Atmos. Chem. Phys. Discuss., 5, S3569–S3573, 2005
www.atmos-chem-phys.org/acpd/5/S3569/
European Geosciences Union

Atmospheric Chemistry and Physics Discussions

Interactive comment on "The effect of systematic measurement errors on atmospheric CO_2 inversions: a quantitative assessment" *by* C. Rödenbeck et al.

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Received and published: 3 November 2005

General comments:

This paper quantifies the magnitude of two sources of systematic errors affecting long-term CO_2 measurement records, then assesses their impact on the CO_2 fluxes estimated by atmospheric inverse analysis. The authors successfully show that these error sources would change current inversion results only slightly. This is a significant finding that is important for the interpretation of previous inversion results.

This reviewer disagrees with the broader assertion made in the conclusions, however,

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that "the systematic measurement errors are not an important error source in present-day inversions" (see specific comments below). I suggest that the paper be published if minor corrections are made: either the rewording of this sentence in the conclusions, or else with the inclusion of a couple extra experiments suggested below.

Specific comments:

This paper calculates the magnitude of two types of systematic errors (or differences) in long-term atmospheric CO_2 mixing ratio measurements: a) the difference between weekly flask measurements and the corresponding hourly mean for a co-located continuous in situ analyzer, and b) differences in the measurement obtained from a single flask sample when the mixing ratio is sampled at two different laboratories (CMDL and CSIRO). Both differences are affected by pure instrument error, while the first is also affected by time-sampling errors and small spatial sampling differences. The high frequency portion of the differences is filtered out to isolate the systematic portion. Surface CO_2 fluxes estimated in atmospheric inversion studies should be expected to suffer from systematic errors due to these systematic measurement errors, if the effects above are not somehow accounted for.

The two types of systematic measurement differences above are then fed into a full-scale global atmospheric inversion to assess their impact on the retrieved surface CO_2 fluxes. The impact is found to be small. The inter-lab measurement differences cause errors of generally less than 0.02 PgC/yr for fluxes reported on the scale of the 22 regions used in the TransCom 3 study, though differences of up to 0.20 PgC/yr are seen in the global flux totals if the correction is applied to the CMDL time series rather than the CSIRO time series (the locations for which both laboratories take measurements). When the continuous in situ measurements at the five sites examined (BRW, CGA, MLO, SMO, and SPO) are replaced with the corresponding flask samples, the estimated fluxes for the 22 regions shift by up to 0.10 PgC/yr when the systematic errors are fed in (i.e., when sub-annual frequencies in the differences are filtered out – Experiment A1) and by up to 0.20 PgC/yr when the full systematic errors are fed in (Ex-

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periment A2). The computed differences from both sources are small when compared to the other errors previously-published atmospheric CO_2 inversions. The authors compute one example of these other errors by computing the difference of modeled CO_2 fluxes obtained with forward-model runs at two different atmospheric model spatial resolutions, taking the difference, and feeding this difference into the inversion to get the impact on the fluxes (Experiment C).

This paper has succeeded nicely in demonstrating its major practical point: that the global atmospheric CO_2 flux inverse results obtained in the past are not greatly affected by the two types of systematic measurement errors considered here. This reviewer would have to take issue with the broader assertion made in the conclusions, however, that "the systematic measurement errors are not an important error source in present-day inversions". That may well end up to be the case, but the experiments performed here do not demonstrate it. We suggest two additional experiments below that could help to demonstrate it. Both use the idea that the measurement differences obtained here for the few sites where they may be calculated (at BRW, CGO, MLO, SMO, and SPO for the flask vs. continuous analyzer comparison, and at ALT, CGO, and SPO for the inter-laboratory comparison using identical flasks) provide a rough measure of the systematic error between either measurement source and the "true" measurement. These systematic errors are then computed for all sites used in the inversion by extrapolation and the corresponding flux errors computed. It is the results of these experiments (not done here) that ought to be used to assess how biased our current inversion results are due to these error sources.

The first experiment ('A3' perhaps) would be similar to Experiment A2, except that psuedo-data would be created for all of the measurement time series used in the inversion besides the five with actual continuous data (BRW, CGO, MLO, SMO, and SPO) by adding systematic errors similar to those in the right panel of Figure 1. This would be done statistically by taking the sample variance between the five existing systematic differences in the right panel of Figure 1 and generating random difference time series for the other sites with variability agreeing with this variance and with a similar time variability spectrum. Rather than filtering out all sub-annual frequencies, as was done in Figure 1, the frequency cutoff could be placed between 1 month to1 week, to retain seasonally-varying systematic differences but to still filter out the time-sampling error. I would expect the resulting flux errors to be larger than the A2 errors in Figure 4 (since the systematic errors would affect all the measurements rather than just the 5 in Experiment A1), even with the high-frequency variability filtered out.

The second experiment ('B3' perhaps) would be similar to Experiment B2 in that systematic measurement errors would be computed for and applied all the sites used in the inversion. However, rather than applying the single CGA-CGO difference time series from Figure 2 to all the sites, separate systematic error time series would be computed stochastically for each site from the sample variance of the four given in the right panel of Figure 2, and these would be fed through the inversion. Such an experiment would capture the spatial variability in the systematic errors (important since the inversion can easily account for a spatially-constant offset at all sites by a relatively small flux spread out nearly evenly across all sites). As in Experiment A3 above, more of the time variability in the systematic errors would be retained, too, by using a monthly-to-weekly filter cutoff frequency in calculating the smooth curves.

The results from these two experiments would better capture the true biases in the inversions caused by the systematic errors from these two sources. I suspect their impact would be greater than for the results shown here. They might even be of the same magnitude as the errors from Experiment C. This may be seen fairly easily by simply comparing the magnitude of the concentration differences in the left panels of Figures 1-3: unsmoothed differences on the order of 0.2 ppm are seen in all three. Using the same linear propagation of errors as in a traditional covariance calculation (applied instead to the discrete biases we have here) would suggest similar flux errors in all three cases. It is likely that the systematic flux errors obtained from the two additional experiments suggested above would still be smaller than the other errors

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affecting the inverted fluxes, but the difference might not be as clear-cut as presented here.

Aside from my quibble with the wording of the conclusions, I thought this was a very well-written paper that made its main point quite nicely. I also thought the description of the three types of errors affecting our inverse results was well done in the Introduction.

Page 8982, line 1: in referring to previous transport model error assessments, I would point out that the TransCom3 interannual variability results (those closest to what is presented here) have been accepted by Global Biogeochemical Cycles and are in press:

Baker, D.F., R.M. Law, K.R. Gurney, P. Rayner, P. Peylin, A.S. Denning, P. Bousquet, L. Bruhwiler, Y.-H. Chen, P. Ciais, I.Y. Fung, M. Heimann, J. John, T. Maki, S. Maksyutov, K. Masarie, M. Prather, B. Pak, S. Taguchi, and Z. Zhu (2005), TransCom3 inversion intercomparison: Interannual variability of regional CO_2 sources and sinks, 1988-2003, Global Biogeochem. Cycles, doi:10.1029/2004GB002439, in press.

Page 8993, line 4: What autocorrelation time scale was assumed in computing these weightings? If it is fairly short (1 day to 1 week) it might well be asked why such a long time scale (1 year) was used in computing the systematic errors in Figures 1 and 2.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 8979, 2005.

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