Karlsruhe Institute of Technology

KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research

Improving QPE with commercial microwave links

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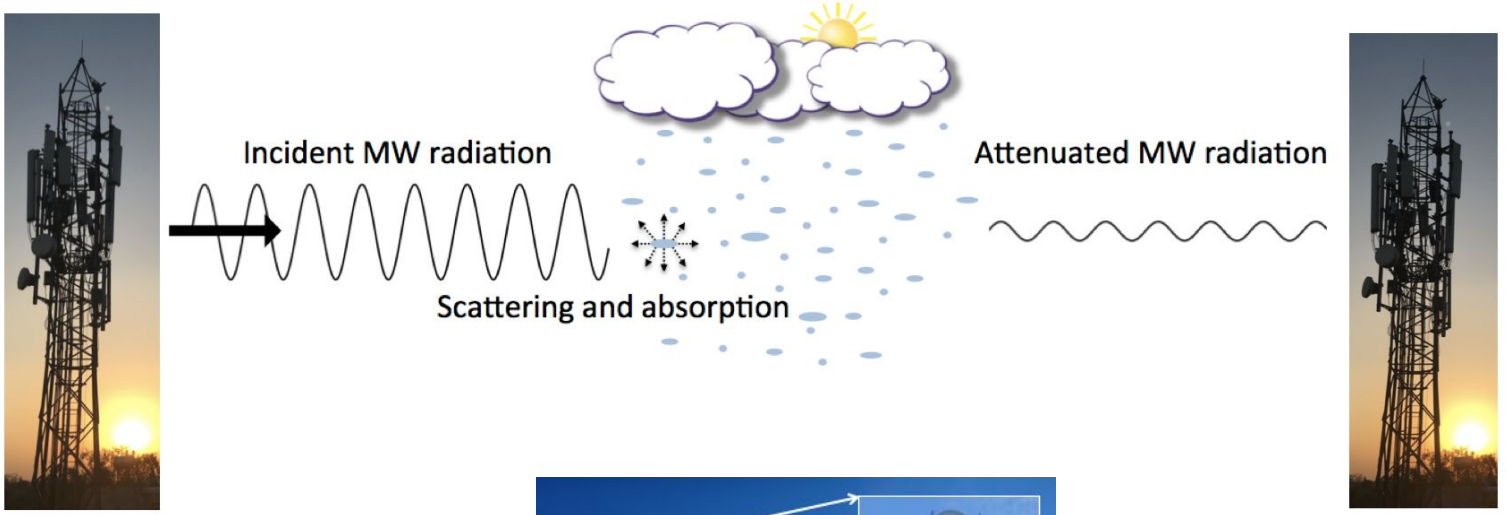
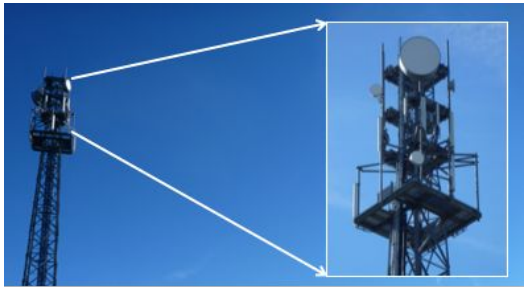
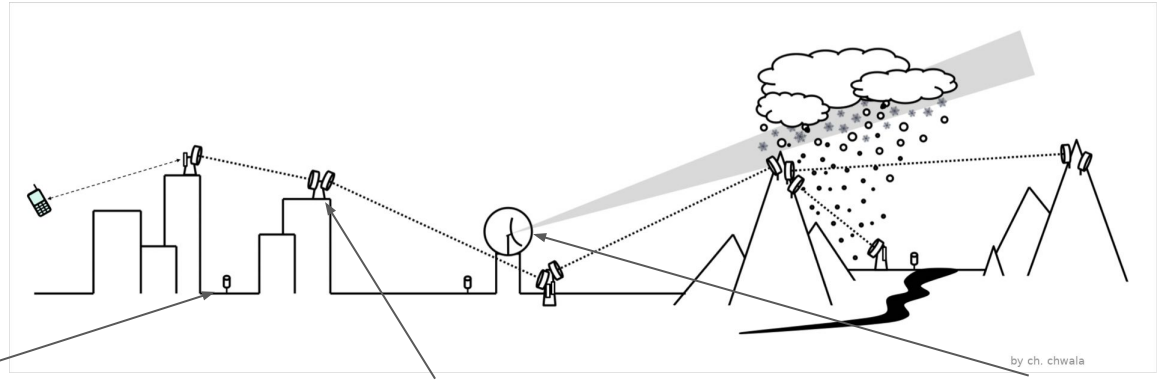
[3] *Department of Informatics and Mathematics, Hochschule für Angewandte Wissenschaften München, Munich, Germany*

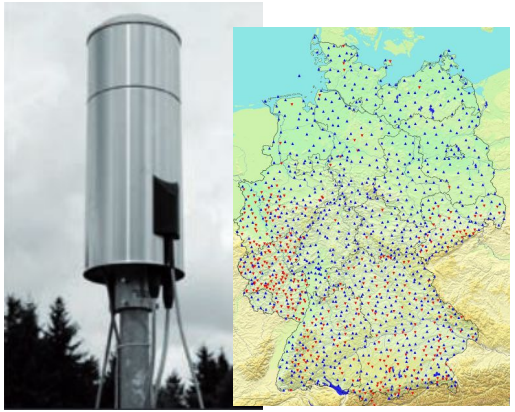

Incident MW radiation
Attenuated MW radiation
Scattering and absorption



Rainfall estimation in Germany

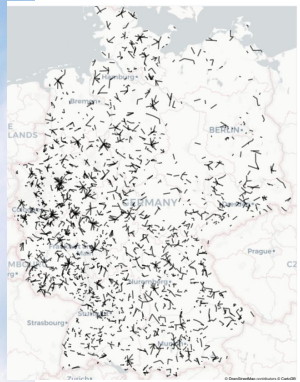


Rain Gauge



Source: DWD

Commercial microwave link (CML)



Source: C. Ruf, KIT

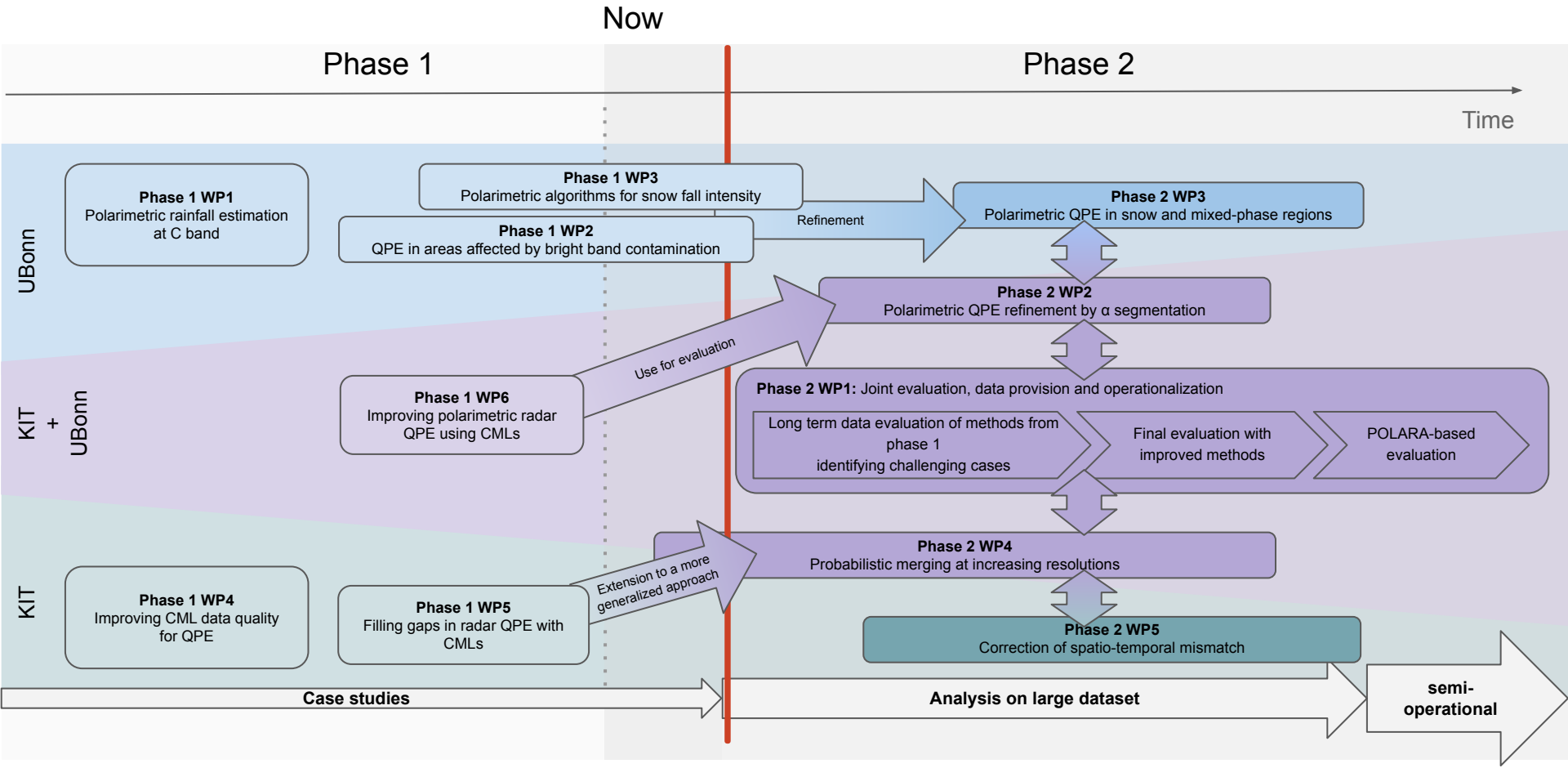
Weather radar

Source: DWD

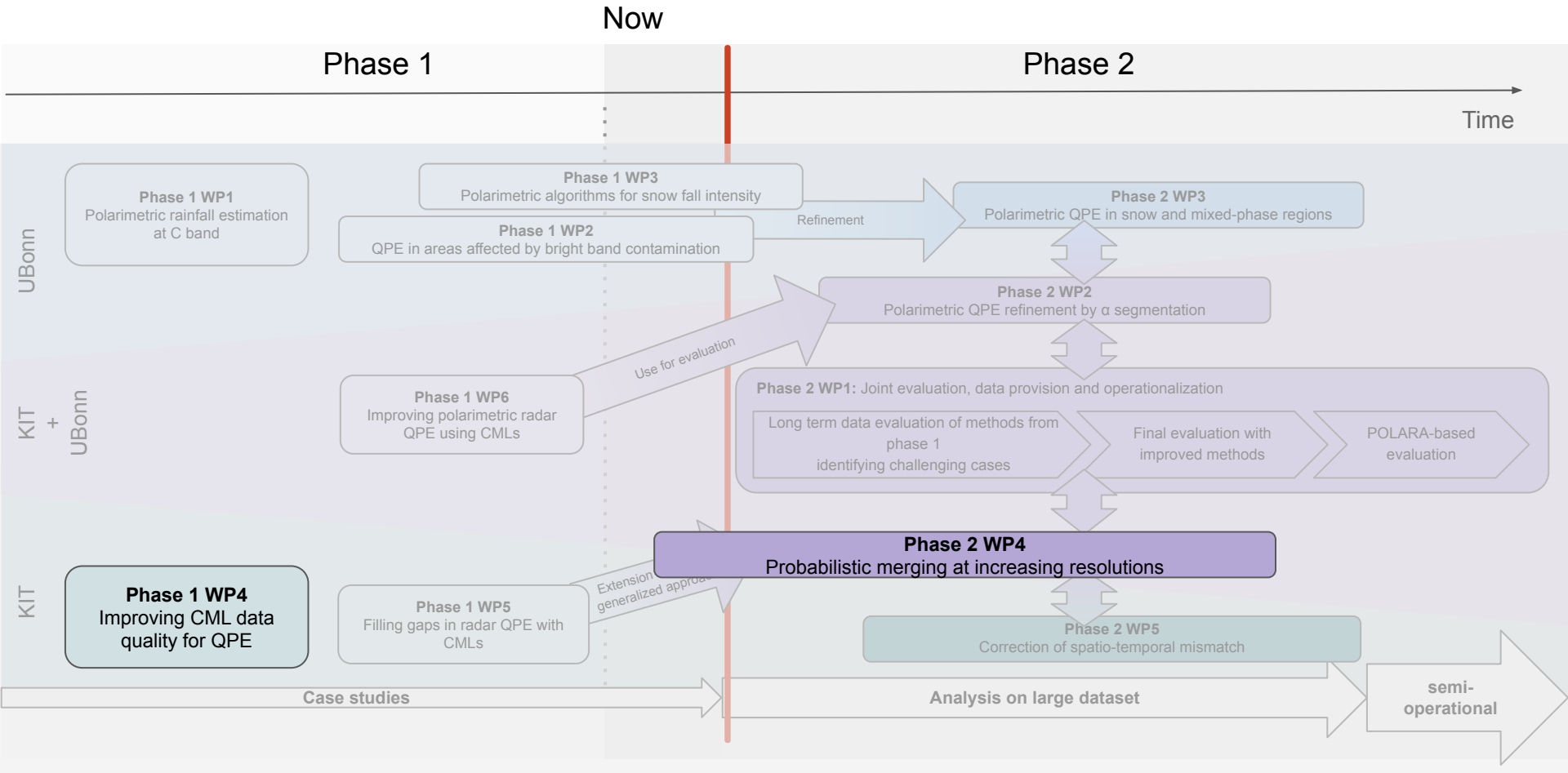
Outline

1. Advection correction and “morphed” radar QPE
2. Deep learning based radar adjustment
3. CML anomalies and outages

P1 Flowchart



P1 Flowchart



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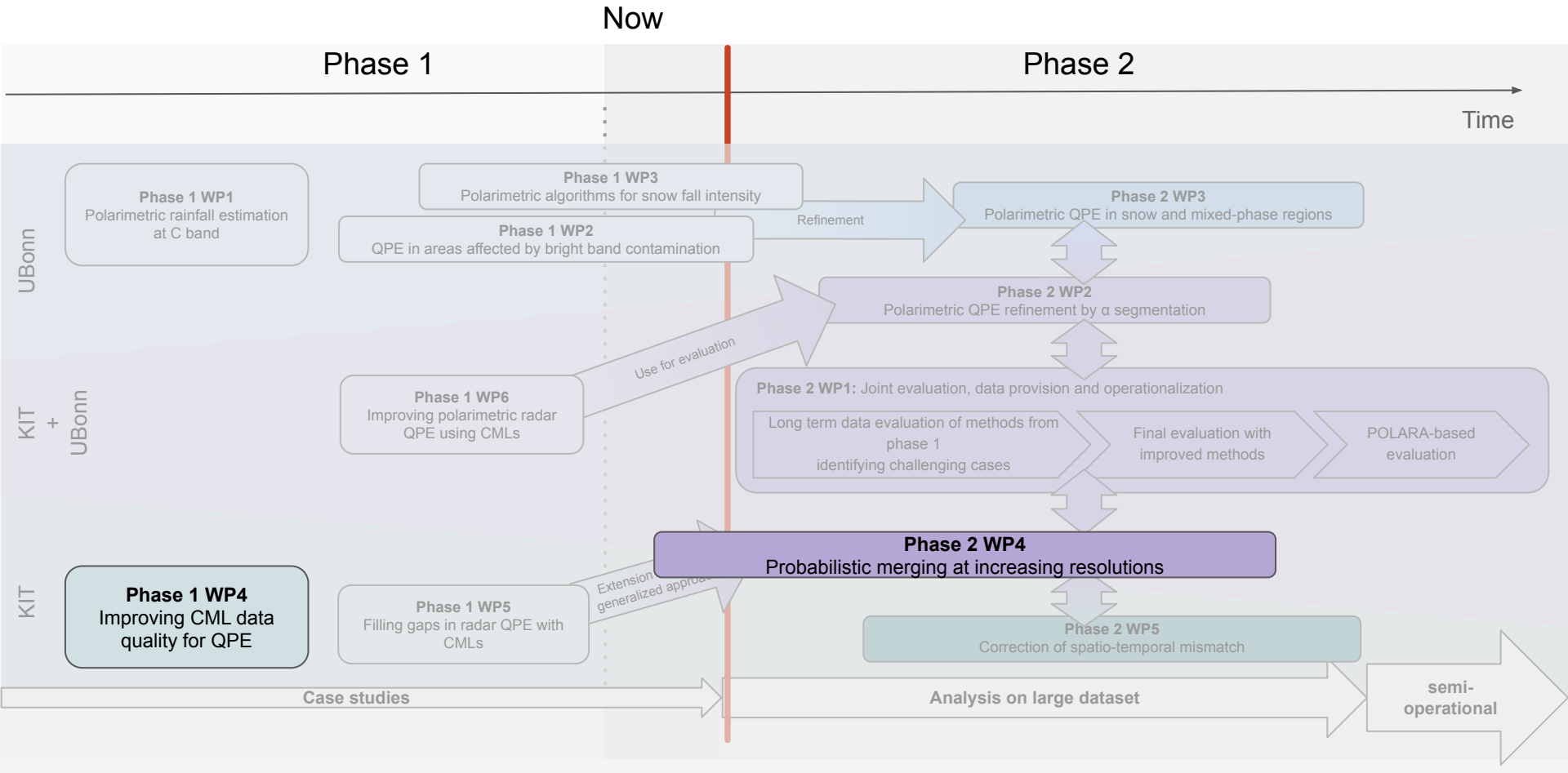

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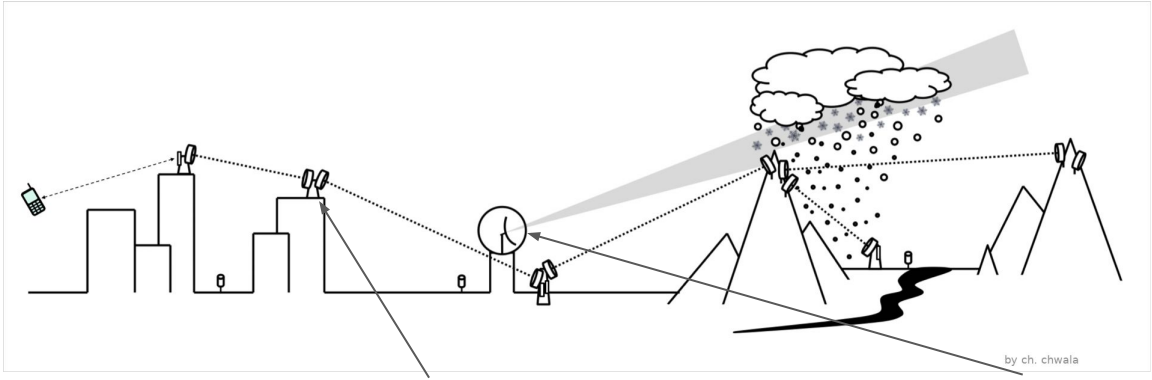

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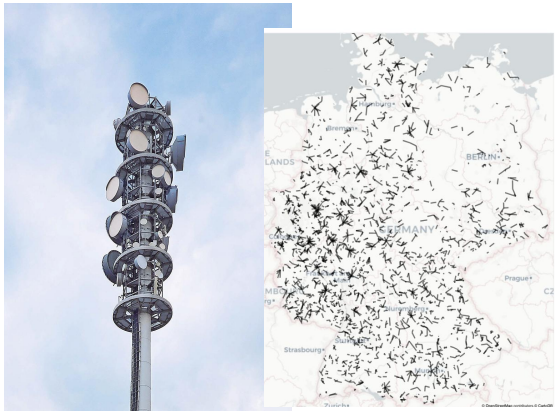
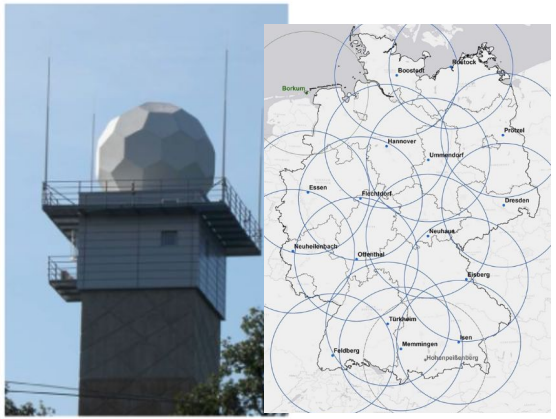


