



UNIVERSITY OF
GOTHENBURG

Coexisting with ice – in a changing climate! Luleå 2026-03-17

Ice thickness, drift and ridges in the Bothnian Bay

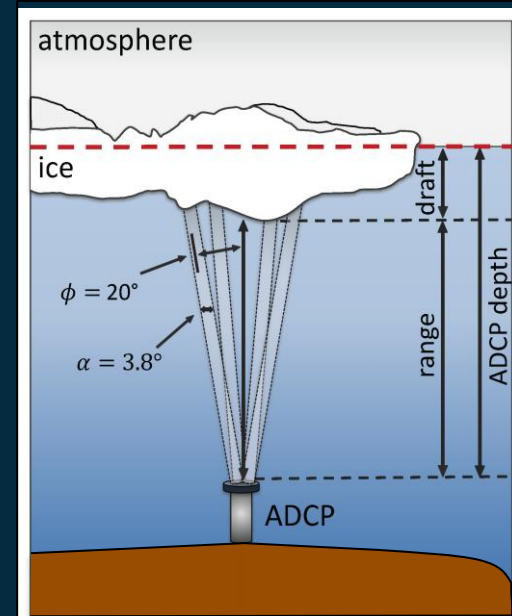
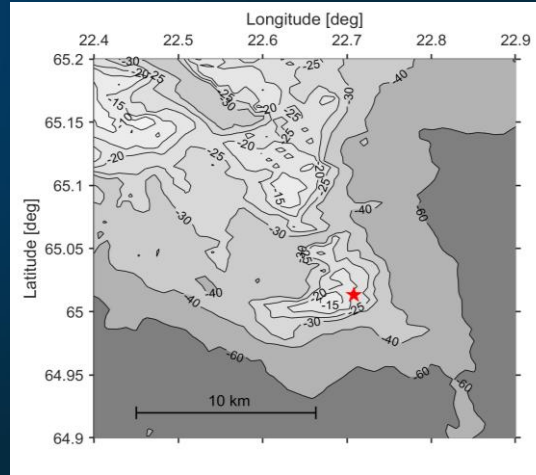
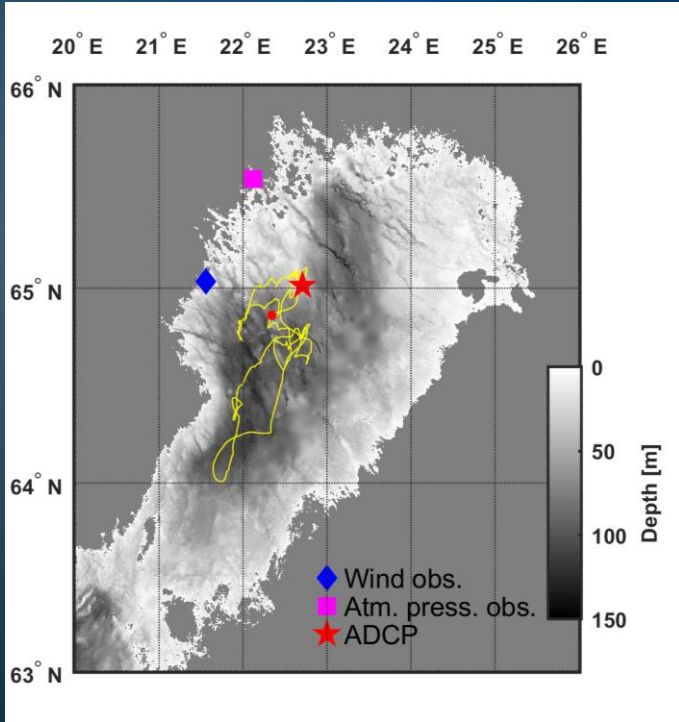
*Göran Björk¹, Göran Broström¹, Lars Arneborg², Anis Elyouncha¹,
Daniel Bergman-Sjöstrand², Per Pemberton²*

¹University of Gothenburg, Dept. of Marine Sciences

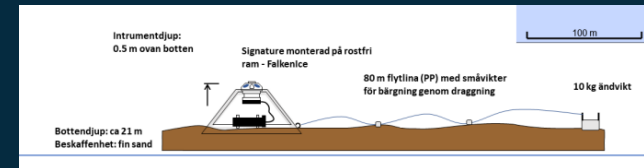
²Swedish Meteorological and Hydrological Institute, SMHI

Björk et al. <https://egusphere.copernicus.org/preprints/2026/egusphere-2026-785/>

