Ocean circulation in a warm world

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Global ocean circulation is a key component of the climate system (Figure 1) and an important driver of palaeoclimate change (Liu et al., 2009). However, its response to a warming climate is poorly understood (Liu et al., 2017). The mid-Pliocene is the last period of Earth history when the climate was warmer than today and atmospheric carbon dioxide was similar to today (Haywood et al., 2016). The previous phase of the Pliocene Model Intercomparison Project (PlioMIP; Haywood et al., 2013) showed inconclusive changes in Atlantic Meridional Overturning Circulation (AMOC; Zhang et al., 2013a), despite interpretations of increased AMOC for many years (Dowsett et al., 1992; Raymo et al., 1996; Robinson et al., 2011). However, simulated Pacific circulation shows a significant change in the models, driven by changes in the Antarctic ice sheet (Figure 2; Hill et al., 2017).

Neodymium (Nd) isotopes are an important new measurement in palaeoceanography, as they provide a more robust tracer of ocean water masses. They do not change in the open ocean and therefore retain the signal from their source waters, which varies across the globe (van de Flierdt et al., 2016). Combining measurements of εNd from a site over time, with knowledge of the different water masses that could contribute to the local oceanographic situation (e.g. Table 1) allow for the changing source waters and the strength of currents to be evaluated. Given appropriate measurements in key locations, this tracer allows the structure and strength of global ocean circulation to be assessed through time (Kender et al., 2018).

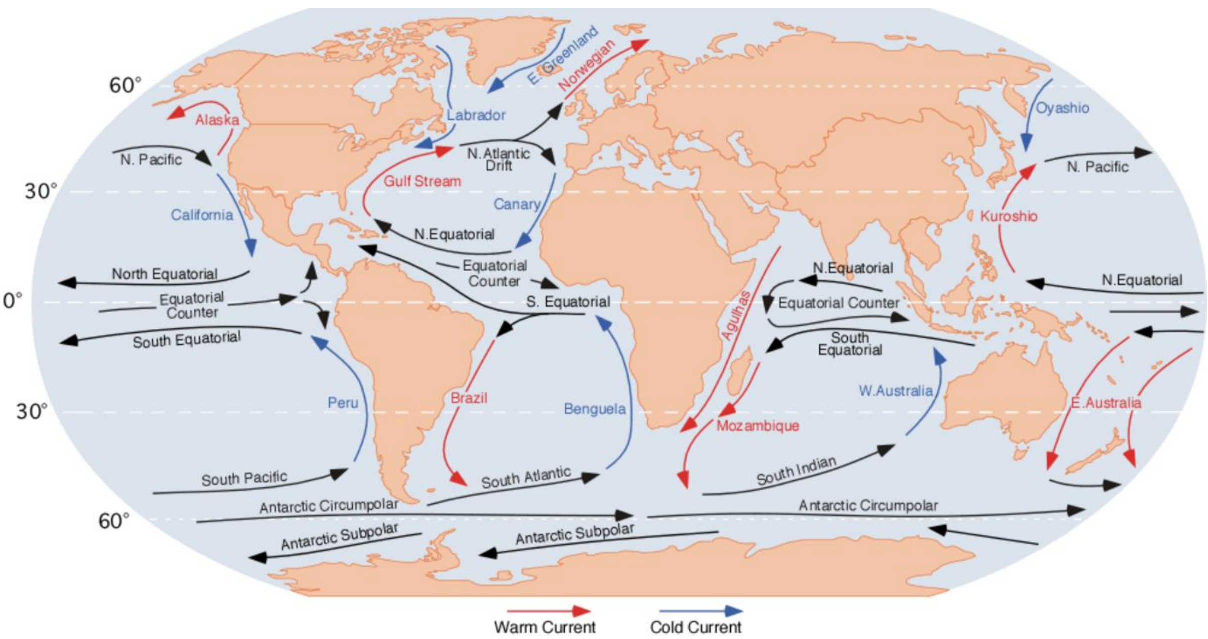

Figure 1 | Schematic of global ocean surface currents. Red arrows show currents that transport warm waters poleward, whereas the blue arrows show surface currents that transport cold water from the poles to lower latitudes.

