Simulated water masses and changes near Antarctica: A comparison of ocean models

Rupert Gladstone (1), Tilo Burghardt (1), Bruno Golenia (1), Oliver Ray (1), Ian Culverwell (2), Jonathan Gregory (2, 3), Hartmut Hellmer (4) and Tony Payne (1)
(1) University of Bristol, UK (r.gladstone@bristol.ac.uk), (2), Met Office Hadley Centre , UK, (3) University of Reading, UK, (4) Alfred Wegener Institute, Germany

Warming of ocean waters over the continental shelf is thought to have caused recently observed thinning of ice streams in the Amundsen Sea sector of West Antarctica, through increased melting at the base of the floating ice. This warming likely indicates an increased inflow of Circumpolar Deep Water (CDW) onto the shelf. Thus in order to make model-based predictions of future marine ice sheet behaviour, ice sheet models need to be forced by realistic future ocean temperature projections. Here we ask whether the CMIP3 atmosphere ocean general circulation models (AOGCMs) give a coherent and plausible representation of ocean circulation in the vicinity of the Pine Island Glacier (Figure 1), and hence whether such models provide adequate tools for driving future model-based ice sheet predictions.

The short answer is "no". The models show a great diversity of ocean temperature patterns near the Pine Island Glacier (PIG, Figure 2). They also show great diversity in terms of trends and variability of temperature near the PIG (Figure 4) and in other regions (not shown, see Figure 1).

Figure 1, study regions

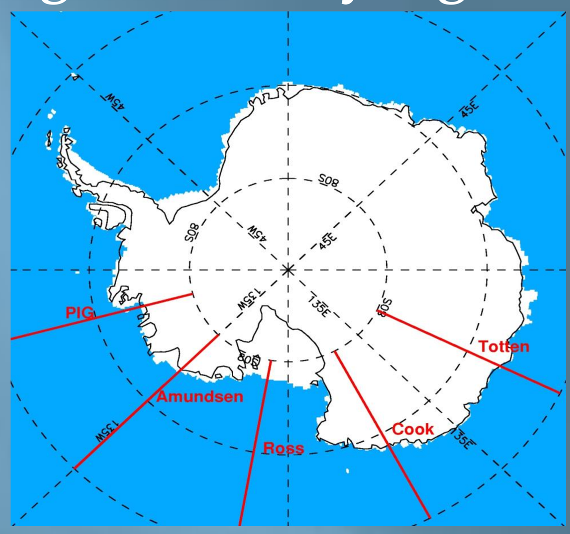
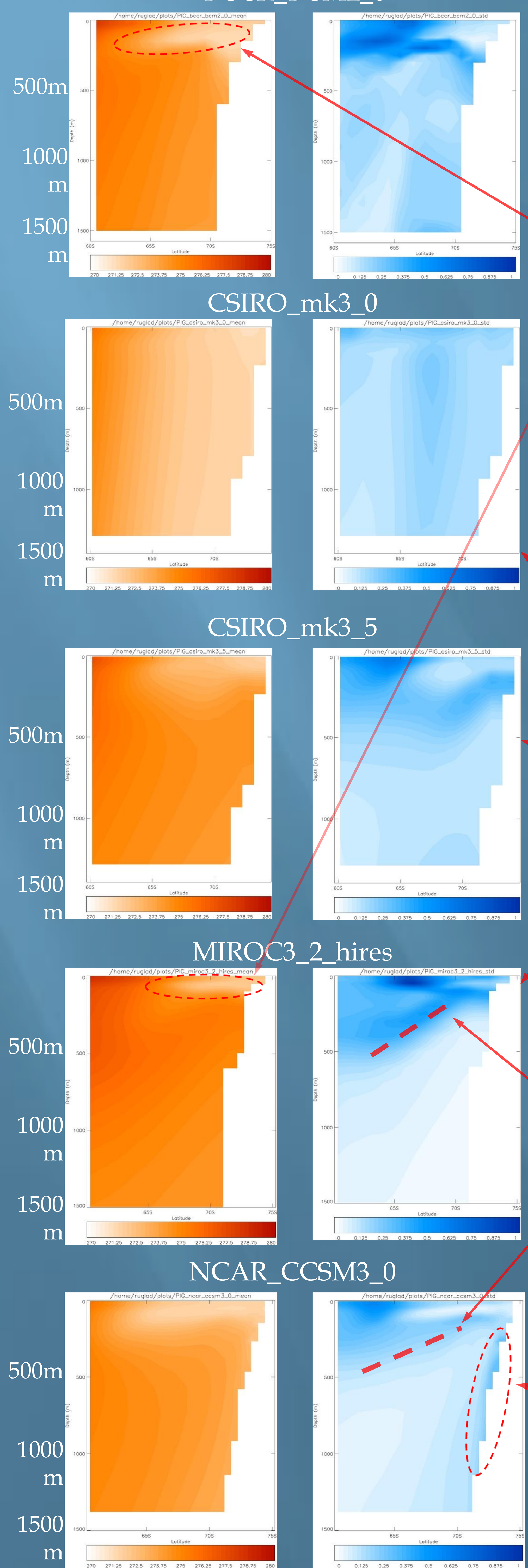


