CCRES

Scientific and technical highlights
3 presentations:

B. Pospichal, Universität zu Köln
W. Schimmel, Universität Leipzig
M. Hajipour, TROPOS

CCRES Workshop, Online –May 3-5th, 2022

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreements No 871115

Observations of the wind profile using Doppler lidar and Doppler cloud radar

Bernhard Pospichal, Marcus Müller, Stefan Kneifel

Universität zu Köln

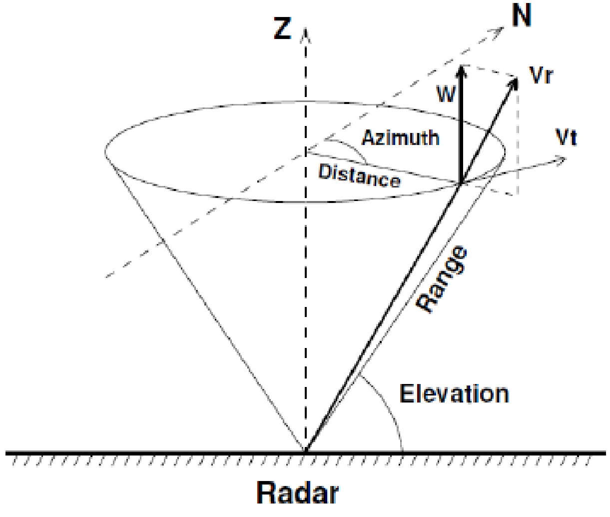
Motivation

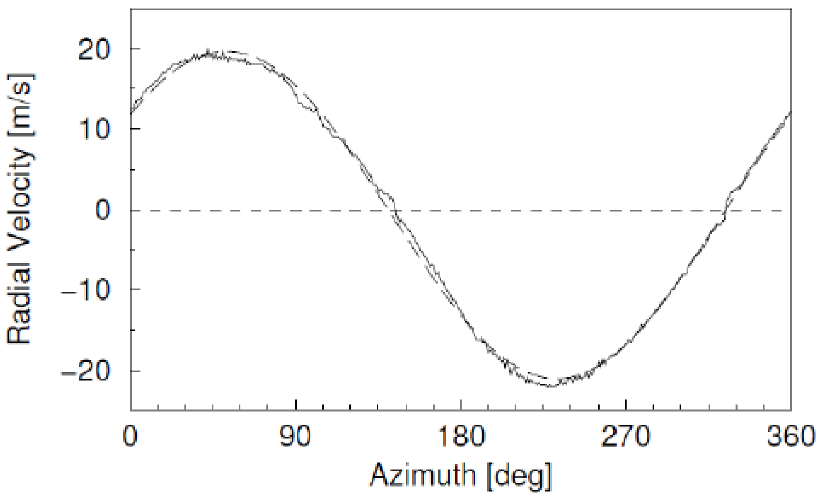
- Profiles of the horizontal wind can be obtained by ground-based remote sensing
  - Radar wind profiler (RWP)
  - Doppler wind lidar (DWL)
  - Doppler cloud radar (DCR)

➢ **ACTRIS cloud remote sensing network can provide wind profiles (DWL, DCR)**

Wind profiles - Methodology

- 3D wind vector can be derived from off-zenith azimuth scans by analyzing the Doppler shift along the line of sight („VAD scan“ Velocity Azimuth Display)





Holleman et al., 2005

Methodology

- Detection needs tracers that float with the air flow
  - RWP: Clear-air fluctuations of the refractive index (Bragg scattering)
  - DCR tracers: Cloud particles, Insects
  - DWL tracers: Aerosols
- Problems/Limitations:
  - Absence of tracers
  - Fall speed of particles (esp. rain)
  - Own movement of tracers (insects)
  - Attenuation of signal (esp. by clouds for DWL)
  - Assumption of homogeneous wind field (turbulence)
- Combination of methods (DCR+DWL) increases coverage

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Combined product for wind profiles

- **Doppler lidar VAD scan**
  - zenith angle 15°, every 15 minutes
  - 10 degrees angular resolution, spatial resolution 30 m
- **Cloud radar VAD scan**
  - zenith angle 8°, every 30 minutes
  - ~5 degrees angular resolution, spatial resolution 30 m
- **Combined product**
  - if both methods are available, a weighted mean of both speed and direction is used depending on the uncertainty of the fit
  - 26 m vertical resolution, 30 min temporal resolution

2 years of observations at JOYCE (Jülich Observatory for Cloud Evolution)

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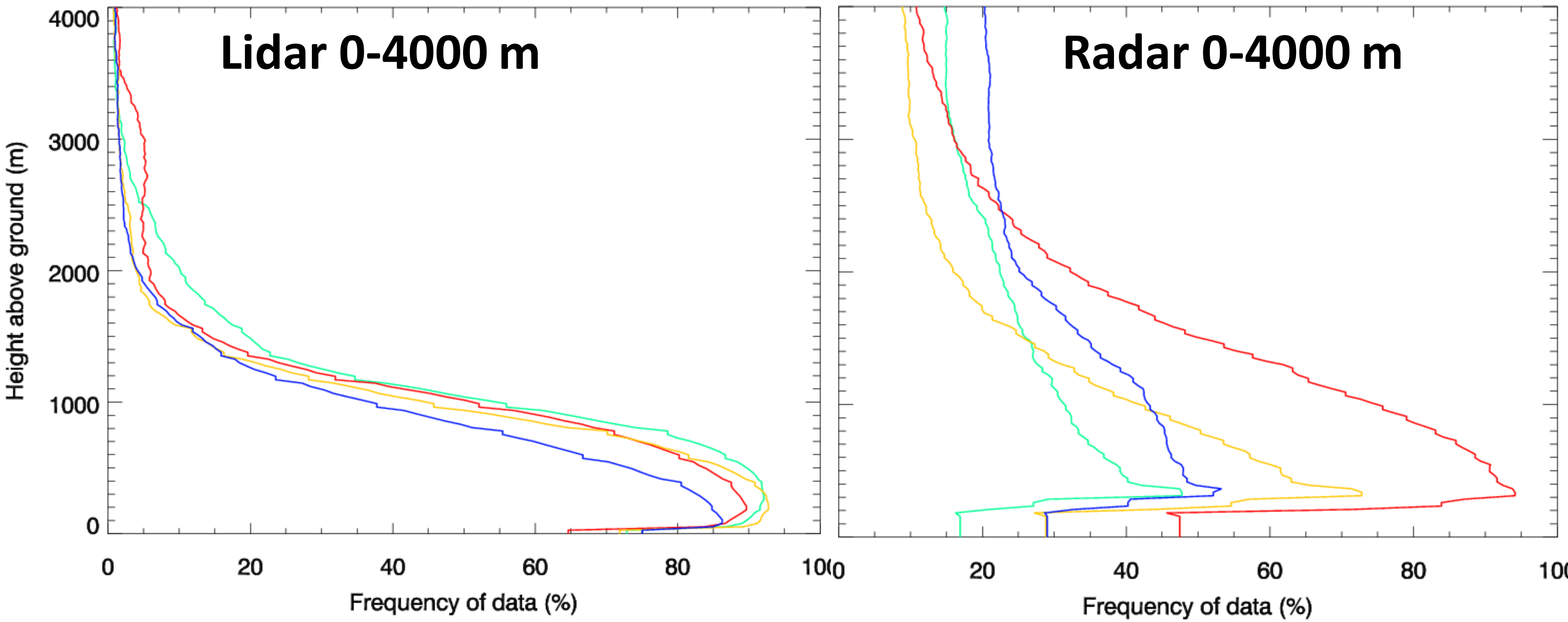
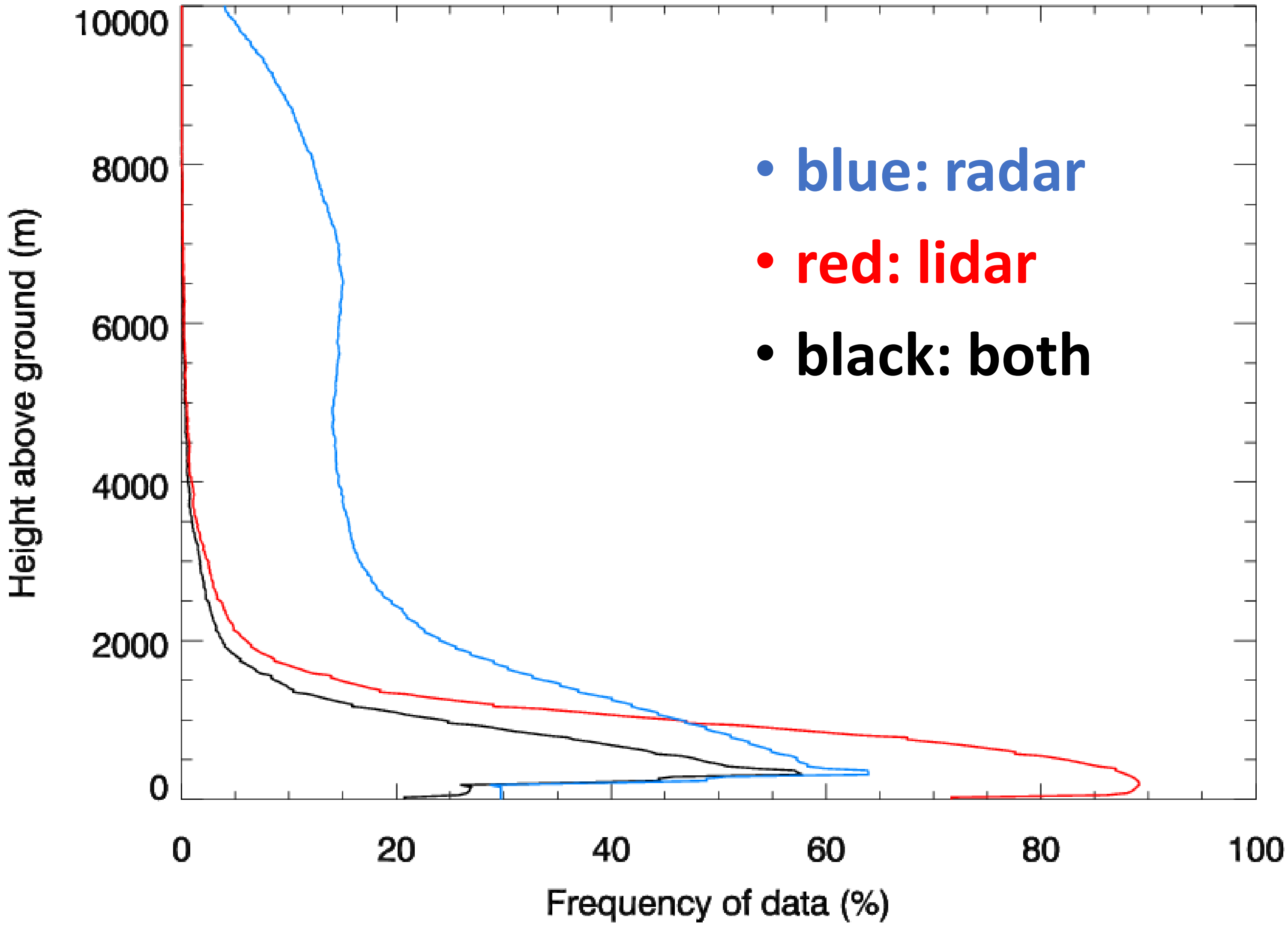
Universität zu Köln

Data availability per season



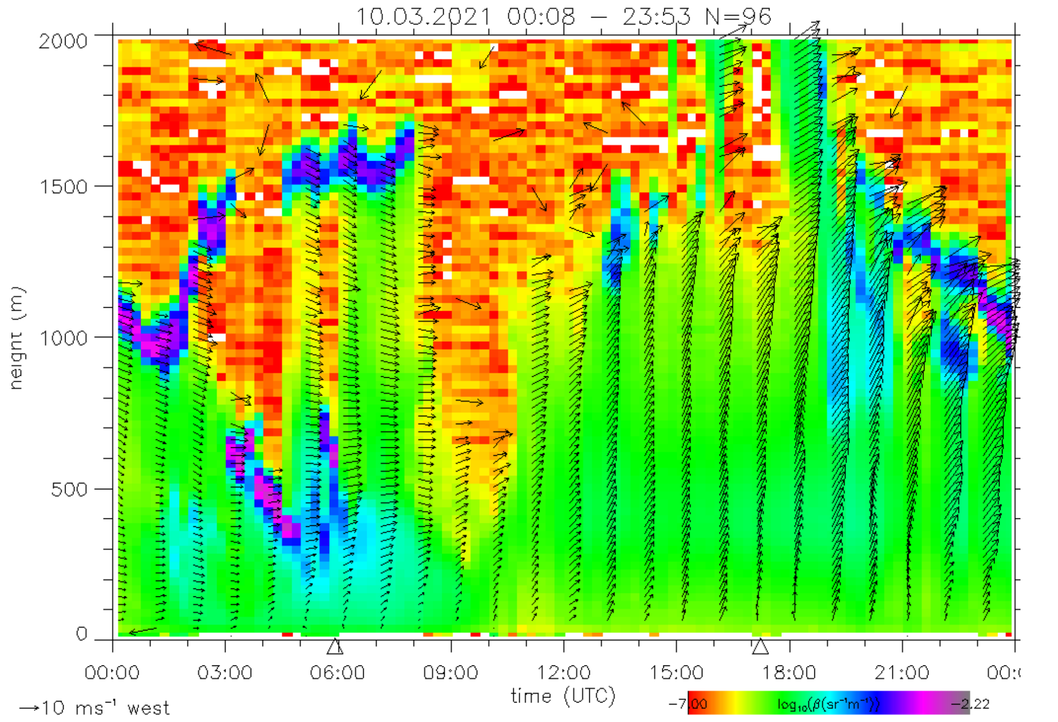
blue: winter, green: spring, red: summer, yellow: fall

Data availability

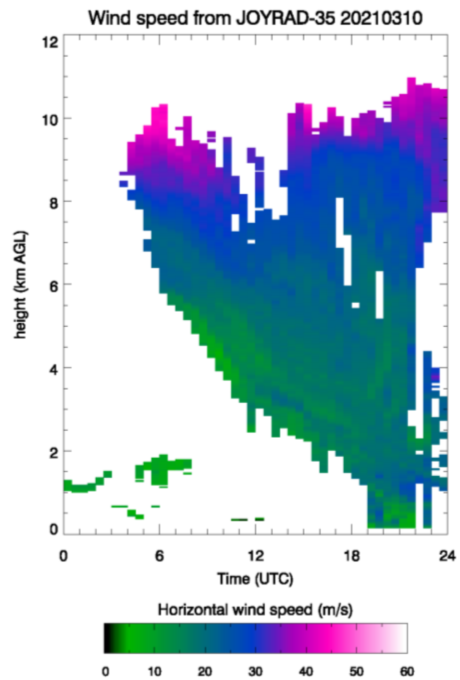


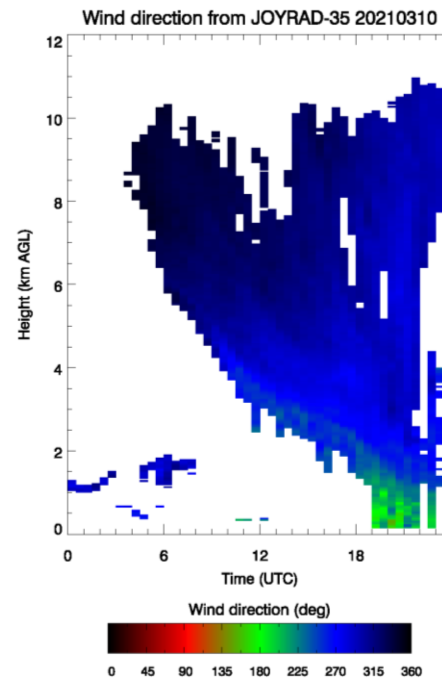
Example day 10.03.2021

- Wind lidar (0-2 km)



