

Special thanks to David Thompson, Andrew Thorpe



Plume Mapping in Four Corners

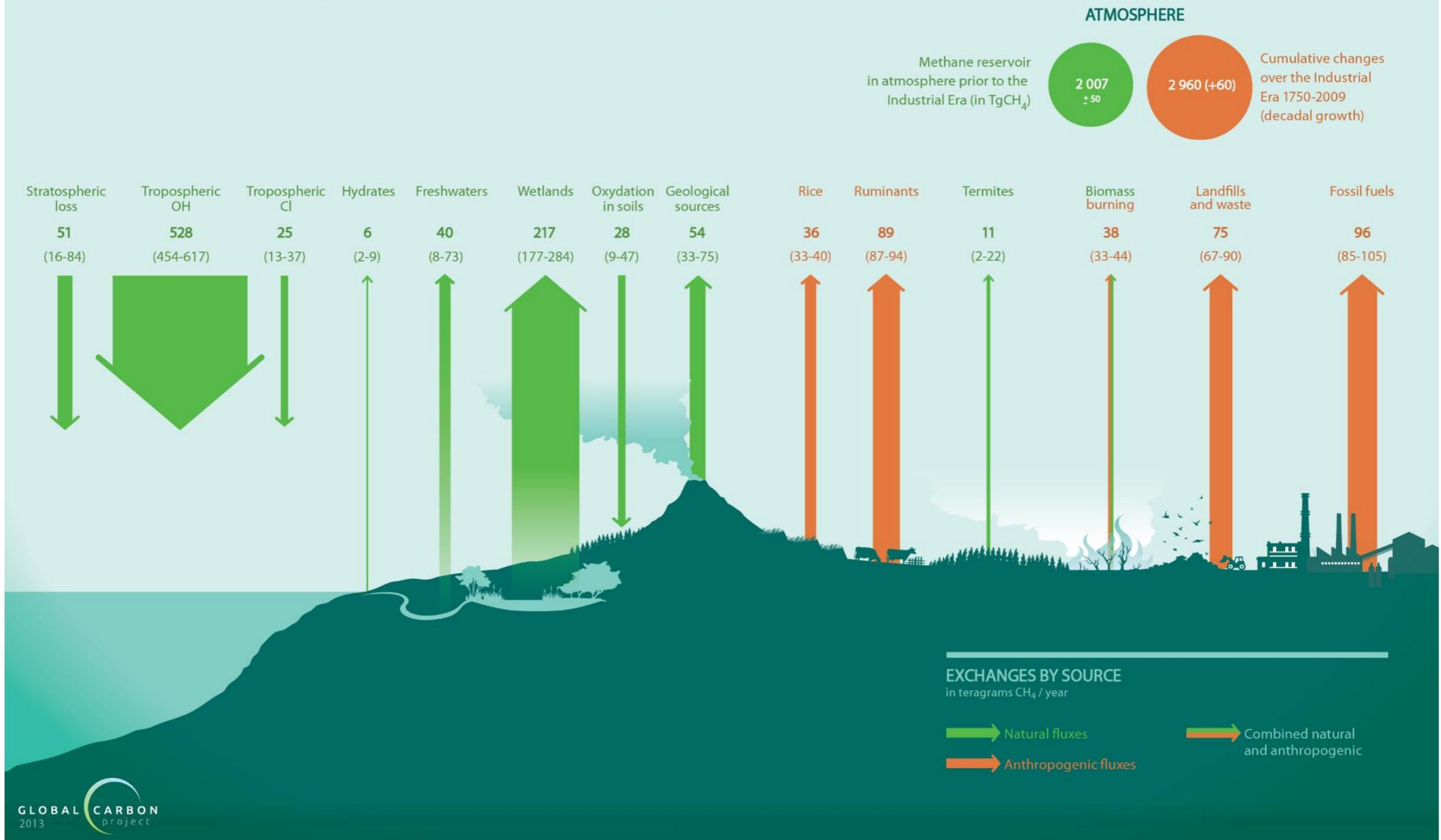
AVIRIS-NG & HyTES teams
JPL/Caltech, University of Michigan, NOAA,
CIRES

Outline

- Little methane intro
- Introduction into JPL airborne spectrometers capable of methane detection
- The 4-Corners methane background in a nutshell
- The April 2015 airborne flight campaign

Global Methane Budget

METHANE BUDGET : 2000-09



Why is methane important (and interesting)?

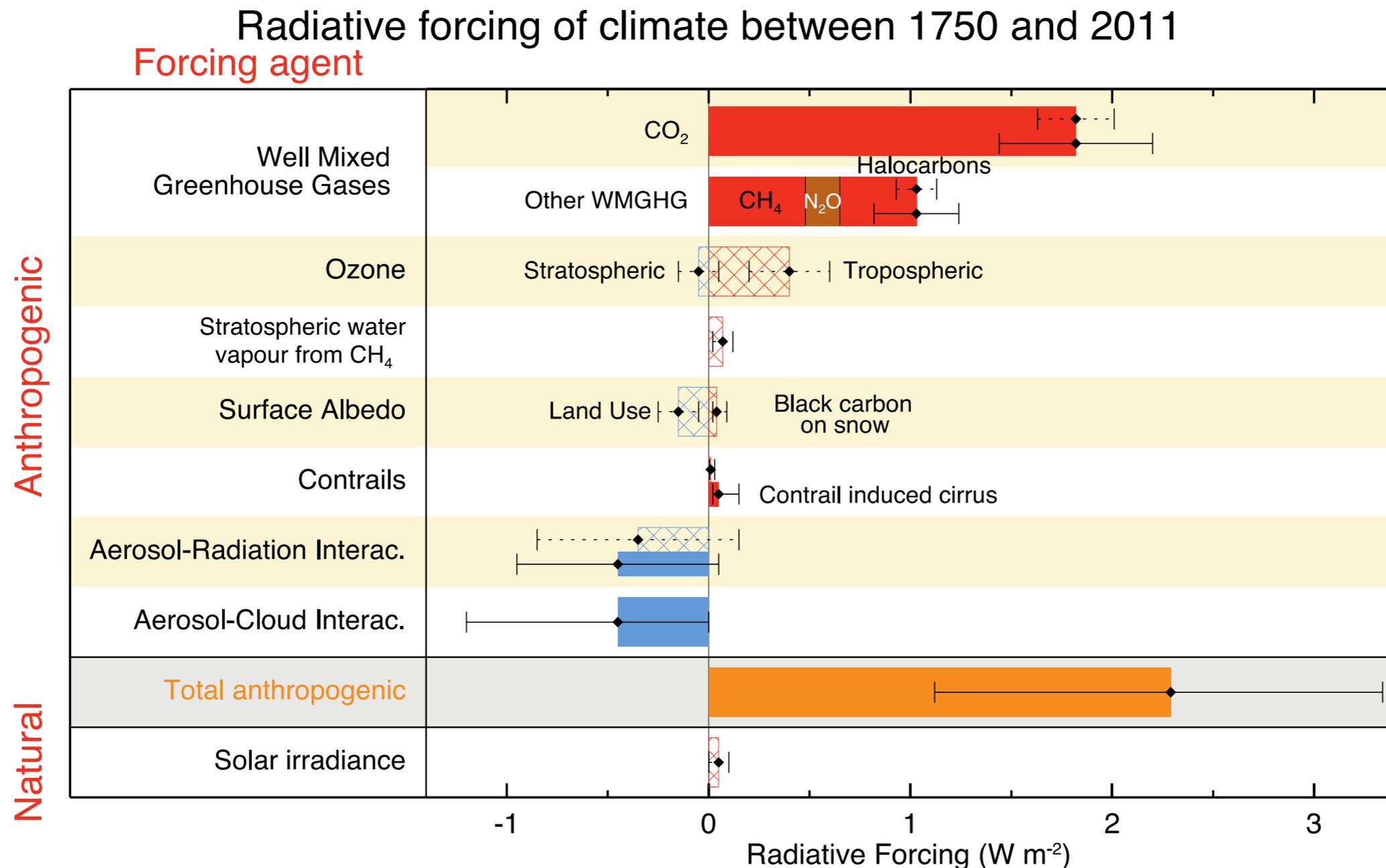
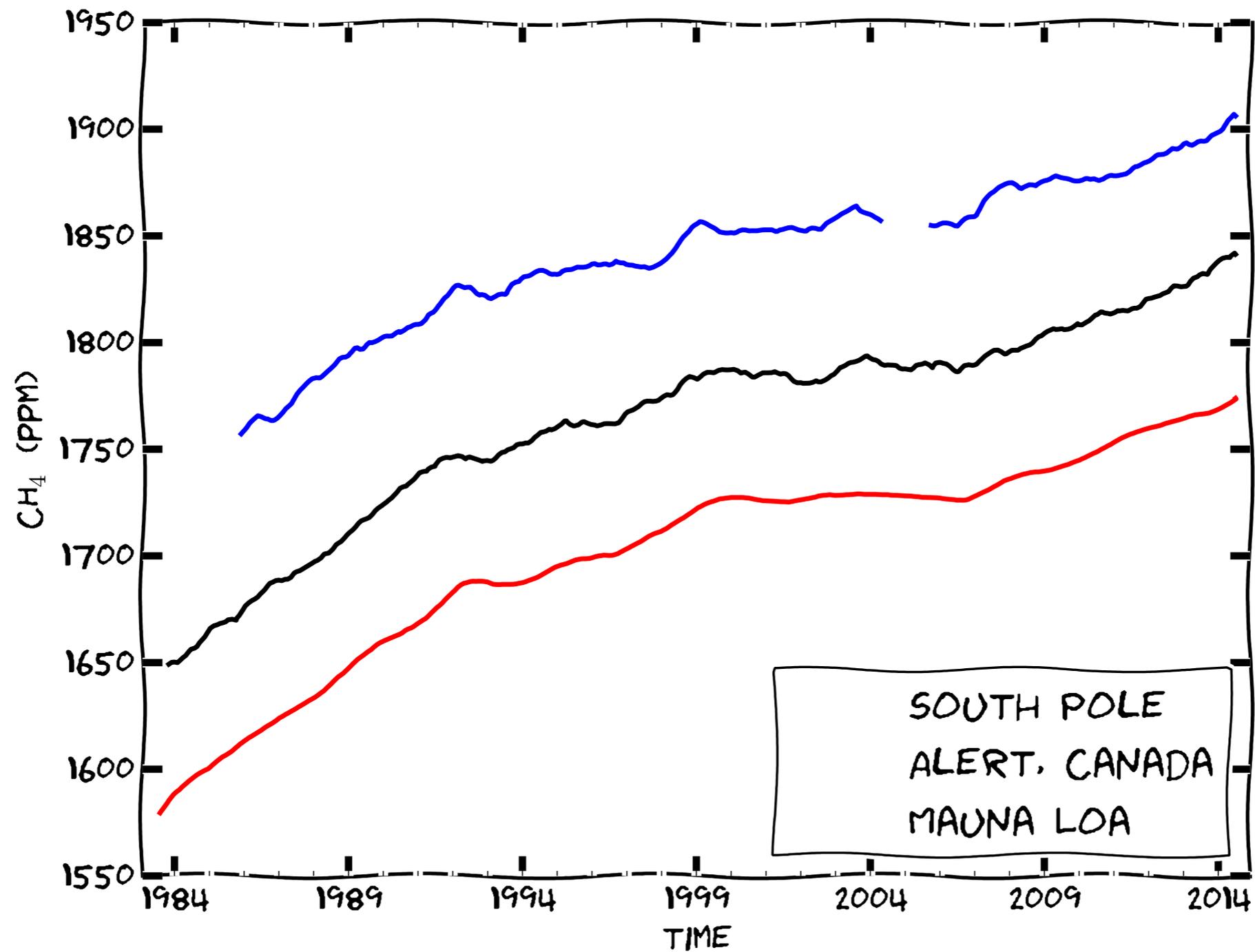
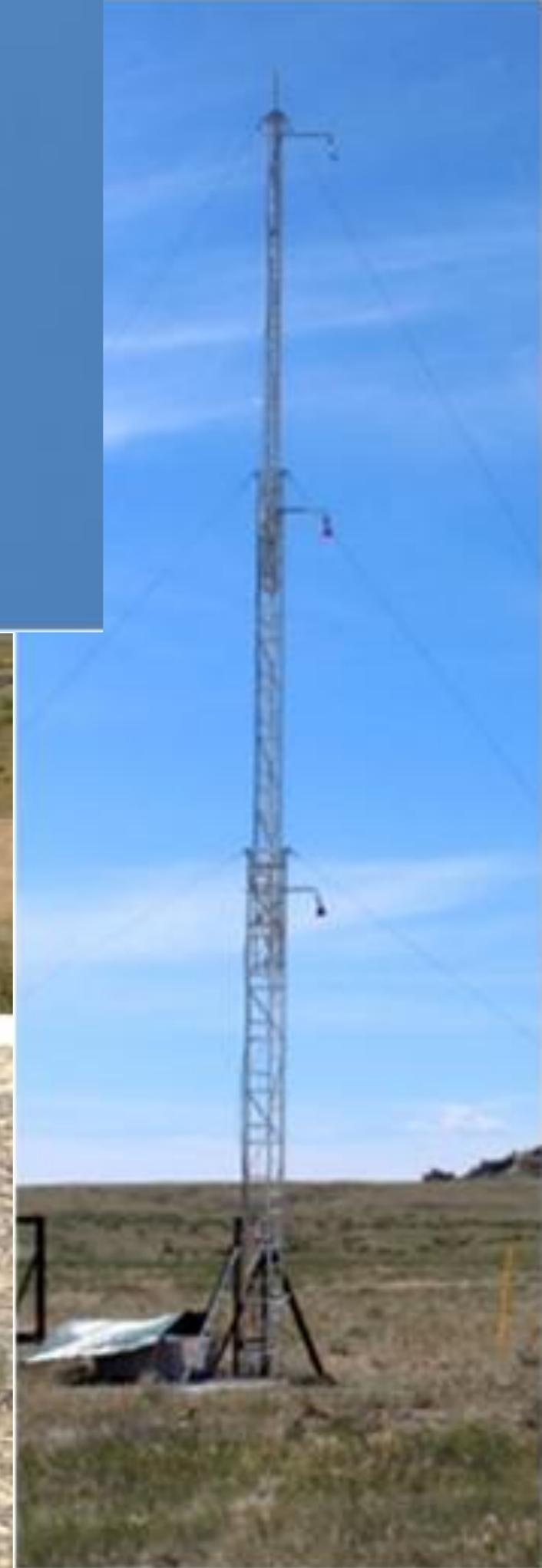
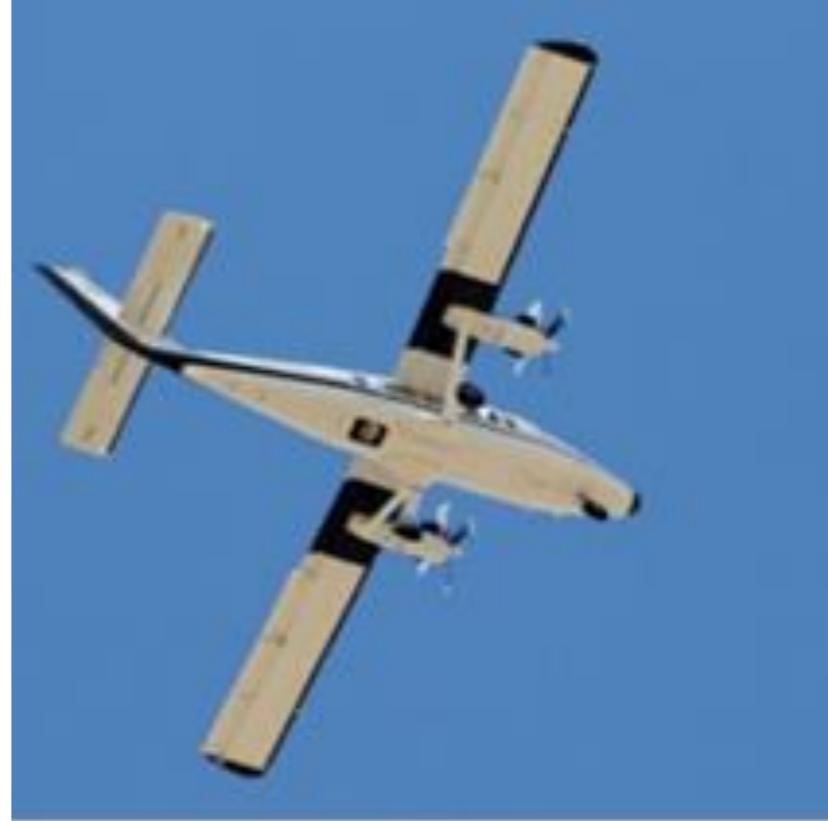


Figure 8.15 | Bar chart for RF (hatched) and ERF (solid) for the period 1750–2011, where the total ERF is derived from Figure 8.16. Uncertainties (5 to 95% confidence range) are given for RF (dotted lines) and ERF (solid lines).

