

Heating up the Holocene

A team from the **British Antarctic Survey** and the **Universities of Cambridge and Exeter** consider the potential impact of uncovering terrestrial Holocene climate variability in the Antarctic Peninsula



PROFESSOR DAN CHARMAN ET AL

With contributions from Professors Dan Charman, Howard Griffiths, Pete Convey, Dominic Hodgson and Drs Matt Amesbury and Jessica Royles

Could you discuss the broader significance of studying past climate change in the Antarctic?

Monitoring and measuring change in the Antarctic Peninsula's past and present climate is critical for understanding and predicting future global change. Major environmental changes, such as the retreat of ice, may be linked to the current rapid increase in air temperature and other climatic changes. However, because the Peninsula's meteorological data have only been directly recorded since the 1950s, our knowledge of the longer-term context of this temperature rise is limited. The main aim of our study is therefore to investigate whether the recorded changes on the Peninsula are unusual compared with past natural climate variability.

You hope to establish a better understanding of climate variability during the late Holocene. How much is presently understood about the Peninsula in this context?

To understand the past climate of the Peninsula it is necessary to document, among other factors, fluctuations in atmospheric temperature and responses to these changes both on land and in the ocean. Until now, there have been no continuous records of plant community responses to late Holocene climate change. Our work shows that plants and their associated microbial communities are responding rapidly to current changes.

How has analysis of surface samples from moss banks enabled you to progress with your investigation and provide further understanding of the processes taking place in these areas?

By analysing surface moss samples and their associated microbial fauna from different

Antarctic Peninsula islands, along with contemporary rainfall and local weather station records, we can understand the relationship between the biological and biochemical characteristics of the moss banks and modern climate. We can then use our understanding of moss growth controls to unlock the signals preserved deeper in the moss bank cores, and try to derive climate conditions from the growth of ancient moss.

The project represents a collaborative effort between three institutions. How does each contribute to the work?

We set out to combine some of the best expertise in the UK to tackle this unusual project. The partners at the University of Exeter are leaders in studying peatlands from around the world; the University of Cambridge scientists provide expertise in understanding plant physiology; and the British Antarctic Survey collaborators provide specific experience in interpreting regional climate changes from a range of historical proxies, as well as years of practical experience undertaking fieldwork in this remote location. We're also working closely with Professor Melanie Leng at the National Environmental Research Council (NERC) isotope geosciences laboratory, as she provides specific scientific expertise in this area.

What have you discovered about specialisms beyond your own since work commenced?

The entire team is keen to understand as much as possible beyond our own specific contributions and have visited each others' labs so that we have practical experience of each stage of the work. During the fieldwork phase, we also ensured that each lab had at least one person involved in the sampling. As

we all come to the research from different angles, we are much better able to challenge assumptions and ask questions that would not otherwise have arisen.

Through what channels are your findings being disseminated?

We hope to reach a wider audience than other academics – we'll be following the traditional routes but have also set up a project website at <http://geography.exeter.ac.uk/antarctica>. In addition, we'll also be visiting schools and colleges in 2014 to run activities based on our work and have already received internet news and radio coverage (see our outreach web page for more information).

Looking ahead, what plans are in place to maximise the impact of this work?

The group will be writing a science summary and policy implications document that will outline the key findings and discuss potential implications for policy on greenhouse gas mitigation and environmental management of the Antarctic Peninsula. The document will be launched at a meeting attended by both policy makers and scientists with an interest in this region. We would encourage any interested parties reading this article to get in touch or keep a look out for future details on our website if they would like to attend.

