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

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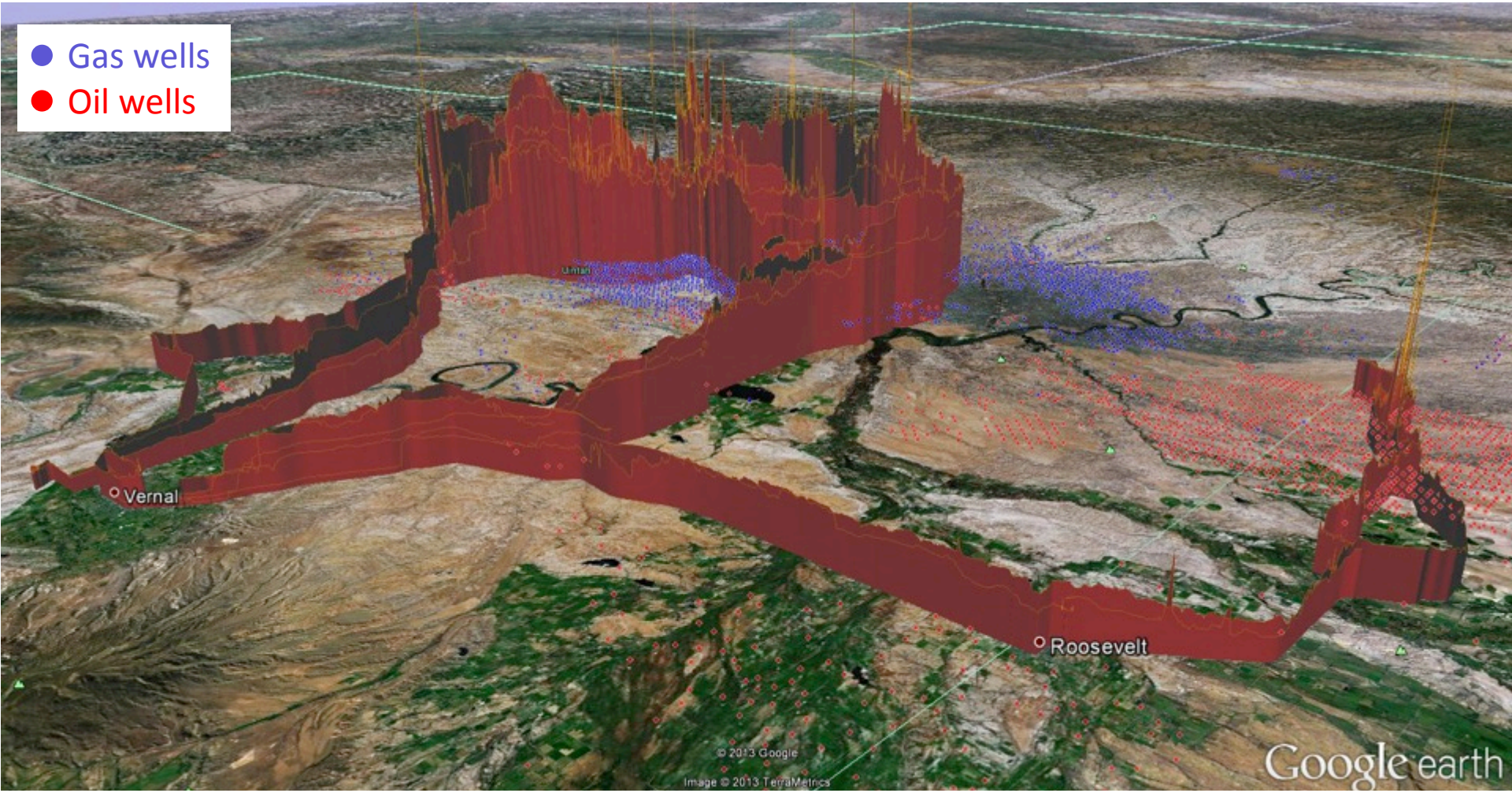
Uintah Shale Basin Methane Concentrations



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

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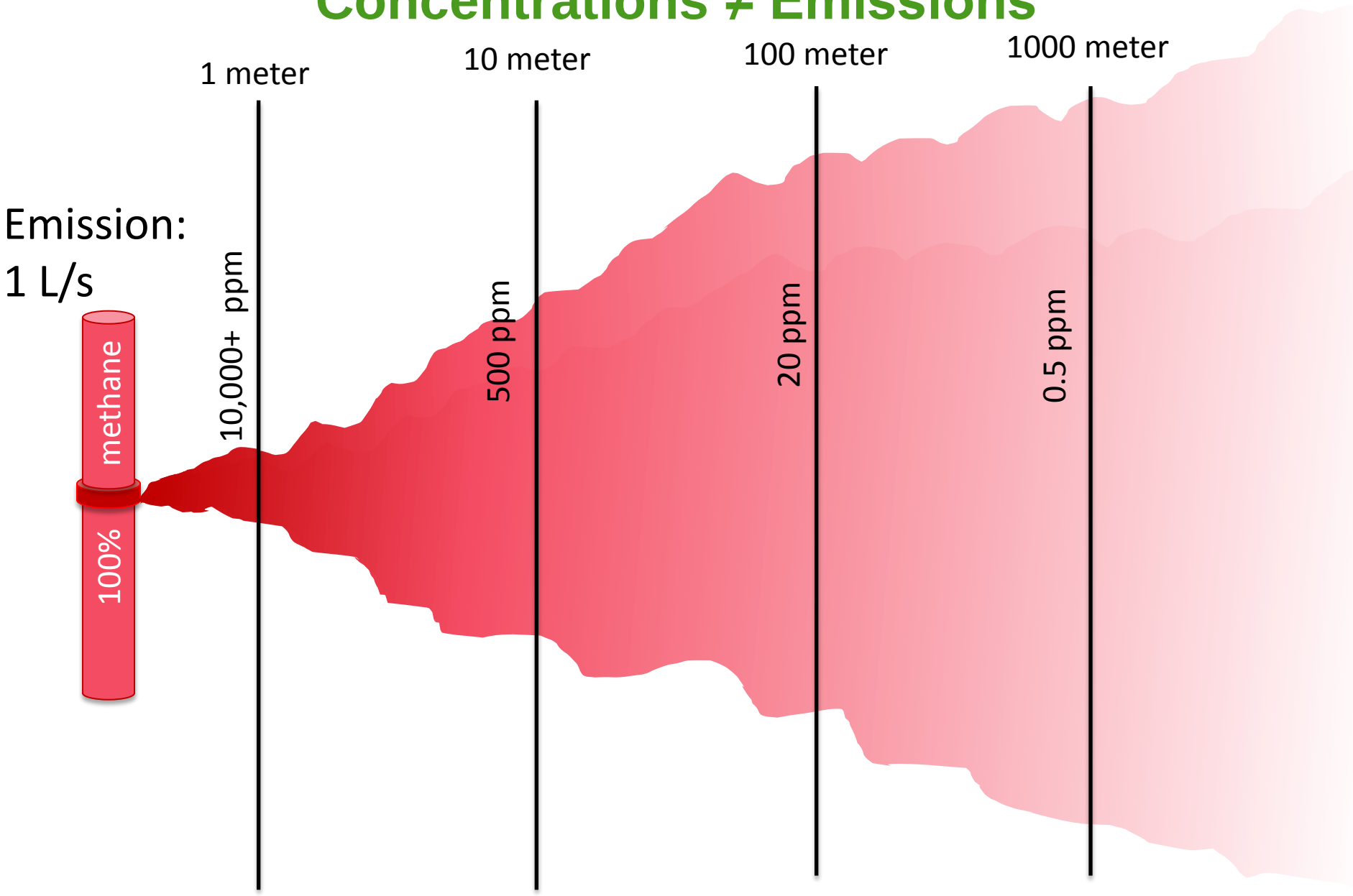
Concentrations ≠ Emissions



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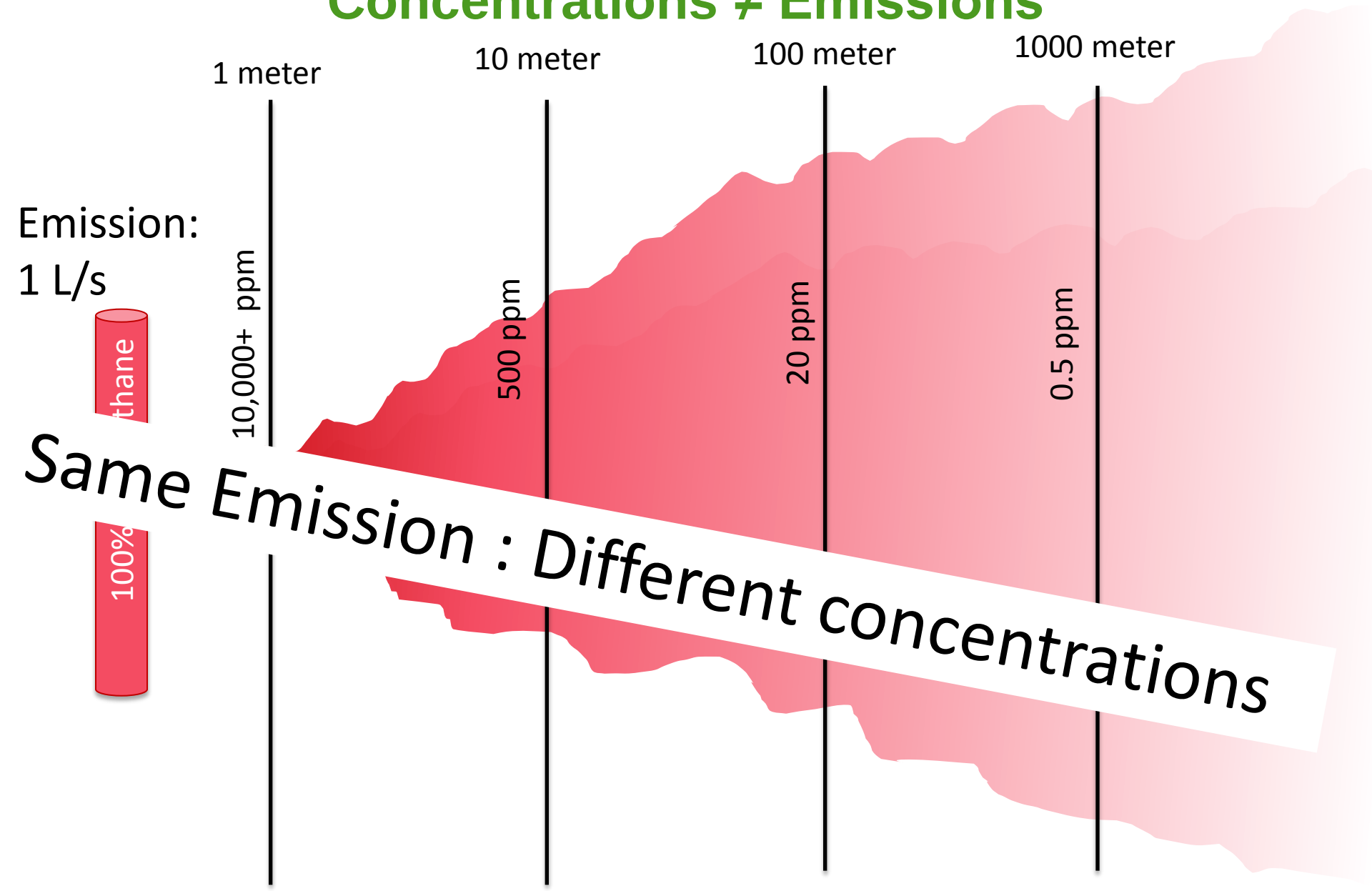
Concentrations ≠ Emissions



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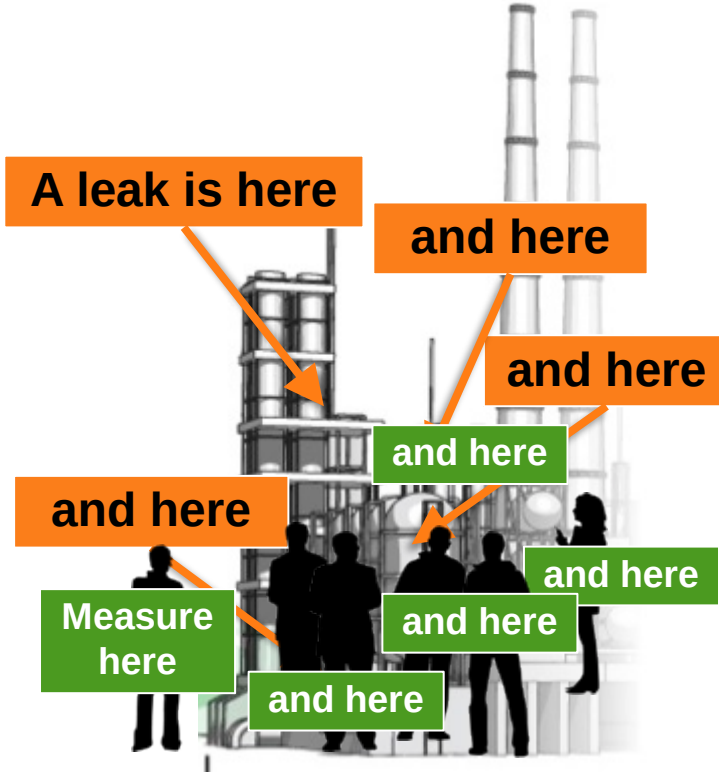
How to quantify emissions of point sources?

