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Abrupt climate change in the Anthropocene

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This briefing contains excerpts from a recently-published article in the journal Proceedings of the National Academy of Sciences (PNAS) by Will Steffen and colleagues. The paper has sparked recent media interest and scientific discussion on the possibility of abrupt climate change that lies outside 'likely' projections, by surpassing climate thresholds and instigation of positive feedback loops. It calls for stronger action on climate mitigation because of this risk. Will Steffen is Emeritus Professor at the Climate Change Institute at ANU, and a Councillor for the Climate Council, an Australian climate change communications organisation.

The following are some extracts from Steffen's paper, followed by some comments on this work. The full article and associated references can be accessed here.

Steffen et al.'s article – in short

We explore the risk that self-reinforcing feedbacks could push the Earth System toward a planetary threshold that, if crossed, could prevent stabilization of the climate at intermediate temperature rises and cause continued warming on a "Hothouse Earth" pathway even as human emissions are reduced. Crossing the threshold would lead to a much higher global average temperature than any interglacial in the past 1.2 million years and to sea levels significantly higher than at any time in the Holocene.

We examine the evidence that such a threshold might exist and where it might be. If the threshold is crossed, the resulting trajectory would likely cause serious disruptions to ecosystems, society, and economies. Collective human action is required to steer the Earth System away from a potential threshold and stabilize it in a habitable interglacial-like state.

Such action entails stewardship of the entire Earth System—biosphere, climate, and societies—and could include decarbonization of the global economy, enhancement of biosphere carbon sinks, behavioral changes, technological innovations, new governance arrangements, and transformed social values.

Our analysis suggests that the Earth System may be approaching a planetary threshold that could lock in a continuing rapid pathway toward much hotter conditions—Hothouse Earth. This pathway would be propelled by strong, intrinsic, biogeophysical feedbacks difficult to influence by human actions, a pathway that could not be reversed, steered, or substantially slowed.

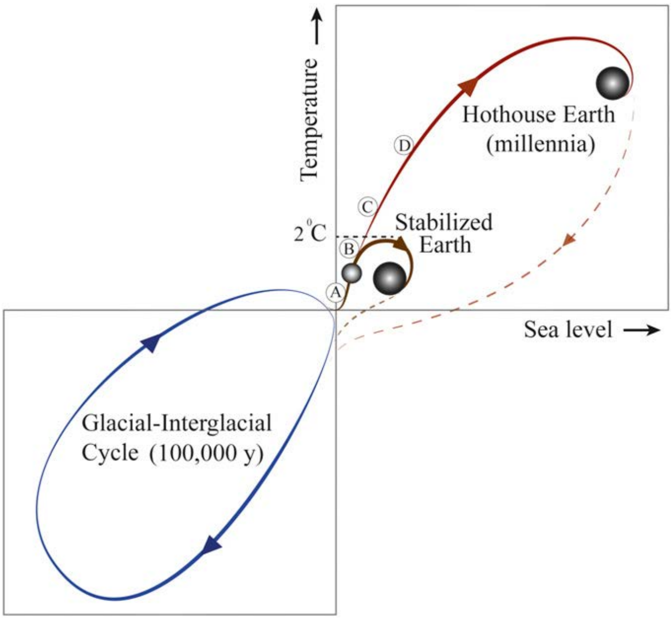

Fig. 1. *A schematic illustration of possible future pathways of the climate against the background of the typical glacial–interglacial cycles (Lower Left). The interglacial state of the Earth System is at the top of the glacial–interglacial cycle, while the glacial state is at the bottom. Sea level follows temperature change relatively slowly through thermal expansion and the melting of glaciers and ice caps. The horizontal line in the middle of the figure represents the preindustrial temperature level, and the current position of the Earth System is shown by the small sphere on the red line close to the divergence between the Stabilized Earth and Hothouse Earth pathways. The proposed planetary threshold at ~2 °C above the preindustrial level is also shown.*

(Source: Steffen et al. 2018)

