Karlsruhe Institute of Technology

Institute for Meteorology and Climate Research,
KIT Karlsruhe, Germany

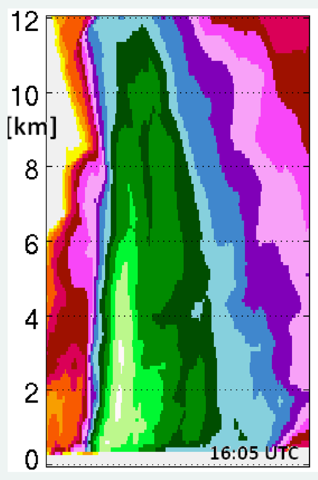
Case studies of severe thunderstorms

Some special radar derived parameters and their development during the life cycle of an isolated multicell storm

Malte Neuper (malte.neuper@kit.edu) and Jan Handwerker (jan.handwerker@kit.edu)

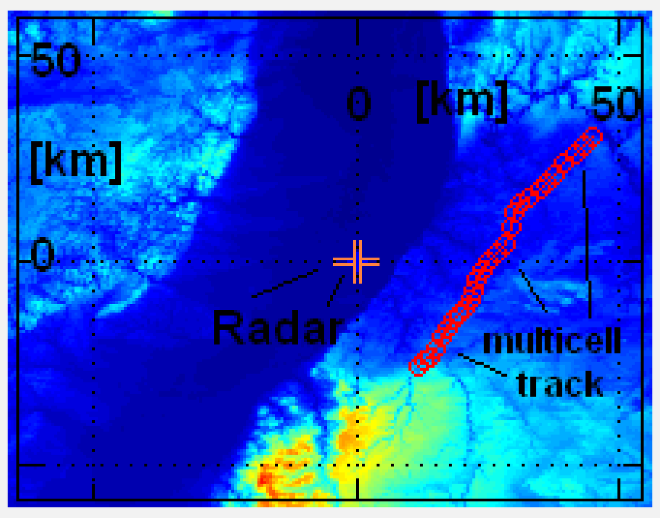
The studied multicell storm

Date: 20. August 2009
Observed by:
C-Band Doppler Radar
Lifetime: 130 min
(15:20-17:30 UTC)
Tracked distance: 65 km
Max. Reflectivity: 68 dBZ



<u>Synoptic Environment</u>:
- Advancing trough over Western Europe
- Unstable warm subtropical air (MLCAPE: 292 J/kg, LI: -1.44 K, PW: 2.82 cm)
- Vertikal shear for storm organization: DLS: 12.1 m/s, LLS: 3.0, BRN: 21.3
- Other relevant convective and thermal heights: LFC: 3750 m, 0°C-level at 4130 m, -10°C-level at 5710m, EL: 10950 m

the thunderstorm track:

