PICARRO

Identification of Methane Emissions in an Urban Setting

Wednesday, Nov. 16, 2011 AWMA Greenhouse Gas Strategies

in a Changing Climate

Eric Crosson, Nathan Phillips, Lucy R. Hutyra, Jocelyn Turnbull, Colm Sweeney, Robert Ackley, Sze Tan, Chris Rella

The World's Highest Performance and Easiest-to-Use Analyzers

Identification of Methane Emissions in an Urban Setting

- Contributors:
  - NOAA – Colm Sweeney Jocelyn Turnbull
  - Boston University – Nathan Phillips, Lucy Hutyra
  - Gas Safety Inc. - Robert Ackley
  - Picarro – Sze Tan, Chris Rella
  - Purdue University - Paul Shepson, Maria Obiminda Cambaliza
  - NIST - James Whetstone, Tony Bova, Kuldeep R. Prasad
  - NASA- Richard Koyler

- Current Focus: Identification of methane sources in Urban Centers.
  - Boston, San Francisco, Indianapolis, San Jose, San Bruno

PICARRO

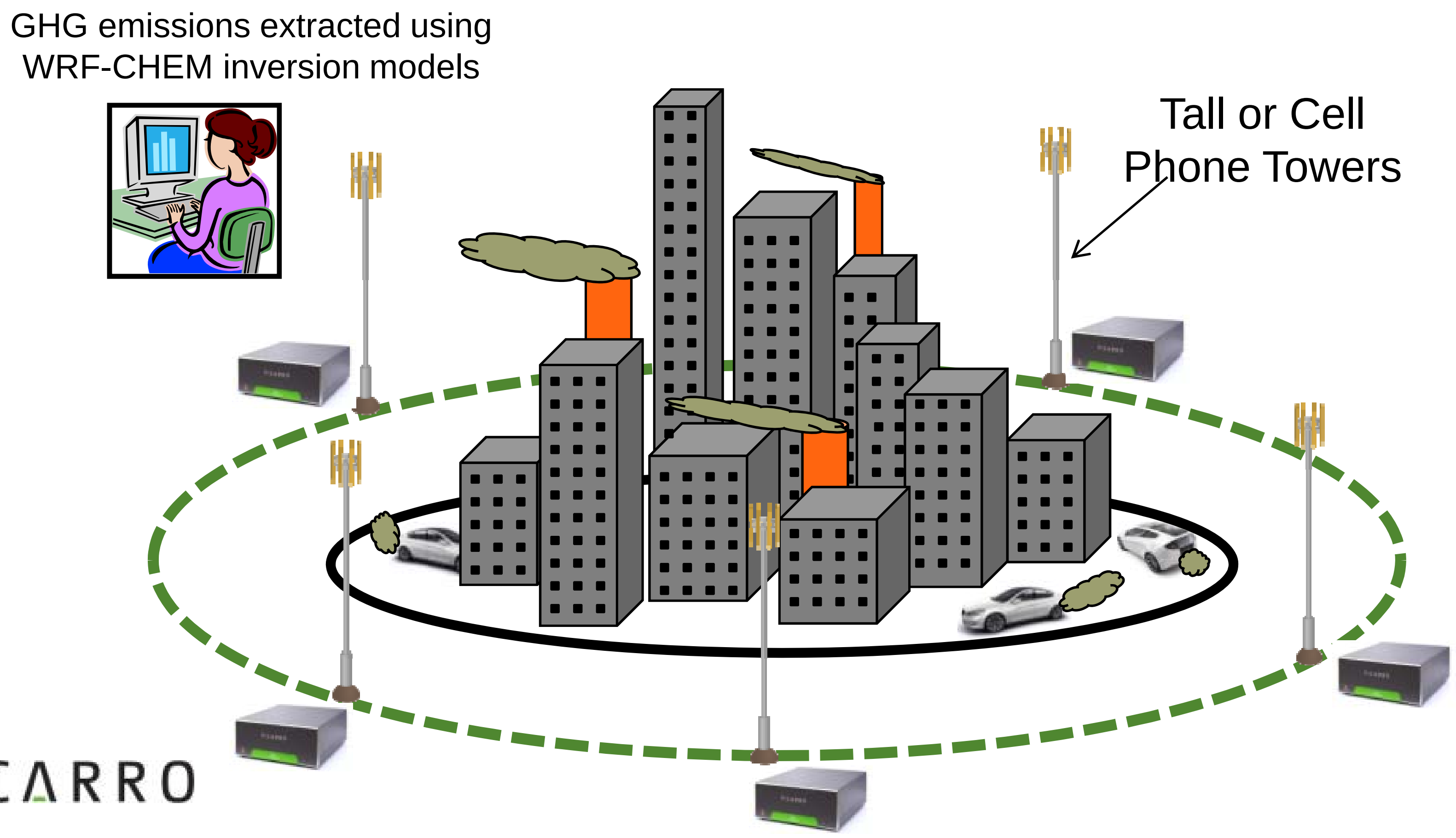
Motivation

- The identification and quantification of greenhouse gas emissions from urban centers are becoming of more interest.
- Recent measurements indicate that urban emissions are a significant source of Methane (CH_4) and in fact may be substantially higher than current inventory estimates.
- As such urban emissions could contribute 7-15% to the global anthropogenic budget of methane*.
- **Current Focus:** **Provide prior knowledge for inversion models.**

* Wunch, D., P.O. Wennberg, G.C. Toon, G. Keppel-Aleks, and Y.G. Yavin, Emissions of Greenhouse Gases from a North American Megacity, Geophysical Research Letters, Vol. 36, L15810, doi:10.1029/2009GL)39825, 2009.

