Improving Radar QPE with CMLs

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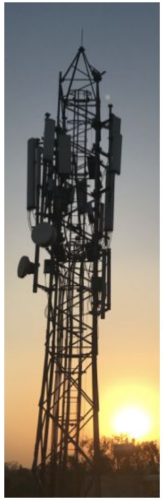
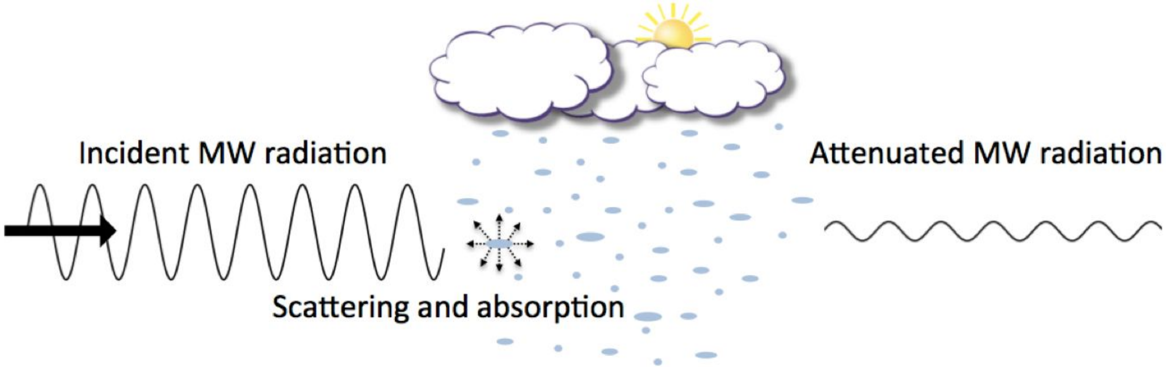
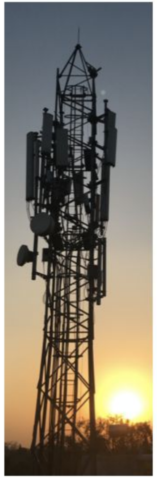
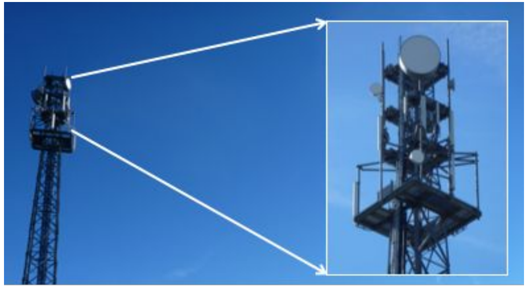
Commercial Microwave Links

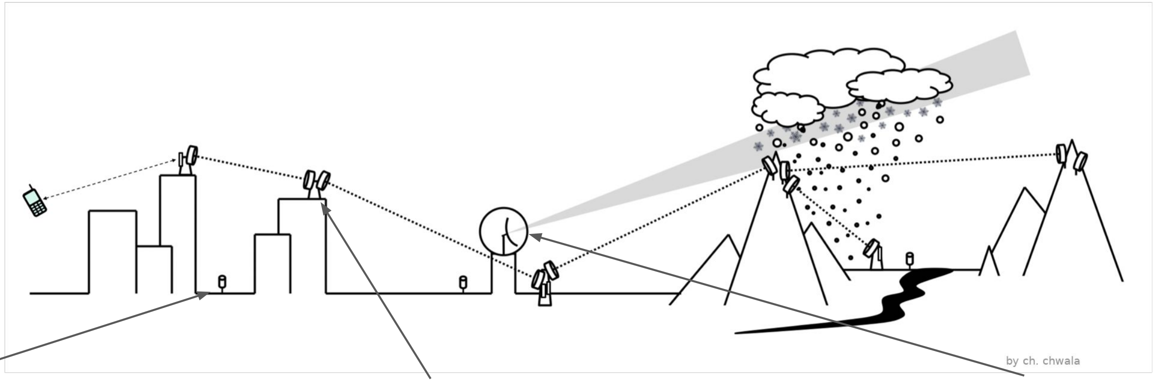








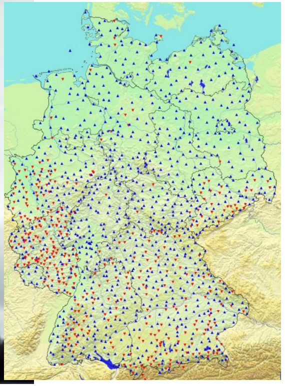
Rainfall estimation in Germany



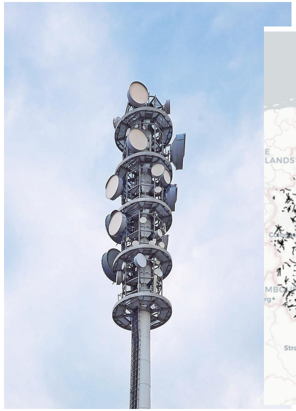
Rain Gauge

Commercial microwave link (CML)

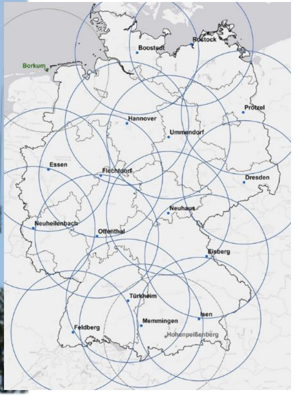
Weather radar



Source: DWD



Source: C. Ruf, KIT



Source: DWD

Topics

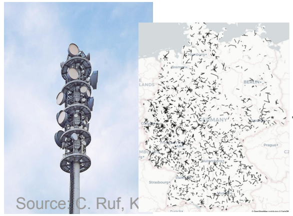
- RealPEP P1 Roadmap
- Updates from the CML data acquisition at DWD
- Collection of rainfall data for upcoming studies
- Deep learning based correction of radar QPE
- High resolution rainfall maps for West Africa

