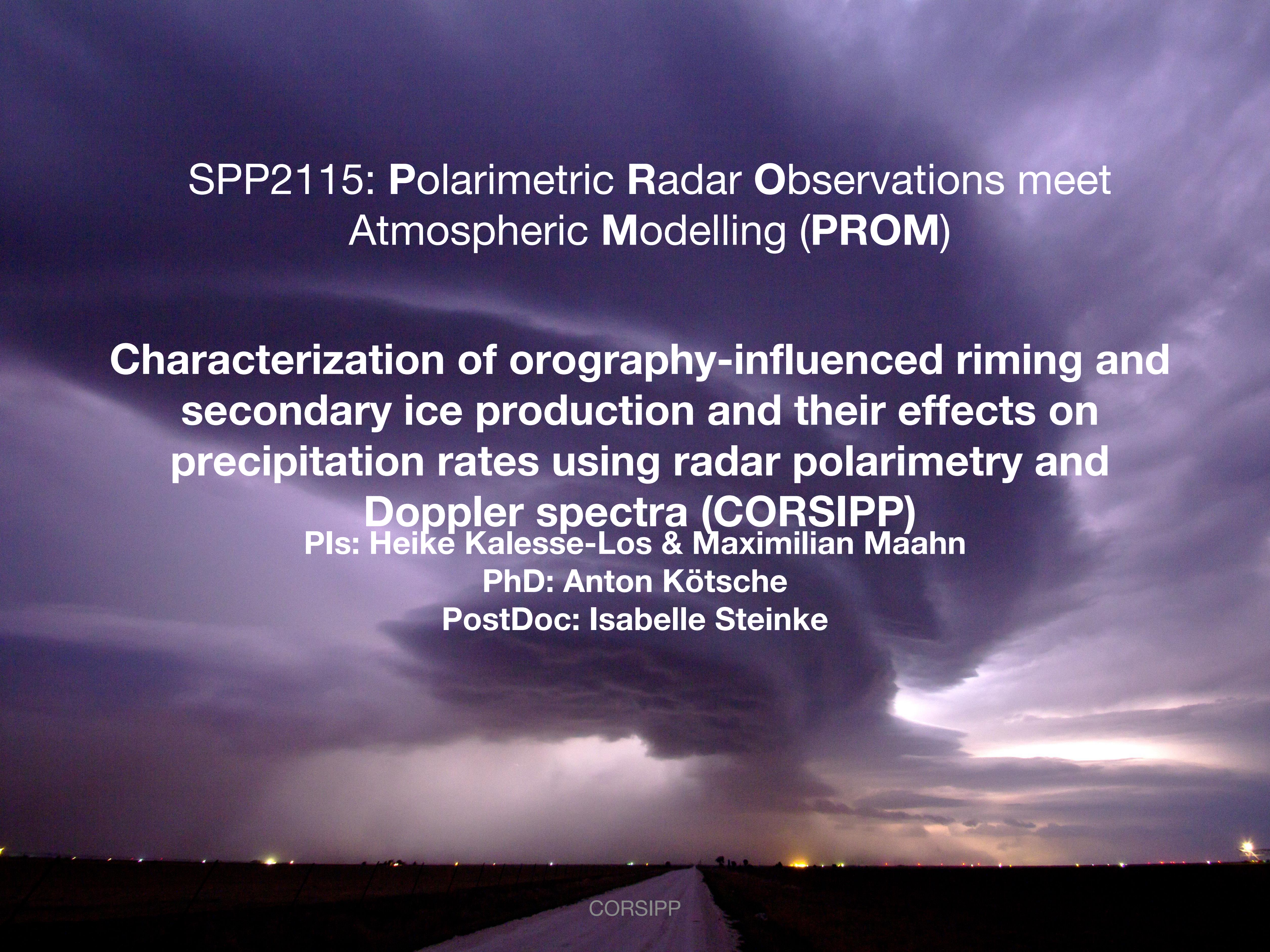


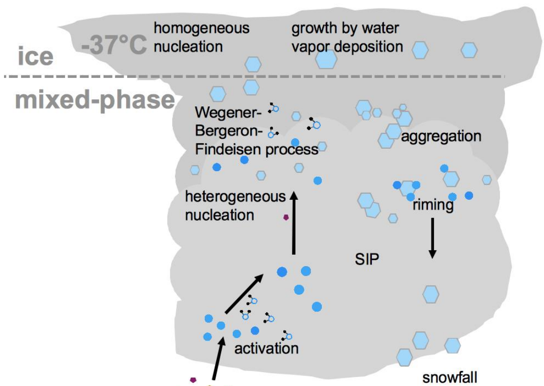
SPP2115: **P**olarimetric **R**adar **O**bservations meet Atmospheric **M**odelling (**PROM**)

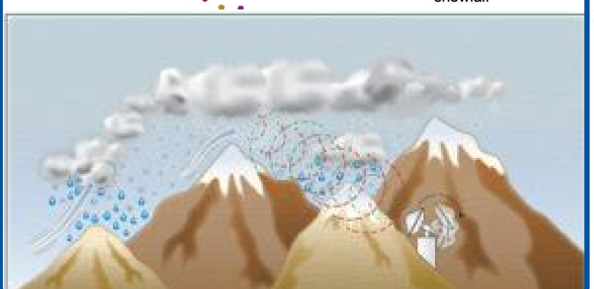
Characterization of orography-influenced riming and secondary ice production and their effects on precipitation rates using radar polarimetry and Doppler spectra (CORSIPP)

PIs: Heike Kalesse-Los & Maximilian Maahn
PhD: Anton Kötsche
PostDoc: Isabelle Steinke

Why?

- Precipitation formation (via ice phase riming, secondary ice production) in complex terrain poorly understood





SIP: Secondary Ice Production

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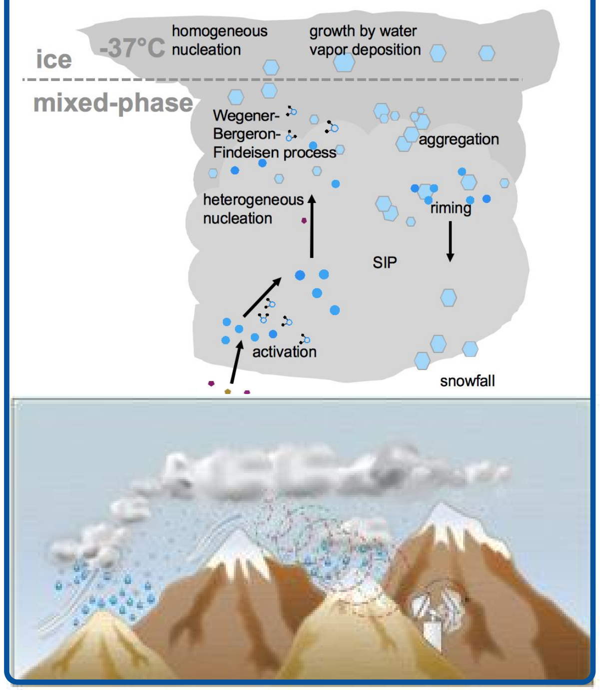
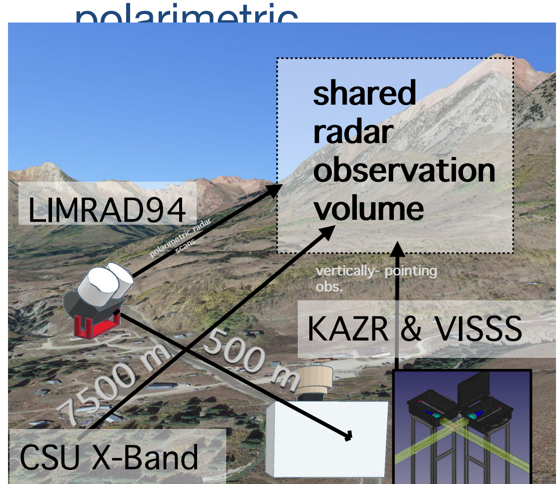
- Precipitation formation (via ice phase riming, secondary ice production) in complex terrain poorly understood



How?

