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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Rain, Snow or Freezing Rain? – Radar-based Surface Precipitation Type Analysis and Verification at DWD

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Several years ago, the scope of operational radar-derived precipitation analysis was on precipitation amount. In recent years, this has been extended by the type of precipitation. Nowadays, areal information on winterly precipitation type and amount are available in near real-time. In addition to providing these data to the general public (e.g. via App), specialized clients i.e. winter road maintenance services benefit from it for optimized operations planning. Deutscher Wetterdienst (DWD) utilizes a C-Band dual-polarimetric weather radar network in combination with synoptic measurements from ground-based stations and output from numerical weather prediction (NWP). In addition to common hydrometeor classification at radar beam height, optimized thermodynamical profiles of NWP model output are used to extrapolate the hydrometeor classes to ground level. Recently, we refined the algorithm to account for supercooling of liquid hydrometeors that reach the ground. The new surface precipitation types "freezing drizzle" and "freezing rain" are operationally used since winter season 2023/2024.

Input Data

Radar data

- Dual-polarimetric quality-assured radar sweep moments: horizontal reflectivity Z_h, differential reflectivity Z_{DR} and co-polar correlation coefficient ρ_{hv} with azimuthal/range/temporal res. of 1°/250 m/5 min
- Grid-based (1 km, 5 min) Vertically Integrated Ice (VII)

NWP data

- ICON-D2 data at horizontal grid spacing of 2.2 km & vertical resolution of 65 layers; update: every 3 h
- 3D profiles of pressure (p), temperature (T) and specific humidity (q) at temporal resolution of 1 h
- 2D field of snowline (above MSL) every 15 min

Station data

- ≈ 600 automated weather stations from D (10 min)
- ≈ 2000 road weather stations from D, NL, CZ (15 min)

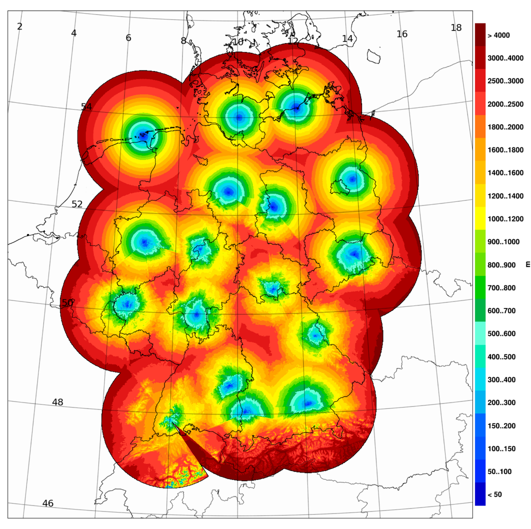

Fig. 1: Operational DWD weather radar network (17 dual-pol radars): Composite of height difference between radar measuring heights of terrain-following low-elevation scan and ground. Geo data: GeoBasis-DE/BKG 2016

Algorithms: HYMEC & NASMA

Method description

- Algorithm chain with 5 major steps (Fig. 2) to analyze and nowcast precipitation type near ground
- Steps are processed every 5 min
- Except for step 1), all steps are performed from analysis up to +2h

1) Hydrometeor classification

- Input: Z_h, Z_{DR}, ρ_{hv}, VII, Snowline
- Pre-Filtering, Fuzzy-logic algorithm

2) Conversion to target grid (1 km)

- HYMEC/NWP: NN-interpolation
- Station data: inverse distance weighted interpolation (IDW) + height correction (Fig. 4, right)

3) Radar data forecast

- Optical-Flow technique (TV-L1)
- Advection of HYMEC composites (class + corresponding height)

4) Vertical profiles of t_{wet}

- Calculate wet-bulb temperature t_{wet} profiles from NWP output
- Height-dependent blending with t_{wet} data from stations (Fig. 5, left)
- Calculate melting and freezing area betw. radar beam and ground level as vertical integral (Fig. 5, right)

5) Vertical extrapolation (NASMA)

- Melting of solid hydrometeors by empirical thresholds of melting area
- Supercooling of liquid/melted hydrometeors by thresholds of freezing area and surface temp.

