

Spatial and Temporal Patterns of Biotic Exchange of CO₂

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Our research is focused on a better quantification of the variations in CO₂ exchanges between the atmosphere and biosphere and the factors responsible for these exchanges. The principal approach is to infer the variations in the exchanges from variations in the atmospheric CO₂ distribution.

The principal tool involves using a global three-dimensional tracer transport model to advect and convect CO₂ in the atmosphere. The tracer model we use was developed at the Goddard Institute for Space Studies (GISS) and is derived from the GISS atmospheric general circulation model. A special run of the GCM is made to save high-frequency winds and mixing statistics for the tracer model. We note the GISS tracer model is widely distributed, and forms the basis for the tracer models at Scripps Institution of Oceanography (Keeling et al., 1989), Max-Planck Institute, Hamburg (Heimann, 1995) and CSIRO, Australia (Enting, et al., 1993).

Source/sink distributions need to be specified for the tracer model. For some sources and sinks, e.g. fossil fuel combustion, the pattern and magnitudes can be specified with some confidence. For others, e.g. biospheric uptake, the patterns and magnitudes are the major unknowns in the carbon cycle. Where possible, we have compiled information about the "better-known" sources and sinks, and gridded the information on carbon exchanges into a format compatible with the atmospheric models. These source/sink patterns are distributed via CDIAC as DB1006. They form the basis for an international tracer model intercomparison (Law and Rayner, 1995).

To deduce the sought-after magnitudes and patterns of the net uptake by the biosphere and by the ocean, and to test hypotheses about "known" sources and sinks, we developed a new approach for the inverse problem. We first divide the biosphere and ocean into units (e.g. a vegetation type or the North Atlantic between 15N and 50N). For each unit, we assign a hypothetical source strength of 1 GtC/y. The tracer model is run for each unit. The resultant atmospheric CO₂ responses are then combined, with the source strength of each unit as those required to provide a best fit between

the simulated and observed atmospheric CO₂ variations.

Each tracer model experiment is integrated for a minimum of 3 years, so that the north-south gradient stabilizes for the specified source/sink. Typically, we divide the biosphere into 11 vegetation types, and the oceans into 15 regions. Together with the fossil fuel and landuse sources, an investigation of a single carbon budget scenario involves ~ 90 model years.

The tracer model experiments are carried out on the successive generations of computers at GISS. With the tremendous leaps in computational capability, the cpu requirement has dropped from 24 cpu hours/model year on the 1983 Amdahl computers to 5 cpu minutes/model year on the 1996 IBM 6000 RISC station.

References

Enting, I. G., C. M. Trudinger, R. J. Francey, and H. J. Granek (1993): Synthesis inversion of atmospheric CO₂ using the GISS tracer transport model. CSIRO DAR Tech. Report No. 29, 44 pp.

Keeling, C. D., S. C. Piper, M. Heimann (1989): A three-dimensional model of atmospheric CO₂ transport based on observed winds: 4: Mean annual gradients and interannual variations. In *Aspects of Climate Variability in the Pacific and Western Americas*, D. Peterson (ed.), Geophysical Monograph 55, American Geophysical Union.

Heimann, M. (1995): The global atmospheric tracer model TM2. Deutsches Klimarechenzentrum, Technical Report No. 10, 51 pp.

Law, R.M. and P.J. Rayner (1995): A comparison of modelled responses to prescribed CO₂ sources. CSIRO DAR Tech. Report No. 36.

The publications resulting from the IAG are listed below.

- Takahashi, T., P. Tans and I. Fung (1992): Balancing the budget: Carbon dioxide sources and sinks, and the effects of industry. *Oceanus*, 35(1), 18-28.
- Bolin, B. and I. Fung (1992): The carbon cycle revisited. In: *Modeling the Earth System*, D. Ojima (ed.), pp. 151-164, OIES Global Change Institute Vol. 3, UCAR, Boulder, CO.
- Graedel, T.E., T.S. Bates, A.F. Bouwman, D. Cunnold, J. Dignon, I. Fung, D.J. Jacob, B.K. Lamb, J.A. Logan, G. Marland, P. Middleton, J.M. Pacyna, M. Placet and C. Veldt (1993): A compilation of inventories of emissions to the atmosphere. *Global Biogeochemical Cycles*, 7, 1-26.
- Fung, I. (1993): Models of oceanic and terrestrial sinks of anthropogenic CO₂: A review of the contemporary carbon cycle. In *The Biogeochemistry of Global Change: Radiative Trace Gases*, R.S. Oremland (editor), pp. 166-189, Chapman and Hall, NY.
- Dai, A.G. and I. Fung (1993): Can climate variability contribute to the "missing" CO₂ sink? *Global Biogeochemical Cycles*, 7, 599-609.
- Tans, P., I. Fung and I. Enting (1995): Storage versus flux budgets: The terrestrial Uptake of CO₂ during the 1980's. In "Biotic Feedbacks in the Global Climatic System: Will the Warming Feed the Warming?" G. Woodwell and F. Mackenzie (eds.), Oxford University Press. pp. 351-366.
- Fung, I. (1995) Perturbations to the biospheric carbon cycle: uncertainties in the estimates. In "Biotic Feedbacks in the Global Climatic System: Will the Warming Feed the Warming?" G. Woodwell and F. Mackenzie (eds.), Oxford University Press pp. 366-374.
- Fung, I. and T. Takahashi (1995): Assessment of factors affecting estimates of air-sea exchanges of CO₂ from pCO₂ gradients. In "The Carbon Cycle", T. Wigley and D. Schimel (eds.) (in press).
- Friedlingstein, P., K. Prentice, I. Fung, J. John, and G. Brasseur (1995): Carbon-biosphere-climate interactions in the LGM climate. *J. Geophys. Res.*, 100, 7203-7221.
- Friedlingstein, P., I. Fung, E. Holland, J. John, G. Brasseur, D. Erickson, and D. Schimel (1995): On the contribution of biospheric CO₂ fertilization to the missing sink. *Global Biogeochemical Cycles*, 9, 541-556.
- Braziunas, T. F., I. Y. Fung and M. Stuiver (1995): The preindustrial atmospheric ¹⁴CO₂ latitudinal gradient as related to exchanges among atmospheric, oceanic and terrestrial reservoirs. *Global Biogeochemical Cycles*, 9, 565-584.
- Denning, A.S., I. Fung, and D. Randall (1995): Strong simulated meridional gradient of atmospheric CO₂ due to seasonal exchange with the terrestrial biota. *Nature*, 376, 240-242.