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Atmospheric Measurement Techniques Discussions

Interactive comment on "Towards accurate methane point-source quantification from high-resolution 2D plume imagery" *by* Siraput Jongaramrungruang et al.

Anonymous Referee #2

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General comments

The manuscript "Towards accurate methane point-source quantification from high-resolution 2D plume imagery" by S. Jongaramrungruang et al. introduces a procedure to quantify the methane flux of a point source from a high resolution 2D imagery of the plume. Large Eddy Simulations are used to deduct the method. The flux inversion is described in detail and an error estimate for the method is given. The procedure is then applied to one case of a controlled release experiment, where it could reproduce the flux rate within the assumed error estimate.

The method seems useful, especially, as it does not need the wind speed as an additional input variable. All required values are only extracted from the 2D scene of the (vertically integrated) plume. This makes this method useful for optical measurements, and also for future satellite missions aiming at high resolution methane retrievals.

The method is novel and clearly outlined, the paper fits well into the scope of AMT. The manuscript is well structured, however, sometimes (long) sentence structures made it hard for me to follow. It would be nice, if the authors invest some time for rephrasing, giving the reader a more fluent reading experience.

The authors should use SI units in the preferred inverse notation throughout the manuscript (as stated in AMT manuscript guidelines), several times ppm-m is used (in the text and figure labels), which may be ppm m in SI units (?).

For better understanding, the authors should avoid synonyms (e.g. synthetic measurements vs. pseudo measurement vs. synthetic observation).

Generally, many of the figure legends, axis labels, and other labels might be to small for a good reproduction in the final publication.

Please, do not forget to add the necessary sections: "Data and code availability", "Author contributions", "Conflict of interest".

I recommend publication in AMT, subject to some improvements.

Specific comments

p. 3, ll. 6ff.: The inclusion of retrieval noise in the simulation of synthetic measurements is mentioned, but I have not found anything about this topic in Sec. 4.1 or Sec. 5, which describe more details. Is additional noise used (and if, which) in preparing the synthetic measurements? Is this affecting the estimated errors (and how)? Maybe more details can be included in Section 4.2.

p. 3, l. 26: A 15 minute revisit time is mentioned, sub-figures of Fig. 1 show instrument overpasses in time intervals of 7 to 9 minutes (as also stated in the figure caption).

p. 6: I recommend to restructure Section 4, as Section 4 itself is empty. It could rather be: "4 Large Eddy Simulation" and "5 Synthetic measurement", following Sections change accordingly. The section on synthetic measurement could be extended by some details on the additional noise added. Maybe the applied detection thresholds could also be included here, instead of in Section 2.

p. 6, l. 14: In this study latent and sensible surface heat fluxes are kept constant.
Was the method tested with other settings (except of the controlled release experiment)? What would happen if these fluxes are varied? How would the plume be affected? Would this impact the method? If the method is still applicable with the derived correlations, would the error estimates change?
Some of these questions are answered in "Discussion and conclusion" and answers may not fit in "LES setup". The authors should consider a reference to the discussion section and a strengthening of the corresponding paragraph there, or an additional section on limitations.

p. 8, ll. 4ff.: If I understand it right, the instantaneous value for U-10 is written out from the LES simulation every minute. When the plume structure is – as stated

in line 7 – influenced by the wind during this minute, the LES model (integration) time-step should be smaller. The model time-step should be somewhere around few seconds, taking into account the high resolution of 5 m. However, I found no value for the model time-step, maybe you could include it in the Section about the LES setup. Maybe a rephrasing of the sentence in ll. 4f. could help to understand that instantaneous wind values are written out from the model simulation. Also, using the term "timestep" for one instance of the model output may a bit misleading, as output does not coincide with every model time-step, maybe you could use "snapshot".

p. 9, ll. 17ff.: For the method to work, has the plume origin to be known for the angular mass binning? For LES simulation and field campaigns this should be no problem (when measuring unknown flux rates from a known point source). Also, for flux inversions of known sources from future high resolution satellite imagery, e.g, for emission monitoring, the method will be useful. In other situations, it might be more challenging. Limitations of the method should be addressed in the discussion section, or an additional section on limitations. (e.g., more than one point source or parts of a second plume included in a scene ...)

p. 10, ll. 16f.: The paragraph about error estimates could be strengthened. Please do not just give the value of χ^2 without interpreting this result. Maybe additional description how the "average percentage error" is calculated, and how the error propagates through all steps of the method could be added.

p. 10, ll. 26ff.: Additional information about the controlled release experiment would be nice. Maybe, include a figure of the scene, or a figure of the angular distribution (comparable to Fig. 8)...

p. 12, ll. 3ff.: This paragraph addresses the limitations arising from using constant sensible and latent surface heat fluxes.

