Nowcasting and very short range forecasting of supercell thunderstorms in a weakly- or moderately sheared environment

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Supercells over Hungary

- Every year ~ dozens of supercells in our country
- Most of these develop in high CAPE and strong deep layer shear (well above 15 m/s)
- Several cases: supercells developed in weak or moderate deep layer shear (below 15 m/s) – multicells were expected, still supercells formed
- Questions:

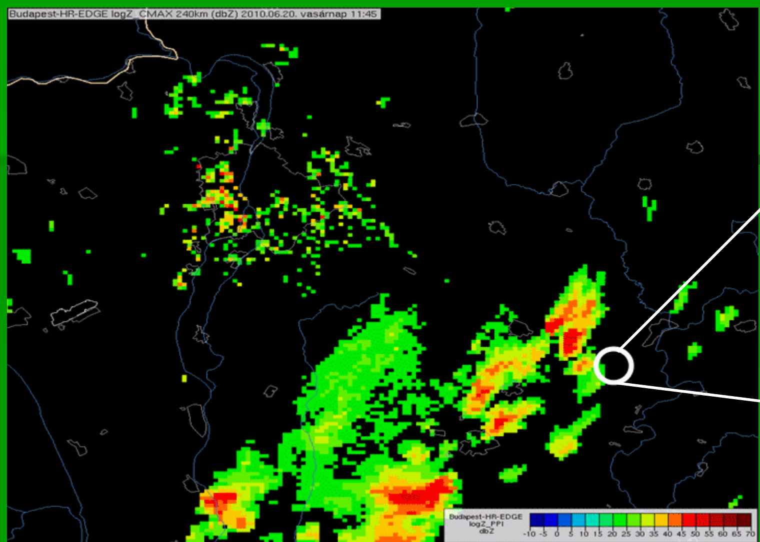
- what mechanisms lead to mesocyclogenesis in these cases
- is there a simple conceptual model that can be applied to forecast these events succesfully

Methodology

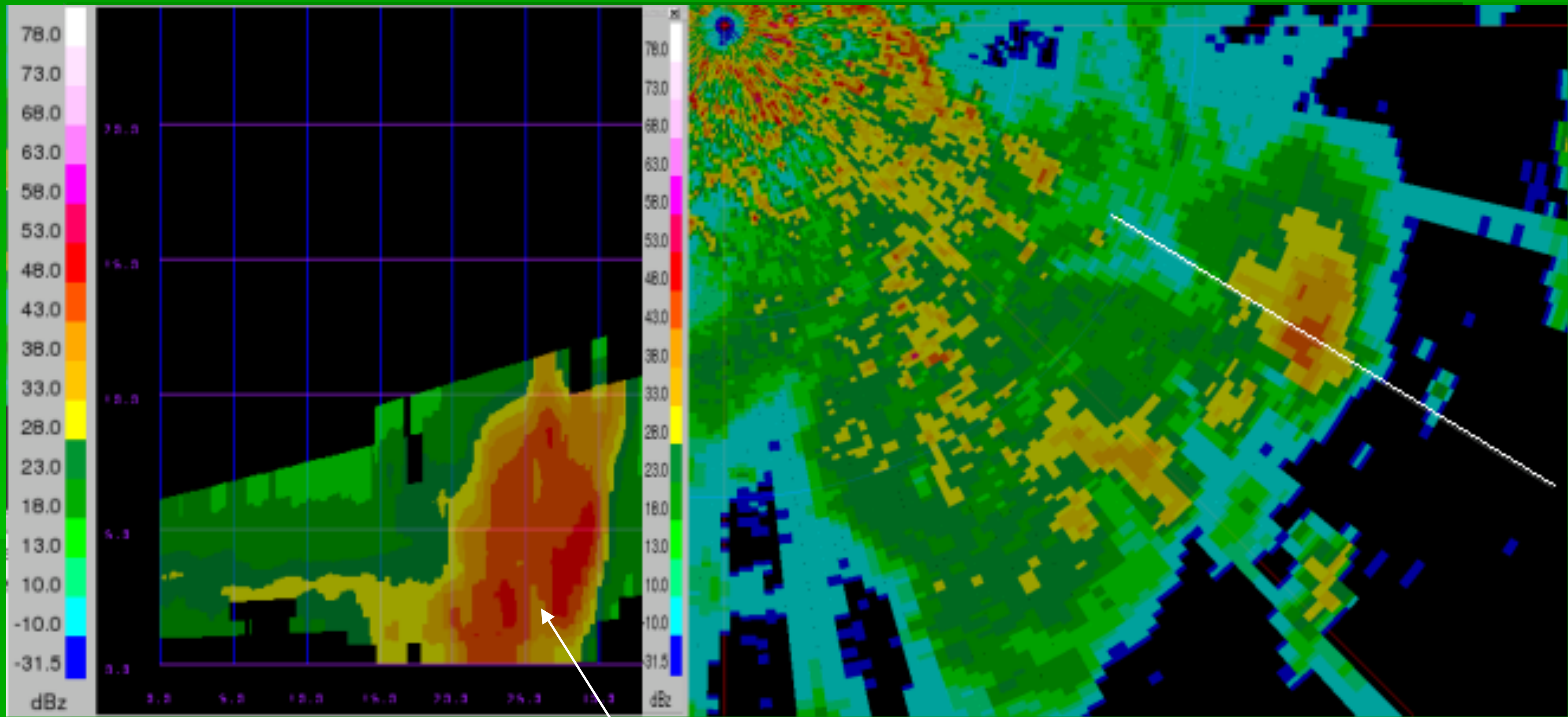
- Several cases were investigated extensively
- They were thoroughly documented by radar measurements (PPI, cross-sections, radial velocity) and observations by storm-chasers (reports and photos)
- Convective indices (various shear parameters, composite parameters etc.) calculated from global model forecasts (ECMWF) were examined
- Non-hydrostatic and high-resolution numerical model tests (WRF) were run to analyse the local properties of these storms – nested domain with 1 km resolution with direct cumulus scheme
- Vorticity analyses were performed on these model fields to clarify the mechanisms that lead to formation of supercells

Case study: 20. 06. 2010.

- At least one supercell formed in the central part of Hungary along a surface convergence line away from any frontal boundaries between 12 and 15 UTC
- One of our stormchasers documented the rotating wall cloud
- Hail was reported with diameter of 2-3 cm



