The PolarCAP project

Combined remote sensing and modelling of cloud microphysical perturbations in super-cooled stratus clouds

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Leibniz Association

LACROS Leipzig Aerosol and Cloud Remote Observations System

ACTRiS

ETH zürich

TROPOS Leibniz Institute for Tropospheric Research

Introduction to Post-Doc 1

(Remote-Sensing Part)

Name: Kevin Ohneiser

New in the PolarCAP project.
PostDoc starts in **January 2023**

Currently: PhD student at TROPOS (3rd year)

Current topic: Lidar measurements of wildfire smoke in the stratosphere on both hemispheres

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PolarCAP:

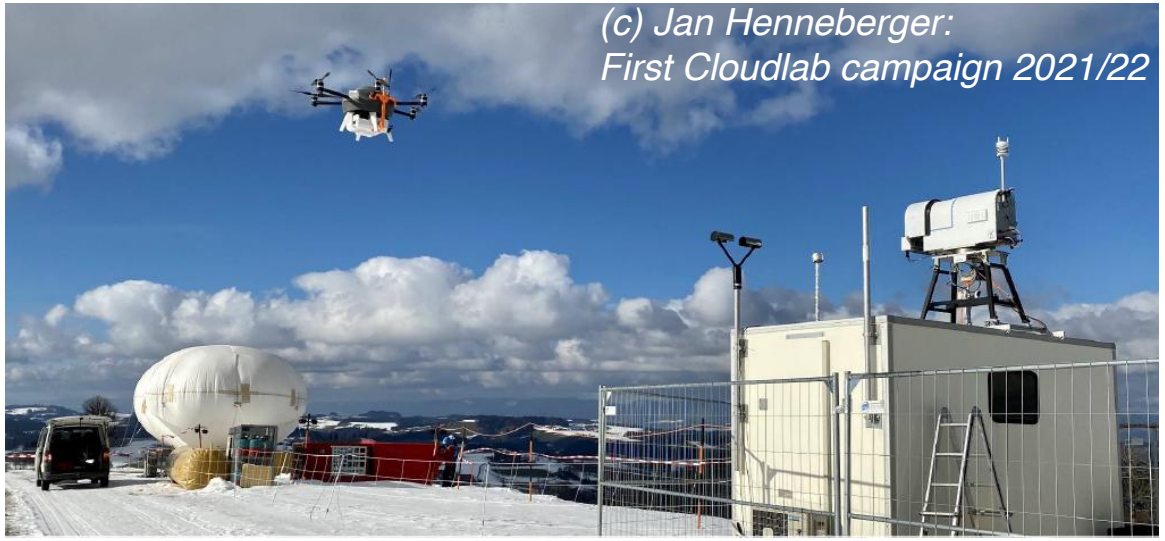
→ Polarimetric Radar Signatures of Ice Formation Pathways from Controlled Aerosol Perturbations

DFG SPP 2115 PROM

- Jointly with ERC project **CloudLAB** of ETH Zürich (U. Lohmann)

→ Utilization of UAV-borne cloud seeding experiments and Holo-Balloon observations of ETH Zürich

- 2023-2025; 3 LACROS winter campaigns near Eriswil, CH
- **Goals:** microphysical closure; spectral-bin model development; forward operators
- 2 PostDocs (1 Obs, 1 Model)



-10...0 °C

supercooled stratus

Seeding drone (ETH)

In-situ drone (ETH)

Holo-Balloon (ETH)

(Willi)

COSMO-SPECS

Seeded INP

Ice crystal

Cloud droplet

LACROS + ETH remote sensing (Kevin)

PROM all-hands

The CloudLAB Team

Close Collaboration with CloudLAB team

https://cloudlab.ethz.ch/

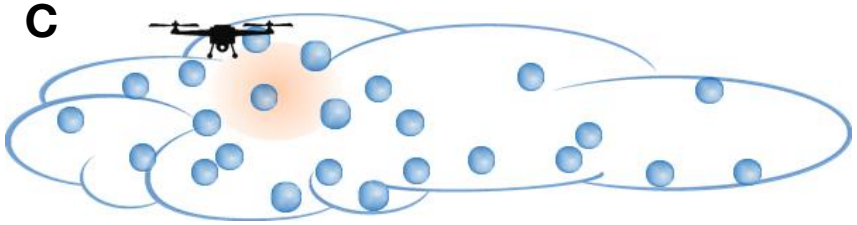
PolarCAP & CloudLAB: Target clouds

Prevailing wintertime low stratus in Swiss Plateau
(mainly supercooled droplets) is chosen for microphysical investigations and considered as **natural lab.**

