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Exploring Noise-induced and CO2-driven AMOC collapses in the PlaSIM-LSG climate model with a Rare Event Algorithm.

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Earth-system Models of Intermediate Complexity (EMICs) are climate models featuring a simplified representation of climate processes and a much lower computation cost. This makes them particularly suitable for exploring phenomena with a large ensemble simulation approach. Here we use the coupled atmosphere-ocean PlaSIM-LSG EMIC to study the possibility of Atlantic Meridional Overturning Circulation (AMOC) spontaneous collapses and how this is altered in the presence of external anthropogenic forcing. Understanding the stability of the AMOC and its response to anthropogenic forcing is of key importance for advancing climate science. The idea of a "safe-operating space" has been proposed in order to define a threshold on anthropogenic forcing within which the AMOC does not lose stability. This requires understanding the combined action of CO2-driven and noise-induced processes in climate tipping events

First, we address the occurrence of noise-induced AMOC collapses, i.e. spontaneous abrupt weakening events induced by chaotic internal climate variability in absence of any external forcing. We address the problem of finding these extreme events via the application of a Rare Event Algorithm, which - via a selective cloning of the most interesting model trajectories - allows a faster exploration of the model phase space in the direction of an AMOC decrease. The algorithm is applied to a PlaSIM-LSG ensemble simulation run at T21 spectral resolution in the atmosphere, and 3.5 degrees in the ocean, with fixed pre-industrial conditions. A number of collapse events, unseen in the pre-industrial control run, are sampled by the algorithm. Looking at the mechanisms causing the AMOC spontaneous collapse, we find that zonal wind stress over the North Atlantic is the main driver of the initial AMOC slowdown, while the suppression of surface convection in the Labrador sea is the likely cause of the subsequent AMOC collapse. Then, we investigate the influence of increasing CO2 levels on the frequency of these spontaneous AMOC collapses. We show that a higher CO2 not only leads to the well-known weakening of the AMOC mean state, but it also increases the possibility of incurring in abrupt noise-induced transitions. The employment of EMICs, combined with the proposed approach, samples a large number of *rare phenomena. This procedure allows us to explore statistical properties that are not accessible with a deterministic approach in state-of-the-art high resolution models.*