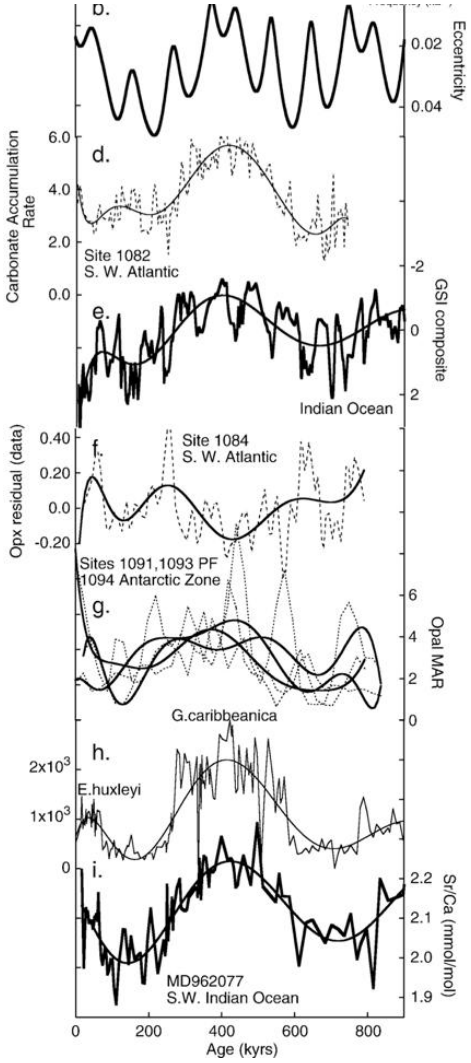
EARTHSCIENCES

Milankovitch, tides and marine mixing: drivers of plankton speciation and productivity

Primary supervisor:	Rosalind Rickaby
Co supervisor(s):	*Helen Johnson (University of Oxford)* *Mattias Green (University of Bangor)*
Key words:	Biogeochemistry, algal productivity
Research theme(s):	• Oceanography, Climate and Palaeoenvironment • Palaeobiology and Evolution
Eligible courses for this project:	• DPhil in Earth Sciences (3-4 years) • Interdisciplinary Life and Environmental Science Landscape Award (ILESLA)



Overview

A 400 kyr cycle in the carbon cycle has been observed over much of Earth history but has never been rationalised and understood. One of the curious aspects of e.g. the history of coccolithophore productivity in more recent times, is that it shows a counterintuitively large signal with a 400 kyr frequency in parallel with the degree of eccentricity of Earth's orbit around the sun. Additionally, detailed morphological records of coccolithophores over the last 2 million years coupled with whole genome analysis have, for the first time, revealed that this 400 kyr periodicity plays out in the speciation and evolution of these calcifying algae. Such changes in productivity are also apparent in records of diatom productivity from the higher latitude Southern Ocean. These changes in productivity and speciation point to some inherent changes in the degree of mixing in the ocean which both changes the vertical supply of nutrients to the surface, and can act to isolate subpopulations of algae leading to speciation. This PhD will aim to unite records of productivity from targeted areas of the ocean over the last 1 million years, together with ocean-scale modelling to test whether the influence of orbital scale change on tides and tidal mixing may be big enough to consistently drive an eccentricity cycle in algal productivity.

It has been increasingly recognised, that changes in biogeochemistry and productivity (and climate) are sensitive to short small amplitude tidal cycles (the 18.6 year nodal cycle for example) but it is likely that orbital change in the rotation of the Earth around the sun, (such as eccentricity) may modulate the tidal cycles and their influence on tidal mixing. Tidally driven mixing is very patchy, with shelf seas dominating the energy budget and so to start, the project aims to use a 1D shelf sea biogeochemistry model to assess whether orbital parameters (particularly those of eccentricity) can force changes in tidal mixing sufficient to influence regional productivity. The project will also test these impacts at the global scale using the Uvic or Climber model which will allow the investigation of the impact of changes in productivity as a driver of the ocean and atmospheric carbon cycle. This scale of model will also allow us to target appropriate areas of the ocean for development or compilation of records of productivity on the 1 million year timescale to iterate between models and palaeorecords to test whether consistent signals can be found.

Methodology

The methodology involves modelling of marine biogeochemistry at the shelf sea and global scale.

It will additionally involve the compilation of existing records of marine productivity, and internal ocean mixing, on the 1 million year timescale as well as the development of new records, likely based on novel interpretations of $\delta^{13}C$ records from all carbonate particles including the planktonic and benthic foraminifera, as well as coccolithophores. It will allow additional insight into “vital effects”.

Timeline

Year 1: Learning and testing of models at the regional/shelf sea scale. Data compilation on ocean productivity over a 1 million year timescale.

Years 2 and 3: Scaling up the global scale in modelling and determination of records that will allow a testing of the hypothesis.

Year 4: Data integration, thesis completion, papers for international journals/conference presentation.

Training & Skills

The student will be given training in shelf sea and global biogeochemical modelling, as well as expertise in proxies that will allow the testing of the models such as $d^{13}C$

References & Further Reading

1. Beaufort, L., Bolton, C.T., Sarr, AC. *et al.* Cyclic evolution of phytoplankton forced by changes in tropical seasonality. *Nature* **601**, 79–84 (2022). https://doi.org/10.1038/s41586-021-04195-7
2. **Bendif, E. M.,** B. Nevado, E. Wong, K. Hagino, I. Probert, J. R. Young, R. E. M. Rickaby and D. A. Filatov, Repeated species radiations in the recent evolution of Gephyrocapsa species, Nature Communications, 10, 4234, 2019

3. Rickaby R. E. M., E. Bard, C. Sonzogni, F. Rostek, L. Beaufort, S. Barker, G. Rees. and D. P. Schrag, Coccolith chemistry reveals secular variations in the global ocean carbon cycle? Earth Planet. Sci. Letts. *253, 83-95,* 2007
4. SB Wilmes, VK Pedersen, M Schindelegger, JAM Green Late Pleistocene evolution of tides and tidal dissipation, Paleoceanography and Paleoclimatology 38 (11), e2023PA004727
5. SB Wilmes, JAM Green, A Schmittner, Enhanced vertical mixing in the glacial ocean inferred from sedimentary carbon isotopes, Communications Earth & Environment 2 (1), 166

Further Information

Contact: Ros Rickaby, Helen Johnson and Mattias Green (rosalind.rickaby@earth.ox.ac.uk; helen.johnson@earth.ox.ac.uk; m.green@bangor.ac.uk)