Recent changes in atmospheric methane

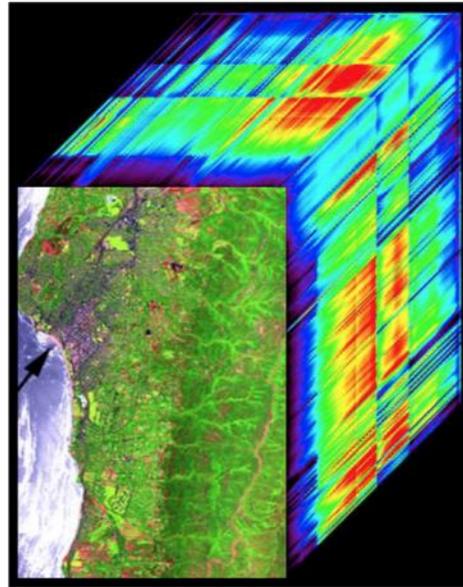


A controlled release
experiment in Wyoming
RMOTC — Rocky Mountain
Oilfield Testing Center

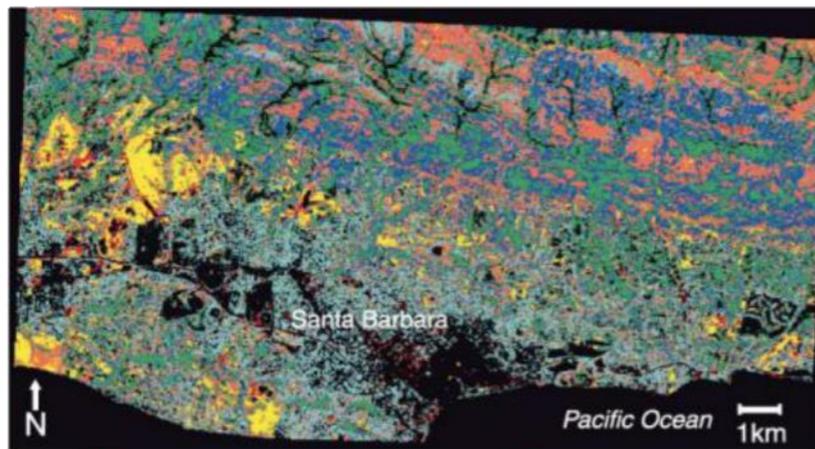


AVIRIS-NG <http://airbornescience.jpl.nasa.gov/instruments/avirisng>

Calibrated
Image Cube

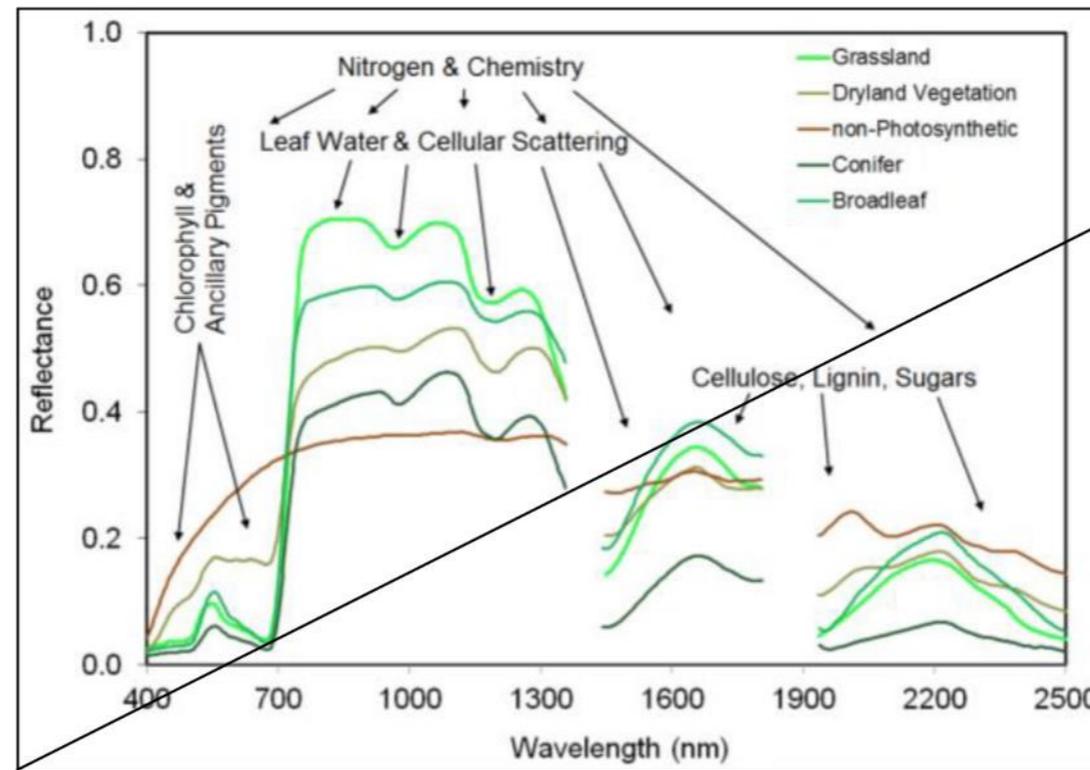


Ecosystem
Species Map



- Adenostoma fasciculatum
- Ceanothus megacarpus
- Arctostaphylos spp.
- Quercus agrifolia
- Grass
- Soil

100's of Parallel Spectrometers

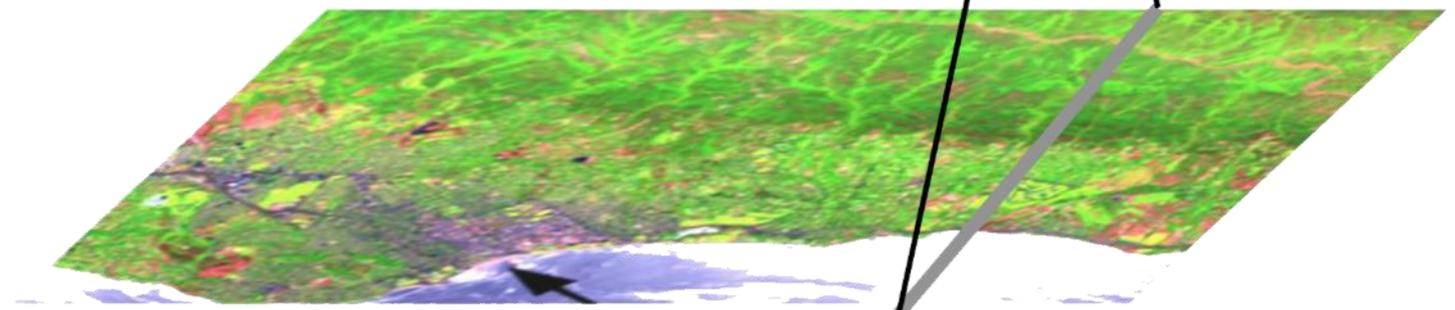


Detector Array

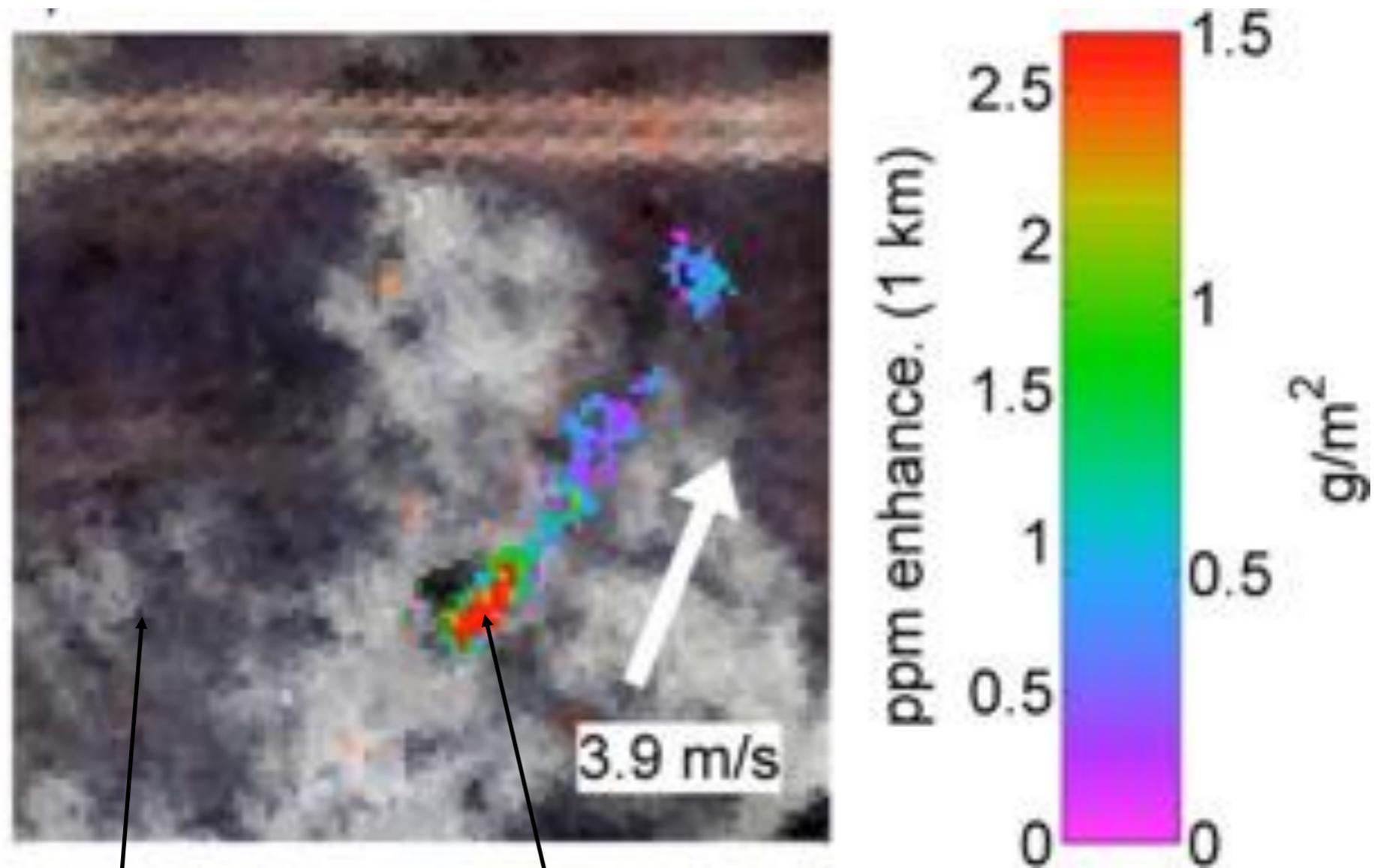
Spectrometer

Slit

Telescope



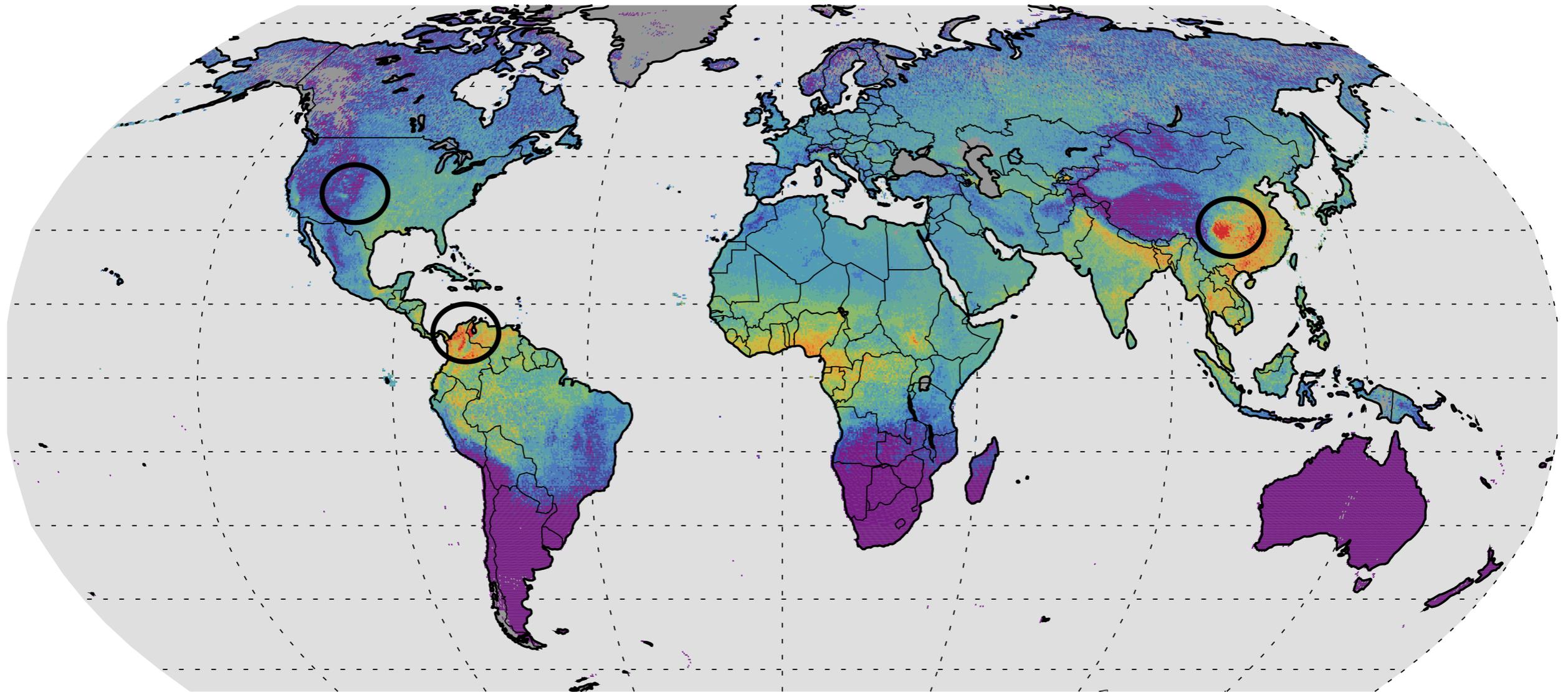
Mapping Methane — AVIRIS-NG



Plume is color-coded

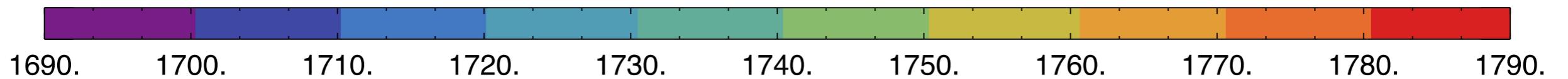
Background is False Color image
(similar to how your eye would perceive it)

Global Methane and a look into 4 Corners?



