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FAKULTÄT FÜR PHYSIK
METEOROLOGIE
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Convective cloud microphysics in numerical weather prediction models with dual-wavelength polarimetric radar observations

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Motivation

Microphysics schemes: How much complexity is enough in a numerical weather model?

→ **Hard to say, because:**

1) Convective situations very **variable**

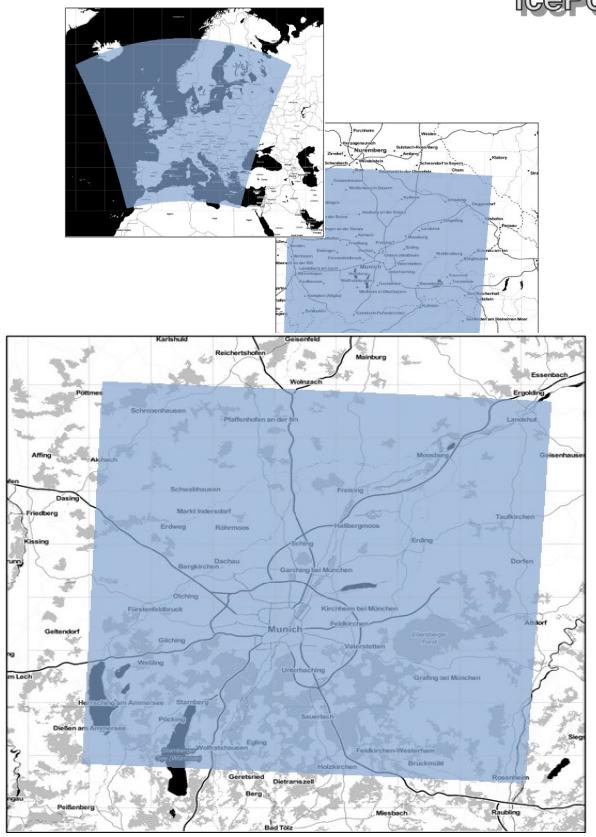
Confident statements about MP-scheme uncertainties only possible based on **statistics** over a large set of data

2) Convective microphysics **hard to observe** on high level of detail

Novel observations needed: Dual-frequency and polarimetric radar **observations**

