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MIS22-09 Room:106 Time:May 27 11:15-11:30

Atlantic meridional overturning circulation in a variable-density, two-layer model: interaction with the Southern Ocean

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The flow of the North Atlantic Deep Water (NADW) forms a global overturning circulation, in which the water sinks in the northern North Atlantic to deep ocean, upwells in the Southern Ocean and elsewhere to the upper ocean, and returns to the North Atlantic within the upper layer. This circulation can be described by a 1.5-layer model with the branch of the circulation after the upwelling and before the sinking contained in the upper layer of the model. Because the connection between the Southern Ocean and each ocean basin is not well understood, however, the description of the circulation by a 1.5-layer model is not complete.

In this study, we examine the boundary layer between the Southern Ocean (where the domain is zonally cyclic) and an ocean basin representing the Atlantic (where the Sverdrup dynamics determines the flow) in detail to derive the matching condition between the two regions, thereby completing the 1.5-layer description of the NADW circulation. This enables us, for example, to theoretically predict the dependence of the strength of the NADW circulation on winds in the Southern Ocean and on the mesoscale-eddy-mixing coefficient.

The governing equations are

$$-f\,V = -P_x - \nu\,U + \tau^x,$$
$$f\,U = -P_y - \nu\,V,$$
$$U_x + V_y = w_e + w_m.$$

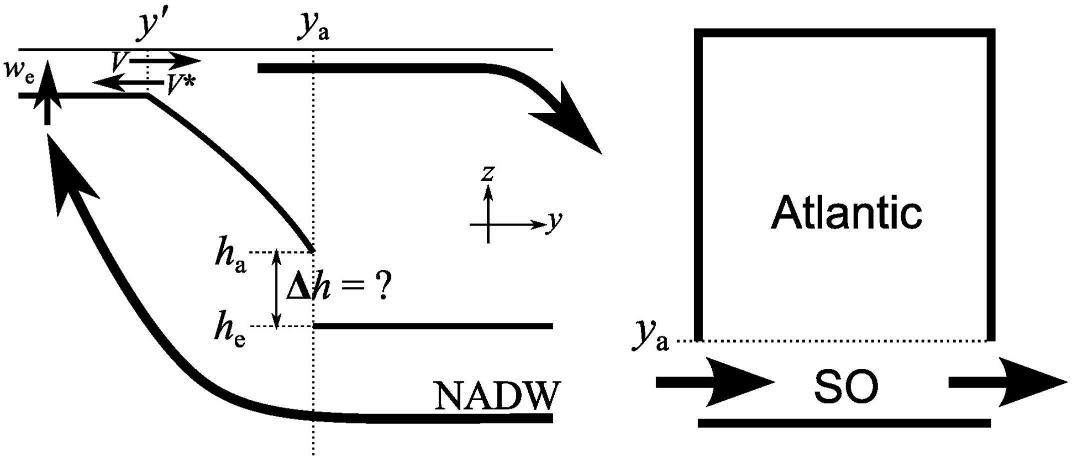
where $(U,V) = (hu,hv)$ is the "residual" transport vector in the upper layer, $P = g'\,h^2/2$ is the integrated pressure, h is the upper-layer thickness, $g' = g\,(\rho_2 - \rho_1)/\rho_2$ is the reduced gravity, τ^x is a zonal wind stress, and interior upwelling due to vertical diffusion w_m is prescribed. "Vertical viscosity" ν is actually an expression of horizontal mass transport due to parameterized mesoscale eddies and can be written as $\nu = \kappa_{GM}\;f^2/(g'/h)$, using the GM thickness diffusivity. Traditionally, κ_{GM} is often assumed constant, but we assume ν to be constant for simplicity.

It is easy to obtain the interior solution within each of the Atlantic basin and the Southern Ocean (not shown), but these solutions do not match, requiring a zonal boundary layer. It can be shown that the boundary layer solution (total solution minus interior solution) approximately obeys (ignoring the western boundary layer)

$$-P''_x = r\,P''_{yy}\,,$$

where $r = \nu/\beta$. This is a "diffusion equation" where $-x$ is analogous to time. In physical terms, this equation describes how pressure anomaly associated with Rossby waves is spread meridionally by viscosity. This equation can be solved under the cyclicity condition $P''(x=0,\,y) = P''(x=-L,\,y)$ for $y > y_a$ and the eastern boundary condition $P''(x=0,\,y) = P_e$ = const. for $y < y_a$, and the matching condition that the total pressure and its y derivative must be continuous across $y = y_a$, where y_a is the latitude of the southern tip of South America. The solution (not shown) determines one of the unknown constants of integration of the interior solutions, thereby closing the problem.

Keywords: analytic model, viscosity, eddy induced transport, wind stress, Ekman transport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NADW
Atlantic
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