EARTH AND ITS RESOURCES
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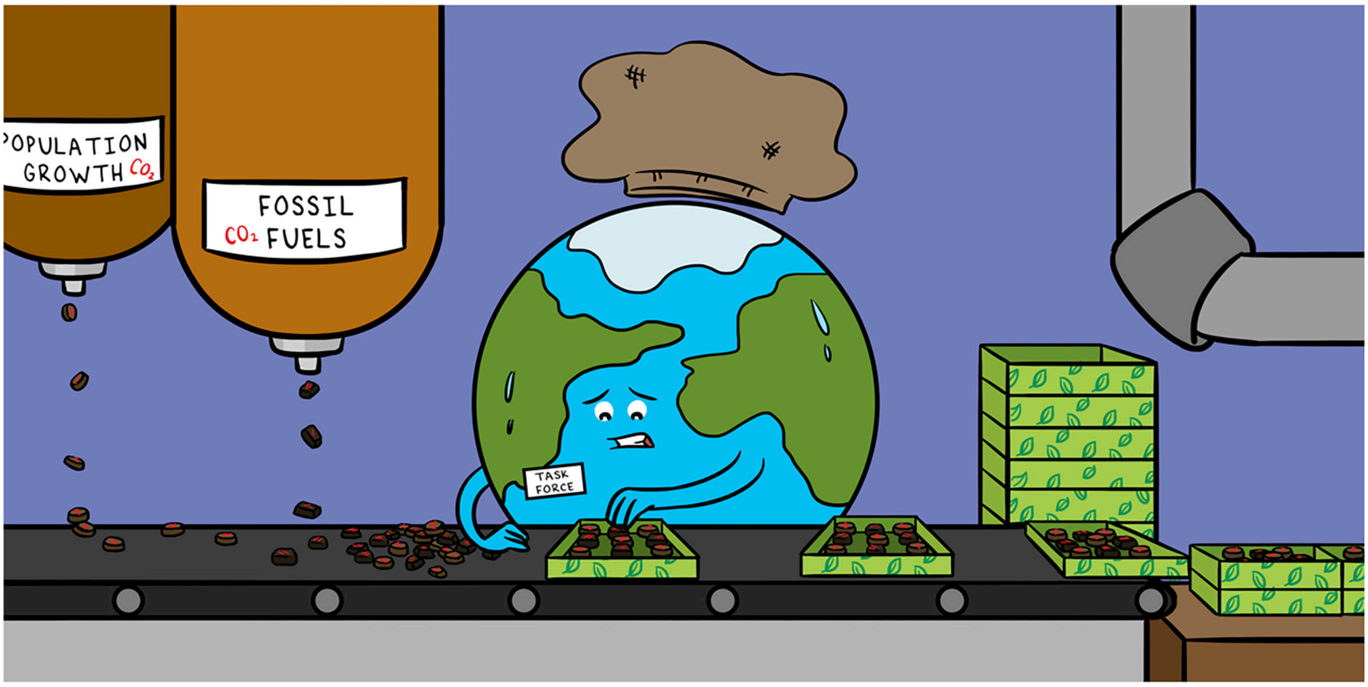

WHAT IS CAUSING OUR CLIMATE TO CHANGE SO QUICKLY NOW?

Rita Nogherotto[1,2*†], Clara Burgard[3†] and Chris D. Jones[4†]

[1] The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy
[2] Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy
[3] University Grenoble Alpes, CNRS, IRD, Grenoble INP, IGE, Grenoble, France
[4] Met Office Hadley Centre, Exeter, United Kingdom

YOUNG REVIEWERS:

ADDY
AGE: 13

TEDDY
AGE: 10

Our planet's climate has been warming much faster over the past 100 years than it has over the 10,000 years before that. In this article, we will explore how we know that the climate has changed so quickly in the last century, what carbon dioxide (CO_2) has to do with climate change, and why humans are responsible for the recent increase of CO_2 in the atmosphere. Understanding the problem is the best way to find a solution!

GLOBAL WARMING OR CLIMATE CHANGE?

It is about 1°C warmer today on Earth than 60 years ago. 1°C can seem like a very small change. After all, the difference in temperature between winter and summer can be 30°C in some regions! So why does **global warming** of a few degrees worry scientists so much?

GLOBAL WARMING

The warming we are experiencing due to the increased greenhouse effect.