from Jan Henneberger, ETHZ, origin:Nov 14, 2018: worldview.earthdata.nasa.gov

PolarCAP: Specific targeted scenarios

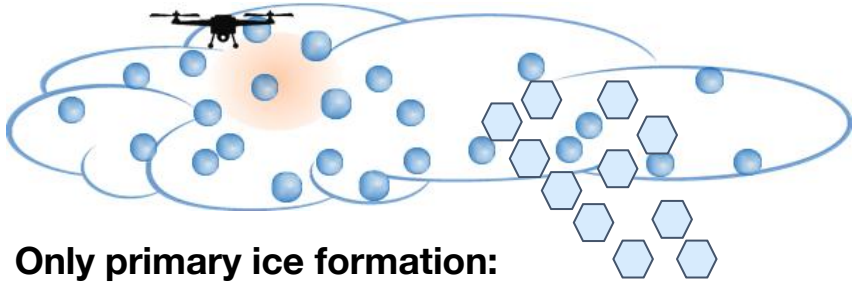
T>0°C



Only liquid clouds:

- Study drizzle formation
- Evaluate retrieval techniques

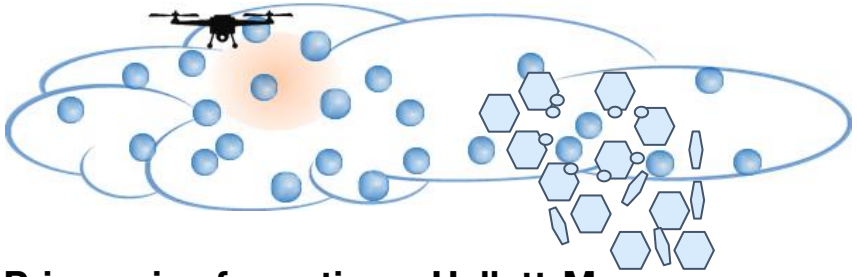
-5<T<0°C



Only primary ice formation:

- direct relationship between INPC and ICNC
- Focus model simulation on primary ice formation

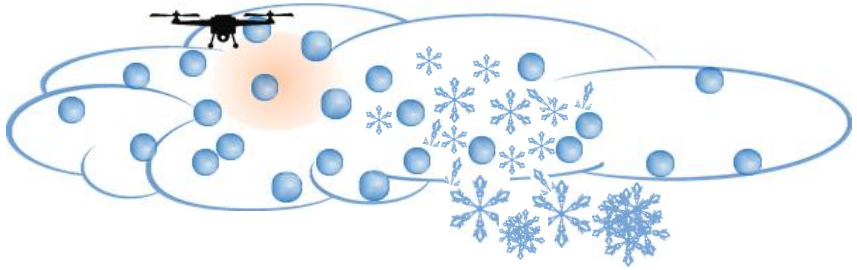
-10<T<-5°C



Primary ice formation + Hallett-Mossop process (HMP)

- Study rime splintering
- Model simulations require riming, aggregation, HMP

-15<T<-10°C



Primary ice formation + breakup + Aggregation

- Study aggregation processes and collision breakup
- Model simulations with full set of het. freezing mech.

