OpenSense

Opportunistic Precipitation Sensing Network

CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

One man's noise is another man's signal the OpenSense project

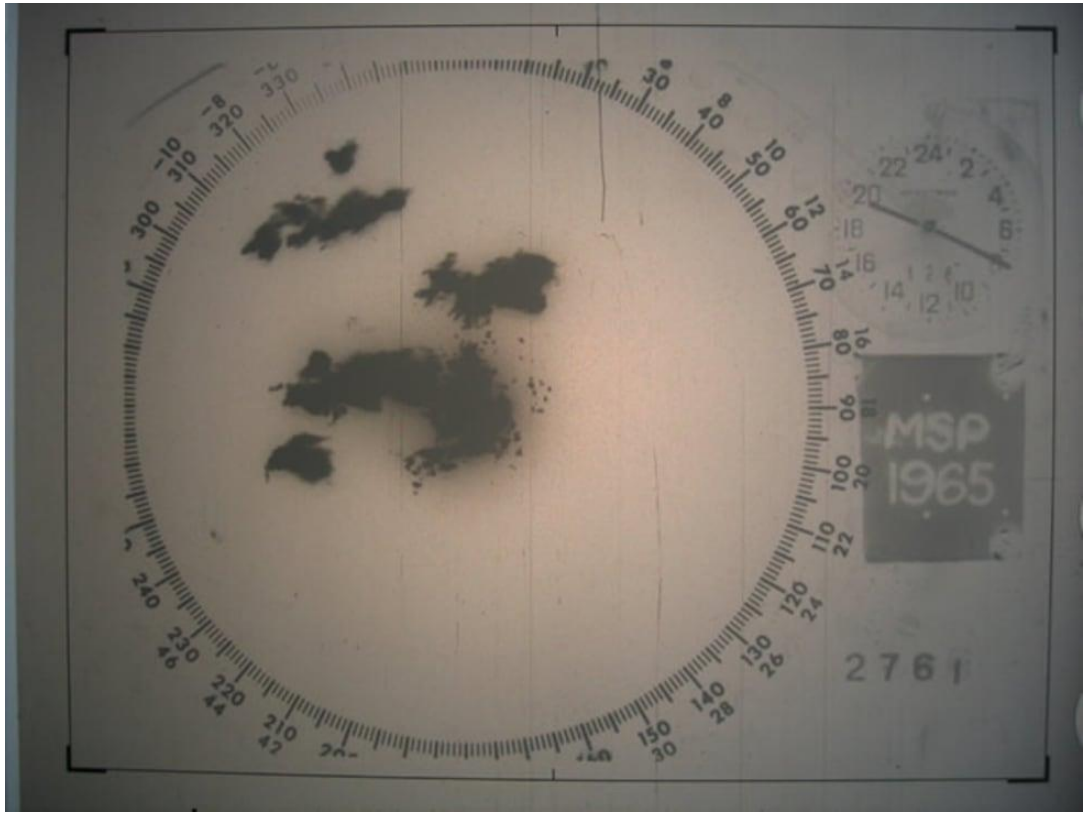
Vojtěch Bareš, Christian Chwala, Martin Fencl, Hagit Messer, Jonathan Ostrometzky, Remko Uijlenhoet, Aart Overeem, Remco van de Beek, Jonas Olsson, Maxmilian Graf, Tanja Winterrath, Soeren Thorndahl, Jochen Seidel, Roberto Nebuloni, and Natalia Hanna

Funded by the European Union

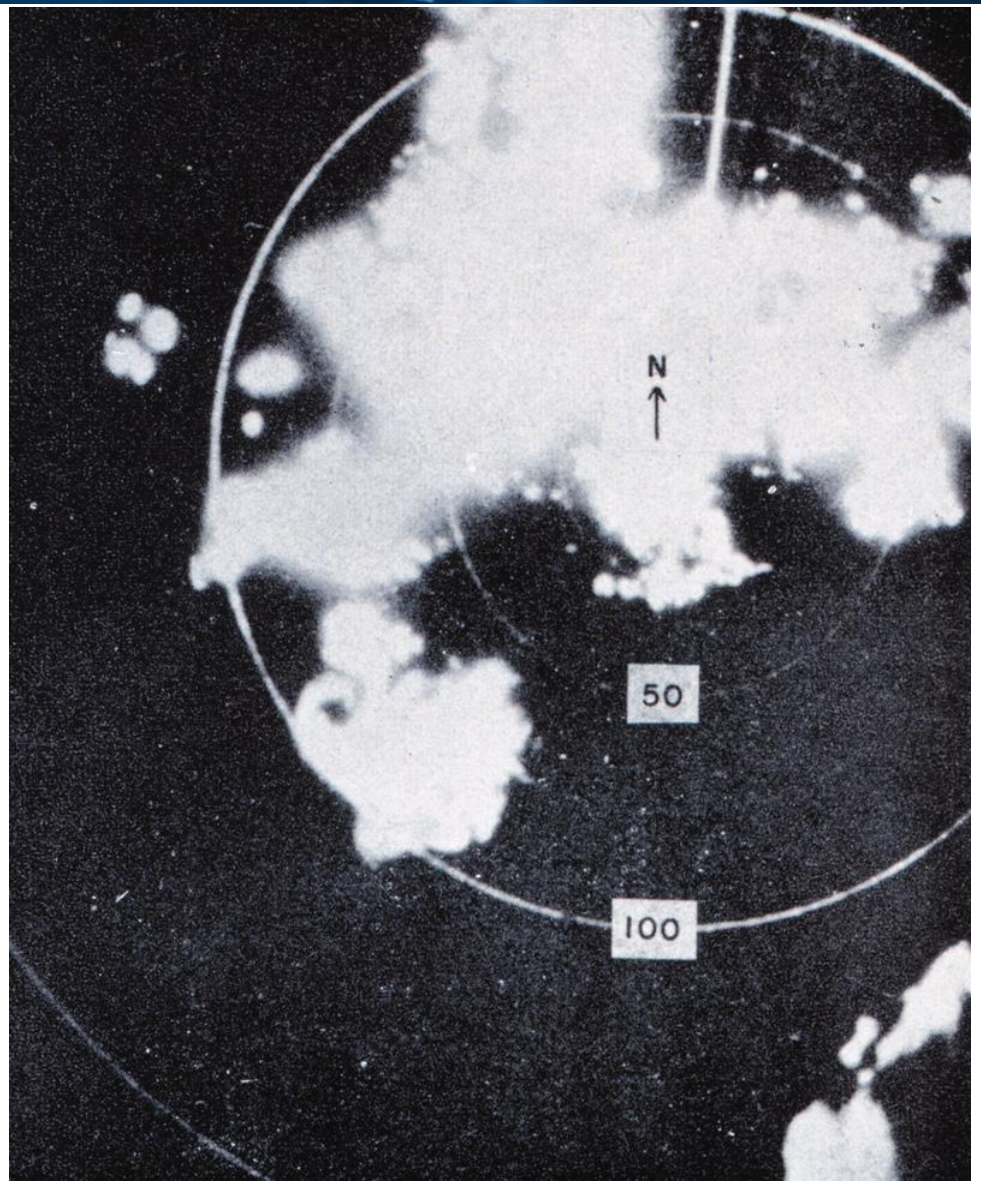
EGU2025, HS7.6 Precipitation and Urban Hydrology

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

One man's noise is another man's signal



(NOAA)



„It is commonly assumed that weather radar was a byproduct of military necessity in World War II“

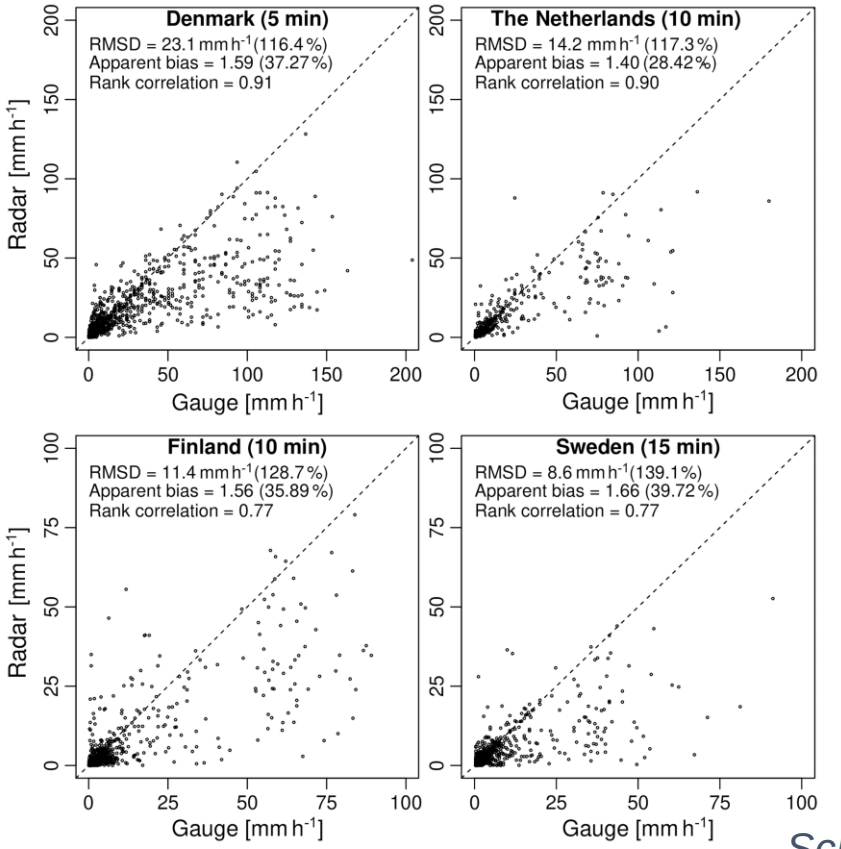
Urban catchments - heavy rainfalls - observations

- Despite the advances in weather radar technologies and merging techniques, accurate estimation of precipitation is a remaining challenge
  - Especially for convective rainfalls

Urban catchments - heavy rainfalls - observations

- Despite the advances in weather radar technologies and merging techniques, accurate estimation of precipitation is a remaining challenge
  - Especially for convective rainfalls

- Deficits are pronounced in:
  - urban hydrology with high demands on spatial-temporal resolution



Discrepancies between biased corrected radar and RG observations

Schleiss et al, 2019, HESS

Urban catchments - heavy rainfalls - observations

- Deficits are pronounced in:
  - urban hydrology with high demands on spatial-temporal resolution
  - low-income countries with missing monitoring infrastructure

Saltikoff et al., 2019, BAMS

- Despite the advances in weather radar technologies and merging techniques, accurate estimation of precipitation is a remaining challenge
  - Especially for convective rainfalls

