Drivers of interannual sea ice variability on the Arctic continental margin north of Svalbard

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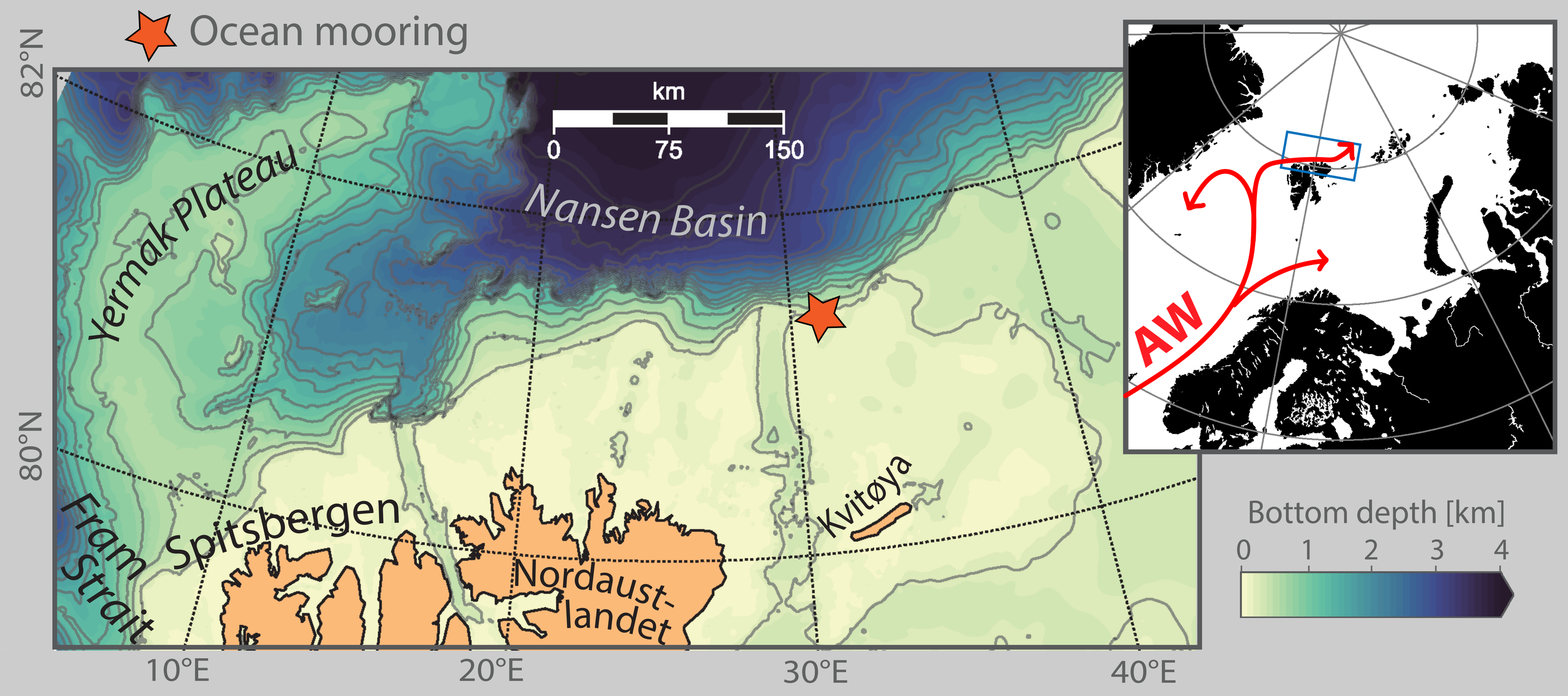


Spring 2016: Abnormally low sea ice concentration

Coincided with **abnormally high air temperatures** and relatively **weak spring sea ice advection** from the north.

2016 was a year of anomalously warm surface air temperatures, and anomalously low sea ice extent for the Arctic as a whole, and particularly in the Barents / Kara Sea (*4*).

