UNIVERSITÄT LEIPZIG

TROPOS

Leibniz Institute for Tropospheric Research

Investigating hemispheric differences in aerosol signatures in mixed-phase cloud processes with spectral polarimetric cloud radar observations

Teresa Vogl

Supervisors : *Heike Kalesse-Los, Patric Seifert*

SPP-PROM meeting, Kiel, July 17, 2023

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...how aerosol influences riming/ aggregation using vertically-pointing cloud radar observations from both hemispheres

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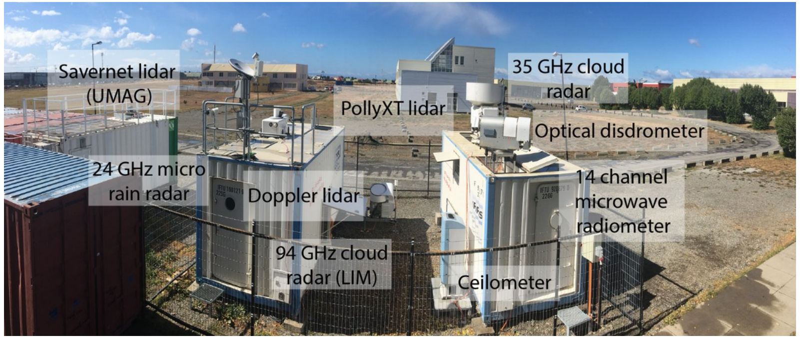
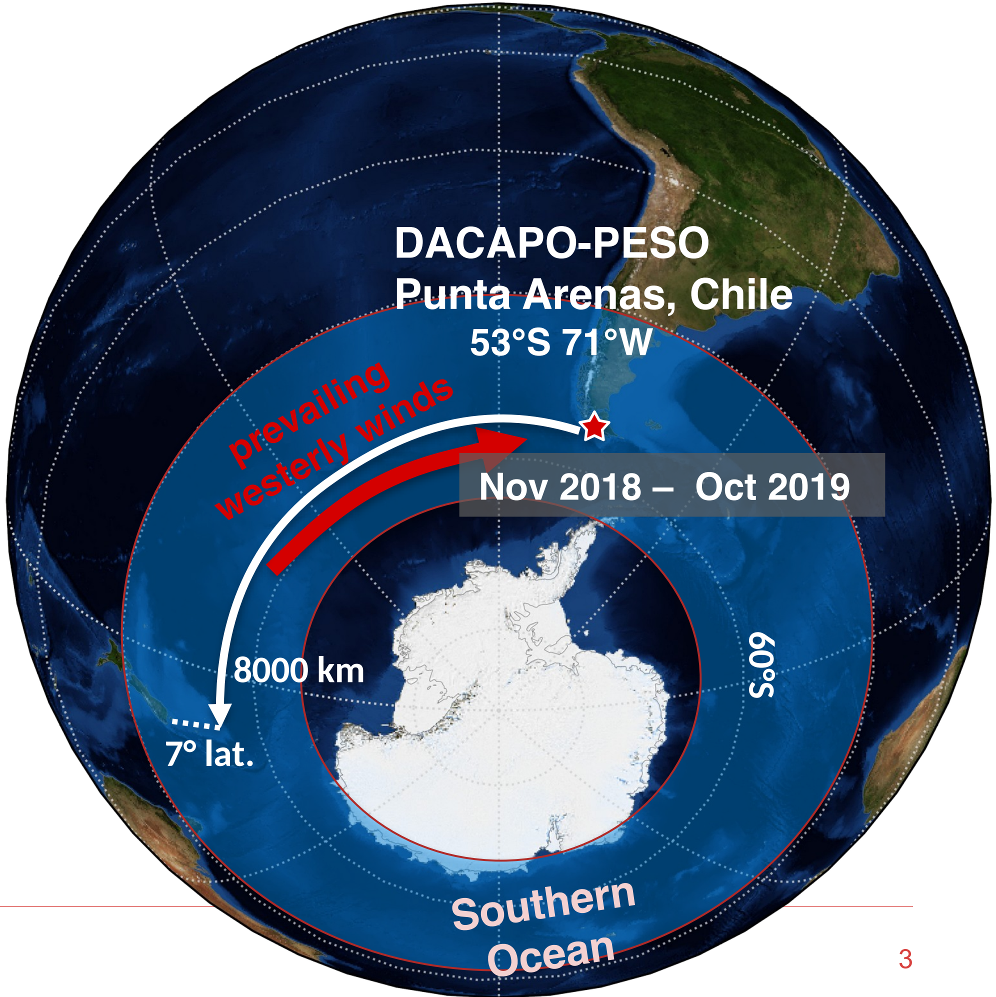
DACAPO-PESO data set

