Click

Country-wide CML rainfall estimation and CML-Radar combination in Germany

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Karlsruhe Institute of Technology

Universität Augsburg University

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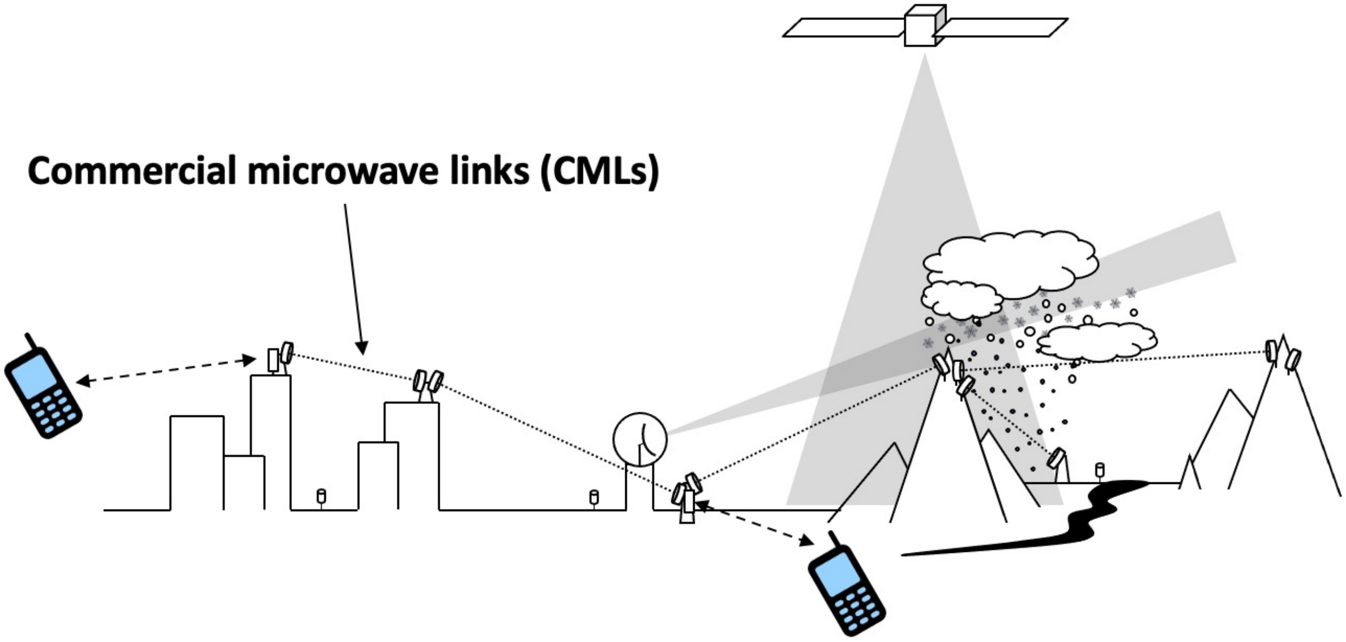
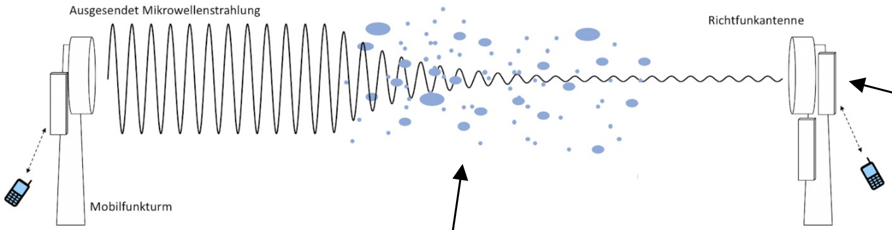
CMLs provide large parts of the backbone of the cellular network and can provide rainfall information in addition to existing observations also in regions where these are scarce



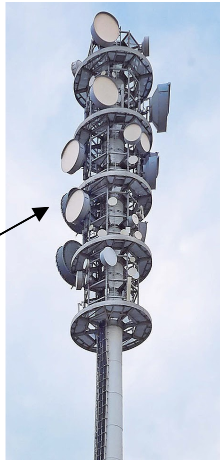
Country-wide CML rainfall estimation in Germany

Overview

CML rainfall estimation (in a nutshell)



Commercial microwave links (CMLs) provide a large part of the interconnections of cellular towers

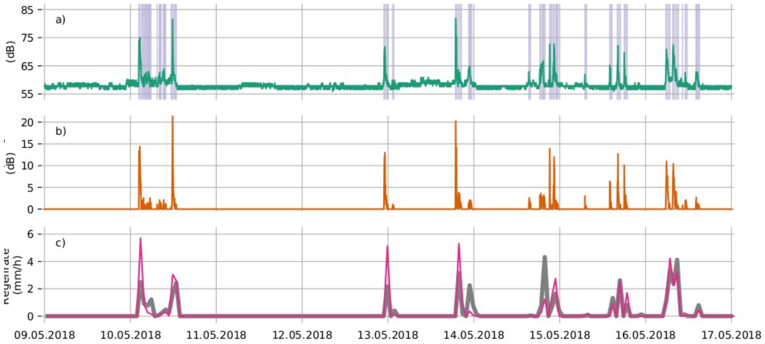


Rainfall attenuates the microwave radiation along the CML path

Raw CML attenuation data

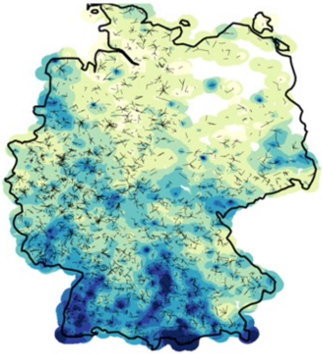
processing

CML rainfall estimation



Spatial interpolation

Data from 4000 CMLs currently available in Germany



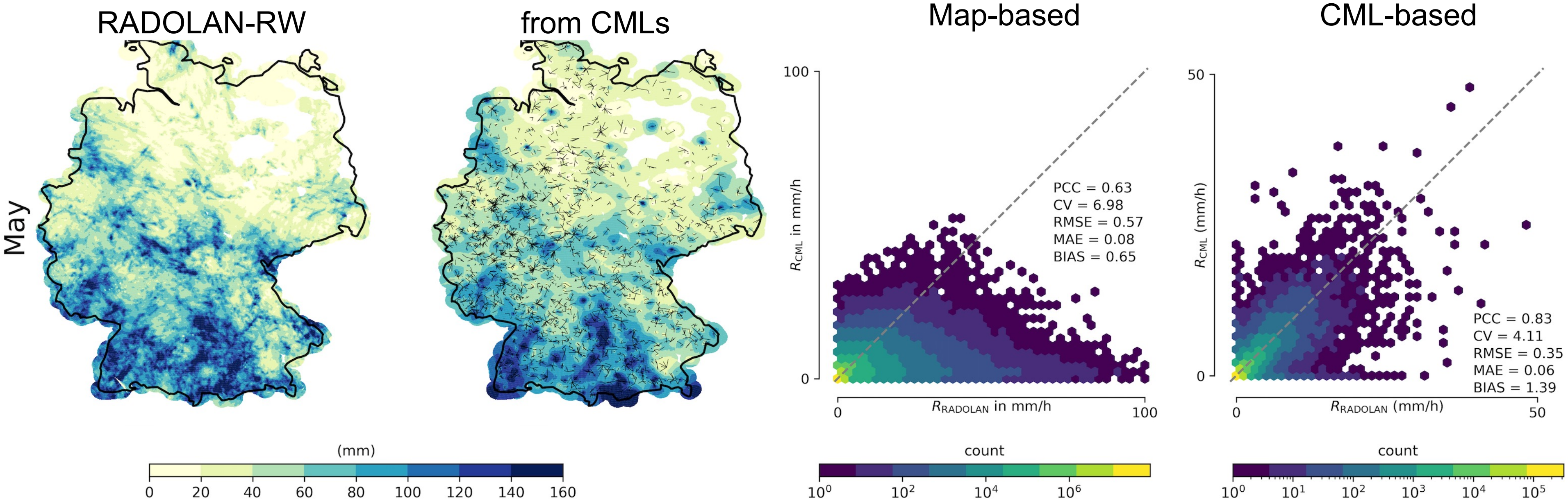
Country-wide CML rainfall estimation in Germany

Analysis of one full year

Graf et al. 2020, HESS: https://doi.org/10.5194/hess-24-2931-2020

CML rainfall estimation compares well with gauge-adjusted radar (RADOLAN-RW) in the warm season