Frankenberg et al, JGR, 2011

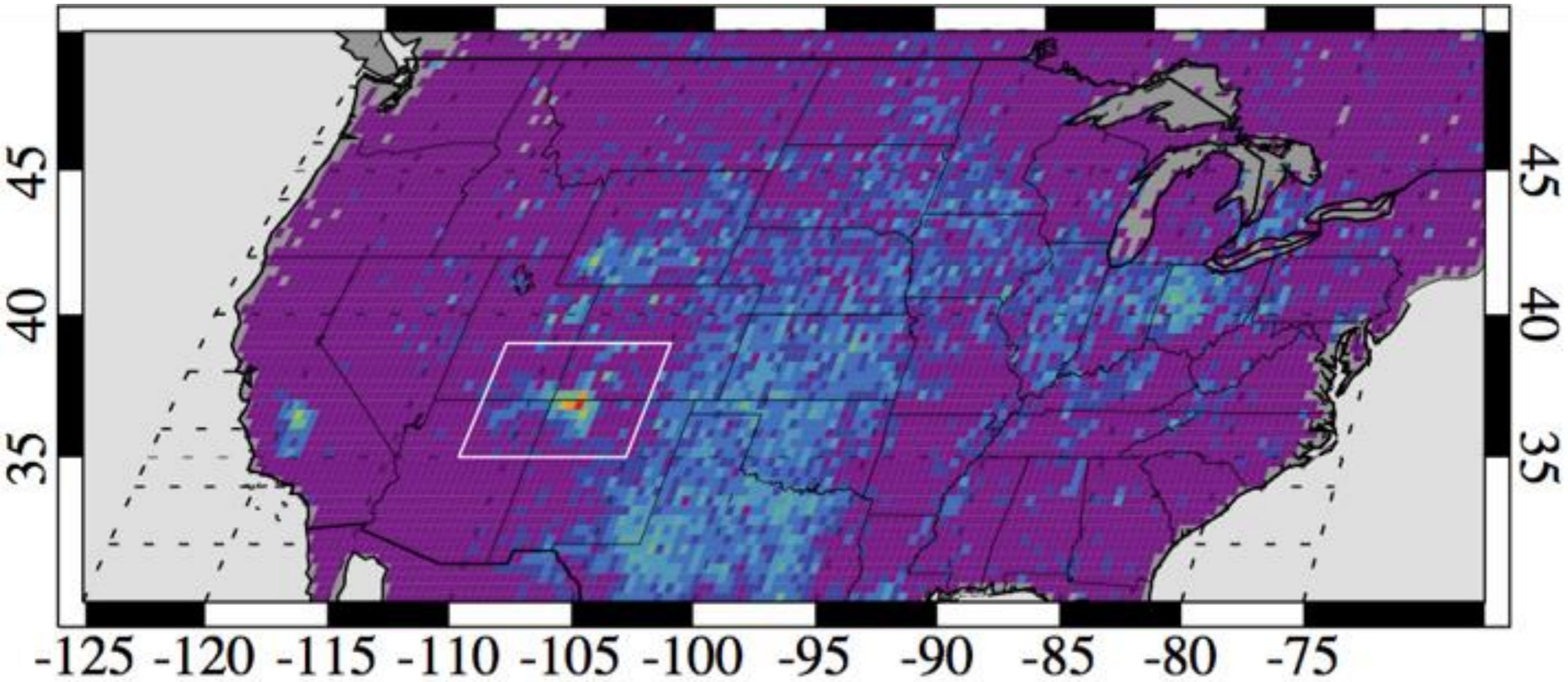
2003-2008 average, SCIAMACHY CH₄ xVMR (ppb)



How it all got started

SCIAMACHY Methane Anomalies

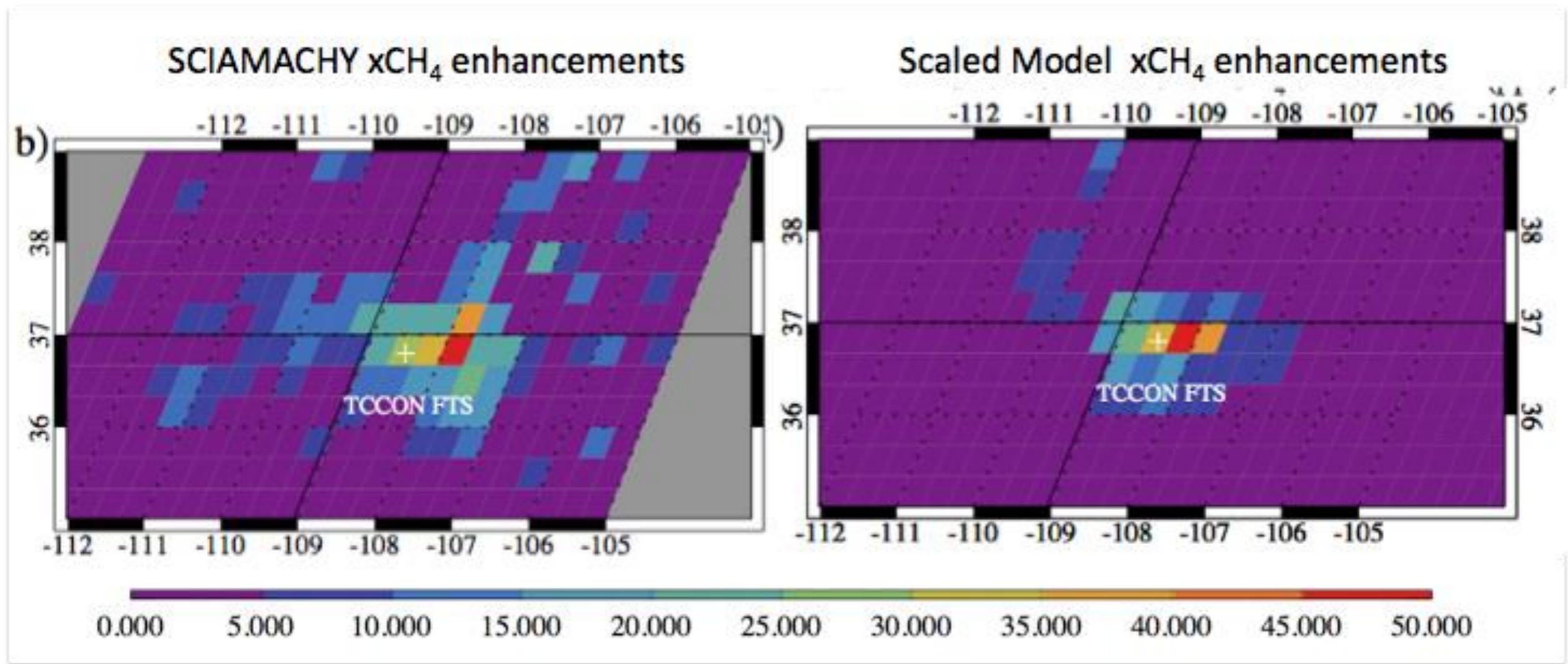
Kort, Frankenberg et al, GRL, 2014



How it all got started

SCIAMACHY Methane Anomalies

Kort, Frankenberg et al, GRL, 2014



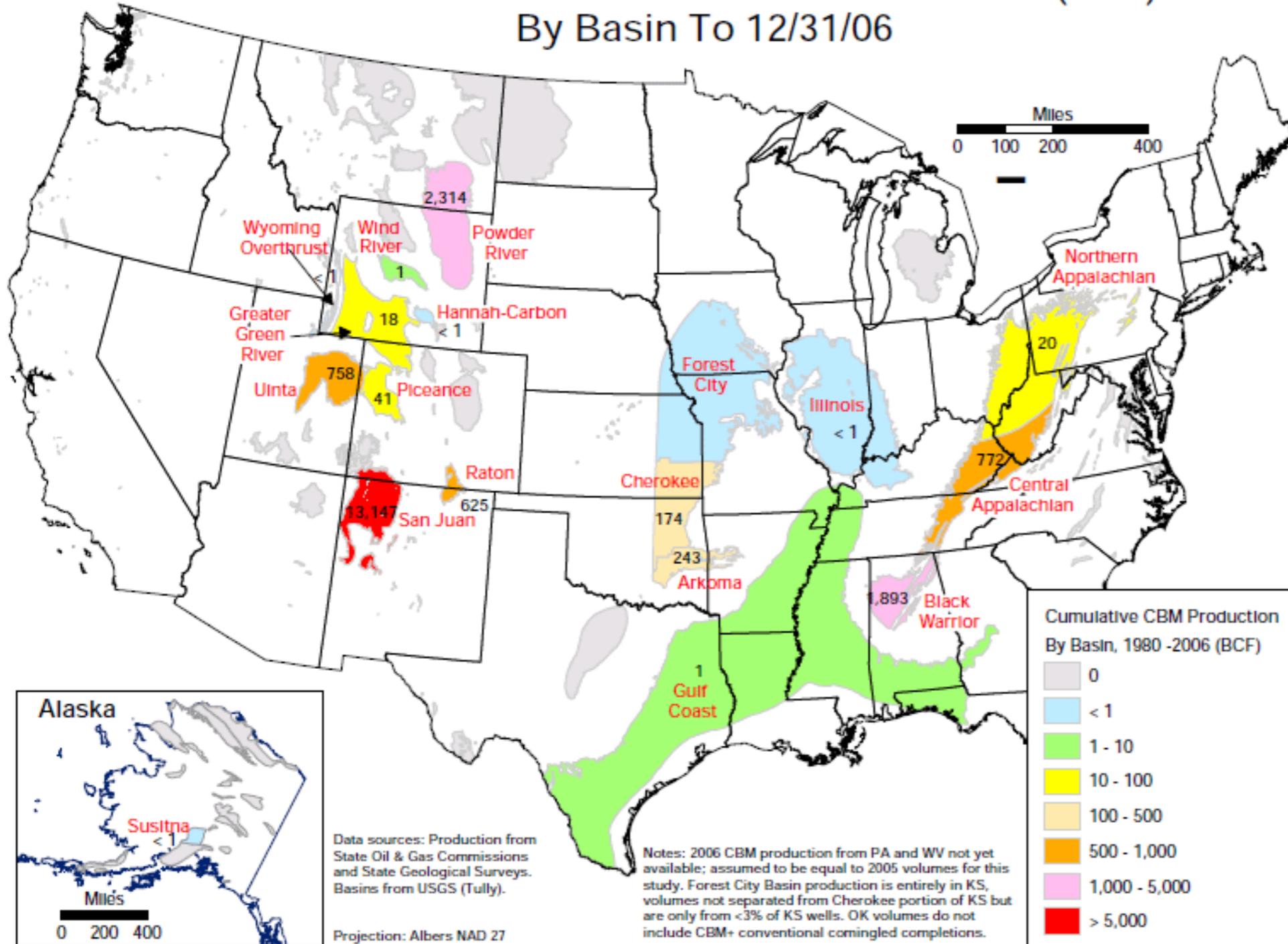
—> Estimated to be about 0.5Tg/yr, almost 10% of US total Oil&Gas