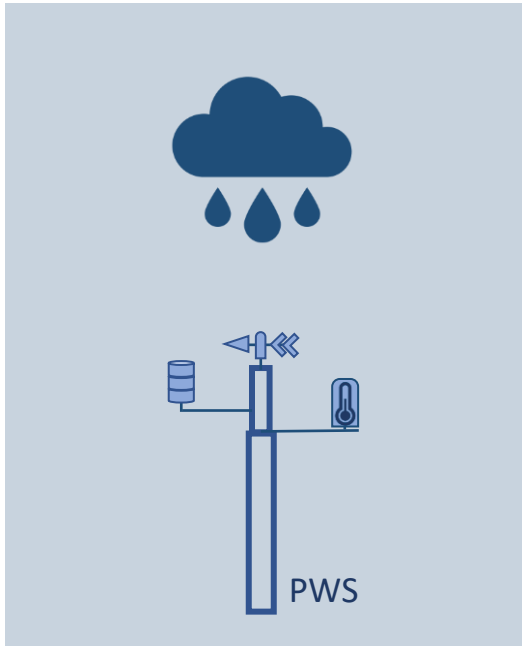
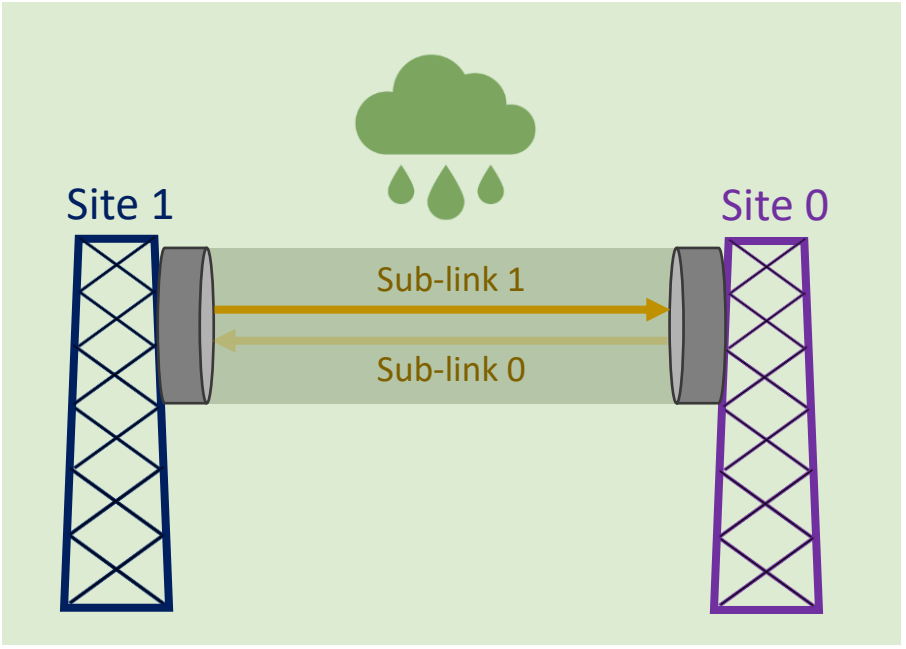
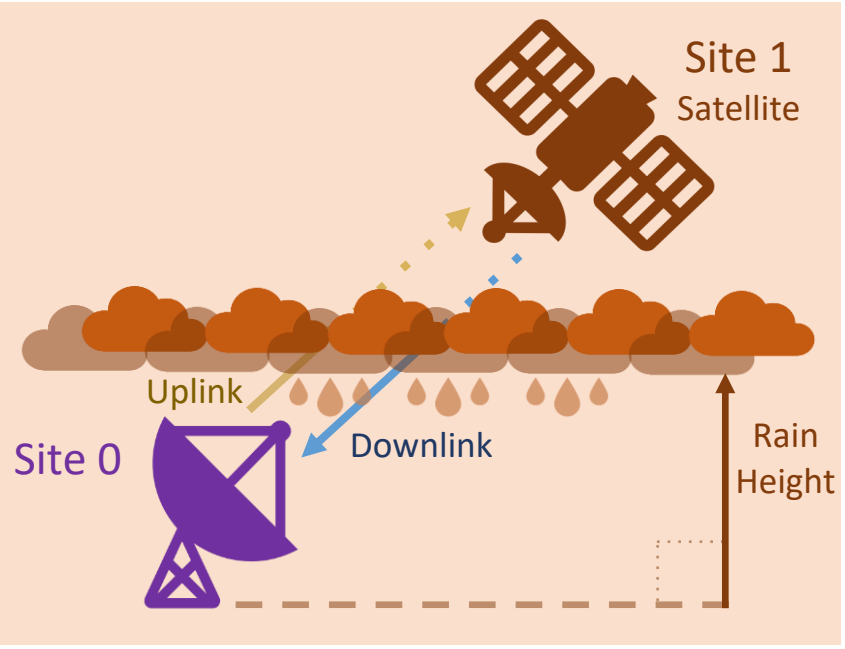
Urban catchments - heavy rainfalls - observations

New rainfall opportunistic data sensors which

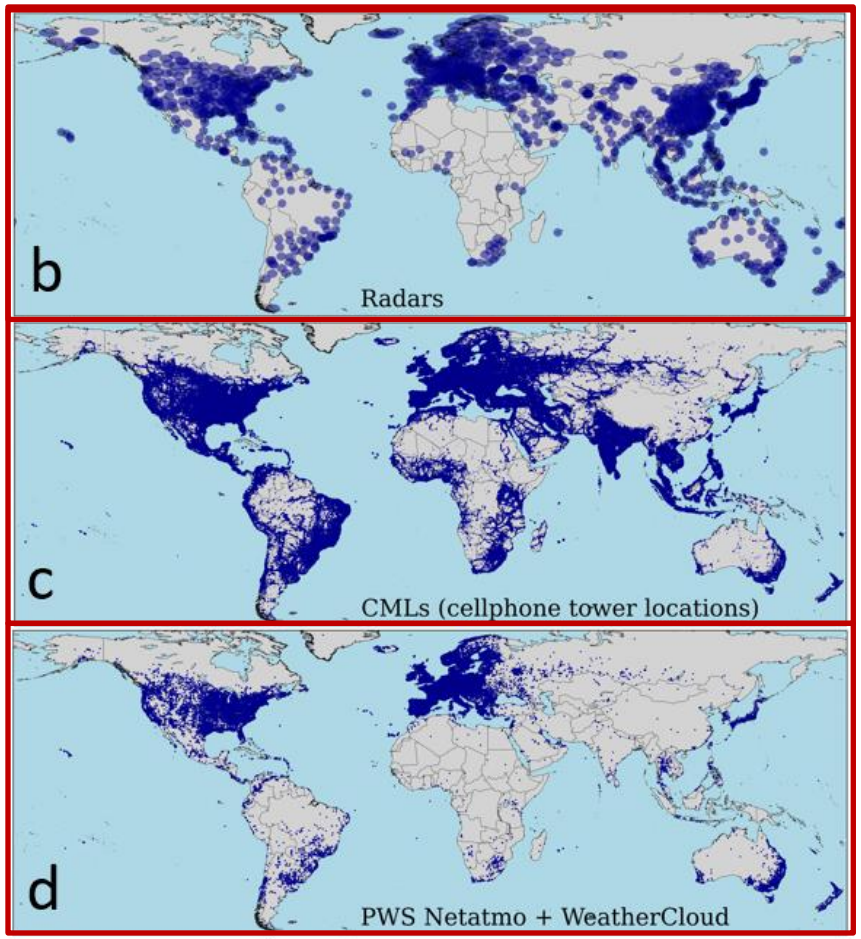
- are sensitive to rainfall
- provide near-ground observations
- have high spatial density
- are accessible in near-real time

Opportunistic rainfall sensors of interest

"Sensors or devices that were not designed/installed for the purpose of large-scale rainfall monitoring but can be used for"

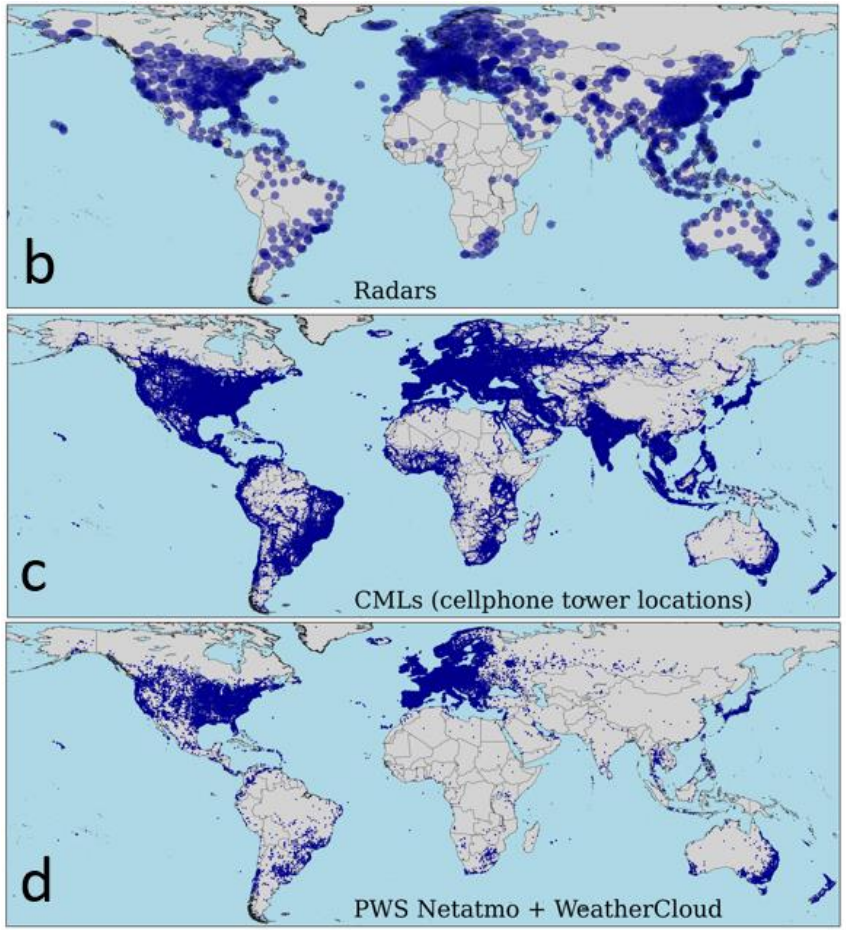
	Personal weather stations	Commercial microwave links	Satellite microwave links
			
Method	Volumetric measurement	MW attenuation - rainfall	MW attenuation - rainfall
Dimension	Point	Horizontal path average	Inclined path average

