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EARTH AND ITS RESOURCES
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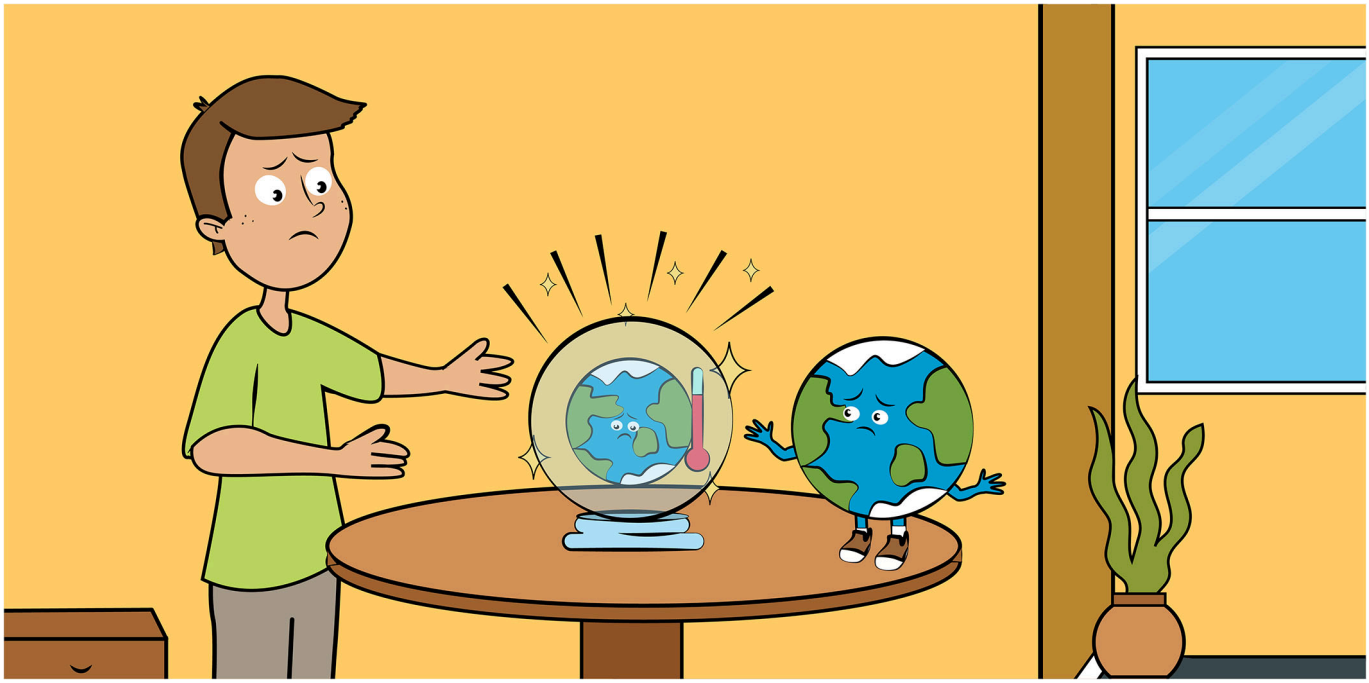

WHAT MIGHT THE FUTURE CLIMATE LOOK LIKE?

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AGE: 12

Our planet's climate is warming rapidly, mostly because of greenhouse gases released by human activities. Earth's future depends on our actions, and getting a glimpse into the future could help us make smart decisions right now. A climate model is a computer-based twin of our planet's climate system, and many different climate models exist because there are many ways to describe the complex planet we live on. Scientists experiment with what the future might look like by changing the amounts of greenhouse gases and particles (pollution) in the computer atmosphere within a climate model. This way, we can figure out the amount of greenhouse gases we can safely emit to avoid dangerous climate change. Currently, climate models estimate that we will end up with a warming of 3°C by 2100, but this can still change depending on our actions.

WHAT ARE CLIMATE MODELS AND WHY DO WE USE THEM?

The Earth's climate has been changing a lot over the last 100 years, especially recently. Some of the changes, like the melting of glaciers, are visible to the naked eye. Others, like changes in how often it rains, are not as easy to see. Luckily, we do not rely only on our eyes to record changes. Scientists have installed instruments all around the globe that constantly measure changes in temperature, rain, wind, and sunshine. We even have instruments out in space on satellites, recording not just weather but climate-related properties of the ocean, the ice sheets, and the land all of which show the state of Earth's climate.

To better understand the reasons behind the observed climate changes, scientists need to do experiments. Let's say a climate scientist is curious to know what would happen if the Pacific Ocean suddenly had double the amount of sea salt as it has now. If the scientist tested this by releasing tons of sea salt into the ocean, the consequences could be catastrophic. Instead, scientists have created a digital copy of Earth on a computer. This copy consists of a computer atmosphere, a computer ocean, and computer land, almost like a video game [1]. This computer copy of Earth's called a **climate model**. In a climate model, it is safe to do experiments. Scientists can add a bunch of sea salt into the ocean or remove all the clouds, if they wish. Scientists use climate models to do both realistic and unrealistic experiments, to deepen their understanding of Earth's climate.

