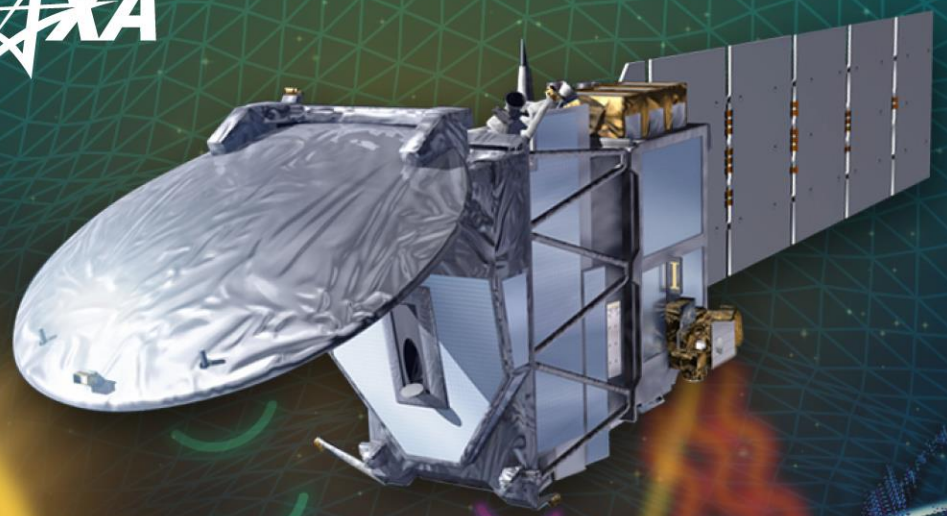

ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop

13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy

FRM4Radar –

Cloud Profiling for Satellite Validation

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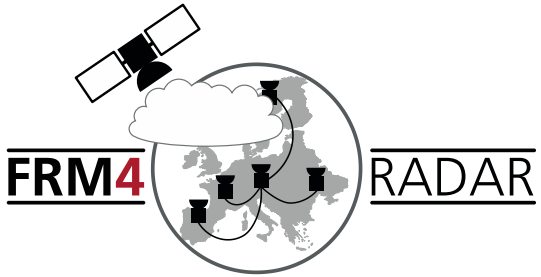
1) University of Cologne, Germany

2) Stony Brook University, NY, USA

3) SMHI, Sweden 4) INOE, Romania 5) Finish Meteorological Institute, Finland 6) ESA / ESTEC 7) ESA / ESRIN

Objectives of the FRM4Radar Project

- Create the foundation for Fiducial Reference Measurements (FMR) for the EarthCARE Cloud Profiling Radar (CPR)
- The role of the FMR's is to deliver confidence to user community in the CPR products by means of ground-based observations
  - Quality check of data: C-FMR, C-CD,
  - Quality check of retrieval products: C-CT, C-CLD, C-PRO
- The EarthCARE CPR FMR is a 94-GHz radar network
  - Uses the same wavelength as the EarthCARE CPR
  - Closes geographical gaps of the European ground-based network
- Foster the development of new Cal/Val products
- Long term monitoring of the data – over years



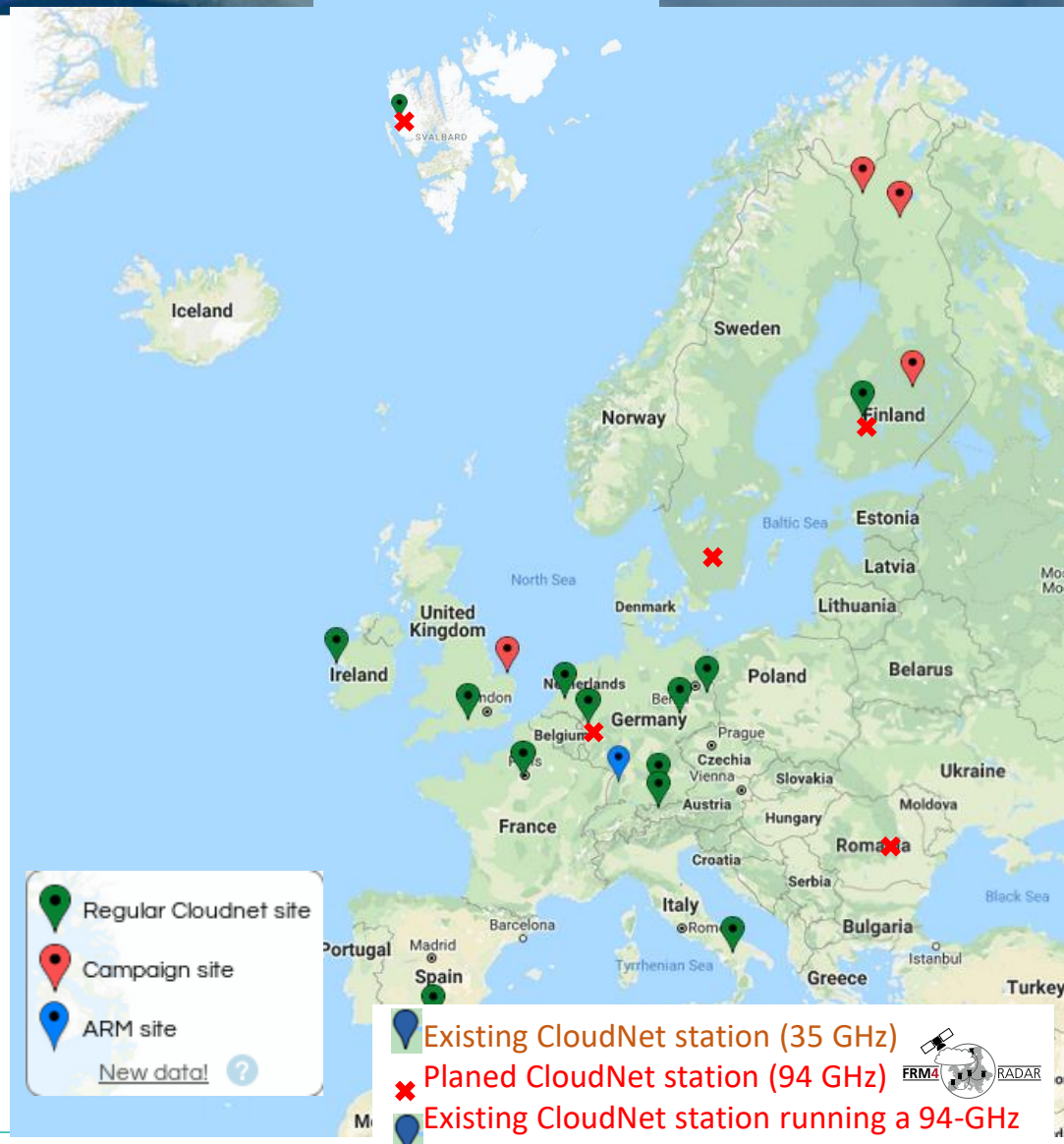
Cloudnet & FRM4Radar Network

- Compliment the existing 94-GHz EU network and fill gaps in under sampled regions (Sweden & Romania)
  - Coverage of different cloud and climate regimes
- Instrumental synergy with ceilometer and microwave radiometer
  - Run 94-GHz version of Cloudnet (no microwave radiometer needed)
  - Improve Cloudnet coverage
  - Validation of CPR retrievals
- Cloudnet: Cloud target classification algorithm (Illingworth, 2007, BAMS, Tukiainen et al., 2020, JOSS)

