyclone*. A so called WER parameter was defined to find the area of WER echoes (next slide).



In case of strong windshear
↓
the storm, its updraft and the radar CAPPI maxima are tilted in the direction of the windshear

A parameter to find area of WER/BWER echo region - to highlight the areas where the <u>radar reflectivity increases with height,</u> which is typical for the updraft region

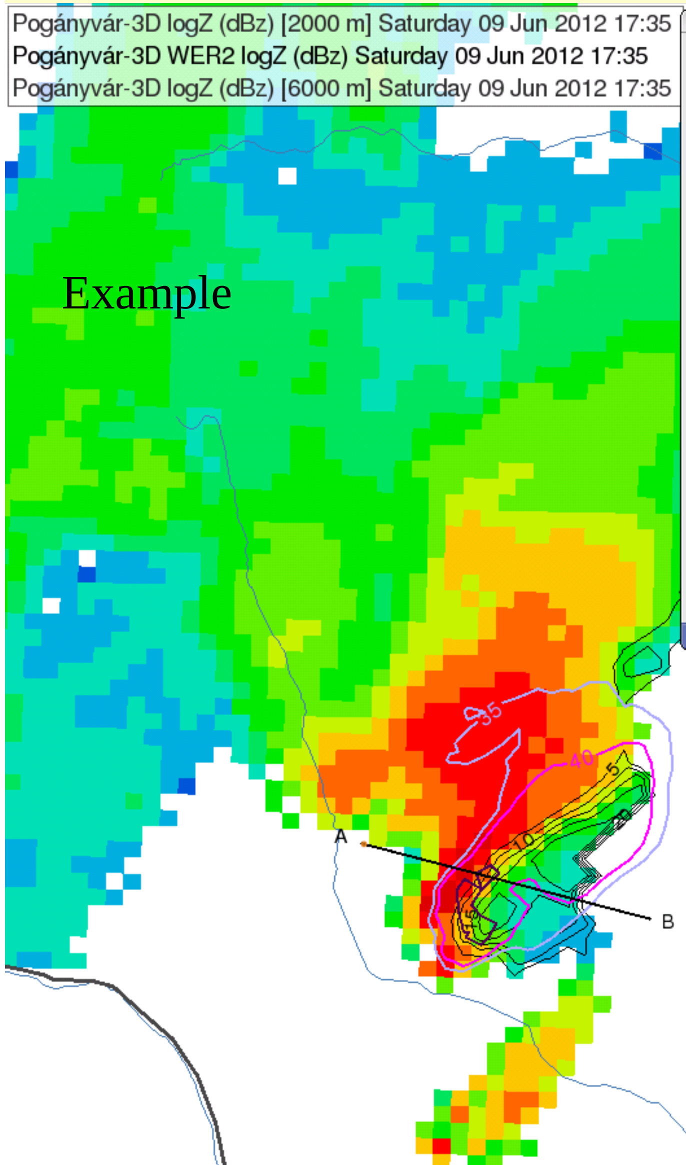


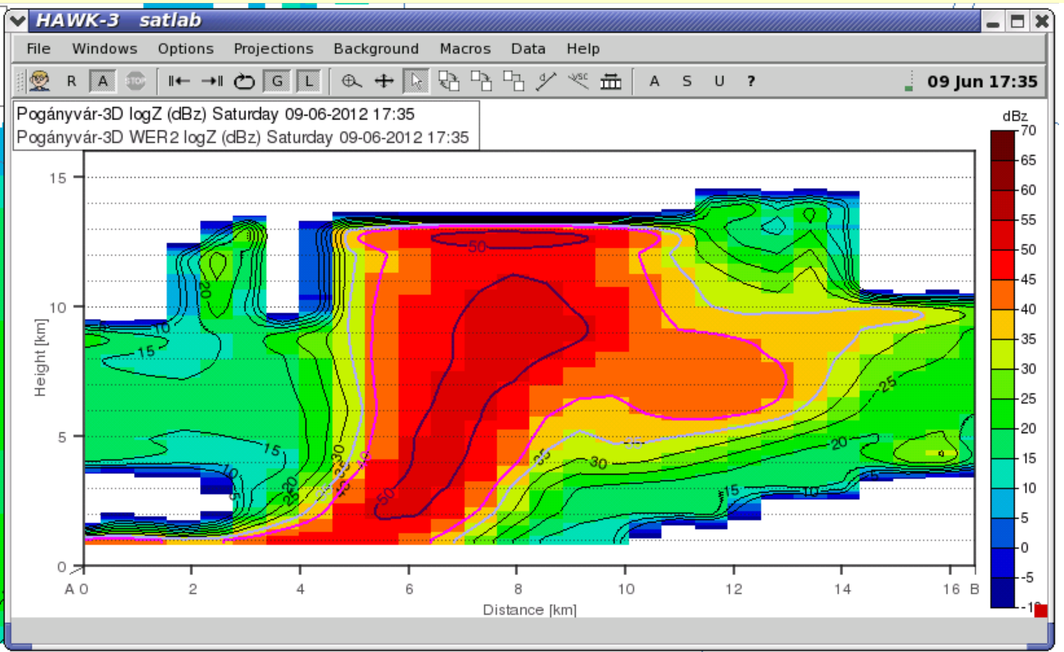
Vertical gradient of radar reflectivity

<u>WER2c --- parameter helps to find WER/BWER echos</u>

- 2 km CAPPI image - colour shades
- 6 km CAPPI isolines – coloured isolines
- **WER2 parameter – grey isolines**

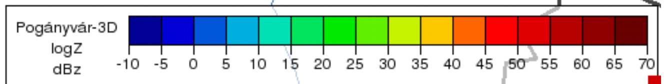
Vertical cross-section along the AB solid black line





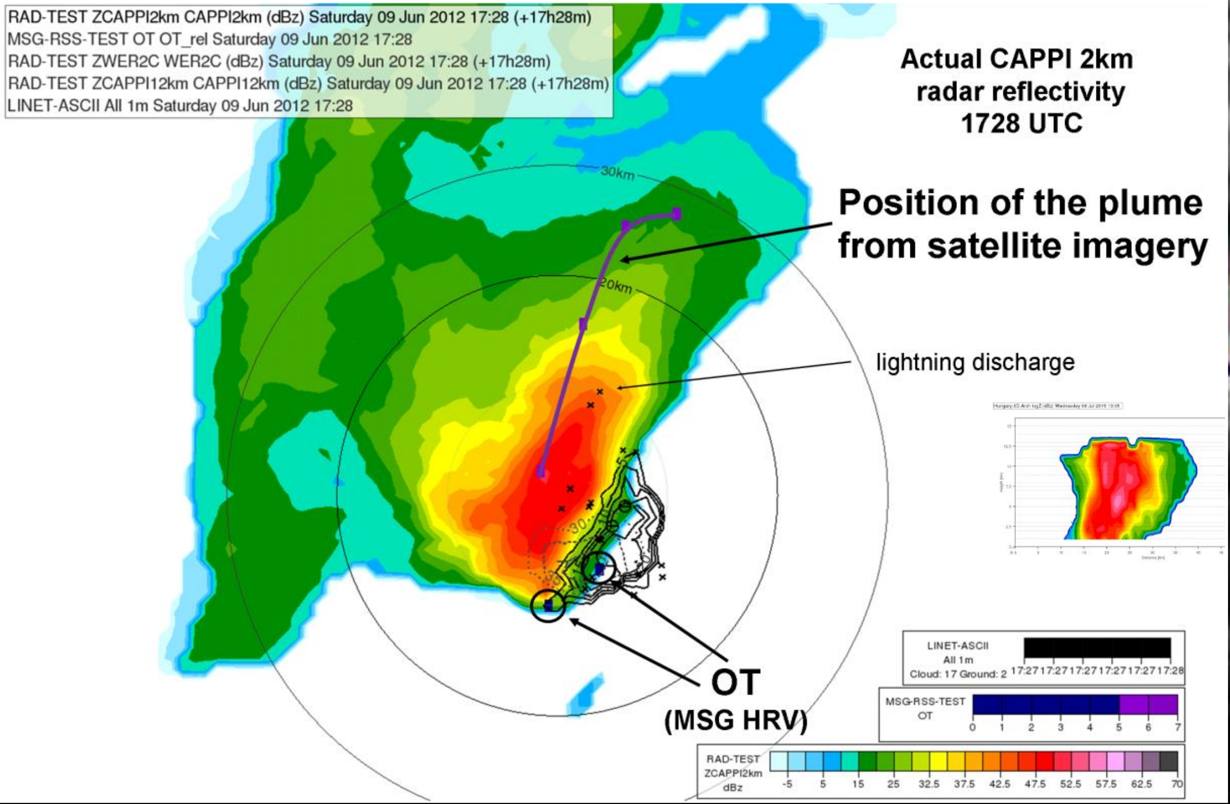
<u>Usefulness of WER2 parameter:</u>

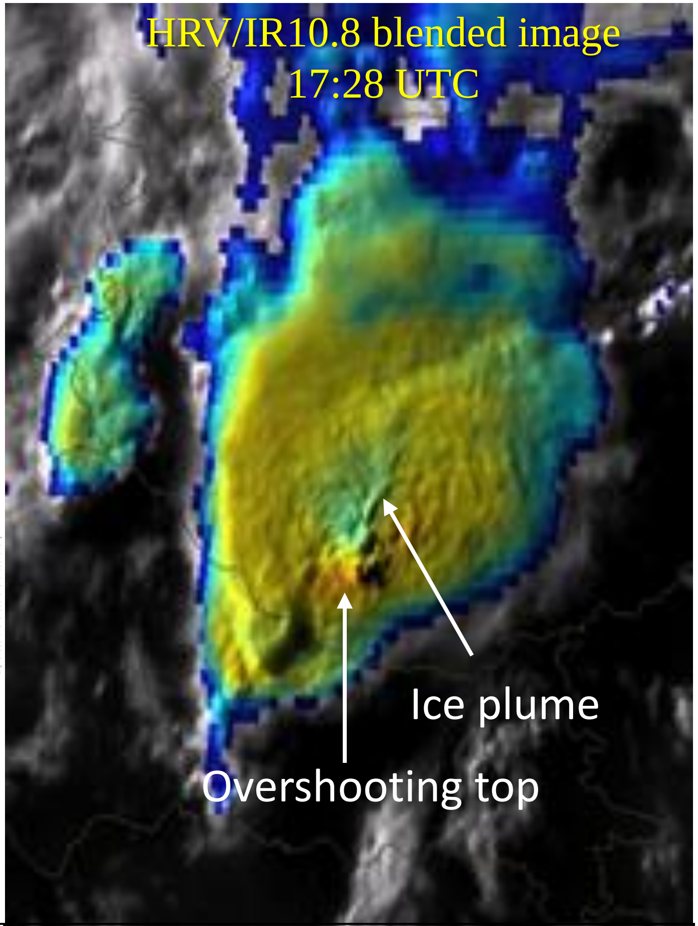
BWER echo in the vertical cross section across the area of high WER2c parameter



Example – storm structure visualisation using radar and satellite data

- Precipitation/downdraft region - 2km CAPPI - colours
- Updraft region
  - WER2c parameters – black isolines
  - 12 km CAPPI – dotted isolines
  - OTs (upper part of the updraft) from parallax shifted satellite data
- Ice plume from parallax shifted satellite data
- Lightning data





Combination of radar, lightning and (parallax-corrected) satellite data. The location of the ice plume's source was over the centre of the storm, later it moved downstream (toward North-Northeast).

Well defined cold ring was present on the cloud top during several hours. Ice plume was also definite.

Spatial distribution of lightning density within the storm structure

To calculate spatial distribution of lightning density we need longer time intervals (~30 min)

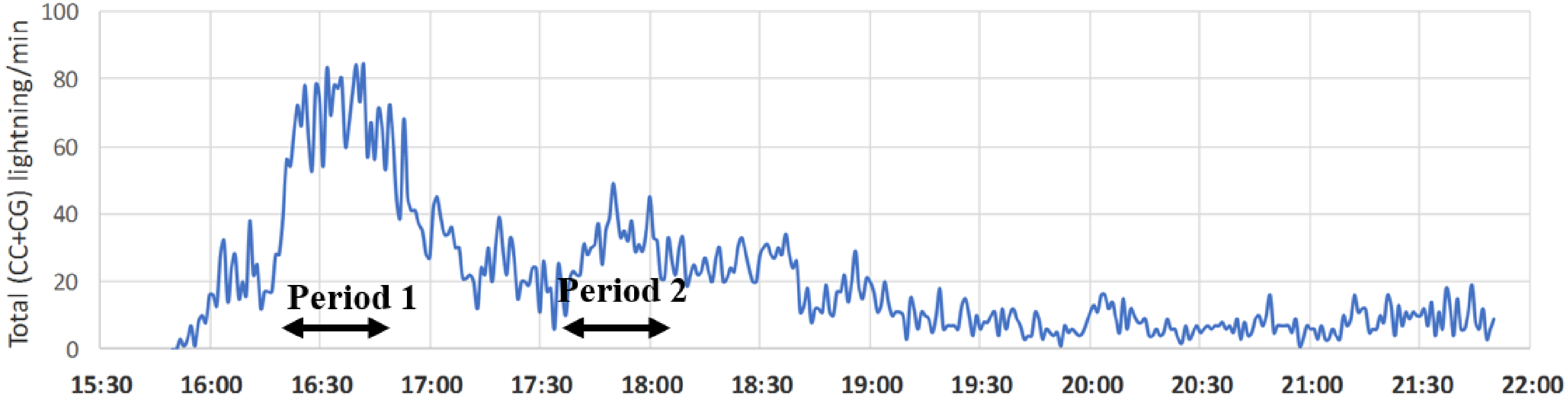
Convert everything into a storm-relative coordinate system

(to make easier temporal summation and averaging)

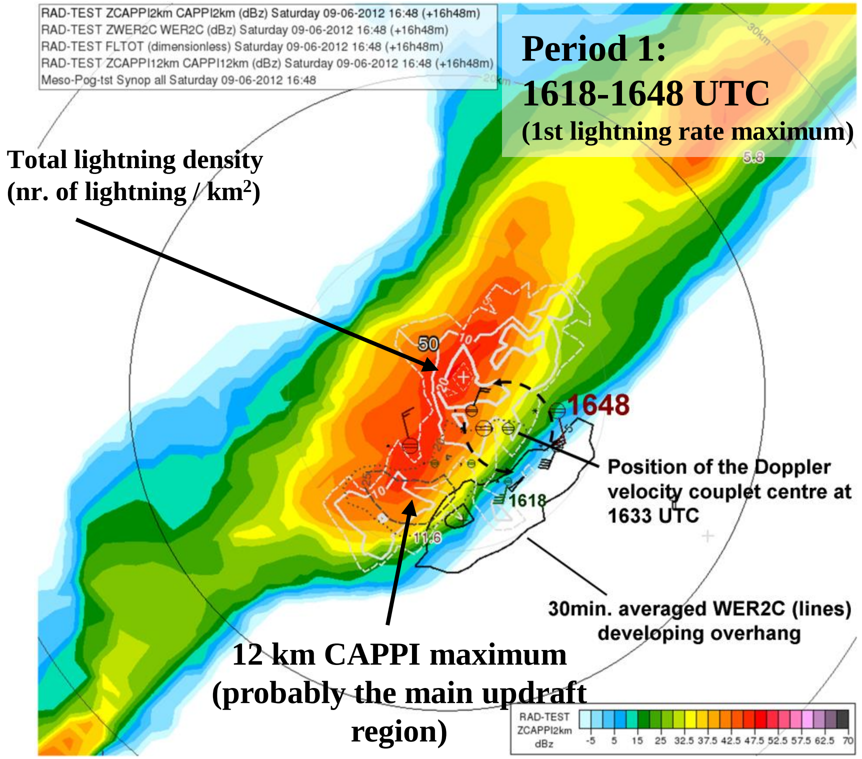
Choose **interesting time intervals** based on the **lightning stroke rate temporal course**

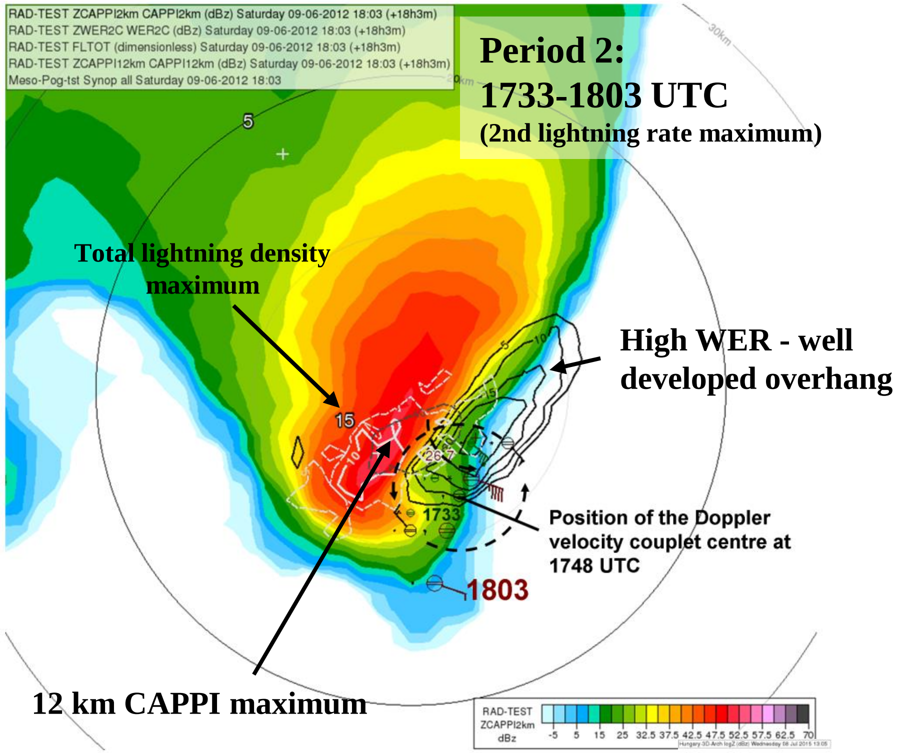
Calculate the

- lightning density distribution
- averaged 2/12km CAPPI and WER2c parameter field to map the downdraft and updraft region in these time intervals

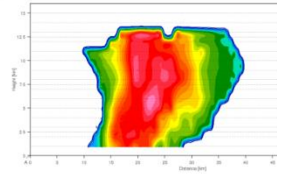


30 min. averaged 2km CAPPI radar reflectivity (color shades) (in a storm relative coordinate system)





The highest lightning density is mostly in the low-level reflectivity core, somewhat dislocated from the main updraft position.
Much less lightning was detected in the overhang area.



