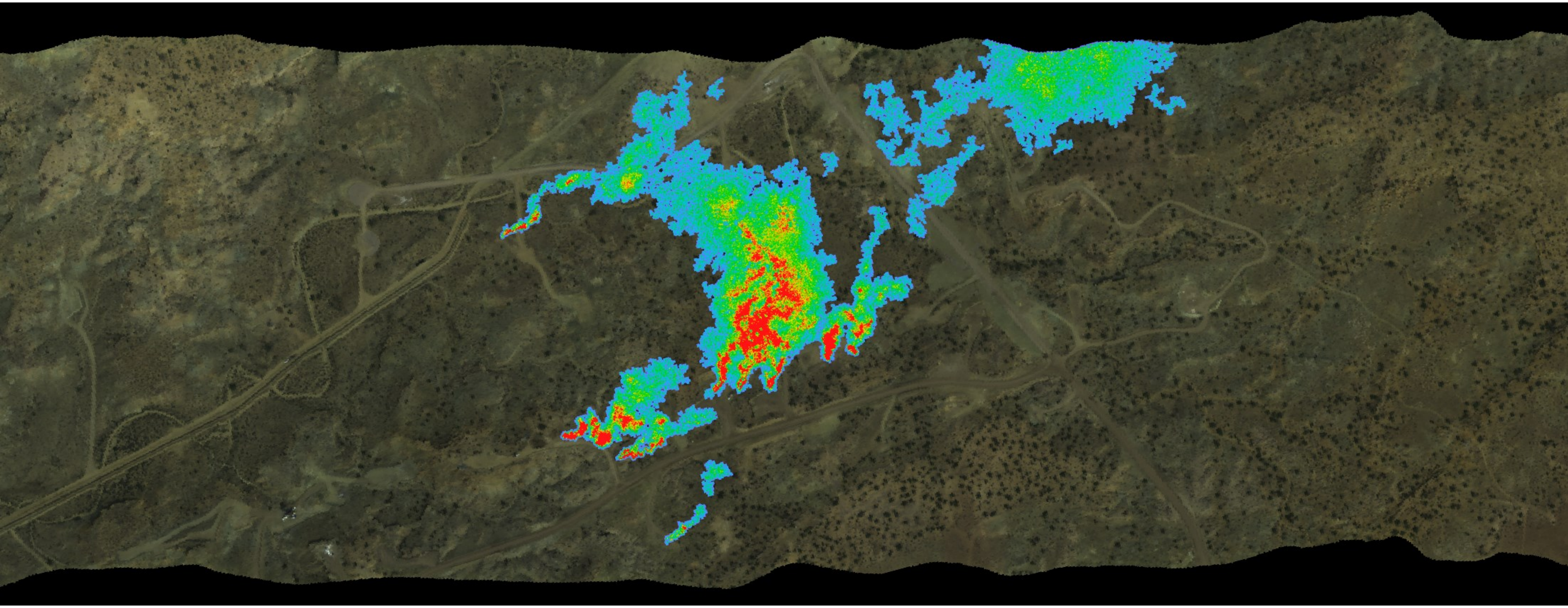
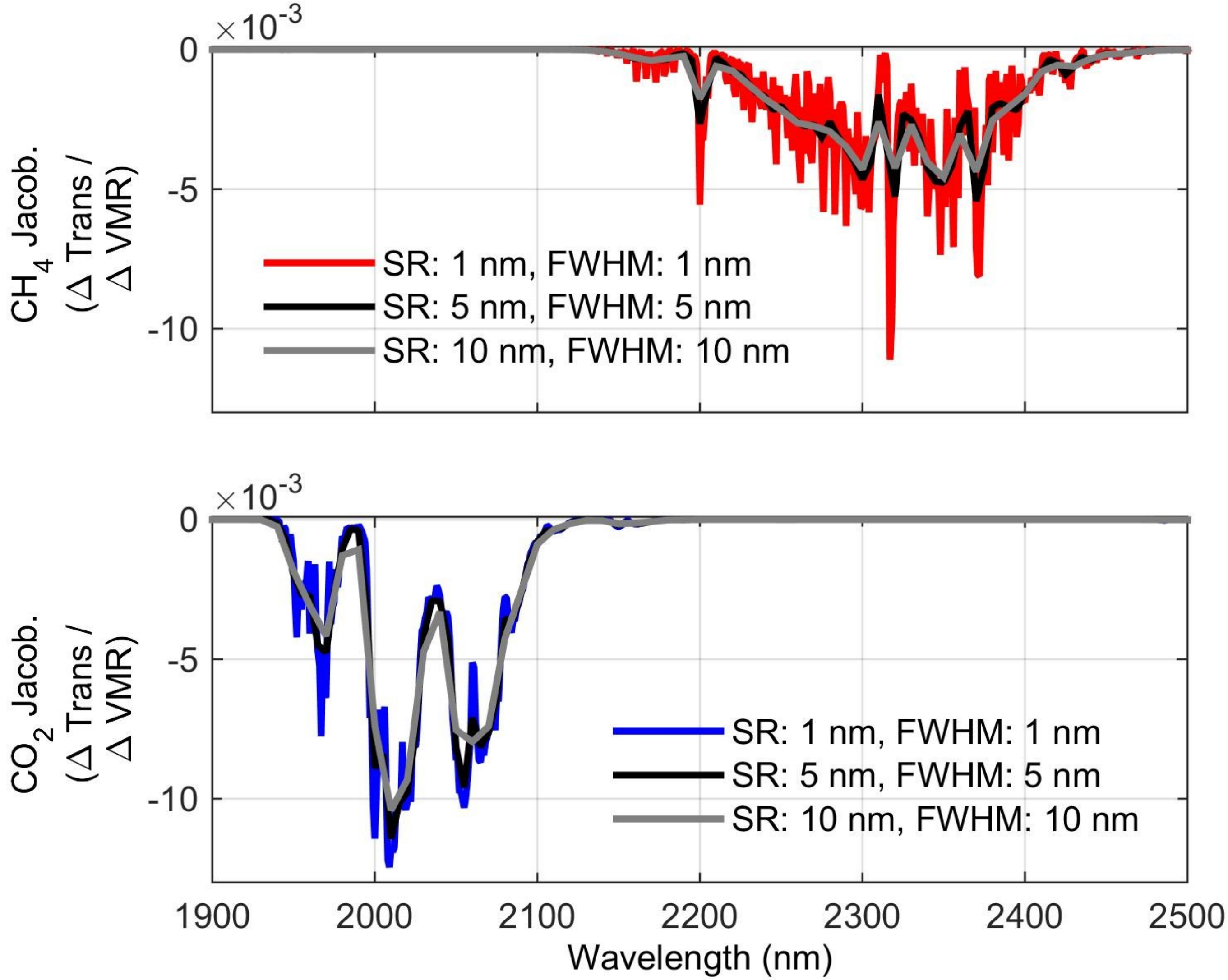
Mapping methane and carbon dioxide point source emissions with SBG type observables



