WHAT INFLUENCES THE ATMOSPHERE

Global warming: once a promise, now a threat

On the research of the greenhouse effect up to the Paris Climate Agreement

By Markus Bernards

Almost 200 years passed between the discovery of the greenhouse effect and today's climate models. A foray through the history of climate change research until it finally found its voice in world politics.

Without greenhouse gases, it would be bitterly cold on our planet. Life would be almost impossible at average temperatures of minus 18 °C. The fact that we owe our mild climate, in which most of the water is liquid, to the greenhouse effect, first occurred to the French mathematician Jean Baptiste Joseph Fourier. In 1824, he wondered how our earth could be so pleasantly temperate, with an average temperature of 14 °C, when the sun sends its warming rays down to earth from such a tremendous distance. About 70 years later, the chemist and later Nobel Prize winner Svante Arrhenius from Sweden presented a theory according to which the greenhouse effect is caused by the gas carbon dioxide (CO_2). CO_2 allows short-wave sunlight to pass through the atmosphere, but absorbs the long-wave infrared light reflected back from the heated earth. CO_2 thus leads to the heating of the atmosphere. According to Arrhenius, water vapour also intensifies the effect of carbon dioxide. Today, the theory, which at that time was only discussed in narrow expert circles, has been confirmed, and what Svante Arrhenius predicted for the unchecked consumption of coal, oil and gas has also been confirmed: namely that the increasing amount of CO_2 in the atmosphere would lead to a significant increase in temperature. However, he was wrong in his conclusion, because he saw the temperature increase very positively: »The increase of CO_2 in the atmosphere will allow future people to live under warmer skies.«

Today, the pleasant »warmer skies« have given way to threatening scenarios of global warming. In 2018, the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) lists the predictions for further global warming in its summary of global research findings: With rising sea levels, coastal cities and islands will sink, droughts in many regions will reduce harvests and make water scarce, elsewhere or at other times heavy rains will flood the land, in addition there will be wildfires and increasingly violent tropical storms. Joachim Curtius, atmospheric scientist at Goethe University, explains why: »The greenhouse gas concentrations in the atmosphere are changing so fast that the climate is also changing fast and neither ecosystems nor humans can adapt that quickly.«

1979: First World Climate Conference in Geneva

Although CO_2 only makes up 0.04 per cent of our air – 78 per cent nitrogen, 21 per cent oxygen and just under one per cent of the noble gas argon – it is the main driver of climate change. It was not until several decades following Arrhenius' calculations that this realisation was accepted. In 1938, shortly before the outbreak of the Second World War, the British chemist Guy Callendar calculated that there had been a

The most deforested part of the Amazon is the Brazilian state of Rondônia on the border to Bolivia. Rainforest clearing is the second largest source of CO_2 after the burning of fossil fuels and is also a threat to biodiversity.

global temperature rise in the previous 50 years and that this correlated with the rise in CO_2. His scientific paper was read in Germany by the climatologist Hermann Flohn and he was so deeply impressed by it that he addressed the possibility of man-made (anthropogenic) climate change in his habilitation three years later. Flohn went on to later become a scientific pioneer of the subject in Germany. He attended an international conference on an island off Stockholm in 1971, where some 60 experts from 20 countries conducted a very controversial discussion of anthropogenic climate change. Hermann Flohn later said about this conference: »We were all convinced that we absolutely had to do something about this problem, but also that it was still much too early to say anything about it.«

But the results of the three-week closed-door meeting found a broad echo in expert circles, and eight years later the World Meteorological Organisation of the United Nations organised the first World Climate Conference in Geneva, setting the international world climate research programme into motion. Intensive work began in the USA, France and Russia, but in Germany, even three years later, there was hardly any research funding for the topic – the Transrapid was more important to the research minister, Flohn remarked bitingly in the special »Weather« issue of Geo magazine in 1982. In the following decades, however, the topic slowly gained priority in German research budgets.

When the Intergovernmental Panel on Climate Change (IPCC) was founded in 1988, climate models were already so sophisticated that the IPCC began its first assessment report in 1990 with the words: »We are certain of the following: there is a natural greenhouse effect which already keeps the Earth warmer than it would otherwise be; emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxide. These increases will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface.« These scientists predicted then what we can measure today: A rise in the average global temperature of around 0.2 °C per decade. They only went too far out on a limb when it came to estimating how quickly concrete consequences would occur. In 2014, the magazine »Cicero« touched this sore spot, running the headline: »Predictions that missed the mark«, because the 50 million climate refugees predicted in 1990 had not materilaised, nor could the extinction of many species be attributed to climate change, and the IPCC had to revise their calculations of economic losses due to climate change downwards. The events of the following years, however, paint a different picture: the dry and hot