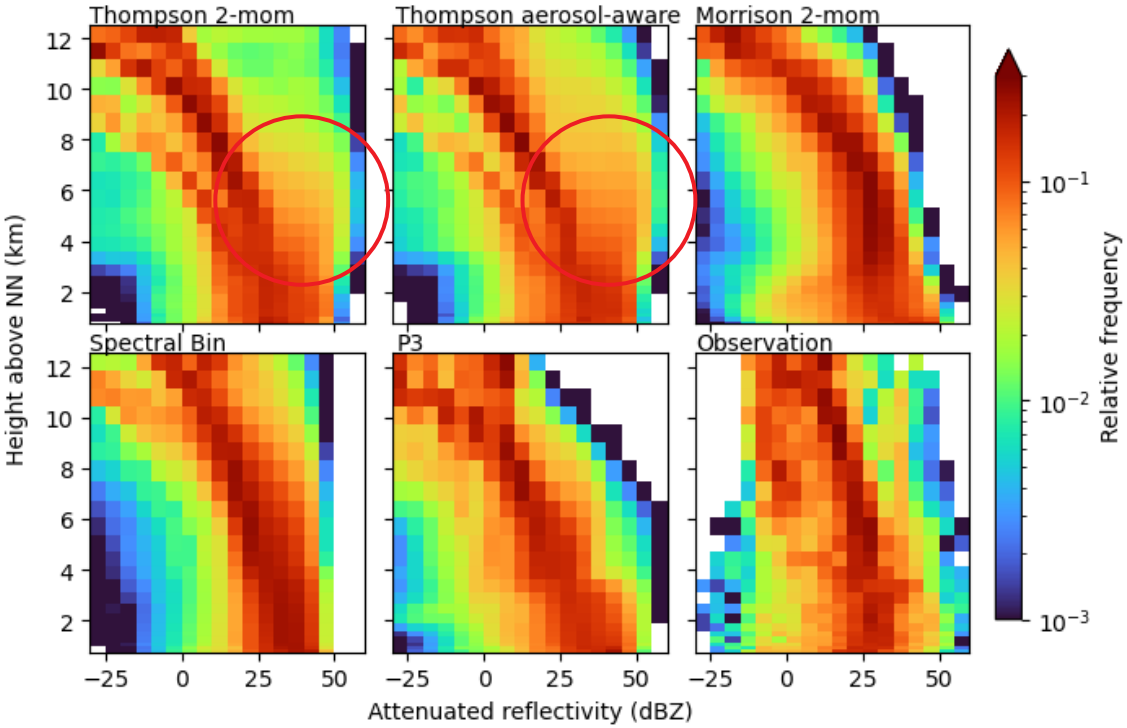
WRF simulations:
Model setup

- **WRF**: Weather Research and Forecasting Model (Skamarock et al, 2019)
  - Regional numerical weather prediction model (NWP)
- Different **MP**-schemes:
  - **Bulk** (Thompson 2-mom, Morrison 2-mom, Thompson 2-mom aerosol aware)
  - **Spectral Bin** (Shpund 2019)
  - **P3** (Morrison and Milbrandt 2015)
- Comparison to operational NWPs:
  - Grid spacing at ~2km (e.g., ICON, 2.1 km)
  - Typically bulk MP-schemes



Munich domain with grid spacing of 400 m

Statistical comparison in radar space:
CFADs of reflectivity



- Thompson often show extreme reflectivities of more than 45 dBZ
- Produced mostly by graupel (and some lifted rain)
  - Simulated graupel could be:
    1) Too **frequent**
    2) Too **large**
    3) Too **dense**

Köcher et al (2022), AMT

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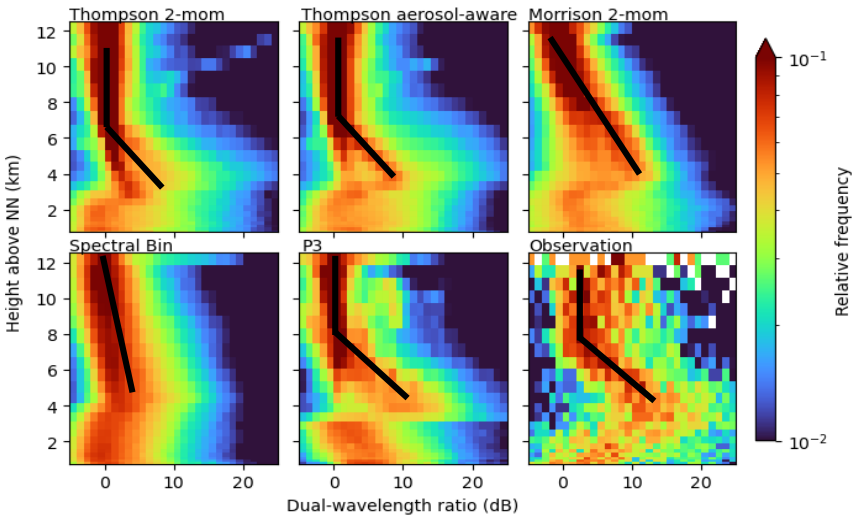
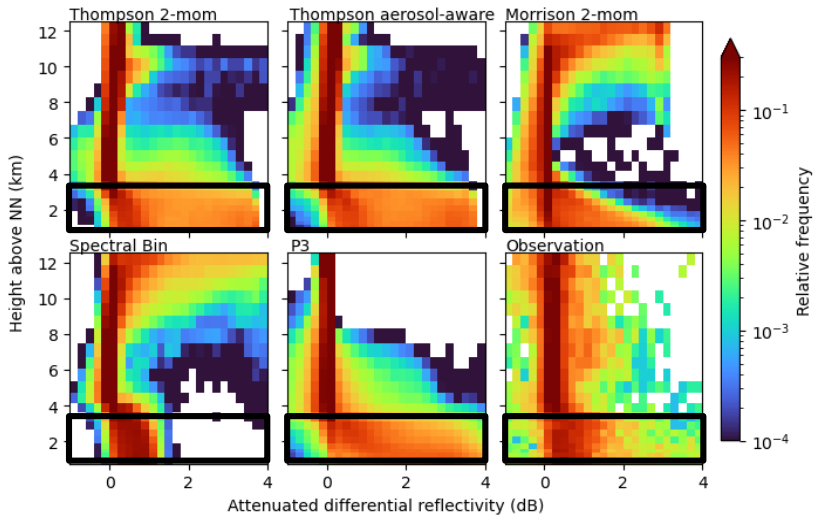
CFADs of radar signals