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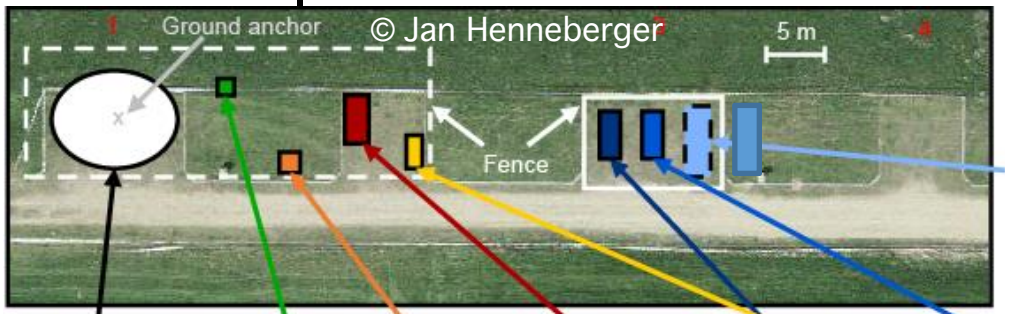
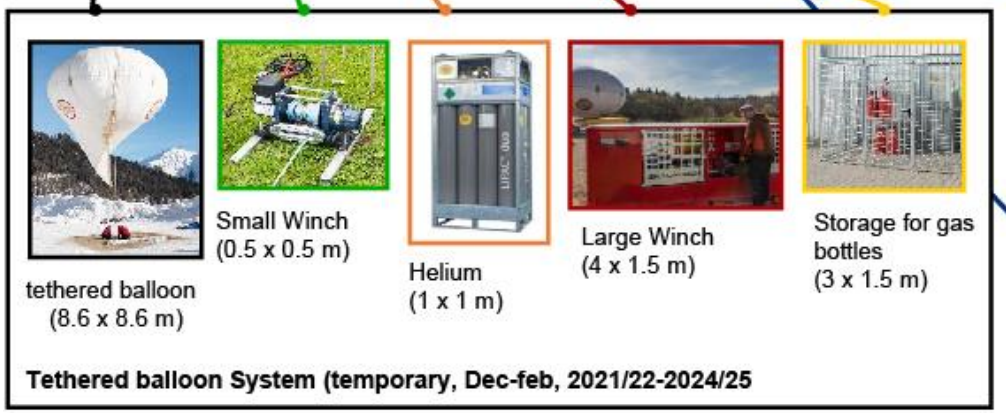