The authors should consider to present the limitations in a separate section. The last sentence of the paragraph should be moved closer to the discussion of the constant surface fluxes. All limitations should be named and discussed.

p. 20, Fig. 8: The figure contains two black lines, which are not explained, I assume they denote something like the main axis of the plume.
If the plume is already rotated, why is the maximum of the normalized angular IME distribution not at 0?

Technical corrections
p. 1, l. 18: "m/s" → "m s^{-1}"
p. 1, l. 19: "kg/hr" → "kg h^{-1}"
p. 1, l. 20: "5m" → "5 m"
p. 2, l. 2: "2^{nd}" → "second"
p. 2, l. 2: "... in the Earth's atmosphere, ..." → "... in Earth's atmosphere, ..."
p. 2, l. 6: "facilities scale" → "facility scale"
p. 2, l. 7: "... while the in-situ measurements ..." → "... while in situ measurements ..."
p. 2, l. 8: "Improved estimates of the CH_4 emissions at this point-source scale is critical ..." → "Improved estimates of the CH_4 emissions at point-source scale are critical ..."
p. 2, l. 13: "3-m" → "3 m"
p. 2, l. 14: "... in the direct vicinity ..." → "... in direct vicinity ..."
p. 2, l. 16: "kgCH_4/hr" → "kg(CH_4) h^{-1}"
p. 2, l. 18: "molecule/cm^2" → "?"
p. 2, l. 29: "... inferred from 10-m wind speed by in-situ ..." → "... inferred from 10 m wind speed by in situ ..."
p. 3, ll. 6ff.: "Using 3D LES model output for each time-step, we simulated synthetic 2D airborne measurements by applying the respective averaging kernels as well as retrieval noise (Section 5-5.1)." → "Using 3D LES model output of each model time-step, we simulated synthetic 2D airborne measurements by applying the respective

averaging kernels as well as retrieval noise (Sec. 4.2)."
p. 3, l. 9: "... imply the wind speed from the plume spatial distribution ..." → "... deduce the wind speed from the plume's spatial distribution ..."
p. 3, l. 22: "... & ..." → "... and ..."
p. 3, l. 26: "... 15-minute revisit time ..." → "... 15 minute revisit time ..."
p. 3, ll. 26f.: "Evidently, the plumes are changing in time and exhibit fine-scaled features due to atmospheric turbulence." → "Evidently, the plume is changing in time and exhibits fine-scaled features due to atmospheric turbulence."
p. 4, l. 1: "Figure 1" → "Fig. 1"
p. 4, l. 2: "5 *n*m" → "5 nm"
p. 4, l. 3: "... (Averaging Kernel) of one at ..." → "... (averaging kernel) of 1 at ..."
p. 4, l. 3: "Figure 2" → "Fig. 2"
p. 4, ll. 5ff.: "It has varying sensitivities in the vertical layer, each of which can be calculated as the derivative of the retrieved total column amount with respect to the change in that particular layer." → "Its varying sensitivity in the vertical can be calculated as the derivative of the retrieved total column amount with respect to the change in a particular layer." ?
p. 4, ll. 10: "... horizontal grid (i,j), Δx, Δy ..." → "... horizontal grid cell (i,j). Δx, Δy ..."
p. 4, ll. 17f.: "On the other hands, ..." → "On the other hand, ..."
p. 4, ll. 18f.: "... even larger than one ..." → "... even larger than 1 ..."
p. 4, ll. 19f.: Can you please rephrase the second part of the sentence: "This means that the instrument is almost blind to methane near the ground, while the enhancement at higher levels can be amplified to be even more than the actual methane amount in the column."?
p. 4, ll. 25f.: "Here, we use an average constant threshold value at 500 ppm-m (or 1.34 10^{18} molecules/cm^2), which is a common range for AVIRIS-NG." → "Here, we use a constant threshold of 500 ppm m (or 1.34 10^{18} cm^{-2}), which is a common value for AVIRIS-NG."
p. 4, l. 27: "Gaussian Plumes Modelling & Its Limitations" → "Gaussian plume mod-

