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Cloud Microphysical Properties of Summertime Arctic Stratocumulus during ACLOUD Campaign

Comparison with Previous Results in the European Arctic

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Scientific Background

The Arctic region is more sensitive to climate change than any other region of the Earth. Clouds and particularly low-level clouds related processes have a major impact on the Arctic surface energy budget. Observations suggest that boundary layer mixed-phase clouds (MPCs, mixture of liquid droplets and ice) are ubiquitous in the Arctic and persist for several days under a variety of meteorological conditions.

The Laboratoire de Météorologie Physique (LaMP, France) is involved since several years in airborne measurement campaigns dedicated to the study of Arctic clouds providing optical and microphysical in-situ measurements (Mioche et al., 2017).

In May-June 2017, the ACLOUD-(AC)3 airborne experiment (Arctic Cloud Observation Using airborne measurements in polar Day conditions) part of the German Transregional Collaborative Research Centre (AC)3 was designed to obtain a comprehensive data set to study physical processes in Arctic clouds. Two research aircrafts were employed to measure cloud properties, aerosol particles and trace gas concentration as well as energy fluxes in the atmospheric column.

The vertical and horizontal variability of cloud properties such as cloud phase, particle size, total water content and precipitation amount was characterized using in-situ measurements and remote sensing observations over different surface conditions (open water, sea ice, marginal ice zone and land).

Processing and Sub Dataset

- Discrimination of liquid and ice particle samples was based on circularity (Crosier et al., 2011), threshold at 1.25 (surface must be larger than 16 pixels).
- Classification of surface based on average sea ice concentration measurements (Young et al., 2016) :
  - Above 90 % is defined as "Sea Ice" (SI)
  - Between 10 and 90 % is the "Marginal Ice Zone" (MIZ)
  - Lower than 10% is defined as "Open Water" (OW)
  - Land correspond to NaN values.
- Tables show the number of samples for each subdataset used to define the vertical profiles presented :
  - Profile over land and during Cold period will not be shown
  - Cold and normal period sub dataset are fused as they have similar air mass origin (Central Arctic)
- Altitudes are normalised (Zn) to be [0 1] in the cloud liquid containing layer, [-1 0] in precipitating ice and Zn = -1 at the surface layer.

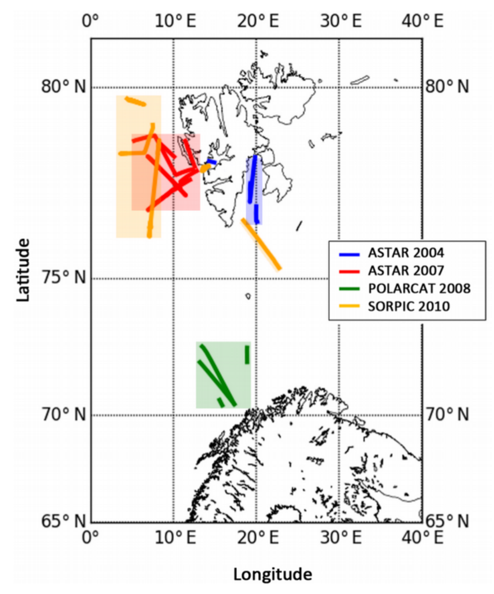
LIQUID samples	Cold Period	Normal Period	Warm Period
Sea Ice > 90%	0	1019	1146
90% > MIZ > 10%	307	48	556
10% > Open Water	56	419	548
Land	0	45	0

ICE samples	Cold Period	Normal Period	Warm Period
Sea Ice > 90%	0	297	1357
90% > MIZ > 10%	93	9	676
10% > Open Water	21	264	49
Land	0	26	0

Instrumentation and Dataset

- In situ measurements from European arctic airborne campaigns in SPRING (ASTAR2004 and 2007, POLARCAT 2008, and SORPIC 2010): 71 profiles (18 flights, (~100 m resolution) performed in single layer MPC). Compared to 66 profiles (10 flights) sampled during ACLOUD in summer with a 10s average (~ 1 km resolution).
- Airborne instrumentation for the measurements of cloud properties:

