ENVIRONMENTAL SCIENCE JOURNAL FOR TEENS

SEPTEMBER 2025

What are good ways to track melting glaciers?

Researchers:
Michael Zemp, Jacqueline Bannwart, and the GlaMBIE Team
Associate Editors:
Miranda Wilson and Rachel Watson

Abstract

Have you ever watched an ice cube melt on a hot day? Well, that's happening to glaciers all over the world. Glaciers have important impacts on water resources, runoff, and sea level rise. Keeping track of how glaciers change is important to predict and plan for these downstream impacts.

We wanted to create a more recent record of how glaciers have changed from 2000 to 2023. So we compared and combined data about glaciers collected using different methods. We found that glaciers worldwide lost about 5% of their mass in this period. In different regions glaciers lost between 2% and 39% of their mass. We saw slight differences between data collection methods that could add up over time. We expect glacier loss to continue, which will lead to some regions losing their glaciers by 2100. It's important to use the most accurate and up-to-date information to make predictions about glacier loss in the future.

Introduction

Only 2.5% of water on Earth is freshwater. And about 69% of that freshwater is stored in **glaciers** and the two continental ice sheets in Greenland and Antarctica. **Climate change** is melting glaciers around the world. It can mess up people's access to freshwater resources for drinking and watering crops. Plus, melting glaciers have been responsible for about 20% of **sea level rise** in the last 20 years. This can cause flooding.

It is important to measure changes in glaciers accurately and precisely. That way we can predict and manage the impacts of glaciers melting.

There are four main ways scientists measure changes in glaciers (see Figure 1 on p.2).

1. Direct observations happen when scientists visit glaciers to measure changes in the height of ice at specific points. They also measure how packed the snow is on glaciers. This can help scientists estimate changes in glacier **mass**.

2. Scientists can map the elevation of entire glaciers using **satellites**. Then they can compare multiple measurements from different times to identify how the glacier elevation changed over time. This is called **digital elevation model differencing**.

3. **Altimetry** is similar to digital elevation model differencing. But satellites measure elevation along a line or band.

4. **Gravimetry** uses distance measurements between pairs of satellites to figure out slight changes in gravity. As the mass of a glacier changes, it impacts the gravitational field.

These four methods differ in how often measurements can be made. They also differ in how much of the glacier they can measure. These things make it hard to compare the results from the different methods.

We wanted to compare the different methods for measuring glaciers. We also wanted to figure out a way to combine data from the different methods. This could help us better compare glaciers and their changes. It would also allow us to look at changes in glaciers at regional and global scales.