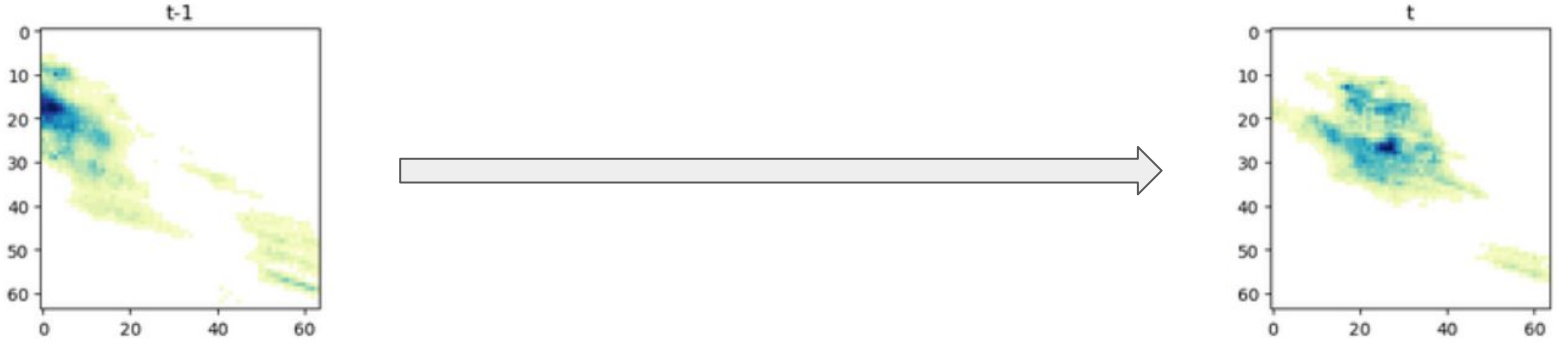
Source: C. Ruf, KIT

Weather radar



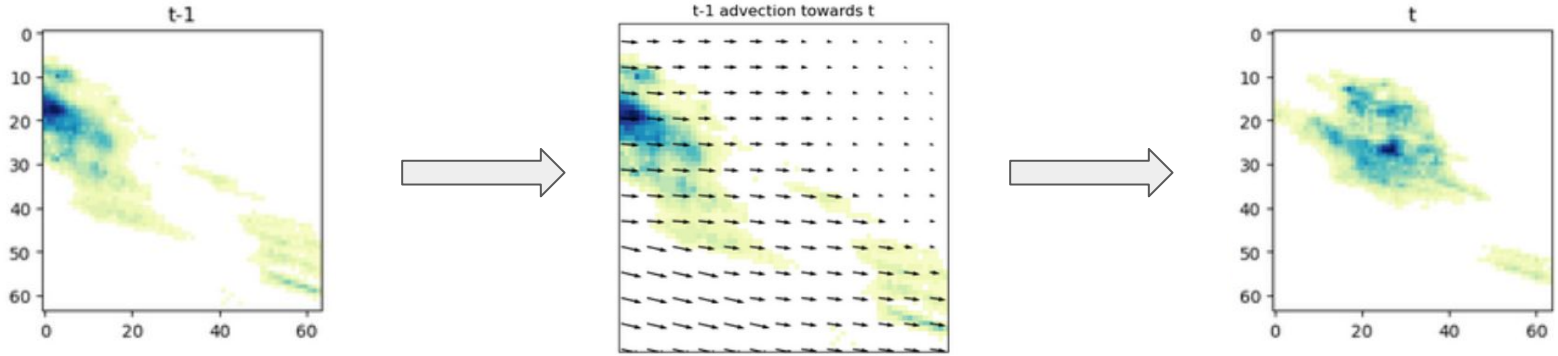
Source: DWD

Advection correction: The concept



Advection correction: The concept

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



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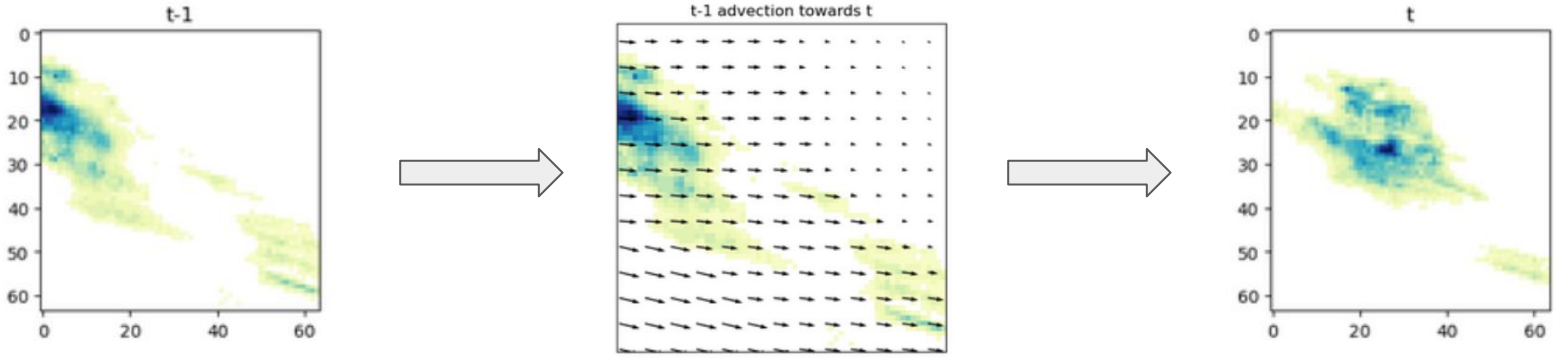
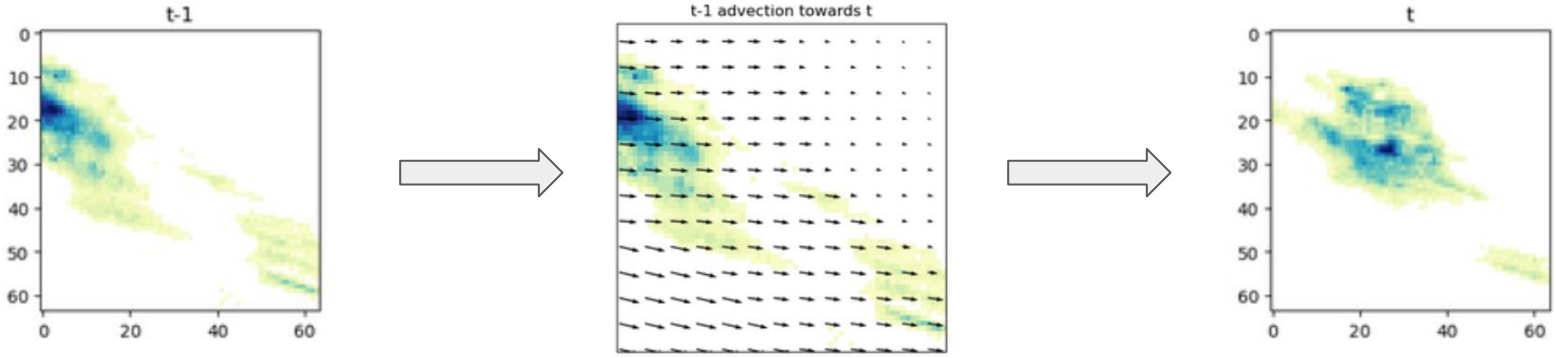


Intermediate timesteps by constant flow
(morphed QPE)

Advection correction by temporal aggregation

Advection correction: The concept

Estimated optical flow by Lucas-Kanade method



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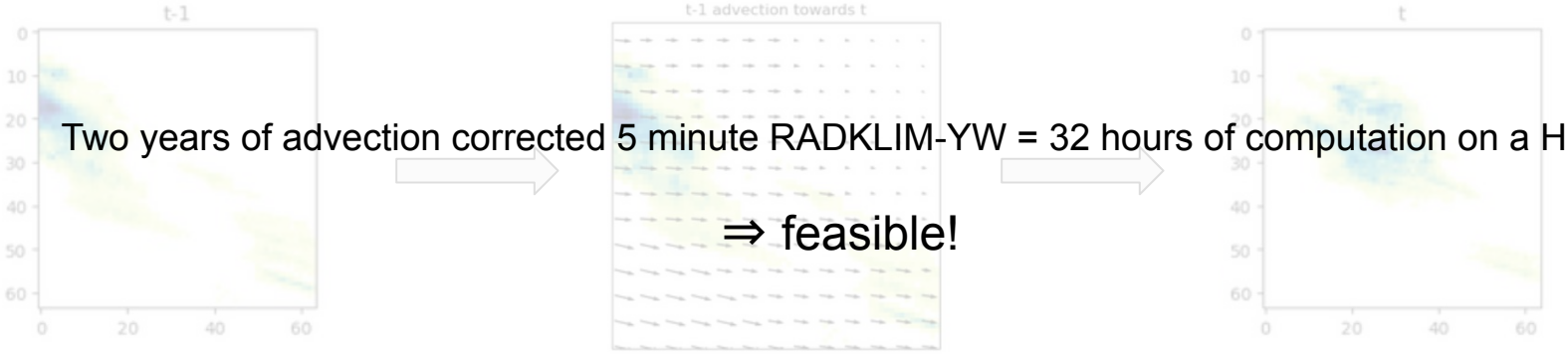


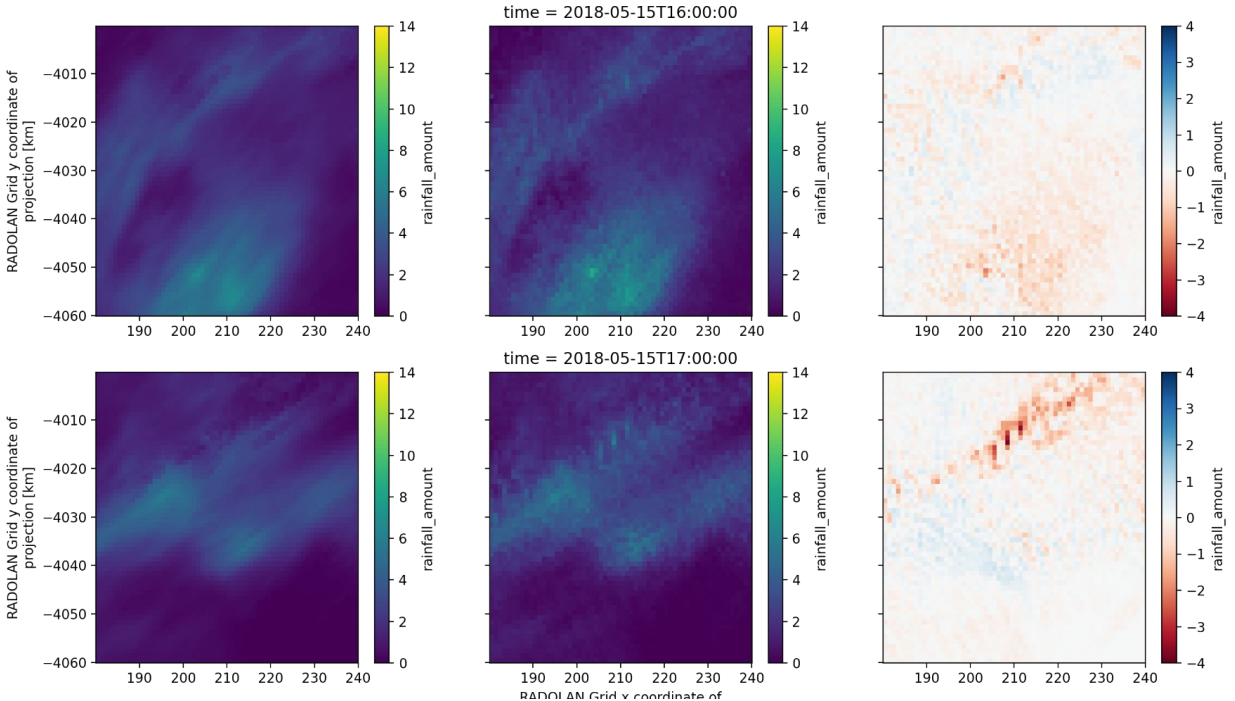
Two years of advection corrected 5 minute RADKLIM-YW = 32 hours of computation on a HPC

⇒ feasible!

Intermediate timesteps by constant flow
(morphed QPE)

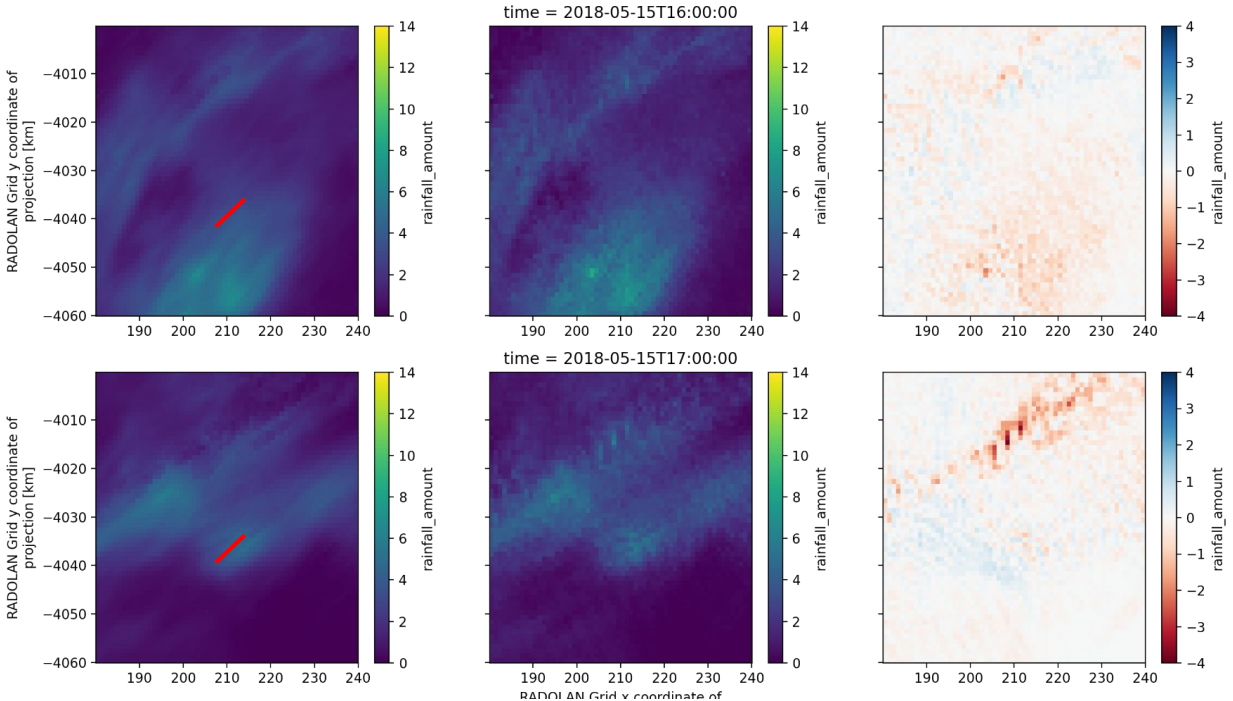
Advection correction by temporal aggregation

Advection correction: hourly aggregates



Probabilistic merging at increasing resolutions

Advection correction: hourly aggregates



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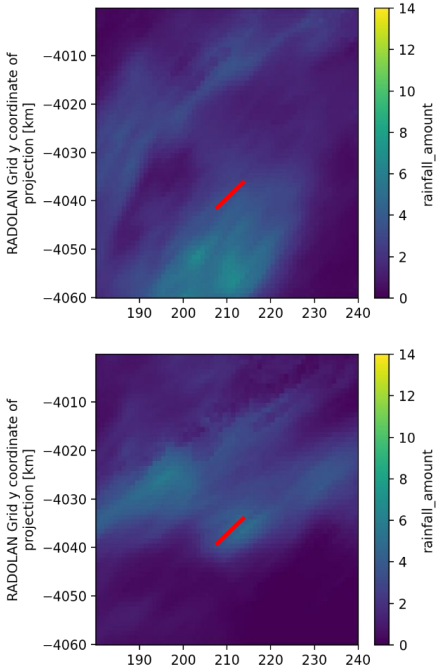
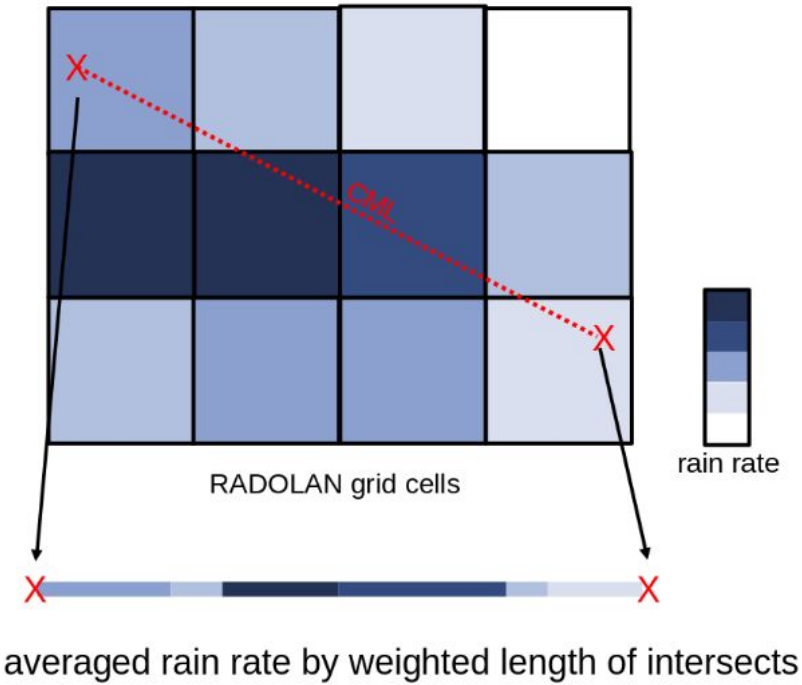
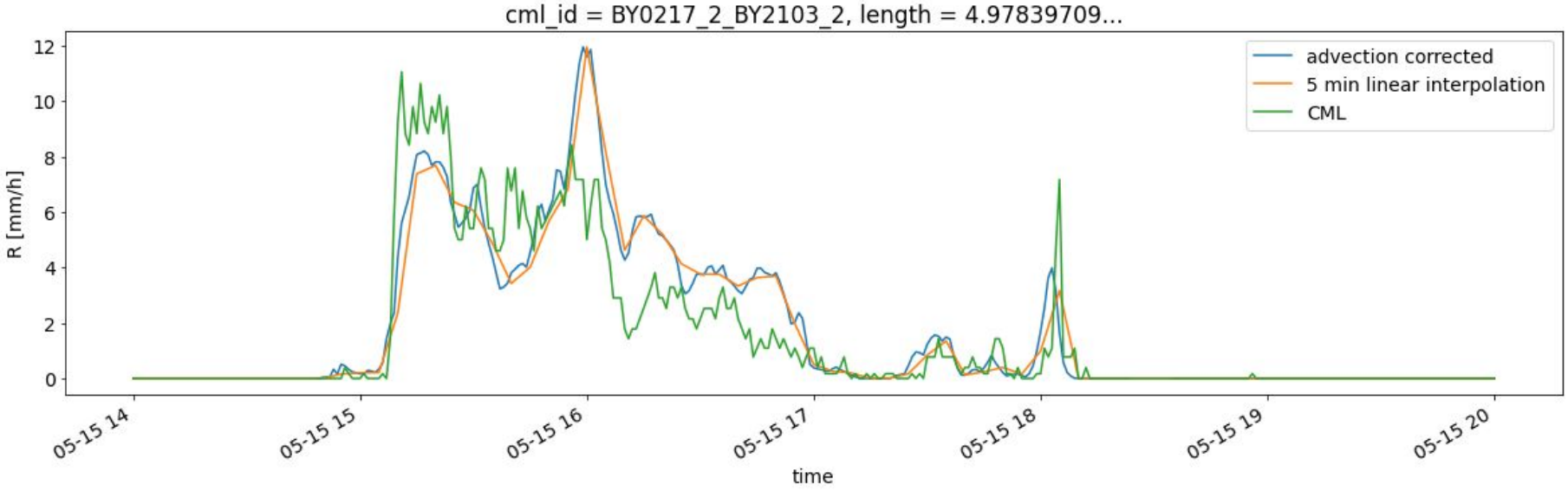




Path averaged rain rate by weighted length of intersects

Probabilistic merging at increasing resolutions

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



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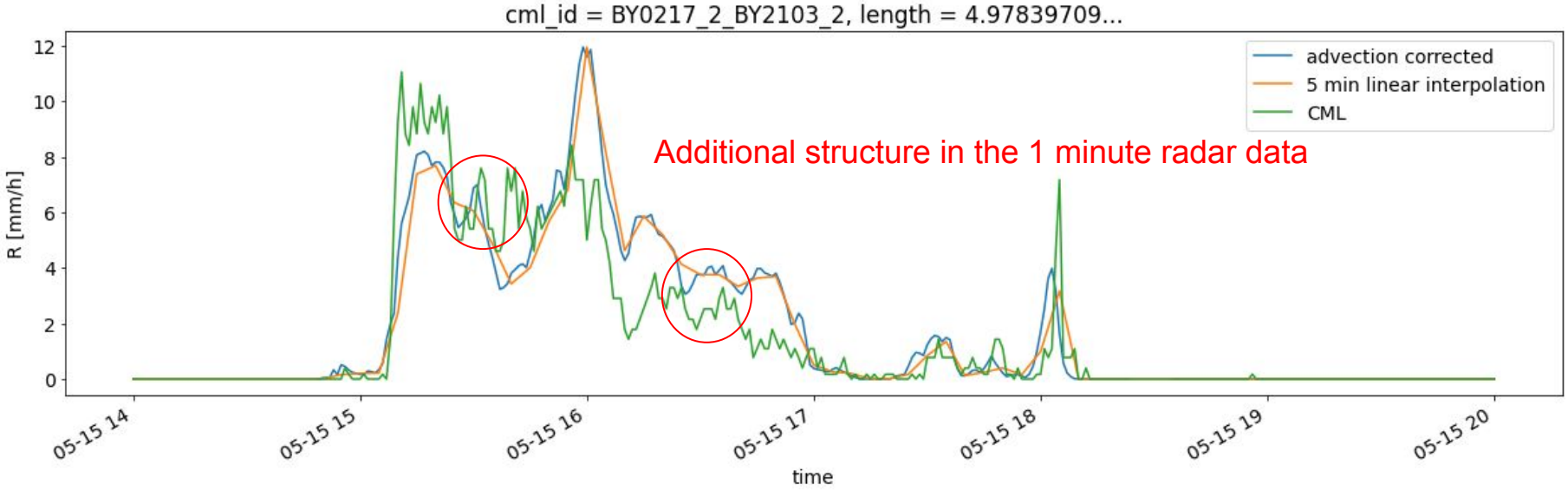

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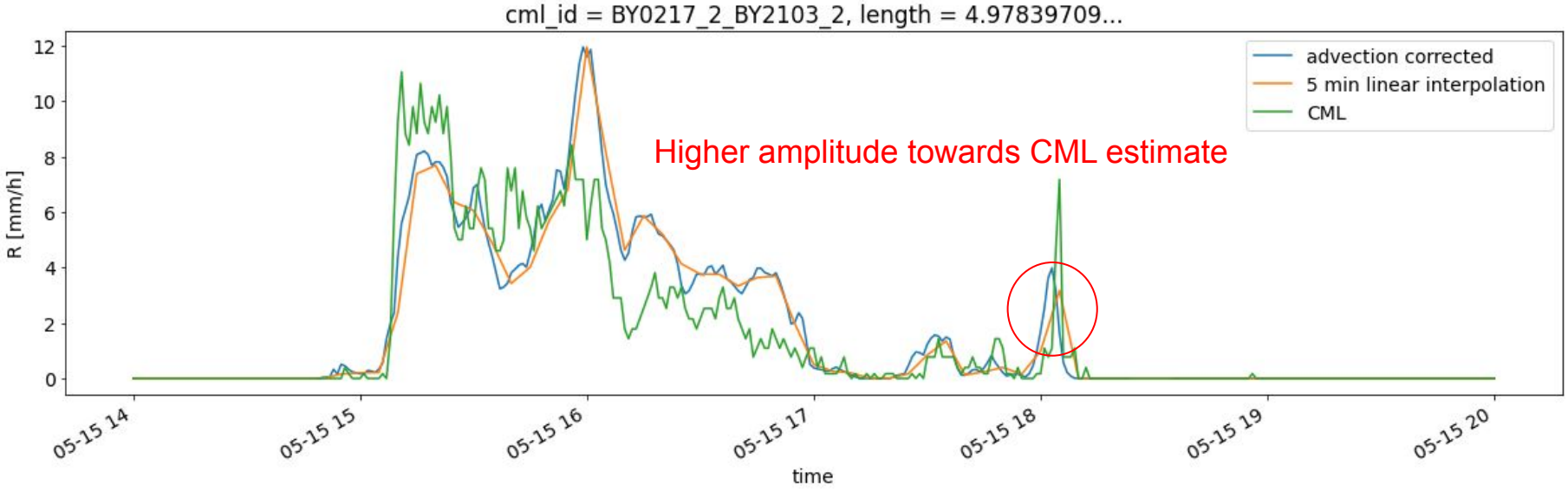