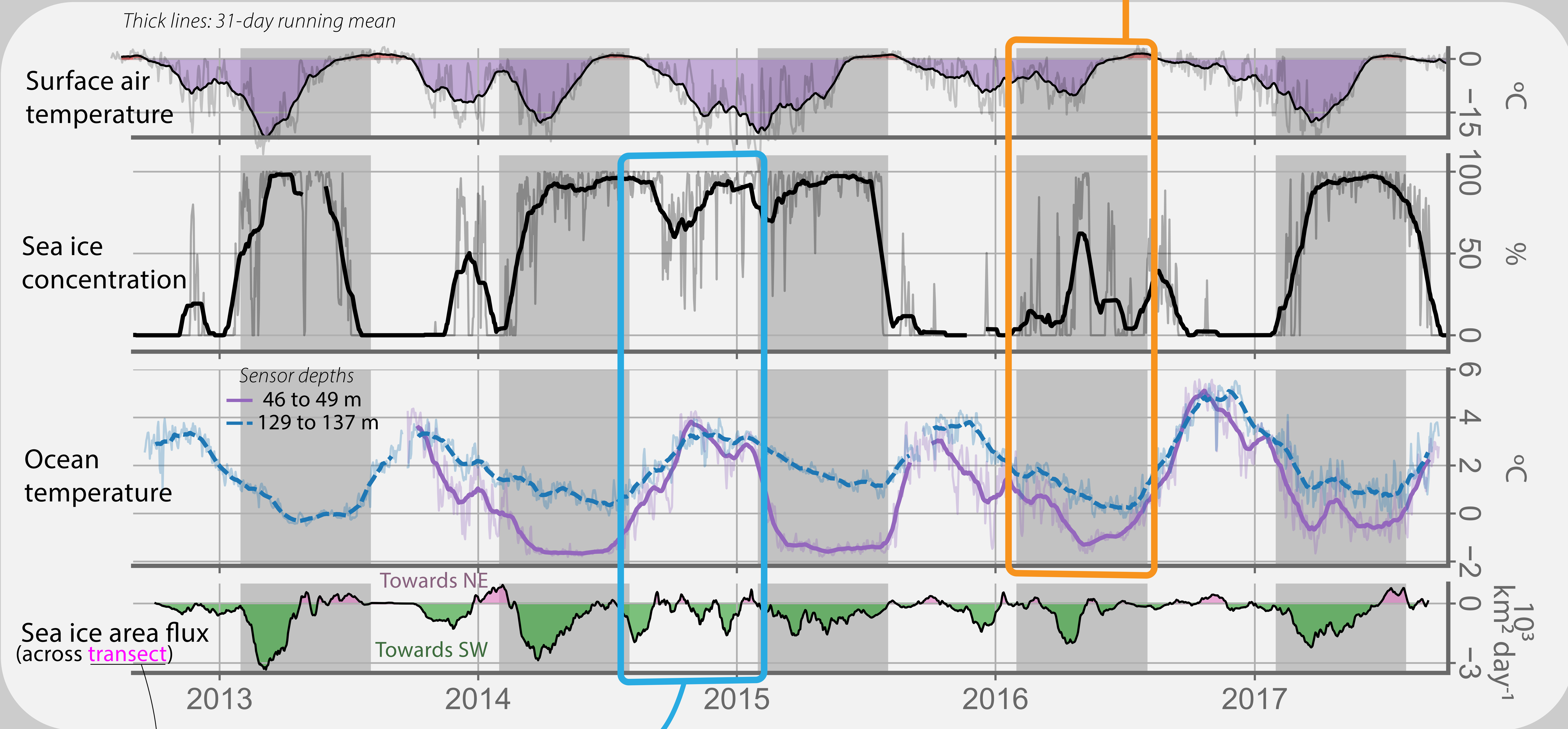
Sea ice concentration north of Svalbard is influenced by several factors:

Warm Atlantic Water is transported with the West Spitsbergen Current and eastward along the slope. Ocean heat melts sea ice from underneath and prevents new ice from forming.

Drift of sea ice from the north and east pushes ice into the area, increasing sea ice concentration. Ice advected in from the north is often thicker and therefore takes longer to melt.

The atmosphere impacts local sea ice melting and formation by heating and cooling. In addition, storms break up sea ice and stir up the top ocean layer, bringing additional ocean heat to the surface.

