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Spin-up and adjustment of the Antarctic Circumpolar Current and global pycnocline

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A theory is presented for the adjustment of the Antarctic Circumpolar Current (ACC) and global pycnocline to a sudden and sustained change in wind forcing. The adjustment timescale is controlled by the mesoscale eddy diffusivity across the ACC, the mean width of the ACC, the surface area of the ocean basins to the north, and deep water formation in the North Atlantic. In particular, northern sinking may have the potential to shorten the timescale and reduce its sensitivity to Southern Ocean eddies, but the relative importance of northern sinking and Southern Ocean eddies cannot be determined precisely, largely due to limitations in the parameterization of northern sinking. Although it is clear that the main processes that control the adjustment timescale are those which counteract the deepening of the global pycnocline, the theory also suggests that the timescale can be subtly modified by wind forcing over the ACC and global diapycnal mixing. Results from calculations with a reduced-gravity model compare well with the theory. The multidecadal-centennial adjustment timescale implies that long observational time series will be required to detect dynamic change in the ACC due to anthropogenic forcing. The potential role of Southern Ocean mesoscale eddy activity in determining both the equilibrium state of the ACC and the timescale over which it adjusts suggests that the response to anthropogenic forcing may be rather different in coupled ocean-atmosphere climate models that parameterize and resolve mesoscale eddies.