Investigation of aerosol effects on precipitation initiation processes in the alternately clean and aerosol-laden environment of New Zealand Aotearoa

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MetService TE RATONGA TIRORANGI

UC UNIVERSITY OF CANTERBURY Te Whare Wānanga o Waitaha CHRISTCHURCH NEW ZEALAND

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Clean Cloud

The Air Quality Collective

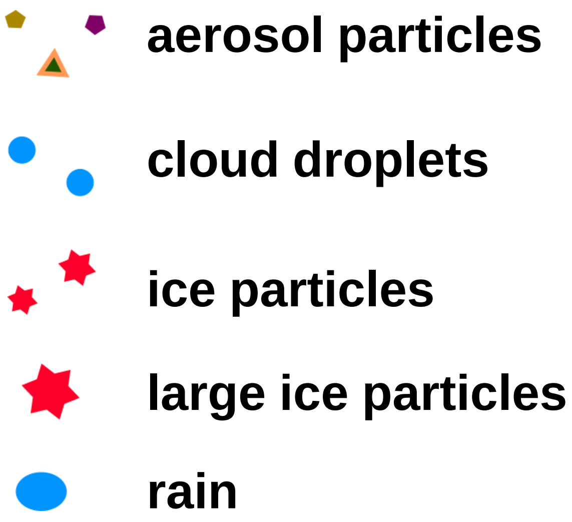
ACTRIS Exploring the Atmosphere

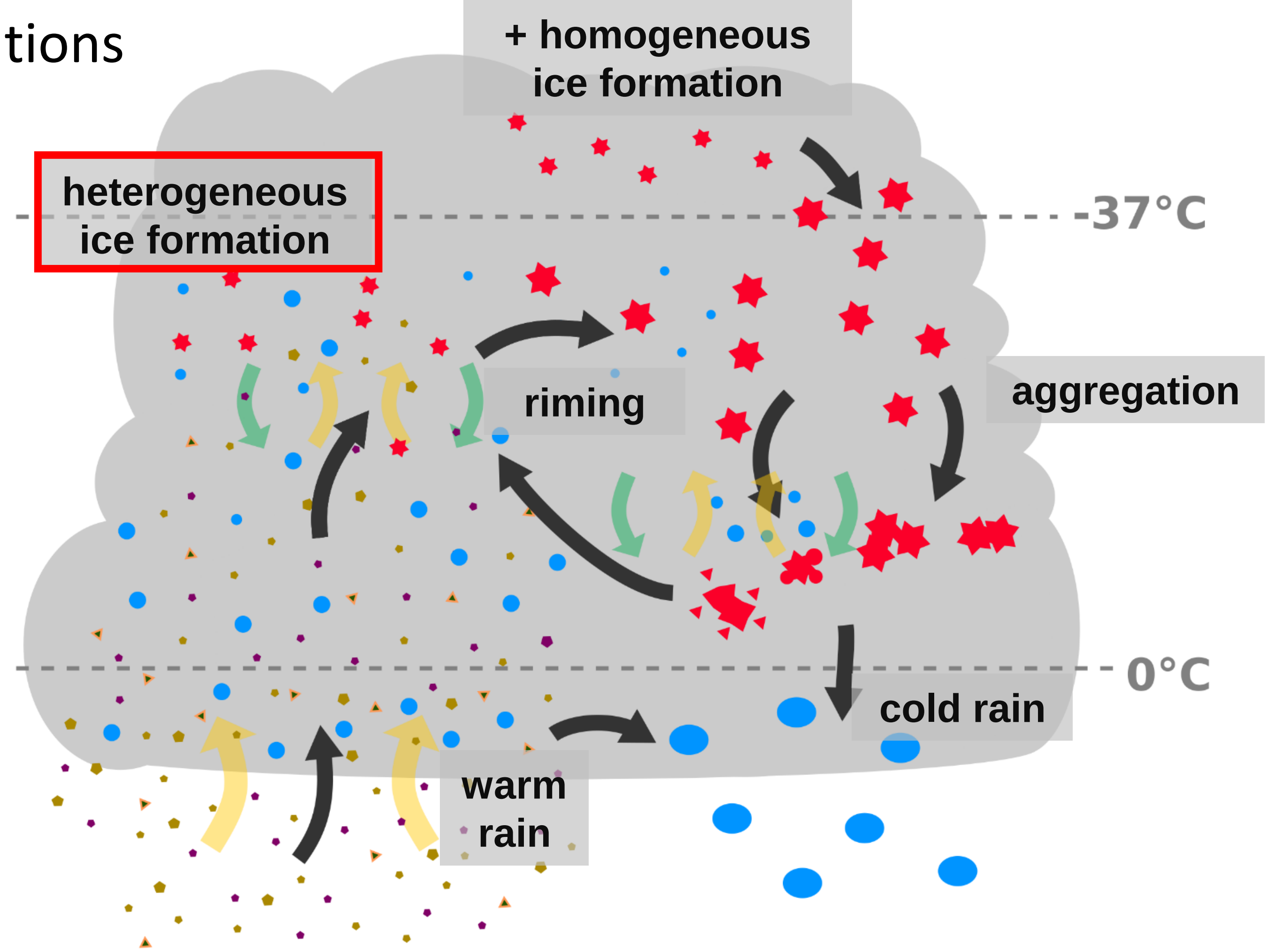
TROPOS Leibniz Institute for Tropospheric Research

Motivation 1 – the masked relevance of aerosol in cloud processes:

- Complex entanglement of aerosol, cloud dynamics and the formation of hydrometeors and precipitation
- Role of aerosol by far not clarified
- But also other (thermodynamic) contributions still not well constrained

What is the role of aerosol and turbulence in the evolution of cloud systems?





