Comparison of cirrus clouds in naturally and anthropogenically influenced regions of the atmosphere

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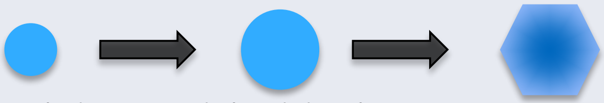
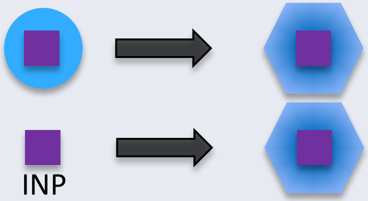
Cirrus clouds – some facts

- Cirrus clouds cover approx. 30% of the Earth.
- Cirrus clouds absorb terrestrial and reflect solar radiation.
- Microphysical properties and location of a cirrus cloud determine its net warming/cooling effect.
- Representation of cirrus clouds in global climate models is difficult and results in large uncertainties in the predicted radiative effect.
  Processes relevant for cloud formation occur in scales of sub-micrometer to several thousands of kilometer.

Formation of Cirrus

Homogeneous ice nucleation	Heterogeneous ice nucleation
T < 235 K RH_{ice} : 140 – 170 %	T < 273 K RH_{ice} : 100 – 140 %
 • Supercooled activated cloud droplet • Pure solution aerosol particle	Immersion Freezing Deposition Ice Nucleation 
n_{ice} between 10^{-1} and 10^{3} #/cm^3 depending on **updraft velocity** and **temperature**	n_{ice} between 10^{-3} and 10^{2} #/cm^3 depending on **amount of INPs**

modfied after Heymsfield et al., 2017

Both processes can coexist:

Homogeneous ice nucleation ↔ Heterogeneous ice nucleation

INP = Ice Nucleating Particle

Anthropogenic influence on cirrus

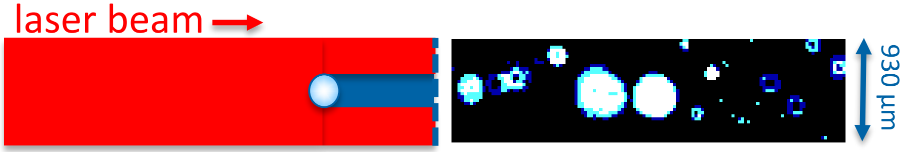
What are possible pathways for anthropogenic actions to influence cirrus appearance and properties (Kärcher, 2017):

- Via modification of occurrence frequency, extent and properties of **other non cirrus clouds.**
- Via altering of upper tropospheric **moisture**, **temperature** and **vertical winds.**
- Via modification of properties of atmospheric **aerosols** (location, abundance and ice-forming ability) which impact cirrus formation and properties.

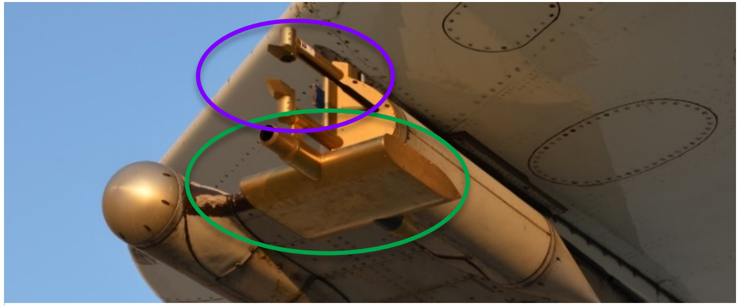
What do we know about location & abundance of atmospheric aerosols?

