Measuring Methane Emissions from Oil and Natural Gas Well Pads in the Barnett Shale Using the Mobile Flux Plane Technique

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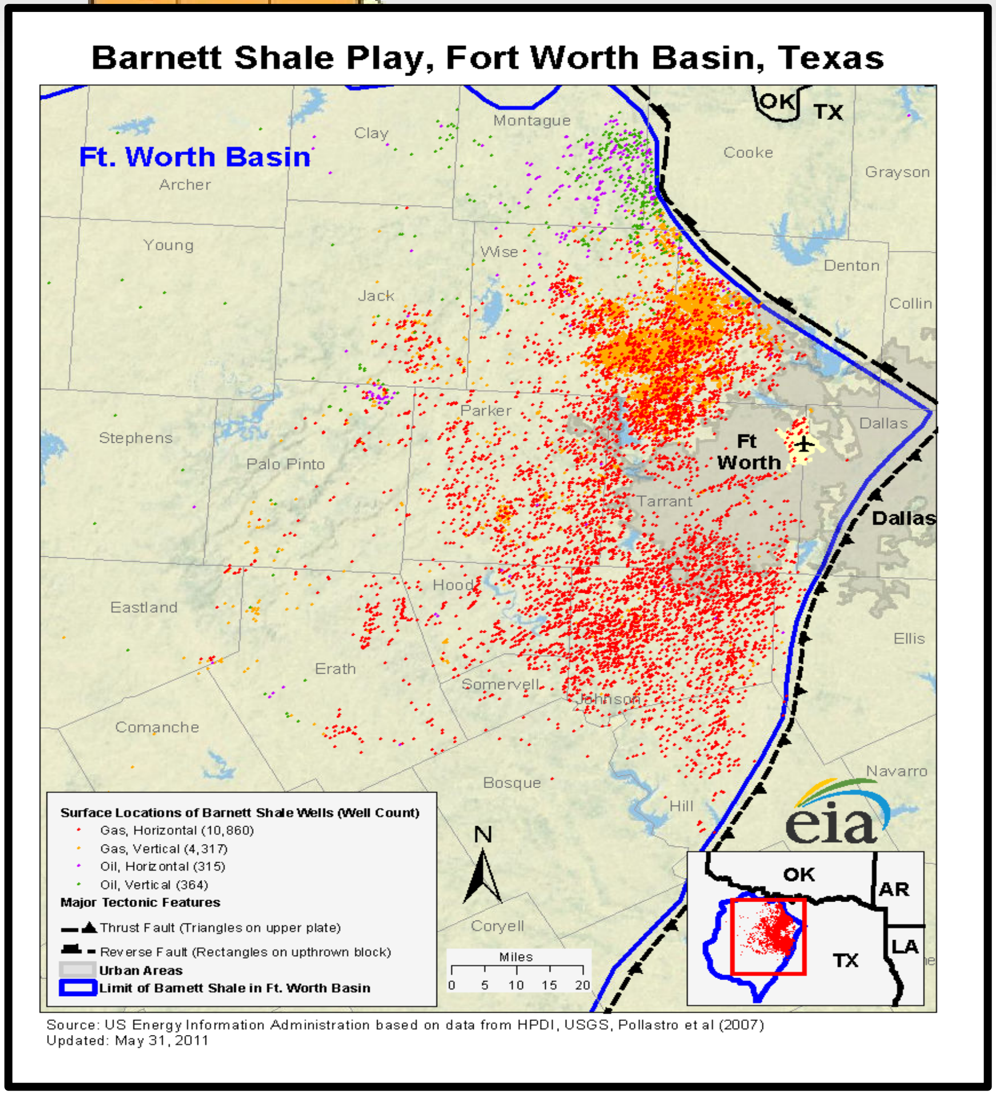
Methane Emissions in the Barnett Shale



- Natural Gas in the Barnett Shale
  - ~8% of total US natural gas production (2013)
  - ~17,500 production well pads (2013)
- Barnett Coordinated Campaign (October 2013)