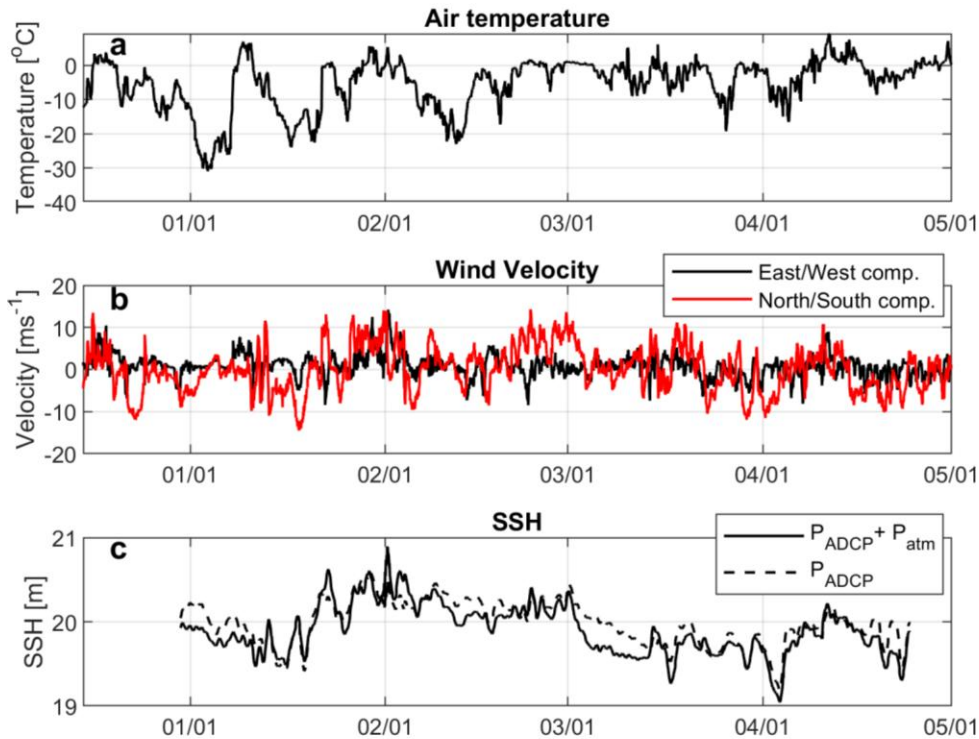
Observations at Falkensgrund winter 2023/2024



