Covariation of deep Southern Ocean oxygenation and atmospheric CO_2 through the last ice age

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Although no single mechanism can account for the full amplitude of past atmospheric CO_2 variability over glacial-interglacial cycles, a build-up of carbon in the deep ocean has emerged as a central mechanism for low CO_2 during the Last Glacial Maximum (LGM). However, the mechanisms by which this deeply sequestered carbon was released again, and the relative importance it played in the history of atmospheric CO_2 prior to the LGM, have remained subjects of debate. Here, we present new sedimentary records from the South Atlantic Ocean that provide an unprecedented reconstruction of transient changes in deep ocean oxygenation and, by inference, respired carbon storage throughout the last glacial cycle. Our results suggest that respired carbon was removed from the abyssal Southern Ocean during the northern hemisphere cold phases of the deglaciation, when atmospheric CO_2 rose rapidly, reflecting - at least in part - a combination of dwindling iron fertilization by dust and enhanced deep ocean ventilation. Furthermore, our new records show that the correlation between atmospheric CO_2 and abyssal Southern Ocean oxygenation was maintained throughout most of the prior 80 kyrs, suggesting a consistent role of the Southern Ocean on millennial timescales through a coupled control on deep ocean circulation and iron fertilization.

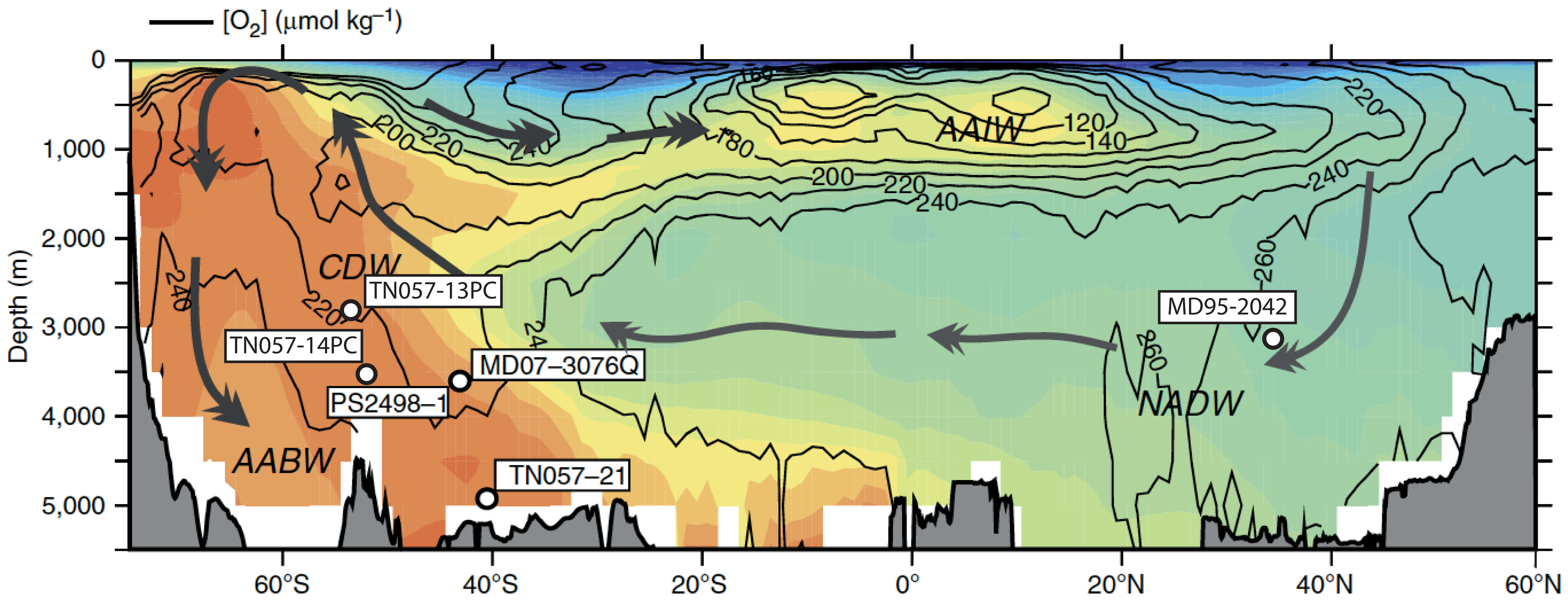

FIG. 1. Modern ocean dissolved oxygen concentrations in a meridional transect across the Atlantic (averaged between 70°W and 20°E). Arrows show general pathways of North Atlantic Deep Water (NADW), Antarctic Bottom Water (AABW), Circumpolar Deep Water (CDW) and Antarctic Intermediate Water (AAIW). Modified after Gottschalk et al., 2016.