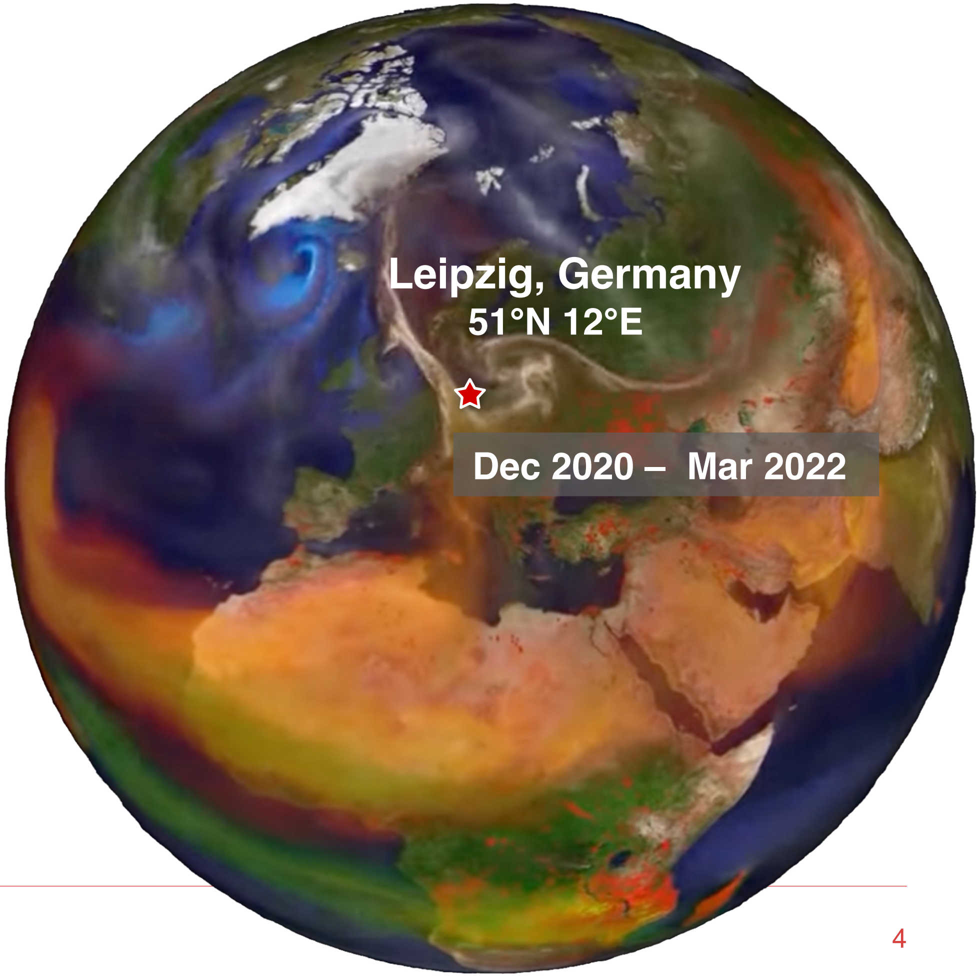
- Punta Arenas, Chile: clean marine site, mostly sea salt aerosol
- Scarcity in INPs
- Mountain ranges causing vertical air motions
- 301 days of measurements





Leipzig data set

- Leipzig, Germany: European continental site with multiple aerosol source regions
- Large abundance of mineral dust
- No orographic lifting
- 488 days of measurements



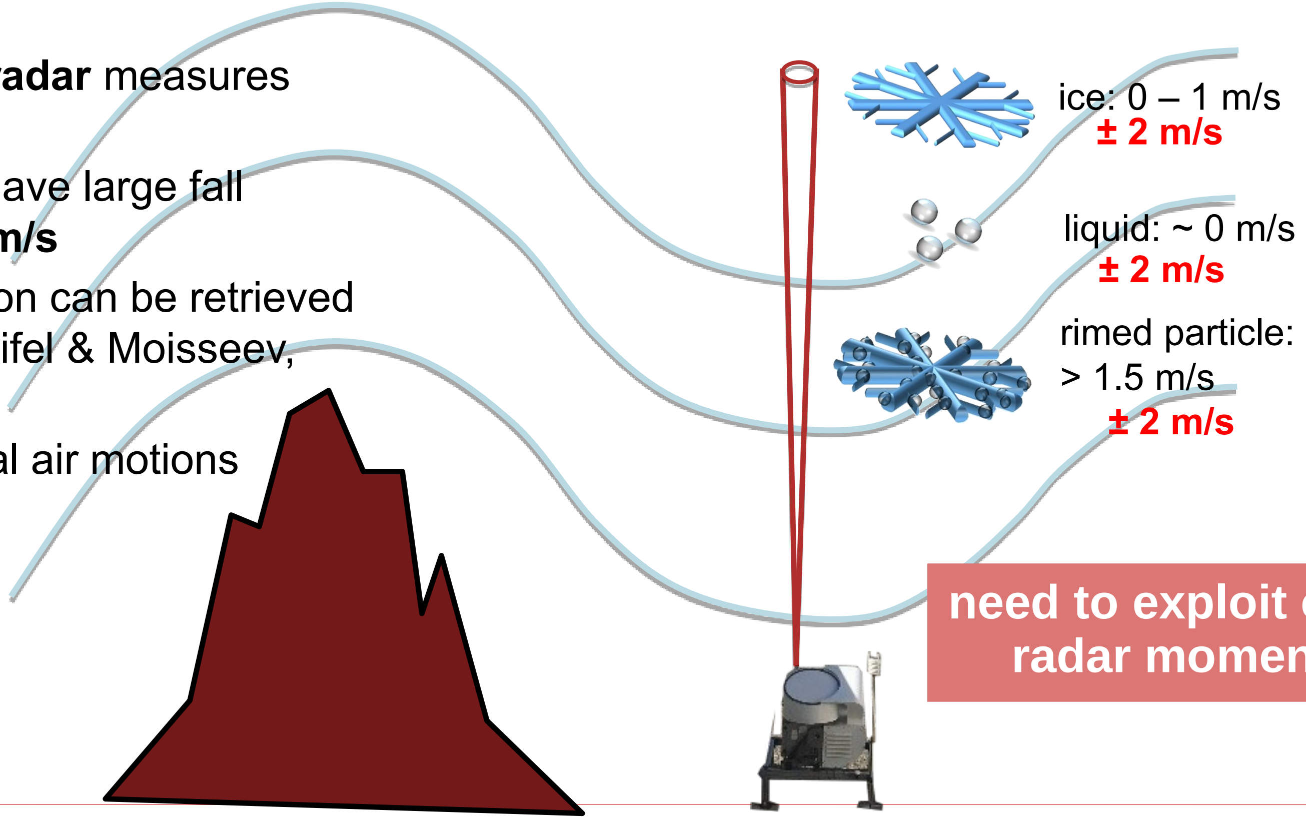
https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=30017&button=popular
https://www.physgeo.uni-leipzig.de/institut-fuer-meteorologie/forschung/arbeitsgruppefernerkundungundarktischesklimasystem/forschung#c287992

OUTLINE

- How to detect riming in orographic cloud systems (method 1)
- Exploiting peaks in cloud radar Doppler spectra (method 2)
- Outlook: application of developed methods to long-term observations