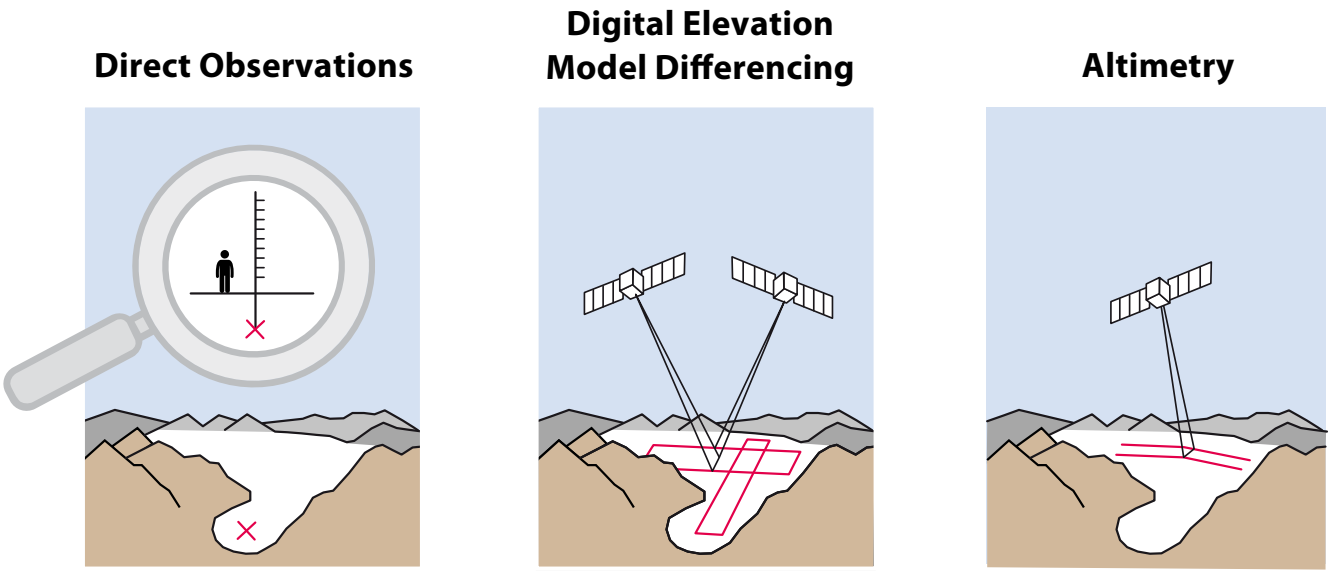

Figure 1: Three of the four main ways scientists measure how glaciers change.

Methods

We collected 233 quality datasets about changes in glacier mass. The datasets are from all the regions with glaciers around the world. They have data about glacier mass changes between 2000 and 2023. We divided the datasets into groups by region. We also divided them by measurement method. And we combined them into a best estimate.

Then we used the data in three ways:

- We compared changes in glacier mass between measurement methods.
- We also compared changes in glacier mass among regions.
- We estimated global changes in glacier mass.

Results

We found that the four ways to measure glaciers were similar. But each method gave us slightly different results that could add up over time.

We found that glaciers in all 19 regions lost ice from 2000 to 2023 (Figure 2). We saw that glaciers from individual regions lost between 2% and 39% of their ice. Regions with less glacier coverage lost a larger percentage of their ice. For example, Central Europe and New Zealand lost 39% and 29% of their ice. In contrast, regions with larger glacier coverage, such as Alaska, lost a smaller percentage of their ice.

Glaciers across the world lost about 5% of their total ice between 2000 and 2023. This represents 18 mm of sea level rise. That is 273 gigatonnes (billion tons) of ice and 0.75 mm of sea level rise each year. That's three Olympic-sized swimming pools of melt water every second! We also saw that ice loss was 36% greater between 2012 and 2023 than it was between 2000 and 2011.

Which region in the figure had the largest percentage of glacier mass loss? Which had the smallest?