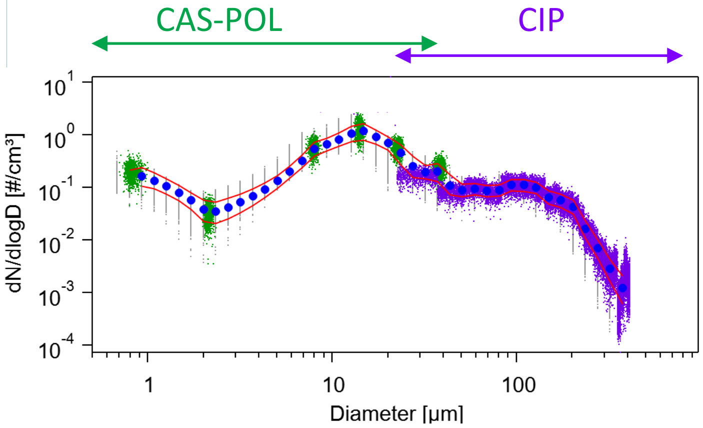
Method: Second generation Cloud, Aerosol, and Precipitation Spectrometer (CAPS)

Component 1: Cloud and Aerosol Spectrometer with Polarization Detection (CAS-POL):
Size of aerosol and cloud particles between ca. 0.5 and 50 µm.
Component 2: Cloud Image Probe (CIP):
Shadow images of aerosol and cloud particles from 15 to 930 µm.

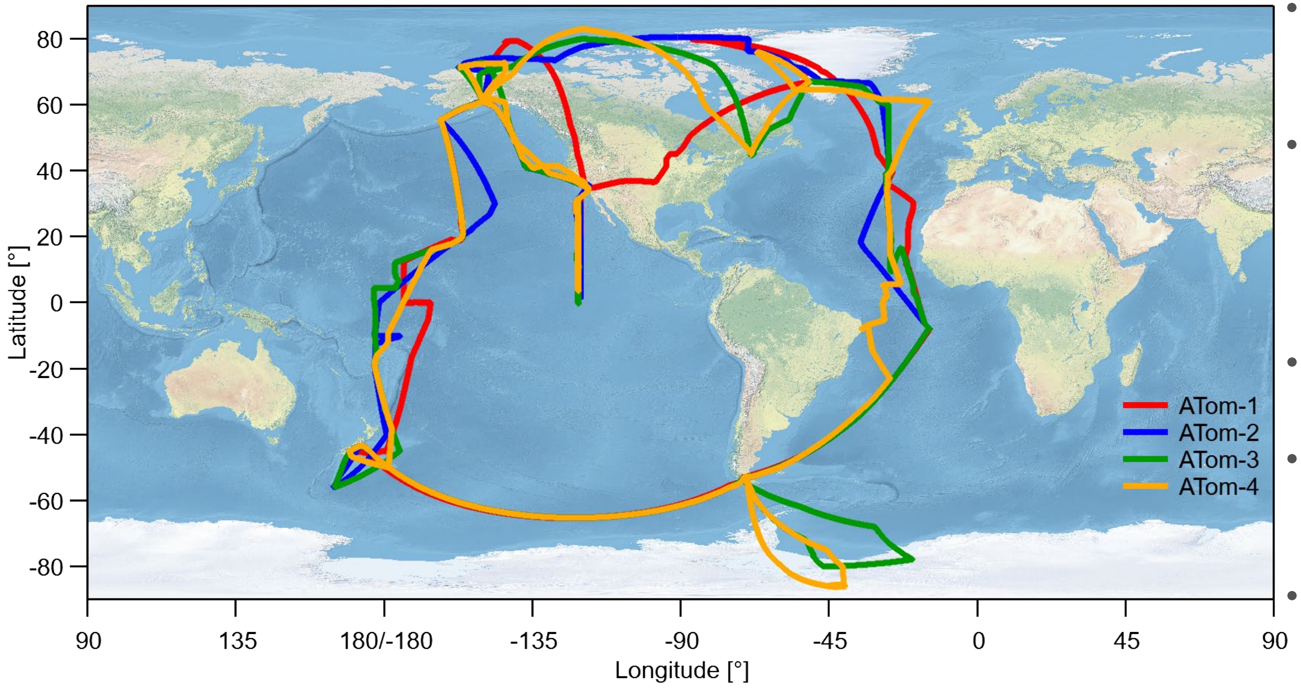


CAPS is the central instrument for coarse-mode aerosol and cloud particle measurements in this study and was deployed in all presented campaigns.