RIMING DETECTION USING GROUND-BASED RADAR

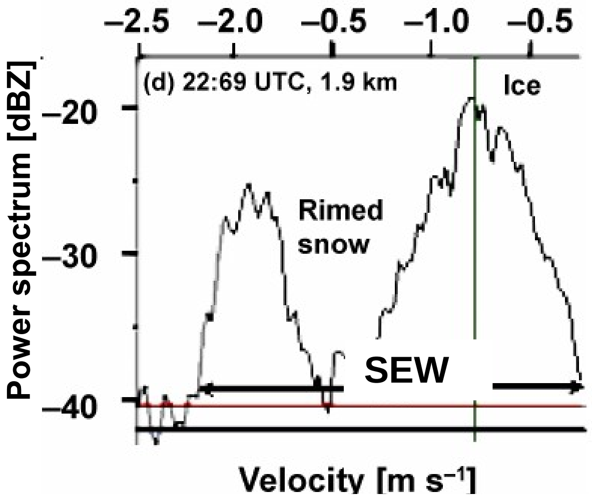
- **ground-based radar** measures Doppler velocity
- rimed particles have large fall velocities **> 1.5 m/s**
- rime mass fraction can be retrieved using **MDV** (Kneifel & Moisseev, 2020)
- **Problem**: vertical air motions



need to exploit other radar moments

FINGERPRINTS OF RIMING

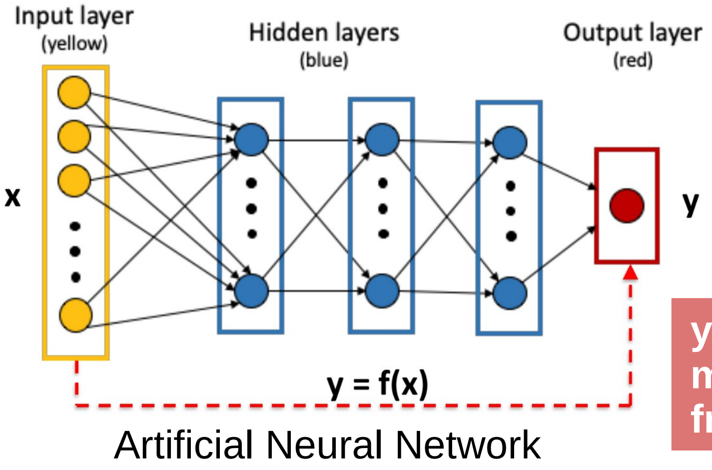
- Increase in **MDV**
- Increase in **width**
- Nonzero **skewness**
- Increased **reflectivity**



Kalesse et al., 2016

- **Machine learning** techniques well-suited for extracting relationships from large data sets
- Easy-to-use Python implementations

