Coupling between atmosphere, oceanic mixed layer and pycnocline under Arctic amplification: The role of sea ice related processes

C04

Torsten Kanzow, Maren Walter
Zerlina Hofmann, Oliver Huhn, Wiebke Körtke, Benjamin Rabe, Monika Rhein, Natalia Sukhikh, Wilken-Jon von Appen

1. Summary

Research questions

Q1 What is the **basin-scale distribution of ocean heat fluxes** coupling the ocean mixed layer, sea ice, and atmosphere?

Q2 Do we already observe **changes in the energy fluxes** between ice, mixed layer, and warm Atlantic Water, and are they related to **changes in the subsurface circulation** of Atlantic Water?

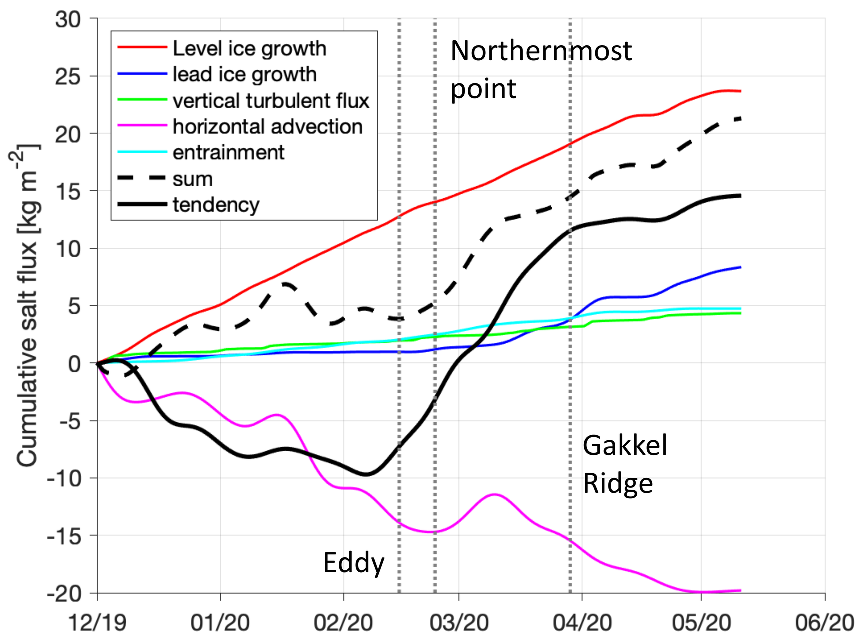
Q3 What is the **quantitative role of upper-ocean processes** in Arctic amplification?

Contribution to CCA1, SQ1 & SQ3

2. Achievements phase II

Mixed layer evolution during the MOSAiC drift

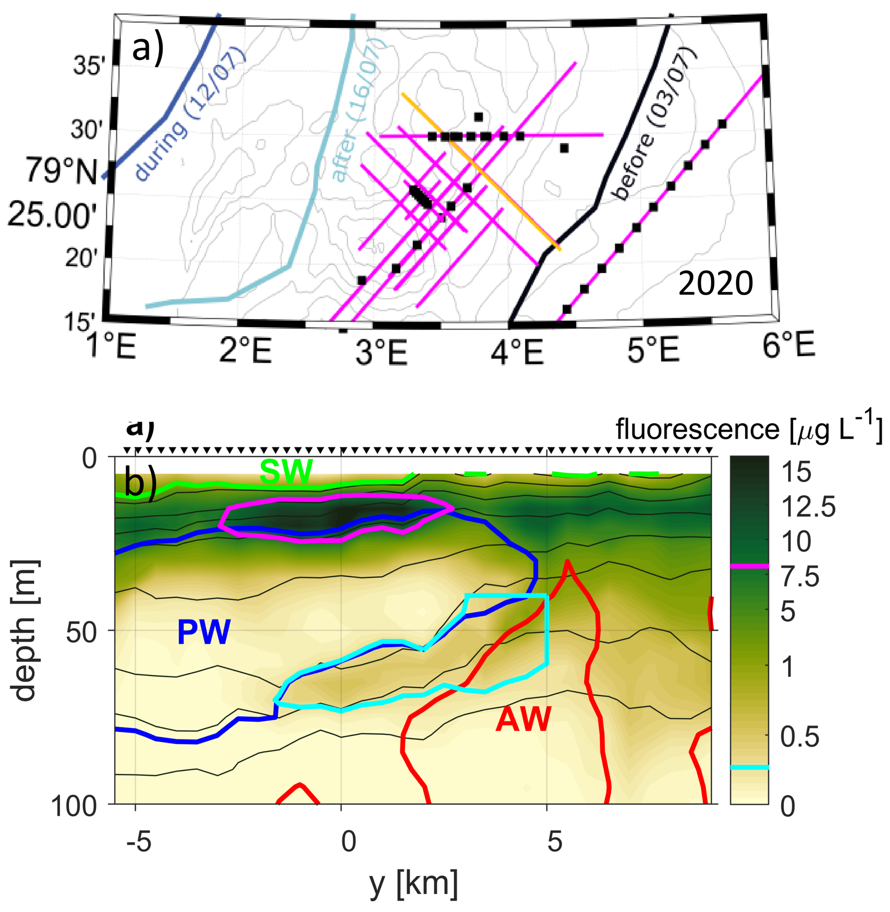
- Analysis of wintertime mixed layer processes and their coupling to atmosphere and stratified ocean during the MOSAiC drift in a coherent framework
- Brine input from ice growth represents largest flux term
- Turbulent salt flux across mixed layer base is coupled to drift speed (wind speed)
- Advective fluxes represent salt sink



