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Southern Hemisphere Surface Climate and Ocean Circulation Response to Antarctic Meltwater in a Warming World

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The Southern Hemisphere (SH) has seen prominent climate changes during the past decades that are not captured by climate models in historical simulations employing observed radiative forcing. One example is the cooling of the Southern Ocean sea surface temperature (SST) in large areas. Another example is the expanding Antarctic sea ice extent since the start of the satellite measurements. The historical simulations, however, do not incorporate the meltwater from the Antarctic ice sheet which is losing mass. Here we investigate by means of dedicated climate model simulations the potential role of Antarctic (AA) meltwater for the SH surface climate and ocean circulation, an influence that is also ignored in most short-term and long-term climate change projections. AA meltwater forcing (up to 0.1 Sv) with varying amplitude and idealized spatial pattern that is constant in time is incorporated in ensemble global warming simulations in which the preindustrial atmospheric carbon dioxide (CO_2) concentration rises at a rate of 1%/year (compound). To distinguish the influence of the meltwater forcing from that of the CO_2-forcing, companion ensemble simulations are conducted, which either do not employ a meltwater forcing or a CO_2-forcing.

When the AA meltwater is incorporated in the global warming simulations, SH surface warming and sea ice retreat is delayed by several decades relative to simulations without the meltwater. The AA meltwater drives significant changes in the oceanic meridional overturning circulation (MOC), in particular a slowing of the Antarctic Bottom Water Cell. Further, the meltwater slows the Antarctic Circumpolar Current (ACC), which is gradually offset by strengthening of the Southern Annular Mode (SAM) developing in response to the rising atmospheric CO_2-concentration: a stronger SAM is associated with more intense and southward shifting westerly surface winds over the SH mid-latitudes, which favors a stronger ACC. The ACC slowing due to the Antarctic meltwater may thus be an important factor when discussing the future evolution of the ACC. This study suggests that climate model projections for the 21st century could benefit from incorporating the meltwater from the Antarctic ice sheet.