4th (AC)³ Science Conference on Arctic Amplification

23 – 26 February 2026 | Cologne | Germany

Conference Booklet

UNIVERSITÄT LEIPZIG
Universität Bremen
UNIVERSITÄT ZU KÖLN
AWI
TROPOS

Mia's Climate Diary is a fun and educational blog where a curious girl named Mia and her polar fox Mika explore questions about climate, weather, and climate change.
Climate science is explained in a simple, engaging way for young readers. Dedicated scientists are warmly invited to answer children's questions and help enrich the blog with their knowledge, making real research accessible and exciting for kids.

Web: www.mias-klimatagebuch.de

Instagram: @mias_klimatagebuch

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Dear Participants,

It is our great pleasure to welcome you to the 4th (AC)³ Scientific Conference on Arctic Amplification, which is hosted this year by our colleagues at the University of Cologne. We extend a particularly warm welcome to our early career researchers, including doctoral candidates and postdoctoral fellows, many of whom are actively involved in the Transregional Collaborative Research Center (TRR 172) on "ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms" **(AC)³**, funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG). We are equally pleased to welcome our senior scientists and project leaders within (AC)³. Furthermore, we are delighted that many international colleagues have accepted our invitation to contribute as keynote speakers and members of the (AC)³ Scientific Advisory Board. We are very happy to have you all here in Cologne.

This conference provides an excellent platform to present and discuss the latest results from the (AC)³ project, which we pursue with great enthusiasm. After more than a decade of stimulating research on Arctic Amplification—and with two years still ahead—it is an ideal time to review, synthesize, and reflect on the scientific achievements accomplished since the start of the (AC)³ project in 2016. At the same time, the meeting offers a unique, and possibly final, opportunity to sharpen and coordinate our research focus for the remaining project phase.

To support these goals, we have designed a program featuring three sessions dedicated to selected research highlights on mixed-phase clouds, aerosols, and sea ice. In addition, three sessions will address the strategic questions (SQs) guiding our work: the drivers of Arctic amplification, meridional transport processes and Arctic–mid-latitude linkages, as well as trends and the long-term evolution of the Arctic climate. The oral sessions will be complemented by four breakout sessions, allowing in-depth discussion of progress in our cross-cutting activities on convection, air mass transformations, parameterizations, and mixed-phase clouds. Results from individual (AC)³ projects will further be showcased in two poster sessions featuring a total of 40 posters. We also look forward to an evening lecture, a social event, and a joint conference dinner.

We are very much looking forward to the scientific discussions and exchanges throughout the conference and hope you will enjoy the time we spend together.

Manfred Wendisch & Marlen Brückner,
on behalf of the (AC)³ community

Conference Venue

Conference Venue, 23 - 26 February 2026

Institute of Geophysics and Meteorology
University of Cologne
Pohligstr. 3
50969 Cologne
https://geomet.uni-koeln.de/en/

The 4th $(\mathcal{AC})^3$ Science Conference on Arctic Amplification will take place at the Institute of Geophysics and Meteorology, University of Cologne. All plenary sessions will be in the lecture hall (upstairs), equipped with projector and computer. The poster sessions will take place in the same room, which will need to be rearranged during the break. Posters from both poster sessions will be displayed, but for logistical reasons they cannot remain on display for the entire duration of the conference. Wireless internet will be available (eduroam, guest accounts, further information will be provided at the registration desk).

How to get to the institute

We recommend you to come by public transport, bike or walking, as we cannot offer any parking spots. The Institute for Geophysics and Meterology can be reached by public transport as follows:

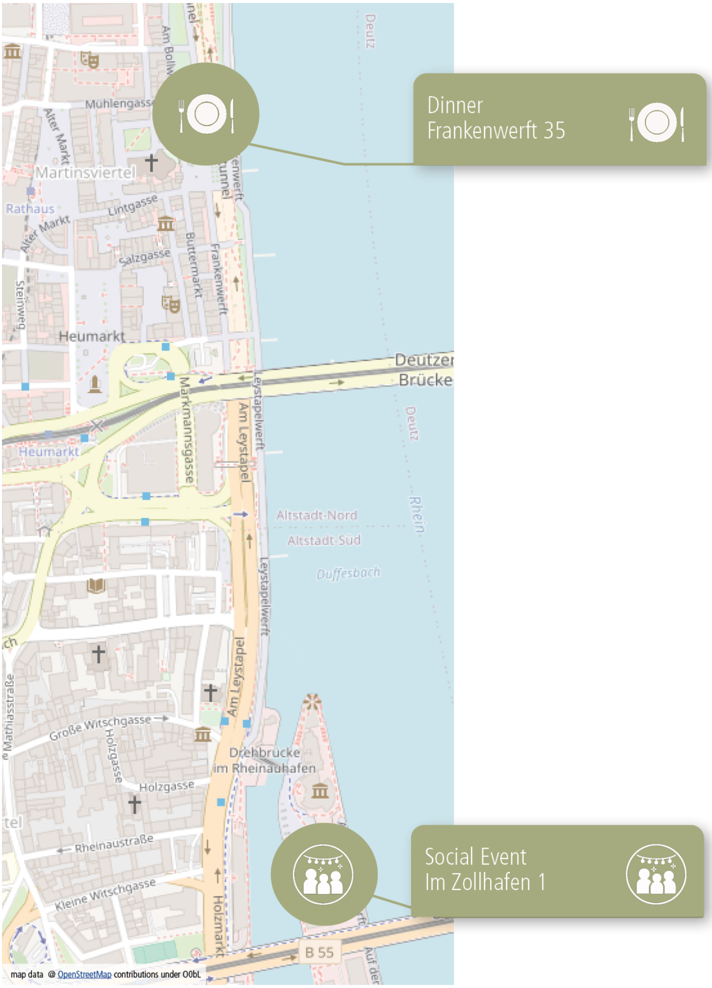
1. Line 12 to tram "Pohligstraße"
2. By Bus 142 to Bus Stop "Pohligstraße"

How to get to the lecture hall

The best way to reach the lecture hall 4.001 is to enter via **Hörniger Weg 100**, ring the bell "Hörsaal Universität zu Köln" and take the elevator or stairs up to the 4th floor. Entering from Pohligstr. 3 is also possible, but the way is much longer and more complicated. There will be signs in any case.

How to get to the social event and dinner

Walk to the nearest tram stop (Pohligstraße) and first take tram line 12 to Rudolfplatz and change there in tram line 1 or 7 towards Heumarkt. Get off at Heumarkt and walk about 10 minutes towards the Rhine. OR walk to the nearest bus stop and take bus 142 towards Ubierring (6 stopps), change at Ubierring to bus 133 towards Breslauer Platz/Hbf (3 stopps). Get off Schokoladenmusuem and walk about 2 minutes to the museum. The German Sport & Olympic Museum is located near the river, next to the Chocolate Museum.



Program Overview

TIME	MON 23 FEBRUARY	TUE 24 FEBRUARY
9:00		9:00 – 10:30 SESSION HIGHLIGHTS Aerosols
9:30		
10:00		
10:30		**COFFEE**
11:00		11:00 – 12:30 STRATEGIC QUESTION 1
11:30		
12:00		
12:30	**REGISTRATION DESK**	**LUNCH**
13:00		
13:30	13:30 – 14:30 WELCOME & INTRO	
14:00		14:00 – 17:00 POSTER SESSION I
14:30	**COFFEE**	
15:00	15:00 – 16:50 SESSION HIGHLIGHTS Mixed-phase Clouds	
15:30		
16:00		
16:30	16:50 – 17:05 SPECIAL TALK	
17:00		17:00 – 18:00 BREAKOUT SESSION
17:30	**GROUP PICTURE**	
18:00	**FINGER FOOD & EVENING TALK**	
18:30		
19:00		

TIME	WED 24 FEBRUARY	THU 26 FEBRUARY
9:00	9:00 – 10:30 SESSION HIGHLIGHTS Sea Ice	9:00 – 10:30 STRATEGIC QUESTION 3
9:30		
10:00		
10:30	**COFFEE**	**COFFEE**
11:00	11:00 – 12:30 STRATEGIC QUESTION 2	11:00 – 12:00 BREAKOUT SESSION
11:30		
12:00		WRAP UP
12:30	**LUNCH**	
13:00		
13:30	13:30 – 16:30 POSTER SESSION II	
14:00		
14:30		
15:00		
15:30		
16:00		
16:30		
17:00		
17:30	**SOCIAL EVENT**	
18:00		
18:30		
19:00		
19:30	**DINNER**	

Instructions for Participants

Instructions for Speakers

- Rooms will have a digital projector, pointer and computer. A microphone system is available.
- We prefer to collect all presentations at one laptop before the session organized by the session chairs.
- A volunteer will be on hand to help.
- The time allocated to each speaker, **including** time to set up and time for discussion, is:
  - Keynote talks: 30 minutes
  - Session talks: 20 minutes

Instructions for Session Chairs

- Please stick to the schedule and moderate questions.

Instructions for Poster Presenters

- There will be two poster sessions on Tuesday and Wednesday. Both poster sessions will take place in the lecture hall as well. (We welcome volunteers to help with the rearrangement.)
- Presenters should arrive in advance to set up their posters.
- Poster boards will be usable on both sides, where one side will be used in Session I, other side in Session II.
- Each presenter will be provided with a 1m x 1.5m poster board and drawing pins (A0 format).
- Poster boards will be grouped according to numbering (please see poster list); labels will be provided so you can easily find the poster boards.
- Presenters should remove their poster at the end of the conference.

Conference Program

MONDAY, 23 February 2026

13:00	*Registration desk*
13:30 - 14:30	**Welcome & Intro**
13:30 - 13:40	Welcome – *Susanne Crewell (University of Cologne)*
13:40 - 14:30	Opening & Status of the project – *Manfred Wendisch (Leipzig University)*
14:30 - 15:00	*Coffee break*
15:00 - 16:50	**Session Highlights – Mixed-phase Clouds**
	Session Chairs: Hannah Sundermann (TROPOS) & André Ehrlich (Leipzig University)
15:00 - 15:30	**Keynote talk:** Arctic mixed-phase clouds: Processes, implications, and questions – *Matthew Shupe (University of Colorado)*
15:30 - 15:50	Multi-Spectral Retrieval of Cloud Phase and Water Path, Validated Using Active Satellite Measurements – *Alexander Mchedlishvili et al. (University of Bremen)*
15:50 - 16:10	Surface-coupling effects on Arctic mixed-phase clouds during MOSAiC – *Hannes Griesche et al. (TROPOS)*
16:10 - 16:30	Confronting resolved turbulence in Large-Eddy Simulations of Arctic mixed-phase clouds with aerial system data collected during the MOSAiC drift – *Xinyuan Zhou et al. (University of Cologne)*
16:30 - 16:50	Flying into the Cold: The NSF Cold-Air outbreak Experiment in the Sub-ARctic (CAESAR) – *Paquita Zuidema et al. (University of Miami)*
16:50 - 17:05	**Special talk:** The Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE): Overview, First Results, and Next Steps – *Tristan L'Ecuyer (University of Wisconsin-Madison)*
17:05	**Group photo**
18:00 - 22:00	**Finger Food & Evening Talk**
19:00	**Evening talk:** Inhabiting Liquescence: How Circumpolar People live with Arctic Amplification – *Franz Krause (University of Cologne, Department of Social and Cultural Anthropology)*

TUESDAY, 24 February 2026

09:00 – 10:30 **Session Highlights - Aerosols**
Session Chairs: Linus Andrae (University of Bremen) & Kathy Law (LATMOS/IPSL-CNRS, Sorbonne Université)

09:00 – 09:30 **Keynote talk:** 40 Years of Arctic Aerosol Research at the Department of Meteorology, Stockholm, Highlights and Open Questions – *Jost Heintzenberg (TROPOS)*

09:30 – 09:50 Effect of Aerosols on Cloud Phase during Atmospheric River Events – *Fathima Cherichi Purayil et al. (Leipzig University)*

09:50 – 10:10 Transport of smoke from boreal wildfires to the Arctic – *Swetlana Paul et al. (TROPOS)*

10:10 – 10:30 Creation and Validation of an Aerosol Optical Depth Time Series of Pan-Arctic Scale – *Linus Andrae & Neha Mehendale et al. (University of Bremen)*

10:30 - 11:00 *Coffee break*

11:00 – 12:20 **Session Strategic Questions (SQ) – SQ1: What are the main drivers and relative contributions to Arctic Amplification?**
Session Chairs: Lena Bruder (University of Cologne) & Dörthe Handorf (AWI Potsdam)

11:00 – 11:20 The effect of improved turbulence parametrization in ICON-NWP on simulations of Arctic winter stable-boundary layers – *Florian Gebhardt et al. (AWI Potsdam)*

11:20 – 11:40 A Python-based package to compute climate storylines applied to arctic-midlatitude linkages – *Richard Alawode et al. (Leipzig University)*

11:40 – 12:00 Evaluation of the ICON Sea Ice Albedo Parametrization against Arctic observations – *Josien Rompelberg et al. (AWI Potsdam)*

12:00 – 12:20 Plenum discussion

12:30 - 14:00 *Lunch break*

14:00 – 17:00 **Poster session I – Mixed-phase clouds & Sea Ice (see poster list)**
including *Coffee break*

17:00 – 18:00 **Breakout session** (parallel)
CCA1 Convection – *Johannes Quaas (Leipzig University)*
CCA4 Air mass transport & transformation – *Sofie Tiedeck (AWI Potsdam)*

WEDNESDAY, 25 February 2026

09:00 – 10:30	**Session Highlights – Sea Ice**
	Session Chairs: Maximilian Ringel (University of Bremen) & Janna Rückert (University of Bremen)
09:00 – 09:30	**Keynote talk:** A new ice fracture model based on thin elastic plate theory – *Bruno Tremblay (McGill)*
09:30 – 09:50	Arctic Ocean Heat Transport and Mixing – *Khaled Al Hajjar et al. (Leipzig University)*
09:50 – 10:10	Sea ice deformation: A dynamics view of Arctic sea ice and its interaction with the climate system – *Linxin Zhang et al. (University of Bremen)*
10:10 – 10:30	Retrieving Arctic Summer Sea Ice Thickness below Melt Ponds from Hyperspectral Optical Measurements – *Maximilian Ringel et al. (University of Bremen)*
10:30 - 11:00	*Coffee break*
11:00 – 12:30	**Session Strategic Questions – SQ2: How do meridional transport change affect Arctic and midlatitude climate?**
	Session Chairs: Awadhesh Pant (University of Cologne) & Susanne Crewell (University of Cologne)
11:00 – 11:30	**Keynote talk:** Characterizing High-Latitude Precipitation Phase During Atmospheric River Events – *Claire Pettersen (University of Michigan)*
11:30 – 11:50	Quantifying the temporal variability of water vapor in Ny-Ålesund and its relation to weather systems – *Christian Buhren et al. (University of Cologne)*
11:50 – 12:10	Diagnosing moisture sources, transport and transformation in the Arctic with water vapor isotopes in atmospheric modeling – *Hannah Marie Eichholz et al. (Leipzig University)*
12:10 – 12:30	Plenum discussion
12:30 - 13:30	*Lunch break*
13:30 – 16:30	**Poster session II – Aerosols, SQ1, SQ2 & SQ3 (see poster list)**
including	*Coffee break*

17:30	**Social event** (reservation required) Deutsches Sport & Olympia Museum (Im Zollhafen 1, 50678 Köln) Guided Tour & Team Event
19:30	**Dinner** (reservation required) Dom im Stapelhaus (Frankenwerft 35, 50667 Köln)

THURSDAY, 26 February 2026

09:00 – 10:30	**Session Strategic Questions – SQ3: What trends from Arctic Amplification are observable, and how will they evolve in a warmer climate?** *Session Chairs: Sophie Vliegen (Leipzig University) & Sandro Dahlke (AWI Potsdam)*
09:00 – 09:30	**Keynote talk:** Arctic change, the polar vortex, winter weather and extremes – *Judah Cohen (Massachusetts Institute of Technology)*
09:30 – 09:50	Arctic cyclones: Impacts on sea ice and future changes – *Lars Aue et al. (AWI Potsdam)*
09:50 – 10:10	How Well Do CMIP6 Models Capture Northern Hemisphere Circulation Patterns? A Data-Driven Analysis – *Abdellah Bizdaz et al. (Leipzig University)*
10:10 – 10:30	Plenum discussion
10:30 - 11:00	*Coffee break*
11:00 – 12:00	**Breakout session** (parallel) CCA2: Surface parametrizations – *Evi Jäkel (Leipzig University)* CCA3: Arctic mixed-phase clouds – *Vera Schemann (University of Cologne)*
12:00 - 12:30	**Wrap up** - *Manfred Wendisch (Leipzig University)*
12:30	**End of conference**

$(\mathcal{AC})^3$ is going to cover the finger foods on Monday, dinner, non-alcoholic drinks and Social Event on Wednesday, as well as all coffee and lunch breaks during the conference via the central project Z01. Childcare is covered via the $(\mathcal{AC})^3$ equal opportunity funds.