integrated in C++ Framework POLARA

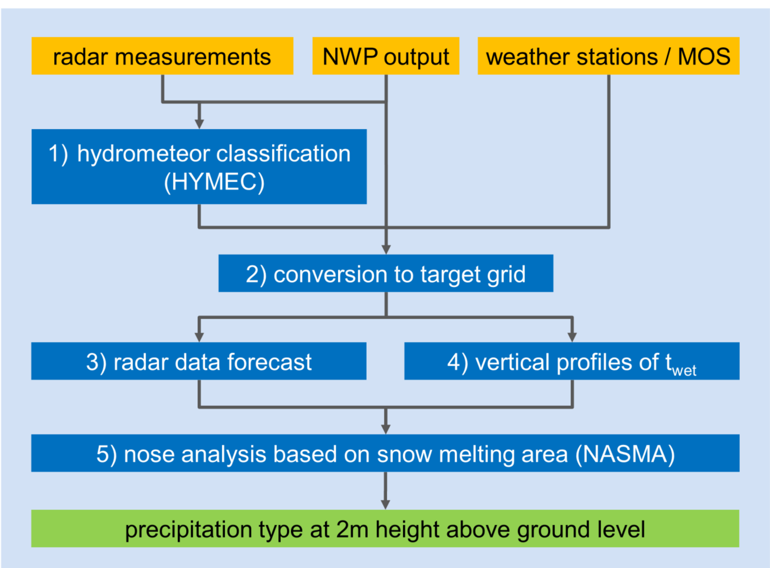

Fig. 2: Flowchart of steps to estimate the precipitation type at 2 m height above ground level.

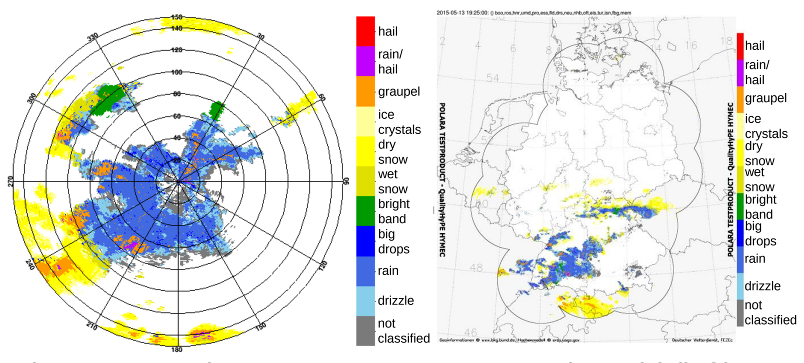

Fig. 3: Exemplary HYMEC output on radar grid (left) & merging of all available radar stations on 1x1 grid (right).

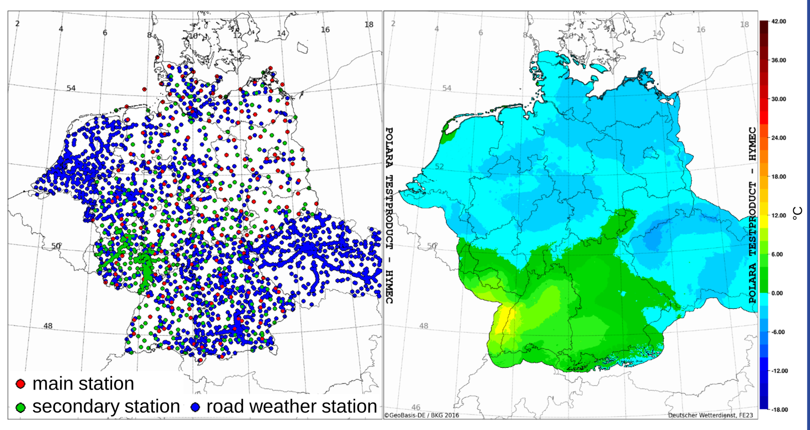

Fig. 4: Locations of used weather stations on a typical day in winter (left) & interpolated field of 2 m wet-bulb temperature based station measurements (right).

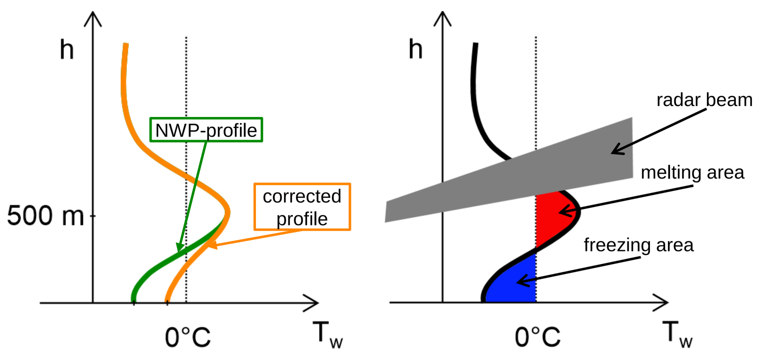

Fig. 5: Sketch of height-dependent correction of wet-bulb temperature profile from NWP with station data (left) and melting/freezing area in relation to corrected profile between radar beam and ground level (right).