Do you remember the last time you had fever? The usual human body temperature is around 37°C. When you have a fever, your body gets warmer by 1 or 2°C but you cannot concentrate well anymore, your body does not work as usual, and you need to rest. In the case of your body, it is a matter of a few degrees between being healthy and being sick. The effect of global warming on the Earth is like that of a fever: when the air at the surface gets warmer, the entire planet does not work as usual. The oceans warm as well. The thick ice melts away in cold and mountainous regions. All over the planet, living beings need to get used to new conditions or move to other regions. The warming of the planet affects everything within it, which is why we prefer to speak of **climate change** rather than of global warming. It is not only a problem of air temperature—there are changes in all elements of the environment around us.

CLIMATE CHANGE

The change of the Earth's climate due to the increased greenhouse effect causing warming of the Earth's surface.

CARBON DIOXIDE

A gas in the atmosphere that is created when we burn fossil fuels. CO_2 is a greenhouse gas and can stay in the air for many years. It is the main cause of climate change.

ATMOSPHERIC CO_2 CONCENTRATION

When measuring gases like carbon dioxide, the term concentration is used to describe the amount of gas in a given volume of air. It is usually measured in ppm (part per million), which is a way of expressing very dilute concentrations of substances. Just as per cent means out of a hundred, parts per million means out of a million.

GREENHOUSE GAS

A gas in the atmosphere which can absorb heat and cause the planet to warm up. These occur naturally, such as carbon dioxide and water vapor, but human activity is putting more greenhouse gases into the air leading to the planet getting warmer.

CLIMATE CHANGE AT PRESENT

In the past, the Earth has been warmer and colder than it is today. These temperature differences were due to changes in the Earth's position compared to the Sun, or to large natural events such as volcanic eruptions. These periods of warming and cooling occurred over several thousands of years. Nature and humans could therefore slowly adapt to the changing climate conditions.

This time it is different: climate change is happening very quickly. In Figure 1, you can see a reconstruction of the Earth's average surface temperature over the past 11,400 years. You can easily see that the temperature has risen much faster in the last decades compared to the temperatures that the Earth experienced previously. It only took 60 years to warm the Earth by around 1°C. Scientists have calculated that the Earth might be 3°C warmer—or even more—in 80 years, if we continue living like we are at the moment. Keep in mind that ice ages were only about 4°C cooler than today's temperatures, so this is actually a big deal! But…what is the difference between today's climate change and past climate changes? And what do humans have to do with it?

To answer these questions, let us go back some years in time. In the 1950s, a young scientist named Charles Keeling was wondering why the Earth had been warming so much over the past 100 years. He decided to measure the amount of **carbon dioxide** (CO_2) in the atmosphere, or what scientists call the **atmospheric CO_2 concentration**. Why CO_2? Charles knew that this gas is a **greenhouse gas**, meaning that it has a role in adjusting the temperature of Earth's atmosphere. The more CO_2 in the atmosphere, the more heat the atmosphere can absorb and send back to the Earth's surface, leading to global warming.

From that moment on, Charles measured the atmospheric CO_2 concentration every day—for years. Every year, he saw more atmospheric CO_2 than in the year before (Figure 2). This increase

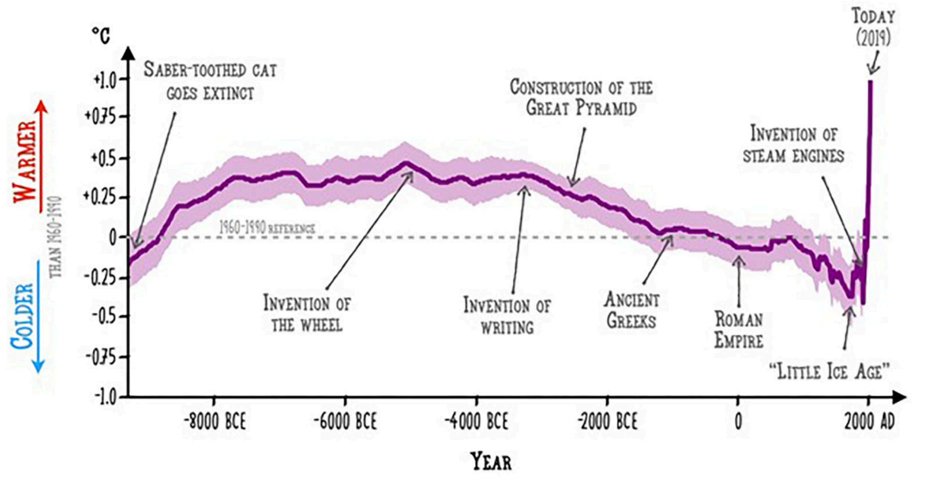

Figure 1

Figure 1

Variations in the Earth's average surface temperature over the past 11,400 years. The purple line is the mean and the shading around it is the uncertainty around the mean. BCE means before common era; AD means Anno Domini (Data until 1,900 compiled by [1]; data for 1900 to 2019 from [2]).

continues today: in 2019, atmospheric CO_2 concentrations were higher than they were at any time in at least 2 million years [4].

