On sea-ice retreat and convection in the Greenland Sea

Marte Vrålstad and Idunn Hana
Marte.Vralstad@student.uib.no, Idunn.Hana@student.uib.no
University of Bergen

ABSTRACT

Convection and deep water formation in the Greenland Sea play crucial roles in the Atlantic Meridional Overturning Circulation (AMOC). Much of this convection occurs along the sea-ice edge, driven by strong temperature gradients between the atmosphere and the exposed ocean. This process leads to the cooling of the surface layer, resulting in increased density and subsequent sinking of surface waters. As the climate changes, due to global warming, the sea-ice edge is retreating, causing a reorganization of water mass transformation. Understanding this reorganization is essential, as the AMOC significantly impacts global climate and temperatures, as well as regional climate here in Bergen. This poster investigates the relationship between sea-ice edge retreat and convection in the Greenland Sea. It highlights a significant retreat of the sea-ice edge along the east coast of Greenland over recent decades, particularly noticeable during the winter months when convection is most active. Additionally, the poster explores how the re-organization of convection could imply both a weakening or even give resilience to the AMOC.

The Greenland Sea

The Greenland Sea is located east of the Island of Greenland (Fig. 1). In this sea, the Greenland Sea gyre enables convection processes, important for generating the densest component of the lower limb of the AMOC. Another contributor to this dense water in the Greenland Sea is the East Greenland Current (EGC), a boundary current flowing southward along the East Greenland shelfbreak.

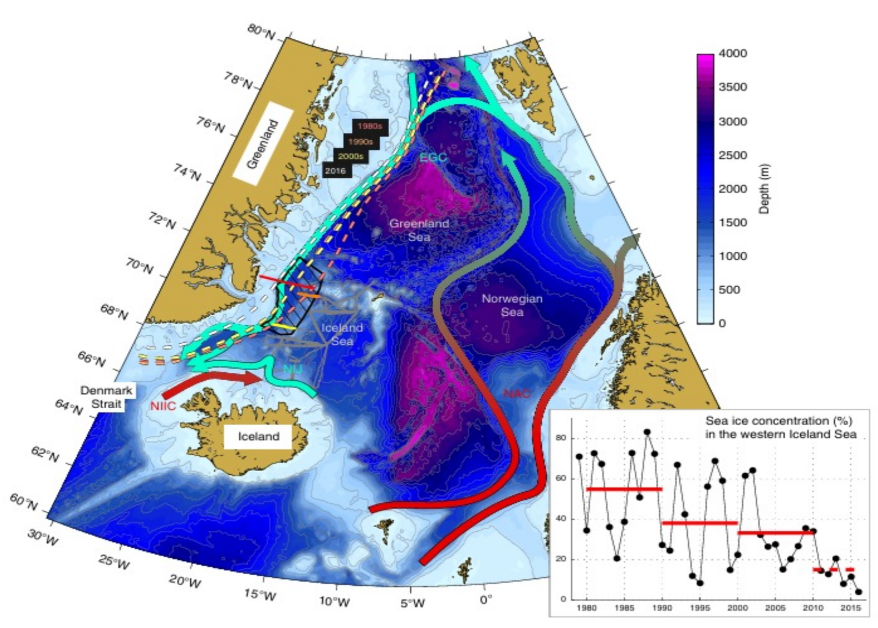

Figure 1: From Våge et al. (2018). Schematic overview of the Nordic seas. Both the Greenland sea and EGC are labeled. The graph shows the winter mean sea ice concentration in the western Iceland seas.

Sea-ice retreat

- Sea-ice cover variability modulate winter-mean turbulent heat fluxes
- There has been a consistent retreat of the sea-ice cover in the Greenland sea the past decades (Fig. 2)
  - Reduced air-sea fluxes over the Greenland Sea gyre
  - Exposure of the EGC to the atmosphere, enhancing air-sea interaction along the sea-ice edge
- Increase of turbulent heat fluxes is largest where the currents orientation is perpendicular to the direction of sea-ice retreat

