A climatic history of West Antarctica

Drs Liz Thomas and **Claire Allen** discuss how they are developing novel techniques that will broaden our understanding of how wind strength has affected the West Antarctic climate over the past 300 years

Could you describe the goal of your project?

LT & CA: We aim to understand how wind strength and atmospheric circulation influences the climate of West Antarctica. We will do this by developing a novel proxy for past wind conditions based on marine diatoms (microscopic algae) preserved in the ice cores, and combine this with known proxies for long-range atmospheric circulation to produce the first comprehensive multi-proxy reconstruction of regional wind strength and atmospheric circulation in the Amundsen Sea and Bryan Coast region covering the past 300 years. This is the first time that marine diatoms will be used as a proxy for past wind conditions.

How have the circumpolar westerlies changed in recent years, and what is the potential impact of this? What is thought to be behind this change?

LT & CA: Winds over the Southern Ocean have increased in strength and shifted closer to the Antarctic continent in recent decades. This is one of the strongest climate trends in the Southern Hemisphere over the last 30 years. These changes have been linked to warming on the Antarctica Peninsula and increased upwelling of warm circumpolar deep water onto the Antarctic continental shelf, and are considered a major contributing factor to the recent accelerated melting, thinning and collapse of Antarctic Peninsula ice shelves. Enhanced circumpolar westerlies in recent years have been linked to greenhouse warming and anthropogenic ozone depletion, and are therefore likely to continue intensifying throughout the 21st Century.

Why is it difficult to validate current models of wind strength and circulation?

LT: Few instrumental records of Southern Ocean winds or West Antarctic climate exist. There are no permanent research stations along the ~3,700 km Pacific sector coastline between Rothera station on the western Antarctic Peninsula and the McMurdo and Scott Base stations near the western Ross Ice Shelf. The lack of reliable long-term observational records makes it difficult to assess the true role of wind strength and atmospheric circulation on upwelling and climate in this region.

What stage is the project at? How much progress has been made to date?

LT & CA: The project began in January 2013 and we are currently measuring the ice chemistry and diatom records from two ice cores drilled on the Bryan Coast, West Antarctica. The annual diatom record from 1979-2010 confirms that diatoms contained within the ice core are a good proxy for past wind strength and direction. Greater numbers of marine diatoms are found in the ice in years dominated by strong onshore northerly winds.

How do your respective backgrounds complement each other? Has a multidisciplinary approach proved important to the success of the project?

LT: My research uses chemical and isotope records from ice cores to understand climate variability in the Antarctic Peninsula and West Antarctica over the past 100-2,000 years.

CA: My research is based on using diatoms to establish past changes in ocean circulation and climate over the past hundred to hundreds of thousands of years.

LT & CA: We are also collaborating with climatologists, including Thomas Bracegirdle from the British Antarctic Survey, to help us understand how well the current climate models are able to capture natural climate variability in this region, and with project partners at the University of Edinburgh School of GeoSciences, who are providing climate model data from pre-industrial control runs to compare with our proxy records. We are working with colleagues at the Natural Environmental Research Council Isotope Geosciences Laboratory to produce the high precision stable isotope records.

The climate is a complex system and only by taking a multidisciplinary approach, collaborating with climatologists, climate modellers, palaeoclimatologists and oceanographers can we begin to understand it.

What do you anticipate the outcomes of your project will be, following its completion?

LT: The new wind proxy records gathered during this study will help us to understand the role of winds and atmospheric circulation on the climate of Ellsworth Land, West Antarctica. However, the development of a novel wind proxy will have implications for the wider ice core and palaeoclimate community and it is hoped that this study could be expanded to incorporate ice cores from across the Antarctic.

Winds of **change**

Pioneering techniques are being developed by the **British Antarctic Survey** to help increase our understanding of long-term climate change in West Antarctica by using marine diatoms as a proxy for past wind conditions

THE LACK OF data on Southern Ocean winds makes it difficult to validate existing models examining the roles of wind strength and circulation on upwelling and climate. A greater understanding of how the wind patterns have changed historically is essential to gaining a clearer view of how they may influence the Antarctic climate in the future. Current climate models predict a poleward shift and the strengthening of surface winds as a result of increased atmospheric CO_2. Understanding the effects and implications of these climatic changes through the study and validation of historical data will enable greater accuracy in predicting forthcoming trends and their implications.

