Abstract View

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The Dynamics of Large-Scale, Wind-Driven Variations in the Antarctic Circumpolar Current

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ABSTRACT

A nonlinear model is developed and analytical results obtained to discuss the response of the Antarctic Circumpolar Current to wind forcing over a wide range of frequencies. The main results are as follows:

(i) The nonlinear equations of motion can be conveniently separated into one “baroclinic” and one “barotropic” mode.

(ii) For forcing with period T equal to less than a few years, wind-driven fluctuations in the Antarctic Circumpolar Current are barotropic and governed by the linearized Laplace tidal equations. Theory suggests that fluctuations in the transport should lag, and be most strongly correlated with, the circumpolar-averaged wind stress. These theoretical results are consistent with recent measurements made in Drake Passage. An interesting untested theoretical prediction is that the sea level fluctuations measured at the southern side of Drake Passage with T between one month and a few years should be coherent at zero lag with sea level fluctuations at the same latitude around the earth.

(iii) For longer period forcing, baroclinic fluctuations are important. The baroclinic pressure, current and associated density variations all decrease exponentially with depth. Exponential depth decay of these baroclinic fields is in fact observed, the decay scale being about 1 km.

(iv) The theory indicates that significant large-scale, wind-driven fluctuations in the strength of the baroclinic Antarctic Circumpolar Current can only occur at frequencies with periodicity $\gtrsim$ 70 years. Climatic changes associated with such variability must therefore consist of oscillations of similar or longer period. This is consistent with limited observations which suggest that wind and sea-surface temperature in the region of the Antarctic Circumpolar Current have fluctuated through one “cycle” over the last 100 years.

(v) The spin-down time scale for barotropic motions appears to be short (observed to be ~ 9 days) while that for the

baroclinic motions is several years or more. The barotropic spin-down may be largely associated with Rossby wave drag over topographic irregularities while the baroclinic spin-down is most likely due to baroclinic instability.

(vi) Sverdrup balance does not hold.

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