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The mountain Lapporten looms over the village and research station of Abisko, Sweden.

ON THIN ICE

The Arctic is the bellwether of climate change, which shows up there first and fastest. **Quirin Schiermeier** visits ecologists struggling to keep up.

On a splendid, freezing spring morning in Sweden's far north, global warming seems far away. The pristine landscape around the Abisko Scientific Research Station, 200 kilometres inside the Arctic Circle, is glistening white. Thick ice covers nearby Lake Torneträsk.

The spring equinox has passed, and the days are quickly getting longer. But it is –15 °C as Gareth Phoenix, a plant ecologist from the University of Sheffield, UK, who has wintered at the station, wades outside to check a 'snow melt' experiment installed between mountain birches.

Thin heating cables and four 1,500-watt lamps hanging half a metre above the ground have melted the snow in small patches, exposing shrubs and lichens. Phoenix looks pleased. "Warming the Arctic outdoors in winter isn't terribly easy," he notes. With Massachusetts-based engineer Frank Bowles, Phoenix has spent weeks tinkering with the array so that it melts snow without toasting the plants. He thinks he's got it right now: the heat has melted 45 centimetres of snow in three-and-a-half days, exactly what can happen during extreme warming events in the Arctic winter.

Such warming events occur much more frequently at Abisko now than at any time since climate records began there in 1913, says the centre's scientific director, Terry Callaghan. Ecologists are worried that the short-lived melting episodes, and the sudden return to cold weather afterwards, could harm plants and soils. Such disturbances could resonate through the whole ecosystem in such areas, they suspect, with potentially devastating knock-on effects for nutrient supply, plant growth and animal populations.

Change comes faster in the Arctic than elsewhere. As the snow-free season lengthens and sea ice becomes less abundant, albedo — the proportion of sunlight reflected by the ocean and the ground — decreases. The sunlight that's not being reflected by snow and ice is absorbed instead, and this amplifies climate warming at high northern latitudes. Computer models and on-the-ground observations both suggest that the most pronounced warming will occur in winter[1].

At the Abisko station, mean temperatures between December and February have risen by around 5.5 °C over the past century — eight times more than the average rise in the Northern Hemisphere[2]. Similar warming has been observed throughout the Arctic, causing glaciers in Greenland to flow faster, permafrost soils in Siberia to thaw, and boreal forests in Russia and Canada to move further north.

The Abisko station has become a prime location for studying the effect of climate change on terrestrial Arctic ecosystems. Streams of very warm air masses have been observed here at least once every winter over the past seven years, causing temperatures near the surface to rise by 25 °C or more within a day. The warm air melts the snow cover, exposing and sometimes killing the plants beneath. If the melted snow then refreezes, the shrubs and lichens become encrusted with ice and are no longer accessible as food for lemmings and reindeer. Recent population crashes of wild reindeer on the Arctic island of Svalbard are thought to be linked with such 'icing' events, although a connection is not proven.

Unknown unknowns

Experiments such as the snow-melt study, which will run for at least three years, are meant to clarify the short- and long-term effects of the melting episodes. Mimicking nature is not nature itself, however: Phoenix says that much more study is needed before scientists can hope to understand the complexity of the changes going on. "The problem is to find out what the most interesting thing is of what you are measuring," he says. "You often don't know what you don't know."

Each year, around 700 scientists and students come to Abisko to study Arctic climate and environment, carbon cycles, lake ecosystems and geomorphology. The station has plenty of rooms and lab space, as well as a new scenic lecture theatre and conference facility. And unlike remote Arctic research bases, Abisko is wired with electrical power. This luxury not only makes a stay at the station a comfortable experience; it is also a prerequisite for running long-term outdoor experiments that require a constant energy supply. "It would hardly be possible to run a winter snow-melt experiment at a place like Toolik Lake station in Alaska, where you have only diesel generators," says Jerry Melillo, co-director of the Ecosystems Centre at the Marine Biological Laboratory in Woods Hole, Massachusetts. For his part, Callaghan argues that many more long-term stations, like Abisko, are needed for the monitoring efforts (see pages 127 and 133).

