VALIDATING HIGH-RESOLUTION TERRESTRIAL BIOSPHERE MODELS USING RADIOCARBON OBSERVATION

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(Poster)

Observations of natural and bomb-produced radiocarbon in the climate system are powerful constraints on the turnover rates of carbon reservoirs. Until now this information has only be marginally used to validate and improve TBMs applied to simulate the anthropogenic CO_2 transient.

We have implemented equations describing ^{14}C and ^{13}C turnover into the Community Terrestrial Biosphere Model (CTBM) which presently includes a version of the High Resolution Biosphere Model (HRBM; Esser, 1987, Esser, 1994). The model has a spatial resolution of 0.5x0.5 degrees. Terrestrial carbon stocks are represented by 4 vegetation, 4 litter and 1 soil pool per pixel. The model was first run towards equilibrium by prescribing the approximate pre-industrial levels of atmospheric CO_2 $^{14}C/^{12}C$ and $^{13}C/^{12}C$ ratios and a mean climatology. For simulations spanning, the historical period the model is forced by the observed history of atmospheric CO_2 and its carbon isotopes.

The release of radiocarbon free and ^{13}C depleted fossil fuel has lead to a decrease in atmospheric $\delta^{13}C$ and $\Delta^{14}C$ until the start of the atomic bomb tests. The atomic weapon tests in the late 50s and early 60s added substantial amounts of radiocarbon to the natural background, leading to maximum tropospheric concentration around 1964. Tracking the the spread of bomb-produced ^{14}C and of the fossil fuel ^{13}C and ^{14}C signals into biosphere and ocean allows one gain insight into the dynamics of these two important carbon reservoirs.

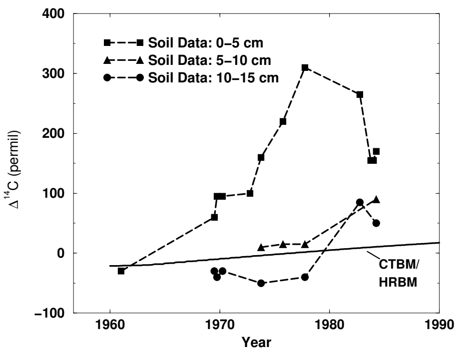

Figure 1: Comparison of measured (Harkness et al., 1986) versus modelled soil radiocarbon at Mathop Wood. The CTBM/HRBM model (solid line) is not able to depict the observed rapid response of soil $\Delta^{14}C$ at Meathop Wood (symbols) to the step rise in atmospheric radiocarbon levels caused by atomic-wapon tests in the late 50s and early 60s.

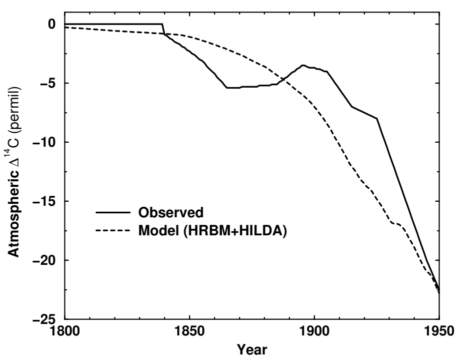

Figure 2: Comparison of observed versus modelled decrease in atmospheric $\Delta^{14}C$ caused by the release of radiocarbon depleted fossil fuel. Model results were obtained by a coupled pulse version of the CTBM/HRBM biosphere model and the HILDA ocean model.

The changing atmospheric $\Delta^{14}C$ levels have lead to a substantial difference between the $\Delta^{14}C$ signature of the fluxes into and out of the terrestrial biosphere. The magnitude of this isotopic disequilibrium depends on the turnover rate of the different carbon reservoirs. Fast overturning pools like leaves and leaf litter follow approximately the atmospheric signal; $\Delta^{14}C$ of slowly overturning pools like wood and soils remain close to the low pre-industrial levels. During the early 1970's the simulated isotopic disequilibrium between the CO2 taken up and released by the biosphere shows large spatial variations exceeding 400 permil in high latitudes and tropical rainforests. In the 1990's the overall disequilibrium is much smaller (approx. 20permil), but exhibits opposite signs in different parts of the world; a pattern that still might be detectable with high precision measurements of ^{14}C in CO_2 from canopy air samples.

