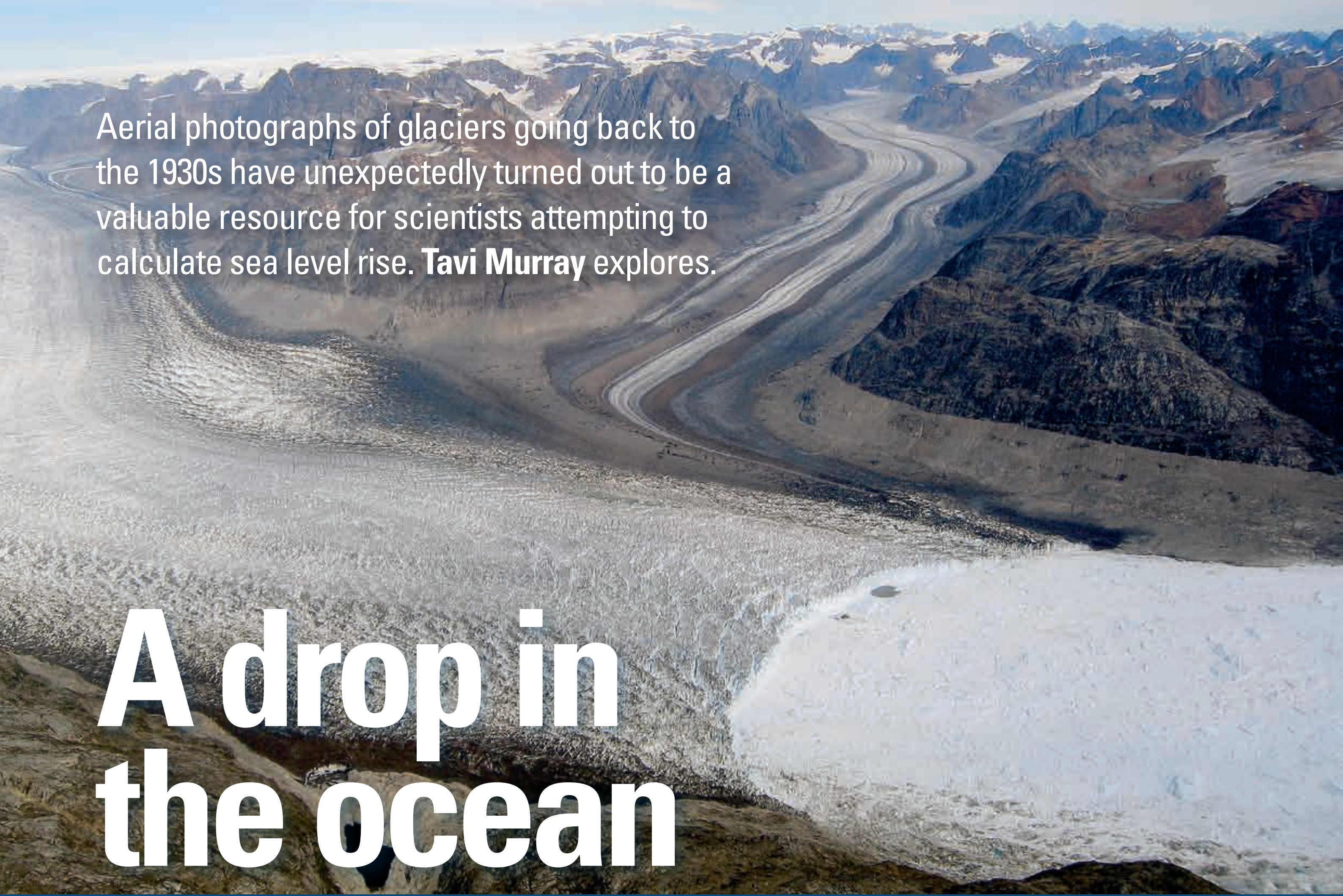
Aerial photographs of glaciers going back to the 1930s have unexpectedly turned out to be a valuable resource for scientists attempting to calculate sea level rise. **Tavi Murray** explores.

A drop in the ocean



A glacier in east Greenland. Nearby glaciers show ice high on the valley walls, a consequence of rapid thinning.

Drip … drip … drip … How many times have you seen melting glacier ice on the news recently? Are those few drops of water really important? Our work suggests they are – and increasingly so.

Antarctica and Greenland trap most of the Earth's frozen water in ice sheets kilometres thick, but so far, climate warming has only had an impact at the margins of these frozen expanses. The centre of the ice sheets are so cold that no melting occurs. But the mountain glaciers and ice caps spread out over every continent are shrinking.

