Comparing raindrop size distributions from the two-moment microphysics scheme of the ICON-RUC model with disdrometer observations

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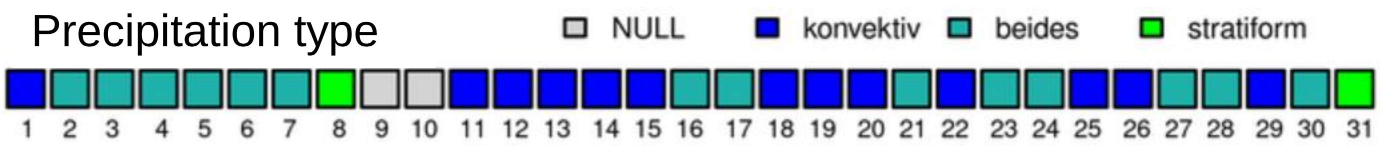
Motivation

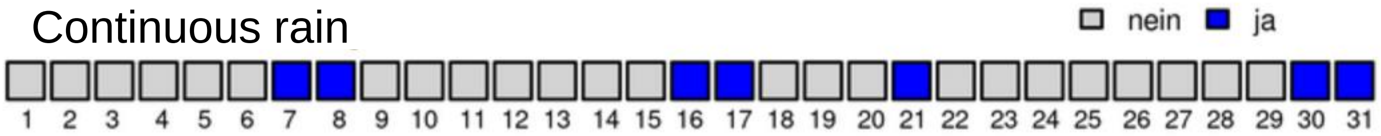
- extreme rain rates in the ICON-D2 are often too high
  - one moment scheme
- extreme rain rates in the RUC sometimes too low
  - 2 moment scheme ⟶ more detailed ⟶ but still not perfect

- DWD has a large measuring network with different instruments
  - more that 150 stations with a disdrometer additional to the conventional precipitation instruments
  - provide information about size and fall speed ⟶ stored but not used at the moment within DWD
  - this information can help to improve the microphysical parameterisation (we start with rain)

Disdrometer

- measuring device that determines the size, falling speed and number of drops by means of a laser
- measurements output in 1-minute intervals; 0.16mm ⟶ 8mm
- precipitation type can be determined
- 28 days selected from 2024 (only rain):
  - May – September ⟶ summer period
  - days marked as days with *permanent precipitation*
  - includes stratiform, convective and mixed precipitation types