Case study: 20. 06. 2010. – radar products



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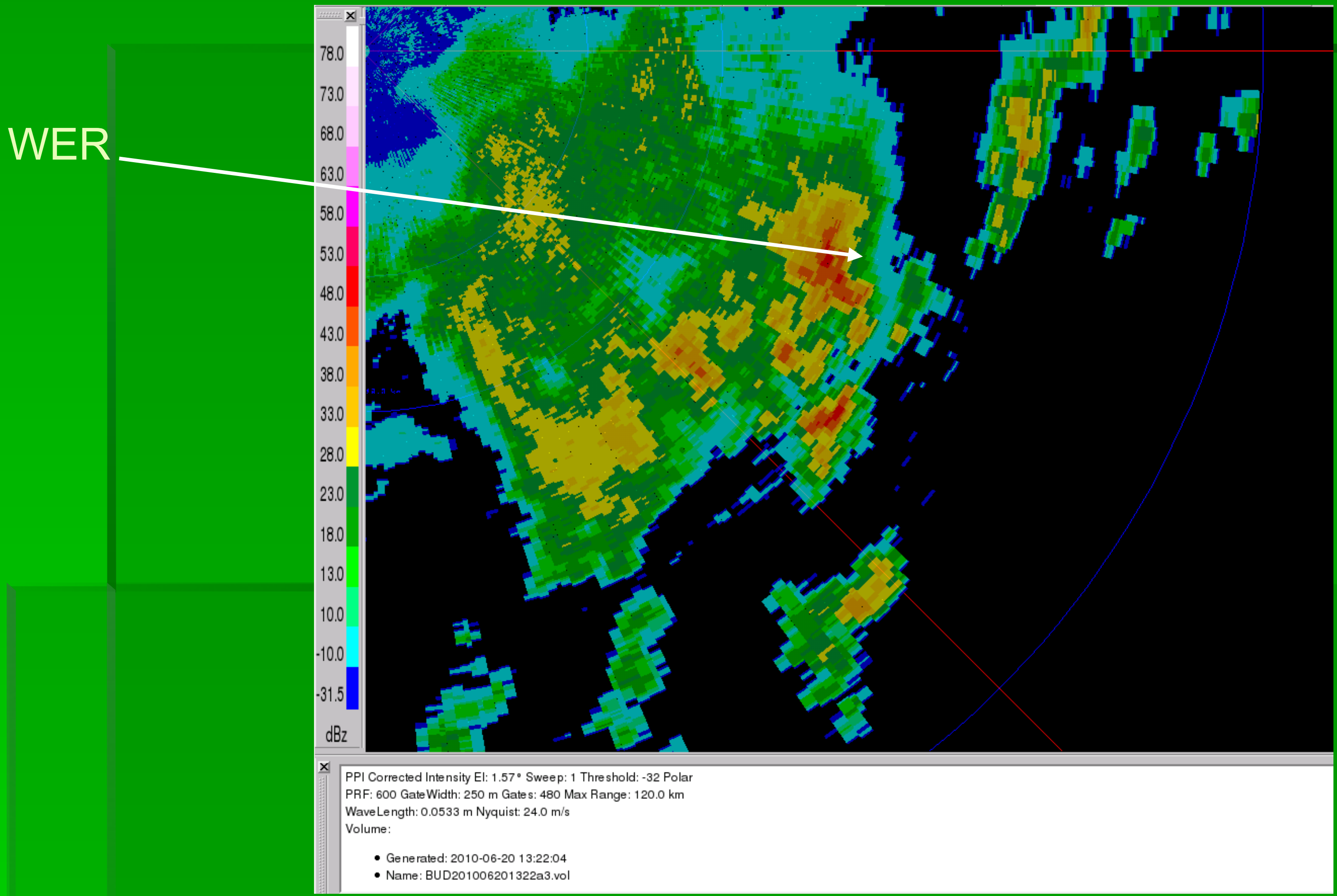
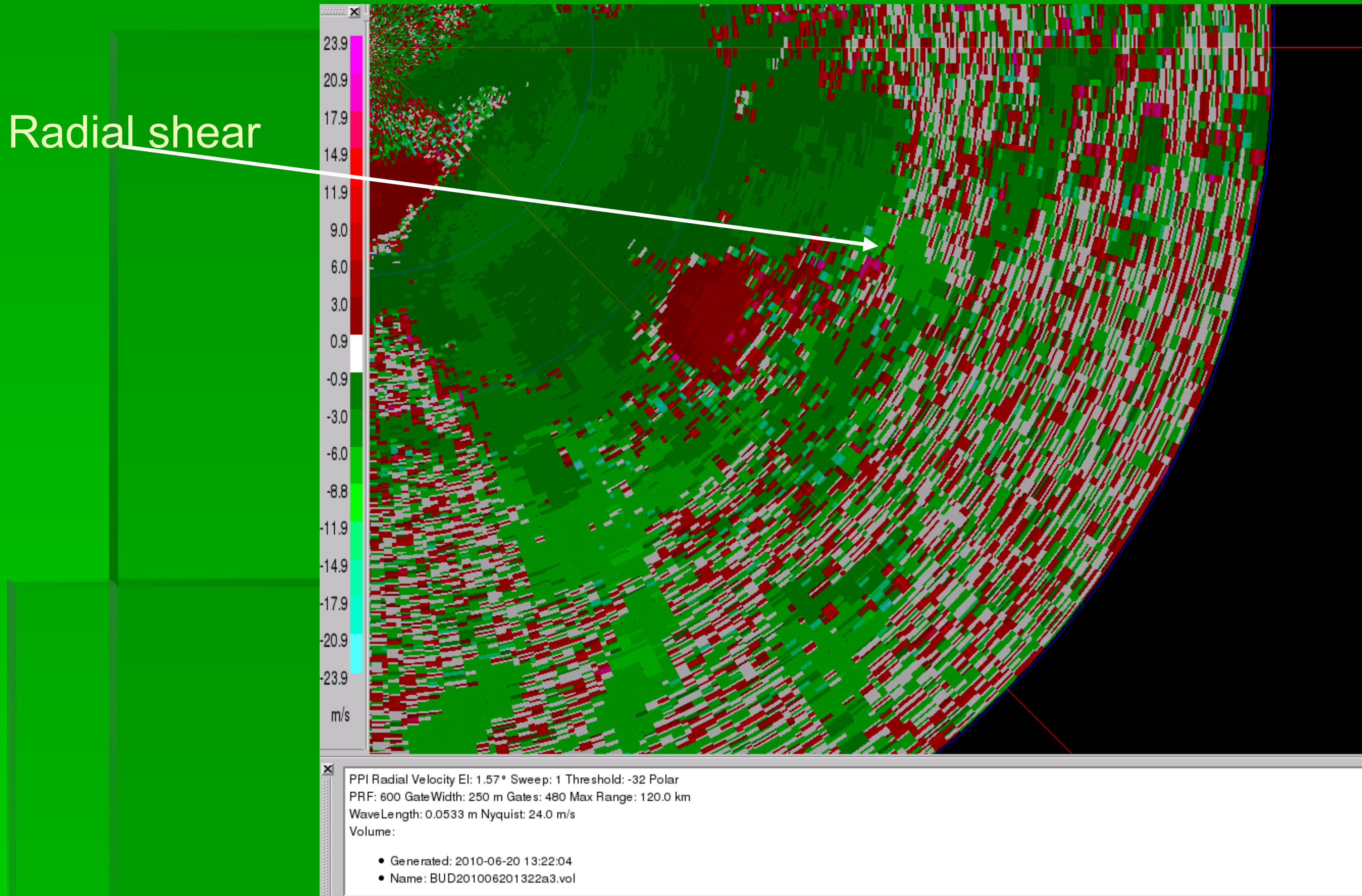
Case study: 20. 06. 2010. – radar products

