In-Field Graphic Estimates of UOW Methane Emission Rates Using a Portable Laser-Based Methane Analyzer Coupled with Wind Speed and Direction Measurements

Nikira Labs Inc.
Science Made Simple

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Motivation

The Interstate Oil & Gas Compact Commission (IOGCC) estimates the number of undocumented orphaned wells (UOW) to be between 310,000 and 800,000 (IOGCC,2021), though the true amount including all states is probably higher. The magnitude of methane emissions from orphaned wells has been documented in numerous studies. In addition to releasing methane, one of the most potent GHGs, into the atmosphere, and impacting human and environmental health, leaking wells are reported as having negative impacts on drinking water (McMahon and others, 2018; Schout and others, 2019). If they are a source of emissions, these problematic wells can be remediated through proper plugging and abandonment after determining their emission rates for plugging priority.

We present here a light-weight battery-operated cavity enhanced absorption spectroscopy (CEAS) based methane analyzer equipped with a 3D sonic anemometer along with in-built graphic visualization software to assist field operators in estimating methane emission rates during field surveys. In order to provide the field operator with rapid and precise measurements, the analyzer offers methane measurement precision of better than 10 ppb (1sigma/1sec) at 3 Hz. These in-field methane estimates offer the operators an immediate insight into the UOWs emissions magnitude and an in-field data-driven decision-making ability to rank the plugging urgency of the surveyed wells.

Technology

Cavity enhanced absorption spectroscopy (CEAS) is an extension of tunable diode laser absorption spectroscopy (TDLAS) and is a proven method of measuring trace gases such as CH_4, CO_2, NH_3, etc. using molecular absorptions in the near infrared. Briefly, light passing into the optical cavity is reflected many thousands of times between the high reflectivity mirrors to amplify the interaction between analyte and probe light resulting in greatly enhanced absorption signals.

Nikira's recent advances in the CEAS electronics and manufacturing have made small, portable, fast and accurate CH_4 measurements possible. The resulting Portable Methane Analyzer (**PMA**) is perfectly suited for measurement of emissions from abandoned wells.

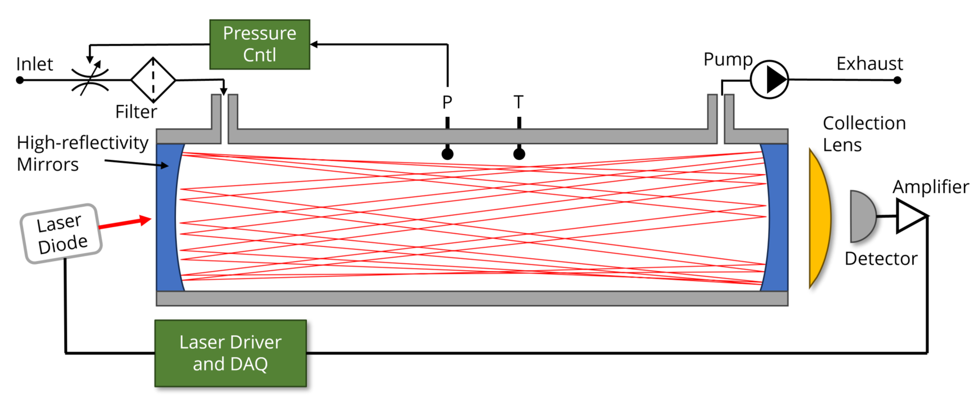

Figure 1. Schematic diagram of the PMA system for measuring methane.

