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Error correlation between CO_2 and CO as constraint for CO_2 flux inversions using satellite data

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Abstract. Inverse modeling of CO_2 satellite observations to better quantify carbon surface fluxes requires a chemical transport model (CTM) to relate the fluxes to the observed column concentrations. CTM transport error is a major source of uncertainty. We show that its effect can be reduced by using CO satellite observations as additional constraint in a joint CO_2-CO inversion. CO is measured from space with high precision, is strongly correlated with CO_2, and is more sensitive than CO_2 to CTM transport errors on synoptic and smaller scales. Exploiting this constraint requires statistics for the CTM transport error correlation between CO_2 and CO, which is significantly different from the correlation between the concentrations themselves. We estimate the error correlation globally and for different seasons by a paired-model method (comparing GEOS-Chem CTM simulations of CO_2 and CO columns using different assimilated meteorological data sets for the same meteorological year) and a paired-forecast method (comparing 48- vs. 24-h GEOS-5 CTM forecasts of CO_2 and CO columns for the same forecast time). We find strong error correlations (r^2>0.5) between CO_2 and CO columns over much of the extra-tropical Northern Hemisphere throughout the year, and strong consistency between different methods to estimate the error correlation. Application of the averaging kernels used in the retrieval for thermal IR CO measurements weakens the correlation coefficients by 15% on average (mostly due to variability in the averaging kernels) but preserves the large-scale correlation structure. We present a simple inverse modeling application to demonstrate that CO_2-CO error correlations can indeed significantly reduce uncertainty on surface carbon fluxes in a joint CO_2-CO inversion vs. a CO_2-only inversion.

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