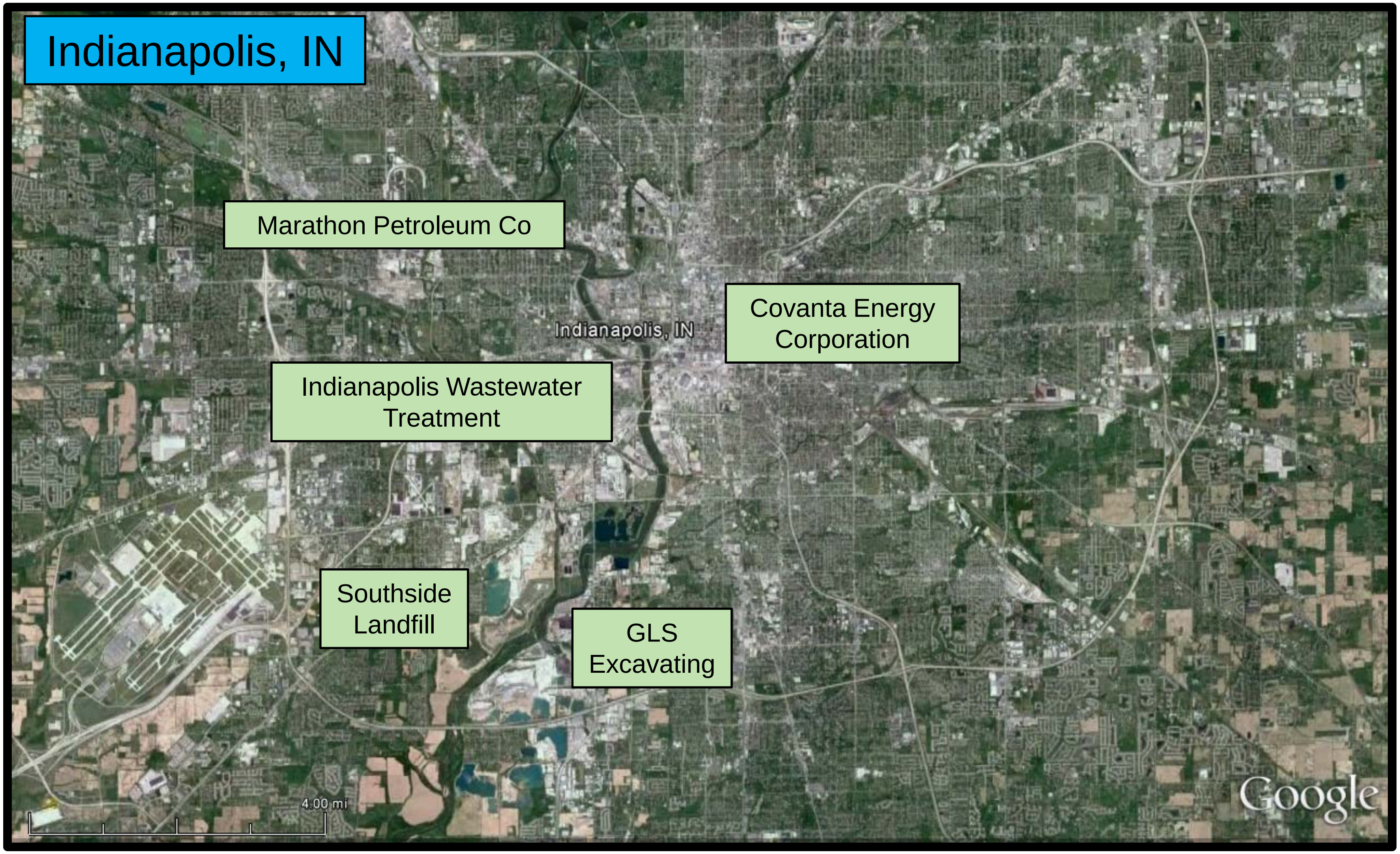
The Problem: Quantifying CH_4 Emissions using a Network of Analyzers, Establishing priors?

- For CO_2- use inventories such as Vulcan as a starting point.
- For CH_4- no such starting point exist.



PICARRO

What are the Likely Large Methane Sources?



PICARRO

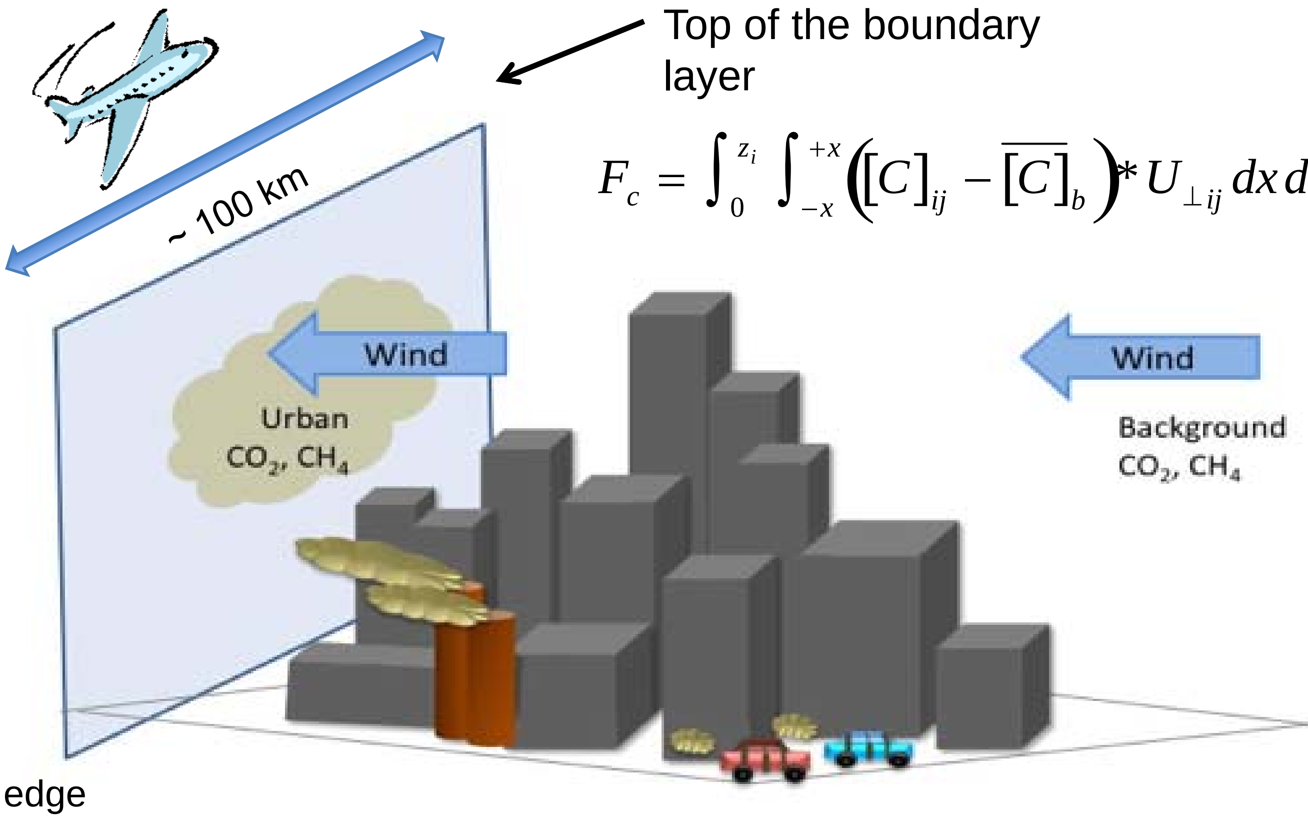
Quantification of Methane Emissions using Flight Based Approaches