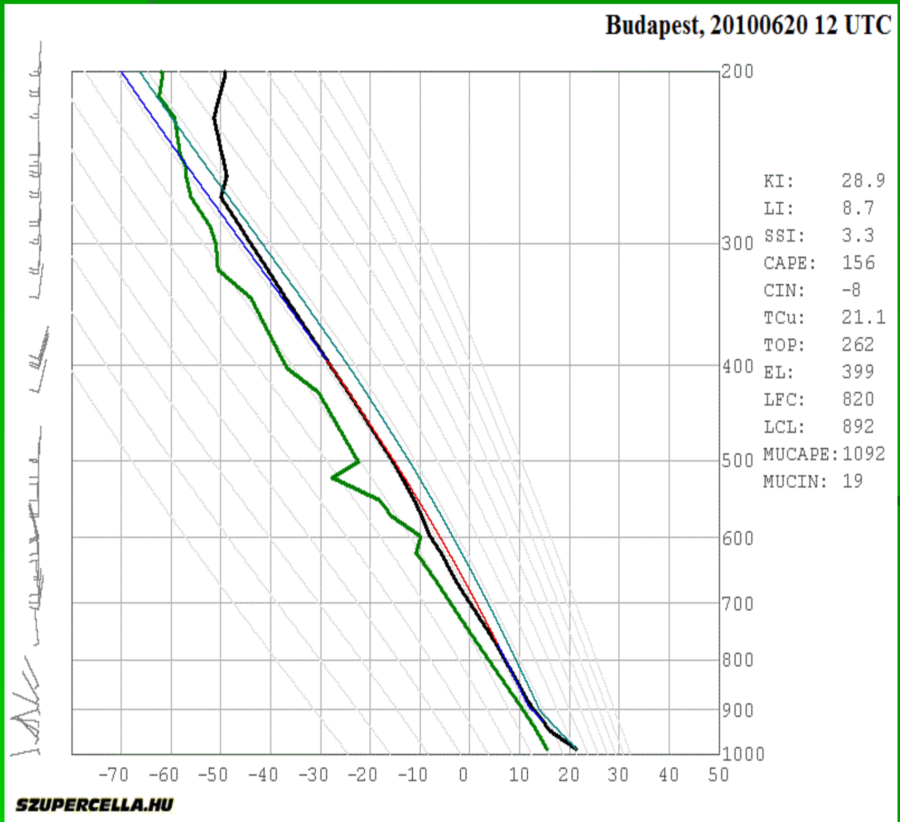


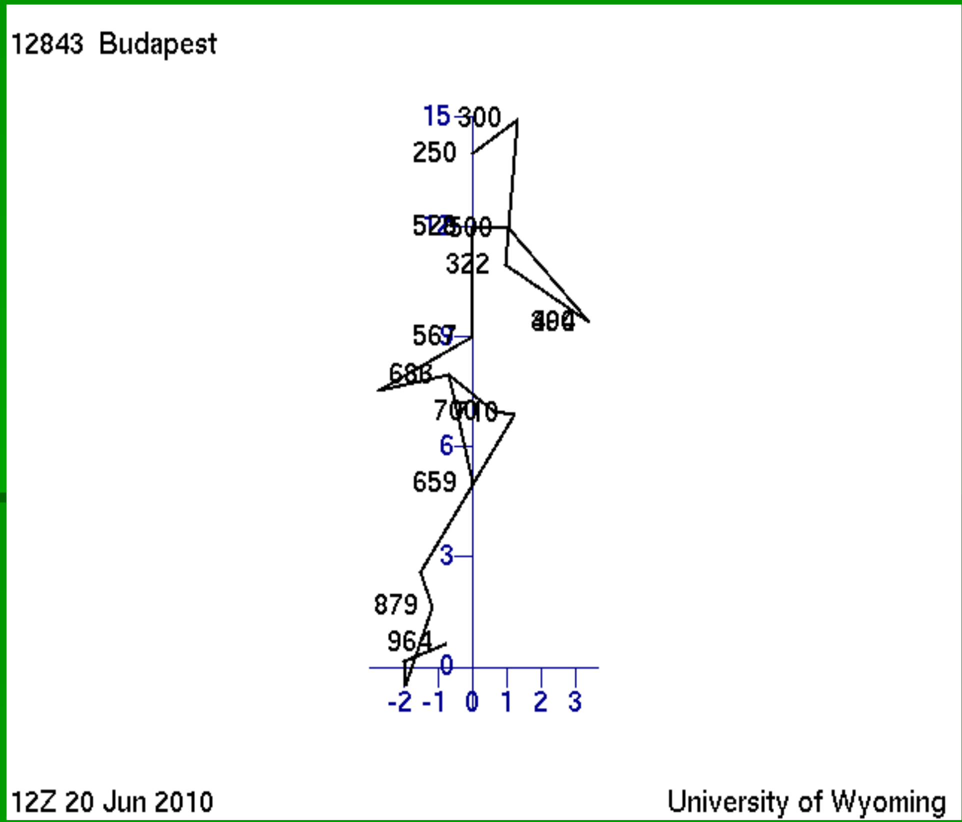
Case study: 20. 06. 2010. – radar products



Case study: 20. 06. 2010. - soundings

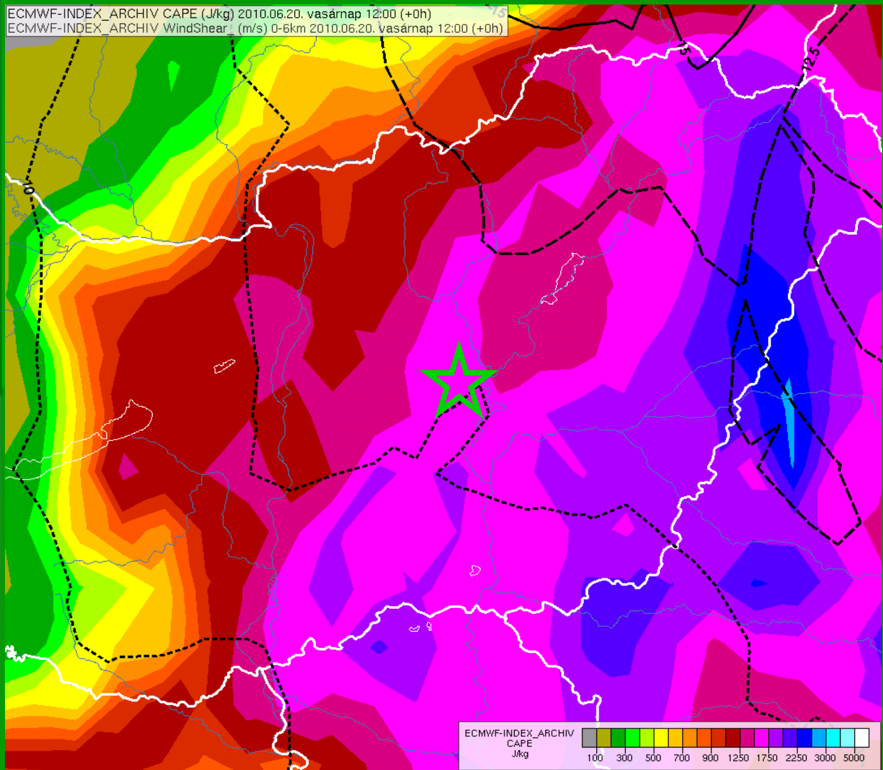
Considerable CAPE, but short hodograph between 6 km and the surface