Sea-ice retreat significantly influences changes in heat fluxes along the EGC

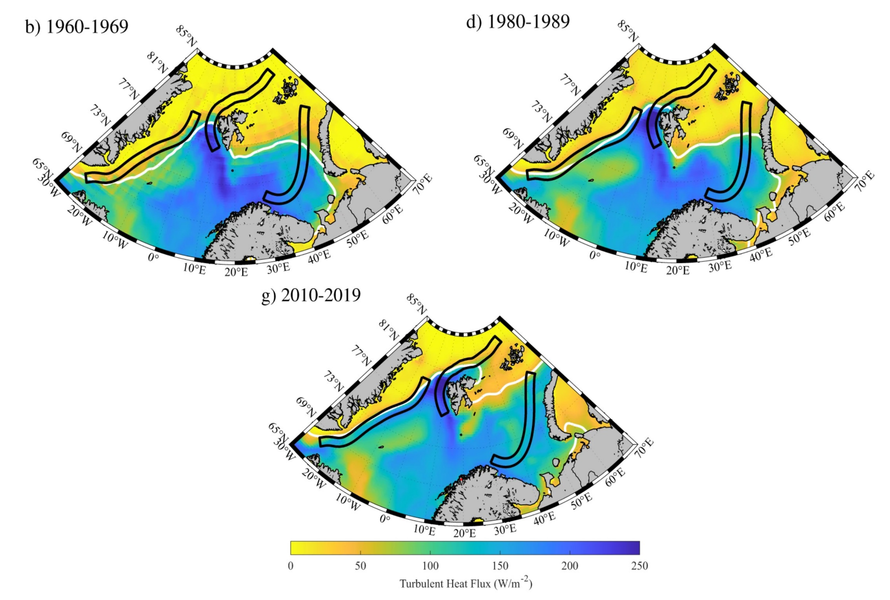

Figure 2: From Moore et al (2022). Spatiotemporal variability in winter mean turbulent heat flux over the Nordic and Barents Seas. The white lines show the 50% sea ice concentration.

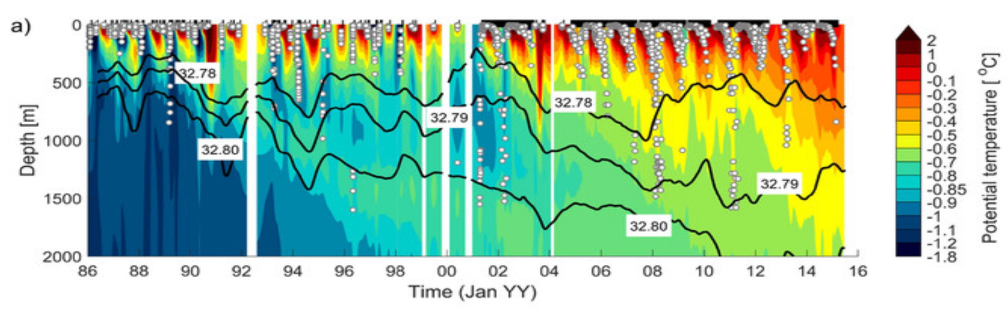

Figure 3: From Brakstad et al. (2019). Evolution of potential temperature within the upper 2000 m of the Greenland Sea gyre from 1986 to 2016.

Convection

- Large temperature gradients between atmosphere and ocean at sea-ice edge
- First meeting between cold air from over ice/land and the warmer ocean
- **Pronounced convection along the sea-ice edge**