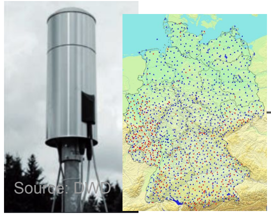
P1 Roadmap

5 minute

Polarimetric retrieval

WP2+3





Intercomparison

WP1

P1 Roadmap

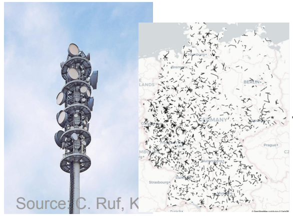
5 minute

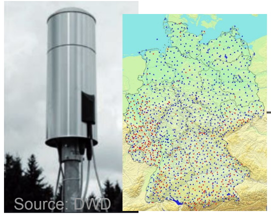
1 minute

Optical flow estimation to compute intermediate timesteps

Polarimetric retrieval

WP2+3



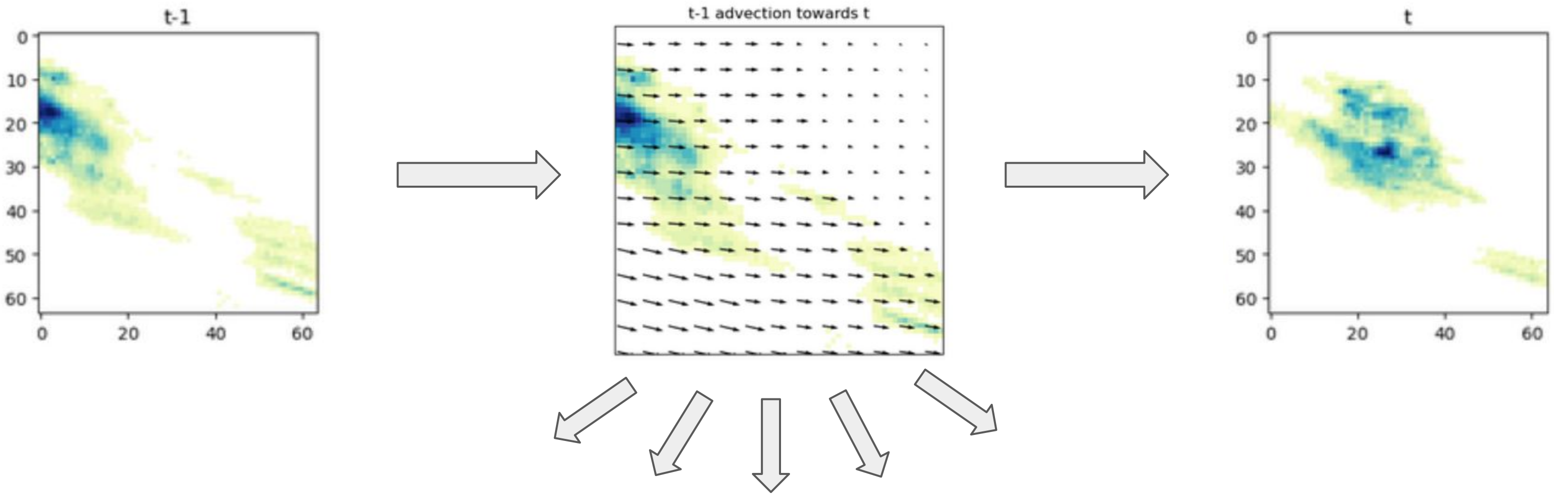


Intercomparison

WP1

Advection correction: The concept

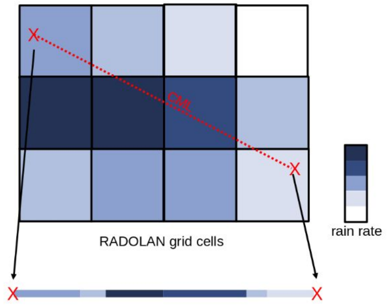
Estimated optical flow by Lucas-Kanade method (from PySTEPS)



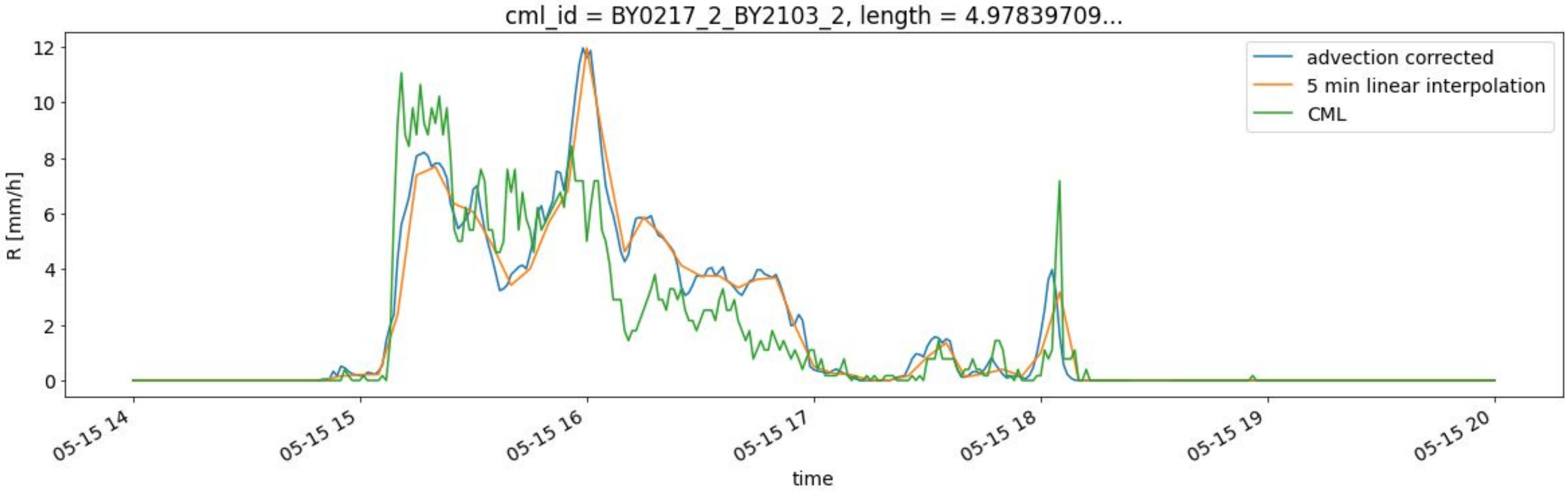
Intermediate timesteps by constant flow
(morphed QPE)