A calm, sunny day near Brown Bluff on the northern tip of the Antarctic Peninsula © Matt Amesbury

DATE FOR THE DIARY
The team's work will be presented at the upcoming biennial SCAR Open Science Conference in Auckland on **25-28 August 2014** – the largest meeting of the international Antarctic research community in the scientific calendar. For more information, please visit www.scar2014.com

Mysteries in the moss

With direct meteorological data on the Antarctic Peninsula only dating back to the 1950s, scientists must search elsewhere for climate change records of the distant past. A series of expeditions to analyse ancient moss are poised to provide a longer-term perspective on the region's warming patterns

ON THE NORTHERNMOST outreach of the Antarctic continent, the altering landscape of the Antarctic Peninsula over recent decades has been used extensively by the media to voice concerns regarding rising temperatures across the globe. Indeed, over the last 50 years, the Peninsula's average temperature has risen by up to 3 °C in some locations – an average increase of 0.56 °C every decade. The Peninsula's two-way role in influencing and responding to the Earth's oceanic and atmospheric circulation makes it a crucial indicator of what may lie in store for global ecosystems.

Current climate models, however, do not accurately provide the context or fully capture the causes of the most dramatic changes affecting the Antarctic Peninsula: alterations to terrestrial and marine ecosystems, reductions in sea ice, the collapse of ice shelves and glacial retreat. In order to grasp what these events really imply and begin to create a roadmap for predicting future climate variability, teams of scientists from the University of Exeter, the University of Cambridge and the British Antarctic Survey (BAS) came together in 2012, integrating diverse disciplines and skillsets to study historical changes in the Antarctic climate.

With funding from the National Environment Research Council (NERC)'s Antarctic Funding Initiative, the six-member team of Earth Science specialists are currently engaged in a 48-month project that involves collecting and analysing moss samples from remote islands in the region. Coordinating this collaborative project is Dan Charman, Professor in Physical Geography and Dean of the College of Life and Environmental Sciences at the University of Exeter. To discover whether recent patterns

in the Antarctic Peninsula fall beyond the late Holocene's natural range of climate variability, ice and ocean cores have proven useful but longer-term, high resolution records are needed for accurate interpretations of past climate events. The UK-based team has subsequently turned to moss to provide answers.

HIDDEN STORES

Samples were collected from moss banks located at sites from Elephant Island, Green Island, King George Island and Alexander Island's Lazarev Bay, spread over a distance of more than 1,000 km. These remote regions are home to large colonies of mosses and lichens whose slow growth and limited decay make them ideal conveyors of ancient climate variation. The Antarctic summer provides moss with photosynthetic conditions that allow for roughly 2 mm of growth before winter freezing begins. The following summer will see it thaw and grow another 2 mm as this process relentlessly repeats itself. On Elephant Island, moss banks almost 3 m in depth are calculated to be around 5,000 years old. In subzero conditions, the mosses are well-preserved by freezing and low levels of decomposition mean radiocarbon dating can be performed with ease. The rates of moss growth allow records of a single decade to be produced from just one sample. "This doesn't sound much, but it allows us to interrogate rapid environmental changes in the late Holocene," explains Dr Matt Amesbury, another team member from the University of Exeter. This makes moss an ideal archive and the only biological source in the Antarctic stretching back sufficiently far for the purposes of this research. Despite the region's importance to the wider international climate change community, the group is the first to use these moss banks to derive a picture of past climate variability.

In extracting meaningful readings from the moss samples, the interdisciplinarity of the consortium becomes important as they must account for a multitude of factors affecting the mosses and their associated microbial communities. By measuring growth, mass accumulation and proxies for photosynthesis and microbial activity, they aim to test whether the recent rise in temperature at the Antarctic Peninsula was paralleled at any time in the late Holocene; if the spatial pattern of variability bears any similarity to historical climate change; and finally, whether plants are responding to the recent change with increased rates of growth.

CALCULATING CHANGE

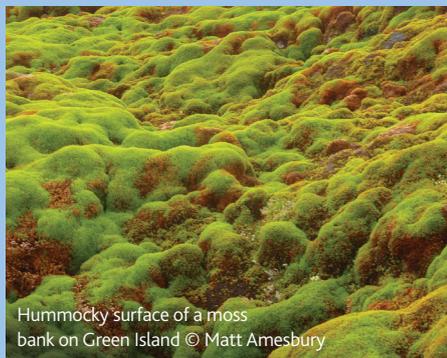
Lazarev Bay is as far south as one can travel before the formation of moss banks stops. Here, due to its isolation, some traditional methods of analysis are difficult to apply, so a combination of unlikely approaches are employed, as



