Reply to the interactive comment on manuscript
ESSD-2016-12 by Anonymous Referee #1

September 9, 2016

Dear Anonymous Referee #1,

thank you for your detailed comments. Here we try to address the concerns you expressed in your report. We start with some general proposals for restructuring the paper to make the information contained more accessible and address the individual comments thereafter.

A. General remarks and restructuring of the manuscript

Several comments are asking for more information on individual data sources and their processing. This information is often given in the appendix of the paper, so it seems that the information in the appendix is not well accessible. We thus merged parts of the appendix into the main text (Appendices B, C) and improved references to the other sections of the Appendix (A, D, E). All references made in this document are to the original Appendix numbering.

Below we answer each individual comment and explain which changes we made to the manuscript.

B. Answers to general comments

Comment 1 *The paper "The PRIMAP-hist national historical emission time series" describes the emission data set for each country and the gases covered by Kyoto protocol. The data set is based on the combination of the published data sets. The added value as well as possible applications of the composite inventory are not clearly articulated in the paper.*

Answer 1. The added value of this dataset compared to the individual datasets used here is its completeness in terms of countries, sectors and time which no existing

dataset can deliver. Furthermore, the methodology has been improved compared to older composite datasets (as explained in the introduction of the manuscript).

Previous versions of the PRIMAP-hist dataset have been used in the UNEP gap report 2015 and the INDC factsheets published by the Australian-German Climate and Energy College (http://www.climate-energy-college.net/indc-factsheets). Predecessors of the dataset, especially the PRIMAP4 baseline [1] have been used e.g. for the Climate Action Tracker[2] and the publication "National post-2020 greenhouse gas targets and diversity-aware leadership" by Meinshausen et al., 2016.

Change to manuscript 1. We have added information on the added value and applications and have provided examples of use of previous versions of the PRIMAP-hist dataset and its predecessors.

Comment 2 *The assessment is biased to the period from 1990, while historical emissions are not covered properly.*

Answer 2. From 1990 on there is more detailed data available, especially data reported by countries and expert reviewed (for developed countries). We use the best available data for each period.

Change to manuscript 2. No changes to manuscript.

Comment 3 *The composite data set is created as a pure statistical exercise through series of multiplications, additions and extrapolations, through it is not clear if the data sets can be combined together, under what condition, and what the final combination actually means.*

Answer 3. We explain the caveats of combining different datasets in the paper, especially in Section 8. The aim of the paper is to create a comprehensive inventory of historical greenhouse gas emissions. The combination of existing emissions sources is our way to achieve this. The methods we use do have underlying models and assumptions which are explained in Sections 4.1 and 8. We also refer to the existing literature on these methods.

Change to manuscript 3. The description of the underlying models in Section 4.1 has been improved.

Comment 4 *The final product is expressed through IPCC 1996 main categories, but is unclear how the diverse categories used in original inventories were converted into IPCC categories.*

[1] https://www.pik-potsdam.de/research/climate-impacts-and-vulnerabilities/research/rd2-flagship-projects/primap/emissionsmoduledocumentation/primap-baseline-reference

[2] www.climateactiontracker.org

Answer 4. Most sources we use in the paper are published using IPCC 1996 categories: CRF2014/2013, UNFCCC2015, BUR2015, RCP, EDGAR42(FT2010). For EDGARHYDE we lay out the mapping in Appendix D. The FAOSTAT database uses different subcategories to the IPCC 1996 categories, but the main categories (agriculture and land use) coincide. CDIAC2015 and BP2015 use categories that have a direct counterpart in the IPCC 1996 categorization and don't need mapping.

Change to manuscript 4. We have added the information on the IPCC categories to the dataset descriptions for all sources which are not published in IPCC 1996 categories.

Comment 5 *Language of the paper also needs correction. The paper is full of jargon and abbreviations, as well as punctuation mistakes.*

Answer 5. Thank you for pointing this out.

Change to manuscript 5. We have checked that all abbreviations are introduced properly and proof read for language again.