Advection correction by temporal aggregation

Advection correction: **1 minute radar along CML**



Path averaged rain rate by weighted length of intersects



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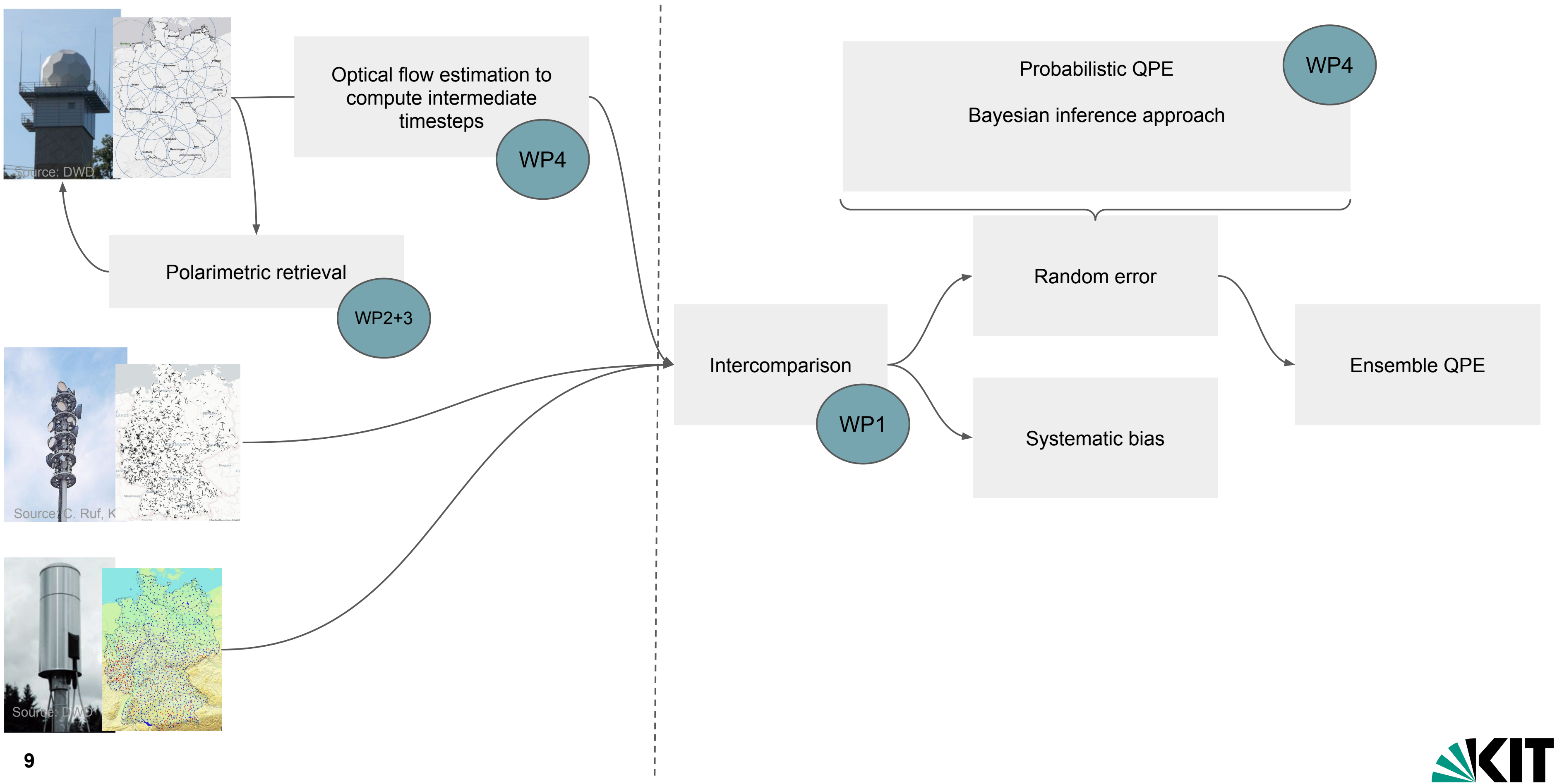
1 minute



P1 Roadmap

5 minute

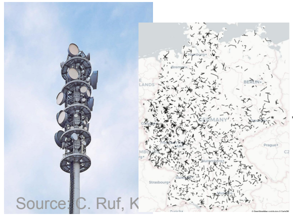
1 minute

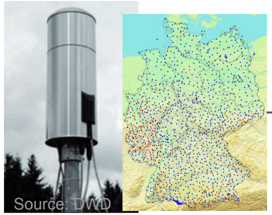
Optical flow estimation to compute intermediate timesteps

WP4

Polarimetric retrieval

WP2+3





Intercomparison

WP1

Probabilistic QPE

Bayesian inference approach

WP4

Random error

Systematic bias

Ensemble QPE

Error sources of radar QPE
(according to Villarini and Krajewski 2010)

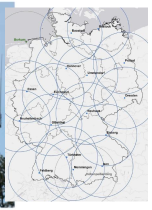
Miscalibration

Ground clutter / Anomalous Propagation

Range degradation

classical correction schemes

Error sources of radar QPE
(according to Villarini and Krajewski 2010)