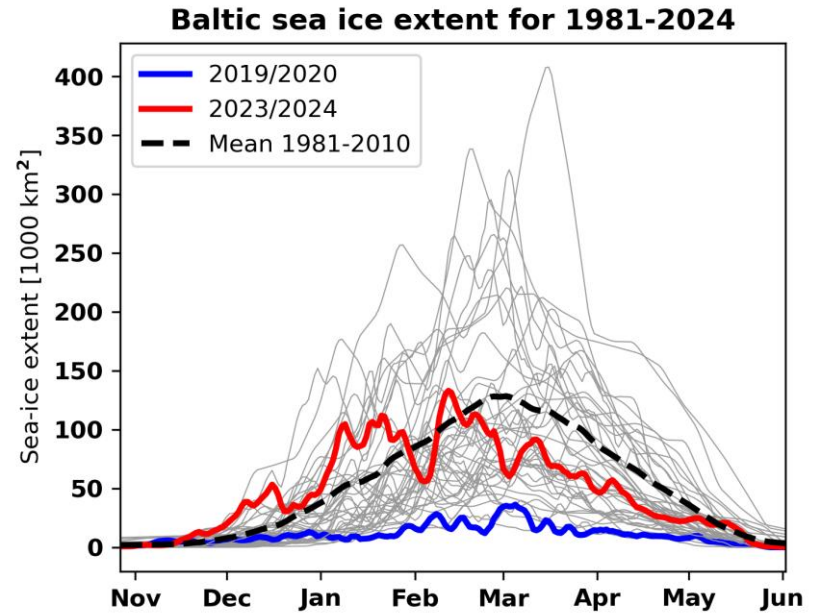
Nortek signature 500 ADCP



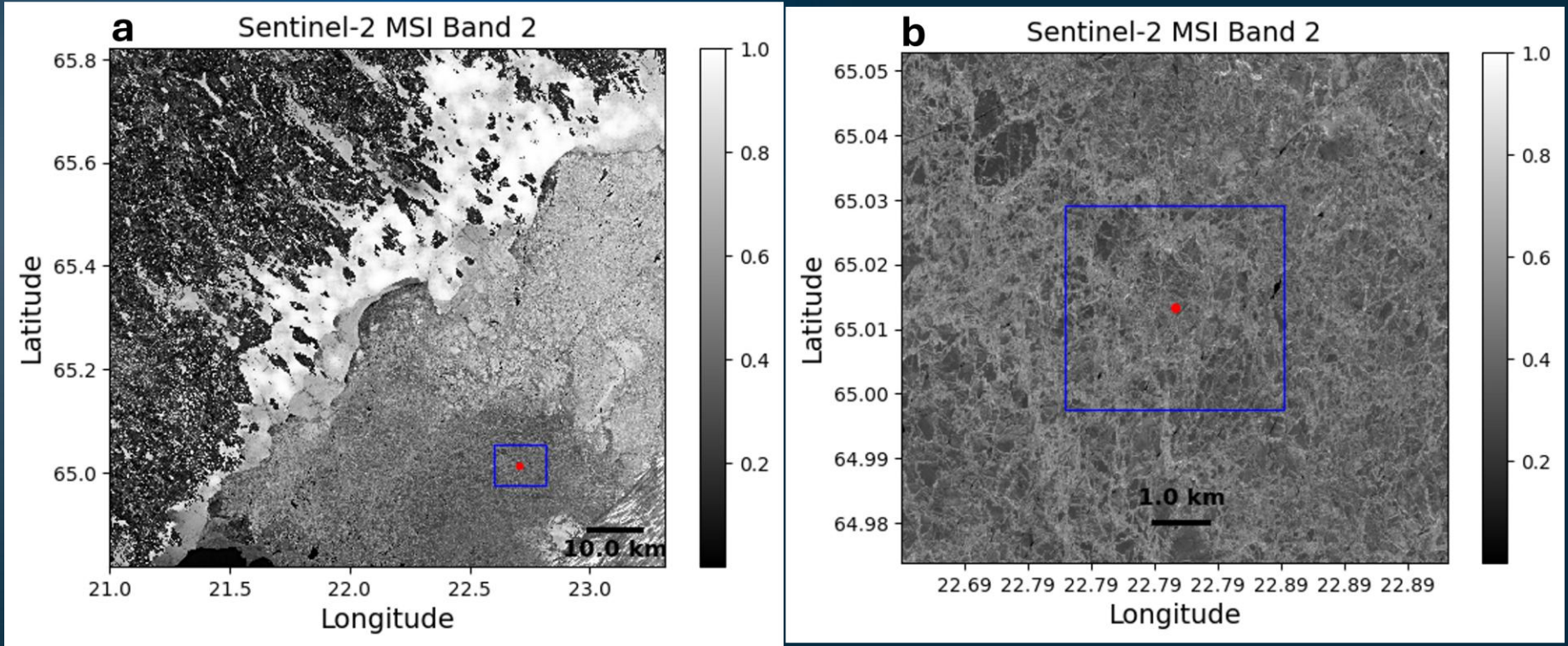
The 2023/2024 ice season



The ice season started unusually early

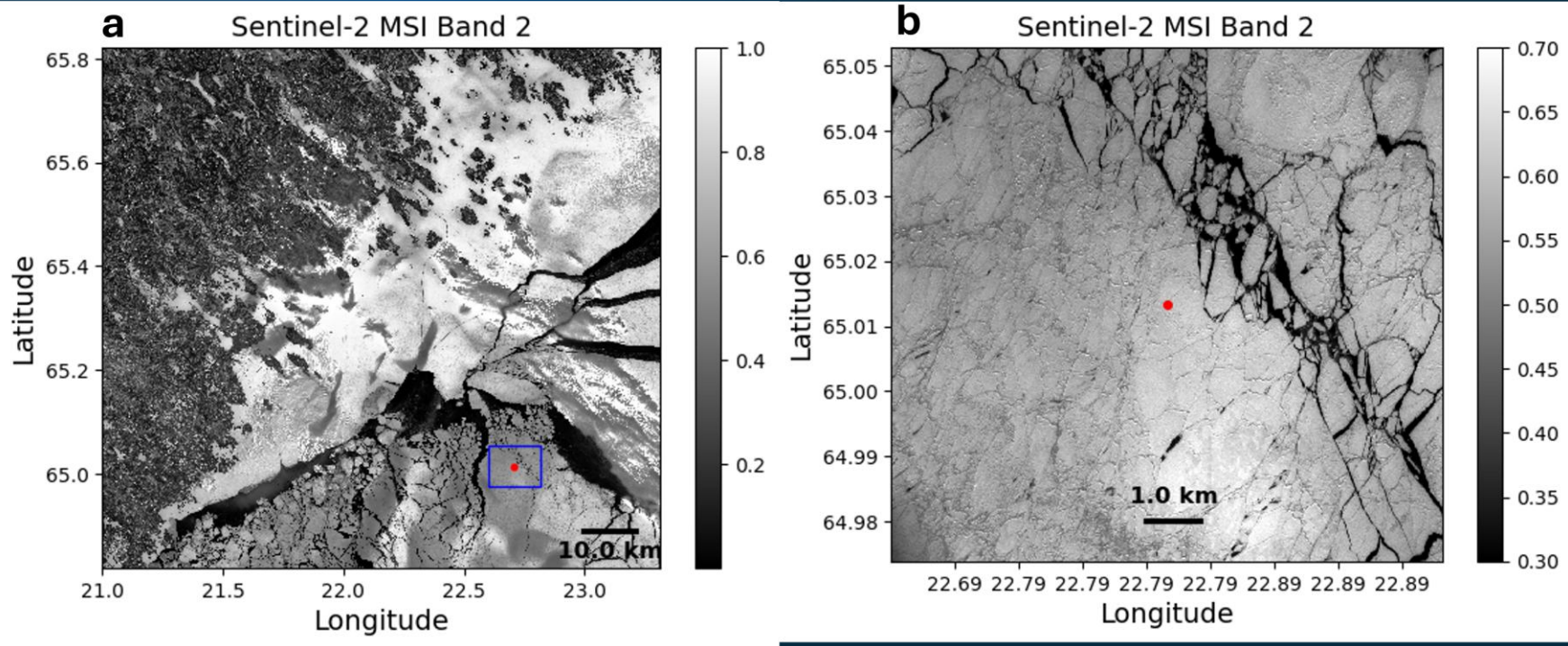