Outlines

Introduction

Five case studies

- Supercell, hailstorm (09 June 2012)
- Hybrid multicell-supercell storm, windstorm (08 July 2015)
- Tornadic storm (16 August 2010)
- Multicell storm and flashflood (31 July 2016)
- Single cell, short-lived local thunderstorm (23 July 2016)

Summary

A hybrid multicell-supercell storm, windstorm 08 July 2015

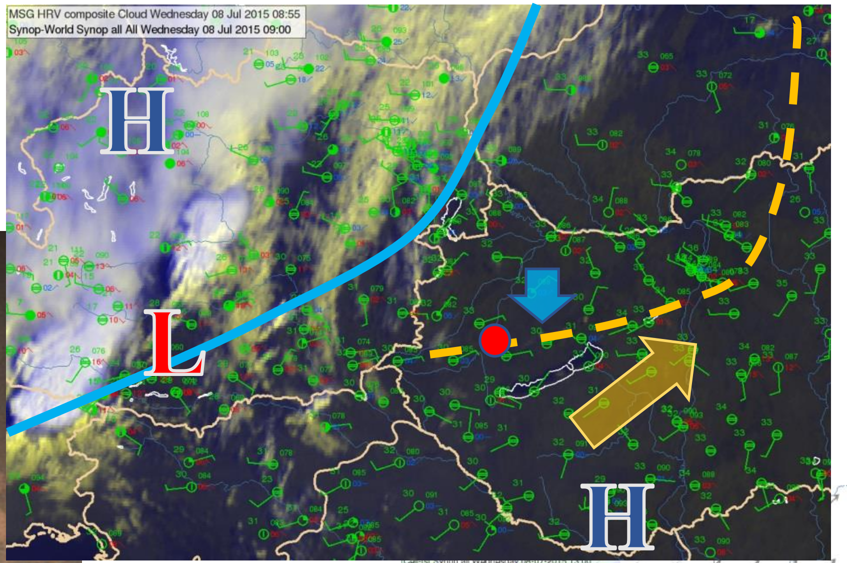
The thunderstorm developed ahead of a propagating cold front and moved along a pre-frontal convergence line.

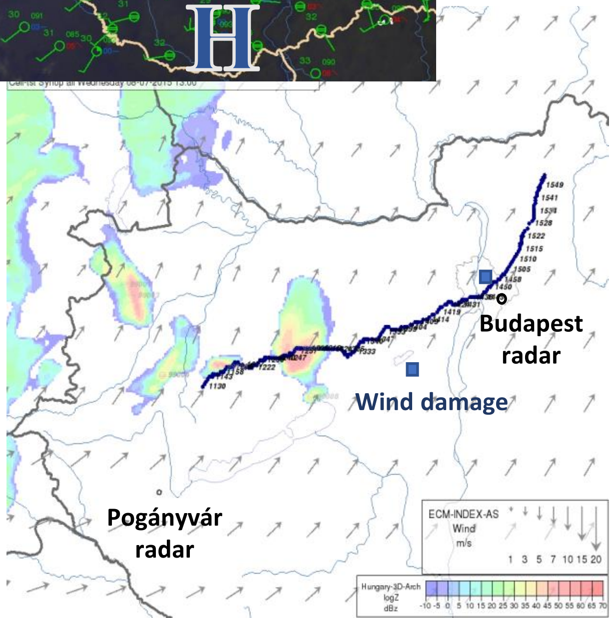
It caused severe wind along its track (up to 35 m/s) + hail.

The storm in its mature phase, west of Budapest.

Cold front

Pre-frontal convergence line



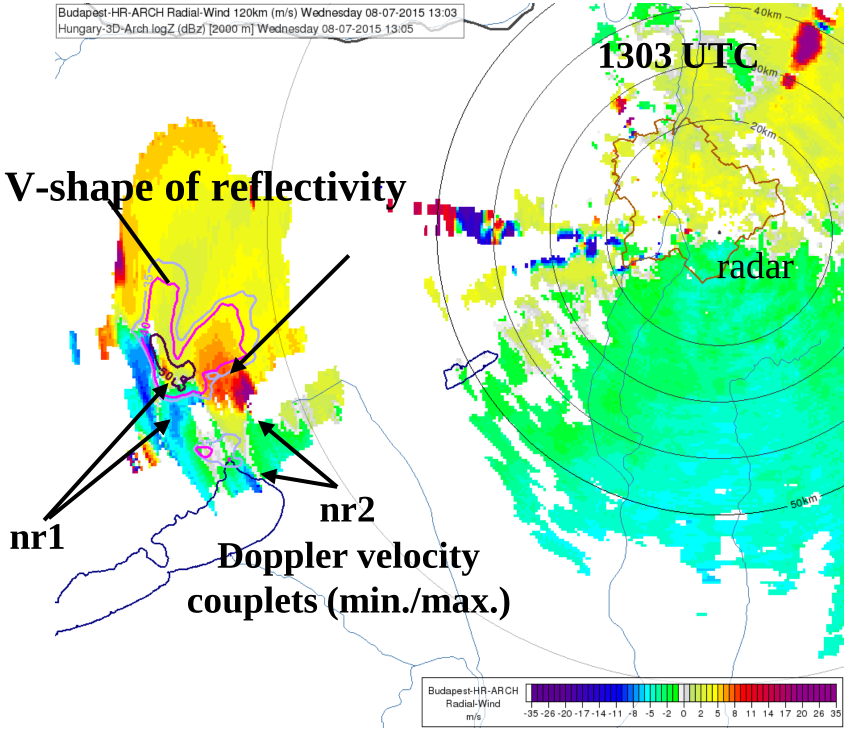


Storm track

Environment: Moderate-to-high wind shear, high humidity, moderate instability.

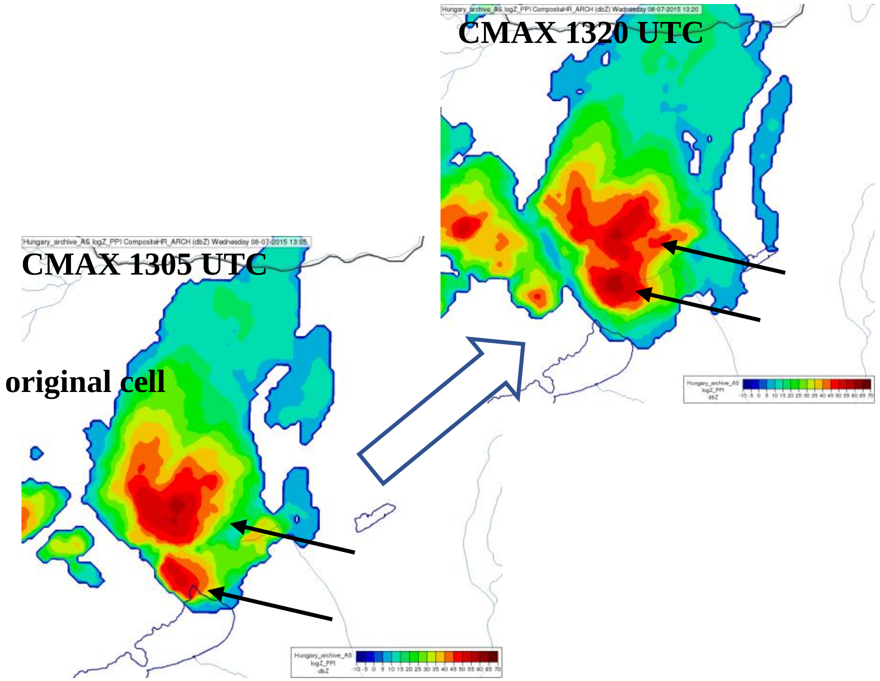
Hybrid supercell/multicell characteristics

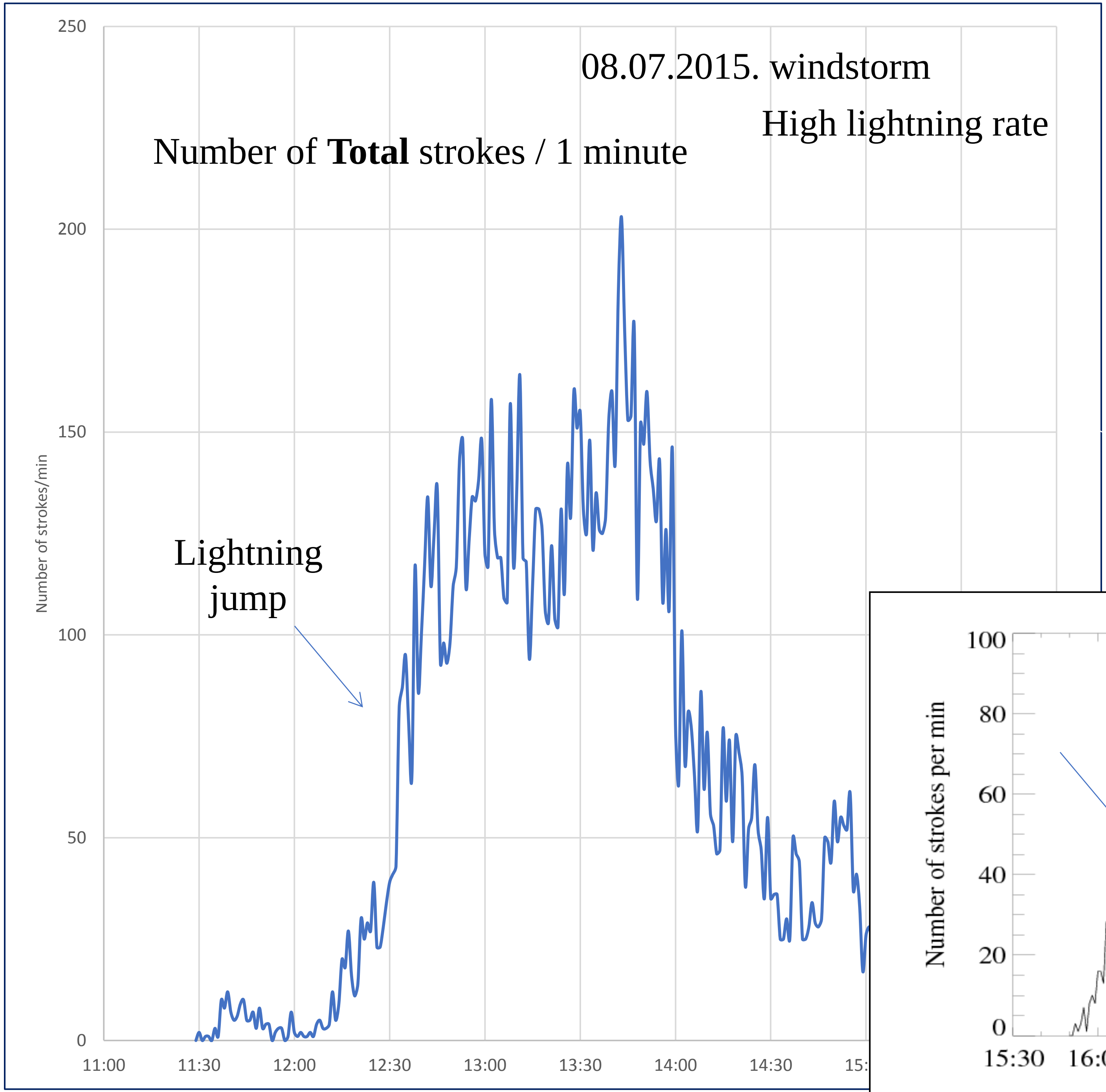
V-shape (V-notch) in radar reflectivity
typical feature of some supercells
Doppler velocity couplets
Several mesocyclones formed



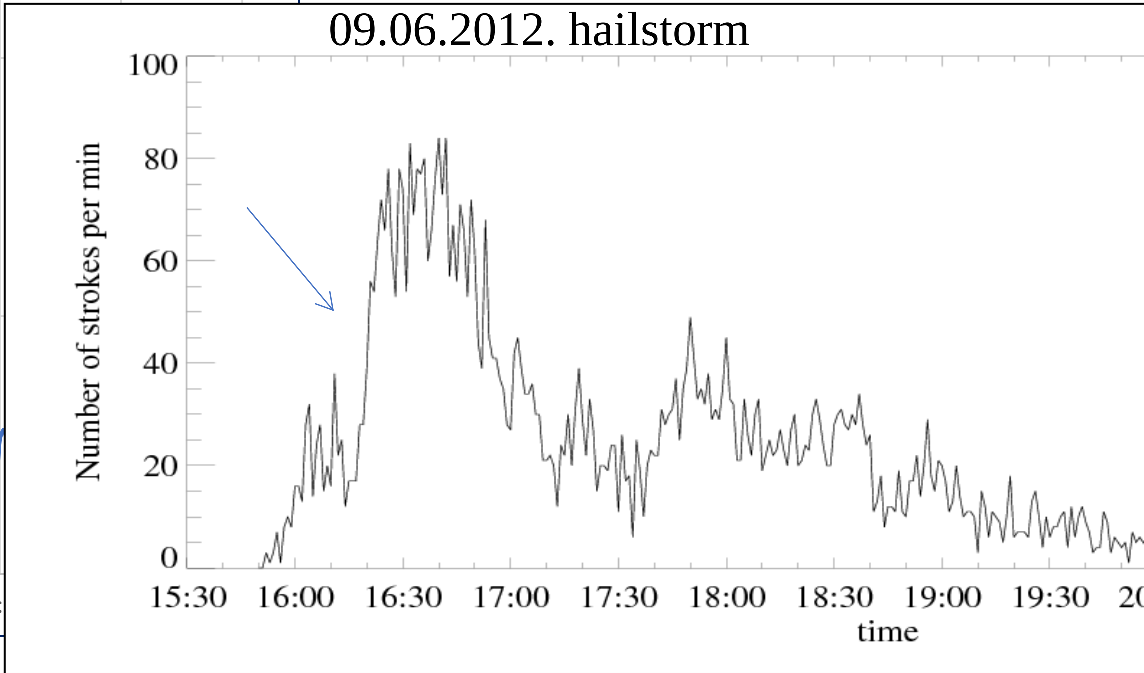
PPI 1° radial Doppler velocity measurement
2 km CAPPI radar reflectivity isolines

