Karlsruhe Institute of Technology

RealPEP

KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research

A probabilistic AI-based merging of Commercial Microwave Link and Radar QPE

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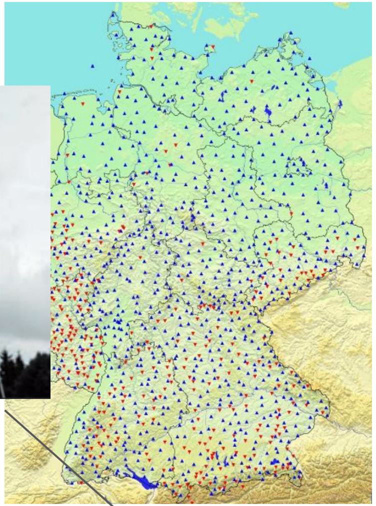
3 Deutscher Wetterdienst (DWD), Offenbach, Germany
4 University of Bonn, Institute for Geosciences - Section Meteorology

Rainfall sensors in Germany

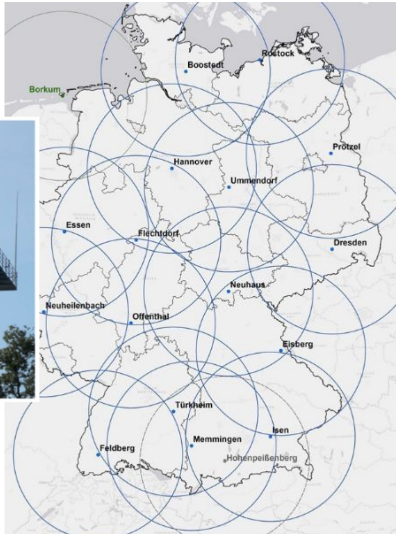
Rain Gauge

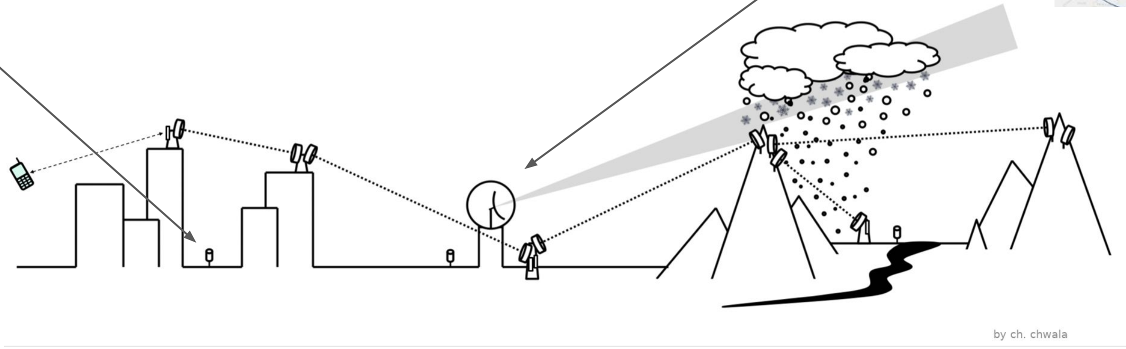


Source: DWD

Weather radar (C-band)

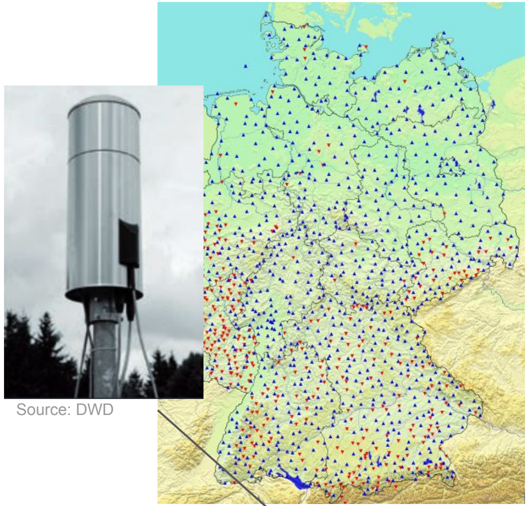
Source: DWD





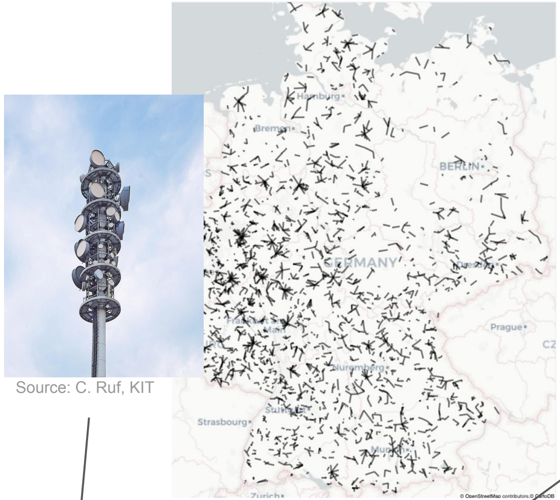
Rainfall sensors in Germany

Rain Gauge



Source: DWD

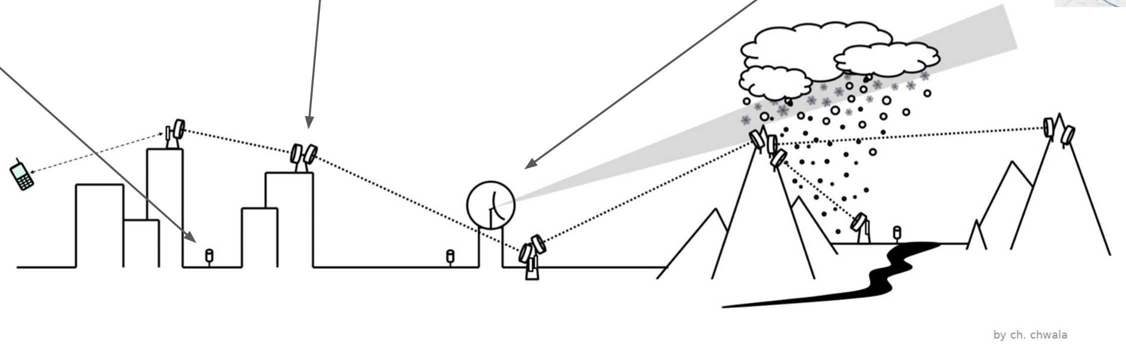
Commercial microwave link (CML)



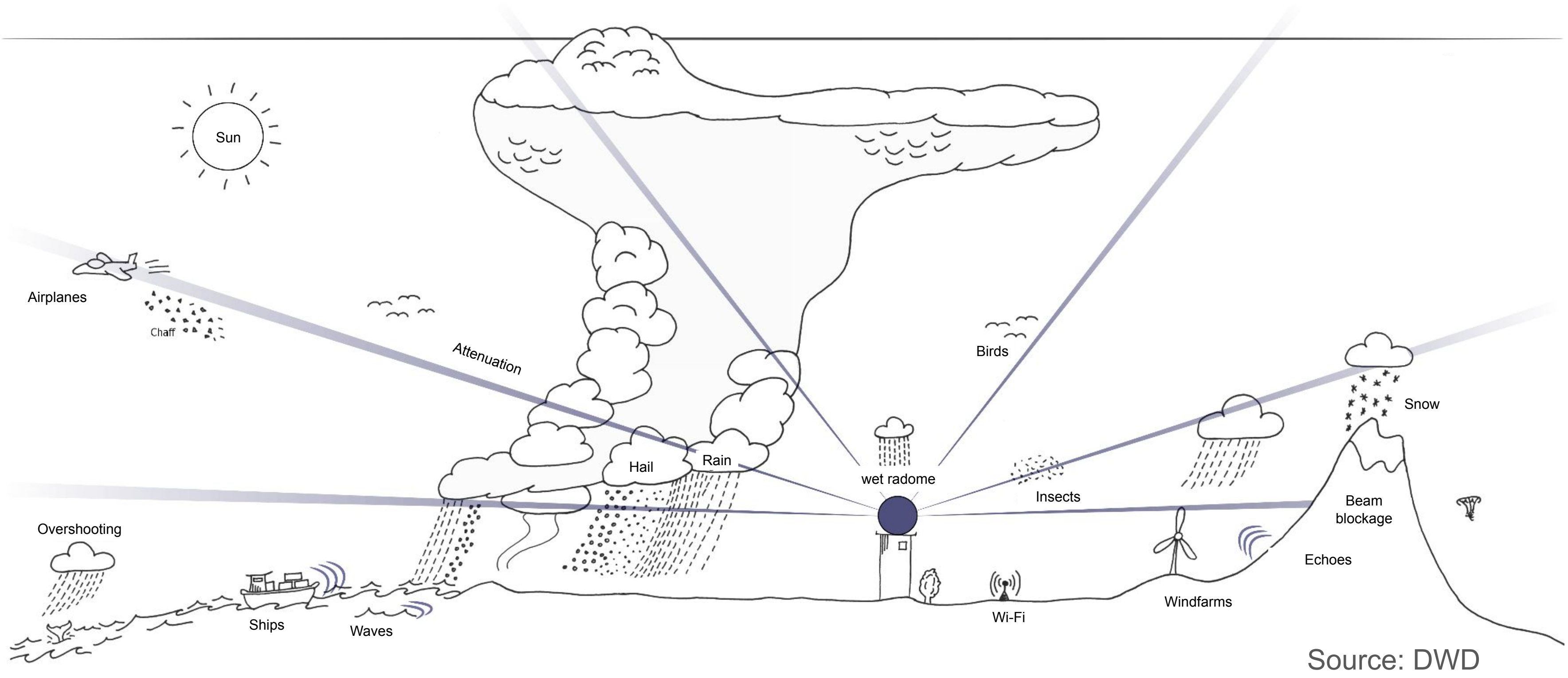
Source: C. Ruf, KIT

Weather radar (C-band)

