Biogeochemical Cycling Rates in the Atlantic Ocean

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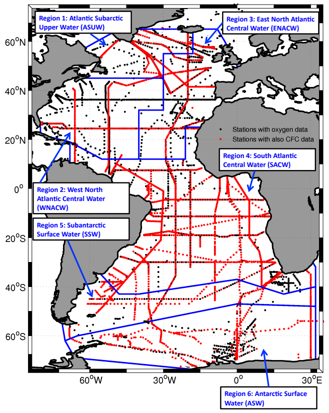
1 Introduction

Tracer data provide the unique opportunity to calculate biochemical cycling rates such as organic matter remineralization and opal and calcium carbonate dissolution rates from ocean interior data on basin-wide scales. Here, we focus on the Atlantic Ocean and the rates of organic carbon remineralization (OCRRs) and organic carbon export from the mixed layer which present an important part of the global carbon cycle.

Following the approach in *Feely et al.* [2004], local gradients of apparent oxygen utilization (AOU) and tracer ages are used to first infer oxygen utilization rates (OURs) and then OCRRs. Mean ages estimated from transit time distributions (TTDs) as well as traditional chlorofluorocarbon (CFC) based pCFC ages are utilized in this calculation, resulting in a range of carbon export values.

2 Atlantic GLODAP Dataset

GLODAP Dataset and Atlantic Water Mass Definitions

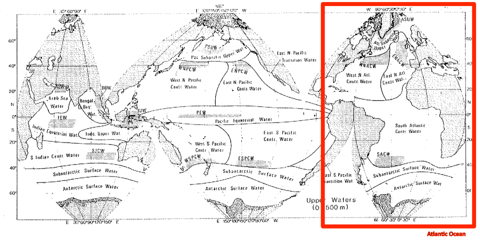


Atlantic GLODAP dataset [*Key et al.*, 2004]:

- WOCE, JGOFS and earlier data (time period: 1972-1998)
- about 147,000 bottle samples
- about 140,00 oxygen samples, 56,000 CFC samples (covering 1983-1998), and 9,000 radiocarbon samples of good quality

The data are divided into six regions following the upper ocean water mass definitions by *Emery and Meincke* [1986] (as done by *Feely et al.* [2004] for the Pacific Ocean).

Upper Ocean Water Mass Definitions by *Emery and Meincke* [1986]



Acknowledgements

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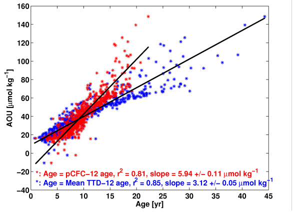
3 AOU vs. pCFC and Mean TTD Ages

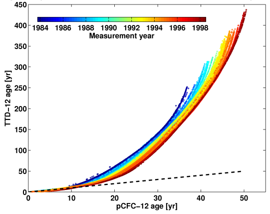
OURs are calculated as the slope of the local (by region) AOU versus pCFC age relationship. CFC-12 is used because it's atmospheric concentrations continued to increase throughout the 1990s.

Example OUR calculation.: WNACW (Region 2), σ_θ = 26.4–26.8 kg m^{-3}



Since pCFC-12 ages can be biased through nonlinear mixing effects, the measured CFC-12 concentrations are also matched with those predicted by 1-D TTDs [e.g. *Waugh et al.*, 2004; assuming Γ/Δ=1, where Γ=mean age and Δ=width of TTD) which implicitly account for mixing.

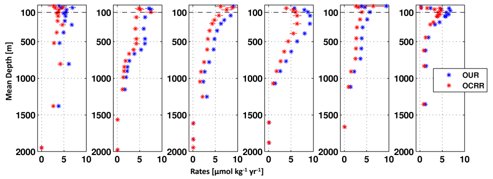
Age Comparison: Atlantic GLODAP CFC Data (CFC–12>0.02 pmol kg^{-1})



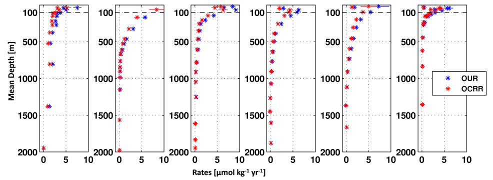
The resulting mean TTD-12 ages are larger than the pCFC-12 ages, especially for older ages. Hence, OURs inferred from the slope of AOU versus TTD-12 age relationships are smaller than when pCFC-12 ages are used.

