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Untangling Glacial and Sedimentary Isostasy in Scandinavia via Modelling and Remote Sensing

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In partnership with School of Civil Engineering and Geosciences, Newcastle University

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Overview

Ice sheets are one of the most efficient erosive agents on Earth but questions remain regarding the amount of material that can be evacuated from a glacial system during a glacial cycle. To understand this, it is important to quantify the spatial and temporal distribution of erosion. One approach to quantifying past glacial erosion patterns is to isolate the geodynamic signal associated with large-scale sediment redistribution. The aim of this project is therefore to understand the long-term geodynamic evolution of a glacial margin in order to identify patterns of glacial erosion and deposition. To achieve this, a combined modelling and data analysis approach will be taken.

The study will focus on Scandinavia for two key reasons: Firstly, quantifying the present-day solid Earth deformation field is made possible because this region is covered by one of the longest-running GPS networks in the world (see Milne et al., 2001), which provides ground-truth constraints on present-day uplift. To complement the GPS data set, satellite radar data (InSAR and satellite altimetry) will be used to produce a time series of surface deformation maps for the region.

Secondly, preliminary studies have suggested that the isostatic response to sediment redistribution may be significant along the Scandinavian margin, and neglect of this process will hinder attempts to interpret observations of surface deformation. Deformation due to the annual water cycle, ongoing glacial isostatic adjustment (GIA), and the isostatic response to sediment redistribution from onshore to offshore all contribute to the signal. The first two processes can be accounted for via elastic and viscoelastic modelling, with the latter based on reconstructions of the Fennoscandian ice sheet during the last glacial cycle. However, the component due to sediment redistribution is currently poorly constrained.

This study will test key hypotheses relating to ice sheet basal processes and the efficiency of ice sheets as an erosional tool. In particular, key questions that could be addressed include:

1. Can past erosion patterns be identified using geodynamic measurements and modelling?
2. Does erosion significantly mask the signal of glacial isostatic adjustment in Scandinavia?

3. Does erosion and deposition significantly impact the evolving response of the ice sheet and the underlying bed?

The project will draw on internationally recognised expertise in geodynamic modelling (Durham), satellite geodesy (Newcastle), and glaciology (Durham).

Methodology

A combination of geodynamic and ice-sheet modelling will be used to gain insight into the processes contributing to present-day solid Earth deformation across Scandinavia. Both forward and inverse modelling will be used to isolate the signal due to sediment redistribution, and therefore test hypotheses regarding the magnitude and extent of glacial erosion across Scandinavia during past glacial cycles. Onshore and offshore data will be used to estimate past rates of erosion and deposition, and there will also be the possibility to gain insight using numerical models of glacial erosion. Model predictions will be constrained using published field observations and those derived from InSAR, GPS and satellite altimetry. The latter three will also be used for validation.

Timeline

Year 1: Training in elastic and viscoelastic modelling. A suite of plausible models of solid Earth deformation in response to annual water cycle changes and ongoing GIA will be developed using published models and data sets. In parallel, training will be provided on InSAR processing, with the aim of producing initial surface deformation maps in the early part of Year 2.

Year 2: Extend the time series of deformation maps as far back as the data will allow; develop hypotheses associated with patterns of glacial erosion across Scandinavia, potentially using numerical models of ice-sheet dynamics; produce two published outputs as the combined work of year 1 and 2.

Year 3: Use surface deformation maps to differentiate between competing hypotheses associated with glacial erosion; use model-data residuals to assign uncertainties to the various processes contributing to ongoing solid Earth deformation; produce a third publication, and combine published outputs and associated material into a PhD thesis.

Training & Skills

The student will be supported in broader skills training via the award-winning Career and Research Development (CARD) group at Durham (thesis writing, writing for publication, presentation skills, enterprise skills etc.) and will benefit from cross-disciplinary training provided as part of IAPETUS. The student will also become a member of the Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET) and will thus benefit from the shared expertise of this group. To embed the student in the international community, they will also attend international summer schools focussed on GIA and ice-sheet modelling, and remote sensing.

Depending on the interests of the applicant, the student will gain valuable skills, including geophysical modelling, management of large geo-datasets, InSAR processing, and ice-sheet modelling. The student will have opportunities to work with international and UK partners and they will travel to national and international scientific meetings to present results. Upon completion, the student will be well equipped for a career in academia or in a range of industries.

References & Further Reading

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