Interaction of meridional ocean heat transports and regional processes in the Arctic Ocean

D04

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1. Summary

Research questions

Q1 To what extent does ocean heat transport control changes in observed sea ice extent and air sea heat fluxes?

Q2 What is the *recent* and *future* evolution of horizontal and vertical ocean transport processes within the Arctic Ocean?

Q3 How do ocean heat transport processes contribute to future Arctic warming?

D04 contributes to SQ1 and CCA1 by studying the Arctic Ocean's contribution to Arctic amplification, especially the surface contribution to the lapse-rate feedback.

2. Achievements phase II

Heat transport into Barents Sea Opening (BSO)

- Local feedback not closed: sea ice decline drives high pressure anomaly over Svalbard. Yet, resulting winds do not increase BSO ocean heat transport
- BSO heat transport forcing: linked to two wind patterns, which are active in different periods. One relates to NAO, the other to atmospheric blocking heavily deflecting synoptic-scale cyclones (cooperation with project **D03**)

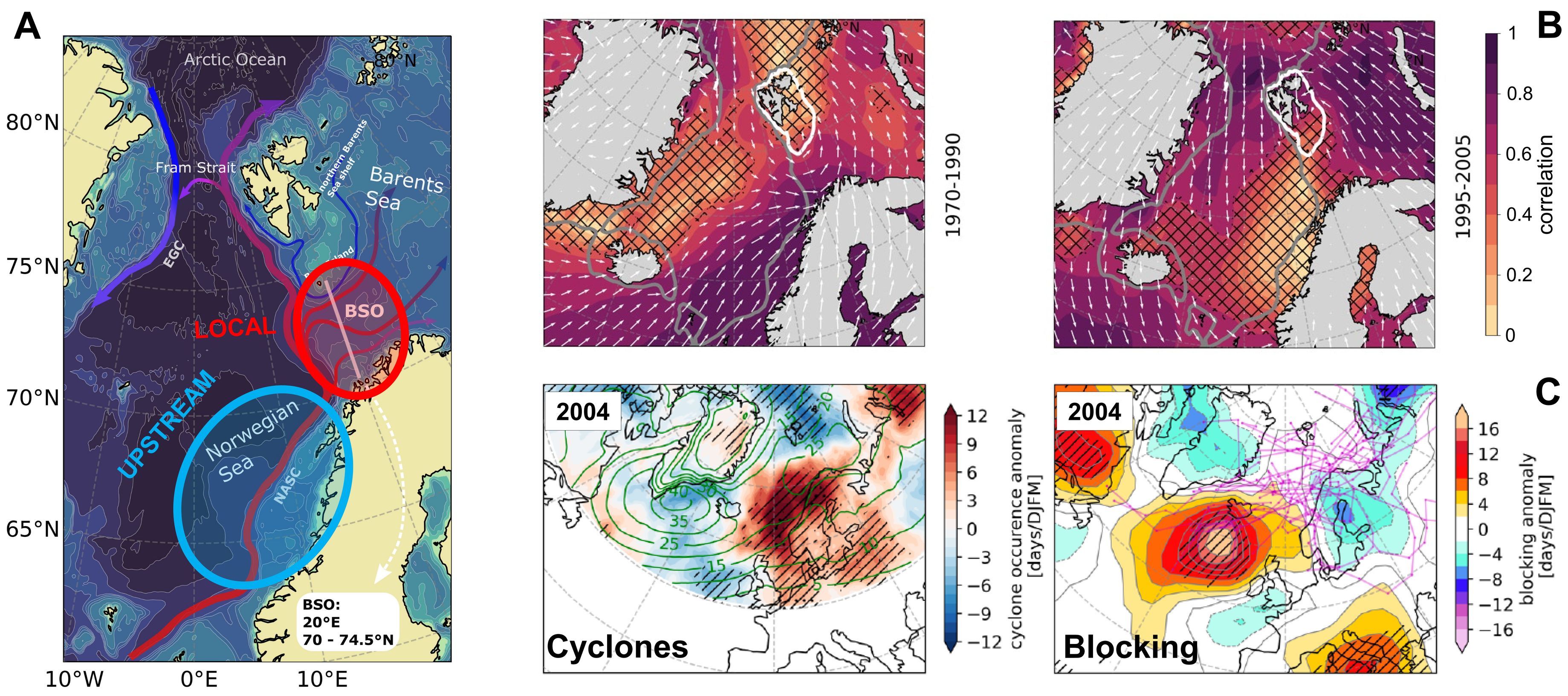

Fig. 1: (A) Subarctic currents. (B) Correlation and regression between surface wind and BSO transport. (C) Cyclone occurrence and atmospheric blocking in 2004 (DJFM) relative to 1970-2019.

