Meteorological analysis of an extraordinary hailstorm on 26 May 2009 („Felix“)

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storm facts…

- Long-living convective system (*derecho*) that moved from Switzerland over Germany to Czech Republic
- Severe damage due to
  - hailstones with diameter >~4 cm
  - maximum wind gusts ~120 km h^{-1}

…questions

- What was the synoptic situation? Which meso-(local)-scale conditions can be analyzed?
- Which characteristics and features of the convective system can be detected?
- What was the resulting damage pattern? How can it be described?

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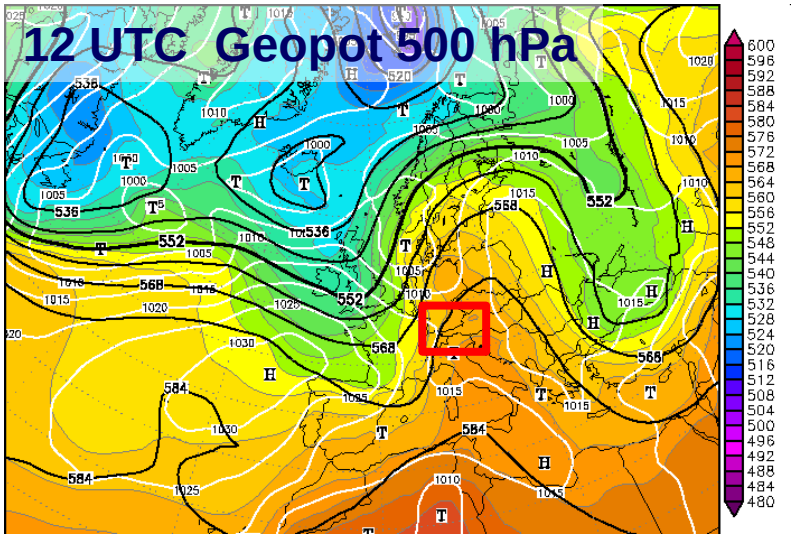
Synoptic conditions

- East side of an extended trough and jet
  → large-scale lifting
- Various convective storms developed over Europe
- Investigation area located in the warm sector of a frontal system, two cold fronts /convergence lines following
  → warm and moist air advection
- High instability (CAPE > 1000 J kg^{-1})



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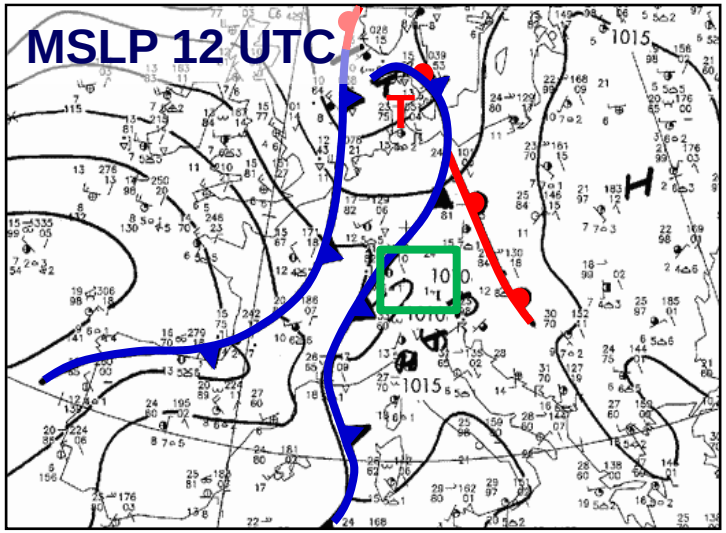

