Advanced Mobile Technologies for the Identification, Attribution, Quantification, and Visualization of Fugitive Methane Emissions from Natural Gas Production

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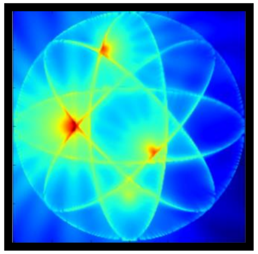
What Is Picarro?

- High-Performance mobile gas and isotope analysis based on Cavity Ringdown Spectroscopy

- Advanced Meteorology & Geospatial Awareness

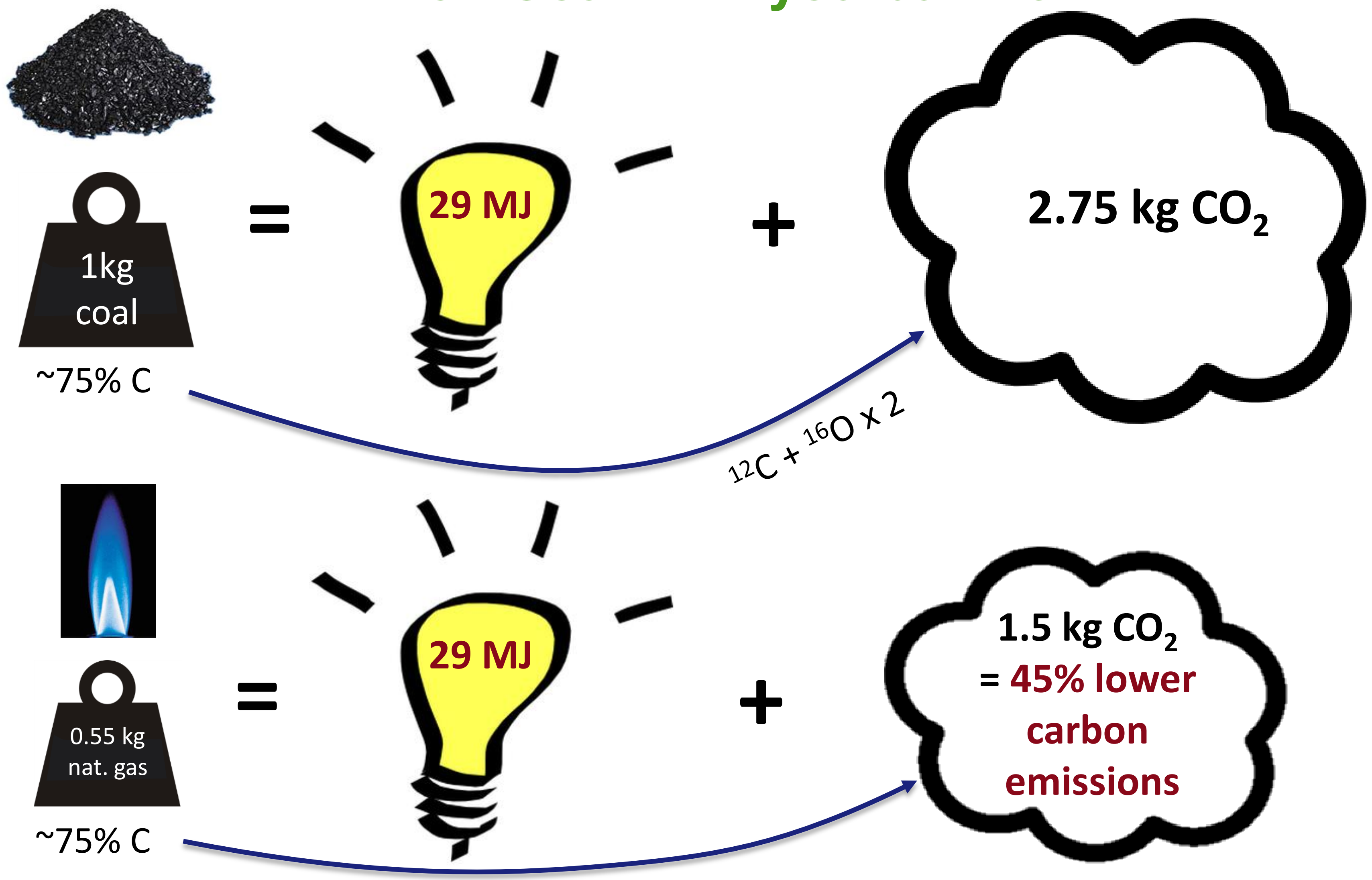
- Sophisticated Scientific Algorithms



- Cloud-based Computing and Visualization

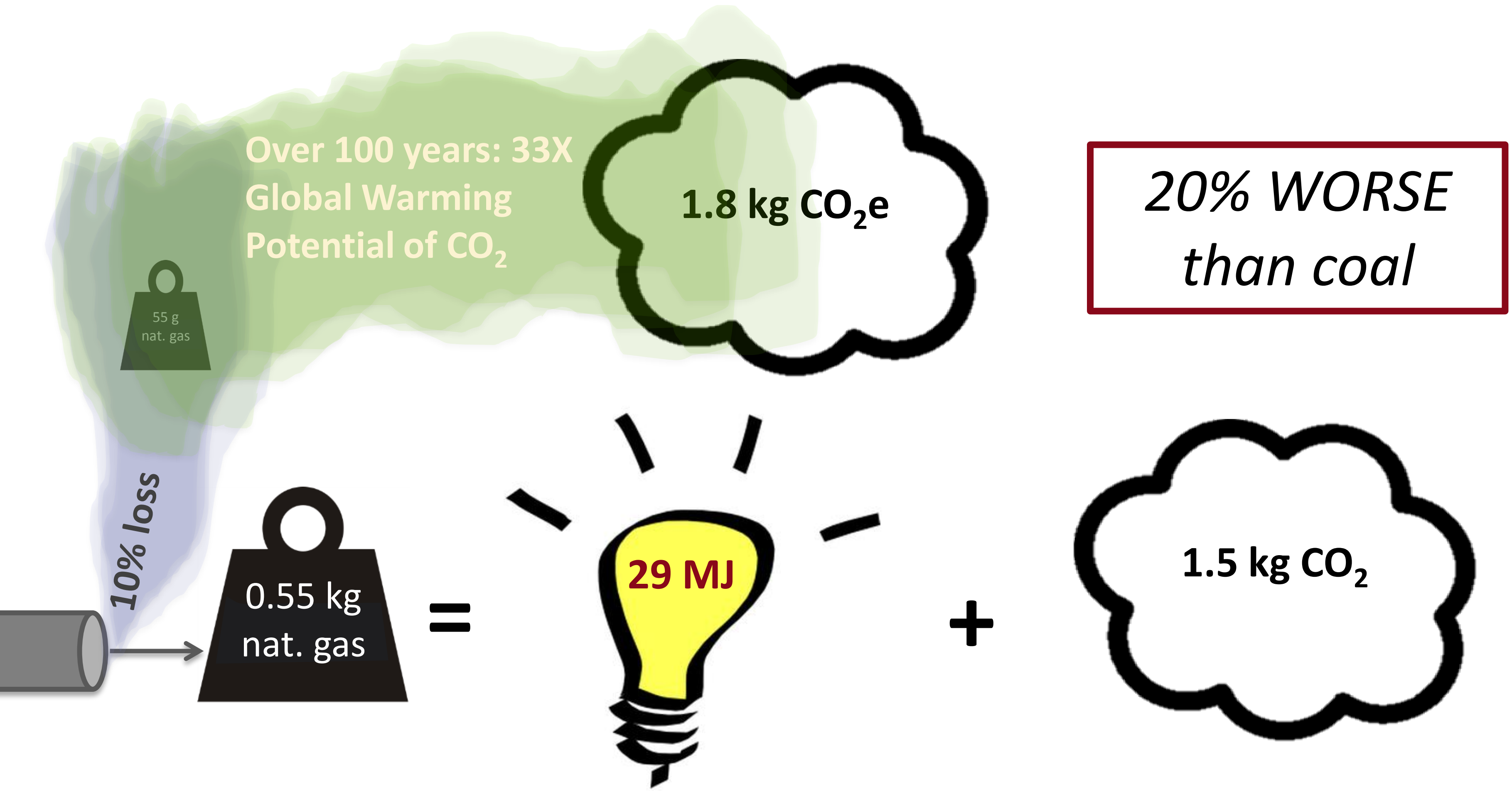
- 15+ Ph.D. Physicists, Chemists, and Environmental Scientists collaborating with dozens of world-class research institutions

Green or Not Green? Natural Gas Emits Less CO_2 Than Coal … IF you burn it



But what if you **don't** burn all the methane?

