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On tracer boundary conditions for geophysical reservoirs

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Recent work on diagnosing transport has focussed on understanding how passive tracers are advected and diffused by the oceanic (or atmospheric) general circulation. One useful approach is to consider how interior water parcels consist of a mixture of boundary source locations and times. This information is contained in the transit-time distribution (TTD) which captures complete information about transport rates and pathways. The TTD can also be used to represent a passive tracer field if the tracer boundary concentration is known (mathematically, a Dirichlet boundary condition). In fact, we rarely know the tracer concentration at the ocean surface, however.

Instead, for most cases of practical interest, passive gaseous tracer enters the ocean from the atmosphere according to a law that specifies the incoming tracer flux $\mathcal{F}$ as

$$\mathcal{F} = k \left(F C_{\mathrm{atm}} - C_{\mathrm{surf}} \right). \qquad (1)$$

Here, C is the tracer concentration, either at the ocean surface (C_{surf}) or in the troposphere (C_{atm}). The gas solubility is F and the piston velocity is k. This condition is a Robin boundary condition and cannot be simply used with the TTD to calculate interior tracer distributions.

Relation (1) is linked here to TTD theory. We show how to use the regular TTD to represent a tracer with such a boundary condition. There are two related issues of practical importance that we discuss: First, the anthropogenic carbon “disequilibrium term” is to do with mis-representing the real air/sea anthropogenic carbon boundary condition (which obeys a flux law like (1)) with a concentration boundary condition. Second, anomalies in sea surface temperature are often viewed as dynamically passive which allows them to be treated as a passive tracer with a boundary condition like (1).