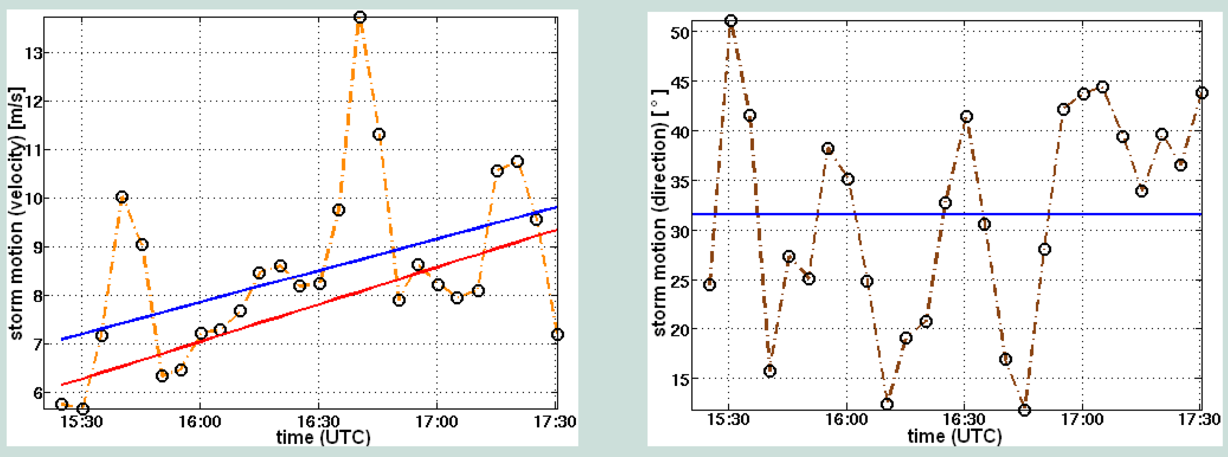


Data handling and quality

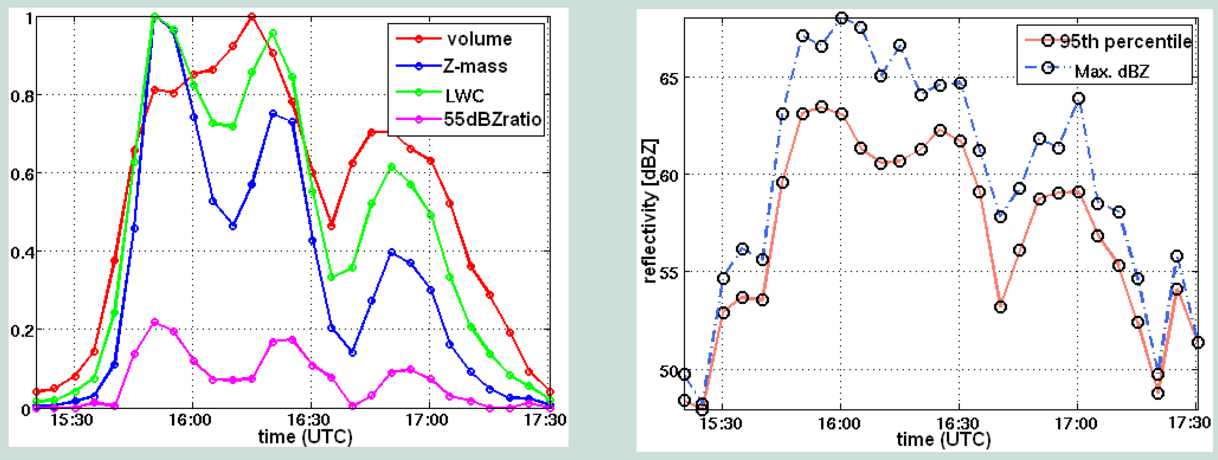
- **Input data:** polar reflectivity data
- **Tracking algorithm:** <u>TRACE3D</u> (Handwerker 2002), modified by using an absolute threshold of **40 dBZ**
- **Data quality:** quite good: isolated cell nearby, use of standard propagation conditions justified, between 15:40 and 16:25 UTC top of the cell possibly in the cone of silence.

Evaluated parameter:

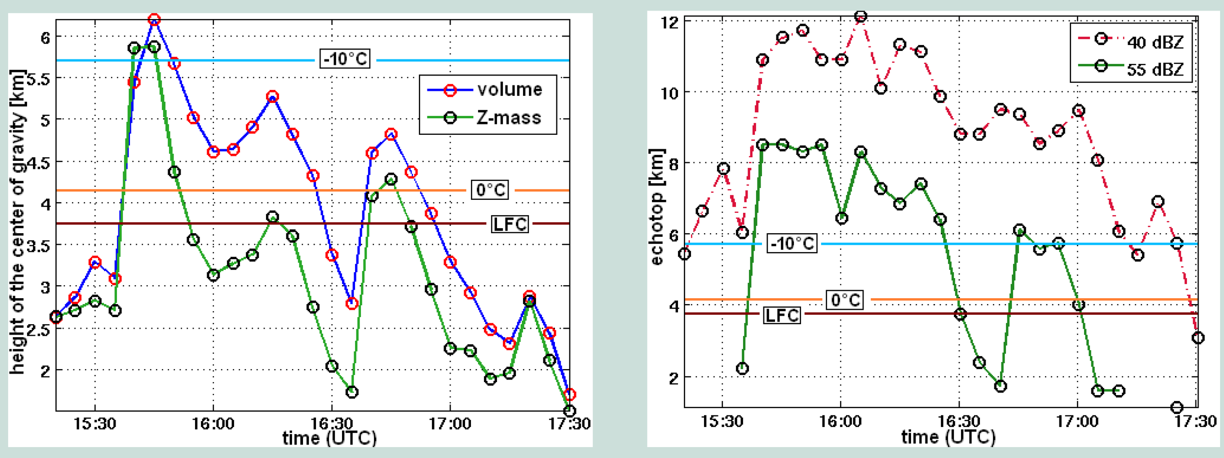
- **speed and direction** of the storms' reference point
- **LWC, 40 dBZ echotop** (top of defined cell), **55 dBZ echotop**
- **maximum reflectivity** and **95th percentile**
- **volume (V)**
- **reflectivity mass** $\left(= \int Z\,dV\right)$
- **height z_V of the volumes' center of gravity** and **height z_M of the reflectivity <u>mass</u>' center of gravity**
- **LFC-, 0°C** and **-10°C-volume-** and **reflectivity mass-ratio** (defined as ratio of volume (or refl. mass) above the specific level to the total volume (refl. mass, resp.) – with -10°C as roughly the beginning of the optimal hail growth zone (Grenier et al. 1983))
- **55dBZ-ratio** (ratio of beam volume elements with Z ≥ 55 dBZ to total volume – with 55 dBZ as very rough estimate for hail occurence (Hohl et al. 2002)



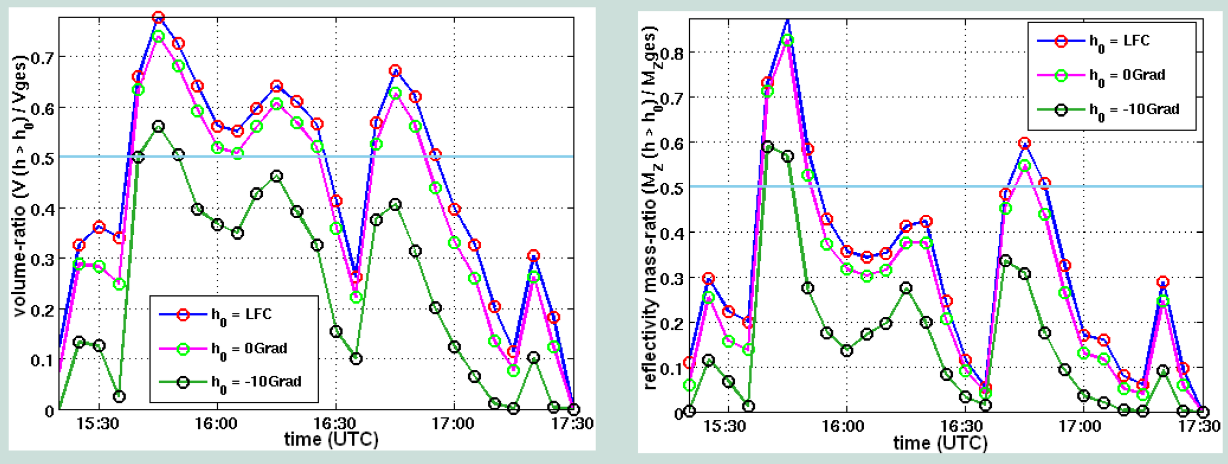
***left:** time series of the storms' speed – with regression lines for all data points (blue) and just all except the outliers (red); **right:** time series of storms' direction – with mean direction (blue)*



***left:** time series of the volume, the reflectivity mass (Z-mass) and the LWC (normalized with maximum value) and the 55 dBZ-ratio; **right:** time series of the 95th percentile and the maximum of the cell representing reflectivities*



***left:** time series of the center of gravity of the volume and of the reflectivity mass, and height of the LFC, the 0°C and the -10C level; **right:** time series of the 40 dBZ echotop and the 55 dBZ echotop*



***left:** time series of the LFC-, 0°C- and -10°C-volume-ratio; **right:** time series of the LFC-, 0°C- and -10°C-reflectivity mass ratio*