Make Sure You Burn All of It!



***100 year**: Methane "breaks even" at **6.9%** atmospheric loss*

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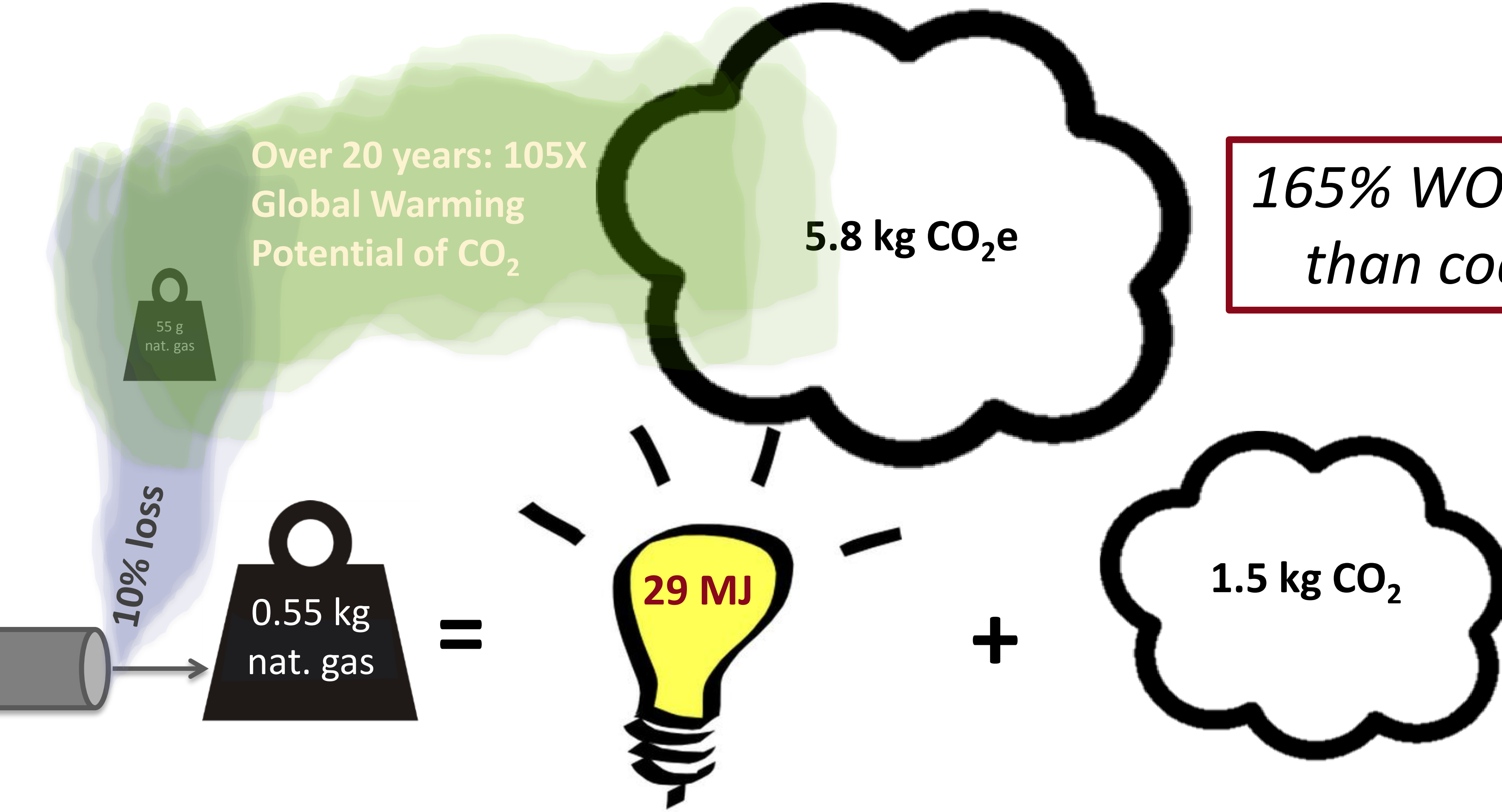
Make Sure You Burn All of It!



165% WORSE than coal

***20 year**: Methane "breaks even" at **2.2%** atmospheric loss*

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Why Are Measurements Vital?

- Methane emissions are “fugitive” emissions – i.e., unintentional emissions
  - Leaks from a pipe or fitting
  - gas that is released episodically during production, transport, or consumption

- Emissions factors and methane inventories are not accurate at estimating unintentional emissions!

Climatic Change (2011) 106:679–690
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LETTER

Methane and the greenhouse-gas footprint of natural gas from shale formations

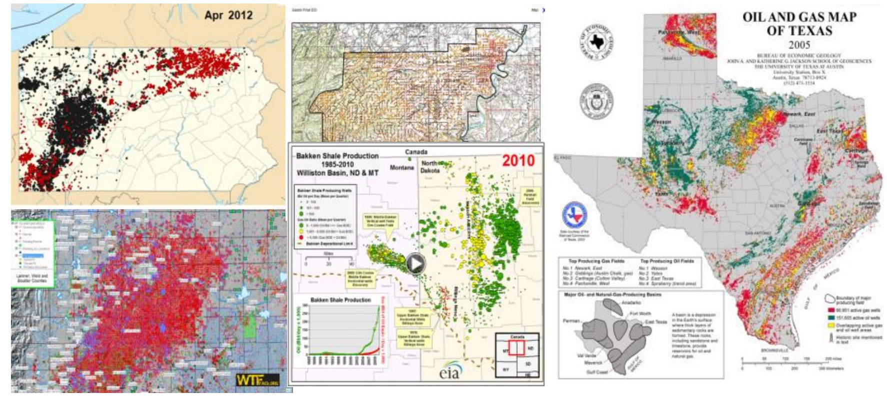
A letter

Robert W. Howarth · Renee Santoro · Anthony Ingraffea

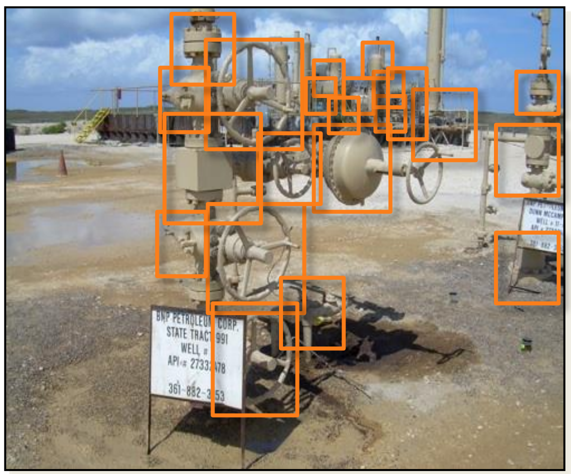
Table 2 Fugitive methane emissions associated with development of natural gas from conventional wells and from shale formations (expressed as the percentage of methane produced over the lifecycle of a well)

	Conventional gas	Shale gas
Emissions during well completion	0.01%	1.9%
Routine venting and equipment leaks at well site	0.3 to 1.9%	0.3 to 1.9%
Emissions during liquid unloading	0 to 0.26%	0 to 0.26%
Emissions during gas processing	0 to 0.19%	0 to 0.19%
Emissions during transport, storage, and distribution	1.4 to 3.6%	1.4 to 3.6%
Total emissions	1.7 to 6.0%	3.6 to 7.9%

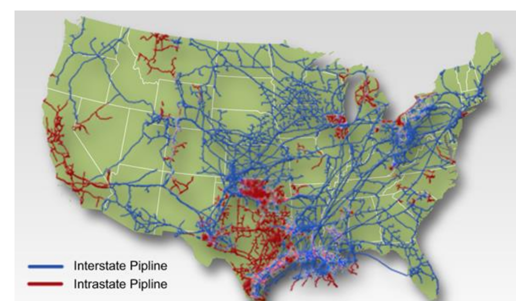
"Houston, We Have a Problem"



- 490,000 wells in the U.S.



- 1000's of potential leaks / well pad



Source: Energy Administration, Office of Oil & Natural Gas Division, Gas Transportation Information System

- 2.5 million miles of (ageing) natural gas pipeline

How do you assess 1,000,000,000 potential leaks without spending **$1,000,000,000** ?

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Our Solution: Drive, and Let the Atmosphere Carry The Methane to You!

