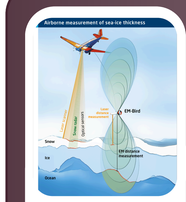
Linking observations of Arctic summer sea ice thickness and melt ponds to model simulations

Lena Buth[1], Thomas Krumpen[1], Niklas Neckel[1], Gerit Birnbaum[1], Melinda Webster[2], Christian Haas[1]

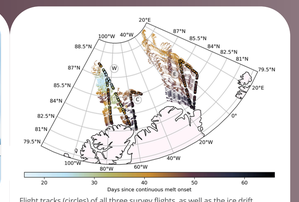
[1] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany
[2] Polar Science Center, University of Washington, Seattle, USA

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

The groundwork

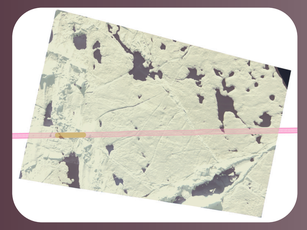


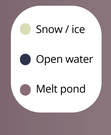
Schematic of the aircraft setup and measurement techniques [1].



Flight tracks (circles) of all three survey flights, as well as the ice drift trajectories over the preceding 70 days. The color scale represents the average number of days of continuous melt for each summer trajectory until the survey time [2].

- Decade(s) of **airborne** campaign data available!
- Among other instruments, there are **simultaneous measurements** by:
  - The EM-Bird, a tethered electromagnetic sensor, providing information on **sea ice thickness, surface profile and ridges**
  - A CANON digital single-lens reflex camera, providing RGB (red, green, blue) **optical images** of the sea ice surface.
- Here, we analyze a total of 5510 images from three flights of the IceBird campaign in 2016 and 2018. [3]
- The data are projected onto the same grid and the images are classified using a random forest classifier [4].
- Ice thickness and ridge information can now be processed together with the imagery.

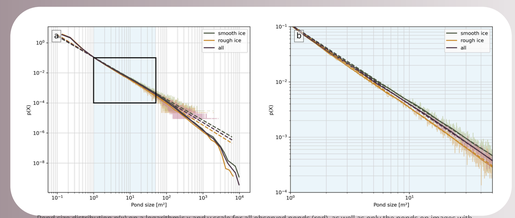




Exploring airborne data

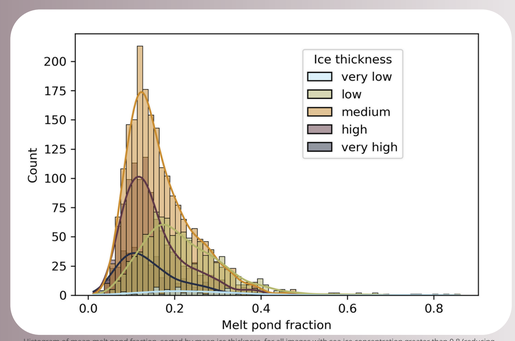
In a previous study, we find connections between the surface morphology and melt ponds [2]. In particular, we find that **high pond fractions are not exclusive to smooth ice**, but can also occur on heavily deformed multi-year ice. Other results include:

- A link between the ridge fraction and the pond size distribution (see below): **Ponds on rough ice exhibit a steeper size distribution**. Thus, the more ridged the ice, the fewer large ponds appear relative to small ones.
- **Melt pond geometry** is also influenced by the ridge fraction: Small ponds are on average more complex in the presence of ridges, while large ponds are restricted in their complexity.



Pond size distribution p(x) on a logarithmic x and y scale for all observed ponds (red), as well as only the ponds on images with smooth (green) and rough (yellow) ice. Dashed lines represent the power law fit for data within the black rectangle [2].

We would like to know whether melt ponds are also **affected by sea ice thickness**. First results suggest: There is a slight dependence, with thicker ice having lower pond fractions. However, this **difference in distributions and mean per thickness category is small**.

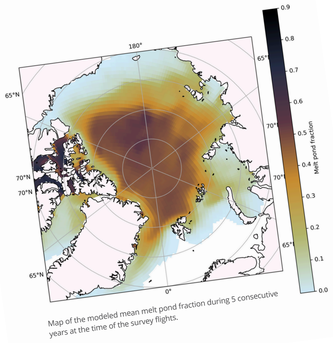


Histogram of mean melt pond fraction, sorted by mean ice thickness, for all images with sea ice concentration greater than 0.8 (reducing thickness bias due to leads). The ice thickness classes (very low to very high) correspond to the ice thickness categories in CESM2.

First look CESM2 model output

CESM2 (Version 2 of the Community Earth System Model) is a **coupled climate model** that includes the Los Alamo Sea Ice Model (CICE5) as sea ice component. When compared to MOSAiC observations, CESM2 **overestimates melt pond coverage** throughout the melt season, with average and peak values significantly exceeding observed fractions [5].

We now aim to extend this comparison using additional airborne observations to **better quantify potential model biases** in simulated melt pond evolution. Here, we use a single model run from the CESM2 Large Ensemble and analyze five years of output as a first step to explore the data.