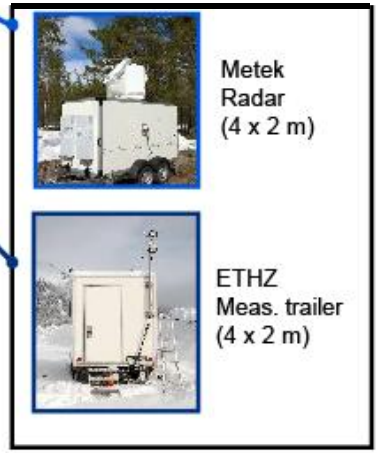
Field site at Eriswil, CH

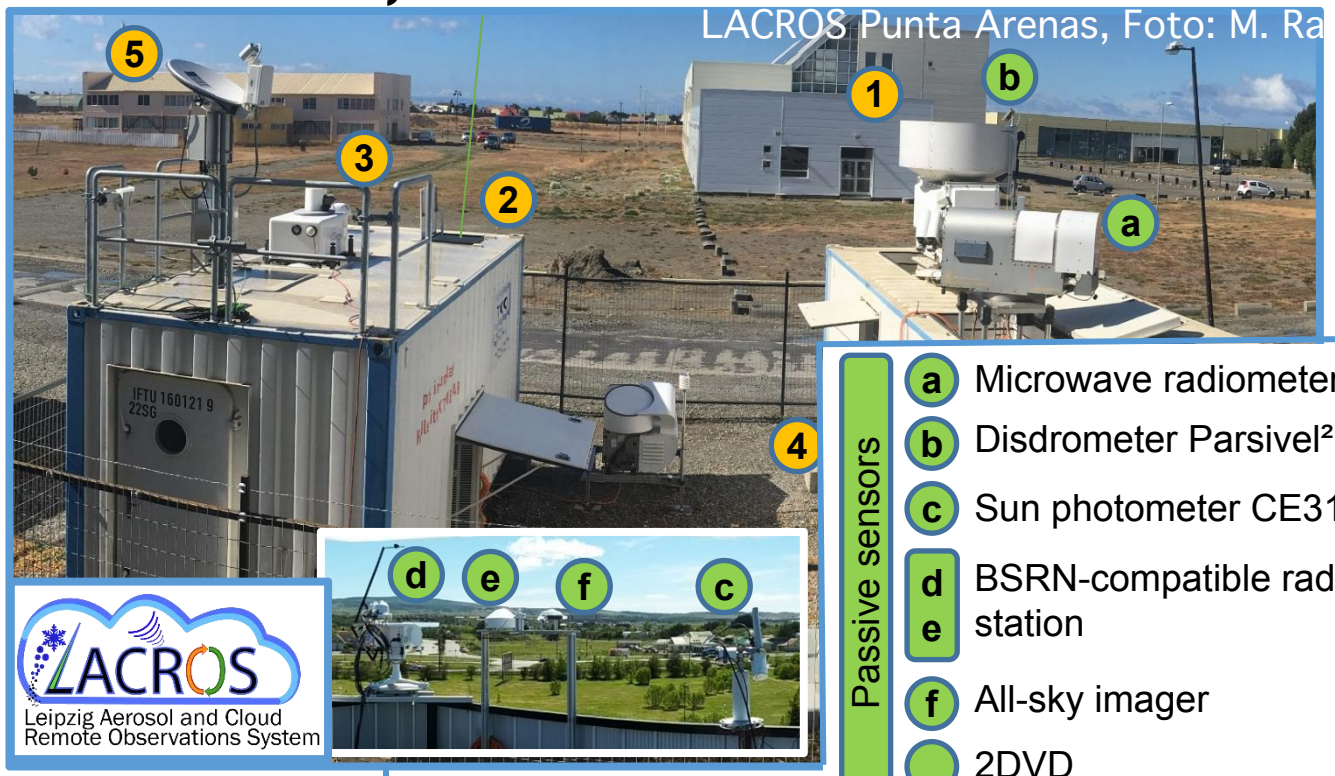
Rapier site at Eriswil, CH
(47.07°N, 7.875°E, 921 m asl)