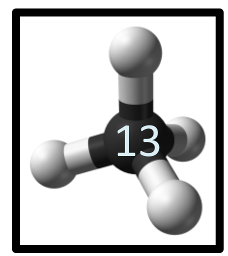
- TRIAGE: figure out where the leaks are (and aren't) at a distance, **without stopping the car**

GPS + Fast, High Precision, Mobile CH_4 Measurements

- LOCALIZE: if you see a leak**, use the wind** to understand where the source of the gas is

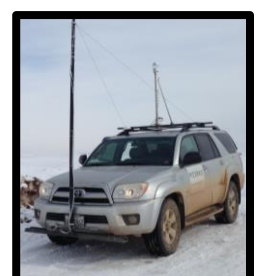
Wind Field Awareness While Driving

- ATTRIBUTE: don't get confused by the **cows**!



Mobile $^{13}CH_4$ Measurements

- QUANTIFY: concentration means (almost) nothing – the only thing that matters is **emission rate**



CH_4 Plume Scanner

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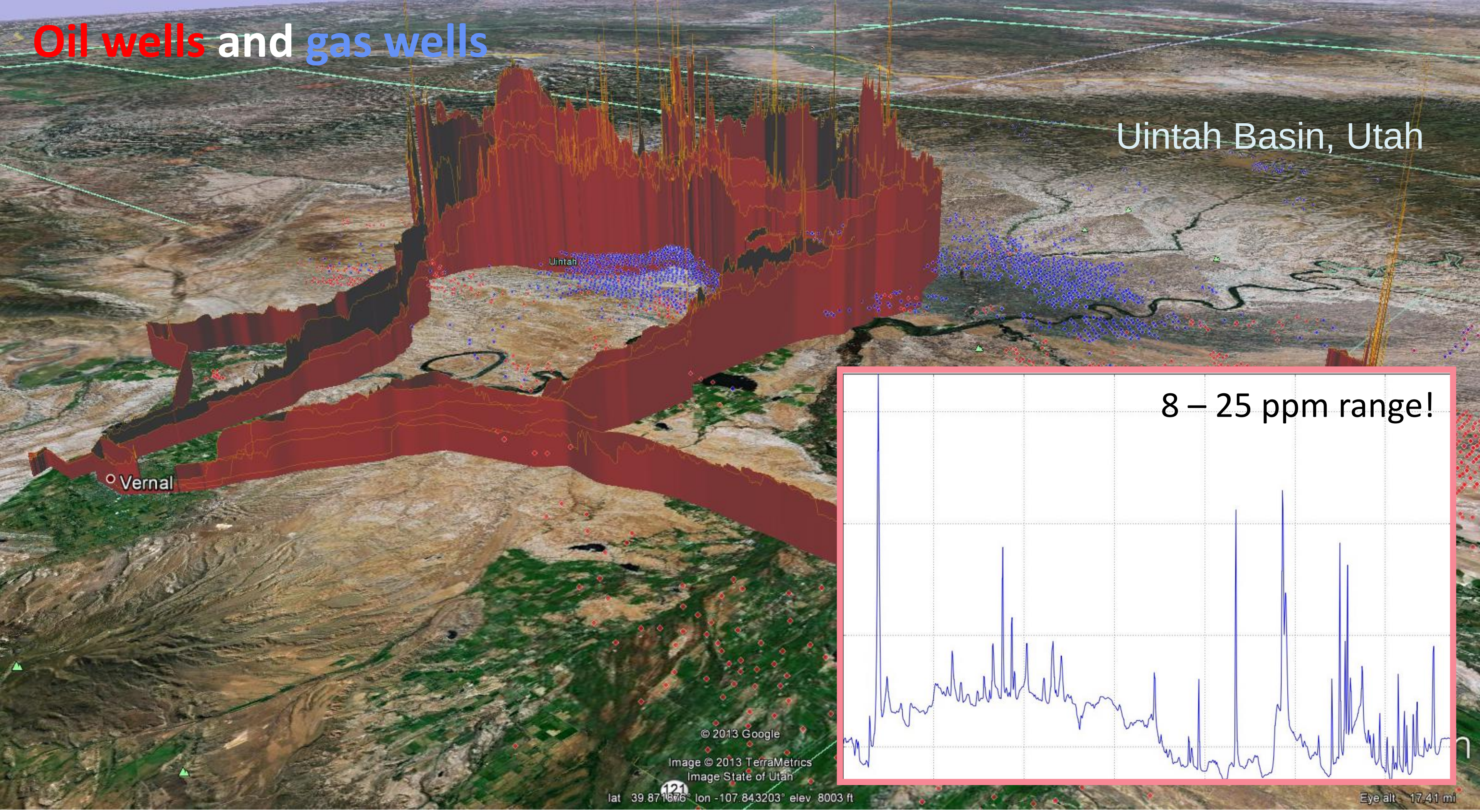

Concentrations 3-5X above background levels over 100’s of square miles … all from natural gas extraction!

Lots and lots of individual emission sources

Example: Compressor Station in the Denver – Julesburg Basin

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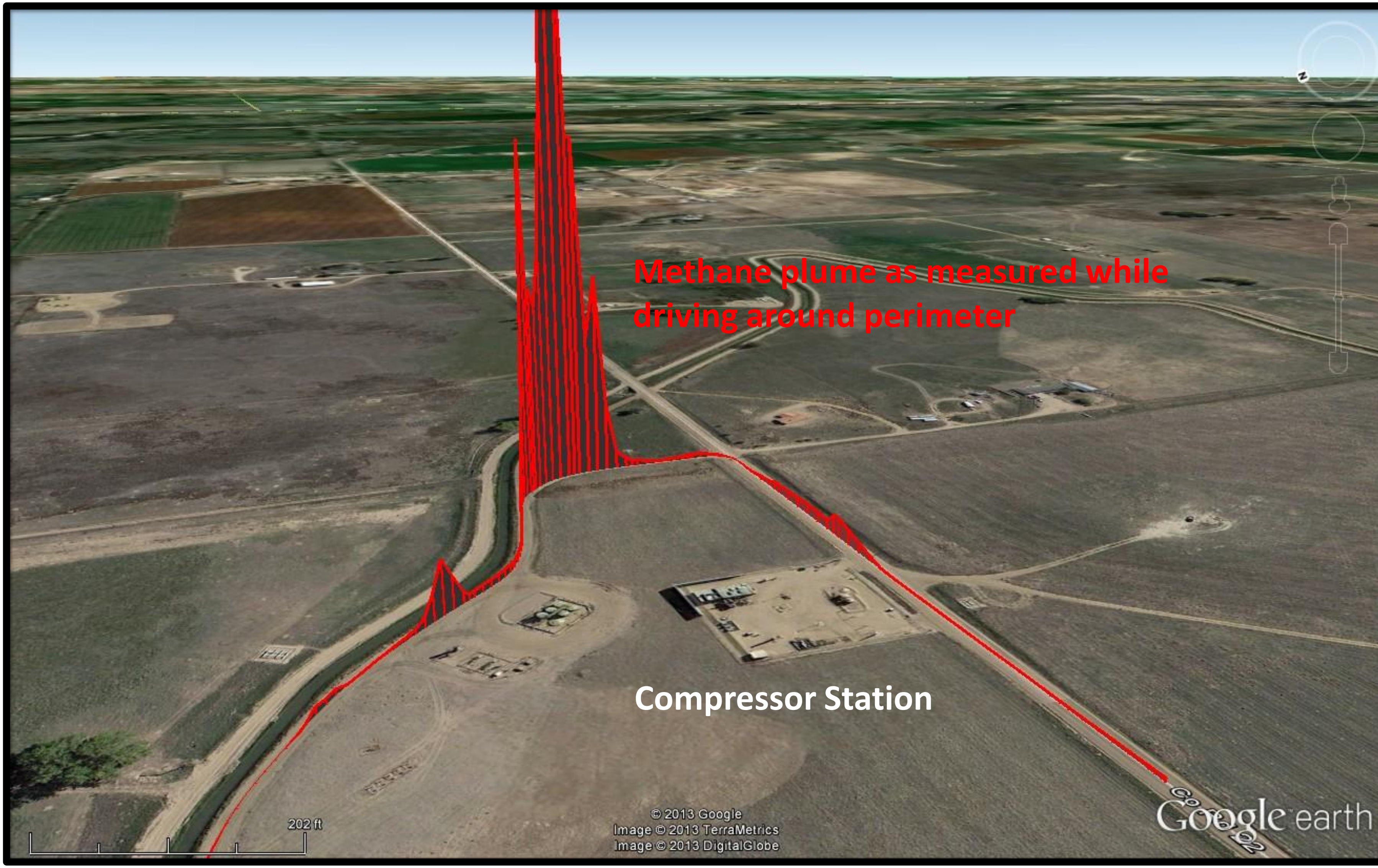
45 Second Drive Around Compressor Station Detects Multiple Methane Plumes