How it all got started

SCIAMACHY Methane Anomalies

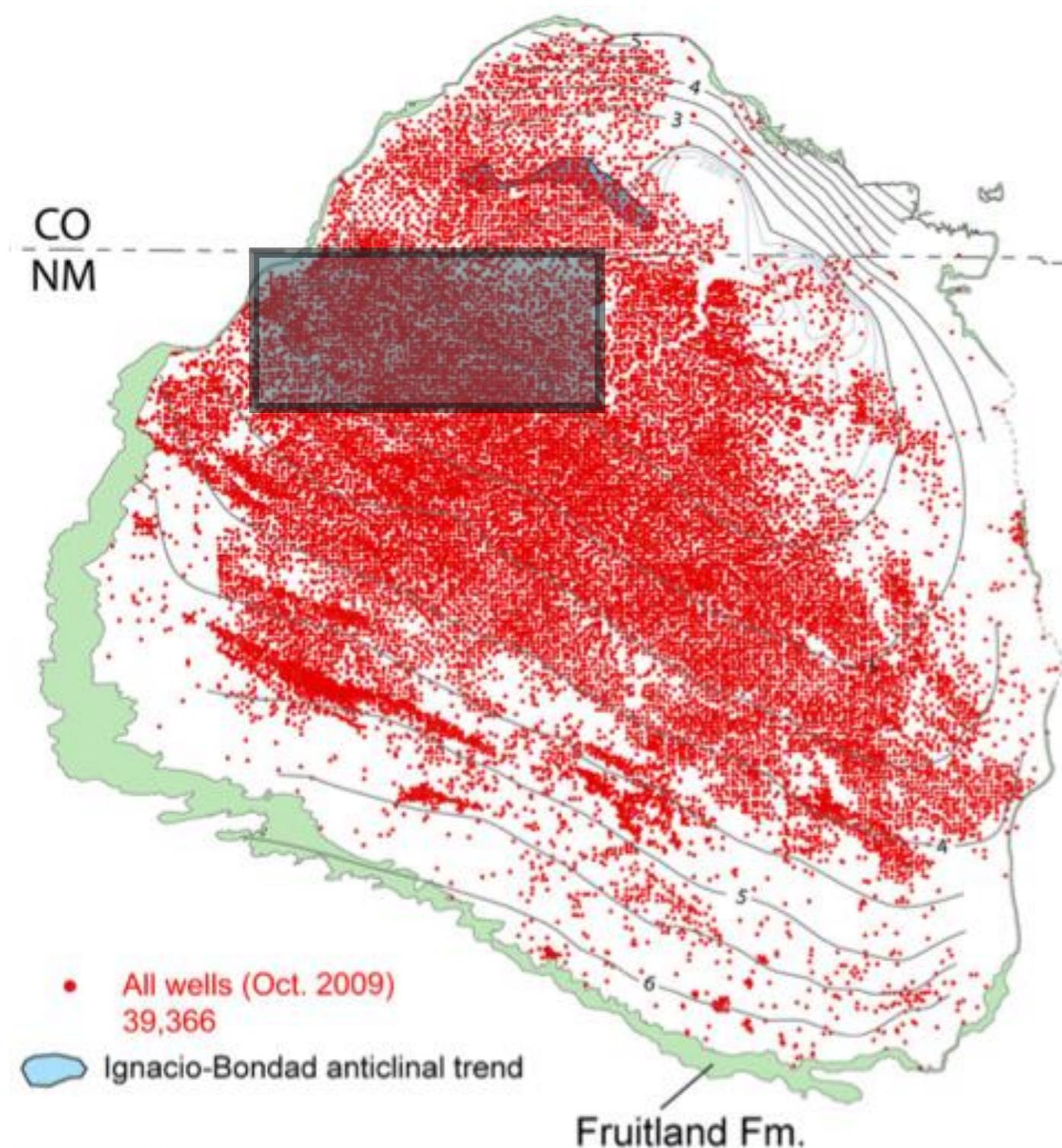
Potential Sources of CH₄ in Four Corners Region

US Coalbed Methane Cumulative Production (BCF)
By Basin To 12/31/06



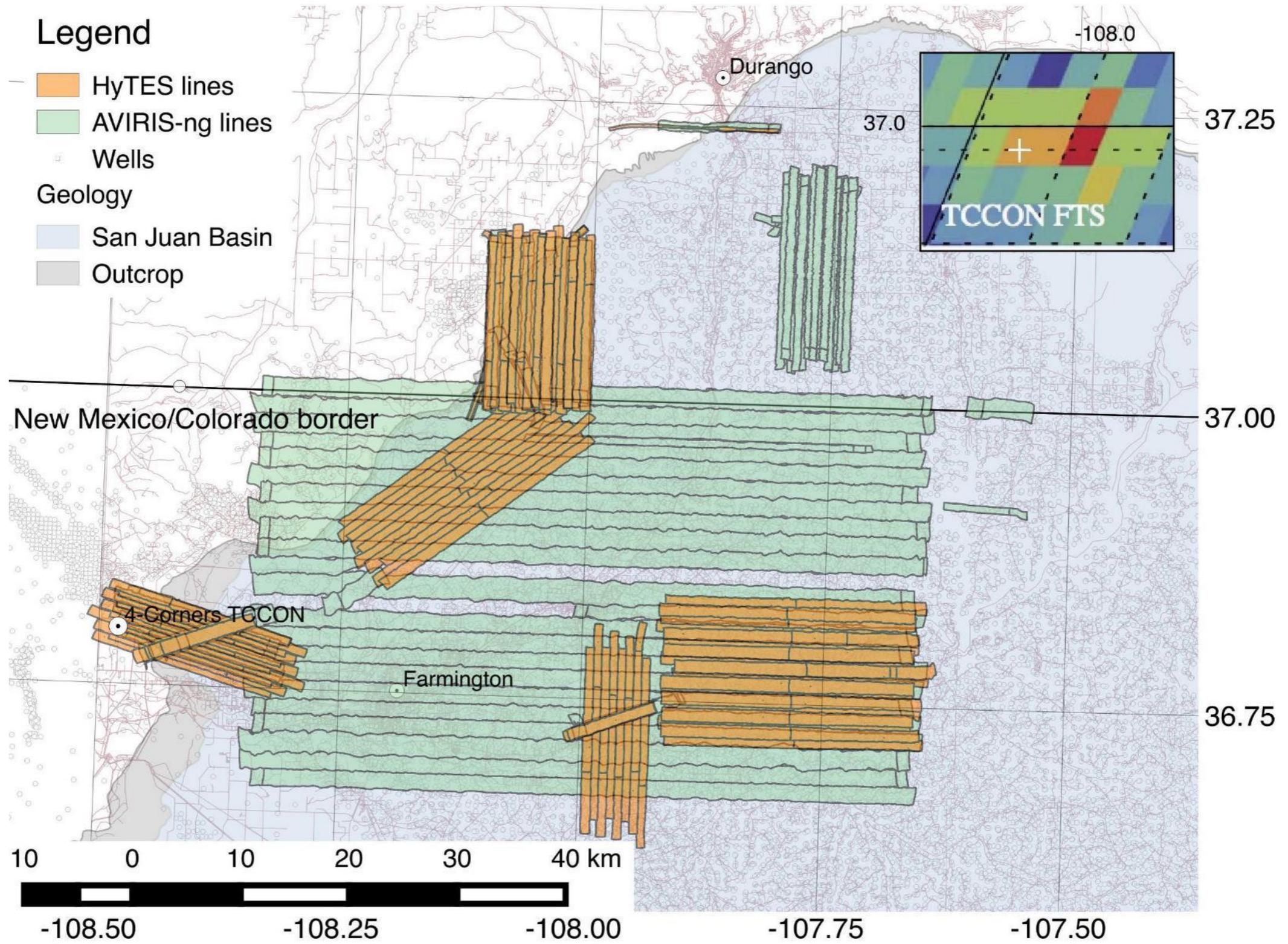
- Total Production rate in San Juan Basin about 1000 billion cubic feet (20Tg/yr)
- 0.5Tg/yr would be about 2.5%
- Largest Coalbed methane production area in US

Potential Sources of CH₄ in Four Corners Region



- Coal bed methane (CBM)
- Tight Sandstone natural gas production
- Active Coal mining
- Geological seeps
- Large Power plants
- Oil production
- Emissions from agricultural sources, waste management facilities and wetlands are small

Campaign Area



Some pictures from the aircraft

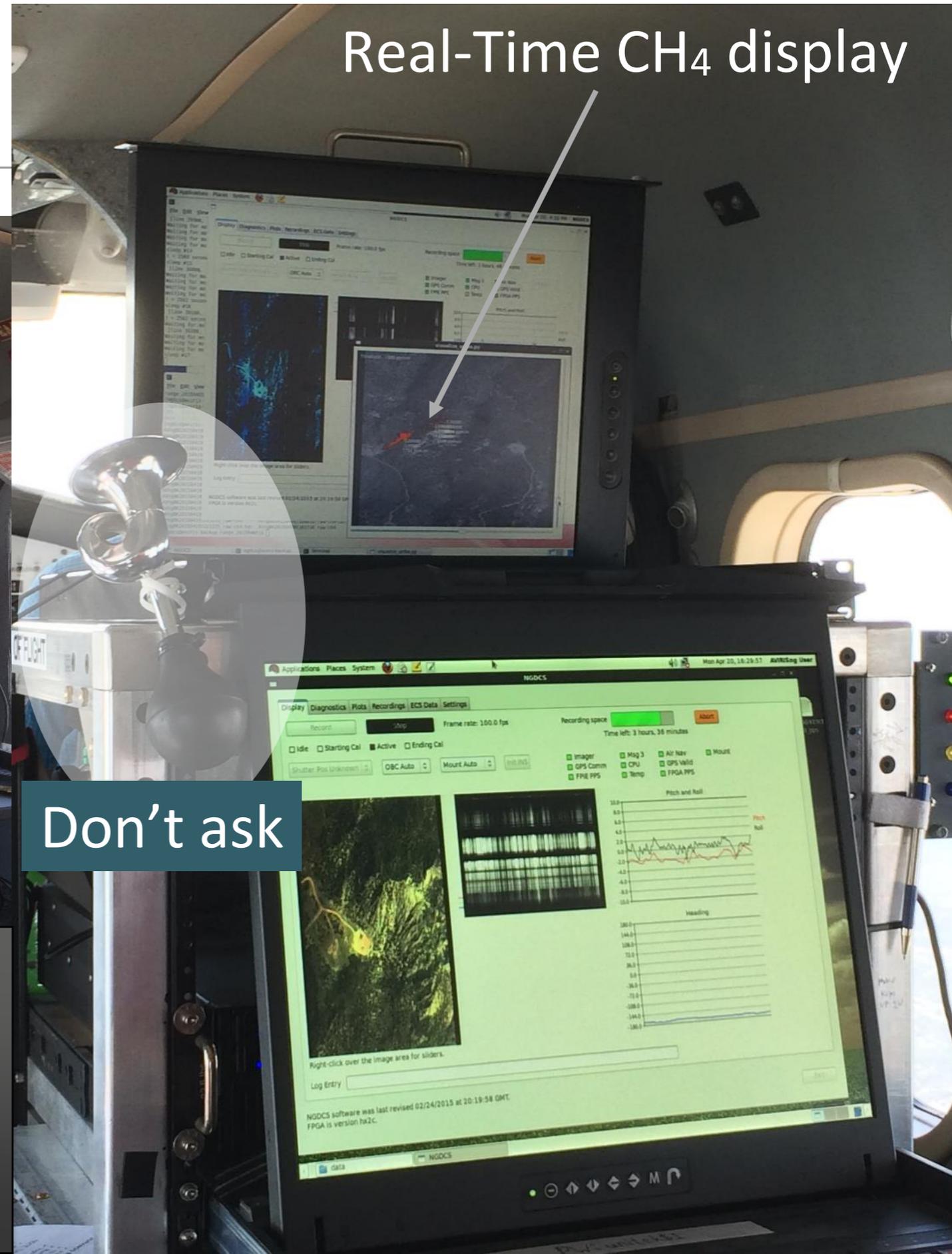


Airborne operations



AVIRIS-NG real time methane detection

David Thompson JPL

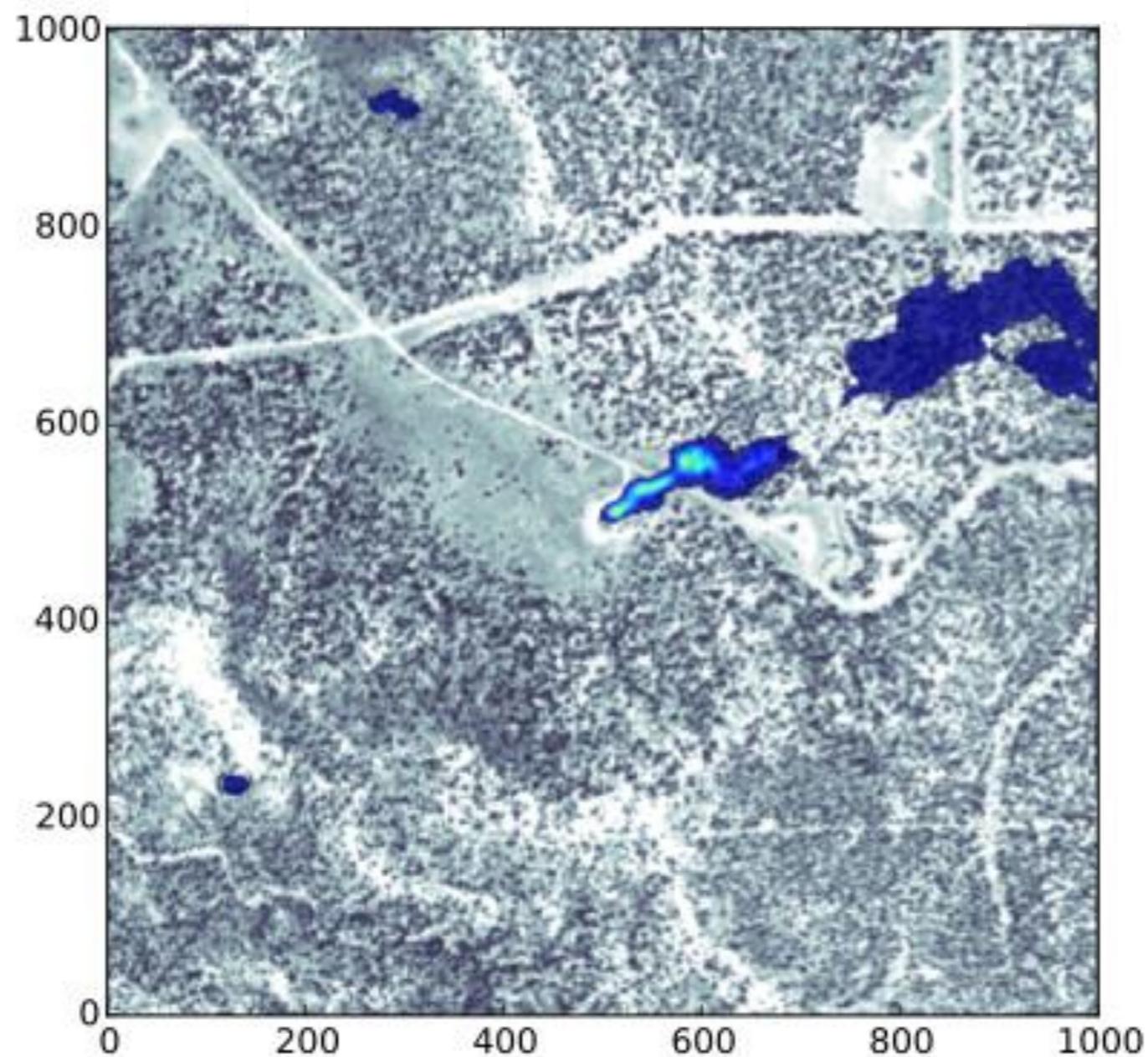
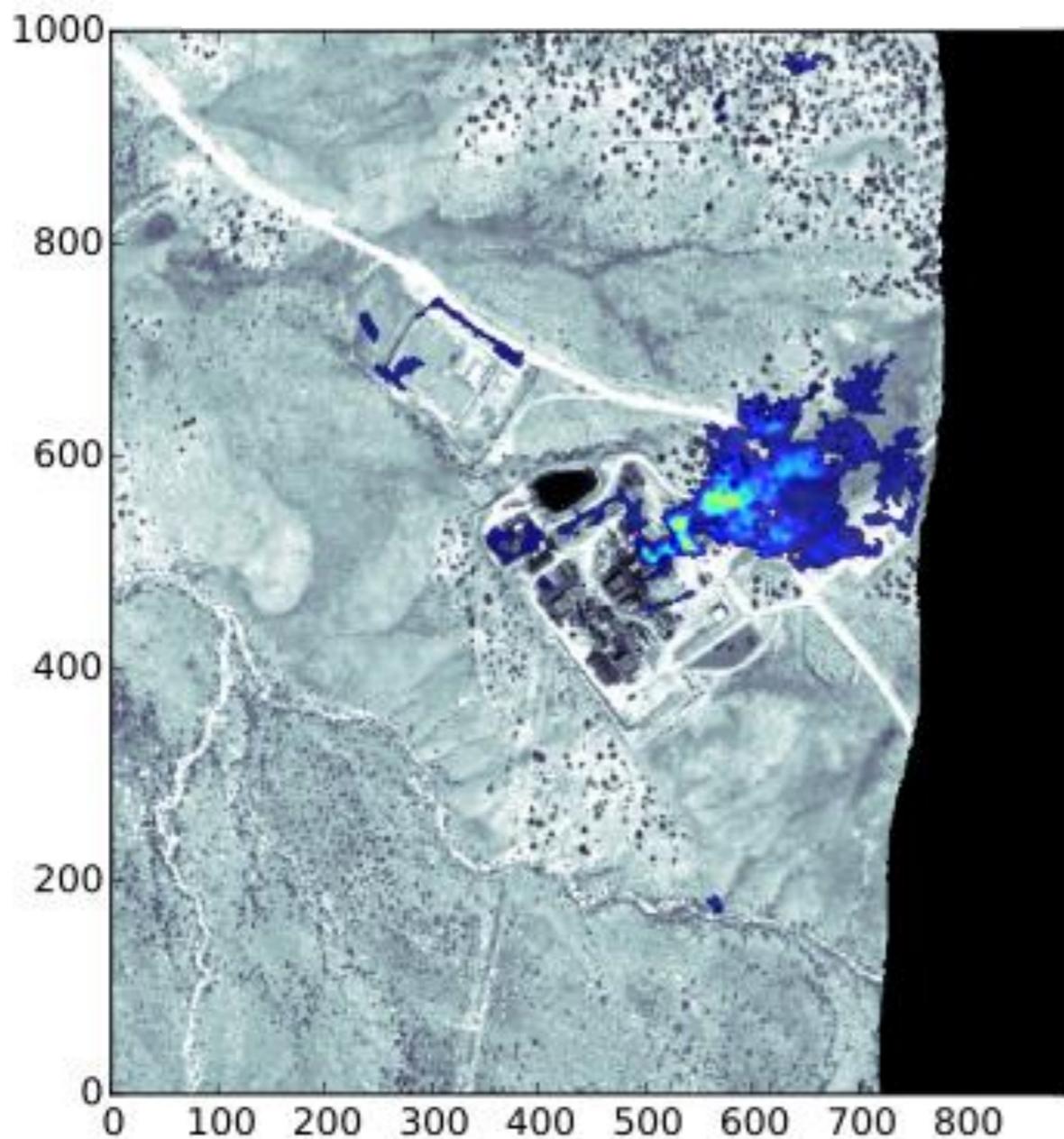


