

Prix de Quervain 2024

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Influences of snow microstructure on the Arctic sea ice energy budget



ETH zürich

Photo: D. Ruché

Contents

- ◇ Introduction to sea ice
- ◇ Measuring snow on Arctic sea ice
- ◇ Chapters
 - ◇ Vapor fluxes
 - ◇ Heat transfer
 - ◇ Radiative transfer (microwave and optical)
- ◇ Responsible fieldwork
- ◇ Outlook



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Sea ice differences....

Image credit: <https://www.samconniff.com/>

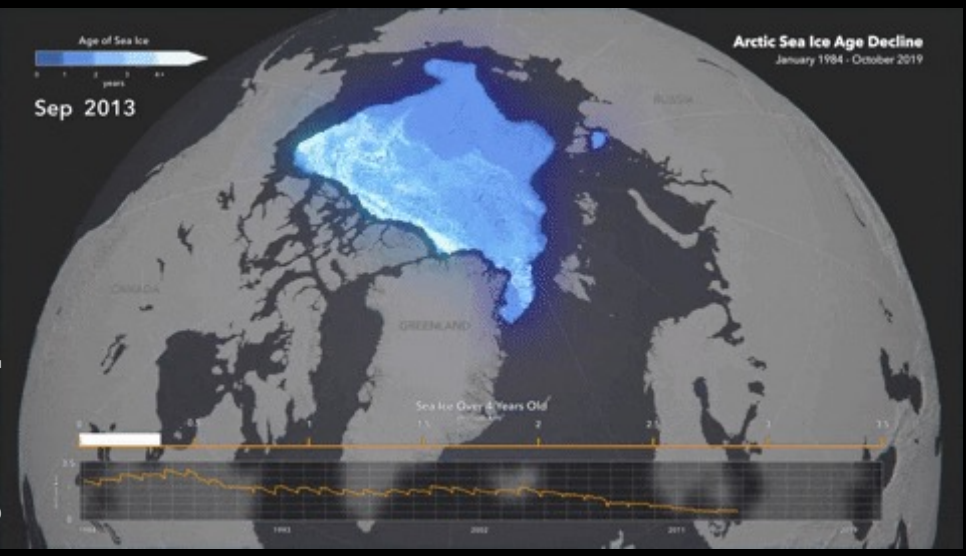
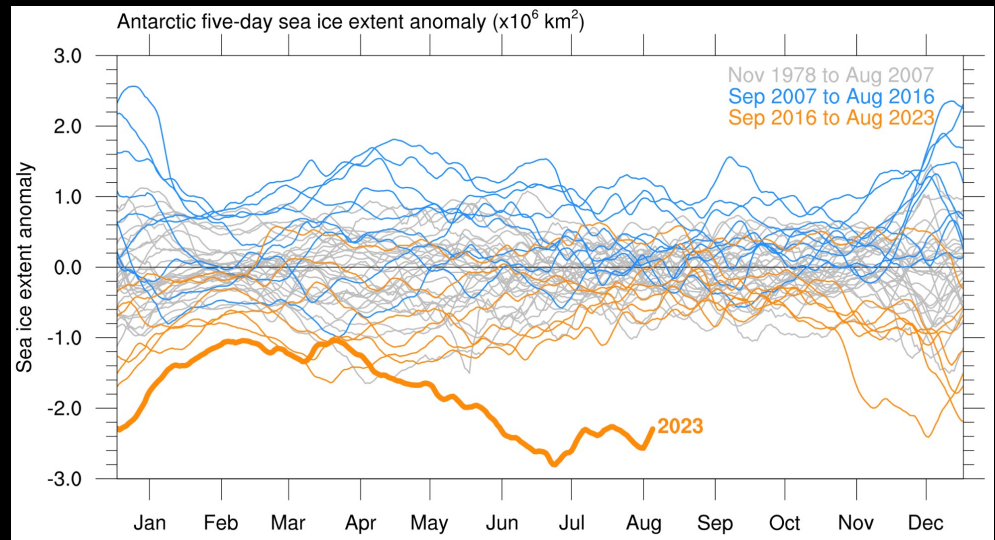
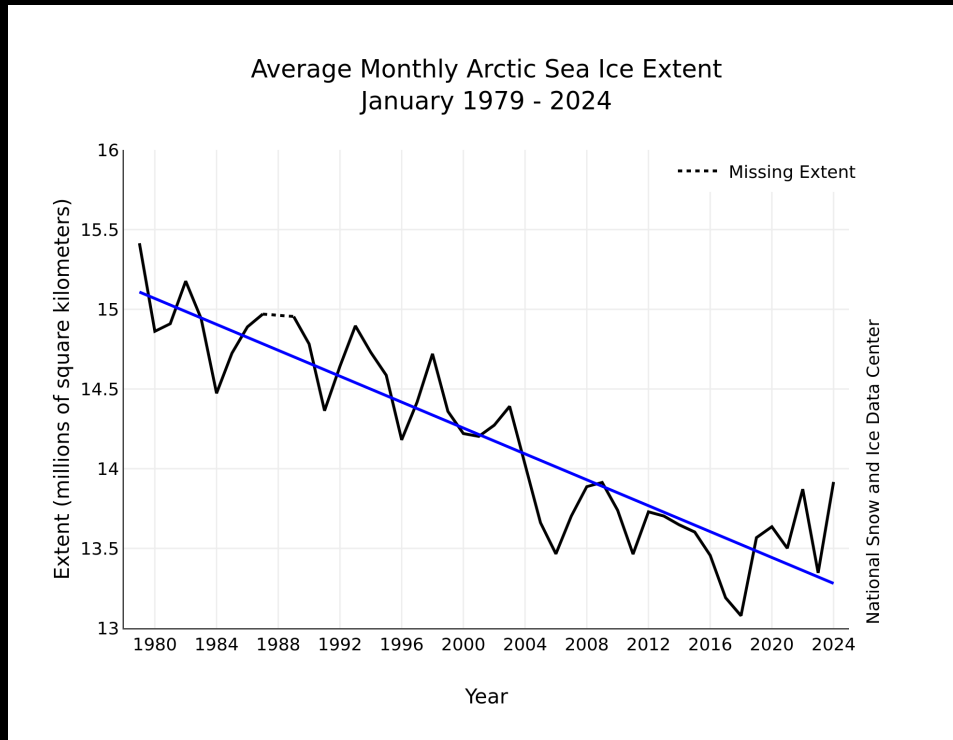


