

# Hydrographic changes and Norwegian Argo activities in the Nordic Seas and Arctic

Kjell Arne Mork, Øystein Skagseth, and Henrik Søiland

Institute of Marine Research

Norway



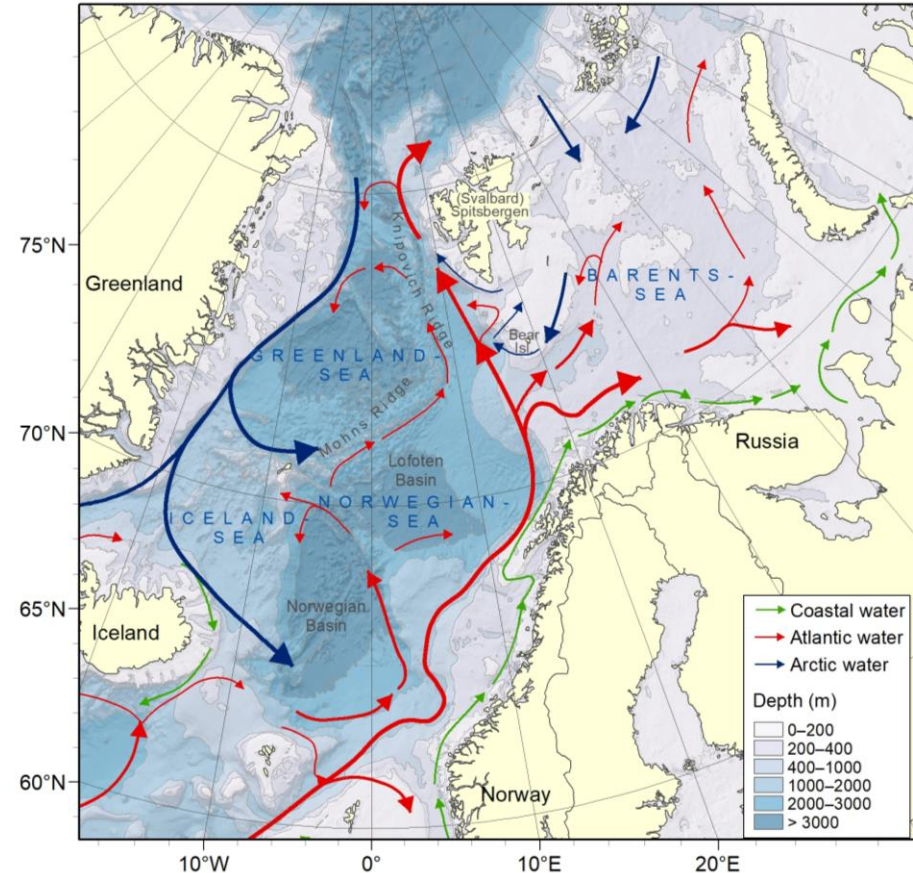
Euro-Argo Science Meeting in Athens 22-23 October 2019



# Content

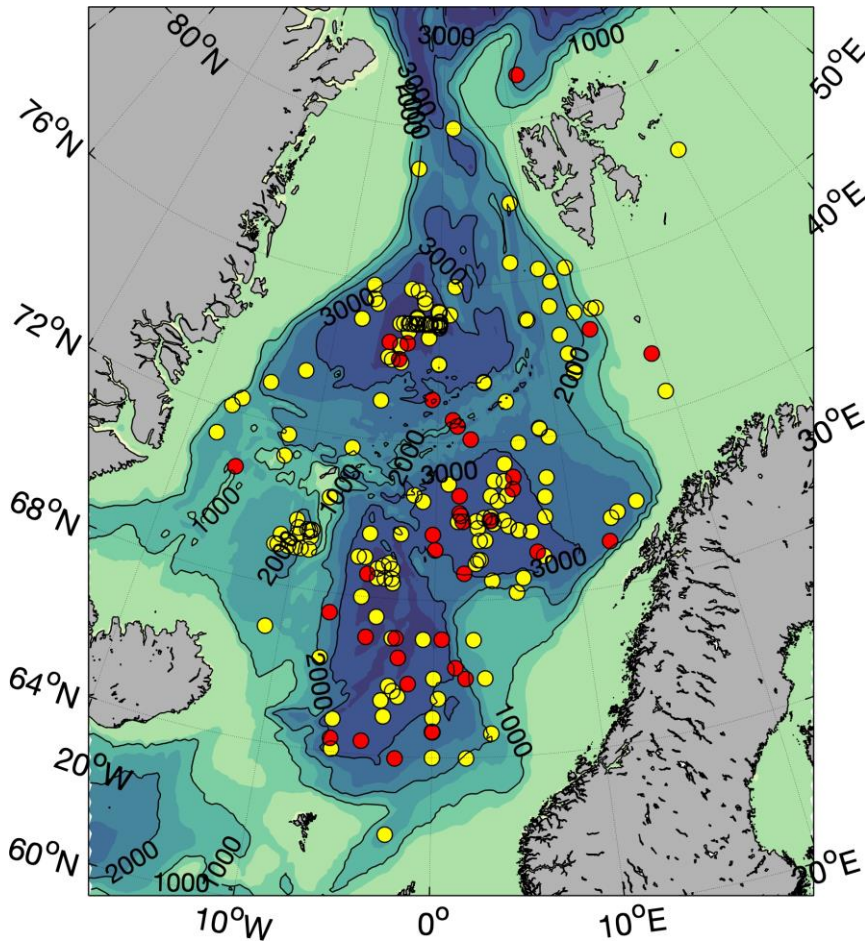
- ❑ Overview of Argo floats in the Nordic Seas, Barents Sea and Arctic Ocean
- ❑ Heat and fresh water content in the Norwegian Sea
- ❑ Norwegian activities and plans

Nordic Seas: the area that includes the Norwegian, Greenland, and Iceland Sea

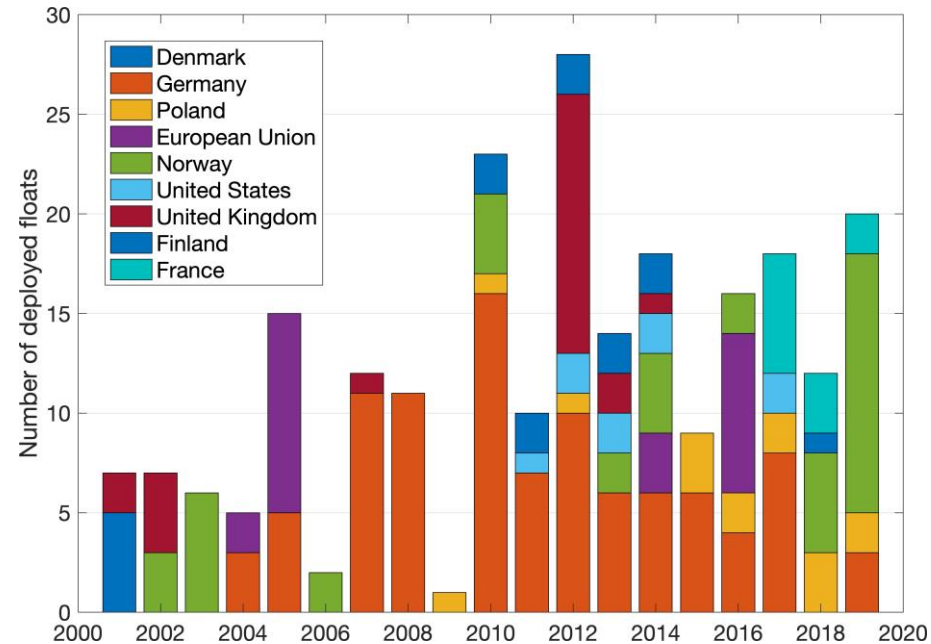


Main surface currents in the Nordic Seas and the Barents Sea

# Deployed Argo floats in the Arctic

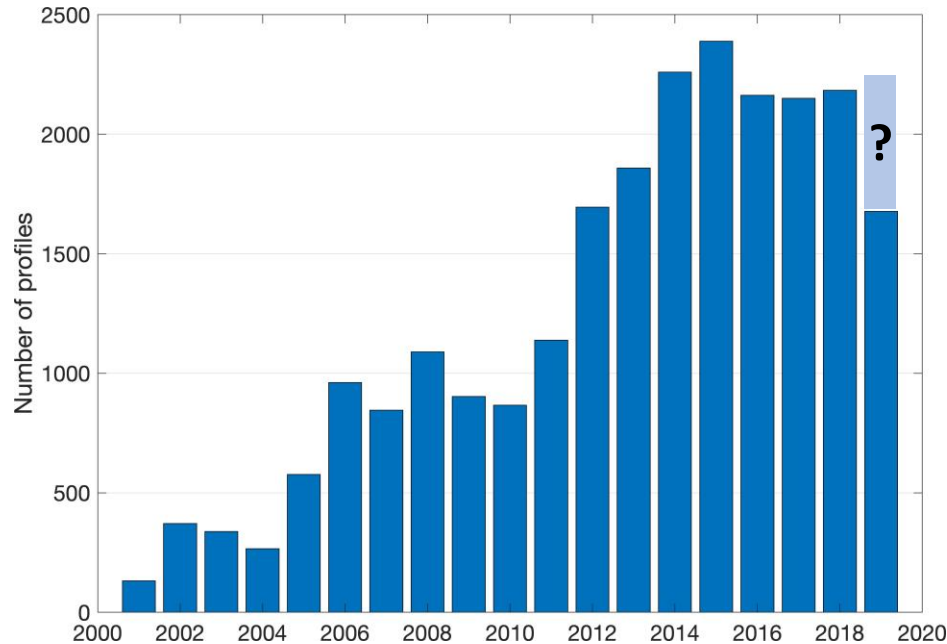


Location of deployed Argo floats.  
Red dots: Norwegian floats.