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Thaw point: an experiment to study what happens to plants when snow cover melts and refreezes.

From sink to source

A key problem, he says, will be to determine whether the Arctic, which currently accounts for one-third of soil carbon storage on Earth, is likely to remain a carbon sink, or whether it will turn into a source of carbon. As soils grow warmer, many worry that greater microbial activity could increase the rate of decomposition and lead to increased releases of methane and carbon dioxide[3].

For the moment, computer models suggest that the Arctic is still a small carbon sink. But the trends are highly inconsistent, says Callaghan. Most Arctic lakes, for example, seem to be saturated with carbon dioxide and have turned into carbon sources.

At Abisko, tall measurement towers and small chambers around individual plants monitor the carbon flowing from soils and vegetation to the atmosphere and back again. Such data are then fed into complex carbon balance and vegetation models. But adding carbon-flux data from just one additional site can have a huge impact on the overall picture.

At Abisko, Callaghan has seen how small perturbations can affect the carbon balance of a whole region. From his office window, he points at a bare slope on the distant shore of Lake Torneträsk. During the exceptionally warm winters of 1950 and 2004, eggs of the autumn moth (*Epirrita autumnata*), a caterpillar feeding on mountain birch, survived there in vast numbers. Later in the year the insects destroyed large swaths of the forest, which has not recovered since. Insect outbreaks such as this can convert a whole area from a carbon sink into a source.

Climate warming sometimes brings what may look like good news. In Lapland, for example, the tree line has risen 60 metres since 1900, and satellite images confirm that forests and shrublands have also increased in the northern parts of Siberia, Canada and Alaska. The extra biomass, some believe, could suck up more carbon dioxide.

"Mean temperatures in winter have risen by 5.5 degrees over the past century."

But once again, the picture isn't simple. Because trees decrease albedo in comparison with the tundra vegetation they replace, their spread might actually accelerate warming in Arctic regions. A recent study in Alaska suggested that terrestrial changes in summer albedo plus lengthening of the snow-free season already has an effect similar in magnitude to the warming expected from a doubling of carbon dioxide. And as shrubs and trees continue to proliferate, as some models predict they will in a carbon dioxide-rich world, they could further amplify Arctic warming by two to seven times[4]. "Despite what governments may say, forest growth may do more harm than good to the climate," says Callaghan.

The Abisko station has taken a lead role in the European Union-funded BALANCE project, which investigates present and future climate-change vulnerabilities in the region. In so doing, the researchers at Abisko have turned to some valuable allies: the local Sami population of reindeer herders, whose indigenous knowledge of the area could help scientists assess changes in terrestrial Arctic ecosystems.

"The Sami are all around the landscape and they see many things we don't," says Callaghan. "They are really the missing link between our individual observations and satellite imagery. And including indigenous knowledge just makes our own experiments more relevant." For instance, this spring saw the launch of a joint research project, including linguists, anthropologists and Sami academics at the Nordic Sami Institute in Kautokeino, Norway. 'Snow and Ice' will assess the impact of environmental changes and extreme events on reindeer herding and the movement of reindeer and people through the region.

Lessons from the winter snow-melt experiment are just one thing scientists at Abisko hope to share with the Sami. As night falls over Lake Torneträsk, the eerie green veils of the aurora borealis drift across the starry sky. Relaxing in the improvised 'tundra bar' in the station's cellar, Callaghan is scheming about supplying the Sami with small, portable weather stations. Then they too could become part of Abisko's science network. ■

Quirin Schiermeier is *Nature*'s German correspondent.

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Herding reindeer has given Norway's Sami population an intimate knowledge of their environment.

1. Arctic Climate Impact Assessment *Impacts of a Warming Arctic* (Cambridge Univ. Press, 2004).
2. Callaghan, T. *et al. Polar Research* (in the press).
3. Mack, M. *et al. Nature* **431,** 440–443 (2004).
4. Chapin, F. *et al. Science* **310,** 657–660 (2005).