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Data-driven estimation of the committor function for an idealised AMOC model

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The Atlantic Meridional Overturning Circulation (AMOC) transports warm, saline water towards the northern North Atlantic, contributing substantially to the meridional heat transport in the climate system. Measurements of the Atlantic freshwater divergence show that it may be in a bistable state and hence subject to collapsing under anthropogenic forcing. We aim at computing the probability of such a transition. We focus on timescales of the century and on temporary collapses of the AMOC. Using simulated data from an idealized stochastic AMOC model, where forcing and white noise are applied via a surface freshwater flux, we compute the transition probabilities versus noise and forcing amplitudes.

Such transitions are very rare and simulating long-enough trajectories in order to gather sufficient statistics is too expensive. Conversely, rare-events algorithms like TAMS (Trajectory-Adaptive Multilevel Sampling) encourage the transition without changing the statistics. In TAMS, N trajectories are simulated and evaluated with a score function; the poorest-performing trajectories are discarded, and the best ones are re-simulated.

The optimal score function is the committor function, defined as the probability that a trajectory reaches a zone A of the phase space before another zone B. Its exact computation is in general difficult and time-consuming. In this presentation, we compare data-driven methods to estimate the committor. Firstly, the Analogues Markov Chain method computes it from the transition matrix of a long re-simulated trajectory. The K-Nearest Neighbours method relies on an existing pool of states where the committor function is already known to estimate it everywhere. Finally, the Dynamical Modes Decomposition method is based on a Galerkin approximation of the Koopman operator. The latter is the most efficient one for the AMOC model when using adaptive dimensionality reduction of the phase space.