ACTRIS-CloudNet classification

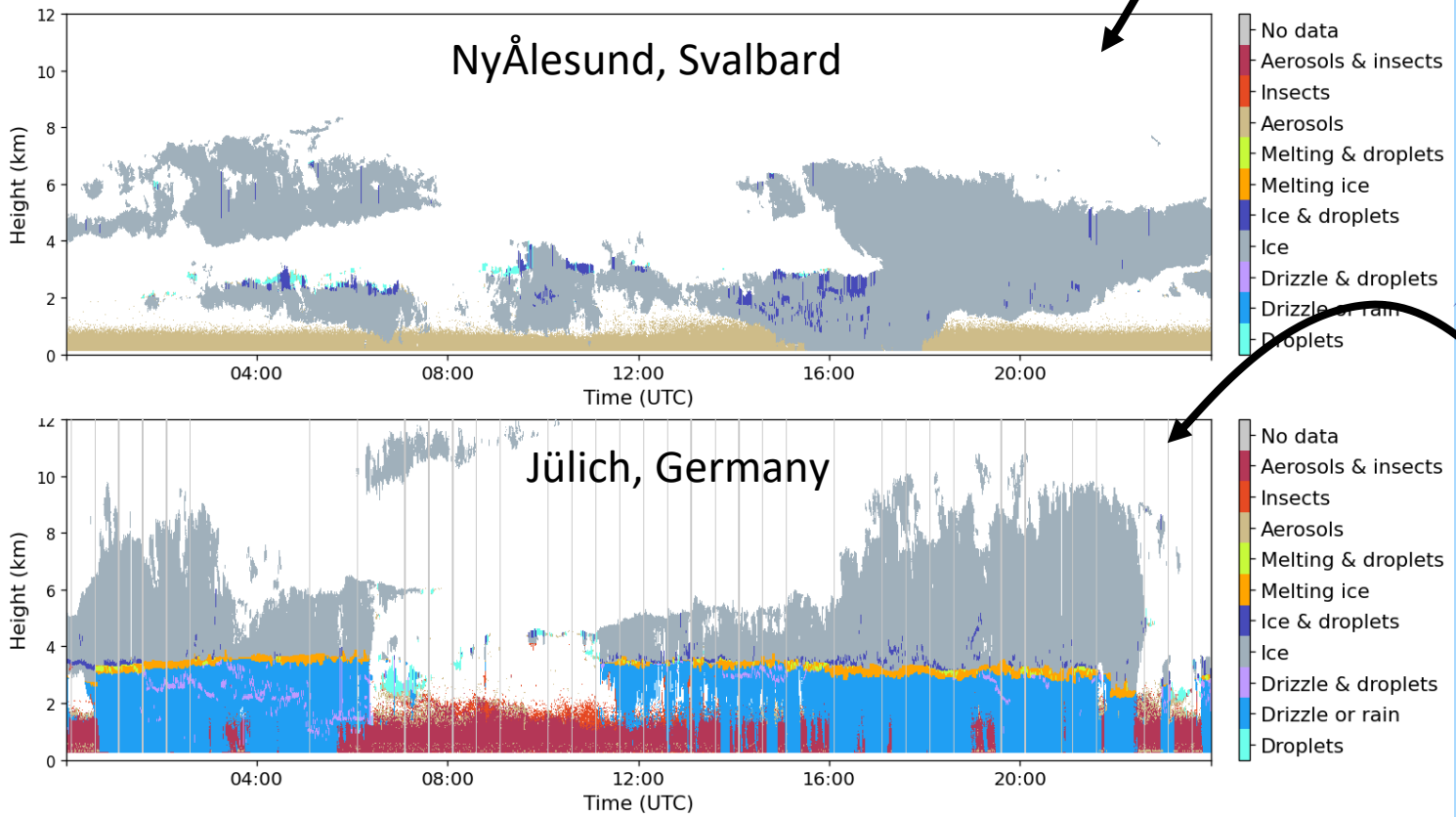
- Cloudnet algorithm
  - Atmospheric target classification algorithm
  - Instrumental synergy
    - ✓ Radar
    - ✓ Microwave radiometer (89 GHz channel radar)
    - ✓ Ceilometer
  - Implementation of the FRM4Radar station into the Cloudnet/ACTRIS network
  - Standardized quality controlled data set

