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Modelling rapid CO_2 and climate change in the Southern Ocean

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Funding and Notes	**Funded by the University of St Andrews via St Leonard's College, The School of Earth and Environmental Sciences, and the School of Mathematics and Statistics** **Deadline: January 20th 2018** **Eligibility: All EU citizens who meet St Andrews entry requirements are eligible for fee costs and a full-stipend**

Project Description

The Southern Ocean plays a fundamental role in the regulation of Earth's climate through its uptake of heat and carbon. Despite representing only 20% of the ocean surface area, it accounts for more than 50% of ocean carbon uptake and more than 75% of ocean heat uptake (Charrassin et al., 2008; Meredith and Hogg, 2006). The reason for the Southern Ocean's disproportionately large impact on the climate system is its intimate link to the deep ocean. This is driven by its unique dynamics, with strong westerly winds and surface buoyancy forcing driving a divergent surface flow, which brings deep (~2000 m) water to the surface, allowing heat and carbon exchange with the atmosphere. These winds and buoyancy forcing also generate the world's largest current system – the Antarctic Circumpolar Current – which transports heat and carbon between the major ocean basins. Despite the importance of the Southern Ocean for climate and carbon cycling, the dynamical understanding of this region is weak, with state-of-the-art climate models consistently showing biases and unrealistic depictions of physical and biogeochemical processes. How the Southern Ocean will respond dynamically to a warming climate, and the implications of those changes on the carbon cycle, represent major uncertainties in our projections of future climate change.

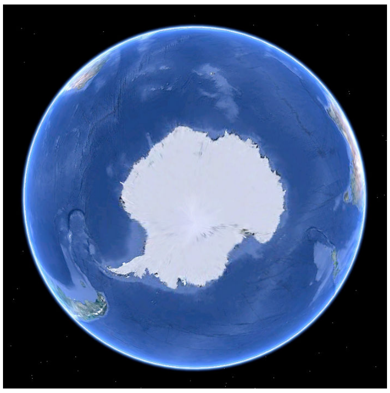

Figure 1: The Southern Ocean around Antarctica plays a critical role in global climate change.

Because of the lack of long term oceanographic measurements in this remote region, our best constraints on Southern Ocean circulation and biogeochemistry under different climate conditions come from the geological record. Using geochemical measurements on sediments cores (Anderson et al., 2009) and deep-sea corals (Burke and Robinson, 2012), it has been shown that changes in Southern Ocean chemistry are closely coupled to atmospheric CO_2 rise at the end of the last ice age (20,000 years ago). Recent work (Rae et al., *submitted*) demonstrates that such changes may even occur on centennial timescales, synchronous with abrupt jumps in atmospheric CO_2 and rapid warming at high Northern Latitudes (10 °C in 10 years). However despite progress in modelling Southern Ocean circulation and carbon cycling under steady-state conditions (Burke et al., 2015; Ferrari et al., 2014), efforts to place transient changes in Southern Ocean circulation into a robust dynamic framework are in their infancy. This impacts our ability to understand both past ice age climates and fast feedbacks under future global warming.

This PhD studentship will transform our understanding of the Southern Ocean's role in rapid CO_2 and climate change using novel dynamical modelling. The essential aspects of Southern Ocean dynamics will be represented in a new model of the ocean's overturning circulation. This model will be based on a framework (Fig. 2) that has been developed to capture the balance between winds and eddies that sets Southern Ocean tracer transport and that can be run efficiently under different boundary conditions. Recent application of similar models have led to several high impact studies (e.g. Burke et al., 2015; Ferrari et al., 2014). However these efforts have been run only at steady state and have no representation of climate feedbacks or carbon cycling. This project will develop this modelling approach to allow rapid climate events to be explored. Specifically the student will:

- develop numerical methods to permit the study of the time-evolving coupled climate system;
- assess the impact of different parameterisations of eddy dynamics and diapycnal diffusivity;
- add key climate and biogeochemical feedbacks.