Figure 2, Pine Island ocean temperatures

(based on yearly means, so without seasonal cycle)



Latitude range is 60S to 75S

BCCR_BCM2_0 is an isopycnal model (using density instead of depth for the vertical coordinate)

Winter water, the base of the winter mixed layer, can be seen in some models. Or is this shelf water (SW)?

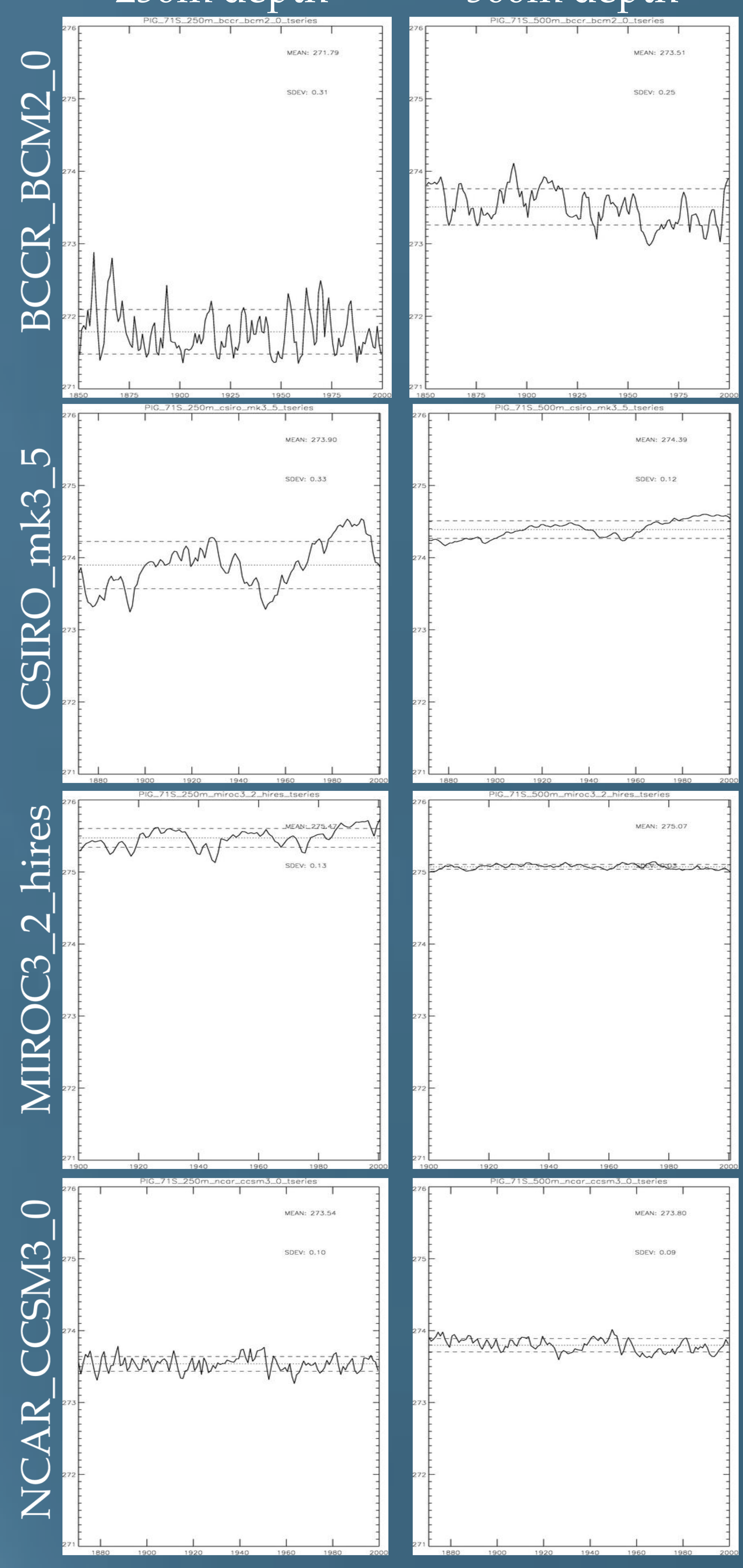
Some models have extremely high flow in the Antarctic Circumpolar Current, associated with a temperature structure dominated by vertical stratification. CSIRO_mk3_0 is an example of this. This is thought to be due to low diffusivity in the eddy parameterisation scheme, corrected in CSIRO_mk3_5 by use of a more recent scheme (Tony Hirst, personal communication).