Source: DWD



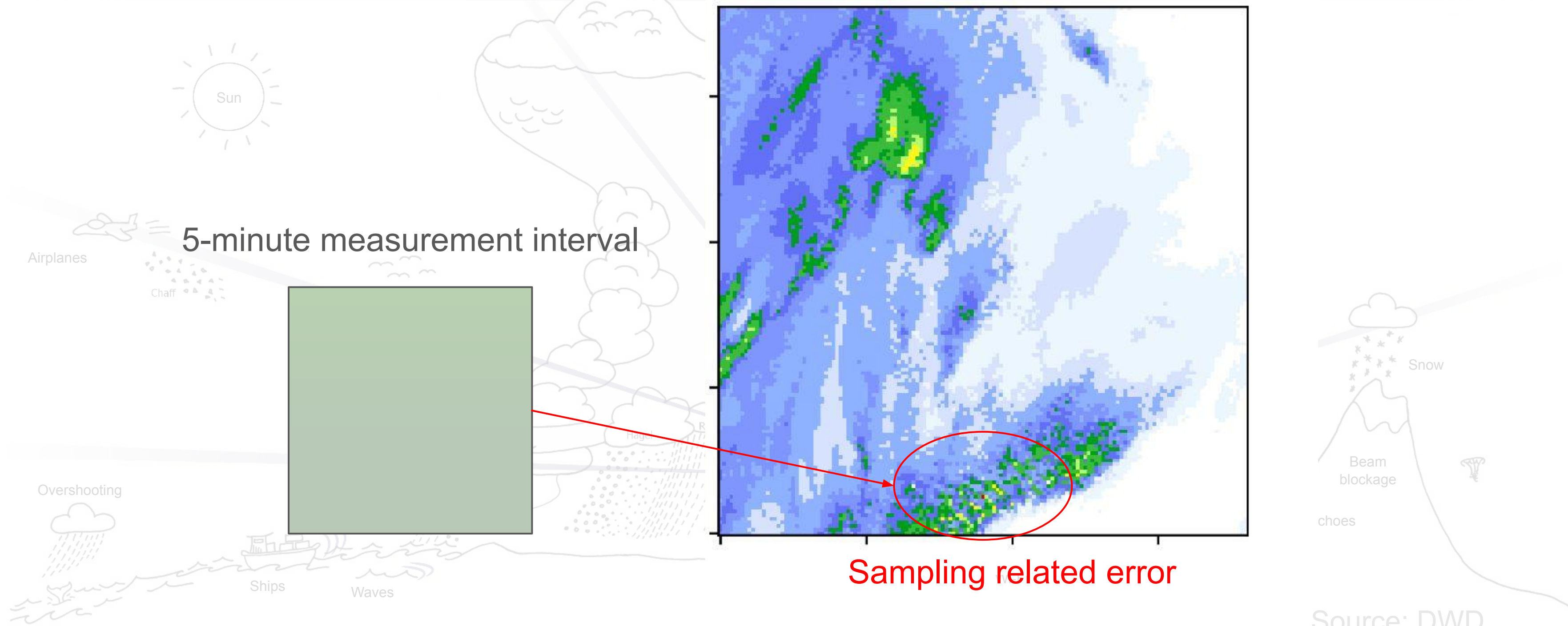
Systematic measurement errors



Systematic measurement errors

3-hour aggregation

5-minute measurement interval

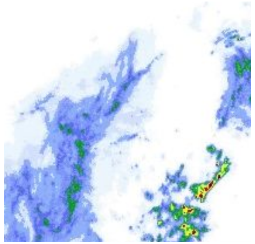


Sampling related error

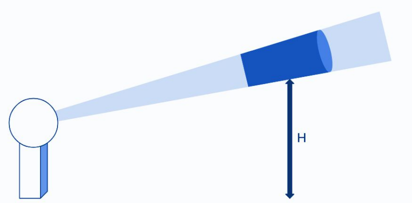
Source: DWD

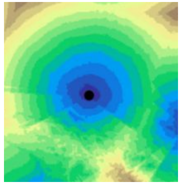
Problem formulation

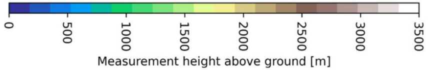
Input:
Radar QPE (RADOLAN-RY)
5 min res.



Radar Measurement height

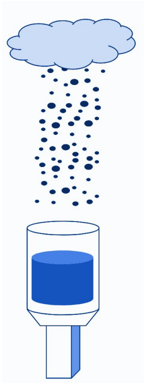






Prediction via deep learning approach

Target:
Rain gauge QPE
1 min res.



Problem formulation

Input:
Radar QPE (RADOLAN-RY)
5 min res.

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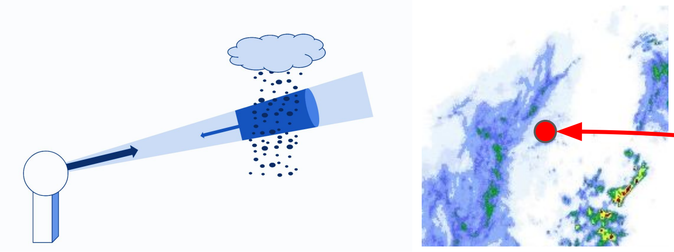
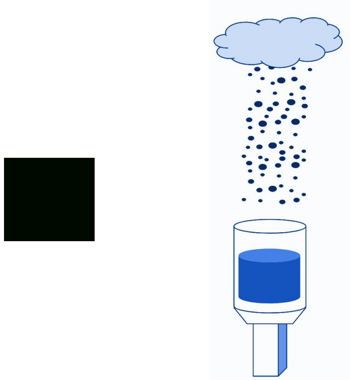
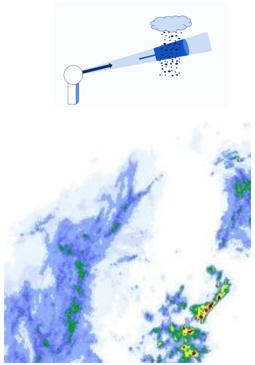
Rain gauge QPE
1 min res.



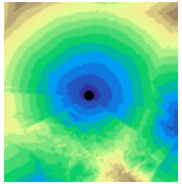


Objectives:

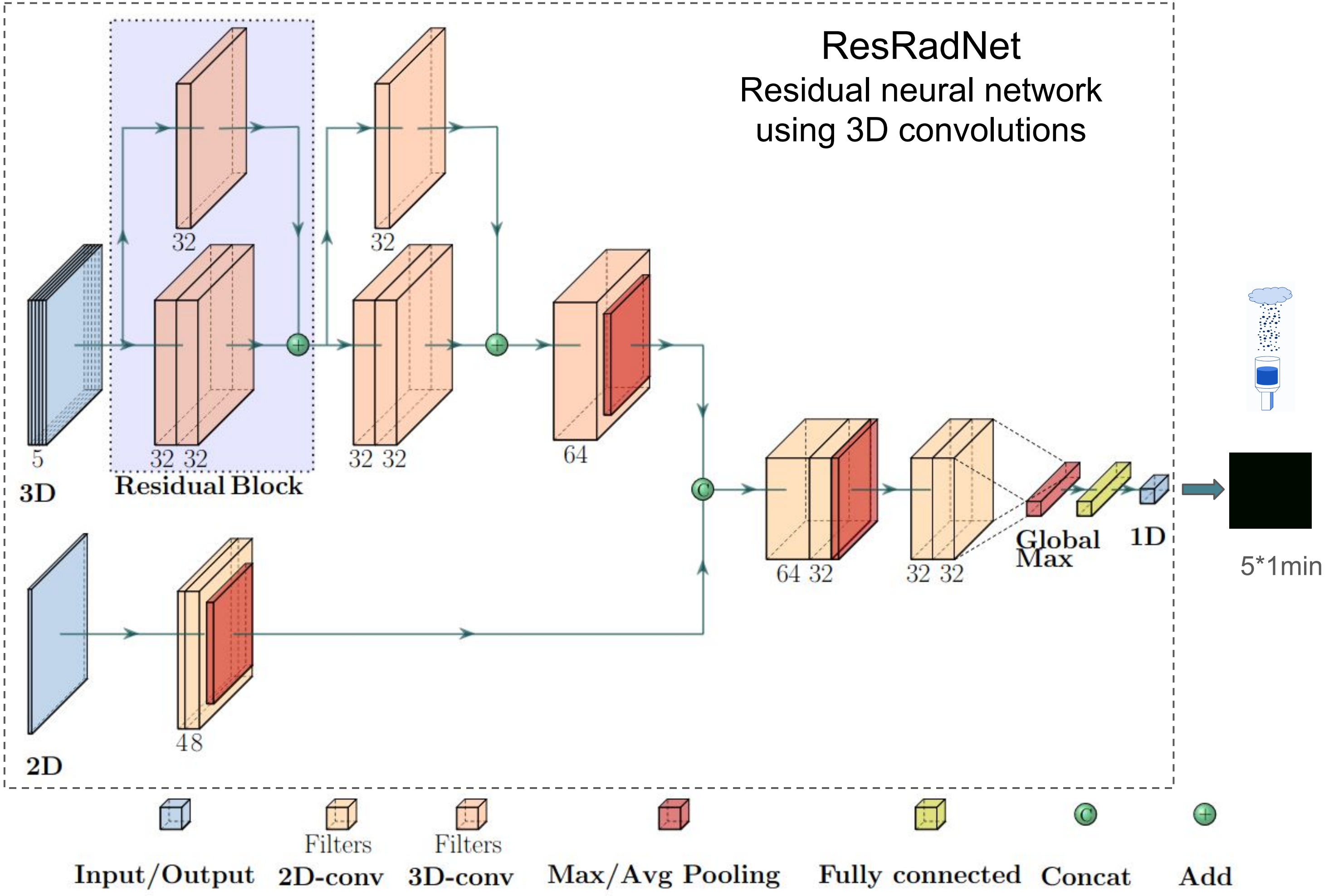
- ➔ Short-term prediction of five 1-min time-steps
- ➔ Reduce biases compared to rain gauges
- ➔ Spatiotemporal consistency of rainfall maps



11km x 11km x 5*5min



11km x 11km



Polz et al. 2024
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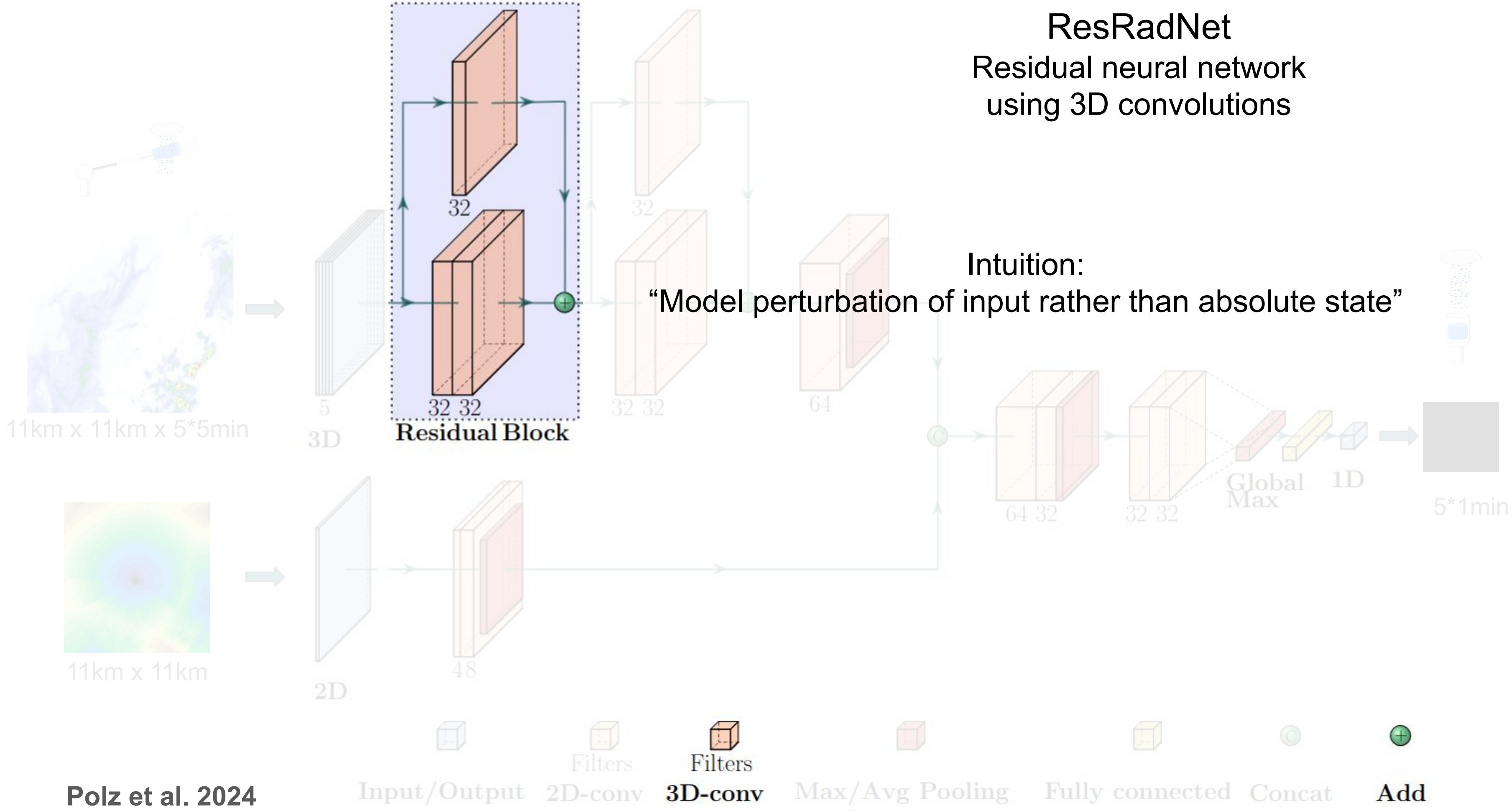
ResRadNet