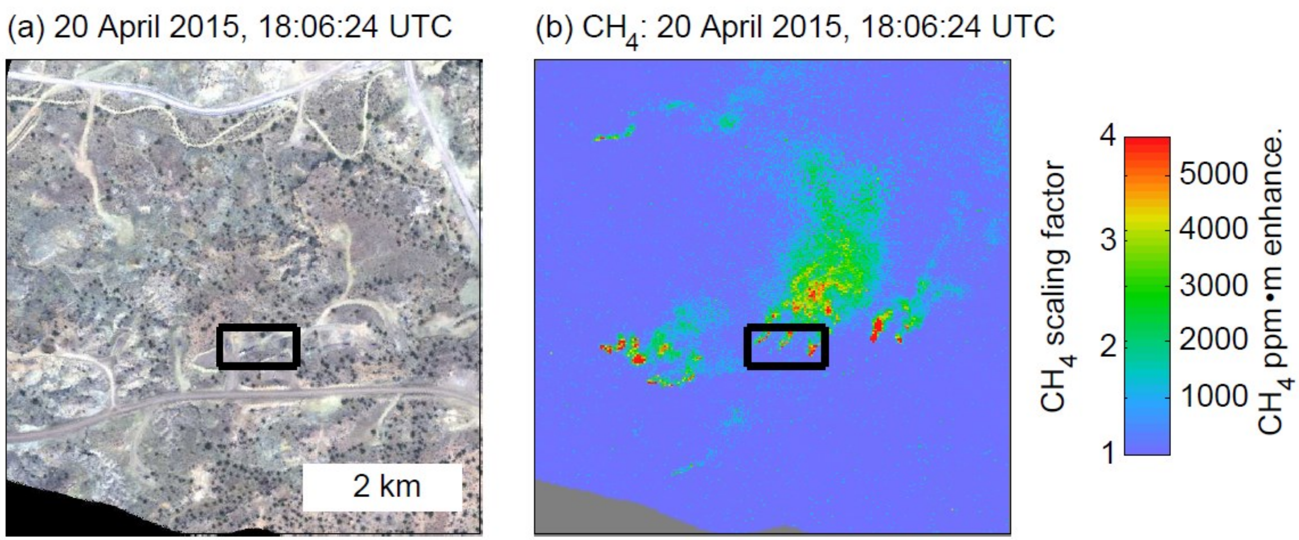
Thorpe, A.K.[1], Duren, R.M.[1], Frankenberg, C.[1,2], Thompson, D.R.[1], Bue, B.D.[1], Dennison, P.E.[3], Foote, M.D.[3], Joshi, S.[3], Roberts, D. A.[4] , Ayasse, A.K.[4], Olson-Duval, W.[1], Mccubbin, I.B.[1], Eastwood, M.L.[1], Green, R.O.[1], Miller, C.E.[1]