Poster Session I - Mixed-phase clouds & Sea Ice

#1 Assessment of Circulation Weather Types around Svalbard and their Impact on the Ny-Ålesund atmospheric column – *Philip Eisenhuth et al. (AWI Potsdam)*

#2 Arctic Cloud Regimes and Their Radiative Effect Based on MOSAiC Observations – *Hartwig Deneke (TROPOS)*

#3 Evaluation of summertime Arctic surface cloud radiative effect derived from satellite products against aircraft observations during NASA ARCSIX – *Sebastian Becker et al. (University of Cologne)*

#4 Impacts of mesoscale subsidence on glaciation and decoupling in Arctic marine cold air outbreaks – *Fiona Paulus et al. (University of Cologne)*

#5 Quantifying the Evolution of Cloud Street Structures During Arctic Marine Cold Air Outbreaks Using Satellite Observations – *Hannah Sundermann et al. (TROPOS)*

#6 Cloud state transitions at Ny-Ålesund: A machine learning supported statistical analysis – *Andreas Walbröl (University of Cologne)*

#7 An assessment of water vapor entrainment fluxes under specific humidity inversions using a year of LES data for the MOSAiC drift – *Patrick Zobec et al. (University of Cologne)*

#8 VAMPIRE dataset - Arctic clouds, water vapor and sea ice emissivity – *Linnu Bühler (University of Cologne)*

#9 Exploring Aerosol-Cloud Interactions in Arctic Mixed-Phase Clouds Using ICON-LEM – *Lena Bruder et al. (University of Cologne)*

#10 IOP4H2O: Investigating the Arctic water cycle in highresolution observations and modeling – *Sabrina Schnitt et al. (University of Cologne)*

#11 Doppler Velocity Derivation and EarthCARE CPR Assessment based on the COMPEX-EC Arctic Airborne Campaign – *Lars van Gelder et al. (University of Cologne)*

#12 Investigation of water vapor isotopes during an atmospheric river event using model data and satellite retrievals – *Angel Ignatious et al. (University of Bremen)*

#13 Investigation of precipitation sublimation and evaporation with active remote sensing in Ny-Ålesund – *Andreas Foth et al. (Leipzig University)*

#14 Retrieving Capacitance and Ventilation Factor Using Observations of Sublimating Snowfall – *Beril Aydin et al. (Leipzig University)*

#15 Evaluating the snow microwave radiative transfer model SMRT over sea ice for atmospheric sounding frequency channels: Comparison to in-situ data from three Arctic ship – *Janna Rückert et al. (University of Bremen)*

#16 Contrasting Optical Properties in Different Sea Ice Regimes – *Florian Zimmer et al. (AWI Bremerhaven)*

#17 Improving and validating the TROPOMI tropospheric BrO retrieval in the Arctic – *Bianca Zilker et al. (University of Bremen)*

#18 The effect of surface heterogeneity on the Arctic surface energy budget: From low-level airborne in-situ observations to satellite retrievals – *Joshua Müller et al. (Leipzig University)*

#19 Recent improvements of the surface albedo scheme in HIRHAM-NAOSIM – *Patrizia Schoch et al. (Leipzig University)*

#20 Snow-age-dependent parameterization of snow density and conductivity for the use in climate models – *Wolfgang Dorn et al. (AWI Potsdam)*

#21 Characterizing dimensionless sea-ice heterogeneity parameters in the Arctic boundary layer – *Ilga Staudinger et al. (University of Cologne)*

#22 Constraints on Southern Ocean Mesoscale Cellular Convective Cell Growth – *Anna Possner et al. (Goethe University of Franktfurt)*

Poster Session II – Aerosols, SQ1, SQ2 & SQ3

#23 Marine carbohydrates in Arctic aerosol particles – connections to oceanic emissions and in-situ processing – *Manuela van Pinxteren et al. (TROPOS)*

#24 In situ aerosol and turbulence observations in Antarctica during the SANAT campaign – *Laura Köhler et al. (AWI Bremerhaven)*

#25 Patterns and Long-Term Trends of Primary Marine Organic Aerosol in the Arctic – *Bernd Heinold et al. (TROPOS)*

#26 Tethered balloon-borne measurements for the characterization of the evolution of the Arctic atmospheric boundary layer at Station Nord – *Henning Dorff et al. (Leipzig University)*

#27 Validation of a Aerosol Optical Depth Retrieval over high albedo surfaces – *Linus Andrae et al. (University of Bremen)*

#28 Patterns and Trends of Arctic Aerosols from a Merged Dataset of Satellite Retrievals Across Different Surface Types – *Neha Mehendale et al. (University of Bremen)*

#29 Radiatively driven entrainment and turbulence forcing at Arctic cloud tops from 2D imaging and atmospheric profiling – *Michael Schäfer et al. (Leipzig University)*

#30 Cloud Regime Classification and Evolution during Arctic Cold Air Outbreaks – *Marcus Klingebiel et al. (Leipzig University)*

#31 Quantifying the influence of Barents-Kara sea ice loss on Ural blocking – *Ernest Agyemang-Oko et al. (Leipzig University)*

#32 Temperature and humidity trends from Ny-Ålesund balloon-borne measurements – *Marion Maturilli et al. (AWI Potsdam)*

#33 Balloon-borne observations and simulations of the transition phases in the wintertime Arctic atmospheric boundary layer at Station Nord, Greenland – *Komal Navale et al. (TROPOS)*

#34 Evaluating Reanalysis Snowfall Estimates in the Arctic using Flight Based Radar Observations – *Awadhesh Pant et al. (University of Cologne)*

#35 Macro- and Microphysical Properties of Atmospheric River Snowfall: Results from Two Instrument Sites – *Jack Richter et al. (University of Michigan)*

#36 Identifying drivers of the thermal-infrared radiative effect of Arctic low-level clouds in cold air outbreaks – *Sophie Rosenburg et al. (Leipzig University)*

#**37** Extending the Surface Energy Budget View on Arctic Atmospheric Rivers: Climatological Classifications and Dependence on the Flavor – *Sofie Tiedeck et al. (AWI Potsdam)*

#**38** A Ground and Satellite Based Characterization of Atmospheric River Impacts on Clouds and Precipitation in Greenland – *Alanna Wedum et al. (University of Michigan)*

#**39** The changing role of convection in the Arctic – *Sophie Vliegen et al. (Leipzig University)*

#**40** Evaluating Fog Forecasts in the Central Arctic Ocean Using AO2025 Observations – *Luise Schulte et al. (University of Cologne)*

Arctic mixed-phase clouds: Processes, implications, and questions

M.D. Shupe[1,2]

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Arctic mixed-phase clouds are iconic: Their role and importance are widely recognized, but few understand their intimate details. This presentation will examine the properties and processes that make mixed-phase clouds so unique and resilient. It will then explore some of the many impacts of these clouds on an Arctic system in rapid transition. Lastly, it will formulate outstanding questions that continue to hinder our understanding and modeling of these clouds and require further research.

Multi-Spectral Retrieval of Cloud Phase and Water Path, Validated Using Active Satellite Measurements

A. Mchedlishvili[1], M. Vountas[1], T. Weichert[2], K. S. Vinjamuri, V. Rozanov, H. Bösch[1]

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Cloud phase is an important parameter in determining climate feedbacks and processes, as well as the Earth's energy budget. This information is particularly valuable in the Arctic, where optically thick liquid clouds can significantly increase the downward infrared radiative flux and thereby contribute to Arctic warming. The retrieval of cloud phase in the Arctic region is made difficult by the bright surfaces like ice and snow, ubiquitous temperature inversion and low temperature contrasts. In-situ and airborne campaigns, and to a lesser degree active satellite measurements, lack the sufficient spatiotemporal sampling to derive an Arctic-wide climatology. For complete Arctic coverage, wide-swath passive instrument retrievals are needed. Here, we demonstrate the capabilities of the Sea and Land Surface Temperature Radiometer (SLSTR) onboard Sentinel-3 in distinguishing liquid, ice, and mixed-phase clouds. Its dual-view geometry, multi-spectral channels, and high radiometric stability enable reliable detection of thin and low clouds. In [1] and [2], the sensitivity of Sentinel-3 SLSTR infrared bands to cloud phase is investigated using SCIATRAN radiative-transfer simulations and validated against CloudSat–CALIPSO (radar/lidar) observations. We have since extended this study to investigate both the near-infrared and mid/long-wave infrared classification indices over different Arctic surface types, validated using EarthCARE observations. Beyond classification, we have also made progress in the quantification of cloud ice and water content. Using SCIATRAN-derived weighting functions, we evaluate the capability of the SLSTR to retrieve liquid and ice water path. We demonstrate that while bright surface types are still a challenge, the passive radiometer is capable of detecting liquid/ice water path over the open ocean. Finally, we present results from testing several machine-learning models to evaluate whether their ability to represent complex nonlinear relationships improves cloud-property retrievals from the SLSTR radiances and brightness temperatures, particularly over snow and ice.

We would like to thank Matt Shupe, Luca Lelli, Hannes Griesche and John Burrows for their support and contributions to this work, as well as ESA, NASA and JAXA for the missions which provided the data we used for this study.

References

[1] Vinjamuri, K. S., Vountas, M., Rozanov, V. et al., *Sensitivity of Near-Infrared Bands to Cloud Phase: An Assessment Using Dual-View Satellite Measurements*, JQSRT (2025). submitted.

[2] K. S. Vinjamuri, M. Vountas, V. Rozanov et al., *Cloud phase classification using SLSTR measured brightness temperatures at 3.74, 10.80, 12 μm*, JQSRT, (2025). submitted.

Surface-coupling effects on Arctic mixed-phase clouds during MOSAiC

H. J. Griesche[1], R. Engelmann[1], M. Radenz[1], J. Hofer[1], D. Althausen[1], A. Ansmann[1], K. Berry[2], J. Creamean[2], C. Jimenez[1], P. Seifert[1]

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Shallow mixed-phase clouds are a prominent feature in the Arctic due to their frequent occurrence, persistent lifetime, and significant impacts on the local climate. These clouds occur either coupled or decoupled from the surface mixed-layer (SML) and the respective coupling state impacts their microphysical properties, especially at slight supercooling temperatures where the conditions for formation of mixed-phase clouds is strongly controlled by the available ice nucleating particles (INP). During a two-months summer cruise in 2017, SML-coupled clouds were observed to contain ice more often than decoupled clouds at low-supercooling temperatures, presumably due to a larger availability of INPs in SML-coupled conditions [1]. Here, the annual cycle of Arctic mixed-phase cloud ice formation temperatures is presented for the year-long Arctic ice-drift experiment Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) in 2019 and 2020. From October 2019 through March 2020 no clouds with cloud minimum temperatures above $-10\,^{\circ}$C were observed. From April to September 2020 an increased fraction of ice-containing clouds was observed for clouds with cloud minimum temperatures between $-7.5\,^{\circ}$C and $-5\,^{\circ}$C (between 40% and 70%). The clouds were separately analyzed by their SML-coupling state. From April to July SML-coupled clouds with a minimum temperature above $-7.5\,^{\circ}$C showed a strongly enhanced fraction of ice-containing clouds, compared to decoupled clouds. SML-coupled clouds during this period showed a 2–3 times higher probability to contain ice at temperatures above $-15\,^{\circ}$C. The found correlation between occurrence of ice in SML-coupled clouds and surface-based INP measurements suggests that the observed phenomena can likely be attributed to the presence of INPs active above $-15\,^{\circ}$C at the surface. Analysis of sea-ice concentration in the surrounding region, the distance of the observational site to the ice edge, and the travel time along the back-trajectories of the observed cloud to the marginal ice zone support this finding. In August + September the ratio of coupled-to-decoupled ice-containing clouds was reduced to 1.3, due to a higher frequency of occurrence of ice-containing decoupled clouds. Free-tropospheric cloud statistics for MOSAiC [2] indicate that these decoupled, ice-containing clouds at $T > -10\,^{\circ}$C in August + September are mostly likely still influenced by surface processes and a clear separation from the surface is only reached in higher altitudes.

References

[1] H. J. Griesche, K. Ohneiser, P. Seifert et al., Atmos. Chem. and Phys. **21** (2021), DOI 10.5194/acp-21-10357-2021.

[2] C. Jimenez, A. Ansmann, K. Ohneiser et al., Atmos. Chem. and Phys. **25** (2025), DOI 10.5194/acp-25-12955-2025.

Confronting resolved turbulence in Large-Eddy Simulations of Arctic mixed-phase clouds with aerial system data collected during the MOSAiC drift

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Mixed-phase clouds play a key role in shaping the Arctic atmospheric boundary layer (ABL). Cloud-top radiative cooling drives turbulent processes within these clouds and influences their microphysical and thermodynamic behavior. In recent years, large eddy simulations (LES) have been increasingly used as a research tool for investigating the Arctic atmospheric boundary layer under different conditions. Although encouraging results have been obtained with LES in Arctic conditions, the observational data needed to critically assess its skill in resolving Arctic turbulence were hard to obtain. The recent MOSAiC expedition provides unique and state-of-the-art in situ data on turbulence in Arctic ABLs that can effectively be used to evaluate LES. Building on this, this work aims to estimate and optimize the simulation performance of the Dutch Atmospheric Large Eddy Simulation (DALES) model on turbulence by comparing with Campaign datasets. A recently published measurement-informed standardized setup is used to simulate the Arctic boundary layer on two selected cases based on MOSAiC data. Preliminary results show it's feasible to compare the LES energy spectrum with observation datasets. LES simulations in both cases show some agreement with observations in turbulent variance profiles. From the energy spectrum, the inertial subrange following -5/3 can be found in LES for both cases. Compared with observation, both cases verify that LES can resolve large-scale eddies in the inertial subrange, and LES is filtered in smaller-scale eddies. The dissipation rates from LES and observations are also nearly in the same order of magnitude. Overall, DALES partially reproduces the turbulence in the inertial subrange from our case study. But further sensitivity test is also needed in the future.

