Saturation of the Antarctic Circumpolar Current transport by mesoscale eddies vs. standing waves

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Abstract

It is now well established that changes in the zonal wind stress over the ACC do not lead to changes in its baroclinic transport, a phenomenon referred to as ``eddy saturation''. Previous studies provide contrasting dynamical mechanisms for this phenomenon: on one extreme, changes in the winds lead to changes the efficiency with which transient eddies restratify the ACC; on the other, saturation occurs via structural adjustments of the ACC's standing meanders. In this study we assess the relative importance of these mechanisms using an idealized, isopycnal channel model of the ACC and a quasi-geostrophic theoretical framework. Via separate diagnoses of the channel model's time-mean flow and eddy diffusivity, we decompose the model's response to changes in wind stress into contributions from transient eddies and the mean flow. A key result is that holding the transient eddy diffusivity constant while varying the mean flow very closely compensates changes in the wind stress, whereas holding the mean flow constant and varying the eddy diffusivity does not. This implies that ``eddy saturation'' primarily occurs due to wind-driven adjustments in the ACC's standing waves/meanders, rather than due to adjustments of transient eddy behavior. Motivated by this finding, we derive a quasi-geostrophic theory for ACC transport saturation by standing waves, in which the transient eddy diffusivity is held fixed, and thus provide insights into the dynamics of standing wave adjustment to wind changes. These findings imply that the key to representing the eddy saturation phenomenon in global models is adequate resolution of the ACC's standing meanders, with dynamically responsive parameterizations of the transient eddies being of secondary importance.

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