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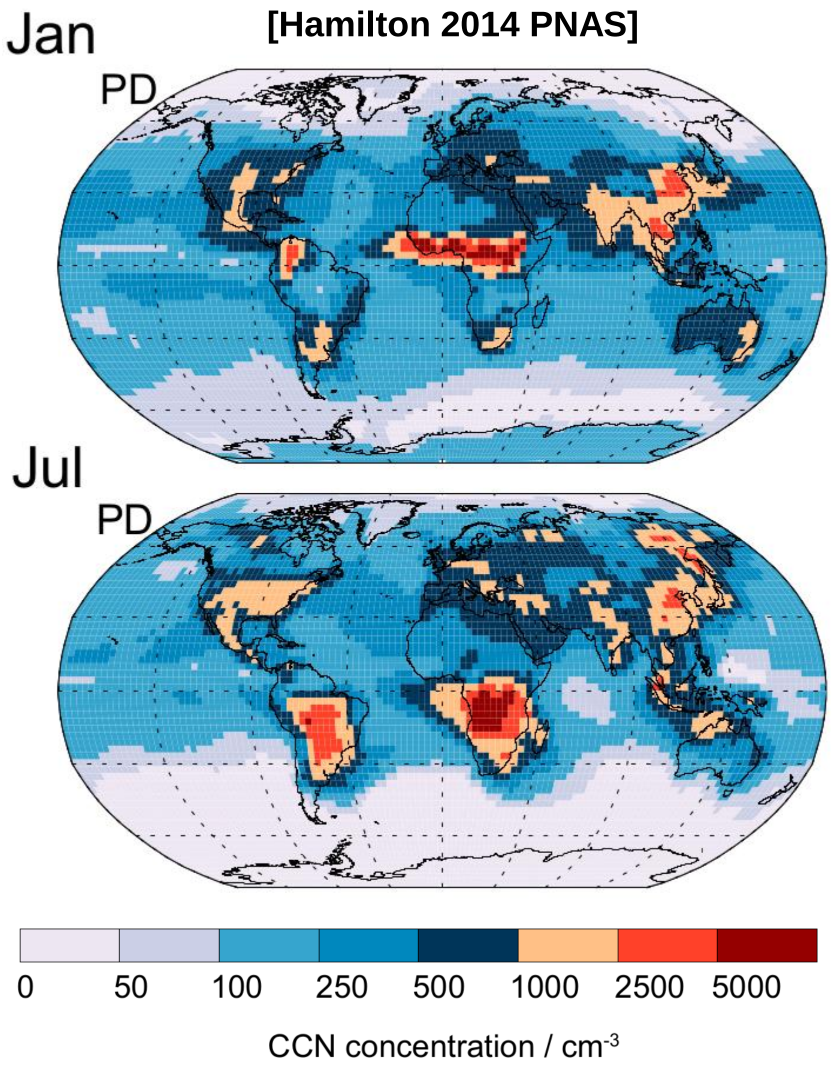
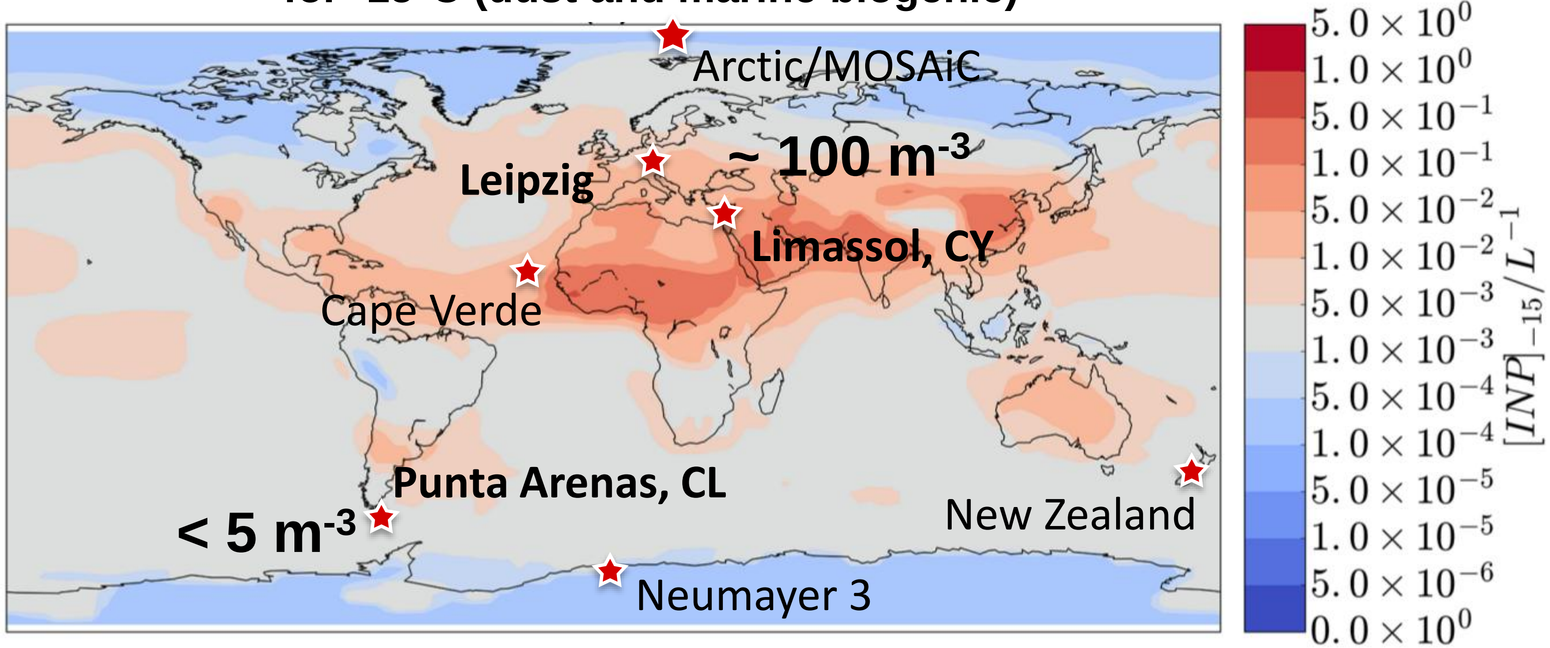
Gobal maps of (near-surface) cloud condensation nuclei (CCN) and ice nucleating particle (INP) concentrations



Locations with long-term ground-based remote sensing by TROPOS Remote Sensing Department (RSD)

Mean concentration of INP at ground

for -15°C (dust and marine biogenic)



[Vergara-Temprado 2017 ACP]

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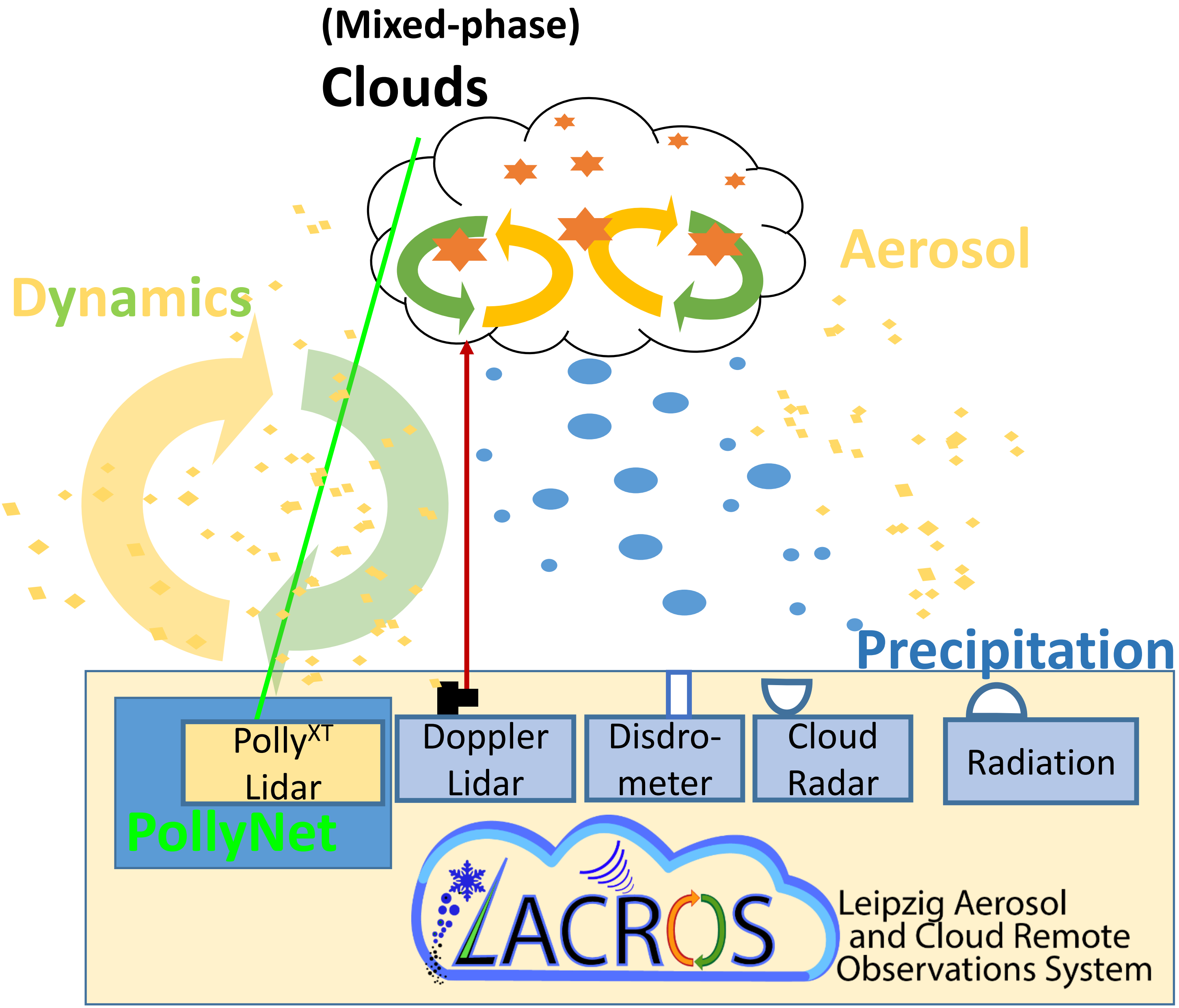
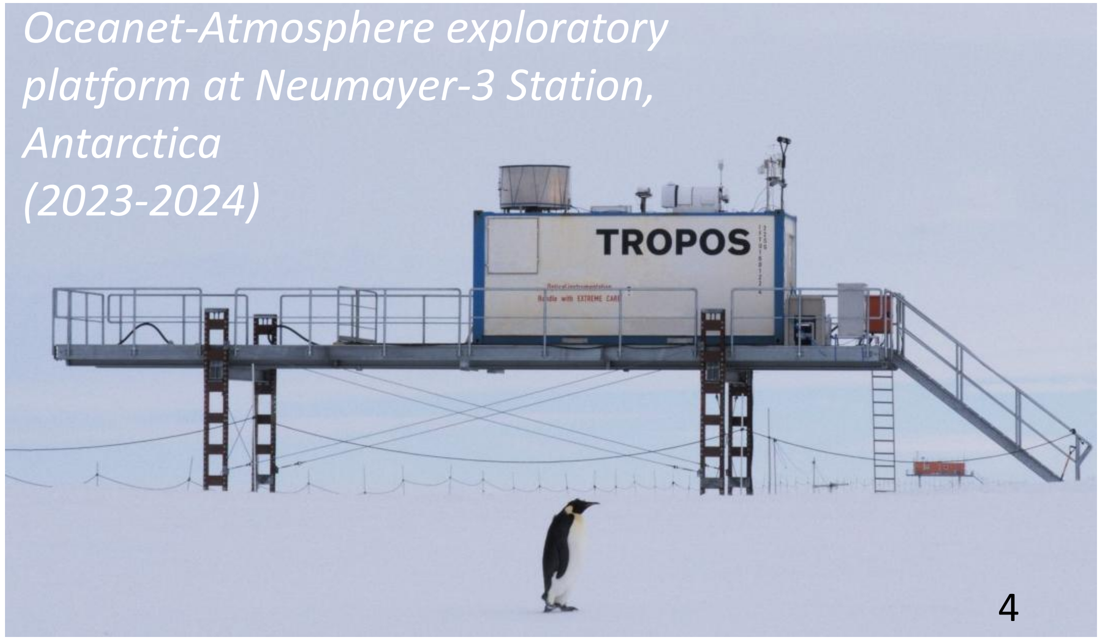
Profiling observations: Study aerosol-cloud-dynamics interaction with synergistic remote-sensing methods





