Combined rainfall estimates from personal weather station and commercial microwave link data in Germany

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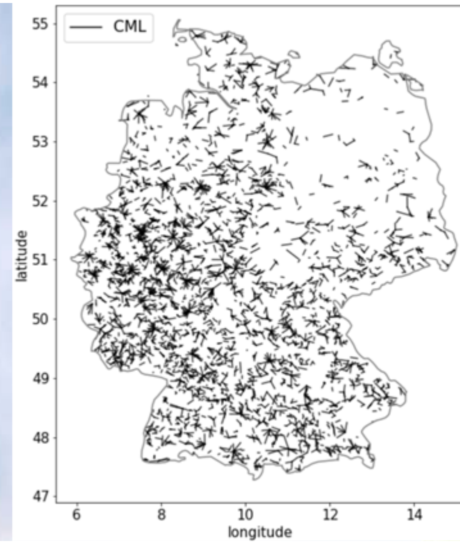
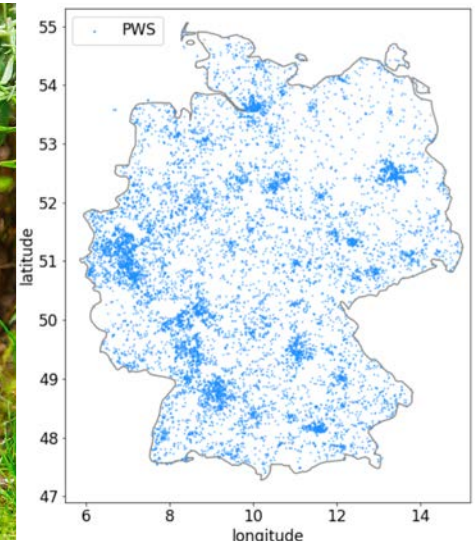
Opportunistic sensors (OS) can be used to for rainfall monitoring

Karlsruhe Institute of Technology





Commercial Microwave Links (CMLs)

- ~ 4000 CMLs
- fixed set of CMLs with custom real time application[1] together with Ericsson
- 10 to 40 GHz with 0.3 to 30 km length

Personal Weather Stations (PWSs)

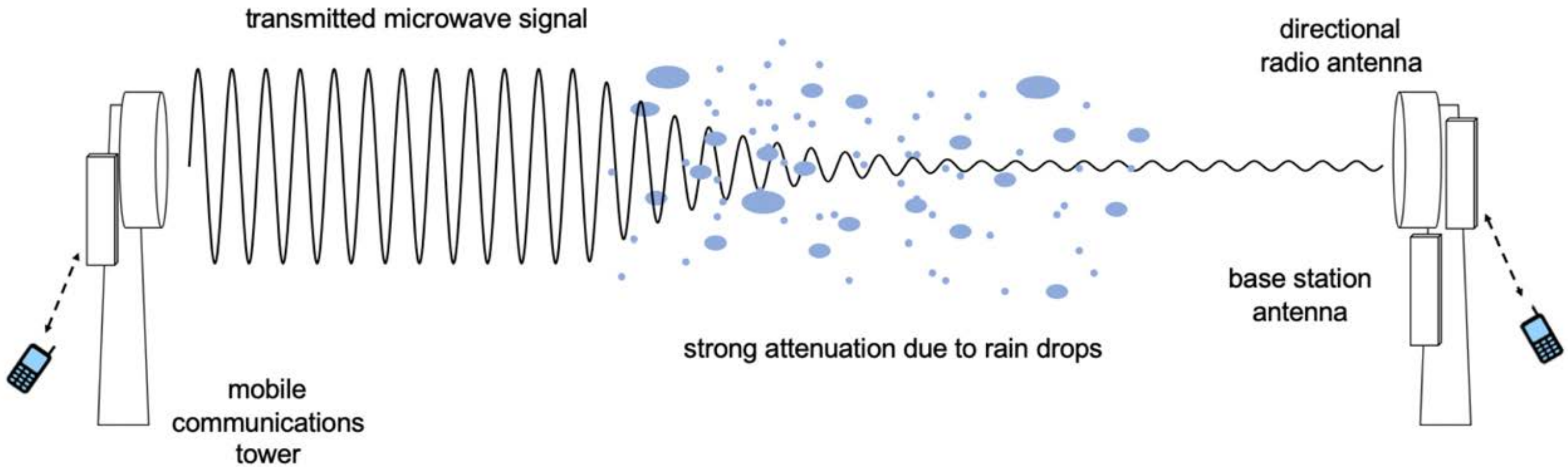
- ~ 20,000 PWSs from netatmo
- number of PWSs is increasing

Other examples from a growing number of opportunistic sensor for environmental monitoring

- Smart phones → temperature, pressure, light
- Windshield wipers → rainfall binary info from windshield wipers
- Satellite TV link path → rainfall
- Surveillance cameras → rainfall