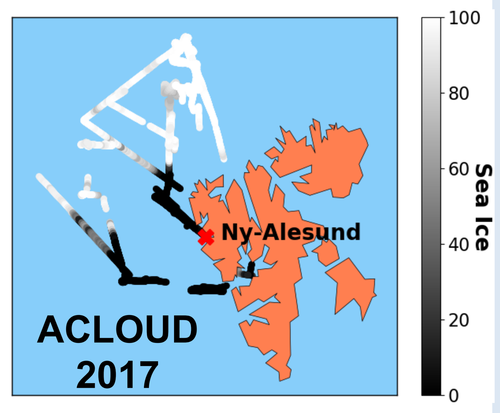
Cloud Probes	Size Range	Parameters
Polar Nephelometer (PN)	Few µm to ~800µm	Scatering phase function, asymmetry parameter (g), extinction coef.
Forward Scatterring Probe (FSSP)	3 µm to 45 µm	Droplets size distribution, LWC
Cloud Particle Imager (CPI)	~15 µm to 2,3 mm	Ice particle size distribution, shape, IWC
Nevzorov Probe	Bulk	LWC, TWC
Cloud Droplet Probe (CDP)	3 µm to 45 µm	Droplets size distribution, LWC
Small Ice Detector (SID3)	3 µm to 45 µm	Droplets size distribution, LWC
Cloud Image Probe (CIP)	~25 µm to 1.6 mm	Ice particle size distribution, shape, IWC



- Classification related to meteorological conditions:

Regime	Mean Cloud Top Temp.	Air Mass origin	Surfaces Overflown	Number of Flights (vertical profiles)
COLD	< -15°C	North (Central Arctic) or Greenland	Open water	6
WARM North	> -15°C	North (Central Arctic) or Greenland	Open water	7
WARM South	> -15°C	South (Europe)	Open water	5
ACLOUD Cold	> -15°C	North (Central Arctic)	Variable	1 (4)
ACLOUD Normal	> -15°C	North (Central Arctic)	Variable	5 (25)
ACLOUD Warm	> -15°C	South (Europe) or Greenland	Variable	4 (37)

As presented in Mioche et al., 2017 (grey underline) and Knudsen et al. 2018 plus local backtrajectories (yellow underline)



- Sea Ice concentration data were produced by the University of Bremen from AMSR2 sattelite data.

Cloud Vertical Profiles

- Figures represent vertical profiles (expressed in normalized altitudes) of liquid droplet (fig. 1 and 2) and ice crystal (fig.3) properties :
  a) Extinction Coefficient
  b) Number Concentration
  c) Mass content
  d) Effective Diameter
- The vertical profile curves correspond to :

Curves	ACLOUD Normal or Warm North	ACLOUD Warm or Warm South
Over Sea Ice > 90%	blue dotted line	red dotted line
Over Marginal Ice Zone	blue dashed line	red dashed line
Over Open Water < 10%	blue solid line	red solid line
Mioche et al., 2017 (Open Water)	black solid line	green solid line