Flying into the Cold: The NSF Cold-Air outbreak Experiment in the Sub-ARctic (CAESAR)

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The NSF-sponsored Cold-Air outbreak Experiment over the Sub-Arctic Region (CAESAR) characterized the aerosol, thermodynamic and dynamic environment occupied by mixed-phase clouds within air masses moving southward off the Arctic sea ice over the Greenland/Norwegian Seas in the spring of 2024. The aircraft campaign, deployed from Kiruna, Sweden, supported an unprecedented suite of remote sensing and in-situ measurements below, within and above the mostly shallow convective clouds. Although the campaign only ultimately included 8 flights, the data quality is high. A typical flight plan began with a high-altitude survey leg that included dropsondes, followed by a spiral descent at the furthest point, then in situ sampling back to the coast. Three flights reached the Greenland Marginal Ice Zone. A golden-case cold-air outbreak was sampled from its origin in clear skies over 100% sea ice to its convergence with a land-skirting polar low. Another flight was dedicated to sampling a polar low, and a third flight characterized a closed-to-open cell transition occurring under high aerosol loading originating from northern Siberia. CAESAR was the first deployment of the downward-pointing Multi-function Airborne Raman Lidar (MARLi) upon the C-130 plane, providing sub-plane temperature and water vapor profiles. An upward-pointing G-band Vapor Radiometer resolved mesoscale super-cooled liquid water path variability. Other active remote sensors include an up- and down- pointing W-band cloud radar, down-pointing K-band precipitation radar, and up-pointing Wyoming Cloud Lidar. The microphysical suite included a Nevzorov hot wire probe, HOLODEC-II imaging, and PHIPS probe. The aerosol data have been merged to capture the full size distribution. Combined ice particle and nucleating particle concentrations suggest most ice production is primary at the most commonly-occurring cloud temperatures (-10 to -20 Celsius), with pockets of secondary ice production. Interest is sought both in integrating the data with $(\mathcal{AC})^3$ cold-air outbreak characterizations and developing a common modeling effort.

The Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE): Overview, First Results, and Next Steps

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NASA's Polar Radiant Energy in the Far Infrared Experiment (PREFIRE) mission launched in summer 2024 to map Earth's emission spectrum and examine the processes that modulate it at high latitudes. The Thermal InfraRed Spectrometers (TIRS) aboard both of PREFIRE's 6U CubeSats, measure emitted radiation from 5 to 53 m with 0.84 m sampling. These near-complete spectra are the first far-infrared measurements of Earth since early experimental missions in the 1970's and 80's offering the potential to provide new insights into the spectral character of surface emission and the atmospheric greenhouse effect (AGHE) in cold, dry polar environments. This presentation will provide an overview of PREFIRE and summarize initial results from its first 18 months in orbit. Examples of PREFIRE's atmospheric and surface property products and preliminary efforts to use them to diagnose the factors that influence polar energy flows will be highlighted. The outstanding PREFIRE mission objectives and validation needs will be discussed to identify areas of potential overlap with upcoming $(\mathcal{AC})^3$ deployments and analyses.

Inhabiting Liquescence: How Circumpolar People live with Arctic Amplification

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Arctic amplification is commonly framed as a problem of feedbacks, thresholds and accelerating physical change. This talk approaches the same phenomenon from a different analytical vantage point: the lived realities of circumpolar Indigenous people for whom amplification is not an abstract signal but an everyday condition of life. Drawing on ethnographic fieldwork, in particular with Gwich'in and Inuvialuit of the Western Canadian Arctic, I argue that Indigenous experiences of a rapidly warming Arctic challenge not only what we know about climate change, but how we know it.
Indigenous knowledges are now firmly established as important sources for studying Arctic change. Yet they are often treated instrumentally: as localised observations to be extracted and translated into scientific models. This talk asks a different question: what if Indigenous knowledges are not supplementary data points, but alternative epistemologies and ontologies—distinct ways of knowing, inhabiting and relating to a liquefying world? What can we learn about arctic amplification if we approach it not in terms of liquefaction (the thawing of ice and ground), but of liquescence (the experience of inhabiting thaw)?
For circumpolar people, climate change intersects with ongoing struggles over self-government, health, education, employment and cultural resurgence. Environmental upheavals are experienced not in isolation, but as part of a broader condition of "overheating" across climate, economy and culture. In Gwich'in and Inuvialuit lands, a warming climate increases uncertainty not uniformly, but seasonally: while summer and winter remain relatively legible, the lengthening and increasingly dangerous periods of freeze-up and break-up now constrain mobility, subsistence and safety.

40 Years of Arctic Aerosol Research at the Department of Meteorology, Stockholm, Highlights and Open Questions

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Since 1978 MISU has been engaged in Arctic aerosol research on both land and ocean. The history of this engagement can be divided into three phases. The first ten years were largely dedicated to the understanding of the phenomenon of Arctic haze, its physico-chemical properties, potential source regions, and effects on the atmospheric energy balance. During this first phase the site-search and establishment of an atmospheric background monitoring station developed as a second research focus. Through major Norwegian investments this effort yielded the Zeppelin station near Ny-Ålesund that has developed into a major monitoring facility serving also as base for advanced Arctic aerosol process studies that became the third and ongoing research phase. Low-level clouds in the high Arctic play a key role in regulating surface energy fluxes that affect how the sea ice freezes and melts. In particular, during late summer, when the albedo of the sea ice is at a minimum, cloud albedo could control the timing of the autumn freeze-up. Thus, the regional aerosol and its sources over the pack ice potentially play a significant role in regulating the surface energy budget through aerosol-cloud interactions. A major part of this third phase was based on five summer research cruises of the Swedish icebreaker Oden to the North Pole in 1991, 1996, 2001, 2008, and 2018. In the light of the dramatic regional climate changes, the evaluation of the long-term aerosol time series at the Zeppelin station and the synopsis of the results of the process studies on the Oden cruises provide the major themes of ongoing research, from which highlights and open questions will be presented.

Effect of Aerosols on Cloud Phase during Atmospheric River Events

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Aerosol atmospheric rivers(AAR) are narrow and long filamentary structures that transport concentrated aerosol plumes from mid-latitudes to the Arctic [1]. Studies suggest that their co-occurrence with the classical atmospheric river can influence the clouds formed during such events [2]. However, the extent to which aerosol-rich ARs enhance glaciation, alter ice fraction, or modulate precipitation during Arctic ARs remains largely unconstrained especially on long-temporal and spatial scales.

In this study, we address this gap by applying a polar specific AR and AAR detection algorithm to identify co-occurring extreme aerosol and moisture transport events over the Arctic over a 44-year period. Using DARDAR-Nice cloud property retrievals, we examine how these aerosol rich ARs modify cloud microphysical properties across the Arctic. We hypothesize that co-occurring AR–AAR events exhibit distinct microphysical signatures on Arctic clouds, differing from AR intrusions without this accompanying aerosol enhancements.

Results suggest that at least 40% of the times an AR is accompanied by an AAR. These aerosols are mainly dust, black carbon or organic carbon. Cloud phase revealed a higher cloud top ice fraction when these aerosol concentration is elevated during ARs, suggesting their role as serving as ice nucleating particles. This higher ice fraction likely enhances precipitation during such events.

These findings indicate that aerosol-rich ARs can modify Arctic cloud radiative properties, precipitation efficiency, and surface energy balance. They highlight the importance of considering co-occurring moisture and aerosol transport in Arctic climate studies, particularly for understanding microphysical cloud responses under aerosol-enhanced conditions.

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Transport of smoke from boreal wildfires to the Arctic

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Weather conditions favoring wildfires will likely become more frequent in a warming climate – this might lead to stronger fire activity, particularly in moderately moist, biomass-rich areas such as boreal forests [1]. Severe wildfires can emit large amounts of smoke, which may be lofted to altitudes reaching the stratosphere, potentially causing a prolonged atmospheric perturbation [2]. Yet, it is not fully clear which role aerosols from high-latitude wildfires play in Arctic warming.
In simulations with the global aerosol-climate model ECHAM6.3.0-HAM2.3 spanning five years (2016–2021), the contribution of boreal forest fire smoke aerosol to the total Arctic aerosol burden was quantified. In the model setup, aerosol emissions originating from boreal wildfires were separated from aerosol emissions from wildfires in other regions, making it possible to distinctly analyze wildfire smoke from the boreal biome.

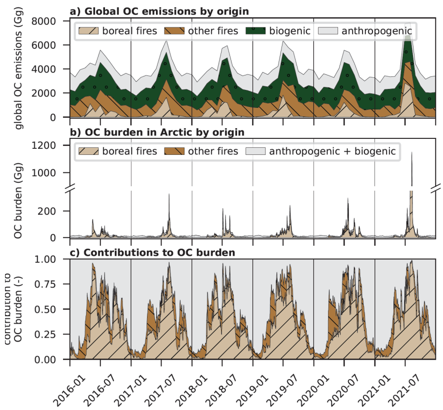

Fig. 1: a) Global emissions of OC by origin. b) Total OC burden over the Arctic by origin. c) Relative contributions to Arctic OC burden.

Although accounting for only a small part of global aerosol emissions, boreal wildfires dominate the Arctic aerosol composition during summer: organic carbon (OC) from summer boreal wildfires globally makes up around 17% of total OC emissions (average over summer months of the modeled period), but contributes to about 60% of the Arctic OC burden (see Fig. 1). Black carbon (BC) from summer boreal wildfires accounts for about 9% of global BC emissions and 52% of the Arctic BC burden. In winter, anthropogenic sources dominate both Arctic OC and BC.
To study the poleward transport of aerosol from boreal wildfires in more detail, we conduct kilometer-scale simulations of forest fires with the ICON-HAM-lite-model, which are particularly well-suited to represent vertical mixing. First results from wildfires in Alaska/Yukon during June 2025 will be presented.

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Creation and Validation of an Aerosol Optical Depth Time Series of Pan-Arctic Scale

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Climate change is influenced by aerosols — liquid and solid particles suspended in the atmosphere — that influence cloud properties and incoming solar radiation [1]. The B02 sub-project tries to answer what role aerosols play in Arctic amplification by building a more complete picture of the aerosol regime and its seasonal and regional differences in the Arctic using satellite data. The Aerosol Optical Depth (AOD) as a measure of total column aerosol load is used to create a long term data set combining different satellite products.
The created long term record is contributing to the strategic question 3 (SQ3), by investigating if any trends in aerosols can be identified in the Arctic over the past decade during Arctic Amplification. Overall, the project contributes to clarify the role of aerosol direct and indirect effects in the specific Arctic environment, addressing strategic question 1 (SQ1) as well.
In this talk the current status of the development of the merged dataset as well as an additional retrieval of AOD over the cryosphere is presented.

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The effect of improved turbulence parametrization in ICON-NWP on simulations of Arctic winter stable-boundary layers

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During Arctic winter conditions turbulent fluxes play a major role coupling the sea-ice surface with the atmosphere aloft. Since climate models often struggle to accurately model this turbulent exchange in the predominantly stably stratified Arctic boundary layer it is still a major source of model uncertainty [1]. Therefore, we implemented an improved turbulent flux parametrization [2] into ICON-NWP based on observations from the SHEBA campaign in 1997 and evaluate the results with observations from the MOSAiC expedition [3]. The new parametrization is tested in a limited-area set-up with 2.5 km resolution as well as in a Pan-Arctic set-up with 11km resolution. The simulations are forced with ERA-5 and use an adapted sea-ice scheme [3]. The new parameterization improves fluxes in very stable situations by strongly reducing turbulent heat flux. This leads to stronger near-surface stability and slightly higher wind speeds while revealing general model deficiencies. These effects are also evident in the Pan-Arctic set-up and show significant changes over all sea-ice covered areas with regional varying patterns that are further investigated.

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A Python-based package to compute climate storylines applied to arctic-midlatitude linkages

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Dynamical storylines explore qualitatively different changes in climate driven by forced responses in large-scale remote drivers, such as Arctic Amplification, tropical amplification, and the stratospheric polar vortex [1–4]. This approach helps address uncertainties in regional climate responses by using physical understanding to link large-scale thermodynamic and dynamic climate responses to regional impacts and present a small set of projections in a conditional way. By contextualizing events within broader climate patterns, dynamical storylines aim to deepen understanding of the uncertainties associated with climate change, particularly in relation to polar, tropical, and global warming. Our project aims to make this advanced methodology accessible to a broader audience through a user-friendly Python package and an intuitive interface. Our package, termed "storypy", provides a set of functions to analyze multi-model ensembles by focusing on the identification of dynamical storylines. With customizable options for selecting remote drivers, target seasons, and climate variables or climatic-impact drivers, the storypy provides flexibility and adaptability for various research and policy applications. We show the usability of the tool by applying it to the case of the Northern hemisphere and analyze regional climate uncertainty associated with drivers including Arctic Amplification and the Stratospheric polar vortex in CMIP6.

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Evaluation of the ICON Sea Ice Albedo Parametrization against Arctic observations

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Climate models have difficulties accurately representing Arctic mid-latitude linkages. This might partly be caused by surface parametrizations that are not able to accurately represent the Arctic surface conditions, resulting in misfitted energy exchanges between surface and atmosphere. Sea ice surface albedo (SIA) is a sub-grid variable that controls the energy input in the Arctic region and therefore the energy exchange between surface and atmosphere. In this project the SIA parametrization for the Icosahedral Nonhydrostatic (ICON) model is evaluated using Arctic observational data. This includes both on-ice measurements to capture the SIA temporal evolution (MOSAiC) and airborne measurements to capture a larger spatial variability (ACLOUD/ AFLUX, MOSAiC, PARACMip, HALO-$(\mathcal{AC})^3$). An offline evaluation, where the SIA parametrization is isolated from the ICON model and uses observations for the parametrization inputs, shows that the MOSAiC SIA is well captured by the parametrization. Agreement with the airborne observations is less good. However, due to the prognostic nature of the parametrization in combination with the constantly changing surface of the airborne measurements, the offline evaluation's appropriateness is limited. Current work in progress focusses on limited area ICON simulations that cover the airborne campaign sites, to evaluate how well the parametrization captures the spatial variability observed, as well as to point out in-model error sources.

A Thin-Elastic-Plate Model of Ocean-Wave-Induced Sea Ice Fracture for Climate Models – A Unified Ocean-Wave-Induced Sea Ice Fracture Model for Climate Models

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Ocean wave ice interactions dictate the width of the marginal ice zone where increased sea ice melt is present in the winter and new ice formation in the winter. Existing sea ice fracture models predict fracture when one of two limits is reached: (i) a maximum strain failure criterion assuming that the ice is a perfectly flexible plate that follows the ocean surface, and (ii) a maximum stress failure criterion assuming that the ice is a perfectly rigid plate that does not deform under the action of buoyancy and gravity forces. The perfectly rigid sea ice plate model is valid for small wavelengths that have a short lever arm, but systematically predicts fracture for long wavelength irrespective of the amplitude because of the long lever arm. Conversely, the flexible plate model is valid for long wavelength but systematically predicts fracture for short wavelengths because of the unrealistically large strain. In this work, we present a unified sea ice fracture model based on elastic beam theory for the bending of a sea ice plate that is valid for all wavelengths and reduces to the rigid plate and fully flexible model for short and long incoming ocean wavelength limits, respectively. The model produces floe size distributions with physically consistent dependencies on ice thickness and elastic properties for realistic fully-developed ocean wave field.

Arctic Ocean Heat Transport and Mixing

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The Arctic Ocean plays a key role in amplifying regional climate warming [1, 2], with ocean heat transport (OHT) and vertical mixing strongly influencing surface temperature and sea-ice evolution [3]. However, heat redistribution pathways and timescales remain poorly constrained due to sparse observations and coarse model resolution [3, 4]. We use simulations with the Finite-volumE Sea ice-Ocean Model (FESOM2) [5], employing a coarse CORE2 mesh and a high-resolution tracer-resolving adaptive (TRAC) mesh [6], to investigate Arctic heat transport and mixing. The TRAC configuration resolves mesoscale features and improves the representation of boundary currents, eddy-driven transport, and ventilation pathways. Passive tracers (CFC-11, CFC-12, SF_6, and an idealized CFC-12) are used to assess circulation and water-mass mixing within the IG-TTD framework [7, 8]. High-resolution simulations substantially reduce tracer biases relative to observations and CMIP6 models, indicating improved mixing and advection. Results show contrasting regional trends from 1979–2018: increased upper-ocean mixing, warming, a thinning cold halocline, and strong sea-ice loss in the Eurasian sector, versus reduced mixing, cooling, halocline thickening, and weaker sea-ice decline in the Canadian sector. These differences suggest enhanced Atlantic and Pacific heat transport into the Eurasian upper ocean, contributing to its faster warming relative to the Canadian sector [9].