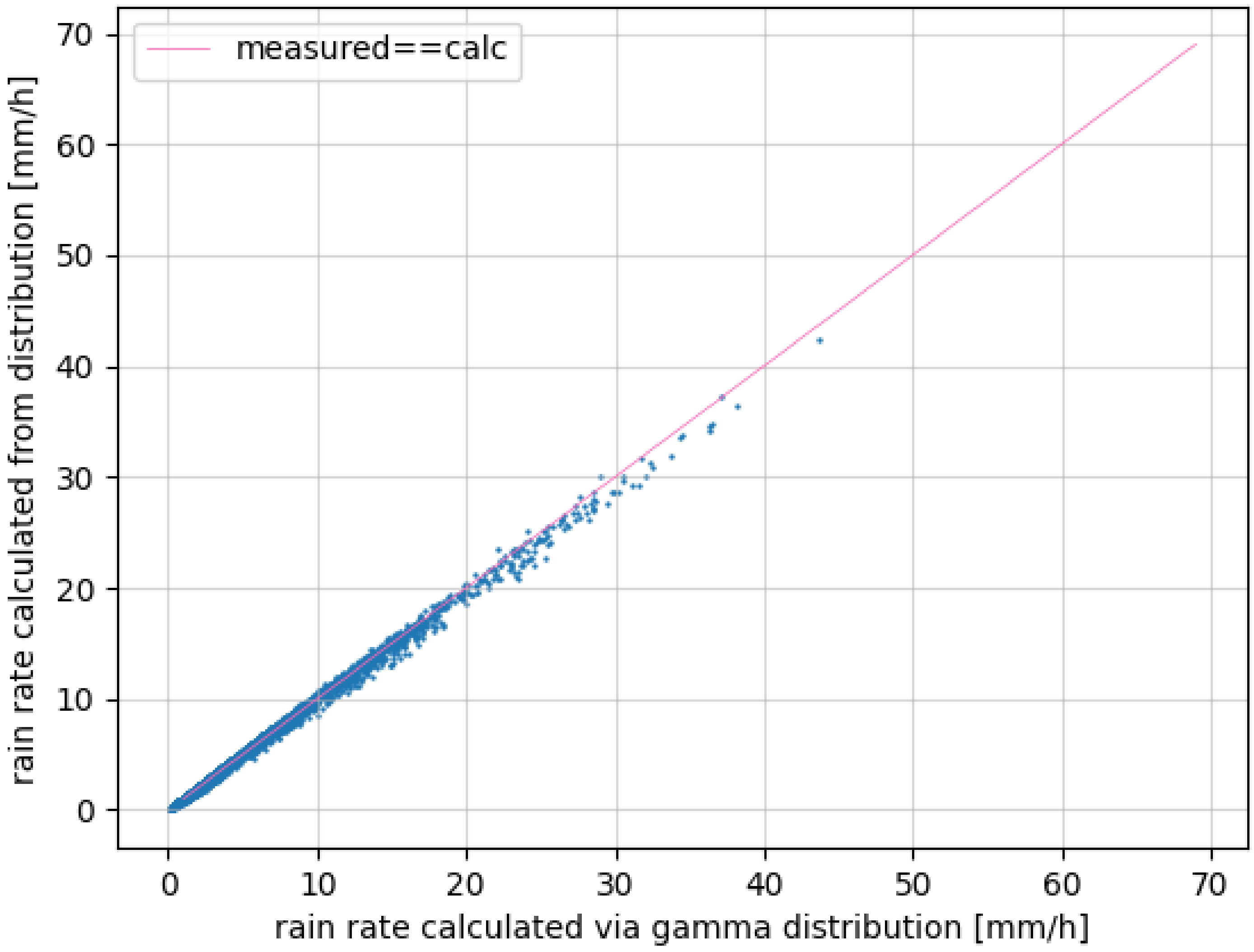


Preparation of the observations
- averaged data over 10 minutes to minimize measurement errors
- dominant precipitation type: rain
- 50’000 measurements to evaluate

Gamma-Size-Distribution:

$$f(D) = N_0 * D^{\mu} * e^{-\lambda * D}$$

Plausibility check of the Gamma-size-distribution



rain rate determined from the measured distribution (particles per size and velocity bin) and from the calculated gamma-size-distribution match

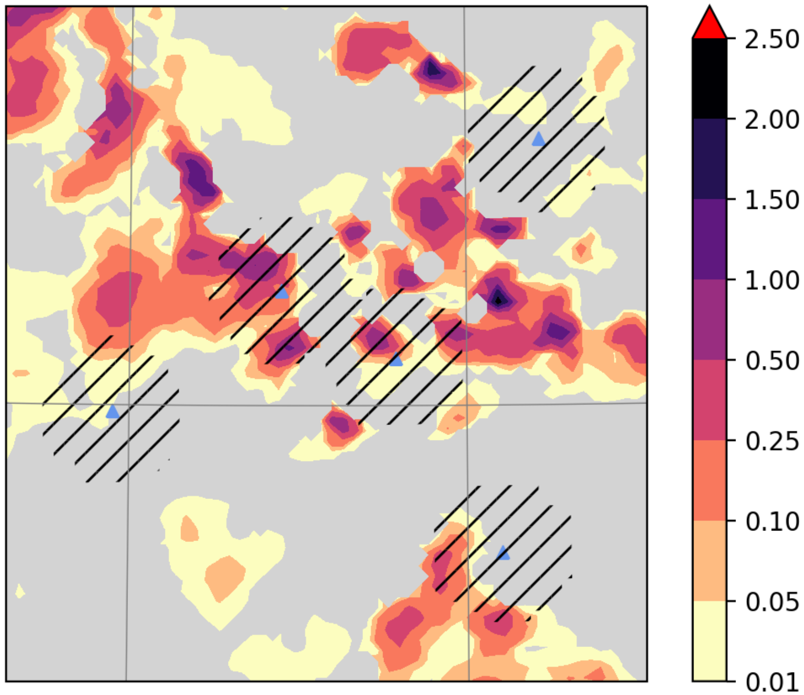
Gamma-size-distribution correct assumption for observations
⟶ can be used further

ICON – RUC

- Rapid Update Cycle (RUC) produces short term forecast with focus on convective (severe) storms
- produces every hour a new forecast with 14h lead time
- contains a 2-moment-microphysics scheme ⟶ includes information about mass and number of particles ⟶ follows a gamma size distribution ⟶ same assumption as in disdrometer measurements
- first guess data from assimilation cycle taken as model equivalent (+1h forecast)⟶ temporal resolution 1h
  - 6UTC ⟶ 21 UTC

Comparison:

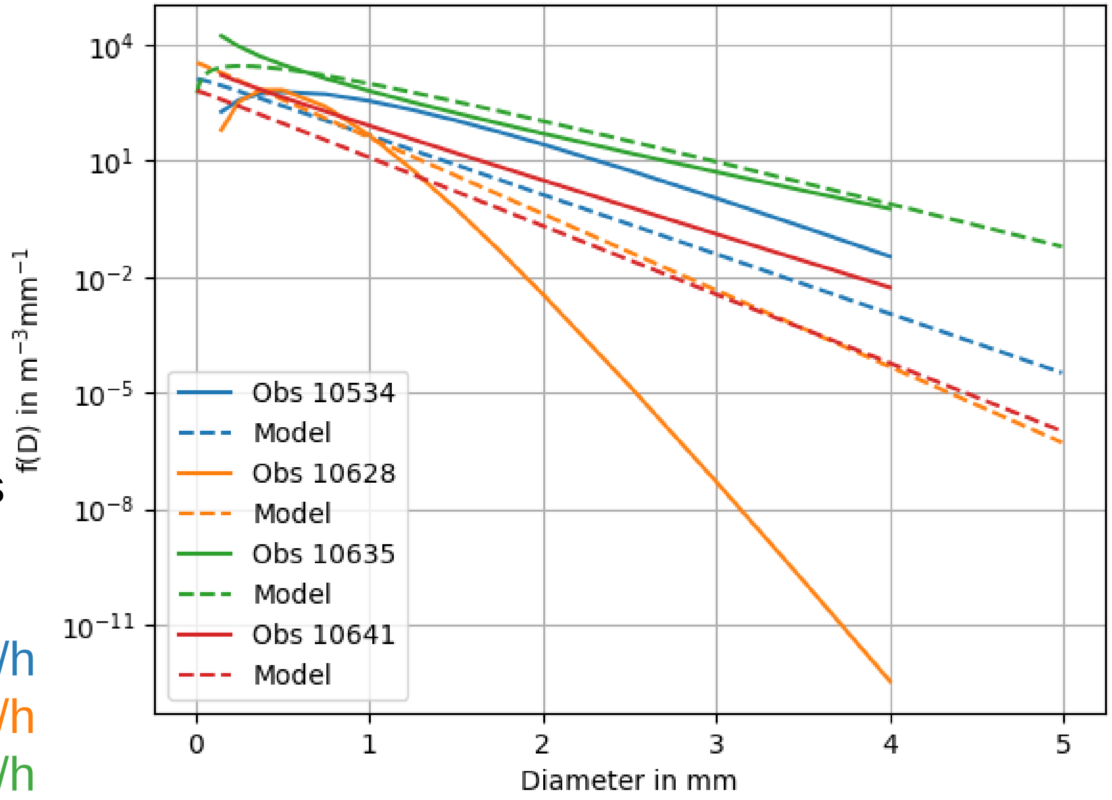
I. measurements assigned in time
⟶ e.g. obs from 8:30 – 9:20 UTC ⟶ 9UTC model data
II. stations with measurements collected ⟶ each station only scored once
⟶ no directly comparison possible ⟶ distortion of the model statistics
III. average and maximum specific mass of the rain determined within a radius of 15 km around the station
IV. calculated from this distribution specific parameters, rain rate and mass weighted diameter ⟶ 13700 model equivalents



Rain-drop-size-distribution

By means of the mass and number concentration from the model **particle size** and **gamma-size-distribution** can be specified for each grid point

- observed size distributions with different rain rates (solid lines)
  - ↳ Station 10534: 7,4mm/h
  - ↳ Station 10628: 0,43mm/h
  - ↳ Station 10635: 17,7mm/h
  - ↳ Station 10641: 1,0 mm/h



- Model size distributions show different distributions compared to observations, but similar rain rates

individual comparison of each measurement not useful; maybe for single specific cases

