Lidar-Based Detection of Dangerous Meteorological Phenomena at the Bratislava Airport

INAIR 2019, Budapest, November 13, 2019

LIDAR-BASED DETECTION OF DANGEROUS MET. PHENOMENA AT THE BRATISLAVA AIRPORT

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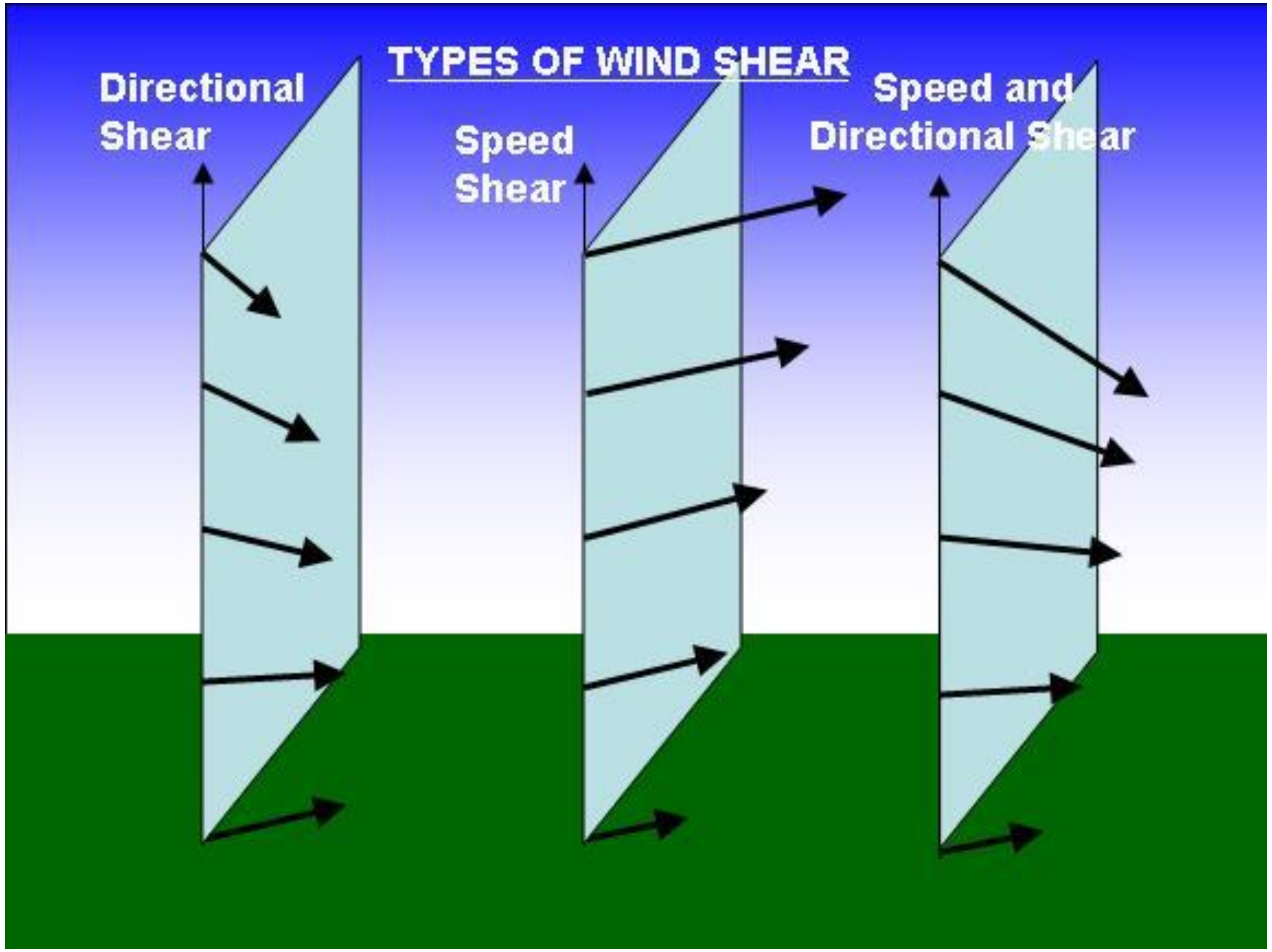
PRESENTATION OVERVIEW

- low level wind shear in aviation
- 3D wind field observation by lidar
- principles of lidar technology
- lidar scanning regime PPI 3°
- detection of a selected hazardous weather event by lidar & radar
    - multiple gust fronts on July 5, 2018
- wind shear on the runways

LOW LEVEL WIND SHEAR

- sudden change in wind speed and/or wind direction up to the altitudes of 1600 ft (500 m) above the ground
- hazardous phenomenon for the aircraft during landing or take-off
- it may dramatically influence aerodynamic circumstances of flight
- **wind shear alert** in aviation:
  - a loss/gain in headwind of $\Delta v \geq 7.5$ m/s
  - along a distance of $d \leq 4$ km

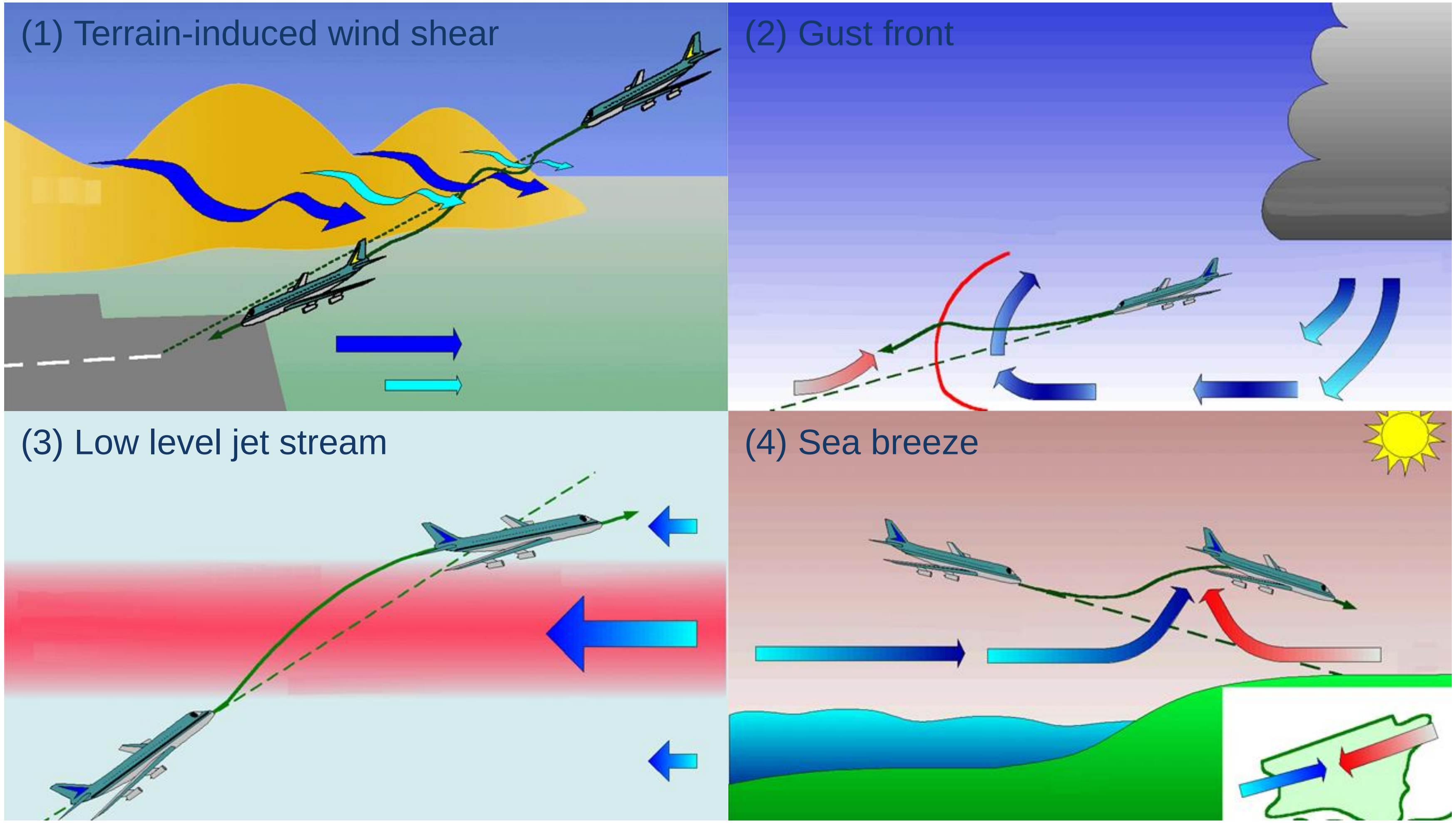


https://weatherstreet.com/

TYPES OF LOW LEVEL WIND SHEAR

low level wind shear is commonly associated with atmospheric processes, such as

1) surface obstructions
2) frontal activity
3) low level jet stream
4) temperature / pressure differences
5) temperature inversion (no illustration)



BRATISLAVA AIRPORT & THE LITTLE CARPATHIANS

(a perspective from SE to NW)

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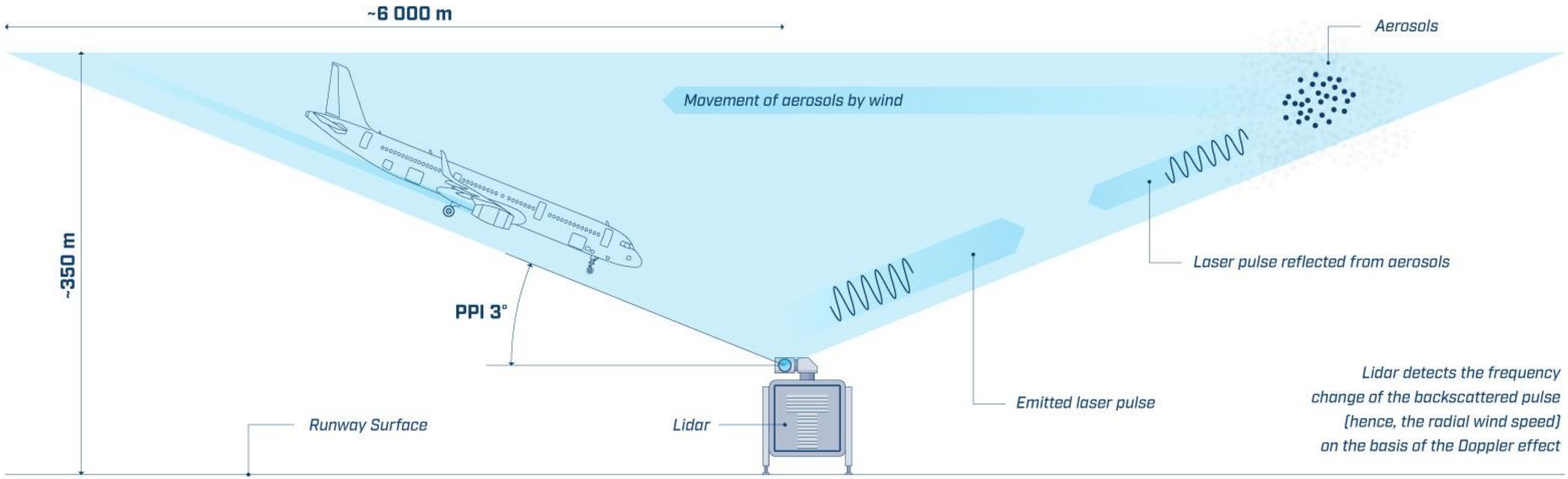
LIDAR LEOSPHERE WINDCUBE 200S

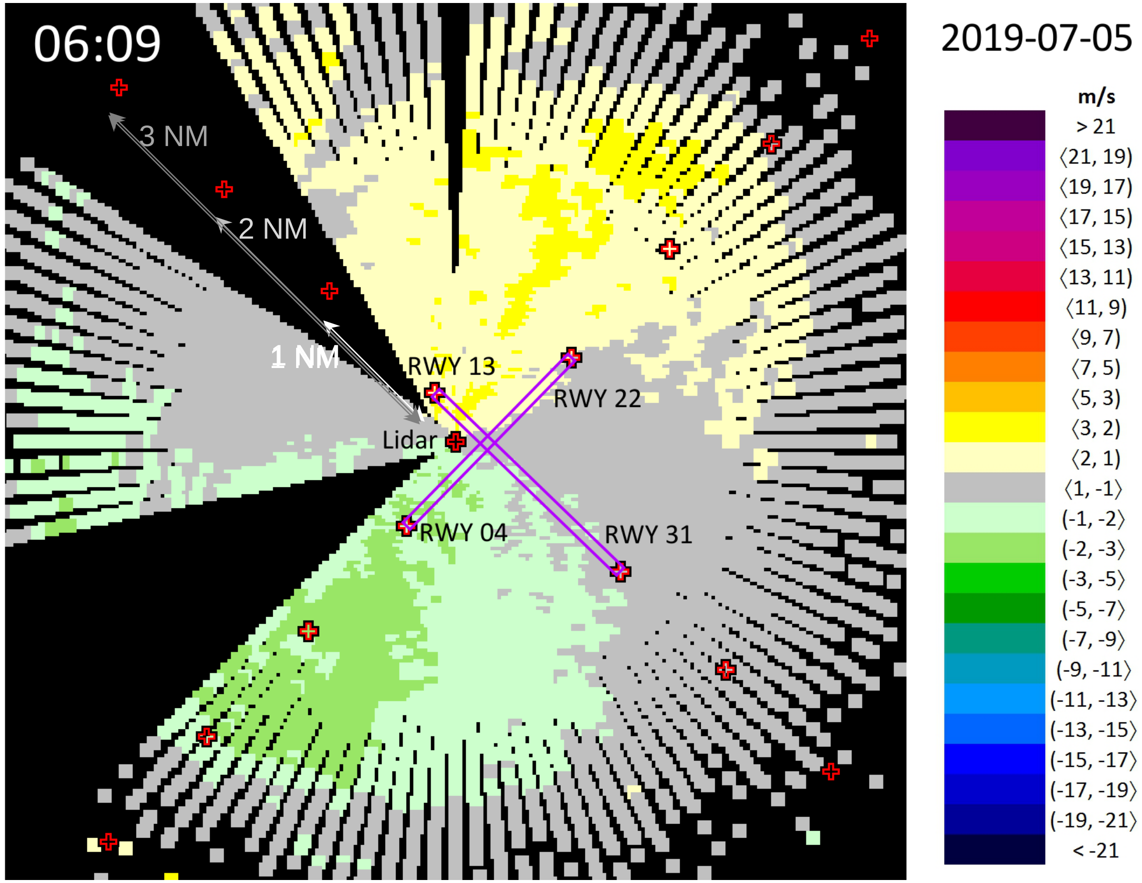
Dimensions:	101 cm x 81 cm x 137 cm
Weight:	232 kg
Laser:	Pulsed @1.54 µm

PRINCIPLES OF THE LIDAR MEASUREMENTS

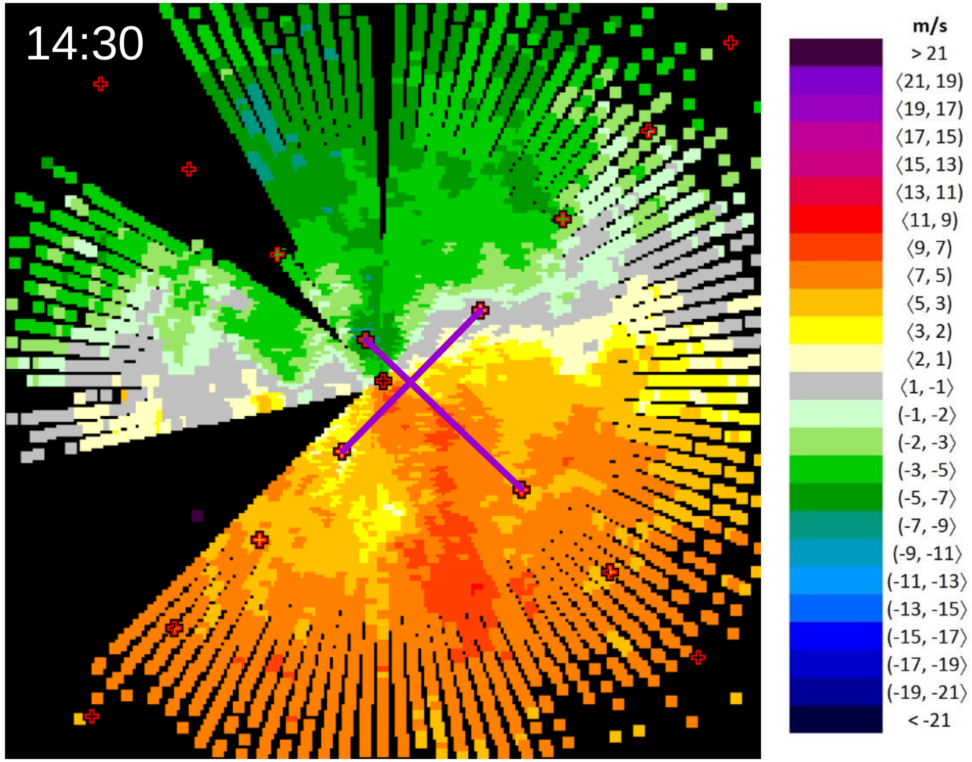


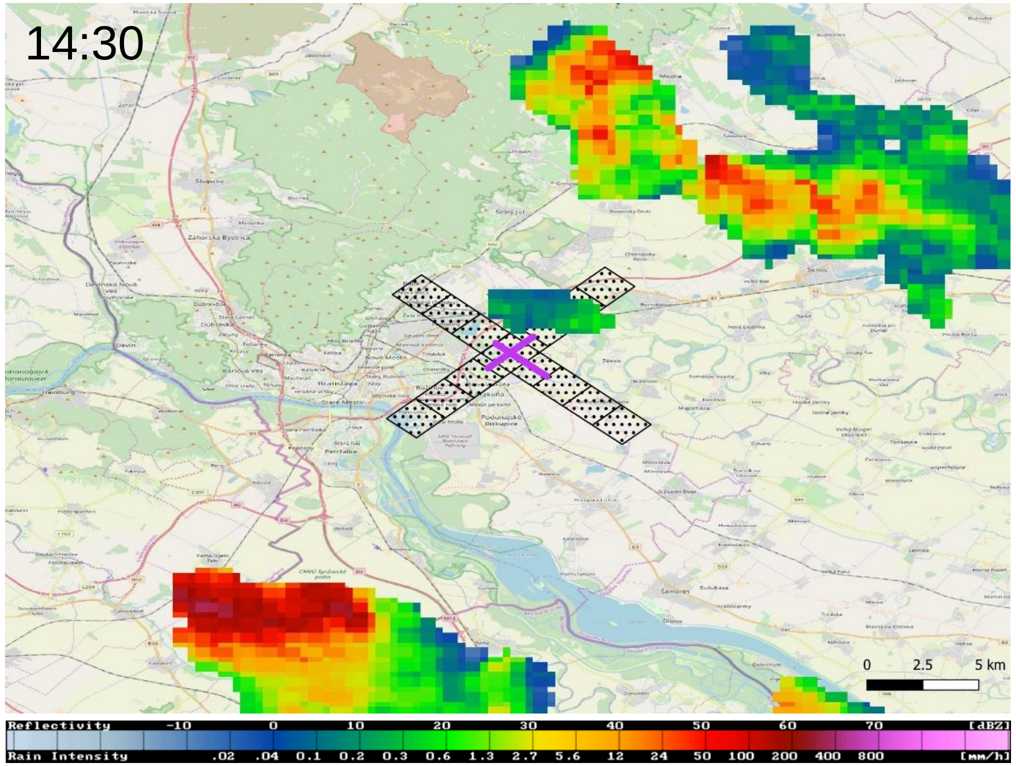
WIND FIELD ON THE LIDAR SNAPSHOTS

- PPI regime (*Plan Position Indicator*):
  - elevation angle is constant (= 3°, glide path)
  - azimuth is continuously iterating 0°-360°
- single scan = cone surface → a circle in 2D
- two blind spots at the Bratislava Airport
  1) 228° … 255°: airport fire station
  2) 306° … 327°: meteorological observatory
- Significant reference points at each runway:
  - the runway end
  - the distances of 1, 2 & 3 nautical miles (NM) from the runway end (1 NM ≈ 1.8 km)
- **Wind blowing towards the lidar is positive**



DETECTION OF GUST FRONTS BY LIDAR & RADAR, 2018-07-05





- stable wind at the airport: 9 m/s from 160°
- no change in wind speed & wind direction with altitude
- [Radar snapshots: the CAPPI 2 km product, each 5 min.]
- a thunderstorm cell ~15 km from the edge of RWY 04

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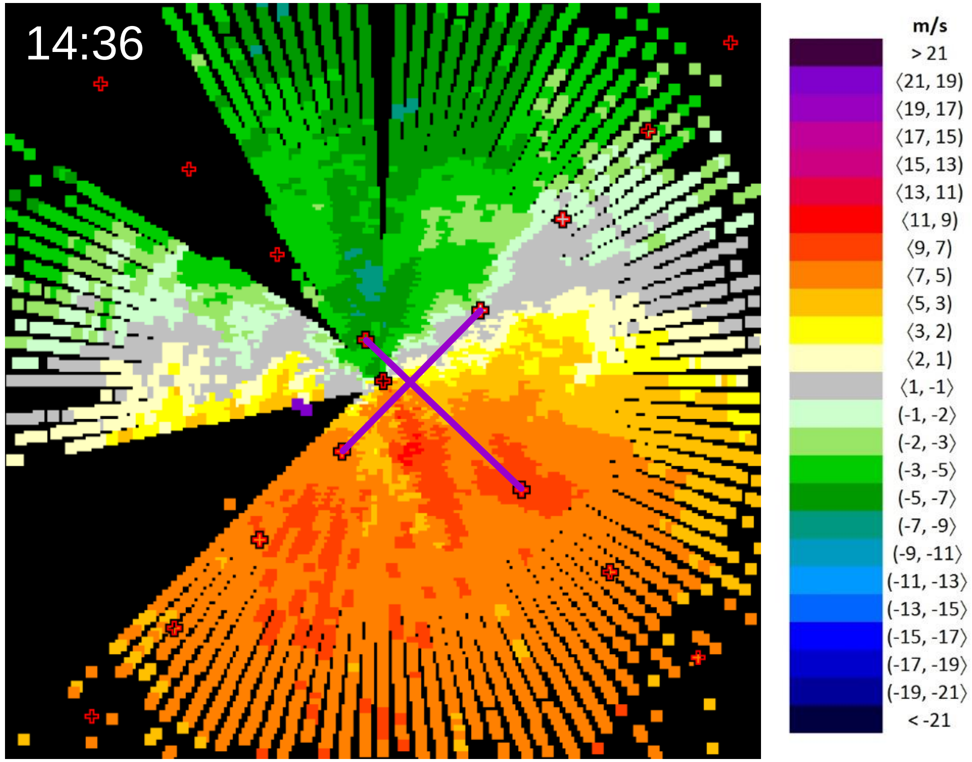