Purdue University - Paul Shepson, Maria Obiminda Cambaliza

NASA- Richard Koyler

The World's Highest Performance and Easiest-to-Use Analyzers

Quantification in Indianapolis using an aircraft-based platform



$$F_c = \int_0^{z_i} \int_{-x}^{+x} \left([C]_{ij} - \overline{[C]}_b \right) * U_{\perp ij} \, dx \, dz$$

F_c: area-averaged emission flux (mols/s)

-x and +x: min and max horiz transect distance limits corresponding to the area bounded by the city

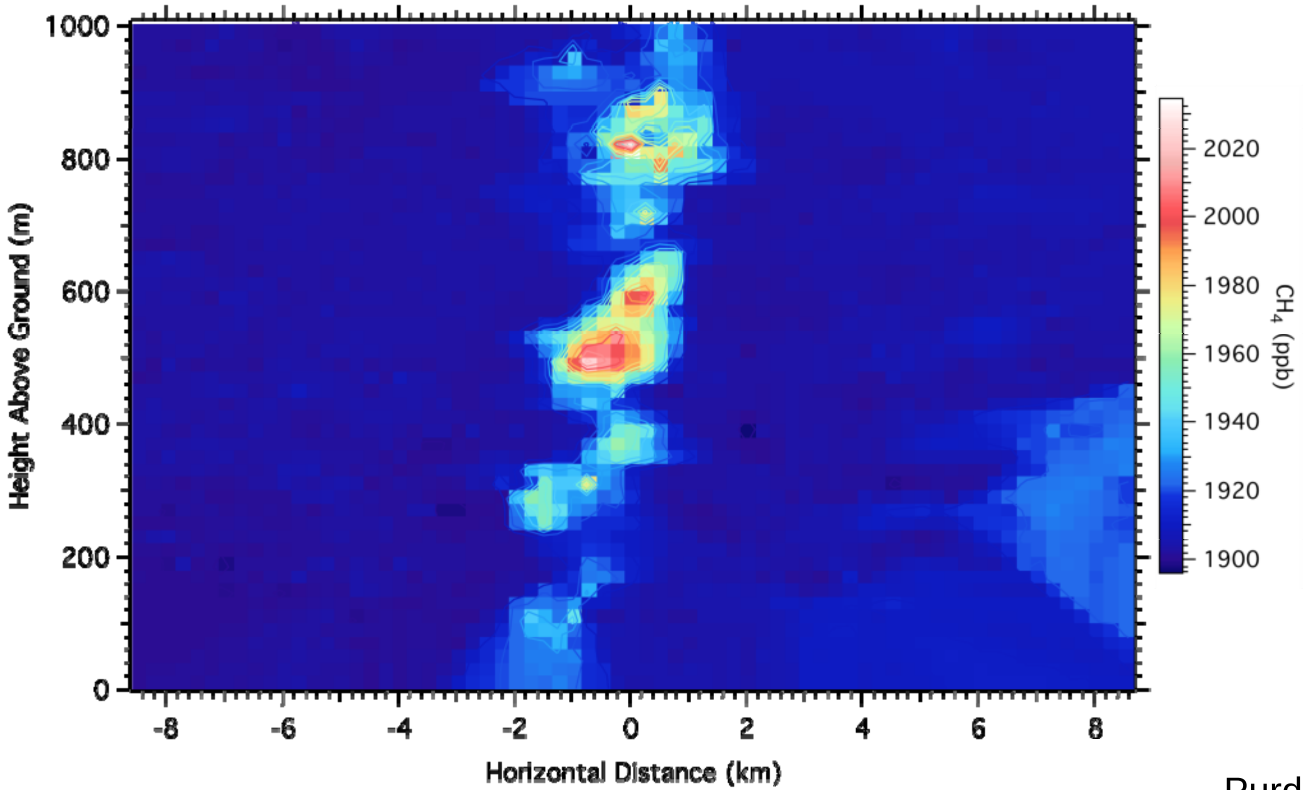
Uij: gridded wind vector perpendicular to the flight path

