Preprint egusphere-2025-644

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

Afshan Khaleghi[1,2], Mathias Göckede[3], Nicholas Nickerson[4], David Risk[1]

[1] Department of Earth and Environmental Sciences St. Francis Xavier University Antigonish, Nova Scotia, Canada
[2] Department of Process Engineering, Memorial University of Newfoundland, Newfoundland and Labrador, Canada
[3] Max Planck Institute for Biogeochemistry, Jena, Germany
[4] Eosense Inc, Nova Scotia, Canada

Correspondence to: Afshan Khaleghi (akhaleghi@stfx.ca)

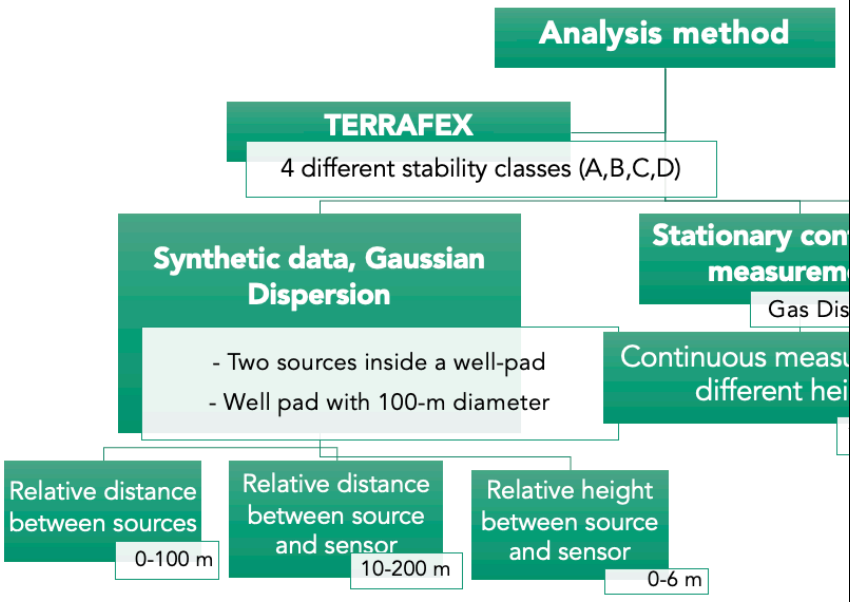
Response to Reviewer (Dr. Hossein Maazallahi)

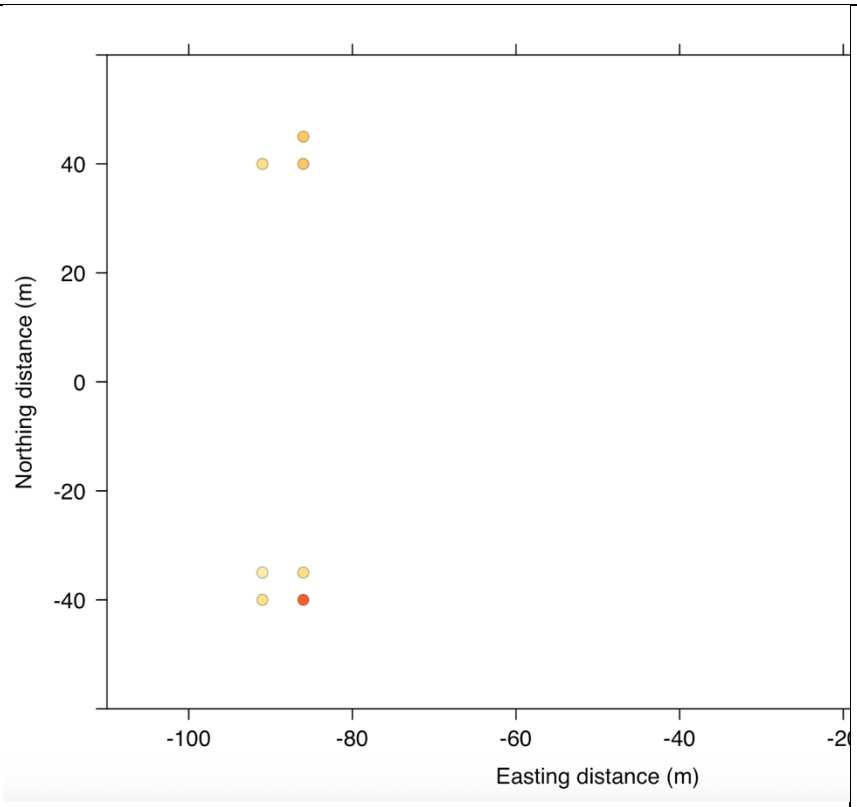
Review Comment	Author' Response	Line changed
Editor		
I am not fully convinced that this approach can be applied in a real world condition. Probably this can be further improved in the manuscript or explained in a better way. While the authors attempt to study this important topic and provide a new approach, they can possibly try to show how this approach is a good way to be	Response: The case study provided in the manuscript is a real-world source localization scenario. We were blind to where the sources are. In this case study there were a total of 4 sources identified. To improve the visualization, the figure will be changed to show how the gradient indicator finds the sources closer to where they are located.	

