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New pathways for high-resolution weather radar products in the Hamburg metropolitan region

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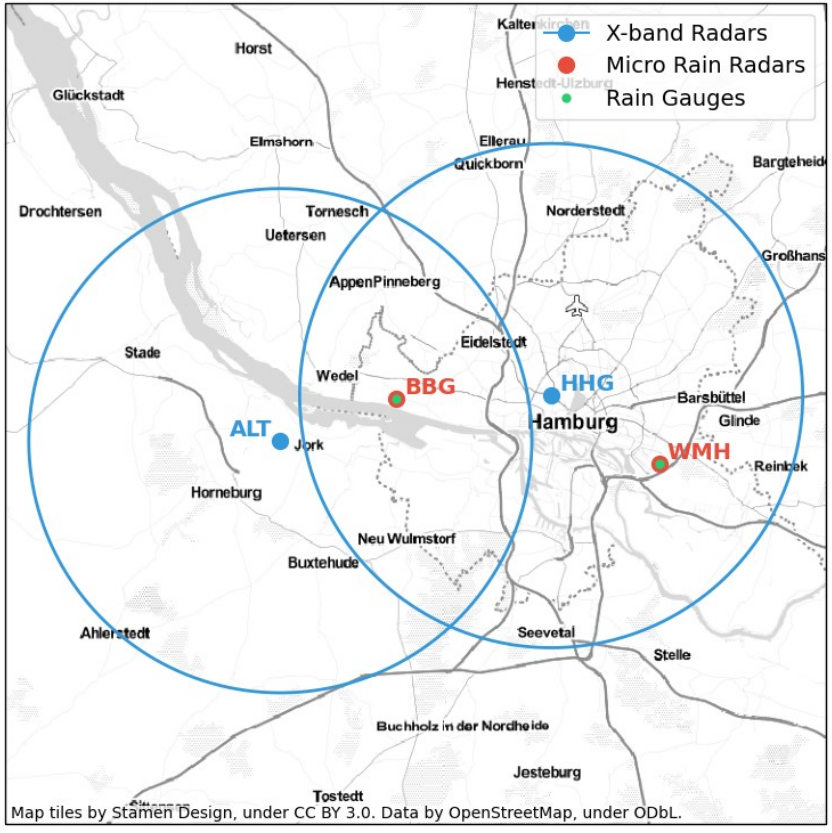
New pathways for high-resolution weather radar products in the Hamburg metropolitan region

Keywords: Weather Radar; Urban Hydrology; X-band; Observation Network; Single Polarization; Small Scale Precipitation Structure; High Spatial and Temporal Scale, Attenuation Correction; Deep Learning Approach; Neural Network, Error Minimization, Python Package; CliCCS – Climate, Climatic Change, and Society

Focus on Networked Observations in Urban Area



Greater Hamburg, Germany

- X-band weather radars
  - spacious high-resolution precipitation measurements
  - supplement nationwide C-band radars
  - HHG radar operational since 2013
  - (ALT radar will start mid 2020)
- (K-band) Micro Rain Radars
  - vertical profiles
  - as calibration reference in relevant height levels
  - calibration of MRRs with rain gauges

Low cost local area weather radar

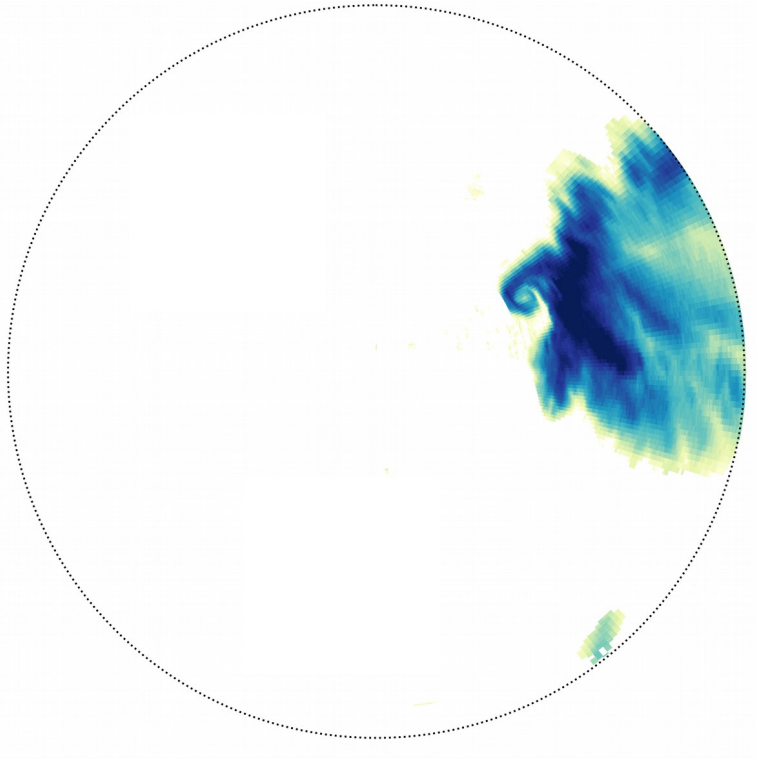
HHG radar in center of Hamburg (100 m rooftop)