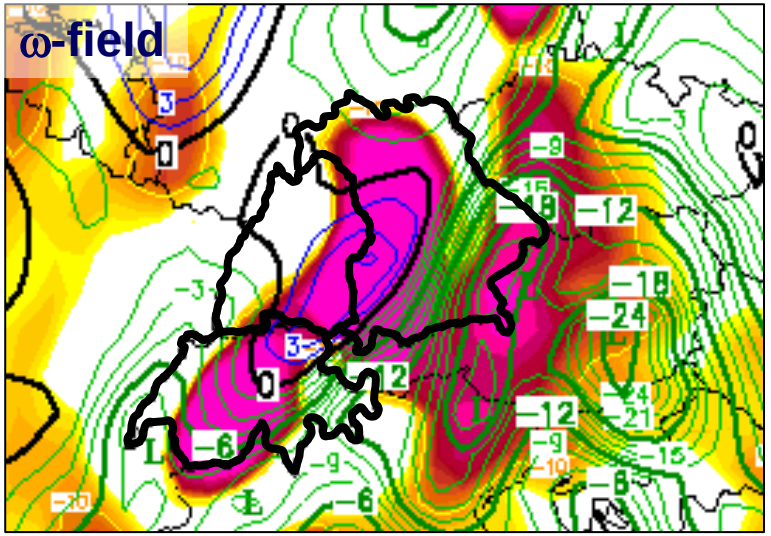

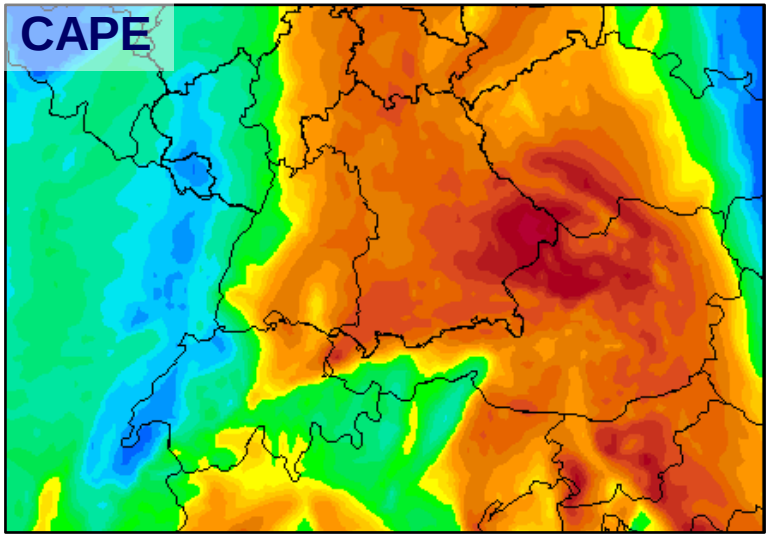

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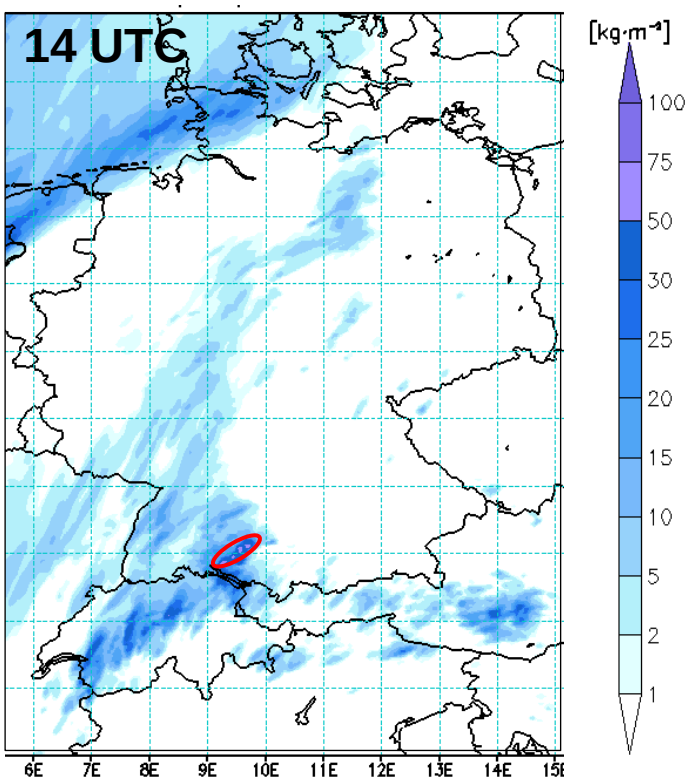
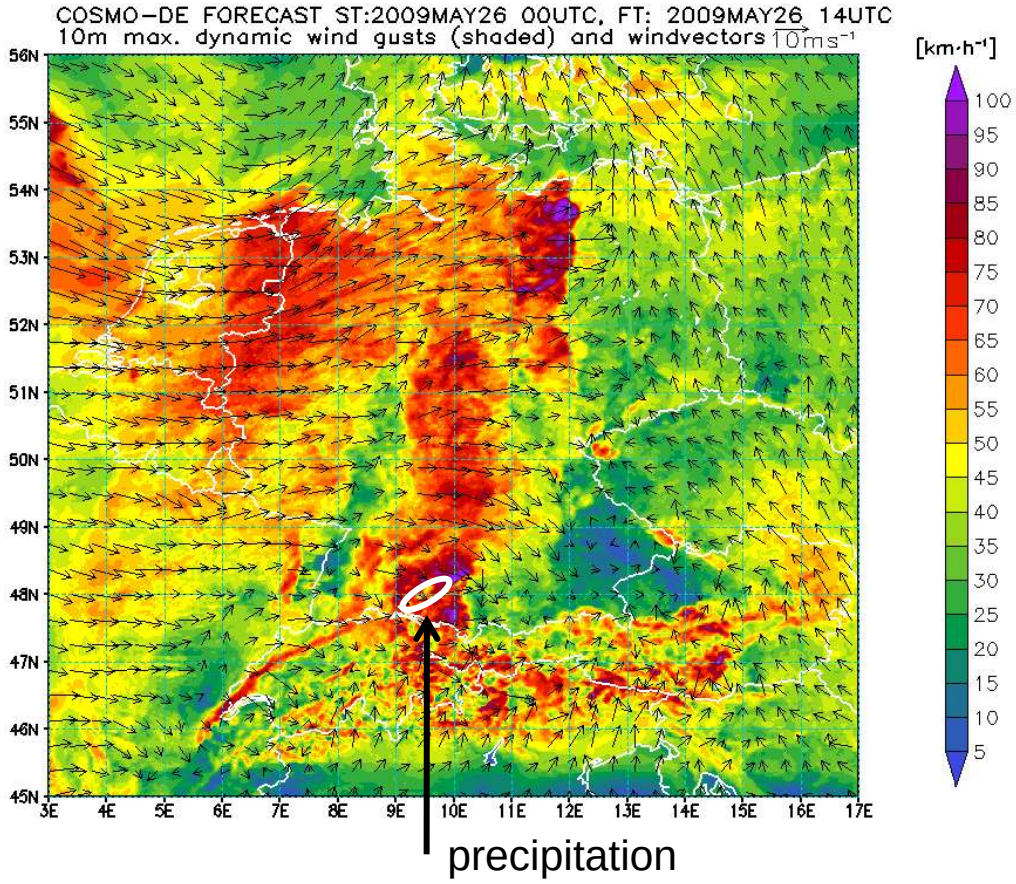
Local-scale conditions: gust wind speed

- COSMO-DE 4.13 (DWD); resolution: **2.8 km** / 52 vertical levels
- Initialized 3-hourly by COSMO-EU **assimilation of radar data by LHN**
- Deep convection directly simulated**;** shallow convection accord. to Tiedke





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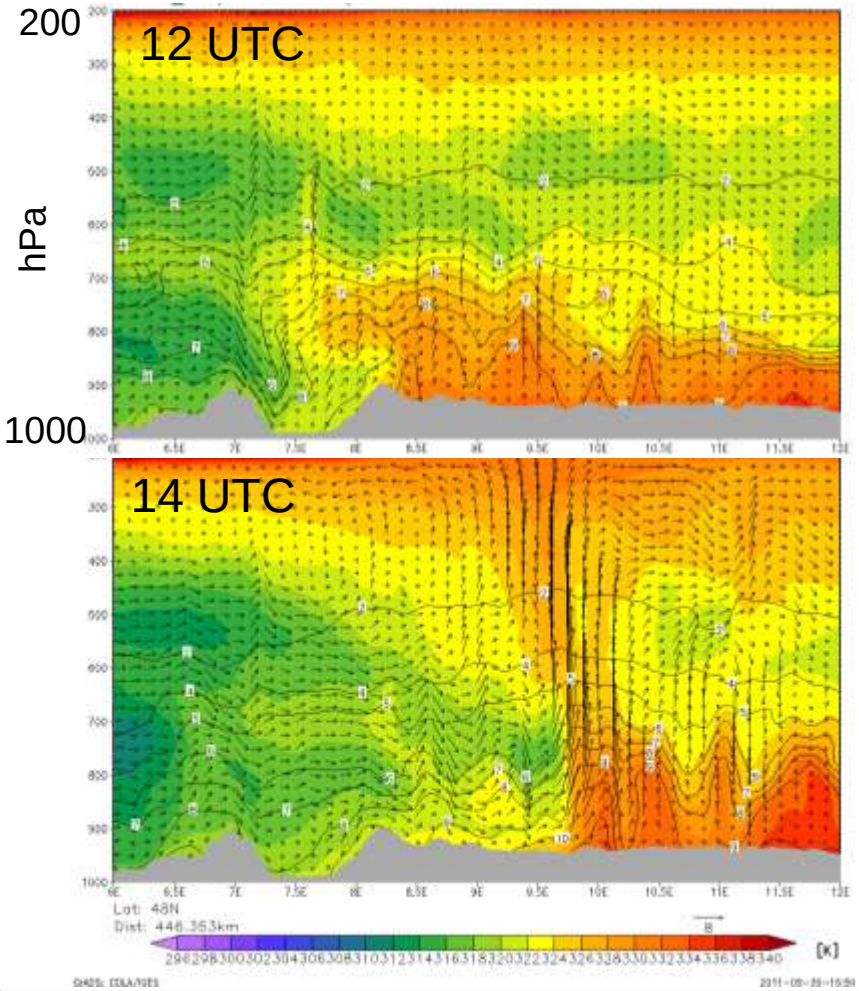
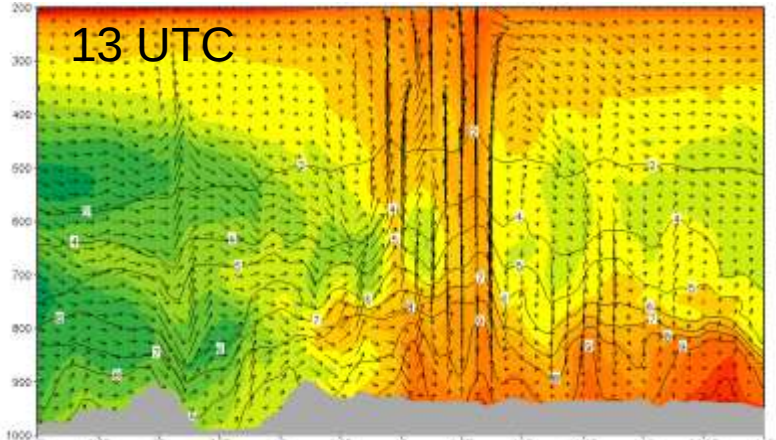
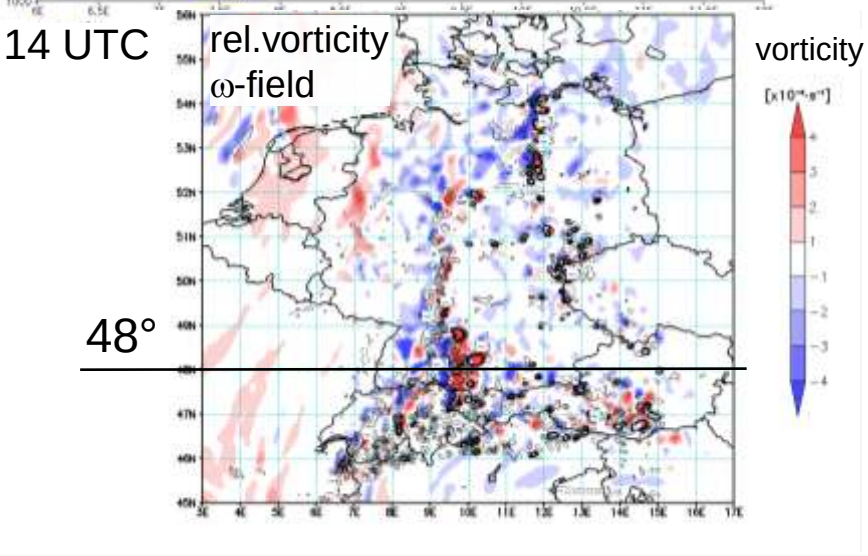
Local-scale conditions: cross sections θ_e, q_v, v