Main take aways





Z

Graupel reflectivity in Thompson schemes too high

DWR

Deviations in slope of distribution and height of DWR increase

ZDR

Only Spectral Bin reproduces measured distribution in rain

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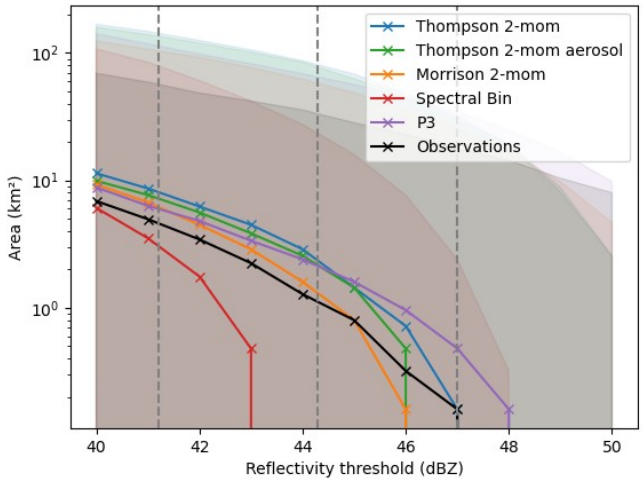
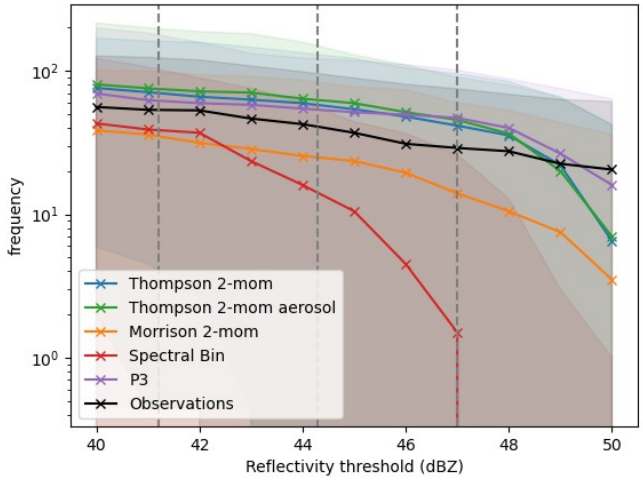
High impact weather statistics:
Area and frequency of heavy rain events

Area of heavy rain events



Frequency of heavy rain events



Steps

1) HMC classification from (simulated) radar signals using Dolan et al, 2013
2) Find pixels classified as rain (graupel/hail)
3) Only consider pixels with reflectivity > varying thresholds
4) Plot of area/frequency medians and 5/95 percentiles

Köcher et al 2022/2023, in preparation

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High impact weather statistics:
Statistics of hail/graupel events

