Constraining past accumulation rates from the interior of Antarctica with radar data: implications for ice sheet dynamics and evolution (Ref IAP2-18-113)

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In partnership with Newcastle University (School of Geography, Politics and Sociology) and British Antarctic Survey (BAS)

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Key Words

Overview

The West Antarctic Ice Sheet (WAIS) is currently losing mass at an accelerating rate. Processes controlling this loss are uncertain, and it is unclear whether the current changes are anomalous over centennial to multi-millennial time spans. Through this project you will reconstruct ice sheet surface accumulation and ice thickness change since the Last Glacial Maximum (LGM), using spatially-extensive and temporally-detailed observations, to provide a long-term context for recent change.

Radio-echo sounding (RES) (see figure) is uniquely positioned to provide information on the spatial pattern and temporal variability of past ice-sheet surface accumulation. Although ice cores are more precise in quantifying rates of past ice-sheet accumulation, they are point measurements and therefore cannot achieve the extensive spatial information that RES techniques allow. Despite the significant potential offered by RES for assessing long-term surface accumulation change, this project will be one of the first to apply this technique across large swathes of Antarctica. The project will develop, and extend, a methodology of Siegert and Payne [2004], who utilised data from a single RES flight line over central WAIS to quantify the rate and variability of surface accumulation during the last 16,000 years. Few studies have undertaken this task at an ice-sheet scale, and none have used RES to assess the impact of past surface accumulation on glacial isostatic adjustment (GIA) models. Such models are used to predict the solid Earth response to past ice-sheet change and this information feeds into estimates of contemporary ice-sheet change [e.g. King et al., 2012].

Figure 1: A RES profile from West Antarctica.

The project will combine airborne RES survey data acquired over the main WAIS ice divides [e.g. Ross et al., 2011] with ice-sheet modelling to quantify post-LGM rate(s) and spatial pattern(s) of surface accumulation, primarily across West Antarctica. The
findings will be used to assess the sensitivity of GIA models to past accumulation variability.

**Methodology**

The project will use geographical information systems (GIS), geophysical visualisation software and numerical modelling to: [1] Identify, trace and map internal layers in RES data across central West Antarctica; [2] Date mapped internal layers by correlation with known, dated stratigraphic units in ice cores; [3] Use the stratigraphic relationships between dated layers to determine the post-LGM rate and spatial pattern of surface accumulation over West Antarctica; [4] Use numerical models of post-LGM ice-sheet behaviour to test the sensitivity of WAIS thickness and extent to the temporal and spatial accumulation patterns identified above, and to evaluate the impact of uncertainty in the accumulation reconstructions on models of glacial isostatic adjustment.

The student will constrain the reconstructed model of past ice sheet change using observations of accumulation derived from shallow ice cores, snow pits, satellite observations, and estimates provided by numerical models. The consistency of the reconstruction will be assessed against glacial geological evidence relating to the post extent and thickness of the WAIS (e.g. cosmogenic isotope dating of terrestrial surfaces, sediment cores and marine geophysical surveys) [e.g. Hillenbrand et al., 2014].

The outcomes and impacts of this project will be: (i) the first reconstruction of long-term rates of surface accumulation across the central WAIS; (ii) improved reconstructions of post-LGM WAIS ice surface evolution; (iii) an assessment of the impact that variability in rates of ice-sheet surface accumulation may have had on the extent and thickness of the post-LGM WAIS and the regional GIA signal; and (iv) an assessment of whether present-day rates of mass loss occurred in the pre-instrumental period, and the timescales over which they were sustained.

**Timeline**

**Year 1:** develop an understanding of surface mass balance processes and GIA; familiarisation and training on radio-echo sounding datasets and software; visits to project partners; commence radar layer picking.

**Year 2:** generate 3D dataset of dated internal layers across the WAIS, facilitated by visits to project partners; identify regional patterns of post-LGM accumulation across the WAIS; receive training in ice-sheet and GIA modelling; develop presentation skills by attending UK-based glaciological conference.

**Year 3:** interpret temporal and spatial patterns of accumulation across WAIS; conduct sensitivity modelling experiments; draft manuscripts for publication; present outcomes at international conference; draft thesis.

**Year 4 (6 months only):** Complete and submit thesis; finalise manuscripts for publication; attend international conferences.

**Training & Skills**

This project will provide cross-disciplinary scientific training in problem solving, data analysis and report writing. It will provide the student with high-level skills in: (a) glaciology; (b) processing and interpretation of geophysical and GIS data; and (c) numerical modelling.

The student will also benefit from broad skills training provided in-house at Durham (e.g. thesis and paper writing, presentation skills etc.), from a broad range of environmental science training provided within the IAPETUS Doctoral Training Partnership framework, and from attending the Karthaus summer school.

The project will also contribute to the newly-formed international ‘AntArchitecture’ science programme, whose goal is “to use radar-imaged information on the internal structure of the Antarctic Ice Sheet to inform palaeo-climatic reconstructions and ice-sheet modelling of the future contributions of the ice sheet to global sea level”. This programme will provide the student with unique opportunities to network with leading scientists in the field.

This project makes use of the diverse skills of the supervisory team, and funds are available to ensure close collaboration with all project supervisors.

**References & Further Reading**

Hillenbrand, C.-D., and 13 others, (2014), Reconstruction of changes in the Weddell Sea sector of the Antarctic Ice Sheet since the Last Glacial Maximum. Quaternary Science Reviews, 100, 111-136.


Ross, N., and 8 others, (2011), Holocene stability of the Amundsen-Weddell ice divide, West Antarctica, Geology, 39(10), 935-938.


Further Information

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