Frequent mergers with neighbouring cells



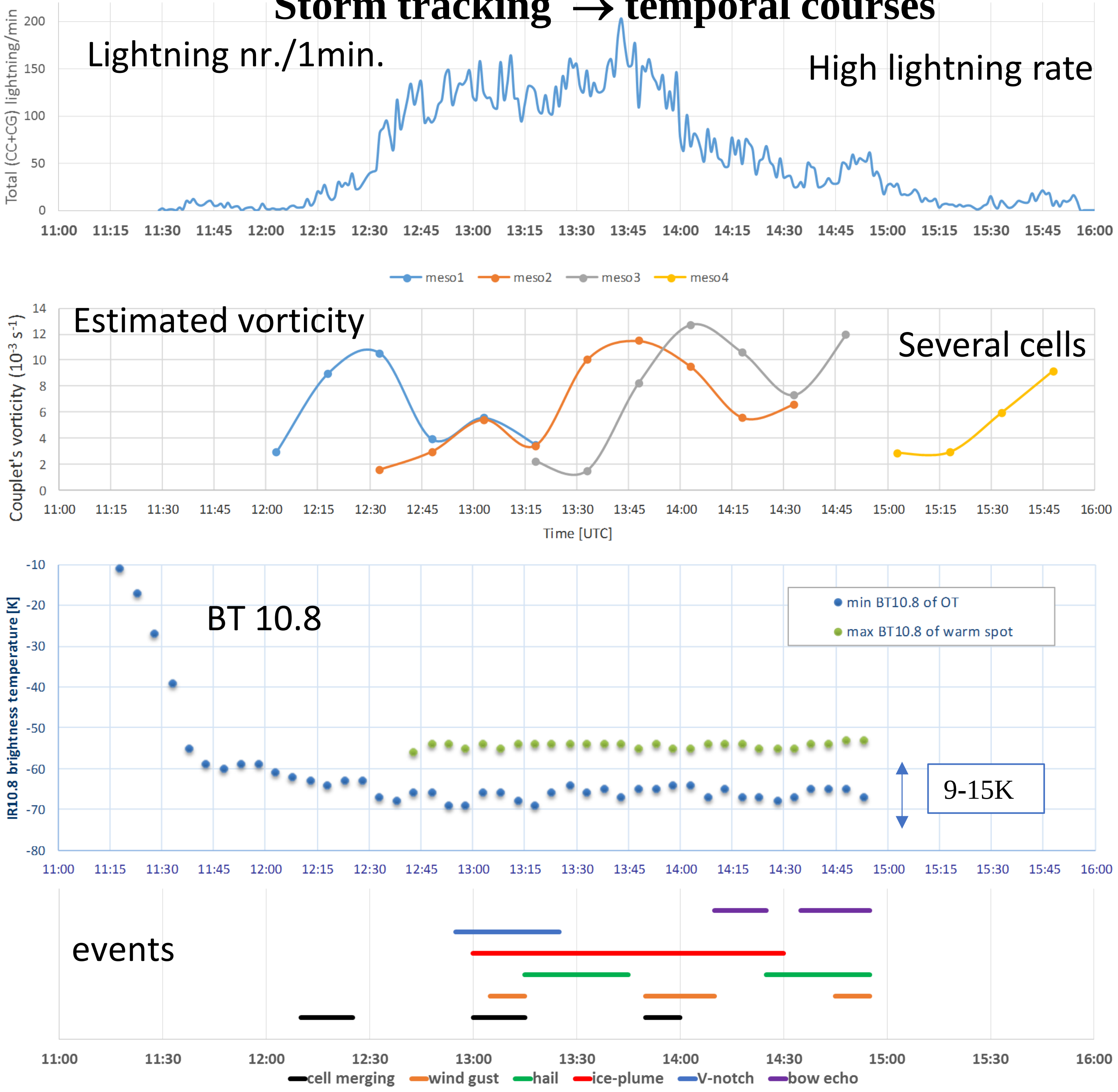


Comparison of the lightning rate to the previous case



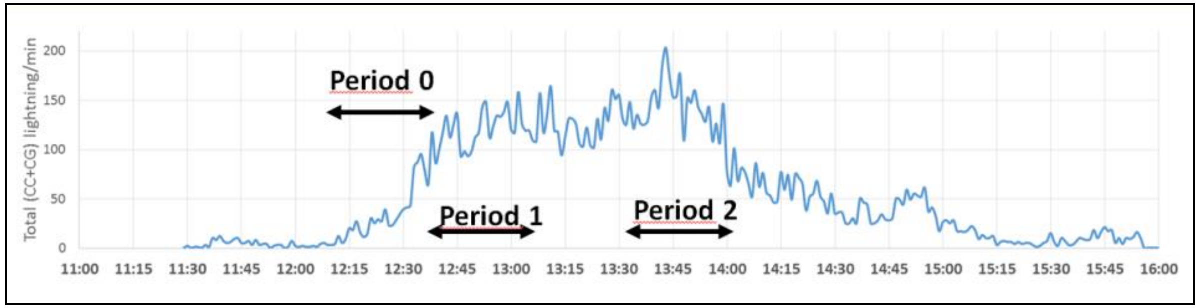
Storm tracking → temporal courses

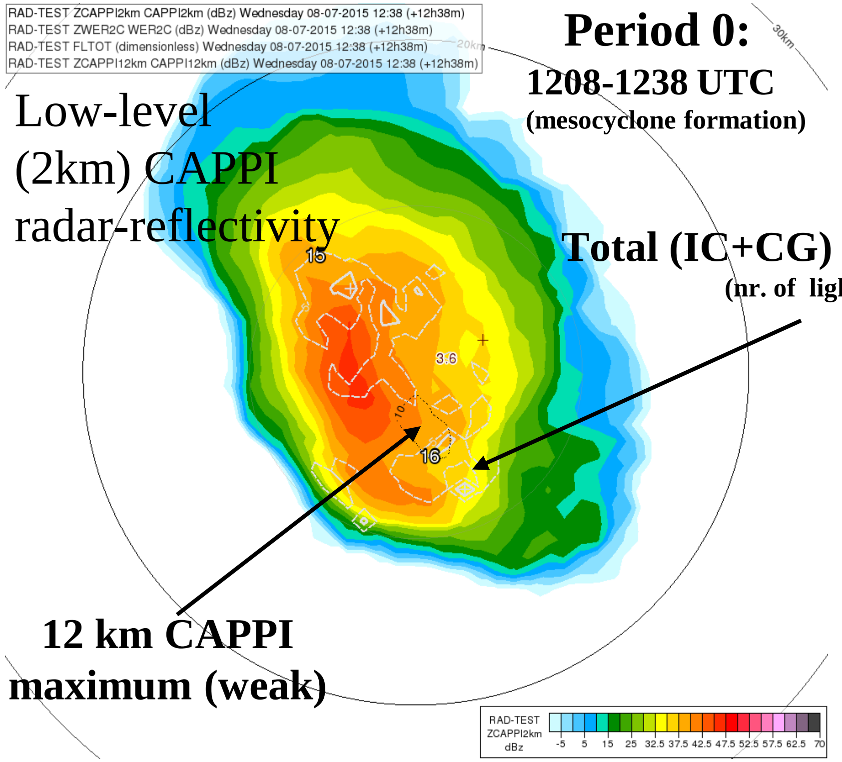
- Increase in lightning rate is observed, when the rotation intensifies. (in periods of mesocyclone intensification).
- First lightning maximum appeared **before** first reports on severe wind gusts (>25 m/s) and hail.
- There is a **remarkable drop of BT10.8** (6-16 K/15min) in the early phase of the storm.
- The 1st lightning occurred 20 min. after the cloud was detected, already in the developing phase.
- **Cold ring** formed just after the first steep increase of lightning rate and the first vorticity maximum.



Storm structure

We studied 30 min. periods, interesting from the storm electrification point of view





Low-level (2km) CAPPI radar-reflectivity

Period 0:

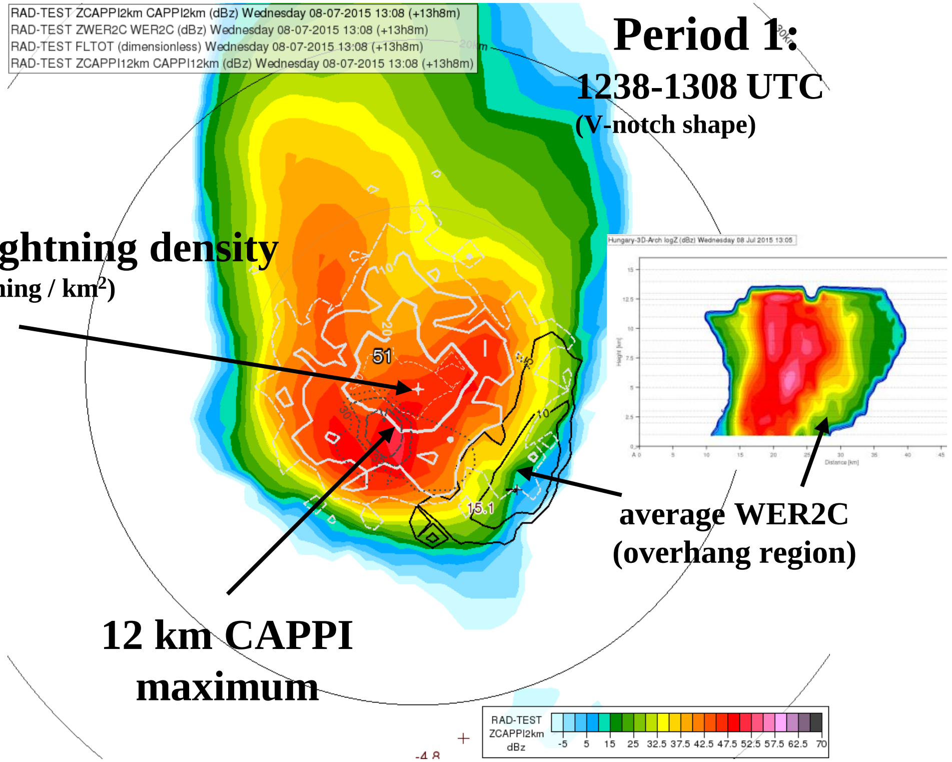
1208-1238 UTC

(mesocyclone formation)

Total (IC+CG) lightning density

(nr. of lightning / km^2)

12 km CAPPI maximum (weak)



Period 1:

1238-1308 UTC

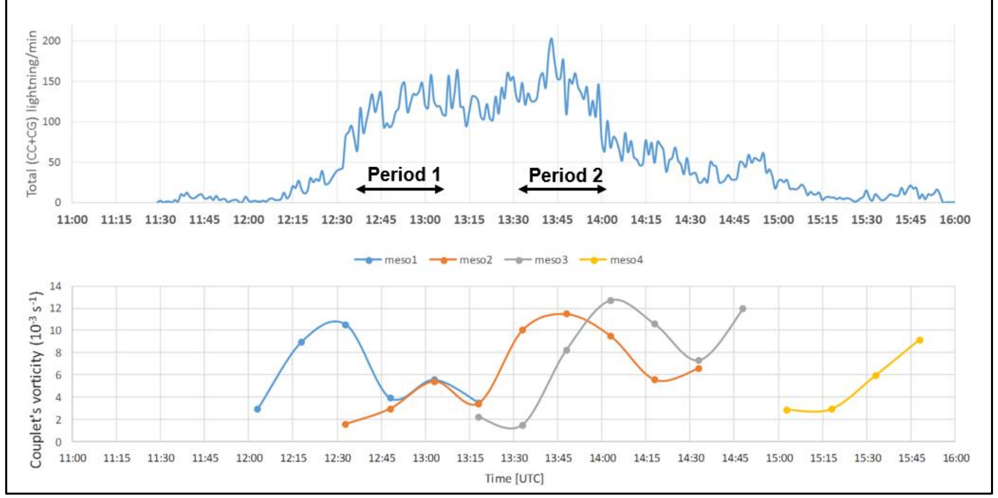
(V-notch shape)

average WER2C (overhang region)

12 km CAPPI maximum

Absence of overhang, low reflectivity at upper levels (12km), lightning density increasing

The maximum lightning density is somewhat to the north of the expected main updraft(s) and west of the overhang



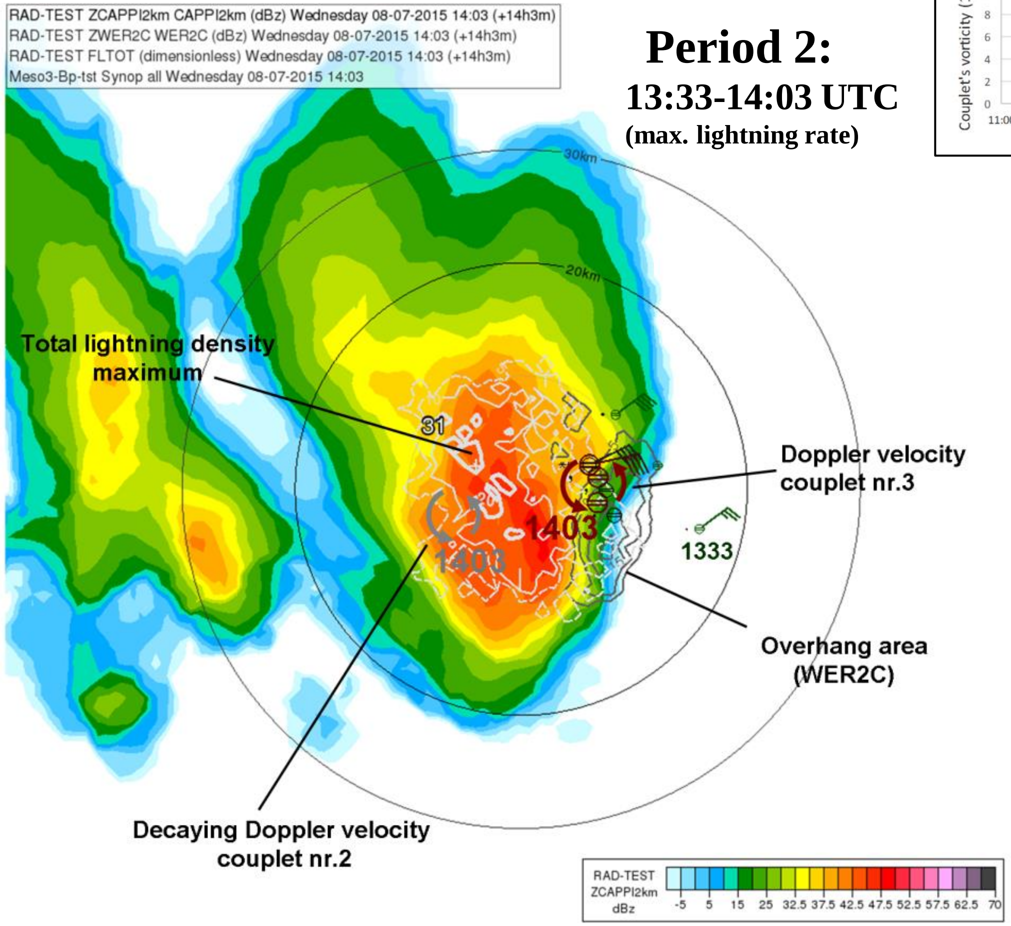
Typical features

(found in several severe storms)

Period 2:

13:33-14:03 UTC

(max. lightning rate)



The cell exhibited intense lightning activity, when also high WER2c and strong cyclonic shear (circulation) were found

- High lightning density (many CGs) is coupled with high low-level radar reflectivity (hail, heavy rain, etc.) – this could help to specify the core of the storm on satellite imagery
- Much less lightning can be found in the overhang area (WER) and centre of the mesocyclonic circulation
- The highest lightning density can be found somewhat off the main updraft, mainly in the later stages of the storm

Outlines

Introduction

Five case studies

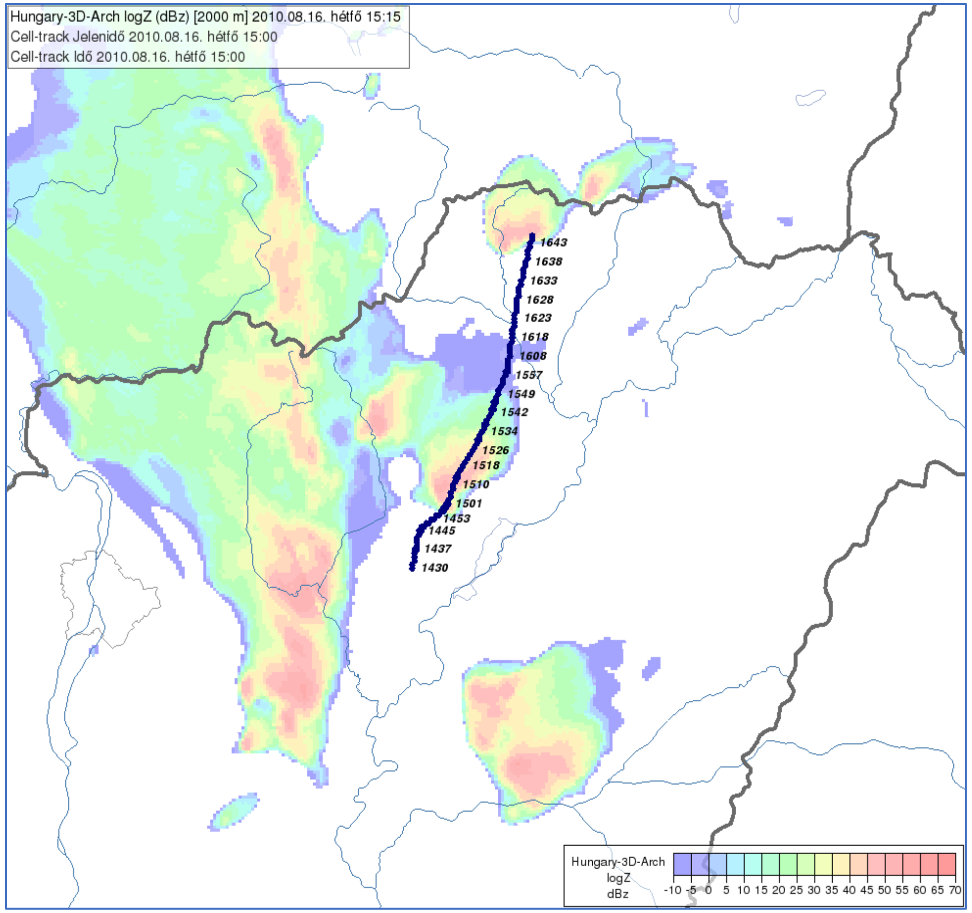
- Supercell, hailstorm (09 June 2012)
- Hybrid multicell-supercell storm, windstorm (08 July 2015)
- Tornadic storm (16 August 2010)
- Multicell storm and flashflood (31 July 2016)
- Single cell, short-lived local thunderstorm (23 July 2016)

Summary

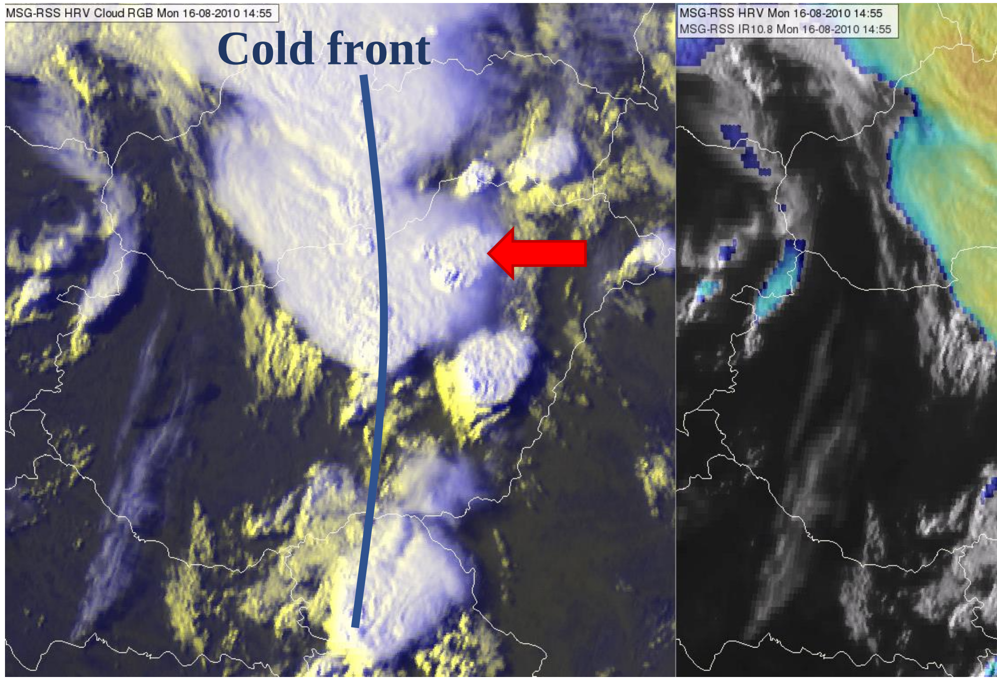
Tornadic storm, 16 August 2010

This day several convective systems formed over Hungary. One produced an F2 tornado.