WHY IS THERE MORE AND MORE CO_2 IN THE ATMOSPHERE?

Charles discussed his findings with other scientists. They knew that more CO_2 in the atmosphere meant that the Earth was warming. And they knew that such warming could have dramatic consequences on the whole climate. They decided to find out what was causing this increase in CO_2. They hoped that tracking down the cause might help prevent more CO_2 from getting into the atmosphere.

As a first step, the scientists looked at the amounts of CO_2 in the atmosphere in the past. They found that, at least for the last 10,000 years (and probably for the last million years!), the amount of CO_2 in the atmosphere had never been higher than the amount Charles measured!

In the past, CO_2 was added and removed from the atmosphere through natural processes. Plants and oceans, for example, can store CO_2 and regularly exchange it with the atmosphere. Sometimes plants and oceans take up CO_2 from the atmosphere, reducing atmospheric CO_2 concentration, and sometimes plants and oceans release CO_2, increasing atmospheric CO_2 again.

These natural processes are very slow—they can take thousands of years to absorb or release large amounts of CO_2. This is why natural processes cannot possibly explain the rapid accumulation of CO_2 in the atmosphere during the last century. If the CO_2 is not coming from nature, then where is it coming from?

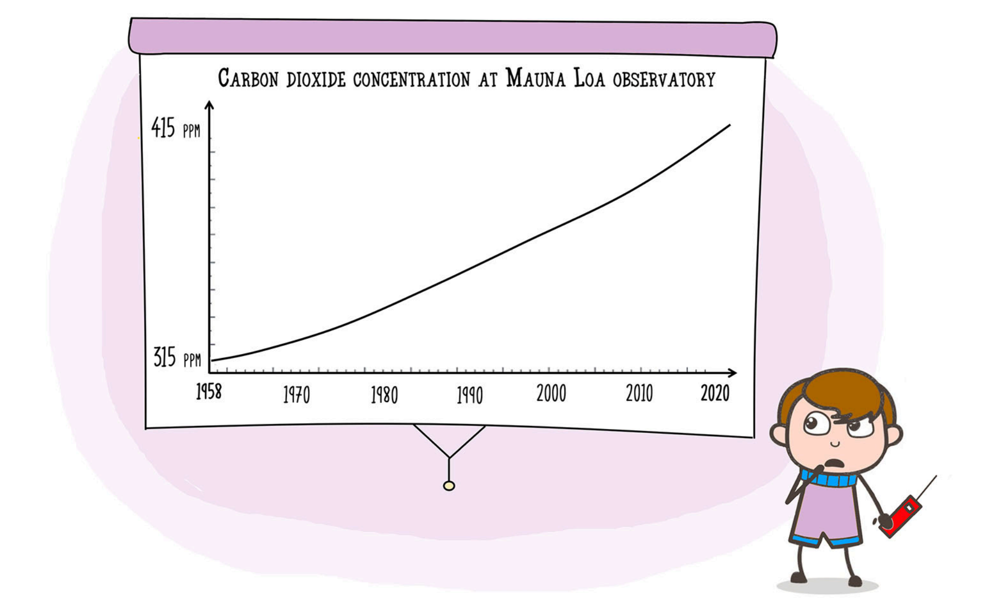

Figure 2

Figure 2

The atmospheric CO2 concentration, as measured on Mauna Loa, has been rising since it was first measured in 1958 (Data from [3]).

The CO_2 concentration started to rise very quickly around 150 years ago, when we started using machines to accomplish more work in a shorter time. To run these machines, we needed energy. We got this energy from burning oil, coal, and natural gas, which are called **fossil fuels**. When we burn fossil fuels, CO_2 and other greenhouse gases, including methane and nitrogen dioxide, are released (emitted) into the atmosphere.

FOSSIL FUEL

Fuels, such as coal, oil, and natural gas that were formed millions of years ago when plants and animals died and became buried. Burning fossil fuels creates CO_2, which goes into the atmosphere.

Over time, we needed more energy to power our cars, to heat our homes, to charge our smartphones, and so on. So, we burned more fossil fuels, leading to more greenhouse gas emissions. In parallel with industrial development, the human population has grown rapidly. To feed more and more humans, forests had to be cut down to create large fields for agriculture. As a result, less CO_2 could be taken up by trees. It is therefore we humans who were behind the fast increase in atmospheric CO_2 over the last century. And, since we have not yet stopped burning fossil fuels, we are still responsible for adding more and more CO_2 into the atmosphere!

