

Southern Ocean circulation and change: Two decades of sustained observations south of Australia

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Over the last 50 years, more heat and anthropogenic carbon dioxide has accumulated in the Southern Ocean than in any other latitude band of the ocean. The storage of heat and carbon dioxide by the Southern Ocean is a result of the vigorous overturning circulation, in which water mass transformations in the Southern Ocean connect the upper and lower limbs of the global overturning circulation. The Antarctic Circumpolar Current (ACC), the largest current in the global ocean, connects the ocean basins and allows a global overturning circulation to exist. The Southern Ocean therefore plays an important role in regulating climate and changes in the Southern Ocean would be expected to have global consequences. For the last two decades, Australia has used a variety of tools (repeat hydrography and XBT sections, moorings, floats, elephant seals and satellite altimetry) to observe the circulation in the Australian sector of the Southern Ocean. The repeat sections have been used to document the invariance of the baroclinic transport of the ACC; describe the filamented nature of the ACC and the robust association of jets with baroclinic streamlines, which has allowed the spatial and temporal variability of the fronts to be assessed from satellite altimetry with unprecedented detail; and tracking of water mass changes throughout the water column. The most notable signal of water mass change is the monotonic freshening since the late 1960s of Antarctic Bottom Water formed in the Ross Sea and Adelie/Wilkes Land. Moored measurements have confirmed a strong western boundary current carrying Antarctic Bottom Water northward along the eastern flank of the Kerguelen Plateau; quantified the export of dense shelf water from the Adelie/Wilkes Land region; and revealed the barotropisation of the Subantarctic Front as it navigates the narrow gaps in the Macquarie Ridge. Floats have been used to identify and quantify the physical mechanisms responsible for subduction of water masses and anthropogenic carbon dioxide; to reveal the circulation pathways of Subantarctic Mode Water; and to document the evolution of changes in Southern Ocean climate. Oceanographic data collected by elephant seals has been used to map high latitude fronts, infer sea ice formation rate, and identify locations where ocean heat may reach the base of floating glacial ice and cause enhanced basal melt. Repeat in-situ measurements have been exploited to develop proxies allowing ACC transport and variability and water mass changes to be diagnosed from satellite altimetry, allowing a detailed, circumpolar view of Southern Ocean change and variability. Taken together, these results demonstrate the power of sustained, integrated observations.