Water Mass	Potential Temperature (°C)	Salinity (ppt)	εNd
Greenland-Scotland Overflow	-0.43±0.59	34.890±0.028	-8.3±0.2
Labrador Sea Water	3.45±0.40	34.906±0.023	-14.15±0.07
Mediterranean Outflow	13.06±0.06	38.462±0.021	-9.4±0.6
Antarctic Intermediate Water	3.26±0.52	34.139±0.250	-8.0±0.3
Antarctic Bottom Water	-0.47±0.45	34.657±0.016	-9.1±0.7

Table 1 | Water mass properties for key components of North Atlantic Ocean circulation, including their εNd values (van de Flierdt et al., 2016).

Combining together Neodymium isotope measurements of marine isotope stage KM5c and the transition from the Pliocene glacial period M2 (Haywood et al., 2016), the PlioMIP phase 2 model ensemble and novel Pliocene simulations varying Antarctic glaciations, this project will investigate ocean circulation in a warmer world and the processes that drive the changes. This will provide much better constraints on Pliocene ocean circulation and how ocean currents could change under future climate warming.

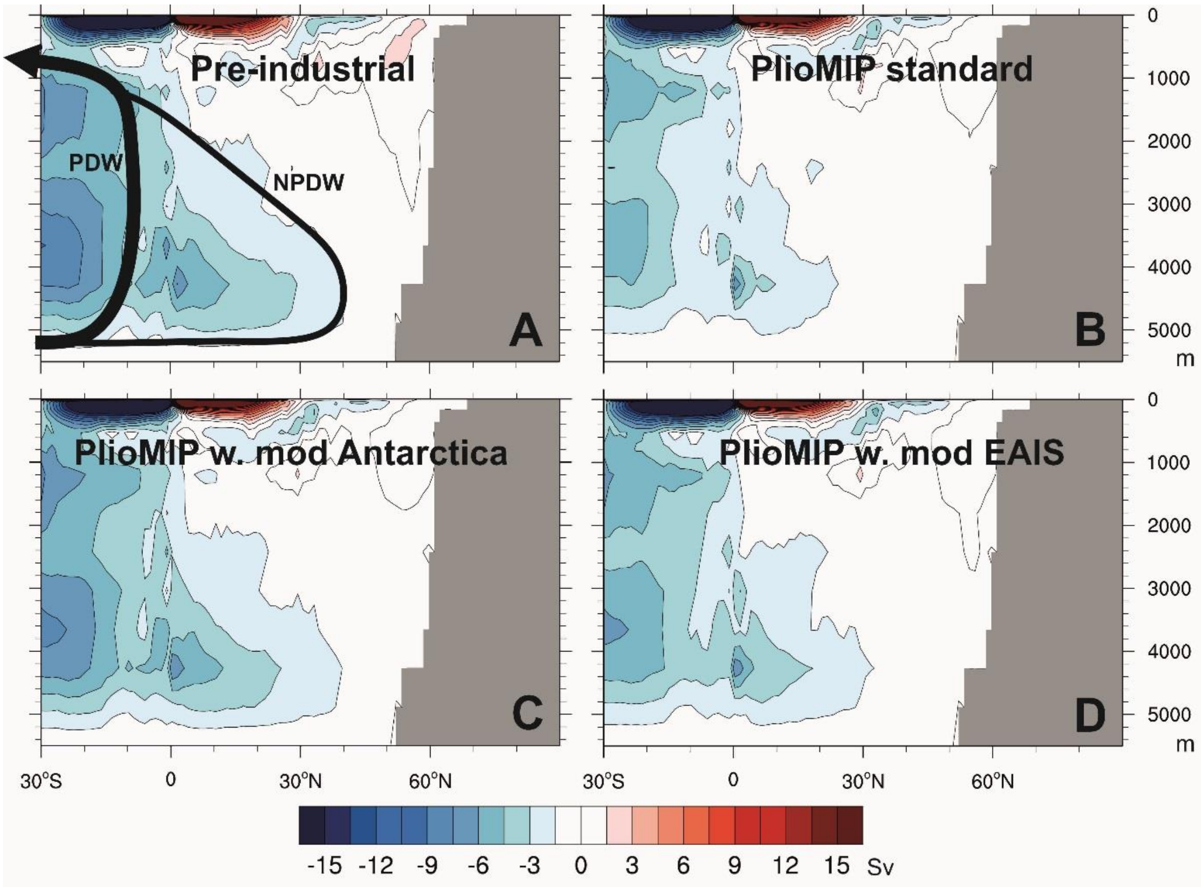

Figure 2 | MOC in the North Pacific from the HadCM3 simulations. Pre-industrial MOC (a) shows schematically the major Pacific deep water masses, the Pacific Deep Water (PDW) and the North Pacific Deep Water (NPDW). The PlioMIP standard simulation (b) shows that the Pliocene NPDW is much weaker and does not penetrate into the North Pacific above 30°N. Introducing a modern Antarctic Ice Sheet (c) largely reintroduces modern Pacific MOC, while a modern East Antarctic Ice Sheet (with an ice free West Antarctica; d) only marginally increases Pacific MOC. Positive values represent clockwise overturning, whilst negative values represent anti-clockwise circulation.

Objectives:

The student will undertake a combined laboratory and modelling approach to investigate Pliocene ocean circulation, in collaboration with their supervisors, the Palaeo@Leeds research group and palaeoclimate modellers from across the globe. There is plenty of scope for the student to tailor the project and prioritise the various aspects of the project according to their own interests. However, the following would be a reasonable expectation for the project.

1. Investigate global ocean circulation in the PlioMIP phase 2 ensemble, analysing the existing simulations and evaluating the model dependency of Pliocene climate.
2. Develop new methodology for bulk sediment Neodymium isotope measurements and apply these to a range of Pliocene marine sediment cores.
3. Compare Neodymium isotope data to simulations of global ocean circulation from the Hadley Centre model and develop new understanding of the role of the Antarctic Ice Sheet in driving changes in ocean circulation.