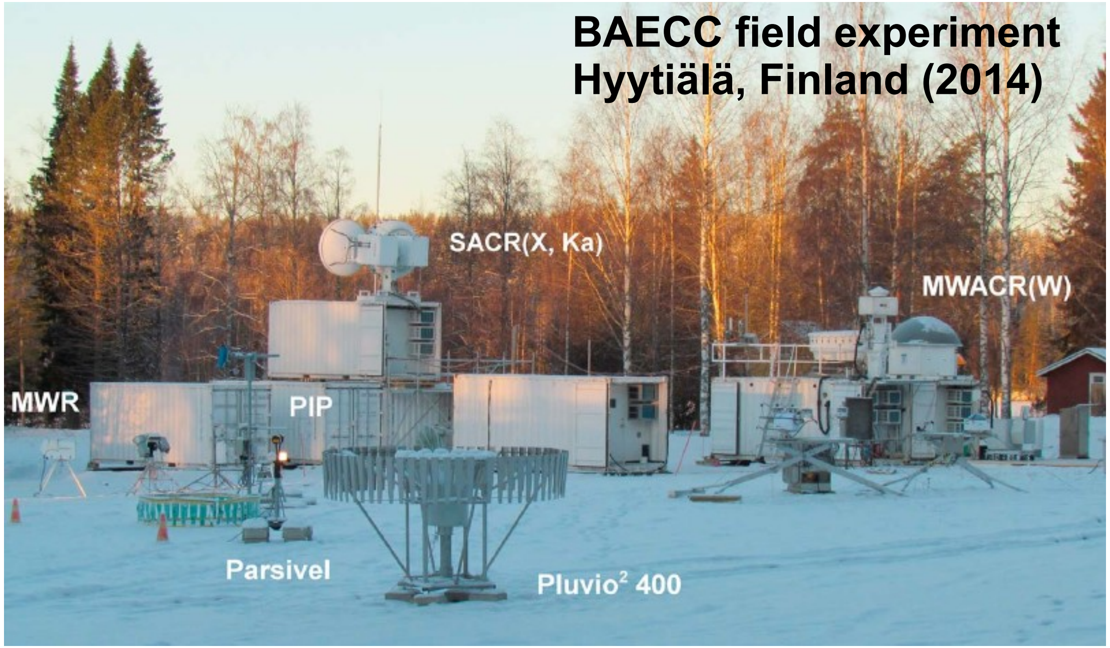
x = Doppler spectrum features



y = rime mass fraction

Ebert Uphoff, 2020

TRAINING DATA SET

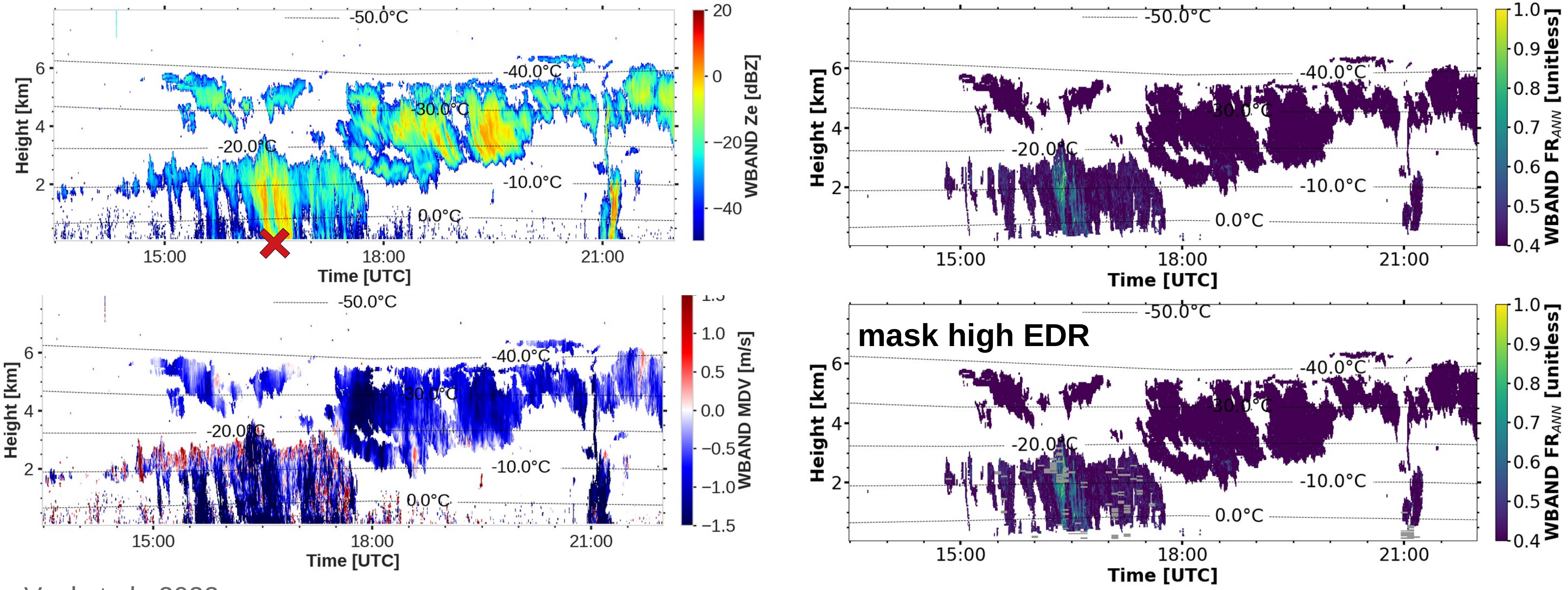


Kneifel et al., 2015

- For training, we need **pairs of input x and output y** → dataset with remote sensing and in-situ observations
- **PIP** (Precipitation Imaging Package) → retrieving rime mass fraction $\mathbf{FR_{PIP}}$
- **KAZR & MWACR cloud radars** (35 & 94 GHz)