Residual neural network
using 3D convolutions



Intuition:
“Model perturbation of input rather than absolute state”

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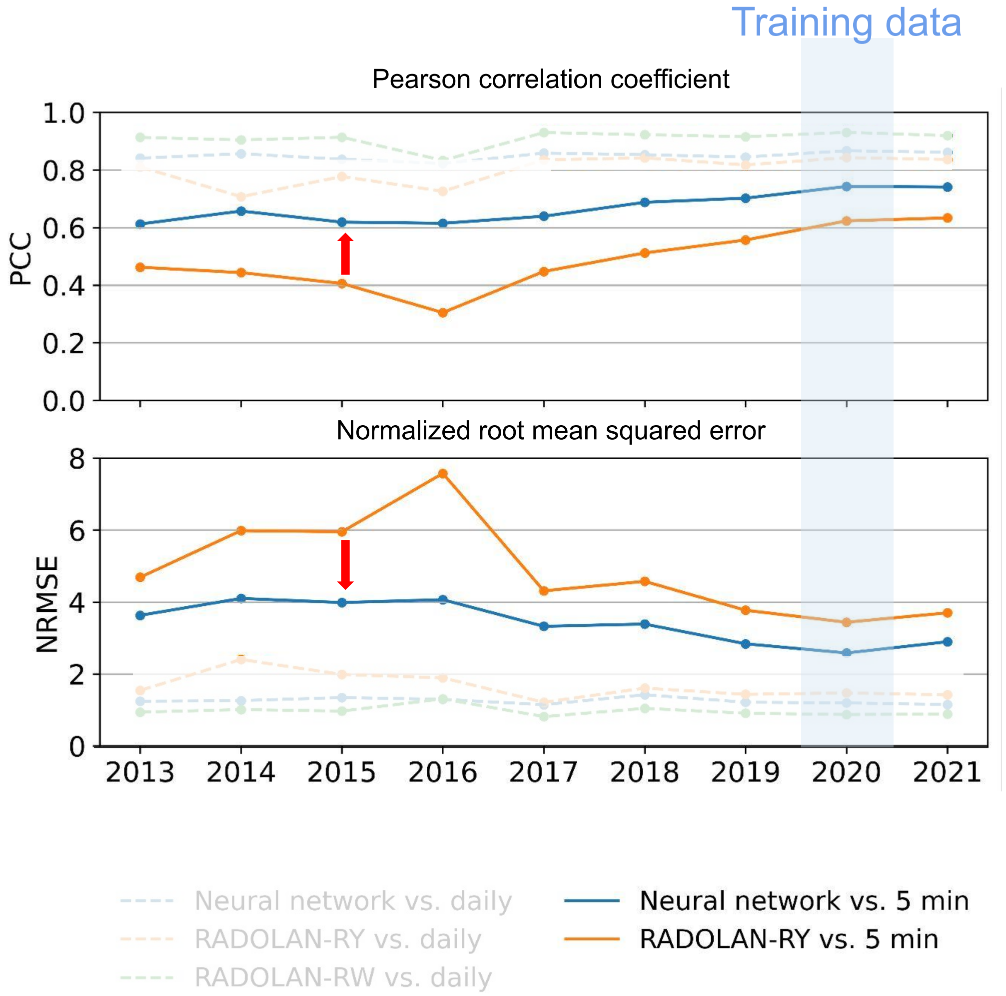
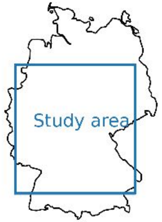
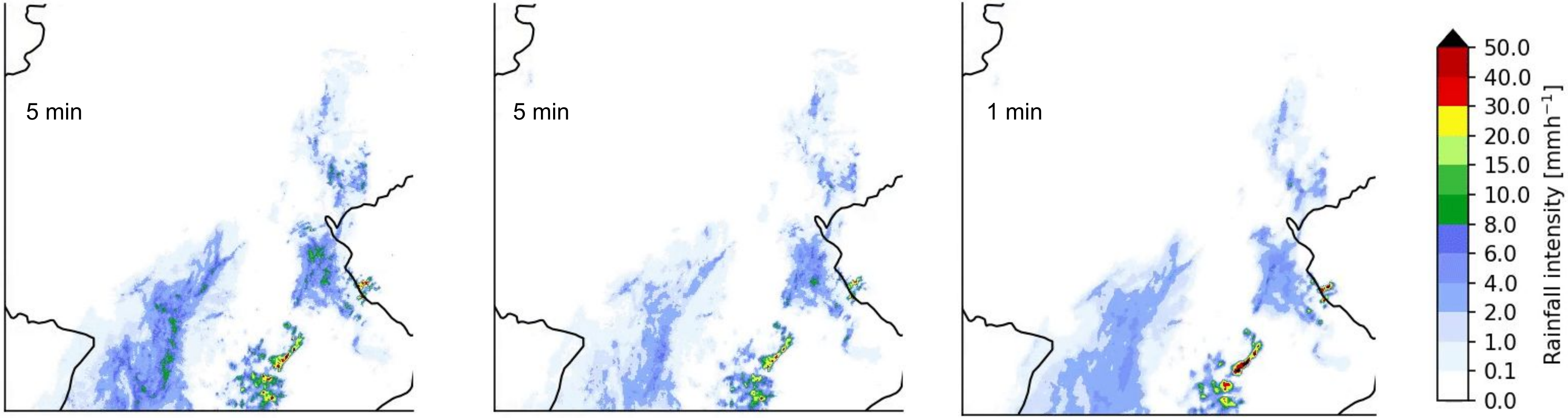


