Geophysical Research Abstracts, Vol. 7, 02674, 2005
SRef-ID: 1607-7962/gra/EGU05-A-02674

Residence time : rigorous definition and model based evaluation

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The residence time is usually defined as 'the time taken by a water/tracer parcel to leave the domain of interest'. This time scale is one of the most widely used concepts to quantify the renewal of water in semi-enclosed water bodies. In environmental studies, it provides for instance a quantitative measure of the time of exposure to pollution stresses.

In many studies, the residence time is computed simply as the ratio of the volume of the control domain to the mean volume flux through this water volume. Sometimes, the residence time is assimilated to an e-folding time. Such approaches, while easy to implement, neglect diffusion or assume immediate mixing and/or assume the stationarity of the flow. They provide therefore poor approximations of the real residence time. They also ignore spatial and temporal variations of the residence time as well as the distribution of residence time among different tracer parcels.

In the framework of the Constituent oriented Age and Residence Time theory (CART), a rigorous generic method is available to evaluate the residence time by means of a numerical model, without any simplifying hypothesis. The method can be used to compute the distribution of residence times or only the mean value of this distribution. The procedure requires the solution of the adjoint problem to the advection-diffusion equation. In the simplest case of conservative tracers, this means integrating backward in time the slightly modified original advection-diffusion problem.

A simplified 1D analytical model and a real case application to the diagnostic of the three-dimensional circulation on the Northwest European Continental Shelf illustrate the concept and prove the power of the approach.