[1] Chwala et al. 2016, AMT

Commercial Microwave Links

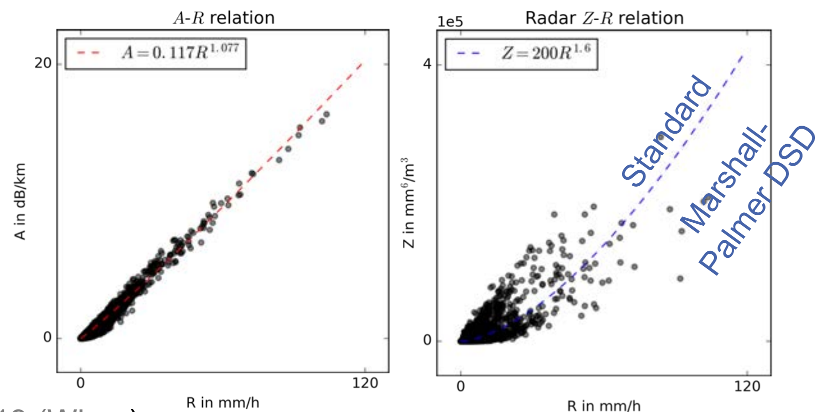


→ Relation between attenuation and rain rate is defined as

A-R power law: $A = aR^b$

[mm/h] (R)

[dB/km] (A)



more information on CML processing

Chwala and Kunstmann, 2019 (Wires)
Polz et al., 2020 (AMT)
Graf et al., 2020 (HESS)

Personal Weather Stations

wireless weather station for the "smart home"

tipping bucket rain gauge

manufacturer's specifications

- range of 0.2–150 mm/h
- precision of 1 mm/h

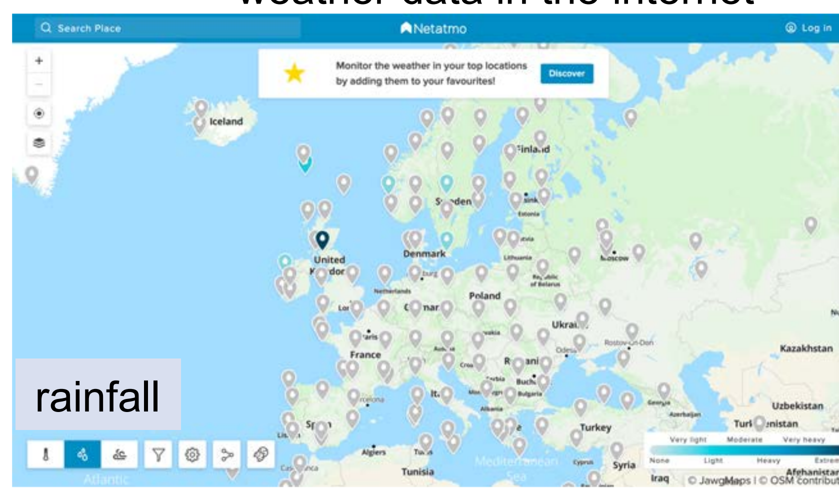
Wi-Fi

indoor/outdoor units

- temperature
- humidity
- pressure
- CO_2

sonic anemomenter

weather data in the internet



netatmo.com

more information on PWS processing

Bárdossy et al. 2020 (HESS)

Evaluating rainfall estimates through scales

What are the challenges?

