

# The glaciers of South Georgia from the 1950s to 2100 CE

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## IAP-25-072

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### Rationale:

The glaciers of the Subantarctic island of South Georgia are sentinels of climate change, being located directly in the path of the rapidly evolving Southern Hemisphere Westerlies. These Westerlies are a critical control on glacier behaviour both in Patagonia and the Antarctic Peninsula. South Georgia therefore offers a unique opportunity to investigate how changes in the Westerlies are reflected in glacier change.

However, the mass balance of South Georgia's glaciers, and their responses to changing climatic variables, is not well known. Glacier mass loss is accelerating in many regions of the world, including on the Antarctic Peninsula (Hugonnet et al., 2021), but longer term trends are not available for South Georgia (Farias-Barahona et al., 2020). This impedes our ability to understand and contextualise current change, and predict future vulnerabilities.

South Georgia is a haven for wildlife. Warming, increasing habitat connectivity and decreased meltwater availability as glaciers shrink will impact important terrestrial and marine ecosystems, including albatross, penguin and seal breeding colonies, and influence the spread of invasive species. Understanding current trends and predicting future glacier change is important for developing management and protection plans.

To date, investigations of glacier change on South Georgia have focused on a combination of geomorphological mapping, aerial photographs and satellite remote sensing. From 2000-2013, glaciers thinned and tidewater glaciers retreated, with the highest rates of change along the north-east coast (Cook et al., 2010; Farias-Barahona et al., 2020). Mapping of terminus fronts from aerial photography from the 1950s-2017 shows widespread recession (Cook et al., 2010), but glacier mass balance remains unresolved over this longer term.

As the availability of satellite imagery has increased, along with new techniques to process digital elevation models from archival aerial photography, there are new opportunities to derive glacier extent and volumetric change over a 60 year time period. In addition, the glaciers of South Georgia have never been simulated in detail, meaning that mass balance sensitivities and future behaviour are unknown. This PhD project will take advantage of these opportunities to develop an improved record of glacier change in South Georgia, and test the response of glaciers to changes in the climate in the past and future.

**Aim:**

To quantify glacier behaviour in South Georgia since the 1950s and explore glacier responses to different climate conditions.

**Research questions:**

How have glaciers evolved from the 1950s to present?

How do surface structures (debris cover, crevasses, icefalls etc) influence glaciology and mass balance?

What are the mass balance sensitivities of glaciers?

How do changes in the Southern Hemisphere Westerlies influence glaciers, and how is this modulated through topographic effects?

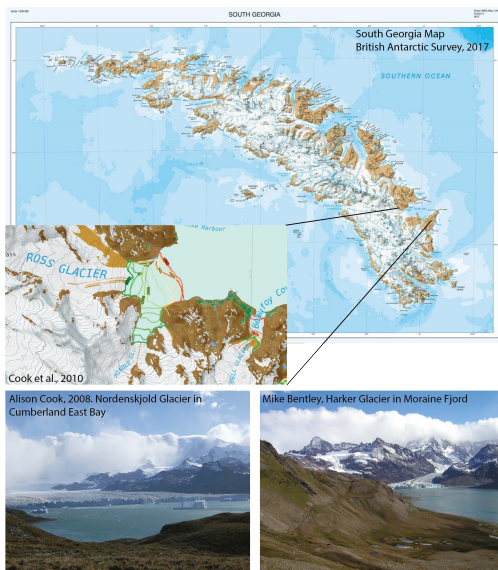
How might the glaciers behave under future climatic conditions?

**Objectives:**

Project objectives are flexible and can adapt in response to student interests.

1. Reconstruct glacier thickness, area and geodetic mass balance evolution using archived aerial photographs and satellite imagery.
2. Map and evaluate the ice surface structures (e.g. debris cover, firn, meltwater, crevasses, icefalls, ogives) across South Georgia's glaciers.
3. Evaluate oceanic and atmospheric datasets to determine driving mechanisms of glacier change.
4. Use numerical glacier models to provide insights into glacier mass balance sensitivities and future glacier behaviour.

These four objectives together will provide a new understanding of the drivers of past and current glacier change on South Georgia, and provide new insights into the future behaviour of these glaciers under different climate scenarios.



## Image Captions

South Georgia map from the British Antarctic Survey, 2017. Inset shows extract of glacier termini mapped on South Georgia from archival aerial imagery (Cook et al. 2010). Photographs show glaciers from South Georgia.

