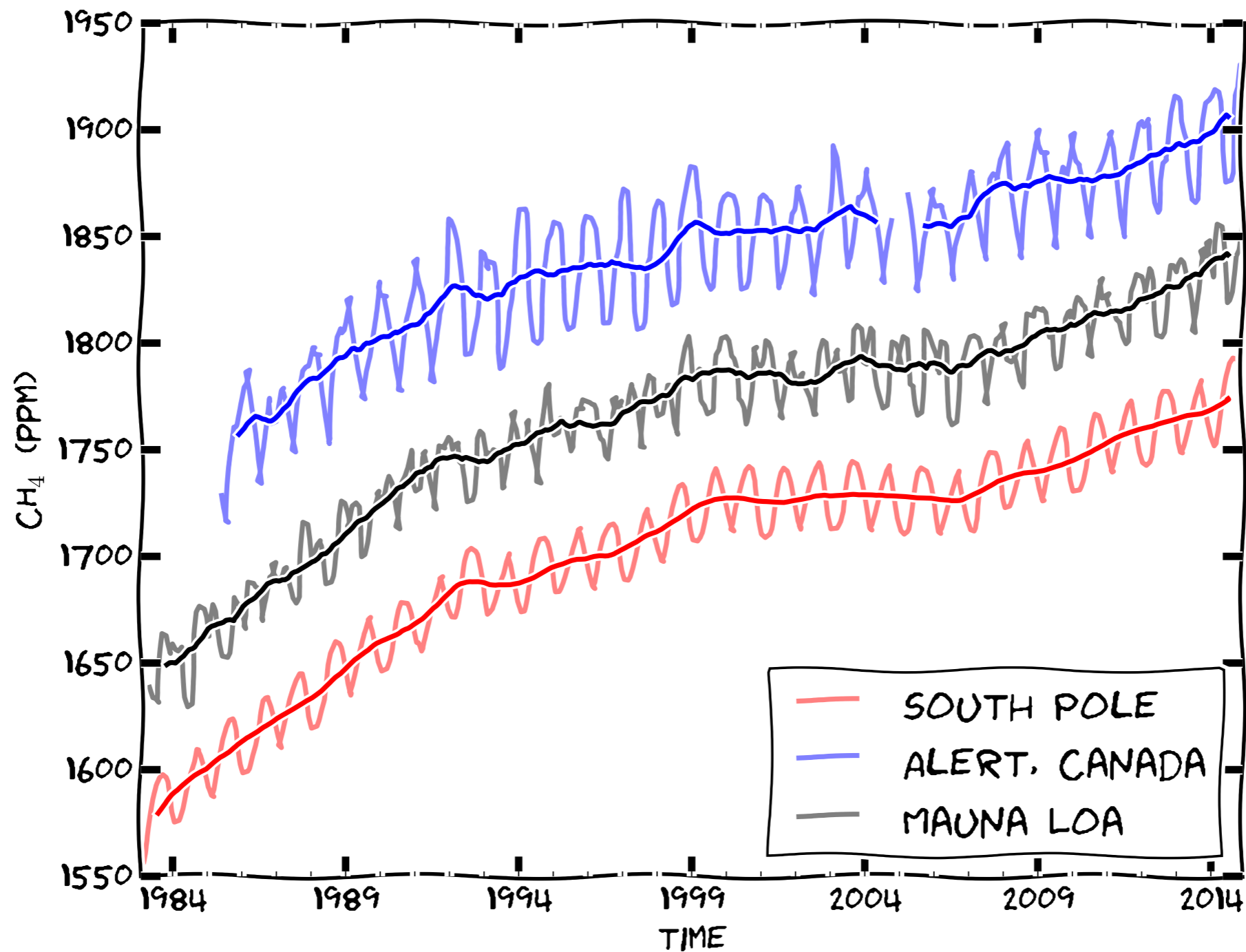




Atmospheric Methane
From a gas well to a hemisphere

Christian Frankenberg
and many others

Recent changes in atmospheric methane



Recent papers on methane rise (just a few of them)

RESEARCH ARTICLE

10.1002/2016GB005406

Key Points:

- Atmospheric methane is growing rapidly
- Isotopic evidence implies that the growth is driven by biogenic sources
- Growth is dominated by tropical

Rising atmospheric methane: 2007–2014 growth and isotopic shift

E. G. Nisbet¹, E. J. Dlugokencky², M. R. Manning³, D. Lowry¹, R. E. Fisher¹, J. L. France^{1,4}, S. E. Michel⁵, J. B. Miller^{5,6}, J. W. C. White⁵, B. Vaughn⁵, P. Bousquet⁷, J. A. Pyle^{8,9}, N. J. Warwick^{8,9}, M. Cain^{8,9}, R. Brownlow¹, G. Zazzeri¹, M. Lanoisellé¹, A. C. Manning⁴, E. Gloor¹⁰, D. E. J. Worthy¹¹, E.-G. Brunke¹², C. Labuschagne^{12,13}, E. W. Wolff¹⁴, and A. L. Ganesan¹⁵

Atmospheric methane isotopic record favors fossil sources flat in 1980s and 1990s with recent increase

Andrew L. Rice^{a,1,2}, Christopher L. Butenhoff^{a,1}, Doaa G. Teama^a, Florian H. Röger^a, M. Aslam K. Khalil^a, and Reinhold A. Rasmussen^b

REPORT

A 21st century shift from fossil-fuel to biogenic methane emissions indicated by ¹³CH₄

Hinrich Schaefer^{1,*}, Sara E. Mikaloff Fletcher¹, Cordelia Veidt², Keith R. Lassey^{1,†}, Gordon W. Brailsford¹, Tony M. Bromley¹, Edward J. Dlugokencky³, Sylvia E. Michel⁴, John B. Miller³, Ingeborg Levin², Dave C. Lowe^{1,‡}, Ross J. Martin¹, Bruce H. Vaughn⁴, James W. C. White⁴

+ Author Affiliations

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† Present address: Lassey Research & Education, Wellington, New Zealand.

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Science 10 Mar 2016:

DOI: 10.1126/science.aad2705

Role of OH variability in the stalling of the global atmospheric CH₄ growth rate from 1999 to 2006

Joe McNorton^{1,2}, Martyn P. Chipperfield^{1,2}, Manuel Gloor³, Chris Wilson^{1,2}, Wuhu Feng^{1,4}, Garry D. Hayman⁵, Matt Rigby⁶, Paul B. Krummel⁷, Simon O'Doherty⁶, Ronald G. Prinn⁸, Ray F. Weiss⁹, Dickon Young⁶, Ed Dlugokencky¹⁰, and Steve A. Montzka¹⁰

From the hemisphere to individual methane plumes (back later)

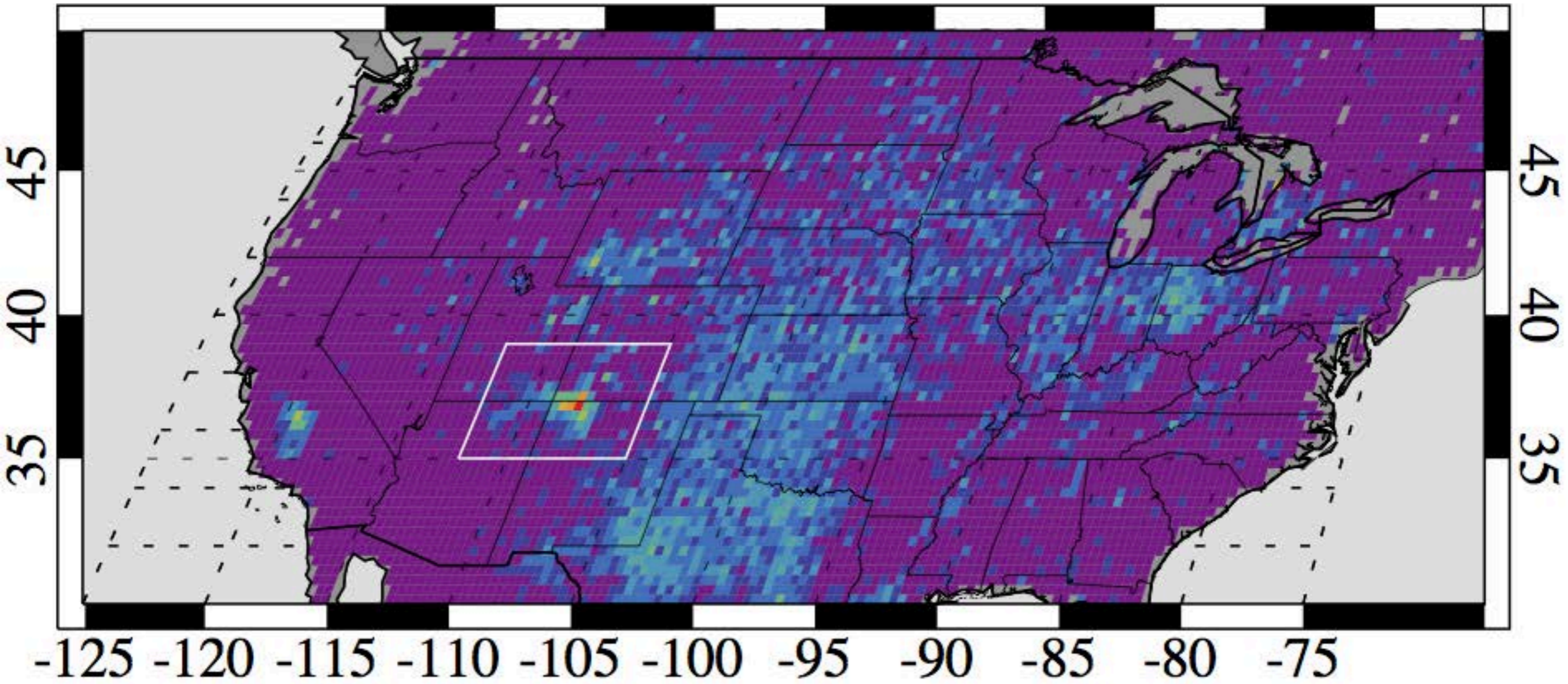
4 Corners airborne campaign

Airborne methane remote measurements reveal heavy-tail flux distribution in Four Corners region

