# Answers to the anonymous reviewer #1

The reviewer's comments are shaded in grey. Text passages that will be transferred to our revised manuscript are written in italic.

**General Comments:**

The only real test of the emission estimate is comparison against measurements (atmospheric concentrations or fluxes). I wonder whether there is scope to include some such comparison against independent flux measurements or atmospheric concentrations. The reference to Hiller (2012) in the Introduction is given as the single Swiss attempt to upscale flux measurements to validate its national inventory. The reference is to the lead author's doctoral thesis (and only the abstract is available from the link provided). That said, some of the key measurements or results from the thesis could usefully be included here.

There are currently two projects (the Swiss Science Foundation funded project CarboCount CH as well as a Swiss Ministry for the Environment funded modelling project) which will use our inventory in combination with atmospheric observations and inverse modelling, but results from these studies are not available yet.

A preliminary version of the inventory, however, has been compared with aircraft measurement-based flux estimates in Hiller (2012). A corresponding journal publication is currently in revision:

Hiller R., Neininger B., Brunner D., Gerbig C., Bretscher D., Künzle T., Buchmann N., and Eugster W. Aircraft based $CH_4$ flux estimates for validation of emissions from an agriculturally dominated area in Switzerland, Journal of Geophysical Research (in revision).

Reviewer 2 criticized that the methods section is already overly long compared to other sections and adding a more detailed description of the aircraft based $CH_4$ flux estimates would further increase this imbalance. Hence we suggest to keep the focus as is and make sure that the present paper is correctly referenced in our JGR manuscript. As an early version of what will be published in our JGR paper, the doctoral thesis by Hiller (2012) is the best reference we can offer in this manuscript. We will update that reference to the JGR paper if citable by the time the page proofs are available from BG.

We will change the sentence on p. 15185 l. 1ff to include the most important findings of the comparison:

*Only one single attempt has so far been made to upscale CH4 flux measurements to national totals or to validate the Swiss CH4 inventory with atmospheric measurements (Hiller, 2012).*

to

*A first attempt was made by Hiller (2012) to compare an earlier, preliminary version of the $CH_4$ inventory presented in this paper with $CH_4$ flux estimates based on aircraft measurements in a valley dominated by agriculture, the single most important methane source in Switzerland. For this valley it was shown that the measured fluxes were in a similar range as the corresponding inventory values, but clearly more extensive evaluations using our inventory are needed.*

The uncertainty analysis is highly relevant given that one of the stated uses of the inventory is as 'a prior emission estimate' for inverse modelling applications. Although the paper addresses the spatial dimension, the authors correctly note the importance of the temporal variability in the methane emissions. In principle, temporal information for specific sectors is available to the authors and this could be used to generate temporal profiles (and uncertainties).

We agree that quite reliable temporal information is available for some minor methane sources like traffic. Profiles of diurnal, day-of-week and seasonal variations have been generated for the purpose of air quality modeling and for classical air pollutants like $NO_x$ and PM, but they are usually not appropriate for methane due to largely different processes causing these emissions. Combustion processes, for example, are a major source of $NO_x$ and PM but are of little relevance for $CH_4$.

We found no suitable information for those sectors dominating Swiss $CH_4$ emissions, i.e. agriculture, gas losses and landfills, which would allow us to specify meaningful and reliable time profiles. Therefore, we decided to only discuss these variations and to cite a number of publications providing qualitative information, but not to include them in the inventory, as stated on p. 15202 l. 24f. The available literature indicates that diurnal and seasonal variations for these sources are relatively small compared to other air pollutant emissions. Another recent publication by Ghao et al. (Adv. Meteorol. 2011b), for example, which investigated diurnal and seasonal variations of dairy cattle emissions, showed comparatively small diurnal and seasonal variations, although peak-to-peak variations during a day can be up to a factor of two related to feeding activities. We will add this information on p. 15204 l. 20 by changing the sentence to:

*…, while Gao et al. (2011a, 2011b) observed diurnal peak-to-peak variation of up to a factor of two following the feeding rhythm. Seasonal $CH_4$ flux variations of about 20% were attributed to lower emissions from manure at lower temperatures.*

Assuming constant emissions is therefore not as bad an assumption as it would be for other species like $NO_x$, PM or $CO_2$. We are aware of the fact that temporal variations may nevertheless be critical when using our inventory in an inverse modelling framework.