Miscalibration

Ground clutter / Anomalous Propagation

Range degradation

classical correction schemes

(Partial) beam blockage

Attenuation

Choice of Z-R / DSD variability

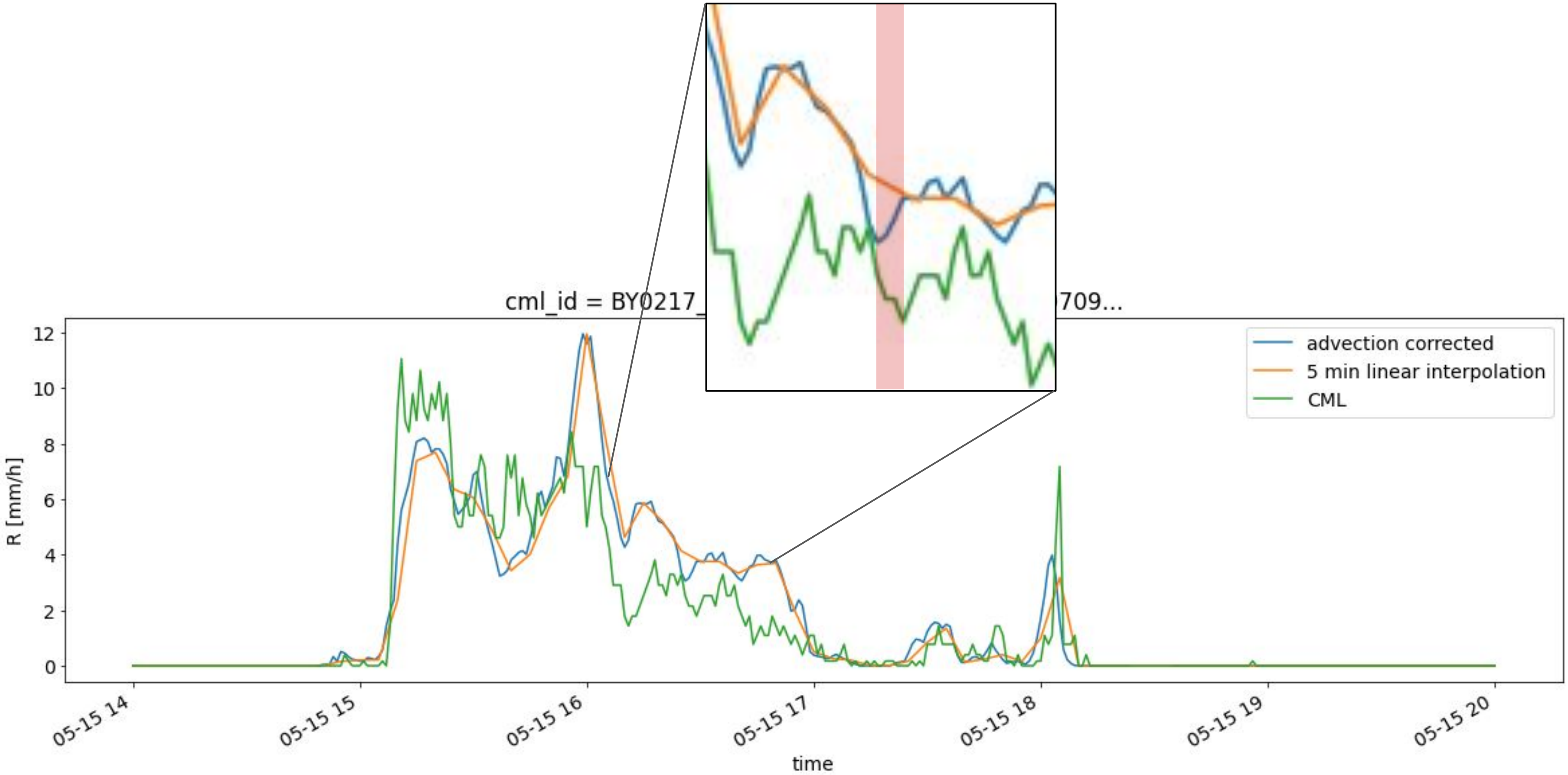
Polarimetry

Error sources of radar QPE
(according to Villarini and Krajewski 2010)

“Spatio-temporal mismatch”

Miscalibration	(Partial) beam blockage	Vertical variability
Ground clutter / Anomalous Propagation	Attenuation	Air motion / Drift
Range degradation	Choice of Z-R / DSD variability	Temporal sampling error
⇩	⇩	⇩
classical correction schemes	Polarimetry	Merging with ground sensors

Advection correction: **1 minute radar along CML**



P1 Roadmap

5 minute

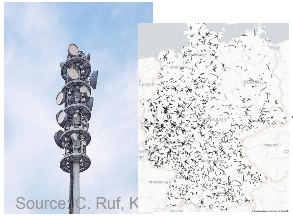
1 minute

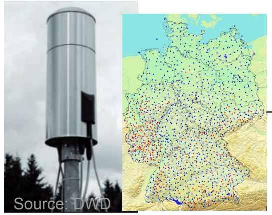
Optical flow estimation to compute intermediate timesteps