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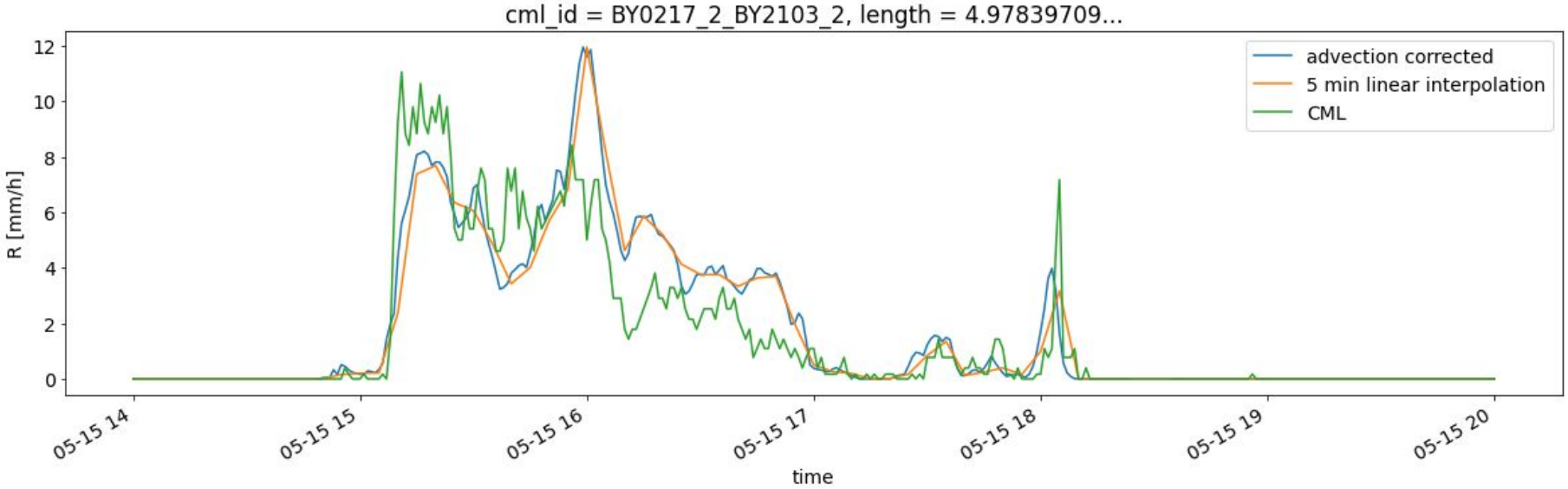
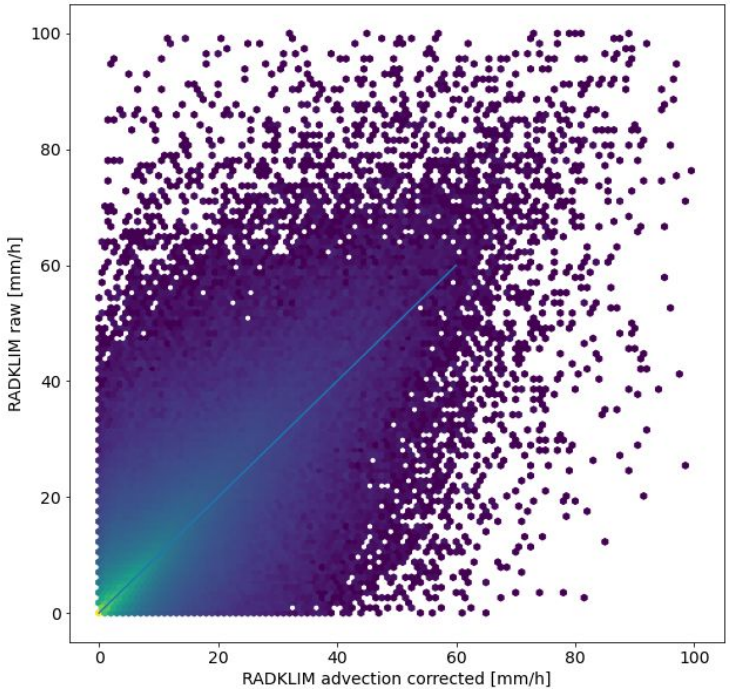


⇒ Qualitative proof of concept that “morphed” 1-minute radar data gives more insights into spatio temporal mismatch

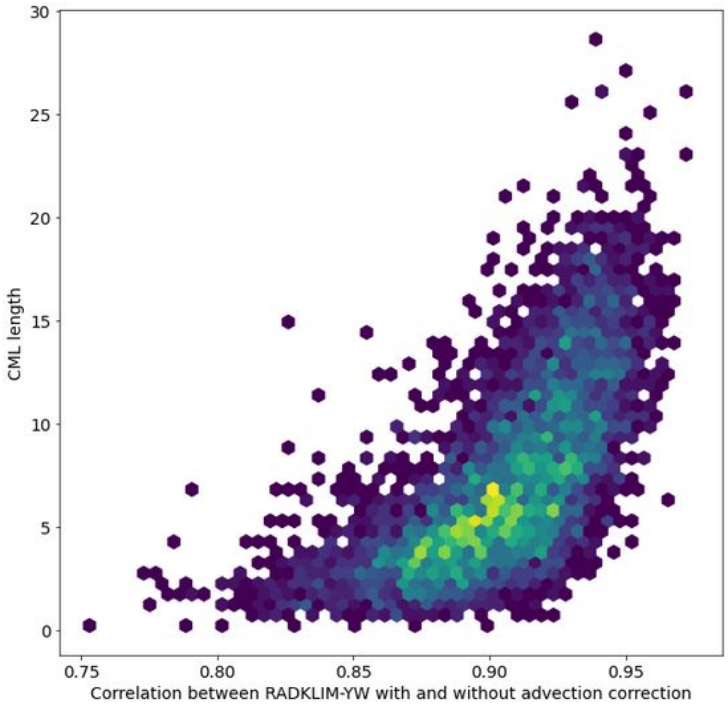
Advection correction: morphing for **1 minute radar along CML**



Raw vs. advection corrected RADKLIM-YW along CML paths (5 min)

⇒ large differences overall

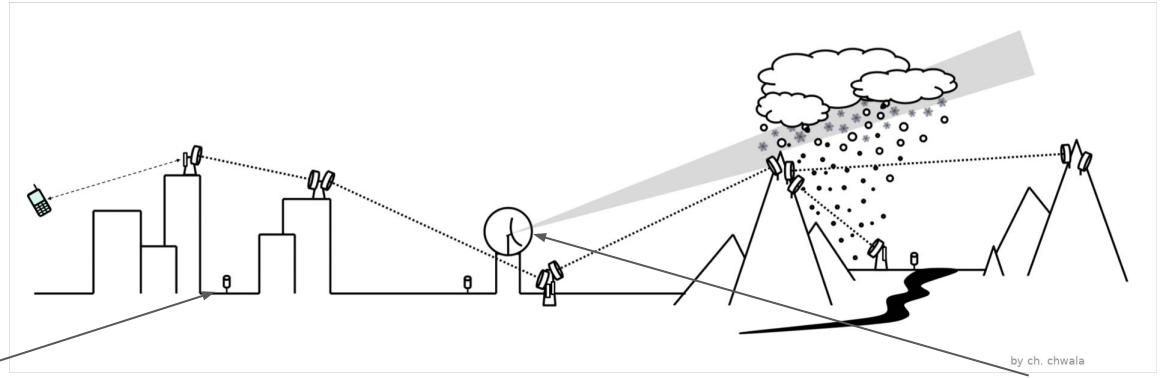
Advection correction: morphing for **1 minute radar along CML**



Correlation between raw and corrected for each CML

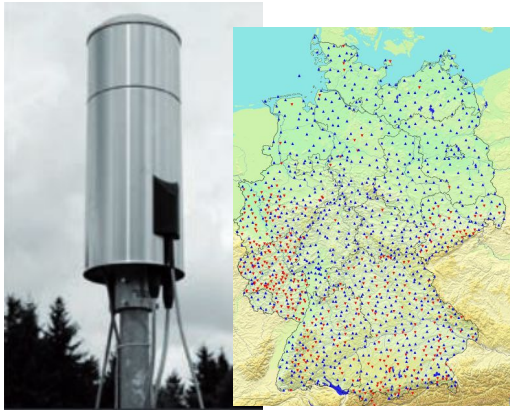
⇒ larger differences for short CMLs

Rainfall estimation in Germany

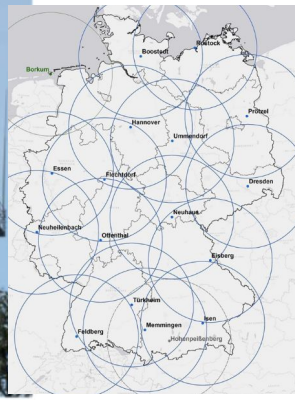


Rain Gauge

Weather radar

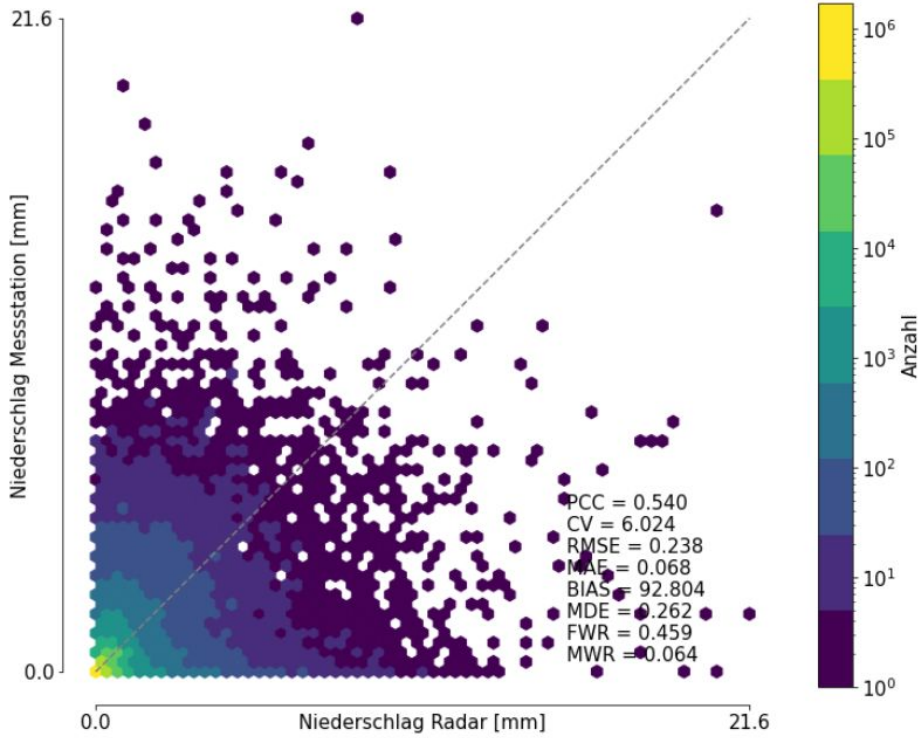


Source: DWD



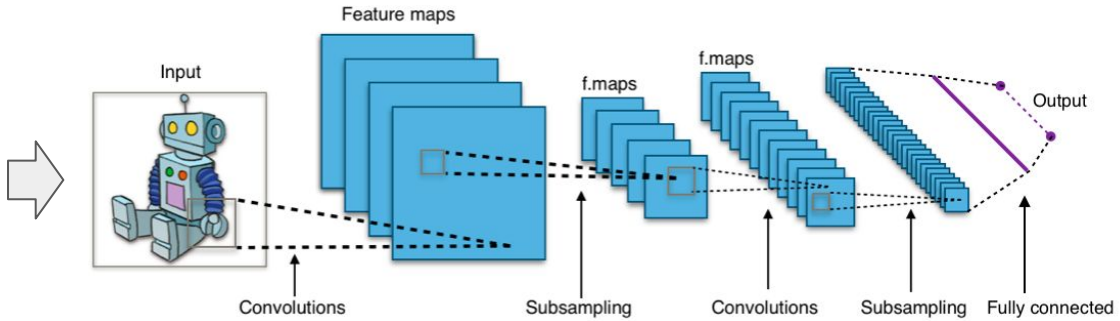
Source: DWD

RADOLAN-RY vs. 5 minute rain gauge data



Test lab: **Radar adjustment and potential merging using deep neural networks**

Source: DWD



Source: Wikimedia

Source: DWD

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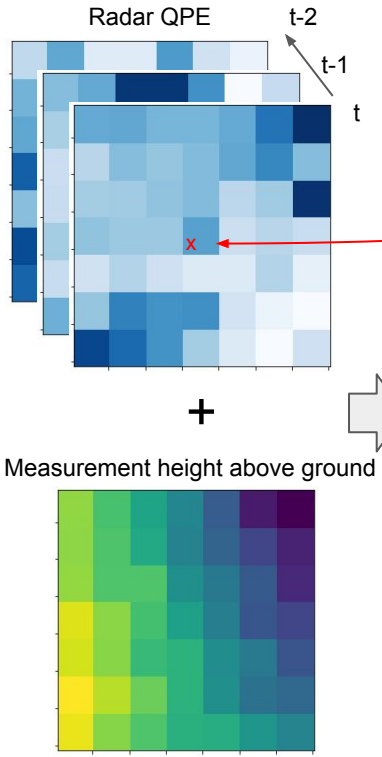

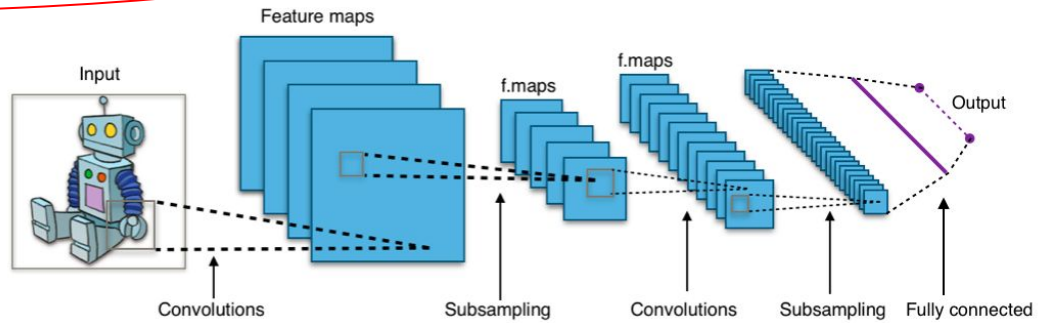

Source: Wikimedia

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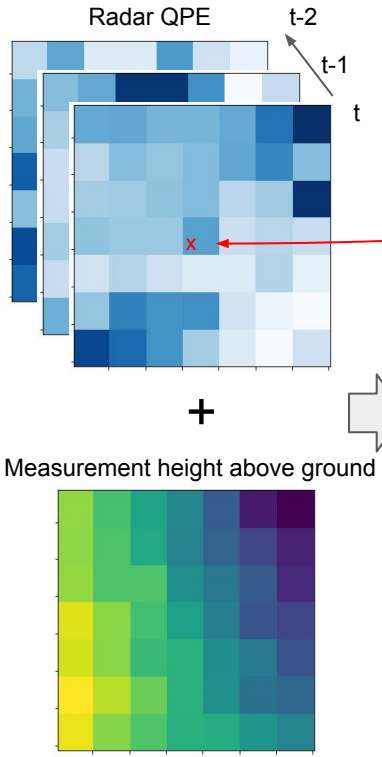
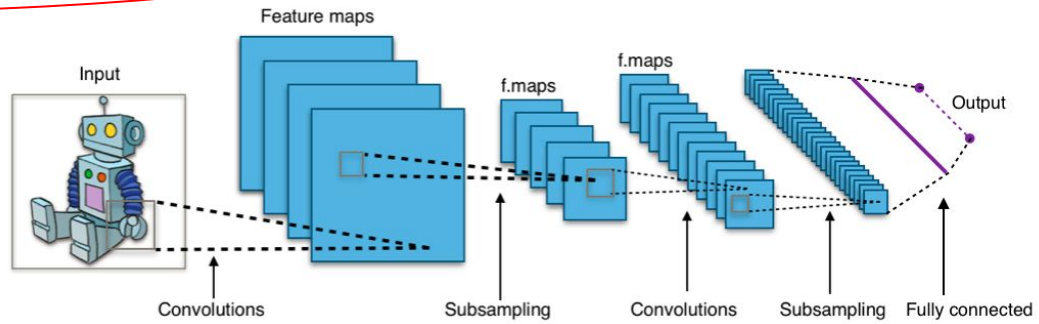
Test lab: **Radar adjustment and potential merging using deep neural networks**

Training data: RADOLAN-RY Summer 2017+2018

Shape: 7x7x3 (QPE) + 7x7 (height) at 5min temporal resolution



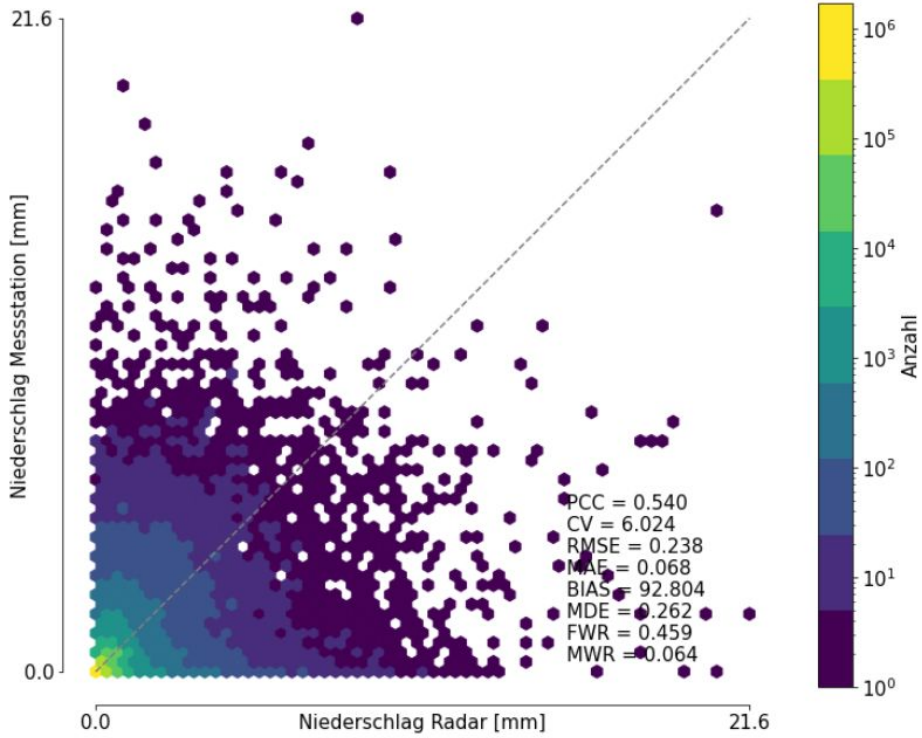


Source: Wikimedia

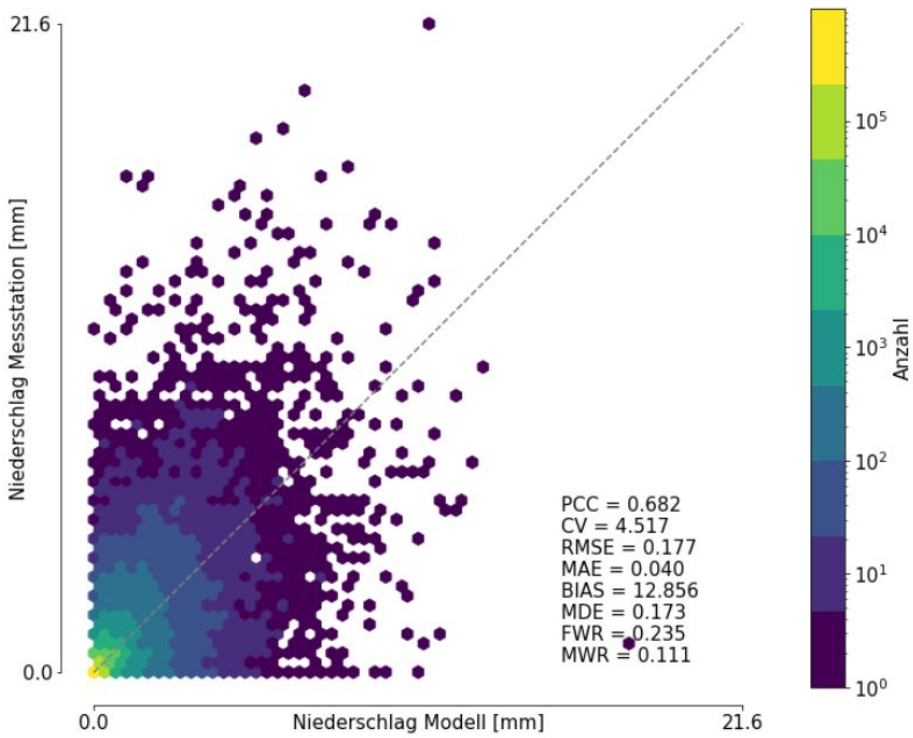
Source: DWD

Test lab: **Radar adjustment and potential merging using deep neural networks**

RADOLAN-RY



Neural network



Test lab: **Radar adjustment and potential merging using deep neural networks**

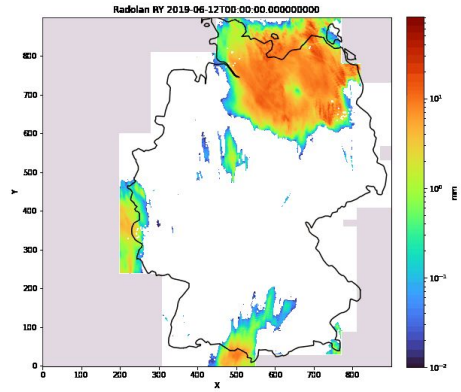
Gauge adjusted

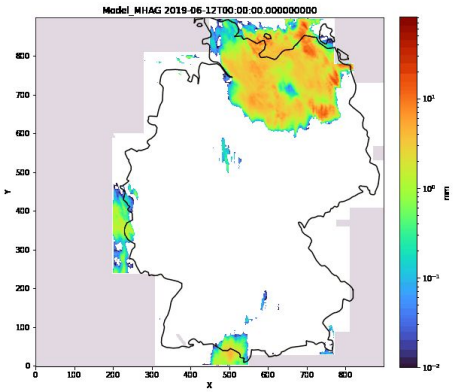
RADOLAN-RY

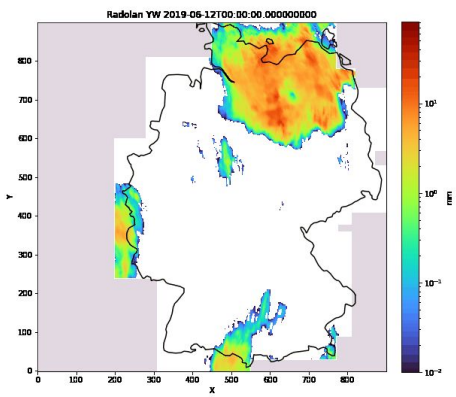
Neural network

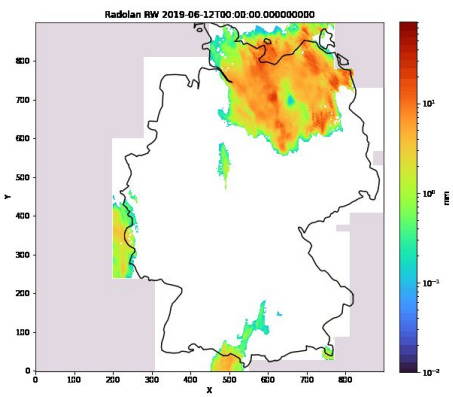
RADKLIM-YW
(advection corrected)

