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Reversing climate overshoot

Temporarily overshooting climate targets is a distinct possibility given our current emissions trajectory. It is crucial that we understand which of the associated impacts are reversible, and to what extent.

Last month the World Meteorological Organization (WMO) published a report suggesting that for the first-time it is more likely than not that global surface temperature will exceed pre-industrial levels by 1.5 degrees in at least one of the next five years[1]. As global temperature continues to rise, the limits set out in the Paris Agreement are fast approaching and may very well be exceeded under current emission trajectories. While the possible overshoot of warming targets may be temporary (Fig. 1), not all the associated impacts are necessarily reversible[2]. As many presentations at the recent European Geosciences Union (EGU, https://www.egu23.eu/) general assembly meeting highlighted, there is much to untangle about just how temporary the consequences are if climate targets are temporarily exceeded. It is critical we understand how the duration and extent of the overshoot may influence the severity and reversibility of climate impacts so that the risks can be fully recognized.

Global action on climate change has been guided in recent years by the target set out in the Paris Agreement to limit warming to 1.5 degrees. This limit was proposed to try and avoid the most devastating impacts of climate change. As the climate warms, a wide range of impacts are expected, from increasing numbers of heatwaves to species loss and extinction[3]. The severity of many of these impacts is expected to increase substantially at higher levels of warming[4]. What is less clear, however, is the extent to which some of these impacts can be reversed if warming is brought back down following the overshoot. Even temporarily exceeding 1.5 degrees may increase the risk of crossing climate thresholds and tipping the climate system into a new state[2].

Large-scale Earth systems, such as the Atlantic Meridional Overturning Circulation, the Greenland Ice Sheet, and the Amazon rainforest, could abruptly transition to a new state at a certain warming threshold[5]. Paleoclimate records have shown this: for example, the Atlantic Meridional Overturning Circulation appears to have abruptly shifted to a weaker state in past climates[6]. Under future warming it is possible that the Greenland Ice Sheet could enter an unstable state due to the melt-elevation feedback, whereby melting reduces the surface height and exposes ice to higher temperatures at lower elevations[7]. And the importance of moisture recycling for the Amazon rainforest puts the system at risk from hydrological changes[8]. All of these tipping elements could have major local and remote impacts and potentially alter weather systems, sea levels, and biodiversity. The risk of passing critical thresholds for the various Earth systems increases with a greater magnitude of overshoot[2]. However, due to the complex interactions and nonlinear behaviour involved, the exact thresholds remain uncertain.

On smaller scales, there may also be impacts which cannot be reversed by bringing temperatures back down. For example, alpine glaciers may not reform once they have melted, leaving a long-term impact on the local hydrology. Similarly, impacts on biodiversity will not always be reversible if species are pushed past the point of recovery. It is important we understand what conditions need to be met to avoid such impacts, and for those which cannot be avoided, accurate information needs to be available for adaptation strategies. Ongoing projects, such as PROVIDE (Paris Agreement overshooting reversibility, climate impacts and adaptation needs, https://climateanalytics.org/projects/provide/), are now tackling these questions, and working to provide accessible information on societal risks.

In the event that climate targets are exceeded, bringing the average global temperature back down quickly to meet the aim of the Paris Agreement will require concerted, and likely expensive, efforts across the globe. Overshoot scenarios rely heavily on implementing carbon dioxide removal techniques like afforestation and direct air carbon capture[4]. While a range of methods provide promise[9], the large-scale capacity and feasibility of carbon dioxide removal are still uncertain. We cannot guarantee that we will achieve substantial negative emissions, so it is imperative that we limit the occurrence, extent and duration of overshoot as much as possible through rapid and deep cuts in emissions. However, with the possibility of overshoot drawing nearer, we must understand the potential long-term consequences that could arise.

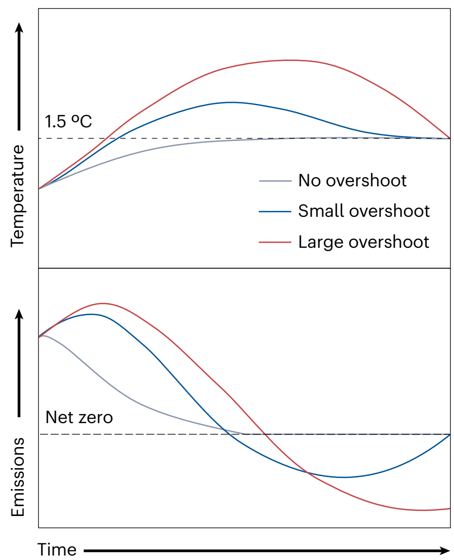

Fig. 1 | Schematic depicting hypothetical overshoot scenarios. The grey line represents a future scenario with no overshoot due to rapid emission cuts. The blue and red lines represent future scenarios with overshoot varying in magnitude and duration.

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