Monthly sum of hourly rainfall maps

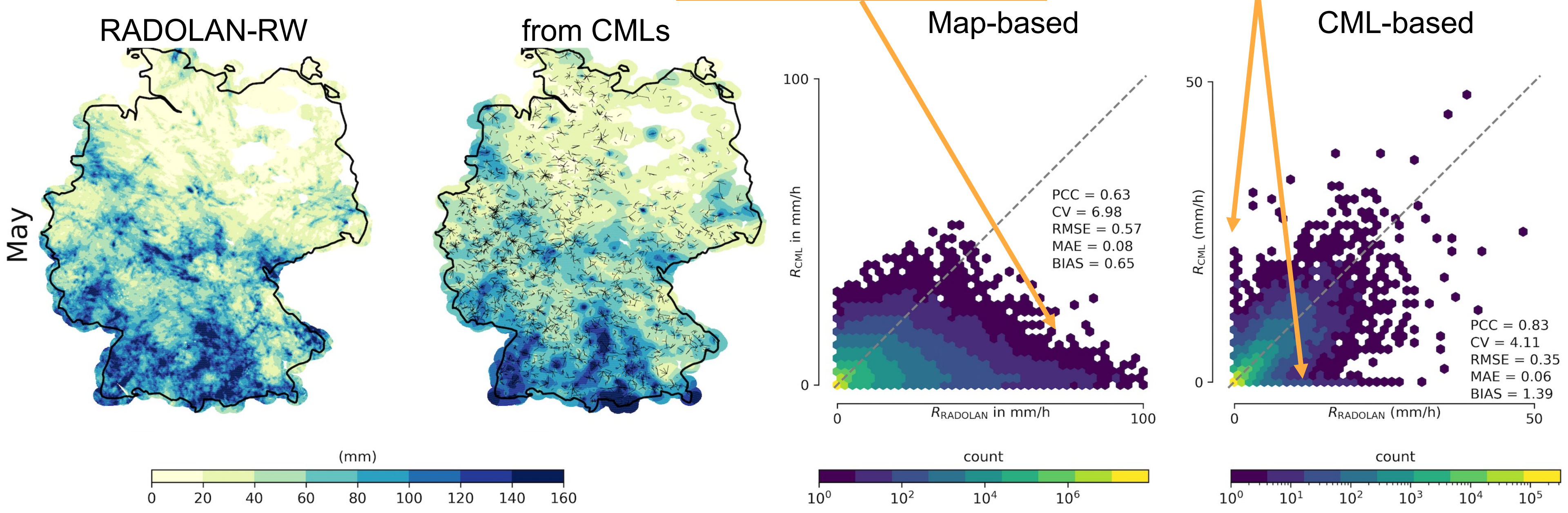


CML rainfall estimation compares well with gauge-adjusted radar (RADOLAN-RW) in the warm season

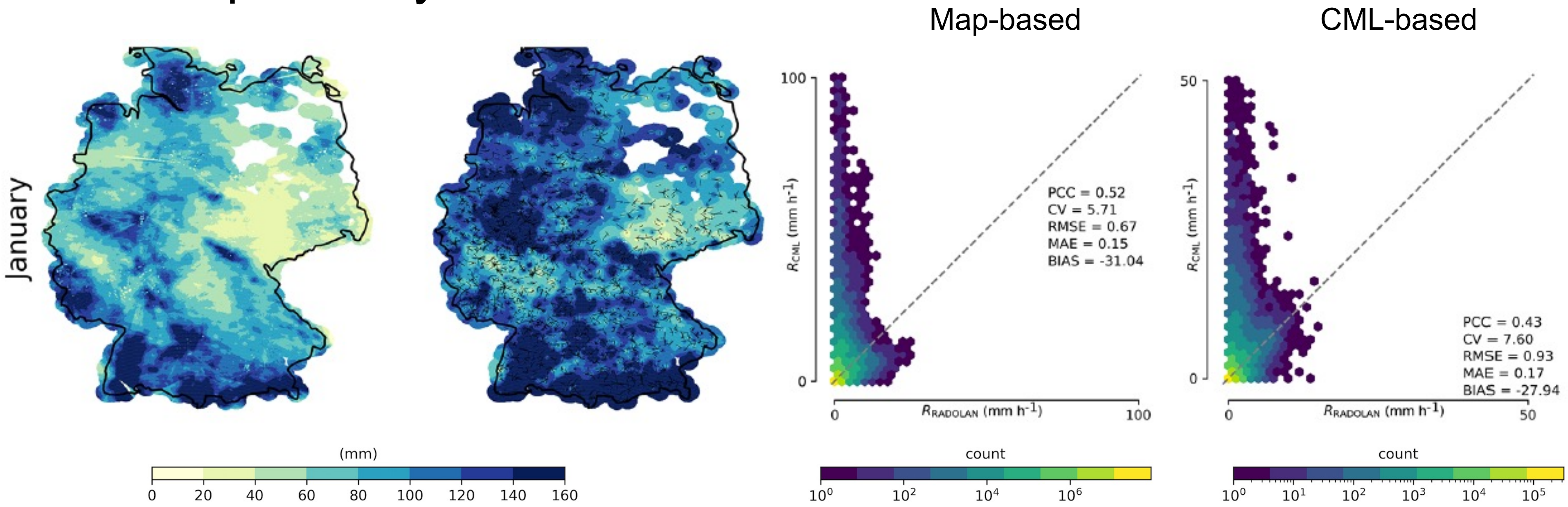
Underestimation of CML rainfall maps due to spatial interpolation

Impact of false-positive and false-negative rainfall estimates visible

Monthly sum of hourly rainfall maps



CML rainfall estimation shows strong overestimation during the cold season, most probably due to additional attenuation from snow on the antennas and due to different attenuation of mixed-phase hydrometeors



Country-wide CML rainfall estimation in Germany

Improved processing with Deep Learning

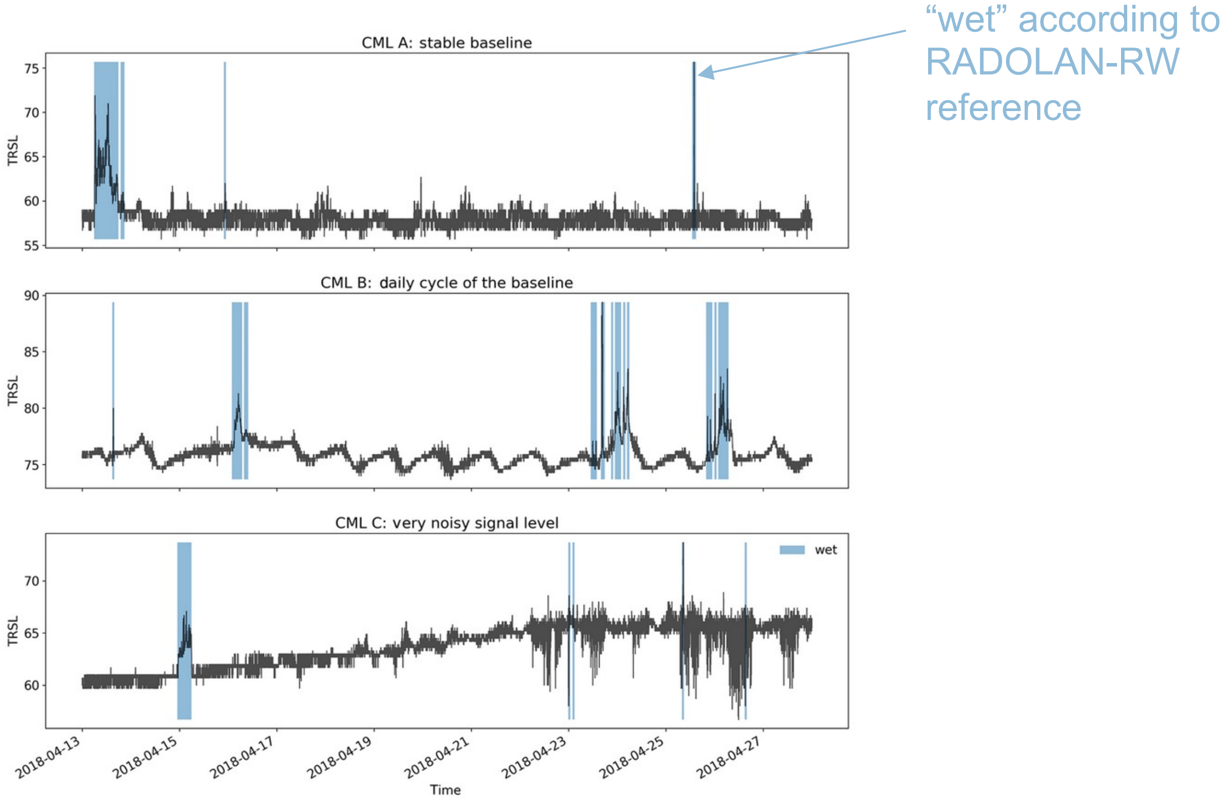
Polz et al., 2020, AMT: https://doi.org/10.5194/amt-13-3835-2020

One of the main challenges for CML rainfall estimation is the detection of rain events in the raw data which can be noisy or affected by erratic fluctuations

CML raw attenuation data (TRSL) with only moderate noise

CML raw data with some diurnal fluctuation

CML raw data with drift and sudden change to erratic fluctuations



We have developed a new method based on a convolutional neural network (CNN) which improves the detection of rain events in the CML raw data