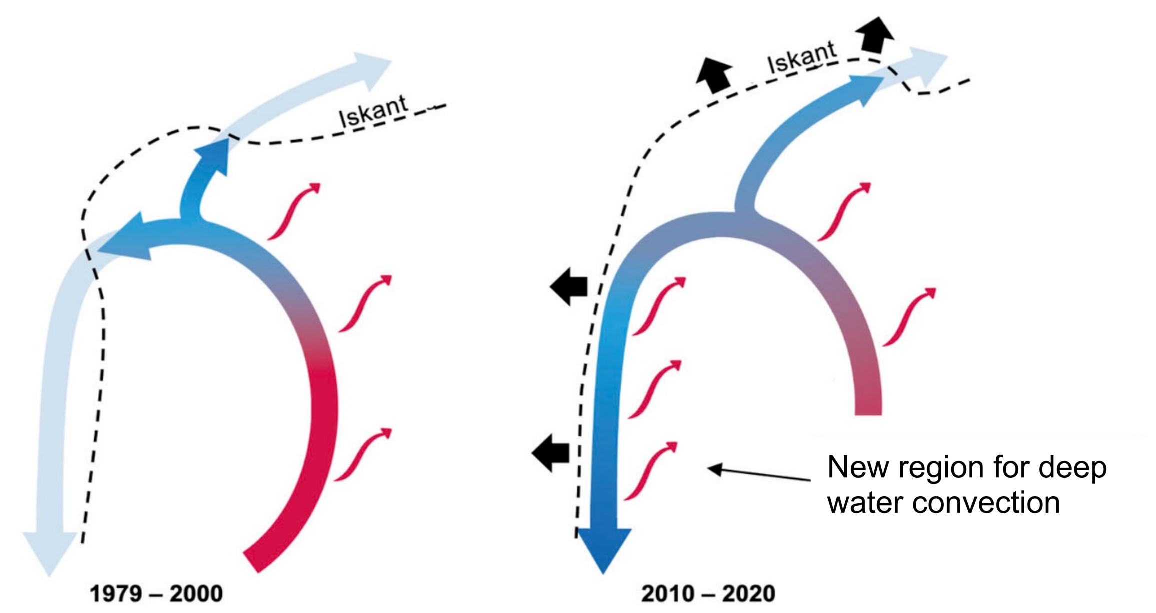

Figure 4: Illustration of how a current is exposed to the atmosphere in the absence of ice, leading to stronger sea-air heat loss over the current (Illustration: Kjetil Våge).

Implications of sea-ice edge retreat on overturning

- As temperatures rise and the sea-ice edge retreats, convection in the Greenland Sea gyre is reduced weakening the overturning
- However the retreading sea-ice edge leads to convection along the previously isolated EGC

If the convection along the EGC is sufficiently strong, it may impart resilience to the overturning circulation, maintaining the supply of dense water to the lower limb of the AMOC.

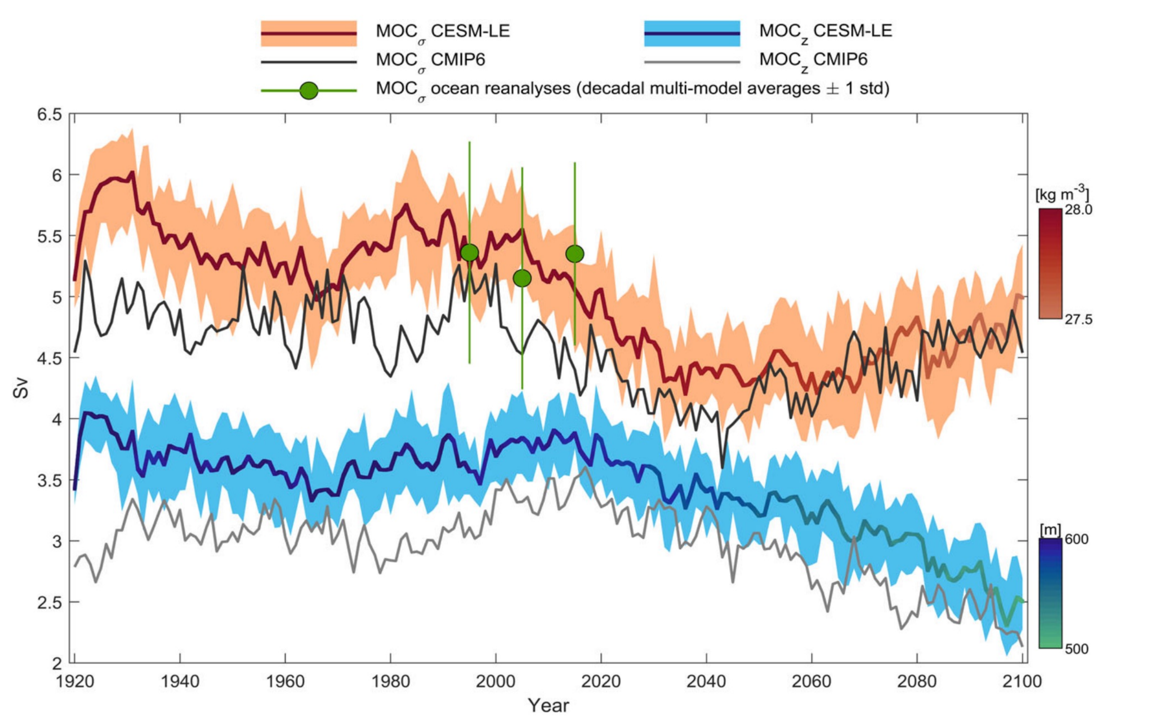

Figure 5: From Årthun et al. (2023). Time series of maximum overturning strength at 70°N in depth-space (MOC_z) and density (MOC_σ) in CESM-LE and CMIP6 models. The color of the solid lines indicates the depth and density of the maximum overturning circulation in depth-space and density-space, respectively.

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