Real-Time CH₄ display

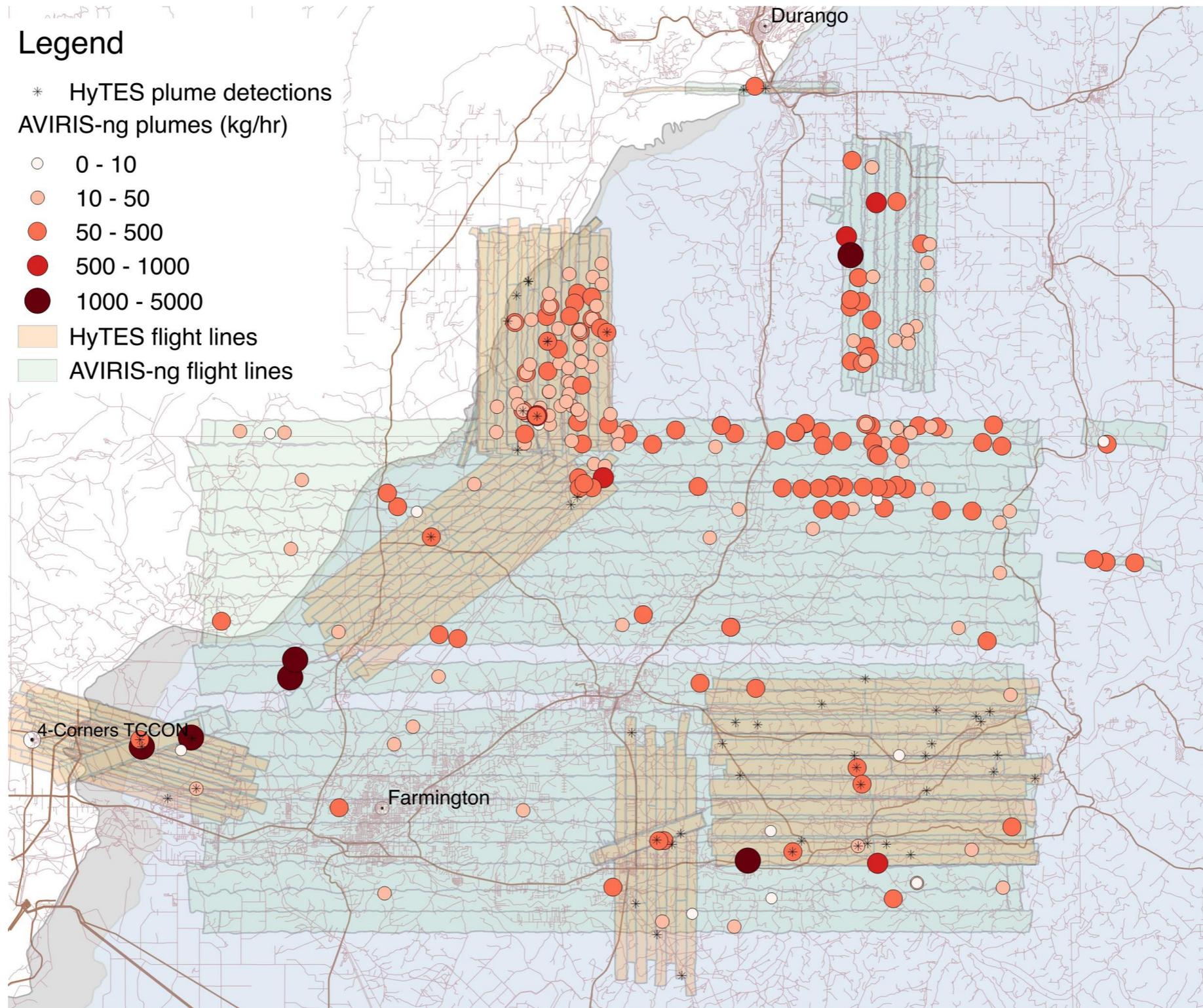
Don't ask

Native resolution examples

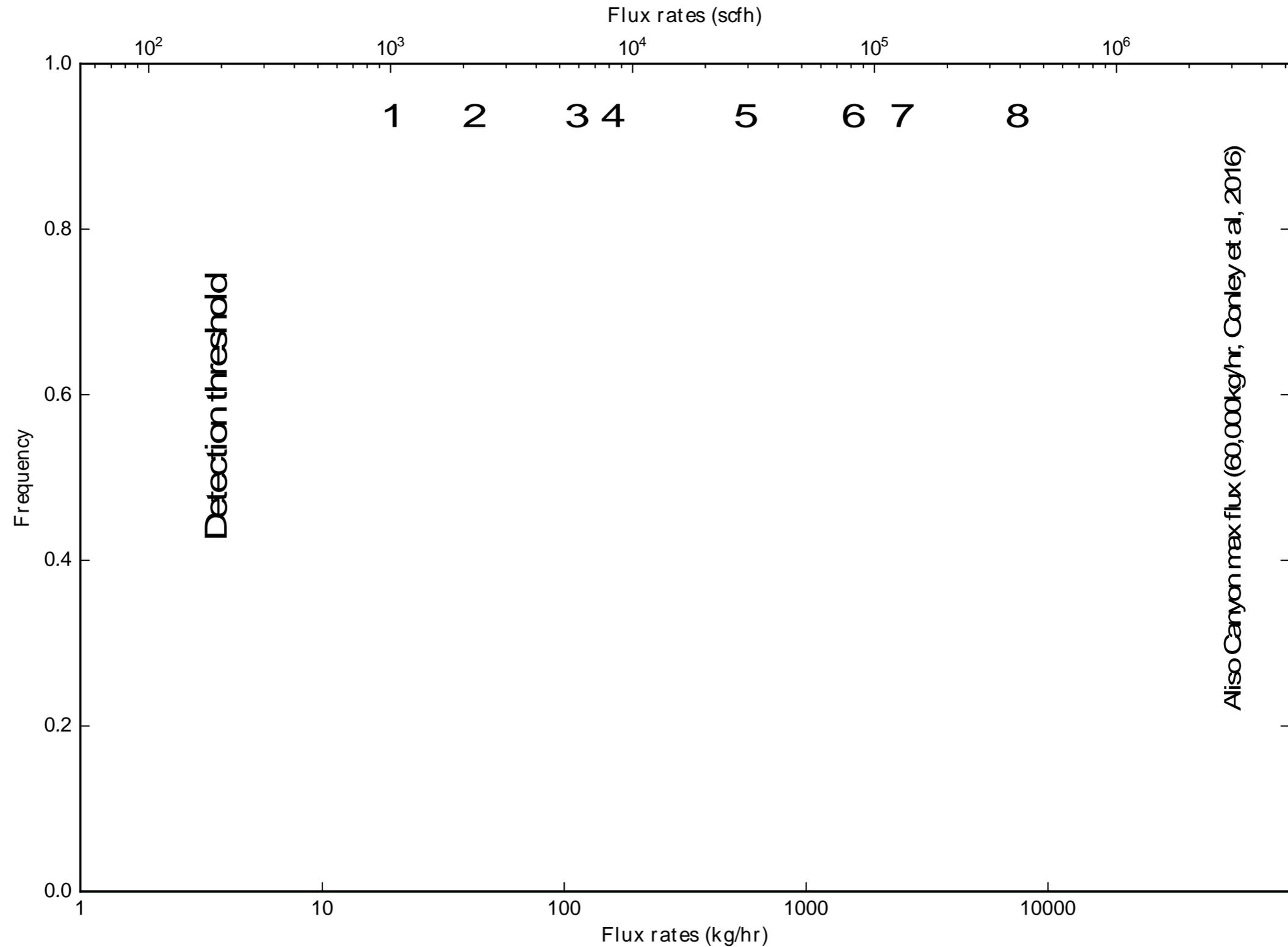
(background is $2.3\mu\text{m}$ radiance in gray, meter axis)



