**Project title:** The physics of permafrost soils: modelling thaw and the carbon cycle.

**Supervisory team:**
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**Summary**
This PhD project will advance our understanding of permafrost thaw and the potential feedbacks between carbon storage in permafrost soils and global climate change.

**Project background**
As the name suggests, permafrost is ground which remains permanently frozen (for two or more years). Much like the carbon stored in the wood of rainforest trees, the carbon frozen into permafrost soils is locked away from the atmosphere and can't contribute to global warming. When permafrost soils thaw carbon can be released as greenhouse gases, resulting in a positive climate feedback. Understanding the fate of the vast quantities of carbon currently stored in permafrost soils is a major international research challenge.

Permafrost soils currently cover 23 million square kilometres globally (about 100 times the size of the UK) including large areas south of the Arctic Circle. However, permafrost thaw rates across northern regions are highly variable, and we don't fully understand what causes this variability. Regional differences in temperature may be important, but other factors are also crucial in determining thaw rates. These factors include, for example, the presence of thick organic soils and mosses or snow, which can act to insulate the soil and protect permafrost.

Current models of permafrost thaw struggle to capture the processes determining local thaw rates, and to replicate the patterns we observe in the field. Furthermore, to accurately represent the biological processes which govern decomposition in soils (and therefore greenhouse gas release to the atmosphere) we need to have an accurate representation of both the physical properties (e.g. temperature and moisture) of the soil profile and the complex biological feedbacks which can occur between soils, microbes and vegetation. Our ability to predict the climate feedbacks from thawing permafrost is currently limited by our understanding of soil processes in these environments.

![Permafrost landscape in Arctic Canada and global permafrost distributions](image)

This PhD project aims to develop more reliable soil physical and carbon models which are able to replicate patterns of permafrost thaw and carbon turnover observed across Arctic and sub-Arctic regions. The project will seek to develop and link existing soil physical models to...
biogeochemical models of soil carbon cycling, in order to test the impact of different climate scenarios on carbon storage.

**Research questions:**

- What properties of ecosystems increase the vulnerability of permafrost to warming?
- How do seasonal changes in moisture, temperature and plant productivity influence biogeochemical processing of carbon at different depths in the soil profile?
- What will be the impact of future climate conditions on soil carbon dynamics?

**Methodology and timetable**

This research project will largely consist of modelling work, with opportunities for fieldwork in Arctic Sweden. In the first year the student will develop and test existing soil physical model to represent heat and moisture regimes in organic Arctic soils (based on the JULES and SPA models with support from supervisors MW and RE). The first year will also involve a field trip to Arctic Sweden to set up logging equipment to collect soil temperature and moisture data which will be used to validate the soil physical model. Fieldwork will be conducted in close-association with research partners at a number of other UK Universities (Heriot-Watt University and the Universities of Stirling and Aberdeen) who will be conducting related research at the same site and there will be opportunity to interact closely with these groups.

In the second and final year the student will link the soil physical model to biogeochemical models of soil carbon dynamics, and will test the linked models against existing data from the discontinuous permafrost region of northern Canada and Arctic Sweden. Model experiments will then be conducted to test the impact of future global change scenarios (e.g. increasing air temperature, precipitation, vegetation dynamics or fire regimes) on soil carbon storage.

**Training**

A comprehensive training programme will be provided comprising both specialist scientific training and generic transferable and professional skills. Full training in fieldwork and field-based measurement techniques will be provided. Support will also be provided in the use of the programming languages to meet the needs of the student (R/Matlab/Fortran) for the purposes of model development and testing.

**Requirements**

This award would suit a student either with qualifications in the physical sciences, especially environmental physics, or a student with an environmental science background with strong quantitative skills. The successful student will need to be competent in one or more programming languages (Matlab, Mathematica, R), but training in a particular language can be provided as required. Experience in conducting fieldwork in remote areas would be valuable but not essential.

**Further Reading**
