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Slowing of the ocean's deep breath

The deepest reaches of the ocean are ventilated by sinking of cold and relatively saline seawater around Antarctica. Observations from the Australian sector of the Southern Ocean reveal a decline in sinking and abyssal ventilation, linked to dropping ocean salinity on the Antarctic shelf.

The deeper half of the World Ocean, below 2 km depth, is renewed by sinking of cold and dense waters in localized gravitational plumes around Antarctica and the North Atlantic¹. Antarctic sinking plumes carry the densest waters, and constitute the primary ventilation pathway—or “respiratory route”—connecting the abyssal ocean (deeper than 3 km) to the atmosphere². By transferring mass, oxygen, nutrients and carbon from the surface to large depths, this pathway influences major ocean circulation cells^{2,3}, Antarctic glaciers⁴, marine ecosystems and global climate⁵. An ongoing slowdown of this ventilation pathway has been suspected based on observed widespread warming of bottom waters⁶. However, trends in Antarctic sinking and causes of abyssal warming have remained elusive due to a lack of direct observations of ocean flows. Writing in *Nature Climate Change*, [Kathryn Gunn et al.](#)⁷ show observational evidence that transport of bottom waters in two important plumes feeding the abyssal Australian Antarctic basin has dwindled since the early 1990s. The transport trends mirror trends in the salinity of source waters on the Antarctic shelf, suggesting that projected mass losses of Antarctic ice⁸ may further stifle abyssal ventilation by freshening and lightening shelf waters.

Observing mass transports in the deep ocean is challenging, because water velocity measurements rely on costly moored arrays of acoustic current profilers. Such moorings provide information about ocean velocities at a single location and typically for only a year or two between deployment and recovery. Basin-scale flow rates, let alone multidecadal trends in flow rates, are therefore extremely difficult to measure. Moreover, inverse methods that infer flow rates from more common hydrographic measurements, such as temperature and salinity, usually reconstruct only a time-mean ocean circulation state⁹. Fundamental observational constraints thus explain why long-term changes in deep ocean circulation, and a fortiori changes in downwelling around the remote Antarctic continent, remain hardly known.

Gunn et al.⁷ circumvent these constraints by making three astute choices. First, they restrict their focus to three main gateways to the deep Australian Antarctic basin, which borders the white continent between 80°E and 150°E and extends to about 50°S. Second, they use one-year-long mooring measurements at these gateways to derive a relationship between

density and speed in the near-bottom layer. By combining this relationship with repeated measurements of temperature, salinity and pressure (which together determine density) at the same locations over recent decades, they obtain temporal changes in the speed of sampled bottom-water plumes. Third, they employ a realistic, high-resolution model simulation to convert local speeds into total mass transports within the near-bottom layer. It is this combination of moored velocity measurements, repeated hydrographic measurements and information from a model simulation that allows the reconstruction of evolving flow rates into this abyssal basin between 1994 and 2017. This reconstruction indicates a decline of net bottom-water transport into the Australian Antarctic basin by about 30% over this time period.

The calculated decline in transport includes a relatively large uncertainty range because it relies on temporally spaced hydrographic observations and imperfect mooring and model derived conversion functions. Even so, separate lines of evidence corroborate the downward trend in transport. In accord with previous work⁶, the authors find a descent of temperature and density surfaces in the considered abyssal basin, of about 60 m per decade. This downward shift of water bodies, observed over much of the water column, is consistent with a loss of the coldest and densest categories of bottom water. Importantly, the authors also report a loss of oxygen in the abyssal layer, which is a hallmark of reduced ventilation—that is, of reduced communication between the atmosphere and abyssal seas. The measured oxygen loss is attributed to slowing gravitational plumes rather than reduced oxygenation of source waters on the Antarctic margin (Fig.1).

Gunn and colleagues⁷ link the slowdown of gravitational sinking to a decrease in the salinity, and therefore in the density, of the dense shelf waters that initiate the cascading down the continental slope of Antarctica. This mechanism is consistent with the model-based expectation that freshening of Antarctic coastal waters—as may result from losses of Antarctic ice—hinders gravitational sinking⁸. In addition, salinity observations on the Ross Sea continental shelf, a key source region for the deep Australian Antarctic basin, support a downward trend over the 1957-2020 period¹⁰. However, strong interannual to decadal variations are superimposed on this downward trend¹⁰, including a pronounced rebound of dense shelf water salinity during 2014-2018, which was linked to transient wind and sea-ice anomalies¹¹. This rebound highlights the difficulty to predict long-term trends and the risk of aliasing short-term variability with temporally sparse measurements. Continuing observations in the major source regions and abyssal gateways are thus of utmost importance to reduce uncertainty in observed changes and their causes.

