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FACULTY

OF MATHEMATICS, INFORMATICS
AND NATURAL SCIENCES

Towards a multi-year urban precipitation climatology at 100 m scale using X-band radar observations

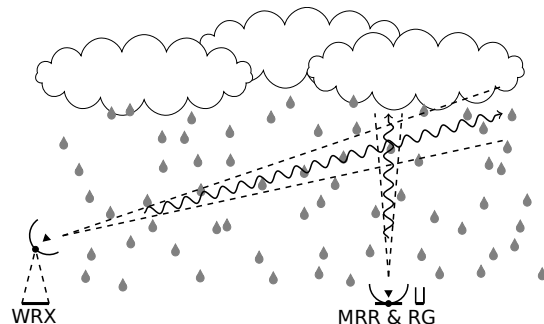
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EGU General Assembly 2021
HS7.6 - Precipitation and Urban Hydrology

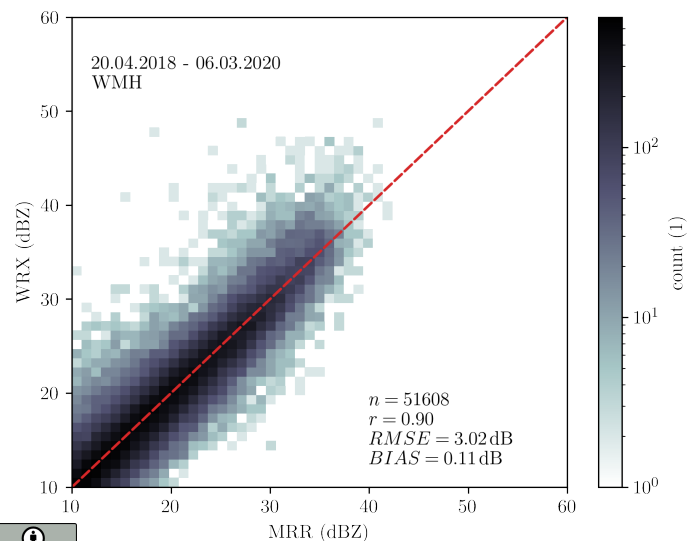
Towards a multi-year urban precipitation climatology at 100 m scale using X-band radar observations

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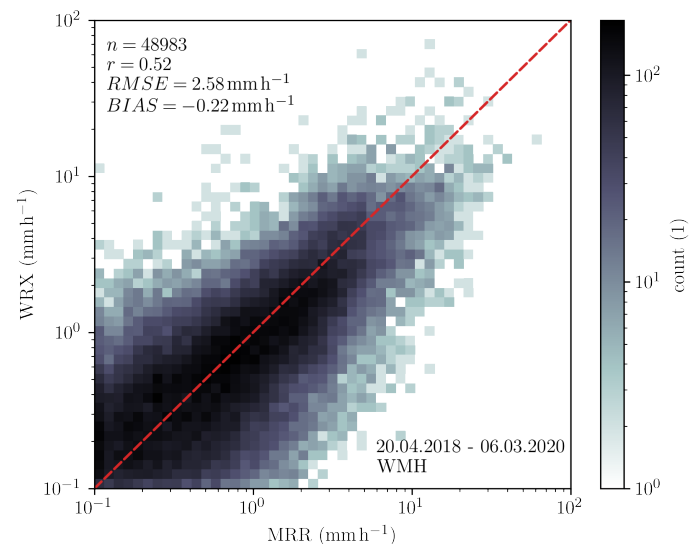
- Precipitation monitoring with an operational, single-polarized, low-cost, local area **X-band weather radar** in **Hamburg** for **eight years**.
- Observational synergy of X-band radar, vertically pointing micro rain radars, and rain gauges



- Aim for quality-tested, long-term precipitation estimate within an urban area with **100 m spatial** and **30 s temporal** resolution.