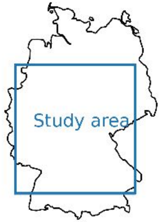
Polz et al. 2024
TGRS



Raw radar | Gauge adjusted radar | ResRadNet



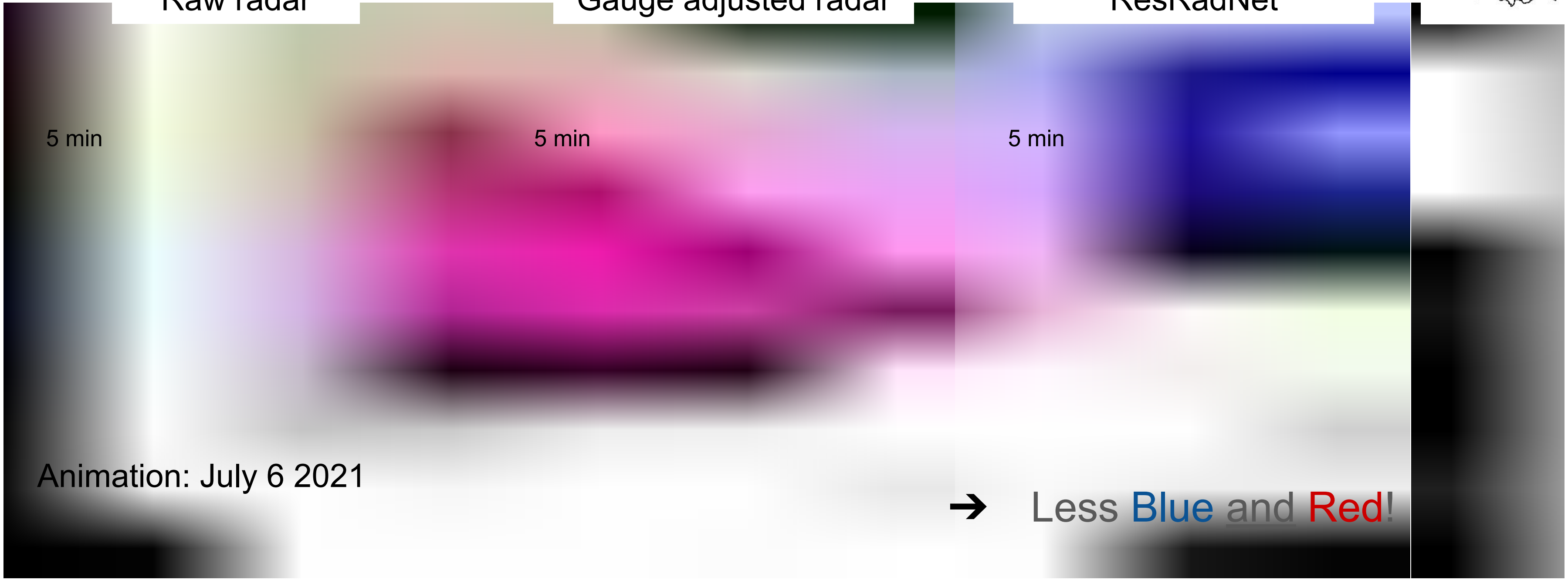
Animation: July 6 2021



Raw radar

Gauge adjusted radar

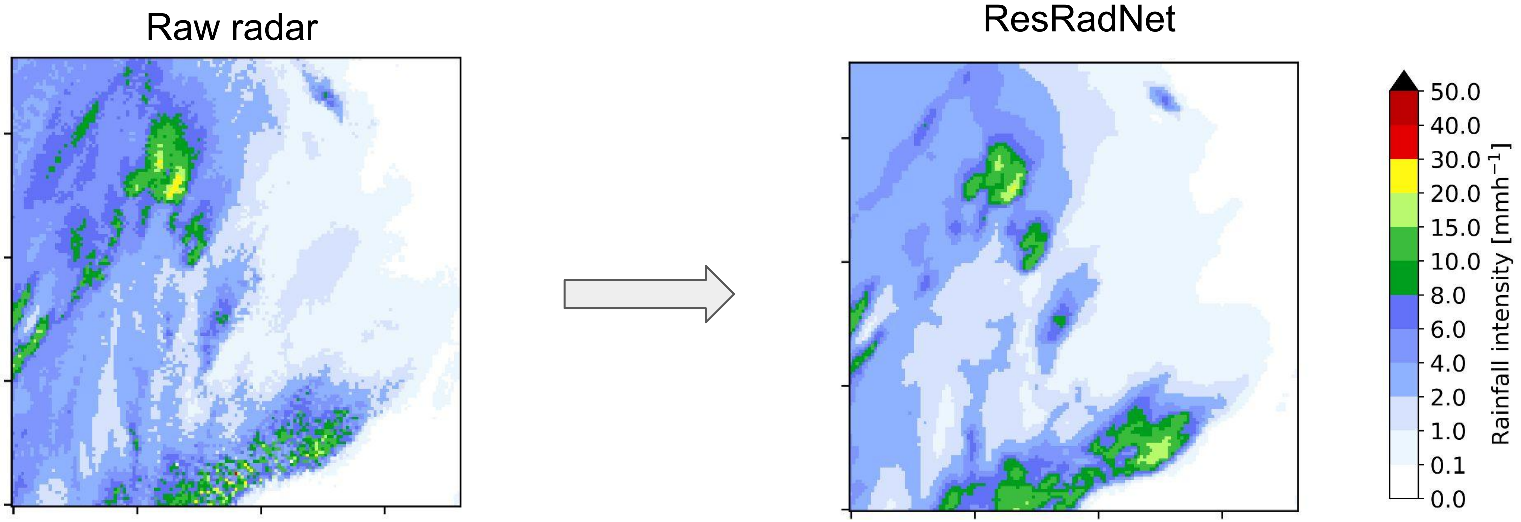
ResRadNet



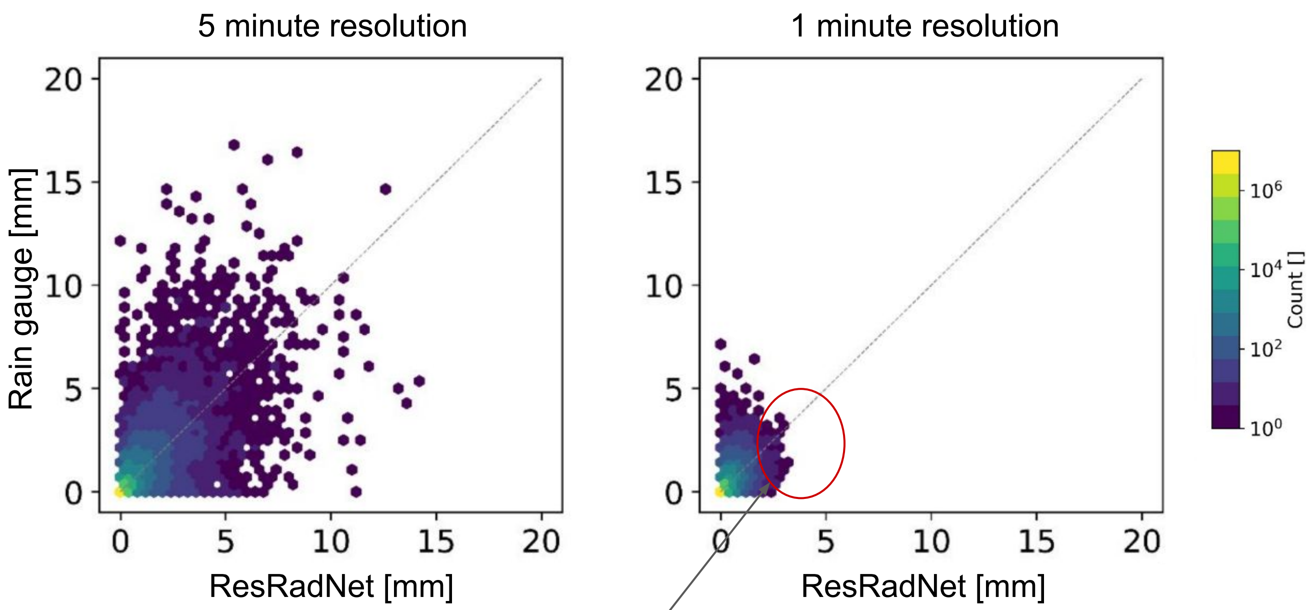
Animation: July 6 2021

→ Less Blue and Red!

Advection correction



Maps of rainfall sum between 16:00 and 19:00 on 6 July 2021

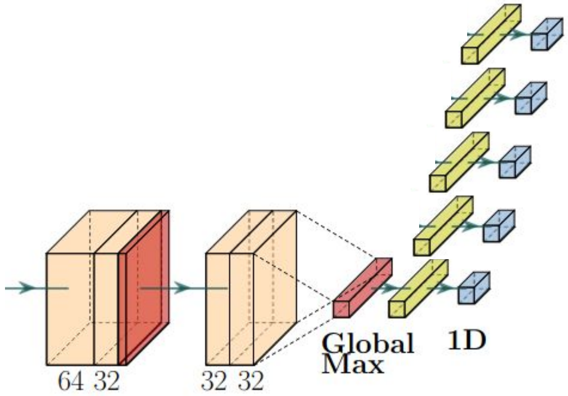


Missing extremes due to uncertainty and double penalty effect
→behaves like an ensemble mean prediction

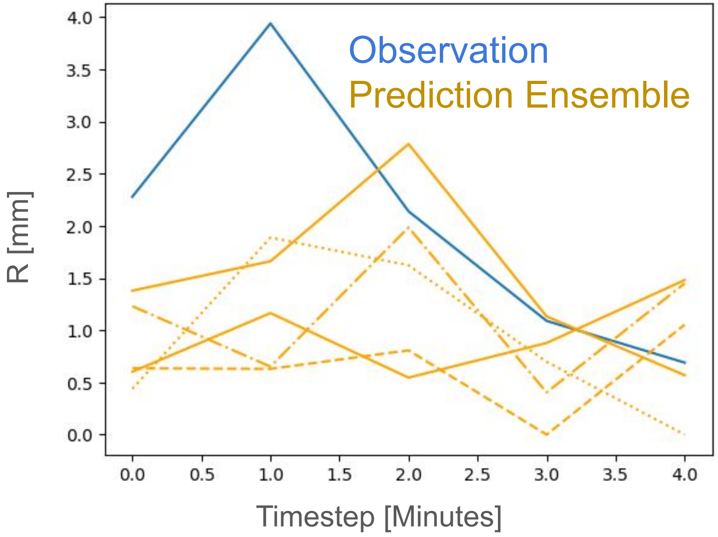
Disclaimer:

The following results are much less validated

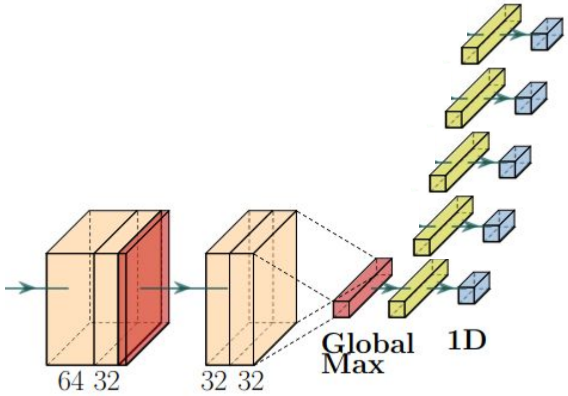
The presented ideas are valid though ;)



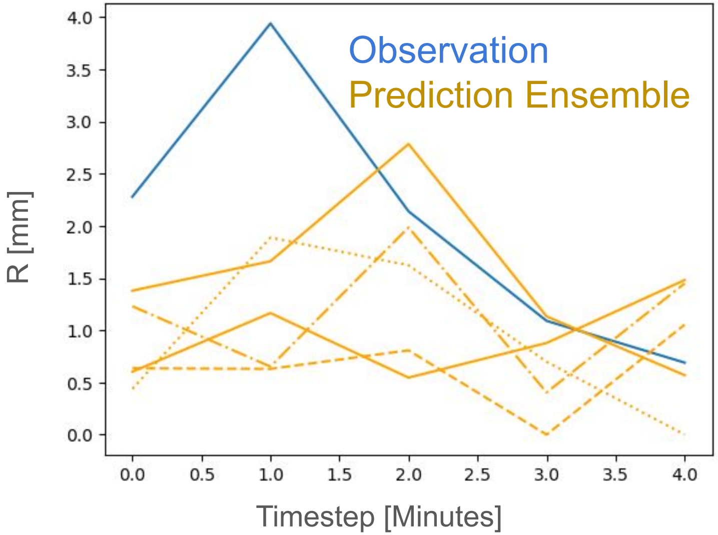
\+ Monte Carlo Dropout[1]

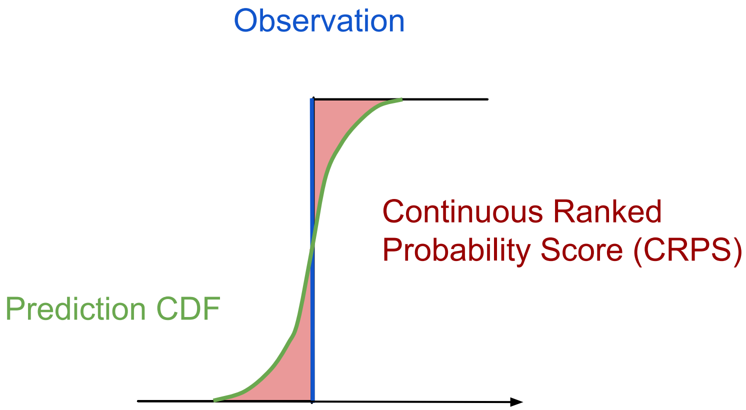


[1] Gal & Ghahramani, 2016. Dropout as a bayesian approximation: Representing model uncertainty in deep learning. ICML

