THE IMPACT OF TRANSPORT AND ESTIMATION ERRORS ON THE SIGNIFICANCE OF INTERANNUAL CO_2 FLUX INVERSION RESULTS

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ABSTRACT

Transport-based inversions of atmospheric CO_2 concentration measurements have been used by several groups [e.g., *Bousquet, et al.*, 2000; *Rödenbeck, et al.*, 2003; *Baker, et al.*, 2005] to estimate monthly regional CO_2 fluxes from the 1980s to the present. When compared at the scale of broad latitude bands, the inter-annual variability (IAV) of these results is broadly consistent. This agreement breaks down, however, when the fluxes are partitioned regionally inside these latitude bands, or even into global land/ocean totals. We show here that this disagreement can largely be explained by random estimation errors and transport model errors affecting the estimates.

METHOD

In the TransCom3 project, a global flux inversion estimated CO_2 fluxes for 22 regions for each month across 1988-2003 [*Baker, et al.,* 2005]. The identical inversion setup was applied using transport from 13 different models, each driven by a single year's winds. The spread in the flux estimates was then used to compute the "transport model" error for any one of the models. This transport error, along with the random estimation error inherent to the inversion, may be thought of as a "noise" obscuring the underlying "signal" of interest, the flux IAV for each region. The probability that the estimated IAV for each region is due solely to the integrated effects of this noise, rather than to the true signal, is assessed using a χ^2 significance test.

	Prior error	Post. error	Transport error	P		Prior error	Post. error	Transport error	P
Boreal N America	0.35	0.19	0.14	0.97	North Pacific	0.28	0.14	0.09	0.00
Temp N America	0.84	0.23	0.22	0.02	West Pacific	0.20	0.13	0.09	0.99
Tropical America	1.34	0.69	0.41	1.00	East Pacific	0.22	0.14	0.05	0.00
Temp S America	0.87	0.51	0.27	0.39	South Pacific	0.38	0.20	0.14	0.00
Northern Africa	0.77	0.50	0.28	0.29	Northern Ocean	0.16	0.09	0.04	0.00
Southern Africa	0.93	0.48	0.31	1.00	North Atlantic	0.18	0.13	0.06	0.98
Boreal Asia	0.70	0.24	0.18	0.96	Trop. Atlantic	0.18	0.14	0.05	0.92
Temperate Asia	0.79	0.25	0.24	0.68	South Atlantic	0.20	0.15	0.06	0.11
Tropical Asia	0.60	0.31	0.25	0.00	Southern Ocean	0.46	0.11	0.06	0.02
Australia	0.32	0.12	0.09	0.11	Tropical Indian	0.26	0.18	0.08	0.01
Europe	0.70	0.19	0.14	0.00	South Indian	0.21	0.12	0.06	0.99
North America	0.91	0.25	0.24	0.02	North Pacific	0.28	0.14	0.09	0.00
Eurasia	1.26	0.28	0.25	0.05	Atlantic 15°N+	0.24	0.16	0.08	1.00
Northern Land	1.55	0.28	0.23	0.00	Northern Oceans	0.37	0.22	0.13	0.00
Tropical Land	1.66	0.69	0.46	0.00	Tropical Oceans	0.44	0.30	0.14	0.03
Southern Land	1.31	0.56	0.31	0.03	Southern Oceans	0.66	0.27	0.19	0.05
Global Land	2.62	0.53	0.29	0.00	Global Ocean	0.88	0.47	0.27	0.00
Northern Total	1.59	0.22	0.22	0.00	Africa	1.21	0.61	0.41	0.32
Tropical Total	1.72	0.58	0.44	0.00	South America	1.60	0.66	0.43	0.99
Southern Total	1.47	0.45	0.30	0.01	Australasia	0.68	0.33	0.27	0.00
Global Total	2.76	0.25	0.13	0.00	Trop. Pacific	0.30	0.18	0.11	0.02

Table 1. The *a priori* and *a posteriori* flux IAV estimation error (1σ) [PgC yr^{-1}], the transport model error (1σ) derived from the 13-model spread [PgC yr^{-1}], and the χ^2 test probability *P* that the estimated IAV could be due solely to the combined effects of the *a posteriori* estimation error and the transport error.

