Single-Blind Determination of Methane Detection Performances using Telops' Hyper-Cam Airborne Mini

Introduction

Methane is a powerful greenhouse gas with a warming impact 86 times stronger than CO_2 per unit of mass over a 20-year period and an atmospheric lifespan of around 12 years. These mean that reducing methane emissions can slow the rate of warming and have positive impacts in our lifetime.

Figure 1. Natural gas processing site.

Over the past several years of research and workshops with scientific and industry leaders, it has become clear that there is no single technology that can survey large areas efficiently and detect emission of all levels. The industry is now leaning toward an array of sensors or a technology toolkit benefiting from the advantages of each sensor to tackle emissions of different sizes. Traditional gas sniffing techniques and optical gas imagers (OGIs) are commonly used to detect gaseous emissions. While these techniques provide strong gas detection capabilities, they can be limited in their ability to accurately identify which gases are present and in what quantities. In addition, these technologies are not suited to survey multiple assets rapidly and cost effectively. The use of aerial surveys overcome these shortcomings and allow accurate detection of methane emissions in an efficient manner. The Telops' Methane Airborne Detection Solution is designed to survey assets in the midstream sector efficiently in order to find, identify, and quantify methane leaks. The solution is based on the Hyper-Cam Airborne Mini sensor, a passive hyperspectral thermal imager capable of imaging methane emissions in real-time. The system facilitates maintenance plans by providing clear and actionable reports about the locations of methane emissions.

AMEP Test Campaign

The Hyper-Cam Airborne Mini was flown on multiple occasions in the past 2 years in all kinds of weather conditions, in different seasons and various locations for both controlled releases and surveys of assets for unknown methane emissions. In order to augment the existing dataset, a campaign was planned with the support of the Alberta Methane Emissions Program to assess the performance of Telops' Hyper-Cam Airborne Mini in single-blind methane releases.

The campaign took place at CMC Brooks facility in Alberta, Canada between September 18th and 23rd 2023. Over a period of 5 days, 605 flyovers were performed over 2 release sites, resulting in 16 883 measurements (datacubes) acquired over a wide range of test conditions.

Figure 2 show the Hyper-Cam Mini installed inside the equipment bay of the Bell 206B helicopter provided by

LiDAR Services International Inc. (LSI) who performed the flights.

Figure 2. The Hyper-Cam Airborne Mini installed in a specially designed comportment at the rear of the Bell 206B helicopter used in the AMEP campaign. The instrument looks nadir through an opening at the base of the equipment bay.

Tests conditions and parameters during the campaign were:

- Methane release rates: 0.07 to 22.2 g/s (0,2 to 80 kg/h) including also "No Release" conditions
- Wind speeds: 1.7 to 4.1 m/s (6.1 to 14.8 km/h)
- Flight speed: 46 to 90 knots
- Flight height (AGL): 250 to 410 m (820 to 1345 ft)
- Thermal contrasts: 0 to 15°C

Flight speed and AGL during the campaign were right around the recommended flight speed and AGL for optimal methane detection sensitivity which are 70 knots and 350 m respectively. At the time of the campaign, thermal contrasts between 0 and 15 °C are to be expected. Summer conditions can bring higher thermal contrasts (> 25 °C) providing lower detection limits. Figure 3 illustrates the two sites surveyed where gas-controlled release apparatus was deployed.

Figure 3. Upper: view of the two release sites from the air. Lower left: picture of the west site. Lower right: picture of the east site.

The Hyper-Cam Airborne Mini

The Hyper-Cam Airborne Mini (Figure 2) is a passive thermal infrared hyperspectral camera. It is similar to a regular camera in the sense that it collects infrared light emitted by objects in the scene. Where it differs from a regular camera, is in its capacity to decompose the IR light into a multitude of contiguous spectral bands leading to a complete and detailed spectrum for every pixel in the image. Its passive nature (in contrast to an active system relying on the reflection of an emitted laser signal) brings excellent detection performance over a wide range of conditions (day or night) including over snow and water. For such a camera, the signal is produced by thermal contrast between the temperature of the background and the temperature of the methane gas plume. So, the signal is proportional to the gas quantity in path length units ($ppm \times m$) and the thermal contrast as described in Eq1.

