

Notes: Line numbers refer to the original manuscript, and may have changed in formatting.

The answers to the questions raised by the referee #1 by T. Oda and S. Maksyutov

We would like to thank the referee #1 for the comments and questions to our manuscript. Here we list our answers to the questions raised by referee #1 and the corrections made to our original manuscript.

p. 16307: the title is misleading. It omits the BP statistics that are a key component of the inventory. Further it should be made clear that the high resolution refers to space and not time.

We will add “(1km x 1km)” in the title to clarify the meaning of “high resolution” and exclude the period “1980-2007” as follows:

“A very high-resolution (1 km x 1 km) global fossil fuel CO₂ emission inventory derived using a point source database and satellite observations of nighttime lights”

We have removed the period “1980-2007” as it does not provide information relating to our focus in this study.

We have not included “BP statistics” in the title. In this paper, we present a method for disaggregating national and regional emissions (as referee #2 also correctly mentioned in his/her comment), and then evaluated the method by comparing the resulting inventory. We feel that it is better to highlight two main key components for disaggregation (a power plant data and nightlight data) in the title, although the BP statistical review is a required component in this study.

p. 16308, I.5: please insert ‘natural’ behind ‘regional’

This has been amended as follows:

Work with emerging satellite-based inversions requires spatiotemporally-detailed inventories that permit analysis of regional **natural** sources and sinks.

p. 16308, I.7: please insert ‘annual’ before ‘fossil’

This has been amended as follows:

We developed a global 1 km × 1 km **annual** fossil fuel CO₂ emission inventory for the years 1980–2007 by combining a worldwide point source database and satellite observations of the global nightlight distribution.

p. 16308, I.20-21: one wonders how a inventory for yrs 1980-2007 helps processing an instrument that has been launched in 2009. The mention of GOSAT here is an anecdote and actually restricts the prospect of the inventory. It should be better removed.

We have rephrased “The inventory will be incorporated into models for operational flux inversions that use observational data from the Japanese Greenhouse Gases Observing SATellite (GOSAT).”

Now reads:

“The inventory **can be extended to the future using updated data, and** is expected to be incorporated into models for operational flux inversions that use observational data from the Japanese Greenhouse Gases Observing SATellite (GOSAT).”

Preparation of a gridded fossil fuel CO₂ inventory, which is useful for regional inverse analysis, is the initial motivation of this study (see P16309, L13- and P16311, L29-). As presented in Table 3, we presented the improvement with our disaggregation method compared previous studies. As presented above, we intend to prepare fossil fuel CO₂ inventory for future flux inversions using the method presented in this paper or its close modification.

We have not removed the sentence because the resulting inventory would be useful for flux inversions, we however are aware that it still needs improvements as a high resolution fossil fuel CO₂ inventory (as referee #2 pointed out). This study presents the disaggregation of national emissions and the resulting inventory would be an approximate of true CO₂ emission distribution (the authors are aware that there are not measurements to verify true emission distribution). It is difficult to construct such a high-resolution inventory without approximation because of the data availability. Regardless of the ramifications expected, the resulting inventory would be useful for atmospheric modeling purpose, which is our initial motivation. We agree with the referee #1’s suggestion and our inventory could be used for other analysis. But we still feel that we should keep the sentence and it wouldn’t restrict the prospect of the inventory.

p.16308, I.26: analysis of what?

We refer to the analysis of emission sources and trends in development in the previous sentence. This has been amended to read:

Inventories of carbon dioxide (CO₂), which is a major greenhouse gas produced by humans, are a basic tool for monitoring compliance with the guidelines for managing national and global CO₂ emissions, and for the analysis of emission sources and trends in development. **The** analysis provides quantitative insights into fossil fuel CO₂ emissions and facilitates the assessment of practical measures for emission reduction,

p. 16309, I.13: why ‘diagnostic’?