- an adequate quality control routine has to be used for opportunistic sensors

→ remove only as much data as necessary to profit from high number of sensors

- find suitable reference data sets to evaluate rainfall estimates from OS

Concept of evaluation

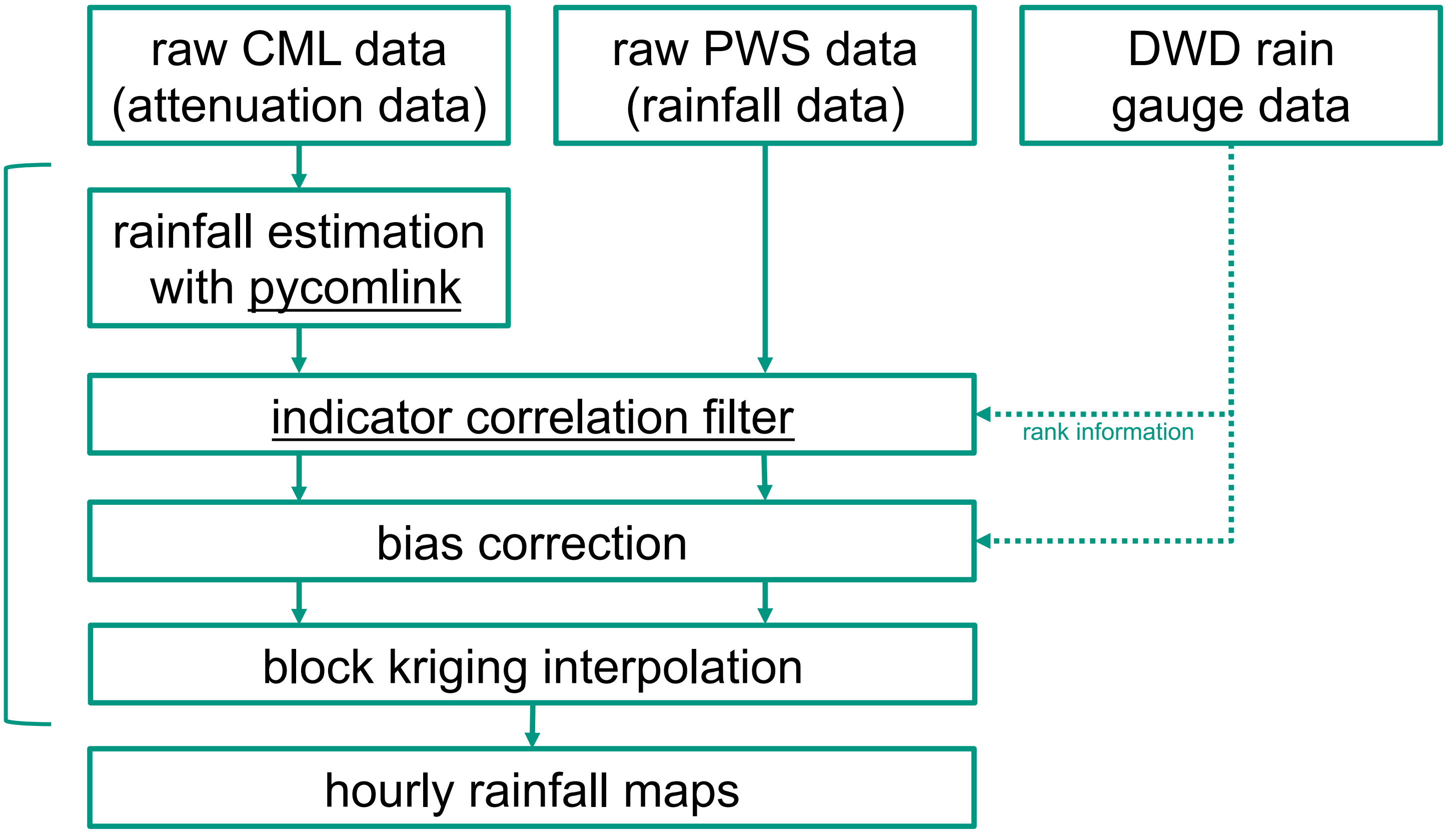
- 7 interpolated products with hourly resolution which consist of PWS, CML and DWD[1] and their combinations
- evaluation of 7 interpolated products for 3 scales
- Analysed period: April – October 2018 and 2019

scale	region	temporal	n stations	data provider
country	Germany	daily	1062	DWD[1]
regional	Rhinland-Palatinate	hourly	169	Agrometeorological Agency of Rhinland-Palatinate
local	Reutlingen	hourly	12	Municipality of Reutlingen

[1]$DWD_{daily} \neq DWD_{hourly}$, these are two different gauge dataset from different locations

Processing and Interpolation

the geometric line characteristic of the CMLs is integrated in all processing steps