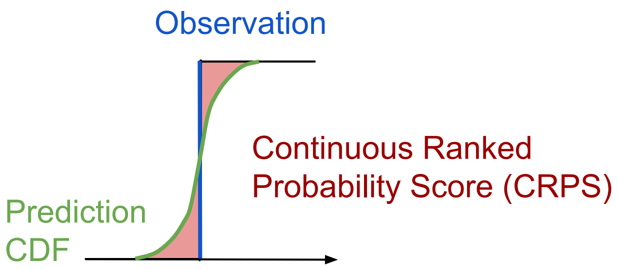


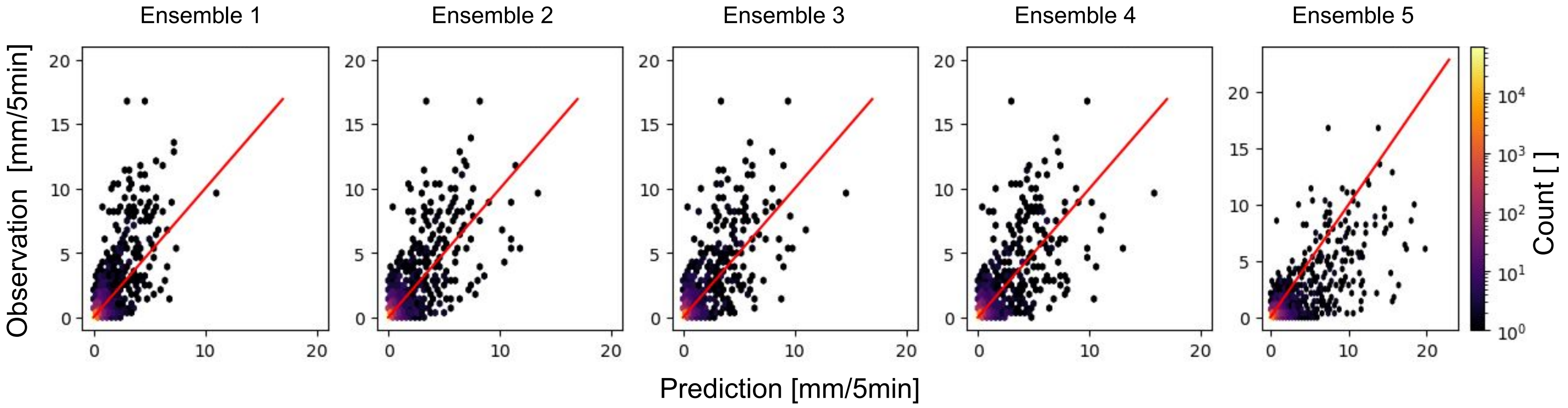
+ Monte Carlo Dropout

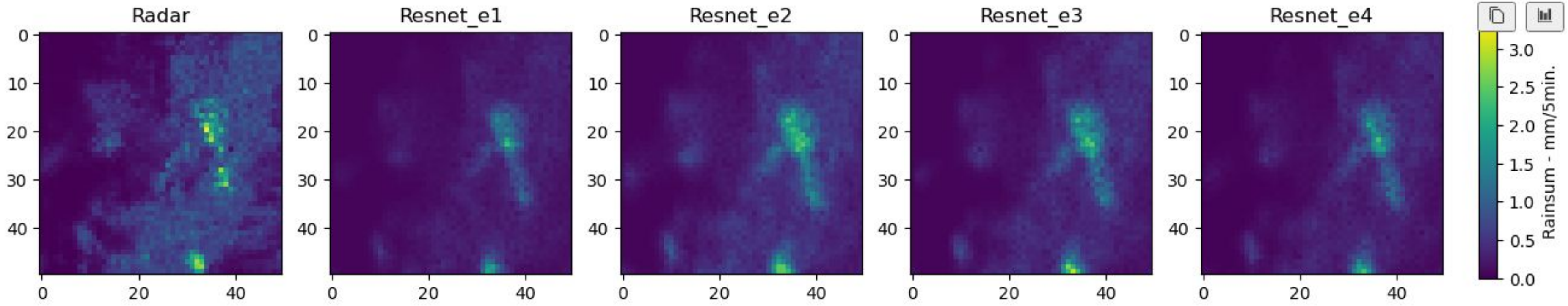




Train: June 2020
Test: July 2020





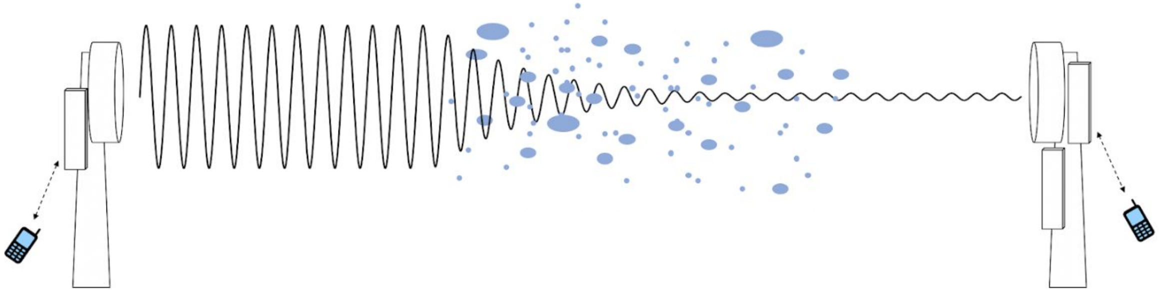


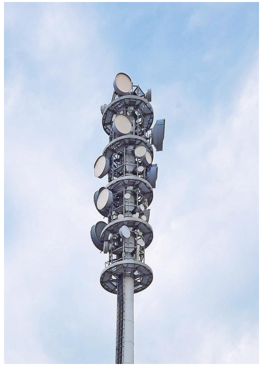
Variability? 😊

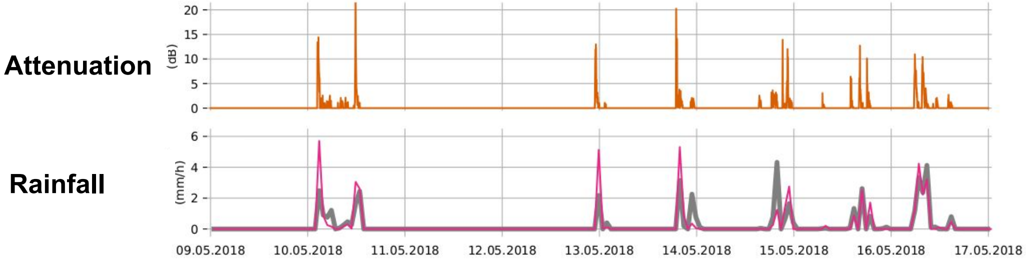
Extremes? 😕

→ explore alternative randomisation

QPE with commercial microwave links

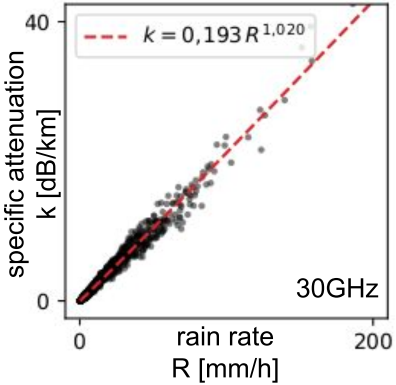






Graf, Polz and Chwala; PiuZ 2021

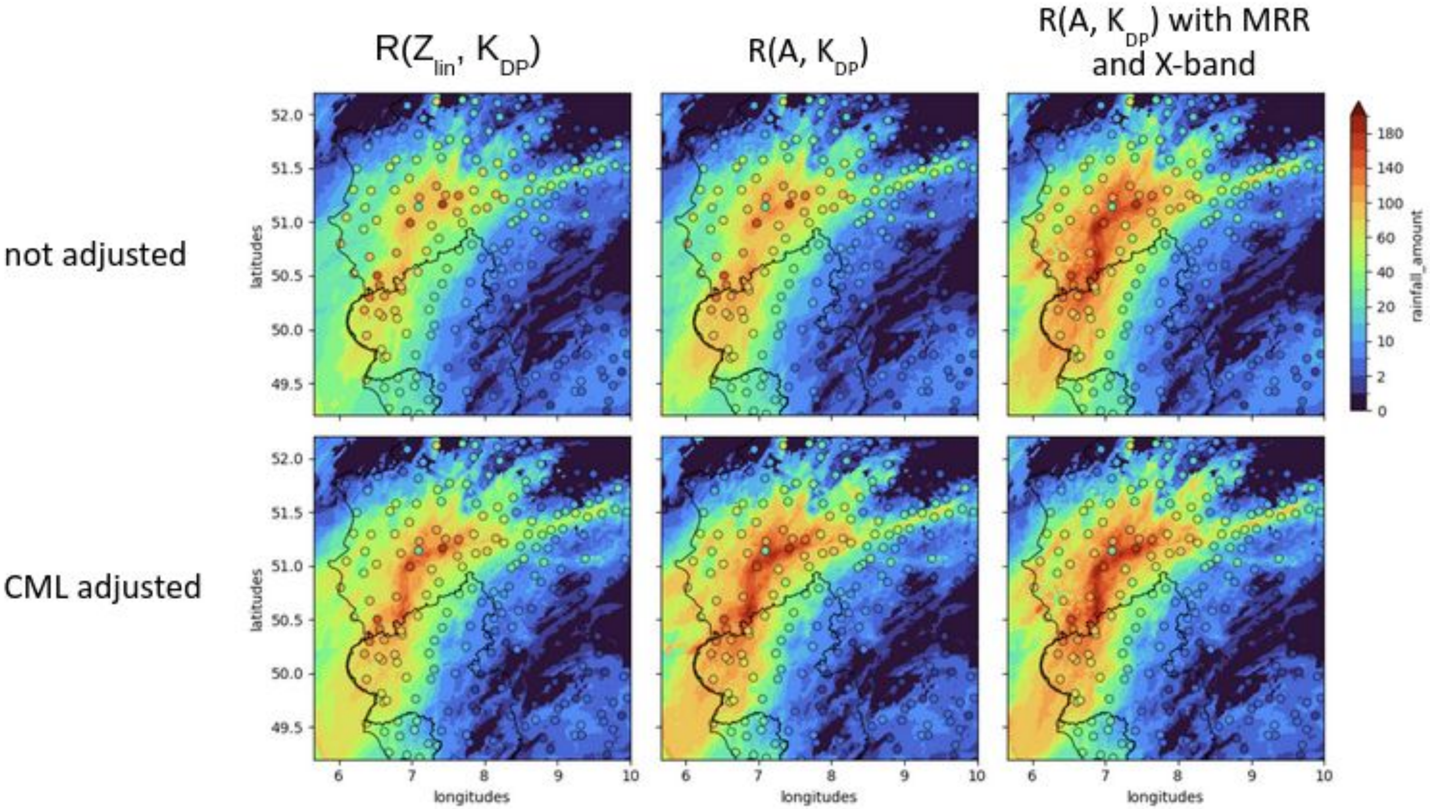
Power law regression

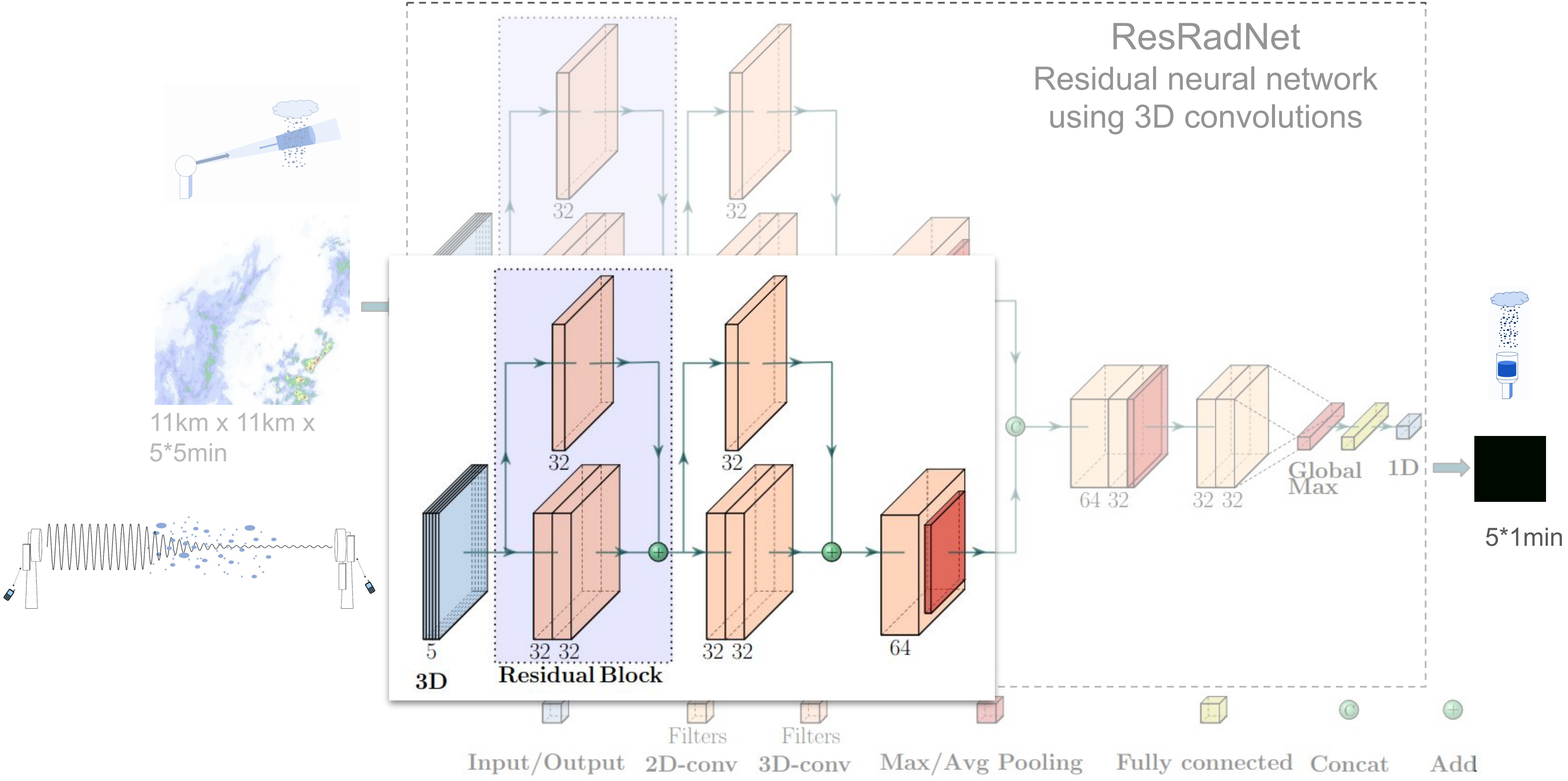


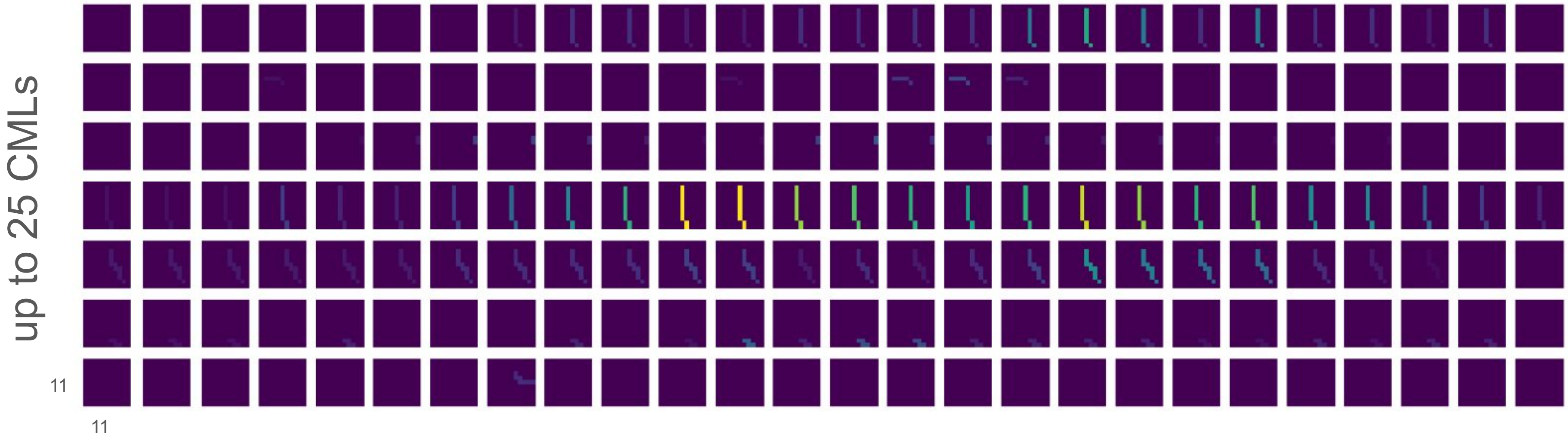
