PLOS Climate

OPINION

Preparing for a potential crossing of an AMOC tipping point

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Citation: Nummelin A, Gjermundsen A, Guo C, de Jong MF, Karpouzoglou T, Labastida RGN, et al. (2026) Preparing for a potential crossing of an AMOC tipping point. PLOS Clim 5(3): e0000881. https://doi.org/10.1371/journal.pclm.0000881

Editor: Jamie Males, PLOS Climate, UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

Published: March 31, 2026

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Funding: This study was financially supported by the Nordic Council of Ministers in the form of a grant (103310) received by AN. No additional external funding was received for this study. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

With continuing global warming, several Earth system components are approaching critical thresholds, potentially triggering state shifts [so-called tipping points; [1]. One such component is the Atlantic Meridional Overturning Circulation (AMOC), a large-scale circulation of the Atlantic Ocean that shapes the global and regional climates by redistributing heat across latitudes and by affecting ocean heat and carbon uptake [e.g., 2]. Climate models project a continuous AMOC weakening within the 21st century, with large uncertainties regarding the timing and magnitude of the weakening [3]. At the same time, a transition to a substantially weaker state or collapse after tipping point crossing cannot be ruled out [1,3], and if it were to occur, it would have major implications for the climate and societies globally, but especially in Europe, across the tropics, and in the world's major monsoon regions [4–6].

While the majority of societies are already preparing for the most certain impacts of climate change, such as warming and extreme weather, comparable efforts to prepare for the less predictable, but potentially even more impactful, changes due to crossing of tipping points are not taking place yet. Preparing for such events is challenging due to the uncertainty surrounding their likelihood, timing, and potential impacts. But given that the impacts are large, the precautionary principle must be applied to avoid these tipping points where possible, to reduce their potential impacts, and to prepare societies for their consequences. In the case of the AMOC, research has primarily focused on the likelihood of crossing a tipping point, the associated timescales, and the degree of reversibility. However, we still lack a good understanding of the regionally differentiated climatic impacts of an AMOC collapse and their societal implications across scales – information that is urgently needed for preparedness planning.

Here we outline key actions that we believe societies should take in order to be prepared for a potential crossing of an AMOC tipping point. These ideas draw from a recent report sponsored by the Nordic Council of Ministers [6]. Our perspective is markedly European, but we note that many of the impacts have global implications that warrant attention – and action – also elsewhere.

The case for an early warning system

Detailed and continuously updated knowledge of the AMOC state would give credibility to societal adaptation measures and allow societies some lead time to prepare for the most significant impacts. Such information could be produced by an early warning system that monitors the state of AMOC and its forcings, either directly, or via proxies. Many of the parts required for such a system already exist, but they need to be funded long-term, operationalized and better connected to each other. Such an effort naturally depends on, and should build upon, existing international collaboration, but also requires leadership and coordination, which for example the EU and associated countries could take the lead on, given that Europe faces many of the largest impacts.

The present observations of AMOC state are based on monitoring arrays [7] which, combined with Argo and satellite data, measure currents and hydrographic properties. In addition, the scientific community uses remote sensing and direct observations to monitor dense water formation in the Subpolar North Atlantic and Nordic Seas, as well as the two main sources of freshwater to these regions, i.e., the Greenland ice sheet [8], and the Arctic Ocean [9]. To effectively contribute to an early warning system, these monitoring efforts should provide data in near real time - improving on the current systems that, in terms of the observational arrays for example, provide data with a delay of several years due to the time between instrument deployment and recovery [7].

In addition to monitoring the state of AMOC, we need to develop trustworthy methods of detecting the forced AMOC decline and the potentially approaching AMOC tipping point. Such detection and attribution methods can be developed using model simulations [e.g., 10,11], and new initiatives, such as the EU Destination Earth, could provide the necessary simulations at unprecedented resolutions. Earth System Models can also connect AMOC to other tipping elements of the Earth system across time and space, providing the means to quantify the added risk of tipping cascades [12].

Irrespective of the details of the technical implementation, an early warning system would only become effective when embedded in adaptive governance – decision making systems capable of learning and reflexivity, acting under uncertainty, linking signals to predefined action, and adjusting responses as risks evolve [13]. To make an AMOC early warning system actionable, it would need to operate across scales: from international oversight and cooperation to national, regional, and local level coordination. Moreover, climate and ecosystem indicators need to be integrated with societal dynamics, and local and indigenous knowledge, to recognise dynamics amplifying risks or accelerating positive transformation.

The case for adaptive governance

AMOC changes, including a potential tipping process, take place over decades and would potentially alter Earth's climatic conditions for centuries. The resulting climate change would not be experienced as a discrete climatic anomaly but as a systemic stressor cascading across food, energy, health, trade and welfare institutions [1,6,14]. Such long-term but potentially catastrophic risks characterized by high levels of uncertainty are poorly accounted for within governance frameworks that are structured around short electoral cycles, and national or local adaptation plans, that are based on gradual warming trajectories, and planning logics that rely on efficiency and future discounting [e.g., 15]. Revisiting these frameworks is therefore necessary. Planning must consider widely diverging future scenarios that are plausible with or without AMOC collapse, focusing on flexible adaptation measures that would succeed in both warmer and colder, wetter and drier conditions.

For governments, preserving the continuity of the vital societal infrastructures and welfare provision is a political necessity: failure to guarantee warmth, nutrition, healthcare and basic security could erode institutional trust and result in legitimacy crises. Therefore, governments should ensure preparedness and conduct systemic risk assessments for AMOC collapse scenarios. This includes quantifying the AMOC driven climate impacts, regionally (e.g., possible winter time cooling, shifts in storm tracks, sea level rise, disturbed marine ecosystems in Northern Europe) and globally (shifts in intertropical convergence zone and monsoon systems), as well as their potential societal impacts.

