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What are tipping points?

Tipping points—they can happen in any system. They can happen in society, they can happen in many familiar walks of life, but they happen in the climate system as well. And they tend to be when a change happens in a particular part of the climate system.

The ocean circulation could be an example where there's a forcing of the system that makes it become unstable and suddenly it flips to a completely new state very rapidly, much quicker than the typical time scale of that phenomenon itself—the ocean as an example. And often when it's changed to this new state, even if you reverse what we call the forcing that's pushed it into that state, it doesn't necessarily come back to where it started from. And that's a signal of what we call irreversibility in the climate system.

The two key things, I think, are that the change happens very rapidly compared to the time scale normally felt by that system, and it's not always reversible even if everything else is reversed.

Colin Jones, Professor of Climate Science, University of Leeds, WP1 Leader

Tipping Points
According to Intergovernmental Panel on Climate Change (IPCC), tipping points are critical thresholds that, when exceeded, can lead to significant and potentially irreversible changes in the climate system.

What are some examples of climate tipping points?

In climate research, we often deal with six major tipping points, which are also called global tipping points because they have an impact on the entire global climate system and even further beyond, on the ecosystem of society. And these six climate tipping points are:

- The large ice sheets on Greenland and Antarctica, which might melt, leading to significant sea level rise.
- Boreal forests.
- Tropical forests, which might die off over time when it gets very warm and dry.
- Permafrost in the northern land regions.
- The ocean circulation system in the North Atlantic—the AMOC, or Atlantic Meridional Overturning Circulation.

Torben Koenigk, Head of Global Climate Modelling, SMHI, WP5 Leader

AMOC
The Atlantic Meridional Overturning Circulation (AMOC) is a large system of ocean currents that transports warm water northward and cold water southward. It plays a crucial role in regulating climate, particularly in regions like Europe.

What might be some consequences if tipping points are exceeded?

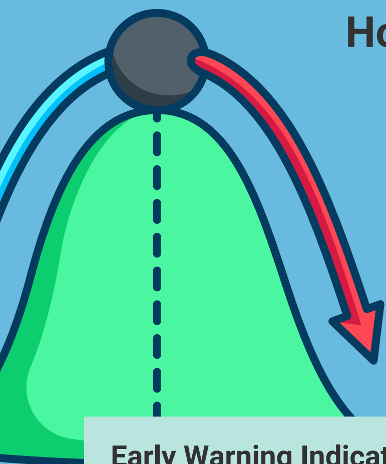
We can give a couple of examples. Torben referred to the Atlantic Meridional overturning circulation. If that halted very rapidly, one of the major consequences would actually be significant cooling over Europe—Northern Europe in particular, but Europe generally—with significant impacts because we're talking about significant cooling. It's believed that AMOC shutdowns in the past—not in the context of when we've had climate change as we do today, but in the past—have led to very significant cold periods over Europe as a result of that shutdown. That would be one example.

Another example would be if this rapid dieback of the Amazon forest, which can self-amplify, occurred. The whole regional climate over South America can change with significant drying out, and the Amazon forest is a significant sink for carbon from the atmosphere. If there's a rapid dieback of the Amazon, then you can end up with more carbon remaining in the atmosphere due to human emissions rather than being taken up by the biosphere. Those will be two examples, among many others.

Colin Jones, Professor of Climate Science, University of Leeds, WP1 Leader

Dieback
Dieback refers to the rapid decline or death of large areas of forest, often due to stress factors such as drought, disease, or other environmental pressures.

How might we know if we are approaching a tipping point?



This one can get quite technical. Turning back to the Atlantic Meridional overturning circulation again, it naturally varies. Even without the effect of humans and things, you can have periods when the Atlantic Ocean's circulation is a little bit stronger and a little bit weaker—often, we call that variability.

When you approach a tipping point, quite often the natural variability begins to change, and the system loses what's called resilience. As the system gets pushed a little bit away from where it wants to be, it finds it harder to get back to its natural state. The variability of the natural system begins to change radically as you approach a tipping point. That can be an early warning indicator that something unusual is about to happen, and a rapid, big change is about to occur as a consequence. We tend to look at variability, and if that begins to change badly and strongly and systems begin to lose what we call resilience, then we think we're maybe approaching a tipping point.

Colin Jones, Professor of Climate Science, University of Leeds, WP1 Leader

Early Warning Indicators
Providing an early warning of tipping events is crucial for effective climate adaptation and societal response and preparedness. It is therefore important to test the reliability of existing early warning indicators, investigate indicators of newly discovered tipping points, and develop new methods to deliver more accurate early warnings.

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How do you investigate tipping points in TipESM?

The main tools we are using in TipESM are climate models—more specifically, Earth system models. These models include not only the physical climate components, like the ocean, atmosphere, and sea ice, but also other components, like vegetation and chemistry in the ocean or atmosphere. What we are doing with these climate models is running them for different future climates. In particular, we bring them up to different global warming levels, warming above pre-industrial values—for example, 2, 3, or 4 degrees Celsius. Then, we look into our simulations and our data from the simulations using statistical methods to see if we identify tipping points and what tipping points would occur at what warming levels. We then look at what is happening before a tipping point occurs and what the consequences are afterwards.

In addition, to better understand and investigate the consequences, we are doing so-called "make it happen" experiments, where we artificially introduce a tipping point into the climate model and then look at what is happening afterwards.

Earth System Models
Earth System Models simulate the interactions of the atmosphere, ocean, land, ice, and biosphere to estimate the future state of the climate. As they increase in their process realism, Earth System Models can also include the impacts of human decision-making in the simulations. Consequently, Earth System Models can provide critical information on water availability, drought, climate and temperature extremes, ice sheets and sea levels, and land-use change

We are using a little bit of a different strategy to both understand what is happening before, how the tipping points are linked to each other, and what the consequences are.

Torben Koenigk, Head of Global Climate Modelling, SMHI, WP5 Leader

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Why are tipping points important to understand?

We already heard that there might be huge consequences when we reach a tipping point, both for the climate system and for the ecosystem or society. We know from many major tipping points that happened much earlier in the past, in paleo periods, but we still do not really know at what warming levels these tipping points might occur, what exactly the consequences of passing these tipping points are, or at which timescales these tipping points or their consequences would happen. So, it is very important to investigate more, to understand it better, and to provide more information on this to society.

Torben Koenigk, Head of Global Climate Modelling, SMHI, WP5 Leader

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