IAPETUS2 Doctoral Training Partnership

IAPETUS2 Project Submission Preparatory Template

Please note, in order to submit a project to the IAPETUS2 2020-2021 Studentship Competition, supervisors must complete the Project Submission Form online. The Project Form will be opened for submissions on Tuesday 1st September 2020 and the web link will be circulated prior to this.

This document details the questions on the online form in the correct order. If you would prefer to complete all/some sections of the form in this Word document then simply copy and paste on to the online form, please feel free to do so. This is not essential though.

Please note, this Word version cannot be used instead of the online form, it is just meant as an aid for supervisors to use when completing the online form.

Please complete all sections (unless they are marked as Optional or If Applicable on the form). Approval for project submissions with missing fields will be delayed.

Please do not use any special characters, as the website will turn them into gobbledygook when publishing.

Please consult the *IAPETUS2 Studentships Competition 2021 Staff Guidance* for further details on the form and the process.

General Information	
Project Title:	
Volcanoes and Climate: novel simulations to probe fundamental interactions	
Lead Institution:	University of St Andrews
Department / School / Institute	School of Earth & Environmental Sciences

Project Team The first supervisor should be from the lead institution. The Second Supervisor should be from a second IAPETUS2 organisation	
Supervisor 1	
Name	Dr Michael Byrne
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Project Details
The information provided here will be used to create the project advertisement online and in pdf format. The overall project description should not normally be longer than 1,200 words in total, including references. Please note that the boxes below are plain-text only, formatting & links will be stripped from the text.

Keywords Add up to 5 comma separated keywords that best describe the project.	Volcanoes, Climate Sensitivity, Computational Models, Big Data, Geoengineering

Overview

Earth's climate has been repeatedly perturbed by major volcanic eruptions. Volcanic cooling is driven by sulfate aerosols that reflect incoming solar radiation causing the planet to cool over 3-5 years (Robock 2000) and changing patterns of precipitation (Iles et al. 2013). The largest volcanic forcing on climate occurs if the sulfur reaches the upper stratosphere, with climatic impacts also being controlled by eruption latitude and season (Toohey et al. 2019).

Climate changes associated with volcanic eruptions in the past have had profound impacts on society, with droughts, crop failures, and political and civil unrest (Manning et al. 2017). Understanding the sensitivity of climate to eruptions can thus provide fascinating insights into the historical record, and help predict the impacts of future eruptions or artificial stratospheric sulfate injections as an attempt to geoengineer anthropogenic climate change. Constraining the response of climate to volcanic forcing can also improve understanding of the feedbacks that determine climate sensitivity more generally (Atwood et al. 2016), and thus improve simulations of future climate change.

However major questions remain on the nature of volcanic forcing and climatic response. In particular, a recent study of ice-core and tree-ring records showed an enhanced Northern Hemisphere temperature response to extratropical vs tropical eruptions (Toohey et al., 2019). This unexplained finding challenges our understanding of the sensitivity of climate to volcanic eruptions and artificial stratospheric sulfate injections, as well as the sensitivity of climate to anthropogenic CO_2 forcing.

Methodology

During this project, you will investigate a fundamental problem: Why is climate more sensitive to extratropical vs tropical volcanic eruptions? To tackle this problem, you will perform novel simulations using the state-of-the-art Community Earth System Model (CESM). Two sets of simulations will be performed:

(1) PRESCRIBED RADIATIVE FORCINGS: The first set of climate simulations will prescribe equal top-of-atmosphere shortwave radiative forcings – mimicking the effects of volcanic eruptions – at a range of tropical and extratropical latitudes. The temperature responses to these forcings will be analysed using the coupled atmosphere-ocean energy budget. Specifically, differences in temperature responses to tropical vs extratropical forcings will be linked to differences in radiative feedbacks and ocean heat uptake between low- and high-latitude regions. Contrasting temperature responses over land and ocean regions will also be investigated. These simulations will identify the processes driving the enhanced sensitivity of climate to extratropical forcings and will also provide new insights into how the Earth system responds to energetic perturbations associated with volcanoes, CO_2 emissions and geoengineering.

(2) PRESCRIBED SULFUR LOADINGS: The second set of simulations will examine how radiative forcing associated with volcanoes depends on eruption latitude and season. Equal sulfur loadings at different latitudes will be prescribed and analysed over time and as function of latitude and height in the atmosphere to better understand how differences in volcanic forcing – for equal

sulfur loadings – arise. Together, simulation sets #1 and #2 will map out, for the first time, the processes determining the volcanic responses across all latitudes. Combined with the results from Experiment 1 we will be able to distinguish the relative importance of forcing vs feedbacks in explaining any enhanced sensitivity to extratropical eruptions. These modelling results will be connected to observational estimates of volcanic loadings/forcings and temperature responses from ice core and tree ring proxies from over the Common Era.

Timeline - Year 1

Year 1 will involve a literature review to allow you to develop understanding of volcanoes and physical aspects of climate change. You will also start using the CESM climate model and setting up the simulations to probe volcano-climate interactions. You will attend a training course on how to run the CESM model at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado.

Timeline - Year 2

Year 2 will focus on running Set #1 of simulations to investigate how prescribed volcanic *forcings* at different latitudes couple to temperature responses. You will draft a research article on this portion of the project and will present the key results at the American Geophysical Union's annual meeting in San Francisco.

Timeline - Year 3

Year 3 will focus on running Set #2 of simulations to investigate how prescribed volcanic *loadings* at different latitudes couple to temperature responses. You will use your simulations to interpret observations of sulfate loadings and temperature responses over recent centuries. You will attend and present your research at an international climate conference.

Timeline - Year 3.5 (6 months only)

Year 3.5 will focus on writing the PhD thesis and drafting a research article on the analyses conducted during Year 3.

Training & Skills

You will be trained on several aspects of physical climate science including radiative forcing and feedbacks, climate modelling and climate change. You will also be trained in highly sought-after technical skills in computational modelling, high-performance computing, and Big Data analyses. You will attend a training course on using the CESM climate model at NCAR in Boulder, Colorado.

References & Further Reading

UPDATE REFFS

Further Information

Please contact Dr Michael Byrne by email mpb20@st-andrews.ac.uk or by phone at 07472179331.