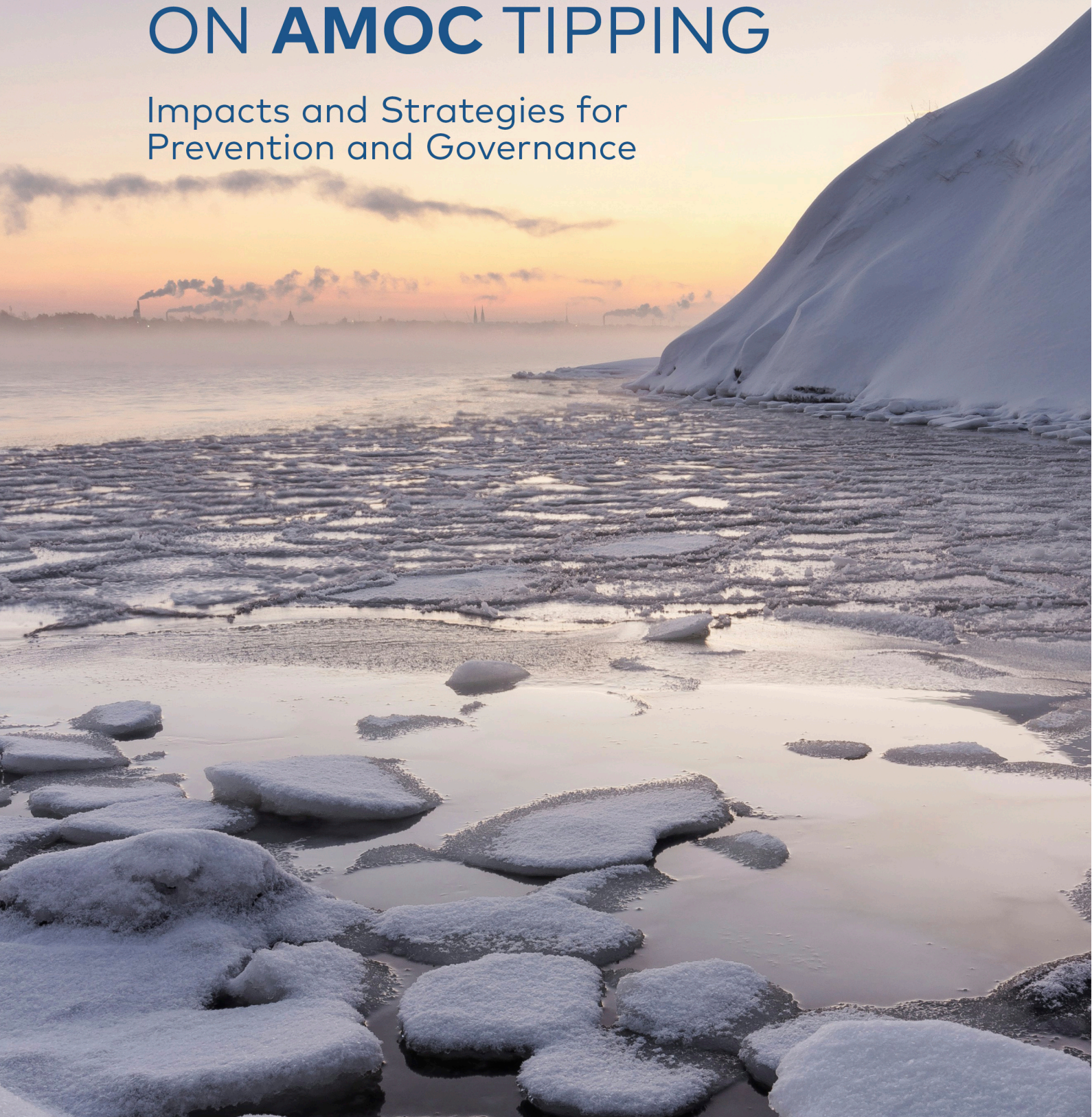


A NORDIC PERSPECTIVE ON **AMOC** TIPPING

Impacts and Strategies for
Prevention and Governance



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Background

Nordic countries have a long history in contributing to climate mitigation and adapting to ongoing climate change by making their societies more climate resilient. However, so far the climate adaptation plans and policies have not been formed with the impacts of crossing key climate tipping points in mind. This lack of preparedness was highlighted by [the Open Letter by Climate Scientists to the Nordic Council of Ministers](#) presented in 2024, suggesting larger than previously assumed risk for The Atlantic Meridional Overturning Circulation (AMOC) collapse.

Motivated in part by the letter, and by Finland's council presidency theme resilience, the Nordic Council of Minister's sponsored 'Nordic Tipping Week' -workshop, arranged in October 21–24, 2025, in Helsinki and Rovaniemi, Finland. The workshop brought together scientist working on different aspects of AMOC dynamics and its impacts, from physical oceanographers to social scientists, and led to the writing of this report. The purpose of this report is to summarize the scientific knowledge on the potential impacts of an AMOC collapse, to suggest ways to mitigate and adapt to these impacts, and to provide an outlook on remaining scientific knowledge gaps. This report is targeted for a wide audience, including policymakers in countries surrounding the North Atlantic, including Nordic countries, the UK, and Canada, as well as government officials and the general public interested in the topic, and for those seeking for practical action points.

Ethics statement

AI was used in summarizing the meeting notes to draft the first version of this report as well as in drafting the text for the two storylines. All the workshop participants have agreed to the use of workshop notes and discussions as the basis for this report.

Acknowledgement

We would like to thank the Nordic Council of Ministers for sponsoring the workshop and all the workshop participants for their inputs. On the next page we list the persons who have contributed with text and comments on this report.



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Suggested Action Points

EXTEND MAXIMUM EFFORTS TO PREVENT: There is currently high uncertainty as to whether AMOC will cross a critical threshold (tipping point), as well as to the level of global warming or timeframe at which this might occur. Until these thresholds are known with greater confidence, a precautionary approach should be assumed: any additional warming, and any increase in duration of "overshoot" of 1.5°C increases the risk of AMOC collapse. It is therefore of importance to push for mitigation that achieves decarbonization and net negative emission targets. In addition, planned adaptation measures, including research into climate intervention technologies and their international governance, should continue.

INVEST IN EARLY WARNING SYSTEMS: Long-term funding should be secured to sustain and operationalize key observational networks and build an AMOC early warning system that couples Earth observations with model simulations. This early warning system should be embedded in policy making processes to create rapid knowledge-to-action abilities. The new EU Ocean Act provides possibilities for coordinating this effort.

PLAN FOR MULTIPLE FUTURES: The future of the AMOC is highly uncertain, but an AMOC collapse could trigger extreme impacts in the Nordic countries that differ from, and in part oppose, those expected from global climate change, especially atmospheric warming. It is essential to develop and adopt flexible climate change adaptation strategies that account for the region's exposure to the impacts of AMOC weakening and would succeed across divergent future trajectories with and without AMOC tipping.

ACT NOW: It is imperative that the potential collapse of the Atlantic Meridional Overturning Circulation (AMOC) be treated as a real and significant risk, to which comprehensive risk management frameworks are applied. To be effective, these frameworks need to be integrated at all levels of climate and ocean governance (scientific assessment, mitigation, adaptation, loss and damage, finance, and capacity building).

Föreslagna åtgärds punkter

UTÖKA MAXIMALA INSATSER FÖR ATT FÖREBYGGA: Det råder stor osäkerhet kring huruvida AMOC kommer att korsa en kritisk tröskel (vändpunkt), såväl som nivån på den globala uppvärmningen, eller tidsramen för när det kan inträffa. Tills man med större säkerhet känner till dessa gränsvärden bör man anta en försiktighetsstrategi: all ytterligare uppvärmning, och all ökning av varaktigheten för överskridande av 1.5 °C, ökar risken för kollaps av AMOC. Det är därför viktigt att driva på för att uppnå minskade koldioxidutsläpp och negativa nettoutsläpp. Dessutom bör planerade anpassningsåtgärder, inklusive forskning om klimatinterventionstekniker och deras internationella styrning, fortsätta.

INVESTERA I VARNINGSSYSTEM: Långsiktig finansiering bör säkras för att upprätthålla och implementera viktiga observationsnätverk, samt för att bygga ett varningssystem, som kopplar observationer med modellsimuleringar, för AMOC. Detta varningssystem bör integreras i beslutsfattande processer, för att skapa snabba processer från kunskap till handlingskraft. Nya EU Ocean Act besitter möjligheter att samordna denna insats.

PLANERA FÖR OLIKA FRAMTIDSSCENARION: AMOC:s framtid är mycket osäker, men en kollaps av AMOC skulle kunna innebära allvarliga konsekvenser för de nordiska länderna. Konsekvenserna skiljer sig från, och delvis motsätter sig, de konsekvenser som förväntas av globala klimatförändringar, framför allt när det kommer till atmosfärisk uppvärmning. Det är viktigt att utveckla och anta flexibla strategier för klimatanpassning som tar hänsyn till regionens exponering för effekterna av en försvagning av AMOC, och som kan fungera i olika framtida scenarior med eller utan AMOC-tippning.

AGERA NU: Det är absolut nödvändigt att den potentiella kollapsen av AMOC behandlas som en verklig och betydande risk, för vilken omfattande riskhanteringsramverk tillämpas. För att vara effektiva måste dessa ramverk integreras på alla nivåer av klimat- och havsförvaltning (vetenskaplig bedömning, begränsning, anpassning, förlust och skada, finansiering och kapacitetsuppbyggnad).

1. Introduction

The Atlantic Meridional Overturning Circulation (AMOC) is a large-scale circulation of the Atlantic Ocean that shapes the global and regional climate by redistributing heat across latitudes (Buckley and Marshall, 2016). This system of currents will slow down due to anthropogenic climate change (Weijer et al., 2020; IPCC 2021; Madan et al., 2023; Bonan et al., 2025), and there is a risk that this slowdown could be both more substantial and occur within a few decades, *if* there is transition of AMOC to another stable state that involves a severely weaker circulation than at present (Stommel, 1961; Rahmstorf 1996, van Westen et al. 2025b). Such a transition could happen if the AMOC surpasses a critical forcing level or climate state threshold, a so-called tipping point (van Westen et al., 2024), with the likelihood of AMOC collapse increasing as global warming progresses (Armstrong-McKay et al. 2022; Möller et al., 2024; Drijfhout et al. 2025; van Westen et al. 2025a; Shin et al. preprint). Several recent studies suggests that the tipping point which starts an AMOC shutdown could occur before 2100 (Rahmstorf, 2024; Ditlevsen & Ditlevsen, 2023; van Westen et al., 2025a; Boers, 2021, Drijfhout et al. 2025). However, it remains unclear how fast a collapse would unfold after crossing such a tipping point, with a timescale ranging from 15 to 300 years (Armstrong McKay et al., 2022).

The impacts of such a collapse in Northern Europe depend on the global warming level at which the collapse occurs. If the transition is more sensitive to global temperature than is currently predicted (taking place around ~2°C warming level with respect to preindustrial), it could result in net cooling in northwest Europe (Romanou et al., 2023; Boot et al., 2024; van Westen & Baatsen, 2025), regulated by the degree of sea ice expansion (Bellomo and Mehling, 2024); at higher warming levels, net cooling becomes less likely. However, other impacts, such as North Atlantic sea-level rise, warming of the southern hemisphere, and a southward shift of the tropical rain belt (intertropical convergence zone – ITCZ), are independent of background global warming and will accompany any AMOC slowdown (IPCC, 2021).

Based on the scientific understanding at the time, the IPCC (2021) assessed that AMOC is unlikely to undergo abrupt changes before 2100, but would have serious consequences if it were to occur. However, a recent letter to the Nordic Council of Ministers – endorsed by 44 climate scientists – argued that the risk has been underestimated and that the outcomes of an AMOC collapse could bring “irreversible impacts, especially for Nordic countries” (Rahmstorf et al., 2024).

Using data from the latest model generation (38 CMIP6 models with over 768 simulations), Drijfhout et al. (2025) found that in most models the AMOC starts to weaken in the late 20th century and weakens substantially through the 21st century, reaching an essentially shutdown state in the 22nd century in many of the simulations that continue beyond 2100. Overall, they estimate a probability of an AMOC shutdown of 70% for high emissions, 37% for intermediate emissions and 25% for low emissions - making it a credible risk. However, the probability and timing of passing the AMOC tipping point are very difficult to predict.

Continuous direct measurements of AMOC strength are available only since April 2004 ([RAPID Array](#)) and show a statistically significant weakening trend (-0.8 ± 0.7 million cubic meters per second per decade; Volkov et al. 2024). Due to the short time series, attributing the trend to a forcing is difficult - it could be due to natural variability and/or to climate change. However, the trend is consistent in magnitude with model simulations that ultimately lead to an AMOC shutdown (Drijfhout et al. 2025) and many indirect estimates of AMOC strength over the historical period (Dima and Lohmann 2010, Drijfhout et al. 2012, Rahmstorf et al. 2015, Caesar et al. 2018, Zhu & Liu 2020, Chafik et al. 2022, Rossby et al., 2022, Qasmi 2023, Li & Liu 2025, Ren et al. 2025, Michel et al., 2025) and the Holocene (Caesar et al. 2021, 2022) suggest a long term AMOC slowdown consistent with global warming contributing to it.