statistical evaluation for different parameters

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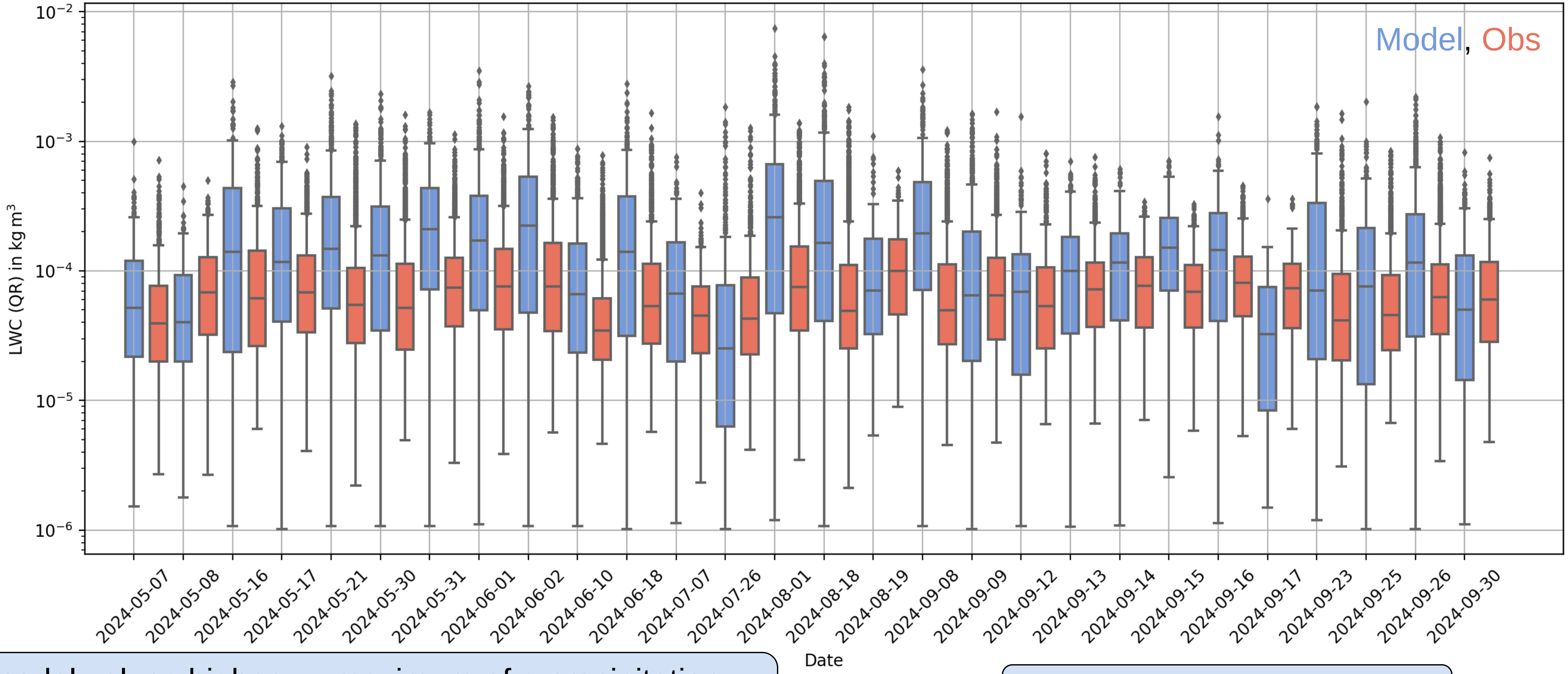
Specific rain content (maximum of qr)

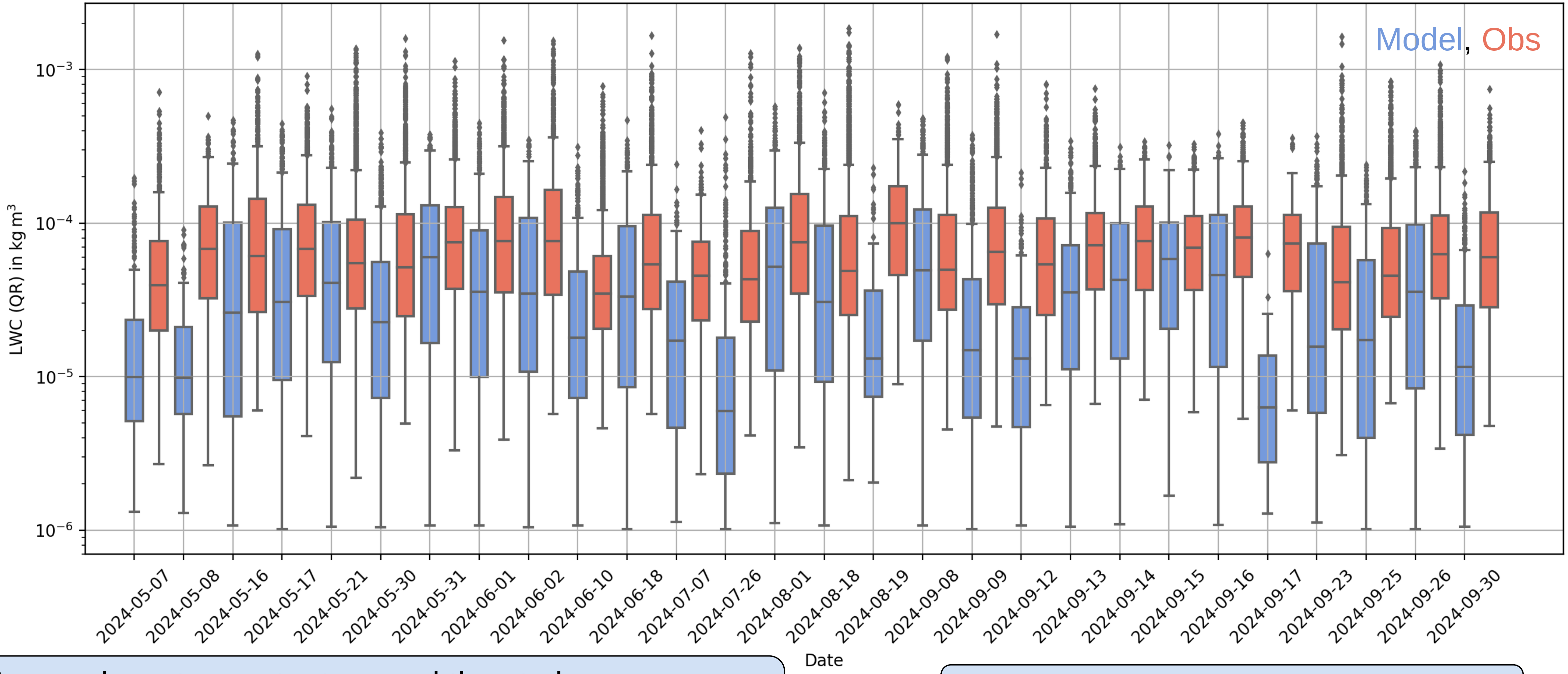


model values higher ⟶ maximum of a precipitation area does not always pass the station