AMOC scenarios should be integrated into climate adaptation plans, national risk frameworks and infrastructure design standards [1,15]. Yet a central constraint is the lack of granular tipping scenario information to inform (sub-)national or sectoral plans. Developing such scenarios would enable targeted adaptation in critical societal functions such as food and energy production, public health and social services. Given the cross-border interdependencies and shared ecosystems, regional coordination and joint scenario exercises would help in addressing shared vulnerabilities [13]. At EU-level, climate action funding and solidarity instruments could be developed to address non-linear risks, including insurance-like mechanisms or catastrophe bonds tailored to tipping events. Also, early warning systems should be institutionally linked to predefined policy triggers, ensuring that emerging signals of destabilisation translate into timely, coordinated responses rather than reactive crisis governance [15].

Recommendations for action

Managing disaster risks is a standard procedure for all societies and while AMOC related impacts are different from those of short-term disasters, they deserve a similar level of risk assessment and preparedness. Here we reiterate the key action points from [6] that we believe are necessary to increase preparedness for AMOC risks:

1) It is necessary to build an operational AMOC early warning system with sustained long-term funding that combines observations with model simulations. We believe Europe could take the lead here, coordinating funding through existing flagship EU programs such as Copernicus, in collaboration with international partners under, e.g., the World Climate Research Program umbrella.

2) The Early Warning System needs to be connected to adaptive governance frameworks that are flexible and built to handle multiple futures. Societal preparedness for the risk of AMOC collapse should be integrated into national adaptation planning, and more concrete research undertaken as to the potential societal implications in each country, given the variation in potential adaptive capacity and resources.

3) To ensure that mitigation efforts account for an AMOC collapse risk, the global stocktake and national commitments should account for the associated AMOC collapse risk – essentially enforcing further mitigation as the risk increases.

We recognize 2026 as a key time for action to ensure that the AMOC early warning system is recognized in preparation of the EU Ocean Act, Integrated Framework of the EU Climate Resilience and Risk Management, and continuation of Horizon Europe (10th Framework Program).

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References

1. Lenton TM, Milkoreit M, Willcock S, Abrams JF, Armstrong McKay DI, Buxton JE, et al. The Global Tipping Points Report 2025. Exeter, UK: University of Exeter; 2025.
2. Katavouta A, Williams RG. Ocean carbon cycle feedbacks in CMIP6 models: contributions from different basins. Biogeosciences. 2021;18(10):3189–218. https://doi.org/10.5194/bg-18-3189-2021
3. IPCC. Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, et al. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2021. https://doi.org/10.1017/9781009157896
4. Jackson LC, Kahana R, Graham T. Global and European climate impacts of a slowdown of the AMOC in a high resolution GCM. Clim Dyn. 2015;45:3299–316.
5. Bellomo K, Meccia VL, D'Agostino R. et al. Impacts of a weakened AMOC on precipitation over the Euro-Atlantic region in the EC-Earth3 climate model. Clim Dyn. 2023;61:3397–416. https://doi.org/10.1007/s00382-023-06754-2
6. Nummelin P, et al. A Nordic perspective on AMOC tipping: impacts and strategies for prevention and governance. TemaNord. 2026;504. https://doi.org/10.6027/temanord2026-504
7. Frajka-Williams E, et al. Atlantic meridional overturning circulation: observed transport and variability. Front Mar Sci. 2019;6:260. https://doi.org/10.3389/fmars.2019.00260
8. Tapley BD, Watkins MM, Flechtner F, Reigber C, Bettadpur S, Rodell M, et al. Contributions of GRACE to understanding climate change. Nat Clim Chang. 2019;5(5):358–69. https://doi.org/10.1038/s41558-019-0456-2 PMID: 31534490
9. Haine TWN, Siddiqui AH, Jiang W. Arctic freshwater impact on the Atlantic Meridional Overturning Circulation: status and prospects. Philos Trans A Math Phys Eng Sci. 2023;381(2262):20220185. https://doi.org/10.1098/rsta.2022.0185 PMID: 37866388
10. Smolders EJV, van Westen RM, Dijkstra HA. Optimal observation locations for early warning of the onset of an AMOC Collapse. Geophys Res Lett. 2025;52(22). https://doi.org/10.1029/2025gl116242
11. Oh J-H, Kug J-S, Shin Y, Geng X, Wang S, Jin F-F, et al. Noise-induced tipping of Atlantic Meridional Overturning Circulation under climate mitigation scenarios. Nat Commun. 2025;16(1):11515. https://doi.org/10.1038/s41467-025-66494-1 PMID: 41390504
12. Jones P, et al. The TIPMIP Earth system model experiment protocol: phase 1. EGUsphere. 2025. https://doi.org/10.5194/egusphere-2025-1899
13. Milkoreit M, Boyd E, Constantino SM, Hausner VH, Hessen DO, Kääb A, et al. Governance for Earth system tipping points – a research agenda. Earth Syst Governance. 2024;21:100216. https://doi.org/10.1016/j.esg.2024.100216
14. KLUG – Deutsche Allianz Klimawandel und Gesundheit e.V., in cooperation with CHARM – European University. How to AMOC: A guide to understanding the uncertainty of Atlantic Meridional Overturning Circulation (AMOC) collapse and navigating effective action. 2025. https://charm-eu.eu/wp-content/uploads/2025/02/AMOC-Guide_250213_ENG.pdf
15. Biesbroek R, Haasnoot M, Mach KJ, Petersen AC. Adaptation planning in the context of a weakening and possibly collapsing Atlantic Meridional Overturning Circulation (AMOC). Reg Environ Change. 2025;25(3):93. https://doi.org/10.1007/s10113-025-02434-5 PMID: 40620821