Observations of Summer Ice Melt and Ice-Ocean Boundary Layer Heat Fluxes in the Marginal Ice Zone North of Fram Strait

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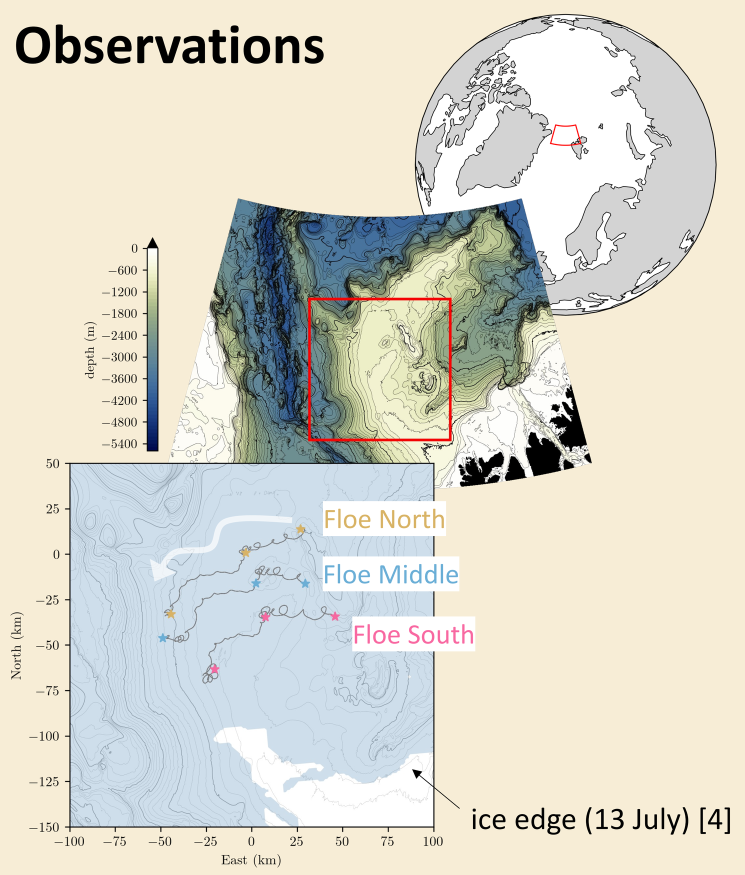
Background

Sea ice meltwater can lead to strong stratification in the **ice-ocean boundary layer (IOBL)**, which mediates the turbulent transfer of heat, salt and momentum between upper and interior ocean. We investigate how ice melt affects ice-ocean coupling across the **marginal ice zone (MIZ)**, focusing on gradients and interaction of key factors *melting* (A), *turbulence* (B), and *stratification* (C).

