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Quantifying the relative contribution of natural gas fugitive emissions to total methane emissions in Colorado and Utah using mobile $\delta^{13}CH_4$ analysis

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Oil & Gas Activities in the Denver – Julesburg Basin

- > **20,000** active oil and gas wells
- Yearly natural gas production (2008):

~3,625 Gg / yr

(~1% of US production)

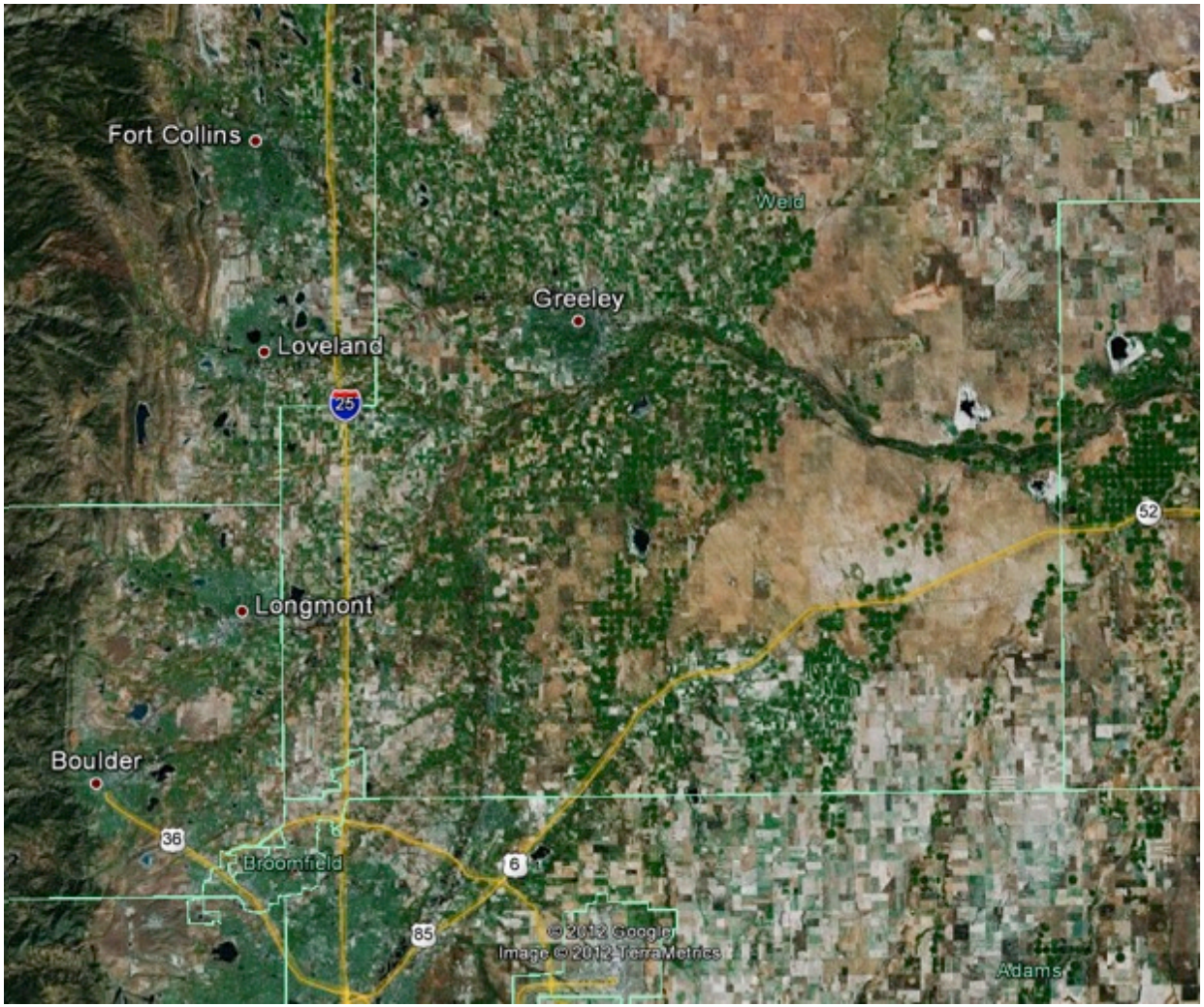
CH_4 emissions

- Bottom-up estimate:

46 – 86 Gg / yr

- Top-down estimates:
  derived from non-methane hydrocarbon measurements and inventories; $\Delta^{14}CO_2$

40 – 272 Gg / yr



Sources: Pétron et al. (2012) "Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study" JGR v117, D04304
La Franchi et al. (2013) "Constraints on emissions of carbon monoxide, methane, and a suite of hydrocarbons in the Colorado Front Range using observations of 14CO2, ACP discussions.

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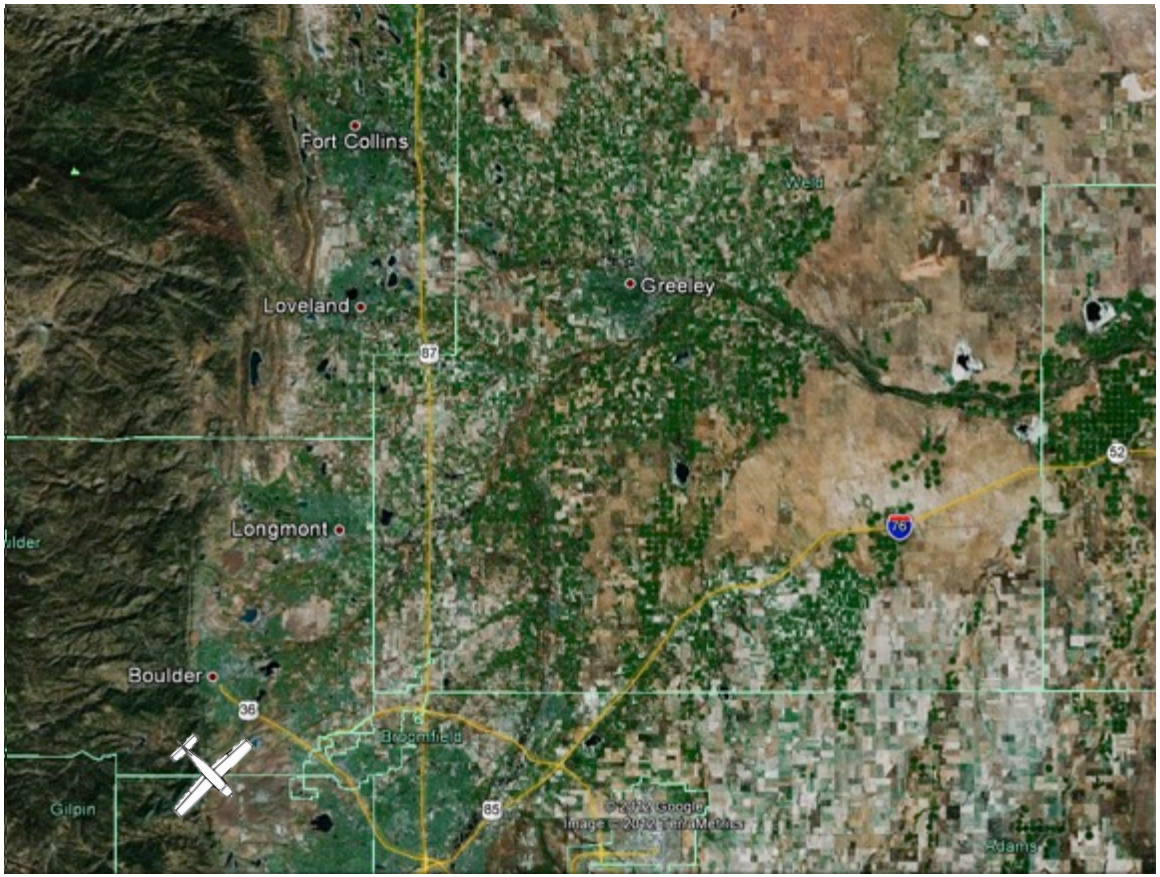
Other Sources of Methane

How do we quantify the O&G fraction of the total emissions?

- O & G[1]:
  46 – 252 Gg / yr
- Landfills[2]:
  16 – 22 Gg / yr
  based on EPA mandatory GHG reporting
- Cattle Feedlots & Manure Mgmt.[3]:
  41 – 58 Gg / yr
  565,000 head of cattle in Weld Co.
- Total:
  103 – 332 Gg / yr
  O&G fraction **37-82%**



Source: [1] Pétron et al. (2012) "Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study" JGR v117, D04304
[2] U.S. EPA (2010) "GHG data from large facilities" http://ghgdata.epa.gov/ghgp/main.do
[3] Pétron et al. (2012) and Johnson & Johnson (1995) "Methane emissions from cattle" J. Anim. Sci 73, 2483 – 2492.

