EEES Project Proposal Form – 2021 entry

Project Title	**OU19 - The evolution of the climate-carbon cycle through the Last Interglacial**
Key words	Paleoclimate, climate modelling, monsoon, carbon cycle
Supervisory team (including email address	**PI:** **Philip Holden** philip.holden@open.ac.uk **Co-I:** **Pallavi Anand** Pallavi.anand@open.ac.uk **Neil Edwards** neil.edwards@open.ac.uk
Is the PhD suitable for part time study?	Yes ☒ No ☐

Project Highlights:

- Training in development and application of a climate model.
- Perform the first transient 3D coupled climate-carbon cycle simulations spanning the Last Interglacial
- Application of new model for understanding climate dynamics during a rapid transition into a warmer-than-present climate state.

Overview:

The Last Interglacial (LIG), a 15,000 year period of relatively warm climate between glacial states, starting around 130,000 years ago, is attracting considerable interest as a future analogue state, with a rapid transition into a warmer-than-present climate with sea-level 6–9m above present and orbital-driven Arctic warming comparable to end 21st century projections.

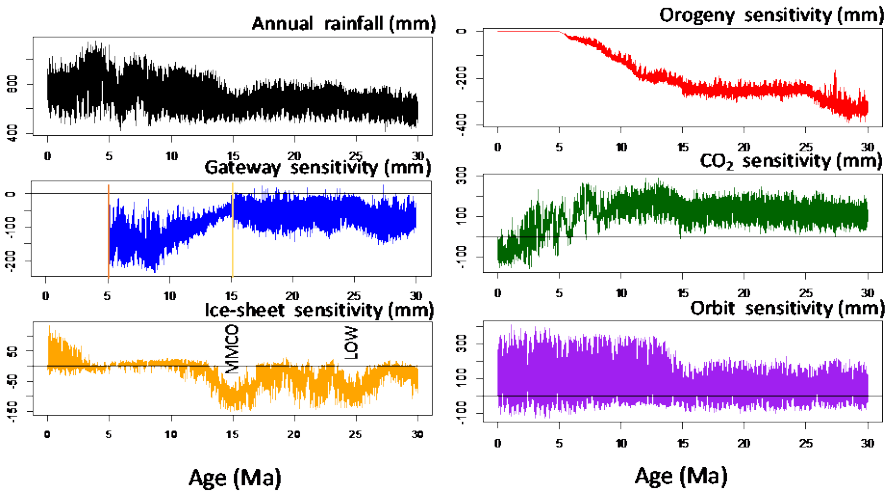

Figure 1: Indian Summer Monsoon rainfall and sensitivities to changing boundary conditions since 30 Ma, showing the difference between the baseline rainfall and rainfall assuming each boundary condition is fixed at its preindustrial value (Jim Thomson, personal communication)

This project will first develop long transient simulations using a 3D atmosphere-ocean GCM with a freely evolving carbon cycle. A reassessment of scientific focus based on the literature review and preliminary results will inform an opportunity to redefine, if required, the scientific focus according to the student's interests. We aim to target two areas of current and considerable debate for investigation:

1) **The carbon cycle is critical to evolution of future climate and the ultimate fate of anthropogenic emissions, yet past changes in CO_2 are not well understood, while future changes represent some of the largest uncertainties in the Earth system models used to project climate change.** Starting from a glacial state with low atmospheric CO_2, we will explore the mechanisms that rapidly drove the world into an interglacial state. Furthermore, the LIG itself was a period with stable atmospheric CO_2, a stability that is not easy to understand given the strong and changing orbital forcing.

2) **Asian Monsoon rainfall supports the livelihood of billions of people, yet the relative importance of different drivers remains an issue of great debate.** Proxy reconstructions tell us what changes happened, but they cannot separate the roles of the different influencing factors. Transient simulations provide the means to extract the influences of these interacting factors. Ongoing work at the OU (Figure 1) is addressing this through statistical models over 30 million years. This PhD project will develop these ideas through transient simulations focusing specifically on the LIG, capturing processes driven by Earth system inertia and climate variability on a range of time-scales.