Eq1. $$Signal \propto \left(Quantity_{gas}\right) \times \left(T_{gas} - T_{bkg}\right)$$

Detection Limit Analysis

The system sensitivity (expressed as the methane detection limit) depends on various parameters such as:

- Flight parameters (speed & AGL)
- Instrument settings (image width)
- Environmental conditions (thermal contrast, wind speed and relative humidity)

Prior to flying, the detection limit is estimated based on the expected environmental conditions in order to facilitate decision making with respect to selecting the appropriate flight parameters, camera settings and time of flight. Post-flight, the detection limit was computed for each individual measurement (refer to Figure 5) based on the measured flight and atmospheric weather parameters (refer to Figure 4). Since the thermal contrast varies within the captured datacube image, the detection limit reported is the median value. From Figure 5, we note that the detection sensitivity improves greatly after 10 am for that time of year. The higher detection limits on September 20th are likely caused by increased cloud cover during those periods.

During this data collection campaign, the detection limit was better than 2.3 g/s for 50% of the collected datacubes. The detection performance for all measurements during the campaign is presented in Figure 6. It is interesting to note that some of the smallest releases at 0.07 g/s (0.24 kg/h) were detected. Some caution has to be taken when looking at the statistics of this campaign because a significant proportion of releases were performed at very small release rates which bias the statistical results.

In fact, 50 % of the test release cases were done at a rate smaller than half of the calculated detection limit. Hence, to calculate the probability of detection (PoD), only the data from methane releases for which the true leak rate is above the detection limit was used. Doing so results in a PoD of 93 % (refer to Figure 7). The PoD increases to 98 % for release rates above 5 g/s (18 kg/h).

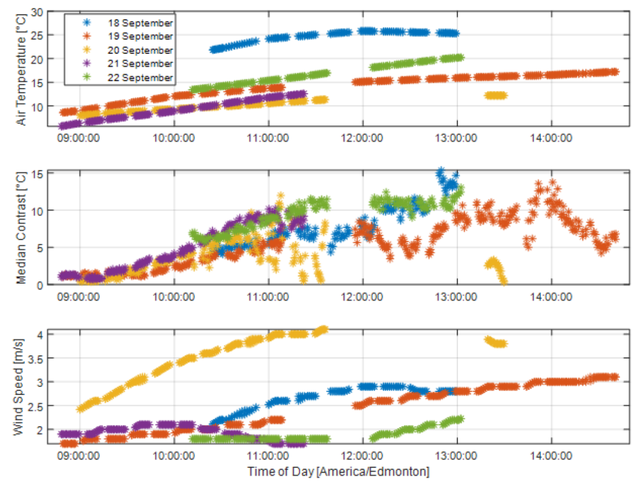

Figure 4. Measured air temperature, thermal contrast and wind speed values for every measurement during the campaign.

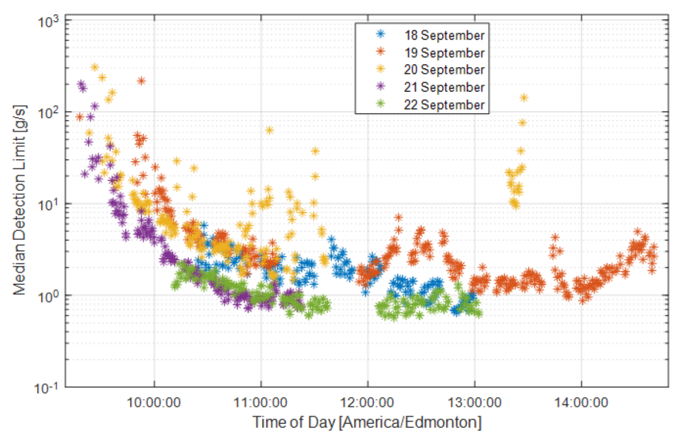

Figure 5. Calculated detection limit for every measurement during the campaign grouped by day.

Quantification

Methane leak rate can be estimated from the collected imagery data using the gas mass per area automatically calculated by the system and the mean gas flow velocity[1]. The gas flow velocity is approximated to be the local wind velocity sourced from weather modeling services.

Figure 8 presents the retrieved methane flow rate as a function of the true release rate. The observed spread in the retrieved values is expected given the important uncertainty in the local wind speeds. We also note a slight underestimation in the retrieved release rates. More work is necessary to understand this effect.