more fluctuation in the model

Specific rain content (mean qr)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Less rain water content around the station ⟶ area dryer or water included in other precipitation type

spread in the model values still higher

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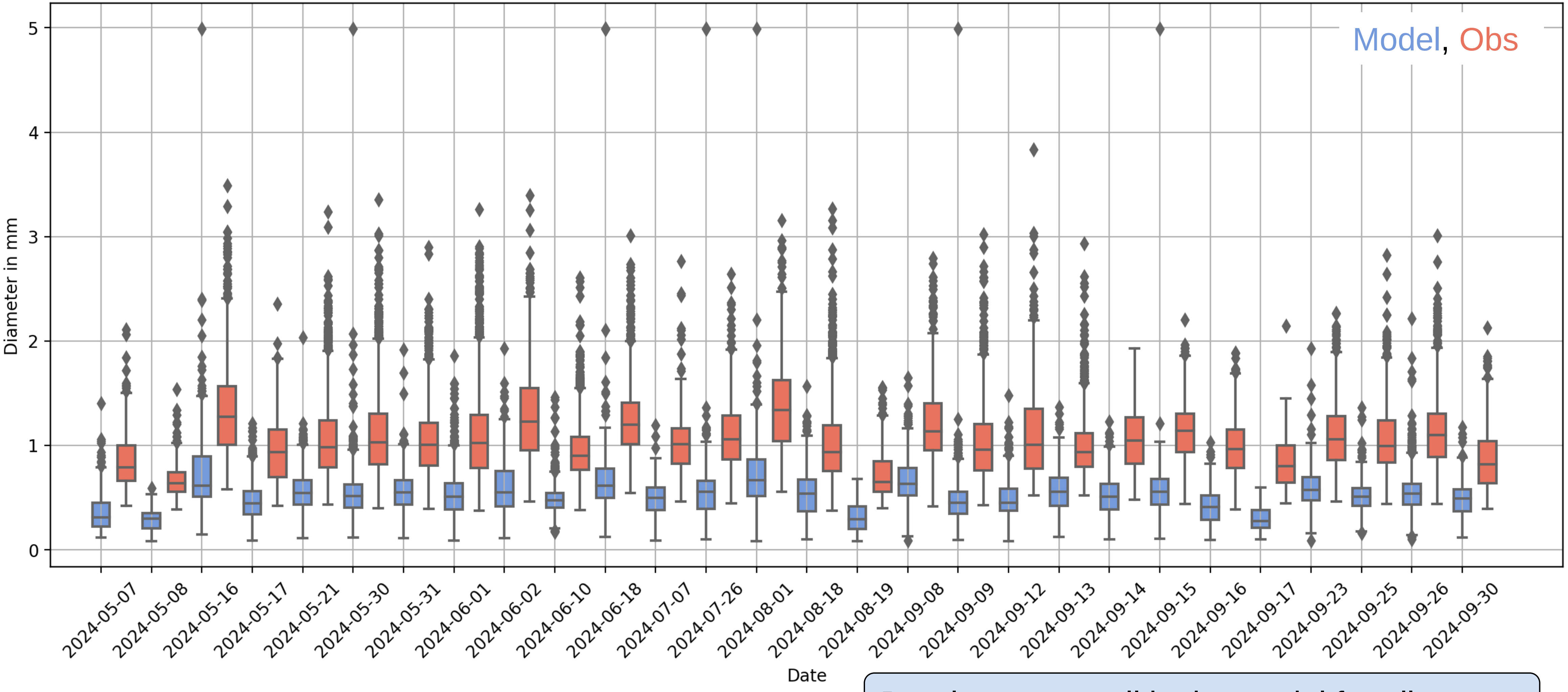
Mass weighted mean diameter at max(qr)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Droplets too small in the model for all cases.