PROM all-hands meeting



LACROS
Leipzig Aerosol and Cloud Remote Observations System

Passive sensors

- a Microwave radiometer HATPRO
- b Disdrometer Parsivel²
- c Sun photometer CE318
- d e BSRN-compatible radiation station
- f All-sky imager
- ○ 2DVD

Active sensors

- 1 35-GHz STSR cloud radar Mira-35
- 2 Raman polarization lidar Polly^{XT}
- 3 Doppler lidar Streamline^{XR}
- 4 Ceilometer CHM15kx
- 5 24-GHz micro rain radar
- ○ 94-GHz cloud radar RPG-94-FMCW

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Introduction to Post-Doc 2
(Modeling Part)

Name: Willi Schimmel, PhD student

New in the PolarCAP project. Post-Doc starts in January 2023

Currently: PhD student at Leipzig Institute for Meteorology (4th year),

Current topic: Radar-Lidar Synergy + Machine Learning to improve hydrometeor thermodynamic phase retrievals

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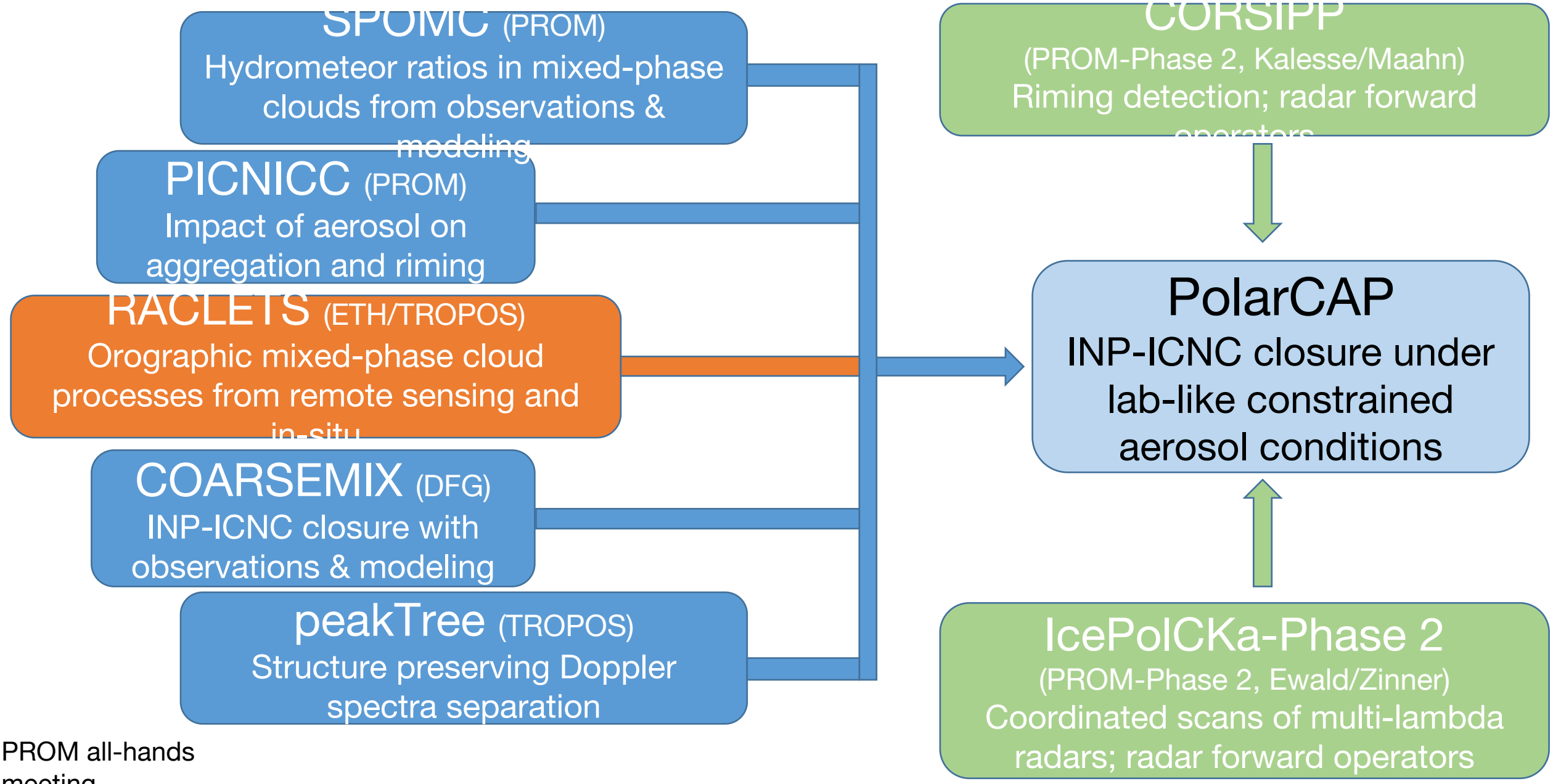
SPOMC (PROM)
Hydrometeor ratios in mixed-phase clouds from observations & modeling
PICNICC (PROM)
Impact of aerosol on aggregation and riming
RACLETS (ETH/TROPOS)
Orographic mixed-phase cloud processes from remote sensing and in-situ
COARSEMIX (DFG)
INP-ICNC closure with observations & modeling
peakTree (TROPOS)
Structure preserving Doppler spectra separation
CORSIPP
(PROM-Phase 2, Kalesse/Maahn)
Riming detection; radar forward operators
PolarCAP
INP-ICNC closure under lab-like constrained aerosol conditions
IcePolCKa-Phase 2
(PROM-Phase 2, Ewald/Zinner)
Coordinated scans of multi-lambda radars; radar forward operators

PolarCAP - Research questions

- Role of contact and immersion freezing in stratocumulus seeding experiment
- Role of secondary ice formation and ice multiplication
  - Depending on temperature-range of observed stratus layers
- Evaluation of microphysical retrievals
  - Unique chance of co-located holographic in-situ imagery aboard tethered balloon
- Challenge the process understanding in models:
  - Constraining the efficiency of ice-nucleating substances
  - Linking microphysical time scales to stratus decay times
- Advance coupling of cloud model simulations and radar forward operators