Increased surface energy fluxes in winter in global climate models

- Related to halocline retreat
- Heat transport more important than seasonal heat storage along major warm water inflow

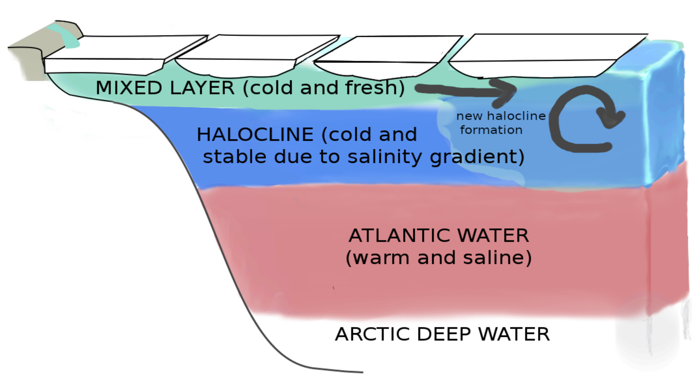

Fig. 2: Schematic based on Rudels et al. (1996), Steele and Boyd (1998).

New method to detect halocline bottom

- Background: halocline protects sea ice from warm Atlantic water
- Idea: develop robust method based on stability
- Highlight: method captures new halocline formation

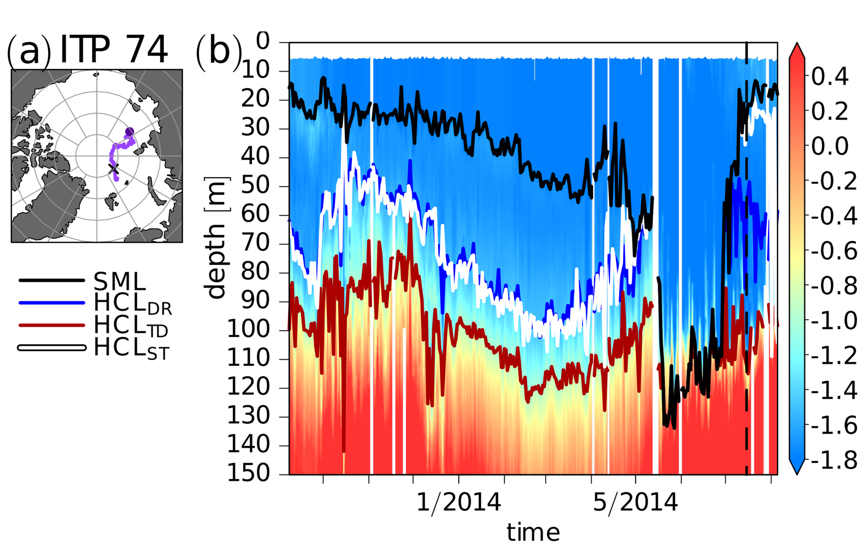

Fig. 3: Halocline (HCL) base from density ratio (DR), temperature difference (TD) and stability (ST).

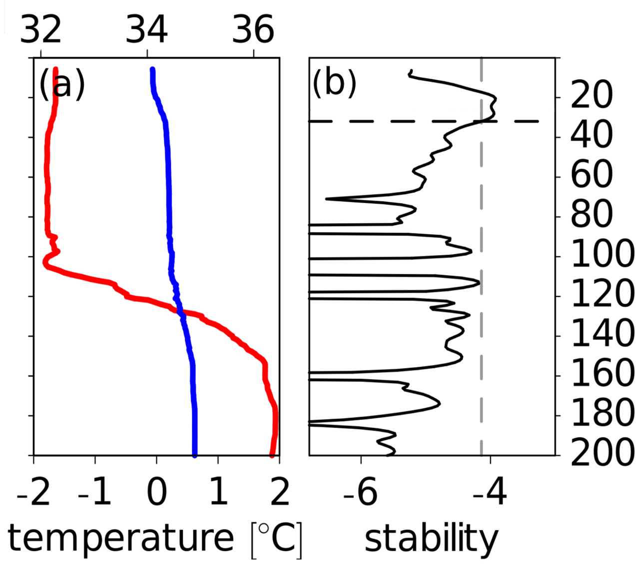

Fig. 4: (a) Temperature and salinity. (b) Vertical stability, stability threshold (vertical line), HCL base (horizontal line).

