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Stochastic theory of AMOC bistability using a minimal set of state variables

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A stochastic analytical model of the Atlantic Meridional Overturning Circulation (AMOC) is presented and tested against climate model data. AMOC stability is characterised by an underlying deterministic differential equation describing the evolution of the central state variable of the system, the average Atlantic salinity. Stability of an equilibrium implies that infinitesimal salinity perturbations are damped, and violation of this requirement yields a range of unoccupied salinity states. The range of states is accurately predicted by the analytical model for a coupled climate model of intermediate complexity. The introduction of climatic noise yields an equation describing the evolution of the probability density function of the state variable, and therefore the AMOC. Given the hysteresis behaviour of the steady AMOC versus surface freshwater forcing, the statistical model is able to describe the variability of the AMOC based on knowledge of the variability in the forcing. The method accurately describes the wandering between AMOC-on and AMOC-off states in the climate model. The framework presented is a first step in relating the stability of the AMOC to more observable aspects of its behaviour, such as its transient response to variable forcing.