We will change the last sentence in Section 3.3.2 (p 15205 l. 22ff) to the following:

*The above listed diurnal and seasonal cycles indicate that observed $CH_4$ fluxes on a single day at a given time may significantly differ from the annual mean fluxes reported in our inventory, although the variations are probably smaller than those of other trace gases such as $NO_x$ which are dominated by traffic, heating, and other strongly varying activities. For the main emission sources (agriculture, landfills, gas losses) the available information is, unfortunately, not sufficient to provide specific time functions. In the absence of such information, inverse modeling studies need to make assumptions on the potential amplitude and correlation structure of such variations to specify realistic a priori uncertainties.*

Taking a broader view, I have a number of questions about the inventory and methodology:
(1) Will the dataset be made available to the research community?

Yes, we plan to publish the inventory in an open data repository and will provide the URL in the final publication of the present article.

(2) How frequently will the inventory be updated?

There are no regularly updates planned at the moment except for a simple rescaling of the sectorial emission distributions to the corresponding totals reported annually to UNFCCC. The inventory is the product of a research project that has already been completed. A regular updating would clearly be desirable and this issue will be discussed with Swiss authorities. This is not only true for this inventory but for all emission inventories currently existing in Switzerland (CO, $NH_3$, PM, $NO_x$, VOC and $CO_2$).

(3) How applicable are the results to other countries?

While the inventory was only produced for Switzerland, the presented methodology can be applied to other countries. As also proposed by the IPCC guidelines, some emission factors are country specific and need adaptation in order to be applied to another country.

We will add the following sentence to the end of our conclusions (p. 15206 l. 26):

*The methodology suggested here is not specific to Switzerland and could be used to derive similar inventories for other countries, provided that country specific emission factors are used where necessary and detailed geostatistical data are available.*

**Specific comments:**

The authors take different approaches for the natural and anthropogenic sources when comparing their emission estimates with existing data. For example, new improved estimates based on in-country measurements are presented for the emissions from rodents, uptake by forests and these are preferred to the older estimates. For the wastewater sector (page 15191), the new emission estimate is ten times higher than the current official estimate (based on a different methodology). The official estimate is preferred for this sector, largely for consistency with the totals reported in the SGHGI (but there is the proviso in the paper that this could be higher). In the absence of atmospheric measurement, we simply do not know which is the more reliable emission estimate (and even here, it would be difficult to fix the emission from this sector).

For minor sources like wastewater treatment plants atmospheric measurements will be of little use (except if performed in the vicinity of a plant) but direct emission measurements at the sources are needed. Without representative measurements of this type we can indeed not definitively evaluate which emission estimate is better and therefore decided to stick with the SGHGI for consistency reason. Based on the critique by reviewer #2, we will include an additional section 3.3.4 “Needs for building more realistic regional and national inventories” where we address future research needs to improve such inventories (see our responses to reviewer #2). Emissions from small wild animals, namely rodents are not included in the SGHGI, and the separate study dealing with these emissions came up with clearly unrealistic numbers. Therefore, we decided to include our new estimate for this category in the inventory. Within a newly started project (http://www.carbocount.ch) we have started continuous atmospheric $CH_4$ measurements from which we expect additional insights that will help validating our $CH_4$ emission inventory in the near future.

Figure 2b (methane emissions from energy) gives some sense of where the major population centres are located. I wonder whether a map of population density could usefully have been included (e.g., in the Supplementary Material). The map of methane emissions from waste (i.e., landfills) contains emissions from small areas and can only be seen clearly by zooming in on the screen. I suspect that it would be hard to distinguish these on the paper copy.

We will add the figure below showing population density to the supplementary material.