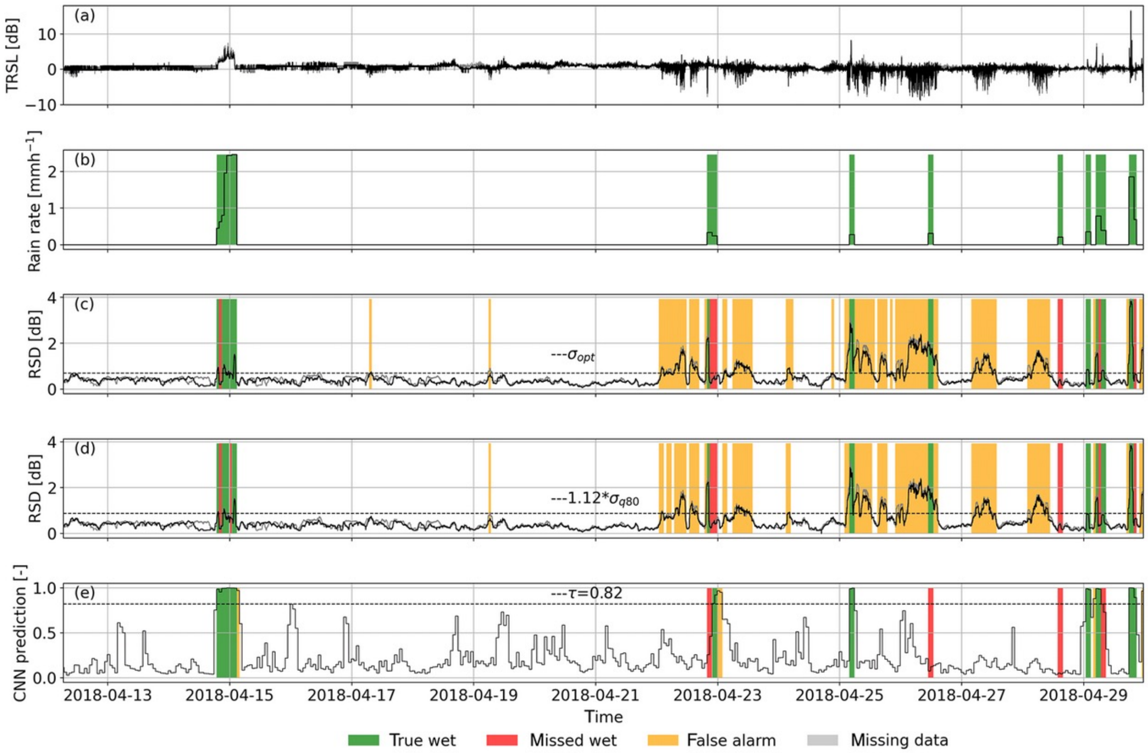
CML raw attenuation data

RADOALN-RW reference

Standard method 1

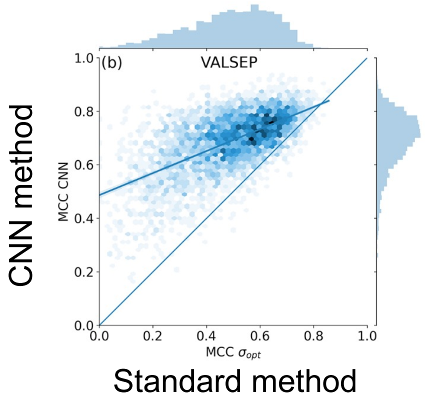
Standard method 2

CNN method

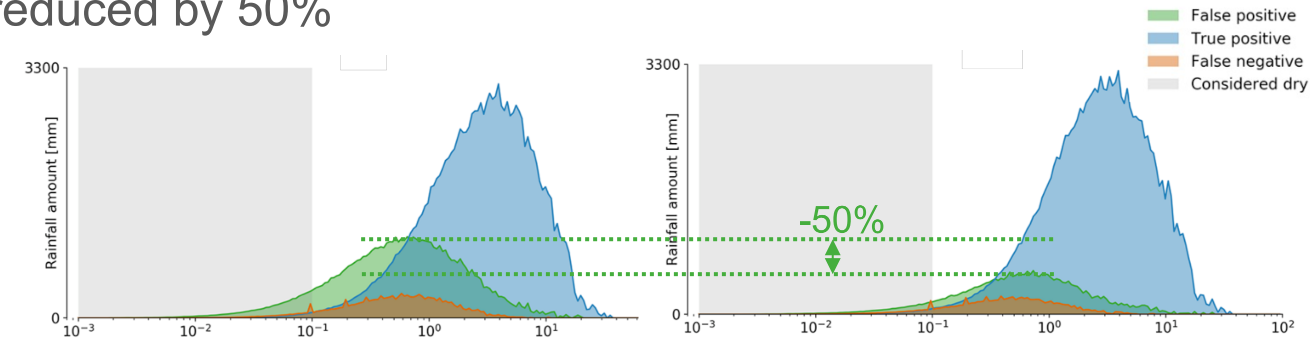


Rain event detection is significantly improved by the CNN method, reducing false-positives rain events and false-positive rainfall amount by approx. 50%

- The Matthews correlation coefficient (MCC), a standard metric for binary classification (in our case “wet“ or „dry“) is significantly improved



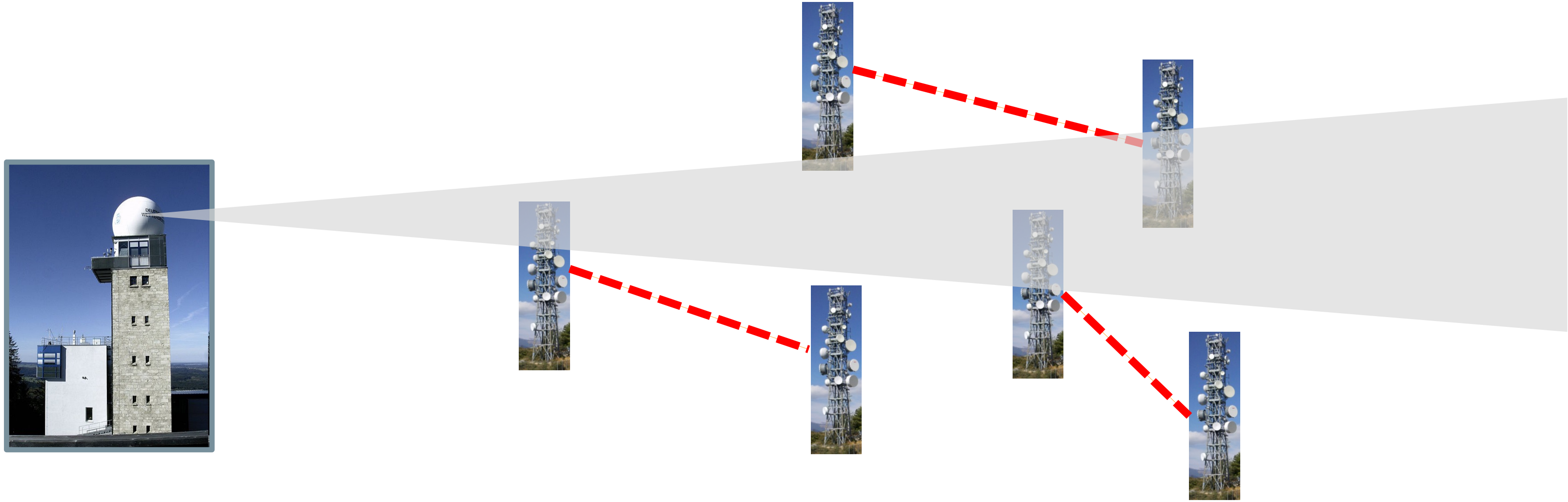
- The amount of rainfall cause by false-positive “wet” periods is reduced by 50%



CML-Radar combination in Germany

Overview

We use CMLs as additional rainfall information in the RADOLAN radar-rain-gauge adjustment



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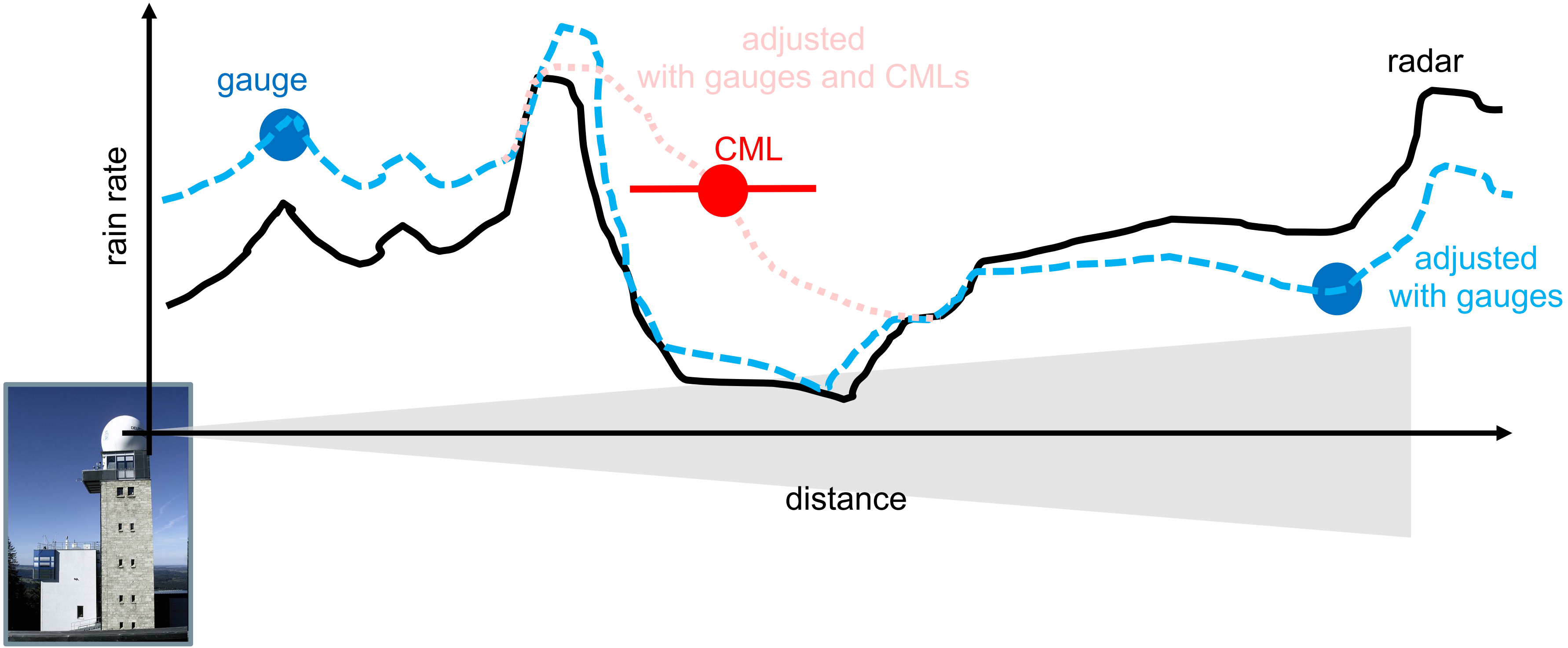
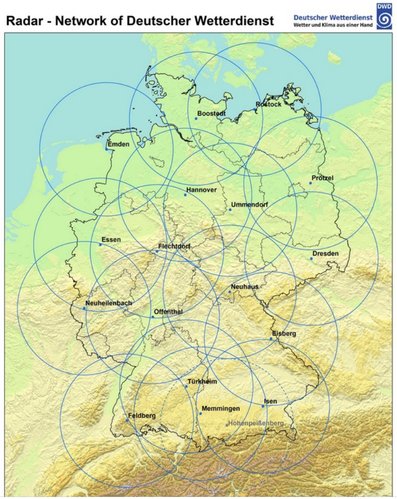
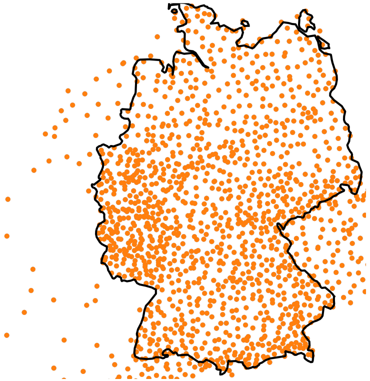