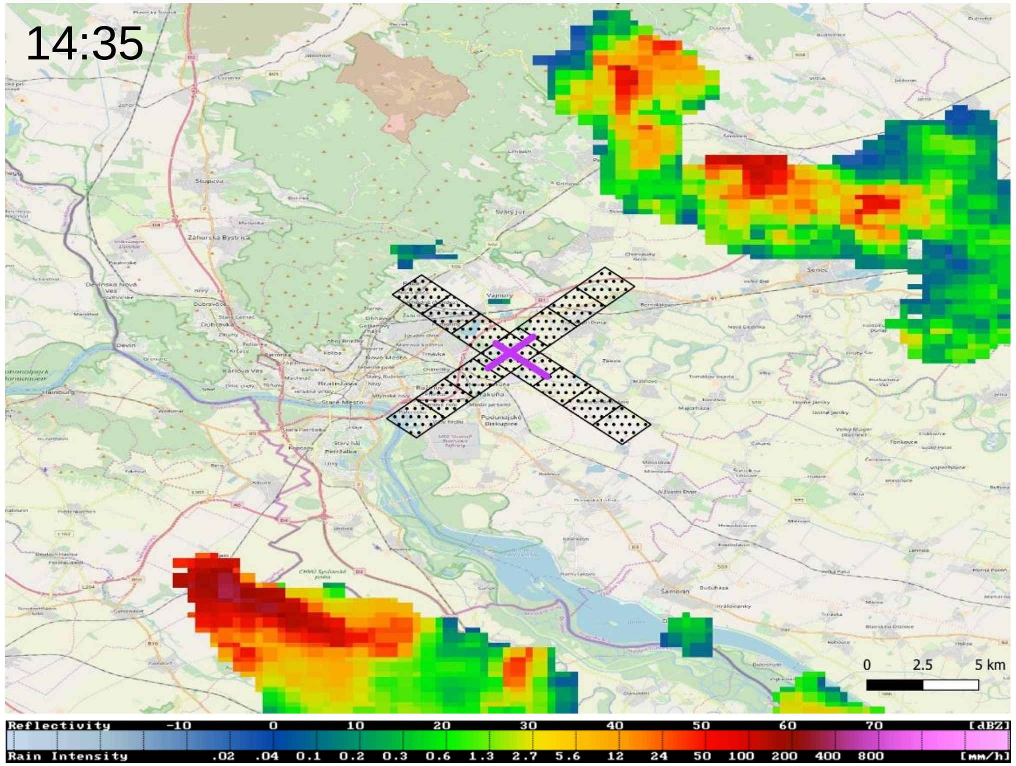

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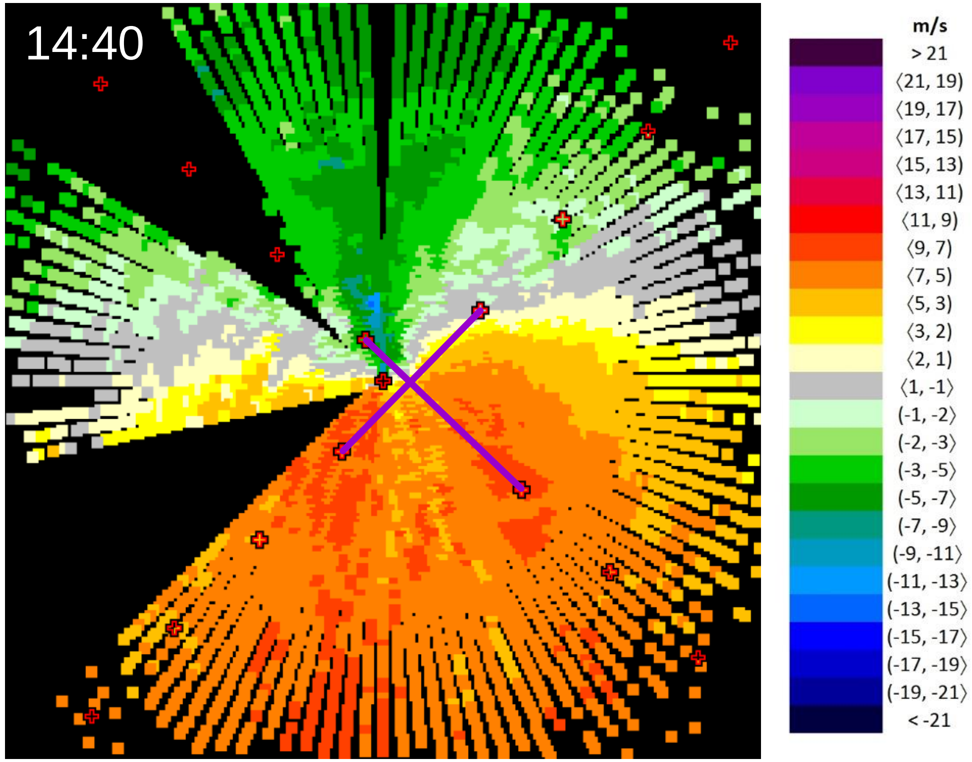

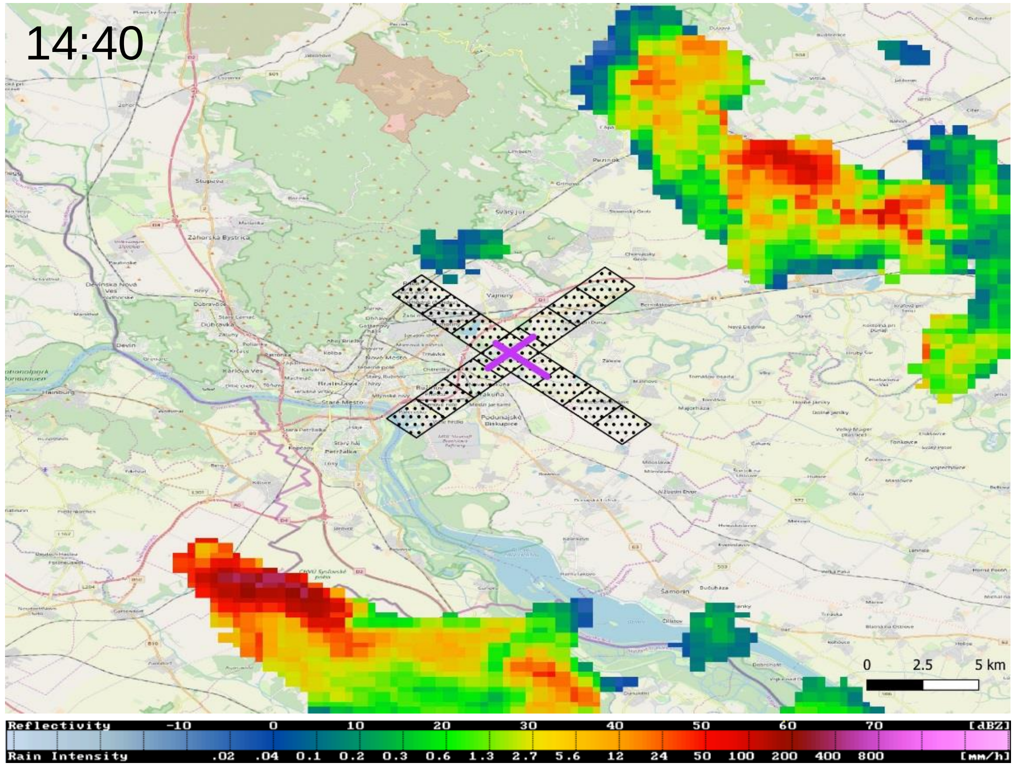

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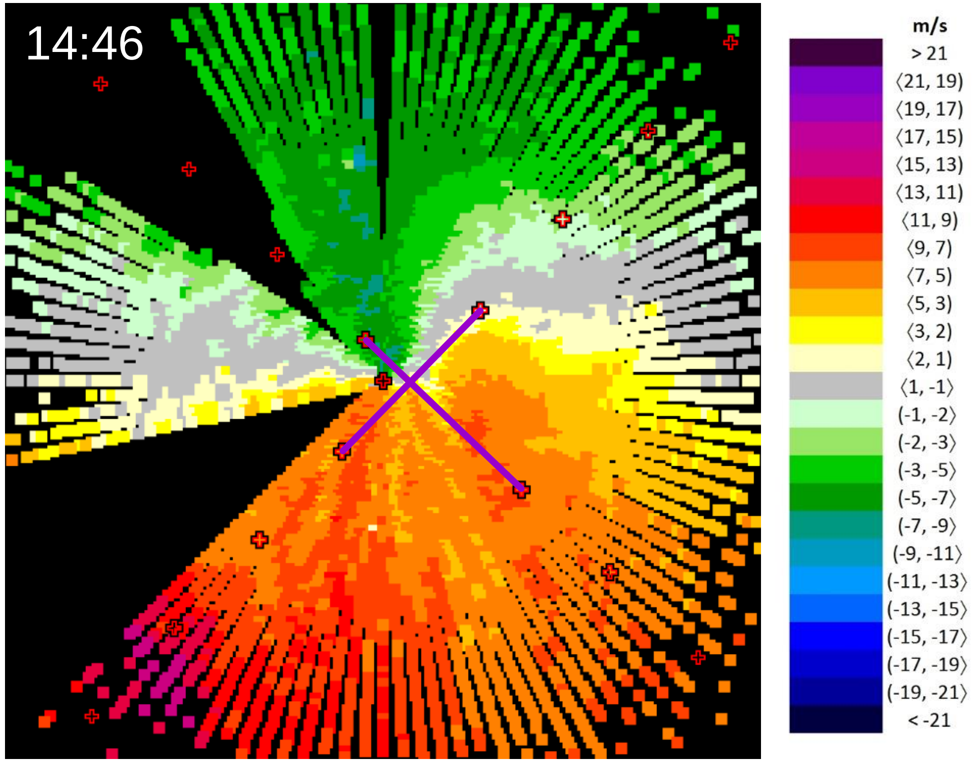

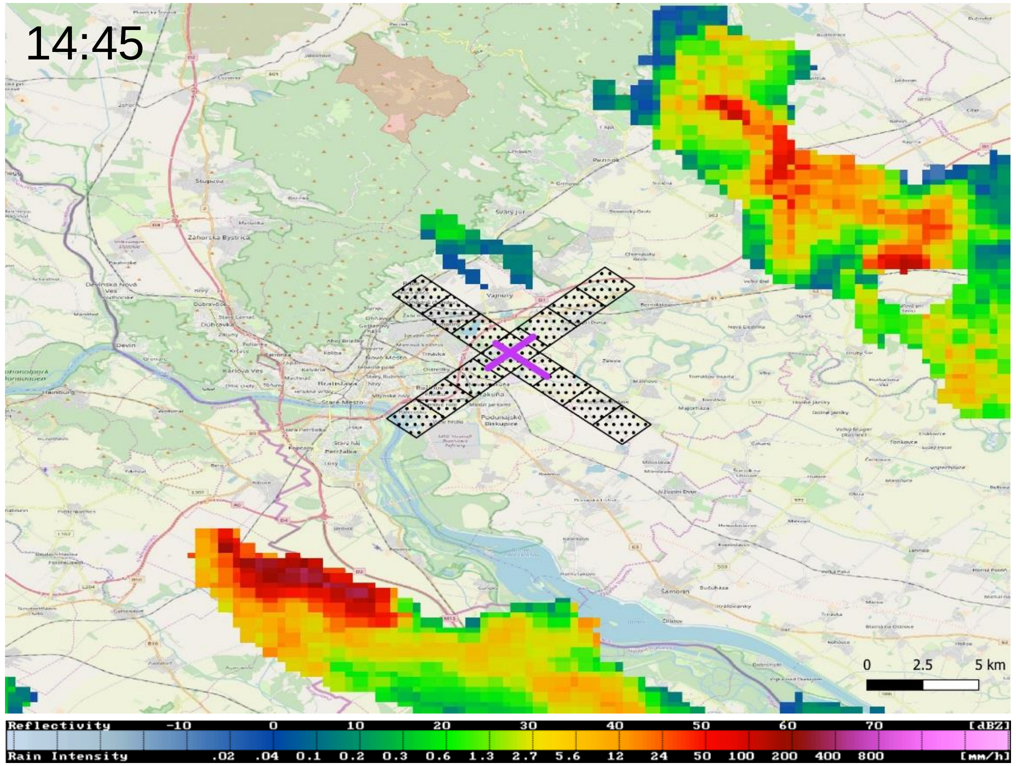

- increase in wind speed in SW
- the thunderstorm cell is approaching RWY 04

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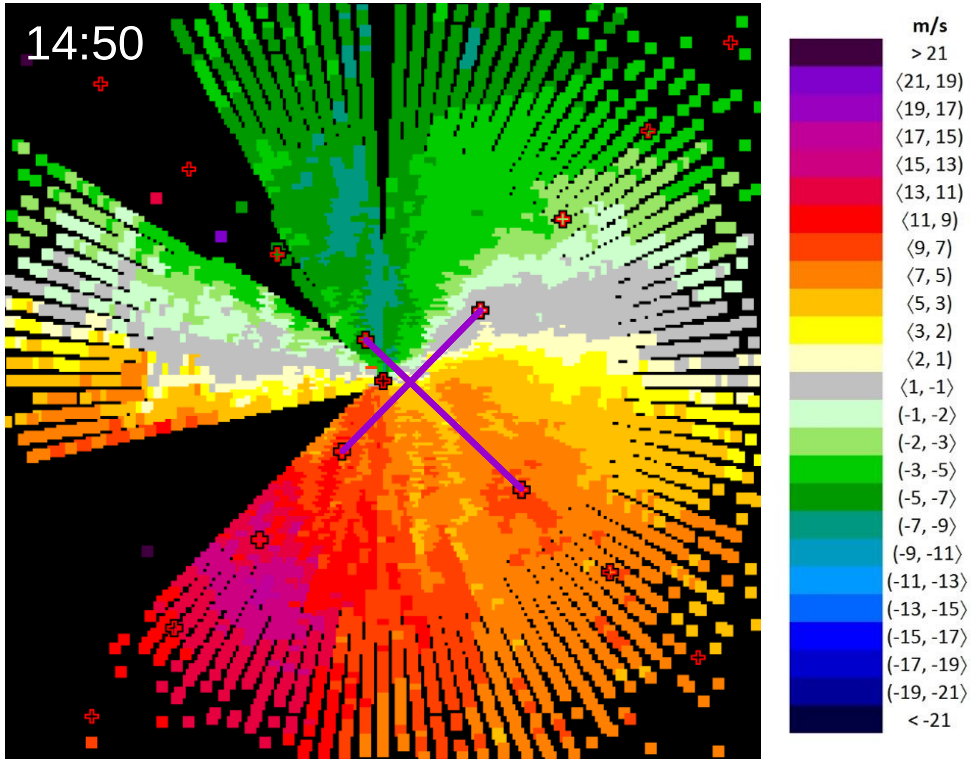

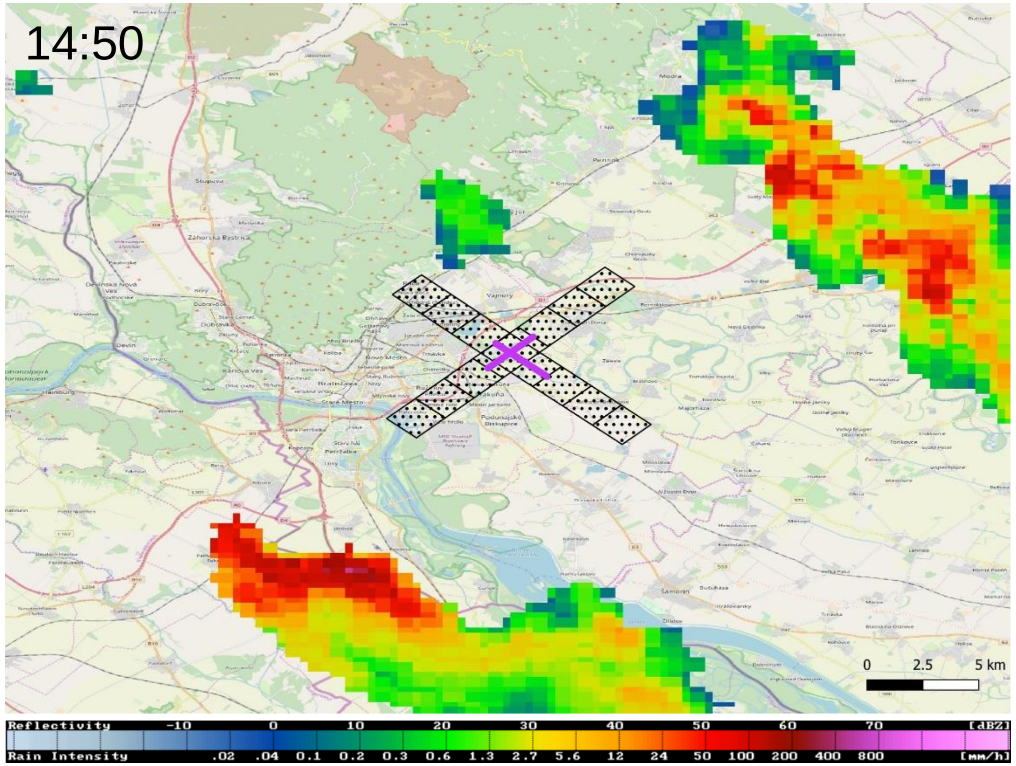

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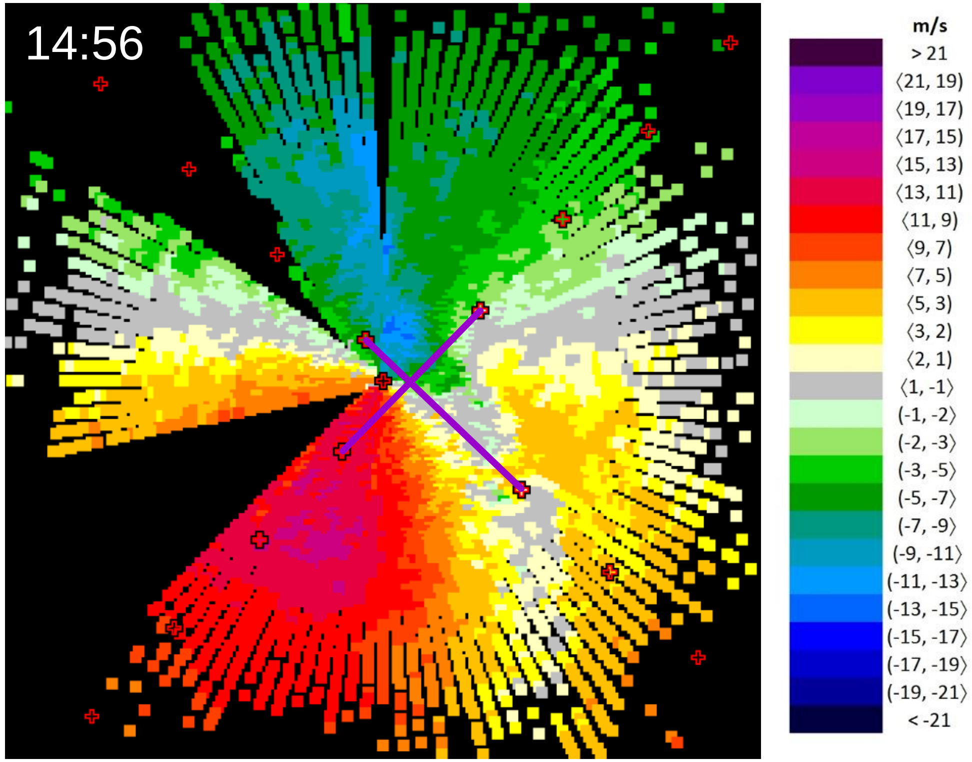

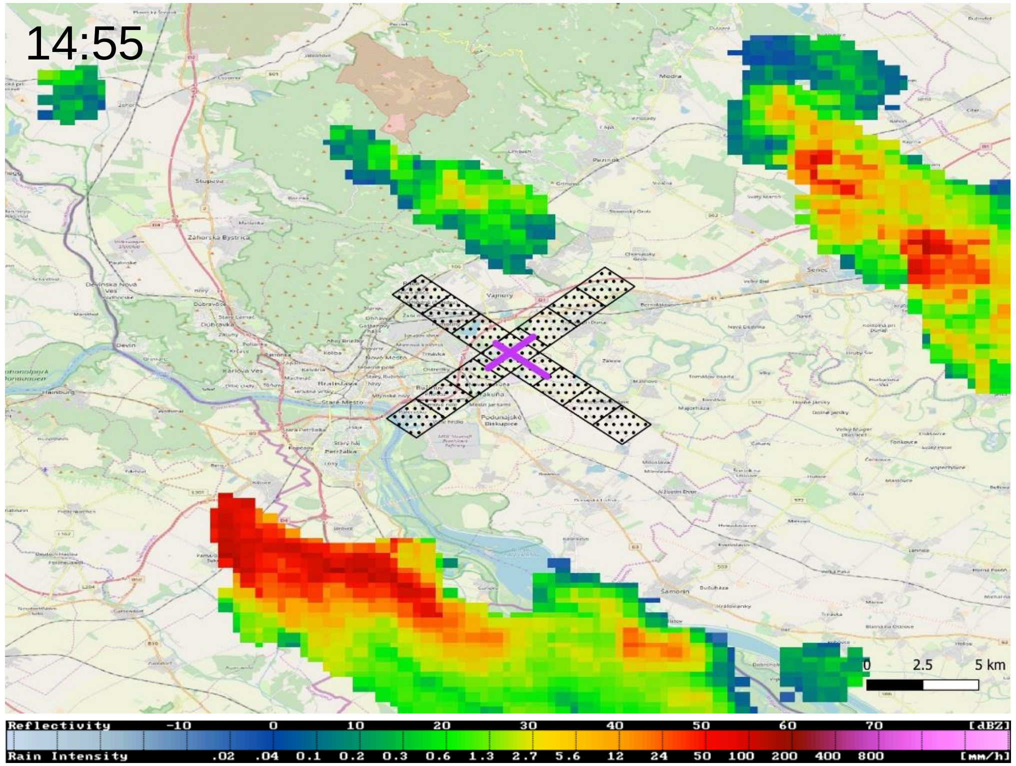

- the gust front (the divergent outflow from the thunderstorm cell) reaches the lidar

