# University of Leeds glacier research

## Flexible, easy-to-use Raspberry Pi cameras and computers lower the cost of 3D glacier modelling

After a successful European trial, researchers at the University of Leeds School of Geography are using Raspberry Pi computers and Raspberry Pi High Quality Cameras in low-cost, long-term glacier degradation warning systems in the Andes and Himalayas.

**Raspberry Pi solution** Raspberry Pi High Quality Camera, Raspberry Pi 4, Raspberry Pi Zero W

**Size of business** Large public sector organisations

**Industry** Scientific research — geography





*Raspberry Pi camera images of the Fjallsjökull glacier in Iceland. Results from this location proved the concept of the system now being applied in Peru and Nepal*

Among the most visible markers of the pace of climate change are the accelerating rates at which ice fields are receding and glaciers melting. NASA's climate observations confirm that the added water from glaciers and ice sheets as they melt, and the expansion of sea water as it warms, are the largest contributors to rising sea levels.

Accordingly, several important studies are closely monitoring the rate at which polar regions are changing. They include Arribada and Penguin Watch's studies using Raspberry Pi cameras for long-term timelapse footage of specific locales, measuring changes in ice and iceberg distribution as well as in wildlife populations over the seasons. However, there are fewer studies into continental glacier shrinkage, not least because of where such glaciers are located. One group of scientists doing this work is the team behind a glacier calving research project at Leeds University's School of Geography, led by lecturer Liam Taylor.

## The stunning results from the cameras exceeded everyone's expectations

*With multiple Raspberry Pi camera units like this, researchers can generate 3D models of glaciers to measure how they are responding to climate change*

## The challenge

To effectively monitor glacier changes, detailed on-the-ground investigations need to go hand in hand with larger-scale observations of glacial landscapes and the environmental changes that are taking place. This is where 3D scanning and timelapse photography can play a vital role. However, while robust timelapse cameras and environmental monitoring systems do exist, their high cost is prohibitive, since resources are often scarce in the very places that are subject to the most extreme effects of global warming. As Taylor observes, "In fact, most glaciers are located in countries like Peru and Nepal, and India."

## Raspberry Pi cameras captured 3D glacier images of similar quality to drones, but at just a fraction of the cost

Often, people living in these areas are at risk of food insecurity as well as the sudden loss of their homes should an environmental catastrophe such as a flood occur as a result of glacier calving. "We are working with indigenous communities out there who are living hundreds of metres from the real risk for things like outburst floods," Taylor explains.

"The crux of the project was, can we develop something that is a monitoring technique of sorts?" says Taylor. His team wanted to develop something that could act as an early warning system for a calving event, in which pieces of glacier break off, with the potential to cause widespread flooding. The Leeds team chose to focus on glaciers because "they are receding faster than ever, the hazards associated with them are growing, and there are more and more people around the world vulnerable to hazards."

Keeping costs very low — under £100 — was an overriding principle of the Leeds team's project, given that one of its aims was to support communities in developing countries.

## The solution

The Leeds University team, Liam Taylor and colleagues Duncan Quincey and Mark Smith, completed a trial process in Iceland. They set up ten monitoring units, each built around a Raspberry Pi High Quality Camera and a Raspberry Pi Zero W, and used them to create photogrammetric images of the Fjallsjökull Glacier. The cameras were placed inside a weatherproof housing — the most expensive part of each camera setup — and were programmed to take a snapshot at preset intervals over several months. The units were powered by batteries that were replenished with solar power, while the cameras themselves were positioned to capture a linear but overlapping view of the glacier.

The resulting photos were collected a few months later and then processed using Agisoft Metashape software to create realistic 3D scenes. The Leeds University geographers ran concurrent tests with an unmanned aerial device (UAV, or drone) focusing on the same area of the glacier, and processed those results with Metashape too. The team compared subsets of the results from each monitoring system, consisting of images of 250-metre-long regions of the glacier.

Following this successful trial, they installed Raspberry Pi-based monitoring devices in the Cordia Vilcanota, approximately 50 miles from Cusco, Peru, where there is a series of glaciers. And over 10,000 miles away, in India and Nepal, the Leeds team has supported local researchers to set up new investigations into Himalayan glacier calving. The local teams are running the research themselves, assisted by the technical knowledge that the Leeds geographers have acquired.

The team is keen for their work to benefit as many people as possible. "The system will always be open source, and we'll always be looking to offer help and support to any citizen scientists looking to implement similar systems to respond to their own challenges."

## Why Raspberry Pi?

The team's requirements were straightforward: they sought low-cost hardware that was capable of the task, available to buy in quantity from local resellers, and simple enough to be set up by someone with only a couple of hours of training.