Figure 1 – LIQUID Phase – Over Open Water

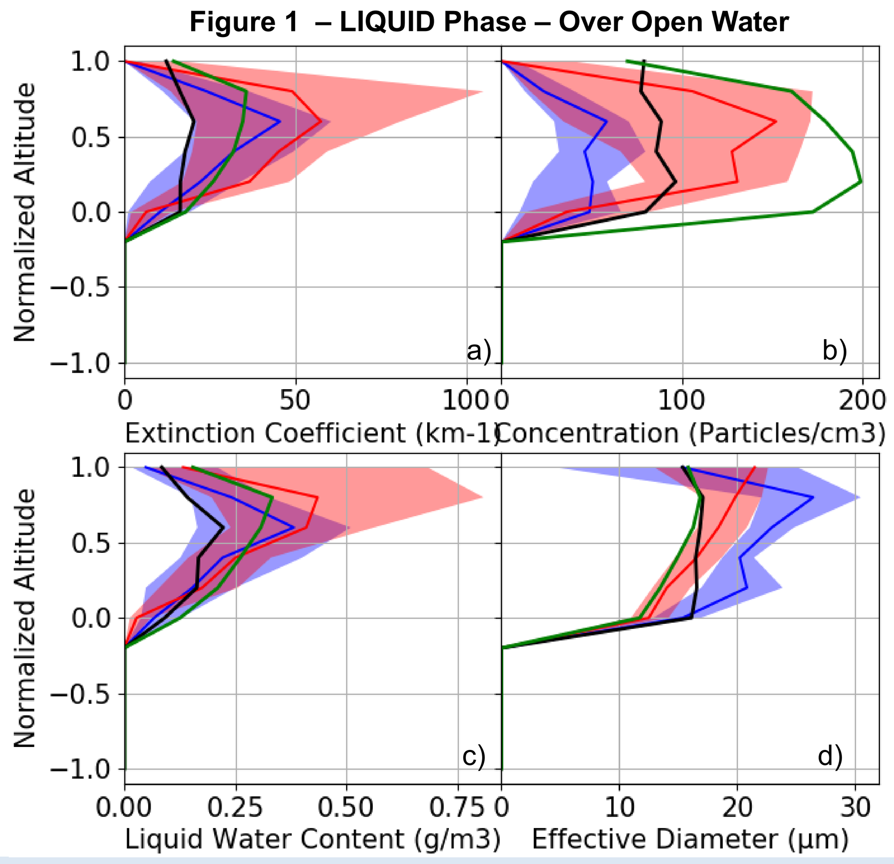


Figure 2 – LIQUID Phase – ACLOUD only

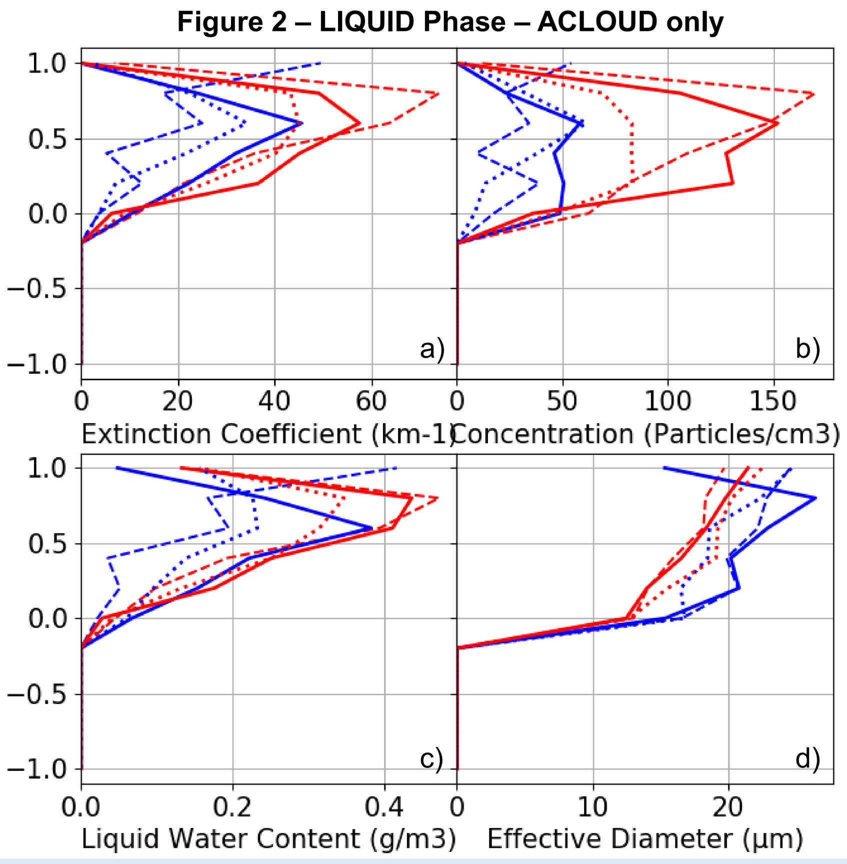
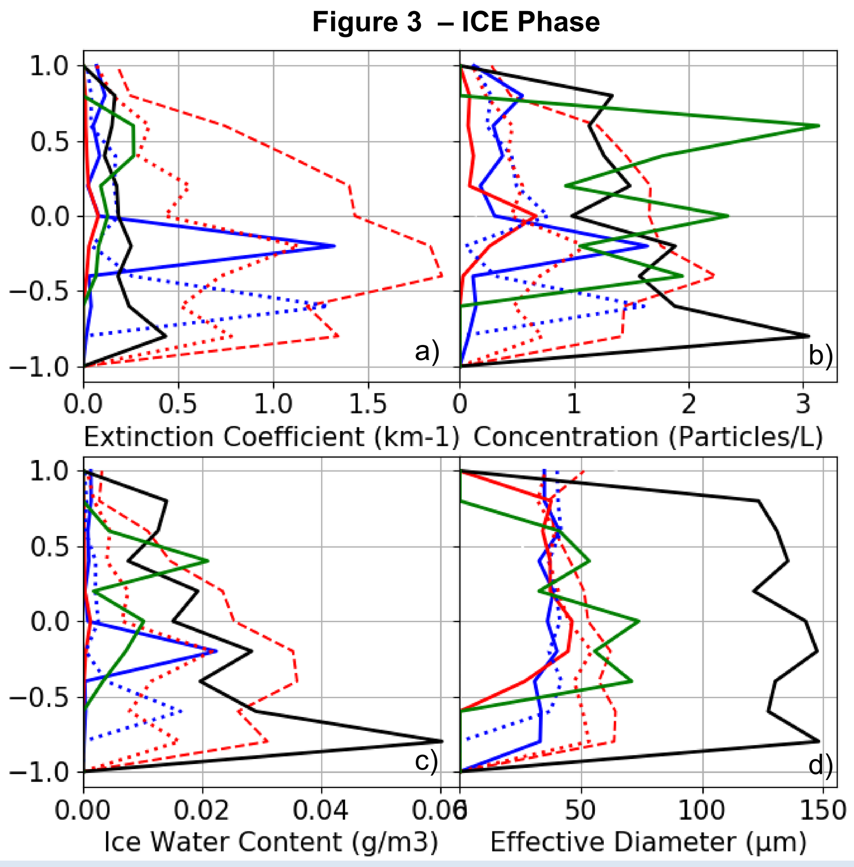


Figure 3 – ICE Phase



Discussion and outlook

- Comparison of **ACLOUD** with our previous studies shows **Spring / Summer** differences :
  - ➔ Liquid phase needs aerosol concentration to conclude difference in droplet concentration (Fig. 1) ;
  - ➔ Few Ice over open water (< $1L^{-1}$) during ACLOUD but Ice phase over MIZ similar to spring cases with small ice crystals (Fig. 3).
- Differences induced by the **surface** overflown :
  - ➔ Liquid phase graphs (Fig. 2) show difference between air mass origin (fewer and larger droplets during Normal period) most likely due to aerosol concentration difference (Twomey effect) ; difference between surfaces may not be only explained by different aerosol source as droplet size is constant while LWC change could indicates change in droplet activation conditions (e.g. supersaturation)
  - ➔ Ice cristals concentration shows that MIZ > SI > OW BUT maximum of $2L^{-1}$.
- **ACCACIA campain** studies (Young et al., 2016 and Lloyd et al., 2015) have shown that :
  - Differences **Spring / Summer** :
    - ➔ Ice conc. in summer x5 those in spring
  - Differences with **surfaces** (measurements in March, top cloud temperature -20°C) :
    - ➔ Ice properties constant, 0.5-1.5 L^{-1}
    - ➔ Droplet concentration : MIZ > SI > OW
- Plans for clearing misunderstandings :
  - Adding aerosol concentration (see S. Mertes presentation) and small ice crystals studies (see F. Waitz poster)
  - Future campaigns in the region : AFLUX 2019 and MOSAIC 2020

Acknowledgements and references

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