- Join ARM SAIL campaign with scanning 94 GHz cloud radar & Video In Situ Snowfall Sensor (VISSS)
- Quantify riming and SIP with empirical relations and inverse methods based on spectral, polarimetric



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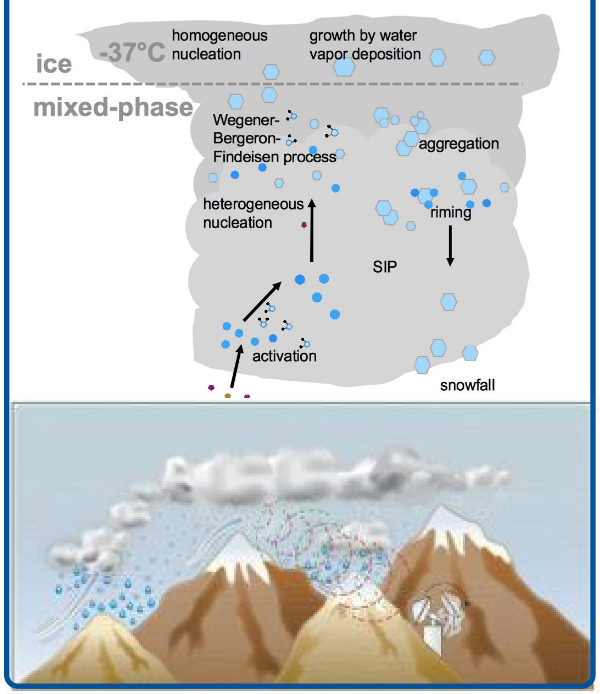

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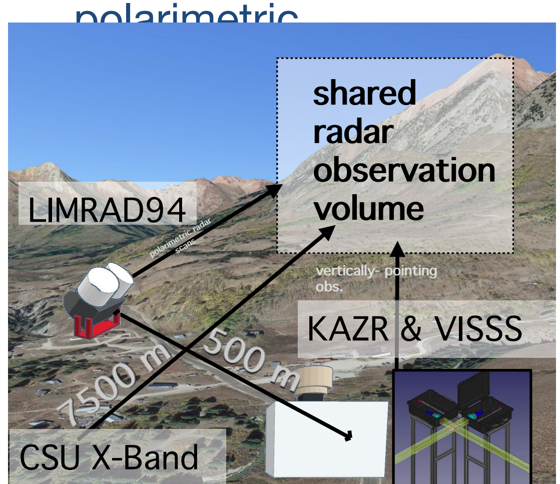
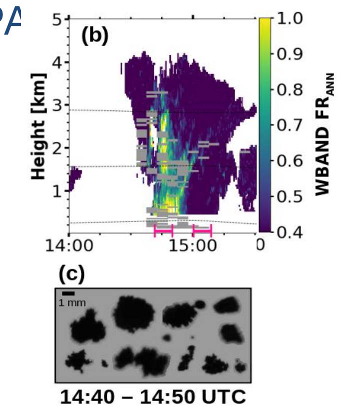


Prior & preliminary work

- Vogl et al., 2022: riming retrieval
- Luke et al., 2021: SIP detection
- Schimmel et al., 2022: liquid detection
- Myagkov and Rose, 2018: spectral polarimetric ice particle formation retrieval

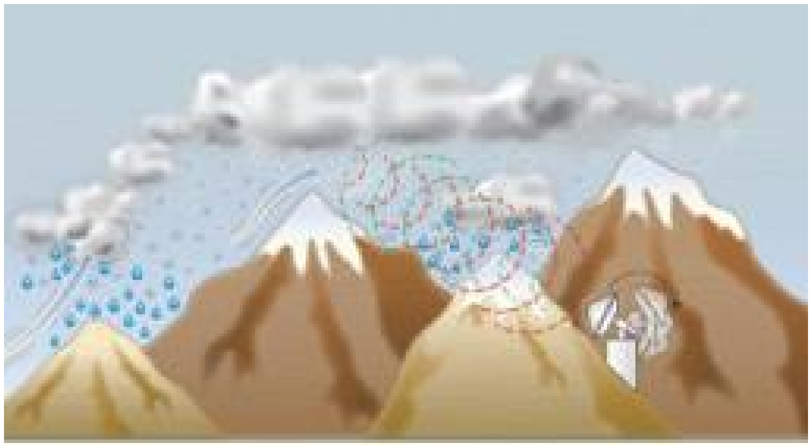
- VISSS snowfall camera
- PA erator



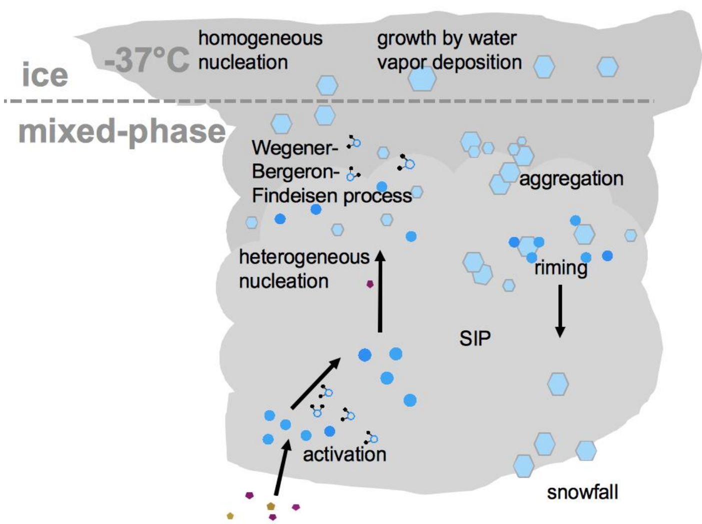
Vogl et al., 2022

SIP: Secondary Ice Production

Why? Research gap



Sail.lbl.gov



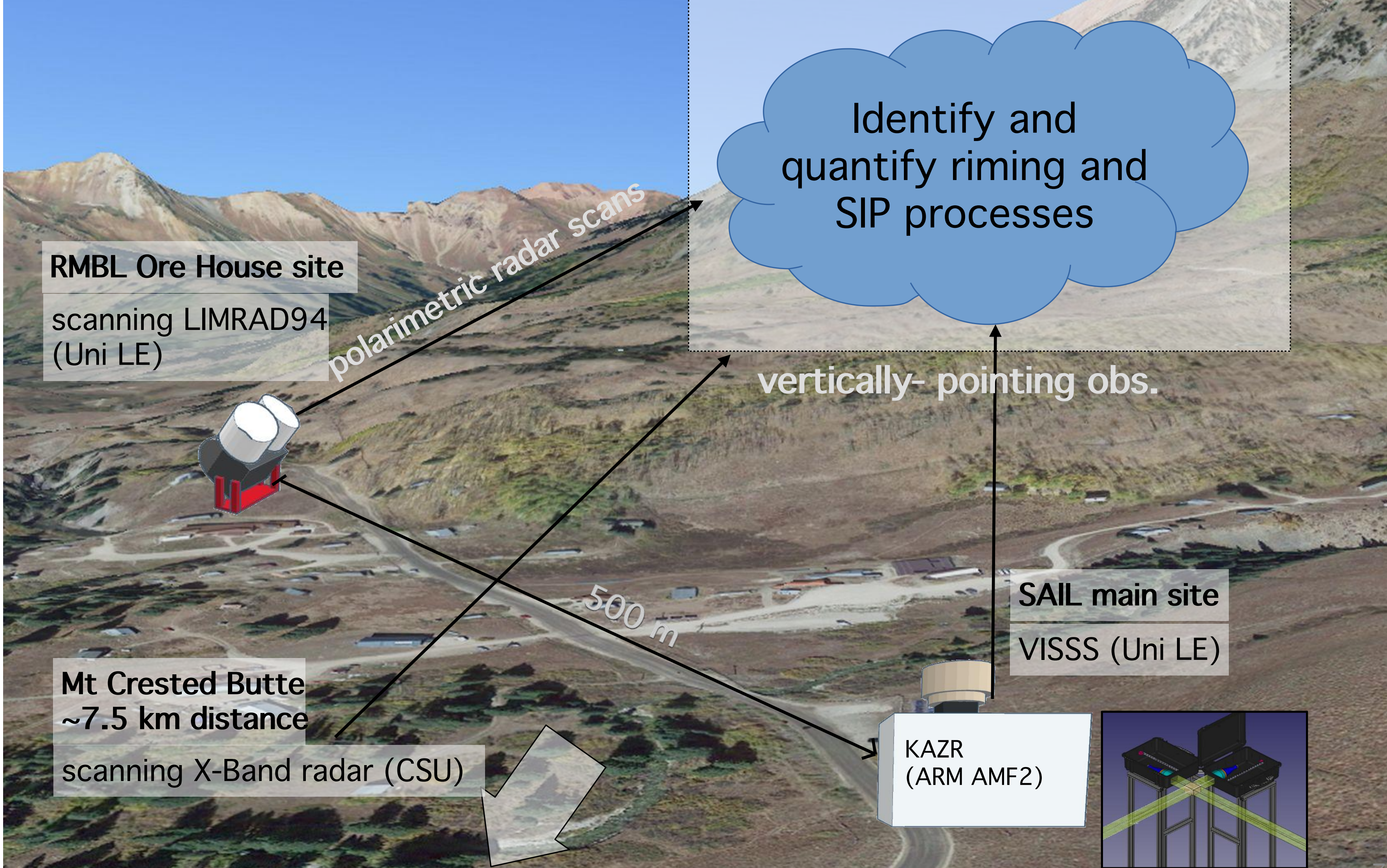
- **Role of riming and SIP for snowfall formation unclear at orographically-influenced site**
- **Lack of understanding of external drivers for riming, secondary ice production and snowfall**
- **Modelling capabilities need improvement (PAMTRA radar forward operator)**