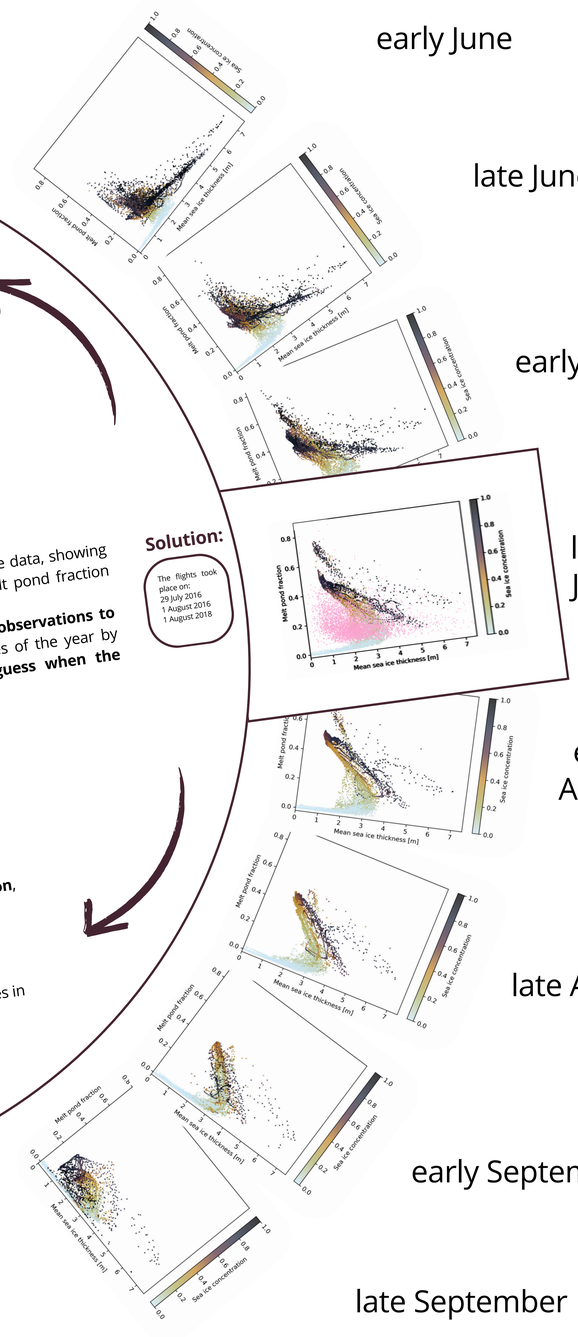


Map of the modeled mean melt pond fraction during 5 consecutive years at the time of the survey flights.

Here is a scatterplot of the airborne data, showing mean ice thickness and mean melt pond fraction per image along the flight tracks.
You can **compare the airborne observations to CESM2 output** for different times of the year by **turning the wheel**. Can you **guess when the survey flights took place?**

Solution:

The flights took place on:
29 July 2016
1 August 2016
1 August 2018



The correct solution may not be what you expected, as the airborne and model data are **quite different**. In this example, the modeled pond fraction shows a **stronger dependence on sea ice thickness**, but also on **sea ice concentration**, with **strong variations during the melt pond evolution cycle**.

Moving forward, we plan to:

- Analyze **more CESM2 output and airborne data**
- Develop a **systematic approach** for evaluating model-data agreement
- Use **Icepack** (column physics of CICE) to isolate and test specific processes in the **melt pond parameterization**

Your input

Here is some space for you to leave your ideas, comments, feedback, contacts details etc.:

References
[1] Sea Ice Portal Infographics: https://meereisportal.de/en/maps-graphics/infographics
[2] Buth, L. G., Krumpen, T., Neckel, N., Webster, M. A., Birnbaum, G., Fuchs, N., Heuser, P., Johannsen, O., and Haas, C.: Characterizing sea ice melt pond fraction and geometry in relation to surface morphology, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-1103, 2025.
[3] Krumpen, T., Von Albedyll, L., Bünger, H. J., Castellani, G., Hartmann, J., Helm, V., Hendricks, S., Hutter, N., Landy, J. C., Lisovski, S., Lüpkes, C., Rohde, J., Suhrhoff, M., and Haas, C.: Smoother sea ice with fewer pressure ridges in a more dynamic Arctic, Nature Climate Change, 15, 66–72, https://doi.org/10.1038/s41558-024-02199-5, 2025.
[4] Fuchs, N., Von Albedyll, L., Birnbaum, G., Linhardt, F., Oppelt, N., and Haas, C.: Sea ice melt pond bathymetry reconstructed from aerial photographs using photogrammetry: a new method applied to MOSAiC data, The Cryosphere, 18, 2991–3015, https://doi.org/10.5194/tc-18-2991-2024, 2024.
[5] Webster, M. A., Holland, M., Wright, N. C., Hendricks, S., Hutter, N., Itkin, P., Light, B., Linhardt, F., Perovich, D. K., Raphael, I. A., Smith, M. M., von Albedyll, L., and Zhang, J.: Spatiotemporal evolution of melt ponds on Arctic sea ice: MOSAiC observations and model results, Elementa: Science of the Anthropocene, 10, 000 072, https://doi.org/10.1525/elementa.2021.000072, 2022.

Lena Buth
lena.buth@awi.de
Connect with me

Chat with me about:
- Sea ice
- Science communication
- Climate activism

Sharing is encouraged

EGU Outstanding Student & PhD candidate Presentation contest

POLMAR
ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG
HELMHOLTZ GEMEINSCHAFT

BREMERHAVEN
Am Handelshafen 12 27570
Bremerhaven
Telefon 0471 4831-0
www.awi.de