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The Atlantic's Pulse: Unpacking the Real Risks of AMOC Stagnation, European Cooling, and Rising Seas

Environment * Climate Change * Marine Life

Introduction: The Pulse of the Atlantic and the 2026 Review

The Atlantic Meridional Overturning Circulation (AMOC) functions as a primary heat conveyor of the Earth System, transporting over one petawatt of thermal energy -- roughly 60 times global energy consumption -- from the tropics to northern high latitudes.[1][3] Driven by temperature and salinity density gradients rather than surface winds alone, this thermohaline circulation carries warm, salty water northward into the Labrador and Nordic Seas, releases heat to warm Northwestern Europe, and sinks as dense North Atlantic Deep Water (NADW) -- a cycle that has stabilized Holocene climate for 11,700 years.[1][3][4]

Whether freshwater forcing from melting ice sheets could trigger an abrupt AMOC collapse is the focus of the 2026 Annual Review of Marine Science synthesis by Henk A. Dijkstra and Ren M. van Westen, "The Probability of an AMOC Collapse Onset in the Twenty-First Century."[1] Integrating their 2024 early warning signal study with multi-model analyses of Southern Ocean wind-driven upwelling, the authors reconcile why the AMOC is already on a dangerous "tipping course" toward severe weakening, even though mechanical wind forcing makes a total 0 Sv shutdown unlikely before 2100.[1][5][11]

Theoretical Foundations: Stommel Bistability, Salt-Advection Feedback, and FovS

First formulated by Henry Stommel in 1961, AMOC bistability arises because thermal gradients promote overturning while high-latitude net precipitation acts as a "saline brake," allowing both a vigorous "On" state and a collapsed "Off" state under identical external radiative forcing.[2][4] Transitions between states are governed by the positive, destabilizing salt-advection feedback: when meltwater from the Greenland Ice Sheet dilutes North Atlantic surface salinity, deep sinking weakens, which slows northward salt transport, freshening the subpolar basin further in a self-reinforcing spiral.[4][5][6]

The key stability diagnostic evaluated by Dijkstra and van Westen is FovS: net meridional freshwater transport by the overturning circulation at 34 deg S.[5][9] A positive FovS (importing net freshwater) creates a stabilizing monostable regime, whereas a negative FovS (exporting freshwater / importing salt) places the Atlantic in a vulnerable bistable regime.[5][7] Crucially, hydrographic observations confirm that the real-world Atlantic has a negative FovS, whereas most IPCC CMIP6 models suffer from freshwater biases that produce a positive FovS, artificially shielding them from collapse.[5][8]

Reconciling the 2024 Early Warning Signal with the 2026 Stability Assessment

Moving beyond noisy statistical proxies in sea surface temperature records, van Westen, Kliphuis, and Dijkstra (2024) forced a complete AMOC collapse (~17 Sv to near zero) in the high-resolution Community Earth System Model (CESM), identifying that FovS at 34 deg S reaches a distinct minimum roughly 25 years before tipping.[5] Observational reanalyses show the modern Atlantic actively trending toward this FovS minimum.[5][9][10]

Why, then, does their 2026 review judge a total collapse before 2100 "unlikely"?[1] Three global mechanisms govern the trajectory:

* Southern Ocean Wind-Driven Upwelling: Around Antarctica, persistent westerly winds drive northward surface Ekman transport via the Coriolis effect, mechanically pulling deep NADW to the surface.[11][12] Even if North Atlantic density sinking fails, this Southern Ocean wind pump sustains a weak circulation floor (~5-8 Sv) rather than a 0 Sv shutdown.[1][11]

* Inefficient Pacific Seesaw Compensation: Although AMOC weakening initiates an embryonic Pacific Meridional Overturning Circulation (PMOC), it reaches only ~5 Sv -- too weak to balance Southern Ocean upwelling, forcing the Atlantic to continue overturning.[1][13]

* Rare-Event Sampling (TAMS): Using Trajectory-Adaptive Multilevel Sampling (TAMS) on bias-corrected models, the authors find a 10-20% probability of crossing the tipping onset this century, while full collapse completion takes decades beyond 2100.[1][14][15]

| Metric | | Physical Definition | | Observational Reality | | CMIP6 Model Bias | | Stability Implication |

| AMOC Strength | | Overturning transport at 26.5 deg N | | ~17 Sv (weakening) | | Varied (10-25 Sv) | | Baseline conveyor vigor. |

| FovS (34 deg S) | | Freshwater transport at 34 deg S | | Negative (Imports Salt) | | Positive (Imports Fresh) | | Real ocean is bistable; models over-stable. |

| FovS Minimum | | Physics-based tipping precursor | | Trending toward minimum | | Dampened without eddies | | System is losing resilience. |