RADOLAN-RW



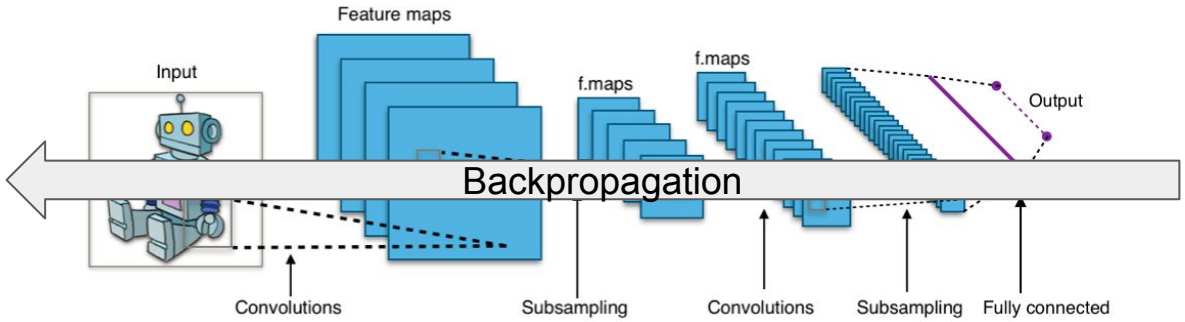






Next step: Heatmaps for advection and mismatch estimation

Source: DWD



Source: Wikimedia

Source: DWD

Probabilistic merging at increasing resolutions

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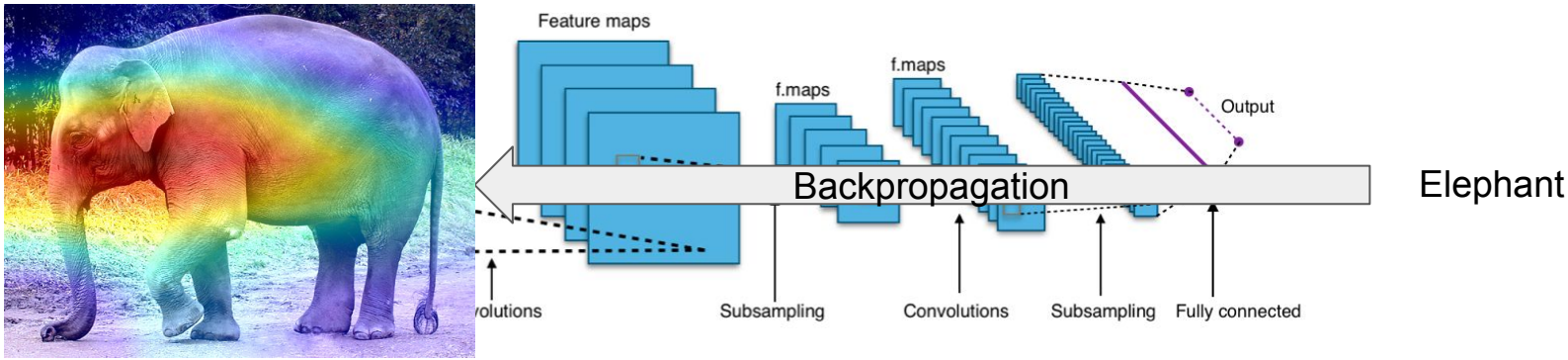
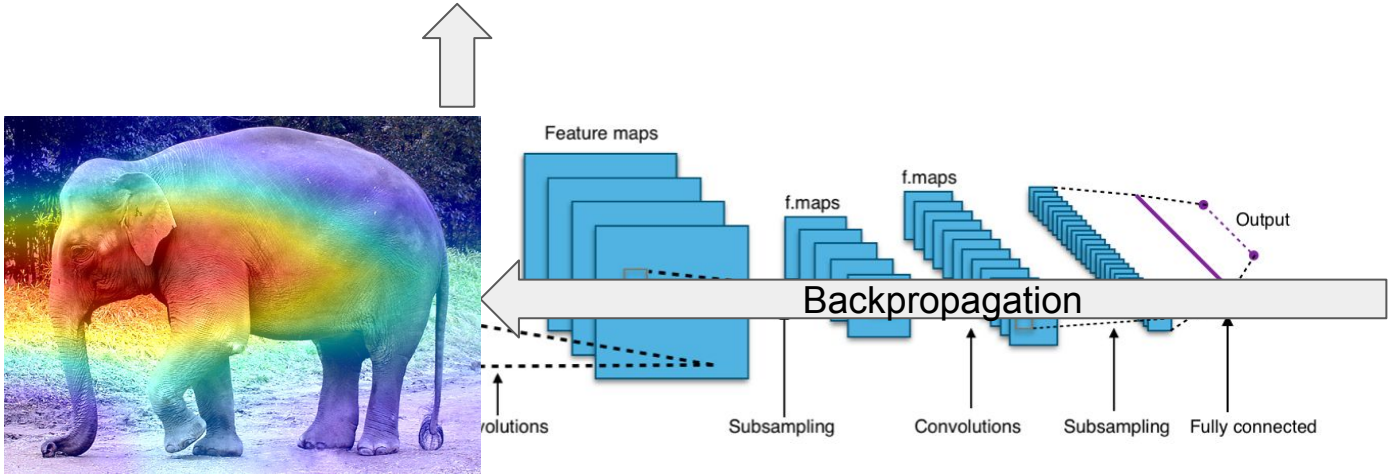


Source: Wikimedia

Probabilistic merging at increasing resolutions

Next step: Heatmaps for advection and mismatch estimation

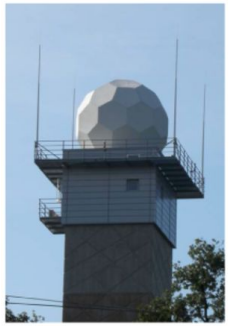
“Center of mass of temporal and spatial importance of input values”
(highly experimental)



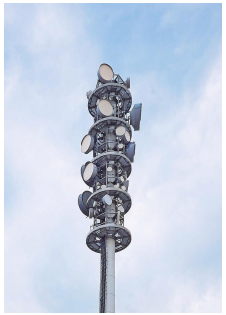
Source: Wikimedia

Probabilistic merging at increasing resolutions

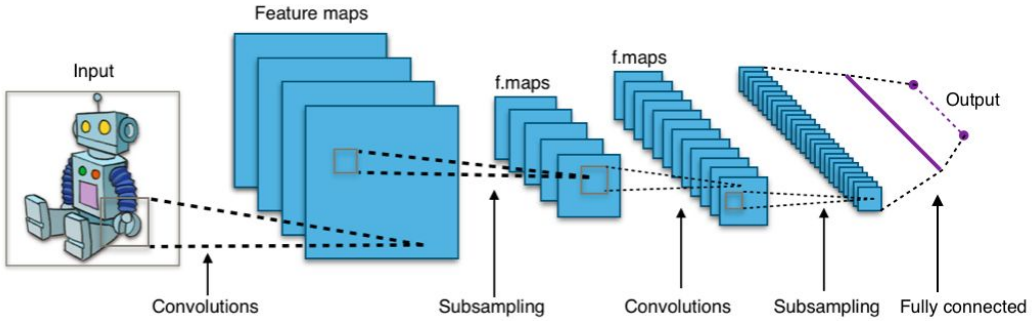
Next step: Potential for merging



Source: DWD



Source: C. Ruf, KIT

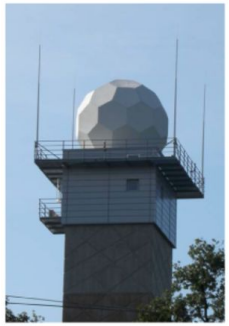


Source: Wikimedia

Source: DWD

Probabilistic merging at increasing resolutions

Next step:



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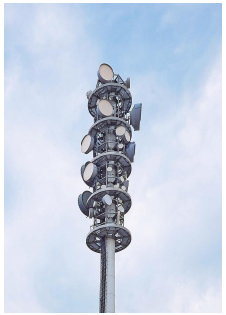

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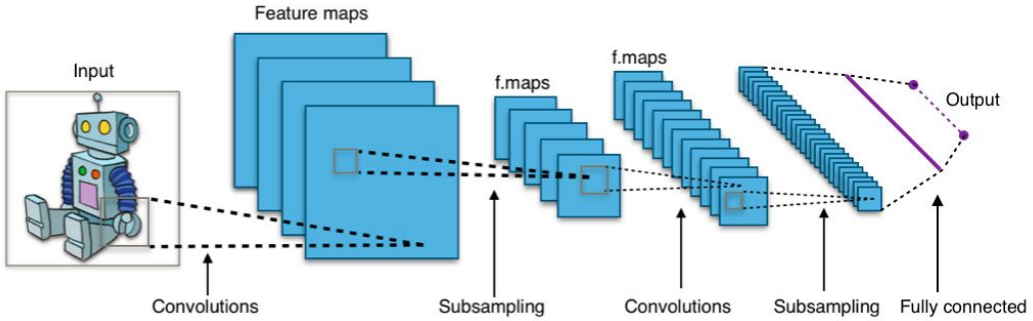
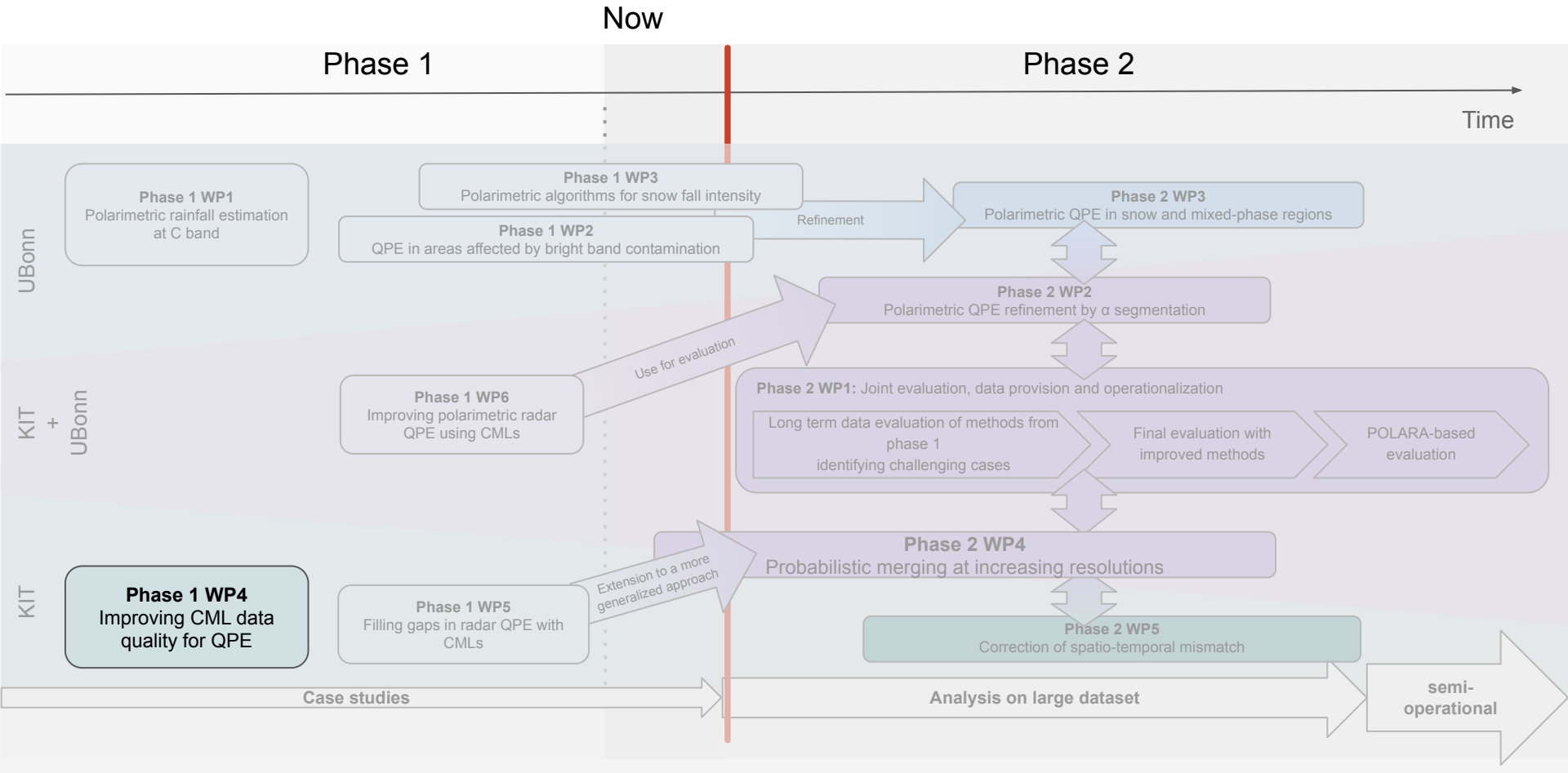


Source: Wikimedia

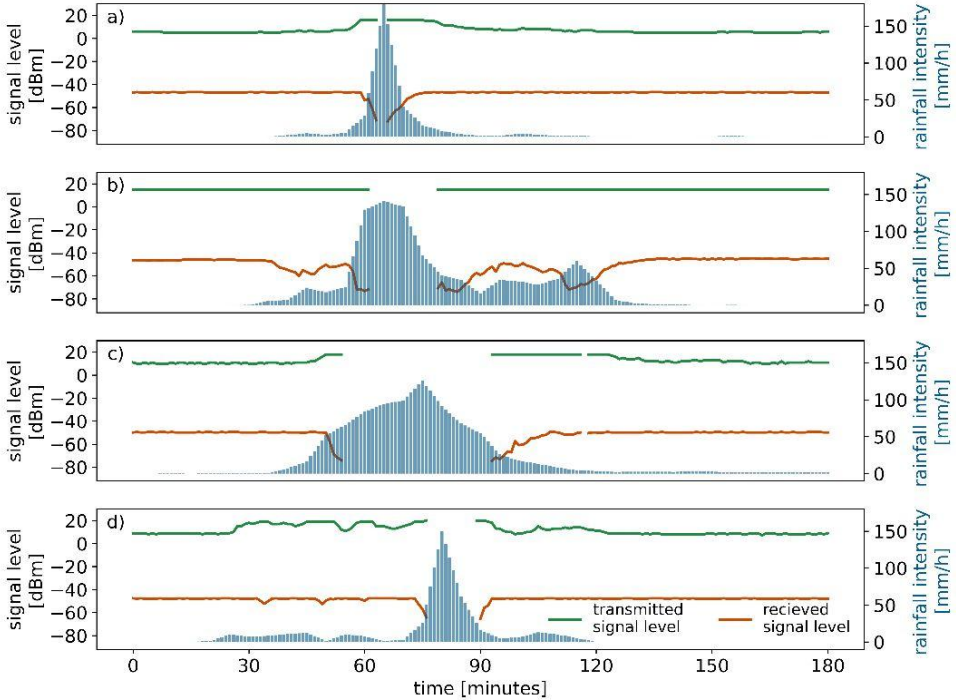
Source: DWD

Probabilistic merging at increasing resolutions

P1 Flowchart



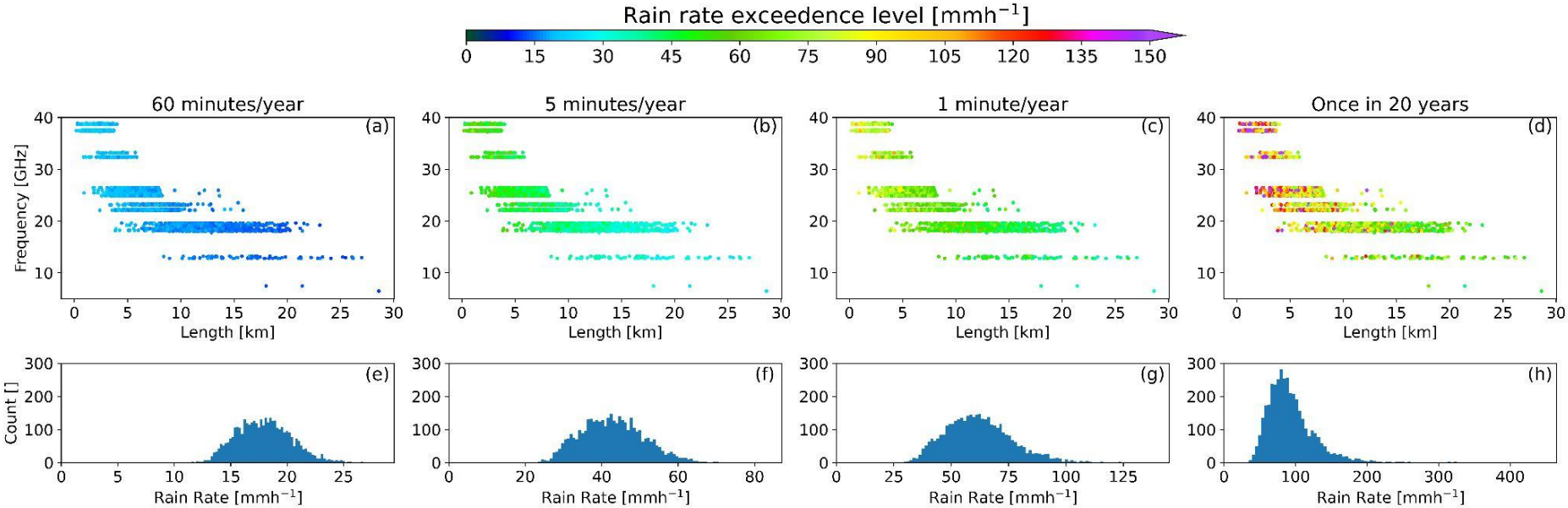
CML blackouts: An attenuation climatology from RADKLIM



From a paper submitted to Geophysical research letters

⇒ During extreme rain events CMLs suffer from complete loss of signal

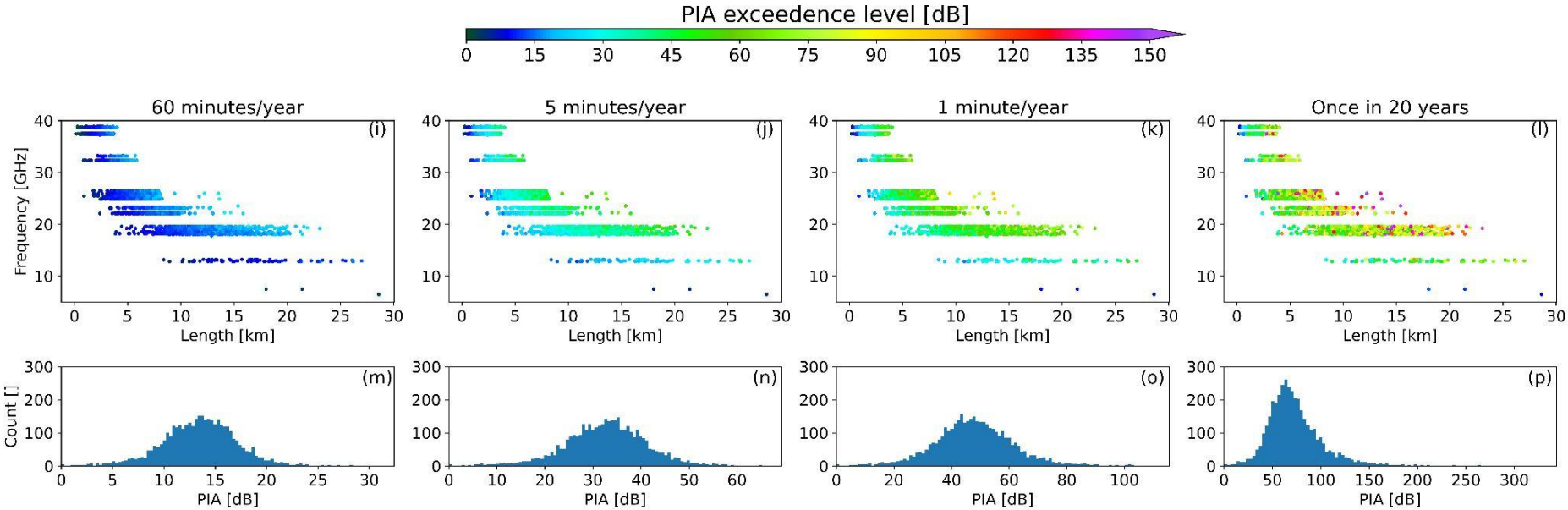
CML blackouts: An attenuation climatology from RADKLIM



Database: 20 years of quasi gauge adjusted RADKLIM-YW at a 5 minute resolution

⇒ larger extreme values for short CMLs

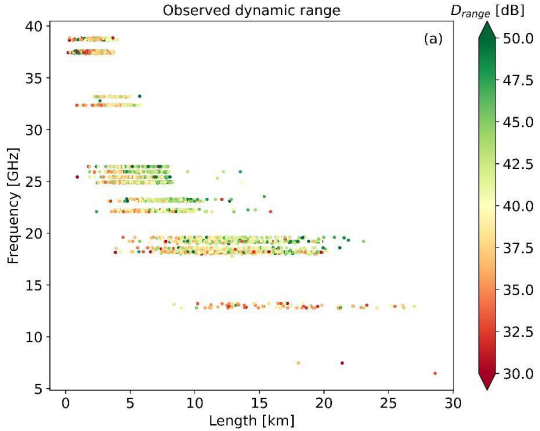
CML blackouts: An attenuation climatology from RADKLIM



Conversion via k-R relation

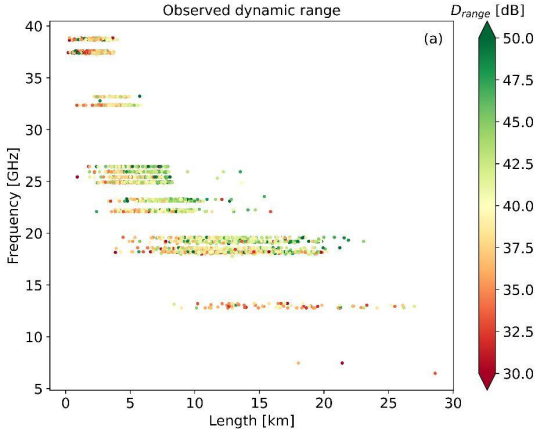
⇒ larger extreme values for long CMLs

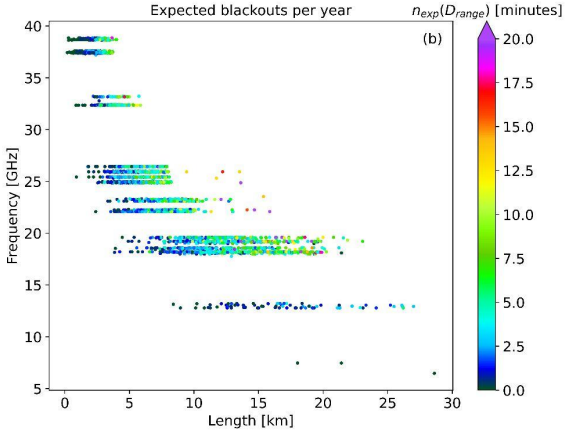
CML blackouts: An attenuation climatology from RADKLIM

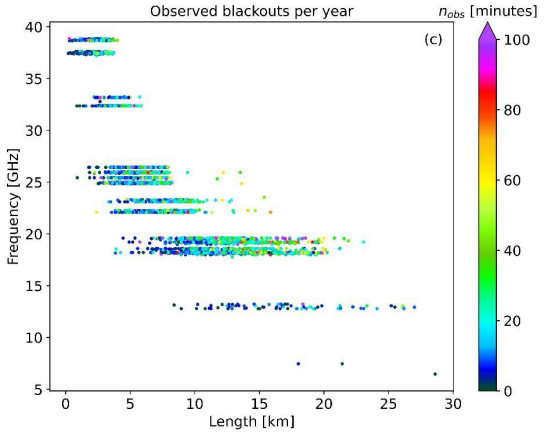


Minimal and maximal signal levels lead to a dynamic signal range estimate, i.e. how much attenuation can we measure?

