Umwelt Bundesamt

Für Mensch und Umwelt

Status: 20. November 2023

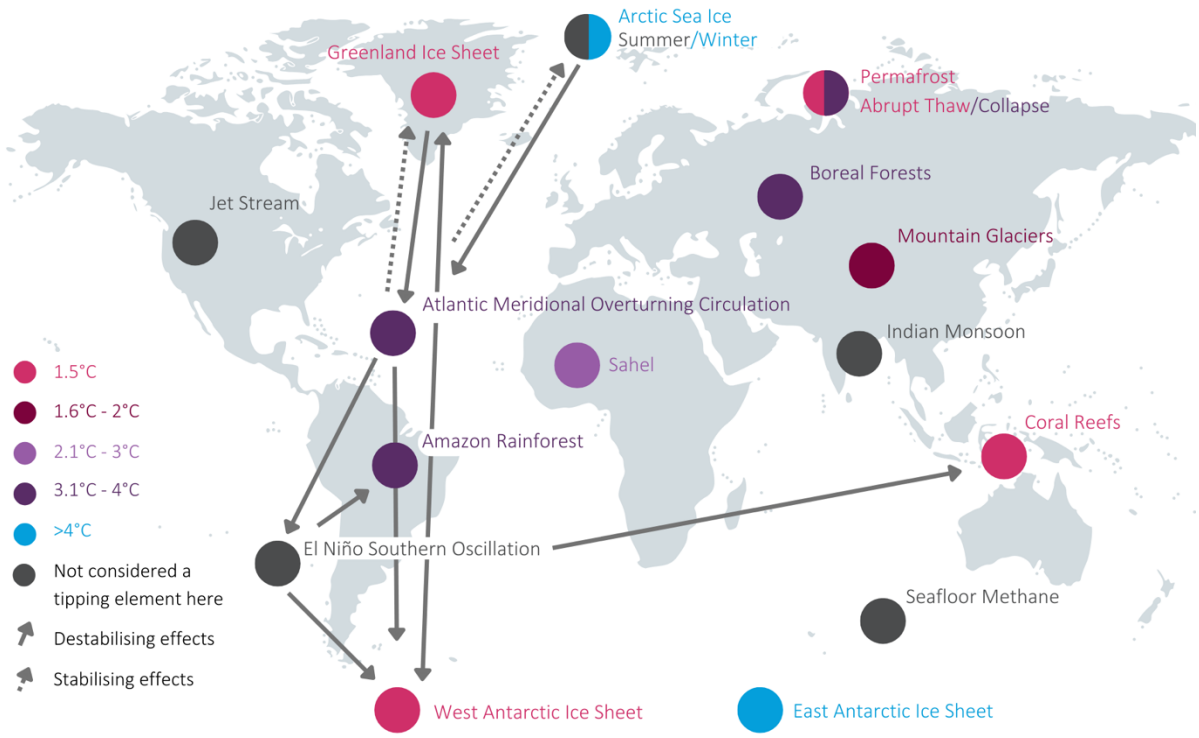
Tipping points and cascading tipping dynamics in the climate system

Individual components of the Earth system, such as ecosystems, ocean circulation and ice sheets, are exposed to strongly changing conditions as climate change progresses. There is a risk that self-reinforcing dynamics will be triggered between different Earth system elements, which could lead to a new system state (such as the melting of an ice sheet). These **tipping dynamics** would not be directly reversible even if the global temperature were to stabilize or decrease.

Components of the Earth system that have been identified as having critical stability thresholds, known as **tipping points**, are referred to as **tipping elements** (Figure 1).

For example, the Amazon rainforest, a globally unique ecosystem, can go into a deforested state if deforestation and climate change exceed certain tipping points. Large current patterns in the oceans may lose their power, with global consequences for weather patterns and climate conditions. {Background paper: Chapter 1}

Figure 1: Tipping elements of the climate system



Important tipping elements and their tipping points at a certain global warming compared to pre-industrial levels (1850 - 1900). Coral reefs, permafrost soils, and the Greenland and West Antarctic ice sheets (red) are already at risk of reaching their tipping points at a sustained global warming of 1.5 °C. The arrows symbolize the possible mutual influence of different tipping elements on a global scale and illustrate the risk of so-called tipping cascades.
Source: Own illustration, Climate Analytics, according to Armstrong McKay *et al.,* 2022 and Wunderling *et al.* 2023

The tipping of individual elements of the Earth system would have significant consequences for societies and ecosystems worldwide. Particular risks have been identified for the following tipping elements, either due to the immediate risk of exceeding the tipping point due to changing climate conditions or with regard to particularly serious consequences: the Greenland ice sheet, the West Antarctic ice sheet, the Amazon rainforest, the oceanic circulation in the North Atlantic and the coral reefs {Background paper: Chapter 2.1}.

