Review of *"Optimizing Methane Emission Source Localization in Oil and Gas Facilities Using Lagrangian Stochastic Models and Gradient-Based Detection Tools"*

The manuscript addresses a critical gap in methane emission monitoring: while detecting emissions is essential, *localizing their sources* is paramount for effective mitigation. The authors present a novel integration of the **TERRAFEX** Lagrangian stochastic model with a **Gradient Indicator (GI) tool**. This work have put large amount of efforts and defining several scenarios to try to advances continuous emission monitoring systems (CEMS) by improving spatial attribution under complex field conditions. Below, I offer general and specific feedback to strengthen the study's impact.

General comments

1- I am not fully convinced that this approach can be applied in a real world condition. Probably this can be further improved in the manuscript or explained in a better way. While the authors attempt to study this important topic and provide a new approach, they can possibly try to show how this approach is a good way to be applied in a real world-conditions. Otherwise, I would recommend that the authors focus on the parameters they studied in the manuscript which influence the POD and/or LA.

2- Probably the authors can explain in the manuscript if the use of TERRAFEX can be also used for a site with more than two emitting sources.

3- The presentation of figures could be enhanced (particularly Figure 7, as detailed in the comments below). Additionally, some formulas may benefit from redefinition or clarification, especially those related to the LA approach (specific suggestions provided below).

4- The manuscript is well-written, but I have identified several editorial suggestions for further improvement.

5- As a recommendation for potential inclusion in the manuscript, please consider evaluating the applicability of the Other Test Method (OTM) 33A quantification method. This approach, developed by the EPA, is designed for stationary measurements of ambient methane emissions (mixing ratio or widely used term

concentration in industry) alongside simultaneous wind direction data. If feasible, you may explore integrating OTM 33A into your algorithm after completing source localization and distance determination. For reference, see: Korben et al. (2022), Omara et al. (2018), and EPA (2014)

Detailed comments

L45 :47 – is this underreporting for Canada or worldwide? In some cases the underreporting is higher than 1.5.

L187-188 – Rephrase, it is a bit vague.

L208 – How did you define the stability classes? Please add few words accordingly.

L230 – the 45° angle changes when the sensor placement increases from the first position as stated in L250. Or did you consider the 45° angle for all sensor locations?

L285 – why did you use Monin-Obukhov length instead of stability class?

Figure 4 – If the edge of well pad is 100 m away from the source, and the sensor position starts from the edge of the well pad at 10 m increment, then the source and sensor cannot be relatively as close as 10 meter to each other, right? See L282.

L315 – The FN was described before.

Figure 6 – Visually speaking, it seems that the plume dispersion from these two sources follow two different wind field. As you can see the plume originated from the north source tends to curve southward and vice versa for the south source. Can you please clarify?

L348 – Wouldn't you get two locations anyway from the TERRAFEX as it seems the algorithm mirrors plume? Can you also do emission back trajectory for more than two locations using the same method?

Table 1, Table 2, Table 3 and L320 – It seems that the formula is for the FNF is not correct. The FNF is usually calculated using $n_{FN} / (n_{FN} + n_{TP})$. This has influence on the values in Table 1.

L321 – shouldn't be LA defined as (n_{TP} + n_{TN}) / n_c or if you are focused on the emitting sources, shouldn't be the formula defined as n_{TP} / n_c? I would suggest to change the formula of LA to average detected distance to the true source +/- uncertainty (e.g. 1 standard deviation). For example something like this:

LA = $\sqrt{(x_d - x_t)^2 + (y_d - y_t)^2}$

In which $(x,y)_d$ is the location of detected source and $(x,y)_t$ is the true location of source. Then you can calculate the standard deviation from all the distances calculated.

Table 1, 2 and 3 – the sum of POD and FNF should be 1 following the abovementioned comment (see comment related to Table 1, Table 2, Table 3 and L320).

Figure 7 – I would recommend to change representation of the POD vs parameters and lines of CIs. Probably it would be better to use POD as y axis and parameters as X-axis and show the 50% CI around the mean or median in the figures. On another point, I can see from Table 2 that POD for <100 values is lower than POD for <75 and <125 while in Figure 7 panel b this is not the case. Check the values.

Figure 8 – So it seems that the sources can be anywhere on the red pixels. Please elaborate how TERRAFEX can be useful in real world conditions. And why did you use the logarithmic scale?

L447 – if the information about the exact location of the sources were not disclosed, how can you determine that the detected sources were within the 10 m distance of actual locations?

Editorial comment

L40 – add parentheses for the year 2023, check referencing style. Also in L67 and L70.

L42 – Add reference to this after '…missions by 30% before 2030.'

L43 – Add reference to the contribution of O&G.

L103 and L105 and elsewhere– check the italic format of the reference.

L196 – check the subscript.

L205 – GDM needs to be spelled out here instead of Sect. 3.1.

L456 – POD?

References:

Korbeń, P., Jagoda, P., Maazallahi, H., Kammerer, J., Nęcki, J. M., Wietzel, J. B., Bartyzel, J., Radovici, A., Zavala-Araiza, D., Röckmann, T., and Schmidt, M.: Quantification of methane emission rate from oil and gas wells in Romania using ground-based measurement techniques, Elem. Sci. Anth., 10, 00070, https://doi.org/10.1525/elementa.2022.00070, 2022.

Omara, M, Zimmerman, N, Sullivan, MR, Li, X, Ellis, A, Cesa, R, Subramanian, R, Presto, AA, Robinson, AL.: Methane emissions from natural gas production sites in the United States: Data synthesis and national estimate. Environmental Science & Technology 52(21): 12915–12925. DOI: http://doi.org/10.1021/acs.est.8b03535, 2018.

EPA, Draft Other Test Method 33A: Geospatial Measurement of Air Pollution, Remote Emissions Quantification - Direct Assessment (GMAP-REQ-DA), Available from: https://www3.epa.gov/ttnemc01/prelim/otm33a.pdf, last access: 11 June 2025, 2014.