

## Antarctic science

### To coldly go

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**Scientists travel to the bottom of the world to investigate the climate, the universe and the limits of life itself**

Arcticphoto



AMUNDSEN came on a dog-sled. Scott came on foot. Most of today's visitors to the South Pole, however, come by plane, courtesy of the New York Air National Guard's special Hercules cargo aircraft, which are fitted with hydraulic skis. Much has changed in the 95 years since people first visited the Pole. Pemmican rations are a thing of the past. Your correspondent can sit in relative comfort within view of the ceremonial Pole marker, drinking tea and contentedly writing e-mails. The recently completed United States South Pole Station, pictured above, has most of the amenities of home, even if its 200 or so occupants are allowed only two-minute showers, twice a week.

Another thing that has changed is motive. Once, Antarctic science was strictly for eccentrics. It was poorly financed and the reason for paying anything at all was as much to do with keeping a toehold in the place as for the sheer joy of acquiring knowledge. Now the continent and its northern antipodes are seen as crucial to understanding the Earth's climate and how it changes. That understanding has become so pressing that some 60 countries are planning to spend a total of \$1.5 billion to send more than 10,000 researchers north and south for the International Polar Year (IPY), which started this month.

One reason why Antarctica matters so much is historical. The continent's ice and the sediments of its seas preserve a pristine record of what has happened in the past. If that past is to illuminate the future, the

continent must be studied in some detail. The other reason is pragmatic. About 90% of the world's ice is in Antarctica. If even part of that ice melted, the sea level would rise dramatically. Knowing how Antarctica's ice is responding to a changing climate, and predicting its future response, are therefore matters of more than academic interest.

## **The past is prologue**

Among the ice historians are the members of the West Antarctic Ice Sheet (WAIS) Divide Ice Core project. This operates, as its name suggests, in the western part of the continent. Over the next four years the project's members will use a long, hollow drill to cut and retrieve a cylinder of ice roughly 3.5km long and 12cm across. The WAIS Divide site has several features that make its ice of special scientific value. In much of Antarctica so little snow falls each year that it is technically a desert. Consequently, the annual layers in most Antarctic ice cores are thin and difficult to interpret. At the WAIS Divide site, however, it snows a lot, and has done so for some time. That provides nice, thick layers. The team's members think that they should be able to count back through 40,000 of these layers, and thus look back 40 millennia.

The reason for doing so is that each of those layers contains bubbles of air trapped when the snow that formed them fell. The WAIS Divide core should thus provide the most accurate record to date of atmospheric carbon dioxide, a greenhouse gas that lies at the heart of climate change. Hitherto, the best records have come mostly from Greenland, but according to Richard Alley, a climatologist at Pennsylvania State University who works on the WAIS Divide project, cores from Greenland contain too much dust to provide a truly accurate record. The dust includes chemicals that can react with the trapped gases, changing their composition. Antarctic ice, which is less dusty, does not suffer from this problem.

The high-quality dating of the WAIS Divide core will thus allow climatologists to work out whether past increases in carbon dioxide led to rises in temperature or merely followed them—a crucial distinction. It will also be possible to correlate this core with the Greenland cores. That will give better insight into how changes in the Arctic and Antarctic climates are related. At the moment no one knows whether the north leads the south, the south the north, or both change simultaneously.

Off the coast near another of America's Antarctic bases, McMurdo Station, the Antarctic Geological Drill (ANDRILL) team have just completed their first field season. ANDRILL is drilling not through ice but through sediment. This first season has retrieved a 1,284-metre-long core of the stuff from beneath McMurdo Sound. Ice cores, by definition, cannot contain information from before the ice formed; in practice, that means tens of thousands of years at most. Sediments, by contrast, can go back millions of years. The ANDRILL team thinks the core they took this year reaches back 6m or 7m years. Next year they plan to drill one that should go back 15m years.

By studying the chemistry of the sediments and looking at the sorts of fossils they contain, the ANDRILL team should be able to reconstruct the temperature of the waters surrounding Antarctica back to a time before the current series of ice ages started. They will also be able to look at the advance and retreat of the ice sheets themselves. Advancing ice brings lots of crud. That results in sediment made mainly of ground-up rock. When the sheets are gone, a larger proportion of the sediment consists of fossils, particularly those of organisms called diatoms.