- Direct Measurement
  - Requires physical access to the leak source
  - Time-consuming process



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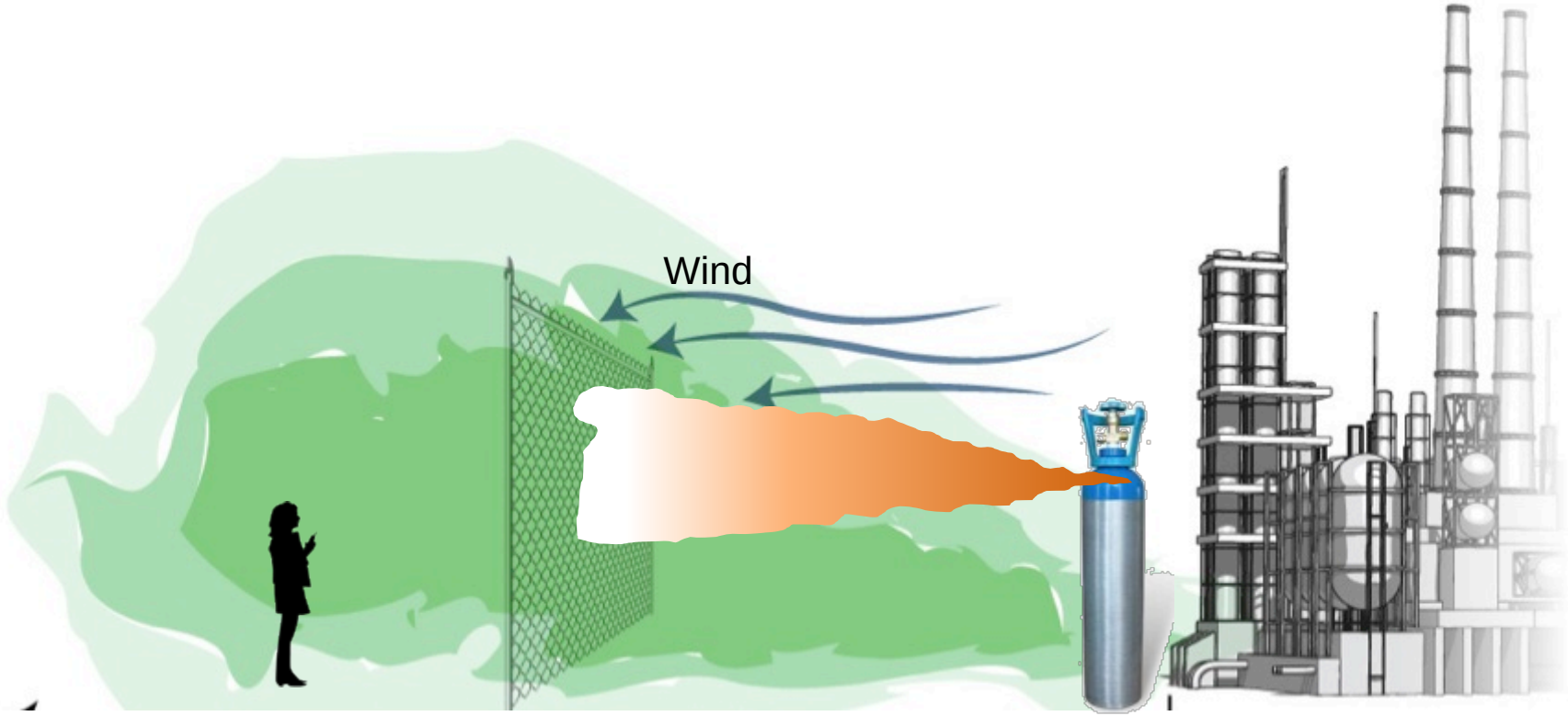
How to quantify emissions?

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



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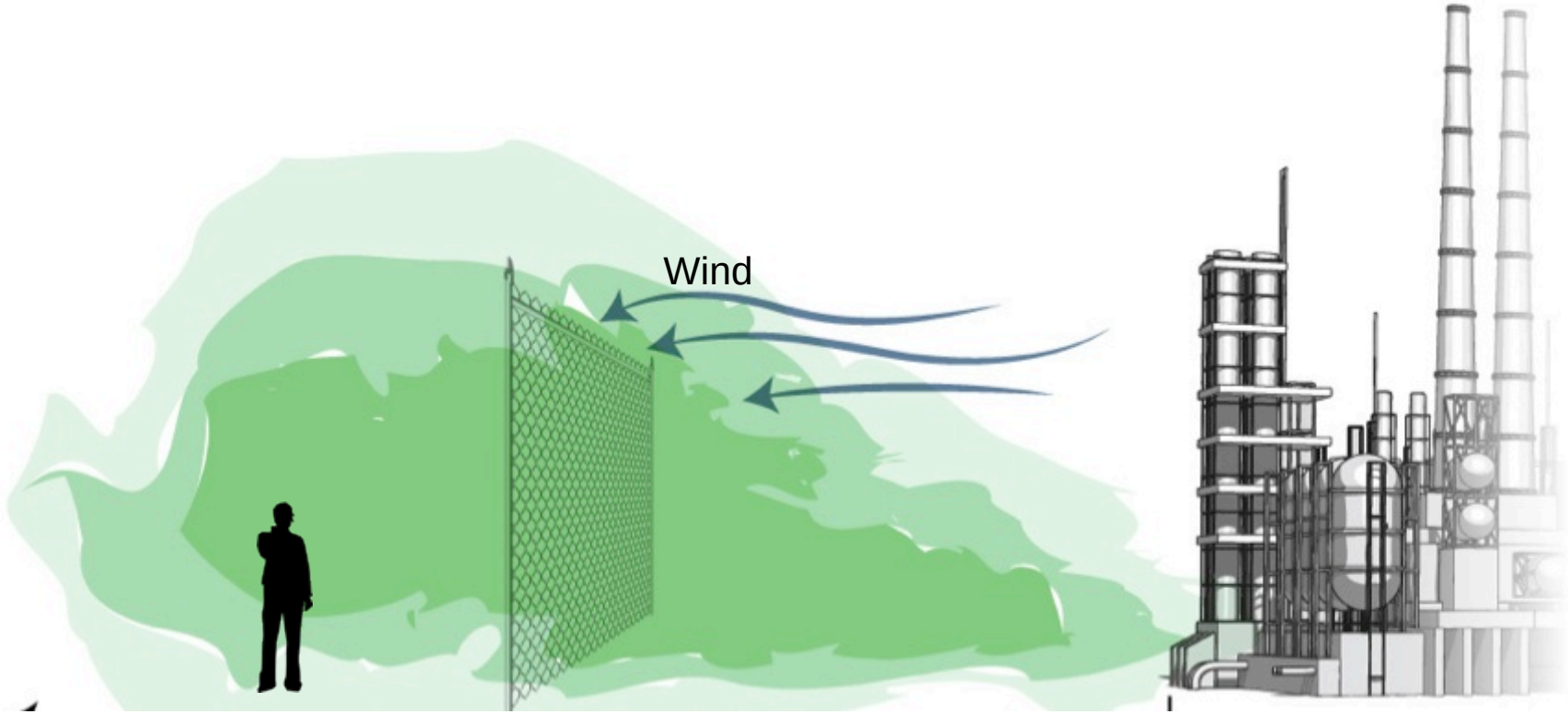
How to quantify emissions?

- Direct Measurement / Tracer Release
- Measurement at a distance + atmospheric modeling
  - Knowledge of source location and height and atmospheric turbulence



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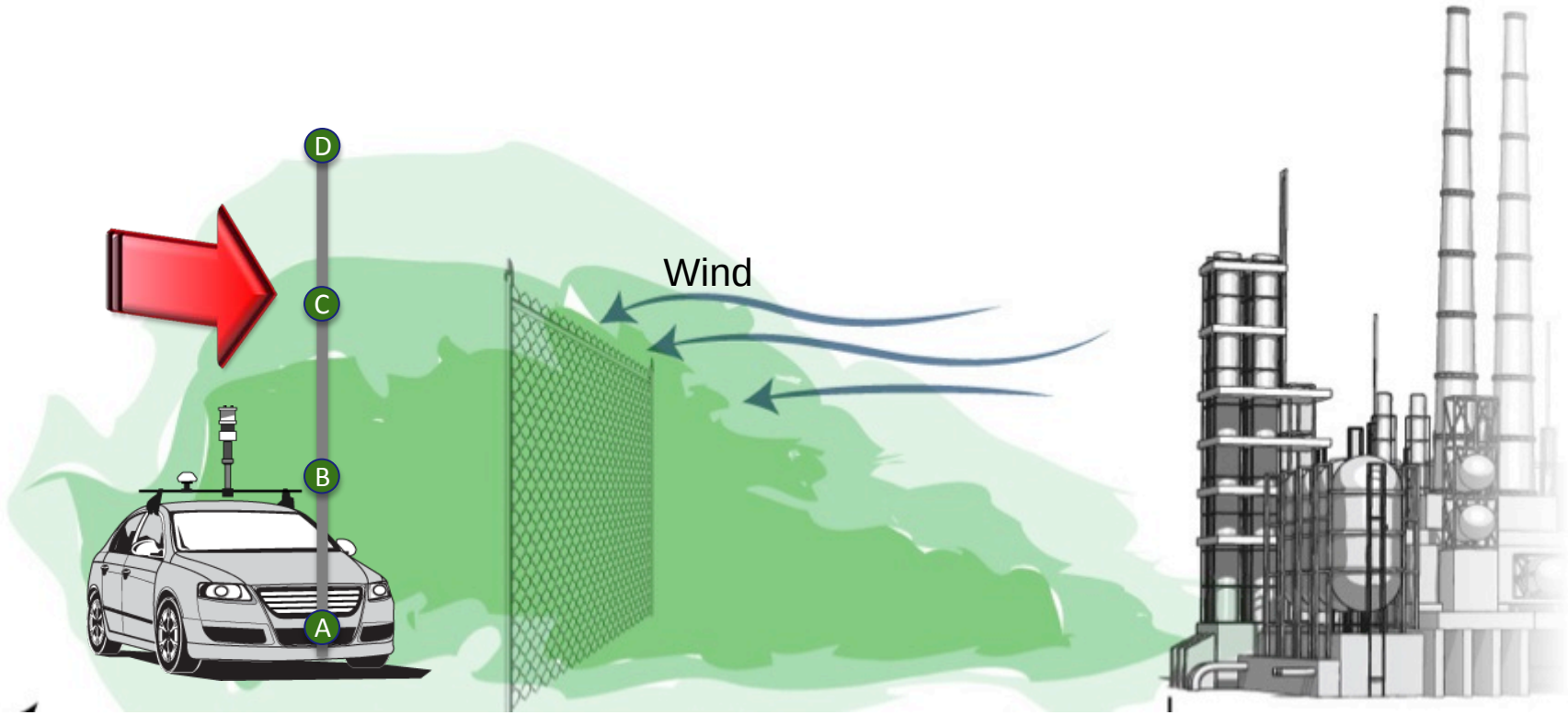
How do we quantify emissions?

