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Importance of sea-ice processes for Southern Ocean stratification inferred from the oxygen isotopic composition of seawater

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Southern Ocean surface waters typically exhibit only a marginal surface density stratification, which is mainly established by a net supply of freshwater to the surface ocean. Accordingly, small temporal and spatial variations in the surface freshwater flux balance can substantially impact the stratification and the related exchange of deep and surface waters; this exchange has strong influences on the transfers of heat and carbon between the ocean and atmosphere, and hence climate. However, observations of surface freshwater fluxes from this region are sparse and have large uncertainties. Here, we present a novel dataset of oxygen isotopes and salinity that we collected during the "Antarctic Circumnavigation Expedition" (ACE) and the "Ocean Regulation of Climate by Heat and Carbon Sequestration and Transports" (ORCHESTRA) project in 2016 and 2017. These data reveal clear isotopic signatures of the atmospheric, sea ice, and land ice freshwater fluxes in different water masses. Oxygen isotope values closely follow the atmospheric signal north of the Subantarctic Front and show very little variation south of the Subantarctic Front due to the influence of upwelling deep waters. We find a dominant contribution of sea-ice freshwater fluxes in the surface waters south of the Subantarctic Front. The net removal of freshwater through sea-ice formation and export in the coastal and bottom waters balances an input of glacial meltwater from Antarctica and a net positive atmospheric freshwater flux. In the open ocean Antarctic surface waters, we find a major contribution of net supply of freshwater from sea-ice melting. Our analysis shows that sea-ice processes play a key role in setting up the Southern Ocean salinity stratification and thereby influence the global ocean meridional overturning circulation.