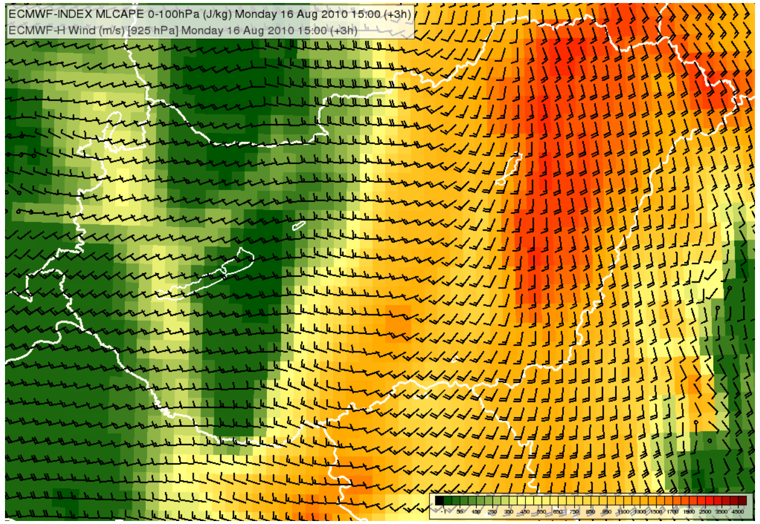
The studied supercell initiated ahead of a cold front. Later it **merged** with the convective cloudiness of the front.



Storm track

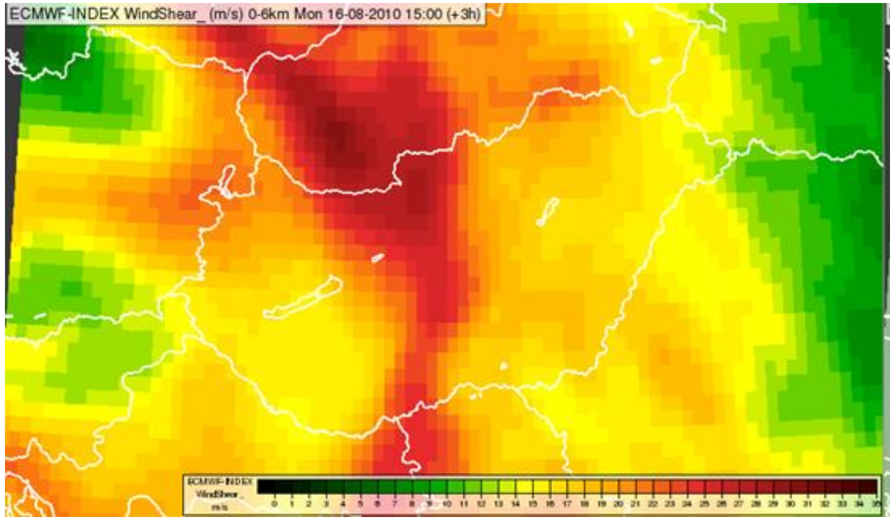


Environment ECMWF forecast for 15 UTC

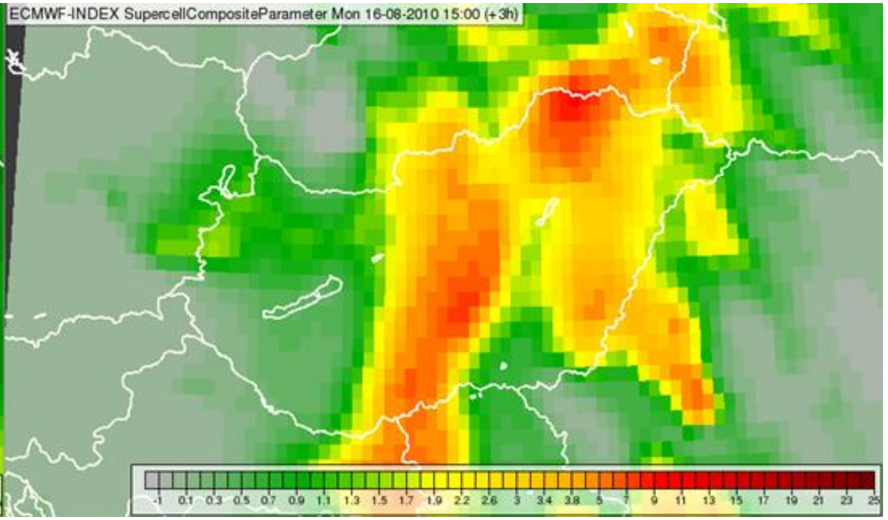


MLCAPE (in J/kg) and wind at 925 hPa,
Convergence line

Moderate to high instability and humidity



0-6 km wind shear

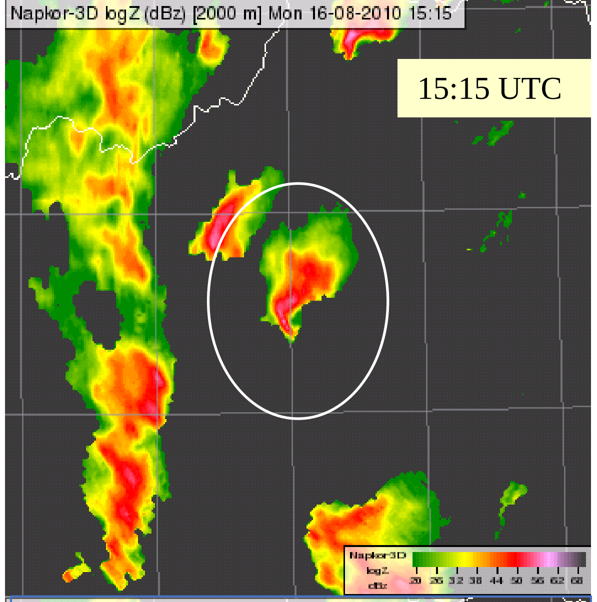


Supercell Composite Parameter

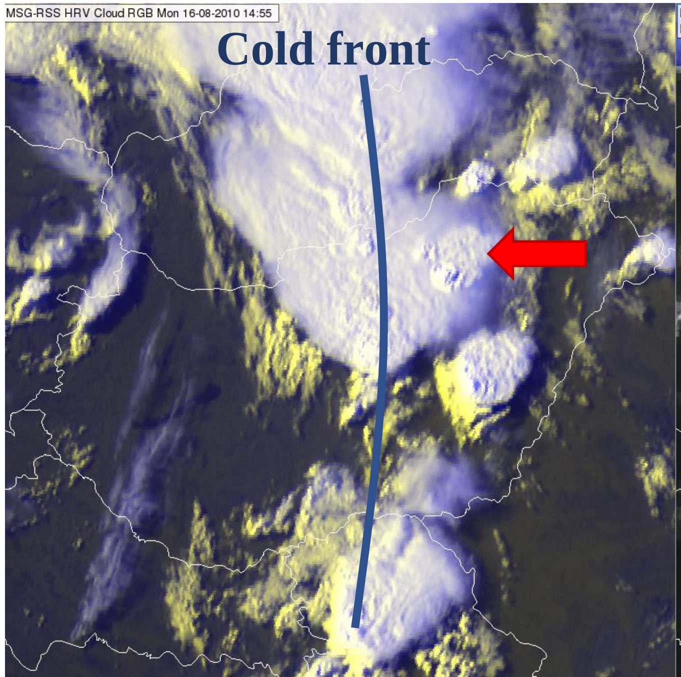
Very high deep-layer wind shear - primary reason for the severity of the storms

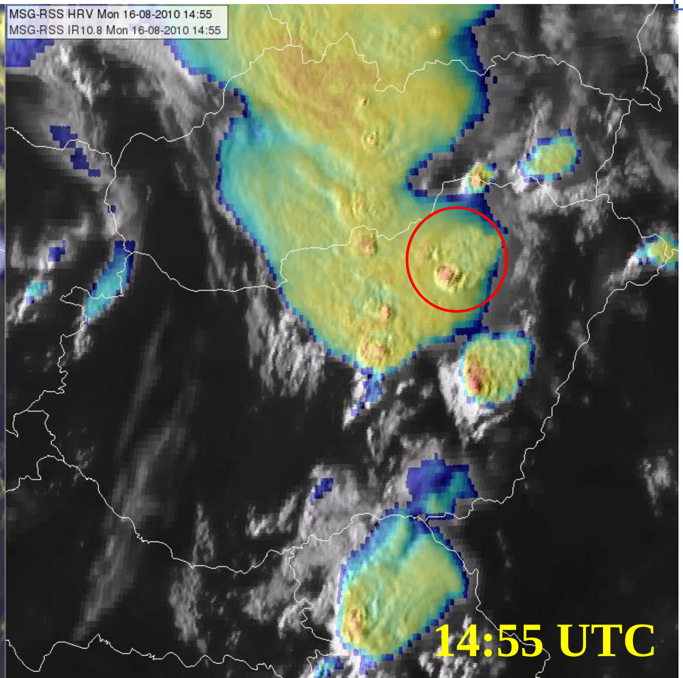
Storm development
Severe storm features

Tornado - observed



Hook echo in 2 km CAPPI around the time when the tornado was observed

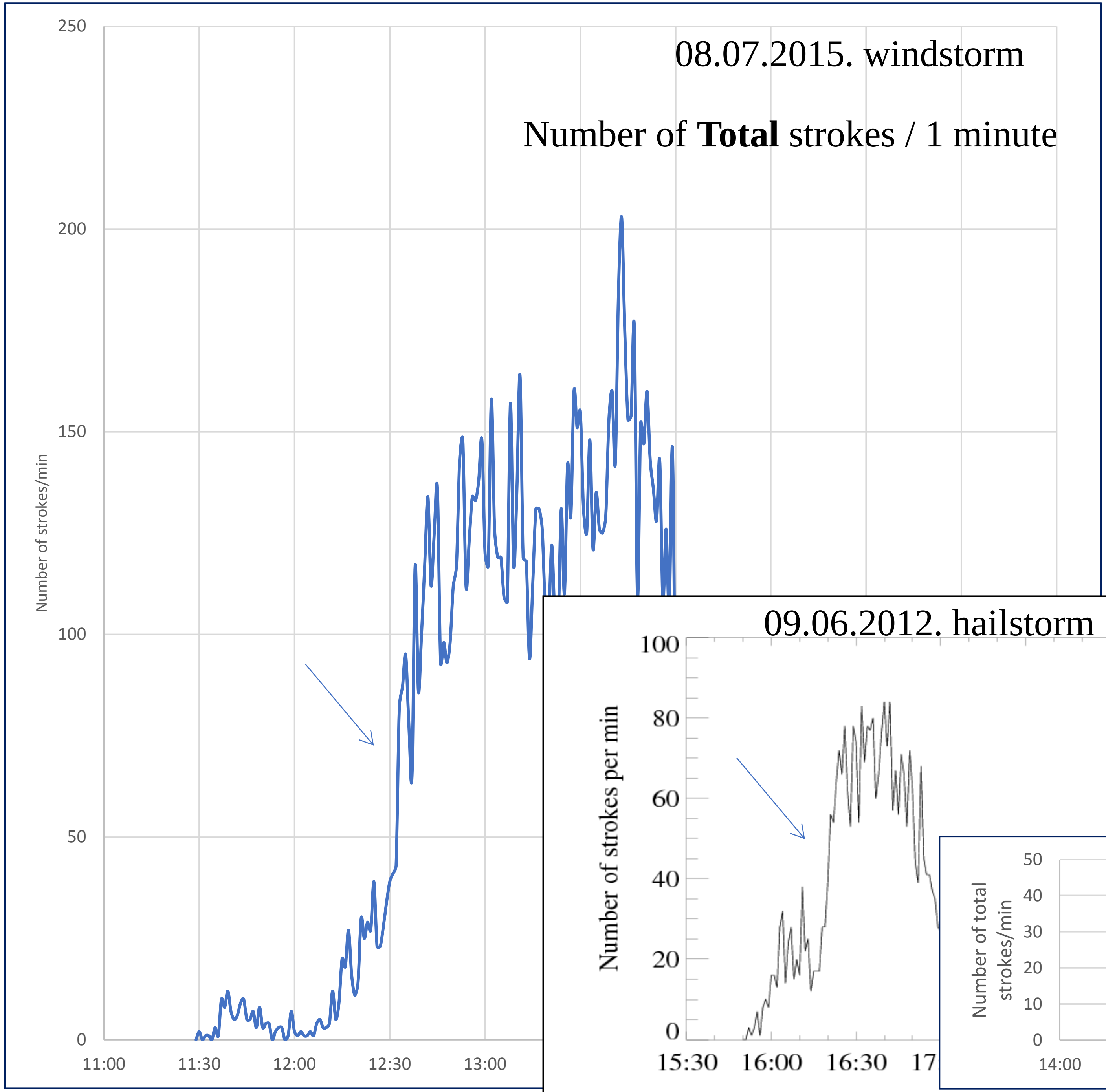


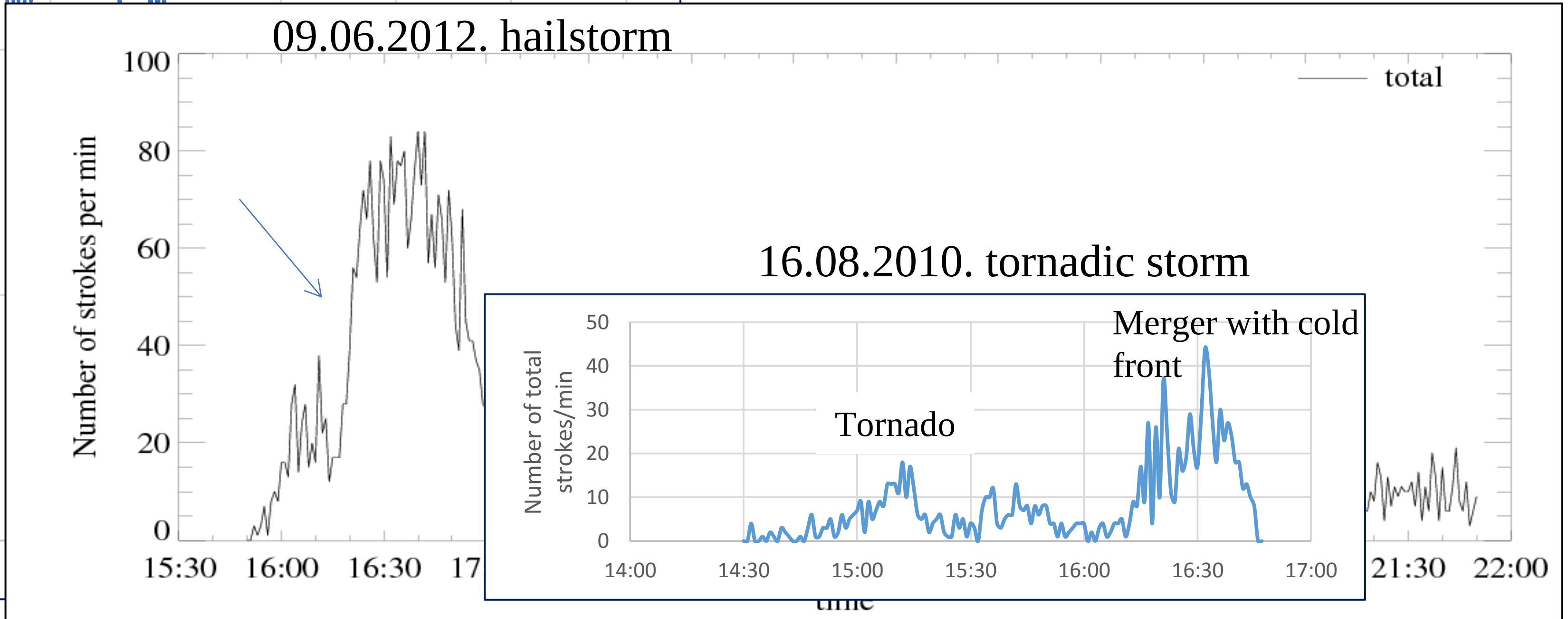


HRV Cloud RGB and HRV/IR10.8 blended images. The **cold ring** formed at around 14:55 UTC.

Comparison of the lightning rate to the previous cases

The total lightning rate was rather low before the supercell merged with the front.
Not the frontal, electrically more active storms were accompanied by the most spectacular weather phenomena.





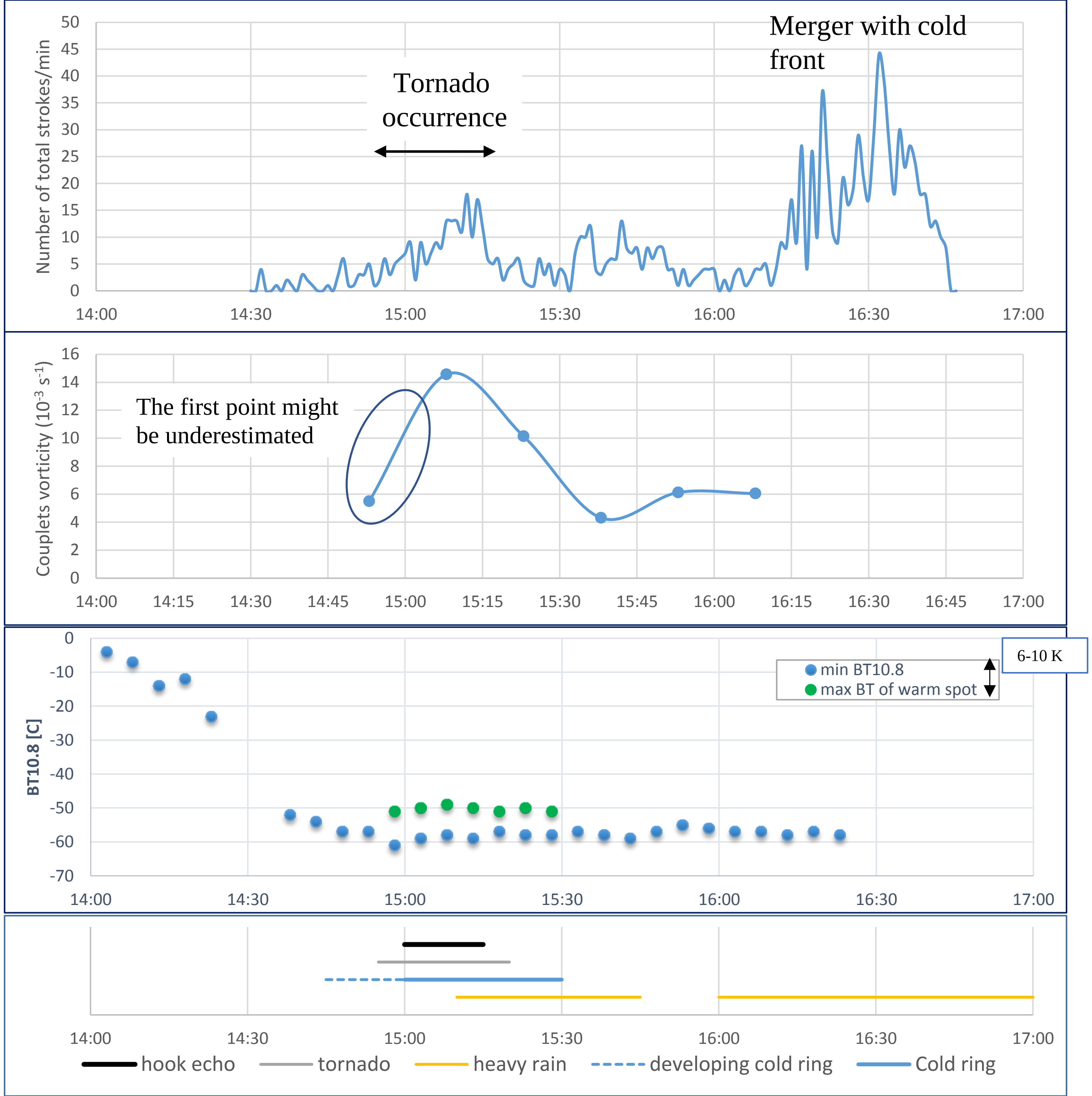
The total lightning rate was rather low before the supercell merged with the front. - In severe storms this can be sometimes caused by **microphysical processes** (e.g. wet-hail growth).

