NAVIGATING RATE-INDUCED TIPPING AND OVERSHOOTS IN THE CLIMATE SYSTEM

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Previous studies report low global warming thresholds above pre-industrial conditions for key tipping elements such as ice-sheet melt. If so, high contemporary rates of warming imply that exceeding these thresholds is almost inevitable, which is widely assumed to mean that we are now committed to suffering these so called bifurcation-induced tipping events. Here we show that this assumption may be flawed, especially for slow-onset tipping elements (such as the collapse of the Atlantic Meridional Overturning Circulation (AMOC)) in our rapidly changing climate. We demonstrate, using conceptual climate models, that a threshold may be temporarily exceeded without prompting a change of system state, if the overshoot time is short compared to the effective timescale of the tipping element. On the other hand, systems may exhibit rate-induced tipping points instead of (or as well as) bifurcation-induced tipping, where a system fails to adapt to rapidly changing external forcing. Such tipping points are much less widely known, and yet are arguably even more relevant to contemporary issues such as climate change. We illustrate this phenomenon using a model for the AMOC and the possibility of avoiding tipping by reversing the forcing. This has the potential to lead to multiple critical rates for the same peak change as the low rates required to avoid rate-induced tipping compete against the fast rates required for overshoots without tipping.