

Interactive comment on “Gridded uncertainty in fossil fuel carbon dioxide emission maps, a CDIAC example” by Robert J. Andres et al.

Anonymous Referee #2

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General Comments:

The subject of this paper is very important for understanding carbon balance at sub-national scales, because the uncertainty of fossil fuel-CO₂ emissions (FF) is a large (if not the largest) component of the uncertainty budget at annual scales. Thus, trying to quantify annual net ecosystem exchange is linked closely to FF and their uncertainty. Moreover, FF and their uncertainty are critically important in their own right from a policy/mitigation perspective.

The paper is primarily a methodological description of the gridded uncertainty calculation. However, for a methodological paper, I found the calculation details hard to follow. This was especially true in section 4.3, which describes the calculation of uncertainty related to distributing national-level FF by use of a population density proxy. This is

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the heart of the paper, and needs to be described more clearly. In fact, at this point I can't be sure if the results are justified, because I don't understand exactly how the uncertainty was calculated.

My confusion with the detailed methods notwithstanding, I have a concern with the general approach. The main question one wants to answer when using population as a within-country proxy for FF is: to what extent are emissions decoupled from population density? The approach used is based on the grid-cell level relationship between the Vulcan FF product and Landsat population (as shown in Figure 8a). However, despite this relationship (and its associated error statistics) only being valid for the United States and for 2002, it is used globally and for all years. Vulcan was used because it "relies least heavily on population", but justification for the large degree of temporal and spatial extrapolation is not provided. Moreover, while we can be fairly certain that modeling FF distribution purely on population will have spatial biases, we don't know that Vulcan is superior to other products such as ODIAC and EDGAR (versions 4.0 and later) that attempt to decouple population from FF by excluding large point source emissions. Comparing these products to gridded CDIAC would have been beneficial, because unlike Vulcan, they have global and interannual coverage. This approach would have specifically tested the uncertainties associated with not decoupling large point sources from the population proxy, a valuable contribution in my estimation. Overall, given the choice to use Vulcan, quantification of the impacts of using US-based error statistics for all countries is not discussed.

Because of this and the confusing explanation of the methodology, I can not recommend this manuscript for publication in its current form.

Other general points: a) Percent uncertainties are a bit misleading, because high percentages (e.g. at borders) may correlate with low absolute emissions. Looking at the range of % uncertainties can also be misleading. Looking at weighted means and standard deviations would be more meaningful. (e.g. in Table 4). b) There is a lot of description/discussion of 'geography' uncertainty (4.2) even though this is a rather

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small component of total uncertainty, as acknowledged later. This section could be greatly condensed by, in particular, eliminating some of the examples of causes that uncertainty that certainly exist but are in fact very small contributors to total uncertainty – e.g. Colorado surveying errors, India/China border dispute (a region with low pop. density), and the northern protrusion of Minnesota into Canada.

c) As pointed out below, at several points in the manuscript other well known fossil fuel emissions products such as FFDAS, ODIAC and EDGAR are alluded to but not referenced explicitly. Being explicit would help the reader follow the arguments better.

Line by line comments: L28. Is temporal uncertainty folded into the total uncertainty? If not, why state it in the abstract?

L42. What is the source of the statement that FF was the least uncertain component in the global carbon cycle? Please provide a reference.

L53. Use of 'significant' is vague here.

L54. By 'direct samples' do you mean 'air samples'?

L65. It would be useful to define 'component fluxes' clearly here. I presume this means land, ocean, fossil and land use-change fluxes, but I'm not sure.

L66. Please provide references for the statement 'present efforts in gridding...'.

L70. Change to 'advances'.

L75. To eliminate confusion with the idea of active sequestration of fossil fuel CO₂, I would simply say 'carbon flux from the fossil fuel reservoir'.

L92. This is an opportunity to cite some other gridded FF products.

L95. For consistency with earlier language, change 'stock' to 'reservoir'.

L95-L101. This paragraph is not necessary and interrupts the flow of the discussion. Moreover, it should be noted that significant seasonal and spatial gaps in satellite CO₂

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products preclude their use to quantify the atmospheric carbon reservoir.

L115. ‘Stable carbon maps’ would actually include both ^{13}C and ^{12}C . Replace with something like “maps of the $^{13}\text{C}:^{12}\text{C}$ ratio (iAd ^{13}C) of CO_2 . . .”

L150. Strike ‘exact’ – redundant.

L175. Add the word ‘degree’ or use the degree symbol after 1×1 .

L177. “geography data” and later “geography map” are confusing terms because ‘geography’ can refer to landforms, population, etc. What is meant here is ‘political [or national] boundaries’, and I suggest using something along those lines.

L196. Are there no population density maps for specific years (or even, say, five year periods) prior to 1989?

L200. At a 1×1 resolution, how different are nighttime and daytime populations? Does this change have any impact?

L210. For clarity, add ‘fixed’ between ‘CDIAC’ and ‘population’.

L214. Delete ‘degree’.

L219. Change ‘present’ to ‘2011’, the last year of the present study, i.e. opposed to 2016 or later.

L227. Delete ‘exact’.

L234. The distinction between ‘specific’ and ‘general’ uncertainty is unclear.