ARM SAIL* AND NOAA SPLASH**

- September 2021 to June 2023
- Provide insights into how Upper Colorado River watersheds interact with the atmosphere to produce water
- Measured quantities: precipitation, clouds, aerosols, wind, energy, temperature, humidity

* SURFACE ATMOSPHERE INTEGRATED FIELD LABORATOR
** Study of Precipitation, the Lower Atmosphere and Surface f
Hydrometeorology

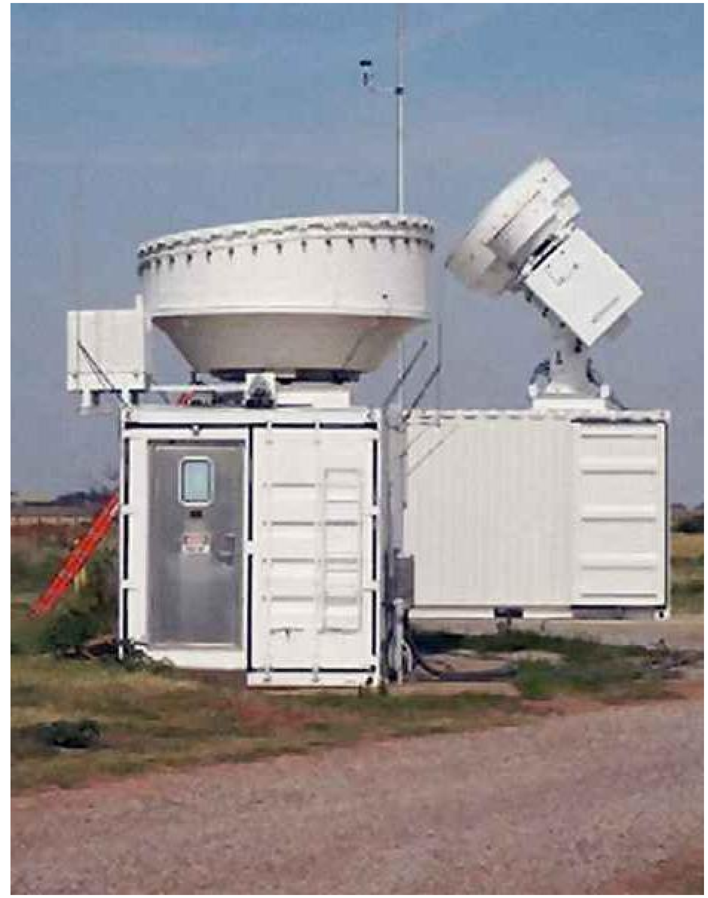
How?


shared radar observation volume
Identify and quantify riming and SIP processes
polarimetric radar scans
vertically- pointing obs.
RMBL Ore House site
scanning LIMRAD94 (Uni LE)
500 m
SAIL main site
VISSS (Uni LE)
Mt Crested Butte ~7.5 km distance
scanning X-Band radar (CSU)
KAZR (ARM AMF2)

Uni Leipzig RPG Cloud Doppler 94 GHz Radar

- NEW: Radar mounted to Scanner
- Operate with individually optimized scanning strategy

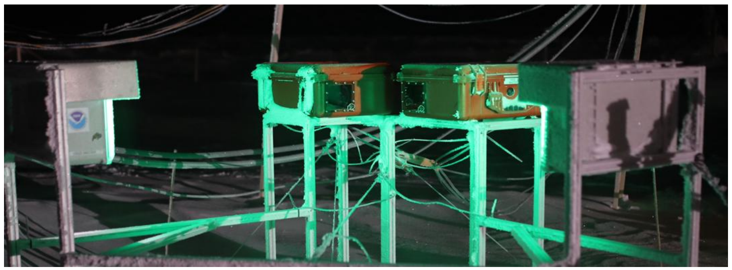
Ka-Band ARM Zenith 35 GHz Radar (KAZR)

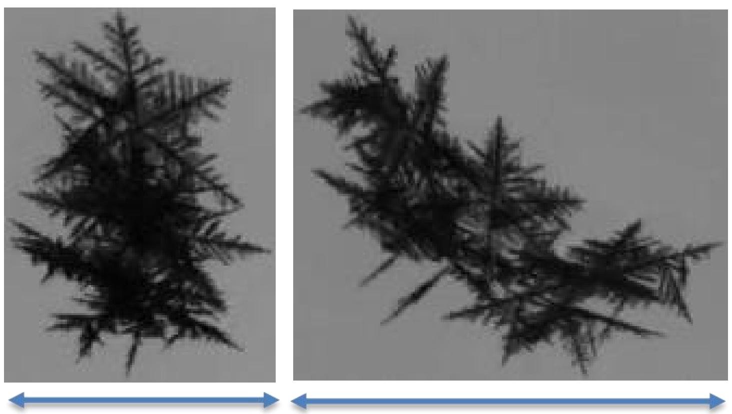


- Vertically pointing
- Only single polarization
- Next to VISSS snowfall camera

Video In Situ Snowfall Sensor (VISSS)

High resolution 2D snowfall camera





7.5 mm

12 mm

- **High quality optical observations** are required for identifying the processes (deposition, aggregation, riming) involved in snowfall formation
- Retrievals of **remote sensing observations** can be better constrained when knowing snow particle shapes and sizes

Maahn, M., M. Radenz, C. Cox, M. Gallagher, J. Hutchings, M. Shupe, and T. Uttal, 2021: Measuring snowfall properties with the Video In Situ Snowfall Sensor during MOSAiC. *EGU21 abstracts*, https://doi.org/10.5194/egusphere-egu21-3306.

Collaborations

M. Kumjian (Pen. State)

D. Moisseev (U Helsinki)

SPP2115

►PolarCAP *P. Seifert* (polarimetric signatures ice formation) → pot. participate in second campaign

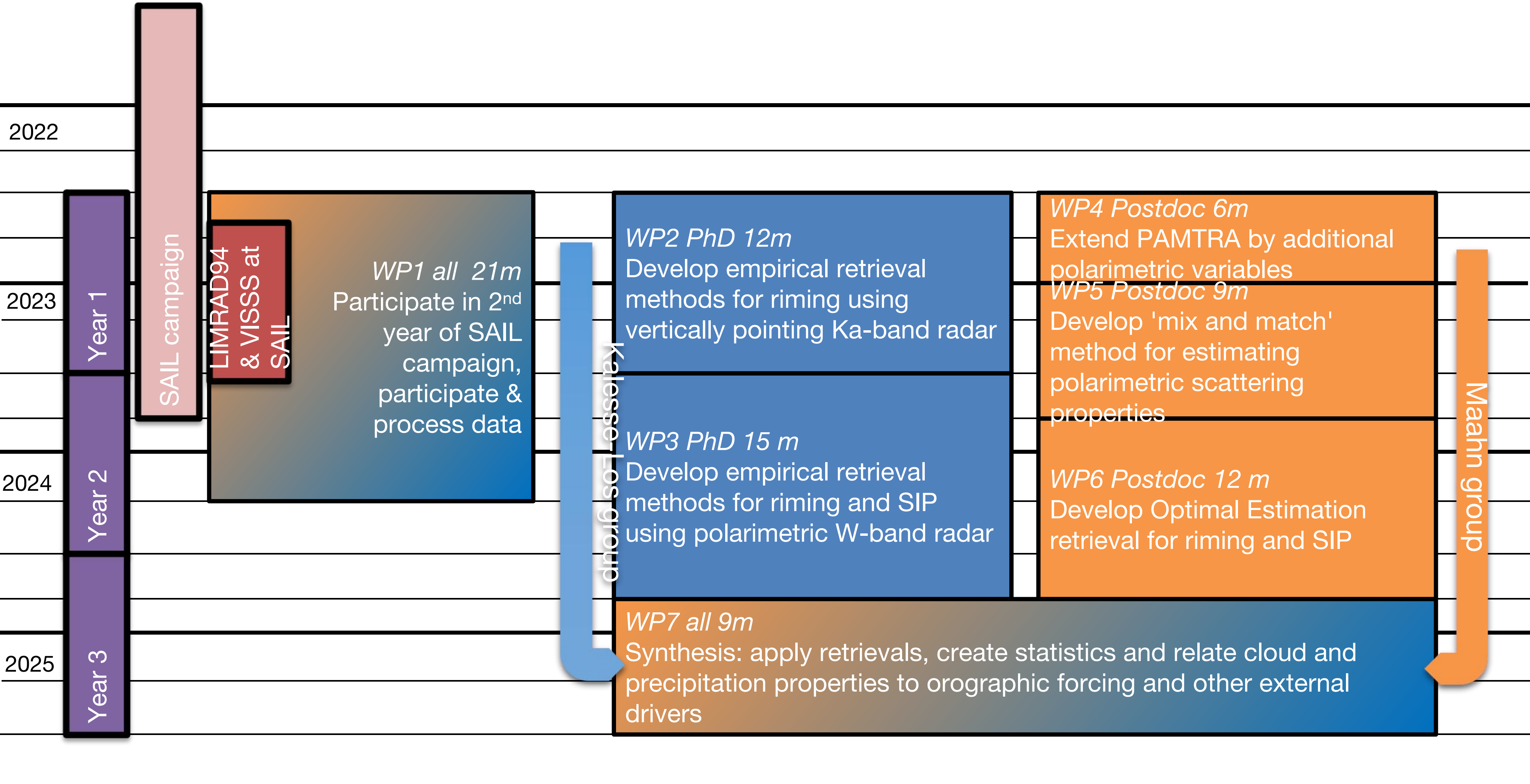
► PRISTINE *D. Ori* → use scattering database

