EGU25-10648, updated on 07 Dec 2025
https://doi.org/10.5194/egusphere-egu25-10648
EGU General Assembly 2025
© Author(s) 2025. This work is distributed under
the Creative Commons Attribution 4.0 License.

Assessing the Probability of CO_2-Driven AMOC Collapses Using Rare Event Algorithms in PlaSIM-LSG

Matteo Cini[1,2], Valerian Jacques-Dumas[3], and Henk A. Dijkstra[3,4]

[1]University of Turin, Department of Physics, Turin, Italy
[2]National Research Council of Italy, Institute of Atmospheric Sciences and Climate (CNR-ISAC), Bologna, Italy.
[3]Institute for Marine and Atmospheric research Utrecht, Department of Physics, Utrecht University, Utrecht, the Netherlands
[4]Centre for Complex Systems Studies, Department of Physics, Utrecht University, Utrecht, the Netherlands

The Atlantic Meridional Overturning Circulation (AMOC) is a key tipping element of the climate system due to its influence in regulating the meridional transport of heat and freshwater. Its stability is influenced by the interplay between external forcings (such as greenhouse gasses increase) and internal climate variability. Due to limitations on the deterministic predictability of the AMOC asymptotic state, the concept of a "probabilistic safe operating space" has been proposed. For this purpose, rare-event techniques, specifically the Giardina–Kurchan–Tailleur–Lecomte (GKTL) and Trajectory-Adaptive Multilevel Splitting (TAMS) algorithms, offer promising tools for testing the multistability of the system and assessing this probability at lower computational costs than traditional Monte Carlo methods. Here, using the intermediate complexity model (PlaSIM-LSG), we estimate the probability of AMOC collapse in sensitivity experiments at different CO_2concentrations and under RCPs scenarios. In particular, TAMS has been applied in order to assess the probability of reaching a low circulation state of the AMOC associated with a 1°C temperature anomaly over central and western Europe. Our findings from sensitivity experiments, consistently with previous studies, indicate that for a wide range of CO_2 concentrations (500-600 ppm), the probability of an AMOC collapse is significantly different from zero (1-10% within 150 years). While such a collapse is unlikely to happen within the 21st century, it becomes likely to happen by 2150 in higher emission scenarios. It is important to note that PlaSIM-LSG does not account for the North Atlantic freshwater flux from Greenland melting which introduces a stabilizing bias for the AMOC-on state. Accounting for this mechanism would likely increase the probability of an AMOC collapse. These results underscore the importance of probabilistic assessments in understanding AMOC stability and highlight the potential for rare-event algorithms to provide insights into the statistical properties of tipping point.