Mathematical modelling of the role of surface melt in the retreat and disintegration of Antarctic ice shelves

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Over hundreds of millennia, ice sheets form on land from accumulated snow and, driven by their own weight, spread out horizontally. When an ice sheet flows into the sea, it forms a floating ice shelf. Although a few small ice shelves exist in the Arctic, most occupy bays around Antarctica. These ice shelves play an important role in the cryosphere through, for example, mediating the delivery of terrestrial ice to the oceans, including buttressing upstream glaciers, influencing water currents and the ocean heat budget, and providing biological habitat.

Ice shelves, unlike ice sheets, can respond rapidly to changing climate conditions. In the last few decades, several ice shelves in the Antarctic Peninsula have retreated, Figure 1. In 2002, Larsen B spectacularly collapsed, leading many researchers to speculate that the Larsen C ice shelf awaits a similar fate (Glasser et al., 2009). The retreat and collapse of ice shelves in the Antarctic Peninsula has been attributed to the local warming trend of 2.5^{o}C in the air temperature over the last 50 years.

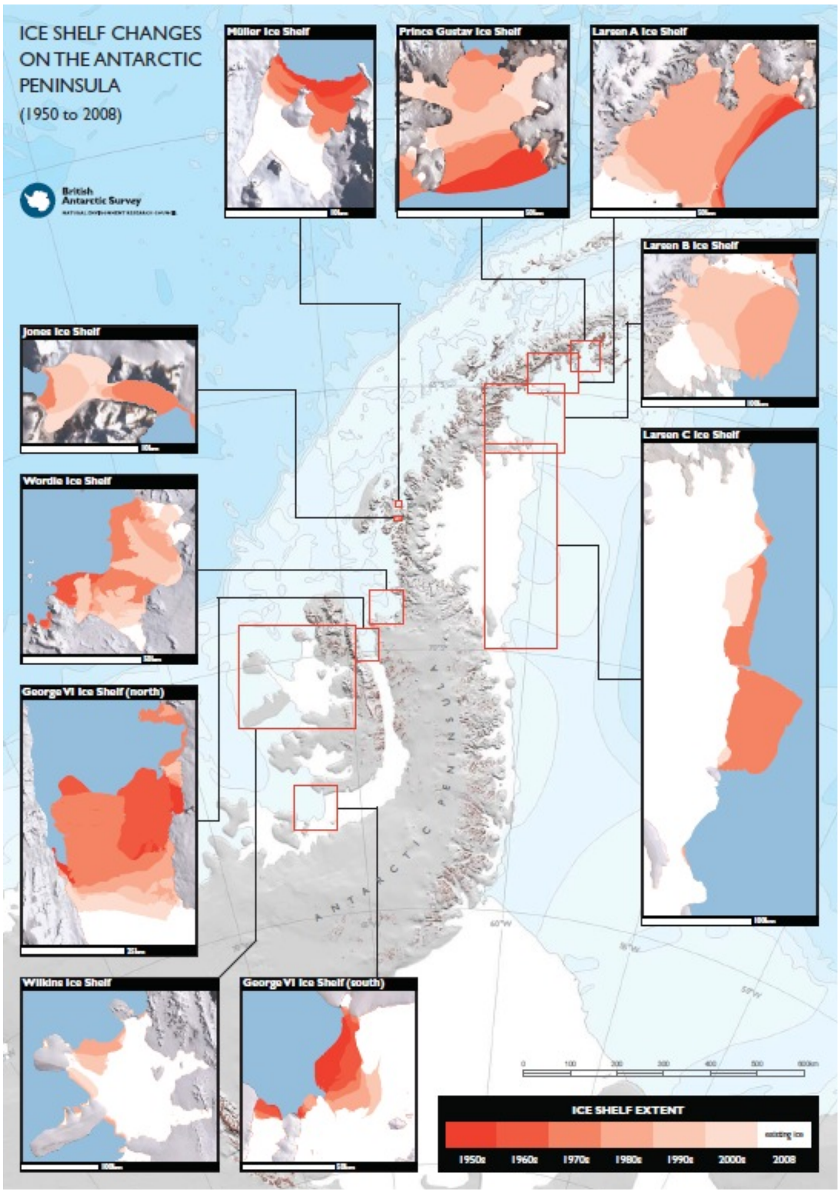

Figure 1, Ice shelf retreat in the Antarctic Peninsula (British Antarctic Science Briefing, 2008).