Potential for high impact outcome

Pliocene ocean circulation has been a hot topic in palaeoclimatology and palaeoceanography for a number of years (Dowsett et al., 1992; Zhang et al., 2013b) and continues to produce high impact papers (Burls et al., 2017; Hill et al., 2017). The PlioMIP project has produced dozens of high impact, highly cited papers and the studentship will perfectly timed to take advantage of the second phase of this international project. This will enable the student to lead an aspect of the analysis of at least 14 climate models from around the world (Haywood et al., 2016).

New Neodymium isotope techniques to be developed by the students will produce a methodological paper, that it is anticipated will be well cited in future. Combining Neodymium isotope data and Pliocene climate simulations should produce well constrained understanding of the Pliocene climate and the impact of climate warming on ocean circulation.

Training

The successful candidate will work closely with supervisors, Daniel Hill, Tracy Aze, Jason Harvey and Alan Haywood, and will play an active role in Palaeo@Leeds research group. Interacting with this group will give the student a broad education in cutting edge palaeoclimate and geochemical research. Specific training in laboratory techniques, the use of climate models and high performance computing will be given both in Leeds and at external training courses. Being part of the Leeds/York NERC DTP (Natural Environment Research Council Doctoral Training Programme) will also give the student access to lots of training in general research and academic skills. Being part of the PlioMIP project will give the student experience of working with lots of different climate models and handling large data sets. The student will also be expected to interact with lots of different scientists and disciplines that work on palaeoceanography and the Pliocene Epoch. This will be facilitated by attendance and presentation at a series of major international conferences. The Urbino summer school in Italy provides general training in palaeoclimate research and the student would be expected to apply to attend the course in summer 2019.

Student profile

This project is highly multi-disciplinary and no candidate will have existing skills in all the necessary disciplines. Applications are particularly encouraged from candidates with a background in physical science, mathematics, Earth science or oceanography. However, as all training will be given to successful candidates, those with any quantitative scientific background would also be suitable.

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