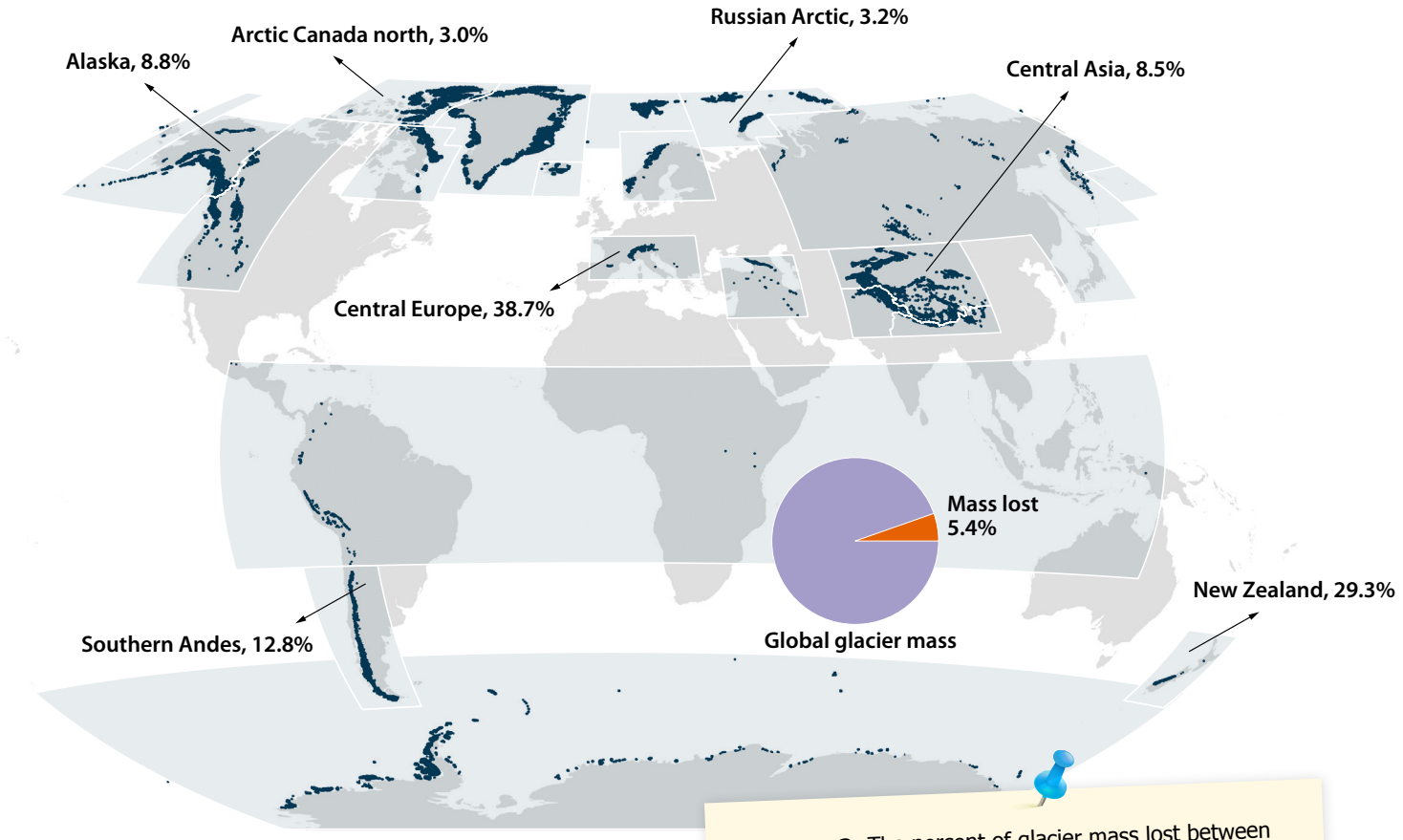

Figure 2: The percent of glacier mass lost between 2000 and 2023 for several representative regions.

Discussion

We were not surprised to find that glaciers around the world are melting. Our results agree with earlier global estimates. But we found that the way scientists measure glaciers makes a difference. This is especially true at a regional scale. Scientists need to know the strengths and limits of their measurements. For example, digital elevation model differencing is good at showing long-term trends for glaciers all over the world. It is not great at showing the differences between years. In contrast, direct observations can provide detailed data, but only from individual glaciers.

We created a more recent and accurate record to compare changes in glaciers. It includes data using all four measurement methods. And includes changes through 2023. Our new record also includes information from around the world.

Our data could be helpful for improving public reports, for example by the **IPCC (Intergovernmental Panel on Climate Change)**. It will help us make plans to protect freshwater resources. It will also help us combat sea level rise and flooding in the future.

Conclusion

Knowing about how climate change impacts glaciers is important. Measuring glaciers is one way to get more information. But how we measure things matters.

Imagine you are trying to tell a friend how big your new paperback book is. You could say it's as big as two hands placed side by side and one finger thick or that it's big enough to cover your teacher's face. You could say it has 300 pages. You could say it weighs 225 grams (8 oz). You could say it's 203 by 130 by 16 mm (5.1 x 8 x 0.6 in). Each of these measurement methods could help your friend understand, but they are very different. And if you want to compare book sizes with your friend, you'll need to both use the same method!

It is important to know the strengths and limitations of your measurement methods. That way you can pick the best one for the question you are asking. So, the next time you need to measure something, make sure you think about all your options.

Glossary of Key Terms

Altimetry - a method for measuring the change in elevation of snow and ice along a glacier. It uses satellites to measure elevation over a line or band at multiple time points.

Climate change - long-term shifts in temperature and weather patterns, today mainly driven by human activity.