MIROC3_2_hires has the highest resolution of the CMIP3 AOGCMs, and is eddy permitting.

Some AOGCMs feature a slanting band of higher variability water, possibly circumpolar deep water subject to wind-driven upwelling.

Some models feature high variability on the continental shelf slope, perhaps indicating bottom water formation.

Figure 3, yearly mean temperatures near PIG from 1850 to 2000



Temperatures are shown at the nearest grid point to 71S at the depths stated. Temperatures are shown on the y-axis, which ranges from 271K to 276K in all plots.

The time mean is shown as a faint dotted line and plus or minus one standard deviation is indicated by the dashed lines.

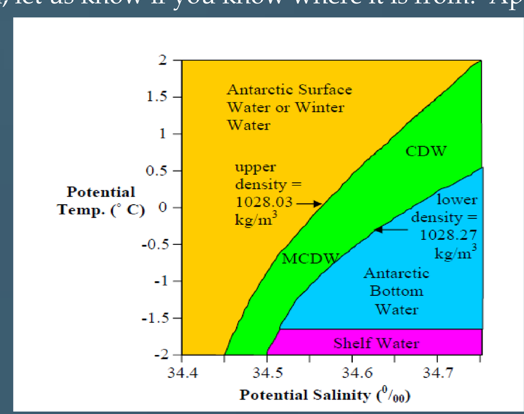
The time mean, variability, and trends differ greatly from model to model.

Water mass identification

Next steps involve comparing the CMIP3 models against high resolution models and against observations. We also want to analyse the behaviour of CDW in the models, but this brings its own problems.