WP4

Polarimetric retrieval

WP2+3





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Spatio-temporal mismatch

WP5

Estimation

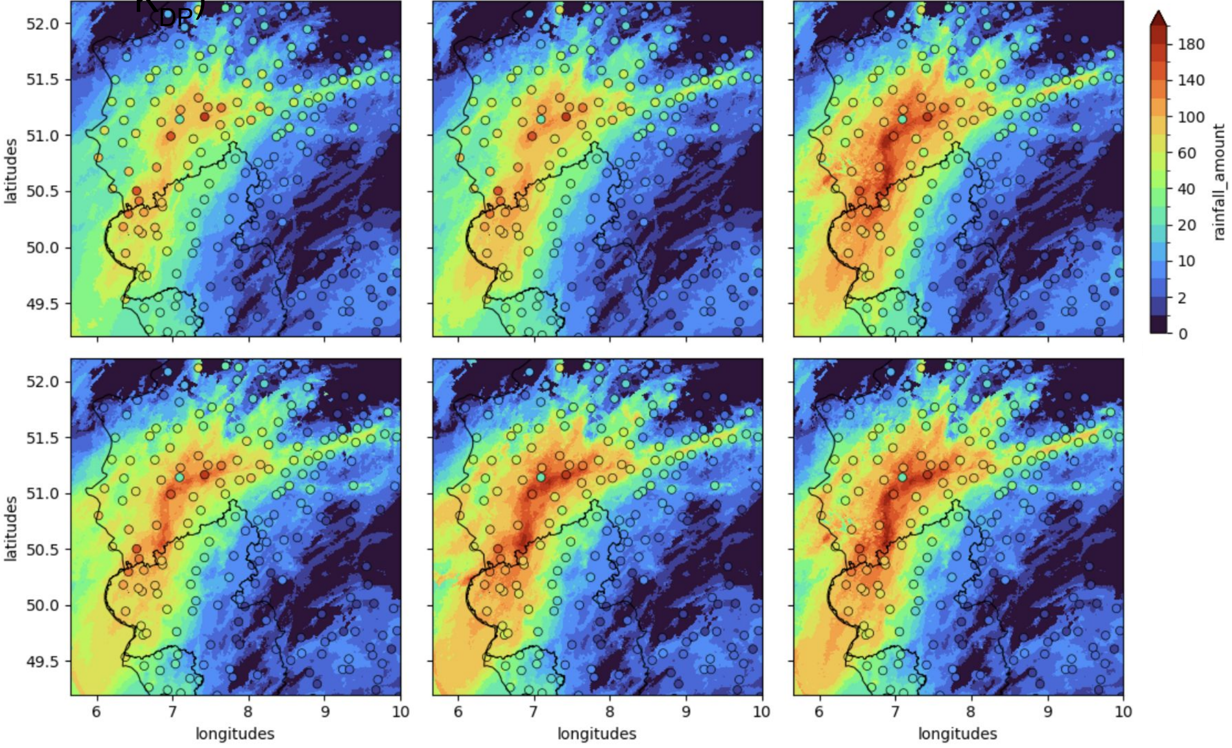
Correction

Merging Radar and CML

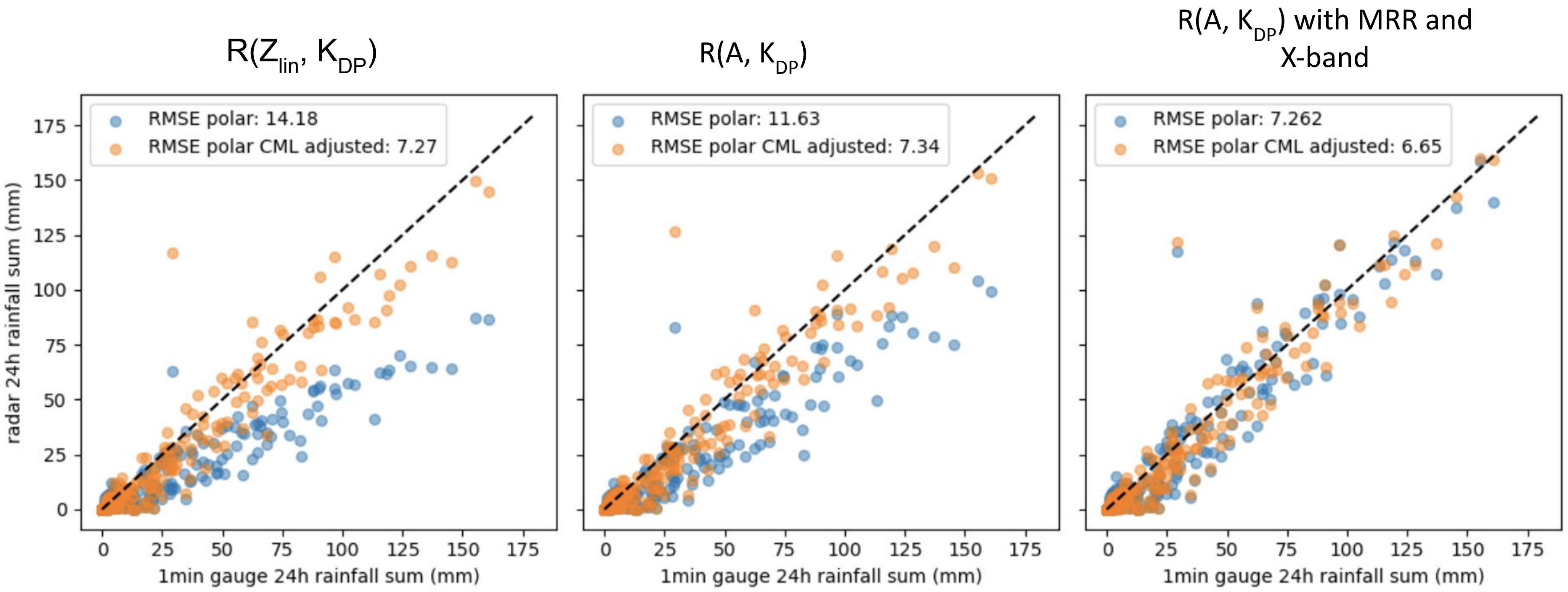
$R(Z_{lin}, K_{DP})$ | $R(A, K_{DP})$ | $R(A, K_{DP})$ with MRR and X-band

not adjusted

CML adjusted



Merging Radar and CML



Current	+1 Step	+2 Step
Simple merging of pol. Radar and CML		
Correction of sampling error for 5 min radar data		

Current	+1 Step	+2 Step
Simple merging of pol. Radar and CML	Probabilistic Radar QPE using error with respect to CML and Gauge	
Correction of sampling error for 5 min radar data	Large scale comparison of 1 min data →years for R(Z) →months for R(A, K_{DP})	

Current	+1 Step	+2 Step
Simple merging of pol. Radar and CML	Probabilistic Radar QPE using error with respect to CML and Gauge	Probabilistic merging of pol. Radar, CML and Gauges
Correction of sampling error for 5 min radar data	Large scale comparison of 1 min data →years for $R(Z)$ →months for $R(A, K_{DP})$	Quantification and correction of spatio temporal mismatch

KIT

Current	+1 Step	+2 Step
Simple merging of pol. Radar and CML	Probabilistic Radar QPE using error with respect to CML and Gauge	Probabilistic merging of pol. Radar, CML and Gauges
Correction of sampling error for 5 min radar data	Large scale comparison of 1 min data →years for R(Z) →months for $R(A, K_{DP})$	Quantification and correction of spatio temporal mismatch

Now, really and if necessary using R(Z) products first

CML DAQ @ DWD

CML DAQ @ DWD

Fact:

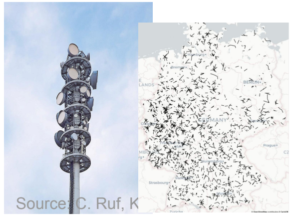
- “operational” real-time data acquisition with a 2 min latency
- >5000 unique paths
- 10s temporal resolution → reduction of uncertainty due to instantaneous sampling
- Hourly R(CML) and R(Z)+R(CML) product using RADOLAN adjustment at 5 min latency

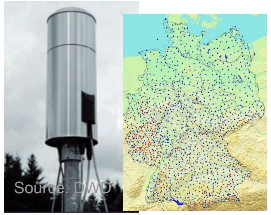
Fiction:

- Potential water vapor estimation at E-band (maybe no E-band, maybe incorrect metadata)

Current data collection at KIT

Current data collection at KIT





- RADOLAN-RY
  - 2001 until today
  - R(Z)
  - 5 min resolution
- RADOLAN-RW
  - 2001 until today
  - R(Z) gauge adjusted
  - 1H resolution
- RADKLIM-YW
  - 2006 until today
  - R(Z) gauge and clim adjusted
  - 5 min resolution

- CML 2017 until today
  - 3900 sensors
  - 1 min resolution
- CML 2023 until today
  - >5000 sensors
  - 10 s resolution