➢ Collaboration with ACTRIS
  - Ze-monitoring
  - antenna miss-pointing

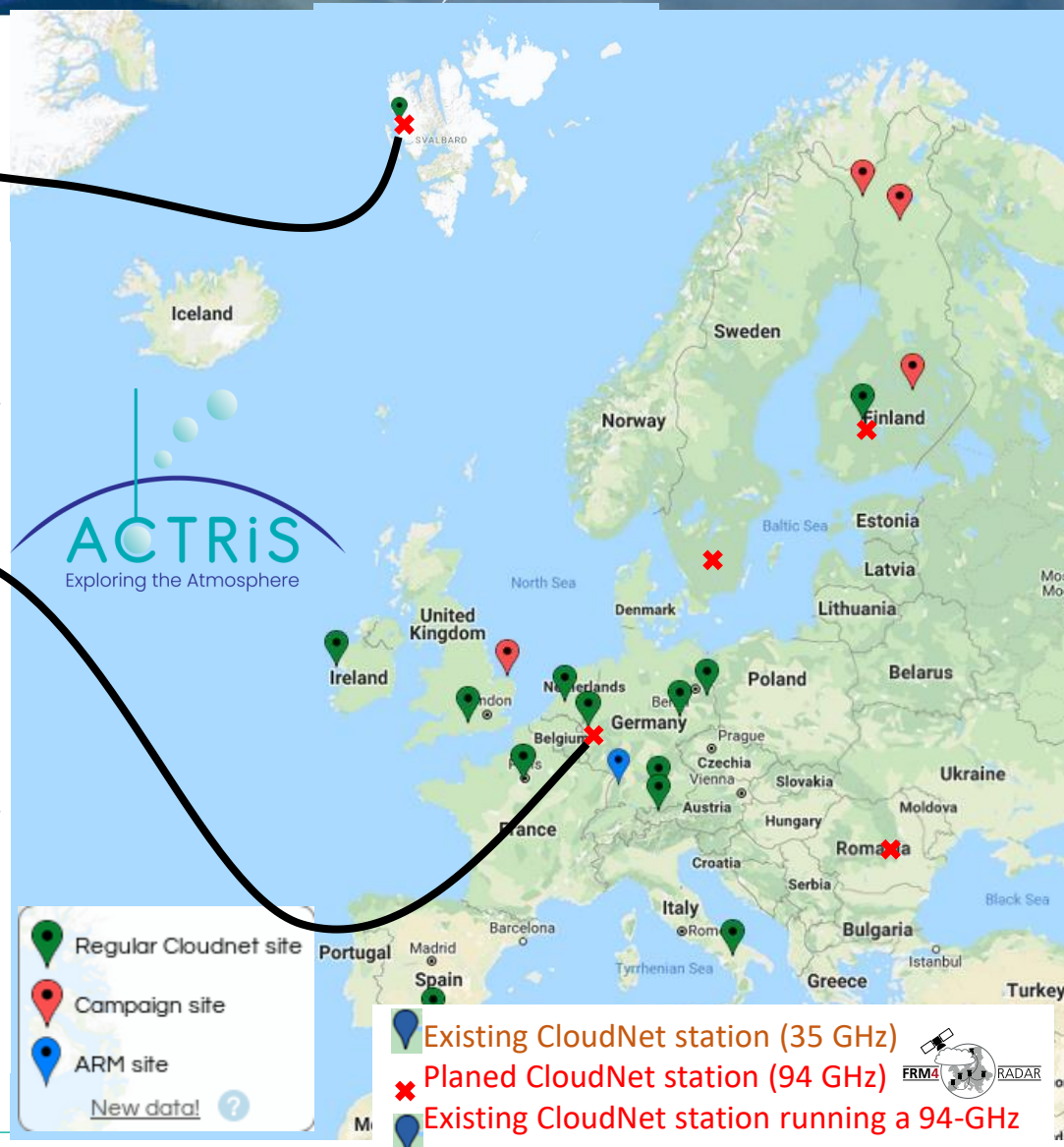


ACTRIS CloudNet classification

Cloudnet Classification 13th Oct 2023



see www.cloudnet.fmi.fi for more



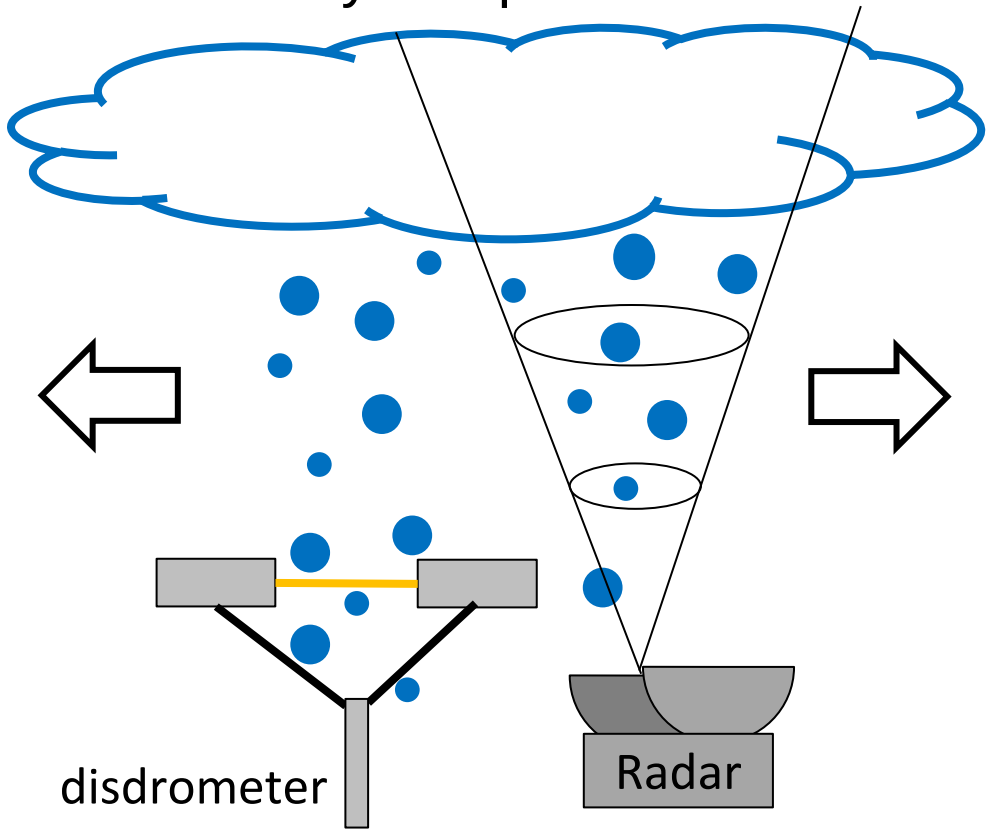
Concept: Radar Ze-monitoring

- Total system calibration monitoring
- Based on Disdrometer radar reflectivity comparison method *

* *Kollias et al., 2019, AMT*
Myagkov et al., 2020, AMT
Chellini, et al., 2022, JGR Atmos

<u>Disdrometer:</u>
optical particle counter
N(D)

- Forward modeling of Ze based on measured N(D)
- Compare forward simulated Ze_dis to radar Ze