- single-polarized X-band weather radar
  - modified ship navigation radar with parabolic dish
    - time resolution 30 s
    - range resolution 60 m
    - sampling resolution in azimuth 1°
    - maximum range 20 km
    - low elevation angle ~4°
  - high sample of 12 rotations include ~67 pulses per 1° and 30 s

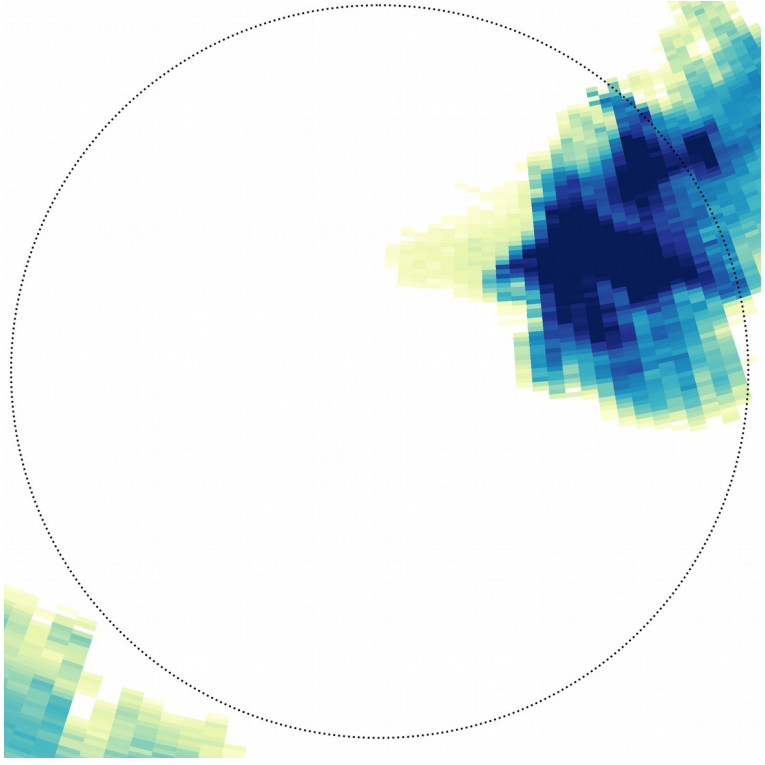
Further tech. details Lengfeld et. al (2014)