Observations

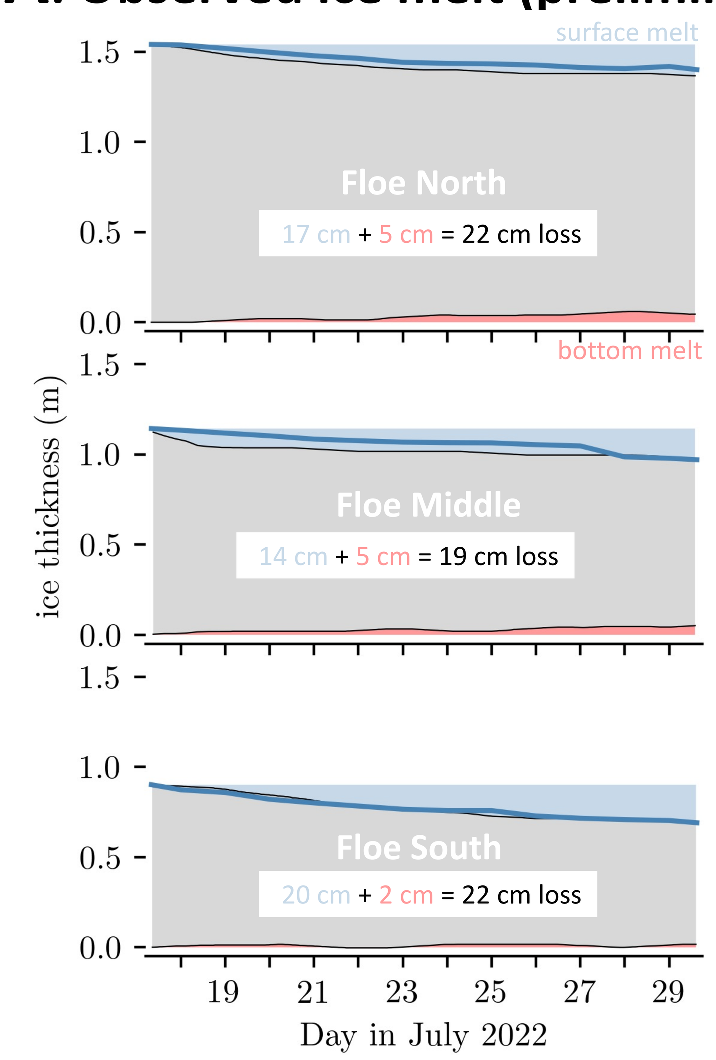


We collected data in the marginal ice zone on an expedition [1] to Yermak Plateau in summer 2022. We occupied three seperate ice floes, which were oriented on a line perpendicular to the ice edge.

Each floe was equipped with autonomous instruments, providing time series of changing ice thickness (**A**), and upper-ocean hydrography and high-resolution velocity profiles (**B**).