We produce two different adjusted radar products

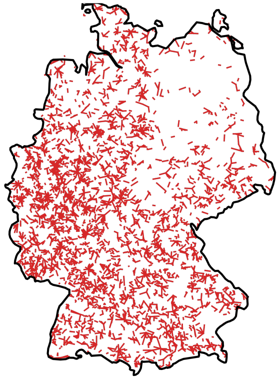
DWD radar network



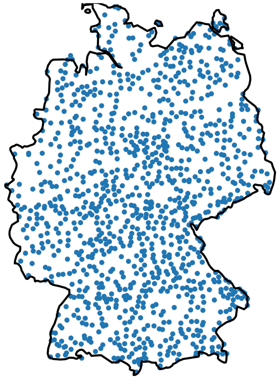
Automatic rain gauges from DWD and neighboring countries



4000 commercial microwave links (CMLs)



Manual rain gauges from DWD with daily data



used as independent validation data set

RADOLAN-RW

RADOLAN-RW-CML (gauges and CML)

We use a Python implementation of the existing RADOLAN-RW gauge-adjustment routine

- CML rainfall information is integrated in the adjustment as path-averaged rain rate for each CMLs

- All RADOLAN-processing steps are implemented, except the final smoothing of the resulting rainfall field

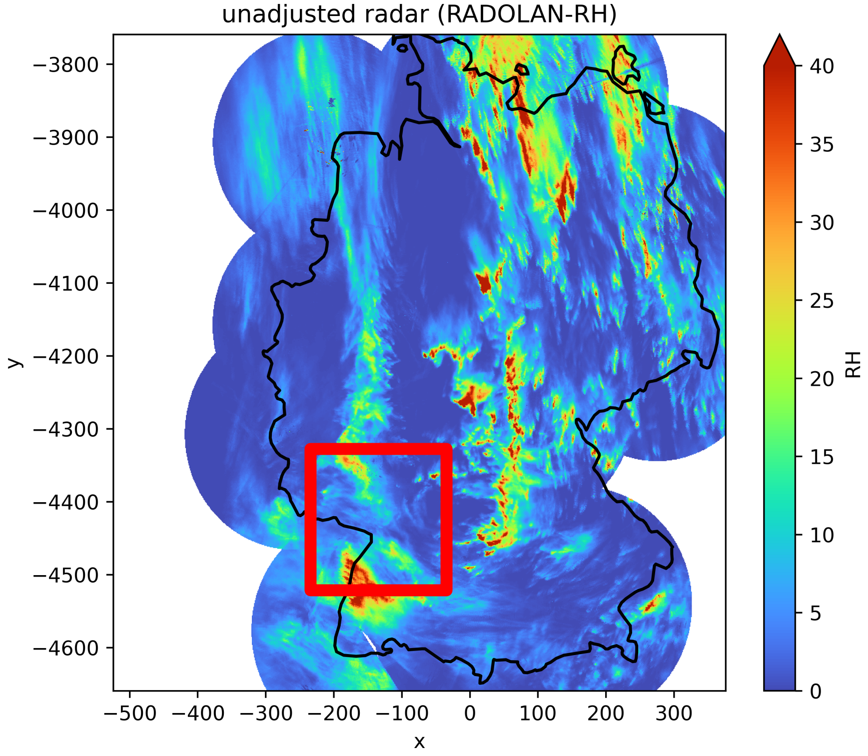
- Fast execution time, approx. 30 seconds for one full adjustment run with 1500 gauges and 4000 CMLs, parallel executions of several time steps is possible using dask

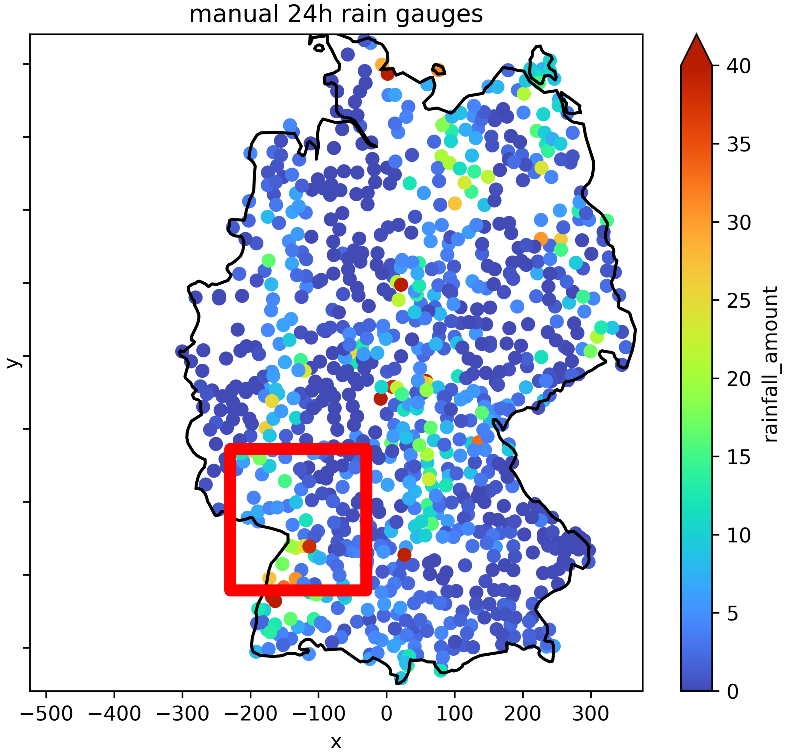
- Built fully from open-source tools: wradlib, numpy, pandas, xarray, dask