Example of sea ice structure from satellite image

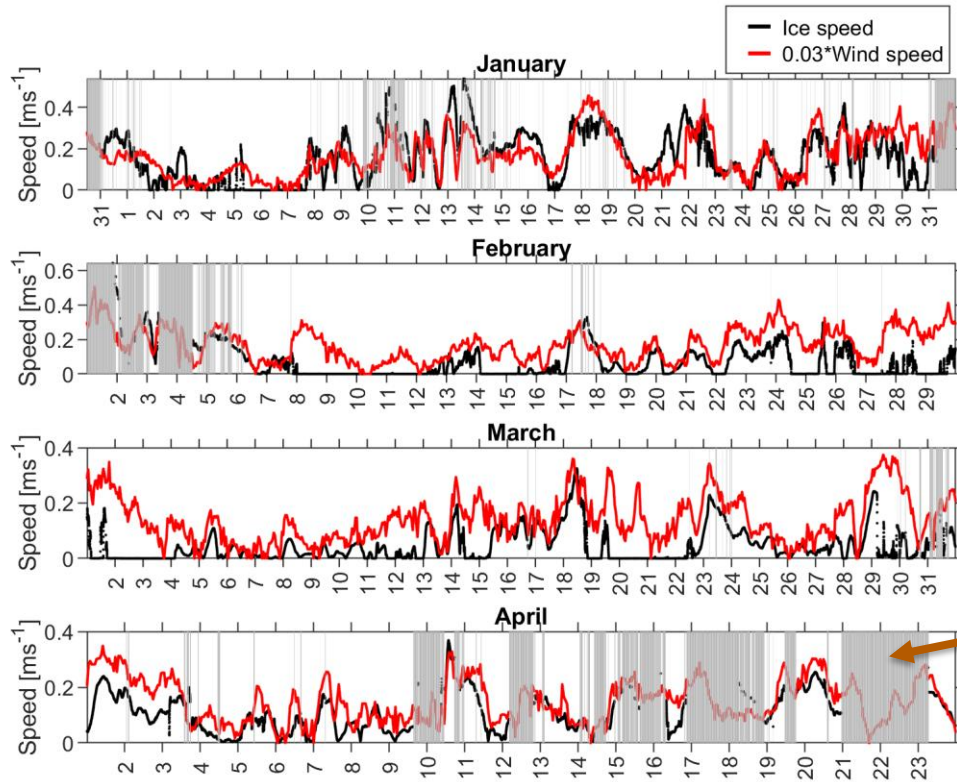


Visual Sentinel-2/MSI image acquired on 2024-02-27. Reflectance (unitless) 10 m resolution. b-panel is a zoom of the blue rectangle in a.

