



Carbon cycle responses differ when meeting a global temperature target after overshoot

Kirsten Zickfeld (1), Katarzyna Tokarska (2), Joeri Rogelj (3,4)

(1) Simon Fraser University, Burnaby, Canada (kzickfel@sfu.ca), (2) University of Edinburgh, Edinburgh, UK (Kasia.Tokarska@ed.ac.uk), (3) Grantham Institute, Imperial College London, London, UK, (4) International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria (rogelj@iiasa.ac.at)

Limiting global mean temperature rise to well below 2°C and pursuing efforts to limit warming to 1.5°C relative to preindustrial levels, in accordance with the Paris Agreement, relies critically on ambitious mitigation efforts on a global scale. Most of the CO₂ emission pathways that reach the 1.5°C and 2°C temperature stabilization level in the long term are based on the assumption that emitting CO₂ and removing it later by the implementation of artificial carbon dioxide removal from the atmosphere (CDR) leads to the same state of the climate system. In such overshoot scenarios, where a given temperature level is first exceeded and then restored by CDR, global mean temperature response has been shown to be reversible. However, the question remains whether the state of carbon cycle differs among scenarios in which a given temperature level is achieved without overshoot, or scenarios where that temperature level is temporarily exceeded and then restored by CDR.

Here we show that exceeding and subsequently restoring a given temperature target leaves a legacy in the carbon cycle response: more carbon is stored in the ocean, and less carbon is stored on land and in the atmosphere, when comparing an overshoot scenario to a scenario without overshoot at the time when the same amount of cumulative CO₂ emissions is reached. These differences increase with increasing level of overshoot. The global mean temperature remains the same in all scenarios despite path dependence in the carbon cycle due to the lagged ocean thermal response compensating the pathway dependence of the carbon cycle responses. Our results suggest that the concept of carbon budget (i.e. cumulative CO₂ emissions level consistent with a given temperature target) should be used with caution when overshoots of the budget are considered, particularly for limiting the environmental change in dimensions other than global mean temperature rise.