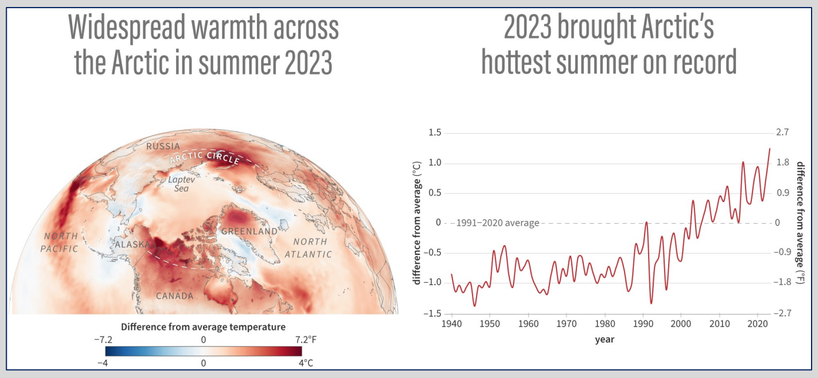
Overturning circulation in a future Arctic Ocean

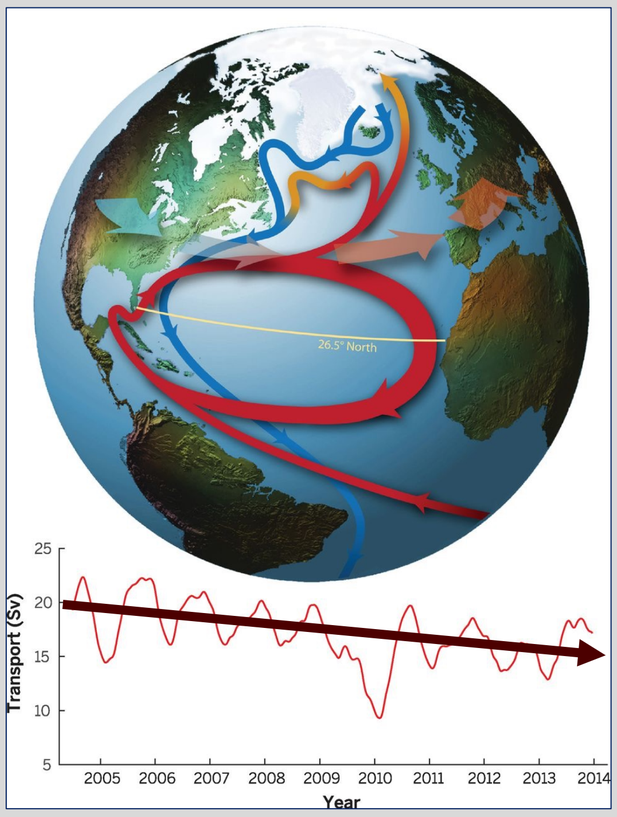
Carlo Mans

A WEAKENING AMOC AND A CHANGING ARCTIC

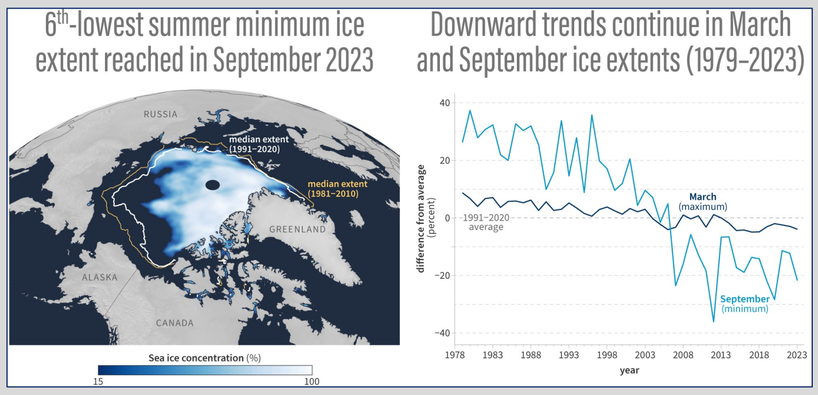
Driven by differences in density, the AMOC* helps keep Western Europe's climate mild by transporting heat. Climate models predict that **the AMOC will slow down** under global warming.[1]