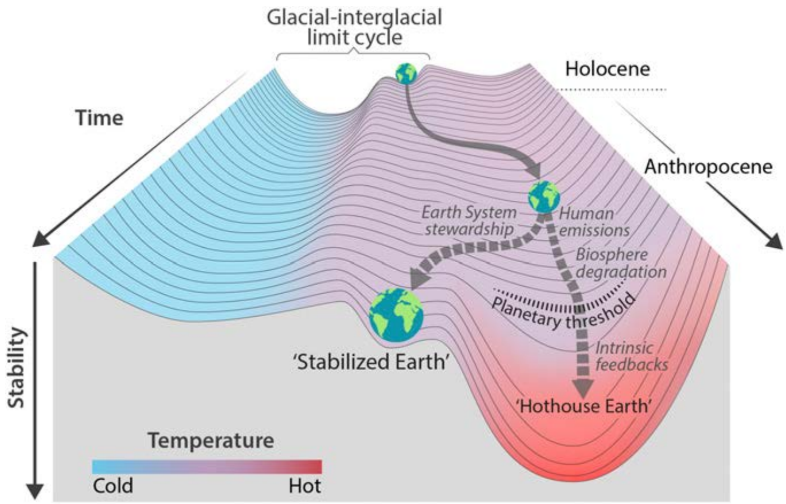

Fig. 2. *Stability landscape showing the pathway of the Earth System out of the Holocene and thus, out of the glacial–interglacial limit cycle to its present position in the hotter Anthropocene. The fork in the road in Fig. 1 is shown here as the two divergent pathways of the Earth System in the future (broken arrows). Currently, the Earth System is on a Hothouse Earth pathway driven by human emissions of greenhouse gases and biosphere degradation toward a planetary threshold at ~2 °C (horizontal broken line at 2 °C in Fig. 1), beyond which the system follows an essentially irreversible pathway driven by intrinsic biogeophysical feedbacks. The other pathway leads to Stabilized Earth, a pathway of Earth System stewardship guided by human-created feedbacks to a quasi-stable, human-maintained basin of attraction. "Stability" (vertical axis) is defined here as the inverse of the potential energy of the system. Systems in a highly stable state (deep valley) have low potential energy, and considerable energy is required to move them out of this stable state. Systems in an unstable state (top of a hill) have high potential energy, and they require only a little additional energy to push them off the hill and down toward a valley of lower potential energy.*

(Source: Steffen et al. 2018)

Where such a threshold might be is uncertain, but it could be only decades ahead at a temperature rise of ~2.0 °C above preindustrial, and thus, it could be within the range of the Paris Accord temperature targets. The impacts of a Hothouse Earth pathway on human societies would likely be massive, sometimes abrupt, and undoubtedly disruptive. Avoiding this threshold by creating a Stabilized Earth pathway can only be achieved and maintained by a coordinated, deliberate effort by human societies to manage our relationship with the rest of the Earth System, recognizing that humanity is an integral, interacting component of the system. Humanity is now facing the need for critical decisions and actions that could influence our future for centuries, if not millennia.

Comments

The idea of abrupt climate change and threshold events is well established and there is evidence in the sedimentary record that such events have occurred multiple times in the past. To provide some context, we are talking about the transition from glacial to interglacial type climate (or vice-versa) within a matter of decades. These thresholds are difficult to forecast but readily identifiable in hindsight. Once a threshold is passed, a feedback loop can develop that reinforces and amplifies the climate signal – and this is the scenario that Steffen et al. explore. However, it is important to highlight that they can equally lead to an abrupt climate signal that is opposite to the initial forcing.

A well-cited example of this is the '8.2 event', where a warming trend led to a sudden decrease in atmospheric temperatures, most notably over the North Atlantic and Europe, around 8,200 years before present. One theory is that warming ocean temperatures in the Arctic led to sea ice melt, which freshened and warmed the surface ocean and inhibited the sinking of salty, cold water to the ocean floor. This mechanism is required to sustain the ocean's thermohaline circulation, of which the Gulf Stream (which transports warm water to NW Europe) is the surface signal. The slowing or closing down of this mechanism around the Arctic may have led to a slowing or deviation of the Gulf Stream, and abruptly cooler air temperatures (on the order of 3 to 4 ° C) over NW Europe. Paleo-climatic evidence suggests this all happened in the space of 20 years. Similarly, today, there is a strong ice melt and positive temperature signal around the Arctic. The climate response is highly complex and difficult to predict.

In their paper, Steffen et al. also use the term 'Anthropocene'. This is a somewhat politically-charged term proposed for the present geological epoch dating from the commencement of significant human impact on the Earth's environment and ecosystems, including, but not limited to, anthropogenic climate change (Waters et al., 2016). The past 10,000 years or so is known as the Holocene (the present inter-glacial period), thus the 'Anthropocene' would be a sub-division of this. There are suggestions that the Anthropocene should start from the beginning of the Industrial Revolution, or even the detonation of the first Atomic Bomb.

However, the International Commission on Stratigraphy (ICS), which has the prerogative of naming geological epochs, does not concur. Almost coincident with the publication of Steffen's paper, the ICS ratified the subdivision of the Holocene and renamed the Late

Holocene as the Meghalayan Epoch, snubbing the term Anthropocene. According to the ICS, the Meghalayan started about 4,250 years ago with a mega-drought that caused the collapse of a number of civilisations in Egypt, the Middle East, India and China about 2,250 years BCE. The ICS objects that the Anthropocene does not arise from geology and is not associated with a "stratigraphic unit" (rock layer); it is based more on the future than the past; is more a part of human history than the immensely long history of Earth; and is a political statement, rather than a scientific one (The Australian, August 11, 2018).

As reported by Mark Maslin (Professor of Earth System Science at University College London) in The Conversation (August 9, 2018), the ICS's decision is a blow to those pushing for tough action on climate change, and "has profound philosophical, social, economic and political implications". Maslin says "there is a huge difference to the story of humanity if we are living in the Meghalayan Age that makes no mention of the human impact on the environment — or in the Anthropocene Epoch, which says human actions constitute a new force of nature. The Meghalayan Age says the present is just more of the same as the past. The Anthropocene rewrites the human story, highlighting the need for planetary stewardship."

The call to arms for stronger mitigation on climate change is a positive one, because it is unlikely any level of planning or adaptation could cope with temperature changes (and associated hazards) of 3 – 4 ° C occurring over a couple of decades. However, inertia - in both the climate system and on a political level - may result in it being too little too late.

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