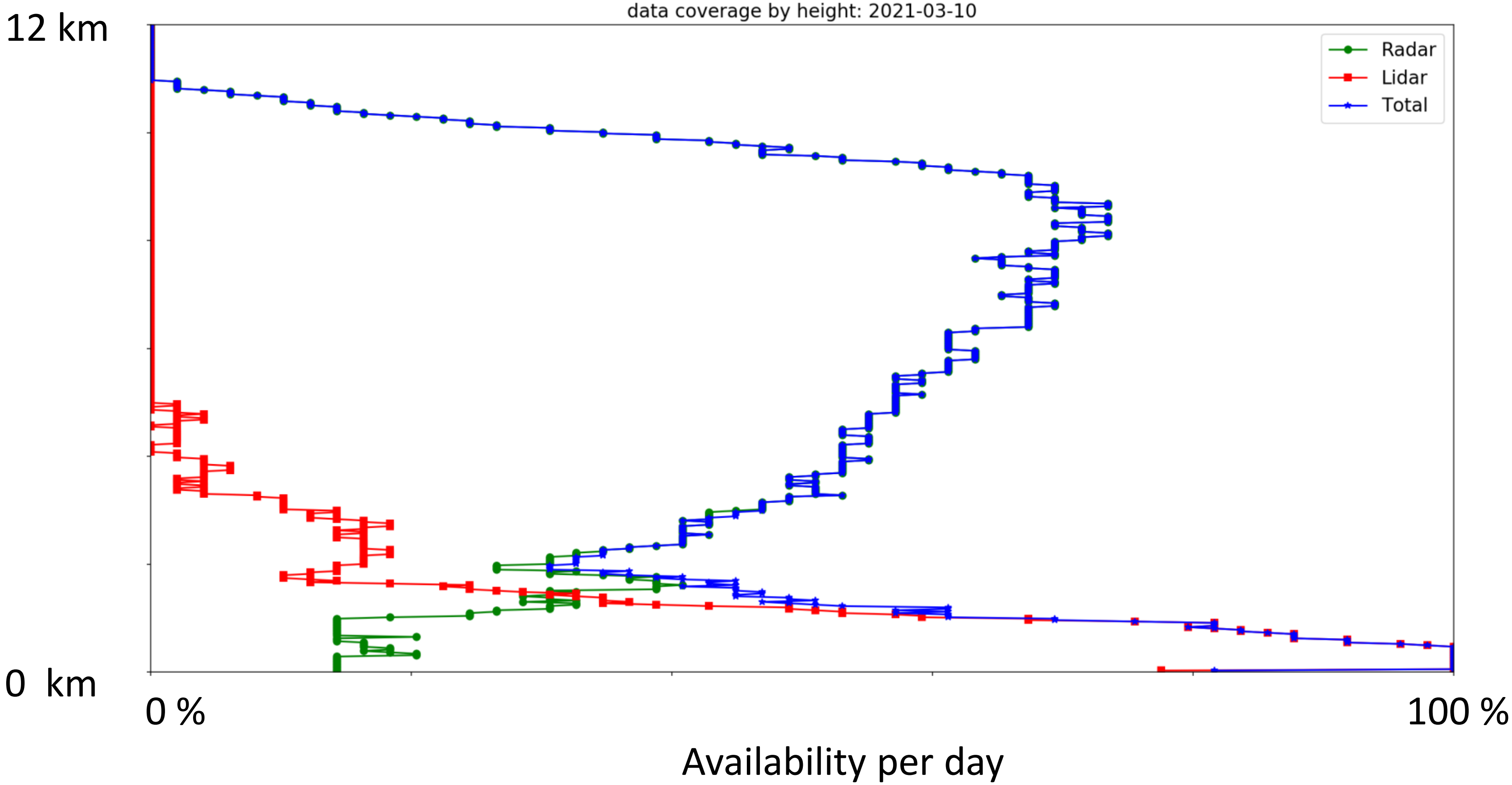
- Cloud radar (0-12 km)





