Settling the science on Himalayan glaciers

The remote glaciers of the Himalayan mountains have been the subject of much controversy, yet little research. **Mason Inman** looks at the clues scientists have garnered on the fate of these glaciers from ground- and space-based studies.

"Every morning you have to rise and decide that it might be a good day not to die," says John Shroder of the University of Oklahoma at Omaha, who has spent decades studying the glaciers of the Karakoram and Himalayan mountains, stretching from Pakistan in the west across India and into Nepal in the east. "Just getting to base camp at K2", in Pakistan, the world's second tallest peak, "is an arduous trek," he says, listing the innumerable hazards en route: rock falls, heatstroke, dehydration, freezing and diarrhoea, among others.

But such dangers are the least of the difficulties facing researchers who study these mountain ranges. Often called the world's highest battleground, the Siachen glacier has been the site of a standoff between the Indian and Pakistani armies for decades. Pakistan's mountains provide a stronghold for Taliban insurgents, and in Nepal, Maoist rebels are holed up in the Himalayas. Several countries in the region limit access to maps and photography of their borderlands. Glaciologists who want to climb these peaks, measuring the terrain using high-tech equipment, aren't always welcome.

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So it's no surprise that field studies have been scarce on glaciers in this part of the world and that scientists have yet to paint a clear picture of how the region is expected to change in the coming decades. This question is not only academic, as rivers that feed more than half a billion people in Pakistan, India and Bangladesh all have their origins in the snow-covered peaks of the Himalayas and Karakoram.

One thing is clear: the glaciers won't vanish by 2035, as the Intergovernmental Panel on Climate Change (IPCC) claimed in its 2007 assessment report[1]. This error and others in the IPCC report's section on Himalayan glaciers — widely reported elsewhere[2] — have now been corrected. But the ensuing furore has highlighted how little is actually known about the fate of glaciers in this region. The errors "were mainly based on the desire to say something", says glaciologist Richard Armstrong of the National Snow and Ice Data Center in Boulder, Colorado. "But you need to know that if there's no data, you shouldn't say anything."

As it stands, no one is even sure how many glaciers are in this part of the world. Current estimates suggest there are about 12,000 to 15,000 in the Himalayas and about 5,000 in the Karakoram. Of these thousands of glaciers, only 15 have been measured on the ground to see if they are gaining or losing ice overall. Despite the scarcity of data, trends are emerging. "It is pretty clear that the Himalayan glaciers have been losing mass, with markedly greater loss in the past decade than earlier," says geographer Graham Cogley of Trent University in Peterborough, Ontario.

JOHN SHRODER

John Shroder and colleagues hiking along the Chandra River valley on the way to the Choto Shigri glacier in the Indian Himalayas.

COMPLEX CONVEYORS

As in many other mountainous zones, temperatures in the Himalayas have risen faster than the global average, so it's as expected that many of the regions' glaciers are shrinking and getting thinner. "Glaciers are the most visually obvious indicator of climate change," Armstrong says.

"But they're also complex," Armstrong adds. "They're [like] big conveyor belts moving ice down from higher elevations." These conveyor belts are fed by snowfall at high elevations, which compacts into ice and then slides downhill over decades, so they're sensitive to changes in snowfall patterns — patterns that may shift with a warming climate. They're also affected by whether they're on a steep slope or flatter terrain, and whether they're in open areas or sheltered valleys.

"Each glacier has its own individual behaviour," says Mats Eriksson of the International Centre for Integrated Mountain Development (ICIMOD) in Kathmandu, Nepal. Some glaciers are shrinking in area, some are flowing faster with rising temperatures, and some are staying relatively stable, Eriksson says. Scientists need to study many glaciers to get a reasonable estimate of their average behaviour, he says.

So far, most on-the-ground measurements in both the Himalayas and the Karakoram range have focused on whether the glaciers' snouts — the points at which they end — are retreating[3]. On-the-ground studies of around 40 Himalayan glaciers' snouts have shown that nearly all have consistently retreated, most at rates of around 10 to 20 metres annually and some by as much as 50 to 70 metres per year, in recent years.

Karakoram glaciers seem to buck the trend, however. Several studies of a handful of glaciers in Pakistan have found that many glaciers there are steady at their snouts, and some have even advanced. Others are flowing at about the same rate as decades ago[4]. "The general story is that these glaciers are pretty healthy," says glaciologist Luke Copland of the University of Ottawa in Ontario. But it makes sense that the Karakoram glaciers would respond differently from those in the Himalayas, says Armstrong. "It's colder. It's higher latitude," up to ten degrees latitude farther north than Nepal. "That's a big difference," he says.

More important than the rate of retreat is the overall loss of ice from the glaciers, says Eriksson. Even while the snout of the glacier holds a steady position, it can be thinning both from melting and from sublimation, in which the ice vaporizes. "Glaciers can be standing still and wasting away," says Cogley. More estimates are needed of mass balance — in other words, whether a glacier is gaining or losing mass. "It's the best way to assess the health of a glacier," Cogley says.

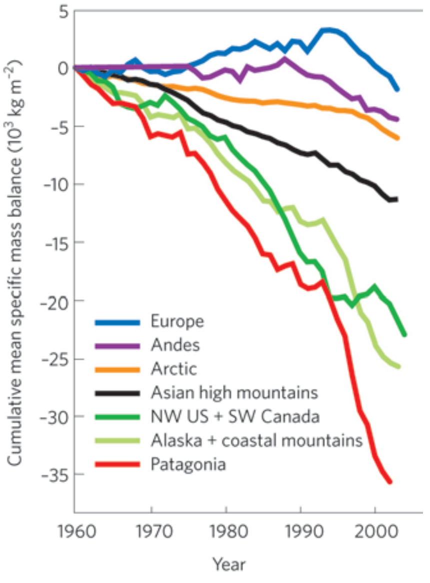

Figure 1 Middle of the pack. Himalayan glaciers are losing mass faster than European glaciers but slower than those in Alaska. Adapted from ref. 4. Courtesy of AGU.