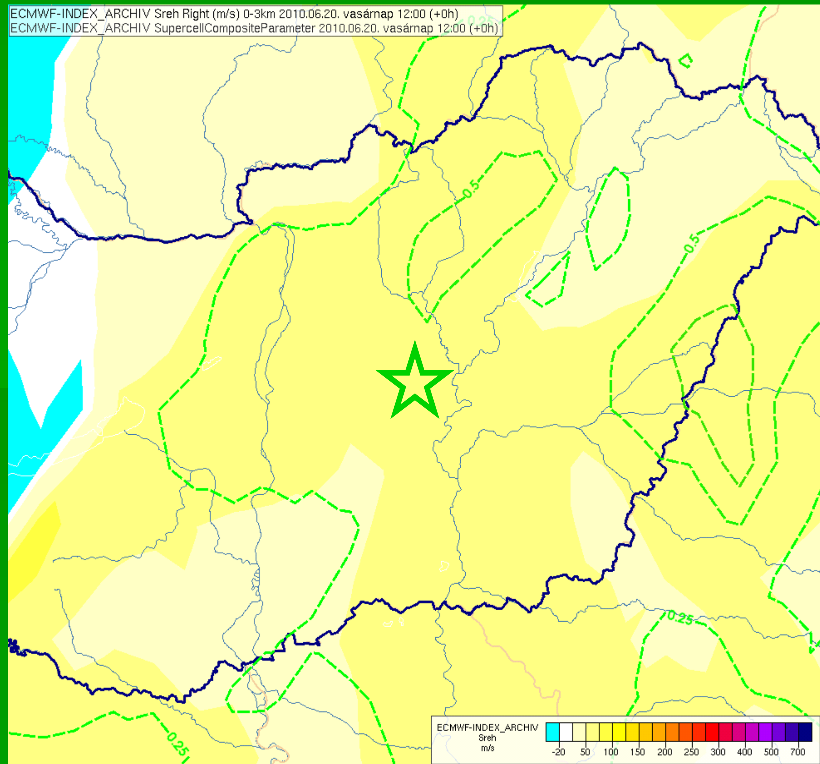




Case study: 20. 06. 2010. - ECMWF analysis and forecast

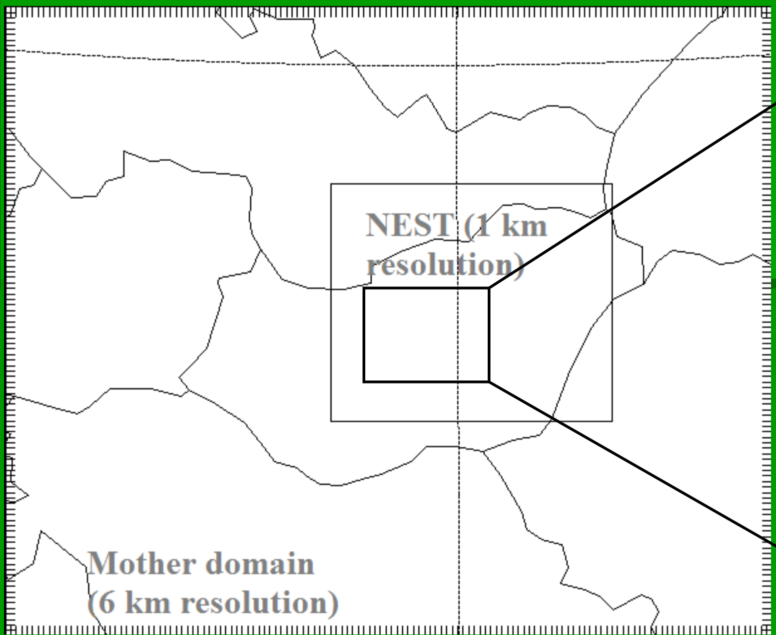
- No significant shear and helicity (80-90 m2/s2 0-3 km SREH, 11-12 m/s DLS, 13-14 m/s hodograph length, 23-24 m2/s2 BRN shear, BRN is above 100) detected on large scale

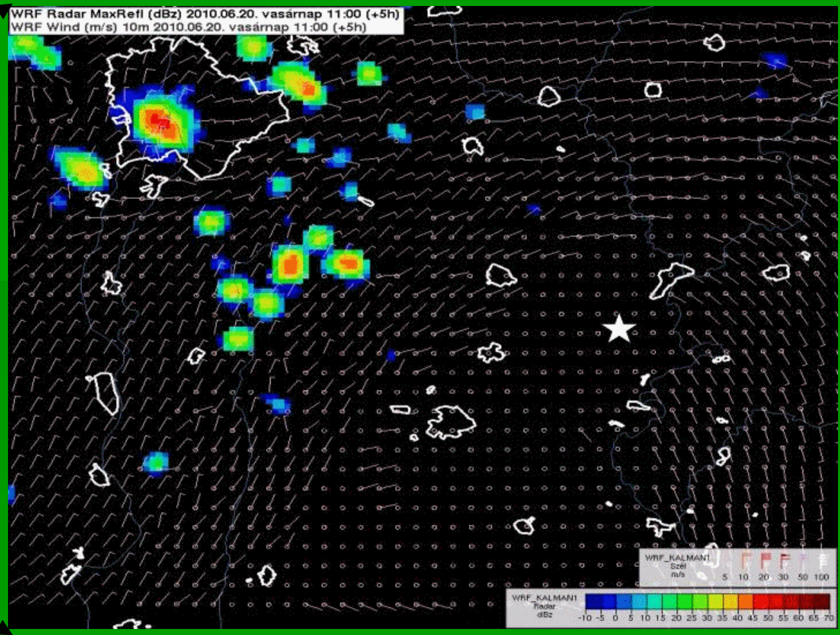




Case study: 20. 06. 2010. - WRF simulation

- Run started at 06 UTC
- Initial and lateral boundary conditions from the 00 UTC ECMWF run
- Output frequency – 5 minutes
- The model predicted the cell almost in the right time and place





Case study: 20. 06. 2010. - Vorticity analysis of the cells

- Simplified frictionless vorticity equation

$$\frac{\partial \zeta}{\partial t} = -\vec{v}_h \nabla_h \zeta - w\frac{\partial \zeta}{\partial z} + \vec{S} \times \nabla_h w \cdot \vec{k} - \zeta div \vec{v}_h$$