Example day 10.03.2021

- Data availability vs. height



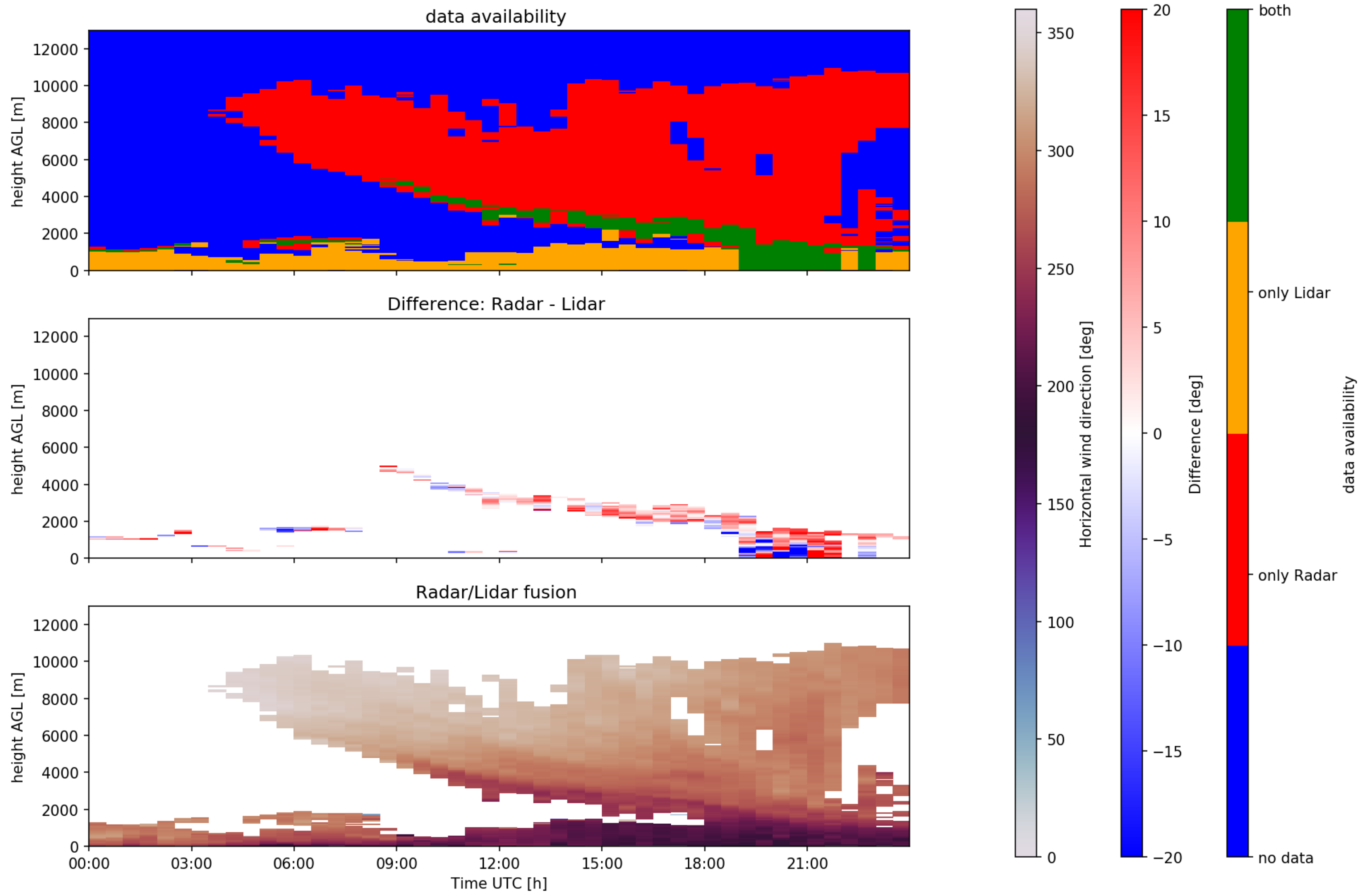
Example day - Wind direction

availability

difference

radar-lidar

fusion

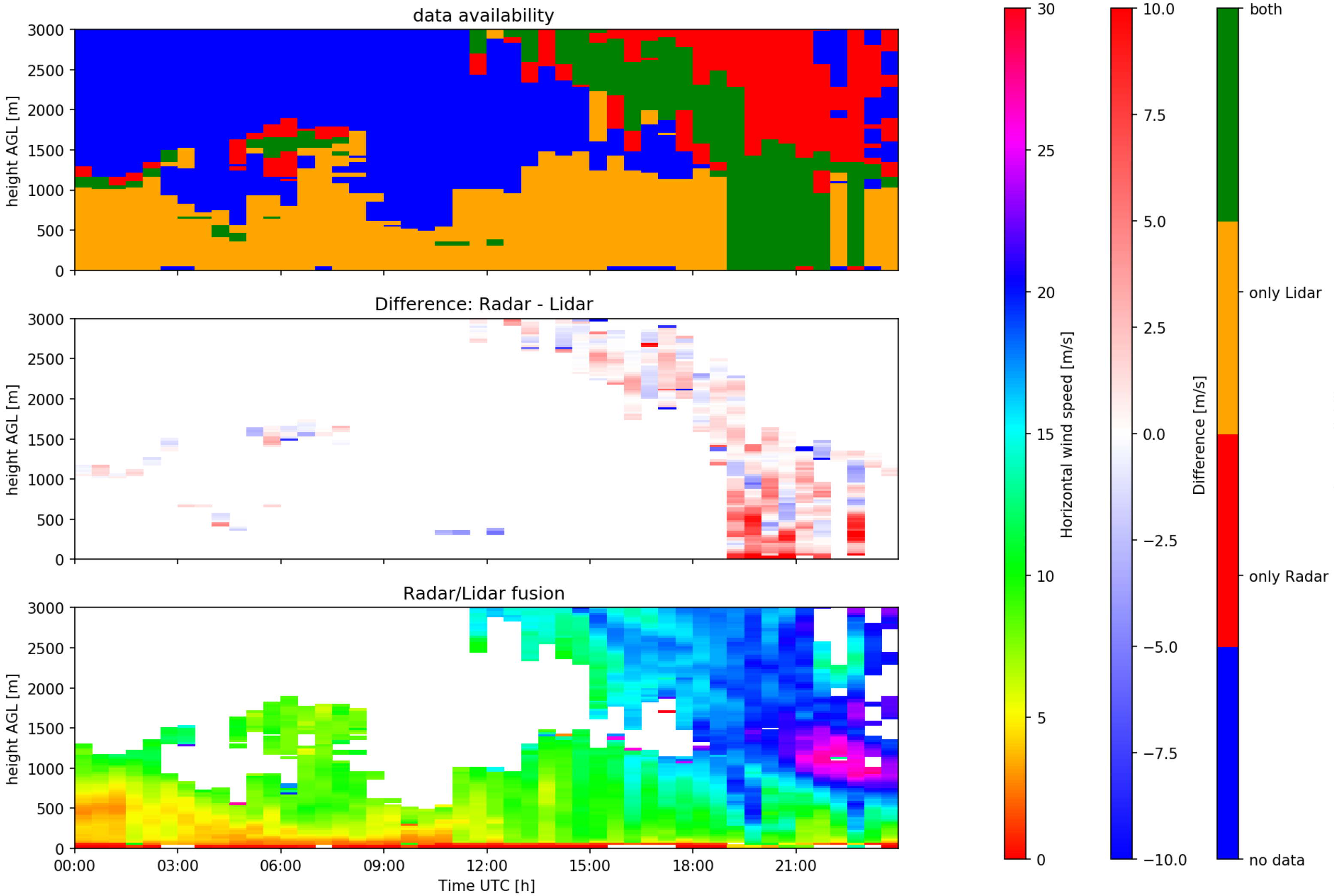


Example day - Wind speed boundary layer

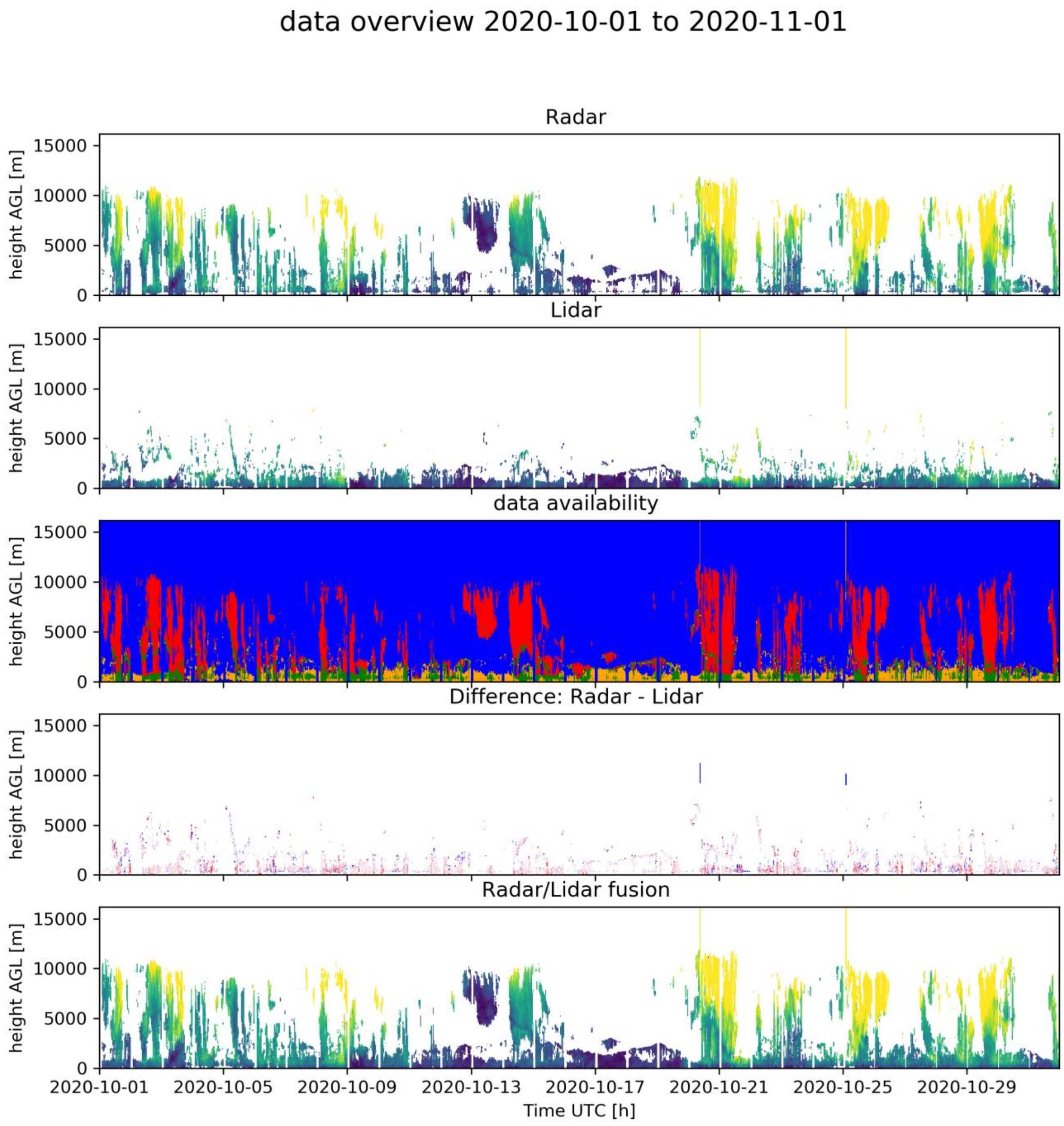
availability

difference radar-lidar

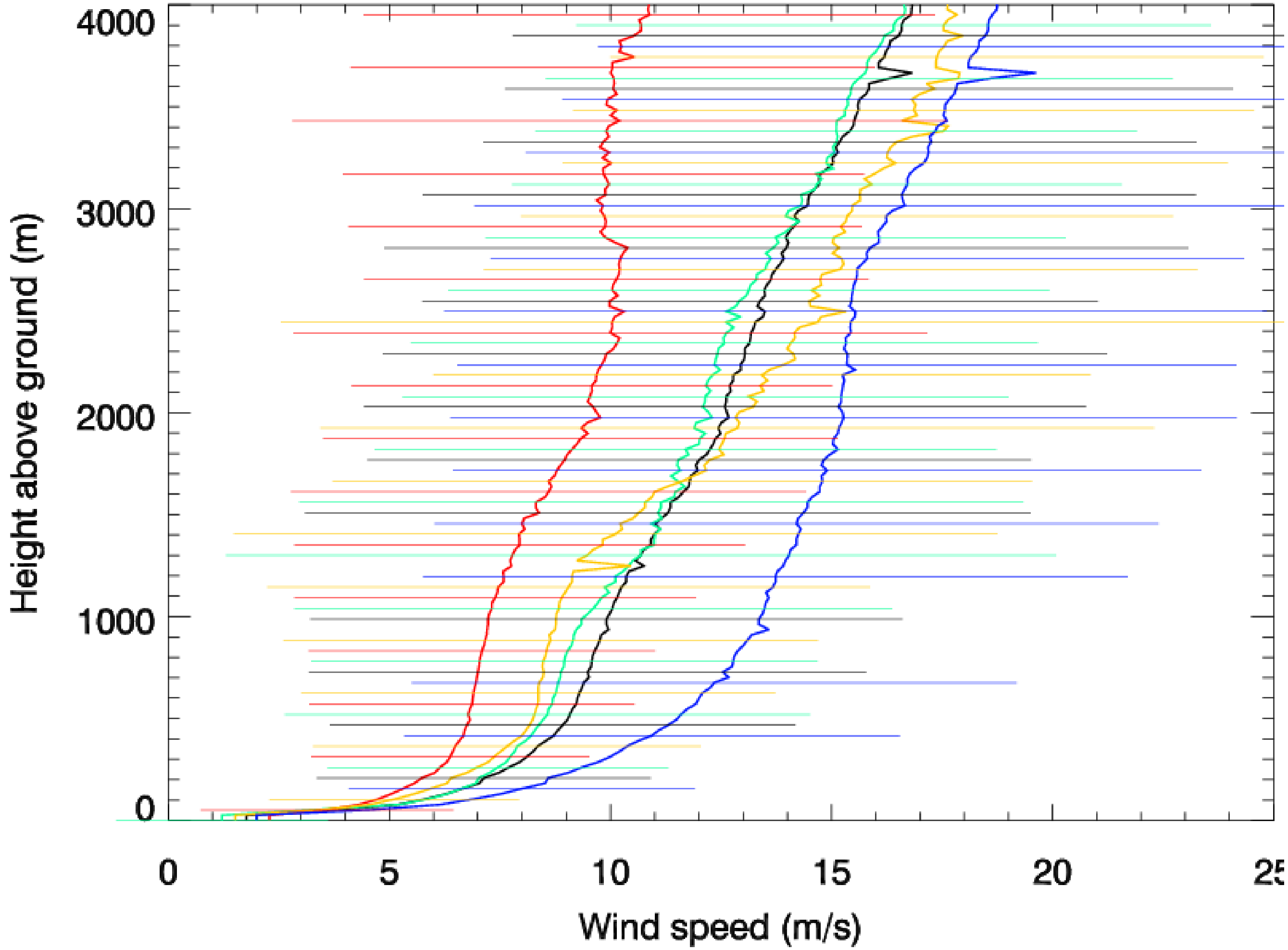
fusion



monthly overview



Statistics: Mean horizontal wind speed per season



blue: winter, green: spring, red: summer, yellow: fall, black: all

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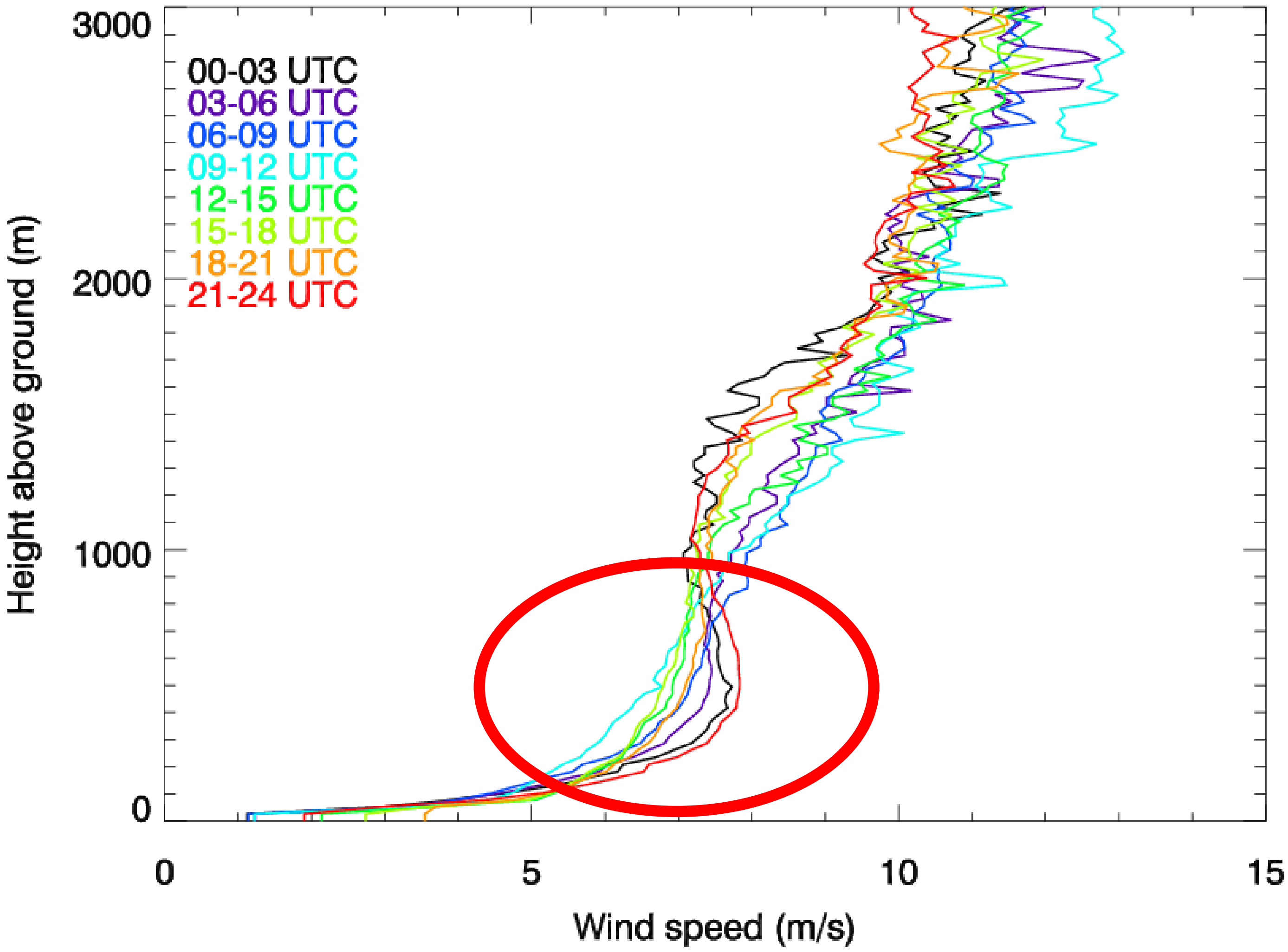
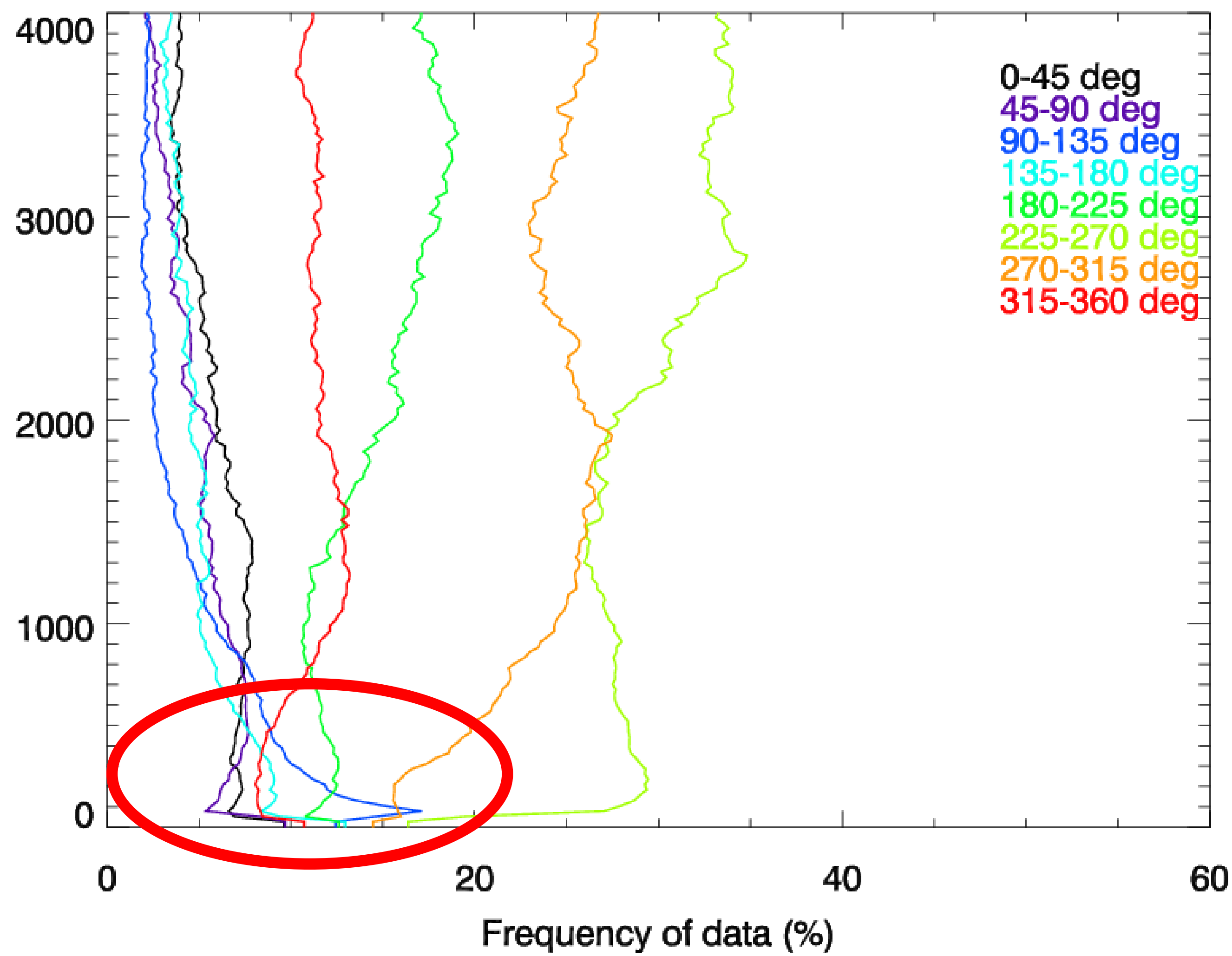
Statistics: Diurnal cycle of wind

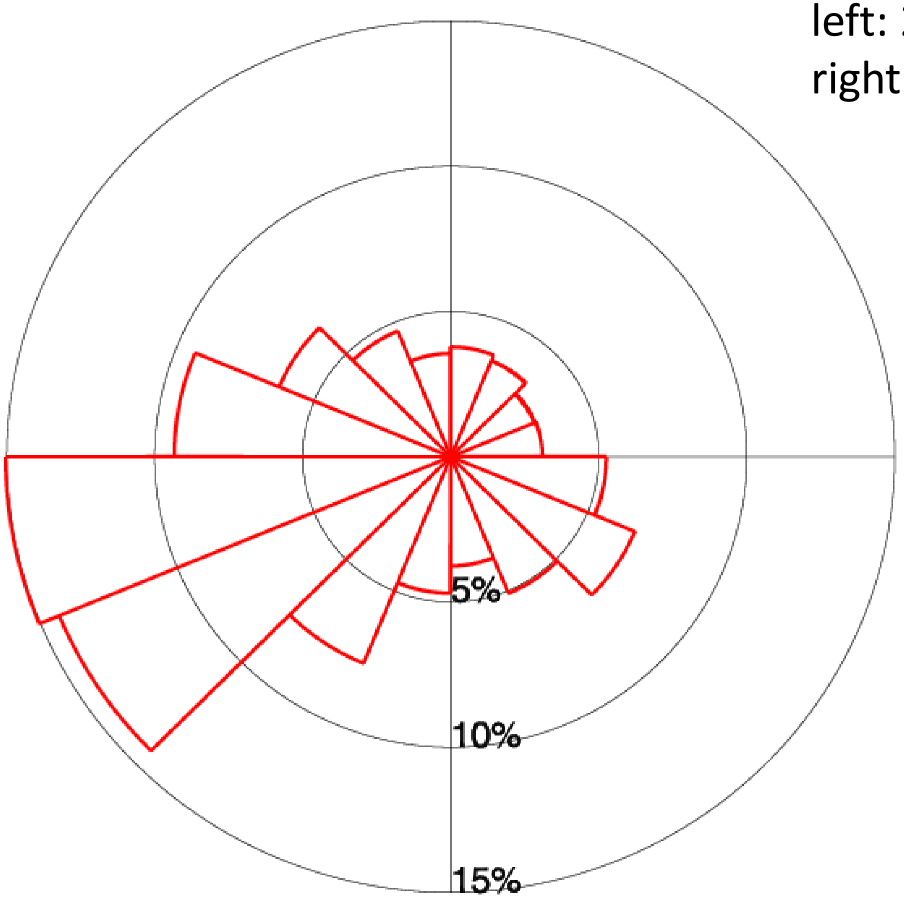


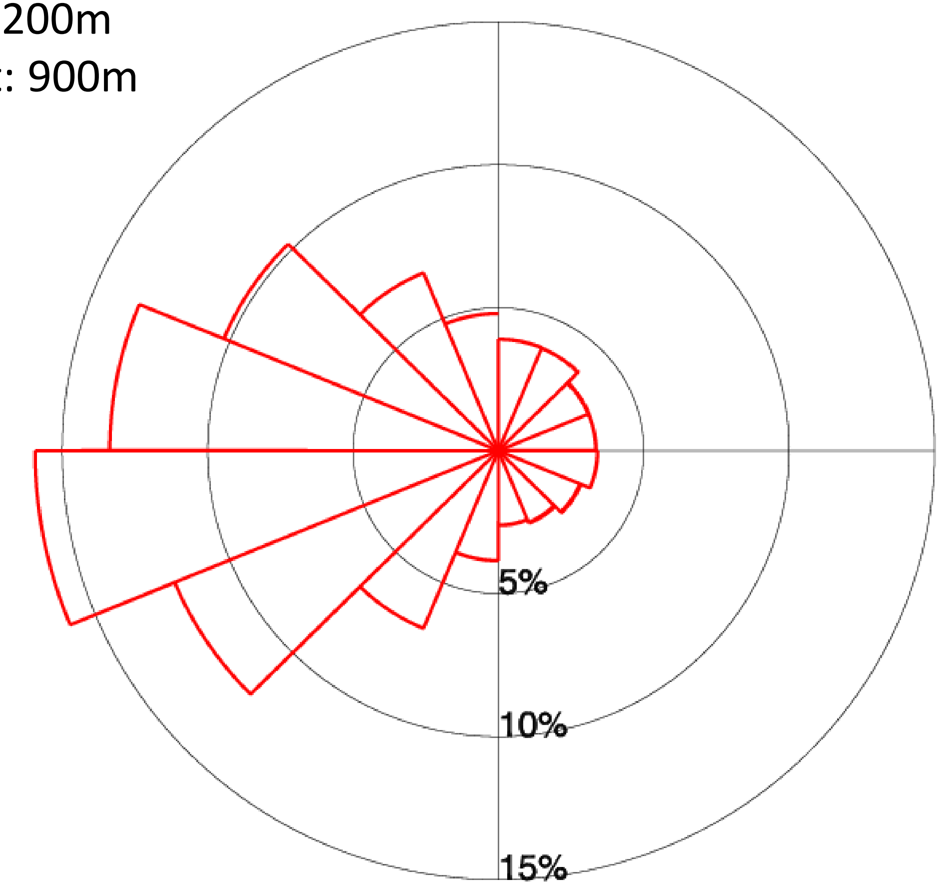
Wind direction profiles



Wind roses

left: 200m
right: 900m





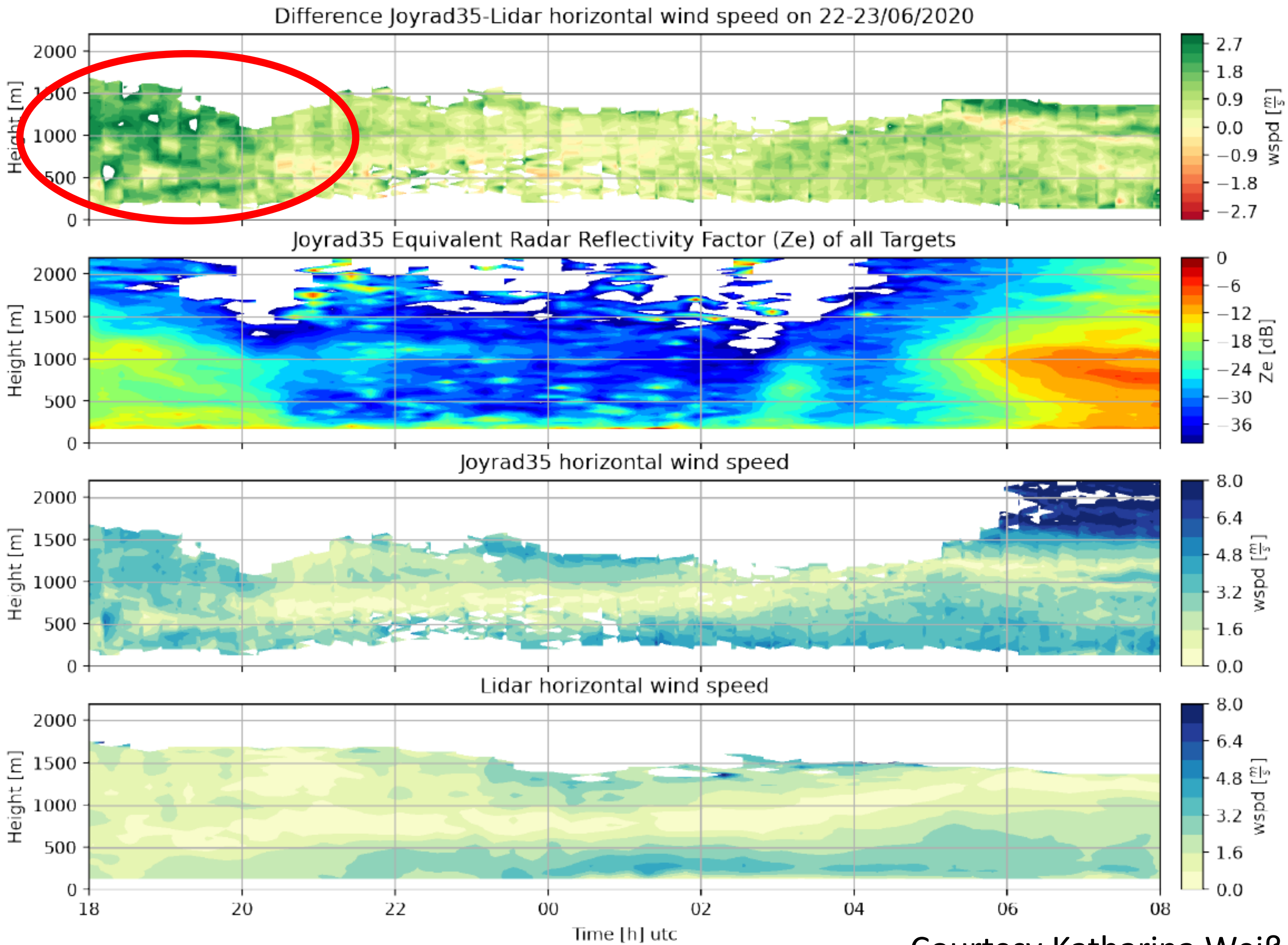
Application: Insect detection

- Insects are efficient targets to produce radar backscatter due to their size (1mm-1cm)
- Lidar backscatter is not affected by insects

