The impact of cold air outbreaks and oceanic lateral fluxes on dense water formation in the Greenland Sea from a ten-year moored record (1999-2009)

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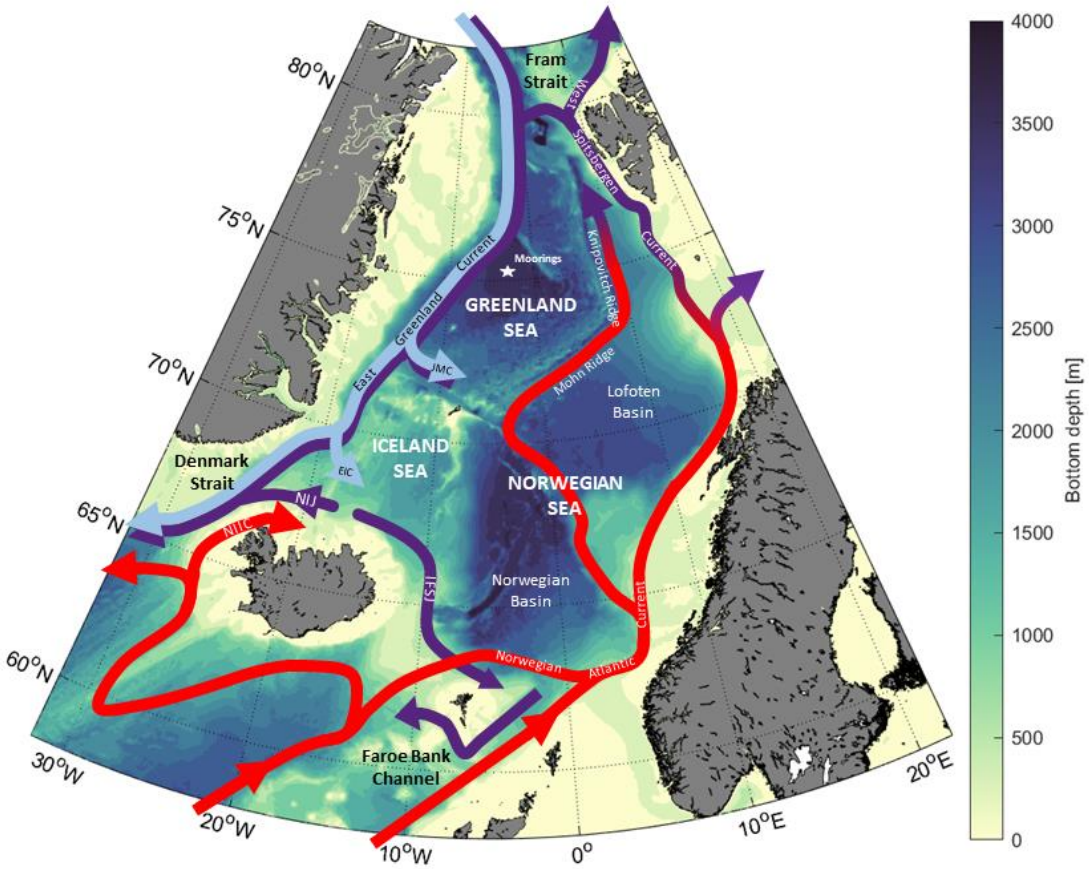
Wilken-Jon von Appen (AWI)

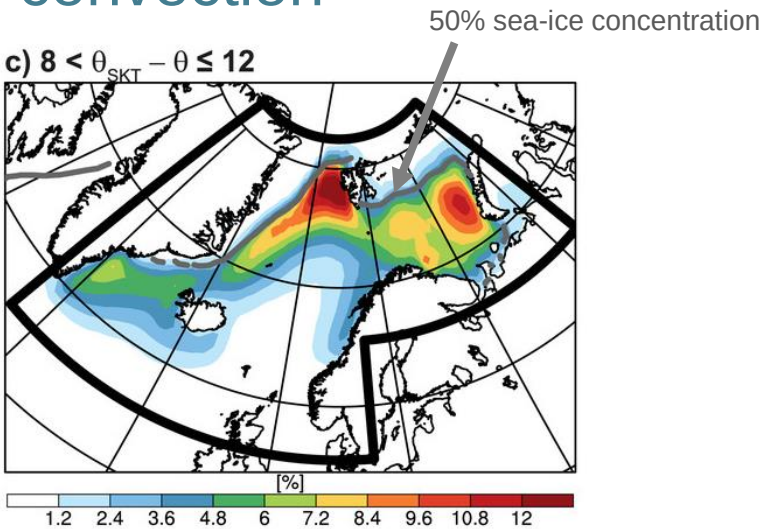
Lukas Papritz (ETH zürich)



The Greenland Sea …

➢ … is an ideal place for open-ocean convection

- Cyclonic gyre circulation
- Weak intermediate stratification
- Located near the sea-ice edge
- Large winter heat loss due to cold air outbreaks



Mean frequency of strong cold air outbreaks
(Papritz and Spengler, 2017)

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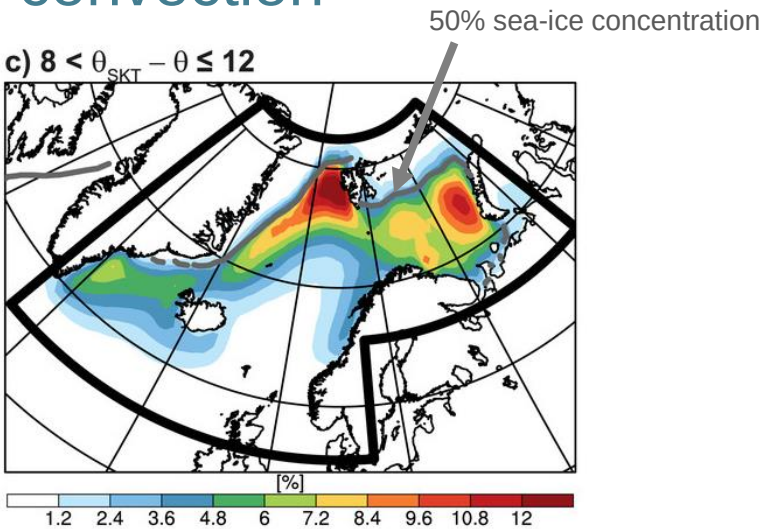

Mean frequency of strong cold air outbreaks (Papritz and Spengler, 2017)

➢ … is origin to a significant portion of the overflow water

- The Greenland Sea is the primary source of the densest portion of the Nordic Seas overflows (Huang et al., 2020)
- Approximately 40% of the total overflow water originates in the Greenland Sea (Brakstad et al., in prep)

Wintertime evolution of the Greenland Sea mixed layer depends on:

➢ Heat loss to the atmosphere

- 60-80% of the heat lost during winter is due to Cold Air Outbreaks (CAOs, Papritz and Spengler, 2017)
- CAOs only last for a few days (Terpstra et al., 2021)

