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‘Climate free fall’: why the biggest risk to our economies is yet to be recognized

Increasing instability of the ocean, ice and atmosphere threatens farming, finance and society. We all need to wake up to that fact.

By Anders Levermann

A farming storage area is flooded in Taiwan — events such as this will become more frequent in an increasingly erratic climate. Credit: Cheng Chia Huang/Getty

I have studied climate tipping points[1] for more than 20 years, and I'm increasingly concerned that scientists have overlooked the most dangerous aspect of these for societies. The potential collapse of major parts of the Earth system — from ice sheets to ocean circulations — will profoundly alter the warming planet and tip it irreversibly into a different state[2]. But the greatest risks might not lie at that endpoint.

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How we get there — how the tipping unfolds — is more important, and there is an urgent need to understand the process. This is missing from current analyses because the scales in time and space it occurs on fall between those of climate and weather. Tipping analyses focus on huge climate changes, often globally, over decades. Weather events are fast and local. But look at the interplay between the two and it's clear that the transition between one climate state and another is not smooth but extremely volatile.

Climate tipping, therefore, will manifest as a period of increasingly dramatic weather volatility, rather than a sharp shift in average conditions. A fluctuating climate will bring swings and crashes in crop yields, flash flooding and erratic storms. It will stress economies by disrupting supply chains and amplifying insurance losses. Societies are unprepared, because weather volatility related to tipping points is absent from risk assessments.

This problem is urgent. Earth subsystems, including oceans, the cryosphere and biosphere, already seem to be destabilizing. The planet is heading for climate free fall.

Climate is destabilizing

By definition[3], tipping points are reached when a series of interlinked changes amplify one another until the whole system becomes unstable and shifts uncontrollably into a different state. Loss of sea ice at the poles, for example, reduces the amount of sunlight reflected into space, further heating Earth's surface, which then accelerates ice loss. These vicious cycles of change define a tipping point, at which the climate cannot return to its former patterns.

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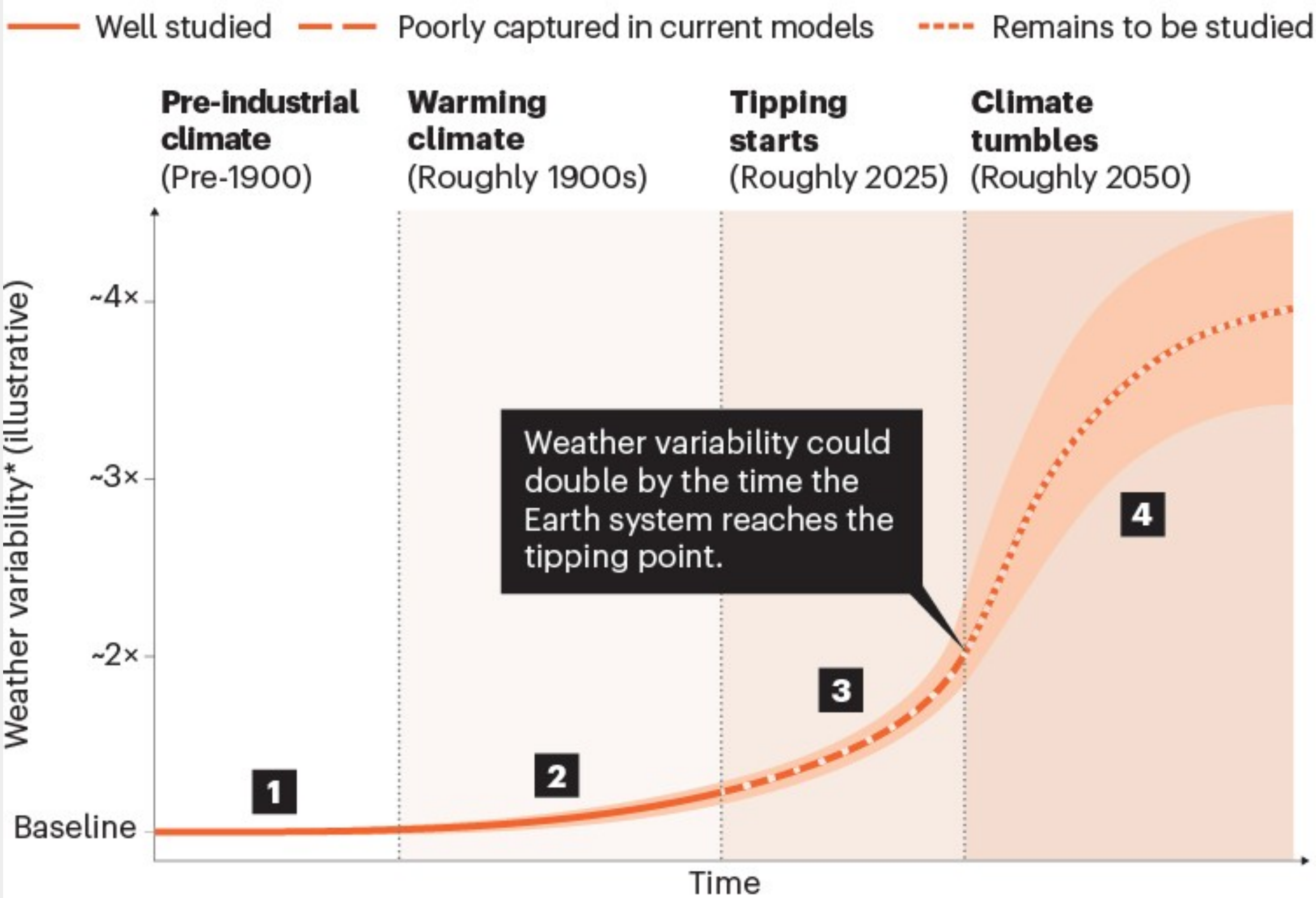
Before that point, the climate system becomes increasingly unstable. It fluctuates considerably — a rise in variability is a well-established property of such 'non-linear dynamical systems' approaching a critical threshold[4,5]. That society will face these fluctuations and that they will intensify through the tipping transition hasn't been realized by scientists and policymakers, so far.