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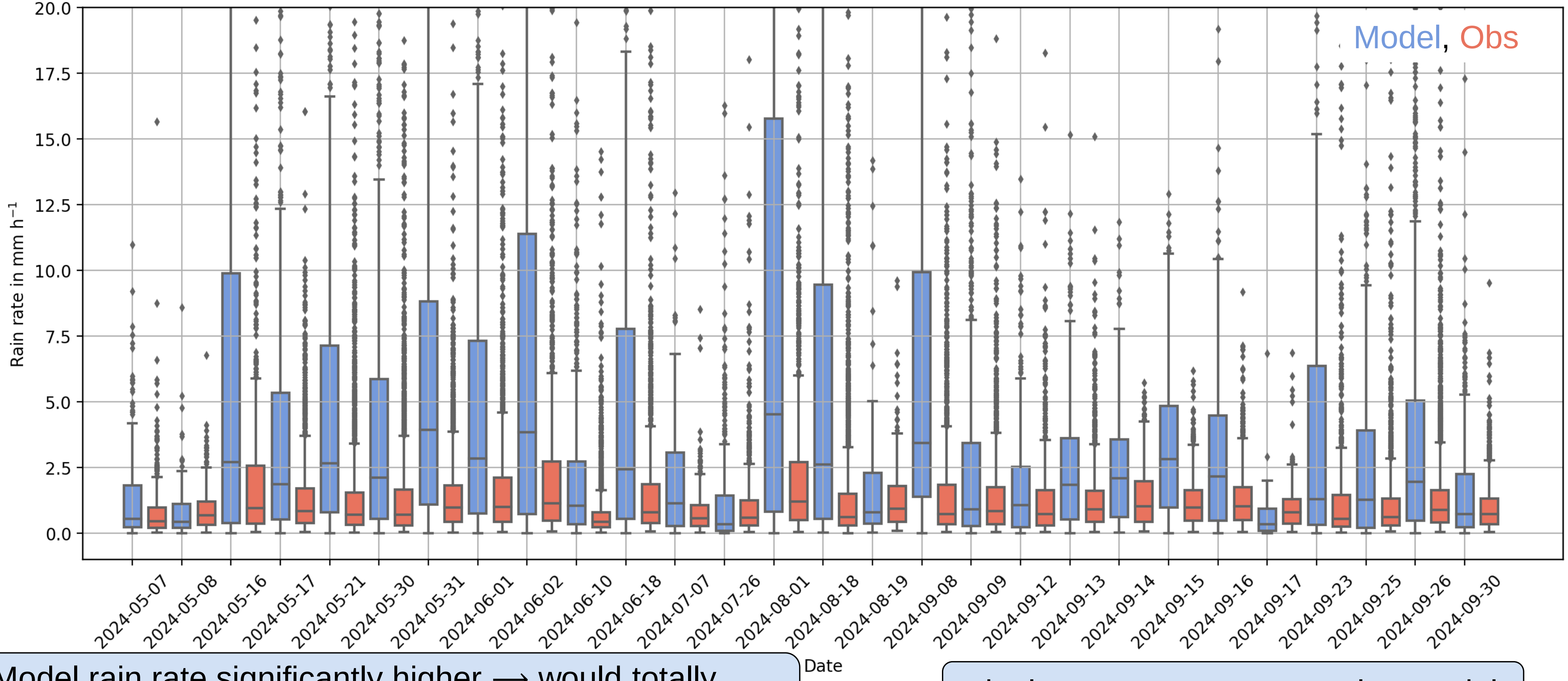
Rain rate estimate from drop size distribution at max(qr)



