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When the Earth goes white: the Snowball Earth attractor

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Using an intermediate complexity climate model we investigate the so-called snowball Earth transition. For certain values (including its current value) 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 changed according to the following scenario: it is decreased continuously and abruptly, over one year, to a state, where only the Snowball Earth's attractor remains stable. This induces an inevitable transition, or climate tipping from the warm climate. The reverse transition is also discussed. Increasing the solar constant back to its original value in a similar way, in individual simulations, depending on the rate of the solar constant reduction we find that either the system stays stuck in the snowball state or returns to a warm climate. However, using ensemble methods i.e., using an ensemble of climate realizations differing only slightly in their initial conditions we show that the transition from the snowball Earth to the warm climate is also possible with a certain probability which depends on the specific scenario used. From the point of view of dynamical systems theory, we can say that the system's snapshot attractor splits between the warm climate's and the snowball Earth's attractor. Despite the limitations of an intermediate complexity climate model, all this reveals that incautious geoengineering (e.g. overdone solar radiation shielding) could even result in a snowball-like climate.