New tool helps researchers study remote glaciers

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Remote glaciers, like the Deming Glacier in Washington, are rarely studied due to the difficulty of access, especially with heavy equipment in tow. Researchers instead have to rely on satellite photos or observations from afar which cannot always give the full picture of the glacier’s retreat. Credit: Jenna Travers

As warming atmospheric temperatures lead to glacier thinning and retreat around the world, understanding how glaciers are responding to climate change, algal growth, and impurities like dust and black carbon is vital. Understanding the response helps scientists, policymakers, and communities mitigate harm and protect watersheds and communities that rely on these glaciers. However, many glaciers are located in remote locations that can be difficult to access and study.

In a paper published in the *Journal of Glaciology* in May 2022, physicist Markus Allgaier collaborated with geologists and geographers to develop a portable tool that can easily be fit into a backpack and carried to remote glaciers to measure the optical properties and composition of their ice.

Gathering data on the ice composition and retreat of glaciers is important for evaluating how glaciers are responding to climate change. The data also help scientists predict how communities downriver of the glaciers might be affected by their retreat. Currently, many glaciologists rely on modeling techniques to evaluate glaciers' ice composition, especially for more remote glaciers that are tricky to access and difficult to survey.

Without being on the glacier, however, it can be hard to accurately measure ice composition, algal growth, and dust and black carbon levels. This deficit makes backpack glaciology—hiking into remote locations with portable equipment for physical measurements on the glaciers—vital for understanding the ice and its behavior.

However, backpack glaciology comes with a tradeoff. For tools to be portable, they are often simple and unable to measure variables such as albedo, which is important for understanding retreat. For instance, the North Cascades Glacier Climate Project, a decades-long project measuring glaciers in northwest Washington, uses a long metal probe with detachable segments, a laser rangefinder, and marked ropes to conduct most of its research. These tools do help researchers collect vital data on snow depth, ablation rates, terminus location, and glacier profiles, but scientists hoping to measure albedo or ice composition on remote glaciers have few choices available.

Allgaier, a postdoctoral physicist at the University of Oregon, is working to address the lack of options and improve the measurement tools available for glaciologists around the world. Allgaier explained in an interview with GlacierHub that while his background is in quantum physics, he wanted to "apply these fields to environmental science and climate research," citing his love of mountains and desire to contribute to research focused on understanding them. He started by researching which optical measurements glaciologists use and thinking about how they could be improved and what was missing in the techniques currently used. He brought in glaciologists, geographers, and hydrologists to develop a tool together.

Allgaier using the device on the Collier Glacier last year. Sunlight can disrupt the data collection, so the researchers had to wait until sunset to test it out. Credit: Markus Allgaier

These collaborations culminated in the development of a device that measures the composition and structure of glacier ice using photons, or subatomic light particles. The device shoots a laser pulse into the glacier ice and measures the time it takes for the photons to bounce off the ice and hit a receiver approximately two meters away. Air bubbles inside the glacier scatter the laser pulse in random directions, changing both the time it takes to hit the receiver and the shape of the pulse when it gets there.

According to Allgaier, "the pulse shape and duration of the detected light is unique, and these tell us how much light is absorbed in the ice and how much scattering there is." This data in turn allows researchers to determine the composition and density of the ice as well as the optic properties of the glaciers. These can be used to predict retreat rate.

Allgaier highlighted the importance of this device for both large and small glaciers, saying that by measuring the composition and structure of the ice, the device provides "a glimpse into what drives melt and why the glacier albedo is what it is."

While this device is perfect for gathering data on difficult-to-access glaciers, it can also be used to verify that remote sensing data of easy-to-access glaciers are accurate and match what's found on the ground. The latter idea originated from Allgaier's collaboration with geographers at the University of Oregon. Johnny Ryan, an assistant professor in the geography department, joined the project to provide perspective on glaciers, ice sheets, and practical uses of the device. Ryan says he and his colleagues in the geography department were able to give suggestions on how to improve the device to best work in the field and provide insights on how the project might fit into the current body of glaciology research.

The geographers were also helpful when testing the laser in the field, according to Ryan—knowing where to go and how to navigate the glaciers as well as how to obtain permits. The group has tested it out on a couple of Oregon glaciers: the Crook Glacier on Broken Top Mountain and the Collier Glacier on the North Sister. Both tests were successful.

So far, only a small proportion of the world's glaciers have been studied, Ryan said. Going forward, this tool will help researchers "study glaciers that haven't typically been studied but are still important for water resources and sea level rise." And by verifying data from satellites and aircraft, this new research is especially important for communities downriver of glaciers that are nestled in mountains too dangerous to ascend. Understanding how their glaciers are changing and retreating is vital to the future of these communities.

More information: Markus Allgaier et al, Direct measurement of optical properties of glacier ice using a photon-counting diffuse LiDAR, *Journal of Glaciology* (2022). DOI: 10.1017/jog.2022.34

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