Available radiocarbon measurements on litter and soils allows one to validate the turnover rate of the model on a pixel basis. The model results for the location of the Meathop Wood forests are compared with observations (Harkness et al., 1986). The CTBM/HRBM underestimates the change in soil $\Delta^{14}C$ (Fig. 1). At 1990, predicted soil $\Delta^{14}C$ is 10 permil, whereas observations at Meathop Wood are between 50 and 80 permil for soil depths between 5 and 15 cm and around 150 permil for the top (0-5 cm) soil layer. Clearly, a single soil reservoir as used in the CTBM/HRBM is not sufficient to model realistically carbon and radiocarbon turnover on decadale time scales.

The radiocarbon uptake of the terrestrial biosphere is essential to establish the global budget of bomb-produced radiocarbon. Previous budget estimates based on box models have revealed an imbalance in the global budget on the order of 10-15 % (Hesshaimer et al, 1994, Joos, 1994). The global uptake of bomb-produced radiocarbon between mid 1965 and mid 1989 as simulated by the CTBM/HRBM is $110 \cdot 10^{26}$ atoms (without land use changes) and $95 \cdot 10^{26}$ atoms when correcting for land use emissions. The latter value can be compared with previous box model estimates by Hesshaimer et al. ($60 \cdot 10^{26}$), Broecker et al. ($45 \cdot 10^{26}$) and Joos ($89 \cdot 10^{26}$). Thus, results of the spatially resolved CTBM/HRBM model do not imply a reduced imbalance in the global ^{14}C budget.

The release of fossil CO_2 has lead to an estimated decrease in atmospheric $\Delta^{14}C$ values by 17.3 $^\circ/_{\circ\circ}$ between 1860 and 1950 and a decrease in atmospheric ^{13}C of about 1.4 $^\circ/_{\circ\circ}$ until 1990. A pulse substitute model of the CTBM/HRBM was implemented which yields identical results for the global net ecosystem production of carbon and carbon isotopes (see Abstract by Meyer et al.). This pulse version of the CTBM/HRBM model was coupled to an ocean pulse substitute version of HILDA (Siegenthaler and Joos, 1992) and a well mixed atmosphere. The combined model yields a decrease of 21 permil in atmospheric $\Delta^{14}C$ between 1860 and 1950 (Fig. 2) and of 1.3 permil in atmospheric $\delta^{13}C$ between pre-industrial time and 1990 when forced by the observed atmospheric CO_2 and fossil fuel emission history. Results of the combined CTBM/HRBM-HILDA model are thus in agreement with observed changes in the atmospheric isotopic composition.

REFERENCES

Esser, G. 1987. Sensitivity of global carbon pools and fluxes to human and potential climatic impacts *Tellus, Ser. B*, **39**, 245–260.

Esser, G., Hoffstadt, J., Mack, F., Wittenberg, U. 1994. High Resolution Biosphere Model (HRBM)–Documentation Model Version 3.00.00. *In: Mitteilungen aus dem Institut für Pflanzenökologie der Justus–Liebig–Universität Giessen (ed. G. Esser). Giessen, Germany*, **2**, 70 p.

Harkness, D.D., Harrison, A.F., Bacon P.J. 1986. The temporal distribution of 'bomb' ^{14}C in a forest soil *Radiocarbon*, **28**, 328-337.

Hesshaimer, V., Heimann, M., Levin, I. 1994. Radiocarbon evidence for a smaller carbon dioxide sink than previously believed *Nature*, **370**, 201-203.

Joos, F. 1994. Imbalance in the budget *Nature*, **370**, 181-182.

Siegenthaler, U., Joos, F. 1992. Use of a simple model for studying oceanic tracer distributions and the global carbon cycle *Tellus, Ser. B*, **44**, 186-207.