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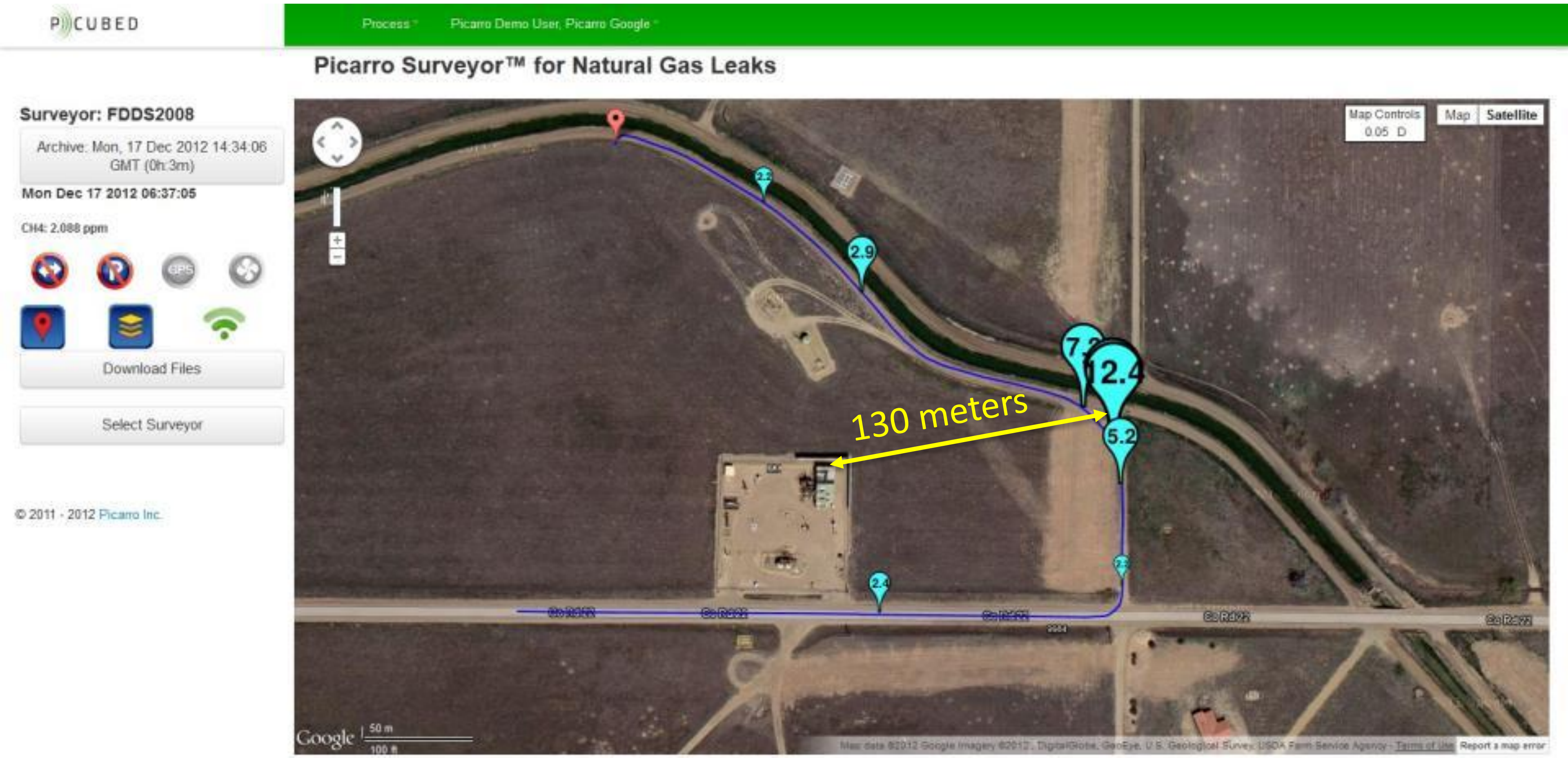
Same Data, Shown on Real-Time Surveyor User Interface



"Bubbles" indicate signatures of methane emission sources via automated plume height and width algorithms

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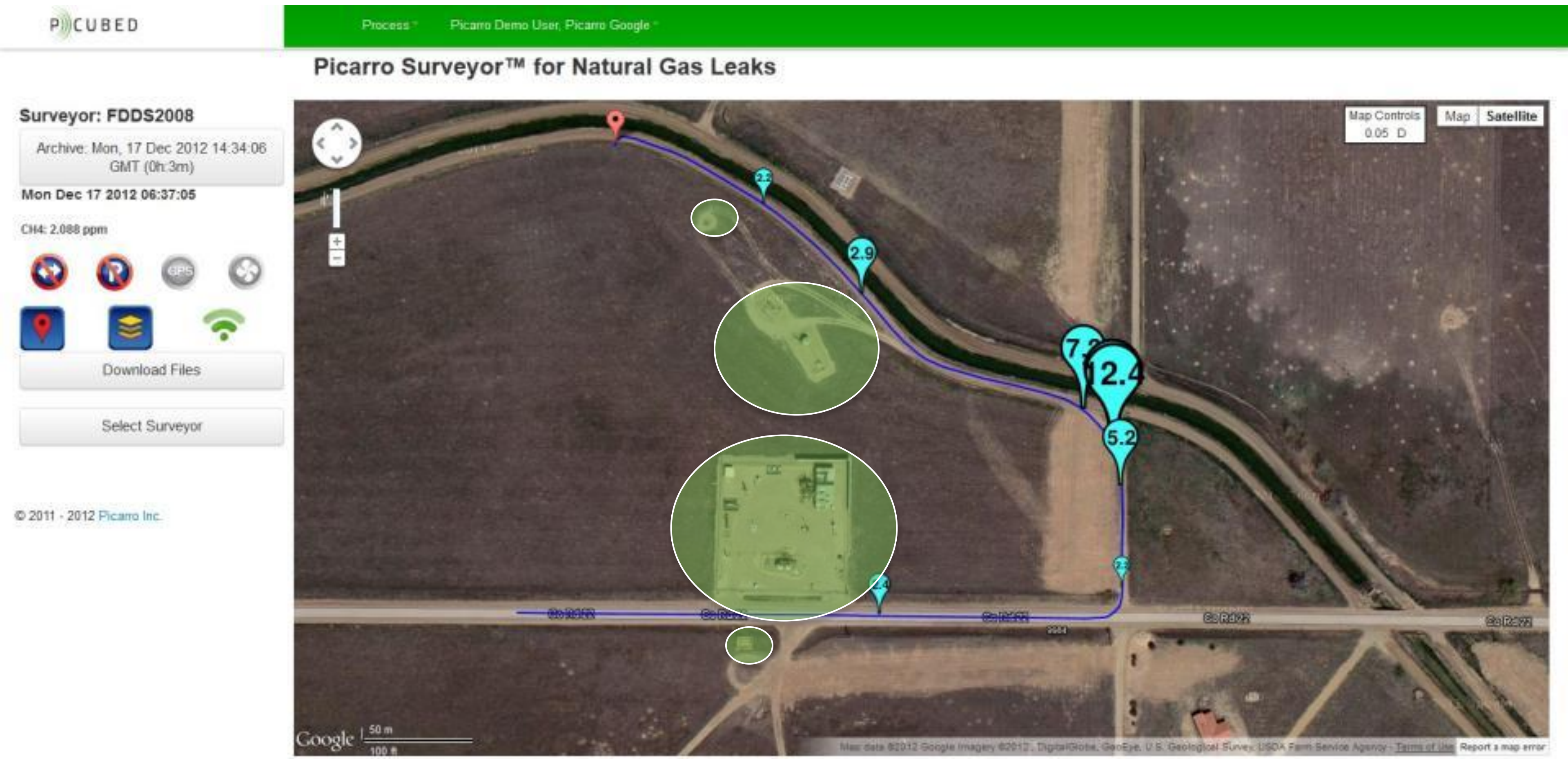
Maps Show Many Possible Sources