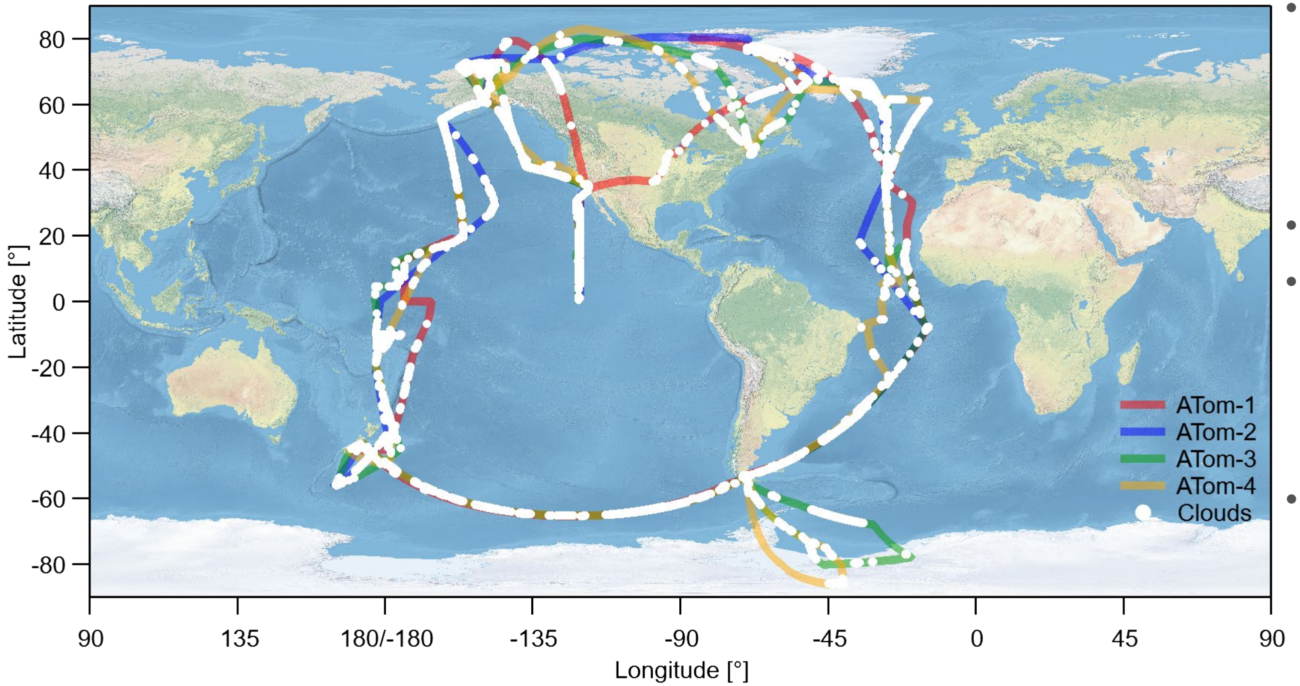


Atmospheric Tomography Mission: ATom



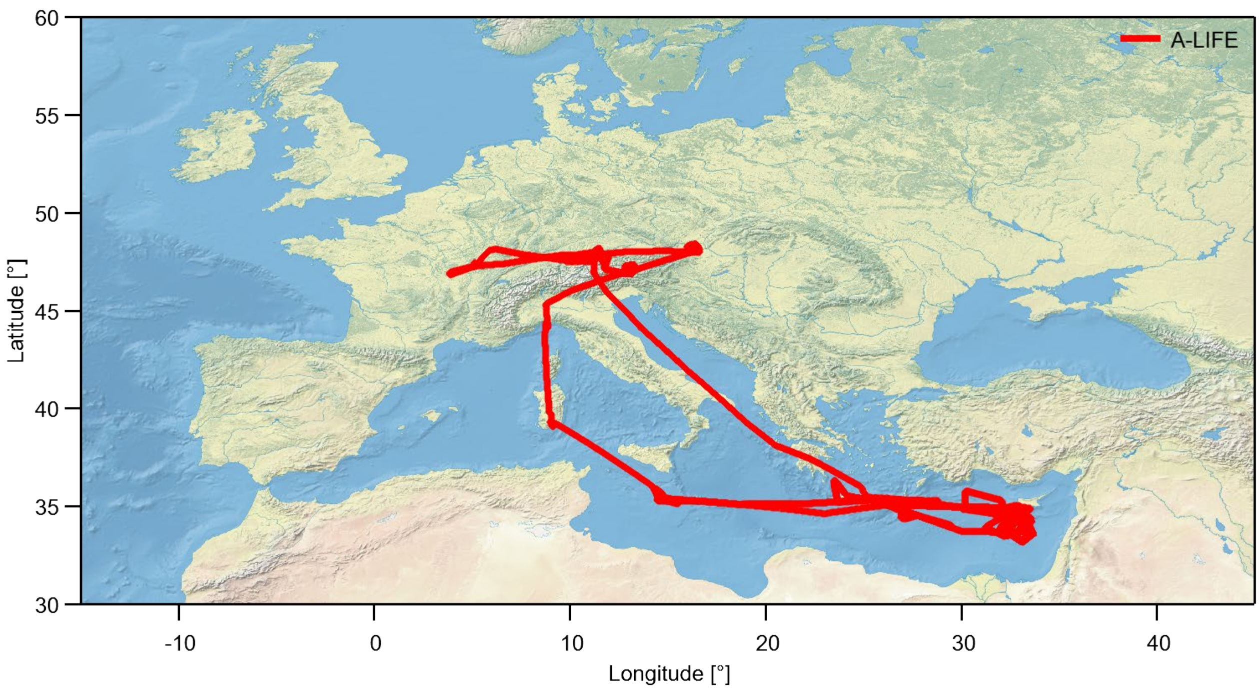
- **Unbiased** sampling of approx. 700 different meteorological, trace gas and aerosol parameters
- Flights in each of **4 seasons**:
  ATom-1 (Jul-Aug 2016)
  ATom-2 (Jan-Feb 2017)
  ATom-3 (Sep-Oct 2017)
  ATom-4 (Apr-May 2018)
- Approx. **600 vertical profiles** between 200 m und 13 km
- Sampling above Pacific and Atlantic Basin between **83° north** and **86° south**
- **Aerosol**- and **cloud** particle measurements between **2 nm and approx. 1 mm**

