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The Constituent-oriented Age Theory (CAT) and some of its applications to marine flows

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The age is a diagnostic quantity widely used for understanding marine flows. In the Constituent-oriented Age Theory (CAT), the age of a particle of a constituent of seawater is defined to be the time elapsed since the particle under consideration left the region in which its age is prescribed to be zero.

The keystone of CAT is the age-averaging hypothesis, according to which the age of a set of particles is the mass-weighted average of the ages of the particles. With this sole assumption and classical mass budget considerations, a Eulerian theory of the age, CAT, is developed, in which advection, diffusion, production, and destruction processes are properly taken into account for evaluating the age of every constituent of seawater — or every group of constituents, such as seawater itself.

The space-time development of the age of passive and radioactive tracers released by a point source in a constant velocity and diffusivity flow is studied. Most ages are seen to be symmetric with respect to the point source, a rather counterintuitive property. This problem is an idealised version of certain age applications in shallow seas.

CAT is also applied to the study of the World Ocean ventilation. The age of the water and the age of surface water — the true measure of the ventilation rate — are seen to obey, at any time and position, a simple algebraic relation. Inequalities obeyed by various ages are derived when Dirichlet conditions are prescribed at the ocean surface. When the more realistic Robin boundary conditions — involving the piston velocity — are used, an asymptotic approach is suggested that might render it possible to estimate the age of the surface water from appropriate tracer data.

An attempt has been made to use CAT in order to help understand the matter fluxes in a marine ecosystem model: theoretical and numerical results are presented. Finally, as the age is not the only timescale that is of use to understand complex marine processes, a theory of the residence time is being developed, in which the latter is obtained as the solution of an adjoint problem. So, CAT is being transformed into CART, the Constituent-oriented Age and Residence time Theory.