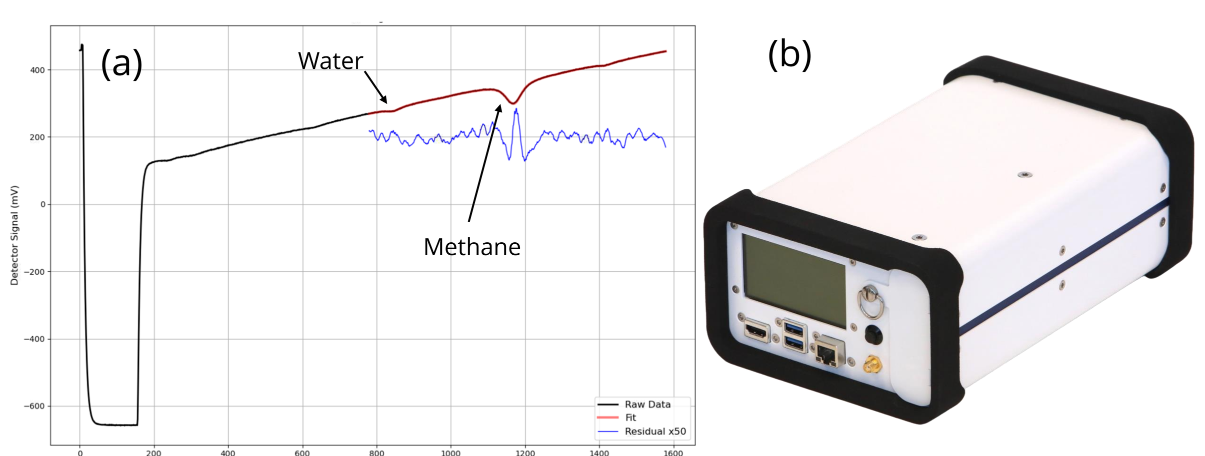

Figure 2. (a) An example spectrum from the PMA. **(b) P**hoto of the PMA analyzer ergonomical enclosure for mobile field use (actual analyzer & field setup on display at Booth# 308).

Table 1. Nikira Labs' Portable Methane Analyzer Operational Info

Parameter	Value
Sample Flow Rate	3 SLPM
Data Connections	Serial (RS-232) via USB dongle
Network Access	Built in Wi-Fi card, Ethernet (RJ-45)
Dimensions	9" x 6" x 3.5"
Weight	5 lbs.
Power Input	14 – 28 VDC, 2.5 A
Power Consumption	< 15 W
Internal Data Storage	30 Gb eMMC
Calibration	Yearly
Consumables	Inlet filters (interval environment specific), Pump (MTBF >10,000 hrs)

Lab Testing

The PMA analyzer has been extensively laboratory tested to determine the precision, accuracy, and time response. Additionally, the analyzers have been stress tested by subjecting them thermal testing from 0 – 50 C and vibration testing with 2 G_{rms}.

Precision

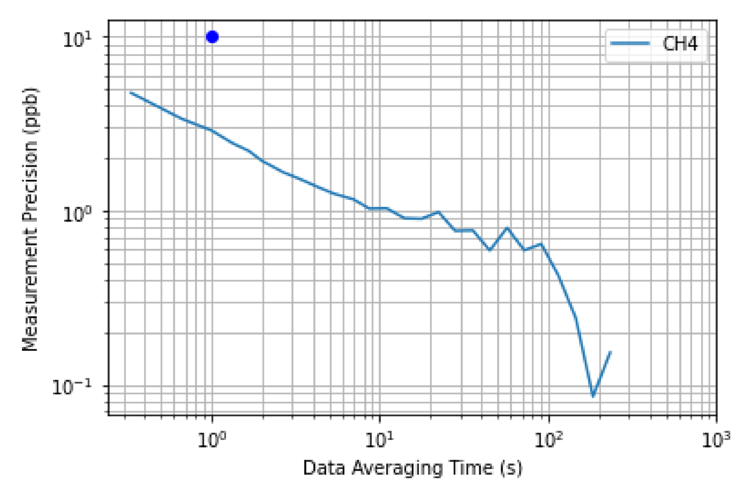

Figure 3. (a) Allan deviation plot of measured, constant source CH_4 with a 1-σ, 1 sec precision of 3 ppb. This level and precision and accuracy makes detection of even small or far away emission sources possible.