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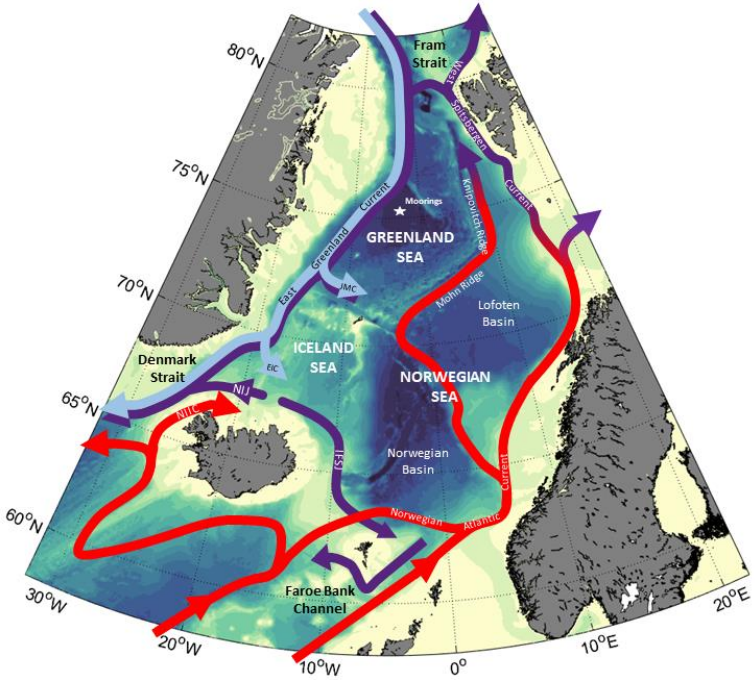
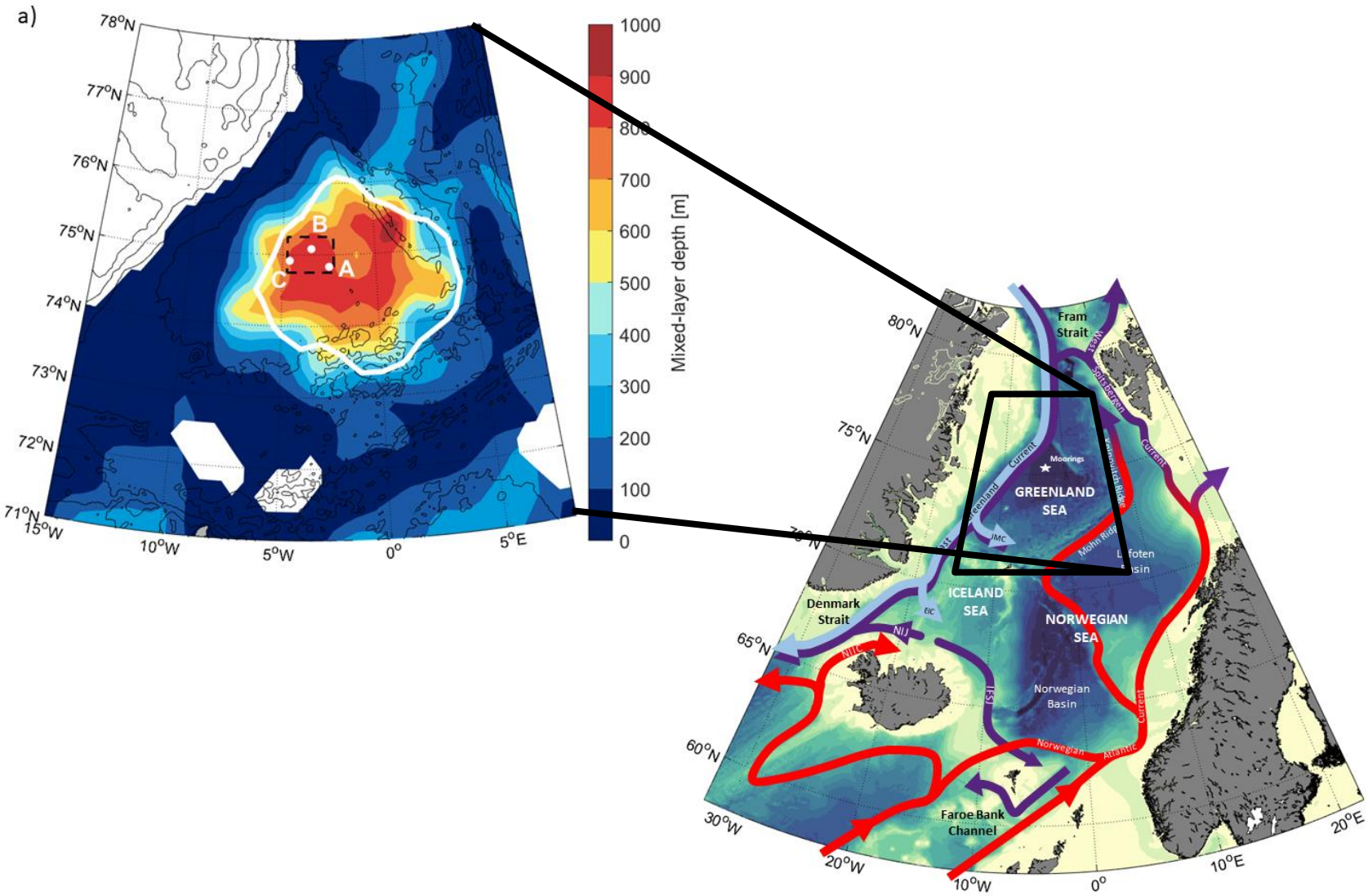
➢ Oceanic lateral fluxes of heat and salt

- Warming and salinification of the central Greenland Sea (1986-2016, Lauvset et al, 2018; Brakstad et al., 2019)
- Depth-integrated lateral heat flux ~60W/m² (Moore et al., 2015: Latarius and Quadfasel, 2016)

Questions remain regarding the vertical distribution and origin of the lateral heat and salt fluxes.

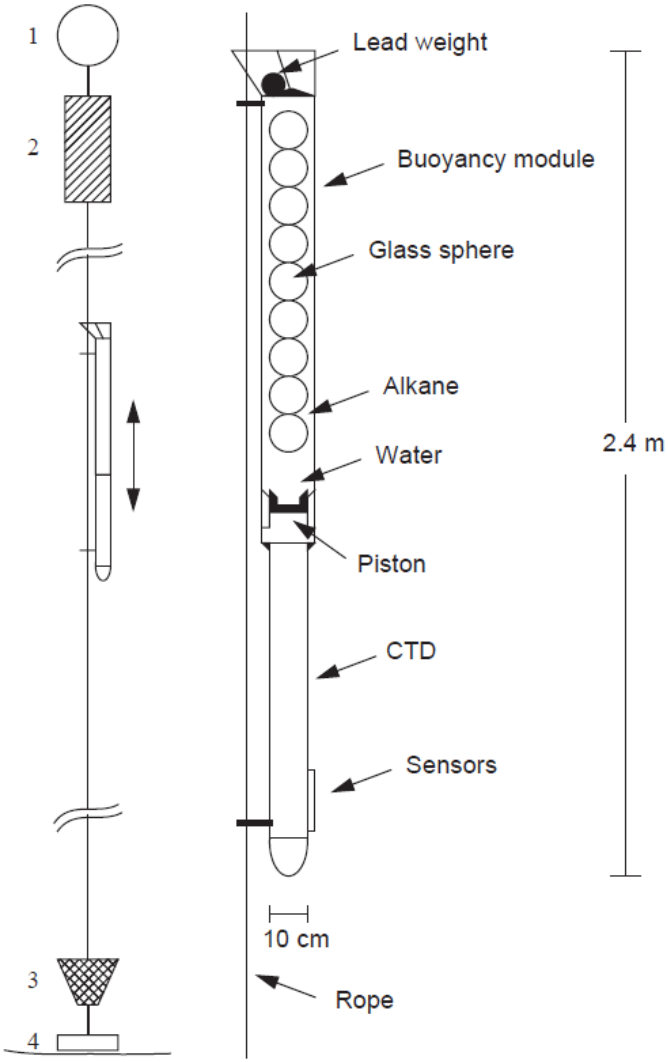


10 years (1999-2009) of profile mooring data from the central Greenland Sea



Mooring setup - photos by Gereon Budéus, AWI

Budéus et al., 2005. DSR
Budéus, 2009. SeaTechnology



''The treasure chest:
Energy for 400 times of 4000m profiling''

https://www.awi.de/en/science/climate-sciences/physical-oceanography/instruments/tiefsee-yoyo/bildserie-zum-aussetzen-der-jojo-verankerung.html