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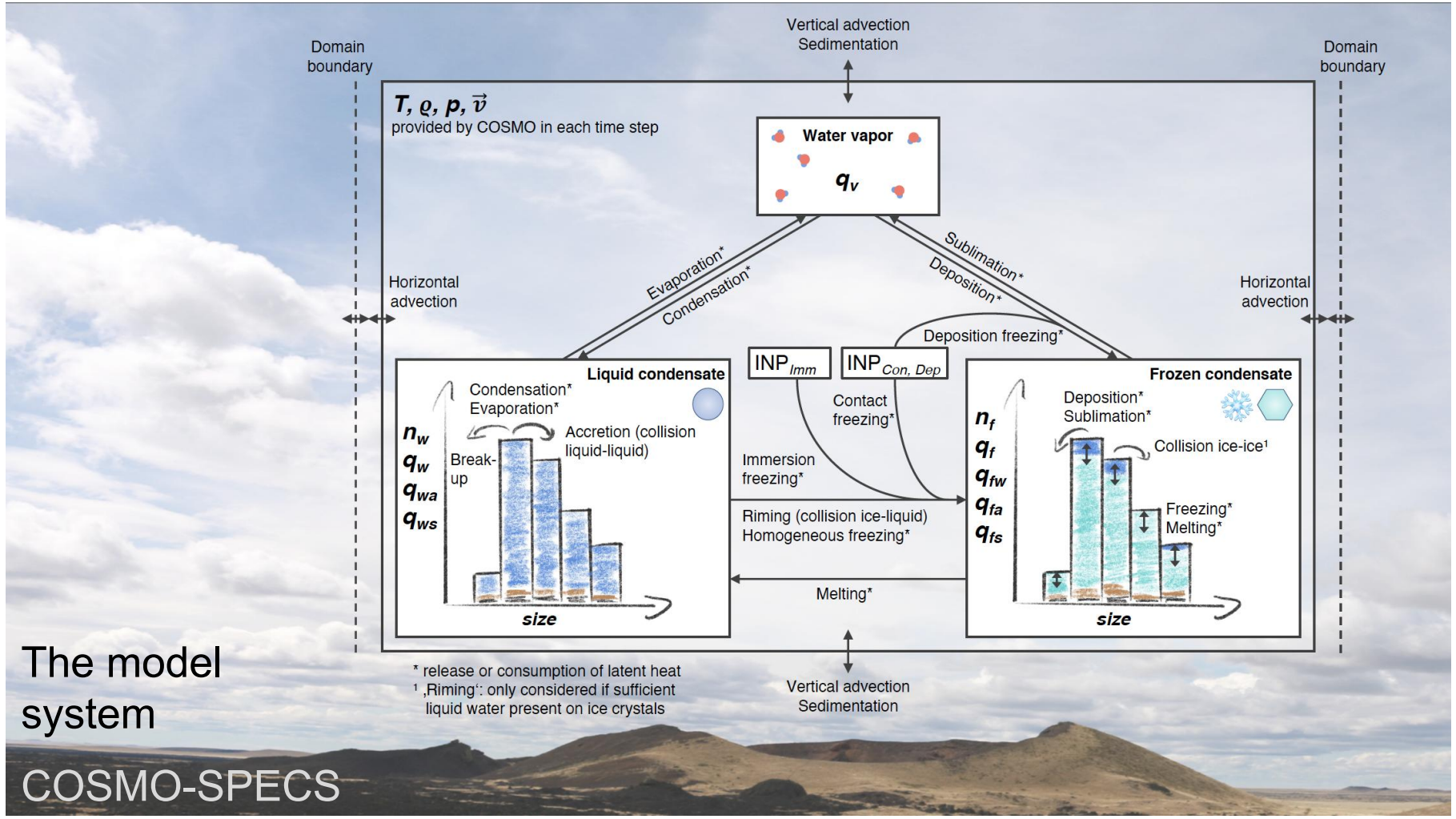
SPECS – SPEctral Cloud microphysicS model [Simmel et al. 2002]



Development Steps

- Task 2.1 prepares nested COSMO-SPECS setup for modelling supercooled stratus
- Task 2.2 derives observables using a polarimetric cloud Doppler radar forward operator (PAMTRA)
- Task 2.3 implements an additional INP tracer

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Closure with radar forward simulator PAMTRA