Linearity

The PMA has an extremely linear and accurate response to methane. The default linear calibration range is 1-100 ppm for CH_4. However, for abandoned well applications a linearizing correction may be applied for high CH_4 concentrations to extend the linear response up to 1% CH_4.

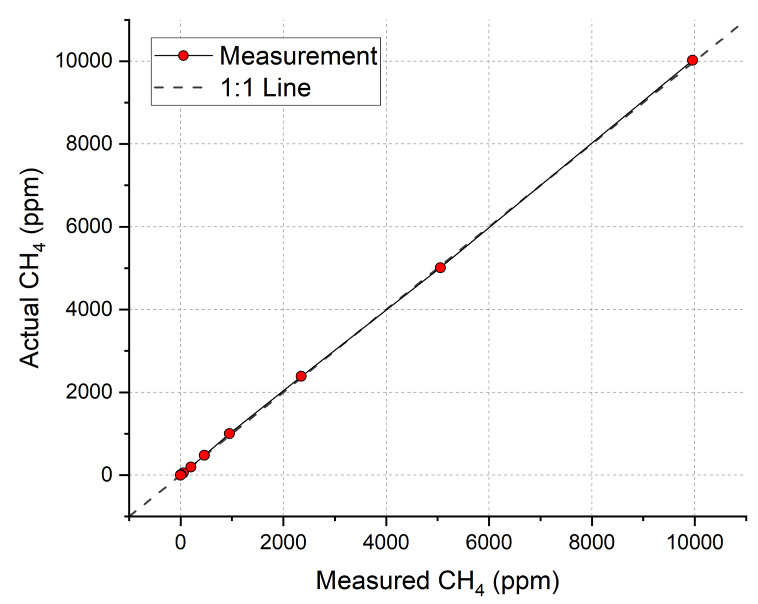

Figure 4. Extremely linear response of CH_4 is demonstrated over a measurement range of 1 ppm – 1% CH_4.

Time Response

Handheld and field measurements in rapidly changing winds demand extremely fast measurement response time. A response time of 0.2 seconds or better is required to allow high fidelity detection. The PMA analyzer exhibits better than 5 Hz response speeds making it more than capable of detecting methane in dynamic and turbulent environments

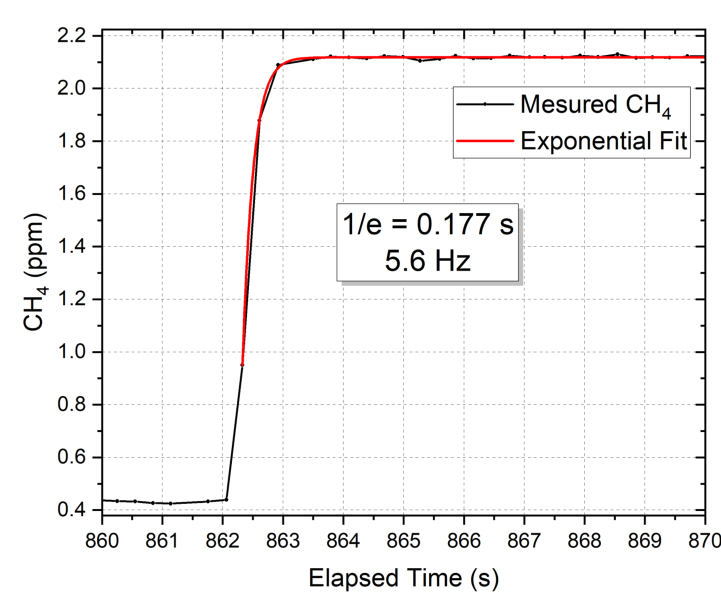

Figure 5. Measurement of the PMA time response. A solenoid valve toggles between compressed SCUBA air depleted of CH_4 (~400 ppb) and room air (~2.1 ppm CH_4). The gas turnover speed is 0.177 seconds or 5.6 Hz.