dx and dz: horizontal and vertical grid spacing

$[C]_b$: ave background estimated from the edge of the transect

PICARRO

Methane emissions from the Caldwell Landfill, Morristown, IN



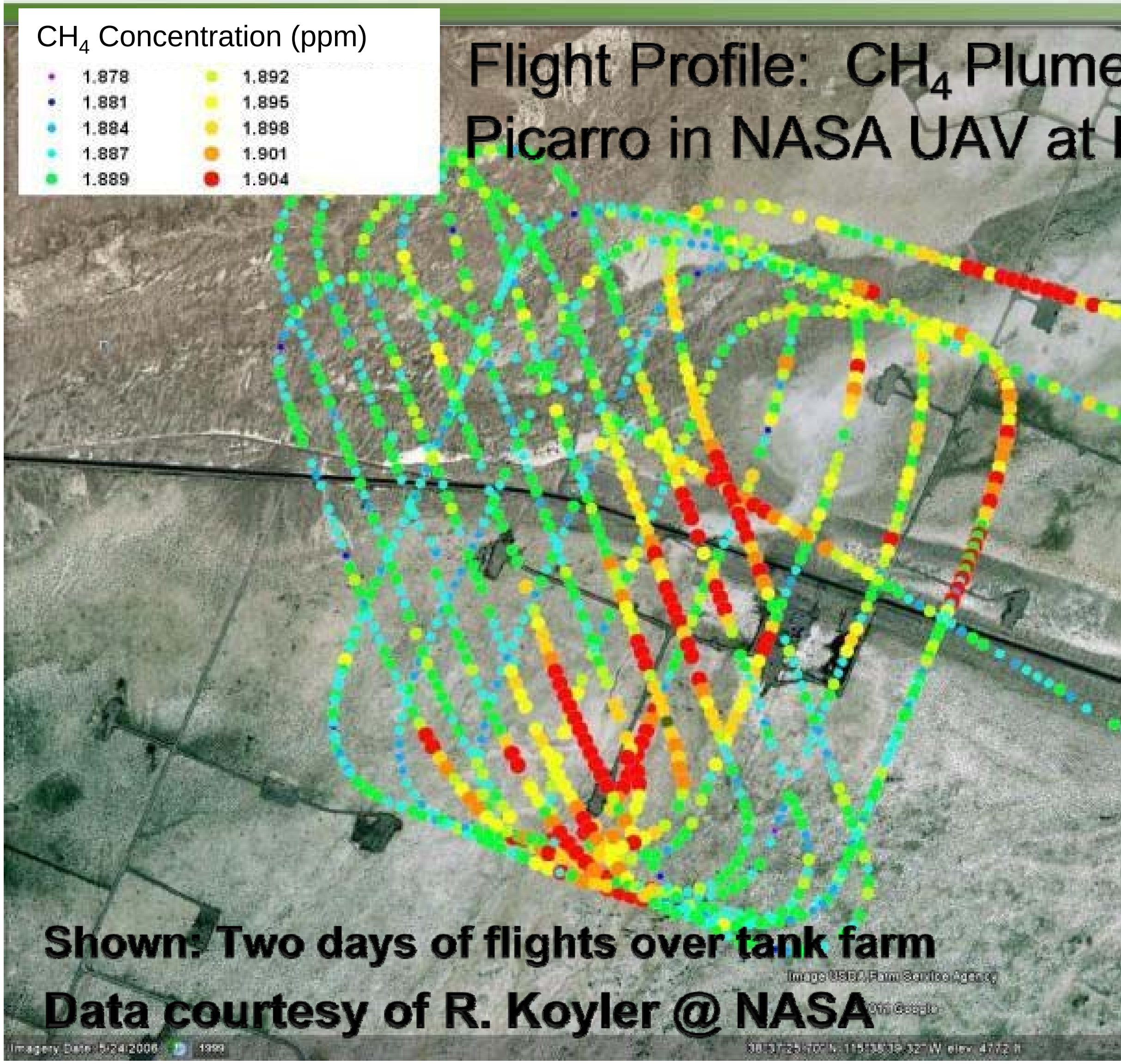
Purdue University - Paul Shepson,
Maria Obiminda Cambaliza

Estimated Flux = 9.1 mols s^{-1} = 821 m^3 hr^{-1}

Emissions from the Caldwell landfill can provide energy for approximately: ~ 1890 households

PICARRO

UAV: CH_4 Plume Detection



PICARRO

Quantification of Methane Emissions using Vehicles

Large Cast of Contributors

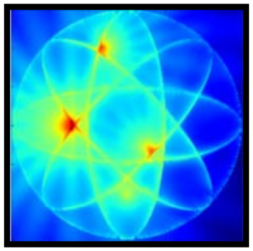
The World's Highest Performance and Easiest-to-Use Analyzers

Quantifying Facility-Level Emissions

Objective: Identify and quantify methane emissions and extrapolate downwind impact to communities.

