THE IMPACT OF REDUCED CARBON OXIDATION ON THE ATMOSPHERIC CO_2 DISTRIBUTION: IMPLICATIONS FOR INVERSE ANALYSES

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ABSTRACT

We evaluate the impact on modeled atmospheric CO_2 concentrations of explicitly representing the tropospheric CO_2 source from reduced carbon oxidation. We also calculate the bias in inverse flux estimates that results from omitting this influence.

INTRODUCTION

Recent inverse estimates of regional CO_2 fluxes have not explicitly resolved the tropospheric CO_2 source from oxidation of reduced carbon species (CO, CH_4, and non-methane hydrocarbons). Instead, this carbon is included in the prior inventories employed in these analyses, where it is represented as surface emissions of CO_2. The tropospheric lifetimes of carbon monoxide and methane range from months to years, hence these reduced carbon species are transported on a global scale far from their surface release location before being oxidized to CO_2. There is, therefore, a systematic discrepancy between the actual distribution of the CO_2 source from reduced carbon oxidation and the modeled representation employed in many inverse analyses. The observations used to constrain the inversion capture the actual distribution of tropospheric oxidation; hence, neglecting its 3-D representation in modeled CO_2 fields introduces a systematic bias in the concentration residuals constraining the inversion and in the derived flux estimates.

We used a 3-D atmospheric chemistry model (GEOS-Chem) to evaluate the magnitude of this effect in modeled CO_2 concentrations and flux estimates. Resolving the 3-D structure of the atmospheric CO_2 source (taken as 1.1 PgC/year), as opposed to emitting this reduced carbon as CO_2 at the surface, yields a decrease in the modeled annual mean surface interhemispheric gradient of 0.21 ppm. Larger concentration adjustments (up to -0.6 ppm) are seen downwind of regions of high reduced carbon emissions.

The TransCom3 annual mean inversion of *Gurney et al.* [2002] reported an interhemispheric difference for the concentration residuals of 2.3 ppm (mean across models) and a mean estimated northern land uptake of 2.2 PgC/year. We employed TransCom3 simulations from three transport models (MATCH-CCM, GISS-UCI, LSCE-TM2) to evaluate implications of our analysis for inversion estimates (Table 1). In annual mean inversions, northern land carbon uptake systematically decreased (by 0.22-0.27 PgC/year) with larger relative impacts seen in regional fluxes.

Our modeled concentration adjustments display distinct seasonal variation driven by variability in reduced carbon sources and OH concentrations, suggesting significant implications for monthly flux

estimates. We will also present these results. Overall, our analysis highlights the need for a realistic description of reduced carbon oxidation in inverse analyses of CO_2 fluxes.

Table 1. Impact on inverse flux estimates. Results are shown for the inverse methodology of the TransCom3 annual mean analysis of *Gurney et al.* [2002], and for three participating models. The 'Bias' column lists the change in flux estimates when modeled concentrations are adjusted to account for the explicit representation of reduced carbon oxidation.

	MATCH-CCM			LSCE-TM2			GISS-UCI		
REGION	Flux Estimates			Flux Estimates			Flux Estimates		
	(Pg C yr^{-1})								
	Original	Adjusted	Bias	Original	Adjusted	Bias	Original	Adjusted	Bias
North America	-0.70 ±0.3	-0.62	0.07	-0.8±0.4	-0.84	0.01	-0.29 ±0.4	-0.25	0.03
Northern Asia and Europe	-1.81 ±0.3	-1.67	0.15	-0.07±0.5	0.17	0.24	-1.06 ±0.5	-0.82	0.24
Northern land[a]	-2.51 ±0.4	-2.29	0.22	-0.91 ±0.5	-0.67	0.25	-1.35 ±0.5	-1.08	0.27
Northern ocean[a]	-0.39 ±0.3	-0.40	-0.01	-1.76 ±0.4	-1.81	-0.05	-2.06 ±0.5	-2.15	-0.08
Tropical land[a]	1.0 ±0.7	0.86	-0.14	0.02 ±0.8	-0.15	-0.17	0.32 ±0.8	0.18	-0.14
Tropical ocean[a]	0.66 ±0.3	0.62	-0.04	0.50 ±0.2	0.48	-0.02	0.98 ±0.3	0.94	-0.03
Southern land[a]	-0.71 ±0.6	-0.73	-0.02	-0.01 ±0.6	0.01	0.02	0.19 ±0.6	0.21	0.02
Southern ocean[a]	-0.88 ±0.3	-0.86	0.02	-0.66±0.4	-0.68	-0.03	-0.90 ±0.4	-0.93	-0.03

[a] Results are shown on a regionally aggregated basis and for three transport models. Also shown for each model are the flux estimates before and after accounting for reduced carbon oxidation (Columns 1 and 2 for each model). A posteriori uncertainties on flux estimates are given in the first column for each model.
The regional totals are aggregated over the TransCom3 regions as follows:
Northern land is the sum of boreal and temperate North America, boreal and temperate Asia and Europe.
Tropical land is the sum of tropical America, tropical Asia and northern Africa.
Southern land is the sum of South America, Southern Africa and Australia.
Northern ocean is the sum of the North Pacific, the North Atlantic and the Northern ocean.
Tropical ocean is the sum of the tropical east and west Pacific, the tropical Atlantic and the tropical Indian ocean.
Southern ocean is the sum of the south Indian ocean, the south Atlantic, the south Pacific and the Southern ocean.

REFERENCE

K.R. Gurney et al. (2002), Towards robust regional estimates of CO_2 sources and sinks using atmospheric transport models, *Nature, 415,* 626-630.