Another example of satellite image 2024-03-26



Sea ice motion in relation to wind speed

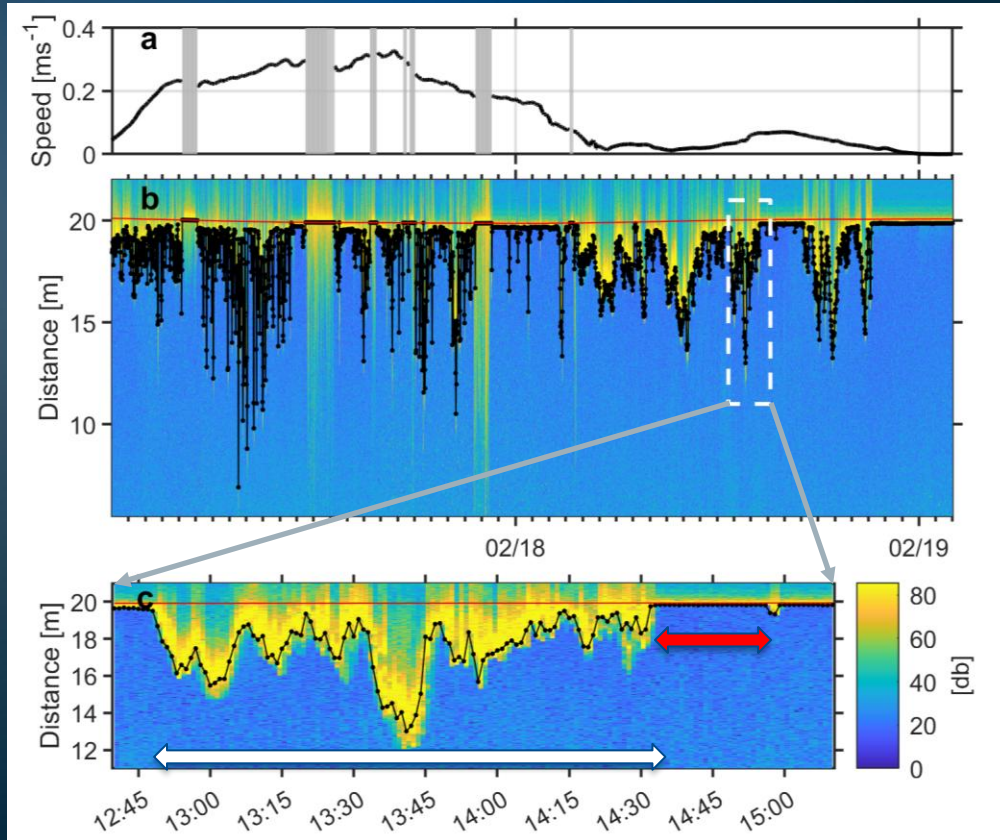


Ice speed = 3 %
of the wind
speed is typical
for free drift

Vertical grey
bars indicate
open water

Example of ADCP echo data

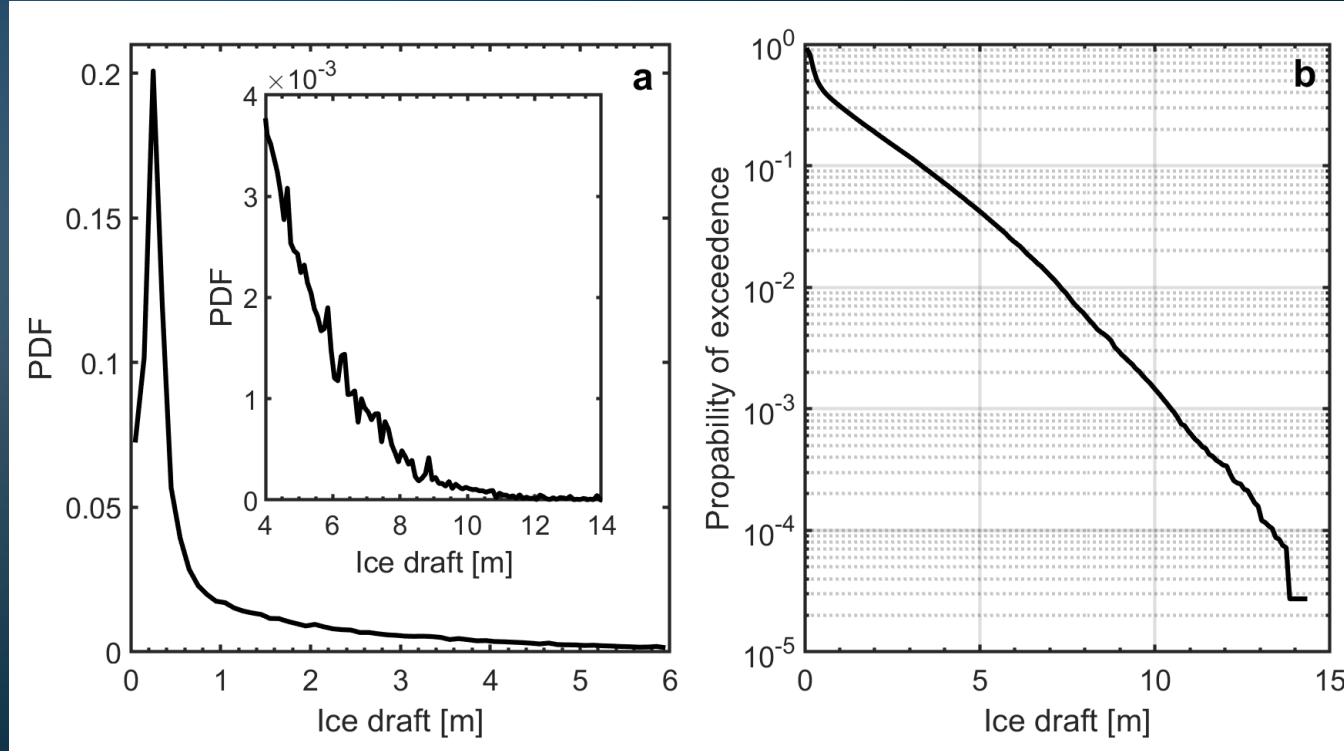
Sampling interval = 1 minute



↔ Level ice - which has grown undisturbed thermodynamically. Typically reaches 40-50 cm thickness.

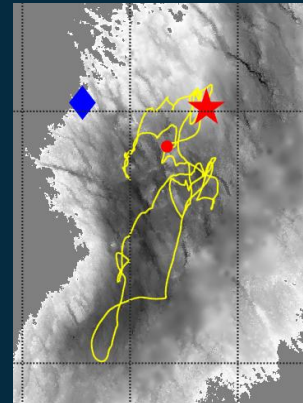
↔ Deformed ice - which is formed by ridging or rafting

Ice draft distribution based on the entire period



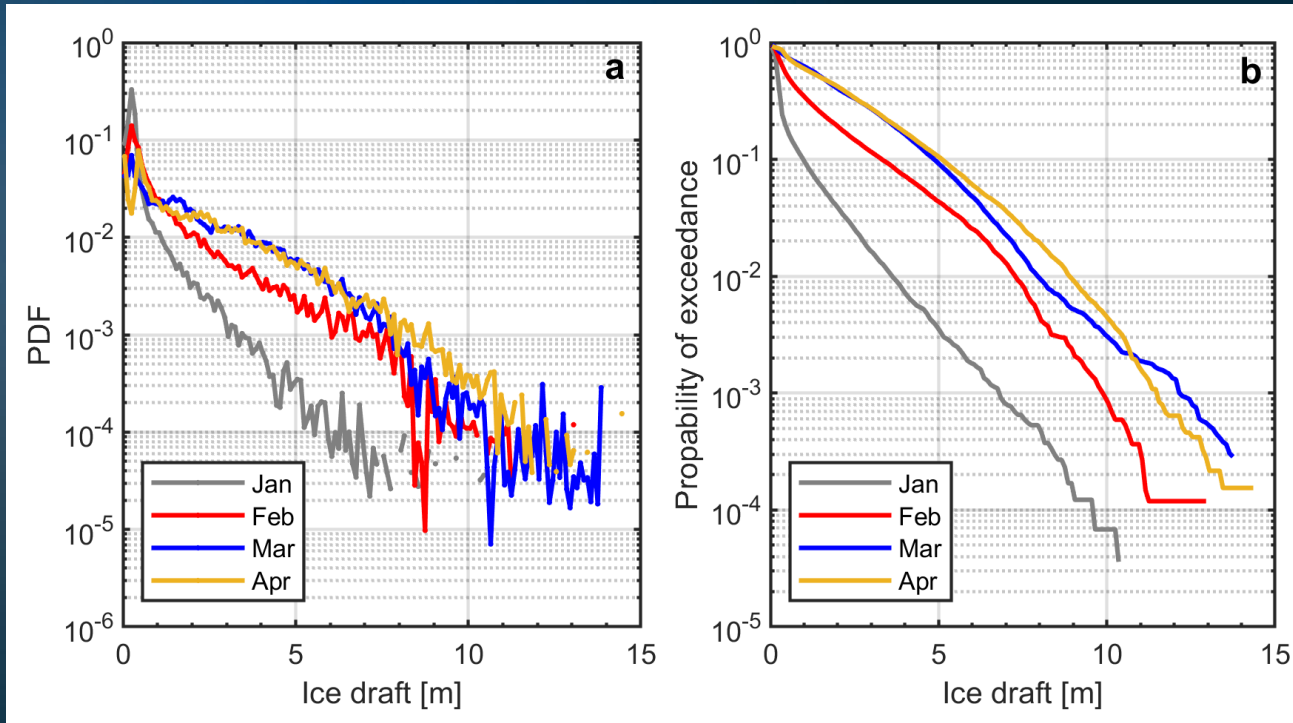
The distribution is based on distance along the track

