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Anthropogenic carbon estimates in the Weddell Sea using an optimized CFC based transit time distribution approach

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We use a 20 year time series of chlorofluorocarbon (CFC) observations along the Prime Meridian to determine the temporal evolution of anthropogenic carbon (Cant) in the two deep boundary currents which enter the Weddell Basin in the south and leave it in the north. The Cant is inferred from transit time distributions (TTDs), with parameters (mean transit time and dispersion) adjusted to the observed mean CFC histories in these recently ventilated deep boundary currents. We optimize that "classic" TTD approach by accounting for water exchange of the boundary currents with an old but not CFC and Cant free interior reservoir. This reservoir in turn, is replenished by the boundary currents, which we parameterize as first order mixing. Furthermore, we account for the time-dependence of the CFC and Cant source water saturation. A conceptual model of an ideal saturated mixed layer and exchange with adjacent water is adjusted to observed CFC saturations in the source regions. The time-dependence for the CFC saturation appears to be much weaker than for Cant.

We find a mean transit time of 14 years and an advection/dispersion ratio of 5 for the deep southern boundary current. For the northern boundary current we find a mean transit time of 8 years and a much advection/dispersion ratio of 140. The fractions directly supplied by the boundary currents are in both cases in the order of 10%, while 90% are admixed from the interior reservoirs, which are replenished with a renewal time of about 14 years. We determine Cant $\sim$ 11 umol/kg (reference year 2006) in the deep water entering the Weddell Sea in the south ($\sim$2.1 Sv), and 12 umol/kg for the deep water leaving the Weddell Sea in the north ($\sim$2.7 Sv). These Cant estimates are, however, upper limits, considering that the Cant source water saturation is likely to be lower than that for the CFCs. Comparison with Cant intrusion estimates based on extended multiple linear regression (using potential temperature, salinity, oxygen, and pressure observations as parameters) at the same Prime Meridian section suggests a reduced Cant source water saturation of 40% relative to that of the CFCs and accordingly a reduction of Cant in the boundary currents to 5.4 umol/kg and 5.9 umol/kg.