- During warm periods (roughly T > 10°C), the Doppler radar signal is dominated by insects

- Comparison between radar and lidar allows the detection of insects and their speed

Insect detection



Courtesy Katharina Weiß

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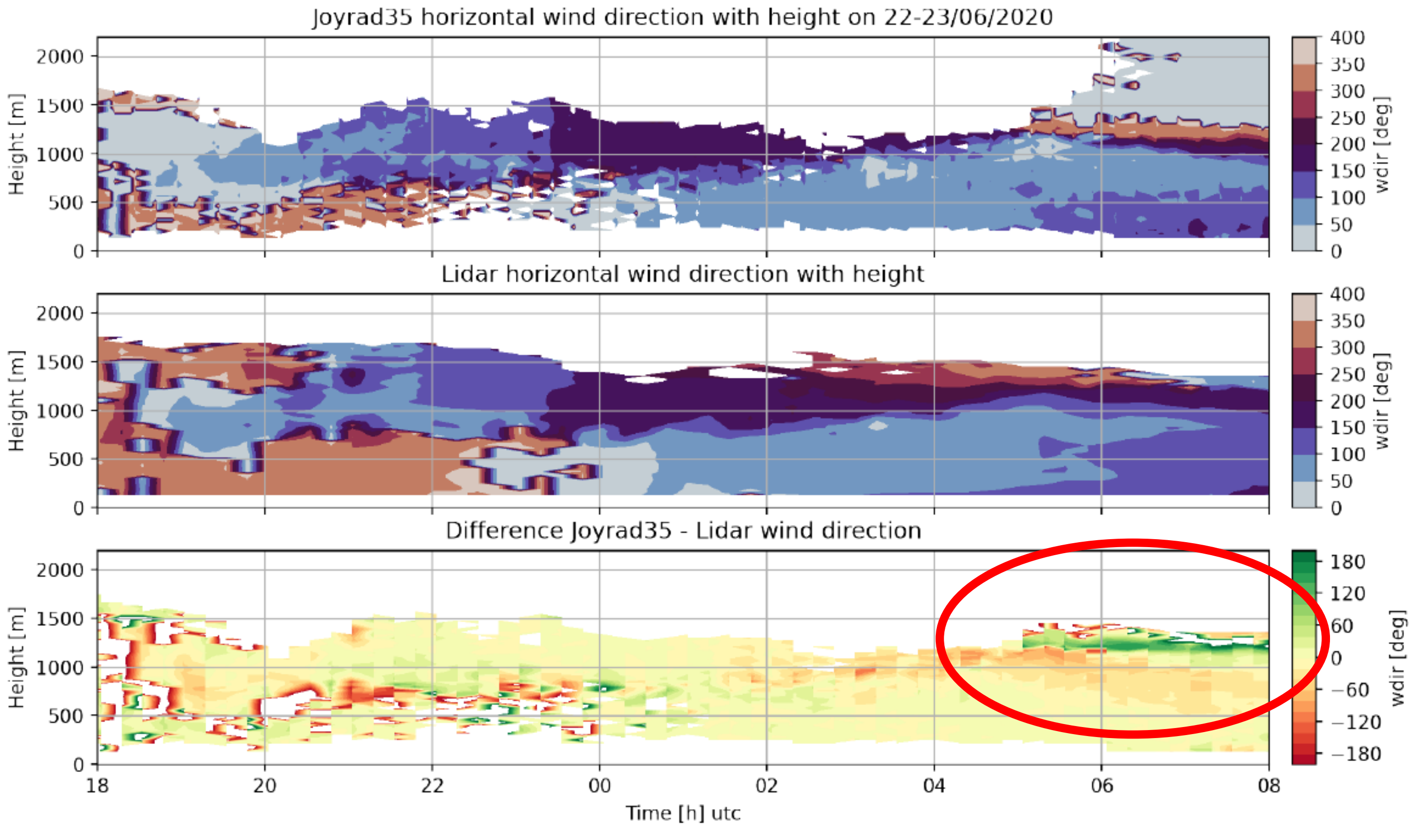
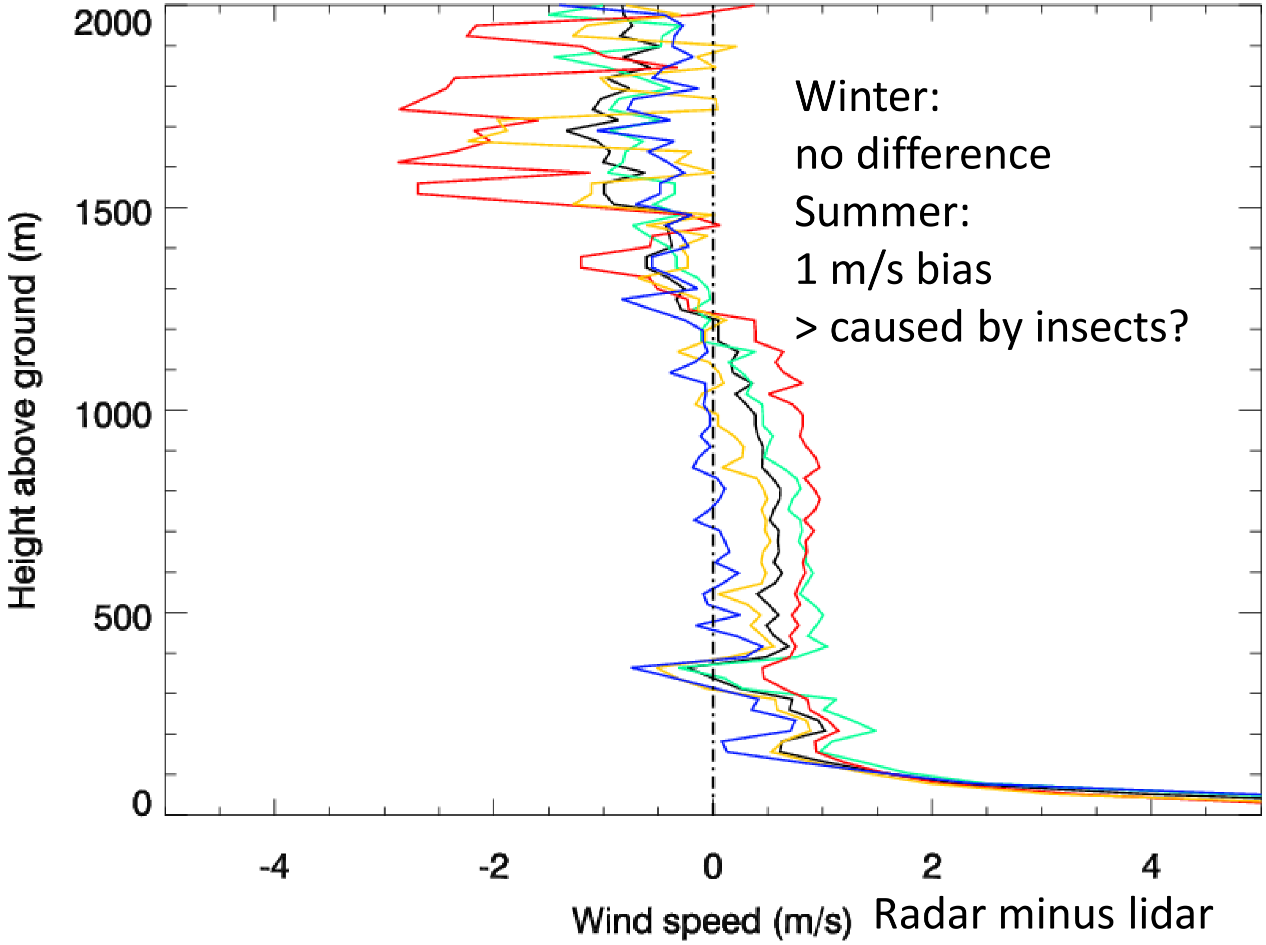
Insect detection



Courtesy Katharina Weiß

Difference wind speed



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Summary

- Wind profiles with a temporal resolution can be derived from a combination of Doppler lidar and Doppler cloud radar
- Synergy gives better coverage than for single instruments
- Future: New product for ACTRIS Cloudnet stations
- Several applications
    - Satellite validation
    - Insect detection
    - Model evaluation

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Thank you !

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Leipzig Institute for Meteorology

VOODOO: REVEALING SUPERCOOLED LIQUID BEYOND LIDAR ATTENUATION

from vertically-pointing cloud radar observations using artificial neural networks

ACTRIS Talk

May 5, 2022

W. Schimmel, H. Kalesse-Los,
T. Vogl, M. Maahn, A. Foth,
P.S. Garfia, P. Seifert*

TROPOS* Leibniz Institute for Tropospheric Research

Europäische Union
Europa fördert Sachsen. ESF Europäischer Sozialfonds
Diese Maßnahme wird mitfinanziert durch Steuermittel auf Grundlage des von den Abgeordneten des Sächsischen Landtags beschlossenen Haushaltes.

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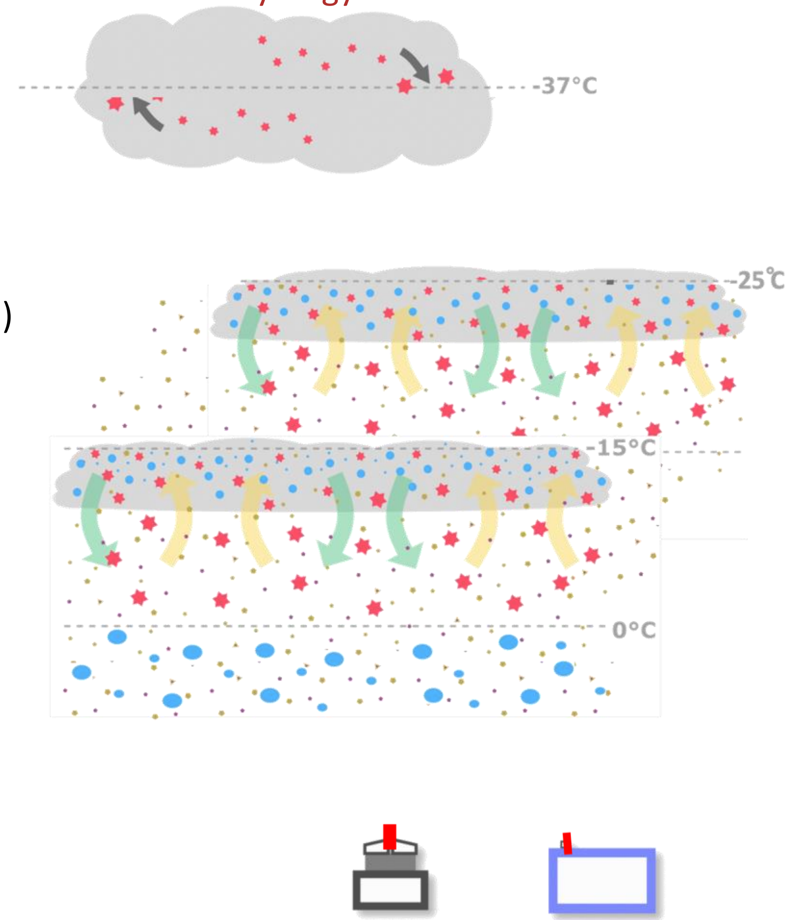
How to quantify the thermodynamic phase of clouds?

Ground-based Radar-Lidar Synergy



Lidar

- profiles of attenuated backscatter (& depolarization)
- most sensitive to numerous small liquid droplets:
  attenuated backscatter coefficient: $\beta \sim N, D^2$
- full signal attenuation at optical depth: $\tau \sim 3$

Doppler cloud radar

- spectral profiles of reflectivity and radial velocity
- most sensitive to large ice crystals:
  equivalent radar reflectivity: $Z_e \sim N, D^6$
- able to penetrate optically thick cloud layers

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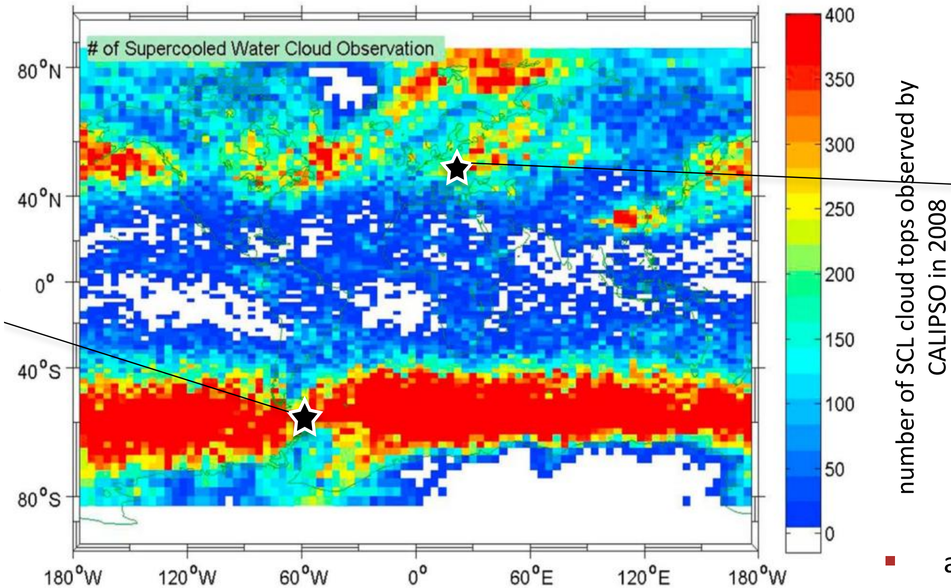
Observations from Punta Arenas, Chile and Leipzig, Germany

DACAPO PESO

Dynamics, Aerosol, Cloud and Precipitation Observations in the Pristine Environment of the Southern Ocean

- pristine environment
- low INP concentrations
- large amounts of supercooled liquid water
- influenced by gravity waves [Radenz et al. ACP 2021]
- W-band observations Nov 2018 - Sep 2019

Number of supercooled liquid tops as observed by CALIPSO in 2008



[HU ET AL., JGR 2010]

Leipzig Institute for Meteorology

- anthropogenic pollutions
- high INP concentrations
- large amounts of supercooled liquid water
- observations Dez 2020 - Mar 2022

