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Biogeosciences Discussions

Interactive comment on "A synthesis of carbon dioxide emissions from fossil-fuel combustion" *by* R. J. Andres et al.

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The paper provides a comprehensive and valuable synthesis of fossil-fuel emission inventories. The authors cover most aspects of fossil fuel emission inventories at various spatial and temporal scales. They also describe the main differences between independent data sets, without performing an extensive intercomparison. The text is of good quality and I recommend the paper for publication. I do, however, have many minor comments. Most of my comments are directed at sections 1-5, and in particularly section 3. While I do not have any problems with the content, I have many suggestions for minor improvements, reordering, modification of some figures, etc. Most of these comments are suggestions which the authors may like to take up, or not!

Minor comments and suggestions

1. The title states "...emissions from fossil fuel combustion", but the first paragraph states "...emissions from fossil fuel combustion and cement production". Perhaps later gas flaring and other process emissions are considered? If so, consider changing the title to something like "...emissions from fossil fuel combustion and process emissions"?

2. The last sentence of the abstract repeats some earlier text (line 6+). Line 6+ explains that the paper covers various issues, but the abstract focuses on very narrow aspects (total emissions, uncertainty). Consider removing the last sentence and including some other findings in the paper, such as on spatial and temporal issues, etc, etc, ...

3. The use of FFCO2 throughout, when sometimes process emissions are included. A short hand is okay, but it would be good to somehow acknowledge that this is more than just FF.

4. Page 1302, line 25. And some inventories may include other, albeit more minor, process emissions. As you mention later.

5. Page 1303, line 1-2: Is the venting included in CO2 only in CDIAC, or is this a standard assumption across all inventories?

6. For all figures. The figures are plotted with lines and symbols. I suggest removing the symbols as it makes it easier to compare the curves.

7. Page 1303, line 18: Perhaps say a few words about what the figure shows?

8. Page 1304, line 8, equation 1. Is this really done for cement and gas flaring? By definition, the emissions are allocated to where they occur, and for cement and flaring the emissions will occur at the point of production?

9. Page 1304, line 8: This is not strictly true. It is true for energy statistics, and most emission statistics. However, emission statistics that are consistent with the system of national accounts should, by definition, include the emissions from bunker fuels allocated to the country where the operator of the ship is resident. This is reported to Euro-

BGD
9, C120–C129, 2012

stat by EU countries for example. E.g. Peters, G.P., Hertwich, E.G., 2008. Post-Kyoto Greenhouse Gas Inventories: Production versus Consumption. Climatic Change 86, 51-66.; Peters, G.P., Marland, G., Hertwich, E.G., Saikku, L., Rautiainen, A., Kauppi, P.E., 2009. Trade, Transport, and Sinks Extend the Carbon Dioxide Responsibility of Countries. Climatic Change 97, 379-388.

10. Page 1305, lines 5-13. I assume this is a CDIAC specific result?

11. Page 1305, lines 5-13. Is it possible to put what share each of the different factors play in the difference?

12. Figure 1b. This figure would be better as an absolute or percentage difference (or both, one on each axis). The difference is too small relative to the difference for the current plot to be useful.

13. A general comment, many of the results and discussions seem to be CDIAC specific. When this is the case, this should be mentioned. You could outline the issue you want to discuss, and then say "In the case of the CDIAC database, . . .". This is done in many cases, but just check it is done in all cases.

14. Page 1305, lines 14+. This seems one good justification why FFCO2 inventories are needed. Perhaps this paragraph could be shifted up towards the start of the introduction.

15. Page 1307, lines 4-5. What confidence interval does the error refer to? These percentages are also different to what was mentioned in the abstract?

16. Page 1307, lines 17. Also, Myhre, Gunnar, Kari Alterskjær and David Lowe, 2009. A fast method to update global fossil fuel carbon dioxide emissions. Environmental Research Letters, 4: pp. 034012. I also think EDGAR might do this for their updates as well, but check?