Case Study: Extensive Freezing Rain Event

17th January 2024 at 13 UTC

- Pronounced persistent air mass boundary separating warm air over S-Germany (T_{850hPa} ~ 7 °C) and cold air mass over N-Germany (T_{850hPa} ~ -7 °C)
- Several hours of freezing rain in the transitional zone over Central Germany and heavy snowfall in northwards areas; warnings distributed via cell broadcasting

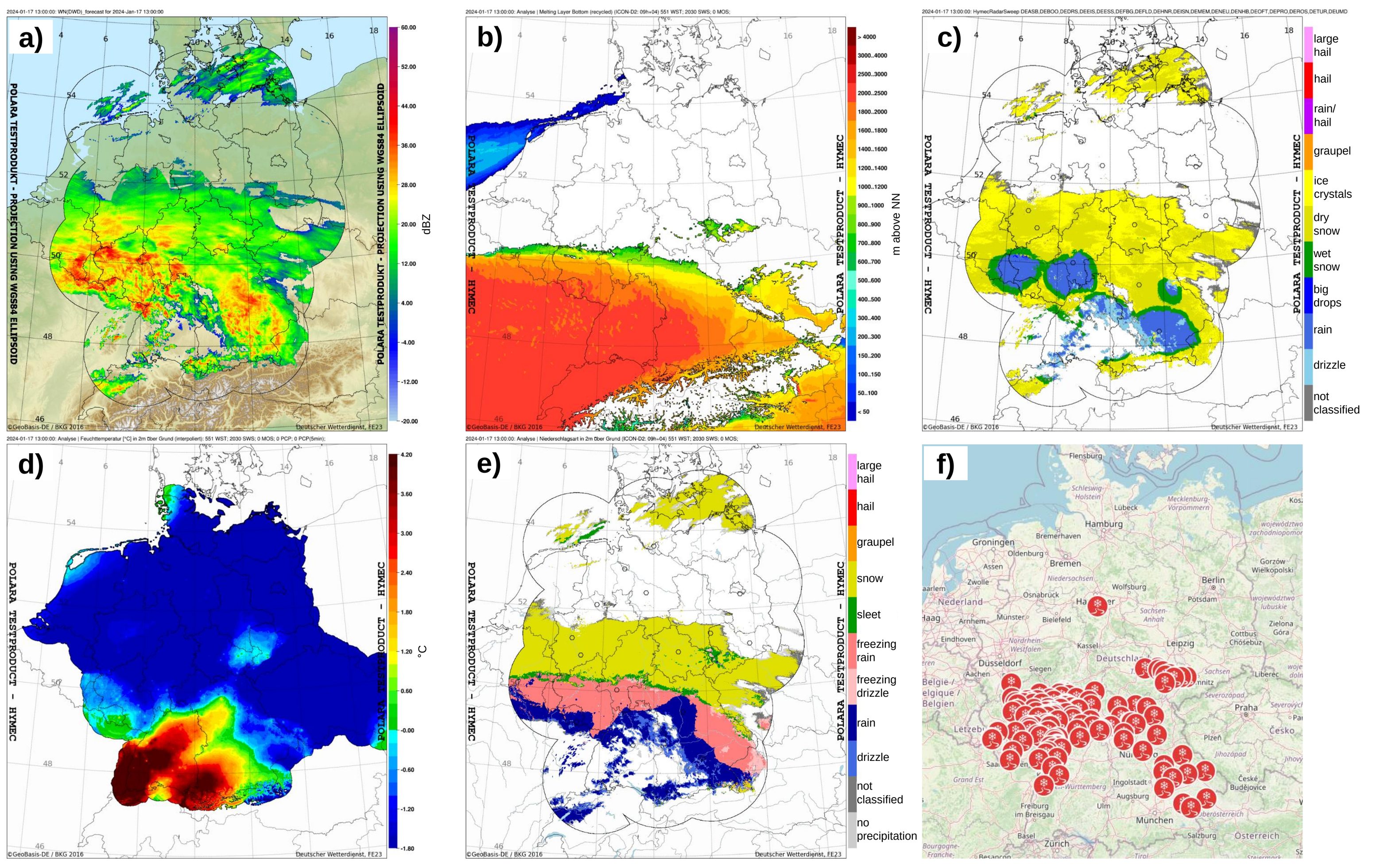

Fig. 6: Ingredients for analysis of precipitation type near ground (a-d). a) radar reflectivity; b) ICON-D2 derived snowline; c) HYMEC classification at radar beam height; d) interpolated 2 m wet-bulb temperature of station measurements; e) precipitation type near ground. The regions with classified freezing drizzle/rain are in agreement with observations reported by WarnWetter-App users about black ice induces by freezing rain, shown in f). Areas without radar reflectivity are masked in a), c) and e).