EDF Environmental Defense Fund

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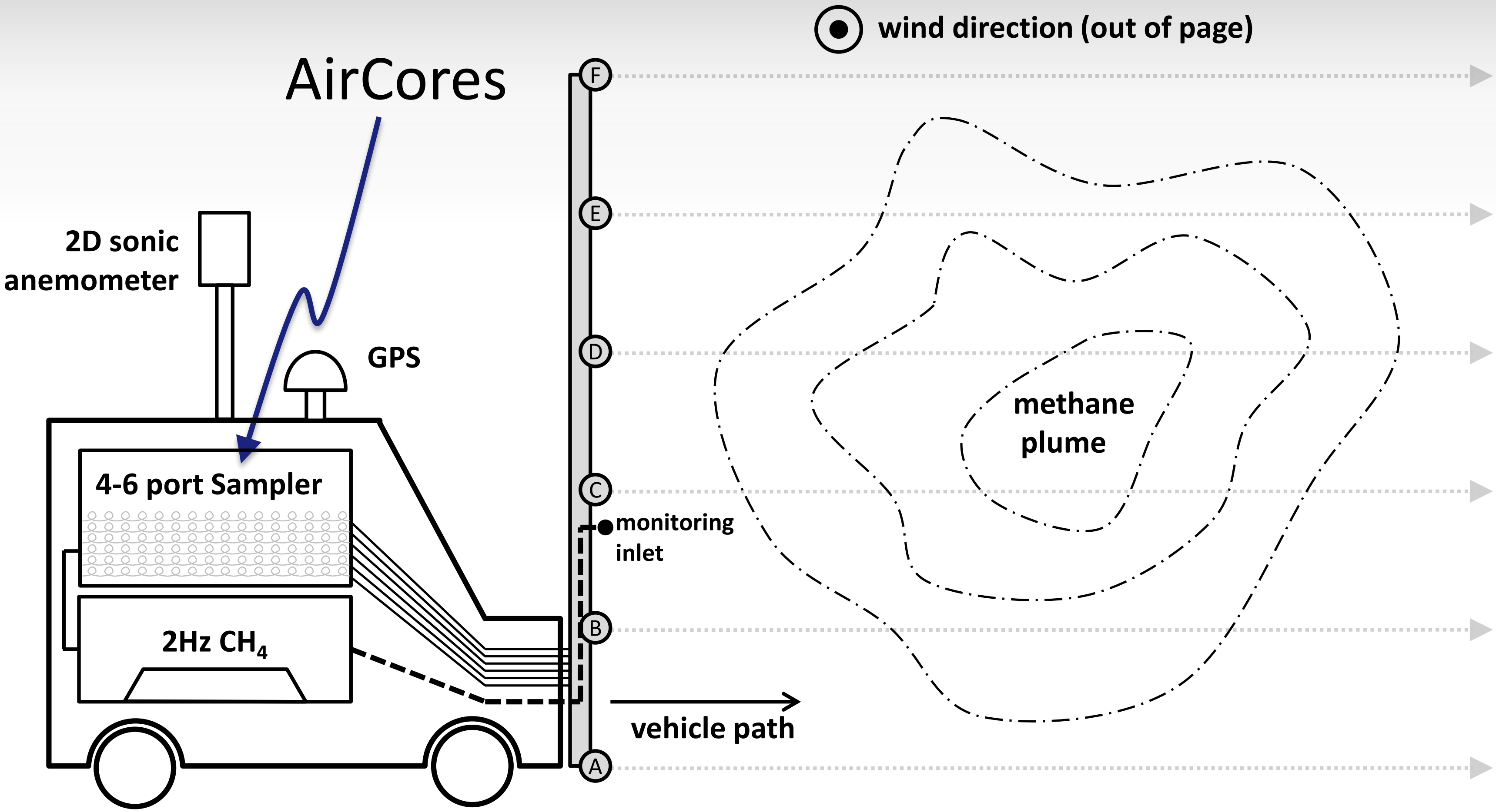
Motivation: Why Measure Well Pad Emissions