The time period of the vorticity maximum is uncertain.

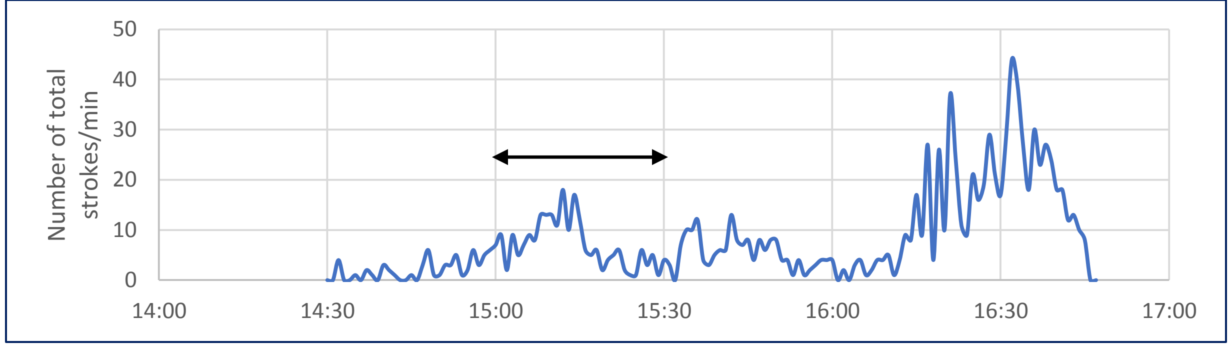
The vorticity maximum either coincides or precedes the total lightning rate maximum.

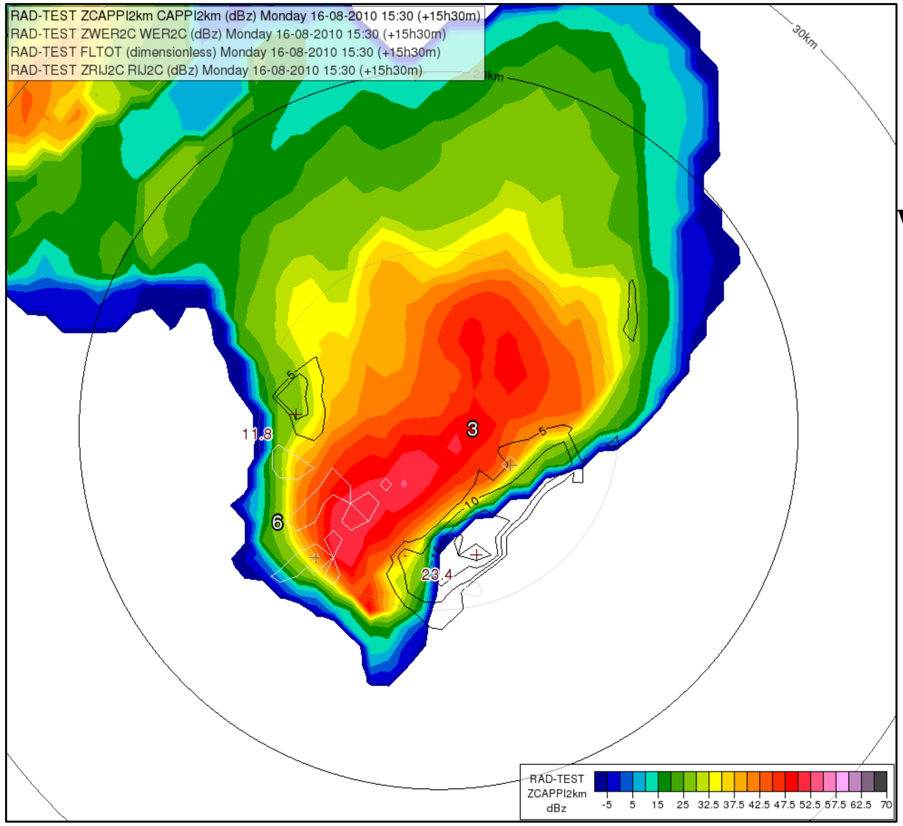
The **cold ring** formed earlier or at about the same time as the vorticity maximum.

The cold ring formed around the time when the tornado was observed.



Lightning density distribution within the storm structure





Well-pronounced hook-echo and WER-echo region

The highest lightning density is in the western flank of the storm, somewhat shifted compared to the areas of maximum radar reflectivity.

Not many lightning strokes → lightning density distribution might be less accurate.

Averaged 2 km CAPPI radar reflectivity (colour shades)
Averaged WER2c parameter (solid, dark lines)
Total lightning density (solid, light lines)
for the period 15:00-15:30 UTC (tornado occurrence)

Outlines

Introduction

Five case studies

- Supercell, hailstorm (09 June 2012)
- Hybrid multicell-supercell storm, windstorm (08 July 2015)
- Tornadic storm (16 August 2010)
- Multicell storm and flashflood (31 July 2016)
- Single cell, short-lived local thunderstorm (23 July 2016)

Summary

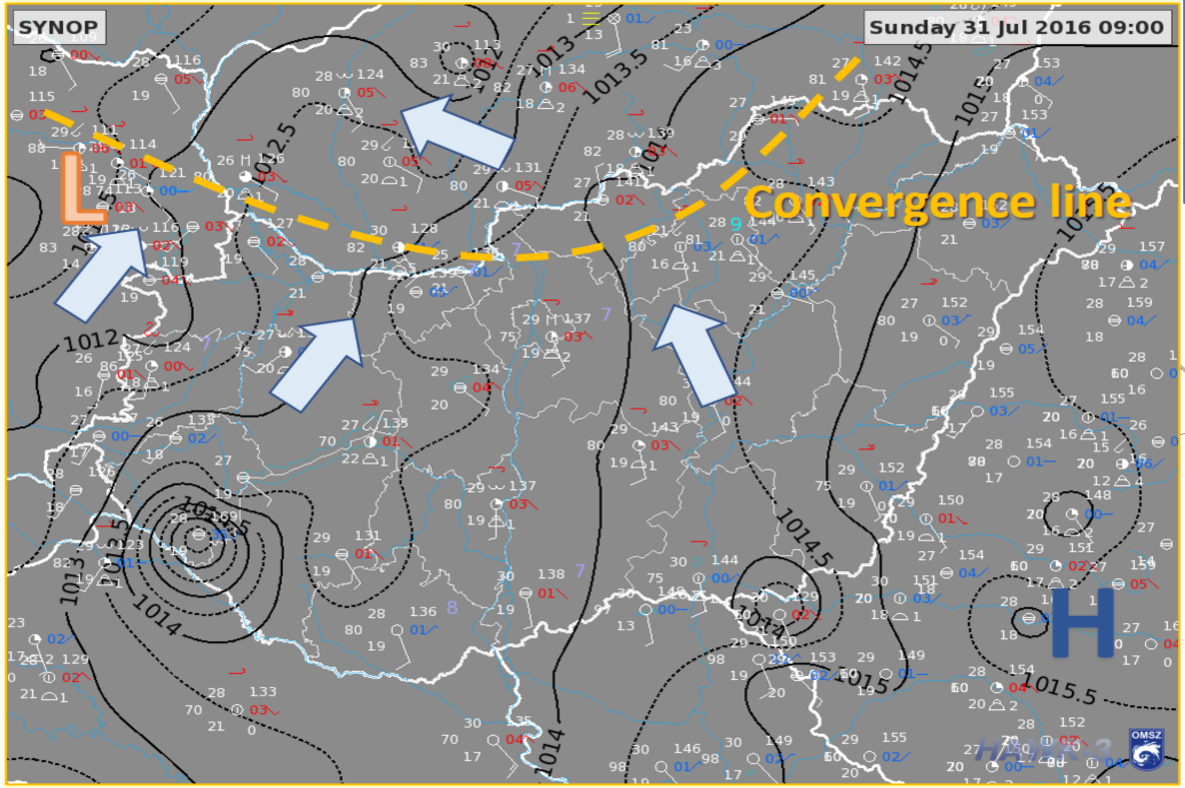
Multicell storm and flashflood
31 July 2016

<u>What happened?</u>

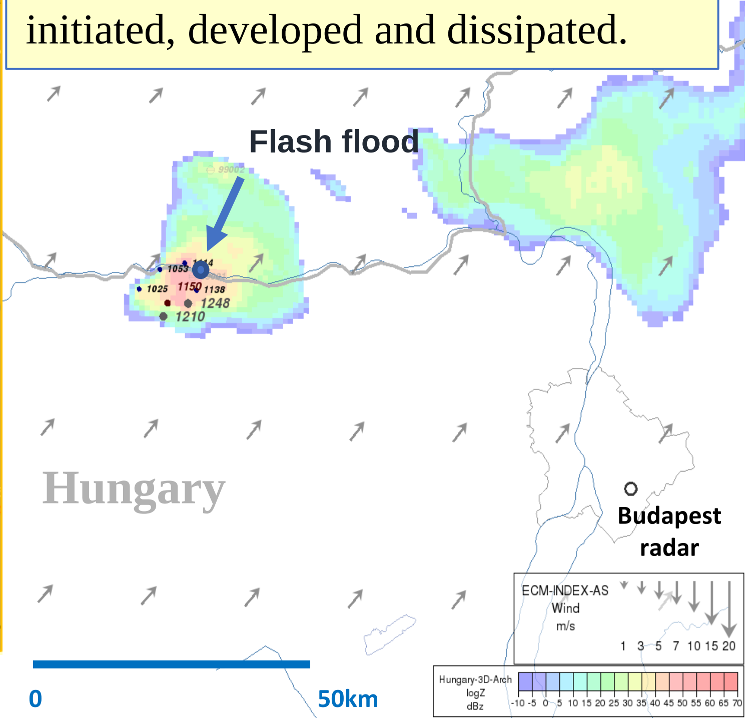
A **flash flood** was reported in Komárom (H) and Komárno (SK).
Highest measured 24-h precipitation was 79 mm. 47 mm was reported within 1 h.
There was also 3-4 cm **hail** and damage due to **wind**.

The convective system developed **<u>along a convergence line ahead a cold front</u>**.

The **propagation of the system was very slow during about 3 hours.** At about the same location several cells initiated, developed and dissipated.

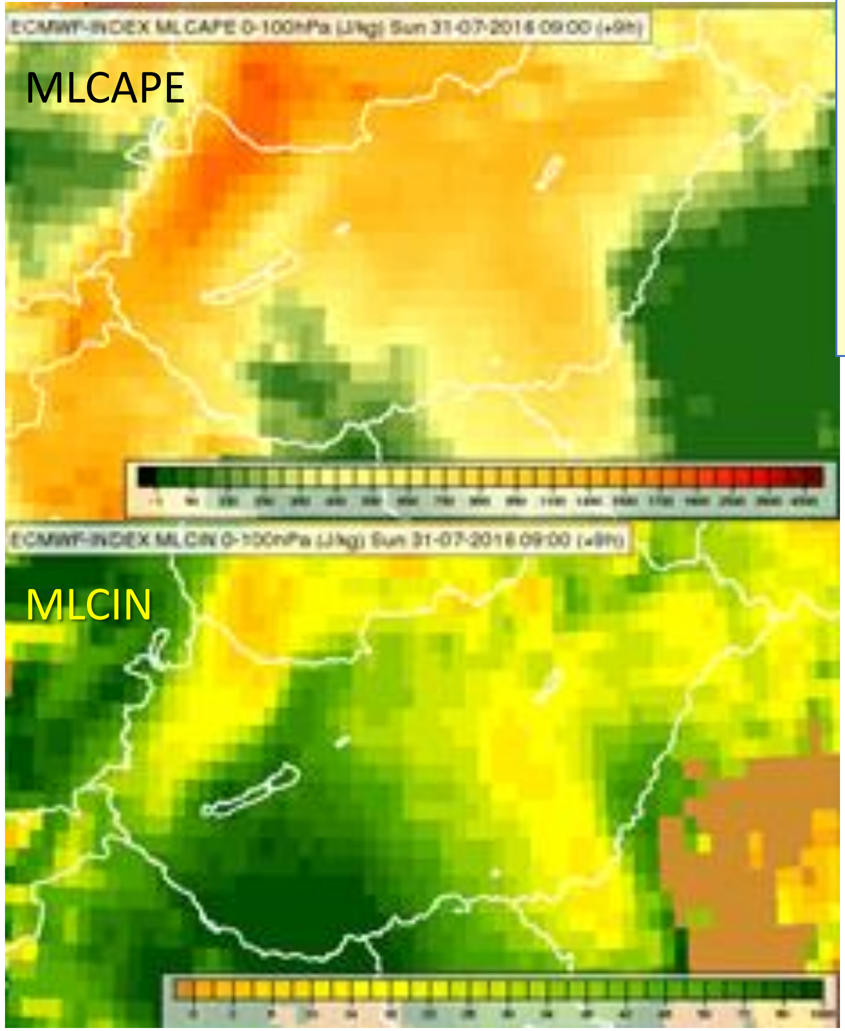


Mesoscale analysis, 31 July 2016, 09 UTC



Environment

ECMWF forecast 09 UTC

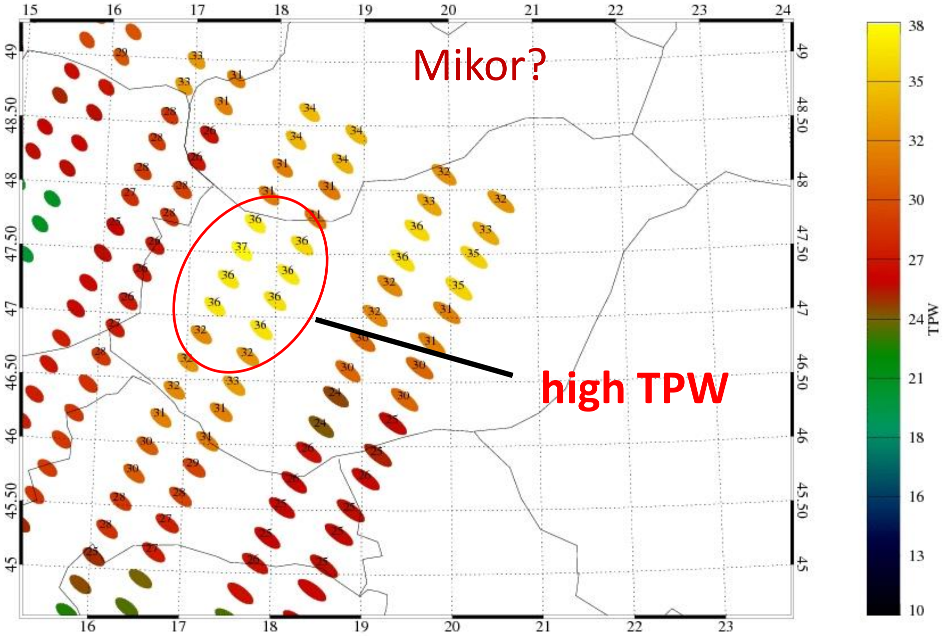


Weak 0-6 km wind shear
+ convergence line

<u>Ingredients, which resulted in a flash flood:</u>

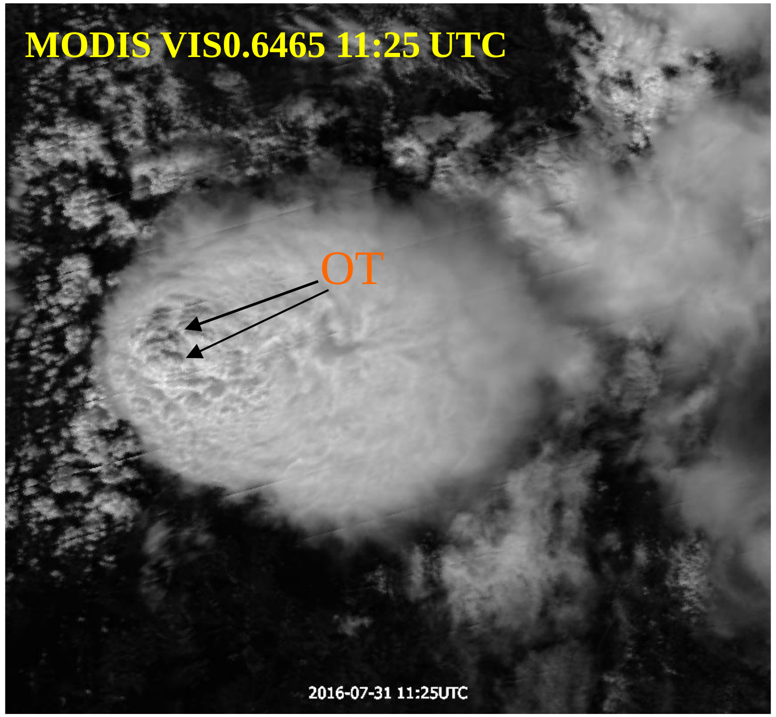
- **Slow propagation**
- **Quasi-stationary convergence:** It was important to trigger new updrafts and also to maintain the convection over nearly the same territory.
- **Locally large CAPE** (forecasted MUCAPE 1500-2000 J/kg)
- **Lot of low-level moisture** (TPW)
- **Convective Inhibition (CIN) around**: To inhibit other clouds to grow and share/destroy the potential energy sources.