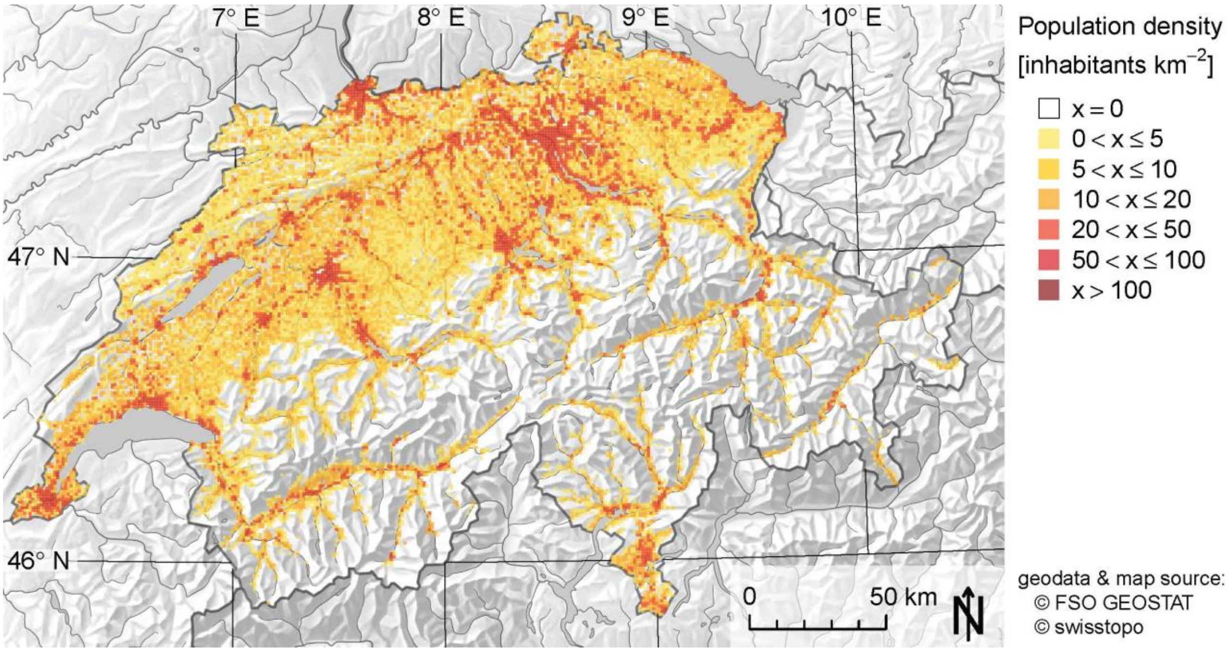


*Figure S1: Swiss population density (BFS GEOSTAT, 2012)*

Concerning point emissions, we agree that such a small map is not the best illustration. Solely enlarging the pixels would lead to a misinterpretation of the fluxes as well. However, being too small to be displayed also tells something. Since we will publish the data set along with the paper and because national totals are provided in Table 2 of the manuscript, we will not modify Figure 2d.

The authors correctly note that the EDGAR inventory used its own methodologies for the collection of activity data, application of emission factors, and spatial allocation whereas the TNO-MACC inventory disaggregated the reported country emission totals. The authors ascribe the difference between the EDGAR and the present inventory to the greater dependence on population density for distributing the emissions in the EDGAR inventories. The comparisons reported in the paper were based on the total methane emissions. In principle, spatial inventories are available at the sectoral level and this might provide further insight into the reasons for the significant difference between the two inventories.

We will compare the inventories at the sectorial level including scatterplots (see reply to the next comment).

I draw the authors' attention to the paper by Winiwarter et al. (2003), in which various methods were investigated to compare different gridded emission inventories (linear regrerssion, line comparisons, Moran coefficient). Perhaps, some linear regression plots could be included or the coefficients from such an analysis could be added to the difference plots.

We will provide scatter plots comparing the inventories in Section 3.2 and modify the text accordingly (see below). The total emissions for the individual inventories slightly changed due to a different calculation approach. Instead of summing up all pixels, we now calculate the average flux across Switzerland and multiply with the area of the country. With this approach, we avoid emission differences due to the different rendering at the borders.

Modified/new text on p15201 l. 7ff:

*Total emission of EDGAR v4.2 clipped to the domain of Switzerland amount to 236 Gg $CH_4$ $yr^{-1}$ for 2008 consistent with the country total reported by EDGAR v4.2 for Switzerland. This total is almost 30 % higher than the 183 Gg $CH_4$ $yr^{-1}$ reported in the SGHGI for the same year. The TNO/MACC inventory adds up to 191 Gg $CH_4$ $yr^{-1}$ over the domain of Switzerland in 2009, which is close to the 180 Gg $CH_4$ $yr^{-1}$ in the SGHGI for 2009 (FOEN, 2013). The difference between EDGAR and TNO/MACC likely reflects the fact that EDGAR is an independent inventory applying its own methodologies for the collection of activity data, application of emission factors, and spatial allocation. The TNO/MACC inventory, in contrast, is scaled to total emissions reported by the individual countries. In both inventories, the spatial allocation of the emissions is based on different and less detailed geostatistical information than available in our study. Figure 4 presents scatter plots of the pixel values of the EDGAR and TNO/MACC inventories versus our inventory mapped to the respective resolution of the coarser inventory. Scatter plots were created for both total emissions and for different categories separately. For the scatterplot, we used the subsectors that represent the emissions in our inventory best, while the comparison of Swiss totals per sector base on all emissions of each sector reported in the respective inventory. In general, the agreement is significantly better for TNO/MACC than for EDGAR expect for the waste sector. The EDGAR inventory tends towards higher fluxes as compared to our inventory, especially for the waste and energy sectors. EDGAR emissions for waste (30 Gg $CH_4$ $yr^{-1}$) and energy (44 Gg $CH_4$ $yr^{-1}$) are substantially higher than in the SGHG inventory (waste: 17 Gg $CH_4$ $yr^{-1}$, energy: 13 Gg $CH_4$ $yr^{-1}$). The relative difference for agricultural emissions is smaller, 162 Gg $CH_4$ $yr^{-1}$ for EDGAR compared to 153 Gg $CH_4$ $yr^{-1}$ in the SGHGI. The TNO/MACC inventory compares well also at the sectorial level (agriculture: 163 Gg $CH_4$ $yr^{-1}$, waste: 17 Gg $CH_4$ $yr^{-1}$, and energy: 10 Gg $CH_4$ $yr^{-1}$ in 2009) against SGHGI (agriculture: 151 Gg $CH_4$ $yr^{-1}$, waste: 16 Gg $CH_4$ $yr^{-1}$, and energy: 13 Gg in 2009). Emissions in the EDGAR inventory are higher in densely populated regions (see Fig. S1 for a population density map) but lower in agriculturally-dominated regions compared to our inventory (Fig. 3c), suggesting that EDGAR is allocating emissions too strongly to population density, consistent with the much higher values assigned to fuel distribution and waste disposal. Spatial differences are less pronounced between the TNO/MACC inventory and our inventory (Fig. 3d). In particular, the TNO/MACC inventory correctly identifies the regions of farming in the southern parts of the Swiss Plateau but the emissions tend to be higher in these areas and lower in the mountains compared to our inventory. These spatial differences are further assessed in Sect. 3.3.1 to obtain a rough estimate of the uncertainty associated with the spatial disaggregation.*

