**University of Leicester Future 100 PhD Scholarship**

**Project Reference: PHYS-Parker**

**Section 1 – *Supervisor Information***

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| **First Supervisor** | Dr Robert Parker |
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| **Proposed Second Supervisor** | Professor Heiko Balzter |
| **Additional Supervisor** | Prof. Tristan Quaife, Department of Meteorology, University of Reading |
| **Additional Supervisor** | Dr Doug Kelley, UK Centre for Ecology and Hydrology |

**Section 2 – *Project Information***

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| **Project Title** | Investigating the Susceptibility of Tropical Forests to Climate Change using Earth System Modelling, Satellite Remote Sensing and Machine Learning | |
| **Project Highlights:** | 1. | Project will bring together advanced capabilities in climate modelling, earth observation and machine learning to better understand the processes by which tropical forests respond to climate change. |
| 2. | Using state-of-the-art climate model predictions from the UK Earth System Model, student will investigate the response of tropical forests under various climate scenarios and assess the potential for irreversible “tipping points” beyond which they cannot recover. |
| 3. | The project will collaborate closely with UK climate scientists and contribute to a funded long-term project involving all NERC Research Centres and the UK Met Office. |
| **Project Overview** | | |
| This project aims to improve our understanding of how tropical forests may respond to climate change and what the consequences of those changes may be in the future. Understanding the current and future response of tropical forests to climate and land use change are fundamental to our ability to adapt to and mitigate the effects of climate change.  Tropical forests act as a vital sink of carbon, removing an estimated (and highly uncertain) 25-33% of human annual carbon emissions from the atmosphere. They are also crucial in providing reliable and clean drinking water and are major sources of biodiversity and medicine. Many have become more susceptible to fire, drought, temperature, and human management changes. Their responses to environmental change remain highly uncertain and there is the potential that due to a combination of degradation and climate change, tropical forests may well pass a “tipping point” where they no longer act as a carbon sink. Indeed, this situation has already occurred for South-East Asian rainforests which now act as a net carbon source with the situation for both the Amazon and Congo rainforests remaining precarious.  There is also the potential for significant (positive and negative) feedback that requires further understanding. For example, increased fire frequency can affect vegetation distribution, ultimately leading to further increased fire risk. However, ecosystems can acclimate to changes in stress, potentially damping the impact of climate change.  There is a huge opportunity to combine the growing number of satellite observations of the terrestrial carbon cycle with the current state-of-the-art process-level understanding available from Earth System models. Powerful new machine-learning techniques focused on explainability have the potential to make advances in our understanding of how these important processes work.  This studentship, based at the headquarters of the UK National Centre for Earth Observation at the new University of Leicester Space Park campus, will focus on using the UK Earth System Model, the UK’s most sophisticated climate model, along with new satellite observations and advanced machine learning methodologies. The student will contribute to TerraFIRMA - a large NERC-funded long-term project involving NERC Research Centres and the UK Met Office. TerraFIRMA will provide novel climate projections using state-of-the-art climate modelling capabilities, giving the student the opportunity to participate in exciting and world-leading climate science. We expect this PhD to benefit greatly from the collaboration, training and placement opportunities provided by NCEO, our fellow NERC Research Centres and the UK Met Office. | | |
| **Methodology** | | |
| The student will be able to take advantage of state-of-the-art climate simulations from UKESM and novel data-model fusion techniques to investigate new methods for analysing satellite observations in order to evaluate and constrain present-day carbon-climate feedbacks.  We will train the candidate in numerical techniques such as machine learning and data assimilation which will be adopted to confront the model with new satellite observations related to the carbon cycle.  During this project, the student will develop an explainable machine-learning based emulator for the terrestrial carbon cycle in UKESM to examine the different driving factors. “Explainable AI” techniques will be used to isolate processes causing discrepancies between model results and observations.  Through this work, the student will investigate the response of the tropical forest carbon flux to key drivers such as precipitation and temperature, evaluating for both present-day and future climate scenarios.  **References**  Relevant publications from the supervisory team that provide background to the project include:  Swaminathan et al. 2022, The Physical Climate at Global Warming Thresholds as Seen in the U.K. Earth System Model, <https://doi.org/10.1175/JCLI-D-21-0234.1>  Braghiere et al. 2019, Underestimation of global photosynthesis in Earth System Models due to representation of vegetation structure, <https://doi.org/10.1029/2018GB006135>  Sellar et al. 2019, UKESM1: Description and Evaluation of the U.K. Earth System Model, <https://doi.org/10.1029/2019MS001739>  Gloor et al., 2018, Tropical land carbon cycle responses to 2015/16 El Niño as recorded by atmospheric greenhouse gas and remote sensing data, <https://doi.org/10.1098/rstb.2017.0302>  Rodríguez-Veiga et al., 2017, Quantifying Forest Biomass Carbon Stocks From Space, <https://doi.org/10.1007/s40725-017-0052-5>  Le Toan et al., 2011, The BIOMASS mission: Mapping global forest biomass to better understand the terrestrial carbon cycle, <https://doi.org/10.1016/j.rse.2011.03.020> | | |