Geophysical Research Abstracts
Vol. 19, EGU2017-10232, 2017
EGU General Assembly 2017
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A model-based evaluation of the transit-time distribution (TTD) method for inferring anthropogenic carbon storage in the ocean

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The transit time distribution (TTD) method is widely used to infer the anthropogenic carbon (Cant) concentration in the ocean with obtained water mass age from transient tracers such as chlorofluorocarbons (CFCs) and sulfur hexafluoride (SF_6). Its accuracy relies on the validity of several assumptions, notably (i) a steady state ocean circulation, (ii) a prescribed tracer saturation history, e.g., a constant 100% saturation, (iii) a prescribed degree of mixing in the ocean, denoted as Δ/Γ, e.g., a unity Δ/Γ in space and time, (iv) a constant surface water air-sea CO_2 disequilibrium with time, and (v) that preformed alkalinity can be sufficiently estimated by salinity or salinity and temperature. Here, these assumptions are evaluated using model-simulated data with known concentrations of Cant. The results give a lower limit of 11.4 Pg C or 7.8% and an upper limit of 19.8 Pg C or 13.6% uncertainty of the estimated global Cant inventory due to above assumptions, which is about half of previous estimate. The (ii), (iv) and (iii) assumptions are the three largest source of uncertainties, accounting for 5.5%, 3.8% and 3.0%, respectively, while the assumptions of (i) and (iv) only contribute about 0.6% and 0.7%. Regionally, the Southern Ocean contributes the largest uncertainty of 7.8%, while the North Atlantic contributes about 1.3%. It suggested that spatial-dependency of Δ/Γ, and temporal changes in tracer saturation and air-sea CO_2 disequilibrium should be considered to reduce the uncertainty of TTD, which is increasingly important under a changing ocean climate.