INVENTORY OF ANTHROPOGENIC CARBON IN THE ATLANTIC

R. Steinfeldt [(1)], M. Rhein [(1)]

[(1)]Institut für Umweltphysik, Universität Bremen, Otto-Hahn-Allee, D-28359 Bremen, Germany,
Email: rsteinf@physik.uni-bremen.de, mrhein@physik.uni-bremen.de

Sinking of water from the mixed layer into the ocean interior is the process which is responsible for the input of dissolved constituents (oxygen, carbon dioxide) from the atmosphere into the deep ocean. The amount of this oceanic ventilation, however, can hardly be observed directly. One method to infer the formation and ventilation rates from observations is the use of transient tracers, e.g. the change of the water mass inventory of chlorofluorocarbons (CFCs). In a recent paper [1], the relation between the tracer inventory of a water mass and the cumulative ventilation rate distribution or mean (volume integrated) transit time distribution (TTD) was investigated. Here we use a modified approach to compute these volume integrated TTDs, which are called Ψ in the following. In a first step, CFC and tritium data are used to infer pointwise TTDs for each single observation. Then these pointwise TTDs are integrated over the volume of specific water masses. These are the components of North Atlantic Deep Water, Labrador Sea Water (LSW), Upper LSW (ULSW), Iceland Scotland Overflow Water (ISOW), and Denmark Strait Overflow Water (DSOW). The integration area comprises the subpolar North Atlantic between 40°N and 65°N.

In contrast to the parameterized mean TTDs from Hall et al. (2007), the mean TTDs Ψ derived from the integration of pointwise TTDs do not increase towards infinity for zero age, but show a distinct maximum (Fig. 1). For ULSW, this maximum occurs at an age between zero and one year and is theoretically identical with the ventilation rate of this water mass [2]. The ventilation rate of ULSW peaked in 1999, in agreement with [3], where the formation rate of ULSW is directly determined from CFC inventories.

Some of the water that made contact with the surface mixed layer is ventilated again in the following winters, which is reflected in the rapid decline of Ψ for ULSW at ages smaller than approximately 5 years. For LSW, no ventilation occurs between 1997 and 2005, so Ψ at zero age is zero. The maximum of Ψ originates from the water ventilated in the period of intense convection during the first half of the 1990s. Comparing the mean TTDs for LSW between 1997 and 2005 shows that this water becomes older and is gradually exported from the subpolar North Atlantic, as the maximum of Ψ is shifted with time towards higher ages and becomes less pronounced.

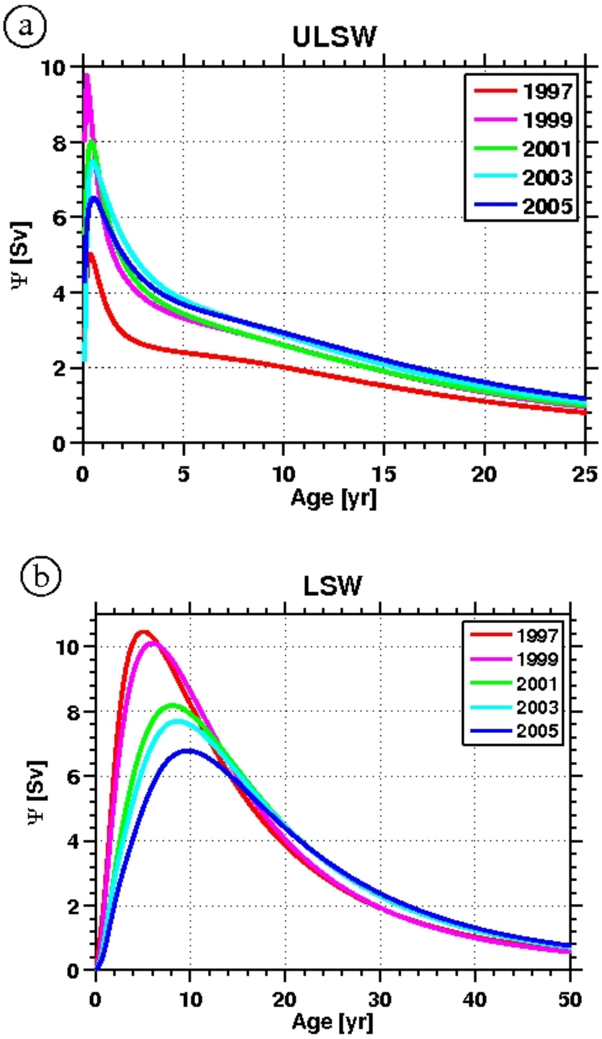

Figure 1. Volume integrated transit time distributions Ψ for Upper Labrador Sea Water (ULSW) (a) and Labrador Sea Water (LSW) (b).

The derivative of the mean TTD Ψ of a water mass is related with the transit time distribution Φ of the exported water [2]. The cumulative sum of Φ as a function of the age τ is the flux of exported water with

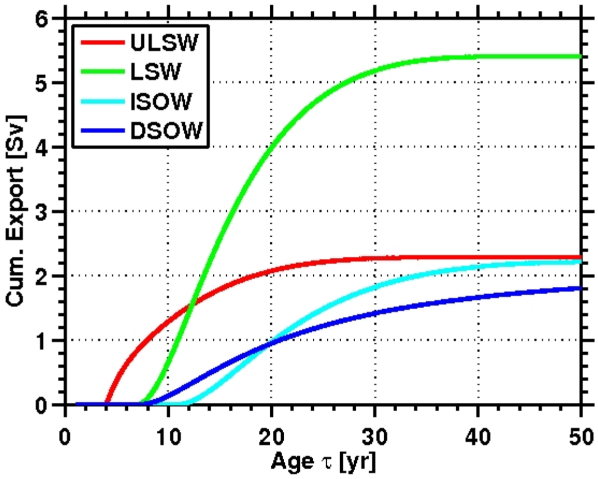

Figure 2. Cumulative sum of NADW exported from the subpolar North Atlantic between 2003 and 2005 as a function of age τ.

ages smaller than τ (Fig. 2). The water exported from the subpolar North Atlantic has an age of at least 5 years, and about half of the exported water is older than 10 year (ULSW), 15 years (LSW) or 20 years (ISOW, DSOW) respectively. This is in qualitatively agreement with observational float data described in Bower et al. (2009), where only about 30% of the floats released near 50°N within the Deep Western Boundary Current have been exported towards the subtropical Atlantic within the first two years.

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