4 OUR and OCRR Profiles

Based on pCFC-12 ages*:



Based on mean TTD-12 ages*:



*At depths > 1500m, radiocarbon ages are used instead of CFC-12 ages.

OUR and OCRR profiles are determined using the mean depths of the density intervals from the slope calculations and the stochiometric C/-O_2 ratios for organic matter remineralization (117/170±0.07; *Anderson and Sarmiento* [1994]).

Profiles based on mean TTD-12 age indicate lower OURs and OCRRs and more of an exponential decline with depth (as predicted by the Martin curve [*Martin et al.*, 1987]) than the pCFC-12 age based ones. However, OURs in this case are lower than those determined for instance near Bermuda [*Jenkins*, 1998] by about a factor of two.

5 Carbon Export

Carbon Export Estimates (through integration of OCRR profiles below 100m)

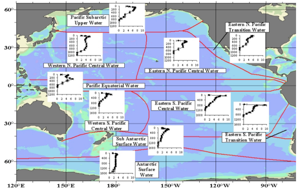
Region	Area [10^{13} m^2]	Export per Area* [moles C m^{-2} yr^{-1}]	Total Export* [Pg C yr^{-1}]	Export per Area** [moles C m^{-2} yr^{-1}]	Total Export** [Pg C yr^{-1}]
ASUW (Reg. 1)	0.42	5.34±0.40	0.27±0.02	1.99±0.14	0.10±0.01
WNACW (Reg. 2)	1.25	3.54±0.18	0.53±0.03	1.50±0.12	0.22±0.02
ENACW (Reg. 2)	1.03	4.00±0.19	0.49±0.02	0.84±0.04	0.10±0.01
SACW (Reg. 4)	3.55	3.39±0.24	1.45±0.10	0.84±0.05	0.36±0.02
SSW (Reg. 5)	0.91	2.40±0.16	0.26±0.02	1.05±0.07	0.11±0.01
ASW (Reg. 6)	1.08	2.54±0.23	0.33±0.03	0.42±0.03	0.06±0.01
Atlantic total	**8.24**		**3.33±0.11**		**0.95±0.03**

*OCRRs based on pCFC-12 ages **OCRRs based on mean TTD-12 ages

Carbon export rates range from 0.95 ± 0.03 Pg C yr^{-1} (mean TTD-12 ages) to 3.33 ± 0.11 Pg C yr^{-1} (pCFC-12 ages). The latter number, somewhat surprisingly, is in better agreement with a recent export estimate of 3.43 Pg C yr^{-1} [*Dunne et al.*, 2007] for a slightly larger area of the Atlantic Ocean (8.94 x 10^{13} m^2).

For OCRR profiles in the Pacific Ocean, *Feely et al.* [2004] used a model-based mixing bias correction for the pCFC-12 ages. This resulted in a smaller range of carbon export values (5.3 vs. 6.9 Pg C yr^{-1} with&w/o correction) than found in this study.

Pacific OCRR Profiles [*Feely et al.*, 2004]



6 Conclusions

Usage of mean 1-D TTD ages (Γ/Δ=1) instead of pCFC ages is likely overcorrecting OURs toward lower values.

The resulting carbon export estimate (0.95 ± 0.03 Pg C yr^{-1}) provides a lower limit for Atlantic Ocean carbon export whereas the pCFC-12 age based estimate (3.33 ± 0.11 Pg C yr^{-1}), although comparable to *Dunne et al.* [2007], should be an upper limit.

Refinement of estimates can be made through inclusion of more data (CARINA/CLIVAR), reduction of box sizes and testing of rates with an inverse model (*Macdonald and Mecking*, this meeting), and inspection of the validity of the TTD assumptions.

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