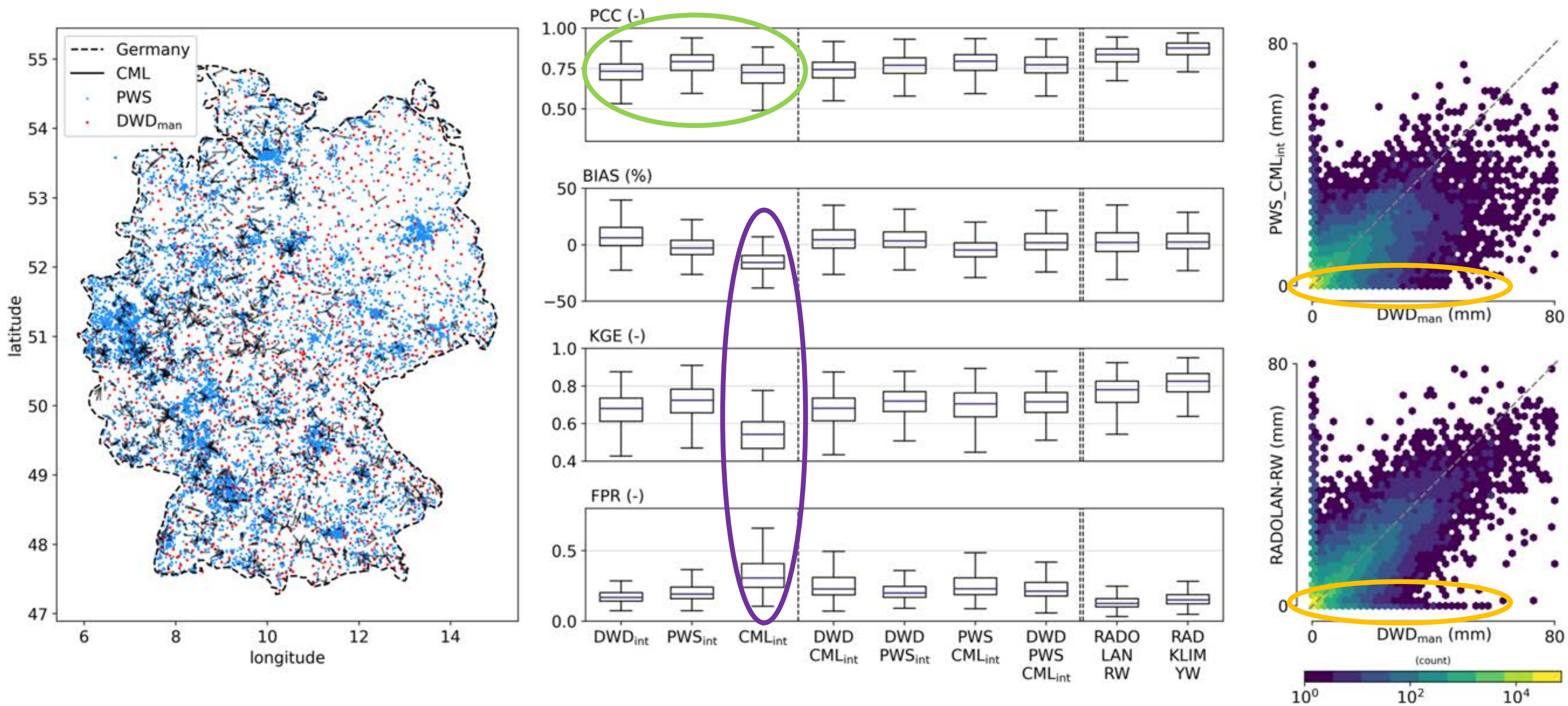


Session HS 7.2
Fri, 30 Apr, 11:35–11:37

Detailed explanation and discussion of the block kriging approach:
Eisele, M., et al.: Rainfall estimates from opportunistic sensors in Germany across spatio-temporal scales – Geostatistical interpolation framework, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-12415, https://doi.org/10.5194/egusphere-egu21-12415, 2021.

Country-wide, daily scale: Germany

performance of interpolated products for 1062 manual, daily rain gauges from DWD (DWD_{man})

