Global
Challenges
Foundation

Climate tipping points

Risk Expert

Johan Rockström,
Professor and Director, Stockholm Resilience Centre

In a remarkably short space of time, industrial societies have pushed Earth into a new geological epoch, the Anthropocene, where human action has become the greatest agent of change on the planet. As a result of exponential growth in environmental pressures following the development of modern industrial societies, the stability of the Earth system is at risk. Greenhouse gas levels as high as today may not have been seen for at least three million years. Three years in a row (2014-2016), we have hit an average global temperature increase of 1°C, the highest on Earth since the last Ice Age. The chemistry of the oceans is changing faster than at any point in perhaps 300 million years . And the planet is losing biodiversity at mass extinction rates.

Over the past million years, Earth has been tipping in and out of different stable states, from cold glacial periods to warm inter-glacial periods. Increasingly, we learn that these shifts are regulated not only by changes in the position of Earth in relation to the Sun, but also by feedback loops and tipping points in the Earth system itself. Now, humanity is "playing the role of the Sun" through our emissions of greenhouse gases from fossil fuels. The global risk is that the rise in global temperatures resulting from this human activity, even if it remained at 1-2°C, could trigger additional tipping points in the biosphere, pushing Earth into a mega-warm state beyond 3-4°C warming.

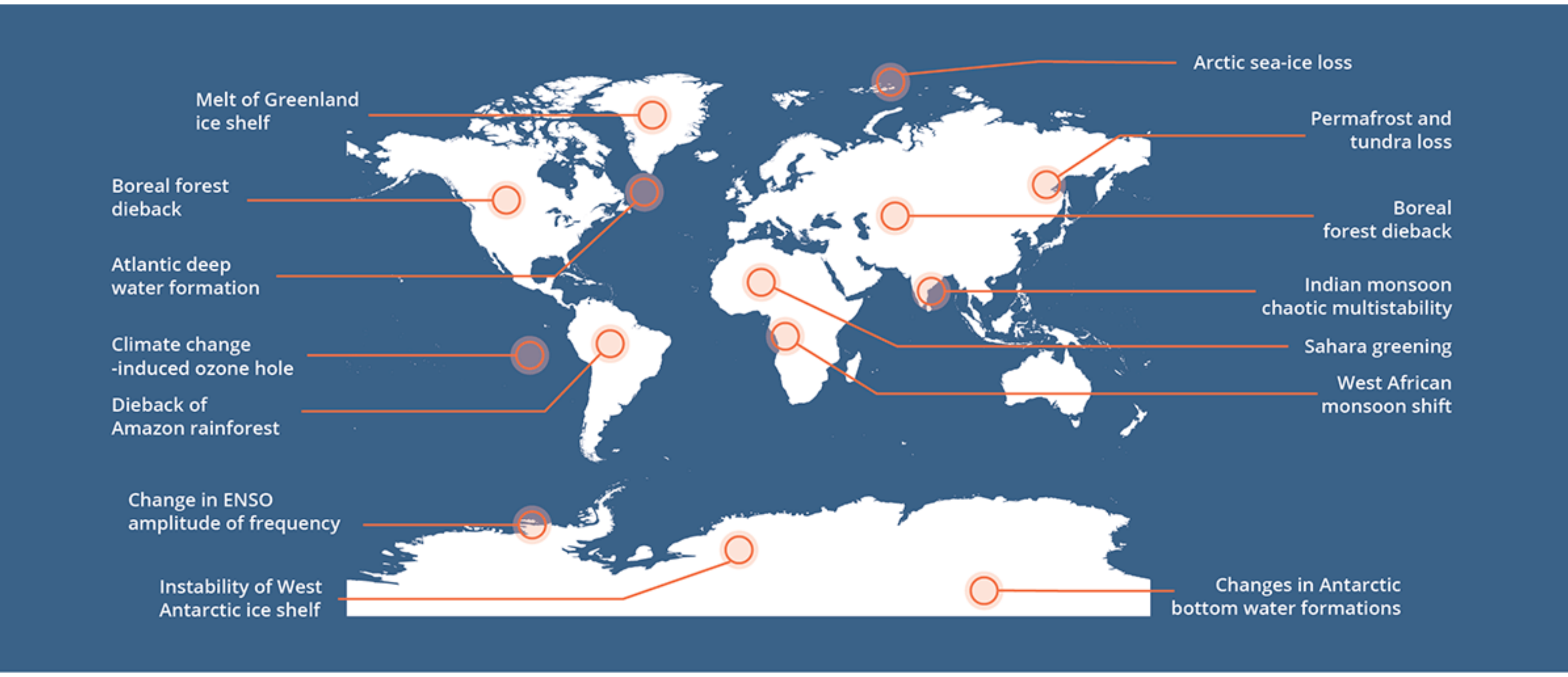
"Burning the remaining known reserves of fossil fuels would add enough greenhouse gases to the atmosphere to trigger the risk of an entire melt of the Antarctic ice sheet."

