Description of Gas Mapping LiDAR™ Technology

Introduction

Bridger Photonics' Gas Mapping LiDAR™ (GML) technology is based on laser-based, beam-scanning, atmospheric light detection and ranging (LiDAR) remote sensing instruments. GML instruments are affixed to aircraft (manned or unmanned, rotary wing or fixed wing) and used to scan target areas for methane emissions. These target areas typically enclose oil and gas infrastructure, but GML technology can be applied to other emission sources such as landfills, agricultural sites, natural methane seeps, and coal mine vents.

A central function of GML instruments is to detect methane gas concentrations that exceed ambient background methane concentrations. For the oil and gas sector, this data is typically used to generate geo-registered RGB imagery of methane gas plumes.

GML data may be delivered via both GIS files and tabular data formats. Within GIS files, methane plume images can be superimposed on aerial photographs that are acquired at the same time as methane measurements (Figure 1). Aerial photography provides contextual information for emissions. For example, it can provide evidence that an emission event is caused by a temporary operation.

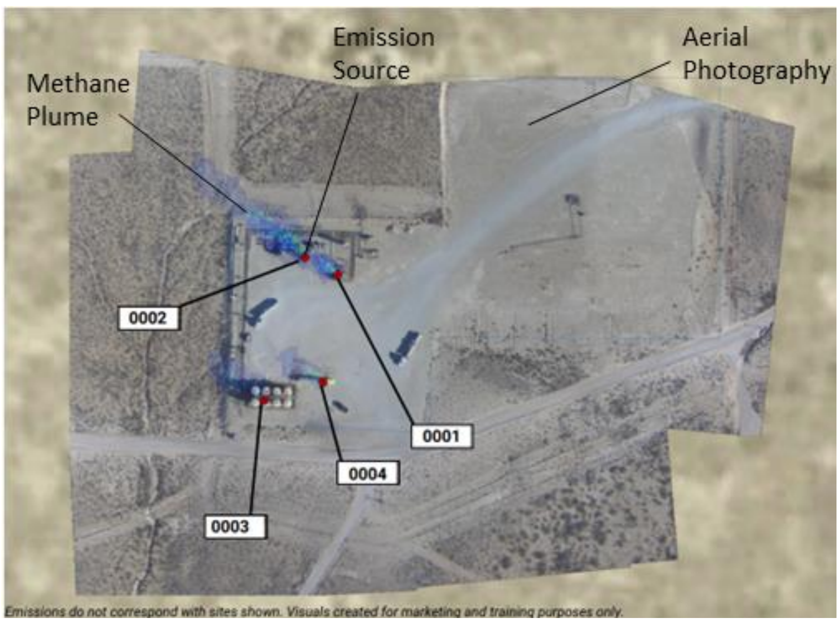

Figure 1. Example GML data showing methane plume imagery, emission source locations, and aerial photography.

In addition to providing contextual information, aerial photography can be used within data processing workflows to identify and label equipment. Because GML technology has high spatial resolution and precisely pinpoints emission sources, when equipment is identified in target areas, emissions can be attributed to equipment units.

The data collected by GML instruments can be used on its own or in concert with other data sources (e.g., windspeed models) to produce additional target area informatics that include the emission rate, source height, intermittency, and other auxiliary data for identified emission sources. GML technology is optimized to provide oil and gas operators with cost effective emissions monitoring that is reliable, comprehensive, and easy to act on. GML data is used not only within leak detection and repair programs, but also for developing source-resolved emissions inventories,[1] identifying emissions drivers across asset bases, targeting emission types for mitigation, and tracking progress towards emissions reduction goals.

The GML Instrument

The GML instrument (Figure 2) is an aerially deployed remote sensor. GML instruments may be affixed to fixed-wing or rotatory-wing aircraft. These aircraft may be manned or unmanned.

Figure 2. A GML 2.0 instrument mounted to the strut of a fixed-wing aircraft.

Within the instrument, a spatially scanning LiDAR system is used to collect methane concentration and ranging measurements. A digital camera is enclosed within the instrument to capture real time aerial photographs of target areas while they are scanned for methane emissions. The instrument is equipped with a Global Navigation Satellite System - Inertial Navigation System (GNSS-INS) that is used to determine the instrument orientation and geospatial coordinates. This information is combined with ranging LiDAR distance measurements and data from a laser measurement angle encoder to locate and geo-register the measurement points and aerial photographs collected across target areas.

Scientific Basis

GML instruments use wavelength modulation spectroscopy (WMS, a form of laser absorption spectroscopy) to measure path-integrated methane concentrations. The WMS technique is similar to that described in Reference 2. Coincident laser beams for methane sensing and ranging measurements are scanned throughout target areas as shown in Figure 3. The GML instrument collects laser light that is backscattered from target areas and the resulting signal is used to determine the methane concentration in the parcel of air between the GML instrument and the backscatter surface. Distance measurements are also acquired.