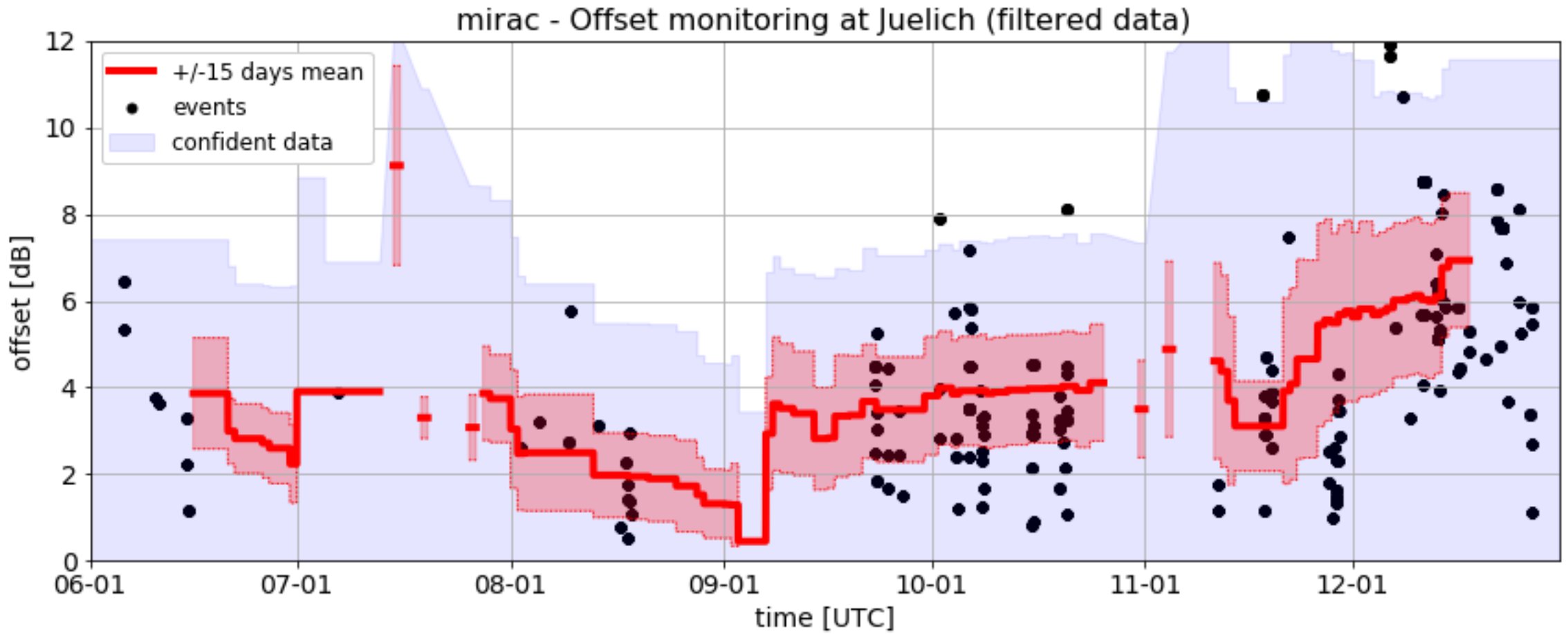


<u>Radar:</u>
Measures reflectivity (Ze) of all drops in volume

- Ze ~ **N(D)** D^6
- Correction of Ze for attenuation
- Compare Ze to Ze_dis calculated from Disdrometer measurements

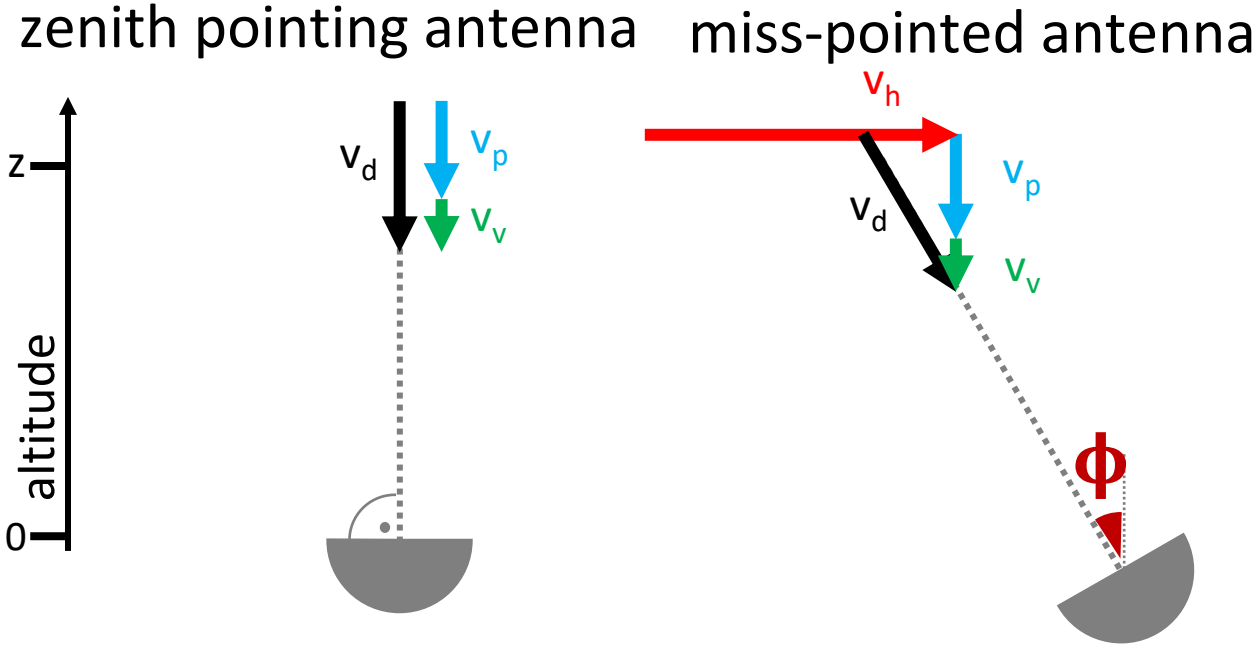
➢ **Cooperation with ACTRIS to get a standard method**

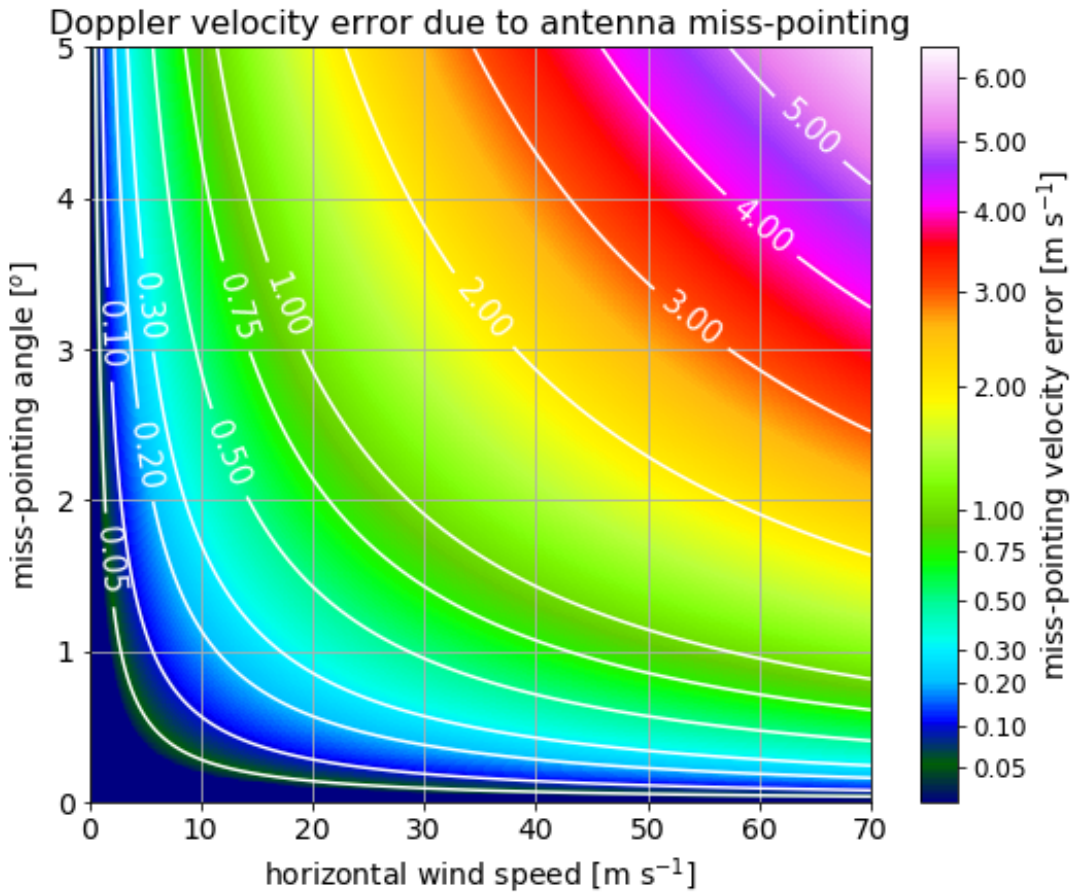
Example: Radar Ze-monitoring, JOYCE, 2019



Next project phase: Why the offset differs that much for different sites?