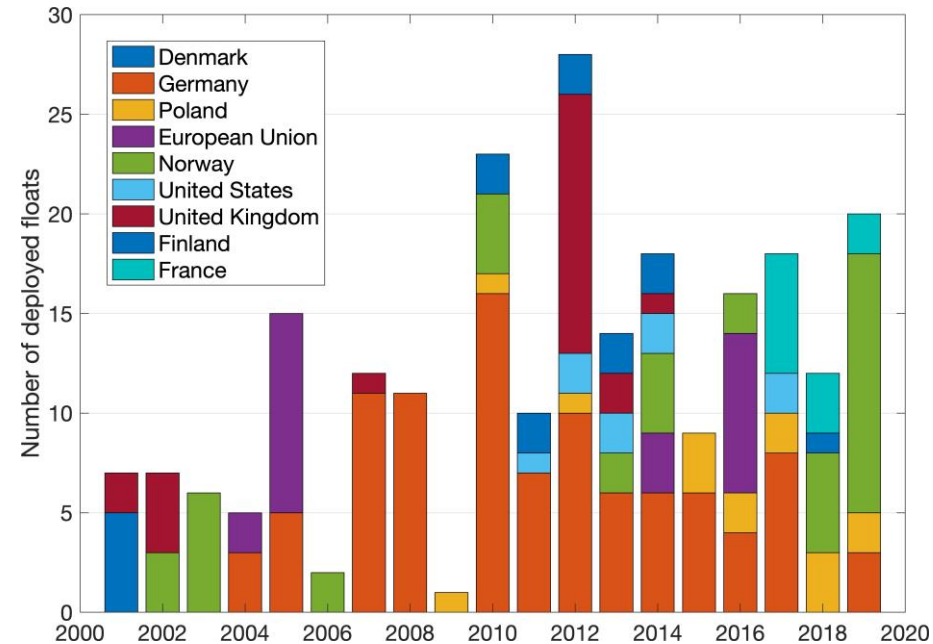


Number of deployed Argo floats divided into country and year

# Deployed Argo floats in the Arctic



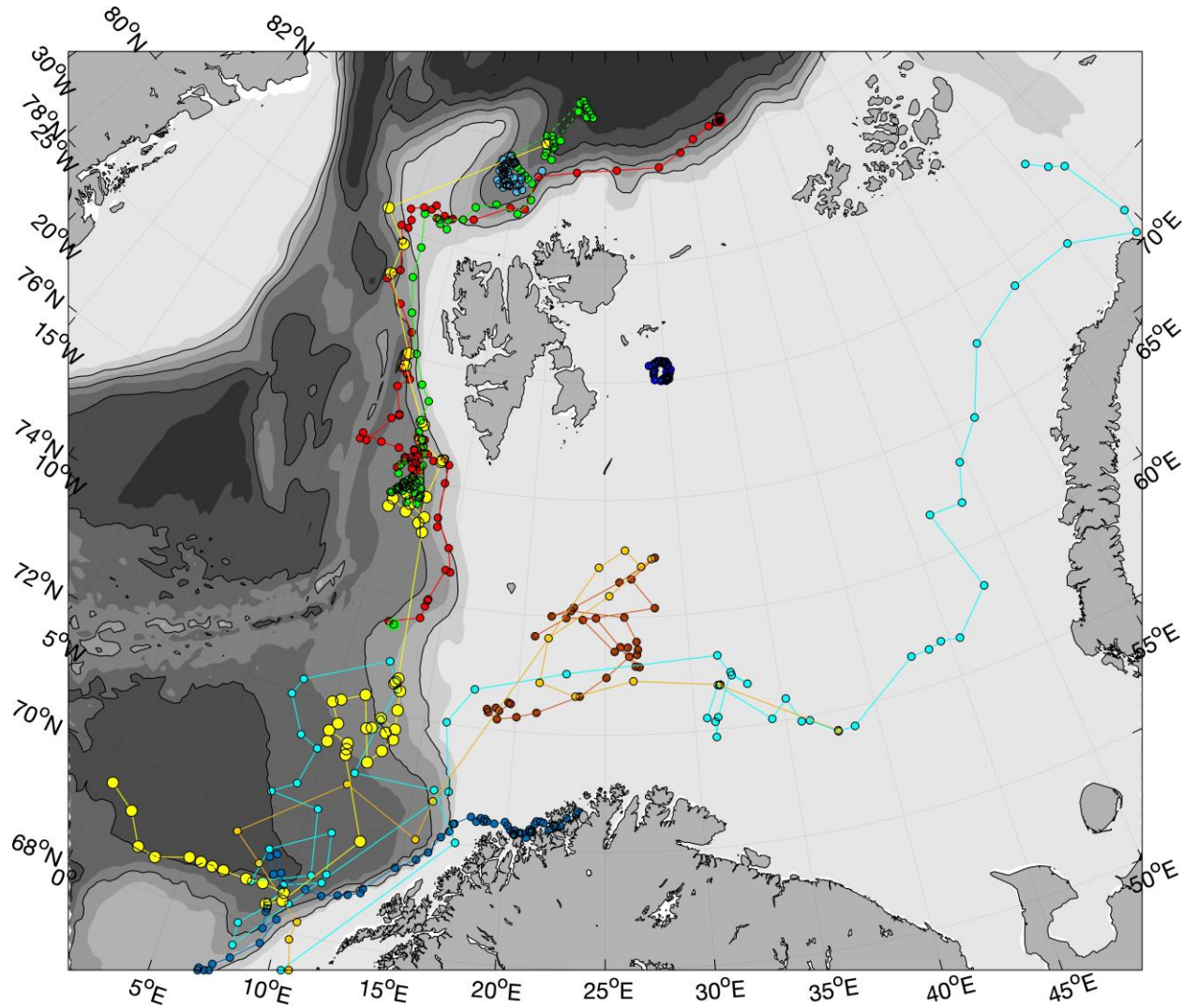
Number Argo profiles per year  
(updated 18. October)