Application to Punta Arenas data

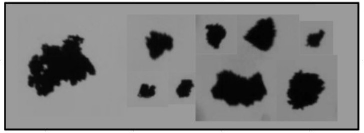
Punta Arenas, 2019-02-21



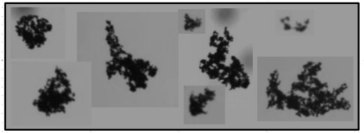
Vogl et al., 2022

Application to Leipzig data

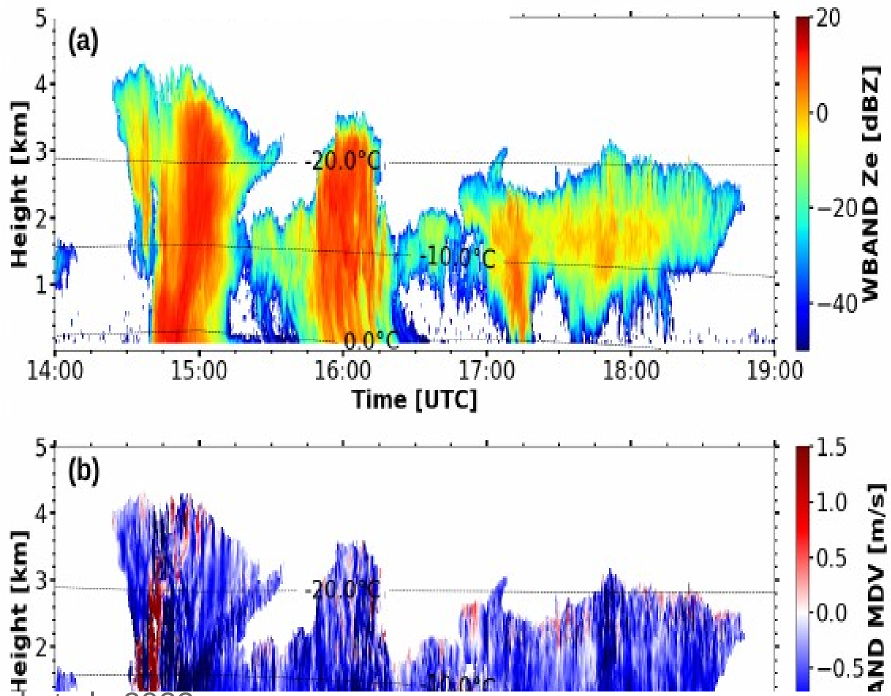
Leipzig, 2021-03-19

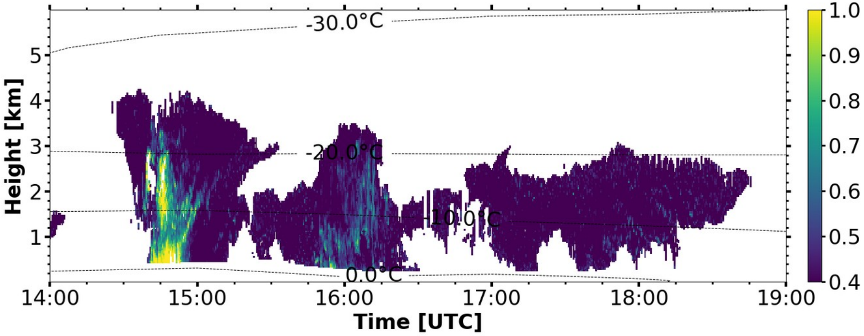


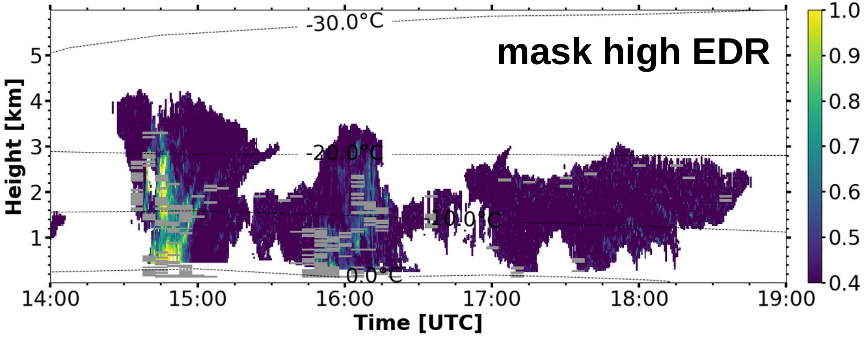
14:40 – 14:50 UTC



15:00 – 15:10 UTC







Vogl et al., 2022

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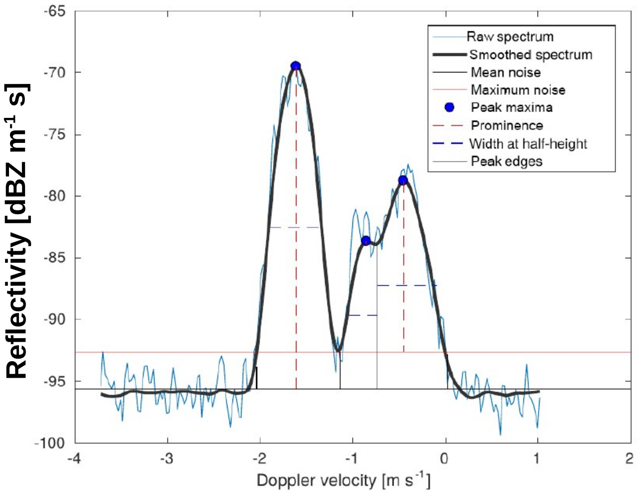
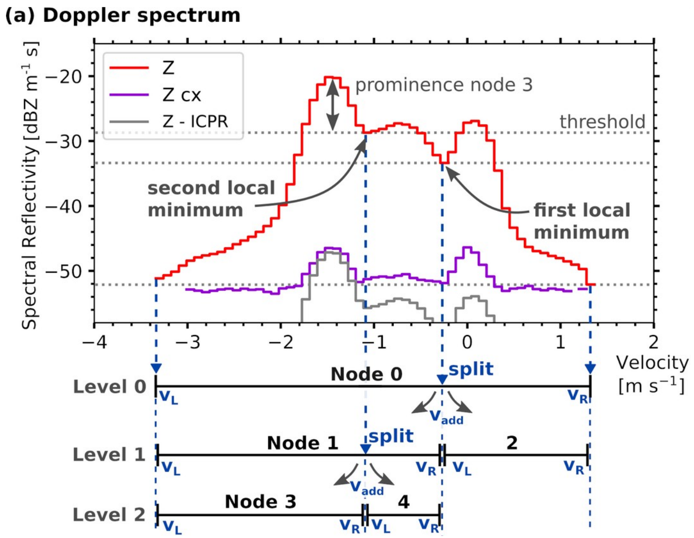
PEAKO & peakTree: peak finding and structuring

- Supervised peak detection using **PEAKO** (Kalesse et al., 2019) parameters: width, prominence, span for smoothing
- Representing sub-peaks in a binary tree structure using **peakTree** (Radenz et al., 2019)



Kalesse et al., 2019



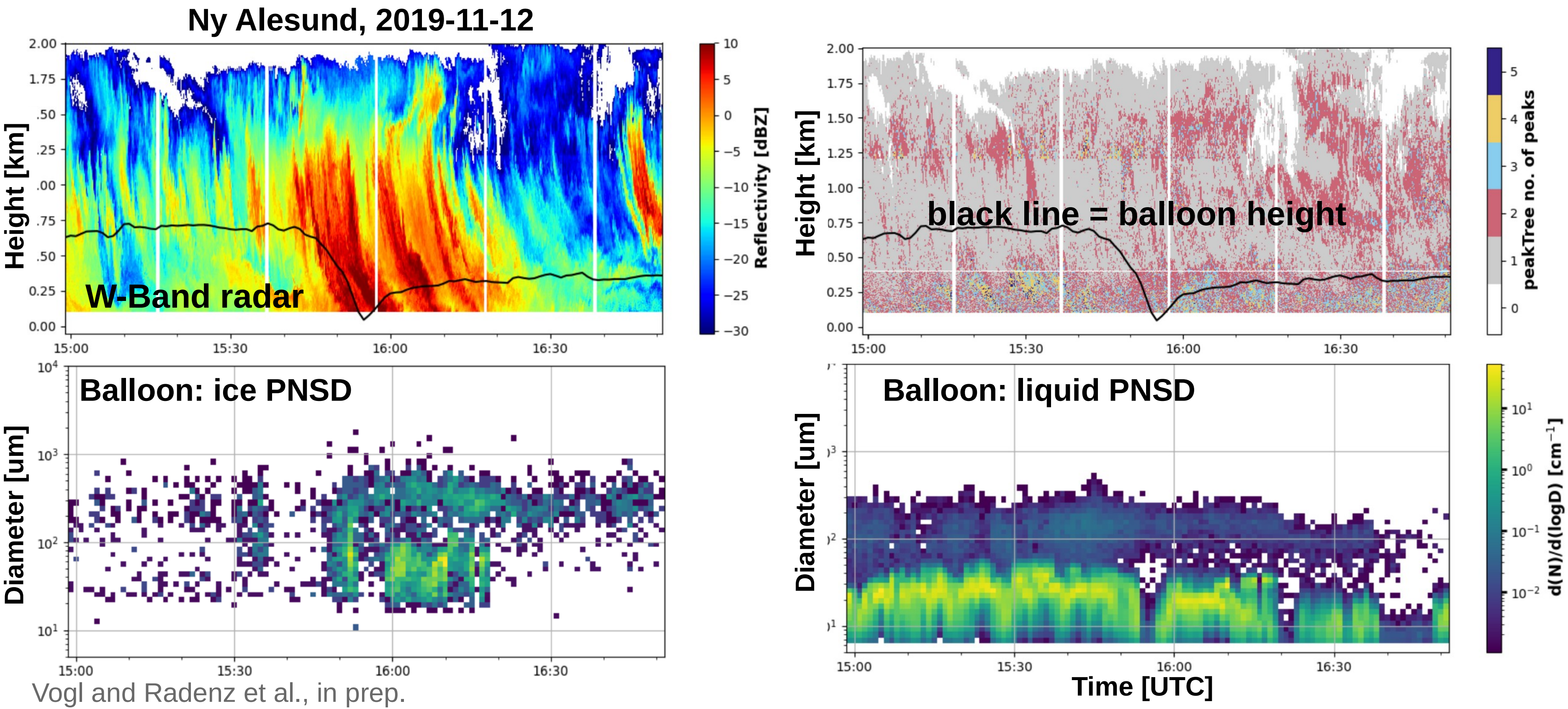
Radenz et al., 2019

Validation with in-situ data (collaboration with Uni Cologne & ETH Zürich)