Given the possibility of an AMOC shutdown, the authors of this report suggest Nordic societies to recognize it as a serious risk which requires a dedicated risk management framework to manage its environmental and societal impacts. We have such existing frameworks for other risks, such as geohazards (earthquakes, tsunamis, asteroid impacts, tropical storms, floods, etc.), which would generally not have as widespread impacts as AMOC shutdown. A key to an AMOC collapse risk management framework is identifying its possible impacts on people and natural ecosystems along with drafting mitigation and adaptation plans. In this report we provide an initial look at possible frameworks, identify existing knowledge gaps, and suggest further actions.

The rest of the report is organized into four sections. [Section 2](#) examines the impacts of an abrupt AMOC collapse. [Section 3](#) lays out possible mitigation and adaptation strategies. [Section 4](#) discusses the possible emphasizes identifying key knowledge gaps and highlights priorities for future research and [Section 5](#) provides key action points for the Nordic countries.

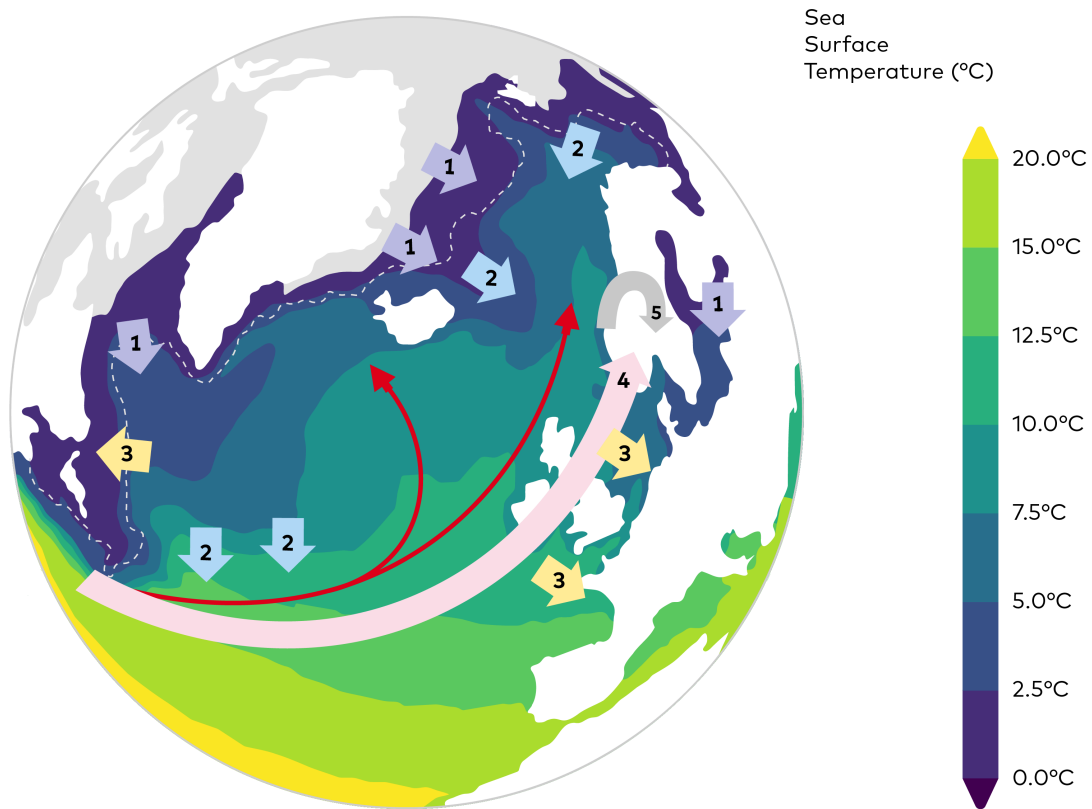


FIGURE 1 Schematic representation of the main impacts of an AMOC collapse on the physical climate system. The background shading shows the climatological February mean sea surface temperature in blue to yellow hues, and minimum sea ice concentration on white to gray hues. The gray lines show the minimum (solid) and maximum (dashed) of local sea ice extent based on satellite observations (OI-SST, 1982–2025) in the North Atlantic. Potential consequences of an AMOC collapse on the physical climate system in the region of the North Atlantic include: (1) sea ice expansion (2) sea surface temperature decrease/displacement of ocean fronts (3) sea level rise (4) changes in mid-latitude cyclones (5) air temperature decrease. Figure credit: FMI, Aleksi Nummelin.

2. Impacts of an AMOC collapse

The impacts of an AMOC collapse divide into direct impacts on the earth system and the consequent second order impacts on society and livelihoods. These impacts, and their uncertainties, vary regionally. For the Nordic Countries, and Northern Europe in general, many of the impacts strongly depend on the background global warming level at which AMOC changes occur (see an example in [Figs. 2–3](#)), with the exception of the AMOC contribution to sea level rise, which directly follows AMOC slowdown. In the following we summarize the state of the art knowledge on the direct and indirect impacts.

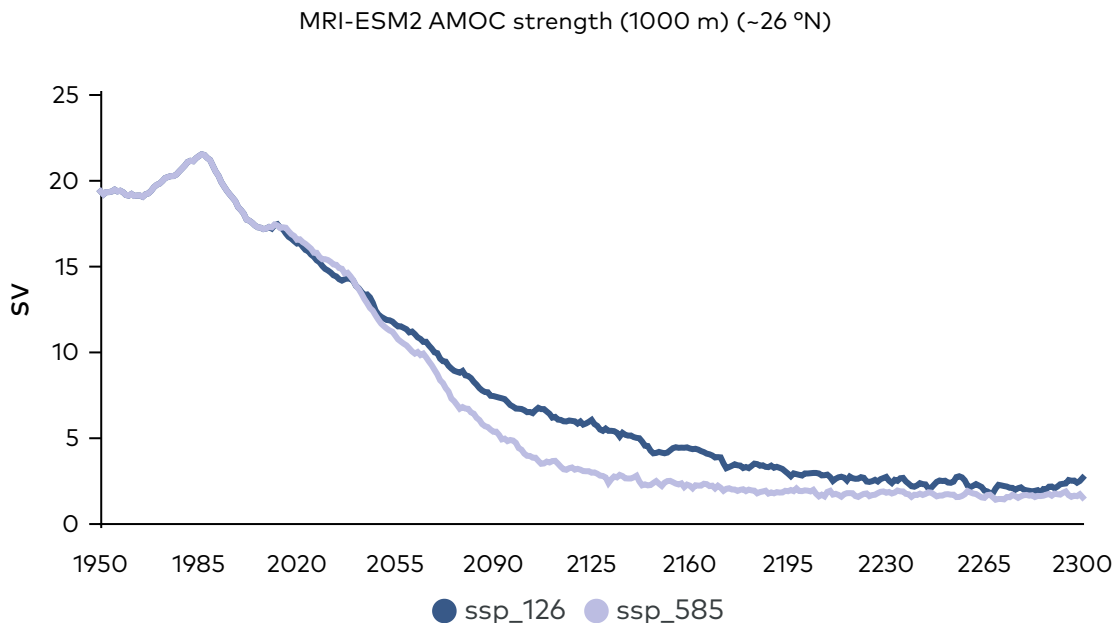


FIGURE 2 AMOC-strength temporal evolution under two climate change scenarios in the MRI-ESM2 model. Figure credit: FMI, Laura Thölix.

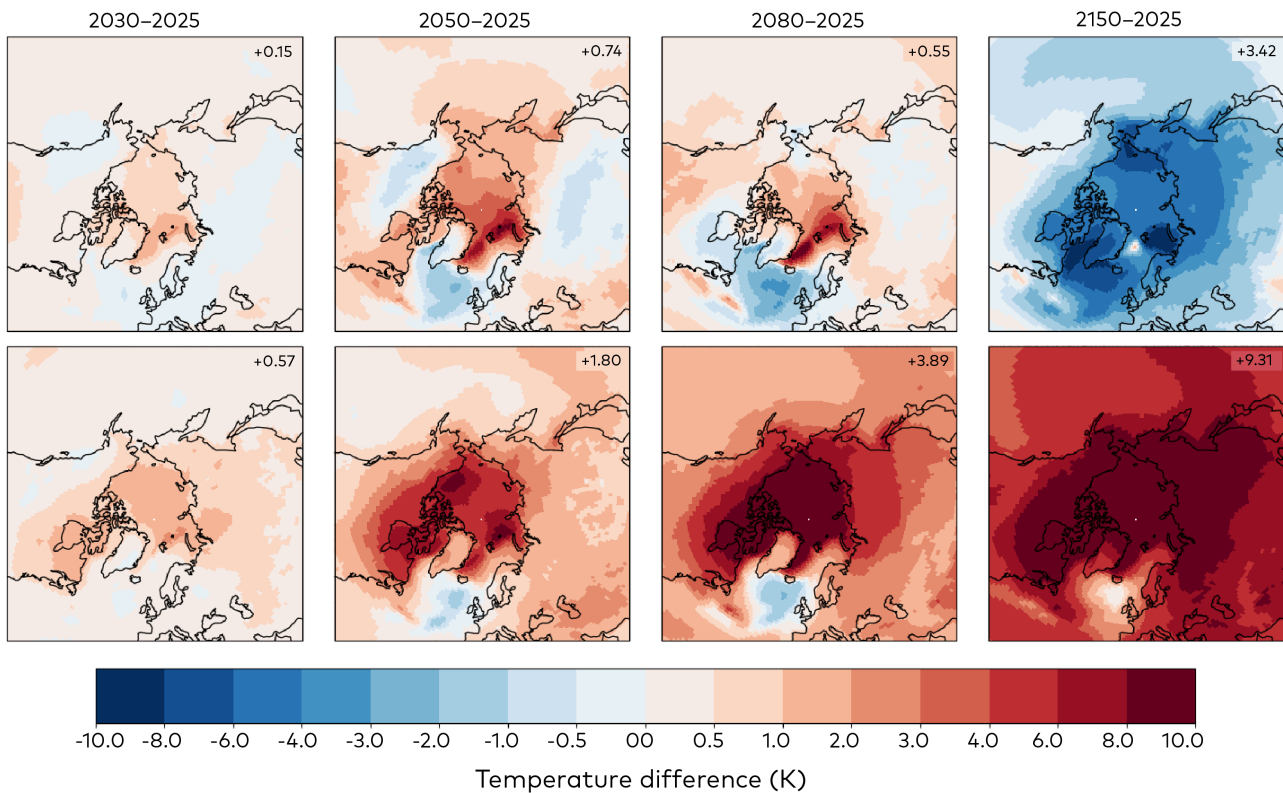


FIGURE 3 Evolution of 20 year mean winter (December-February) surface temperature anomalies in respect to the 20 year mean around 2025, in two climate change scenarios (weak emissions, ssp126, top row; strong emissions, ssp585, bottom row) in which AMOC slows down by a similar amount (see [Fig. 2](#)) in the MRI-ESM2 model. The columns (from left to right) show temperature anomalies in years 2030, 2050, 2080, and 2150. Figure credit: FMI, Laura Thölix.

2.1 Impacts on the physical climate

The present-day AMOC redistributes heat from the Southern Hemisphere to the Northern Hemisphere (Buckley and Marshall, 2016). When the AMOC weakens, this heat transport is reduced, causing the Northern Hemisphere to cool (Menary & Wood, 2018; Gervais et al., 2018; Liu et al., 2020; Li & Liu, 2025) and the Southern Hemisphere to warm (Orihuela-Pinto et al., 2022). As a consequence, not only the natural and human systems of the Northern Hemisphere will be affected but also AMOC's global teleconnection will have implications in different parts of the world. The southward shifting of inter-tropical convergence zone (ITCZ) – the tropical rain belt - from its present-day mean position in the Northern Hemisphere is one such example (Ben-Yami et al., 2024) with possibilities of disastrous consequences for monsoon dependant regions such as Sahel and India (IPCC AR6).

It has been shown that under increased warming due to rising GHG emissions, the AMOC will weaken substantially, but with low likelihood for cooling outside the sub-polar gyre region by 2100 (IPCC AR6). However, this assessment focused on changes until 2100 and did not include the possibility of increased freshwater forcing at the surface of the subpolar gyre where overturning takes place, due to freshwater input from the melting of Greenland ice sheet (e.g., Jackson et al 2022), and extreme internal variability (Romanou et al, 2023), both of which would increase the likelihood of AMOC collapse. Over longer timescales, however, the models project an AMOC shutdown over the 21st and first half of the 22nd centuries, even without additional freshwater input (Drijfhout et al. 2025). While AMOC weakening in models takes several decades, deep mixing in the subpolar gyre could shut down more abruptly, with an associated local 1–2 °C cooling over 10–15 years (Gu et al., 2024; Falkena et al., 2025; Drijfhout et al., 2025), a northward shift in the jetstream, and increasing risk of summer heatwaves in Europe (Swingedouw et al., 2021). A subpolar gyre convection collapse precedes AMOC shutdown in simulations (Drijfhout et al., 2025). However, as deep convection may shift poleward under warming, the role of subpolar convection as a necessary precursor for AMOC shutdown remains uncertain (Årthun et al., 2025; Moore et al., 2022; Brodeau & Koenigk, 2016).

The shift in global distribution of heat, and the associated impacts, directly follow from an AMOC slowdown, independent of the timing and the speed of the slowdown itself (Bellomo and Mehling, 2024). However, the regional impacts in the Nordic countries and Europe in general depend on three key factors. First, the amount of global warming; second, the timing for the onset of AMOC collapse; and third, is the strength and pattern of the regional cooling signal.