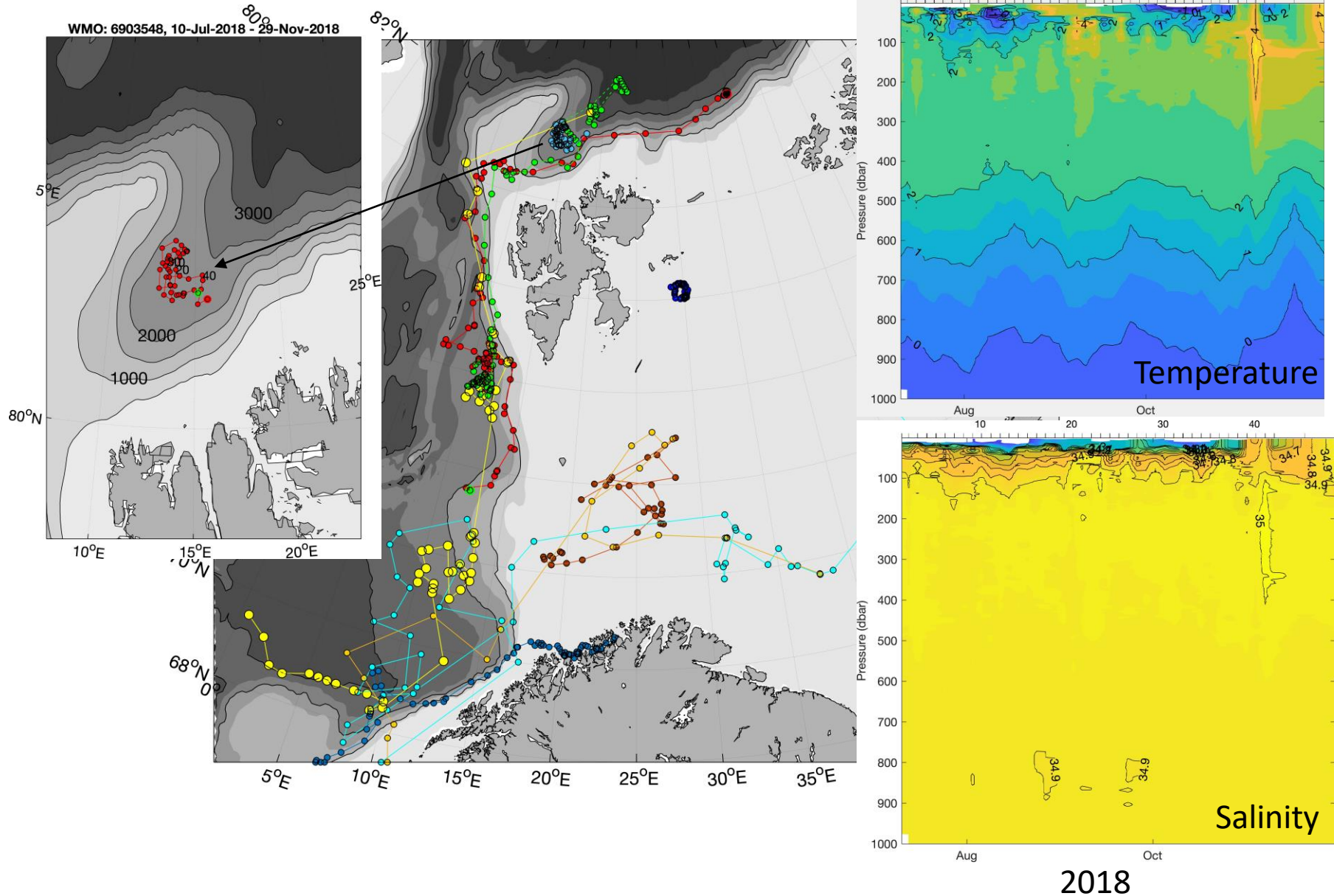
Number of deployed Argo floats divided  
into country and year



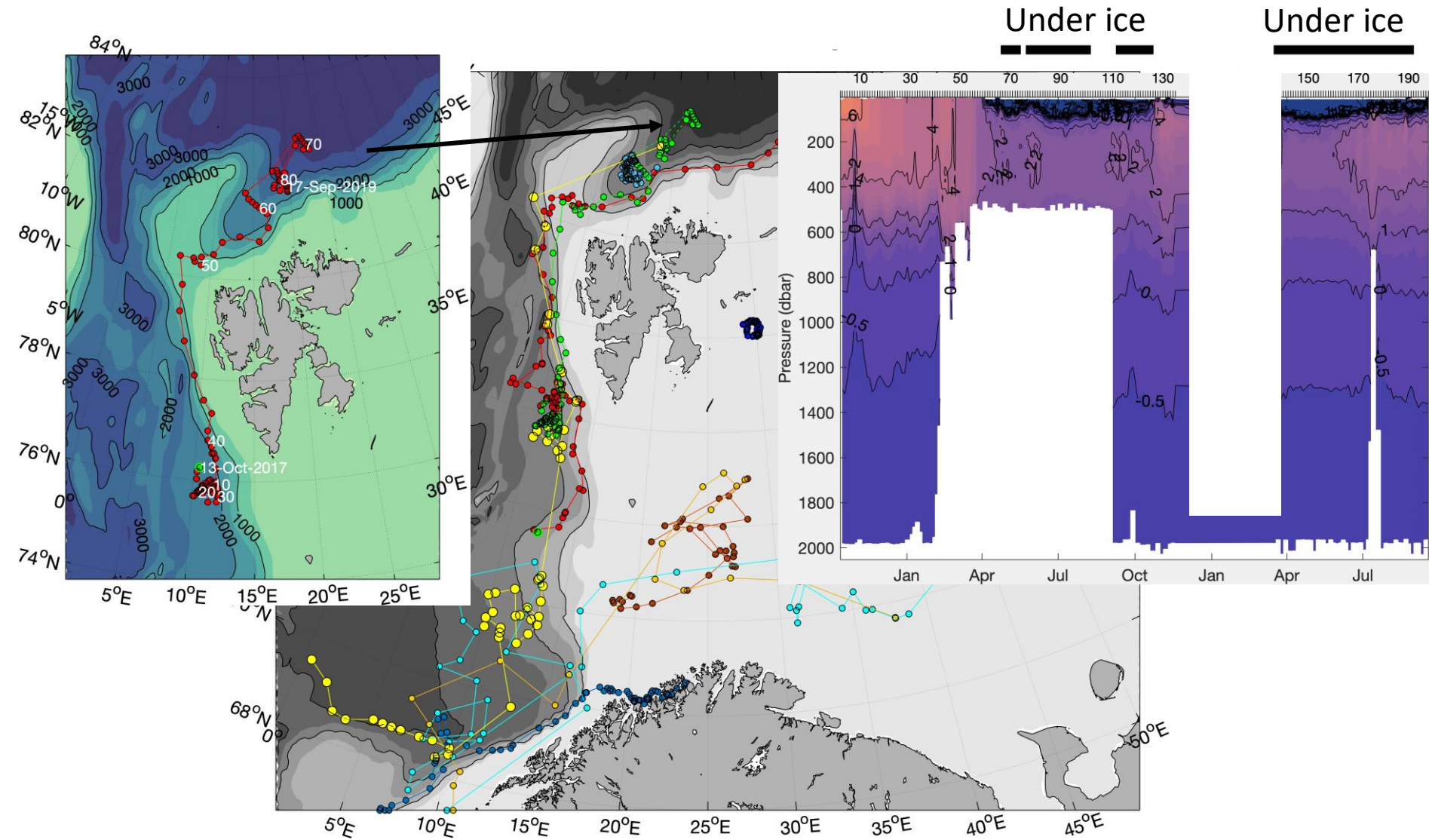
# Argo floats in the Barents Sea and Arctic Ocean



# Argo floats in the Barents Sea and Arctic Ocean



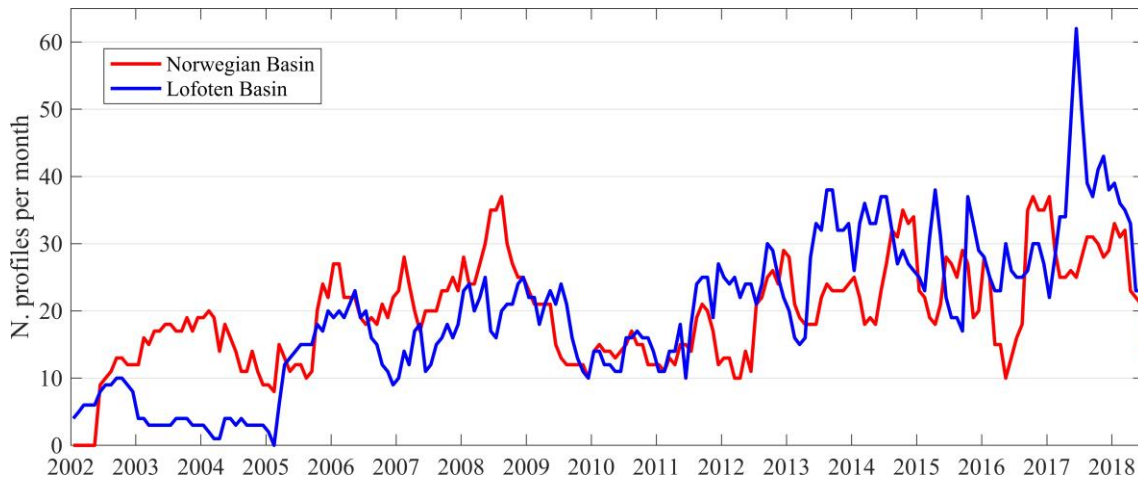
# Argo floats in the Barents Sea and Arctic Ocean





