The role of climate-forced ice shelf melt in biological production of the Amundsen Sea, West Antarctica

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Summary. This project makes use of physical and biogeochemical ocean modelling in combination with in-situ and remote sensing observations in order to quantitatively understand the contribution of glacier melt to biological activity and carbon uptake in coastal regions of West Antarctica.

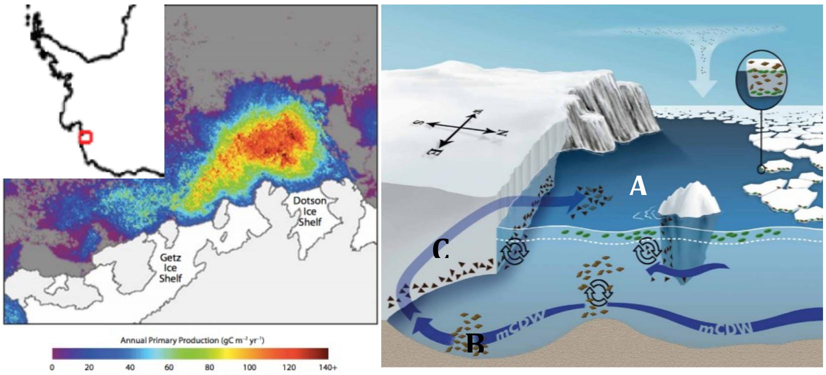

Figure 1: (left) Primary productivity in the Amundsen Polynya in 2011. (right) Schematic illustrating various proposed iron pathways in the polynya (A), including upwelling and dissolution of iron from the sea bed driven by ice shelf cavity overturning (B) and release of frozen sediment from the ice shelf base (C). Both mechanisms require strong CDW-driven melting. From Yager et al [2012].

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Project Background. The Southern Ocean is a critical region for ocean biological productivity and air-sea exchange of heat and climate-active gases. Upwelling of deep ocean waters brings heat, nutrients and carbon dioxide to the surface ocean, where heat and carbon dioxide can be exchanged with the atmosphere and nutrients can be utilised by phytoplankton. Carbon dioxide can also be taken up by biological and physical processes and exported to the deep ocean, making the Southern Ocean an important carbon sink. Primary production is limited across much of the nutrient-rich Southern Ocean by iron and light availability. Primary production per unit area is highest around the Antarctic coast and in polynyas – areas of the surface ocean free of sea ice – where iron limitation in particular is thought to be relieved by land-based sources. Polynyas near the Antarctic coast are far more productive than open-ocean polynyas, and the Amundsen Sea Polynya, West Antarctica, is known to be one of the most productive polynyas on an annual basis [Yager et al, 2012].

The Amundsen Sea Polynya lies adjacent to the Pine Island Glacier and Dotson Ice Shelf, which are currently experiencing melt rates greater than any other ice shelves in the world, due to intrusion onto the continental shelf of warm Circumpolar Deep Water (CDW) [Rignot et al, 2013]. It is thought this melting plays a strong role in the delivery of iron to the Amundsen and Pine Island polynyas – both by providing an iron source, in the form of sediment frozen in basal ice – and by driving a strong overturning circulation which brings dissolved iron species to the ocean surface. Additionally, the upwelling of warm water could aid in polynya formation [Mankoff et al, 2012]. However, these mechanisms have not been quantitatively investigated; and moreover, there could be competing effects from ice shelf melt, such as an increase in water opacity due to turbidity; and an increase in stratification on the continental shelf due to buoyant melt-laden water, inhibiting nutrient upwelling.

Aims and Methodology. The aims of the project are to assess the impact of ice shelf melt on biological productivity in the Amundsen Sea polynyas within a range of uncertainties. The principal tool will be an ocean model capable of representing ice shelf-ocean interactions as well as biogeochemical cycling. The MIT General Circulation Model (MITgcm) is ideal for this study, as it is extensively used for both [Dutkiewicz et al, 2012; Dansereau et al, 2014].

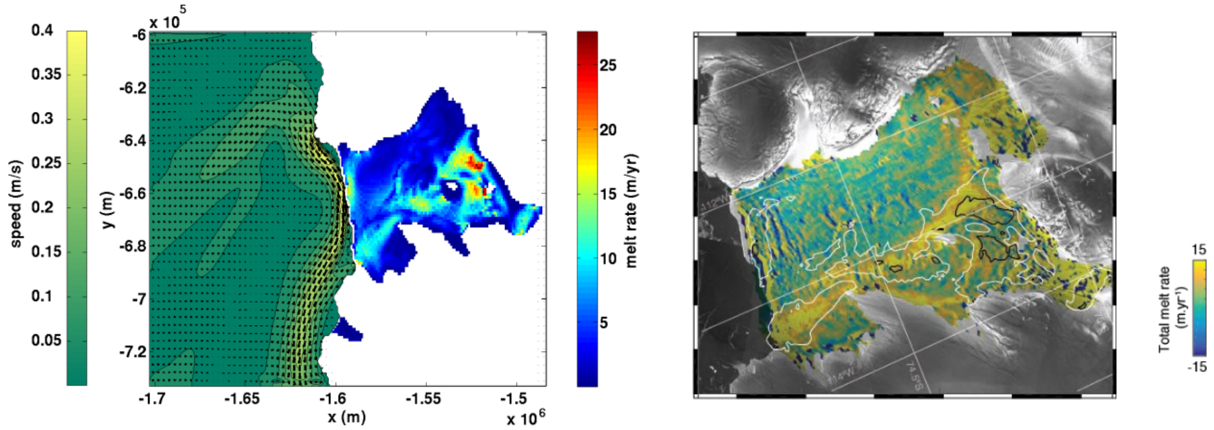

Figure 2: (left) Melt rate calculated under Dotson ice shelf (shading) and ocean surface speed (arrows and filled contours) calculated with MITgcm. (right) Comparison of melt pattern (7 m/yr contour in white, 15 m/yr contour in black) against satellite-observed thinning (shading).

Recently, melt rates have been simulated under Dotson Ice Shelf (Fig. 2). Strong agreement with satellite-observed thinning was seen, and modelled circulation suggests a strong outflow from the ice shelf near the surface. The role of the student will be to extend this model to include biogeochemical cycling and sea ice, using code “packages” that are included as part of the MITgcm, and then carry out modelling investigations of this region, assessing sensitivity to external climate forcing on biological productivity. Remotely sensed observations of ice shelf thinning and primary productivity in certain years will be used for comparison and validation of model results. The result will be a deeper understanding of the role of CDW and ice-ocean interactions in governing primary production, carbon fixation and ecosystem structure in this climatically-sensitive Southern Ocean region.

Training. The qualified student will join both the Cryosphere and Oceans and Past Climate groups, key components of the Global Change Research Institute in the University of Edinburgh’s School of GeoSciences. S/he will be trained in cutting edge biological and ice-ocean modelling techniques. The student will also receive support to attend conferences to disseminate findings to the (inter) national scientific community, and to visit Dr Jones as well as others at the British Antarctic Survey who are expert in ocean data collection, analysis, and modelling. There will also be the opportunity for Antarctic fieldwork.

Requirements: We seek a motivated student with a suitable Undergraduate or Masters Degree in physics, mathematics or a relevant science subject. The student should have basic familiarity with computer programming.

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