Coupled Cryosphere/Atmosphere/Ocean Modelling

Rupert Gladstone[1], Tony Payne[1], Victoria Lee[1], Jonathan Gregory[2], Jeff Ridley[2]
1. Bristol Glaciology Centre, School of Geographical Sciences, University of Bristol, U.K.
2. Hadley Centre, Exeter, U.K.

Figure 1: Components of the coupled system and exchange of key variables

Abstract

A coupled computer model (or simulator) is being constructed incorporating key Cryosphere – Earth system interactions. This simulator will be validated through comparison with observations of the recent past, in particular the thinning of the Pine Island Glacier (PIG), a part of the West Antarctic Ice Sheet (WAIS). The simulator can then be used to make predictions about the future behaviour of the WAIS, much of which is a marine ice sheet (i.e. resting on bedrock below sea-level) and hence potentially vulnerable to rapid retreat leading to several metres of sea level rise.

Expanding the coupling between the ice sheet simulator and ocean simulator is key for WAIS simulations. The movement of the grounding line (the division between grounded and floating ice) is strongly influenced by basal melt rates under the floating ice shelves. Changes to the basal melt rate are largely induced by changing oceanic conditions. Hence we will use ice front ocean properties from an ocean simulator to drive a plume model (representing sub ice shelf cavity circulation) which in turn will calculate basal melt rates.

The coupling of climate model FAMOUS (essentially a lower resolution version of HadCM3) to the ice sheet model GLIMMER was carried out by Jonathan Gregory and colleagues at Reading. This coupling code is in use at the Bristol Glaciology Centre, where it now functions with HadCM3 and is being further developed.

Modelled ocean variability

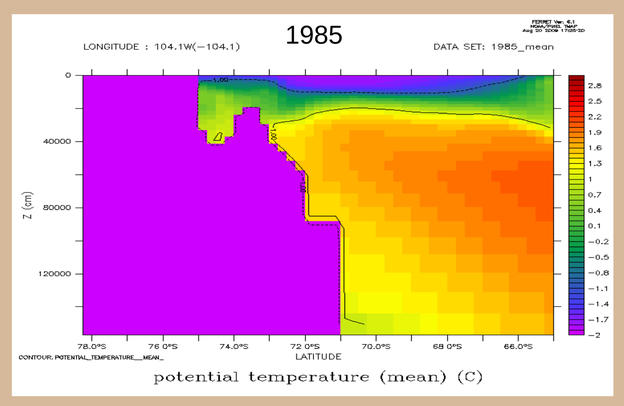
In order to make realistic use of ice shelf front ocean properties, we need firstly to check whether changing ocean conditions are captured by the ocean simulator(s). Figures 2 and 3 show ocean temperatures with depth and latitude for two different ocean simulators in the vicinity of the PIG.

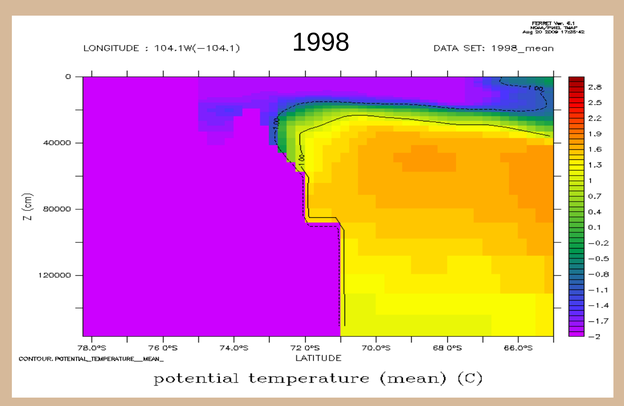
Figure 2 shows ocean potential temperature from the OCCAM ocean simulator. This is a high resolution (1/4 degree shown but 1/16 degree also available) ocean simulator that has been used to attempt to reproduce recent past ocean circulation. We do not yet know whether the high temperatures in 1985 are due to OCCAM spin up processes or are genuinely anomalously high temperatures. From late 80s to 2003 (the current limit of available OCCAM data) the interannual variability of temperatures is typically a few tenths of a degree, up to around one degree max. From 1998 to 2000 a warmer band of water (blue in the figures) can be seen sinking below the shelf break level. The 1ºC and -1ºC degree contours are shown.

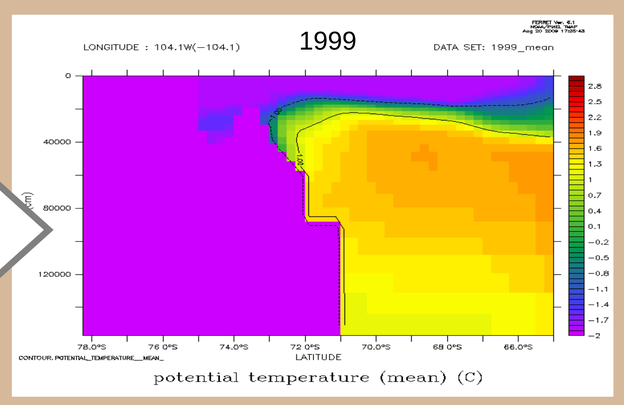
Figure 3 shows ocean temperature from a pre-industrial HadCM3 ocean sub model simulation. A variability of a few tenths of a degree can be seen near the shelf break. This run was with constant forcing, all variability is internal. The 0.8ºC and -0.8ºC degree contours are shown.

We are currently planning both fully coupled simulations using HadCM3, and 'offline' (i.e. without interactive atmosphere/ocean coupling) simulations where OCCAM will drive the ice sheet/plume model system.

Figure 2: OCCAM output







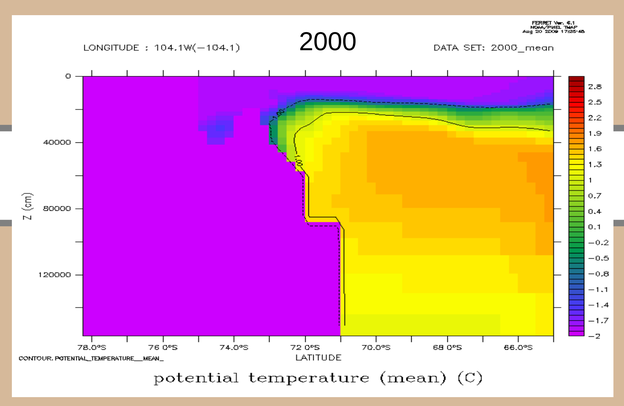


Figure 3: HadCM3 output