Validating High-ResolutionTerrestrial Biosphere Models Using Radiocarbon Observations

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SCOPE:

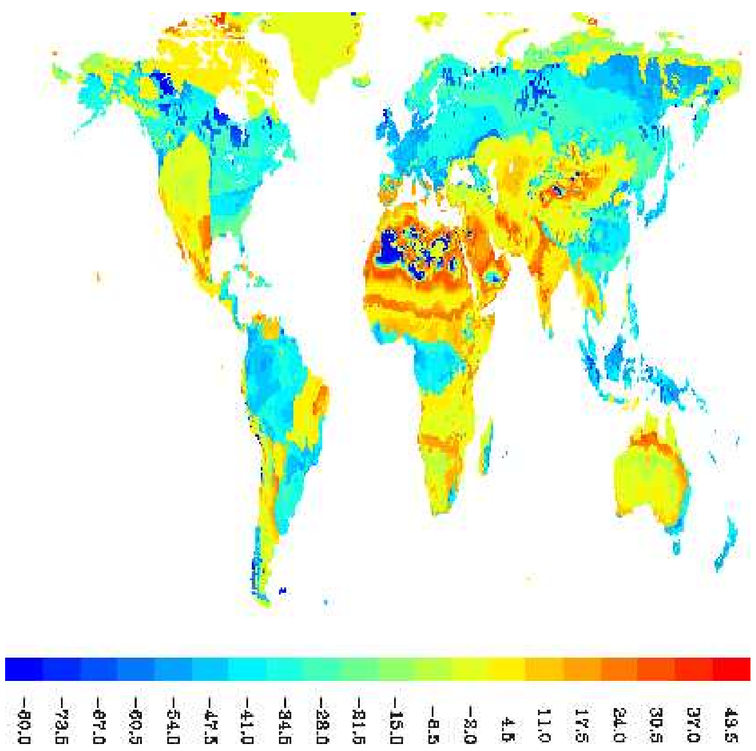
Radiocarbon has been implemented in the High-Resolution Biosphere Model (HRBM, Esser, 1987; Esser et al., 1994)

- **to validate the model using available radiocarbon data.**
- **to make a range of predictions (isotopic disequilibrium, terrestrial sources and sinks, bomb-produced ^{14}C uptake, ^{14}C distribution in soils and vegetation)**

A MAIN CONCLUSION:

- **The isotopic difference between assimilated and respired carbon exhibits a significant spatial variability of several tens of permil $\Delta^{14}C$.**
- **It is suggested to measure this isotopic disequilibrium in order to study carbon turnover rates and to test terrestrial biosphere models.**

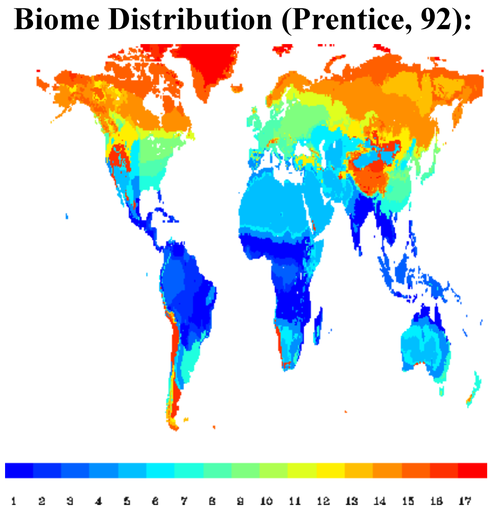
The Air-biota $\Delta^{14}C$ Disequilibrium



$\Delta^{14}C$ of heterotrophic respiration minus $\Delta^{14}C$ of NPP as simulated by the HRBM for the year 1990. The $\Delta^{14}C$ signature between assimilated (NPP) and respired (heterotrophic) carbon varies in space and time. Although this isotopic difference has decreased during last decades it is probably still detectable. Measurements on atmospheric air have the advantage that they aggregate over larger space scales as compared to measurements on soil radiocarbon. We suggest that isotopic disequilibrium measurements are taken in order to validate the prediction of terrestrial biosphere models.