- High instability up to 600 hPa (decrease in θ_e; color shading)
- Convection develops in a region with locally max q_v (isolines)







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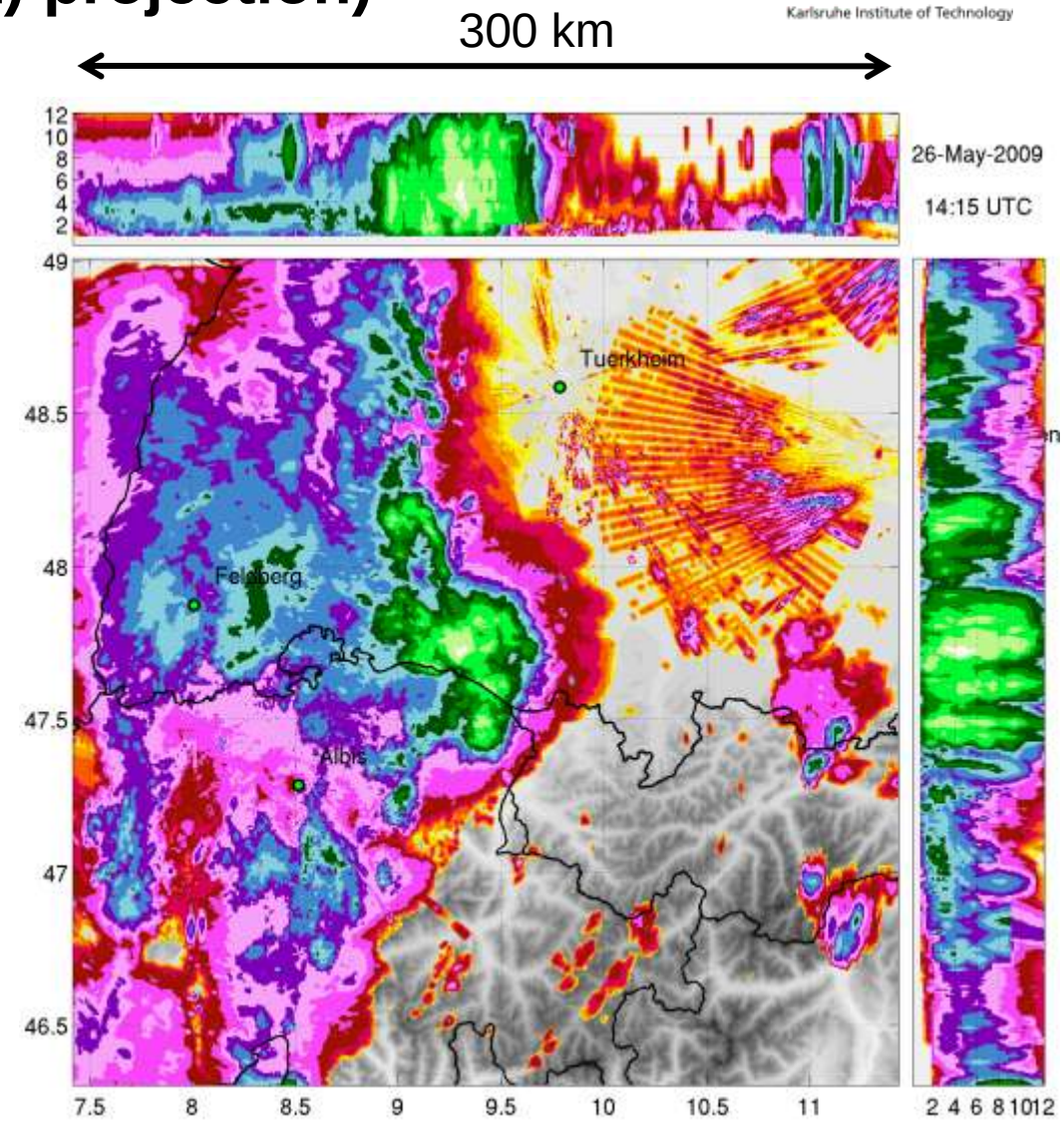
Radar composite (Max(Z) projection)

- Highest reflectivity at the forefront of the system
- various multicellular structures
- severe gust winds

