Interactive comment on “Observational constraints on methane emissions from Polish coal mines using a ground-based remote sensing network” by Andreas Luther et al.

Dear referee,

Thank you very much for your review! Answers are written in italics, changes regarding the manuscript are written in blue italics.

Reviewer comments:

Line 45: “The setup largely mimics previous network deployments for quantifying urban greenhouse gas emissions in Berlin (Hase et al., 2015), Paris (Vogel et al., 2019), St. Petersburg (Makarova et al., 2020), Munich (Dietrich et al., 2021), Indianapolis (Jones et al., 2021) and other places.”

This statement makes me ask:

What were the major findings from these deployments?

The mentioned studies generally show the technical feasibility of EM27/SUN networks and they report on emission estimates with a focus on urban settings. Generally, there is a technical evolution for the instrumental part from the early demonstrator studies such as in Hase et al. (2015) towards the latest installation of a long-term almost autonomous urban network in Dietrich et al. (2021). There is also an evolution of the analytical techniques used for inferring emissions. Essentially, it is still an open question - also somewhat depending on the location - how to best set up meteorological models and inverse techniques to deliver reliable emission estimates. All locations come with their own configurations in terms of domain size, topography, meteorological situation and thus, they require a dedicated setup of the instruments and of the data interpretation tools. The quoted sentence serves the purpose to list the previous work that our study builds on. Our study is unique in that it addresses the USCB, the largest source of fossil CH_4 in Europe characterized by dozens of strong point sources for which we deliver “instantaneous” emission estimates. Our study is also unique in that it uses a trajectory modelling and inverse estimation approach that has not been used before in the context of these ground-based networks. For clarification we added the following sentence to the introduction: This work demonstrates emission estimation of a methane emitting hotspot based on a FTS network combined with a Phillips-Tikhonov regularized inversion approach.

As shown in the previous deployments, what are the strengths and limitations of your methodology for constraining emissions?

Generally, a particular strength of the EM27/SUN networks is that they deliver precise and accurate total columns i.e. unlike for in-situ ground-based or aircraft measurements, there is no need to account for the “unobserved” portion of CH_4 (or CO_2) plumes above or below the sampling point. Another strength is that, if the network nodes are arranged along the prevailing wind direction, we can directly *pair upwind-downwind measurements and infer the enhancements due to the local emissions in-between the nodes. A weakness is that the EM27/SUNs require sunlight and fair weather conditions which reduces the sampling density. Some earlier studies also suffered from poor knowledge of the wind fields which is typically the largest error source for the emission estimates. In that context, there is a need to further improve on the data interpretation in terms of using meteorological models and inverse techniques to estimate emissions from the pair-wise concentration gradients.*

Have you addressed the limitations that were identified in previous deployments? That is,is your setup better than earlier setups?

The focus of our study is not only methodological. We want to report on a successful independent estimation of CH_4 emissions from Europe's fossil CH_4 hotspot and on the methods how we have achieved this. The key technical novelties of our study are the following: We deployed 3 windlidars together with the EM27/SUNs i.e. we have excellent knowledge on the wind fields. We employed state-of-the-art meteorological modelling (WRF, wind lidar data assimilation, FLEXPART) and we used an inverse estimation technique that allows for rigorously discussing the information content of our data. Combining these aspects, we believe that, also from a methodological perspective, our study is a useful and original addition to previous work.

Is there anything new or novel about your setup relative to the previous ones?

See previous comment.

Is the importance of this manuscript mainly in the application of the setup to a new emissions source?

Following our comments above, we see two key messages: 1. We deliver emission estimates for CH_4 from coal mining in the USCB. These are estimates of instantaneous emissions and thus, comparison to the annual E-PRTR reporting is questionable, but our estimates tend to be larger than the E-PRTR analogues and they are also different from previous campaign reports (Luther et al., 2019; Kostinek et al., 2020). That is, if we want to be certain of how much CH_4 comes out of the USCB, we need longterm measurements by various techniques. 2. The methods that we have used are rigorous with respect to the quality of wind information (3 wind lidars assimilated into WRF) and with respect to the analysis of the information content (FLEXPART trajectories, Tikhonov inverse method with averaging kernels). So, we suggest that others consider using similar approaches.

Last paragraph of Section 6: Discussion and Conclusions

Since this setup has been used before, how feasible (e.g., from a cost perspective) would it be to use this setup to quantify major emission sources around the world? That is, could it be easily commercialized? Or is this setup primarily for scientific research? My motivation for these questions is the need for affordable options for constraining CO_2 and methane emissions given that satellites, especially for observing CO_2, have limitations that do not always allow for reliable space-based constraints.

The MUCCNET (Dietrich et al., 2021) is probably quite close to a commercialized setup. It requires at least 4 EM27/SUNs to cover the cardinal directions with respect to the target location. The EM27/SUNs typically do not require frequent maintenance and the instrument operations are quasi-autonomous such that the network can be handled by a single person. Moreover, the COCCON data processing tools are freely available to any potential users. Both the operation of the spectrometers and the subsequent data analysis are much simpler than the operation of a TCCON site, which definitely requires engineering and scientific expertise. Thus, we believe that EM27/SUN networks can be useful and cost-effective addition to monitoring systems for greenhouse gas emissions operated by , e.g., environmental agencies. The cost of an EM27/SUN spectrometer is in the order of magnitude of TDLAS based in-situ sensors applied for high precision measurements of atmospheric greenhouse gas abundances.

In the vein of satellites, have you compared your results to space-based constraints, especially for methane? Could your method be used to validate satellite emission constraints?

For the study in the USCB put forward here, we found that the satellite records from TROPOMI und GOSAT were too sparse (after cloud and quality screening) to allow for a meaningful comparison. But, we have conducted satellite validation studies with our ship-borne variant of the EM27/SUN (Klappenbach et al., 2015; Knapp et al., 2021; Butz et al., 2022). In particular, Butz et al. (2022) is a review for use cases of mobile EM27/SUNs including satellite validation aspects.

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