Hypothesis

Ocean heat transport is becoming increasingly important for Arctic amplification and is coupled to atmospheric dynamics and sea ice decline

3. Research plan phase III

Q1 – Ocean heat transport impact on *observed* sea ice variability and air-sea fluxes

- **Process attribution**: isolate the roles of ocean heat transport and atmospheric heat transports into the Arctic Ocean in driving observed sea ice decline
- **Approach:** use partial coupling (Modini) approach of observed ocean wind forcing and nudging of atmospheric winds in AWI Climate Model
- **Analysis:** compare both experiments to observed sea ice variability and decline

Q2 – Heat transport and vertical heat flux in the Arctic Ocean

- Study role of redistribution of subsurface heat by ocean advection and mixing for sea ice melt and warming the atmospheric boundary layer
- Investigate role of changing halocline for surface warming
- Use tracer diagnostics to study ocean transport and vertical mixing in climate models
- **Tracer implementation** of SF6, CFC-11, and CFC-12 into the ocean component of the AWI-CM
- Compare to *observed* tracer observations, especially from **project C04**
- Investigate whether tracer output from CMIP6 can be used to constrain projections

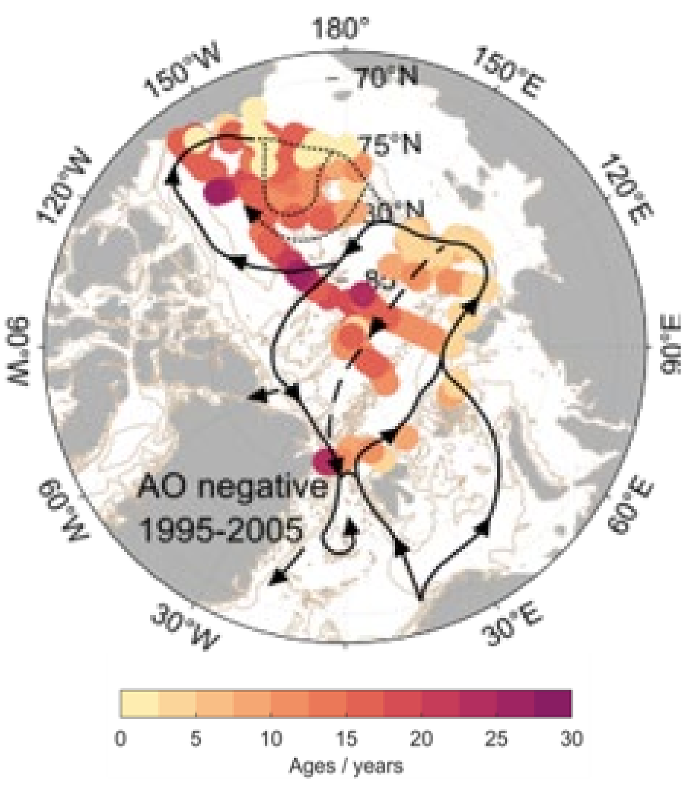

Fig. 5: Age of Atlantic Water inferred from tracer observations (project C04; courtesy of W. Körtke).