We have changed “ (p.16309, L13-) National inventory datasets are often available in gridded form (e.g., Andres et al., 1996; Brenkert, 1998; Olivier et al., 2005) (typically at 1° resolution) and are

used as input data for physical models, such as Global Climate Models (GCMs) and atmospheric chemical transport models (CTMs), that simulate the state of atmospheric CO₂ in both diagnostic and prognostic ways (e.g., IPCC, 2007).”

to:

“National inventory datasets are often available in gridded form (e.g., Andres et al., 1996; Brenkert, 1998; Olivier et al., 2005) (typically at 1° resolution) and are used as input data for physical models, such as General Circulation Models (GCMs) and atmospheric chemical transport models (CTMs), that simulate the state of atmospheric CO₂ (e.g., IPCC, 2007).”

p. 16309, I.24 19: *please insert ‘a priori’ before ‘knowledge’*

This has been amended to read:

“Flux inversions, which search for the optimal balance between sources and sinks that is consistent with observations, require **a priori** knowledge of fossil fuel CO₂ emissions as well as knowledge of biospheric exchange and oceanic fluxes.”

p. 16312, I.1: *see the above comment about GOSAT.*

We have not done this because of the reason mentioned before (see the answer to the comments for p. 16308, I.20-21).

p. 16314, I.22: *why has this range of years been chosen? Why not a shorter or a longer period?*

The end year 2007 came from the end year of the BP statistical review we used. The starting year came from periods of global CO₂ model simulations, dictated by availability of CO₂ observations. As shown earlier, the period “1980-2007” was removed from the title.

p. 16315, I.14: *this is a very poor assumption for a 17-year period.*

As far as the authors are concerned, CARMA database is the only available power plant database that has both global coverage and is freely available. There is no other global power plant database that could supplement CARMA data for additional years, which are not included in the present CARMA. We are aware that extending the CARMA data for a single year (2007) to a 28-year period might be a weak assumption and it would cause errors (as referee #2 also pointed out). As mentioned earlier, this study presents a disaggregation method to derive an approximate distribution of true CO₂ emission distribution (the authors are aware that there are not measurements to verify true emission distribution). It is difficult to construct a very high-resolution inventory without approximation because of the data availability. Regardless of the ramifications expected, the resulting inventory would be still useful for atmospheric modeling purpose as

indicated by the comparison with Vulcan (see Table 3) where three different disaggregation methods were compared. We think that the use of extended CARMA data, though it is based on a weak assumption, would not change the conclusion in this study.

In the revised manuscript, we will describe assumptions we used and the possible errors associated with our resulting inventory. See also our answers to section 3.3, and our response to referee #2.

p16320, 1.5-15: *I do not understand the meaning of these sentences. Please rephrase.*

We have rephrased

“Single use of a surrogate may underestimate point source emissions and overestimate non-point sources, especially when one expects to look at finer spatial scales. Because the six major geographical regions are aggregated categories of countries and regions that are not included in BP (2007), we assumed that the countries and regions within each major region had the same fraction of CO₂ emissions from point sources and non-point sources. The fraction of total emissions from point sources appeared to be smaller than the fraction of emissions from point sources in 61 countries and regions. This discrepancy may result from the fact that most industrial countries and regions were included in the 61 countries and regions. However, CO₂ emissions from point sources in the six geographical regions may still account for a considerable fraction of the total emissions.”

to:

“Single use of a surrogate may lead to underestimate point source emissions and overestimate non-point sources, especially when one expects to look at finer spatial scales. As the six major geographical regions are aggregated categories of countries and regions that are not included in BP (2007), we assumed that the countries and regions within each major region had the same fraction of CO₂ emissions from point sources and non-point sources. The fraction of total emissions from point sources appeared to be smaller than the fraction of emissions from point sources in 61 countries and regions. This discrepancy may result from the fact that most industrial countries and regions were included in the 61 countries and regions. However, CO₂ emissions from point sources in the six geographical regions may still account for a considerable fraction of the total emissions.”

Section 3.3: *the section lacks numbers to characterize the various uncertainties. For instance, the authors could use the CARMA data for 2000 to assess the impact of the use of the 2007 data for the whole 28-yr period. Further, the authors could exploit the comparison between their inventory and Vulcan to estimate the biases and standard deviations of their inventory for the US as a function of spatial resolution. Compared to the results presented in Table 3, the scaling should be removed for such exercise.*

We will added more text with numbers partly describing about level of error associated with our scaled point source emissions (shown below). Error quantifications however have not been achieved because of the availability of the independent power plant data for evaluation.

