Overshooting climate targets could significantly increase risk for tipping cascades

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Temporarily overshooting the climate targets of 1.5–2 degrees Celsius could increase the tipping risk of several Earth system elements by more

than 70% compared to keeping global warming in line with the United Nations Paris Agreement range, a new risk analysis study by an international team of researchers shows. This tipping risk increases even if in the longer term the global temperature would stabilize within the Paris range. Avoiding an overshoot would hence limit the risks, the researchers conclude.

"We show that the risk for some tipping events could increase very substantially under certain global warming overshoot scenarios," explains Nico Wunderling, scientist at the Potsdam Institute for Climate Impact Research and lead-author of the study to be published in *Nature Climate Change*.

"Even if we would manage to limit global warming to 1.5 degrees after an overshoot of more than two degrees, this would not be enough as the risk of triggering one or more global tipping points would still be more than 50%. With more warming in the long-term, the risks increase dramatically."

"To effectively prevent all tipping risks, the global mean temperature increase would need to be limited to no more than one degree—we are currently already at about 1.2 degrees," Jonathan Donges, Co-Lead of the FutureLab on Earth Resilience in the Anthropocene at PIK adds. "The latest IPCC report is showing that we're most likely on a path to temporarily overshoot the 1.5 degrees Celsius temperature threshold."

Emergence of at least one tipping event increases with rising peak temperatures

To arrive at these results, the scientists, together with co-authors from the Earth Commission—a group of leading scientists convened by Future Earth—used global warming overshoot scenarios with peak

temperatures from two to four degrees and applied these to a set of four interacting tipping elements: the Greenland ice sheet, the West Antarctic ice sheet, the Atlantic Meridional Overturning Circulation AMOC, and the Amazon rainforest.

The researchers applied a risk analysis approach based on millions of model simulations to reflect the uncertainties in relevant parameters such as the uncertainty in critical temperature thresholds as well as interaction strengths and interaction structure.

Such a quantity of simulations would be too computationally expensive based on fully coupled Earth system model simulations. For the overshoot scenarios, the research team then analyzed the risk of crossing critical thresholds and the potential for triggering cascading interactions between the four elements, depending on the magnitude and duration of the overshoot as well as the warming remaining on the long-term.

"We found that the risk for the emergence of at least one tipping event increases with rising peak temperatures—already at a peak temperature of three degrees Celsius, more than one third of all simulations showed a tipping event even when overshoot durations were limited strongly. At four degrees Celsius peak temperature, this risk extends to more than half of all simulations," explains Nico Wunderling.

Tipping mechanisms under warming overshoots

"Especially the Greenland and the West Antarctic ice sheet are at risk of tipping even for small overshoots, underlining that they are among the most vulnerable tipping elements. While it would take a long time for the ice loss to fully unfold, the temperature levels at which such changes are triggered could already be reached soon," says Ricarda Winkelmann, Earth Commissioner and Co-Lead of the FutureLab on Earth Resilience in the Anthropocene. "Our action in the coming years can thus decide

the future trajectory of the ice sheets for centuries or even millennia to come."

The other two tipping elements considered in the study, the AMOC and Amazon rainforest, have higher critical temperature thresholds. Yet, they would react much faster once the tipping process has started. Therefore, it is much more difficult to stop their tipping process once initiated by a temporary global warming overshoot.

Current mitigation policies are expected to lead to 2–3.6 degrees Celsius of global warming by the end of this century. "This is not enough. Even though a temporary temperature overshoot would definitely be better than reaching a peak temperature and remaining there, some of the overshoot impacts may lead to irreversible damages in a high climate risk zone and this is why low-temperature overshoots are key here," explains Jonathan Donges. Ricarda Winkelmann adds: "Every tenth of a degree counts. We must do what we can to limit global warming as quickly as possible."

More information: Nico Wunderling, Global warming overshoots increase risks of climate tipping cascades in a network model, *Nature Climate Change* (2022). DOI: 10.1038/s41558-022-01545-9. www.nature.com/articles/s41558-022-01545-9

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