The Ny-Ålesund Aerosol Cloud Experiment 2019-2020

https://www.aces.su.se/research/projects/the-ny-alesund-aerosol-cloud-experiment-nascent-2019-2020/

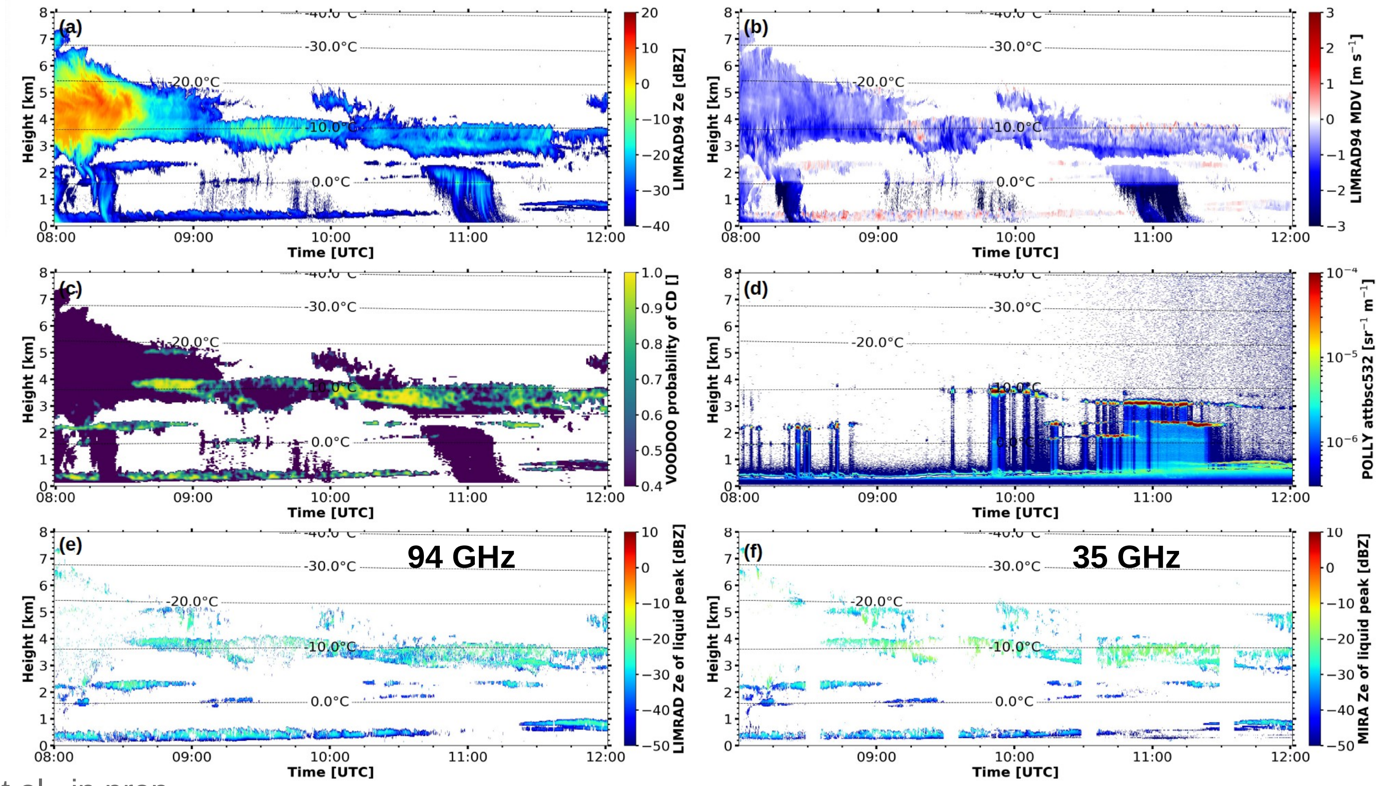
Validation with in-situ data (collaboration with Uni Cologne & ETH Zürich)



Vogl and Radenz et al., in prep.

liquid peak detection & comparison to liquid predicting neural network (Schimmel et al., 2022)

Punta Arenas, 2019-03-13



Vogl and Radenz et al., in prep.

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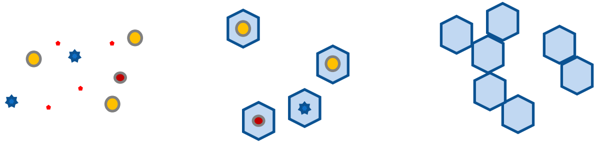
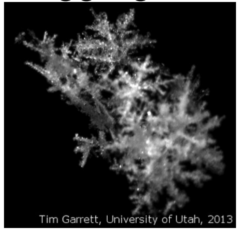
HYPOTHESIS: MICROPHYSICAL GROWTH PROCESSES IN MIXED-PHASE CLOUDS ARE SUSCEPTIBLE TO AEROSOL PERTURBATIONS

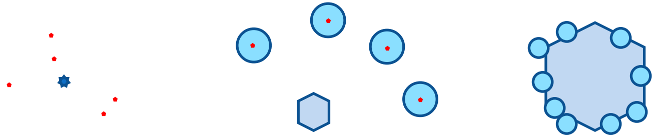
1. High aerosol loads and high INP concentrations → higher ice crystal concentrations → more aggregation