Motivation 2 - Why New Zealand? → The Southern-Ocean cloud bias

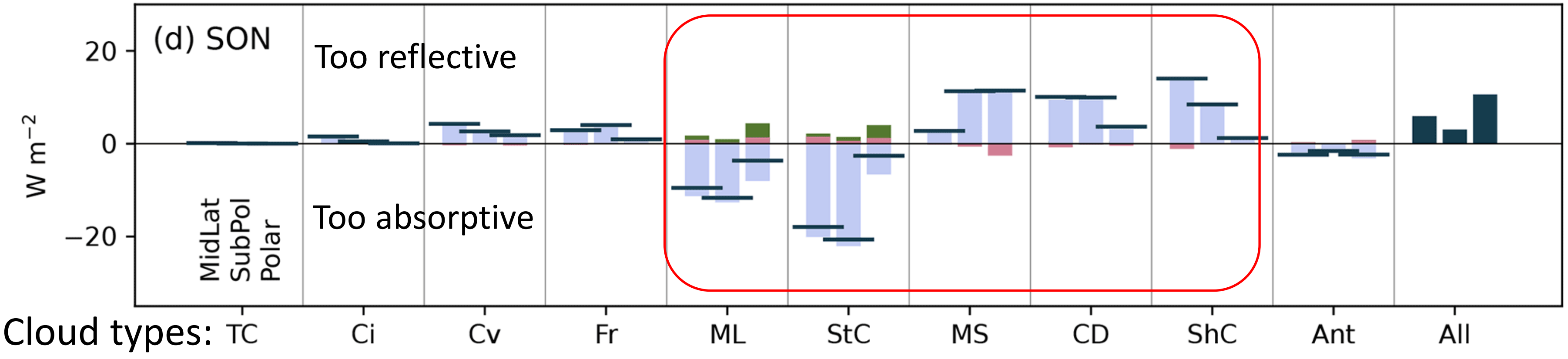
- Models don‘t manage to accurately simulate the solar radiation budget at the surface of the southern hemisphere mid- and high latitudes!

→ Wrong amount of sunlight is predicted to reach the surface!

- **Reasons**:
  - → Wrong representation of macrophysical and microphysical cloud properties
  - → Distributions of cloud fraction and thermodynamic phase simulated much worse compared to their northern-hemisphere counterparts

→ **What is the role of lack of aerosol???**

Shortwave cloud radiative feedback at top of atmosphere of the southern hemisphere



[Fiddes et al., 2022, ACP]

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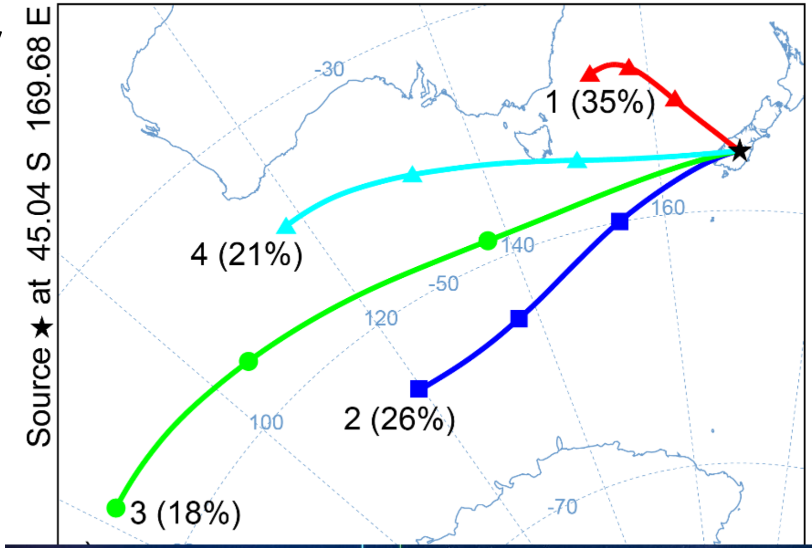
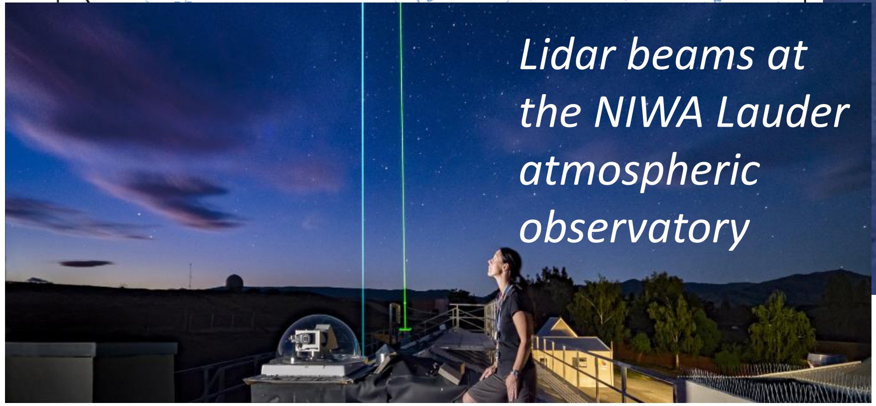
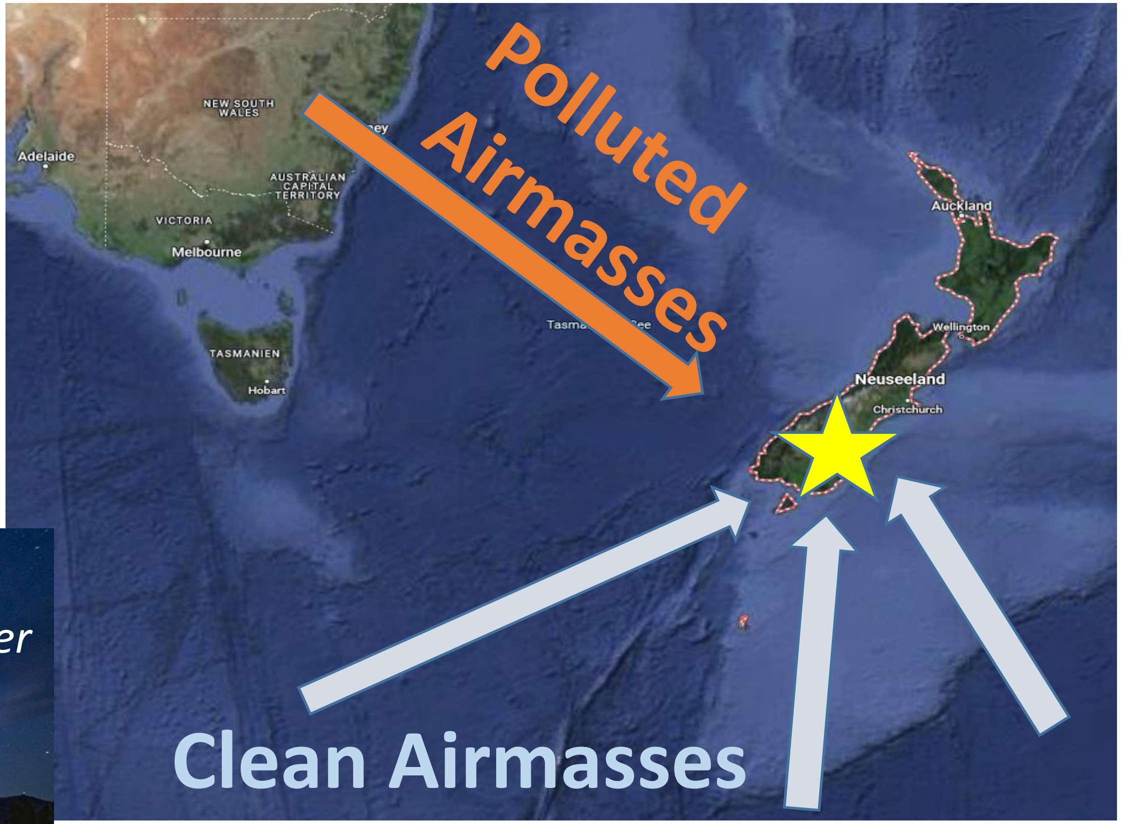
Motivation 3 – New Zealand is great to study contrasting aerosol environments!

