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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Three years of greenhouse gascolumn-averaged dry air mole fractionsretrieved from satellite – Part 1:Carbon dioxide" *by* O. Schneising et al.

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Retrieving carbon dioxide from space is a highly demanding task and, even though SCIAMACHY is not a dedicated greenhouse gas mission and features only very moderate spectral resolution in its CO2 channel, results presented here look encouraging and we appreciate the efforts of the authors on this highly important research topic.

Instead of commenting on the entire paper we would like to focus on the claim that the SCIAMACHY measurements indicate regionally enhanced carbon dioxide over Europe's most populated areas pointing to anthropogenic emissions. The two reviewers commented only shortly on this point either being unconvinced or finding this a too

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bold statement. We share their concerns, and are of the opinion that what is missing is a discussion of how these results fit into what is already known about the carbon cycle. Anthropogenic CO2 emissions are in fact fairly accurately known and it is rather straightforward to estimate the expected impact of these emissions on total column CO2 to verify whether or not the SCIAMACHY measurements could point to anthropogenic CO2 emissions.

On page 5504 the authors say: "Figure 16 shows that the XCO2 regional enhancements are only on the order of 1 percent (4 ppm) even for regions of very strong emission sources". This suggests that a systematic increase of the total column by 1% CO2 is not very much, but how much emission would be needed to sustain such a gradient? Unfortunately, the presented comparison with CarbonTracker cannot provide an answer since its resolution of 6x4 degree is too low to resolve any regional CO2 enhancements. The presented maps of population and anthropogenic emissions are graphically appealing, but there is no direct relation with total column CO2 because of atmospheric mixing. Besides this, we should note that the color scale of the emission map is rather misleading, since, according to the EDGAR emission inventory, the highest anthropogenic emissions are found over the German industrial area "Ruhrgebiet" and exceed the range of the color scale by a factor 3. This plot should therefore be adjusted, after which the comparison with SCIAMACHY CO2 will look differently. To determine the expected multi-annual mean CO2 increase due to anthropogenic emissions we ran CarbonTracker (Peters et al., 2007) at a resolution of 1x1 degree over Europe and sampled it at SCIAMACHY overpass times. The results show a 0.4 ppm gradient from the marine background to central Europe. Superimposed on this regional scale gradient are grid-scale enhancements over polluted regions with maximum amplitude of 0.5 ppm. The location of the maximum CO2 enhancement was over the German Ruhrgebiet where fossil CO2 emissions peak, and not strongly west of that region as shown in Figure 16 of the Schneising et al. paper. Taking into account the SCIAMACHY averaging kernel and the (low) uncertainty of the anthropogenic emissions the model could support an anthropogenic signal in the region Netherlands /

ACPD

8, S2530–S2534, 2008

Belgium / Western Germany up to 1 ppm at most. For this reason we conclude that the reported 4 ppm increase is not small as reported, but very large and in fact too large to be explained by anthropogenic emissions only.

What else could explain the SCIAMACHY measurements? One possibility is the heterogeneous sampling in time and space due to selection of cloud free measurements. The CO2 variability over land is governed by climatic variability and its influence on CO2 exchange by the land biosphere and atmospheric transport. Much of this variability could cancel out by averaging several years of data, but the extent to which this happens depends on the number of measurements and how evenly they are distributed in time and space. For Western Europe, because of frequent cloud cover, the number of useful SCIAMACHY measurements is not high and likely biased to certain climatic conditions (see Corbin et al., 2008). In that case there might be no efficient cancellation of the action of the biosphere in the multi-annual mean and significant biospheric signals could remain.

In addition to this, we believe that in urban areas a significant contribution of retrieval errors due to aerosols is to be expected and even more crucial than the aforementioned problem as it holds for urban areas in general. Its influence is expected to be highly systematic and will therefore not cancel out in a multiyear mean. On page 4591-4592 the authors comment on the retrieval method Barkley et al are using and who use different prior aerosol scenarios for urban, maritime and rural climatologies. The comment is as follows: "This approach is not considered to be superior compared to our approach as it also does not take aerosol variability fully into account and might introduce additional complications such as discontinuities of the retrieved CO2 near cities and coast lines." One might wonder whether discontinuities are caused because an urban aerosol scenario is implemented as prior in the retrieval scheme or whether discontinuities are caused by the very existence of urban aerosols if not properly accounted for in the prior aesorol scenario. We think that the main idea behind the approach by Barkley et al is to minimize aerosol interferences in urban areas and that discontinuities

ACPD

8, S2530–S2534, 2008

in urban areas are quite likely what Schneising et al. found in their long-term mean. In table 4, the authors list some estimates of systematic errors caused by aerosols. Given OPAC background aerosols, CO2 would be underestimated by about 0.5% even though the difference in aerosol optical density as compared to the look-up table default is only about 0.07 at 750nm. Given that aerosol optical densities in urban areas certainly differ more strongly than 0.07 from background values, we do believe that a plume as detected in this paper could be more easily explained by systematic errors due to aerosols than by anthropogenic emissions which are expected to be maximally 1 ppm (i.e. 0.26%, being smaller than most aerosol error estimates provided in table 4). We also consider the aerosol optical densities in the look-up table default as rather high. A comparison with the Aeronet measurement network would show that in most places on earth aerosol optical densities should be well below the default used here. In addition, error estimates are only provided at an albedo of 0.1 and assumed identical for both the O2 and CO2 spectral window, whereas Table 2 nicely illustrates that in fact the albedos for both spectral regions is always very different. Aben et al. (2006) show that systematic errors caused by aerosols strongly depend on surface albedo and the choice of albedo 0.1 is in general providing a low estimate of this error. The authors already nicely show the strong effects of desert dust aerosols and how they can be avoided by using TOMS AAI. However, it should be noted that strong aerosol load in urban areas cannot be filtered out as the AAI index is only sensitive to absorbing aerosols and also not to the boundary layer, a region that would be most affected in urban areas.

Because of the tight correlation between aerosols and anthropogenic sources of CO2 one should be very cautious presenting spatial patterns of retrieved CO2 as evidence of anthropogenic CO2 emissions. Overall, we are of the opinion that the assertion that SCIAMACHY can detect an anthropogenic plume of CO2 over Western Europe is not supported by evidence. Both the pattern and amplitude of the observed feature disagree substantially from what is expected for anthropogenic CO2 (which is far better known than biospheric fluxes, rendering such a tremendous underestimation of

ACPD
8, S2530–S2534, 2008

CO2 caused by fossil fuel emissions highly unlikely). Furthermore, the combination of systematic retrieval errors due to aerosols and a biased sampling provides a plausible alternative explanation of the observed CO2 variations.

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Interactive comment on Atmos. Chem. Phys. Discuss., 8, 5477, 2008.