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On timescales significantly greater than 105 years, atmospheric pCO2 is controlled by the rate of mantle outgassing relative to the set-point of the silicate weathering feedback. The weathering set-point has been shown to depend on the distribution and characteristics of rocks exposed at the Earth's surface, vegetation types and topography. Here we argue that large- scale climate impacts caused by changes in ocean circulation can also modify the weathering set-point and show evidence suggesting that this played a role in the establishment of the Antarctic ice sheet at the Eocene–Oligocene boundary. In our simulations, tectonic deepening of the Drake Passage causes freshening and stratification of the Southern Ocean, strengthening the Atlantic meridional overturning circulation and consequently raising temperatures and intensifying rainfall over land. These simulated changes are consistent with late Eocene tectonic reconstructions that show Drake Passage deepening, and with sediment records that reveal Southern Ocean stratification, the emergence of North Atlantic Deep Water, and a hemispherically asymmetric temperature change. These factors would have driven intensified silicate weathering and can thereby explain the drawdown of carbon dioxide that has been linked with Antarctic ice sheet growth. We suggest that this mechanism illustrates another way in which ocean–atmosphere climate dynamics can introduce nonlinear threshold behaviour through interaction with the geologic carbon cycle.