# An updated 3D radar-based hail statistic for Germany including further characteristics

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## Backstory

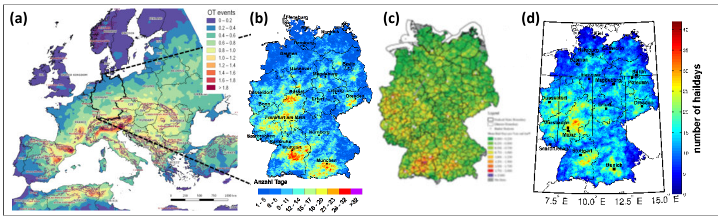
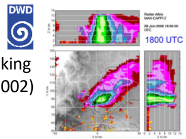


*Fig. 1: For Germany, several hail climatologies already exist based on different data sets (satellite, radar, eyewitness, weather station, lightning, and insurance data):*
***(a)*** *Punge et al., 2014; 2017 (based on overshooting tops, 2004–2014);*
***(b)*** *Puskeiler et al., 2016 (3D radar, hail tracks, 2005–2011);*
***(c)*** *Junghänel et al., 2016; 2D radar, 2002–2011);*
***(d)*** *Schmidberger, 2018 (3D radar, hail tracks, 2005–2015).*

Weather radars are the most powerful remote sensing tools for indirect hail detection. In particular, hail detection algorithms using volumetric (3D) radar reflectivity provide reliable estimates of hail on the ground. We present an **update of an existing hail climatology for Germany** (Schmidberger, 2018; 2005–2015) based on **hail tracks** identified by a cell detection and tracking algorithm (TRACE3D) by incorporating recent data **(new period: 2005–2021)**.

## Data & methods

- ✗ Data basis: **3D radar data** of *Deutscher Wetterdienst* (DWD)
- ✗ 17-year period: **2005 – 2021** (summer-half year)
- ✗ Radar-based cell detection and tracking algorithm **TRACE3D** (Handwerker, 2002) based on 15 min time steps (at least 3 time steps)



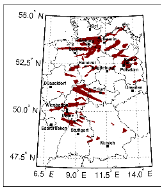


*Fig. 2: Visualization of potential hail tracks as polygon tracks, detected by TRACE3D, on 15 July 2015.*

- ✗ **What's new**: new filter algorithms (e.g., false detections, split and merge artefacts, etc.)

## Hail track statistics

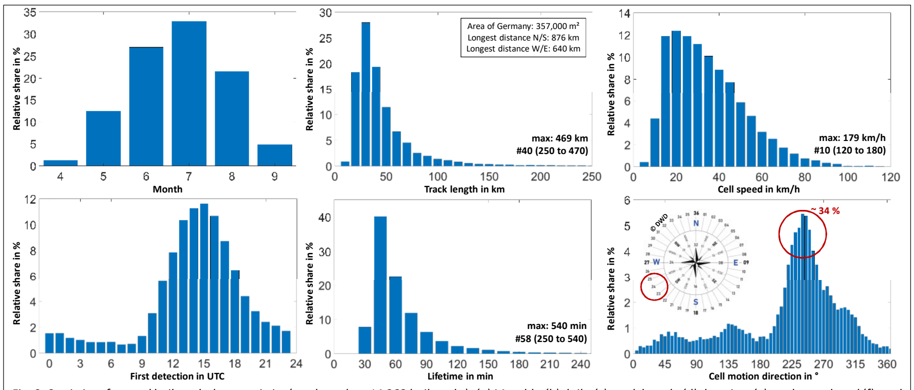


*Fig. 3: Statistics of several hail track characteristics (total number: 14,268 hail tracks): (a) Monthly, (b) daily, (c) track length, (d) duration, (e) track speed, and (f) track direction distribution (as relative share in relation to the total number).*

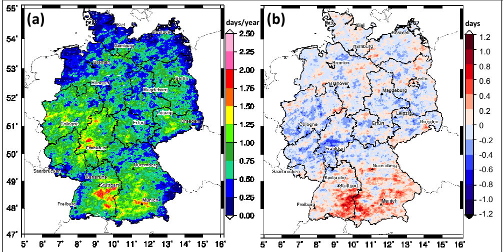


*Fig. 4: (a) Annual number of hail days (2005–2021). (b) Differences (total number) between the new hail statistic and the previous one (2005–2015; based on Schmidberger, 2018).*