Although the response of ice shelves to changes in surface warming by thermal conduction is slow, due to the thickness of the ice shelves and their low thermal conductivity, surface warming that creates meltwater that accumulates in ponds or lakes may have a more dramatic impact (Scambos et al., 2000). The collapse of the Larsen B ice shelf was preceded by the formation of an extensive melt pond coverage.

Meltwater is believed to play a role in hydrofracture of an ice shelf: meltwater that accumulates in surface cracks (crevasses) will provide a downwards and outwards pressure that may exceed the ice overburden pressure, which would tend to close the cracks. If the cracks are filled with sufficient meltwater, the weight of the water can force the cracks to penetrate through the ice shelf, impacting its structural integrity. Melt water-driven fracture has been held responsible for the collapse of the Larsen B ice shelf.

The purpose of this project is to:
(i) develop a mathematical model of the surface melt of an ice shelf, particularly accounting for the effect of meltwater on the surface radiative balance (pond-covered ice has a lower albedo than bare ice, which will enhance surface melt) and the role of snow densification;
(ii) explicitly calculate meltwater volume and flow paths for a given surface topography so that we can see where there is sufficient meltwater to cause hydrofracture; and
(iii) examine the mechanism of hydrofracture, and in particular evaluate the relative role of horizontal fracture versus vertical fracture since horizontal fracture would increase crevasse volume and decrease the impact of a given meltwater volume on vertical cracking.

Stages (i) and (ii) of this project will extend existing theory and models developed in the context of meltpond formation on sea ice (e.g. Scott and Feltham, 2010), with the main new conceptual development being the treatment of snow densification. Stage (iii) will develop fracture mechanics modelling of ice shelves.

The project work will lead to new insights into the role of meltwater in triggering ice shelf collapse and, through a more explicit treatment of the thermal budget, to future improvements of ice shelf and climate models.

Student Prerequisites

A successful candidate will have a degree (2(i) minimum) in applied mathematics, physics, engineering, or a similar numerate subject, along with an aptitude for applying physical principles to solve real world problems and computer programming.

Training and support

The student will receive instruction in the physics of ice mechanics and thermodynamics, guidance in the computational and mathematical model development, and conduction of numerical experiments and analysis of results. UCL has a programme of courses promoting transferable skills such as time management, presentation, and report writing.

Application procedure

If you are interested in this PhD position, contact Dr. Feltham directly dlf@cpom.ucl.ac.uk. In order to apply for Departmental funding for this studentship, an application must be received no later than Monday 13 Feb 2012. If this deadline is missed, there may be other opportunities for funding. NERC funding is only available for UK students. More information about CPOM can be found at www.cpom.org.

References

Scambos, TA, Hulbe, C, Fahnestock, M, and J Bohlander, The link between climate warming and break-up of ice shelves in the Antarctic Peninsula, *J. Glaciology*, 46 (154), pp 516-530, 2000.

Glasser NF, Kulessa, B, Luckman, A, Jansen, D, King, EC, Sammonds, PR, Scambos, TA and KC Jezek, Surface structure and stability of the Larsen C ice shelf, Antarctic Peninsula, *J. Glaciology*, **55** (191), 400-411, 2009.

Scott, F, DL Feltham, A model of the three-dimensional evolution of Arctic melt ponds on First-year and Multi-year sea ice, *J. Geophysical Research,* doi:10.1029/2010JC006156, 2010.