There is strong scientific evidence today that large systems on Earth, such as the ocean circulation system, permafrost, ice sheets, rainforests and atmospheric circulation can abruptly shift when pushed across tipping points. Moreover, human activities, such as industrial scale farming and fishing, are reducing the resilience of these subsystems, and pushing them toward new states. If one system collapses to a new state, it may trigger positive feedback loops, amplifying the change, and triggering changes in other subsystems, thus causing a "cascading collapse". Since the stability of the Earth system underpins human civilization and welfare, avoiding this scenario would seem an attractive course of action. The figure on the next page shows what level of increase in global temperature would risk triggering tipping points in major biophysical systems on Earth, on the basis of the best current science. At temperatures of between 2–3°C above pre-industrial levels, the risk of various subsystems collapsing becomes high. In fact, even within the "Paris range" of 1.5 – 2°C global warming, the world faces the real risk of irreversible and abrupt shifts in several key regulating systems. As far as we know, tropical coral reefs could collapse before 2°C warming. Alpine glaciers and Arctic summer sea ice are at risk at 2°C, as are Greenland and the West Antarctic ice sheets, though with a much wider range of uncertainty.

Melting from underneath the West Antarctic ice sheet, caused by warmer waters, has now reached a point where no natural barrier will prevent further melting. This could lead to the complete collapse of the West Antarctic ice sheet and cause global sea levels to rise six meters or more. It has also been shown that burning the remaining known reserves of fossil fuels would add enough greenhouse gases to the atmosphere to trigger the risk of an entire melt of the Antarctic ice sheet, which alone will raise sea levels by around 58 meters.

The tipping point risk that humanity faces is double. The first aspect is that human-induced global warming could trigger tipping points with major impact on human societies, such as rising sea levels or the collapse of coral reef systems. The second is the risk of crossing tipping points in the Earth system itself with cascading effects on global warming. These include the gradual weakening of carbon sinks, forest dieback and permafrost thawing. See the figure below.

Tipping points in the earth system



To stand a reasonable chance (> 66 %) of staying under 2°C, the remaining global carbon budget – or amount of carbon that we can release in the atmosphere – is approximately 225 GtC. The 5th Assessment of the Intergovernmental Panel on Climate Change (IPCC AR5), published in 2013, shows that the absorption capacity of the land and ocean carbon sinks, which currently store large amounts of greenhouse gases, could decline by 157 Gigatons of Carbon (GtC) around 2.5°C of warming above pre-industrial in 2100. Even though the remaining carbon budget hedges for a decline in biosphere carbon sinks, it is unclear whether it takes full account of the risks from self-reinforcing warming. In other words, it cannot be excluded that the remaining global carbon budget of 225 GtC compatible with the 2°C guardrail may have to be further reduced in order to account for the lower absorption capacity of land and ocean carbon sinks.

"The latest science shows that tipping points with potential to cause catastrophic climate change could be triggered at 2°C global warming."

Permafrost thawing and forest dieback are additional self- reinforcing processes that can contribute to further destabilise the climate system, and which are not included in the global carbon budget emerging from the IPCC AR5 of 225 GtC. Carbon loss from permafrost thawing has been studied under a range of climate scenarios, and forest dieback linked to climate change is a global concern. It remains uncertain how much carbon loss could be associated with permafrost thawing and forest dieback at 2°C global warming, but the risks lie in a range of 50 GtC, or about one full decade of fossil-fuel burning.

Human burning of fossil-fuels destabilises energy flows in the Earth system, in a way similar to shifts in solar radiation when Earth gradually tips in and out of Ice Ages. The big question is how Earth responds. Science clearly shows that the response is complex. So far, negative feedbacks where the biosphere dampens and reduces global warming have dominated. But these could very well shift to positive feedbacks, and trigger abrupt, irreversible and potentially catastrophic tipping points. The latest science shows that tipping points with potential to cause catastrophic climate change could be triggered at 2°C global warming, i.e. at the upper range of the agreed Paris Climate Agreement. These include the risk of losing all tropical Coral Reef systems on Earth, and irreversible melting of inland glaciers, Arctic sea ice and potentially the Greenland ice sheet.

We must now also seriously consider the global risks of triggering tipping points in the biosphere. We can no longer exclude that if human emissions of greenhouse gases from fossil-fuel burning, air pollutants, land use change and agriculture, cause global warming up to 2°C, we may be faced with a risk of an inevitable further warming of perhaps up to 0.5°C due to tipping points in the biosphere.

This requires the adoption of a planetary resilience strategy. Risks are always associated with uncertainty. Humanity now faces a new spectrum of global risks related to Earth's self-reinforcing tipping points. To avoid these risks requires a global insurance behaviour, which entails backing-off from the danger zone of irreversible and potentially catastrophic Earth system thresholds. It is high time to apply human precaution in order to support Earth resilience, and provide humanity with a genuine chance to continue developing within the safe operating space of a stable planet.