So far, it looks as if the ice sheets have advanced and retreated more than 50 times over the past 5m years. Understanding how this back-and-forth movement relates to subtle changes in past temperatures may provide important clues to the future. Together, the ice sheets of Antarctica and Greenland hold enough water to raise the sea level by 70 metres. No one is suggesting that all this water is likely to be released in the near future, but there is evidence that sea levels have risen by up to 20 metres in less than 500 years during past episodes of change in the Earth's climate.

## **Present indicative**

Surprisingly, finding out what is happening to the ice sheets at the moment is almost as hard as looking at their past. Whether a sheet is growing or shrinking depends on whether it picks up more snow in the winter than it loses to calving icebergs and meltwater in the summer. Here, a bird's-eye view can help.

What is happening to the ice sheets now is therefore the province of satellite measurements. Over the past decade such measurements, which allow for the monitoring of entire ice sheets all at one time, have transformed efforts to understand how ice sheets change with the seasons. Researchers can bounce radio waves or lasers off the ice surface to measure a glacier's height and how fast it is moving. Indeed, they can do more. The satellites of GRACE (the Gravity Recovery and Climate Experiment) allow their operators to measure minute changes in the Earth's gravity produced by the thickening and thinning of ice sheets.

These measurements have already shown that different things are going on in different places. In eastern Antarctica increased snowfall is causing the ice sheet to thicken at the moment. The west Antarctic ice sheet, however, is thinning at between 10cm and one metre a year.

The satellites also show that this thinning in the west is accompanied by faster movement of the glaciers. One reason may be that much of the western ice sheet lies on bedrock that is below sea level. That makes it easier for seawater to get underneath it and lubricate its movement. And it seems to be happening fast. Until recently, glaciologists had assumed it would take decades for coastal changes to make their way deep inland. In fact, measurements from Greenland have shown they can do so in a matter of years.

All of which goes to show how fields of research that once looked esoteric can become relevant with astonishing speed. And, scientists being scientists, the esoteric is also part of the curriculum. In particular, two projects for which the continent is uniquely suited reach out beyond the confines of the Earth. Astrophysicists are using Antarctica to explore some of the earliest and most energetic events in the universe, and glaciologists and biologists are studying vast lakes under the ice that they hope will show how life evolves in the sort of conditions more commonly found elsewhere in the solar system.

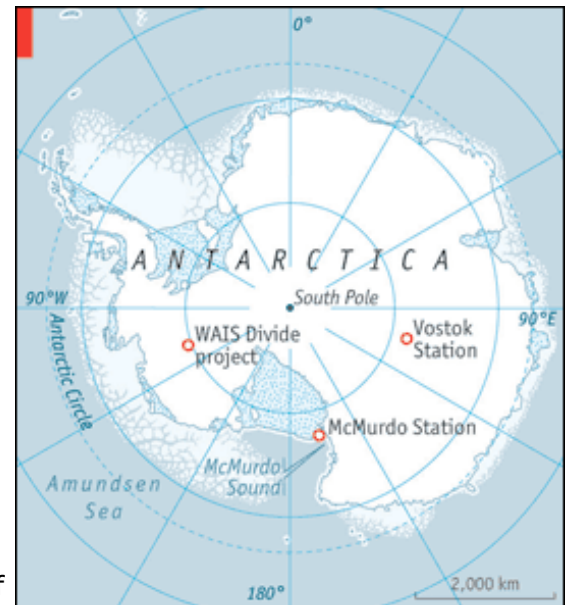
## Through thin and thick

For those astronomers who want to observe the cosmic microwave background (CMB)—the remnant radiation that has been travelling through the universe since shortly after the Big Bang itself—the South Pole is an unusually inviting place. The Pole's high altitude (2.8km above sea level) means the atmosphere is thin there. Its cold air keeps the amount of water vapour low (water absorbs microwaves, which is why food gets hot in a microwave oven). And the atmosphere at the Pole is extremely stable, which minimises the amount of twinkling—a phenomenon that affects the CMB as much as it does stars. Over the years, therefore, a long string of experiments designed to look at the microwave background have been brought to the Pole. The latest of these, the South Pole Telescope (SPT), opened for business at the end of January.