elling and its limitations"
p. 4, l. 30, p. 5, l. 1: "The dispersion functions depend on the atmospheric stability classification (e.g., Pasquill, 1961)." → "The dispersion functions depend on the atmospheric stability."
p. 5, l. 3: "The three-dimensional Gaussian plume equation is given by (Eq.2, Matheou and Bowman, 2016)" → "The three-dimensional Gaussian plume equation is given by (Matheou and Bowman, 2016)"
p. 5, ll. 8f.: "By integrating Equation 2 in the Z-direction, the methane column enhancement can be modelled in analytical form as (Eq.3)" → "By integrating Eq. 2 in z-direction, the methane column enhancement can be modelled in analytical form as"
p. 5, l. 11: "Based on this model, we can vary source rates, wind speeds, and stability categories to simulate the 2D concentration field." → "Based on this model, we can vary source rate, wind speed, and stability category to simulate the 2D integrated concentration field."
p. 5, l. 13: "300 kg/hr" → "300 kg h^{-1}"
p. 5, l. 27: "... plumes structure." → "... plume structure."
p. 6, l. 1: "Large-Eddy Simulation and Pseudo-Measurement" → "Large Eddy Simulation and synthetic measurement"
p. 6, l. 2: "LES Set Up" → "LES setup"
p. 6, l. 4: "... 3-dimensional spatial CH_4 distribution ..." → "... 3-dimensional CH_4 distribution ..."
p. 6, l. 5: "... currently available from aircraft ..." → "... currently available from aircraft measurements ..."
p. 6, l. 10: "... mixed layer-inversion-free troposphere structure with ..." → "... mixed layer inversion free troposphere with ..."
p. 6, l. 12: "The inversion is $\Delta\theta/\Delta z = \frac{12}{100}\,K\,m^{-1}$" → "The lapse rate is $\Delta\theta/\Delta z = 0.12\,K\,m^{-1}$"
p. 6, l. 13: "m/s" → "m s^{-1}"
p. 6, l. 14: "... heat fluxes are 400 and 40 W/m^2, based on the typical field campaign

data." → "... heat fluxes are 400 and 40 W m^{-2}, based on typical field campaign data."
p. 6, l. 16: "The model domain is 10.24 x 2.56 x 1.5 km in the x, y, and z directions and ..." → "The model domain is 10.24 x 2.56 x 1.5 km^3 in the x, y, and z direction and ..."
p. 6, l. 19: "Furthermore, the 10-m and 2-m wind speeds ..." → "Furthermore, the 10 m and 2 m wind speeds ..."
p. 6, l. 23: "... LES runs ..." → "... LES simulations ..."
p. 6, l. 27: "This allow us ..." → "This allows us ..."
p. 7, ll. 3ff.: "The left column of Figure 4 represents a single snapshot of plumes, while the right column shows the time-averaged plumes from an ensemble of 60 timesteps, spanning a duration of 60 sequential minutes in total, under distinct background wind speeds but with the constant flux rate." → "The left column of Fig. 4 shows single snapshots of the plume, while the right column shows the time-averaged plume snapshots over 60 timesteps, spanning a duration of 60 sequential minutes in total, under distinct background wind speeds but with a constant flux rate."
p. 7, ll. 6f.: "The ensemble averages in the right column ..." → "The temporal averages in the right column ..."
p. 7, l. 13: "... evident in the plume snapshots as well as their ensemble means as shown in Figure 4." → "... evident in the plume snapshots as well as in their ensemble means shown in Fig. 4."
p. 7, ll. 14f.: "... synthetic observations from AVIRIS-NG and those from HyTES over the same plume ..." → "... synthetic measurements for AVIRIS-NG and HyTES of the same plume ..."
p. 7, l. 16: "... the measurements from HyTES ..." → "... the synthetic measurements for HyTES ..."
p. 7, l. 18: "... resulting in the plume ..." → "... resulting in a plume ..."
p. 8, l. 2: "... 2-m (U-2) or 10-m (U-10) ..." → "... 2 m (U-2) or 10 m (U-10) ..."
p. 8, ll. 10f.: "... as the ideal case of having continuous U-10 output, it has been found in our work to provide a robust correlation with the overall pattern of the plume (see Section 5.2)." → "... as the ideal case of having continuous U-10 output, it provides a

