

## Exploring atmospheric CH<sub>4</sub> monitoring network expansion in Italy using inverse modelling

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In the presented study, the authors perform Observing System Simulation Experiments in order to evaluate the expansion of the atmospheric monitoring network in Italy to improve the estimation of methane emission in this country. Multiple potential additional observation sites are identified and assessed in different network scenarios using an inverse modeling setup with multiple scenarios representing the true state of CH<sub>4</sub> emissions. The impact of the candidate sites is thereupon assessed with regard to error and flux uncertainty reduction. The authors find that in particular two of the potential sites are promising candidates for a future expansion of the monitoring network in Italy in order to ensure a better estimation of CH<sub>4</sub> emission.

Overall, the developed framework makes a valuable contribution to the assessment and optimization of atmospheric measurement networks, with the aim of improving greenhouse gas monitoring. I found the study to be thoroughly prepared and presented in a comprehensive and well-structured manner. I recommend publication after considering of the following comments:

### General comments

1. It would be good if you could highlight why you chose Italy as a case study and reflect on the limitations of the current state of the network in constraining CH<sub>4</sub> emission in this country to underline the need for additional sites. So far, this has only been briefly mentioned in the abstract 'Compared to other countries, Italy remains poorly covered by ICOS atmosphere sites [...]', yet I would assume that other countries within ICOS face equally severe, if not more severe, limitations. Regarding the current state of the ICOS network, I think an important point worth mentioning that limits the estimations of CH<sub>4</sub> emissions in Italy is not only the number of the sites, but also the high altitudes at which many of the stations are located, both within and close to Italy.
2. It would be really helpful if you added more references to the figures you are describing, and checked that you are referencing the correct ones (see more in the specific comments). For example, you should label the sub-figures of Figures 5 and 6 (e.g. a, b, c, d) and refer to them in the text; otherwise, it is difficult to identify which sub-figure is being referenced and comprehend the described conclusions. For instance, on page 17, you write, 'However, while

averages over the truth scenarios suggest that ECO, LMT, and CGR generally outperform VND in the South, a notable fraction of the realizations (20–40%) indicate better performance for VND.', and I think you are referring to figures 5 and 6, 'Southern Italy'. However, it is often unclear where the reader should look for the evidence presented in the text. The same goes for Figure 7, which is not mentioned at all in the corresponding section.

## Specific comments

P2, L36:

I agree that the ICOS network is very advanced, still I think that the term 'world-class' is too subjective for a scientific publication.

P5, L131-L137:

I think the description of the TNO-AVENGERS inventory can be shortened here, since the additional GHGs and available temporal resolutions are not relevant to the study. Otherwise, please state which temporal resolution was used for the CH<sub>4</sub> emissions (I assume monthly?) and include the definition of LULUCF for complicity.

P5, L139:

'According to this dataset [...]' is misleading here because it sounds like you are still referring to the GFED dataset from the sentence before. (Whereas you are referring to the total anthropogenic emissions, I assume?)

P5, Section 2.3.1:

Would it be possible to include a short explanation or reference on how the prior datasets are adjusted to the icosahedral grid?

P8, L194-L195:

'Includes only ICOS sites located in countries bordering Italy' is misleading, because those would only include stations in France and Switzerland, which is not in line with Figure 2.

P10, L292:

Unfinished sentence 'We briefly present here.'?

P12, L310:

I think you mean Figures 3c and 3d?

P17, Figure 5:

This figure is, unfortunately, quite hard to interpret since there is a lot of overlapping of the different scenarios. Could you possibly reconsider the design?

P18, L406:

‘Fig 7 for TUR’ do you mean figure C2?

P20, Section 3.4:

There are a lot of abbreviations in the section. I think it would be beneficial to use the names of the different seasons, instead of the abbreviations of the months.

P33, Figure C3 and P34, Figure C4:

Please copy the caption of Figure 7 and adjust it accordingly, as it is more reader-friendly than having to scroll up and down in the publication.

## Technical corrections

P1, L2:

Missing comma: ‘Here, we focus on Italy, [...]’

E.G. P1, L4 and P2, L38:

Careful with the grammar: ‘ICOS Atmosphere site/network’ is usually written with a capital A, to indicate that the station is part of ICOS Atmosphere. Otherwise, ‘atmospheric site/measurement/network’ should be used. Please check throughout the manuscript including the captions of the figures and tables.

P14, L336:

I wouldn’t say ‘skill’ is the correct word here, maybe ‘In contrast, the capacity of the network is slightly weaker in Central Italy’?

P15, Figure 4:

Better: ‘[...] while the national value is displayed in bold in the lower-left corner of each panel.’

P16, L367:

One comma too many: ‘[...] no monitoring stations because of a lack of information.’