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A CHANGING ANTARCTICA: HOW COMPUTER MODELS HELP SCIENTISTS LOOK INTO THE FUTURE

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YOUNG REVIEWERS:

AVA
AGE: 11

OLIVIA
AGE: 12

QUINN
AGE: 13

As the temperature of the Earth warms, ice in Antarctica melts. As ice flows off the land and into the sea around the edges of Antarctica, warm ocean waters melt the ice from below. Warm air also melts ice at the surface. This melting ice raises sea levels around the world, flooding our coasts and causing serious damage to our buildings and roads. We do not know exactly how much warmer our world might get in the future, but we can use computer models to predict how much Antarctic ice could melt, and how much sea-level rise might happen. Our models suggest that the future of Antarctica is unclear, and we need more scientists helping to solve this problem. To avoid the worst impacts of sea-level rise, we must keep temperatures as low as possible and reduce greenhouse gas emissions as much, and as quickly, as we can.

WHY DO WE CARE ABOUT ANTARCTICA?

The Antarctic **ice sheet** is a very special place on Earth. It is a continent that is almost entirely covered by a thick layer of ice. Antarctica is about twice the size of Australia, 1.5 times the size of the United States, and bigger than all the European countries combined! Because of its massive size and very thick ice, Antarctica contains more than 90% of all ice on Earth. This is a lot of ice! As Earth's temperature gets hotter, some of the ice in Antarctica will melt, just like an ice cube melts on a hot summer day and creates a small water puddle (Figure 1). When the ice in Antarctica melts, most of the water goes into the ocean, causing **sea-level rise**. Even though it is frozen, the ice also flows very slowly from the center of Antarctica to the coasts, and the ice flows faster as the climate warms, meaning that even *more* ice reaches the edges of the land and melts into the oceans. What worries scientists is that there could be a "tipping point" after which Antarctica might melt faster and faster, more quickly than we could control or adapt to (Read more here). Higher seas mean that some cities are at risk of being under water. We already see that some cities flood more often than they used to, affecting more than one billion people in 2050, worldwide.

ICE SHEET

A very large and thick body of ice that covers a vast land surface. Today's ice sheets are the Greenland and Antarctic ice sheets.

SEA-LEVEL RISE

The measured height of water in the ocean. This changes constantly because of multiple factors, including how much ice melts from Antarctica.

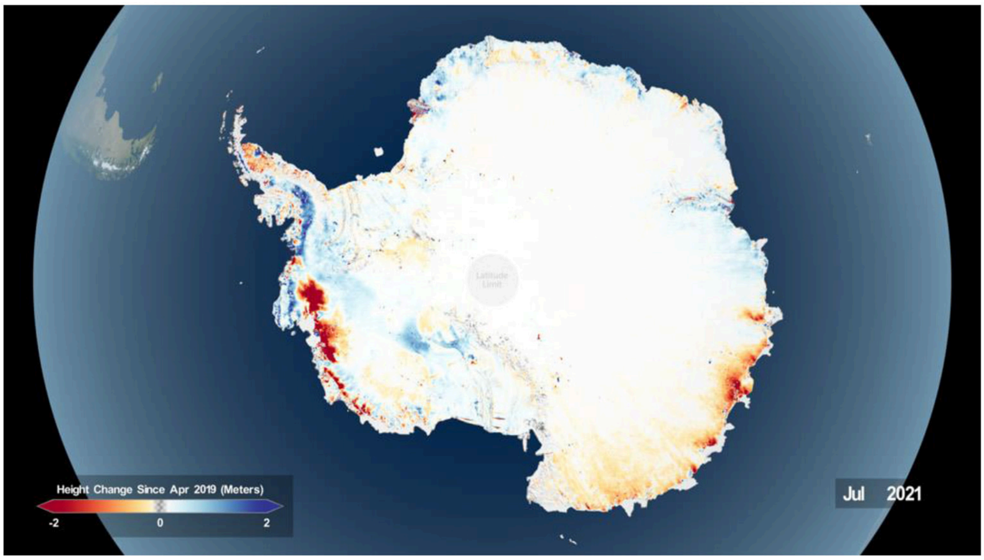

Figure 1

Figure 1

Surface height change of Antarctica as measured by satellites, in response to a warming atmosphere and ocean. Red colors show where the ice sheet has gotten thinner and blue shows where the ice has gotten thicker. Satellite measurements can tell us how Antarctica has changed in the past, but they cannot tell us how it will change in the future. This is why we need ice sheet models. Image credit: NASA's Scientific Visualization Studio.