Christian Frankenberg^{a,b,1}, Andrew K. Thorpe^b, David R. Thompson^b, Glynn Hulley^b, Eric Adam Kort^c, Nick Vance^b, Jakob Borchardt^d, Thomas Krings^d, Konstantin Gerilowski^d, Colm Sweeney^{e,f}, Stephen Conley^{g,h}, Brian D. Bue^b, Andrew D. Aubrey^b, Simon Hook^b, and Robert O. Green^b

^aDivision of Geology and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125; ^bJet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109; ^cDepartment of Climate and Space Sciences and Engineering, University of Michigan, Ann Arbor, MI 48109; ^dInstitute of Environmental Physics, University of Bremen, 28334 Bremen, Germany; ^eCooperative Institute for Research in Environmental Sciences, University of Colorado-Boulder, Boulder, CO 80309; ^fGlobal Monitoring Division, Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO 80305; ^gScientific Aviation, Boulder, CO 80301; and ^hDepartment of Land, Air, and Water Resources, University of California, Davis, CA 95616

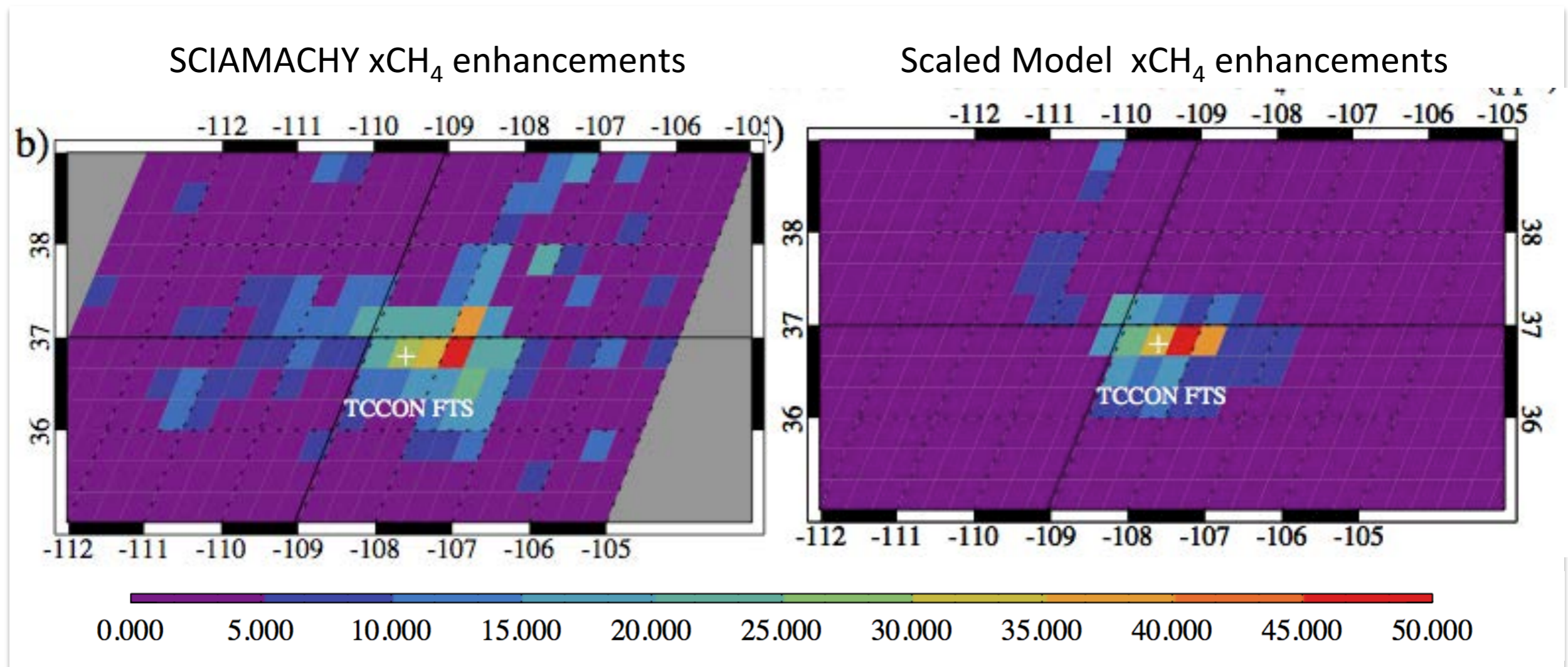
Kort, Frankenberg et al, GRL, 2014



How it all got started

SCIAMACHY Methane Anomalies

Kort, Frankenberg et al, GRL, 2014



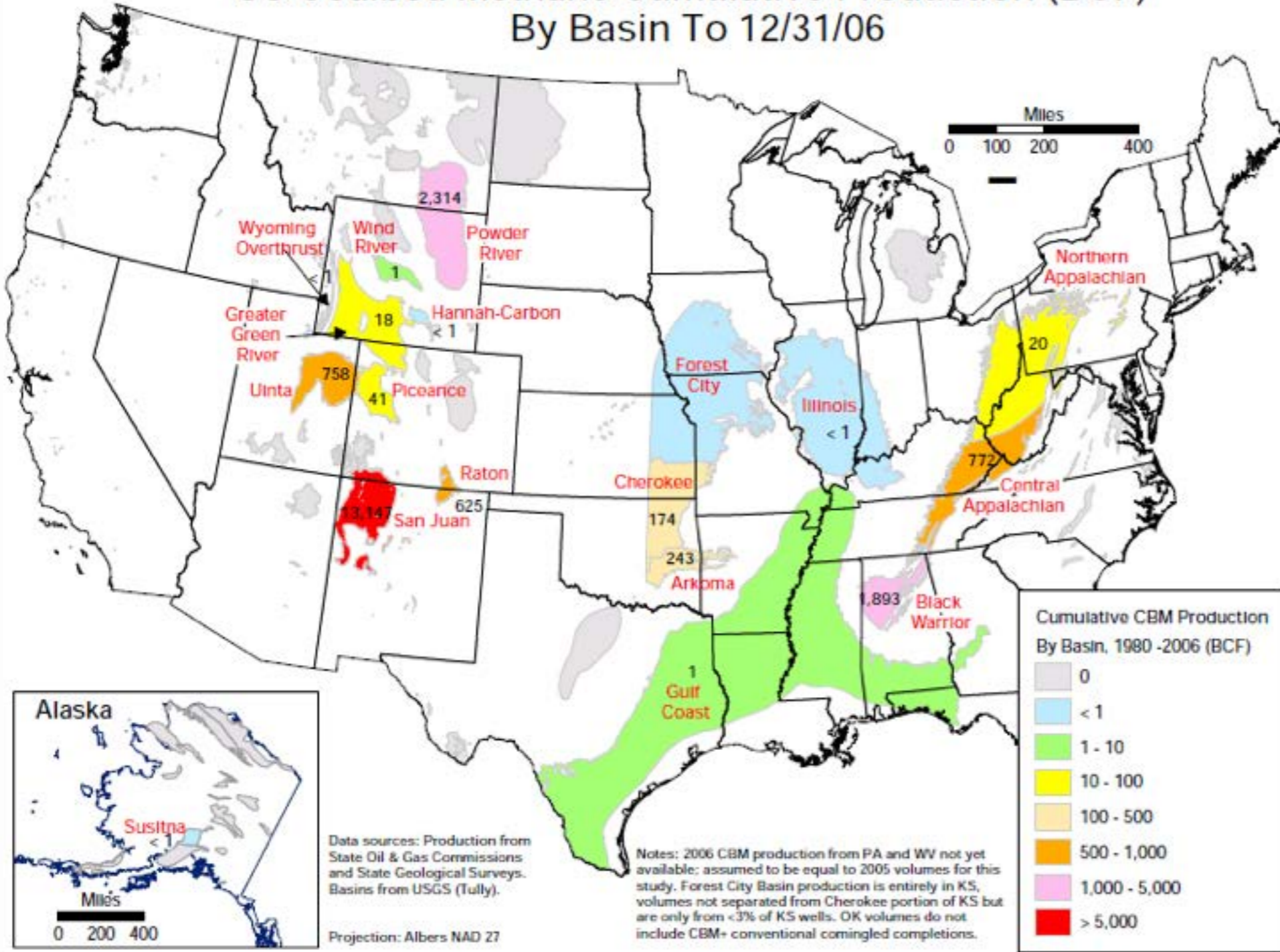
—> Estimated to be about 0.5Tg/yr, almost 10% of US total Oil&Gas