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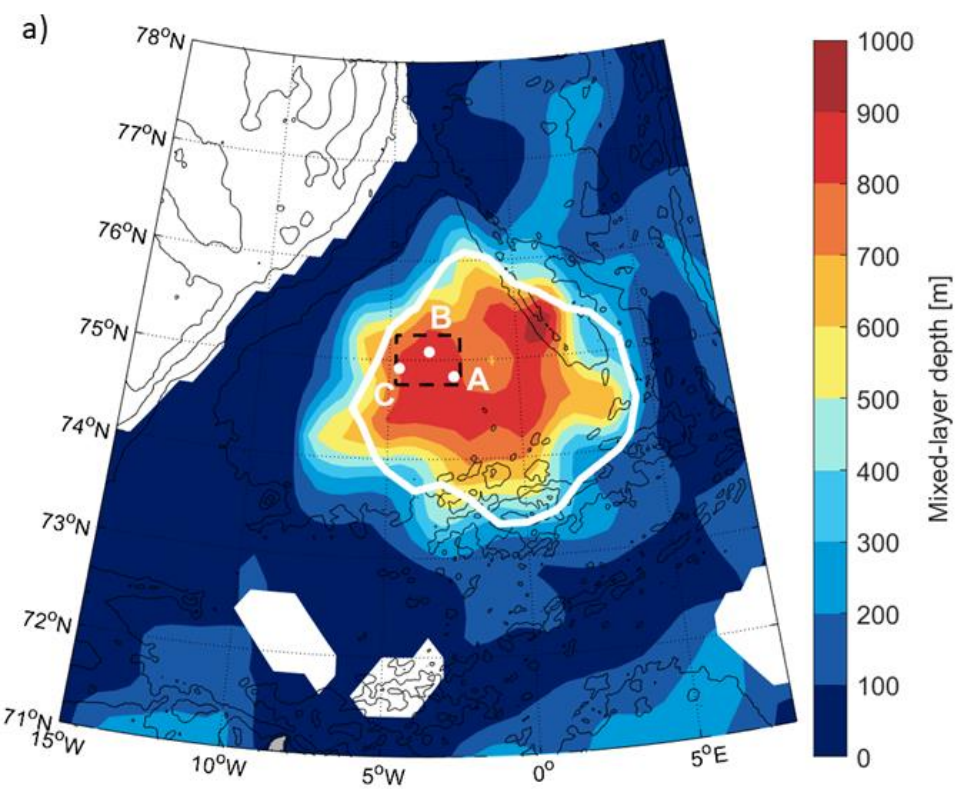
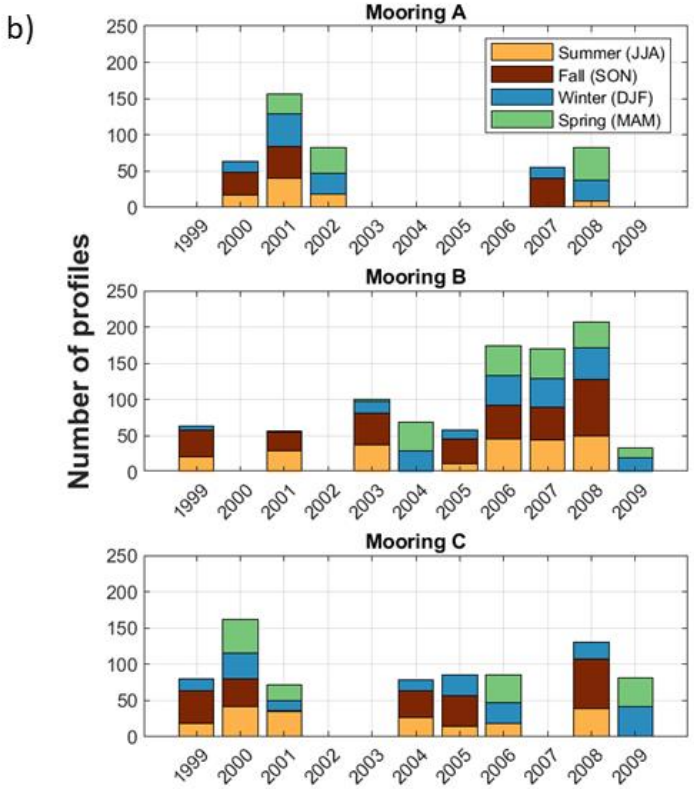
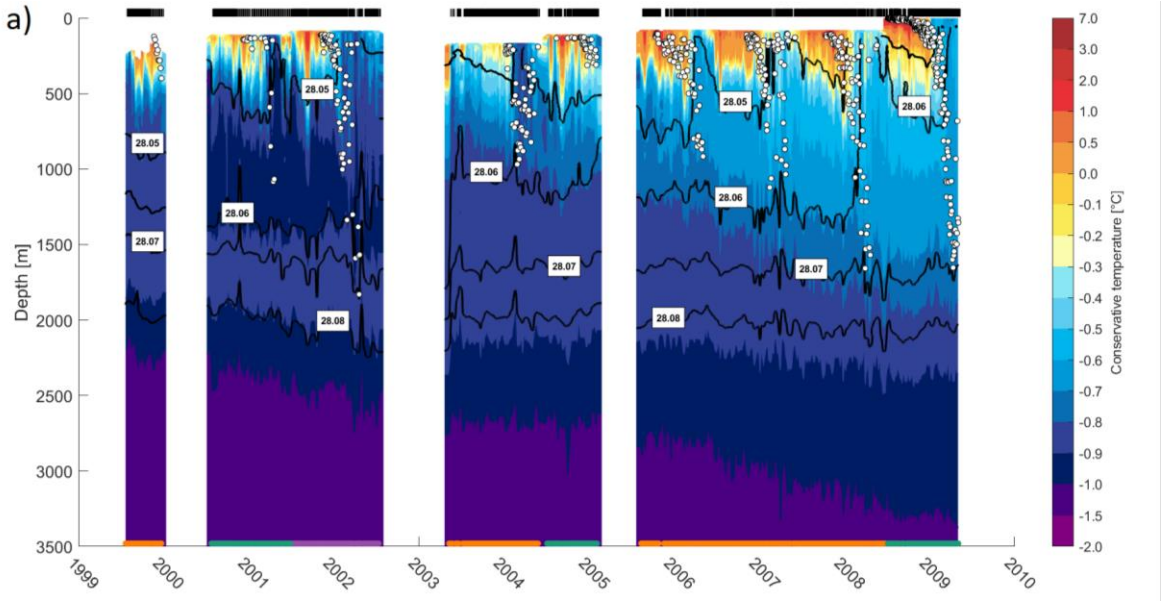
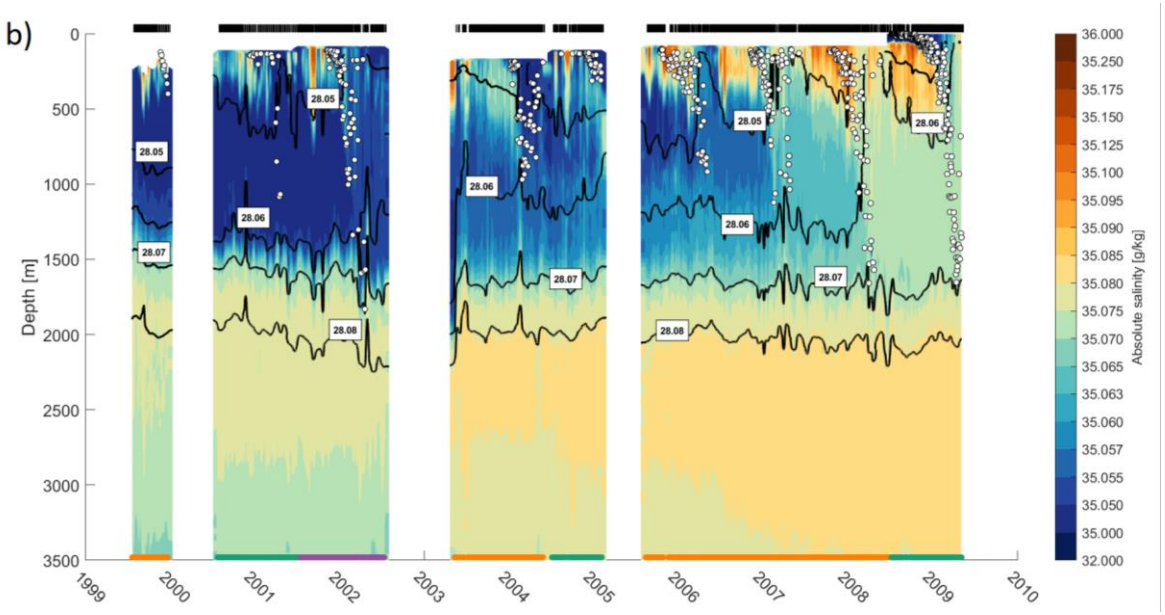