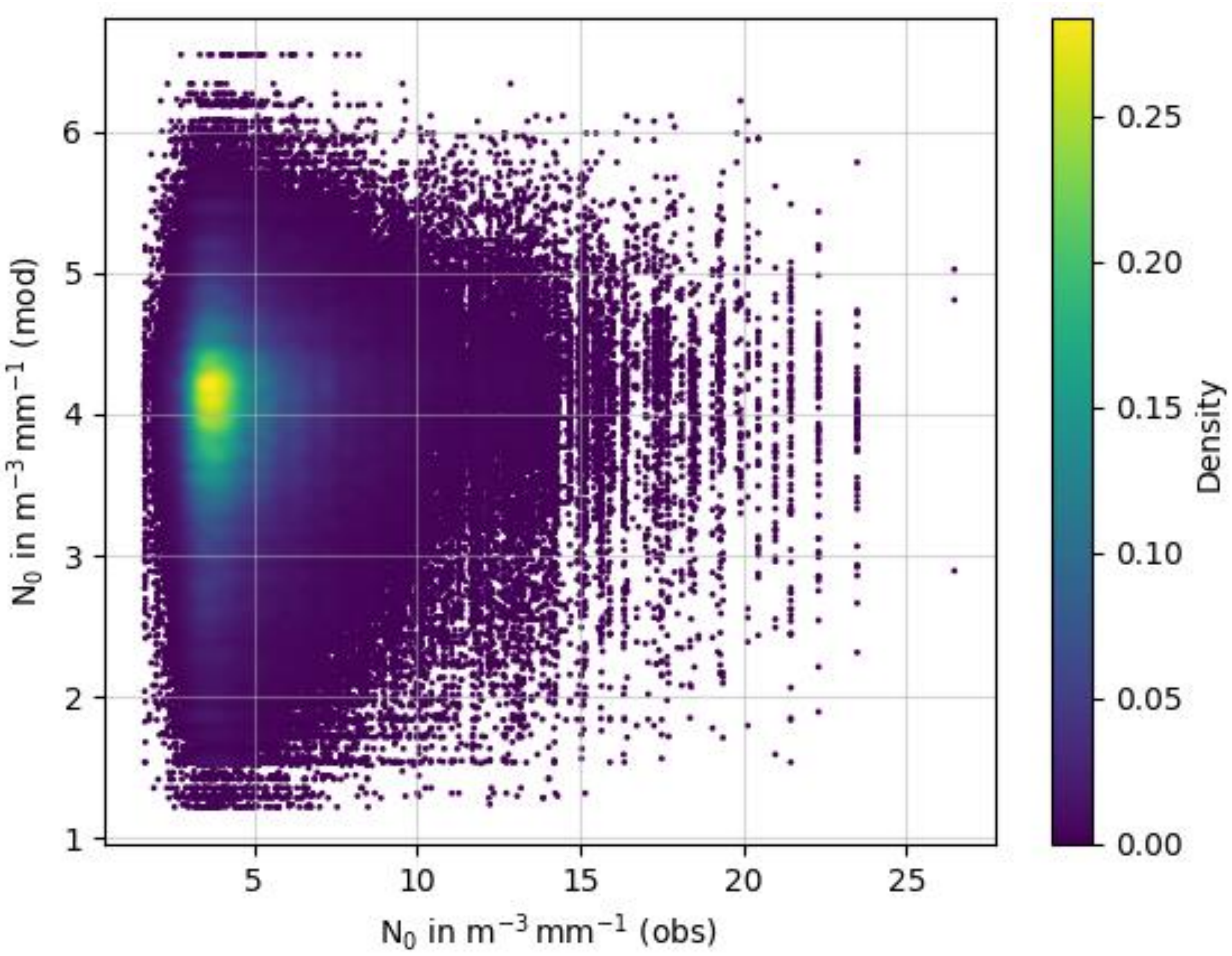
Model rain rate significantly higher ⟶ would totally over estimate the rain rate ⟶ unequal to model output!

single measurements equal to model

Comparison of the intercept parameter N0

Gamma-Size-Distribution:

$$f(D) = N_0 * D^{\mu} * e^{-\lambda * D}$$



- most of the data around 10^4 particles per volume air and droplet size in both datasets

↓

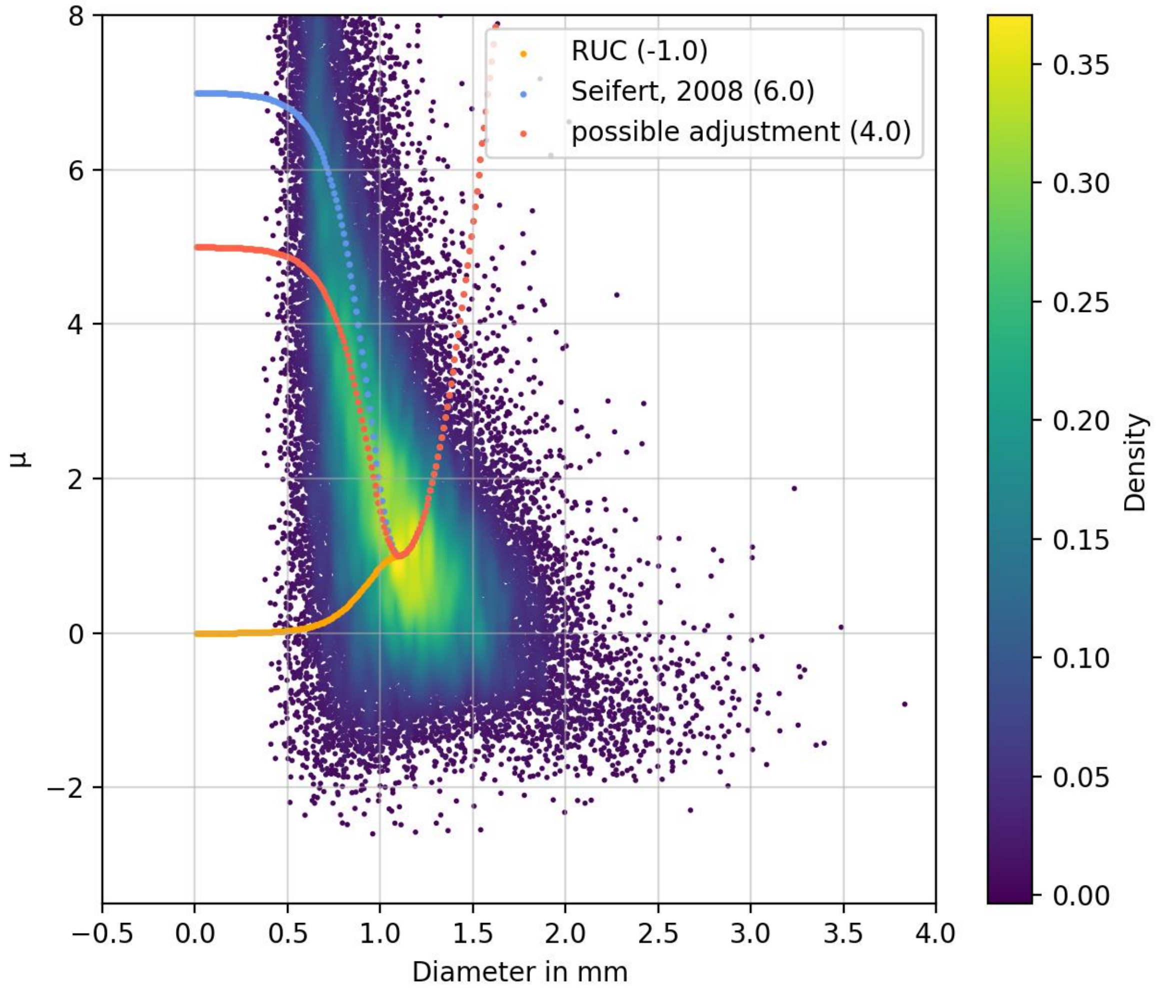
- model values between 10^3 and 10^5 particles
- observation between 10^3 and 10^7 particles