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



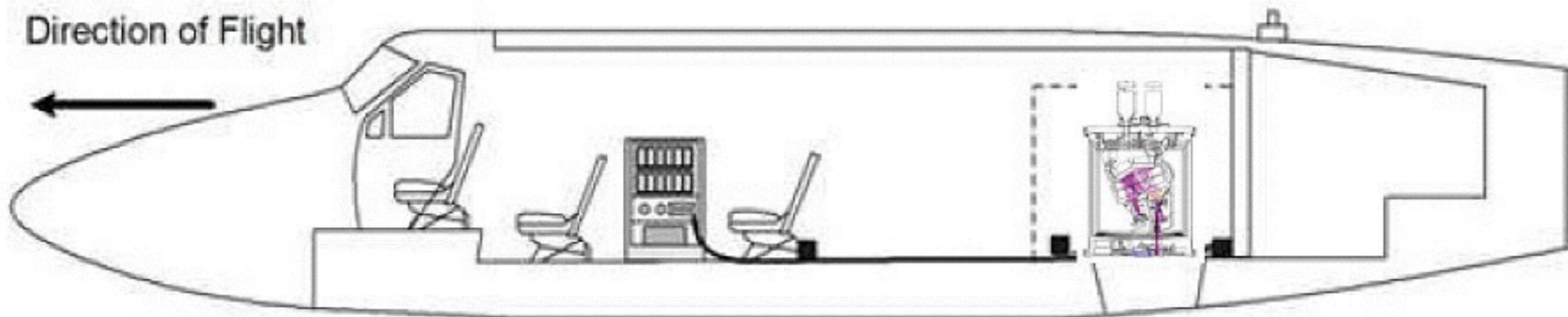
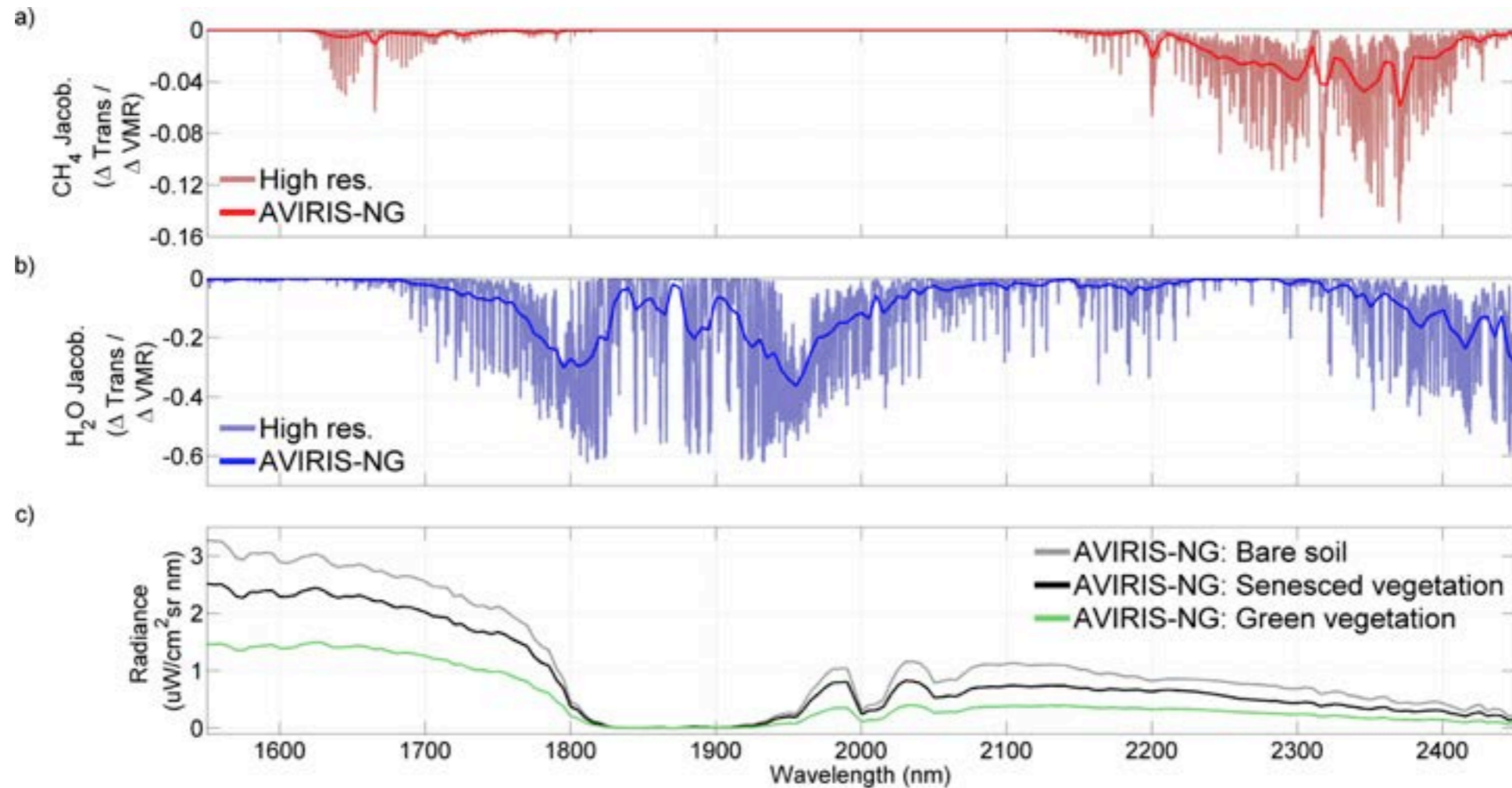
- Total Production rate in San Juan Basin about 1000 billion cubic feet (20Tg/yr)
- 0.5Tg/yr would be about 2.5%
- Largest Coalbed methane production area in US

Data sources: Production from State Oil & Gas Commissions and State Geological Surveys. Basins from USGS (Tully).
Projection: Albers NAD 27

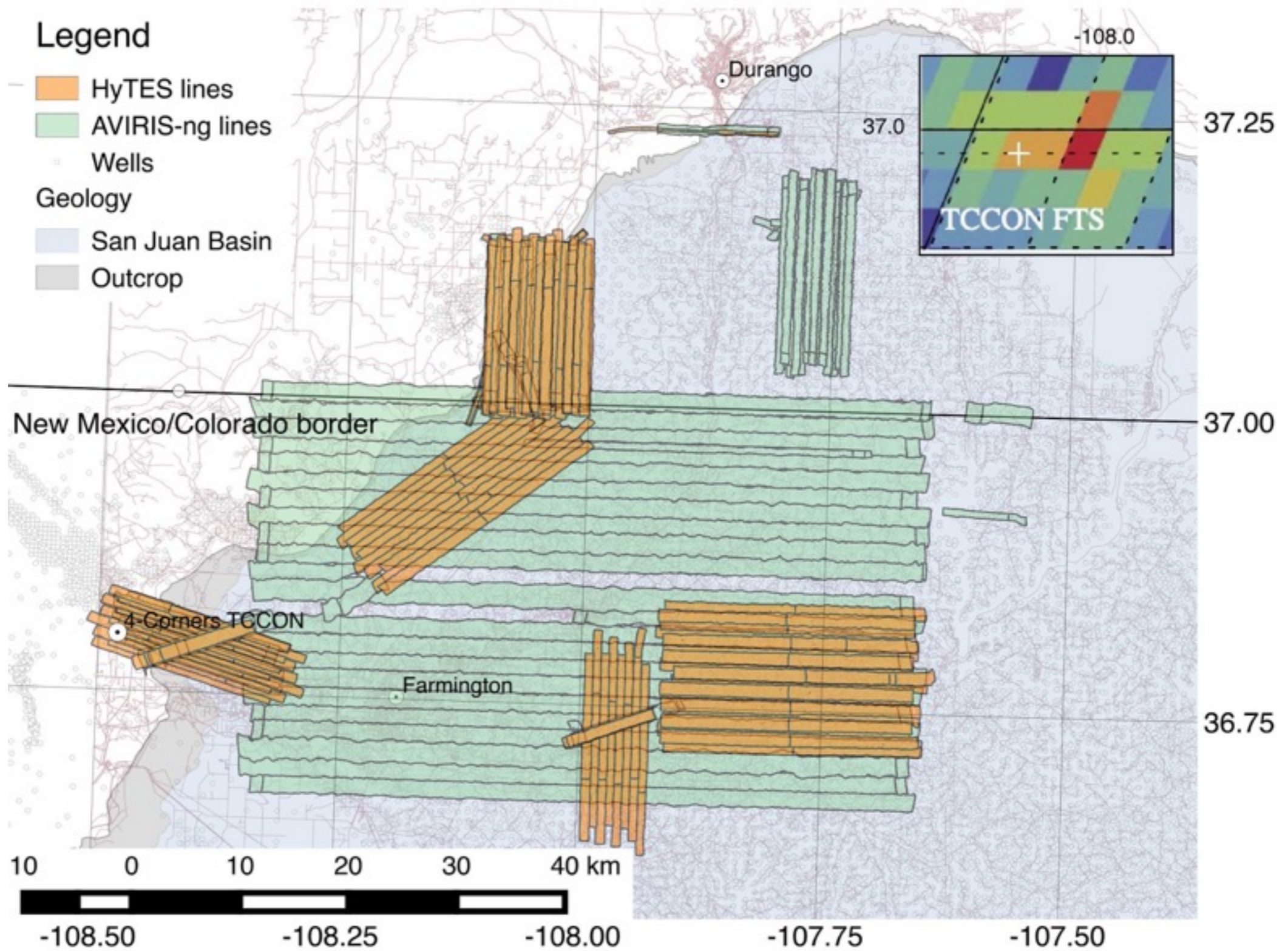
Notes: 2006 CBM production from PA and WV not yet available; assumed to be equal to 2005 volumes for this study. Forest City Basin production is entirely in KS, volumes not separated from Cherokee portion of KS but are only from <3% of KS wells. OK volumes do not include CBM+ conventional comingled completions.