Image credit: NASA



A decrease in Arctic + Antarctic sea ice extent



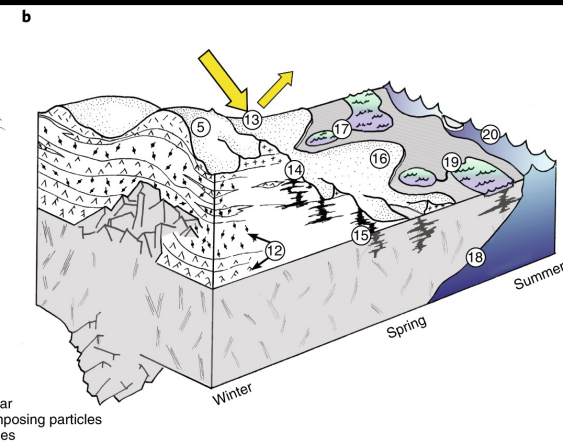
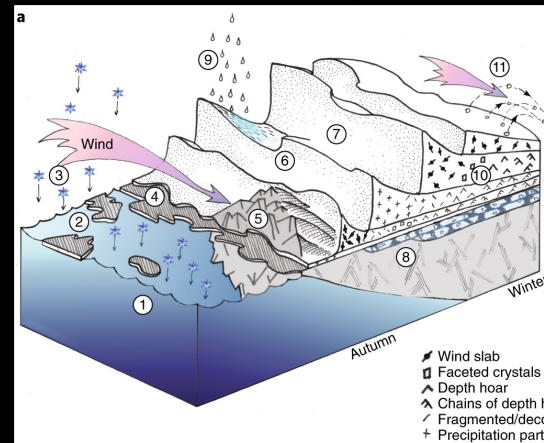
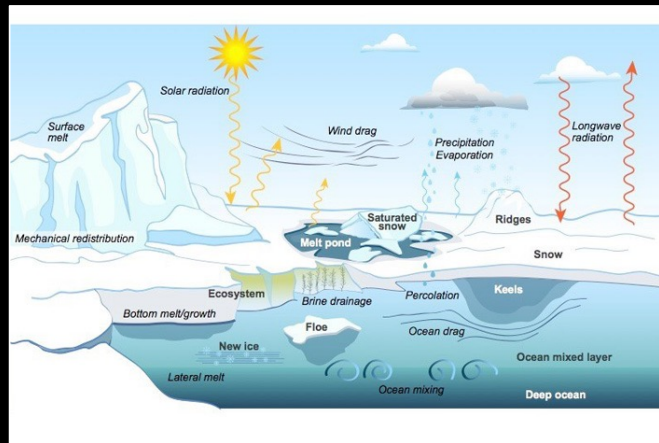
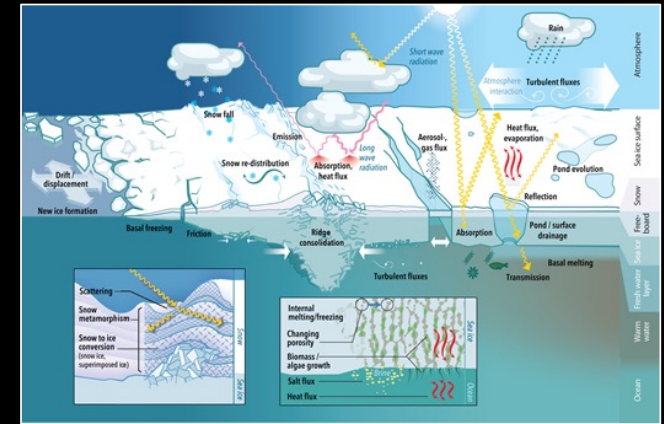
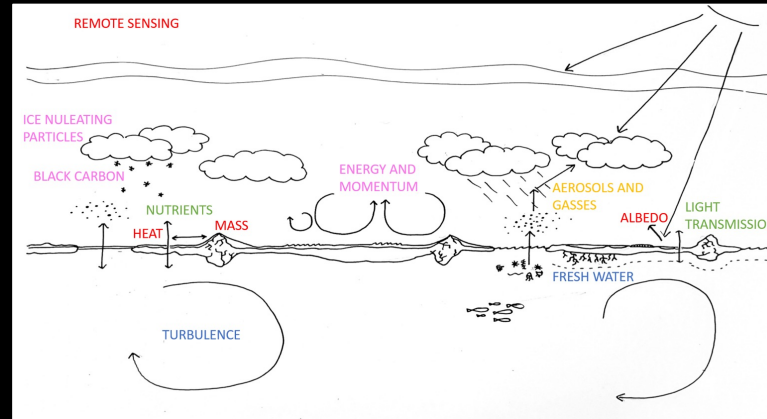
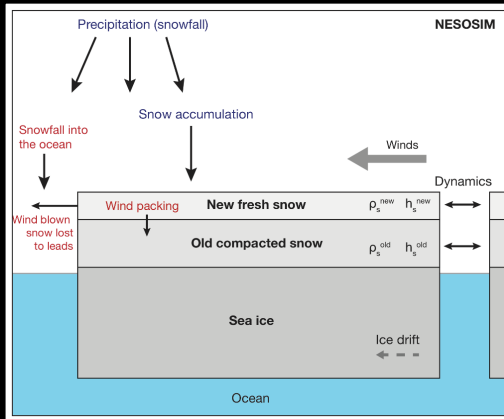
Purich & Doddridge 2023

Source: National Snow and Ice Data Center



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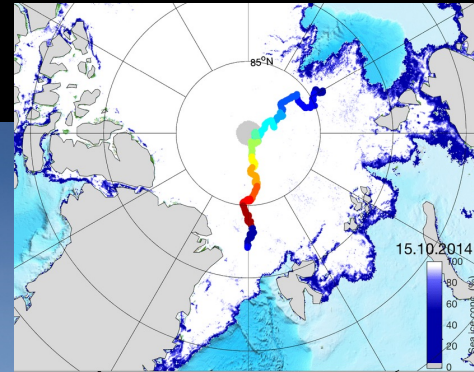
The role of snow in the sea-ice system



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Measuring snow on sea ice

Photo: M. Grutsch



credit: NOAA

All datasets are published
OPEN ACCESS

PANGAEA.
Data Publisher for Earth & Environmental Science

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Schneebeil, Martin; Dadic, Ruzica; Wagner, David N; Arndt, Stefanie; Clemens-merle, Stefan; Hannula, Henna-Reetta; Jaggi, Matthias; Kolabutin, Nikolai; Lehning, Michael; Matero, Ilkka; Nicolaus, Marcel; Oggier, Marc; Pirazzini, Robert; Raible, Christopher; Rapp, Michael; Reuter, Christof; Sankar, Dhanraj; Schmale, David; Schuler, Michael; Seifert, Johannes; Smith, Madison M; Sponoff, Joshua; Stenke, Alexander; Tegtmeier, Tobias; Willemann, Johannes; Ziska, Peter; 21): Snowpit raw data collected during the MOSAiC expedition [dataset bundled 4, <https://doi.org/10.1594/PANGAEA.935934>

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A Database of Snow on Sea Ice in the Central Arctic Collected during the MOSAiC expedition

Amy R. Macfarlane, Martin Schneebeil, Ruzica Dadic, Aikaterini Tavrì, Antonia Immerz, Chris Polashenski, Daniela Krampe, David Clemens-Sewall, David N. Wagner, Donald K. Perovich, Hannula Henna-Reetta, Ian Raphael, Ilkka Matero, Julia Regnery, Madison M. Smith, Marcel Nicolaus, Matthias Jaggi, Marc Oggier, Melinda A. Webster, Michael Lehning, Nikolai Kolabutin, Polona Itkin, Reza Naderpour, Roberta Pirazzini, ... Steven Fons | Show authors