Abandoned Well Emissions

Nikira Labs has demonstrated the detection and rate estimation capabilities of the PMA with several days of methane leak surveys at a previously capped abandoned well in Hectorville, Oklahoma. The well emission rate was measured while capped and while temporarily opened. As seen in Figure 6, the PMA consistently measured the well emissions both capped and uncapped. For these measurements, the PMA is augmented with a small sonic anemometer to record wind speed and direction concurrent with the methane measurement. A standard Gaussian Plume Model (GPM) has been incorporated to automatically calculate the estimated emission rate in g/hr (given distance to the source) [Dubey 2023] and to plot the rate vs. wind direction.

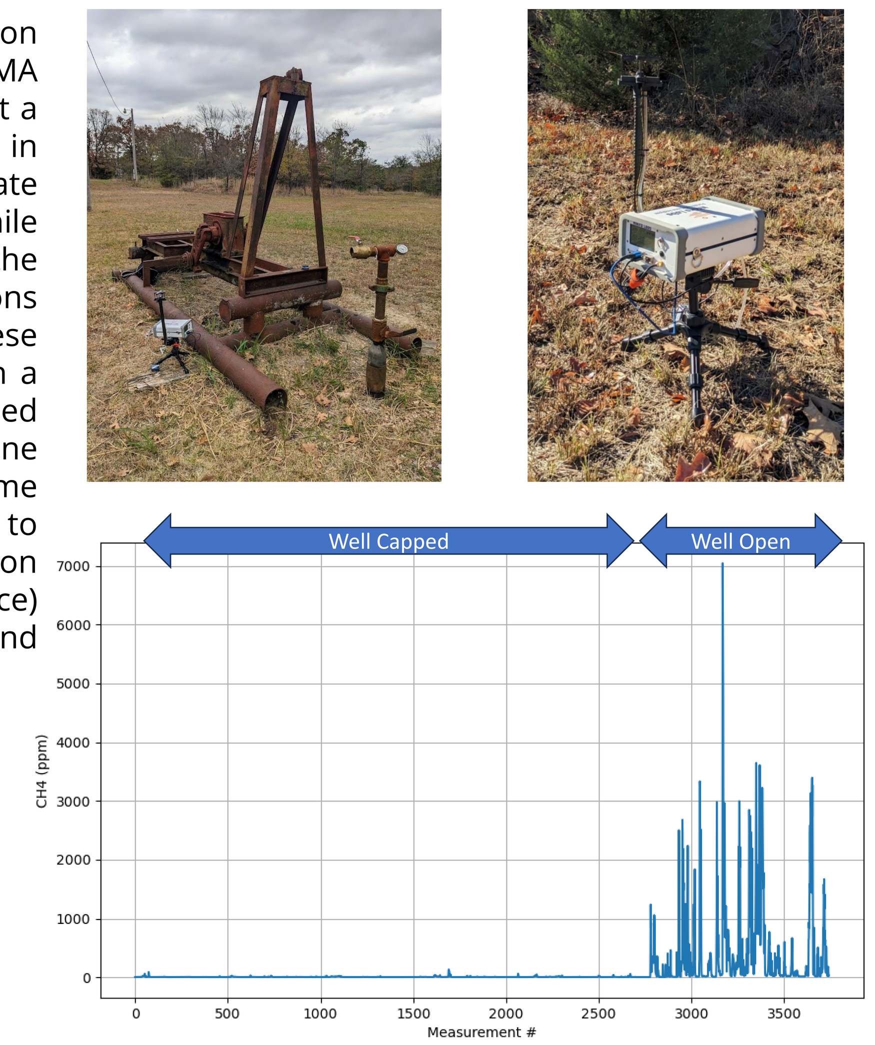

Figure 6. Measured CH_4 emissions from the studied abandoned well. Comparatively small emissions are present from the well when capped that are attributable to underground casing cracks. After the well is temporarily opened for rate emission studies, the emission rate reaches very high levels.

The source emission rate corresponds to the maximum calculated emission rate over a roughly 15–30-minute measurement. This highest measured values correspond to the downwind plume intersecting the PMA and thus represent the best estimate of emission rate from the classical GPM.