Mountain glaciers cover a tiny fraction of the Earth – just 0.3 percent of the total land surface. However, their melt contributes substantially to current sea level rise. It is second only to that caused by the expansion of warming ocean water. The remaining water comes from melt at the edge of the Greenland ice sheet and perhaps Antarctica.

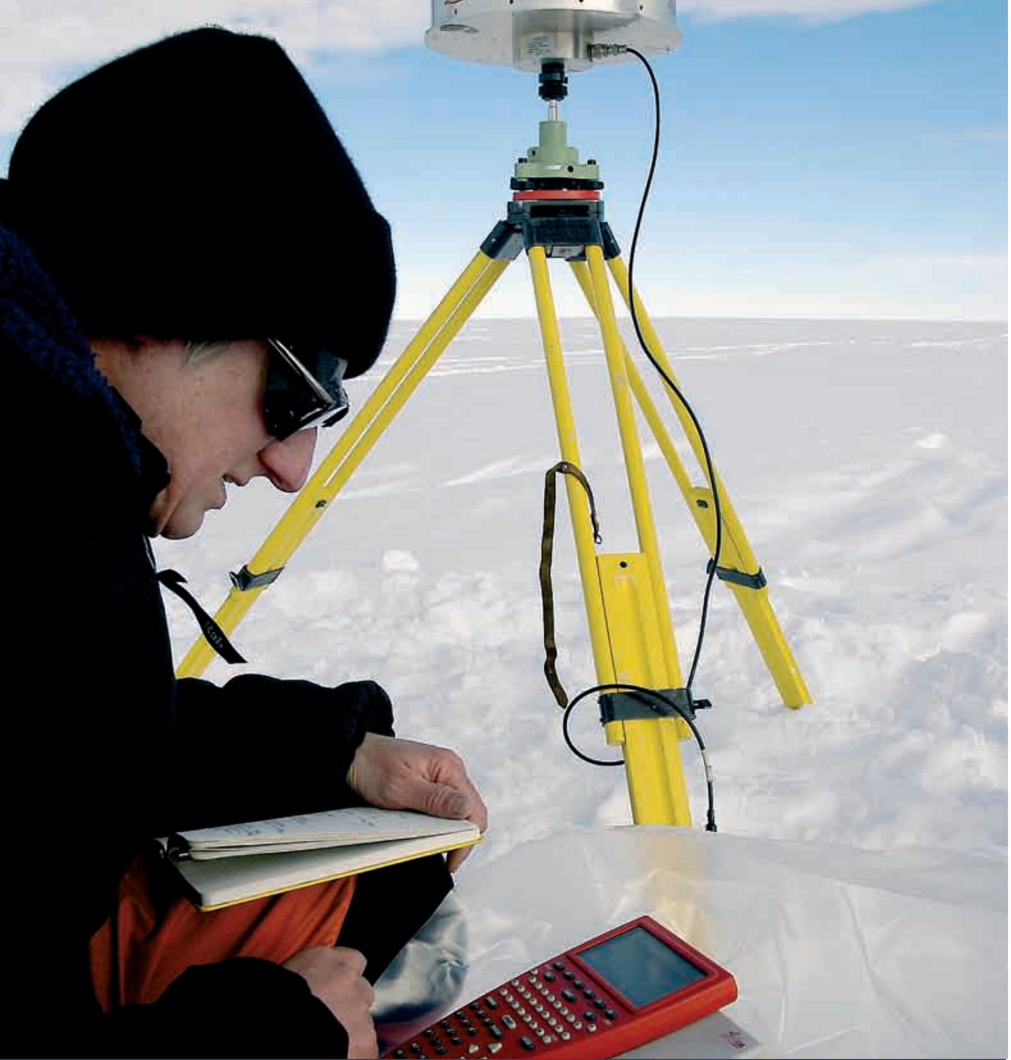
Measuring how these small glaciers are changing in volume world-wide is difficult. At a few glaciers, researchers make intensive efforts to calculate volume change each year. They dig snow pits in spring to gauge the snow added; in summer they drill stakes into the ice surface to determine melt. The process is labour intensive and must continue each year – no wonder that only a few small glaciers are measured. Current satellite sensors are only really useful for very large glaciers and ice sheets, and satellite data span back just a short period, often less than a decade.

Intriguingly, in many areas of the world, aerial photos of glaciers exist going back to the 1930s. The photographs were originally collected for mapping, so crucially, they overlap. We can combine these photographs to make a 3D image of the Earth's surface like the way our left and right eyes provide images to our brain. Potentially, they could provide valuable evidence for ice loss in the last century. The problem has been that to produce quantitative information about the surface, we need a small number of points whose location on the Earth is known. We call these ground control points, and often choose rock outcrops or mountain peaks because they are stable.