  → triggering of new cells

  → bow echo



dBZ

0 10 20 30 40 50 60 70

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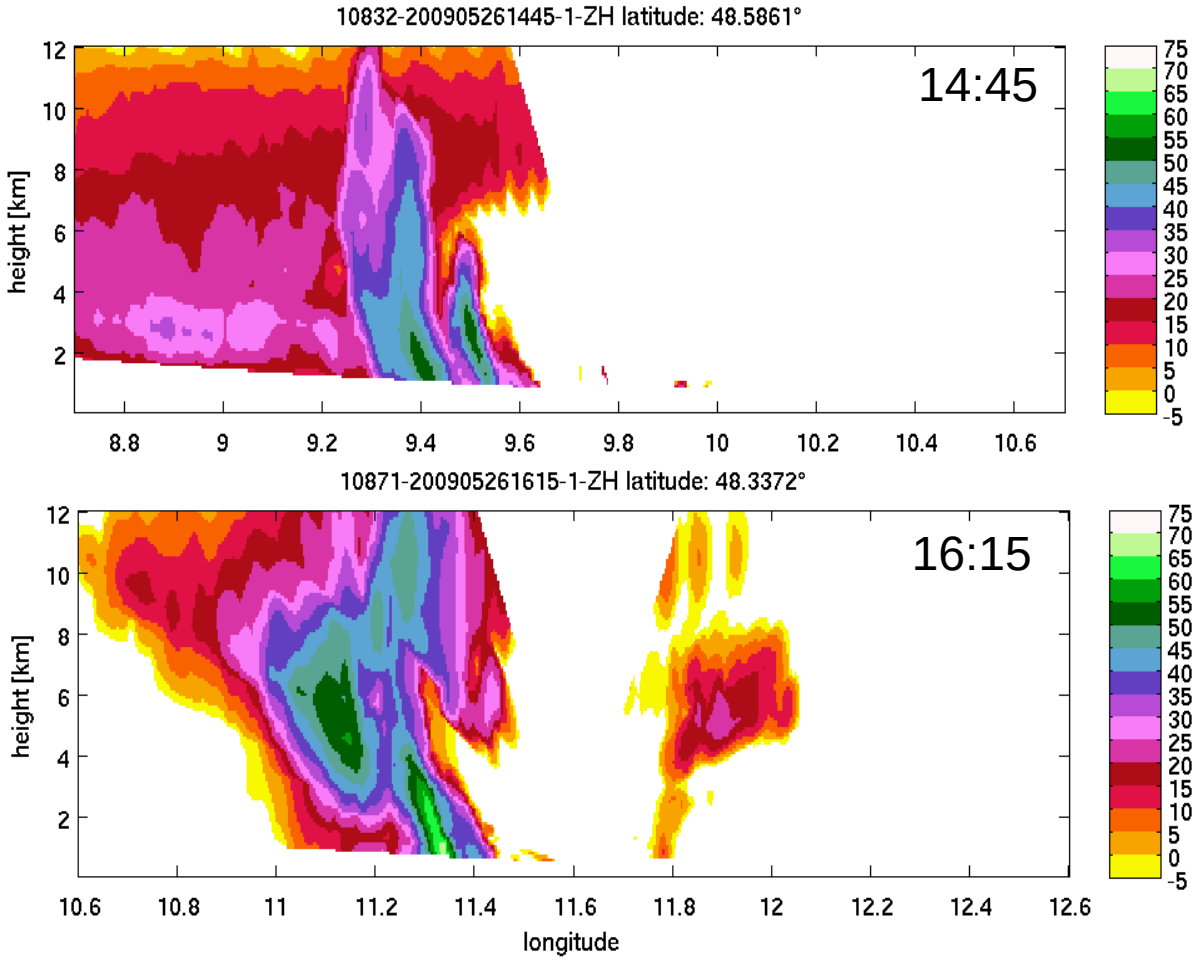
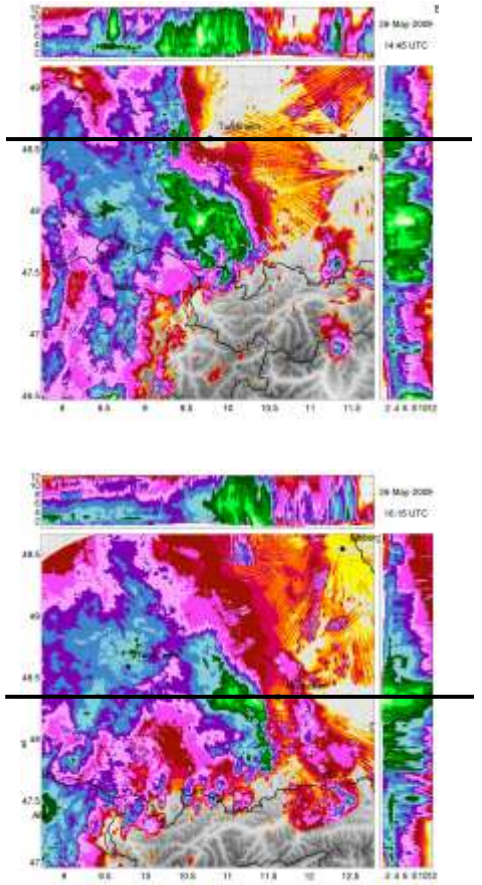
Radar composite: vertical cross-section

- *Pseudo* RHI: extended anvil + gust front triggering new cells





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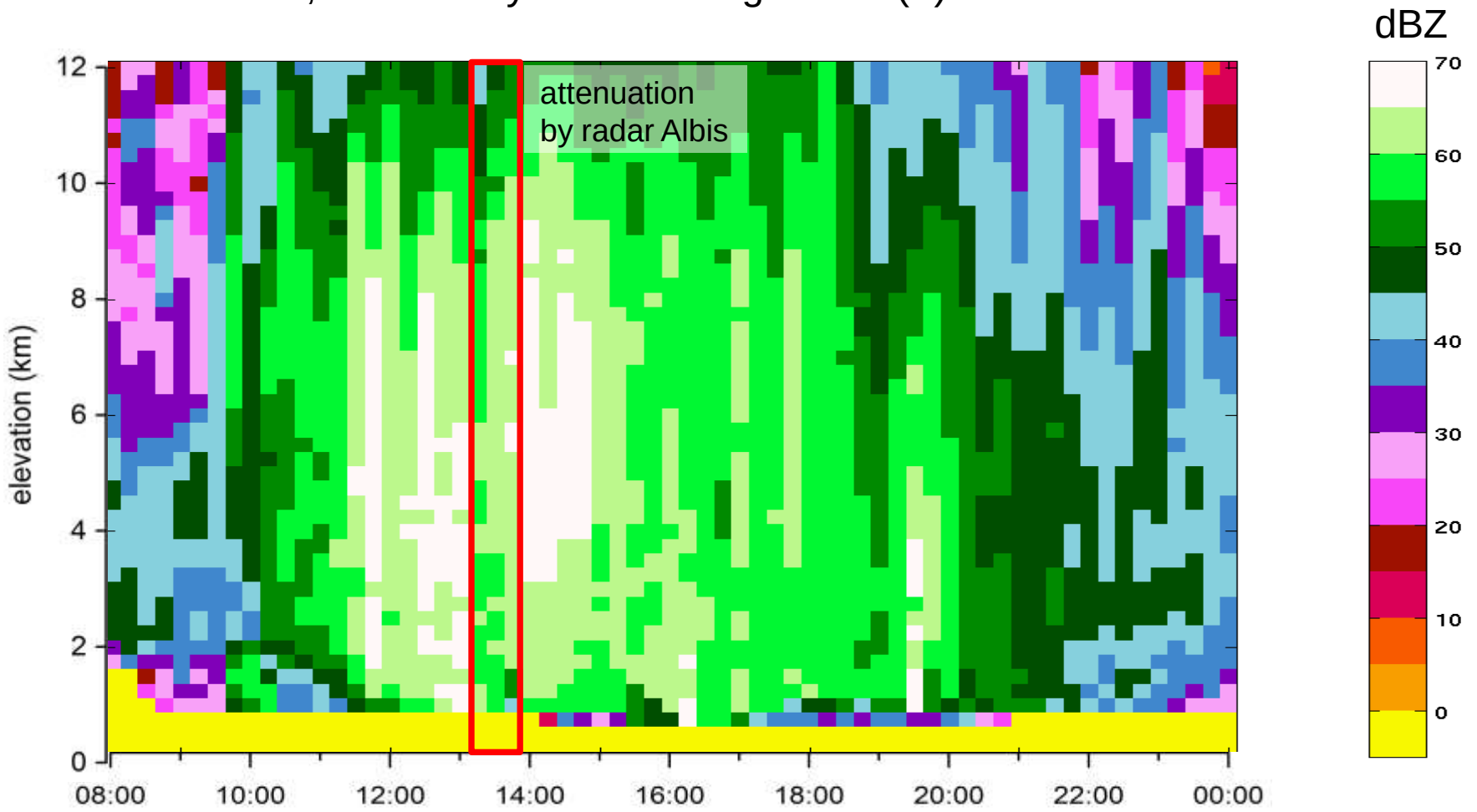
Time series / cross section of radar reflectivity