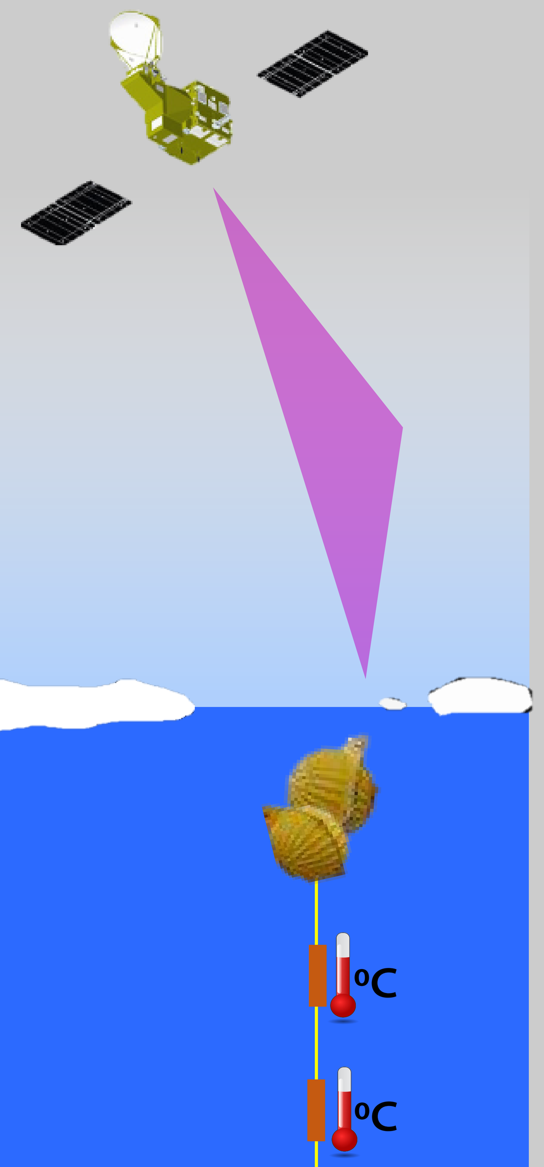
What governs interannual variability in sea ice concentration?



Upper ocean temperature does not explain major sea ice concentration anomalies:

Ice-free periods generally correspond to periods of warm (>1ºC) Atlantic Water in the ocean below.

However, the ocean was neither particularly cold during the high-ice anomaly in fall 2014, or particularly warm during the low sea ice anomaly in spring 2016.



Data

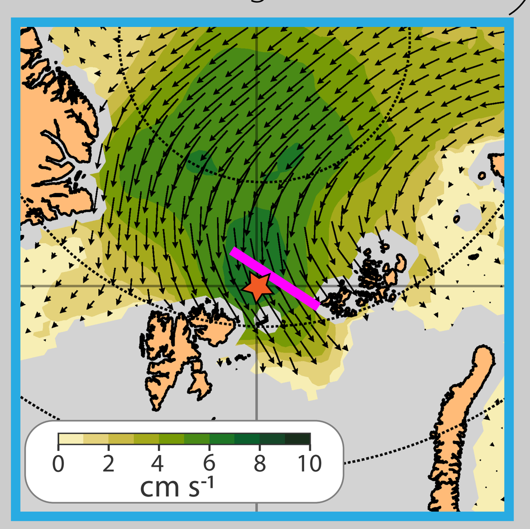
Ocean mooring located at 200 m depth, with temperature sensors at ~50 and ~130 m depth.

Sea ice concentration from AMSR2 ASI-SIC 6.25 km product (U of Bremen, *1*).

Sea ice drift from Polar Pathfinder Daily 25 km EASE-Grid Sea Ice Motion Vectors product (NSIDC, *2*).

Atmospheric variables from ERA-5 reanalysis (ECMWF, *3*).

Average sea ice drift vectors Jul-Aug 2014



Autumn 2014: Abnormally high sea ice concentration

Coincided with **abnormally large sea ice advection** into the area. In particular, leftward deflection of the Transpolar Drift Stream in July-August 2014.

Air temperature was abnormally low towards the end of 2014 - likely a result of decreased ocean-atmosphere heat flux.

Additional content:

The Atlantic Water pathway north of Svalbard as a sea ice sink

Although variability in sea ice concentration was not driven by ocean heat content, the overall pattern in sea ice extent is closely related to the distribution of Atlantic Water.

In the supplementary document, we show that the spatial patterns of sea ice concentration loss and ocean temperature are closely correlated in the region around Svalbard.

Conclusions

Large interannual variability in sea ice concentration - changes from year to year are nearly as large as the seasonal cycle.

Ocean heat is not the primary driver of interannual variability in sea ice concentration - local subsurface ocean temperature alone is a poor predictor of seasonal anomalies.

A **positive sea ice anomaly** in fall 2014 appears to have been related to large-scale ice flux from the Arctic Ocean rather than local conditions.