CML-Radar combination in Germany

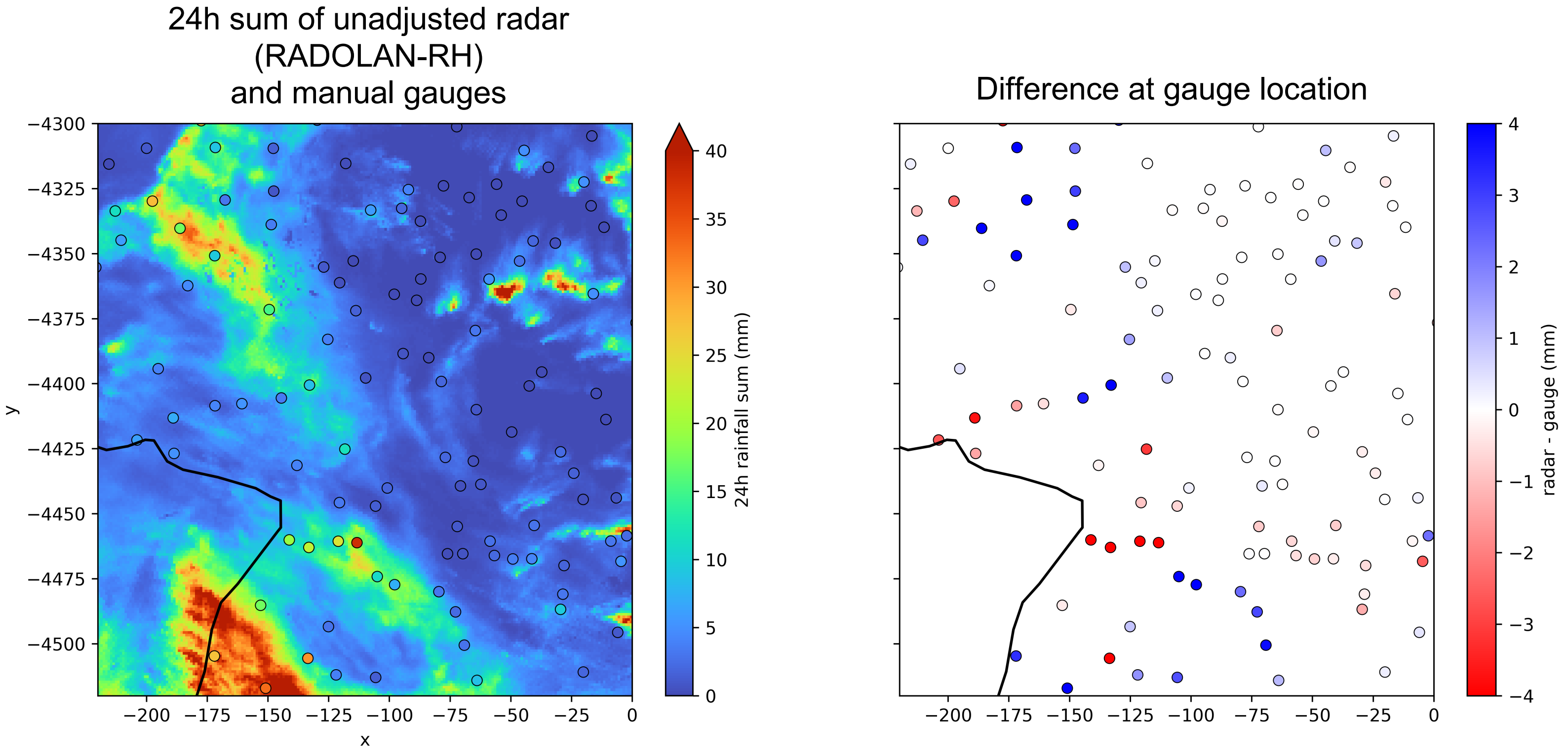
Analysis for specific day and region (10th of May 2018)

For this analysis we focus on a region in south-west Germany where coverage with gauges and CMLs is good

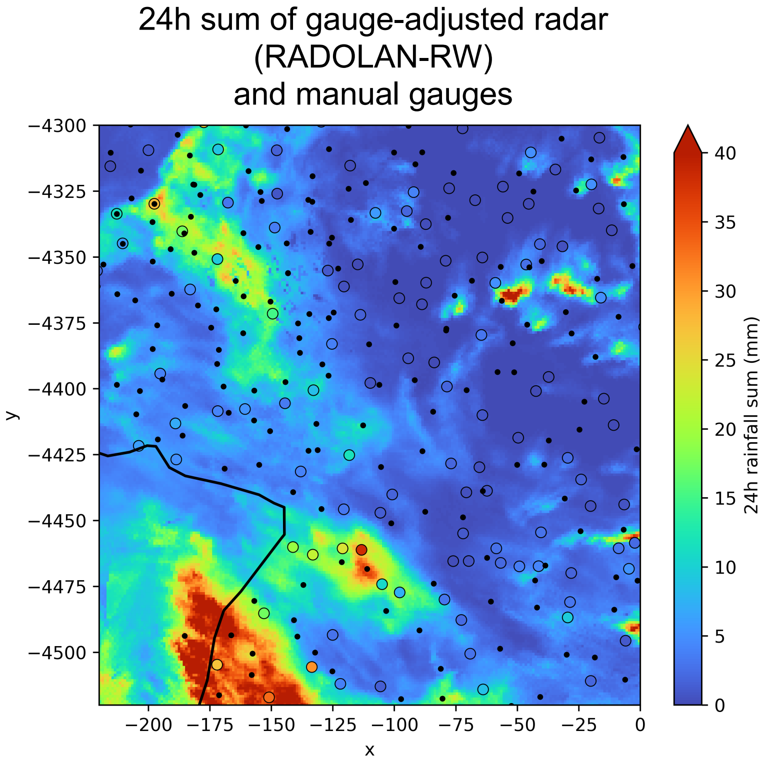


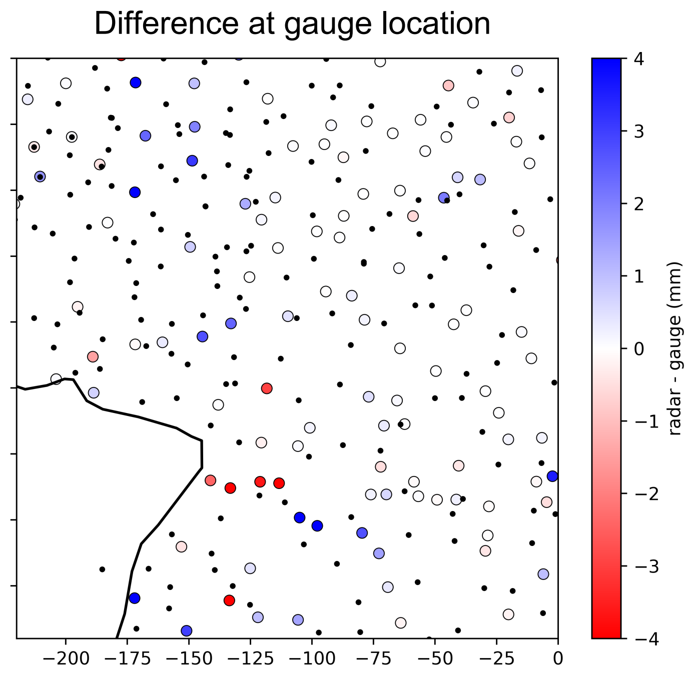


Unadjusted radar shows large differences to gauge reference

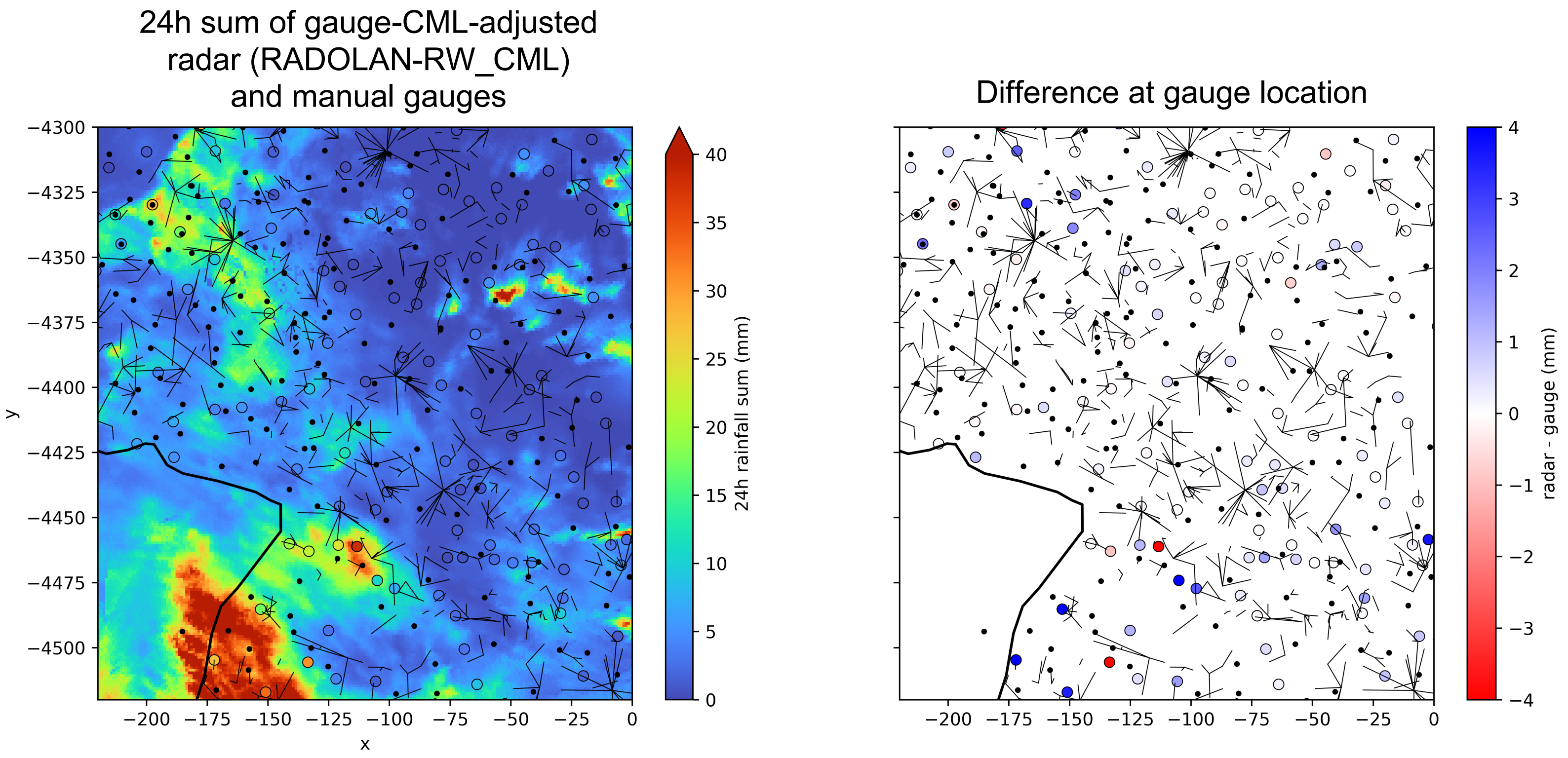


Gauge adjustment improves radar rainfall field in general but many regions still biased compared to gauge reference





