Responses to reviewer comments

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Field inter-comparison of low-cost sensors for monitoring methane emissions from oil and gas production operations

Torres, et al.

Reviewer 1:

Comment: Overall, this study strongly advances the important topic of near-source emissions detection for oil and gas applications. This is a high-quality study of significant scope, and the manuscript is generally well-written. This work should be of interest to the readers of this journal and a wider audience. In this reviewer's opinion, this manuscript should be published after considering revisions.

The authors conclude that the tested sensors demonstrate the ability to detect methane concentration enhancements in the range of 500 ppb to 1 ppm at 1-min time resolution. Coupled with impressive data completeness, the authors conclude that these systems are suitable for long term methane emissions monitoring at oil and gas sites. The analysis presented generally supports the detection performance statement for certain monitoring conditions, but the analysis could be significantly strengthened regarding the primary monitoring objective of detection of emission plumes. Currently, it is not clear that all sensors can detect rapidly changing concentrations indicative of near-field source emissions at the stated performance objective.

The modeled sensor performance criteria in Section 3.2 states that a sensor should be able to detect enhancements of 500 ppb to 1 ppm over background with 1 min time esolution. However, the analysis does not strongly examine sensor performance against these levels. Table 2, for example, shows gas challenges at 10 ppm and 100 ppm but data should be available at 2.2 PPM as well.

Response: Data for the response at 2.1 and 2.2 ppm has been added to the manuscript; the added text and table is (blue font):

Using these metrics, Table 2 reports the results of the challenge gas tests for the four sensors with 10 ppm and 100 ppm calibration gases over the study period. Table 3 reports the results for the 2.1 and 2.2 ppm calibration gases. For the 2.1 and 2.2 ppm challenges, the objective was to test the ability of sensors to discriminate between close concentrations near the background concentration. Table 3 reports the difference between responses to the 2.1 and 2.2 ppm challenge gases for each of the sensors.

Table 3. Summary of responses to the 2.1 and 2.2 ppm challenge gas tests

Sensor	CH_4 gas concentration	Number of comparisons	Sensor mean response	Mean difference 2.1 vs 2.2 ppm
Scientific Aviation	2.1 ppm	8	5.44	-0.819 ± 0.883
Scientific Aviation	2.2 ppm	8	4.62	
Aeris	2.1 ppm	6	2.04	0.106 ± 0.026
Aeris	2.2 ppm	6	2.14	
Canary	2.1 ppm	7	2.83	0.013 ± 0.167
Canary	2.2 ppm	7	2.84	
Quanta 3	2.1 ppm	8	2.14	0.080 ± 0.118
Quanta 3	2.2 ppm	8	2.22	

Comment: Regarding comparisons to QC-TIDLAS, concentration enhancements observed by near-source sensors typically represent a superposition of slowly varying background signal and rapidly varying emission plume signal from the potential emission source under study. The performance criteria for source-proximate emission detection approaches should center on the sensor's ability to detect proximate emission plumes. A sensor's ability to track slow diurnal changes in methane with high accuracy is somewhat less important. This paper could be strengthened by adding a subset analysis focused on temporally sharp, multi-ppm enchantments likely representing plume signal from the adjacent site. For example, using QC-TIDLAS determined short term excursions (e.g. > 5 ppm), what percentage of these peaks were successfully detected by the sensors under study. This type of analysis will separate slowly varying background data from source-induced concentration enhancements (the primary application).

As it stands, the ability of the sensors to track dynamic concentration changes indicative of near-field emission plumes is difficult to understand. For example, Figure 7(d) is illustrative of baseline offset but lacks the 5-ppm signal excursions for comparison to other cases in the same figure. Looking at Table 3, how much of the decorrelation in the slow MOX sensor is due to baseline drift and how much is due to insufficient temporal response to rapidly varying plume signal that is properly captured by QC-TIDLAS reference instrument?

Response: The reviewer correctly identifies slow response as one of the reasons for the decorrelation between the metal oxide sensing system and the QC-TILDAS reference instrument. We have added text and figures highlighting this issue in the revised manuscript. Rapidly varying ambient concentrations make it difficult to quantitatively account for this lag with a simple delay in response, therefore we have added text describing the average concentrations recorded by the metal oxide sensor when the QC-TILDAS instrument was recording

measurements in various concentration measurements (unmatched in time). The revisions to the text are given below (blue font)

In addition to the baseline correction, Figure 10 also suggests a delayed response for the Scientific Aviation sensor, relative to the QC-TILDAS sensor. Examples of this delay are shown in Figure 11. Rapidly varying ambient concentrations make it difficult to quantitatively account for this lag with a simple delay in response, however, the average concentration recorded by the Scientific Aviation sensor can be calculated for periods when the QC-TILDAS instrument was recording measurements in various concentration measurements. For example, for the 3,709 minutes when the QC-TILDAS instrument recorded nixing ratios greater than 20 ppm at the sampling site adjacent to the Scientific Aviation sensor (mean of 30.8 ppm), the Scientific Aviation sensor recorded a mean mixing ratio of 24.3 ppm. For the 13,927 minutes when the QC-TILDAS instrument recorded mixing ratios greater than 10 ppm (mean of 18.0 ppm), the Scientific Aviation sensor recorded a mean mixing ratio of 13.7 ppm. These results suggests that the Scientific Aviation sensor is generally detecting methane enhancements over background, but separately accounting the impacts of baseline drift and time lags is challenging.

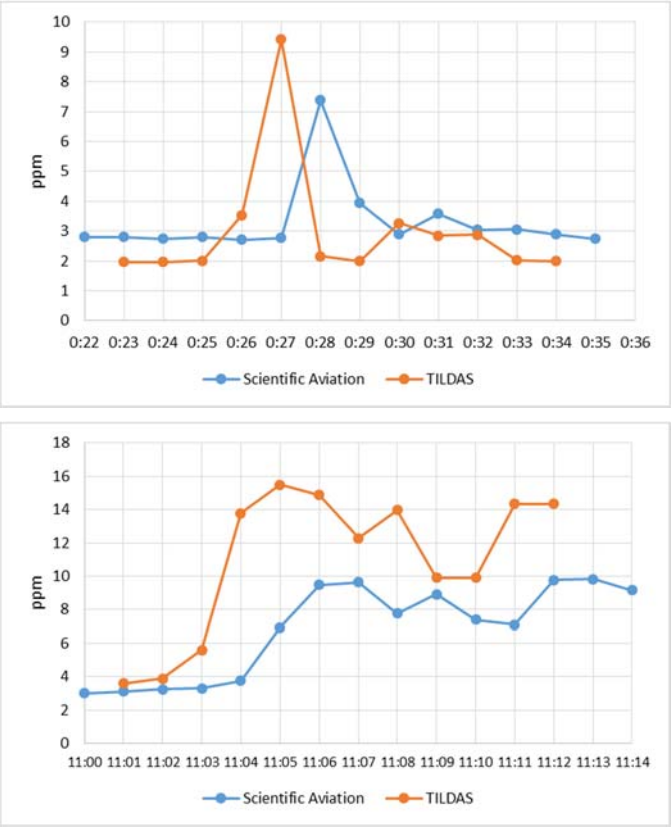

Figure 11. Examples of time lags between the QC-TILDAS and Scientific Aviation measurements