CLIMATE MODEL

A climate model is a model world built on a computer. Some climate models are more complicated than others.

Before trusting climate models, scientists want to check that the models work properly, so they simulate the recent past and compare the model results to actual observations. Such an experiment is called a historical simulation. This can be done by starting a climate model in the year 1850 and adding pollution (including greenhouse gases and small particles in the atmosphere) every year, stopping the experiment in the present day. Adding pollution is meant to represent human activity since the **Industrial Revolution**, which began in 1850. Using this historical model, we can compare climate change on our computer version of Earth to climate change on real Earth, as measured by our instruments on Earth and in space. If the changes are similar, we know our climate models are working properly, and that we have created a good model of Earth's climate. There are many climate models because there are multiple ways to describe the complex processes on Earth.

INDUSTRIAL REVOLUTION

The period beginning in 1850, when manufacturing processes started releasing greenhouse gases and small particles into Earth's atmosphere.

When we look at the results from a historical simulation, we often average the results of many models and present the data as one. For example, the red line in Figure 1 is based on 48 climate models! Figure 1 shows temperature change data from climate models, together with the real temperature change that has been measured by instruments, from the Industrial Revolution to 2014. The data from these models closely match the actual data and illustrate the temperature increase

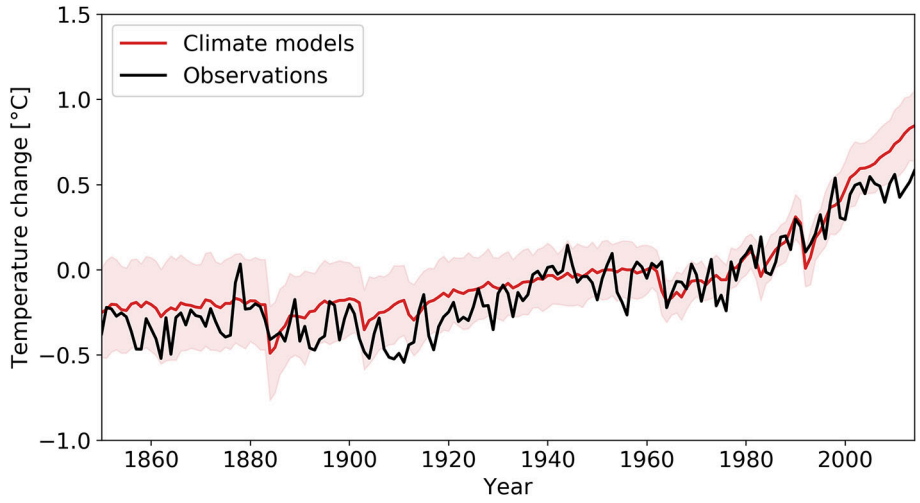

Figure 1

Figure 1

Historical development of global temperature as averaged from 48 climate models (red) and observations (black) from 1850 to 2014. The light red shading shows the uncertainty of the climate models, or in other words: how much the models are varying, since all 48 of them do not show the exact same temperature change.

known as **global warming**. The red line is very close to the black line, so we can see that the models are doing a good job of representing the evolution of Earth's temperature. We can also see that the temperature increased over time, first slowly and then more rapidly. This is what is called global warming.

Accurate climate models can be used not only to *estimate* the future, but also to guide human actions in the future. Our future climate depends on our future actions, and scientists use climate models to help us prevent dangerous climate change from happening.

HOW DO WE ESTIMATE THE FUTURE WITH CLIMATE MODELS?

Climate change is mainly caused by an increased **emission** of **greenhouse gases**, specifically carbon dioxide (CO_2). A climate model is a great tool to assess future climate change since we can use it to experiment with varying levels of pollution that might occur in the future. It is impossible to know exactly how much pollution humans will emit in the future, but we can create different stories of what the future might look like. We call these stories **scenarios**. One scenario could be that the entire world collaborates to strongly reduce the amount of greenhouse gases we emit, maybe even capturing CO_2 from the air. This scenario is very hopeful, and we can call it a best-case scenario or, as many scientists, say, a low-emission scenario. The worst-case scenario is that humans continue to emit more and more CO_2 into the atmosphere in the future, just as we have done from 1850 until today.

Experiments using climate models are performed by changing the amount of pollution in the computer atmosphere for every year in the future, either decreasing pollution levels to examine the best-case

GLOBAL WARMING

The measured temperature increase over the past 150 years, caused by an increased emission of greenhouse gases.

EMISSION

The release of something, in this case, into the atmosphere.

GREENHOUSE GASES

Greenhouse gases (GHGs) are ones which act to warm the air, causing global warming. The most well-known one is carbon dioxide.

SCENARIO

A potential story of how the future looks like. There are many scenarios for our future which depend on how much pollution we emit.