- There are about 500,000 natural gas wells in the U.S.
- Well pads during routine production (i.e., not including drilling and well completion) account for about 2% of total natural gas production [1]
- The distribution of emission rates from well pads is a skewed distribution, with a relatively small number of well pads contributing the bulk of the emissions
- ***Our Goal: To develop a simple, rapid, and accurate method for quantifying well pad emissions to identify the largest emitters***

[1] Howarth, R. W., Santoro, R., & Ingraffea, A. (2011). Methane and the greenhouse-gas footprint of natural gas from shale formations. *Climatic Change*, *106*(4), 679-690.

Mobile Flux Plane: Create a Virtual Net to “Catch” the Methane



$$q = \iint_A k(C(y,z) - C_o)\, u(z)\, dy\, dz$$

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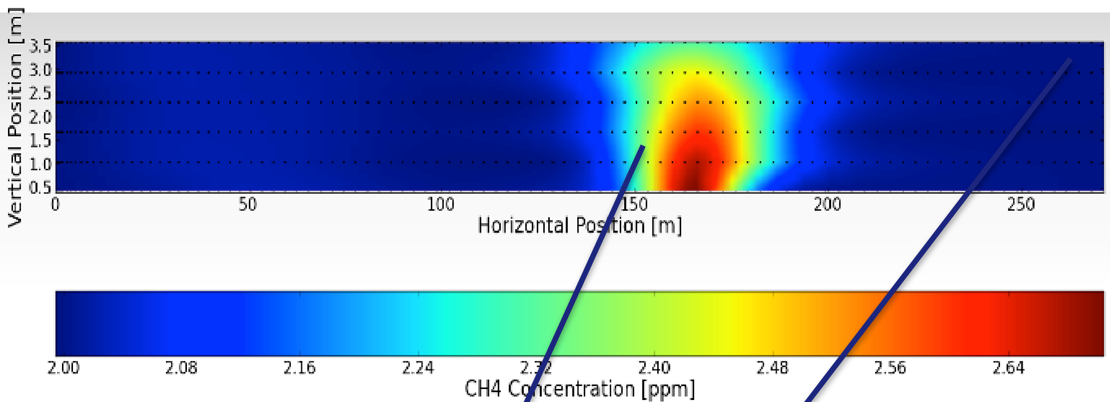
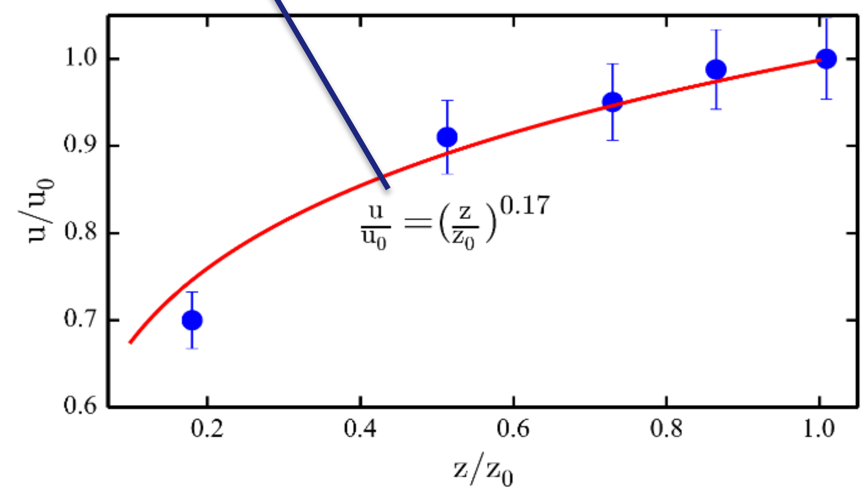
Calculating the Emission Rate



$$q = \iint_A k(C(y,z) - C_o)\, u(z)\, dy\, dz$$

- The 2D concentration image plus the vertical wind profile is used to calculate the emission rate
- No atmospheric transport model or knowledge of emission location is required for the calculation