Total Precipitable Water (mm) from IASI profiles:



High TPW on the SW flank of the cell (possible inflow area)

Storm development



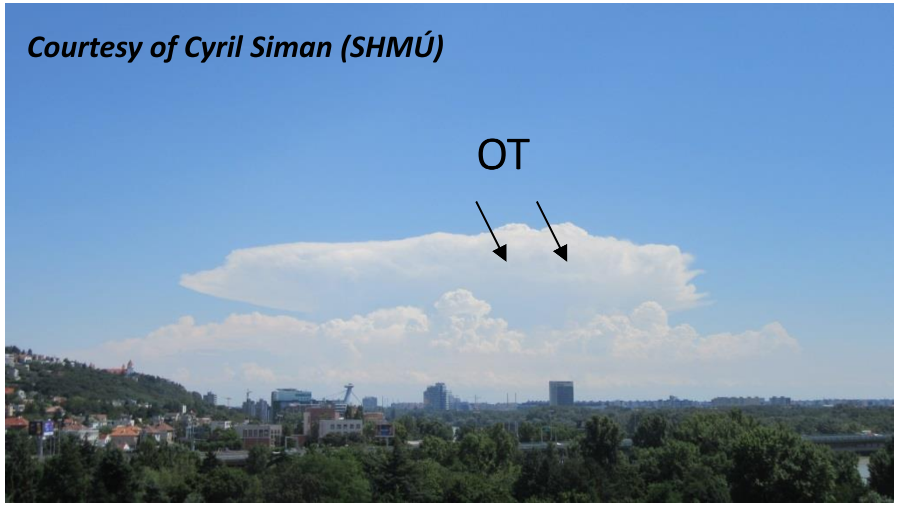
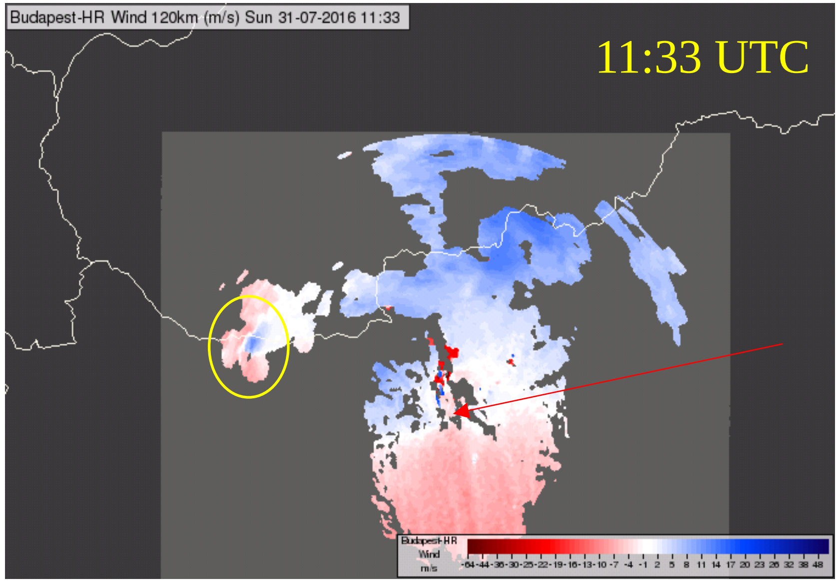


Photo of the storm 90 km from Northwest
at around 1130 UTC

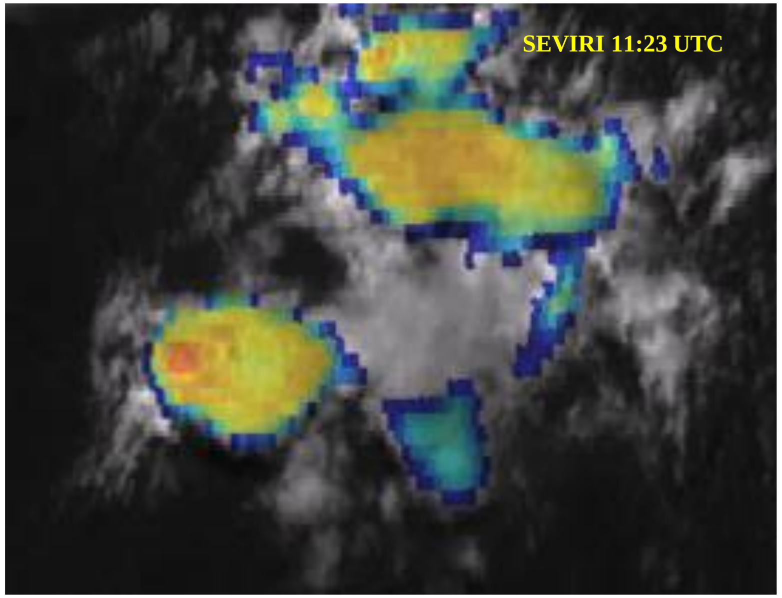
The **multicell system** developed along the convergence line.

Mid-level convergence was observed also by the **Doppler radar velocity measurements**



The arrow shows the location of the radar

Features indicating possible severity



long lived cold ring

Unusually high lightning rate and the lightning density (comparable with the other cases).

The thin cirrus arch cloudiness (induced maybe by gravity waves in the stratosphere) spread from the OT position. Likely related to sudden strengthening of the updraft.

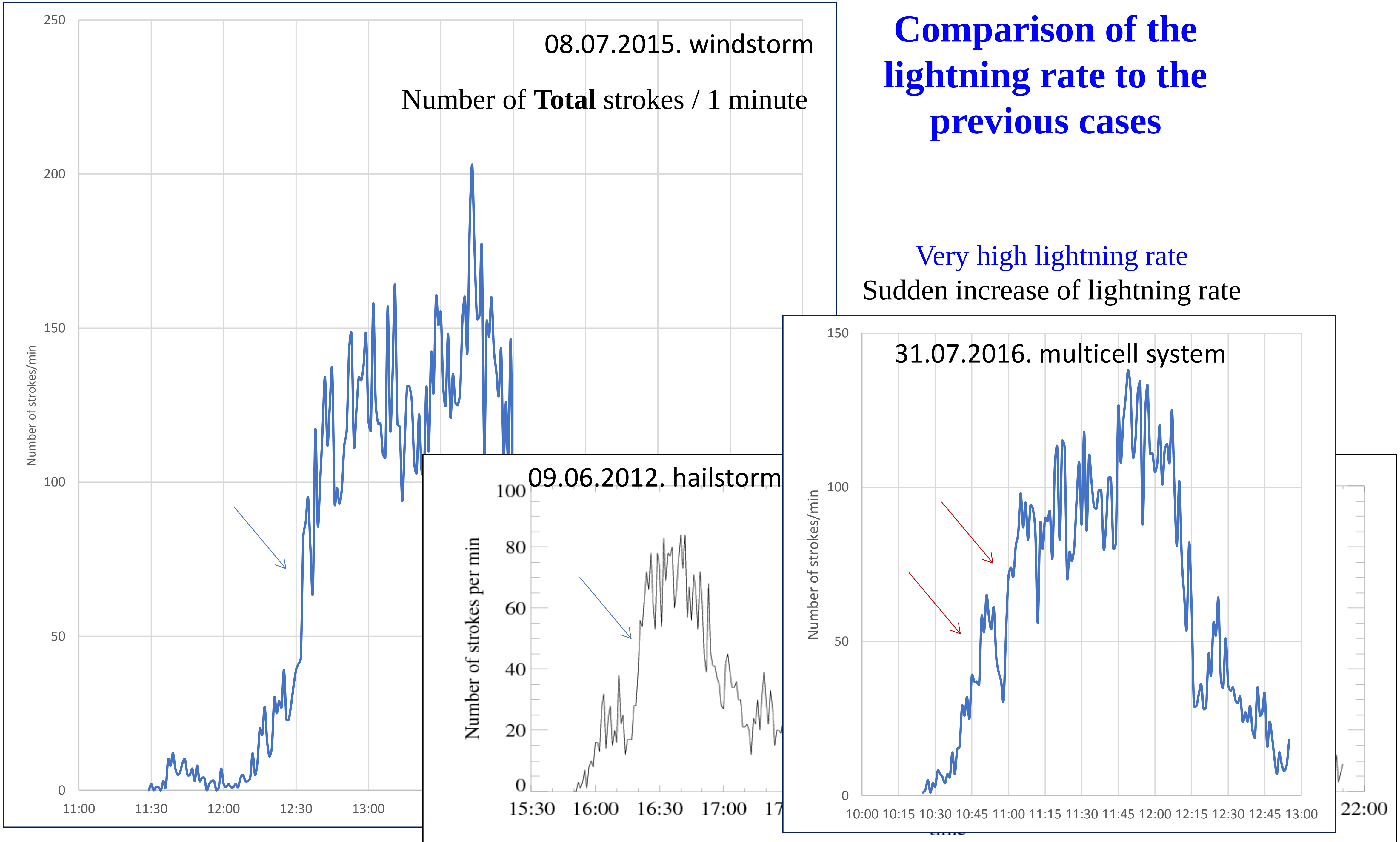
Photo taken around 11:55 UTC by Miroslav Šinger (SHMÚ)

At the time of the lightning rate and the convergence intensity maxima (see later)

Comparison of the lightning rate to the previous cases

Very high lightning rate

Sudden increase of lightning rate



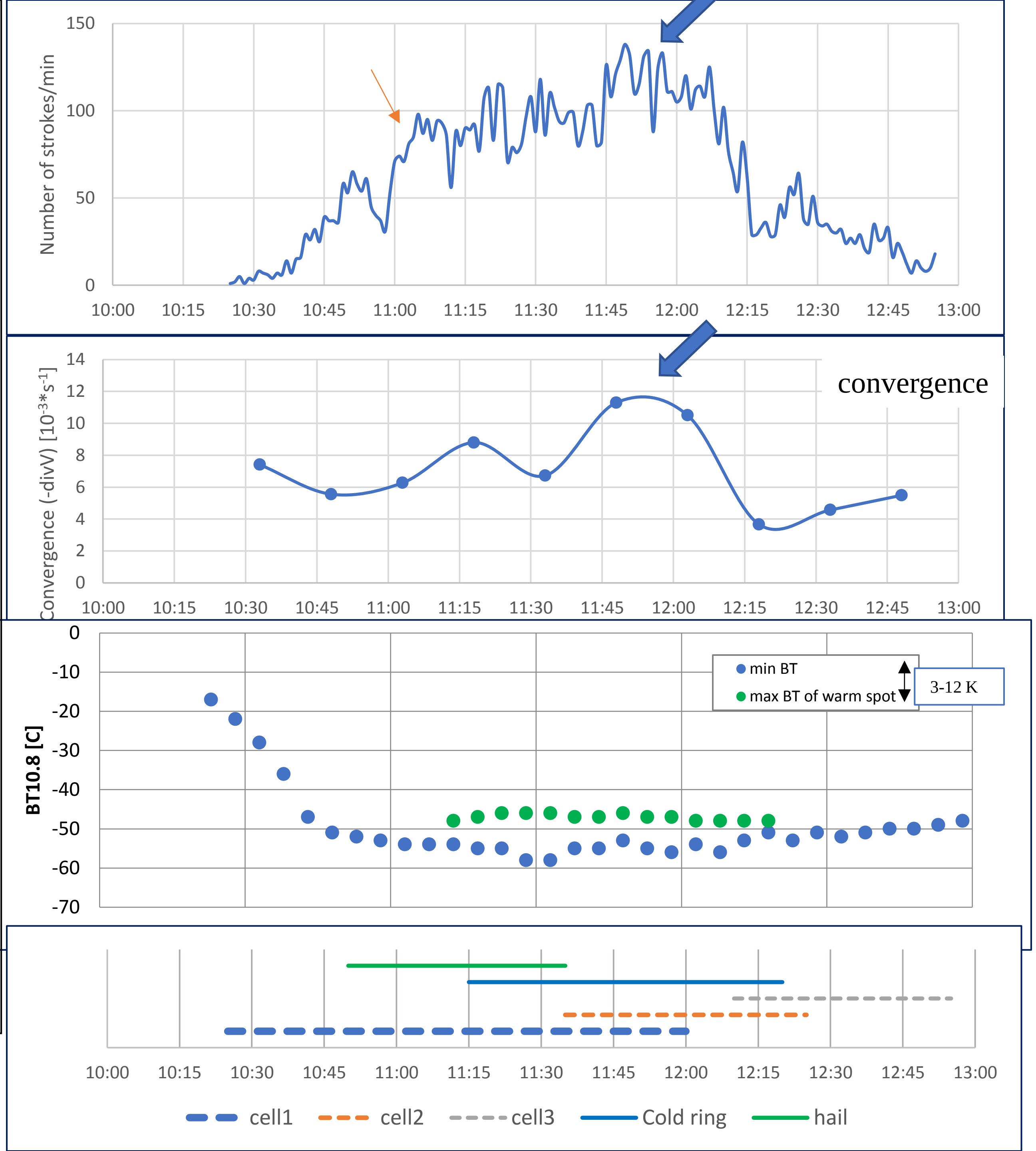
•The lightning activity period started already in the developing phase of the storm before its top reached the tropopause.

•Between 11:00-11:10 UTC there was a sudden increase in total lightning rate likely due to strong updraft

•**Cold ring** formed at just after the strengthening of lightning rate and convergence, likely due to strong updraft.

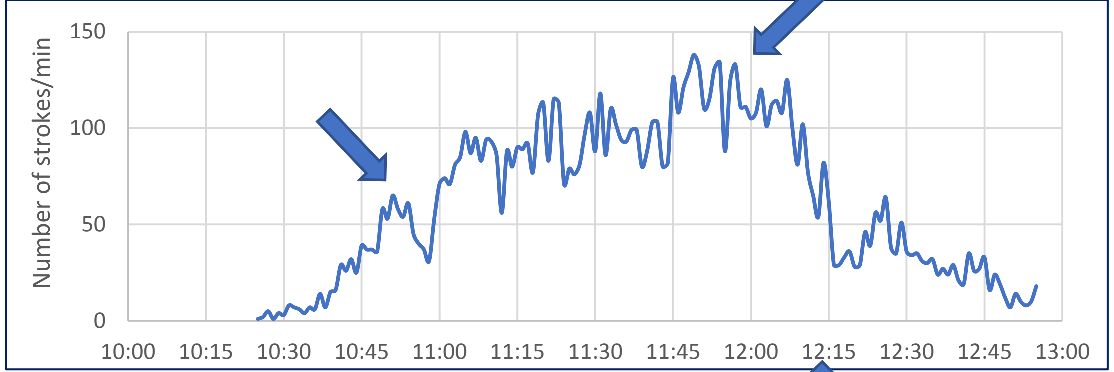
•The **maximum of the total lightning rate** coincided with the 2nd cell development and the **higher (second) maximum of the convergence**.

•The 1st intense lightning activity preceded the heavy rain and (more or less) coincided with hail reports.

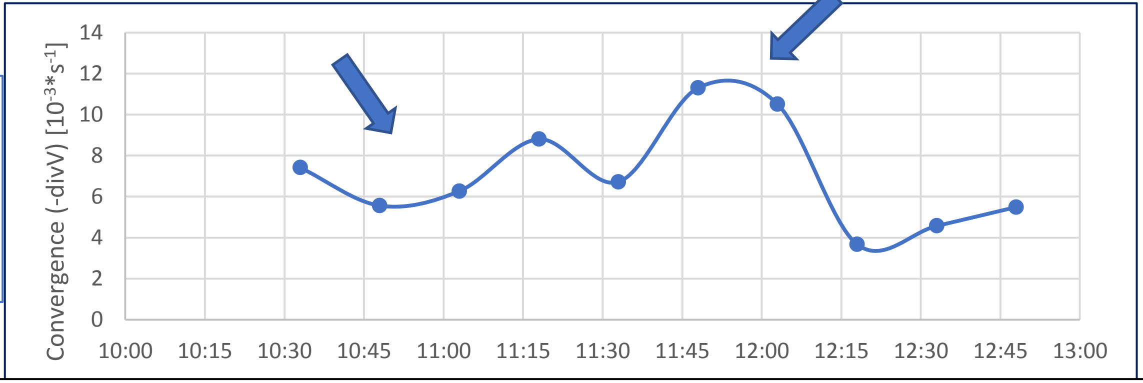


Three major cells evolved and decayed during the severe weather period.

The first lightning rate increase was possibly related to appearance of large hail (increase in Colum maximum radar reflectivity areal sum after 10:45 UTC).