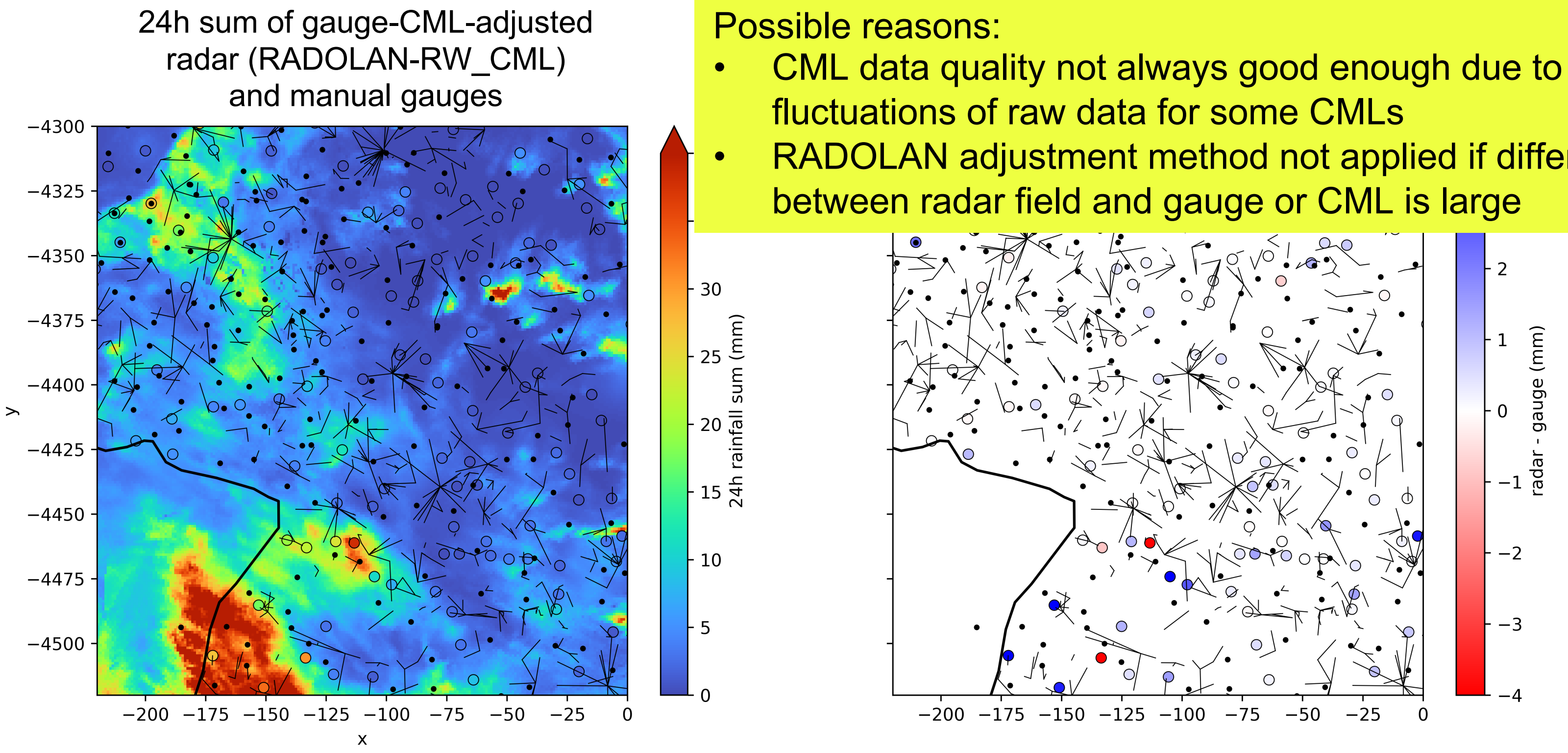
Adding CMLs to the adjustment leads to significant improvement in some regions but unresolved bias remains



Adding CMLs to the adjustment leads to significant improvement in some regions but unresolved bias remains

Possible reasons:

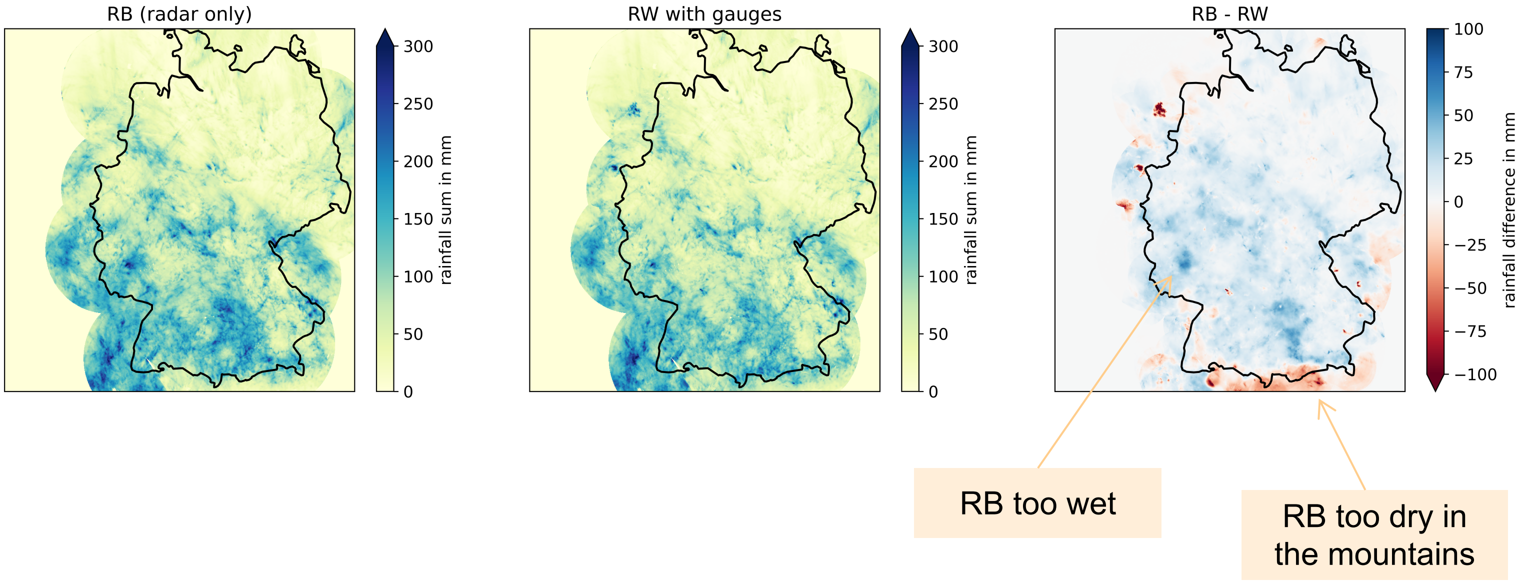
- CML data quality not always good enough due to erratic fluctuations of raw data for some CMLs
- RADOLAN adjustment method not applied if difference between radar field and gauge or CML is large



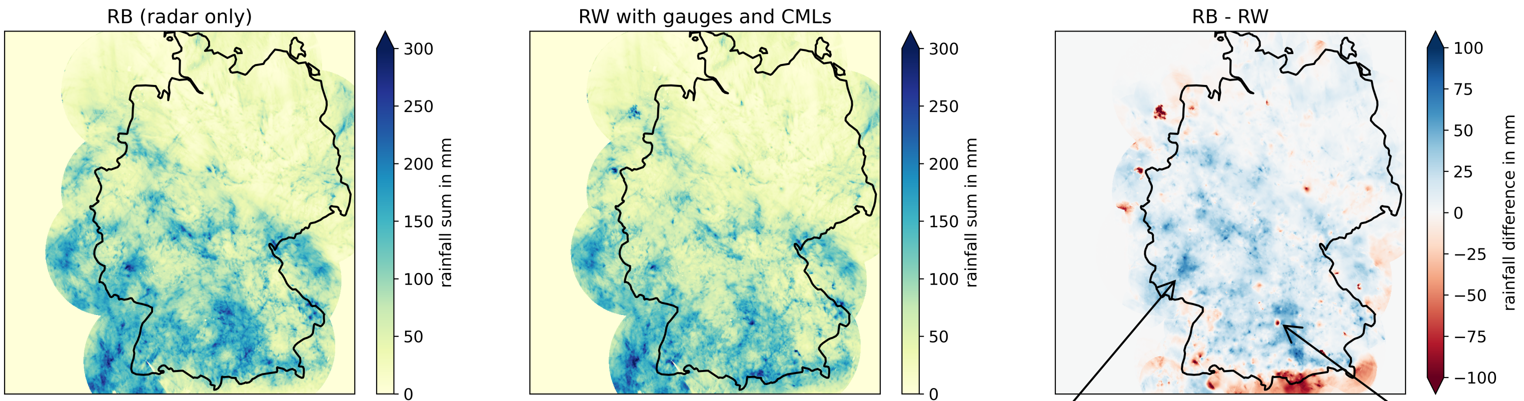
CML-Radar combination in Germany

Analysis for monthly rainfall sum
(May 2018)

The monthly aggregation of the 1h-rainfall map (here for RADOLAN-RW with gauges only) looks as expected