WHAT IS A MODEL OF ANTARCTICA?

A model is a representation of something. An example of a model is a castle that you build from building blocks, like Legos or Minecraft. Your creation will have all the important parts of what makes a castle: it can have towers, a drawbridge, and protective walls. In the end, your model castle will be different from a real castle, but it will be made up of similar parts.

When scientists create models of Antarctica, instead of building blocks they use computer programs. And, just like the building-block castle, they must also make sure that the **computer model** includes everything that scientists think is important about Antarctica. For example, the ice in Antarctica is the result of snowfall over thousands of years. So, a key part of a model of Antarctica, called an **ice sheet model**, is that it keeps track of how much ice there is, by adding snow that falls on the ground and removing the snow that melts.

COMPUTER MODEL

A computer program that contains all the knowledge scientists have about how something works. There are computer models of ice sheets (ice sheet models) and the whole Earth (climate models).

ICE SHEET MODEL

A computer model of Antarctica. It uses the amount of snow falling on the ice sheet as input and calculates how fast ice flows.

The early models of Antarctica were similar to giant snowballs. Scientists would keep track of how much snow had fallen and should be added to the giant snowball over time, or how much snow should be removed because it was getting warmer. But as scientists continued to study and understand Antarctica, they realized that a giant snowball was a bad model of Antarctica. A better model is very cold syrup or honey that you pour on pancakes! This is because Antarctica, like cold syrup, does not keep the same shape over time. Ice slowly flows and slides over the land underneath and, by doing so, it spreads out and gets thinner. Next time you are in the kitchen, pour cold honey or syrup on a plate, and you will see it slowly spread out and get thinner. Antarctic ice does the same thing—but much more slowly!

So, a good way to describe how Antarctica's ice moves in space and time is to treat it as a very cold, sticky liquid. And that is exactly how scientists treat ice in today's ice sheet models. Of course, we must still keep track of how much snowfall to add to the model, to know how much the ice should grow—this is like knowing how much syrup or honey is poured onto your plate. We must also understand how quickly the ice that is touching the ocean is melting (Figure 2). But now our ice sheet model also knows that the ice that is added due to snowfall also needs to slowly spread. The ice sheet models that scientists create try to capture all that we know about Antarctica and, as scientists learn new things about ice, we update our models.

WHY DO WE NEED COMPUTER MODELS OF ANTARCTICA?

Scientists use computer models to make predictions about what the future will look like or what the past was like. These models help us to understand how Antarctica could change in shape and size under many possible temperatures and climates. Our models also help us test ideas, for example, whether we can slow down sea-level rise if Earth's temperatures do not rise as fast as they have recently.

PROJECTION

An estimate of what the future will look like. This can also be called a prediction, which in our case comes from models.

To make **projections** (predictions) about the future, we also need to understand what is happening in Antarctica right now. Even though we know a lot, there are still some very important things that we do not know about Antarctica. For example, we do not really know what is going on underneath the very thick ice. Is the ice stuck (or