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



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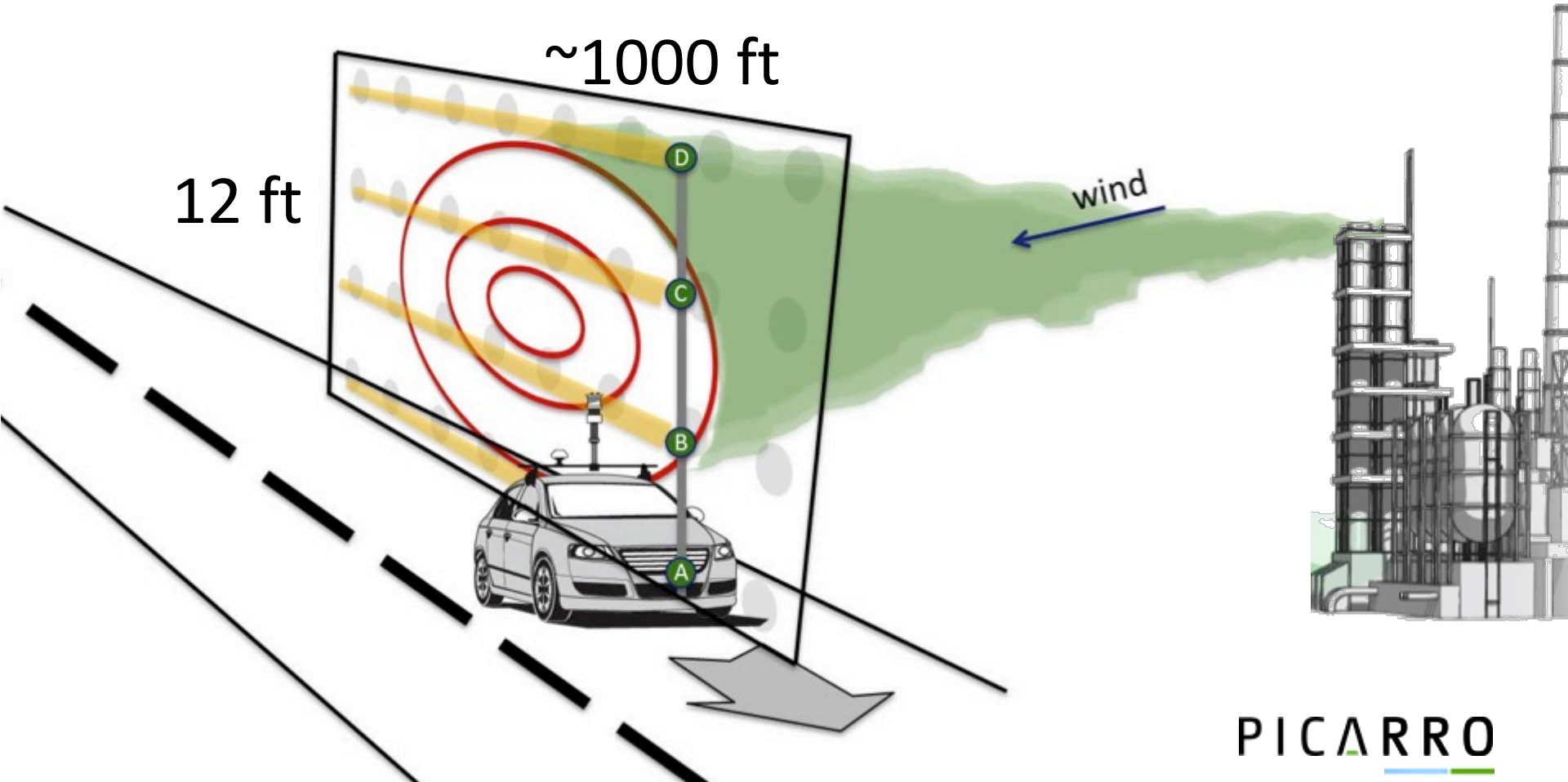
Throw a virtual net to “catch” methane

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

$$Flux = \iint (\mathrm{C}(\mathrm{y},\mathrm{z}) - C_o) \cdot \overrightarrow{u(x,y,z)}\, dy\, dz$$



PICARRO

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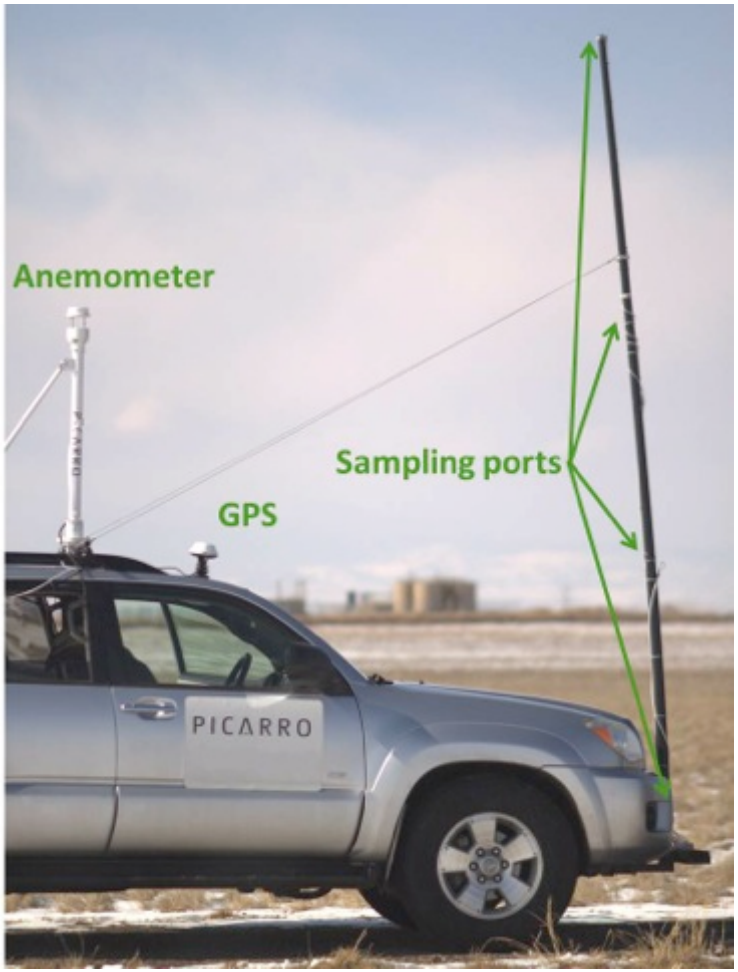

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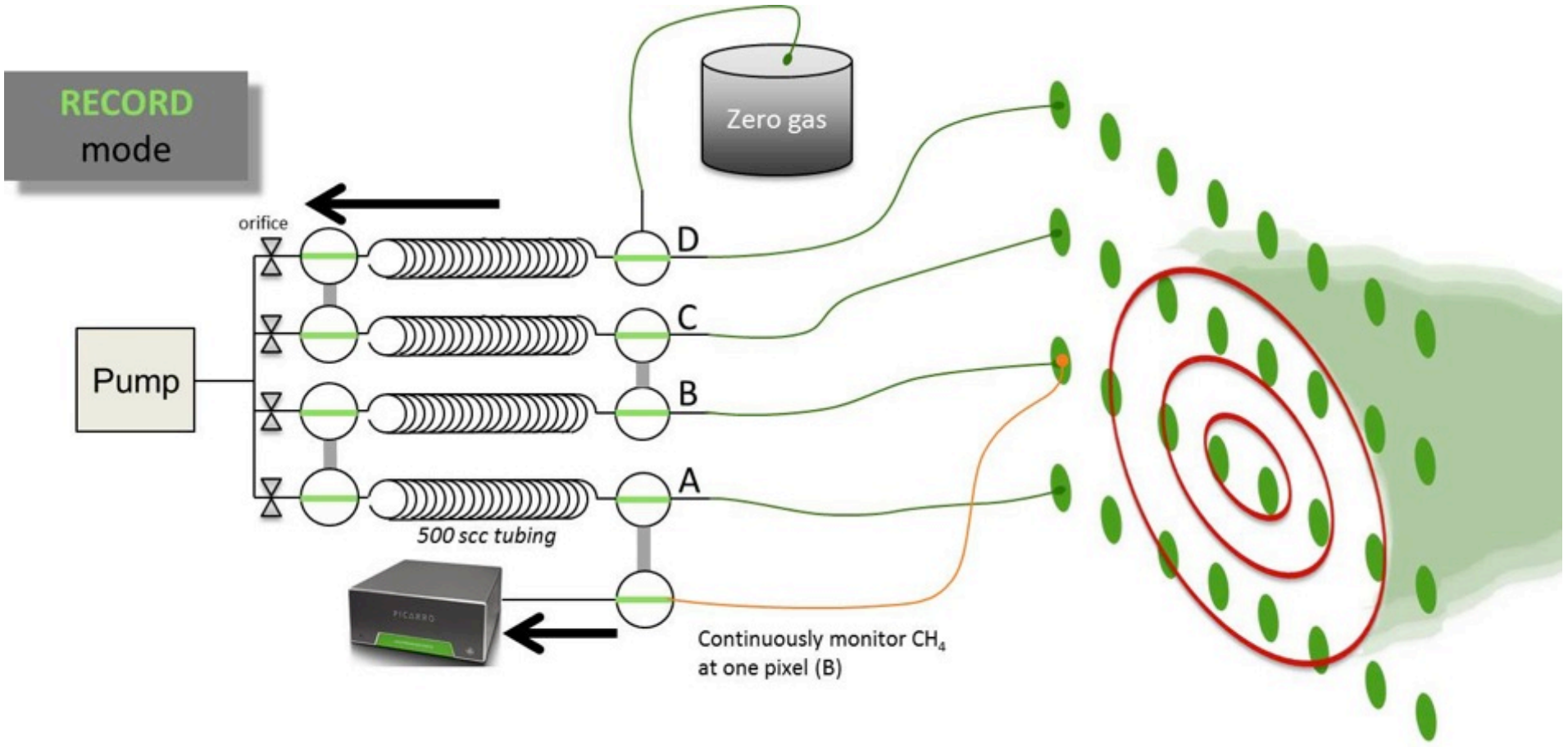
How to simultaneously measure Four Pixels

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



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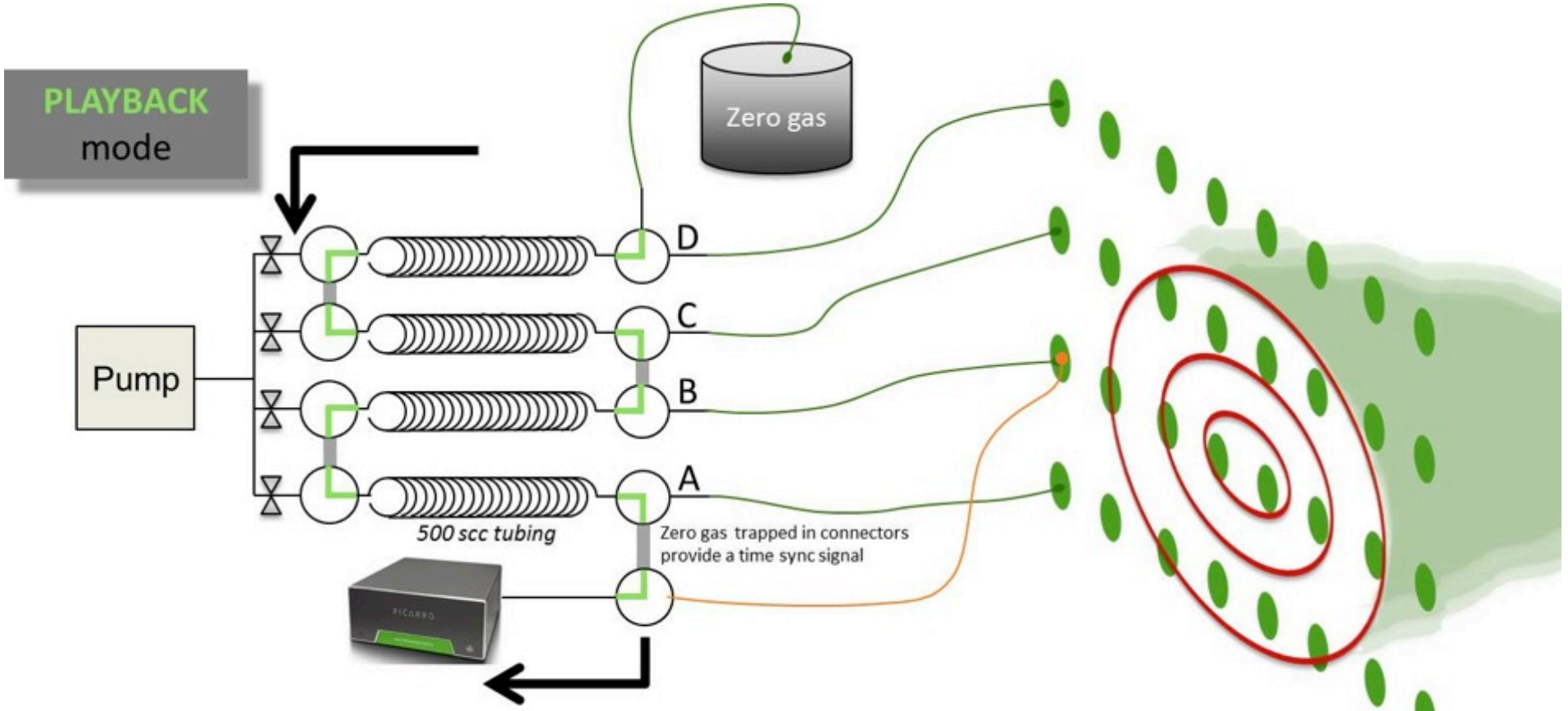
How to Playback Four Pixels

