Blanket of rock debris offers glaciers more protection from climate change than previously known

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Rock debris cover on glaciers in the Alaska Range. Credit: Northumbria University, Newcastle

A new study which provides a global estimate of rock cover on the Earth's glaciers has revealed that the expanse of rock debris on glaciers, a factor that has been ignored in models of glacier melt and sea level rise, could be significant.

The Northumbria University study, which has been published in *Nature Geoscience* this week, is the first to manually verify the rock debris cover on every one of the Earth's glaciers.

As glaciers shrink, their surrounding mountain slopes become exposed and eroded rock debris slides down and accumulates on glacier surfaces. This debris forms a protective layer that can be many metres thick, reducing the rate at which the ice below melts. Although the effects of this protective cover are known, it has never been carefully mapped until now, and so has not been included in global glacier models.

As well as revealing where rock debris is located on Earth's glaciers, the researchers also found and corrected key errors within the Randolph Glacier Inventory—a global inventory of glacier outlines on which hundreds of studies are based.

Using Landsat imagery, the research team from Northumbria University's Department of Geography and Environmental Sciences and the Swiss Federal Research Institute WSL spent three years painstakingly examining and manually verifying more than 923,000 square kilometres of glacier worldwide.

The exercise allowed them to analyse the debris cover on a global-, regional-, as well as individual glacier-scale and created the world's first baseline dataset of glaciers in their current state.

They found more than 29,000 square kilometres of the world's mountain glacier area is covered in rock debris—an area equivalent to almost 500

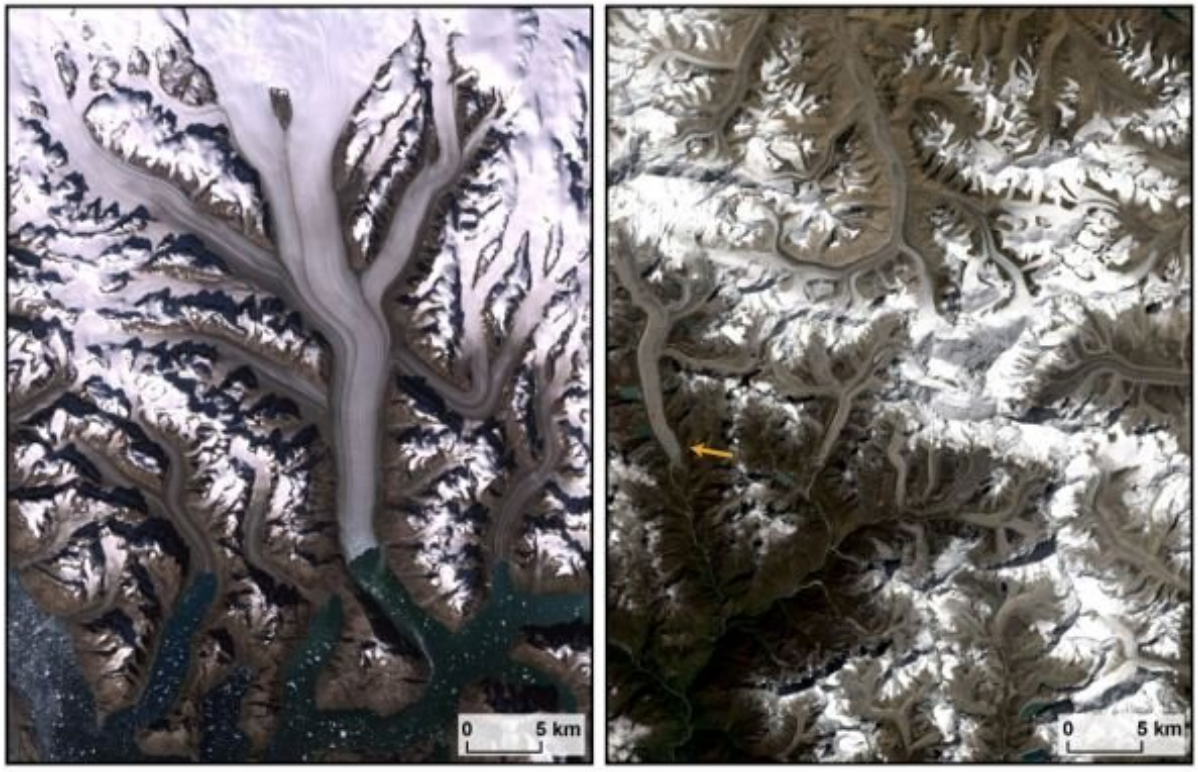
Manhattan Islands.