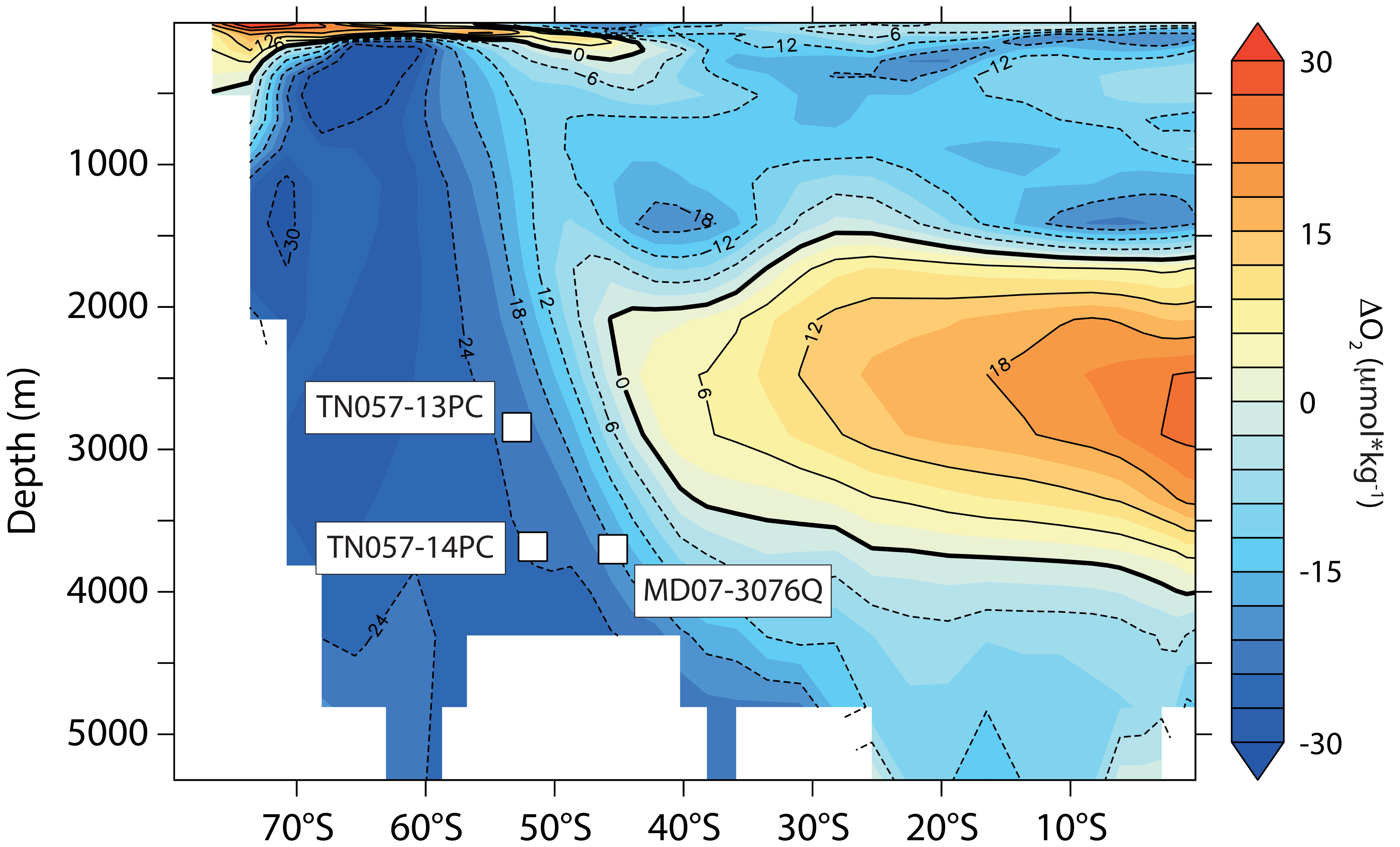

Fig. 2. Idealized model experiments illustrating the impact of AABW production on dissolved oxygen relative to the core locations. Shaded contours show the difference in dissolved oxygen averaged between 25°W and 10°E, for a coupled model simulation with strong Weddell convection compared to a simulation with moderate Weddell convection (Jaccard et al., 2016).