Earth will experience an increasingly erratic climate: more and stronger fluctuations in flows of melt water, ocean circulations and the extent of sea ice. These changes will lead to more frequent and intense extremes in temperature, precipitation and storms — leading not only to more heatwaves and droughts, but also to more cold spells and floods.

The scale of the consequences might not be obvious at first — ice sheets and ocean currents are so large that their responses to warming are relatively slow and delayed. Once a critical temperature threshold for instability is crossed, it takes time for such systems to collapse, but the collapse is inevitable (see 'Tipping into trouble').

TIPPING INTO TROUBLE

In a warming climate, heatwaves, storms and floods are becoming more extreme and frequent. The variability of weather will keep increasing as different parts of the Earth system destabilize and reach tipping points, and increase again as the planet settles into a new state. Such volatility from tipping systems is understudied and will affect economies and societies and dominate weather patterns for the next three generations.



1 Stable, no warming

2 Weather extremes increase as more heat and moisture are held in the atmosphere

3 Instabilities grow as oceans and ice sheets exceed temperature thresholds

4 Weather becomes highly volatile before settling into a new state

*Variance in local weather measures, such as temperature, precipitation and storm strength, for example. Uncertainty in variability grows over time, as shown by the shaded range.

Source: A. Levermann

Ice sheets in West Antarctica[6] and Greenland[7] have already passed their tipping temperature. Arctic sea ice will do so in a few years. For the Atlantic Ocean, scientists simply don't know[8]. The period between passing the tipping temperature and reaching the tipping point is when fluctuations increase dramatically.

Research into early warning of tipping points has identified increased climate variability as a signal of reduced stability and used it to estimate the time remaining before widespread tipping begins. But variability caused by instability as a mechanism of climate impact has been widely neglected.

Modern economies are adapted to relatively stable climatic baselines. Agricultural productivity, infrastructure design, insurance pricing and financial risk management all rely not only on expected mean conditions but also on the predictability of variability.

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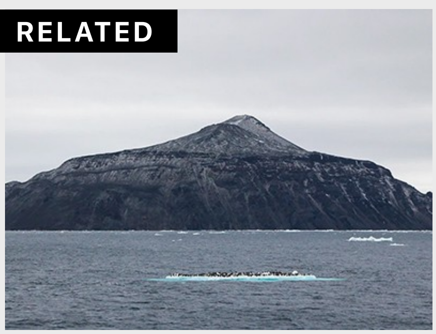

Protect Antarctica — or risk accelerating planetary meltdown

Farmers need to factor in lost harvests; architects and urban planners need to account for extremes of temperature, wind and rainfall; and financiers and insurers need to consider the cost and scale of damages. But once these factors are no longer predictable, all bets are off — life becomes uninsurable and the world becomes unsafe.