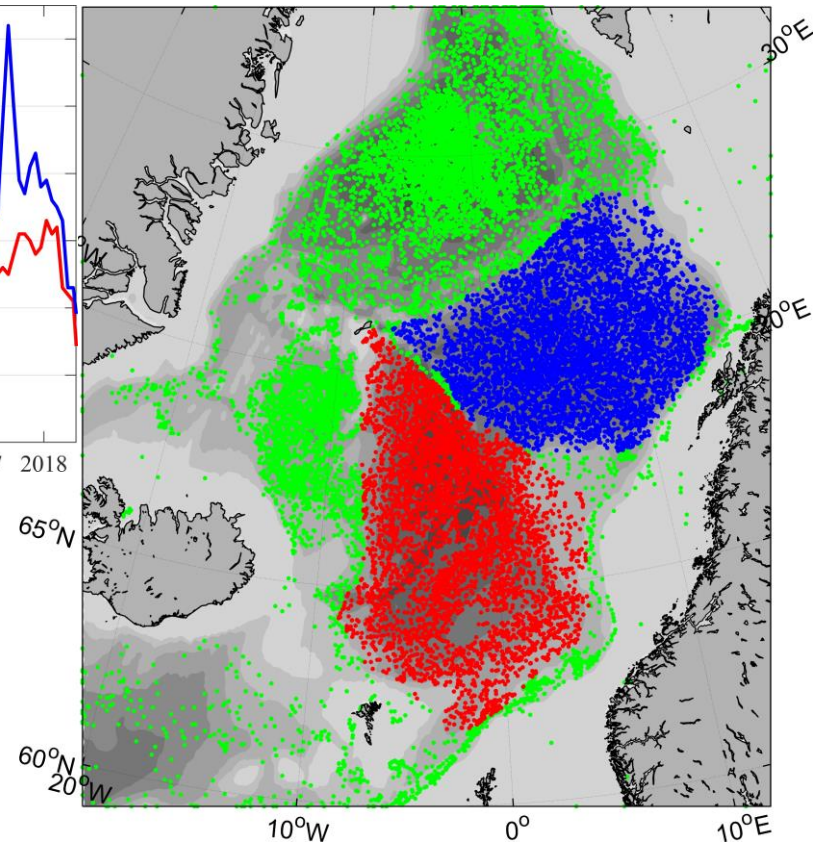
# Hydrographic changes in the Norwegian Sea

From Mork, Skagseth and Sjøiland, JCLI. 2019.



Number Argo profiles per month in each of the two basins: the southern Norwegian Basin and the northern Lofoten Basin

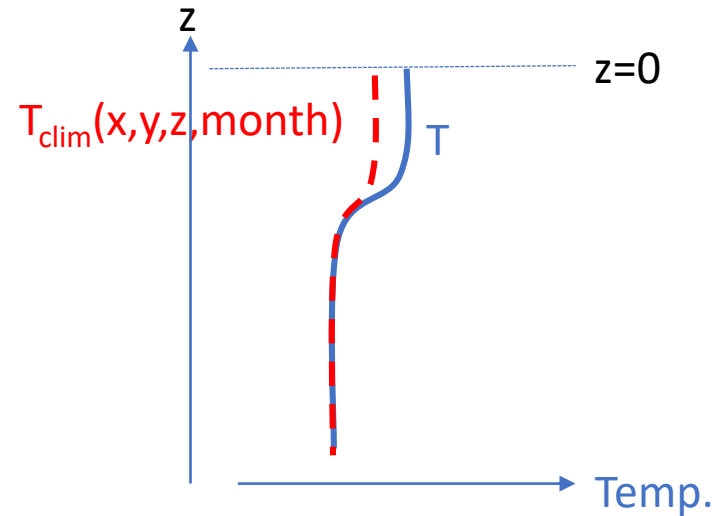
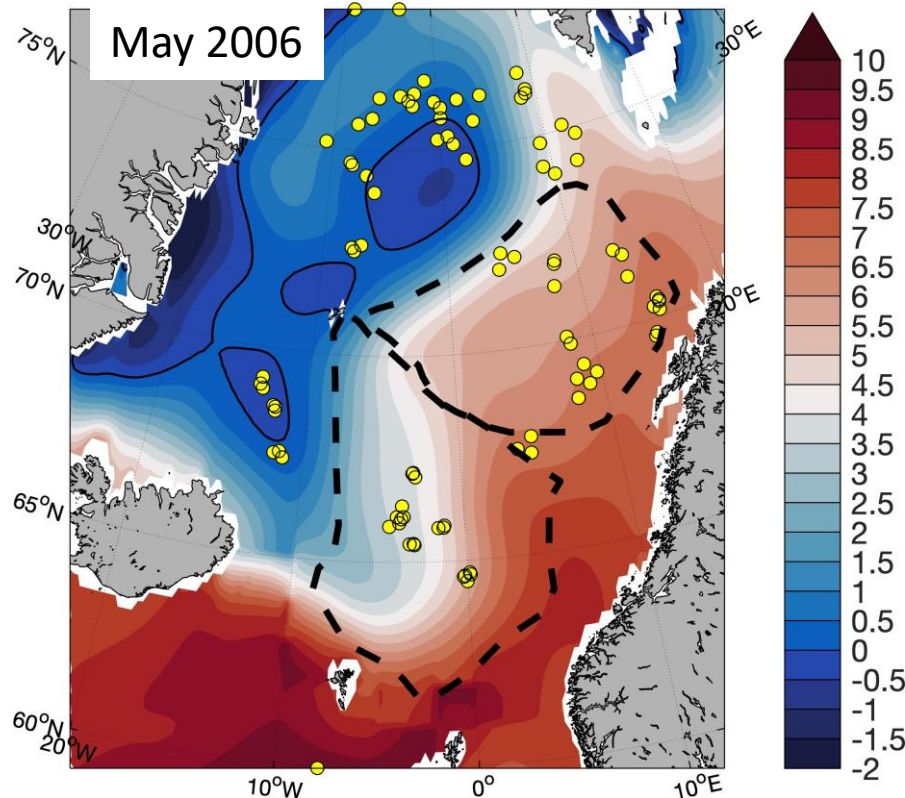
Calculate heat and fresh water content within each basin per month



Locations of all Argo profiles in the Nordic Seas



# Heat content relative to climatology (WOA18)



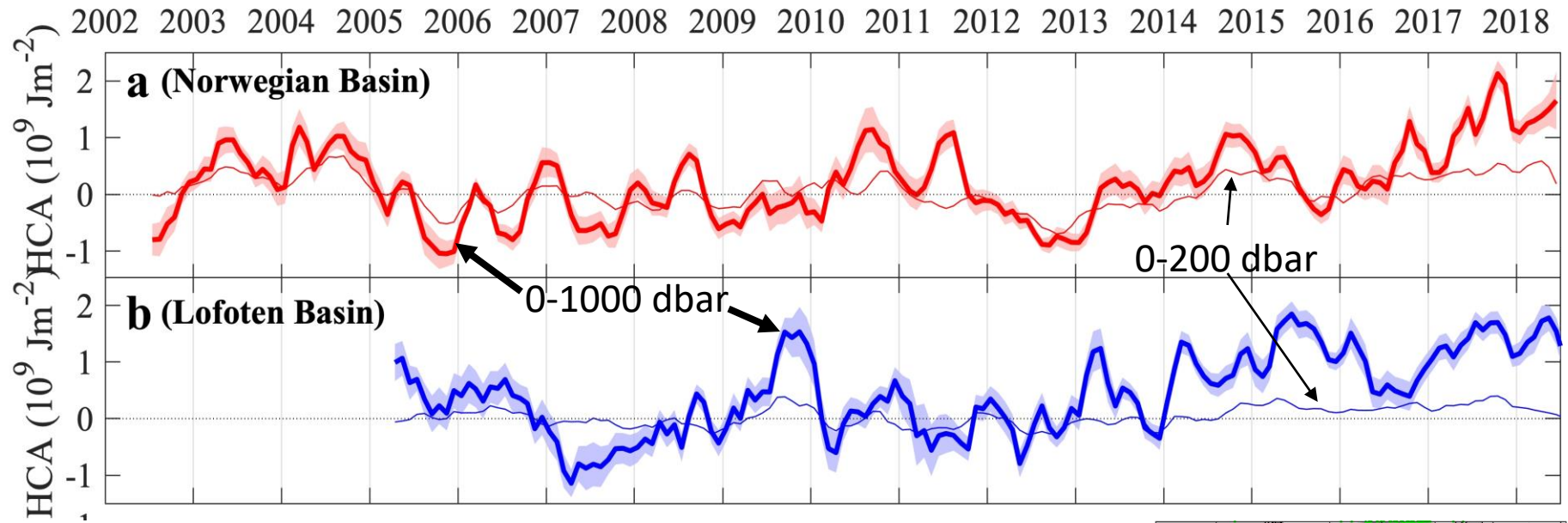
$$H' = H - H_{\text{clim}} = c_p \rho_0 \int_{-h}^0 (T - T_{\text{clim}}) dz (\text{Jm}^{-2})$$

$$F' = F - F_{\text{clim}} = -S_{\text{ref}}^{-1} \int_{-h}^0 (S - S_{\text{clim}}) dz (\text{m})$$