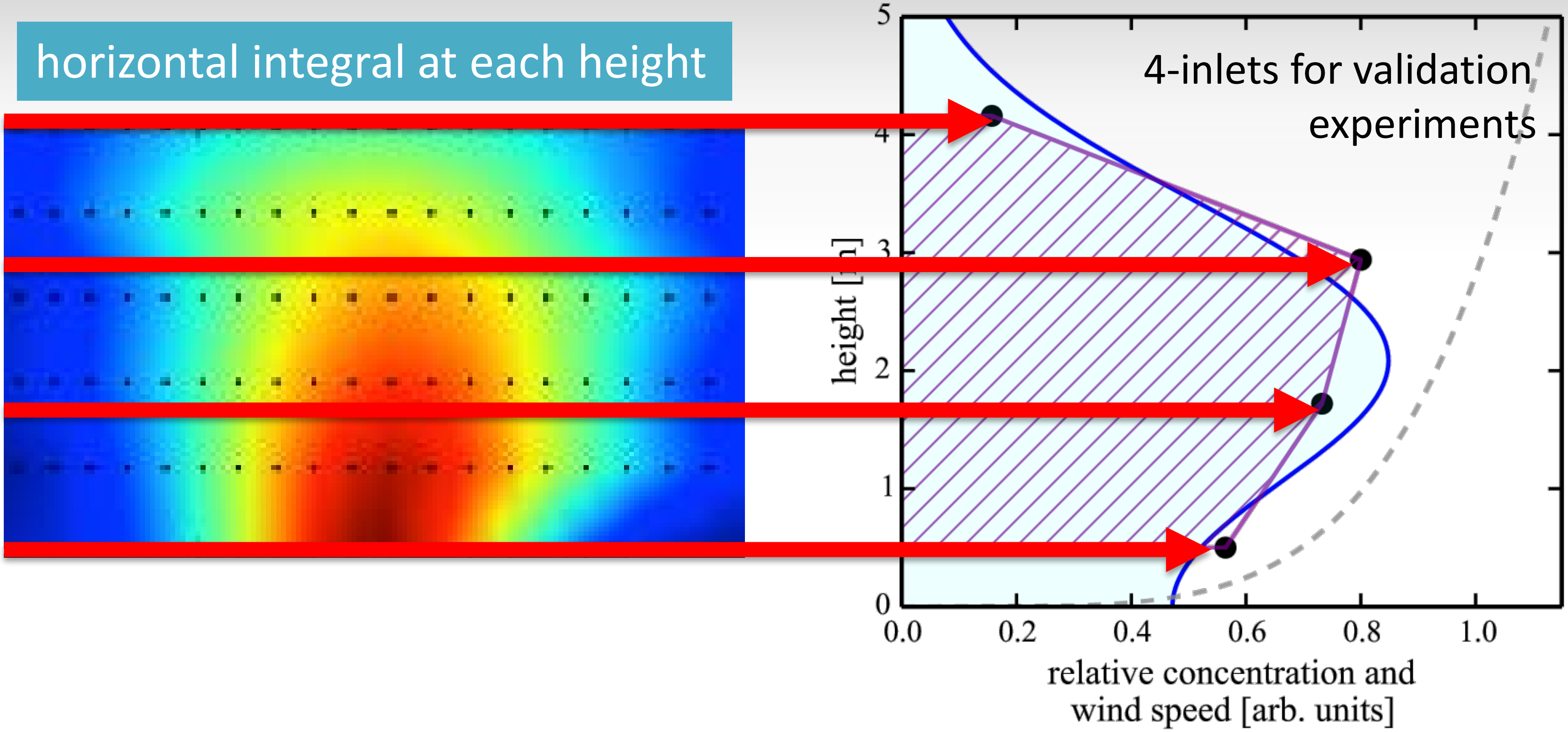


Controlled Release Validation Experiments

- Measurements under different atmospheric stability classes (A, B, C, and D) and different surfaces (high grasses, hard-packed earth, low grasses, paved surface)