Long-term evolution of the hydrographic properties in the Greenland Sea Gyre

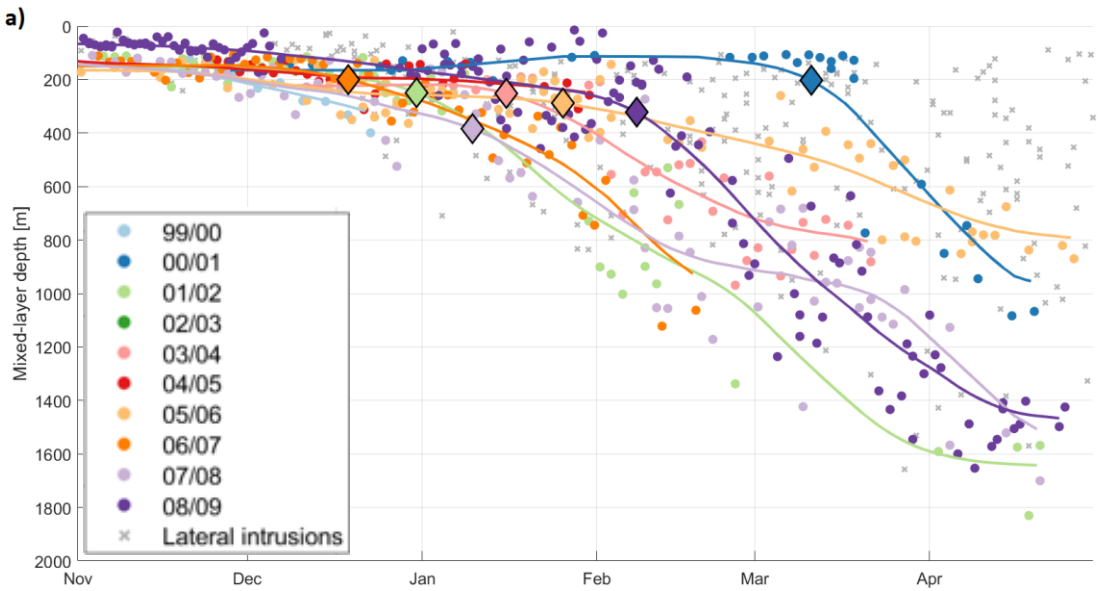


Temperature



Salinity

Mixed-layer evolution through winter



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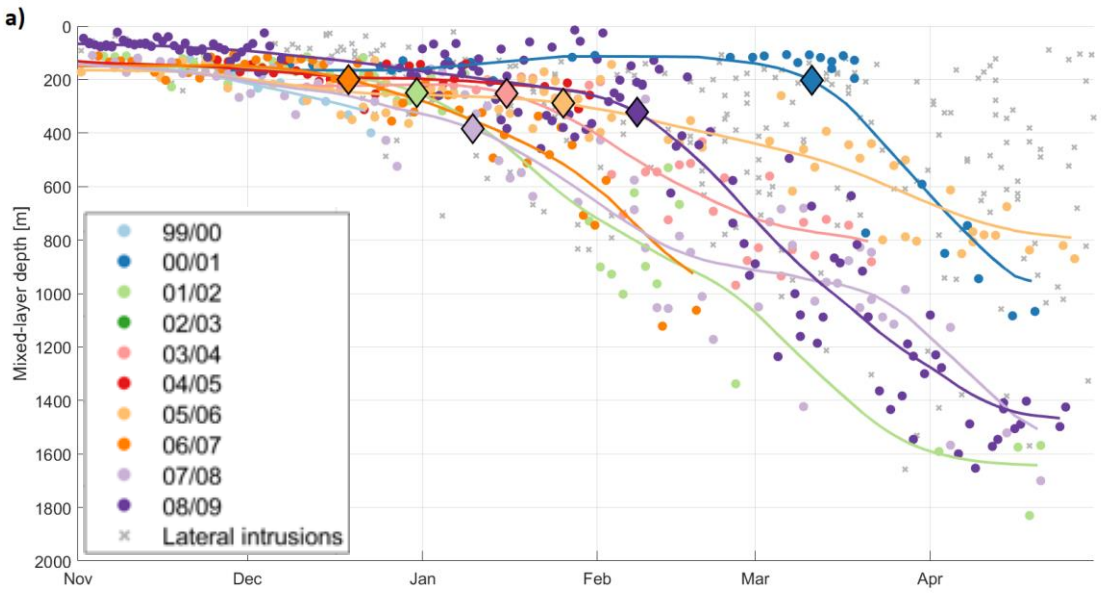
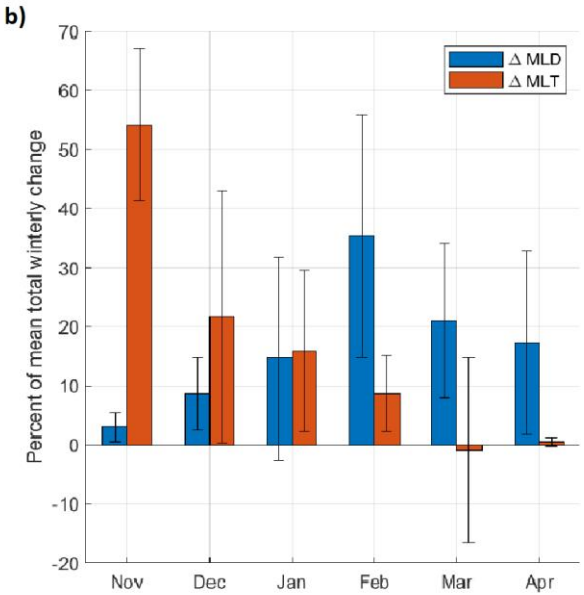
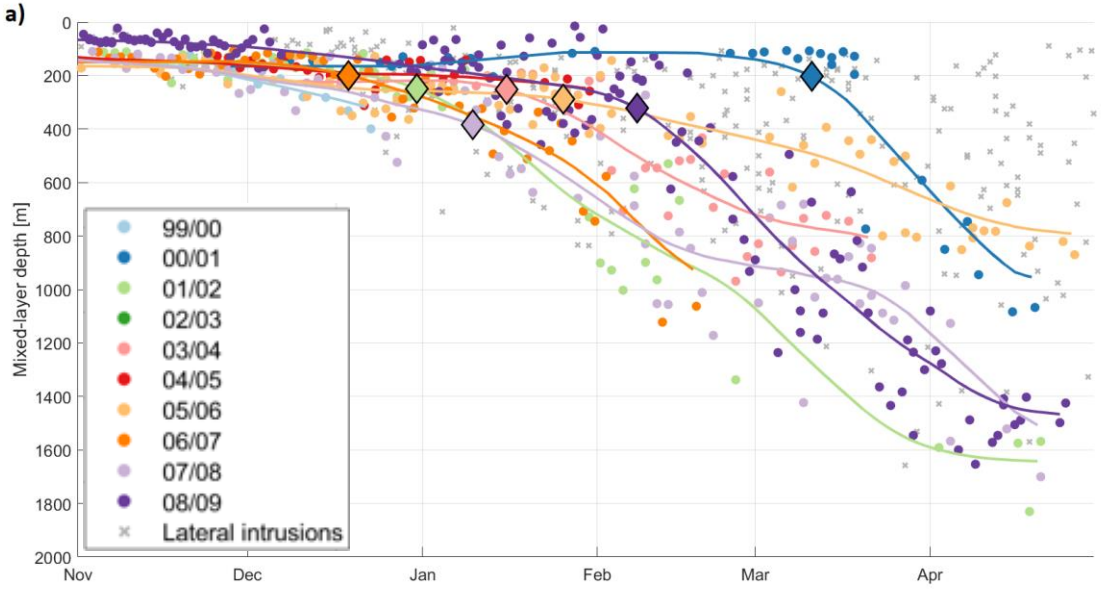