17. Page 1307, line 13. I am not sure exactly what is being said here. It is often assumed that the CO2 inventories include the C that ultimately ends up as CO2, even if it

BGD
9, C120–C129, 2012

goes via CH4 or CO? But perhaps this is not the case for some of the global datasets? Or the amounts are so small it does not affect the inventory? Or is there some inconsistency between CO2, CH4, CO, BC, ash, ... inventories as they should all add to the C in the fuel? I think this is an important point and could be explored a little more. This paper is also relevant in this context, Boucher, O., Friedlingstein, P., Collins, B., Shine, K.P., 2009. The indirect global warming potential and global temperature change potential due to methane oxidation. Environmental Research Letters 4, 044007.

18. Table 1, EDGAR, global total on a common basis seems to be missing?

19. Figure 2. This is a nice figure, but I am not sure why it is reported by GDP per cap? I think for emission inventories it would be better to sort by size of emissions. This would be approx. a cone shape with the big emitters at the top (presumably more certain, give or take a China, India, Russia, etc) and the small emitters at the bottom with larger uncertainty. Also, it might be worth cutting Gibraltar and mention it in the caption to give more detail on the x-axis.

20. Page 1309, line 5 writes "Figure 2 and Table 1 summarize the published comparisons", but the Table or Figure do not have such information. Or did I miss something?

21. Table 1 on the UNFCCC and 191 countries, it is probably with a footnote that says that x countries are updated annually (Annex I countries I assume), and the remainder are irregular.

22. Page 1309, line 11. Put UNSO in words the first time.

23. Page 1309. For the IEA description, detail is given on how the energy data is converted to CO2 (using IPCC approaches). There is no such description for CDIAC, it does not mention how the energy is converted to CO2. Perhaps mention this for all datasets to make consistent?

24. Page 1311, line 9. But also not remarkable. Many of the data ultimately start at the same place, but undergo different processing. The energy statistics, emission

BGD
9, C120–C129, 2012

factors, etc, will be different in each data set, but sometimes one data set will be an overestimate and other times an underestimate. The law of many numbers would then indicate that many of the differences will cancel. What would be more interesting, and time-consuming, would be to see what causes the differences between data sets. For example, go through a set of stepwise calculations were 1) use the same energy statistics in each data set and compare results, 2) use the same emission factors in each data set and compare, 3) . . . In other words, what is the cause of the differences? I am not sure if anyone has done this, and I am not really suggesting you do it (it would be another paper), but I think the use of the work "remarkable" could be expanded on a little bit. As I mentioned at the start, you could also argue it is non-remarkable.

25. Page 1311, line 12. This is a little misleading. At the global level, yes, but not at the country level (as in Figure 2). Also, from my experience, the datasets can also vary considerably over time (for example, two data sets can be very similar for some years, but then there may be a period where one data sets shows a drop in emissions and another doesn't). I think it is okay to use CDIAC through the paper, but I think it should be emphasised that there is a lot more variation in the datasets then the global total indicates.

26. Page 1312, line 1: E.g., Peters, G.P., Marland, G., Quéré, C.L., Boden, T.A., Canadell, J.G., Raupach, M.R., 2012. Rapid growth in CO2 emissions after the 2008–2009 global financial crisis. Nature Climate Change 2, 2-4.

27. Fig 3a. This could be dropped as it has the same data as Figure 1a (though, see my earlier comment on this).

28. Page 1312, line 8: It is not "evident" from the figures, but evident from the work of Raupach et al.

29. Page 1312, line 20: While biofuels are strictly not included in FFCO2, that does not they are unimportant. How big are the biogenic CO2 emissions in relation to FFCO2? Maybe EDGAR has this data (short cycle CO2). Is this share growing over time? While

BGD
9, C120–C129, 2012

it is generally assumed that biogenic is CO2 (flux) neutral, it does not have a neutral impact on climate (Cherubini, F., Peters, G.P., Berntsen, T., Strømman, A.H., Hertwich, E., 2011. CO2 emissions from biomass combustion for bioenergy: atmospheric decay and contribution to global warming. GCB Bioenergy 3, 413-426.). Also, are biogenic CO2 emissions not important for modelling the global carbon cycle? In any case, it would be good to add a few more words on the biogenic CO2 emissions, even if they are not FFCO2.