Parameter	Conditions min – max (mean ±std. dev.)	Comments
Distance to source	5 – 81 m (34 ± 15 m)	
Release Height	1 – 3.66 m (2.2 ± 0.9 m)	Measurements above 3 meters were made on top of a ~2 m tall trailer to simulate a tank leak
Methane Flow Rate	0.43 – 2.14 kg / hr (1.07 ± 0.69 kg / hr)	
Wind Speed	1.0 – 16 m / s (3.6 ± 2.95 m/s)	

Integration Methods – Validation Experiments



- Plume integrated horizontally (along path of vehicle)
- Two methods of vertical plume integration:
  - Trapezoidal integration
  - Ground reflected Gaussian plume model with vertical width and center as fit parameters

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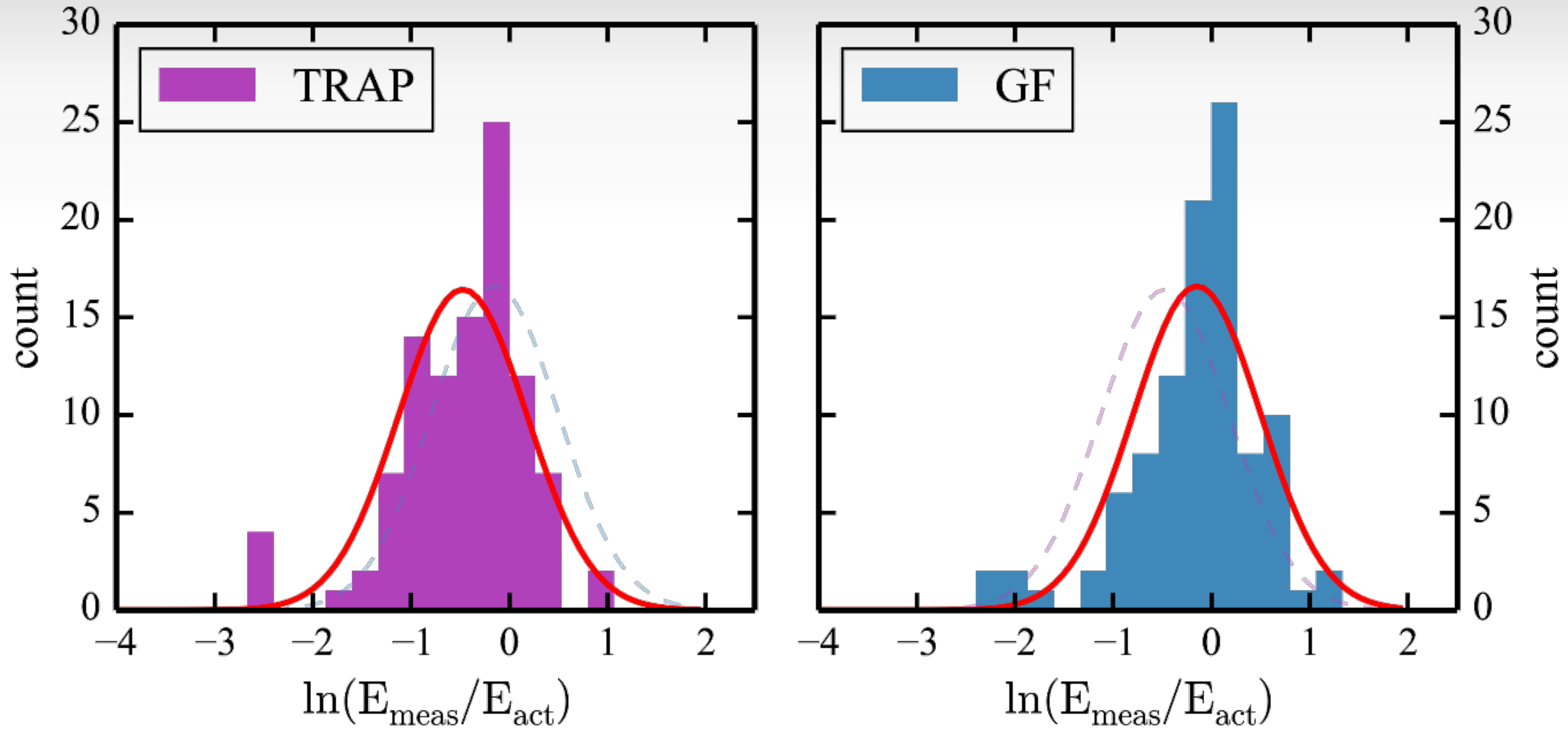
Validation Experiments Results

