

## ***Interactive comment on “Inverse modeling of European CH<sub>4</sub> emissions: sensitivity to the observational network” by M. G. Villani et al.***

**M. G. Villani et al.**

maria-gabriella.villani@jrc.ec.europa.eu, mgvillani@gmail.com

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### **Replies to the third reviewer’s comments**

*“ Model representativeness error: On page 21078, 3rd paragraph, a reference is given for the method to estimate the model representativeness error, however the Bergamaschi et al. 2009 paper does not elaborate on this; instead it is mentioned that the new scheme will be discussed in more detail elsewhere. Given the importance of understanding how well different sites are represented within the model framework I would strongly recommend this to be discussed within this paper. Also it is not clear how the 50% is justified. It should be kept in mind that this error needs to account for model data- mismatch due to several issues: neglected subgrid scale variations in emissions, but also transport model error in advection and vertical mixing*

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*(including neglecting of mesoscale circulations of stations in complex terrain or close to the sea). It should also be justified why this uncertainty can be represented as random, uncorrelated noise. Both, transport errors and lack of subgrid variability might have a component that is correlated from day to day, or even a bias component. For example having a site that is 80 km away from a larger city, the site could still be in the same gridcell as the station and would thus continuously “see” average emissions rather than sporadic influence depending on wind direction. For a conservative estimate of the constraint that the network has on CH<sub>4</sub> emissions a careful treatment of this is recommended. ”*

The model representativeness error is based on the spatial gradient of modelled CH<sub>4</sub> mixing ratios at the monitoring sites, using all (horizontally and vertically) adjacent model grid cells (Bergamaschi et al., 2005). As in Bergamaschi et al. (2009), we applied a new scheme, which includes estimates of the impact of the subgrid- scale variability of emissions on simulated mixing ratios for stations in the boundary layer. A new paper will describe the scheme in more details (Bergamaschi et al., “Inverse modeling of European CH<sub>4</sub> emissions 2001-2006”).

We chose 50% on an arbitrary base. We assumed this value to represent a proper estimate for potential errors, thus taking into account transport and subgrid scale variability. As a first approach, for simplicity’s sake, we assumed this error to be random and uncorrelated noise. We will report this in the revised manuscript.

## Specific comments

1. “ P 21077 L 6: ‘6-h forecasts’: given the 12 hour cycle of the ECMWF IFS, either analysis fields plus 6h forecasts are used, or hours 3-12 from each forecast cycle is used. This should be specified.”

We will check if we used the hours 3-12 from each forecast cycle, and report in the revised manuscript.

2. “ *P 21078 L 27: Do the synthetic measurements include gaps due to instrument breakdown as usually happens in a real network? To make the estimate conservative I would recommend this, or at least assessing the potential impact. ”*

First experiments were conducted with observations mimicking time series of a ‘real’ network (e.g. time series with gaps). We were also about to analyse the difference with ideal datasets, where no gaps were present. While preparing this manuscript, we decided to exclude them in order to make the synthetic experiments more consistent. Future analyses could definitely set an ‘ad hoc’ experiment framework aiming at better quantifying the influence of gaps and biases in observations used in our TM5 4DVAR system.

3. “ *P 21080 L 15: It should be explained in more detail what is meant by “Gaussian functions” for spatial correlations. ”*

For this point, please refer to our answers given to P. Rayner.

4. “ *P 21086 L 27: I disagree with the statement. The change in correlation length scale from 50 km to 200 km causes a larger change in the En-EU27 than changing from S1 to S2 or S3, and the same holds for changing the prior uncertainty from 300% to 1000%. This means that the impact of an improved network is smaller than that of a change in prior correlations. ”*

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For all sensitivity tests (S1.1 to S1.4) we used the CS observational network. This network provides good constraints over the NWE sector, as we showed in our discussion. Therefore, for these analyses, we should take the NWE sector into consideration rather than the En-EU27, where many areas (Southern and Eastern Europe) have been proven to be poorly constrained. When we changed the correlation length and the prior uncertainty values (scenarios S1.1 and S1.2), we found that a correlation length of 50 km and a prior uncertainty of 300% gave the best agreement between derived and true emissions over the NWE sector (based on Table 4). Therefore, we chose these values to evaluate the influence of the different observational networks.

We could change L26 P21086 to L01 P21087 in : “Results from scenarios S1.1 and S1.2 suggest that the choice of our experimental framework is rather robust regarding the choice of the correlation length (50 km) and the error on the a priori emissions (300%). These values produced the best agreement between derived and true emissions over the NWE sector (e.g. Table 4), regions where the CS observational network provides good constraints.”

5. “ P 21092 L 15: “*emission peak values are smaller compared to the S1 and S1.1 scenarios*” this does not seem to be the case for the area north-east of the HUI site. Is there an explanation for this? ”

This could be an artifact caused by the optimization process. The inversion system selects the most efficient way to match the pseudo observations. With small correlation lengths, increasing the emissions in one grid box close to the station results in a lower perturbation of the background term of the cost function (Eq. 1) than enhancing emissions over larger areas. A larger correlation length has the effect of reducing artificial large emissions at some stations, but also smears

out the retrieved peak values. In the areas north-east of the HU1 site, the system 'detects' large emission patterns. Not having enough information from the observations (the CS network cannot properly constrain the Eastern European regions), higher emission values are distributed over neighbouring grid cells according to the correlation length value.

## References

- Bergamaschi, P., Krol, M., Dentener, F., Vermeulen, A., Meinhardt, F., Graul, R., Ramonet, M., Peters, W., and Dlugokencky, E. J.: Inverse modelling of national and European CH<sub>4</sub> emissions using the atmospheric zoom model TM5, *Atmos. Chem. Phys.*, 5, 2431–2460, 2005.
- Bergamaschi, P., Frankenberg, C., Meirink, J. F., Krol, M., Villani, M. G., Houweling, S., Dentener, F., Dlugokencky, E. J., Miller, J. B., Engel, A., and Levin, I.: Inverse Modeling of global and regional CH<sub>4</sub> emissions using SCIAMACHY satellite retrievals, *J. Geophys. Res.-Atmos.*, 114, doi:10.1029/2009JD012287, 2009.

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