Higher temporal and spatial resolution

X-band

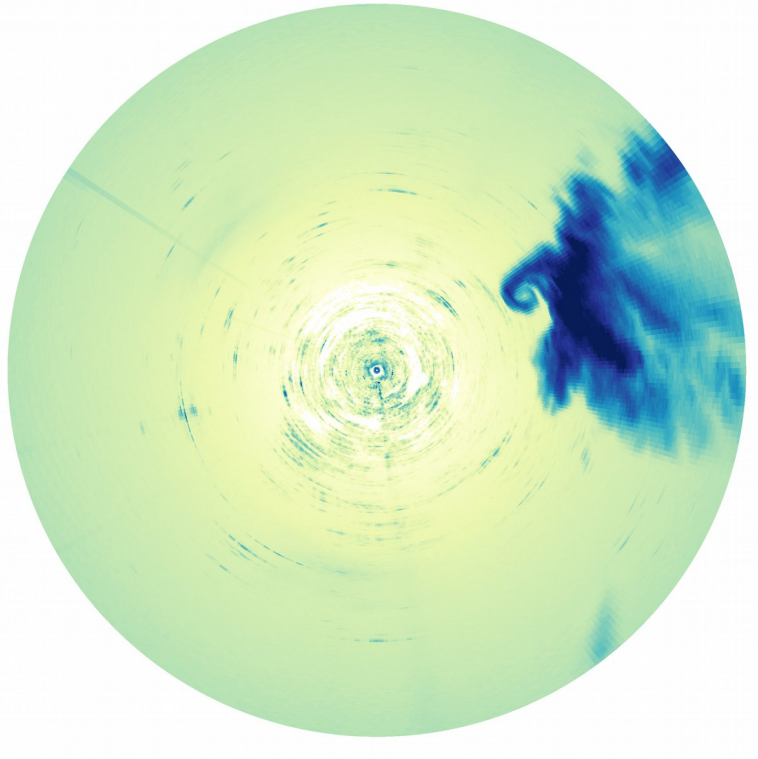


C-band



- valuable information on the small-scale structure of rain events in urban region (this example shows a tornado in a rain event)

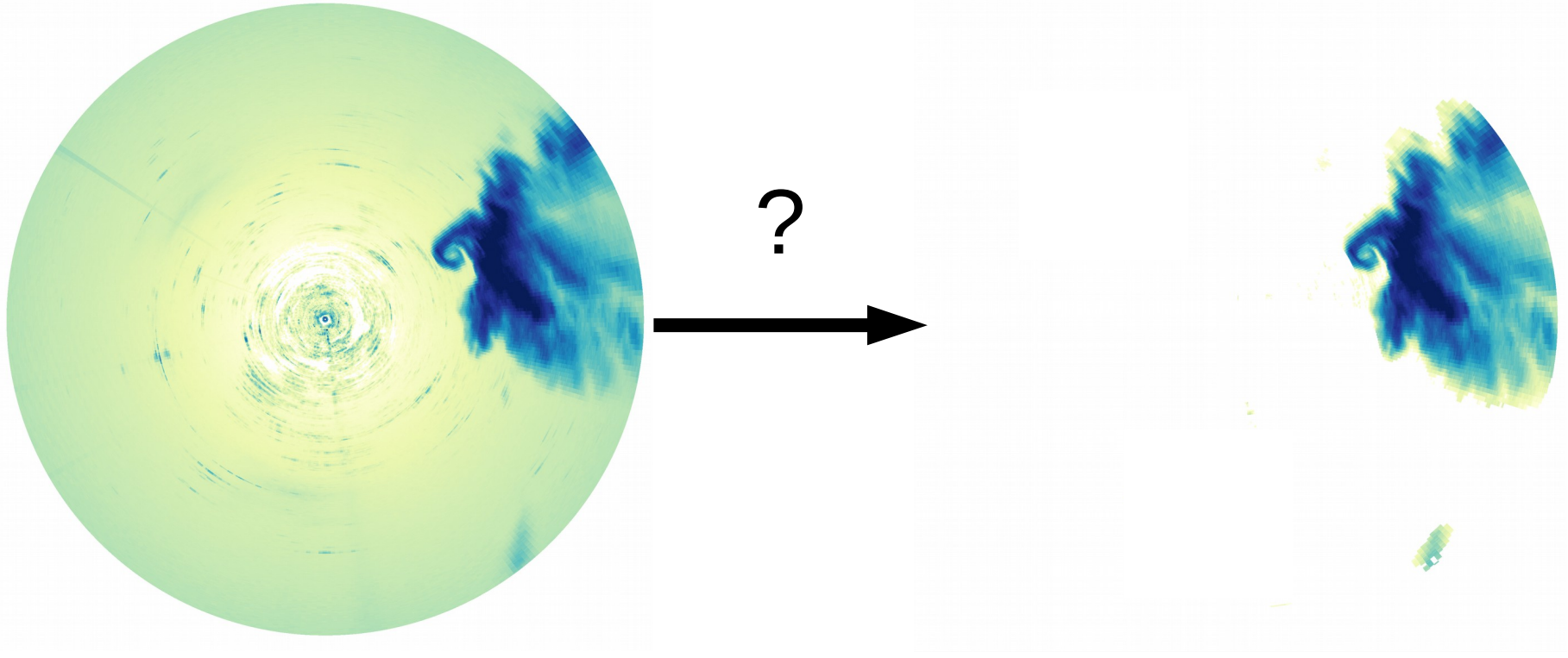
Single polarization and small wavelength is challenging issue