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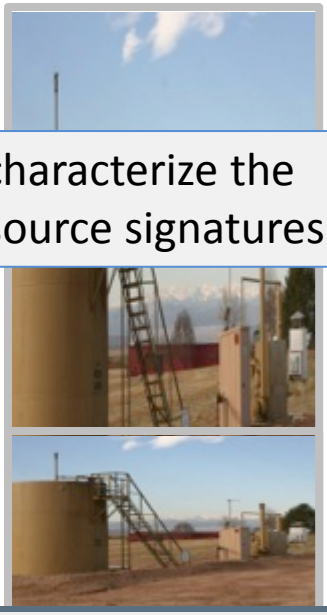
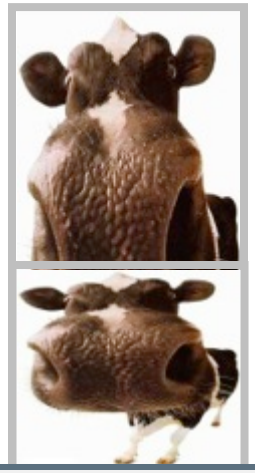
Using Stable Isotopes to Identify Sources

$$\delta^{13}CH_4(‰) = 1000\left[\frac{^{13}CH_4/\,^{12}CH_4}{r_{PDB}} - 1\right]$$

$$\delta_{tot} \approx \frac{E_{O\&G}\delta_{O\&G} + E_{cow}\delta_{cow} + E_{land}\delta_{land}}{E_{O\&G} + E_{cow} + E_{land}}$$

Step #1: characterize the individual source signatures





-30 -35 -40 -45 -50 -55 -60

Step #2: quantify the overall source signature

Source Signature

Source: Quay et al. (1988) "isotopic composition of methane release from wetlands: implications for the increase in atmospheric methane" Glob. Biogeochem. Cycl. v2, 385-397.

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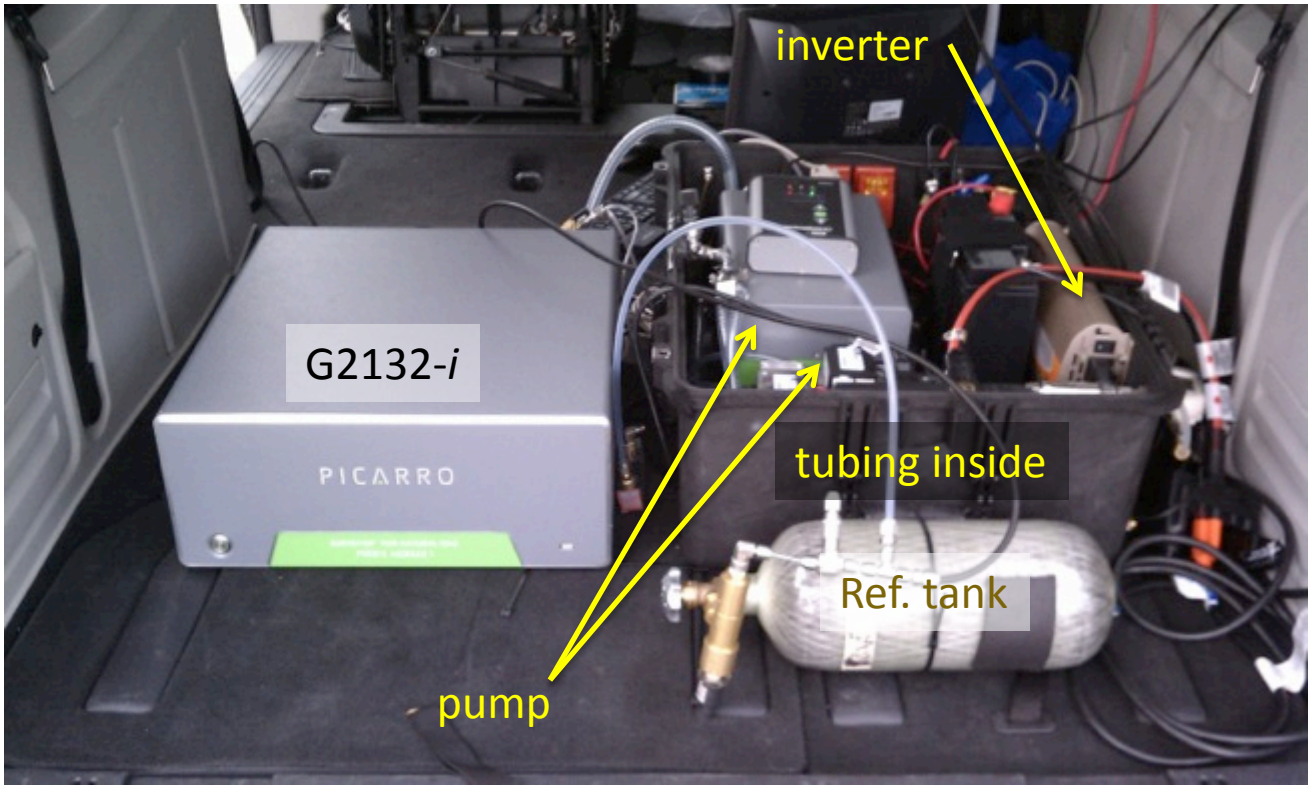
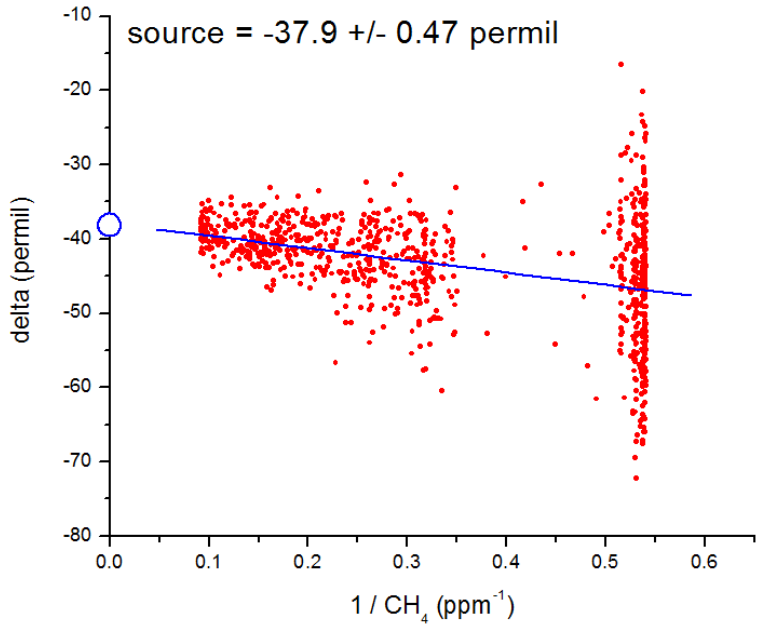
Mobile Laboratory – the Picarro G2132-*i* isotopic CH_4 analyzer

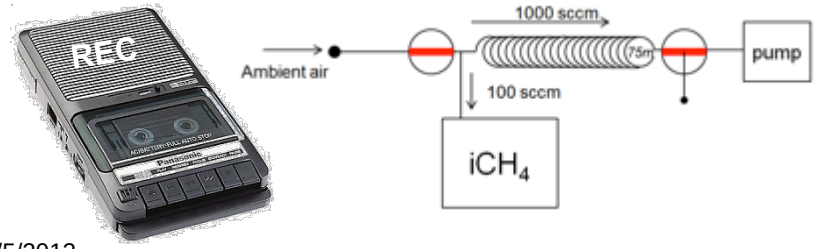


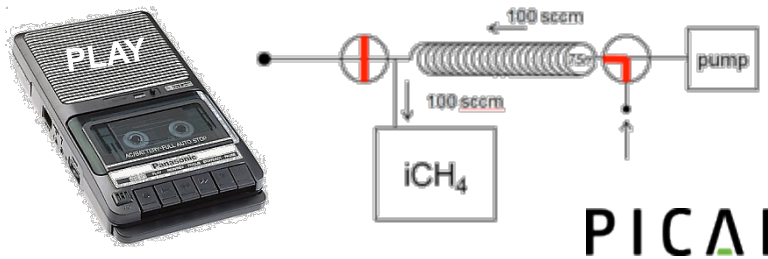
Precision, $\delta^{13}C$ in CH_4 (1-σ , 1 hr window)	< 0.8 ‰ guaranteed precision at > 1.8 ppm 5 min. average < 0.5 ‰ guaranteed precision at > 1.8 ppm, 15 minute average

