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Eddy heat flux in the Southern Ocean: Response to variable wind forcing

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We assess the role of time-dependent eddy variability in the Antarctic Circumpolar Current (ACC) in influencing warming of the Southern Ocean. For this, we use an eddy-resolving quasigeostrophic model of the wind-driven circulation, and quantify the response of circumpolar transport, eddy kinetic energy and eddy heat transport to changes in winds. On interannual timescales, the model exhibits the behaviour of an "eddy saturated" ocean state, where increases in wind stress do not significantly change the circumpolar transport, but instead enhance the eddy field. This is in accord with previous dynamical arguments, and a recent observational study.

The instantaneous response to increased wind stress is to cool temperatures through increased northward Ekman transport of cool water. But, in the longer term, the enhanced eddy state is more efficient at transporting heat, leading to a warming of the ocean. The total eddy heat flux response is greater than the Ekman transport heat flux in this model by a factor of 2, indicating that coarse (non-eddy resolving) models may fail to adequately capture the key processes. We also test the model response to long-term changes in wind forcing, including steadily-increasing circumpolar wind strength over a 30 year period. The model shows a response in eddy heat flux, and a change in ocean temperature not dissimilar from observed Southern Ocean warming. These findings suggest that eddy heat flux, energised by increasing wind stress, may be a significant contributor to the observed warming of the Southern Ocean.