IN A NUTSHELL

- Natural greenhouse gases made life on Earth possible.
- Especially due to the release of CO_2 from fossil resources, the temperature is rising faster than the earth's ecosystems can cope with.
- To limit climate change to 1.5 °C global emissions must be drastically reduced within a few years.

summers of 2018 and 2019 and the forest fires of the past years have caused not only ecological but also major economic damage worldwide. Reinsurers rank climate change among the three biggest business risks, not only as a result of increased forest fires, but also due to crop failures, heavy rainfall and storms. And in 2019, the World Biodiversity Council IPBES estimated that one million species are at risk of extinction. Although increased land use is the main cause, it is exacerbated by climate change.

coral death. This death is visible as coral bleaching, where the coral polyps expel the unicellular algae they live with because the algae produce toxins when water temperatures are too high. For a short time, the corals can survive without their algae partners. If the water does not cool down, they die. In 2020, a quarter of the Great Barrier Reef off Australia was severely damaged in this way; following 2016 and 2017 it was the third coral bleaching of this largest coral reef on earth within a few years. It is questionable whether the scientists of the Hawai'i Institute of Marine Biology at the University of Hawai'i will be faster in their attempts to breed more heat-resistant corals than the continuing rise in temperatures. »We have already lost fifty per cent of the Earth's coral reefs«, says the Institute's director Ruth Gates. The coral reefs, also called »rainforests of the sea« because of their biodiversity, are not only threatened by long periods of higher water temperatures with one to two degrees being enough. More frequent storms and the acidification of the oceans are also affecting them, as CO_2 dissolves into carbonic acid in water.

Global warming is impressively demonstrated by the retreat of glaciers: The Pedersen Glacier in Alaska retreated two kilometres from Aialik Bay between 1940 (left picture) and 2005. The former lagoon is filled with sediments and overgrown with grass and bushes.

Corals: When ecosystems topple

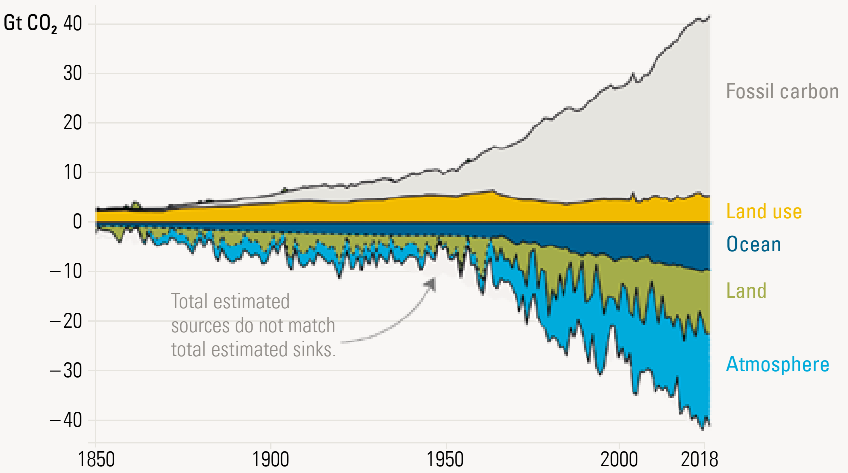
Nevertheless, models that make predictions about the effects of climate change are very difficult, as Joachim Curtius is well aware: »Certain interactions have not yet been described as well as we would like. For example, we don't know how much CO_2 and methane would be released from thawing permafrost. We would also like to know a lot more about whether and how, for example, the tracks of low-pressure systems are changing, or whether blocking high-pressure areas over Europe are becoming more frequent.« At the same time, however, he is certain: »We have understood the basic physics very, very well. So the fact that there is a greenhouse effect at all and that we will have a completely different planet with two, three or four degrees of warming – there is no reason to doubt that.«

If permafrost thaws, it could be one of the tipping points of climate change, with a small change in temperature of half a degree on average having big consequences – in this case a sudden release of large amounts of greenhouse gases. Another tipping point may be imminent:

Government reaction

Climate change has been on the agenda of world politics for 30 years. The first step was taken at the UN Conference in Rio de Janeiro in 1992, during which the international community accomplished a paradigm shift: environmental protection was placed on an equal footing with poverty reduction and social justice. Countries wanted to voluntarily reduce greenhouse gas

