CENTA Project Proposal Form – 2024 entry

Project Title	Reconstruction of Indian Monsoon dynamics in response to Pliocene climate
University (where student will register)	The Open University
Which institution will the student be based at?	As above
Theme (Max. 2 selections)	Climate & Environmental Sustainability ☐ Organisms & Ecosystems ☐ Dynamic Earth ☒
Key words	Monsoon, Geochemical proxies, Foraminifera, Pliocene
Supervisory team (including institution & email address	**PI: Pallavi Anand** **Co-I: Kate Littler (Exeter University),** **Phil Holden (OU)** **Collaborators: Clara Bolton (CEREG), Mel Leng (BGS), Marci Robinson (USGS), Masafumi Murayama (Kochi University, Japan)**
Is the PhD suitable for part time study?	Yes ☒ This is a requirement of NERC

Project Highlights:

- Reconstruct first orbital-resolution Pliocene Indian monsoon runoff
- Training in multi-proxy geochemical and micropaleontological reconstructions
- International collaboration with IODP expedition scientists

Overview:

The Indian Monsoon (IM) precipitation is the main seasonal driver of water availability, supporting billions of people. The future projection of mean annual ISM rainfall is highly variable under different warming scenarios and an increase in the frequency of extreme precipitation has been suggested if global mean temperature increases ≥ 3 °C[1]. Our ongoing proxy and modelling work suggest multiple competing controls on IM dynamics (precipitation and wind) during the Plio-Pleistocene linked to atmospheric carbon dioxide (CO_2), global cooling, orbital forcing factors and gateway closure[2]. Nevertheless, the past evolution of IM remains elusive since it is grossly under-represented in Asian monsoon palaeoclimate proxy records. This project aims to produce new proxy records to both fill gaps in our knowledge and test competing forcing factors affecting IM dynamics during the early to mid-Pliocene (3 to 5 Ma), capturing the prevailing warm, high atmospheric CO_2 conditions and gateway closure[3].

This project provides flexible opportunity to be trained and employ data/model approached to understanding past IM variability in response to Pliocene climate. Examples include application of a multi-proxy approach to reconstruct IM rainfall/runoff, seasonality of monsoon rainfall/runoff and marine productivity in response to IM wind variability on orbital timescales from the core IM region of the Bay of Bengal (BoB) or work on integrating existing data and numerical model. The selected International Ocean Discovery Programme (IODP) sites boasts from X-Ray Fluorescence (XRF) elemental ratios and foraminifera assemblage data (collaborator Robinson). New records from this project will be compared with published monsoon and climate records to identify the nature of the linkage between Asian Monsoon subsystems and global climate. This project will primarily utilise

continuous sedimentary successions from the BoB (IODP Expedition 353, Sites U1445 and U1443 and legacy ODP site 722 in the Arabian Sea) to address some of the key questions: what is the response of IM dynamics during the evolving boundary conditions of early- and mid-Pliocene? How are IM dynamics linked to the other Asian and tropical monsoon regions?

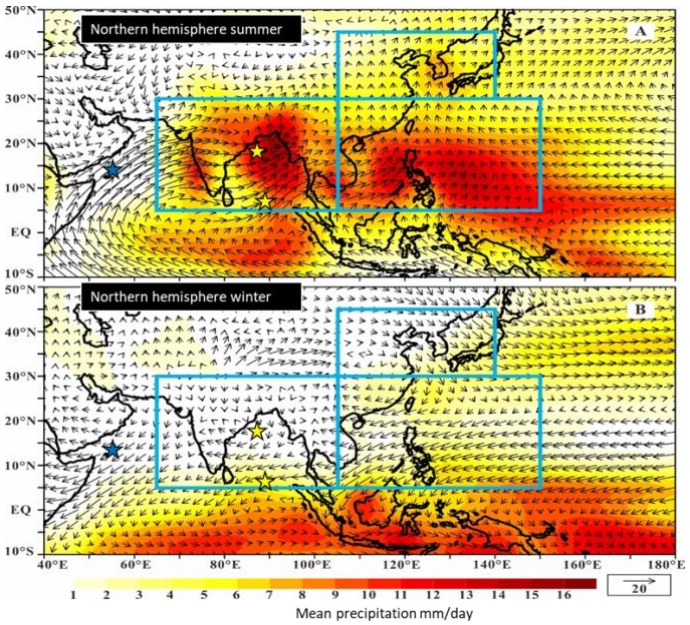

Figure 1: Modern rainfall superimposed with wind stress in Asia during the northern hemisphere summer and winter showing different monsoon regions (modified after Wang et al., 2003). Samples are available from IODP Exp 353 Sites (yellow stars) and ODP site 722 (blue star) for this project.

