# How close are we to climate tipping points?

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The melting Greenland Ice Sheet. Credit: [Christine Zenino]

As world leaders gather at the United Nations Climate Change Conference (COP26) in Glasgow, Scotland, to take bolder action against climate change, human activity has already warmed the planet 1.1°C above pre-industrial levels.

The Intergovernmental Panel on Climate Change (IPCC) has warned that exceeding 2°C of warming could have catastrophic consequences and that we need to keep global warming to 1.5°C. The world is currently on track to surpass both of those limits. Under the most optimistic scenario, if all 140 countries that have announced net zero targets or are considering them actually reach these goals, as well as their more ambitious 2030 commitments under the Paris Agreement, warming could be limited to 1.8°C by 2100. But will overshooting 1.5°C push us over climate tipping points, triggering irreversible and abrupt changes? The IPCC's latest report warned of that possibility, and UN Secretary-General Antonio Guterres recently said, "…time is running out. Irreversible climate tipping points lie alarmingly close."

## What are the tipping points? And how close are they?

A tipping point is the point at which small changes become significant enough to cause a larger, more critical change that can be abrupt, irreversible, and lead to cascading effects. The concept of tipping points was introduced by the IPCC 20 years ago, but then it was thought they would only occur if global warming reached 5°C. Recent IPCC assessments, however, suggested that tipping points could be reached between 1°C and 2°C of warming.

Here are the major climate tipping points.

## Greenland ice sheet

The Greenland ice sheet contains enough water to raise global sea levels by over 20 feet and its melting is accelerating. From 1992 to 2018, it lost close to four trillion tons of ice. While its disintegration is not likely to be abrupt, there could come a point beyond which its eventual collapse is irreversible for millennia.

A new study found that ice-sheet height and melting rates in the Jakobshavn basin, one of the fastest melting basins in Greenland, are destabilizing the ice sheet. Most of the melting occurs on the ice surface because of warming temperatures, but as the height of the ice sheet is reduced, the surface is exposed to warmer air at lower altitudes, which further speeds melting.

In addition, less snowfall leaves the ice surface darker so it absorbs more of the sun's heat and warms faster. Scientists are not sure if a tipping point has been passed but the study found that there would likely be more melting in the near future. In other research, scientists speculated that the critical temperature range at which the Greenland ice sheet would go into irreversible disintegration is between 0.8°C and 3.2°C of warming above pre-industrial levels.

## The West Antarctic Ice Sheet (WAIS)

The WAIS is vulnerable to collapse because it sits on bedrock below sea level and is affected by the ocean's warming. A 2018 study found that the WAIS went from ice loss of almost 58.5 billion tons a year between 1992 and 1997 to 175 billion tons from 2012 to 2017. The Thwaites Glacier on West Antarctica's Amundsen Sea has lost a trillion tons of ice since the early 2000s, and some scientists believe it could be headed for an irreversible collapse, which could threaten a large part of the WAIS and raise global sea levels by two feet or more.

The Pine Island glacier, also on the Amundsen Sea, is thinning rapidly as well. A new study found that current policies, heading for almost 3°C of warming, would result in an abrupt hastening of Antarctic ice loss after 2060, while other research suggests that the tipping point for the WAIS lies between 1.5°C and 2.0°C of warming.

Another new study found that if the WAIS melted, it could raise sea levels three feet more than previous projections of 10.5 feet; Antarctica as a whole contains enough ice to raise global sea levels by over 200 feet.

## Atlantic Meridional Overturning Circulation (AMOC)

The AMOC is one of the main global ocean currents and is critical to regulating climate. Cold salty water, which is dense and heavy, sinks deep into the ocean in the North Atlantic, and moves along the bottom until it rises to the surface near the equator, usually in the Pacific and Indian Oceans. Heat from the sun then warms the water, and evaporation leaves the water saltier. The warm salty water travels up the coast via the Gulf Stream, warming the U.S. East Coast and Western Europe. Once the water releases its heat and reaches the North Atlantic, it becomes cold and dense again, and the cycle, which can take water 1,000 years to complete, continues. But as glaciers and ice sheets melt, they add fresh, less dense water to the North Atlantic, which prevents the water from sinking and impedes circulation. This may be why AMOC has slowed 15 percent since the 1950s. A recent study found that the AMOC is in its weakest state in 1,000 years. Moreover, the latest climate models project that continued global warming could weaken the AMOC by 34 to 45 percent by 2100.