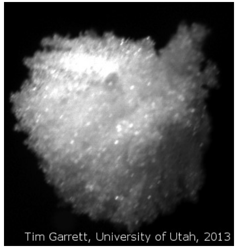
aggregate



2. Low aerosol loads and scarcity of INP → thicker/ more persistent supercooled liquid layers → more riming



rimed ice particle



www.inscc.utah.edu/~tgarrett/Snowflakes/Gallery/

Bringing everything together…

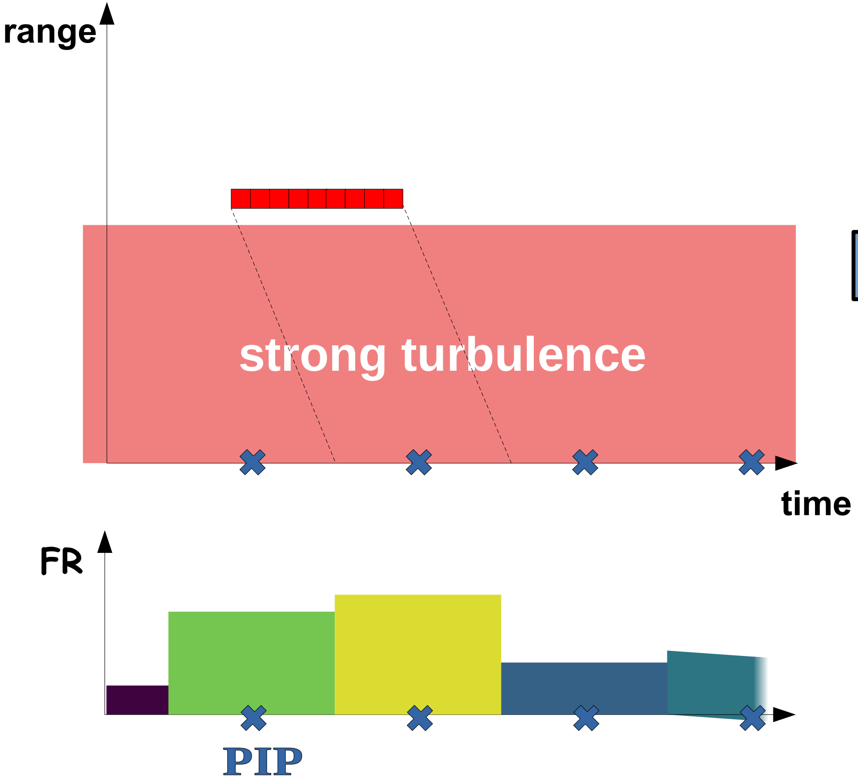
How does aerosol influence riming?

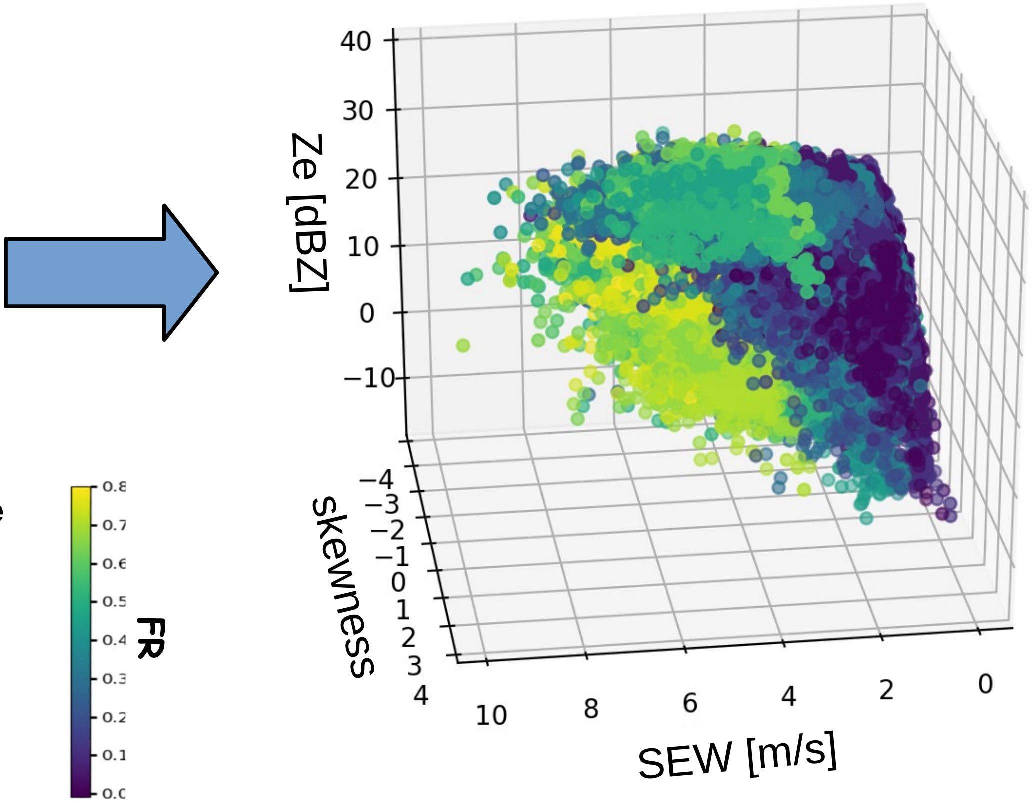
- **Riming**: ANN-based retrieval, particle shape from scans (→ Audrey's work)
- Information on **CCN / INP**: Can be derived from lidar profiles
  (Mamouri & Ansmann, 2016; Gong et al., 2022)
- **Attribution: Which part of the difference we observe is due to aerosol effects (and not due to meteorology/ orography)?**


Thank you!