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Data paper



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Conditions onboard

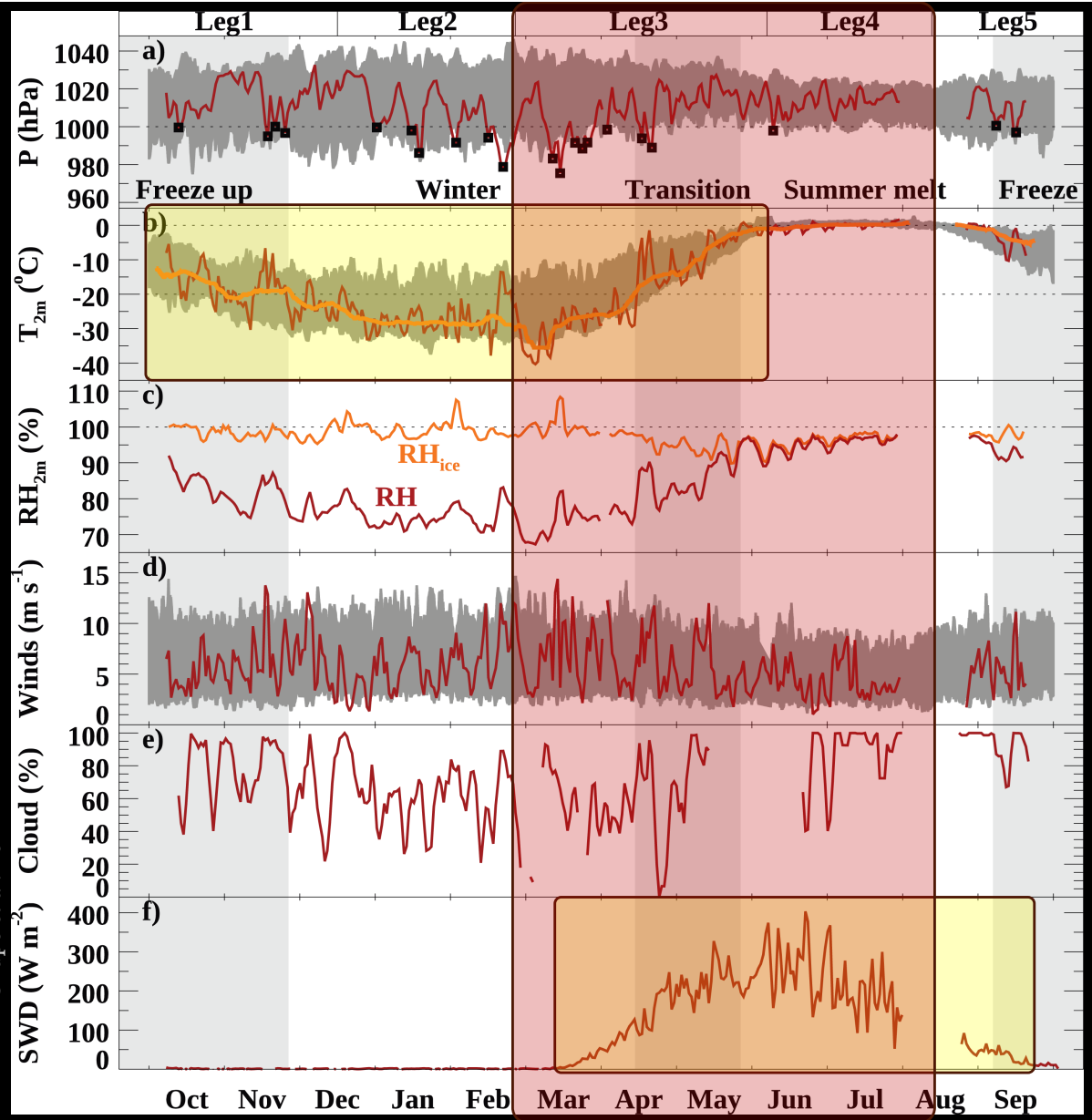
Photo: M Jaggi



Photo: M Gutsch



Shupe et al. 2022

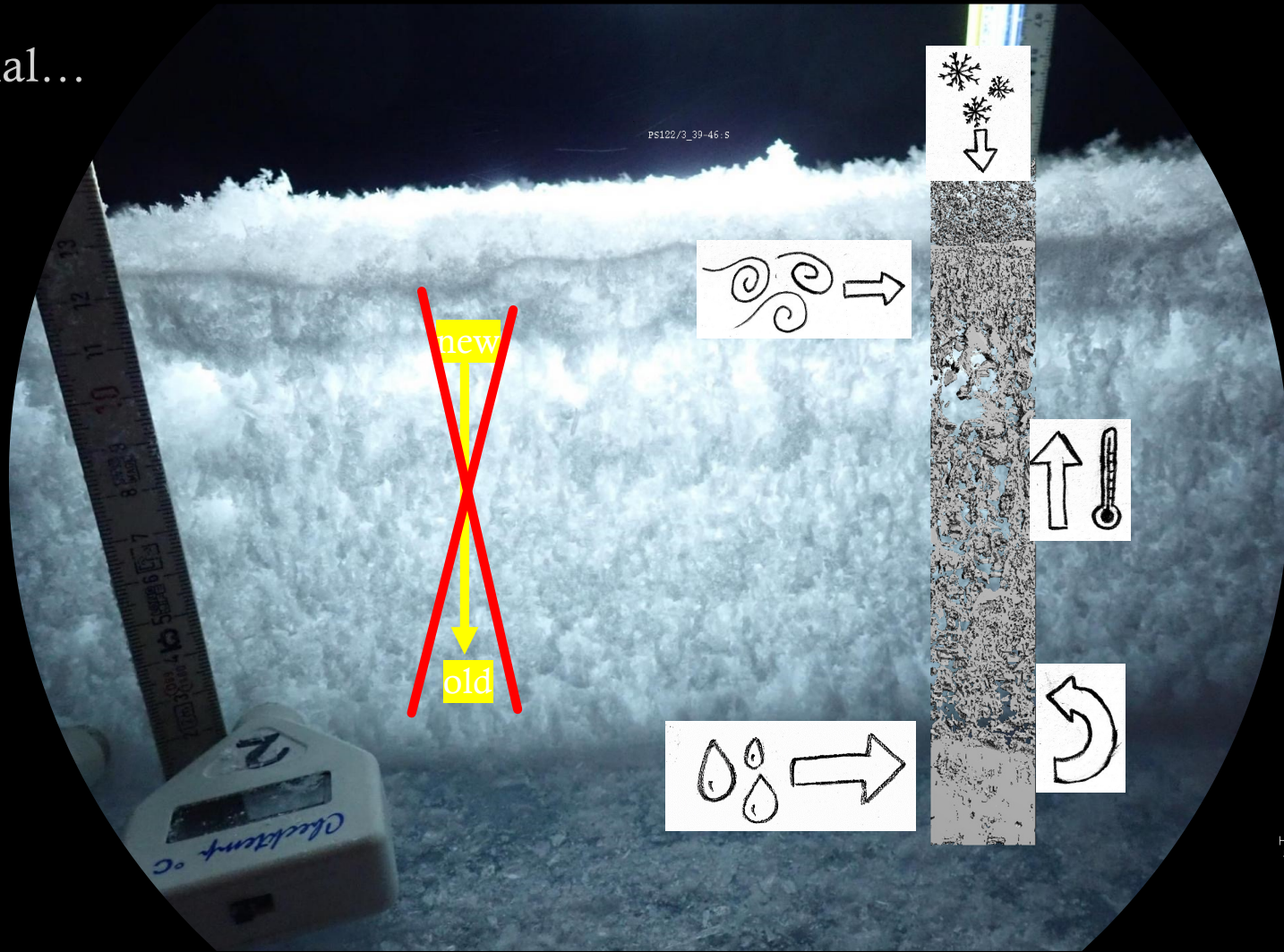


Snow as a material...



Snow as a material...