Global Consequences and Paleoclimate Precedents

Even without a 0 Sv shutdown, a 30-50% AMOC stagnation -- considered likely (>66%) this century -- triggers severe global impacts:[1][16]

* European Cooling and Winter Storms: Against background climate change warming, subpolar heat loss cools Scandinavia and the UK by 3 deg C to 8 deg C under severe weakening while intensifying the North Atlantic storm track.[16][17]

* Dynamic U.S. East Coast Sea-Level Rise: Relaxing geostrophic Coriolis deflection causes water to slump westward against North America, adding 20 to 80+ cm of dynamic sea-level rise from Miami to Boston.[18][19]

* Monsoon Shift and Ocean Deoxygenation: A southward shift of the Intertropical

Convergence Zone (ITCZ) dries the West African Sahel and disrupts Asian monsoons, while reduced deep ventilation starves abyssal ecosystems of dissolved oxygen and surface phytoplankton of nutrients.[11][20][21]

| 21st-Century Scenario | | Probability | | Primary Driver | | Key Regional & Global Impacts |

| Stagnation (30-50% decline) | | Likely (>66%) | | Thermal stratification & meltwater | | Regional European cooling, 15-30 cm U.S. dynamic SLR, ITCZ rain shift. |

| Total Shutdown (0 Sv) | | Unlikely (<10%) | | Runaway salt-advection feedback | | 3 deg C-8 deg C European cooling, >50 cm dynamic SLR, monsoon failure, deep anoxia. |

Paleoclimate archives -- including the Younger Dryas (12,900 BP), when Lake Agassiz meltwater plunged Greenland by 10 deg C, and the 8.2 ka event -- confirm that once freshwater thresholds are crossed, the Atlantic conveyor reorganizes abruptly.[22][23][24][25]

Conclusion: Navigating a Narrowing Stability Margin

Dijkstra and van Westen's 2026 review demonstrates that while Southern Ocean wind upwelling likely prevents a total 0 Sv shutdown before 2100, negative FovS observations confirm the Atlantic is bistable and losing resilience.[1][5][11] Mitigating the severe risks of a 30-50% AMOC stagnation -- from U.S. coastal inundation to European cooling and tropical monsoon disruption -- requires urgent emissions reductions and eddy-resolving ocean monitoring at 34 deg S.[1][9][16][18]

Works Cited

* [1] Dijkstra, H. A., & van Westen, R. M. (2026). The Probability of an AMOC Collapse Onset in the Twenty-First Century. Annual Review of Marine Science. https://doi.org/10.1146/annurev-marine-040324-024822

* [2] Rahmstorf, S. (1995). Bifurcations of the Atlantic thermohaline circulation in response to changes in the hydrological cycle. Nature. https://doi.org/10.1038/378145a0

* [3] Buckley, M. W., & Marshall, J. (Mar 2016). Observations, inferences, and mechanisms of the Atlantic Meridional Overturning Circulation: A review. Reviews of Geophysics, 54(1), 5-63. https://doi.org/10.1002/2015RG000493

* [4] Hofmann, M., & Rahmstorf, S. (2009). On the stability of the Atlantic meridional overturning circulation. Proceedings of the National Academy of Sciences. https://doi.org/10.1073/pnas.0909146106

* [5] van Westen, R. M., Kliphuis, M., & Dijkstra, H. A. (2024). Physics-based early warning signal shows that AMOC is on tipping course. Science Advances. https://doi.org/10.1126/sciadv.adk1189

* [6] Rahmstorf, S. (2024). Is the Atlantic Overturning Circulation Approaching a Tipping Point? Oceanography. https://doi.org/10.5670/oceanog.2024.501

* [7] Haines, K., Ferreira, D., & Mignac, D. (2022). Variability and Feedbacks in

the Atlantic Freshwater Budget of CMIP5 Models With Reference to Atlantic Meridional Overturning Circulation Stability. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2022.830821

* [8] van Westen, R. M., & Dijkstra, H. A. (2024). Persistent climate model biases in the Atlantic Ocean's freshwater transport. Ocean Science. https://doi.org/10.5194/os-20-549-2024