Verification: Winter Season 2023/2024

1st December 2023 – 28th February 2024

- Reference 1: auto. weather reports, every 10 min, ≈ 180 stations, disdrometer
- Reference 2: reports by users of DWD's WarnWetter-App with plausibility check

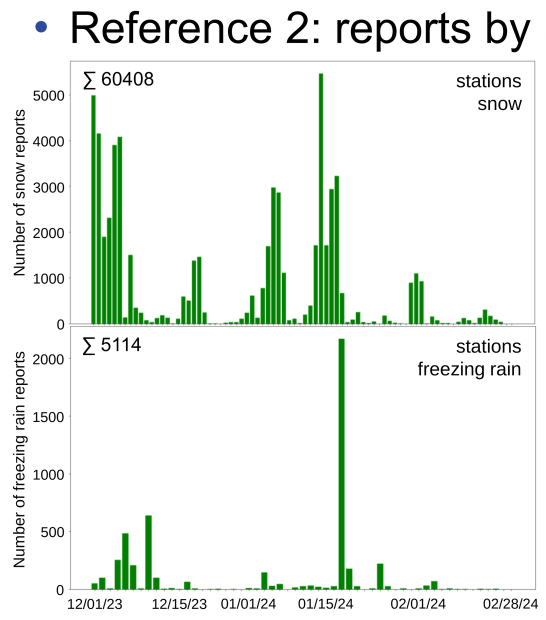

Fig. 7: Time series (daily sums) of automatic weather reports for snow (top) and freezing rain (bottom).

Tab. 1: Verification of precipitation type analysis against automatic weather reports and user reports for snow (top) and freezing rain (bottom). Verification metrics for different spatiotemporal accuracy targets (denoted with Δt and Δx) and additional intensity thresholds (RR10min = observed rain sum in 10 min) are shown. Reports without corresponding radar signal are excluded.

snow	Frequency Bias	POD	FAR	CSI
stations, Δt=0 min, Δx=0 km	1,07	0,81	0,24	**0,65**
stations, Δt=0 min, Δx=0 km, RR10min >= 0.1 mm	0,93	0,85	0,08	**0,80**
stations, Δt=5 min, Δx=5 km	1,57	0,90	0,43	**0,54**
stations, Δt=5 min, Δx=5 km, RR10min >= 0.1 mm	1,15	0,92	0,20	**0,75**
user reports, Δt=0 min, Δx=0 km	1,02	0,90	0,12	**0,80**
user reports, Δt=5 min, Δx=5 km	1,19	0,97	0,19	**0,79**

freezing rain	Frequency Bias	POD	FAR	CSI
stations, Δt=0 min, Δx=0 km	0,66	0,40	0,40	**0,31**
stations, Δt=0 min, Δx=0 km, RR10min >= 0.1 mm	0,60	0,44	0,27	**0,38**
stations, Δt=5 min, Δx=5 km	1,29	0,47	0,63	**0,26**
stations, Δt=5 min, Δx=5 km, RR10min >= 0.1 mm	1,07	0,56	0,46	**0,39**
user reports, Δt=0 min, Δx=0 km	0,84	0,44	0,48	**0,31**
user reports, Δt=5 min, Δx=5 km	1,21	0,56	0,54	**0,36**

Outlook

Further developments currently in internal evaluation by forecasters

- Consideration of supercooled water drops in HYMEC using icing potential
- Apply evaporation correction scheme between radar beam height and ground
- Change NWP input from ICON-D2 to SINFONY's ICON-RUC with hourly runs

Ongoing and future work

- Explore Machine Learning (ML) techniques for HYMEC and NASMA
- Expansion to ensemble system and seamless combination with NWP

References:
(1) promet – Meteorologische Fortbildung, Heft 107 (2024), 45-55, DOI: 10.5676/DWD_pub/promet_107_04.
(2) Steinert, J., Tracksdorf, P., & Heizenreder, D. (2021). Hymec: Surface Precipitation Type Estimation at the German Weather Service, Weather and Forecasting, 36(5), 1611-1627.

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