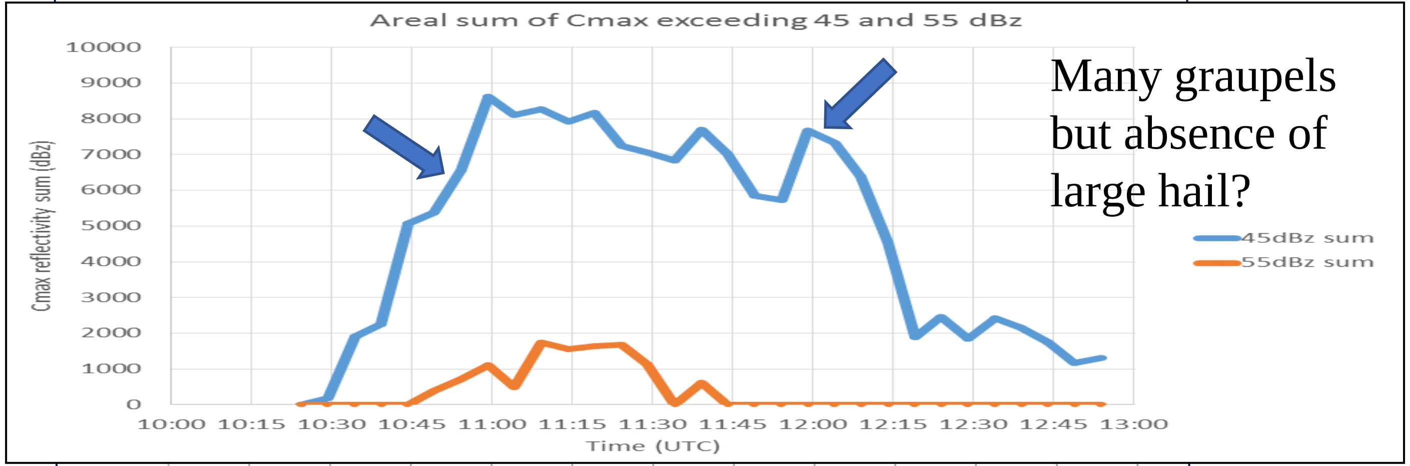


The later lightning rate maximum correlated with mid-level convergence (strong updraft).

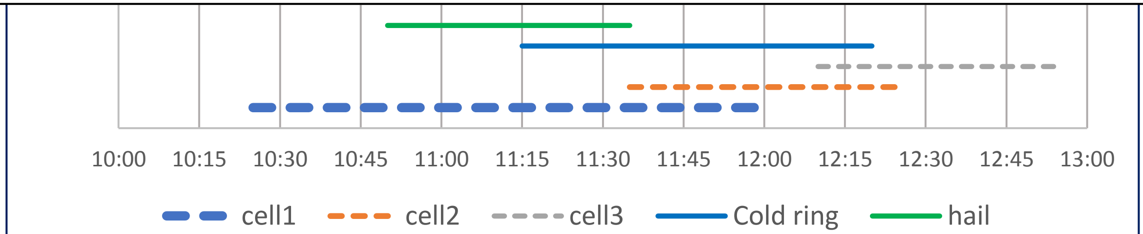


At the time of the maximum lightning activity, there were no echoes exceeding 55 dBz, although there was a peak of reflectivity higher than 45 dBz.

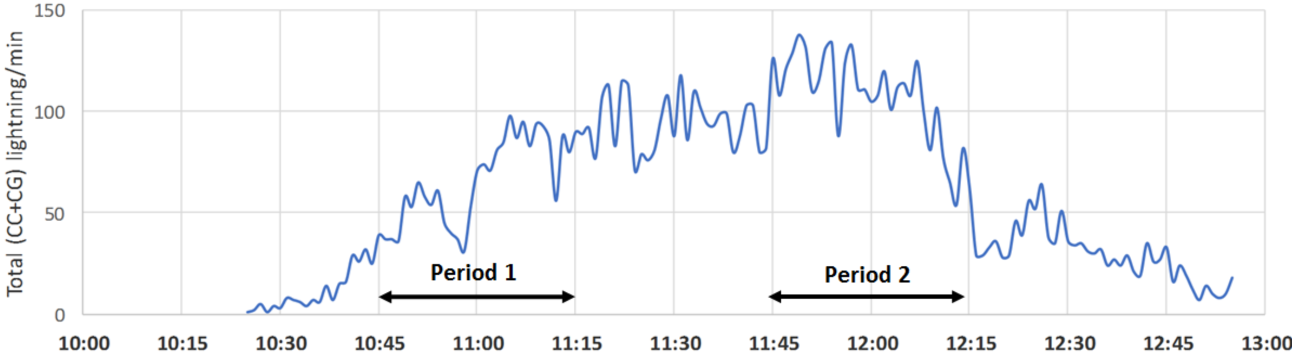
This suggests that the charge was produced in environment with (many) graupels or small hail but less (or absent) large hail.



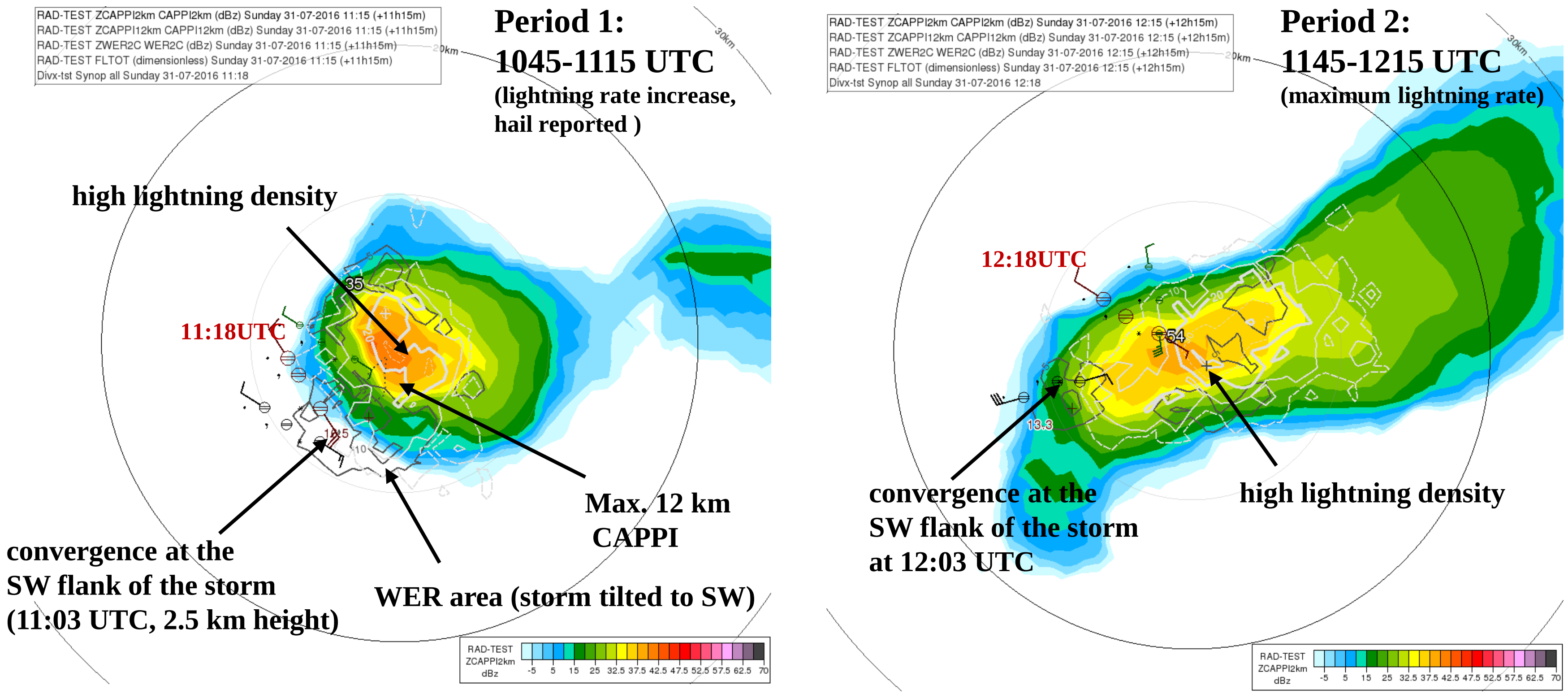
Many graupels but absence of large hail?



The highest **lightning** density (exceeding 50 lightning/km^2) among the studied cases.



30 min. averaged 2km CAPPI radar reflectivity in a relative coordinate system, following the storm



The lightning density is collocated with the precipitation area.

We could not map the updraft region: 1) No rotation, 2) Location of OT were hard to observed on satellite imagery, 3) High level CAPPI was not strong, 4) **There is no stable, strong WER area, no strong vertical gradient of radar raflectivity.**

Outlines

Introduction

Five case studies

- Supercell, hailstorm (09 June 2012)
- Hybrid multicell-supercell storm, windstorm (08 July 2015)
- Tornadic storm (16 August 2010)
- Multicell storm and flashflood (31 July 2016)
- Single cell, short-lived local thunderstorm (23 July 2016)

Summary

Short-lived, local thunderstorm at Balaton
23 July 2015

Synoptic situation

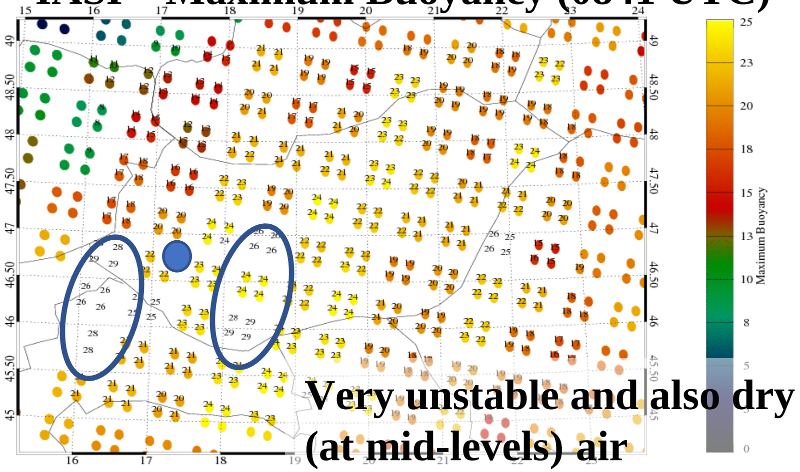
The studied thunderstorm formed in a warm pre-frontal airmass.

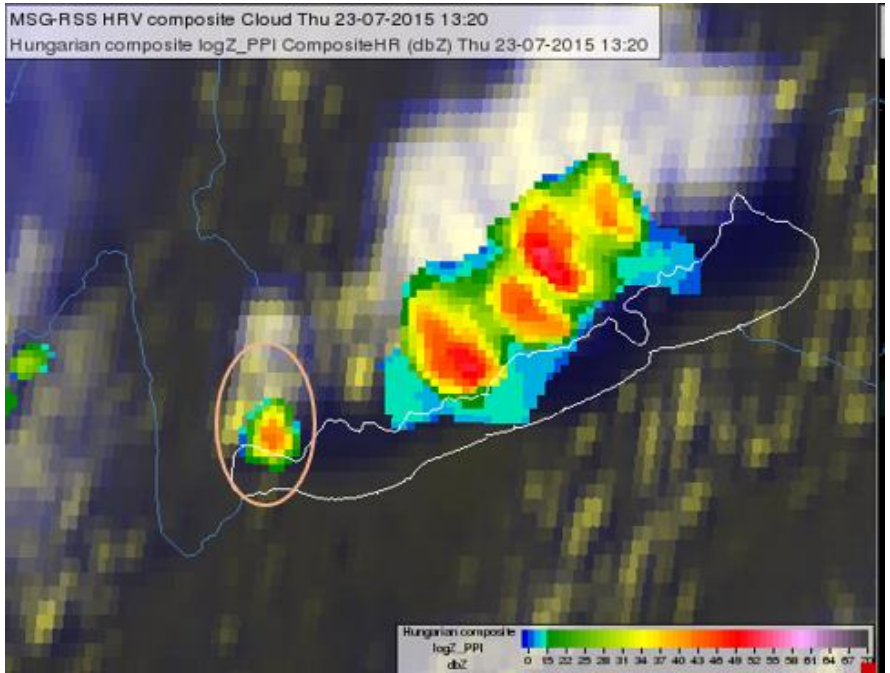
Environment

- Very high TPW (> 30 mm).
- very unstable environment
- dry mid-levels
- no persistent low level convergence
- very low wind shear,

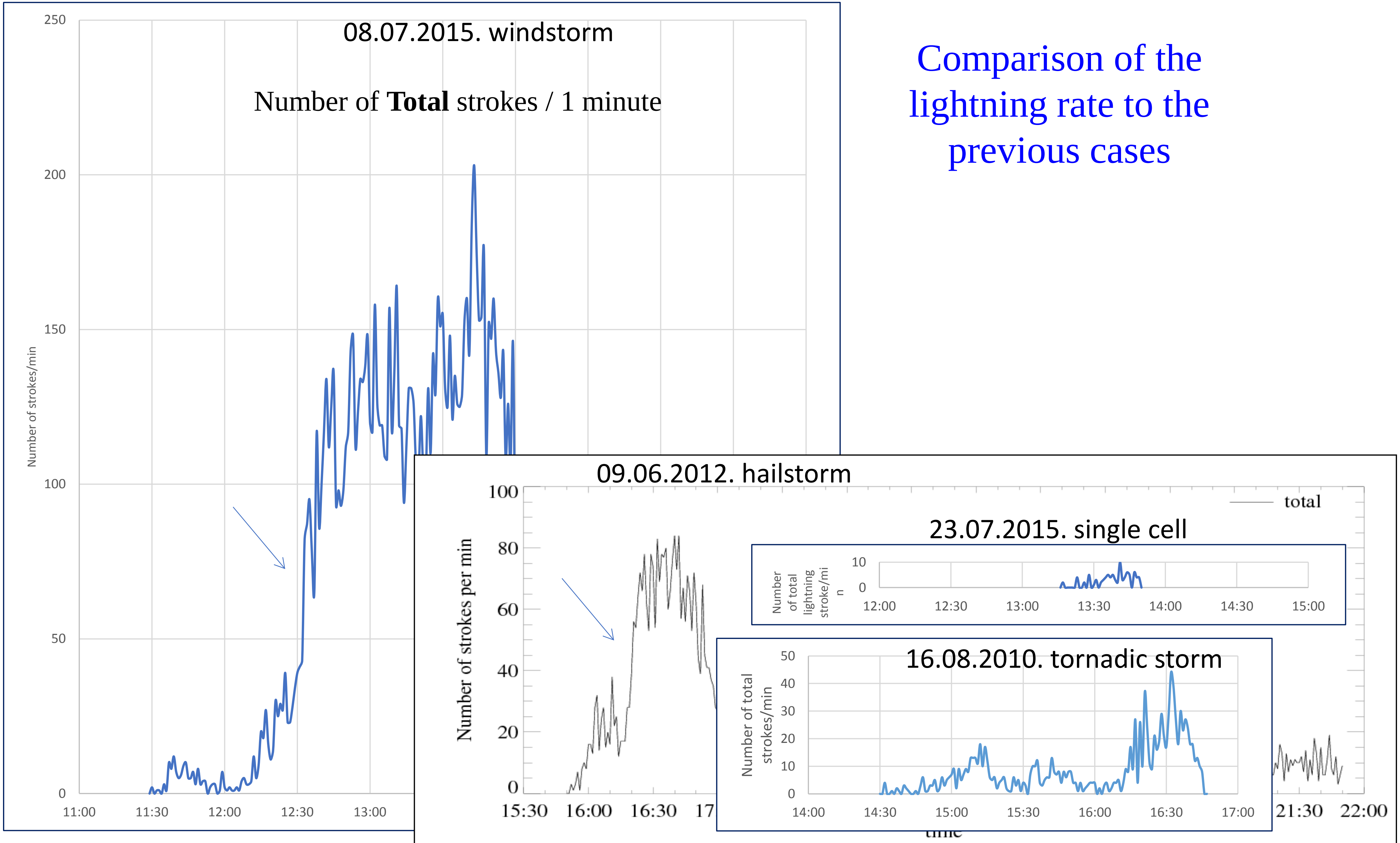
Single thunderstorm with high lightning activity (two injuries). Rapid development and dissipation, short lifetime, slow motion
Wind gusts up to 15 m/s

IASI – Maximum Buoyancy (0841 UTC)





Comparison of the lightning rate to the previous cases



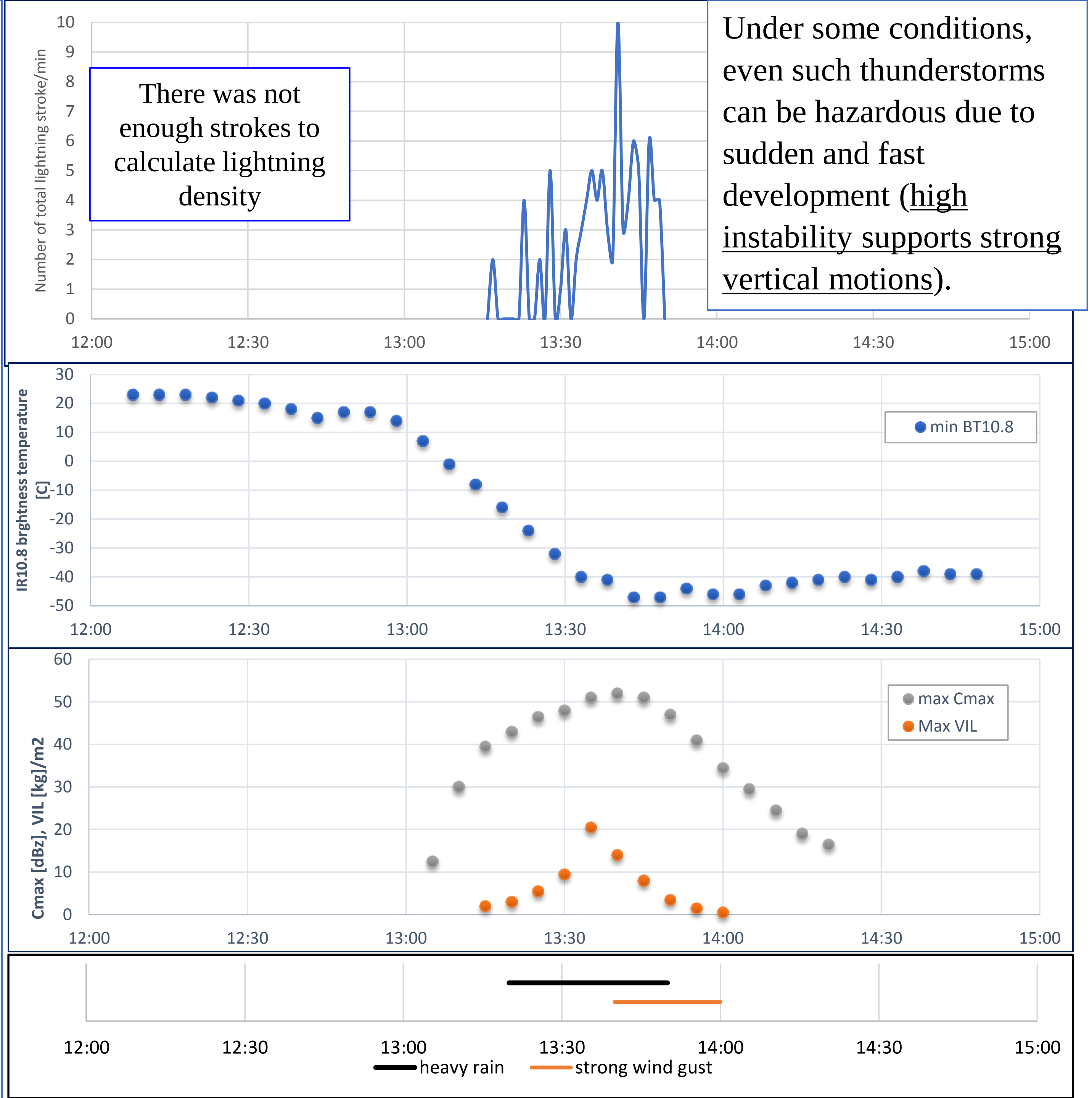
No severe storm characteristics (e.g. WER, Cold ring) in radar or satellite data.