- Advection
- Convection
- Tilting
- Stretching

Case study: 2010. 06. 20. - Horizontal vorticity analysis

W

rel. vorticity

tilting

stretching

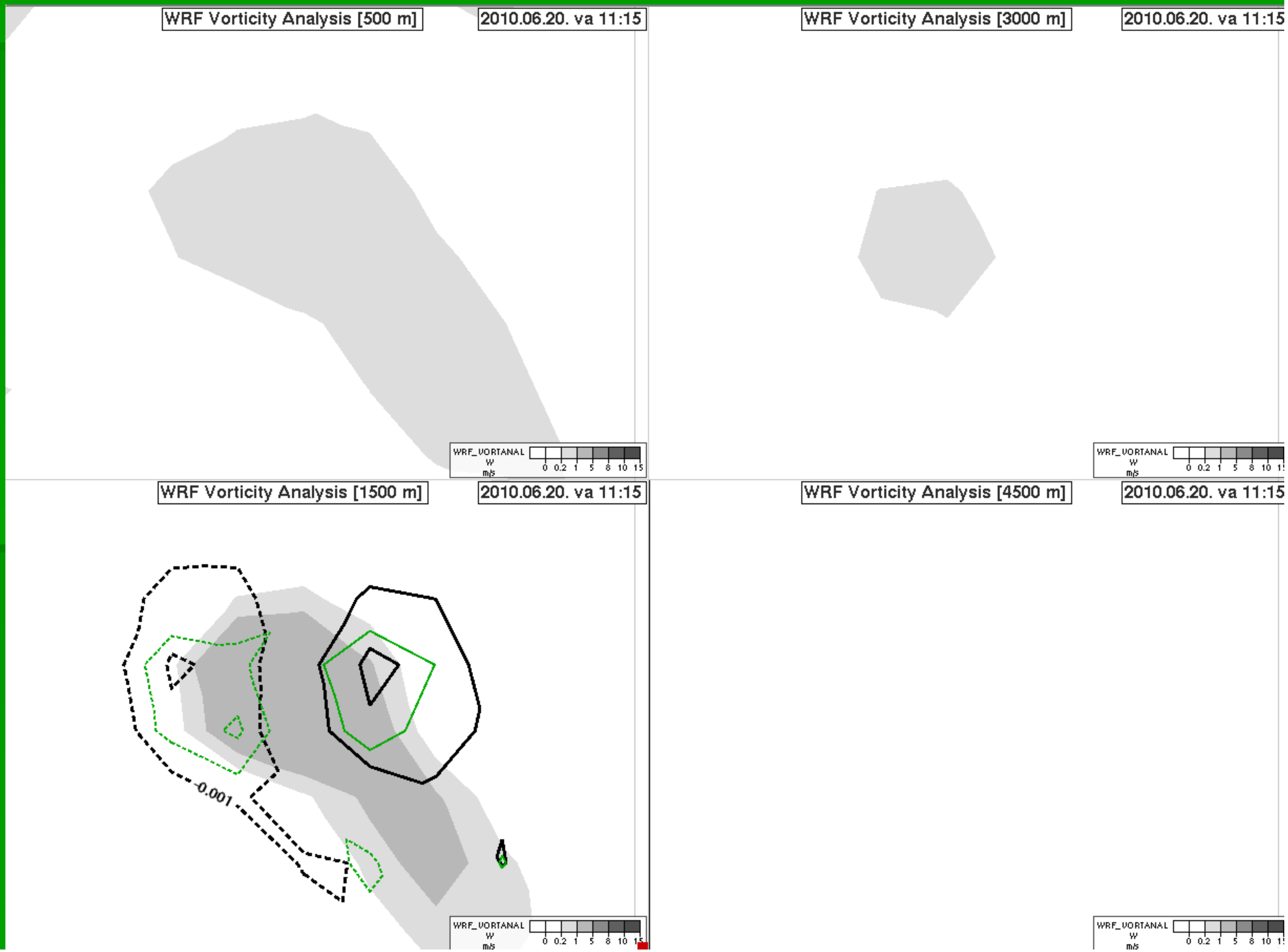
advection

convection

Vorticity isolines at every 1×10^{-3} 1/s

Other isolines at every 5×10^{-6} 1/s^2

Solid lines: positive
Dashed line: negative



Case study: 20. 06. 2010. - Horizontal vorticity analysis

- W
- rel. vorticity
- tilting
- stretching
- advection
- convection

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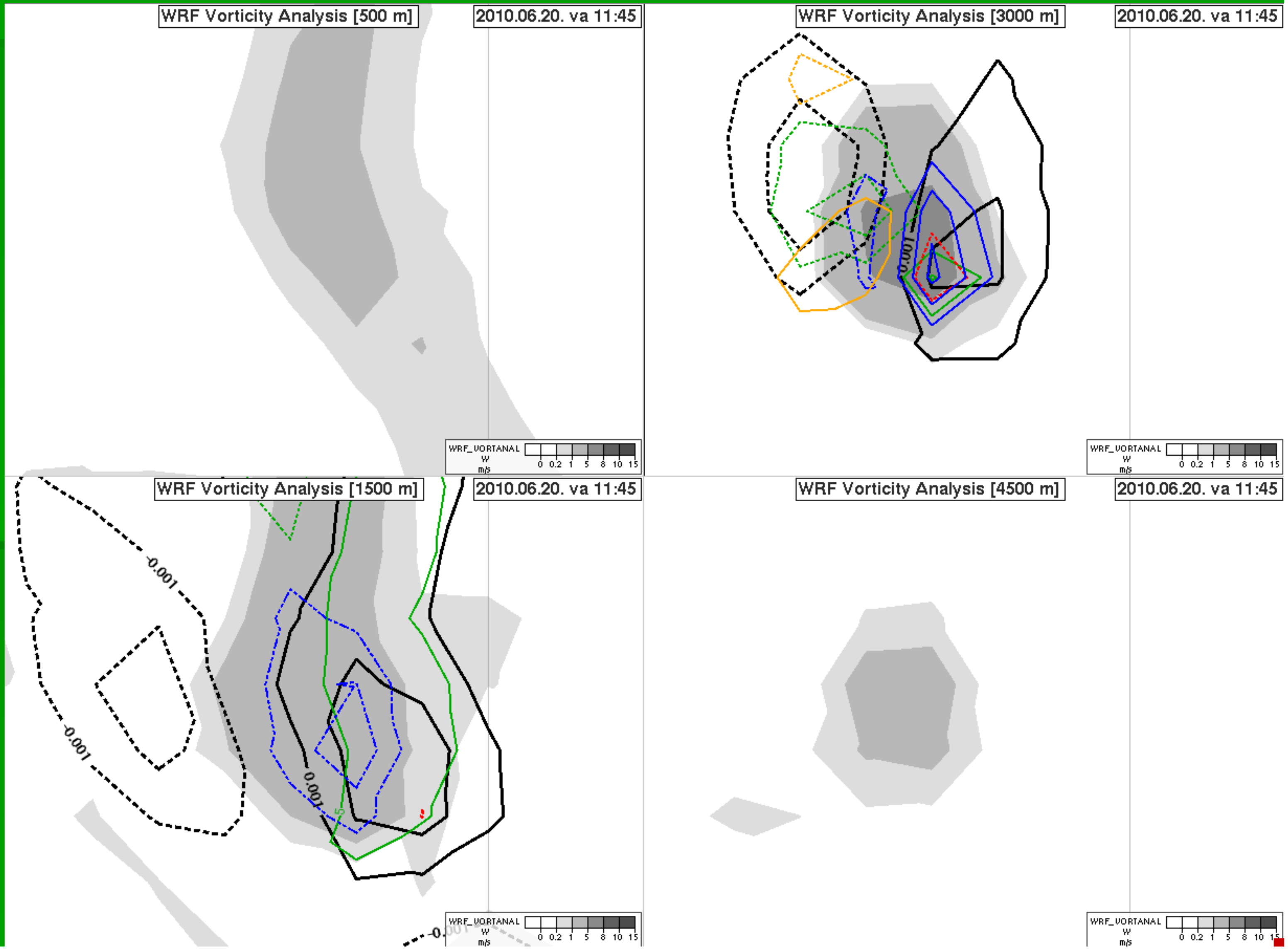