BACKUP SLIDES

TRAINING DATA SET

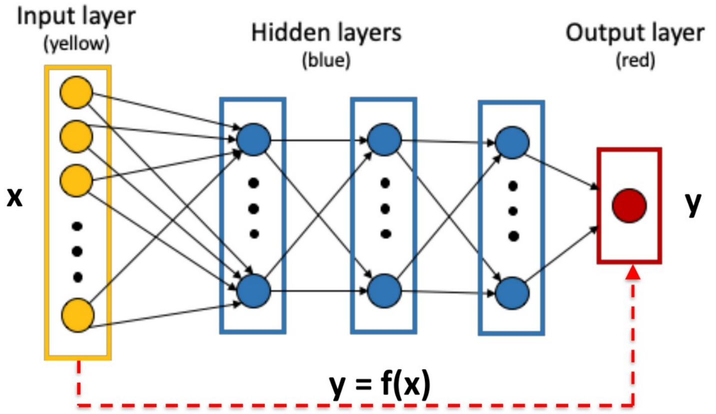




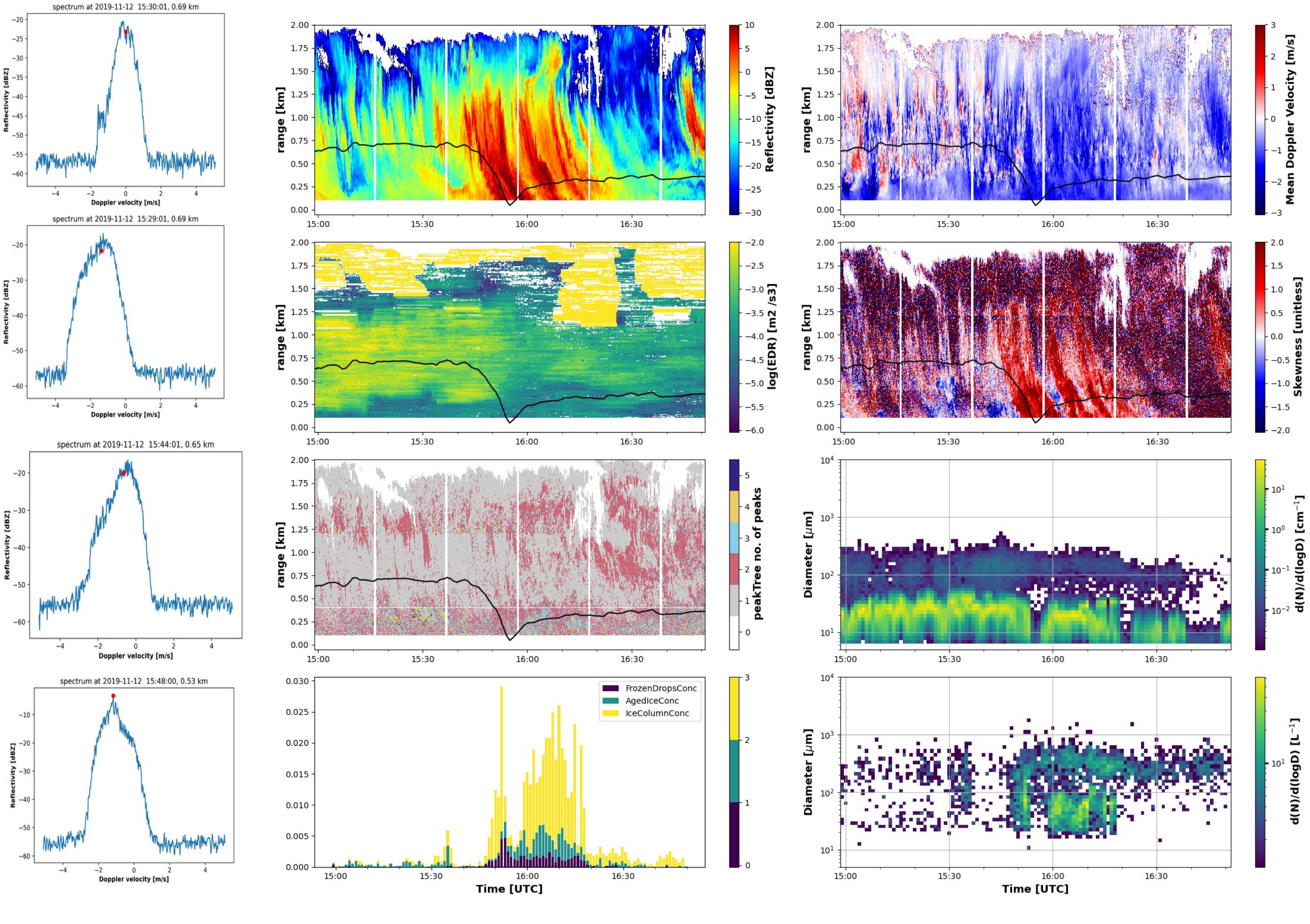
ANN specifications

- split into **training/ validation** & **testing** data sets
- **scaling** the input data using a robust scaler
- **k-fold cross validation** to determine **hyperparameters**

- **ANN#1:** x = Ze, SEW, skewness, MDV
- **ANN#2:** x = Ze, SEW, skewness



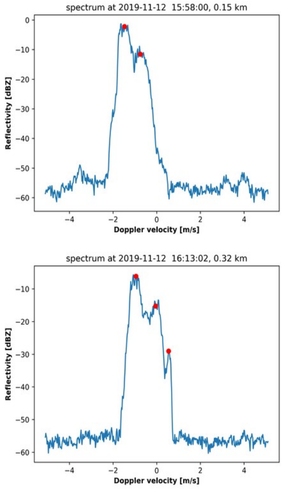
Artificial Neural Network



~15:30: turbulence, drizzle + cloud, one peak detected

~15:45: skewness signal increases in the fall streak (due to more drizzle?), still one peak only

~15:50: three changes happening at once: chirp change, less turbulence, ice appears in in-situ data, 2+ peaks are detected



Schimmel et al. 2022

Table 2. Overview on location, data availability, climate, aerosol load, and related studies for the data sets used. The altitudes are given above mean sea level (a.s.l.).

Location	Punta Arenas, Chile, 53.1° S, 70.9° W	Leipzig, Germany, 51.3° N, 12.4° E
Station altitude	9 m a.s.l.	125 m a.s.l.
Campaign name	DACAPO-PESO	LIM
Measurement period	301 d	488 d
Cloudnet availability	262 d	400 d
Climate	Southern mid-latitudes	Northern mid-latitudes
Typical aerosol load	Marine, occasionally continental	Continental background, occasionally dust
Related studies	Kanitz et al. (2011)	Ansmann et al. (2005)
	Ohneiser et al. (2020)	Seifert et al. (2010)
	Bromwich et al. (2020)	Bühl et al. (2013)
	Jimenez et al. (2020)	Bühl et al. (2016)
	Floutsi et al. (2021)	Radenz et al. (2021)
	Radenz et al. (2021)	Vogl et al. (2022)
	Vogl et al. (2022)	