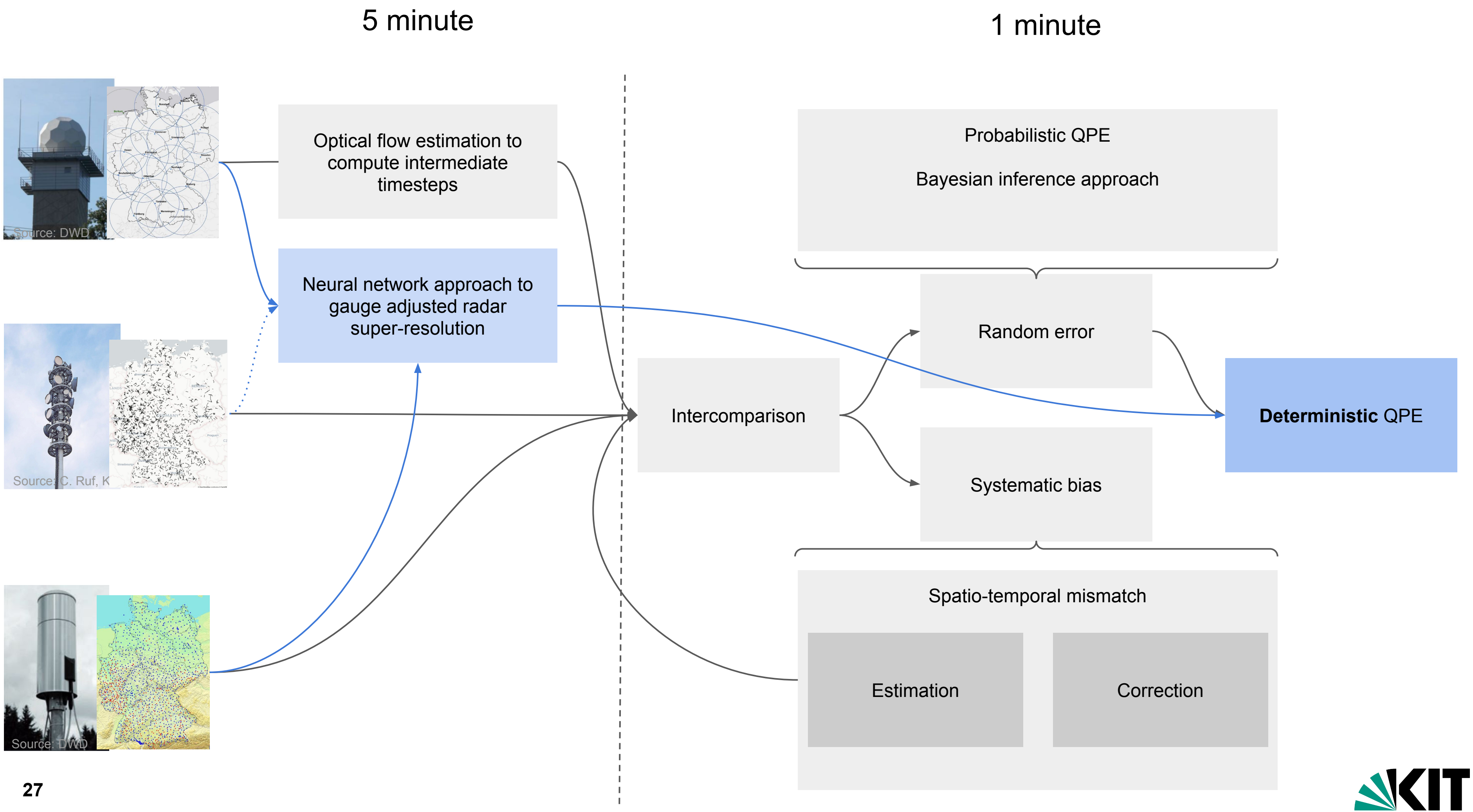
- Automatic
  - from 2007
  - ~1000 rain gauges
  - 1 min resolution
- Manual
  - from 1900 to today
  - ~1000 (year >2010)
  - daily resolution

Deep learning based correction of radar QPE

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING

Temporal Super-Resolution, Ground Adjustment and Advection Correction of Radar Rainfall using 3D-Convolutional Neural Networks

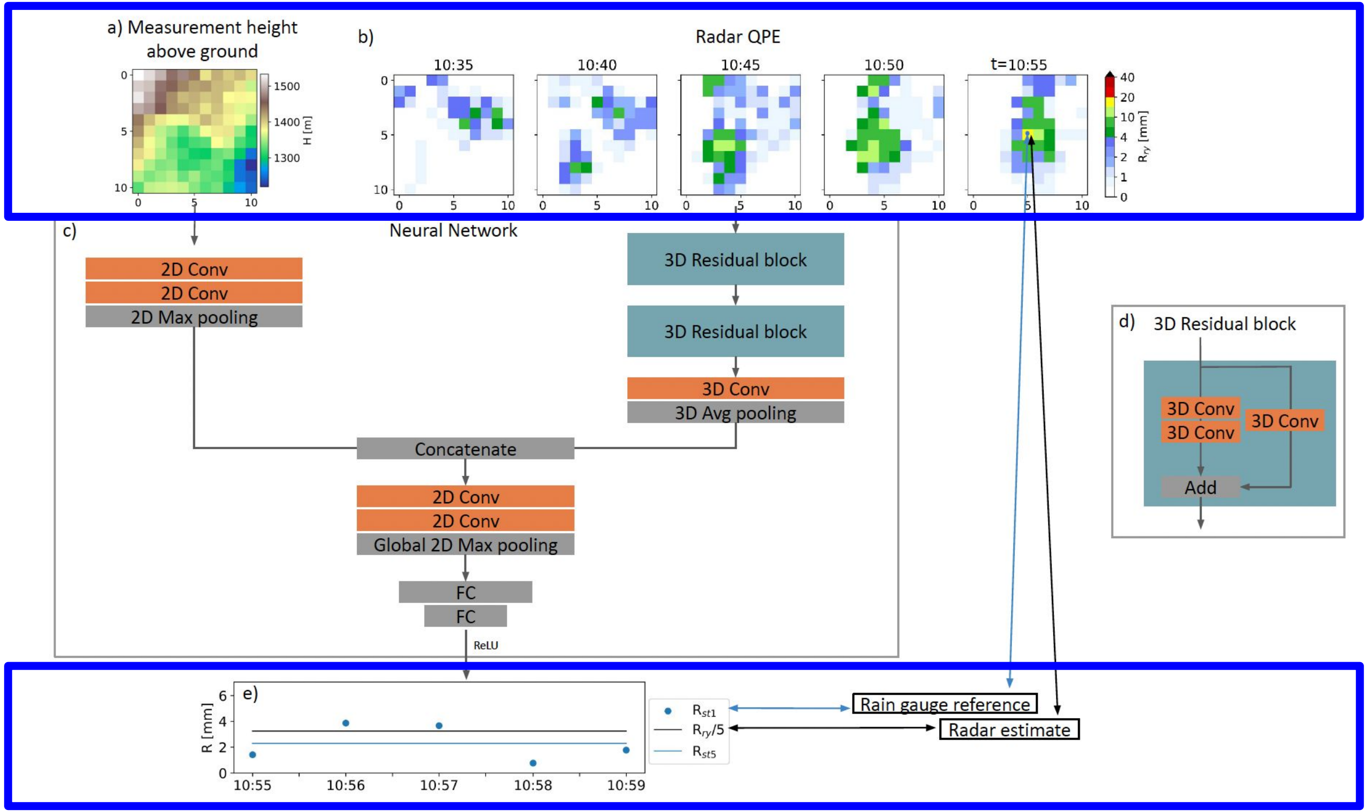
Julius Polz, Luca Glawion, Hiob Gebisso, Lukas Altenstrasser, Maximilian Graf, Harald Kunstmann, Stefanie Vogl, and Christian Chwala


5 minute
1 minute
Source: DWD
Optical flow estimation to compute intermediate timesteps
Neural network approach to gauge adjusted radar super-resolution
Source: C. Ruf, K
Source: DWD
Probabilistic QPE
Bayesian inference approach
Random error
Intercomparison
Deterministic QPE
Systematic bias
Spatio-temporal mismatch
Estimation
Correction