Despite the scarcity of mass-balance estimates, some trends can be teased out. "Most glaciers are thinning, except at the highest elevations," says Cogley. They're losing mass overall, and possibly at an accelerating rate. Looking at all the available measurements, he says, "It suggests, at least to me, that the rate of loss is greater than a few decades ago." This fits with measurements from other glaciers around the world, which have been losing mass since the 1960s, and increasingly since the early 1990s.

But such studies don't show any support for another claim in the IPCC report that "glaciers in the Himalaya are receding faster than in any other part of the world". According to a 2006 review by Cogley and others[5], the Himalayas are in the middle of the pack, with European glaciers losing the least mass and those in Alaska losing the most (Fig 1).

SOLUTIONS FROM SPACE

To get a better picture of how glaciers are changing in these hard-to-reach areas, researchers are turning to satellites. Most satellite studies have used photos of the glaciers to determine whether the snouts are retreating, but a few have also been able to measure changes in the glaciers' thickness. One of the first of these studies of thickness[6], in 2007, found that the glaciers were thinning across a wide area of the western Himalayas. At low elevations, they lost about eight to ten metres of thickness, and at high elevations two metres — reinforcing glaciologists' suspicion that there is more mass loss from low elevations than high elevations. What's more, the study found "an increase in the pace of glacier wastage", with glaciers thinning twice as fast in recent years as they were in the late 1970s.

New analyses from gravity-sensing satellites and a soon-to-be-launched precision radar satellite will enable researchers to gain a better understanding of these changes. A pair of satellites launched in 2002 and known as GRACE — for Gravity Recovery and Climate Experiment — can detect subtle changes in the Earth's gravity field, caused by on-the-ground variations in water, ice or plant life. In theory, GRACE should be able to detect the loss of ice in mountains such as the Himalayas.

The first GRACE-based study of Asia's glaciers, published in February by Koji Matsuo and Kosuke Heki of Hokkaido University in Sapporo, Japan, estimates the mass loss of ice from the Himalayas, Karakoram and the Tibetan Plateau at about 50 billion tonnes per year[7] over the period 2003 to 2009. This may be an overestimate, however. Farmers in the plains of northern India have pumped up groundwater much faster than it has been replaced — so much that the area is losing mass, regardless of any loss from the glaciers, according to a 2009 study that was the first to use GRACE measurements of this region[8].

Another new study, as yet unpublished, may clear things up. John Wahr of the University of Colorado in Boulder and his colleagues have found that in the Karakoram, farther from the north Indian plains where groundwater is greatly declining, there is a clear loss of mass in the mountains, similar to what Matsuo and Heki found. If these results hold up and the ice loss continues, the apparent healthiness of the Karakoram glaciers may prove to be an illusion.

Scientists may use another eye in the sky — the satellite Cryosat-2 — to inform them of these changes. Launched by the European Space Agency (ESA) in February, Cryosat-2 will use radar to detect changes in the heights of glaciers and ice sheets, and should be able to detect centimetres of change over an interval of months to a year, says Mark Drinkwater, head of ESA's Mission Science Division.

RUNNING DRY?

If the glaciers across these mountains are shrinking, thinning or pulling back, what will it mean for the region's water supply? The IPCC presented a dire scenario in its fourth assessment report: "The Ganga, Indus, Brahmaputra and other rivers that criss-cross the northern Indian plain could likely become seasonal rivers in the near future as a consequence of climate change." But this is exaggerated, says Cogley. Upmanu Lall, director of the Columbia Water Center at Columbia University in New York, agrees. Lall says the idea that the rivers could run dry because of shrinking glaciers seems to stem from a confusion about how much glaciers contribute to river flows, compared with the contribution from melting of the seasonal snowpack. "Strictly speaking, we should separate the long-term ice in the glacier from the snow melt," he says. "The reality is that 10 to 20 per cent of the dry-season flow comes from glaciers themselves."

Initial studies of how the rivers will respond to ice loss show modest changes in stream flow — far from the IPCC report's dire scenario of rivers running dry. Even if the glaciers were lost completely, flows down the Indus would drop about 15 per cent overall, with little or no change in the dry-season flow, one recent study found[9]. Lall cautions, however, that climate models are poor at simulating rain and snowfall, especially for the Asian monsoons. "I wouldn't hold these models to be very accurate," he says.

In the absence of clear predictions of what's to come, close monitoring of changes in the mountains is all the more important, as rising temperatures will probably affect the whole water cycle, says Eriksson of ICIMOD. "There has been too much focus on the glaciers as such," he says. "It's urgent to understand the whole [impact] of climate change on snow, ice and rainfall, and that is not happening."

Further satellite missions in the future could give a better picture of what's occurring in these mountains, several researchers say. A planned successor to GRACE, for example, would give higher-resolution measurements of mass loss. More satellites would also provide continuous, long-term measurements, which are sorely lacking now.

But between now and when the next IPCC report is prepared, the picture is unlikely to change much. "Nothing we are likely to learn in the next couple of years is going to alter our understanding of the climatic health of glaciers dramatically," Cogley says. "For the moment we have to work with what we've got, and what we've got is not reassuring."

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