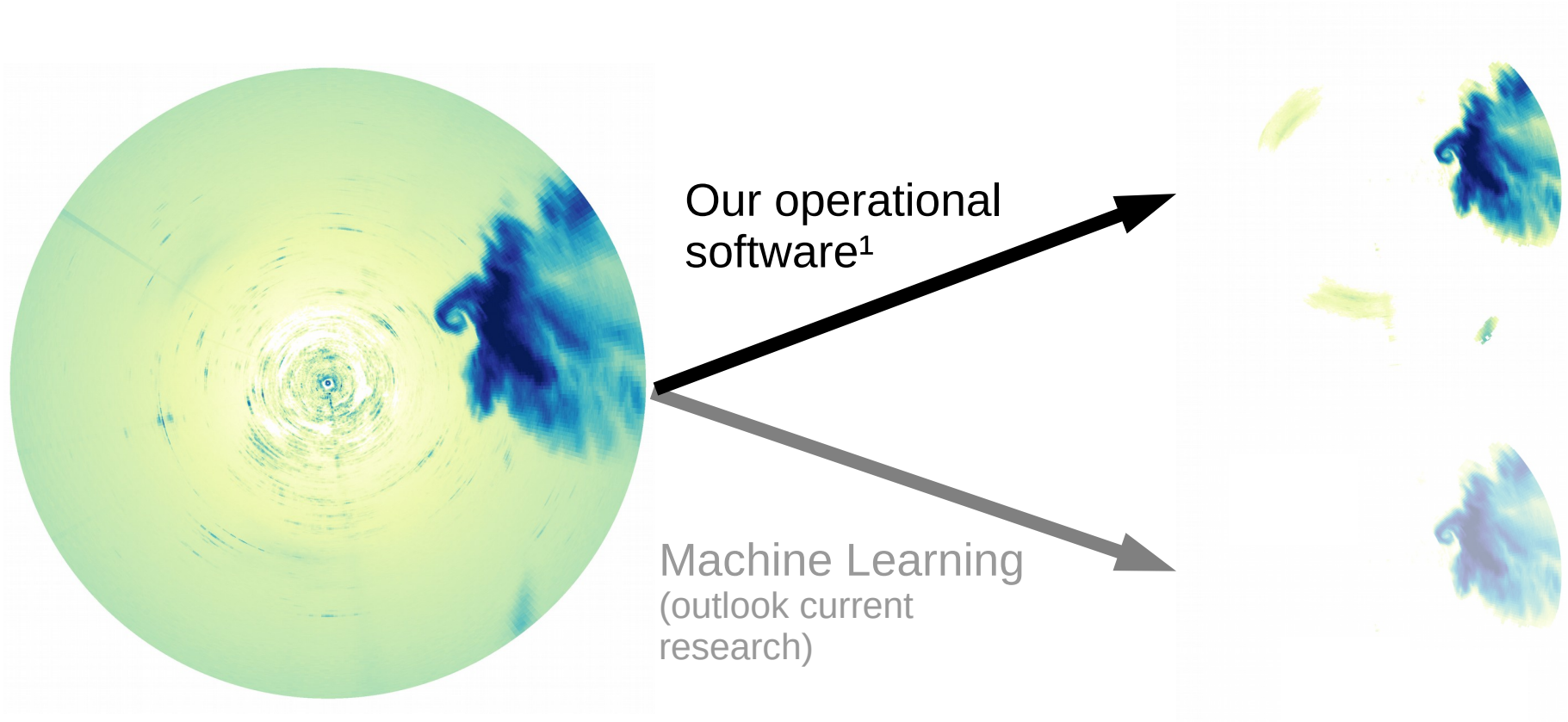
Initial disturbed weather radar observation:

- strong attenuation
- background noise (induced by the atmosphere or the internal electronic)
- variety of non-meteorological echoes (increased in urban environment)

How to derive a undisturbed product?

