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Characterising meridional overturning bistability as a dynamical system using a minimal set of state variables.

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Multiple steady states of the Atlantic overturning circulation (AMOC) and the collapse of the formation of North Atlantic Deep Water (NADW) remain poorly understood. Box models offer a simplified analogue of the more complex numerical models, with the benefit of more easily understood dynamics. However, the nature of the relationship between the highly simplified systems and reality is uncertain, and rigorous quantitative comparisons are lacking. Here, we take an alternative approach via a simplified but remarkably accurate mathematical description of the net salt exchange between the Atlantic and the rest of the world ocean, thus circumventing ambiguities inherent in box models. In particular, all component variables of the dynamical system can be verified against a numerical model or observations. A precise formulation of the Atlantic salinity feedback is then used to characterise AMOC stability, yielding surprising results discussed in this talk. Stability of NADW “on” and “off” is linked to the effect of feedbacks on the growth of infinitesimal salinity anomalies on the average Atlantic salinity. The simplified dynamical system model describes the emergent laws governing the complexities of the numerical circulation model, offering a close approximation of key aspects and behaviours. Time dependent behaviour is accurately described by a time-delayed version of the differential equations governing the equilibrium states in the simple mathematical model. The bistability structure consisting of the equilibrium branches as a function of a control parameter is thus related to the time dependent behaviour of the system. This may assist in determining the existence of stable NADW "off" states in computationally expensive numerical climate models where hysteresis experiments are not feasible. The results presented here help understand the dynamics underlying the AMOC response to past and future climatic changes, and the possibility of a NADW collapse in particular.