Temperature gradients



5.0 mm

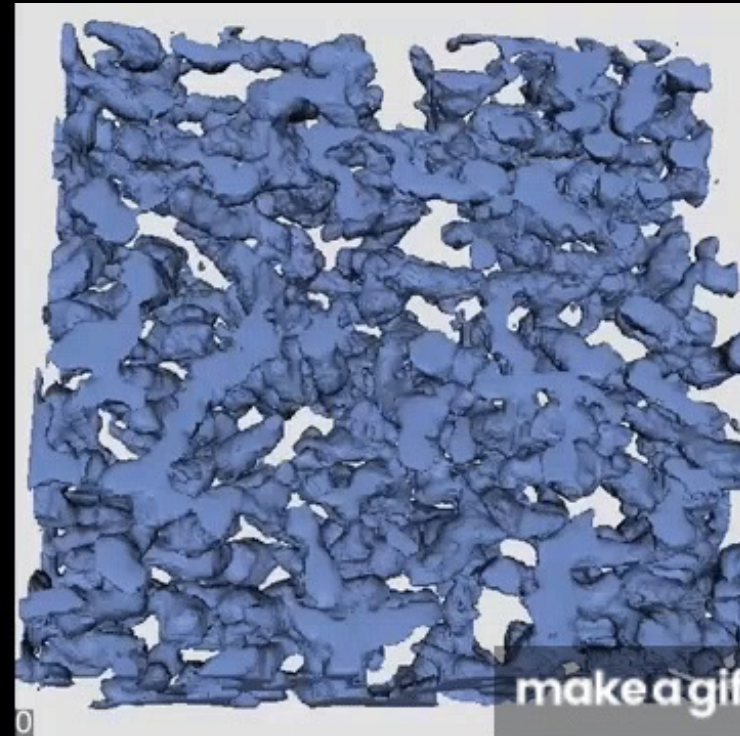
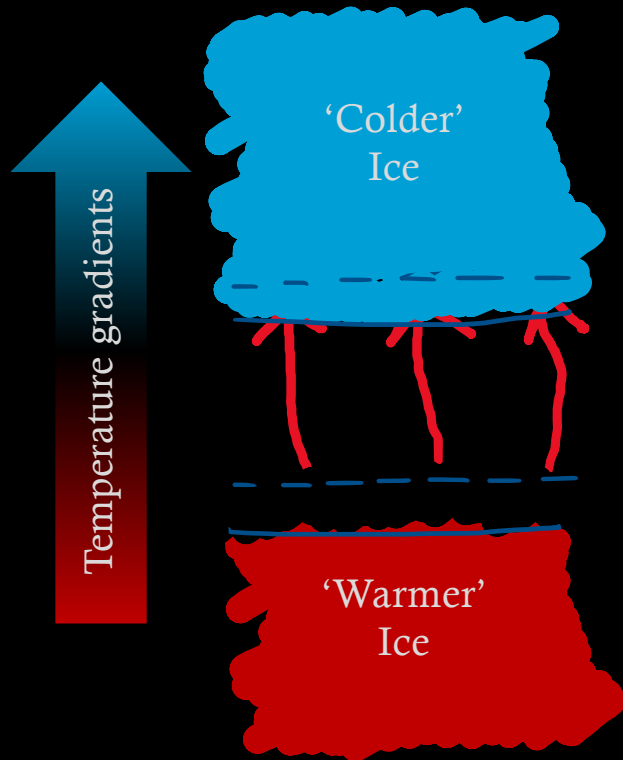


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Vapor movement within the snowpack

... sublimation (ice → vapor) and deposition (vapor → ice) = snow metamorphism!

https://youtu.be/Eee3en_3bKE

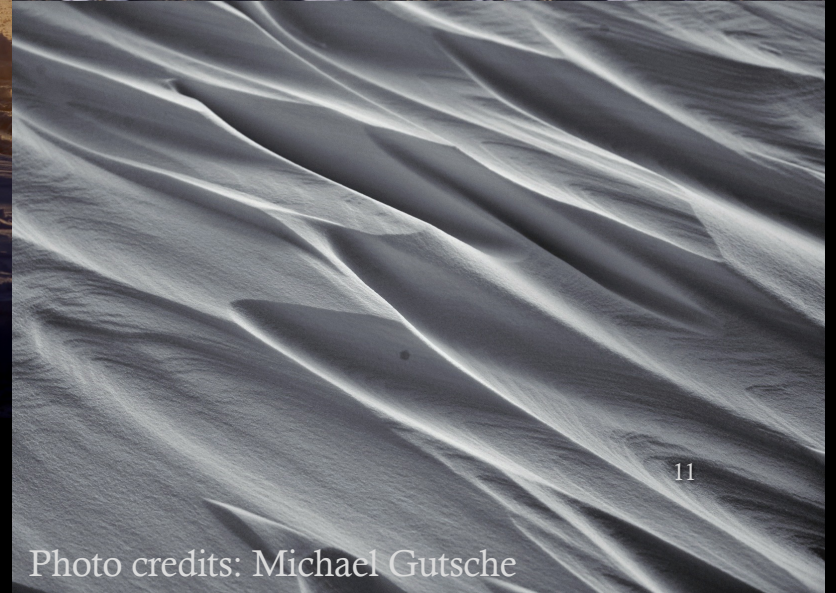


Hours

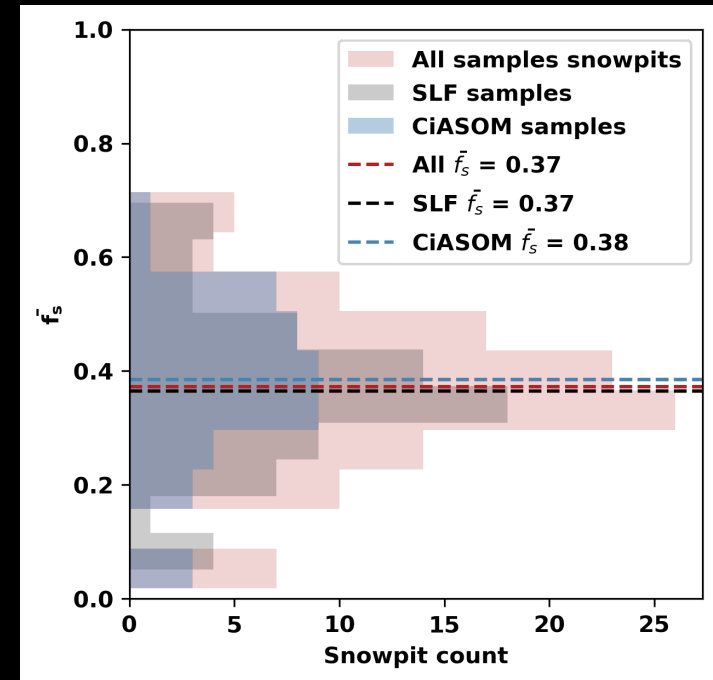
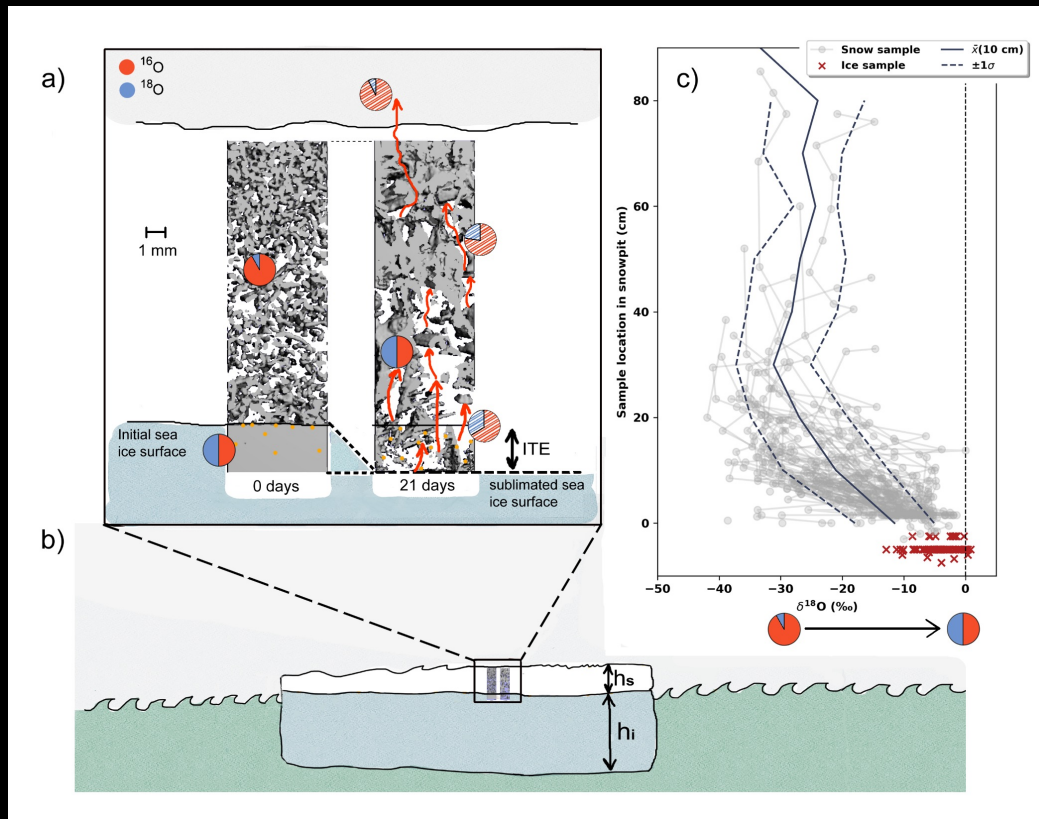


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We know there is a lot of vapor in the sea-ice system...