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.		
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.	Response: There were four potential fugitive emission sources, and CH4 was measured using an Axetris LGD Compact-A CH4 with 0.01 ppm precision at 2 Hz frequency	
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).	This will be considered for the revised version.	
The manuscript is well-written, but I have identified several editorial suggestions for further improvement.	Response: Editorial improvements will be implemented in the revised version.	
As a recommendation	Thanks for the suggestion. This study was an attempt to merge with the OTM33A concept. In other words, the attempt is to	

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).	localize the sources to make it possible to use OTM for cases where source locations are unknown.	
L45 :47 – is this underreporting for Canada or worldwide? In some cases the underreporting is higher than 1.5	Response: The studies mentioned in the paper for 1.5 times underreporting are all in Canada.	

L187-188 – Rephrase, it is a bit vague.	We propose to make this more straightforward with: "It's important to note that a gradient length indicator can, at best, provide an approximate estimate of the source location."	
L208 – How did you define the stability classes? Please add few words accordingly.	Response: For synthetic data, the stability classes were chosen to vary from A to D, and the sigma values are calculated using Turner 1970 as described in the paper. This can be added to the case study: "The stability class for each measurement day was defined using data from the closest airport."	
L203 –the 45 angle changes when the sensor placement increases from the first position, as stated in L250. Or did you consider the 45-degree angle for all sensor locations?	Suggested modification: "The alignment angle is always relative to the line that passes (0,0) over the edge of the well-pad."	
L285 – Why did you use Monin-Obukhov length instead of stability class?	The Lagrangian method uses Monin-Obukhov length as described in lines 142-147	
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.	The edge of the well-pad is located at (0,0), as shown in Figure 2. So when the sensor is located at (0,0), the source at (-10, 0) is 10 meters away from the sensor. That is the case shown in Figure 2, first scenario.	

	Suggested modification to Figure 4:  	
L315 – The FN was described before.	This extra text can be removed.	
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?	There is a difference between these two, as described before. One is the Lagrangian back trajectory that shows the sum of backtracked concentrations from the sensor. For the right picture, it can be seen that the sum is more intense around the (-100,0), which is the superposition of the two plumes. For clarification, the gradient indicator results can be added:	

		
L348 – Wouldn't you get two locations from the TERRAFEX, as it seems the algorithm mirrors plume? Can you also do an emission back trajectory for more than two locations using the same method?	Response: High-quality areas will appear when two sources are close, making it harder to pinpoint the exact location. The second point is an excellent observation, which is addressed in the case study involving four sources under real-world conditions.	
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.	The reviewer is correct that Equation 3 was in error. The FNF value should be corrected in Table 1, Table 2, and Table 3.	

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 = $\sqrt{(\_xd-xt)\_2\_+\_(\_yd-yt)\_2\_\_}$ 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.	Response: We are looking at "How many detections were correct," which only concerns TP and FP as described in Eq. 5. $(n_{TP} + n_{TN}) / n_c$ It is defined as overall correctness. Our main goal was to control the fraction of corrected detections. We wanted to be able to define TP and FPs here, so we decided to assume that if a source is 10 m away from its actual location, it is still valid as a detection.	
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).	Response: FNF was corrected in a comment above.	

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.	I am not sure if I understand the difference here. POD is the y-axis, and the parameter is on the x-axis. Also in Figure 7, b <100 comes before 75 and 125. Response: The graph from Table 2 should be adjusted to display the x-axis in increasing order.	
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?	Response: Thanks for pointing this out. We propose replacing the figure with a clearer one to show the gradient indicator localization. The log scale is applied purely for visualization to better distinguish low background values without affecting the underlying data.	
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?	Thank you for the comment. We acknowledge that the wording may have led to confusion. To clarify, the magnitudes of the sources were not disclosed, but the locations of potential sources were known to the team (as shown in Figure 5). We have revised the manuscript to make this distinction more straightforward and avoid similar misunderstandings. Suggested modification in text: “Although the source magnitudes were not disclosed during the experiment, the approximate locations of the emission sources were known to	

	the research team, as shown in Figure 5. This allowed us to assess detection accuracy based on proximity to the known locations.”	
L40 – add parentheses for the year 2023, check referencing style. Also in L67 and L70.	Should be repaired.	
L42– Add reference to this after ‘…misdions by 30% before 2030.’	Should be repaired.	
L43 – Add reference to the contribution of O&G.	Should be repaired.	
L103 and L105 and elsewhere– check the italic format of the reference.	Should be repaired.	
L196 – check the subscript.	Should be repaired.	
L205 – GDM needs to be spelled out here instead of Sect. 3.1.	Should be repaired.	
L456 – POD?	?	