EGU22-4470
https://doi.org/10.5194/egusphere-egu22-4470
EGU General Assembly 2022

Abundant multistability and intermediate tipping points in a global ocean model

Johannes Lohmann
University of Copenhagen, Physics of Ice, Climate and Earth, Niels Bohr Institute, Copenhagen, Denmark (johannes.lohmann@nbi.ku.dk)

Several climate sub-systems are believed to be at risk of undergoing abrupt, irreversible changes as a tipping point (TP) in Greenhouse gas concentrations is reached. Since the current generation of climate models is likely not accurate enough to reliably predict TPs, a hope is to anticipate them from observations via early-warning signals (EWS). EWS have been designed to identify generic changes in variability that occur before a well-defined TP is crossed.

Such well-defined, singular TPs are believed to arise from a single dominant positive feedback that destabilizes the system. However, one may ask whether the large number of spatio-temporal scales in the climate system, and associated second-order feedbacks, could not lead to a variety of more subtle, but discontinuous reorganizations of the spatial climate pattern before the eventual catastrophic tipping. Such intermediate TPs could hinder predictability and mask EWS.

We performed simulations with a global ocean model that shows a TP of the Atlantic meridional overturning circulation (AMOC) due to freshening of the surface waters resulting from increased ice melt. Using a large ensemble of equilibrium simulations, we map out the stability landscape of the ocean circulation in high detail. While in a classical hysteresis experiment only one regime of bistability is found, by very slow increases in forcing we observe an abundance of discontinuous, qualitative changes in the AMOC variability. These are used to initialize smaller-scale hysteresis experiments that reveal a variety of multistable regimes with at least 4 coexisting alternative attractors.

We argue that due to chaotic dynamics, non-autonomous instabilities, and complex geometries of the basins of attraction, the realized path to tipping can be highly sensitive to initial conditions and the trajectory of the control parameter. Further, we discuss the degree to which the equilibrium dynamics are reflected in the transient dynamics for different rates of forcing. The results have implications regarding the expected abruptness of TPs, as well as their predictability and the design of EWS.