SCL … supercooled liquid
INP … ice nucleating particles

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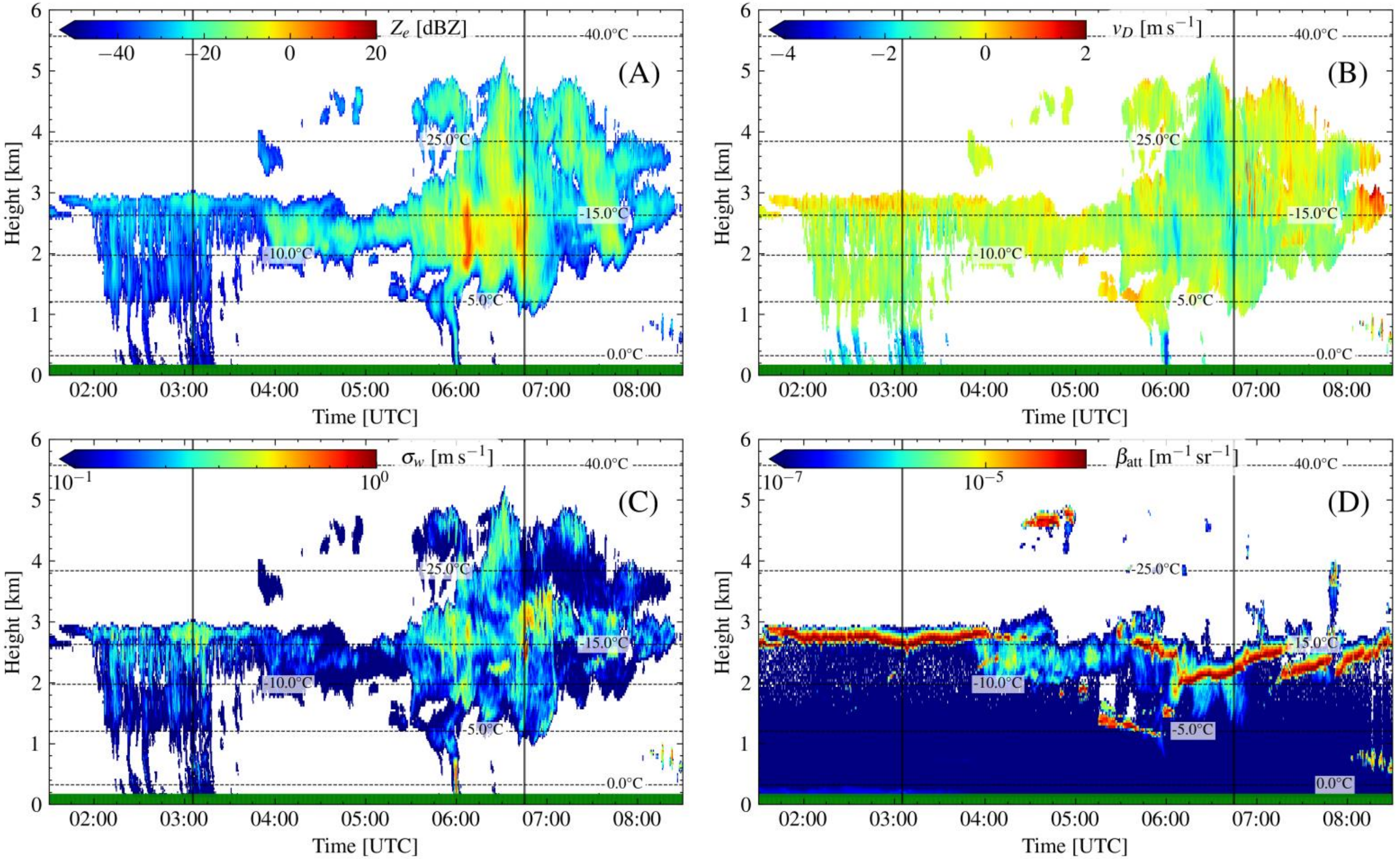
Case study from 1. August 2019, Punta Arenas, Chile

radar Z_e

radar v_D

radar σ_w

lidar β_{att}



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Hydrometer Classification: Cloudnet

ACTRIS

Cloudnet

Synergistic retrieval, producing cloud properties at high temporal and vertical resolution

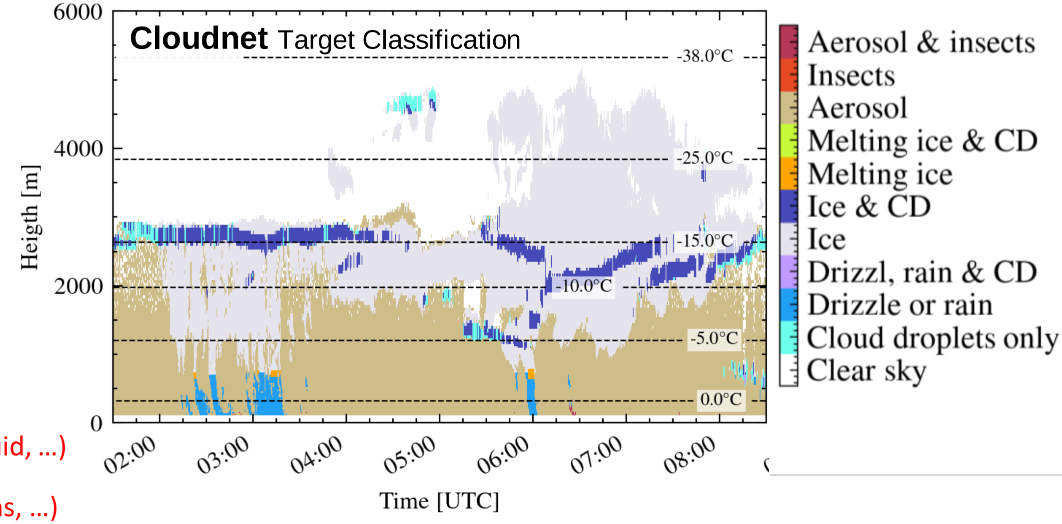
[Illingworth et al. BAMS 2007, Tukiainen et al. 2020]

required instruments:

- Doppler Cloud Radar (moments)
- Lidar (attenuated backscatter)
- Microwave Radiometer (LWP, IWV)
- *Model data: ECMWF (temperature, pressure)*

retrieved products:

- categorization (averaged profiles, common grid, …)
- atmospheric target classification (aerosol, ice, liquid, …)
- quality control flag (instrument availability, corrections, …)



LWP … liquid water path
IWV … integrated water vapor
ECMWF … European Centre for Medium-Range Weather Forecasts
GDAS … Global Data Assimilation System
CD … Cloud droplets

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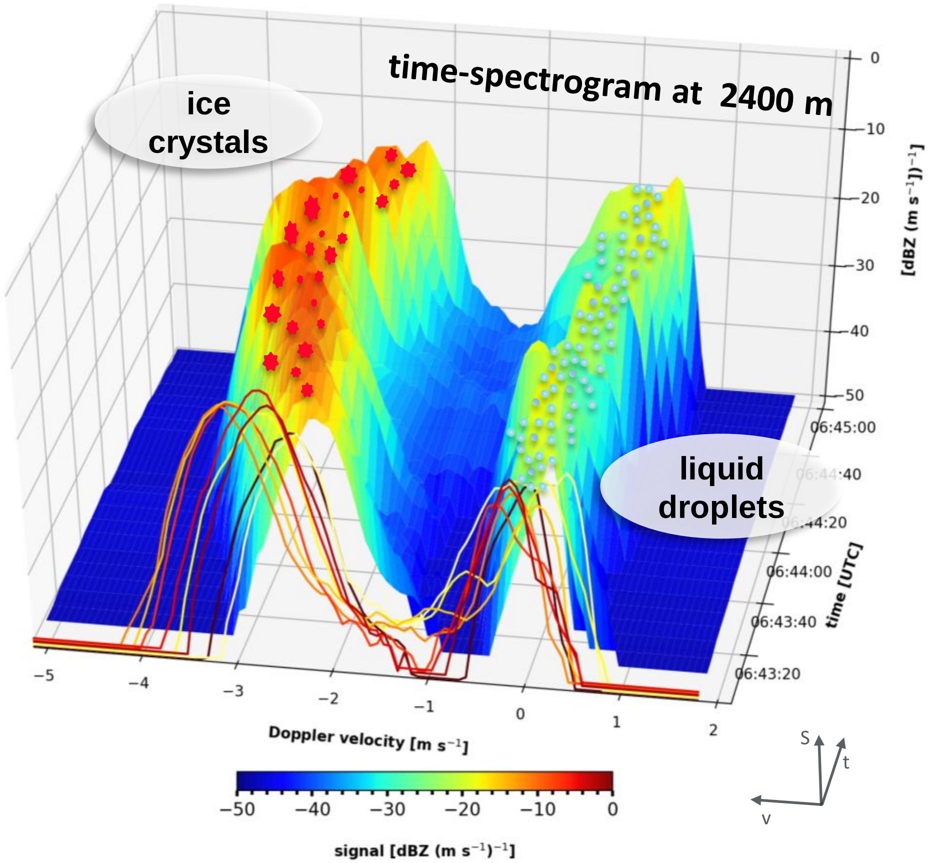
New Machine Learning Approach

Feature sampling

- use 6 consecutive (high res.) spectra, each range gate = 30 sec time-spectrograms
- noise/fill-values replaced by radar sensitivity limit
- 3D Doppler spectra S → 4D features X:
  - $\dim(S) = (n_{\text{time}}, 289, 256)$
  - $\dim(X) = (n_{\text{samples}}, 256, 6, 1)$
- normalization: $\|X\|_{(-50,+20)[\text{dBZ}]} \Rightarrow \|X\| \in [0,1]$
- encode corresponding Cloudnet label* y:
  - $y(\text{"CD"}) = (1\ \ 0)^T$ ***or*** $y(\text{"no-CD"}) = (0\ \ 1)^T$

➢ **no manual feature extraction nor labeling**



Punta Arenas, Chile: 1. August 2019 at 2.4 km

CD … cloud droplets present
no-CD … no cloud droplets present

Cloudnet label* *… only good radar and lidar echos*

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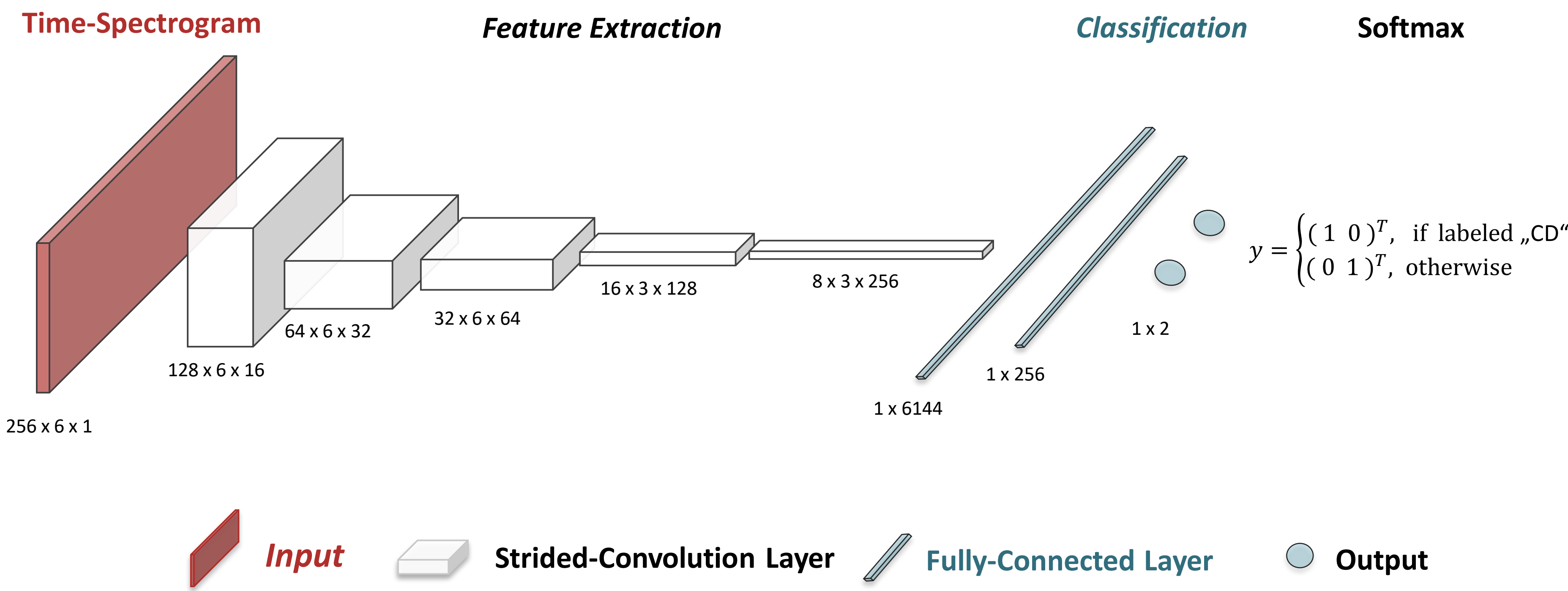
Machine Learning Model Architecture



CD … cloud droplets present
no-CD … no cloud droplets present

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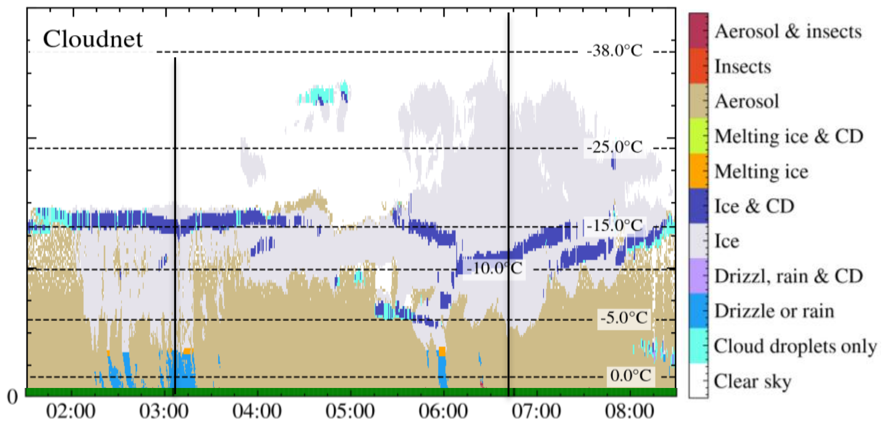
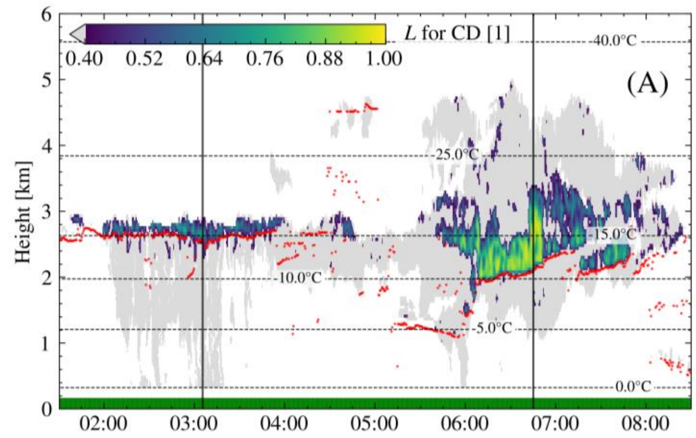
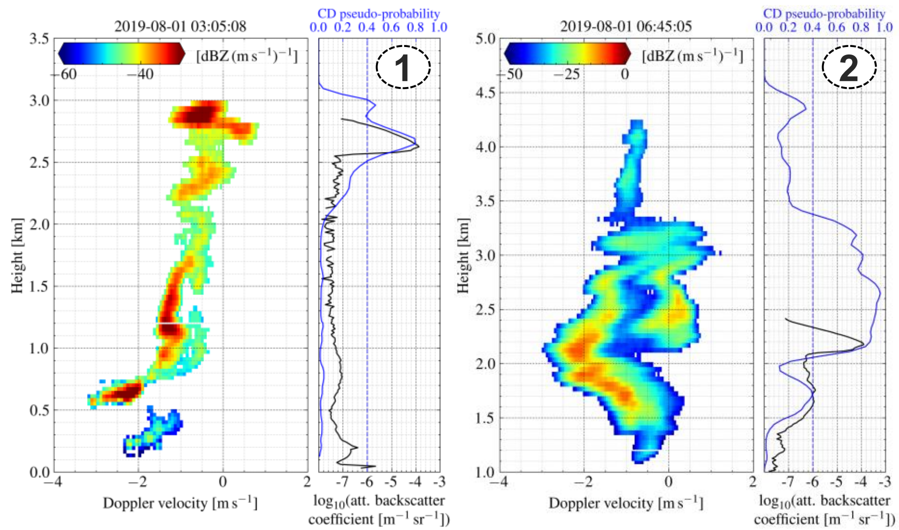
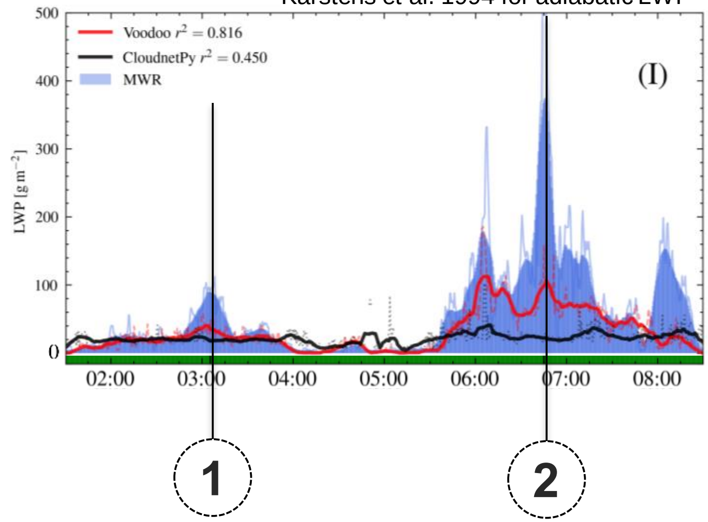
Case study of 1. August 2019, Punta-Arenas, Chile