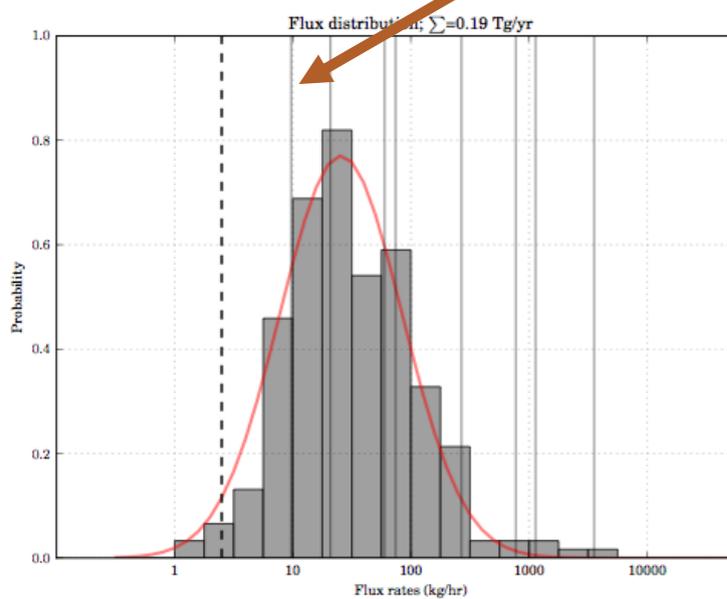
>200 plumes detected during campaign



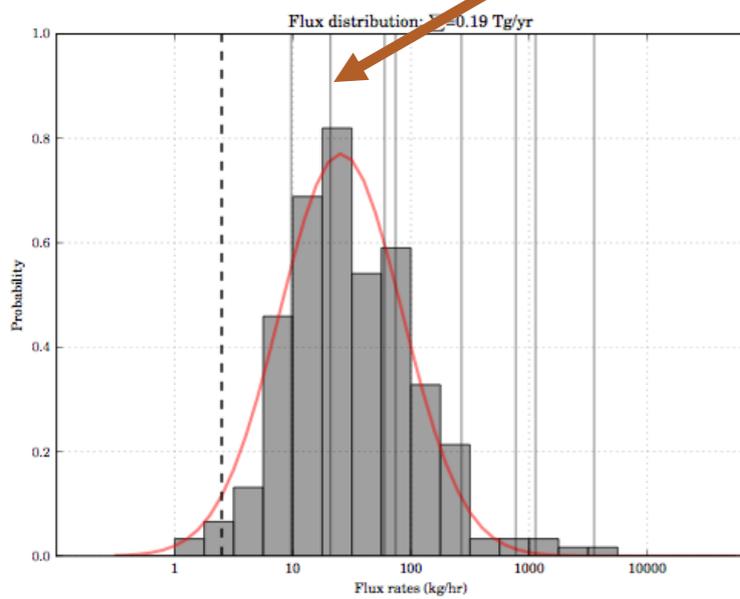
Plume distribution — Pareto's law



Plume distribution — Wellhead



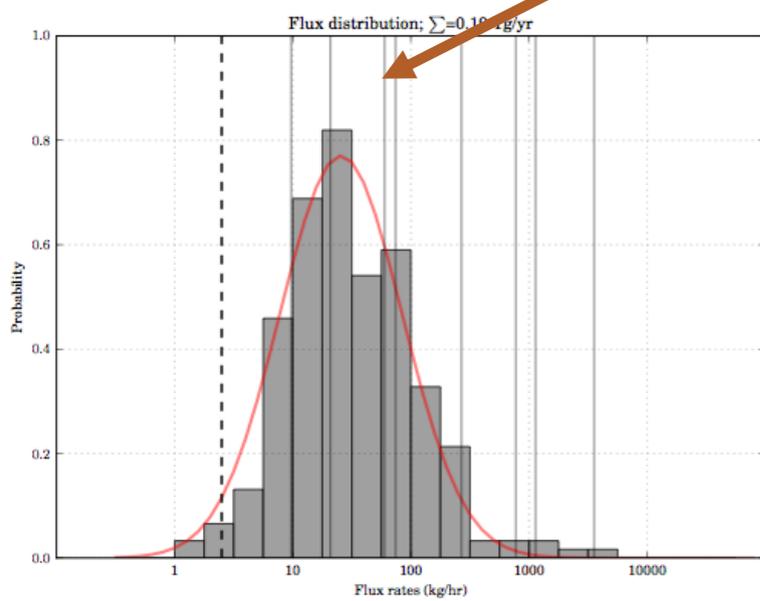
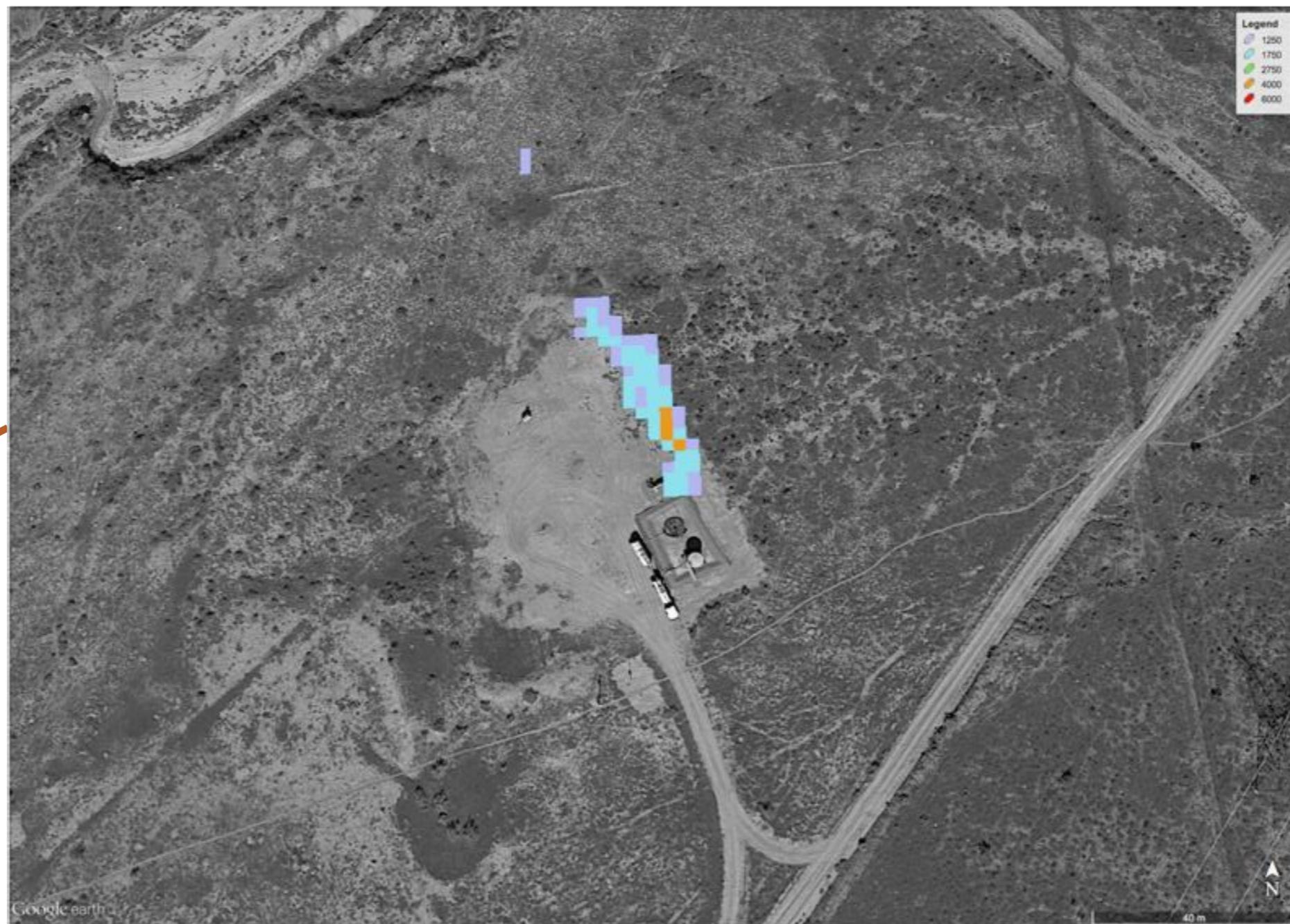
Plume distribution — ???



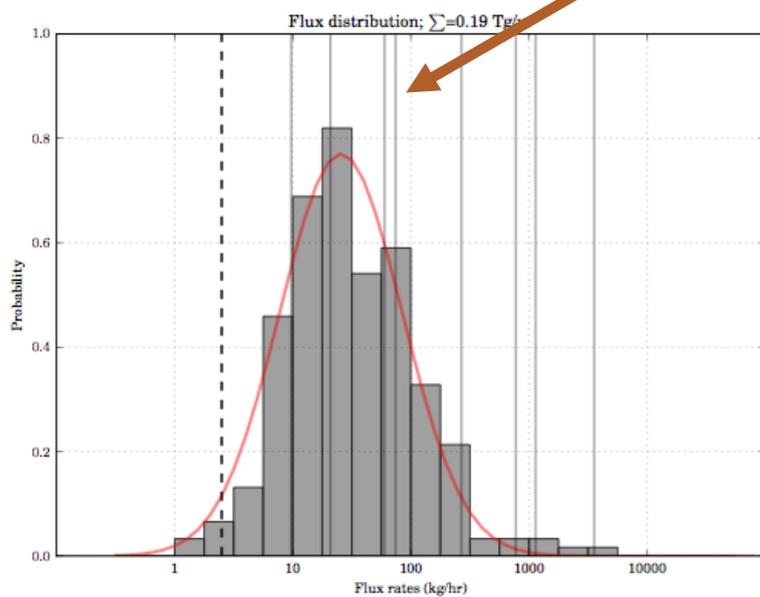
Methane plume



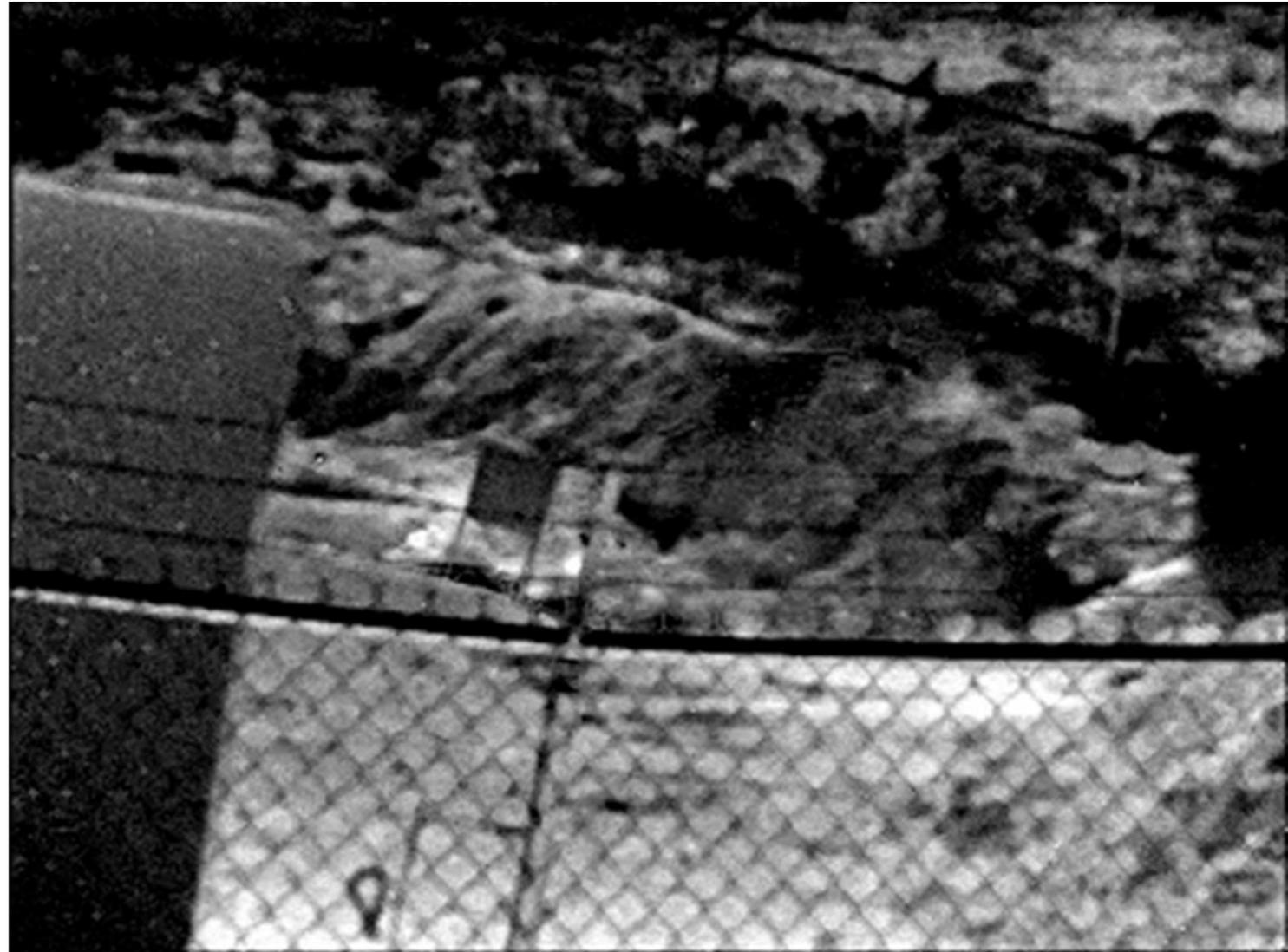
Plume distribution



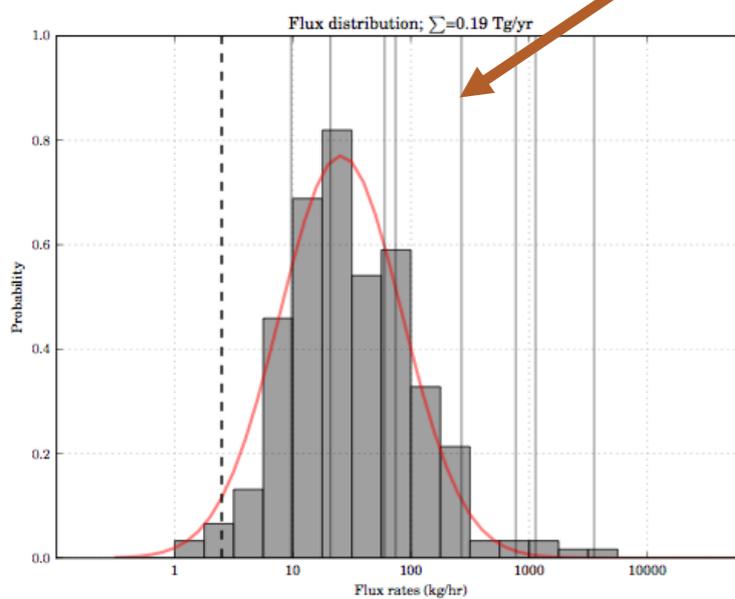
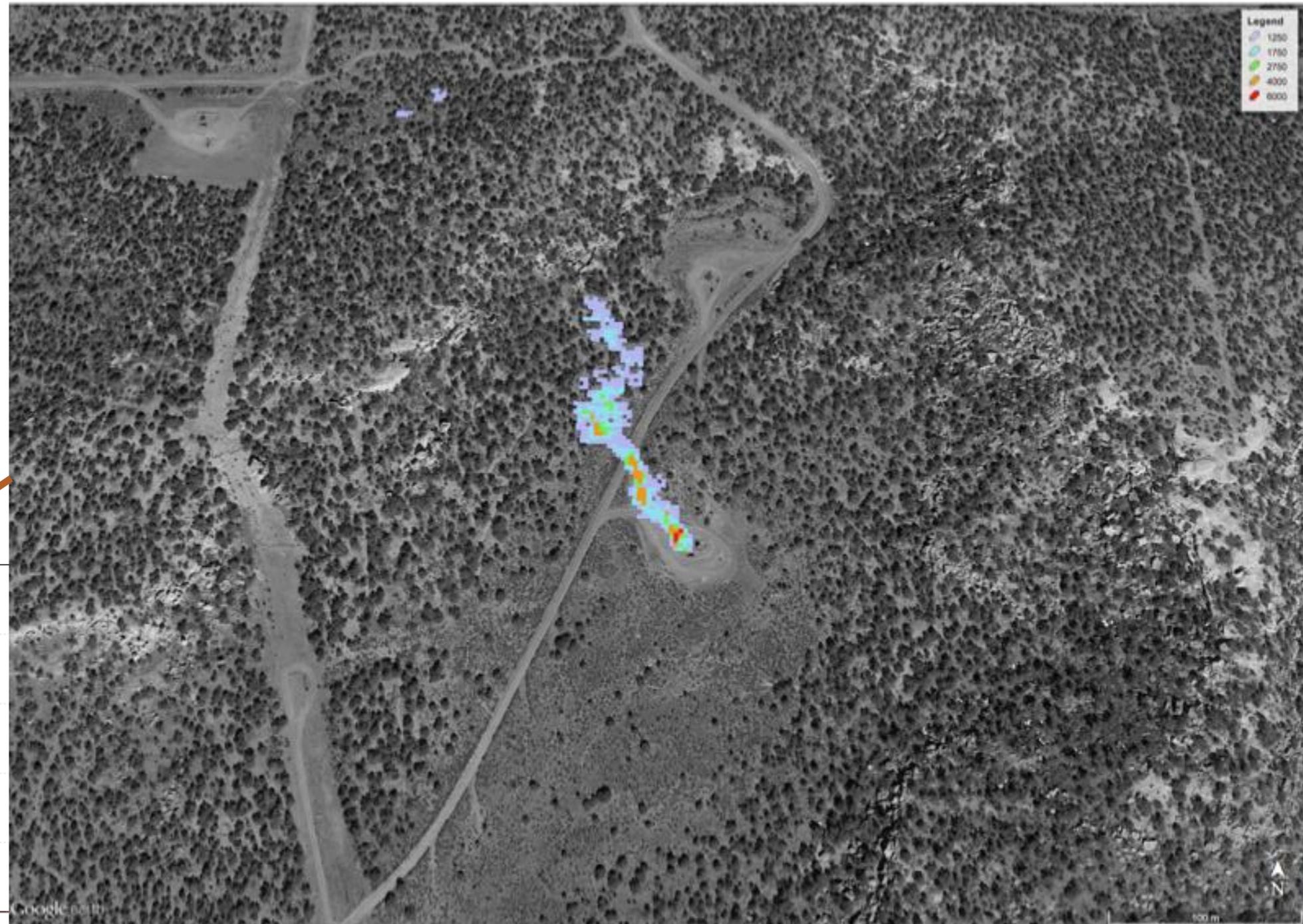
Plume distribution — underground storage tank



