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Warming, Contraction, and Freshening of Antarctic Bottom Water since the 1990s, with a Potential Ice-Sheet Melt Feedback.

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We analyze changes in Antarctic Bottom Waters (AABW) around the deep Southern Ocean using repeat section data collected between 1981 and 2012. The international World Ocean Circulation Experiment (WOCE) Hydrographic Program collected a global high-quality baseline of full-depth, accurate oceanographic transects in the 1980s and 1990s. Since the 2000s, some of these transects are being reoccupied, again through international collaboration, as part of GO-SHIP (The Global Ocean Ship-Based Hydrographic Investigations Program). The average dates of the first and last data used to estimate these trends are circa 1991 and 2008.

Temperature analyses reveal a nearly global-scale signature of warming in the abyssal ocean ventilated from the Antarctic. In the deep basins around Antarctica, AABW warmed at a rate of 0.02 to 0.05 ºC per decade below 4000 m. In addition, the waters between 1000 and 4000 m within and south of the Antarctic Circumpolar Current warmed at a rate of about 0.03 ºC per decade. With this warming, cold, deep isotherms are sinking in the Southern Ocean. The 0 ºC potential isotherm sinking rate is around 100 m per decade, implying a 8.2 ($\pm$2.6) Sv contraction rate of AABW, about 7% per decade.

In addition to this contraction, AABW freshening is observed within the Indian and Pacific sectors of the Southern Ocean. The freshening signal is stronger closer to AABW sources. Its spatial pattern implies recent changes in AABW formation, perhaps partly owing to freshening of the shelf waters, which has been linked to increases in glacial ice sheet melt. The observed rate of water-mass freshening for AABW colder than 0ºC in the Indian and Pacific Sectors of the Southern Ocean is about half of the estimated increase in mass lost by glacial ice sheets there in recent years.

A positive feedback loop might link the AABW contraction and ice sheet melt-influenced freshening as follows: Increased ocean heat flux drives enhanced basal melt of floating ice shelves. Increased meltwater freshens shelf waters, increasing their buoyancy and reducing the formation rate and/or density of AABW. The contraction of AABW results in expansion of relatively warm Circumpolar Deep Water (CDW). If expansion of CDW increases the ocean heat flux to the base of the ice shelf, a positive feedback loop is completed. Such a feedback would imply a stronger sensitivity of both AABW formation and mass balance of the Antarctic ice sheet to ocean warming than in the absence of such a process.

Deep ocean warming makes a significant contribution to global energy and sea-level rise budgets and influences the rate and magnitude of climate change in response to a given greenhouse gas forcing. Better understanding the potential mechanisms for effecting such deep warming, such as the one proposed here, may aid the goal of improved climate change projections, based on coupled climate models that better represent these processes.