Total sampling track length = 737 km



Note! Ice thickness can be obtained by multiplying the draft with an isostatic factor, typically around 1.15

Monthly ice draft distributions



Note! Significantly less amount of thick ice in January.

Basic measures of the ice draft distribution

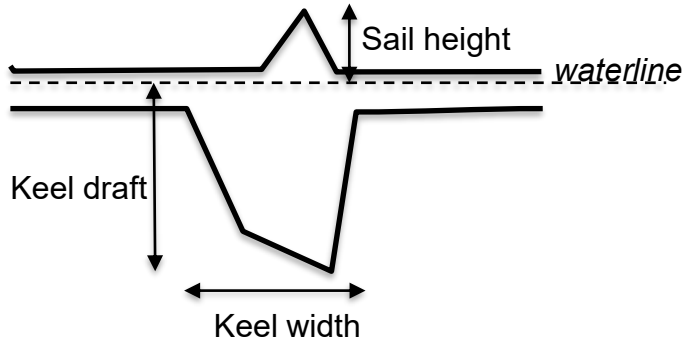
	Mean draft [m]	Track length [km]	Fraction of track length with deformed ice (draft > 1m) [%]	Fraction of track volume* with deformed ice (draft > 1 m) [%]
January	0.48	368	9	43
February	1.26	123	33	78
March	2.14	116	62	92
April	2.20	130	59	91
All months	1.17	737	30	65

*Volume per unit width

Note that the mean draft in March and April is much larger than the level ice thickness due to the dynamic ice production.

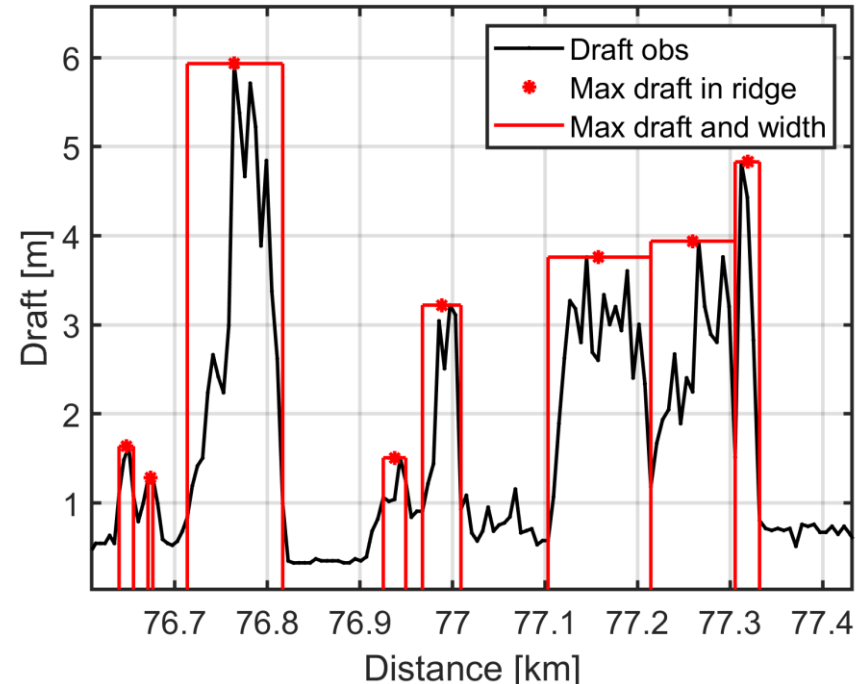
Identification of individual ice keels - using a Rayleigh criterion and draft > 1 m