Concept: Antenna pointing correction





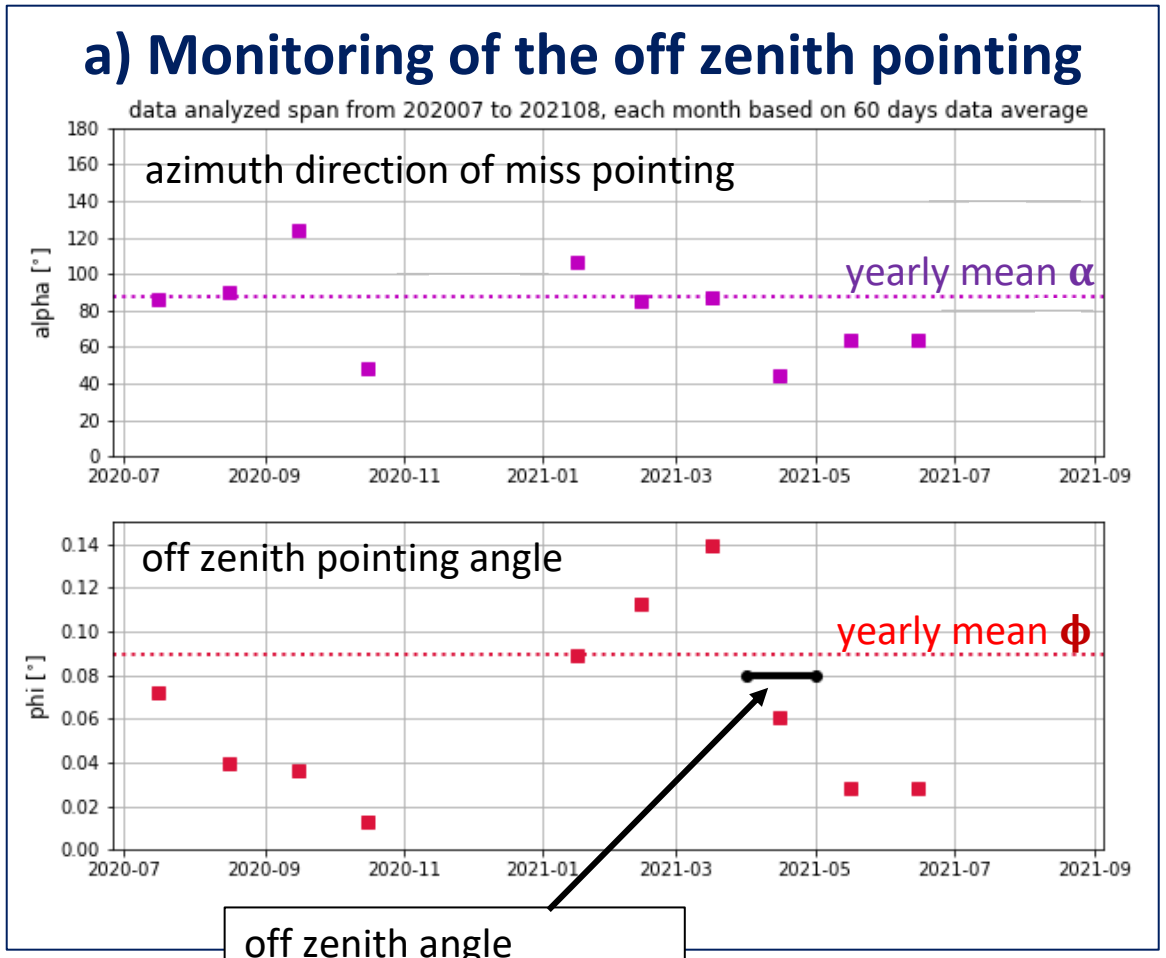
Doppler velocity is velocity component along the line of sight

- V_d = particle fall velo + air motion
- V_d = particle velo + air motion + hor wind contribution

So V_d is a function of V_h, and of the miss-pointing angle ϕ

Horizontal wind information from ECMWF IFS or retrieved from radar PPI scans

Example: Antenna pointing correction



work in progress

90 days of Doppler velocity measurements and wind direction data (ECMWF IFS)