The risk of cascading tipping dynamics

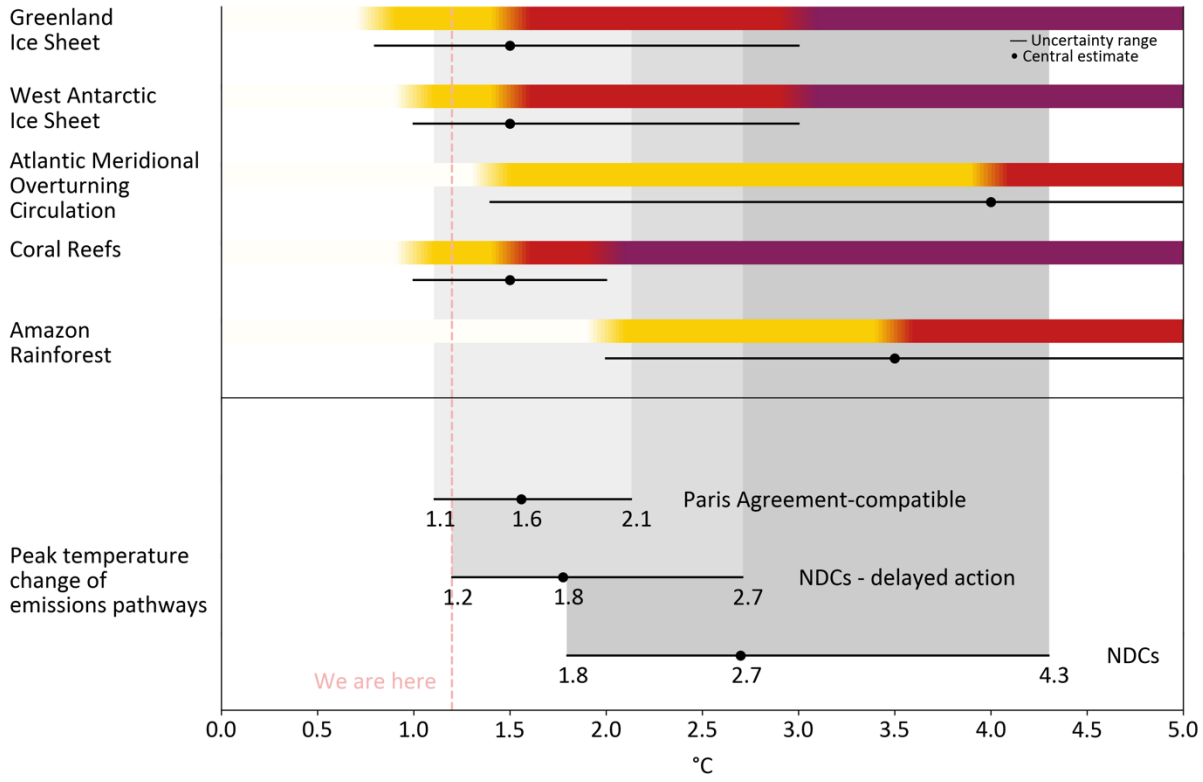
The components of the earth system are connected by interactions such as heat and mass transfer. This means that the tipping of one element can promote the tipping dynamics of other elements. The concept of tipping cascades illustrates the strong interconnectedness of the Earth system and the potential for often unforeseen climatic and ecological consequences. A network of connected tipping elements is shown in Figure 1. Assuming strong interactions between the tipping elements, tipping dynamics for individual elements could already be triggered at significantly lower warming levels. {Background paper: Chapter 2.2}

Climate and security policy implications

The findings on the risks of tipping elements and cascading tipping dynamics increase **the urgency of political action**. {Background paper: Chapter 3.1, 3.2}