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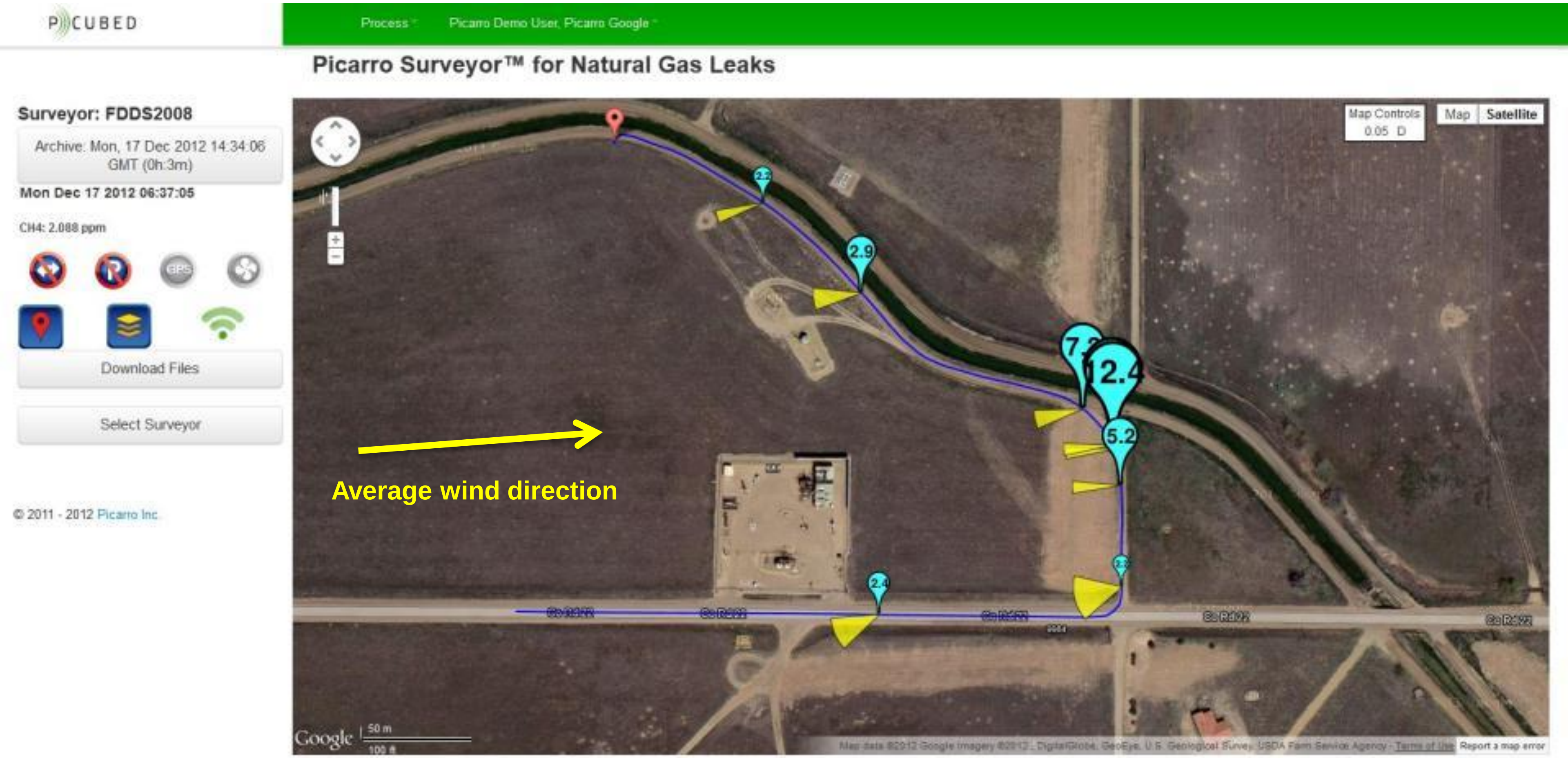
Leak Source Indicators ► Indicate Plume Origin



Wind direction (and standard deviation) determines possible wind angles, with car motion removed

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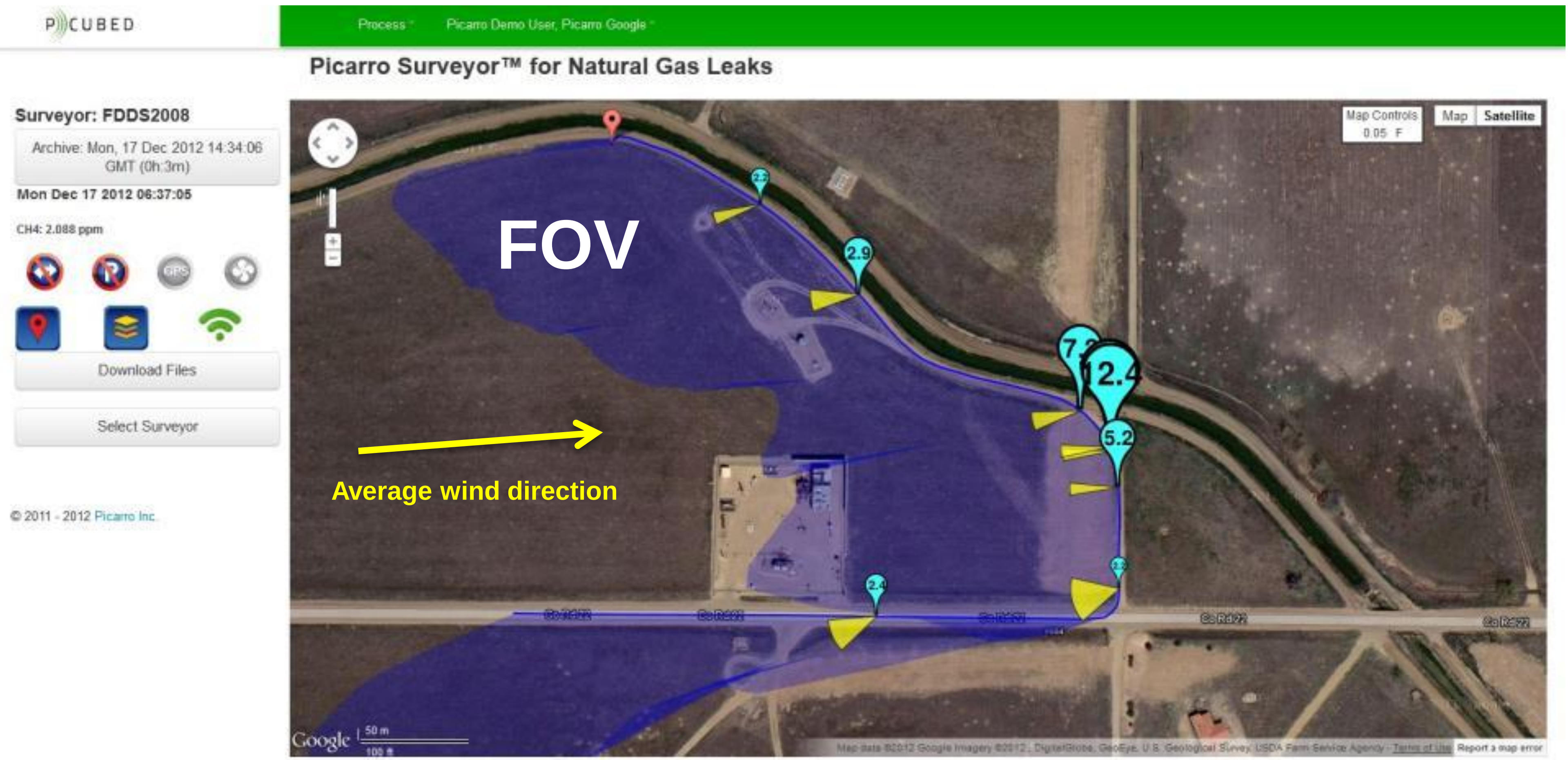
Field of View Indicates Area Measured



Field of view calculated for small leak and narrow plumes – larger leaks can be detected at greater distances