- Alternating periods of clean air and polluted air above New Zealand
- Clouds and aerosol conditions for both scenarios can be observed at one location.
- First feasability study (TROPOS + NIWA Lauder):
  - **Hofer et al., 2024, ACP, https://doi.org/10.5194/acp-24-1265-2024**

- ○ One back-trajectory for each observed cloud layer
- ○ ~35% air from Australia → „polluted"
- ○ ~40% air from Southern Ocean → „clean"







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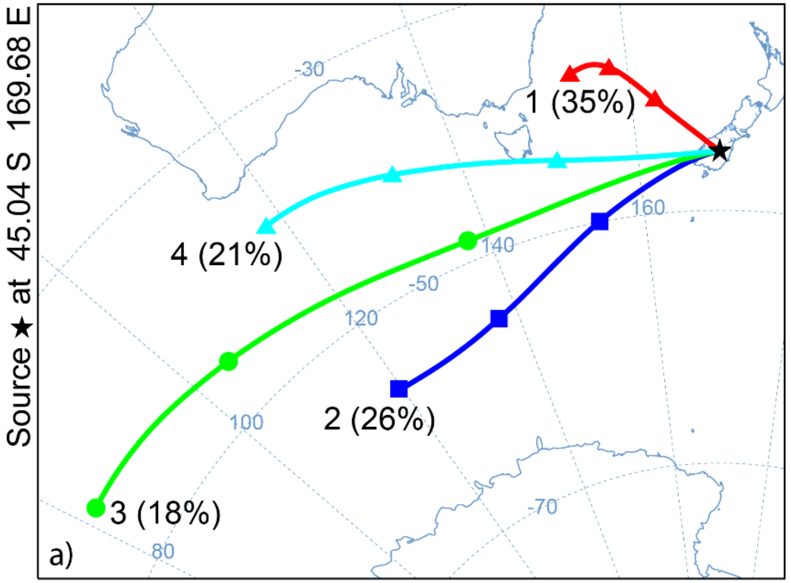
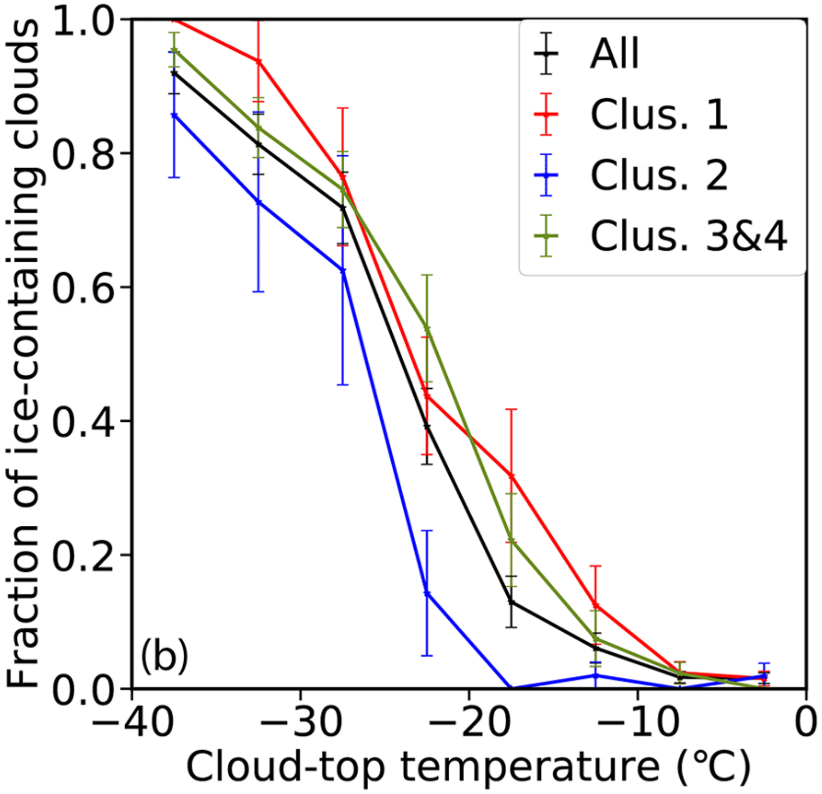




Low aerosol load

Reduced efficiency of ice formation

Increased reflectivity of clouds for solar radiation

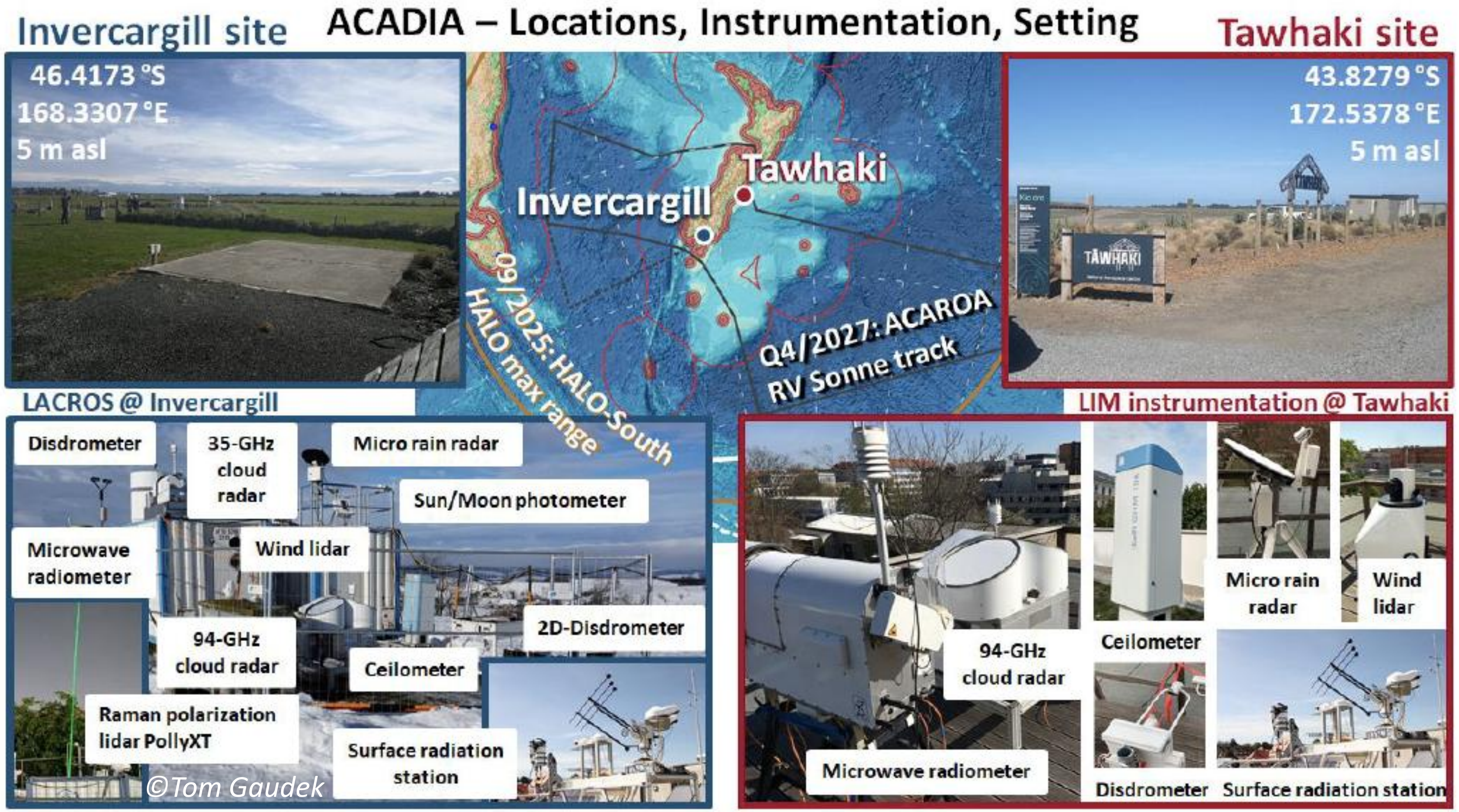
Investigating Aerosol-Cloud-rADiation-interactioN over Aotearoa (ACADIA) as part of the goSouth-2 umbrella project

Hypothesis:

The alternation of aerosol-limited and aerosol-burden air mass regimes over New Zealand lead to observable contrasts in the (microphysical and radiative) properties of clouds and precipitation.