The Terrestrial Biosphere Model

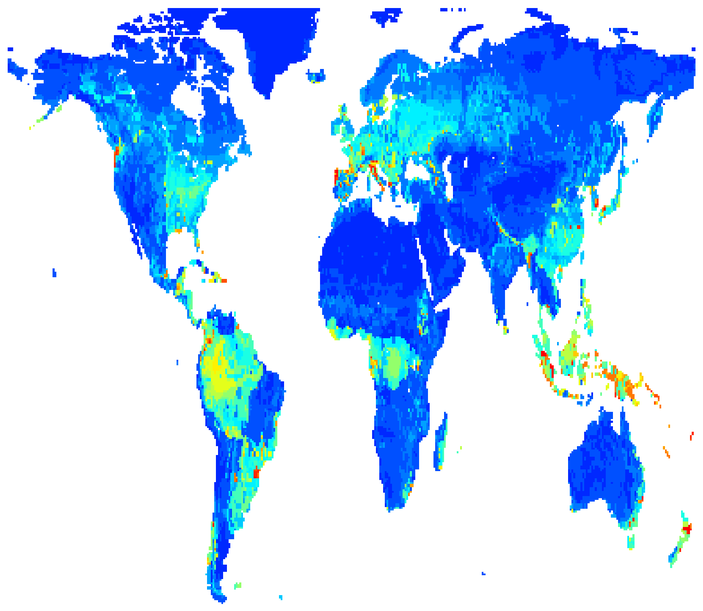
Biome Distribution (Prentice, 92):



1:Tropical Dry Forest/Savannah
2: Tropical Seasonal Forest
3: Tropical Rain Forest
4: Xerophytic Woods/Shrub
5: Hot Desert
6: Warm Grass/Shrub
7: Broadleaf Evergreen/Mixed Forest
8: Temperate Deciduous Forest
9: Cool Mixed Forest
10: Cold Mixed Forest
11: Cool Conifer Forest
12: Cool Grass/Shrub
13: Cold Deciduous Forest
14: Boreal Forest
15: Tundra
16: Semidesert

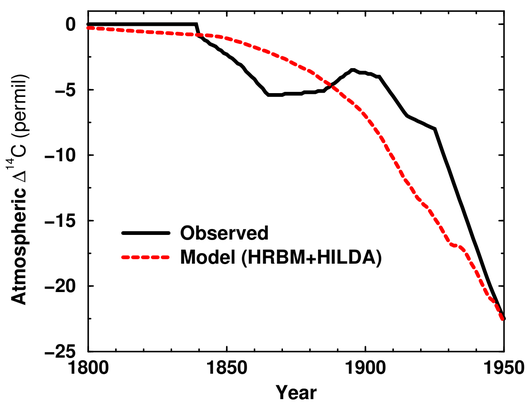
A version of the High Resolution Biosphere Model (HRBM) has been implemented in the Community Terrestrial Biosphere Model. Equations describing the turnover and the exchange with the atmosphere of ^{14}C and ^{13}C have been added. The model has a spatial resolution of 0.5x0.5 degrees. Carbon stocks are represented by 4 vegetation, 4 litter and 1 soil pool per pixel. The model was first run towards equilibrium by prescribing pre-industrial atmospheric levels of CO_2 and its isotopes. Then, observed concentrations were prescribed for the historical period (1765-1990). All simulations were carried out using 'potential vegetation' and a mean climatology.

