Doubling of sea ice thickness through ridging and rafting of ice floes

How much did deformation contribute to sea ice thickness change in the North Greenland Polynya?

von Albedyll, L., Haas, C., Hollands, T., Dierking, W., Krumpen, T., Hendricks, S., Rohde, J.

Introduction

An unusual latent heat polynya was observed in late winter 2018 in North Greenland[1] (Fig 1). Overflights from a polar research aircraft shortly after presented a unique opportunity for sea ice dynamics studies.

The open water area refroze and its ice was deformed by convergent ice dynamics, further increasing its thickness.

Analyzing the sea ice thickness distribution (Fig. 3) one month after the maximum extent leads to the question:

How much did deformation contribute to the ice thickness change?

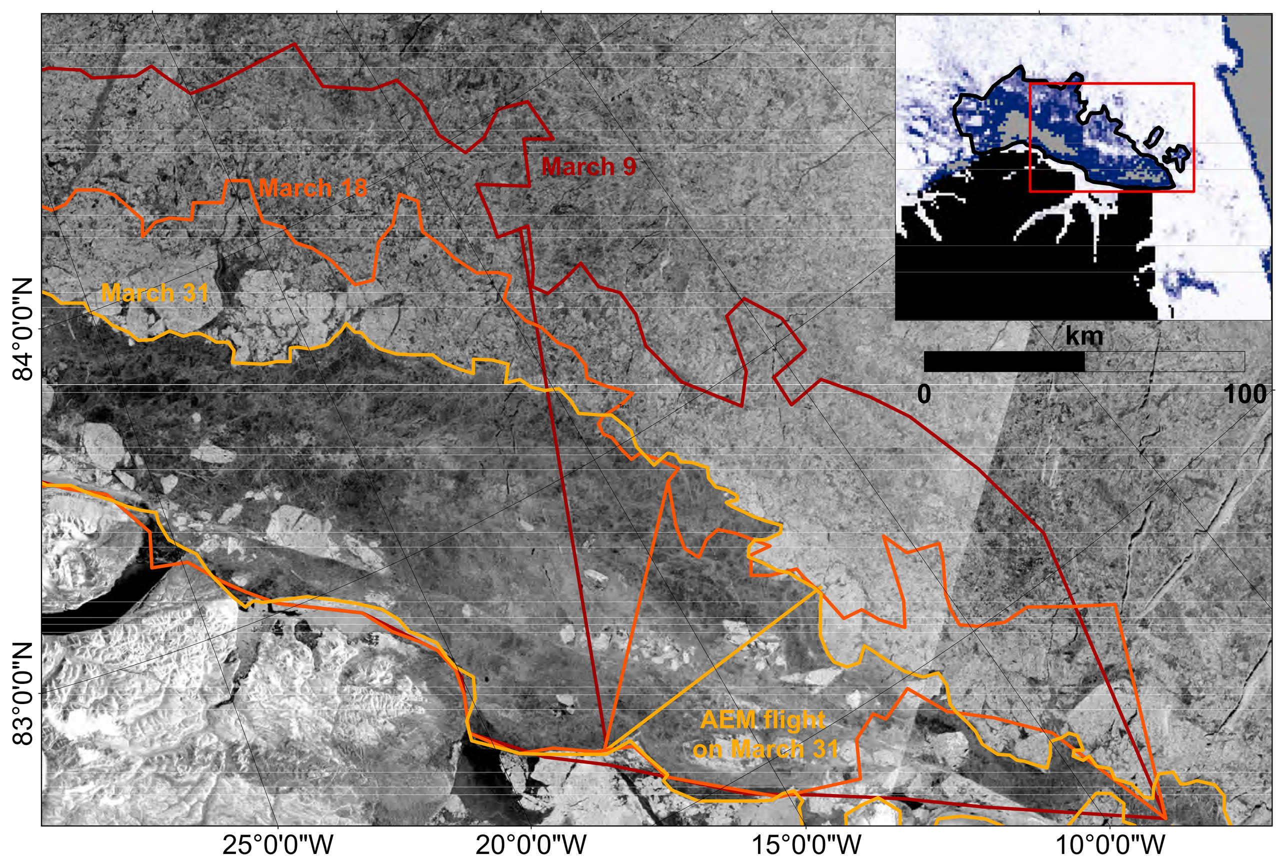


Fig. 1: Sentinel-1 image of the polynya region on March 31, with the extent of the polynya on March 6 and 18. Airborne electro-magnetic (AEM) profile line and the back-tracked, imagined lines corresponding to March 6 and 18.