6 scientific goals

GOAL 1: long-term ground-based observations



- 1yr obs (Sep 2025 – Aug 2026)
- Timing in-sync with goSouth2 campaign series, including HALO-SOUTH campaign (Sep – Oct, 2025)
- Deployment of LACROS instrumentation at INV financed by TROPOS
- Deployment of LIM instrumentation (Uni Leipzig) at TAWHAKI applied for
- 2 PhDs (3 yrs) applied for

- **Plus auxilliary in-situ instrumentation at Invercargill for:**
  - Aerosol size distribution from 5 nm to 32µm;
  - Cloud Condensation Nuclei Counter (CCNC) and Ice Nucleating Particle (INP) analysis

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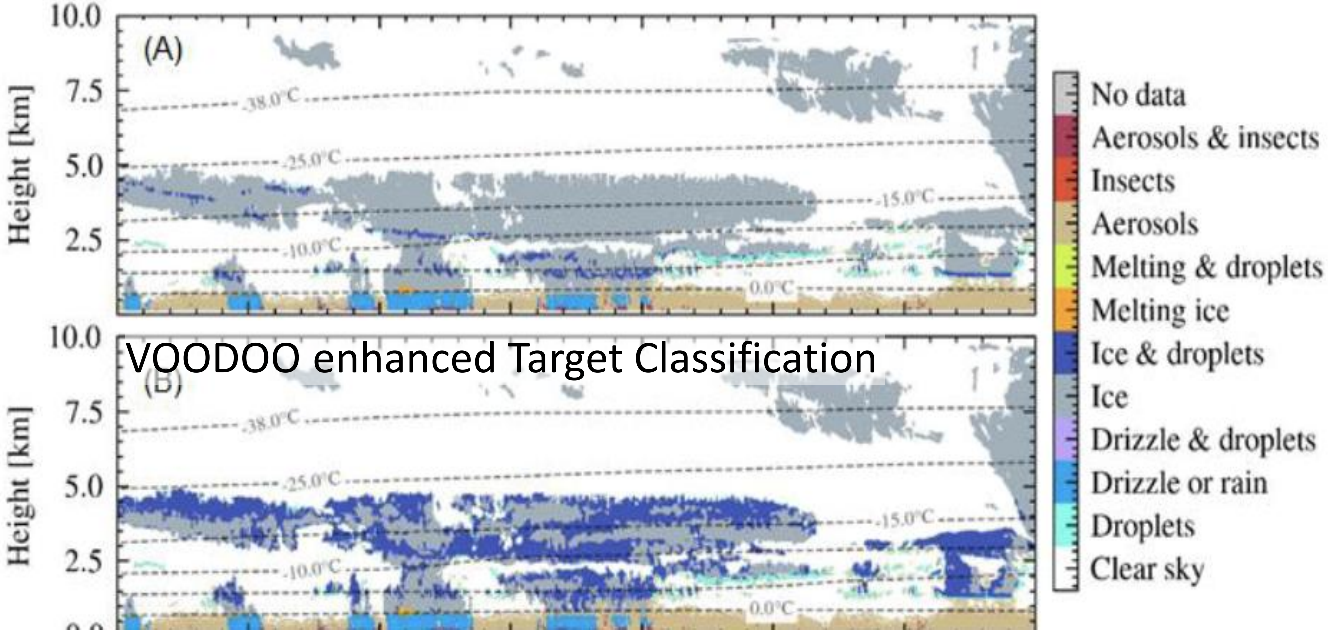
Science GOAL 2:

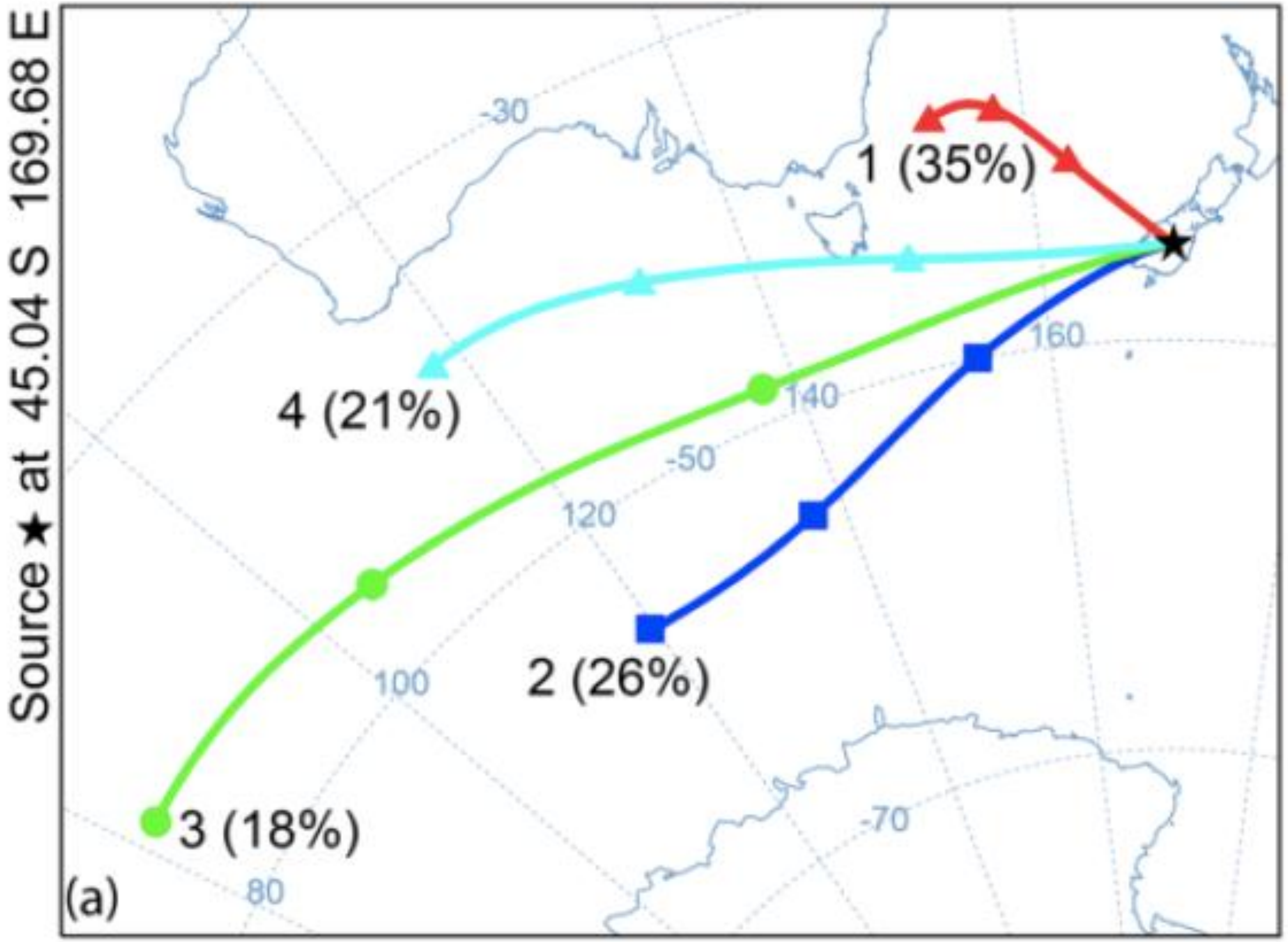
1. Fill data gap of long-term aerosol, cloud and precipitation observations over ANZ to create data base of Southern Ocean cloud properties
2. **Best estimates of cloud thermodyn. profiles**

Standard Cloudnet Target Classification



(Schimmel et al., 2022)