Commercial microwave links (CML)

- ➔ 3904 CMLs
- ➔ instantaneous measurement of **transmitted and received signal level**
- ➔ 1-minute resolution

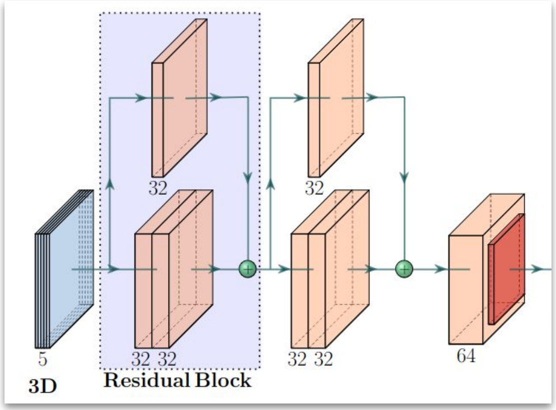
Merging Radar and CML



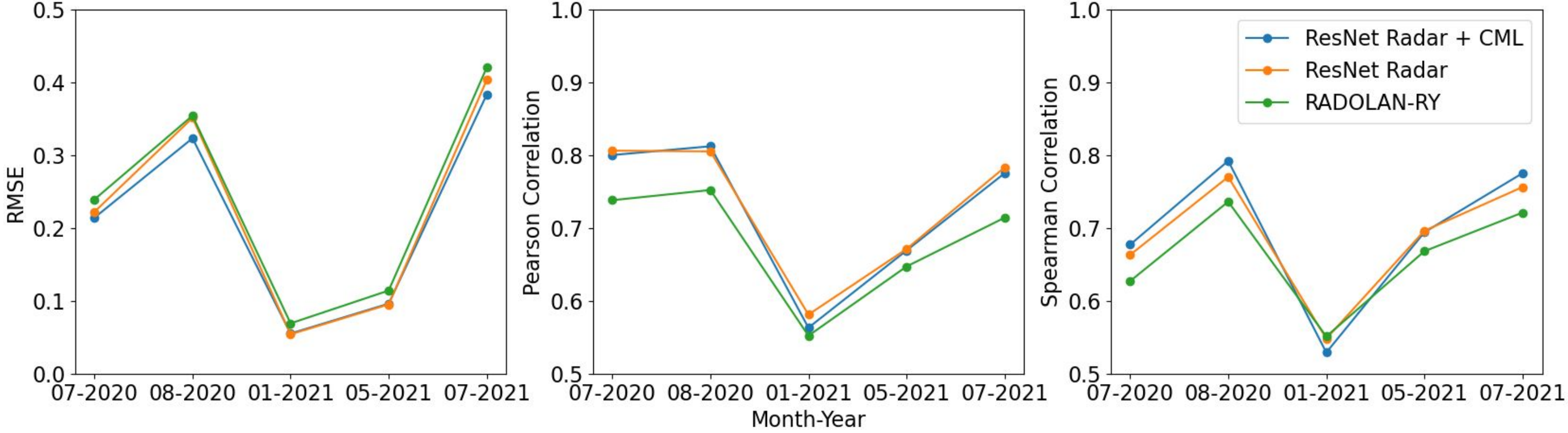

ResRadNet
Residual neural network
using 3D convolutions
11km x 11km x
5*5min
5
3D
32
32 32
Residual Block
32
32 32
64
64 32
32 32
Global
Max
1D
5*1min
Input/Output
Filters
2D-conv
Filters
3D-conv
Max/Avg Pooling
Fully connected
Concat
Add

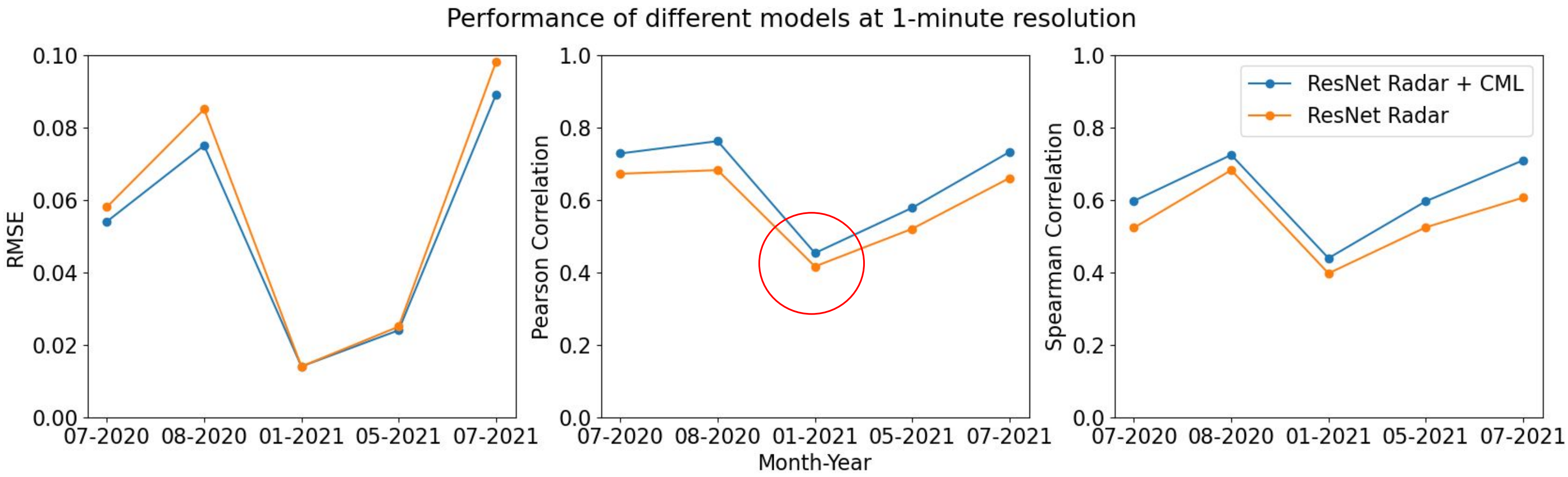


25 1-minute time steps



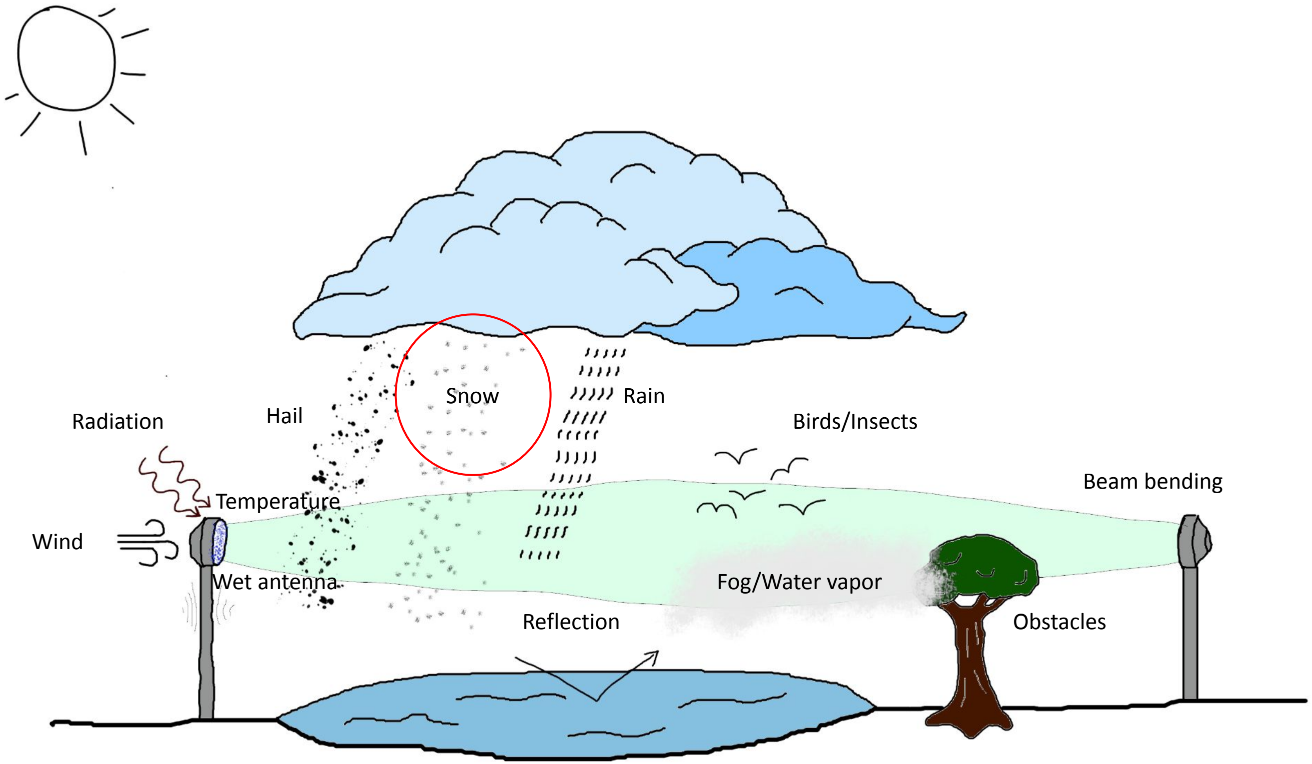
Performance of different models at 5-minute resolution