Simple model of dynamic thickness change

Model aim:

- temporal evolution of mean ice thickness due to deformation

Model assumptions (Fig. 2)

- 1D, only convergence without shear
- ice is deformed only once and does not grow thermodynamically after deformation
- deformed area is a fraction (a) of the decrease in polynya width per time step (S)

Input:

- decrease of polynya width (see Fig. 4)
- thermodynamic growth based on a degree day model[2]

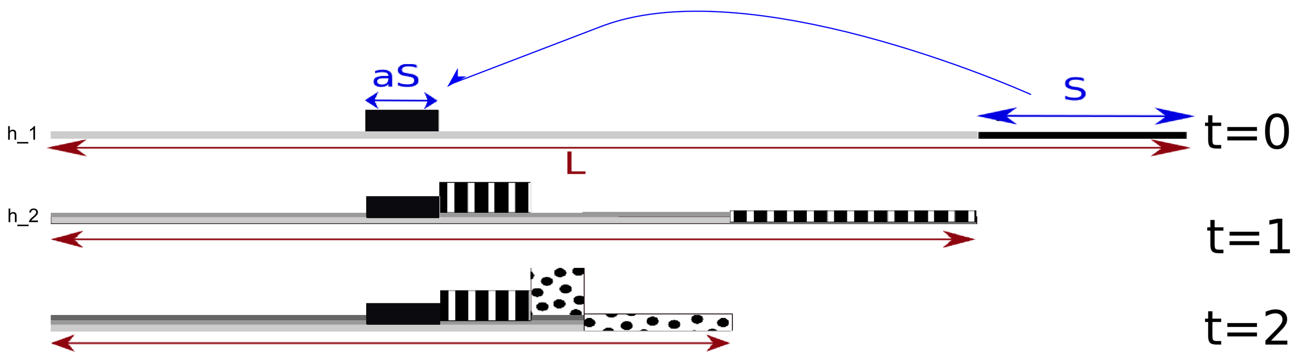
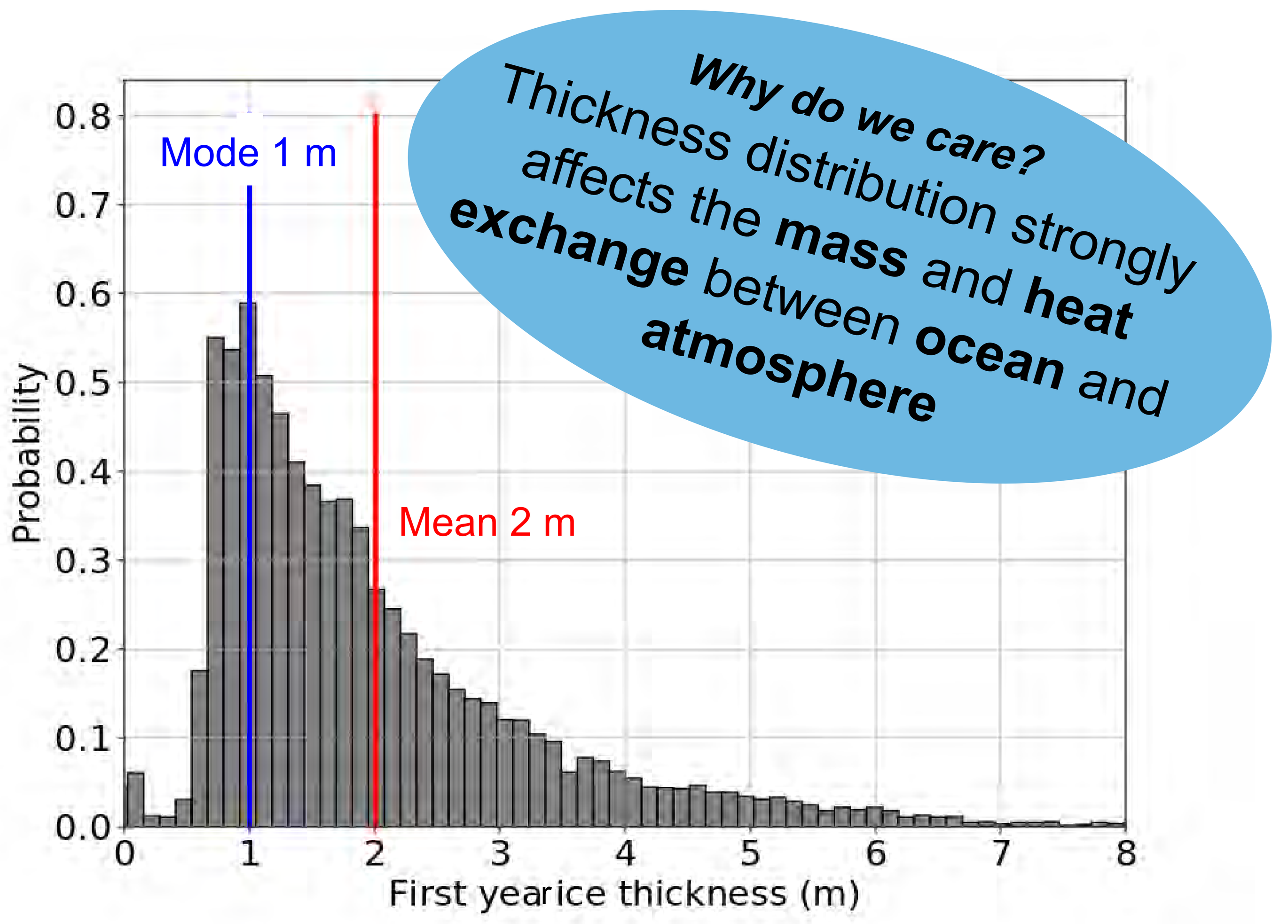