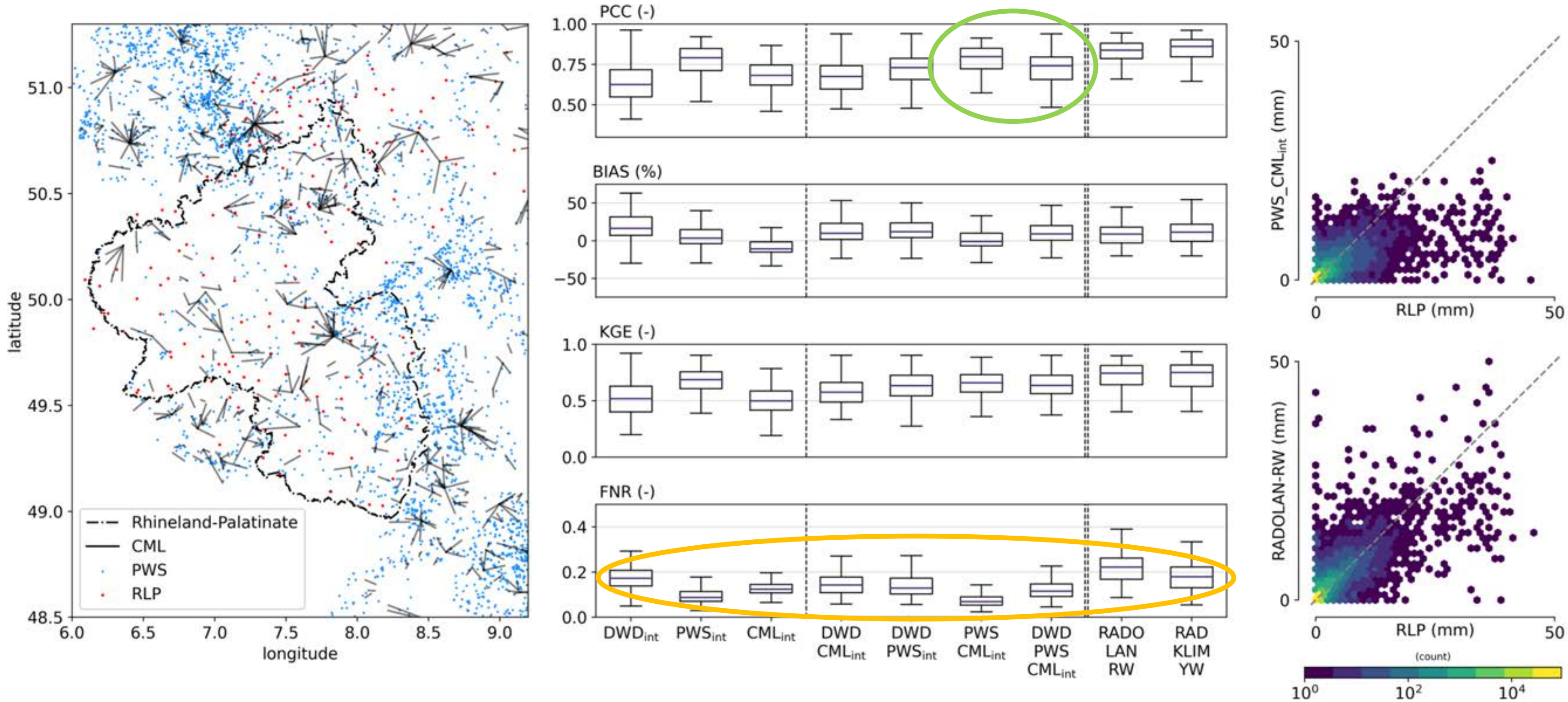


- OS products correlate similar or better to the reference than one of DWD rain gauges
- OS have less false negatives than radar products, especially for higher rainfall sum
- interpolated CMLs show a negative bias and high false positive rate mainly due to their uneven distribution in relation to the DWD_{man} gauges

PCC: Pearson's Correlation Coefficient
KGE: Kling Gupta Efficiency
FPR: False Positive Rate
RADOLAN-RW/RADKLIM-YW: radar products from DWD

Regional, hourly scale: Rhineland-Palatinate

performance of interpolated products compared to 169 hourly rain gauges operated by the Agrometeorological Agency of Rhinland-Palatinate (RLP)

