Modelling marine organic aerosol and its impact on clouds in the Arctic

D02

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1. Summary

Role of **aerosol and aerosol-cloud processes in the Arctic climate** by global and Arctic-focused **aerosol-climate modelling**:

Phase I: long-range transport, black carbon (BC), and low-level-mixed-phase clouds

Phase II: local marine aerosol sources and their impact clouds

Research questions:

Q1 When including marine organic aerosol, and improving mixed-/ice-phase cloud microphysics, how much better is the model compared to new satellite and ship- and airborne observations?

Q2 What **feedback loop** involving marine organic aerosol and their impact on clouds is simulated by the revised model? What does this imply for Arctic amplification?

Hypothesis

A feedback loop between sea ice retreat, oceanic aerosol emissions, and clouds impacted by extra cloud condensation nuclei and ice nucleating particles enhances the Arctic amplification.

2. Achievements phase I

Aerosol transport and direct radiative properties

- Improvement of anthropogenic sources and long-range transport in the aerosol-climate model ECHAM6.3-HAM2.3.
- Quantification of BC direct radiative effects (DRE), albedo effect and uncertainties.
- Preliminary regional transport simulations, accompanying ACLOUD/PASCAL campaign.

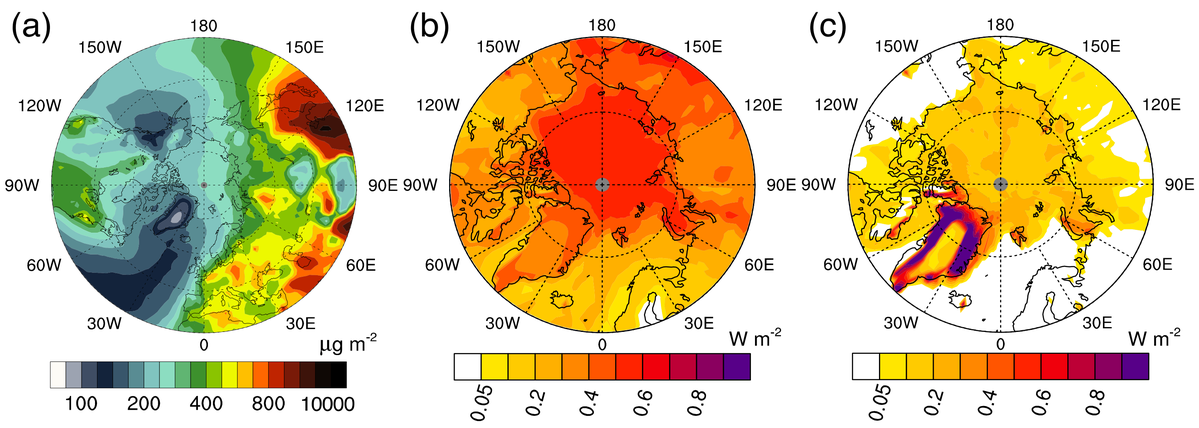


Fig. 1: 2005–2015 annual mean of (a) BC column burden, (b) net all–sky DRE of BC at top-of-atmosphere, and (c) solar BC-in-snow albedo effect as computed with ECHAM-HAM (Schacht et al., ACP, 2019).

Improvement of clouds in GCM vs. satellite data

ECHAM overestimated low clouds over sea ice and snow (Fig. 2)

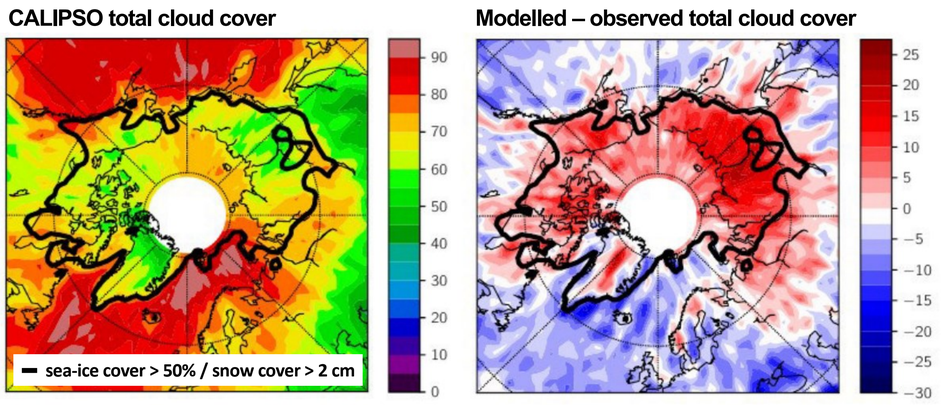


Fig. 2: Arctic cloud cover from CALIPSO satellite lidar and difference between ECHAM GCM + satellite simulator and CALIPSO (Kretzschmar et al., ACP, 2019).