We have changed the first paragraph of section 3.3 (also considering changes suggested by referee #2) as shown below:

“The use of a point source database is an appealing feature of the procedure presented in this paper. To our knowledge, there are no other power plant databases publicly available that cover the entire globe. This fact was the primary motivation for utilizing the CARMA database in our development. However, CARMA obviously does not cover all existing power plants worldwide, and the emission estimate was performed using limited data (Wheeler and Ummel, 2008). In addition, geographical coordinates provided by CARMA sometimes indicate false locations. One cause of these errors is the method for deriving coordinate information. The location of power plants was generally indicated by the plants postal address in the original public data or commercial subscription data. As the postal addresses were converted into coordinate information (latitude and longitude) via fuzzy matching using geographical information systems (Wheeler and Ummel, 2008), the addresses were sometimes erroneously assigned to places with the same name or a similar name. Assuming the locations are correct, we cannot place emissions to exact source locations if emitting points, for example boilers, are located apart from its main facility (e.g. grid system). Apart from the CARMA database, we extended the CARMA emissions for the year 2007 to the years 1980–2007 using national emission trends, under the assumption that the power plants had persistently contributed emissions over the intervening years. Therefore, uncertainties may increase in the years prior to 2006, which is actually the year 2007 in the CARMA database. Considering these points, uncertainties arising from the extrapolation of emissions may be larger than those associated with selection of the base year. In the extrapolation, we do not consider changes in emission intensities and distributions due to possible reasons such as construction/destruction and maintenance, as such information are not provided even for single year data of CARMA. We thus extrapolate data for 2007, instead of filling the gap in data for 2000 and 2007. Total emission of CARMA power plants for the year 2000, which is the sum of 2000 emissions from 17668 CARMA power plants used in this study, is 2138 MtC/yr and is smaller than that of year 2007 by 30% (650 MtC in emission). The difference (change in 7 years) could be explained by changes in emission intensities and power plants which are not in operation at the time. In fact, 2543 CAMRA power plants out of 17668 for 2007 (14.4%) were indicated as not operated (emission = 0) in year 2000. As a result, our scaled CARMA using BP trends overestimated by 8% in total emissions calculated from CARMA 2000.”

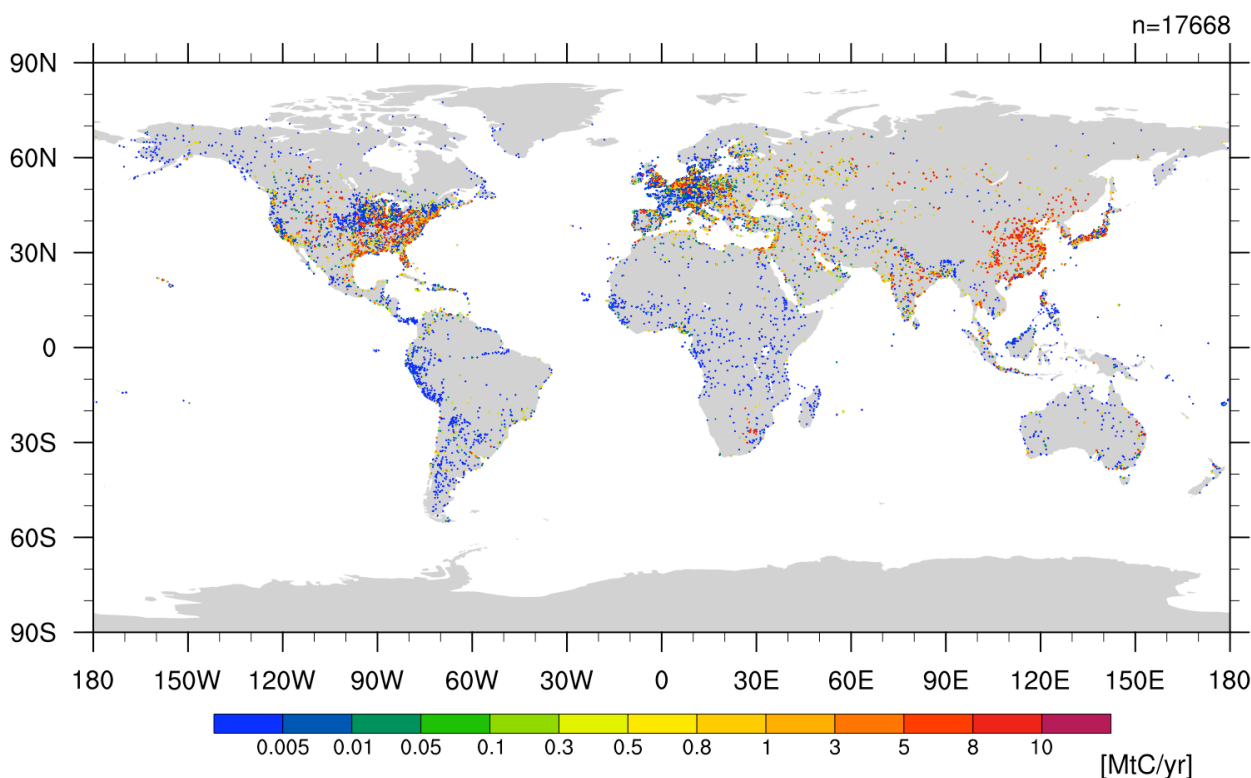
We have not performed the further suggested analysis such as evaluation of biases and standard deviation using Vulcan. Direct comparison of emissions is difficult because our emission lacks several components due to the use of BP statistics (as referee #2 mentioned) and we would not get meaningful figures even if we assume Vulcan emission number is true. We think it is beyond the focus of this study and will work on the analysis after improving our emission dataset. “

