FIFTY PEOPLE, TWO YAKS AND A GOAT

A TEAM OF RESEARCHERS COMBINED SCIENCE AND ADVENTURE TO GATHER IMPORTANT NEW INFORMATION ON ONE OF THE WORLD'S GREAT MOUNTAIN SYSTEMS, PAKISTAN'S KARAKORAM RANGE, WHERE A CLIMATE ENIGMA BRINGS POTENTIALLY DEVASTATING CONSEQUENCES. JOHN STENMARK REPORTS

Sergiu Jiduc's journey to Pakistan's Shimshal Valley began with three colleagues, a jeep and a minivan. It ended with 50 people, two yaks and a goat. In the process, Jiduc and his colleagues developed a new understanding of one of the world's most beautiful and dangerous landscapes – the Karakoram mountains.

Jiduc, an environmental geoscientist with the University of Edinburgh in the UK, was in Pakistan to investigate why, while mountain glaciers in other parts of the world are receding and shrinking due climate change, many Karakoram glaciers are advancing. The effect, known as the Karakoram Anomaly, has drawn the attention of scientists around the world. Jiduc and his team had traveled to Pakistan to add to the understanding of the glaciers' behaviour and the risk they present to people living in the region.

As the expanding glaciers descend the steep mountains and move into the river valleys, they can create dams of ice and rock that block the rivers' flow. Dangerous and unstable glacial lakes build up behind these dams. If the dams breach or fail, the lakes can drain in a matter of minutes or hours.

Known as glacial lake outburst floods (GLOF), they can devastate downstream communities.

Slow-moving glaciers are not the only source of environmental trouble in the Karakoram. The region is also home to numerous 'surging glaciers'. These glaciers exhibit short periods of rapid movement and sudden advance – some have moved as much as 50m per day. Surges, which occur semi-periodically, have been occurring for centuries and don't appear to be related to climatic changes. The differences between naturally occurring surge glaciers and glacial changes resulting from climate change are important. Understanding the two allows scientists to use glacial variations more effectively in studying climate behaviour.

During periods of glacial surging, the risk of GLOF rises as the glaciers collide with the valley floors and walls, increasing the potential to form unstable lakes. Currently, about 30 potential glacier dams are known, over half of them in the western and central Karakoram.

In addition to climate studies, people living in the area can benefit from understanding the conditions and behaviour of the Karakoram glaciers. But the region's difficult access and remote, desolate terrain

The team ascends onto a glacier in the Shimshal valley. Instead of the familiar white snow and ice, the surfaces of many Karakoram glaciers are covered by rock and dust falling from the steep mountainsides. (© Tim Taylor, Karakoram Anomaly Project)

mean that only limited empirical data exists on the glaciers. Most of the data consists of historic photographs and local records, which are insufficient to fully understand the Karakoram Anomaly. This dearth of information inspired Jiduc to assemble an expedition to collect data in one of the Karakoram's most vulnerable regions, the Shimshal Valley in northeast Pakistan.

Jiduc, working with colleagues Oliver Forster, Matthew Farrell and Tim Taylor, developed an understanding of the region's glacial floods. He focused on climate change and natural hazards in Pakistan, with a particular emphasis on water. "The interplay of climate change, topography, geology and glaciology are putting many people at risk by destabilising regional water resources and exacerbating natural hazards such as GLOFs," he says.

The initial research revealed a history of GLOFs in the Karakoram. In the past 130 years, more than 20 floods have been recorded in the Shimshal valley. The floods produced damage and destruction to roads and bridges, buildings and farms. "When we look at the region's big floods almost half of them originate in Shimshal Valley," Jiduc explains.

The team developed aggressive objectives for the expedition. They planned to measure the surface velocity of the Yukshin and Khurdopin glaciers; create geomorphologic maps of the two glaciers' termini; develop knowledge of current risk of GLOFs; and share the information with the residents of the Shimshal region. The team gathered an array of technologies to gather the data. Their gear included photographic and video equipment, rangefinders and Trimble GNSS receivers, as well as equipment for weeks of camping in the high mountains.