If AMOC sensitivity to global warming is at the high end of the most recent estimates (Drijfhout et al., 2025) and AMOC would slowdown at ~2 °C global warming level, then a strong cooling, especially during winter, is likely in the North Atlantic and Nordic Countries ([Figure 3](#)). The extent of the area that experiences net cooling is uncertain and depends on how sea ice will respond (van Westen & Baatsen, 2025; Romanou et al., 2023). Possible changes include a strong reversal in sea-ice cover trends, with winter sea-ice reaching the entire coastline of Iceland, the Scandinavian coast in the north, and with increasing ice extent also in the Baltic Sea (Drijfhout et al., 2025). This regional cooling would increase the north-south temperature gradient across the North Atlantic storm track and lead to more intense mid-latitude storms, but with less precipitation (van Westen & Baatsen, 2025). In such a scenario moderate summertime cooling and shorter growing seasons in Scandinavia are also likely (Ritchie et al., 2021; van Westen et al., 2025d).

However, if the AMOC is more stable and a rapid slowdown takes place in a 3–4 °C warmer world, then net cooling in winter with increasing storminess is unlikely in the North Atlantic and Northern Europe and summers are very likely to be warmer than today, dominated by the greenhouse gas-driven warming. However, even without net cooling, many serious climatic impacts such as warming of the Southern Hemisphere, associated ITCZ shift and increasing sea level rise would still play out following an AMOC collapse.

Independent of the timing of an AMOC collapse, such a collapse implies fresher and lighter water in the North Atlantic. Lighter water masses occupy larger volumes leading to dynamic sea-level rise, with recent estimates suggesting up to about 50 cm sea-level rise along European coastlines (van Westen et al., 2025c). Combined with the warmer Southern Hemisphere and possibly faster warming of the Western Antarctic Ice Sheet, as well as the melting of the Greenland Ice Sheet, the global warming driven sea-level rise accelerates following an AMOC collapse (Wunderling et al., 2024).

2.2 Impacts on the socio-ecological system

Due to lack of research, our understanding of the AMOC collapse impacts on the socio-ecological systems is incomplete. Here we review some of the main physical changes and their anticipated impacts on key systems, notwithstanding the lack of research, especially on the impacts on social systems.

Impacts on marine ecosystems: Collapse in marine primary productivity; species redistribution; biodiversity loss.

A collapse of deep convection in the sub-polar gyre can influence marine ecosystems in several ways. The collapse can lead to a shift in the timing of the spring bloom (Kelly et al., 2025), which, if higher trophic levels cannot respond to this shift, might lead to strong changes in ecosystem functioning (Asch et al., 2019; Cyr et al., 2024). Besides a shift in the timing of the bloom, the magnitude of the bloom is projected to decrease lowering overall productivity (Henson et al., 2022; Boot et al., 2023; Oliver et al., 2025). Depending on the amount of warming, the recovery of the magnitude of the bloom could take centuries (Oliver et al., 2025). Furthermore, as mixing reduces, small phytoplankton will outcompete large phytoplankton leading to a potential regime shift (Boot et al., 2023, 2025; Lee et al., 2025) that also influences higher trophic levels (Boot et al., 2025). When a collapse of deep convection is accompanied by a strong AMOC weakening, total marine ecosystem biomass will decline strongly over the North Atlantic, and specifically the subpolar gyre, with strong implications for fisheries (Boot et al., 2025)

Sea temperature drops would affect not only the size of fish stocks, but also their location, which may move to new regions or to deeper waters. The Northern European Shelf seas, particularly the North Sea and the Baltic Sea are under stress due to strong anthropogenic influence and warming. It is not clear how the impact of AMOC collapse would influence these habitats, but changes in temperature, sea level, and sea ice cover would likely be important for the local ecosystem health. As mentioned above under "food security", cooling and decreased vertical mixing could affect fisheries around Iceland.

Impacts on food, energy, and social security, and their geopolitical implications: Vulnerability due to cooling, drying, and unpredictable seasonality; Increased heating demand; Risk of negative impacts on renewable energy production; migration from ITCZ shift affected regions; geopolitical instability.

An AMOC collapse at relatively low global warming levels could cause significant regional cooling and prolonged winters across Northern Europe, severely disrupting agriculture (Merikanto et al., 2024; Ritchie et al., 2020). Shortened growing seasons and delayed sowing due to heavy snowfall, late frosts, and spring flooding could reduce crop productivity, while drier summers and altered precipitation patterns could further undermine yields and soil quality. Livestock systems could also suffer from reduced pasture growth and increased energy demands for housing and feed. Terrestrial ecosystems would experience major shifts, with boreal forest productivity declining under strong cooling, although permafrost melt might be prevented (Boot et al., 2024). It is unclear how these changes impact Indigenous and local, such as reindeer herding – the local communities participating in the Rovaniemi workshop delivered a coherent message of their adaptive capacity being dependent on the amount of land area, and different ecosystems, in their disposal. Nevertheless, it is likely that all land-based livelihoods in the Nordic countries and thereby personal and cultural identities and values, would be affected.

Oceanic changes linked to AMOC tipping – such as overall cooling, shifts in ocean fronts, and collapse of deep convection – could reduce phytoplankton and fish stocks around Iceland and Greenland, though uncertainties remain in marine ecosystem models (Post et al., 2020; Hatun et al., 2016; Boot et al., 2025). Combined with agricultural decline, these disruptions could trigger widespread domestic food insecurity in Northern Europe, increasing reliance on imports and vulnerability to global trade shocks. A southward shift of the ITCZ could exacerbate drought in regions like the Sahel, northern Amazon, and India, further straining global food systems and social safety nets, potentially leading to institutional failures.

Hydropower and municipal water systems would be highly sensitive to precipitation shifts, rain-on-snow events, and frost, while severe winter storms could cause energy grid breakdowns. Offshore energy infrastructure could face risks from changing sea ice and storm conditions, and heating demand could surge under cooling scenarios, possibly increasing carbon emissions if fossil fuels are used (J. Lee et al., 2025). Broader consequences include migration from ITCZ shift affected regions, heightened geopolitical instability, and security challenges for Nordic countries and NATO. AMOC-driven climate shifts could also reshape Arctic resource competition and Northern Sea Route accessibility, influencing trade, energy extraction, and regional geopolitics. The AMOC collapse driven local sea level rise, could harm infrastructure, ecosystems, agriculture, and potentially even displace people in low-lying areas like the Netherlands (J. Lee et al. 2025).

Impacts on economies and trade: Unequal global effects; disrupted trade and supply chains; maritime transport challenges.

AMOC weakening would have highly unequal economic effects across the globe. Low amounts of cooling might reduce some of the adverse effects of global warming in the Northern Hemisphere, but strong cooling and drying as a consequence of complete AMOC collapse might lead to strong negative economic impacts in Northern countries (Kotz et al., 2022). At the same time, additional warming in the Southern Hemisphere would exacerbate the economic impacts of climate change in the hardest-hit regions of the globe (Waidelich et al., 2024), and the AMOC-related monsoon shift would further adversely affect economies in the subtropics and tropics (Ben-Yami et al., 2024). The increased sea level rise due to an AMOC collapse would further lead to globally and regionally differentiated economic impacts (Diaz, 2016).

These unequal economic impacts across space and income levels raise important questions about justice and sustainable development. They could also disrupt global trade patterns in multiple ways.

Although uncertain, the authors of this report foresee the potential for AMOC collapse driven large scale disruptions to the global supply of goods and services with adverse impacts in the Nordic region. The Nordics depend on imports of food, goods and agricultural and industrial inputs from other countries, many of which are produced in the Global South. Disruptions to monsoon patterns and agricultural productivity could significantly constrain supply chains beyond what is expected under gradual warming. Consequently, international trade could be heavily affected, increasing prices and reducing availability of critical imports. Additionally, increased atmospheric carbon dioxide concentrations due to reduced ocean carbon uptake in response to an AMOC collapse could, until the end of the century, cost several trillion US dollars in additional economic damages due to stronger global warming (i.e., without accounting for possible regional effects; Schaumann & Alastrué de Asenjo, 2025).

With a potential net cooling, winter navigation would become more difficult and expensive due to extensive sea-ice cover in the North Atlantic and the Baltic Sea. Sea-level rise (on top of other sources of sea level rise) and increased winter storminess would damage coastal and offshore structures and increase flood risk. For example, Finland's security of supply is highly dependent on maritime shipping, as most goods are transported via the Baltic Sea (Fjäder, 2018). Handling, transporting, and storing temperature-sensitive products such as food and medicines could also become more difficult, adding further economic and logistical pressures.

3. Governance imperatives for AMOC tipping risks from a Nordic perspective

The potential weakening or collapse of the AMOC represents a high-impact climate tipping risk for the Nordic countries, with implications across ecological, economic, and societal systems. Addressing this risk requires governance that operates across scales – from global mitigation efforts to local preparedness – and spans multiple policy domains. Core principles such as precaution, prevention, anticipatory and adaptive governance, and multigenerational justice provide an essential foundation for action.

Preventing AMOC collapse is the most important governance objective, reinforcing the need for ambitious global climate change mitigation action and new efforts to minimize overshoot of 1.5 °C. Strengthened regional and national risk assessment, operational monitoring, and early-warning capacities will be essential to support timely and well-informed decision-making. At the same time, Nordic countries must integrate AMOC-related risks into adaptation and preparedness strategies at national and local levels, supported by coordinated regional and EU-level planning.

Although the AMOC's most immediate impacts are felt in the regions bordering the North Atlantic, it is fundamentally a global system with far-reaching consequences. A collapse would influence both hemispheres and could carry substantial economic repercussions, particularly for rapidly developing countries in the Global South. For this reason, the AMOC should be viewed not as a concern limited to Nordic nations but as a global policy priority requiring broad international cooperation and a global-scale systemic understanding of risks and their interdependence. At the same time, the Nordic region shares similar vulnerabilities to AMOC disruption and benefits from long-standing cooperation mechanisms, including the Nordic Council of Ministers, which together create a strong foundation for joint leadership in addressing tipping-point risks.

In the following sections we examine:

[\(3.1\) the role of multiscale risk and vulnerability assessments](#)

[\(3.2\) the imperative of preventive action and revised approaches to climate mitigation that limit 1.5 °C overshoot](#)

[\(3.3\) The preventive measures beyond zero emissions](#)

[\(3.4\) the need to anticipate and prepare for AMOC impacts through strengthened resilience and adaptation planning.](#)

3.1 AMOC from a risk management perspective

Crossing Earth system tipping points such as the AMOC collapse could set off irreversible, self-reinforcing changes with cascading effects across the biosphere, global economy and human security. This escalating risk landscape calls for a fundamental shift in mindset: From managing gradual and predictable climate change to preparing for nonlinear and high-impact transformations of the Earth system that may unfold within decades. Conventional impact-probability matrices are ill-suited to capture tipping-point dynamics, calling for new risk management approaches that better reflect complexity, interactions and cascades (Lenton et al., 2025; Wunderling et al., 2021)

Many geohazards are routinely addressed through established risk management frameworks, such as the [Sendai Framework for Disaster Risk Reduction](#). It is essential that suitable risk management frameworks are applied to the risk of AMOC collapse, but to do so may require significant adaptation of existing frameworks, as they do not generally capture deep uncertainty, threshold dynamics or cascading impacts. Some efforts to that extent are emerging (e.g., [Hald-Mortensen, 2024](#)), but much remains to be done. Formally recognizing AMOC collapse as a national security or strategic risk, as has been done in Iceland ([Reuters, 2025](#)) could help mobilize resources and institutional attention, enabling the development of practical mitigation and adaptation measures.

A more suitable paradigm is temperature-threshold-based risk assessment, which links tipping risks to scientifically defined warming ranges and classifies them by severity and irreversibility (Abrams et al., 2025). This consequence-focused approach prioritizes cascading impacts, feedback amplification and cross-system interactions over conventional probability estimates and better supports policy-relevant decision-making.

Such an approach has clear governance implications. By focusing on thresholds and the severity of potential impacts, decision-makers can act proactively under deep uncertainty, supported by anticipatory and adaptive governance across sectors and scales. Continuous monitoring, dedicated science–policy interfaces and polycentric coordination are essential to detect early-warning signals, manage cascading risks and enable timely action. (E.g., Abrams et al., 2025; Biesbroek et al., 2025; Milkoreit et al., 2024)

Established marine ecosystem management frameworks (e.g., [Papadopoulou et al., 2025](#)) may provide additional guidance for a holistic approach to ocean–climate system governance. Strengthening the links between climate governance and ecosystem management communities could allow reconciling frameworks for tipping point governance ([Milkoreit et al. 2024](#)) with more established frameworks. For example, the Drivers-Pressures-State change-Impact-Response (DPSIR ([Patricio et al. 2016](#)); and its extension to DAPSI(W)R(M) ([Elliot et al. 2017](#))), calls

for identifying those human needs (Drivers) that are the root cause of the environmental Pressures and need to be managed. In the case of AMOC collapse this first part of the framework is clear, calling for a green societal transformation that motivates the prevention measures - mainly the rapid reduction in greenhouse gas emissions (see [section 3.2](#)). The second part could be used to create those indicators (compare to Good Environmental Status indicators in the EU Marine Framework Directive) that need to be monitored to follow the State, and those assessments that are needed to estimate the Impacts and societal Responses to them. Realising that AMOC can undergo strongly non-linear transformations suggest that the indicators to follow the State, and their limits that trigger further prevention and adaptation measures (see also [section 3.2](#) and [5](#)), need to follow the pre-cautionary principle and trigger early action to avoid the Impacts. Yet, society should create adaptation plans that minimize the Impacts to society.