CML blackouts: An attenuation climatology from RADKLIM

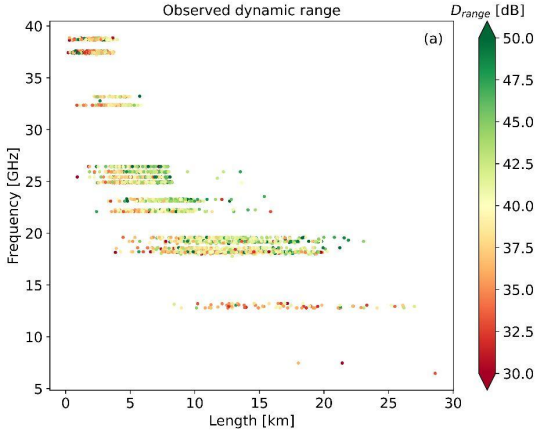


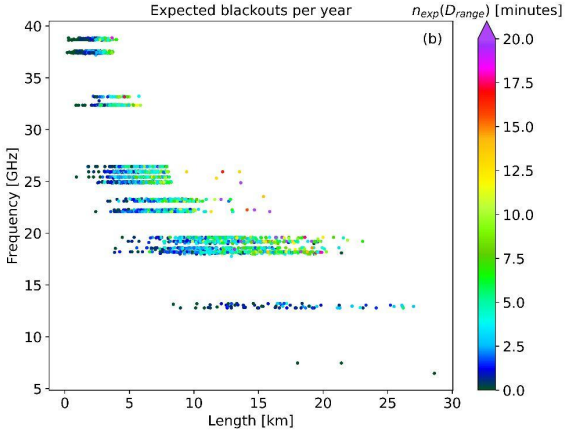


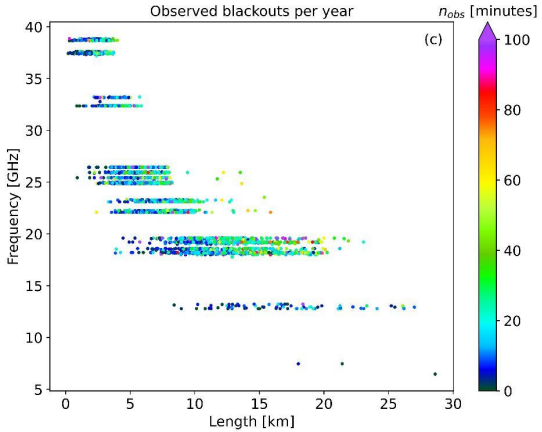


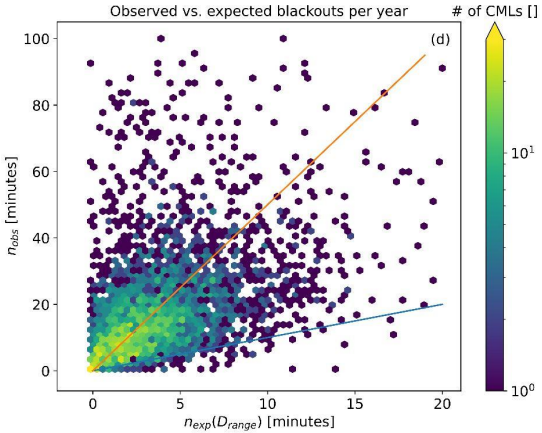
Dynamic range and attenuation climatology allow for expected blackout estimate

CML blackouts: An attenuation climatology from RADKLIM









Key message: RADKLIM-YW based PIA underestimates extreme values


03
MY4658_2_MY1905_3
Save flags
Flag period
trsl1 trsl2 R
count 44313.000000 44313.000000 44194.000000
mean 62.751846 69.587708 0.070667
std 0.977011 0.833733 0.409807
min 60.299999 67.199997 0.000000
25% 62.200001 69.099998 0.000000
50% 62.500000 69.400002 0.000000
75% 63.099998 70.000000 0.000000
max 70.599998 77.500000 8.916553
Delete all flags
Delete selected type of flags
Delete selected type of flags
Dry
Wet
Anomaly
Dew
LOL
CML signal level
channel 1
channel 2
Dry Wet Anomaly Dew LOL
CML and radar rainfall
R_CML
RADOLAN-RW
RADKLIM-YW
Surface temperature
Dew point tempreature
ERA5land
3/01
3/08
3/15
3/22
4/01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channel 1
channel 2
Dry Wet Anomaly Dew LOL
R_CML
RADOLAN-RW
RADKLIM-YW
Surface temperature
Dew point tempreature
3/05
12h
3/06
12h
3/07
12h
Dew on antenna

Thank you!

Discussion points:

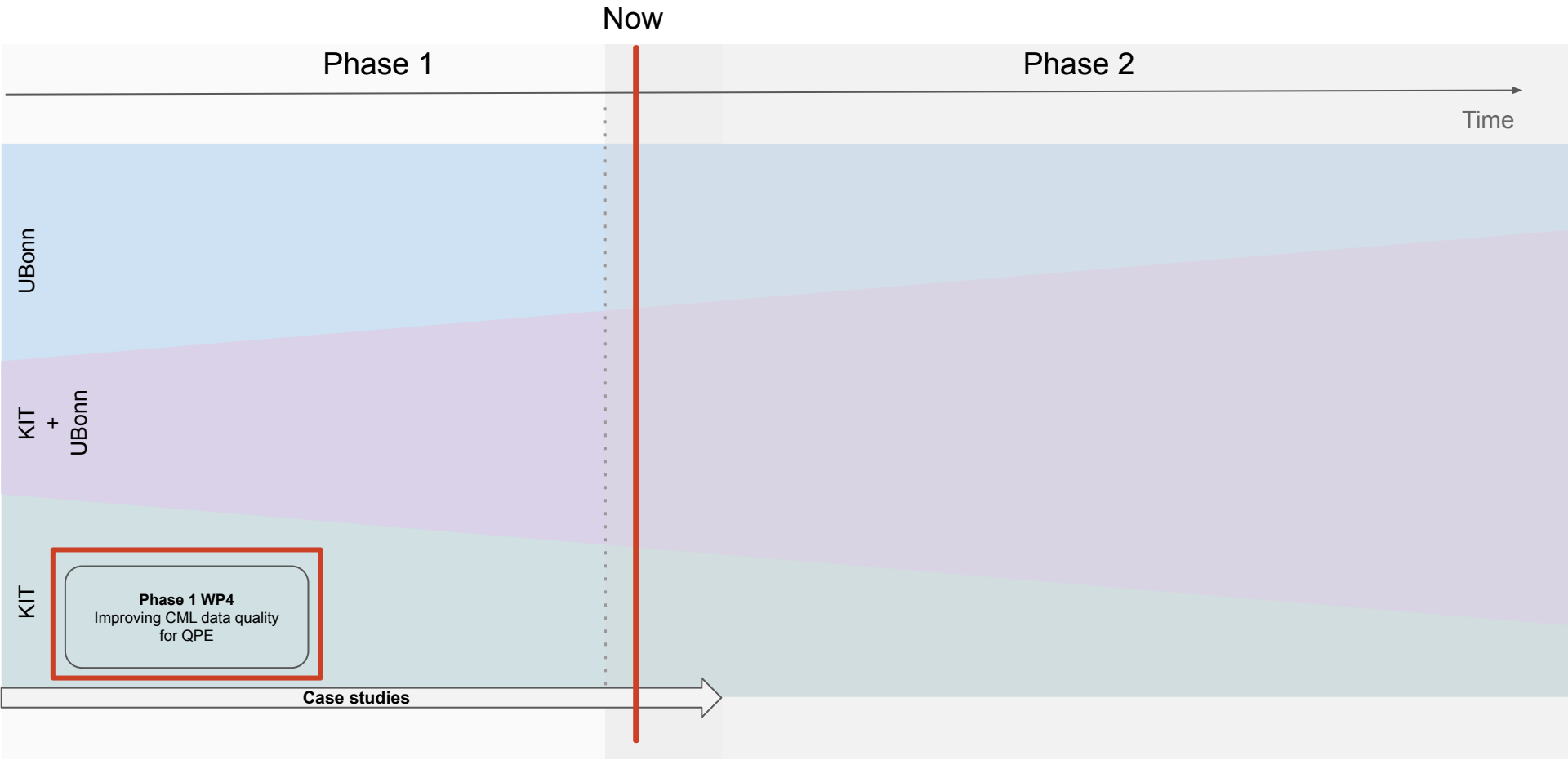
- Who has insights/experience with advection correction? Why is this not standard procedure?
- What next?

Discussion points last time:

- Date for possible Bonn/Garmisch visit/exchange for multiple days to accelerate progress
  - I could travel in March or April
- Who can share experience with PySTEPS?
- Phase 2: Who started when and are we aligned?
- 3 month data: discuss later?
- Joint case study paper: What is the objective? RealPEP showcase or “competition” for best analysis? 😉

Backup

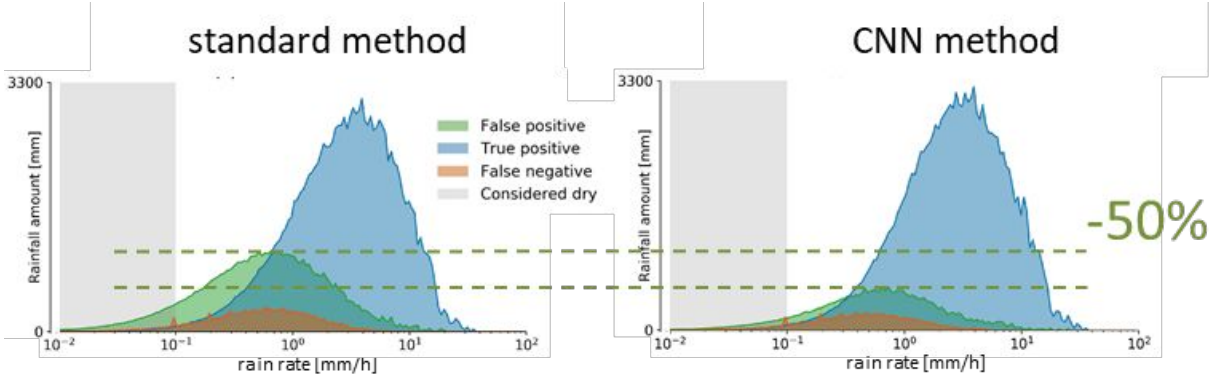
P1 Flowchart



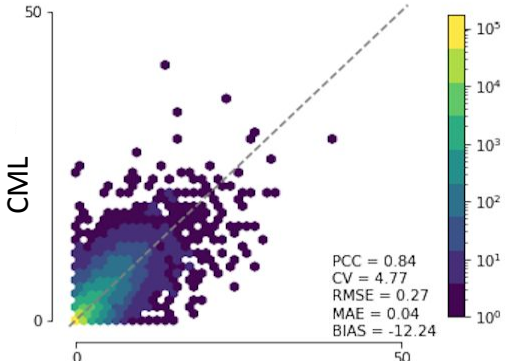
Phase 1 WP4
Improving CML data quality for QPE

Improved detection of wet periods

Significant reduction of false-positive rain events with CNN method



Large scale evaluation demonstrated good CML performance

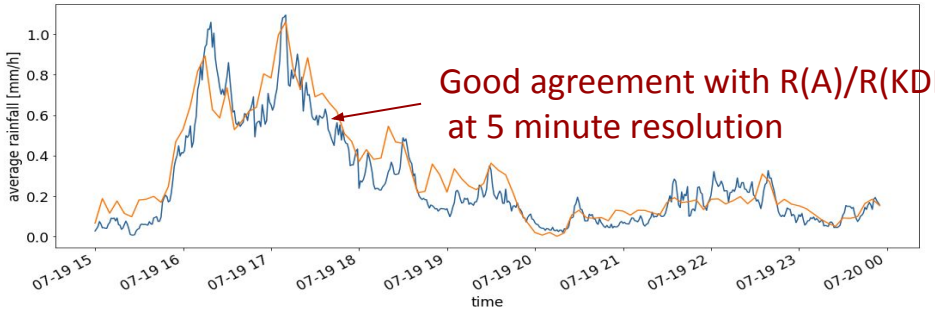


RADOLAN-RW along CML

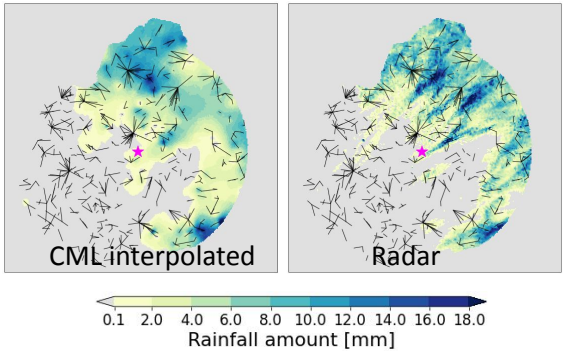
Phase 1: CML+Radar Case study days

Average intensity over all CML paths

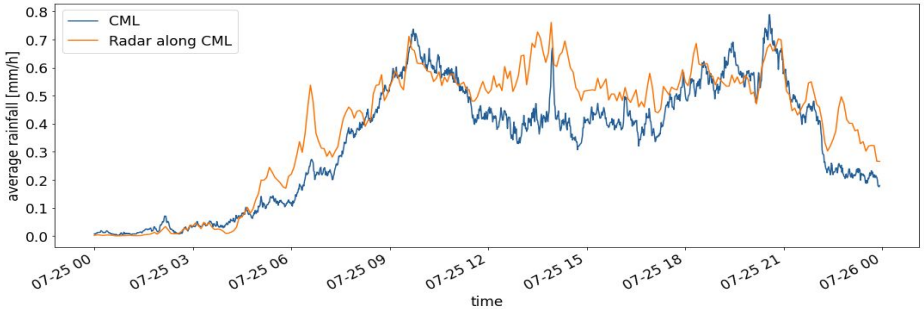
2017-07-19 - Convective rainfall - OFT Radar



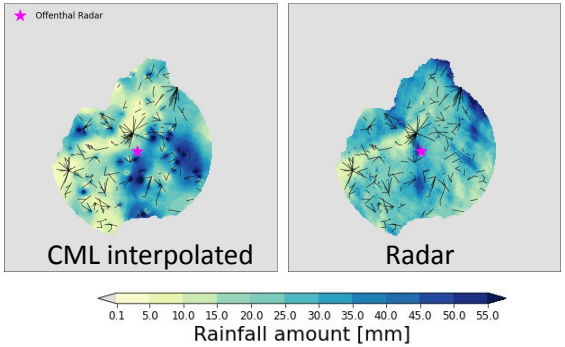
Sum over event



2017-07-25 - Stratiform rainfall - OFT Radar



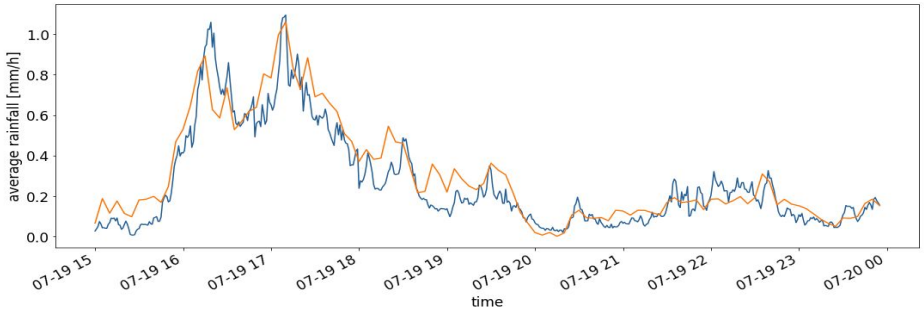
Sum over event



Phase 1: CML+Radar Case study days

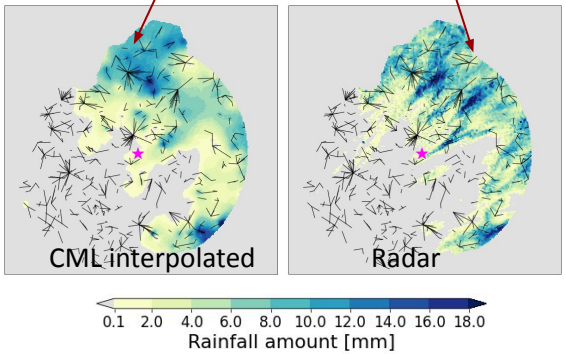
Average intensity over all CML paths

2017-07-19 - Convective rainfall - OFT Radar

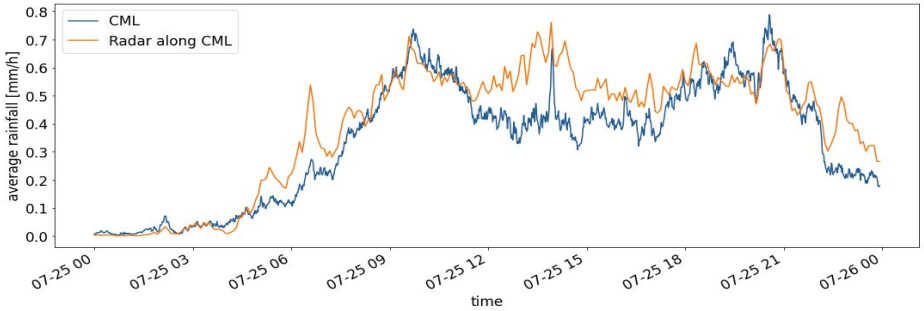


Good agreement of event sum

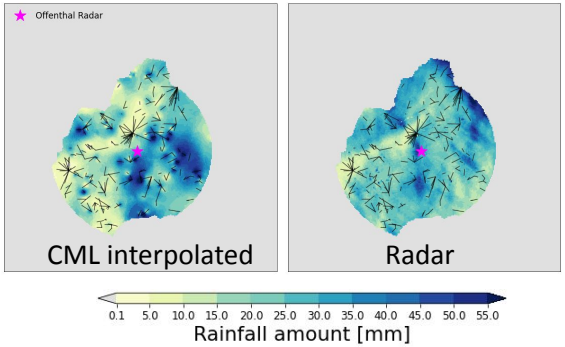
Sum over event



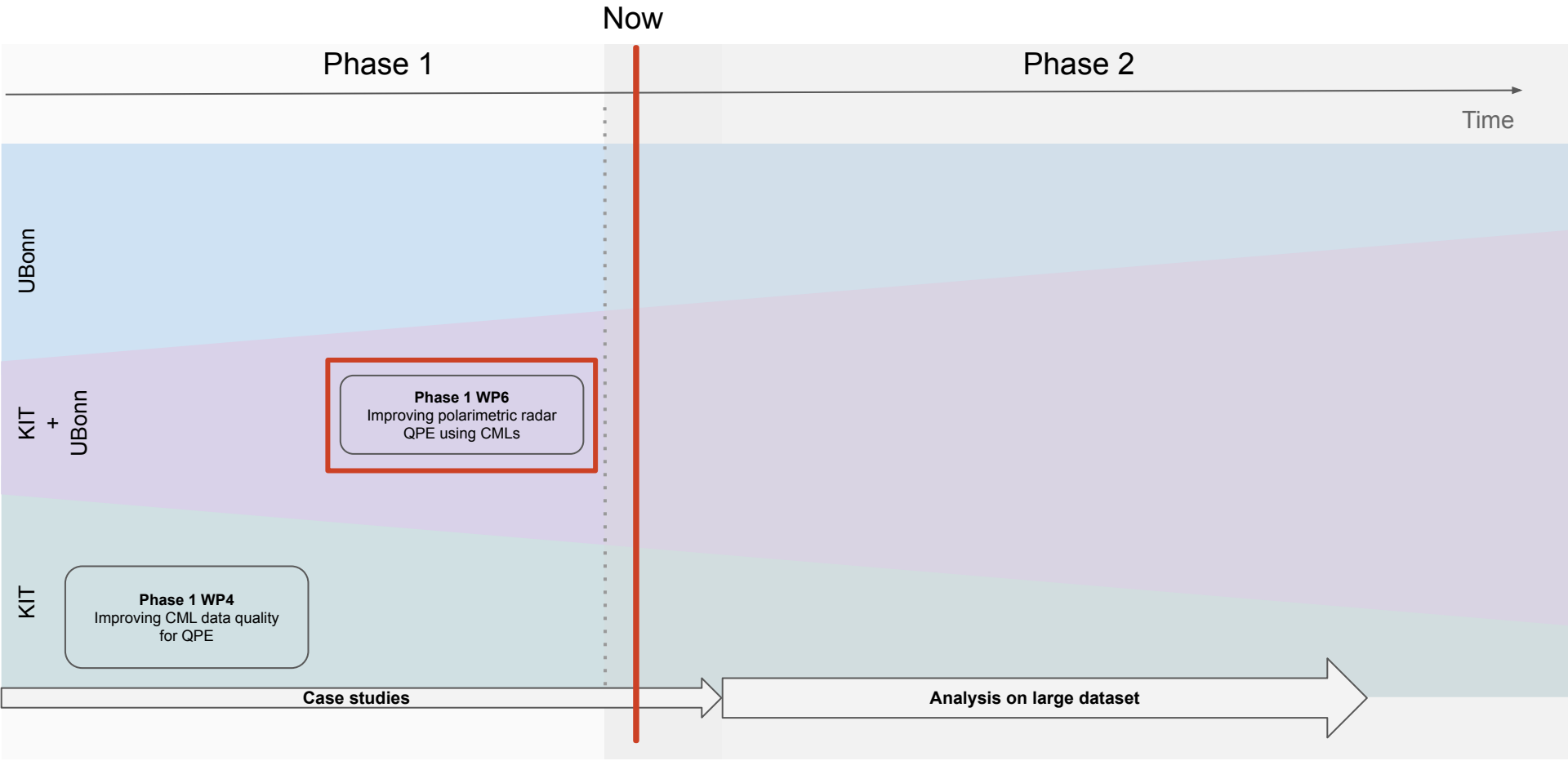
2017-07-25 - Stratiform rainfall - OFT Radar