- Total analysis or playback time ~ 7 minutes



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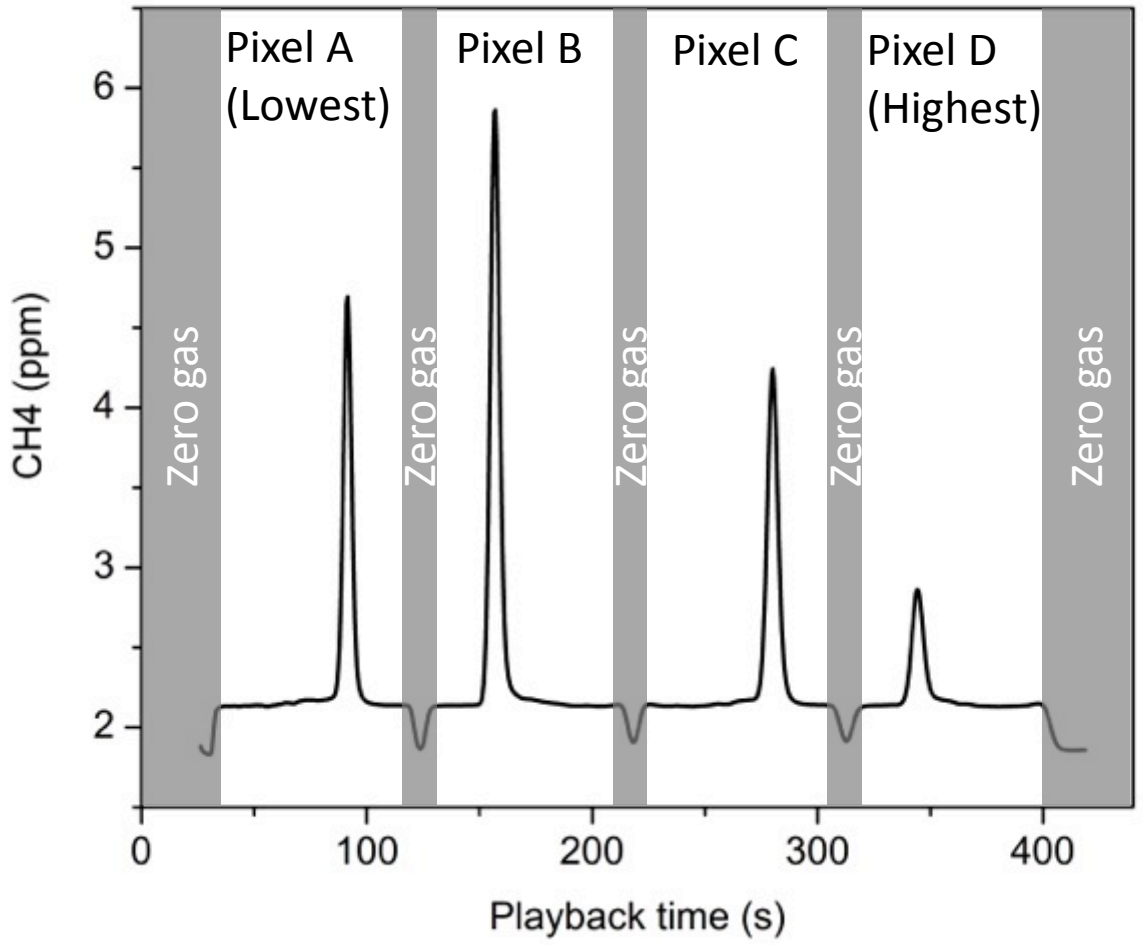
Result: Plume Image

Raw Playback data



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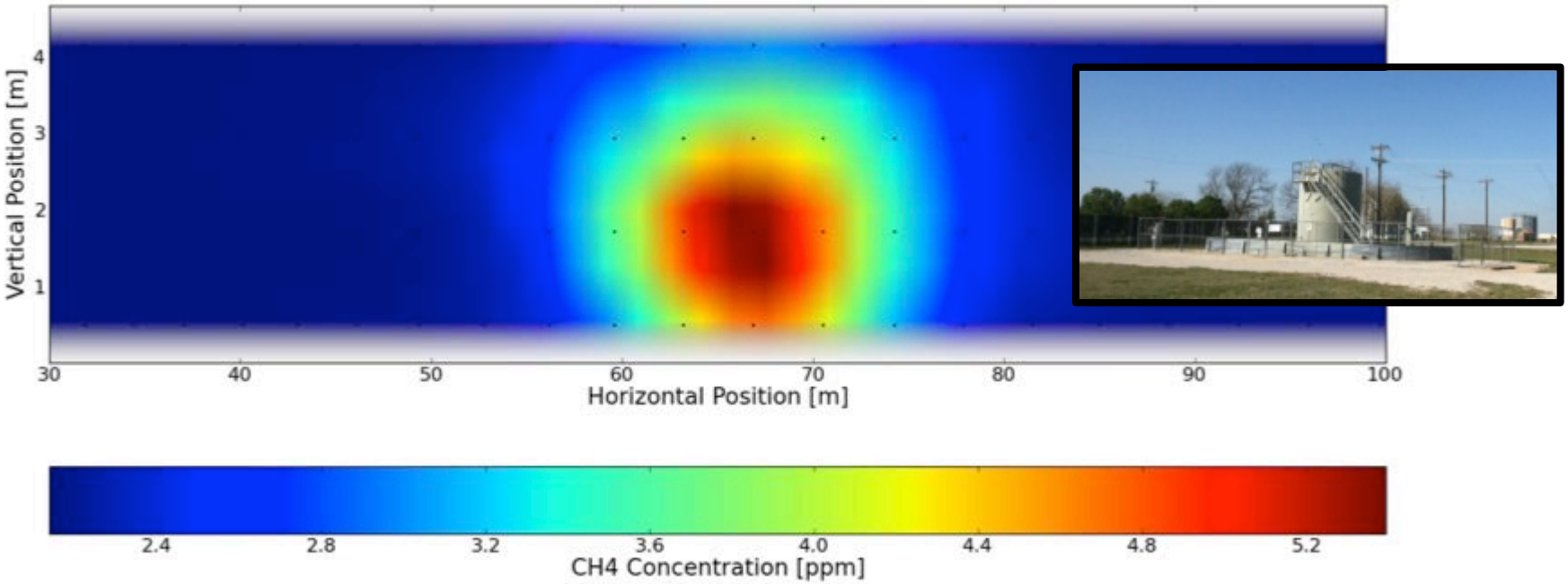
Result: Plume Image and Flux



+

Wind data

= Flux of **31 lpm**

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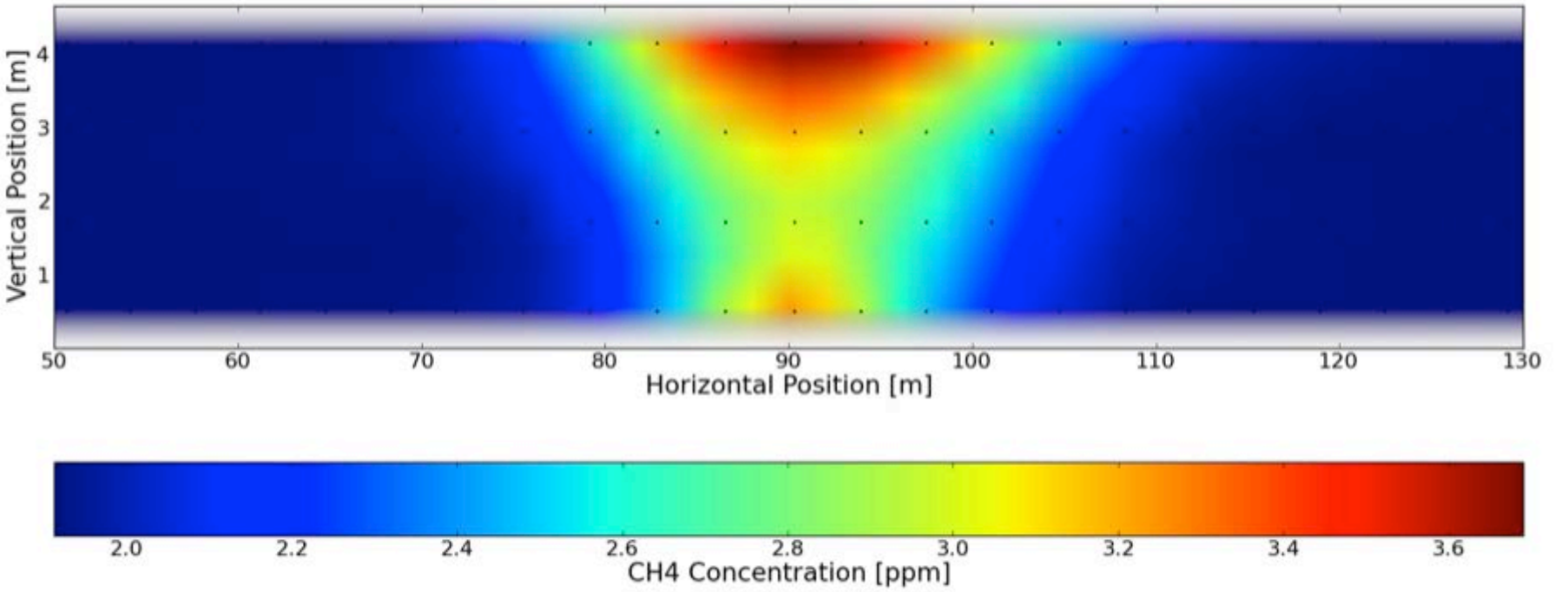
Plume Image indicates data quality

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

Flux > **12 lpm**



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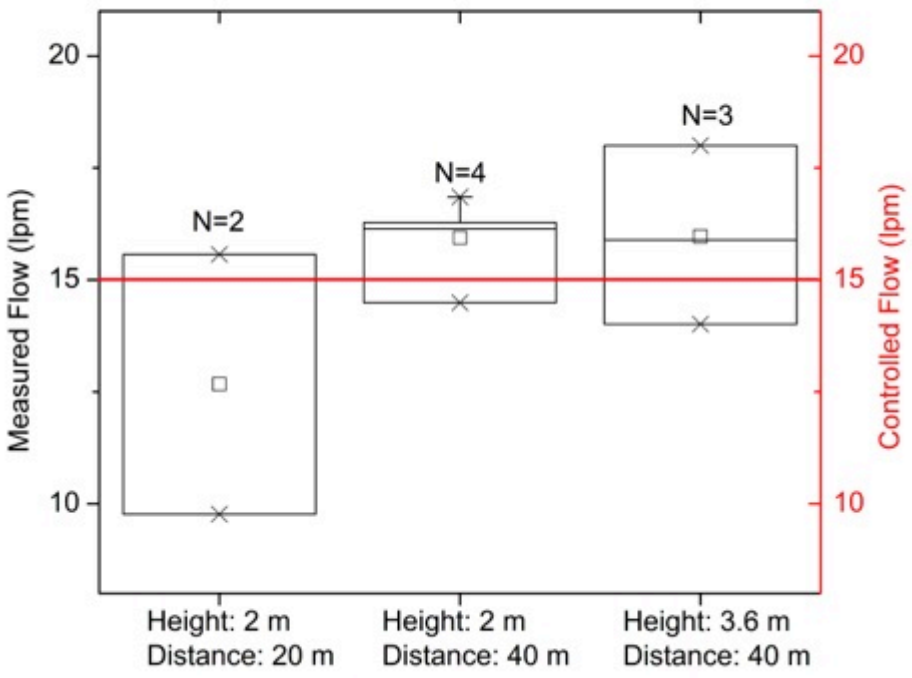
Verification: Controlled releases

- 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 (σ): 2.3 lpm (15%)

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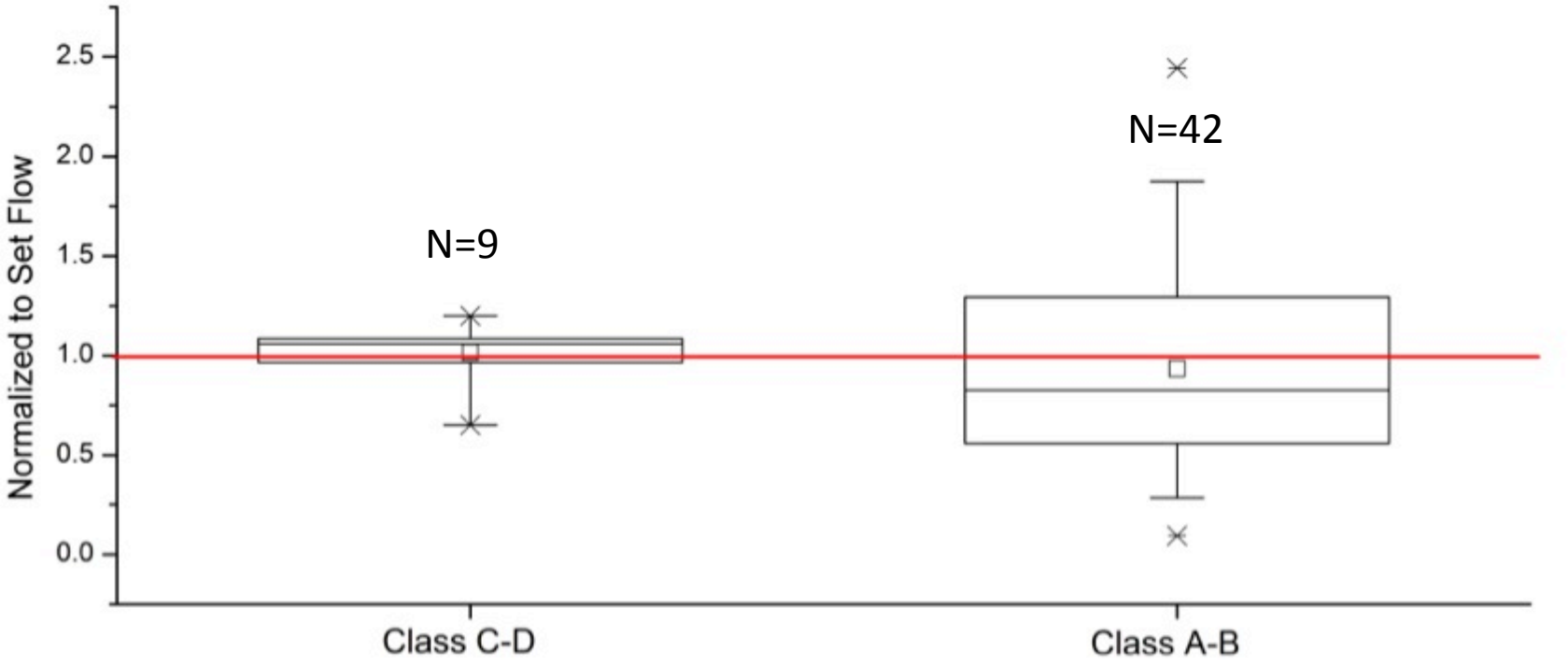
Reproducibility scales with stability class