3.2 Prevention

Global temperature increase is the key driver of observed and projected weakening and the potential collapse of the AMOC (Weijer et al., 2020), creating a direct link between the AMOC tipping point and the emission of greenhouse gases (GHG). The uncertainty range for the AMOC tipping point is currently 1.4 °C – 8 °C of global warming (Armstrong McKay et al., 2022). Preventing AMOC tipping would require minimizing the time global average temperature is within this range. Given that global average temperature today is already approximately 1.4 °C above the pre-industrial level (Kirchengast and Pichler, 2025; Foster et al., 2025) and 1.5 °C will be reached within years (Bavacqua et al. 2025), **minimizing AMOC tipping risks requires immediate efforts to minimize further temperature increase, keeping global peak temperature increase as close to 1.5 °C as possible and returning the temperature increase back to 1.4 °C or lower.**

Current mitigation strategies for CO₂ and short-lived climate pollutants (SLCPs) need to be revised to create global emission pathways that limit overshoot of 1.5 °C (Lenton et al., 2025). Accelerated GHG emission reductions in line with requirements set by the Paris Agreement remain the central strategy to reduce AMOC tipping risks, delay its collapse and limit potential physical impacts. To achieve this, a rapid phase out of fossil fuel is required globally, particularly targeting fossil-fuel production with just phase-out plans and sectors with the highest consumption in the Nordics such as energy, industry, heating, transport, and agriculture (Engström et al., 2024; International Energy Agency, 2024). The Nordics should support the Fossil-Fuel Roadmap initiative led by Colombia and The Netherlands after COP30 and consider how their national efforts to transition away from fossil fuels in a planned and equitable manner can be accelerated. Emissions reduction measures should be supported by strengthening, expanding and recovering carbon sinks, particularly through the Land Use, Land-Use Change

and Forestry (LULUCF) sector. Additional support could come from increasing carbon sinks through afforestation, agriculture practices that increase soil carbon, and ecosystem restoration in land and marine ecosystems - all of which could be prioritised within national climate targets.

Investing in the scaling of sustainable and ethical carbon removal technologies including nature-based (e.g., BECCS, afforestation) and engineered solutions (e.g., direct air capture or marine carbon dioxide removal), is a necessary component of strategies that limit temperature overshoot (Geden and Reisinger 2025; Lenton et al., 2025), enabling the reduction of global temperature back down from its peak (net negative emissions). The scale of carbon removal needed depends on the degree to which emission reductions succeed - the more emission reductions are delayed, the more carbon removal is needed. Fostering carbon removal must not distract from or weaken efforts to reduce carbon emissions. The latter is the more important and more cost effective measure.

It would be in the best interest of the Nordic countries to take the lead in global efforts to limit emissions reductions and temperature increase with a multi-scale strategy. Using their collective, diplomatic influence, they could foster the acceleration of emission reductions within the Paris Agreement's ambition cycle (NDCs, BTRs, Global Stocktake), support the development of a Roadmap away from Fossil Fuels following COP30, and support ambitious policies and emission reduction timelines within the EU. Simultaneously, they could support strengthening multilateral governance of SLCPs, which currently consist of voluntary measures, e.g., the Global Methane Pledge. Third, the Nordic countries should foster multilateral initiatives to rapidly scale up carbon removal, e.g., building on Denmark's effort to create a Group of Negative Emitters ([GONE](#)). All of these multilateral approaches need to be grounded in strengthened national targets, policies and plans with accelerated timelines for reaching net zero and net negative emission targets.

These measures are not only in line with international commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement (ICJ AO 2025), but will also result in co-benefits for the reduction of risks related to other tipping elements besides the AMOC.

3.3 Climate interventions

Climate interventions, or geoengineering solutions could provide additional means to limit global warming levels. In particular, solutions to reflect sunlight and cool the Earth (Solar Radiation Modification, SRM) or stabilise the cryosphere have been suggested as possible complement – not substitution (AGU, 2024) – for emission reduction and negative emission techniques.

SRM aims to reflect $\approx 1\%$ of incoming sunlight (NAS 2021). The most prominent SRM methods are Stratospheric Aerosol Injection (SAI), i.e., injecting reflecting particles into the higher atmosphere, and Marine Cloud Brightening (MCB), i.e., making clouds over oceans more reflective by injecting salt dust. SAI would not be expensive compared to climate impacts (20 Billion \$/year per degree cooling; Smith, 2020), but global coverage would require novel airplanes to dump payloads at $\approx 20\text{km}$ height. Polar-only SAI could be feasible more quickly, rebuilding existing aircraft (Smith, 2024; Duffey et al., 2025). A local MCB pilot project is underway (Hernandez-Jaramillo et al., 2024).

No SRM perfectly offsets greenhouse gas impacts: Regional climate change would remain even if global mean surface temperature were restored. However, well-implemented SRM would likely reduce climate change (Irvine et al., 2019), including in the Arctic (Mettinen 2022). Modelling studies suggest SRM could reduce climate tipping risks for some, but not all tipping points, but uncertainties are large (Futerman et al. 2025; Hirasawa et al., 2023). Several modelling studies suggest global (Fasullo et al. 2018; Xie et al., 2022; Tilmes et al. 2020, Pflüger et al., 2024) and probably polar (Bednarz et al., 2025) SAI reduces AMOC weakening. SAI may be unable to restore previous AMOC weakening, and the combination of an already-weakened AMOC and SAI may overcool the North Atlantic (Pflüger et al., 2024). MCB over the North Atlantic may likewise reduce AMOC weakening (Henry 2025).

However, SRM would entail a range of side effects, including moderate air pollution (Visioni et al., 2020), delayed recovery of the ozone hole (Tilmes et al., 2022), shifts in tropical rainfall due to hemispheric overcooling (Haywood et al., 2013), and rapid global warming if SRM were abruptly terminated (Parker & Irvine, 2018; Trisos et al., 2018). Additional serious consequences may include the weakening of mitigation and prevention efforts (McLaren, 2016) and the emergence of international conflicts (Nielsen, 2025).

Cryosphere interventions may affect AMOC indirectly. Glacial climate interventions aim to stabilize ice sheets (Macayeal 2024; Lockley 2020; Wolovick & Moore 2018; Moore 2018) but may not be effective for rapidly retreating marine-terminating glaciers undergoing rapid retreat (Zhao et al. 2025). If effective, they might reduce Greenland freshwater input. Sea ice preservation (Desch et al. 2017, Field et al. 2018) might cause regional cooling and change North Atlantic salinity distribution, influencing AMOC in complex ways (Liu and Fedorov, 2022). These technologies are still quite speculative.

There is no coherent legal or governance framework for SRM research (particularly large-scale field experiments) or deployment (Reynolds 2021; Brent, 2021), though frameworks developed for other purposes, such as the [London Protocol](#) on Ocean Iron Fertilisation or the Montreal Protocol on ozone-depleting substances might serve as models (Vinders et al. 2024). Some (regional) cryosphere interventions

might fall under on-global bodies (Moore et al., 2021), though unanimous agreements in e.g., the Arctic might be unlikely (Mettinen et al 2022). In recent years, several international commissions ([Overshoot Commission](#), [EU Report SRM](#)) converged around recommending a (temporary) moratorium on SRM implementation and large-scale experiments but also accelerating international, transparent, inclusive research SRM's potential benefits and risks. The scientific community has developed several guidelines on SRM research (AGU 2024, Hubert, 2021) and decision-making (Gardiner and Fragnière, 2018).

Any decision on climate interventions must balance the risks they alleviate against those they cause. In particular, potential benefits for AMOC cannot be viewed in isolation. Nordic countries should push for balanced, ethical research, for regulation against premature or unilateral implementation, and for building global governance structures ahead of potential implementation.

3.4 Adaptation and Preparedness

The risk for rapid AMOC slowdown calls for flexible approaches to climate adaptation and preparedness ([Biesbroek et al. 2025](#); Lenton et al. 2025). At regional, national, and local levels, climate change adaptation plans, and policies are key governance instruments. Presently, they are based on warming scenarios and do not consider AMOC or subpolar gyre tipping (see e.g., Gregow et al. 2021). Existing adaptation policies need to be revisited to consider the implications of potential tipping scenarios. This will be challenging, given that expected climate change impacts differ markedly between tipping and no-tipping futures. Planning for widely diverging trajectories of change under significant uncertainty will require novel approaches, focusing on solutions that would succeed in both warmer and colder, wetter and dryer conditions. There is a need for flexible, long-term measures, such as adaptive multipurpose infrastructures (e.g., building insulation, dikes, electric grid resilience).

In many cases, the revision of climate adaptation strategies will require developing scale-specific (e.g., local or national) AMOC collapse scenarios, which do not exist today. Development of these plans also highlights the increased need for and potential benefit of regional adaptation coordination and planning (e.g., Nordic scenario exercises) in the style of regional climate change strategy processes. Regional interdependencies could create additional/increased vulnerability to AMOC impacts, e.g., intra-regional food trade and interconnected electricity market.

The basis for effective climate adaptation is granular tipping scenario information that can be used for development of sector specific plans – such data is currently lacking. Here we present a few expert-opinion based suggestions for sector specific adaptation measures that account for an AMOC collapse risk. Suggestions for the new data and research needs are found in [section 4. Knowledge gaps and needs for further research](#).

At EU-level the instruments under the [funding for climate action](#) and the [solidarity fund](#) could be further developed to account for longer term AMOC related risks, possibly including insurance-like mechanisms for resource sharing. For example, catastrophe bonds have proven successful in recovery from natural disasters and the covid pandemic. Developing such bonds for climate change induced non-linear changes, such as AMOC tipping, could provide extra funding for adaptation.

Having a diverse and resilient energy system serves both the regular climate change and AMOC collapse scenarios. Depending on the timing of the collapse, the energy system should be capable of dealing with growing heating demand and possible disruption of offshore systems and hydropower provision.

In terms of the transportation sector, increased ice-breaking capacity would serve both the current need to operate in the Arctic, but also the possible expansion of the sea ice in Northern Europe. Regarding land-based transportation, securing the infrastructure resilience for roads and rail transport and maintaining human know-how (local/indigenous knowledge) for harsh winter conditions also in a warmer future is essential. Coordination at different governance levels, as well as emphasizing education and cross-generational learning, is likely useful. Since AMOC collapse induces sea level rise in all AMOC slowdown scenarios, it would be essential to factor the AMOC contribution into the national regulations, such as building regulations and coastal flooding preparedness plans.

Some sectors, such as reindeer herding and winter tourism may benefit from moderate cooling, although possibly associated changes in precipitation and weather extremes create uncertainty. Here again, granular information of both changes in the mean climate and extremes events are needed for creating adaptation plans.

In general, essential social systems such as public health, education, housing, and social services would also likely be heavily affected by the impacts of an AMOC collapse and therefore need to be involved in preparedness and adaptation planning.

AMOC from a bottom-up perspective: The role of private actors and local communities

AMOC risks connected to climate change cannot be managed at a single scale. Following Milkoreit et al (2024), Earth system governance, including climate governance frameworks, require cross-scale and multi-level governance. This also requires articulating an adaptive governance approach that specifies top and bottom-down governance that includes and involves private and societal actors. The private sector includes large multinational corporations with global supply chains and markets that both contribute to greenhouse gas emissions and are also

directly affected by AMOC, as well as small and medium-sized enterprises (SMEs) that mainly need to adapt to changes, and climate entrepreneurs who might have a role in both mitigation and adaptation.

To include a bottom-up approach and engage companies and local communities in AMOC governance we provide an example of the regenerative governance concept to showcase the ability of communities to care for ecosystems and connect with others through place-based and function-specific solutions to national, regional and global challenges (Albareda & Branzei, 2024). The potential collapse of the AMOC highlights the need for regenerative governance community-based action through different phases of change: Before collapse (preventing), during reorganization, and in rebuilding (Hiedanpää et al, 2020). As an adaptation measure, prior to the AMOC collapse, regenerative governance could be adopted by local communities, who have a sustainable mix of traditional and modern food practices and supply chains. The governments can support and invest to gather and share their workable practices and experience, and to co-create adaptation strategies for other communities and societal actors. If an AMOC collapse were to happen, the self-sufficient local communities could adapt by working bottom-up by setting up novel livelihoods adapted to the new stable state by promoting regenerative leadership. Governments and other upper level structures should be ready to support the bottom-up adaptation measures.

4. Knowledge gaps and needs for further research

In the following we identify the most pressing knowledge gaps and research needs that are needed for a well-informed AMOC risk management. In section 5, we make concrete suggestions on how the Nordic countries could take action to close these gaps.