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Sea ice deformation: A dynamics view of Arctic sea ice and its interaction with the climate system

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Sea ice deformation is defined in terms of spatial velocity gradients, including horizontal opening, closing (divergence and convergence), and shearing. These dynamic processes of sea ice, shape its surface by ridging and thereby influence the distribution of sea ice thickness, can create cracks and leads, and regulate thermodynamic ice growth. In recent decades, Arctic sea ice has undergone significant changes, including increased speed and deformation [1]. Changes in ice deformation can either be caused by changes in the atmosphere and/or ocean forcing, i.e., winds and ocean currents, or by changes of the sea ice itself, i.e., weakening of the ice by thinning or roughening (more ridges), which makes it more susceptible to wind and ocean forcing. During past decades changes in wind are not dominating the ice dynamics changes and ice thinning has contributed [1]. However, now that the Arctic sea ice volume is varying around a new low state during the last decade [2], the impact of winds on sea ice dynamics is less clear. A detailed analysis and attribution of the different processes to ice deformation variability is missing.
Currently, most existing sea ice dynamics studies rely on Synthetic Aperture Radar (SAR) imagery and buoy records [3], which are limited in spatial coverage and temporal resolution. While studies utilizing passive microwave radiometer data to investigate Arctic-wide sea ice deformation patterns remain scarce. There is still a need for long-term (multi-decadal), full-Arctic-coverage sea ice deformation datasets. In this presentation, we will provide an introduction to sea ice deformation and will present our recent sea ice deformation results, which mainly focus on obtaining deformation based on passive microwave satellite data (European OSI SAF sea ice drift products), the spatio-temporal distribution and its long-term changes. A comparison among different deformation results derived from different sea ice motion products (e.g., SAR) will also be presented. Besides, the relationship between ice deformation and atmospheric circulation patterns based on ERA5 wind data during the same period will be explored. This will provide a way to explore the role of sea ice deformation within the Arctic climate system and investigate how external (ocean and atmospheric) forcing might drive the future evolution of Arctic sea ice dynamics.

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Retrieving Arctic Summer Sea Ice Thickness below Melt Ponds from Hyperspectral Optical Measurements

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This study aims to retrieve the ice thickness of melt pond bottoms for Arctic summer sea ice from optical measurements. Models and measurements show that melt pond reflectance, especially between 400–500 nm, exhibits a distinct relationship with pond-bottom ice thickness. Based on this relationship a new retrieval concept for optical field and satellite observations is presented.
Sea ice thickness retrievals using this new approach could add crucial information about the sparsely observed sea-ice thickness during the summer melt season. Surface melt and wet snow disrupt microwave radar penetration and passive microwave emissivity, precluding standard sea ice thickness products during the melt season. The presented approach is new in demonstrating that thickness beneath melt ponds can be retrieved from passive optical reflectance measurements. The relation between the two said parameters is derived from an in-situ dataset of 67 hyperspectral optical images with co-located ice thickness and melt-pond depth measurements, collected during the CONTRASTS expedition on RV Polarstern (PS149, July–August 2025 [1]. Physical forward simulations of melt pond reflection agree well with the observed empirical relation. These simulations also affirm observed significant differences in reflectance spectr a between homogenous pond bottom structures and bottom structures with enclosed air bubbles.
We plan to present a preliminary empirical ice thickness retrieval and will validate it for case studies of field observations before it is applied to case studies of satellite observations of the Sentinel-2 Multispectral Imager (MSI).

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Characterizing High-Latitude Precipitation Phase During Atmospheric River Events

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Climate change increases variability in meridional atmospheric moisture transport, affecting precipitation occurrence and intensity in high-latitude regions [1, 2]. These regions are projected to experience rapid changes with more frequent precipitation extremes [3], often linked to Atmospheric Rivers (ARs), narrow corridors of enhanced water vapor transport. High-latitude ARs are associated with deep, anomalously warm and moist air masses [4, 5], which elevate atmospheric melting levels and increase the likelihood of precipitation phase transitions from snow to rain [6]. During cold seasons (winter, spring, fall), rain-on-snow events can accelerate snowmelt and ice sheet loss, enhance runoff, and increase flood risk [7]. Based on previous work, we hypothesize that precipitation depth, vertical structure, and phase differ markedly in the presence of ARs. The presented work leverages 10 years of observations (2014–2024) from the NASA Global Precipitation Measurement (GPM) Mission Dual Precipitation Radar (DPR), focusing on high-latitude regions near the maximum overpass latitude (61°N), to examine precipitation phase in the North Atlantic and Pacific. DPR observations are combined with AR events identified using reanalysis data and the Mattingly et al. [8] detection scheme. Over the 10-year record, rainfall during cold seasons (winter, spring, fall) occurs significantly more often during AR events (>50% increase), and some high-latitude regions receive wintertime (DJF) rain only when an AR is present. In contrast, no increase in rainfall occurrence is observed during summer (JJA). Across all seasons, rainfall intensity and rate distributions remain unchanged during ARs. The precipitation melting level, derived from the DPR bright band, is substantially higher during ARs, consistent with deeper, warmer air masses, increasing by 0.5–1 km in DJF and 1–1.5 km in JJA. Overall, ARs enhance cold-season rainfall frequency and raise melting levels year-round in high-latitude North Atlantic and Pacific regions.

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Quantifying the temporal variability of water vapor in Ny-Ålesund and its relation to weather systems

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The role of Water Vapor (WV) in Arctic amplification remains uncertain and is under investigation [1]. Understanding its role in the mechanisms driving Arctic amplification requires detailed information on its spatio-temporal variability. However, WV variability in the Arctic has rarely been examined. Temporally highly resolved integrated water vapor (IWV) data from ground-based MWR observations are ideally suited for the analysis of WV temporal variability. In this study, we make use of 13 years of measurements of the Humidity and Temperature PROfiler (HATPRO) at the AWIPEV atmospheric observatory (Ny-Ålesund, Svalbard). Extreme events of atmospheric moistening and drying are identified, characterized, and further related to the prevailing circulation weather systems. Because WV transport into the Arctic is episodic and typically associated with cyclones [2], these events require detailed analysis. We identify IWV minima and maxima and define extremes using amplitude thresholds within given time intervals. Events may consist of single or multiple maxima/minima.

When focusing on extreme atmospheric moistening and drying events, we find that absolute IWV amplitudes are highest in summer and lowest in winter. Events last between 2 and 142 hours. In contrast, winter shows greater relative variability than summer, with IWV changes exceeding 250% within a few hours. Events with only one maximum (moistening) or minimum (drying) are short-lived (75% last less than 24 hours), while those with multiple maxima/minima last longer, with a mean duration of 48 hours. Extreme atmospheric moistening and drying at Ny-Ålesund proceed differently: drying occurs more rapidly but with smaller amplitudes than moistening. The synoptic regimes favoring moistening and drying also differ. For moistening, the weather types AS, ASW, AS, and CSE account for half of the extreme events, with anticyclonic types transporting moisture over the North Atlantic. In contrast, CSE is associated with moisture transport over Scandinavia and West Russia, spanning the Barents and Kara Seas. For drying, significantly different weather systems can be responsible. Other studies report a positive trend in cyclone activity over the Barents Sea (e.g., [3]), which could favor greater moisture transport driven by CSE.

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Diagnosing moisture sources, transport and transformation in the Arctic with water vapor isotopes in atmospheric modeling

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The Arctic has undergone a marked moistening over the past four decades, influencing clouds, precipitation, and radiative processes and thereby contributing to Arctic amplification. While part of this trend can be attributed to local warming and sea-ice decline, the role of large-scale moisture transport into the Arctic remains insufficiently understood. Because most Arctic water vapour originates from lower latitudes, a clearer picture of how air masses transform along their pathways is essential for understanding present and future hydrological changes.
To investigate these processes, we use the isotope-enhanced climate model ICON-ART-iso, developed by Johannes Eckstein [1]. The simulations are initialized with ECHAM6-wiso data nudged to ERA5 provided by Martin Werner. For the evaluation of ICON-ART-iso, we use high-resolution COSMOiso simulations of Ny Ålesund in March 2021, provided by Harald Sodemann. These serve as a reference to assess the model's representation of isotopic signatures and moisture transport (Fig.1).
The presentation will show these first results, demonstrating the model's ability, and current limitations, in reproducing realistic isotopic patterns and providing insights into moisture transport relevant for Arctic amplification.

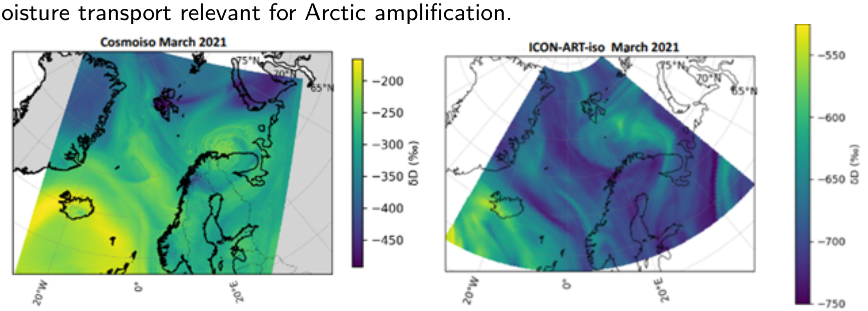

Fig. 1: Total column integrated delta D. Representing March 2021. On the right ICON-ART-iso, compared to COSMOiso (left).

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Arctic change, the polar vortex, winter weather and extremes

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The term "polar vortex" entered public conversations and has become synonymous with extreme cold and snow since the winter of 2013/14. That year did mark the beginning of an important transition in polar vortex behavior with significant societal impacts. The polar vortex is strongly coupled to the jet stream and is related to the weather across the mid- to high-latitudes. How is the polar vortex responding to a dramatically changing Arctic and the jet stream? Given the relationship between the polar vortex and our weather, what are the implications for winters in a rapidly warming Arctic? In this presentation, I will discuss current understanding of these features, contextualize the winter so far, argue the important influence of the polar vortex, and how does this winter match the paradigm that I constructed.

Arctic cyclones: Impacts on sea ice and future changes

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Short-term changes in Arctic sea-ice area are largely driven by weather events such as synoptic cyclones, typically causing ice loss during unusually warm and stormy conditions in the Arctic. Physical mechanisms of this ice loss include enhanced sea-ice divergence, poleward ice drift, and changes in surface energy budget due to advection of warm-moist air masses. In extreme cases, also enhanced basal melt of sea ice occurs due to up mixing of relatively warm ocean water. However, cyclones can also locally increase sea-ice area, specifically in the cold season, if ice is advected southward and openings in the ice cover in regions with diverging ice drift refreeze rapidly. To this end, the role of cyclone-sea ice interactions regarding future Arctic Amplification remains unclear. In principle, cyclones can contribute to enhanced Arctic warming by reducing the sea-ice area, which can strengthen the ice-albedo feedback in summer and enhance oceanic heat release to the atmosphere in winter. However, local surface changes in the Arctic and an amplified warming compared to the mid-latitudes can also alter atmospheric circulation and thereby modify Arctic cyclones. Thus, a positive feedback involving more frequent/intense cyclones and intensified sea-ice loss cannot be ruled out. To advance our understanding of this topic, we analyze output from CMIP6 coupled climate model projections. An evaluation compared to ERA5 for the historic reference period (1985-2015) reveals that some models struggle to capture present-day cyclone impacts on sea ice, but a suitable number of models with acceptable performance remains for further analysis. We choose a subset of these models focusing on the SSP370 scenario, the cold season (NDJFM) and the warm season (MJJA), and following a storyline approach: Previous work revealed a strong sensitivity of projected near-surface air temperature changes in the Arctic to I) sea-surface temperature changes in the Barents Kara Seas, and II) Arctic tropospheric warming [1]. Subsequently, we choose three models per season, which exhibit contrasting future changes in these two predictors. In the warm season, our storyline reveals a contrasting future warming of Arctic Ocean and land masses, in the cold season, a regionally different warming of the Arctic Ocean is found. Ongoing work consists of analyzing future changes in Arctic cyclones and their impacts on sea ice for the selected climate models.

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How Well Do CMIP6 Models Capture Northern Hemisphere Circulation Patterns? A Data-Driven Analysis

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Arctic amplification is expected to reshape atmospheric circulation by altering temperature gradients, storm tracks, and planetary wave behavior. Building confidence in projections of these changes first requires understanding how well current global climate models reproduce present-day circulation regimes. In this study, we evaluate the capacity of the latest generation of GCMs contributing to the sixth phase of the Coupled Model Intercomparison Project (CMIP6) to reproduce observed large-scale atmospheric circulation patterns over the Northern Hemisphere. The assessment was conducted against ERA5 reanalysis data. Our approach leverages a physically informed convolutional autoencoder combined with k-means clustering, a data-driven climate classification workflow using unsupervised deep learning that reduces the dimensionality of spatiotemporal climate simulation data into compact representations. Our results show that CMIP6 models generally reproduce the persistence and frequency of Northern Hemisphere mean sea level pressure (MSLP) patterns by ERA5, particularly in winter, though model skill varies across the ensemble. Our findings also indicate that the ensemble mean tends to underestimate the strength of MSLP anomalies in every season. Even so, it captures the main pattern frequencies fairly well, especially in spring. This provides a reasonable basis for using CMIP6 models to investigate how circulation patterns may shift under Arctic Amplification and their related impact.

Assessment of Circulation Weather Types around Svalbard and their Impact on the Ny-Ålesund atmospheric column

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The meteorological conditions in Ny-Ålesund (NYA) are strongly shaped by the prevailing large-scale weather regime, such as southerly, northerly, cyclonic, or anticyclonic weather patterns. To systematically classify these regimes, we applied the Jenkinson–Collison (JC) algorithm to the Svalbard region, generating a set of characteristic circulation weather types (CWT) that affect the NYA atmospheric column. Using hourly ERA5 850hPa geopotential height (GEOP) reanalysis data, we constructed a 40+ year CWT catalogue and investigate composites and trends in key thermodynamic variables, derived from AWIPEV observations such as radiosonde (RS) launches and Baseline Surface Radiation Network (BSRN) measurements.

Arctic Cloud Regimes and Their Radiative Effect Based on MOSAiC Observations

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Understanding the role of clouds in Arctic amplification remains a major scientific challenge. In particular, the partitioning of cloud volumes into ice, mixed-phase, and liquid regions - together with the influence of aerosol on freezing, and potential shifts under Arctic warming - introduces substantial uncertainty into climate modelling and projections. In this study, we present an updated data set of radiative fluxes simulated from active remote-sensing cloud profiling observations collected during the year-long MOSAiC expedition [1]. We summarize the key updates and assess their impacts on simulated radiative fluxes. We introduce a novel method for defining cloud regimes by applying k-means clustering to two-dimensional joint histograms of cloud optical thickness and cloud-top height, adapting an earlier satellite-based approach [2] to ground-based observations. The resulting cloud regimes are compared with traditional cloud-type classifications from the Atmospheric Radiation Measurement (ARM) Program [3]. For each cloud regime, we quantify the associated radiative effect in the solar, thermal-infrared, and broadband ranges, and across different seasons. Biases and scatter between observed and simulated surface radiative fluxes are evaluated to identify regimes with the largest uncertainties in their simulated cloud radiative effects. Finally, we analyze the partitioning of total cloud optical thickness into liquid and ice contributions, accounting for retrieval uncertainties and assumptions about ice-particle optical properties. We identify regimes with particularly large variability or uncertainty in phase partitioning and evaluate the sensitivity of their radiative effects to these phase differences. Implications for how the radiative impact of mixed-phase cloud regimes may evolve in a warming Arctic are discussed.