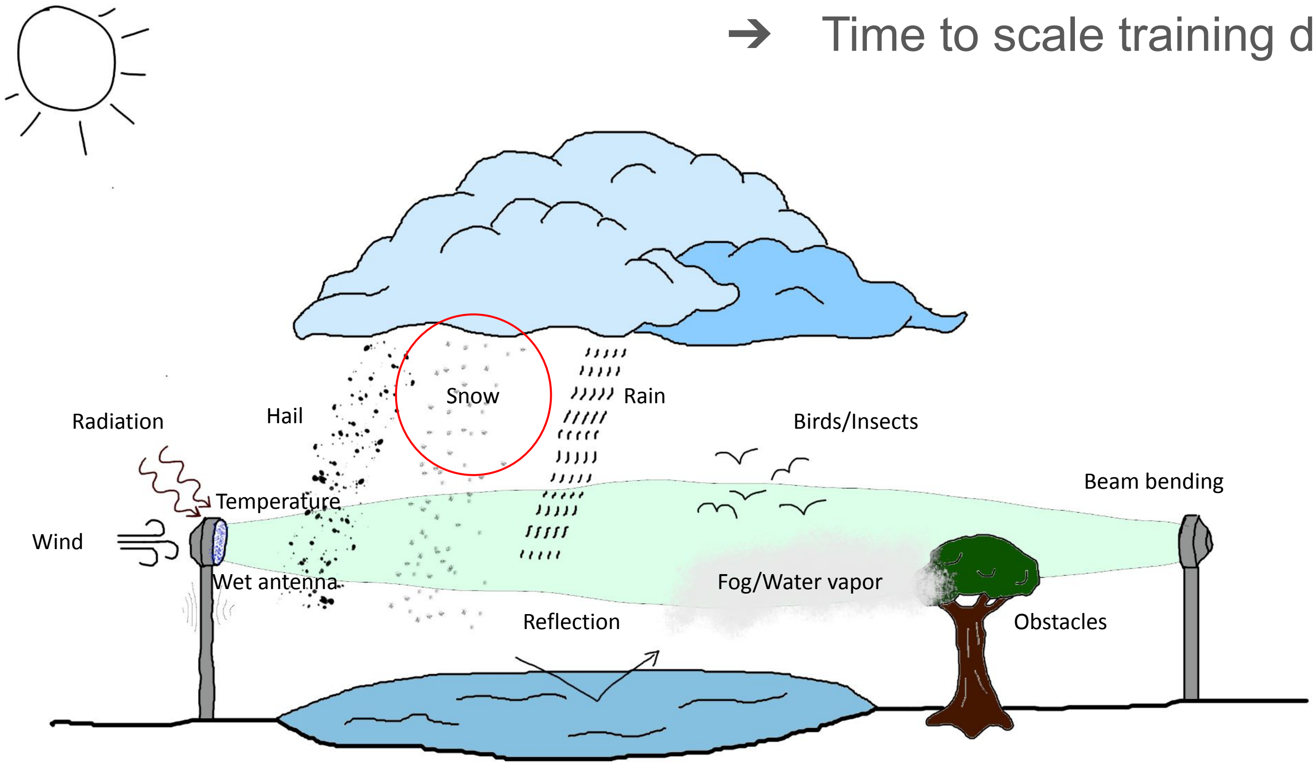
Model not trained on winter data

Systematic measurement errors - CML



Systematic measurement errors - CML

➔ Time to scale training data



Conclusion:

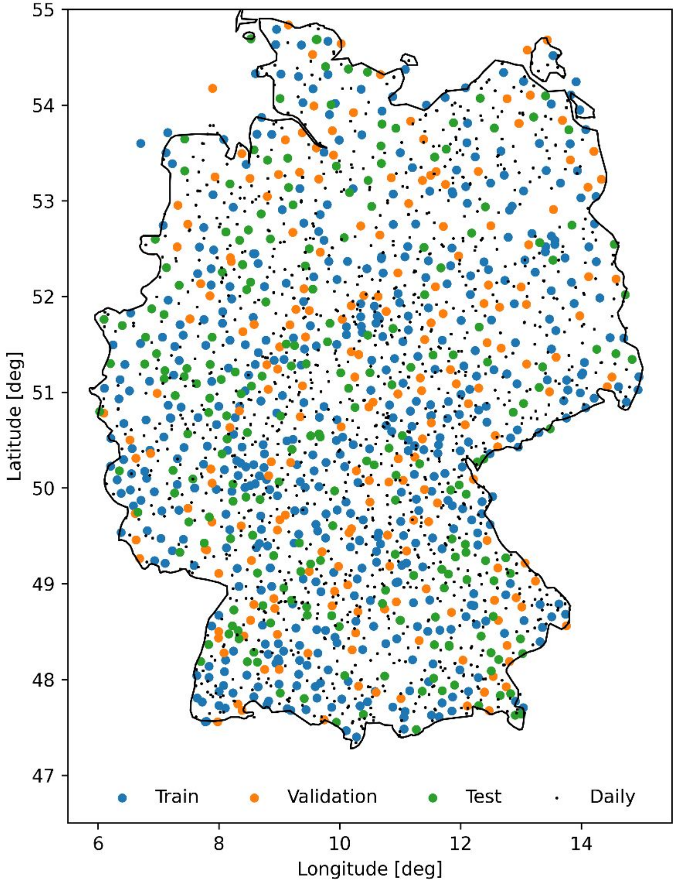
- ResNet approach for radar adjustment works

- CRPS loss + dropout
  - creates reasonable variability
  - does not solve missing extremes

- CMLs provide valuable information, especially at 1-minute resolution

Thank you!

Data splitting



Train
➔ 60% of stations, 2020

Test
➔ 20% of stations, 2021

Validation
➔ 20% of stations, 2013-2021

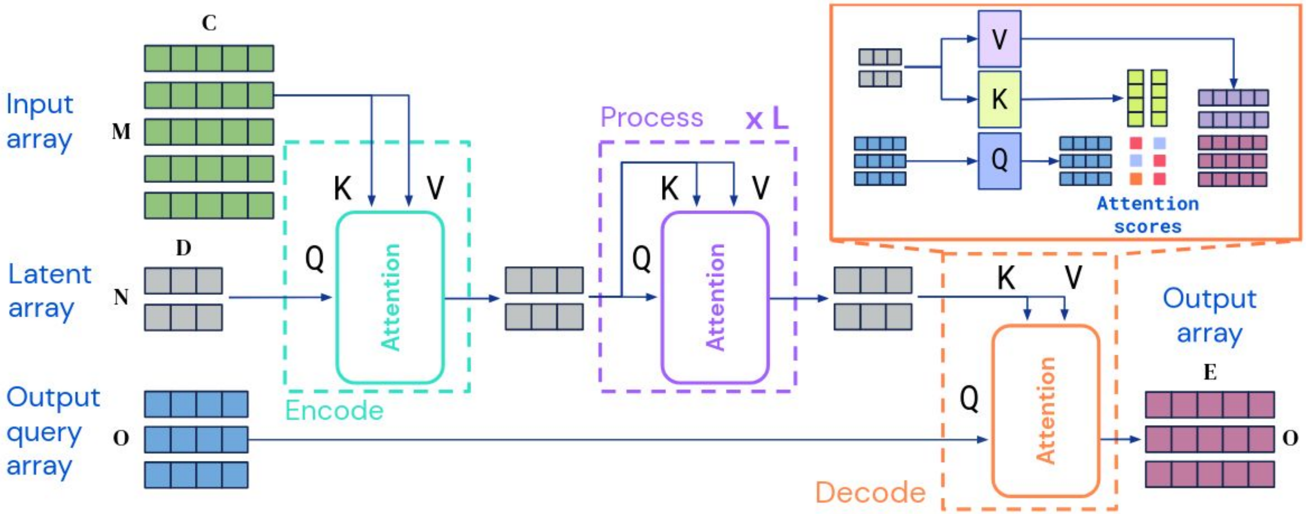
Daily validation
➔ >1000 independent stations, 2013-2021

Important: spatio-temporally independent validation!

Polz et al. 2024
TGRS

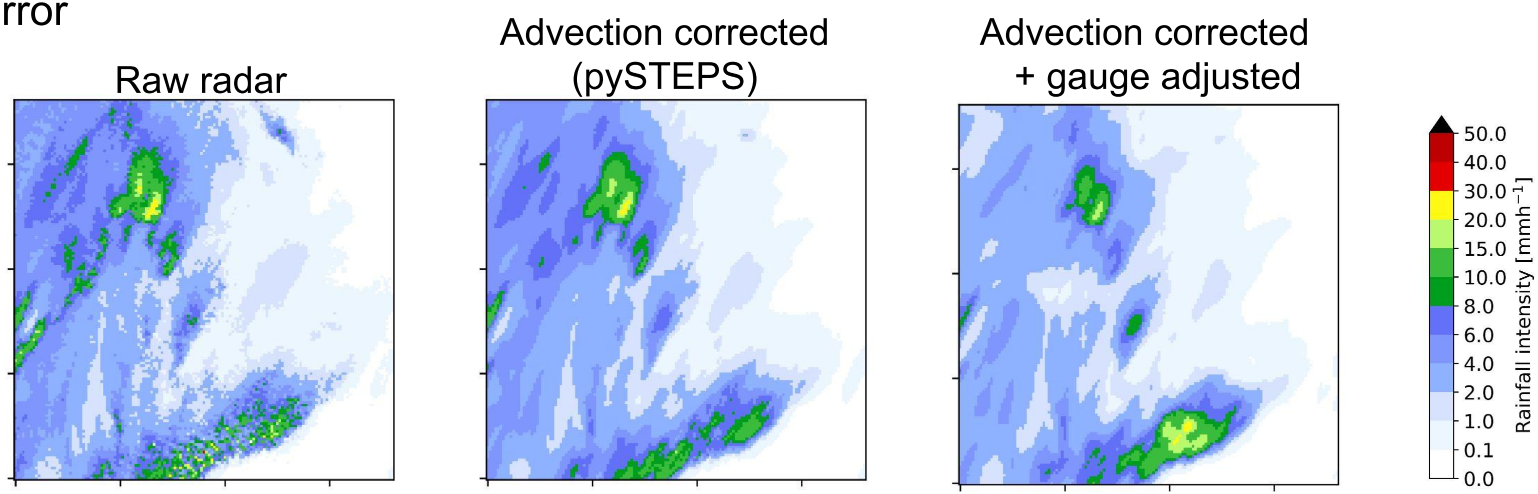
Apart from the obvious scaling and calibration than needs to be done,

we require a more flexible approach to digest the CML data



Jaegle, A., Borgeaud, S., Alayrac, J. B., Doersch, C., Ionescu, C., Ding, D., ... & Carreira, J. (2021). Perceiver io: A general architecture for structured inputs & outputs. *arXiv preprint arXiv:2107.14795*.