Set flow: 15 lpm

- Class C-D
- Average Measured Flux: 15.3 lpm
- Error: 1.5%
- Reproducibility (σ): **2.3 lpm (15%)**

Set flow: 16 lpm

- Class A-B
- Average Measured Flux: 14.9 lpm
- Error: -6.6%
- Reproducibility (σ): **8.7 lpm (58%)**



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Field Case: Barnett Shale, Texas

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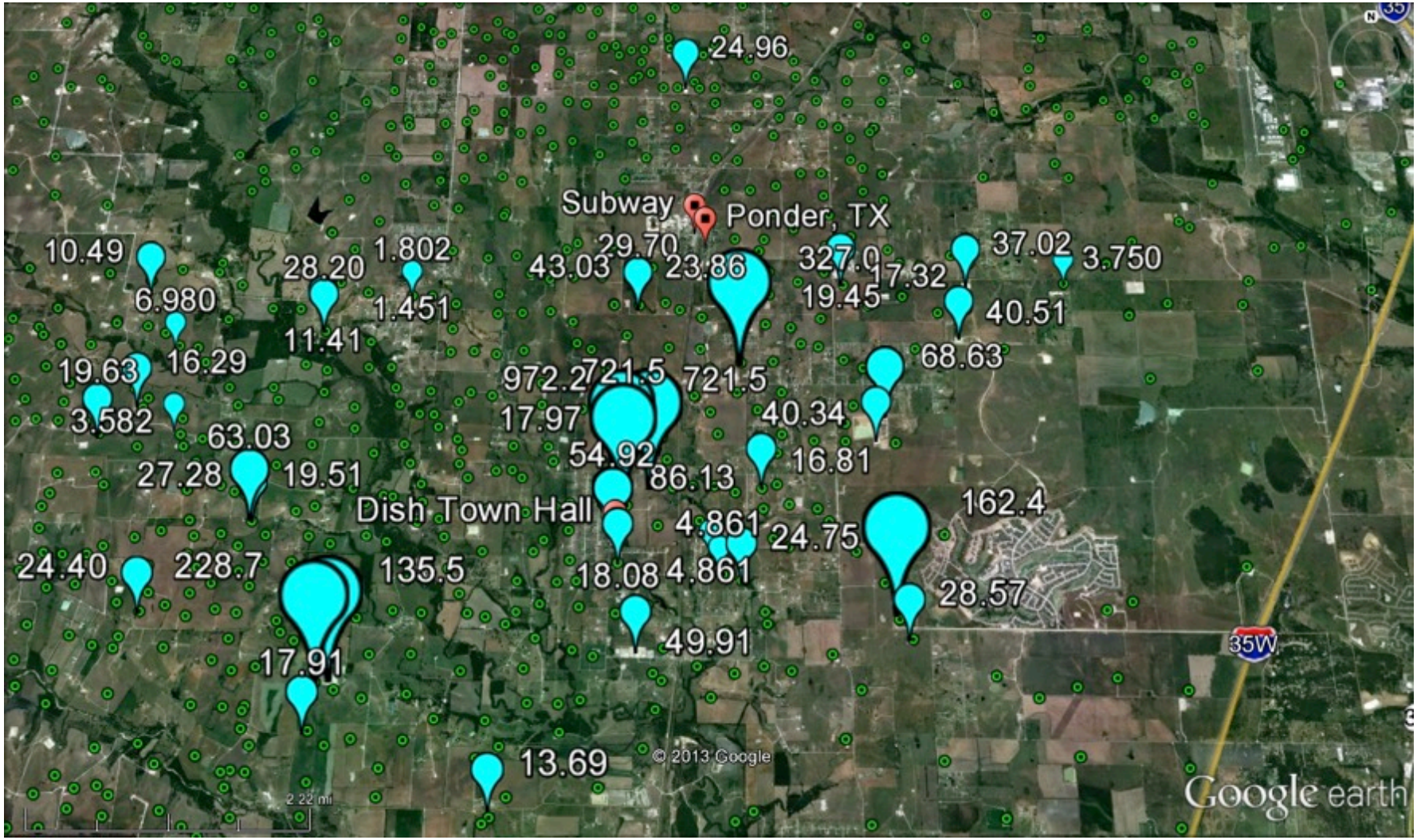
Barnett Shale: Ponder and Dish Area (5 by 10 miles)



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Field Case: Ponder and Dish Area (5 by 10 miles)

- Measured emissions of 52 sites

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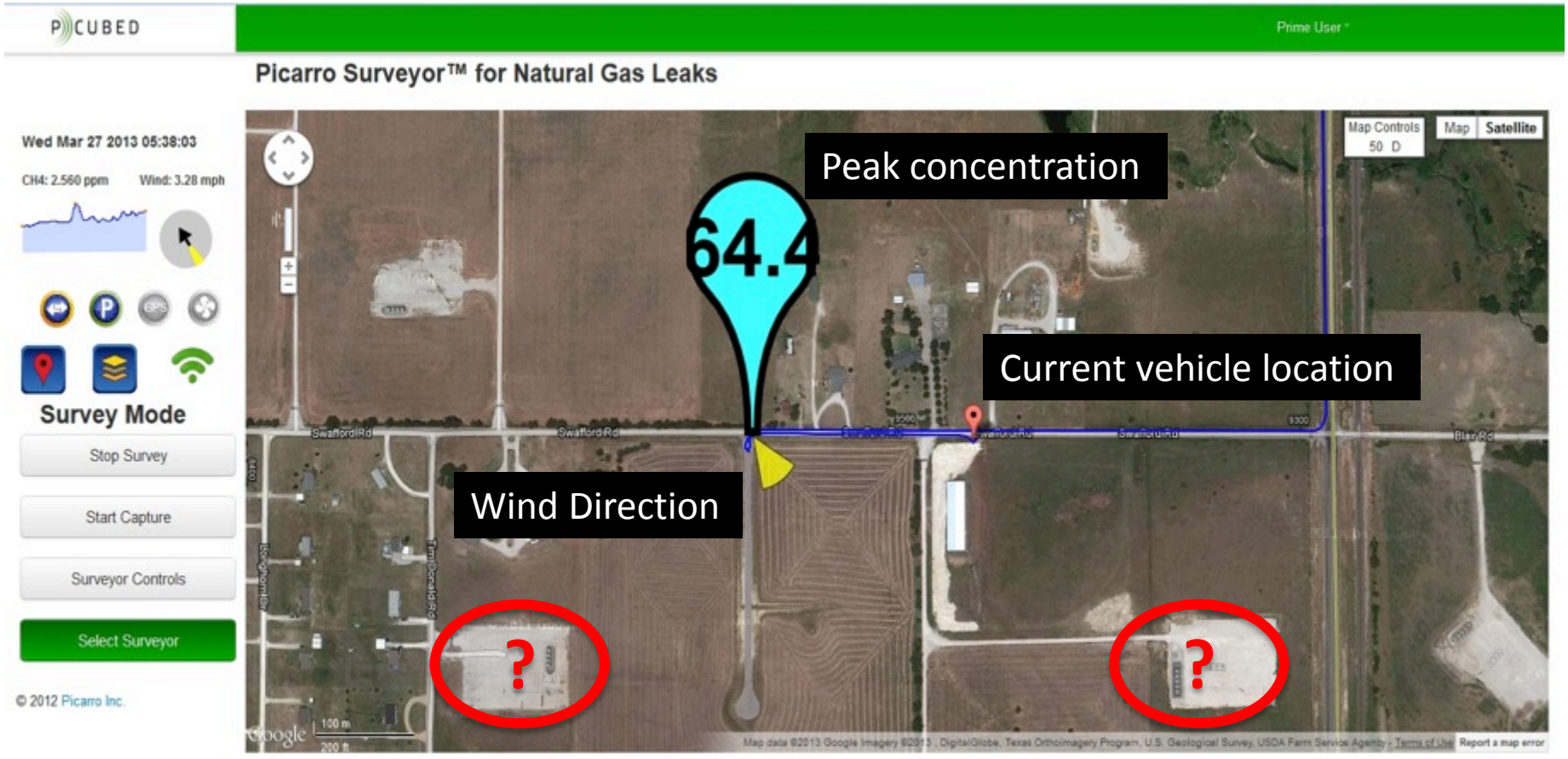
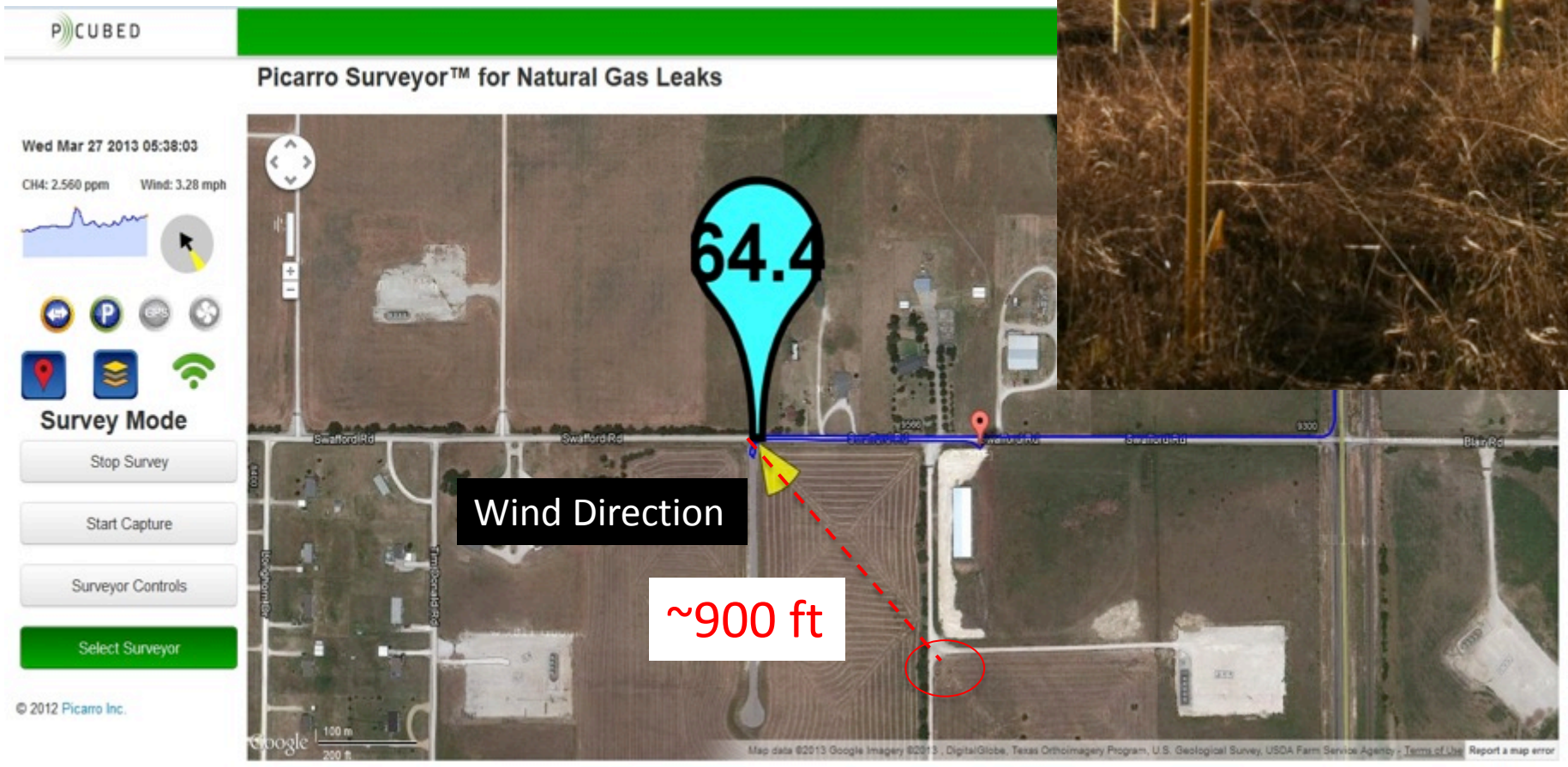
Step 1: Survey the area

