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Earth System Science Data Discussions

# *Interactive comment on* "Gridded maps of geological methane emissions and their isotopic signature" *by* Giuseppe Etiope et al.

**Anonymous Referee #2**

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The manuscript presents a global map of geological methane emissions, accounting for on-shore, off-shore macro and micro seepage as well as geothermal emissions. To test the consistency between inventory estimates and atmospheric data it is crucial to have such a map. Until now, it was left up to atmospheric modelers to make their own maps using the available information, and make assumptions regarding missing inputs – such as globally representative isotopic fractionation factors. Clearly, the experts in geologic emissions are much better equipped for this task. Therefore, the effort that went into this study is serves a valuable purpose. With that an important requirement for publication is met: The manuscript fits well in the scope of the journal and will have scientific impact. The next important requirement is that the information that is provided has a solid scientific basis. This may be the case, but is much more difficult to judge.



As explained further below, the description of the method is very brief and it is not always clear which data are used, and where they come from. This makes it difficult to verify the numbers, let alone to reproduce the inventory from the underlying data sources. Revisions will be needed to improve transparency.

GENERAL COMMENTS

According to the abstract the global mean isotopic signature of geologic emissions is -48.5 to -49.4 per mil. In addition to the global average, a global map of fractionation factors is provided. The question is how those numbers were derived. The section on on-shore seeps mentions (section 4.3) that it is a combination of measurements and estimates. The measurements are 'as indicated in the literature' without references. The estimates follow 3 rules that are listed without specifying which rule applies when. A global mean is used in regions for which no data exist. It is unclear, however, where this applies. The descriptions of the other subsections on isotopic information are similarly general, and unspecific. It is unclear how the range between -48.5 and -49.4 should be interpreted. Is this supposed to be an uncertainty range? Some of the paragraphs dealing with uncertainty in d13C mention 15 per mil as a range of reported numbers. Then how is it possible to arrive at an uncertainty on the global fractionation within 1 per mil? These short comings will have to be repaired.

Important for the application of the geologic emission map to inverse modelling is the information on uncertainty that is provided. However, the method that is used to quantify uncertainties is questionable. For example, for some sources (e.g. OS and SS) it is stated that the uncertainty in the geographical distribution is practically zero. While this may apply to specific sources that have been located, there should be uncertainty from sources that have not yet been found. The question then becomes to what fraction of the emissions this may apply. Section 4.6 on onshore seeps describes contributions to uncertainty, but does not provide a single number. For the uncertainty in the isotopic fractionation factor a maximum difference between estimates is mentioned, but it is unclear how representative that maximum is. Table 5 mentions $\pm 1$ per mil, which seems

quite accurate, but it is unclear where this number comes from. In the description of GM uncertainties, the emission estimates are discussed without providing a clue of what the uncertainties may be. To summarize: The treatment of uncertainties requires several clarifications.

If I understand correctly the gridded emission maps do not account for the global extrapolation, i.e. they account for 37 Tg/yr of methane emissions. For the remainder no specific information is available, which raises the question what the extrapolation of almost a quarter of the emissions is based on. The assumptions underlying the extrapolation are not spelled out, which is critical not only for trying to understand how they were derived, but also to guide users of the emission dataset as to where missing emissions are to be expected (see my earlier remark about the uncertainty in the spatial distribution of the emissions). Besides a clearer description of the assumptions underlying the extrapolation, some discussion is needed of what are reasonable assumptions (in terms of geographical regions) to put the remaining sources or to account for their uncertainty.

Some discussion is needed of how to distribute the emissions not only spatially but also temporally. Without this information, modelers will probably assume that all emissions are constant over the year. Besides eruptions, for which you would obviously need to know the timing, continuous emissions may vary with environmental conditions (temperature, soil water content?). A few sentences of discussion would be useful to provide information to guide the choice of temporal distribution, and the uncertainty assigned to it (for atmospheric modelers it is relevant to know within what bounds continuous emission may vary over the year)

SPECIFIC COMMENTS

Page 3, line 10: What are 'originally ad hoc developed datasets'? Which parts of the inventory are based on such data?

Page 4, line 8: '. . . reported in the supplement'. Add '(S6)'.