We further obtained vertical hydrographic profiles (**C**) during three occupations per floe (asterisks in lowest figure to the left).

A: Observed ice melt (preliminary results)



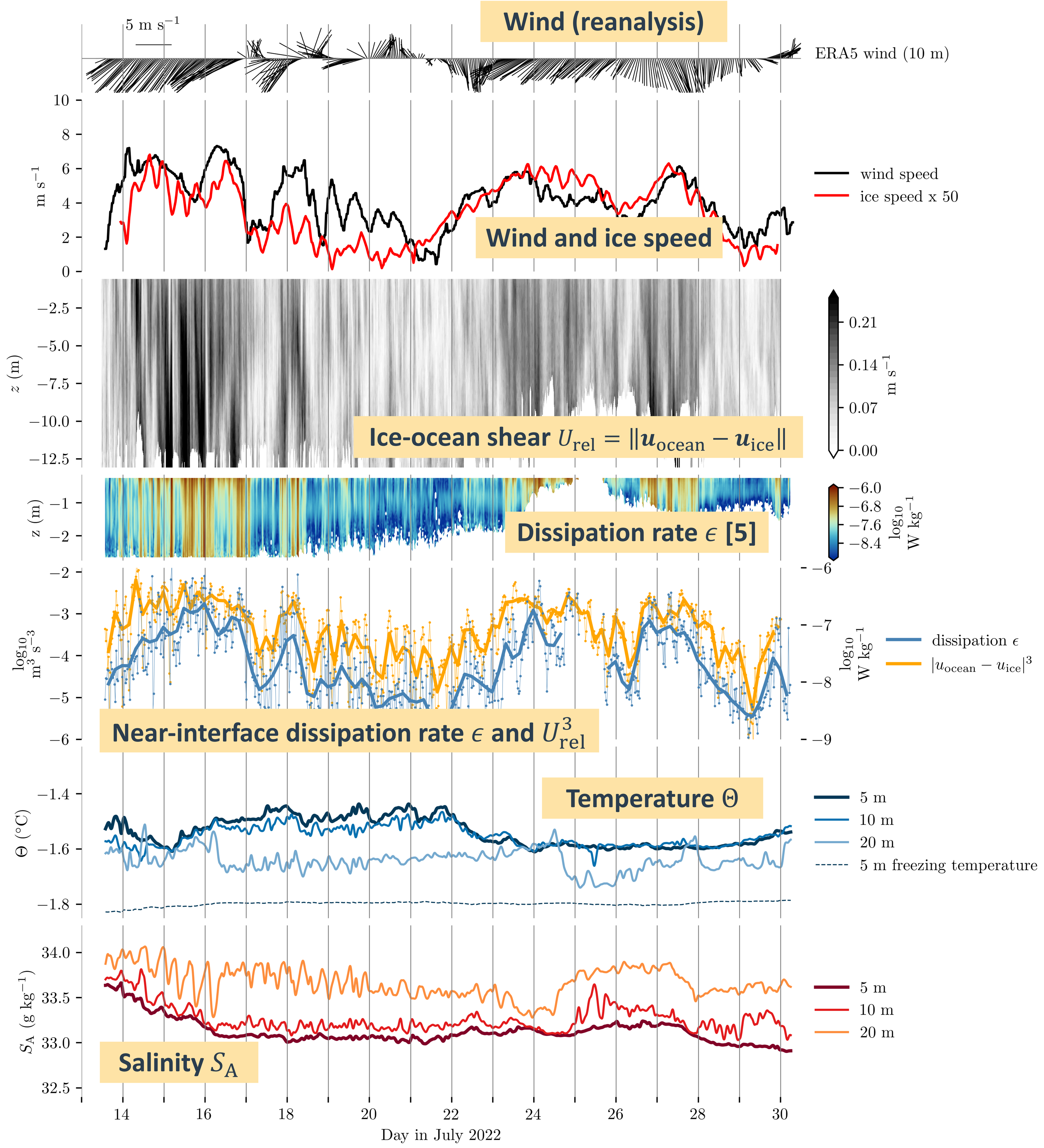
Left: Ice thickness evolution of the three floes from thermistor chain data (shaded areas) and surface melt from ablation stakes (thick blue lines) for a time period with full data availability. The shaded areas depict ice thickness (grey), thickness loss on top (blue) and bottom (red).