Liam and colleagues looked at what was available in street markets near regions where they hoped to set up glacier monitoring. They found that Raspberry Pi computers and cameras met all of their requirements and were available to buy locally at just a fraction of the cost of conventional hardware.
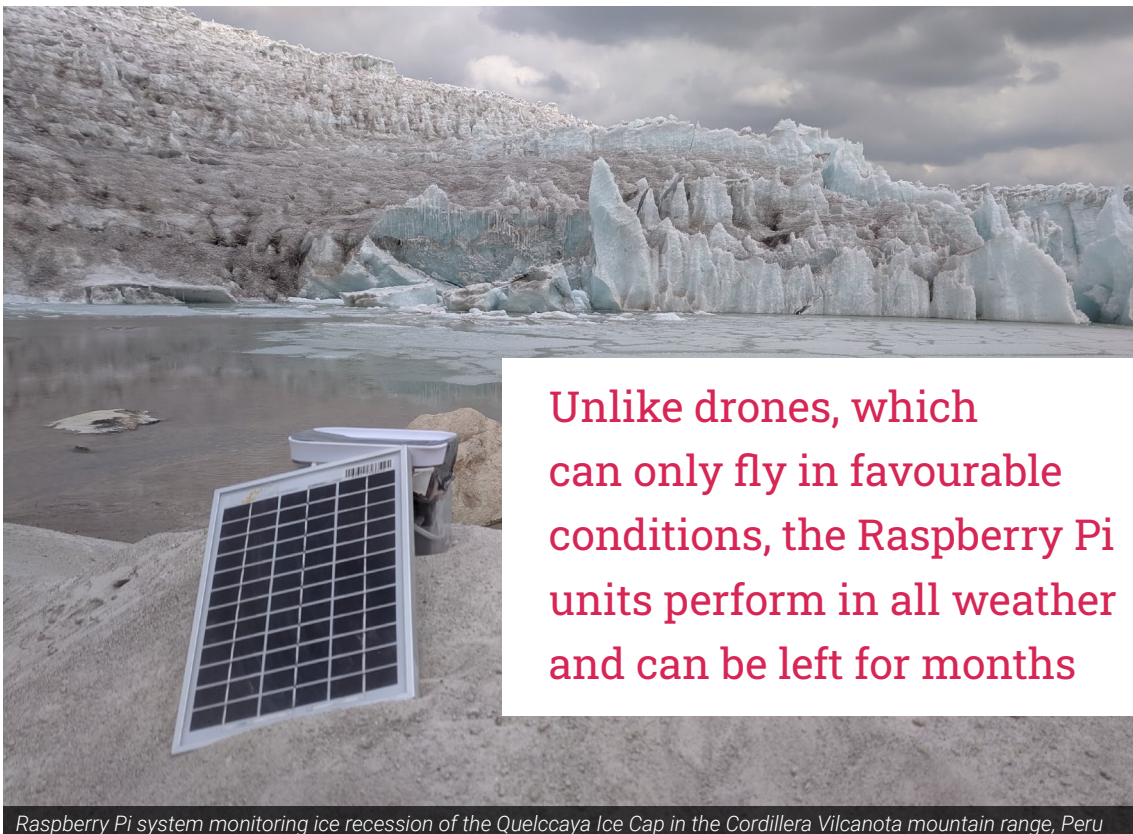


Unlike drones, which can only fly in favourable conditions, the Raspberry Pi units perform in all weather and can be left for months

*Raspberry Pi system monitoring ice recession of the Quelccaya Ice Cap in the Cordillera Vilcanota mountain range, Peru*

## The results

The stunning results from the cameras, even judged alongside those from drones with powerful cameras designed for surveillance tasks, exceeded everyone's expectations. Raspberry Pi cameras were able to capture 3D glacier images of similar quality to drones, at a dramatically lower cost. Better yet, since the computational demands of the task are moderate, the system also works on the super-low-cost Raspberry Pi Zero.

The team's research paper evaluating the suitability of Raspberry Pi hardware for glacier monitoring, published in early 2023 and available for free, presents their full findings and analysis.

The Raspberry Pi camera setups can be left in place for months at a time, allowing for low-cost timelapse photogrammetry that produces 3D modelling with error tolerances well within range of the accuracy of a UAV: impressively, their mean error is less than one metre from a distance of 1.5km, with as few as ten such cameras needed to create this level of three-dimensional detail. Unlike a drone, which is subject to the vagaries of poor weather and can only fly when the conditions are favourable, the resilient Raspberry Pi camera setups perform in all weather, and require human intervention only when a researcher comes to collect an SD storage card so the photos can be analysed.

The affordability and availability of the Raspberry Pi hardware mean that local researchers can speedily assemble additional units once initial training has been completed. The Leeds University team is particularly keen for the research to be left in the hands of local environmental research teams, giving them relevant skills and knowledge along with agency over their own environmental investigations.

Work to further extend the capabilities of the monitoring setup continues: in Nepal, one of the Raspberry Pis will be used in tandem with a Raspberry Shake seismograph along with a microphone to listen to the glacier as it "groans along". The Leeds team also hopes to locate sensors covering a region of the Swiss-Italian Alps at high risk of glacier collapse events, with the aim of providing advance warning and protecting life.

At the end of 2022, the team headed back to Peru for an international climate summit to demonstrate their impressive photogrammetric research, and to show national and local governments that this kind of monitoring could form part of their adaptation to climate change. Their effective and affordable Raspberry Pi-based setup attracted interest from a number of government bodies in Peru, as well as charity organisations. "We're trying to go out there to get more money to put in the hands of communities so that they can spend it on these Raspberry Pi tools that we now know work."

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*University of Leeds researchers are monitoring the Quelccaya Ice Cap in Peru, one of just a few tropical ice caps in the world*

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