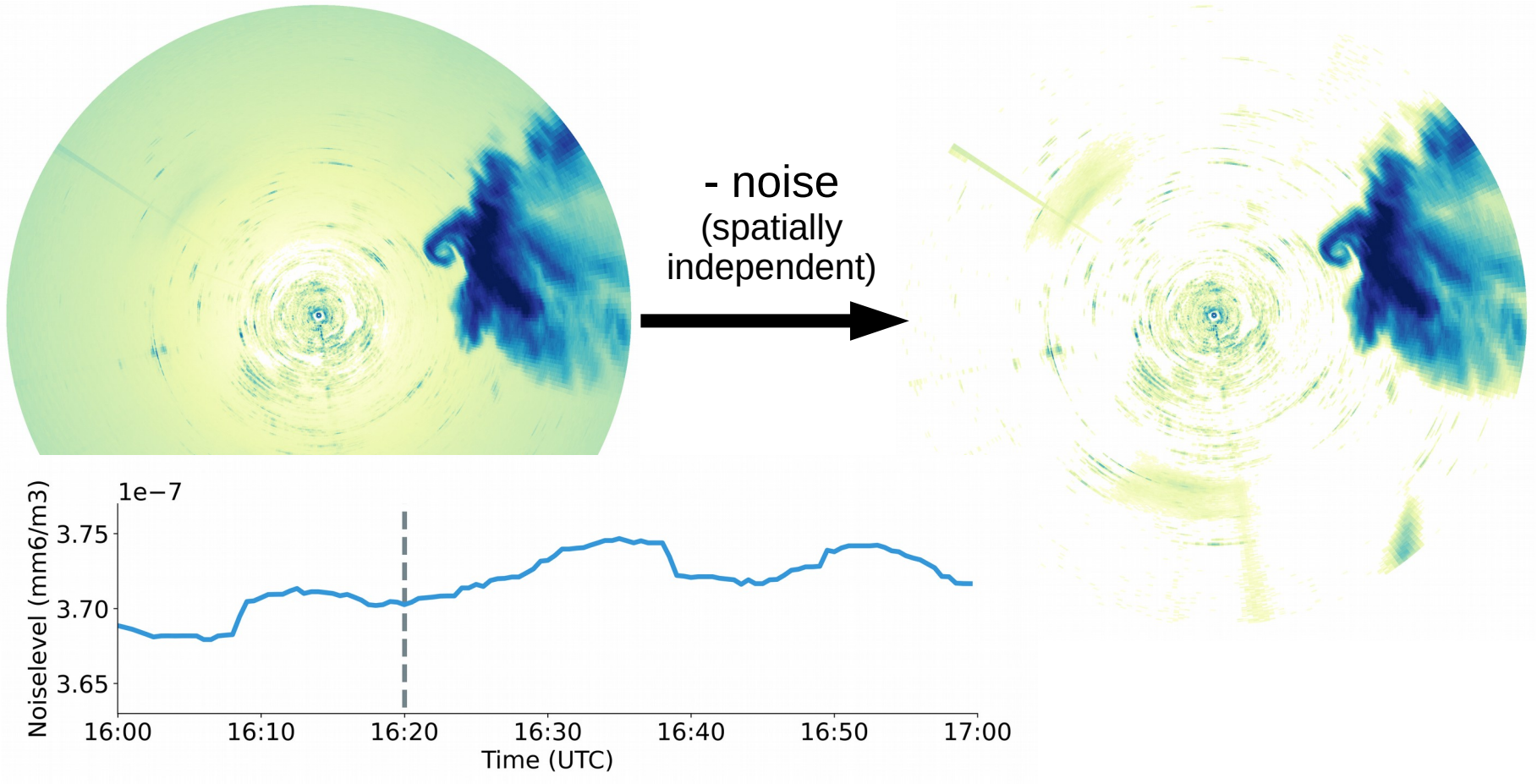


How to derive a undisturbed product?

