PROJECT TITLE: Volcanic Eruptions on Snow and Ice: Predicting Dynamics and Hazards from Pyroclastic Density Currents and Lahars

DTP Research Theme(s): Solid Earth

Lead Institution: University of Bristol

Lead Supervisor: Dr Jeremy Phillips, School of Earth Sciences, University of Bristol

Co-Supervisor: Dr Alison Rust, School of Earth Sciences, University of Bristol

Co-Supervisor: CASE Partner Dr Geoff Kilgour, GNS Science, New Zealand

Co-Supervisor: Dr Wim Degruyter, School of Earth and Ocean Sciences, Cardiff University

Project Enquiries: j.c.phillips@bristol.ac.uk

Project keywords: volcanic hazards, pyroclastic density currents, lahars, laboratory experiments, numerical models, Ruapehu Volcano

Explosive eruption of Ruapehu, New Zealand, 1995 (courtesy Arthur Pengelly) Lahar from Nevado del Ruiz, Colombia, 1985 (courtesy USGS)

Project Background

Pyroclastic density currents (PDC) and lahars (volcanic mudflows) are the most devastating volcanic phenomena. Responsible for significant losses of life and infrastructure, these volcanic flows are regularly generated at cone volcanoes worldwide. In the case of PDC, we know little about the coupling between the relatively hot flow and the substrate, especially when the substrate consists of snow and/or ice. We know that the large temperature difference can lead to rapid melting, and generation of melt water and steam, but the scale of the effect is unknown – does it help or hinder flow? We know that the largest, most destructive lahars are generated from eruptions of PDC onto snow and ice covered volcanoes, but we do not know what controls the dynamics of their initiation – how does the combination of hot pyroclastic material and melting substrate become mobile, and how is this controlled by slope? While there exist predictive modelling frameworks for PDC and lahar hazard assessment including Titan-2d (https://vhub.org/resources/titan2d) and LaharFlow (www.laharflow.bristol.ac.uk), these tools cannot be used for eruptions onto snow and ice without answering these fundamental questions. This PhD project will undertake fundamental science to close these knowledge gaps and extend capability for hazard assessment at high-altitude volcanoes.

Project Aims and Methods

The aim of this PhD research is to characterise and quantify fundamental processes of ice and snow melting by pyroclastic materials, and their influence on flow mobility and secondary flow generation. We will specifically focus on Mt. Ruapehu, New Zealand due to its high eruption frequency, variable snow/ice conditions, the high hazard potential on the ski fields, and the presence of a large crater lake. The research will include fieldwork to understand variable snow/ice conditions, laboratory experimentation, and numerical modelling using existing simulation tools, with the specific objectives:
1. **Quantification of melting by pyroclastic materials in realistic flow configurations.** Laboratory experiments will be used to identify key controls on rates of melting and vapourisation created by hot pyroclastic materials, developing idealised studies of Walder (2000) and existing laboratory experiments in Bristol. Melting and vapourisation rates will be parameterised as functions of deposition rate, temperature and substrate slope angle, to provide a scaling law for melting rate that can be included in numerical models for hazard assessment, following the approach of Dufek et al, (2007) for PDC flowing over water.

2. **Quantification of effects of substrate melting on mobility.** Laboratory experiments will be used to measure the mobility of hot pyroclastic materials over a melting substrate in well-studied configurations. Parameterisations for flow mobility and substrate erosion will be developed, based on friction laws for wet granular flows (Guazzalli & Pouliquen, 2018), basal fluidisation (Dufek et al, 2007) and basal shear erosion.

3. **Development and calibration of a hazard model for volcanic flows over ice and snow.** Parameterisations of substrate melting and basal resistance to motion will be implemented into the surface flow hazard framework of LaharFlow to create a hazard modelling tool for PDC and lahars on ice and snow. The model will be calibrated against field observations of PDC at Ruapehu volcano undertaken as part of the internship with GNS Science.

**Candidate Requirements**
This PhD project would suit a quantitative geoscientist with a strong physical volcanology background, or a student from a physical science or engineering background with a strong interest in volcanology, who is keen to develop skills in laboratory experimentation and theoretical analysis.

**CASE or Collaborative Partner**
The CASE partner is GNS Science who provide scientific advice for active volcanoes in NZ. The partner will host an internship for the student to visit New Zealand to conduct larger-scale laboratory experiments, to collaborate on the calibration of hazard model with field observations, and provide experience of engagement with stakeholders.

**Training**
The student would receive training in the design and scaling of laboratory fluid dynamics experiments, volcanological fieldwork, theoretical analysis of coupled flow and heat transfer processes. The student will also be taught how to run the LaharFlow model, and will be introduced to programming languages, including MATLAB and Python, to analyse and present their experimental and model results. In addition to these skills, the student will also be exposed to active volcano monitoring at a national volcano observatory in New Zealand.

**References / Background reading list**


**Links:**
School URL  
http://www.bristol.ac.uk/earthsciences/courses/postgraduate/

NERC GW4+ DTP Website:  
http://nercgw4plus.ac.uk/

Bristol NERC GW4+ DTP Prospectus:  
http://www.bristol.ac.uk/study/postgraduate/2019/doctoral/phd-great-western-four-dtp/

Application deadline:  16:00 GMT, Monday 7 January 2019

**How to apply to the University of Bristol:**  
http://www.bristol.ac.uk/study/postgraduate/apply/

**General Enquiries:** Bristol NERC GW4+ DTP Administrator  
Email: bristol-nercgw4plusdtp-admin@bristol.ac.uk