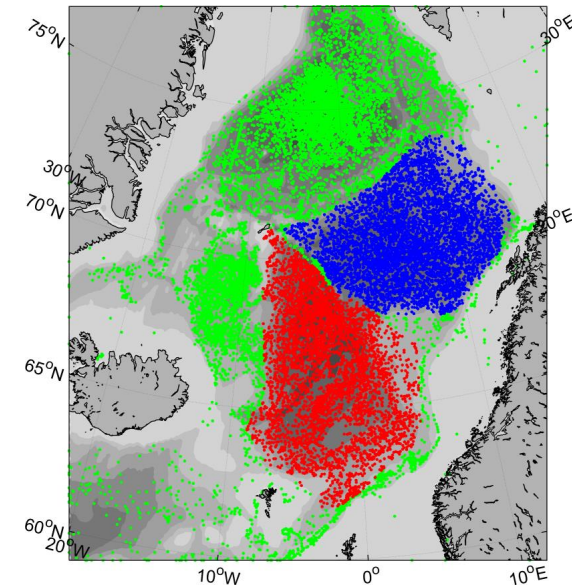
$H'$  and  $F'$  are independent of the reference value and less influenced by the location (i.e., less spatially biased)

Average all  $H'$  and  $F'$  within each basin per month

# Monthly estimates of ocean heat content anomaly

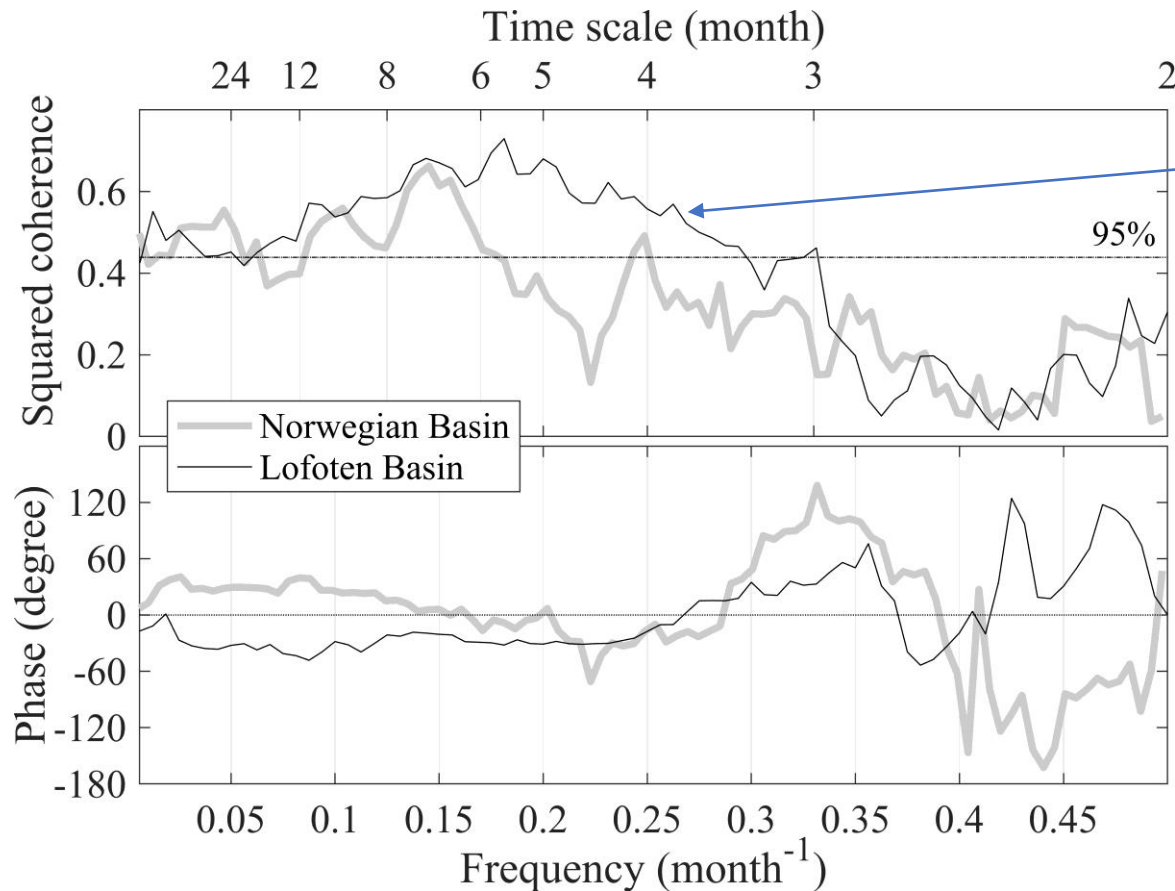


Heat content anomaly HCA (0-1000 dbar). The thin lines are (0-200 dbar). The time series are filtered with 3 months moving averages.



# Ocean heat content versus air-sea heat flux

Coherence analysis between ocean heat content change in the upper 200 m and air-sea heat flux anomaly (ERA-Interim)

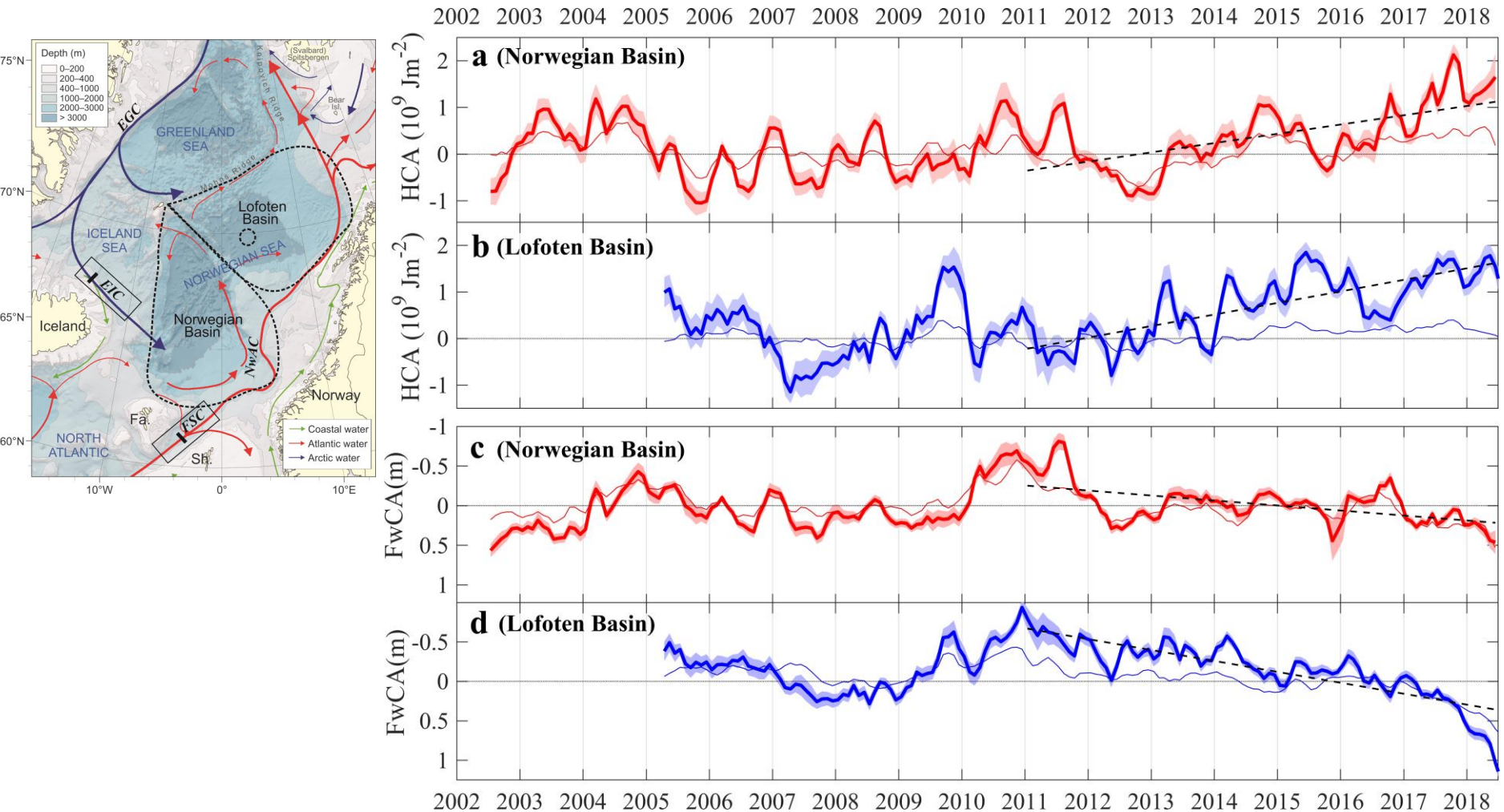


**The air-sea heat flux explained half or even more of the local ocean heat content change**

Squared coherence and phase as function of time scale/frequency.  
Positive phase indicates that air-sea heat flux leads.