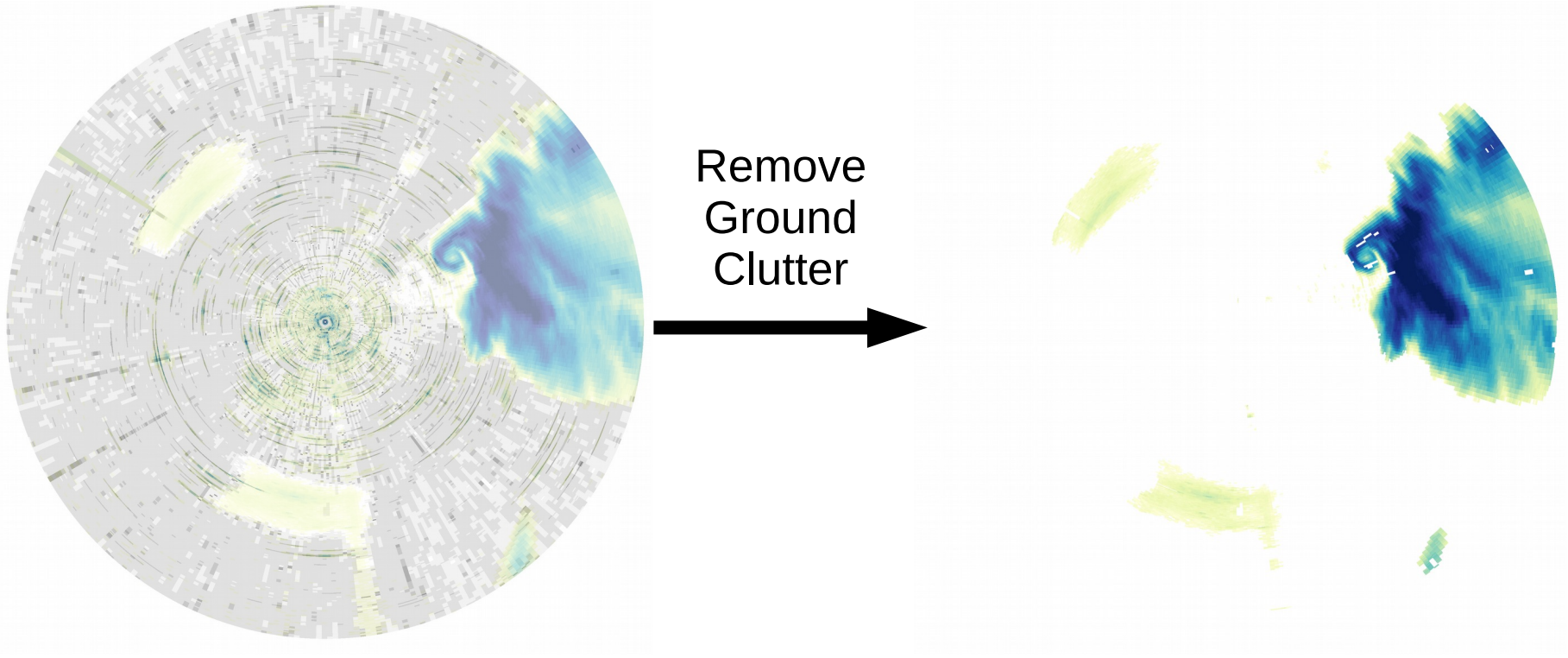


[1]pylawr – A python package for operational weather radar processing
Burgemeister, F., T. S. Finn, M. Schaper, Y. Büchau, M. Clemens, and F. Ament, 2020, in prep.