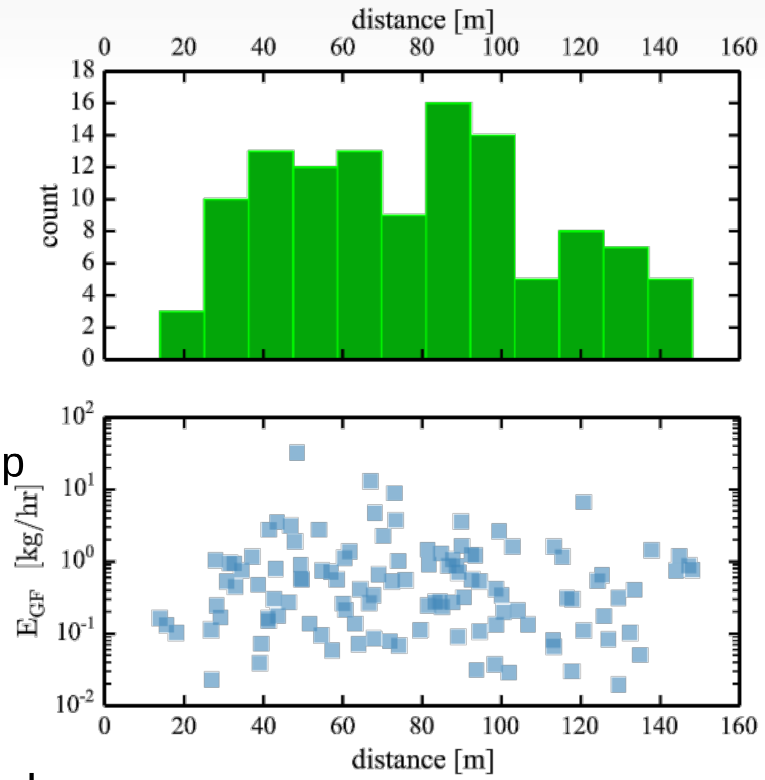


Emeas / Eact = 1.0 → ideal

- Trapezoidal integration (TRAP): mean = 0.77; 1-sigma range: 0.40 – 1.47
- **Gaussian Plume Fit (GF): mean 1.07; 1-sigma range: 0.56 – 2.04; 2-sigma range: 0.29 – 3.9**

Barnett – well pad study methodology

- Driving path randomly selected from Barnett region, based on wind direction and proximity of well pads to public roads
- Emissions were quantified for all detected plumes (N = 207). Data selection criteria were applied for
  - wind speed > 1 m/s (N = 200)
  - plume attributable to a single well pad (N = 177)
  - distance to well pad < 150 m (N = 150)
  - centroid of the Gaussian plume fit was below the top inlet (N = 142)
  - vertical width from the Gaussian plume fit was less than 5 m (N = 115)