Salt budget terms of mixed layer during the MOSAiC drift.

The Marginal Ice Zone in Fram Strait: a look into the future of an atlantifying Arctic

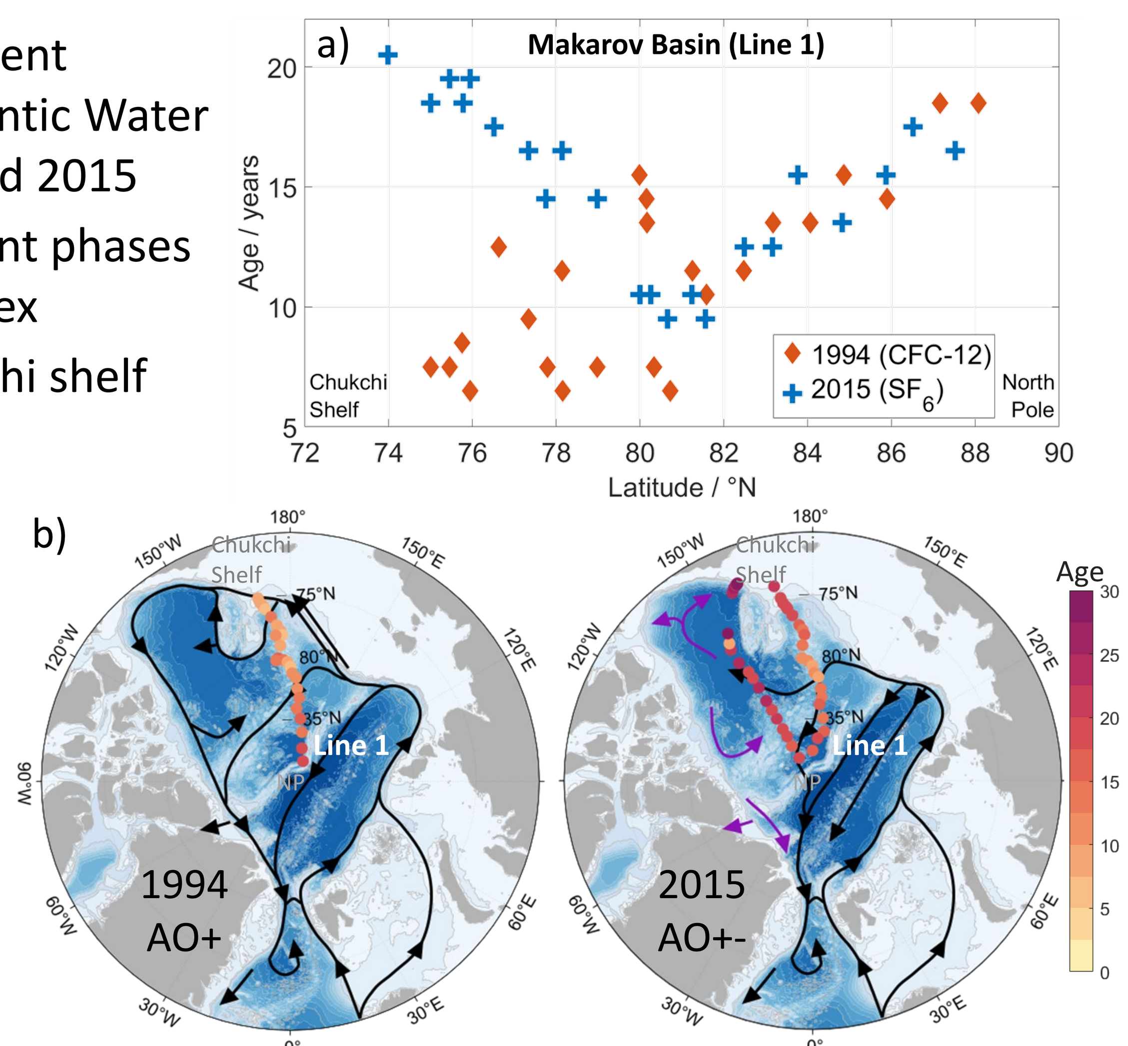
- (Sub-)mesoscale fronts between Atlantic Water (AW), Polar Water (PW) and Surface Water (SW) are ubiquitous near the marginal ice zone
- Vertical subduction of water and biogeochemical properties occurs along these fronts, in spite of a stratified surface layer