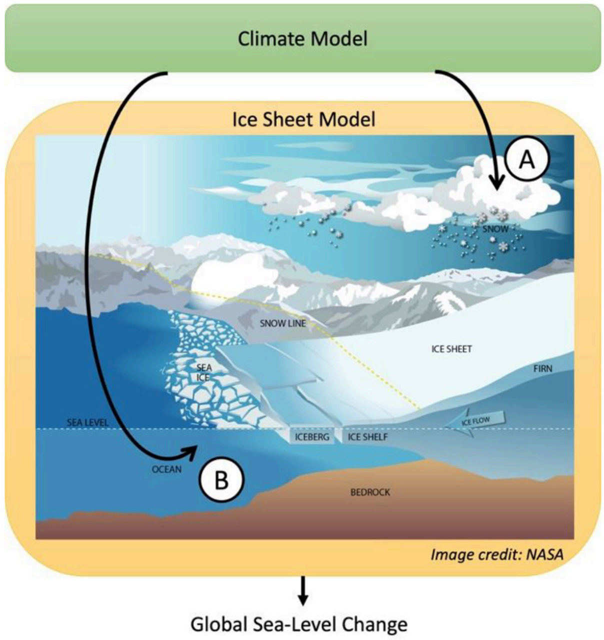

Figure 2

Figure 2

Flow chart of an ice sheet model, which uses information about **(A)** snowfall and **(B)** ocean temperature changes from another type of models, called climate models, to simulate how the ice sheet will grow or shrink over time and predict how the ice sheet will add or subtract from global sea-level change.

frozen) to the very hard ground, or is the ice sliding over very soft ground? When scientists try to understand what Antarctica will look like in the future, they may use an ice sheet model to check what would happen if the ice was sliding, compared to if the ice was frozen to the ground. Scientists can run the model with as many different setups as they can think of, and this will allow them to explore the range of future possibilities.

WHAT WILL ANTARCTICA LOOK LIKE BY THE END OF THE CENTURY?

To see what Antarctica could look like in the year 2100, a big group of scientists from all around the world used different computer models of Antarctica to run the same set of experiments [1]. To run these ice sheet models, they need to know, how much snow will be falling on top of the ice sheet and how warm the ocean will be around the edges of the ice. These two things come from a different type of model: a **climate model**. These are computer models of the whole Earth (Read more here) that can be used to understand how much the air and ocean will warm up, depending on the amounts of **greenhouse gases** that are added to the atmosphere. The Antarctica ice sheet model experiments looked at two possible future climate scenarios: one in which people continue to release greenhouse gases the way that we currently do ("high emissions") and one in which people limit greenhouse gas emissions ("low emissions").

CLIMATE MODEL

A computer model of the whole Earth. It uses the amount of greenhouse gases in the air as input and calculates how much the air and ocean will warm.

GREENHOUSE GASES

Gases in the atmosphere that can warm Earth's climate. Many of these gases are the result of human activities, such as the carbon dioxide coming from burning fossil fuels.

In the end, 13 ice sheet modeling groups took part in these experiments and their projections for how much sea-level rise could come from Antarctica are shown in Figure 3 [2, 3]. You can see that the ice sheet models do not all agree on the future of Antarctica, and this is because of differences in both the climate and the ice sheet models. Most ice sheet models show that Antarctica will continue to lose ice and increase sea level, but some models also show that perhaps there will not be very much change. In fact, some ice sheet models predict that Antarctica will grow over time!

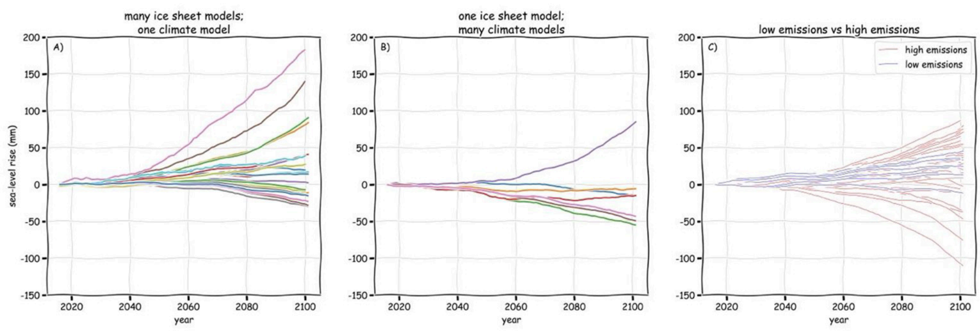

Figure 3

Figure 3

The amount of global sea-level change from the melting of Antarctica is uncertain. **(A)** Projections from many ice sheet models for one given future climate, in which the Earth warms by 4.3°C by the year 2100. **(B)** Projections from one ice sheet model for many future climates. This takes into account the differences in various climate models. **(C)** Projections for a low-emission climate, in which greenhouse gases are limited, vs. a high-emission climate. These graphs show the complexity in understanding the future of the Antarctic ice sheet, because it depends on both the future climate *and* the way that Antarctica will react to the climate.