RESULTS

Table 1 gives the 1σ transport and estimation errors obtained, along with the significance given by the χ^2 test, for the IAV for each of the 22 regions and for various grouping of the regions. It shows that the IAV for half of the 11 ocean regions, and for all but three of the 11 land regions, are not significant at the 98% confidence level ($P<0.02$). The total flux grouped into 3 latitude bands is significant, but when split into land/ocean components inside these bands the significance becomes marginal in the south and for the tropical oceans.

Figure 1 gives the 13-model mean estimated IAV time series at the continent/basin scale for the northern and tropical latitudes. The land/ocean breakdown in the extra-tropical north is on the edge of significance (Table 1): transport errors here confound an otherwise well-constrained estimate. In the tropics, the estimation errors (due to the sparsity of measurement sites) alone render the IAV for South America and Africa insignificant.

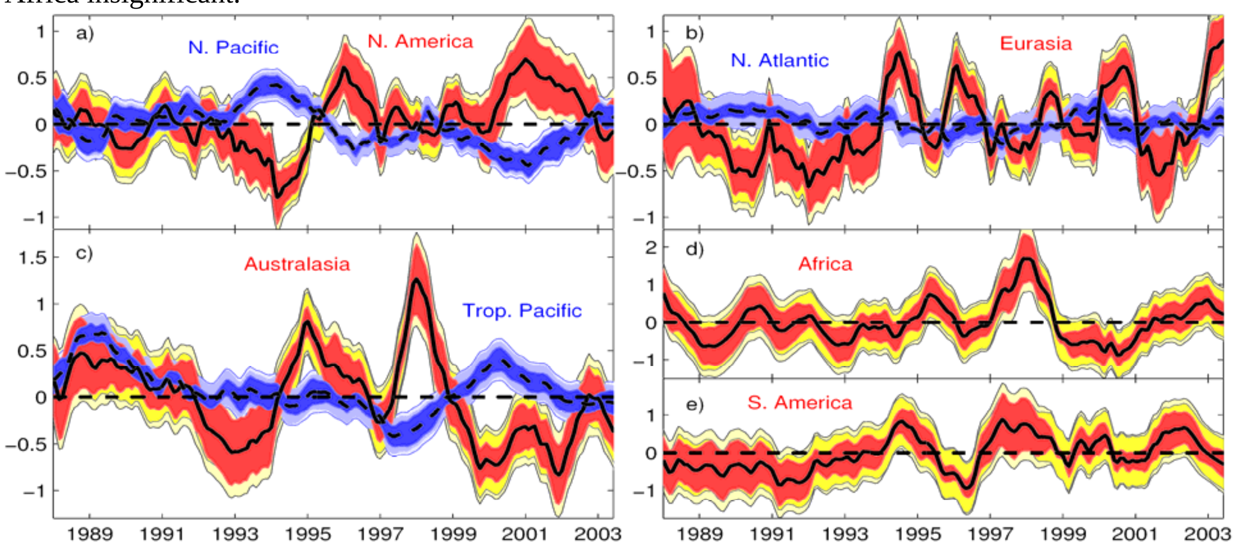

Fig. 1. The 13-model mean regional flux IAV [PgC yr^{-1}] for selected land (solid) and ocean regions (dashed), plus the *a posteriori* estimation error (light shading) and transport model error (dark shading).

For the regions with significant IAV, note that the estimated response for Australasia during the 1997-98 El Niño agrees well in timing and magnitude with the carbon release from Indonesian fires then. The East Pacific IAV also displays a reduced outgassing during that El Niño (as would be expected with the capping of the thermocline) and increased outgassing during the following La Niña.

While the error sources considered here could largely explain the differences between the published CO_2 flux IAV results, differences in how the inversions constrain the fine-scale fluxes probably also play a role. We are exploring the sensitivity of our results to various regularization approaches (SVD truncation, frequency truncation, regional grouping, and use of a tight prior).

REFERENCES

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