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Global cooling: the Snowball Earth transition in a climate model with drifting parameters

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Using an intermediate complexity climate model (Planet Simulator), we investigate the so called Snowball Earth transition. For certain values of the solar constant, the climate system allows two different stable states. One of them is the Snowball Earth, covered by ice and snow, and the other one is today's climate.

In our setup, we consider the case when the climate system starts from its warm attractor (the stable climate we experience today), and the solar constant is decreased continuously in finite time, according to a parameter drift scenario, below the bifurcation point, where only the Snowball Earth's attractor remains stable. This induces an inevitable tipping transition from the warm climate.

The reverse transition is also discussed. Increasing the solar constant back to its original value, we find that the system typically stays stuck in the Snowball state. However, using ensemble methods i.e. using an ensemble of climate realizations differing only slightly in their initial conditions we show that the tipping transition from the Snowball Earth to the warm climate is also possible, but with a much lower probability. From the point of view of dynamical systems theory, we can say that the system's snapshot attractor splits unevenly between the warm climate's and the Snowball Earth's attractor.