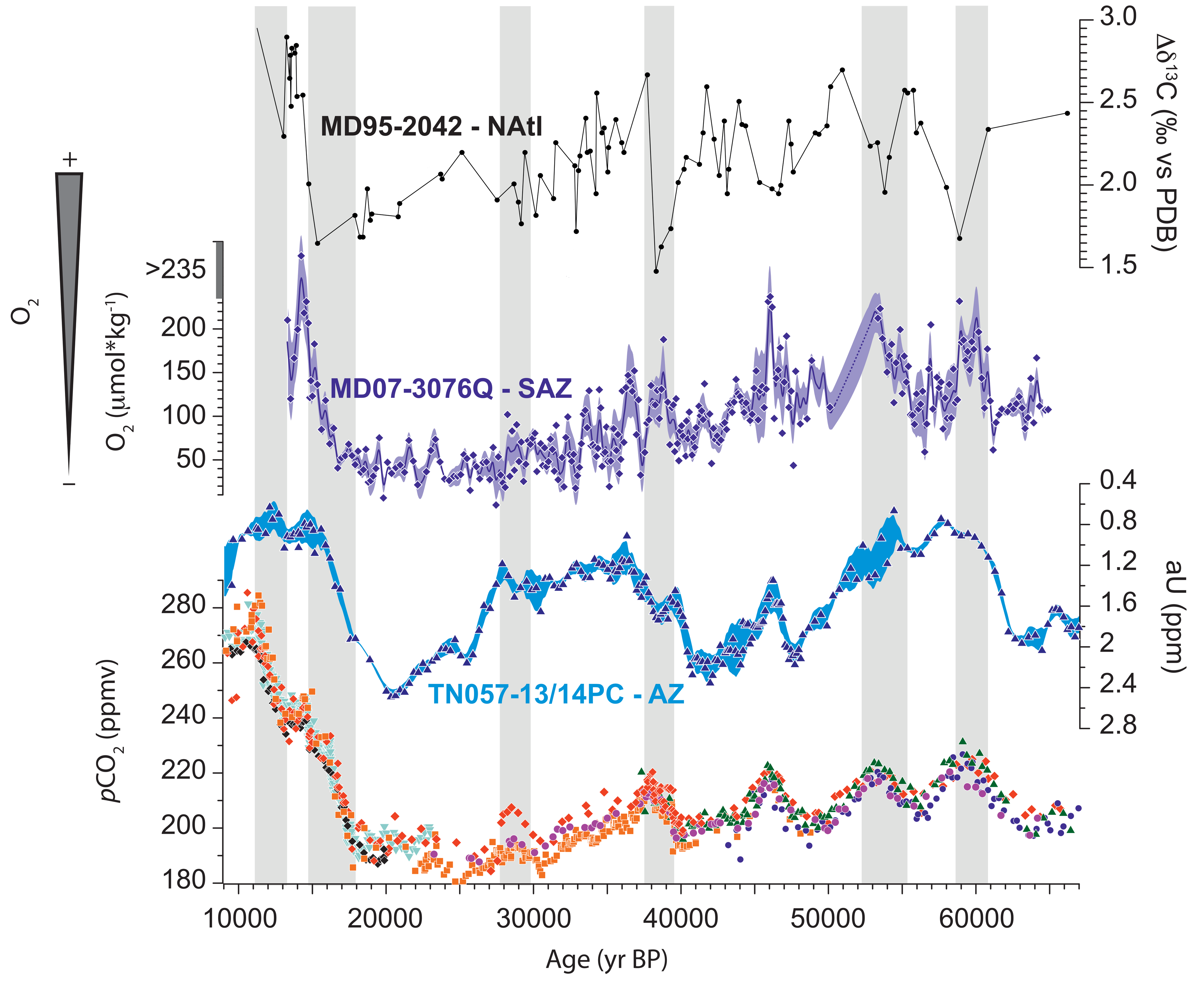

Fig. 3. Atlantic Ocean bottom water O_2 during the last glacial and deglacial periods. (a) downcore $\Delta\delta^{13}C$ at North Atlantic site MD95-2042 (Hoogakker et al., 2015); (b) $\Delta\delta^{13}C$-derived bottom water O_2 at Subantarctic site MD07-3076Q (Gottschalk et al., 2016); (c) sedimentary authigenic U (aU) concentration at Antarctic sites TN057-13/14PC (Jaccard et al., 2016); (d) composite $CO_{2,atm}$ variations recorded in Antarctic ice cores (Ahn & Brook, 2014; Bereiter et al., 2012; Marcott et al., 2014). All data refer to the AICC2012 age scale (Veres et al., 2013).