The amount of CO_2 we emit is very small compared to that exchanged naturally between plants, oceans, and the atmosphere. So why does this small amount emitted by humans have such a big impact on our planet's temperature? Cannot plants and oceans just take up more CO_2? Let us take a sneak peek into the natural "CO_2-control task force" and how the atmosphere, plants, and the oceans divide the work between them.

HUMANS INTRODUCED AN IMBALANCE IN NATURAL CO_2 EXCHANGE

Nature likes a balance between different elements. For example, when you open your window in winter, cold air from outside and warm air from inside mix until they reach a common temperature—the indoor and outdoor temperatures are balanced. Over thousands of years, nature adapted to keep such a balance in the Earth's CO_2. If the amount of CO_2 in the atmosphere was higher than usual, the plants and the oceans would take up more CO_2 than usual, until CO_2 amounts were all in balance again. The atmosphere, plants, and the oceans form what could be considered a natural CO_2-control task force, because together they regulate the exchange of CO_2.

When humans started burning fossil fuels, more CO_2 started accumulating in the atmosphere in a short period of time. The change in atmospheric CO_2 was so fast that the CO_2-control task force could not keep up with establishing the balance. The fast rise in atmospheric CO_2 concentration and the resulting atmospheric warming put the plants and the oceans under pressure. The task force did not have time to adapt to higher amounts of CO_2, as it could in the past. As a result, the atmospheric CO_2 concentration increased even more, leading to more atmospheric warming, putting plants and oceans under even more pressure, and so on. This is what we call the **vicious circle** of the **carbon cycle** (Figure 3). This vicious circle has only a small effect compared to the human CO_2 emissions coming from the burning of fossil fuels, but it is expected to have a larger effect in the future! You should know that there are many such vicious circles in nature. For example, different vicious circles are responsible for the very fast warming in polar regions. Other greenhouse gases are also increased by human activity, although CO_2 is the biggest cause of climate change. Methane (CH_4) and nitrous oxide (N_2O) have also increased a lot since pre-industrial times because of the burning of fossil fuels and the increase in agriculture.

VICIOUS CIRCLE

A chain of events in which a change compared to the usual situation has the effect of creating new problems which then cause the original change to change more, creating new problems and more change again and again.

CARBON CYCLE

The movement of carbon through nature—plants absorb CO_2 from the air as they grow, and release it again when they die. The water in the oceans dissolves CO_2. This cycle is called the carbon cycle.

IN CONCLUSION

The amount of CO_2 that humans send into the atmosphere may appear small at first glance. However, it is enough to throw off the balance between the atmosphere, the oceans, and plants.

The good news is that Charles' measurements started a scientific investigation into the changes in atmospheric CO_2. Ever since Charles' first measurements in the 1950s, the crowd of scientists trying to understand climate change has grown. Today, we know much more than we knew in Charles' time. We know that it is humans who are behind the rise in atmospheric CO_2 concentration. And it is therefore also humans who will be able to *stop* climate change. By reducing CO_2 emissions, we can slow down climate change: every ton of CO_2 that