A **negative sea ice anomaly** in spring 2016 was associated with high surface air temperature across the Arctic, was therefore a result of large-scale atmospheric circulation anomalies rather than processes specific to the Atlantic Water inflow region.

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The observations and analysis are supported by RCN projects **SIOS-InfraNor (269927)**, the **Nansen LEGACY (276730)** and the Fram Centre Arctic Ocean flagship project **A-TWAIN (66050).**

References

1. Spreen, G., L. Kaleschke, and G.Heygster (2008). Sea ice remote sensing using AMSR-E 89 GHz channels J. Geophys. Res., vol. 113, C02S03, doi:10.1029/2005JC003384.

2. Tschudi, M., W. N. Meier, J. S. Stewart, C. Fowler, J. Maslanik (2019). Polar Pathfinder Daily 25 km EASE-Grid Sea Ice Motion Vectors, Version 4. Arctic subset. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/INAWUWO7QH7B.

3. Copernicus Climate Change Service, C3S (2017). ERA5: Fifth generation of ECMWF atmospheric reanalyses 380 of the global climate. Copernicus Climate Change Service Climate Data Store (CDS). https://cds.climate.copernicus.eu/cdsapp#!/home

4. Boisvert, L. N., Petty, A. A., & Stroeve, J. C. (2016). The impact of the extreme winter 2015/16 Arctic cyclone on the Barents–Kara Seas. Monthly Weather Review, 144(11), 4279-4287.

Additional content

The Atlantic Water pathway north of Svalbard as a sea ice sink

Supplementary content to:

Drivers of interannual sea ice variability on the Arctic continental margin north of Svalbard

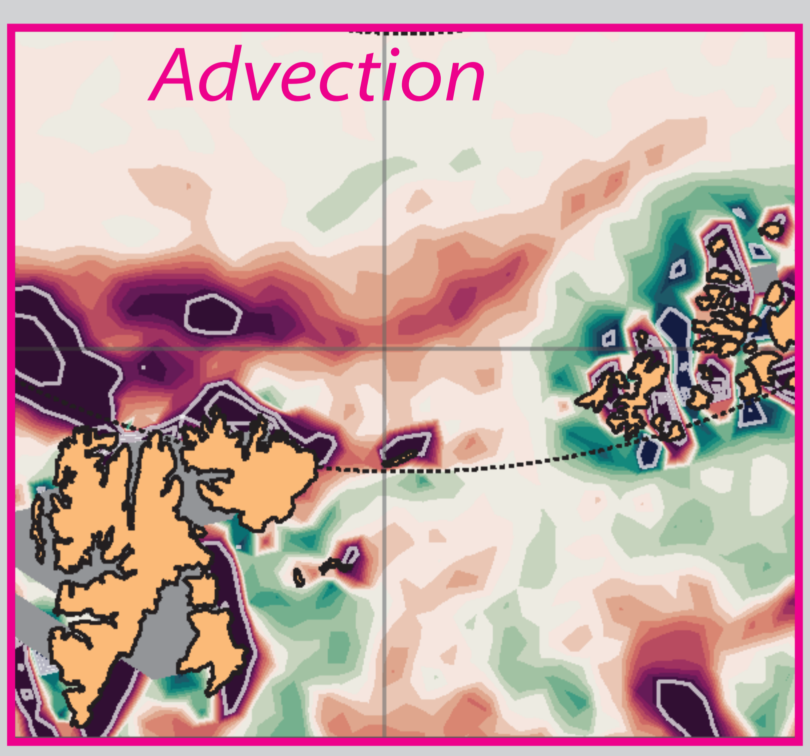
Although interannual variability in sea ice concentration at the study site was not driven by changes in ocean heat content, the overall pattern in sea ice extent is closely related to the distribution of Atlantic Water.