Spatial coverage global

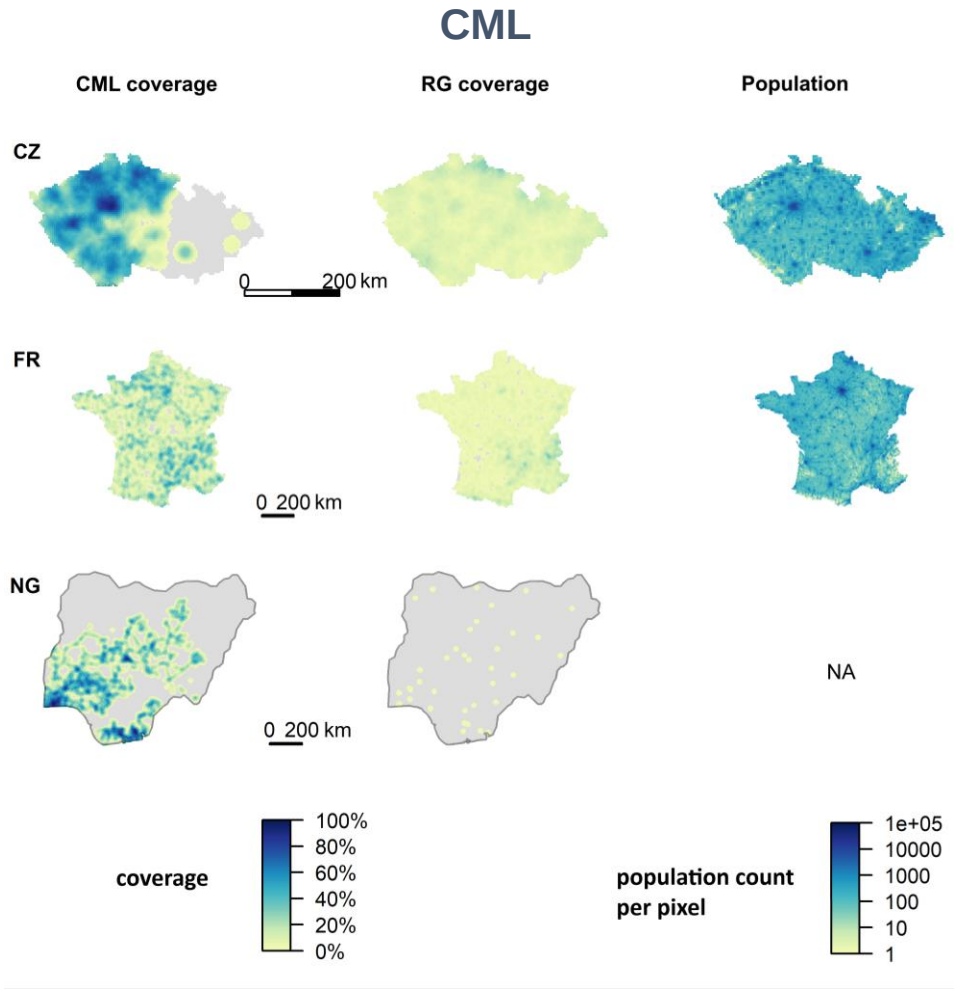


Olsson et al, 2025, AR, in review

Spatial coverage country-wide CML

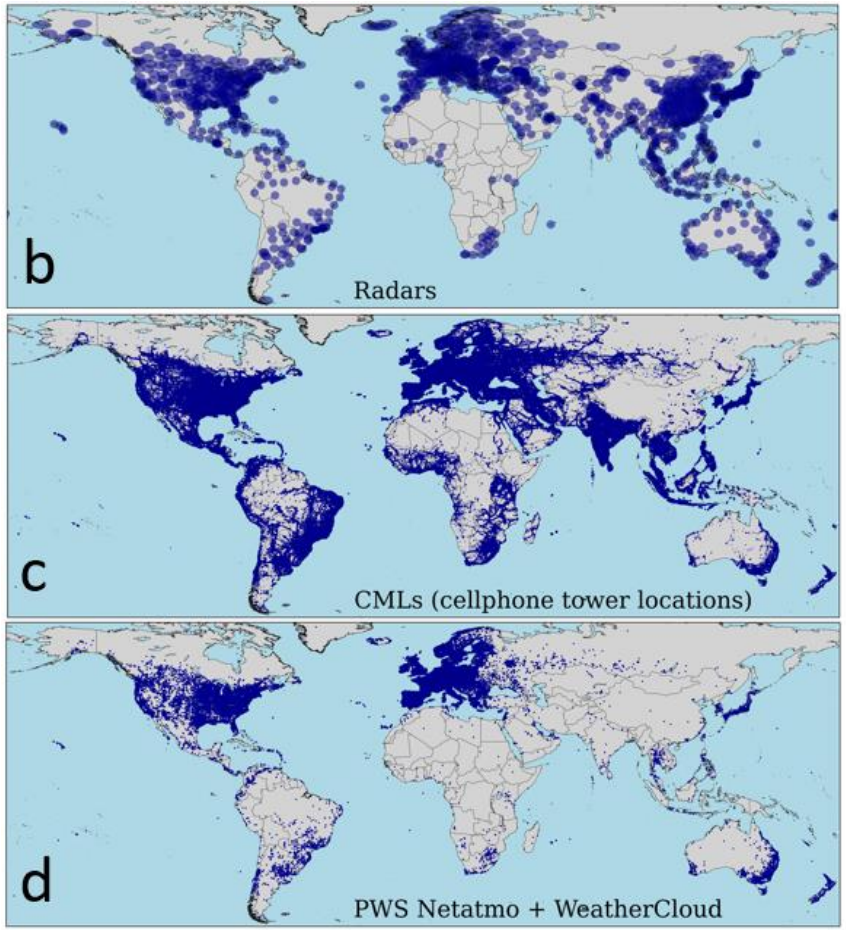


Olsson et al, 2025, AR, in review

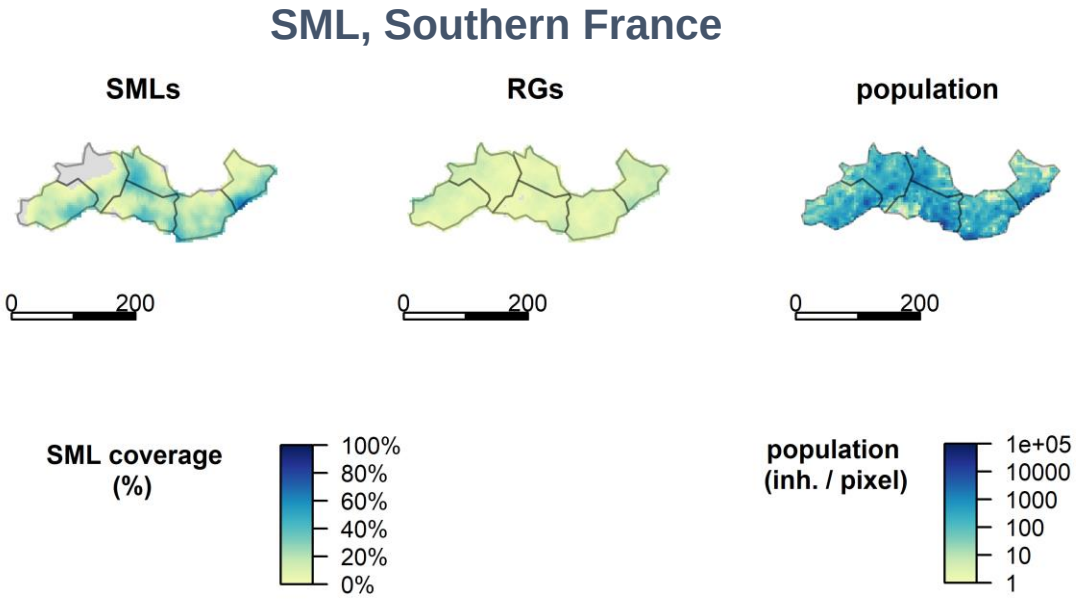


Fencl et al, 2025, in preparation

Spatial coverage country-wide SML

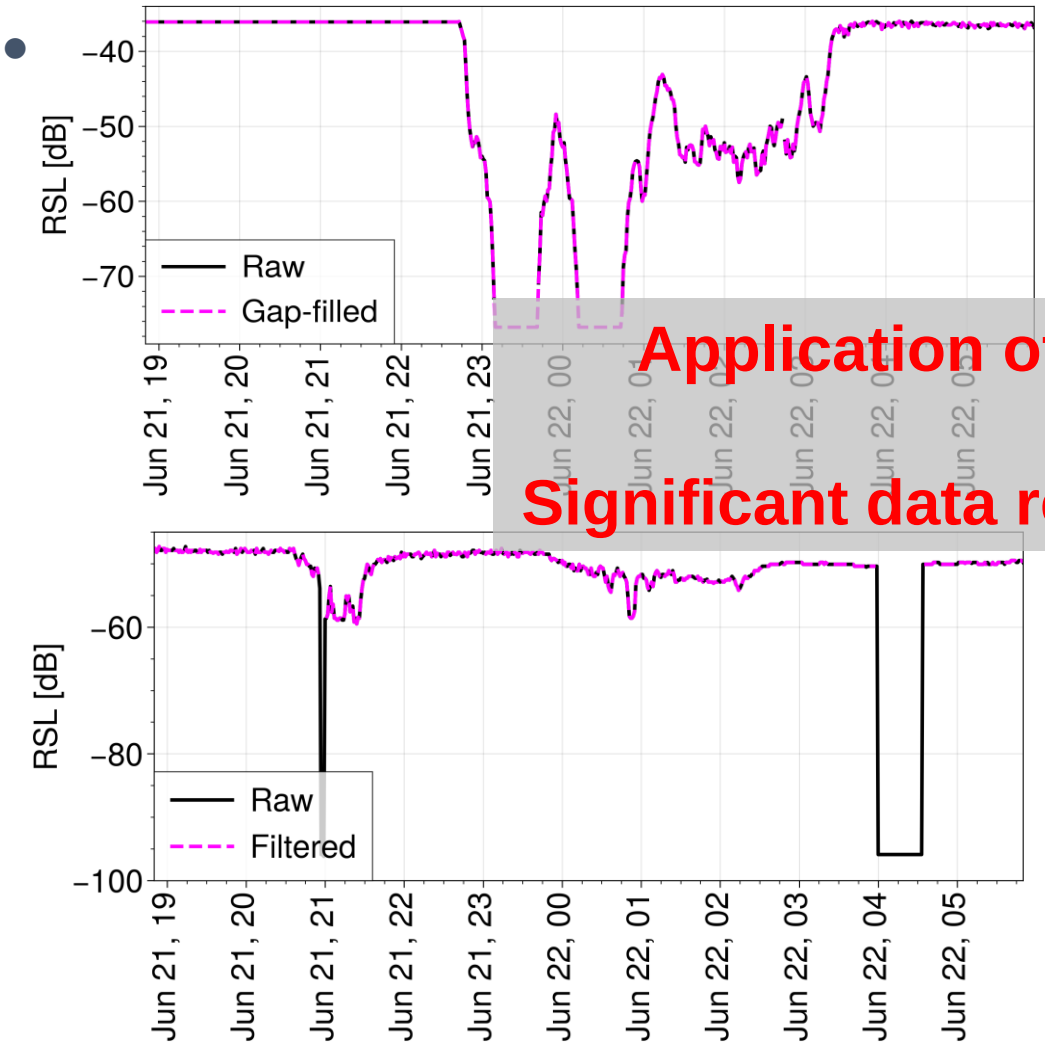


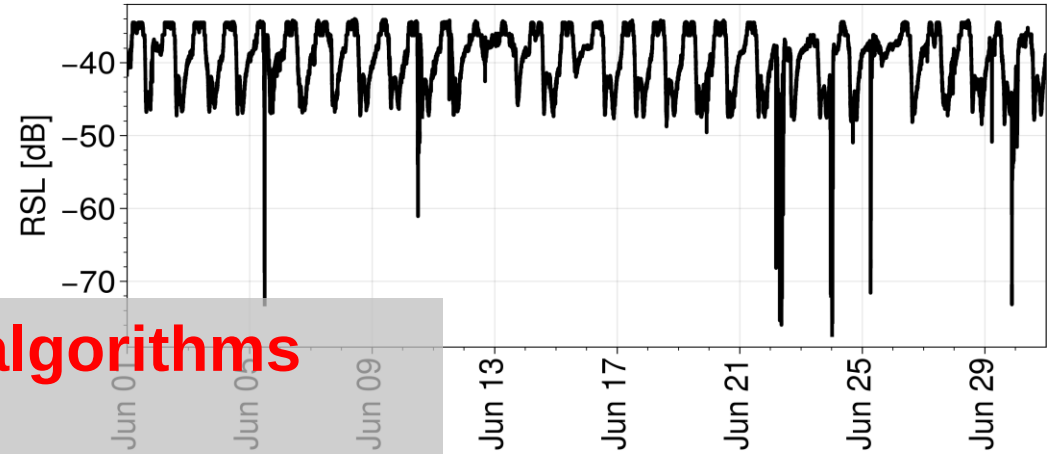
Olsson et al, 2025, AR, in review

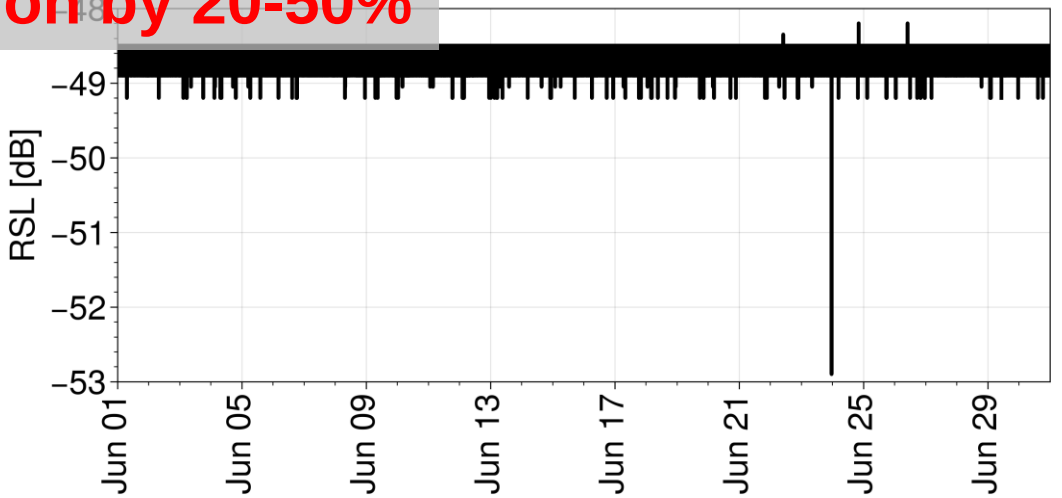


Fencl et al, 2025, in preparation
(source: HDRain https://www.hd-rain.com)

Fundamental challenges in OS







Application of QC algorithms

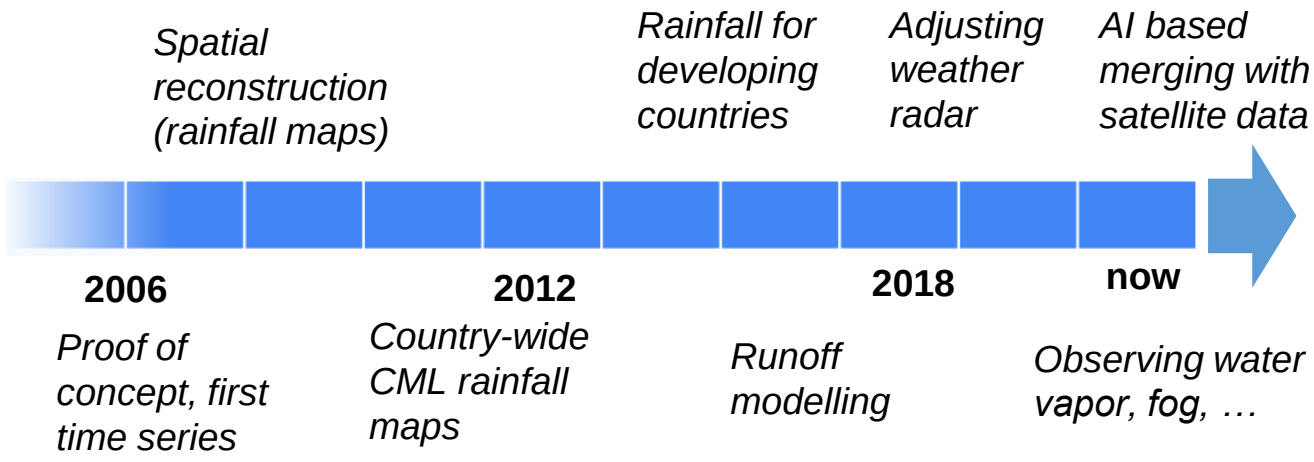
Significant data reduction by 20-50%

Blettner et al, 2025, ESS

Fundamental challenges in OS

- Variable sensitivity to rainfall
- Variable density of sensors
- Point x line observations
- Private ownership

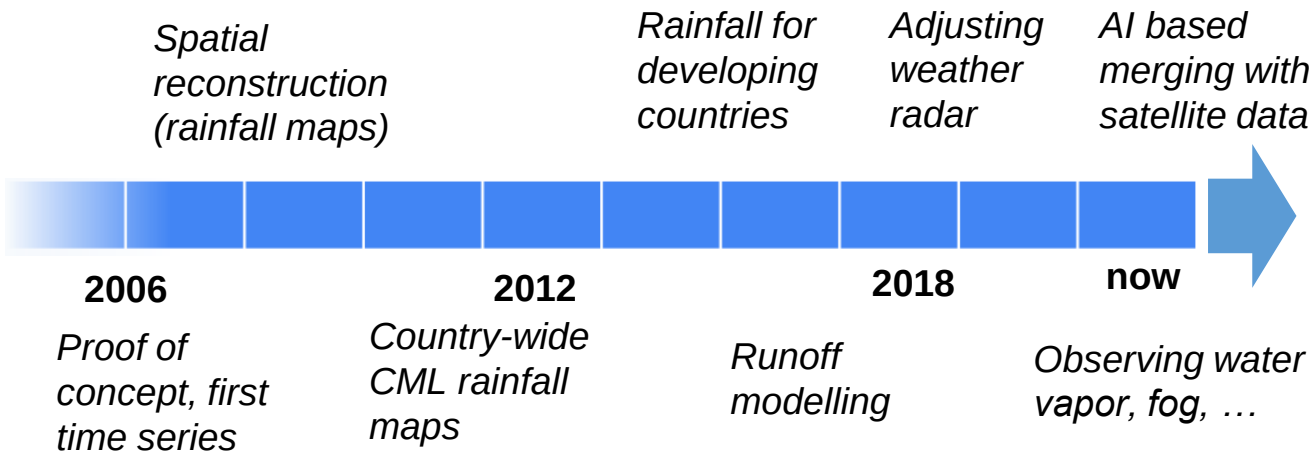
State of the art prior the OpenSense – example CML



Promising results

BUT…..

State of the art prior OpenSense – example CML

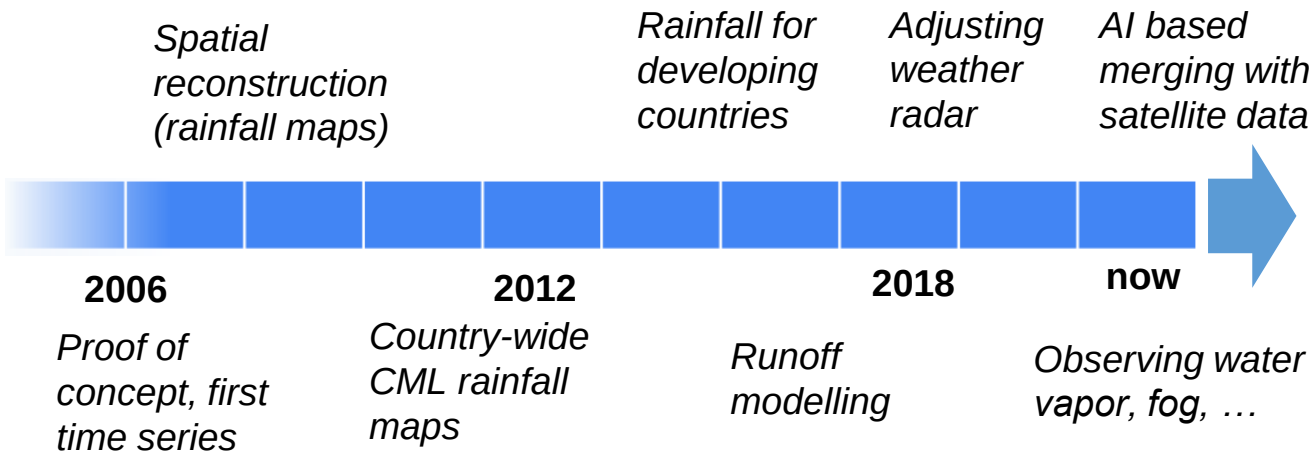


Promising results

BUT…..

- **No open access** to large scale data sets
- **Low interoperability** of data and codes
- **Questioned reproducibility** of processing methods
- **Diverse quality assurance**

State of the art prior OpenSense – example CML



Promising results

BUT…..

- Small research progress
- Difficult upscaling of DAQ, processing chains and data usage
- Low acceptance by end users

- **No open access** to large scale data sets
- **Low interoperability** of data and codes
- **Questioned reproducibility** of processing methods
- **Diverse data quality assurance**

Joint action

OpenSense

Opportunistic Precipitation Sensing Network (OPENSENSE)

https://opensenseaction.eu/

OpenSense mission

Connect stakeholders

Connect experts

- Hydrology & meteorology
- Radio-wave propagation
- Signal processing
- Telecommunication

Data owners | Researchers | End users

Action selected and supported by European Commission to:

- Improve access to OS observations
- Improve reliability of OS observations
- Use OS in operational forecasts
- Upscaling of DAQ and usage

OpenSense members

- *Researchers from academia*
- *EUMETNET + 8 European NHMSs*
- *GSMA + mobile network operators + hardware vendors*
- *Consultancy companies*

Data and metadata standards for CML, SML and PWS

- Defined a standard for data storage and naming conventions
  - CML, SML, PWS
  - NetCDF format
  - metadata description

Open Research Europe

Rapid publication and open peer review for research stemming from Horizon 2020, Horizon Europe and Euratom funding across all subject areas.