Comment 6 *In places explanations are extremely brief and do not allow to judge if the sources of information are appropriate for combination or not.*

Answer 6. Thank you for pointing this out.

Change to manuscript 6. We have added to the source descriptions based on the detailed comments.

Comment 7 *The paper is also unspecific in many places in relation to what gases and what sectors are addressed (everything is just emissions).*

Answer 7. Thank you for pointing this out.

Change to manuscript 7. We have made the language more specific based on the detailed comments.

C. Answers to more specific comments

Comment 8 *p.1 (abstract) – what is a temporal resolution of the composite inventory*

Answer 8. The composite dataset uses a yearly resolution for all time periods.

Change to manuscript 8. The information has been added to the abstract.

Comment 9 *p.2 (10-15) – to what extent current IPCC emission categories are applicable to historical emissions (as there was a substantial change in technology, use of fuels, efficiency etc.)?*

Answer 9. The categories itself are applicable for all time periods, though the detailed categories were created with current technologies in mind. Where categories refer to specific technologies, no emissions are reported before this technology was available (e.g. for the categories tailored towards the use and production of fluorinated gases). However, the technology specific categories are not on the upper levels on the category tree that is used for the PRIMAP-hist dataset. An exception being categories 1 and 2 where we do use subcategories for CO_2. For category 1 the subcategories we use are technology independent as the distinction is between emissions from burning of fossil fuels and fugitive emissions which are again split into two subcategories based on the fuel types. For category 2 most subcategories are again technology independent and based on industrial sectors like chemical industries or mineral products. Technological improvements change emissions in these categories, but the categories itself are applicable independent of the technologies used.

Change to manuscript 9. No changes to manuscript.

Comment 10 *p.3 (20) – reference is made to the use of growth rates. Are these emissions growth rates (at what temporal resolution)? How those are constructed?*

Answer 10. The use of growth rates is explained in more detail later in the paper in Section 4.1 and Appendices A4 and A5.1.

Change to manuscript 10. We added details and a reference to Section 4.1 and Appendices A4 and A5.1.

Comment 11 *p.4 – CDIAC is presented as a country specific inventory. How the historical boarders are taken into consideration in this inventory?*

Answer 11. The CDIAC publication from Andres et al., Carbon dioxide emissions from fossil-fuel use, 1751–1950 (Tellus, 1999) [3] states the following: "*Almost all political entities represented in the pre-1950 production and trade data were already represented in the modern CDIAC time series. The major exception was a united Korea, under Japanese hegemony, which existed from 1905 to 1944 and was assigned the discrete country code of 409. Land exchanges between countries were also accommodated, when possible. For example, the emissions from Alsace-Lorraine were included with Germany or France, reflecting which political unit governed these lands at any given time. This maintained the integrity of political entities despite changes in national borders.*" Where CDIAC issues different country codes for countries that merged or split apart we sum or downscale the CDIAC data to obtain data for the countries currently existing.

[3] http://www.tellusb.net/index.php/tellusb/article/view/16483

Change to manuscript 11. We have included the pieces of information which are not present already in our description of the emissions accounting in the PRIMAP-hist dataset.

Comment 12 *p.5 (7) – please spell out KP*

Answer 12. Thank you for noting this.

Change to manuscript 12. We have spelled out KP at its first occurrence.

Comment 13 *p.7 – sections 2.3.1 and 2.3.2 are very brief. How do these pieces complement each other or do they provide a repetitive information. Do both sources use the same emission factors for their calculations? How different are the estimates based on fossil fuel consumption and fossil fuel burning and flaring? Section 2.3.2 refers to the emissions based on the statistics of fossil fuel production and trade combined with the information on the chemical composition (of what?) for the period 1751 to 1949. Where does such information come from?*

Answer 13. The two datasets described in Sections 2.3.1 and 2.3.2 contain information for similar sectors. CDIAC covers more sectors than BP as it also provides CO_2 emissions from flaring and cement production while BP only provides energy related fossil fuel burning emissions. However, the BP time series is more up to date and provides information for the latest years that is not contained in the CDIAC time series. Therefore BP complements CDIAC and we use both sources. It is generally the case that several sources provide information for the same sectors and years, but none of the sources is complete in terms of sectors, gases, countries, and years.