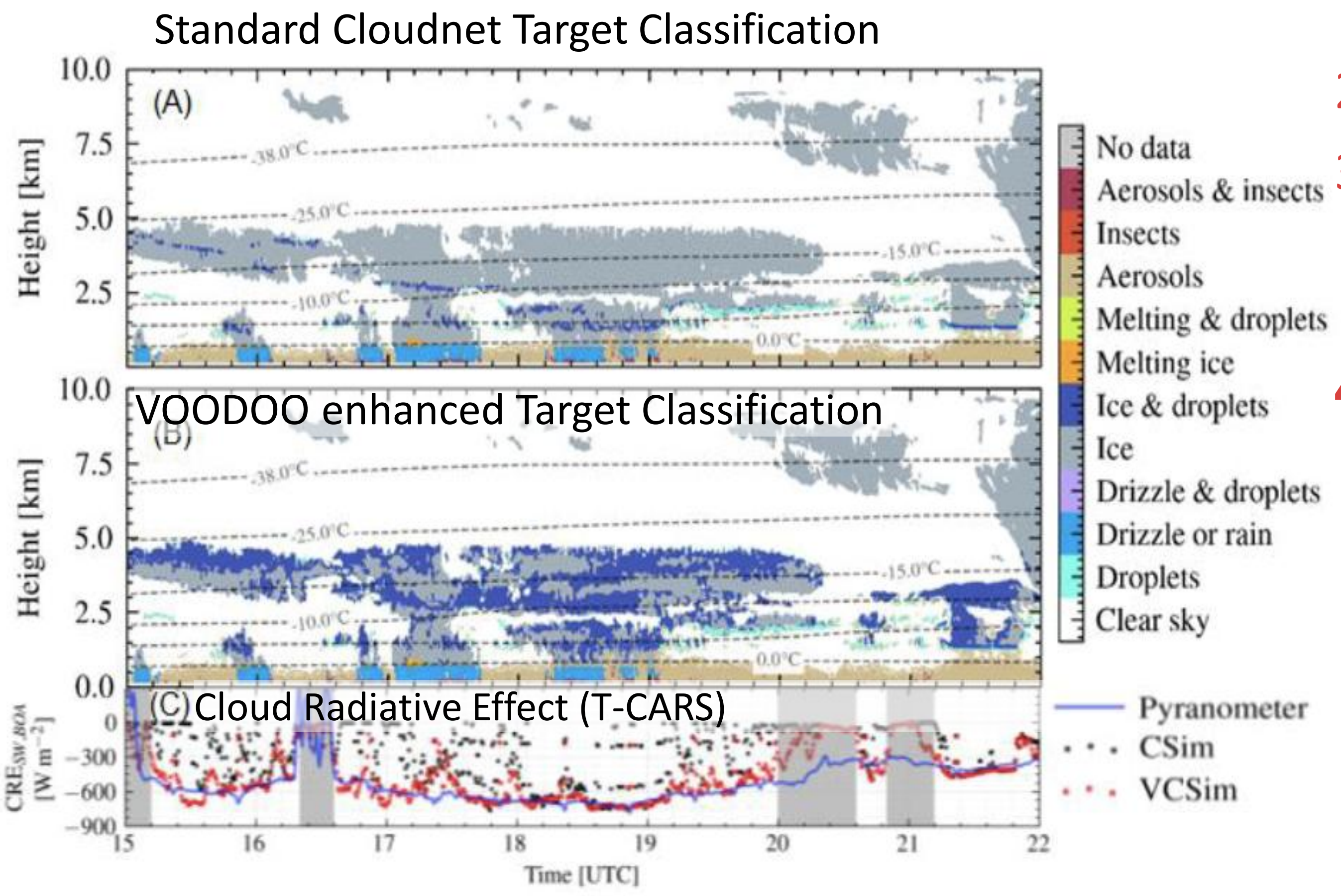
Science GOAL 3:



Cluster analysis of back-trajectories for altitudes of stratiform mixed-phase cloud tops (Hofer et al., 2024)

1. Fill data gap of long-term aerosol, cloud and precipitation observations over ANZ to create data base of Southern Ocean cloud properties
2. Best estimates of cloud thermodyn. Profiles
3. **Conduct contrast studies for clouds and aerosols for different air mass regimes over Invercargill and Tawhaki**

Science GOAL 4:



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1. Fill data gap of long-term aerosol, cloud and precipitation observations over ANZ to create data base of Southern Ocean cloud properties
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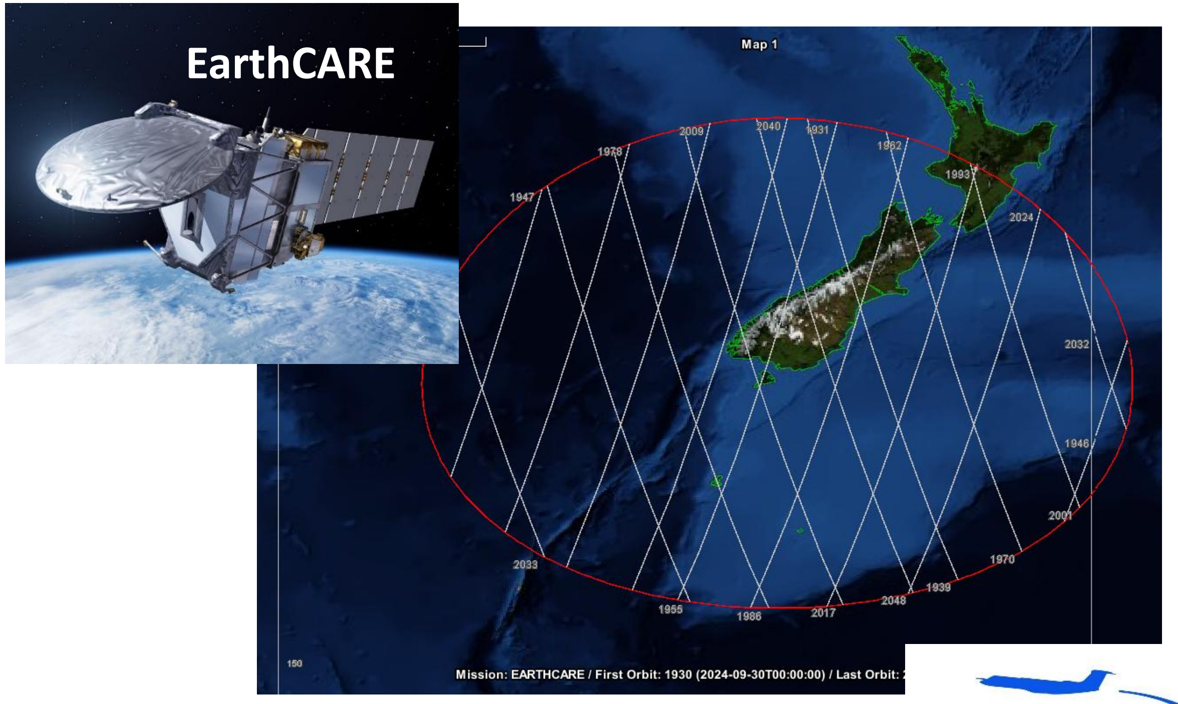
3. Conduct contrast studies for clouds and aerosols for different air mass regimes over Invercargill and Tawhaki
4. **Perform radiative closure studies**

Science GOAL 5:

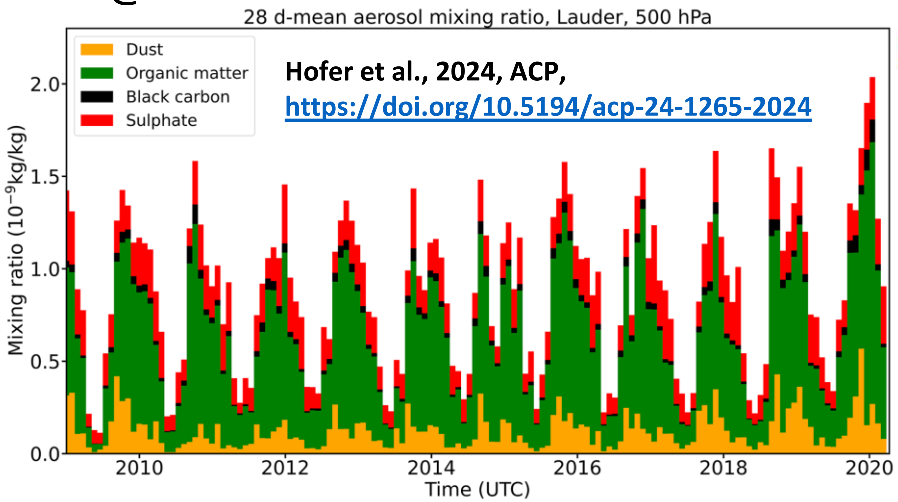
Air mass transformation along 450 km path over South Island of ANZ?

