Interactions of snow on sea ice with atmospheric constituents including black carbon

C02

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1. Summary

Research questions (Phase 1):

C02 aimed at quantifying the abundance, microphysics, and radiative effects of black carbon (BC):

Q1 How BC is horizontally and vertically distributed in the **atmosphere** and **snow surface**?

Q2 What are the typical **transport pathways** and deposition processes of BC in remote Arctic areas?

Q3 How strong BC reduces **snow albedo** in different spatial and temporal scales?

Q4 Do BC particles significantly contribute to the **surface radiative effects** and accelerate the snow metamorphism?

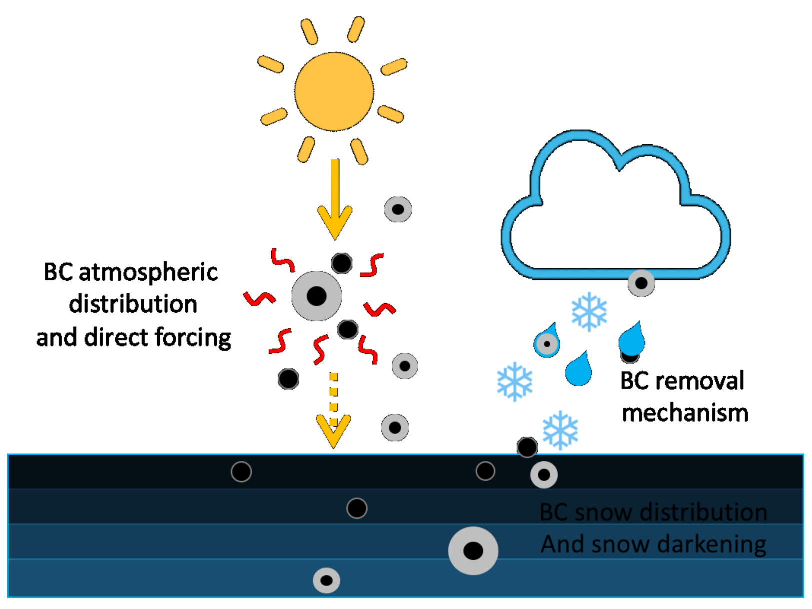


Fig. 1: Schematic of black carbon process-properties investigated in C02.

2. Achievements phase I

BC distribution in the atmosphere and snow

- Airborne and ground-based characterization of BC (Wendisch et al. 2017)
  - ACLOUD/PASCAL – early summer 2017: dominated by the onset of snow melt
  - PAMARCMiP – spring 2018: cold period with dry snow
- BC concentration in the atmosphere confirm the **annual cycle** (Schulz et al. 2019)
- Correction of BC measurements in snow for **sea salt contamination**
- BC concentration in the snow is **controlled by snow melting**

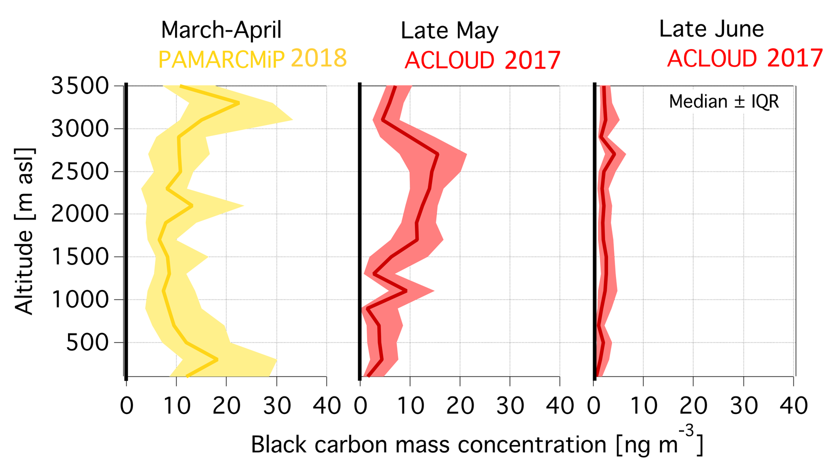


Fig. 2: Profiles of BC concentrations (median and interquartile range) measured during ACLOUD and PAMARCMiP.