Change to manuscript 13. We have added information on why we use BP additionally to CDIAC and updated the CDIAC source description to provide missing information.

Comment 14 *p.7 (26-30) – the paragraph claims that emissions in EDGAR are calculated using technology dependent emission factors for EACH technology determined by the end of pipe measurements. If each emission factors could have been determined as claimed, the emission inventories would have been much more precise. There are plenty of technologies, especially in developing countries, which are very poorly described in a sense of emission factors, the same applies to historical emission factors.*

Answer 14. "*end of pipe* **measurements**" was actually a typo, correctly it should say "*end of pipe* **measures**". Thank you for pointing to that.

The EDGAR methodology [4] states that "*Emissions (EM) for a country C are calculated for each compound x on an annual basis (y) and sector wise (for i sectors, multiplying on the one hand the country-specific activity data (AD), quantifying the human activity for each of the i sectors, with the mix of j technologies (TECH) for each sector i, and with their abatement percentage by one of the k end-of-pipe (EOP) measures for each technology j, and on the other hand the country-specific emission factor (EF) for each sector i and technology j with relative reduction (RED) of the uncontrolled emission by installed abatement measure k, as summarized in the following formula:*

$$EM_C(y,x) = \sum_{i,j,k} [AD_{C,j} \cdot TECH_{C,i,j}(y) \cdot EOP_{C,i,j,k}(y) \cdot EF_{C,i,j}(y,x) \cdot (1 - RED_{C,i,j,k}(y,x))]$$ "

The EDGAR inventory as well as some other inventories (CRF, UNFCCC) offer a greater level of detail than used for the PRIMAP-hist dataset. However, to combine the different inventories we have to use the least common denominator and use the resolution of the datasets with less sectoral resolution. Especially for historical emissions before 1970 there is no data available which offers significantly more detail than the main IPCC 1996 categories. The uncertainties for emissions in the individual categories of the EDGAR dataset are substantial so we do not see a contradiction to your (certainly correct) assessment that a lot of the technologies are poorly described by emission factors.

Change to manuscript 14. The typo has been corrected.

Comment 15 *p.8 (5)- The sentence states that land use emissions are categorized into forestland, grassland, cropland and biomass burning, but they are applicable to CO2 only. It is a bit confusing though, as cropland should theoretically include rice paddies, which are one of the important source of CH4. Line 10 later speaks of agricultural emissions. What is the difference between cropland land use emissions and agricultural emissions? How these emission categories are mapped into IPCC categories?*

Answer 15. The land use emissions do not cover the emissions directly introduced by agricultural use, but emissions from soil changes that are caused by agricultural use of the soil. FAOSTAT states that "*Greenhouse gas (GHG) emissions data from cropland are currently limited to emissions from cropland organic soils. They are those associated with carbon losses from drained histosols under cropland.*"[5]. The emissions from the agricultural use itself are covered under the agriculture sector where rice cultivation is a subsector[6]. As stated in Appendix D the aggregate land use and agricultural sectors we work with in this paper coincide with IPCC 1996 sectors so no mapping is required for this paper.

[4] http://edgar.jrc.ec.europa.eu/methodology.php
[5] http://faostat3.fao.org/modules/faostat-download-js/PDF/EN/GC.pdf
[6] http://faostat3.fao.org/browse/G1/GR/E

Change to manuscript 15. We have added information to make the definitions of the land use and agricultural sectors more clear.

