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The leaky funnel model, a metaphor of the ventilation of the World Ocean

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The ventilation rate of the World Ocean governs to a large measure the uptake of anthropogenic CO2. Thus, for climate change studies, it is important to estimate the ventilation rate. Of use are numerical simulations and field measurements of appropriate tracer concentrations. However the intrisic 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.

In this study, it is seen that an idealised model may suggest an appropriate scaling of the water age, which is regarded as a measure of the ventilation rate. We use a 1D advection-diffusion model 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. With the definition of the age of a tracer as the time elapsed since it left the surface mixed layer, the analytical solutions to the steady-state problem are readily obtained. The domain averaged-ages are expressed as a function of 3 independent dimensionless numbers which determine the flow characteristic scales.

Sensitivity studies are then performed with 3D models of the World Ocean. The domain averaged ages of the water and of radioactive tracers are computed for various sets of velocities and diffusivities.

The agreement of the ages predicted by the 1D funnel model and those obtained in the 3D simulations is excellent. Furthermore, the parameters derived from the 1D representation have a clear physical meaning; the length scale of trajectories and the diffusivity scale being consistent with our current knowledge of the World Ocean circulation.

The 1D simple model also helps in explaining circulation features in 3D global models; it could be a useful analogy in model intercomparison studies.