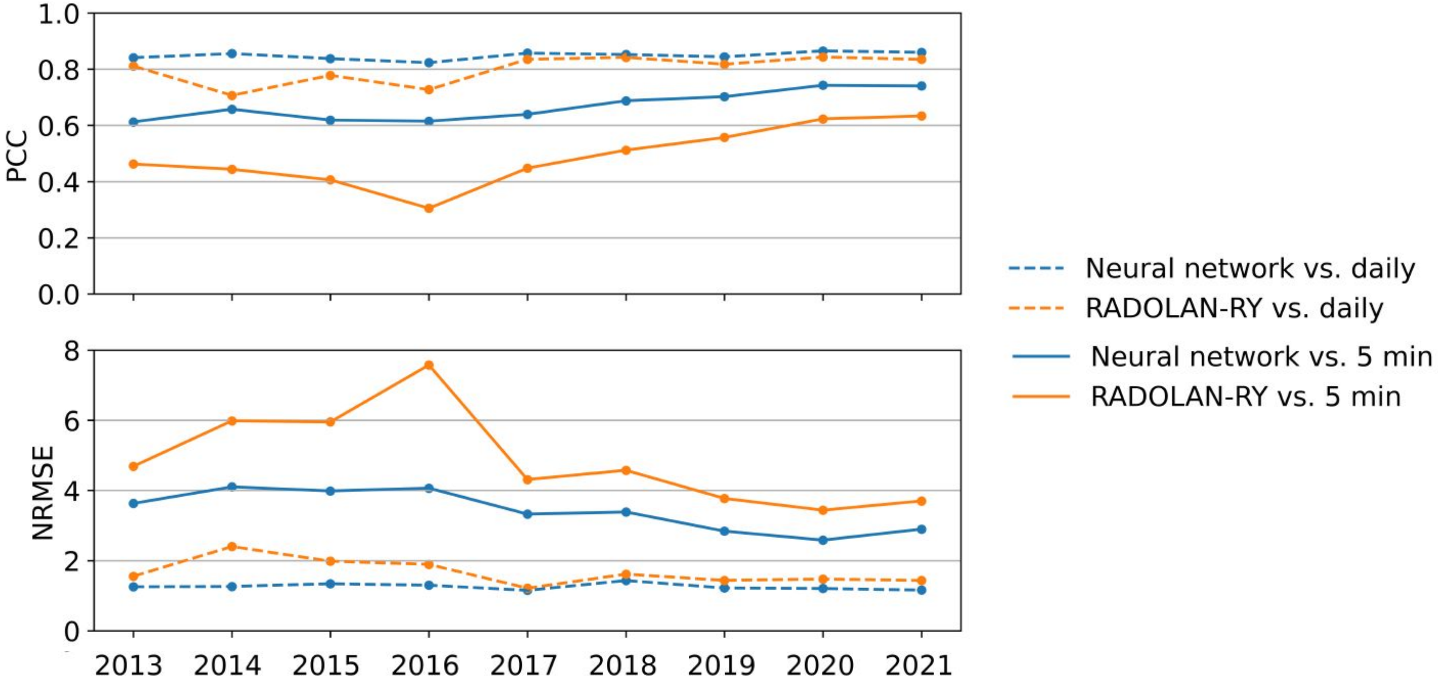
ResRadNet

Input

Output

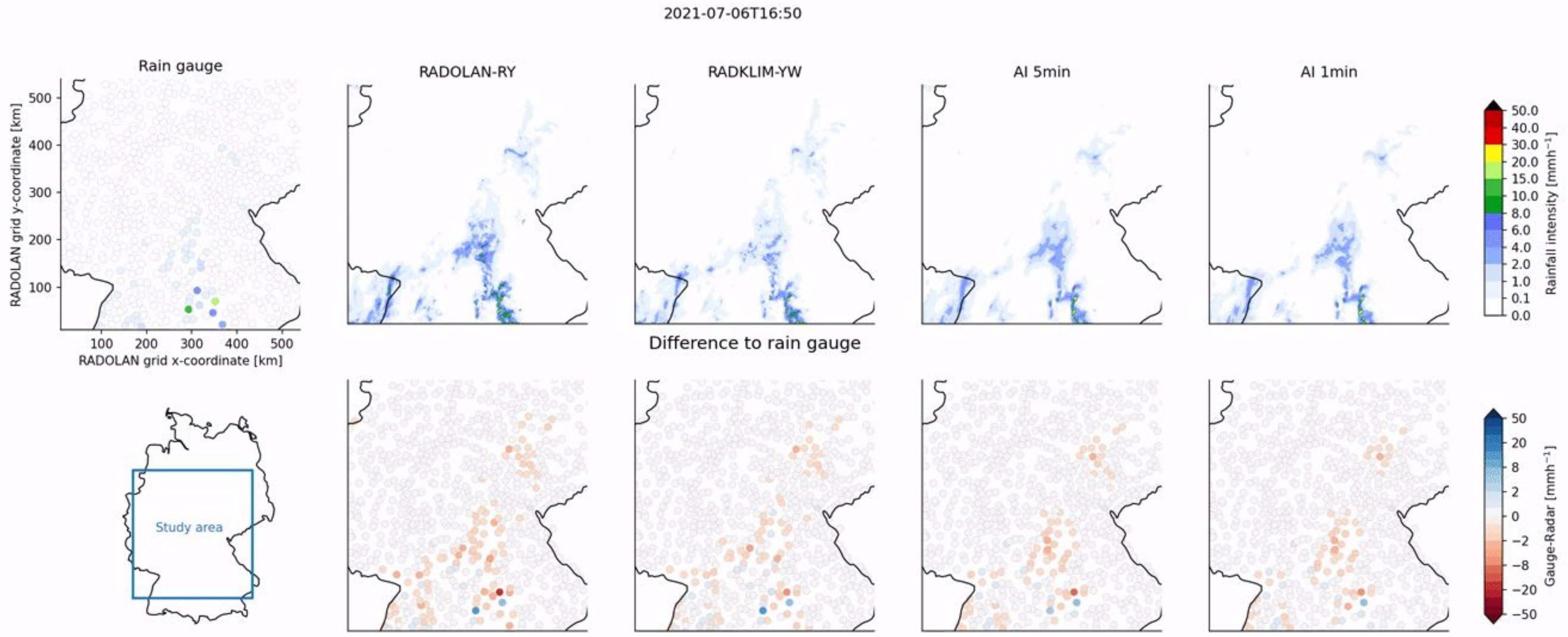


ResRadNet



PCC
1.0
0.8
0.6
0.4
0.2
0.0
NRMSE
8
6
4
2
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
Neural network vs. daily
RADOLAN-RY vs. daily
Neural network vs. 5 min
RADOLAN-RY vs. 5 min

