

# ***Interactive comment on “Methane leak detection and sizing over long distances using dual frequency comb laser spectroscopy and a bootstrap inversion technique” by Caroline B. Alden et al.***

## **Anonymous Referee #1**

Received and published: 13 November 2017

### General comments

The paper proposes a special observing system and statistical analysis to continuously detect and monitor methane leaks from gas production sites. The suggested method combines line-averaging concentration measurements with an atmospheric transport model and a novel statistical method to derive the spatially dependent methane concentration. In this way, the paper presents innovative concepts and fits within the scope of AMT.

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The introduction gives a clear and concise motivation for the study, however related line-averaging measurement techniques and their advantages and disadvantages are not sufficiently addressed (e.g. Open-Path Tunable Diode Laser OP-TDL and Open-Path Fourier transform infrared spectroscopy OP-FTIR). Additionally, the non-zero minimum bootstrap (NZMB) method is introduced without explaining the motivation behind this development in comparison to other possible methods of inverse data analysis. An extended description of the state of the art is necessary to evaluate and classify the new measurement and analysis method.

The atmospheric transport model is one of the central methods of the data analysis. The authors apply a Gaussian plume model assuming a constant methane source through the time for the synthetic data tests and for the field data under similar conditions. This approach and the application of a Gaussian plume model for the purpose of continuous methane leak detection in a real environment are extremely questionable. The Gaussian plume model for atmospheric dispersion is assuming steady-state air concentrations and mass fluxes. There are many references that show the applicability of the Gaussian model: it is primarily used to calculate seasonal or annual statistical values of air concentrations near the ground. It is recommended to use more sophisticated and realistic transport models to ensure a general applicability of the proposed method in the future. The measurement and analysis concept has a high potential of applicability if weak points of single methods will be eliminated, especially regarding the atmospheric transport model.

### Specific comments

1. Introduction: It is highly recommended to give proper credit to related work regarding the measurement technique (line-averaging measurement methods to derive gas concentrations, e.g. OP-FTIR) and the statistical analysis methods.
2. p. 2, l. 8: The 'high global warming potential' should be quantified (in comparison to carbon dioxide) to further explain the strong motivation for this study.

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3. p. 2, l. 9: What is the reference value for the threshold leak rate in percent (3.2%)?
4. p. 2, l. 18: 'Cold temperatures' is a rather colloquial expression, better: lower temperature values.
5. p. 3, l. 1: What does it mean 'agreement of measurements under different conditions'? Which range of air temperature/pressure values? Which range of atmospheric stability and turbulence conditions?
6. p. 3, l. 2: What does it mean 'long periods of time'? How long is it?
7. p. 3, l. 4: What is the 'measurement uncertainty'? Give a short explanation of this quantity: Is it a statistical value (estimated from the standard deviation) or the technical uncertainty (depending on the device) or the analysis uncertainty or...?
8. p. 3, l. 4: What does it mean 'long pathlengths'? Please be more precise or give an example or a range.
9. p. 3, l. 4: Are the data and results of Coburn et al. freely available and reproducible in the meantime?
10. p. 4, l. 5: Is the applicability of the method influenced by the special environmental conditions (e.g., wind speed and direction, atmospheric stratification) of this day in January, 2017?
11. p. 4, Gaussian plume atmospheric transport model: The application of a Gaussian plume model for the purpose of continuous methane leak detection in a real environment is extremely questionable because the model assumes steady-state air concentrations and mass fluxes. The Gaussian model maybe applied under the limited conditions of the synthetic and the real-world experiments described by the authors. However, the general applicability of the proposed measurement and analysis method is limited due to the atmospheric transport model. The cited paper of Leuning et al. (2008) contains one example of a more realistic dispersion model, the Lagrangian stochastic (LS) dispersion analysis. LS analysis can be used when the assumptions

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of constant and homogeneous turbulence (e.g., eddy diffusivity) are not satisfied. In contrast to the Gaussian plume model, LS models incorporate wind shear. It is highly recommended to use such a kind of transport model to allow a general and continuous applicability of the proposed measurement and analysis method under different environmental conditions.

12. p. 5, l. 22: What does the term '(c/x)modelled' describes, the relationship between the point source emission and the line-averaged concentration (=spectrometer beam)? Please explain the relationship between the different scales: point source (emission) – concentration and line-averaged measurements of concentration together with the atmospheric transport model.

13. p. 5, section 2.2: Which spatial and temporal resolution for the derived gas concentration can be achieved using this method? How much is the environmental influence (e.g., background air temperature)?

14. p. 6, l. 4: Which fluxes? Please describe values more specific.

15. p. 6, l. 7: Is the system rather overdetermined or underdetermined for your examples? See also l. 19. The system is overdetermined including uncertainties/errors into the system, really?

16. p. 6, l. 17 and p. 7, l. 16: How did you estimate and quantify the several kinds of uncertainty? Did you only use the standard deviation as a value for the statistical uncertainty? It is highly recommendable to calculate the total uncertainty of the combined measurement and analysis method (uncertainty due to devices, measurement methods, transport model, inversion model. . .).

17. p. 8, l. 4: What does it mean 'idealized scenario', homogeneous wind fields (wind speed and direction)?

18. p. 8, l. 7: How long is the sampling time of each beam?

19. p. 9, l. 2: Which influence of atmospheric stability can be expected?

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20. p. 9, section 2.5.4: An enhanced estimation of all parts of total uncertainty is necessary to evaluate the applied range of model-data mismatch values.

21. p. 10, l. 9: Please give an example for 'long periods of time'.

22. p. 11, l. 1: It can be expected that a local wind circulation is developing at Table Mountain. The assumption of homogeneity and stationarity of turbulent fields is highly questionable under these conditions (Gaussian plume model for atmospheric transport). It has to be checked that the assumptions of the Gaussian plume model are valid for the investigated location and time period.

23. p. 11, l. 5: Can you give a reference for the applied threshold of 0.8 m/s?

24. p. 14, l. 2: The (short) averaging time of 1-2 min disagrees probably with the assumption of stationarity of the Gaussian plume model. It is questionable if the assumptions of atmospheric transport model are satisfied. At least, an enhanced contribution of uncertainty should be included in the analysis (and conclusions).

25. p. 16, section 6: The critical discussion of the used atmospheric transport model is missing here. If a simple assumption (Gaussian plume model) is used for real (complex) environmental conditions, a comprehensive analysis of uncertainties is needed to evaluate the potential and the general applicability of the method.

26. Fig. 10: Are the concentration data referred to the length of the beam? Please provide the wind direction according to meteorological conventions: 0 deg = north, 180 deg = south, 90 deg = east, 270 deg = west). Which averaging time was used to provide the data?

#### Technical corrections

1. p. 3, l. 4: 'Coburn' – 'et al.' is missing.

2. p. 5, l. 28: 'Truong et al.; Waxman et al.' – The year is missing.

3. p. 5, l. 32: 'Coburn' – 'et al.' is missing.

4. p. 5, l. 33: 'tempus lorem' – misprint?

5. p. 8, l. 8: 'that that' – delete one 'that' 6. Table 2: Source Location 1 and NZMB solution: unit must be kg/s

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Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2017-262, 2017.

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