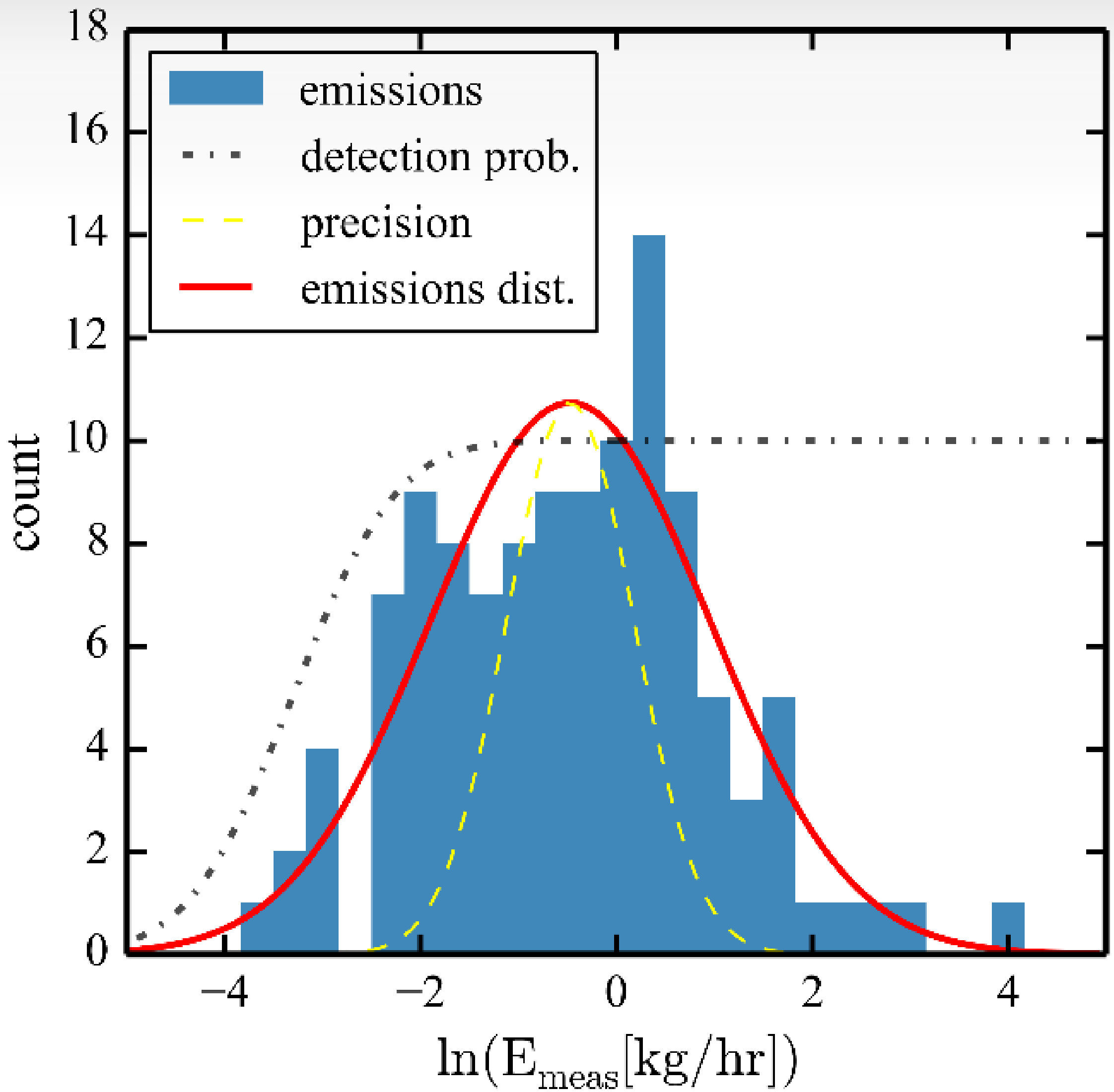


- 37% of well-pads upwind of the vehicle track and within a nominal distance of about 90 meters of the vehicle had NO detectable emissions

Barnett – Distribution of Emissions

- For all leaks with detectable emissions, the arithmetic mean of the distribution is 1.63 kg / hr,
  - 1-sigma (67%) range of 0.46 – 5.7 kg / hr
  - 2-sigma range (95%) of 0.13 – 20 kg / hr

- The distribution of the emissions is much broader than the measured precision from the validation experiments