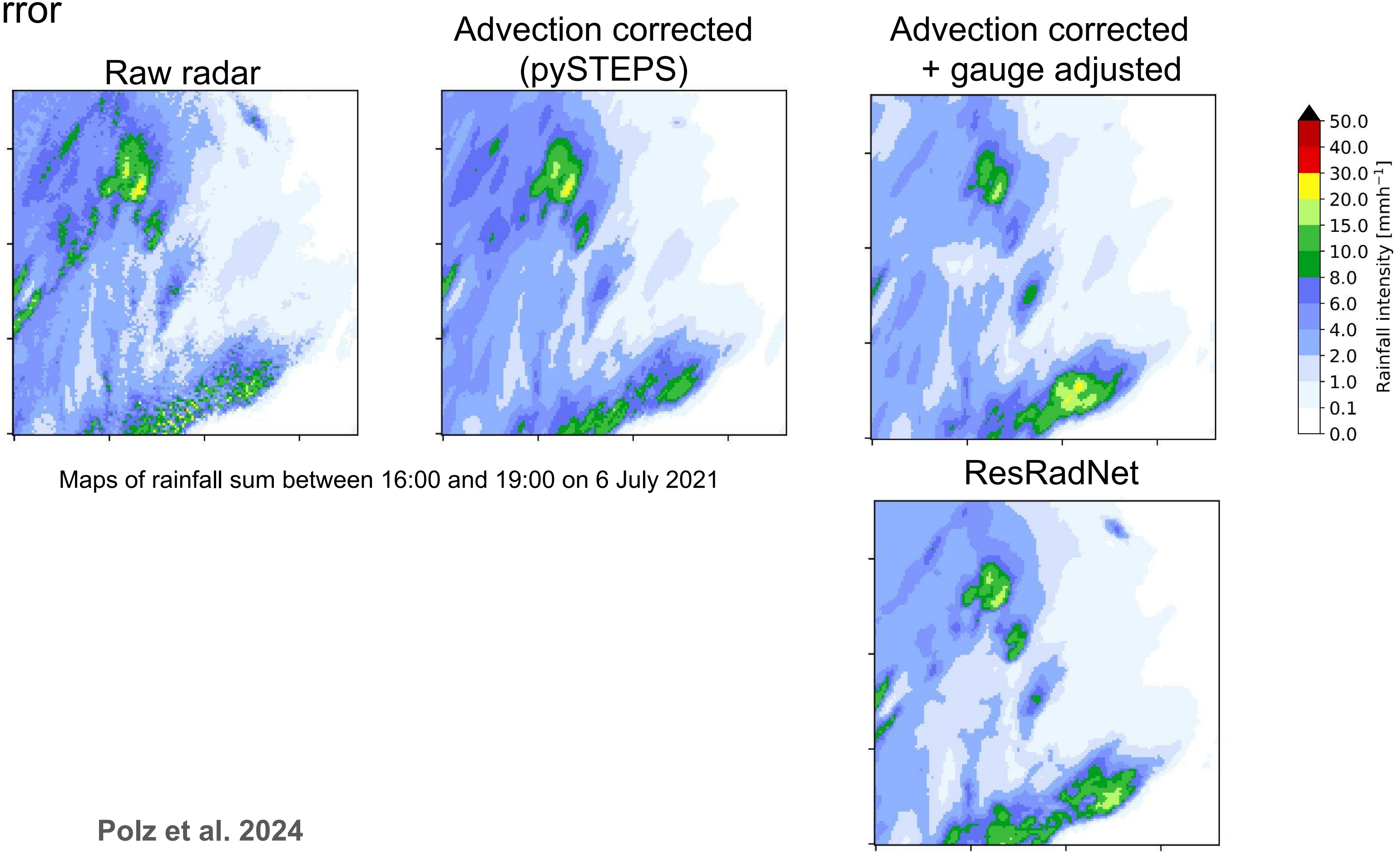
Sampling error



Maps of rainfall sum between 16:00 and 19:00 on 6 July 2021

Polz et al. 2024
TGRS

Sampling error



Maps of rainfall sum between 16:00 and 19:00 on 6 July 2021

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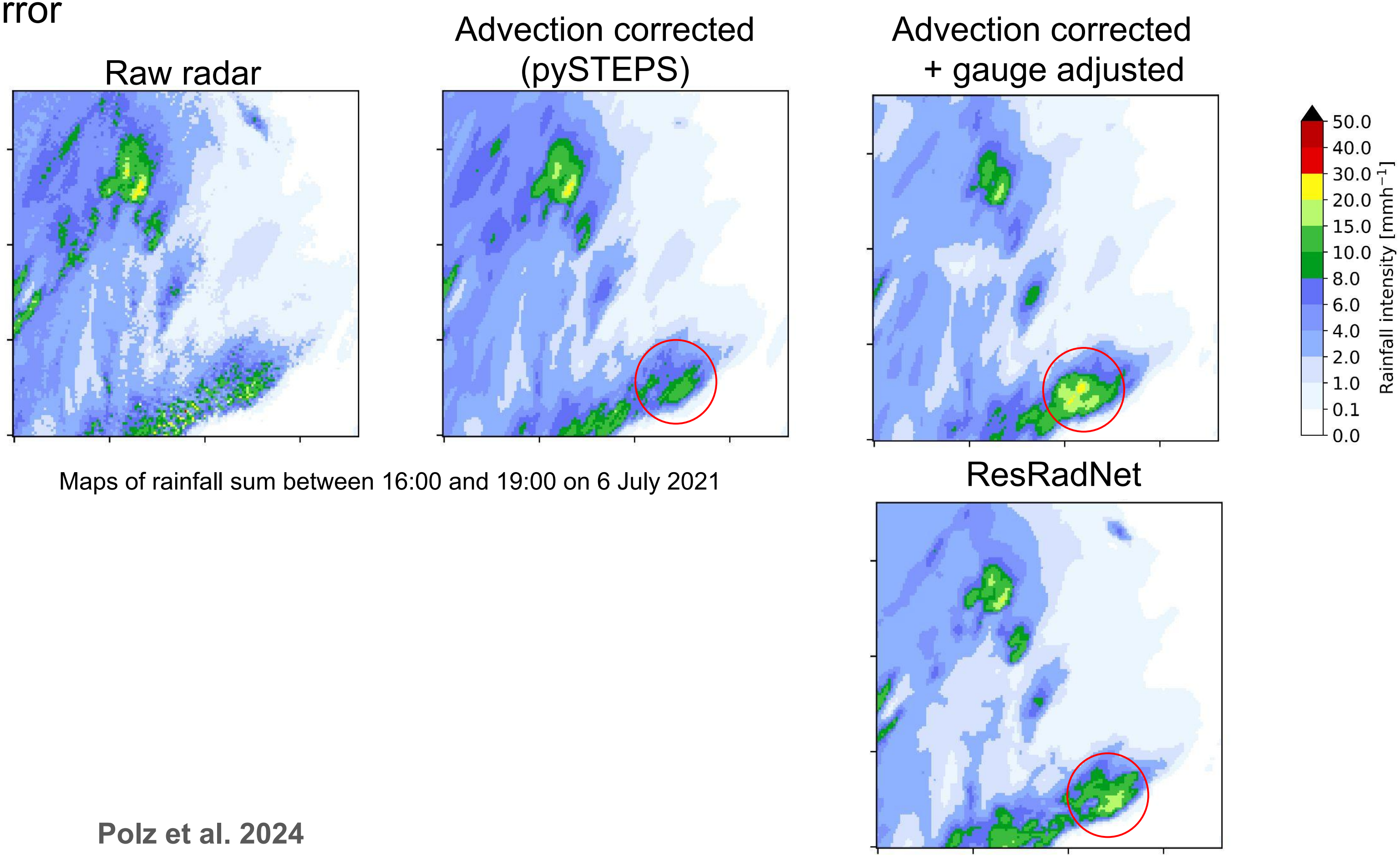
Sampling error



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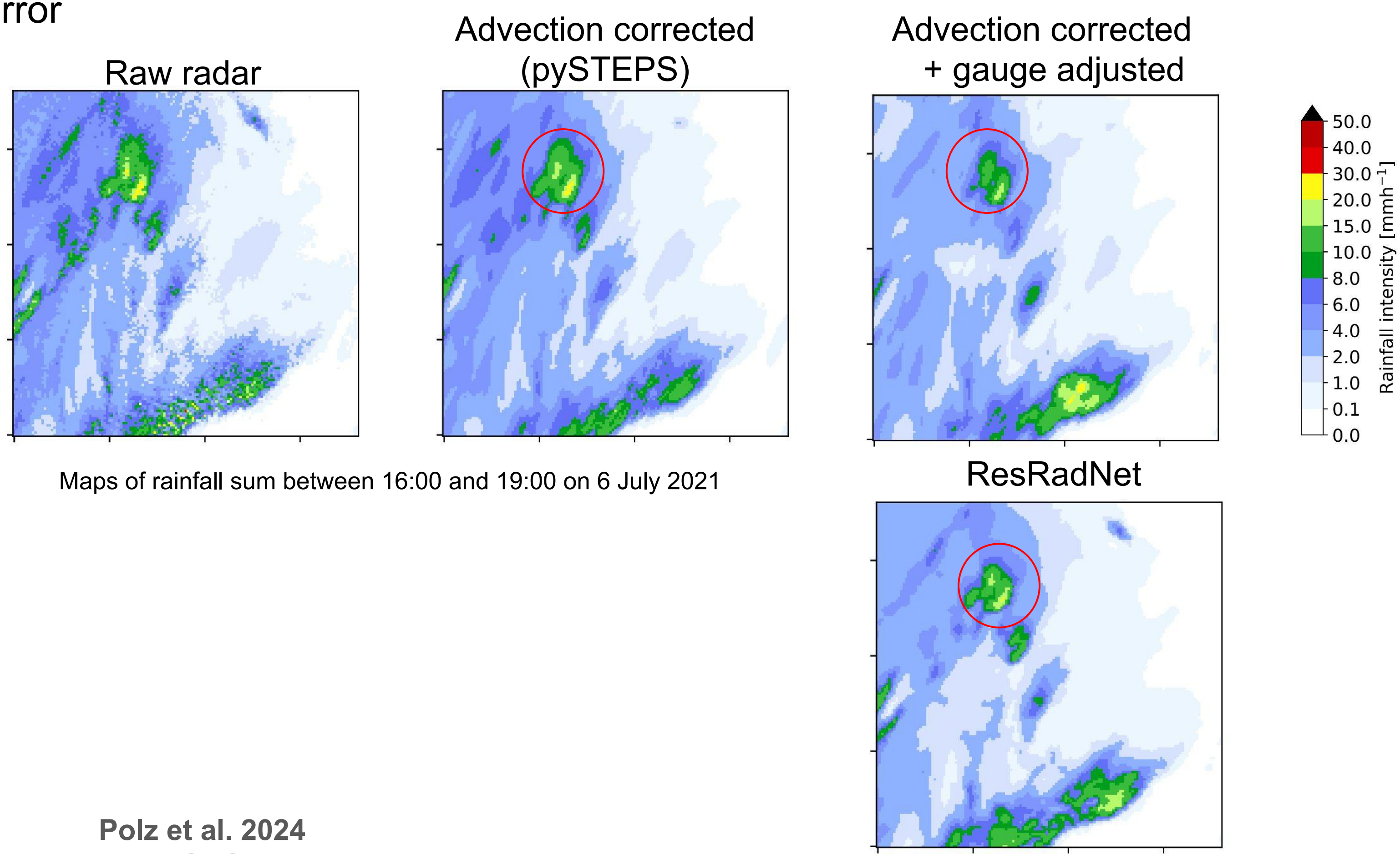

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