The lightning intensity was sometimes significant but short-lived and much lower compared to other presented cases.

The lightning activity period started already in the developing phase of the storm.

The lightning rate maximum preceded the strong windgust by 5 min.

The maxima of the lightning stroke rate and radar reflectivity, and the minimum of IR10.8 cloud top temperature roughly coincided.



Under some conditions, even such thunderstorms can be hazardous due to sudden and fast development (<u>high instability supports strong vertical motions</u>).

Outlines

Introduction

Five case studies

- Supercell, hailstorm (09 June 2012)
- Hybrid multicell-supercell storm, windstorm (08 July 2015)
- Tornadic storm (16 August 2010)
- Multicell storm and flashflood (31 July 2016)
- Single cell, short-lived local thunderstorm (23 July 2016)

Summary

Conclusions (based on these 5 cases)

- The lightning activity started already in the developing phase of the storms' life-cycles.
- The lightning rate can be high or relatively low in supercells. (Lightning activity depends not only on the updraft strength but on the microphysics as well.)
- The lightning rate can be higher in a multicell system than in a supercell.
- We found sudden increase in lightning rate in 2 supercell cases and in the multicell case.
- **The course of lightning rate correlates with the course of vorticity** estimated from radial Doppler velocity measurements - in supercell cases with high lightning rates (2 cases). (We found significant peaks in total lightning, when the mesocyclone strengthened, both are likely related to the *intensification of the **storm's updraft**).*
- **Cold ring** formed just after the sudden increase of lightning rate (2 supercell + multicell cases) at around the time of the first vorticity maximum (3 supercell cases). (Cold ring is also related to *strong updraft*.)
- The course of lightning rate showed some correlation with the course of the *convergence* intensity in the case of the *multicell system*. Likely common reason is the *updraft strengthening*

Conclusions cont.

- **In periods of lightning intensification we find other characteristics of severe storms**: (like Doppler velocity signatures, OT-s, cold rings and ice plumes, WER echoes) in the supercell cases + multicell case.

- **High lightning rates often can be found prior to observed severe weather** (hail, windgust, heavy rain). (Note, that the time of the severe weather events were often uncertain, for example in case of hail, as we worked with ESWDB report (+ high radar VIL data) and not with hail pad data.)

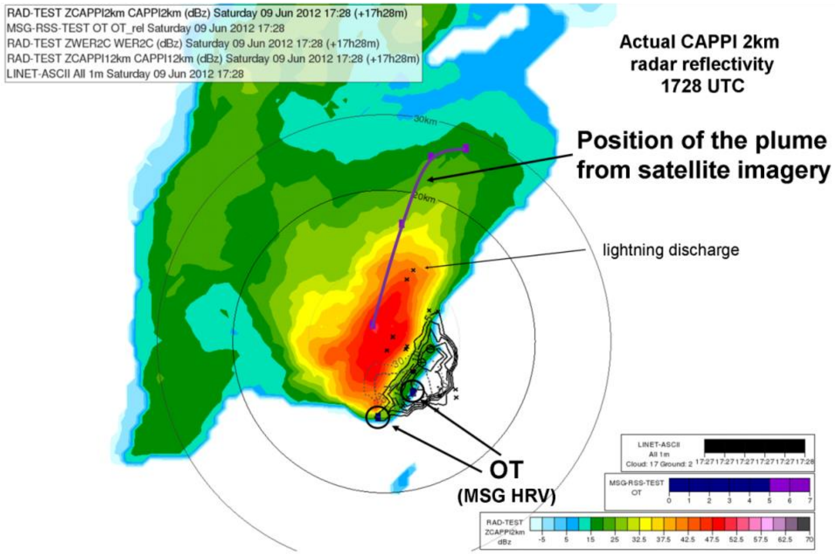
- There is no simple relation between lightning rate and hail on the ground. In the later stages we can find large hail with relatively low lightning rate and no hail with high lightning rate.

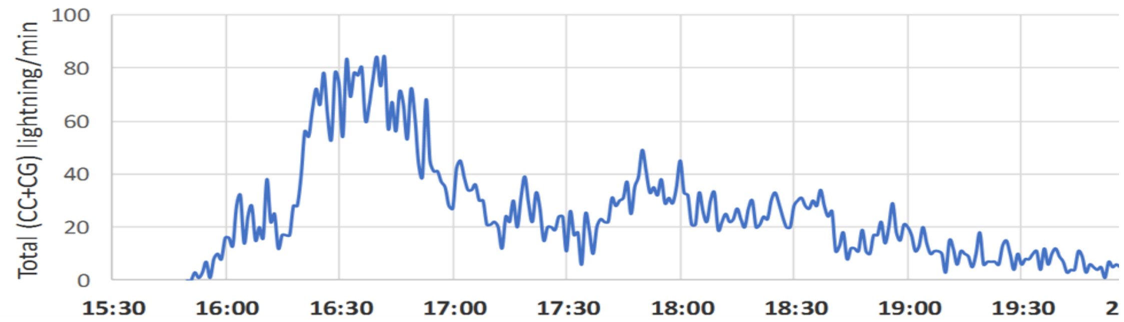
- The lightning density of a supercell is not necessarily higher than in a non supercell severe weather. The highest lightning density was found in the multicell system.

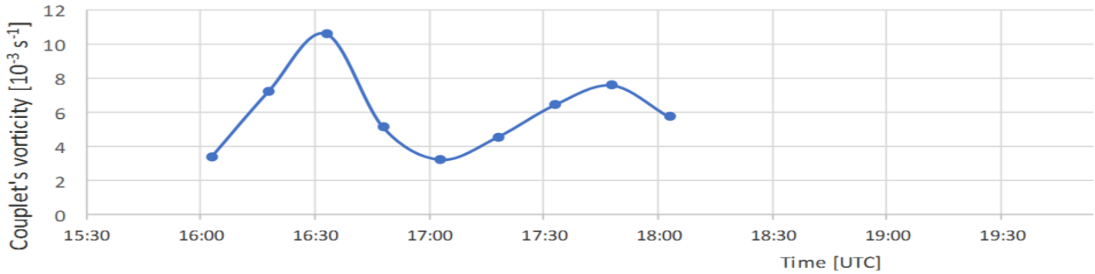
- The highest lightning density mostly occurred in high radar reflectivity area at 2 km (heavy precipitation/hail). - In supercells, this maximum can be dislocated from the strongest echoes at higher (6, 12 km) levels. Much less lightning was detected in the overhang areas with high WER2c (3 supercell cases).

For more general conclusions - More cases needed

Thank you for your attention!

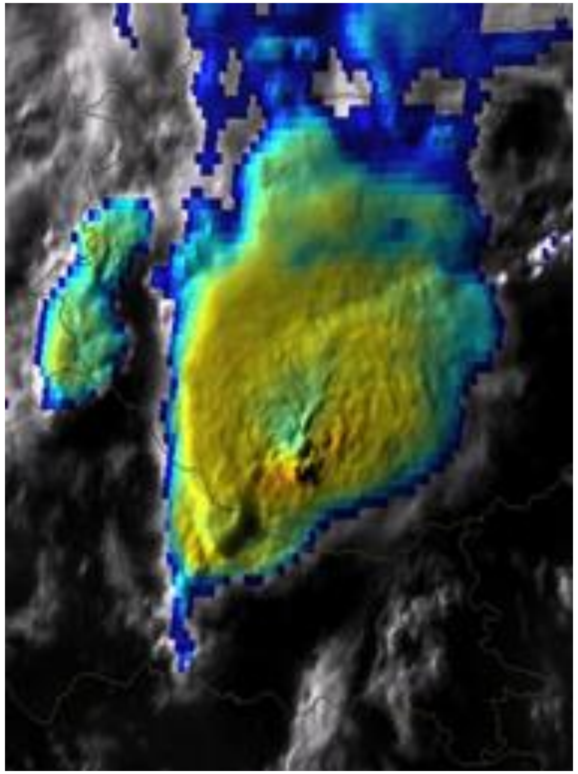






Acknowledgements

- This study was supported by EUMETSAT, (contract number: EUM/CO/16/4600001802/KJG). We are grateful to Jochen Grandell and Thomas August (EUMETSAT) for the valuable advises and IASI data.
- We thank Nowcast GmbH Munich for providing us lightning data for the case studies.



References

Simon, A., Putsay, M., Zsófia Kocsis , Zs. and Ildikó Szenyán, I. (2016): Analysing a convective event (09 June 2012) with satellite, radar and lightning data, Convection Working Group workshop, Florence, Italy, 4-8 April 2016.

Betz, H.D., Schmidt, K., Laroche, P., Blanchet, P., Oettinger, W.P., Defer, E., Dziewit, Z., and *Konarski, J.*, 2009: LINET— An international lightning detection network in Europe. *Atmos. Res. 91*, 564–573.

Kaňák, J., Jurašek, M., 2004: Tracking algorithm for Meteosat data as a CEI nowcasting tool. The 2004 EUMETSAT Meteorological Satellite Conference Proceedings. Darmstadt, 360

König, M., Tjemkes, S. A., Kerkmann, J., 2001: Atmospheric Instability Parameters Derived from MSG SEVIRI Observations. 11th Conference on Satellite Meteorology and Oceanography.

M. Setvák, D. T. Lindsey, P. Novák, P. K. Wang, M. Radová, J. Kerkmann, L. Grasso, S-H Su, R. M. Rabin, J. Šťástka, Z. Charvát., 2010: Satellite-observed cold-ring-shaped features atop deep convective clouds. Atmos. Res., 97 (2010), 80–96.

Wang, P. K., 2007: The thermodynamic structure atop a penetrating convective thunderstorm. Atmos. Res., 83 (2007), 254–262.

Complex case study of a severe storm
Main emphases on remote sensing data : satellite, radar, lightning

Technical information on the applied remote sensing data

Satellite

METEOSAT SEVIRI RSS (5 minute data)

Lightning – data of LINET network - operationally used at OMSZ

European Lightning Detection NETwork (~130 sensors in Europe, 7 sensors in Hungary)
every stroke: time [ms], location, height, type (CC, CG), current amplitude estimation [+/-kA], location uncertainty
It detects at low frequency (very long wave)
It **discriminates CC from CG strokes according their heights** (software based on high precision time measurement)
(ratio of CC and CG in Hungary ~ 1:1)

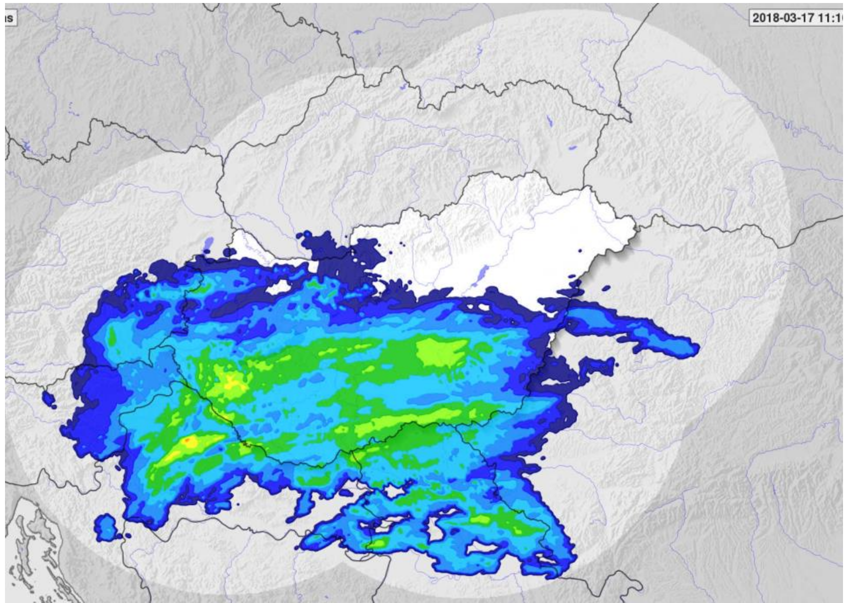
Hungarian radar system

Three/four Doppler dual-polarization DWSR radars working at 5,3 cm wavelength

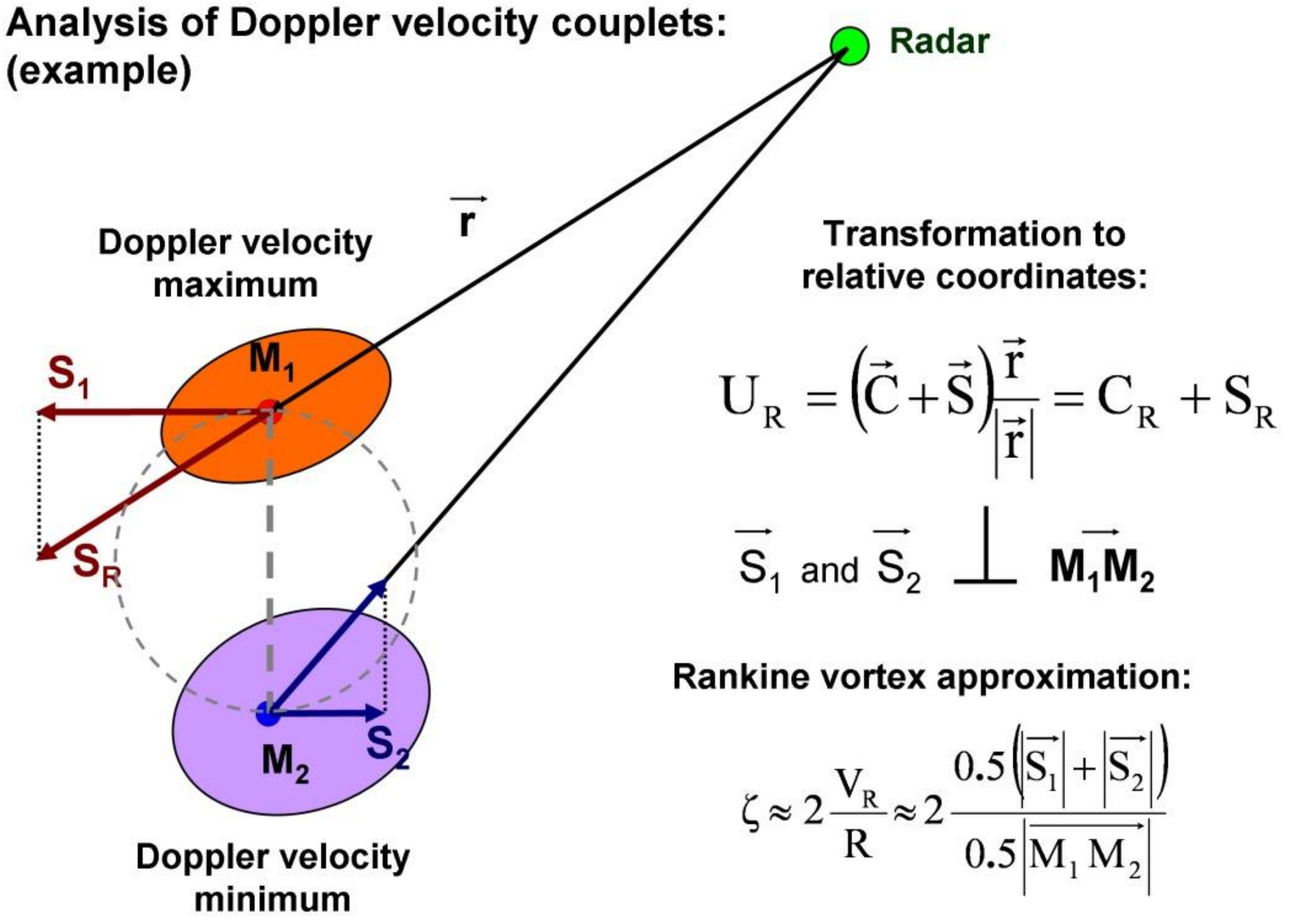
- **5 minute** reflectivity data at 10 elevation angles (0.0, 0.5 ,1.1, 1.9 ,3.0 ,4.7, 7.0, 10.0, 14.2, 20), in 240 km radius area
- **15 minute** wind measurement in 5 elevation angles (1.1, 1.9, 3.0 ,6.5 ,14.0), in120 km radius area (3 minute shift)

Volume data→ products with 1x1 km resolution

- For each radar: PPI, CAPPI, Cmax, VIL, ETOPS
  + Hungarian composite images (Cmax, VIL, ETOPS)
- Doppler wind measurements



Vorticity or convergence can be estimated from radial Doppler velocity couplets (when present).



Estimation of couplet's vorticity, mostly at 2-3 km height (PPI data)