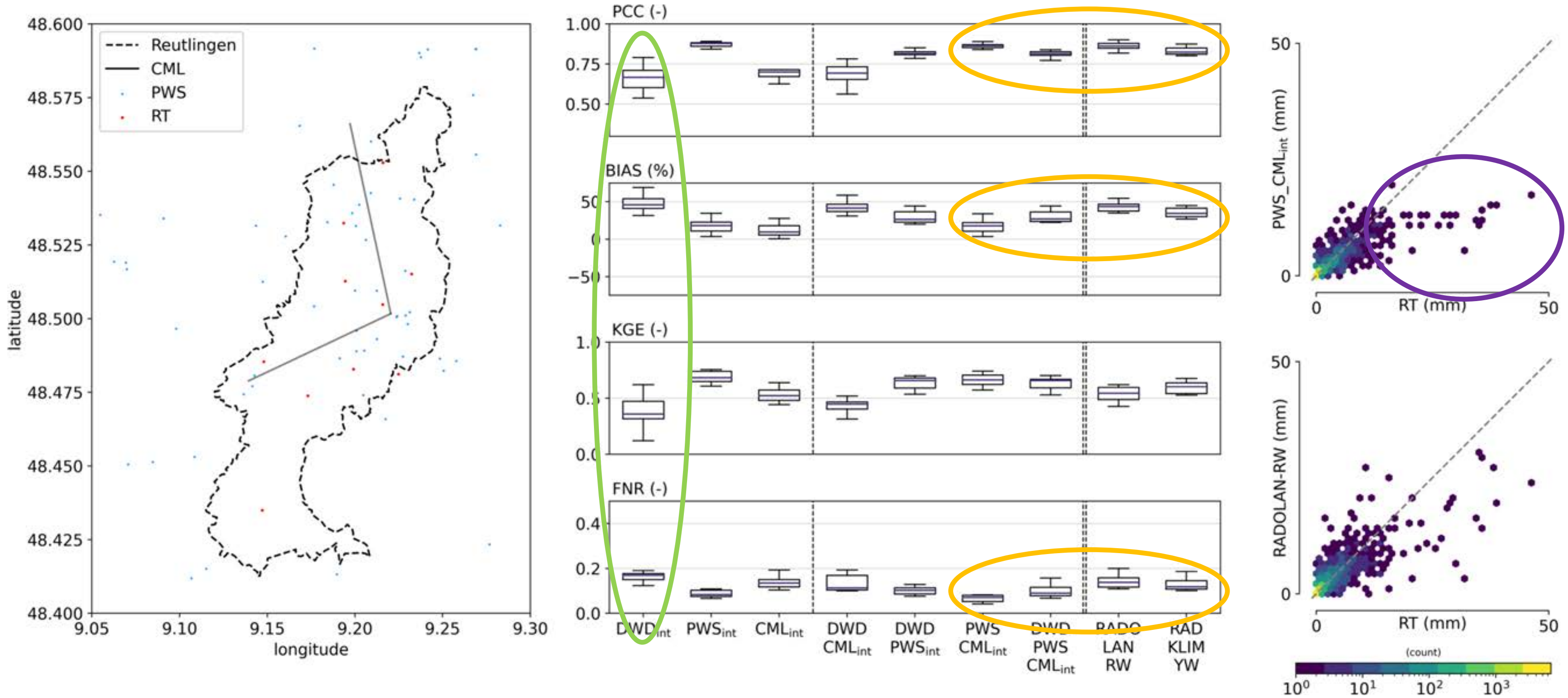


- combination of OS performs better than combination of OS with DWD
- False negative rate of OS and combinations is lower than DWD or radar
- Even though OS do not measure at the validation stations (RLP) they perform reasonable in comparison to radar measurements at such locations

PCC: Pearson's Correlation Coefficient
KGE: Kling Gupta Efficiency
FPR: False Positive Rate
RADOLAN-RW/RADKLIM-YW: radar products from DWD

Local Scale: Reutlingen

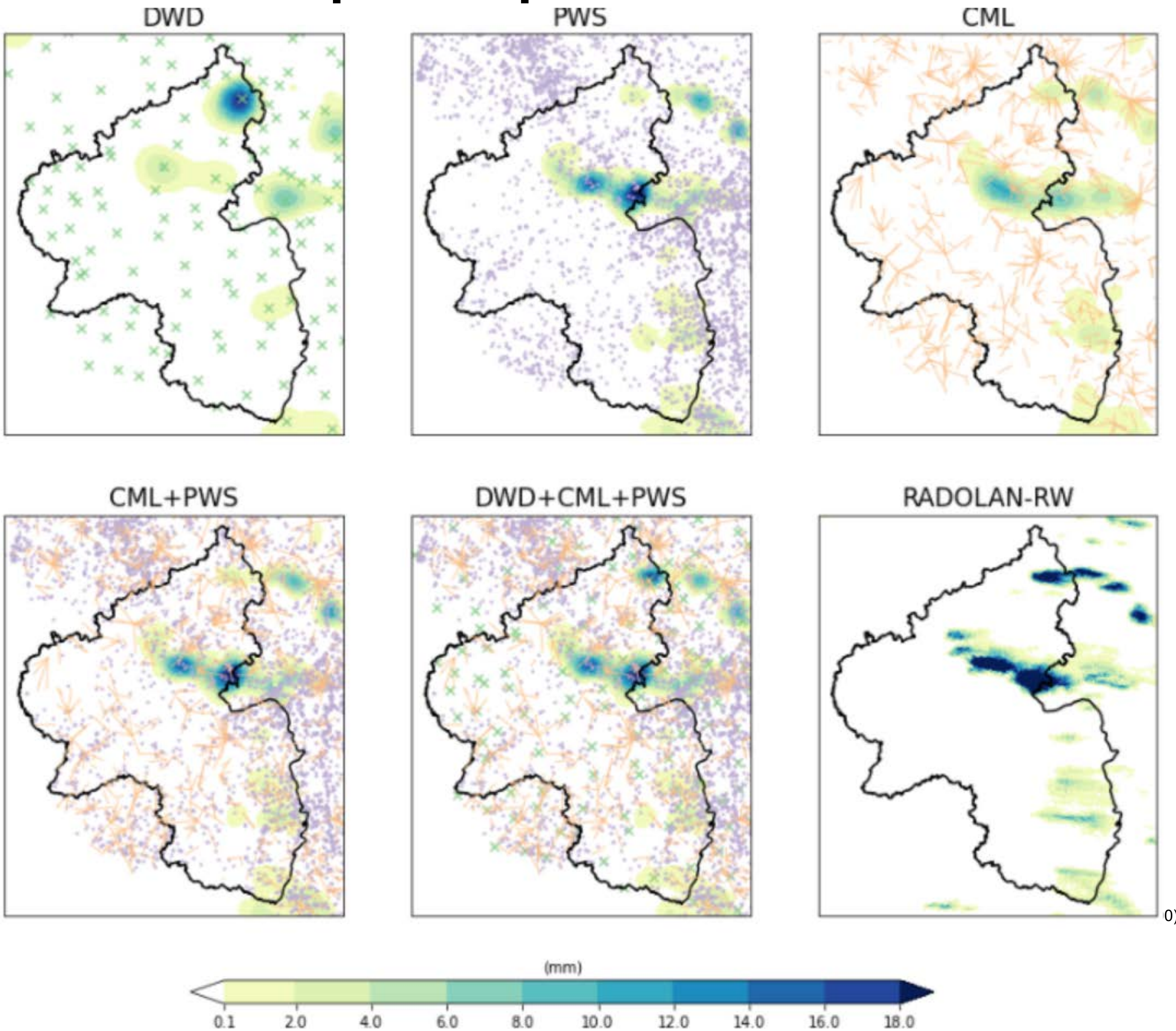
performance of interpolated products compared to 10 hourly rain gauges operated by the Municipality Reutlingen (RT)