►FRAGILE & POMODORI *S. Kneifel* → discuss polarimetric signatures

A. Myagkov (RPG)

D. Feldman (LBNL)

Work Program

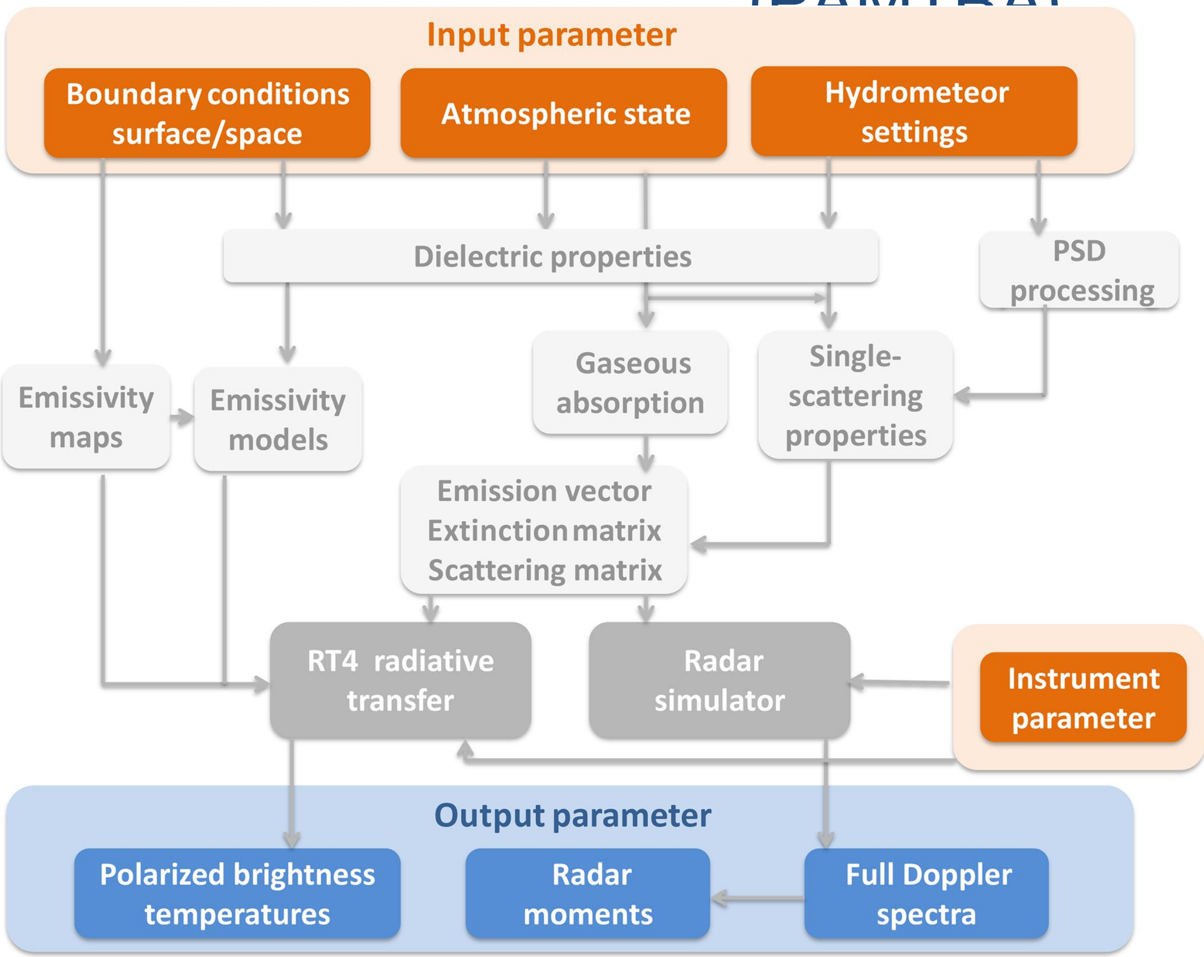


SPP2115: **P**olarimetric **R**adar **O**bservations meet Atmospheric **M**odelling (**PROM**)

Thank you for your attention!

If you want to be our new post-doc…dm us ☺

Passive and Active Microwave radiative TRAnsfer model (PAMTRA)



Approach

- Use a forward operator to simulate the observed atmospheric state (i.e., the polarimetric backscattering signal associated with the presence of different types of hydrometeors)
- Extend beyond spheroidal particles by integrating DOE-ARM scattering database + PRISTINE *D. Ori*

Mech, M., M. Maahn, S. Kneifel, D. Ori, E. Orlandi, P. Kollias, V. Schemann, and S. Crewell, 2020: PAMTRA 1.0: the Passive and Active Microwave radiative TRAnsfer tool for simulating radiometer and radar measurements of the cloudy atmosphere. *Geosci. Model Dev.*, **13**, 4229–4251, https://doi.org/10.5194/gmd-13-4229-2020.

Collaborations

M. Kumjian (Pen. State)

Discuss polarimetric signatures / Bayesian retrievals

D. Moisseev (U Helsinki)

Discuss polarimetric signatures

SPP2115

▶PolarCAP *P. Seifert* (polarimetric signatures ice formation) → participate in second campaign

▶ PRISTINE *D. Ori* → use scattering database

▶FRAGILE & POMODORI *S. Kneifel* → discuss polarimetric signatures

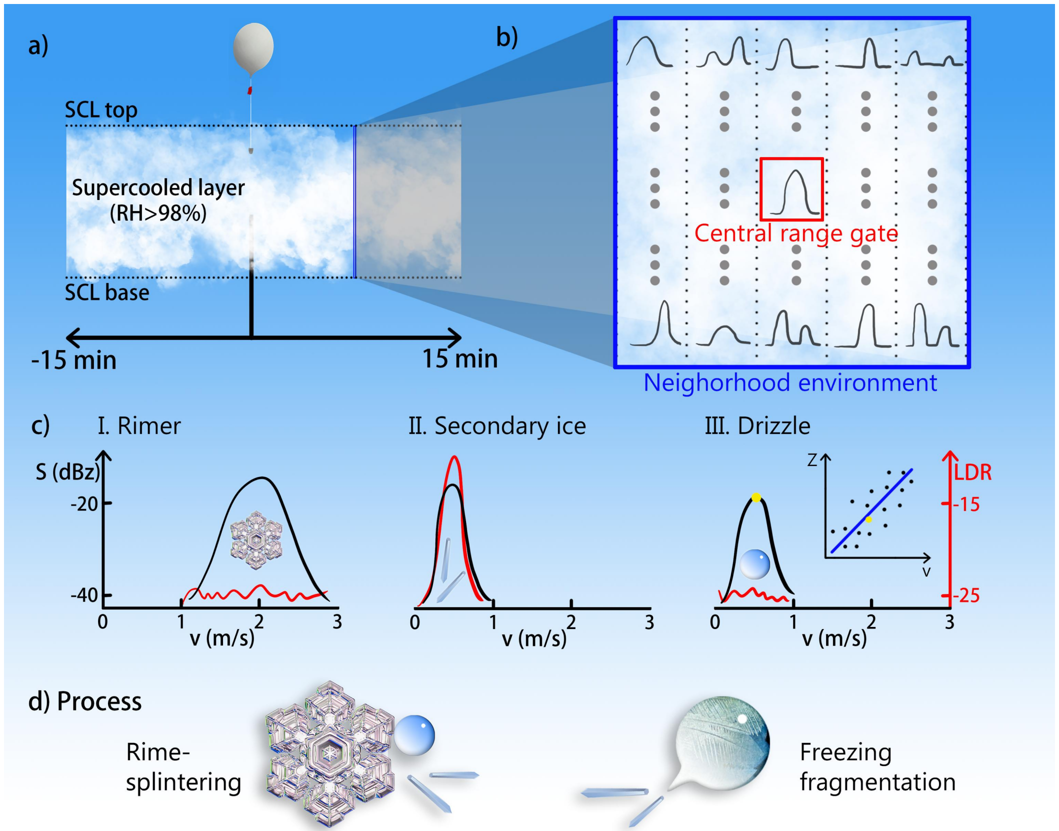
A. Myagkov (RPG)

