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Analysing Conceptual Climate Models with Monte Carlo Basin Bifurcation Analysis

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Many high-dimensional complex systems such as climate models exhibit an enormously complex landscape of possible asymptotic state. On most occasions these are challenging to analyse with traditional bifurcation analysis methods. Often, one is also more broadly interested in classes of asymptotic states. Here, we present a novel numerical approach prepared for analysing such high-dimensional multistable complex systems: Monte Carlo Basin Bifurcation Analysis (MCBB). Based on random sampling and clustering methods, we identify the type of dynamic regimes with the largest basins of attraction and track how the volume of these basins change with the system parameters. In order to due this suitable, easy to compute, statistics of trajectories with randomly generated initial conditions and parameters are clustered by an algorithm such as DBSCAN. Due to the modular and flexible nature of the method, it has a wide range of possible applications. While initially oscillator networks were one of the main applications of this methods, here we present an analysis of a simple conceptual climate model setup up by coupling an energy balance model to the Lorenz96 system. The method is available to use as a package for the Julia language.