## Methodology

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### Objective 1:

Archives of aerial photographs (1950s-present) from South Georgia are held at the British Antarctic Survey. These photographs and later, satellite imagery, have been used to reconstruct tidewater glacier terminus position from the 1950s to 2017 (Cook et al., 2010; available in the South Georgia GIS (<https://sggis.gov.gs/>)).

Objective 1 will compile these datasets and apply photogrammetric techniques (e.g., Davies et al., 2024) to derive novel orthomosaics and digital elevation models of South Georgia's glaciers.

These novel datasets will be compiled with published datasets of global glacier thickness change from 2000-2019 (e.g. Hugonnet et al., 2021) and novel satellite-derived digital elevation models (e.g. Pléiades; REMA) to generate a 60 year record of ice thickness and glacier area change. This long record of geodetic mass balance of glaciers will allow identification of regional variations, locations of high vulnerability, and decadal scale patterns of change.

### Objective 2:

Glacier surface features, such as debris cover, crevasses, ice falls, ogives, firn water content and meltwater ponds and streams, are important modulators of glacier mass balance (e.g., Davies et al., 2022; 2024).

Objective 2 will derive new glaciological maps of these features for the first time in the Subantarctic, using manual mapping informed optical satellite imagery (e.g. Sentinel) and aerial photographs. These datasets will be used to understand the influence of topography and ice-flow dynamics and how these influence glacier response to external climate forcings.

### **Objective 3:**

Across the Antarctic Peninsula, glaciers are responding strongly to ocean heating, the foehn effect and atmospheric rivers (e.g. Davison et al., 2024), resulting in glacier acceleration and grounding line recession. The sensitivity to ocean and atmospheric temperatures on South Georgia is unknown. The decadal scale record of geodetic mass balance across South Georgia allows comparison with trends in ocean and atmospheric changes.

Compile datasets of change from weather stations (e.g. SCAR READER), ERA-5 reanalysis data and datasets of sea surface temperature. This objective will provide the climatic datasets required to understand external drivers of glacier change.

### **Objective 4:**

Glacier models such as the Open Global Glacier Model (OGGM) can provide insights into glacier mass balance sensitivities, allowing testing of hypotheses regarding glacier response to external forcing factors.

This objective will initialise OGGM using existing bed topography, ice velocity and geothermal heat flux datasets, and climatic datasets from Objective 3.

Model performance will be evaluated against glacier extents measured in objective 1 and will then explore glacier sensitivity to different climatic variables.

## **Project Timeline**

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### **Year 1**

Literature review.

Training in remote sensing and photogrammetry.

Compile datasets (satellite and aerial photograph) for glacier change analysis.

Visit to archives at the BAS.

Derive new digital elevation models for glaciers.

Mapping of glacier surface features.

Explore, with partners, the possibility for fieldwork and placement.

Training in key techniques by supervisory team.

Karthus workshop for PGRs.

### **Year 2**

Complete analysis of geodetic mass balance of glaciers.

Publication of map of glacier surface features.

Explore numerical modelling approaches and OGGM.

Depending on the outcome of Year 1 explorations, potential in-territory visit to South Georgia, or possible internship at the Government of South Georgia and the South Sandwich Islands.

OGGM residential course for PGRs.

### Year 3

Initialise and evaluate OGGM on South Georgia.

Compile datasets of past atmospheric and oceanic temperature and precipitation and compare against record of glacier mass change.

Publication of geodetic record of mass balance.

### Year 3.5

Complete writing up.

Publication of final outputs.

## Training & Skills

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Training in key techniques will be provided by supervisory team.

The candidate will be encouraged to apply for and attend OGGM and Karthaus workshops for PGRs.

References & further reading

Cook, et al., 2010. Antarctic Science 22, 255-263.

Davies et al. 2024. Nature Communications 15, 5099.

Davison et al. 2024. The Cryosphere 18, 3237-3251.

Farías-Barahona et al. 2020. Environmental Research Letters 15, 034036.

Gordon et al., 2008. Global and Planetary Change 60, 72-84.

Tielidze et al. 2025. The Cryosphere 19, 2677-2694.

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Supervisory Team

**Prof. Bethan Davies**

Newcastle University

**Professor Stewart Jamieson**

Durham University

**Professor Neil Ross**

Newcastle University

**Professor Dominic Hodgson**

British Antarctic Survey

**Professor Mike Bentley**

Durham University

Collaborative Partners

**Dr Alison Cook**

Scottish Association of Marine Sciences (SAMS)

Lead Institution

**Newcastle University**

Geography / GPS

Further Information

for informal enquiries, contact:

Prof. Bethan Davies

Bethan.davies@newcastle.ac.uk

Newcastle University

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