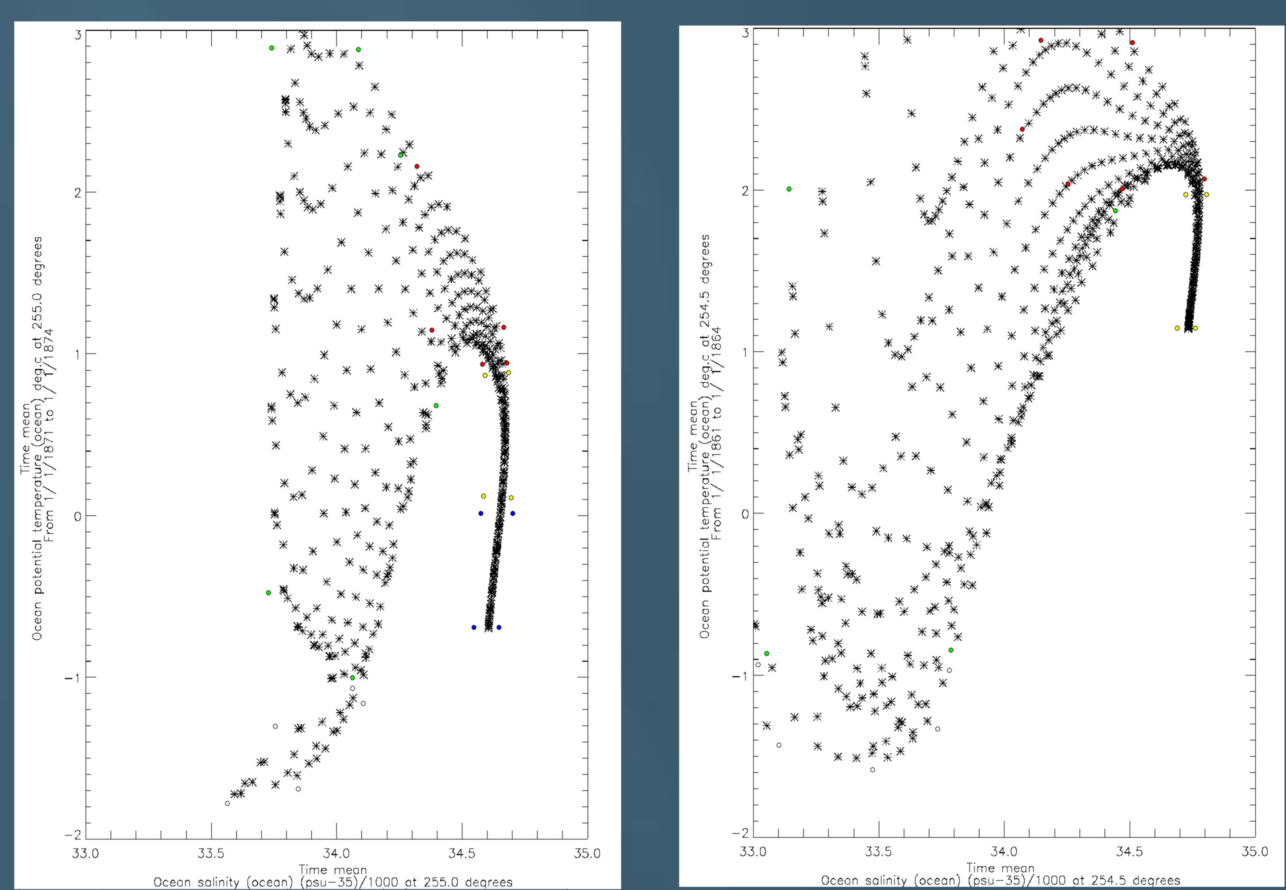
Figure 4, water mass classification.

Credit: unknown, we think this came from a PhD thesis from University of Tasmania, let us know if you know where it is from! Apologies.



Water mass definitions in the published literature are based on partitioning temperature salinity (TS) space, usually with density (potential or neutral) contours, e.g. Figure 4. But given the varying strucures in TS space from model to model (Figure 5) such a rigid classification may not be appropriate.

Figure 5, annotated TS plots from 2 different AOGCMs



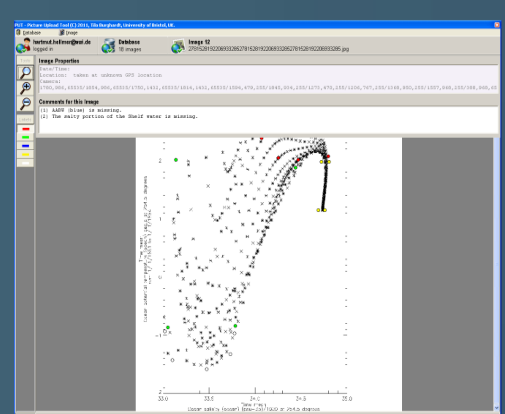


Figure 6, Annotation software

We are currently using software for image annotation (Figure 6), along with AI and image processing techniques, to capture and automate the water mass identification processes of human experts.