If the AMOC shuts down, it would cause significant cooling along the east coast of the U.S. and Western Europe. This, in turn, would alter rainfall patterns, make sea levels rise, cause more drying, and reduce agriculture in the U.K. It could also potentially set off other tipping points. And even if global warming is reversed, once shut down, the AMOC would not switch back on for a long time. Scientists believe this occurred during the last ice age when a glacial lake burst and poured freshwater into the Atlantic. As the AMOC shut down, the Northern Hemisphere entered a cold spell that lasted 1,000 years.

While there are still many uncertainties, some studies suggest that the AMOC's tipping point could be reached between 3°C and 5.5°C of warming.

## Amazon rainforest

The Amazon rainforest, the world's largest tropical rainforest, stores 200 billion tons of carbon—equal to about five years of global carbon emissions from the burning of fossil fuels—and is home to millions of species of plants and wildlife. The moisture from the Amazon's rainfall returns to the atmosphere from the soil through evaporation and from plants through transpiration. This self-sustaining process creates clouds and more rainfall.

Because of logging, ranching, mining, agriculture, and fires, the Amazon has lost about 17 percent of its tree cover and at the current rate of deforestation, could reach a loss of 27 percent by 2030. The policies of Brazil's pro-development president, Jair Bolsonaro, have led to widespread clear-cutting and the rate of deforestation in Brazil is the highest since 2008.

If 20–25 percent of the Amazon were deforested, its tipping point could be crossed, according to one study. Fewer trees would mean less evapotranspiration, and without enough rainfall to sustain itself, the Amazon could start to die back. In other words, parts of the rainforest could transition into a savannah, a drier ecosystem characterized by grasslands and few trees. In the process, it would potentially release 90 gigatons of $CO_2$, exacerbating climate change. Crossing this tipping point would also result in the loss of biodiversity and ecosystem services, affect global weather patterns, and threaten the lives of 30 million people, many Indigenous, who depend on the rainforest to survive. One study found that dieback would occur if we reach 3°C of warming.

The Amazon is already feeling the effects of climate change, as over the last century, temperatures in the region have increased 1°C to 1.5°C. The Amazon is experiencing longer and hotter dry seasons that make it more vulnerable to wildfires, reduced evapotranspiration in response to higher levels of $CO_2$, and there are now more drought-tolerant tree species.

Scientists are unsure whether the Amazon has a single overall tipping point, or when exactly it might be reached, and the ecosystem has some ability to adapt to changing conditions. But fires and drought could cause local changes that spread drying conditions to other regions because of an overall reduction of moisture. Twenty-eight percent of the eastern part of the Amazon is already losing more carbon than it is absorbing due to deforestation. And some climate models predict that by 2035, the Amazon will be a permanent source of carbon.

## Thawing permafrost

Permafrost is ground that remains frozen for two or more consecutive years and is composed of rock, soil, sediments, and ice. Some permafrost has been frozen for tens or hundreds of thousands of years. It is found in northern hemisphere lands without glaciers, including parts of Siberia, Alaska, northern Canada and Tibet. In the Southern Hemisphere, there is permafrost in parts of Patagonia, Antarctica and the Southern Alps of New Zealand.

Fourteen hundred billion tons of carbon are thought to be frozen in the Arctic's permafrost, which is twice as much carbon as is currently in the atmosphere. But the Arctic is warming two times faster than the rest of the planet—it has already warmed 2°C above pre-industrial levels. As it warms and thaws the permafrost, microbes come out of hibernation and break down the organic carbon in the soil, releasing $CO_2$ and methane, which then trigger even more warming and melting. The 2019 Arctic Report Card from NOAA found that the Arctic's thawing permafrost could be releasing 300 to 600 million tons of carbon per year into the atmosphere.

Methane stored in ice-like formations called hydrates are also found in permafrost in ocean sediments. This methane may be released as hydrates are thawed by warming seawater. Scientists recently discovered methane leaking from a giant ancient reservoir of methane below the permafrost of the Laptev Sea in the East Siberian Arctic Ocean.

Scientists don't know exactly how much carbon could ultimately be released by thawing permafrost or when. According to one report, 2°C of warming could mean the loss of 40 percent of the world's permafrost.