- High radar reflectivity (> 55 dBZ) up to 10 km
- Fast increase, slow decay and lowering of max(Z)



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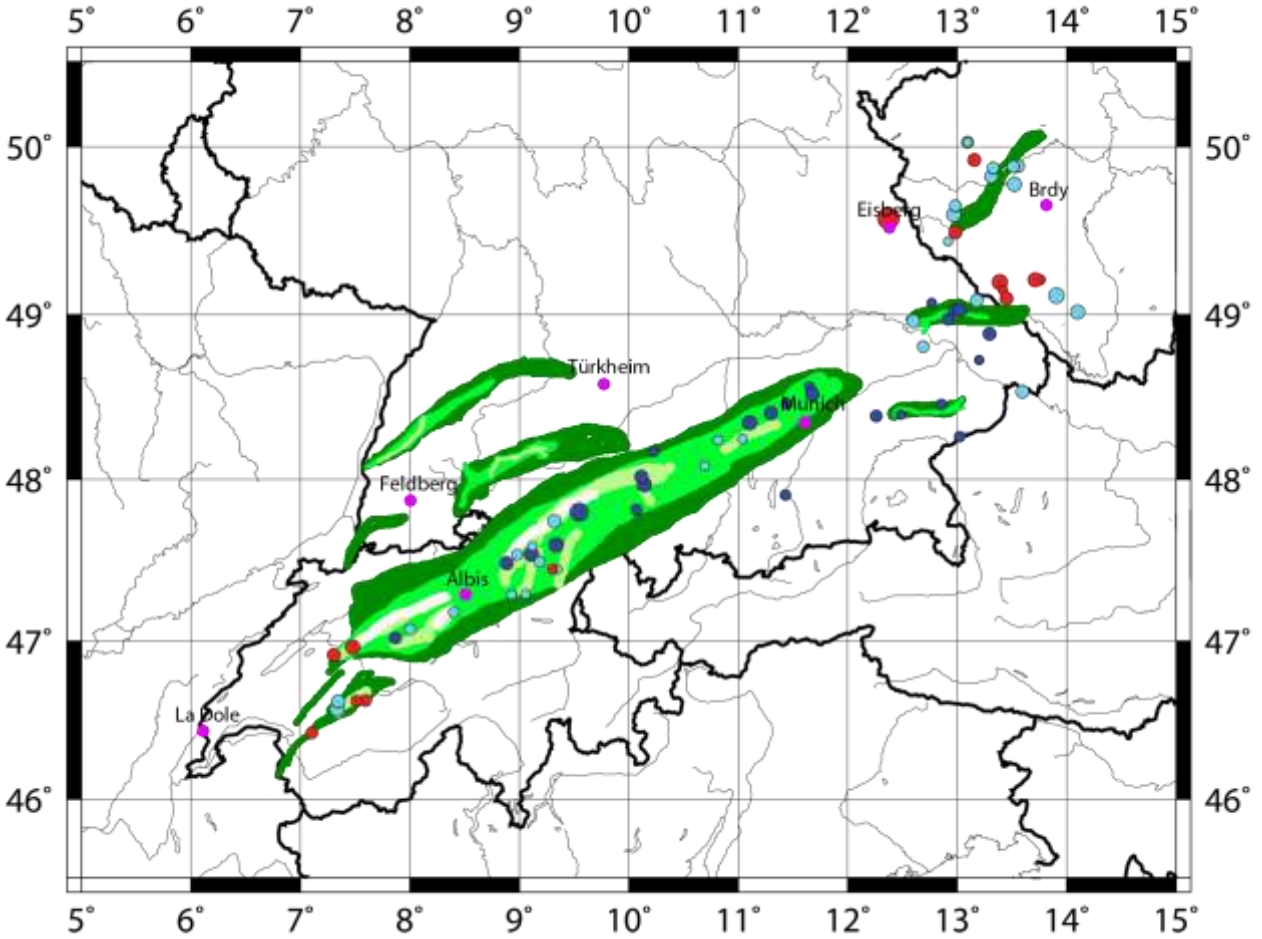
Radar reflectivity track and OTs

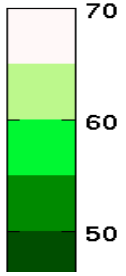
- Highest reflectivity coincides well with lowest OT temperatures



OT: 10.8 μm brightness temperature (Bedka, 2011)