- with sparse spatial coverage (no gauge in the Figure), interpolated DWD gauges perform worse than OS for this local example
- OS an combinations are able to hold up and even outperform radar products, while PWS have better correlation, CML improve the bias
- the highest events are all captured but underestimated by

PCC: Pearson's Correlation Coefficient
KGE: Kling Gupta Efficiency
FPR: False Positive Rate
RADOLAN-RW/RADKLIM-YW: radar products from DWD

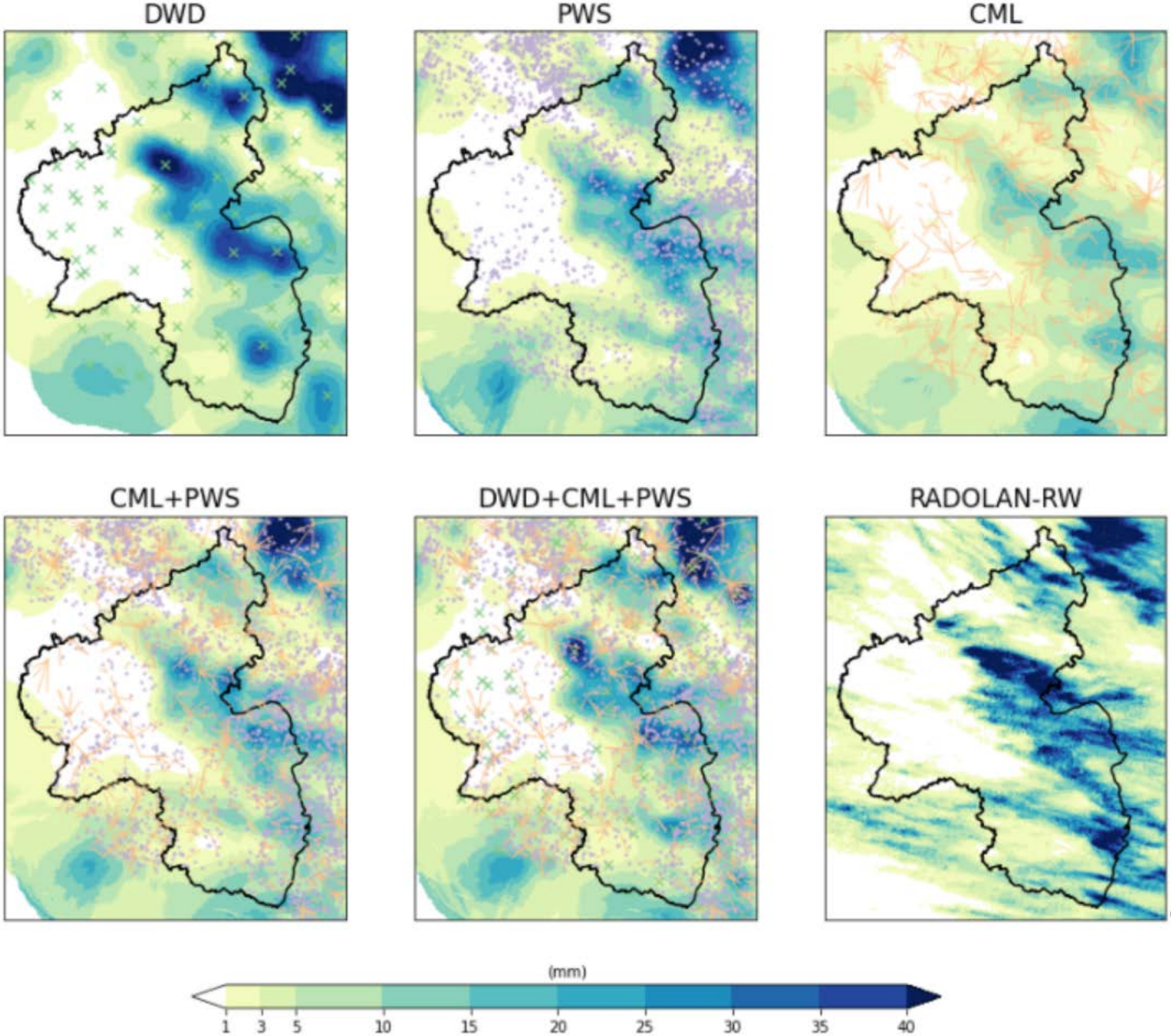
Rainfall map example for one hour



Traditional gauge networks are sparse and rainfall fields influenced by the network layout