Net ^{14}C Air-to-biota Fluxes



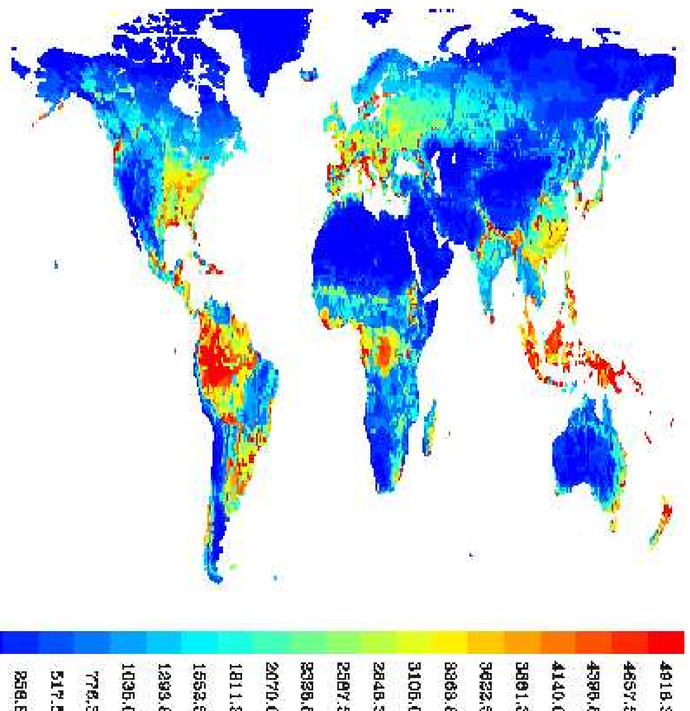
The net carbon flux from the atmosphere into the biosphere at 1990 in units of 10^{-12} mol m^{-2} yr^{-1}. The distribution of ^{14}C sources and sinks contribute to the observed atmospheric radiocarbon distribution. At 1990, the model simulates in most regions a biospheric uptake of radiocarbon. The largest sinks are found in the high-productivity areas in the Tropics. Note that the simulation is for potential vegetation and that fluxes in areas used for agriculture are probably overestimated.

The Suess Effect

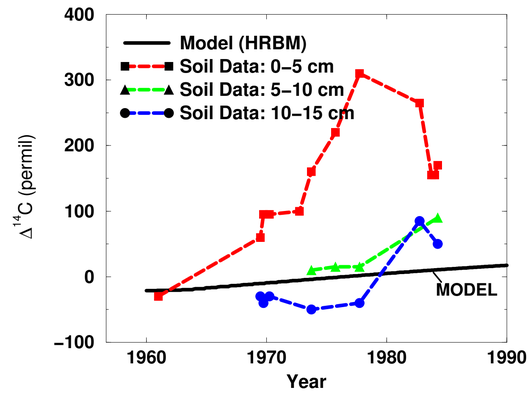


Observed versus modeled decrease in atmospheric $\Delta^{14}C$. About 17 permil of the observed decrease between 1860 and 1950 is attributed to the release of ^{14}C depleted fossil fuel; an additional decrease of 3 permil is due to variations in the cosmic ^{14}C production. Model results were obtained by a coupled version of the HRBM model and the HILDA ocean model forced by the fossil emission history. The model is able to simulate the estimated decrease due to fossil fuel only within the uncertainty of the data.

The Uptake of Bomb-produced ^{14}C



The inventory of bomb-produced radiocarbon in the terrestrial biosphere as simulated for 1990 (units: 10^{12} atoms m^{-2}). The atomic-bomb tests in the late 50s and early 60s added substantial amounts of ^{14}C to the natural background, leading to maximum tropospheric concentrations around 1964. Tracking the spread of bomb-produced ^{14}C yields insight into the dynamics of carbon reservoirs. The high-productivity region in the tropics show the largest inventories. Note that the simulation is for potential vegetation.



Comparison of measured versus modeled soil radiocarbon at Meathop Wood. The 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. The results suggest that a single soil reservoir as used in the HRBM is not sufficient to model realistically carbon and radiocarbon turnover on decadal time scales.