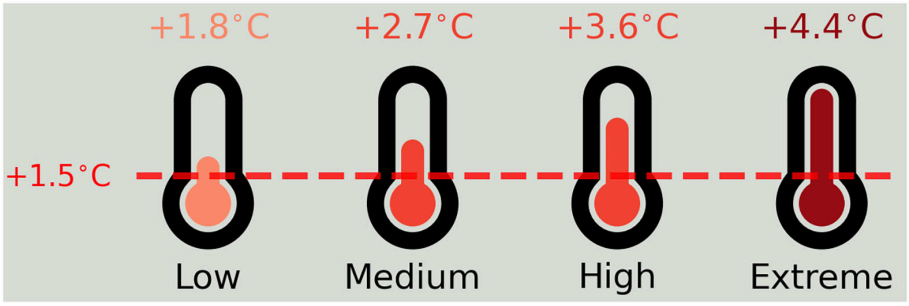

Figure 2

Figure 2

The amount of global warming Earth will experience in the future (up to 2100) depends on human emissions of greenhouse gases. 1.5°C of warming is the "safe" amount of warming agreed upon by politicians in Paris in 2016. "Low" refers to low emissions of greenhouse gases, in which we would end up with a warming of 1.8°C. On the opposite end we find "Extreme" which refers to a scenario where we emit extreme amounts of greenhouse gases, and the world would warm by 4.4°C in 2100.

HISTORICAL SIMULATION

A climate model experiment which starts in 1850 and ends in the present day, which includes emissions of pollution. A historical simulation is compared to observations.

scenario or increasing them to examine the worst-case. One difference between climate modeling and the **historical simulation** mentioned earlier is that the historical simulation starts in 1850 and ends in the present day, while modeling the future starts in the present day and might end in the year 2100. Since we do not have any real-world measurements from instruments in the future, this means we cannot compare our model Earth to real Earth when we look at the future, which is why just one scenario is not enough. We need a number of climate models so that we can understand the best-case scenario, the worst-case scenario, and scenarios that are in between. With this information, we can make the choices that will best shape the future.

WHAT DO THE CLIMATE MODELS TELL US ABOUT THE FUTURE?

Our computer models of Earth tell us that our planet will continue to warm over the upcoming decades. However, how hot Earth will get will depend directly on how we all live, which foods we eat, and how much we will continue to pollute our planet.

One thing that all our models tell us is that we need to reduce our pollution quickly (Figure 2). If all countries around the world start to reduce their CO_2 emissions today, Earth would only warm by 1.8°C by the end of this century. In this optimistic case, we would stop sea levels from rising too fast, so our coastal cities would not get flooded. Temperatures would not get too hot to grow our food, and we would also limit extreme weather events like heatwaves and droughts. However, this optimistic best-case scenario can only be achieved if humans reduce their emissions to a very low level, and ideally to zero.

If we continue polluting for a few more decades before we stop, Earth will certainly develop a high fever. In these medium- and high-emission stories of our future, model Earth would warm by 2.7°C or 3.6°C. Just like a fever in the human body, a temperature increase of just a few degrees makes Earth struggle. Glaciers in the mountains

and in the Arctic would completely melt away. Many plants, trees, and animals and humans, too would struggle to adapt to this hotter world. We should certainly try to avoid such a story of our future.

In a worst-case scenario, we would not simply continue to pollute our planet at today is pace, but we would even increase our emissions. In such an extreme scenario, Earth would develop a massive fever and get very hot. Our model Earth would warm by 4.4°C, which would have catastrophic consequences for humans and animals.

The good news is that some countries have already started to reduce their emissions, so we will probably not follow such an extreme scenario. The bad news is that our models and observations tell us that the low-emission story the best-case scenario is getting increasingly unlikely, too. Our best current estimate is that we are heading for roughly 3°C [2] of warming in 2100. A 3°C degree warmer Earth would be above the safety threshold of 1.5°C of warming that politicians from all around the world have agreed on. However, our models also tell us that it is still possible for us to stay below 1.5°C of warming!

CONCLUSIONS

Climate models can be used for experiments that would not be possible in real life. These models can be used to estimate both the future and the past, but our future story depends on how much pollution humans will emit. Researchers have created several scenarios for future emissions. Climate models show that global warming could increase from 1.8 to 4.4°C by 2100. Currently, climate scientists estimate that we will end up with a global warming of roughly 3°C [2], and such a world will look very different from today's world. It is very important to remember that this estimated warming does not have to happen. There is still time to make changes that will limit climate change, even to the low-emission scenario of 1.8°C of warming. If we all work together for strong and rapid reductions in our greenhouse gas emissions, we can keep Earth healthy and habitable.

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I am a 12 years old girl, very curious about our planet and engaged in promote actions to take care of our world. I like reading, dancing and acting. I hope to support our planet with art and science!

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I am a Norwegian climate scientist interested in climate models. I am specifically interested in how small particles emitted by human activity affects how much sunlight reaches the surface of the Earth. When I am not researching I enjoy fishing and olympic weightlifting. *komoseid@gmail.com

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