OS can can better capture local rainfall structure

Rainfall map example for one day



OS networks have irregular coverage

but still can help refine rain events spatially

Conclusion

Goal

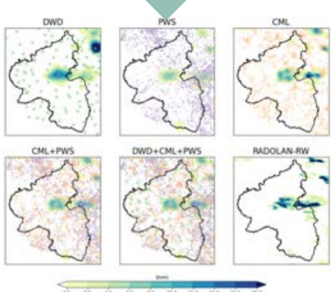
- Estimation of rainfall in Germany with opportunistic sensors

Challenge

- opportunistic sensors need extra care during quality control and processing

Results

- opportunistic sensors can improve rainfall estimates



Outlook

- use high temporal resolution (5 minutes) of OS
- refine filtering routines
- use OS derived rainfall estimates for hydrological modelling

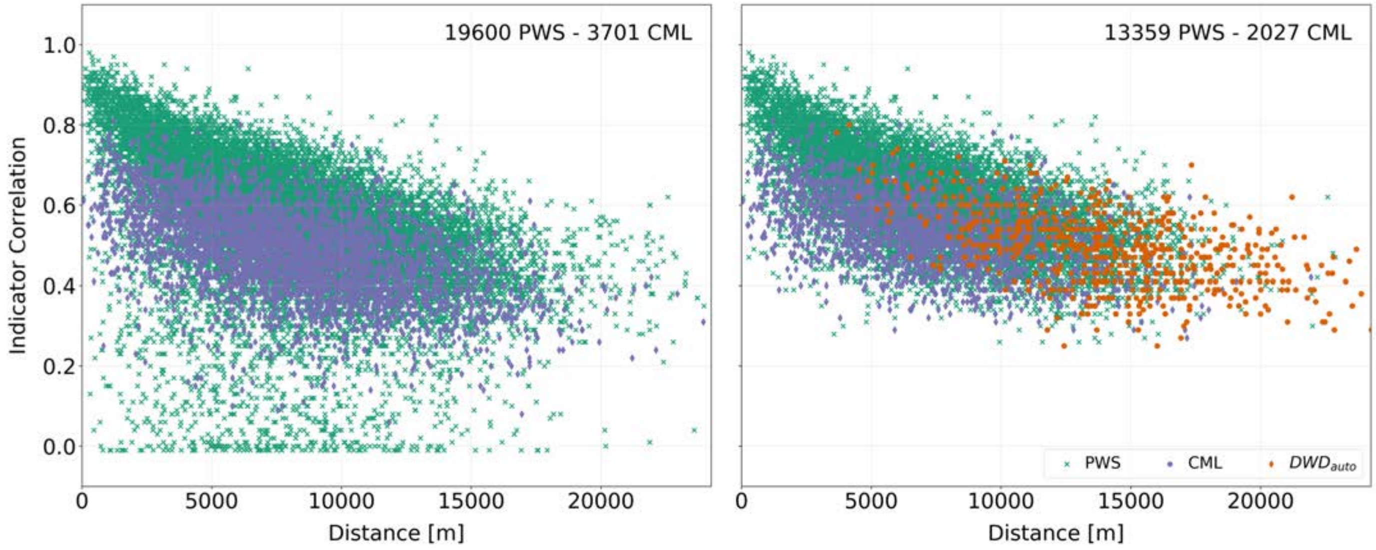
Acknowledgments

We want to thank Ericsson Germany, in particular the IT team ,for their support with the CML data acquisition

and HGF, DFG and BMBF for funding and support of our research.

Indicator correlation filter

indicator correlation (IC): rank correlation of individual PWS, CMLs or DWD_{auto} to their next neighbors



PWS and CML are removed when their IC is lower then the IC with the next DWD_{auto} station

Interpolation Framework: (Block-) Kriging

Include uncertainty of opportunistic sensors

$$Z(x^*) = \sum_{i=1}^{n} \lambda_i Z(x_i) + \sum_{i=1}^{m} \alpha_i Z(y_i) + \sum_{i=1}^{k} \beta_i Z(L_i)$$

DWD_{auto} PWS CML

$$\sum_{i=1}^{n} \lambda_i + \sum_{i=1}^{m} \alpha_i + \sum_{i=1}^{k} \beta_i = 1$$

Account for line characteristic of CMLs

$$\bar{\gamma}(x_i, L_j) = \frac{1}{|L_j|} \int_{L_j} \gamma(x_i, u)\, du$$

$$\bar{\gamma}(L_i, L_j) = \frac{1}{|L_i||L_j|} \int_{L_i} \int_{L_j} \gamma(u, v)\, du\, dv$$

abbreviation	input data
DWD_{int}	DWD_{auto}
PWS_{int}	PWS
CML_{int}	CML
DWD_CML_{int}	DWD_{auto}, CML
DWD_PWS_{int}	DWD_{auto}, PWS
PWS_CML_{int}	PWS, CML
$DWD\_PWS\_CML_{int}$	DWD_{auto}, PWS, CML