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Rate-limiting processes during rapid deglaciation of marine ice sheets

D. G. Vaughan
British Antarctic Survey, Cambridge, United Kingdom (d.vaughan@bas.ac.uk)

The debate concerning the stability of marine ice sheets has continued for many years. Recent contributions have advanced the debate substantially, and shown that under specific conditions, marine ice sheet margins could be unstable. This insight has reinforced widely held concerns that marine ice-sheet collapse could substantially add to sea-level rise in coming centuries. However, determination of the stability-condition of marine ice sheet margins is only one step towards evaluating the risk inherent in such ice sheets. This risk crucially depends on the rate at which collapse could occur. For example; if collapse occurred over several millennia then the additional rate of sea-level rise would be comparable to that arising from other sources, and would probably be considered manageable by many coastal defence planners; conversely, collapse of a major marine ice sheet in less than one millennia, would have profound and costly implications.

In this paper, I will consider the most rapidly changing, and probably the most vulnerable marine ice sheet remaining on the planet; the Amundsen Sea Embayment of West Antarctica. And in particular, ask what would be required to deglaciate this ice sheet within a period of around 500 years. This rate of collapse implies a loss of ice from the ice sheet, at roughly 10-times the current balance flux. To maintain such a retreat, would require that the extra ice-loss would either have to be melted in situ, or exported from the continental shelf as icebergs. I will argue that it is highly unlikely that ice-loss at this rate could be achieved while maintaining an ice-sheet configuration comparable to what we see today, and in particular, that the maintenance of ice shelves is unlikely. With this constraint in mind, I discuss two possible configurations that could maintain ice-loss at this rate, and discuss the rate-limiting processes that might govern the retreat rates that could be achieved. I conclude that the critical processes, which determine the risk posed by marine ice sheets, lie in the interactions of the ice sheet with the surrounding ocean. And in particular, the processes that limit heat-delivery towards ice sheet, and limit export of potentially large icebergs from the continental shelf, are ones that may ultimately control the rates at which marine ice sheets may ultimately be lost.