The expedition base camp in a lateral moraine on the Yukshin Glacier overlooks the glacier and Shimshal valley below. Ice and debris from the Yukshin and Khurdopin glaciers covers much of the valley floor. (© Tim Taylor, Karakoram Anomaly Project)

Sergiu Jiduc, left and Oliver Forster prepare to measure a velocity point on the Yukshin Glacier. The team found that marking points on boulders was more effective than drilling into the ice to set measurement points. The peak of Yukshin Gardan Sar is between the two men. (© Tim Taylor, Karakoram Anomaly Project)

Sergiu Jiduc and Mathew Farrell install a measurement point atop a glacial mound. Though difficult to access, the high points provided good, recoverable locations for measurements. (© Tim Taylor, Karakoram Anomaly Project)

A team labours to drill measurement points into glacial ice. The points needed to survive and be recoverable for 20 days to enable repeated measurements

A difficult journey

The four researchers arrived in Pakistan in July last year. To reach the Shimshal Valley, they traveled in vehicles along the Karakoram Highway. Part of the highway through the Hunza valley had been submerged since 2010, when a landslide dammed the valley to create a new lake. The team hired boats to ferry them across the obstacle. When they reached the Shimshal Valley, they discovered that a rock avalanche had destroyed the road connecting the people in the valley with the outside world. The team used satellite phones to arrange for suitable vehicles that could carry them across the rock avalanche.

The vehicle journey ended in Shimshal village, roughly 20km from the planned worksite. "In Shimshal village, we assembled a convoy of 50 porters, 10 donkeys, two yaks and one goat to carry our 950kg of equipment and supplies to the base camp," Jiduc said. "For two days, we marched like a 19th-century expedition." They trekked past the Yazghil glacier to reach their destination, a rocky campsite in a lateral moraine alongside the Yukshin glacier, about 8km beyond the Yazghil.

After establishing their base camp at roughly 3,680m, the team began to collect data. They used a Trimble R10 GNSS receiver to establish a reference station near the camp. The station coordinates were determined in the WGS84 coordinate system via extended autonomous measurement and then transformed to UTM values. The station had clear views of more than 20km across the glaciers and would provide good coverage for RTK measurements.

The team needed to establish at least 40 measuring marks on each glacier. The plan called for drilling holes into the glacier to set marks for the repeated measurements required to calculate velocity. The surveys began at the higher elevations, with points measured on prominent stable landforms as well as in depressions such as supraglacial valleys. Additional points set at the confluence of the Yukshin and Khurdopin provided higher resolution data on the interaction between the two glaciers.

Simply getting to the measurement points proved a challenge. The team negotiated steep slopes, ice, crevasses and constant worry of rockslides from above or shifting ice below their feet.

Drilling

It required four days to drill into the ice and set velocity stakes. Unstable ice covered with thick debris made drilling difficult. The team had a contingency plan for the fieldwork: in case the velocity stakes failed, they would use large boulders. As the work progressed, they used boulders more than velocity stakes – melting rates were so fast that the 50cm-deep holes drilled for the stakes melted away, making it imprecise to use them. The team marked the boulders with paint and recorded rough coordinates with handheld GPS. Then they marked a small point for the precise measurements.

The points ranged in distance from the base station from 350m to 4.5km, and were measured with a working precision of 1cm horizontally and 2cm vertically. At each point, the team used a Trimble R10 GNSS RTK rover with Trimble TSC3 controller running Trimble Access to capture two six-minute datasets. Returning to camp at the end of each day, they downloaded the data to Trimble Business Center running on a laptop. In the evenings, they could analyse and verify the success of the measurements and plan the next day's activities. In addition to precise GNSS, Jiduc's team used handheld, consumer-grade GPS units and laser rangefinders to collect measurements to construct geomorphologic maps of the glaciers and valleys. They also worked to capture digital photographs that matched historic photos of the area, with the intention of comparing recent and historic images to analyse long-term changes to the glaciers.

The effort to reach the points for the second round of measurements was made difficult by new streams and uncrossable crevasses. The team used their TSC3 controller to find new routes to the points. Even with their attempts to identify stable locations, some of the boulders had toppled in the 20 days between measurement sessions. The massive fallen rocks provided a tangible reminder of the power and instability of the glacial surface.

While the team anticipated that some measurement issues might arise due to difficult weather conditions and long distances, none of the problems were unmanageable. They used a solar panel and petrol-fuelled generator to provide power and charge batteries.

"The Pakistani team was key to the success of the survey, especially Ali Muhammad Saltoro," Jiduc says. "His resourcefulness and problem-solving skills were invaluable for our expedition."