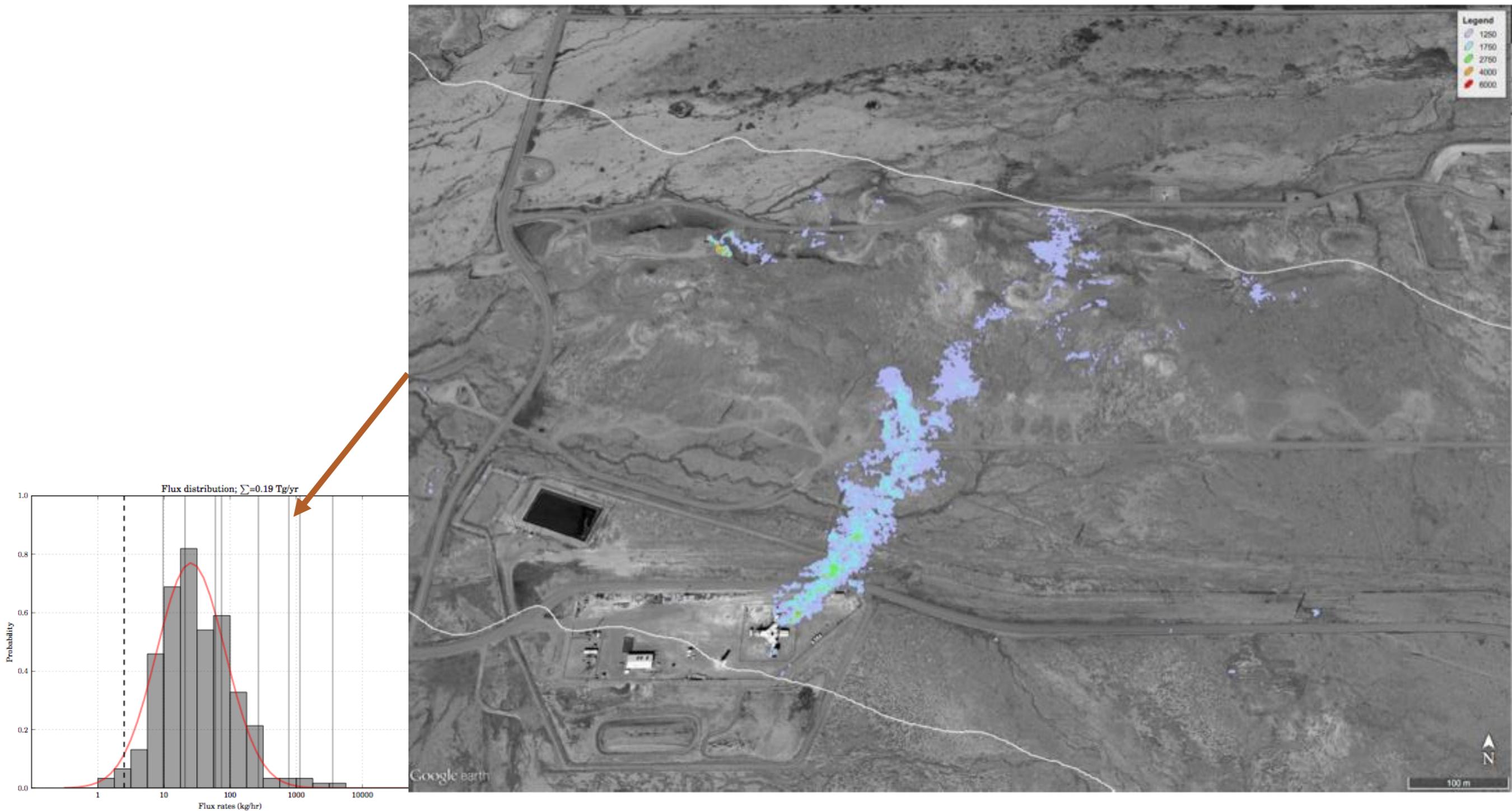
Methane plume from tank



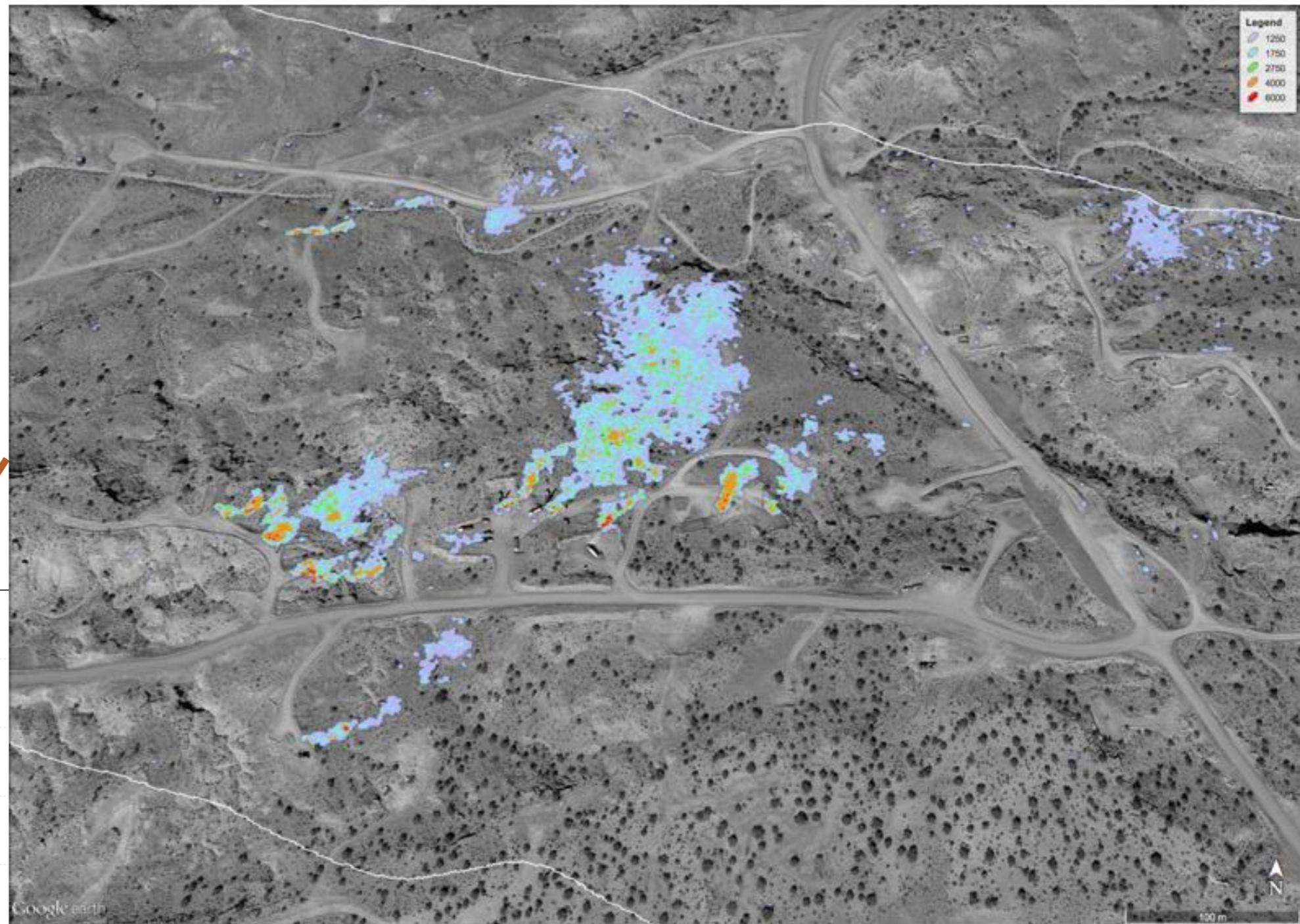
Plume distribution - Wellhead



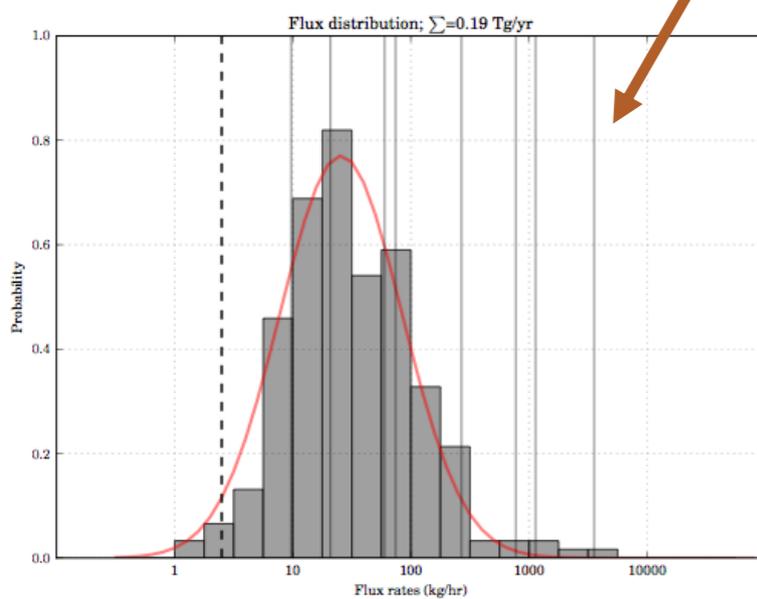
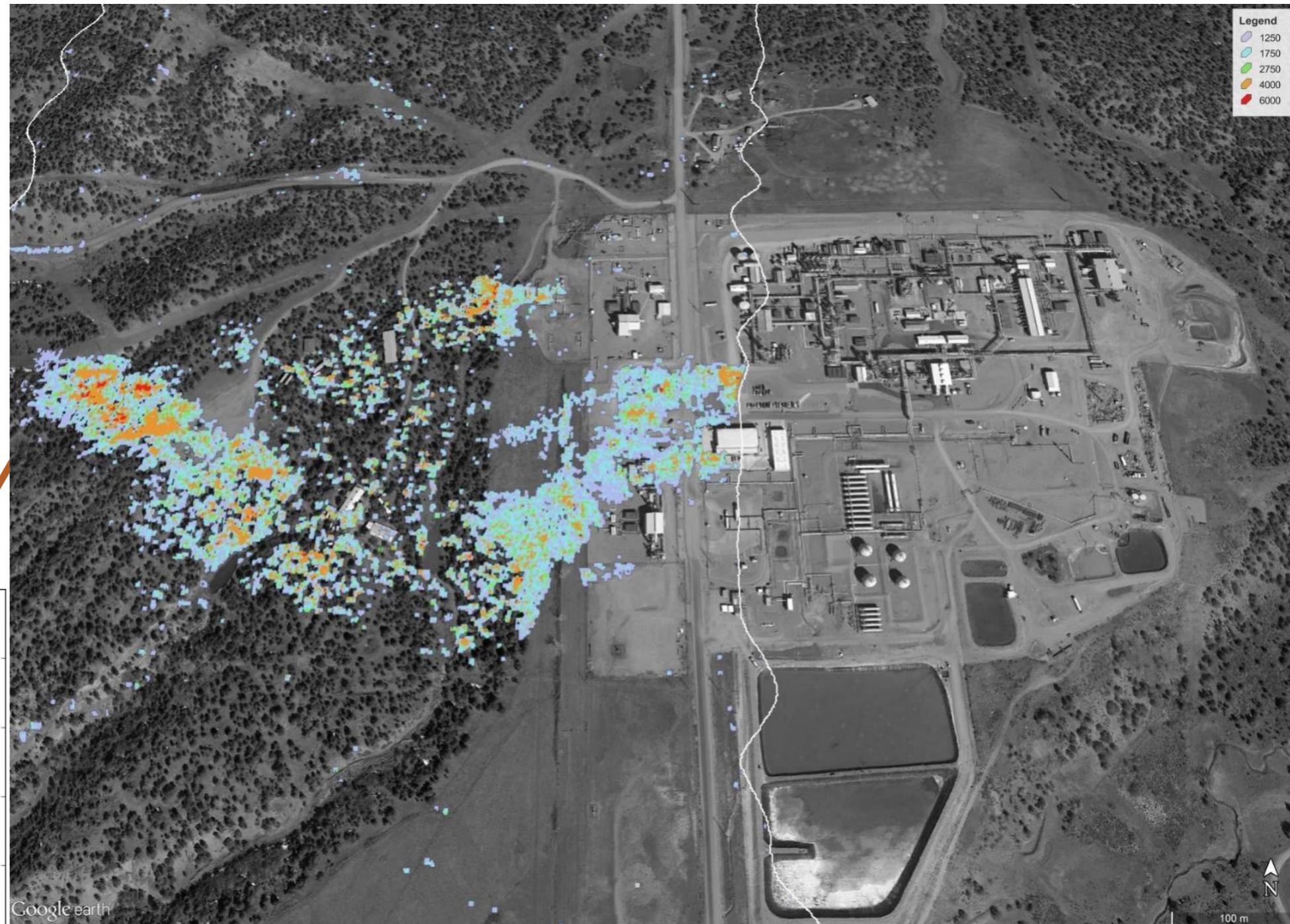
Plume distribution — Guesses welcome



