Assessing the World Ocean ventilation timescales with simple analogs - the leaky funnel model

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The rate at which the ocean can sequester excess heat and carbon from the atmosphere is determined by its ventilation i.e. the renewal of interior waters by seawater that has been in contact with the atmosphere. Hence it is of importance to better assess this ventilation rate and its properties. Of use are numerical simulations and field measurements of appropriate tracer concentrations. However the intrinsic complexity of water masses circulation and the huge amount of information provided by OGCMs make it difficult to extract the most relevant information on spatial and temporal scales characterising ventilation.

In [Mouchet and Deleersnijder, 2008] it is seen that an idealised model may suggest an appropriate scaling of the water age. A 1D advection-diffusion model is proposed in which the deep ocean is represented as a leaky pipe with decreasing section (i.e. a leaky funnel) - allowing recirculation of water and tracers toward the surface. The analytical solutions to the steady-state problem are readily obtained and yield expressions of the domain averaged-ages as functions of three independent numbers which determine the flow characteristic scales. A suite of experiences with a 3D OGCM allow us to calibrate and validate the leaky funnel representation. The agreement between the domain-averaged ages (water and radiocarbon) as obtained with the OGCM and with the leaky funnel is excellent. Further the parameters derived from this exercise have a clear physical meaning; the turnover time, the length scale of trajectories, and the diffusivity scale being consistent with our current knowledge of the World Ocean circulation.

The reasons for the excellent agreement between the 1D representation and the 3D OGCM remains rather elusive. Additional developments based on the age volume distribution function offer now the opportunity to revisit the leaky funnel model. These new developments provide for a supplementary and fully coherent validation of the leaky funnel representation. Eventually the age volume distribution suggests some interpretation of the deep ocean ventilation properties which result in the excellent correspondence between 3D and 1D domain-averaged ages.

This simple analog has a potential for applications in modelling studies. It may help in evaluating the relative importance, at the largest scales of motion, of advection and diffusion in 3D models. It also offers the opportunity to get an estimate of the numerical diffusivity even in the case of complex numerical schemes.

REFERENCES


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