IMPERIAL

PhD Project Description

Project Title

Subglacial geothermal heating and ice dynamics

Supervisors

Lead Supervisor: Jonathan Kingslake

Co-supervisor(s): Fred Richards

Research Group

Glaciology Group (will be established starting June 2026) and Solid Earth–Fluid Earth Interactions (SoEFEI) Group.

Jonathan Kingslake's website can be found here; Fred Richards' here.

Project Summary

Ice sheets work in fascinating, complex ways that are important to understand because when ice sheets shrink, sea levels rise globally, impacting coastal communities worldwide.

The future of our ice sheets is controlled by how they interact with other parts of the Earth system. This project will focus on ice sheets are controlled by the rock, sediments, and water beneath them. In particular, we will draw on expertise from across the Earth Science & Engineering department and elsewhere to study how heat supplied by the deep interior of the Earth influences ice-sheet flow and retreat.

Areas the student could focus include (1) using geodynamic modelling to better constrain deep conductive heat flow towards the ice base, (2) applying newly developed models of subglacial hydrothermal convection to understand how deep heat flow is translated through subglacial aquifers to the ice-sheet base, and (3) using coupled models of subglacial hydrology and ice dynamics to understand how variations in geothermal heating change ice flow velocities.

Research Context and Objectives

Our ice sheets are shrinking. Accurately projecting how this process will evolve is vital for mitigating climate risk throughout society. Significant uncertainty in projections is associated with the unknown future of the ice-sheet base – the interface between the ice and the lithosphere beneath. Where the ice is heated sufficiently by friction and by conduction from the lithosphere, it melts, permitting sliding and feeding a subglacial drainage system which dictates the sliding rate through water pressure. This sliding is a primary control on how quickly ice flows into the ocean.

Recent work by Fred Richards has improved how we constrain deep geothermal heat fluxes using geodynamic models informed by joint inversions of seismological observations and experimental rock mechanics data. Meanwhile, work led by Fiona Clerc, Stony Brook University, and involving Jonathan Kingslake, is shedding light on the hydrothermal dynamics of subglacial aquifer systems and how these dynamics produce complex spatial and temporal variability in heating at the ice sheet base, even when the deeper heat flux is relatively uniform. At the ice-sheet base, modelling led by George Lu, Columbia University, and supervised by Kingslake has demonstrated how ignoring changes in the water pressure generated by coupling between ice and water flow could lead ice-sheet models to underestimate ice-sheet retreat.

Bringing these insights together suggests that current knowledge of deep heat fluxes are insufficient to understand how they will influence ice sheet dynamics for several reasons: first, direct observations of deep heat flux are sparse and predictive model estimates are highly uncertain; second, it is unclear how this flux is transferred to the ice-sheet base through widespread subglacial aquifers; and third, our understanding of how the melt generated by heating at the ice-sheet base influences water pressure is limited. This project will tackle these issues by tracing heat flow from Earth's deep interior through to its influence on ice flow and sea level rise, by building on the modelling work described above and combining data with models in novel ways to validate their predictions.

Collaborators and partners on the project:

Depending on the direction taken by the student, potential project partners include

- George Lu, Columbia University
- Fiona Clerc, Stony Brook University
- Stacy Larochelle, UCLA
- Andrew Hoffman, Columbia/Rice University

Further reading:

Lu, George, and Jonathan Kingslake. "Two-Way Coupling between Ice Flow and Channelized Subglacial Drainage Enhances Modeled Marine-Ice-Sheet Retreat." The Cryosphere 18, no. 11 (2024): 5301–21.

Hazzard, J. A. N. and Richards, F. D. (2024). "Antarctic Geothermal Heat Flow, Crustal Conductivity and Heat Production Inferred from Seismological Data". *Geophys. Res. Lett.,* 51, e2023GL106274.

Who are we looking for?

The ideal candidate will have a background in Earth science, physics, applied mathematics, or a related field.

Essential experience: strong computational and mathematical skills, data analysis, some mathematical modelling, a strong interest in geodynamics/glaciology/polar science, an independent approach to science, and a strong desire to better understand the fundamental workings of Earth system processes, both because they are important for society and because they are fascinating.

Desirable experience: Numerical solution of differential equations, satellite remote sensing, glaciology or polar science; advanced scientific computing; and advanced communication and scientific writing skills.