Karstens et al. 1994 for adiabatic LWP



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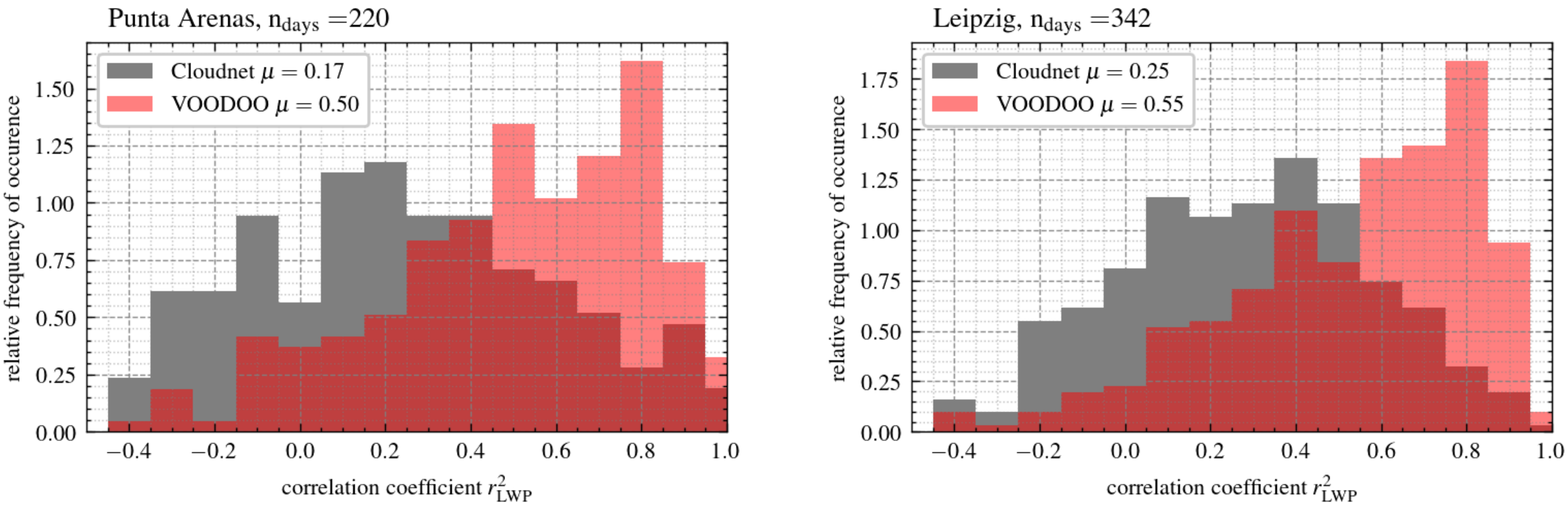
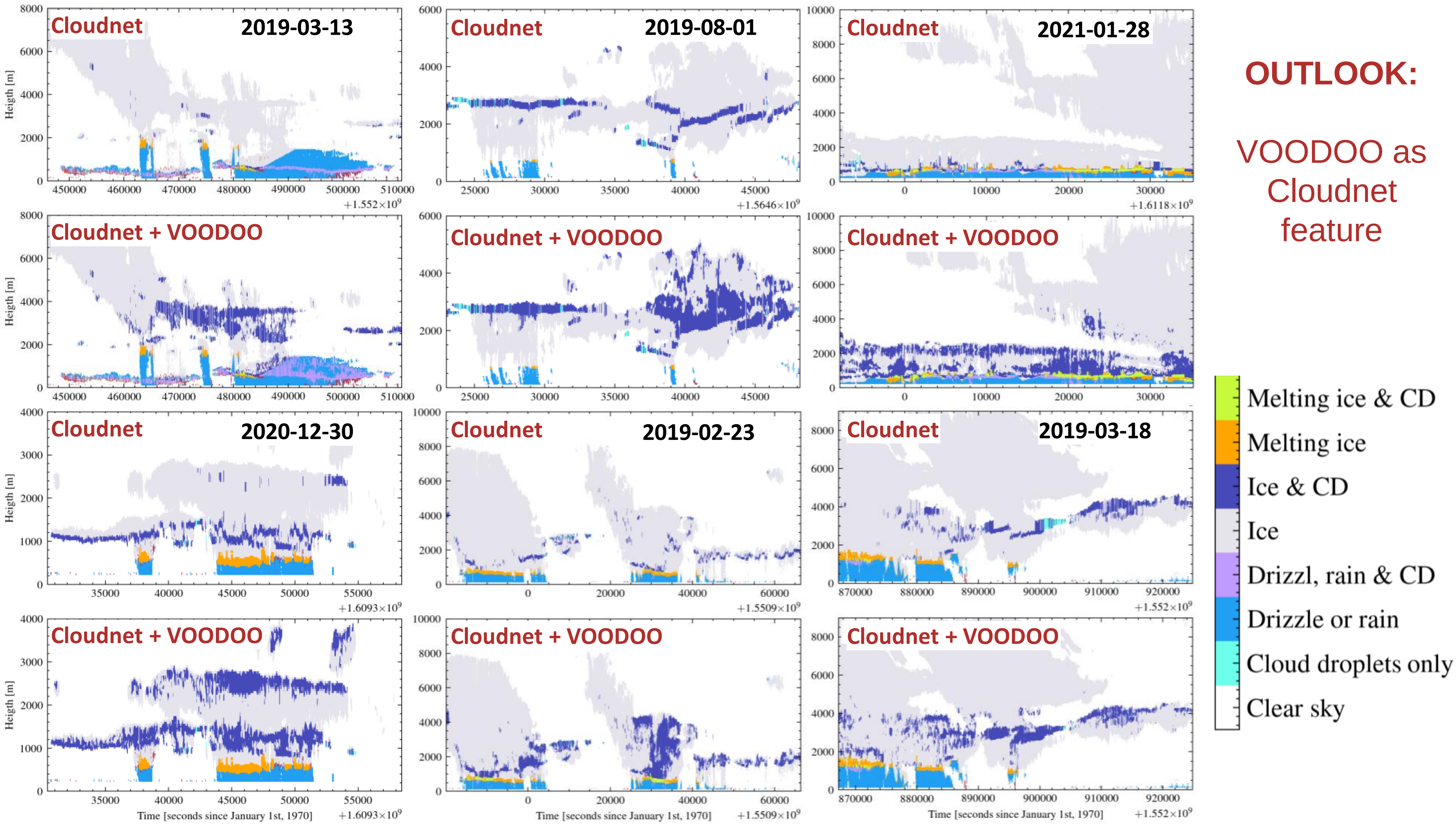
Distribution as function of correlation coefficient of LWP



Result:

- frequency for higher correlation coefficient r^2_{LWP} increases for VOODOO predictions
- best performance for $\mathrm{LWP} > 100\ \mathrm{g\ m^{-2}}$
- ➢ VOODOO able to accurately identify liquid layers beyond lidar attenuation



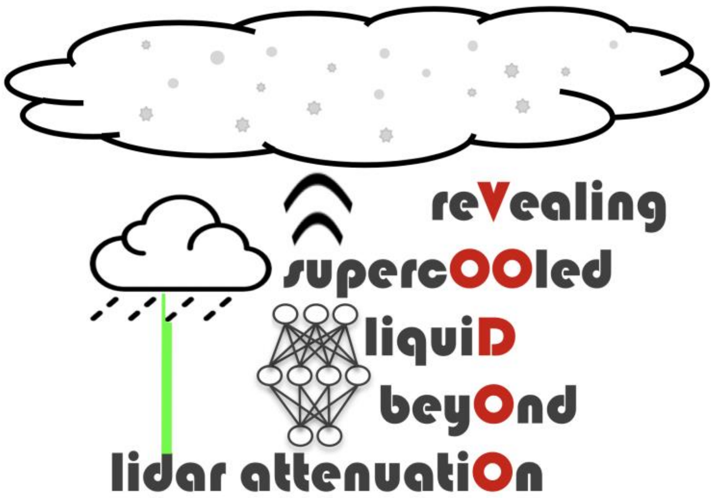
OUTLOOK:

VOODOO as Cloudnet feature

Summary

Remote-Sensing + Machine Learning

- Goal: Better estimation of ice/liquid distribution.
- VOODOO able to relate spectral morphologies to the availability of cloud droplets.
- Shows ability to extend the classification beyond full lidar attenuation.
- **Future usage:**
  - different geographical regions (Arctic data sets)
  - different Doppler radar (MIRA-35/KAZR/MWACR)
- **Outlook:** VOODOO as feature for Cloudnet



➢ **github.com/remsens-lim/Voodoo**

Retrieval of shape and orientation of multiple hydrometeor types from observations of scanning hybrid-mode Ka-band cloud radar

Majid Hajipour[1]

Cloud Remote Sensing Community workshop
Tuesday 3rd and Thursday 5th May 2022

Co Author: Patric Seifert[1]

1: Leibniz Institute for Tropospheric Research (TROPOS), Leipzig, Germany

Leibniz Association

ACCEPT

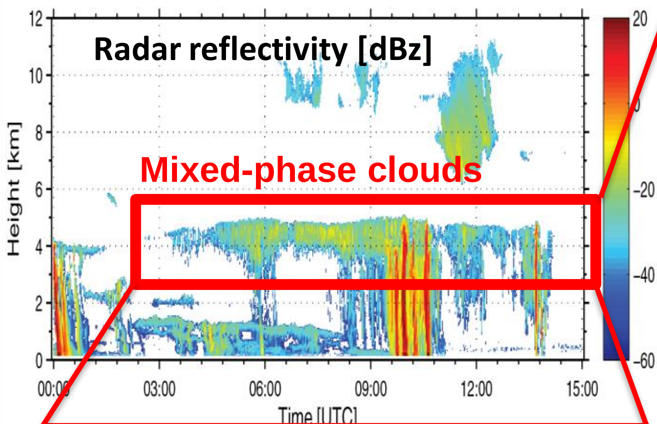
DFG

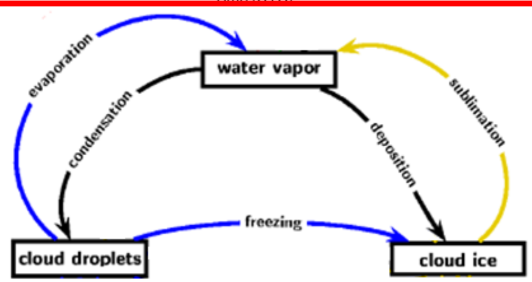
PROM

TROPOS
Leibniz Institute for Tropospheric Research

Motivation: shape retrieval idea in mixed-phase clouds

Layered clouds, 30 Oct 2014, Cabauw, Netherlands

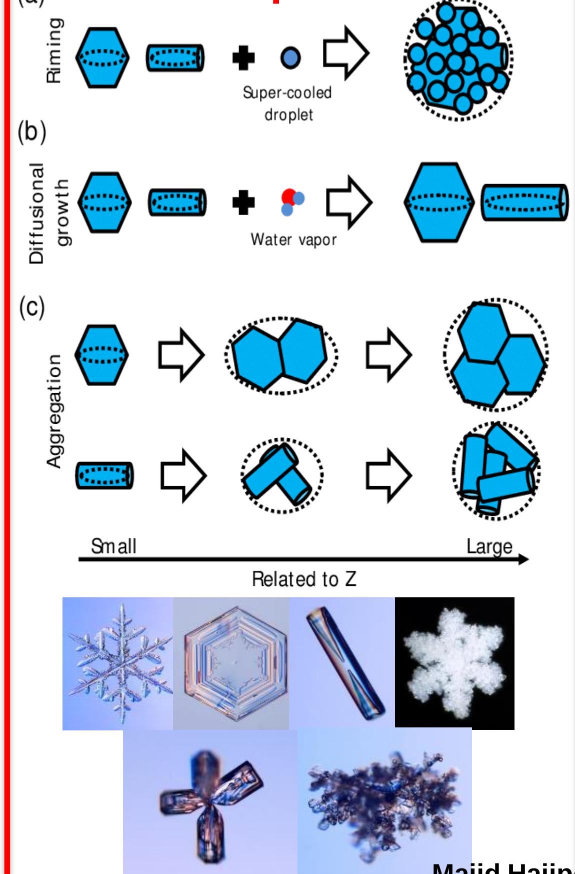




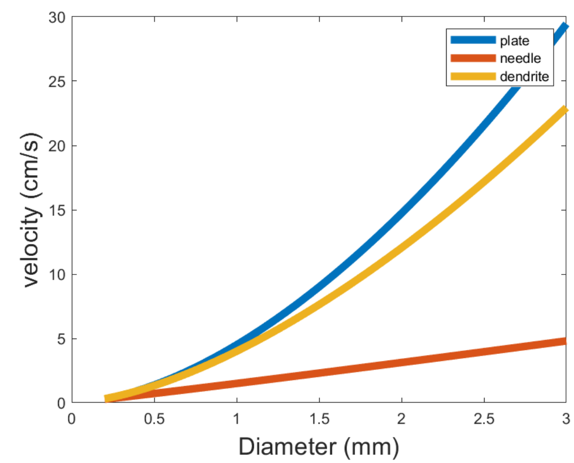
Thin mid-level cloud (mixed-phase)

Guichard et al. (2017)

Growth processes



Size-fall velocity relationships



Pfitzenmaier et al. (2018)