1. Fill data gap of long-term aerosol, cloud and precipitation observations over ANZ to create data base of Southern Ocean cloud properties
2. Best estimates of cloud thermodyn. Profiles
3. Conduct contrast studies for clouds and aerosols for different air mass regimes over Invercargill and Tawhaki
4. Perform radiative closure studies
5. **Identify regimes when INV and TAW were subsequently passed by same air mass to assess transformation of aerosols and clouds over South Island of ANZ**

Science GOAL 6:



CAMS @ Lauder



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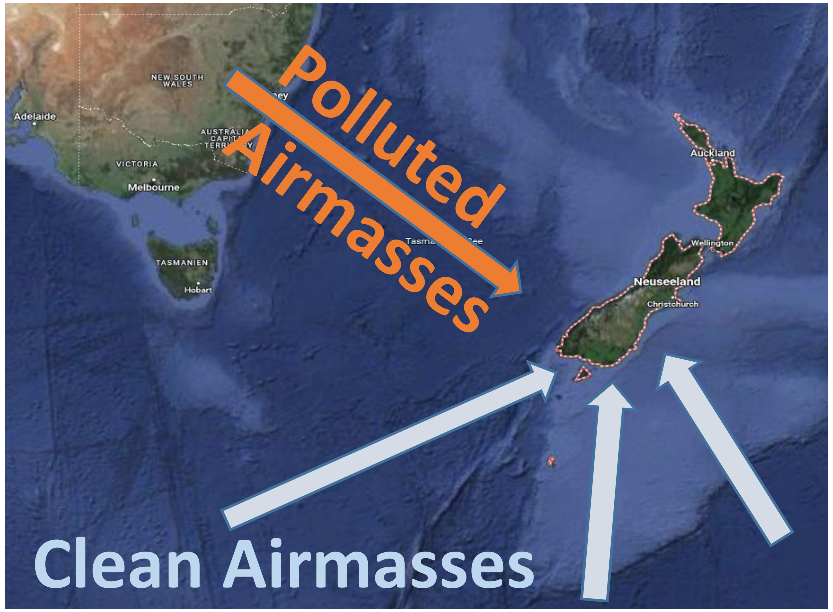
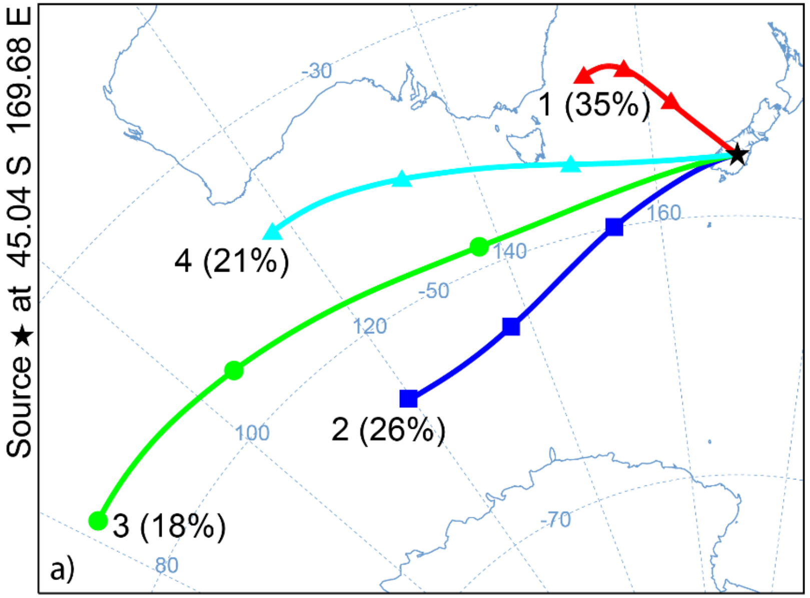
4. Perform radiative closure studies
5. Identify regimes when INV and TAW were subsequently passed by same air mass to assess transformation of aerosols and clouds over South Island of ANZ
6. **Contextualize observations with HALO-South Obs./EarthCARE obs. and model simulations (e.g., CAMS and hopefully more)**

Summary

- **Problem**:
  - Persistent false model representation of cloud properties in the mid- and high latitudes of the southern hemisphere
- **Possible reason:**
  - Lack of cloud-relevant aerosol (CCN, INP) not accurately represented in the simulation setups
- **Approach**:
  - goSouth-2 & ACADIA
  - Characterization of aerosol and cloud properties during long-term deployment of ground-based remote sensing instrumentation to New Zealand
  - Aerosol-Cloud-Interaction contrast studies
  - Unprecedented characterization of cloud microphysical structure for improved radiative transfer simulations





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Thank You


HALO Aircraft (HALO-South 09/2025)

Tawhaki Aerospace Center

Limassol, Cyprus (2016-2018)


MetService, Invercargill

+ RV Sonne (ACAROA, Q1/2028)

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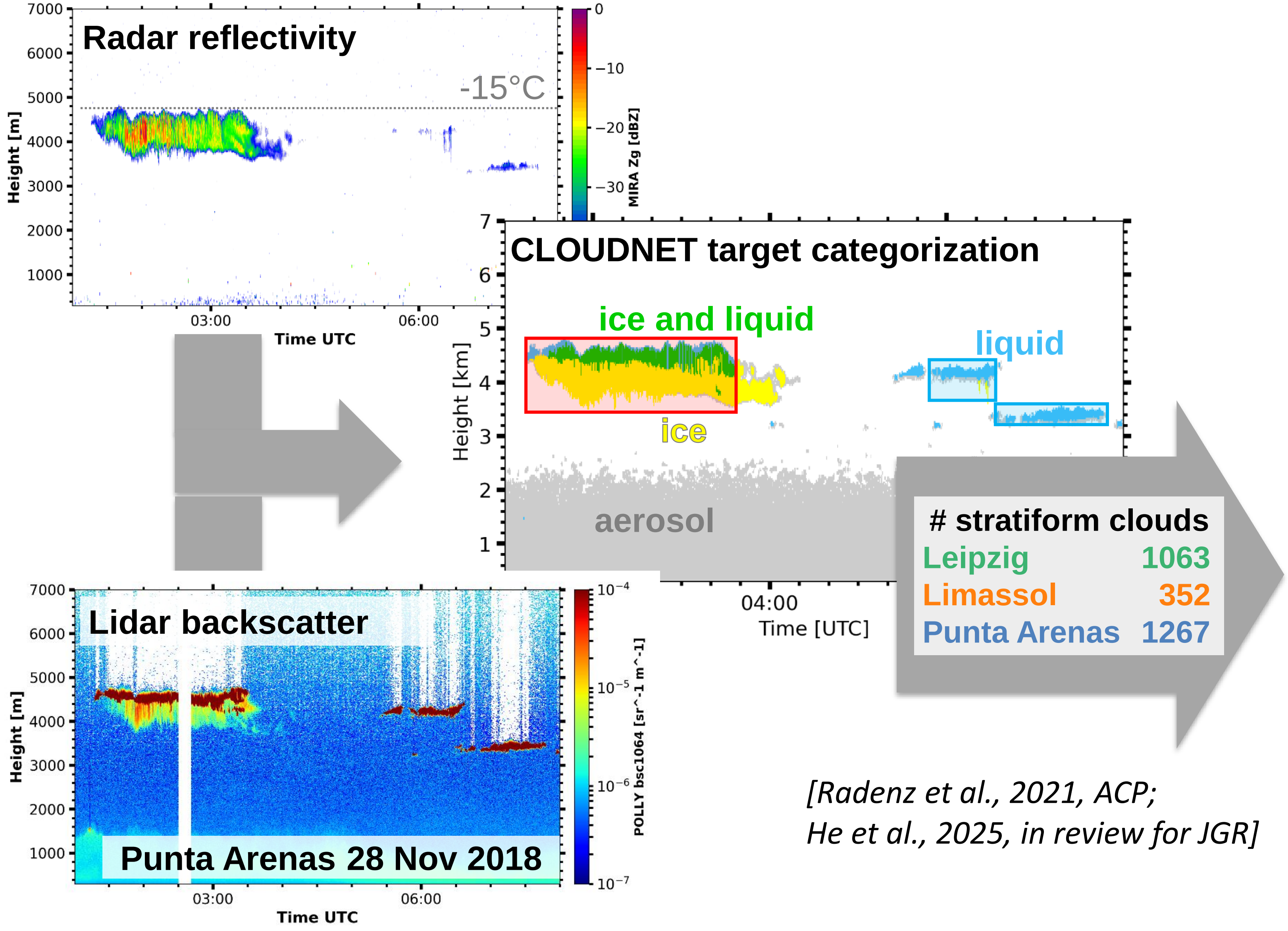
One approach to identify ACI: Picking target scenarios from long-term observations

- E.g:
  - stratiform supercooled liquid clouds
  - Defined turbulence



[Radenz et al., 2021, ACP; He et al., 2025, in review for JGR]