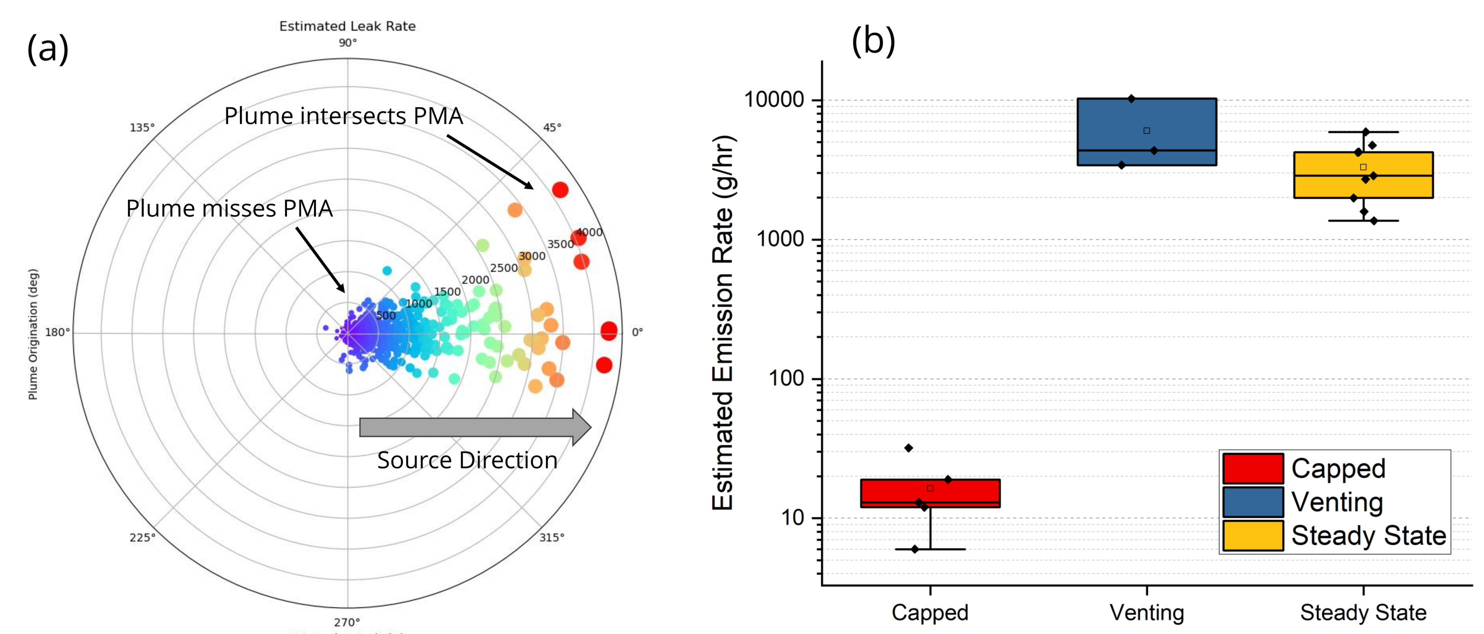

Figure 7. (a) Example plot of the estimated emission rate measured by the PMA field kit. The 0° direction is oriented towards the well. The radial coordinate indicates the calculated emission rate for each measured CH_4 and wind value over approximately 20 minutes. **(b)** Measured emission rates from the studies well. Capped emission is approximately 15 gr/hr, while emissions jump to nearly 10 kg/hr when venting from a capped pressure of 200 psi. Once the head pressure has vented down, the steady state emission rate estimated by the Nikira system is approximately 3.5 kg/hr.

Required Measurement Time

The measurement method described here has significant advantages due to the ease of setup: it requires no connections or tenting, the PMA warm-up time is less than 1 minute and can measure sources with a variety of heights and from a distance. Additionally, the time required to yield a measurement within 90% of the final value is very short, which allows surveyors to quickly collect a rate estimation and move on to the next well site.