Communities are already feeling the effects of a rise in extreme weather[9]. And such events might quickly spiral once climate subsystems start to tumble. For example, once the Greenland ice sheet approaches its tipping point, its surface will be even more vulnerable to surface melt. More-variable local weather will create more-variable amounts of melt water, which will be injected into the North Atlantic Ocean.

Such injections will increase the variability in ocean convection and mixing, and, therefore, the extent of Arctic sea ice. All of this will lead to greater fluctuations in sea surface temperature in the Atlantic Ocean, which will have consequences for the stability of the jet stream, and, therefore, weather variability across Europe, North America and Asia.

Weather is different in a tumbling climate

Despite the scale of this threat, there is no coherent framework — in climate physics or economics — for analysing climate subsystems during tipping transitions. Research has focused on identifying tipping points of individual subsystems, such as the Atlantic overturning circulation[10], the Amazon rainforest[11] and the West Antarctic ice sheet, and on estimating their long-term consequences, such as sea level rise. How the systems behave after the tipping point and how their behaviour interacts with weather remain mostly unstudied.

A sunflower plantation wilts during a drought in Utrera, Spain. Credit: Lucas Vallecillos/VWPics/Redux/eyevine

This gap reflects a deep assumption: climate change is generally treated as the response of a stable system to external forces. That assumption holds for global mean temperature, because feedback (the Planck response) between incoming solar and outgoing heat radiation stabilizes Earth’s energy fluxes. But it breaks down for subsystems undergoing tipping dynamics.

If a system is merely forced out of equilibrium, it will tilt, and that might be dangerous, but it will stabilize. As an analogy, if one side of a china cabinet is lifted with a jack, the cabinet will tilt but will then settle when pumping of the jack stops. Climate modellers assume such stability when they select simulations that are consistent with a pre-industrial climate.

If you push the climate system past a tipping point, however, it does not stabilize. Its parts will tumble like falling pieces of china, even if the ‘cabinet’ they are in hasn’t toppled yet. For the climate, this downfall will take decades. And during that period, what will happen is hard to pin down and to predict. The weather will be very different in a tumbling climate than it is in a stable one, even if that stable one is affected by external forces.

We need science of a falling elevator

Climate scientists need to shift their perspective. To assess future climate impacts, they need to study weather in a tumbling climate. And researchers and policymakers must recognize that weather variability is the most destructive climate force for the economy and society.

Instead of analysing future climate as a sequence of quasi-equilibria — as a system that will settle when the world stops emitting carbon — researchers must treat it as an unstable system that is reorganizing while society tries to phase out carbon-based energy.

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That means understanding variability with time-dependent boundary conditions — such as freshwater fluxes from ice sheets or changes in moisture or the amount of sunlight that a surface reflects owing to rainforest degradation. And it means prioritizing which subsystems to study on the basis of how much their tipping effects matter for life on Earth. For example,

about where society is heading

people living in the Northern Hemisphere will be affected by Arctic and Atlantic tipping points, as well as the influence of these on the jet stream. Two billion people will be affected by the impacts of tipping points on the dynamics of monsoons.

Economic assessments of climate change will also need to focus on changes in weather[12–14], not just annually averaged temperatures[15–17]. Scientists and policymakers know that the mounting costs of climate change will far exceed those of mitigation. But, given the inherent non-linearity of the instabilities, the real damages will greatly surpass those estimates. How tipping volatility will unfold must inform big decisions in the coming years around building infrastructure, allocating capital, determining insurance premiums and setting policies.

The climate isn't just changing — it is becoming less predictable and more unstable. It might be difficult for economists. It might be difficult for physicists. But this process needs to be understood, because it will dominate the next century.

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COMPETING INTERESTS

The author declares no competing interests.

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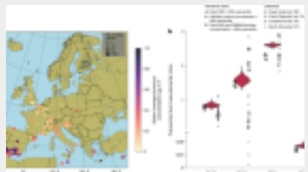

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