Improving Methane Emission Estimates with Airborne Active Remote Sensing

Ball Aerospace & Technologies, Boulder, CO 80301
Betsy Farris
Systems Engineer
bfarris@ball.com

Jarett Bartholomew (PI), Orion Esch, Lyle Ruppert, Carl Weimer, Phil Lyman, Steve Solga, Jeremy Craner, Mats Bennett

2019 International Emissions Inventory Conference, GHG/Remote Sensing Session
Outline

• Active Sensing of Methane Emissions
• Methane Monitor
• Demonstration Case Study
• Applicability to Emissions Inventories
• Next Steps
Active Sensing of Methane Emissions

The **Methane Monitor** is a Integrated Path Differential Absorption Lidar (IPDA) system that measures methane total column density from an airplane flying 1,000 meters above the ground.

Spectrometer integrates entire path through atmosphere, possibly including distant concentrations.

IPDA integrates only the path between aircraft and ground.
Active Sensing of Methane Emissions

IPDA: Integrated Path Differential Absorption Lidar

- Two lasers form a pulse pair
- One pulse is absorbed by methane (on-line)
- One pulse is absorbed less by methane (off-line)
- All pulse intensities measured at transmission and return
Methane Monitor

Cessna TU206 with Camera Port

Upstream oil and gas operations
Distribution networks
Natural seeps
Landfills
Agriculture
Methane Monitor
Sensor Integration

- Vibration isolated rack installed over the camera port
- Weight: 240 lbs
- Power consumption: 650 W
- Rack dimensions: 20”x20”x32”
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Wavelengths</td>
<td>1645.40 (off) 1645.55 (on)</td>
</tr>
<tr>
<td>Sensing Swath</td>
<td>Up to 400 m (¼ mile)</td>
</tr>
<tr>
<td>Altitude</td>
<td>800-1800 m (2,600-6000 ft) AGL</td>
</tr>
<tr>
<td>Methane Emission Rate</td>
<td>50-100 SCFH depending on wind speed</td>
</tr>
<tr>
<td>Detection Threshold</td>
<td></td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>~3 m</td>
</tr>
<tr>
<td>Geo-location Accuracy</td>
<td>2-5 m depending on altitude</td>
</tr>
<tr>
<td>CH$_4$ Error</td>
<td>50-60 ppm-m</td>
</tr>
</tbody>
</table>
Demonstration Case Study
Denver-Julesburg Basin

- 720 sq. mi. of survey data collected in 8 days
- Pinpointed location of 63 sources of methane emissions

Cloud-based analytics tools give methane contour map visualization over imagery
Identified 4 broken gathering lines outside of the oil & gas operators’ fenced facilities

- Leaks escaped detection, in some cases for years, with inspections performed using routine optical gas imagery
- Entire area dataset analyzed for leaks in ~5 hours using Ball’s cloud-based, scalable big data analytics tool set hosted on Amazon Web Services
- All four leaks were communicated to the pipeline operators and subsequently repaired
Smallest of the 4 flow line leaks was in a center-pivot irrigation corn field

- 80 ft. diameter circle of dead corn from methane emission
- Difficult to find with handheld sensor
- Landowner notified
Demonstration Case Study

This leak had persisted for 6 years

- Source located near an operator’s equipment yard and along an irrigation ditch
- Leak rate ~3,000 SCFH
- >300 ft diameter dead patch
Demonstration Case Study

This leak was along a dirt road and was well above the lower explosive limit for methane – a hazard

- Local rancher reported ground bubbles from leak location when it rains
- Largest leak found and could have been overlooked if erroneously attributed to the adjacent livestock operation

Note that the appearance of two plumes is due to two flyovers at separate times with different wind directions.
Demonstration Case Study

Last indication was from piping associated with a shuttered bio-gas production facility

- It was not clear if the emission was associated with the facility itself or the pipes that would have fed the bio-gas into the normal natural gas system
- Upon follow-up the plant facility foreman confirmed that it had been turned off
Demonstration Case Study

**Summary**

- Over 60 sources of methane emission identified with 8 days of survey covering over 700 square miles
- Cloud-based post-processing in <12 hours after collect
- Cloud-based tool enables detailed data review of >700 square miles in 5 hours by human analyst
- Four leaks from underground gathering lines found, verified, and reported to operators for remediation
- Emissions from agricultural operations readily discernable from oil and gas operations
Active Sensing for Emission Inventories

Benefits and Advantages
- Identify and quantity Super Emitters
- Source agnostic
- Tracer for other species, VOCs

Limitations and Challenges
- Intermittent measurements
- Controlled airspace

Seep mapping in Fruitland Outcrop
Active Sensing for Emission Inventories

Benefits and Advantages
- Identify and quantity Super Emitters
- Source agnostic
- Tracer for other species, VOCs

Limitations and Challenges
- Intermittent measurements
- Controlled airspace

An example emission from a fenced production facility
Next Steps

- Improvements to target 10,000 ft operation for operation above Class B airspace
- Faster area coverage
- Sensitivity improvements
- Advanced emission quantification
- Persistent imaging platforms

Conclusions

- Active Methane Monitor is ready to save the world!
- How can we use this tech to improve inventories?
Acknowledgements

• Acknowledging PHMSA R&D support via 2013 and 2015 BAAs
  • DTPH5613T000004
  • DTPH5615T00016

• Thanks also to API & PRCI for opportunities to learn about industry needs and share research results!

Thank You!
Active Sensing for Emission Inventories

The IPDA Equation

• Derived from the Beer-Lambert law:

\[
\log \frac{I}{I_0} = -\varepsilon [CH_4] l
\]

• Adding a reference measurement to account for the unknown target reflectivity:

\[
[CH_4] l = -\frac{1}{\varepsilon} \log \left( \frac{T_{off} R_{on}}{T_{on} R_{off}} \right)
\]
Active Sensing for Emission Inventories

Wavelength Jitter Correction and Background Subtraction

• Transmission through a methane cell is measured for every pulse and the absorption coefficient is corrected for wavelength jitter:

\[
\frac{1}{\varepsilon} = \frac{[\text{CH}_4]_{\text{cell}} l_{\text{cell}}}{-\log \left( \frac{T_{\text{off}} C_{\text{on}}}{T_{\text{on}} C_{\text{off}}} \right)}
\]

• Background methane is subtracted to yield exceedance:

\[
[\text{CH}_4]_{l_{\text{plume}}} = [\text{CH}_4]_{\text{measured} l} - [\text{CH}_4]_{\text{background} l}
\]
Cloud Based Data Processing and Viewing

Methane Monitoring as a Service

- Cloud based data processing using Amazon Web Services
- Web based data viewing and delivery
- Less than 24 hour delay from data collection to web viewing
- Context imagery displayed with methane overlay
- Plume analytics, emission rate