robust correlation with the overall pattern of the plume (see Section 5.2)."

p. 8, ll. 17f.: "For each wind speed and flux rate, we have 60 timesteps of methane plumes from the LES model output, each with one minute apart." → "For each wind speed and flux rate, we have 60 snapshots of methane plumes from the LES model output, with an temporal interval of one minute."

p. 8, l. 18: "... across these ensembles." → "... across these snapshots."

p. 8, l. 19: "Although the shape of the plumes can vary ..." → "Although the shape of a plume can vary ..."

p. 8, ll. 23f.: "The mean values corresponding to various background wind speed and flux rate are plotted in Figure 6." → "The mean values corresponding to various background wind speeds and flux rates are plotted in Fig. 6."

p. 8, ll. 28f.: "The non-linearity can be explained from the fact that we impose the detection threshold value to mask out the plume." → "The non-linearity can be explained from the fact that we impose a detection threshold to mask out the plume."

p. 9, l. 1: "kg/hr" → "kg h^{-1}"

p. 9, ll. 5f.: "This is a primary reason why the IME varies with the flux rate with different degree of non-linearity at different wind speeds as found in Figure 6." → "This is the primary reason why the IME varies with the flux rate with different degree of non-linearity at different wind speeds as found in Fig. 6."

p. 9, ll. 6ff.: "The background wind speed is the integral component that drives the spatial distribution of the plume and entangles the IME and the flux rate inversion." → "The background wind speed is the integral component that drives the spatial distribution of the plume and correlates the IME with the flux rate."

p. 9, l. 11: "... reanalysis weather data." → "... reanalysis data."

p. 9, l. 24: "... 10-1000 kg/hr." → "... 10-1000 kg h^{-1}."

p. 9, l. 26: "... of the plume at high wind speed case, i.e. 10 m/s, is narrower..." → "... of the plume at highest wind speed of 10 m s^{-1} is narrower ..."

p. 9, l. 31: "... time-snapshots ..." → "... time snapshots ... / ... temporal snapshots ..."

p. 10, l. 2: "... with the IME in the plume as explained earlier in Figure 6, ..." → "... with

the variation of IME with flux rate (Fig. 6), ..."

p. 10, l. 6: "... , we can draw a line to estimate ..." → "... , we can estimate ..."

p. 10, l. 11: "... wind speed, both the mean value and the uncertainties from the lower and upper 1-SD error bars in the plot." → "... wind speed, the mean value and the uncertainties from the lower and upper estimate of 1 standard deviation."

p. 10, l. 18: "... this method permits estimation of emission magnitude." → "... this method permits estimation of total emission flux rate."

p. 10, l. 22: "The size of 30 is chosen arbitrarily but is large enough represent a situation when we consider the total fluxes from a region." → "The sample size of 30 is chosen arbitrarily but is large enough to represent a situation for the estimation of total fluxes from a region." ?

p. 10, l. 23: "The comparison between the predicted and the actual sum of 30 plumes aggregation is shown in Figure 13." → "The comparison between the predicted and the actual total flux aggregated over 30 plumes is shown in Fig. 13."

p. 10, l. 24: Please rephrase: "Most of the aggregation predictions lie on 1-to-1 line, implying that there are no significant systematic biases in our method."

p. 10, l. 25: "The mean percentage error of all these aggregates is 2.9**p. 10, ll. 26f.:** "To further demonstrate the validity of this method, we applied this to a controlled release experiment from a natural gas pipeline with the flux rate of 89 $\pm$ 4 kg/hr." → "To further demonstrate the validity of this method, we applied it to a controlled release experiment from a natural gas pipeline with a flux rate of 89 $\pm$ 4 kg h^{-1}."