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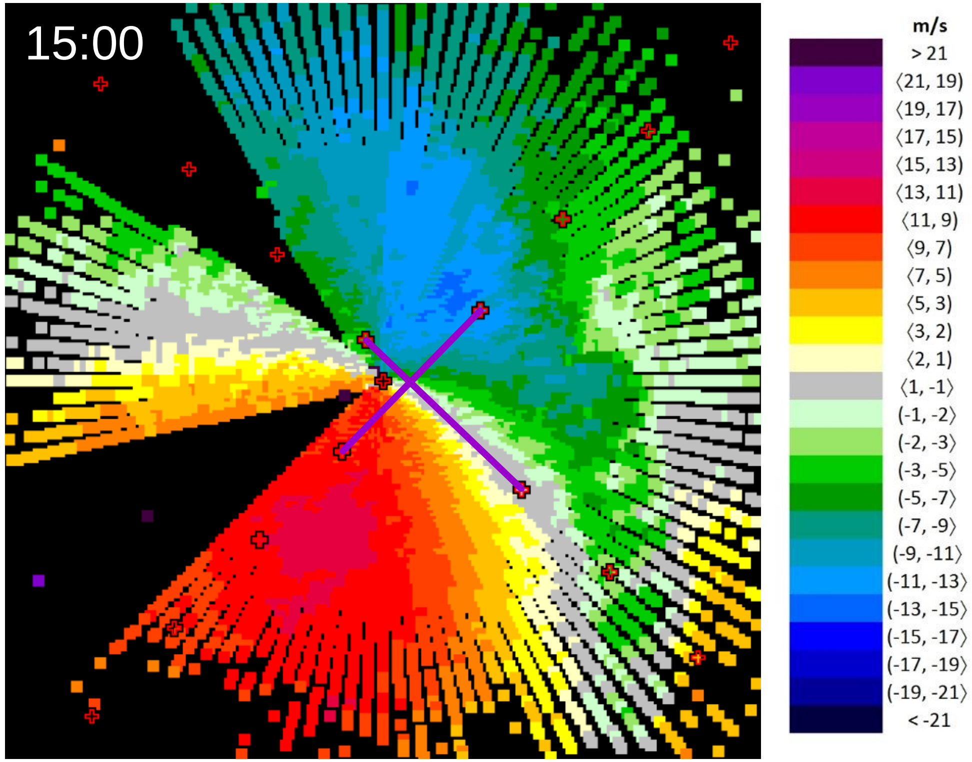

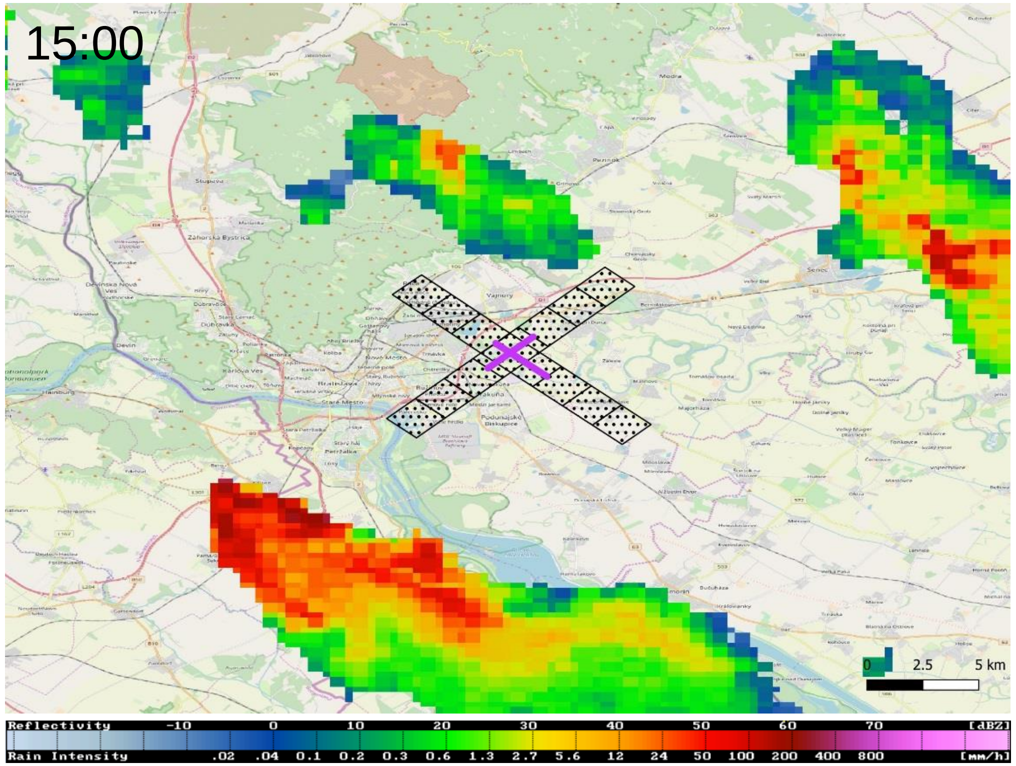

a complete redistribution of the wind field:

- maximum radial wind speed 15 m/s
- wind direction: from ~210°

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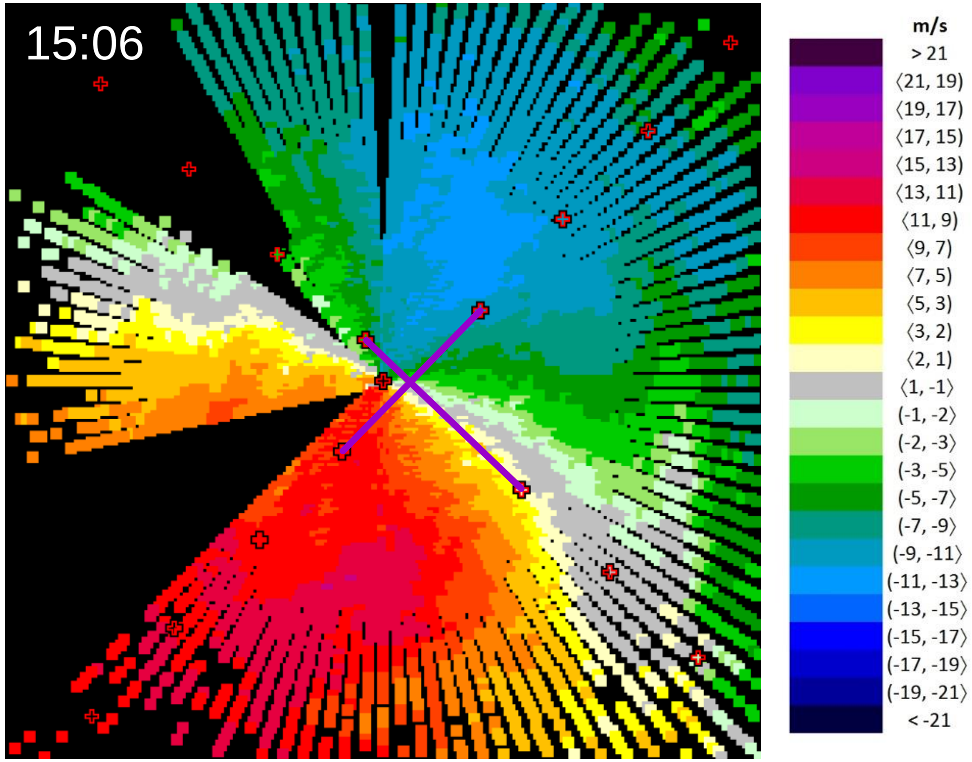

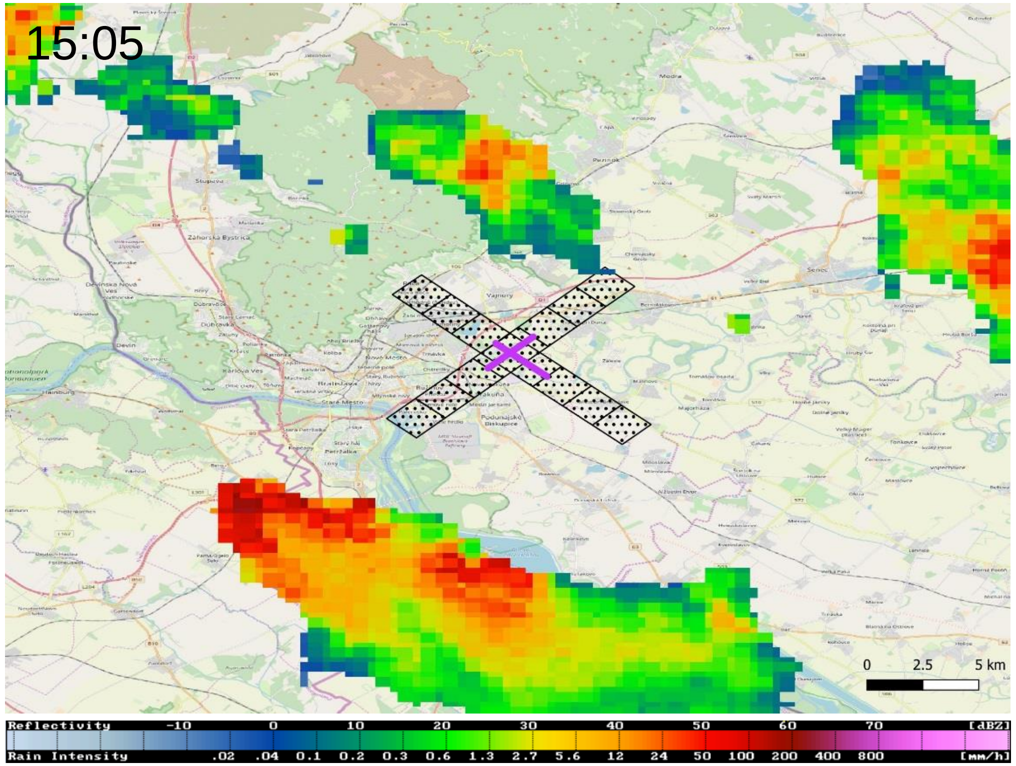

- the new situation remains stable for ~20 minutes

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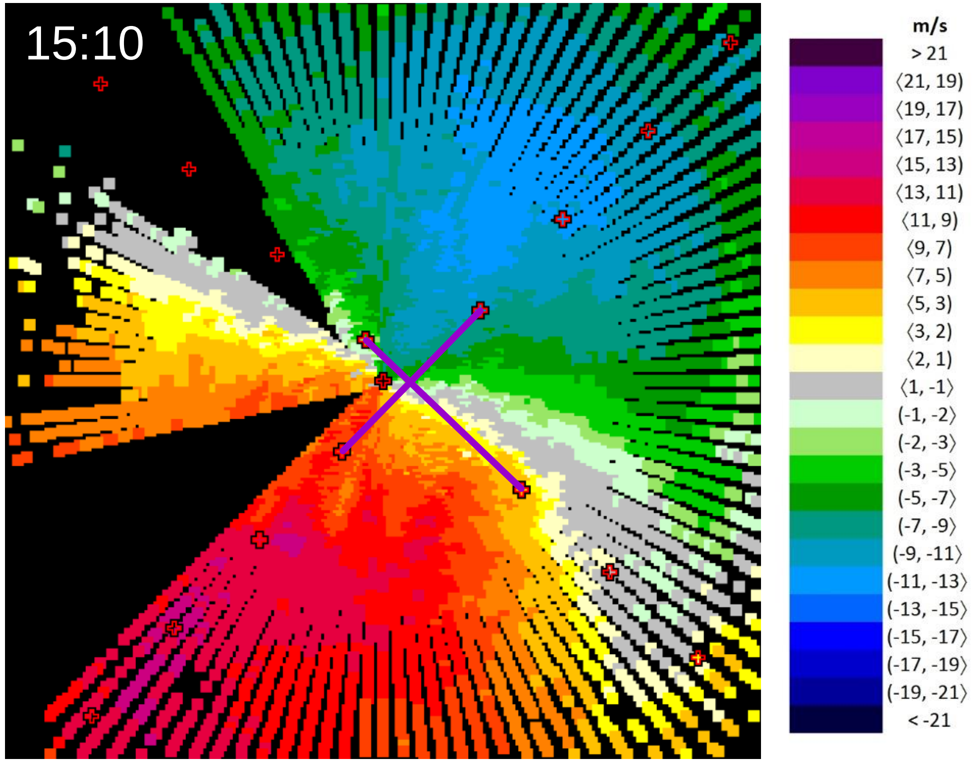

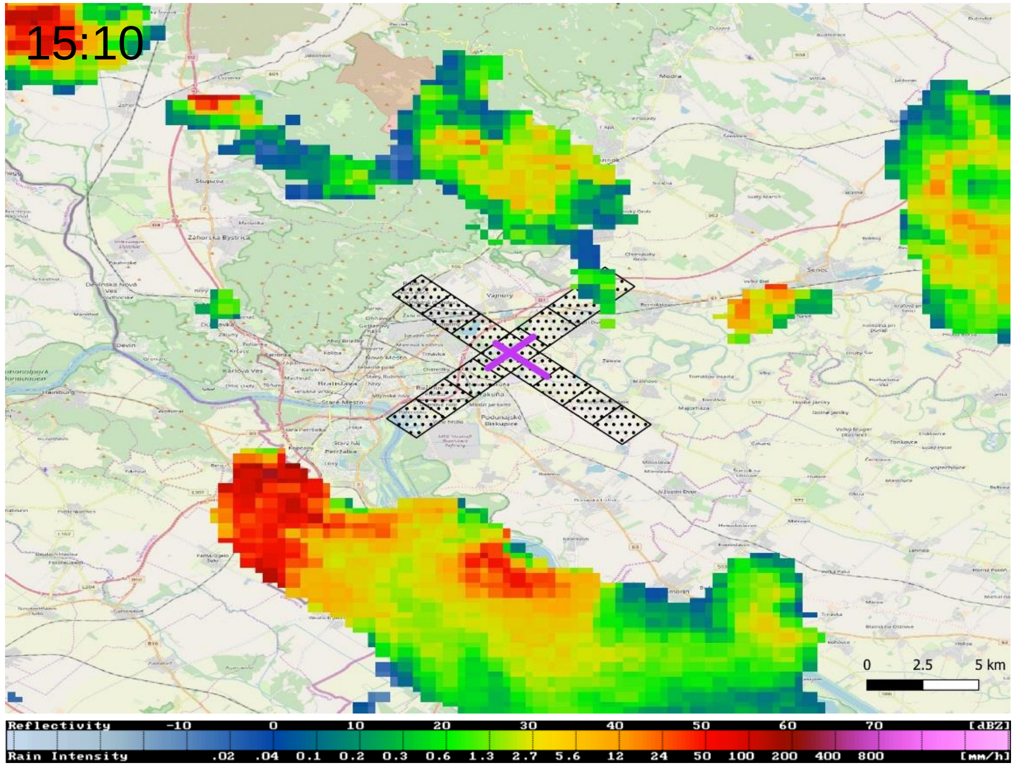

- the cell in SW weakens
- but a new thunderstorm cell is being formed in N-NE-E

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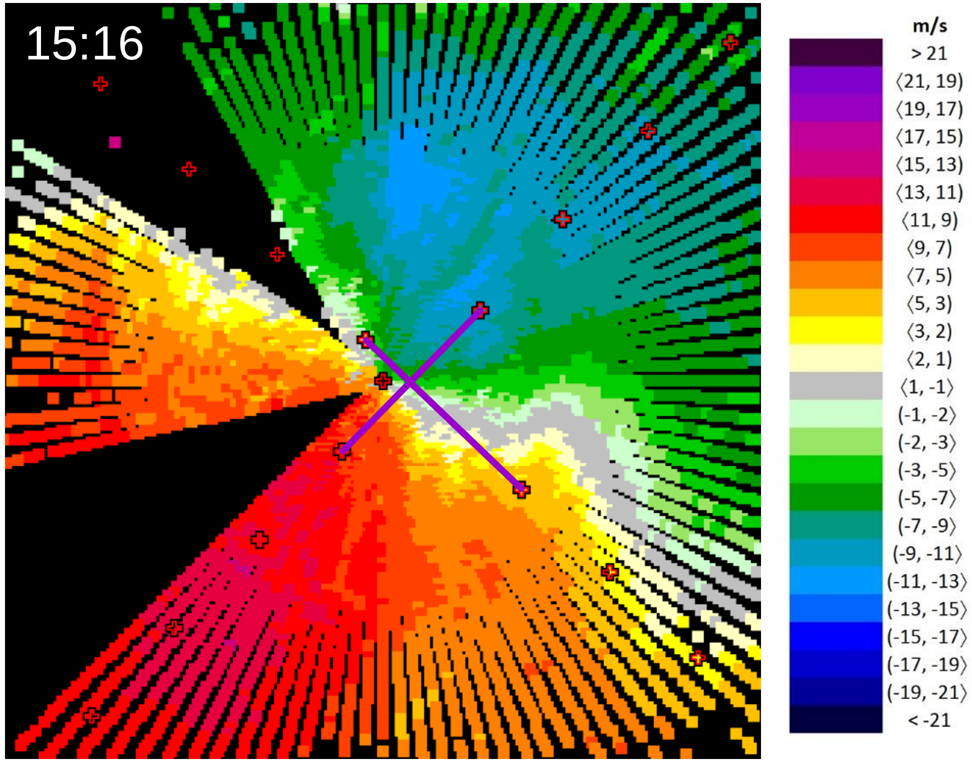

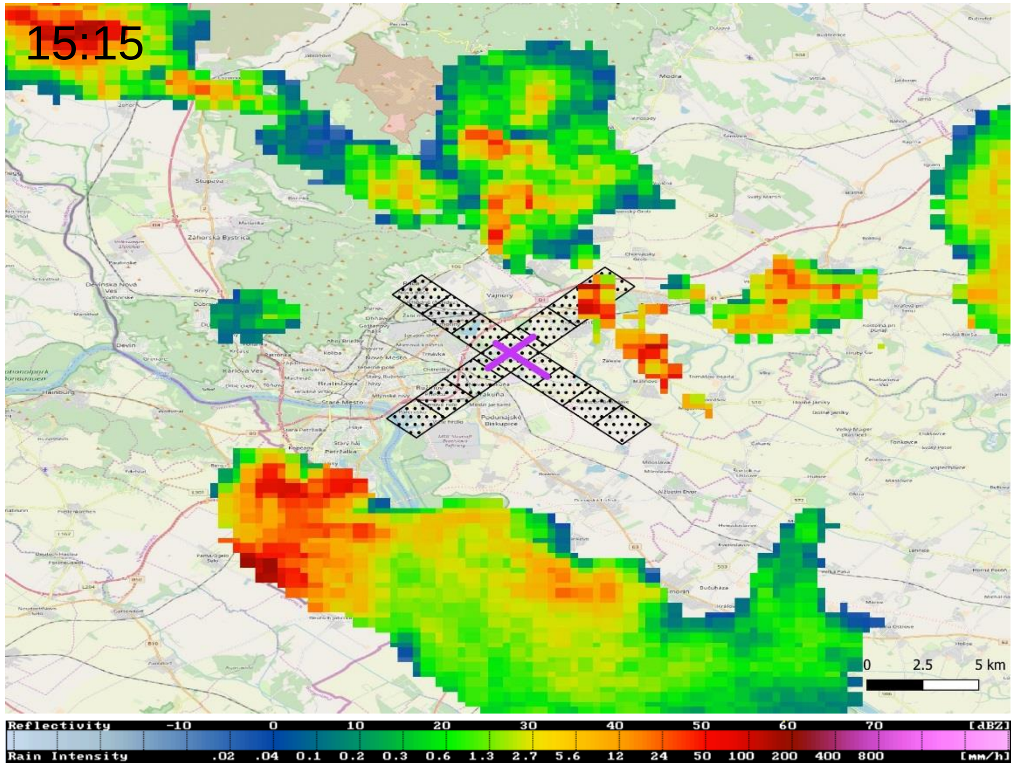

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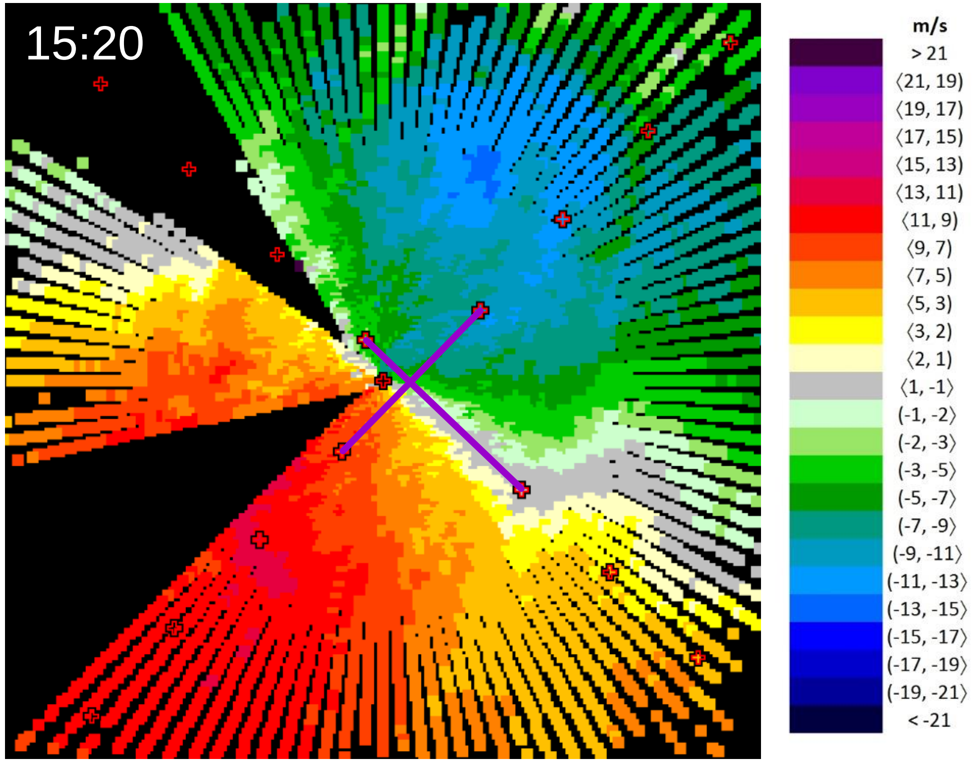