This will allow the student to address fundamental questions about the Southern Ocean's role in the climate system, including:

- the role of Southern sea ice in setting the global overturning circulation;
- the potential of the Westerly winds to drive transient circulation and CO_2 outgassing anomalies;
- the response of the Southern Ocean to rapid climate change in the Northern Hemisphere.

Ultimately this work will improve understanding of the Southern Ocean's behaviour during rapid climate change and will help develop predictive models of future heat and CO_2 exchange in this crucial region.

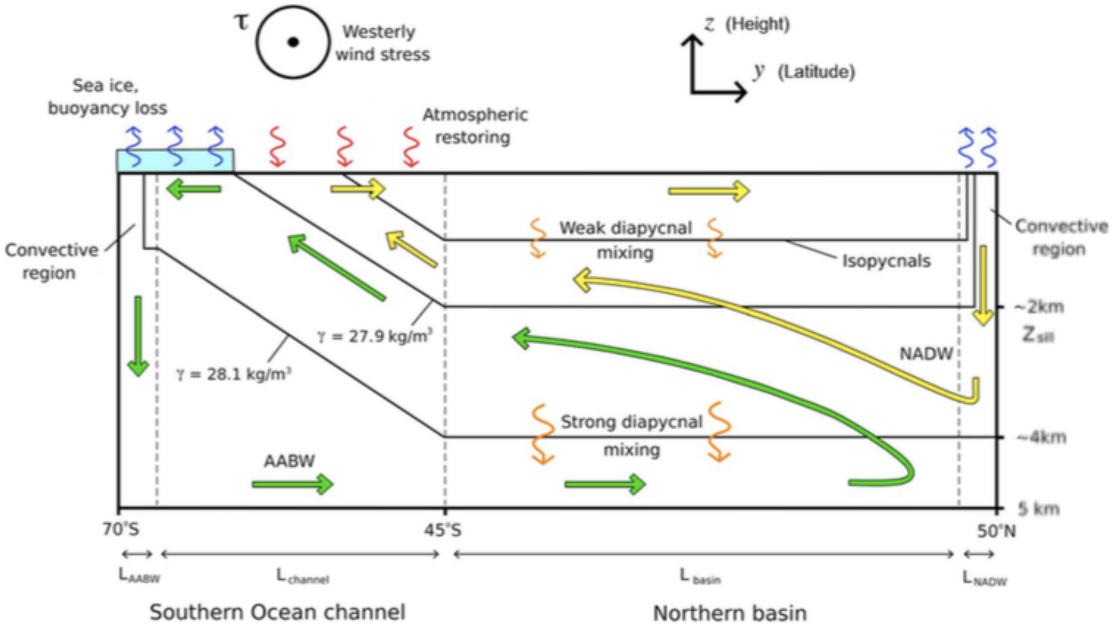

Figure 2: ***from Burke et al., 2015*** **.A conceptual model of the ocean's overturning circulation. The thick arrows indicate mass transports, and thin curvy arrows indicate the directions of buoyancy fluxes. The green and yellow arrows correspond to lower and upper overturning cells, respectively. The dynamic model proposed here will capture these essential features of the ocean circulation in a flexible mathematical framework informed by the latest understanding of fluid dynamics, and explore its behavior under different climate states.**

Training & Skills

This St Leonard's College Interdisciplinary studentship will provide training in climate science, dynamical modelling, numerical methods, oceanography, biogeochemical cycling, and paleoceanography/paleoclimatology. The student will be a member of both the Climate and Global Change research group in the School of Earth and Environmental Sciences and the Vortex Dynamic research group in the School of Mathematics and Statistics, with desk space in both Schools. In addition to the specific training received through the PhD, the student will have the opportunity to improve general transferrable skills through University courses run by CAPOD, external research workshops, and presentations at group meetings. The student will also have the opportunity to attend and present their research at national conferences, and at least one international conference.

References & Further Reading

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Further Information

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