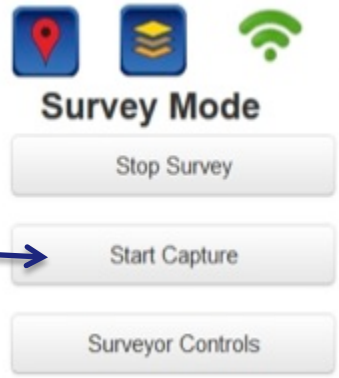


Step 1: Survey the area

- Leak location is NOT necessary for emissions measurement

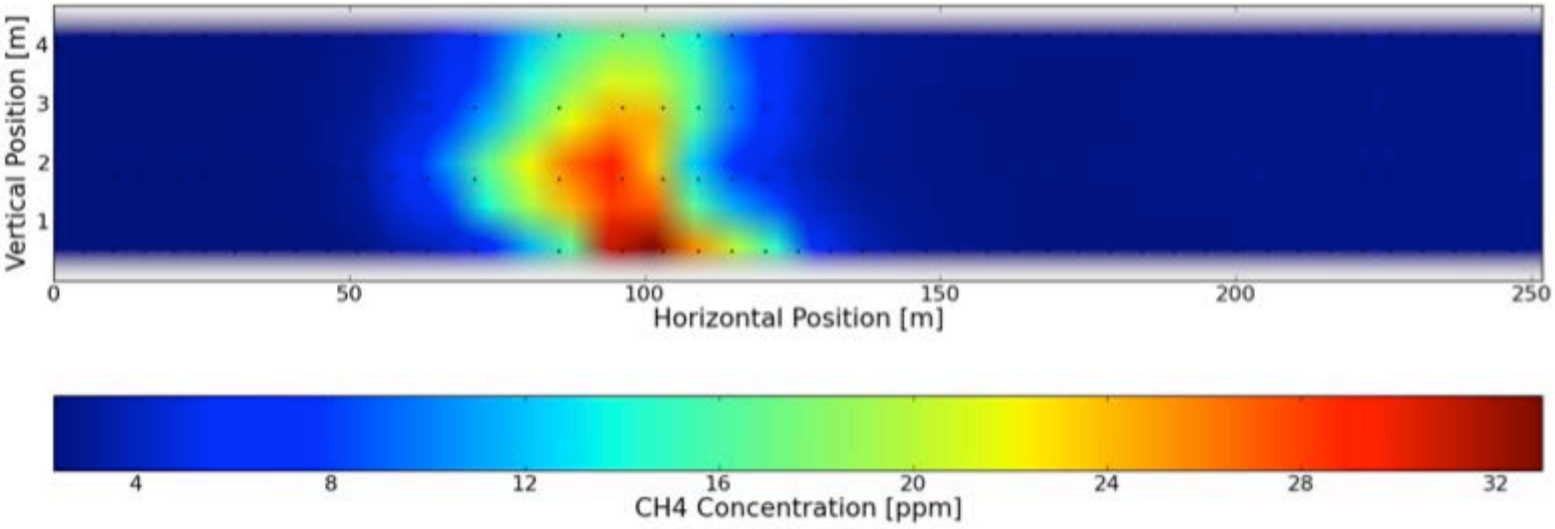


Step 2: Capture the Plume



- 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



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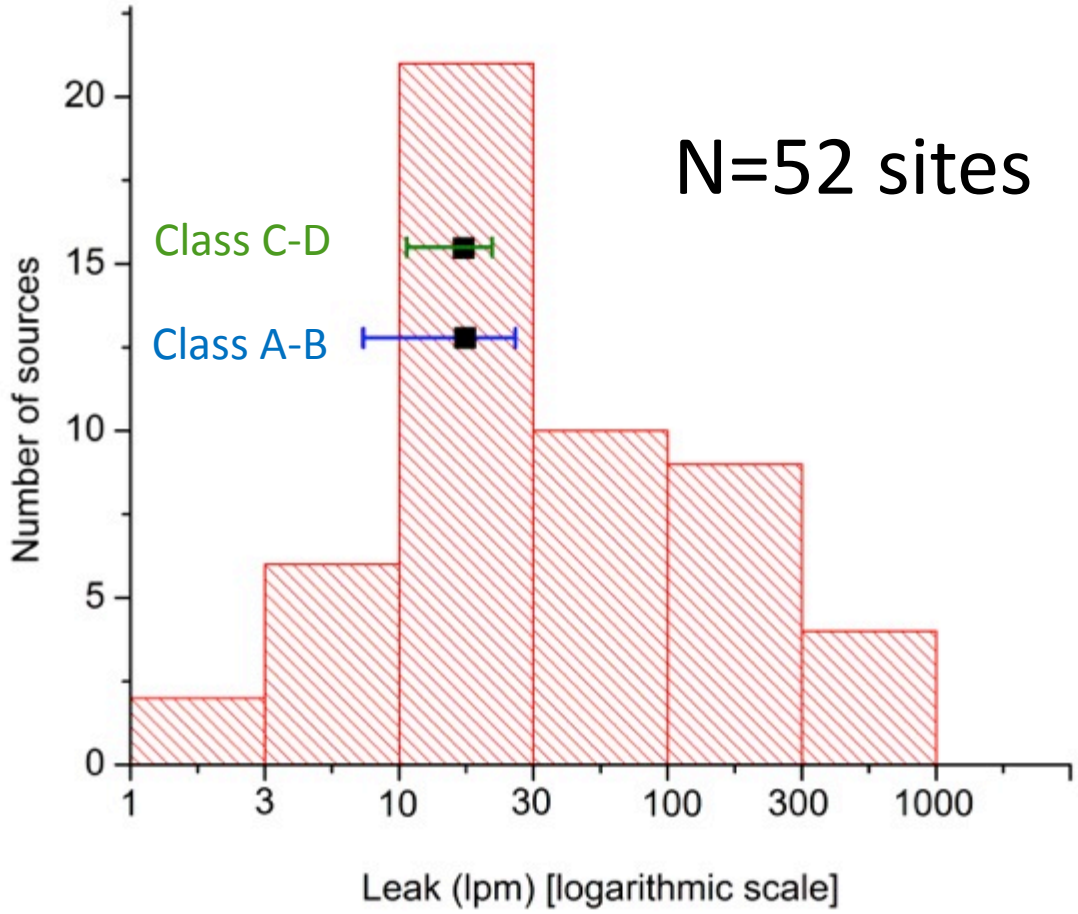
Emissions sampled in Dish, Texas area

- Emissions ranged from 1.5 to 970 lpm



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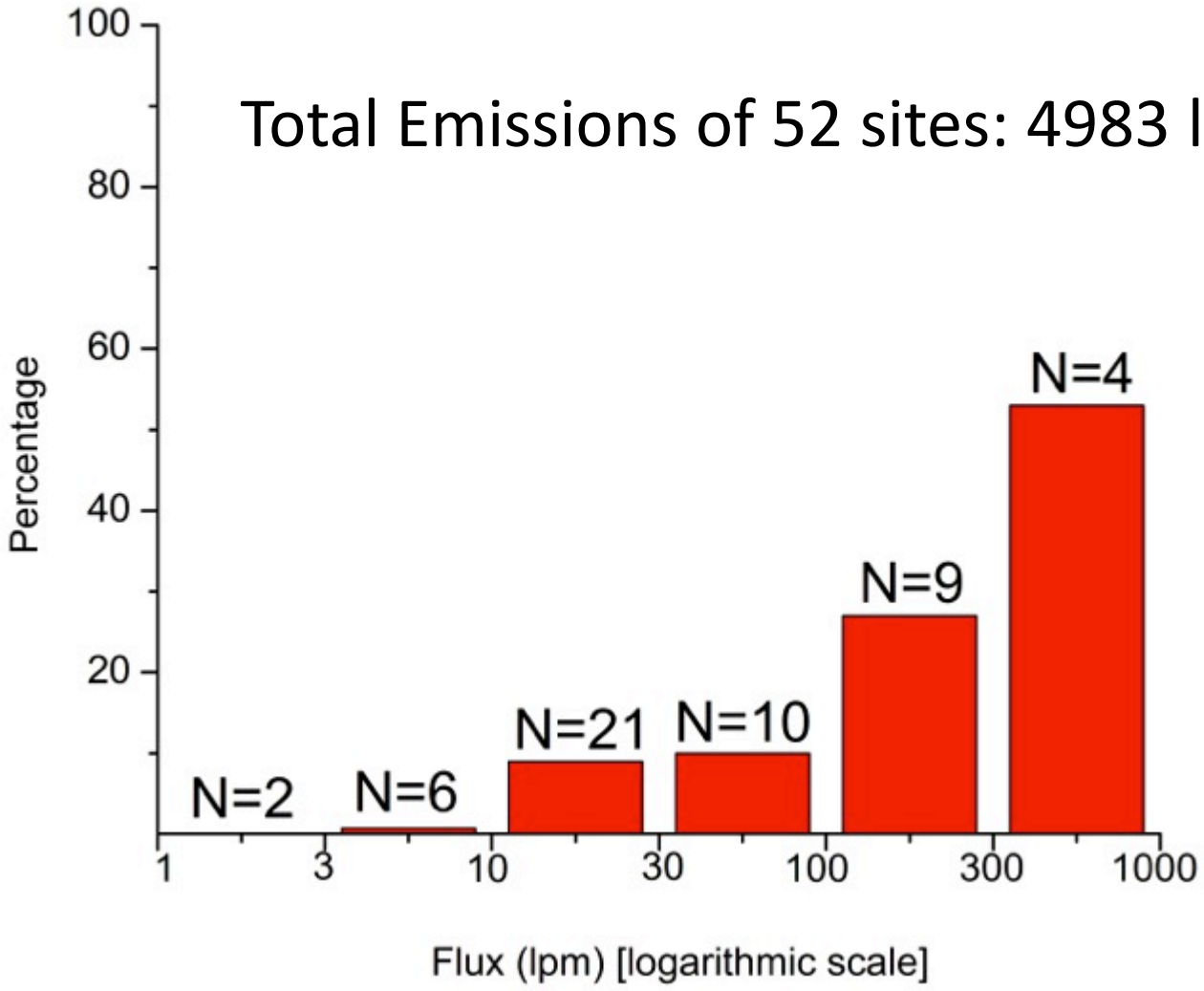
Emissions sampled in Dish, TX area



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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

ARL

Air Resources Laboratory

Conducting research and development in the fields of air quality, atmospheric dispersion, climate, and boundary layer

Pasquill Stability Classes

A: Extremely unstable conditions	D: Neutral conditions
B: Moderately unstable conditions	E: Slightly stable conditions
C: Slightly unstable conditions	F: Moderately stable conditions
G: Extremely Stable	

Meteorological conditions defining Pasquill stability classes.

	Daytime insolation			Night-time conditions	
Surface wind speed (m/s)	**Strong**	**Moderate**	**Slight**	**Thin overcast or > 4/8 low cloud**	**<= 4/8 cloudiness**
< 2	A	A - B	B	E	F
2 - 3	A - B	B	C	E	F
3 - 5	B	B - C	C	D	E
5 - 6	C	C - D	D	D	D
> 6	C	D	D	D	D

Source: Pasquill, 1961.

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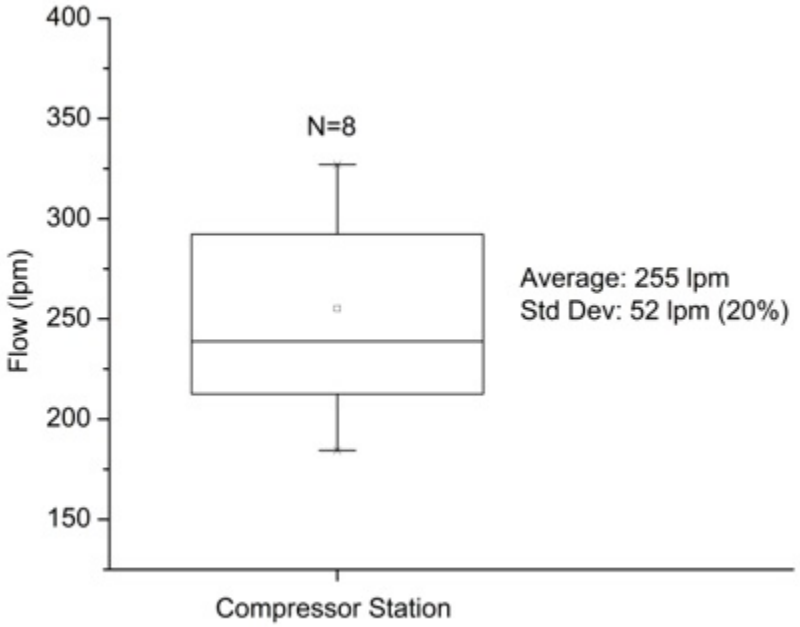
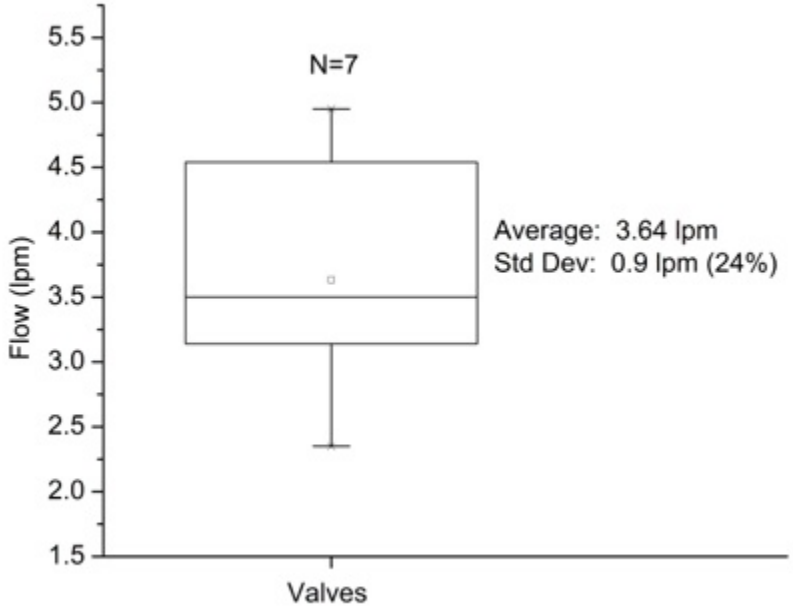
Verification with natural gas facilities