Methane Airborne Remote Sensing

AVIRIS-NG (5nm sampling, 400-2500nm)



Campaign Area



Airborne operations



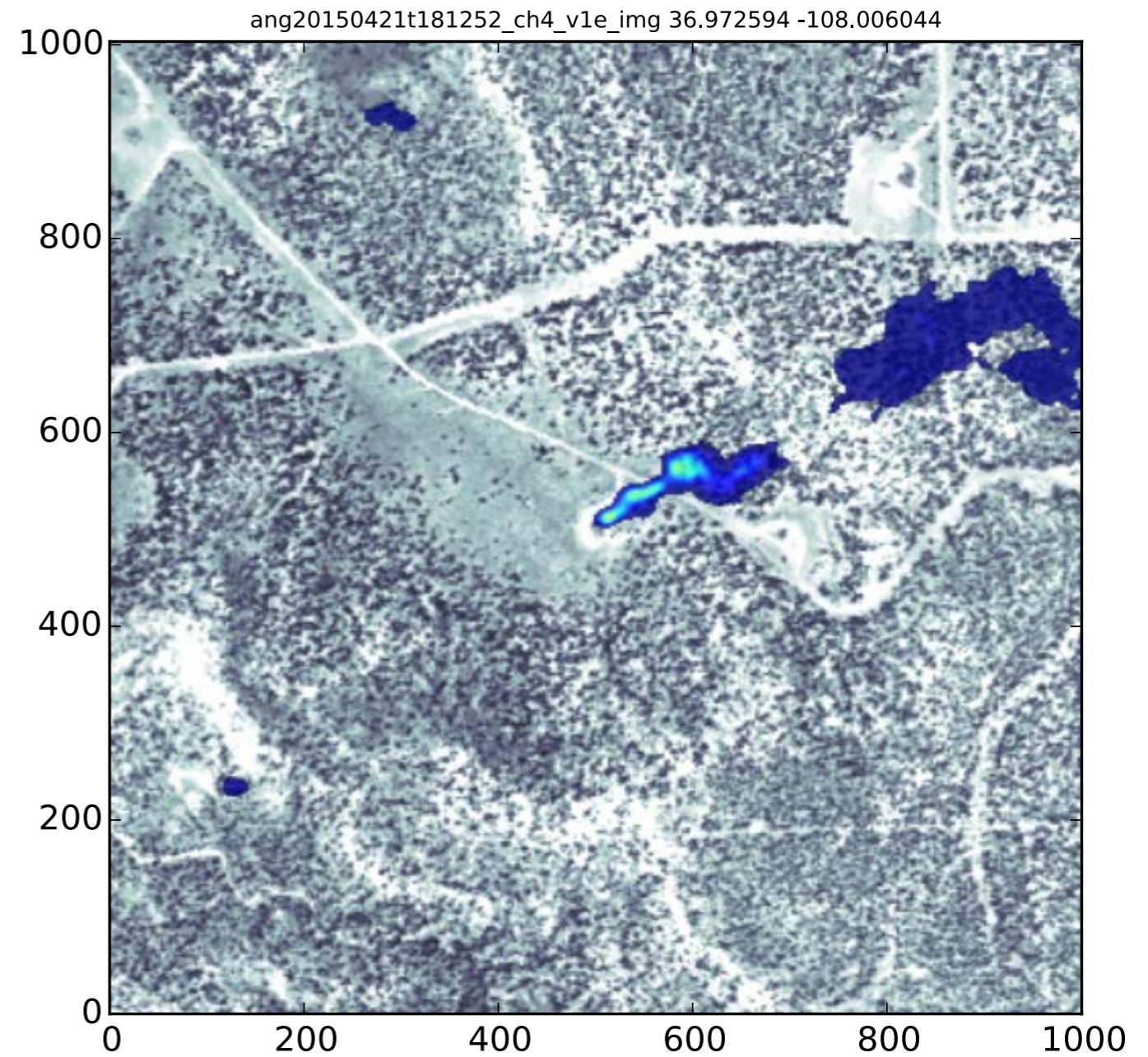
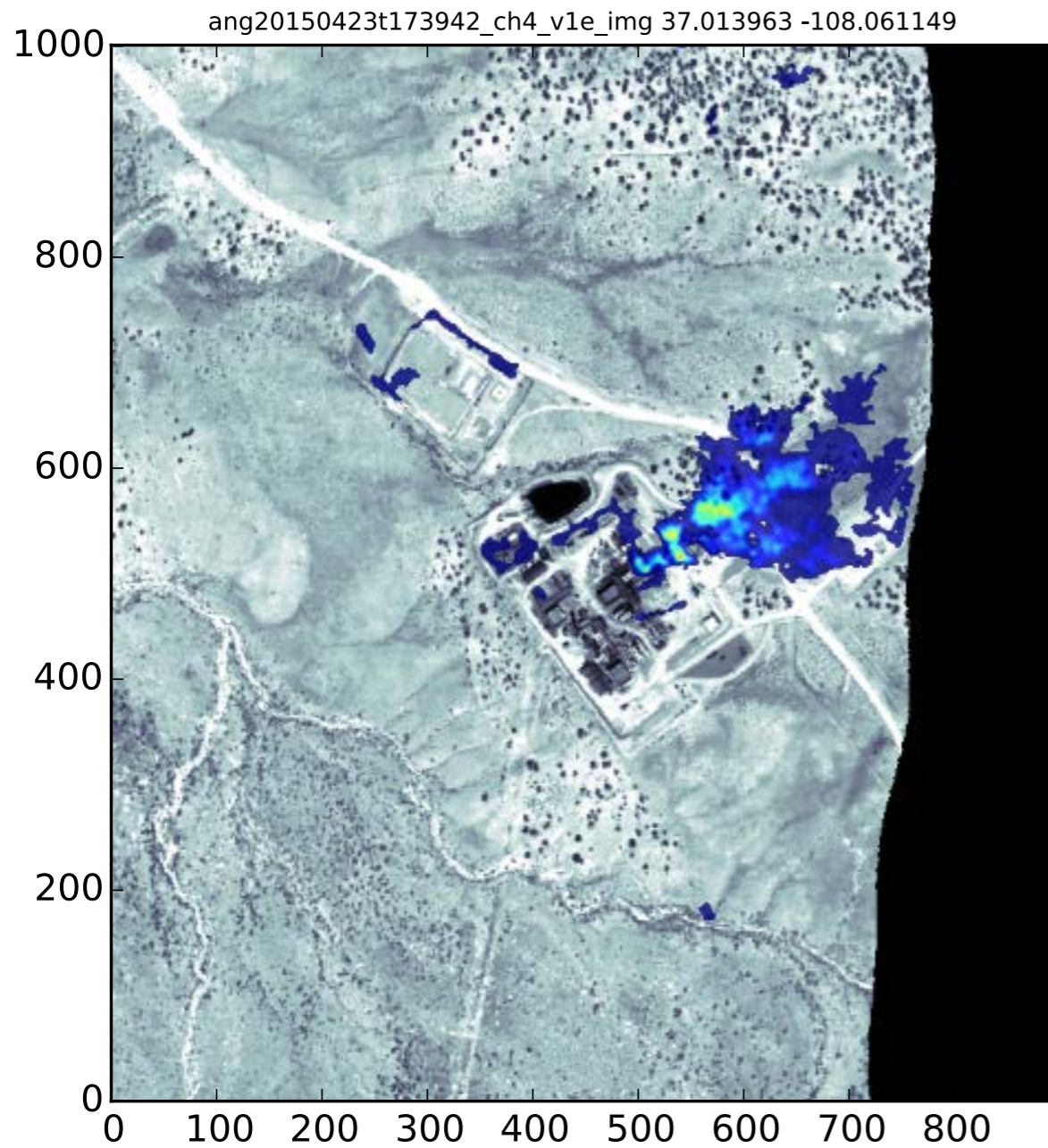
AVIRIS-NG real time methane detection
(Thompson et al, AMT)