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Evaluation of summertime Arctic surface cloud radiative effect derived from satellite products against aircraft observations during NASA ARCSIX

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The summertime evolution of sea ice characteristics plays an important role for the currently ongoing transformations of the Arctic climate system and is highly dependent on the radiative energy budget (REB) at the surface. Therefore, accurate knowledge of the REB as a function of surface, thermodynamic, and cloud properties is crucial. In particular, low-level clouds can have a significant impact on the surface REB, which is quantified by the cloud radiative effect (CRE) and can be a warming or cooling effect depending on the environmental conditions. Continuous and long-term monitoring of the surface REB and CRE is only feasible using observations from passive imagers onboard polar-orbiting satellites with their high revisiting frequency in high latitudes. However, satellite retrievals of surface and cloud properties have shown several deficiencies compared to ground-based or airborne measurements, limiting the accuracy of the calculated CRE. For example, satellite products providing spectral surface albedo over sea ice are not available so far. Furthermore, a case study comparison of REB measurements and simulations initialized with satellite-derived cloud properties revealed that a large amount of optically thin clouds was undetected [1].
Similar to [1], this study applies radiative transfer simulations to compare the surface CRE retrieved from collocated satellite and aircraft observations of surface, cloud, and thermodynamic properties. Furthermore, the potential CRE differences over sea ice are attributed to biases of the input parameters. The aircraft observations were acquired during the NASA Arctic Radiation-Cloud-Aerosol-Surface Interaction eXperiment (ARCSIX), which was performed from Pituffik Space Base (Greenland) in two phases between May and August 2024, covering late spring and summer conditions. It will be shown that clouds with an apparent total cooling effect according to satellite observations actually warm the surface in late spring due to an underestimated surface albedo, while the difference between satellite- and aircraft-derived CRE in summer is smaller. Despite being significant, discrepancies in cloud and thermodynamic properties only cause minor CRE differences.

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Impacts of mesoscale subsidence on glaciation and decoupling in Arctic marine cold air outbreaks

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Marine cold-air outbreaks (MCAOs) generate deep, surface-coupled boundary layers and mixed-phase cloud fields whose evolution is strongly modulated by large-scale meteorology. Transitions from closed stratiform clouds to deeper broken cloud fields have frequently been linked to boundary-layer decoupling and enhanced precipitation ([1, 2]), consistent with mechanisms proposed for mesoscale cellular convection in which latent-heating-driven updraft strengthening enhances entrainment and accelerates decoupling ([3]). However, the influence of larger-scale vertical motion on these transitions remains poorly constrained in the Arctic due to limited observations of subsidence.

This study examines how mesoscale subsidence shapes boundary-layer evolution, cloud phase, and precipitation during a shallow MCAO observed in the Fram Strait in March 2022 during the HALO–$(\mathcal{AC})^3$ campaign. We conduct quasi-Lagrangian large-eddy simulations (LES) exclusively initialised and driven by in-situ and remote-sensing measurements, including mesoscale dropsonde arrays providing robust estimates of subsidence. The control simulation accurately reproduces the observed thermodynamic structure of the transforming air mass, capturing boundary-layer depth, integrated water vapour, and cloud water paths.

Sensitivity experiments in which subsidence is systematically perturbed reveal that weaker subsidence substantially alters the cloud-phase evolution by allowing more rapid boundary-layer deepening. This promotes earlier internal decoupling, which triggers convective graupel formation and accelerates liquid-water depletion. We find a strong link between decoupling dynamics, glaciation onset, and liquid-water-path evolution. These results provide a process-based framework for interpreting how large-scale vertical motion conditions Arctic air-mass transformations, reinforcing the role of subsidence as a key modulator of mixed-phase cloud persistence and breakup.

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Quantifying the Evolution of Cloud Street Structures During Arctic Marine Cold Air Outbreaks Using Satellite Observations

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Strong winds associated with Arctic marine cold air outbreaks (MCAOs) advect cold, dry air masses from sea ice-covered regions over relatively warm open ocean. The resulting large temperature gradient across the air-ocean interface induces large energy and moisture fluxes and promotes the formation of low-level mixed-phase clouds. Hence, MCAOs are an important phenomenon of Arctic weather and climate. Their intensity is expected to weaken due to climate change and Arctic amplification.

The clouds associated with MCAOs exhibit characteristic structures, initially forming as roll clouds or cloud streets parallel to the wind, and eventually breaking up into a cumuliform cloud field.

Here, a novel correlation-based metric, the Correlation clOud Street Index (COSI) is introduced. It is defined as the Pearson correlation coefficient between an image and an optimally oriented and scaled Gabor kernel, providing a quantitative measure of cloud street presence and distinctness. The calculation of this index also extracts cloud street spacing (wavelength) and orientation as structural properties.

Applied to satellite observations with extensive spatial and temporal coverage, we utilize the COSI to get novel insights into the spatio-temporal evolution of cloud street structures in marine cold air outbreaks. We quantify the increasing cloud street wavelength with increasing distance from the ice edge. Additionally, we assess the aspect ratio (wavelength divided by cloud top height) across a larger data set and its dependence on the MCAO strength is evaluated. The cases analysed correspond to periods with $(\mathcal{AC})^3$ aircraft campaigns, allowing the aircraft observations to be placed in a broader context. Additionally, the aircraft measurements can be used to evaluate satellite data quality and support the analysis when satellite resolution or data quality is insufficient.

Cloud state transitions at Ny-Ålesund: A machine learning supported statistical analysis

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Over the past nine years we have gathered comprehensive cloud and precipitation observations at AWIPEV in Ny-Ålesund with the 94-GHz cloud radars, which operated in synthesis with other in-situ and remote sensing instruments (i.e., microwave radiometers, lidar, disdrometers, ...). These observations have substantially improved our understanding of mixed-phase clouds in the Arctic (e.g., macro- and microphysical properties and ice growth processes under different atmospheric conditions [1–3]).

In this study, we aim to use the full nine years of cloud radar data to advance out understanding of Arctic clouds on multi-annual time scales by performing a statistical analysis of cloud states and their transitions, as well as their relation to other meteorological observations such as the radiation budget. We examine how atmospheric conditions affect the cloud states and transitions, which further influence other atmospheric parameters.

Modern machine learning algorithms are well suited to analyse big data sets and reveal features imperceptible to the human eye because of the complexity of the problem. We train a Vision Transformer with height-resolved cloud radar reflectivities, Doppler velocities, ceilometer data and liquid water path-sensitive brightness temperatures at 89 GHz in a self-supervised framework. The Vision Transformer learns to identify distinct features in the training data and therefore find different cloud states without direct human intervention.

Here, we present our first steps which focus on interpreting the output of the machine learning model and fine tune the settings to better discern the cloud states identified by the model. Different cloud macro- and microphysical properties are tested to understand the nature of each cluster the machine learning algorithm produced.

Later, we will apply the trained machine learning algorithm to synthetic radar data simulated with PAMTRA based on ICON output. By comparing the observation-based analysis with that performed on the simulated radar data we aim to to further shed light on the strengths and weaknesses of ICON regarding cloud states and transitions in a multi-year data set.

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An assessment of water vapor entrainment fluxes under specific humidity inversions using a year of LES data for the MOSAiC drift

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Persistent mixed-phase clouds (MPC) play a key role in Arctic climate, and how they affect its rapid amplification is not yet fully understood. The interplay between radiative cooling, turbulence, and microphysical processes that control the cloud's evolution is complex and hard to measure, but can be explored using high-resolution Large-Eddy Simulations (LES) based on field campaign data. This study examines the humidity entrainment flux from an overlying specific humidity inversion (SHI) into MPCs using LES results for MOSAiC. These SHIs are layers of high moisture content which can commonly be found in the Arctic, and if they are located above a cloud, they can serve as a moisture source for the MPC. Quantifying this influence remains challenging. The simulations cover the full MOSAiC year and provide high-resolution output of turbulent and radiative properties, which are hard to obtain observationally. Therefore, a combination of the model and observations enables a detailed study of the processes in MPCs. The overarching goal is to qualify and quantify the downward vapor flux out of SHIs, and how it can contribute to the persistence of Arctic MPCs. An automated algorithm is used I) to identify MPCs below SHIs and ii) to quantify the latent heat flux from the inversion into the cloud. Further, the sensitivity of the vapor entrainment flux to variations in humidity and temperature profiles, cloud-top height, and cloud radiative properties is assessed, as well as the influence of liquid droplet sedimentation near cloud top.

VAMPIRE dataset - Arctic clouds, water vapor and sea ice emissivity

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The increased warming in the Arctic greatly impacts its atmospheric water cycle [1]. Particularly in the Arctic, where data are scarce, water vapor, clouds, and precipitation present significant challenges for weather and climate models, and are essential components of feedback mechanisms that affect the Arctic amplification.

Satellites provide much-needed measurements of clouds and water vapor properties and their variability in the Arctic. However, retrievals are affected by the unknown and highly variable surface emissivity. The VAMPIRE dataset contributes reference measurements for surface emissivity in addition to providing insight into key variables of the water cycle: properties of mixed-phase clouds, atmospheric water vapor, and precipitation.

The VAMPIRE dataset was collected in the summers of 2024 and 2025 during four months in total in the Central Arctic Ocean on the research vessel *R/V Polarstern*. On board was a large suite of remote sensing instruments: a dual wavelength G-band radar, a W-band cloud radar, two microwave radiometers spanning from 22.24 GHz to 340 GHz and scanning between atmosphere and surface. Alongside these instruments, wind and precipitation instruments were installed on board, as well as surface and sky cameras in the visual and infrared, and 6- to 12-hourly radiosondes were launched every day. At each ice station, in-situ surface snow and ice measurements were conducted in the microwave radiometers' footprint. The contribution will present the dataset, discuss retrievals and synergies applied to the data and illustrate the possibilities the dataset offers for investigating the Arctic water cycle and surface characteristics.

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Exploring Aerosol-Cloud Interactions in Arctic Mixed-Phase Clouds Using ICON-LEM

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The contribution of Arctic mixed-phase clouds (MPCs) to Arctic amplification remains uncertain and challenging to model due to the complex interactions between microphysical processes and environmental forcing. Cloud condensation nuclei (CCN) concentrations influence MPC properties; however, current models often prescribe concentrations that are much higher than those typically observed in the Arctic. To address this gap, we investigate the sensitivity of MPC properties to CCN concentrations using 600-m ICON-LEM simulations.

Our initial experiments, spanning mimicked Arctic, maritime, and polluted CCN regimes, already show clear CCN effects: reduced CCN leads to lower LWP and higher Ze, primarily due to enhanced rain and graupel, which have a strong impact on reflectivity. Yet despite these sensitivities, the model still underestimates the observed Ze, suggesting shortcomings in the representation of phase partitioning. The results further suggest a potential dependence of microphysical sensitivity on cloud height, with low-level MPCs appearing to respond more strongly than high-level layers.

Therefore, we will extend the current ICON-LEM simulations by separating cloud layers relative to the melting layer, incorporating additional summer and winter low-level MPC cases, and performing INP (ice nucleating particle) sensitivity experiments to assess their influence on phase partitioning and precipitation. Identifying suitable CCN–INP combinations may enhance MPC representation in ICON-LEM and contribute to a deeper understanding of the processes relevant to SQ1 on the causes and mechanisms of Arctic amplification.

IOP4H2O: Investigating the Arctic water cycle in highresolution observations and modeling

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The Arctic water cycle is at the heart of feedback mechanisms driving amplified Arctic warming. The water cycle components, that is clouds, water vapor and precipitation, are tightly intertwined by cloud and precipitation processes, sublimation, and water vapor transport and variability. Understanding these links, quantifying the variability of their properties, and assessing their representation in state-of-the-art modeling requires observations at high vertical and temporal resolution in the observation-scarce Arctic environment.
During the IOP4H2O intensive observation period in February 2025, the G-band Radar for Water vapor and Arctic Clouds (GRaWAC, [1]), a snow-particle counter, as well as additional radiosonde launches complemented the continuous core remote sensing and in-situ measurements at AWIPEV station, Ny-Ålesund, Svalbard. The rich suite of instruments allowed the simultaneous and continuous observation of all water cycle components, including cloud and precipitation microphysical properties, sublimation occurrences as well as all-weather in-cloud water vapor profiles.
In this contribution, we analyze the variability of observed micro- and macro-physical cloud and precipitation properties as well as sublimation strength and occurrence during the anomalously warm observation period [2]. We investigate how these are connected to changing water vapor conditions, and further assess how the identified connections are represented in high-resolution ICON runs. Model comparison will be performed in observation space by using the Passive and Active Microwave TRAnsfer (PAMTRA, [3]) simulator.

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Evaluating EarthCARE's CPR reflectivities and Doppler velocities with MiRAC airborne measurements from the Arctic COMPEX-EC campaign

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Low-level Arctic clouds, especially mixed-phase clouds, are key drivers of regional climate and Arctic amplification, yet their microphysical and dynamical properties remain difficult to observe in data-sparse regions. EarthCARE offers new opportunities to address these gaps; however, its measurements require validation using independent reference data. As a contribution to these validation activities, the Polar 5 research aircraft of the Alfred Wegener Institute has been equipped with an EarthCARE-like instrument suite and operated during the COMPEX-EC (Clouds over cOMPlEX environment – EarthCARE) in April 2025 from Kiruna, Sweden. During seven research flights, we collected more than 5 hours of along-track airborne radar measurements collocated with EarthCARE overpasses, covering diverse Arctic conditions from marine cold-air outbreaks (CAO) over the Norwegian Sea to cloud fields over northern Scandinavia.

For moving platforms like an aircraft, corrections addressing horizontal and vertical motion, as well as attitude need to be applied to some of the measurements. Hereby, the Doppler velocity is especially challenging, and this is further complicated by the installation of the W-band Microwave Radar/radiometer for Arctic Clouds (MiRAC) [1] on Polar 5 in a belly pod with a 25° inclination under the aircraft, which enhances the complexity. MiRAC is complemented by a microwave radiometer, a lidar, radiative sensors, and dropsondes, which were also operated.

Recent improvements in the correction of Doppler velocities now allow for more accurate retrievals of vertical air motions and hydrometeor fall speeds, enabling the separation of liquid and ice hydrometeors, the identification of turbulent layers, and the detailed analysis of mixed-phase cloud structure. Dropsondes released during overpasses supply thermodynamic and wind profiles that support the interpretation of observed dynamical features. The data not only provide EarthCARE CPR performance assessments, together with precipitation retrievals based on Ze–snowfall rate relation, but also address broader questions on how cloud-driven vertical motions and Arctic precipitation development influence regional and mid-latitude weather.

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Investigation of water vapor isotopes during an atmospheric river event using model data and satellite retrievals

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The Arctic has shown a significant moistening trend over the past 30-40 years [1]. While the region's atmosphere is becoming more humid, it remains unclear whether this increased moisture originates primarily from local sources such as enhanced evaporation from newly ice-free ocean surfaces or is transported from lower latitudes [2]. Atmospheric rivers (ARs) are key drivers of poleward moisture transport and play a critical role in Arctic climate processes [3].
Hydrological processes such as evaporation and condensation are mass-dependent, isotopic fractionization occurs during such phase transitions. Thus, the isotopic composition of water vapor in air serves as an integrated tracer of an air parcel's history, providing complementary information on moisture transport that can help improve our understanding of Arctic atmospheric moisture processes.
We investigate the isotopic composition of water vapor during an atmospheric river event that occurred in March 2021 and which made landfall in Northern Scandinavia. We analyze data from the isotope-enabled COSMO model (COSMO-iso) and evaluate it against observations from the TROPOMI satellite instrument and ground-based stations to contrast and diagnose the behavior inside and outside the atmospheric river.