Hands-on support and use retrieval

D. Feldman (LBNL)

Context with SAIL / ARM database

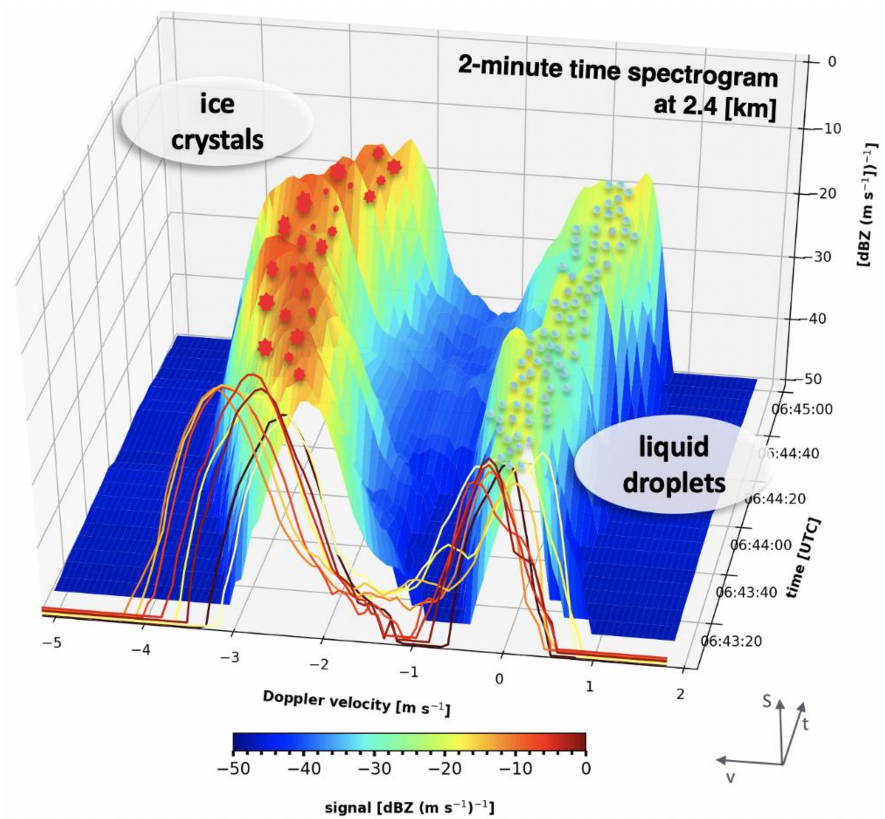
SIP detection



- Use Dual-polarized radar Doppler spectra for different range gates
- Identify hydrometeors in each range gate by thresholds of downward velocity, radar reflectivity and LDR
- Investigate neighborhood rangegates of rangegate with secondary ice
- Draw connection to process leading to SIP

Luke, E. P., F. Yang, P. Kollias, A. M. Vogelmann, and M. Maahn, 2021: New insights into ice multiplication using remote-sensing observations of slightly supercooled mixed-phase clouds in the Arctic. *PNAS*, **118**, https://doi.org/10.1073/pnas.2021387118.

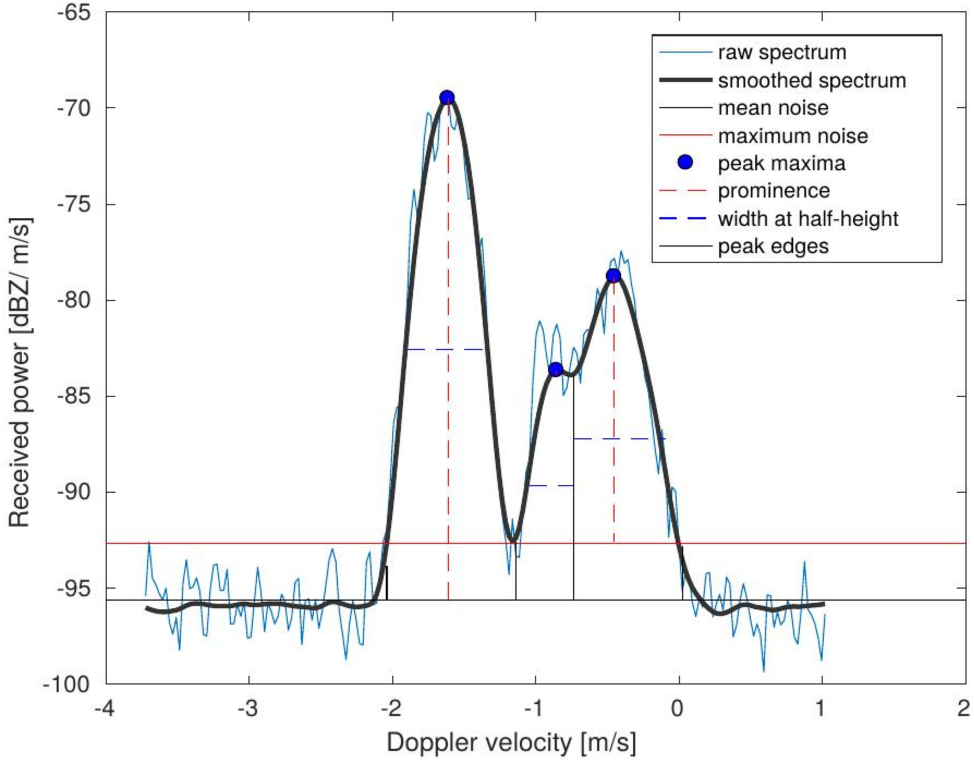
VOODOO



- neural network-based retrieval (beyond lidar attenuation)
- mapping radar Doppler spectra to the probability for the presence of cloud droplets (Cloudnet as supervisor)
- VOODOO yields the probability for cloud droplets directly at Cloudnet grid resolution
- Detect supercooled liquid droplets from existing data at RMBL site

Schimmel, W., H. Kalesse-Los, M. Maahn, T. Vogl, and A. Foth, Predicting cloud droplets beyond lidar attenuation from vertically-pointing cloud radar observations using artificial neural networks. in preparation

PEAKO…is currently being merged with peakTree (M. Radenz et al., 2019) by Teresa Vogl



Dealing with complex multi-peak Doppler spectra

Kalesse, H., T. Vogl, C. Paduraru, and E. Luke, 2019: Development and validation of a supervised machine learning radar Doppler spectra peak finding algorithm. *Atmospheric Measurement Techniques*, 1–37, https://doi.org/10.5194/amt-2019-48.

Myagkov polarimetric signature study

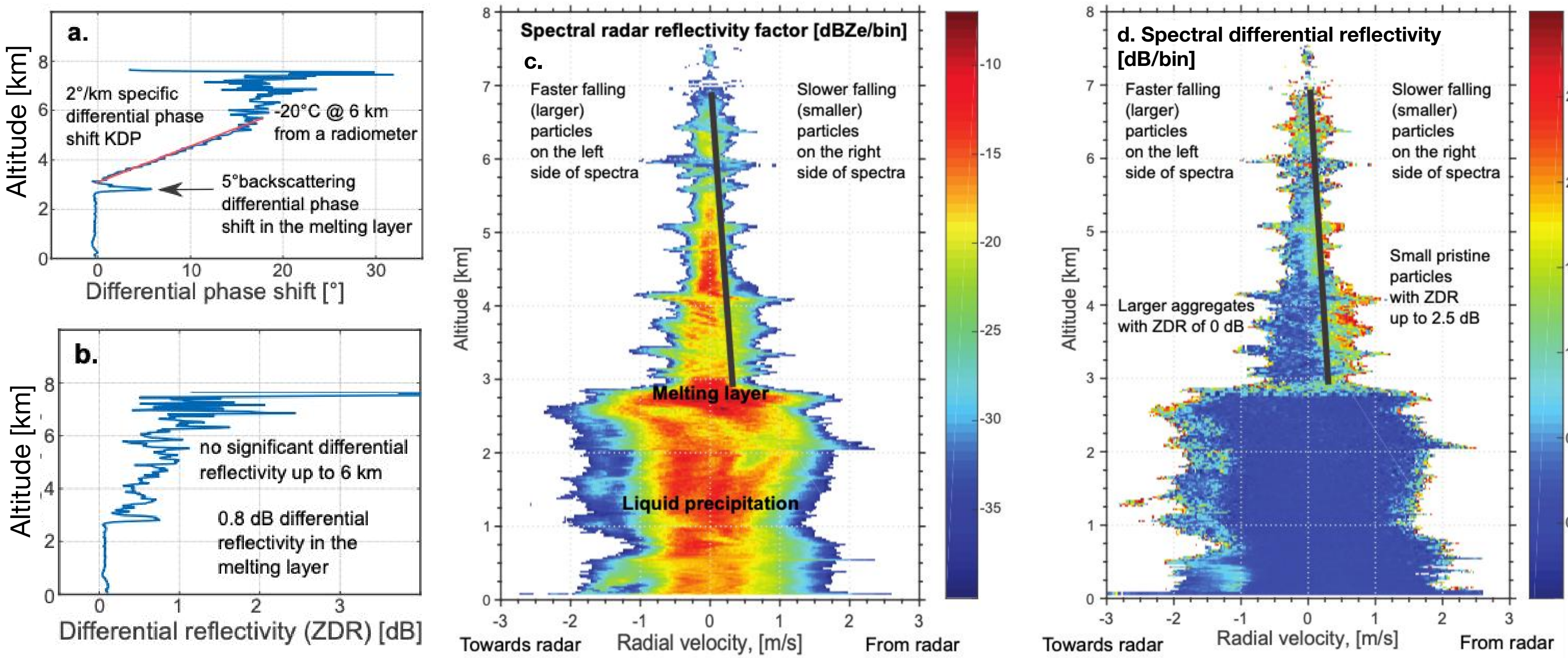
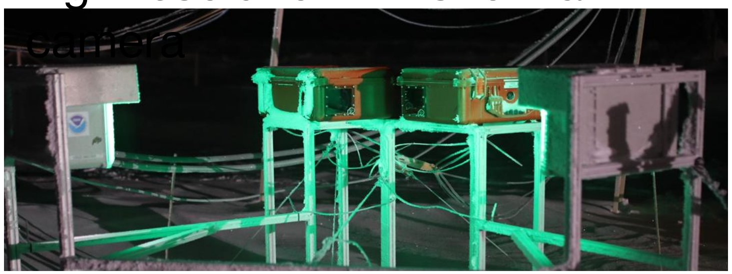
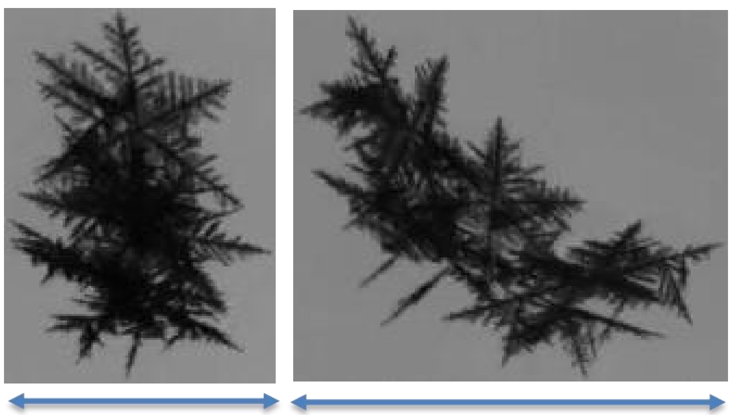