Some definitions

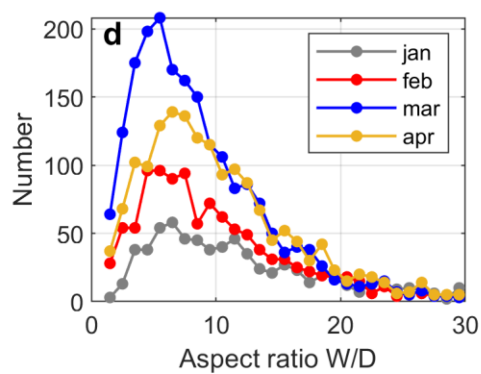
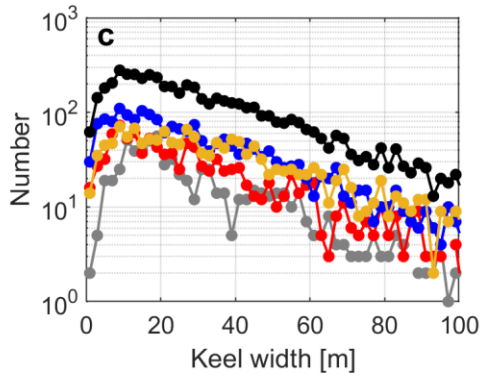
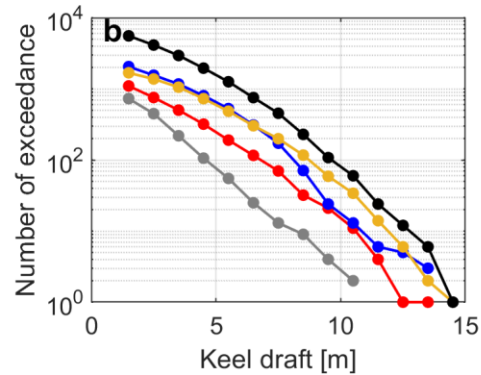
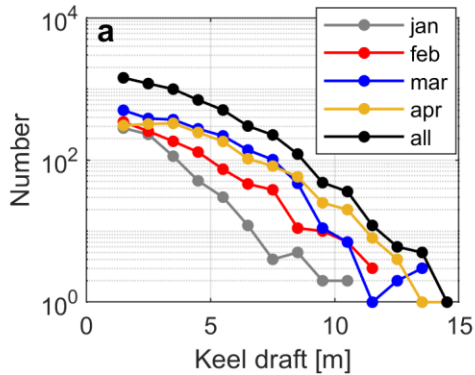


The horizontal extent of an independent keel is defined using the Rayleigh criterion that the troughs on either side of the keel crest (point of maximum draft) must descend at least halfway towards a threshold (1 m) which should represent the local level ice surface (Wadhams and Horne, 1980).

Example of identified keels



Statistics of individual ice keels with draft > 1 m



Ice keel statistics

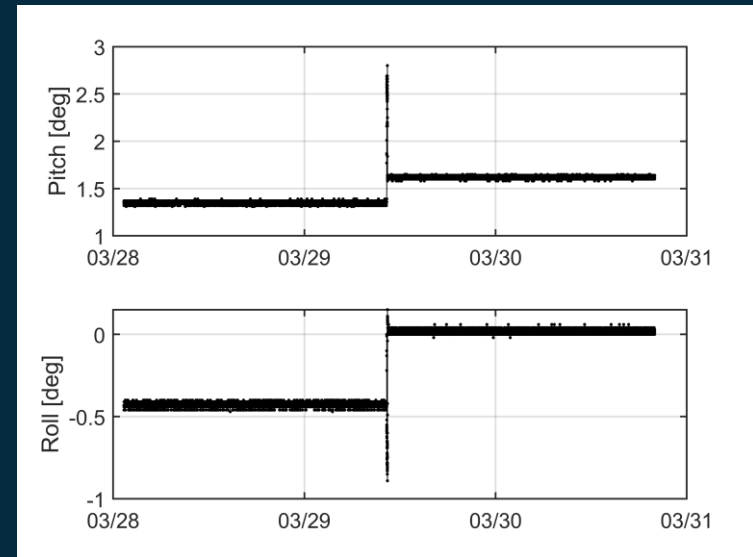
	No. of keels	Mean keel draft [m]	Max keel draft [m]	Median keel width [m]	Mode aspect ratio	No. of rubble fields > 100 m	Max rubble field width [m]
January	729	2.7	10.5	23.7	6.5	33	307
February	1099	3.3	13.1	20.9	5.5	40	275
March	2054	3.8	13.9 (~20)*	21.5	5.5	82	254
April	1683	4.1	14.4	34.0	6.5	147	564
All mon.	5565	3.6	14.4 (~20)*	27.4	5.9	302	564

*Observation of ice keel touching the instrument (29/3).

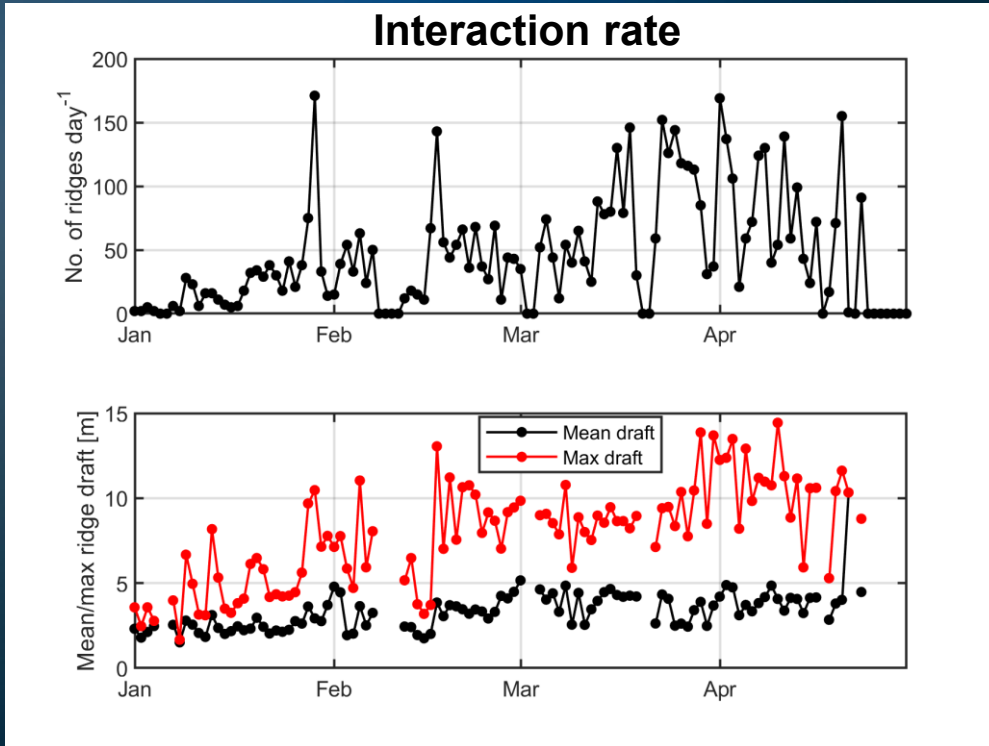
Some issues regarding the observed maximum draft