Sea ice sublimation contributes to the snow mass



Macfarlane, et al (In review)

20-60% of the snowpack originates from the underlying sea ice vapor

High temperature gradients are because the snow INSULATES



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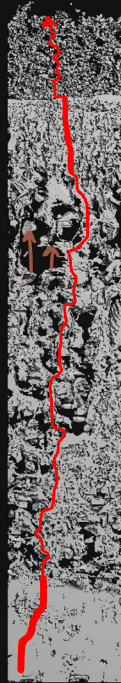
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Photo credits: Michael Gutsche

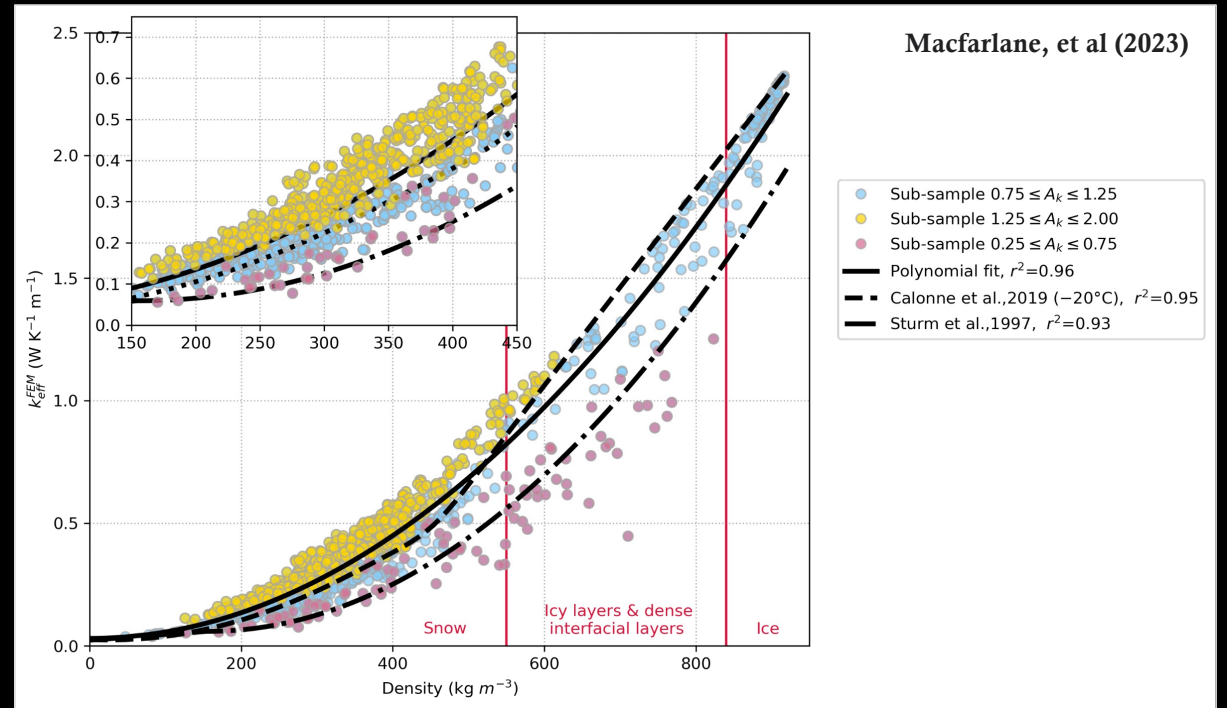
Snow thermal conductivity (Ks)

PS122/3_39-46_s

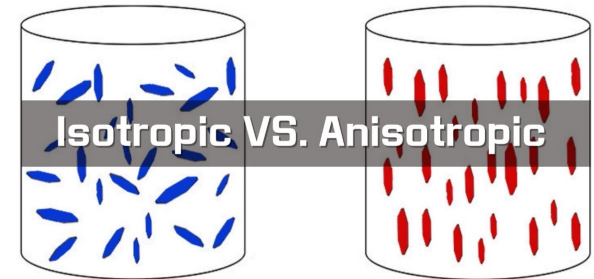
Diffusivity is relatively negligible



Ice conductivity is dominant

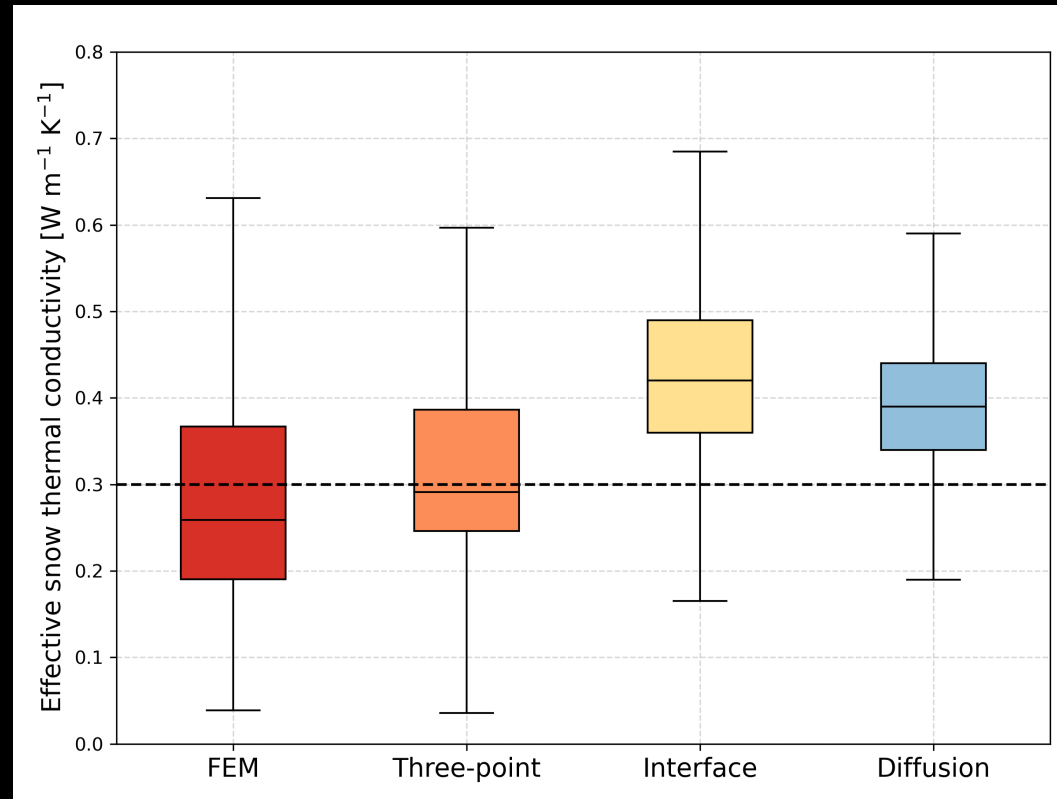


Snow density $\propto K_s$



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Snow thermal conductivity (Ks)



Macfarlane et al.(2023)