- The **central importance of the goal agreed in Paris of limiting global warming to 1.5°C** is underpinned by **new knowledge on the risks of tipping elements.**
- Current climate protection efforts are insufficient to prevent tipping points from being exceeded and urgently need to be **sharpened in this "critical decade"**. The combined risk of a strong warming response of the Earth's climate system in general and the crossing of tipping points of various tipping elements increases sharply if action is delayed (Figure 2).
- A variety of measures are required to limit global warming to 1.5 °C compared to pre-industrial levels and to minimize tipping risks. The **use of atmospheric CO2 removal** is unavoidable but is also accompanied by concerns about its feasibility and sustainability.
- A possible crossing of tipping points harbors **risks for adaptation to climate impacts**. Even at the current level of global warming, some limits of adaptability for humans and ecosystems have already been reached, and these would be further strained if tipping dynamics were triggered

Figure 2: **Joint uncertainties of tipping points and global warming as a result of different emission pathways**



Tipping points of the five most urgent tipping elements and possible ranges of peak temperatures in the 21st century compared to pre-industrial levels (1850-1900) for selected emission pathways from the IPCC 6th Assessment Report. Source: Own representation, Climate Analytics, according to Kloenne, *et al.,* 2023

The sometimes drastic consequences of tipping dynamics can promote regional conflicts and crises {Background paper: Chapter 3.3}:

- Crossing tipping points can **escalate existing resource conflicts**; for example, the loss of glaciers and changes in the Indian monsoon regime could exacerbate water conflicts on the Indian subcontinent.
- A widespread loss of the Amazon rainforest, with 3-4°C warming and on a time scale of several decades to 100 years, would have serious consequences for the global carbon cycle, but also for South America's climate in particular. **The risk of droughts and water-related conflicts would increase significantly.**
- The loss of ecosystems with unique species richness, such as the Amazon rainforest or tropical coral reefs, which would already be threatened with extinction at a warming of 1.5°C and on a time scale of a few years to decades, would mean **a biodiversity catastrophe of geological proportions.** The associated loss of ecosystem services would affect hundreds of millions of people worldwide.
- A collapse of the Atlantic overturning circulation, increasingly likely at 4°C warming and over several decades, would have severe impacts on the North American, European and Near Eastern climate and with drastic consequences **for global food security**, as several major agricultural regions would be affected.

- **A sea level rise of several meters** as a result of exceeding ice sheet tipping points, which could be reached with sustained warming of over 1.5°C and would result in melting over millennia, **would fundamentally change the global coastlines and have serious consequences for coastal areas worldwide** and the habitability of entire countries.

Crossing **tipping points would have far-reaching security policy consequences**. It is therefore important to address these risks not only in international climate forums such as the Framework Convention on Climate Change, but also in other **bodies within the United Nations, other multilateral forums such as the G7 and G20, as well as security policy alliances**, for example. {Background paper: Chapter 3.4}

Sources

Armstrong McKay DI, Staal A, Abrams JF, et al. (2022): Exceeding 1.5°C global warming could trigger multiple climate tipping points. Science 9: 377. DOI: 10.1126/science.abn7950

Kloenne U, Nauels A, Pearson P, DeConto RM, et al. (2023): Only halving emissions by 2030 can minimize risks of crossing cryosphere thresholds. Nat Clim Change 13 (1): 9–11. https://doi.org/10.1038/s41558-022-01566-4

Wunderling N, Von Der Heydt A, Aksenov Y, et al. (2023): Climate tipping point interactions and cascades: A review. EGUsphere [preprint]. Verfügbar unter: https://doi.org/10.5194/egusphere-2023-1576

Imprint

Publisher
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
buergerservice@uba.de
Internet: www.umweltbundesamt.de
/umweltbundesamt.de
/umweltbundesamt

Status: November 2023

Authors, Institution
Kai Kornhuber, Uta Klönne, Dalia Kellou, Carl-Friedrich Schleußner
Climate Analytics gGmbH, Berlin

Editorial office
Department V 1.1 - Climate protection

The content of this factsheet summarizes the results and content of the background paper on the project "Tipping points and cascading tipping dynamics in the climate system - findings, risks and relevance for climate and security policy" (FKZ 37A23 01 001 0).