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Investigation of precipitation sublimation and evaporation with active remote sensing in Ny-Ålesund

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The focus of this work is on sublimation and evaporation of precipitation. Precipitation is an essential component of the Arctic climate system as part of the hydrological cycle, linking the atmosphere and cryosphere. Much of the Arctic precipitation sublimates or evaporates before it reaches the ground due to dry sub-cloud layers.
We use long-term atmospheric observations at Ny-Ålesund with vertically-pointing cloud radars and backscattering lidars to identify and quantify atmospheric sublimation/ evaporation. Radar observation-based sub-cloud precipitation profiles are studied by employing a virga detection tool, the so-called Virga-Sniffer [1]. The quantification of the sublimation/ evaporation is based on sub-cloud vertical gradients of radar moments. First statistical results of precipitation phase, virga depth, and full sublimation/ evaporation altitude above ground will be shown.
Furthermore, the frequency of virga and surface precipitation in different weather types such as cyclones, fronts, and atmospheric rivers is contrasted. We will also show investigations on wind direction dependence on virga statistics. Air masses advected from the Arctic Ocean are more humid and lead to more precipitation reaching the ground and thus less virga. Air masses advected over Ny-Ålesund from Easterly directions (i.e. the island of Svalbard itself) are often characterized by low-humidity sub-cloud layers leading to more evaporation/ sublimation and hence a higher fraction of virga.

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Retrieving Capacitance and Ventilation Factor Using Observations of Sublimating Snowfall

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Precipitation is one of the key components of Arctic climate system, acting as a vital link between the atmosphere and the cryosphere through hydrological cycle. In the Arctic, a substantial portion of precipitation sublimates or evaporates within dry sub-cloud layers before reaching the surface [1]. Investigating sub-cloud sublimation and evaporation processes is crucial because these mechanisms reduce near-surface snowfall amounts. Numerical models have difficulties simulating sublimation rates accurately since these processes heavily depend on complex hydrometeor properties such as the capacitance and ventilation factor that interact through complex feedback mechanisms affecting cloud microphysical characteristics.

To address these challenges and reduce model uncertainties, we retrieve the capacitance and ventilation factor from observations conducted in Ny-Ålesund, of cases with partial sublimation where snowfall still reaches the surface. We calculate the sublimation process rate using textbook assumptions for capacitance and ventilation factor from the observed in situ particle size distribution and thermodynamic profiles from radiosonde to estimate the past sublimation of the particle size distribution along a back-trajectory. The back-trajectory particle size distribution will be converted to cloud radar observables and compared to the radar observations to validate and adapt our assumptions for capacitance and ventilation factor.

This study will provide a foundation for improving sublimation parameterization that shows the effect of complex ice particle types/shapes such as aggregates or rimed particles on sublimation processes and will help us better understand how sublimation interacts with the Arctic atmosphere.

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Evaluating the snow microwave radiative transfer model SMRT over sea ice for atmospheric sounding frequency channels: Comparison to in-situ data from three Arctic ship campaigns

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Here, we present the results of comparing modeled microwave emissions using the active and passive multilayer radiative transfer model for snow, sea-ice and lake ice (SMRT) [1] to measured brightness temperatures from ship-based microwave radiometers. The radiometers measured at frequencies from 22 to 340 GHz at a viewing angle of 53 degree off-nadir during three Arctic expeditions, that is, at frequencies and viewing geometries similar to existing and upcoming satellite missions (e.g., Metop-SG, Arctic Weather Satellites, AMSR2/3, AMSU-A/B, MHS).
The simulations are based on snow and sea ice data measured in-situ during 22 ice stations within the footprint of the radiometers and include temperature, density and salinity profiles as well as microstructure and surface roughness information. The expeditions were carried out in the months July to October. The ice often exhibited a surfaces scattering layer of several centimeters but also snow depths up to 10 cm were observed.
Both brightness temperature and in-situ measurements were carried out within the framework of the $(\mathcal{AC})^3$ projects WALSEMA [2], VAMPIRE and VAMPIRE-2 in each of the three expeditions (PS131 in 2022, PS144 in 2024, and PS149 in 2025).
We demonstrate SMRT's ability to simulate the measured brightness temperatures using the ground truth input data, i. e., the measured geophysical snow and ice parameters, taking also the uncertainty of the input parameter measurements into account.
Good agreement can only be achieved as long as the observed brittle, strongly scattering ice layer (the surface scattering layer) on top of the ice is taken into account and, within the SMRT framework, modeled as granular snow. For frequencies at 53.86 GHz and higher we achieve similarly good agreement without the need of a complex model but by simply assuming constant emissivities taken from [3]. The objectives of our study are twofold: First, we aim to provide the first validation of the sea ice module in SMRT using in-situ data to provide both a reference for users as well as to identify model limitations. Second, the results can help to better assimilate satellite microwave data in numerical weather prediction schemes which are currently heavily underused in sea-ice covered regions because of the unknown surface emissions. Thus, our work bridges the sea ice and atmospheric observation communities.

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Contrasting Optical Properties in Different Sea Ice Regimes

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The Arctic Ocean is undergoing a series of changes. These include a decreasing sea ice extent [1], decreasing sea ice thickness [1] and a shift towards younger sea ice [2]. Against this background, the 149th Polarstern campaign "CONTRASTS" took place in the summer of 2023 to observe 3 different sea ice regimes over the course of the summer. The regimes represent seasonal (or first year ice), older second year ice (both regimes are found in the transpolar drift) and very old multi-year ice that has survived several summers in the Beaufort Gyre. The remotely operated vehicle (ROV) of the sea ice section of the Alfred-Wegener-Institute plays a central role in observing ice-ocean interface. ROV measurements were carried out for all 3 regimes on 3-4 visits each. The focus of these measurements was the spatial structure and intensity of the under-ice light field. These data facilitate the quantification of energy input into the upper layers of the ocean by radiative fluxes. Consequently, they are essential for the accurate estimation on basal melting and as boundary conditions for biological processes.

Furthermore, single-point draft measurements as well as multibeam draft measurements were performed to obtain topographic changes in the ice underside and information on ice thickness. In this poster, we present first results from the analysis of the radiative data. The primary focus is the statistical description of the under-ice light field, with particular attention to its homogeneity and spatial structure. Diverse parameters, including the mean value, distribution function, Shannon entropy, and Moran's I, are essential for this analysis. Another focus is the differences in these parameters across the various regimes and their seasonal evolution. In some cases, differences in seasonal development can be attributed to synoptic weather events; other influencing factors include ice thickness, melt pond size and coverage, and ice age. These factors help describe the regimes and their transmissive properties.

This data set enables a precise description of sea-ice transmission properties during the summer months for the different regimes and thus provides an optimal basis for developing new parameterizations that integrate properties such as ice thickness and age. This points to promising approaches for upscaling procedures and simulations. An initial example focuses on changes in transmission behaviour under thinning and increasingly juvenile ice conditions.

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Improving and validating the TROPOMI tropospheric BrO retrieval in the Arctic

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Satellite observation of tropospheric BrO, particularly in the Arctic, have been conducted for over two decades. However, detecting tropospheric BrO from satellite remains challenging, as most BrO is located in the stratosphere, while the sensitivity of the satellite is the lowest near the surface, where tropospheric BrO occurs. The launch of the TROPOMI instrument on board the S5P satellite in October 2017 provides a high-resolution tool for large-scale BrO measurements. Seo et al. (2019) [1] developed a BrO column retrieval algorithm for TROPOMI, which is still in use today.
To enhance the accuracy of tropospheric BrO retrievals over the Arctic, we propose two key improvements. First, we update the air mass factor (AMF) lookup table, to account for the specific surface reflectivity of each TROPOMI pixel. Since AMF calculations require knowledge of the vertical distribution of the trace gas, we evaluate the impact of applying BrO profiles derived from aircraft measurements during the CHACHA campaign, taking place in Alaska, in spring 2022 [2].
Second, we further address the critical step of removing stratospheric BrO from the total column, the so-called stratospheric correction, to obtain the amount of tropospheric BrO. [3] showed that different correction methods yield varying tropospheric BrO columns, underscoring the need for refinement. Since June 2023, the Copernicus Atmospheric Monitoring Service (CAMS) provides global forecasts of atmospheric composition, including multi-level BrO data. This offers a new approach for estimating stratospheric BrO, which we test and validate using MAX-DOAS BrO measurements from Ny-Ålesund.

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The effect of surface heterogeneity on the Arctic surface energy budget: From low-level airborne in-situ observations to satellite retrievals

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Leads, narrow openings in the sea ice, strongly modify the Arctic surface energy budget due to their elevated skin temperature relative to the surrounding pack ice. Their sizes range from meters to several kilometres, with sub-kilometre features being most common, yet their heat contribution remains difficult to quantify due to the scarcity of observations close to the surface.
We use low-level airborne measurements of sensible heat flux (SHF) collected with the T-BIRD platform [1] over heterogeneous sea ice during the airborne measurement campaign Boundary layer and Aerosol and Cloud Study in the Arctic, based on aircraft and T-Bird Measurements II (BACSAM-II) in April 2024. The effective sampling heights below 30 m allow for a direct comparison between in-situ fluxes and bulk aerodynamic estimates, including the stability corrections of Gryanik and Lüpkes.[2].
In parallel, we estimate SHF using satellite based retrievals of surface temperature and from reanalysis data, and evaluate these estimates against the airborne measurements. An initial comparison indicates a root-mean difference of $17\,\mathrm{Wm}^{-2}$ for the sampled conditions. Building on this evaluation, we will apply the same approach to previously derived high-resolution surface temperature and surface type maps [3] to investigate how SHF relates to lead characteristics across spatial scales. Understanding the impact of sea ice structure on SHF will also identify how a change of the sea ice structure in a warming Arctic contributes to Arctic amplification; a question related to SQ1.

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Recent improvements of the surface albedo scheme in HIRHAM-NAOSIM

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The spread of climate model results in terms of quantifying the snow–ice surface albedo feedback is partly caused by the sensitivity of the simulated sea ice surface albedo to surface warming. The accurate representation of the Arctic sea ice and its evolution throughout the year, particularly in the melting period, is crucial to obtain reliable climate model projections.

Melt ponds increase the surface heterogeneity in the melting season, altering the albedo and adding more complexity for modeling the surface albedo. A new melt pond fraction parameterization has been developed using satellite data. This new parameterization includes a retarded response to temperature changes with different change rates for thin and thick ice. The offline analysis and first model results will be presented.

Further improvements were made to the cloud effect on snow albedo. Earlier work showed that the current model version overestimates the effect of thin optical clouds, which mostly occur in the Arctic spring [1]. A new approach was evaluated offline against airborne and ground-based datasets, incorporating new parameters such as dependence on snow grain size, total water path, and snow depth. This approach relies on the coupling of radiative transfer simulations in the snow and atmosphere in combination with measurement data from the MOSAiC expedition. The effects of the new parameterizations on the radiative energy balance are discussed.

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Snow-age-dependent parameterization of snow density and conductivity for the use in climate models

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Arctic amplification is related to a couple of feedback processes in which the surface energy budget (SEB) plays a central role. Over Arctic sea ice, the conductive heat flux through the ice and snow is one of the main contributors to the SEB. The magnitude of the conductive heat flux is driven by variation in the atmospheric heat flux, depends on sea-ice thickness, and is significantly damped by the presence of an insulating snow layer. The thermal properties of snowmay vary considerably in space and time; however, they are mostly considered as constants in climate models.

A simple prognostic calculation of the snow age is presented. It is shown that the calculated snow age correlates with the snow densities measured during the MOSAiC expedition in the central Arctic. The correlation further increases when wind effects are taken into account, with the result that the measured snow density can be adequately reproduced by regression to snow age and 10-m wind speed.

The effective thermal conductivity of snow is then derived from the calculated snow-age-dependent snow density using equation (4) by [1].

The effects of the snow-age-dependent snow density and conductivity on the SEB and the sea-ice growth are demonstrated in simulations of the coupled regional climate model HIRHAM–NAOSIM and evaluated against flux measurements from the MOSAiC expedition.

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Characterizing dimensionless sea-ice heterogeneity parameters in the Arctic boundary layer

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Heterogeneity in sea-ice cover strongly influences the Arctic climate, with leads affecting regional temperature, atmospheric stability, and surface-atmosphere fluxes in winter. This heterogeneous surface causes complex nonlinear surface-atmosphere interactions as for example the heat exchange above leads, which causes secondary circulations. Therefore, this heterogeneous surface cannot be quantified using solely the ice fraction within a grid cell of a numerical model, as in standard Earth System Models (ESMs). [2] showed that dispersive fluxes, which emerge in a time-averaged but spatially variable mean flow, explain the differences in total surface fluxes across heterogeneity patterns. To improve surface-flux models at ESM grid scales, heterogeneity parameters are identified to subsequently determine scaling relations relating surface heat or momentum fluxes to selected surface heterogeneity characteristics and atmospheric stability [1]. This study aims to identify dimensionless heterogeneity parameters that capture the interaction between fractured sea-ice patterns and the atmospheric boundary layer based on observations.

We extend the thermal heterogeneity parameter defined in [2], which defines the ratio between buoyancy effects of surface thermal contrasts to the inertia of the mean flow. One such extension is given by incorporating the lead-width distribution according to a power law, which has been already observed. A dimensional analysis identifies relevant dimensionless groups based on key variables including temperature difference between the sea-ice and water surfaces, the angle between geostrophic wind and lead orientation, roughness lengths and typical length scales as for example the boundary layer height. The derived parameters are calculated using data from the MOSAiC campaign, including surface temperatures with a spatial resolution of 1 m [3]. In addition, turbulence data from flight campaigns such as BACSAM I and BACSAM II is used to estimate dispersive fluxes. Turbulence was measured at two different heights simultaneously: on the aircraft and 60 m below the aircraft using a passive trailing body called T-bird, enabling unique measurements at very low heights of around 10 m above surface. The aircraft data are analysed with a wavelet transform, enabling a multiscale decomposition of the fluxes following the flight tracks. The multiscale decomposition is used to extract a mesoscale contribution to the fluxes. The relationship between this mesoscale contribution and surface heterogeneity is analysed by exploring correlations with the obtained heterogeneity parameters.

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Constraints on Southern Ocean Mesoscale Cellular Convective Cell Growth

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Mesoscale cellular convection (MCC), which can be found in- and outside marine cold air outbreaks (MCAOs) over the Southern Ocean (SO), has been shown to influence the cloud radiative effect and potentially shortwave cloud feedbacks. While MCC morphology and cell-size scaling have been studied extensively in the subtropics and North Atlantic MCAOs, far less is known about how these relationships behave in the SO, where mixed-phase clouds dominate. In this study, we investigate the physical controls on MCC cell size and its variability during SO MCAOs based collocated active and passive remote sensing products and reanalysis fields.

Specifically we combine MODIS retrievals of liquid water path and 0.86 m reflectance for MCC classification and cell identification, ERA5 reanalysis for dynamical and thermodynamic fields, and DARDAR-v2 radar–lidar profiles to determine cloud-top height, cloud-top temperature, and cloud phase. Image segmentation applied to 200 $\times$ 200 km^2 scenes along DARDAR overpasses yields a catalogue of 19,500 MCC cells, 86% of which are supercooled—a clear reflection of the high prevalence of mixed-phase clouds in the SO.

Contrary to established behaviour in shallow NH boundary layers, we find no evidence of a constant aspect-ratio regime and no systematic deepening of the BL during MCAO evolution. Open and closed cells exhibit similar median diameters (~36–37 km), although open cells display a longer tail toward larger sizes. Thermodynamic and dynamic conditions—including stability parameter M, BL depth, and surface forcing—show minimal influence on cell-size variability. Approximately half of all mixed-phase open cells occur within MCAO regimes defined by $M > -5$ K, yet cell diameter remains largely insensitive to the strength of the outbreak.