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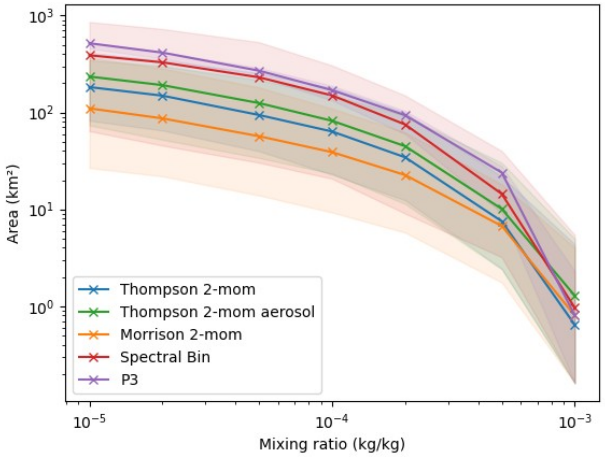
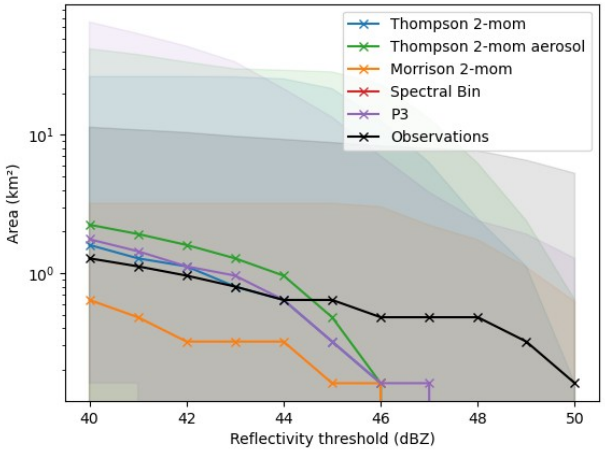
Model directly



Area of graupel/hail events in terms of **mixing ratio**:

Similar between schemes

From (simulated) radar signals



Area of graupel/hail events classified from **radar signals**

Large differences between schemes in some cases

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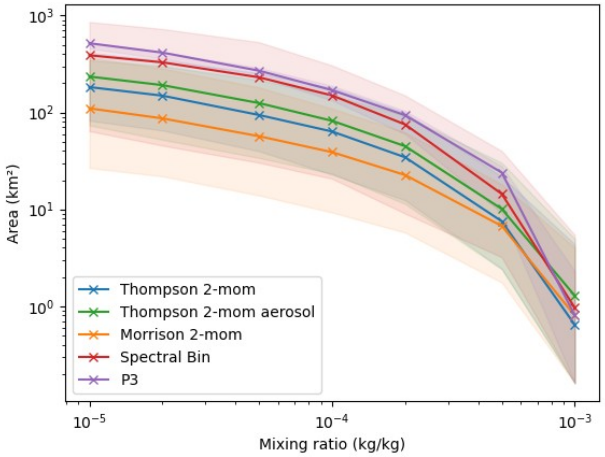
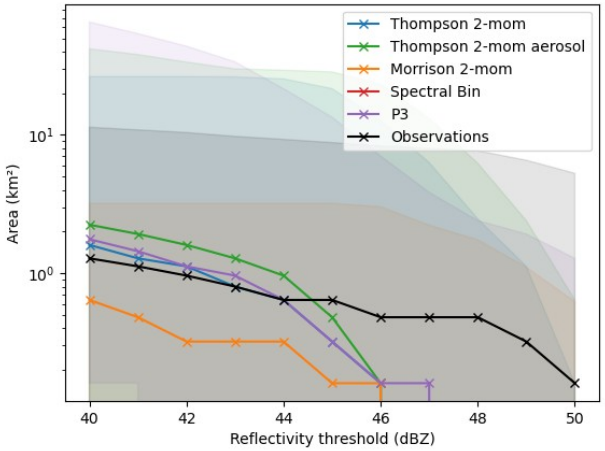
High impact weather statistics:
Statistics of hail/graupel events

Model directly



From (simulated) radar signals



Statistics derived from radar reflectivity (~D^6) are different to statistics from mixing ratio (~D^3)

(with PSD serving as a link)

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Summary:

CFADs of radar signatures:

- **Z**: Graupel reflectivity too high Thompson schemes
- **DWR**: Slope and height of beginning DWR increase vary between schemes
- **ZDR**: Distribution in rain reproduced only by Spectral Bin scheme

→ Demonstration on how to utilize radar signals to statistically evaluate cloud microphysics

High impact weather statistics

- SBM/Morrison miss most hail/graupel events
- Missing deep convective cells in all events?

Köcher, G., Zinner, T., Knote, C., Tetoni, E., Ewald, F., & Hagen, M. (2022). Evaluation of convective cloud microphysics in numerical weather prediction models with dual-wavelength polarimetric radar observations: methods and examples. Atmospheric Measurement Techniques, 15(4), 1033-1054.