$^{14}CO_2$ as a Diagnostic for Vertical Transport in Atmospheric Transport Models

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Atmospheric transport models can be used in combination with trace gas observations to infer sources and sinks of these gases. However, if the model transport is uncertain, this translates directly to uncertainties in the inferred sources and sinks. Recent studies indicate that the vertical transport in particular is poorly represented in most current models, especially over the continents. In the Transcom model intercomparison, the 12 different model estimates of the Northern Hemisphere land biosphere carbon sink ranged from 0.8 GtC/yr to 3.6 GtC/yr, with the differences likely attributable to differences in vertical transport.

Comparison of modeled and observed distributions of a surface-emitted tracer with a well-known flux distribution can be used to better constrain the vertical mixing. Observations of the radiocarbon content of atmospheric carbon dioxide ($\Delta^{14}CO_2$), as a proxy for fossil fuel CO_2 emissions, have the potential to be an excellent tool for this application.

Results from two atmospheric transport models (LMDZ and TM5) demonstrate that (^{14}C-free) fossil fuel CO_2 emissions are the dominant flux driving spatial variability in $\Delta^{14}CO_2$ over the Northern Hemisphere continents, contributing 90% of that variability.

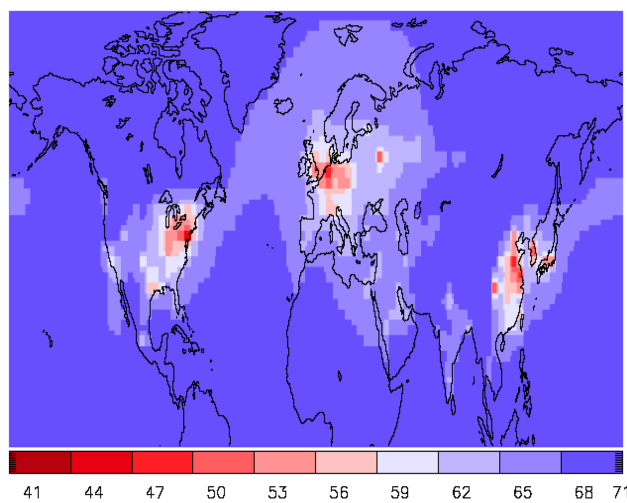

Figure 1. Mean annual Northern Hemisphere $\Delta^{14}CO_2$ surface distribution from LMDZ (for 2002-2007), demonstrating that the $\Delta^{14}CO_2$ distribution is dominated by the impact of fossil fuel CO_2 emissions, with low $\Delta^{14}CO_2$ values in regions where fossil fuel CO_2 is emitted, and values gradually increasing as the fossil fuel CO_2 is dispersed away from the source.

Other fluxes (including CO_2 fluxes from the terrestrial biosphere and oceans, and natural and anthropogenic ^{14}C production) have little impact on the $\Delta^{14}CO_2$ distribution in the Northern Hemisphere. However, different vertical mixing parameterizations in the models produce large differences in the simulated $\Delta^{14}CO_2$ spatial distribution (driven by the underlying fossil fuel CO_2 emissions), both in vertical profiles and surface transects, and these differences between models are large relative to uncertainties in the fossil fuel CO_2 flux. Recent advances in precision and sample size requirements for $\Delta^{14}CO_2$ measurements mean that $\Delta^{14}CO_2$ measurements can now be made routinely, using existing flask sampling networks, with sufficient precision to discriminate between model mixing scenarios. Initial $\Delta^{14}CO_2$ observations from a surface transect taken on the Trans-Siberian railway (TROICA-8 expedition), and for vertical profiles from several aircraft profiling sites, demonstrate the potential of this method.