ESTIMATING THE WORLD OCEAN AIR-SEA GAS EXCHANGE RATE USING BOMB ^{14}C: REVISITED

C. Sweeney[1], E. M. Gloor[2], A. R. Jacobson[2], R. M. Key[2], G. A. McKinley[3], J. L. Sarmiento[2] , and R. Wanninkhof[4]

[1]*Climate Monitoring and Diagnostics Laboratory, NOAA, 325 Broadway, Boulder, CO 80305-3328; colm.Sweeney@noaa.gov*
[2]*Atmospheric and Ocean Science Program, Princeton University, Sayre Hall, Forrestal Campus, Princeton, NJ 08544-0710; emg@princeton.edu, andyj@splash.princeton.edu, key@princeton.edu*
[3]*Department of Atmospheric and Oceanic Sciences, University of Wisconsin – Madison, 1225 W. Dayton Street, Madison, WI 53706: galen@aos.wisc.ed*
[4]*NOAA/AOML 4301 Rickenbacker Causeway Miami, FL 3314: rik.wanninkhof*

ABSTRACT

Wind-speed dependent bulk formulations of gas transfer velocity have traditionally been scaled to the oceanic inventory of bomb ^{14}C [1992, *Wanninkhof and McGillis* 1999) and average global wind speeds [*Esbensen and Kushnir* 1981] . The recent advances in our ability to estimate both the first two moments of global wind-speeds and the inventories of bomb ^{14}C inventories call for a reanalysis of this anchor point as well as an exploration of its implications on oceanic carbon uptake. We present a reanalysis of the globally averaged air-sea transfer velocity of CO_2 using an inverse calculation of bomb $^{14}CO_2$ air-sea fluxes from point measurements of ^{14}C in the ocean interior and several oceanic transport GCMs. This inverse calculation permits us to estimate both the total inventory of bomb $^{14}CO_2$ that has entered the ocean from 1953 to 1998 (Figure 1) and the temporal and spatial evolution of surface $p^{14}CO^2$ from 1954 to 1998. Using a best fit, in a least squares sense, between 8,000 measurement-based estimates of bomb ^{14}C in the upper 1500 m of the water column and three different configurations of a GCM we see a discrepancy between the resulting gas transfer velocity and the Broecker et al. [1985 and 1995] gas transfer velocity which was used by Wanninkhof [1992] and Wanninkhof and McGillis [1999]. Our results suggest that the average global piston velocity may be over estimated by as much as 50%. Combining this result with more recent estimates of world ocean wind speeds from the National Center for Environmental Prediction [NCEP, *Kalnay, et al*. 1996] we calculate that the anchor point tying down the relationship between wind speed and air-sea gas transfer velocity is roughly 44% lower than previously thought (Fig. 2). Using the Takahashi et al. [2002] surface ocean air-sea gradient in CO_2 for 1995, we estimate a air-sea flux of 0.9 and 1.3 GT of carbon into the world oceans. Our analysis supports other work [i.e. *Hesshaimer, et al.* 1994, *Peacock* 2004, *Key, et al*. 2004] which suggest that Broecker et al [1985 and 1995] may have underestimated the ocean bomb ^{14}C inventory by as much as 25%. Our results also suggest that previous estimates, which depend on crude box models, may not have taken account of a significant back flux of bomb-derived $^{14}CO_2$ into the atmosphere as well as variability in CO_2 solubility and surface ocean $^{14}CO_2$ that has been suggested by our inverse estimates.

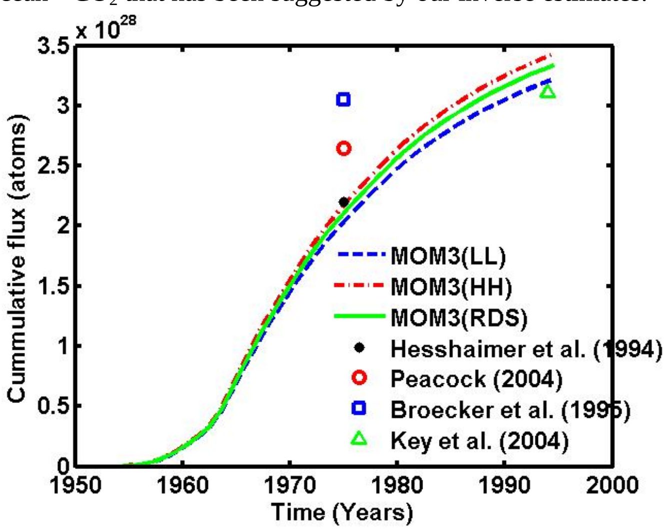
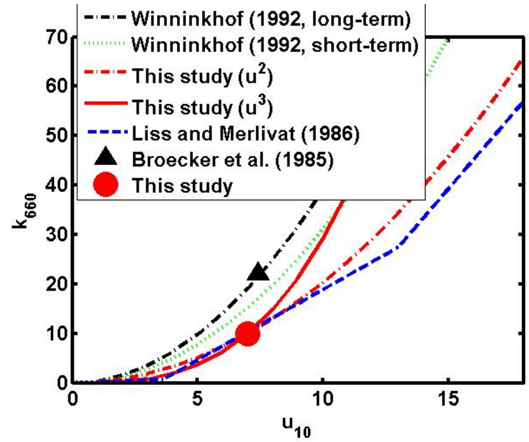


Fig. 1. Time history of bomb $^{14}CO_2$ inventory in the world oceans. Blue (dashed), red (dot-dashed) and green lines show cumulative inventory of $^{14}CO_2$ over the last 50 years using a suite of the GFDL MOM3 models to represent possible spread in time history of inventory due to model parameterizations of isopycnal velocity and diapycnal diffusion. The open blue box shows the Broecker [1995] estimate while the black circle shows the Hesshaimer et al. [1994] inventory estimate for 1975 and the green triangle is from GLODAP [*Key et al.* 2004]. This figure indicates that our results agree very well with that of Hesshaimer et al. [1994] and Key et al. [2004].

Fig. 2. Gas Transfer Velocity (k) normalized to a schmit number of 660 verses wind speed at 10 meters. Black triangle and back dot-dash represent global average bomb ^{14}C derived from the transfer velocity and associated quadratic fit of Winninkhof [1992]. Red circle, solid line, dot-dash line represent global average bomb ^{14}C derived transfer velocity and associated quadratic and cubic fit from this study. Blue dashed line shows Liss and Merlivat [1986].



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