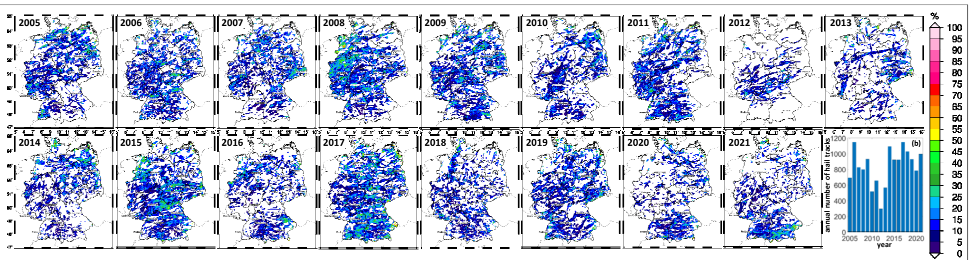


*Fig. 5: Annual percentage of the total hail statistic from 2005–2021 (Annual total number of hail tracks / total number of hail tracks); (b) annual number of identified hail tracks by TRACE3D; demonstrating the high temporal and spatial variability (Please note that in 2012 several radar outages were in the South Germany).*

## Skill of the Bunkers motion method in Germany

### How well does the parameterization of supercell motion by BUNKERS et al. (2000) work for Germany?

- ✗ Identification of **354 supercells (SHY, 2013–2016)** based on the hail track algorithm TRACE3D combined with a mesocyclone detection algorithm from DWD (meso-objects; Hengstebeck et al., 2018)
- ✗ Classification into right- and left-movers (using deep-layer wind shear)
- ✗ Adaptation of the Bunkers supercell motion method (Bunkers et al., 2000; with D = 7.5 m/s); calculation with assimilation analysis data (DWD, COSMO-EU; Δx = 7 km)

$$\vec{v}_{rm} = \vec{v}_m \pm D\left[\frac{\vec{v}_s \times \hat{k}}{|\vec{v}_s|}\right]$$

- ✗ Further sample separation into different object classes regarding severity level, track length, lifetime, and number of meso-objects.

➡ Distinct differences in observed and parameterized supercell motion

➡ Application of parameterization possible, but improved result by modifying parameter D (D = 4.0 m/s; Tonn et al., in review)

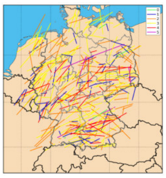


*Fig. 6: Storm tracks of all 354 supercells (April to September;* ***2013–2016****); colors indicate the highest severity level of the associated meso-objects obtained throughout the life cycle (Tonn et al., in review).*

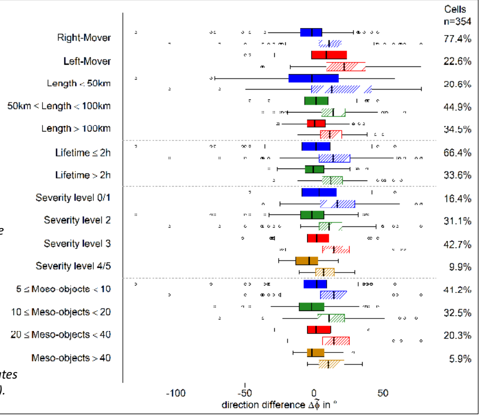


*Fig. 7: Box- and Whiskers plots for the direction difference $\Delta\tilde{\varphi}$ with* ***adjusted parameter D = 4.0 m/s (filled boxes)*** *and* ***original parameter D = 7.5 m/s (hatched boxes)*** *for all 354 supercells divided into different categories:*
*1) cell motion direction,*
*2) track length,*
*3) lifetime,*
*4) severity level and*
*5) number of associated meso-objects; boxes.*
*In addition, the respective fraction of cells which contributes to a special category is given (right; Tonn et al., in review).*

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