LETTER ▸ Open Res Eur. 2024 Feb 13;3:169. Originally published 2023 Oct 10. [Version 2] doi: 10.12688/openreseurope.16068.2

▸ Other versions

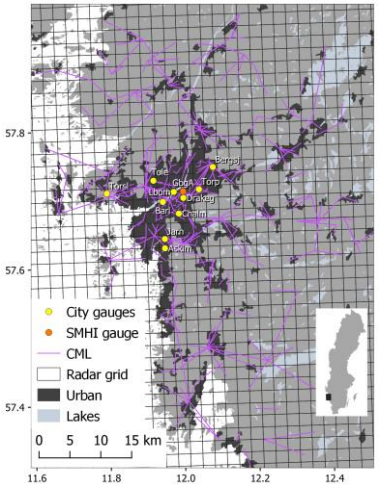
Data formats and standards for opportunistic rainfall sensors

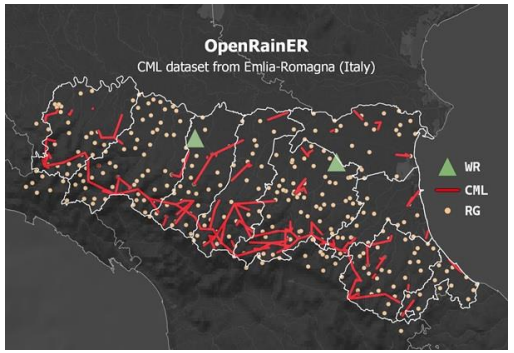
Martin Fencl [1,a], Roberto Nebuloni [2], Jafet C M Andersson [3], Vojtech Bares [1], Nico Blettner [4,5], Greta Cazzaniga [6], Christian Chwala [4], Matteo Colli [7], Lotte de Vos [8], Abbas El Hachem [9], Charles Galdies [10], Filippo Giannetti [11], Maximilian Graf [4,5], Dror Jacoby [12], Hai Victor Habi [12], Petr Musil [13], Jonatan Ostrometzky [12], Giacomo Roversi [14,15], Fabiola Sapienza [11], Jochen Seidel [9], Anna Spackova [1], Remco van de Beek [3], Bas Walraven [16], Karina Wilgan [17], Xin Zheng [12,18]

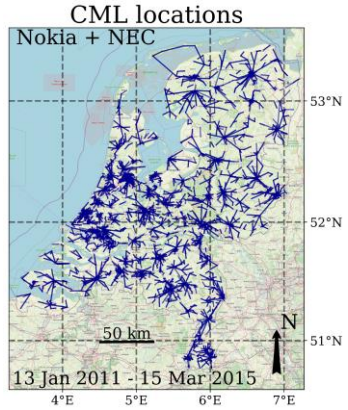
Fencl et al, 2024, ORE

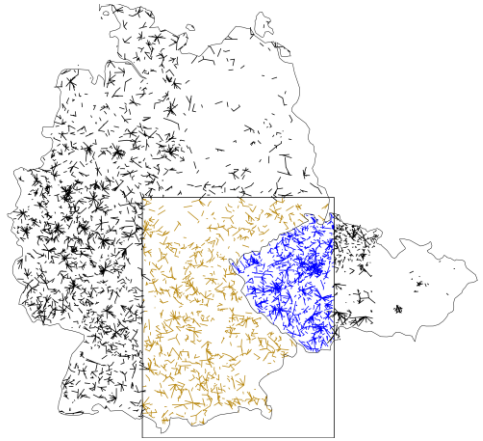
OA datasets

- OA datasets with CML, gauge and radar data
  - OpenMRG (city of Gothenburg, Sweden) Andersson et al. (2022) https://doi.org/10.5194/essd-14-5411-2022
  - OpenRainER (Emilia-Romagna, Italy)
    Covi and Roversi (2024)
    https://doi.org/10.5281/zenodo.10593848
  - Four-year commercial microwave link dataset for the Netherlands
    Overeem et al (2024)
    https://doi.org/10.4121/be252844-b672-471e-8d69-27269a862ec1.v1
  - In preparation country-wide data sets from
    - Germany (7-years)
    - Czech Republic (6 months)



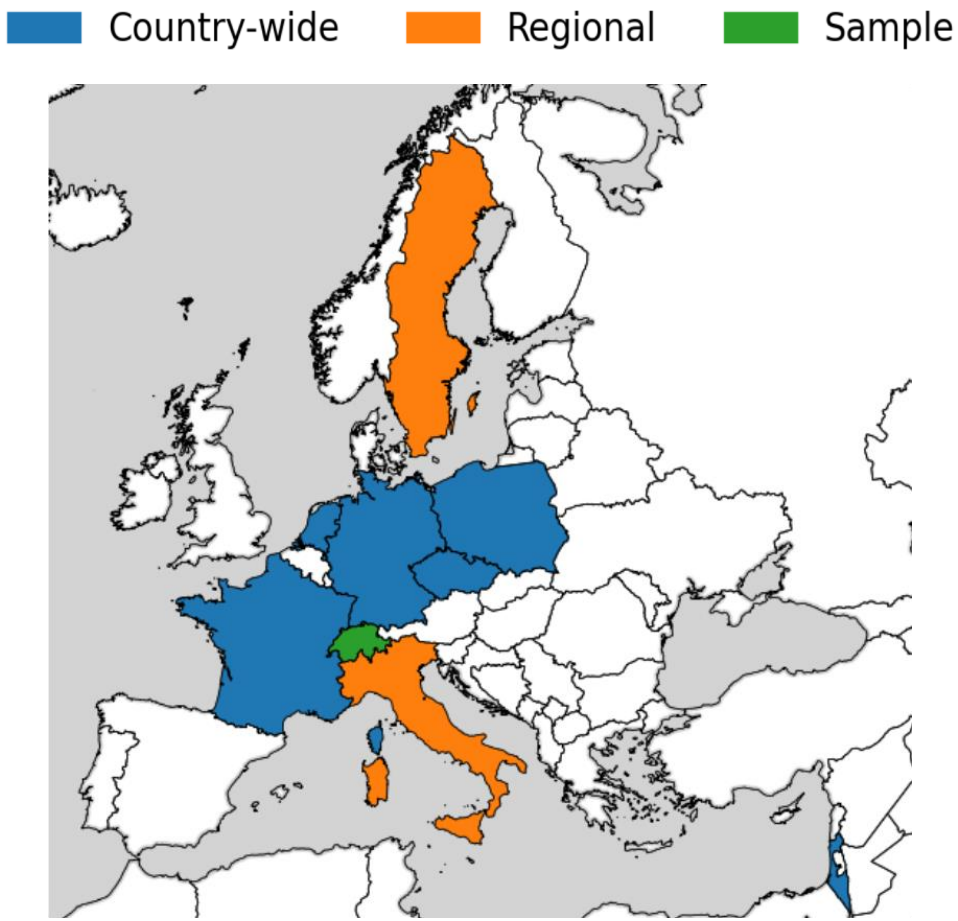






OA datasets

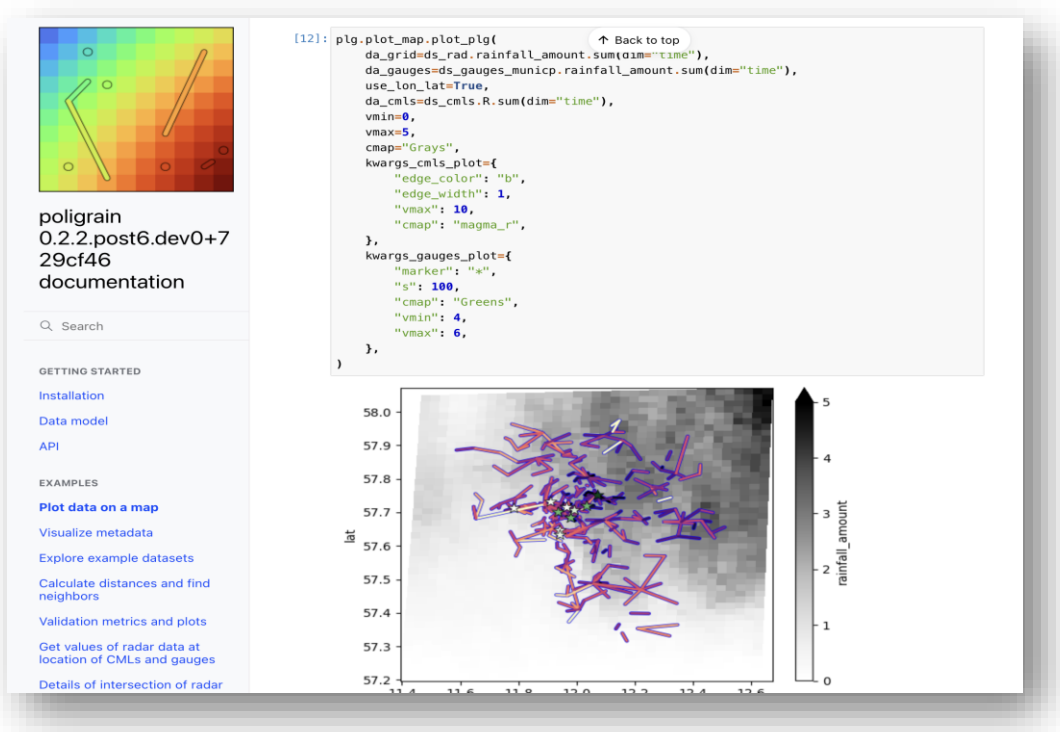
- OA datasets with CML, gauge and radar data
  - OpenMRG (city of Gothenburg, Sweden) Andersson et al. (2022) https://doi.org/10.5194/essd-14-5411-2022
  - OpenRainER (Emilia-Romagna, Italy)
    Covi and Roversi (2024) https://doi.org/10.5281/zenodo.10593848
  - Four-year commercial microwave link dataset for the Netherlands Overeem et al (2024)
    https://doi.org/10.4121/be252844-b672-471e-8d69-27269a862ec1.v1
  - In preparation country-wide data sets Germany (7-years), Czech Republic (6 months)
- Other internal OpenSense datasets – CML, SML, PWS



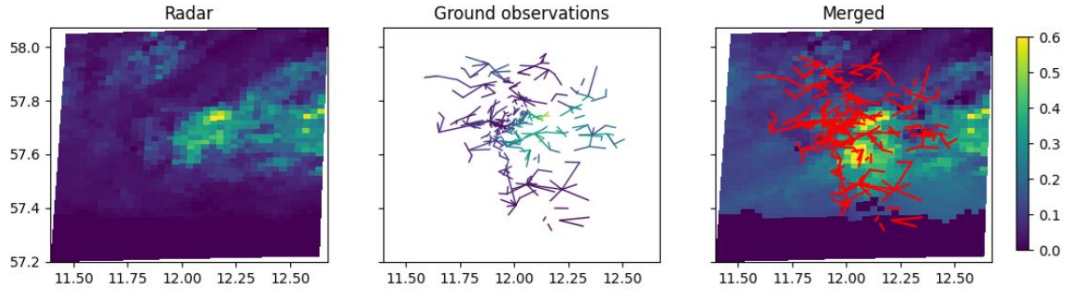
CML OpenSense datasets in Europe

Software and codes homogenization and benchmarking

- Review of existing implementations
- Joint development of:
  - *poligrain*
    - Simplify common tasks for working with point, line and gridded rainfall sensor data
    - https://github.com/OpenSenseAction/poligrain
  - *pycomlink*
    - Processing methods for CML rainfall estimation
    - https://github.com/pycomlink/pycomlink
  - *pypwsqc*
    - Quality control methods for PWS data
    - https://github.com/OpenSenseAction/pypwsqc
  - *mergeplg*
    - Merging of point line grided data sets using different methods
    - https://github.com/OpenSenseAction/mergeplg