4.1 Observations

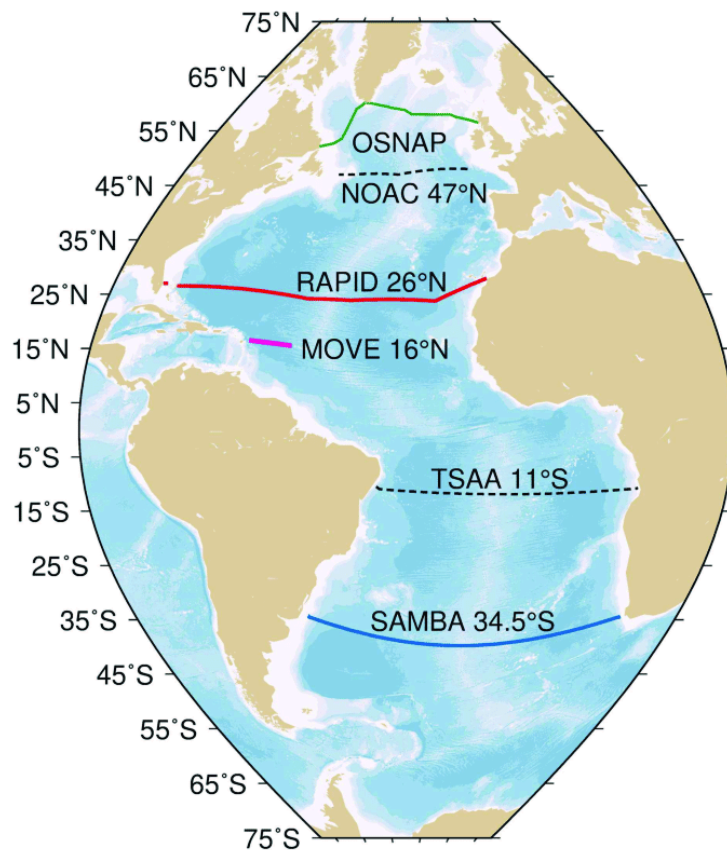


FIGURE 4. Location of AMOC observing arrays, with the figure reproduced from Frajka-Williams et al. (2019). The colors correspond to the operational observational arrays as follows: OSNAP, green; RAPID 26 °N, red; MOVE, magenta; SAMBA 34.5 °S, blue. The two arrays that have not been continuously covered until the present day, NOAC 47 °N (Wett et al., 2023) and TSAA 11S are shown in black dashed lines.

Currently only three programs monitor AMOC strength using direct observations across the full basin width (McCarthy et al. 2017; Frajka-Williams et al. 2019; Figure 4.). RAPID/MOCHA in the subtropical North Atlantic (26.5 °N), °OSNAP in the subpolar North Atlantic (53–59 °N) and SAMBA in the South Atlantic (34.5 °S). Three other programs measure partial transport TRACOS 11 °S, MOVE 16 °N, GSR 60–66 °N. These measurements have given great insight into the complex system of the AMOC and have taught us that on interannual timescales the AMOC responds to different processes on different latitudes (Johns et al. 2023, Fu et al. 2024). However, monitoring efforts have started relatively recently (RAPID 2004, OSNAP 2014, SAMBA 2009) and thus observations are not long enough to attribute the observed AMOC trends to the climate change signal (Volkov et al, 2024; Fu et al, 2024, McCarthy et al 2025). Monitoring efforts in the Atlantic are bottom up initiatives, largely coordinated by individual scientists, with no guaranteed funding in the long term. Some components, such as the Florida Current cable measurements and part of SAMBA are maintained by NOAA (USA). As a result, monitoring efforts are vulnerable to socio-economic and political factors in individual countries. To secure the long-term operation of AMOC monitoring, an international coalition with a dedicated fund and automated data stream (preferably near real-time, e.g., OSNAP currently has a ~2.5 year lag) is needed. Such an initiative not only would secure the long-term monitoring of the AMOC, but it would also contribute to data availability to policymakers. The Nordic countries can and should play a leading role in such an international cooperation that will ensure an early warning system for future AMOC changes.

An AMOC early warning system (see [section 4.3](#)) should also include observations of essential ocean variables (EOVs) such as temperature, salinity, and mixed layer depth – as well as forcing terms, such as runoff from Greenland and freshwater export from the Arctic. The Arctic outflow is presently monitored by small-scale observational systems in the Arctic gateways, i.e., the Fram and Davis straits (Curry et al, 2014; Karpouzoglou et al, 2022), however, funding limitations and extensive sea-ice conditions hinder large scale monitoring, resulting to great uncertainties in the magnitude of the Arctic freshwater outflow (Karpouzoglou et al, 2023). Temperature, salinity, and mixed layer depth observations require both sustaining and expanding the automated buoy (Argo) network and ensuring continued satellite missions for both temperature, salinity and sea surface height. Here, the Nordic countries can play a key role by ensuring continued funding through the Euro-Argo network and ESA – as well as explore possibilities to complement the [Norwegian glider surveys](#). There may also be potential in innovative monitoring (e.g., sensors on submarine cables). Also, indirect estimates (statistical 'fingerprints' , paleo-proxies) of AMOC strength and Northward Heat transport should be further developed and validated against multiple lines of evidence as they appear sensitive to forcing (McMonigal et al., 2025).

All of these monitoring methods have some dual use potential and as such synergies with the increased defense spending should be explored, and especially the scientific access to non-sensitive data should be ensured.

4.2 Modeling & Simulation

As a result of short observational time series, our understanding of AMOC weakening or collapse relies foremostly on modelling studies and proxy evidence. Although climate models compose a great tool in projecting future climate change, they are subject to certain limitations. More specifically, many present-day models poorly represent convection in the north Atlantic Ocean localising it in the Labrador Sea and underestimating the contribution from the Irminger and Iceland Basins (Lozier et al, 2019). Furthermore, most climate models do not resolve the overflow waters from the Greenland Scotland Ridge (~ 5 Sv; Østerhus et al, 2019), which link deep convection in the Nordic Seas with the AMOC. As a result, these models may not correctly account for the resilient dense water formation in the Nordic Seas and the Arctic (Årthun et al, 2025; Moore et al, 2022), that can supply a stable overflow branch to the lower limb of the AMOC (Larsen et al, 2024). Determining the probability (and timing) of crossing an AMOC tipping point is further complicated due to effects of ocean circulation changes beyond the North Atlantic, such as within the Southern Ocean and Indo-Pacific Ocean (Baker et al., 2025; which the models may not adequately simulate due to insufficient resolution), as well as due to the lack of inclusion of coupling to ice sheets (Ackermann et al., 2020; Sinet et al., 2023; Pöppelmeier and Stocker, 2025).

On top of uncertainties surrounding AMOC stability and projections, the climatic impacts of AMOC weakening also play out in different magnitudes across models. While the direction of the impacts of AMOC weakening is consistent across models, the magnitude of these impacts can vary widely across models (Jackson et al., 2023).

To reduce the uncertainty in the likelihood of AMOC collapse, we need better projections of the freshwater and heat budgets in the subpolar North Atlantic. Essential components of such a model system would be a coupled Greenland Ice Sheet (Goelzer et al., 2025; Haubner et al., 2025), eddy resolving ocean resolution ($1/12^\circ$ horizontal resolution) to capture the eddy driven heat and freshwater exchanges between the subpolar gyre and its boundaries (e.g., Schiller-Weiss et al., 2024), and ideally high enough atmospheric resolution to allow for capturing the regional circulation and Greenland Ice Sheet mass balance. A promising approach are global models with regional grid refinement, combining global coherency with regional detail (Herrington et al., 2022). Since the response in Northern Europe is so heavily influenced by sea ice expansion, these model systems should minimize their sea ice biases and be able to capture the observed sea ice trends. Understanding

the broader impacts on climate evolution and the global carbon budget such simulations should be emission driven and include the land vegetation and ocean biogeochemistry.

To reduce the uncertainty in the impact of AMOC collapse, we need sectoral information at regional scales. To do so, we need regionally downscaled AMOC collapse scenarios or global model simulations at high enough horizontal resolution. One such global system could be the EU Destination Earth Climate Digital Twin – albeit it lacks coupling to the Greenland Ice Sheet. At regional scales, the EURO-CORDEX activity could consider protocols for downscaling some of the existing global simulations in which AMOC collapses – ideally such simulations would be done with a regional coupled climate model.

4.3 Early Warning & Indicators

An early warning system for monitoring AMOC tipping point needs to be built using a combination of different approaches. We can aim to monitor the state of the system itself either directly, via proxies, together with timeseries analysis as an indicator of approaching tipping point (Smolders et al., 2025). It remains unclear what kind of lead time direct monitoring of AMOC strength (i.e., timeseries based indicators) could provide, but since AMOC is sensitive to the deep water formation, built up in stratification leading up to cessation in convection can give a decadal lead time. Decadal predictions, initialized on the current ocean state and forecasting near-term forcing, also need to be advanced. Another approach is to monitor the forcing and rely on our theoretical understanding of certain forcing levels being an indicator of forthcoming collapse. For example, freshwater from the Arctic Ocean and Greenland Ice Sheet reaches the subpolar gyre convective regions on 5–10 year timescale (Dukhovskoy et al., 2019).

Currently, we are monitoring the AMOC strength via mooring arrays (and ship based observations), strength of convection in key locations via Argo floats and moorings, and strength of forcing via monitoring Greenland Ice Sheet mass balance and freshwater outflow via Fram and Davis Straits. In addition, satellite observations provide us estimates of sea surface salinity, temperature, and surface current strengths and positions. It would be imperative that these observations continue and that we improve them by:

1. Sustain current monitoring efforts and making the direct mooring array estimates near real time (NRT) – this could potentially be done by renewing equipment and adding a surface unit to allow for NRT data transfer and by automating the data processing into the final AMOC estimate.
2. Ensuring dense enough Argo/ship/other observations and satellite coverage of temperature and salinity for monitoring freshwater, stratification, mixed layer depth, sea surface height and ocean currents, within the key convective

regions within the Subpolar Gyre and the Nordic Seas – including observations below 2000 meters (deep Argo) especially south of the Greenland Scotland Ridge.

3. Link observations between different monitoring systems and study the forcing mechanisms imposing the observed variability by combining models and observations (state estimation).
4. Link AMOC observations with other monitoring efforts such as the regularly maintained hydrographic sections along the coasts of Iceland and Norway in order to better understand impacts on local climate and ecosystems.

In an operational early warning system, observations would be complemented by model simulations. Within the EU, the Copernicus Marine Service, Digital Twin of the Ocean, and Destination Earth Digital Twin of Climate all provide platforms that can be useful. The direct AMOC observations could be operationalized by funding through the Copernicus program. The mass balance of Greenland Ice Sheet is monitored from different satellite products, including the GRACE-FO that is joint US-German effort (and the [planned continuation of gravity measurements](#) to make up a full MAGIC constellation), and ground based observations by Greenlandic/ Danish actors. The DTO and DestinE Climate DT could both serve as a basis for the European early warning model system. For example, the Climate DT system would have the necessary resolution, but lacks coupling to the Greenland ice sheet.

4.4 Socio-Economic & Sectoral Research (impacts and adaptation)

There is an urgent need for interdisciplinary work combining climate physics, ecology, and social sciences along with transdisciplinary work which goes beyond academic disciplines and includes non-academic actors such as local communities, private sector and policy makers.

Most coverage has emphasized physical change – colder winters, altered precipitation, ecosystem disruption (Lenton et al., 2023). The IPCC AR6 defined Climate Impact Drivers (CID) that are relevant for different socio-economic drivers. To help link the physical impacts to societal impacts, a first step could be to map those CIDs that are most impacted by AMOC. Potential areas that have a link to AMOC are agriculture, forestry, fisheries, industrial production, transportation, job markets, energy production, security and supply chains. Agriculture in particular needs priority given its potential impact on social stability and human survival. The change in temperature and precipitation patterns would have direct impacts, such as decreasing agricultural yield or even recurring crop failure particularly in European countries in the Northwest, such as UK, Norway or Finland (OECD 2022, Merikanto et al. 2024).

Social science offers means of interpreting and translating climate science into impacts on societies how change would affect vulnerability. It is also necessary to examine the impacts of AMOC collapse alongside ongoing megatrends in the Nordic countries, including population aging, the dependence ratio, resource scarcity, and mistrust in science. Better science education and communication skills might help to prevent the spread of dis- and misinformation. The impacts of AMOC collapse, as well as the effects of communicating about AMOC collapse on the psychological state of populations and on social acceptance of climate policies, merits research.

The AMOC impact and adaptation research could draw from existing climate change adaptation. For example, Central India has seen an increase in extreme weather events and an increase in temperature, and as an adaptation measure, India has adopted the Dry Farming program to make agriculture climate-resilient. Other efforts to build resilience include laying significant emphasis on organic farming, farming of indigenous crops and cropping style such as paddy cum pisciculture (fish farming in the rice fields; e.g., Apatani community in Arunachal Pradesh). For example, ensuring that cold resilient indigenous crops have large enough seed reserves for further development and eventual use in large scale agriculture would be a plausible adaptation measure for the risk of AMOC collapse. Use of measures such as Geographical Indicator (GI) tags may ensure the continued use of indigenous species that may have relatively low yields. These emphases have empowered people with better alternatives providing them socio-economic resilience which indirectly contributes to climate resilience as well (Rai, 2005; Houmai et al. 2021).