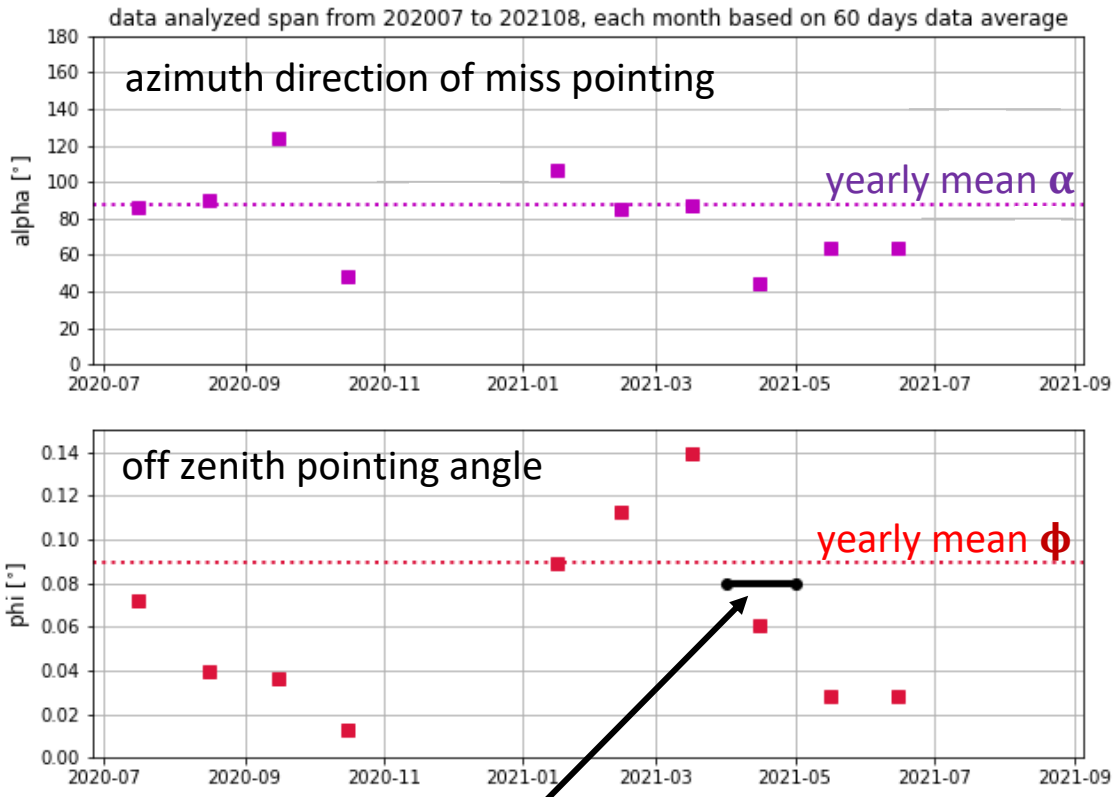
Fit the model against the data set

obtain ϕ: off zenith pointing angle

obtain α : azimuth direction of ϕ

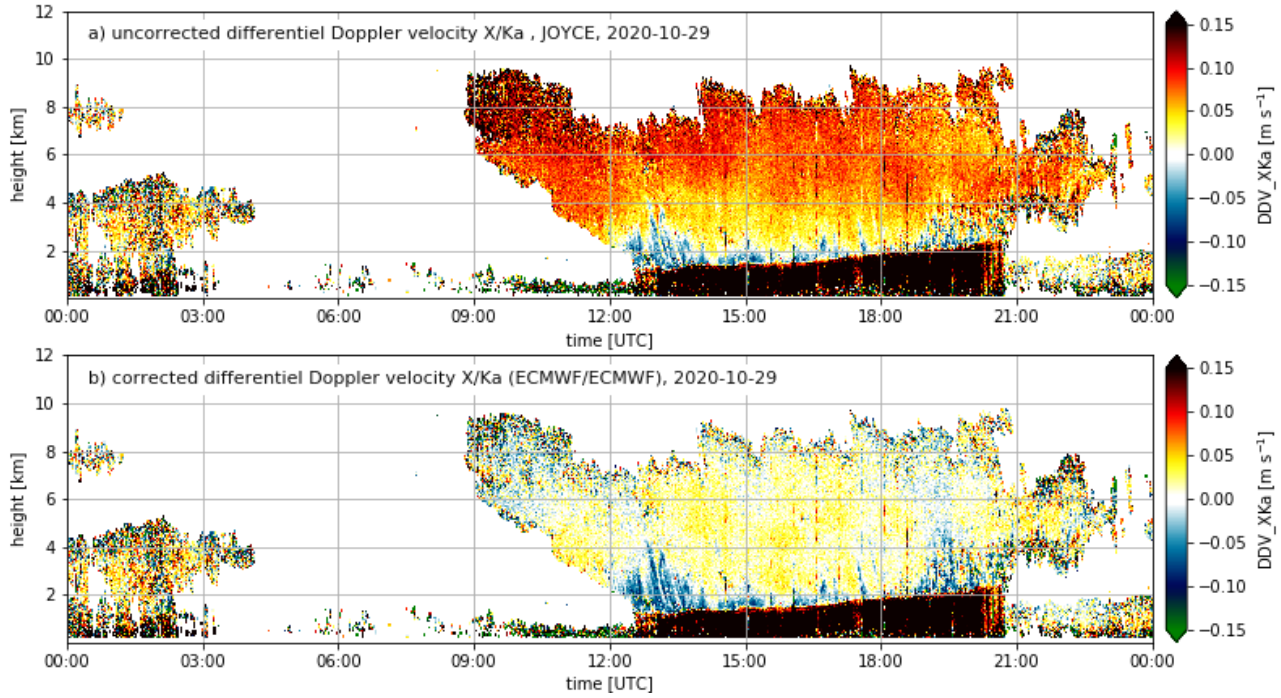
Example: Antenna pointing correction

a) Monitoring of the off zenith pointing



work in progress

b) Correction of Dual Doppler velocities



Doppler velocity difference X/Ka should be 0 at cloud top

Off-zenith poiting cause errors up to 0.15 m s^{-1}

After correction of each radar

reduction to the X- band Doppler velocity resolution

CPR forward simulation tool

Motivation:

- Create data base for CPR Cal/Val
- Usage of existing long time data sets
- Easy usage -> python code (github)

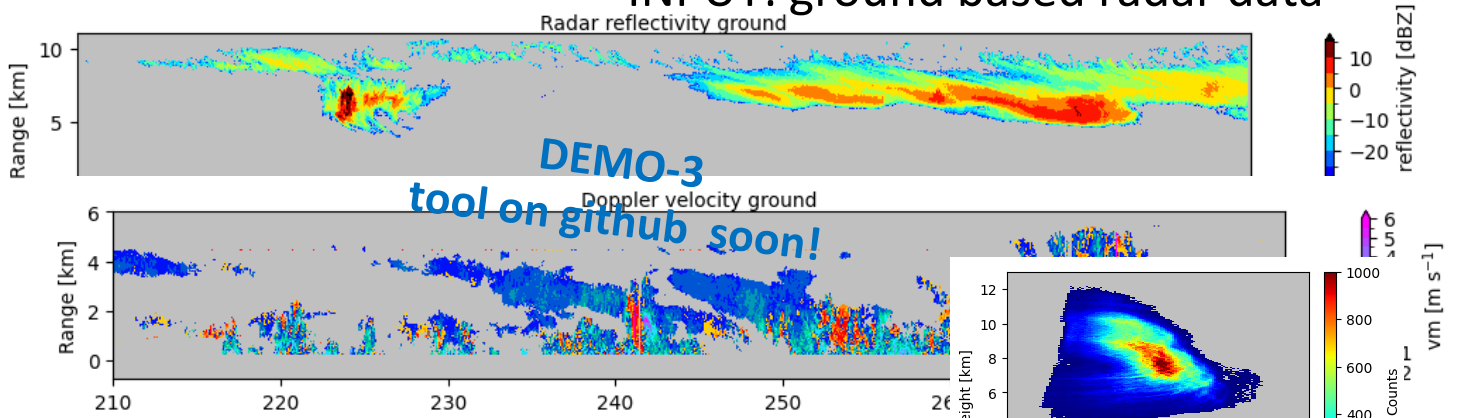
INPUT: Ground based radar data:

- Readers ACTRIS, GEOMS, airplane radar (Polar5, RASTA)
- sites act as ‘ground truth’ for EarthCARE CPR simulations
- flexible satellite configuration
  - CloudSat
  - EarthCARE