Mobile Measurements

Real-time Met data



Atmospheric Models

Emissions Maps

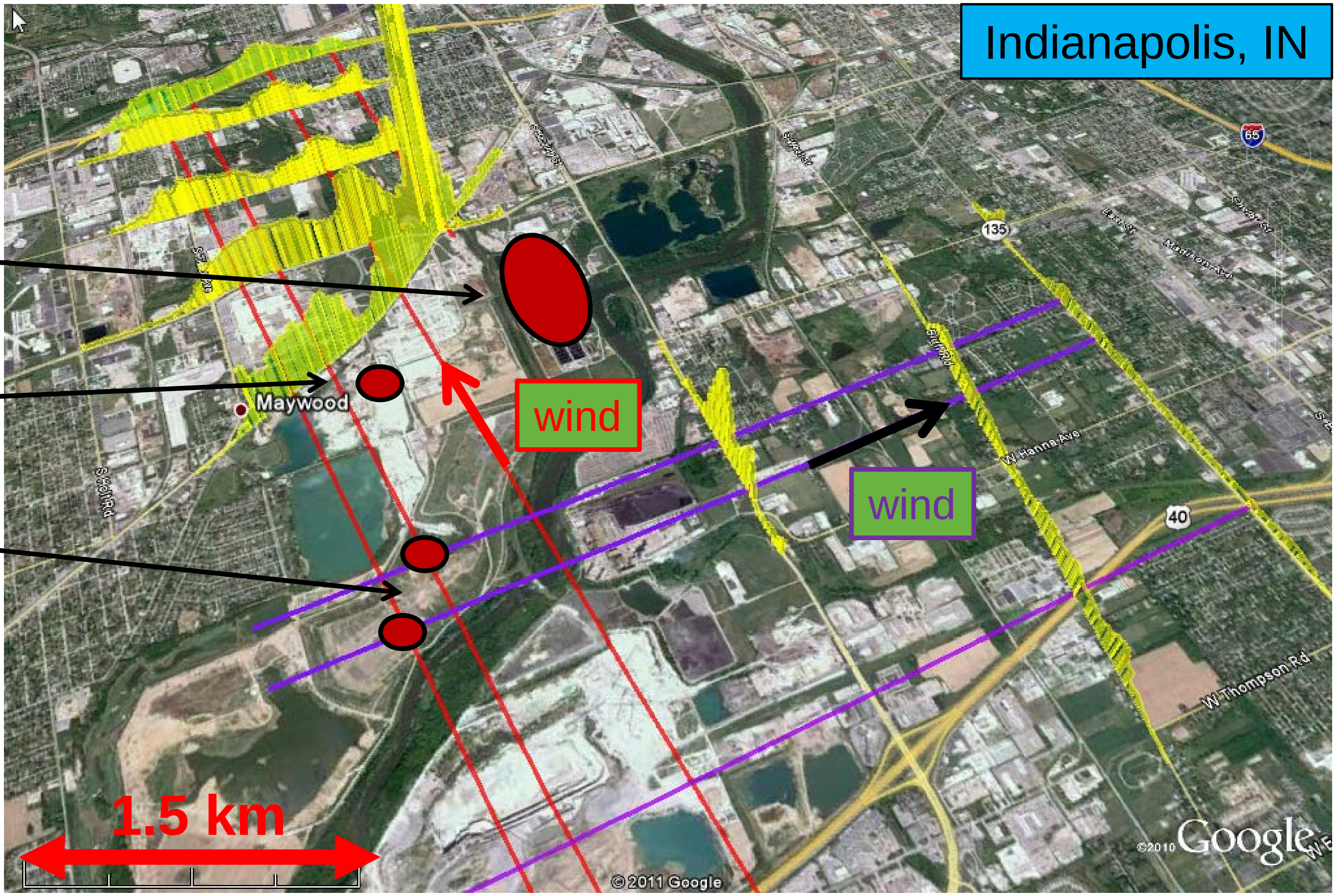
PICARRO

Locate and Quantify Methane Sources and Emissions

Waste Water Treatment Facility

Petro Facilities

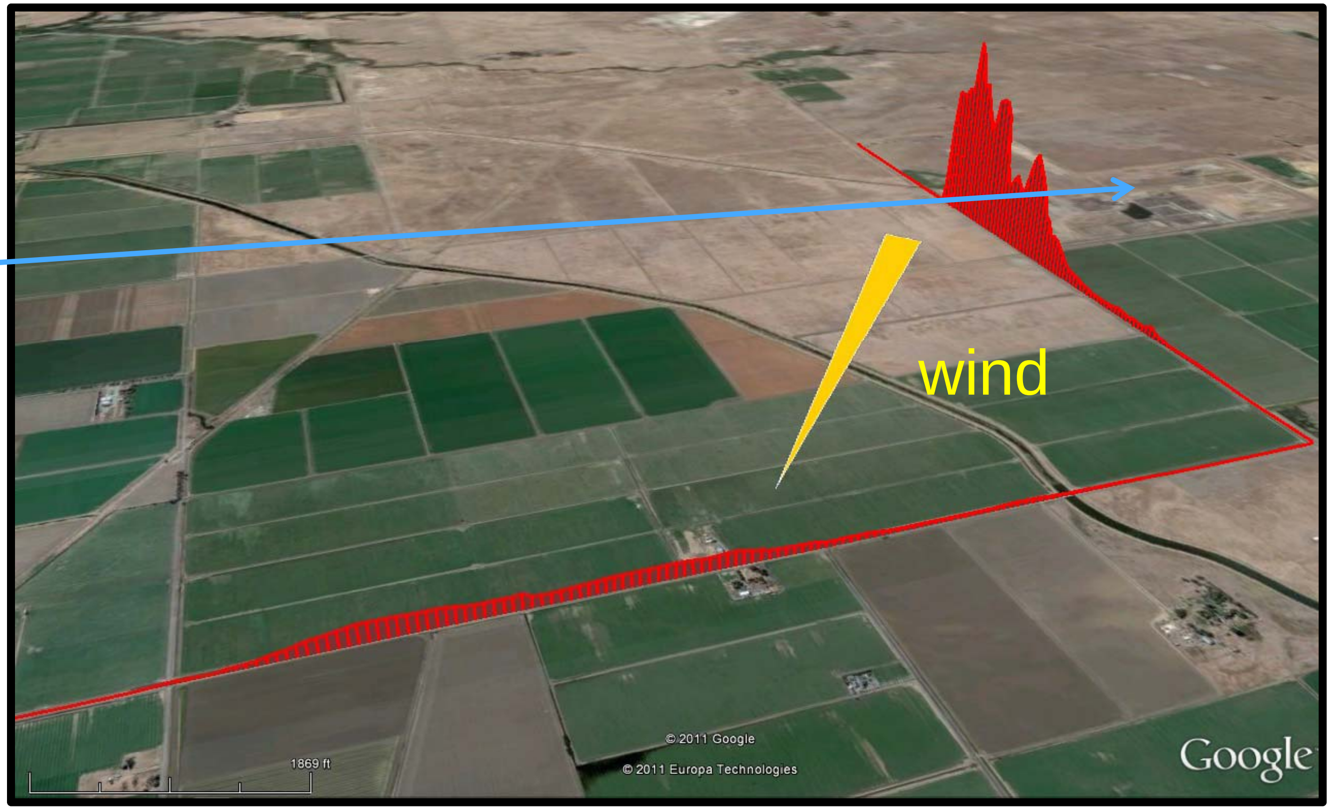
Landfill



PICARRO

Typical plume

- Driving speeds of 20-30 mph
- Vacaville landfill
- Late evening wind conditions were very stable:
  - Speed 8.2 ±1.3 m/s
  - Direction 224.2 ± 5.0 deg



- This was late evening with a very flat topography – estimated stability class is E or F
  $(\sigma_z \sim 21 - 28\ m\ at\ 3.5\ km\ from\ landfill)$

$$C(x,y,z) = \frac{Q}{\pi V \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \exp\left(-\frac{z^2}{2\sigma_z^2}\right)$$

