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Influence of Antarctic Ice Sheet Lowering on the Southern Hemisphere Climate: Model Experiments Mimicking the Mid-Miocene

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Conditions in Antarctica have varied substantially in the Earth's climate history. During the early Miocene (23-17 Ma), as suggested by records from the Ocean Drilling Program (ODP) Sites 1090 and 1218, the ice volume was approximately 50%-125% of its present-day values. It has been argued that the rapid Cenozoic glaciation of Antarctica was induced by a decline in atmospheric CO_2 from 4 times to 2 times preindustrial atmospheric level over a 10-Myr period. Minor contributions to this glaciation have also been associated with the opening of Southern Ocean gateways between Antarctica and the Australia-Tasmanian Passage, and Antarctica and the South America-Drake Passage, although it has been argued that the total amount of water owing in the Drake passage during the Eocene/Oligocene boundary may have been insufficient for reducing the poleward heat transport. The AIS is responsible for the greater amount of reflected solar radiation in the SH, and has significantly influenced meridional circulation due to its role in the characterization of the latitudinal thermal gradient. Moreover significant interaction between the polar and tropical regions through the link between the ENSO and West Antarctica has been demonstrated. It has been suggested that warming episodes during the Miocene were closely related to small changes in the Southern Ocean's freshwater balance. Paleorecords (ODP Sites 1090 and 1218) have also been utilized to disentangle the nature of deep-sea water mass. The analyses have demonstrated that warmer bottom water coexisted with increased production of Antarctic Bottom Water during the Plio-Pleistocene (1.6Ma) compared to today.

We have investigated impacts of changes to the AIS topography on the climate system by using a coupled climate model, an Earth Model of Intermediate Complexity (EMIC), namely Speedy-Ocean (SPEEDO). We have designed experiments to inter-compare the nature of the atmospheric and oceanic circulation under modern conditions and those conditions induced by anomalous AIS topographic forcing. Based on different climate simulations of the present day and conducted with distinct Antarctic ice sheet topography, it is found that the reduction of the AIS induces warming of the Southern Hemisphere and reduces the meridional thermal gradient. Consequently, the transient low level eddy heat flux and the eddy momentum flux are reduced causing the reduced transport of heat from the mid-latitudes to the pole. The stationary flow and transient wave anomalies generate changes in the SSTs which modify the rate of deep water formation, strengthening the formation of the Antarctic Bottom Water. Substantial changes are predicted to occur in the atmospheric and oceanic heat transport and a comparison between the total heat transport of the atmosphere-ocean system, as simulated by the current and the reduced AIS runs, shows that the reduction of the Antarctic ice sheet height leads to reduced Southern Hemisphere poleward and increased equatorward heat transport. Further, these results yield reduced storm track activities and baroclinicity.