Cloud sampling during ATom



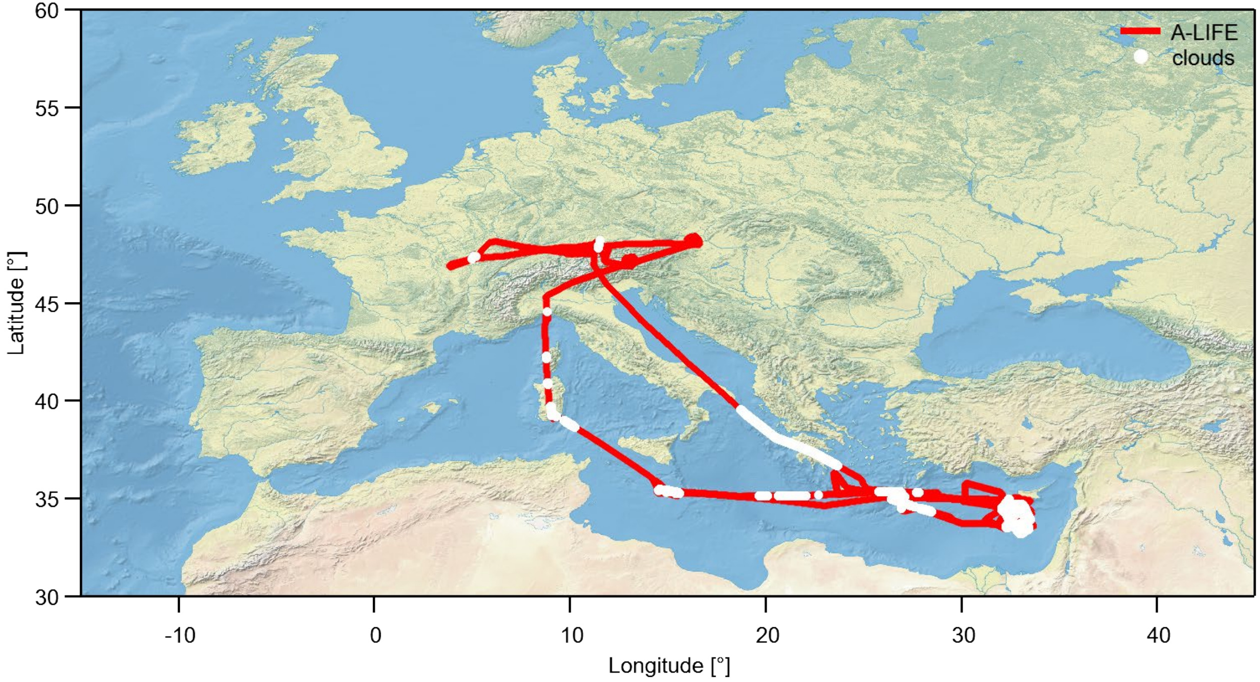
- **Unbiased** sampling of clouds (except for deep convective systems) above Pacific and Atlantic Ocean from the Arctic to Antarctica.
- In total **53h** spent in clouds.
- Fraction of time spent in clouds:
  ATom-1: 11%
  ATom-2: 16%
  ATom-3: 14%
  ATom-4: 11%
- Cloud, Aerosol and Precipitation Spectrometer (CAPS) as core instrument for cloud measurements

Absorbing aerosol layers in a changing climate: aging, lifetime and dynamics (**A-LIFE**)



- Key objectives of A-LIFE: **Absorbing aerosol** layers and their **interaction** with the atmosphere as well as aerosol **lifetime**.
- 22 mission flights (ca. 80 flight hours) with DLR Falcon equipped with aerosol and lidar payload in **Eastern Mediterranean** in April 17.
- Coordination with **ground-based in-situ** and **remote sensing** measurements.
- Aerosol- and cloud particle measurements up to 1mm.

Cloud sampling during A-LIFE



- Focus on **aerosol-cloud interaction**.
- Targeted sampling of clouds in aerosol layers. Special focus on **dust-impacted clouds**.
- In total **3h** (4%) spent in clouds.
- Cloud, Aerosol and Precipitation Spectrometer (CAPS) as core instrument for cloud measurements

How to tackle the problem…

universität wien

Comparison of cirrus clouds in naturally and anthropogenically influenced regions of the atmosphere

Naturally influenced cirrus

A-LIFE
(dust-impacted clouds)