We would like to keep the analysis presented in Table 3 without modification. In the analysis, we compared our disaggregation method among existing inventories by compared the resulting inventory, not the emission intensity (Comparison of emission is difficult, as referee #2 pointed out). Scaling total emissions with respect to Vulcan allow us to sorely compare the resulting spatial

distributions. Vulcan is a very-detailed bottom-up type inventory and does not employ disaggregation. We think it would be useful as a reference for comparison, though it is limited over US and year 2002. As a result, our methodology showed better agreement than Brenkert [1998], which has been used for many inversion studies, and Rayner et al. [2010], which is another nightlight-based inventory (see P16325, L25).

Tables and Figures: some of the numbers are given in Mt CO₂/yr and MtC/yr.
Please make a choice.

This has been amended. MtC/yr is used. Due to the change we made here, the color increment has been changed,



Revised Figure 1.

We have also changed “(p. 16315, L24) In particular, power plants that generated emissions exceeding 15 Mt CO₂ /yr (4 Mt C/year), which were ranked as the top 100 emitting power plants in CARMA, were located mainly in these countries.”

To

“In particular, power plants that generated emissions exceeding 4 Mt C/year) which were ranked as the top 100 emitting power plants in CARMA (orange-red-magenta dots in Figure1), were located mainly in these countries

Table 3: the definition of ‘diff ’ should be more precise here.

We have changed “The total emissions of the participating inventories were scaled with respect to the Vulcan total emission level for the year 2002, and the absolute differences (diff) and spatial correlations with the Vulcan map (corr) were calculated at different spatial aggregation levels (0.5° – 4°) (Rayner et al., 2010).”

to:

“The total emissions of the participating inventories were scaled with respect to the Vulcan total emission level for the year 2002, and the sum of the absolute value of the Vulcan values minus the map being compared (diff) and spatial correlations with the Vulcan map (corr) were calculated at different spatial aggregation levels (0.5° – 4°) (Rayner et al., 2010).”

Figure 2: the bars of the geographical regions (bottom right) do not seem to have the same scale than the rest. Please check.

This has been checked.

Additional changes

In addition to the changes shown above, we would like to add changes listed below:

The reference of Rayner et al. (2010) has updated as

Rayner, P. J., Raupach, M. R., Paget, M., Peylin, P., and Koffi, E.: A new global gridded data set of CO₂ emissions from fossil fuel combustion: Methodology and evaluation, *J. Geophys. Res.*, 115, D19306, doi:10.1029/2009JD013439, 2010.

We would like to add a citation for satellite-observed CO₂ data as:

“(p,16310, L1) CO₂ concentration data are available from the Atmospheric Infrared Sounder (AIRS) satellite (e.g. Strow and Hannon, 2008), *SCIAMACHY* (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) *onboard the Environmental satellite (Envisat)* (e.g. Schneising et al., 2008) and the Japanese Greenhouse Gases Observing SATellite (GOSAT) (e.g. Yokota et al., 2009).