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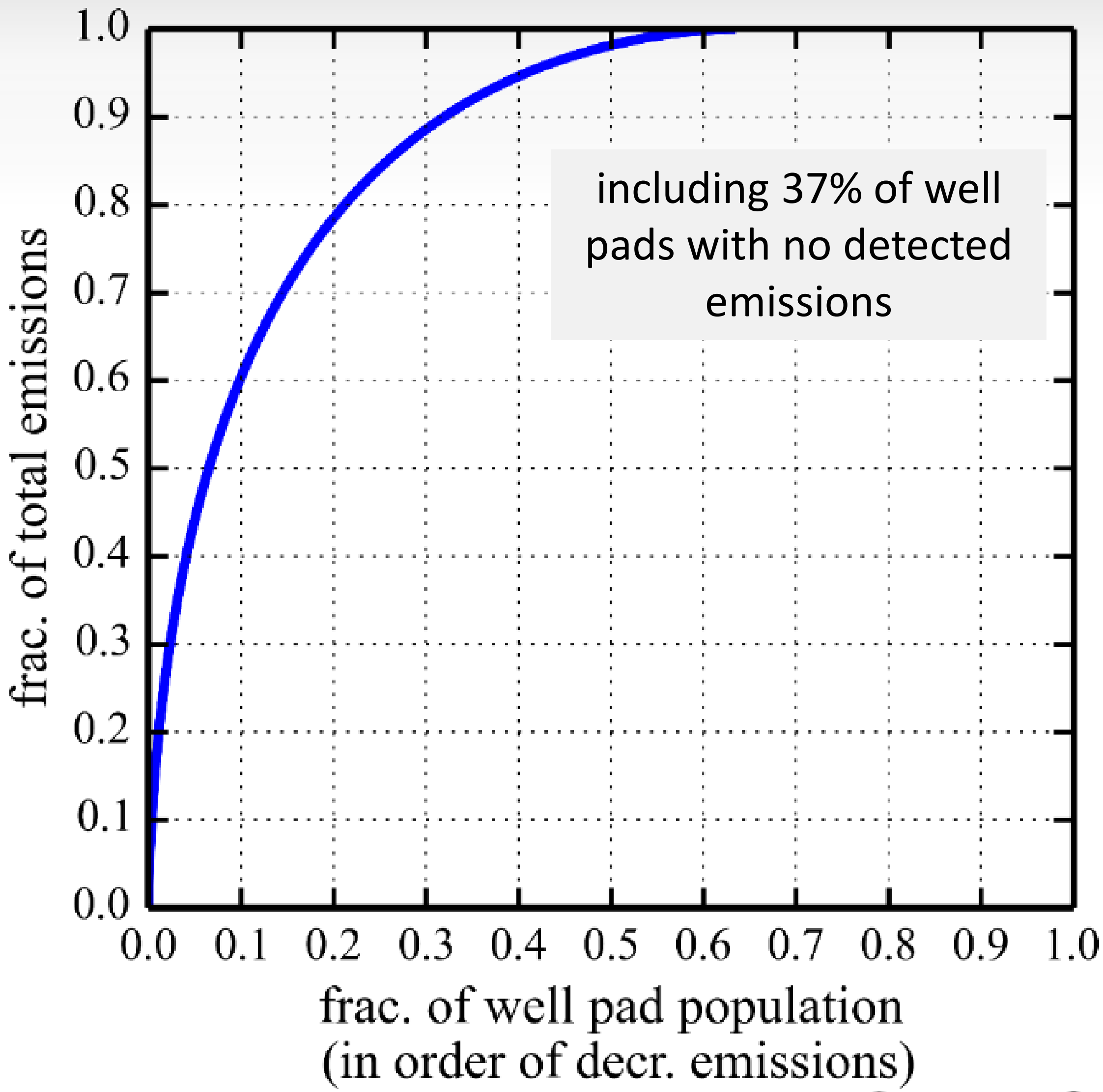
Well Pads: Distribution of Emissions

- 10% of the total emissions is from the top 0.3% of the sources
- 20% of the total emissions is from the top 1.1% of the sources
- 50% of the total emissions is from the top 6.6% of the sources
- 80% of the total emissions is from the top 22% of the sources
- The bottom 50% of the sources contribute less than 2% of the total emissions.



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Thank You!