Lead researcher Sam Herreid undertook the study for his Ph.D. at Northumbria University and is now believed to be the only person who has examined every glacier on Earth, manually correcting the Randolph Glacier Inventory and bringing a level of consistency that has never before been present in a global glacier dataset.

He explained: "The structure of the debris cover of each glacier is unique and sensitive to climate, but until now, global glacier models have omitted debris cover from their forecasts of how glaciers respond to a changing climate.

"We now know that debris cover is present on almost half of Earth's glaciers, with 7.3% of the world's total mountain glacier area being debris covered.

"When we consider that much of this debris cover is located at the terminus, or toe, of a glacier where melt would usually be at its highest, this percentage becomes particularly important with respect to predicting future water resources and sea level rise."



'Young' debris cover in SE Greenland (left) and 'old' cover in the Everest region of the Himalaya, with the arrow pointing to one of the debris covered glacier tongues.

The 'young vs. old' spectrum of debris cover: 'Young' debris cover in SE Greenland (left) and 'old' cover in the Everest region of the Himalaya, with the arrow pointing to one of the debris covered glacier tongues. It is believed that the debris bands in the Everest region would have looked similar to Greenland many hundreds of years ago, but have widened over time, filling the full width of the glacier with rocks. Credit: Northumbria University, Newcastle

The study also uncovered errors within the Randolph Glacier Inventory, finding an error rate of 3.3%. One of their findings revealed that 10,000 square kilometres of mapped glacier area was not actually glacier, but rather bedrock or vegetated ground that was either incorrectly mapped previously or glacier area that has since melted away.

This, combined with the melt reduction from debris insulating the ice below, means that all past global glacier models based on the Inventory are likely to have overestimated the true volume of glacier melt, run off and subsequent contribution to global sea level rise.

They described the 10.6% of glacier area that requires an updated approach to estimating melt as "an alarmingly high number" and said that their work provides a key dataset for revising, and likely lowering, the glacier contribution to sea level rise.

The team also devised a way to analyse how the world's debris-covered glaciers will evolve over the coming centuries.

By comparing the many states of glaciers present on Earth today, from those considered to be 'young' and icy in Greenland, to 'old' and rock covered in the Himalaya, they were able to piece together a conceptual timeline which they believe outlines how a glacier might evolve in the future.

Their timeline reveals that many glaciers are at the older end of the spectrum and can therefore be considered to be on the decline.

Co-author Francesca Pellicciotti of the Swiss Federal Research Institute WSL and an Associate Professor at Northumbria University, explained: "The upper levels of the glaciers are constantly accumulating snow and will always be debris free, so we looked only at the lower levels of glaciers which is where rock debris can accumulate.

"Ice melts and flows away as water, but the rocks do not, and accumulate at the surface. Changes in the rate of mountain erosion as well as glacier changes in a warming climate will affect the size and shape of the rock layer at the surface of a glacier at any one time.

"Although we can't say exactly what year a glacier will evolve to a certain state, say, a state where it is almost entirely covered in rocks, we were able to place each glacier on a conceptual timeline and learn roughly how far along this line each glacier is to becoming almost entirely covered in rocks.

She added: "We found that the bulk of glaciers that have a debris cover today are beyond a peak debris cover formation state and are trending closer to the "old" Himalayan glaciers that might not be around for much longer.

"From a climate change perspective this is one more indication of the toll a warming climate is having on Earth's glaciers. However, we now have a benchmark measurement of debris cover for all of Earth's glaciers and new tools to monitor and predict the rate of changes couple to a warming climate."

The study, "The state of rock debris covering Earth's glaciers," is now available in *Nature Geoscience*.

More information: Sam Herreid et al. The state of rock debris covering Earth's glaciers, *Nature Geoscience* (2020). DOI: 10.1038/s41561-020-0615-0

Provided by Northumbria University