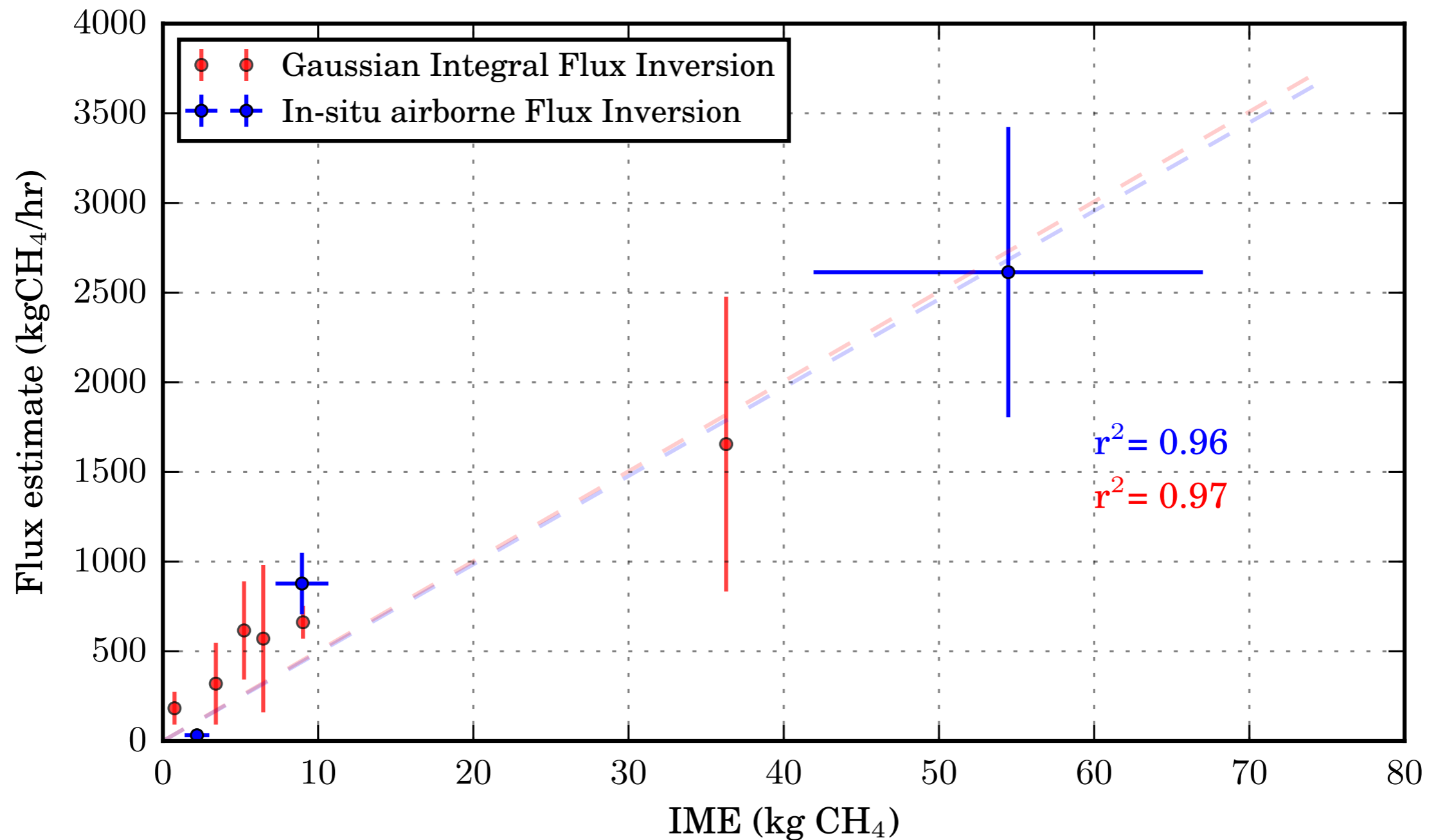
Real-Time CH₄ display

Native resolution examples

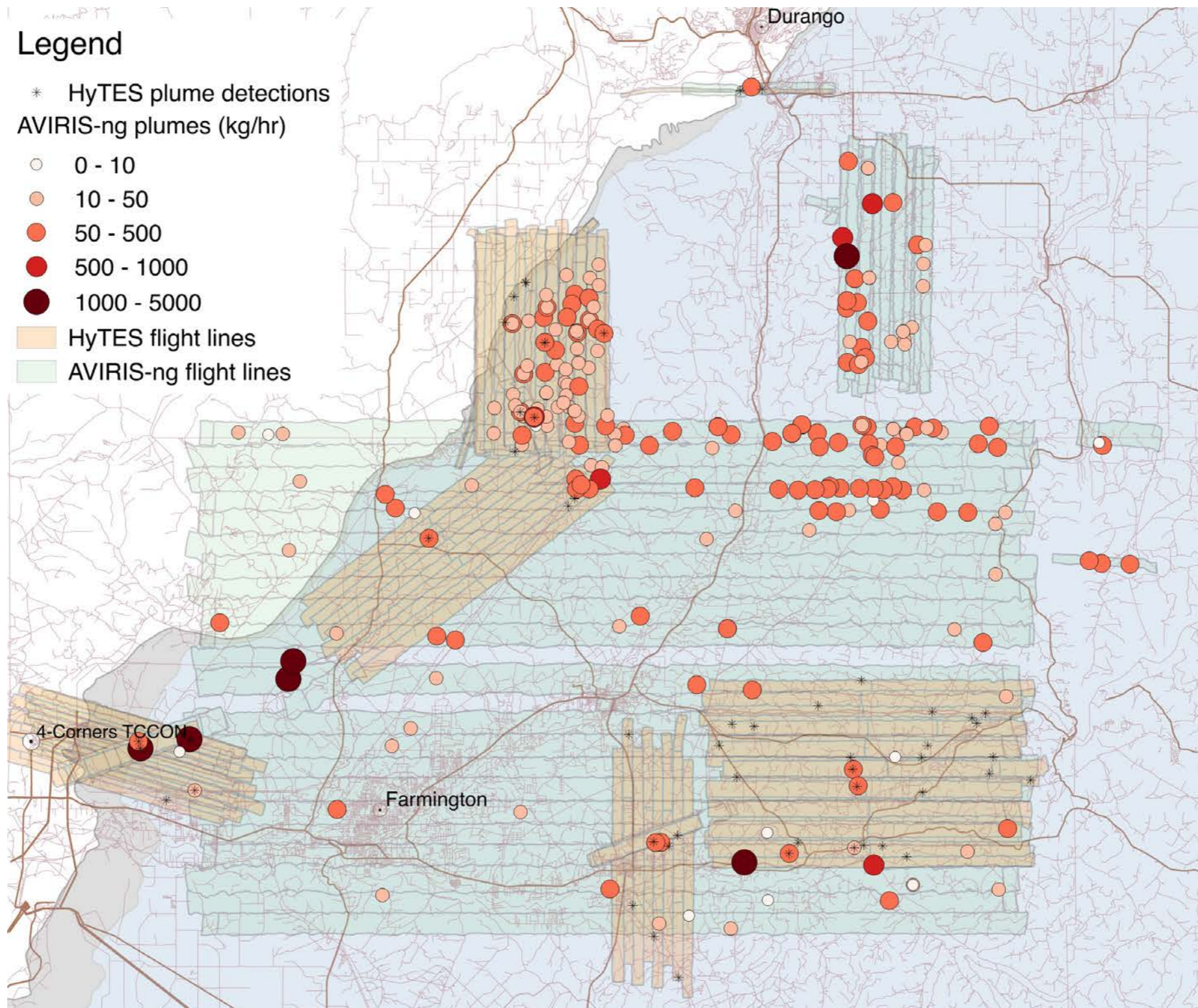
(background is $2.3\mu\text{m}$ radiance in gray, meter axis)



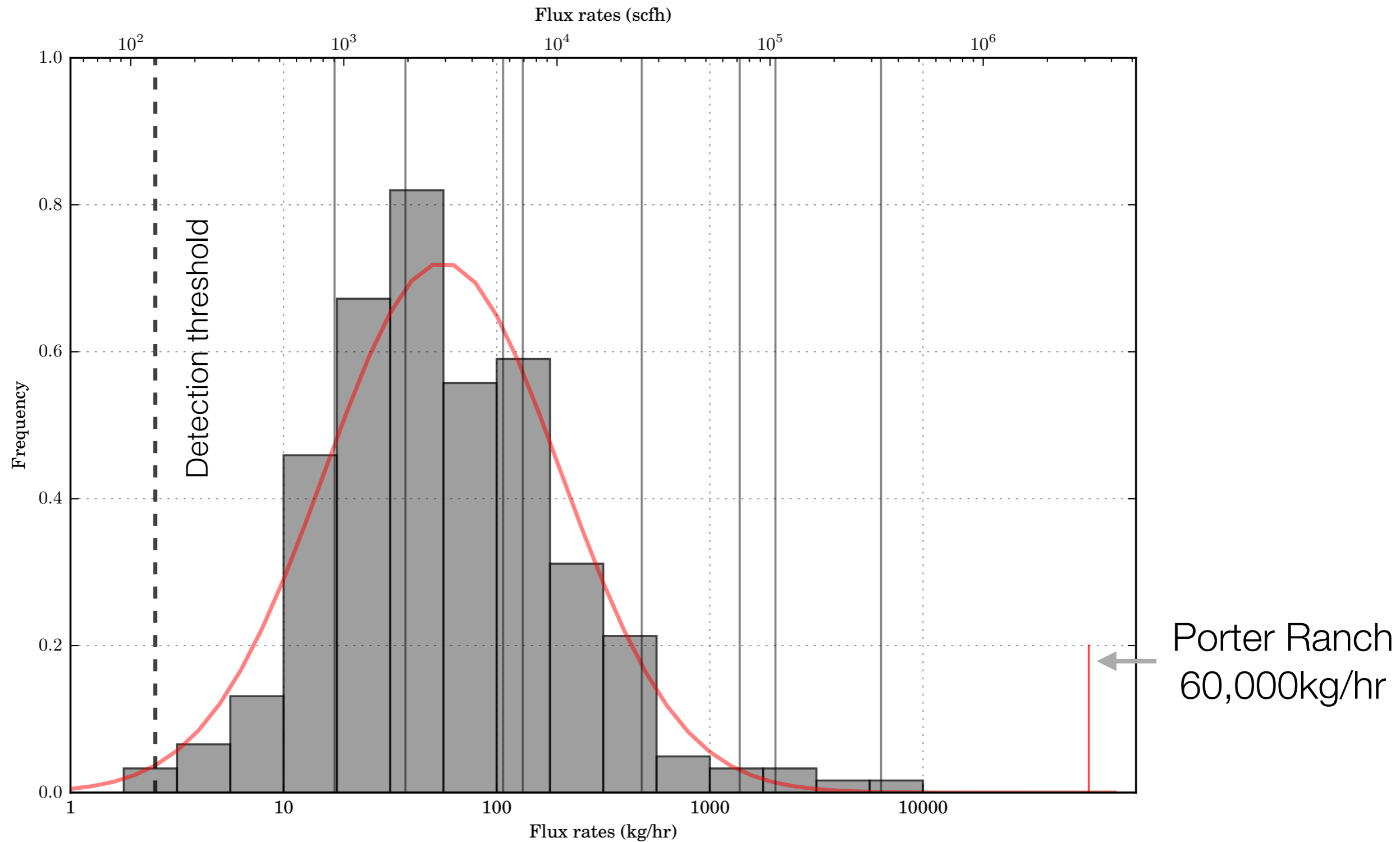
Up-scaling to fluxes (integrate methane amount in plume)