4.5 Indigenous & Local Knowledge

Indigenous Peoples, particularly the Sámi, and local communities in the Arctic practice traditional nature-based livelihoods like reindeer herding and fishing. They possess extensive, experience-based knowledge of environmental change accumulated over centuries. For example, the Northern Sámi language contains over 100 words for snow, highlighting detailed knowledge rooted in its importance for everyday practices. Practitioners of nature-based livelihoods develop expertise through daily interaction with their environment and are often the first to experience climate change impacts, including potential effects of AMOC changes. Hence, scientific monitoring of climatic and environmental change can be significantly enriched by integrating it with indigenous and local knowledge. Relying only on scientific data risks neglecting place-specific, practical manifestations of environmental change in the North, including winter melt-refreezing cycles and summer heat waves affecting reindeer herding communities. Conversely, relying only on indigenous and local knowledge may miss the wider picture on AMOC, including its drivers, mitigation strategies and manifestations across geographical

areas. Adaptation strategies for nature-based livelihoods should thus be co-created with local practitioners and policymakers to ensure fit-for-purpose and maximized impact. Overall, integrating scientific, indigenous, and local knowledge systems provides a fuller picture on environmental and climatic changes related to AMOC. There is a need to map existing knowledge gaps and include a mixed-method approach that integrates both qualitative and quantitative methodological approaches – as well as to develop structures to maintain experience-based knowledge through decades.

5. Suggestions for Nordic Action

The Nordic Countries could actively engage in AMOC monitoring, and take a leading role in coordinating the establishment, and in funding of, an early warning system, and in funding impact research. To achieve this, there are several avenues.

1. **It is necessary to build a resilient AMOC monitoring and early warning system that combines earth observations with model simulations.** Several components of this already exist (see section 4), but their funding is scattered, project based, and they often rely on the work of few individuals. The Nordic Countries could push for a European solution for operationalizing the current efforts with sustained funding. For example, funding could be funneled through the EU Copernicus (Marine Services) and/or EMODnet programs in close collaboration with non-EU partners including the UK, Norway and Iceland as well as North American partners. The first step would be identifying the current actors and their operating costs, based on which an operational program could be designed – here one can benefit from the ongoing Dutch effort at NIOZ to do so for the direct observations of AMOC strength.
 - a. **Early 2026 is a key time to act** and make sure that an early warning system could become a part of key EU level initiatives, as the EU is preparing the Ocean Act (following the Ocean Pact), planning for the continuation of Horizon Europe (10th Framework Program), and as there is an ongoing transition of Mercator Ocean International to an intergovernmental organization.
2. **To produce regionally relevant climate information for different sectors, the Nordic Countries could take direct action,** funding coupled climate downscaling activities and production of sectorial adaptation plans through NordForsk, joint national research council programs, or wider funding initiatives such as the JPI Climate/Oceans or the Sustainable Blue Economy Partnership. These efforts could be done in close collaboration with countries affected by shifts in the tropical rain belt (ITCZ) and southern hemisphere warming, such as India and China, but also key South American and African nations. Relevant simulations to be downscaled are those that are part of the upcoming Coupled Model Intercomparison Project phase 7 (CMIP7) activity.
3. **To reduce uncertainty on the impacts of AMOC collapse in the Nordic region,** the Nordic Countries could ensure that the global scientific cooperation, including assessments done under IPCC, are focused on this question and adequately funded.

4. **To ensure that mitigation efforts take the risk of an AMOC collapse into account**, the Nordic Countries could develop a framework in which the global stocktake and national commitments depend on the associated AMOC collapse risk – essentially enforcing further greenhouse gas emission reductions as the risk increases.
5. **To account for the AMOC tipping risk in national and EU/NATO level climate change adaptation and preparedness planning**, the Nordic countries could create suitable risk management frameworks and, by building upon the suggestions 1–4, identify sectorial impacts and corresponding adaptation/preparedness measures.
6. **To allow sufficient funding for adaptation efforts**, the Nordic countries could work with key agencies to develop products for the catastrophe bond market that could allow for releasing funds in the case of an AMOC collapse.

Storylines

The following two storylines are meant to give the reader an impression of what living in a world with an AMOC collapse might look like. The stories are fictional narratives set in the future and depict different people's local experiences of how they have managed to adapt to changes in the climate.

The first is set in a scenario in which AMOC collapses in low global warming levels causing sea ice expansion in the Nordic Seas toward Iceland. The second is set in Northern Finland in a world where AMOC collapse takes place at an intermediate global warming level with winter time cooling, but summertime warming. Both scenes are set to the year 2087 which is unrealistically soon for the level of impacts imagined, but was a conscious choice by the report writers as the impact of technological development beyond 2150, by which these impacts become more likely, is hard to estimate.

Spring in Iceland in 2087

Ragnar Hjörleifsson still wakes before the February dawn, though there is no dawn anymore – only the slow whitening of the horizon. The sea beyond Þórshöfn lies unmoving, a solid sheet of sea ice that glows faintly under the pale sky. Now 42, Ragnar has fished since he was twelve. His father's boat, *Brynja*, sits half-buried in snow at the pier, ropes frozen into stiff coils. The cooperative that used to own ten boats, fifty men, now stands empty – its office windows blind with frost.

Ragnar remembers when the sea ice began to drift south, around 2068. "*Just a cold year*," they said. Then came 2075, when ice blocked the fjords until May. The coastal fisheries were first to collapse as spawning failed on the ice covered shelves – at the same time, cod and other species Ragnar used to catch from the Iceland Sea, is now out of reach far to the east of the Icelandic waters where the ocean still stays free of ice. People have started to leave – first the younger ones, to Denmark, to Canada, places that still have fish.

At the café, which is one of the last open places in town, Ragnar and other men sit in silence with their hands around cups of synthetic coffee, watching the Ministry's numbers scroll across the wall screen.

Excerpt from the Icelandic Ministry of Economic Development, Report
No. 14/2087

"Fish export revenues declined by 83% between 2079 and 2086. The collapse of pelagic stocks is now total. Domestic food insecurity is projected to reach 62% by winter 2088. Immediate intervention from Nordic and EU partners remains under negotiation."

There's discussion in Parliament of evacuating the northern settlements entirely, consolidating everyone around geothermal hubs in the southwest. Others speak of joining a "Nordic Recovery Bloc" if Norway and Finland agree to share their food reserves.

Addendum: Parliamentary Session Transcript, 18 March 2087

Minister for Trade:

"With the North-West and North-East Passages impassable, global shipping routes are collapsing. Iceland's strategic value has shifted from maritime to geothermal. The age of the ocean is over."

Opposition MP:

"Then what are we, without the sea?"

Ragnar listens, but says nothing. He knows what those words mean: *Emigration*. The end of what his family had done for generations. That night he walks down to the pier, ice cracking under his boots. Beneath the frozen sheet, somewhere deep below, lie the fishing grounds where cod once shimmered like silver dust. He places his hand on the cold rail of *Brynja*, feels the memory of the engine's rumble, the smell of salt and diesel. He knows they cannot stay. There will be nothing to catch, nothing to sell, nothing to eat.

See article about [Snow-covered Iceland](#).

Autumn 2087 in Rovaniemi, Northern Finland

Liisa, 32, has woken up to another morning in Rovaniemi and hurries along the rivershore between the oak trees. Today's tourist group is soon at the docks waiting for her to show up. The riverside park reminds her of her childhood in Copenhagen, though she remembers that her favorite childhood park no longer has trees. None survived the increasingly frequent coastal flooding.

Rovaniemi has been her home for the past twenty years, ever since her family moved back to Finland when her parents found work during the booming 2060s. By that time, the year-round operations along the Northwest Passage and Northeast Passage since the 2050s had led to huge investments in ports along the Norwegian and Russian Barents and Kara Sea coasts. During that time Finland had finally completed a railroad connection up north, which is now the main route for fish and deep-sea mining products to European markets.

Liisa meets the tourist group at the docks and makes sure the German travellers escaping the notorious Hamburg summer heat have their life vests secured. Once everyone is aboard, she steers the boat out of the docks and towards the Ounasjoki river. It would be fun to drive up Kemijoki river as well, but she knows that tourists wouldn't appreciate the view of datacenters along the way. Instead, their destination is a reindeer farm farther upstream, one of the last ones still in operation. Widespread mining and renewable energy developments, combined with summers now too hot for the reindeer calves, have forced most herders out of business.

However, now a new kind of change is at hand. The morning's news once again discussed the slowdown of the North Atlantic ocean circulation and the consequences for the Nordic economy. Last winter marked the deployment of the ICEPACK-era icebreakers along the North West Passage. The seasonal forecast now indicates that this year the North East passage is also likely to remain frozen from November onward, while breaking news suggest that also the Northern Baltic Sea coast may freeze as early as in December for the second year in a row. Built in the 2030s, the icebreakers are now over 50 years old, prompting the Finnish government to consider constructing new vessels. Unfortunately, much of the know-how has been lost, and it remains unclear how quickly it could be rebuilt. The pace of change has been rapid and surprising to many, although scientists had warned that the rapid melting of the Greenland Ice Sheet would have far-reaching consequences. Unfortunately, the proposed early warning system for monitoring the North Atlantic ocean currents was dismissed as a waste of money in the warming world and was never implemented.

People in Lapland, Liisa among them, have grown used to mild winters. During the past two winters, when the temperatures have been below -30 °C, she has been finding herself wondering how her grandfather ever managed to get to school during the winters of the 2020s. After the harsh winter, the snow melted relatively early again this year, as it usually does, and a dry summer has left the water level in the river at a record low. Liisa knows that she must navigate carefully.

While the tourists take their holiday photos, Liisa worries about the electricity bills ahead of the forecasted cold winter. Hydropower from the Kemijoki river is unlikely to heat her apartment as reliably as before, and once again she is grateful that her air conditioning unit also functions as a heat pump.

On the way back, the autumn colours paint the landscape in shades of orange, while the sky turns red with wildfire smoke drifting from massive fires raging across northern Russia and Canada. The tourists take their final photos of the Rovaniemi skyline before boarding the night train bound for Hamburg.

References

Abrams et al. (2025). Chapter 2.1: Introduction to Earth system tipping points risks. In Global Tipping Points 2025 Report.

Ackermann et al. (2020). AMOC recovery in a multicentennial scenario using a coupled atmosphere-ocean-ice sheet model. *Geophys. Res. Lett.*, 47, e2019GL086810. <https://doi.org/10.1029/2019GL086810>

AGU, 2024. Ethical Framework Principles for Climate Intervention Research. <https://agu.mediavalet.com/portals/ethicalframework>

Albareda, L., & Branzei, O (2024). Biocentric work in the Anthropocene: How actors regenerate degenerated natural commons. *Journal of Management Studies*. Online. <https://onlinelibrary.wiley.com/doi/full/10.1111/joms.13080>

Armstrong-McKay et al. (2022) : Exceeding 1.5 C global warming could trigger multiple climate tipping points, *Science* 377.DOI:10.1126/science.abn7950

Asch et al. (2019). Climate change impacts on mismatches between phytoplankton blooms and fish spawning phenology, *Glob. Change Biol.* 25: pp. 2544–2559. <https://doi.org/10.1111/gcb.14650>

Baker et al. (2025). Continued Atlantic overturning circulation even under climate extremes. *Nature* 638, 987–994. <https://doi.org/10.1038/s41586-024-08544-0>

Bellomo, K., & Mehling, O. (2024). Impacts and state-dependence of AMOC weakening in a warming climate. *Geophysical Research Letters*, 51(10), e2023GL107624.

Ben-Yami et al., (2024). Impacts of AMOC Collapse on Monsoon Rainfall: A Multi-Model Comparison, *Earth's Future*. <https://doi.org/10.1029/2023EF003959>

Berdahl et al. (2014). Arctic cryosphere response in the Geoengineering Model Intercomparison Project G3 and G4 scenarios. *Journal of Geophysical Research: Atmospheres*, 119(3), 1308–1321.

Bednarz, E. M., et al. (2025). Stratospheric aerosol injection could prevent future Atlantic Meridional Overturning Circulation decline, but injection location is key. *Earth's Future*, 13, e2025EF005919. <https://doi.org/10.1029/2025EF005919>

Berx et al. (2021). Climate-relevant ocean transport measurements in the Atlantic and Arctic Oceans. Pp. 10–11 in *Frontiers in Ocean Observing: Documenting Ecosystems, Understanding Environmental Changes, Forecasting Hazards*. E.S. Kappel, S.K. Juniper, S. Seeyave, E. Smith, and M. Visbeck, eds, A Supplement to *Oceanography* 34(4), <https://doi.org/10.5670/oceanog.2021.supplement.02-04>.

Biesbroek R et al. (2025) Adaptation planning in the context of a weakening and possibly collapsing Atlantic Meridional Overturning Circulation (AMOC). *Regional Environmental Change* 25(3): 93. <https://doi.org/10.1007/s10113-025-02434-5>

Bonan et al. (2025): Observational constraints imply limited future Atlantic meridional overturning circulation weakening, *Nature Geoscience*, <https://doi.org/10.1038/s41561-025-01709-0>

Boot et al. (2023). Effect of Plankton Composition Shifts in the North Atlantic on Atmospheric pCO₂, *Geophysical Research Letters*, 50, e2022GL100230. <https://doi.org/10.1029/2022GL100230>

Boot et al. (2024). Response of atmospheric pCO₂ to a strong AMOC weakening under low and high emission scenarios. *Climate Dynamics*, 62(8), 7559–7574.

Boot et al. (2025). Global marine ecosystem response to a strong AMOC weakening under low and high future emission scenarios, *Earth's Future*, vol. 13, no. 1, DOI: 10.1029/2024EF004741.