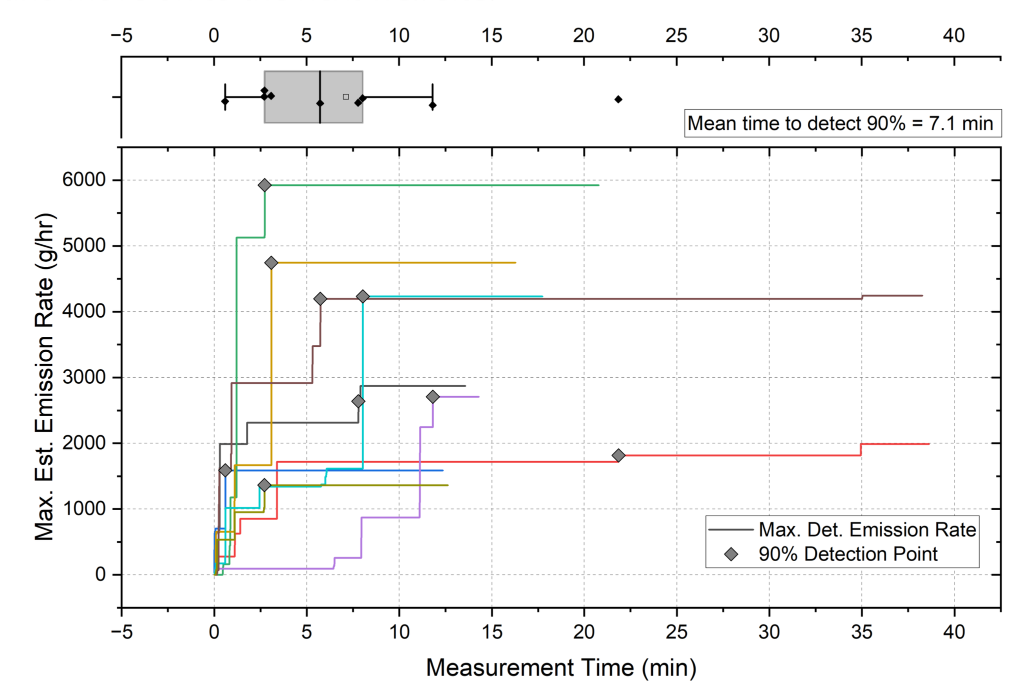

Figure 8. Maximum measured emission rate vs. time spent at each location. The gray diamonds mark the time when the 90% of maximum was reached. The box plot at the top shows the distribution of required measurement times with a median value of just 6 minutes.

Estimating Plume Width

The plume width used in GPMs is usually pulled from tables produced by Pasquill and Giffords. However, these are not universally applicable, especially for short distances. Using the data collected with Nikira's PMA and anemometer kit, it is possible to estimate the plume width in real time.