Step #1: Individual Source Characterization

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







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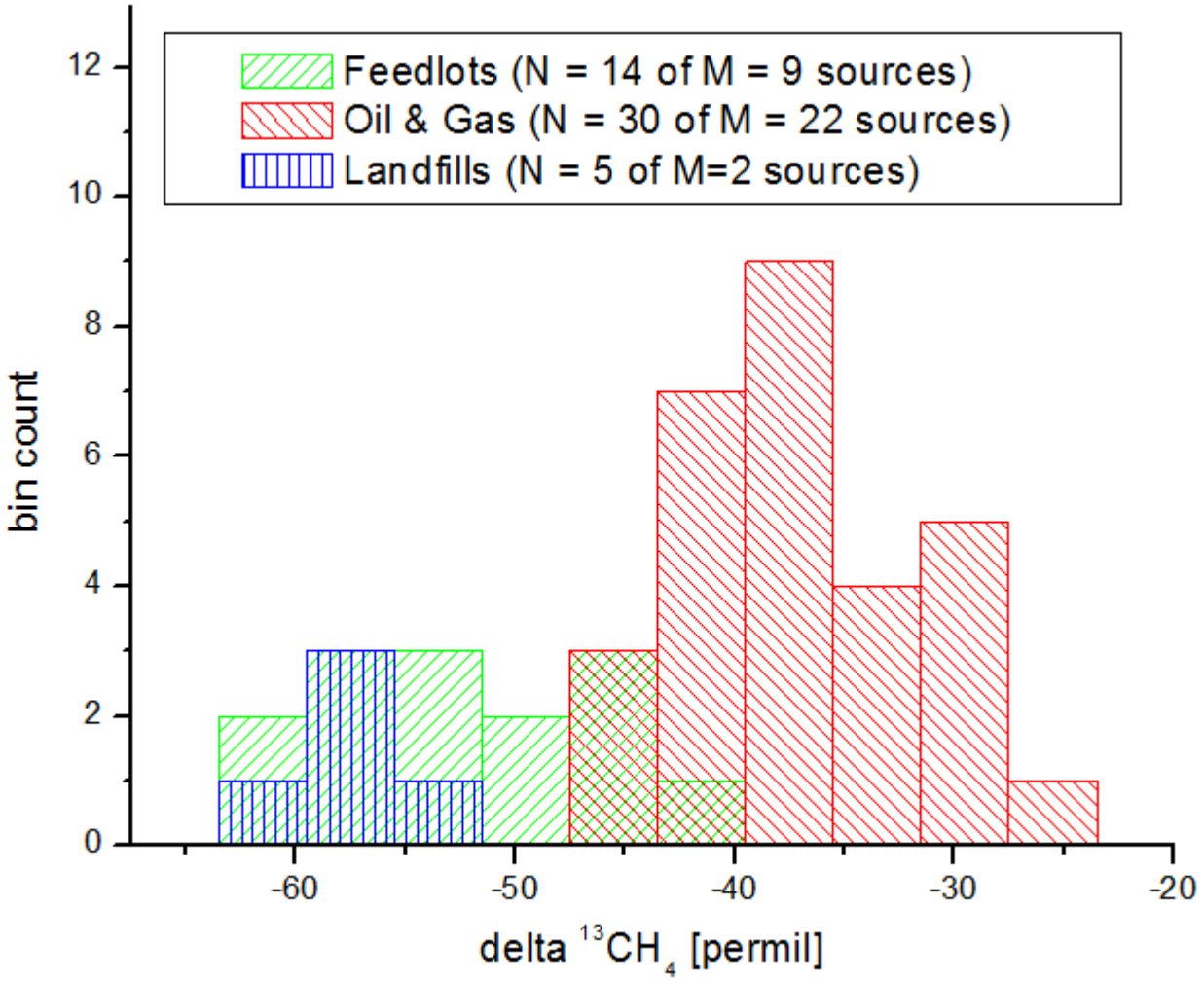
Individual Sources (33 sources total)



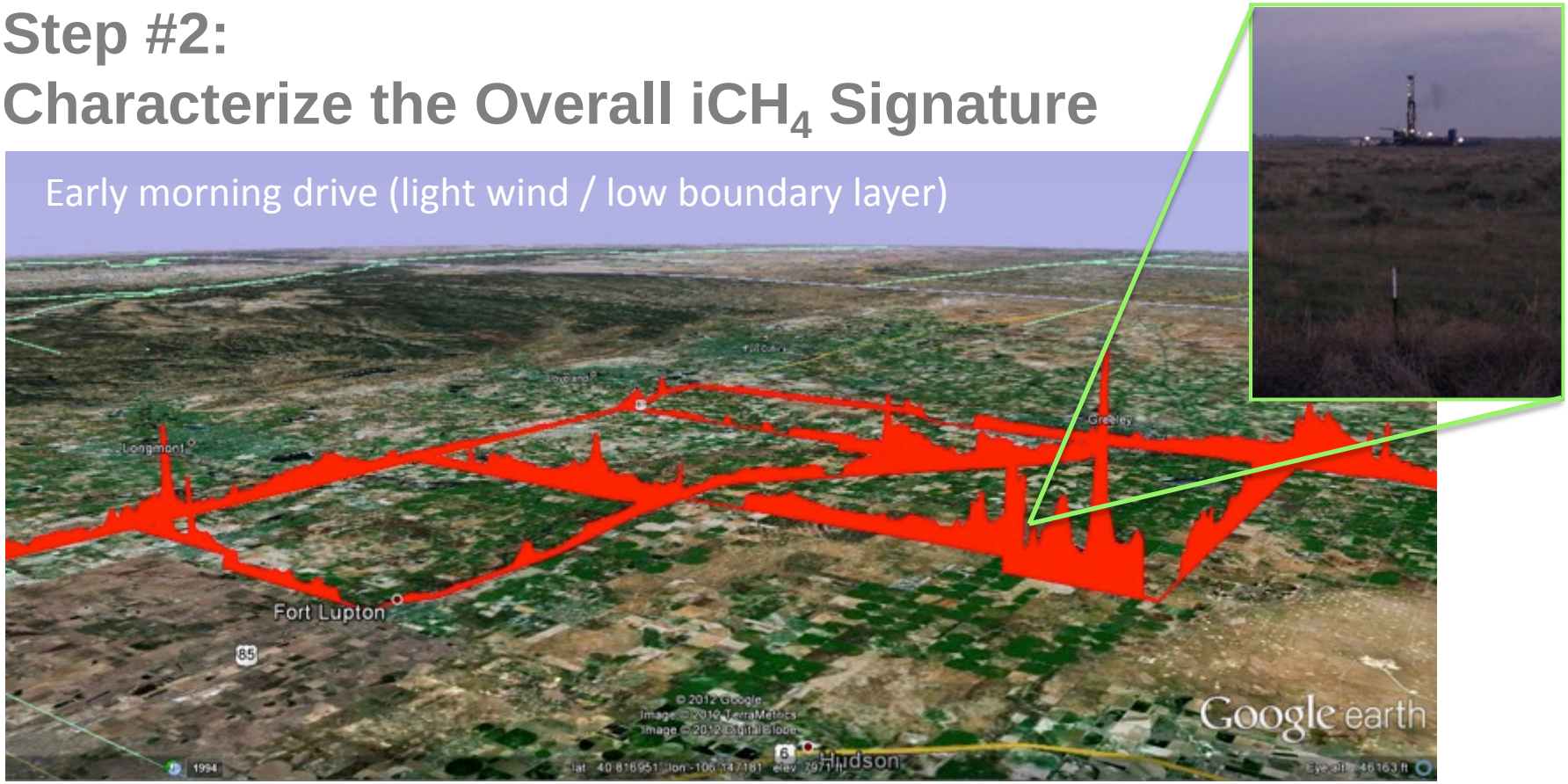
δ_{cow}	– 45 to – 55 (C4 diet)
$\delta_{O\&G}$	– 30 to – 60
δ_{land}	– 48 to – 56