- 195-200 K
- 200-205 K
- > 205 K

dBZ



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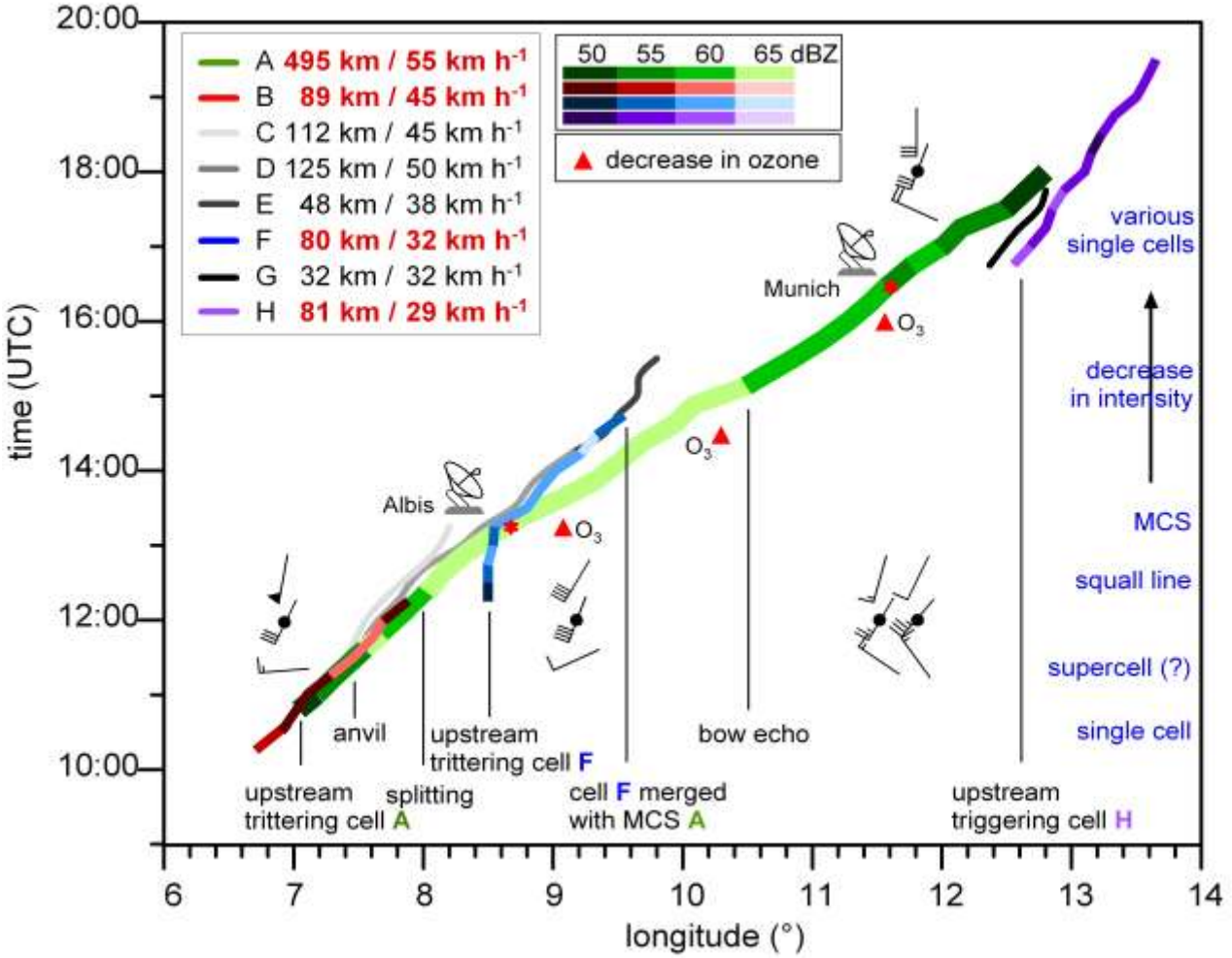
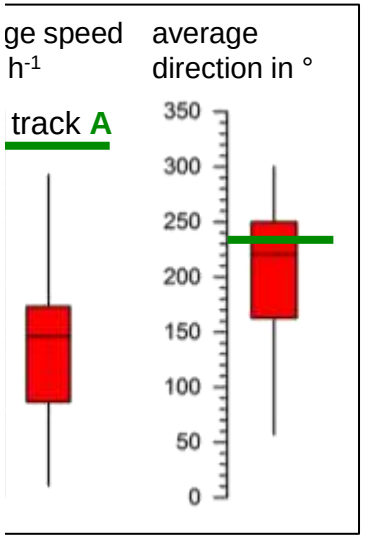
Tracks of convective cells on 26. May 2009

- Tracking criterion: 50 dBZ forward flank of the 15 min scans



atology SW-Germany
el, 2010)



wind from soudings

300 hPa

500 hPa

850 hPa

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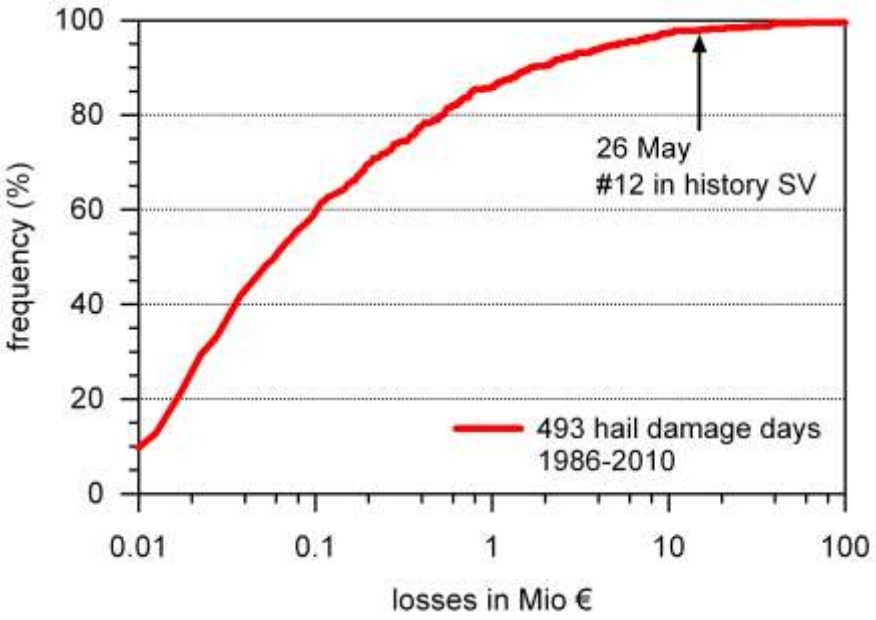
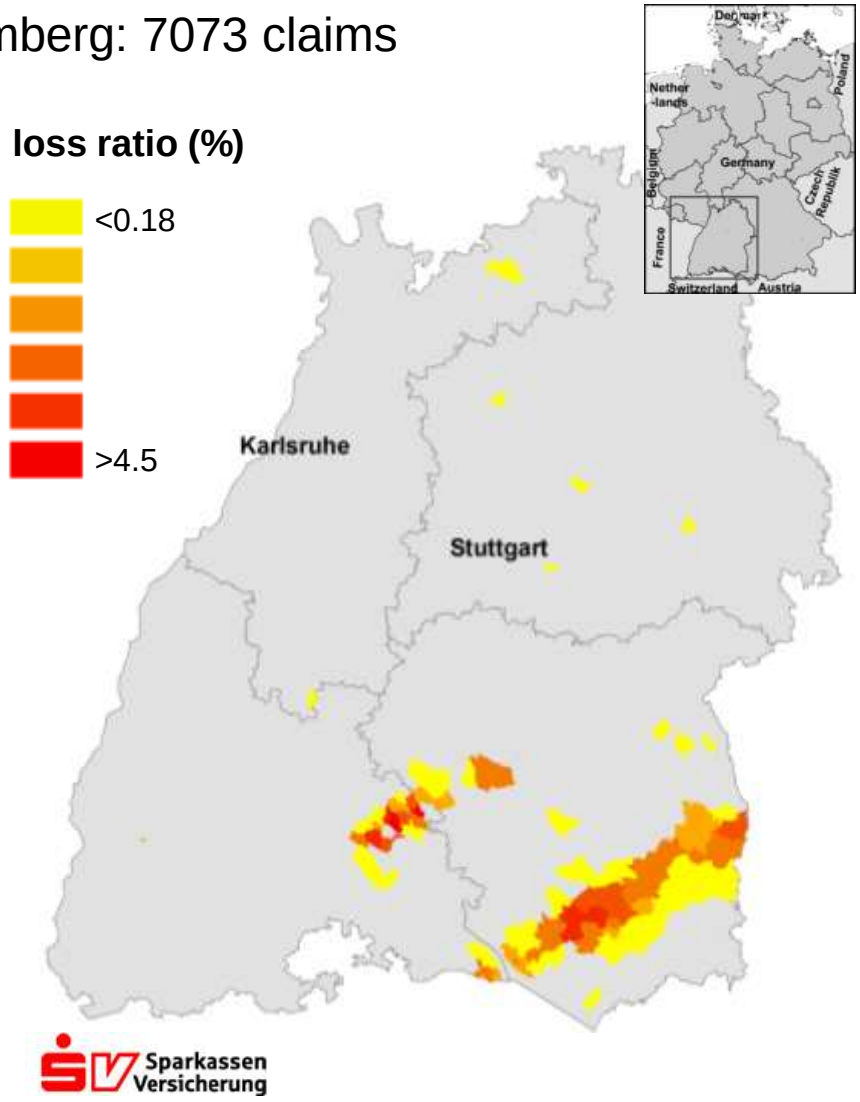
Damage analysis: (a) residential buildings