L264. Is the discussion of monthly emissions estimates and their uncertainty relevant to this paper? It’s not clear to me reading the paper whether the uncertainty analysis pertains to annual or monthly global FF maps. On the one hand this paragraph discusses monthly uncertainties, but at the end of this section (4.1) it is clearly stated that “There are 62 uncertainty assessments completed for the 1950-2011 time series. . .” (i.e. not 62×12 uncertainty maps.)

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L285. As mentioned above, condensing this section (currently ~100 lines) would improve the flow of the paper, allowing the reader to get to the most relevant methods and findings more quickly.

L393. Change to 'assumes each country has'

L397. References to/descriptions of the FF products that use these approaches would be useful.

L408. The second sentence of this paragraph seems too obvious to be worth including.

L417. As pointed out above, this assessment is only carried out (and valid) for the United States.

L431. Strike 'axes'.

L431. Because of the very large y-axis range in Fig. 8b, it's very hard to see how much non-linearity there is.

L432. How was the best fit line and its 2-sigma confidence intervals calculated? In addition to using the values generated by a software package, one could use a bootstrap or other techniques; different approaches may be more or less sensitive to outliers or have other beneficial characteristics. Additionally, there may be an effect on the slope (assuming a "model-I" regression was used) by plotting FFCO₂, the more uncertain value, on the y-axis compared to the x-axis. Was this effect investigated by switching the axes?

L435. The description of the Monte Carlo process to produce a "constrained" 2-sigma confidence interval is confusing to me.

First (L436), why does the selection of a population need to be random? Couldn't all the grid cell population values in Fig 8 (a or b) be dealt with sequentially?

Second, the statement 'selecting an adjustment. . .in accordance with a robust 2 sigma interval. . .' is unclear. A) What is meant by 'robust'? Because of this, it is also hard

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to understand why 'the robust 2 sigma interval minimizes the effect of outliers.' B) The method of the adjustments to the 'regression fit FFCO2' is also not totally clear. Are these adjustments random draws from the 2 sigma intervals calculated in the log-log fit shown in 8a? (And is this what is repeated 1000 times?) If the 2 sigma intervals were calculated from a linear fit, this process would be straightforward, but to make adjustments to FFCO2 (not $\ln(\text{FFCO2})$), the original 2 sigma distribution needs to be transformed, which is not straightforward. Is it that both the random draws and the adjustments take place in log-log space, and then are transformed to FFCO2 space?

Third, I do not understand the mechanism by which the sum of FFCO2 from all grid cells is made to equal the national total. After calculating an FFCO2 distribution associated with the population of each 1x1 grid cell, is there a selection process to ensure that the total FFCO2 of all cells equals the national total (and thereby creating the constrained fit)?

L442. Given that there is a distribution of 1000 elements, wouldn't it be more straightforward to calculate the 2.5 and 97.5 percentile bounds, to allow for asymmetry? (or is this what is meant by the present use of 'sigma'? If so, it would be clearer to refer to confidence intervals instead of sigmas, which carry the connotation of symmetry.).

L445. The 2 sigma intervals in the upper panel appear symmetrical about the best-fit line, contrary to what is stated.

L446. What is the break point between low and high population values in determining whether to use the +2 sigma or -2 sigma curves.

L475. Is there any expectation of negative populations or emissions?

L477. 'Fourth. . .' How could this not be true if there are no negative populations of FF emissions – both of which should be obvious.

L478. 'Fifth. . .' How is this effect shown in Fig. 8b?

L487. Change to 'These maps' to be consistent with previous sentence.

L488. Instead of assigning uncertainty to zero, could single grid cell countries be assigned uncertainties linked to their population (via Fig. 8c)?

L501. Recommend inserting 'that' after 'was'.

L506. Change 'this' to 'which'

L533. Could it also be that the 2011 population maps have higher resolution than the 1950 ones? For example, in the 1950 map, Australian states appear to have uniform population density, as do some countries like India.

L547. I'm not sure of the value of the breakdown of what fraction of cells have uncertainty dominated by which uncertainty component, because in many cases these cells may have very low emissions.

L558. Given annual maps, isn't the time scale of this example much too fast to matter?

L585. Replace 'Other map distributions. . .' with specific examples like ODIAC, FFDAS, EDGAR, etc.

L609. Which efforts has CDIAC supported? References?

L612. Change 'a honest' to 'an honest'

L615. Provide references for the 36% value and for the subsequent 15-20% value.

L626. Regarding INFLUX, would comparison to results of Turnbull et al, JGR 2014 be better since they were able to focus just on FFCO2?

L649. Please provide a reference for the 'known spatial deficiencies'.

L666. How were the population and political border uncertainties reduced? Arbitrarily?

L669. Why does one tenth of a grid cell correspond with 10% uncertainty?

L685. Is it fair to compare uncertainties for 0.25 deg. Vs. 1.0 degrees? Using a higher resolution population database along with Vulcan could result in higher uncertainties in

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this study and an even bigger contrast with Rayner et al.

L735. Decrease in uncertainty with aggregation could be tested directly using the methods in this paper by simply aggregating both Vulcan and Landsat to, 2x2, 3x3 degrees, etc.

Interactive comment on Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-258, 2016.

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