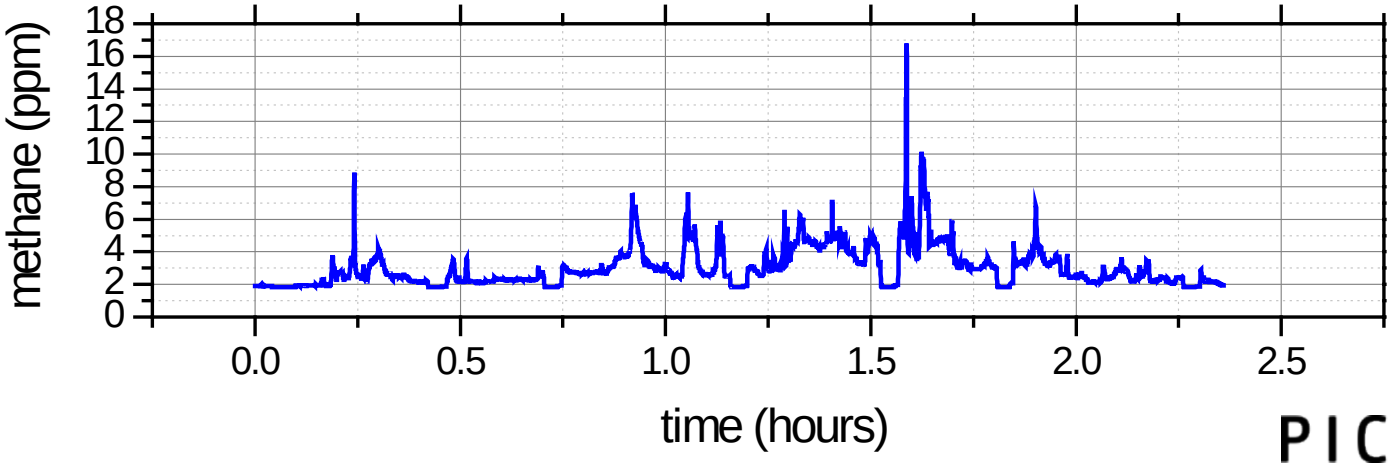
Quay et al. (1988)

(10-15 minutes of analysis / sample)

Step #2:
Characterize the Overall iCH_4 Signature

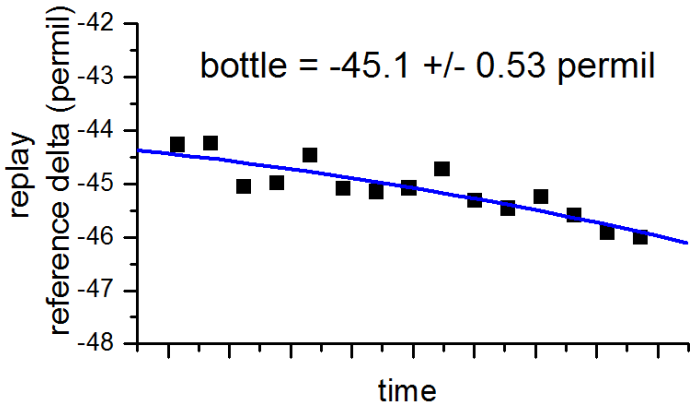
Early morning drive (light wind / low boundary layer)

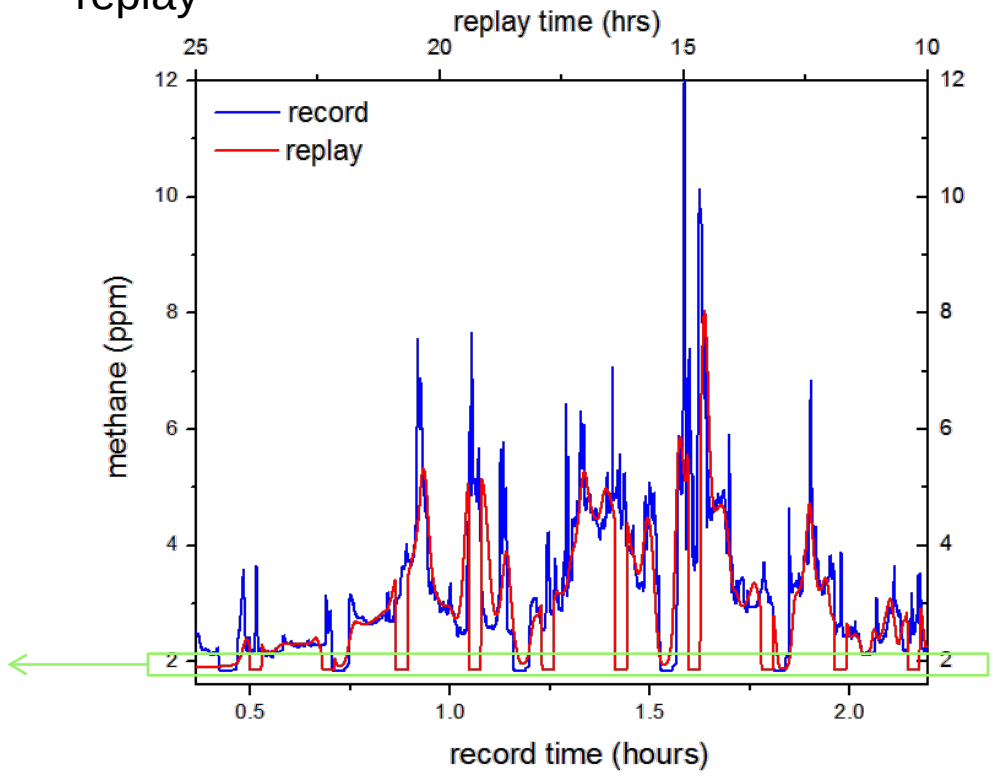




MegaCore: A Really Big Air Core

- 1500’ ft of ½ O.D. synflex tubing
- Sample ambient air during ~2 hour drive
- Playback sample into *i*CH4 analyzer for 15 hours in the laboratory
  - Reference gas used during recording AND replay





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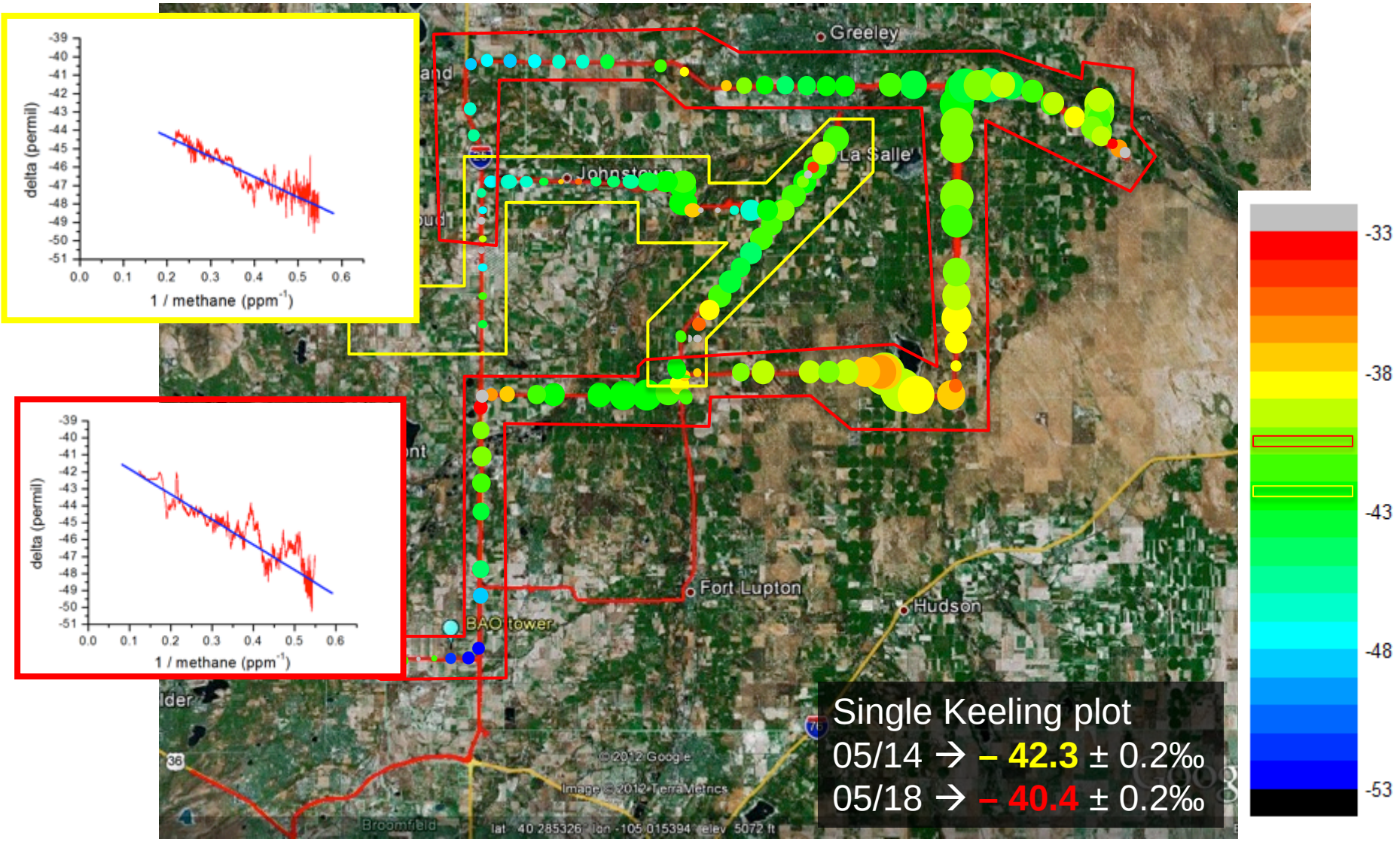
Two MegaCore Campaigns: May 14th and 18th 2012



