The southern limb of the ocean’s meridional overturning circulation plays a key role in the Earth’s response to past and future climate change. The rise in atmospheric CO$_2$ during glacial-interglacial transitions has been attributed to outgassing of enhanced upwelling water masses in the Southern Ocean, while subducting water masses currently represent a significant fraction of the global anthropogenic CO$_2$ and heat sinks.

Previous modelling studies of the Southern Ocean have focused on the effect of wind stress forcing on the overturning, while largely neglecting the response of the upper overturning cell to changes in surface buoyancy forcing. Using a series of eddy-permitting, idealised simulations of the Southern Ocean, we show that surface buoyancy forcing in the mid-latitudes is likely to play a significant role in setting the strength of the overturning circulation. Air-sea fluxes of heat and precipitation over the Antarctic Circumpolar Current region act to convert dense upwelled water masses into lighter waters at the surface. Additional fluxes of heat or freshwater thereby facilitate the meridional overturning up to a theoretical limit derived from Ekman transport.

The sensitivity of the overturning to surface buoyancy forcing may influence the future uptake of CO$_2$ by the Southern Ocean and also provides support for the hypothesis that changes in upwelling during deglaciations may have been driven by changes in heat and freshwater fluxes, rather than changes in wind stress.