Plume Scanner Technology to Quantify Fugitive Methane Emission of Point Sources Quickly and Easily

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Mobile methane measurements showing concentration above worldwide background levels collected on 1/31/2013 – 2/3/2013 [view from Northwest]
Concentrations ≠ Emissions

Emission:
1 L/s

100% methane

1 meter 10 meter 100 meter 1000 meter

10,000+ ppm 500 ppm 20 ppm 0.5 ppm
Concentrations ≠ Emissions

Emission:
1 L/s

Same Emission: Different concentrations
How to quantify emissions of point sources?

- **Direct Measurement**
  - Requires physical access to the leak source
  - Time-consuming process
How to quantify emissions?

- Direct Measurement / Tracer Release
  - Requires physical access to the leak source
  - Time-consuming process
How to quantify emissions?

- Direct Measurement / Tracer Release
- Measurement at a distance + atmospheric modeling
  - Knowledge of source location and height and atmospheric turbulence
How do we quantify emissions?

- Direct Measurement at a distance
  - Drive through the plume to throw a virtual net to “catch” all the methane
Throw a virtual net to “catch” methane

- 4-pixel (gas inlet) two-dimensional methane “image”

\[ \text{Flux} = \int \int (C(y, z) - C_0) \cdot u(x, y, z) \, dy \, dz \]
Throw a virtual net to “catch” methane

- 4-pixel (gas inlet) two-dimensional methane “image”

\[
Flux = \int\int (C(y, z) - C_o) \cdot u(x, y, z) dy \, dz
\]
How to simultaneously measure Four Pixels

- Use 4 AirCores (thanks Pieter Tans & NOAA team) to store or “record” previous 30 s of gas samples
How to Playback Four Pixels

- Total analysis or playback time ~ 7 minutes
Result: Plume Image

Raw Playback data

Pixel A (Lowest)  Pixel B  Pixel C  Pixel D (Highest)

Zero gas  Zero gas  Zero gas  Zero gas

CH4 (ppm)

Playback time (s)
Result: Plume Image and Flux

Wind data +

= Flux of 31 lpm
Plume Image indicates data quality

- Plume image indicates if the measurement quantifies the flux or provides an assessment of the lower bound

 Flux > 12 lpm
Verification: Controlled releases

- Controlled release at 15 lpm at various release heights and distances
- Stable atmospheric conditions (Class C-D)

- Average Measured Flow: 15.3 lpm
- Error: 1.5%
- Reproducibility ($\sigma$): 2.3 lpm (15%)
Reproducibility scales with stability class

Set flow: 15 lpm
- Class C-D
- Average Measured Flux: 15.3 lpm
- Error: 1.5%
- Reproducibility ($\sigma$): 2.3 lpm (15%)

Set flow: 16 lpm
- Class A-B
- Average Measured Flux: 14.9 lpm
- Error: -6.6%
- Reproducibility ($\sigma$): 8.7 lpm (58%)
Field Case: Barnett Shale, Texas
Barnett Shale: Ponder and Dish Area (5 by 10 miles)
Field Case: Ponder and Dish Area (5 by 10 miles)

- Measured emissions of 52 sites
Step 1: Survey the area

Picarro Surveyor™ for Natural Gas Leaks

- Peak concentration
- Current vehicle location
- Wind Direction

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Step 1: Survey the area

- Leak location is NOT necessary for emissions measurement
Step 2: Capture the Plume

- Arm the system to capture
- Drive through the plume again
- Wait ~7 min for instrument to analyze the captured plume and to generate a plume image and flux measurement

Flux: 660 lpm
Emissions sampled in Dish, Texas area

- Emissions ranged from 1.5 to 970 lpm

N=52 sites
Emissions sampled in Dish, TX area

Total Emissions of 52 sites: 4983 lpm
What does 5000 liters per minute mean?

- **83** balloons every second!
  (60 g/s)
- **$340,000** of lost product/year
- Natural gas consumption of **1,300** homes
- The carbon footprint of **~2,000** citizens
Thank You!

Somewhere in Colorado
Extra Slides
### Pasquill Stability Classes

<table>
<thead>
<tr>
<th></th>
<th>A: Extremely unstable conditions</th>
<th>D: Neutral conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>B:</td>
<td>Moderately unstable conditions</td>
<td>E: Slightly stable conditions</td>
</tr>
<tr>
<td>C:</td>
<td>Slightly unstable conditions</td>
<td>F: Moderately stable conditions</td>
</tr>
<tr>
<td>G:</td>
<td>Extremely Stable</td>
<td></td>
</tr>
</tbody>
</table>

### Meteorological conditions defining Pasquill stability classes.

<table>
<thead>
<tr>
<th>Surface wind speed (m/s)</th>
<th>Daytime insolation</th>
<th>Night-time conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strong</td>
<td>Moderate</td>
</tr>
<tr>
<td>&lt; 2</td>
<td>A</td>
<td>A - B</td>
</tr>
<tr>
<td>2 - 3</td>
<td>A - B</td>
<td>B</td>
</tr>
<tr>
<td>3 - 5</td>
<td>B</td>
<td>B - C</td>
</tr>
<tr>
<td>5 - 6</td>
<td>C</td>
<td>C - D</td>
</tr>
<tr>
<td>&gt; 6</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

Verification with natural gas facilities

Compressor Station

Valves Station

Box plot for Compressor Station:
- Average: 255 lpm
- Std Dev: 52 lpm (20%)
- N=8

Box plot for Valves:
- Average: 3.64 lpm
- Std Dev: 0.9 lpm (24%)
- N=7
Reproducibility scales with stability class

- Set flow: 15 lpm
  - Average Measured Flow: 15.3 lpm
  - Error: 0.02%
  - Reproducibility ($\sigma$): 2.3 lpm (15%)

- Set flow: 16 lpm
  - Average Measured Flow: 14.9 lpm
  - Error: -0.06%
  - Reproducibility ($\sigma$): 8.7 lpm (58%)

.9 lpm
58%
Carspeed 4.073073 m/s with 0.271812 m/s
Windspeed 1.42506896552 m/s with 0.560892 m/s and weighted average of 1.631265
Background 1.895000 ppm
GPS Lat: 35.970049; GPS Long: -79.093794; FWHM: 1.975514 m
Flux: 0.100074 L/s or 0.059705 g/s
Carspeed 8.172122 m/s with 0.077034 m/s
Windspeed 2.18495 m/s with 0.162801 m/s and weighted average of 2.147154
Background 1.909000 ppm
GPS Lat: 35.897164; GPS Long: -78.872264; FWHM: 2.817477 m
Flux: 0.203176 L/s or 0.121217 g/s
Run 2: 0.5 L/s
Result: Plume Image
Result: Plume Image and Flux

Wind data

+ 

= Flux of 143 lpm
How do we quantify emissions?

• Direct Measurement at a distance
  – Throw a virtual net to “catch” all the methane
  – Requires no knowledge of source location and height
Step 1: Survey the area

- Optional: Locate leak
- Leak location is NOT necessary for emissions measurement