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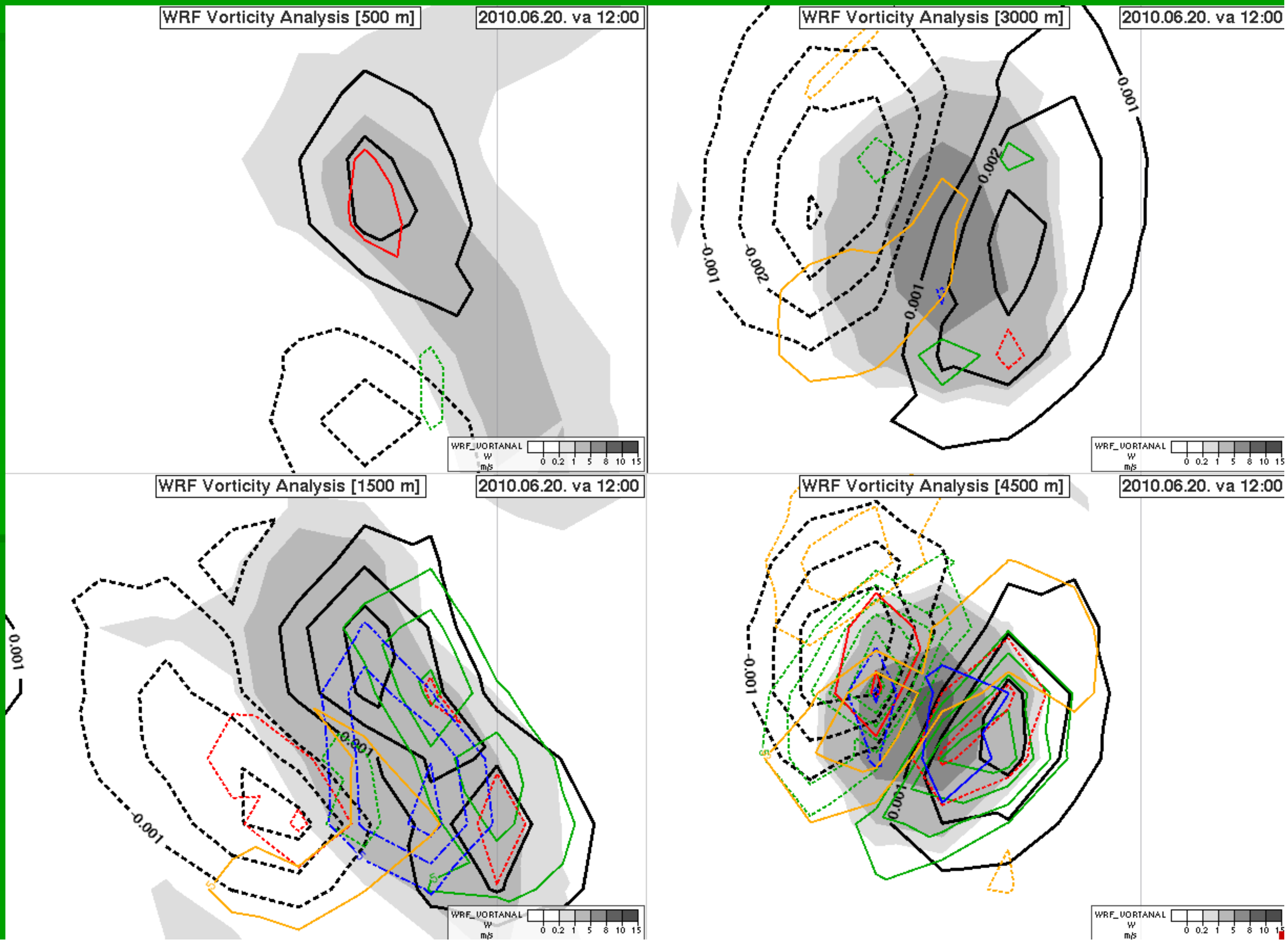

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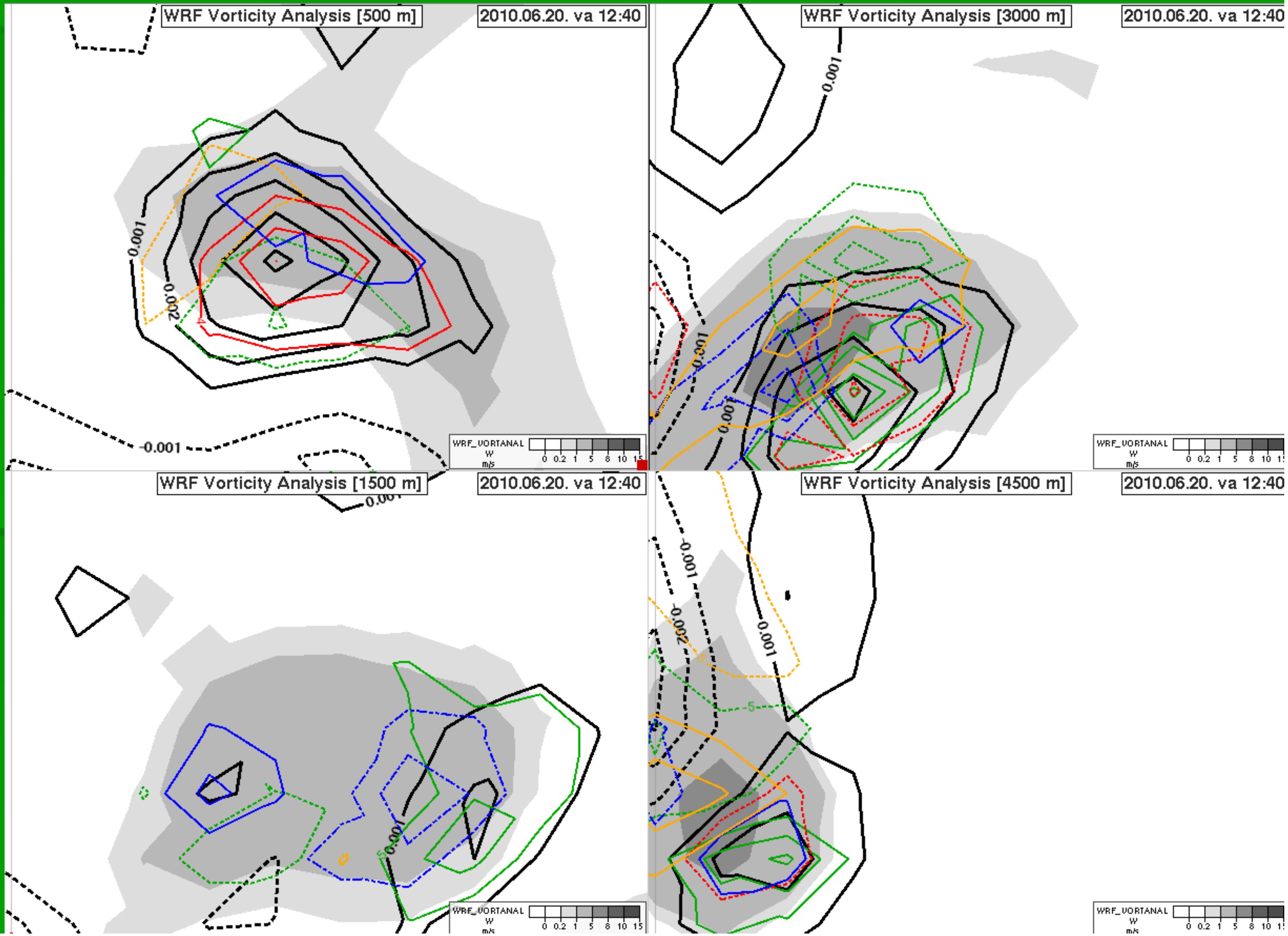
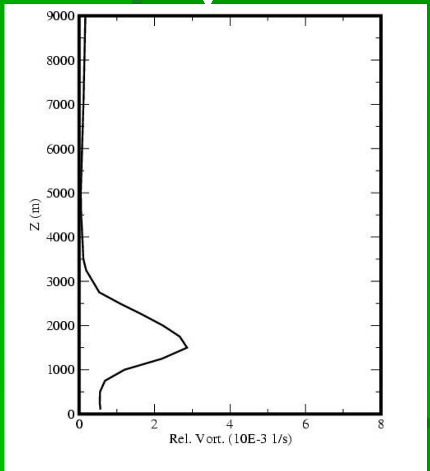