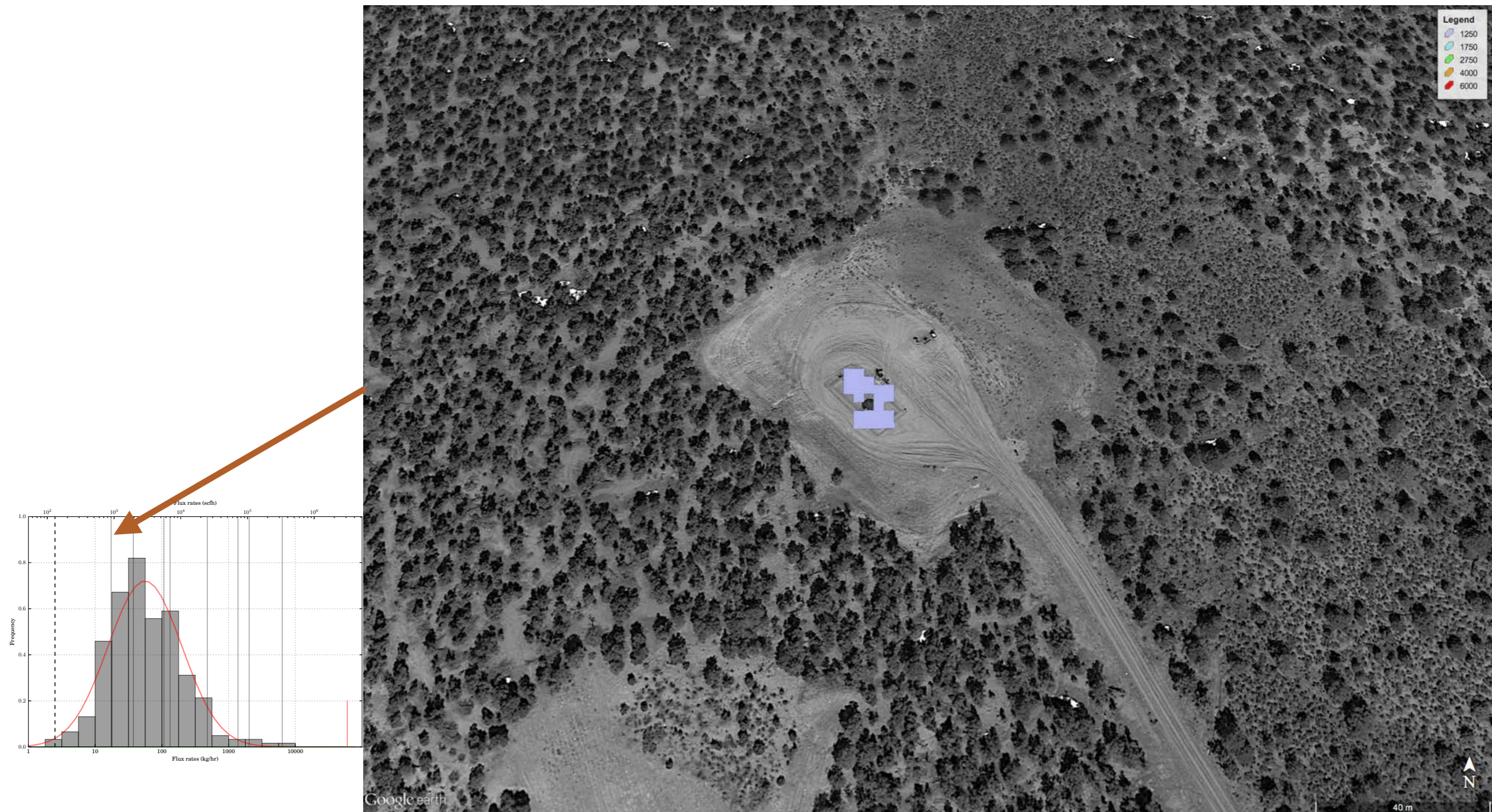
>200 plumes detected



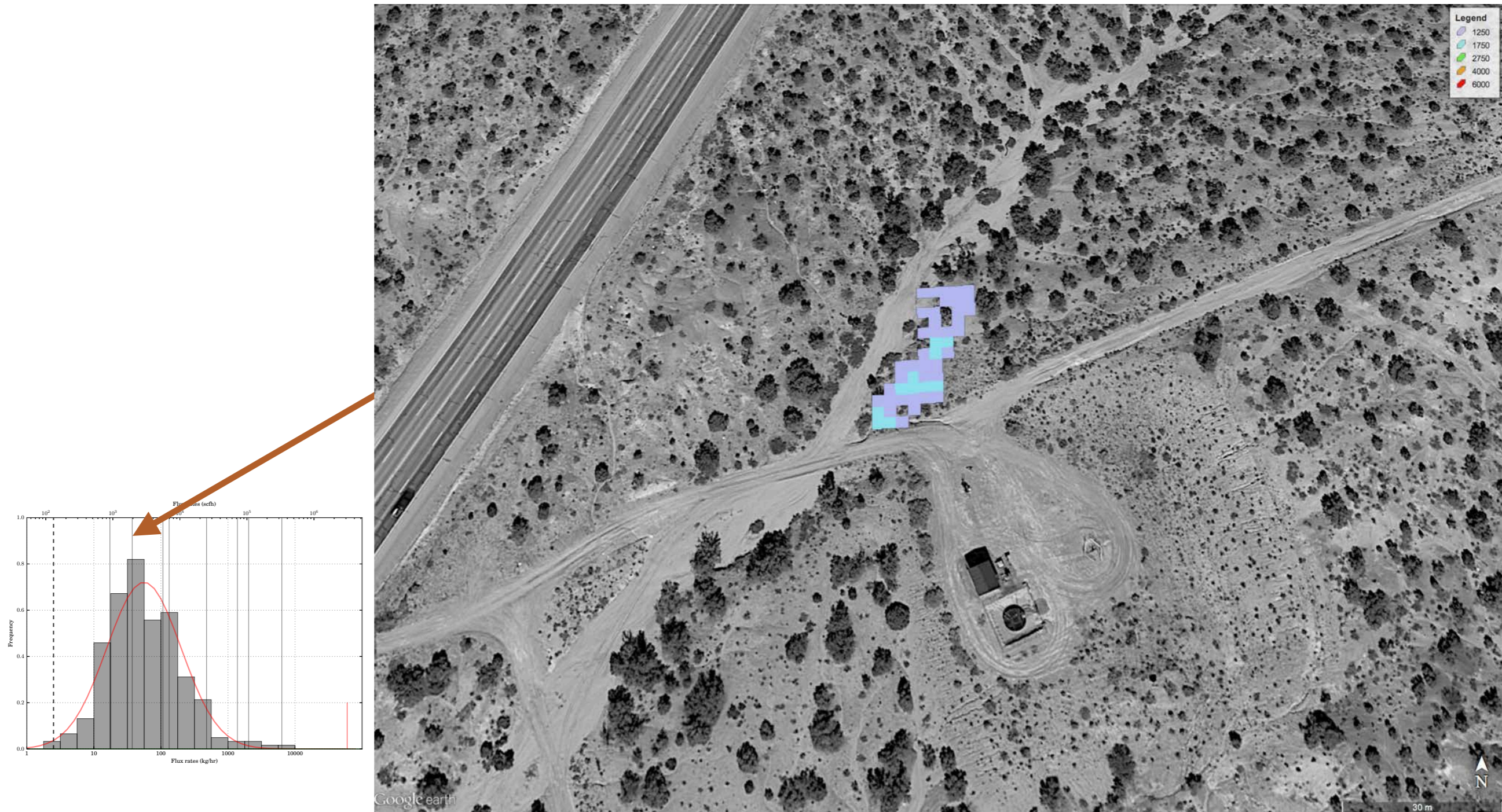
Plume distribution — Log-normal



Plume distribution — Wellhead



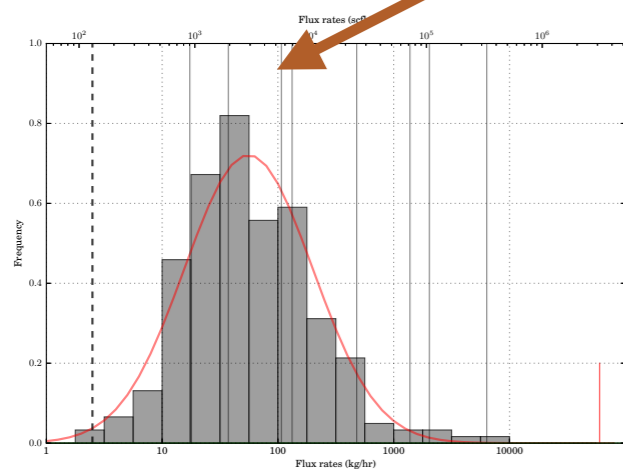
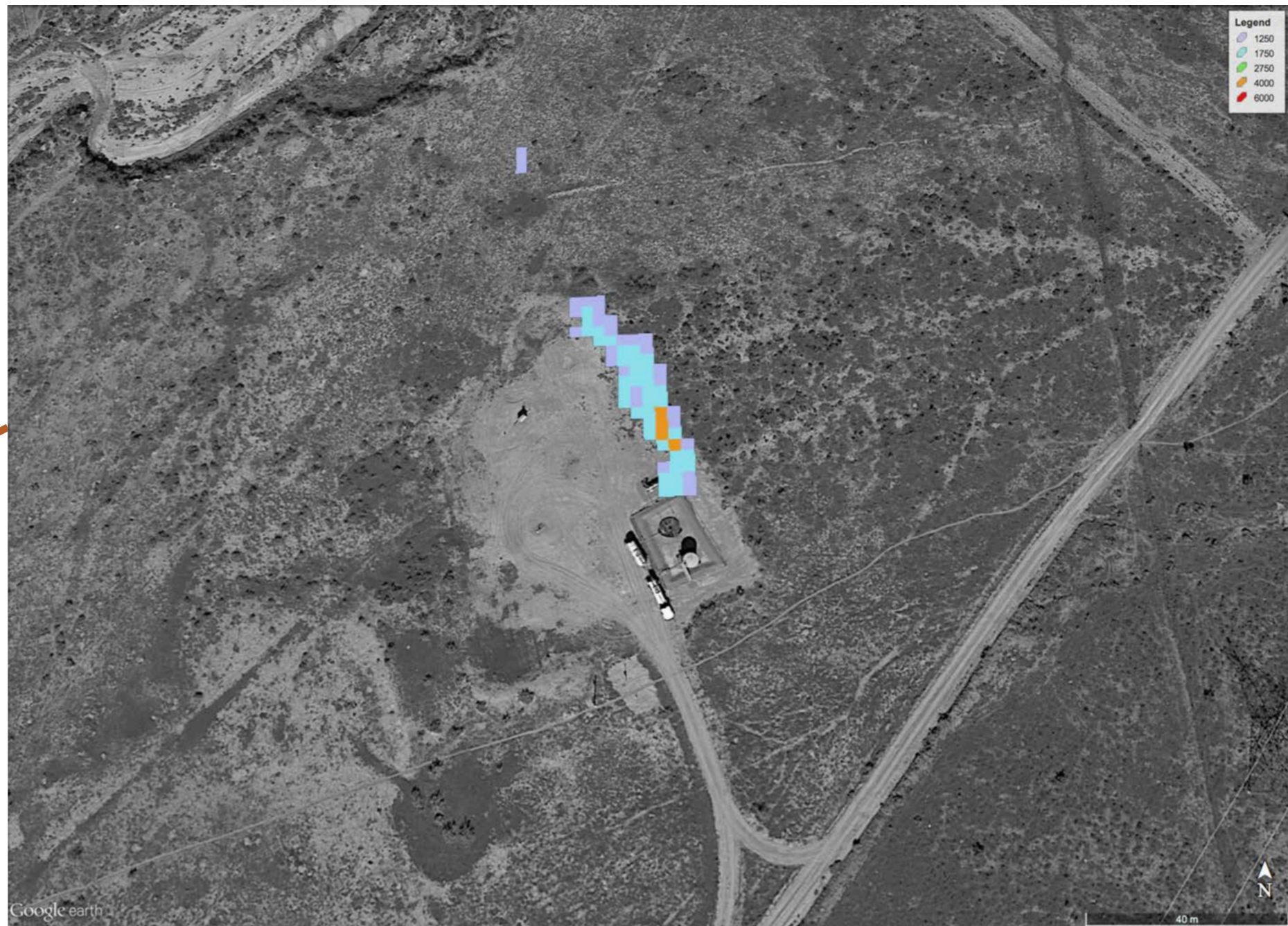
