1 Climate tipping points: a critical moment for action

This introductory chapter provides a short overview of current understanding of climate system points, including on how this knowledge has evolved over the years, and introduces some notions and definitions relevant for the remainder of the chapters. While uncertainties remain, the chapter alerts to the fact that there is high confidence that current levels of climate action fall far short from what is needed to avoid the dangerous impacts of crossing climate tipping points.

According to the Intergovernmental Panel on Climate Change (IPCC), a tipping point is “a critical threshold beyond which a system reorganises, often abruptly and/or irreversibly” and a tipping element is “a component of the Earth system that is susceptible to a tipping point” (Chen, 2021[1]). Climate system tipping points may lead the global or regional climate to change from one stable state to another stable state — one that is potentially much less suitable for sustaining human and natural systems — or may result in changes that occur non-linearly and faster than the rate of change expected from climate forcing [1] (Alley et al., 2003[2]; Lee, 2021[3]). Such abrupt and/or irreversible changes are particularly dangerous because they can occur on timeframes that are short enough to defy the ability and capacity of human societies to adapt to environmental pressures. As such, the impacts of crossing climate tipping points would be severe and widespread, with potentially catastrophic consequences for human and natural systems. The goal of the present report is to review the state of knowledge on climate system tipping points and to reflect on the implications for near-term climate action. The report does not aim to be comprehensive in its literature review of the different climate system tipping points. Rather it aims to provide to policy makers needed relevant information that can lead to development of climate strategies that directly integrate the threat of tipping points.

The issue of climate tipping points was first introduced by the IPCC about two decades ago when they were projected to possibly occur in “the next few centuries if greenhouse gas concentrations continue to increase” (IPCC, 2001[4]). However, more recent IPCC reports recognise the risk of crossing tipping points at much lower levels of warming and therefore at considerably shorter timescales (IPCC, 2018[5]; IPCC, 2019[6]). Indeed, the latest IPCC report recognises that low-likelihood outcomes, that is, outcomes with a low-probability of being crossed at low-levels of warming including the crossing climate tipping points, cannot be ruled out already this century and must be an integral part of risk management strategies (IPCC, 2021[7]). More recent research shows that current global warming of ~1.1°C above pre-industrial already lies within the uncertainty range of important tipping elements and that further tipping elements will become “possible” or even “likely” within the Paris Agreement range of 1.5 to <2°C warming (McKay et al., 2022[8]). These findings highlight the immediate danger of tipping points, and question whether it remains pertinent to continue classifying tipping points as low-likelihood outcomes.

There is evidence that a number of tipping points may already have been crossed or are close to being crossed. For example, it cannot be ruled out that West Antarctic Ice Sheet (WAIS) and the Greenland ice-sheet tipping points have already been crossed, while low-latitude coral reefs and the abrupt permafrost thaw tipping points are likely to be crossed if temperatures increase above 1.5°C (McKay et al., 2022[8]). In addition, the Atlantic Meridional Overturning Circulation (AMOC) has been slowing down in the last two decades (Good et al., 2018[9]) and is at its weakest for over a millennium (Caesar et al., 2021[10]; Boers, 2021[11]). If triggered, these tipping points could potentially lead to cascading global impacts, including triggering further tipping points, with dramatic effects on human and natural systems (Lenton et al., 2019[12]).

At the global scale, such cascading effects, where the crossing of one tipping point leads to the triggering of further tipping elements, could lead to a new ‘hothouse’ global climate that would be less suitable for human existence (Steffen et al., 2018[13]; Lenton et al., 2019[12]). At the regional level, individual tipping points are associated with different types of potentially severe regional or local impacts, such as extreme temperatures, higher frequency of droughts, forest fires and unprecedented weather (Arias et al., 2021[14]). Given the dynamic interaction between these potential climate hazards and socio-economic systems, it is particularly important to better understand tipping point dynamics and their likely impacts in order to minimise and manage the risk of crossing tipping point thresholds.

However, uncertainties remain in understanding the climate risks associated with crossing tipping points. Climate risk can be understood as the result of the interactions between climate-related hazards and the exposure and vulnerability of the affected human and ecological systems to the hazard (IPCC, 2021[15]). Uncertainties in understanding the risk of climate tipping points stem therefore from these different determinants of risk. First, uncertainties arise from the complexity of earth and climate systems, with multiple stressors unfolding in parallel and the potential for cascading impacts across systems, making it impossible for singular climate related hazards to be predicted with accuracy with current knowledge (Ara Begum, 2022[16]). Second, uncertainties arise as vulnerability, exposures, socio-economic development and decision making may change over time (*Ibid*). Climate risk is a highly complex notion due to the dynamic nature of the interaction of its determinants, the behaviour of complex systems in which it operates, including non-linear responses and the potential for surprises, as well as the complex nature of the responses to climate risks themselves (*Ibid*).

There are also large uncertainties that arise when estimating the potential costs of crossing tipping points. A recent study estimated that climate tipping points increase the social cost of carbon (SCC), a common measurement of the economic impact of climate change, by approximately 25%, with positively skewed results indicating a 10% chance that the SCC is more than doubled (Dietz et al., 2021[17]). While uncertainties and ambiguities remain in the understanding of some aspects of how climate change will unfold, especially regionally or locally, they must not be a cause of inaction. Indeed, considering the very high level of confidence in the relationship between global greenhouse gas emissions and global average temperature rise, as well as on the severity of potential impacts, larger uncertainties generally imply the possibility of larger climate risks and should therefore amplify, rather than weaken, the case for early, ambitious and effective climate action (OECD, 2021[18]).