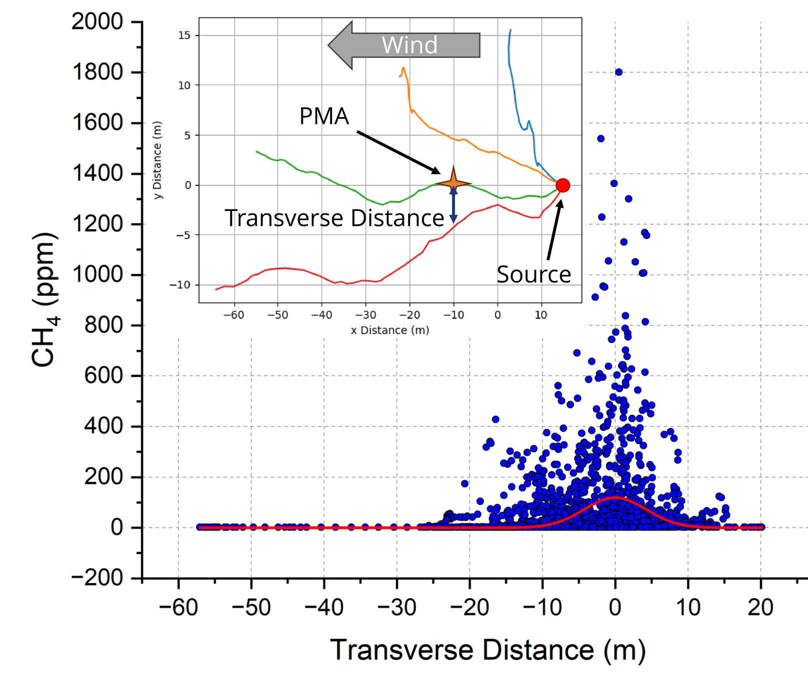

Figure 9. (inset) 4 example reconstructed particle streamlines show the approximate position of the plume relative to the PMA detection point. These streamlines are used to calculate the transverse distance from the plume center to the PMA for each measurement. **(main)** The measured methane vs. transvers distance (blue dots) may be used to estimate the actual, time averaged plume width. The resulting fit is shown in red and has a 1/e² width of 4.3 m.

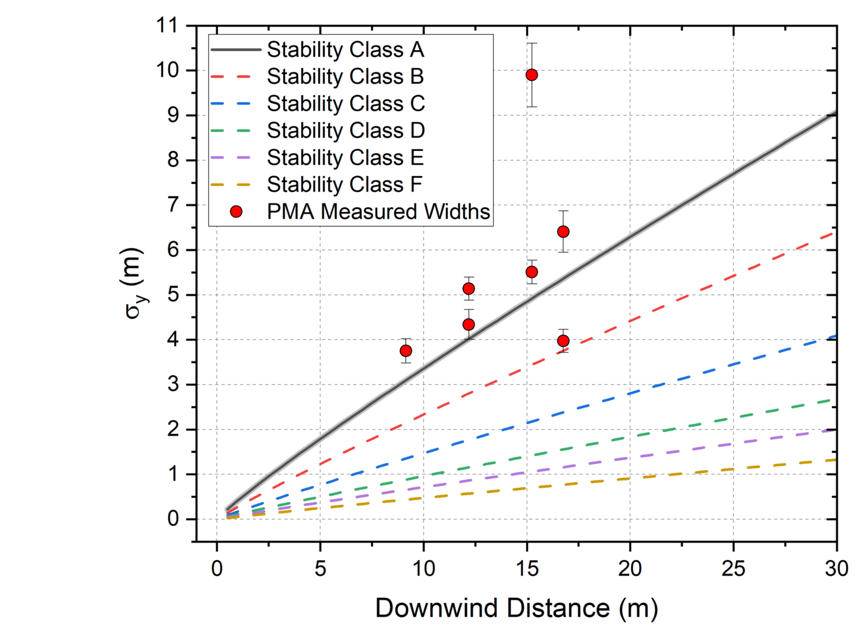

Figure 10. Comparison of the measurement-derived plume widths vs. Pasquill-Giffords values from reference 3. Conditions on the day of measurement indicate Stability Class A should be used. The plume widths fit from measured values are shown in as red dots and are in good general agreement with the classical widths.

Conclusions

- Nikira Labs has developed an **extremely precise & accurate** portable methane analyzer for handheld field use.
- The PMA analyzer is **fast, light, and battery-powered**.
- When paired with a sonic anemometer, the **PMA yields simple yet accurate emission rate estimations**.
- The PMA obtains an emission rate estimate within just few minutes of measurements (median = 6min).
- The collected data can also be used to estimate *in situ* plume widths.

Acknowledgments

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[1] Dubey, Manvendra Krishna, et al. *How to estimate O&G well leak rates from near field concentration and wind observations?*. No. LA-UR-23-20659. Los Alamos National Laboratory (LANL), 2023.
[2] EPA-454/B-95-003b "User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, Volume 2 Description of Model Algorithms"