30. Just a general comment on all the CDIAC related figures. Why not show the results up until 2010, the most recent value available?

31. Fig 3b/3c. It would be interesting to see this figure as percentage growth rates as well. Figure 3c is remarkably uninteresting (given it just integrates Fig 1c). I think the percentage growth rates would be more interesting than 3c? See my later comments on Fig 3h.

32. Page 1313, line 9: "Figure 3c also highlights . . . that more than 50% of FFCO2 has been emitted since 1980." I could not detect that by looking at the figure?

33. Page 1313, line 3-10: The airbourne fraction discussion could do with a little more elaboration. For example, the work of Knorr, Sarmiento, etc that critique some of the cited literature.

34. Table 2a/2b. I think this needs a bit better explanation. The n refers to the number of countries, but are the values in the table the growth rates at the country level or the global level? I guess at the country level with (2007-19XX)/19XX, but then the word "annual growth factor" is used? Are the statistics based on finding all the growth rates, then doing a min, max, med, avg? An alternative could be to do a regression (making the end point less important also). And some of the values are remarkably high, which makes me think this is done at the country level and we are looking at statistical noise for the max. It seems that the method chosen is skewed by outliers? Another way to approach this would be a little in the spirit of Figure 2. For example, have a scatter

BGD

9, C120–C129, 2012

plot with mean(emissions) on the x-axis and mean(growth rate) on the y-axis. The different time periods could be different colours? The mean would be calculated as regression/meanvalue. It may be possible to label some of the most relevant countries. This might be an easier way to portray the results in the table.

35. Page 1314, section 3.2. At the start, you could give more detail on the results. There is only really one sentence, but there are some other interesting features that could be pointed out. Since you mention it would be interesting to show a developed/developing split, why not do it? Also, for the last paragraph perhaps backing up with references (Baiocchi, G., Minx, J.C., 2010. Understanding changes in the UK's CO2 emissions - A global perspective. Environmental Science and Technology 44, 1177-1184.; Peters, G.P., Minx, J.C., Weber, C.L., Edenhofer, O., 2011. Growth in emission transfers via international trade from 1990 to 2008. Proceedings of the National Academy of Sciences 108, 8903-8908.)

36. Fig 3g, it might be more interesting to show this as a share of total cumulative emissions? This would presumably show that Annex I has dominated, but that dominance is decreasing (in both annual and cumulative emissions).

37. Section 3.3. This is a much better description of the data. It might be worth mentioning early on when discussing Fig 3e, that the drop in 1990 is primarily caused by the former Soviet. You mention the UK and Germany later on, but I think the former Soviet issue needs to be emphasised. The last two paragraphs seem a little misplaced though, but they should be mentioned somewhere. The last paragraph should cite Raupach et al 2007, and it would be even better if there was a plot of CO2 intensity as a function of time in B and non B (e.g., Caldeira, K., Davis, S.J., 2011. Accounting for carbon dioxide emissions: A matter of time. Proceedings of the National Academy of Sciences 108, 8533-8534.)

38. Page 1318, line 15: While I have no problems with the cited literature, I have discovered recently it can be misleading. Allen et al, for example, seek a relationship

BGD

9, C120–C129, 2012

with peak T and cumulative emissions for all time (that is, the integration continues past the peak)! I find this a little bizarre, but I am not an expert on such things. Matthews et al look at T(t) and cumulative emissions as a function of time, so that the T and cumulative emissions are compared at the same time.

39. Page 1318, line 25: Suggest to include Peters, G.P., Marland, G., Quéré, C.L., Boden, T.A., Canadell, J.G., Raupach, M.R., 2012. Rapid growth in CO2 emissions after the 2008–2009 global financial crisis. Nature Climate Change 2, 2-4.

40. Fig 3c, could be dropped given Figure 3h.

41. Page 1318, section 3.4. I am not convinced that this is the correct section heading. I think perhaps "The importance of cumulative emissions" or similar. If so, then I think that the cumulative emissions material from earlier could be moved into this section.