- Precipitation estimate affected by several sources of errors, e.g.:
 - Radar calibration
 - Alignment
 - Attenuation
 - Noise
 - Non-meteorological echoes
 - Z-R relation

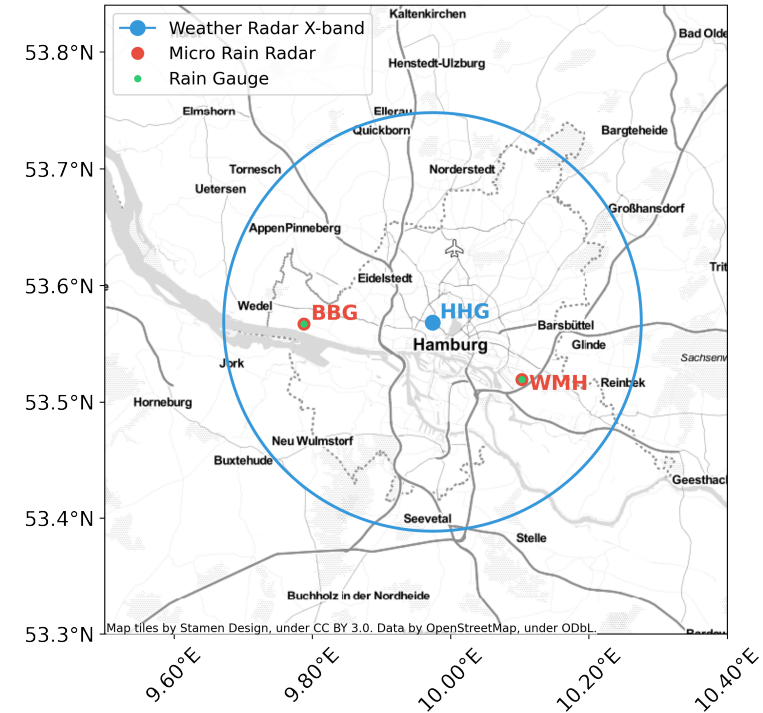


Towards a multi-year urban precipitation climatology at 100 m scale using X-band radar observations

Keywords: Weather Radar; Urban Hydrology; X-band; K-band; Observation Network; Long Term; Single Polarization; Small Scale Precipitation Structure; High Spatial and Temporal Scale; Error Minimization; CliCCS – Climate, Climatic Change, and Society

Multi-year Precipitation Monitoring in Urban Area

- X-band weather radar (WRX)
 - **spacious high-resolution precipitation measurements**
 - HHG radar **operational since 2013**
 - refines nationwide C-band radars
 - Previous open issue: **missing quality assessment**
- Micro Rain Radars (MRR)
 - vertical profiles of drop size distributions
 - as reference in relevant height levels (e.g. calibration)
 - calibration of MRRs with rain gauges



Technical details

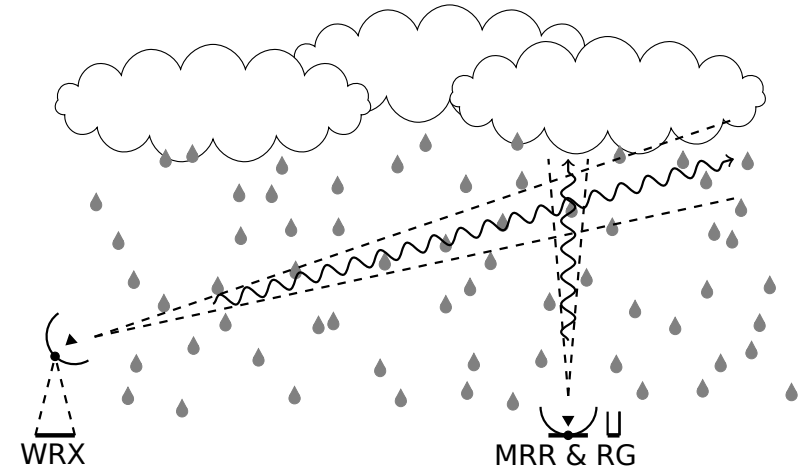
- X-band weather radar (WRX)
 - Single-polarized, low-cost, local-area weather radar
 - Modified ship navigation radar with parabolic dish
 - Time resolution 30 s
 - Range resolution 60 m
 - Sampling resolution in azimuth 1°
 - Elevation angle $\sim 3.5^\circ$
 - High sample of 12 rotations include ~ 67 pulses per 1° and 30 s
- Micro Rain Radars (MRR)
 - Vertically pointing K-band radar
 - Time resolution 10 s
 - Range resolution 35 m