Even the trip home after the project proved difficult. While working on the glacier, the team was notified by satellite phone that one of the bridges in the valley downstream had been destroyed by a rockfall. Fortunately, local residents had improvised a small wooden bridge that enabled the researchers to leave the valley.

The results

The Karakoram team's measurements indicate that Khurdopin glacier is moving slowly, traveling roughly 1cm to 5cm per day or 3m to 20m each year; points on the Yukshin glacier are moving at 5cm to 35cm per day or 20m to 130m per year. During previously documented periods of glacial surging on the Khurdopin, measured surface displacements reached more than 5km per year.

Based on their data, the team concluded the glaciers are not surging and currently are in a quiescent phase. There is a gap of roughly 20m between the Khurdopin glacier's snout and the Shimshal valley flank, allowing the river to flow without serious obstruction. Overall, Jiduc said, the glaciers appear to be retreating.

"The people of Shimshal are safe for now," Jiduc says. "Presently there is no significant risk of GLOFs – the Shimshal River drains suitably along the length of its contact with Khurdopin. However, from the topographic relief point of view, the glacier continues to change every year due to continuous ice degradation."

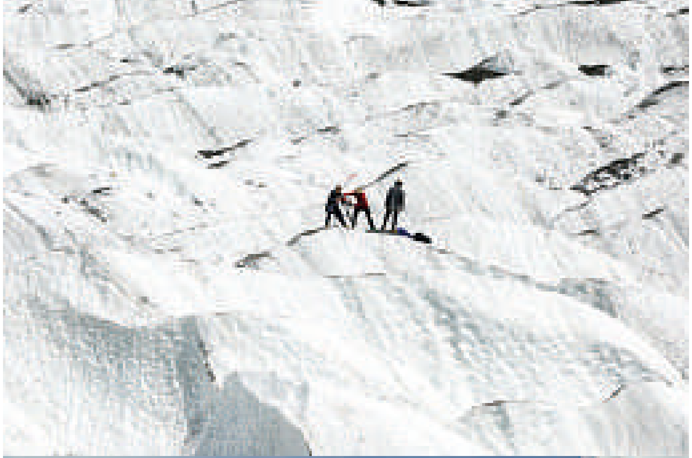
He notes that the surface of the Yukshin and Khurdopin glaciers showed an increase in the number of thermokarst features such as rapidly changing depressions and supraglacial ponds. The surge surface topography became less chaotic and smoother as compared with observations from earlier expeditions by other researchers, but the issue of debris covering the ice may complicate the story.

"The question of Yukshin-Khurdopin as a trigger mechanism still remains. When will the valley be blocked again is difficult to predict, but it will take at least five years," he says.

Jiduc says that GNSS was essential to the project. "GNSS technology is a useful tool for obtaining precise information about the movement of glaciers and the deployment of continuous or semicontinuous monitoring stations," he says.

RTK methods enabled his team to monitor surface movements with the precision and temporal frequencies necessary to study glacial motion. The team's work provided quantitative data that can be used for objectives such as updating global glacier databases with velocity and displacement information. It can also aid risk assessment and natural hazard mitigation and adaptation schemes.

Their next steps include combining remote sensing, terrestrial photogrammetry and synthetic aperture radar to add context to the in-situ GNSS measurements and produce a comprehensive picture of the surface velocity field of the terminal part of Yukshin and Khurdopin glaciers.



An uncertain future

"We have gathered important scientific data and media material," Jiduc concludes. "It will be used to raise awareness of the GLOF and surging glaciers issues in the Karakoram and to advance scientific understanding pertaining to the subjects. We hope that our project will continue to deliver strong and positive impacts to the regions and people that most need it."

There is still uncertainty about how climate change will impact GLOFs in the Shimshal region. Jiduc's colleague, geoscientist Oliver Forster, suggests that more research is needed to understand the complex relationship between glacial movements and glacial lake outburst flooding in Shimshal Valley. "Permanent glacial monitoring, as used in the European Alps and the American Rockies, would allow us key insight into glacial lake formation," he said. "Maybe one day it can allow us to predict and avoid glacial lake flooding altogether."

GNSS TECHNOLOGY IS A USEFUL TOOL FOR OBTAINING PRECISE INFORMATION ABOUT THE MOVEMENT OF GLACIERS

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