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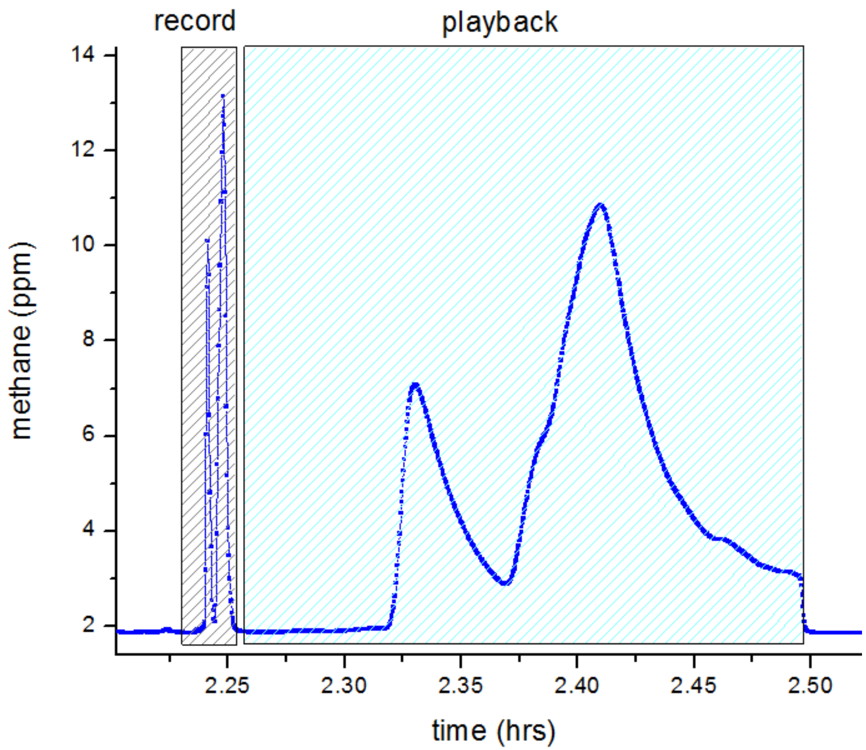
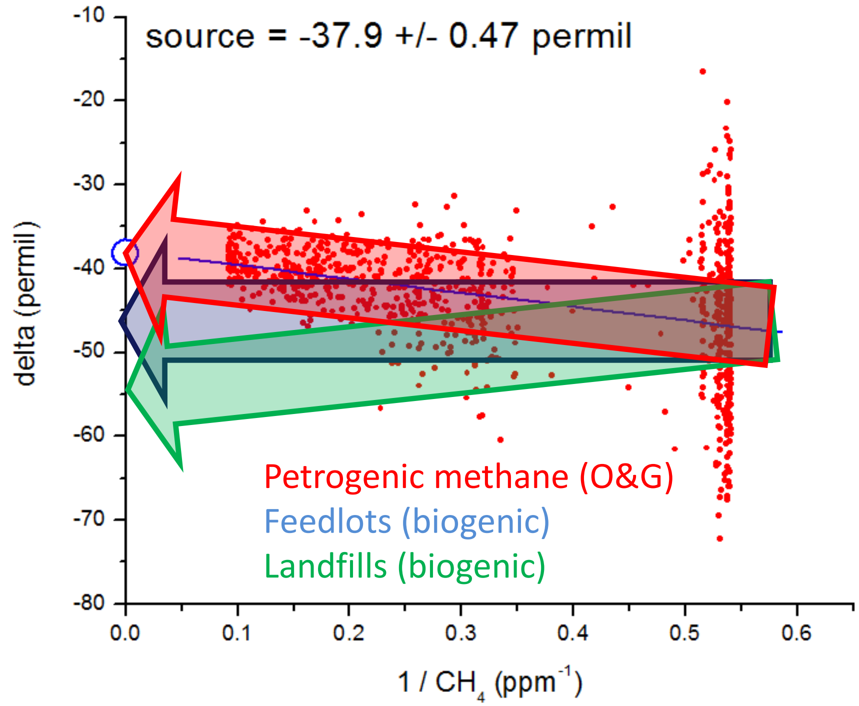
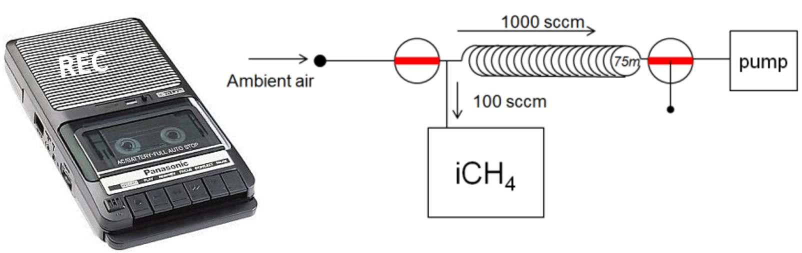
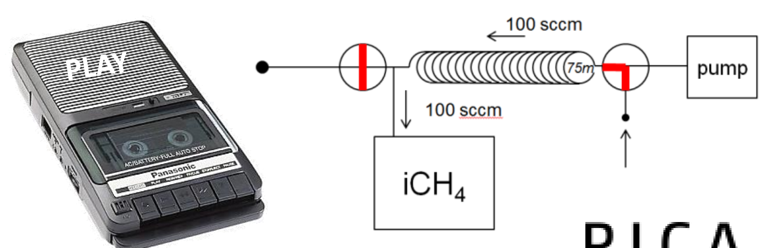
Source Attribution Using Stable Isotope Analysis

Drive-by isotope analysis with Air Core (thanks Pieter Tans & NOAA team)!









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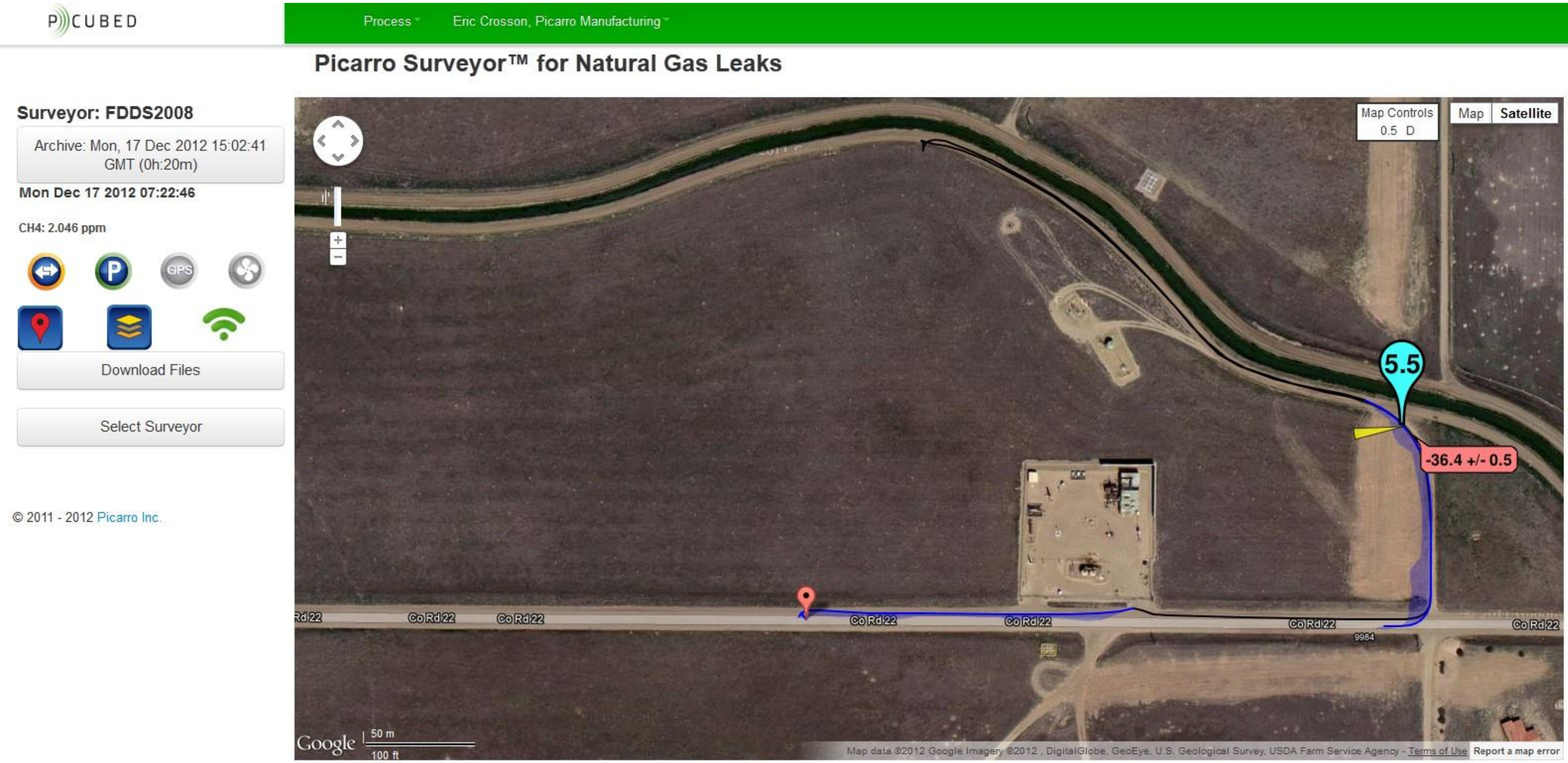
Isotope Ratio Analysis in 10 Minutes



We know where the leak is, and that it is from O&G activities. But, how do we QUANTIFY the emission rate?