HHG radar in center of Hamburg (85 m rooftop)

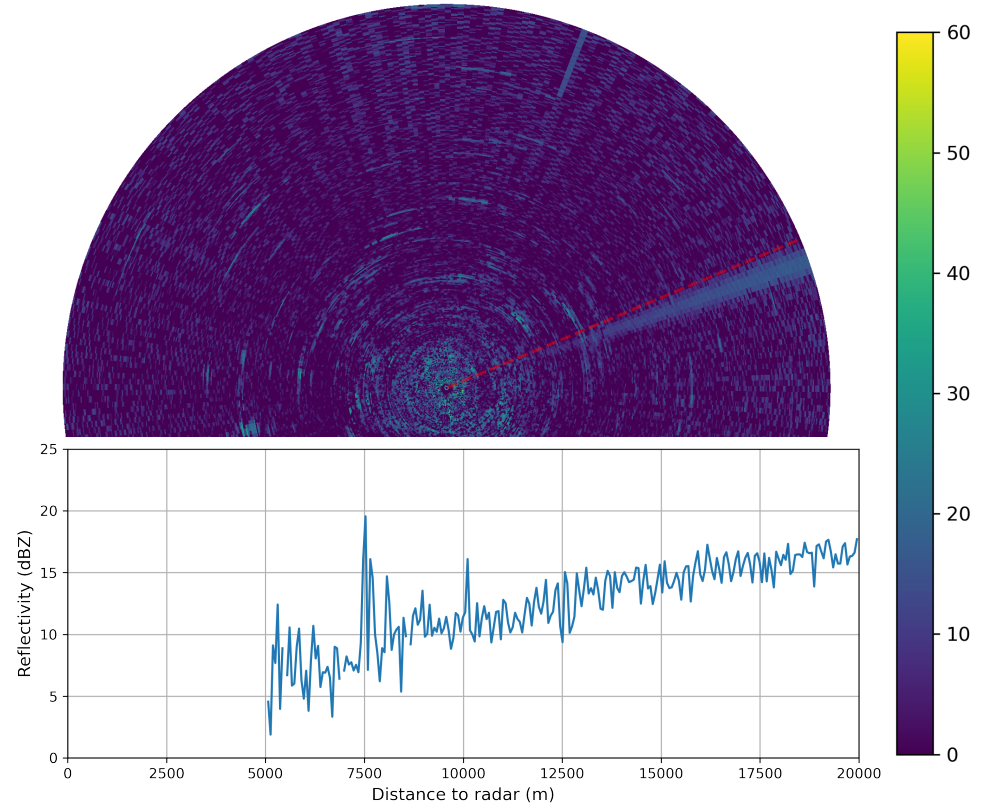
How can we infer a reliable precipitation estimate based on these multi-year weather radar observations?

- Several sources of errors affecting the radar-based precipitation estimate, e.g.:
 - Radar alignment
 - Radar calibration
 - Attenuation
 - Noise
 - Non-meteorological echoes
 - Z - R relation
- MRRs provide drop size distributions yielding relevant quantities
 - Radar reflectivity
 - Rain rate
 - Attenuation