Comment 16 *p.8 – sections 2.4.1 and 2.4.2 are extremely short. How these two sources compare to each other? Do they use the same regional definitions and source categories? If not, how the original data were processed for the composite inventory? Line 21 refers to constant emissions outside of tropical regions prior to 1990. Where do these data come from? Based on what principle the HOUGHTON2008 is downscaled to country level? Description of RCP historical dataset is very poor. What gases are covered? In what cases atmospheric inverse modelling is used?*

Answer 16. The Houghton dataset described in Section 2.4.1 contains only CO_2 emissions from land cover change. The RCP dataset described in Section 2.4.2 contains emissions for all Kyoto gases and sectors. However, the land use CO_2 emissions of the RCP dataset are not used for PRIMAP-hist as they are based on the Houghton dataset (and regional detail is lost).

The constant emissions outside tropical regions in the Houghton dataset are obtained using the assumption that emissions calculated for 1990 are also valid for the subsequent years by the original authors of the dataset. We do not use the extrapolated data in the PRIMAP-hist dataset. The downscaling of the Houghton data is described in Section 4.2.2.

For more detailed information on the RCP historical emissions please also consult the paper "The RCP greenhouse gas concentrations and their extensions from 1765 to 2300"[7] and the RCP scenario data group website[8].

Change to manuscript 16. Information has been added to Sections 2.4.1 and 2.4.2.

Comment 17 *p.9 (7) – the need for categories mapping is indicated, but details of how it is done are not provided*

Answer 17. Details are provided in Appendix D.

Change to manuscript 17. A reference to Appendix D has been added.

Comment 18 *p.9 – sections 2.6.1 and 2.6.2 have very short description of data sources. What emission categories and gases are covered? How do these inventories compare with the one of FAO?*

Answer 18. The datasets covered in these sections do not contain any emissions data. Instead SAGE contains data for potential vegetation and HYDE contains simulation data of past real vegetation. By comparing those we can determine areas where deforestation has occurred which we use to downscale the Houghton data to country level. More information on the use of these datasets is provided in Section 4.2.2.

[7] Meinshausen, M., Smith, S.J., Calvin, K. et al. Climatic Change (2011) 109: 213. doi:10.1007/s10584-011-0156-z

[8] http://www.pik-potsdam.de/ mmalte/rcps/

Change to manuscript 18. We have added an introduction to Section 2.6 to clarify that the gridded datasets we use do not contain emissions data.

Comment 19 *p.11 presents the source preprocessing but does not describe how diverse categories are mapped against IPCC before being used in the composite source generator*

Answer 19. Please see answer to Comment 4.

Change to manuscript 19. Please see answer to Comment 4. Additionally we have added a reference to the source specific preprocessing which includes category mapping.

Comment 20 *p.13 – the compilation of the composite source as presented on the figures creates a question of consistency. If the inventories are different during one period and you just combine them multiplying by coefficients, what value does it bring? What additional uncertainty is introduced through such data treatment?*

Answer 20. The method uses the year to year growth rates of the lower priority source to extend the higher priority sources. The prioritization of the sources takes the completeness and reliability of the absolute values into account to use the most reliable absolute values and the year by year growth rates of the other sources to extend those data. A similar method is employed in the Global Carbon Project.[9] The uncertainty of the final time series can be calculated using the error propagation formulas. For a scaling f the standard deviation of a scaled time series $C = f \cdot B$ would be $s_c = \sqrt{s_f^2 + s_B^2}$, where s_B is the standard deviation of the time series B and s_f is the standard deviation of the scaling factor which depends on s_B and s_A in a manner determined by the exact matching algorithm (A denotes the time series which B is adjusted to).

Change to manuscript 20. We have added information on the uncertainty propagation of this operation to the uncertainty section.

Comment 21 *p.15 (15-16) – how far back can the RCP growth rates based on atmospheric concentration measurements be extended? Is this approach applicable to all countries and all sectors?*

Answer 21. We use the RCP data from 1850 forward to the 20th century with the exact end date differing by gas, category, and country. We do not have to extend RCP data as it already covers the wanted time period. The RCP dataset only contains global emissions on an economy wide level. It is a simplification to use the same growth rates for all countries and sectors, however, there is no other dataset available, so the only other option would be to use numerical extrapolation or to leave a gap in the dataset which we find worse than using global growth rates.