Plume distribution — ???



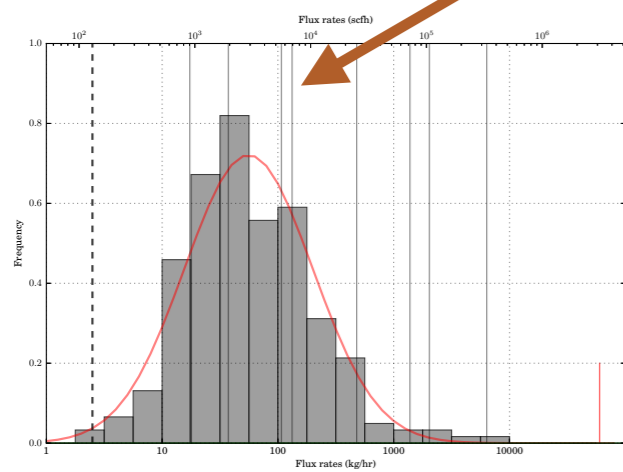
Methane plume



Plume distribution



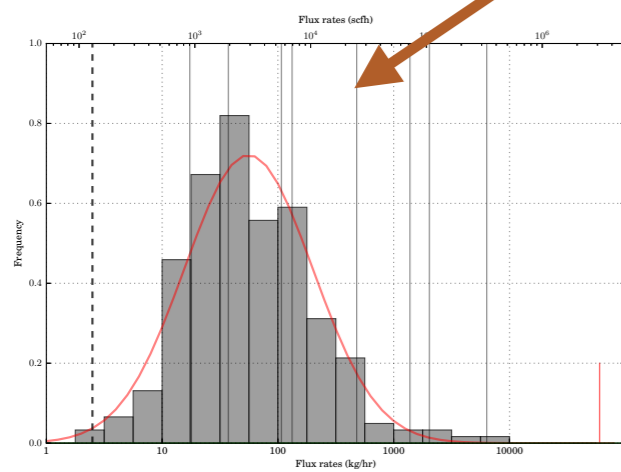
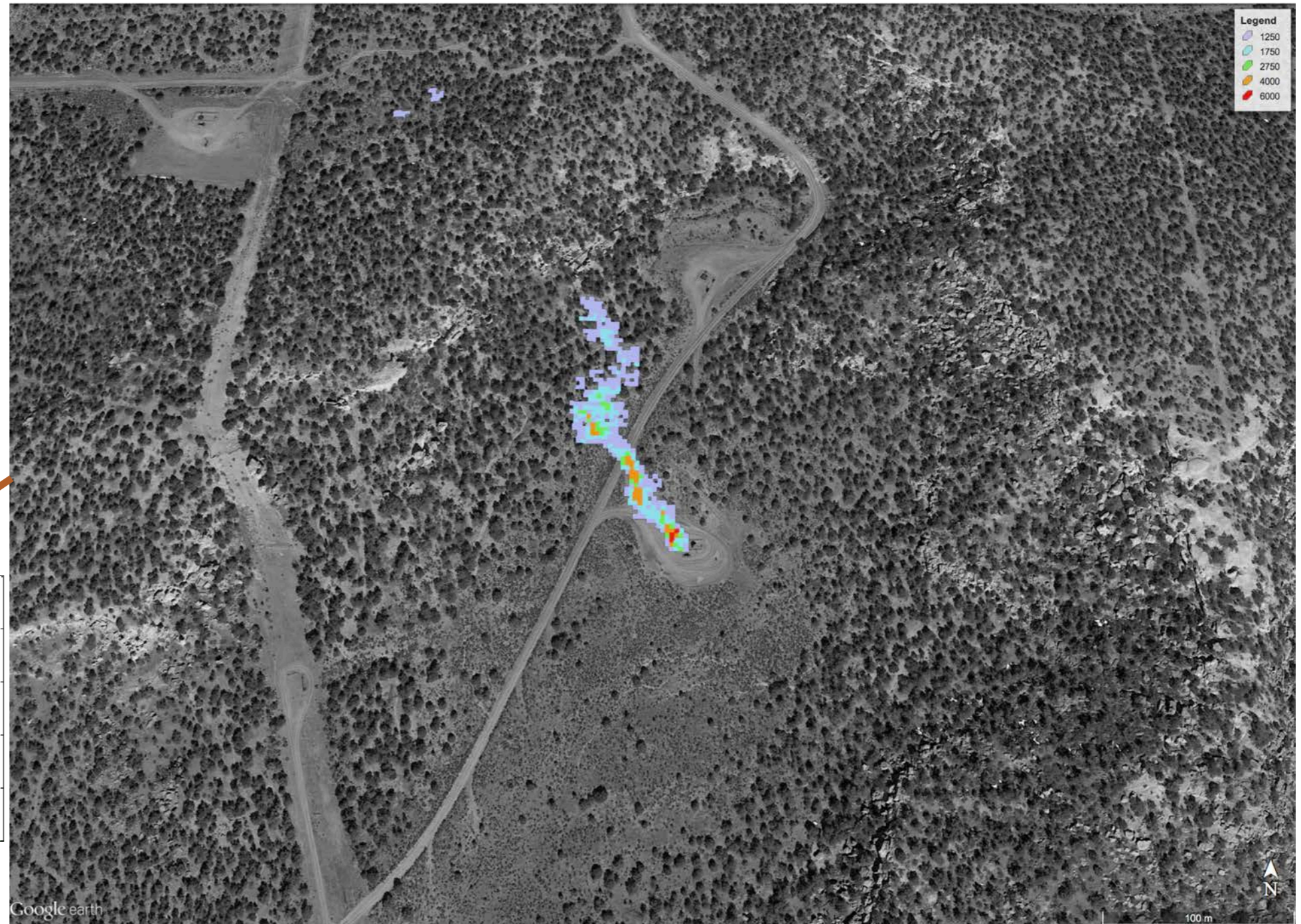
Plume distribution — underground storage tank