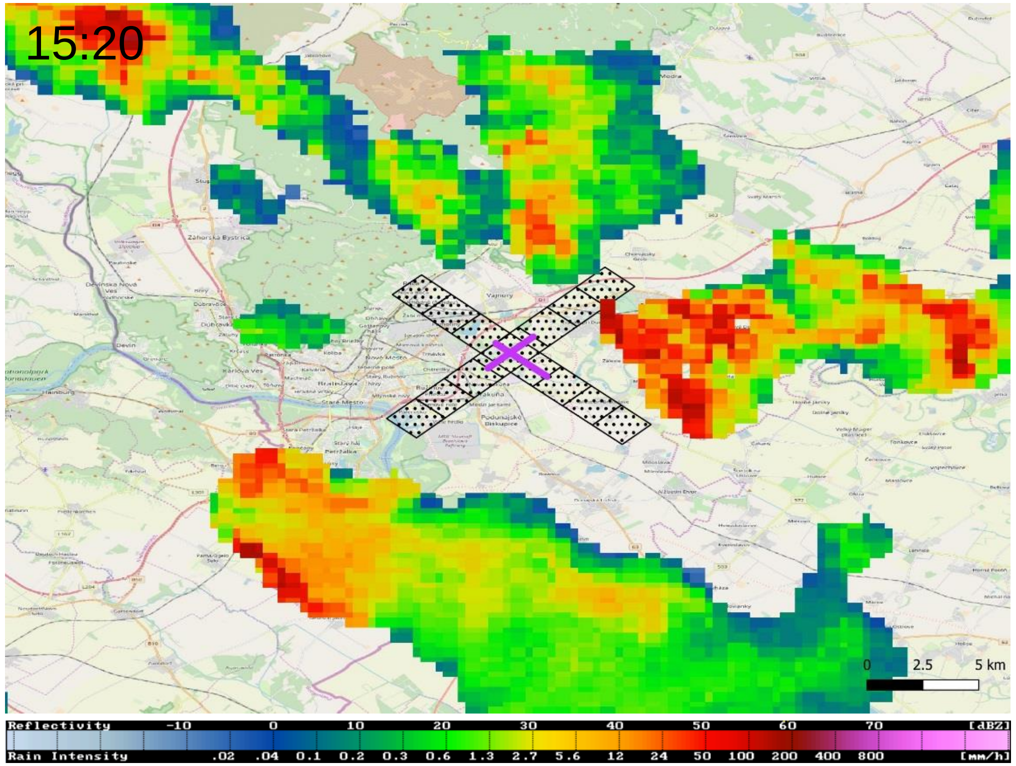

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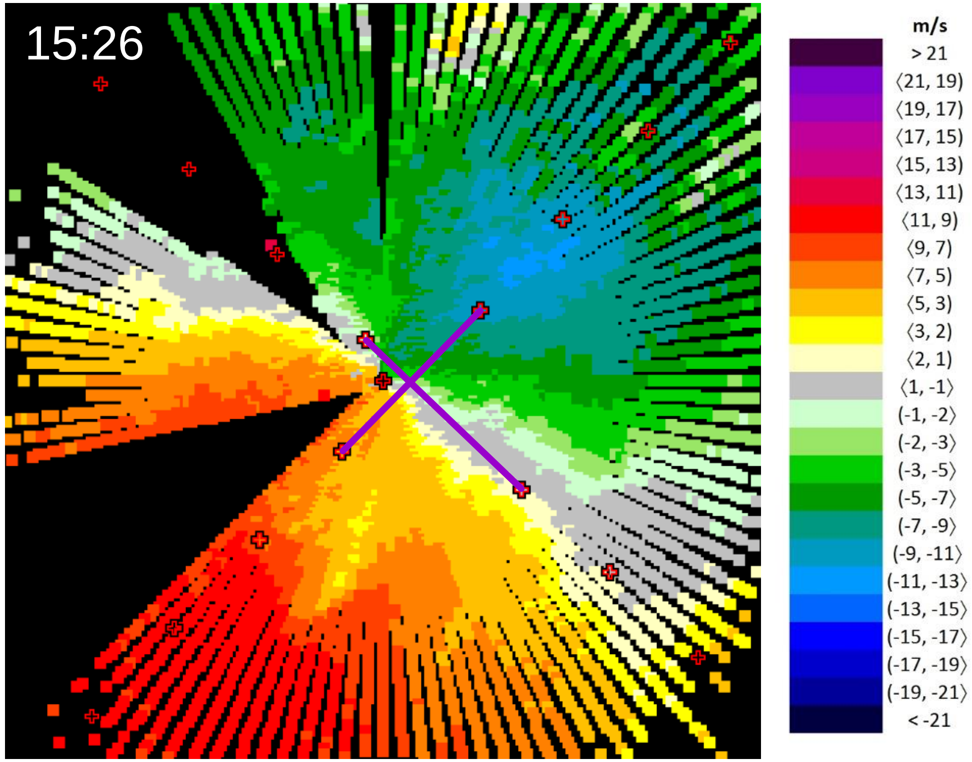

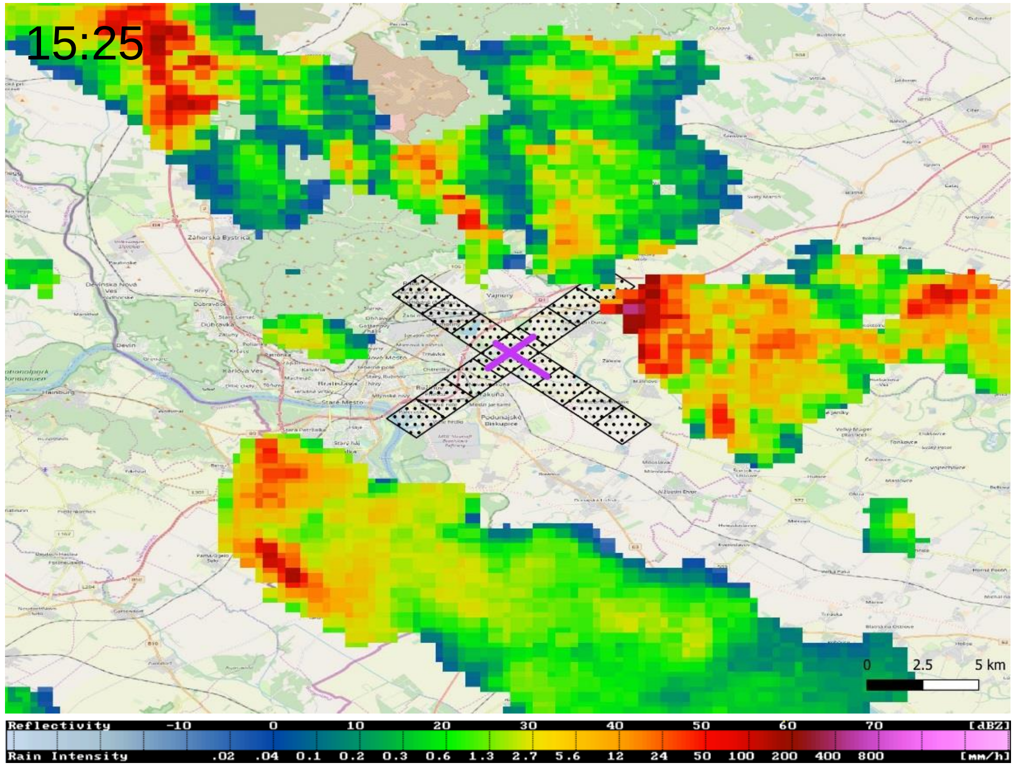

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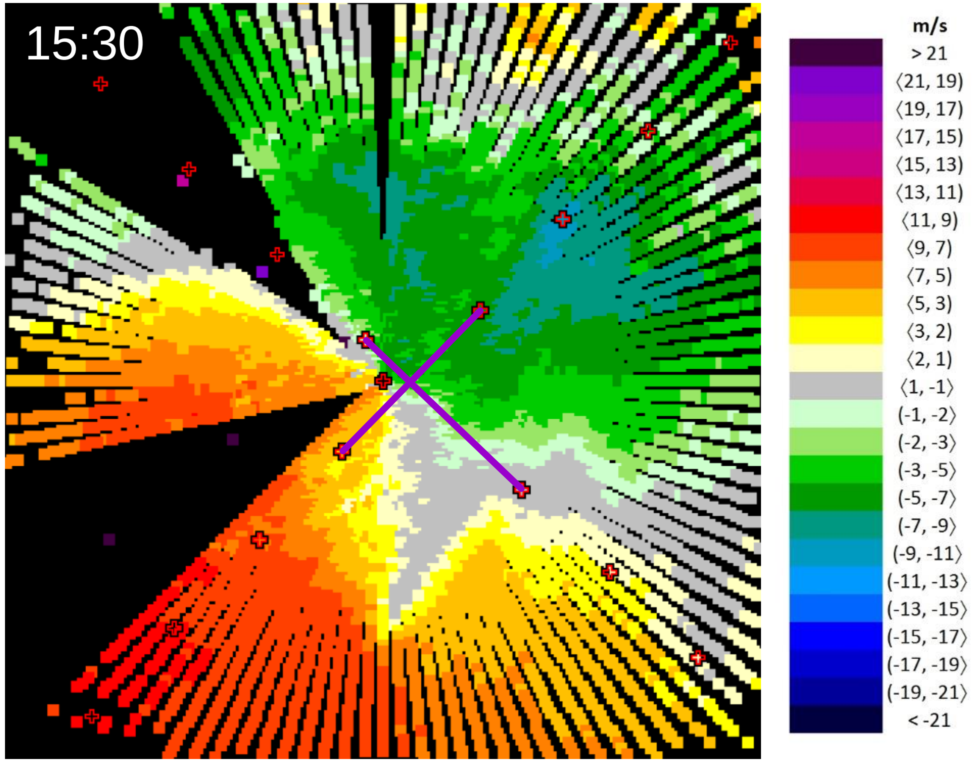

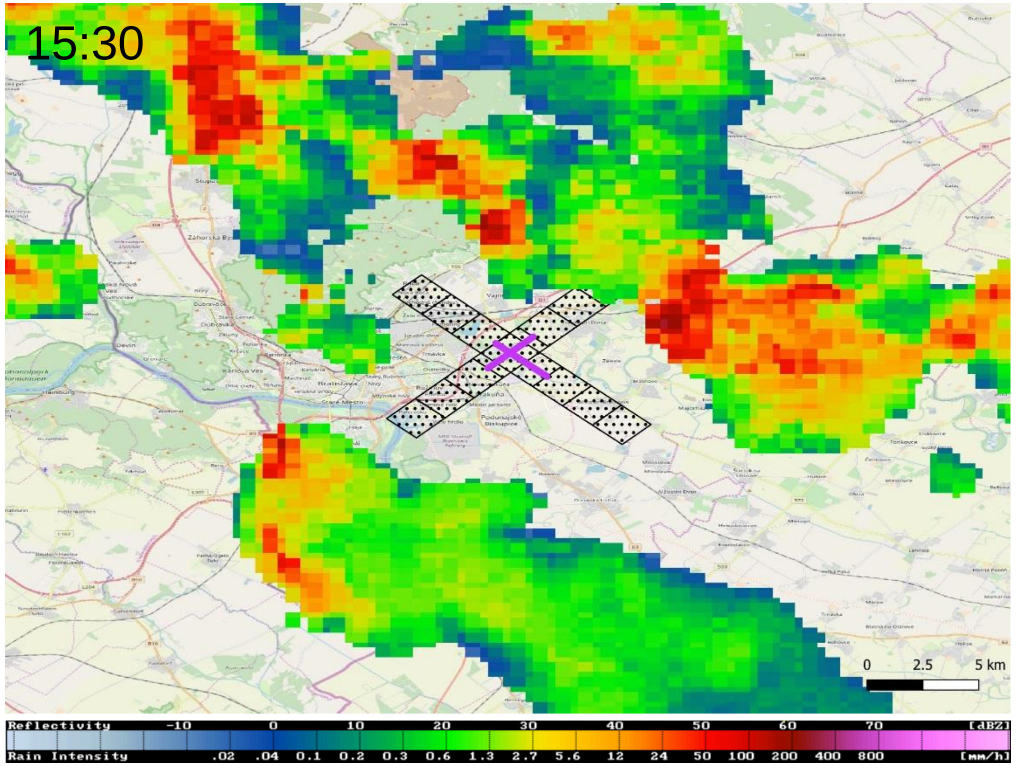

- the wind field starts changing from NE

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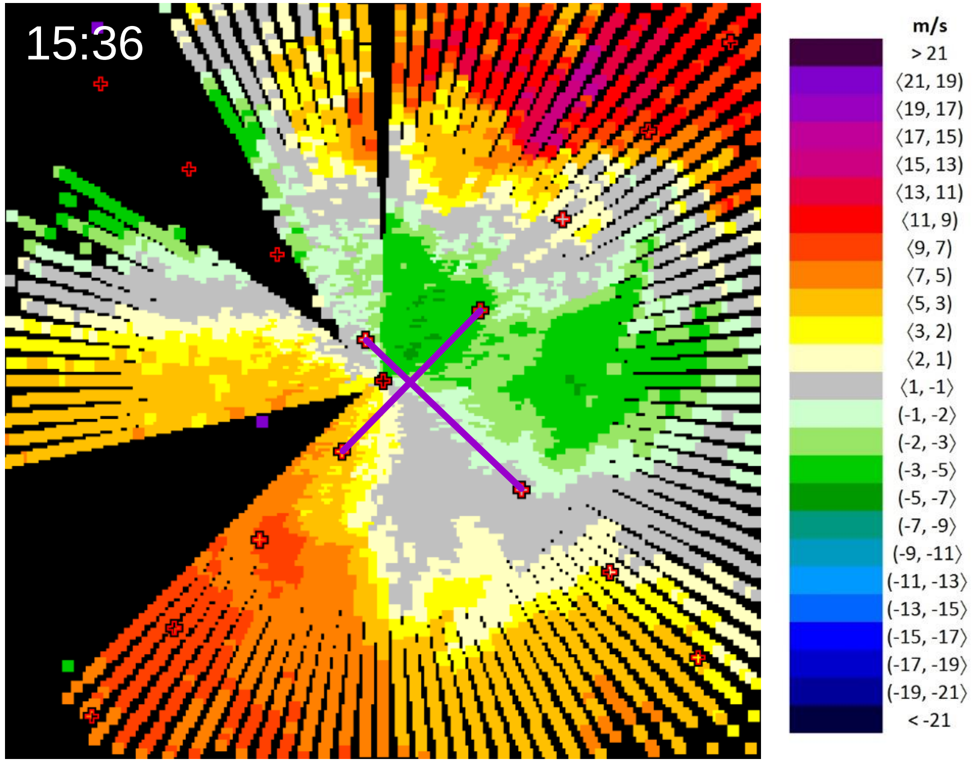

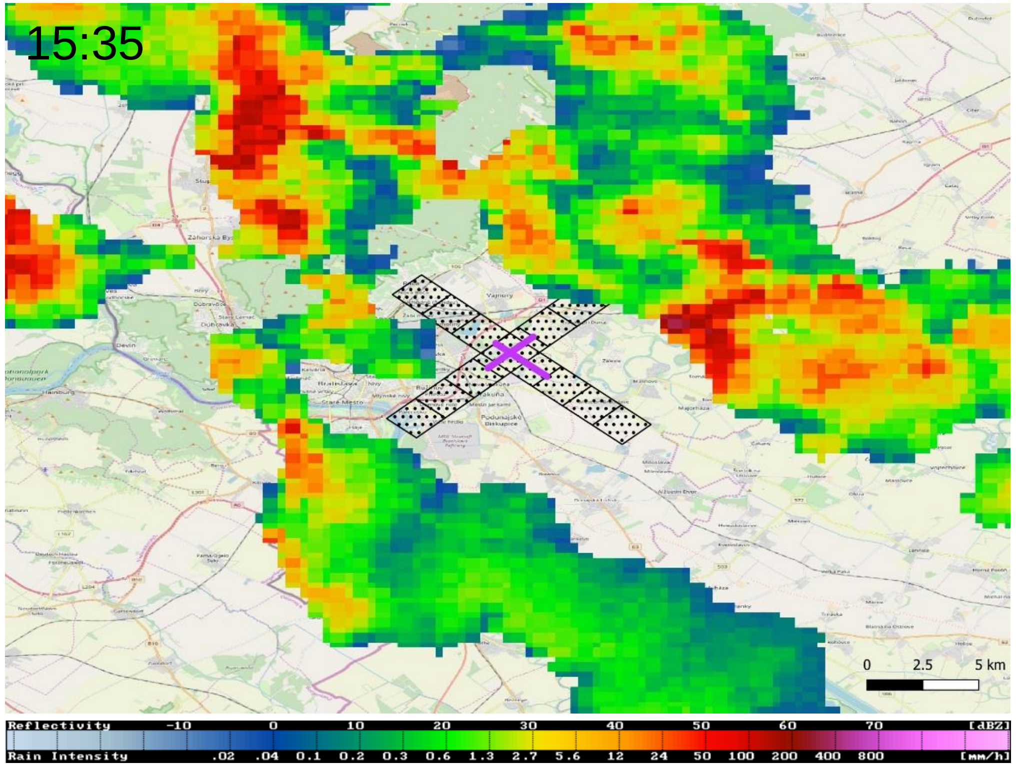

- a further gust front (#2) is moving rapidly towards the airport from NE

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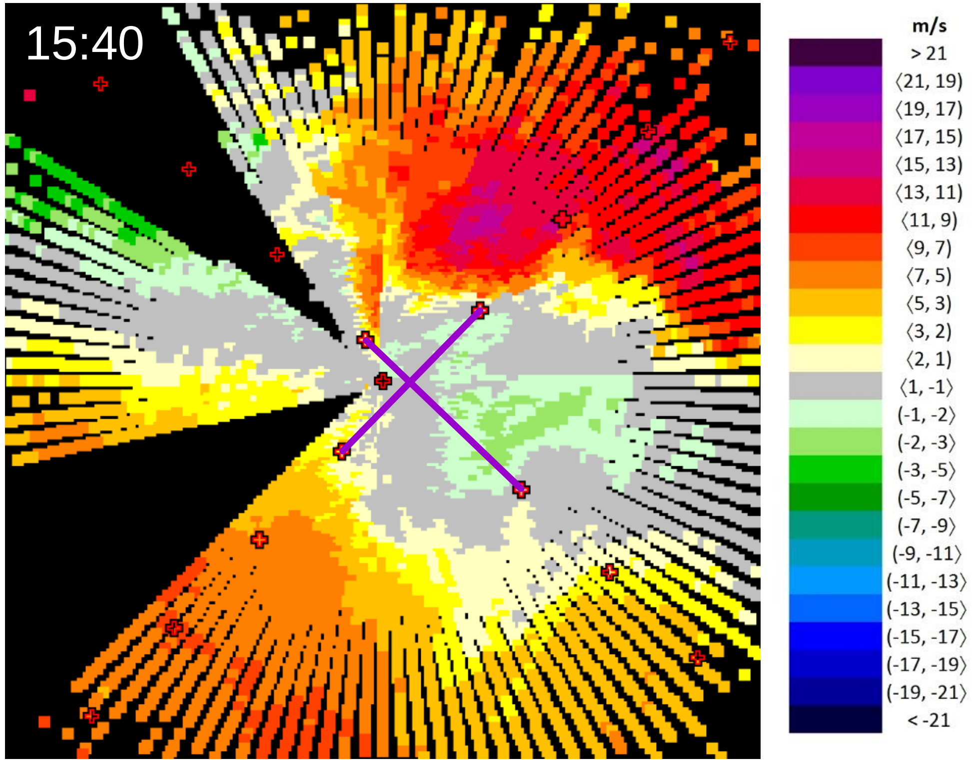

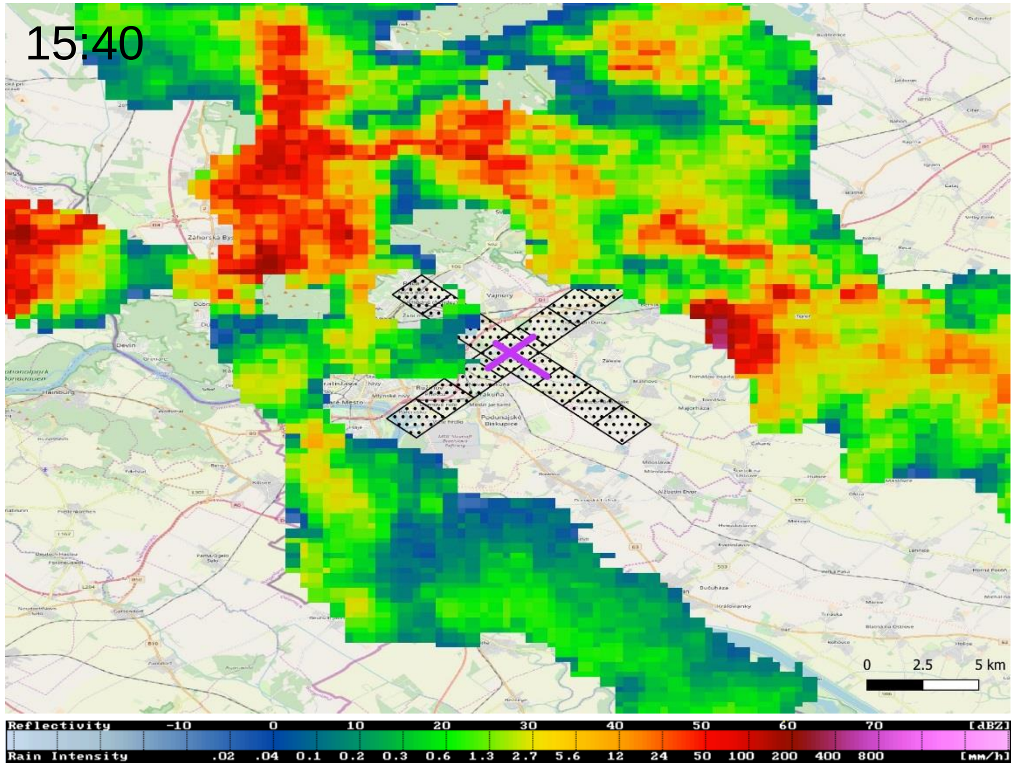

the wind blows towards the lidar from 2 directions:

- from NE (due to gust front movement), and
- from SW (due to the prevailing flow in the area)

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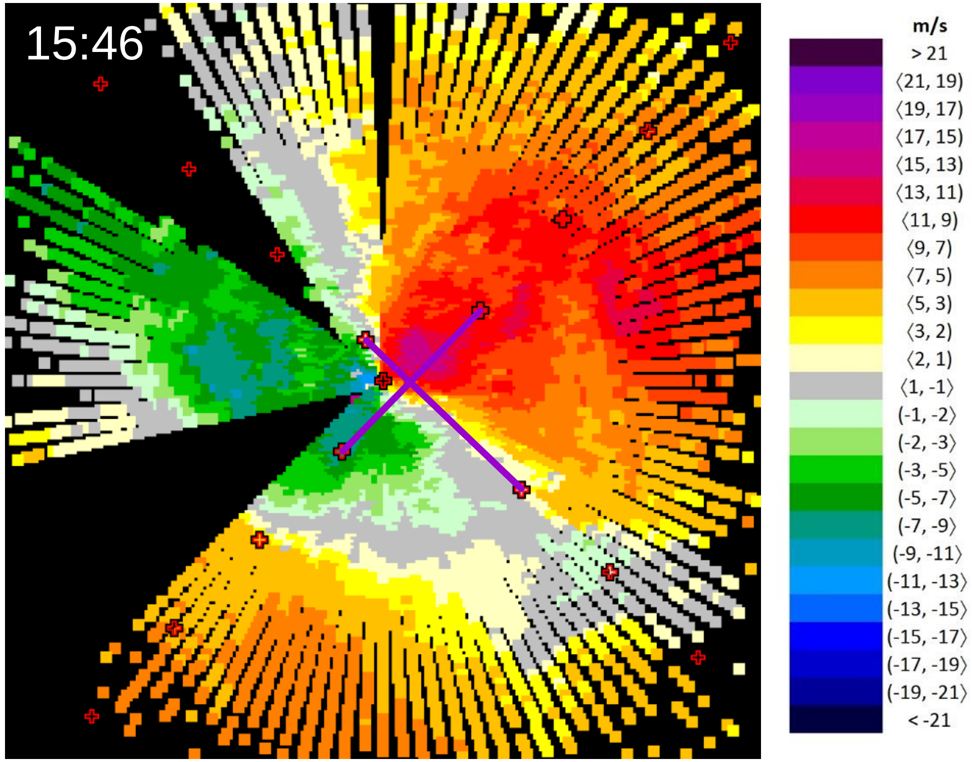

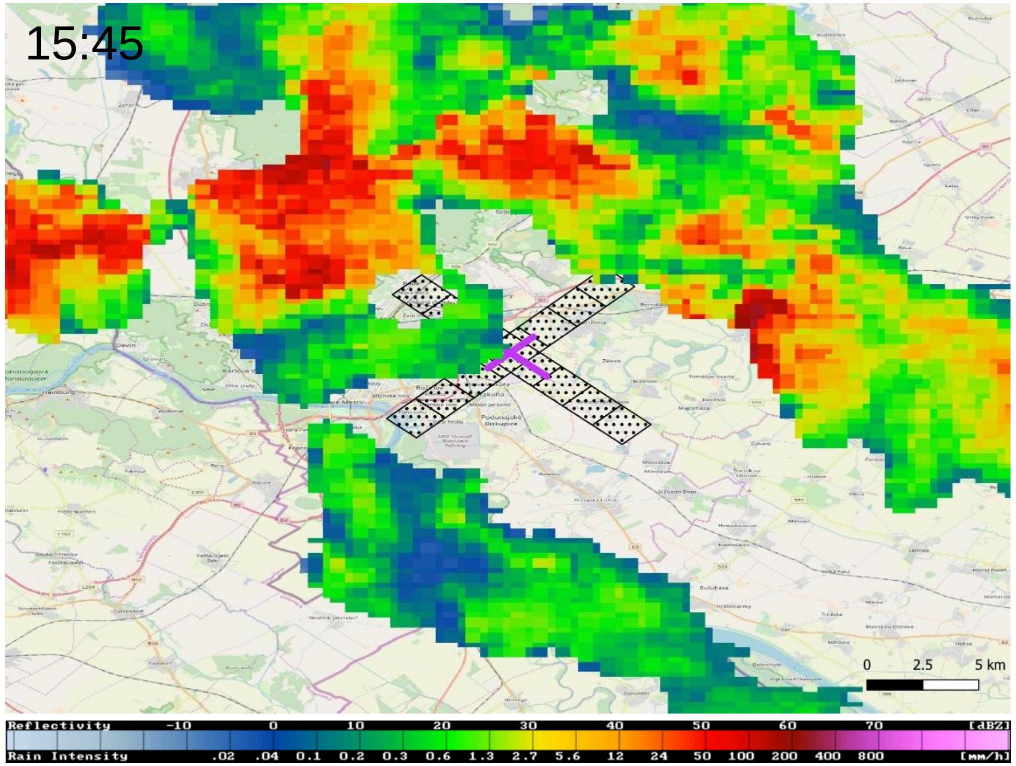

- another thunderstorm cell is developing in W-NW

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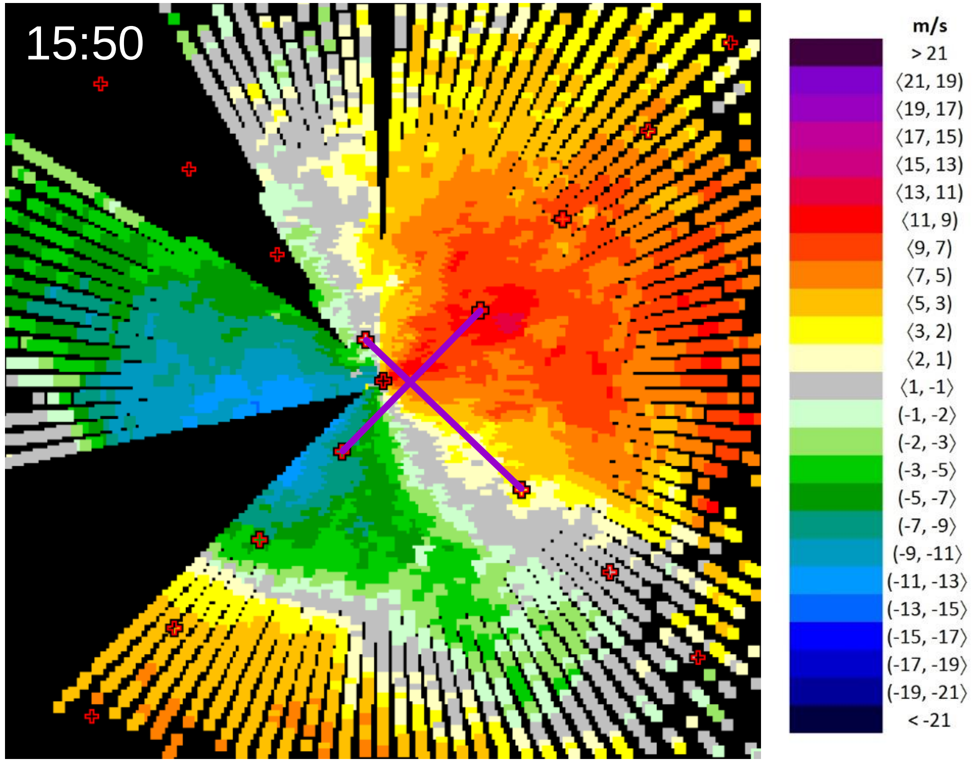

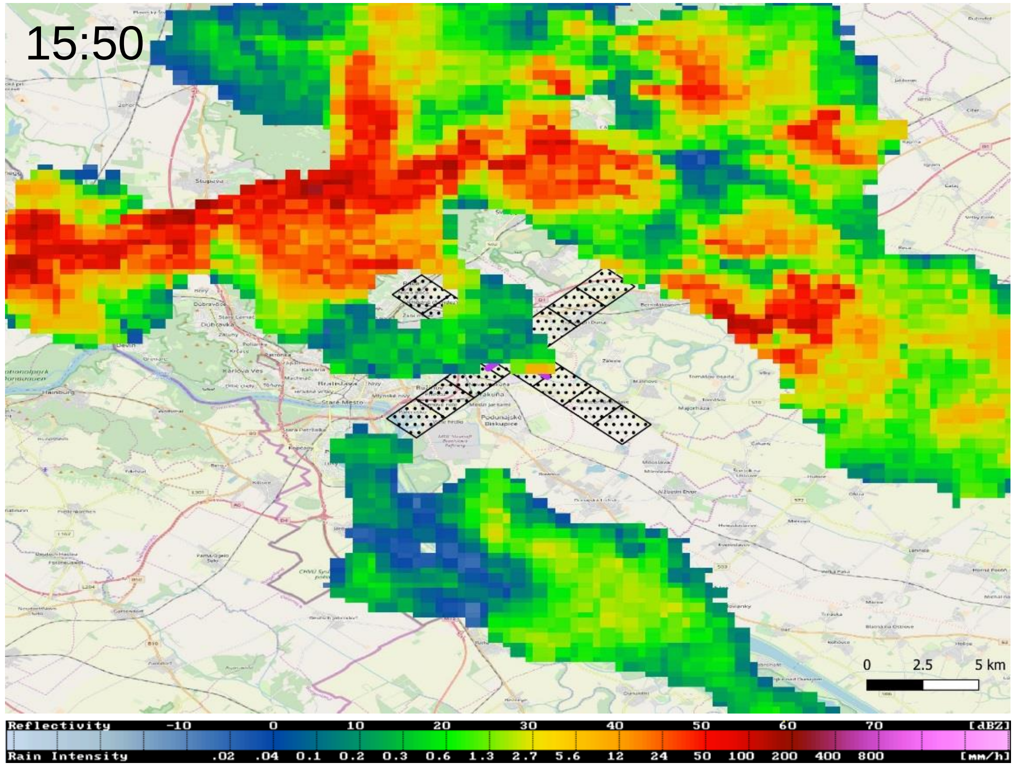

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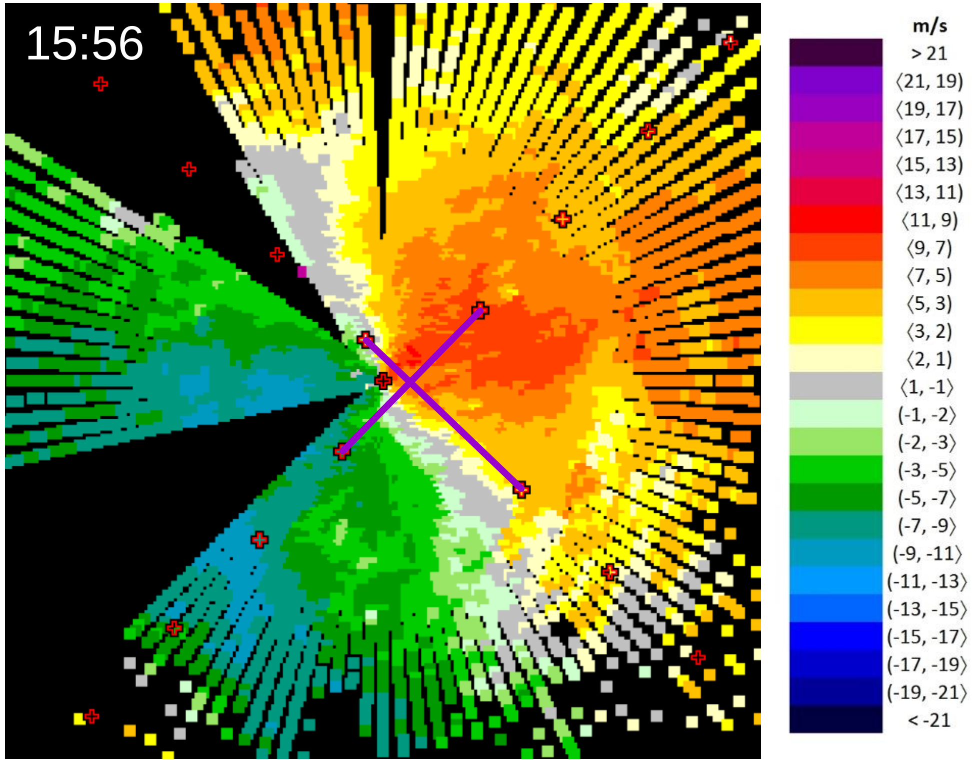

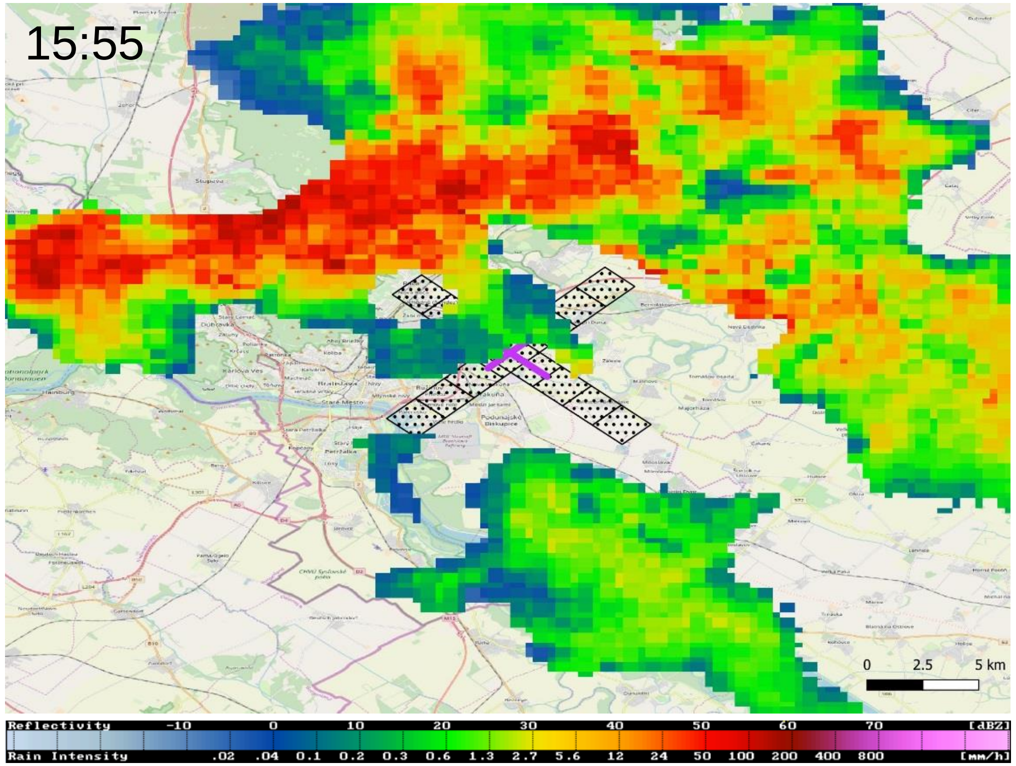

the new stable wind field after passing the gust front #2:

- wind direction from ~40°
- maximum radial wind speed 13 m/s

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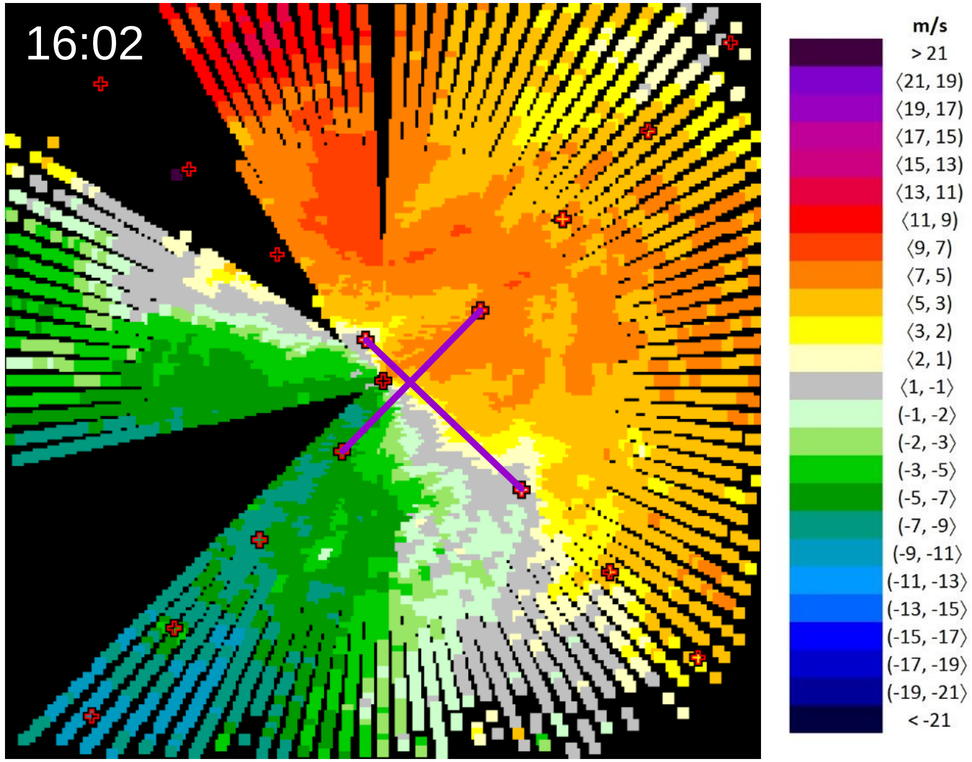

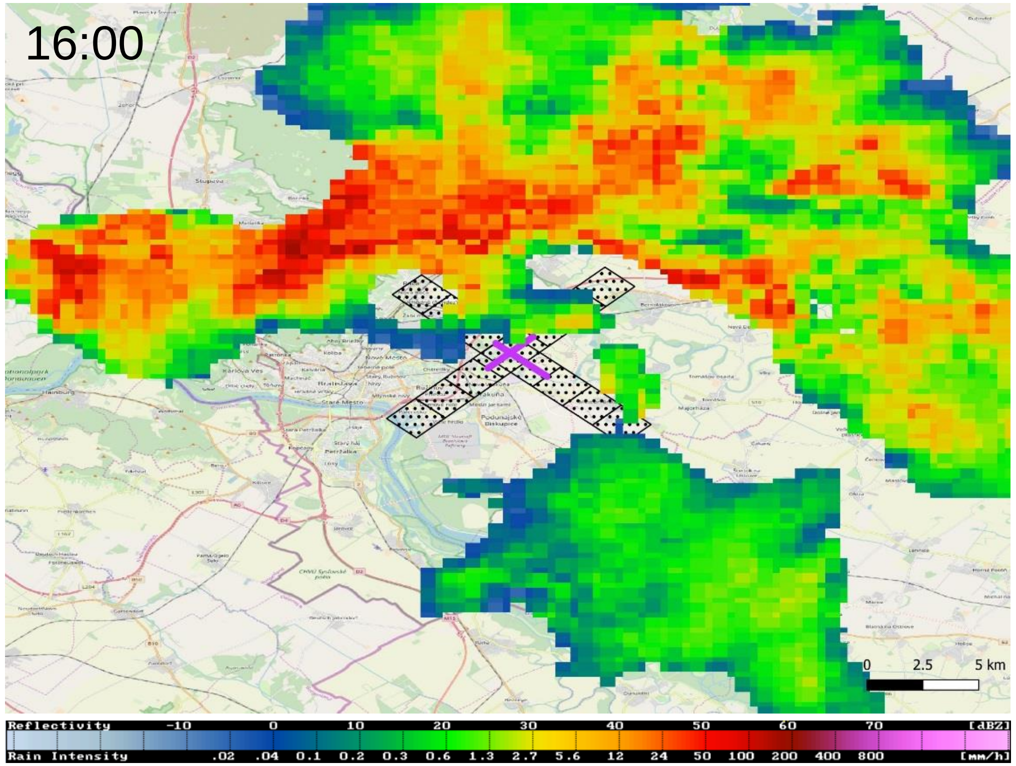

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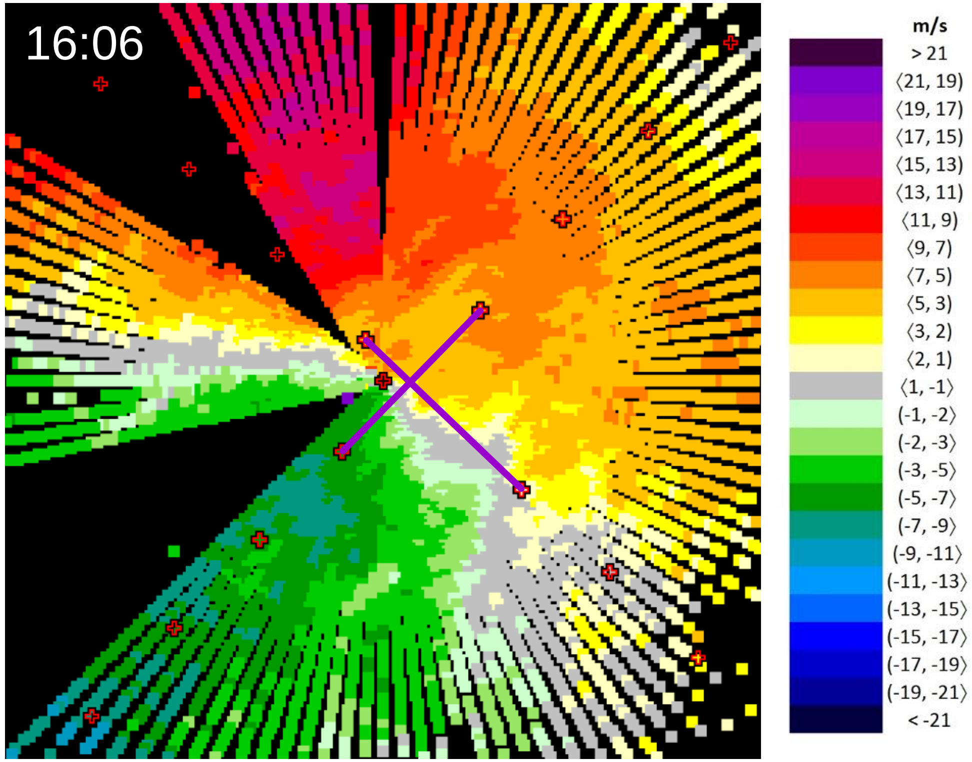