PICARRO

Vacaville Landfill

PICARRO

Line integration

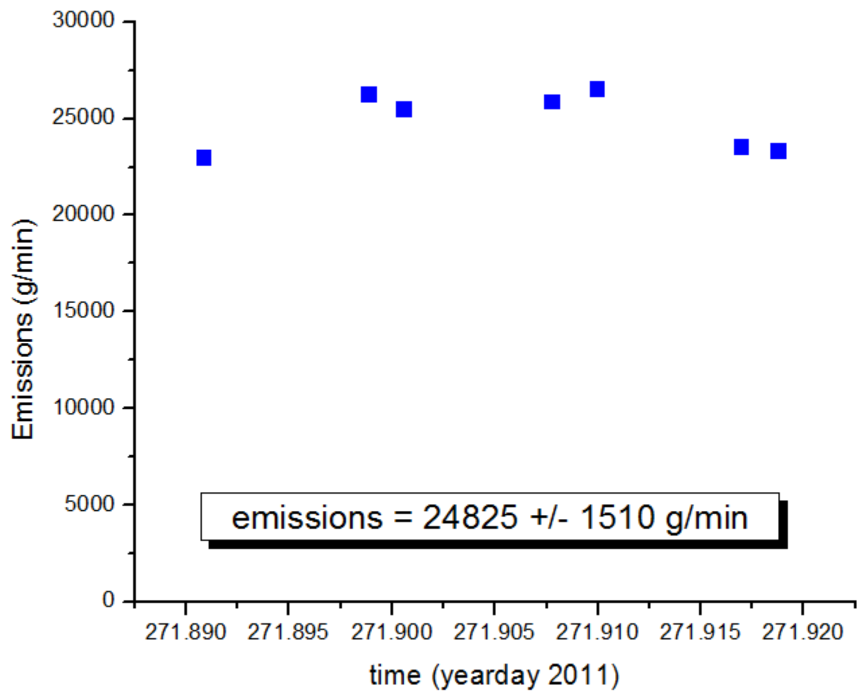
Path integral

$$\int_{-\infty}^{\infty} c(l)dl = \int_{-\infty}^{\infty} dl \frac{Q}{\pi V \sigma_y \sigma_z} e^{-y^2/2\sigma_y^2} e^{-z^2/2\sigma_z^2}$$

$$= \frac{Q}{\sqrt{\pi/2}\, V \sigma_z} \sec\theta \, e^{-z^2/2\sigma_z^2}$$

- Emissions from the landfill can provide heating for approximately:

  ~ 9000 households



PICARRO

Methane Signals Can be Confusing

Storm Drains

Natural Gas Vehicles

Inefficient Vehicles

Sewer Systems

Petroleum Facilities

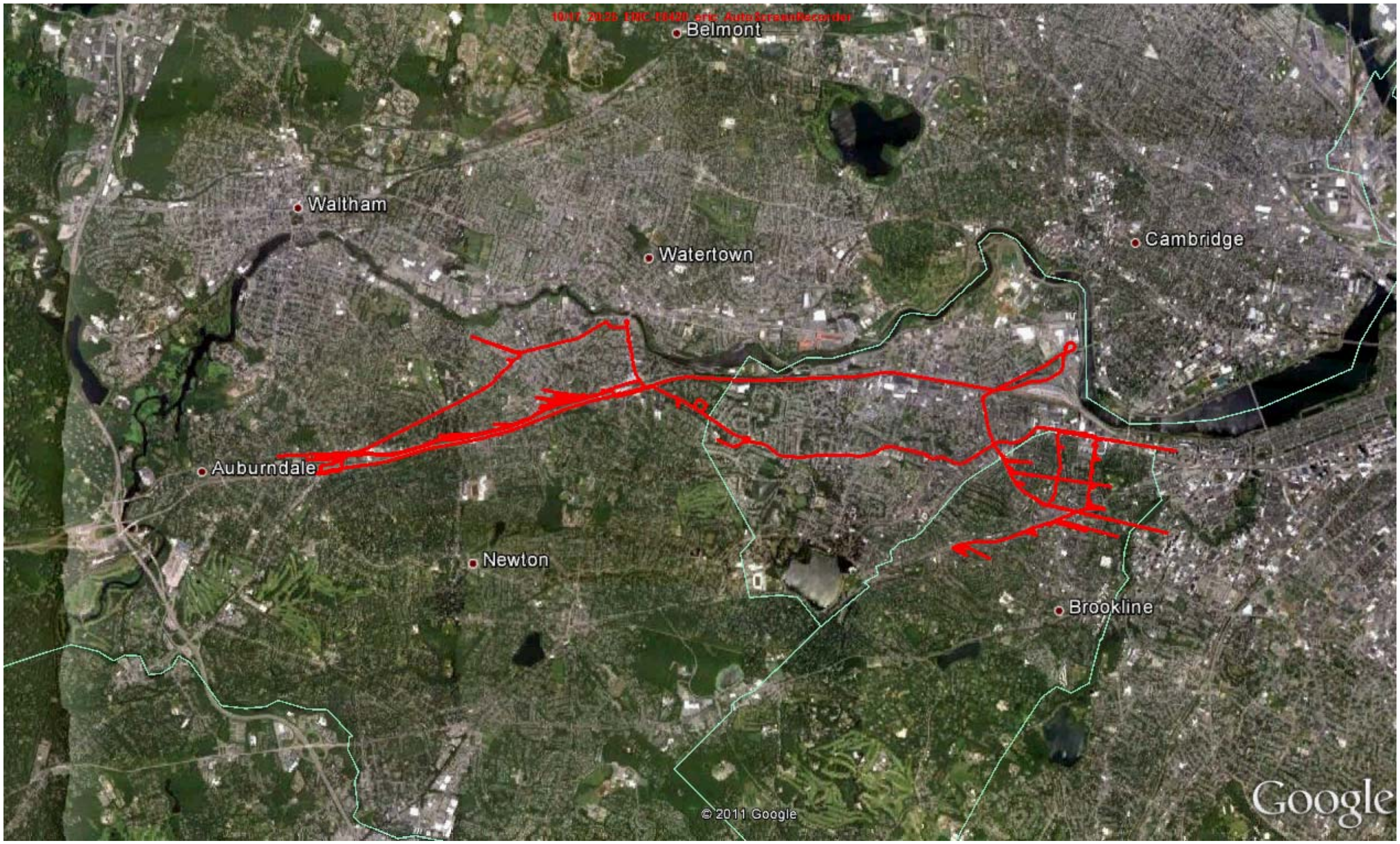
Landfills

Natural Gas Leaks

For example: in Boston …………

PICARRO

Boston



PICARRO

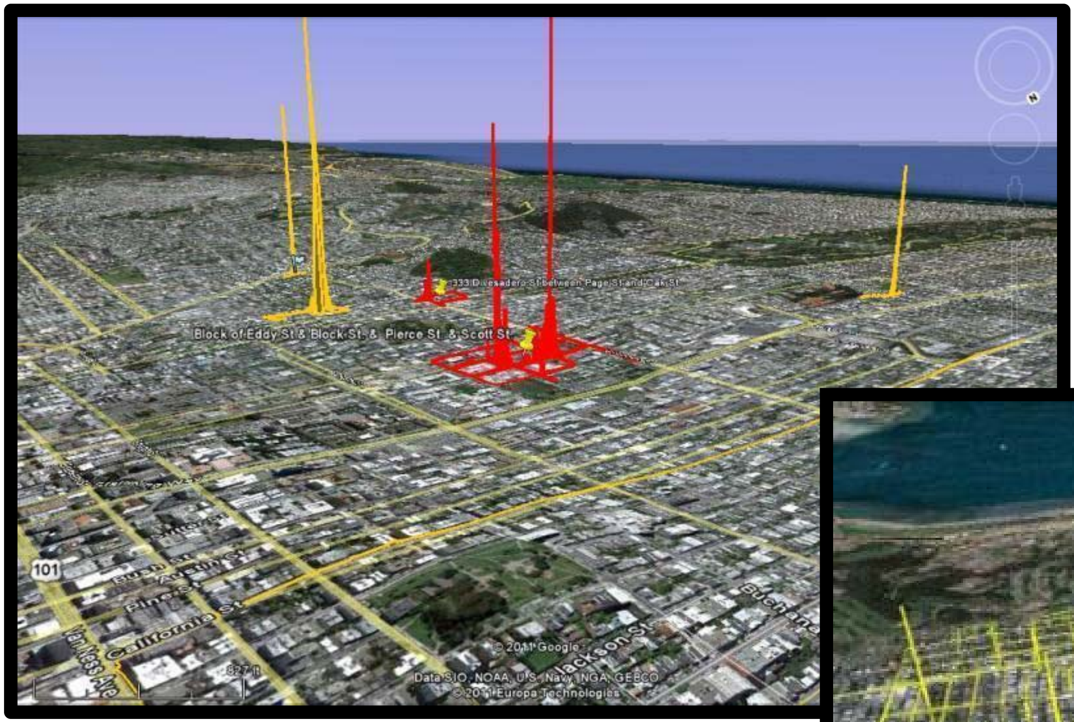
The Scope of the Natural Gas Leak Problem in Boston

- In Massachusetts:
  - Total number of leaks = 25,000 to 30,000.
  - With 8.2 billion cubic ft of unaccounted for gas.
  - Average cost to fix per leak $3,000.
- Leaks in aging natural gas pipelines are killing trees.
  - Natural gas leaks can kill trees by displacing oxygen in the soil and drying out their roots.
  - 7,500 to 10,000 trees affected in Boston area alone.
- Several cities are asking for damages in excess of $1M each.