We set up the instrument to record echo intensity from 6 m above the instrument to the sea surface. This gives a maximum observable draft of about 14 m. We based this setup on earlier (2004) ADCP measurements at the same spot showing a maximum draft of about 7 m. **This was a mistake.** There are actually historical observations of maximum ridge draft of **14.9 m** (Läpperanta and Hakala, 1992) and **28 m** (Palosuo, 1975).

In March 29 a deep keel likely hit the instrument at 20 m depth.



Another way to present data is the interaction rate – which is the number of ridge impacts per day



The interaction rate is particularly useful for design of offshore structures.

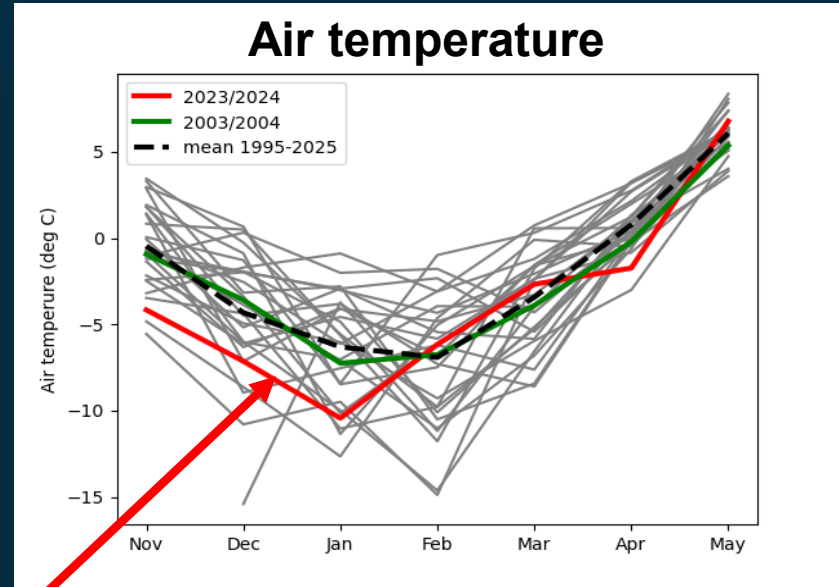
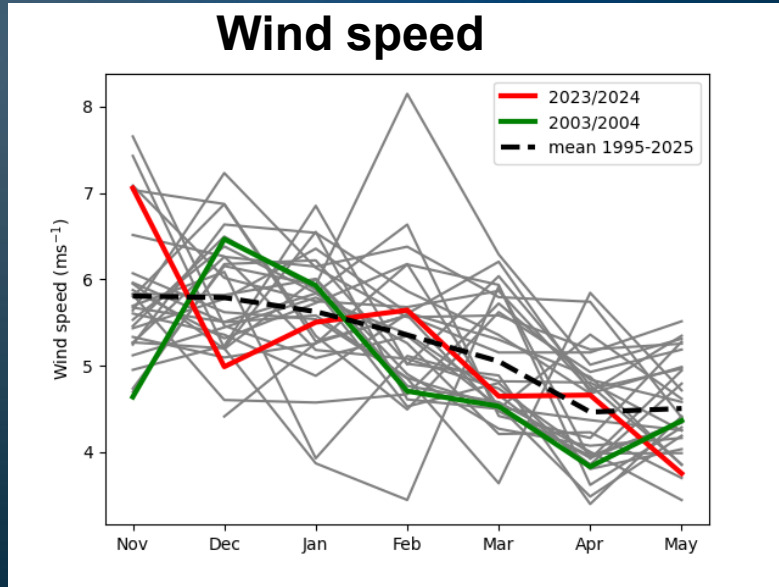
The 2023/2024 ice season compared with other seasons

ADCP observations at Falkensgrund in 2004 with lower resolution (Björk et al., 2008)

Mean draft 2024 = 1.87 m*

Mean draft 2004 = 0.73 m* (max keel draft 7 m)

*February-April



Colder than average during Nov-Jan

Conclusions

- A significant amount of thick ice was observed. 5 % of the track had a draft larger than 5 m in March-April.
- The mean draft was around 2 m in March-April which is much larger than the pure thermodynamic growth (40-50 cm).
- ~70 ridges with keel draft > 10 m were identified.
- Early freezup due to unusually cold temperatures in Nov-Dec indicate that ice cover 2023/2024 was more deformed and with thicker ridges than average.