Majid Hajipour (hajipour@tropos.de), CCRES workshop

TROPOS

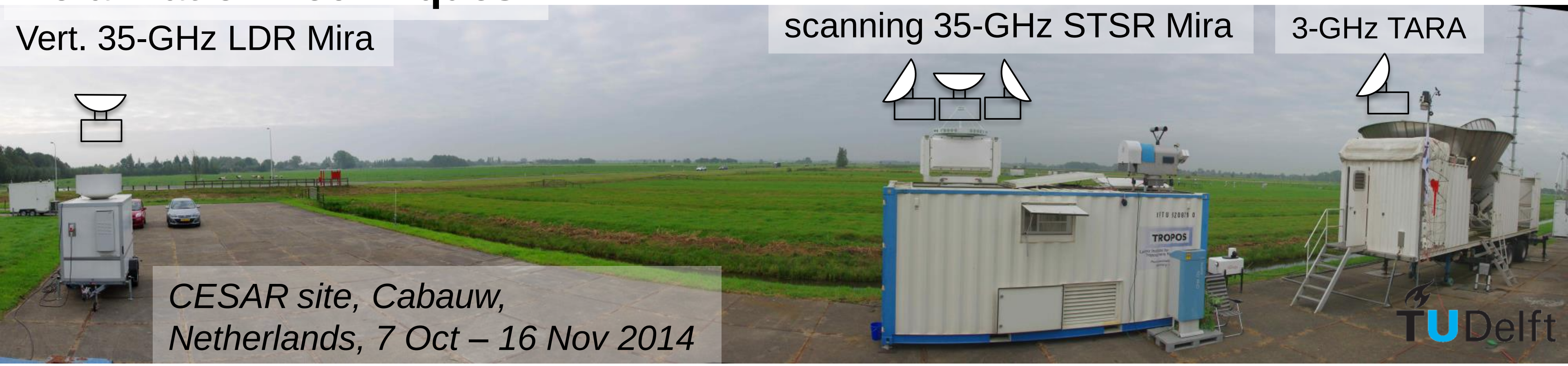
ACCEPT campaign

ACCEPT

Analysis of the Composition of Clouds with Extended Polarization Techniques

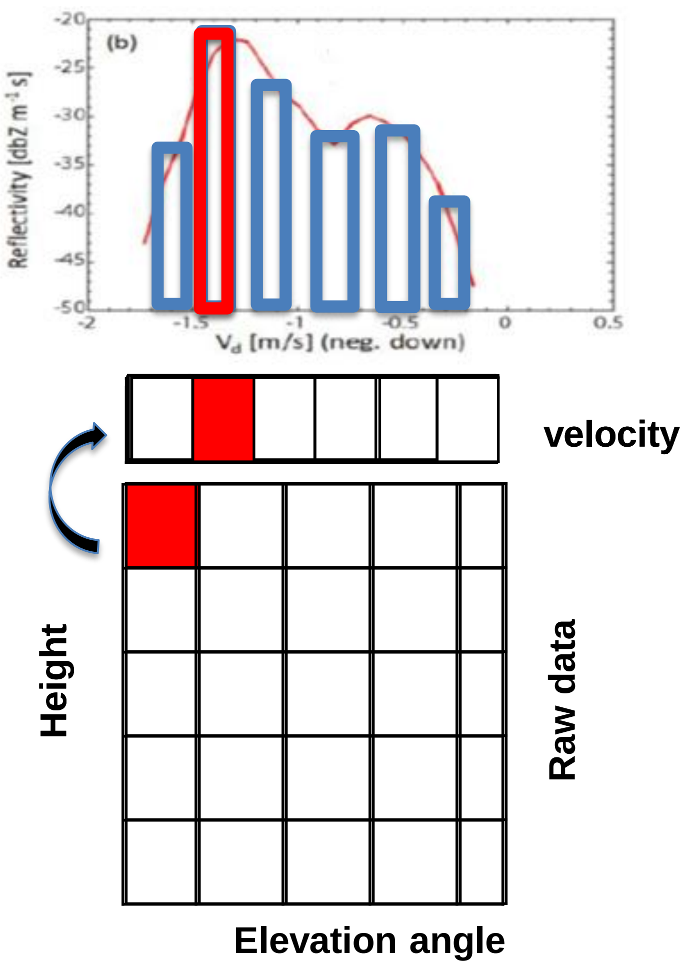
- 6-week measurement campaign at CESAR obs., Cabauw
- **Vert. pointing LDR-mode Mira-35 (TROPOS)**
- **Scanning STSR-mode Mira-35 (TROPOS/Metek)**
- Tilted full polarimetric S-band TARA (TU Delft)

+ Lidars, MWR, Doppler lidar, wind profiler, radiosondes



TROPOS

Original shape retrieval approach: Main peak of Doppler spectrum



Modeling

Simulation of polarimetric variables ZDR and ρ_{hv} for different values of shape and orientation as a function of antenna elevation

Observation

Selecting main peak of Doppler spectrum for each pair of height and elevation angle

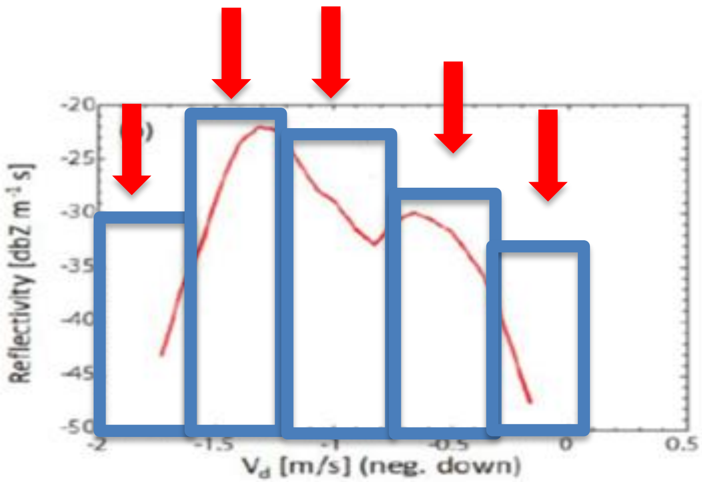
Comparing observed and modeled ZDR and ρ_{hv} to find best agreement. (using minimum mean square error)

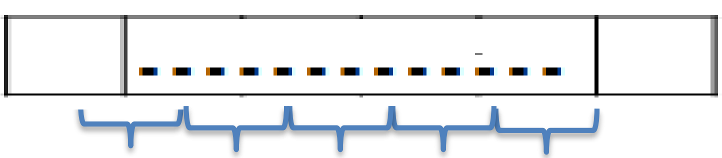
Shape & orientation

Majid Hajipour (hajipour@tropos.de), CCRES workshop

Extension of Myagkov et al. 2016 (AMT) shape retrieval approach

Retrieval method





Modeling

Simulation of polarimetric variables ZDR and ρ_{hv} for different values of shape and orientation as a function of antenna elevation

Observation

Splitting Doppler spectrum into 5 bins for each pair of height and elevation angle

↓

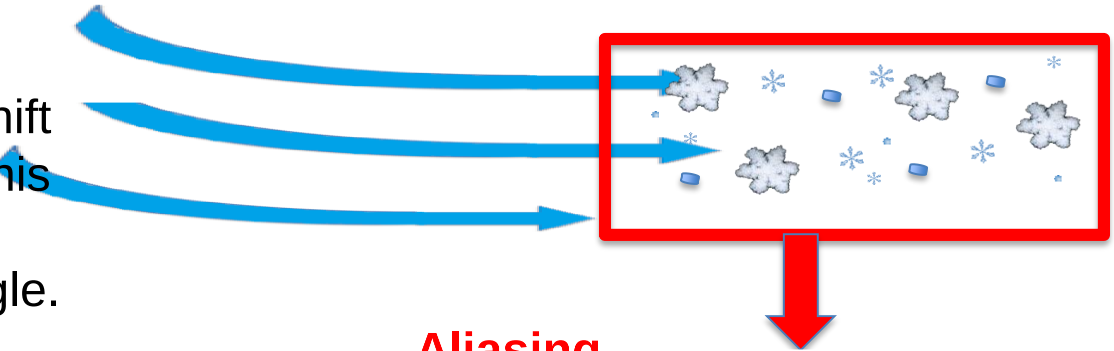
Comparing observed and modeled ZDR and ρ_{hv} to find best agreement. (using minimum mean square error)

↓

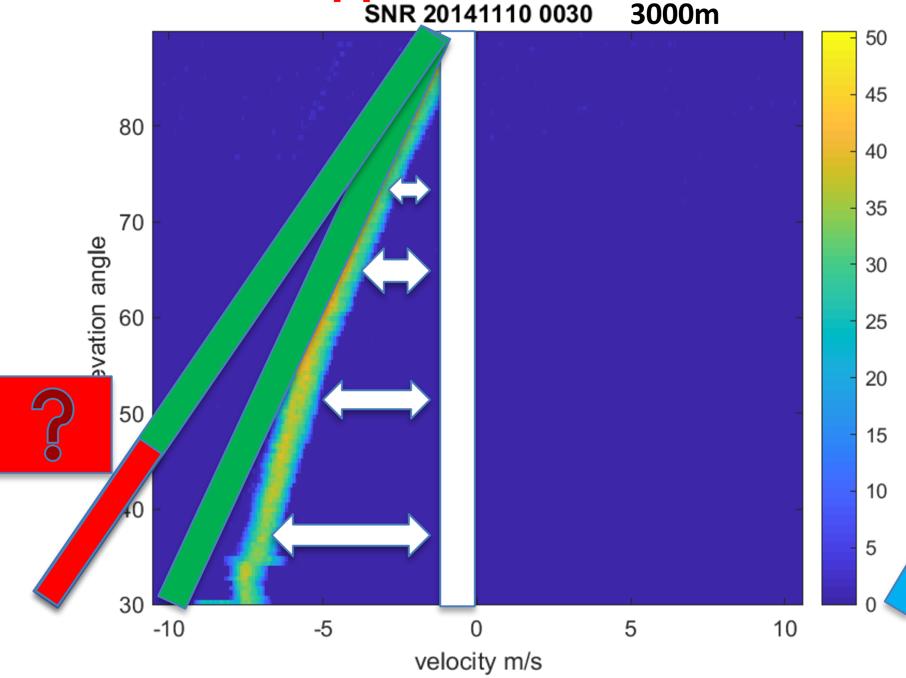
Shape & orientation

Wind effects

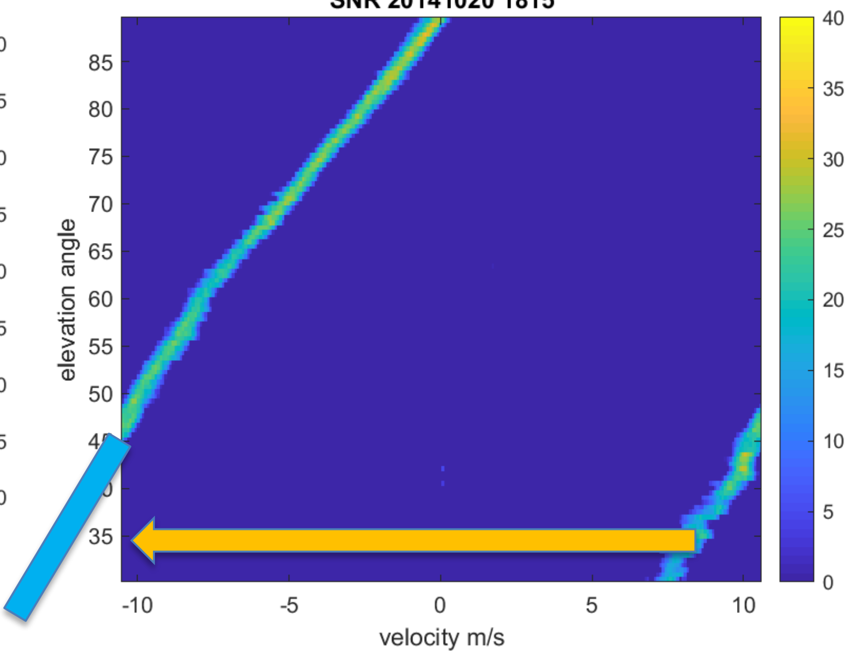
✓ horizontal wind effects shift the Doppler spectrum. This shift increases with decreasing elevation angle.



Doppler shift



Aliasing

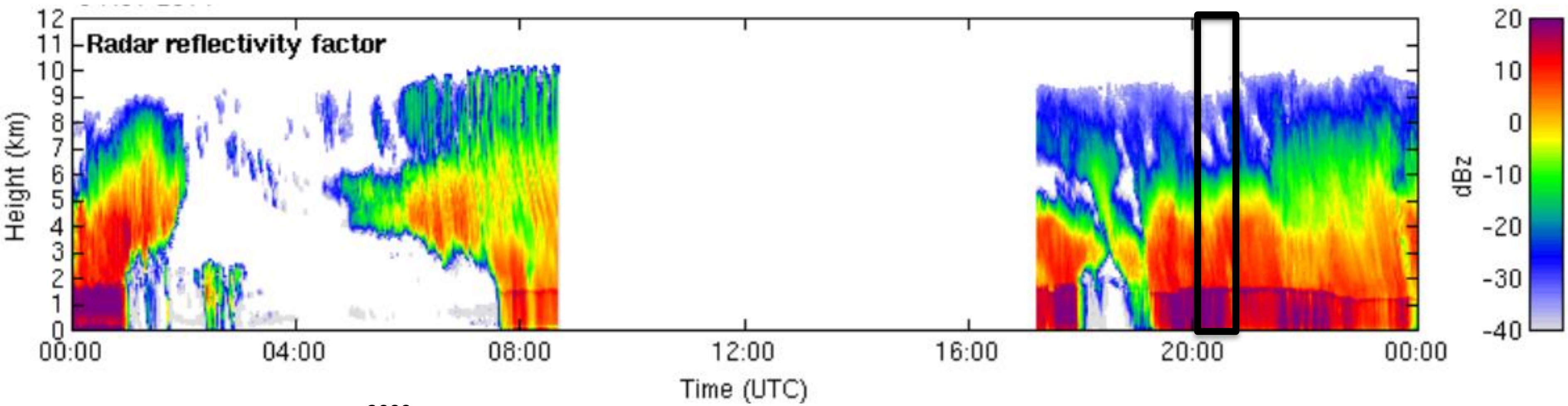


Majid Hajipour (hajipour@tropos.de), CCRES workshop

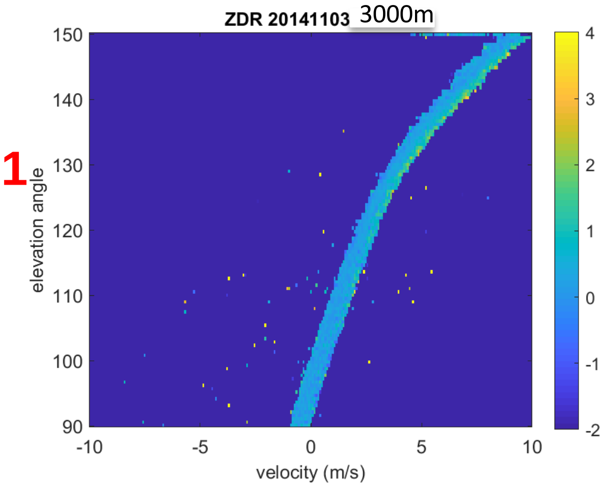
TROPOS

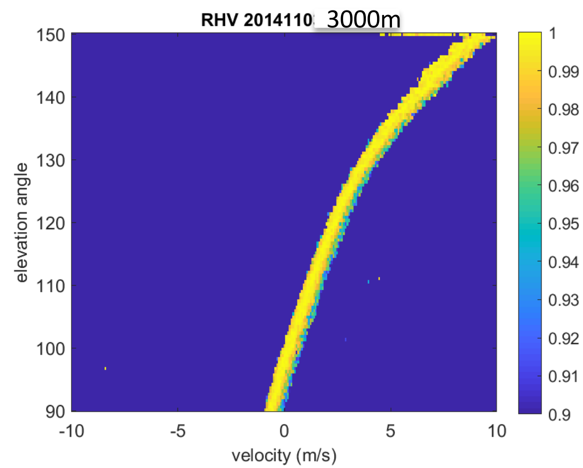
Result:

Case study: Date: 2014.11.03 Time: 20:00-20:15 Height: 3000 m



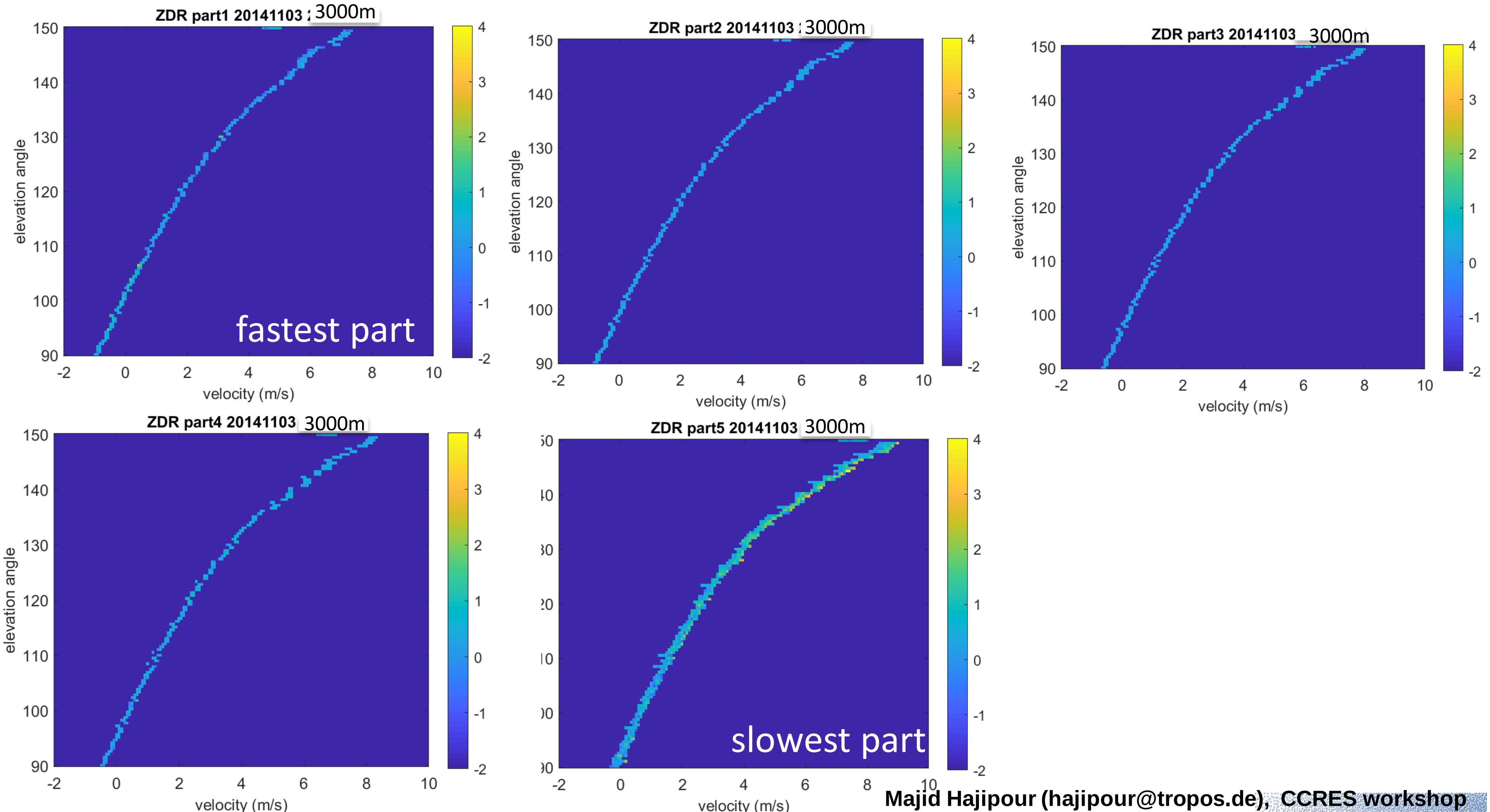
RHI 1





Split of RHI-scans of Doppler spectra of ZDR and RHV into 5 parts

Differential Reflectivity (ZDR) for each Doppler part



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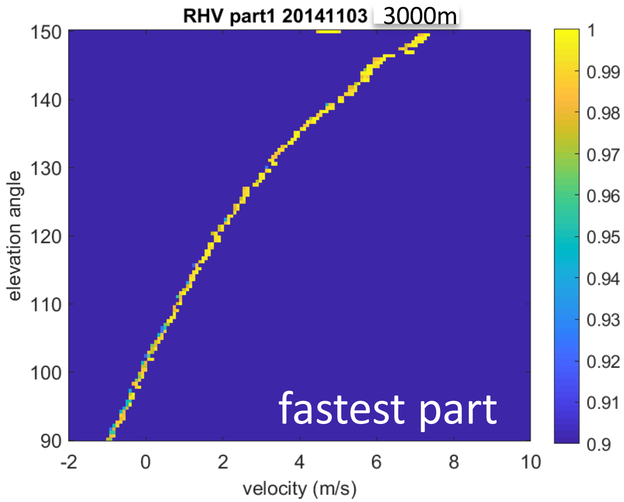
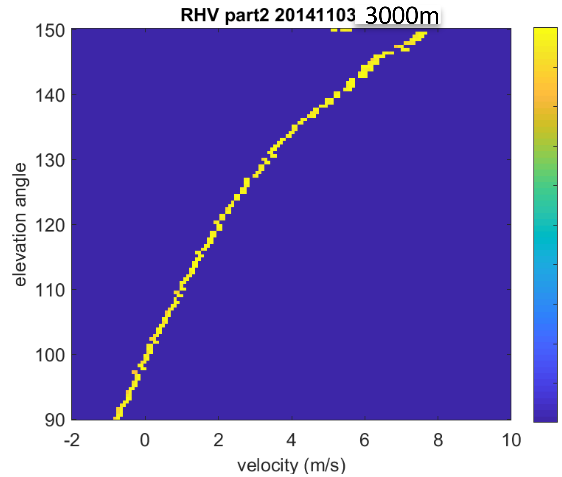
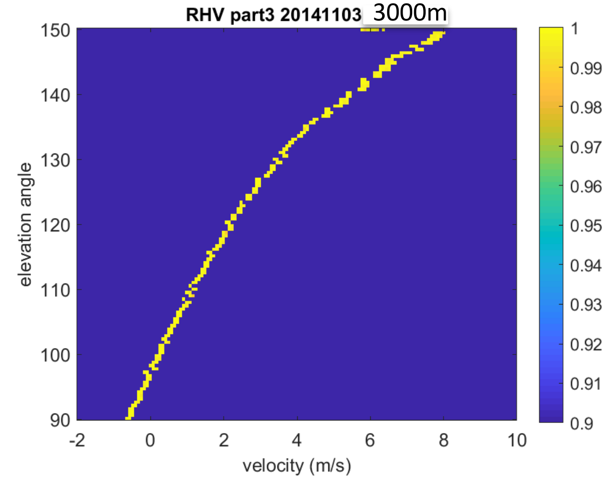
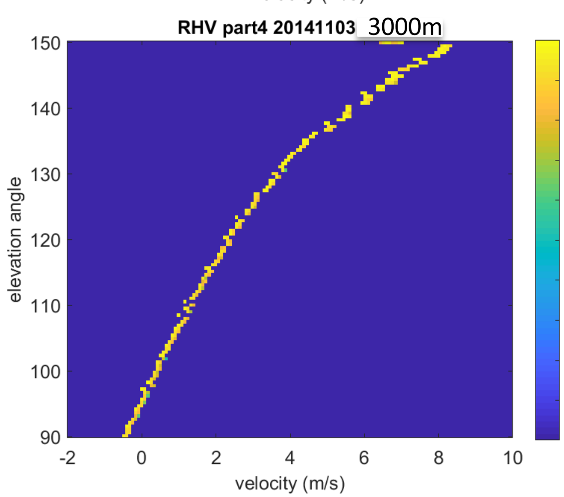
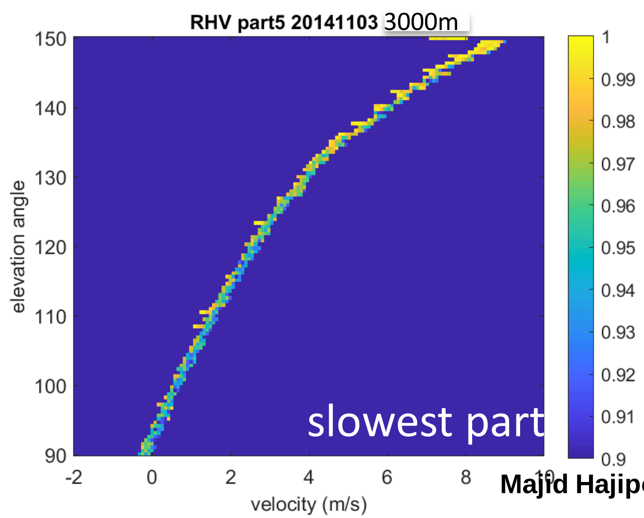
Correlation Coefficient (RHO_HV) for each Doppler part











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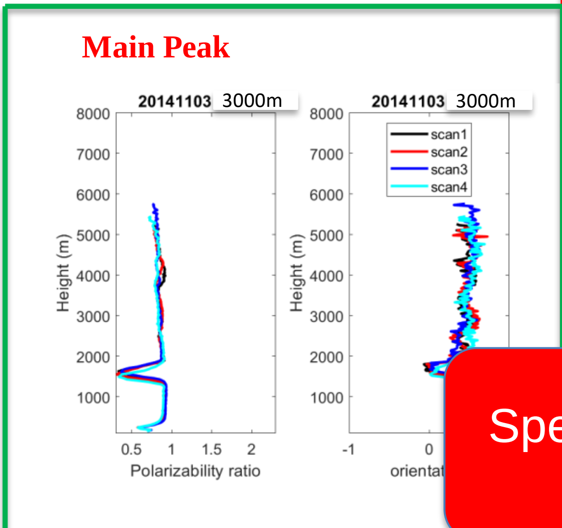
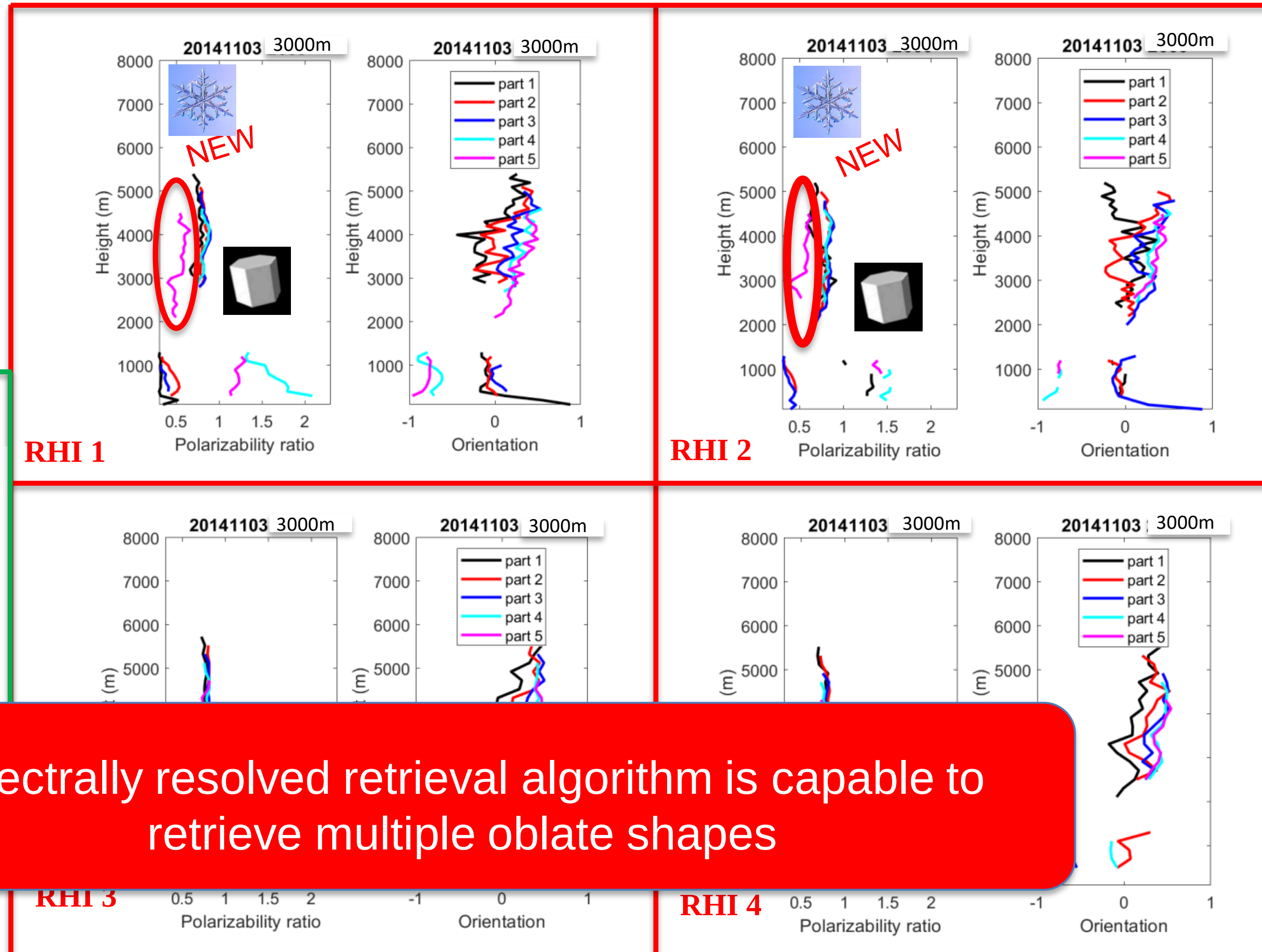
Retrieval results

Date: 2014.11.03
Time: 20:00-20:15
Height: 3000 m



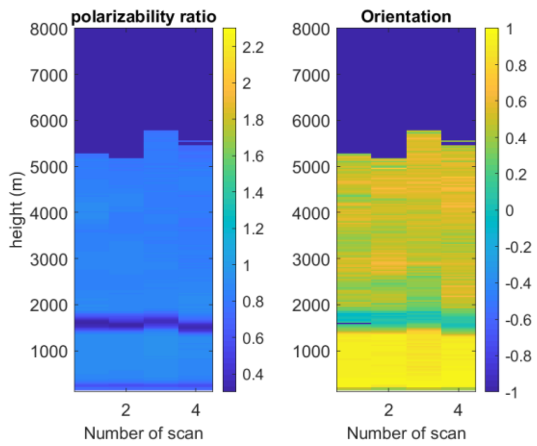


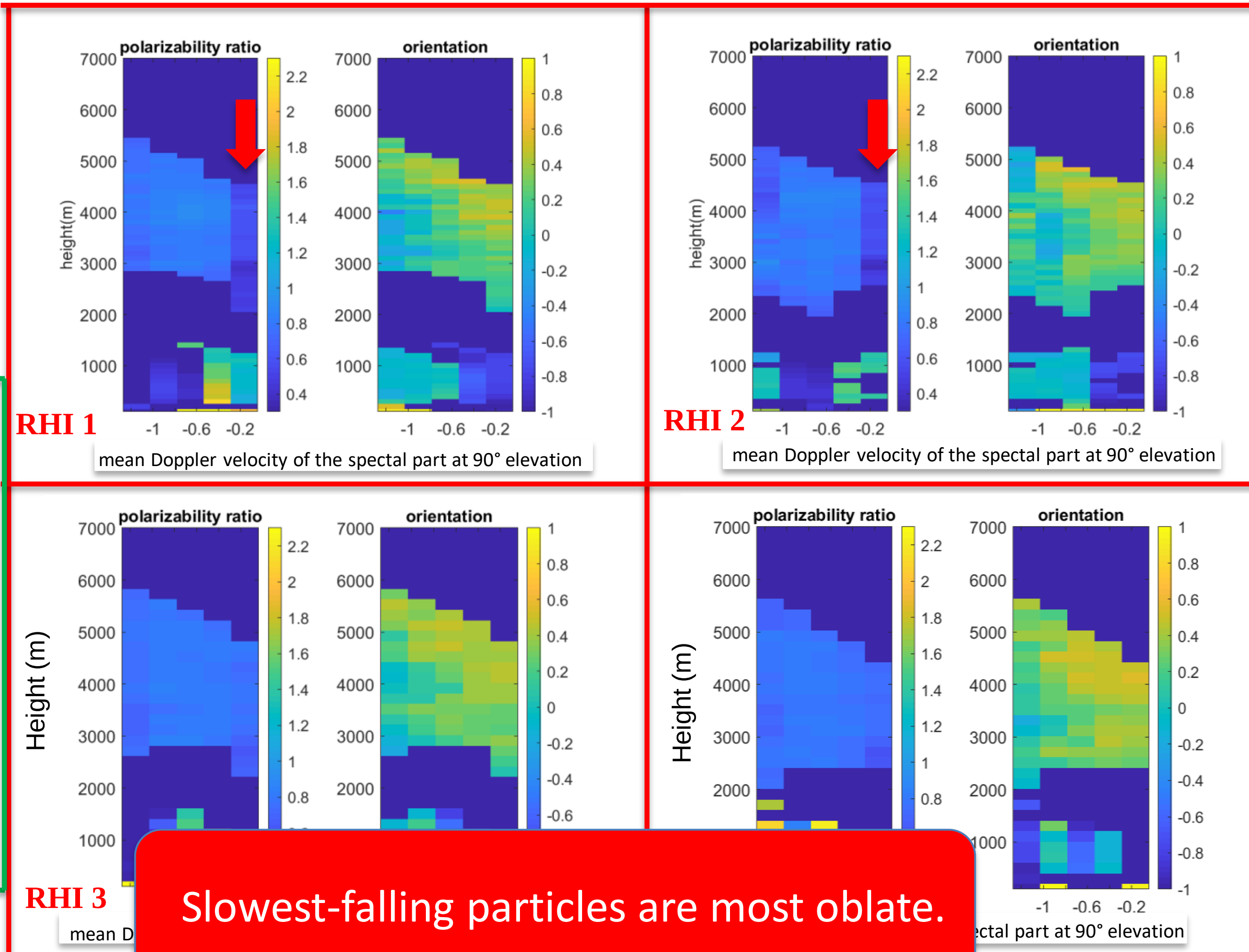
Spectrally resolved retrieval algorithm is capable to retrieve multiple oblate shapes

Retrieval results

Date: 2014.11.03
Time: 20:00-20:15
Height: 3000 m

Main Peak for 4 RHI scans





Slowest-falling particles are most oblate.

Summary

- Scanning polarimetric cloud radar enables us to retrieve shape and orientation of ice particles.
- Using spectrally resolved approach, multiple hydrometeor types can be retrieved.
- Automatic retrieval exists
- Based on one 5-minute RHI scan of ZDR and RHV, information about shape distribution can be obtained regularly
- Quantitative approach which can be applied to STSR(hybrid-mode) polarimetric (cloud) radars.

Thanks for your attention!