p. 10, ll. 27ff.: "Based on a sample from the actual AVIRIS-NG scene over the source location, we measured the IME, constructed the angular distribution of the plume to obtain the width to predict the wind speed and hence predicting the flux rate." → "Based on a sample of the actual AVIRIS-NG scene over the source location, we calculated the IME, constructed the angular distribution of the plume to obtain its width to deduce the wind speed and hence predicting the flux rate."

p. 10, ll. 29f.: "The value that we predict is 118 $\pm$ 30 kg/hr, consistent with the actual release flux within an error estimate." → "The value that we predict is 118 $\pm$ 30 kg h^{-1},

consistent with the actual release flux within the error estimate."
p. 11, l. 24: "Given that point source are..." → "Given that point sources are..."
p. 11, l. 25: "... single-measurement ..." → "... single measurement ..."
p. 11, l. 30: "... validated from the application ..." → "... validated by the application ..."
p. 11, l. 32: "This provides great values in ..." → "This provides added value in ..."
p. 12, l. 1: "... point sources emissions ..." → "... point source emissions ..."
p. 12, l. 3: "... LES runs ..." → "... LES simulations ..."
p. 12, ll. 8f.: "For our purpose, we set the threshold value to 500 ppm-m throughout our study to match the current capability of the current instrumentations." → "In this study, we set the threshold to 500 ppm m to match the capabilities of the current instrumentations."
p. 12, l. 11: "Repeat overflights that results in multiple snapshots of the same source can also further reduce the uncertainties from the transient variations of the plume due to turbulence." → "Repeat overflights that result in multiple snapshots of the same source can also further reduce uncertainties from transient variations of the plume due to turbulence."
p. 12, ll. 14f.: "These methods could be applied ..." → "This method could be applied ..."
p. 15, Fig. 2: "A plot showing column averaging kernels ..." → "Column averaging kernels ..."
p. 16, Fig. 3: Labels are too small.
"ppm-m" → "ppm m"
"kg/hr" → "kg h^{-1}"
p. 17, Fig. 4: Labels are too small.
"ppm-m" → "ppm m"
"m/s" → "m s^{-1}"
"kg/hr" → "kg h^{-1}"
"... detection threshold is set at 500 ppm-m." → "... detection threshold set to 500 ppm m."

"Note that the average did not reach a true ensemble average yet as sample size was finite (i.e. the average still exhibit fine structure)." → "Note that the temporal averages do not reach a true ensemble average as sample sizes are finite (i.e. the averages still exhibit fine structure)."
p. 18, Fig. 5: Labels are too small.
"ppm-m" → "ppm m"
"kg/hr" → "kg h^{-1}"
"... when observed by AVIRIS-NG instrument ..." → "... when applying the AVIRIS-NG instrument ..."
"... but instead observed with HyTES." → "... but applying the HyTES averaging kernel."
"... detection threshold is set at 500 ppm-m." → "... detection threshold is set to 500 ppm m"
p. 19, Fig. 6: "kg/hr" → "kg h^{-1}"
"m/s" → "m s^{-1}"
p. 19, Fig. 7: "kg hr-1" → "kg h^{-1}"
"ppm-m" → "ppm m"
p. 20, Fig. 8: Labels are too small.
"ppm-m" → "ppm m"
"m/s" → "m s^{-1}"
"kg/hr" → "kg h^{-1}"
"... its angular distribution across the plume (right) and its Cartesian distribution along the plume (top)." → "... its angular distribution of IME across the plume (right) and its Cartesian distribution of IME along the plume (top)."
p. 20, Fig. 9: Please, include description of error bars in caption.
p. 21, Fig. 10: Please, include description of shading.
"... averaged over time steps and flux rates." → "... averaged over snapshots and flux rates." ?
p. 21, Fig. 11: Please, include description of shading.

"... flux rates and wind speeds ..." → "... flux rate and wind speed ..."
p. 22, Fig. 12: "kg hr^{-1}" → "kg h^{-1}"
"methods" → "method"
Please, include description of error bars.
p. 22, Fig. 13: "kg hr^{-1}" → "kg h^{-1}"

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