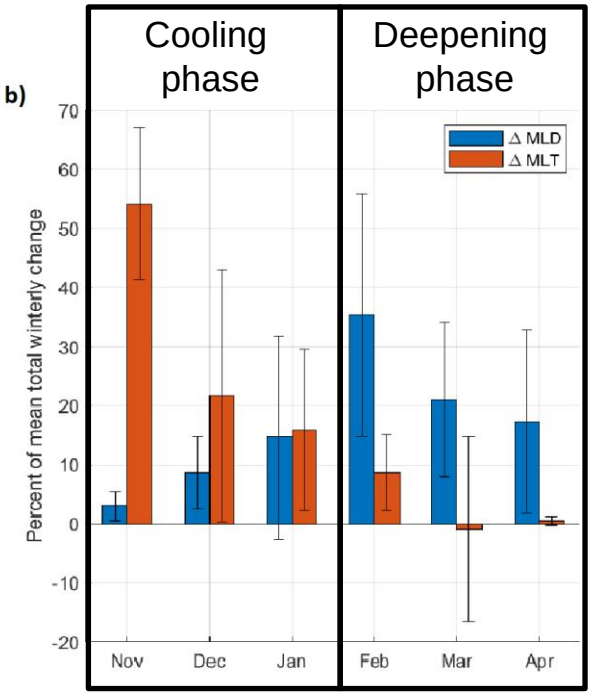


Mean total change in mixed-layer:

- Temperature: -2.55˚C
- Depth: 1554m

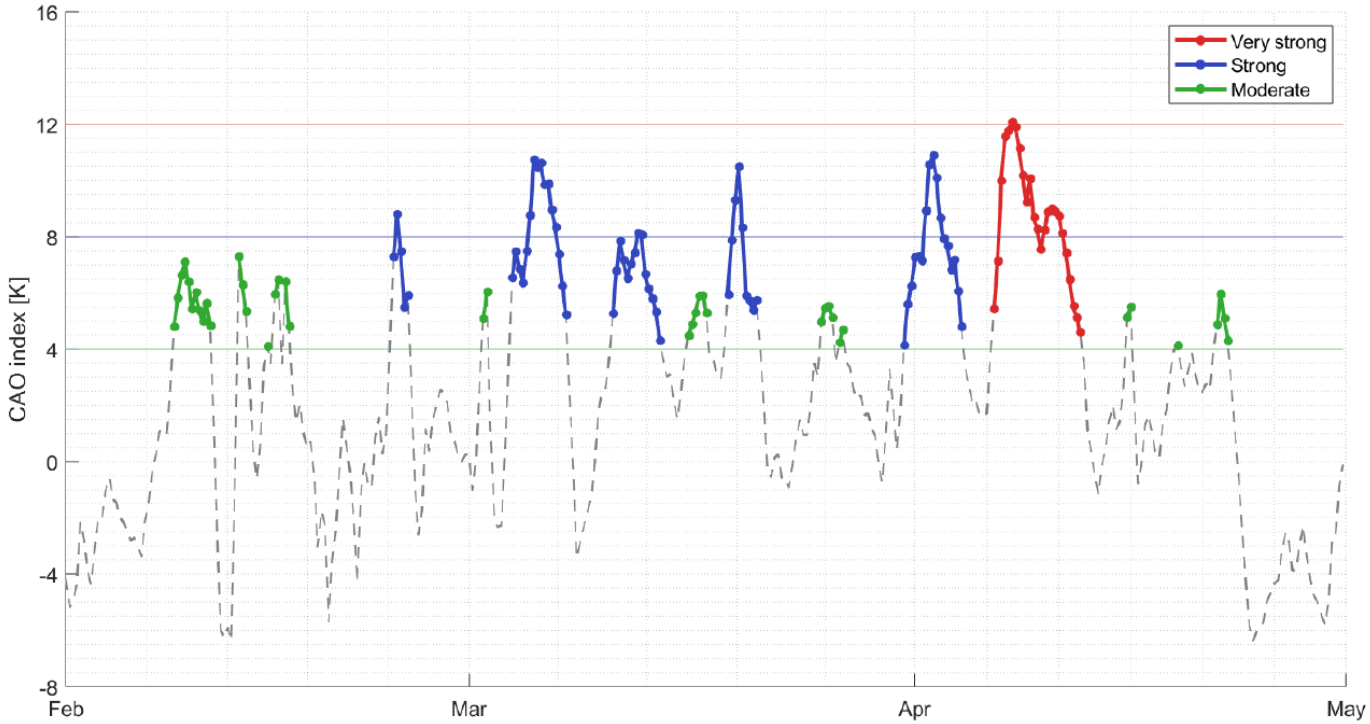
Mixed-layer evolution through winter



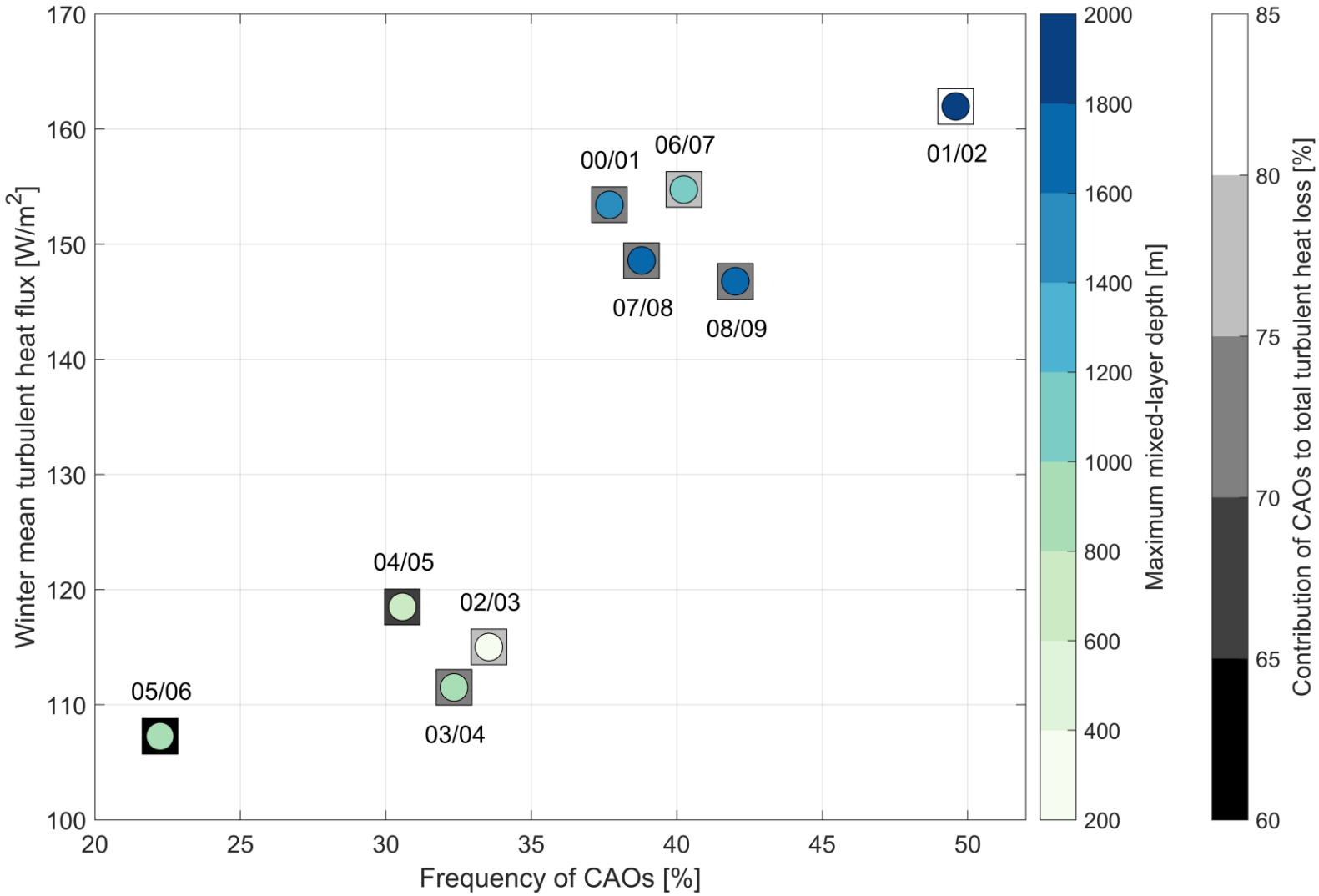


Cold Air Outbreaks (CAOs)

CAO index = surface skin temperature – potential temperature at 900 hPa



The impact of cold air outbreaks on the mixed layer



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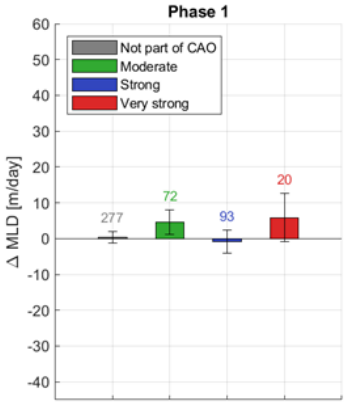
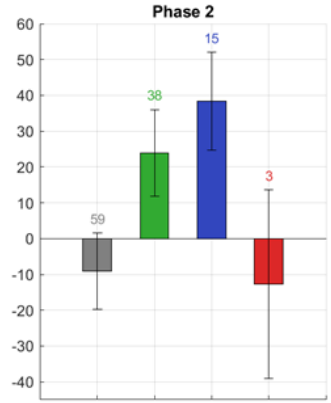
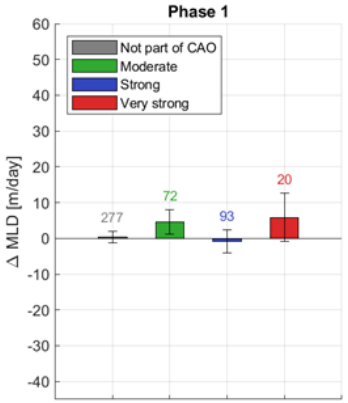
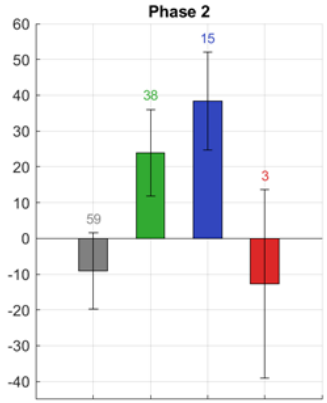
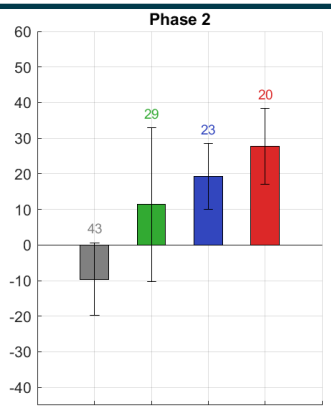
	Cooling phase (median CAO index)	Deepening phase (median CAO index)
Change in mixed-layer depth		

The impact of cold air outbreaks on the mixed layer

	Cooling phase (median CAO index)	Deepening phase (median CAO index)	Deepening phase (90 percentile CAO index)
Change in mixed-layer depth			