Fig. 2: Scheme of the simple dynamic growth model. At t=0, the polynya width is shortened by the length S. Ice of thermodynamically grown thickness h_0 and length S+aS is shortened to a length aS and a mean thickness a/(1+a). At t=1, undeformed ice continues to grow thermodynamically to h_1 and is then deformed as described above.

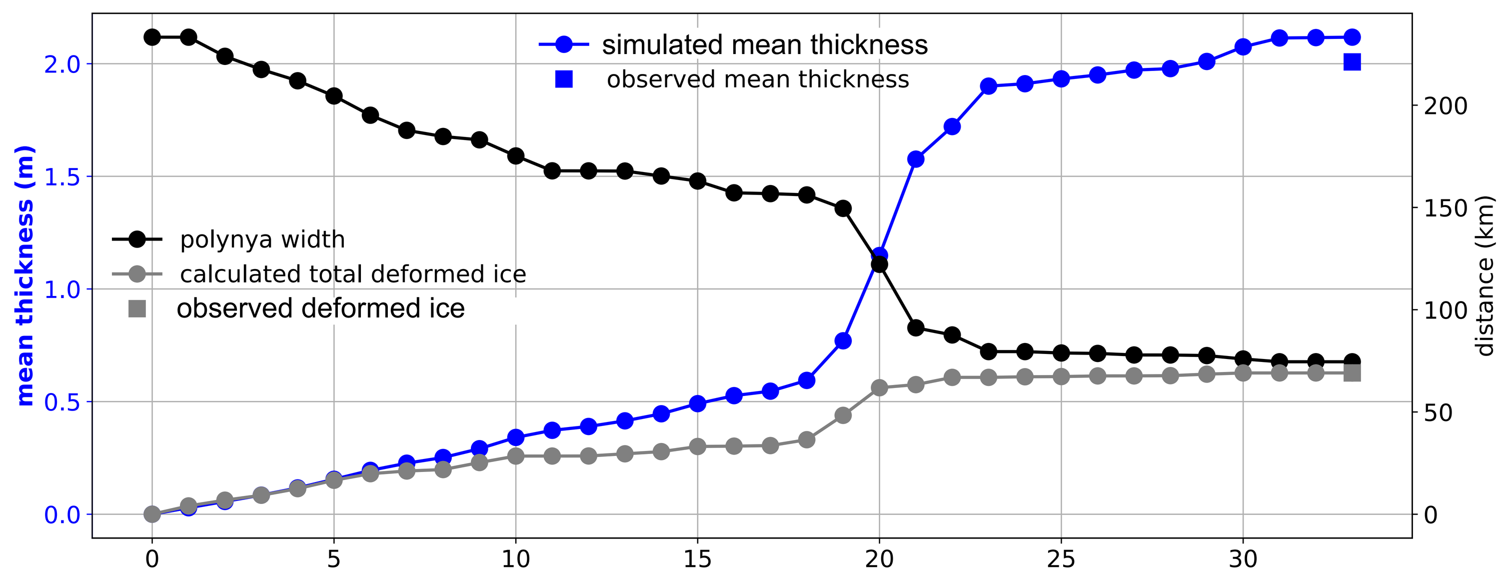
Results

Ice thickness distribution

- The most frequent ice thickness (mode) is associated with the undeformed, thermodynamically grown ice.
- After one month, we observe 1 m (mode) of thermodynamically grown ice.
- The mean ice thickness of 2 m indicates that dynamic processes doubled the ice thickness compared to only thermodynamic growth.



Time series of mean thickness change



- 1D model simulates a mean thickness of 2.1 m (Fig. 4), resembling well the observed mean (5% difference).
- Width of the polynya (estimated by identifying the northern endpoint of the AEM profile on Sentinel 1 images, Fig.1) decreased by 68%.