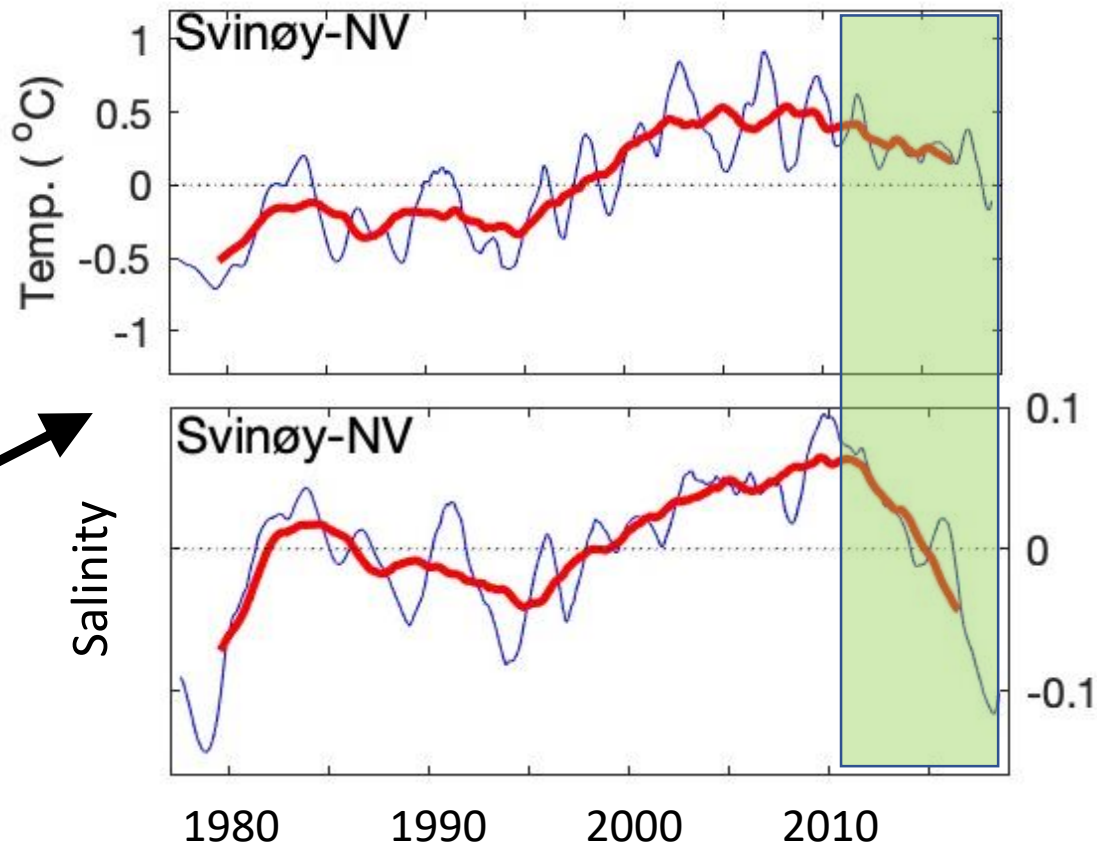
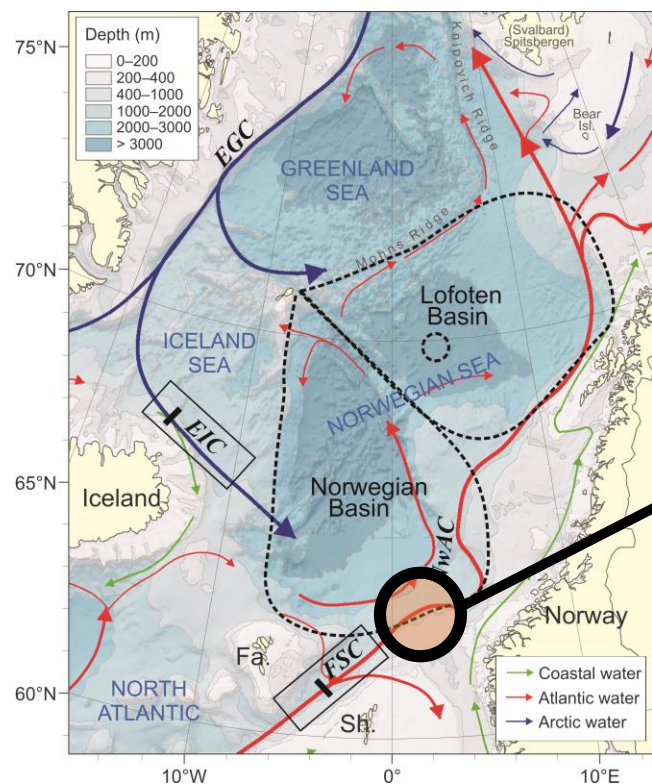
# Warming and freshening during 2011-2018



a,b) Heat content anomaly. c,d) are the freshwater content anomaly (y-axis is reversed). From Mork, Skagseth and Søiland, JCLI. 2019.

**Decoupling of temperature and salinity during 2011-2018.**

# Temperature and salinity in the Atlantic inflow during 2011-2018

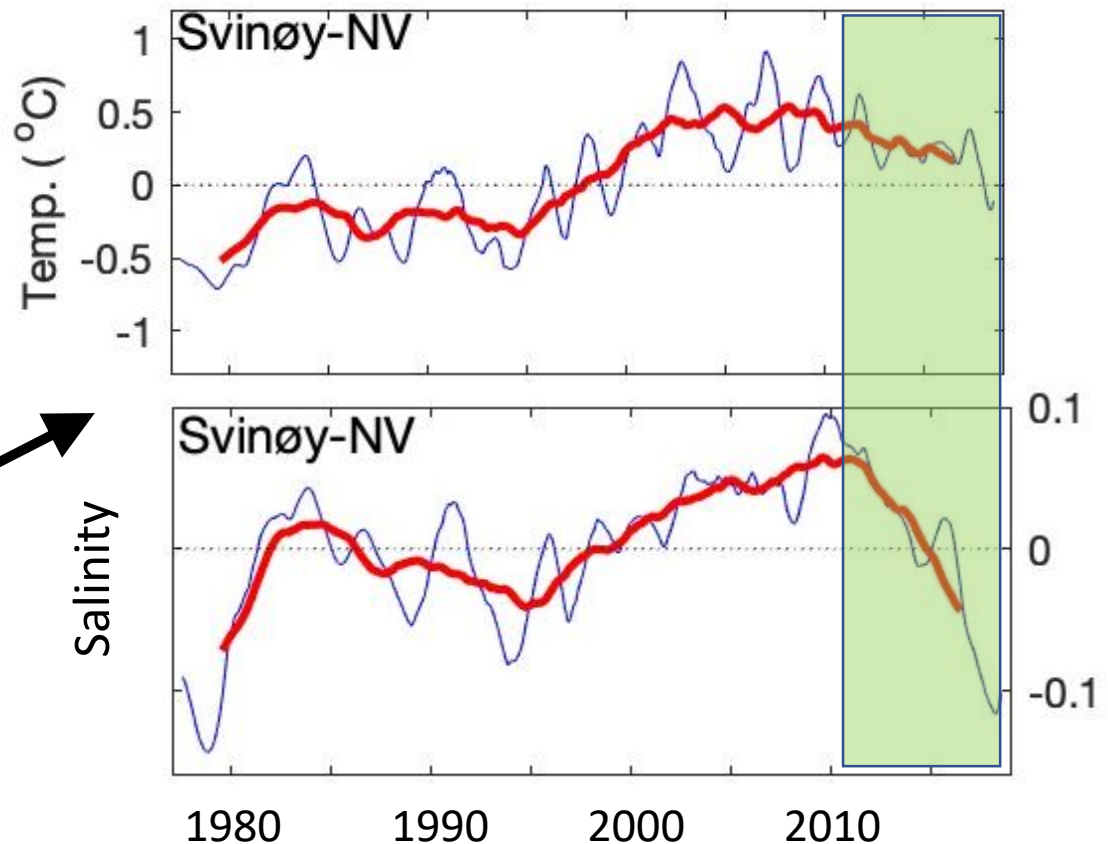


Five and one year moving averages of  
temperature and salinity at 50-200 m depth

