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Topological Climate Change

Climate change is undoubtedly one of the most impactful crises affecting humanity today. An increase in carbon emissions due to human activity induces a slew of additional climate effects such as rising sea levels, increase in extreme weather events, and more. The Earth's climate is a complicated combination of interdependent parts and behaves in a highly nonlinear fashion. Applying the mathematical theory of bifurcation to climate science allows for a new lens through which to view the challenges posed when attempting to model the climate. Such a model is better tuned to forecast major changes in the climate, as opposed to methods that capture gradual variations. An energy balance model in the form of a two-dimensional dynamical system is reduced to a single dimension on an centre manifold and transformed into the normal form of a cusp bifurcation. Four parameters, the carbon dioxide concentration of the atmosphere; the meridional ocean heat transport; the relative humidity; and an albedo switch function smoothness parameter; are investigated as potential unfolding parameters of the codimension-2 cusp bifurcation. The analysis shows that the most suitable choice for the application to paleoclimates is the carbon dioxide concentration and meridional ocean heat transport parameter combination. The paleoclimate problems of the Warm Equable Climate, Eocene-Oligocene Transition and the Pliocene Paradox are resolved by nature of the bistability and hysteresis exhibited by the cusp bifurcation. The appearance of significantly different climates states for the paleoclimates are due to the topological inequivalence of these states.