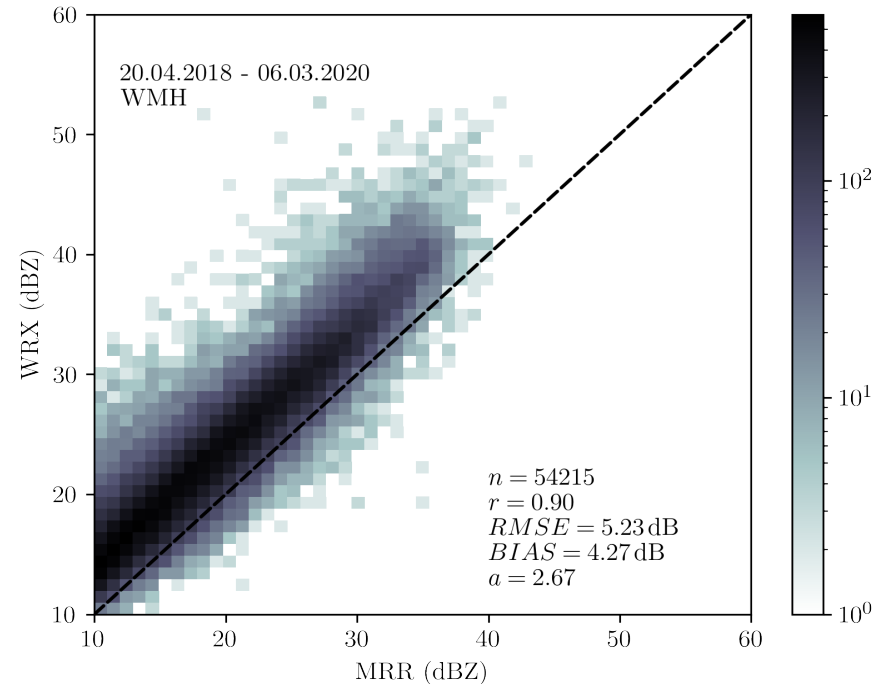
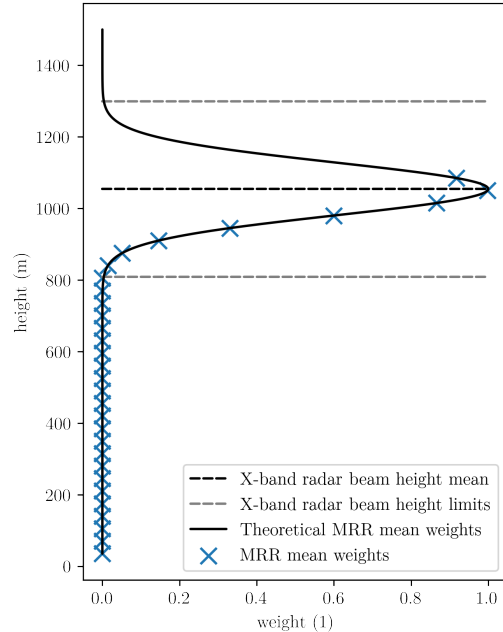
Radar alignment

- Exact radar alignment mandatory, e.g. for the calibration of the X-band radar
- **Estimate the radar beam elevation and azimuth bias by using the sun**
- Operational radar measurement detects solar signals during sunrise and sunset
- Continuously strong signal and known position of the sun (pysolar; Stafford et. al):
 - Between 2013 and 2021 different technical setups due to maintenance
 - Elevation angle: 2.0° to 6.1° within seven different periods
 - Azimuth offset: 0.9° to 5.6° within eight different periods



Biased reflectivity

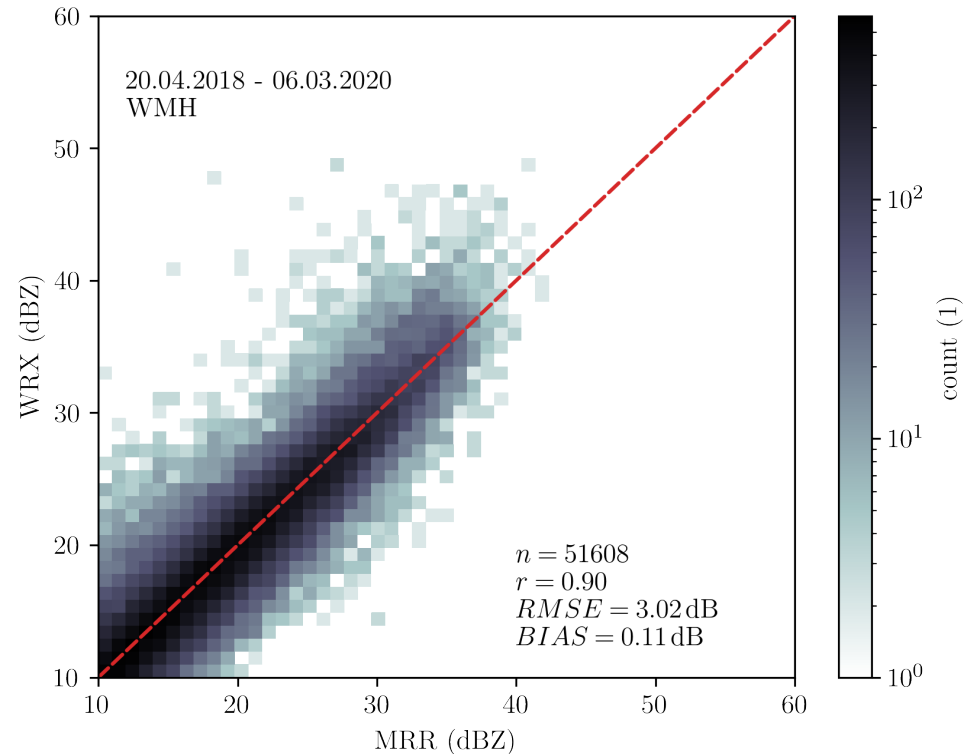
- Correction of the radar reflectivity bias between the X-band radar (WRX) and the micro rain radar (MRR)
- Time weighted (30 s) and height weighted mean of MRR profile within the radar beam:



- For this exemplary period (~ 2 years) a positive bias of the radar reflectivity of WRX has to be corrected.
- Neglecting snow and ice by using ERA5 (Hersbach et al., 2018) zero degree level > 1500 m

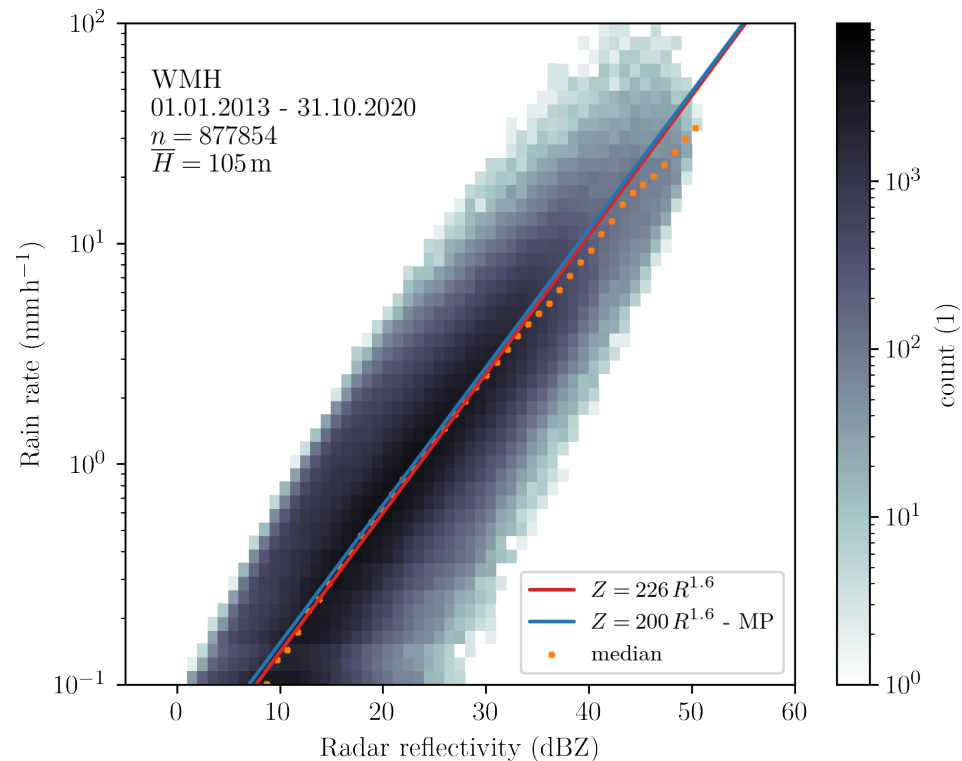
Corrected reflectivity

- Previous dynamic and static clutter removal, noise removal and interpolation corrects radar reflectivity using internal python package *pylawr* (in preparation for open source)
- Calibration using MRR profile adjusts radar reflectivity
- Attenuation correction using python package *wradlib* (Heistermann et al., 2013) based on *k-Z* relationships (Kraemer and Verworn, 2008; Jacobi and Heistermann, 2016)
- MRR indicates quality of corrected WRX radar reflectivity
 - Correlation $r = 0.9$
 - RMSE = 3.02 dB