Alt text: There are two maps shown vertically that captures Indo-Pacific regions between 10°S to 50°N latitudes and 40 °E to 180 °E longitude. The maps show wind vectors and mean precipitation (ranging between 1-17 mm/day. The precipitation colour shading grades from red (maximum) to orange to light yellow (minimum). The maximum rain in the Indo-Pacific region occurs during the northern hemisphere summer (top) and drier conditions during the northern hemisphere winter. There are three boxes shown on both figures that approximately show Asian Monsoon regions: East Asian on the top (covering east China) below which is a box that represents South East Asian (covering west Pacific and Japan) and to the left is Indian or South Asian (covering Indo-Myanmar area). There are two yellow stars showing IM study Sites (U1445 in the north and U1443 in the south) and a blue star in the Arabian Sea showing ODP Site (722).

Methodology:

The deep-sea mud samples will be washed and the coarse fraction (>150 μm) will be used for picking foraminifera for geochemical work (oxygen and carbon isotopes measurements) in the fully equipped laboratories at The Open University. Benthic foraminifer oxygen isotope measurements will be used to extend the ongoing work on Pliocene stratigraphy. Tooth-pick samples will be used for obtaining coccolithophore assemblage data at CEREGE (Dr Bolton). The study sites already have XRF scanned bulk sediment geochemical data which will be coupled with coccolithophore and foraminifera (in collaboration) assemblage data to infer changes in surface water stratification, productivity and runoff in response to monsoon variations. Further, targeted intervals will be used for multi-species planktic foraminifera geochemical (coupled trace element and oxygen isotope)

data to reconstruct ISM dynamics. Additionally, planktic foraminiferal geochemical data will be utilised to infer orbital and/or seasonal scale variations in rainfall/runoff and put in context with model output[4].

Training and skills:

Students will be awarded CENTA2 Training Credits (CTCs) for participation in CENTA2-provided and 'free choice' external training. One CTC equates to 1⁄2 day session and students must accrue 100 CTCs across the three years of their PhD.

In addition, the student will receive specific training on coccolithophore assemblage data collection and interpretation from Dr Bolton (at CEREGE) and work closely with collaborators.

The student will receive project specific training with supervisors (PA and PBH) and additional OU training.

Specific skills that will be acquired during this project include:

- Nannofossil assemblage and geochemical analyses
- Data handling and interpretation from a wide variety of sources
- Scientific communication through writing, poster and oral presentations to academic and non-academic audiences
- Co-supervision on your own devised OU's master's project and teaching research methods to year 12 students through Nuffield research placement.

Partners and collaboration (including CASE):

This project will benefit from international collaborations and networking opportunities with IODP 353 expedition scientists. There will be collaboration with scientists working on the Pliocene for stratigraphy, foraminifera assemblage (Marci Robinson, USGS) and productivity proxies (Emmeline Gray, Bristol University).

Possible timeline:

Year 1: Obtain training in sample processing of core material for microfossils (taxonomy), inorganic geochemical and stable isotope techniques. Generate benthic oxygen isotope stratigraphy and coccolithophore productivity data and interpret together with existing XRF data. Present at UK-IODP annual or UK Paleoclimate Society meetings.
Year 2: Prepare a manuscript based on age model, productivity and XRF data. Generate planktic geochemical data to support preliminary observations (yr 1). Present geochemical data at the Geochemistry Research in Progress meeting or Palaeopercs seminar.
Year 3: Finish remaining data analyses, data integration in existing model and present results at an international conference and write up thesis and manuscripts.

Further reading:

1. Bhowmick, M. Sahany, S., and Mishra, S. K. (2019) Projected precipitation changes over the south Asian region for every 0.5C increase in global warming, Environmental Research Letters, 14, https://doi.org/10.1088/1748-9326/ab1271.
2. Thomson., J., Holden P., Anand, P., Harris, NWB, Porchier, C, and Edwards, N. (2021) Tectonic and climatic drivers of the Asian Monsoon evolution, *Nature Communications,* 4022 (12), doi.org/10.1038/s41467-021-24244-z

3. McClymont, E., Ho, S.-L., Ford, H., Bailey, I., Berke, M.A., Bolton, C. T., De Schepper, S., Grant, G. R., Groeneveld, J., Inglis, G. N., Karas, C., Patterson, M. O., Swann, G. E. A., Thirumalai, K., White, S. M., Alonso-Garcia, M., Anand, Pallavi et al., (2023) Climate Evolution through the mid-Pliocene warm period and the intensification of Northern Hemisphere Glaciation, Reviews of Geophysics, 2022RG000793, DOI: 10.1029/2022RG000793
4. Nilsson-Kerr, K., Anand, P., Holden, P. B., Leng, M. J., and Clemens, S.C. (2021) Dipole patterns in tropical precipitation were pervasive across landmasses throughout Marine Isotope Stage 5, *Communications Earth and Environment*, 2, doi.org/10.1038/s43247-021-00133-7

Further details:

The successful candidate will join Palaeoenvironmental Change group researching on proxy data-model paleoclimate reconstructions. We welcome applications from those with learning research methodology in proxy/model reconstructions and enthusiasm for palaeoclimate research. Please contact Pallavi Anand (pallavi.anand@open.ac.uk) for more information.