Dynamic estimation of background noise

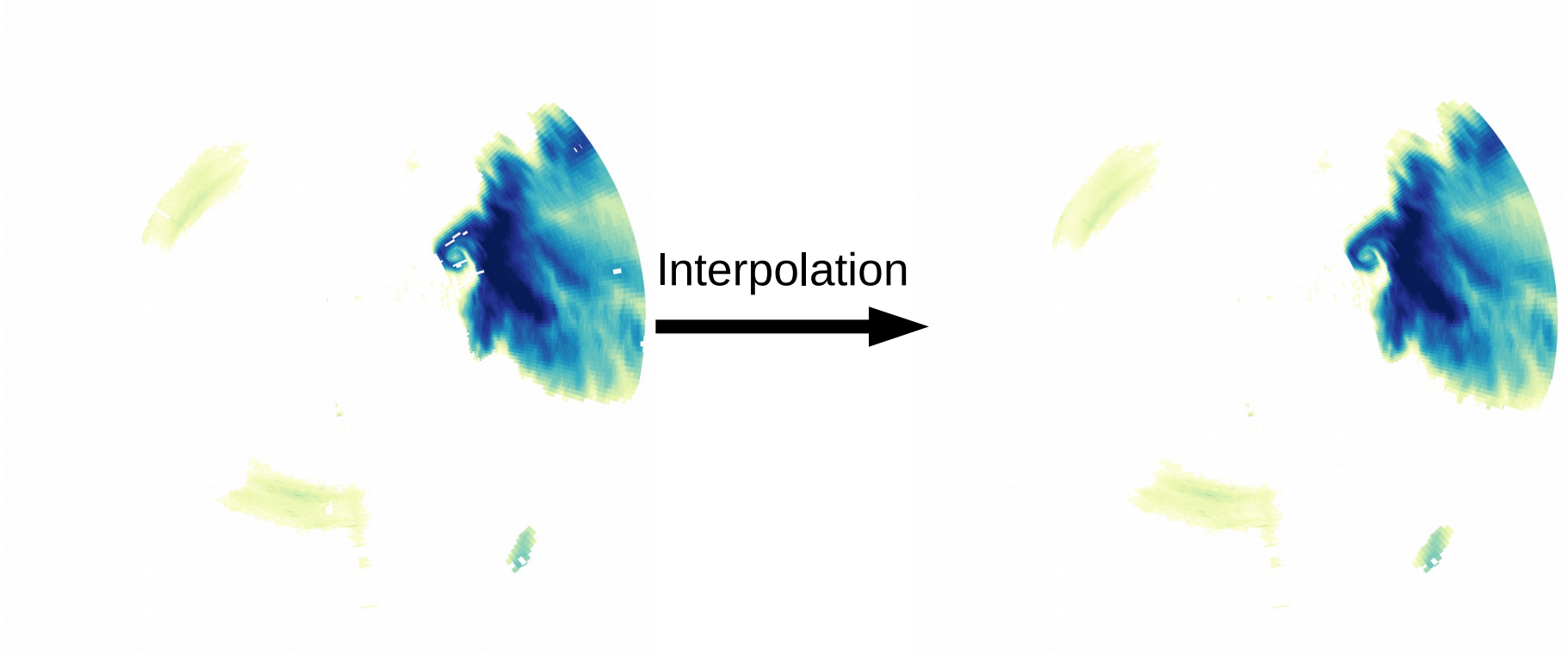


Dynamic estimation of non-meteorological echoes



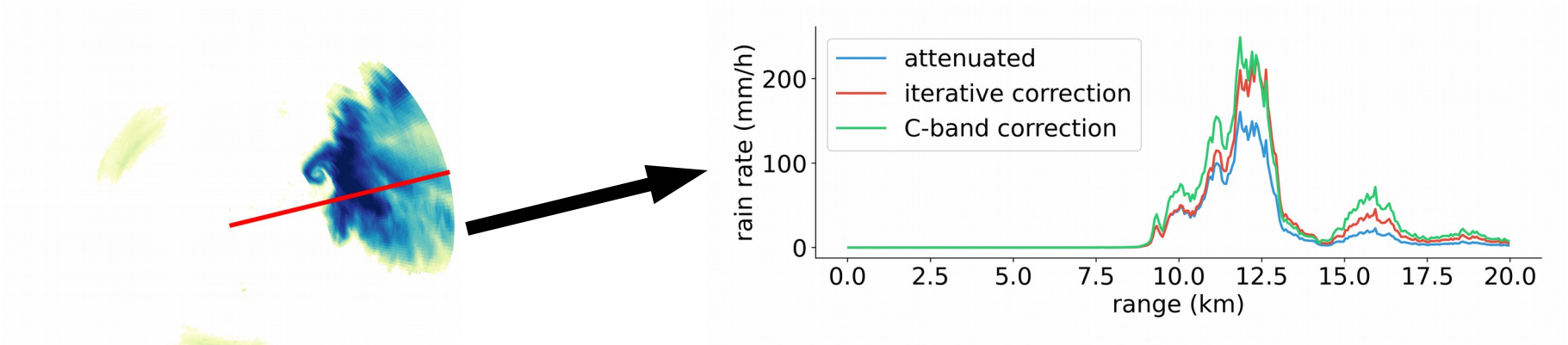
multiple applications of Gradient-based filters + Optical filters + Time-dependent filters