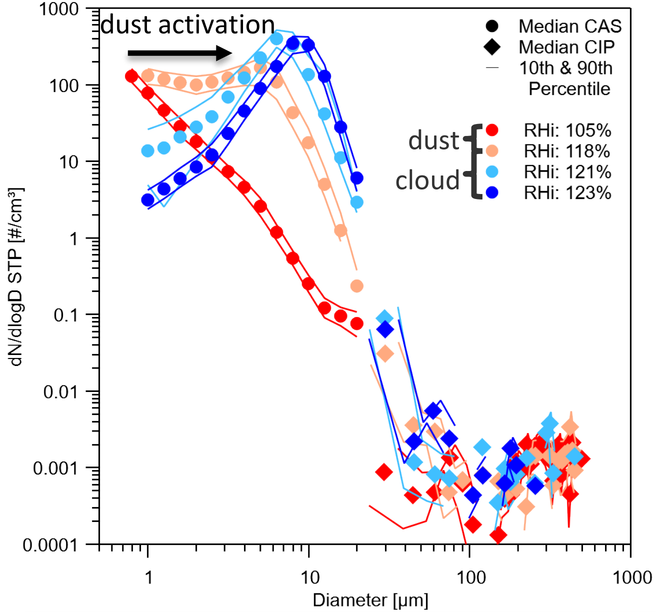
Uninfluenced cirrus

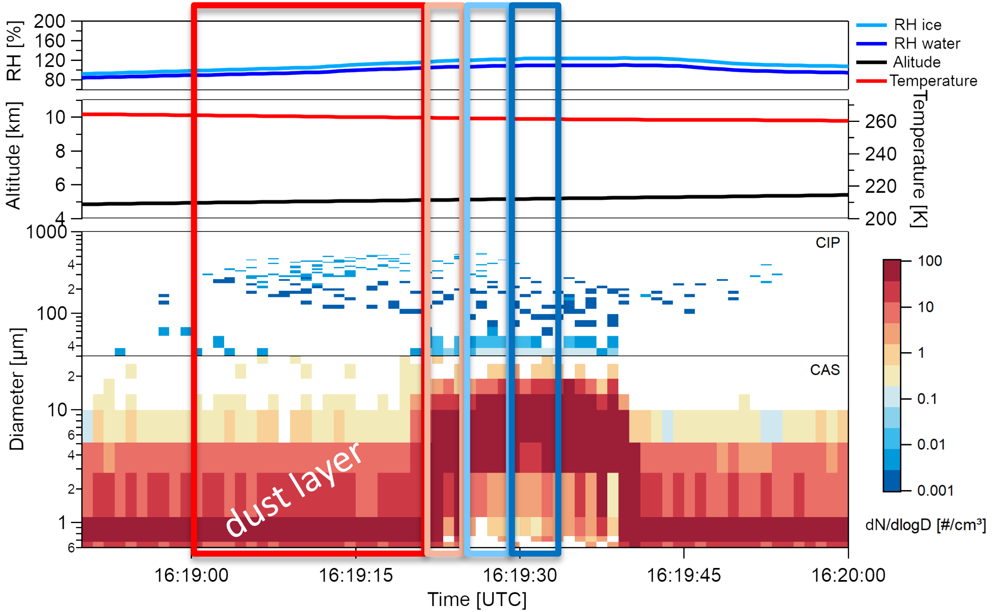
ATom
(clouds in pristine regions)

