Multi-model assessment of the deglacial climatic evolution at high southern latitudes

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The Quaternary climate is characterized by glacial-interglacial cycles, with the most recent transition from the last glacial maximum to the present interglacial (the last deglaciation). While the deglacial warming at high southern latitudes is mostly in phase with atmospheric CO2 concentrations, some proxy records indicate that the onset of the warming occurred before the CO2 increase. In addition, high southern latitudes exhibit a cooling event in the middle of the deglaciation known as the “Antarctic Cold Reversal”. In this study, we analyse transient simulations of the last deglaciation performed with six different climate models as part of the 4th phase of the Paleoclimate Modelling Intercomparison Project (PMIP4) to understand the processes driving high-southern-latitude surface temperature changes. As the protocol of the last deglaciation sets the choice of freshwater forcing as flexible, the freshwater forcing is different in each model, thus complicating the multi-model comparison. While proxy records from West Antarctica and the Pacific sector of the Southern Ocean suggest the presence of an early warming, only half the models show a significant warming at this time. All models simulate a major warming during Heinrich Stadial 1, concurrent with the CO2 increase and with a weakening of the Atlantic Meridional Overturning Circulation (AMOC) in some models. However, the simulated Heinrich Stadial 1 warming over Antarctica is smaller than the one suggested from ice core data. During the Antarctic Cold Reversal, simulations with an abrupt AMOC strengthening exhibit a high-southern-latitude cooling, in relative agreement with proxy records, while simulations with rapid North Atlantic meltwater input exhibit a warming. Using simple models to extract the relative AMOC contribution, we find that all climate models simulate a high-southern-latitude cooling in response to an AMOC increase with a response timescale of several hundred years, suggesting the choice of the North Atlantic meltwater forcing substantially affects high-southern-latitude temperature changes. Thus, further work needs to be carried out to reconcile the deglacial AMOC evolution with the Northern Hemisphere ice sheet disintegration and associated meltwater input. Finally, all simulations exhibit only minimal changes in Southern Hemisphere westerlies and Southern Ocean meridional circulation during the last deglaciation. Improved understanding of the processes impacting Southern Hemisphere atmospheric and oceanic circulation changes accounting for deglacial atmospheric CO2 increase is needed.

Keywords: deglaciation, climate model, southern Ocean, AMOC