Backward trajectory analysis indicates that time since cold air mass formation may play a more decisive role: larger cells tend to reside in older, more mature MCAO air masses. Our findings suggest that, in the SO, MCC cell growth is primarily constrained by air-mass age rather than boundary-layer deepening or thermodynamic forcing.

Marine carbohydrates in Arctic aerosol particles – connections to oceanic emissions and in-situ processing

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Carbohydrates are important components of marine organic aerosol particles and may influence Arctic cloud formation and properties, yet their sources and atmospheric fate remain poorly understood. We present the first year-round measurements of combined and dissolved carbohydrates (CCHOaer; DFCHOaer) in aerosol particles collected throughout the annual cycle of the MOSAiC expedition in 2019-2020. CCHOaer were detected in all seasons (0.5-17 ng m^{-3}), and contributed between 0.03 and 2.2% (mean 0.3%) to the particulate mass. Their molecular composition was relatively stable and dominated by glucose, xylose, and galactose, with additional presence of uronic acids in summer. Both, CCHOaer and DFCHOaer showed pronounced summer maxima and seasonal variability that partially aligned with chlorophyll-a, nanophytoplankton, and heterotrophic microorganisms, indicating enhanced biological contributions after sea ice melt. The summer increase in DFCHOaer also coincided with warmer temperatures and higher humidity. In winter, the presence of carbohydrates may be sustained by microbial degradation or viral lysis of organic material in under-ice environments. CCHOaer and DFCHOaer concentrations showed no direct correlation to wind speed or air mass origins instead displaying a high variability in summer. The seasonal behavior of CCHOaer in Arctic aerosol particles differed from primary marine tracers like sodium that was associated with direct oceanic sources in summer and blowing snow in winter. This contrast suggests that carbohydrates, while possibly originated from marine biological sources, undergo significant atmospheric modification that overlay direct source signatures. Strong correlations between CCHOaer and low-molecular-weight organic acids further point to photochemical oxidation as an additional driver of secondary carbohydrate processing. CCHOaer displayed seasonal trends similar to warm-temperature ice-nucleating particles and hyper-fluorescent aerosol particles, supporting their role within a broader Arctic bioaerosol particle population. Overall, our results indicate that the marine ecosystem provides a continuous source of atmospheric carbohydrates, but their composition is strongly modified by both biotic and abiotic processes, particularly in summer.

In situ aerosol and turbulence observations in Antarctica during the SANAT campaign

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From 3 January to 16 February 2026, the SANAT campaign was carried out from Neumayer III Station in Antarctica. Measurements with the polar research aircraft *Polar 6* were conducted using a similar instrument configuration as during the Arctic campaigns BACSAM I (autumn 2022) and BACSAM II (spring 2024), both based in Longyearbyen, Svalbard. A comprehensive suite of aerosol instruments provided observations of aerosol parameters such as number concentration and size distributions, complemented by the aircraft's nose boom, which enables high-frequency (100 Hz) measurements of meteorological variables and turbulence. For SANAT, the setup is complemented by the Aircraft-based Laser ABlation Aerosol MAss spectrometer (ALABAMA), which was not part of the BACSAM campaigns. These measurements are one of the first aerosol profile observations collected in the vicinity of Neumayer III Station.

In addition, the Turbulence-Bird (T-Bird) was towed up to 80 m below the aircraft, providing simultaneous aerosol and turbulence measurements at a second altitude. This dual-level setup offers unique opportunities for studying particle fluxes and is particularly valuable for investigations of the boundary layer.

Here, we present an initial overview of the SANAT campaign and highlight the range of atmospheric conditions encountered.

Patterns and Long-Term Trends of Primary Marine Organic Aerosol in the Arctic

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Rapid changes in Arctic climate have accelerated the retreat of sea ice, altering ocean–atmosphere interactions and impacting marine ecosystems. The reduction in sea ice cover is expected to enhance emissions of primary marine organic aerosol (PMOA) via bubble bursting, influencing aerosol–cloud interactions. This study investigates the emission patterns, seasonal variability, and long-term trends of key PMOA components –polysaccharides (PCHO), amino acids (DCAA), and polar lipids (PL) – across the Arctic from 1990 to 2019. PMOA emissions are highly variable, largely driven by marine productivity and sea-salt production, with peak emissions typically occurring from May to September. Over the 30-year summer period (July–September), a marked decline in sea ice is observed alongside rising concentrations of organic compounds in inner-Arctic waters. Positive anomalies in PMOA emissions have become increasingly common during the last 15 years, and overall PMOA production has grown at an average rate of 0.8% per year since 1990. Among the biomolecules, PCHO exhibits the most substantial increases in both emissions (1.3% per year) and aerosol concentrations (0.8% per year) [1]. The seasonal cycles and long-term trends of PMOA were investigated using the ECHAM6.3-HAM2.3 aerosol–climate model, which incorporates outputs from the offline biogeochemistry model FESOM2.1-REcoM3 [2]. Atmospheric transfer of the three biomolecule groups is parameterized using OCEANFILMS, improving the simulation of marine aerosol emissions. While PCHO dominates seawater concentrations, PL is more prevalent in aerosol particles due to its higher air–sea transfer efficiency. Both ocean and aerosol concentrations show clear seasonal cycles, peaking in late spring to early summer and gradually declining toward late summer. Modeled PMOA seasonal patterns generally align with available observations, within the uncertainties of model assumptions and measurements. Spatial differences in biomolecule production and aerosol emissions are evident, and long-term trends indicate a strong link between PMOA emissions and sea ice decline, with overall emissions increasing by at least 24% over the three decades. PCHO consistently demonstrates the most pronounced upward trends, highlighting its central role in Arctic marine aerosol dynamics.

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Tethered balloon-borne measurements for the characterization of the evolution of the Arctic atmospheric boundary layer at Station Nord

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We present a post-processed comprehensive balloon-borne measurement dataset, which was collected from a dedicated Arctic observation campaign conducted from 19 March to 18 April 2024 in the transition from polar night to polar day at the Villum Research Station (Station Nord, STN, Greenland), as part of the $(\mathcal{AC})^3$ project Balloon-borne observations and dedicated simulations of the transitions between typical states of the Arctic atmospheric boundary layer (A02). The objective of the observations was to characterize the temporal evolution of the Arctic atmospheric boundary layer (ABL), focusing on key transition periods, including cloud development, low-level jet evolution, and day to night shifts.

The measurements were taken by the Balloon-bornE moduLar Utility for profilinG the lower Atmosphere (BELUGA) tethered-balloon system performing in-situ observations of temperature, humidity, wind speed, turbulence, and thermal infrared irradiance from the surface to several hundred meters altitude, with frequent profiling in high vertical resolution. Twenty-eight research flights delivered more than 300 profiles, with up to 8 profiles per hour, complemented by daily radiosonde launches. For the BELUGA instrumentation at STN, we specify the data processing procedures. The post-processed Level-2 data (BELUGA and radiosonde) are provided in instrument-separated data subsets listed in a data collection [1].

One major application of these balloon-borne data is to evaluate different model types—such as numerical weather prediction, single-column models, large-eddy simulations—in representing processes that control the Arctic ABL. As a preparation, we give an overview of the observations, environmental conditions during the campaign, and highlight specific events that are particularly valuable for model comparison. These events include variable cloud scenarios, where transitions between cloudy and cloud-free conditions induce changes in temperature rates and radiative heating rates, thereby influencing the ABL inversion and lapse-rate. Additionally, we examine an observed Arctic low-level jet which we compare with reanalysis. More details about our data can be accessed from the corresponding ESSDD manuscript [2].

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Validation of a Aerosol Optical Depth Retrieval over high albedo surfaces

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The influence of aerosols — liquid and solid particles suspended in the atmosphere — on cloud properties and incoming solar radiation influences climate change, especially in the Arctic region. Using satellite remote sensing data, the Aerosol Optical Depth (AOD), the total reduction along the light path through the atmosphere due to aerosols, can be retrieved. Most algorithms don't work over the cryosphere, due to the high albedo surfaces that falls outside of the assumed parameter range.
The AOD retrieval algorithm AEROSNOW [1] was developed to retrieve AOD over snow-covered surfaces using AATSR data, an instrument which flew on the ENVISAT satellite from 2002 to 2012.
[2] and [3] improved cloud detection and adapted and validated the algorithm for pan Arctic use.
This approach is now being adapted to the SLSTR instrument on Sentinel-3. The results from the validation with ground based AERONET stations [4] as well as sensitivity analysis are presented and an outlook given on the expected changes to the method to further improve accuracy and reduce error.

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Patterns and Trends of Arctic Aerosols from a Merged Dataset of Satellite Retrievals Across Different Surface Types

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Aerosols affect the Arctic energy budget through interaction with radiation and clouds. Satellite retrievals of a parameter called the aerosol optical depth (AOD) can be used to get a pan–Arctic picture of the changes in aerosols over the period of Arctic Amplification. AOD retrieval algorithms differ based on the type of underlying surface and are particularly challenging over bright Arctic surfaces.

Presented here are first results from a merged product of AOD from the instruments Moderate Resolution Imaging Spectroradiometer (MODIS) [1, 2] (over dark and moderately bright surfaces) and Advanced Along-Track Scanning Radiometer (AATSR) (over bright surfaces)[3, 4]. The spatial and temporal patterns emerging from this observational product will be compared to existing model and reanalysis datasets.

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Radiatively driven entrainment and turbulence forcing at Arctic cloud tops from 2D imaging and atmospheric profiling

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Arctic clouds strongly influence the regional energy budget and boundary-layer structure, making them a key factor in understanding Arctic amplification. However, the processes governing radiatively driven turbulence and cloud-top entrainment remain poorly constrained, limiting our ability to assess their role among the main causes and relative contributions to Arctic amplification (SQ1). Improving this process-level understanding is therefore essential for reducing uncertainties in weather and climate models.
To contribute to a better understanding, this study combines near-infrared (NIR) radiance measurements from specMACS (spectrometer of the Munich Aerosol Cloud Scanner) [1], thermal-infrared (TIR) brightness temperature (7.7 12 μm) fields from VELOX (Video airbornE Longwave Observations within siX channels) [2], and co-located dropsonde atmospheric profiles to retrieve radiatively driven process rates in the Arctic. The data were collected during the HALO-$(\mathcal{AC})^3$ campaign in March/April 2022 [3].
For selected scenes, cloud optical thickness (τ) and effective droplet radius (reff) are retrieved from the NIR radiance measurements using radiative transfer simulations performed with libRadtran, following an extended Nakajima-King approach. In parallel, the TIR brightness temperature data are used to determine the cloud-top height for each spatial pixel. An approximate estimate of the cloud base altitude is obtained from the atmospheric dropsonde profiles. Combining the retrieved τ, reff, and cloud-top height fields with the cloud base and adiabatic assumptions enables the construction of physically consistent vertical cloud profiles. These profiles are then used in TIR radiative transfer simulations to derive heating rate profiles within and around the cloud. From the uppermost layer, horizontal fields of cloud top heating rates are then derived. Those radiative heating rates can be set into context of the local atmospheric profiles to quantify radiatively driven entrainment rates and turbulence-forcing quantities at cloud top. We expect that the cloud top position relative to the temperature inversion will play a crucial role.

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Cloud Regime Classification and Evolution during Arctic Cold Air Outbreaks

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Arctic Cold Air Outbreaks (CAOs) are a crucial driver of meridional transport, moving airmasses from the Arctic towards mid-latitudes. During the transport, the airmasses experience a significant transformation when they acquire large amounts of heat and moisture over the open ocean. This rapid change affects the downstream weather and climate further south. In particular, the characteristics of boundary-layer clouds are known to change along the air mass trajectory, which then feeds back into the radiative effect of the clouds and precipitation. Our study utilizes comprehensive observations from three Arctic $(\mathcal{AC})^3$ aircraft campaigns, merging dropsonde and satellite-based analysis for cloud regime classification. We investigate the full lifecycle of the boundary layer, from initial organization characterized by shear-driven cloud streets to the final state of unorganized, buoyancy-driven cellular structures. Using more than 500 dropsonde profiles we present the first large-sample observational validation of the stability parameter -H/L, defined as the negative ratio of the boundary-layer height and the Monin-Obukhov length, which we use as a predictor of cloud regimes in marine CAOs. From our study two regimes emerge: a shear-driven regime (positive M-Index, smaller -H/L) and a buoyancy-driven regime (positive M-Index, larger -H/L). The shear-driven regime has horizontal wind speeds that are about 6 m s-1 higher than in the buoyancy-driven regime. Our analysis of three classified cloud patterns (cloud streets, isotropic clouds, and open cells) reveal a systematic transition from shallow, cold and dry to deep, warm and moist boundary layers along the air mass trajectory. Cloud streets occur primarily when the M-Index exceeds a value of 3.6, indicating a minimum instability threshold for roll convection and establishing a robust observational link between boundary-layer stability and cloud organization. Our findings provide observational evidence that under a future warming climate, the boundary layer might favor buoyancy-driven cloud regimes in the initial phase of CAOs, characterized by greater radiative impact, precipitation, and cloud fraction.

Quantifying the influence of Barents-Kara sea ice loss on Ural blocking

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Arctic amplification has been linked to significant changes in mid-latitude weather patterns, including the increasing frequency and persistence of extreme weather events [1]. This study quantifies the influence of Barents-Kara (BK) sea ice variability on winter Ural blocking and their link to Eurasian cold winters. We analyse these linkages within a causal network framework, considering ENSO as a potential common driver of BK sea ice and Ural blocking (UB). Using ERA5 and two blocking indices (the Absolute (AGP) reversal and Anomaly-based), we assess blocking frequency and persistence. We show Ural blocking events occur more frequently and last longer during years with low BK sea ice. We quantify this response by regressing UB on BK sea ice, controlling for ENSO by including it as a covariate and separating by phases. We find a robust influence of BK sea ice variability on UB. Results are sensitive to blocking index but remain qualitatively consistent. Composite analyses of surface temperature anomalies during UB events show a warm-Arctic/cold Eurasia pattern that becomes more pronounced during winters with low BK sea ice and La Niña [2, 3]. We further quantify the contribution of BK sea ice variability to temperature trends through its influence on Ural blocking. Given the limited observational record and large internal variability, we use large-ensemble simulations to attribute the influence of BK sea ice on temperature trends. By quantifying the links between Arctic sea ice, Ural blocking and Eurasian temperature, this work advances the understanding of Arctic-midlatitude interactions and improves the predictability of Eurasian cold extremes.

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Temperature and humidity trends from Ny-Ålesund balloon-borne measurements

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Connecting the long-term surface and upper-air meteorological observations in Ny-Ålesund with circulation regime analysis reveals how changes in meridional transport impact weather and climate in the Svalbard region.

At Ny-Ålesund, Svalbard, daily radiosondes are launched since 1993, resulting in a data series >30 years of height-resolved temperature, humidity and wind which allows for climate trend studies in the troposphere and lower stratosphere. From these, a general tropospheric warming is observed over the entire period, with varying strength for the different decades, and varying intensity of the warming signal in the different seasons, respectively. While autumn and winter encounter a significant bottom-amplified warming of the entire troposphere, temperature increase in spring is hardly recognizable. The latter can be attributed to prevailing atmospheric circulation patterns in the month of March, which also lead to a higher incident of marine cold air outbreaks [1], and contribute to a weakening of the overall warming trend.

Atmospheric transport events also influence the moisture content of the tropospheric column. Cyclones carry moist air from lower latitudes, and together with moist intrusions and atmospheric rivers are driving the observed wintertime humidity increase. Nonetheless, over climatic time scales, a wintertime increase of humidity is observed even when the air originates from the Central Arctic [2].