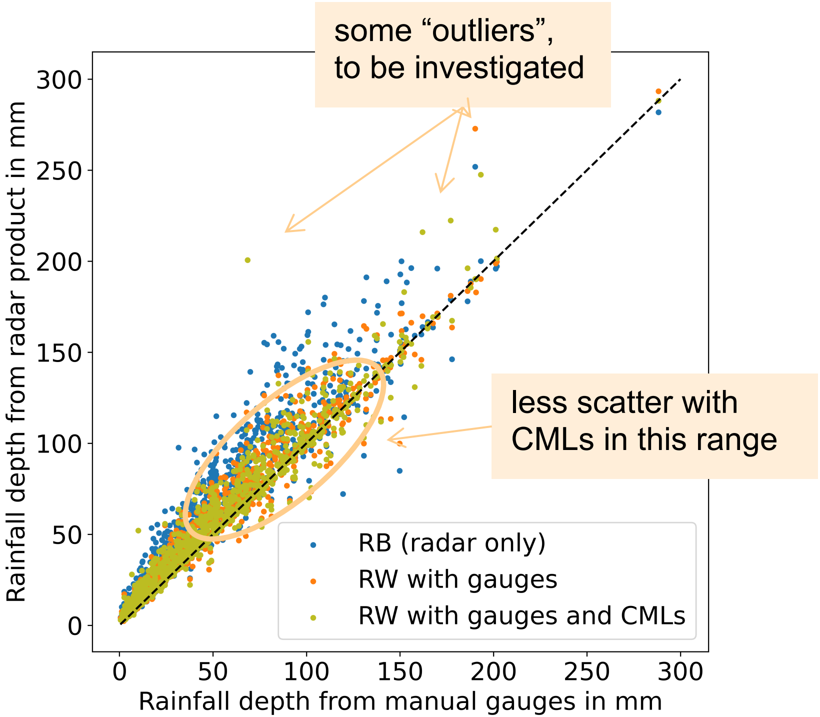
With CMLs included, the general picture stays the same, with a slightly dryer adjusted product and some more significant differences on the small scale

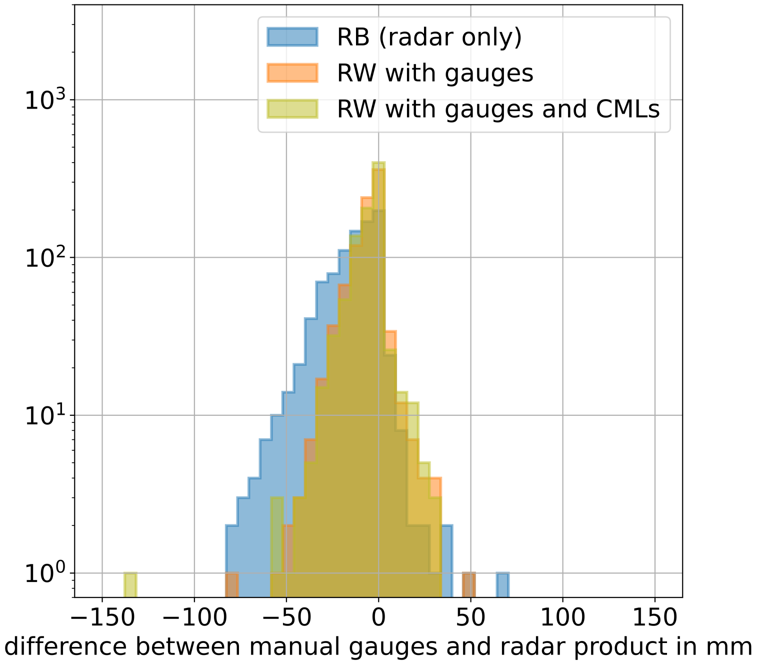


Similar adjustment than with “gauges only” but more spatial structure

Strong local adjustments could be cause by CML artifact (not yet investigated)

Adding CMLs shows small improvement for rainfall depth over one month using the manual gauges as reference





Note that the CMLs have not (yet) used any radar information to improve their processing, potentially increasing their data quality

CML-Radar combination in Germany

Conclusion and outlook

Conclusion

- Adding CMLs to the radar adjustment can improve the resulting rainfall field significantly
- But the impact of CMLs depends on their spatial distribution in the region of interest
- Variable CML data quality adds uncertainty and should be improved or accounted for in the adjustment

Next steps

- Detailed analysis of effect of CMLs
- Use radar information to detect erratic CML fluctuation and to improve CML data quality
- Use real-time CML data to do RADOLAN-RW adjustment with CMLs continuously
- Investigate potential of radar adjustment with path-averaged CML observations for higher temporal resolutions (5-minutes or 15-minute)

Acknowledgments

ERICSSON

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DFG

HELMHOLTZ

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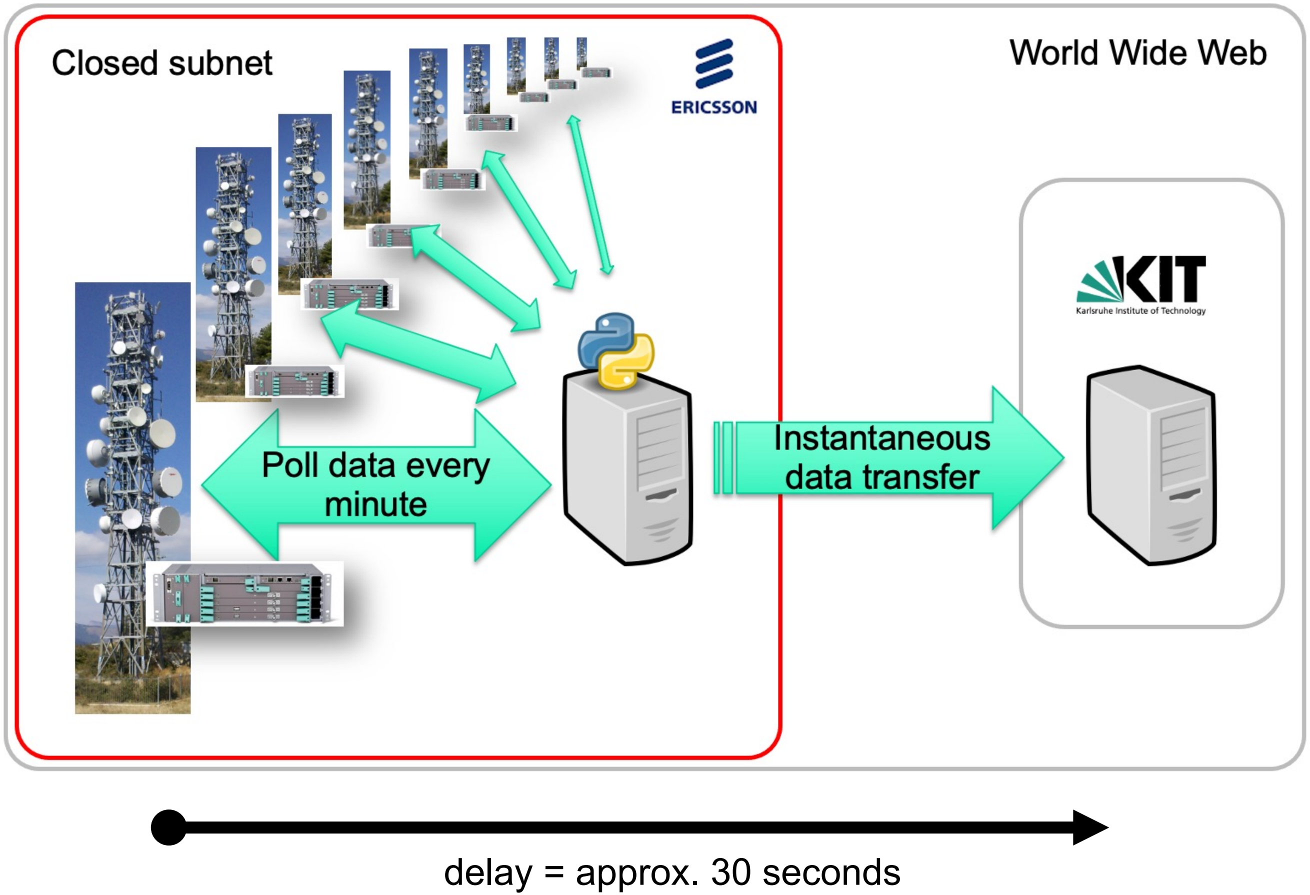
Graf, M., Chwala, C., Polz, J., and Kunstmann, H.: Rainfall estimation from a German-wide commercial microwave link network: Optimized processing and validation for one year of data, Hydrol. Earth Syst. Sci. Discuss., [accepted for publication], 2020. https://www.hydrol-earth-syst-sci-discuss.net/hess-2019-423/