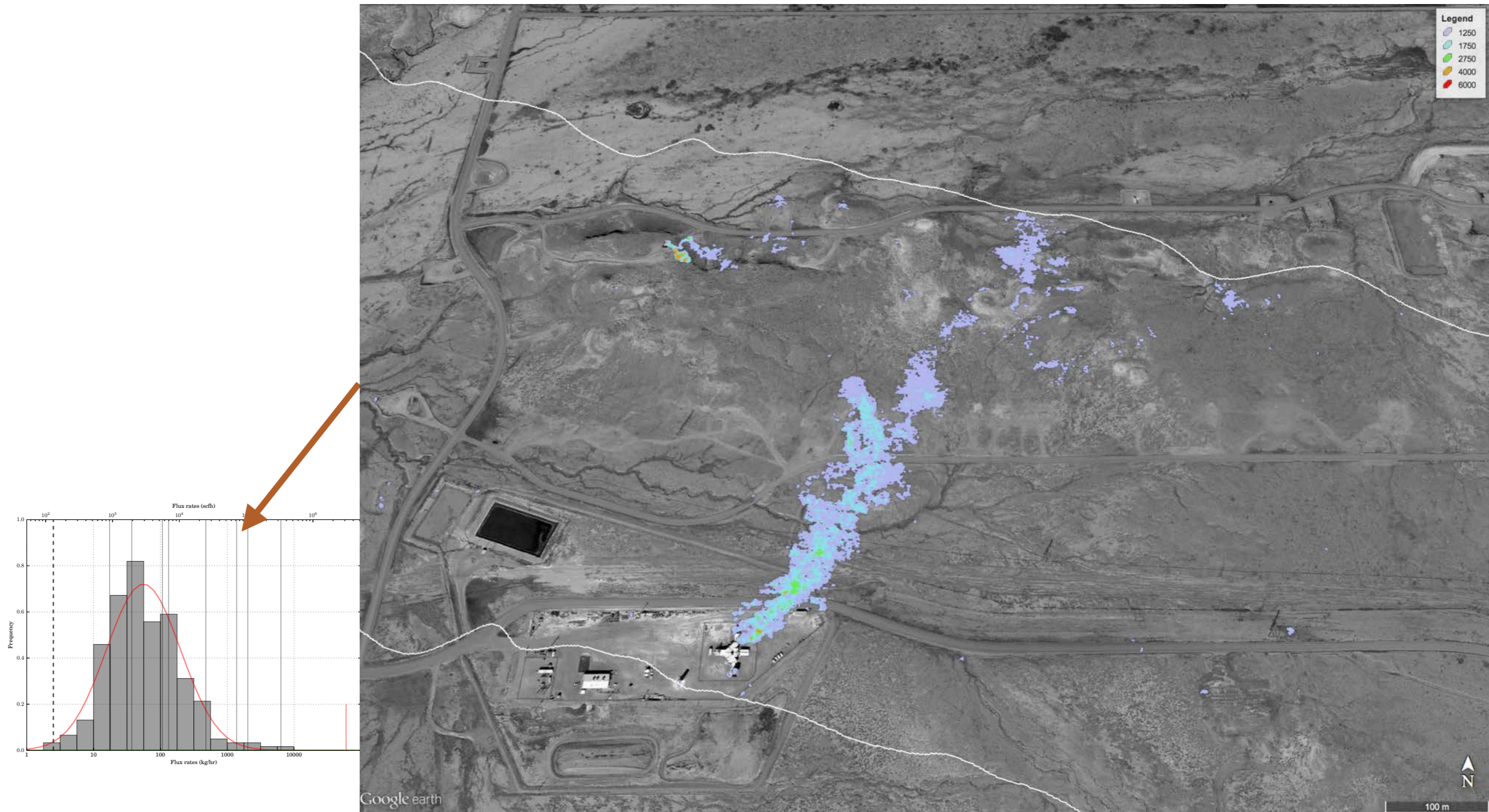
Methane plume from tank



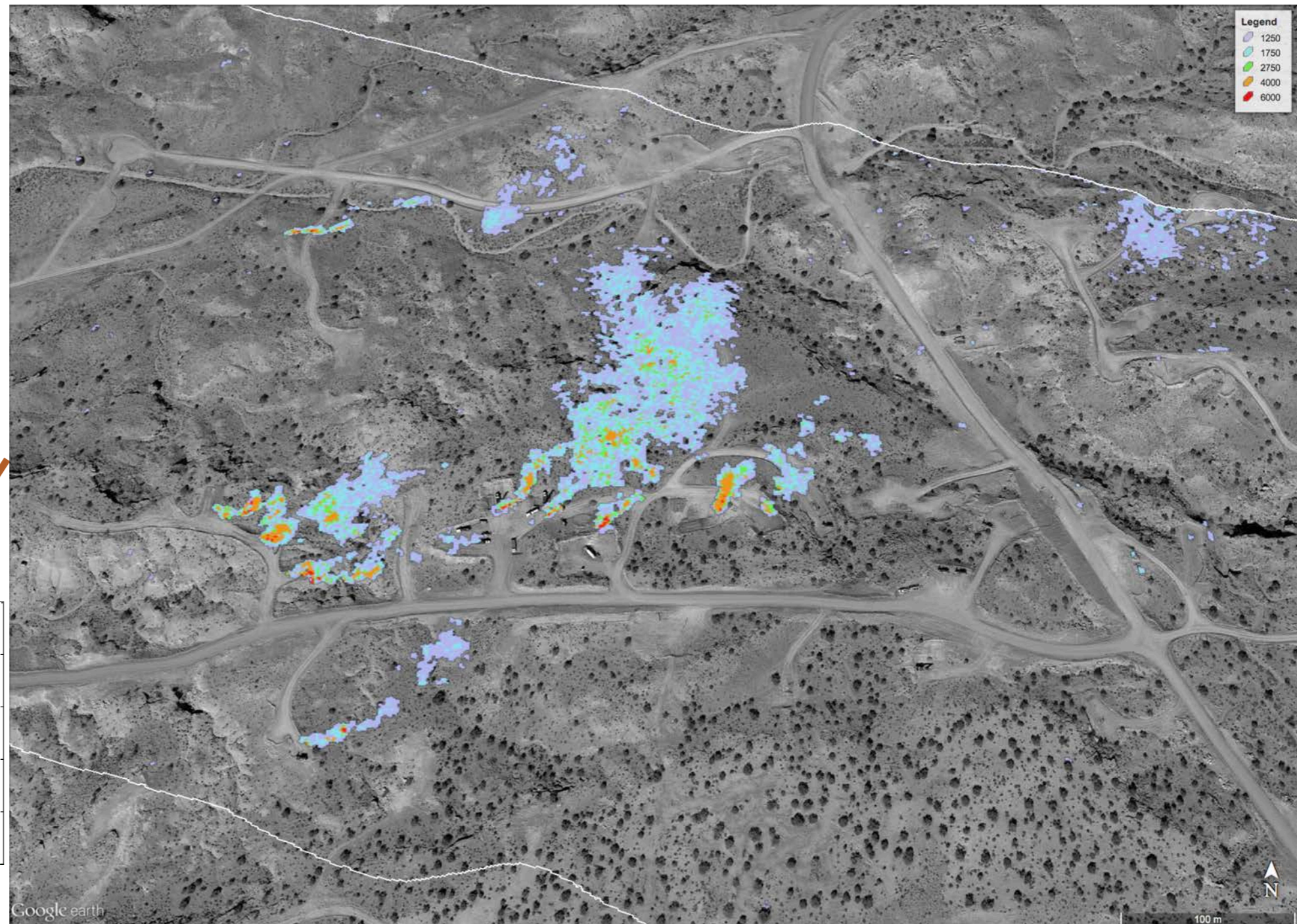
Plume distribution - Wellhead



Plume distribution — Guesses welcome



Plume distribution — Unclear (multiple sources, maybe well completion? Near coal-mine)



What does the log-normal distribution imply?