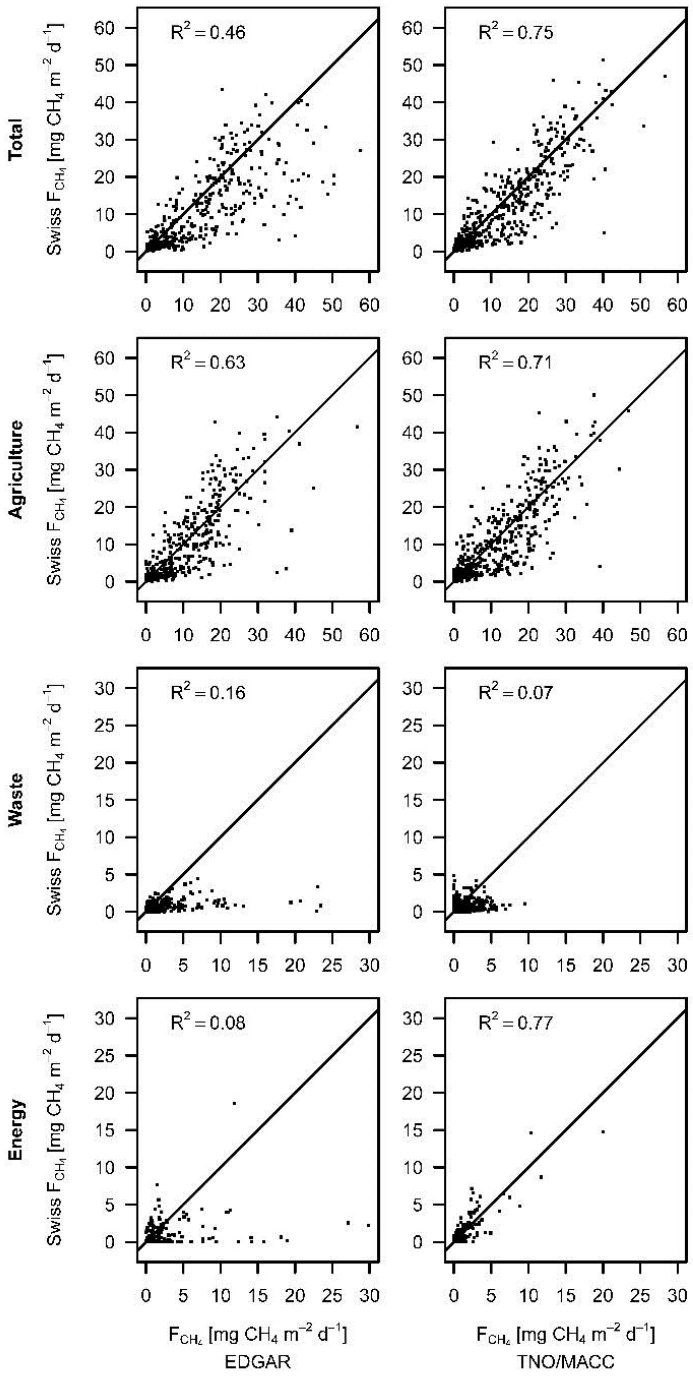


*Fig. 4. Scatterplot between all pixel values in the EDGAR v42 and TNO/MACC inventories in Switzerland versus our inventory reduced to the respective resolution of the coarser inventory. Plots are shown for total emissions as well as for the sectors agricultural (EDGAR: IPCC_4A, IPCC4B and TNO/MACC: SNAP code 10), waste (EDGAR: IPCC_6A_6C, IPCC_6B and TNO/MACC: SNAP code 9) and energy (EDGAR: IPCC_1B2b and TNO/MACC: SNAP code 5) separately. The solid lines indicate the 1:1 relationship. The panels were scaled to show as much detail as possible and hence a few very large emissions were omitted.*

The derivation of the uncertainty in the spatial emission inventory is not completely clear. The uncertainty in the emission from each grid square was assumed to be a fraction of the absolute emission in that grid square. This fraction was then derived using Gaussian error propagation to match the requirement that the overall uncertainty was equal to the uncertainty in the national inventory (16%). It looks as if the same fractional error was assumed for each grid square. Is this for the total or for the sectoral emission in that grid square? Further, the error co-variances were then derived from the correlation length scale. Two length scales were derived from the analyses of the differences between this inventory and the scaled EDGAR and TNO-MACC inventories. Which one was used or was the average taken?

To better explain and motivate our approach, we will replace lines 7-13 on p.15203 by the following:

*Uncertainties associated with the spatial disaggregation are difficult to assess. They depend on the accuracy of the spatial data sets, on quantization errors due to the use of discrete classes, on the relative weights assigned to individual sources, and on the often crude assumptions made for spatial disaggregation.*

*Here we try to quantify the uncertainty of the emissions at the grid-cell level together with an error correlation length scale in a way that is consistent with the uncertainty of the country total of 16%. For simplicity, uncertainties are only specified in terms of relative uncertainty of the grid cell total, but no distinction is made between different categories contributing to the total. The error covariance matrix* ***C****, which is an important input for inverse emission estimation, can then easily be formulated with diagonal elements*

$$C_{ii} = (f\, E_i)^2$$

*and off-diagonal elements*

$$C_{ij} = f\, E_i\, f\, E_j\, e^{-h/L}$$

*where $E_i$ is the total emission in grid cell i (the 2-D grid cell indices are combined here into a single index i), f is the relative uncertainty, h is the horizontal distance between grid cells i and j, and L is the error correlation length scale.*

*The total emission of the country is given by*

$$E_{tot} = \sum_i E_i$$

*and the uncertainty of the total by*

$$\sigma(E_{tot}) = \sqrt{\sum_i \sum_j C_{ij}}$$

*As described below, the error correlation length L was determined by comparing the spatial representation of the emissions in our inventory with that in EDGAR and TNO/MACC, all scaled to the same country total. The relative differences between the inventories are thus assumed to be a measure for the uncertainty associated with the spatial disaggregation. The relative uncertainty factor f, was finally chosen so that the relative uncertainty $\sigma(E_{tot})/E_{tot}$ is 16%.*

*To determine a representative error correlation length scale, we analyzed …*

The last paragraph of Section 3.3.1 will be replaced by

*Assuming that the smaller correlation length scale of 8 km is more realistic, we obtain a value for the relative uncertainty f of 130%. Emissions in individual grid cells thus have a large uncertainty and could well be double or half as large as estimated.*

**Technical comments:**

There are some minor typographical errors and comments:

Page 15197, line 2: ’row’ should be ’roe’

Page 15197, line 7: ’dear’ should be ’deer’

We will change these errors as suggested by the reviewer.

Supplementary material, page 5: The entry in Table S2 ’gardens in settlements’ looks out of place in this table on wetland types.

Even though looking odd, it is listed as such in the Federal Inventory of Raised and Transition Bogs of National Importance; FOEN (2008b). The reason is the following: the definition of wetlands used by FOEN is following the legal concept, not the scientific one.

Added references:

FSO GEOSTAT: Population and household statistics, (STATPOP) 2011, ha-grid, Federal Statistical Office (FSO), 2012.

Zhiling Gao, Huijun Yuan, Wenqi Ma, Jianguo Li, Xuejun Liu, and Raymond L. Desjardins, Diurnal and Seasonal Patterns of Methane Emissions from a Dairy Operation in North China Plain, Advances in Meteorology, 190234, 2011. doi:10.1155/2011/190234, 2011b.