**Temperature and salinity in the inflowing Atlantic Water to the Nordic Seas declined during 2011-2018**

# Temperature and salinity in the Atlantic inflow during 2011-2018

Reduced ocean heat loss to the atmosphere can partly explain (30-60%) the warming in the Norwegian Sea



Five and one year moving averages of temperature and salinity at 50-200 m depth

**Temperature and salinity in the inflowing Atlantic Water to the Nordic Seas declined during 2011-2018**



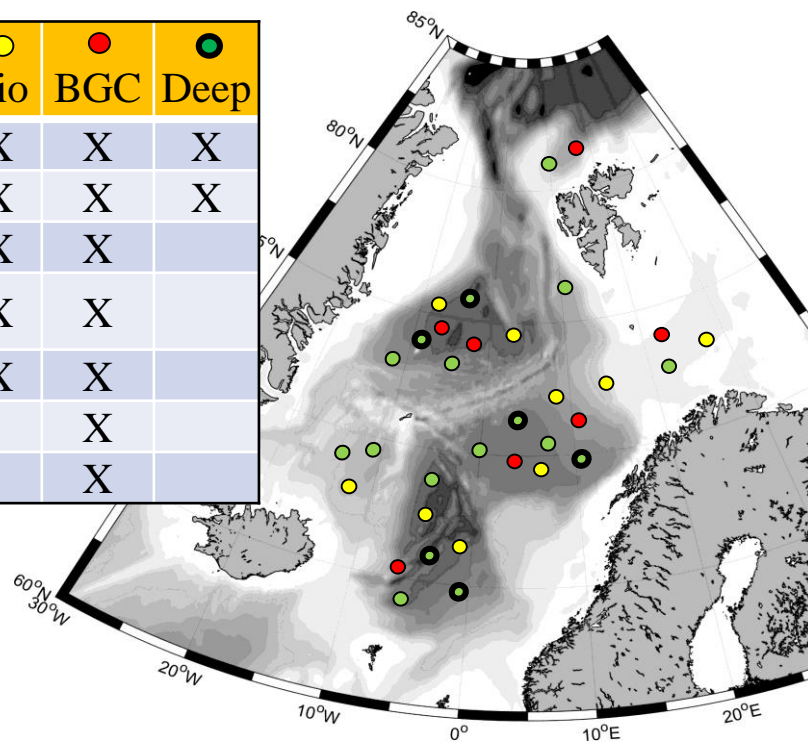
# NorArgo2 (2018-2023)



The goal is to have minimum 30 operative floats in the Nordic Seas, Barents Sea and Arctic Ocean



Variables / Sensors	Core	Bio	BGC	Deep
Press, temp., salinity	X	X	X	X
Oxygen		X	X	X
Chlorophyll-Fluor.		X	X	
Particle conc. (backsc.)		X	X	
Irradiance, PAR		X	X	
pH			X	
Nitrate			X	



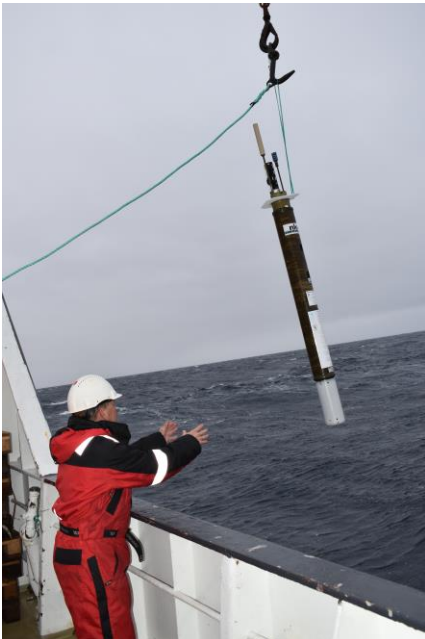
Bio(APEX), Deep (Arvor) and BGC (Provor CTS4). Photo: Tor de Lange



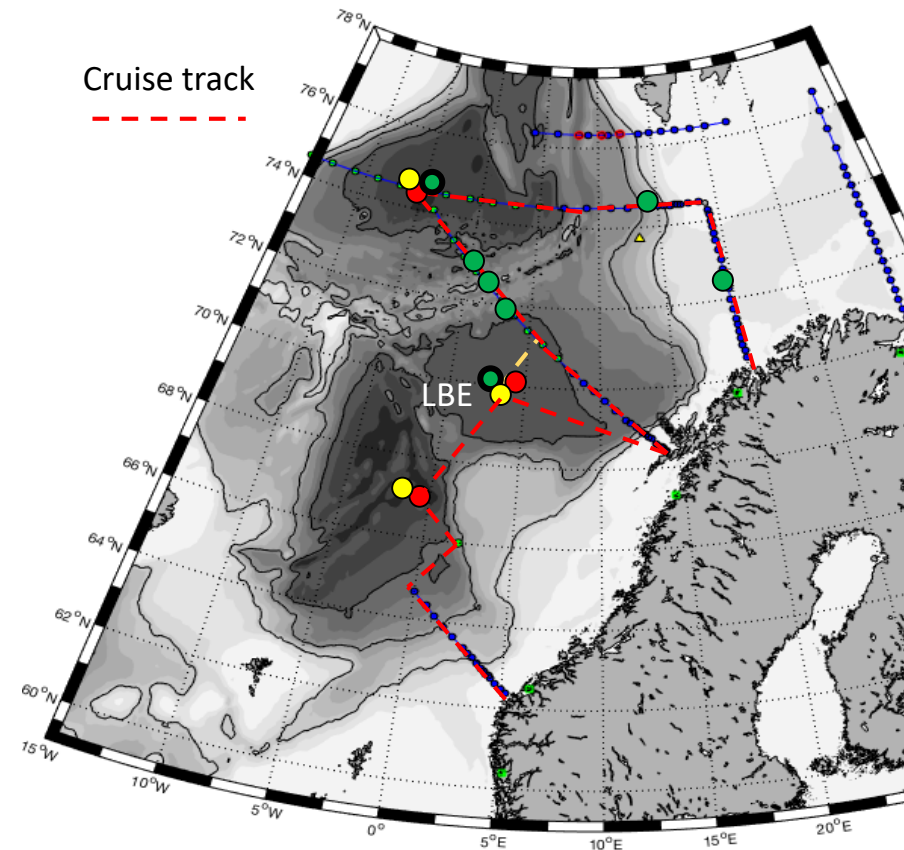
# Argo float deployments in 2019 during R/V Johan Hjort cruise 15 May – 4 June

## Deployment of 13 floats:

- 3 BGC floats.   ● (NKE: PROVOR CTS4)
- 3 Bio floats.   ● (TWR: APEX)
- 2 Deep floats.   ● (NKE: Deep ARVOR)
- 5 Core floats   ● (ARVOR through ERIC)



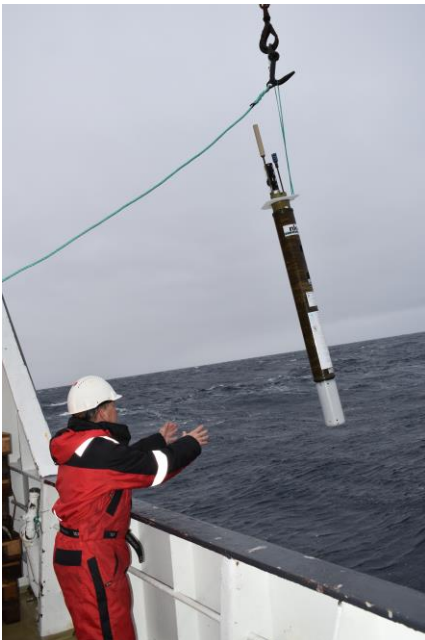
Deployment of a Deep  
Arvor. Photo: Tor de Lange