The SPT is designed to use the microwave background to search for a mysterious ingredient of the universe known as dark energy. No one knows what dark energy is. The reason physicists believe it exists is that they need something to explain why the expansion of the universe that started with the Big Bang is speeding up, rather than slowing down as might, naively, be expected.

The SPT team plan to search for signs of dark energy by measuring the distribution of groups of galaxies farther back in time than has been done so far. The formation of galaxies and clusters of galaxies in the early universe is extremely sensitive to how much dark energy was around then, and to how fast the universe was expanding. By measuring accurately how such structures formed, cosmologists should be able to work out the influence and properties of dark energy.

To see so far back in time, though, requires a trick. The SPT researchers will use something known as the Sunyaev-Zeldovich effect. When photons that make up the CMB pass through regions of hot gas in a cluster of galaxies, they receive kicks, giving them a bit more energy. By measuring the energy of the CMB with



precision, in order to detect the influence of this effect, the team hope to be able to tell where in the sky ancient galaxy clusters are found, and thus how they are distributed.

Microwaves are not the only things coming from space that are best observed at the South Pole. While the SPT is looking up at the sky there, another group of astronomers are trying to observe the universe by looking straight down. The IceCube experiment is building a scientific instrument out of the polar ice sheet itself. The aim is to detect neutrinos—ghostly subatomic particles that interact only rarely with normal matter.

When a neutrino does interact with a piece of normal matter, the result is a stream of other particles. Some of these give off light—and it is this light that IceCube is designed to detect. IceCube's drillers are using a high-pressure jet of hot water to melt a series of 2.5km-deep holes in the ice. When each hole is finished, a 1km-long array of light detectors is lowered into it and the hole is allowed to refreeze. The aim is to embed a cubic kilometre of ice with sensors.

When the array is complete, it will be able to indicate which direction a neutrino has come from by the pattern of light arriving at the different detectors. That will enable it to answer the question of what creates high-energy neutrinos (low-energy ones come from the sun, and are of no interest to IceCube's scientists). It may also help to answer questions about sub-atomic physics that are beyond the capabilities of today's particle accelerators.

## **Still waters run deep**

Another reason to look beneath your feet in Antarctica is that you might be standing on a lake. More than 140 subglacial lakes of varying sizes have been discovered there so far. The largest and most famous is Lake Vostok, which is located 4km below the ice at Russia's Vostok Station. It is 250km long and 50km wide—a little smaller than Lake Ontario—and it has been sealed from the surface in complete darkness and cold for about 15m years.

Subglacial lakes such as Vostok are interesting in their own right, of course. Their isolation means that unusual forms of life may have evolved in them. But what really excites researchers is the thought that similar lakes may exist under the ice of Jupiter's frozen moon, Europa. If places such as Lake Vostok turn out to harbour life, well, who knows?

Several factors allow lakes to form kilometres below an ice sheet. One is that ice melts more easily at the high pressures found at such depths. Another is that ice is a good insulator. The ice sheet thus protects the bottom layers from cold surface air and traps heat produced deep inside the Earth. In the right conditions, then, the bottom layers of an ice sheet can melt and pool in depressions in the bedrock, forming large bodies of water.

Although researchers have, in the past, detected microbes in samples from the bottom of the ice sheet over the surface of the lake, they are not quite sure that these bacteria were not contaminants taken down with the drillhead. It was the risk of such contamination that persuaded a Russian team drilling towards Lake Vostok to suspend operations in 1998. The team has, however, started up again and recently announced that they plan to breach the lake during the IPY. After puncturing Vostok and allowing some of its pressurised water to flow back up into the borehole, they plan to let it freeze and then bring it up to the surface.

Researchers from other countries have been critical of this plan and think smaller lakes that are easier to characterise should be studied before compromising the integrity of the granddaddy of them all. A British-led consortium, for instance, is planning to study Lake Ellsworth, a 10km-long body of water in western Antarctica. Later this year the team will begin detailed geophysical studies of the lake and its surroundings, using sonar. In addition, they will design a probe to study any life that might happen to be in the lake. The idea is to drill through the ice with hot water and then deploy the probe, which would melt through the last bit of ice to retrieve samples. If things go according to plan, they will actually breach the lake in 2012.

Esoteric? Certainly. And in truth, the likelihood of there being life on Europa is slim. But few would have thought 20 years ago that Antarctica's ice might hold the key to the future of life on Earth.