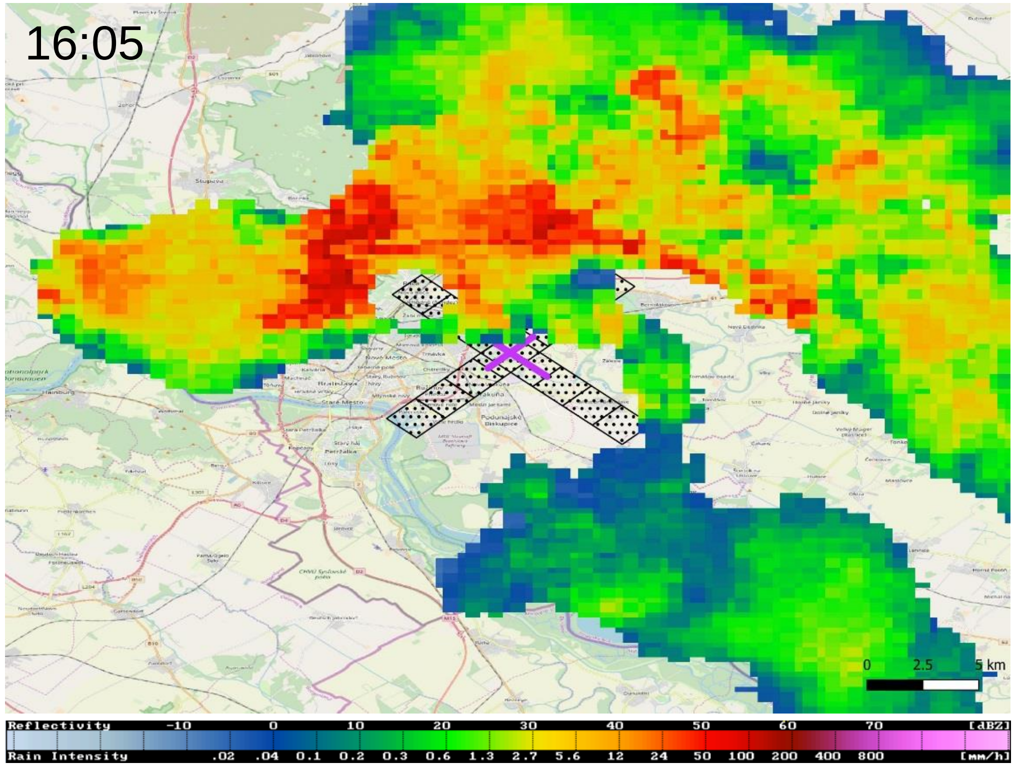

- the last gust front (#3) is approaching from NW

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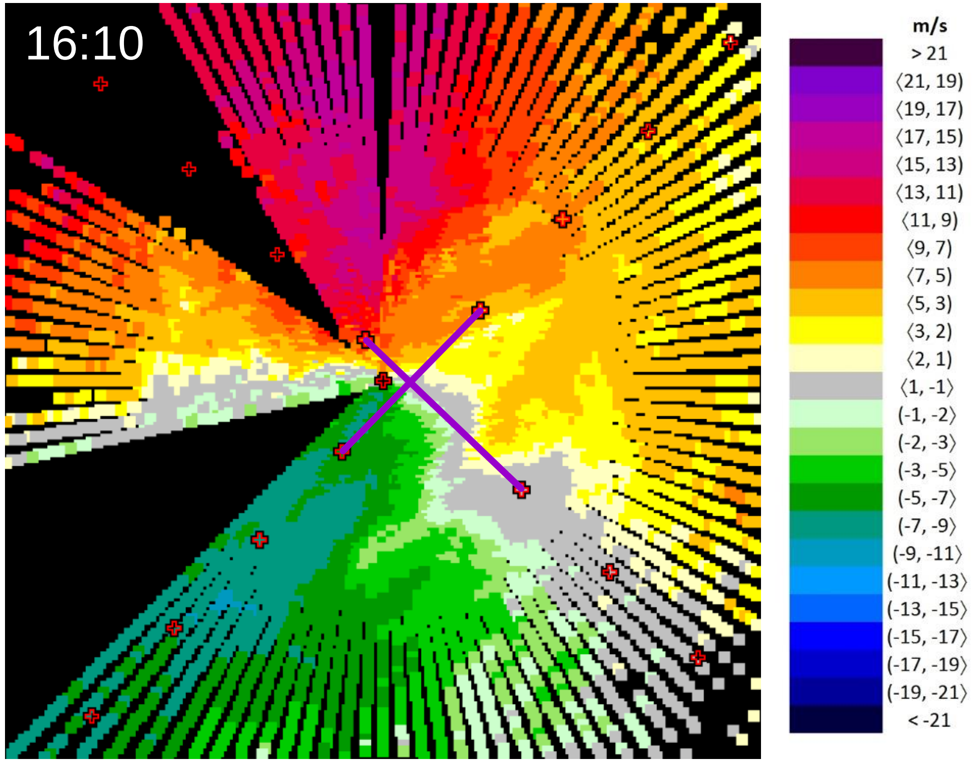

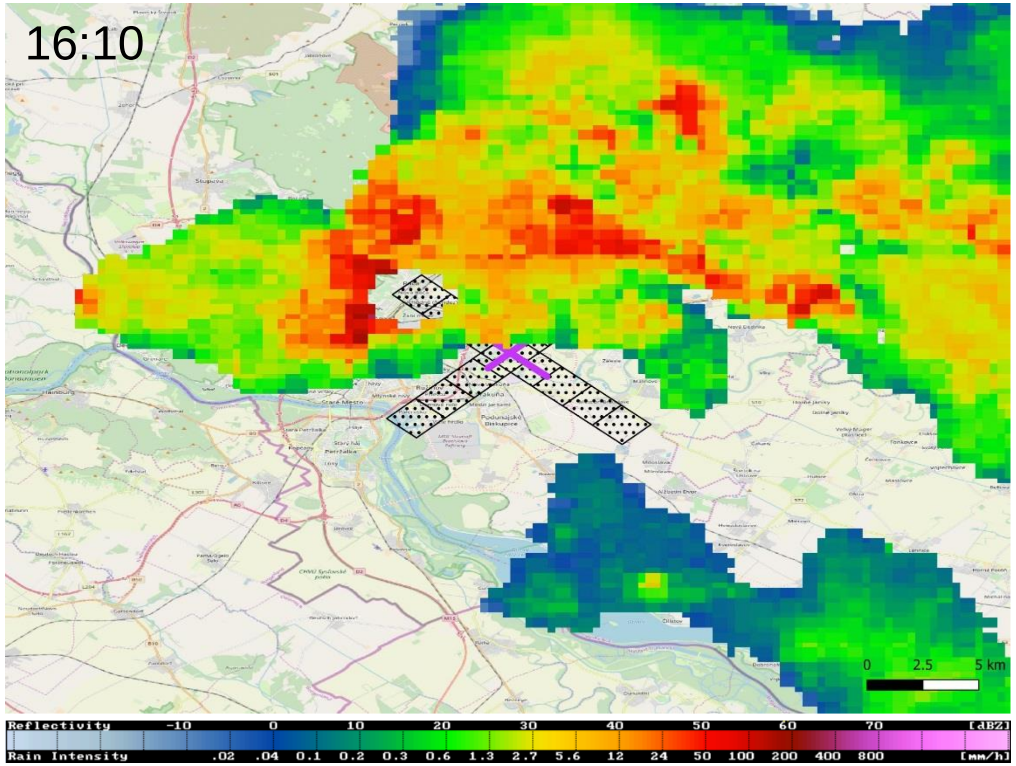

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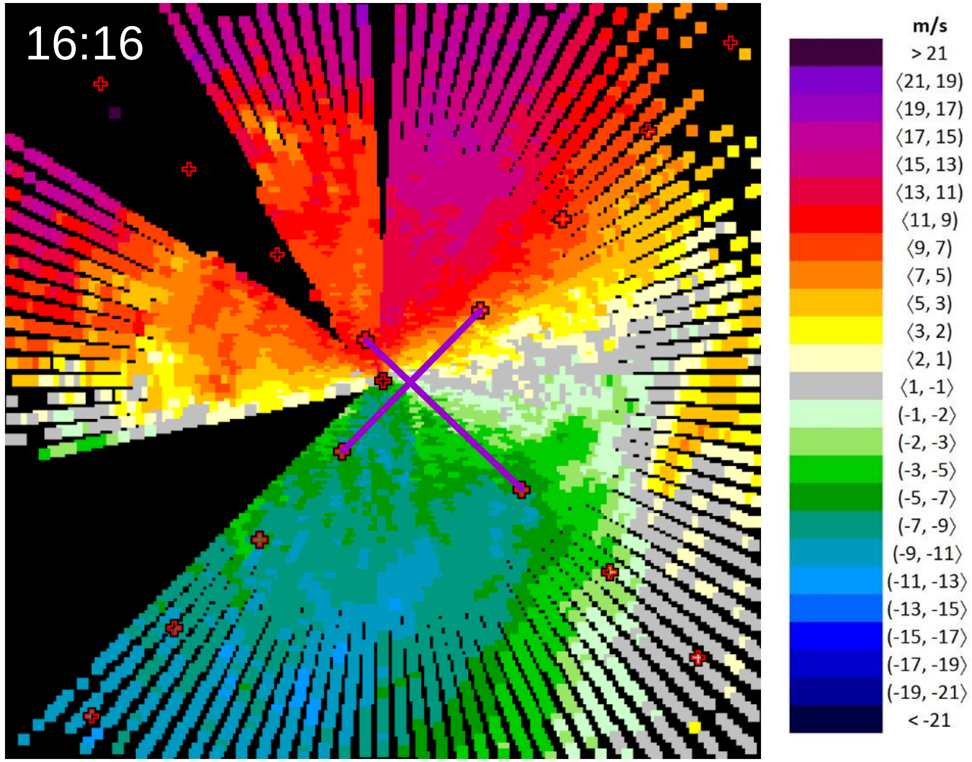

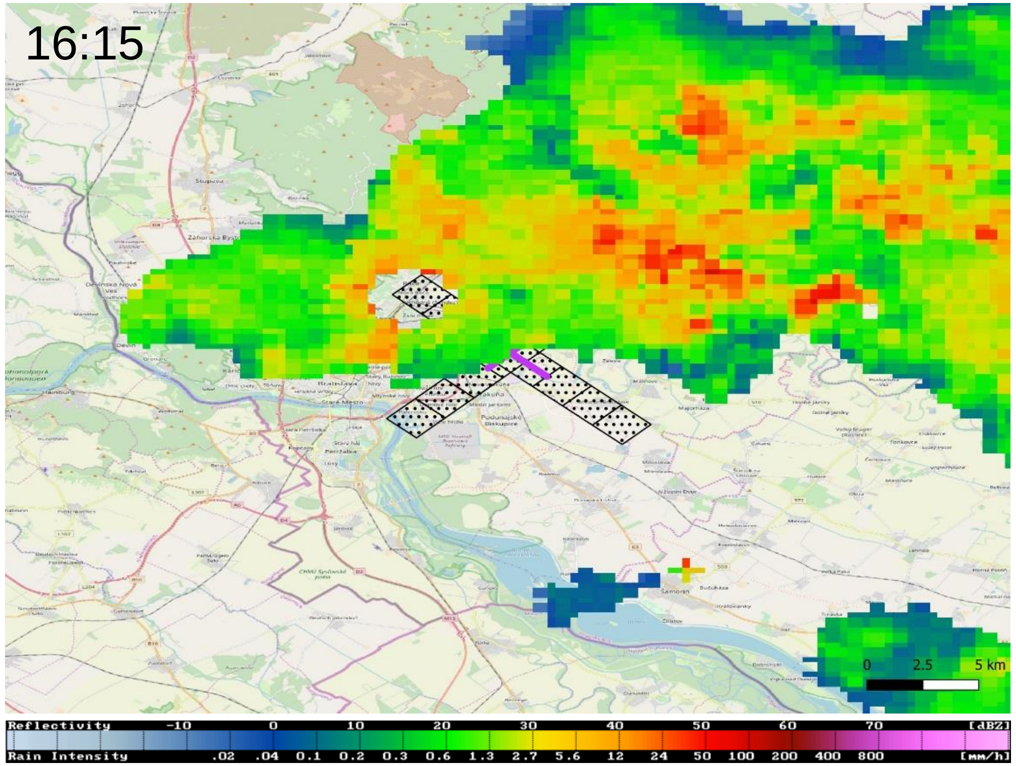

- maximum radial wind speed: 19 m/s

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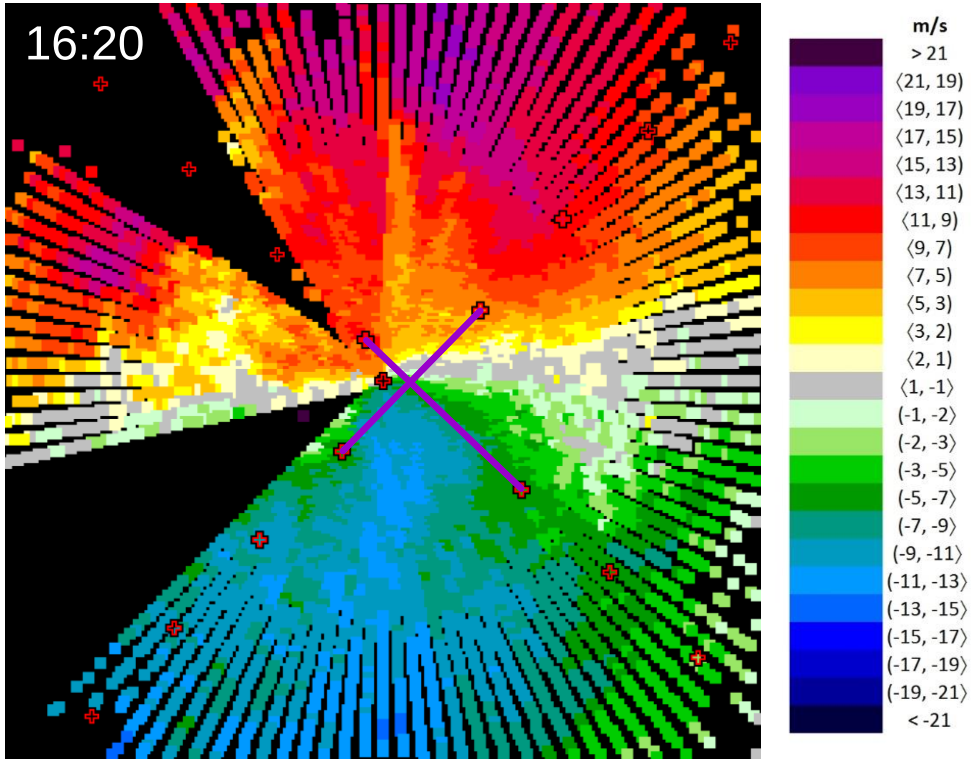

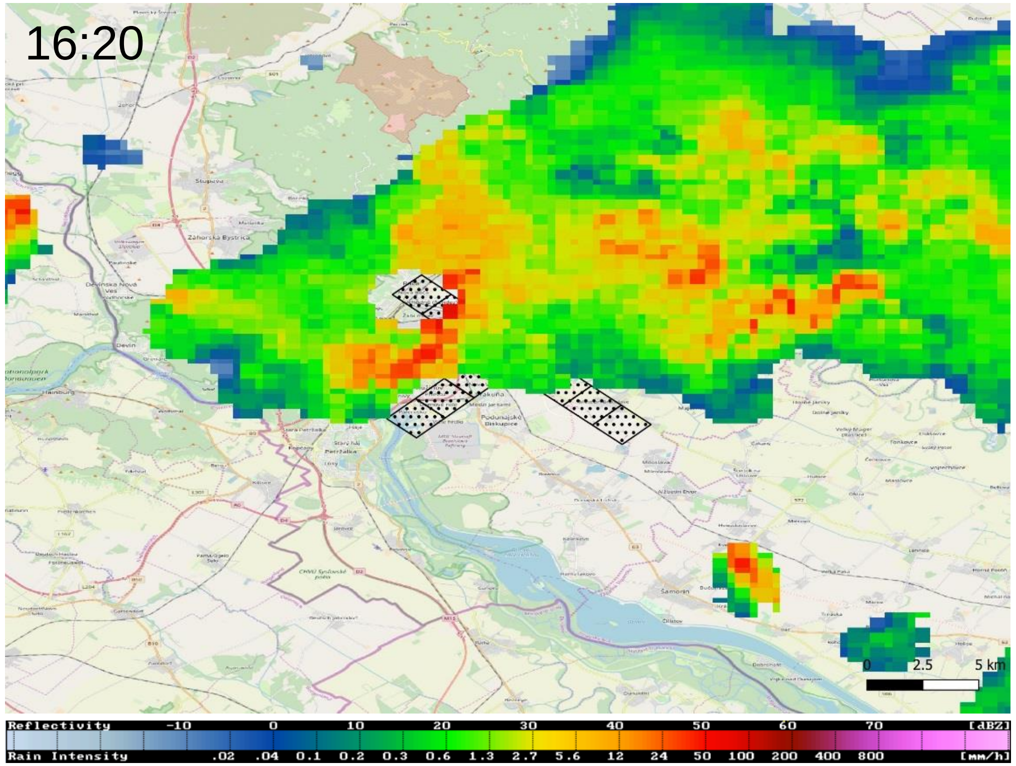

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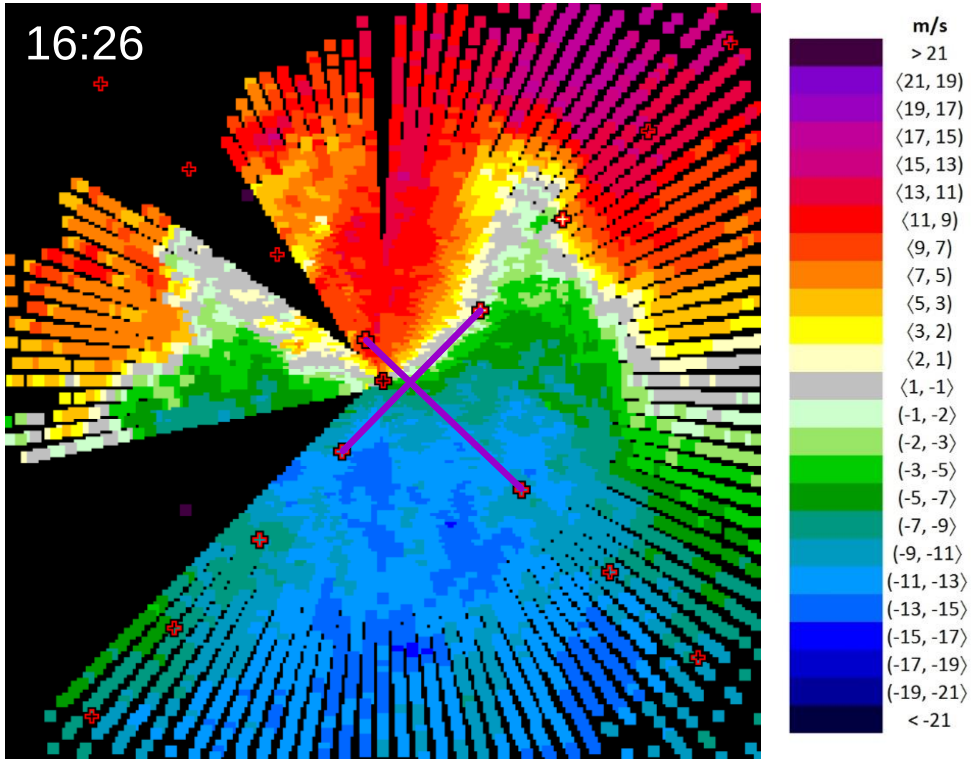