*Atlantic Meridional Overturning Circulation

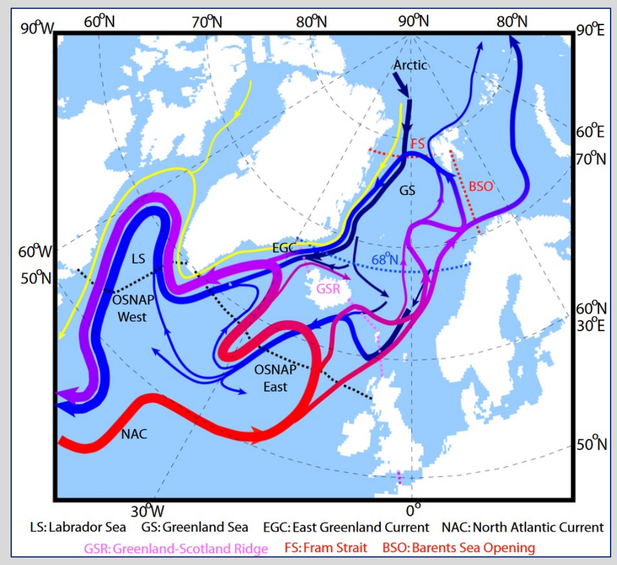




At the same time, the **Arctic is undergoing major changes**. The Arctic is heating at a disproportionate rate, the sea ice edge is retreating, the Greenland ice sheet is melting, and the hydrological cycle is intensifying. These changes have both local and global consequences, providing a link to the potential slowdown of the AMOC.



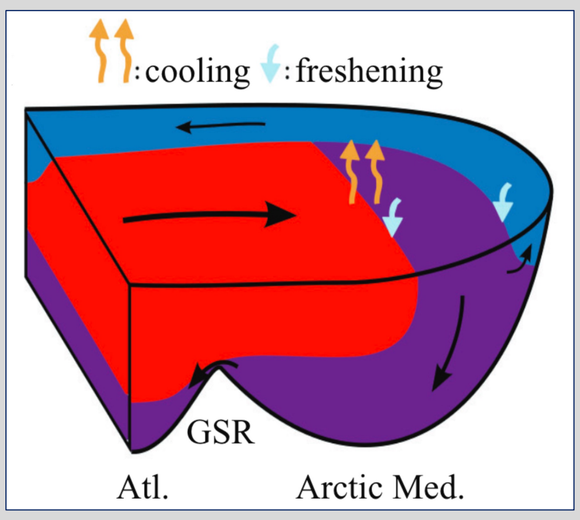
THE ARCTIC OCEAN AS ENDPOINT OF THE AMOC



Schematic of long-term mean AMOC pathways.[2]

Recently, the **Arctic Ocean has been recognized as the northern endpoint of the AMOC**. Almost half of the dense Atlantic Water inflow transformed in the Nordic Seas is further transformed in the Arctic, due to heat loss and mixing with dense shelf waters. The resulting waters return south and contribute to GSR overflow, making the deep AMOC branch across the Fram Strait and the Barents Sea Opening the densest source water for downstream overflows.[2]

ARCTIC OVERTURNING MECHANISMS



Schematic representation of Arctic overturning cells.[3]

Inflowing warm and salty Atlantic Water is transformed by extraction of heat to the atmosphere, addition of meteoric freshwater and interaction with ice. The **estuarine cell** represents the transformation of AW to *cool* and *fresh* surface Polar Waters, and the **thermal cell** represents the transformation of AW to *dense* & deep Overflow Waters.[3]