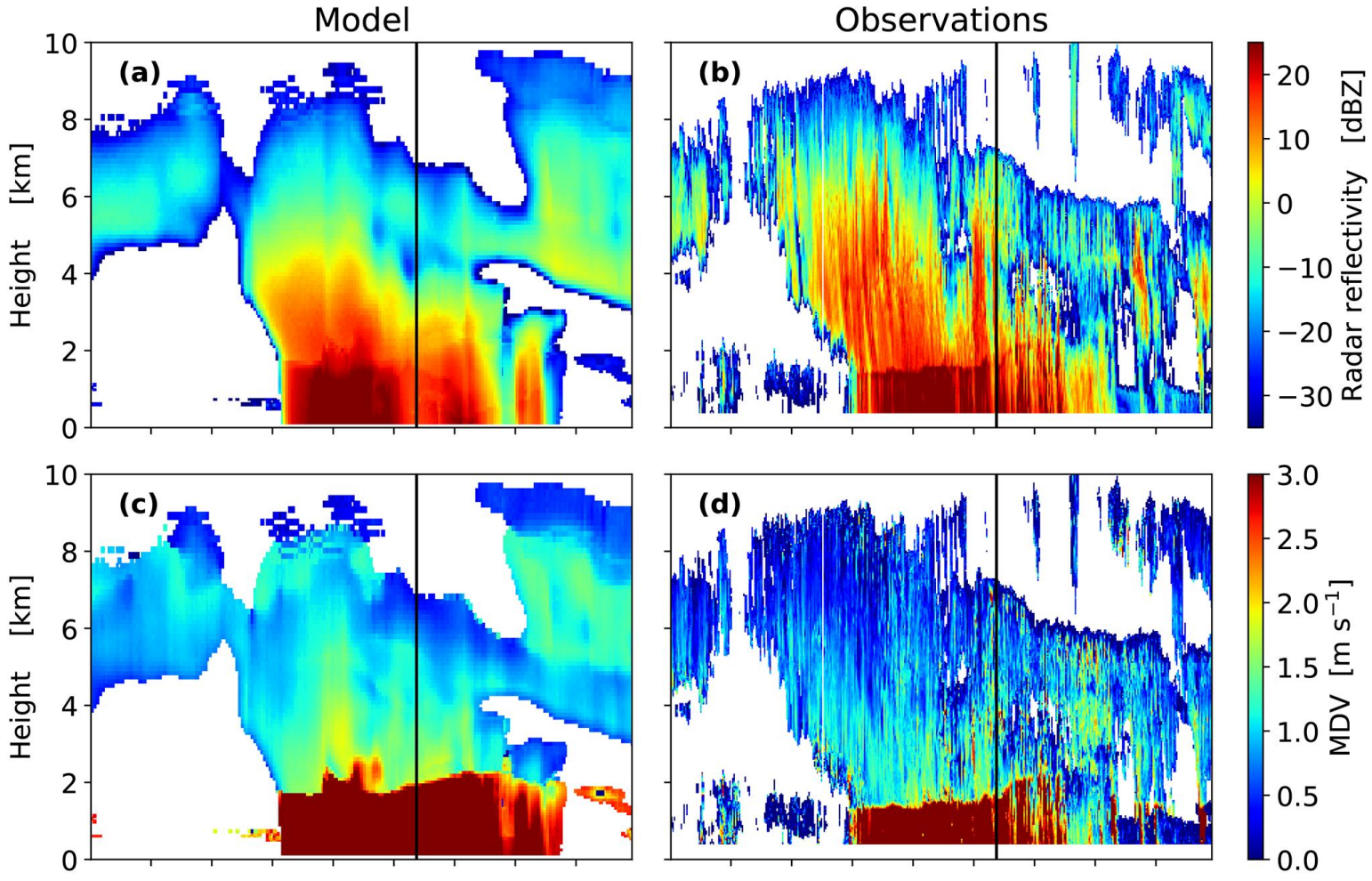
the **P**assive and **A**ctive **M**icrowave radiative **TRA**nsfer tool for simulating radiometer and radar measurements of the cloudy atmosphere

Input:

- the atmospheric state
- the assumption on absorption, scattering, and surface emissivity,
- instrument specifications

Output:

- polarized radiances or brightness temperature for the passive part
- **radar Doppler spectra** and derived **moments**



Mech et al. 2020 GMD

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How? Work program of PolarCAP

observations Kevin

modelling Willi

WP	Task	Year 1				Year 2				Year 3			
		2023				2024				2025			
1	**Remote Sensing**												
T1.1	Field campaigns												
T1.2	Establish and evaluate scan strategy during seeding												
T1.3	Characterization of cloud and aerosol conditions												
2	**Modelling of aerosol-induced perturbations**												
T2.1	Nested COSMO-SPECS setup for supercooled stratus												
T2.2	Revise coupling to cloud Doppler radar forward operator												
T2.3	Implementation of an additional INP tracer												
T2.4	Execution of numerical cloud seeding experiments												
3	**Synergy: PolarCAP←→ CLOUDLAB**												
T3.1	Statistical assessment of different cloud-top-temperature and turbulence regimes												
T3.2	Quantifying the role of contact and immersion freezing												
T3.3	Quantifying the role of secondary ice formation												

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Expected Outcome

- new insights into the interplay of contact and immersion freezing, secondary ice formation and ice multiplication at different temperature regimes under rather controlled conditions
  → **innovative observational dataset**

- advance cloud-resolving modelling and its coupling to radar forward operators

- achieve progress in the ability to constrain the efficiency of different ice nucleating substances and challenge our current cloud-microphysical process understanding and its representation in atmospheric models.

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