ResRadNet



Proof: High potential to reduce overall error including sampling error

Low hanging fruit: Test deep learning based polarimetric retrieval

1 year of training data enough
→ Test with 3 months used in RealPEP
→ Repeat using polarimetric QPE (post-processing)
→ Repeat using polarimetric observables (full retrieval)

Why? → The full processing pipeline exists and only the input changes. Very low effort!
Why not? →

High resolution rainfall maps for West Africa

Journal of Hydrometeorology

Article Type: Research Article

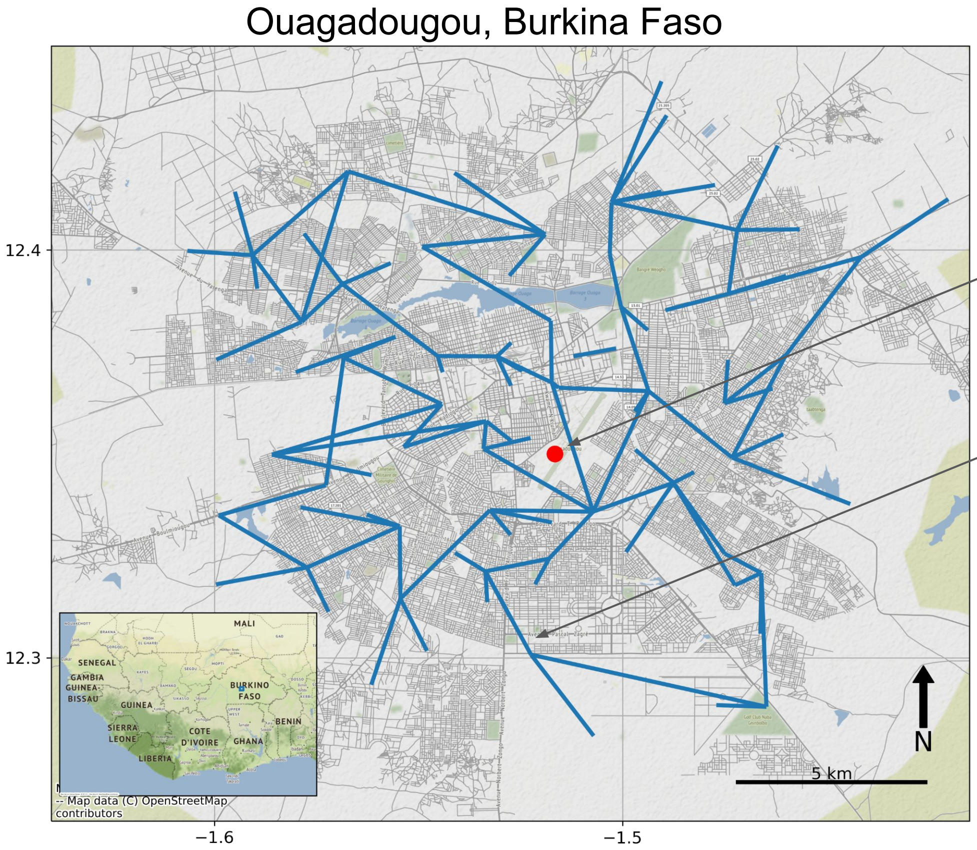
High-resolution rainfall maps from commercial microwave links for a data-scarce region in West Africa

Moumouni Djibo, Christian Chwala, Maximilian Graf, Julius Polz, Harald Kunstmann, and François Zougmoré

Online Publication: 09 Aug 2023

DOI: https://doi.org/10.1175/JHM-D-23-0015.1

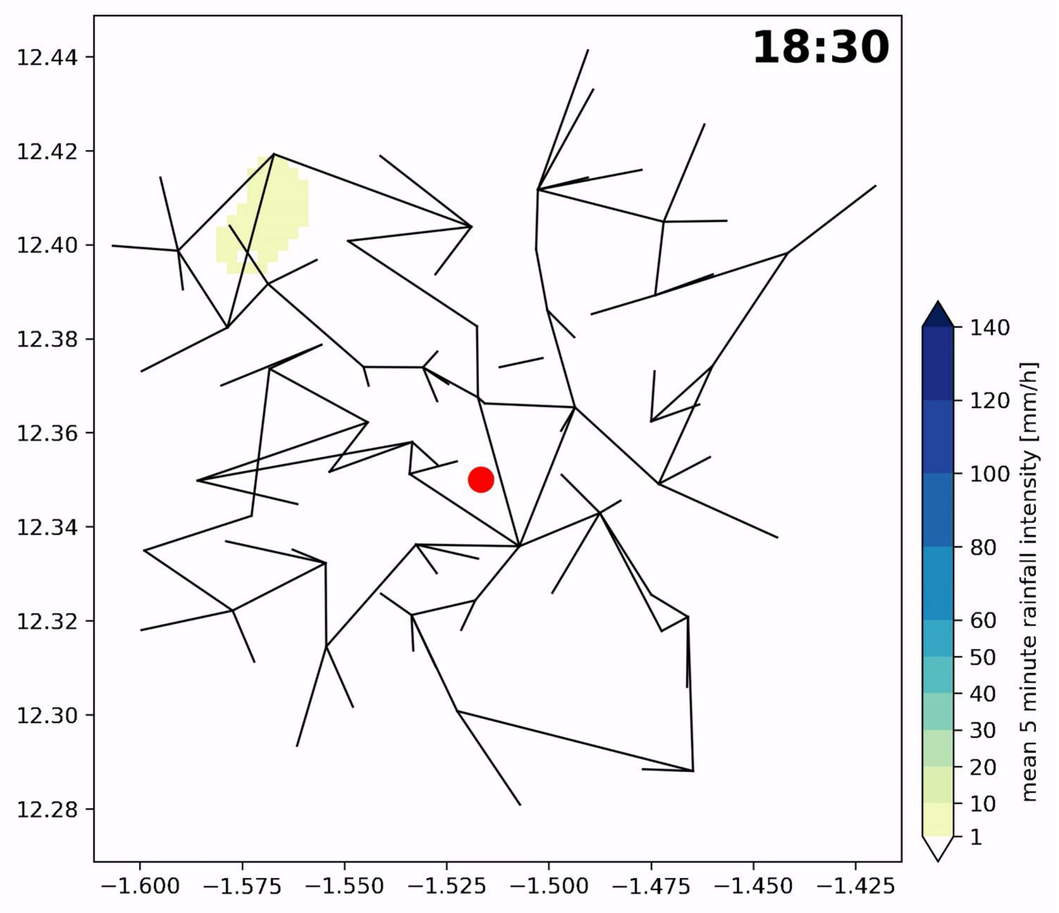
High resolution rainfall maps for West Africa



Only one available rain gauge with daily resolution

Dense CML network

High resolution rainfall maps for West Africa



Thank you!

Questions?