- Damage to **buildings** in Baden-Württemberg: 7073 claims = 14.88 millions €
- Loss ratio: **< 8%**
- Return period : **2.1 yrs** (based on losses 1986-2010)





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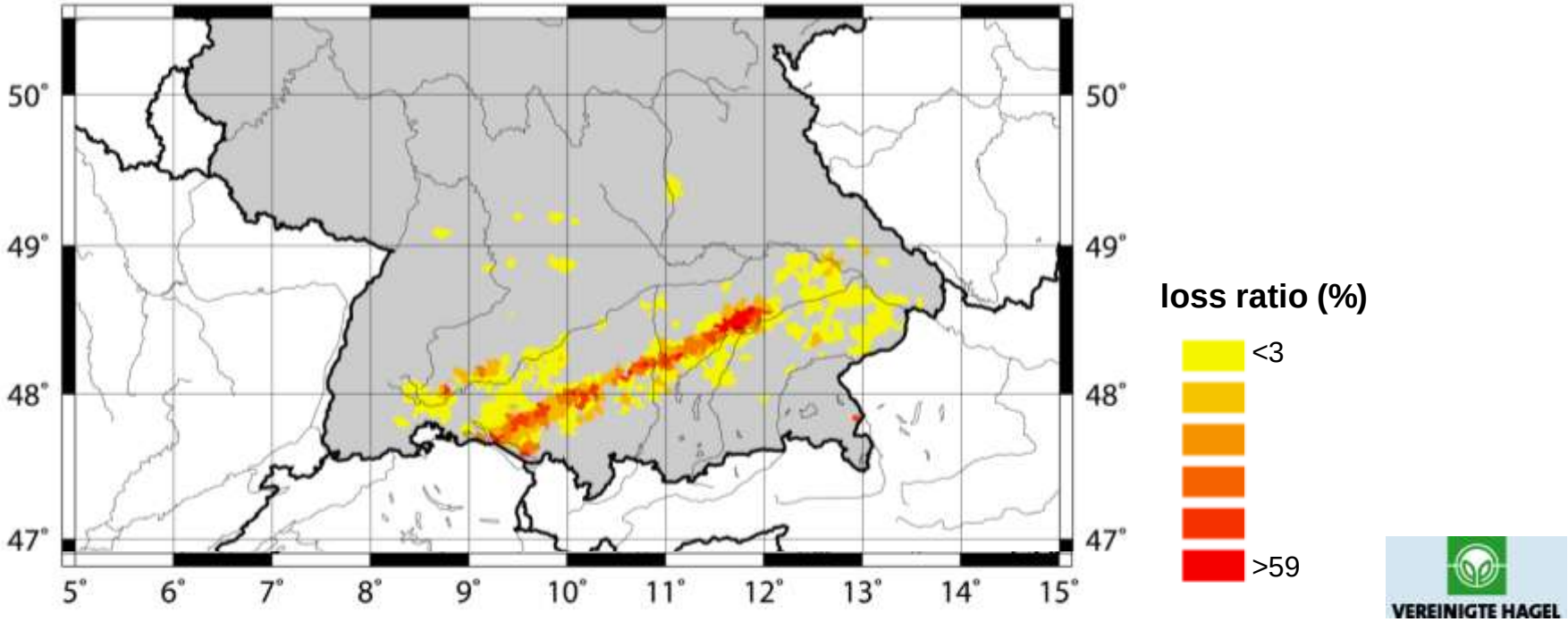
Damage analysis: (b) crops

- Damage to **crops** in Baden-Württemberg: > 100 millions €
- Loss ratio: **> 60%**
  - > 2/3 vinyards destroyed at Lake Constance
  - ~ 1/3 hops destroyed in SW-Germany



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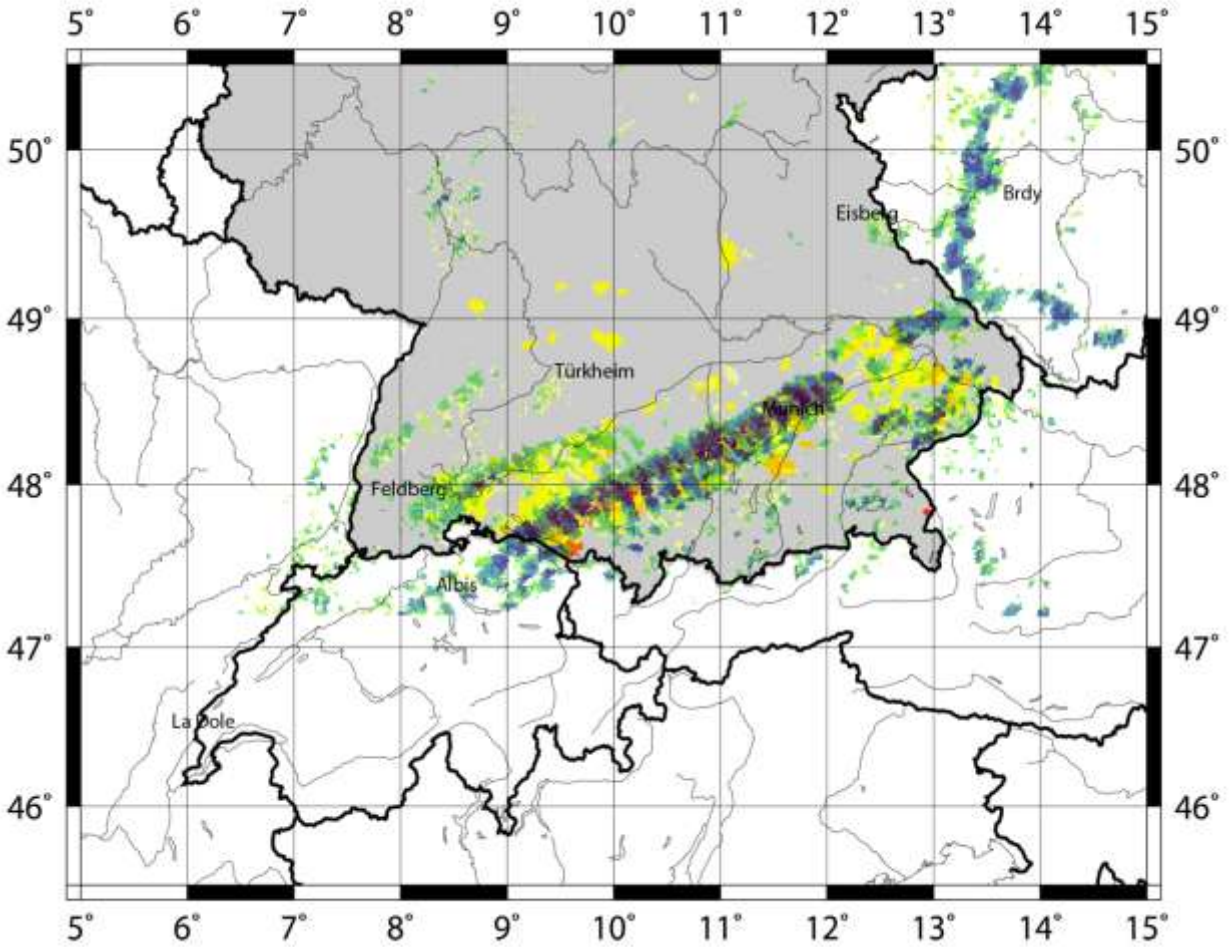
Hail damage estimation from radar