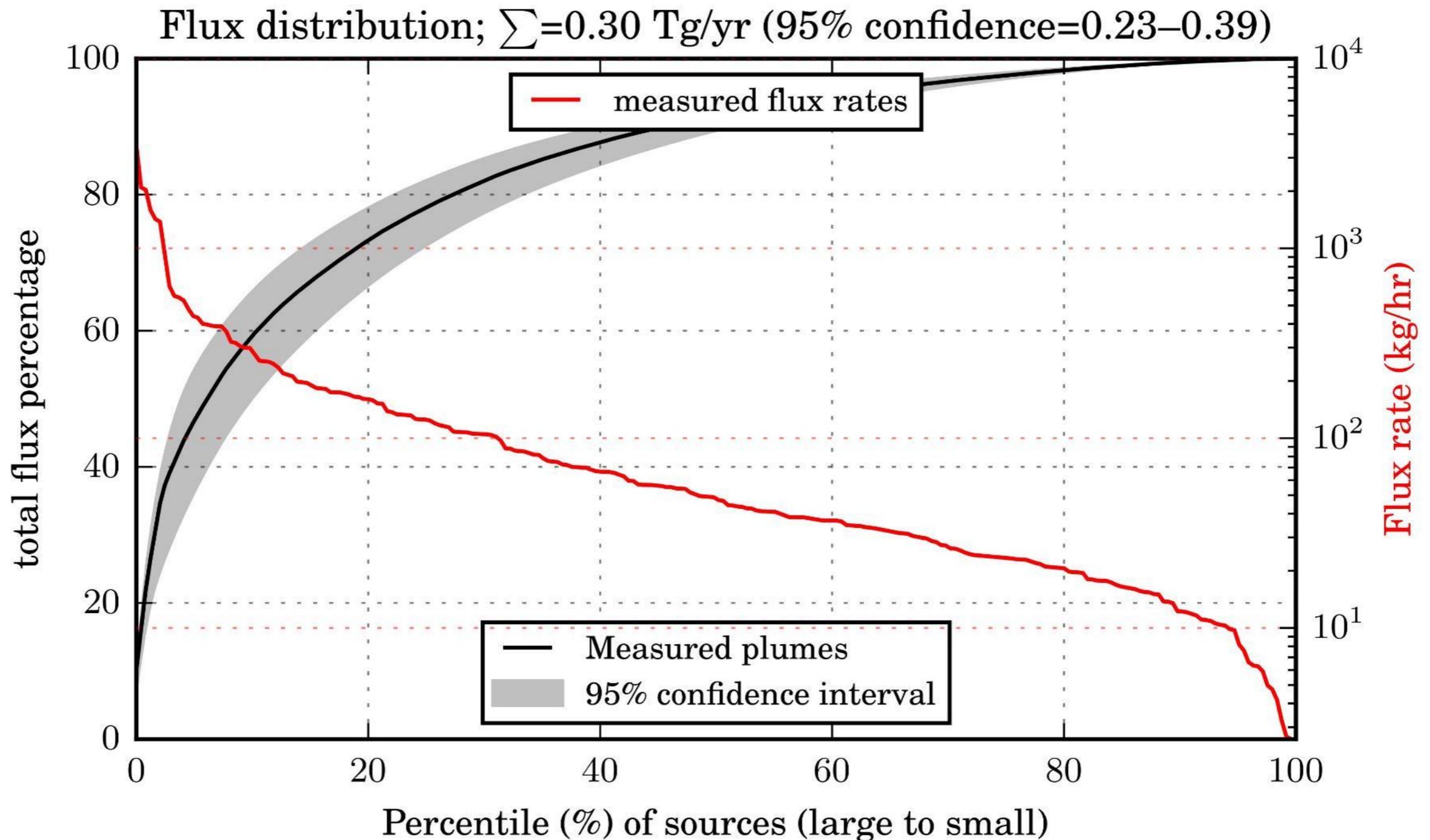
Plume distribution — Unclear (multiple sources, maybe well completion?)



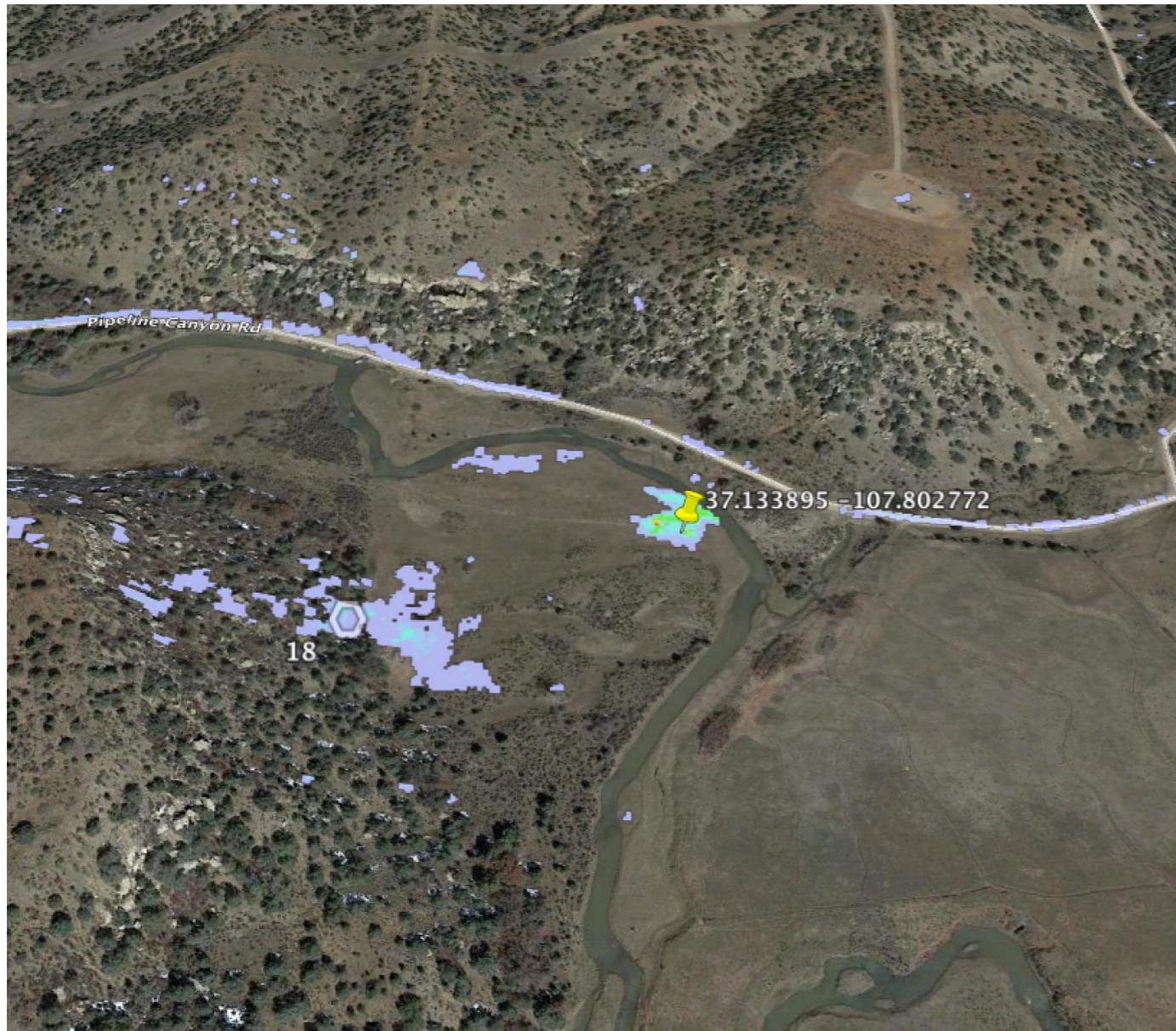
Plume distribution — Gas Processing Facility (temporary plume)



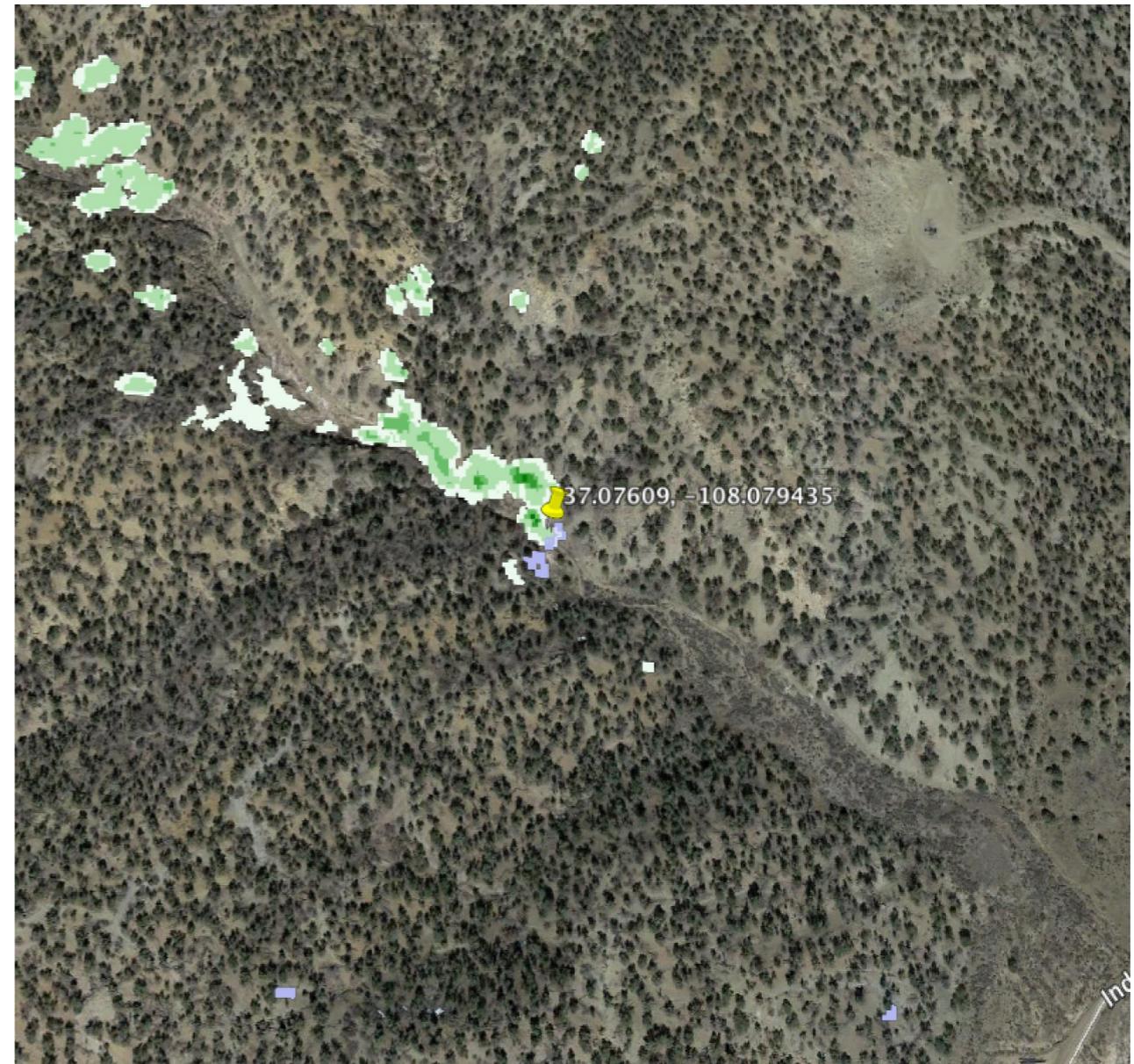
What does the log-normal distribution imply?



Further sources (unknown origin at the time of publication)



Another pipeline (3rd)



Natural Seep

2015



Untitled Map
Write a description for your map.

- Core Sites
- Relocatables
- Domain Boundary

Legend

- 📍 37.133895, -107.802772
- Feature 1
- Transect1

2016



Untitled Map
Write a description for your map.

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- ▭ Domain Boundary

Legend

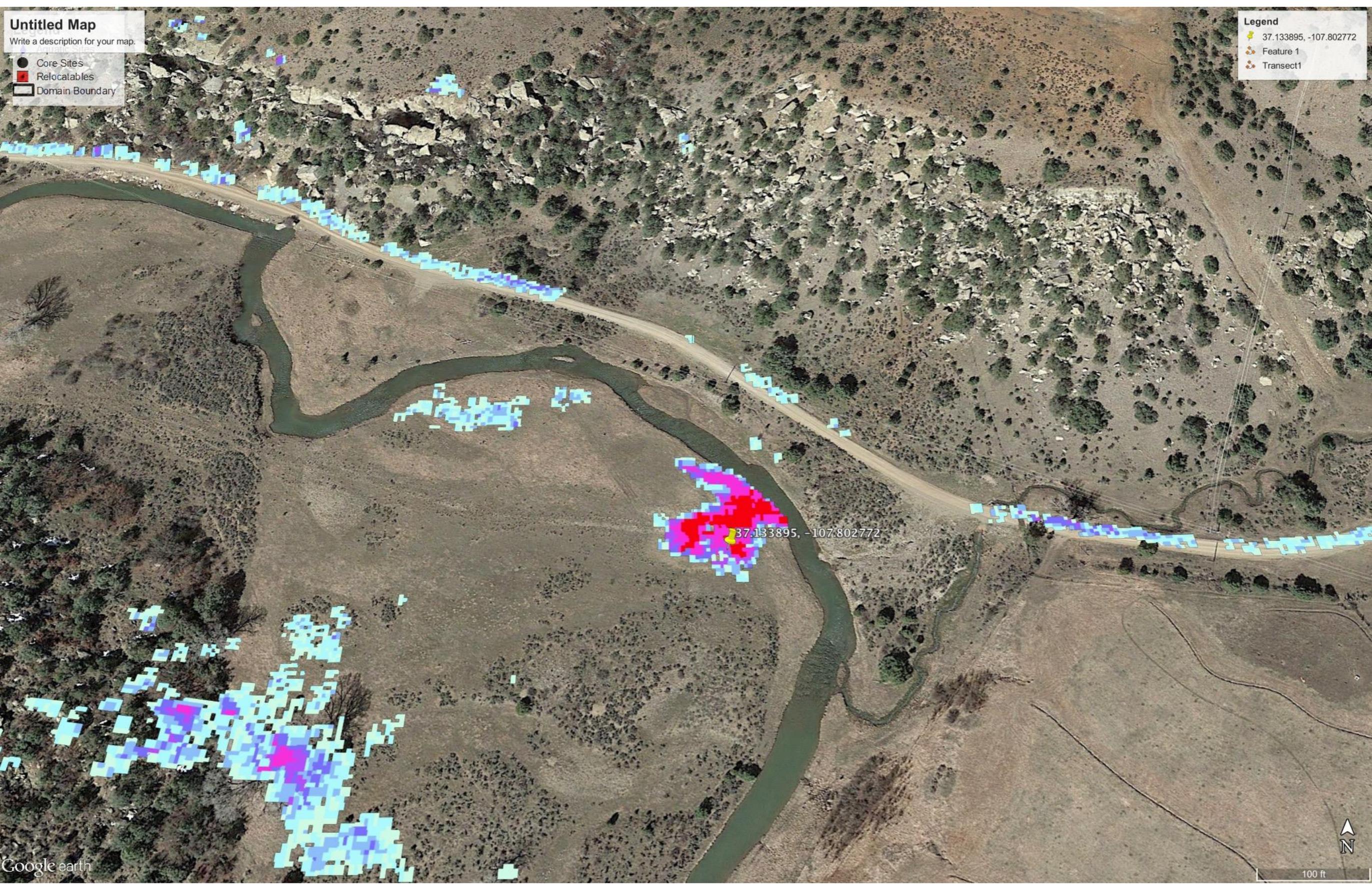
- 📍 37.133895, -107.802772
- 🔗 Feature 1
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Write a description for your map.

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- ▭ Domain Boundary

Legend

- 37.133895, -107.802772
- Feature 1
- Transect1



Overall Findings

- We observed more than 200 methane plumes, most of which could be associated with industrial activities (some natural seeps were seen as well)
- Flux rates follow a distribution that implies that the 20% top emitters explain 70-75% of the overall flux
- Estimate of 0.3Tg/yr is not much smaller than total flux estimates, observed plumes explain a large share of area total
- 2 Pipeline leaks were detected and fixed the day after we found them