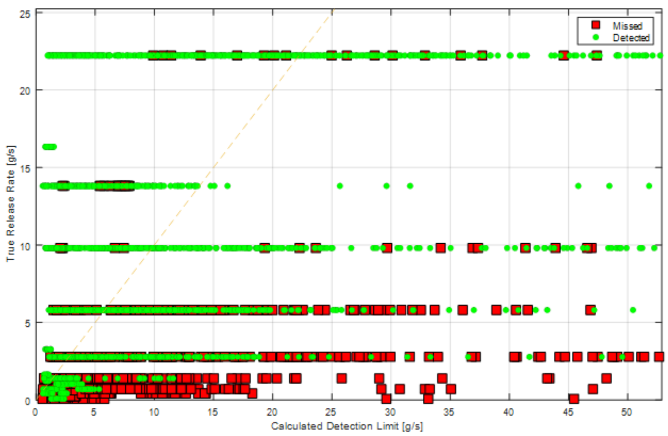

Figure 6. True methane release rate as a function of the calculated detection limit for all measurements. Green squares indicate valid detections while red squares indicate missed detection events.

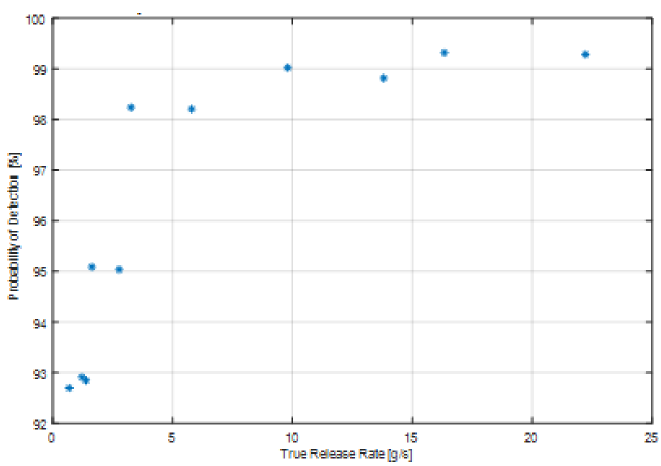

Figure 7. Probability of detection when the true release rate is above the calculated detection limit. Each point takes in account every measurement collected at the true release rate value.

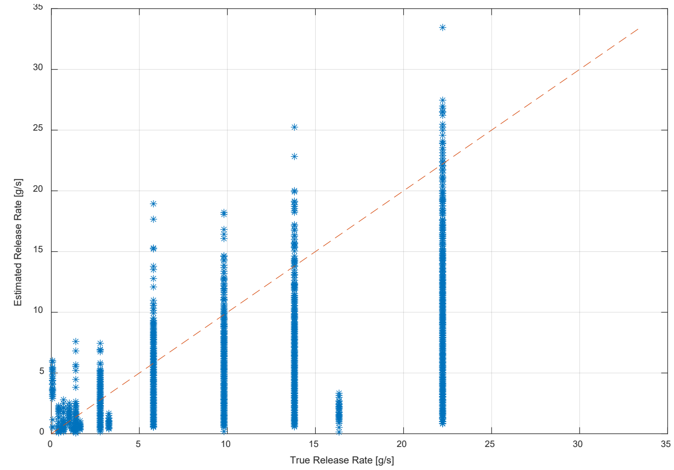

Figure 8. Estimated methane flow rates as a function of the true release rate in g/s. Dashed red line indicate the parity line.

Conclusion

The single-blind test campaign organized in partnership with the Alberta Methane Emissions Program (AMEP) and LSI lead to a detailed performance analysis of the Hyper-Cam Airborne Mini for the detection of methane. Test cases included release rates ranging from 0.07 to 22.2 g/s, in various atmospheric conditions. The fact that the detection limit is calculated for every measured scene provides good confidence in the inspection results. The probability of detection was found to be 93 % when the release is at a rate equal or higher than the calculated detection limit. The PoD increases to 98 % when the release is larger than 5 g/s and higher than the calculated detection limit.

References

1. J. -P. Gagnon, V. Farley and S. Boubanga-Tombet, "Comprehensive Summary of Methane Airborne Quantification Results," IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium, 2022, pp. 7363-7366, doi: 10.1109/IGARSS46834.2022.9884894.