Page 4, line 14: How were the 'single OS, SS, MS, and GS shapefiles' derived? Aren't these just lists of coordinates of reported seeps? If so, this needs to be made clear to avoid the impression that unspecified information went into these shape files.

Page 5, line 13: '. . . listed without coordinates' Does this mean that no geographical information is provided at all?

Page 5, line 15: 'The total number of 3439 OS represents about 30% . . .' Does this mean that the remainder is part of the 'global extrapolation'? This question applies as well to the 50% mentioned later in this paragraph.

Page 5, line 33: 'theoretical values were used'. The explanation that follows makes clear what these values account for, but it is unclear what the values are and based on which criteria they are assigned.

Page 5, line 38: What is the difference between 'micro' and 'mini' seepage?

Page 6, line 38: As discussed on Etiope et al, 2009, the isotopic signature of the reservoir may be a poor indicator of the isotopic signature of the emissions due to fractionation due to advective segregation. In light of this, what is justifying the use of the reservoir signature here?

Page7, line 8: '. . . because of multiple counting of 57 seeps . . .' but I thought the point of using ArcGIS was to deal with this kind of issues. Why not assign the emission proportional to area or something like that? There must have been an easy way to avoid double counting.

Page 7, line 16: '. . . OS grids are not meant to update or refine . . .' but the reference is to a paper that was published 10 years ago. Table 1 lists data sources for category OS that are of more recent dates. What does this statement mean for those updates?

Page 7, line 22: '. . .those estimates are indicated in the Table as upper limits . . .' Are marine MV larger emitters as onshore MV's? Otherwise I don't understand this statement. It seems not obvious to me, since a fraction of the emissions from submarine

MV's will be oxidized in the water column.

Page 8, line 10: The total mean value is just the average of all reported d13C values? Since emission weighting seems such an obvious improvement of this estimate why are both estimates mentioned?

Page 8, line 35: '< 500 m deep ... McGinnis et al, 2006' According to McGinnis it is unlikely that seeps from deeper than 100m can contribute significant amounts of methane to the atmosphere. Therefore, the threshold should be 100m instead of 500m.

Page 11, line 34: 'The similar order of magnitude ... log normal behavior' If the mean and median are the same than this suggests rather a normal distribution. I don't see why the mean and median in the same order would point to a log normal distribution.

Page 13, line 23: Implicit here is that the shallower reservoirs have a heavier isotopic signature than a deep reservoir. Is this generally true? If so, then why?

Page 14, line 2: What explains the $\sim$10% difference between gridded and reported area in this case?

Page 14, line 37: 'buffer applied to individual seeps' I don't understand what this means. The reference should probably be to section 6.2.1.

Page 15, line 16: The result of 2 different ways of averaging does not sound as a reliable estimator of uncertainty. This seems confirmed by 2 per mil being very small given the range of the fractionation values.

Page 16, line 6: 'Accordingly, the total emission estimate ... (Etiope et al, 2008)' Why is this? Because the accounting approach that is adopted here is not considered meaningful?

Page 17, line 4: What explains the exceptionally heavy isotopic signature of GM emissions?

Page 18, line 2-5: If I understand correctly, the emission maps are referred to here as



gridded emissions. It means that they only account for 37 Tg/yr.

Page 18, line 10: The combined d13C uncertainty depends on the individual uncertainties. The more important question of how they are combined should also be answered.

Page 19, line 23-24: 'It is expected that using the updated ... (all else equal)' I don't understand why this would be the case. At -49 per mil atmospheric 13C is really insensitive to geological emissions as it is so close to the mean atmospheric composition.

Page 19, line 32-34: It is unclear to me why this would be the case (see my previous point).

Suppl. Page 9: '... considered for the text file' Which text file?

Suppl. Fig S3: To what extend could the difference in slope between the two regression lines be explained by the use of the erroneous syringe method for the larger MV's (increasing the micro seepage would bring the lines closer together)

Suppl. Page 8: 'tested' or 'evaluated' i.o. 'checked'. The latter suggests that the validity of the sensitivity was verified using some external information, which is not the case.

TECHNICAL CORRECTIONS

Page 6, line 31: 'emission' i.o. 'output'

Page 8, line 37: 'emission' i.o. 'output'

Page 16, line 24: 'Grubbs' i.o. 'Grubs'

Table S3, caption: 'Azerbaijan' i.o. 'Azerbaiajn'

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