Brent, K. A. (2021) Solar Geoengineering Is Prohibited under International Law." Chapter. In *Debating Climate Law*, edited by Benoit Mayer and Alexander Zahar, 274–84. Cambridge: Cambridge University Press. <https://doi.org/10.1017/9781108879064.021>

Brodeau, L., Koenigk, T. Extinction of the northern oceanic deep convection in an ensemble of climate model simulations of the 20th and 21st centuries. *Clim Dyn* 46, 2863–2882 (2016). <https://doi.org/10.1007/s00382-015-2736-5>

Buckley et al. (2016) , Observations, inferences, and mechanisms of the Atlantic Meridional Overturning Circulation: A review, *Rev. Geophys.*, 54, doi:10.1002/2015RG000493.

Caesar et al. (2021) . Current Atlantic Meridional Overturning Circulation weakest in last millennium. *Nature Geoscience* 14: 118–120 doi: 10.1038/s41561-021-00699-z.

Caesar et al. (2022). Reply to: Atlantic circulation change still uncertain. *Nature Geoscience* doi: 10.1038/s41561-022-00897-3.

Chafik et al. (2022). Irminger Sea is the center of action for subpolar AMOC variability. *Geophysical Research Letters*, 49, e2022GL099133. <https://doi.org/10.1029/2022GL099133>

Chen et al. (2023). Northern-high-latitude permafrost and terrestrial carbon response to two solar geoengineering scenarios. *Earth System Dynamics*, 14(1), 55–79.

Chen et al. (2020). Mitigation of Arctic permafrost carbon loss through stratospheric aerosol geoengineering. *Nature Communications*, 11(1), 2430.

- Curry et al. (2014). Multiyear Volume, Liquid Freshwater, and Sea Ice Transports through Davis Strait, 2004–10. *J. Phys. Oceanogr.*, 44, 1244–1266, <https://doi.org/10.1175/JPO-D-13-0177.1>.
- Cyr et al. (2024) Physical controls and ecological implications of the timing of the spring phytoplankton bloom on the Newfoundland and Labrador shelf, *Limnol. Oceanogr. Lett.*, 9, pp. 191–198. <https://doi.org/10.1002/lol2.10347>
- Desch, S.J., et al. (2017), Arctic ice management. *Earth's Future*, 5: 107–127. <https://doi.org/10.1002/2016EF000410>
- Diaz, D.B (2016). Estimating global damages from sea level rise with the Coastal Impact and Adaptation Model. *Climatic Change* 137, 143–156. <https://doi.org/10.1007/s10584-016-1675-4>
- Dima, M. & Lohmann, G. Evidence for two distinct modes of large-scale ocean circulation changes over the last century. *J. Clim.* 23, 5–16 (2010).
- Ditlevsen, P. D., & S., Ditlevsen (2023). Observation-based early-warning signals for a collapse of the Atlantic Meridional Overturning Circulation. *Nature Communications*, 14, 4254. <https://doi.org/10.1038/s41467-023-39810-w>
- Drijfhout et al. (2012). Is a Decline of AMOC Causing the Warming Hole above the North Atlantic in Observed and Modeled Warming Patterns?. *J. Climate*, **25**, 8373–8379, <https://doi.org/10.1175/JCLI-D-12-00490.1>.
- Drijfhout et al. (2025) . Shutdown of northern Atlantic overturning after 2100 following deep mixing collapse in CMIP6 projections. *Environmental Research Letters*, 20(9), 094062. <https://doi.org/10.1088/1748-9326/adfa3b>
- Duffey et al. (2025). Low-altitude high-latitude stratospheric aerosol injection is feasible with existing aircraft. *Earth's Future*, 13, e2024EF005567. <https://doi.org/10.1029/2024EF005567>
- Dukhovskoy, D. S., et al. (2019). Role of Greenland freshwater anomaly in the recent freshening of the subpolar North Atlantic. *Journal of Geophysical Research: Oceans*, 124, 3333–3360. <https://doi.org/10.1029/2018JC014686>
- Engström et al. (2024). *Policy options for reducing consumption-based emissions: A Nordic survey* (TemaNord 2024:545). Nordic Council of Ministers. <https://doi.org/10.6027/temanord2024-545>
- Falkena et al. (2025). Causal mechanisms of subpolar gyre variability in CMIP6 models. *Earth System Dynamics*, 16 (5), 1833–1844. <https://doi.org/10.5194/esd-16-1833-2025>
- Fasullo, J.T., et al (2018). Persistent polar ocean warming in a strategically geoen지니어ed climate. *Nature Geosci* 11, 910–914. <https://doi.org/10.1038/s41561-018-0249-7>

Field, L., et al. (2018). Increasing Arctic sea ice albedo using localized reversible geoengineering. *Earth's Future*, 6, 882–901.

<https://doi.org/10.1029/2018EF000820>

Fjäder, C. (2017). Talous, infrastruktuuri ja huoltovarmuus. In J. Kielenniva, M. Hyytiäinen, H. Hovi, J. Raitasalo, K. Himberg, J. Eskola, & J. Mölsä (Eds.), *Turvallinen Suomi 2018: Tietoja Suomen kokonaisturvallisuudesta* (pp. 87–102). Turvallisuuskomitea.

Felgenhauer, T., et al. (2022). Solar Radiation Modification: A Risk-Risk Analysis, Carnegie Climate Governance Initiative (C2G), March, New York, NY:

<https://www.c2g2.net/wp-content/uploads/202203-C2G-RR-Full.pdf>

Forster et al. (2025) Indicators of Global Climate Change 2024: annual update of key indicators of the state of the climate system and human influence, *Earth Syst. Sci. Data*, 17, 2641–2680, <https://doi.org/10.5194/essd-17-2641-2025>

Frajka-Williams et al., (2019) Atlantic Meridional Overturning Circulation: Observed Transport and Variability. *Front. Mar. Sci.* 6:260. doi: 10.3389/fmars.2019.00260

Fu et al. (2025). Characterizing the interannual variability of North Atlantic subpolar overturning. *Geophysical Research Letters*, 52, e2025GL114672.

<https://doi.org/10.1029/2025GL114672>

Futerman, et al. (2025) The interaction of solar radiation modification with Earth system tipping elements, *Earth Syst. Dynam.*, 16, 939–978,

<https://doi.org/10.5194/esd-16-939-2025>

Gardiner S.M. and A. Fragnière (2018). The Tollgate Principles for the Governance of Geoengineering: Moving Beyond the Oxford Principles to an Ethically More Robust Approach. *The Tollgate Principles for the Governance of Geoengineering: Moving Beyond the Oxford Principles to an Ethically More Robust Approach* 21, 143–174

Geden, O. and Reisinger, A. (2025). Overshoot: Returning to 1.5°C Requires Net-negative Emissions Targets. SWP Comment, November. Berlin, Germany: Stiftung Wissenschaft und Politik (SWP). Available at: <https://www.swp-berlin.org/publikation/overshoot-returning-to-15c-requires-net-negative-emissions-targets> (accessed 17 December 2025).

Gervais et al. (2018). Mechanisms governing the development of the North Atlantic warming hole in the CESM-LE future climate simulations. *J. Clim.* 31, 5927–5946

Goelzer et al. (2025): Interactive coupling of a Greenland ice sheet model in NorESM2, *Geosci. Model Dev.*, 18, 7853–7867, <https://doi.org/10.5194/gmd-18-7853-2025>

Gregow et al. (2018). Ilmastomuutokseen sopeutumisen ohjauskeinot, kustannukset ja alueelliset ulottuvuudet. Suomen ilmastopaneeli.

<https://doi.org/10.31885/9789527457047>

Gu et al. (2024) Wide range of possible trajectories of North Atlantic climate in a warming world, *Nat. Commun.*, 15, 4221, <https://doi.org/10.1038/s41467-024-48401-2>

Haubner et al. (2025) Limited global effect of climate-Greenland ice sheet coupling in NorESM2 under a high-emission scenario, *EGUsphere* [preprint, accepted], <https://doi.org/10.5194/egusphere-2024-3785>

Haywood, J., et al (2013). Asymmetric forcing from stratospheric aerosols impacts Sahelian rainfall. *Nature Clim Change* 3, 660–665. <https://doi.org/10.1038/nclimate1857>

Henry et al. (2025). Marine cloud brightening to cool the Arctic: An Earth system model comparison. *Earth's Future*, 13, e2025EF006508. <https://doi.org/10.1029/2025EF006508>

Henson et al. (2022). Uncertain response of ocean biological carbon export in a changing world. *Nat. Geosci.* 15, 248–254 (2022). <https://doi.org/10.1038/s41561-022-00927-0>

Hernandez-Jaramillo et al. (2024) New airborne research facility observes sensitivity of cumulus cloud microphysical properties to aerosol regime over the great barrier reef, *Environ. Sci.: Atmos.*, 4, 861–871, <https://doi.org/10.1039/D4EA00009A>

Herrington et al. (2022). Impact of grids and dynamical cores in CESM2.2 on the surface mass balance of the Greenland Ice Sheet. *Journal of Advances in Modeling Earth Systems*, 14, e2022MS003192. <https://doi.org/10.1029/2022MS003192>

Hiedanpää et al. (2020). Beliefs in Conflict: The Management of Teno Atlantic Salmon in the Sámi Homeland in Finland. *Environmental Management*, 66:1039–1058. <https://doi.org/10.1007/s00267-020-01374-6>

Hirasawa, et al. (2023). Effect of regional marine cloud brightening interventions on climate tipping elements. *Geophysical Research Letters*, 50, e2023GL104314. <https://doi.org/10.1029/2023GL104314>

Houmai et al. (2021). Black-rice of Manipur: A potential waiting to be unlocked. *Food and Scientific Reports*, 2(8), 62–64.

Hubert, A-M (2021) A Code of Conduct for Responsible Geoengineering Research. *Global Policy* 12, 82–96. <https://doi.org/10.1111/1758-5899.12845>

Irvine et al. (2019) Halving warming with idealized solar geoengineering moderates key climate hazards. *Nat. Clim. Chang.* 9, 295–299 (2019). <https://doi.org/10.1038/s41558-019-0398-8>

Jackson et al. (2023) Understanding AMOC stability: the North Atlantic Hosing Model Intercomparison Project, *Geosci. Model Dev.*, 16, 1975–1995, <https://doi.org/10.5194/gmd-16-1975-2023>

Karpouzoglou et al. (2022). Observed changes in the Arctic freshwater outflow in Fram Strait. *Journal of Geophysical Research: Oceans*, 127, e2021JC018122. <https://doi.org/10.1029/2021JC018122>

Karpouzoglou et al. (2023). Freshwater transport over the Northeast Greenland shelf in Fram Strait. *Geophysical Research Letters*, 50, e2022GL101775. <https://doi.org/10.1029/2022GL101775>

Kelly et al. (2025) 'Abrupt Changes in the Timing and Magnitude of the North Atlantic Bloom Over the 21st Century', *Journal of Geophysical Research: Oceans*. 130, e2024JC022284. <https://doi.org/10.1029/2024JC022284>

Kirchengast, G. and M. A. Pichler (2025). Traceable global warming record and clarity for the 1.5°C and well-below-2°C goals. *Commun Earth Environ* 6, 402. <https://doi.org/10.1038/s43247-025-02368-0>

Kotz et al. (2022). The effect of rainfall changes on economic production. *Nature* 601, 223–227 (2022). <https://doi.org/10.1038/s41586-021-04283-8>

Larsen et al. (2024). The Coldest and densest overflow branch into the North Atlantic is stable in transport, but warming. *Geophysical Research Letters*, 51, e2024GL110097. <https://doi.org/10.1029/2024GL110097>

Lee, D. G. et al. (2025) Irreversible phytoplankton community shifts over Subpolar North Atlantic in response to CO₂ forcing, *Earth Syst. Dynam.*, 16, 2101–2111, <https://doi.org/10.5194/esd-16-2101-2025>

Lee, J. et al. (2025). Global increases of salt intrusion in estuaries under future environmental conditions. *Nat Commun* 16, 3444 (2025). <https://doi.org/10.1038/s41467-025-58783-6>

Lenton et al. (2023). The Global Tipping Points Report 2023. University of Exeter. <https://report-2023.global-tipping-points.org/>

Li, KY and W. Liu (2025) Weakened Atlantic Meridional Overturning Circulation causes the historical North Atlantic Warming Hole. *Commun Earth Environ* 6, 416 (2025). <https://doi.org/10.1038/s43247-025-02403-0>

Liu et al. (2020). Climate impacts of a weakened Atlantic meridional overturning circulation in a warming climate. *Sci. Adv.* 6, eaaz4876, <https://doi.org/10.1126/sciadv.aaz4876>

Liu, W., and A. Fedorov (2022). Interaction between Arctic sea ice and the Atlantic meridional overturning circulation in a warming climate. *Clim Dyn* 58, 1811–1827. <https://doi.org/10.1007/s00382-021-05993-5>

Lockley et al. (2020). Glacier geoengineering to address sea-level rise: A geotechnical approach. *Advances in Climate Change Research*, 11(4), 401–414. <https://doi.org/10.1016/j.accres.2020.11.008>