Although all climate models say that the atmosphere and ocean around Antarctica will warm up, the future for Antarctica is not certain because the climate models may not agree on where or when the warming will happen. And it gets even trickier: some climate models predict that, in a warmer world, we may get more snow over Antarctica, but others predict that we may get more rain. More snow means that some parts of Antarctica may get bigger and gain ice; on the other hand, more rain could lead to melting at the surface of the ice or help break up the ice. Warmer oceans always lead to ice being lost but, in the end, the future of Antarctica depends on whether the ice loss (due to warm ocean water or melting at the ice surface) is greater than any ice gained by more snow.

CONCLUSION

Antarctica could contribute a lot to sea-level rise in the future because it holds a lot of ice. To predict how much the sea level could rise and when this might happen, scientists create computer models of Antarctica's large ice sheet. Scientists put all their knowledge into building the ice sheet models, but each model is slightly different because there is a lot that we still do not know about Antarctica. The future of Antarctica also depends on how the atmosphere and ocean will change in a warming world. The models do not all agree, so the future of Antarctica is really not clear. To improve the clarity of Antarctica's future, we must continue taking measurements around Antarctica and using these measurements to improve computer models. Until then, we can also try to limit the warming that the Earth is seeing. Ice always melts when it is warm, but we can try to slow down the melting as much as possible.

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REFERENCES

1. Nowicki, S., Payne, A. J., Goelzer, H., Seroussi, H., Lipscomb, W. H., Abe-Ouchi, et al. 2020. Experimental protocol for sea level projections from ISMIP6 standalone ice sheet models. *The Cryosphere*. 14:2331–68. doi: 10.5194/tc-14-2331-2020
2. Seroussi, H., Nowicki, S., Payne, A.J., Goelzer, H., Lipscomb, W.H., Abe-Ouchi, A., et al. 2020. ISMIP6 Antarctica: a multi-model ensemble of the Antarctic ice sheet evolution over the 21st century. *The Cryosphere* 14:3033–3070. doi: 10.5194/tc-14-3033-2020
3. Payne, A.J., Nowicki, S., Abe-Ouchi, A., Agosta, C., Alexander, P., Albrecht, T., et al. 2021. Future sea level change under coupled model intercomparison project phase 5 and phase 6 scenarios from the Greenland and Antarctic ice sheets. *Geophys. Res. Lett.* 48:e2020GL091741. doi: 10.1029/2020GL091741

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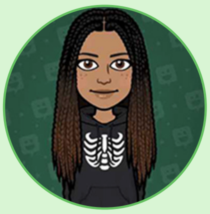
CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

AVA, AGE: 11
I am 11 years old and in the fifth grade. I enjoy science as I get to spend time with people like me and explore science on field trips. I want to join the science field and join NASA as an astronaut.



OLIVIA, AGE: 12
I am a student at YSA and a member of the Student Government Association. Science is one of my greatest passions, specifically environmental and forensic science. I hope to change the world one day, and contribute to making it a better place!

QUINN, AGE: 13
I am 13 years old and in the 7th grade. I love to travel, try new foods, and I like reading murder mysteries! I have one little brother, a dog, and baby ducklings.

AUTHORS

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Sophie Nowicki is an Empire Innovation Professor at the University at Buffalo, USA. She uses models and observations of the ice sheets to understand how they may change in the future. She has a piece of Antarctica named after her, the Nowicki Foreland, that she hopes to 1 day visit and have a snowball fight.
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Denis Felikson is a research scientist at NASA's Goddard Space Flight Center in Greenbelt, MD, USA. He studies the ice sheets and sea-level change using satellite measurements and models. Other icy things that he likes are ice skating, ice cream, and snowball fights.

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Isabel Nias is a lecturer in glaciology at the University of Liverpool, UK. She is interested in calculating uncertainty in ice sheet model predictions, and how we can use satellite observations to reduce this uncertainty. She was super excited to be able to set foot on Antarctica and have a snowball fight.