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:	
Future of Continental Heatwaves	
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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Supervisor 2	
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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.	Heatwaves, Climate change, Computational modelling, Big Data

Overview

Climate change is the critical challenge facing modern societies. The impacts of global warming will predominantly be experienced on continents, where the rapidly increasing risk of severe heatwaves represents an existential threat to societies and ecosystems. The exceptional summers of 2018 (the UK's joint hottest on record) and 2019 (which featured the UK's hottest-ever day) represent ominous portents of the future.

Despite their societal importance, our fundamental understanding of continental heatwaves remains strikingly limited. We know that carbon dioxide-induced global warming over continents will be substantially larger than over oceans on average (Sutton et al 2007), and that this enhanced warming over land is tightly linked to aridity (Byrne & O'Gorman 2013; Byrne & O'Gorman 2018). But how climate change will affect heatwaves over continents is uncertain (Fischer & Knutti 2015), with no robust theory to interpret or corroborate predictions from complex and imperfect climate models.

Methodology

During this project, you will take a new approach to transform understanding of continental heatwaves in a changing climate. Combining computational models with physical theory, the project will tackle three key objectives:

(1) A NEW THEORY FOR CONTINENTAL HEATWAVES. A new theory for continental heatwaves and their response to climate change will be developed. This work will build on influential research linking average continental temperatures to land aridity and ocean warming (Byrne & O'Gorman 2013; Byrne & O'Gorman 2018). The goal is to build a robust, conceptual understanding of the mechanics of continental heatwaves. The new theory will challenge the current heatwave paradigm based on complex computational models and will fill a notable gap in our knowledge of how the climate system operates.

(2) INNOVATIVE CLIMATE SIMULATIONS TO ADVANCE UNDERSTANDING. A novel hierarchy of climate models, from simplified continental configurations to state-of-the-art simulations, will be performed and analysed to investigate continental heatwaves under climate change. The goal is to test and refine the theory for continental heatwaves developed in Objective 1 in a systematic manner. Simulations will also be designed to probe the processes controlling how continental heatwaves in different regions (e.g. low versus high latitudes) respond to global warming.

(3) EMERGENT CONSTRAINTS FOR CONTINENTAL HEATWAVES. The theory and simulations from Objectives 1 and 2 will be combined to develop "emergent constraints" for continental heatwaves for the first time. Emergent constraints are observable quantities in the current climate that have great potential to provide a new pathway to narrowing uncertainty in future predictions, but have not yet been developed for continental heatwaves. Potential emergent constraints will be tested using the simulations described in Objective 2 and, if successful, will be applied to narrow uncertainty in heatwave predictions from state-of-the-art climate models.

For Objective 2, you will perform novel climate simulations using the Community Earth System Model (CESM). These simulations will be designed to investigate the dynamics of continental heatwaves and their response to climate change. For Objective 3, the student will analyse heatwaves in state-of-the-art climate simulations from the CMIP6 data archives, with the aim of narrowing the large uncertainty in future projections.

Timeline - Year 1
Year 1 will involve a literature review to allow you to develop understanding of heatwave dynamics and physical aspects of climate change. The ingredients of a new theory for continental heatwaves will also be built up. You will also start using the CESM climate model and setting up the simulations of continental heatwaves in a changing climate. 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 (a) running the set of idealised climate simulations to investigate continental heatwaves in different climates and (b) using the simulations to test and refine the new theory for heatwaves. 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 involve applying the insights into heatwave dynamics developed in Years 1 and 2 to state-of-the-art climate simulations from the CMIP6 archive. This will involve substantial Big Data analyses with the objective of narrowing the large uncertainty in future heatwave projections. You will attend and present your research at an international conference on extreme weather events.
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 atmospheric dynamics, heatwaves, 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
[1] Byrne & O'Gorman (2013): *Land-ocean warming contrast over a wide range of climates: convective quasi-equilibrium theory and idealized simulations*, Journal of Climate, vol. 29, pp. 9045–9061. [2] Byrne & O'Gorman (2018): *Trends in continental temperature and humidity directly linked to ocean warming*, Proceedings of the National Academy of Sciences, vol. 115, pp. 4863–4868. [3] Fischer & Knutti (2015): *Anthropogenic contribution to global occurrence of heavy-precipitation and high-temperature extremes*, vol. 5, pp. 560–564. [4] Sutton et al (2007): *Land/sea warming ratio in response to climate change: IPCC AR4 model results and comparison with observations*. Geophysical Research Letters, vol. 34, L02701.
Further Information
Please contact Dr Michael Byrne by email mpb20@st-andrews.ac.uk or by phone at 07472179331.