The AMOC and the Ice

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Can AMOC variability drive changes in Arctic sea-ice or in the Greenland Ice Sheet?
Arctic Sea Ice Change

Arctic Report Card, 2021
Modes of Arctic Sea Ice Loss

FIG. 1. (a) March (blue), September (red), and annual mean (black) Northern Hemisphere sea ice extent, 1979–2016. Shaded regions indicate plus and minus one standard deviation. Linear sea ice concentration trends (% decade$^{-1}$) in (b) September and (c) March, 1979–2016. Black contours show the mean sea ice edge.

Onarheim et al. 2018
Spreading of Atlantic water in the Arctic

Atlantic Water at the surface

Atlantic Water

Timmermans and Marshall, 2020
Atlantification of the Barents Sea: Sea ice retreat with Atlantic Water (Heat) Transport increase

Arthun et al. 2012
Increased penetration of Atlantic Water, reduction in sea-ice cover, greater vertical mixing, vertical heat flux from the Atlantic layer into the surface layer

Polyakov et al. 2017
Multidecadal and long-term AMOC and sea-ice

Delworth et al. 2016

Barents Sea sea-ice extent in CESM LE

Arthun et al. 2019
Mass Loss from the Greenland Ice Sheet: surface mass balance plus dynamic changes

Shepherd et al. 2020, Mankoff et al. 2021
Increased net surface melt, SMB

Increased ice discharge, D

Arctic Report Card, 2021

Straneo and Heimbach, 2013
Increased ice discharge, $D$

Increased net surface melt, $SMB$

Rising Air Temperature

Rising Air and Ocean Temperature

Arctic Report Card, 2021

Straneo and Heimbach, 2013
Impact of AMOC on Greenland =

1. Air temperature over Greenland

2. Heat transport to the margin of glaciers
Hypothesis: Cold blob drove a reduction in ice loss from Iceland

Noel et al. 2022
Iceland’s Glaciers and North Atlantic Cooling

North Atlantic Cooling is Slowing Down Mass Loss of Icelandic Glaciers

Brice Noel¹, Guðfinna Ádægeirsdóttir², Finnur Pálsson², Bert Wouters¹, Stefaan Lhermitte³, Jan M. Haacker³, and Michiel R. van den Broeke¹

Iceland Glacier mass loss driven by increased surface melt (runoff)

Runoff/Surface Melt correlated with Iceland air temperature

Air temperature correlated with subpolar North Atlantic SST

Noel et al. 2022
Iceland’s Glaciers and the AMOC

CESM-2
SSP5-8.5
(high emission scenario)

Noel et al. 2022
Increased ocean-driven melting of glaciers leads to dynamic mass loss

- Increased ocean heat transport to a glacier
- Increased submarine melting
- Increased surface melt
- Terminus retreat and potentially dynamic ice loss
Glacier response depends on geographic parameters, glacier dynamics as well as oceanic and atmospheric forcing.

Slater and Straneo, submitted

Carr et al. 2017; Porter et al. 2018; Catania et al. 2018
Greenland rate of loss and atmospheric/oceanic variability

Updated from Straneo and Heimbach, 2013 – Ice loss (Mankoff et al. 2021); Fylla updated from Ribergaard (2014) using annual NAFO SCR reports by J. Mortensen; SPG Heat content EN4, AMO and NAO from climate data ucar.
Investigating Ice Sheet Response to Atmospheric and Oceanic Forcing

Extrapolation of properties in fjords

Retreat function of ocean and atmosphere

\[ \Delta L = K \times \Delta \left( Q^{0.4} TF \right) \]

Slater et al., 2019, 2020
Ocean Forcing of Helheim Glacier (SE Greenland)

Assumption: Properties in fjord = Properties on shelf above sill depth

Slater et al. 2019
Nowicki et al. 2019
Greenland Ice Sheet Model Projections in AR6

Goelzer et al. 2020

Papers: Ocean Forcing Greenland: Slater et al. 2020; Model Selection Bartel et al. 2020; Protocol: Nowicki et al. 2020; see The Cryosphere Special Issue ISMIP6

Greenland:
21 simulations
14 modeling groups
9 countries
Summary AMOC, Sea-ice and Land-Ice

Increased AW transport into Barents Sea and Arctic (eastern) leads to decreased wintertime sea-ice

Not a simple relation between AMOC and AW transport into the Barents Sea and Arctic

Surface mass balance of Arctic/Greenland glaciers affected by air temperatures over ice (potential indirect influence by the ocean)

Dynamic glacier retreat influence by atmosphere and fjord properties which are partly tied to shelf properties and hence AMOC?