Spatial distribution of deformation

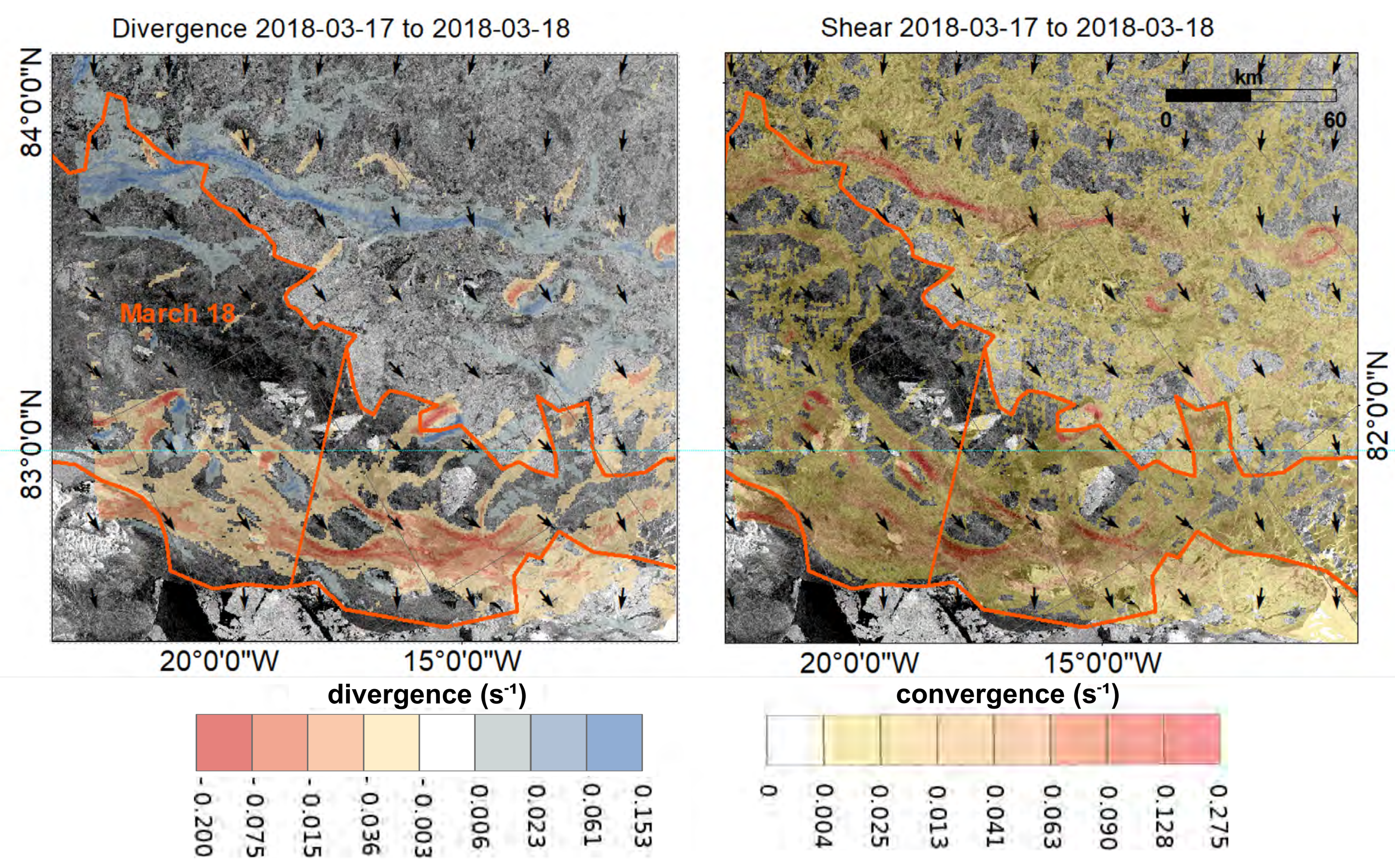


Fig. 5: Sentinel-1 image from March 18 with extent of polynya, velocity field, back-tracked AEM profile and total deformation between March 17 and 18.

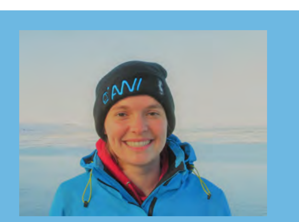
- Drift and deformation was calculated using a pattern-matching algorithm[3] from Sentinel-1 scenes, maximum 1.5 days apart at a final resolution of 1.4 km.
- In the polynya, strong convergence was observed in proximity of the coast and divergence along a narrow stripe further North (Fig. 5).
- Zones of strong convergence were formed in the young ice area around multi-year ice floes.

Outlook

- Set up an idealized model run of the North Greenland Polynya using a general circulation model.
- Identify the relevant processes and parameter that lead to a realistic ice thickness distribution.

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

References
1: Moore, Schweiger, Zhang, and Steele (2018) doi: 10.1029/2018GL080902
2: Rabenstein, Hendricks, Martin, Pfaffhuber, and Haas (2010), doi:10.1029/2009JC005846
3: Krumpen, Belter, Boetius, Damm, Haas, Hendricks, Nicolaus, Noethig, Paul, Peeken, Ricker, and Stein (2019), doi: 10.1038/s41598-019-41456-y
4: Hollands and Dierking (2011) doi:10.3189/172756411795931462, 2011
5: Haas, C. (2017) doi:10.1002/9781118778371.ch2



luisa.von.albedyll@awi.de