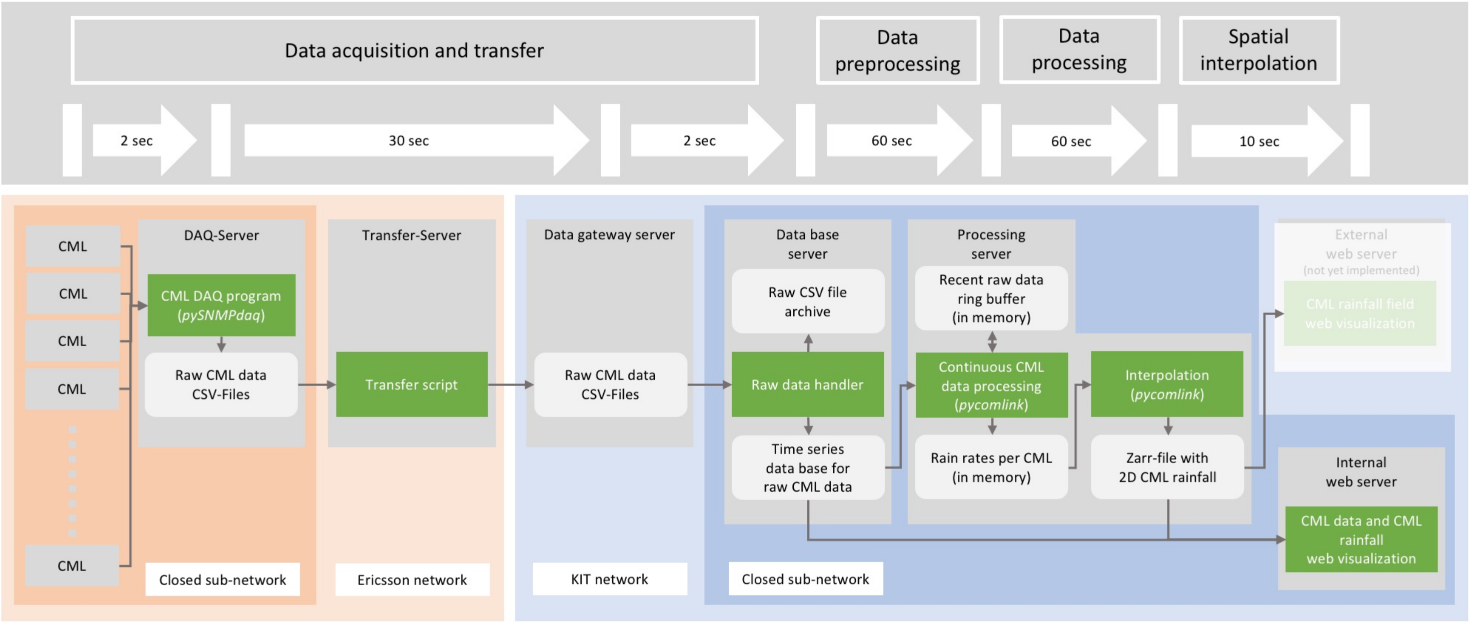
Polz, J., Chwala, C., Graf, M., and Kunstmann, H.: Rain event detection in commercial microwave link attenuation data using convolutional neural networks, Atmos. Meas. Tech. Discuss., in review, 2019. https://www.atmos-meas-tech-discuss.net/amt-2019-412/

Backup slide: CML real-time system

We receive CML data in real-time



We can derived rainfall maps with 5-minute delay using our newest CML-processing with a CNN



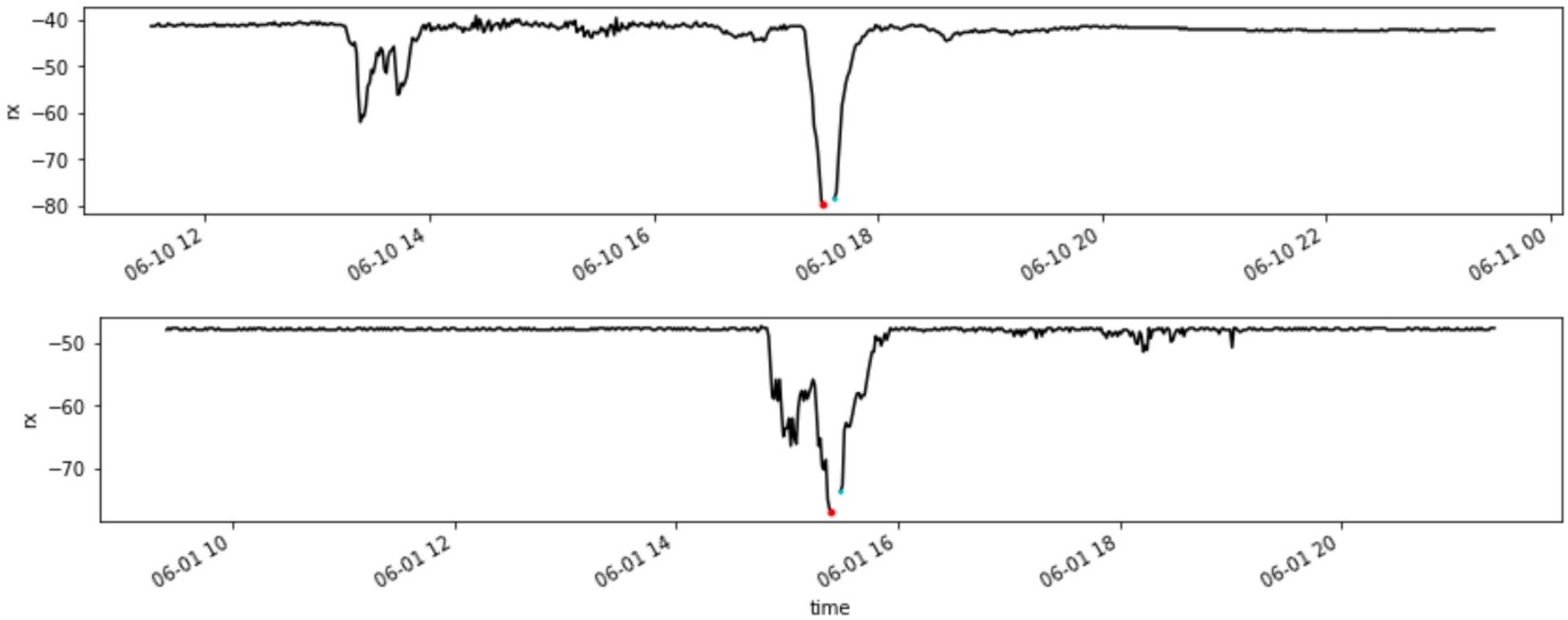
The challenge is to keep the recent data of 1 day of CML data in memory for 4000 CMLs, because CML processing requires "knowledge" of past time steps

CNN wet-dry classification published in Polz et al. 2020 https://doi.org/10.5194/amt-13-3835-2020

Backup slide: CML limitations

CMLs can experience complete loss of signal (blackout) when attenuation is too large for the receiver to operate

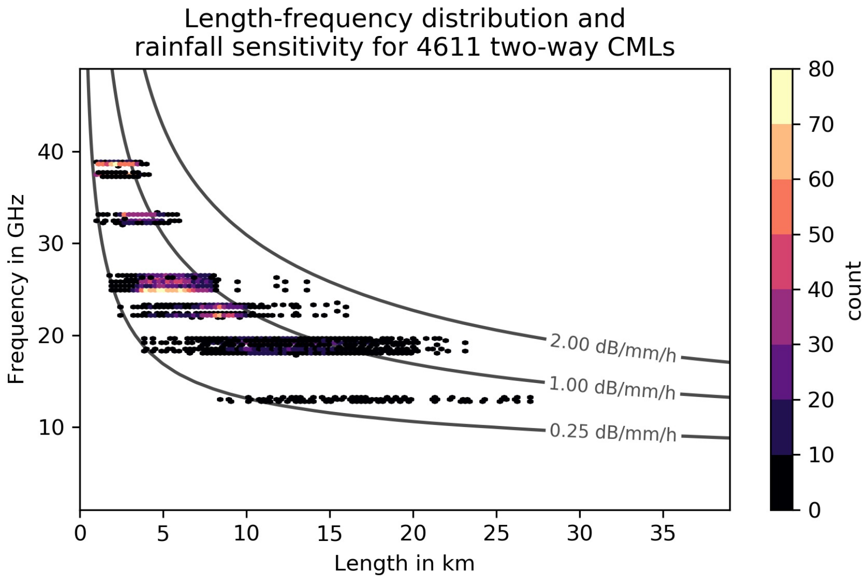
- Below a certain RSL (here at -80 dBm) no attenuation data can be recorded due to non-functioning communication along the CML



CML networks are planed so that blackouts statistically only occur approximately 0.001% of the time, i.e. 5 minutes/year

- Length and frequency of CMLs are chosen so that the sensitivity due to rainfall (iso lines in the plot) is in the range of 1.0 dB/mm/h

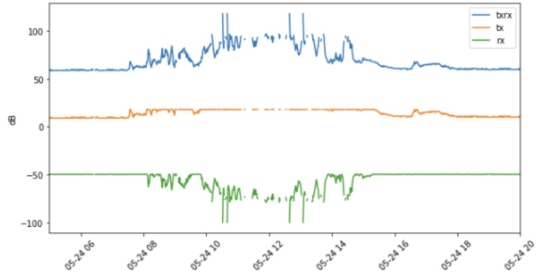
- The likeliness of high values of path-averaged rainfall increases with decreasing link length. Hence, spatial rainfall statistics are required to get a clearer picture
- (the iso lines in the plot assume homogeneous rainfall distribution along the path)



Mitigation of blackout gaps using simple interpolation

- Data gaps can be interpolated, e.g. using linear interpolation
- The question is: What is the maximum allowed length of a data gap
- Interpolating longer gaps, increases the estimated rainfall amount
- But, during the gaps, CMLs do underestimated rainfall because the attenuation would be higher than the observed one
- Better to set hours with “long” (how long?) gaps to Nan

Raw data with gaps



temporal interpolation of gaps

Resulting 1-hour rain fall sum for interpolation up to different gap length