Case study: Vorticity analysis - vertical profiles in the vortex core

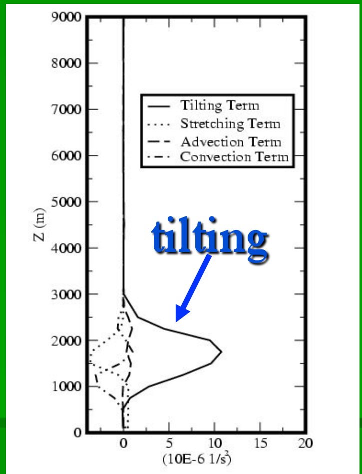
11:15 UTC

11:20 UTC

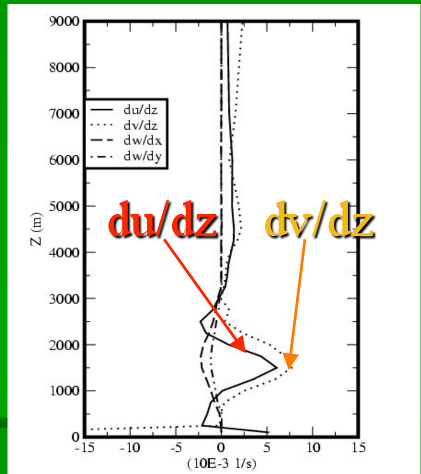
Vorticity profile



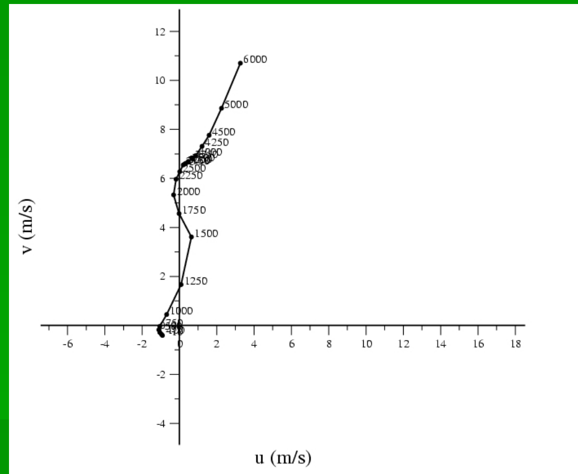
Vorticity terms profile



Tilting terms profile



Pre-storm Hodograph



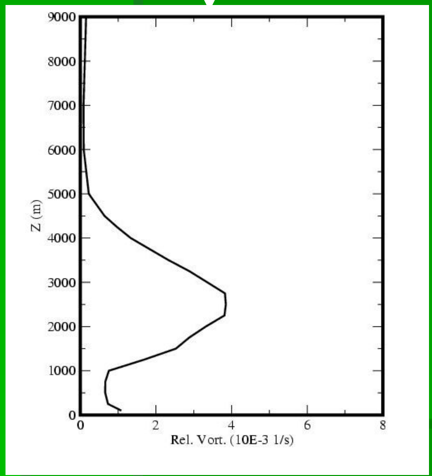
The vortex develops at first at around 1500 m via tilting