Q3 – Role of ocean dynamics in the *future* evolution of the Arctic

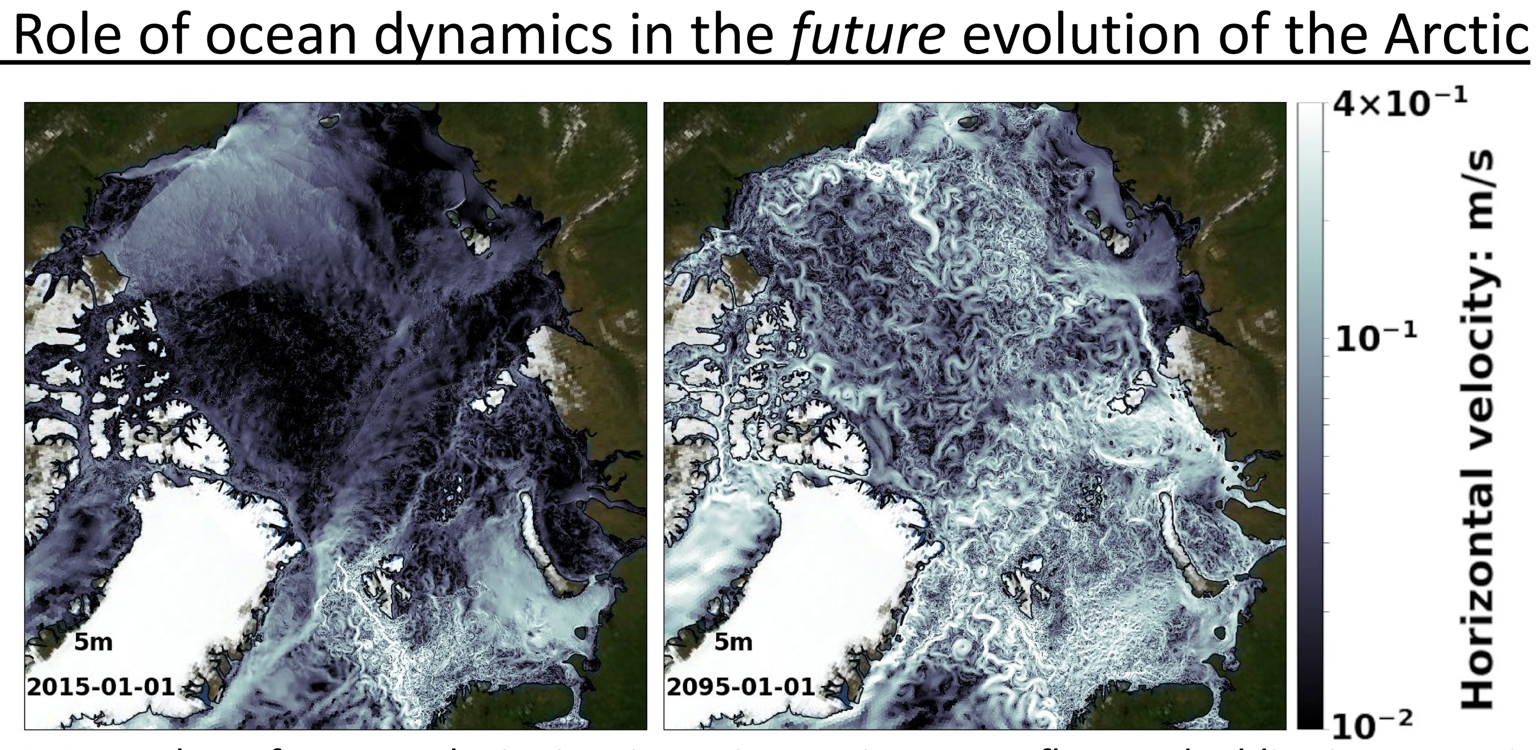

Fig. 6: Snap shot of ocean velocity in winter: increasing mean flow and eddies in a warming world, eddy-permitting resolution simulation (4.5 km) with FESOM2.

- **Ocean mesoscale represents shortcoming in CMIP models**
- **Compare two AWI-CM future climate projections** (until 2100), one with standard resolution ocean-sea ice model and the other with an eddy-resolving one
- **Ocean eddies**: Study effect of the realism in ocean dynamics on simulated warm water pathways and vertical heat fluxes. Assessment atmospheric mesoscale (cyclone) response (**project D03**)
- **Arctic amplification**: Investigate relation of spatial pattern of lapse rate feedback (kernel technique) to patterns of ocean heat fluxes and ice cover

4. Legacy & Major expected results

Project Legacy

- Energetically and dynamically consistent modeling approach relying on AWI-CM to isolate atmosphere and ocean contributions to sea ice decline in the Arctic
- Novel method to detect halocline bottom
- Implementation of tracer diagnostics in FESOM Ocean Model
- Explicit link between ocean dynamics and Arctic amplification

Major expected results within phase III

- Demonstration that ocean heat transport through the Arctic Gateways is a major driver of observed variability of Arctic sea ice over the past decades
- Tracer-based assessment of ocean heat transport pathways (with C04)
- Demonstration that ocean dynamics strongly shapes the spatial pattern and amplitude of the Arctic lapse rate feedback and thus of Arctic amplification

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