Compressor Station



Valves Station



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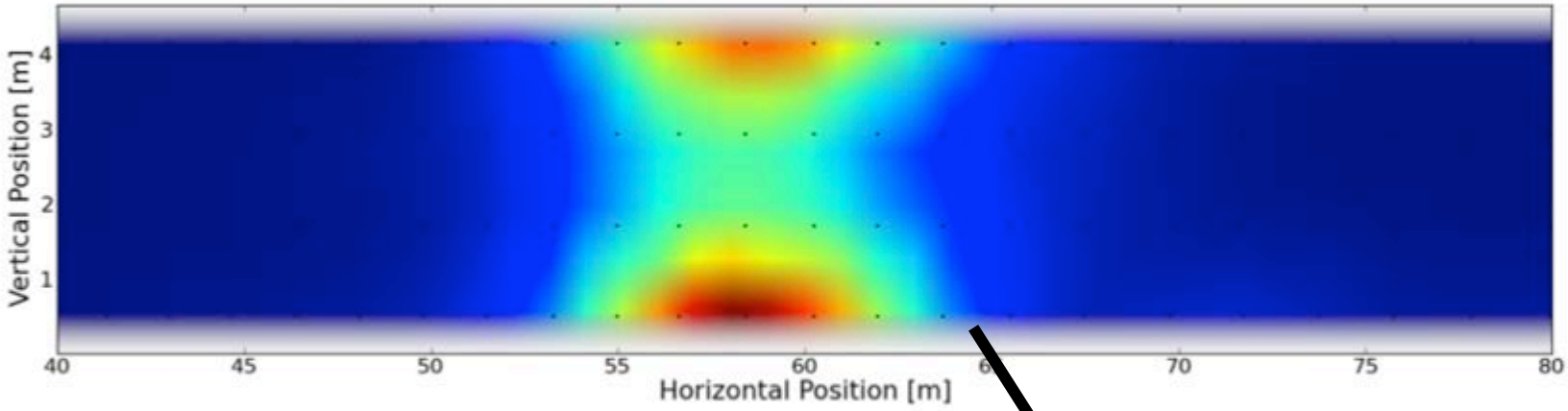
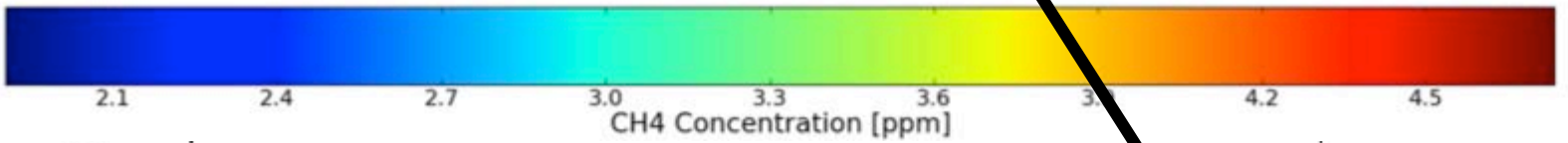
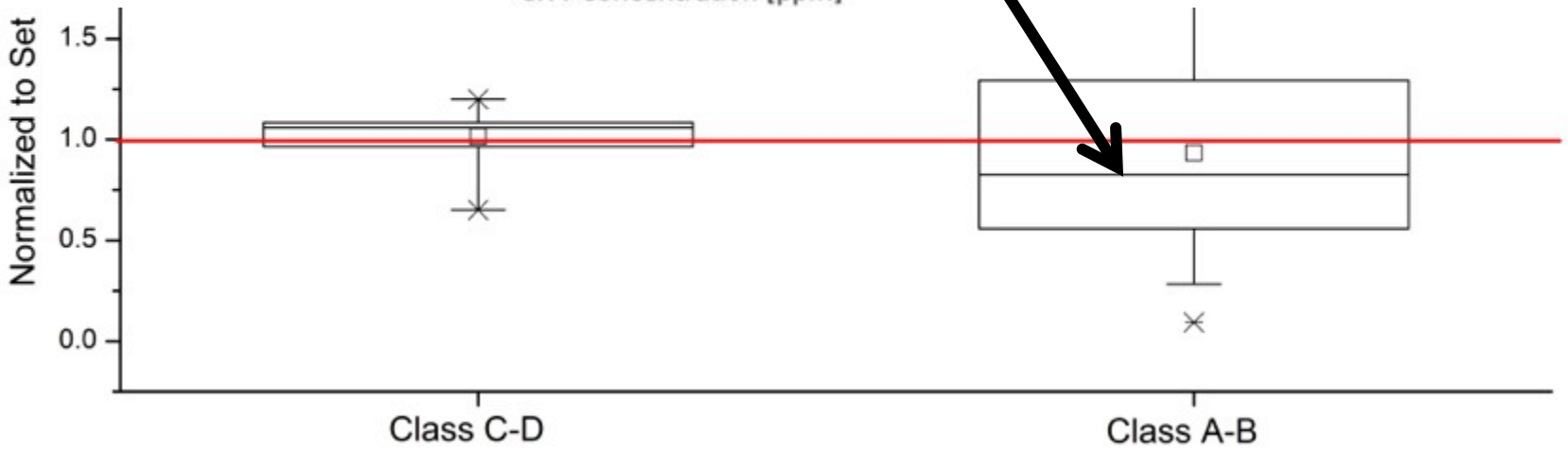
Reproducibility scales with stability class



.9 lpm

58%)





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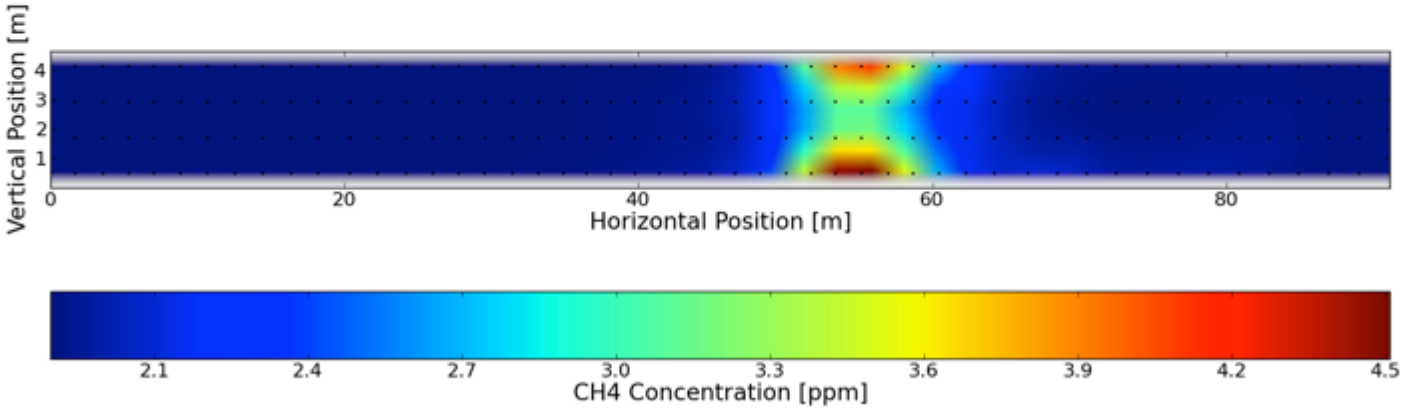
C:\Users\ttsai\Desktop\Uintah Basin Field Campaign\EPA\data\plume_1368472465_2013_5_13__12_14_unpickled.txt
v23_piecewise_compSR saved Mon May 13 12:21:37 2013
Carspeed 4.073073 m/s with 0.271812 m/s
Windspeed 1.42506896552 m/s with 0.560892 m/s and weighted average of 1.631265
Background 1.895000 ppm
GPS Lat: 35.970049; GPS Long: -79.093794; FWHM: 1.975514 m
Flux: 0.100074 L/s or 0.059705 g/s



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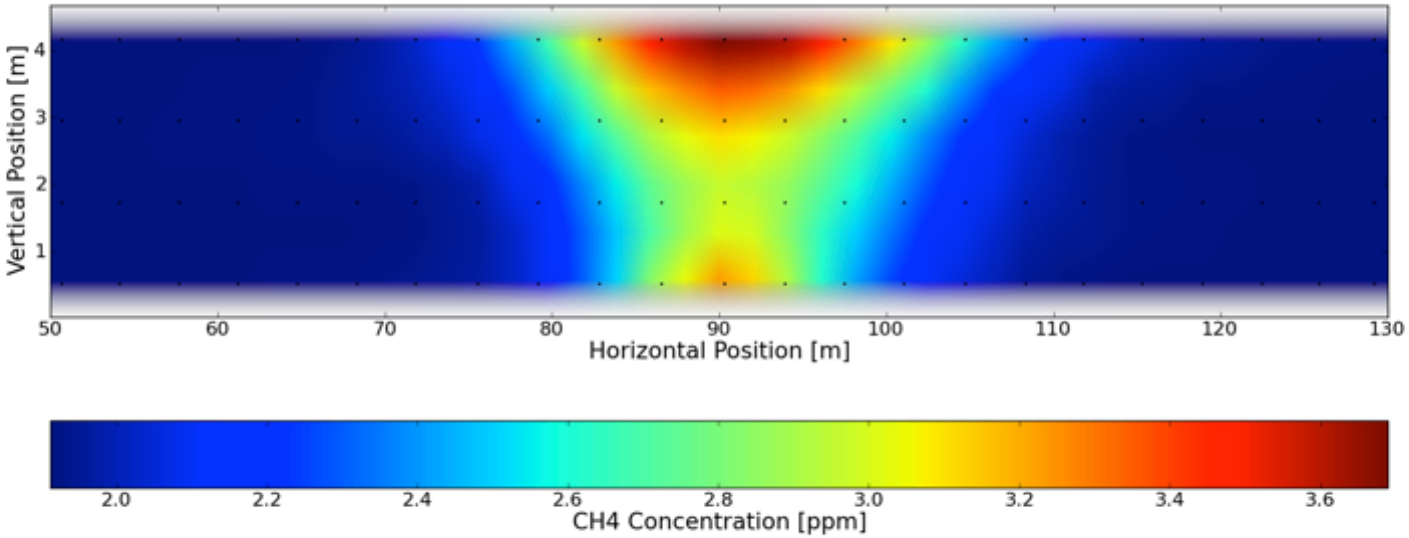
C:\Users\ttsai\Desktop\Uintah Basin Field Campaign\EPA\data\05_13\plume_1368455217_2013_5_13__7_26_unpickled.txt
v23_piecewise_compSR saved Sat May 18 16:12:31 2013
Carspeed 8.172122 m/s with 0.077034 m/s
Windspeed 2.18495 m/s with 0.162801 m/s and weighted average of 2.147154
Background 1.909000 ppm
GPS Lat: 35.897164; GPS Long: -78.872264; FWHM: 2.817477 m
Flux: 0.203176 L/s or 0.121217 g/s