Interpolation of missing values



Adaptive Kriging including time-dependent update of parameters

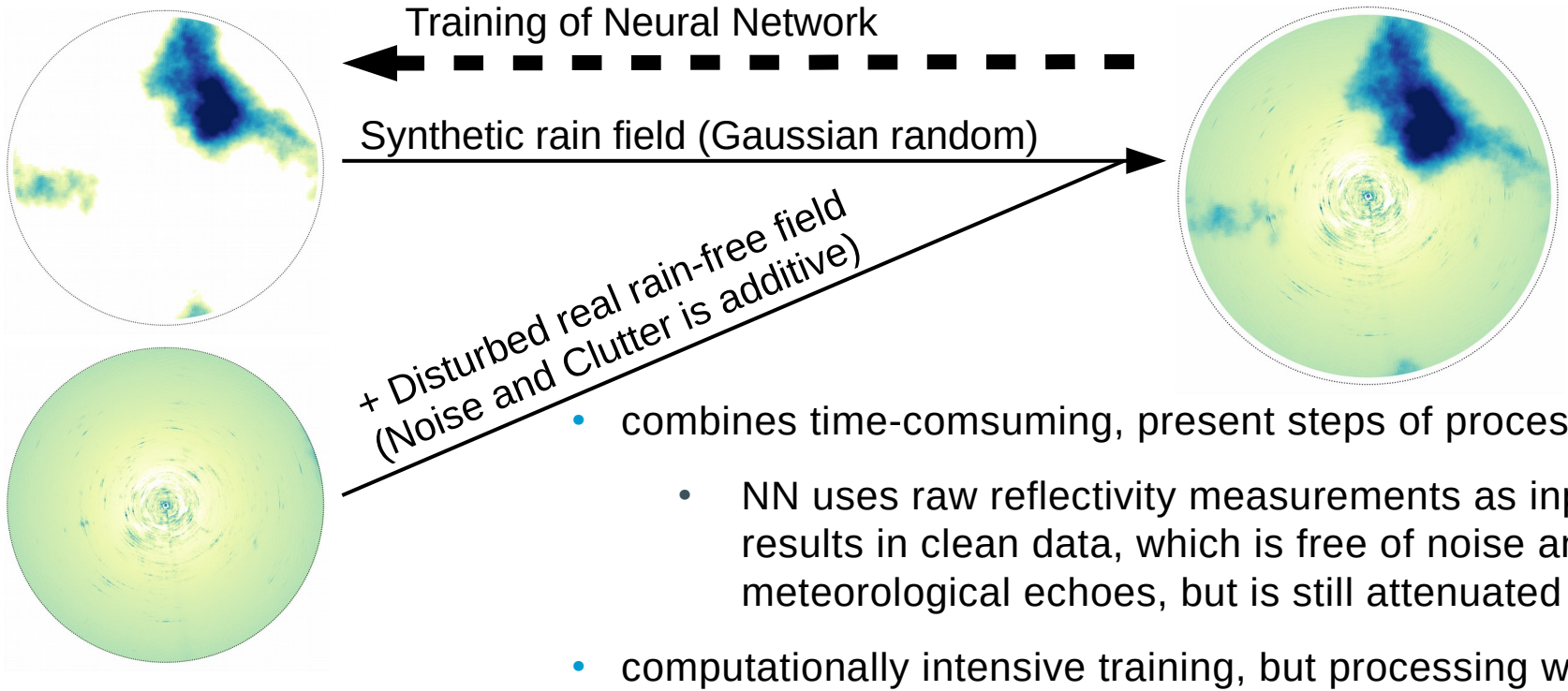
Attenuation correction



Implemented correction methods for significant attenuation caused by water at X-band

- iterative correction over the range integrated from *wradlib* (Heistermann, Jacobi and Pfaff, 2013)
- correction by less attenuated C-band radars using isotonic regression of ratios (Lengfeld et al., 2016)
- at this example: extreme rain rates probably because of hail

Outlook: Convolutional Neural Network for Radar Data



- combines time-comsuming, present steps of procesing
  - NN uses raw reflectivity measurements as input and results in clean data, which is free of noise and non-meteorological echoes, but is still attenuated
- computationally intensive training, but processing with trained network less computational than pylawr.
- good at structures, but amplitudes differ
- further research needed for explicit application

Machnitzki, 2019

Summary

- high-resolution X-band weather radars supplements the nationwide, coarser C-band observations within the greater urban area of Hamburg, Germany
- We are capable to **minimize the errors of single-polarized X-band weather radar** observations with our python package *pylawr* combining well-established algorithms:
    - Background noise + Non-meteorological echoes + Attenuation correction
- **neural network can process radar observations** resulting in images, free of noise and non-meteorological echoes
    - trained neural network is significant faster than *pylawr*
    - NN results in better structure of rain field, but *pylawr* results in more accurate values
    - suggest combination of NN and *pylawr* (example NN for detection of non-meteorological echoes)
- recent research focuses on **uncertainty of precipitation estimation from weather radar** observations oriented on urban hydrology within the **Cluster of Excellence CliCCS – Climate, Climatic Change, and Society** and **Universität Hamburg**