Dr Jessica Royles taking a frozen moss core on Elephant Island © Dan Charman



Moss swatches the landscape on Ardley Island © Dan Charman



Hummocky surface of a moss bank on Green Island © Matt Amesbury



Close up of *Polytrichum strictum* moss on Green Island © Matt Amesbury

Charman states: “We are using methods tried and tested in other geographical regions, but their application together in the context of the Antarctic Peninsula is novel”. By analysing the stable carbon isotope composition (¹³C) of a 40 cm moss sample, they found that the conditions for photosynthesis have been improving since the late 1950s. By observing concentrations of fossil testate amoebae, which likely populated the moss bank soon after its establishment, the researchers also found that from the mid-1960s to early 1990s, amoeba shell concentrations rose from 1,000 per cm² per year to 3,000. At the end of the 1990s the population per cm² peaked at 6,000. Peat accumulation of the moss bank itself appears to have begun around 1860 at an annual rate of 1.25 mm, which continued from the late 19th Century into the early 20th Century. By the close of the 1970s, however, the build-up of peat had increased massively to 5 mm a year before declining to 3.5 mm – a rate that has been maintained ever since.

These findings, borne from the measured rise in temperature that the Antarctic Peninsula has experienced over the last 50 years, are a necessary validation of the collaborators’ novel approach. “We showed for the first time from terrestrial biological data that these changes are unprecedented in at least the past 150 years,” Royles enthuses. With the ability to link changes in biological activity to climate, moss banks almost 3 m in depth mean it is now possible to look back across several millennia of the Peninsula’s climate history.

THE URGENCY FOR ACTION

Using these unique terrestrial archives to uncover the past, the team is confident their work will help others attempting to use the Earth’s changing climate to understand how it may behave in the future. Likely of benefit to palaeoclimate scientists and climate modellers, this collaborative project will also prove particularly useful to plant scientists, as a lack of funding makes repeated plant monitoring a real challenge in these remote regions. The moss bank samples collected from the Antarctic Peninsula provide vital information on past growth patterns, temperature and precipitation that might otherwise have remained unknown. Indeed, these data at present indicate several scenarios of climate-related competition among the flora that could see Antarctic moss lose out to native and foreign flowering plants.

In addition, the importance of their data to policy makers and scientific advisors is highlighted. As one of the most rapidly warming areas on the planet, the effects of anthropogenic climate change are felt sooner here than almost anywhere on Earth. With the moss samples enabling scientists to look back over thousands of years’ worth of climate fluctuations, the project’s findings could have huge impact if recent changes in the planet’s climate are demonstrated to be a unique occurrence; as Professor Pete Convey from the BAS states: “It would increase the urgency for political action on anthropogenic climate change”.

INTELLIGENCE

TERRESTRIAL HOLOCENE CLIMATE VARIABILITY ON THE ANTARCTIC PENINSULA

OBJECTIVES

To reconstruct the past climate variability of the western Antarctic Peninsula using peat moss banks as a novel archive for regional climate change and biotic responses.

PARTNERS

University of Exeter • University of Cambridge • British Antarctic Survey • British Geological Survey

FUNDING

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PROFESSOR DAN CHARMAN is the lead academic on the project and an expert in peatland environments and the study of past changes in climate.

PROFESSOR HOWARD GRIFFITHS is a plant physiological ecologist at the University of Cambridge. His research interests are broad ranging across molecular, physiological and environmental processes that regulate plant productivity.

PROFESSOR PETE CONVEY is a terrestrial ecologist at the British Antarctic Survey and a highly experienced polar scientist.

PROFESSOR DOMINIC HODGSON is a Quaternary Earth scientist at the British Antarctic Survey and has been working on Antarctic projects since 1991.

DR MATT AMESBURY is a research scientist at the University of Exeter, studying climate histories and developing multi-proxy peat-based Holocene palaeoclimatic records.

DR JESSICA ROYLES is a research scientist studying Antarctic moss at the British Antarctic Survey and the Department of Plant Sciences at the University of Cambridge.