Size = magnitude of CH_4 signal | color = delta

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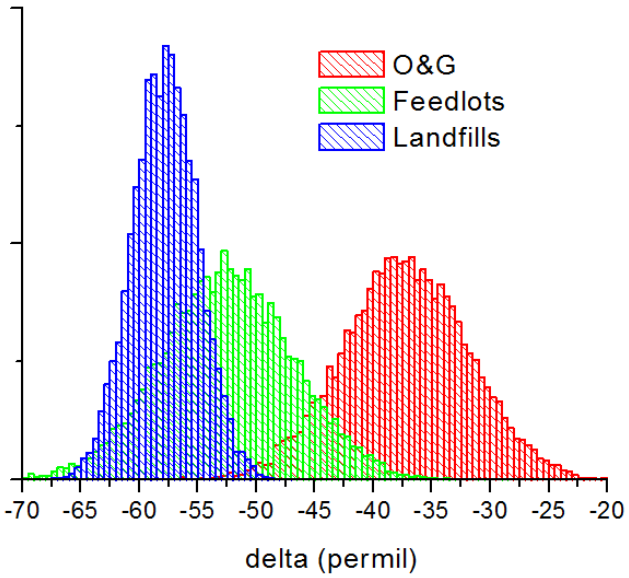
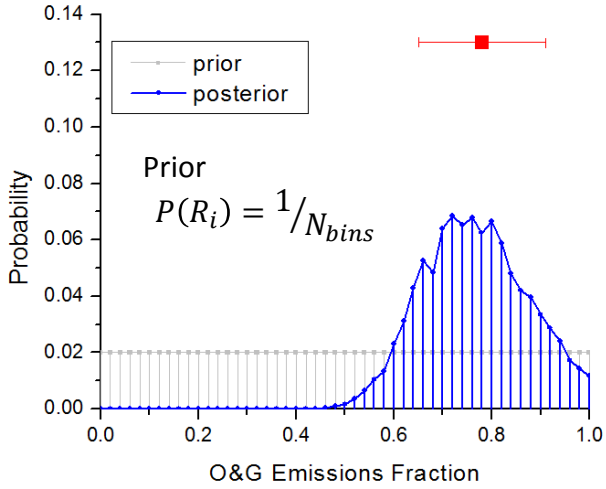
Emissions & Isotopes Model

$$\delta_{tot} = R_{O\&G}\delta_{O\&G} + (1 - R_{O\&G})\delta_{C\&L}$$



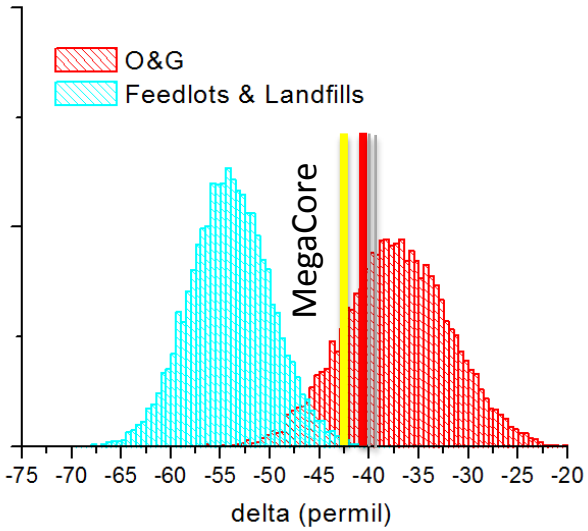
Bayesian analysis of O&G Emissions Fraction (hypothesis) given the MegaCore data (evidence)



$$P(R_i|\delta_{obs}) = \frac{P(\delta_{obs}|R_i)P(R_i)}{\sum_{R_j=0-1} P(\delta_{obs}|R_j)P(R_j)}$$

Monte Carlo simulation of feedlot and landfill emissions and isotope signatures to generate combined feedlot & landfill source profile

$$\delta_{C\&L} = \frac{E_{cow}\delta_{cow} + E_{land}\delta_{land}}{E_{cow} + E_{land}}$$



- O&G is **78 ± 13%** of total emissions
- With E_{land} = 19 and E_{cow} = 47 Gg / yr

$E_{O\&G}$ = 239 Gg / yr

Cf.: inventory : 46 - 86

top-down : 72 - 252

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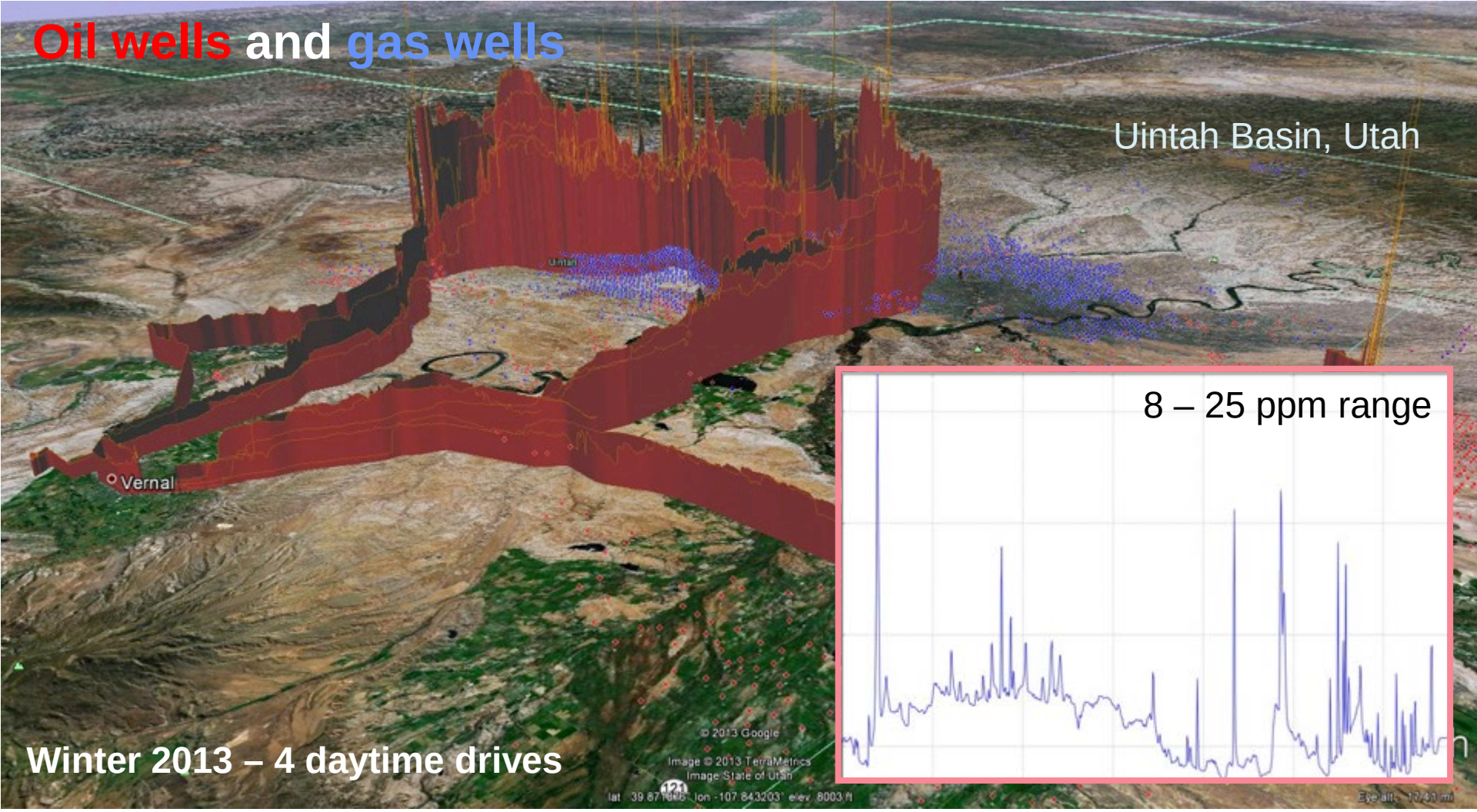