Digital elevation model differencing - a process in which satellites measure the elevation of glaciers at multiple time points. Scientists can then use that data to calculate changes in elevation of entire glaciers over time.

Glacier - a large body of ice that forms on land and moves slowly downhill. They are formed by snow building up and getting packed down to ice over tens to thousands of years.

Gravimetry - a method for measuring how the mass of the Earth near a glacier changes. When glaciers melt, the gravitational field changes. By measuring the distance between two satellites, scientists can figure out changes in the gravitational field. They use this to estimate changes in mass. The final step is to separate the mass of the glacier from the mass of all the other water sources in the area.

IPCC (Intergovernmental Panel on Climate Change) - a group of scientists assembled by the United Nations who assess science related to climate change. They publish a report every 5–7 years providing information to policymakers and the public.

Mass - a fundamental property that describes the amount of matter in something.

Satellite - a spacecraft in orbit around the Earth that can take a variety of measurements.

Sea level rise - the increase in mean global sea level. This is caused by the expansion of water as it gets warmer and from melting glaciers and ice sheets.

Acknowledgment: This article's adaptation was supported by the GM Foundation.

Check your understanding

1. Why are melting glaciers a problem?

2. Compare and contrast the four different methods for measuring changes in glacier mass.

3. Time for some math! We found globally that glaciers lost 273 gigatonnes of ice each year. The region of Alaska lost 60.8 gigatonnes of ice each year. How many gigatonnes of ice were lost globally between 2000 and 2023? How many gigatonnes of ice were lost in the Alaska region? How many Olympic-sized swimming pools would this amount of water fill each second? (Assume an Olympic-sized swimming pool holds 2.5 million liters and that 1 Gt = 10^12 liters.) What percentage of the ice lost from glaciers globally was from the Alaska region?

4. We looked at data across 24 years. What differences did we see between the first half and the second half of that time period? Why do you think this happened?

5. The IPCC is working on their next report about climate change. Imagine you want to make sure the IPCC is aware of our study and that they provide good data about glaciers melting. What would you tell them, and why do you think it's important?

REFERENCES

The GlaMBIE Team: Michael Zemp, Livia Jakob, Inés Dussaillant, Samuel U. Nussbaumer, Noel Gourmelen, Sophie Dubber, Geruo A, Sahra Abdullahi, Liss Marie Andreassen, Etienne Berthier, Atanu Bhattacharya, Alejandro Blazquez, Laura F. Boehm Vock, Tobias Bolch, Jason Box, Matthias H. Braun, Fanny Brun, Eric Cicero, William Colgan, Nicolas Eckert, Daniel Farinotti, Caitlyn Florentine, Dana Floricioiu, Alex Gardner, Christopher Harig, Javed Hassan, Romain Hugonnet, Matthias Huss, Tómas Jóhannesson, Chia-Chun Angela Liang, Chang-Qing Ke, Shfaqat Abbas Khan, Owen King, Marin Kneib, Lukas Krieger, Fabien Maussion, Enrico Mattea, Robert McNabb, Brian Menounos, Evan Miles, Geir Moholdt, Johan Nilsson, Finnur Pálsson, Julia Pfeffer, Livia Piermattei, Stephen Plummer, Andreas Richter, Ingo Sasgen, Lilian Schuster, Thorsten Seehaus, Xiaoyi Shen, Christian Sommer, Tyler Sutterley, Désirée Treichler, Isabella Velicogna, Bert Wouters, Harry Zekollari, and Whyjay Zheng (2025) *Community estimate of global glacier mass changes from 2000 to 2023.* Nature.
https://www.nature.com/articles/s41586-024-08545-z

European Space Agency: Animation of glacier ice loss over two decades
https://www.esa.int/ESA_Multimedia/Videos/2025/02/Revealed_glacier_ice_loss_over_two_decades

World Wildlife Fund: Why are glaciers and sea ice melting?
https://www.worldwildlife.org/pages/why-are-glaciers-and-sea-ice-melting

World Meteorological Organization: Glacier melt will unleash avalanche of cascading impacts
https://wmo.int/news/media-centre/glacier-melt-will-unleash-avalanche-of-cascading-impacts