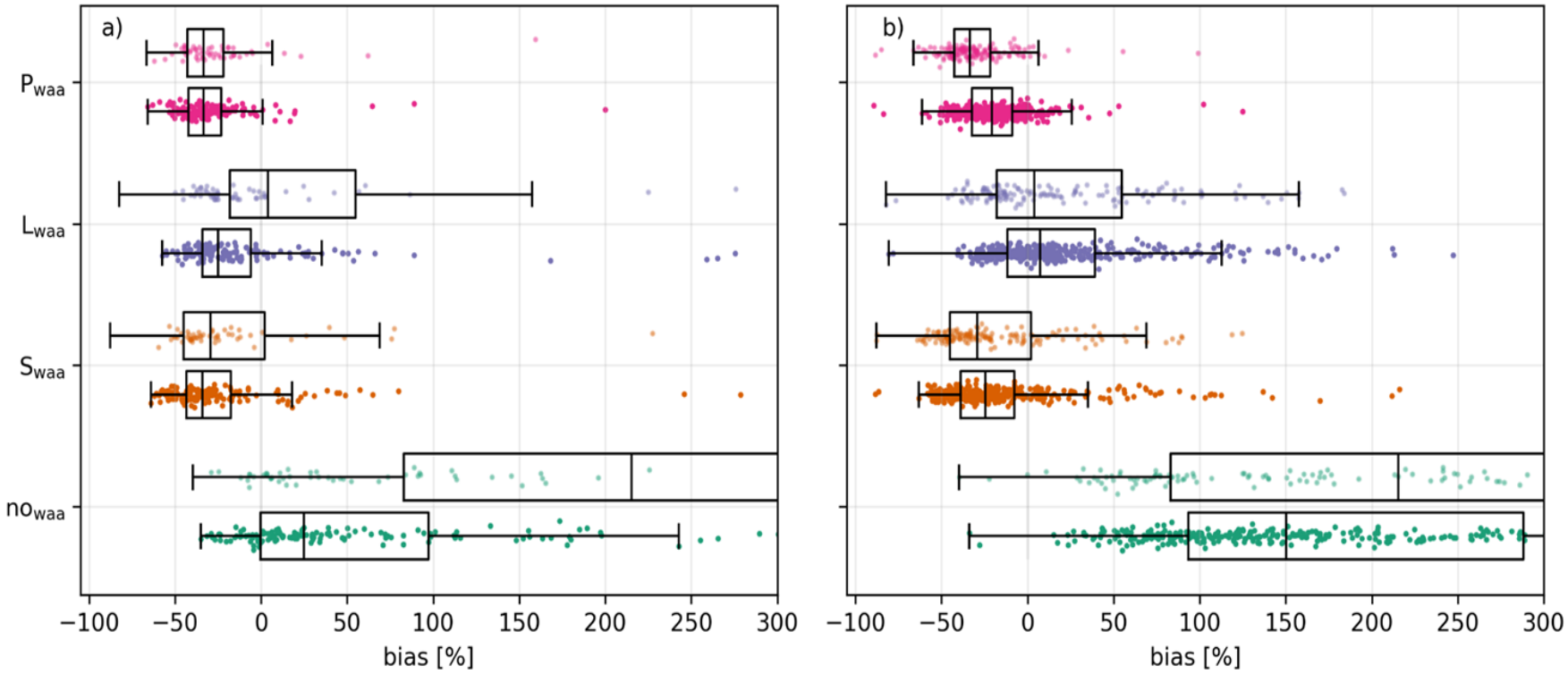


Chwala et al, 2025, in preparation



Software and codes homogenization and benchmarking

- Example of intercomparison of CML processing methods
  - Comparison of wet antenna correction methods
  - Using OpenMRG and OpenRainER dataset