Anthropogenically influenced cirrus

ATom & A-LIFE

A-LIFE: dust-impacted cloud as example for naturally influenced cirrus

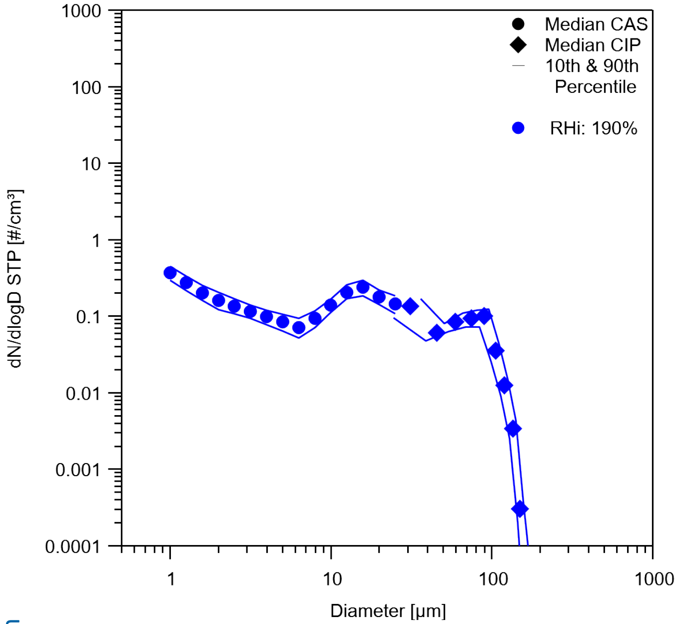


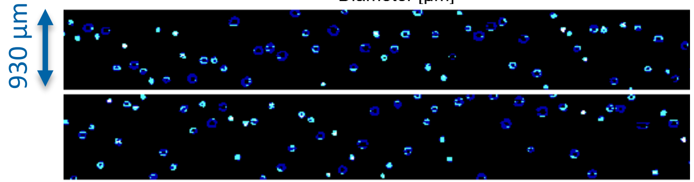


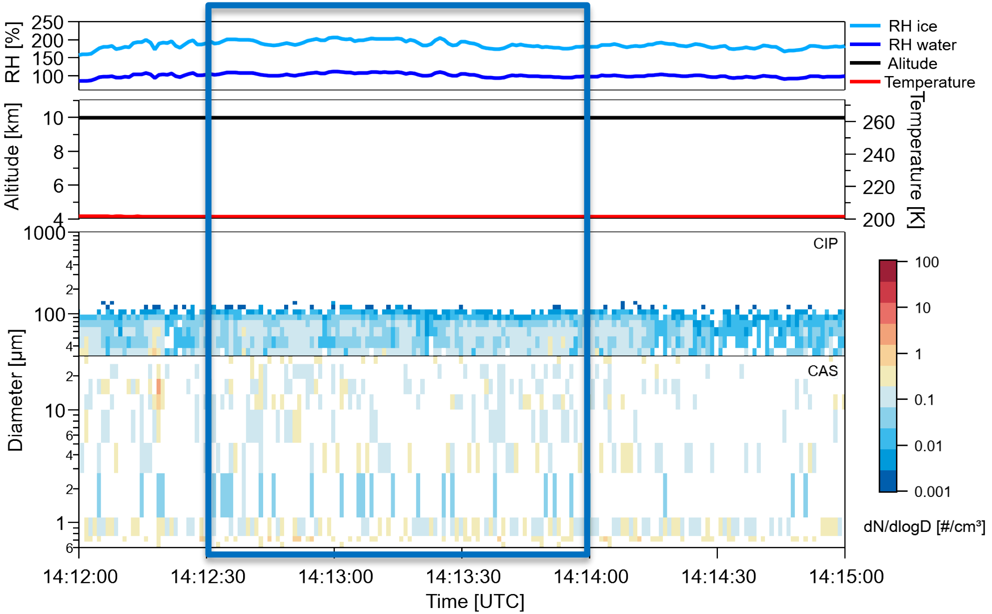
Left plot shows a growing mode at ~10 µm which corresponds to dust activation to cloud particles. Different colors indicate position in the cloud and correspond to boxes in right plot.

Colored boxes represent periods of corresponding size distributions. Altitude and relative humidity increase from box color red to blue with decreasing temperature (upper part of plot). Lower part shows time resolved size distribution. Activation of dust starts with RH(ice) increasing to 115% and temperature decreasing to 262 K.

ATom: cloud in pristine air above Antarctica as example for uninfluenced cirrus







Size distribution of cirrus cloud sequence in pristine air in the region of Antarctica. Average RH(ice) and temperature of sequence is 190% and 201 K, respectively. High RH(ice) and cold temperatures allow homogeneous ice nucleation as potential origin of cirrus cloud → uninfluenced cirrus.

Summary and outlook

Summary

- Dataset of ATom and A-LIFE offer nearly 60h of measurements inside clouds in various environments.
- Unbiased sampling during ATom provides measurements of uninfluenced and anthropogenically influenced cirrus.
- Targeted measurements during A-LIFE enable the investigation of naturally influenced cirrus (e.g. dust-impacted clouds).
- Presented two case studies for uninfluenced cirrus and dust-impacted cloud.

Outlook

- Complete analysis of all ATom and A-LIFE cloud cases.
- Statistical analysis of obtained data.
- Comparison of cirrus clouds in naturally and anthropogenically influenced regions of the atmosphere.

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