Case study: Vorticity analysis - vertical profiles in the vortex core

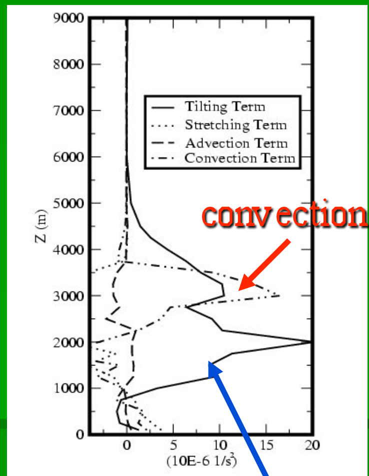
11:45 UTC

11:50 UTC

Vorticity profile



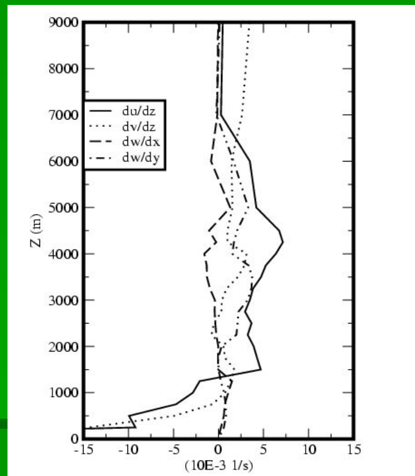
Vorticity terms profile



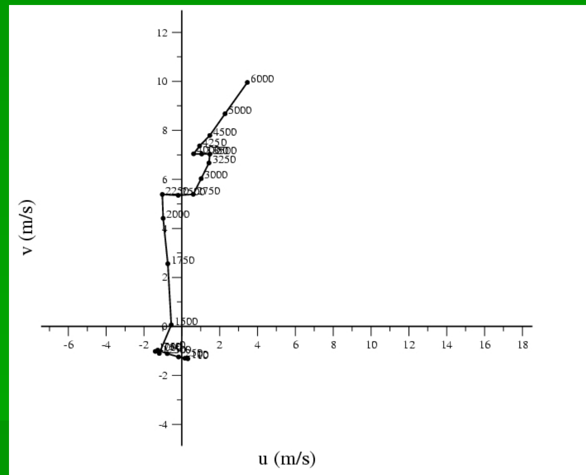
convection

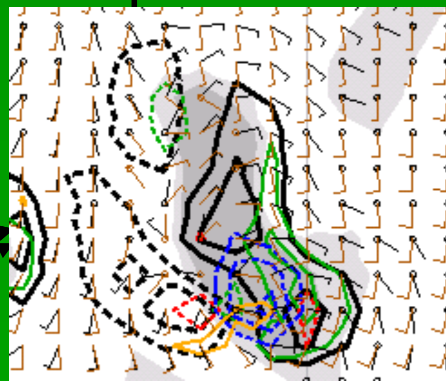
tilting

Tilting terms profile



Hodograph





The vortex spreads abruptly upward to midlevels via tilting and convection

Black barbs: wind at 1250 m

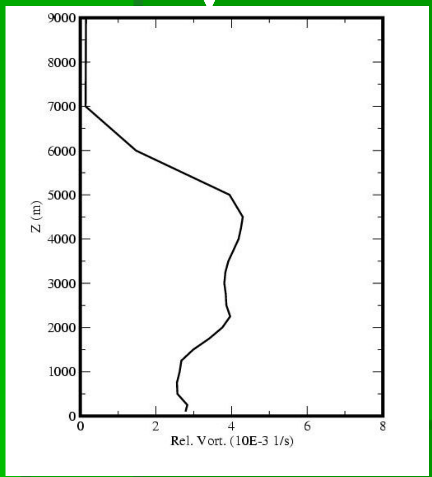
Red barbs: wind at 1750 m

Case study: Vorticity analysis - vertical profiles in the vortex core

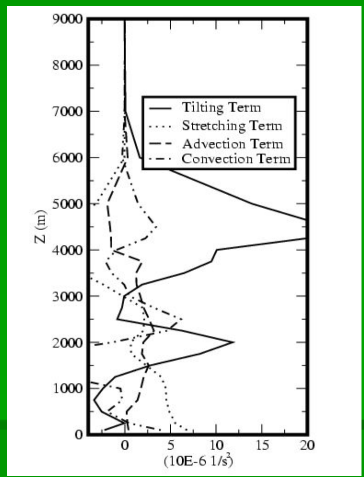
12:00 UTC

12:05 UTC

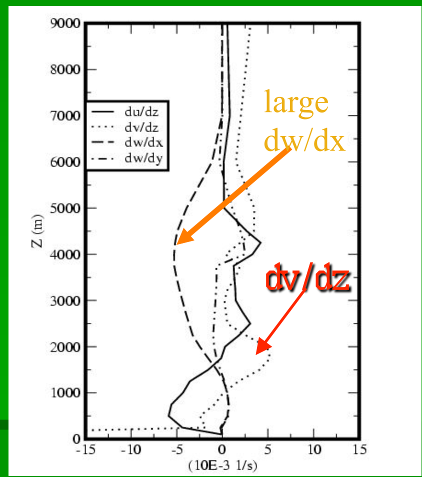
Vorticity profile



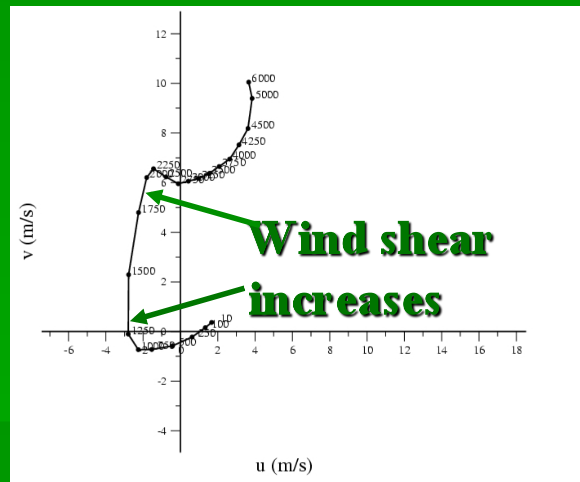
Vorticity terms profile



Tilting terms profile

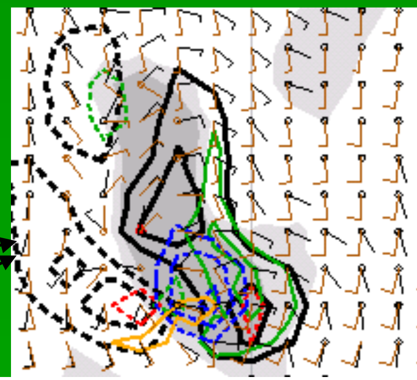


Hodograph



At lower levels (around and below 2000 m) mainly the locally increased wind shear, at midlevels (around 4000 m) the large vertical velocity in the vicinity of the storm enhances the tilting, hence deep mesocyclone develops

Black barbs: wind at 1250 m
Red barbs: wind at 1750 m

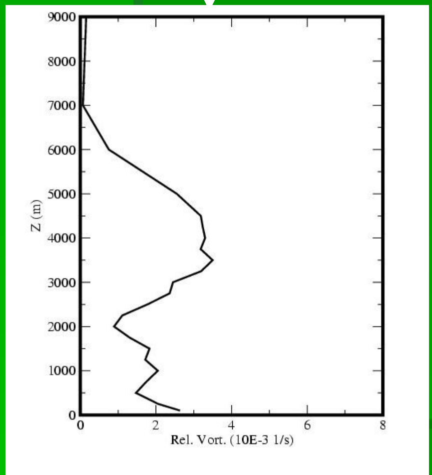


Case study: Vorticity analysis - vertical profiles in the vortex core

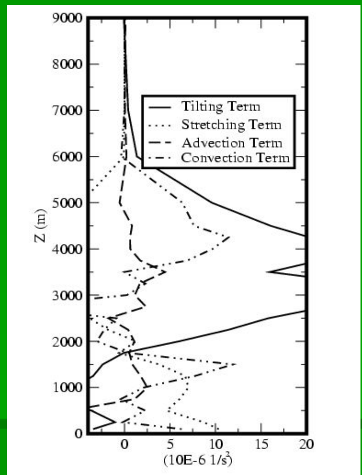
12:40 UTC

12:45 UTC

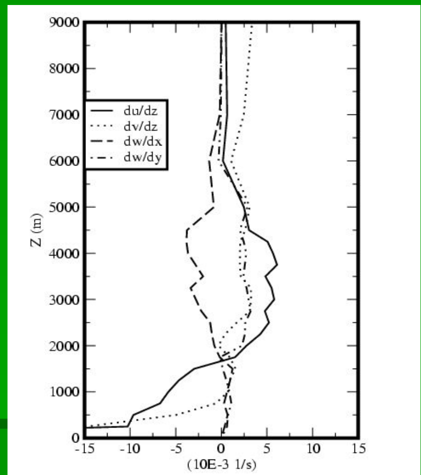
Vorticity profile



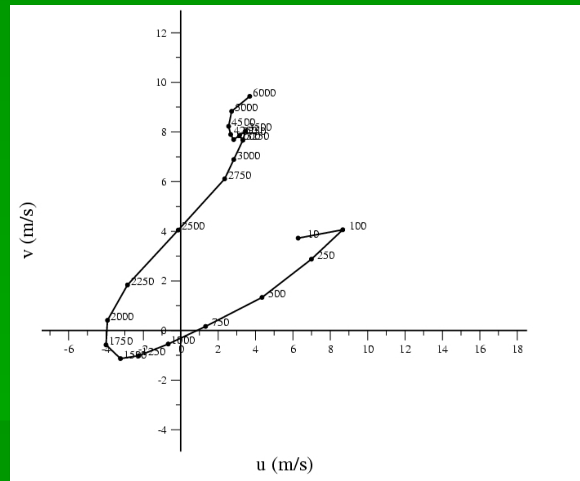
Vorticity terms profile



Tilting terms profile



Hodograph



The supercell in its mature phase: the mesocyclone descends to the surface levels

Conclusions and future plans

- Supercells can develop in environment characterized by deep layer wind shear well below 15 m/s
- The tilting mechanism and hence the vortexgenesis can be enhanced by the local increase of vertical wind shear induced by the storm inflow
- The mesocyclogenesis can start at lower levels (below 2000 m) mainly via tilting and then spread to midlevels via convection and tilting

We are planning:

- To investigate other weakly or moderately sheared cases to generalize the results (other cases in progress)
- To run idealized WRF test with similar shear properties
- To examine cases with similar shear conditons when multicell storms developed
- To find a good predictor (parameter) in these „grey cases” which can discriminates between supercell and multicell storms

Thank you for your attention!

This research is implemented through the CENTRAL EUROPE Programme co-financed by the ERDF