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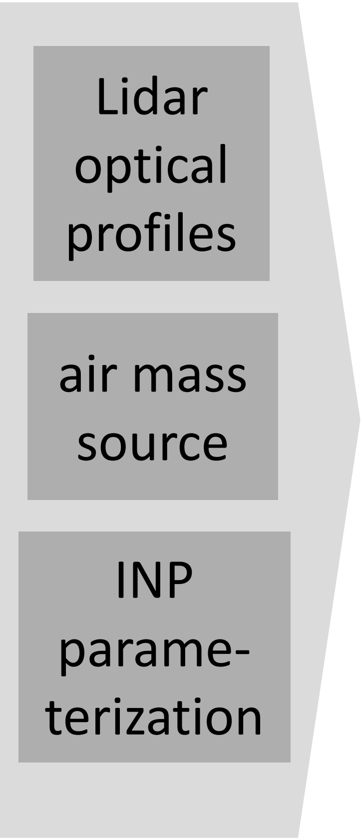
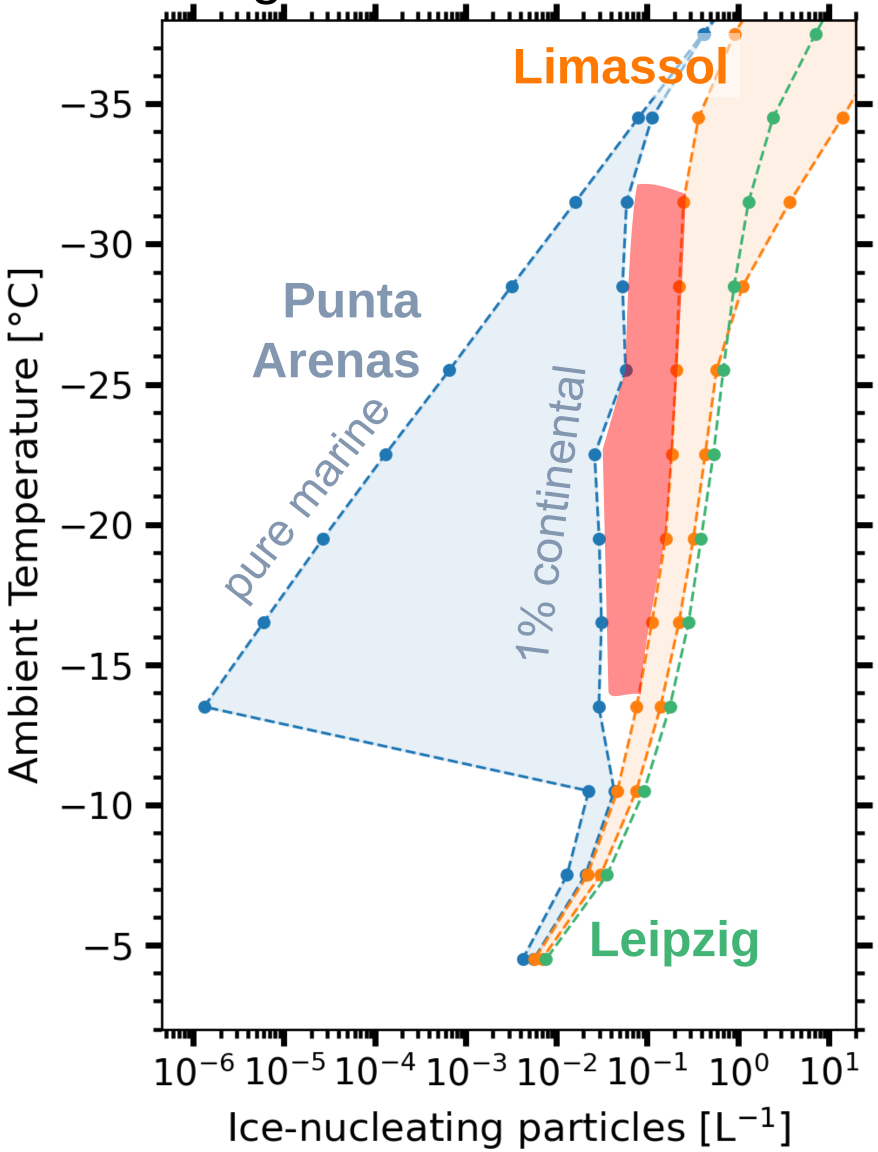
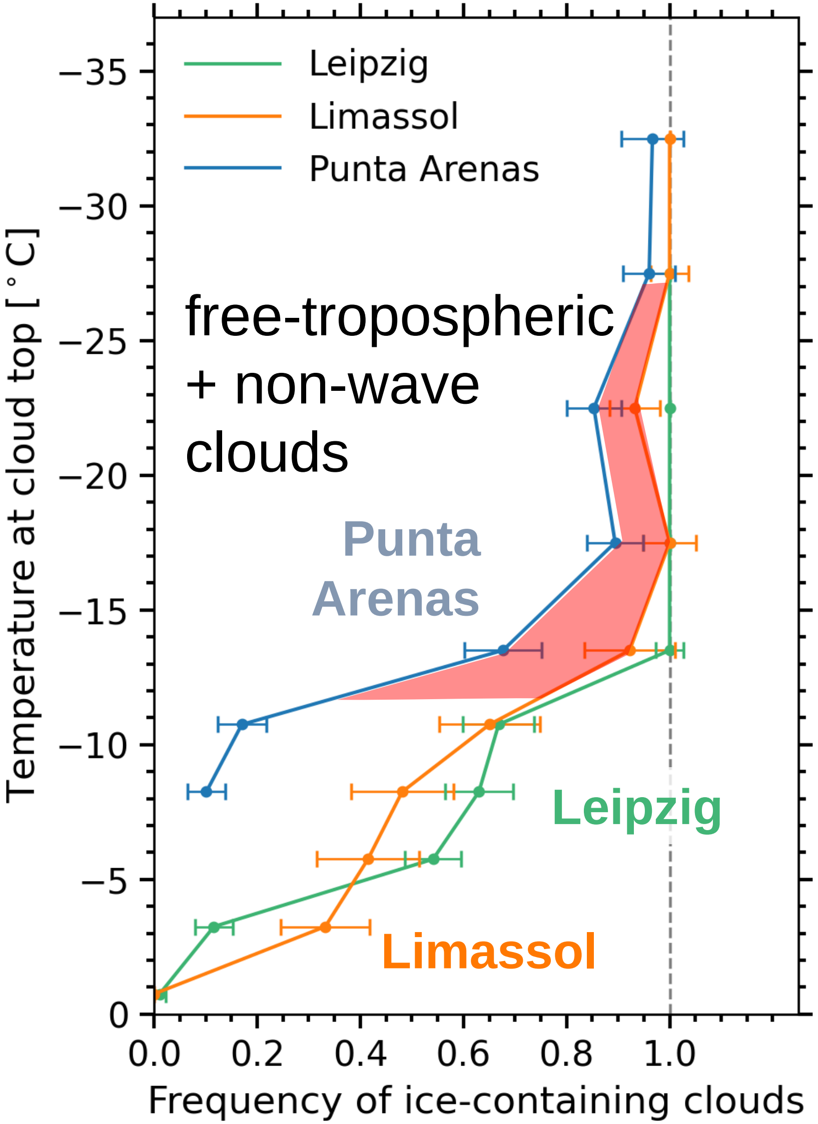
Occurrence of heterogeneously formed ice vs. INP concentrations



Estimate of average INP concentrations





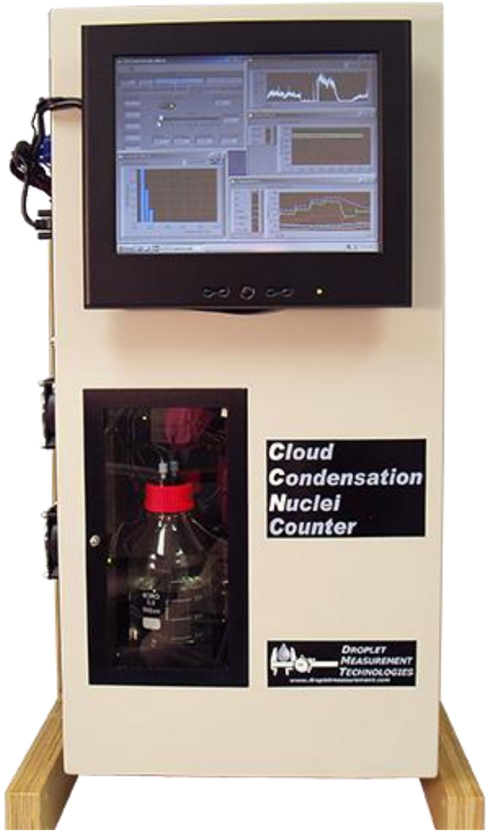
Less frequent ice formation at temperatures, where INPs are at least a factor 10 less common

[Radenz et al., ACP, 2021]

Auxilliary in-situ instrumentation at Invercargill

- Aerosol size distribution from 5 nm to 32µm
- Cloud Condensation Nuclei Counter (CCNC)
- Ice Nucleating Particle (INP) analysis

SMPS DURAG EDM 665 WRAS



Cloud Condensation Nuclei Counter

Low-Volume Filter sampler

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