42. Section 3 and Figs 3. Overall. I think there is a lot of useful information here, though I think there might also be a little bit of redundancy. I think some figures could be combined, some pieces of text reordered. On occasion, the same information could probably be portrayed in the same figure (ie, combine some figures and make use of the left and right axis). For example, the figures on cumulative emissions could probably all put together side by side. If the Kyoto figure was added as an addition subplot in Figure 3h, then all the cumulative figures would be in the same row of subplots. Likewise, Figs on growth rates could be put side to side to have the global and Kyoto figures next to each other. There is also redundancy with Figure 1b and Figure 3a. Before I mentioned the global total could be put on one axis and the different on the other axis. The sector figure and the fuel type figure (1a and 3d may go well together next to each other). Essentially, I think all this information is useful and needs to be there, but I think it may be combined a little better to reduce the number of figures and put relevant information together and not split between figures.

43. Page 1319, line 10. I am not sure "Discretizing" is the right word?

BGD

9, C120–C129, 2012

44. Page 1320, lines 26+ and Fig 5. I am not sure why this discussion is here? Fig 5 has 5 hand-picked countries and thus the discussion is irrelevant? Fig 5, I see that Libya and Grenada were chosen as the min and max. However, it may be more relevant to include 5 politically relevant countries? If doing the max min, it may be worth including all the countries in the figure, but put the remaining 117 in a light grey line plot or something? This would demonstrate the point more clearly. Following this idea further, all countries could be put in light grey colour and then 5 politically relevant countries selected for highlight. This would show the bounds and allow you flexibility to include more interesting countries. Just an idea.

45. Page 1322, section 5.1. There was no mention of the EDGAR gridded data (perhaps this is to come later) and perhaps more city based inventory could be mentioned (e.g. Greenhouse Gas Emission Baselines for Global Cities and Metropolitan Regions, C. A. Kennedy, A. Ramaswami, S. Carney, and S. Dhakal, in Cities and Climate Change World Bank). Perhaps contact one of those authors for some more references on city level inventories. It may also be worth mentioning that there are methodologies for corporate level and city level inventories, though non-standard (WRI and WBCSD, 2004. The Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard. World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD)., ICLEI, 2009. International Local Government GHG Emissions Analysis Protocol. ICLEI - Local Governments for Sustainability, and probably more). I don't think this has to be an extensive review or reference list, but mentioning the main references to allow the reader to research themselves would be useful.

46. Page 1325, section 6.1. A reference on the importance of altitude would be useful.

47. Page 1328. I know you mention the ordering, but I would consider putting 6.2.2 first. My thinking is that the ordering would make sense from less detailed to most detailed?

48. Page 1331, section 6.2.4. But can other emissions be measured and correlated

BGD

9, C120–C129, 2012

with CO2? E.g., Akimoto, H., Ohara, T., Kurokawa, J.-i., Horii, N., 2006. Verification of energy consumption in China during 1996-2003 by using satellite observational data. Atmospheric Environment 40, 7663–7667.

49. Page 1331, section 6.3. I guess there are too issues here. First, emissions can be assumed to occur at the surface elevation using digital elevation models (ie, meters above sea level). This can be done with any gridded data set (each grid is just moved vertically up according to the DEM). Second, in addition to this, emissions can be located at where they occur (e.g., smoke stacks, aircraft, etc). The discussion seems to imply the second. Is the first also important, should they both be included, etc? It would be worth mentioning this differentiation and explain what is required.

50. Fig 7a. It is useful to show the spread in uncertainty. Though, this could be shown in Fig 3 and remove fig 7a? In particular, it would be interesting to show the 95% band on the global and the Kyoto figures as it might visually show the effect of the uncertainty in non-Annex I countries.

51. Page 1341, line 14. I did not see this spline in the figure?

52. Page 1343, line 2 and Fig 7b. What is IER?

53. Page 1344+, Conclusion. The conclusion drifts a little of topic, for example, discussing weather and climate models and impacts on agriculture.

54. Figures. I suggest to remove the symbols and just have lines.

Interactive comment on Biogeosciences Discuss., 9, 1299, 2012.