The Australian Antarctic basin occupies just one fifth of the latitude band encircling Antarctica, and its abyss is fed from source regions known to be influenced by increased meltwater release from the West Antarctic ice sheet^{8,10}. Observational studies in other sectors of the Southern Ocean are in need to probe the circumpolar trend in Antarctic sinking, and to discriminate the relative roles of wind, sea-ice and glacier changes on global abyssal ventilation. Such efforts are likely to uncover previously unforeseen interactions between the ocean, atmosphere and cryosphere in this data sparse region.

Potential changes in North Atlantic dense water formation and sinking have received substantial attention for several decades. In comparison, changes in Antarctic sinking, and

their repercussions on climate, sea level and marine ecosystems, are only emerging concerns. Gunn et al.⁷ orient and impel this field of research by bringing to light the mechanism and magnitude of ongoing abyssal ventilation changes, in a basin that channels a sizeable proportion of bottom waters in transit from Antarctica to the global ocean abyss.

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Competing interests

The author declares no competing interests.

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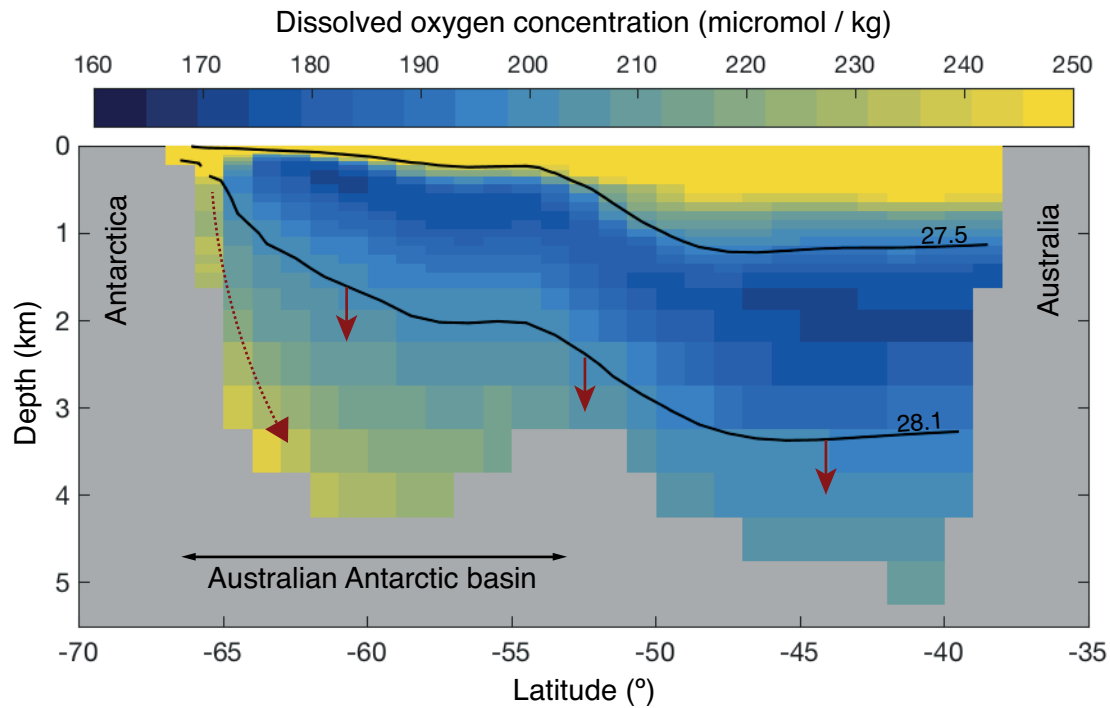


Fig. 1: Slowdown of Antarctic sinking drives deoxygenation of the deep ocean. Shading shows observed dissolved oxygen concentrations, from the gridded product GLODAPv2 (ref. 12), along a 140°E transect joining Antarctica and Australia. This transect cuts through the Australian Antarctic basin, which lies south of 53°S. Black contours mark two selected density surfaces (neutral density values of 27.5 and 28.1) that separate low-oxygen mid-depth waters from high-oxygen upper and abyssal waters. In the high-density abyssal volume, oxygen is supplied by sinking along the Antarctic continental slope. Gunn and co-authors⁷ show that an ongoing decline in sinking (dashed red arrow) drives substantial oxygen loss in the deep ocean via contraction of the well-ventilated abyssal volume (downward red arrows).