Concentrations 3-5X above background levels over 100's of square miles

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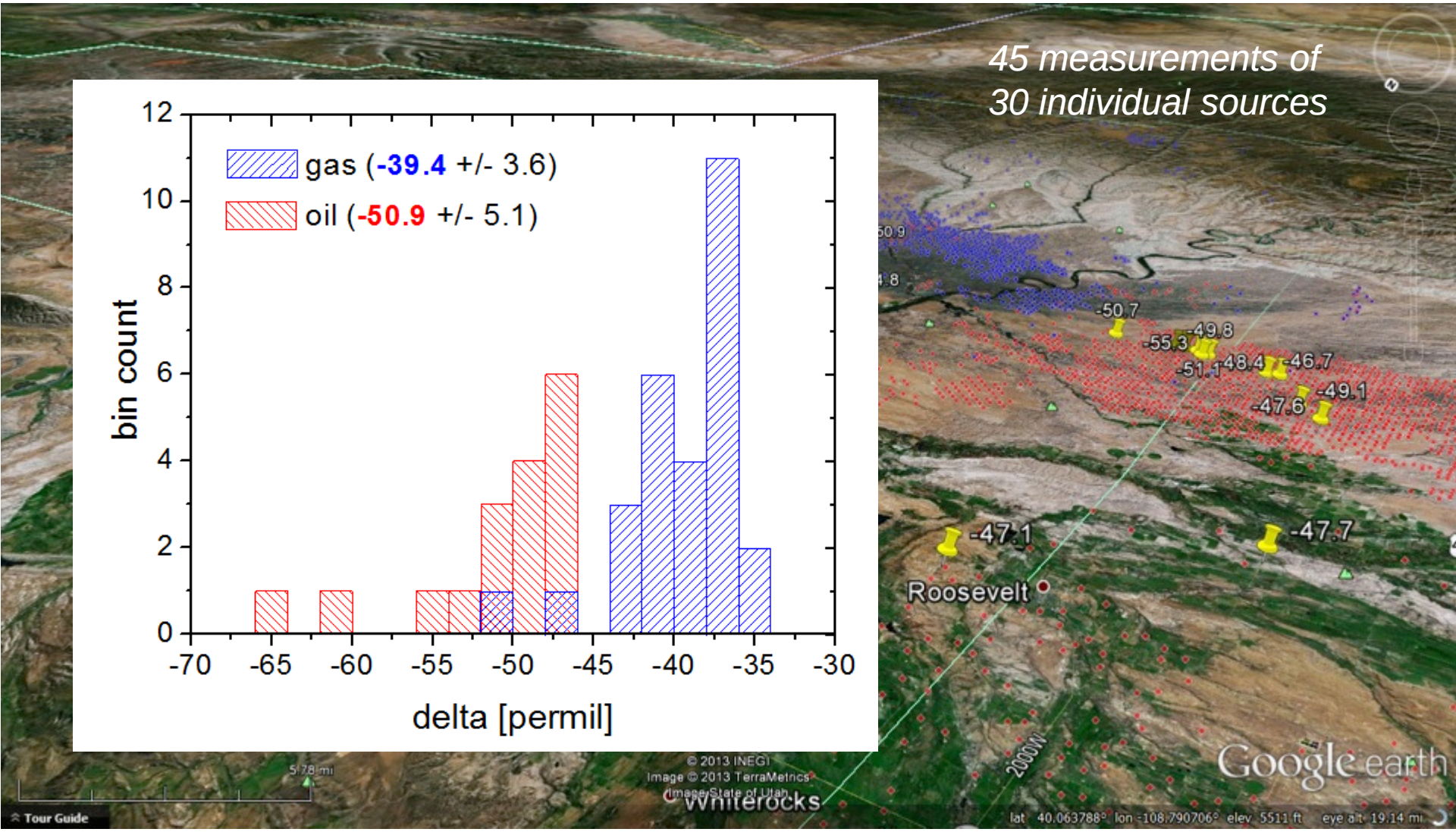
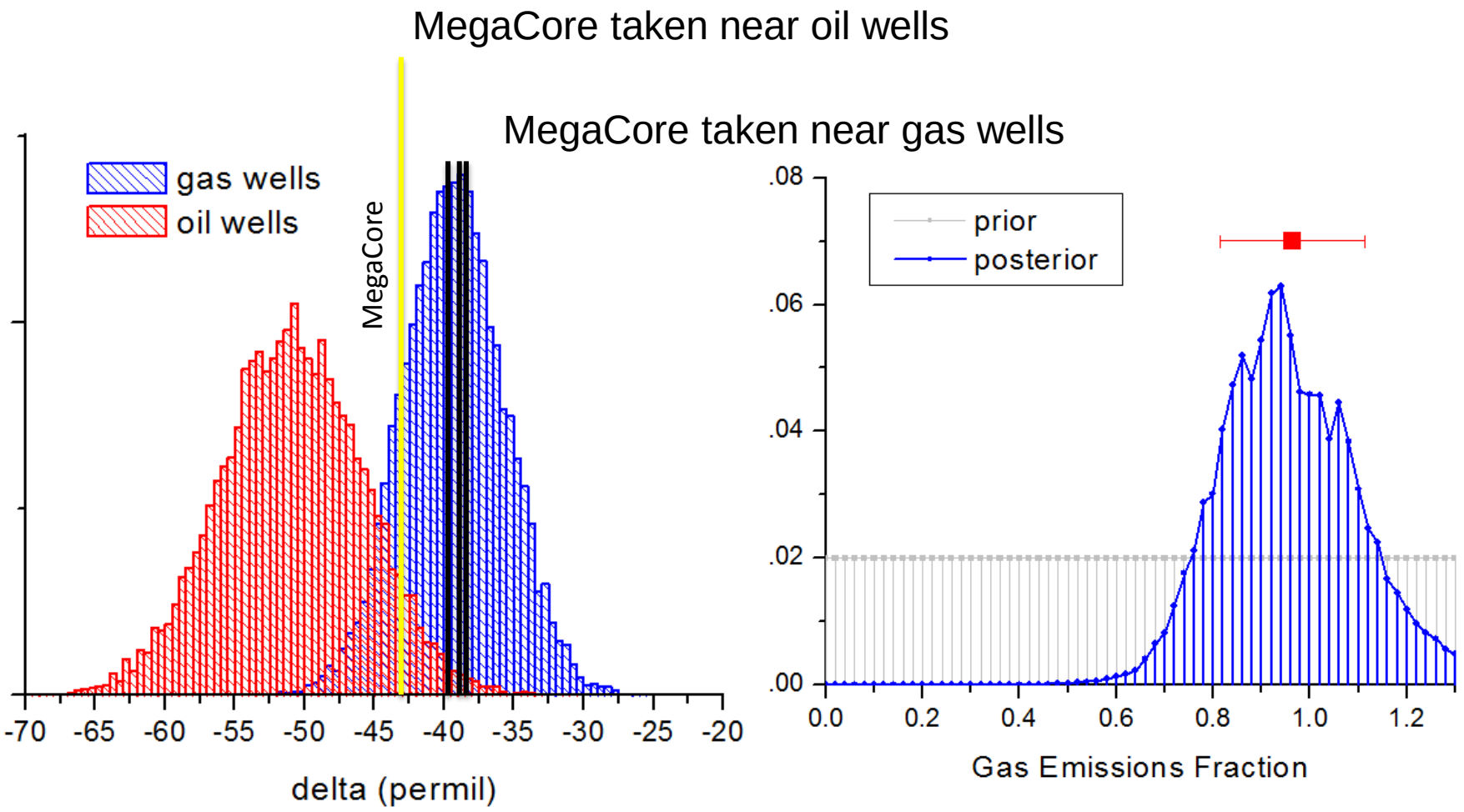
Uintah Individual Source Isotopes