Sum over event

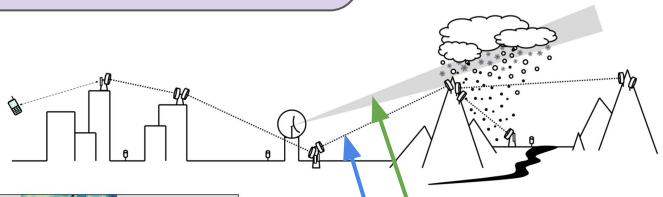


P1 Flowchart

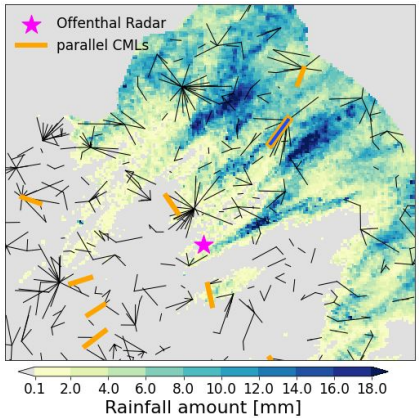


Phase 1 WP6
Improving polarimetric radar QPE using CMLs

Temporal shift needs compensation



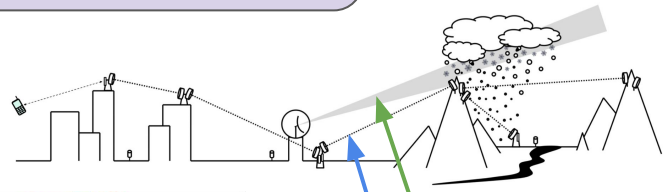
$$\alpha = \frac{2PIA_1(5.66GHz)}{\Delta\varphi_{DP}}$$



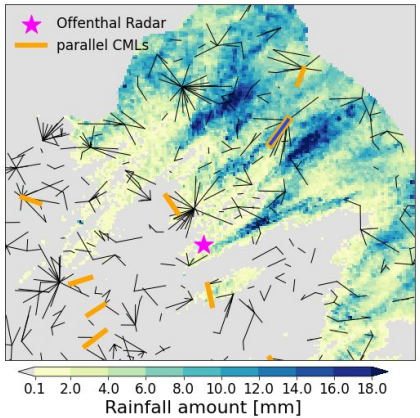
Trömel et al. 2014

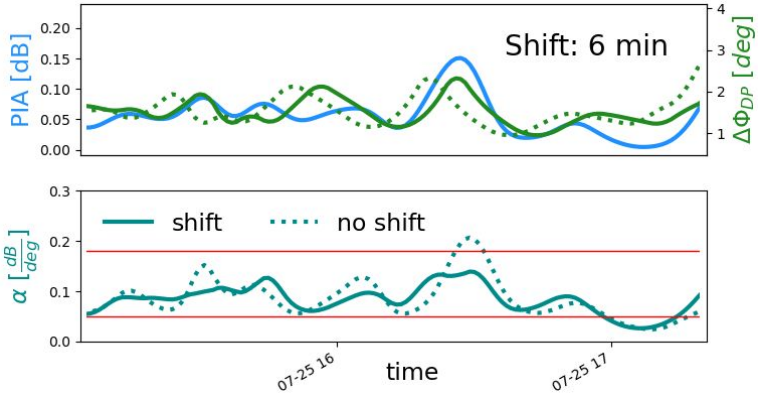
Phase 1 WP6
Improving polarimetric radar QPE using CMLs

Temporal shift needs compensation



$$\alpha = \frac{2PIA_1(5.66GHz)}{\Delta\varphi_{DP}}$$

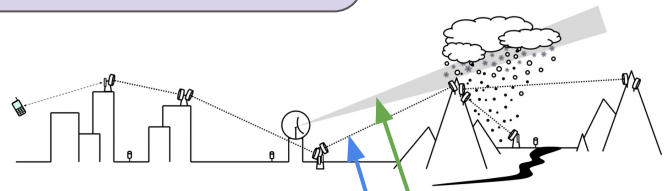




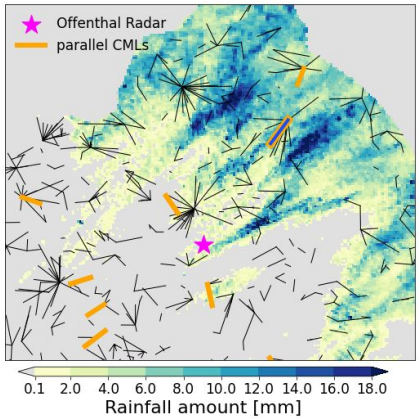
Trömel et al. 2014

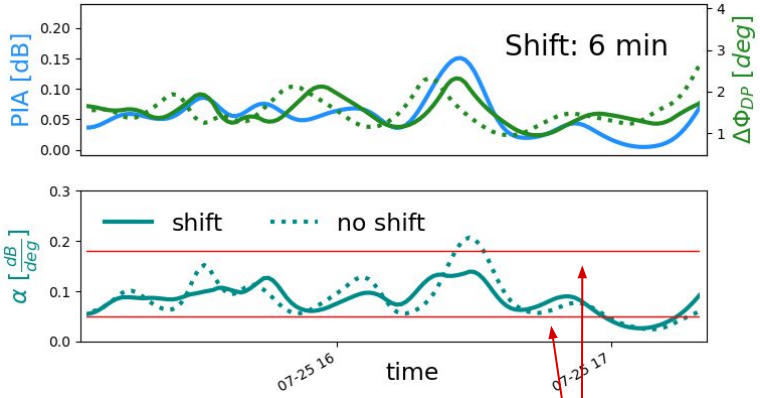
Phase 1 WP6
Improving polarimetric radar QPE using CMLs

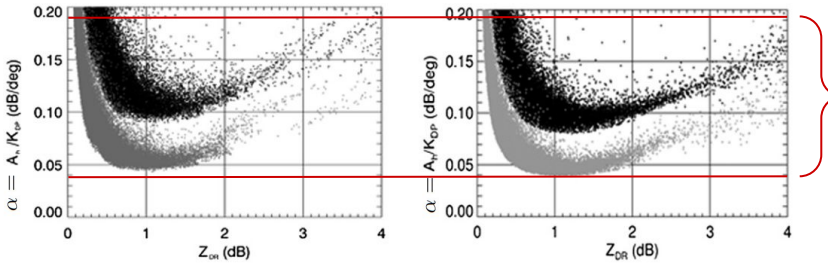
Temporal shift needs compensation



$$\alpha = \frac{2PIA_1(5.66GHz)}{\Delta\varphi_{DP}}$$





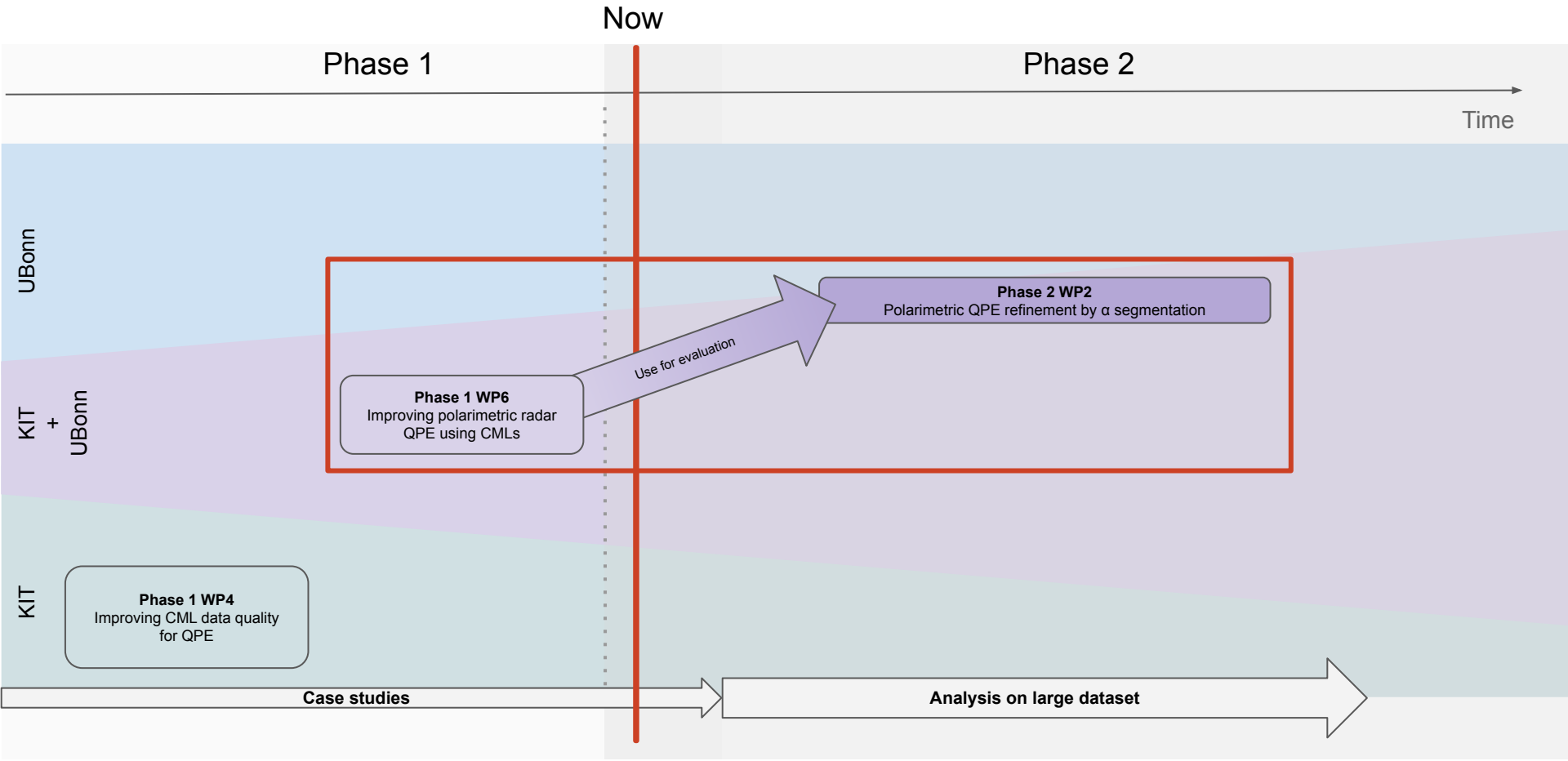


physical bounds

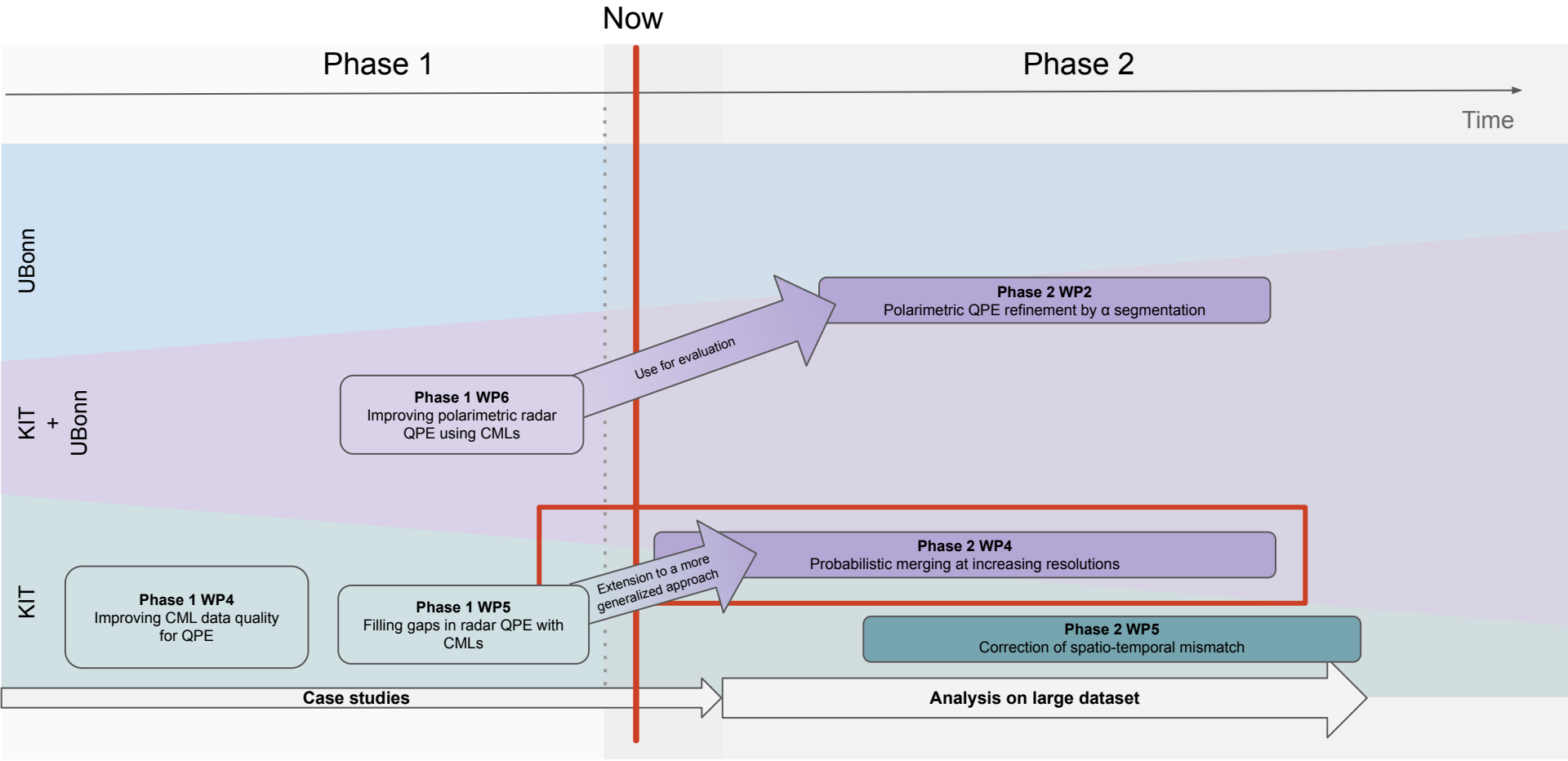
FIG. 2. Scatterplots of $\alpha = A_h/K_{DP}$ vs Z_{DR} at C band based on disdrometer measurements in (left) Bonn and (right) Oklahoma at 0° (black dots) and 30°C (gray dots).

Trömel et al. 2014

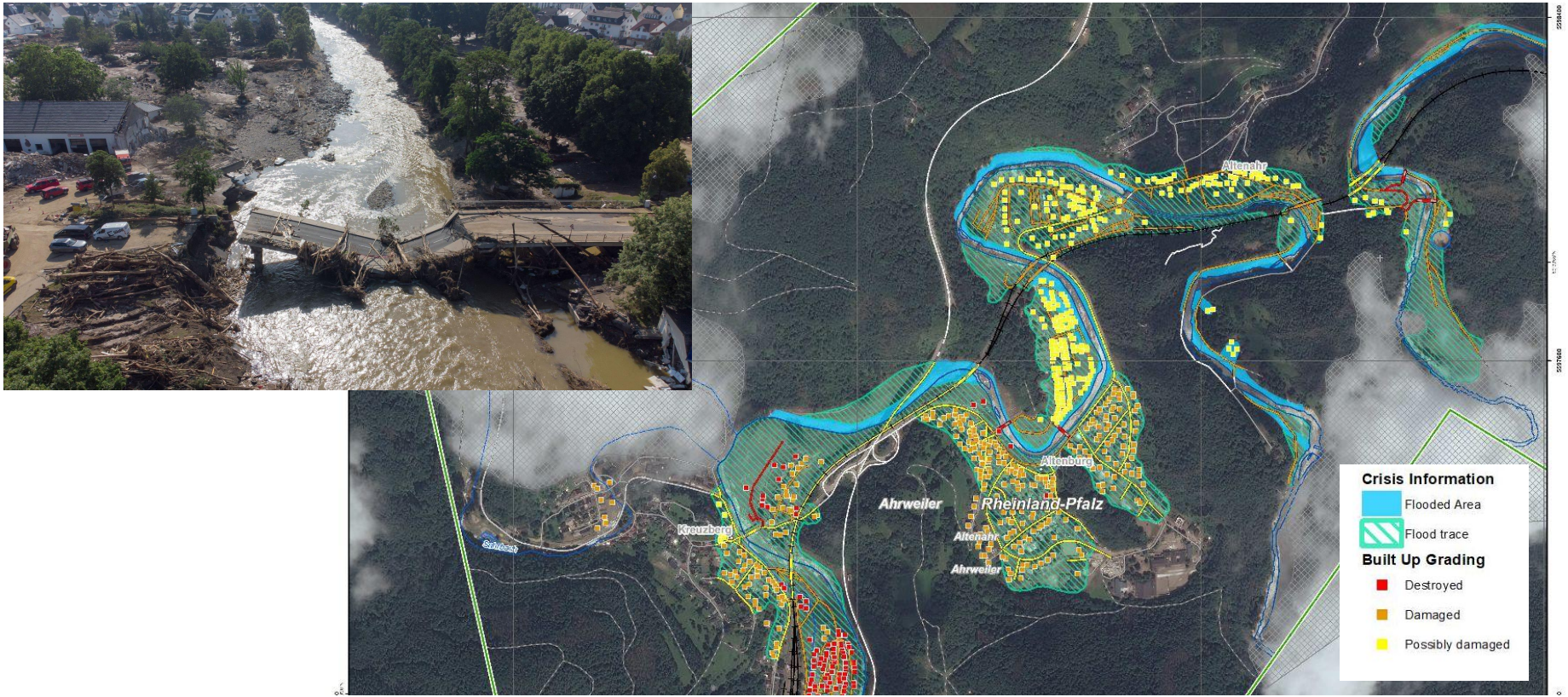
P1 Flowchart



P1 Flowchart

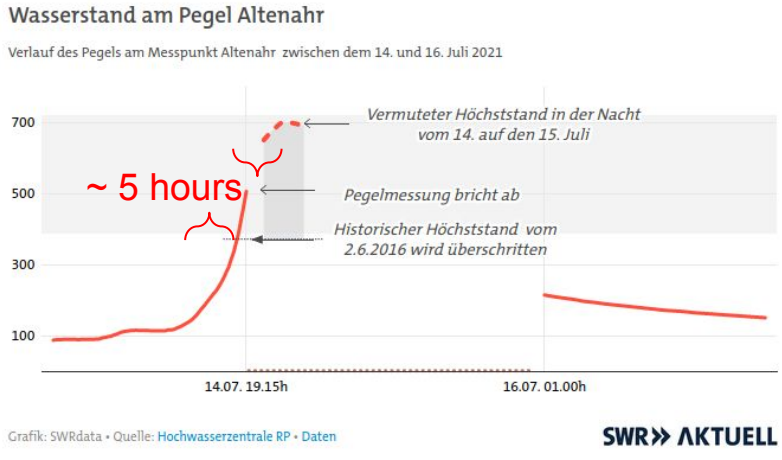


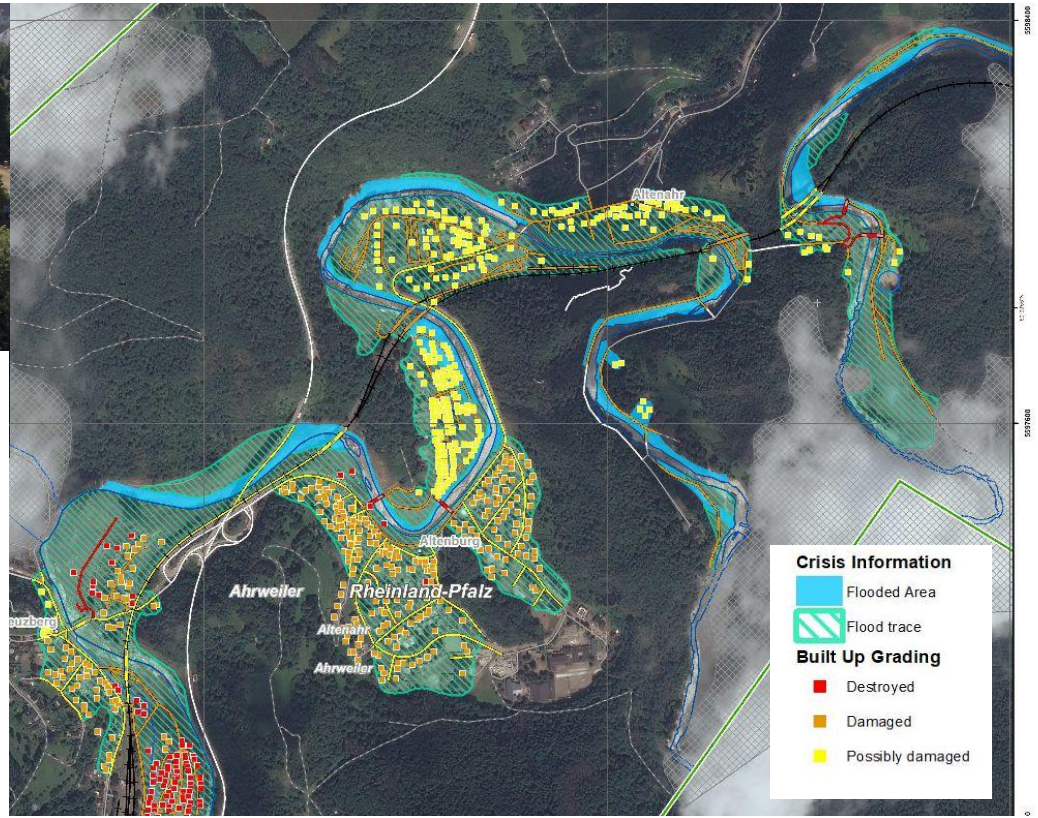
Ahrweiler, Germany, Situation as of 18.07.2021



Source: https://emergency.copernicus.eu/mapping/list-of-components/EMSR517/GRADING/EMSR517_AOI15