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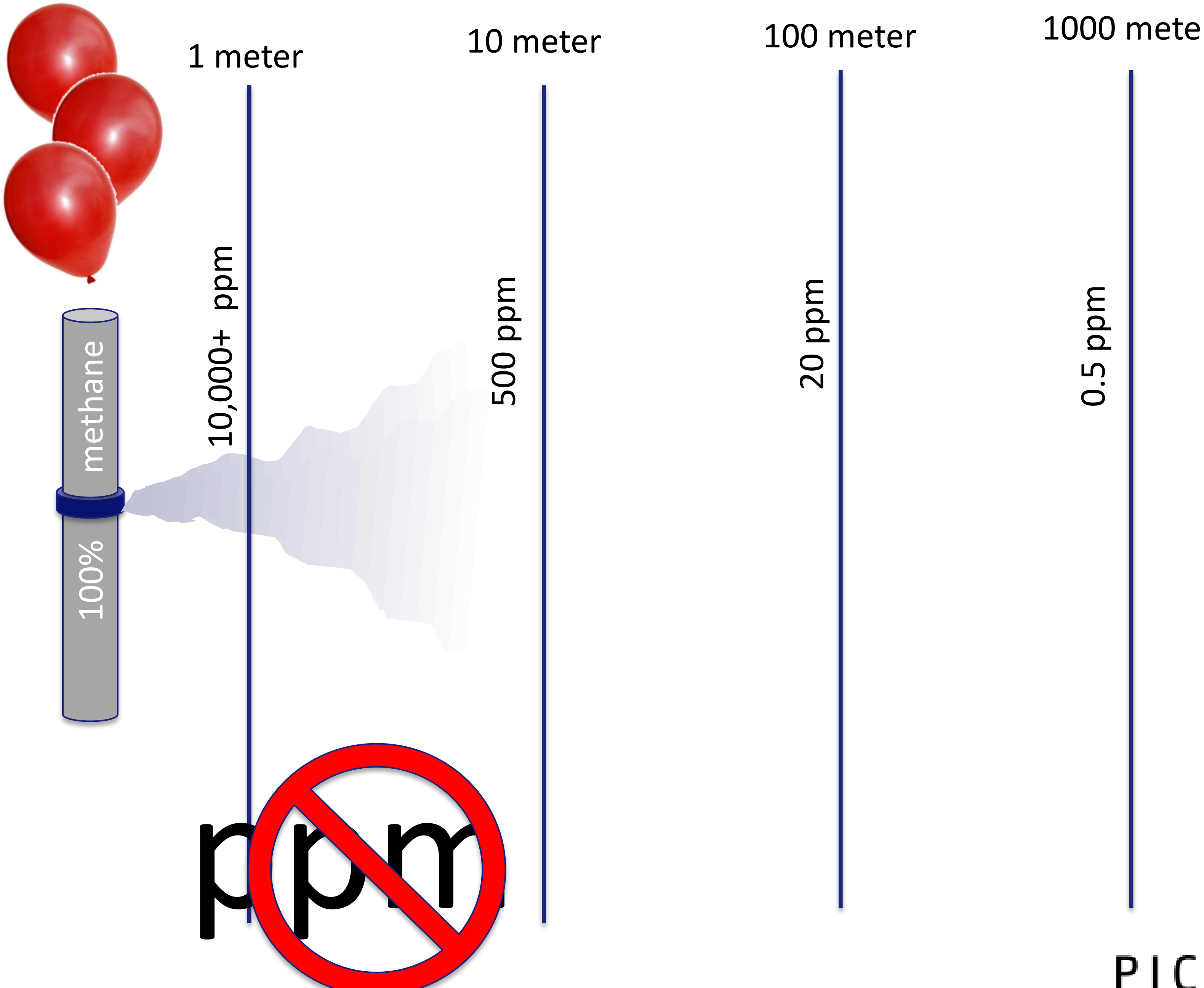
Measuring Emissions Rate: A 1 liter / second leak



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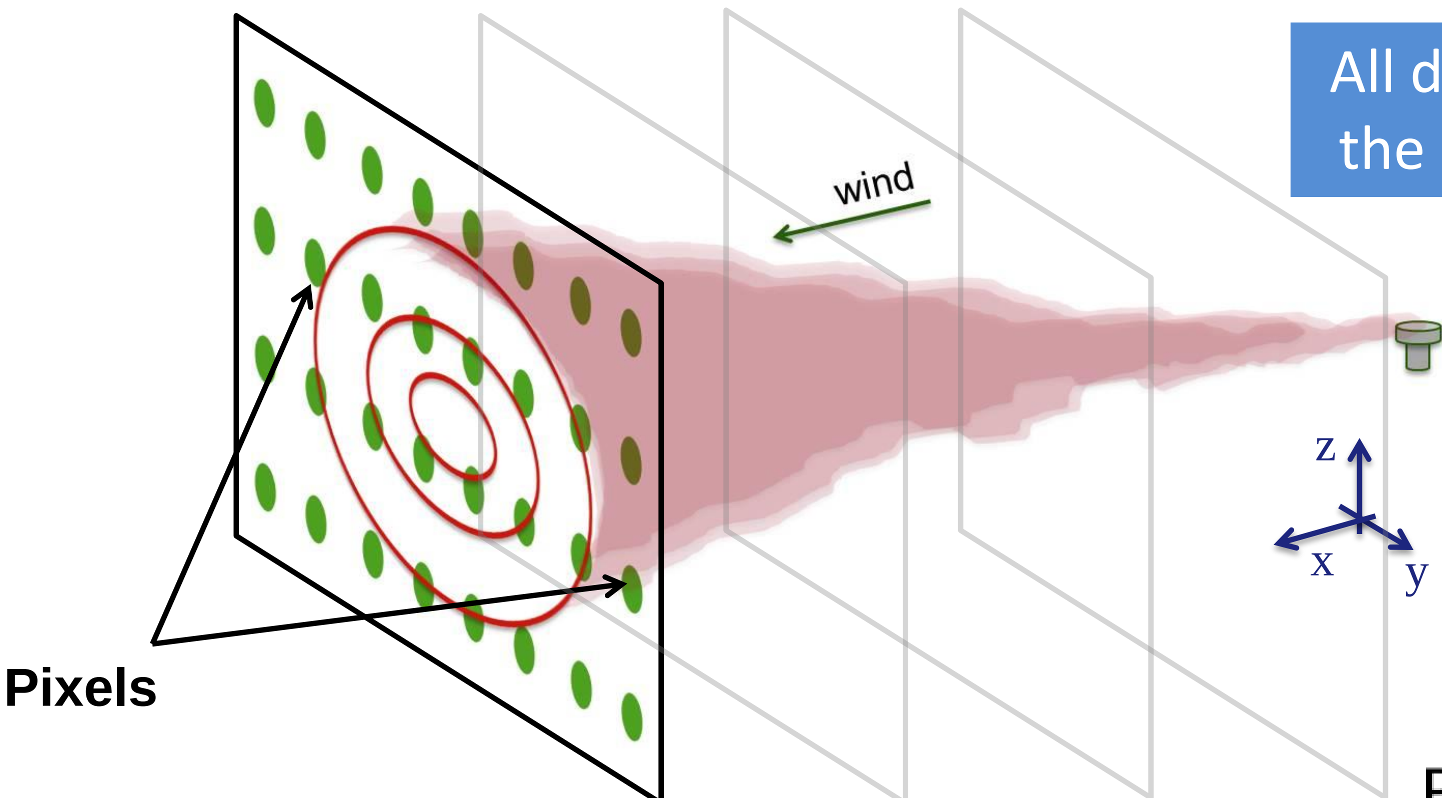
Three Ways To Measure the Emission Rate

- Direct Measurement of the emissions
  - requires physical access to the leak
- Measurement at a distance + Atmospheric Modeling
  - Use downwind measurements + atmospheric measurements + atmospheric models to back calculate emission rates
  - Requires knowledge of distance to source, height of source, and atmospheric turbulence
- **Direct Measurement of plume through a downwind surface**
  - **Measure downwind concentration map and wind speed only**
  - **No knowledge of distance, source location, and atmospheric turbulence required**