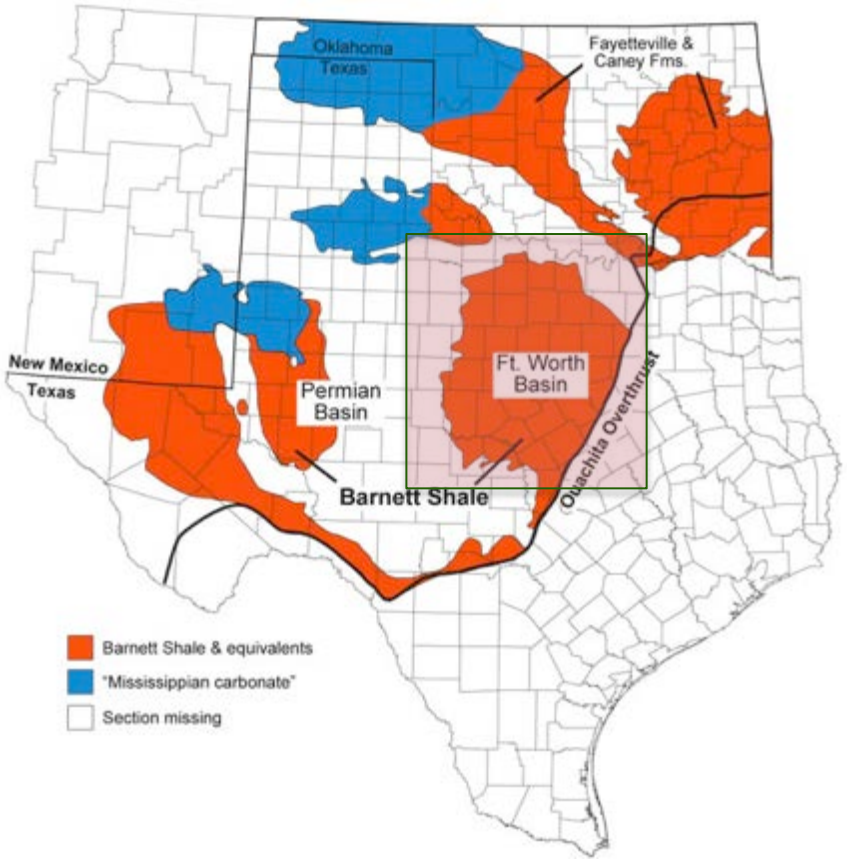


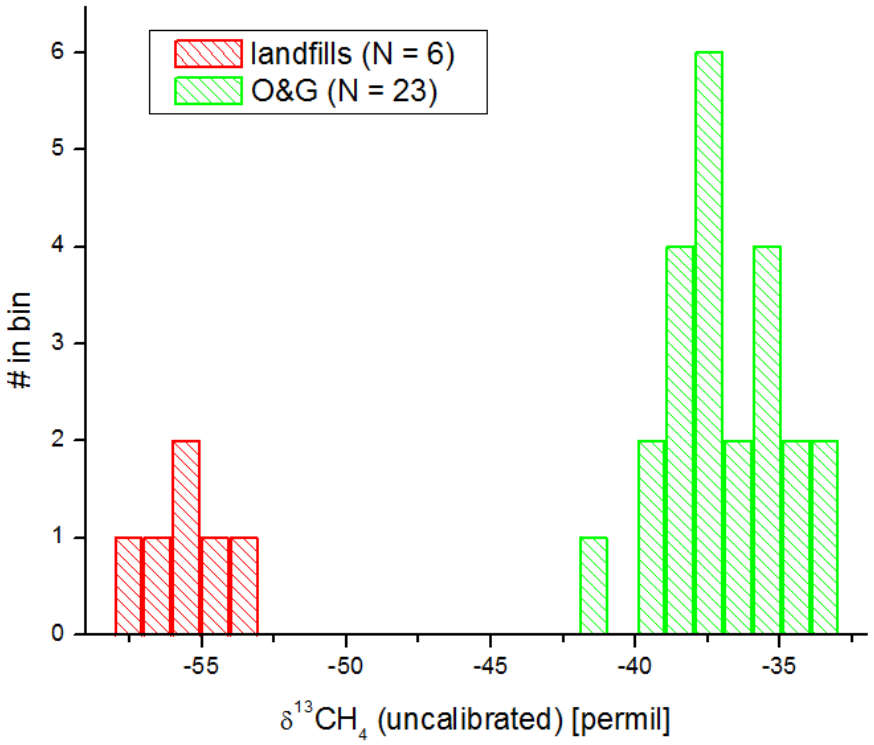
Uintah – Partitioning between Oil and Gas Wells



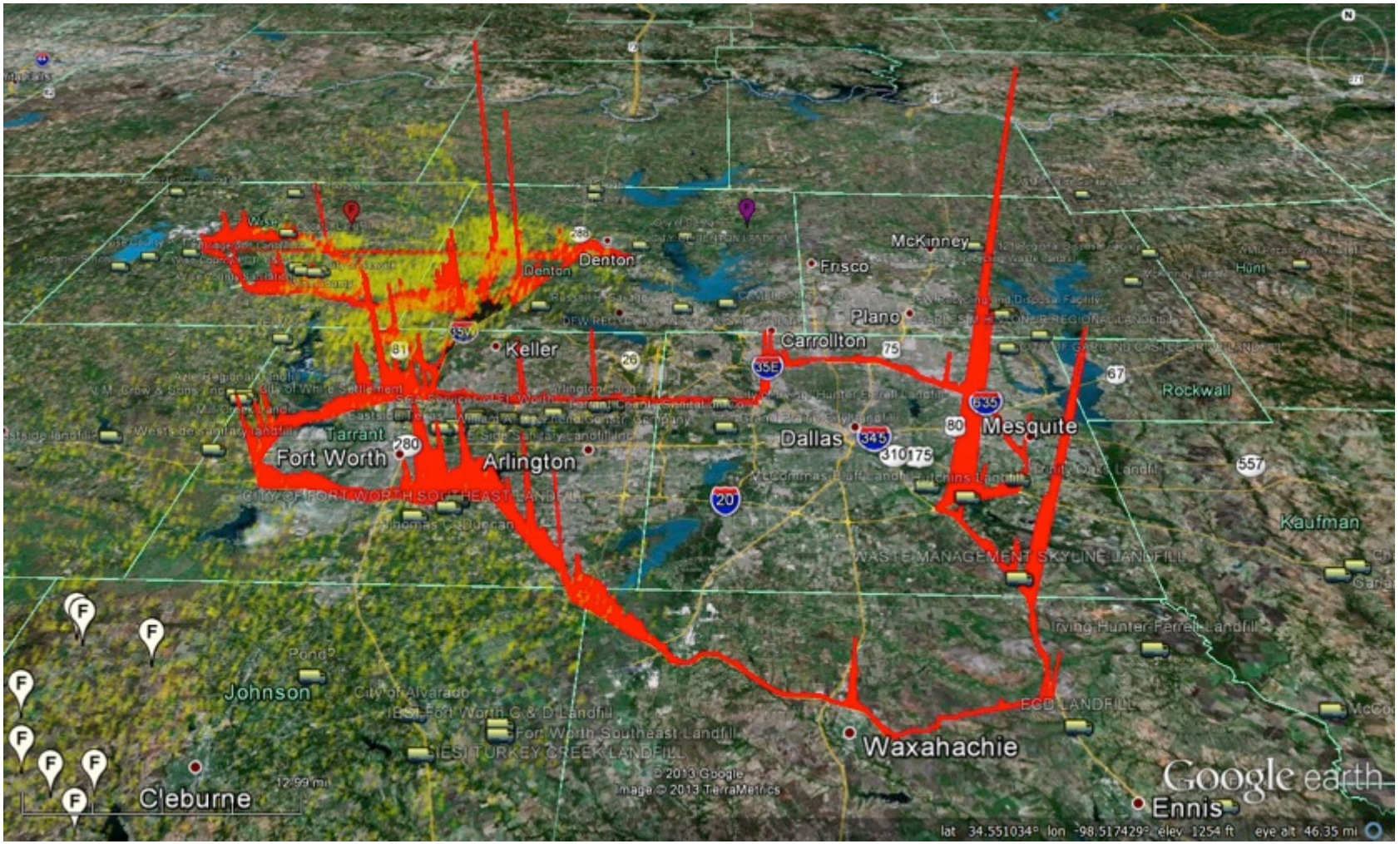
Gas wells are **96 ± 15%** of total emissions