Results

- Time series show a <u>distinct oscillation</u>, which is characteristic for a multicell storm.
- Peaks in storms' speed and shift in direction show new development of daughter cell during multicell life cycle by new updraft pulse on left flank (internal shift).
- **<u>Pattern revealed by cross correlation analysis</u>**:
  - <u>first</u>: local maximum of $\mathbf{z_M}$ and **-10°C-refl. mass-ratio** and maybe **0°C-refl. mass-ratio**
  - <u>second</u>: increase of storms' **speed,** shift of **direction,** local maximum of $\mathbf{z_V}$, **LFC-, 0°C and -10°C-vol. ratio** and **LFC-refl. mass-ratio**
  - third: local maximum of the total **volume**, total **refl. mass**, the **LWC** and the **55dBZ-ratio**

→ Pattern is consitent with conceptional model of convection development:

- New updraft leads to more hydrometeors aloft (especially above the -10°C level).
- Further growth of hydrometeors in amount and size, but cell stays top heavy.
- Fall down, but still further growth of hydrometeors, mass of cell concentrated near the base: <u>precipitation core unloads.</u>
- Transition to decay phase; later eventually new updraft pulse initiates development of new daughter cell and new life cycle.

<u>Possible forecast value</u> (to be further tested):

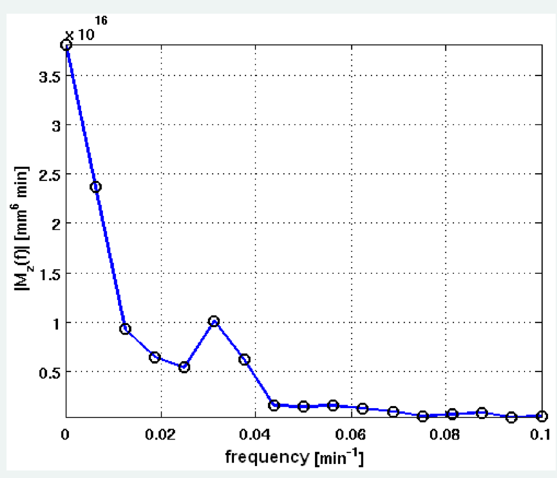
- Comparison of the height dependent parameters to LFC, 0°C and -10°C level is „case sensitive" (as e.g. the „VIL of the day concept").
- Strength of updraft best indicated by $\mathbf{z_V}$, $\mathbf{z_M}$ and the **level related volume ratios**.
- Next mature stage will be „stronger" (max. refl. ≥ 58 dBZ), if:
  - $\mathbf{z_V}$ ascends above 0°C level and/or $\mathbf{z_M}$ at least above LFC.
  - **LFC-** and **0°C-volume-ratio** reach at least 0.5 and **-10°C-volume-ratio** at least 0.3.
- Next mature stage remains „weaker" (e.g. 95th percentile ≤ 55 dBZ), if:
  - **LFC-** and **0°C-volume-ratio** stay below 0.5 and **-10°C-volume-ratio** below 0.3.
- Last multicell cycle indicated by $\mathbf{z_V}$ and $\mathbf{z_M}$ **stay** below 0°C level, LFC resp. during the mature stage.

→ Enough „reflectivity mass" has to be lifted above the convective relevant levels for a stronger / further cell development.

Oscillation frequency

cycle period by visual analysis:
- 25 minutes, if one analyses 5 cycles
- 32.5 minutes, if one analyses 4 cycles

cycle period by Fourier transform:



→ secondary maximum at 0.031min

Cycle Period of 32 min

one sided amplitude spectrum of the total refl. mass

References:

- Grenier, J.C., Admirat, P., Zaui, S., 1983 : Hailstone growth trajectories in the dynamic evolution of a moderate hailstorm. *J. Climate Appl. Meteor.,* **22**, 1008-1021
- Handwerker, J., 2002: Cell tracking with TRACE3D – a new algorithm. *Atmos. Res.,* **61,** 15 – 34
- Hohl, R., Schiesser, H., Aller, D., 2002: Hailfall: the relationship between radar-derived hail kinetic energy and haul damage to buildings. *Atmos.Res.,* **63 (3-4),** 177-207.