Huge tipping events have dominated the evolution of the climate system

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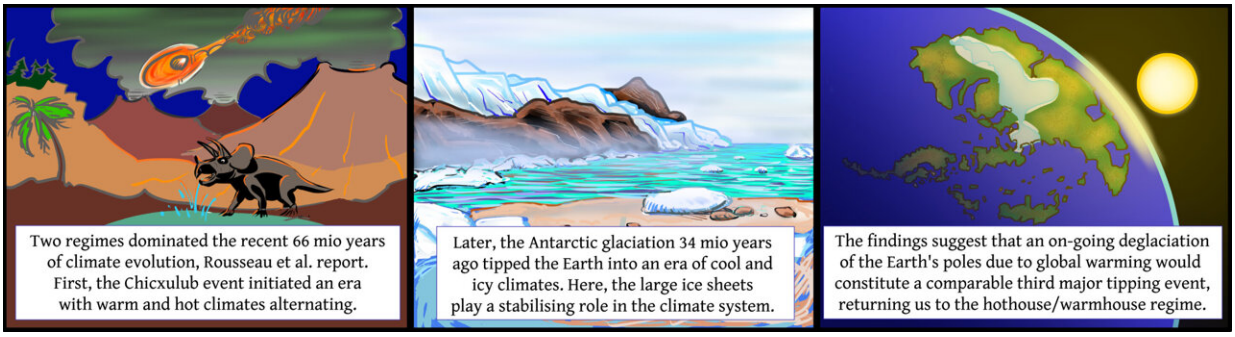

Two major climate events dominated the last 66 million years of climate change. Credit: TiPES/HP

An analysis of the hierarchy of tipping points suggests that during the last 66 million years, two events set the scene for further climate tipping and for the evolution of the climate system in particular. If the anthropogenic climate change of today leads to complete deglaciation, the evolution of Earth's climate will be influenced on a geological time scale, the authors suggest.

The work by Denis-Didier Rousseau, Université Montpellier, France; Witold Bagniewski, Ecole Normale Supérieure, Paris, France; and Valerio Lucarini, University of Reading, UK is published in *Scientific Reports* and is part of the European TiPES project on tipping points in the Earth System.

Inspired by a theory of evolution

The new insight into the history of climate change was inspired by the theory of punctuated equilibrium, which ranks evolutionary changes into hierarchies.

The idea was introduced in the 1970s by Eldredge and Gould as an alternative to classic evolution theory. Punctuated equilibrium proposes that some evolutionary changes determine the evolution of a species more than others. It also explains why species have a tendency to adapt in short evolutionary spurts, rather than gradually over time.

Rousseau and colleagues speculated that a similar approach of ranking the importance of historical climate changes through tipping events might prove equally beneficial. For that, they applied advanced statistical methods to two series of climate data with clear signs of critical transitions.

The results indeed suggest that the idea of hierarchies in the evolution of the climate system can lead to new insights. The analysis reveals that two major events out of ten dominated the evolution of the Earth's climate system over the last 66 million years.

A hierarchy of climate tipping events

The first event was the Chicxulub meteor impact in Mexico, which killed off the large dinosaurs approximately 65.5 million years ago. This catastrophe marked the beginning of a very warm period with high levels of CO_2. For the following 30 million years, this regime dictated which climatic changes were possible and kept it within the regime of hot and warm climates.

The second crucial event was the tipping point associated with the glaciation of the Southern hemisphere 34 million years ago, when the Antarctic continent was isolated at the South Pole due to plate tectonics. The forming of the large ice sheet led to the glaciation of the North as well, and marked the beginning of a considerably colder type of climate on Earth, again dictating the scope of future climate changes.

The analysis additionally suggests that our current global climate system still belongs to the latter climate regime and still depends on the existence of the gigantic ice bodies built within the Coolhouse/Icehouse era.

Serious repercussions

In the event that the ice sheets should not withstand anthropogenic global warming, the deglaciation will therefore represent a landmark tipping point similar to the two that have dominated Earth's history, leading to a new, unknown climate landscape.

"The ice sheets are key components in the present climate system. But they are very sensitive. They presently experience a negative mass balance, and there are numerous reports of evidence of melting under the impact of the current climate warming, translating a trend towards a potential tipping point that could accelerate the disappearance at least of Greenland and West Antarctica, with serious repercussions for our societies" says Rousseau.

"Crossing tipping points has been a recurrent feature in climate evolution . Our study reveals a better understanding now of the mathematics of such events. As a consequence, strategies of adaptation to and mitigation of climate change should now take into account the possible destabilization of tipping elements," adds Lucarini.

More information: Denis-Didier Rousseau et al, A punctuated equilibrium analysis of the climate evolution of cenozoic exhibits a hierarchy of abrupt transitions, *Scientific Reports* (2023). DOI: 10.1038/s41598-023-38454-6

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