Key improvements:

- Retuned Bergeron-Findeisen process
- Allow for ice supersaturation
- Adjusted surface fluxes

Plus: Use of 1.2-km ICON-NWP for analysis of ACLOUD field campaign data

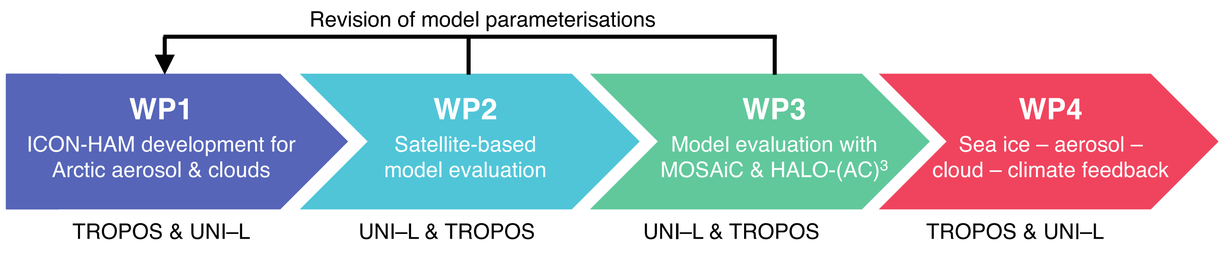
3. Research plan phase II

WP1: Aerosol-climate model ICON-HAM development

- Extend marine emission scheme to consider potentially ice-active species of marine primary organic aerosol (MPOA); present day setup.
- Key improvements to the representation of Arctic clouds building on D02 phase I; including Arctic MPOA as ice nucleating particles (INP).

WP2: Model evaluation with satellite observations

- Thorough evaluation and further improvement of ICON-HAM using new active satellite remote sensing retrievals together with (AC)³ satellite projects.
- Examine extra marine aerosol as INP and the impact of boundary-layer dynamics, i.e., state of cloud-surface coupling.

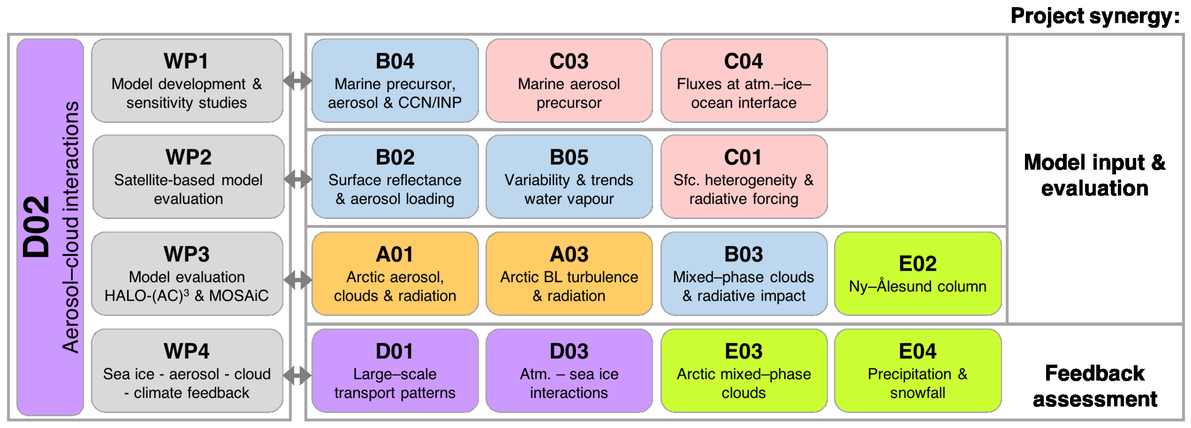


WP3: Model evaluation with MOSAiC & HALO-(AC)³ campaign data

- Process-level evaluation of inner-Arctic patterns in global and nested (40 → 13 → 5 km) ICON-HAM simulations using MOSAiC data.
- Investigate aerosol and cloud processes during meridional air mass exchange using HALO-(AC)³ data.

WP4: Analysis of sea ice – aerosol – cloud – radiation feedback loop

- Evaluation of present-day conditions of marine aerosol and its impact on clouds and radiation (relative to total aerosol) with global ICON-HAM runs.
- Projections with ICON-HAM for different sea-ice cover to assess the hypothesised climate feedback loop.



4. Role within (AC)³ & perspectives

Collaborations within (AC)³

- D02 plays key role to **integrate progress in understanding** of aerosol and aerosol-cloud processes into modelling at regional and GCM scales.
- Key collaborations with **C03 for marine aerosol sources** and **E03 for cloud model representation**.
- D02 contributes to the **cross-cutting activities 'lapse-rate' and 'surface-linkages'**.

Perspectives

- Exploit achievements of previous (AC)³ phases.
- Include aerosols and aerosol-cloud interactions in **fully coupled atmosphere-ocean-sea ice climate simulations**.
- **Conclusive evaluation** of aerosol / aerosol-cloud processes in Arctic amplification based on D02, cross-cutting activities, and collaboration with cluster E.

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printed at Universitätsrechenzentrum Leipzig