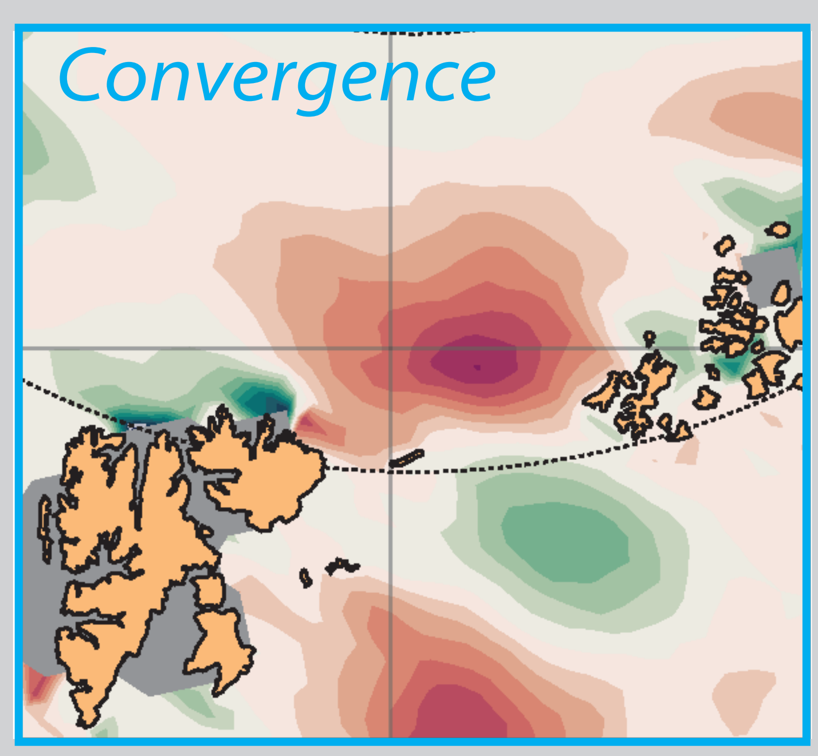
The figures below show the terms of the sea ice concentration budget (see ***1***) evaluated at each point in the domain, and averaged from 01.09.2012 to 01.09.2017. (The left hand side was within 20 % year^{-1} everywhere).

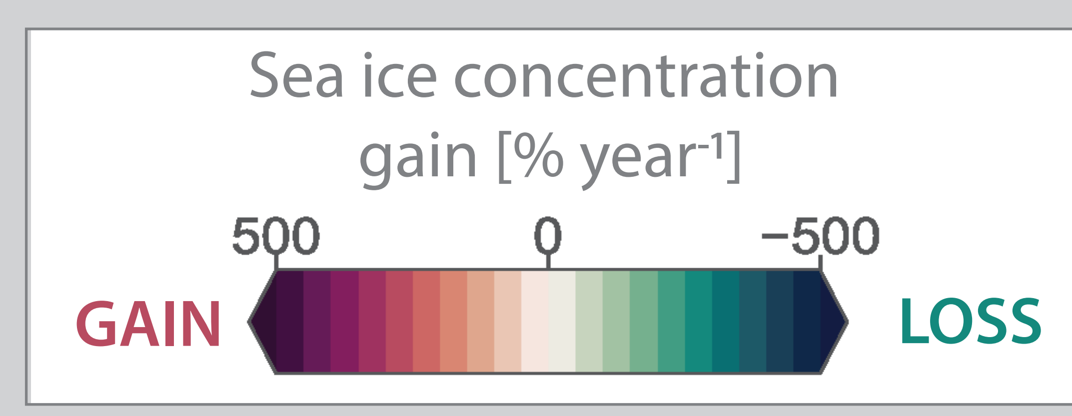
Sea ice concentration conservation equation