Quantify emissions using direct plume measurements

- Counting molecules passing through an area
  - Measure CH_4 concentration on a spatial grid downwind of the source
  - Measure wind through the surface

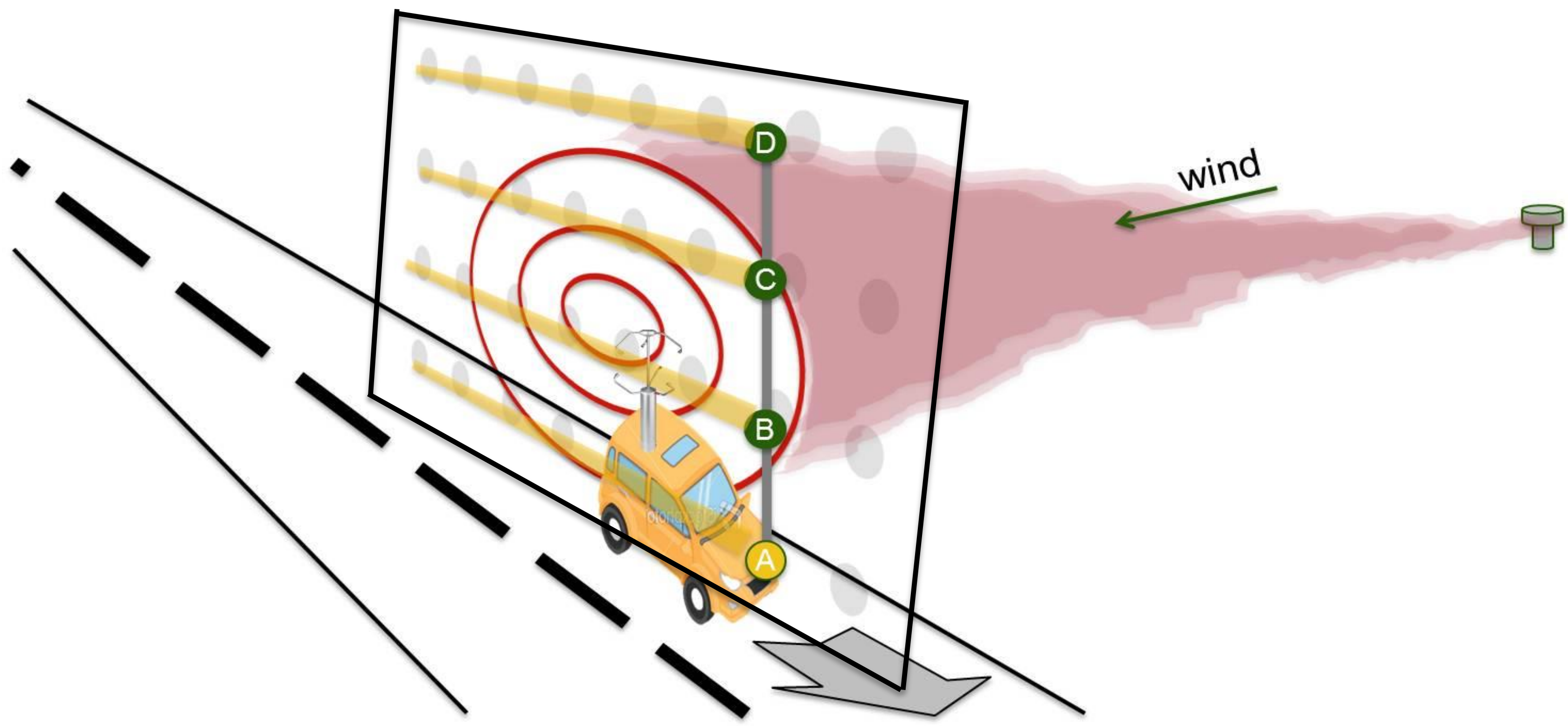
$$Q(t) = \int_A k(C(y,z,t) - C_0)\overrightarrow{u(x,y,t)} \cdot \hat{n}\, dA$$



All distances give the same result!

Quantify emission using plume measurements

- Drive through plume while measuring methane concentrations from four elevations (4 pixels) and simultaneously measuring vehicle position and speed, and wind velocity.



Use a virtual net to ‘catch’ the methane molecules

Measuring Emissions Rates in Real Time

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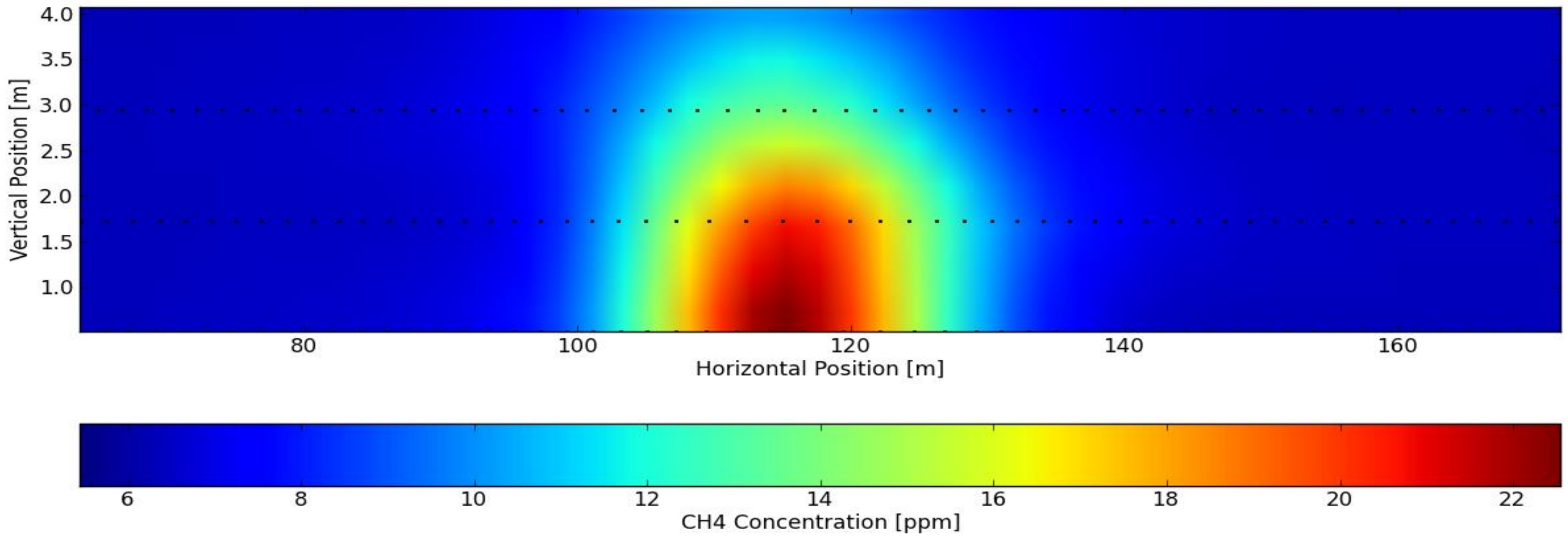
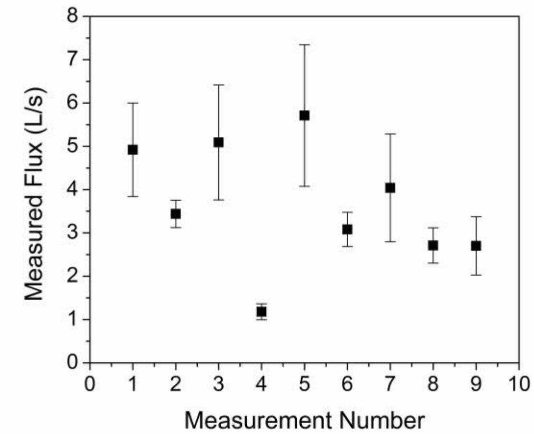
Final Reconstruction of 2D Plume Picture
Measurement Time = ~ 5 minutes



CH4 Plume Observed 1 Feb 2013 12:21	
Car Speed	10.8 m/s
Lateral Wind Speed	2.5 m/s
Flux Estimate	**1.5 L/s (± 0.3 L/s)**

Compressor Station Findings



Average Leak was 3.5 L/s (± 1.4 L/s):

- 3.5 balloons in 1 second!

- Enough CH_4 to heat 35 homes

- The carbon footprint of ~100 citizens

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Thank You!

Uintah Basin, Utah