http://natgaspollutes.com

PICARRO

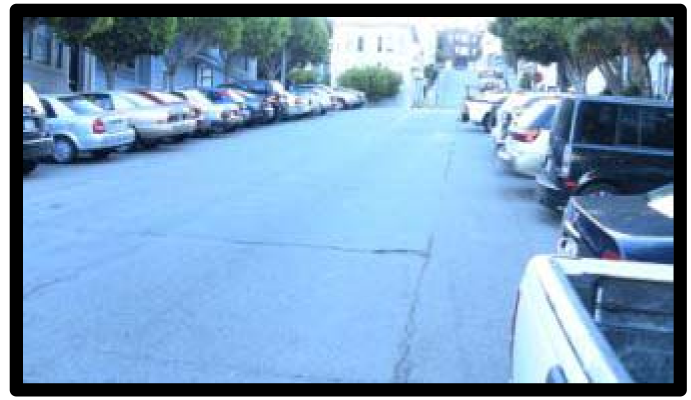
San Francisco

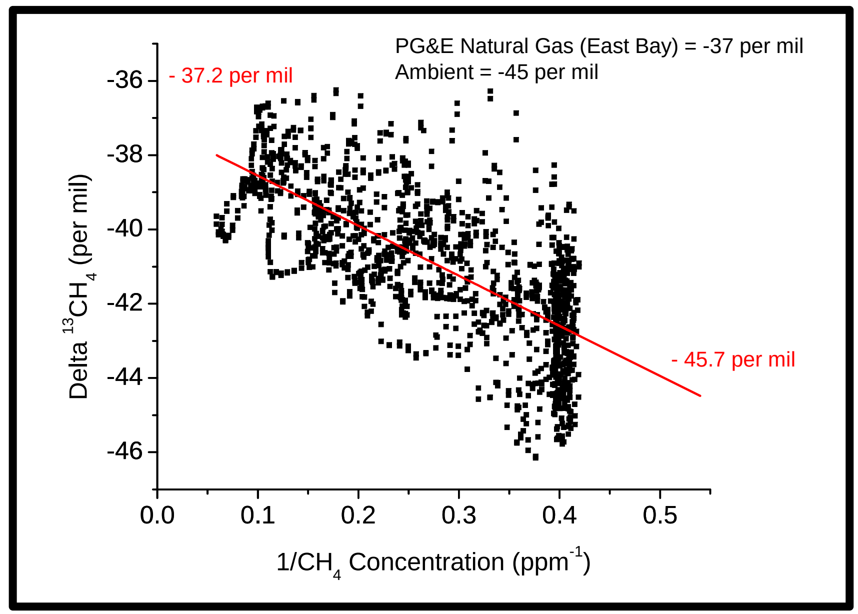


PICARRO

Specificity is a problem with traditional detection technology

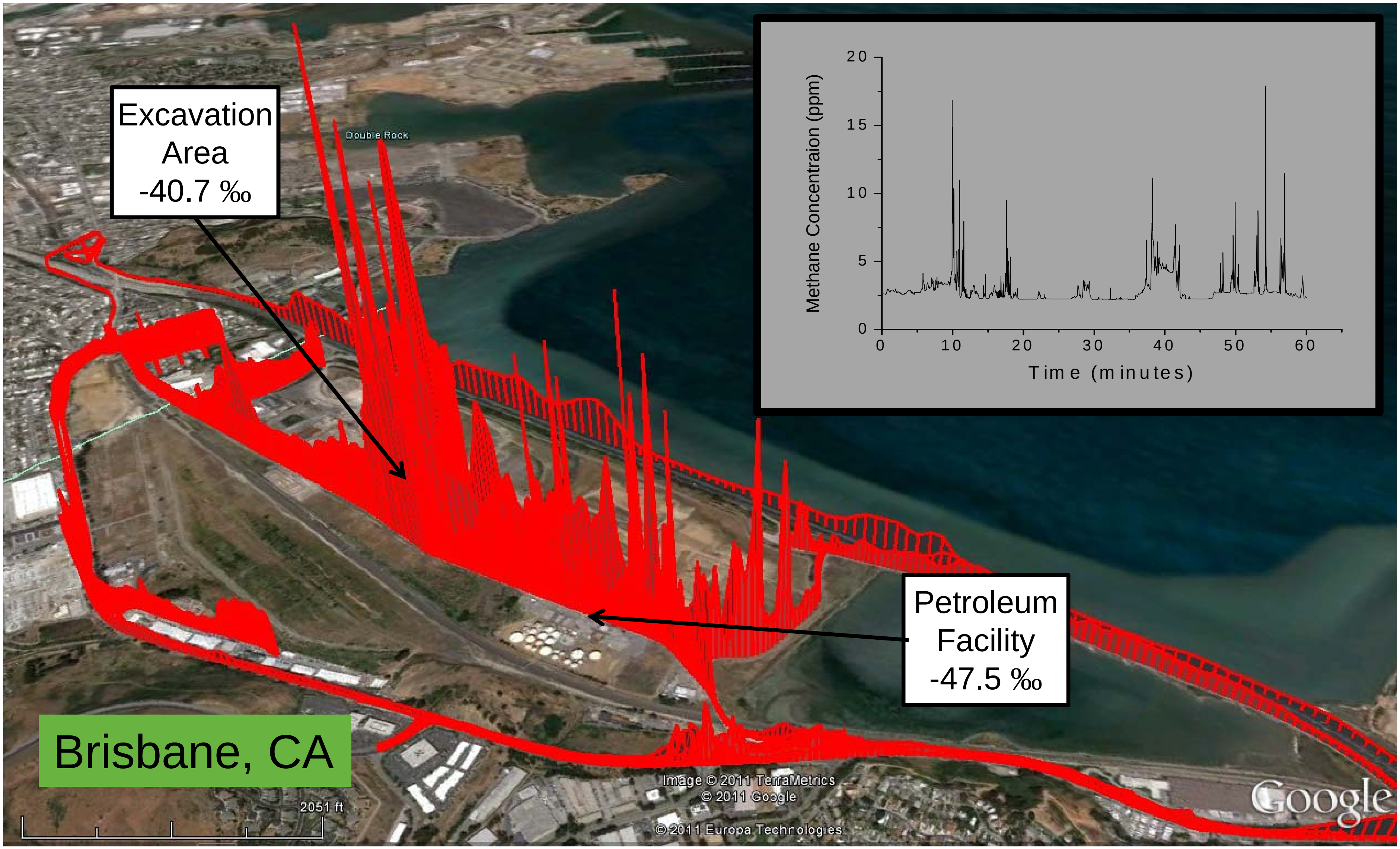
How can one help to identify the source?





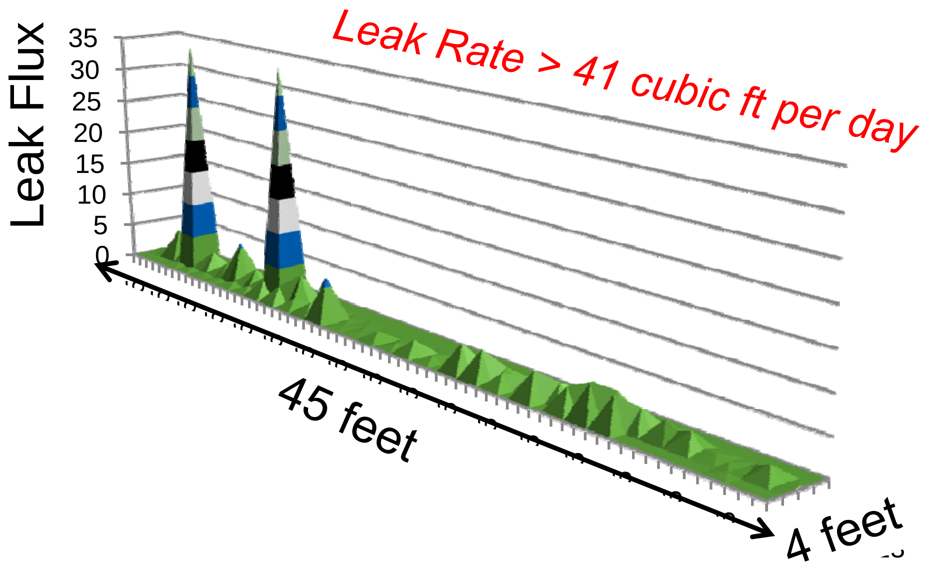
PICARRO

Separating Out Methane Sources using Isotopes



Check to see where the Methane is Originating

- Using chamber measurements, one can obtain a lower limit on the total leak rate
- Found leaks ranging from 40 -300 sccf/day.
- As a guideline, the natural gas used in the "average" American home is 200 standard cubic ft per day.



Conclusions

- Two major anthropogenic sources of CH_4 identified as
  - Natural gas pipeline leaks
  - Large area emitters such as landfills and petroleum facilities.
- Isotopic information can identify and may help separate co-located methane sources.
- Systematic measurements should provide much needed prior knowledge for inversion CH_4 models of urban areas.