The methane sensing laser average wavelength is actively stabilized to match the center wavelength of a methane gas absorption line near 1651 nm. The wavelength-stabilized laser beam is then intentionally wavelength modulated at a pre-determined frequency. Where the laser beam path propagates through methane gas, a portion of the laser light is absorbed, which is used to determine the methane concentration integrated along the light path traversed by the laser. The use of laser light sources, instead of ambient light sources, makes the WMS technique applicable to a wide range of environmental conditions because it is not subject to challenges including cloud cover, shadows, or low solar irradiance.

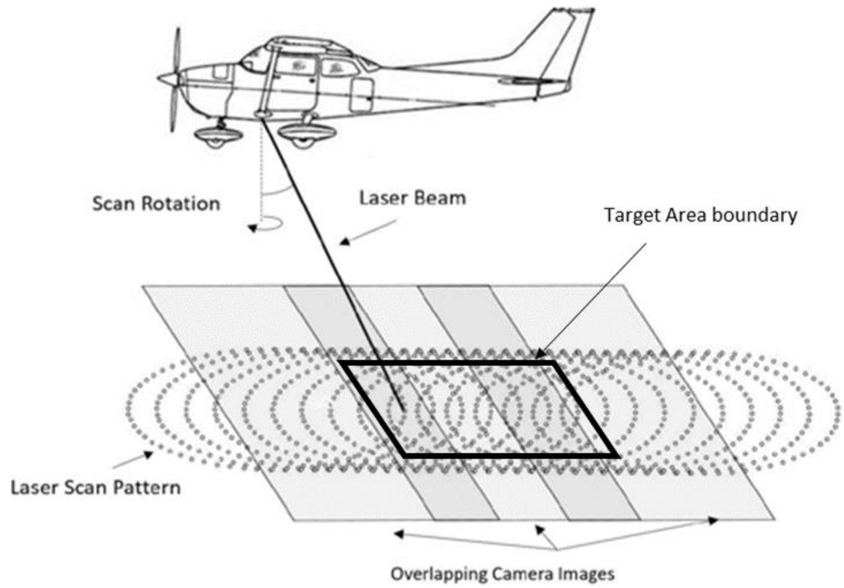

Figure 3. Conceptual diagram showing laser beam scanning, target area, and overlapping camera images.

To determine the presence and extent of elevated methane concentrations (i.e., methane plumes) statistical algorithms are used similar to that described in Reference 3. This algorithm identifies methane plumes relative to background gas concentrations. A model for gas concentration measurement noise is described in Reference 4, and is used to determine statistical detection limits of the instrument measurements in the field. Background methane concentrations are determined using path integrated methane measurements and distance measurements.

The size of emissions reliably detected by GML technology is well described by an emission rate (methane emission mass flow rate) probability of detection (POD). Primary factors that influence POD include the magnitude of laser light returned to the GML instrument, the density of measurement points within the target area, and the concentration of methane in the light path. Bridger deploys GML sensors under flight parameters and environmental conditions that are needed to achieve specific emission rate PODs (e.g., 1 kg/hr with 90% POD). GML technology detection sensitivity has been vetted by 3rd parties through single- and fully-blinded controlled release testing.[5]

Despite the utility of controlled release testing, it does not represent the specific environmental conditions and operational parameters experienced during each deployment. A vast array of factors impacts detection sensitivity. For example, flight altitude, flight speed, and terrain reflectivity collectively influence measurement point density and the magnitude of light received by GML instruments, and higher ground wind speeds disperse gas, making emissions more difficult to detect. To determine and validate the POD that GML technology achieves in each deployment, Bridger developed a deployment-invariant POD model that determines the detection sensitivity performance achieved for each target area scan.[4] This model consolidates all operational and environmental conditions into two measurable independent variables: wind speed, and gas concentration measurement noise, both of which are determined during field operations. The deployment-invariant POD model is informed by and validated against controlled release testing in a variety of contexts and environmental conditions. An example of an average detection sensitivity for an entire region that was determined through application of this model is provided in Figure 4.