A NOVEL APPROACH

At the British Antarctic Survey (BAS), Drs Liz Thomas and Claire Allen are developing a novel approach which, by incorporating marine, continental and atmospheric tracers, will for the first time enable a comprehensive multi-proxy reconstruction of both the regional and hemispheric wind strength and atmospheric circulation in the Amundsen/Bellingshausen Sea over the past 300 years. Thomas is a highly experienced palaeoclimatologist with over 10 years of experience in ice core research. Working in the BAS' Chemistry and Past Climate programme, she is currently leading their investigations into climate variability over the past 2,000 years. Allen, meanwhile, is an expert in modern and fossil diatom assemblages from the Antarctic, and has led multiple studies on Antarctic marine diatoms. She has also been involved in the development of novel approaches using diatom assemblage data to complement studies in other disciplines.

Combining this wealth of knowledge and experience, the researchers aim to develop a novel proxy, which involves extracting a record of marine diatoms and terrigenous grains incorporated within the annually deposited ice core layers. "The diatom abundance, species assemblages and total particulate content vary from year to year," they explain. "These are believed to be related to the local/regional wind strength and circulation patterns that influence the onshore northerly winds that entrain the diatoms from the ocean surface and transport them to the ice cores sites." This interdisciplinary approach will provide the first reconstruction of regional wind strength and atmospheric circulation in the Amundsen Sea and Bryan Coast region from 2010-1700 CE.

CLIMATIC EFFECTS

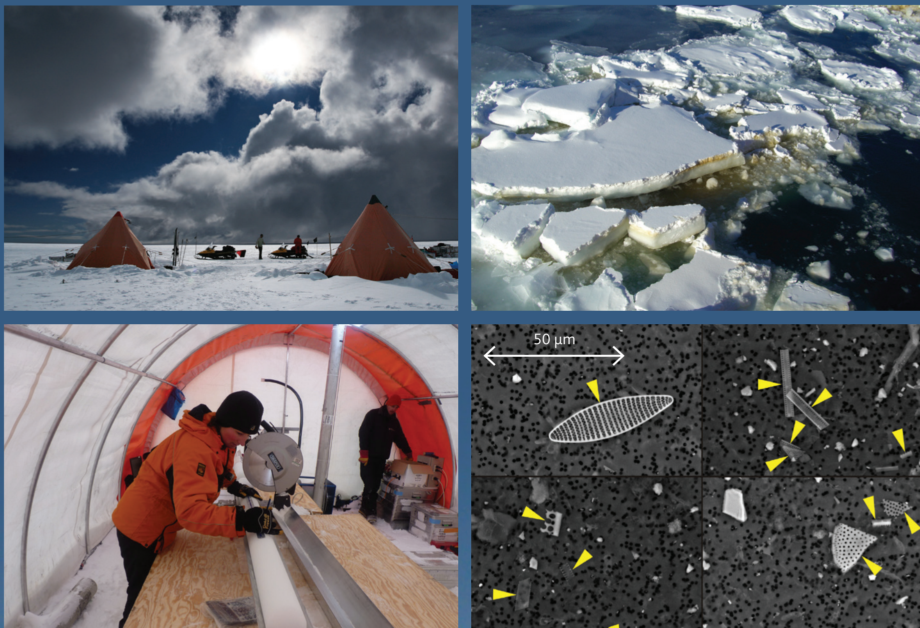
The winds in West Antarctica drive the overturning circulation in the region and thus act as the primary control in the regulation and exchange of heat and CO_2 between the ocean and atmosphere along the West Antarctic margin. Warming, increased precipitation on the Antarctica Peninsula and increased upwelling of warm circumpolar deep water (CDW) onto the Antarctic continental shelf have both been attributed to changes in wind strength and circulation patterns within the region. Delivery of CDW to the glacier-ice margin is considered to be a large contributory factor in the collapse of many Antarctic Peninsula ice shelves during the 1990s and 2000s, due to its promotion of melting and thinning at the base of ice shelves. Gaining an understanding of how wind strength has changed in the region historically is therefore of high importance in predicting forthcoming trends.