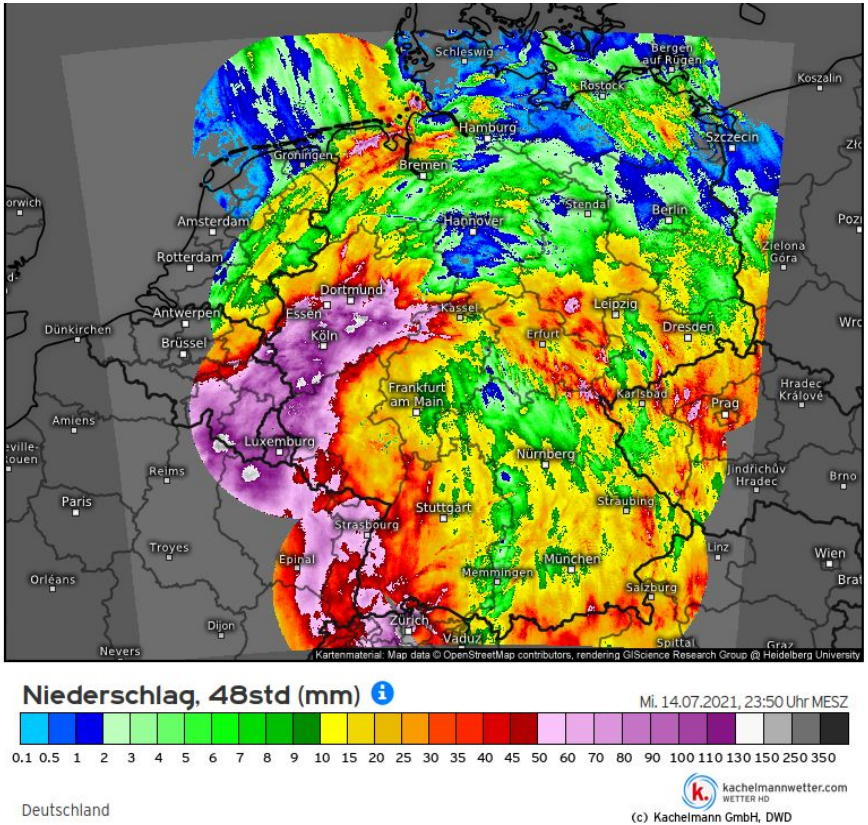
Ahrweiler, Germany, Situation as of 18.07.2021

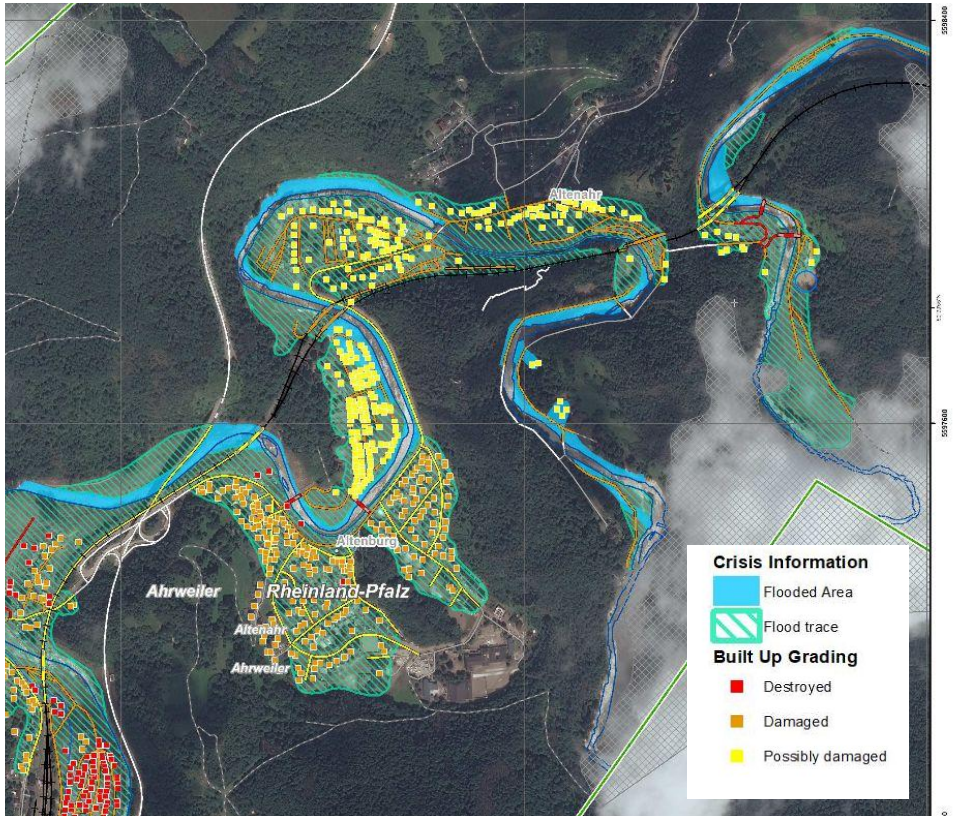




Source: https://emergency.copernicus.eu/mapping/list-of-components/EMSR517/GRADING/EMSR517_AOI15

Germany, 48h rainfall sum until 14.07.2021 11:50PM

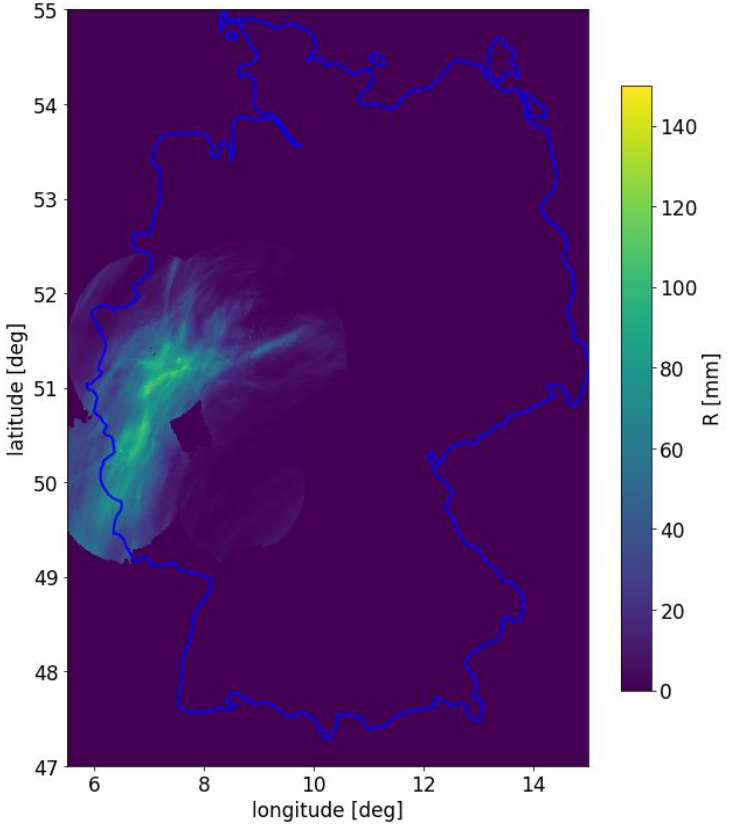




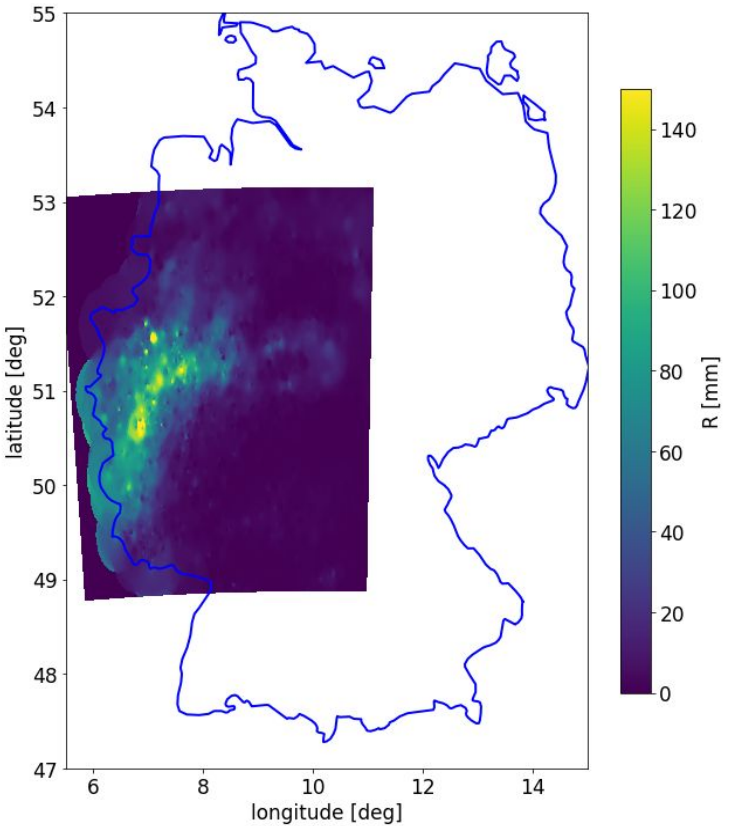
Source: https://emergency.copernicus.eu/mapping/list-of-components/EMSR517/GRADING/EMSR517_AOI15

24h rainfall sum on 14.07.2021

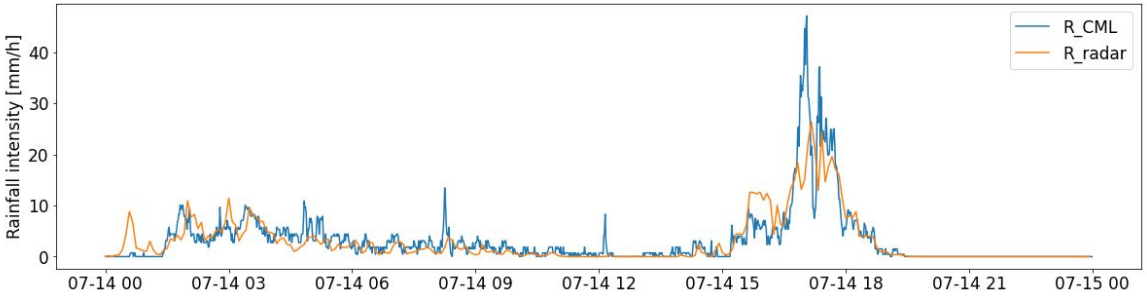
RAHKDP

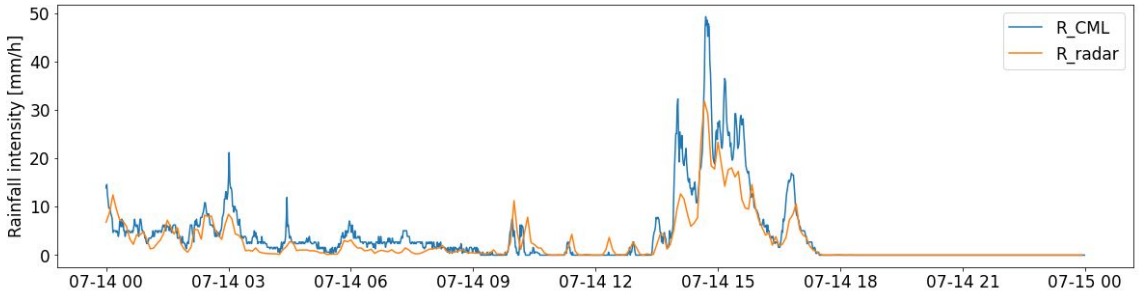


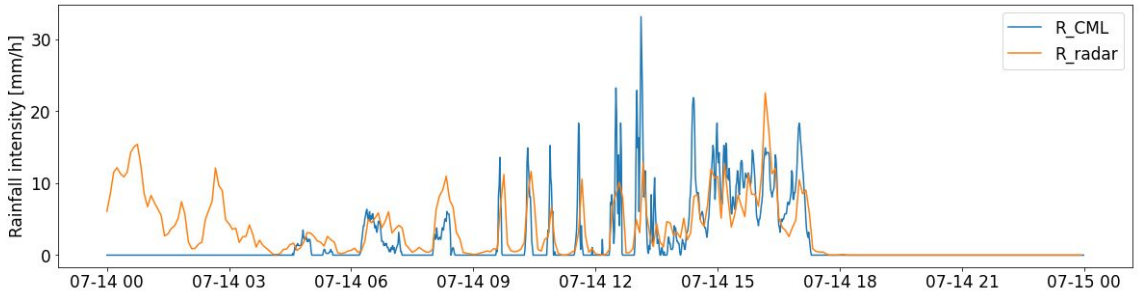
CML



Radar underestimation!?

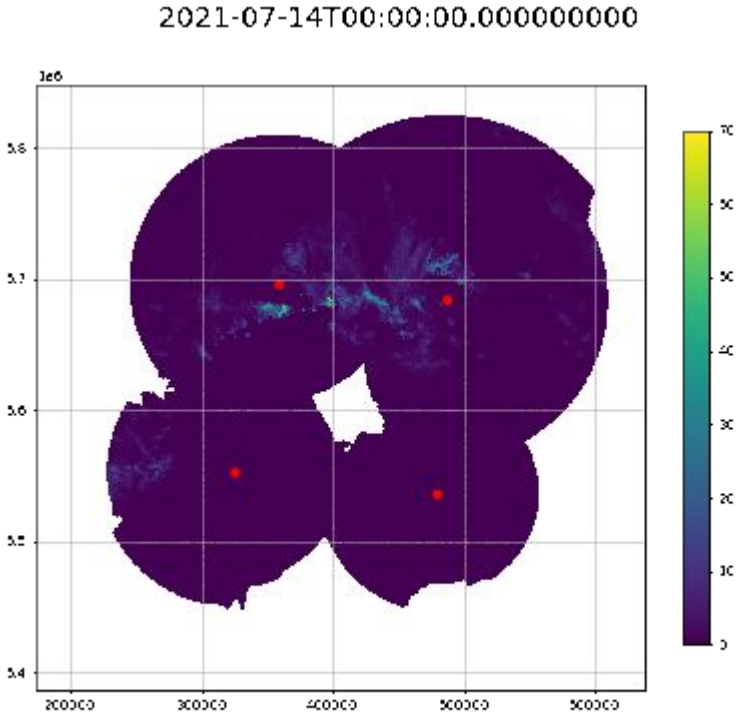




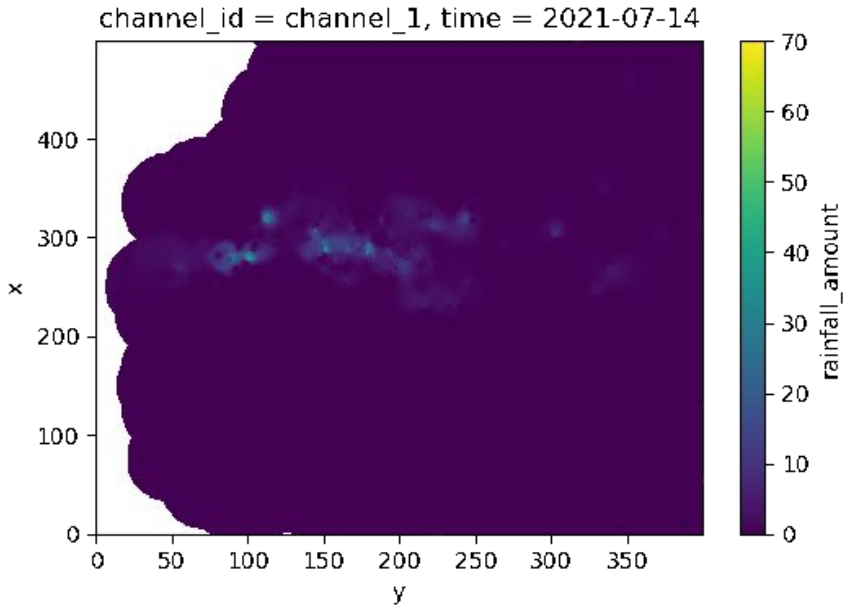


24h rainfall sum on 14.07.2021

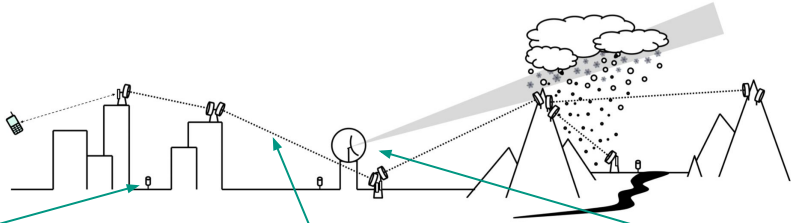
RAHKDP



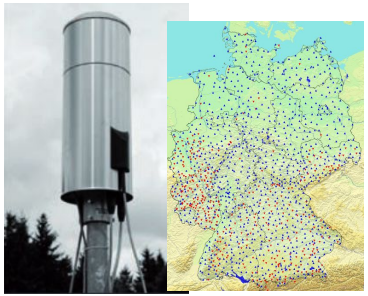
CML



Different integration characteristics



Rain Gauge



Source: DWD

QPE + Random error

Commercial microwave link (CML)

Source: C. Ruf, KIT

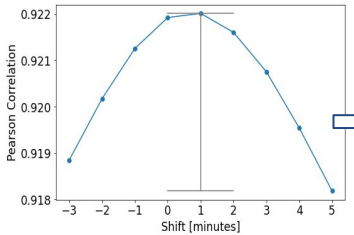
QPE + Random error

Dual-pol weather radar

Source: DWD

QPE + Random error

Bayesian merging framework

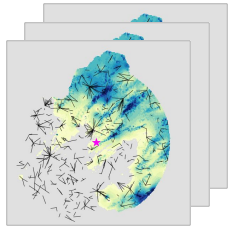


QPE

+ correct systematic error
+ compensate mismatch

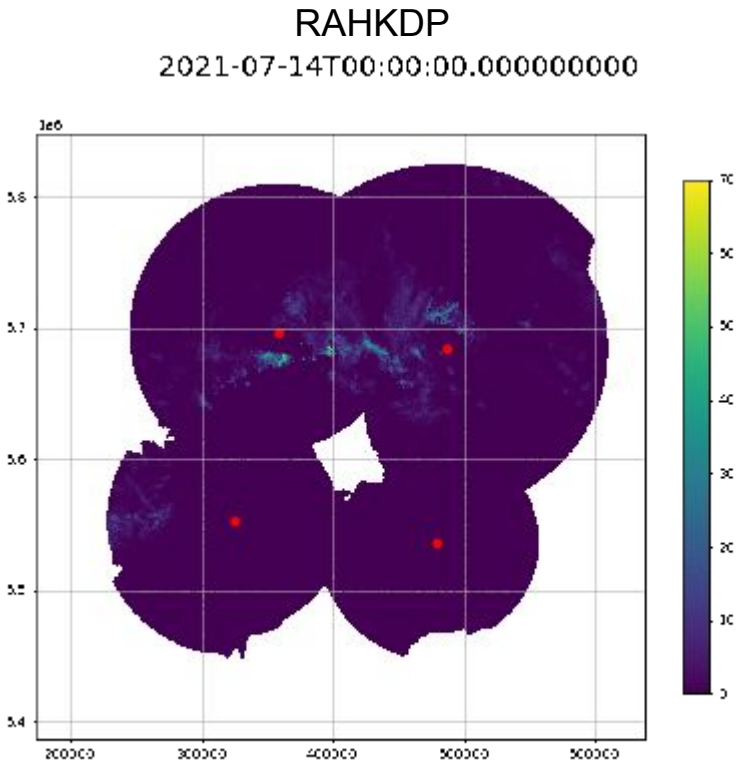
Random error

+ combine individual error models



WP-P1-4: Probabilistic merging at increasing resolutions (UBonn and KIT, months 1 - 33)

M-P1-10: Precipitation estimates from different sensors are compared at a 1-minute resolution (month 6)



Next step:

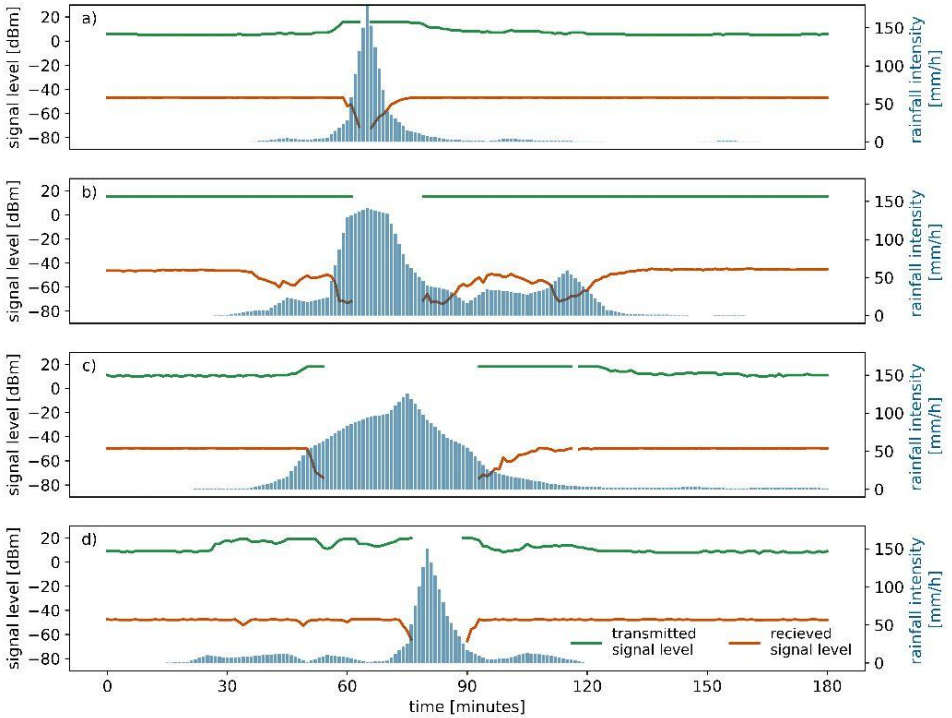
Use PySTEPS advection correction to produce “intermediate” steps at a 1 minute resolution.