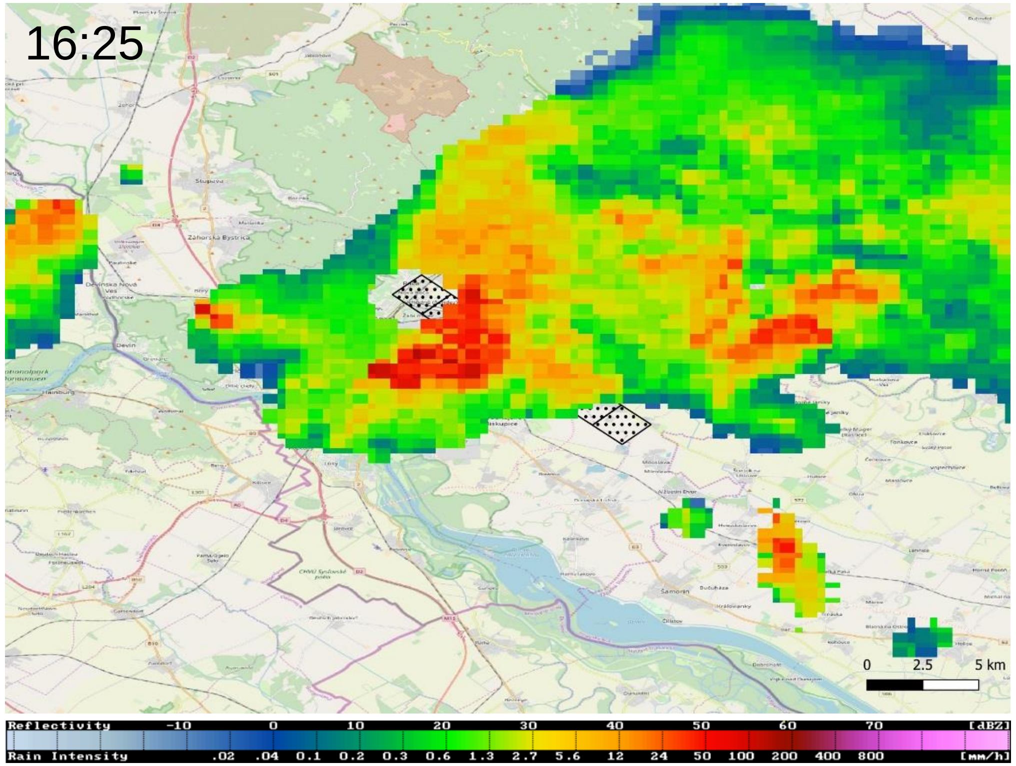

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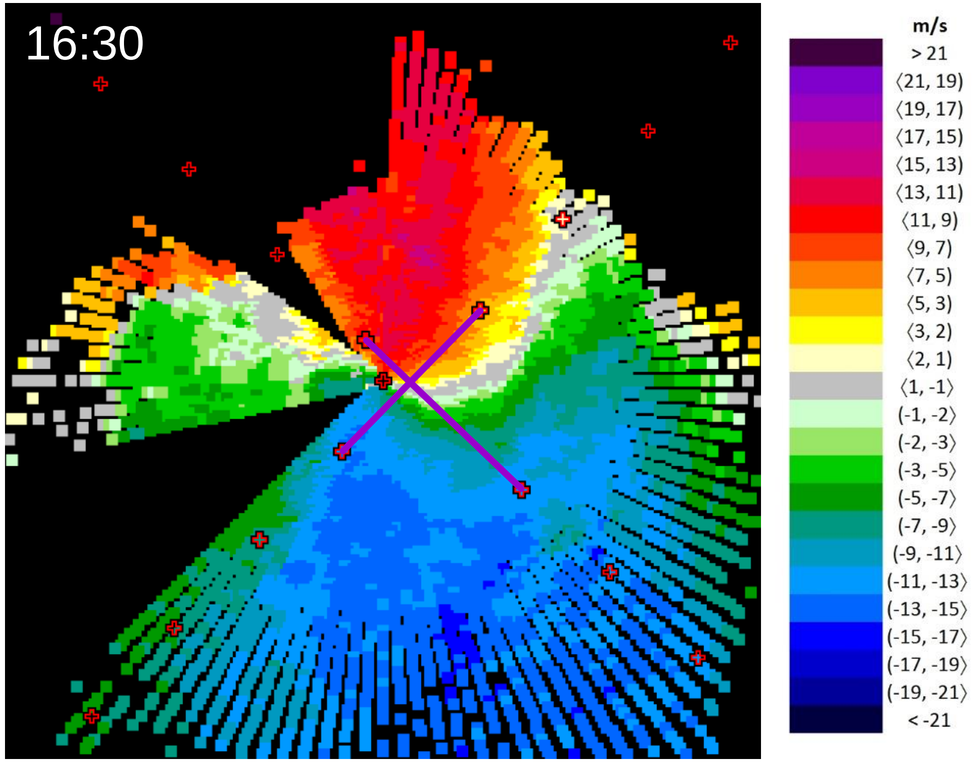

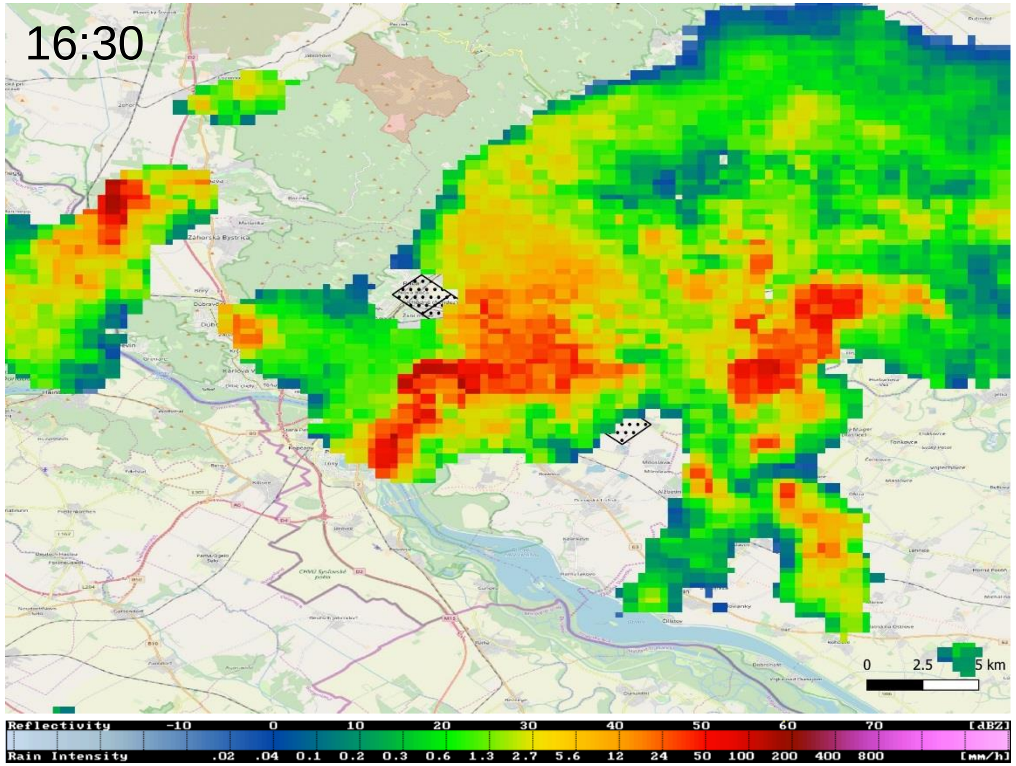

- attenuation of the laser beams of the lidar …
- … due to the thunderstorm cell crossing over the runways

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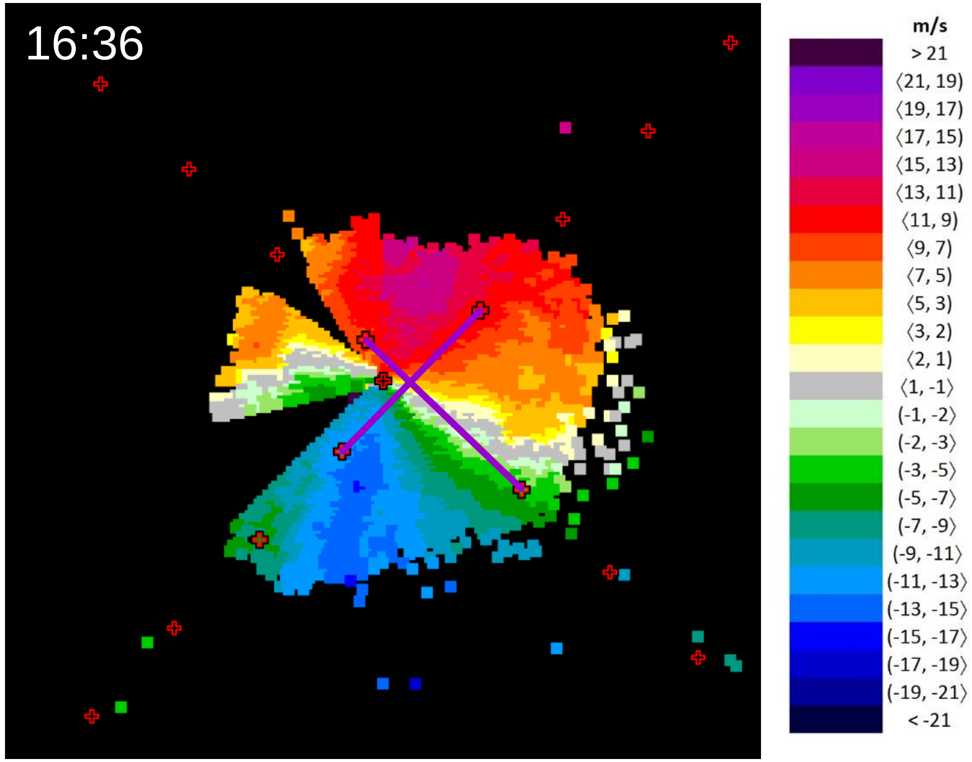

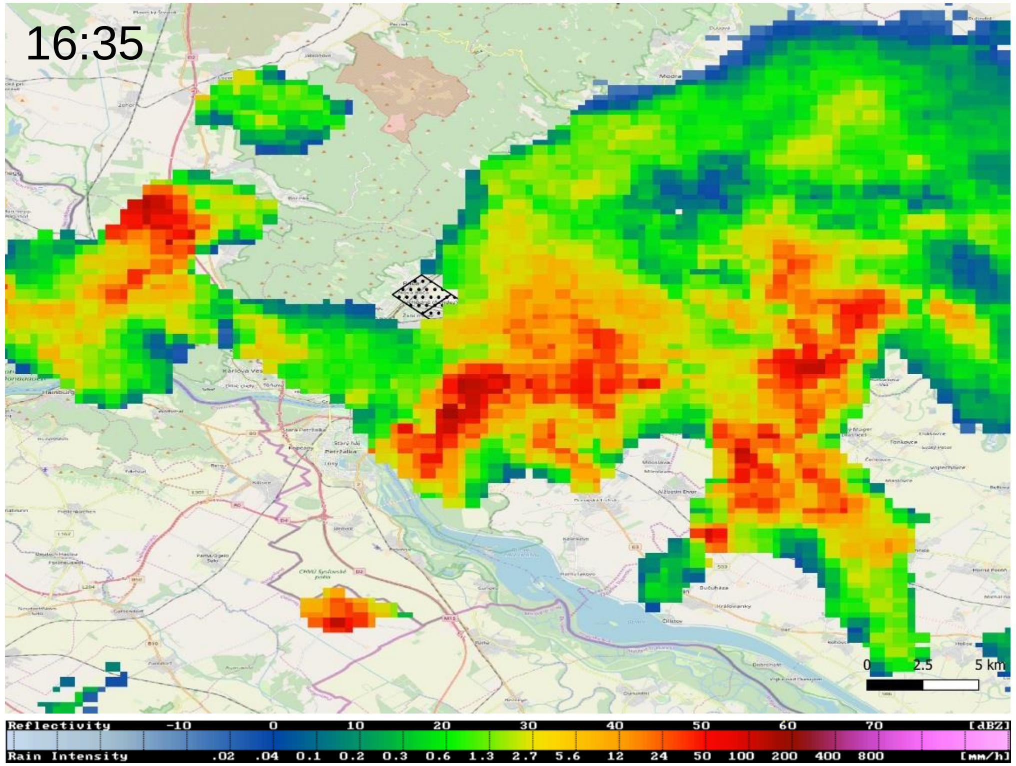

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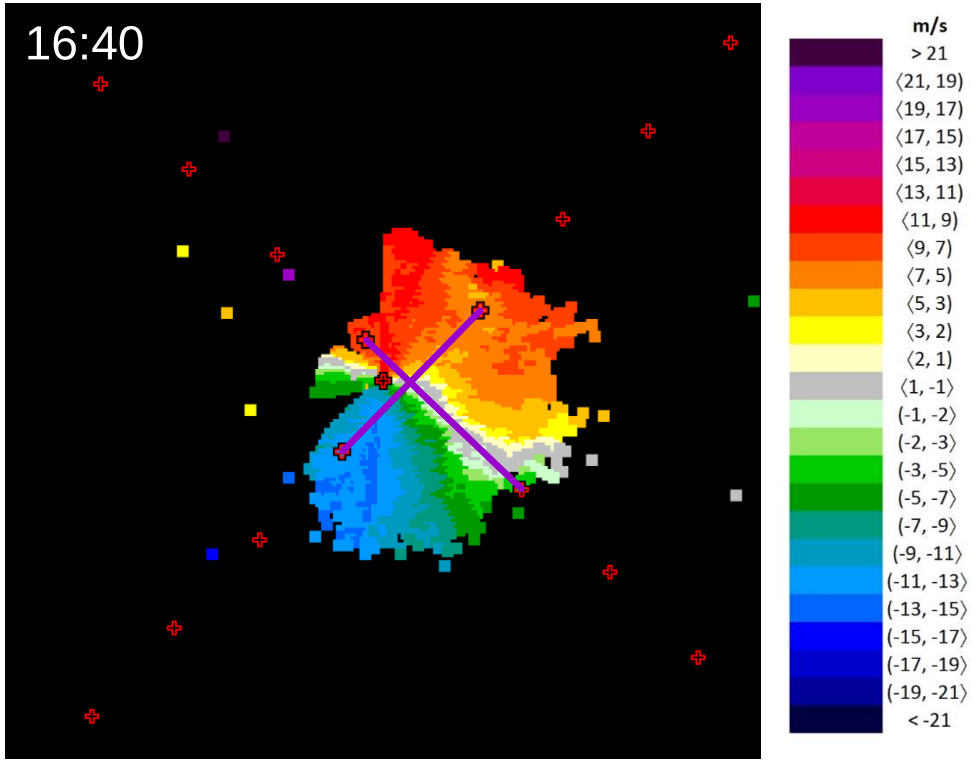

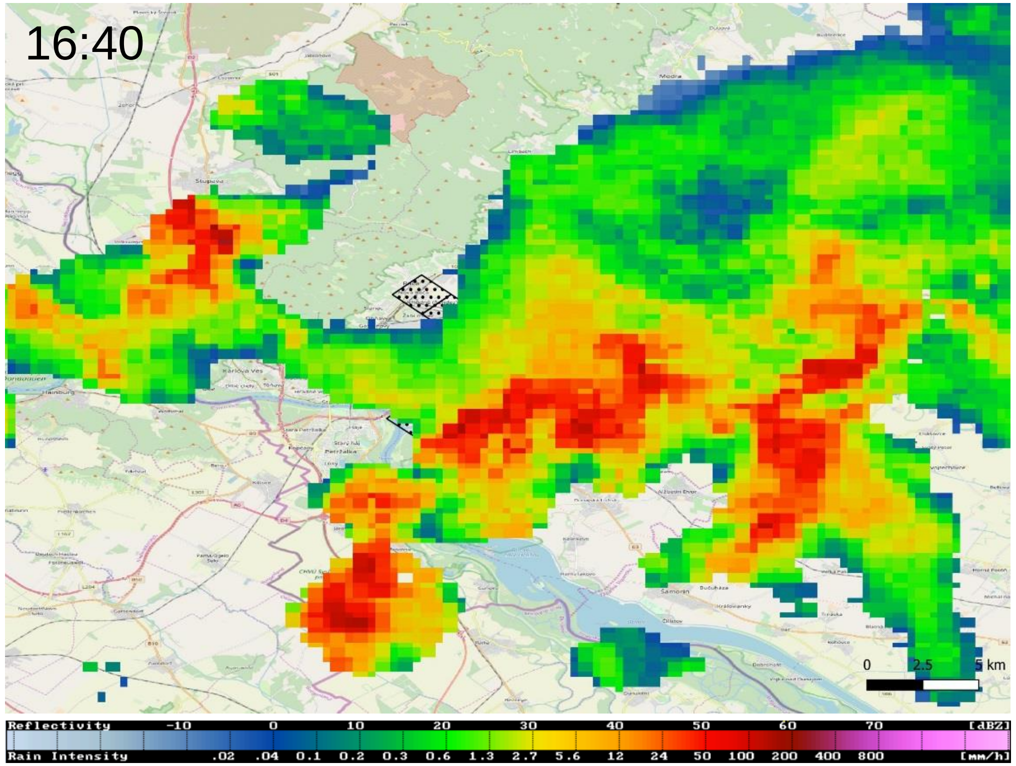

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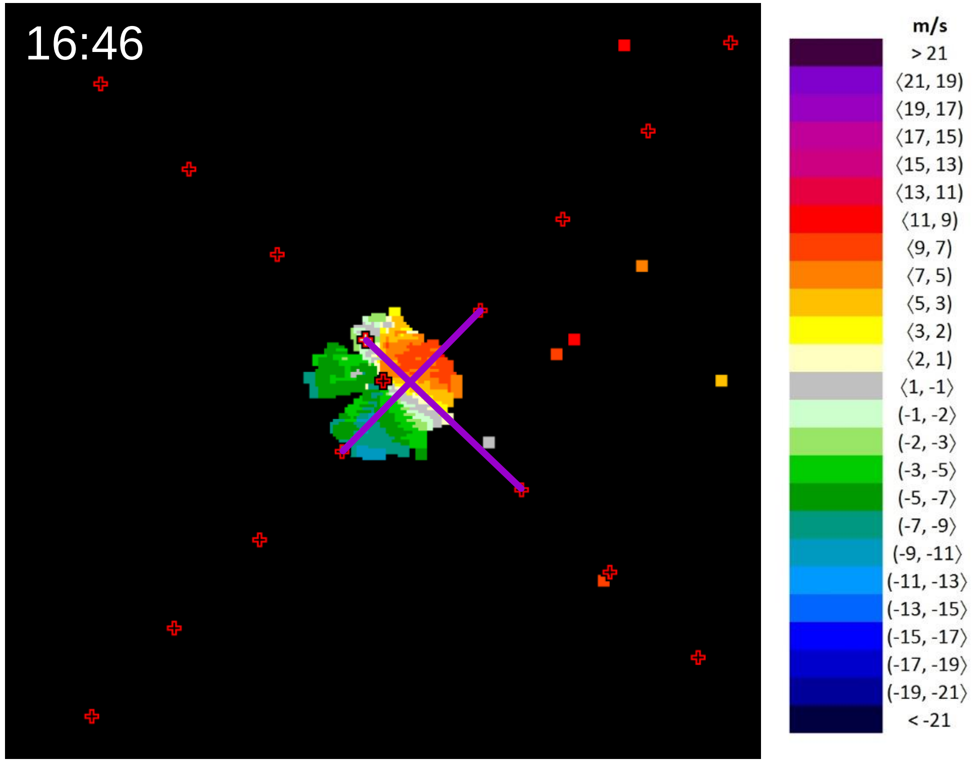