Output: EarthCARE CPR view like data

- Validation of L1 with ground
- Creation of long term data sets

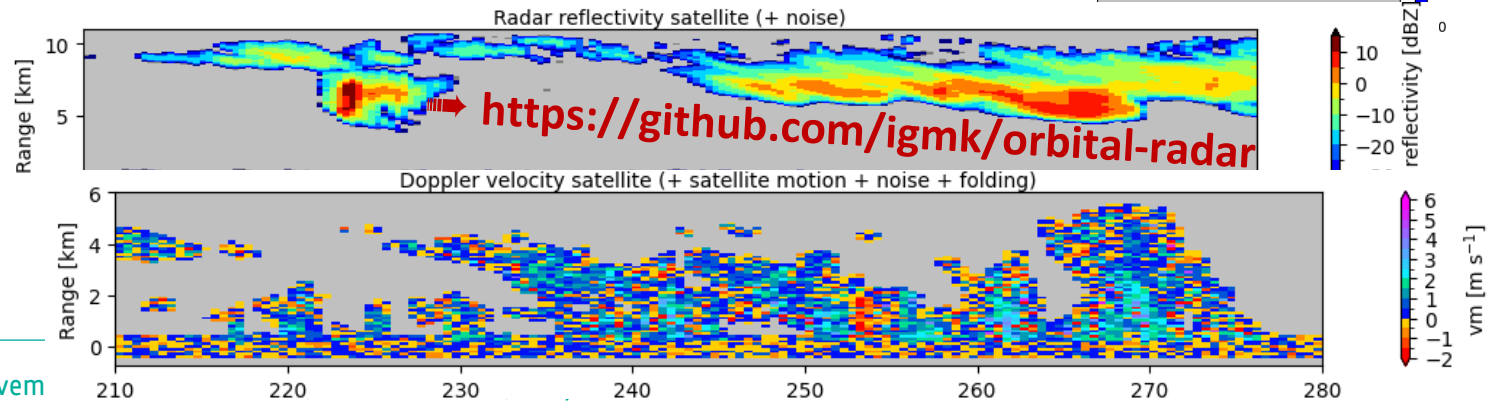
INPUT: ground based radar data



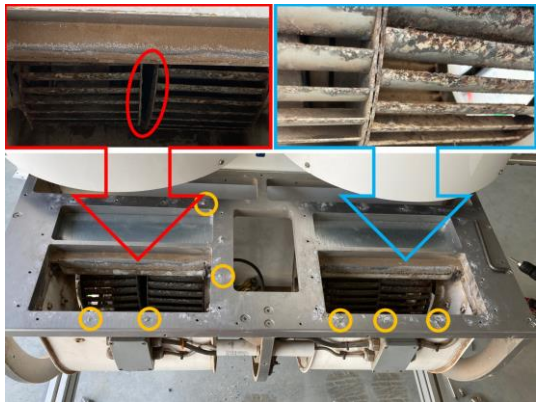
simulator/ python tool

FRM4 RADAR & ACPV

OUTPUT: EarthCARE synthetic CPR



Results

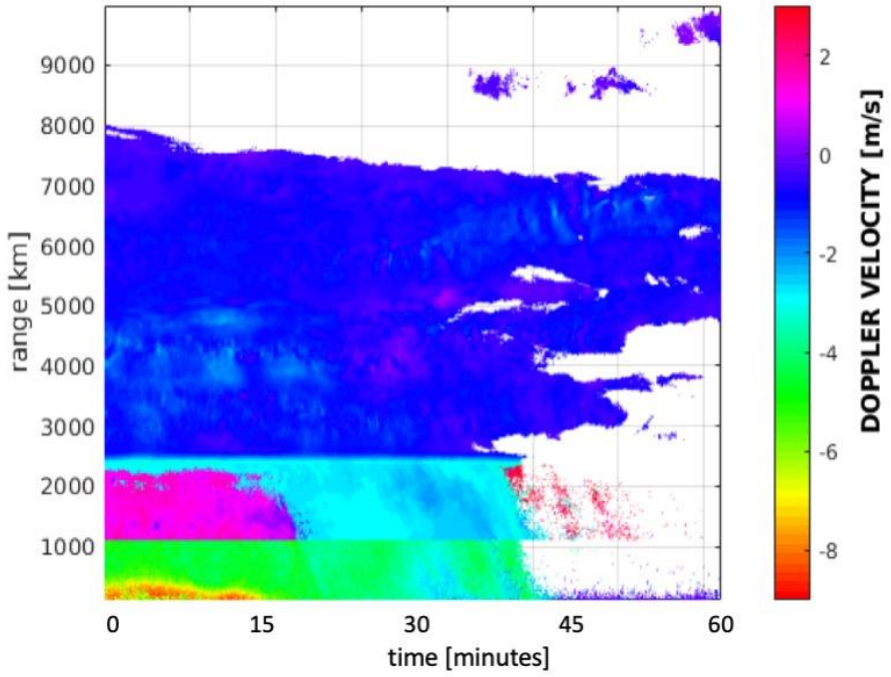


- Lessens learned in radar and disdrometer operation
- Radar data processing (Matlab on github)
  - ➢publication planned
- INOE radar part of ASKOS campaign at Cape Verde
  - ➢Data uploaded to EVDC
- Simulation tool to create synthetic EarthCARE CPR data
  - ➢Release planed soon, latest till March 2024
- FRM4Radar method on its way to be implemented in ACTRIS cloud remote sensing processing
  - Ze-monitoring – ACTRIS started the implementation
  - Antenna pointing monitoring – work in progress

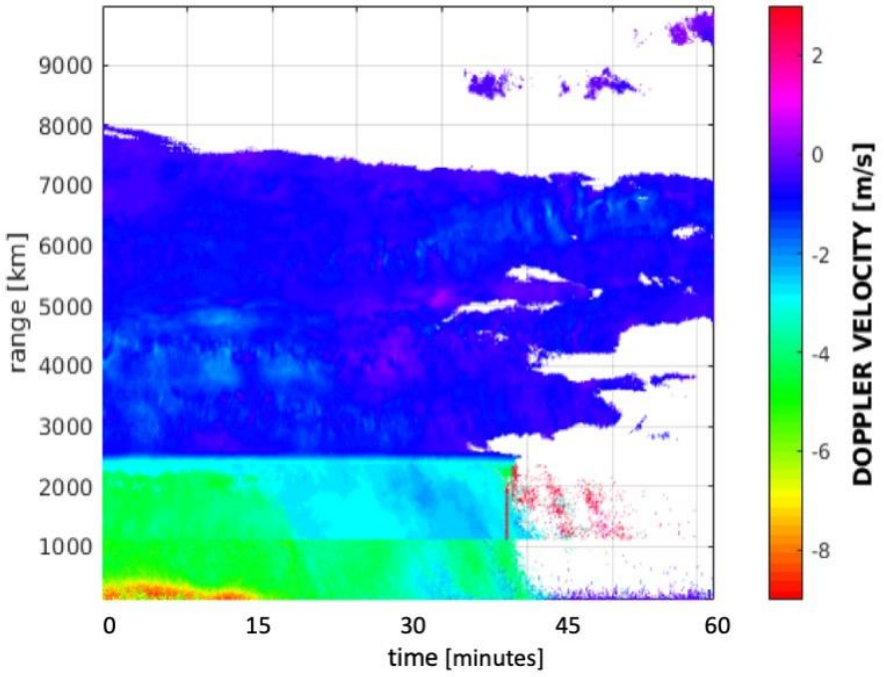
Appendix: 94-GHz cloud radar processing code