↓

in reality more very small rain drops, but model close enough

Connection between μ and mean diameter

Gamma-Size-Distribution:
$f(D) = N_0 * D^{\mu} * e^{-\lambda * D}$



Calculation of μ (shape parameter) in the model depends on the mean diameter

$$\mu = \begin{cases} 6\tanh[c_1(D_m - D_{eq})]^2 + 1, & D_m \leq D_{eq} \\ 30\tanh[c_2(D_m - D_{eq})]^2 + 1, & D_m > D_{eq} \end{cases},$$

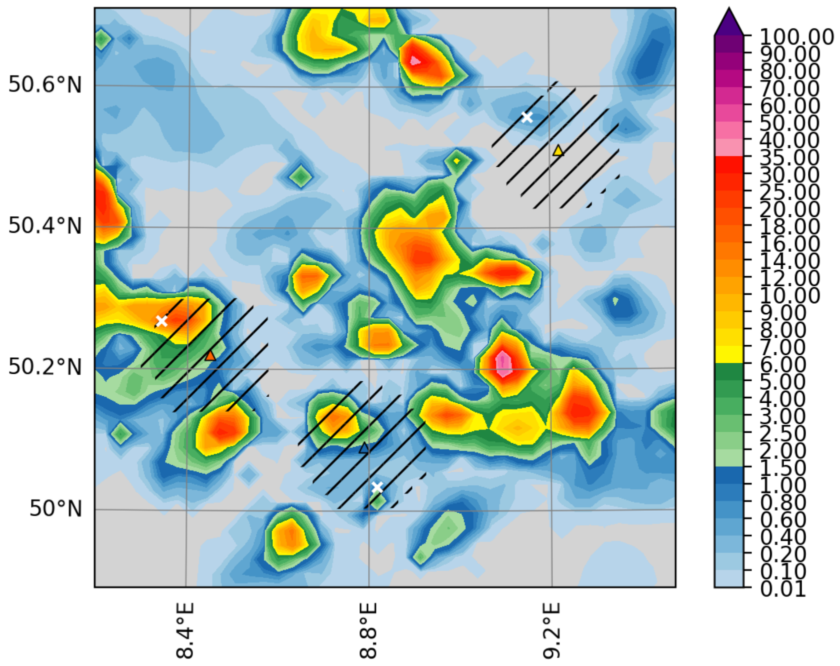
$D_{eq} = 1.1mm$

for larger droplets the distribution should shift to a exponential size distribution

- value for very small particles set to 7 in the default setting
- at the beginning RUC had produced too-little drizzle ⟶ changed to 0
- forecasting of drizzle in the RUC has improved ⟶ could be set to a higher value or back to the original

Conclusion and further work

- mass weighted mean diameter is significantly underestimated ⟶ median = maximum of the distribution ⟶ distribution has to be shifted to higher particle sizes
- adjust the connection of the µ and particle mean diameter in the model
- find a new fitting for µ - λ – dependence ⟶ try it in the model
- include parameters in the area of the observations statistically ⟶ not just the maximum value
- recalculate the forecasts for he case days:
  - direct temporal comparisons possible, temporal aspect can be examined (are we too early/too late/just right)
  - comparison of rain rate possible



Thanks for listening!