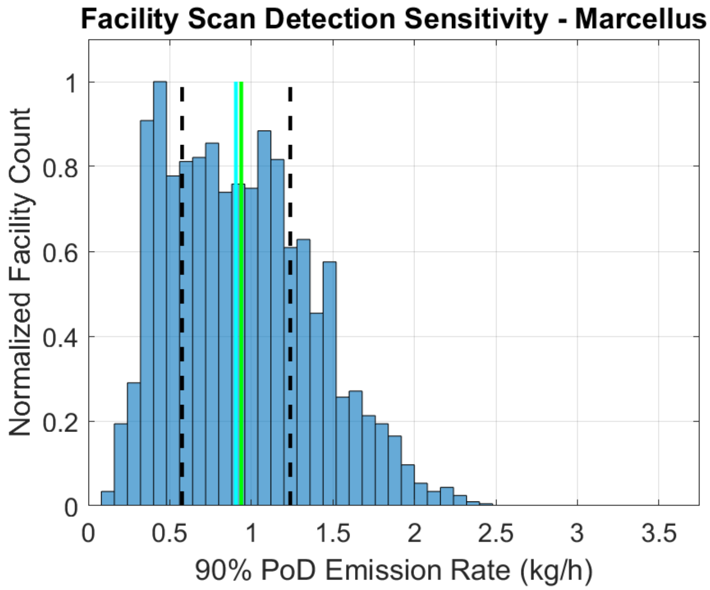

Figure 4. Example histogram of detection sensitivity (90% POD) achieved for many target areas scanned during field operations in the Marcellus Basin. The cyan (green) line represents the median (mean) emission rate, and the black dashed lines represent the interquartile, of the sample set.

For detected emission events, the emission rate can be quantified. The method that GML technology uses to calculate emission rates is described in Reference [6]. The quantification approach uses methane plume imagery to determine gas flow direction and then then uses gas concentration profiles in up to three spatial dimensions along with the gas flow speed (e.g., wind speed) profiles in up to three spatial dimensions to determine emissions rates. Averaging is performed over methane plume regions that are less perturbed by turbulence, local structures, foliage, topography, or other factors. Similar to detection sensitivity, quantification accuracy has also undergone extensive 3rd party testing. An example of results from internal and 3rd party testing is shown in Figure 5.

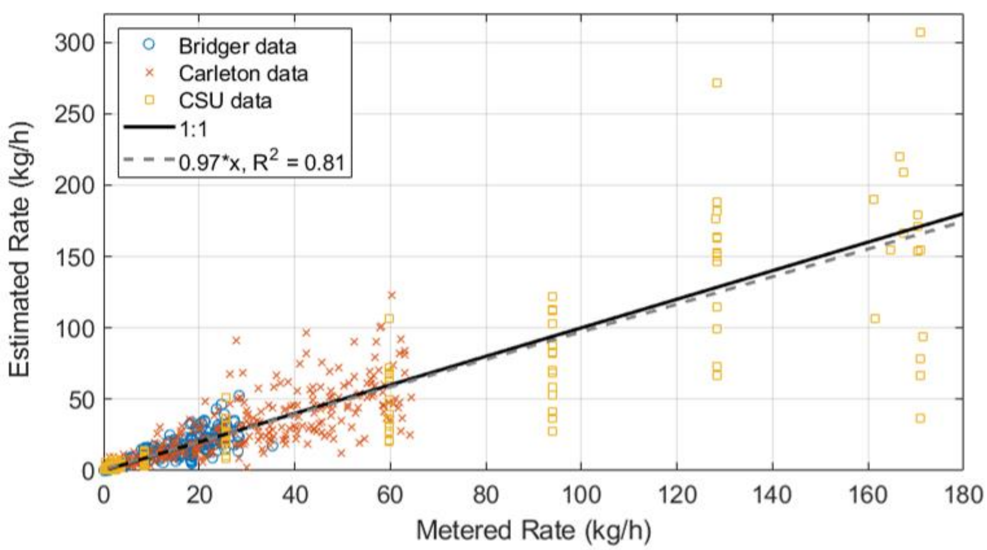

Figure 5. Plot of Estimated Rate versus Metered Rate for three controlled release test data sets – Bridger sensor QA data, Carleton single- and double- blind release data (Reference 7), and CSU single blind controlled release data (Reference 8). The black solid line represents 1:1 parity and the gray dashed line represents an ordinary least squares linear regression with slope = 0.97 and R^2 = 0.81.

Technology Limitations

GML technology may be limited by certain environmental, atmospheric, and operational conditions, including conditions needed for safe flight, low visibility to the ground, high ground wind speed, standing water, low surface reflectance for target areas, high flight altitude, low measurement point density, ambient temperature outside of allowed instrument operating conditions, and interfering species. For chemical interference, 3rd party testing has demonstrated negligible interferences from chemical species other than methane that are common at oil and gas facilities and would be suspected as possible interfering species based on spectroscopic fingerprints.[8] Deleterious impacts from the remaining sources of interference are avoided by selecting appropriate GML deployment conditions. The performance achieved during target area scans is validated using deployment-invariant POD model described earlier in this document along with assured using other quality assurance protocols.

References

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