Methodology:

This project will apply PLASIM-GENIE, a recently developed intermediate complexity 3D dynamic atmosphere-ocean model with a coupled carbon cycle climate model that has been applied in future (Holden et al 2018) and in several paleoclimate studies, extending back to the Eocene (Keery et al 2017). It is significantly more efficient than other models in its class. Detailed ice-sheet, land-sea mask and glacial meltwater boundary conditions have been developed for the PMIP4 model inter-comparison project (Menviel et al 2019). These will be used to derive boundary condition inputs files, coding the model for time varying-boundary conditions, and performing simulations running from 140ka to 122ka. The carbon cycle will be run in both forced mode (with prescribed CO_2) and coupled mode (where CO_2 is allowed to freely evolve). Experiments will be run under forcing sensitivity (e.g. varying boundary conditions in isolation) to disentangle the effects of these different drivers.

Training and skills:

Full support will be provided to the student to learn how to install, configure and run complex climate models and analyse their outputs. Depending on the preferences of the student and the analytical directions they choose to take, there could be training in statistical skills, using state-of-the-art approaches in ensemble design and statistical emulation.

Partners and collaboration:

Laurie Menviel will collaborate on the project. Laurie is closely involved in the design and implementation of the PMIP4 LIG transient experimental protocols (Menviel et al 2019, https://pmip4.lsce.ipsl.fr/doku.php/exp_design:degla_t2) and has performed transient LIG simulations with the LOVECLIM model. This collaboration will be a huge benefit to the student in providing a link to the established paleoclimate modelling community that controls the PMIP exercises and via PMIP the connection to the wider IPCC climate modelling community globally.

Possible timeline:

Year 1: Literature survey and extraction of published LIG data and knowledge. Develop ice-sheet, land-sea mask and glacial meltwater boundary conditions and submit simulations. Present simulations at a virtual conference.

Year 2: Analyse simulated carbon-cycle/Asian monsoon/other dynamics for publication. Present results at an online conference such as Palaeo PERCS (for early career researchers).

Year 3: alyse simulated carbon-cycle/Asian monsoon/other climate dynamics for a second publication. Present results at an international conference. Write thesis chapters for submission.

Further reading:

Holden, P.B., Edwards, N.R, et al. (2018) 'Climate-carbon cycles uncertainties and the Paris Agreement', *Nature Climate Change*, 8, 609-613.

Keery, J.S, Holden, P.B, and Edwards, N.R. (2018) 'Sensitivity of the Eocene climate to CO_2 and orbital variability', *Clim. Past.* 14, 215-238.

Menviel, L., et al (2019) 'The penultimate deglaciation: protocol for Paleoclimate Modelling Intercomparison Project (PMIP) phase 4 transient numerical simulations between 140 and 127 ka, version 1.0', *Geosci. Model Dev.*, 12, 3649-3685, doi:10.5194/gmd-12-3649-2019

Further details:

Students should have a strong background in physical sciences and enthusiasm for Earth science

If you're not sure whether your academic background is suitable, please contact one of the supervision team or Olivia Acquah at STEM-EEES-PhD@open.ac.uk. We'd be happy to hear from you.

The successful student will join well-established teams researching Earth system science at the Open University.

Applications should include:

- A covering letter that includes:
    - Your motivation to study for a PhD in general
    - Your interest in this project in particular
    - The project-specific skills, aptitude and experience you bring to the project
- an academic CV containing contact details of three references, one of whom should be able to comment on your academic abilities.
- and an Open University application form.
    - If you are British, please use the Home form
    - If you are not British, please use the International form

Applications should be sent to **STEM-EEES-PHD@open.ac.uk** **by 12 noon on Monday 1st March 2021.**