In many glaciated areas, simply getting to a glacier is challenging, and collecting enough control points would be a slow, hazardous and often costly procedure. We could use helicopters to fly to mountain peaks, but this is expensive. So, despite the large number of aerial photographs of glaciers held worldwide that could provide an excellent record of glacier volume change and climate change, we've used virtually none because of the lack of ground control.

Since 2003, as part of the NERC-funded project SLICES (Sea Level Rise from Ice in Svalbard), we have worked with the NERC Airborne Remote Sensing Facility (ARSF) to overcome this problem. We've been using a lidar system mounted on NERC's Dornier aircraft. Lidar is a mapping system which scans a laser across the surface beneath it and measures the distance between the ground and the aircraft. It can cover a swath around 800m wide.

The instrument collects millions of closely spaced points in a single survey to produce a map of the ground beneath the plane. The difficulty is knowing exactly where the rapidly moving plane is above the surface, and which direction the laser is pointing as it scans. To solve this, we can use the navigation systems on the plane together with a GPS base station close by on the ground. But many glaciers are tens of kilometres from the nearest base station,



Tavi programs a GPS base station.

so the first challenge with collaborators in Newcastle was to improve the GPS processing to ensure our lidar measurements were accurate enough to act as ground control.

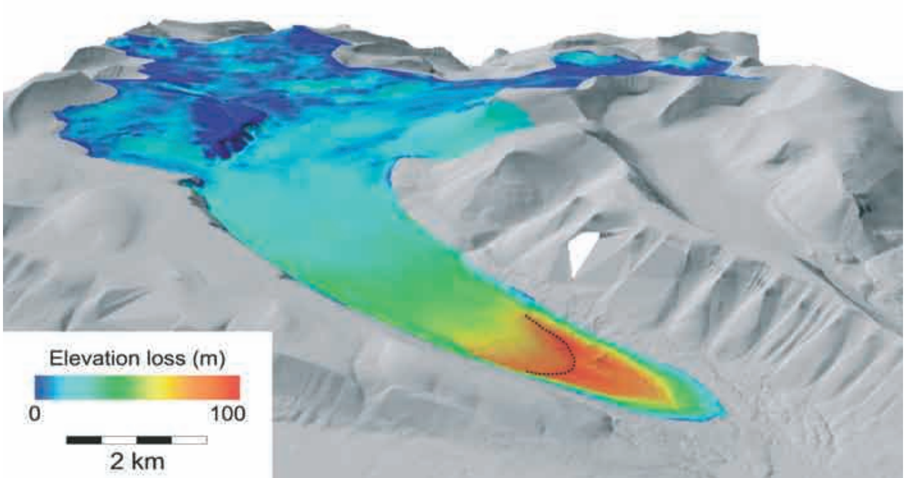
Once we'd processed the lidar data to produce the surface around a glacier, we selected ground control points. We use these to make a surface map from photographs taken decades ago. Computers can work out the difference between these maps and current glaciers, allowing us to calculate the volume change.

Our first targets were small glaciers in Spitsbergen in the Norwegian High Arctic, because we know this area is particularly sensitive to climate change and is making a surprisingly large contribution to sea level rise. For example, a glacier called Slakbreen descends from a small ice cap in central Spitsbergen. We can now show for the first time that thinning rates increased by more than four times between 1961-1977 and 1990-2003. At Slakbreen's front margin, which retreated by 1.4km since 1961, thinning has been more than 100m. All the Svalbard glaciers we have measured show an increasing rate of volume loss throughout the twentieth century.

This may all sound straightforward, but airborne remote sensing brings its own challenges. Lidar only works when the weather is fine – a rarity in many polar environments. A key personal requirement is the ability to remain calm and unstressed, while the clock ticks and the weather just won't improve, but once airborne, the breathtaking beauty of the landscape is a worthwhile payback.

With three years experience targeting glaciers all over Spitsbergen, and having solved the ground-control problem, in 2007 we targeted the margin of the Greenland ice sheet as part of a major Leverhulme Trust-funded project. Because of recent rapid changes in their ice-flow rates, the ice-sheet margins are a critical area to understand if we are to predict future sea level rise.

We have just returned from a highly successful campaign with the ARSF aircraft to East Greenland. The sheer scale of the ice sheet has required us to rethink the manner in which we collect data (and the number of bugs was a new challenge). However, stranded ice blocks and sharp trimlines – geographical features close to glaciers – high on the valley walls are evidence of the rapid rates of recent thinning and retreat. Knowing whether these very recent changes in ice volume at the Greenland margin will continue adding to sea level rise is key to predicting future sea levels. ✿



The Slakbreen glacier, Svalbard. The glacier shows thinning of up to 100m and retreat of 1.4km at its front margin since 1961. The dotted line is the 2003 margin.

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http://geography.swan.ac.uk/glaciology/slices/

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