Figure 2: *Slanted profiles of differential phase shift (a), differential reflectivity ZDR (b), spectral reflectivity factor (c), and spectral differential reflectivity (d) taken by a 94 GHz (W-band) radar similar to the LIMRAD94 at 10 UTC on 12 June 2018 at Meckenheim, Germany. The profiles were measured at 30 ◦ elevation. For the spectral plots (c, d), mean Doppler velocity has been removed individually for each altitude bin in order to mitigate the influence of horizontal air motions. The figure is adopted from a poster presentation by Myagkov and Rose (2018) given at ERAD2018. The melting layer is at 3 km altitude. Particles on the right side of the spectra are smaller (moving slowertowardstheradar)thanthoseontheleftside.Basedonscatteringcalculations(notshown),KDP values of 2◦ km −1 (a) indicate the presence of small ice particles with relatively high ice density. Large aggregated or rimedparticleswouldcausenearly-zeroKDP values.Eventhoughsmalliceparticleshavehigh(upto2–3dB) values of ZDR, their backscattering polarimetric signatures are masked by larger particles with ZDR of 0.5–1 dB (b). The small ice particles are also not clearly visible in the Doppler spectrum (c) but the spectral differential reflectivity (d) indicates clearly the presence of small particles.*

Video In Situ Snowfall Sensor (VISSS)

high resolution 2D snowfall camera





7.5 mm

12 mm

Approach

- Two synchronized cameras observe snow particles in front of green backlight
- No sizing error due to telecentric optics
- Measurement volume approx. 8 x 8 x 6 cm
- Optical resolution 41.57 μm
- Temporal resolution 200 Hz

Maahn, M., M. Radenz, C. Cox, M. Gallagher, J. Hutchings, M. Shupe, and T. Uttal, 2021: Measuring snowfall properties with the Video In Situ Snowfall Sensor during MOSAiC. *EGU21 abstracts*, https://doi.org/10.5194/egusphere-egu21-3306.

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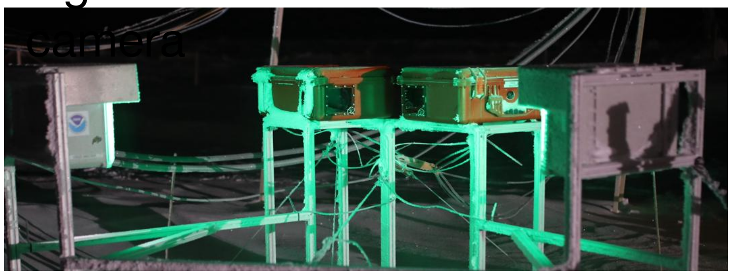

Approach

Dual camera configuration helps with:

- getting the 3d track of the particle through the sampling volume
- estimating the 'true' maximum dimension and estimating the fall velocity

Maahn, M., M. Radenz, C. Cox, M. Gallagher, J. Hutchings, M. Shupe, and T. Uttal, 2021: Measuring snowfall properties with the Video In Situ Snowfall Sensor during MOSAiC. *EGU21 abstracts*, https://doi.org/10.5194/egusphere-egu21-3306.

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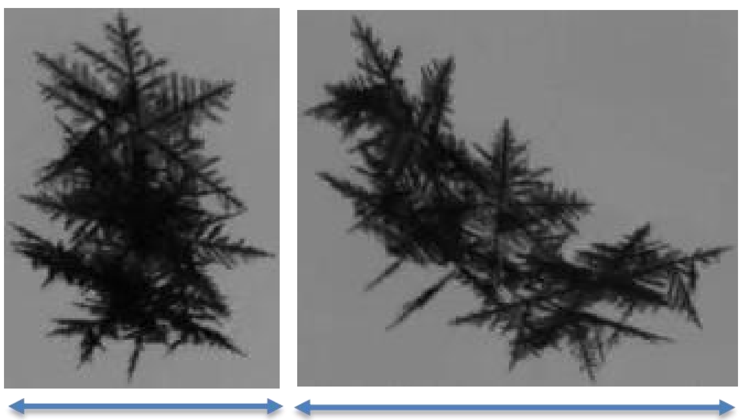
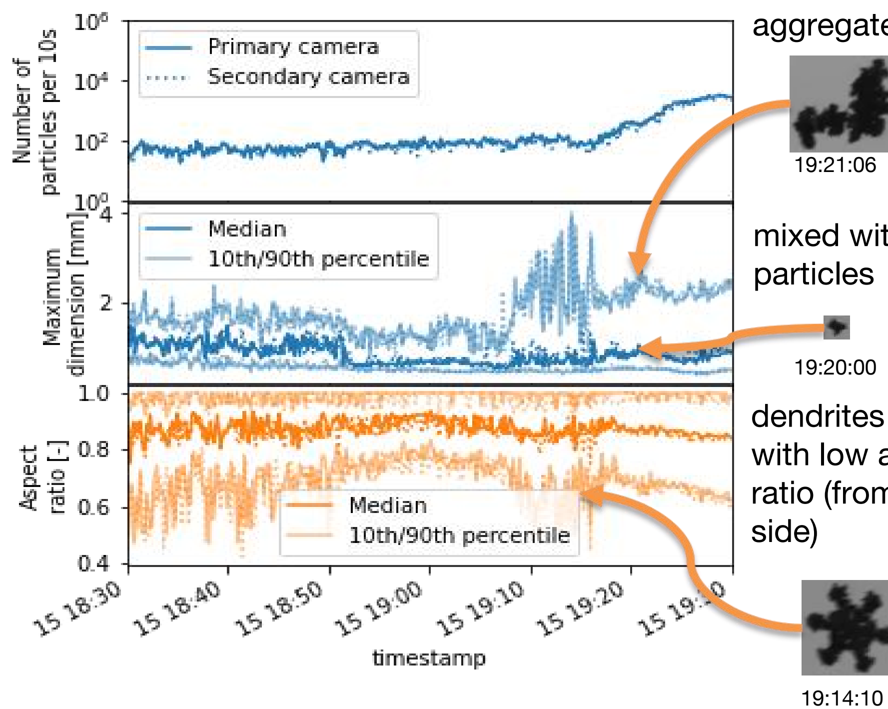
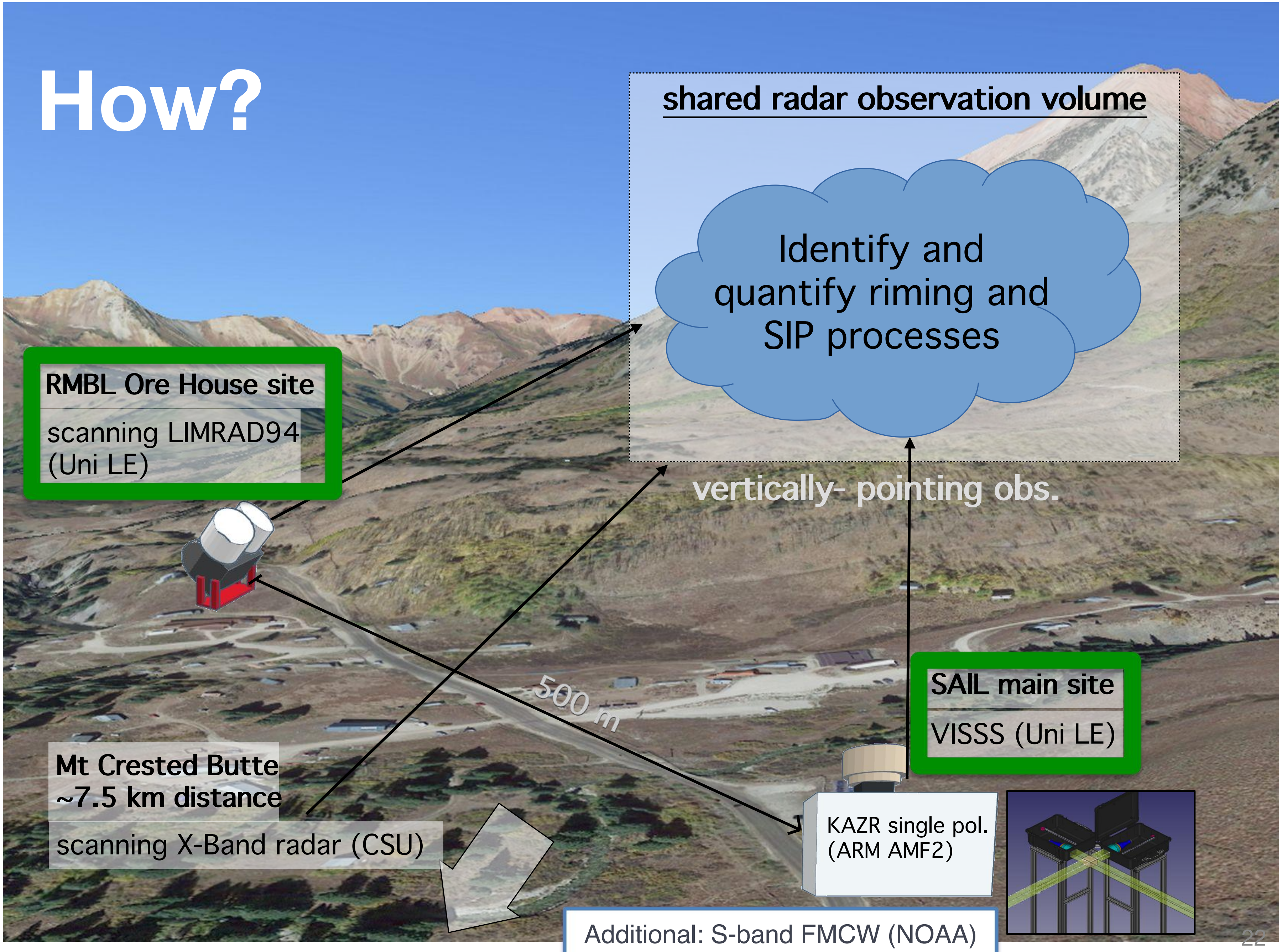