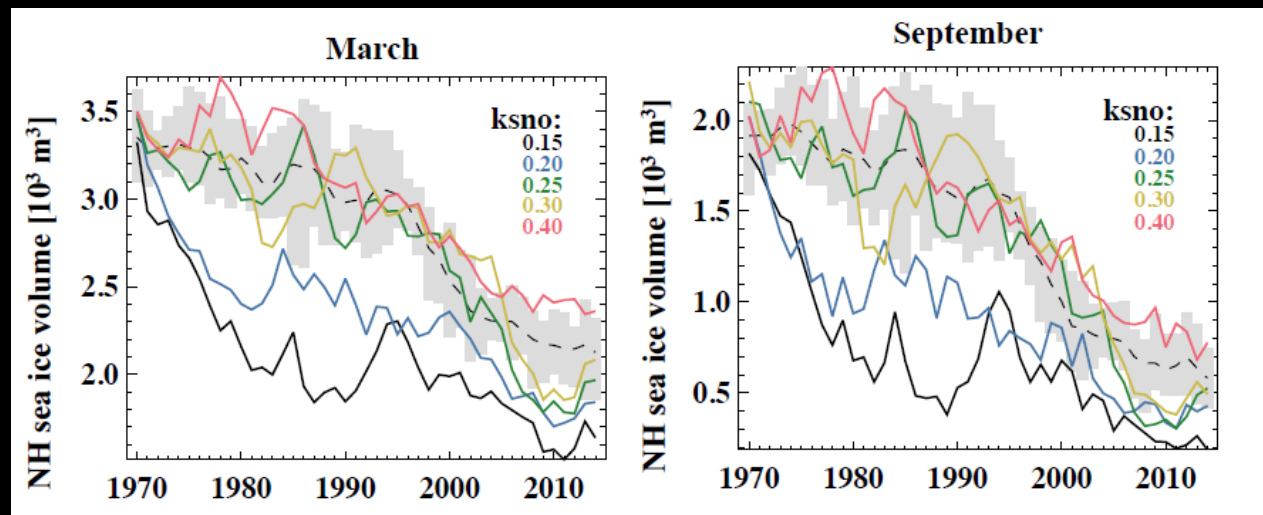
Perovich et al.(2023)

Rafael et al.(2024)

Sledd et al.(2023)

How sensitive is sea ice volume to k_s ?

- CESM2 run in the Arctic for 1970-2014
- K_s varied between 0.15 \rightarrow 0.4 $\text{W m}^{-1} \text{K}^{-1}$
- Sea ice volume sensitive to K_s changes between 0.15 and 0.25
- Above 0.25 likely due to internal variability



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Sledd et al. (in prep)



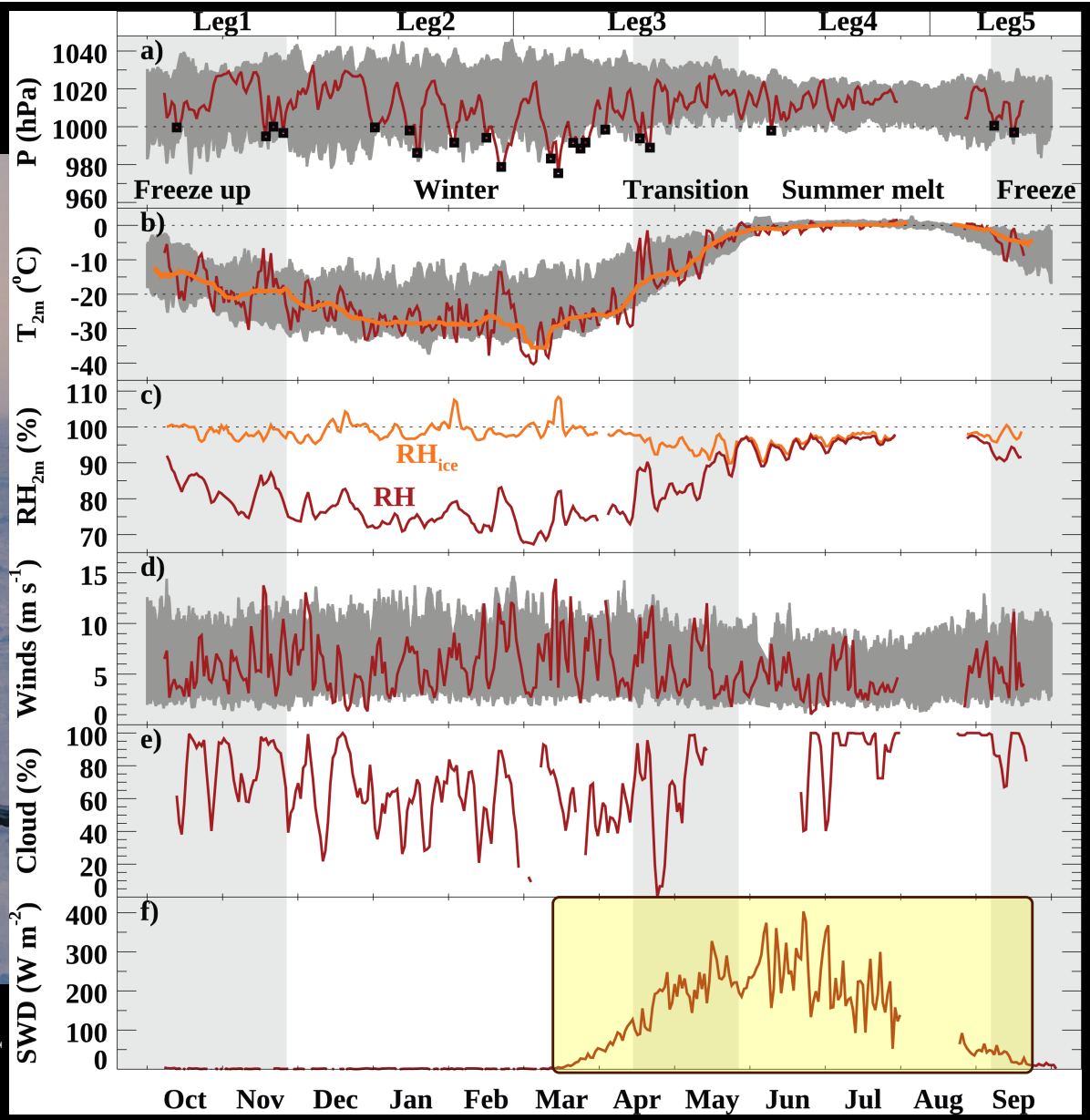
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Conditions onboard