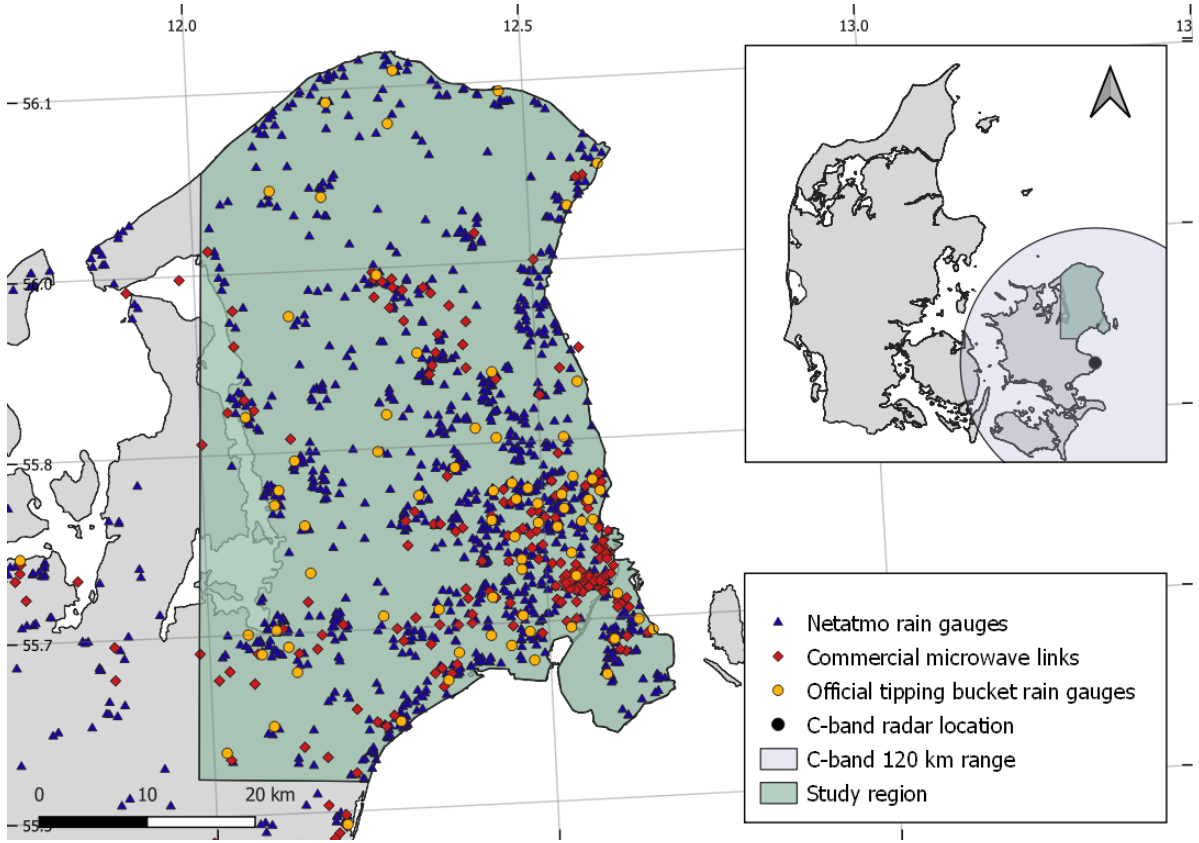
Bias depending on WAA methods

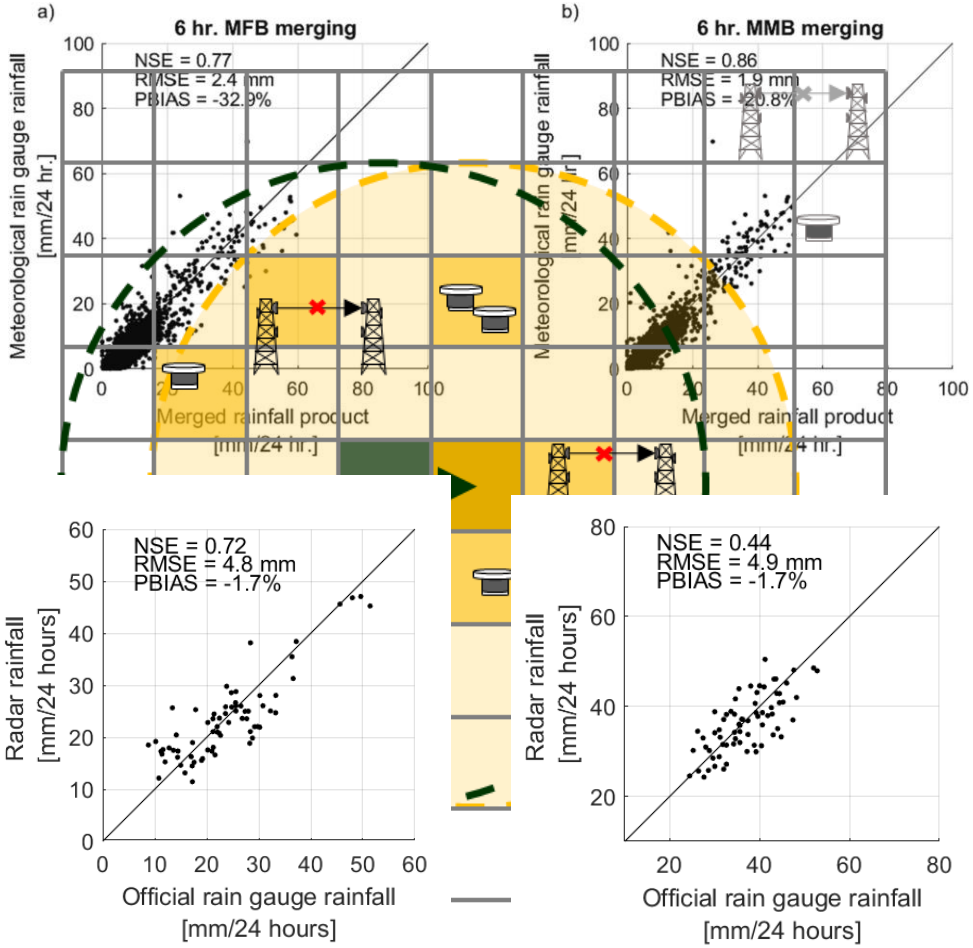
Graf et al, 2025, in preparation

Merging weather radar with OS data

Subdaily and event scale merged product

The study region: North Eastern Zealand, Denmark

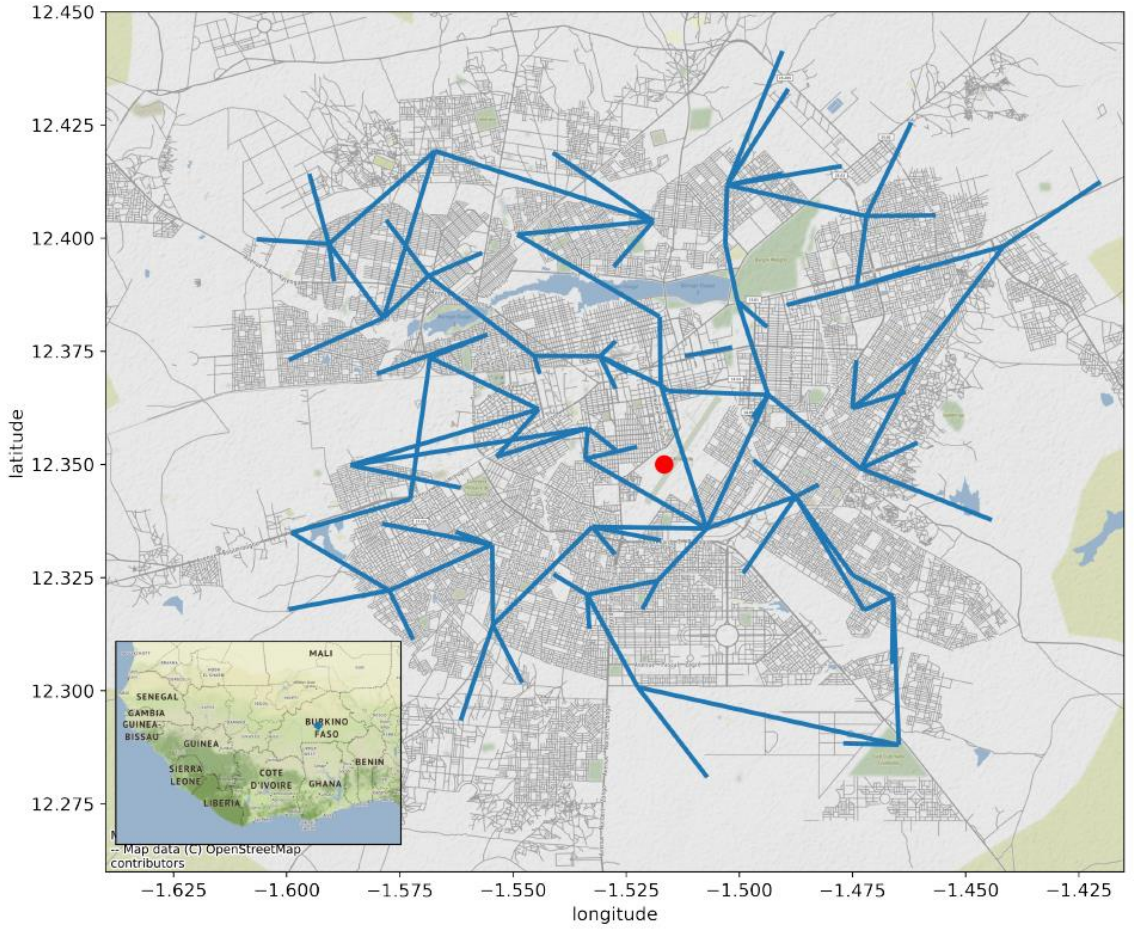




Nielsen et al, 2024, AR

CML city rainfall maps in Africa

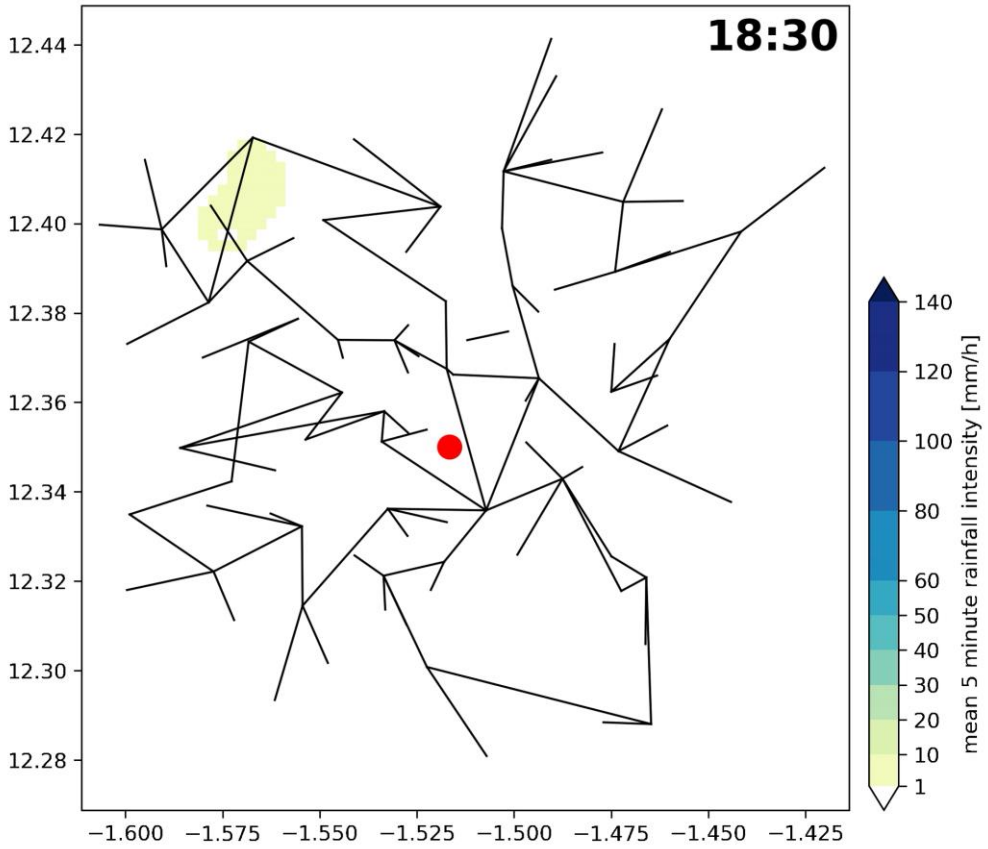
Ouagadougou, Burkina Faso – high resolution rainfall map 5 min

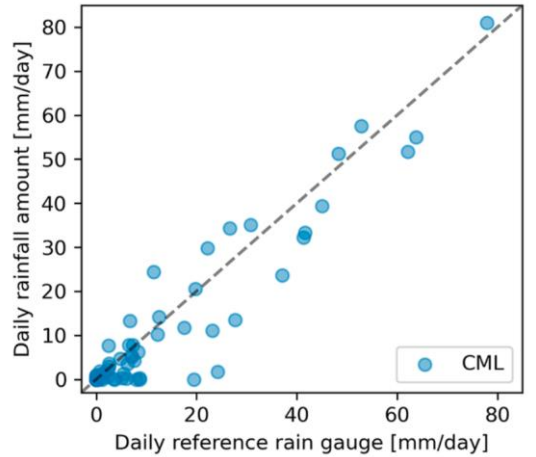


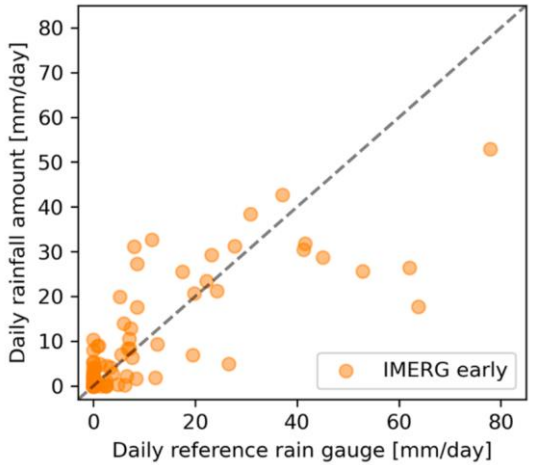
Djibo et al, 2023, JHM

CML city rainfall maps in Africa

Ouagadougou, Burkina Faso – high resolution rainfall map 5 min



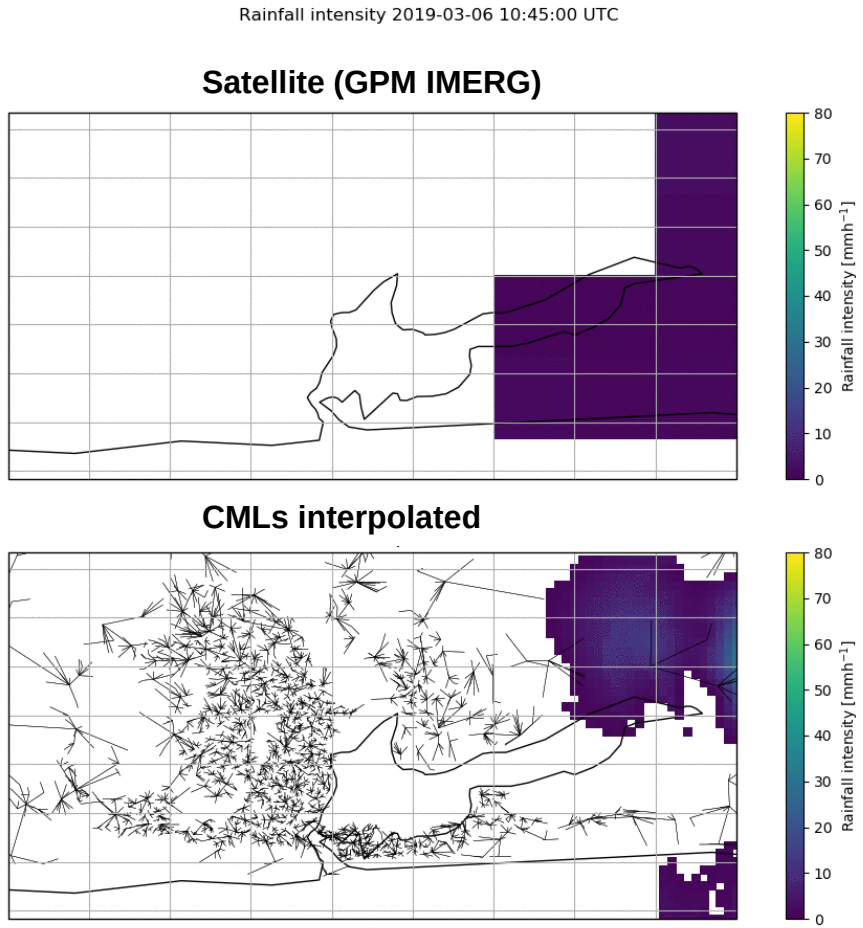




Djibo et al, 2023, JHM

CML city rainfall maps in Africa

Lagos, Nigeria – high resolution 15 min



Droste et al, 2021, EGU

Operationalization of precipitation products

- **Deutscher WetterDienst**
  - Weather radar adjustment with commercial microwave links: the HoWa-PRO project
  - Quasi-operational test of pyRADMAN
  - RAD+CML comparable to RADOLAN-RW with significantly shorter latency
  - Started market survey to potentially acquire CMLs on a long term basis

https://howapro.de

- **MeteoFrance**
  - 19 months of continuous data, ≈ 4500 links at each time step (> 5300 different links)
  - Comparison between standard Antilope, classic Antilope+CML and ML Antilope+CML versions, with or without radar calibration in the merging

Operationalization of precipitation products

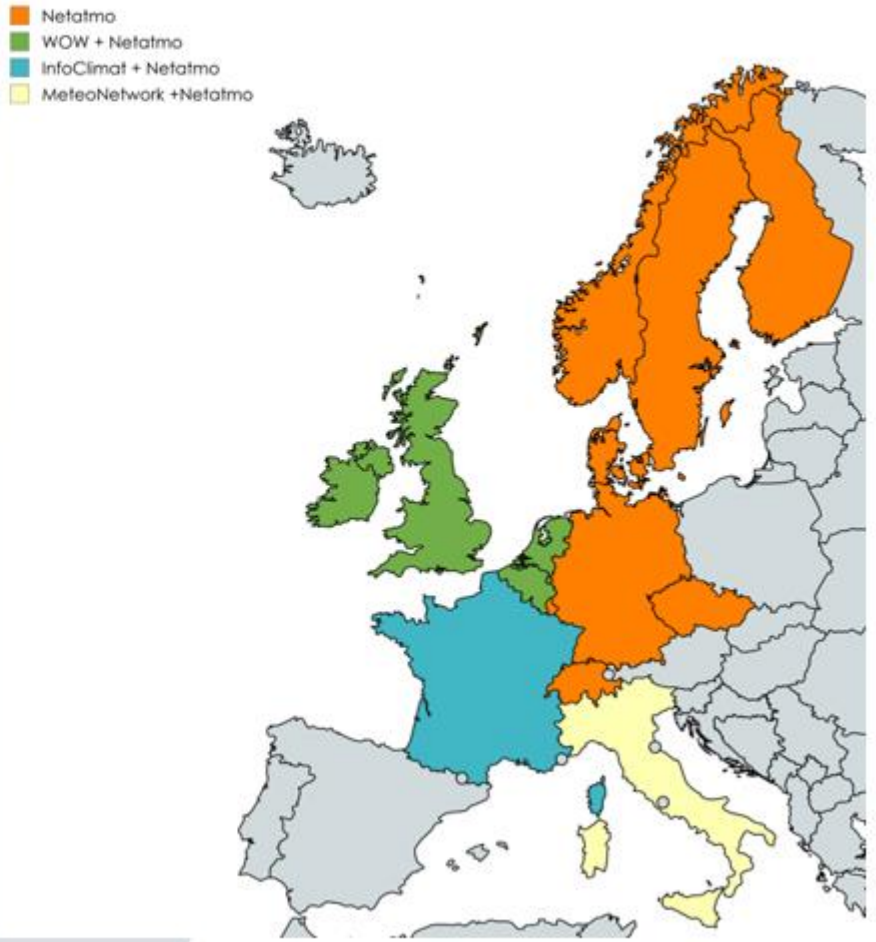
IoT pilot project data access

Data provision (free of charge for Pilot Project):

- Met Office for WOW data (mostly UK, Ireland, Belgium, Netherland).
- DMI for smartphone pressure data (mostly Denmark).