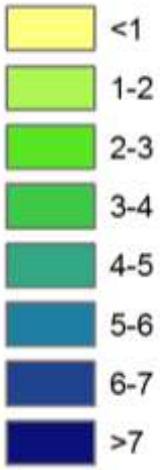
- **Hail criterion**: distance between 0°C and 45 dBZ echotop (Waldvogel et al., 1979)



Result: hail criterion vs damage (threshold: 6 km)

- **HSS = 0.44**
- **TSS = 0.43**
- **POD = 0.47**
- **FAR = 0.52**

hail crit. (km)



(cf. Puskeiler et al., 2011)

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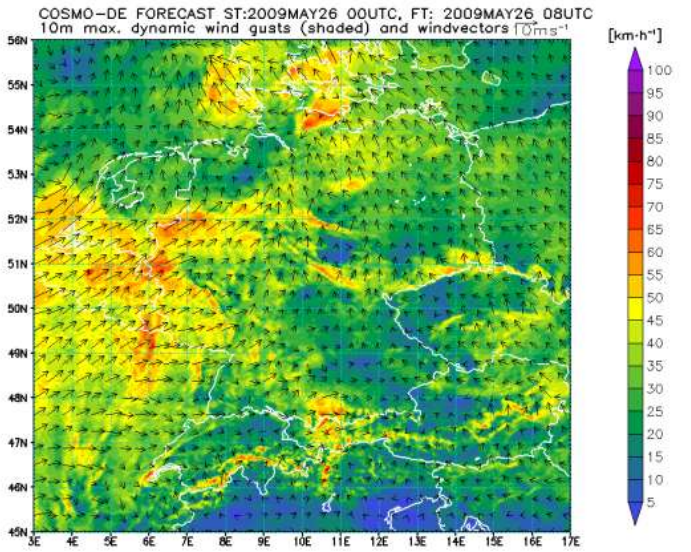
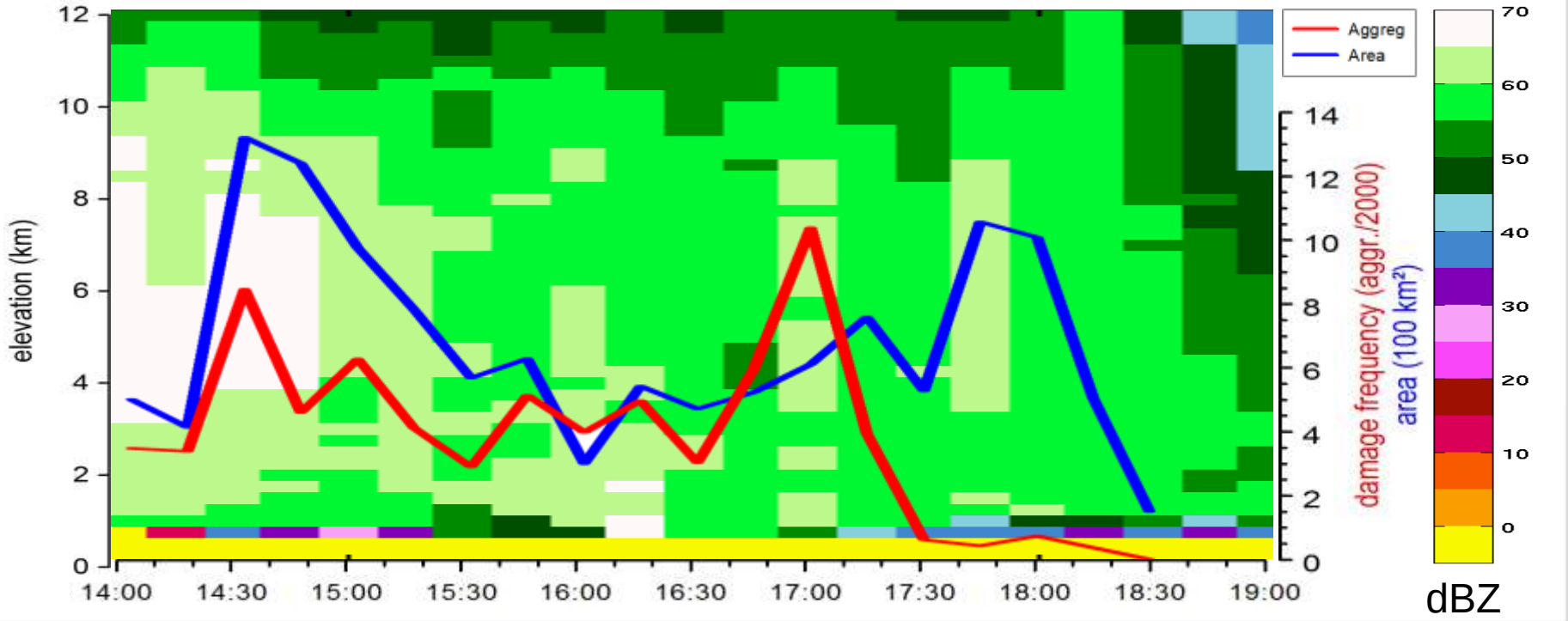
Damage vs reflectivity

- First damage maximum can be explained by magnitude and vertical extent of reflectivity
- Second maximum driven by high gust wind speed





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Conclusions

- Development of a pre-frontal severe MCS with various cullular characteristics in a moist, unstable environment, triggered by large-scale lifting
- Severe gust front (derecho) caused triggering of various new cells
- Damage patterns can be explained by the combination of large hail and high gust wind speeds; (more or less) proportional to the height difference between 45 dBZ reflectivity and 0°C level
- MCS resembles the famous Munich hailstorm (1984); however, large cities were not hit
- In case of hailstorm hazard or risk assessment, one must be aware that such long-living systems basically can be occurred everywhere

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