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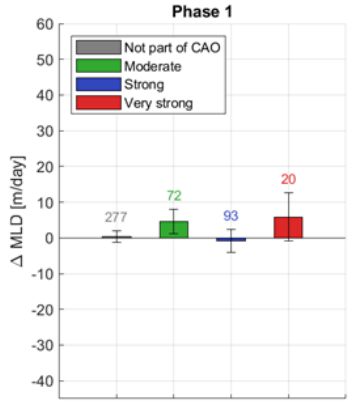
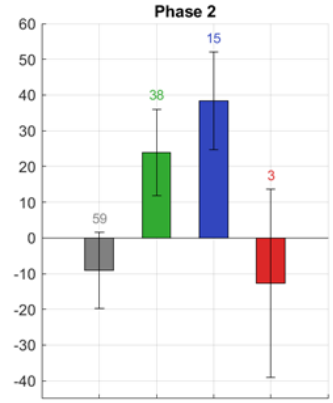
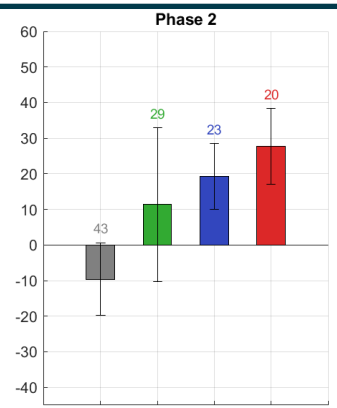
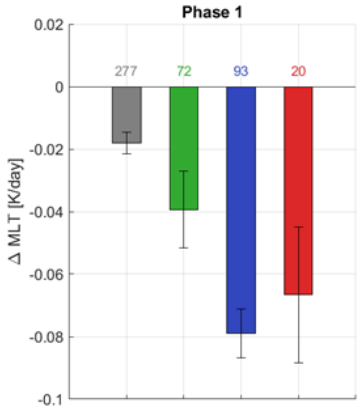
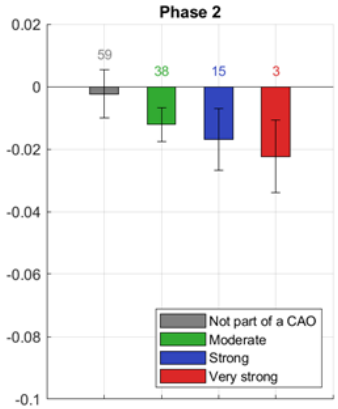
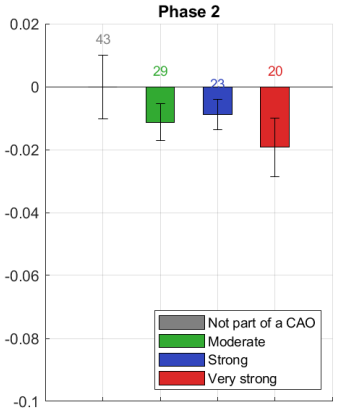
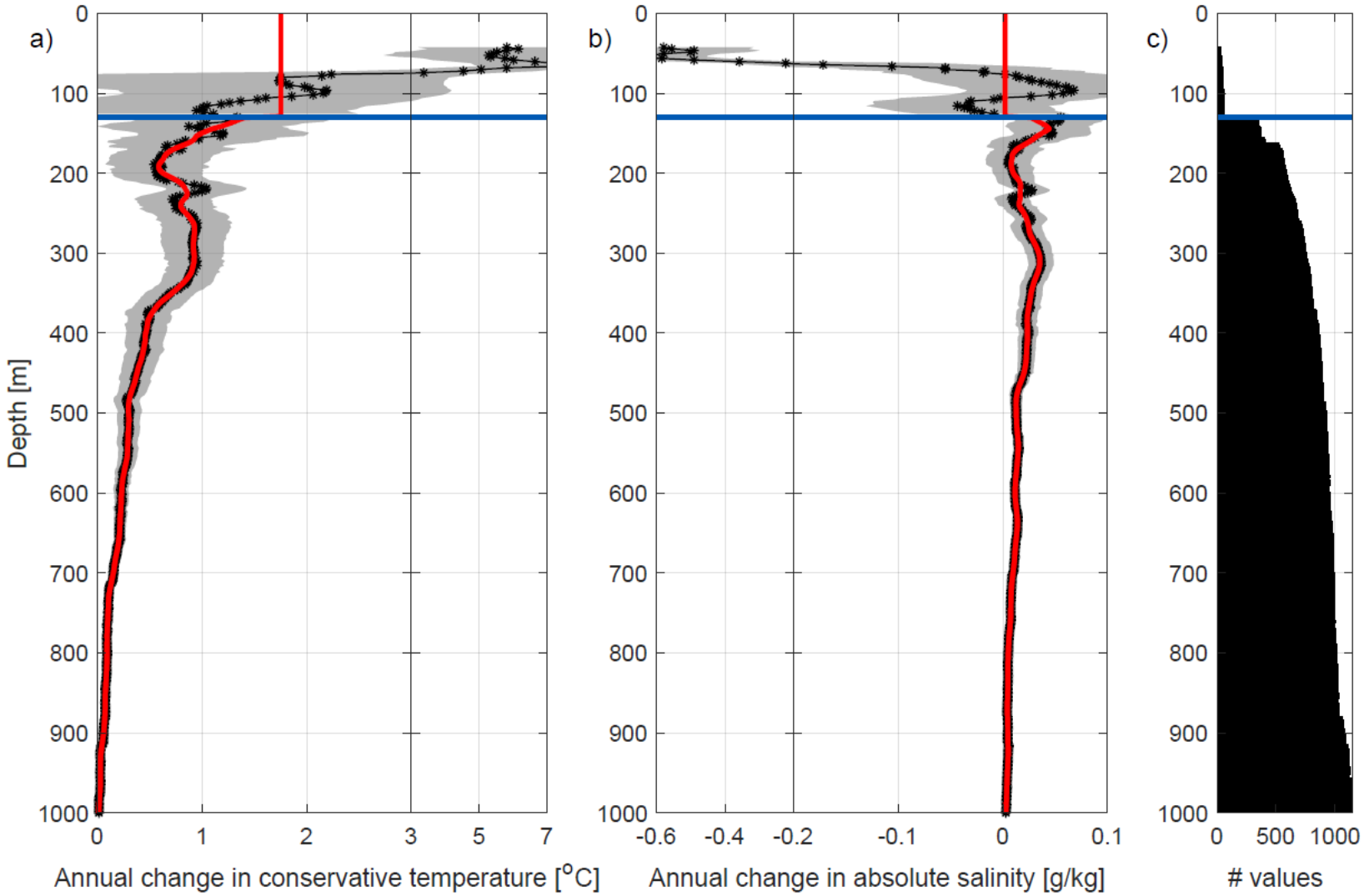
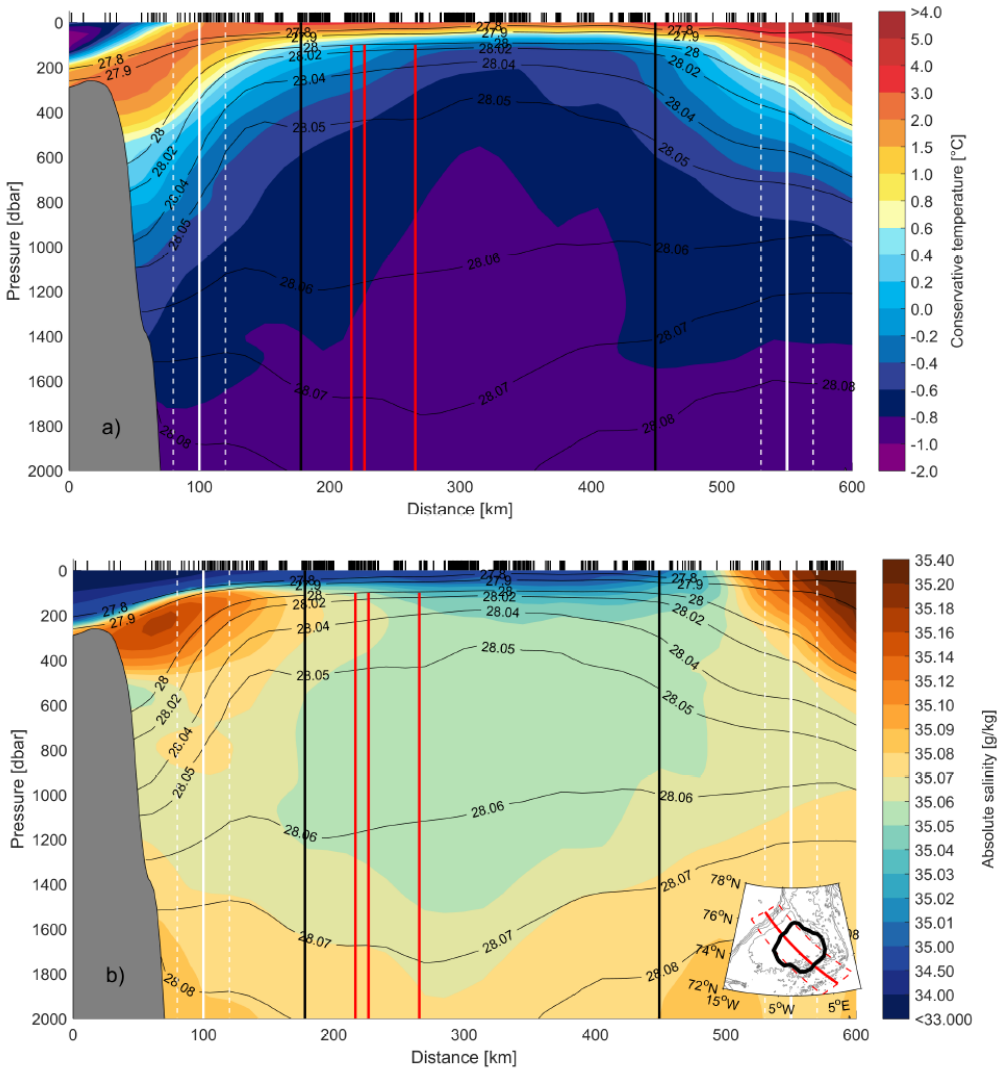
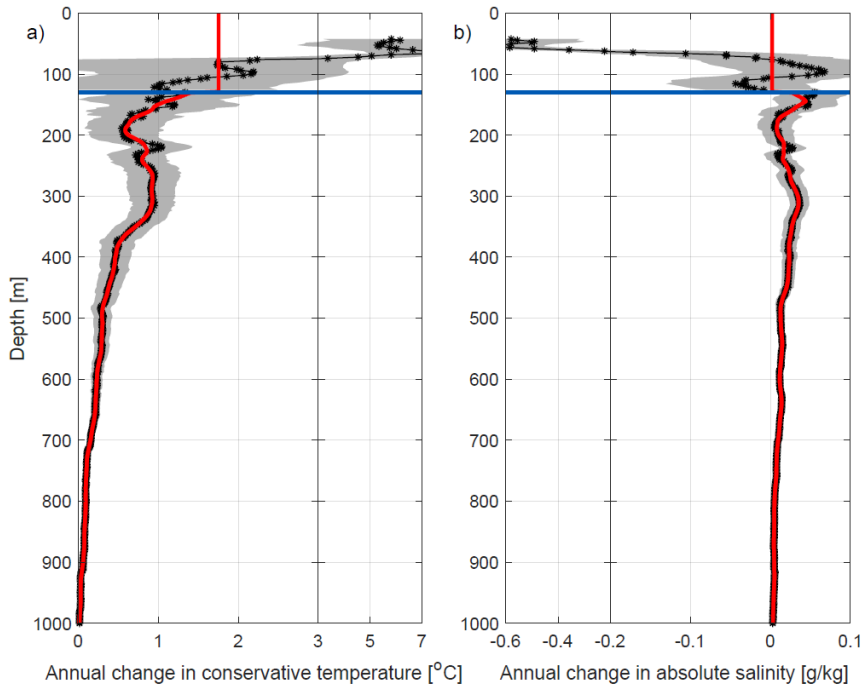
Change in mixed-layer depth			
Change in mixed-layer temp.			