(a) Map with position of ice edge (20% sea ice contour) in relation to study area; (b) Transect of fluorescence with 75% water mass fraction contours (green/blue/red), (sub-)surface maxima of fluorescence (magenta/cyan), and isopycnals (black). Triangles indicate profiles along transect (orange line in map).

Transient tracers constrain response of Atlantic Water circulation to atmospheric changes

- Age distributions from transient tracers show changes in Atlantic Water circulation between 1994 and 2015
- Different patterns for different phases of Arctic Oscillation (AO) index
- Largest differences on Chukchi shelf



(a) Tracer ages of Atlantic Water temperature maximum along Line 1. (b) Age distribution of Atlantic Water temperature maximum for 1994 and 2015. Black arrows: Atlantic Water circulation patterns for positive and mixed Arctic Oscillation phases.

Hypothesis

Under Arctic amplification, oceanic kinetic energy increases, and hence ocean-sea ice-atmosphere heat fluxes in the Arctic intensify.

3. Research plan phase III

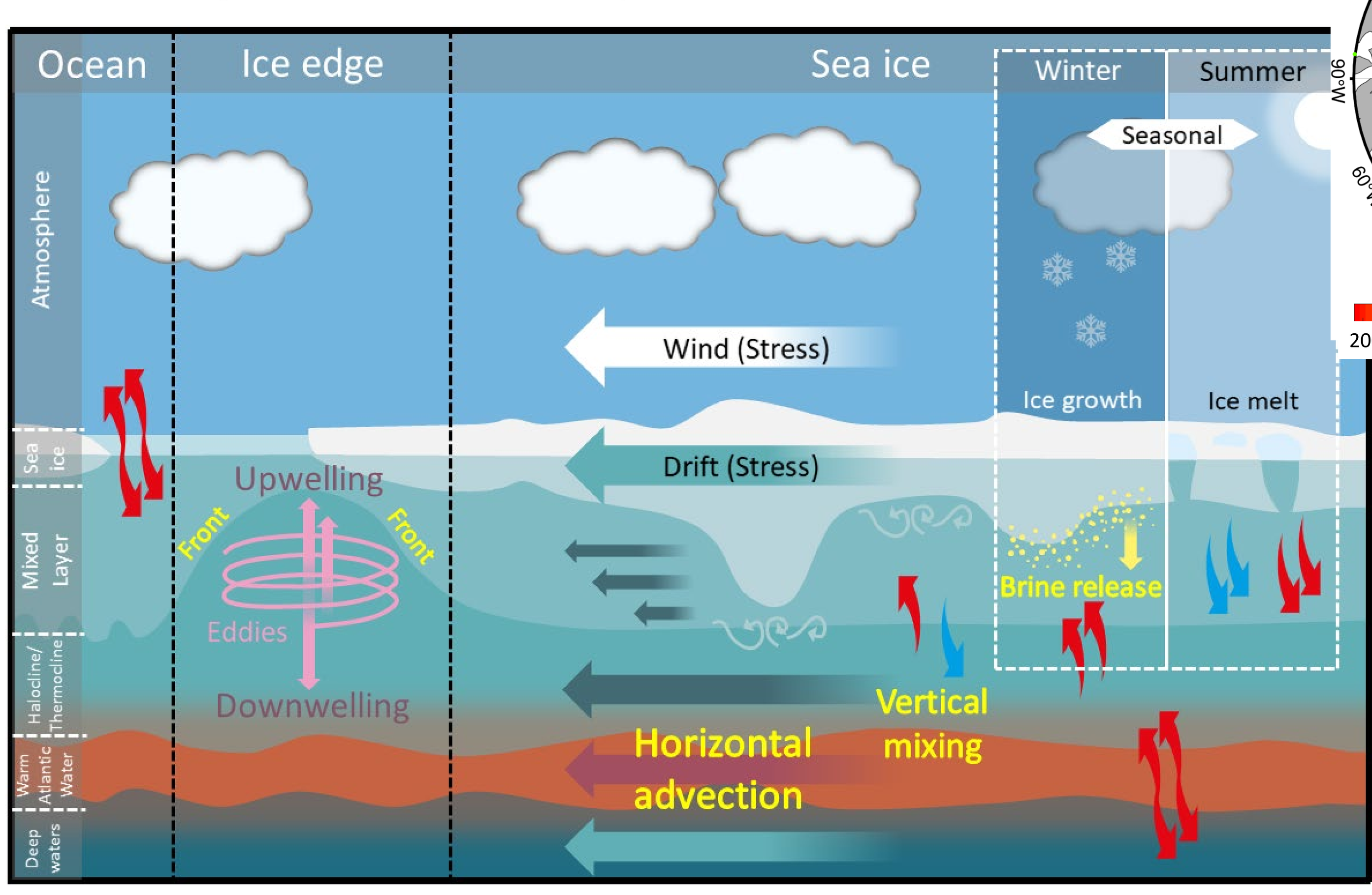
Subsurface-ocean heat transport and upward heat fluxes become increasingly important for Arctic amplification. C04 will:

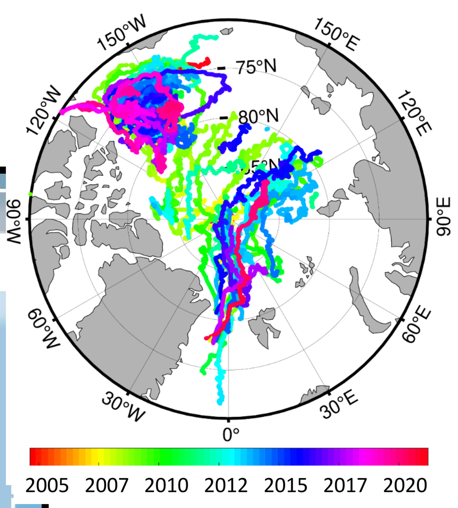
- clarify the upper oceans' role for sea ice loss and atmospheric convection (SQ1)
- identify and quantify regional varying sensitivities of ocean-ice-atmosphere heat fluxes from observations, and their representation in model simulations (SQ3)

in collaboration with D04, C01, C03, D03, E01, and contributing to CCA1

Q1 – Arctic-wide estimates of vertical heat fluxes in the mixed layer

- Calculate heat fluxes in the central Arctic Ocean from ice-tethered profilers
- Integrate heat fluxes in Arctic Ocean using multi-platform approach
- Close critical gap of wintertime heat fluxes (moorings in Arctic boundary currents)





Drift trajectories of ice tethered profilers.

Schematic of upper-ocean processes relevant for the coupled ocean - sea ice - atmosphere system

Q2 – Heat supply by Atlantic Water transport

- Assess the advective heat supply by subsurface circulation of Atlantic Water
- Study water-mass ages from both historical and new measurements of trace gases
- Infer present day circulation patterns based on tracers and remote sensing
- Integrate regarding interdecadal heat supply changes over the past decades using tracers, climate modeling and atmospheric circulation indices

Q3 – Synthesis - The role of the Arctic Ocean in Arctic amplification

- Link the heat-flux estimates (Q1) and the subsurface heat advection (Q2)
- Provide comprehensive picture of the patterns of ocean heat pathway in the ice-covered and ice-free Arctic Ocean
- Investigate hot spot and trends in heat fluxes
- Link heat flux patterns to sea ice decline and atmospheric warming, interpret in the context of atlantification

4. Legacy & Major expected results

Project Legacy

- Data sets: Tracer data from MOSAiC, high-resolution front data from MSM93
- Better understanding of role of small-scale ocean processes for atlantification
- Data-model integration of changing Arctic Ocean circulation in atlantification
- Assessment of shortcomings in observed ocean heat fluxes (➜ CCA1)

Major expected results within phase III

- Observation-based spatial pattern of present-day vertical ocean heat fluxes
- Documentation of decadal-scale ocean advective heat supply changes
- Documentation of growing importance of ocean processes for Arctic amplification

TRR 172 Transregional Collaborative Research Centre
(AC)³ ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms
Coordinating University
Universität Leipzig
Universität Bremen
Universität zu Köln
Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung
TROPOS Leibniz-Institut für Troposphärenforschung