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Sensitivity of East Antarctic outlet glaciers to future climate change

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Durham University, Department of Geography
In partnership with Newcastle University, Department of Geography

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Key Words	**East Antarctic Ice Sheet; outlet glacier; climate change; remote sensing; numerical modelling**

Overview

Dynamic changes in marine-terminating outlet glaciers in Greenland and West Antarctica indicate that their contribution to sea level rise has accelerated in the last two decades *[1]*. This is largely due to increased velocity, thinning and retreat, which has been linked to both atmospheric and oceanic warming. In contrast, the world's largest ice sheet - the East Antarctic Ice Sheet (EAIS) - has generally been perceived as much less vulnerable, with recent estimates suggesting that its sea level contribution is negligible *[2]*. However, mass loss has been detected in some regions (e.g. Wilkes Land) *[2]*, and recent work suggests that its marine-terminating outlet glaciers respond rapidly to external forcing at decadal time-scales *[3]*, even though the precise contribution of oceanic versus atmospheric forcing is unknown. This suggests that the EAIS may be more vulnerable to future climate change than previously thought, and numerical modelling suggests that some regions grounded below sea level may be close to the threshold of instability *[4]*.

Despite growing evidence for the potential vulnerability of the EAIS, and unlike in Greenland and West Antarctica, there are very few detailed observations of marine-terminating outlet glaciers (Figure 1). As such, we know very little about what controls the behaviour of outlet glaciers in the EAIS. To address this issue, *the overall aim of this project is to use remote sensing observations and numerical modelling to explore the sensitivity of major East Antarctic outlet glaciers to oceanic and atmospheric forcing.*

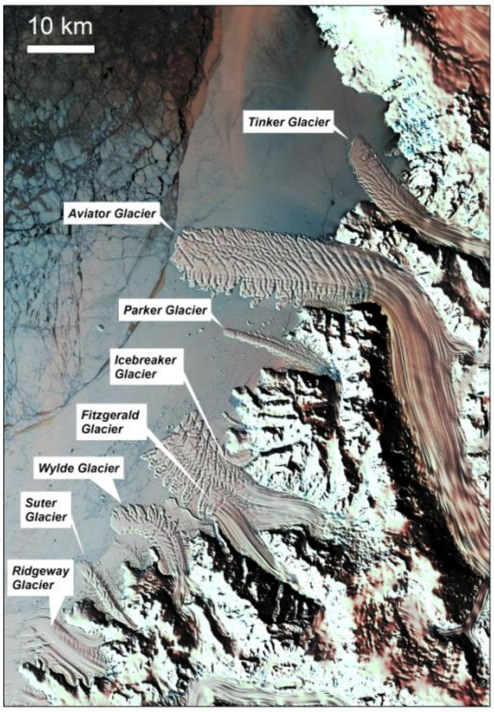

Figure 1: Major outlet glaciers draining the East Antarctic Ice Sheet in Victoria Land.

The primary research questions are:

- Are EAIS outlet glaciers more sensitive to atmospheric or oceanic forcing?
- Do changes in sea-ice substantially influence their behaviour?
- How does outlet glacier response to forcing vary between different climatic or topographic settings?
- How do specific glacier characteristics increase or decrease sensitivity to various forcings (e.g. the presence of ice tongues, ice shelves, or different topographic settings)?

Methodology

Similar to recent work in Greenland *[5]*, the project will focus on a sample (5-10) of large (> 10 km wide) marine-terminating outlet glaciers that represent the major types of climatic and topographic settings within the EAIS. Initially, a variety of remote sensing imagery (e.g. Landsat, ERS, ENVISAT, ASTER) will be used to determine frontal position change over the last 50 years (depending on image availability), with annual to sub-annual resolution available from the 1990s. Temporal trends will then be compared to possible atmospheric (air temperatures, precipitation) and oceanic forcing (temperatures at various depths, sea ice concentrations). These data will be obtained from readily available satellite and reanalysis products (e.g. NCEP/NCAR climate reanalysis data; Hadley Centre EN3 ocean temperature data; etc.), and, where available, meteorological and ship-based measurements. Evaluation and statistical analysis of these empirical datasets will be used to develop a series of hypotheses to explain outlet glacier behaviour in the different climatic and topographic settings, which will then be tested using numerical modelling.

The modelling will use a 1-dimensional flow-line model that includes a fully dynamic treatment of marine glacier termini and has been widely used in previous work *[e.g. 5]*. This is a state-of-the art model for single outlet glaciers that allows the application of oceanic and atmospheric forcing processes, such as surface melt, ocean melt, changes in ice shelf or sea-ice buttressing, and basal lubrication *[5]*. Initially, we will build reference states for each outlet glacier and tune parameters to best reproduce the remotely sensed observations of their recent behaviour. We will then apply perturbation experiments to examine the sensitivity of each outlet glacier to different forcing processes. A second component will be to explore their future behaviour under different climatic and oceanic warming scenarios, using an ensemble of runs to explore different parameter ranges. The candidate will also explore the feasibility of using a 2D or 3D model to generate a regionally-integrated assessments of glacier response for specific sectors of the ice sheet that the 1D modelling indicates might be particularly vulnerable.

Timeline

Year 1: Training in Remote Sensing and GIS; collection and analysis of remote sensing datasets of major East Antarctic outlet glaciers
Year 2: Collection and analysis of atmospheric and oceanic datasets; set-up 1D numerical modelling and perform validation against observations
Year 3: Sensitivity experiments of future behaviour using 1-D flow-line model; prepare research papers; conference attendance; explore possibility of 2D and 3D modelling
Year 4: Further modelling and submission of research papers and thesis; conference attendance

Training & Skills

The student will receive both generic and bespoke training in Remote Sensing and GIS, including software such as ERDAS Imagine, ArcGIS and NEST Array. Numerical modelling skills will be provided via 'hands-on' training from the supervisory team, and specific training in Matlab and statistical software (e.g. Stata), supplemented with an internationally-recognised summer school in Karthaus. Broader transferable skills (e.g. communicating science, thesis writing, writing for publication, presentation skills) will be developed through formal training at Durham University via the award winning Career and Research Development (CARD) group.

References & Further Reading

[1] Shepherd *et al.* (2012) A reconciled estimate of ice sheet mass balance. *Science*, 338, 1183-1189.
[2] Rignot *et al*. (2008) Recent Antarctic ice mass loss from radar interferometry and regional climate modelling. *Nature Geoscience*, 1, 106-110.
[3] Miles *et al*. (2013) Rapid, climate-driven changes in outlet glaciers on the Pacific coast of East Antarctica. *Nature*, 500, 563-566.
[4] Mengel, M. & Levermann, A. (2014) Ice plug prevents irreversible discharge from East Antarctica. *Nature Climate Change*, 4, 451-455.
[5] Nick et al. (2013) Future sea-level rise from Greenland's main outlet glaciers in a warming climate. *Nature*, 497, 235-238.

Further Information

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