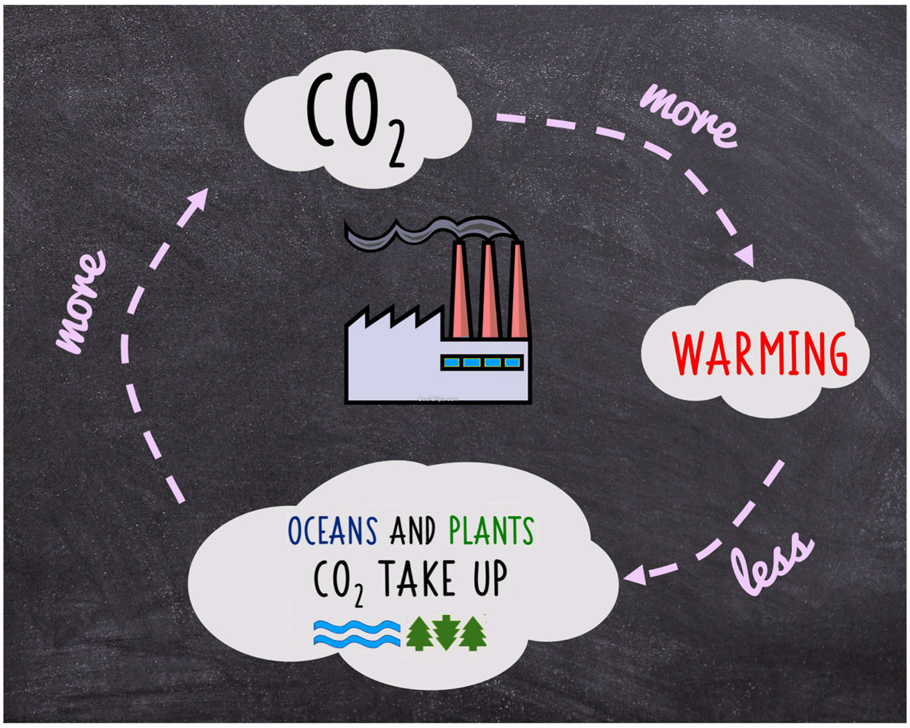

Figure 3

Figure 3

The vicious circle in CO_2 exchange. Humans add CO_2 to the atmosphere. This leads to atmospheric warming, putting oceans and plants under pressure. Oceans and plants take up less CO_2, which leads to more CO_2 in the atmosphere. This leads again to more warming, less CO_2 uptake, more CO_2 in the atmosphere, and so on.

does not go into the atmosphere means less warming. Our actions *now* are essential to avoid future climate change [5]! We need smart, creative, and hopeful people to think of new ways to live our lives! Maybe you will be one of those people?

BRIEF SUMMARY

Climate change: we hear about it almost every day now. We hear that our planet is warming and that this warming is caused by us. But why is that a problem? And what exactly are the mechanisms driving climate change at the moment? In this article we try to explain to a younger audience (8–11 years old) what are the causes of the recently observed changes in our climate. These changes are occurring faster than past changes. They cannot be caused by natural events only. Understanding the causes of climate change is crucial to figure out what is going on and what can be done to limit its consequences.

REFERENCES

1. Marcott, S. A., Shakun, J. D., Clark, P. U., and Mix, A. C. 2013. A reconstruction of regional and global temperature for the past 11,300 years. *Science*. 339:1198–201. doi: 10.1126/science.1228026
2. Available online at: `https://climate.nasa.gov/vital-signs/global-temperature/`

3. Keeling, C. D., Bacastow, R. B., Bainbridge, A. E., Ekdahl, C. A., Guenther, P. R., and Waterman, L. S. 1976. Atmospheric carbon dioxide variations at Mauna Loa Observatory, Hawaii. *Tellus*. 28:538–51. doi: 10.3402/tellusa.v28i6.11322
4. IPCC. 2021. "Summary for policymakers," in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, eds V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (Cambridge: Cambridge University Press).
5. Trascasa-Castro, P., and Smith, C. 2021. What can we do to address climate change? Front. Young Minds. 9:672854. doi: 10.3389/frym.2021.672854

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ADDY, AGE: 13

I am in 7th grade and really enjoy volunteering at my local museum. I really like helping animals and I hope to become a veterinarian when I get older. My favorite class in school is my dance class (I am very flexible) and I love to travel.

TEDDY, AGE: 10

I want to be an engineer. I have really enjoyed trying and struggling to learn how to engineer and code things. I am dyslexic. I really love math (especially algebra and geometry). I like to travel. I bike 30 miles a week most weeks.

AUTHORS

RITA NOGHEROTTO

I am a postdoctoral physicist. During my Ph.D., I worked on modeling the complex processes occurring inside the clouds. Their representation in climate modeling is very important and crucial to understand the future climate. I am now focusing on extreme events related to climate change, such as floods and fires. Science, travels, books, and small adventures are my passion. I also love to share the things I learn and to promote scientific thinking. *nogherotto@gmail.com
†https://orcid.org/0000-0003-1718-542X

CLARA BURGARD

I am a climate scientist particularly interested in the climate of cold regions where there is a lot of ice and snow, like the Arctic and the Antarctic. Specifically, I like to investigate the interactions between ice floating on the ocean and the ocean underneath. To better understand the consequences of climate change on the ice and the ocean at the poles, I use calculations done by large supercomputers and pictures taken by satellites from space. †https://orcid.org/0000-0003-3847-3172

CHRIS D. JONES

Chris D. Jones is a climate researcher at the Met Office Hadley Center in Exeter in the UK. He has over 25 years of experience of writing computer programmes to model how climate affects our natural ecosystems and how the carbon cycle helps reduce the amount of CO_2 pollution in the atmosphere. He leads a research programme with partners in Brazil and has visited research sites in the Amazon rainforest. The photo here is on top of the Mauna Loa volcano in Hawaii where CO_2 is measured. †https://orcid.org/0000-0002-7141-9285