## ENSO

El Niño and La Niña are the warm and cool, naturally occurring weather patterns across the tropical Pacific—the El Niño-Southern Oscillation, or ENSO. Every two to seven years, the pattern alternates, bringing disruptions in temperature and precipitation. El Niño causes impacts around the world, such as more drought in India, Indonesia and Brazil, and flooding in Peru. As the ocean warms, it could push ENSO past a tipping point, which would make El Niño events more severe and frequent and could increase drought in the Amazon.

## Tipping point interactions

A recent study of the WAIS, the Greenland ice sheet, the AMOC, ENSO, and the Amazon rainforest tipping points found that they could interact with one another before temperatures reach 2°C. This interaction would enable tipping to occur at lower thresholds than previously expected. The risk analysis found that a cascade could potentially begin with the melting of the ice sheets because their critical thresholds are lower. For example, as the Greenland ice sheet releases fresh water into the North Atlantic, the AMOC could slow. This would result in less heat being transported towards the north. As the North got colder, it could potentially help stabilize the Greenland ice sheet. However, it would also result in warmer water in the Southern Ocean and this could lead to more drought in some parts of the Amazon while others get more rainfall. Changes in the AMOC could also trigger changes in ENSO, leading to a more permanent El Niño state, whose impacts could lower the critical threshold for Amazon dieback.

The scientists say that these changes would occur over long time scales, and that the limits of computing power make it impossible to represent each climate system's tipping point or their interactions exactly.

## Can we avoid the climate tipping points?

Seventy-three percent of people in G20 countries think Earth is close to climate tipping points, according to a Global Commons Alliance poll. And much research indicates that if we do not curb our carbon emissions immediately to keep global warming below 2°C, we are headed for irreversible and catastrophic conditions. But some experts are more sanguine.

Robin Bell, a polar scientist at Columbia University's Lamont-Doherty Earth Observatory, who specializes in ice sheet dynamics, doesn't believe the ice sheets are at a tipping point yet.

"The most recent science is suggesting that maybe some of the runaway mechanisms we were worried about, might not occur," she said. "For example, in terms of the WAIS, pressure on the giant river of ice could keep it from flowing. It means either we just need to keep icebergs in the way, or maybe it's something we can think about engineering. It's not that we have to hold the whole thing back, we just have to put a little pressure on it, and it will possibly not collapse—the ice sheet may not be as bad as we thought and maybe we have some time to get our act together."

Bell worries more about the social tipping points than the physical ones. Will they occur fast enough to forestall climate tipping points? Social tipping points are the points where many members of society quickly and dramatically change their behavior or thinking. A 2020 study proposed six social tipping points that could help stabilize Earth's climate: removing fossil-fuel subsidies and incentivizing decentralized energy generation, building carbon-neutral cities, divesting from assets linked to fossil fuels, clarifying the moral implications of fossil fuels, expanding climate education and engagement, and making greenhouse gas emissions transparent.

"The real question is: Is there the social will to act?" Bell said. "And it appears that the social will is emerging. We really are starting to have serious conversations. People from the individual scale to the government scale are taking action, and that's what needs to happen."

Steve Cohen, senior vice dean of Columbia University's School of Professional Studies and a professor in the Practice of Public Affairs at Columbia's School of International and Public Affairs, places his hope in technology. "The most important driver of change in the modern world has been technology," he said. "And it's a pretty simple equation: technological change leads to economic change, leads to social and cultural change, which leads to political change."

Technological change can be difficult to predict but can sometimes lead to rapid changes, said Cohen, citing the ubiquitous and indispensable smart phone as a prime example. "The phone is the most important thing you take when you leave the house because it's a portable computer that you bring around with you. Would anybody have predicted that 25 years ago?"

He also puts great hope in young people. "If you look at polling data, young people by a huge margin understand the climate issue. And it cuts across ideology, cuts across everything. It you're under 30, you know, there's a climate crisis."

The pledges countries make in Glasgow at COP26 and the policies they implement afterwards will ultimately determine how close the world will come to climate tipping points.

Greta Thunberg, the 18-year-old Swedish climate activist with millions of young followers, went to Glasgow to join a climate strike and put pressure on politicians to get them to make real commitments to curb climate change.

"We know that change is possible because we can look back in history and see that there have been massive changes in society that have been unprecedented," Thunberg said. "If we felt like there wasn't any hope, we wouldn't be activists."

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