- Lozier et al. (2019). A sea change in our view of overturning in the subpolar North Atlantic. *Science* 363,516–521(2019). <https://doi.org/10.1126/science.aau6592>
- Macayeal et al. (2024). Glacial Climate Intervention: A Research Vision (Version 2). U.S. Antarctic Program (USAP) Data Center. <https://doi.org/10.15784/601797>
- Madan et al. (2023). The weakening AMOC under extreme climate change. *Climate Dynamics*, 62, 1291–1309. <https://doi.org/10.1007/s00382-023-06957-7>
- McCarthy et al. (2025). Signal and noise in the Atlantic meridional overturning circulation at 26°N. *Geophysical Research Letters*, 52, e2025GL115055. <https://doi.org/10.1029/2025GL115055>
- McCarthy et al. (2017). The importance of deep, basinwide measurements in optimized Atlantic Meridional Overturning Circulation observing arrays, *J. Geophys. Res. Oceans*, 122, 1808–1826, <https://doi.org/10.1002/2016JC012200>
- McLaren, D. (2016), Mitigation deterrence and the “moral hazard” of solar radiation management. *Earth's Future*, 4: 596–602. <https://doi.org/10.1002/2016EF000445>
- McMonigal, K., et al. (2025). Fingerprints of AMOC decline are sensitive to external and mechanistic forcing. *Geophysical Research Letters*, 52, e2025GL116307. <https://doi.org/10.1029/2025GL116307>
- Menary M. B. and R. A Wood (2018). An anatomy of the projected North Atlantic warming hole in CMIP5 models. *Clim. Dyn.* 50, 3063–3080. <https://doi.org/10.1007/s00382-017-3793-8>
- Merikanto, J. et al. (2024) 'The Significance of Climate Tipping Points for Finland: Latest Information on the Possible Shutdown of the Atlantic Meridional Overturning Circulation (AMOC) and Preventive Climate Actions', Policy Brief, https://www.acccflagship.fi/wp-content/uploads/Tipping_points_Policy_Brief_english.pdf
- Mettiäinen et al. (2022). 'Bog here, marshland there': tensions in co-producing scientific knowledge on solar geoengineering in the Arctic. *Environ. Res. Lett.* 17, 045001. <https://doi.org/10.1088/1748-9326/ac5715>
- Milkoreit et al. (2024). Governance for Earth system tipping points – A research agenda. *Earth System Governance*. 21, 100216. <https://doi.org/10.1016/j.esg.2024.100216>
- Moat et al. (2022) Atlantic meridional overturning circulation observed by the RAPID-MOCHA-WBTS (RAPID-meridional Overturning Circulation and Heatflux Array-Western Boundary Time Series) array at 26°N from 2004 to 2020 (v2020.2), British Oceanographic Data Centre, Natural Environment Research Council [data set], <https://doi.org/10.5285/e91b10af-6f0a-7fa7-e053-6c86abc05a09>
- Moore J.C. et al. (2018). Geoengineer polar glaciers to slow sea-level rise. *Nature* 555, 303–305. <https://doi.org/10.1038/d41586-018-03036-4>

- Moore J.C. et al. (2024). Multi-model simulation of solar geoengineering indicates avoidable destabilization of the West Antarctic ice sheet Earth's Future 12, e2024EF004424. <https://doi.org/10.1029/2024EF004424>
- Moore, J.C., et al. (2021), Targeted Geoengineering: Local Interventions with Global Implications. Glob Policy, 12: 108–118. <https://doi.org/10.1111/1758-5899.12867>
- Moore, G.W.K., et al. (2022). Sea-ice retreat suggests re-organization of water mass transformation in the Nordic and Barents Seas. Nat Commun 13. <https://doi.org/10.1038/s41467-021-27641-6>
- Moriyama et al. (2017). The cost of stratospheric climate engineering revisited. Mitigation and Adaptation Strategies for Global Change, 22(8), 1207–1228. <https://doi.org/10.1007/s11027-016-9723-y>
- Möller, T., et al. (2024) Achieving net zero greenhouse gas emissions critical to limit climate tipping risks. Nat Commun 15, 6192. <https://doi.org/10.1038/s41467-024-49863-0>
- Nielsen J., (2025) The big green button: stratospheric aerosol injection as a geopolitical dilemma during strategic competition between the United States and China, and implications for expanding aerosol injection near-term research, Oxford Open Climate Change, Volume 5, Issue 1, kgaf009, <https://doi.org/10.1093/oxfclm/kgaf009>
- OECD (2022), Climate Tipping Points: Insights for Effective Policy Action, OECD Publishing, Paris, <https://doi.org/10.1787/abc5a69e-en>
- Oliver et al. (2025). The North Atlantic sub-polar gyre and phytoplankton bloom under potential future climate scenarios. ESS Open Archive . September 22, 2025. DOI: 10.22541/essoar.175855713.32401547/v1
- Orihuela-Pinto et al., (2022) : Interbasin and interhemispheric impacts of a collapsed Atlantic Overturning Circulation, Nature Climate Change. <https://doi.org/10.1038/s41558-022-01380-y>
- Parker, A., and P. J Irvine. (2018). The Risk of Termination Shock From Solar Geoengineering. Earth's Future, 6, 456–467. <https://doi.org/10.1002/2017EF000735>
- Pflüger, D., et al. (2024). Flawed emergency intervention: Slow ocean response to abrupt stratospheric aerosol injection. Geophysical Research Letters, 51, e2023GL106132. <https://doi.org/10.1029/2023GL106132>
- Rahmstorf, S. (1996) On the freshwater forcing and transport of the Atlantic thermohaline circulation. Climate Dynamics 12, 799–811 (1996). <https://doi.org/10.1007/s003820050144>
- Rahmstorf, S. 2024. Is the Atlantic overturning circulation approaching a tipping point? Oceanography 37(3):16–29, <https://doi.org/10.5670/oceanog.2024.501>.

Rahmstorf et al. (2024) . Open letter on the risk of AMOC collapse and the need for urgent action [Open letter]. Icelandic Met Office.

https://en.vedur.is/media/ads_in_header/AMOC-letter_Final.pdf

Rai, S. C. (2005) . Apatani paddy-cum-fish cultivation: An indigenous hill farming system of North East India. Indian Journal of Traditional Knowledge, 4(1), 65–71

Reynolds JL (2021). Solar Geoengineering Could Be Consistent with International Law. In: Mayer B, Zahar A, eds. Debating Climate Law. Cambridge University Press:257–273. <https://doi.org/10.1017/9781108879064.020>

Ritchie et al. (2021). Shifts in national land use and food production in Great Britain after a climate tipping point, Nature Food, <https://doi.org/10.1038/s43016-019-0011-3>

Ritchie et al. (2025). Global tipping points report 2025. Implications of overshooting 1.5° C for Earth system tipping points [Chapter 2.3]. Global tipping points report 2025

Robock et al. (2008). Regional climate responses to geoengineering with tropical and Arctic SO₂ injections. Journal of Geophysical Research: Atmospheres, 113(D16).

Rossby et al. (2022). What can hydrography between the New England Slope, Bermuda and Africa tell us about the strength of the AMOC over the last 90 years? Geophysical Research Letters, 49, e2022GL099173.

<https://doi.org/10.1029/2022GL099173>

Schaumann, F. and E. Alastrué de Asenjo (2025). Weakening AMOC reduces ocean carbon uptake and increases the social cost of carbon, Proc. Natl. Acad. Sci. U.S.A. 122 (9) e2419543122, <https://doi.org/10.1073/pnas.2419543122>

Schiller-Weiss, I., et al. (2024). Emerging influence of enhanced Greenland melting on boundary currents and deep convection regimes in the Labrador and Irminger Seas. Geophysical Research Letters, 51, e2024GL109022.

<https://doi.org/10.1029/2024GL109022>

Seidov et al. (2025). AMOC and North Atlantic Ocean Decadal Variability: A Review. Oceans, 6(3), 59. <https://doi.org/10.3390/oceans6030059>

Shin et al. (2025). Reconciled warning signals in observations and models imply approaching AMOC tipping point. <https://doi.org/10.48550/arXiv.2503.22111>

Sinet S et al. (2023) AMOC Stabilization Under the Interaction With Tipping Polar Ice Sheets. Geophysical Research Letters 50:e2022GL100305.

<https://doi.org/10.1029/2022GL100305>

Smeed et al. (2018). The North Atlantic Ocean is in a state of reduced overturning. Geophysical Research Letters, 45, 1527–1533.

<https://doi.org/10.1002/2017GL076350>

Smith et al. (2024). On thin ice: Solar geoengineering to manage tipping element risks in the cryosphere by 2040. *Earth's Future*, 12(8), e2024EF004797.
<https://doi.org/10.1029/2024EF004797>

Smith, W. (2020) The cost of stratospheric aerosol injection through 2100, *Environ. Res. Lett.* 15 114004 [dx.doi.org/10.1088/1748-9326/aba7e7](https://doi.org/10.1088/1748-9326/aba7e7)

Smolders et al. (2025). Optimal observation locations for early warning of the onset of an AMOC collapse. *Geophysical Research Letters*, 52, e2025GL116242.
<https://doi.org/10.1029/2025GL116242>

Stommel (1961): Thermohaline convection with two stable regimes of flow, *Tellus*,
<https://onlinelibrary.wiley.com/doi/abs/10.1111/j.2153-3490.1961.tb00079.x>

Swingedouw et al. (2021) , On the risk of abrupt changes in the North Atlantic subpolar gyre in CMIP6 models. *Ann. N.Y. Acad. Sci.*, 1504: 187–201.
<https://doi.org/10.1111/nyas.14659>

Tilmes, S., et al. (2020). Reaching 1.5 and 2.0°C global surface temperature targets using stratospheric aerosol geoengineering, *Earth Syst. Dynam.*, 11, 579–601,
<https://doi.org/10.5194/esd-11-579-2020>

Tilmes, S. et al. (2022). Stratospheric ozone response to sulfate aerosol and solar dimming climate interventions based on the G6 Geoengineering Model Intercomparison Project (GeoMIP) simulations, *Atmos. Chem. Phys.*, 22, 4557–4579,
<https://doi.org/10.5194/acp-22-4557-2022>

Trisos, C.H., et al (2018). Potentially dangerous consequences for biodiversity of solar geoengineering implementation and termination. *Nat Ecol Evol* 2, 475–482.
<https://doi.org/10.1038/s41559-017-0431-0>

Van Westen et al. (2024). Physics-based early warning signal shows AMOC is on tipping course, *Science Advances*. <https://doi.org/10.1126/sciadv.adk1189>

van Westen & Baatsen (2025). European temperature extremes under different AMOC scenarios in the community Earth system model, *GRL*.
<https://doi.org/10.1029/2025GL114611>

van Westen et al. (2025a): [Physics-based indicators for the onset of an AMOC collapse under climate change](#), *JGR-O*

van Westen et al. (2025b): A saddle-node bifurcation may cause the AMOC collapse in the Community Earth System Model; *ESD*, <https://doi.org/10.5194/egusphere-2025-14>

van Westen et al. (2025c): [Dynamic and Steric Sea-level Changes due to a Collapsing AMOC in the Community Earth System Model](#), *Ocean Science Discussions*, <https://doi.org/10.5194/egusphere-2025-5102>

- van Westen et al. (2025d): [Changing European Hydroclimate under a Collapsed AMOC in the Community Earth System Model](#), HESS
- Vinders, et al. (2024). Deliverable 2.2: Scoping note on applicable legal frameworks. Co-CREATE project. <https://co-create-project.eu/publication/scoping-note-on-applicable-legal-frameworks/> (accessed 15.12.2025)
- Visioni et al. (2020) What goes up must come down: impacts of deposition in a sulfate geoengineering scenario. Environ. Res. Lett. 15 094063, doi.org/10.1088/1748-9326/ab94eb
- Volkov et al. (2024). Florida Current transport observations reveal four decades of steady state. Nat Commun 15, 7780, <https://doi.org/10.1038/s41467-024-51879-5>
- Waidelich et al. (2024). Climate damage projections beyond annual temperature. Nat. Clim. Chang. 14, 592–599. <https://doi.org/10.1038/s41558-024-01990-8>
- Weijer et al., (2020). CMIP6 models predict significant 21st century decline of the Atlantic Meridional Overturning Circulation. Geophysical Research Letters, 47, e2019GL086075. <https://doi.org/10.1029/2019GL086075>
- Wett et al. (2023). Meridional connectivity of a 25-year observational AMOC record at 47°N. Geophysical Research Letters, 50, e2023GL103284. <https://doi.org/10.1029/2023GL103284>
- Wolovick, M.J., and J.C. Moore (2018). Stopping the flood: could we use targeted geoengineering to mitigate sea level rise? The Cryosphere 12, 2955–2967. <https://doi.org/10.5194/tc-12-2955-2018>
- Wunderling et al. (2024). Climate tipping point interactions and cascades: a review, Earth Syst. Dynam., 15, 41–74, <https://doi.org/10.5194/esd-15-41-2024>
- Xie et al. (2022) Impacts of three types of solar geoengineering on the Atlantic Meridional Overturning Circulation. Atmospheric Chemistry and Physics, 22, 4581–4597, <https://doi.org/10.5194/acp-22-4581-2022>
- Yue et al. (2023). Thermosteric and dynamic sea level under solar geoengineering, npj Climate and Atmospheric Science 6:135; <https://doi.org/10.1038/s41612-023-00466-4>
- Zhao et al. (2025). Active ice sheet conservation cannot stop the retreat of Sermeq Kujalleq glacier, Greenland. Commun Earth Environ 6, 186. <https://doi.org/10.1038/s43247-025-02120-8>
- Årthun et al. (2025). Atlantification drives recent strengthening of the Arctic overturning circulation. Sci. Adv. 11, <https://doi.org/10.1126/sciadv.adu1794>
- Østerhus et al. (2019). Arctic Mediterranean exchanges: a consistent volume budget and trends in transports from two decades of observations, Ocean Sci., 15, 379–399, <https://doi.org/10.5194/os-15-379-2019>

About this publication

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