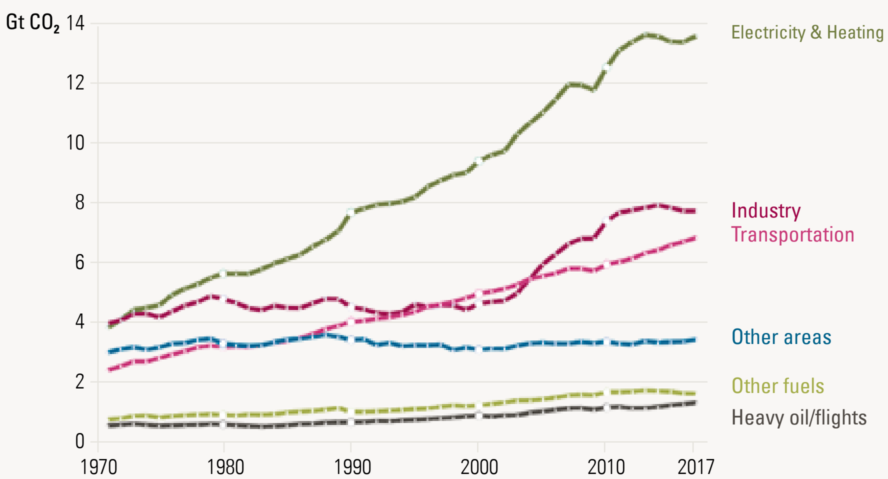
The CO_2 balance



Source: CDIAC; NOAA-ESRL; Houghton and Nassikas 2017; Hansis et al 2015; Joos et al 2013; Khatiwala et al. 2013; DeVries 2014; Friedlingstein et al 2019; Global Carbon Budget 2019

Fossil fuels and land use change – mainly rainforest clearing – have pushed annual CO_2 emissions up to nearly 40 gigatonnes between 1850 and 2018 (above the zero line). Not all emissions remain in the atmosphere: oceans absorb CO_2. Most is dissolved as carbonic acid and contributes to acidification. On land, CO_2 is stored by forests, bogs, humus, grasslands and lime formed during rock weathering.

CO_2 emissions from fossil fuels according to area



Source: IEA 2019; Peters et al 2019; Global Carbon Budget 2019.

According to the Global Carbon Project 2017, 45 per cent of CO_2 emissions from fossil fuels worldwide are generated for electricity and heating, 23 per cent by industry, 19 per cent by national transport and 3.5 per cent by international aviation and heavy oil consumption by ships. The remaining sectors account for just under 10 per cent.

According to the German Environment Agency, 85 per cent of the 720 million tonnes of greenhouse gases with which Germany heated up the atmosphere in 2018 were produced in the generation of energy. Electricity and heat production accounted for half of this, followed by transport (20 per cent), industry (15 per cent) and trade, commerce and service providers (5 per cent).

emissions. In the 1997 Kyoto Protocol, all industrialised countries except the USA committed to reducing annual greenhouse gas emissions to at least five per cent below 1990 levels. For many years and several conferences, no significant progress was made until the international community agreed in the 2015 Paris Agreement to keep global warming well below 2 °C and, if possible, to limit it to 1.5 °C.

In order to achieve this goal, climate researchers have calculated that humanity must not emit more than another 700 gigatonnes of CO_2. In view of the annual emissions of more than 35 gigatonnes of CO_2 via the burning of fossil fuels and cement production, this is not too much, especially since the concrete reduction targets of the Paris Agreement will not be sufficient. Joachim Curtius: »If all countries fully comply with their Paris commitments, we will still end up with about 3 °C of warming in 2100, which is much more than the Earth can cope with. We have an extreme time problem: 1.5 degrees of warming will already be reached by 2040 with current emission trends.«

It is therefore high time for drastic reductions in global CO_2 emissions. In November 2020, the United Nations therefore called for a »Race to Zero [Emissions]«. Joachim Curtius from Goethe University is also participating as a »Scientist for Future« in science's warning cry to the global community: »When it comes to the climate crisis, I see the danger that we will not experience the consequences first-hand until it is too late, because of the long time lag with which the climate reacts to greenhouse gas emissions. One of many challenges is to convince countries and the fossil fuel industries to stop producing coal, oil and gas. The remaining carbon budget of 700 gigatonnes is much, much less than theamount of CO_2 that will be released to the atmosphere if all the known fossil fuel reserves were exploited and burnt. That's why we have to convince states and companies to leave fossil energy reserves in the ground.« ●

About Joachim Curtius

Prof. Dr. Joachim Curtius is a professor for experimental atmospheric research at the Institute for Atmospheric and Environmental Sciences at Goethe University.
On page 107 he explains why he believes that we can still achieve the 1.5 °C goal of the Paris Climate Agreement.

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