Abstract View

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A Quasi-Linear Model of the Combined Wind-Driven and Thermohaline Circulations in a Rectangular β-Plane Ocean

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ABSTRACT

Three-dimensional temperature and velocity fields are calculated analytically for a rectangular β-plane ocean model, forced by a prescribed wind stress and surface heat flux. A basic thermal state involving a balance of lateral and vertical heat diffusion is assumed. There is a net heating applied at the top, balanced by a heat diffusion out through the polar boundary; this diffusion may represent the heat lost in the formation of deep water. The wind stress is chosen such that two complete mass transport gyres (a tropical and a subtropical gyre) are generated. Effects of nonlinear heat advection are calculated by a perturbation method.

The results can be summarized as follows:

The basic (zero-order) temperature field gives a rough overall representation of the oceanic thermocline. Associated with this field there is a baroclinic eastward flow in the upper part, with a westward return flow below. This circulation is closed through thin up- and downwelling layers at the sides as described by Hidaka and by Pedlosky. Superimposed there is a barotropic wind-driven circulation, with a transport field of the type described by Munk. The interior temperature field to the next order is affected not only by interior heat advection but by heat advection in the Ekman layer, in the up- and downwelling layers, and in the main western boundary current. The interior meridional and vertical heat advections counteract, with the vertical part dominating, making the isotherms sink in the subtropical gyre and rise in the tropical gyre. The Ekman layer advection cools the upper layer at high latitudes and warms it at low latitudes, while the up- and downwelling layers cool the water near the western boundary and warm it near the eastern boundary. The western boundary current causes a marked warming of the western half of the subtropical gyre. For representative values of the critical parameters $RoEh^{-1}$ (Ro = thermal Rossby number, Eh = horizontal Ekman number) and σ* (ratio of the wind-forced to the thermally-forced transports) the isotherms show realistic variations meridionally and zonally. The thermocline is shallow and concentrated at the equator, while the isotherms reach a maximum depth at middle latitude and tend to reach the surface at the pole- ward side. The isotherms slope up to the east in the interior subtropical gyre, down to the east in the interior tropical gyre. The associated velocity field exhibits a baroclinic interior meridional flow and a baroclinic western boundary current. The surface tropical

gyre is displaced equatonvard from the transport gyre re- sulting in a broad region of westward surface flow between the subtropical and tropical gyres.

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