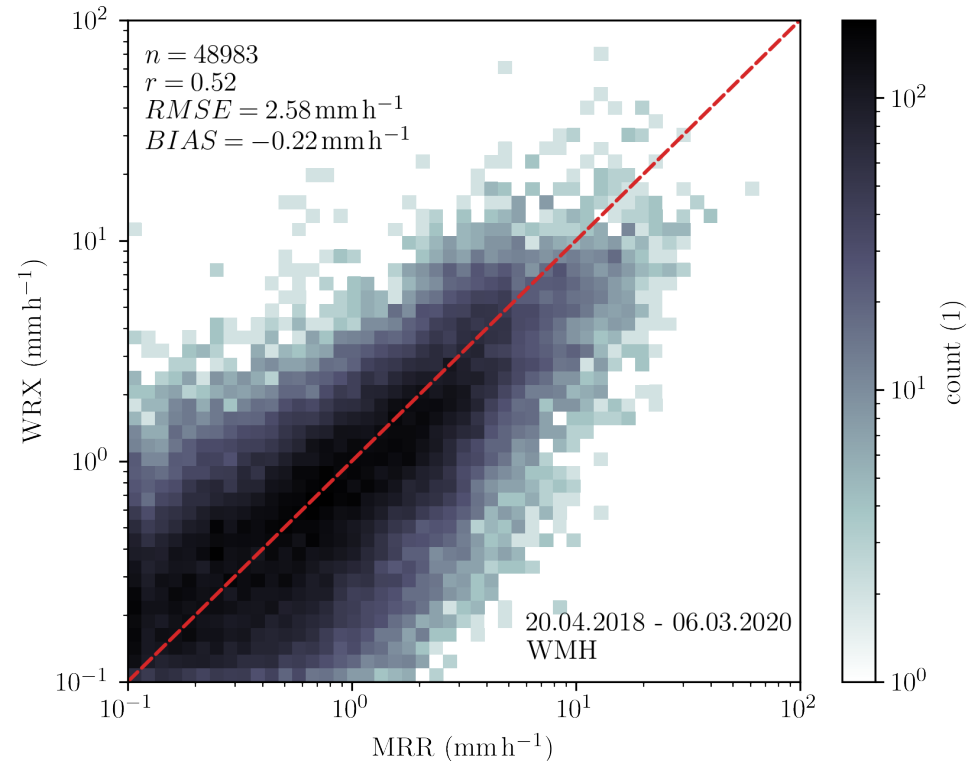
Z-R relation

- Needed for a rain rate estimate
- Infer Z-R relation from multi-year MRR observations
 - time resolution 10 s
 - Height level 105 m
 - zero degree level > 1500 m (ERA5)
- Methodology impacts empirical fit/relationship
- Additional different results for convective and stratiform rain
- Instead propose a new Z-R relation, use standard relation by Marshall et al. (1955) because of good agreement (right figure)



Estimated rain rate

- Apply standard Z - R relation to corrected radar reflectivity to estimate the rain rate
- Check validity of rain rate estimate $R(Z)$ with MRR rain rate based on drop size distribution $R(D)$
 - MRR rain rate at 105 m height level
 - Missing representation of strong variable Z - R relation using one fit
 - Correlation = 0.52
 - RMSE = 2.58 mm/h
 - Note comparison at 30 s time resolution



Summary

- Aim for a eight-year precipitation climatology with 100 m spatial and 30 s temporal resolution in urban area of Hamburg
- Rain rate estimate based on step-by-step correction for several periods between 2013 and 2021 due to different technical setups
- Observational synergy of a single-polarized, low-cost, local-area X-band radar, vertically pointing micro rain radars, and rain gauges
- Micro rain radars provide drop size distributions at relevant height, which increases the data quality (e.g. calibration, statistical relations) and assesses the statistics of the X-band radar precipitation estimate (shown for a period of ~2 years)
- This precipitation climatology may reveal further insights in sub-hourly precipitation characteristics
- Multi-year urban precipitation analysis is groundwork for further hydrological research within the project *Sustainable Adaption Scenarios for Urban Areas – Water from Four Sides* of the Cluster of Excellence *Climate, Climatic Change, and Society* (CliCCS)