- Netatmo data for 14 countries
- MeteoNetwork (Italy).
- InfoClimat (France).

Providers and coverage of PWS data access for the Pilot Project



Take home messages and community achievements

- Opportunistic rainfall sensors can improve rainfall observation especially in short temporal and spatial scales and in low income countries
- Benefits for operational urban hydrology and runoff predictions
- Significant community achievements in OS data and codes interoperability and reproducibility
- Ongoing usage and operationalization of OS data by NHMSs

Upscaling of CML global data collection remains a challenge

The Global Microwave link Data collection Initiative (GMDI)

→ Solve CML data accessibility issue via the "Global Microwave Link Data Collection Initiative" (GMDI)

OpenSense

ITU

WMO

+ EUMETNET, NHMSs, MNOs, Hardware vendors

International Conference on Opportunistic Sensing of Precipitation - OpenSense

Final Conference of European COST Action CA20136 OpenSense

ADMISSION FREE

Offenbach, Germany

June 25-26, 2025

OpenSense

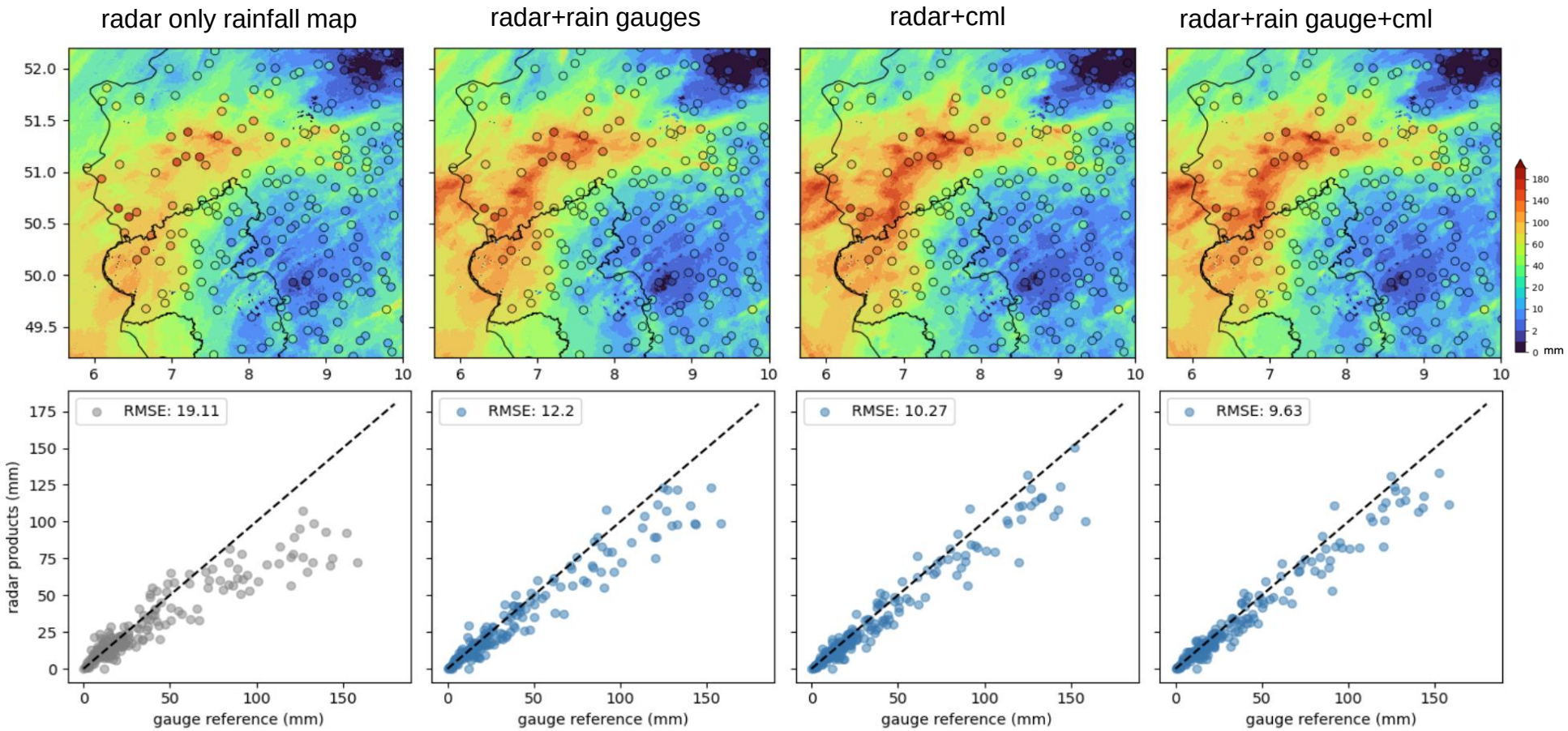
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Funded by the European Union

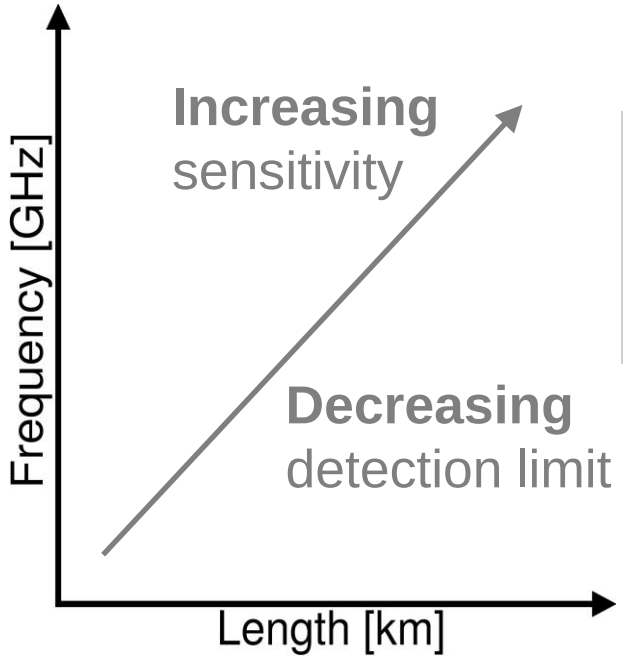
Merging weather radar with OS data

The study region: Ahr Valley 2021, Germany, DWD

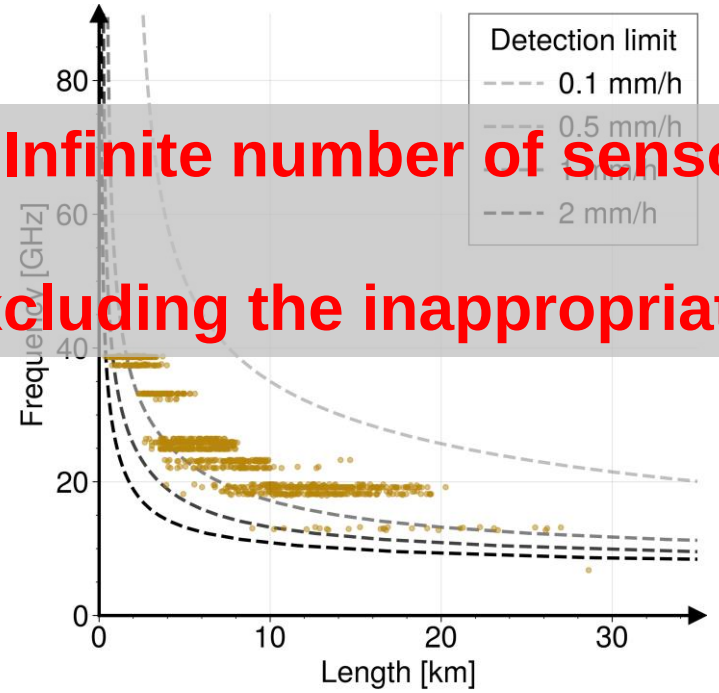


Fundamental challenges in OS

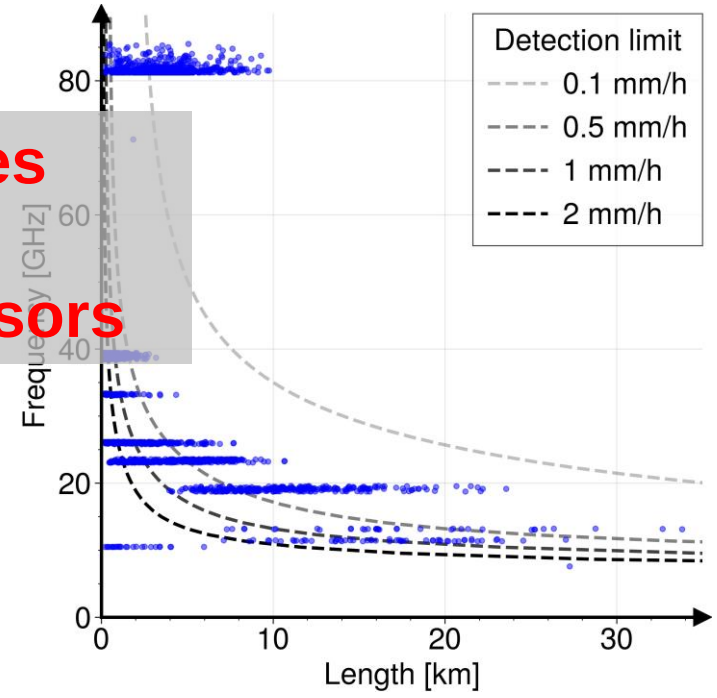
- Variable sensitivity to rainfall



German CMLs



Czech CMLs



Infinite number of sensor types

Excluding the inappropriate sensors