This indicates that

- surface melt accounts for up to 90 % of the thickness changes
- net thickness loss was similar between all floes (22, 19, 22 cm) during a commonly covered time period

How relevant is the oceanic contribution to summer sea ice melt in the MIZ?

B: Observations from an autonomous drifting station (Floe North)



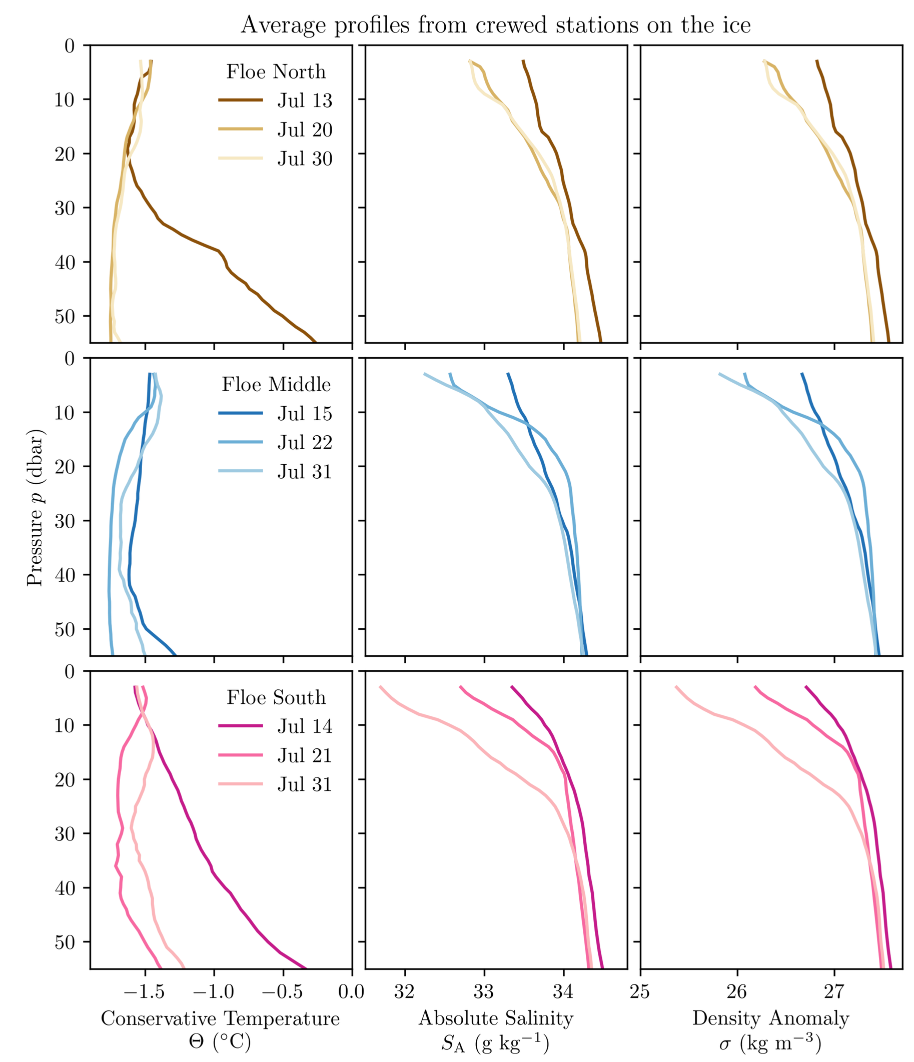
Above: Time series from tethered instruments and acoustic doppler current profilers (ADCPs) on Floe North. Oscillations at tidal frequencies were removed from the velocity time series of ice and ocean by complex demodulation [3].

