Geophysical Research Abstracts, Vol. 7, 10055, 2005
SRef-ID: 1607-7962/gra/EGU05-A-10055

Transit time distributions in chaotic flow

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Recent studies show that there is a range of pathways for transport from the ocean surface to the ocean interior, and hence a transit time distribution (TTD) instead of a single age. TTDs capture the tracer-independent flow properties (advection and mixing) and connect tracer distributions to these properties. This concept is valuable for the interpretation of oceanographic tracers. Most studies of ocean TTDs have focused on (or assumed) a steady flow, however. Here, we explore the TTD properties in double-gyre circulations that range from steady to periodic to chaotic under different forcing regimes

In a steady circulation, the TTD depends only on the transit time. It can be simulated in a numerical ocean GCM using a single tracer with an impulsive boundary condition. For unsteady flows, however, this method does not yield the TTD. One may construct the TTD from a series of simulations with impulsive boundary conditions but doing so requires great computational effort. If one has an interest in a particular region and final state, then a much more efficient way to derive the TTD is to use the adjoint circulation model

We present TTD results from numerical experiments in unsteady, chaotic, double-gyre circulations. We compare and contrast the two methods mentioned above for finding the TTD. The distribution over transit time of a tracer released into the forward flow from an impulsive boundary condition differs from the TTD as expected. But in some cases of statistically-stationary flow their expectations appear to be equal. This result may be of practical benefit to the efficient estimation of the TTD in an unsteady ocean GCM without resorting to the adjoint model. We also find that variations in TTDs are highly correlated with variation of tracer ages and potential vorticity (PV) in some regions. Such correlations may well exist in the real ocean. If so, PV anomalies, from hydrographic data for example, could be directly related to anomalies in the real ocean TTD.