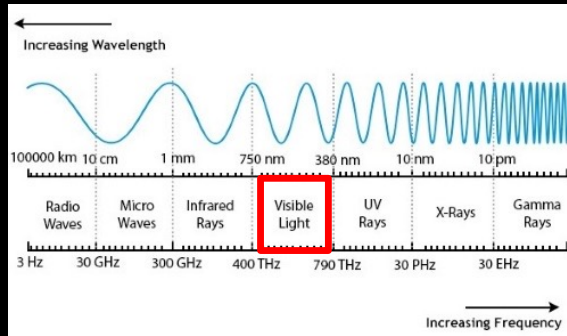


Photo: M Grutsch

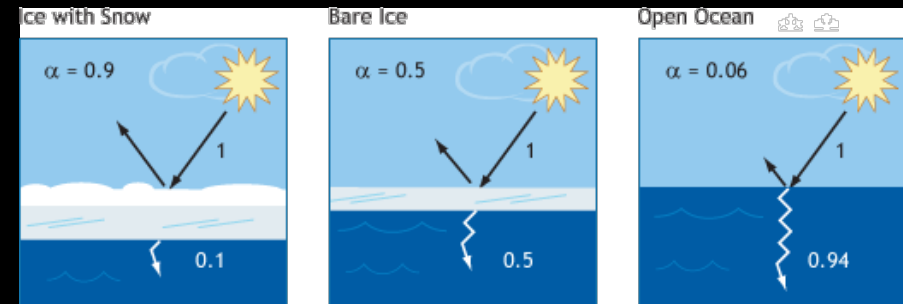
Shupe et al., 2022



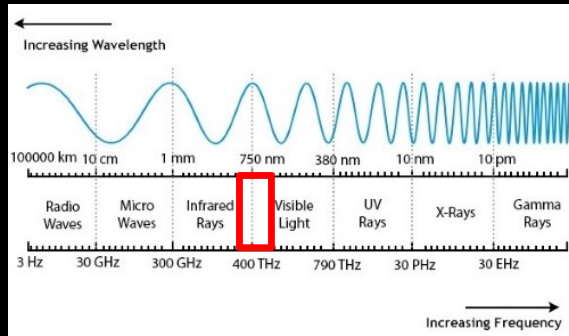
Radiative transfer



◆ Details about surface microstructure is relevant for Albedo

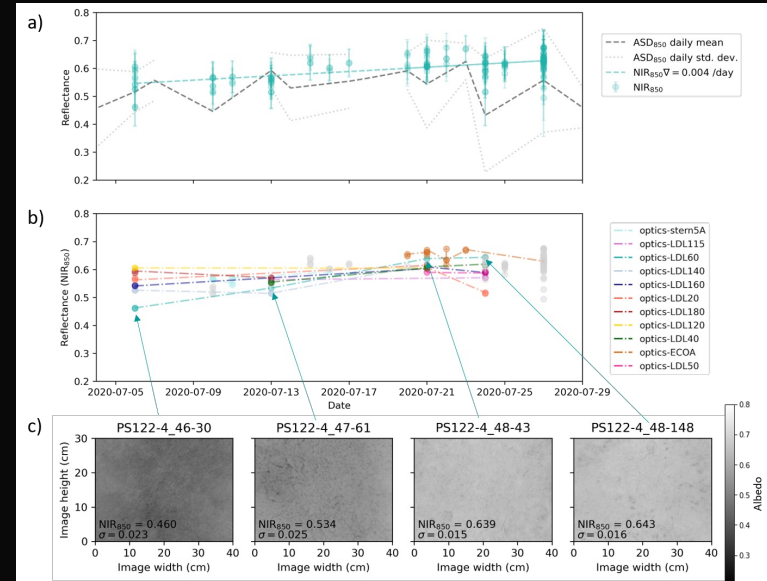


Radiative transfer

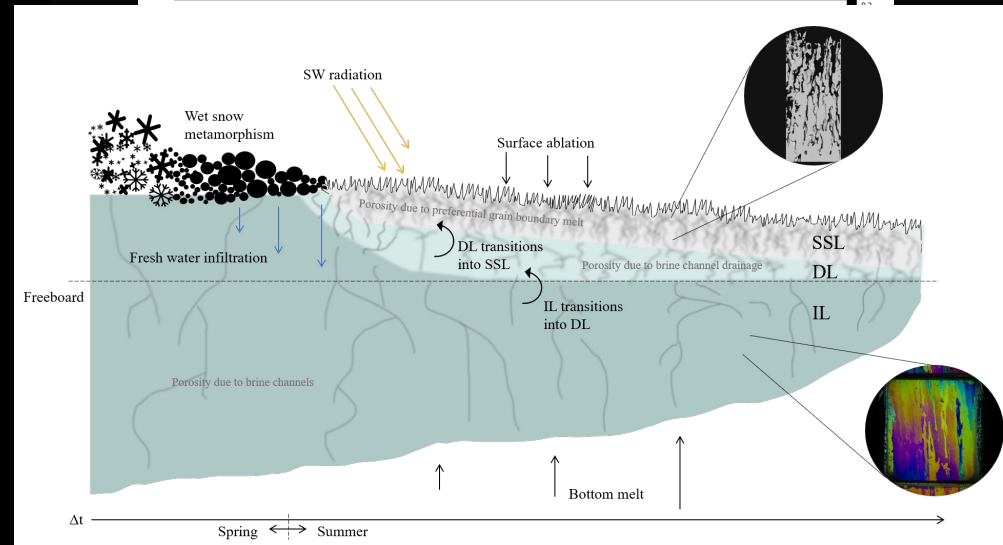


◆ Details about surface microstructure is relevant for Albedo

Using generic rounded-grained microstructure in models leads to underestimations of albedo by ~10%



Macfarlane, et al (2023)