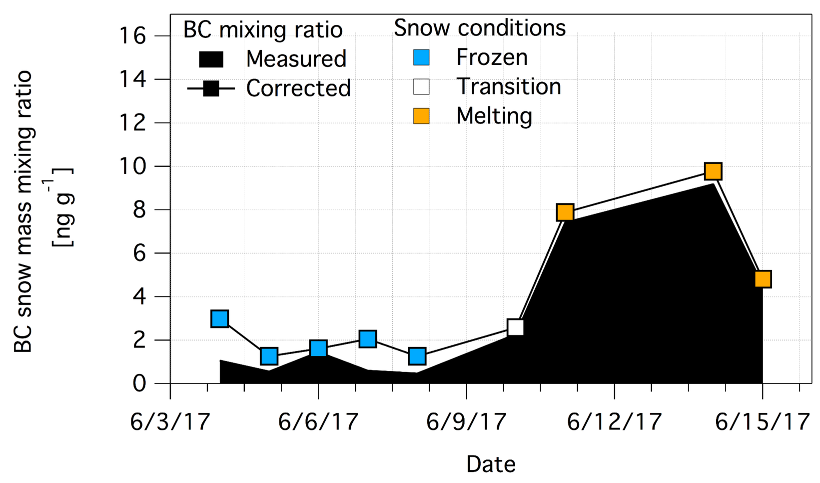


Fig. 3.: BC snow mass mixing ratio measured during the start of the melting season observed during PASCAL. The measurements are corrected for the sea salt bias.

- **Air mass history**: local sources in low altitudes; continental sources in high altitudes

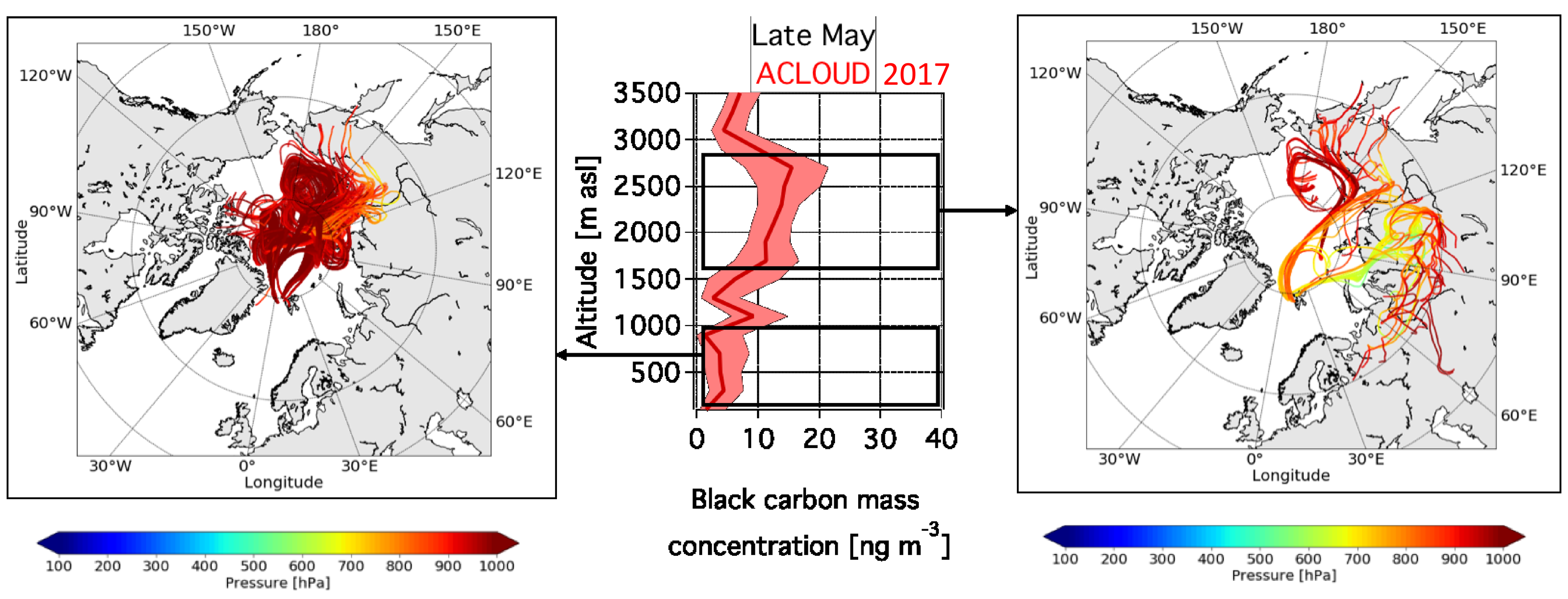
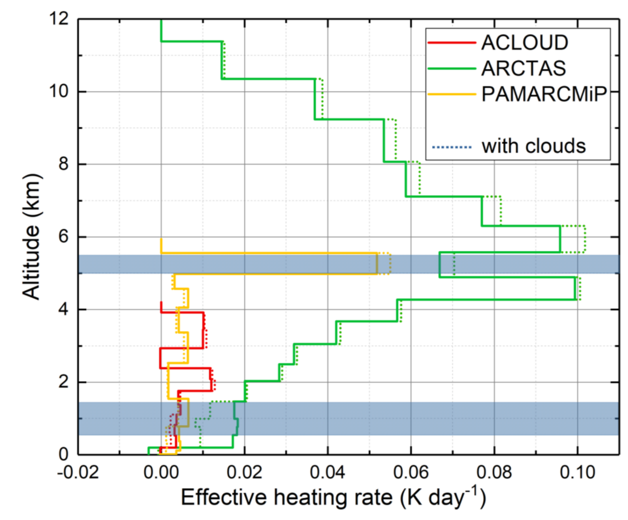