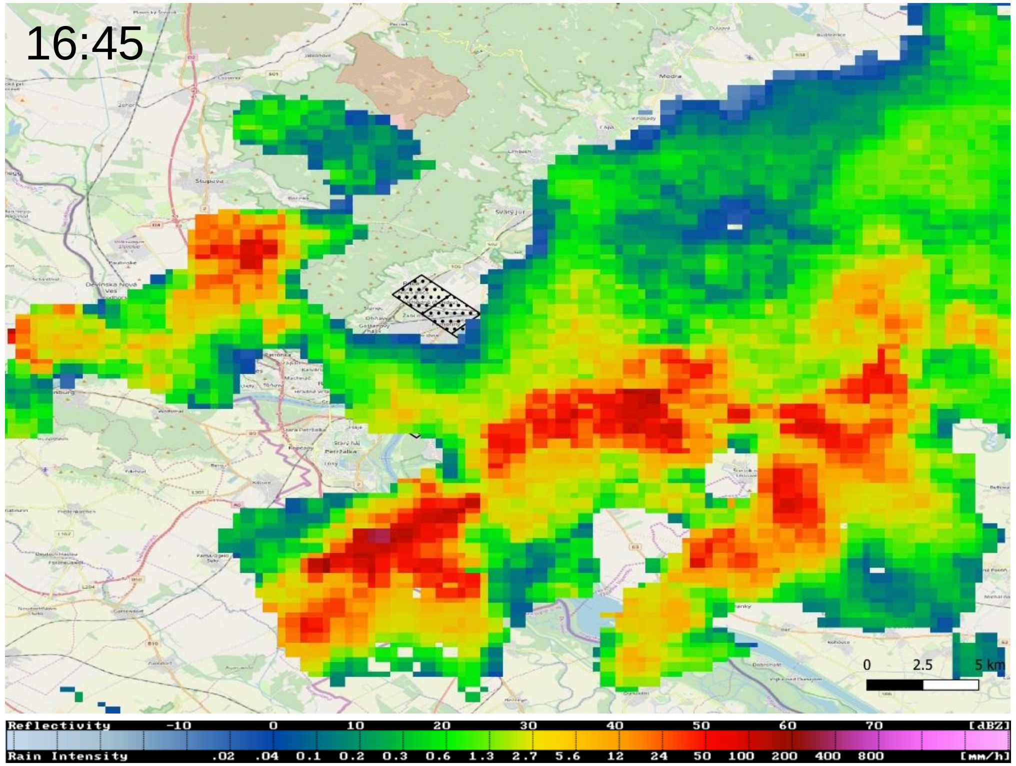

- practically no lidar signal due to the intense rainfall

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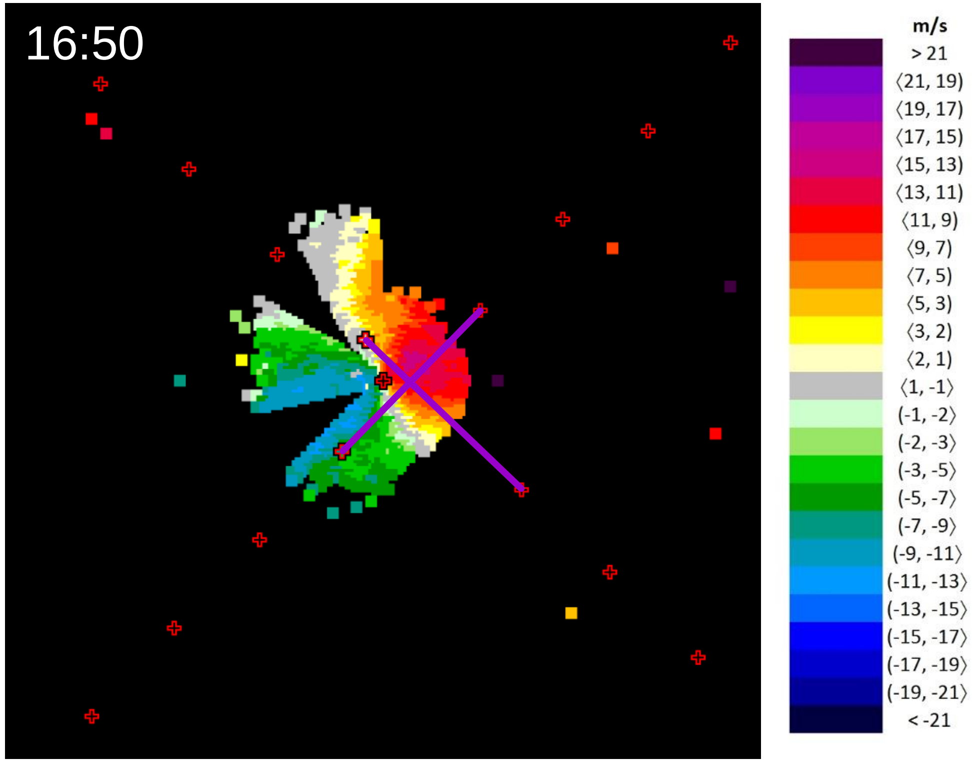
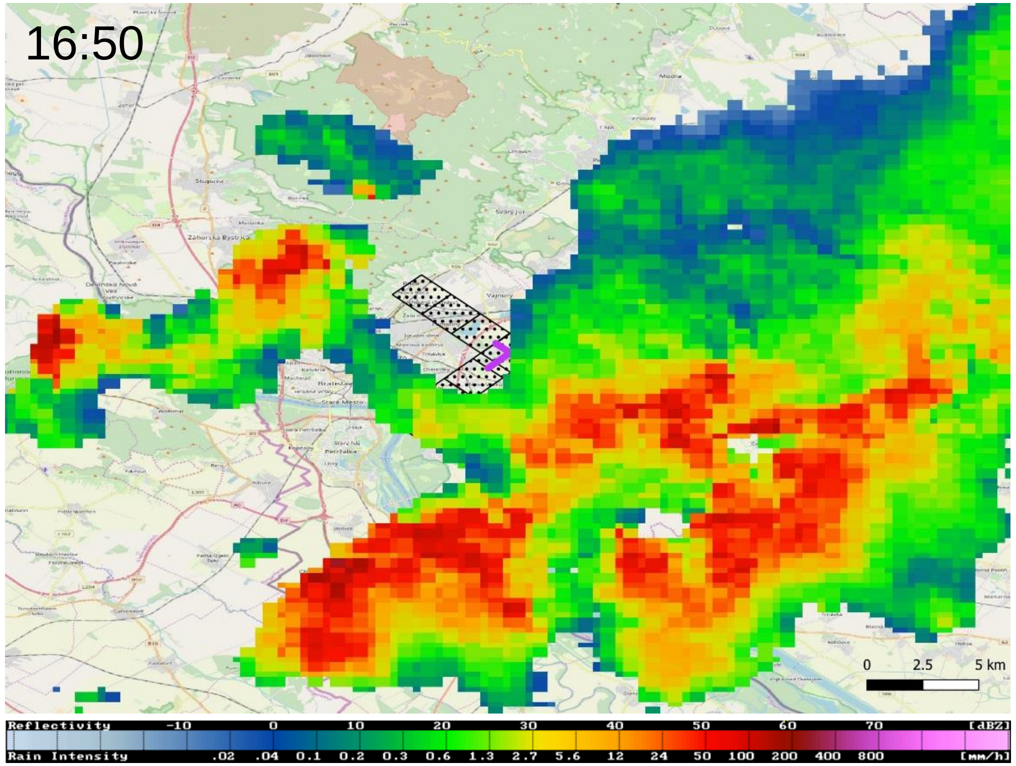
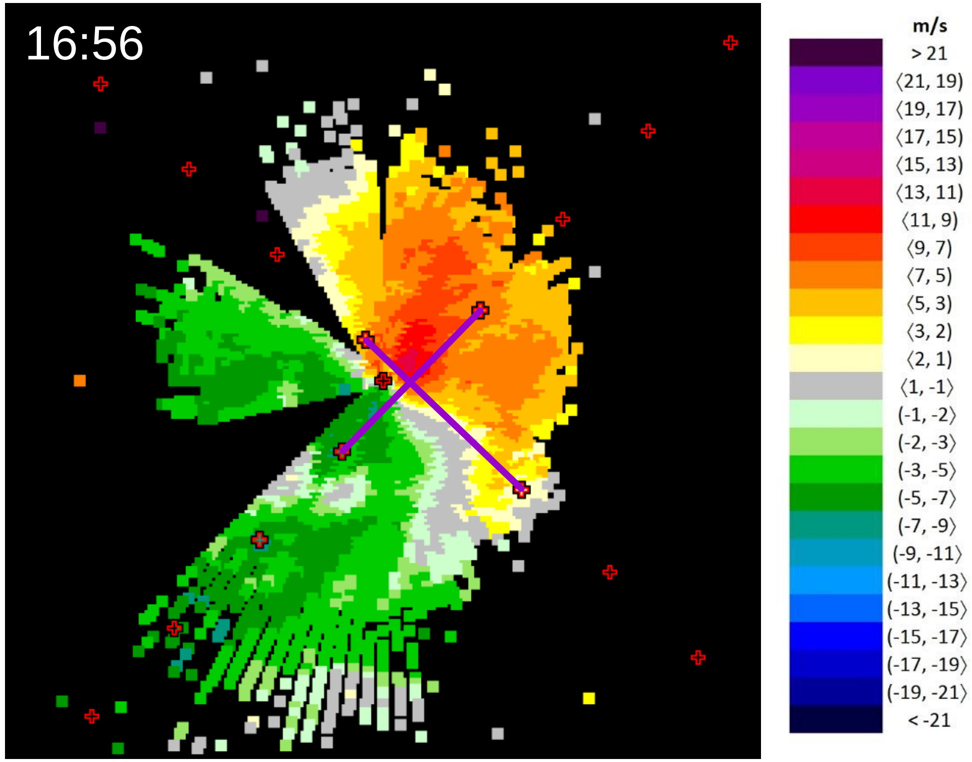
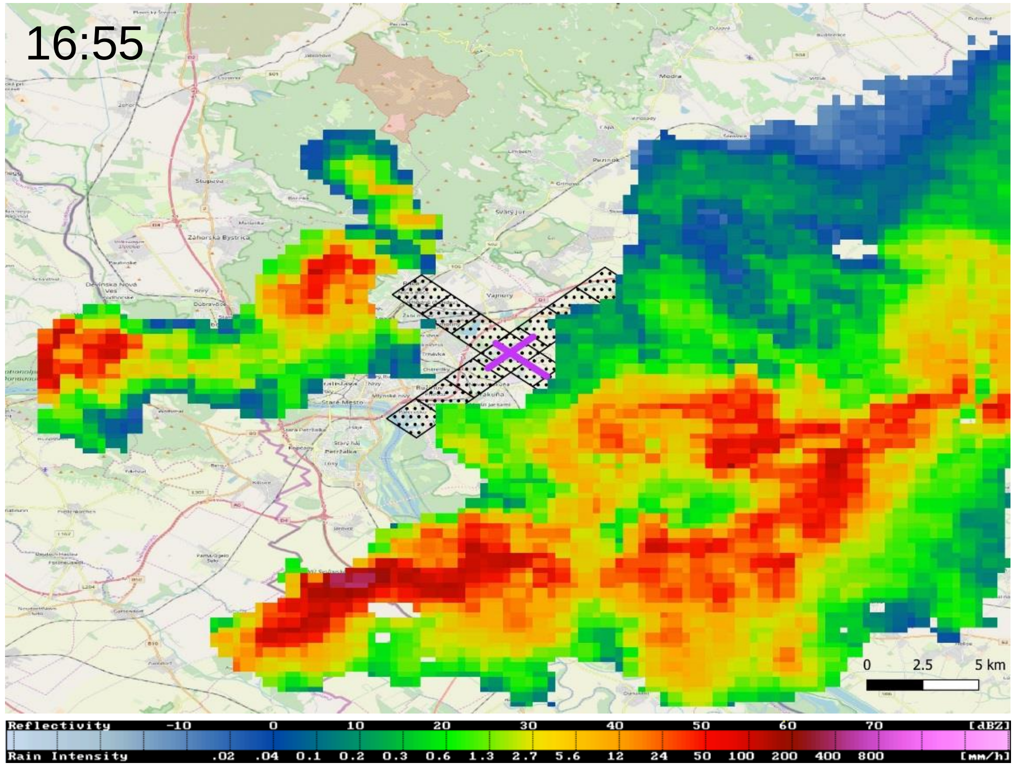
DETECTION OF GUST FRONTS BY LIDAR & RADAR, 2018-07-05





DETECTION OF GUST FRONTS BY LIDAR & RADAR, 2018-07-05





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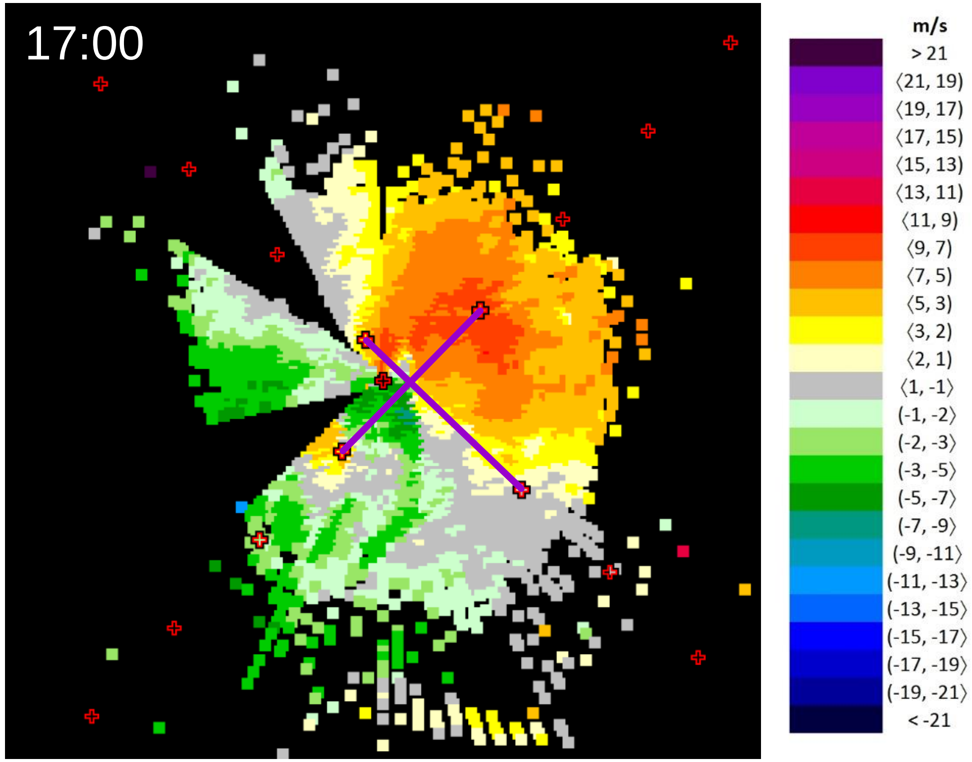
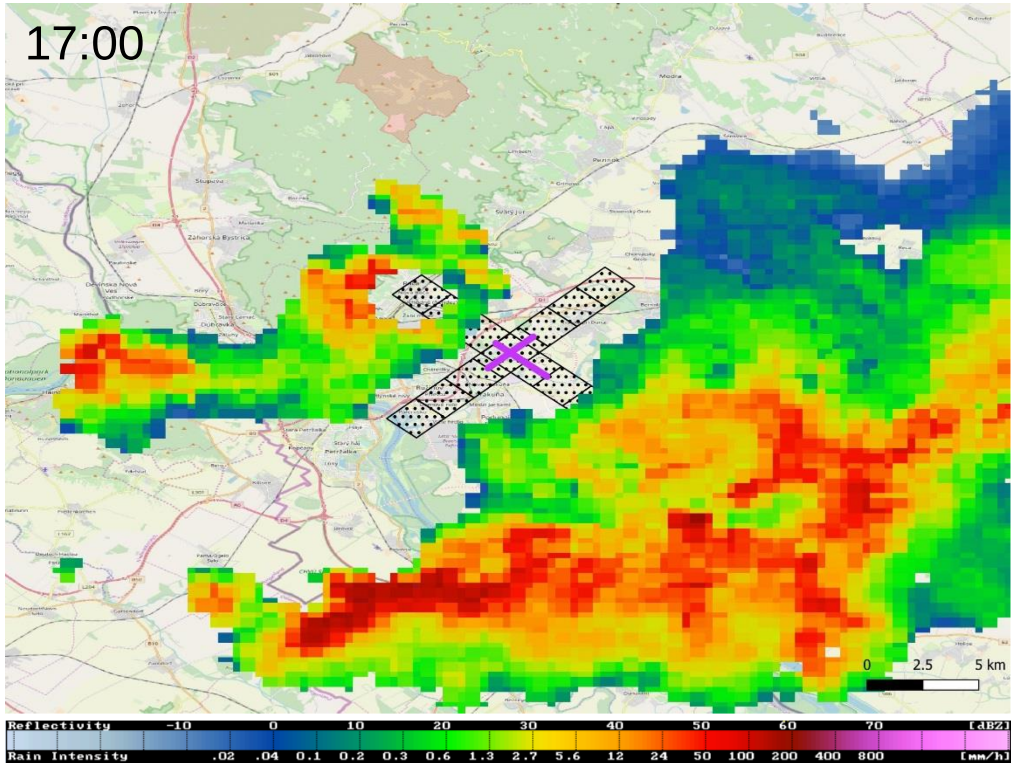
DETECTION OF GUST FRONTS BY LIDAR & RADAR, 2018-07-05





- the wind finally calms down…
- … as the storm cell leaves the area of the airport

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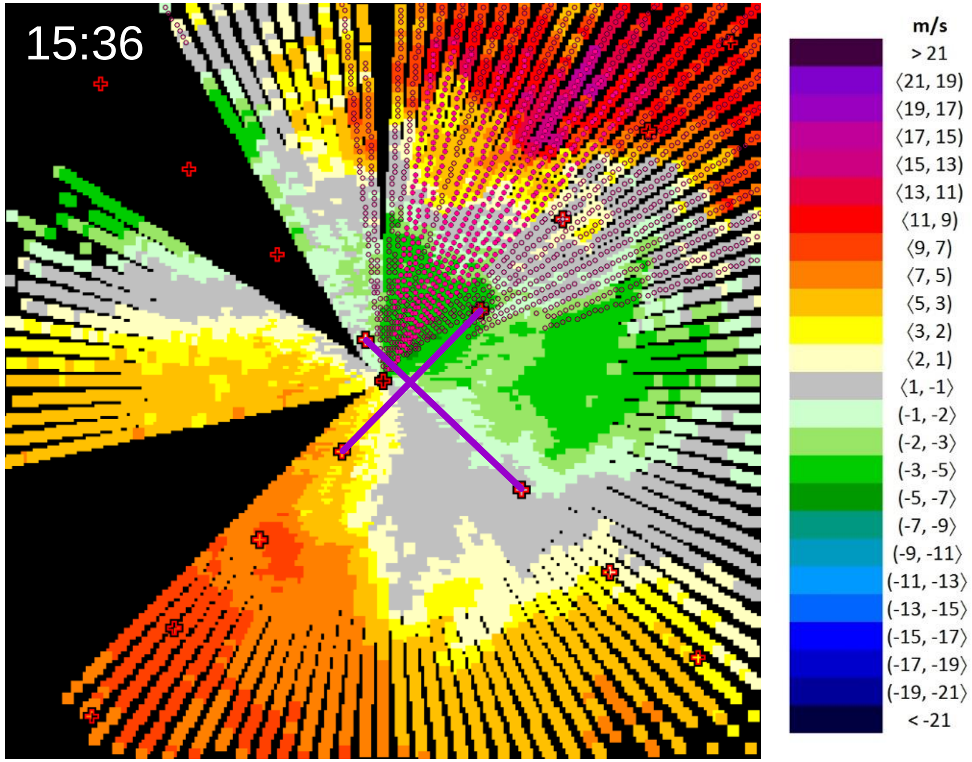
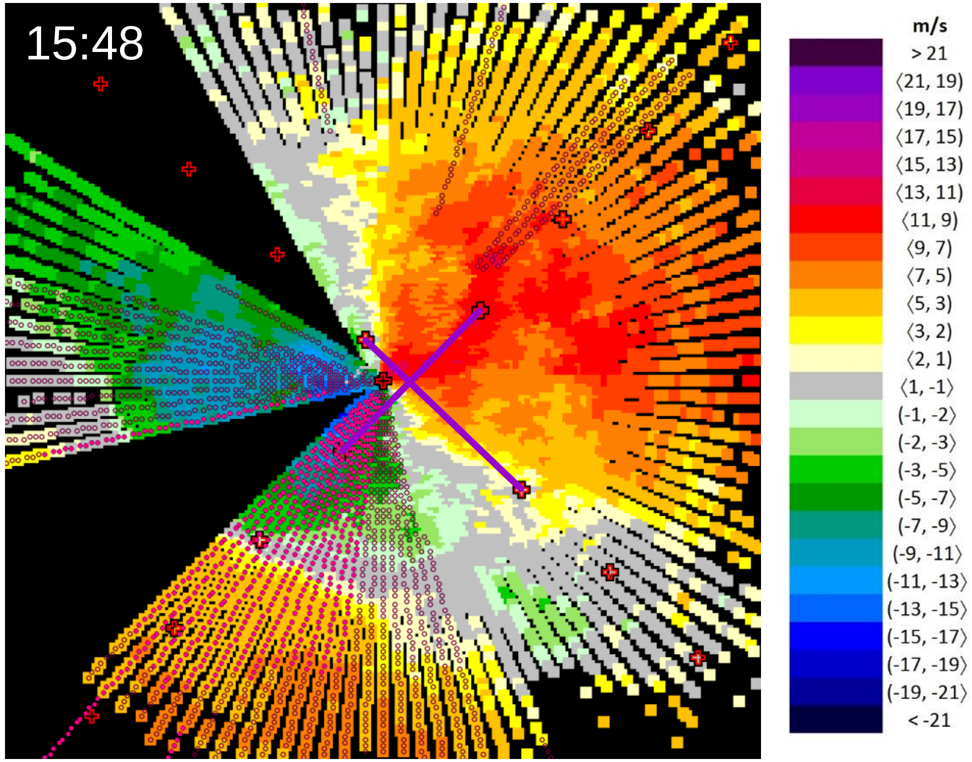
WIND SHEAR ALERTS DURING THE EVENT - EXAMPLES





- wind shear alert on RWY 22 (empty pink circles)
- microburst alerts in the sector N-NE (full pink dots)
- maximum wind shear: 22.0 m/s @ azimuth: 33°

- microburst alert on (& around) RWY 04 (full pink circles)
- maximum wind shear: 19.7 m/s @ azimuth: 225°

LIDAR AT THE BRATISLAVA AIRPORT - CONCLUSIONS

- Lidar monitors the evolution of weather events in high spatial and temporal resolution.
- Lidar & radar supplement each other
  - in rain: lidar beam are attenuated → radar reaches further
  - in the specific conditions of Bratislava: radar cannot see the airport
- Analysis of low level wind shear and issuing wind shear alerts (ICAO) is possible by means of the lidar.

- Many of the dangerous weather situations are “invisible” – wind shear occurs in clear/peaceful atmosphere
  - <u>Example</u>: thermodynamic inversion where different wind regimes are below and above the inversion (vertical wind shear) → lidar may help to pilots to land or take-off in such situations

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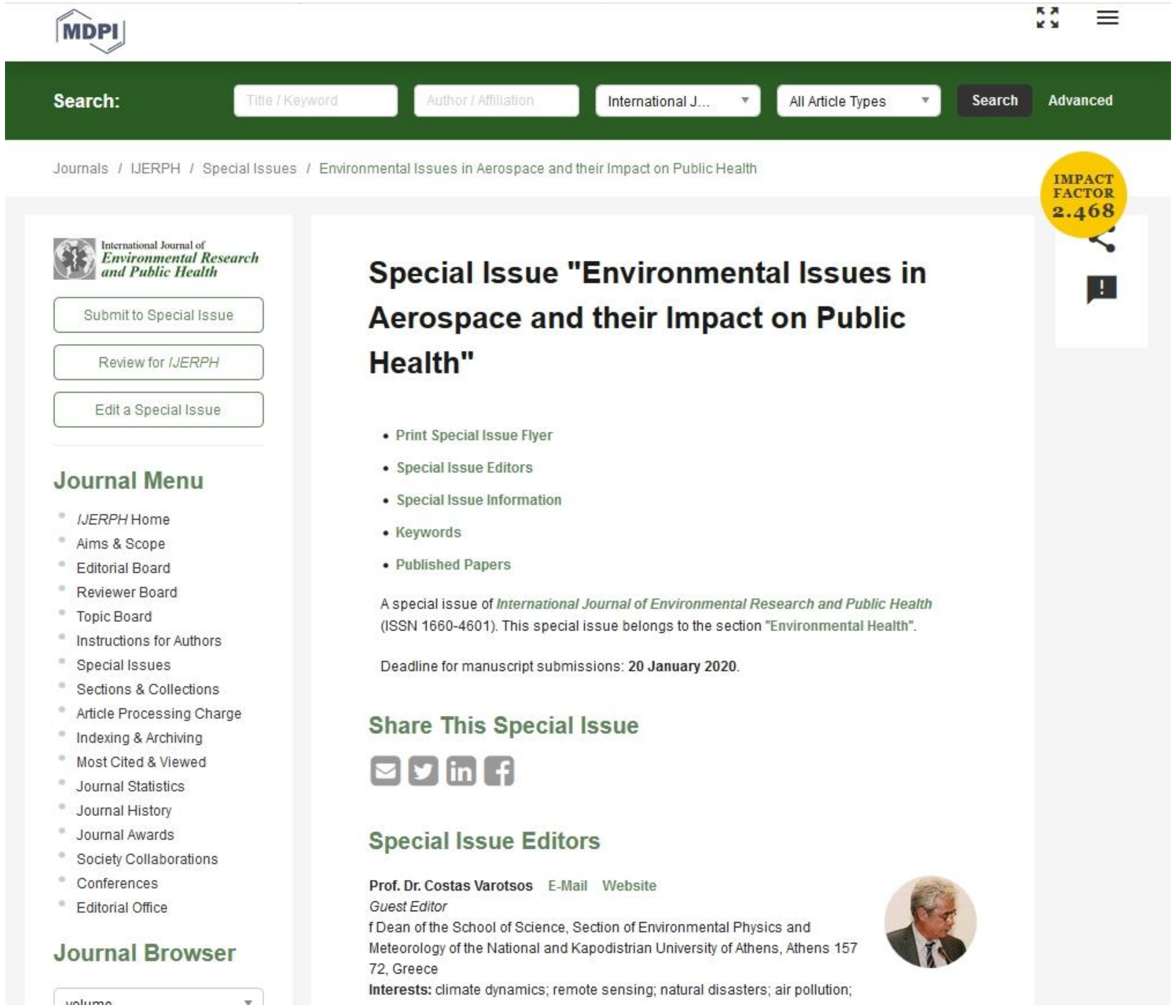
FURTHER INFORMATION ON THE TOPIC

Our full paper is coming soon…

- Nechaj et al.: *Monitoring of Low Level Wind Shear by Ground-based 3D Lidar for Increased Flight Safety, Protection of Human Lives and Health*
- special issue *Environmental Issues in Aerospace and their Impact on Public Health*
- *International Journal of Environmental Research and Public Health*



THANK YOU!

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