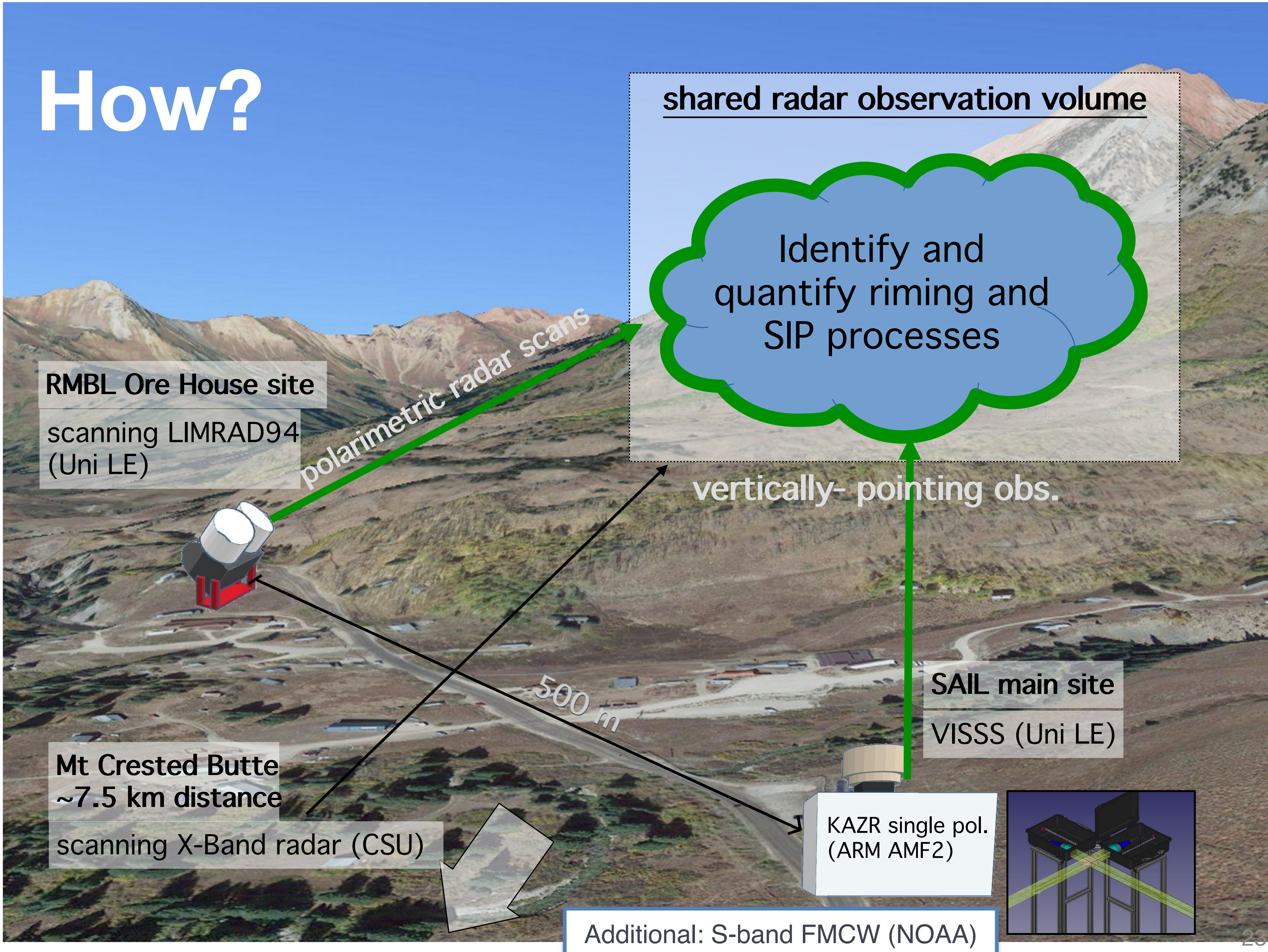
7.5 mm 12 mm



Maahn, M., M. Radenz, C. Cox, M. Gallagher, J. Hutchings, M. Shupe, and T. Uttal, 2021: Measuring snowfall properties with the Video In Situ Snowfall Sensor during MOSAiC. *EGU21 abstracts*, https://doi.org/10.5194/egusphere-egu21-3306.


How?
shared radar observation volume
Identify and quantify riming and SIP processes
vertically- pointing obs.
RMBL Ore House site
scanning LIMRAD94 (Uni LE)
500 m
SAIL main site
VISSS (Uni LE)
Mt Crested Butte ~7.5 km distance
scanning X-Band radar (CSU)
KAZR single pol. (ARM AMF2)
Additional: S-band FMCW (NOAA)

How?