We observe

- an initial freshening of the surface layer,
- relatively weak temperature elevation above freezing at 5 m,
- demodulated ice drift and under-ice dissipation appear to be mostly wind driven,
- magnitude of ice-ocean shear and turbulent dissipation changes with wind direction.

How do turbulent scales like mixing length and friction velocity vary across the MIZ, whose range is (only) partially covered by the occupied floes?

C: Upper ocean stratification from individual floe visits



Left: Vertical profiles of conservative temperature Θ, absolute salinity S_A and density anomaly σ for Floe North, Floe Middle, and Floe South during the three visits per floe (averages of multiple casts).

The largest density change due to meltwater occurs on the southernmost drifting station, closest to the ice edge. Note that this meltwater may come from local melting, lateral advection or other processes such as melt pond drainage and surface runoff, lateral and internal melt.

Under which conditions is meltwater suppression of turbulence an important process for controlling summer sea ice melt in the MIZ?

What comes next?

- Estimation of Reynolds stress in upper IOBL using 5-beam ADCP methods [6].
- Estimation of turbulent heat flux from the continuous observations.

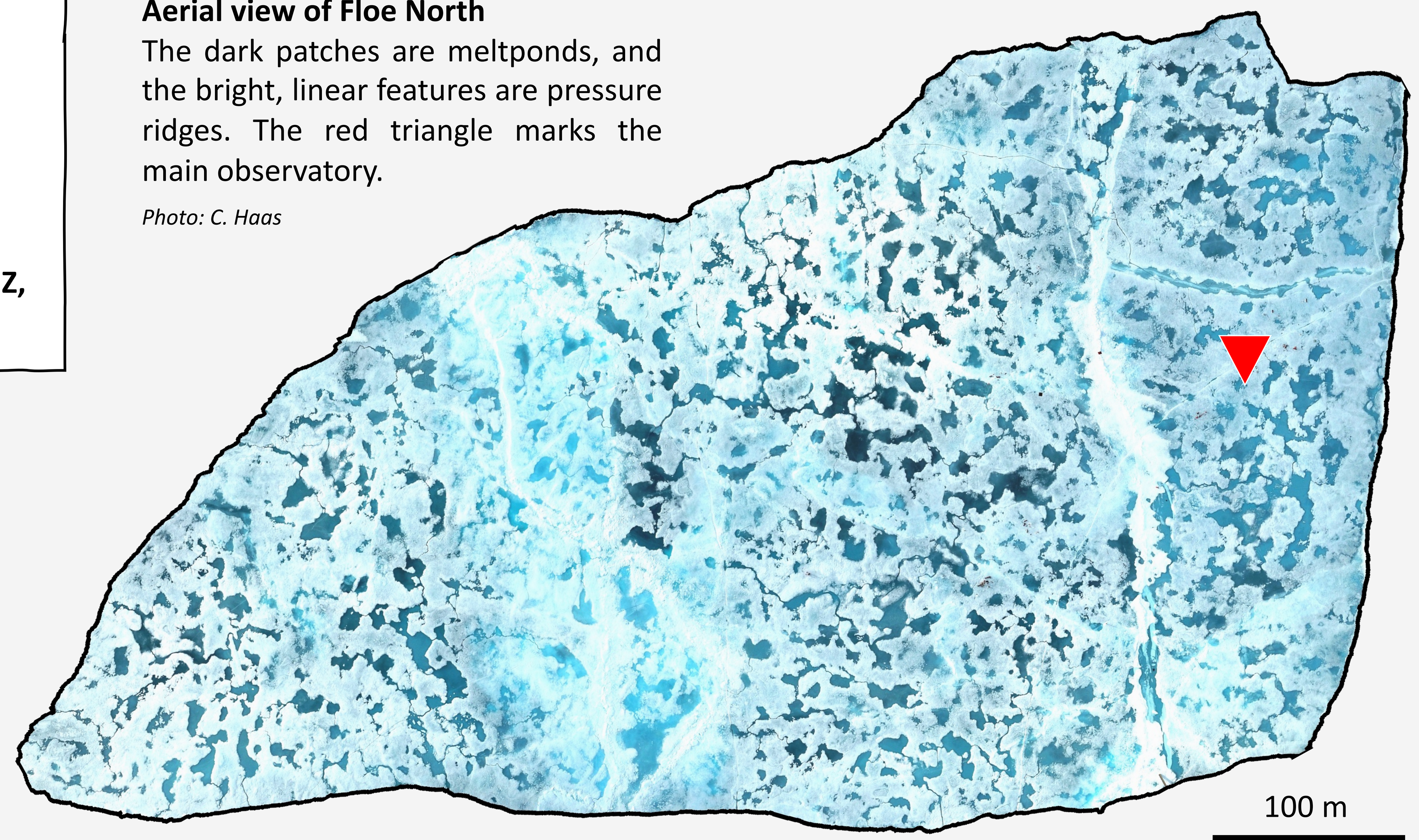
Outlook

Drifting stations require stable ice floes, which constrains the observation capabilities to a distance from the ice edge. We will use high-resolution towed profiler data from the same expedition to study (sub)mesoscale ocean dynamics on transects covering the transition of 100 % sea ice concentration to the open ocean.

Aerial view of Floe North

The dark patches are meltponds, and the bright, linear features are pressure ridges. The red triangle marks the main observatory.

Photo: C. Haas



References & Notes

[1] The cruise report is available here: https://doi.org/10.57738/BzPM_0770_2023
[2] ERA5 reanalysis data is available here: https://doi.org/10.24381/cds.adbb2d47
[3] McPhee (1988): *Analysis and Prediction of Short-Term Ice Drift*, https://doi.org/10.1115/1.3257130
[4] MASIE ice cover data is available here: https://doi.org/10.7265/N5GT5K3K
[5] Dissipation rates were estimated from 5-beam acoustic doppler current profiler data using the structure function method, following the recommendations and conventions of the SCOR Working Group on analyzing ocean turbulence observations to quantify mixing (ATOMIX, http://wiki.uib.no/atomix).
[6] Guerra & Thomson (2017): *Turbulence Measurements from Five-Beam Acoustic Doppler Current Profilers*, https://doi.org/10.1175/JTECH-D-16-0148.1

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