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The structure and stability of transport and mixing barriers in the Antarctic Circumpolar Current

C. Wilson (1), J. R. Blundell (1), C. W. Hughes (1), M. Mazloff (2), E. Shuckburgh (3), and A. F. Thompson (4)

(1) National Oceanography Centre, United Kingdom (cwi@noc.ac.uk), (2) Scripps Institution of Oceanography, UCSD, United States, (3) British Antarctic Survey, United Kingdom, (4) California Institute of Technology, United States

As well as transporting water large distances between ocean basins, the ACC also regulates transport and mixing across its flow. Understanding the spatial and temporal variations in transport behaviour is highly relevant for modelling and predicting the global Meridional Overturning Circulation, the spread of heat content anomalies to or from Antarctica and the transport of dissolved carbon dioxide by the ocean.

Both the multiple jet structure of the ACC and its intermittent mixing inhibition are locally describable by a zonally-uniform model of potential vorticity dynamics, called the Potential Vorticity Staircase, used to explain temporally-intermittent mixing across the atmospheric ozone hole boundary and the persistence of jets on Jupiter. In a previous study, we found support for the zonally-inhomogeneous Southern Ocean analogue of the PV Staircase, and that the PV structure changes downstream of major features of seafloor topography.

Here, we test the details of the PV Staircase model in the Southern Ocean using over 600 years of eddy-resolving experiments with the Q-GCM, OFES and SOSE models. We develop tools based on kernel density estimation to identify the staircase structure in the isopycnic potential vorticity. Under present-day and increased eastward wind stress experiments, we determine the relationship of the structure and its stability to mesoscale eddy intensity, measures of transport and mixing, mean flow and seafloor topography. From the multi-decadal ensemble of wind stress trend experiments we find evidence of 'eddy saturation': minimal response in the zonal transport with respect to increasing wind stress. There is a relationship between the strength of the wind stress and of the eddies, and hence substantial changes to the multiple jet structure, as expected from the PV Staircase. However, this relationship is complicated by regional variations in seafloor topography and by internal variability.