[9] Le Quéré, C., Moriarty, R., Andrew, R. M., Canadell, J. G., Sitch, S., Korsbakken, J. I., ... Zeng, N. (2015). Global Carbon Budget 2015. Earth System Science Data, 7(2), 349–396. http://doi.org/10.5194/essd-7-349-2015

Change to manuscript 21. No changes to manuscript.

Comment 22 *p.17 (10) – does the statement mean that you assume no land use emissions before 1850?*

Answer 22. We do not consider emissions before 1850 in this paper, but implicitly we assume no emissions before 1850 when setting the 1850 value to zero. We use 0 in 1850 to rather under- than overestimate emissions when extrapolating. Using growth rates is difficult for land use because of the strong fluctuations. This extrapolation is just used for very few small countries. Pre-1850 land use emissions have a small effect on cumulative emissions and accounting for them would "results in a shift of attribution of global temperature increase from the industrialized countries to less industrialized countries, in particular South Asia and China, by up to 2–3%" according to Pongratz And Caldeira (2012)[10]. Pre-industrial land use change emissions could be included in a future version of this dataset.

Change to manuscript 22. Information on the impact of pre-industrial land use emissions has been added. A list of countries which are affected by the linear extrapolation has been added.

Comment 23 *p.18 – how large forest fires are reflected in the considered historical emissions?*

Answer 23. The publications describing the dataset states that only direct (deliberate) human induced activities are covered.[11][12] Thus generally, forest fires are not included except for fire clearing. However, for the USA wildfires and the effect of measures for fire suppression are included.

Change to manuscript 23. The information has been added.

Comment 24 *p.21 (23) – what emissions are discussed here? The paragraph is absolutely unclear.*

Answer 24. All references to "emissions" in this sectors shall be read as references to "emissions of aggregate Kyoto greenhouse gases".

Change to manuscript 24. We have clarified the language in the section.

[10] Pongratz, J., and Caldeira, K. (2012). Attribution of Atmospheric CO2 and Temperature Increases to Regions: Importance of Preindustrial Land Use Change. Environmental Research Letters, 7(3), 34001. http://doi.org/10.1088/1748-9326/7/3/034001

[11] HOUGHTON, R. A. (2003), Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management 1850–2000. Tellus B, 55: 378–390. doi:10.1034/j.1600-0889.2003.01450.x

[12] Houghton, R. A. (1999). The annual net flux of carbon to the atmosphere from changes in land use 1850–1990*. Tellus B, 298–313. doi:10.1034/j.1600-0889.1999.00013.x

Comment 25 *p.22 (27) – it is very unfortunate that the uncertainty estimate of the dataset is left for a future publication as uncertainty is a natural part of any dataset delivered and allow for evaluation of applicability of the data set for specific tasks.*

Answer 25. As explained in Section 7 there is a gross lack of uncertainty data for the individual datasets. As long as uncertainty data for the individual datasets is not available, for a detailed uncertainty analysis one would need to make several assumptions on the uncertainty of emission factors etc. Without detailed knowledge and understanding of the methodology underlying the individual datasets this is a new source of uncertainty. This is not feasible to do for all the datasets used in this paper in the scope of this paper.

Change to manuscript 25. No changes to manuscript.

Comment 26 *p.26 – section 7.0.2 presents the comparison of the compiled product with the other data sources, though the comparison is made with the data sources used to create the composite inventory. It is obvious that as it is a composite product of original datasets it will follow the features the authors prioritize in compilation, hence such a comparison does not bring any value and cannot be considered as an independent verification.*

Answer 26. The comparison is not intended as an independent verification but to show how the composite sources compares to the individual source and older composite sources. A comparison of the composite source with the individual sources is meaningful, as we only use the year to year growth rates of the lower priority sources such that the absolute values of the composite source are governed by the highest priority source.

Change to manuscript 26. We have improved the section to clarify the goal and legitimacy of the comparison and to make sure that we don't say more than intended to and possible from the data.

best regards
Johannes Gütschow on behalf of all co-authors