[1]ADWF= North Atlantic Deep Water [2]SPCO: Southern Pacific Climate Oscillation [3]ADW: Antarctic Deep Water

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TIPPING POINTS

TIPPING ELEMENTS

- subsystems of our planet
- at least subcontinental scale
- Small perturbations can tip them

Time scales for tipping vary from **years** to **decades** to **centuries.**

TIPPING POINTS

- Tipping points are the **critical points** at which the corresponding systems are qualitatively altered
- They occur when there is strongly **self-amplifying feedback** within a system
- Processes that lead to tipping are **difficult to model**

Problem:
Different data sources, analytical approaches and variables considered as well as a lack of large-scale monitoring systems

EFFECTS OF TIPPING

Tipping of systems can lead to **long-term irreversible changes**. This can encompass either
- **abrupt, linear responses** (e.g. conversion of the Amazon rain forest to a savanna) or
- **gradual, self-perpetuating responses** (e.g. large-scale loss of permafrost).

→ can counteract stabilization-efforts like reducing human emissions
→ **self-reinforcing feedbacks** within the Earth system **instead of human influences** will become the main drivers of change past the tipping points

ARCTIC SEA ICE LOSS

- Tipping point for the Arctic sea ice has probably been reached already
- ~13% of ice cover is lost every decade
- The ice shield is steadily thinning
- Some models show that the Arctic will be completely ice free in summer by the end of the century

→ Amplification of global warming due to the darker ocean's lower Albedo
→ Habitats for Arctic life are endangered

AMAZON RAINFOREST DIEBACK

- Amazon's tipping point is estimated to be at between 20-40% forest-cover loss
- In 2019 17% of forest cover was already lost due to the changing climate and deforestation
- The Amazon ecosystem is strongly linked to the El Niño phenomenon and regional precipitation

→ Change in the greater region's climate
→ Profound loss of biodiversity
→ Loss of living spaces for hundreds of indigenous peoples

DOMINO EFFECTS

Due to the **interconnectivity** of our Earth's subsystems there is a strong possibility for so-called domino effects.
→ Tipping one system leads to the **subsequent tipping** of one or more systems
→ Requires strong **causal connection**
→ Requires strong **network connectivity**

The **risk for domino effects** was found in **45% of possible interactions**. Besides the tipping domino effect, other non-tipping elements can interact with a system to amplify changes.

Example:

arctic sea ice loss amplifies global warming
→ increasing Arctic and Greenland ice melting
→ increasing amounts of fresh water
→ slowing down of the Atlantic Meridional Overturning Circulation
→ destabilization of the West African Monsoon
→ induction of a state of drought in the Sahel region
→ ...?

COUNTERACTIONS

Research highlights the importance of **limiting global warming to 1.5°C** over pre-industrial times (as per Paris Climate Agreement) to maintain the Earth-System in Holocene-like conditions.

Stabilizing the Earth's climate requires
- drastic **reductions** in **greenhouse gas** emissions,
- protection and augmentation of **carbon sinks**,
- **removing** of greenhouse gasses from the atmosphere and
- **adaptation** to unavoidable climate changes.

It appears as if some **systems are already past their tipping point.** This means the change will be most likely **irreversible**. However, the **rate at which change happens** and therefore if and how humanity can adapt to it can still be influenced.

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