SIMULATING THE GLOBAL BOMB RADIOCARBON CYCLE: CLOSING THE BUDGET

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ABSTRACT

We estimated the production of bomb radiocarbon using available information on atmospheric nuclear bomb tests, the simple (radio-)carbon cycle model GRACE (Global RadioCarbon Exploration Model) and atmospheric observations as constraints. Subsequent forward simulations of the bomb radiocarbon inventory in the different carbon reservoirs turned out to be in very good agreement with recent observation-based estimates, therewith for the very first time allowing to close the global bomb radiocarbon budget. Besides confirming original stratospheric bomb ^{14}C data published in the reports of the Health and Safety Laboratories [*Telegadas*, 1971, and references therein], our results confirm recent observation-based ocean bomb radiocarbon inventory estimates for the time of GEOSECS (1970s) and WOCE (1990s) from *Peacock* [2004] and *Key et al*. [2004], but refute the GEOSECS ocean inventory estimates from *Broecker et al.* [1985, 1995].

INTRODUCTION

A successful model simulation of observed bomb radiocarbon inventories in the main global carbon reservoirs serves two purposes: First, it is an excellent validation of the model performance, but – equally important – it is an independent confirmation (or refutation) of observation-based ^{14}C inventory estimates in these carbon reservoirs [*Hesshaimer et al.*, 1994]. Ocean bomb radiocarbon inventories are difficult to estimate from observations, however, together with atmospheric and oceanic $\Delta^{14}C$ observations, they provide an indispensable constraint for air-sea gas exchange of CO_2 [*Wanninkhof* 1992] and thus of the uptake of CO_2 by the oceans. The GRACE model allows to simulate the bomb radiocarbon distribution in the different carbon reservoirs. It also permits to independently test the important observation-based ocean bomb ^{14}C inventory estimates as well as to indirectly estimate a biospheric bomb ^{14}C inventory based on available atmospheric and oceanic observations.

METHOD

The GRACE model consists of a 22-box zonally averaged two-dimensional atmosphere coupled to a well-mixed 4-reservoir biosphere. Biospheric model parameters are consistent with standard assumptions about the global carbon cycle (NPP: 60PgC/yr, global carbon inventory: 2200Pg). Ocean-atmosphere ^{14}C exchange was calculated from observed tropospheric and ocean surface $\Delta^{14}C$. The model comprises all relevant sources of radiocarbon, i.e. the natural production, production by nuclear bomb tests and by the nuclear industry. The seasonal air mass exchange between model boxes was calibrated with stratospheric and tropospheric $^{14}CO_2$ observations as well as tropospheric observations of SF_6 and the $^{10}Be/^{7}Be$ ratio and validated independently with SF_6, CO_2 and $\delta^{13}C$ observations. The total ^{14}C production by atmospheric nuclear bomb tests was determined with the help of the model and available stratospheric and tropospheric ^{14}C observations [see *Hesshaimer and Levin*, 2000, and *Naegler*, 2005]. The influence of the large uncertainties in the explosive force of atmospheric nuclear bomb tests was investigated by using different bomb test compilations. Furthermore, we accounted for a possible small bias in the available stratospheric bomb radiocarbon observations by testing the different bomb test compilations with both, uncorrected and corrected stratospheric ^{14}C observations. For each of the scenarios of the total bomb ^{14}C burden, the model simulated the distribution of bomb radiocarbon between the carbon reservoirs stratosphere, troposphere, biosphere, and ocean.

RESULTS

The different bomb radiocarbon production scenarios result in a total ^{14}C injection between 1945 and 1980 of 600-$630 \cdot 10^{26}$ atoms. Model simulated bomb radiocarbon inventories (see Fig. 1) turned out to be in good agreement with all available stratospheric and tropospheric radiocarbon observations as well as with the latest estimates of the ocean bomb radiocarbon inventories during the GEOSECS and WOCE surveys from *Peacock* [2004] and *Key et al.* [2004], when corrected for ocean areas missing in these analyses [*Naegler*, 2005]. However, our results refute the observation-based ocean inventory estimate for the time of GEOSECS from *Broecker et al.* [1985, 1995].

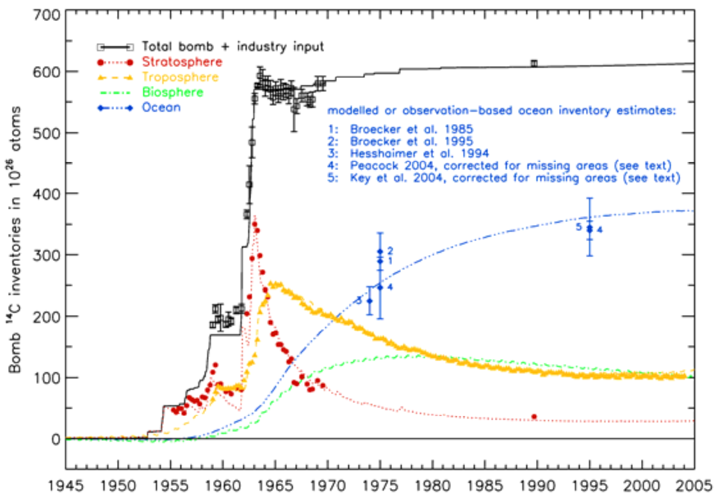

Fig. 1: Comparison of simulated (lines) and observed (symbols) bomb radiocarbon inventories in the stratosphere, the troposphere, the biosphere and the ocean. The solid line is the simulated accumulated bomb ^{14}C production, the open squares are the sum of observed tropospheric and stratospheric inventories plus simulated biospheric and oceanic inventories. Simulation results are for the *Yang et al.* [2000] bomb test compilation and uncorrected stratospheric data. For details see *Naegler* [2005]. Note that no direct observation-based estimate of the bomb ^{14}C inventory in the biosphere is available.

CONCLUSIONS

For the very first time, our model is capable of closing the bomb radiocarbon budget in the global carbon system. The implied consequences of the new ocean bomb radiocarbon inventory estimates on the parameterisation of CO_2 air-sea gas exchange are discussed in an accompanying presentation [Naegler et al., this issue]. Furthermore, it is now in principle possible to estimate a biospheric bomb radiocarbon inventory as the residual between the accumulated bomb ^{14}C production and the observed resp. observation-constrained simulated bomb ^{14}C inventories in the troposphere, the stratosphere and the ocean. This indirect biospheric bomb ^{14}C inventory estimate may then be used to constrain the setup and parameterisation of biosphere models.

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