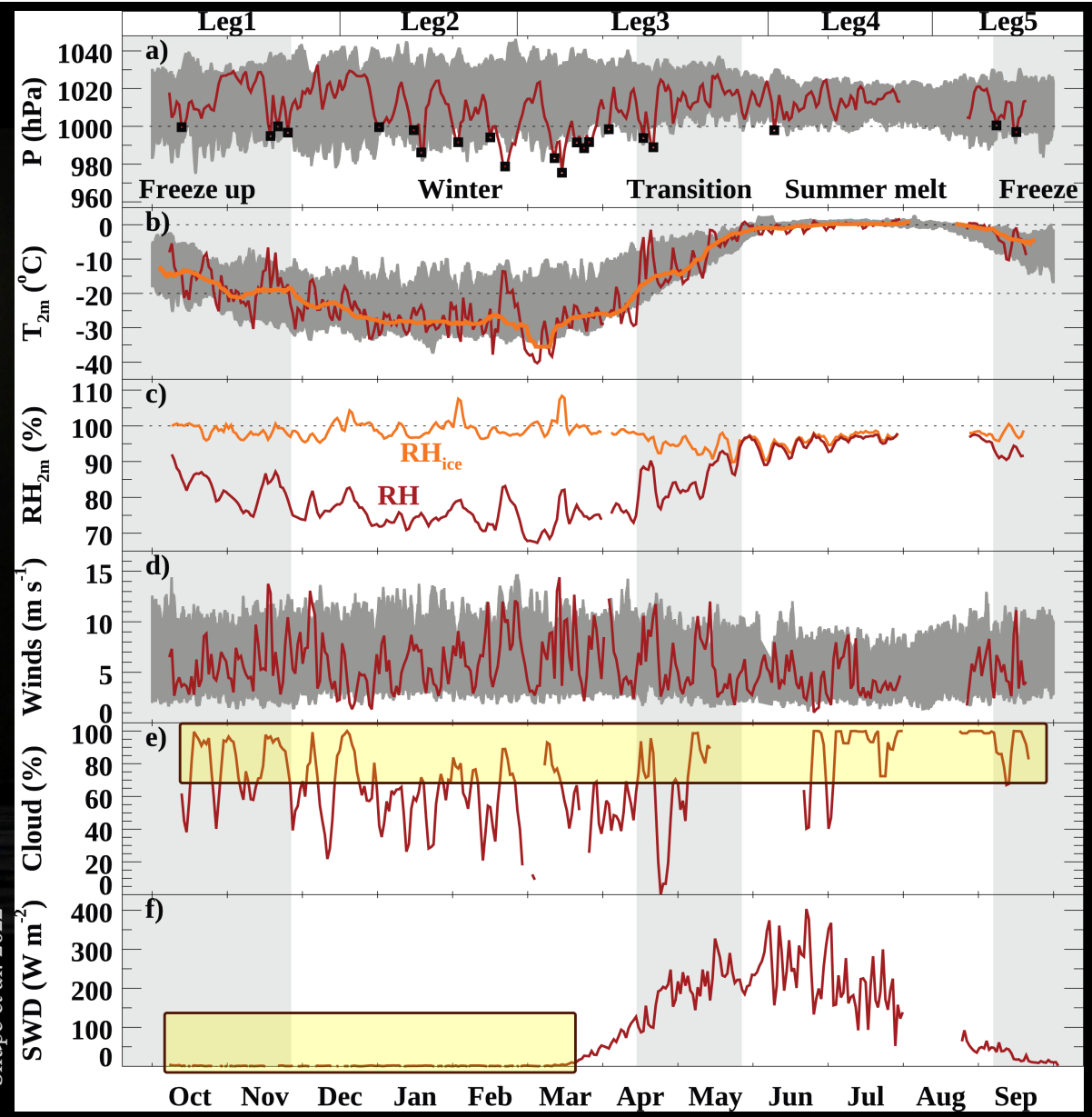
Prix de Quervain 2024

Conditions onboard

Photo: M Jaggi



Shupe et al., 2022



Radiative transfer models

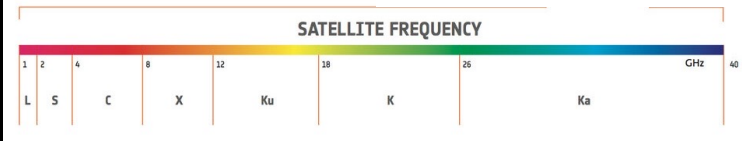
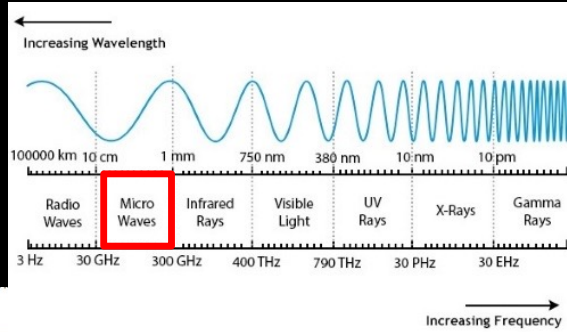
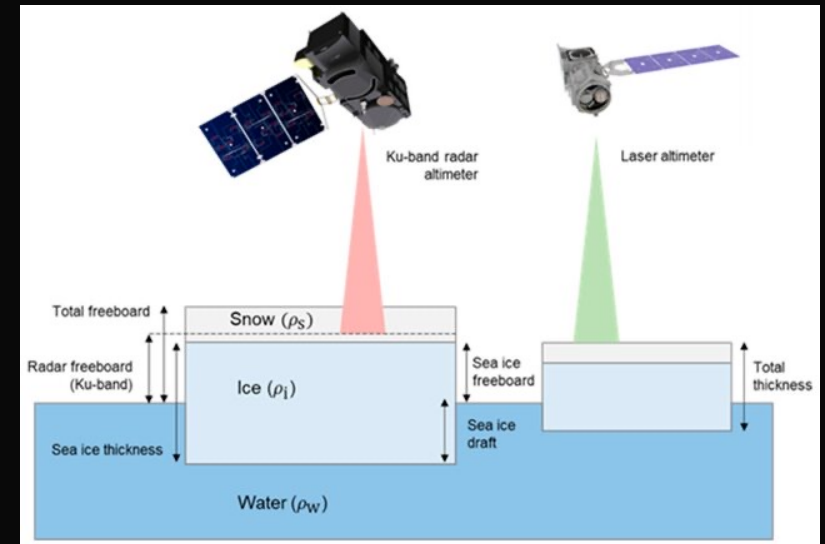


Photo: M. Jaggi



Silva et al., 2023



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Radiative transfer models

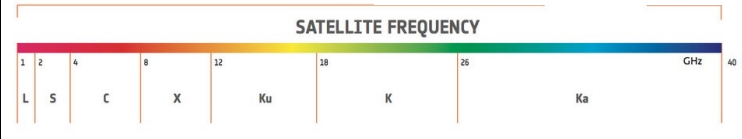
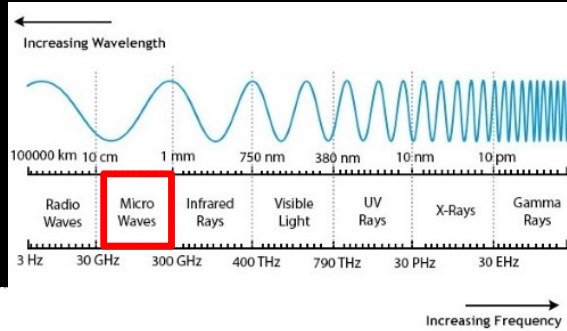
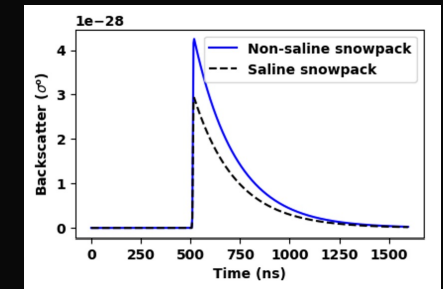
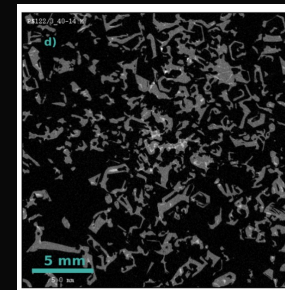


Photo: M. Jaggi

Current research

SNSF.Postdoc mobility (2024-2025)

- Understanding the effect of saline inclusions on permittivity in microwave RT models



- Snow microstructure influence on microwave backscatter



Responsible Science Initiative (RISE) APECS Project Group

Frontiers in Sustainability | Sections | Articles | Research Topics | Editorial board | About journal

OPINION article
Front. Sustain., 09 February 2024
Sec. Sustainable Organizations
Volume 5 • 2024 | <https://doi.org/10.3389/frsus.2024.1338660>

A call for funding bodies to influence the reduction of environmental impacts in remote scientific fieldwork

Amy R. Macfarlane^{1*} Tamara Ben-Ari² Guillaume Blanc^{3,4} Deborah Bozzato⁵
Radiance Calmer⁶ Sophie Haslett⁷ Svenja Holste⁸ Emilie Jardé⁹ Christian Rixen¹
Delphin Ruché¹⁰ Martin Schneebeli¹ Madison M. Smith¹¹ Linda Thielke¹²
Ségolène Vandavelde^{13,14} Helen C. Wheeler¹⁵

- ◆ Advocate for transparent environmental impact documentation
- ◆ Increase scientific community involvement
- ◆ Encourage research & development of equipment design
- ◆ Host workshops and conference sessions
- ◆ Influence national/institutional policies

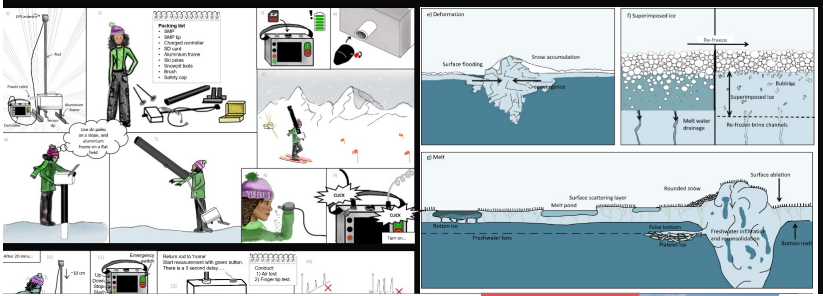
1 Environmental Impact Assessments of Scientific Fieldwork 2 as a Path to Sustainability: a Case Study from the MOSAiC 3 Expedition

4 Amy R. Macfarlane^{1,2,3*}, Madison M. Smith^{4*}, Radiance Calmer^{5,6*}, Elise S.
5 Droste^{7,8}, Sandra Tippenhauer⁷, Hélène Angot⁵, Verena Mohaupt^{9*}

6 ¹Physics and Technology, UiT The Arctic University of Norway, Tromsø, Norway



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Thank you!

- ◆ Swiss Academy of Sciences (SCNAT)
- ◆ Swiss Committee on Polar and High Altitude Research (SKPH)
- ◆ The Commission for the Research Station on Jungfrauoch (SKJF)
- ◆ The Swiss Foundation for Alpine Research (SFAR).

Planned use of Prix de Quervain prize:

- ◆ Environmental Impact Assessment / Environmental, Social and Governance (ESG) risk certification
- ◆ GUI course to help snow data post-processing
- ◆ Scientific illustration course



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Extended thank you



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