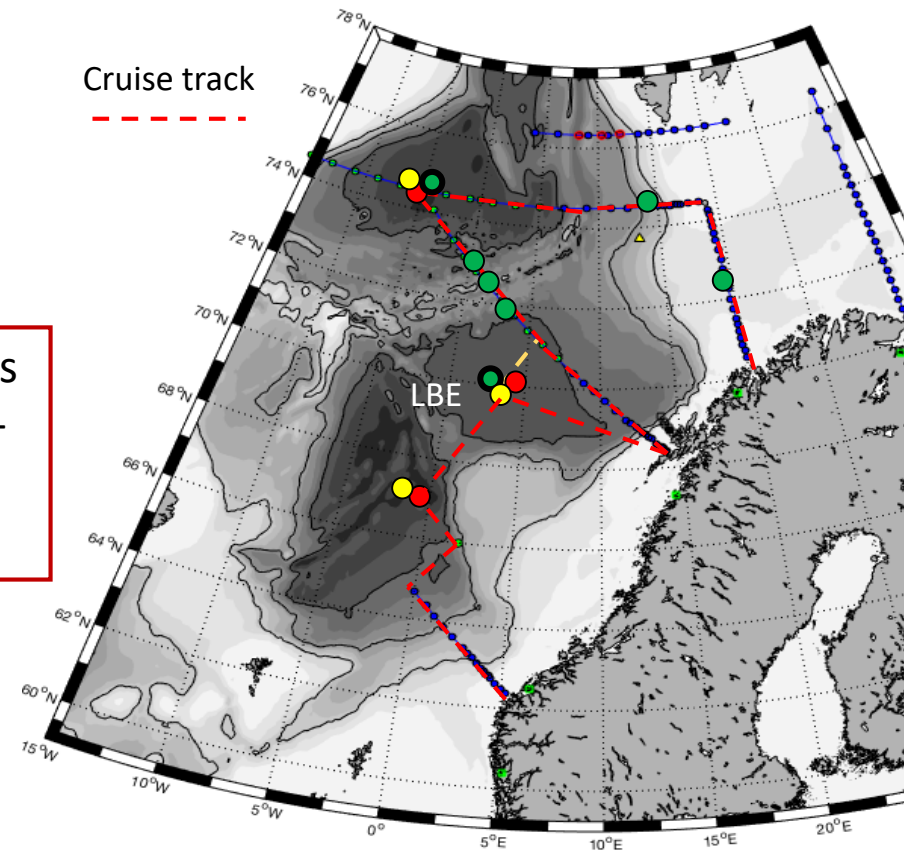
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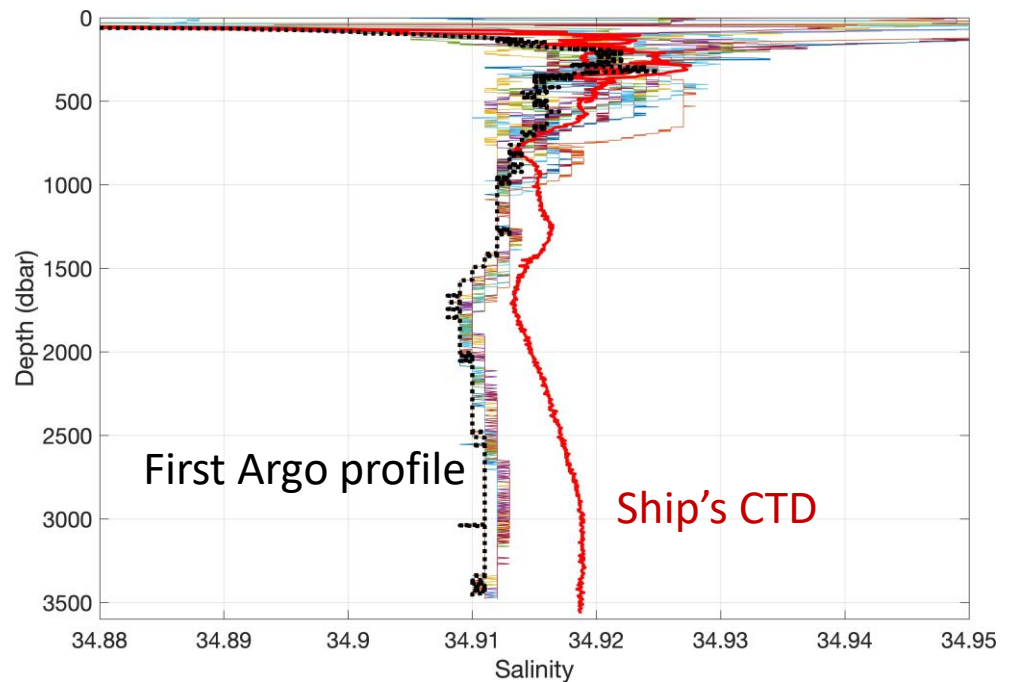
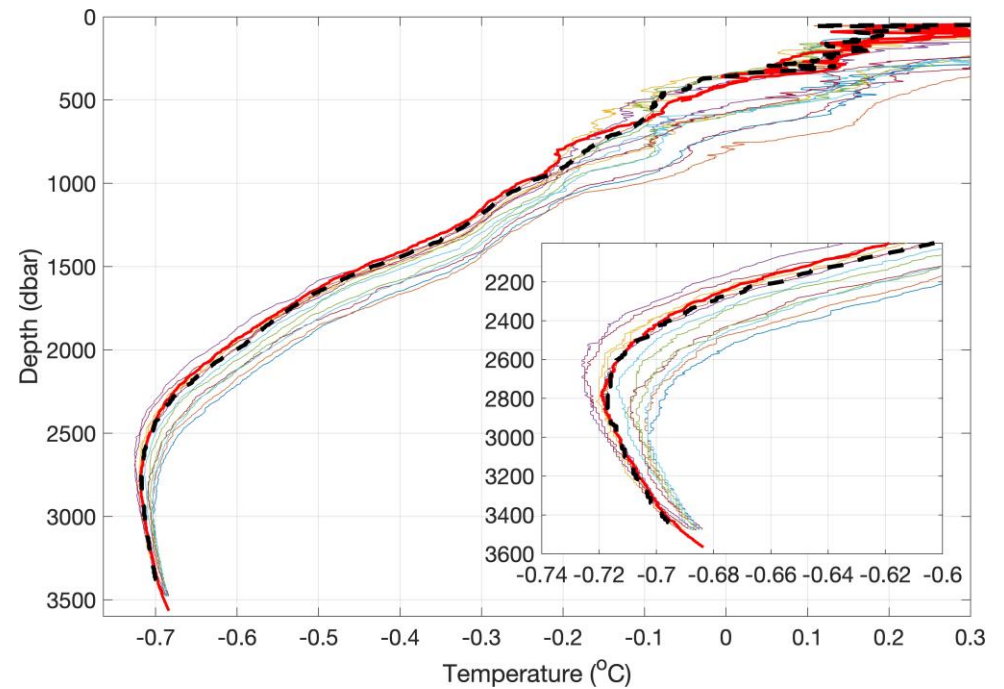
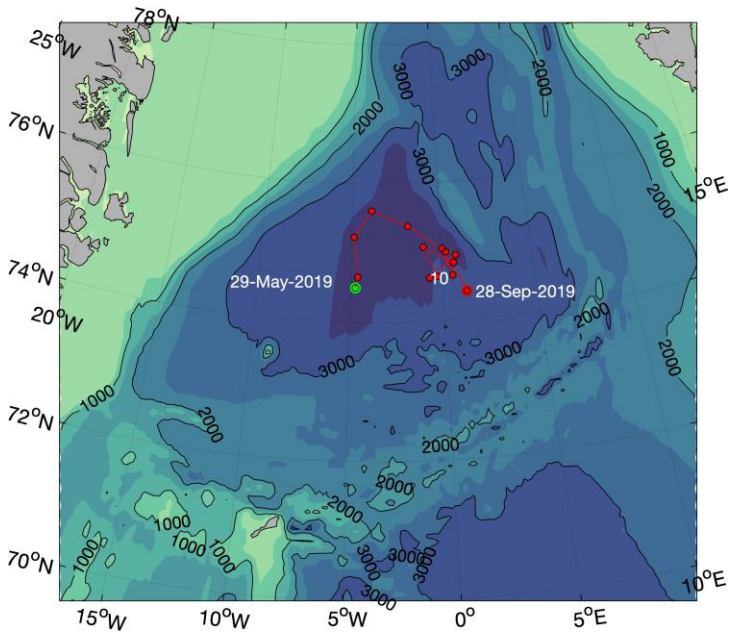
Planned deployments  
the next years (2020-  
2022) will be about  
similar as in 2019



Deployment of a Deep  
Arvor. Photo: Tor de Lange



# Deep Arvor in the Greenland Sea May-Sep 2019 (6903558)



# Summary

- Extension of Argo: into Barents Sea, Arctic Ocean, Deep and BGC-floats
- The local air–sea heat fluxes are important in modifying the ocean heat content (explains ~50% but depends on time scale and basin)
- The recent freshening trend (2011-2018) is caused by fresher inflowing Atlantic Water
- The recent warming trend (2011-2018) is not explained by warmer AW, but partly by less air-sea heat loss (30-60%)

This freshening and warming could further, in a much wider sense, affect the deep water formation in the Greenland Sea and the properties of the overflow water that exits the Nordic seas.

**Thanks**