shared radar observation volume
Identify and quantify riming and SIP processes
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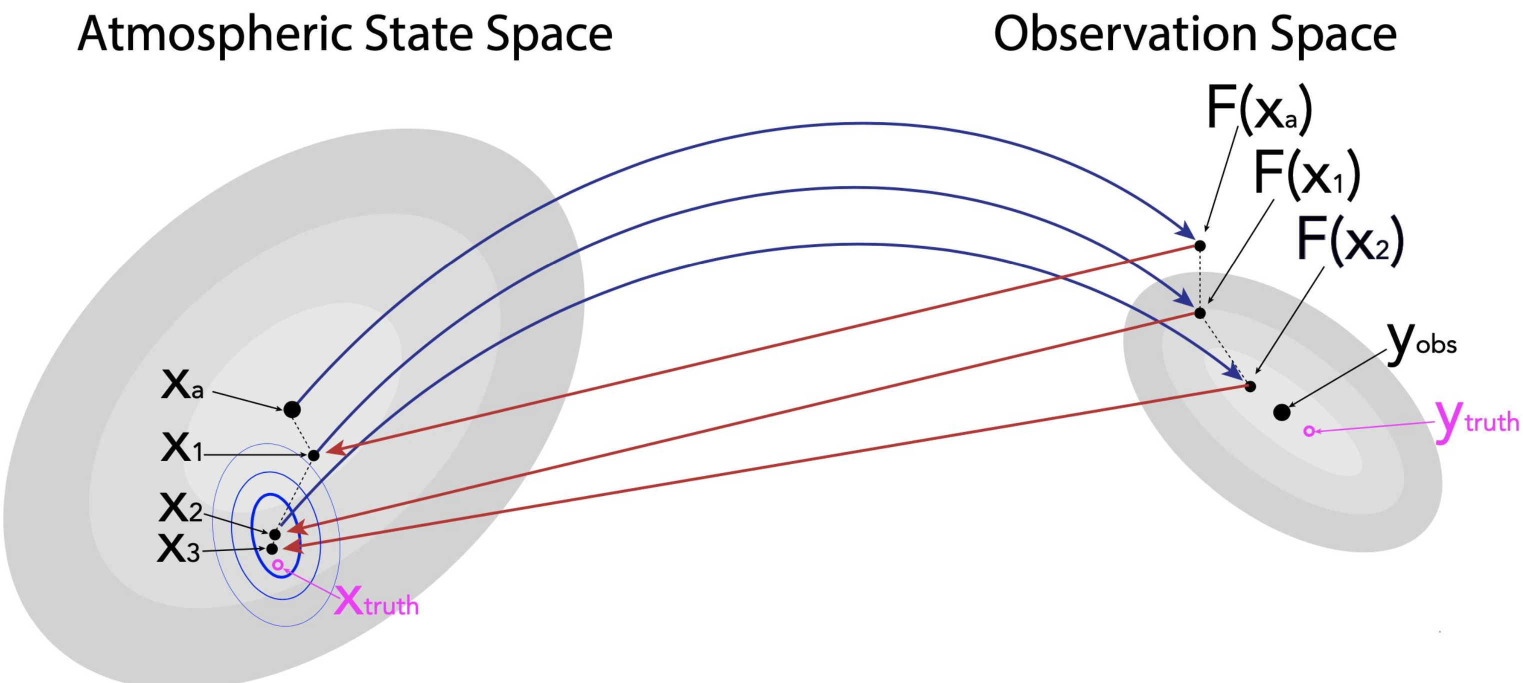
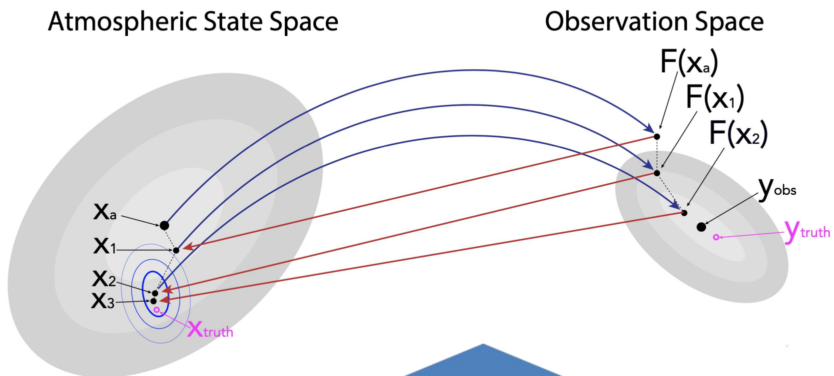
KAZR single pol. (ARM AMF2)
Additional: S-band FMCW (NOAA)

Optimal Estimation - achieving closure between modeling and observations



Maahn, M., D. D. Turner, U. Löhnert, D. J. Posselt, K. Ebell, G. G. Mace, and J. M. Comstock, 2020: Optimal Estimation Retrievals and Their Uncertainties: What Every Atmospheric Scientist Should Know. *Bull. Amer. Meteor. Soc.*, **101**, E1512–E1523, https://doi.org/10.1175/BAMS-D-19-0027.1.

Optimal Estimation - quantification of riming and SIP processes

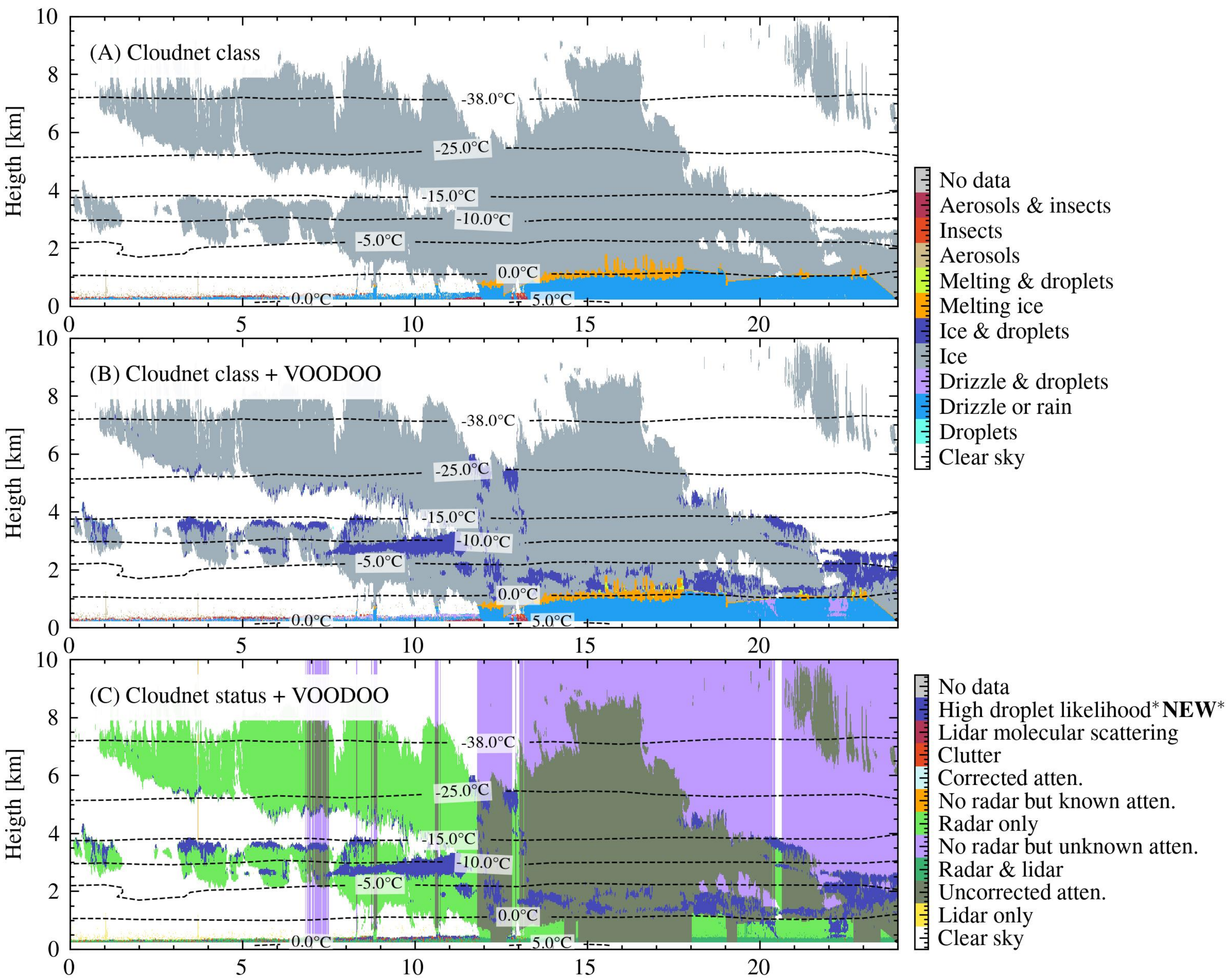


Closure studies:
Use PAMTRA to simulate scattering properties of diverse hydrometer population and optimize parameters to represent observed cloud s

Mehr zur Synthese erzählen?

Why? Research gap

- **Role of riming and SIP for snowfall formation unclear:** Understand the role of riming and secondary ice production at an orographically-influenced site with respect to frequency of occurrence and snowfall rates
- **Lack of understanding of external drivers**: Determine external drivers for riming and secondary ice production processes and snowfall rates
- **Modelling capabilities need improvement:** Advance the PAMTRA radar forward operator to improve the polarimetric modelling of ice particles.


(A) Cloudnet class
(B) Cloudnet class + VOODOO
(C) Cloudnet status + VOODOO
Heigth [km]
-38.0°C
-25.0°C
-15.0°C
-10.0°C
-5.0°C
0.0°C
5.0°C
No data
Aerosols & insects
Insects
Aerosols
Melting & droplets
Melting ice
Ice & droplets
Ice
Drizzle & droplets
Drizzle or rain
Droplets
Clear sky
No data
High droplet likelihood* **NEW***
Lidar molecular scattering
Clutter
Corrected atten.
No radar but known atten.
Radar only
No radar but unknown atten.
Radar & lidar
Uncorrected atten.
Lidar only
Clear sky