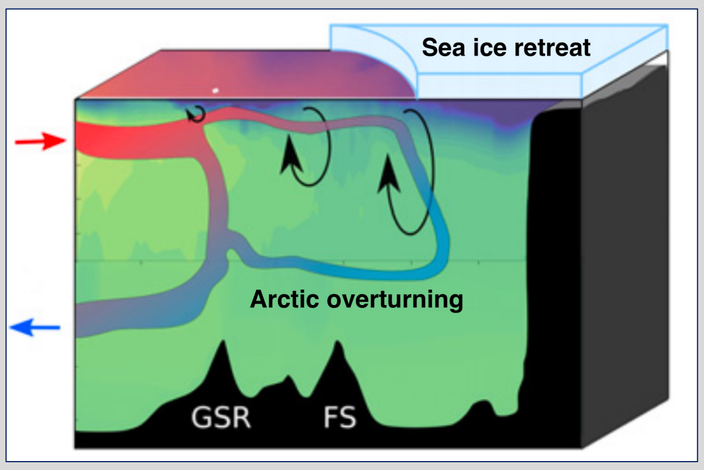
PROJECTED CHANGES AND FUTURE OUTLOOK

Due to the concurrent drastic changes happening in the Arctic, it is unclear what will happen to the overturning circulation in the Arctic. Våge et al. (2018) notes increased water mass transformation in the EGC with a retreating sea ice edge. Similarly, Lique & Thomas (2018) find a northward shift of deep convection in a warming climate. Hence, **Arctic overturning may strengthen.**

In a changing climate, we expect:

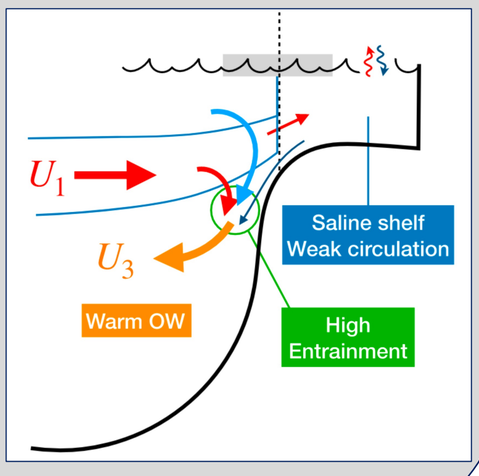
- A northward shift of the sea ice edge
- Changing air-sea heat fluxes
- Increased meteoric freshwater fluxes
- An increased Atlantic Water heat flux

Schematic of Arctic thermal overturning circulation under sea ice retreat.[7]



Conversely, with increases in the AW heat flux and meteoric freshwater fluxes, Haine (2021) predicts a **shutdown of the estuarine cell** in a so-called 'Heat Crisis' - the inability for the ocean to lose enough heat.

Schematic showing the collapse of the estuarine cell in a heat crisis.[6]



Concluding remarks: In a rapidly changing Arctic, different processes may mitigate a slowdown of the AMOC by strengthening overturning processes in the Arctic, or, instead, drastically lead to the collapse of one of the overturning cells. These conflicting predictions highlight the need for a greater understanding of Arctic overturning processes and further research into Arctic overturning in a future warming scenario.

References:

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[4]Våge, K., Papritz, L., Håvik, L. et al. Ocean convection linked to the recent ice edge retreat along east Greenland. *Nat Commun* **9**, 1287 (2018).

[5]Lique, C., Thomas, M.D. Latitudinal shift of the Atlantic Meridional Overturning Circulation source regions under a warming climate. *Nature Clim Change* **8**, 1013–1020 (2018).

[6]Haine, T. W. N. (2021). A Conceptual Model of Polar Overturning Circulations. *Journal of Physical Oceanography*, **51**(3), 727-744

[7]Bretones, A., Nisancioglu, K. H., Jensen, M. F., Brakstad, A., & Yang, S. (2022). Transient Increase in Arctic Deep-Water Formation and Ocean Circulation under Sea Ice Retreat. *Journal of Climate*, **35**(1), 109-124.

carlo.mans@uib.no

https://www.uib.no/en/persons/Carlo.Jeffrey.Mans

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