- Post-processing of the 94-GHz radar data
  - Unfolding of the recorded Doppler spectra
  - Moment estimation: Ze, Vm, Sw and higher moments such as S_K and K
  - Estimation of LDR
  - Data output in GEOMS

a) Example folded Doppler velocity



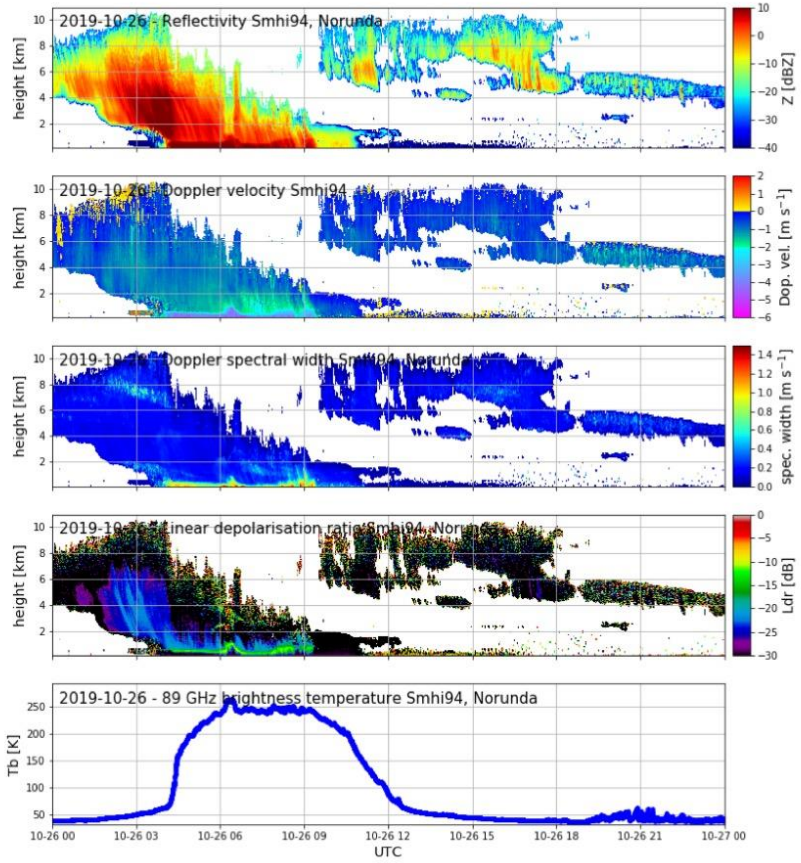
b) Example: unfolded/corrected Doppler velocity



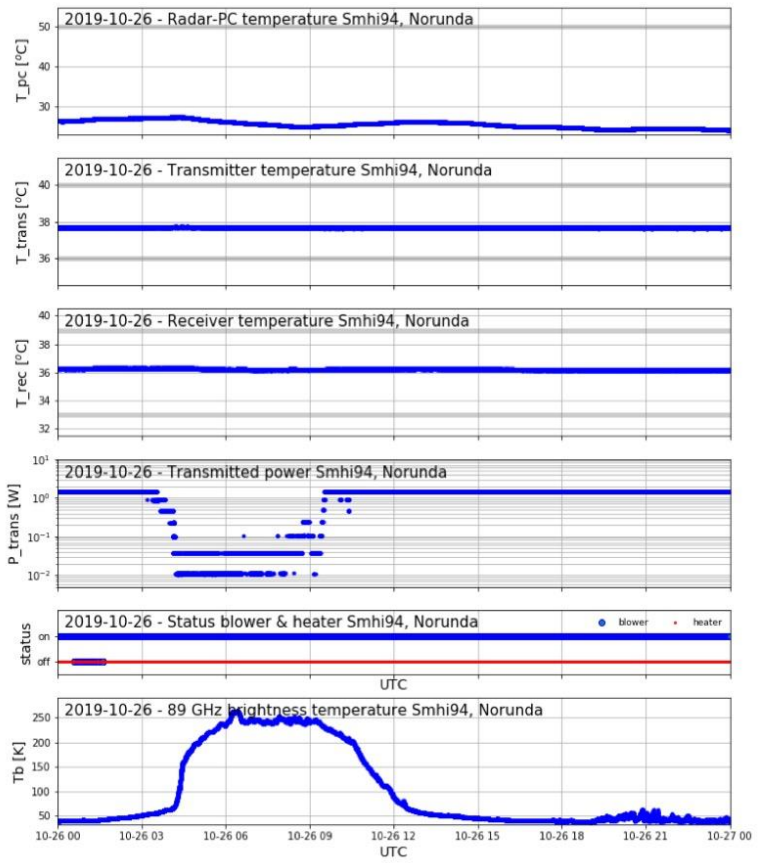
Ze: Reflectivity
Vm: Doppler velocity
Sw: Doppler spectral width
SK: Doppler spectrum Skewness
K: Kurtosis

Radar Quicklook browser / data archive

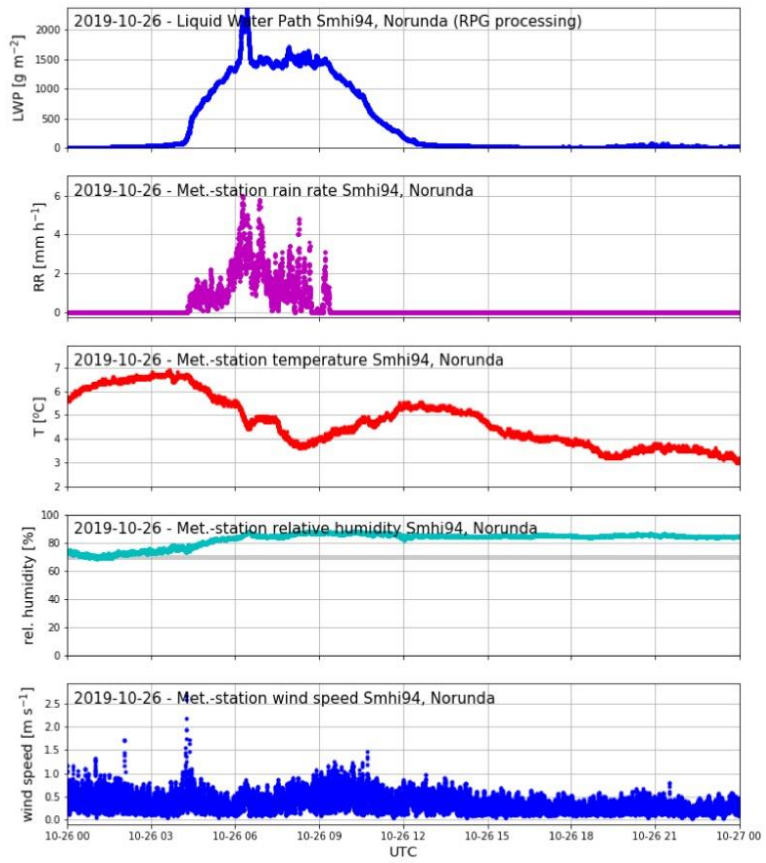
radar overview



radar status



weather station



https://atmos.meteo.uni-koeln.de/~lpfitzen/dataBrowser/dataBrowser2.html