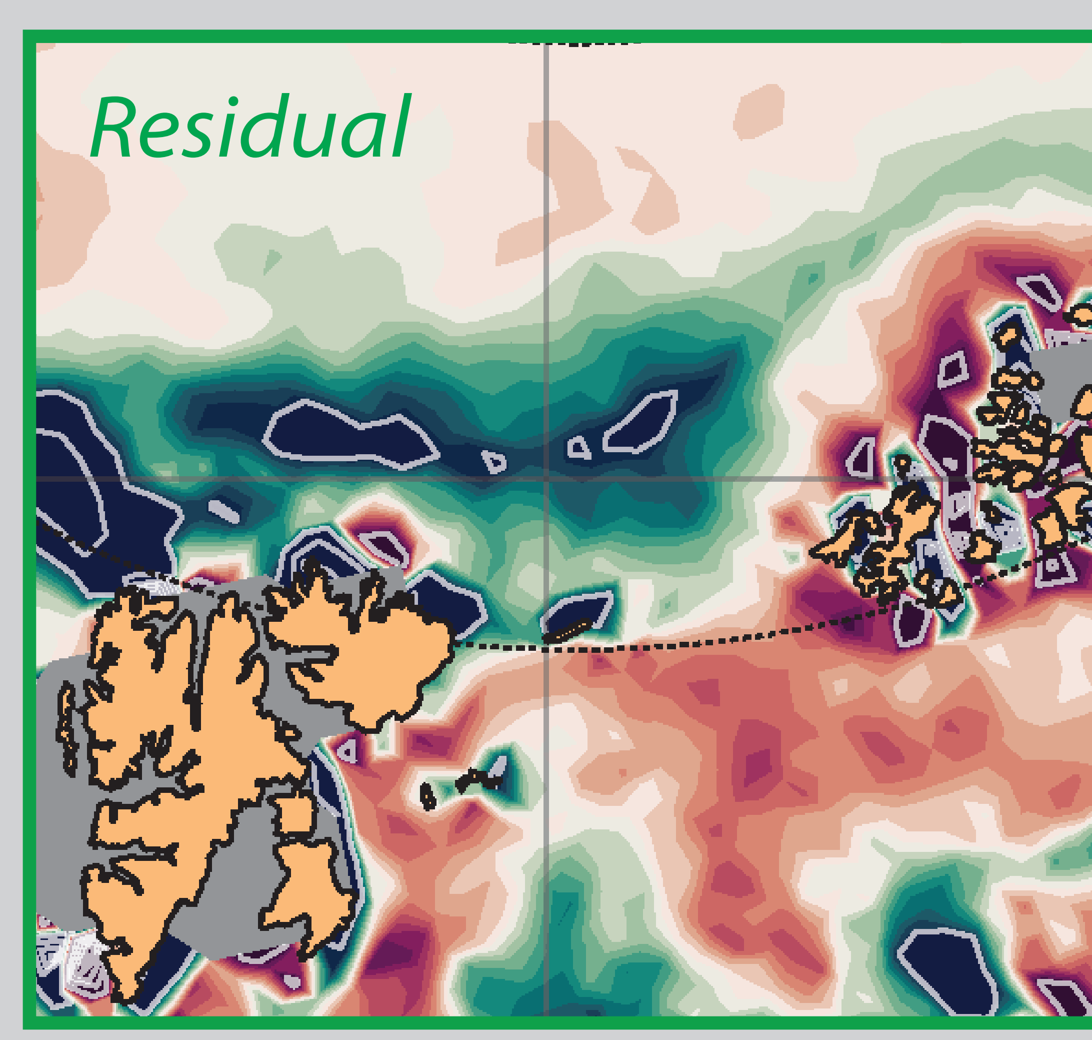
$$\frac{\partial C}{\partial t} = -\underbrace{\mathbf{u}\cdot\nabla C}_{\text{Advection}} - \underbrace{C\nabla\cdot\mathbf{u}}_{\text{Convergence}} + \underbrace{R}_{\text{Residual}}$$

C	*Sea ice concentration (from **2**)*
$\mathbf{u}$	*Sea ice horizontal velocity vector (from **3**)*
R	*Residual*









A **negative residual term** means that there is a **net loss of sea ice concentration** locally. This can be due to deformation (such as sea ice ridging) or local sea ice melt.

North of Svalbard, the negative residual term coincides with the continental slope where warm Atlantic Water is transported eastward (***4***).

Sea ice concentration loss is greatest along the pathway of warm Atlantic Water.

References

1. **Holland, P. R., & Kimura, N. (2016).** Observed concentration budgets of Arctic and Antarctic sea ice. Journal of Climate, 29(14), 5241-5249.

2. **Spreen, G., L. Kaleschke, and G.Heygster (2008).** Sea ice remote sensing using AMSR-E 89 GHz channels J. Geophys. Res., vol. 113, C02S03, doi:10.1029/2005JC003384.

3. **Tschudi, M., W. N. Meier, J. S. Stewart, C. Fowler, J. Maslanik (2019).** Polar Pathfinder Daily 25 km EASE-Grid Sea Ice Motion Vectors, Version 4. Arctic subset. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/INAWUWO7QH7B.

4. **Menze, S., Ingvaldsen, R. B., Haugan, P., Fer, I., Sundfjord, A., Beszczynska-Moeller, A., & Falk-Petersen, S. (2019).** Atlantic water pathways along the north-western Svalbard shelf mapped using vessel-mounted current profilers. Journal of Geophysical Research: Oceans, 124(3), 1699-1716..

1 NORWEGIAN POLAR INSTITUTE

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