Thomas and Allen anticipate that their novel approach will also be applicable to other areas of the Antarctic, which is highly significant in light of the fact that more widespread or intensified CDW upwelling is predicted to pose a threat to the stability of the remaining large ice shelves in the Bellingshausen and Amundsen Seas. This includes the ice shelves of the largest and fastest flowing glaciers in West Antarctica, the Pine Island Glacier, and the glaciers surrounding it.

IMPACT ON CO_2 AND SEA LEVELS

CO_2 emissions resulting from human activity accounts for two-thirds of modern atmospheric levels. Some of this will be removed from the atmosphere in various CO_2 sinks – where absorption of CO_2 exceeds venting – both on land and in the oceans. The large expanse of cold Antarctic waters could be a substantial sink for anthropogenic CO_2; however, stronger or more southerly winds over the Southern Ocean have reduced the potential of the Antarctic waters to absorb atmospheric CO_2 not only by deepening the mixed layer of the surface ocean, but also by increasing the upwelling of warm, carbon-rich CDW onto the continental shelf in the western Antarctic Peninsula and Amundsen Sea.

In addition to this, this influx of CDW was a likely contributing factor in the recent collapses of the western Antarctic Peninsula ice shelves and in the accelerated basal melting of glaciers and ice shelves in the Amundsen Sea Embayment (ASE), evidenced by the inland migration of grounding lines, accelerated glacier flow and significant thinning of the upstream ice field; glacier melt in the ASE already contributes ~0.22 mm per year to global sea level rise. Left unchecked, this melting could result in significantly increased



Clockwise from top right: sea ice with brown algae-rich layer; diatom and diatom fragments collected from the ice cores; drilling the Bryan Coast ice cores; Antarctic field camp. (also shown below)

sea levels across the globe – it is estimated that the melting glaciers of the ASE could increase global sea levels by ~1.5 m.

ICE CORES

Thomas, Allen and their co-investigator Dr Thomas Bracegirdle will utilise all available ice core proxies and observational records in order to examine the role of winds on climate in the Amundsen/ Bellingshausen Sea. Ice cores hold vital information about past climate and atmospheric circulation. The stable water isotope ratio in precipitation can be used as a proxy for past surface temperatures and hydrological cycling and the seasonal deposition of chemical species in the ice not only provides a means of accurately dating the ice cores but also a record of annual snowfall in the region. Measuring dust and continental ion species provides a record of large-scale atmospheric circulation while emissions from marine algae will provide a record of local sea ice conditions. The ice core proxies will be calibrated using reanalysis data, provided by the European Centre for Medium Range Weather Forecasts, and satellite data available from 1979 onwards, together with pre-industrial climate simulations. Combined with their new marine diatom proxy, this integrated and novel approach will enable the researchers to study and understand the climatic history of one of the most important regions in the world for the very first time.

INTELLIGENCE

RECONSTRUCTING WIND STRENGTH AND ATMOSPHERIC CIRCULATION IN WEST ANTARCTICA OVER THE PAST 300 YEARS

OBJECTIVES

To understand how wind strength and atmospheric circulation influences the climate of West Antarctica.

PARTNERS/KEY COLLABORATORS

Dr Thomas Bracegirdle, British Antarctic Survey

The School of Geosciences, University of Edinburgh

NERC Isotope Geosciences Laboratory

FUNDING

NERC: NE/J020710/1

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DR ELIZABETH THOMAS is a palaeoclimatologist at the British Antarctic Survey specialising in ice core research. She has undertaken several ice core drilling projects in Antarctica and Greenland and is currently principle investigator on a multidisciplinary project investigating the impact of wind strength and circulation on climate variability in West Antarctica.

DR CLAIRE ALLEN is highly experienced in working with modern and fossil diatom assemblages from the Antarctic. She brings a wealth of knowledge and practical experience in Antarctic diatom taxonomy and ecology, having led and supervised a wide variety of studies on Antarctic marine diatoms.

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