Fig. 4.: 10 days LAGRANTO back trajectories calculated for the cold period observed during the ACLOUD campaign from 23 to 29 May 2017.

Hypothesis (Phase 1)

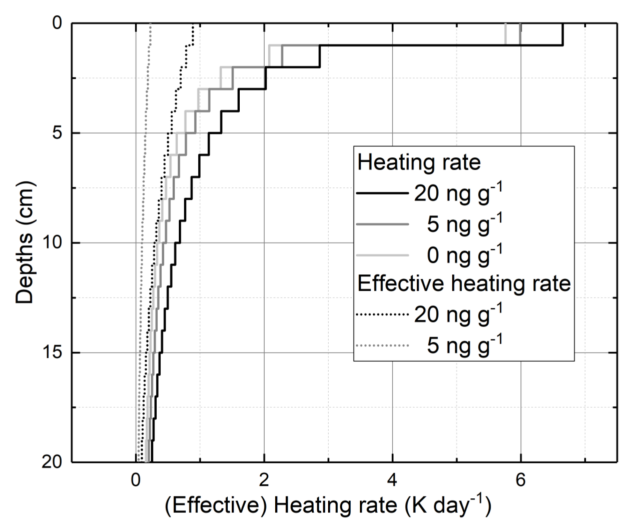
BC-containing aerosol particles lead to a surface warming when locally produced/emitted constituents reside at low altitudes and are partly deposited onto snow. Contrarily, long-range transport of BC, remaining in higher atmosphere layers cool the surface.

Radiative effects



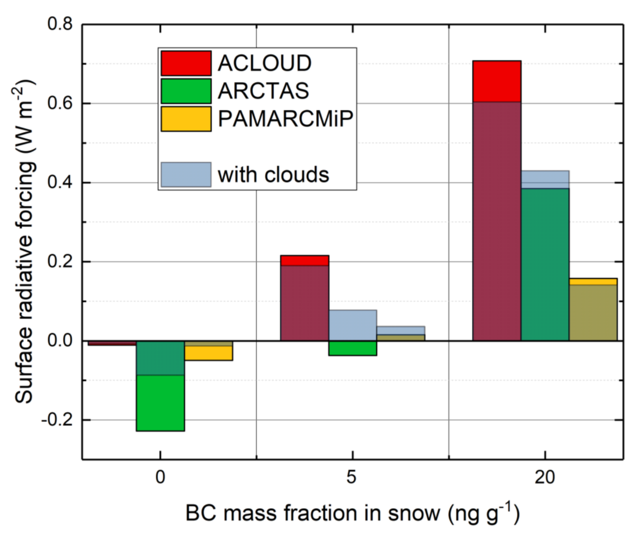
- absorption enhancement due to internal mixing of BC (Zanatta et al. 2018)
- Iterative **coupling of snow and atmosphere** radiative transfer models
- Comparison of cloud-free and **overcast conditions**

Fig. 5: Profiles of BC radiative heating rates based on the BC mass ratio of ACLOUD, PAMARCMiP, and ARCTAS simulated with and without clouds (light blue bars).