Overall, tropospheric temperature and humidity over Svalbard are related to large scale atmospheric circulation, affecting the local ambient conditions by altering clouds, radiation, and precipitation on synoptic time scales, while leading to distinct temperature and humidity trends for each season on climatic time scales.

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Balloon-borne observations and simulations of the transition phases in the wintertime Arctic atmospheric boundary layer at Station Nord, Greenland

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Arctic amplification is strongest in winter, when pronounced near-surface temperature inversions and shallow, stable atmospheric boundary layers (ABLs) prevail. To quantify the impact of the main drivers of the Arctic amplification in the Arctic winter, we have performed a four-week tethered-balloon campaign at Station Nord, Greenland, in March–April 2024. We have collected high-resolution profile data of the Arctic ABL during transitions between cloudy and cloud-free conditions [1].

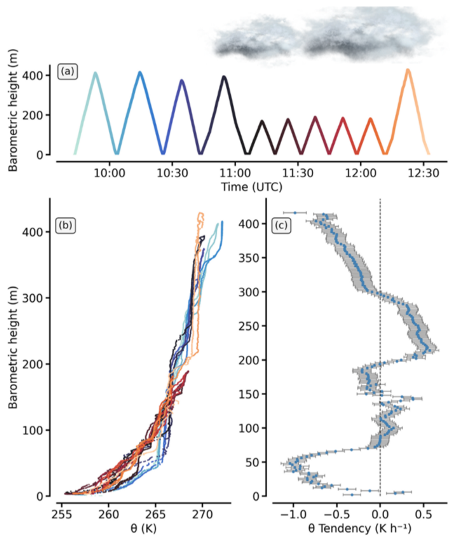

Fig. 1: Near-surface thermal structure (a) flight altitude over time, (b) corresponding potential-temperature profiles, and (c) potential-temperature tendencies-differences between first and last θ profiles.

We analyze how measured profiles of thermodynamic and radiative properties evolve during these transition processes. Additionally, we investigate how temperature lapse rate, inversion height, and cloud distributions influence surface warming. Fig.1 illustrates that during the transition, the near-surface inversion weakens, accompanied by distinct height-dependent temperature tendencies.

To complement the observations, we have initiated preliminary experiments with the Dutch Atmospheric Large-Eddy Simulation (DALES) which reproduce key features of the observed transition, offering insight into how high-resolution models represent ABL transition processes. These combined observational and modeling efforts aim to improve understanding of the processes controlling Arctic surface temperature response and the role of lapse-rate feedback.

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Evaluating Reanalysis Snowfall Estimates in the Arctic using Flight Based Radar Observations

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Arctic precipitation is a major challenge when it comes to its measurement due to the sparseness of observations ([1]). It becomes more challenging over the ocean, where snowfall is frequently related to Marine Cold-Air Outbreaks (MCAOs). The nature of the often low-intensity snowfall stemming from low-level clouds building up in the convective boundary layer during MCAOs introduces uncertainty, making it difficult to capture in numerical weather prediction models. They produce widespread precipitation over the Arctic, predominantly in the North Atlantic sector of the Arctic. These precipitation characteristics and the few available observations make them poorly constrained in reanalysis. This study aims to assess how well snowfall rates during MCAOs are captured by two reanalysis datasets: ERA5 and the regional high-resolution Copernicus Arctic Regional Reanalysis (CARRA).

The analysis uses snowfall estimates derived from radar-based (94 GHz Cloud Radar) observations during three flight campaigns performed in the Arctic as part of the **(AC)³** "Arctic Amplification" project. These aircraft campaigns were carried out in the spring between 2017 and 2022 [2] and probed several MCAOs. For each measurement the MCAO index is derived from the reanalyses as the difference between potential temperatures at surface (skin) and 850 hPa pressure levels. The snowfall estimates are calculated using a radar reflectivity Ze – snowfall rate S relationship specifically tailored for MCAO conditions ([3]). These high-resolution radar-based snowfall estimates can serve as a reference for evaluating the spatial and temporal variability of snowfall in ERA5 with 27 km horizontal resolution and CARRA with 2.5 km, especially during the MCAOs conditions.

Through this intercomparison, we aim to assess reanalysis performance over a wide range of snowfall intensities, and understand how well current reanalyses represent the precipitation formed in low-level, often related to mixed-phase clouds, which are typical of MCAO conditions. The study also aims to quantify how similar or different the two reanalyses (ERA5 and CARRA) are. The results can aid in the development of improved microphysical representations in reanalysis considering their different resolutions and contribute to better snowfall estimates in the Arctic region.

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Macro- and Microphysical Properties of Atmospheric River Snowfall: Results from Two Instrument Sites

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Atmospheric rivers (ARs) are filamentary structures of enhanced water vapor transport that lead to heavy precipitation events. While ARs are commonly associated with extreme rainfall in coastal regions, they also contribute to wintertime snowfall in the mid- and high-latitudes. Previous studies have shown that ARs can lead to increased snowfall accumulation, but no study has extensively examined if and how ARs may impact the microphysical properties of snowfall. This study leverages remotely sensed and in situ observations at long-term ground validation instrument sites in Marquette, Michigan and Hyytiälä, Finland to evaluate snowfall properties during ARs and compare to snowfall properties not during ARs (NoAR). A snowfall classification scheme is first applied that identifies large-scale snowfall events and classifies them as either AR or NoAR at each of the long-term instrument sites. To identify differences between the two regimes, reanalysis data products and ground-based observations are utilized to examine the large-scale properties, environmental conditions, and macro- and microphysical characteristics of AR and NoAR snowfall. During AR snowfall, there is a preferential large-scale setup at both instrument sites that results in enhanced water vapor transport. The AR snowfall events produce higher snowfall rates, as well as a higher number of denser and faster-falling snow particles compared to NoAR snowfall [4].

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Identifying drivers of the thermal-infrared radiative effect of Arctic low-level clouds in cold air outbreaks

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Marine cold air outbreaks (CAOs) represent an important meridional transport mechanism out of the Arctic to lower latitudes. The cloud field properties change along the air mass transformation [1], and the cloud radiative effect (CRE) is increasing in the downstream direction. These evolution processes are important to understand current and future CAOs in a warming Arctic, which will favor weaker events. Here, we aim to identify the driving factors of this increase for different CAO events of varying intensity, which were observed during the HALO-$(\mathcal{AC})^3$ campaign in spring 2022. The High Altitude and LOng range research aircraft (HALO) sampled CAOs in a quasi-Lagrangian way with a remote sensing payload [2]. The thermal-infrared imager VELOX (Video airbornE Longwave Observations within siX channels; [3]) provided 2D broadband (7.7 µm to 12.0 µm) brightness temperature fields of cloud tops and the surface with a spatial resolution of 10 m for a 10 km target distance. Those fields are used to determine cloud fractions and estimate cloud top temperatures. Furthermore, a pixel-wise CRE at flight level is derived, providing the small-scale VELOX perspective, which is mainly dependent on the cloud top temperature. Those VELOX products can be combined with the lidar cloud top height to analyze the downstream cloud top height and temperature change. To expand the spatial dimension of the CRE to a larger scale, broadband radiometer measurements and cloud-free simulations are used. This large-scale CRE at flight level depends on cloud top temperature as well as cloud fraction. Thus, both CREs can be used in combination with the cloud mask to identify the driving factors of the CRE increase during the initial hours over open ocean. The results imply that the strength of this increase depends on the CAO intensity and is in general driven by increasing cloud fraction and changing cloud organization. Thus, this analysis provides a TOA-like perspective on the thermal-infrared radiative impact of a low-level cloud field, which is (trans-)forming during the initial stages of a CAO.

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Extending the Surface Energy Budget View on Arctic Atmospheric Rivers: Climatological Classifications and Dependence on the Flavor

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Atmospheric rivers (ARs) significantly impact the Arctic climate, for example, by modifying the surface energy budget (SEB) and thus impacting sea ice and the Greenland ice sheet. Based on the ERA5 reanalysis, we present new aspects of ARs' impact on the SEB in the central Arctic (>65°N, 1979–2021). We extend the statistical investigation of AR-related SEB anomalies by a percentile-based analysis quantifying the commonness of these anomalies, and ARs' relevance for the seasonal mean SEB. Further, we distinguish between two AR flavors: moisture- and wind-dominated. Their differences in moisture, wind speed, and liquid water path are linked to differences in the SEB impact. Three factors primarily dominate the climatological SEB impact of ARs: surface type, season, and AR flavor. The largest anomalies occur during moisture-dominated winter ARs over open ocean, where also the largest climatological contribution of ARs occurs. Conversely, the statistically rarest impact manifests in winter over sea ice.
This contribution presents the recently published paper [1].

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A Ground and Satellite Based Characterization of Atmospheric River Impacts on Clouds and Precipitation in Greenland

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Atmospheric rivers (ARs) are long bands of strong horizontal water vapor transport responsible for over 90% of total integrated vapor transport in extratropical and polar regions. Using a 12-year record (2010-2022) of ground-based remote sensing, radiosonde, snow stake, and reanalysis data from Summit Station, Greenland, we quantify the impacts of 41 AR events on snowfall, clouds, and the atmospheric state [1]. Although ARs occur 0.97% of all times and 2.68% of snowing times, they contribute 5.8% to total snowfall, enhance snowfall rates by 80%, and double daily snowfall accumulation relative to general snowing conditions. AR events increase near-surface and atmospheric profile temperatures by over 7 °C up to 350 hPa and increase specific humidity by 66%, deepen clouds and increase radar reflectivity. While ARs contribute only a modest fraction to total accumulation in central Greenland, they consistently produce clouds and snowfall and create an environment that fosters more complex snow processes in an area typically characterized by cold, dry conditions. We additionally present findings from CloudSat 2C-SNOW-PROFILE and 2C-RAIN-PROFILE and find that when ARs are on the Greenland Ice Sheet they snow more than 60% of the time that they are present, increase snowfall rates by 3-4x the CloudSat climatology, and increase snowfall frequency. ARs are present between 1% and 10% of all time in the Greenland-North Atlantic region but over 30% of rain occurrence in the ocean west of Greenland coincides with an AR, and ARs coincide with nearly all high latitude rain observations. We hypothesize that ARs which reach the accumulation zone will exhibit distinct cloud and liquid water characteristics as they evolve on their pathway from ocean to the highest altitudes of the ice sheet.

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The changing role of convection in the Arctic

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The strong warming of the Arctic has profound implications for the atmospheric energy budget. Recent studies indicate that the Arctic energy balance is transitioning from a predominantly radiative-advective equilibrium towards a radiative-advective convective regime [1]. Consequently, convective processes are expected to play an increasingly important role in the Arctic atmosphere under future climate conditions.
Using monthly CMIP6 model output from an idealized CO2-forcing scenario, we analyze changes in the occurrence of convective precipitation relative to total precipitation. Our results show a pronounced seasonal and surface-dependent signal. The highest fractions of convective precipitation are found over open ocean and sea ice during winter, while over land they dominate in summer. This pattern is also reflected in the associated trend estimates. However, the inter-model spread across the CMIP6 models is substantial, with individual models even exhibiting opposing trend signs. This large spread is consistent with pronounced differences in simulated sea ice extent among the models, suggesting potential linkages to other key variables.
Further, we investigate the past 50 years of ERA5 reanalysis data. While the overall seasonal patterns are broadly comparable, some differences can be observed. In particular, the strongest increasing wintertime trends in the fraction of convective precipitation are detected over regions of retreating sea ice. This signal may be linked to enhanced marine cold-air outbreaks, highlighting the interaction between the atmosphere and sea ice.

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Evaluating Fog Forecasts in the Central Arctic Ocean Using AO2025 Observations

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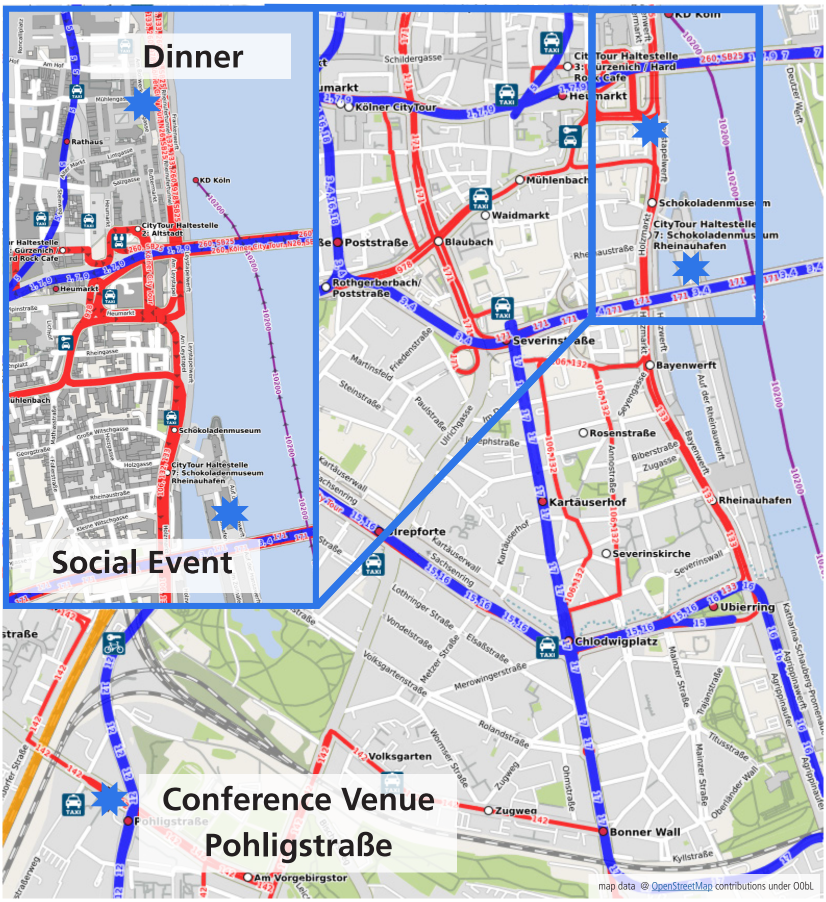
Fog is a critical factor for Arctic ship operations, yet its prediction remains challenging due to limited observational coverage and model uncertainties. Most satellite instruments struggle to detect fog and low clouds, making ship-based campaigns essential for improving forecasts. However, verification of fog prediction in the Central Arctic Ocean is still scarce.
We use observations from the Canada–Sweden Arctic Ocean 2025 (AO2025) expedition to evaluate short-range (24–48 h) visibility forecasts from the ECMWF Integrated Forecasting System (IFS). Doppler cloud radar and ceilometer measurements are combined to determine whether reduced visibility is caused by fog or precipitation. Our analysis reveals visibility biases linked to a misrepresentation of cloud base height. We perform sensitivity experiments addressing these biases to provide guidance for improving Arctic fog prediction. The developed diagnostics can be applied to more ship campaigns and model frameworks.



Conference Venue

University of Cologne
Institute of Geophysics and Meteorology
Pohligstraße 3, 50969 Köln

Social Event

Deutsches Sport & Olympia Museum
Im Zollhafen 1, 50678 Köln

Dinner

Dom im Stapelhaus
Frankenwerft 35, 50667 Köln

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Program

Monday, 23 February 2026
Session Highlights – Mixed-phase Clouds
Evening Talk

Tuesday, 24 February 2026
Session Highlights – Aerosols
Session Strategic Question 1
Poster Session I: Mixed-phase Clouds & Sea Ice
Breakout Sessions – Crosscutting Activities (CCA)

Wednesday, 25 February 2026
Session Highlights – Sea Ice
Session Strategic Question 2
Poster Session II: Aerosols & SQs
Social Event & Dinner

Thursday, 26 February 2026
Session Strategic Question 3
Breakout Sessions – Crosscutting Activities (CCA)

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