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?
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\(^{-1}\))
Synoptic conditions

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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

COSMO-DE FORECAST ST:2009MAY26 00UTC, FT: 2009MAY26 14UTC
10m max. dynamic wind gusts (shaded) and wind vectors [m s⁻¹]

[Map showing gust wind speed with precipitation highlighted]
Local-scale conditions: cross sections $\theta_e$, $q_v$, $v$

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

![Radar Composite Image](image-url)
Radar composite: vertical cross-section

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

![Radar composite images with color scale and timestamp annotations](image-url)
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)

![Image of radar reflectivity time series and cross section]
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
Tracks of convective cells on 26. May 2009

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

Climatology SW-Germany
(Kugel, 2010)

- average speed in km h⁻¹
- average direction in °

Wind from soundings:
- 300 hPa
- 500 hPa
- 850 hPa
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)

![Graph showing frequency and losses over time]

*loss ratio (%)*

- <0.18
- >4.5
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
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

(cf. Puskeiler et al., 2011)
Damage vs reflectivity

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

- Development of a pre-frontal severe MCS with various cellular 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.