- Atmospheric BC effect **negligible in summer** (ACLOUD)
- **Melting rates** (for snow density 300 kg m^{-3})
  - BC only: 0.5 mm per day
  - Snow grains: 5 mm per day

Fig. 6: Calculated profiles of BC radiative heating rates in snow for different BC concentrations.



- **Surface solar radiative effects** of atmospheric BC and snow BC **counteract** (Schacht et al. 2019)
- Cooling by atmospheric BC dominates in spring
- Warming of snow BC dominates in clean summer

Fig. 7: Calculated BC surface radiative forcing based on the measured BC mass ratio of ACLOUD, PAMARCMiP, and ARCTAS for different BC concentrations in snow. Simulations are run with and without clouds as indicated in Fig. 5.

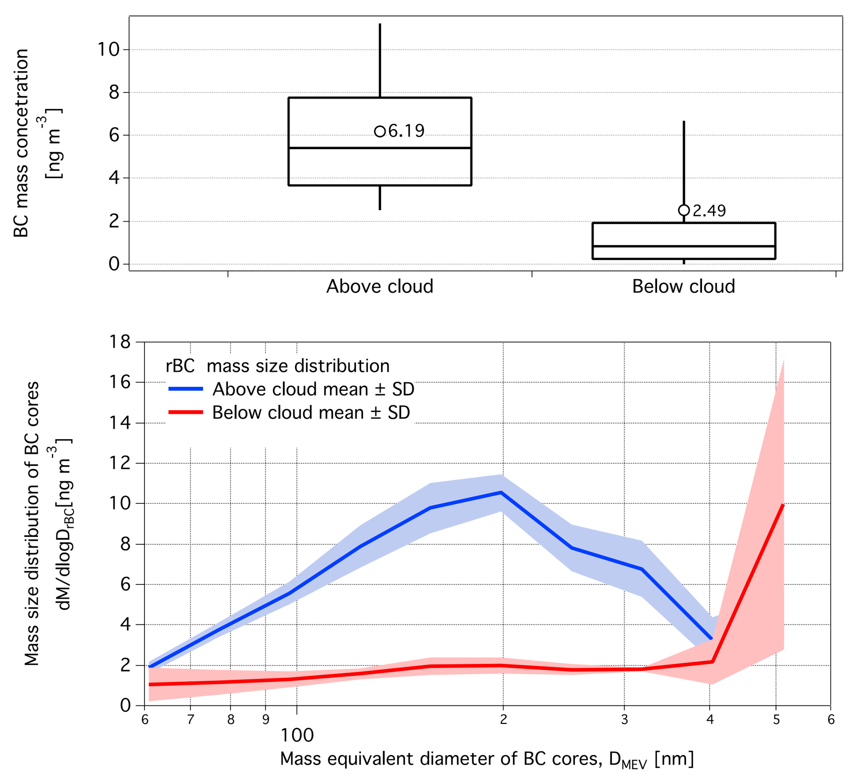
3. Perspectives

Remote sensing and radiative effects of BC

- Detection of BC from spectral albedo is strongly affected by other snow properties
  → with current instrumentation impossible
- The direct radiative effects by:
  - atmospheric BC << water vapour
  - BC in snow << changes of snow grain size (snow metamorphism)

BC transport and deposition

- Role of BC in cloud formation and precipitation → **B04**



BC depleted below cloud

- Impaction scavenging?
- Aerosol subsidence from upper troposphere?

"Giant BC" below cloud

- Effect of non-precipitating clouds

Fig. 8: Atmospheric BC properties sampled above and below cloud layers during ACLOUD.

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