* [9] Ocean to Climate (Feb 10, 2024). Sustained ocean measurements at 34 deg S crucial for estimating the distance to an AMOC collapse. https://ocean2climate.org/2024/02/10/sustained-ocean-measurements-at-34s-crucial-for-estimating-the-distance-to-an-amoc-collapse

* [10] The Guardian (Feb 9, 2024). Atlantic Ocean circulation nearing 'devastating' tipping point, study finds. https://www.theguardian.com/environment/2024/feb/09/atlantic-ocean-circulation-nearing-devastating-tipping-point-study-finds

* [11] Baker, J., et al. (2025). Continued Atlantic overturning circulation even under climate extremes. Nature. https://doi.org/10.1038/s41586-024-08544-0

* [12] Liu, W., et al. (2021). The Driving Mechanisms on Southern Ocean Upwelling Change during the Last Deglaciation. Geosciences. https://doi.org/10.3390/geosciences11070266

* [13] Burls, N., et al. (2017). Active Pacific meridional overturning circulation (PMOC) during the warm Pliocene. Science Advances. https://doi.org/10.1126/sciadv.1700156

* [14] Jacques-Dumas, V., Dijkstra, H. A., & Kuehn, C. (Jul 2, 2024). Resilience of the Atlantic Meridional Overturning Circulation. arXiv:2407.04740. https://arxiv.org/abs/2407.04740

* [15] Jacques-Dumas, V., et al. (2024). Estimation of AMOC Transition Probabilities Using a Machine Learning-Based Rare-Event Algorithm. Artificial Intelligence for the Earth Systems. https://doi.org/10.1175/aies-d-24-0002.1

* [16] van Westen, R. M., et al. (2025). Changing European hydroclimate under a collapsed AMOC in the Community Earth System Model. Hydrology and Earth System Sciences. https://doi.org/10.5194/hess-29-6607-2025

* [17] Keating, C. (Jun 11, 2025). Ocean current 'collapse' could trigger 'profound cooling' in northern Europe - even with global warming. Carbon Brief. https://www.carbonbrief.org/ocean-current-collapse-could-trigger-profound-cooling-in-northern-europe-even-with-global-warming/

* [18] NOAA Climate.gov (Jun 11, 2024). Drivers and improved predictability of sea level rise along the U.S. Southeast Coast. https://www.climate.gov/news-features/feed/drivers-and-improved-predictability-sea-level-rise-along-us-southeast-coast

* [19] Yin, J. (2023). Rapid Decadal Acceleration of Sea Level Rise along the U.S. East and Gulf Coasts during 2010-22 and Its Impact on Hurricane-Induced Storm Surge. Journal of Climate. https://doi.org/10.1175/jcli-d-22-0670.1

* [20] Ocean to Climate (Dec 28, 2025). A Collapse Of The AMOC Would Drastically Alter Global Monsoons. https://ocean2climate.org/2025/12/28/a-collapse-of-the-amoc-would-drastically-alter-global-monsoons/

* [21] Ben-Yami, M., et al. (2024). Impacts of AMOC Collapse on Monsoon Rainfall: A

Multi-Model Comparison. Earth's Future. https://doi.org/10.1029/2023ef003959

* [22] School for Climate Studies, Stellenbosch University (Oct 3, 2025). AMOC shut-down by 2100 - should important new results be used to update an approved IPCC consensus on risk? https://climate.sun.ac.za/uncategorized/amoc-shut-down-by-2100-should-important-new-results-be-used-to-update-an-approved-ipcc

* [23] Delworth, T. L., Clark, P. U., Holland, M., et al. (2008). Chapter 4: The Potential for Abrupt Change in the Atlantic Meridional Overturning Circulation. In Abrupt Climate Change (CCSP SAP 3.4), NOAA GFDL. https://www.gfdl.noaa.gov/bibliography/related_files/td0802.pdf

* [24] Kilhavn, H., et al. (2022). The 8.2 ka event in northern Spain: timing, structure and climatic impact from a multi-proxy speleothem record. Climate of the Past. https://doi.org/10.5194/cp-18-2321-2022

* [25] Duan, P., et al. (2024). A series of climate oscillations around 8.2 ka revealed through multi-proxy speleothem records from North China. Climate of the Past. https://doi.org/10.5194/cp-20-1401-2024