Lucas-Kanade optical flow algorithm is ready, but results are not. More advanced algorithms to be tested

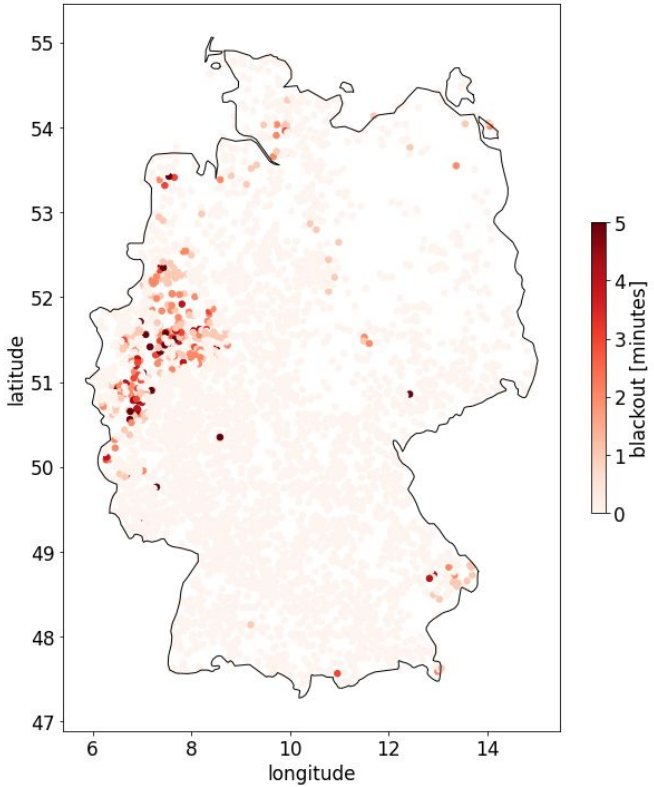
⟶ Prepare to process 3 months of data

CML “blackouts” on 14.07.2021

Extreme example blackouts - Path averaged Intensity from RADKLIM-YW

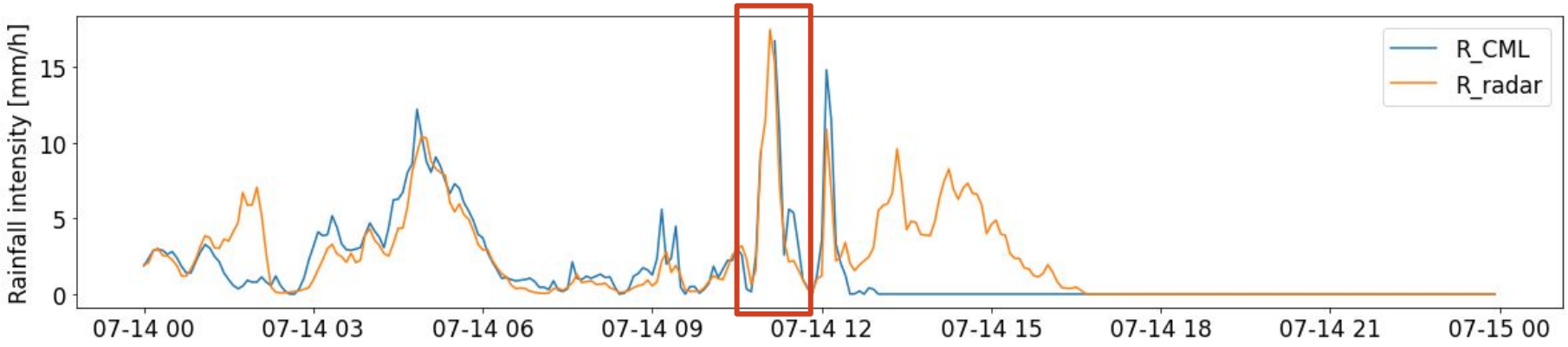


Cumulative blackouts



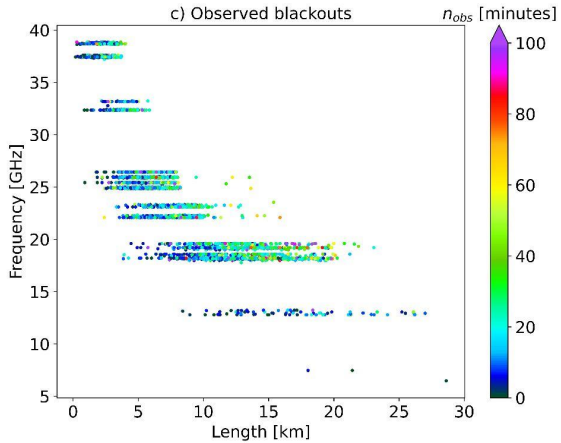
CML “blackouts” on 14.07.2021

Missing CML rainfall peak →new QPE algorithm will assume maximum attenuation

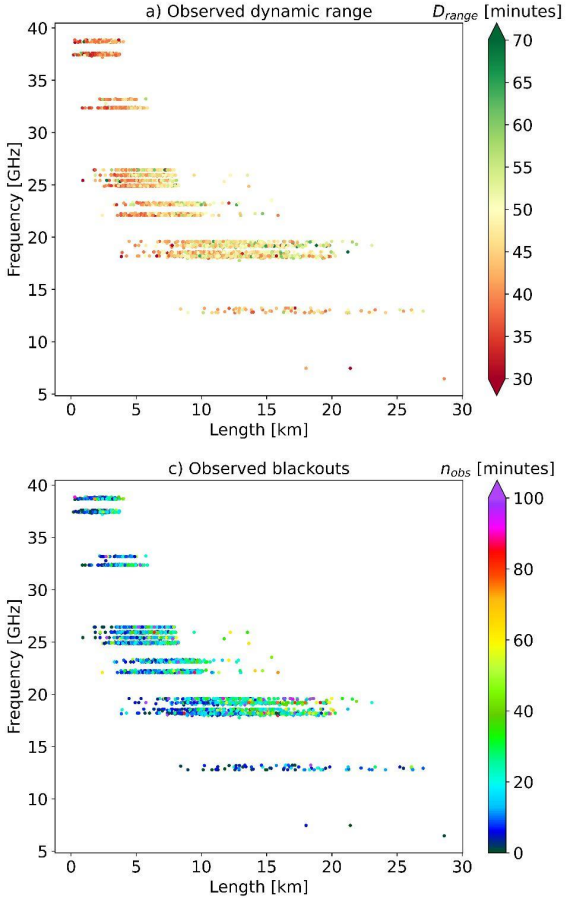


CML “blackout” climatology

Observed CML blackout minutes per year from 2018 to 2020

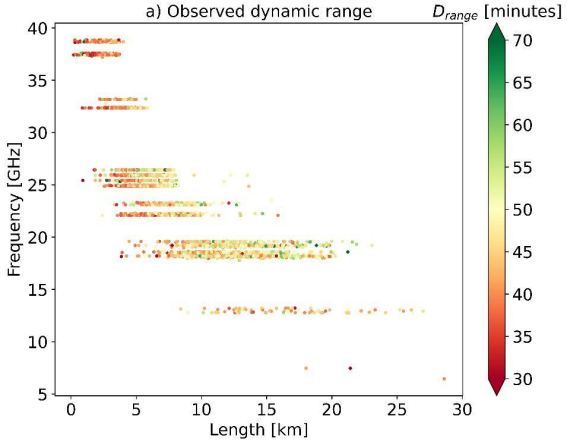


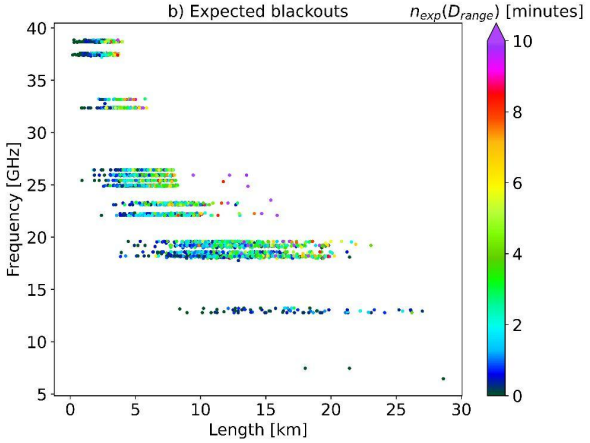
CML “blackout” climatology

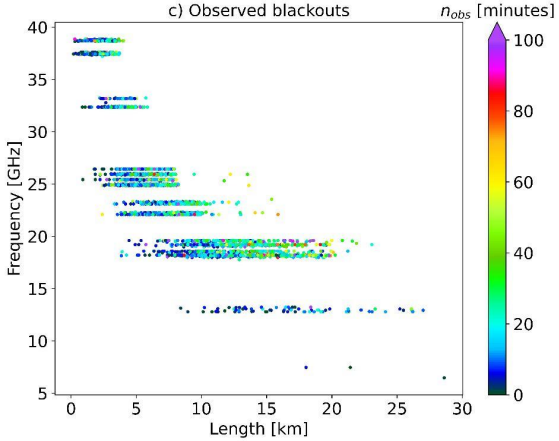


Dynamic range is the maximal PIA that can be measured before a blackout occurs

CML “blackout” climatology

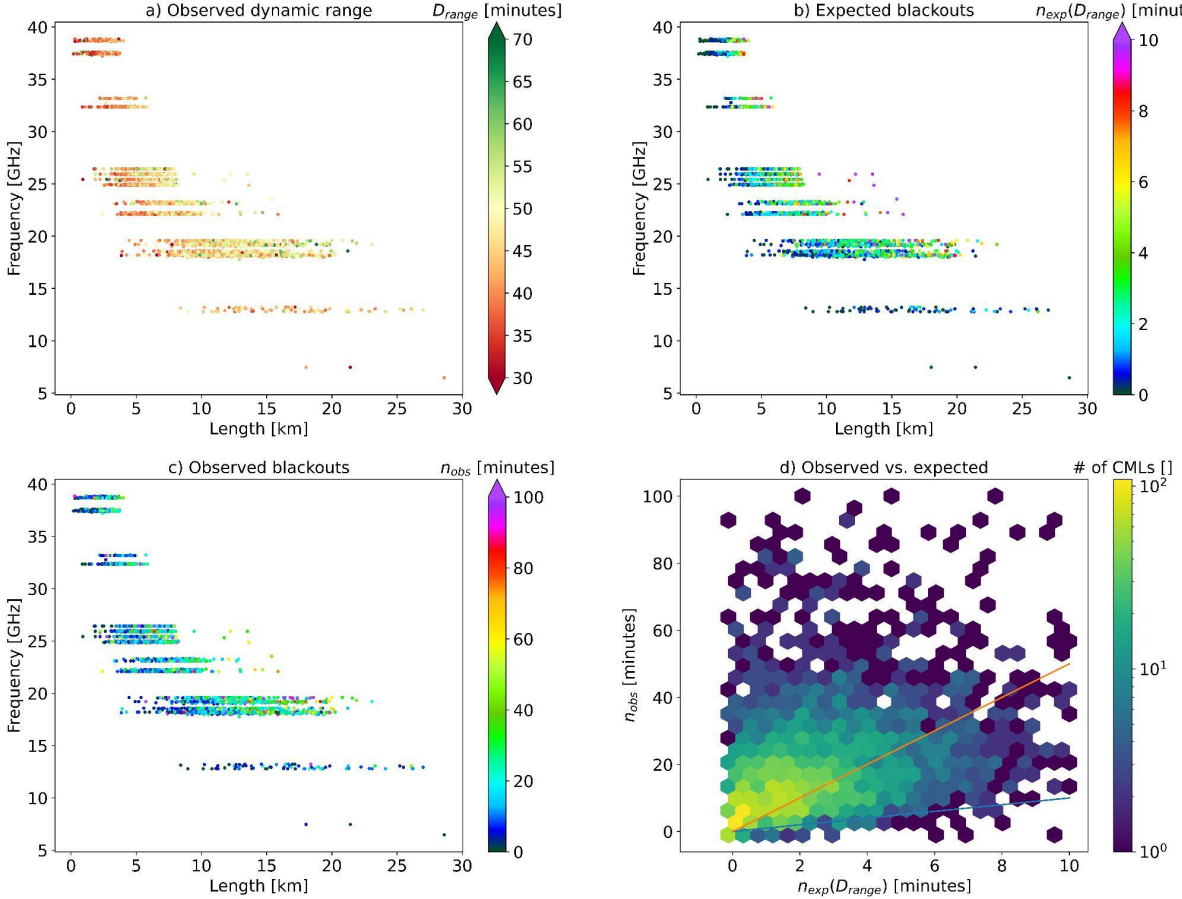




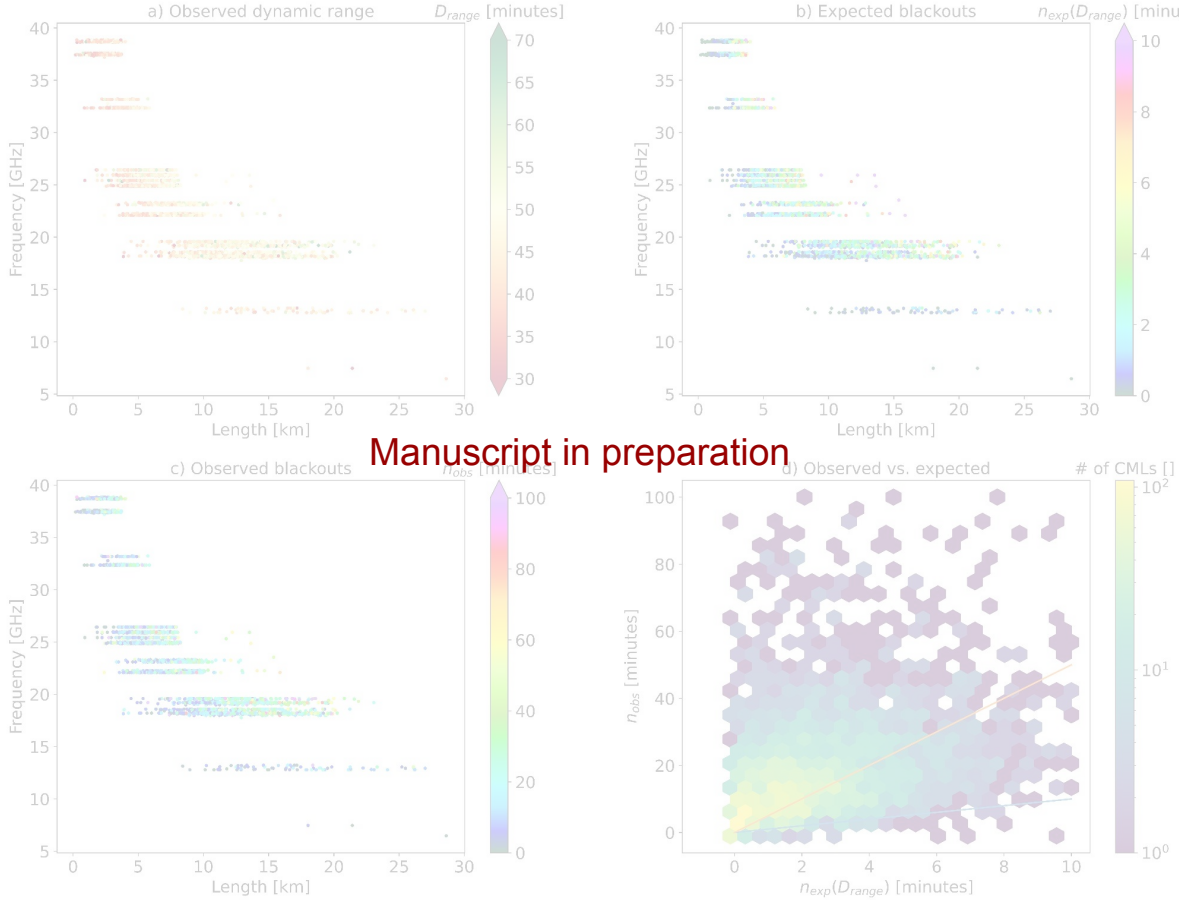


20 years of RADKLIM derived PIA suggests much less blackouts than actually occurring.

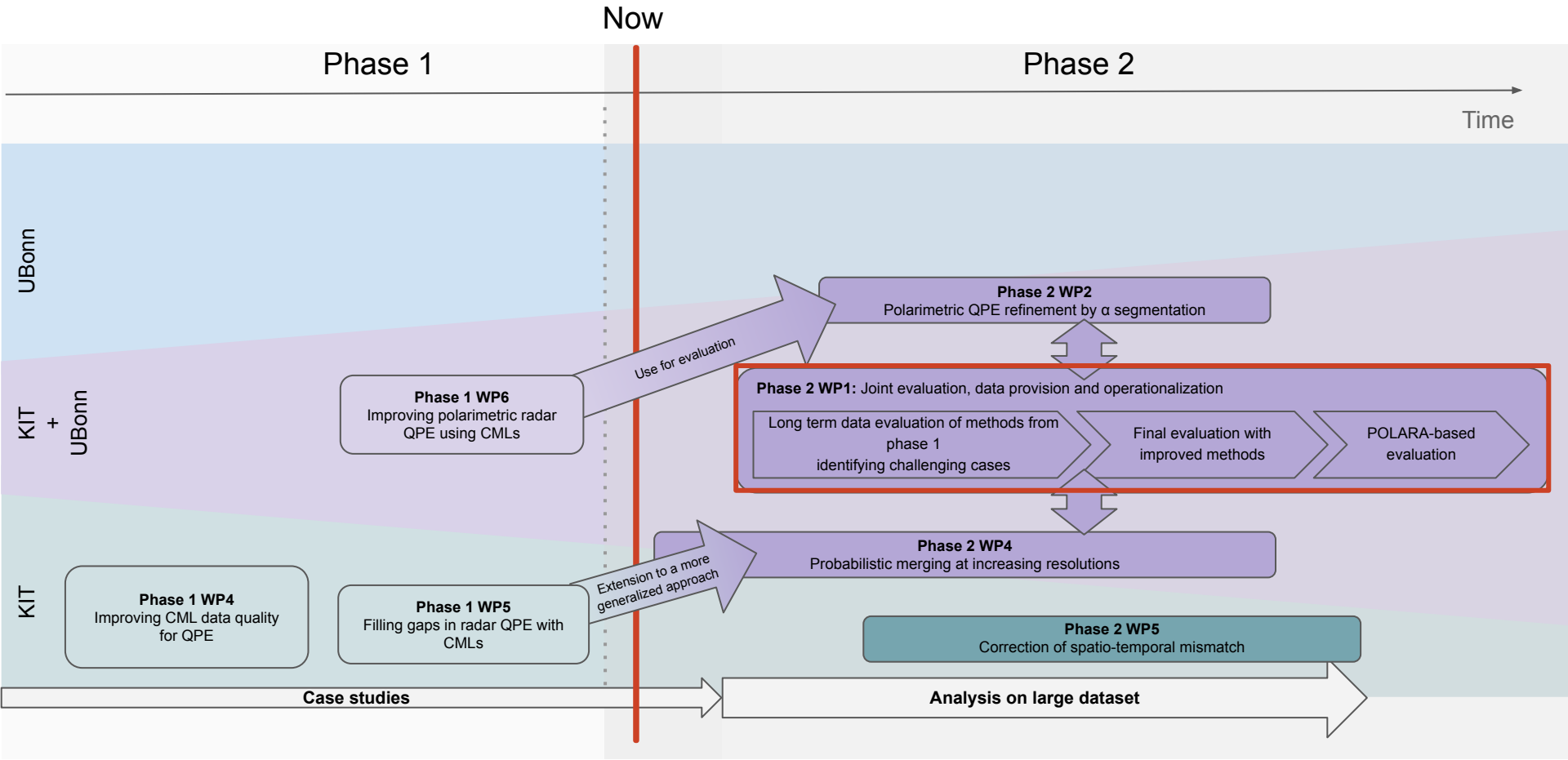
CML “blackout” climatology



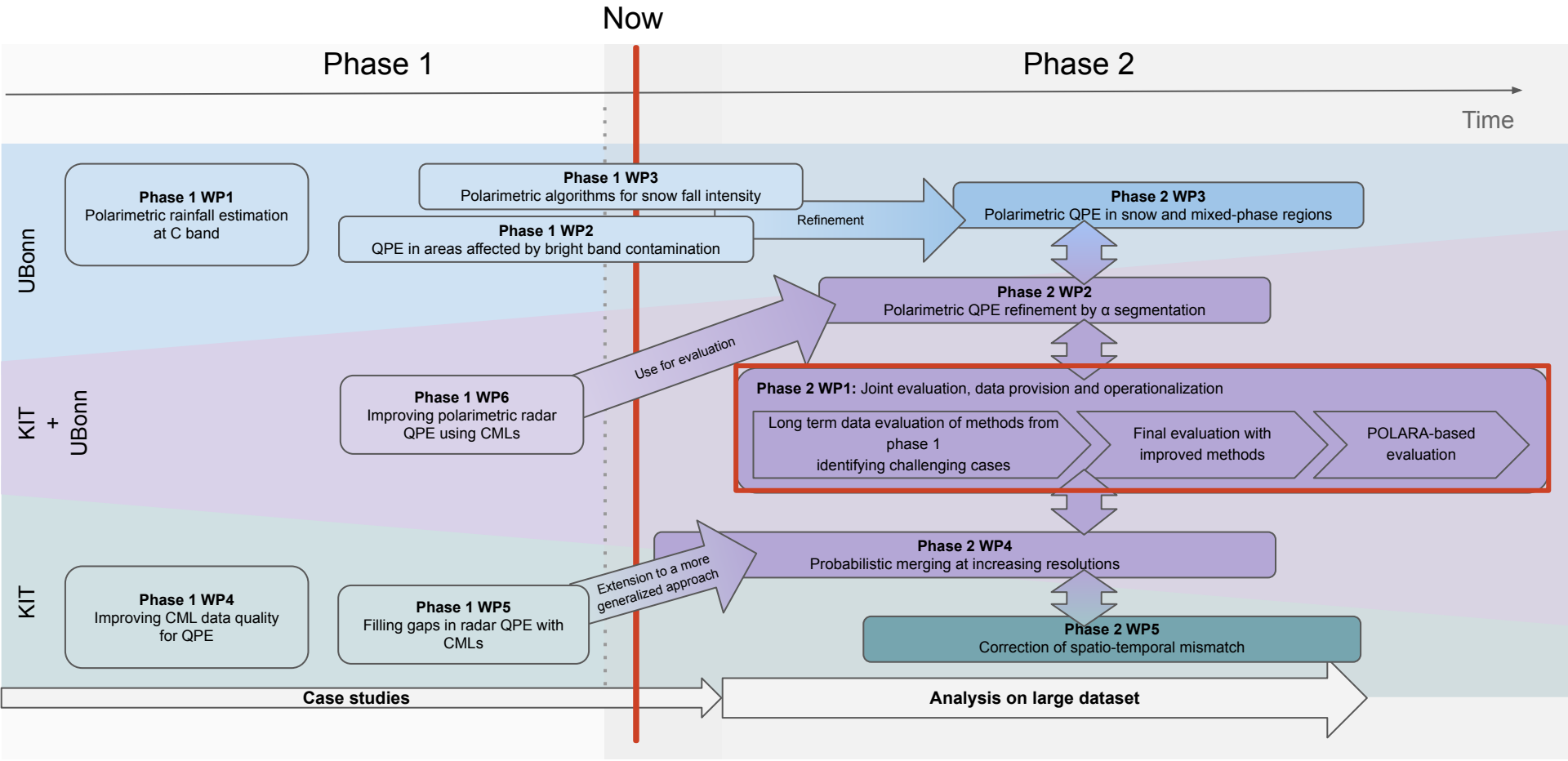
CML “blackout” climatology



P1 Flowchart



P1 Flowchart



News:

- HoWa-pro will move CML data acquisition to DWD
  - increase of temporal resolution to 10 seconds
  - possible increase of CMLs by up to 20k
    - ➢ benefit for merging and mismatch correction in RealPEP
- Ongoing MSc thesis for AI based radar adjustment
- Ongoing MSc thesis for AI based radar downscaling

Discussion points last time:

- Date for possible Bonn/Garmisch visit/exchange for multiple days to accelerate progress
  - I could travel in March or April
- Who can share experience with PySTEPS?
- Phase 2: Who started when and are we aligned?
- 3 month data: discuss later?
- Joint case study paper: What is the objective? RealPEP showcase or “competition” for best analysis? 😉