Barnett Shale – Individual Source Signatures



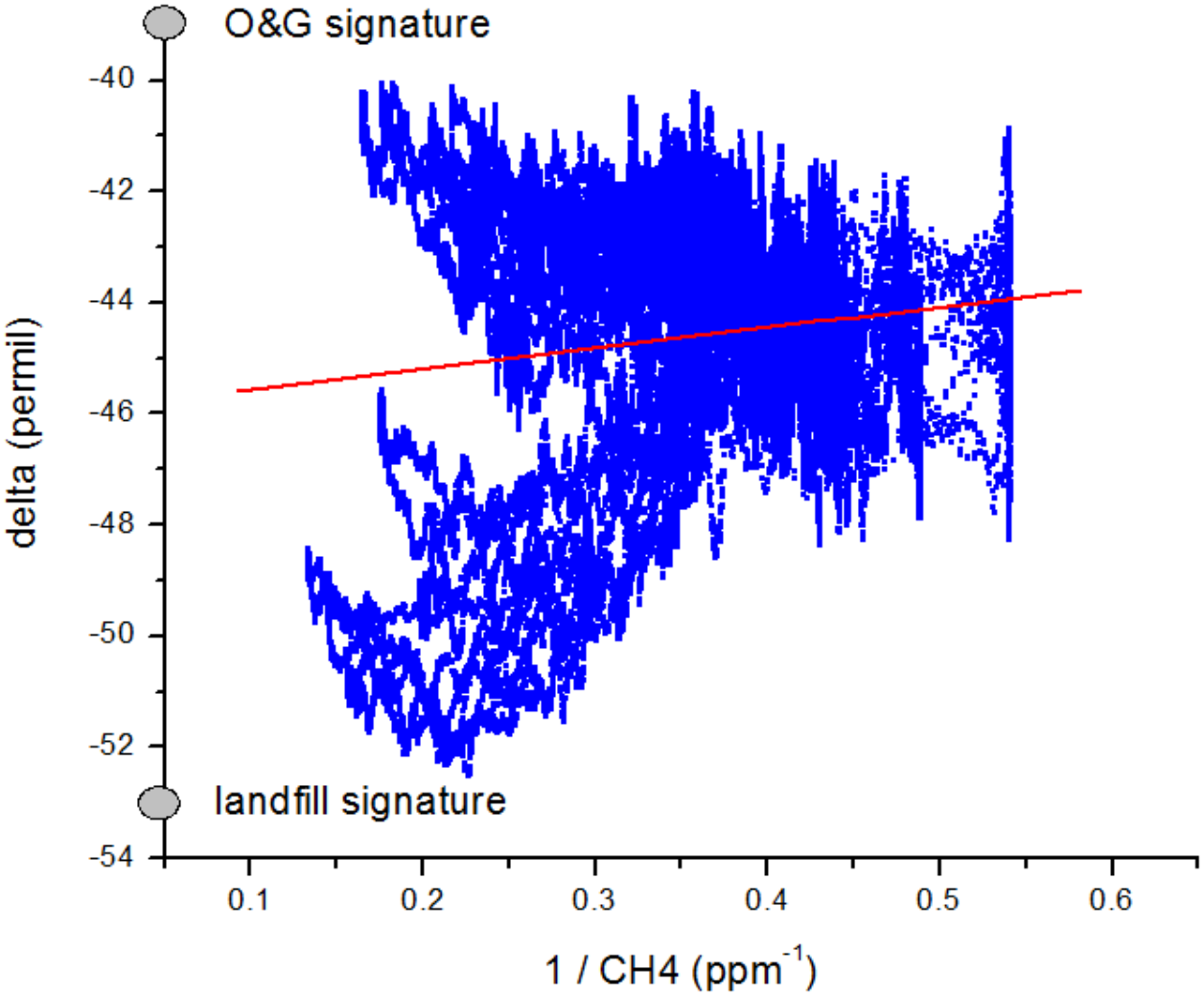


Barnett Shale – 4.5 hour drive (1 APR 2013)

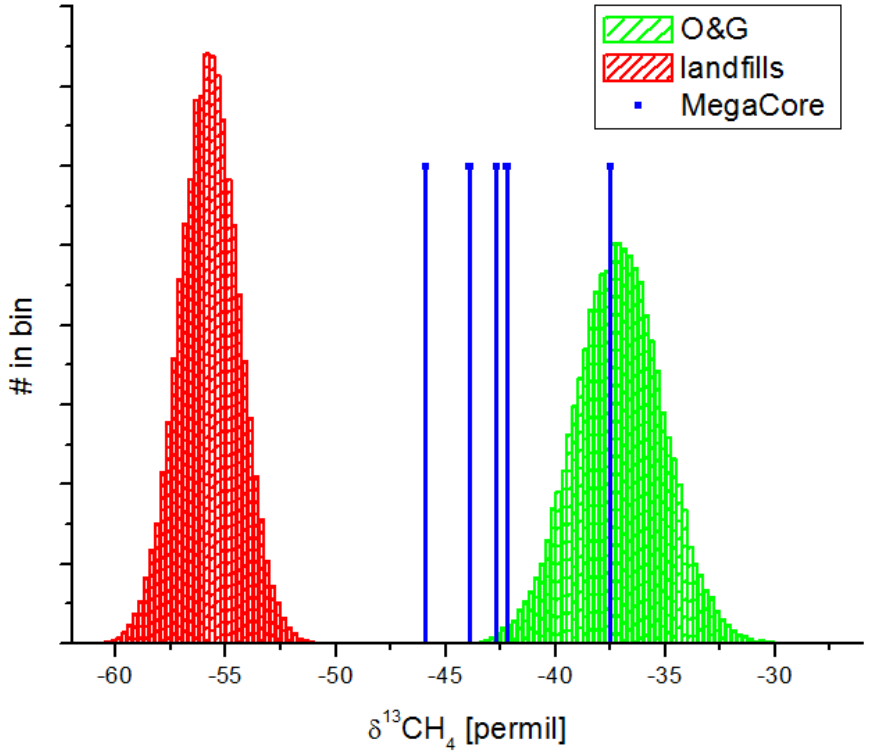


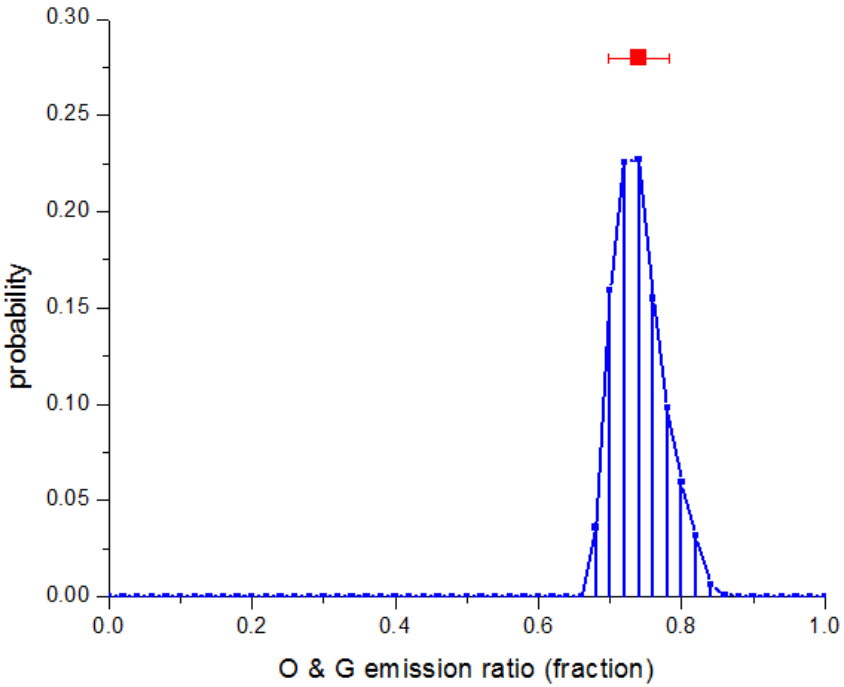
- Primary sources are Landfills (Trucks) and O&G (yellow points)
- Very few feedlots (F)

Barnett Shale – Geospatial Heterogeneity of Isotope Signatures



Emissions Estimate - Barnett





- Emissions Estimate = **74 +/- 3.5 %** from Oil and Gas
- Working on alternative analysis methods to handle spatial inhomogeneity


– Thank You!! –