Annual change in temperature and salinity as a result of lateral fluxes



Origin of lateral heat and salt fluxes into the Greenland Sea Gyre?





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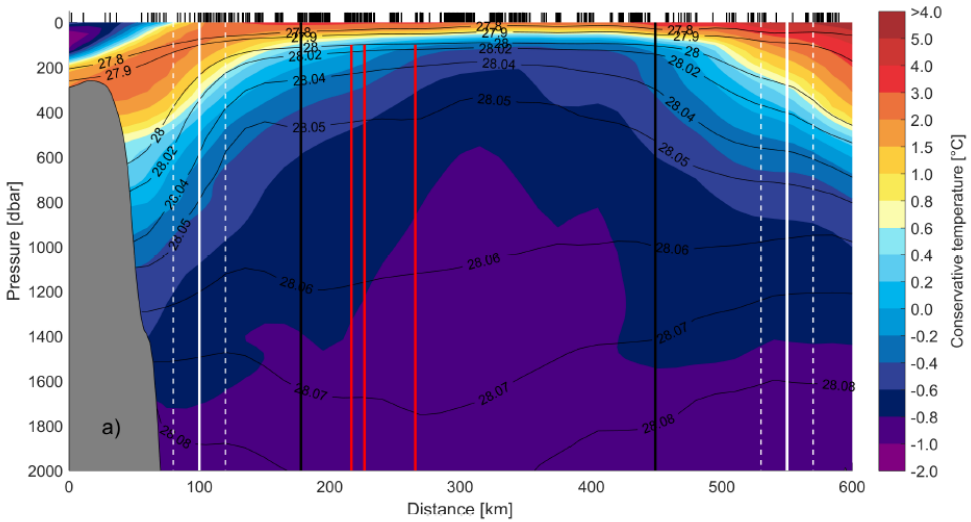

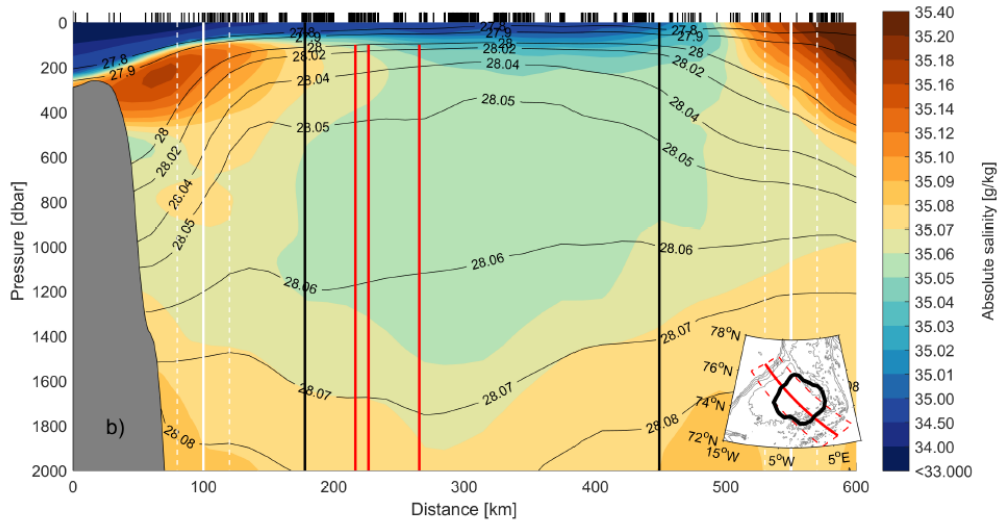

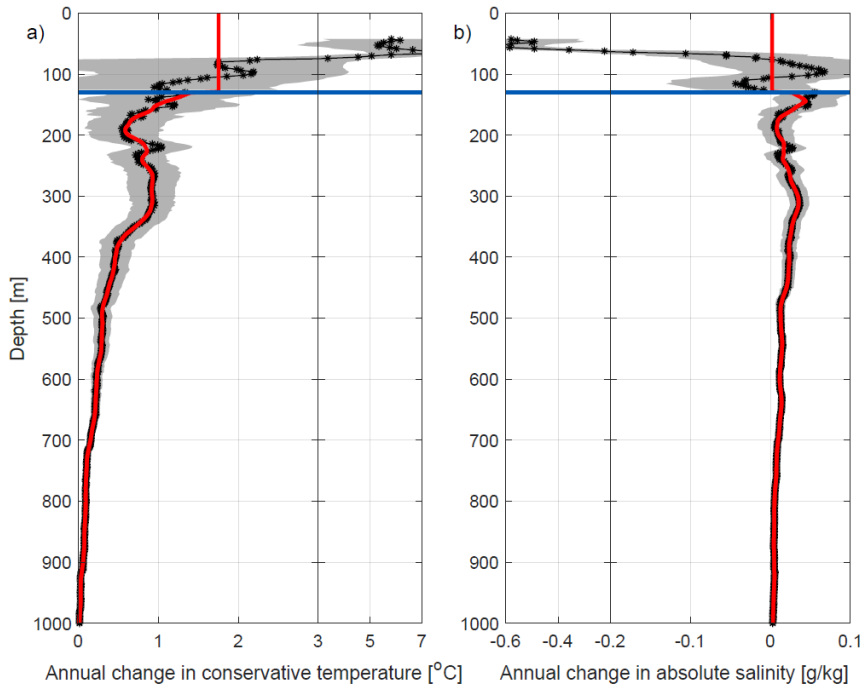

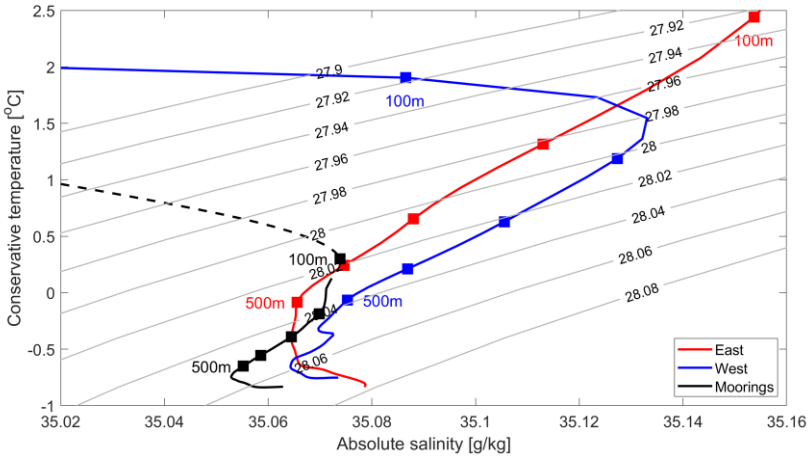

Summary

60-82 % of the heat lost to the atmosphere during winter is due to CAOs

Winters with a large frequency of CAOs, generally have a deeper mixed layer

Mixed-layer development through winter can be divided into two phases:

- During the **cooling phase** (Nov-Jan): strong CAOs cool the mixed layer by ~0.08K/day
- During the **deepening phase** (Feb-Apr): strong CAOs deepen the mixed layer by ~40m/day

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Magnitude and vertical distribution of lateral heat and salt fluxes were quantified.

- Depth-integrated heat flux (72W/m^2) is roughly 10W/m^2 larger than previous estimates
- Maximum in added heat and salt at 300 m depth
- Indications that exchange with the East Greenland Current is important for fluxes of heat and salt into the gyre

Idealized mixed-layer simulations suggest that oceanic lateral heat and salt fluxes combined lead to a 200-m reduction in the end-of-winter mixed-layer depth