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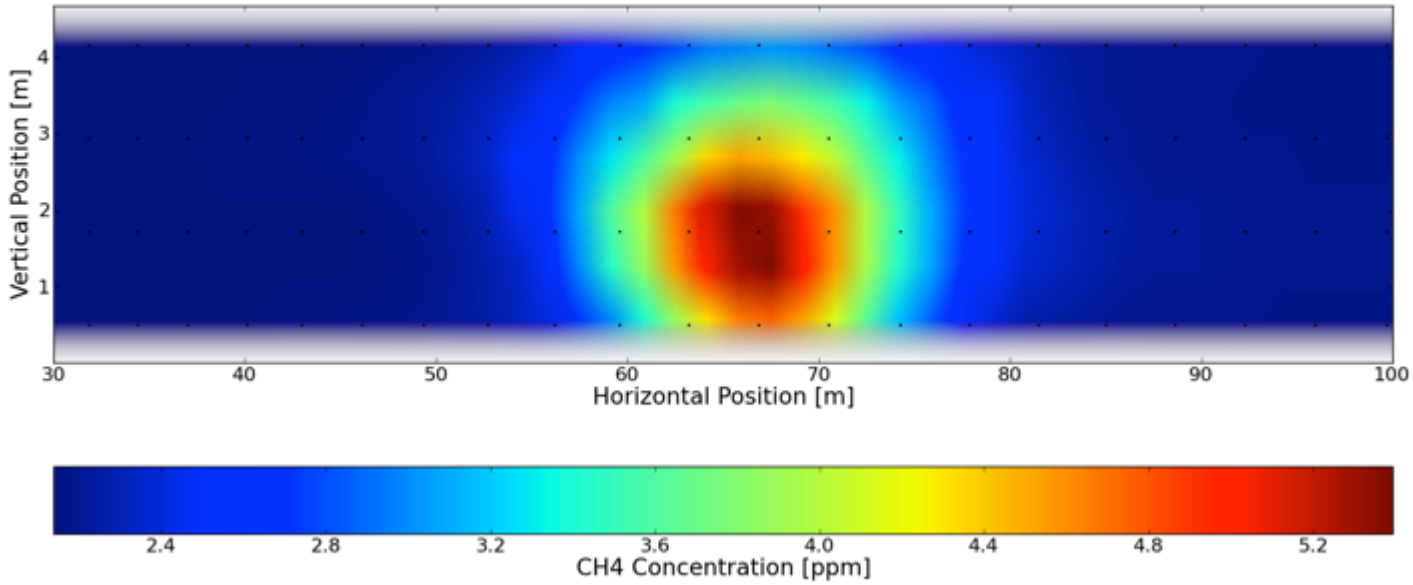
Run 2: 0.5 L/s

C:\Users\ttsai\Desktop\Uintah Basin Field Campaign\Texas field campaign\data\03_27_13\Plume3 Dish condensate tank\plume_1364396477_2013_3_27__8_1_unpickled.txt
v23_piecewise_compSR saved Sat May 18 16:29:30 2013
Carspeed 7.628597 m/s with 0.275167 m/s
Windspeed 3.97196363636 m/s with 0.380184 m/s and weighted average of 3.819721
Background 2.133000 ppm
GPS Lat: 33.142412; GPS Long: -97.299364; FWHM: 1.691215 m
Flux: 0.518498 L/s or 0.309340 g/s



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Run2 Surveyor

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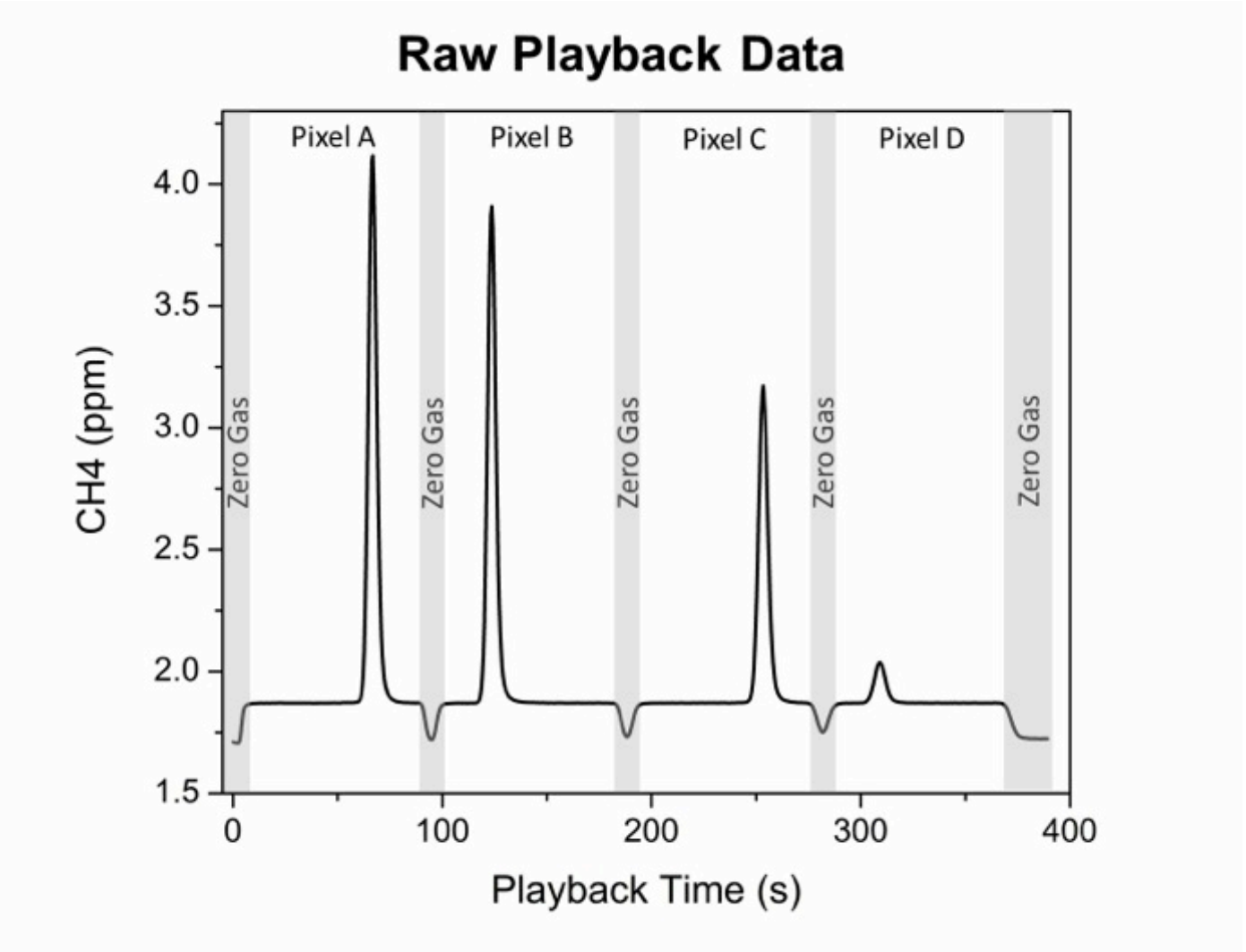
Result: Plume Image



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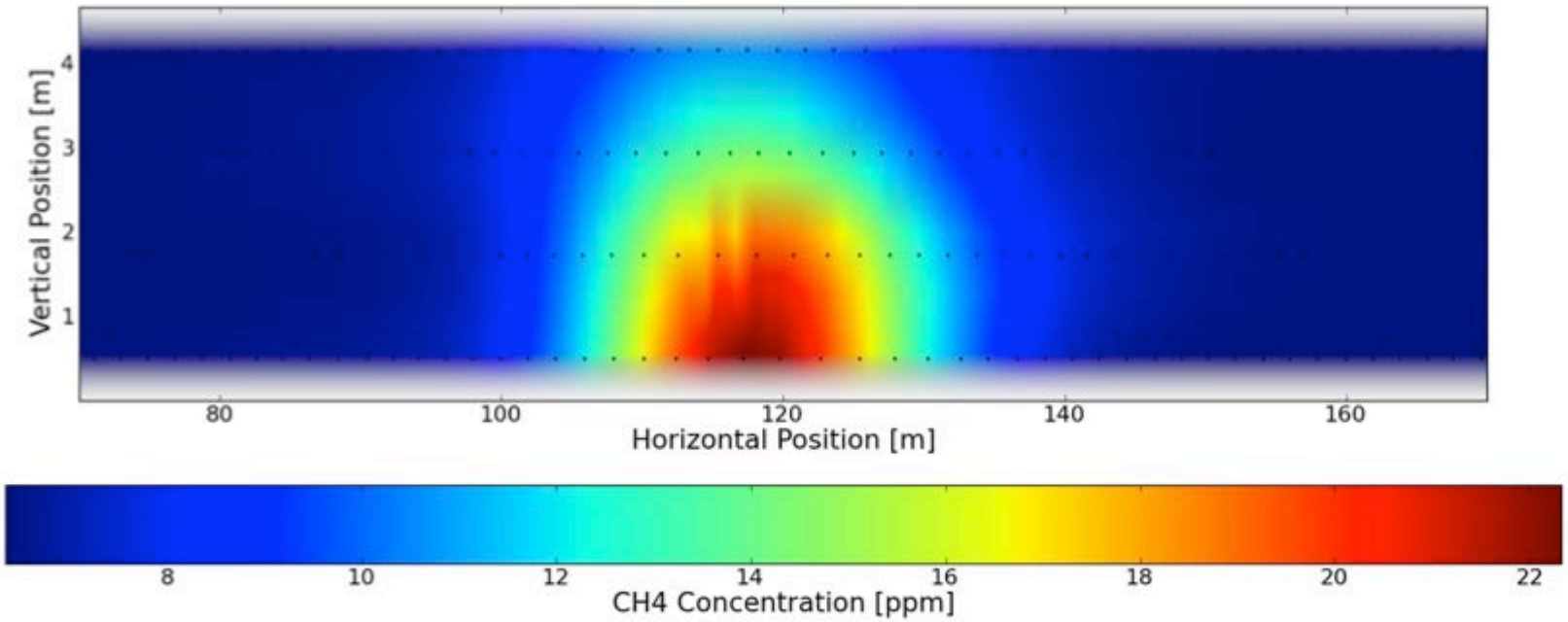
Result: Plume Image and Flux



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Wind data

= Flux of **143 lpm**

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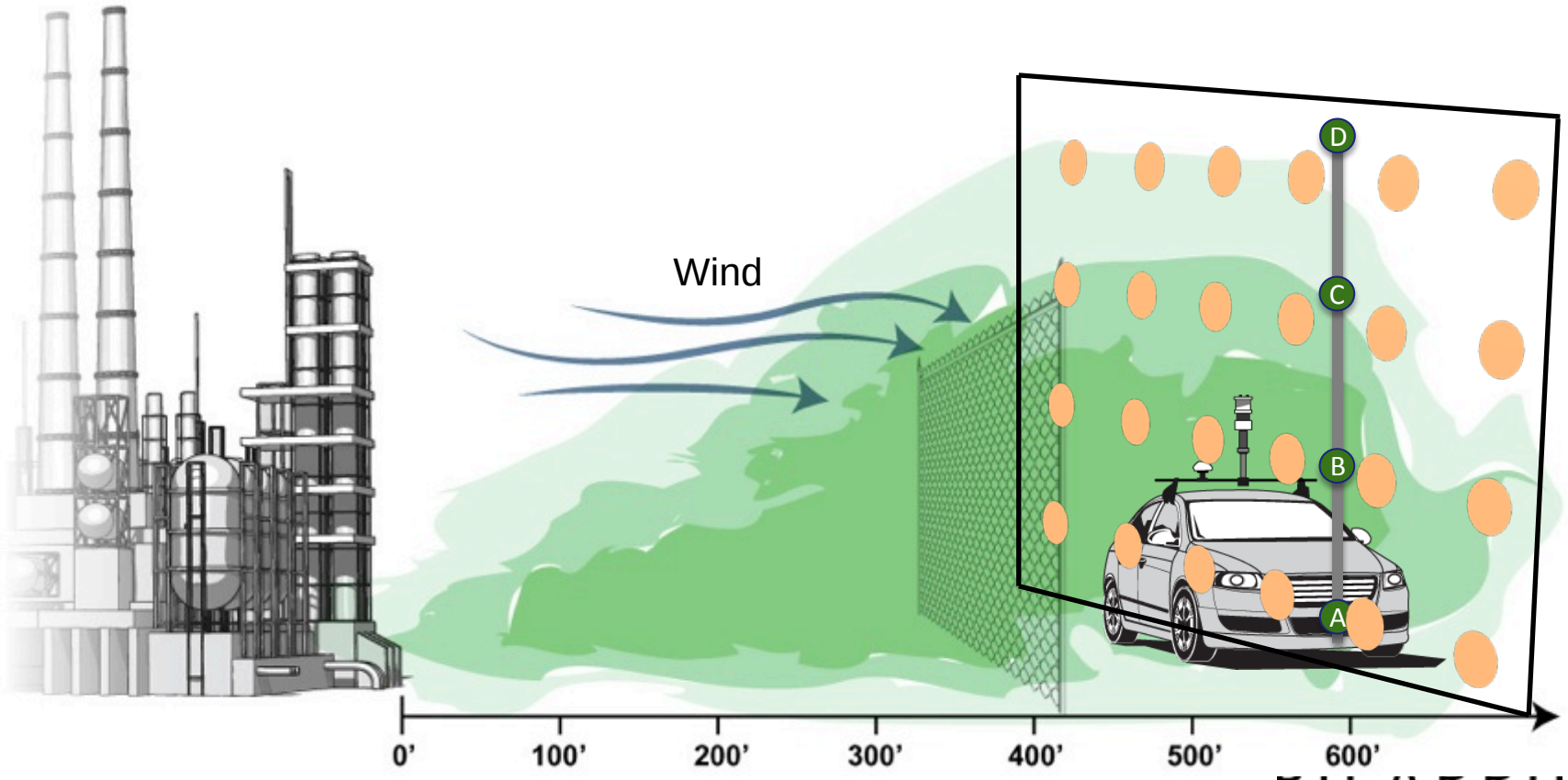
How do we quantify emissions?

- 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