Scientific advances are systematically leading to higher confidence in the potentially catastrophic impacts of continued warming, including evidence that irreversible tipping elements in the Earth's systems could already be triggered this century, with long-lasting effects over a timeframe of centuries to millennia (Lee, 2021[3]). The Working Group II (WGII) contribution to the Sixth Assessment report (AR6) of the IPCC assesses that the risk associated with crossing critical thresholds or tipping points remains *moderate*[2] at current levels of warming of about ~1.1ºC (high confidence) (WMO, 2022[19]). Such risks are projected to transition to *high* with warming between 1.5–2.5ºC (medium confidence) and to *very high* with warming between 2.5–4.5ºC (low confidence) (O'Neill, 2022[20]). This prediction emphasises the increased risks associated with surpassing or overshooting 1.5 ºC of warming during this century, even if temperature levels are brought back down at the end of the century.

These advances underline the urgent need for strategies that specifically address the risks of tipping points. Despite this significant progress, global policy efforts and action explicitly targeting those risks, both on reducing GHG emissions and adapting to potential impacts, remain intangible and highly insufficient. Global collective action on mitigating greenhouse gas emissions falls far short of what is needed to meet the globally agreed temperature goal of the Paris Agreement of "holding global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (Paris Agreement, 2015[21]). If pledges made by COP26 including in the Nationally Determined Contributions (NDCs) submitted and mid-century long-term legally-binding targets (e.g. net-zero by mid-century targets) are met, end-of-century temperature increase would reach 2.1°C (CAT, 2021[22]). If *all* net-zero targets are fully achieved (i.e. those adopted and those under discussion), the resulting temperature increase by the end of the century would be 1.8°C. Emissions trajectories in line with current policies and actions are however not in line with NDCs and would lead to a 2.7°C increase in global average temperature by the end of the century. All the more concerning is that global CO_2 emissions have rebounded since the COVID pandemic to their highest levels in history, indicating that emissions are going in the opposite direction even relative to insufficient NDCs. This lays bare the considerable discrepancy between short- and long-term targets and action on the ground (CAT, 2021[22]).

At current levels of action, there is therefore a high risk that the Earth system will cross critical thresholds or tipping points as temperature increase is projected to surpass 1.5ºC. The existence of climate tipping points requires stringent early action on GHG emissions, limiting the permissible temporary overshoot beyond 1.5ºC and thereby the ways by which the Paris agreement goal can be met, and rendering the current low level of climate action considerably more dangerous.

Efforts to adapt to climate change are increasingly being implemented worldwide but, similarly to mitigation, the rate and scale of adaptation progress still falls short of what is needed to keep up with growing risks (UNEP, 2021[23]). The IPCC estimates that at present 3.3 to 3.6 billion people are highly vulnerable to climate change (IPCC, 2022[24]). Climate tipping points exacerbate these risks. Their systemic scale, dramatic impacts and abrupt[3] nature pose significant challenges for human systems to adapt. For example, after a tipping element has been triggered, severe impacts can occur in short timescales, too rapidly for effective reactive adaptation responses, imposing hard limits for human systems to be able to identify, develop and adopt solutions to adapt to these impacts. Thus, taking into account climate tipping points is crucial for a comprehensive analysis of climate risk, not just to inform mitigation pathways, but also for effective adaptation design and implementation.

The first part of the report provides an accessible digest of the most recent scientific information on selected climate system tipping points in terms of the type of impacts associated with the crossing of tipping elements and associated probabilities and timescales. While non-exhaustive, this review intends to better characterise the risks of tipping points and identify knowledge gaps and potential ways to overcome these. Building on this scientific knowledge, the second part of this report discusses courses of action for better reflecting the risks of tipping points in climate policies and strategies. Notably, it aims at providing insights on how the knowledge available today on the longer-term effect of tipping points can inform near-term policy planning for mitigation, adaptation and other areas of action.

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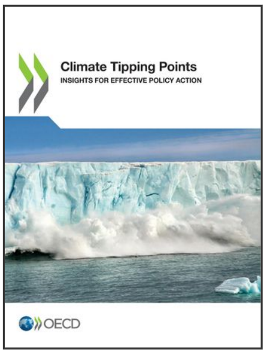
Notes

[1] Climate or radiative forcing is the change in energy flux in the atmosphere caused by natural or anthropogenic factors of climate change, such as greenhouse gas emissions or increased water vapour. It is a direct measure of the amount that the Earth's energy budget is out of balance by external drivers of change.

[2] This assessment takes into account the different drivers of risk, i.e. physical hazards and the vulnerability and exposure of communities and ecosystems, based on literature-based expert judgement (Pörtner et al., 2022[25])

[3] According to the IPCC, "a large-scale abrupt change in the climate system that takes place over a few decades or less, persists (or is anticipated to persist) for at least a few decades and causes substantial impacts in human and/or natural systems." (IPCC, 2021[15])



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