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, United States
[2] California Institute of Technology, Pasadena, California, United States
[3] University of Utah, Salt Lake City, Utah, United States
[4] University of California, Santa Barbara, Santa Barbara, California, United States

CH_4 and CO_2 absorption features

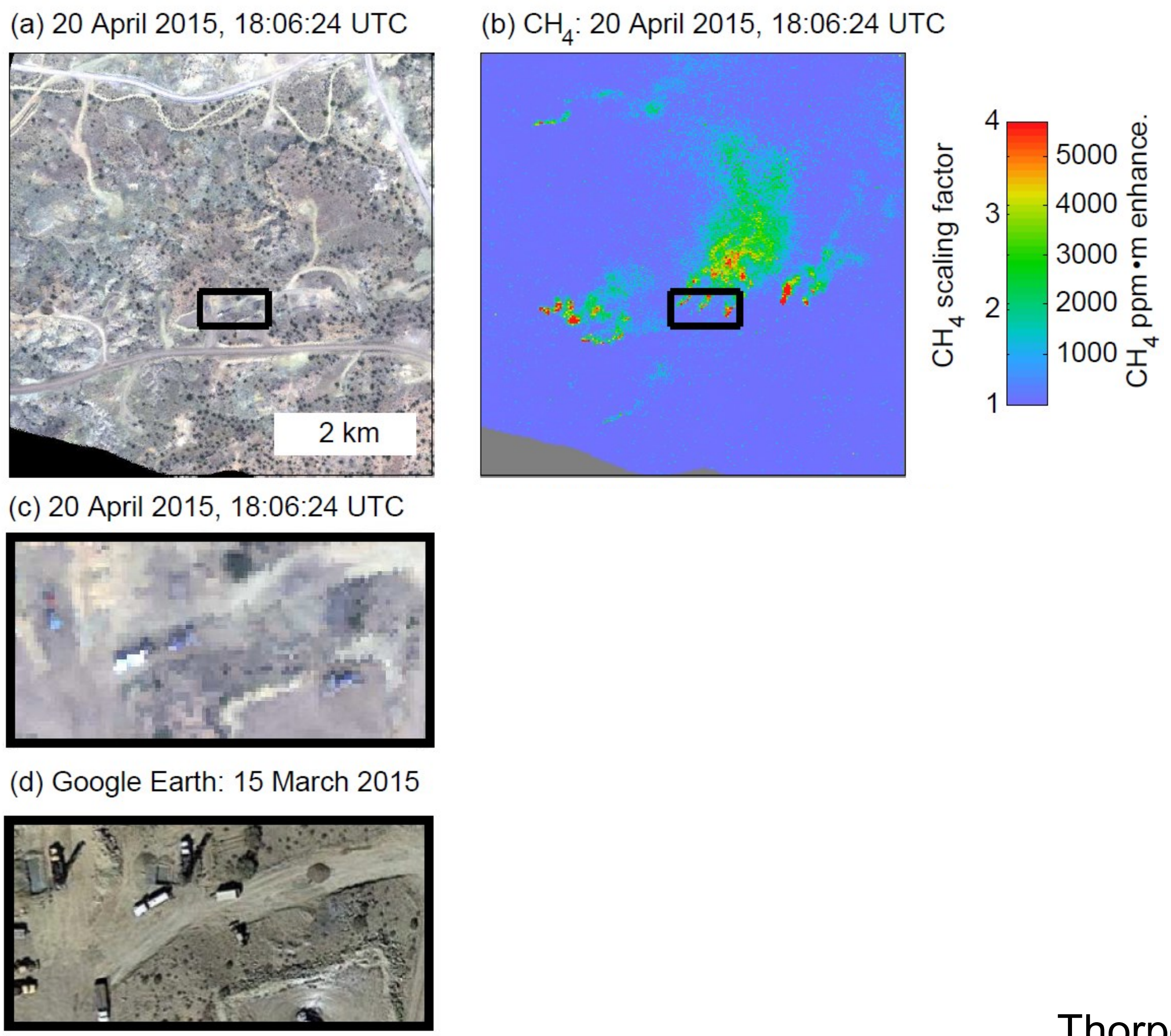


- Coal mine ventilation shaft emissions



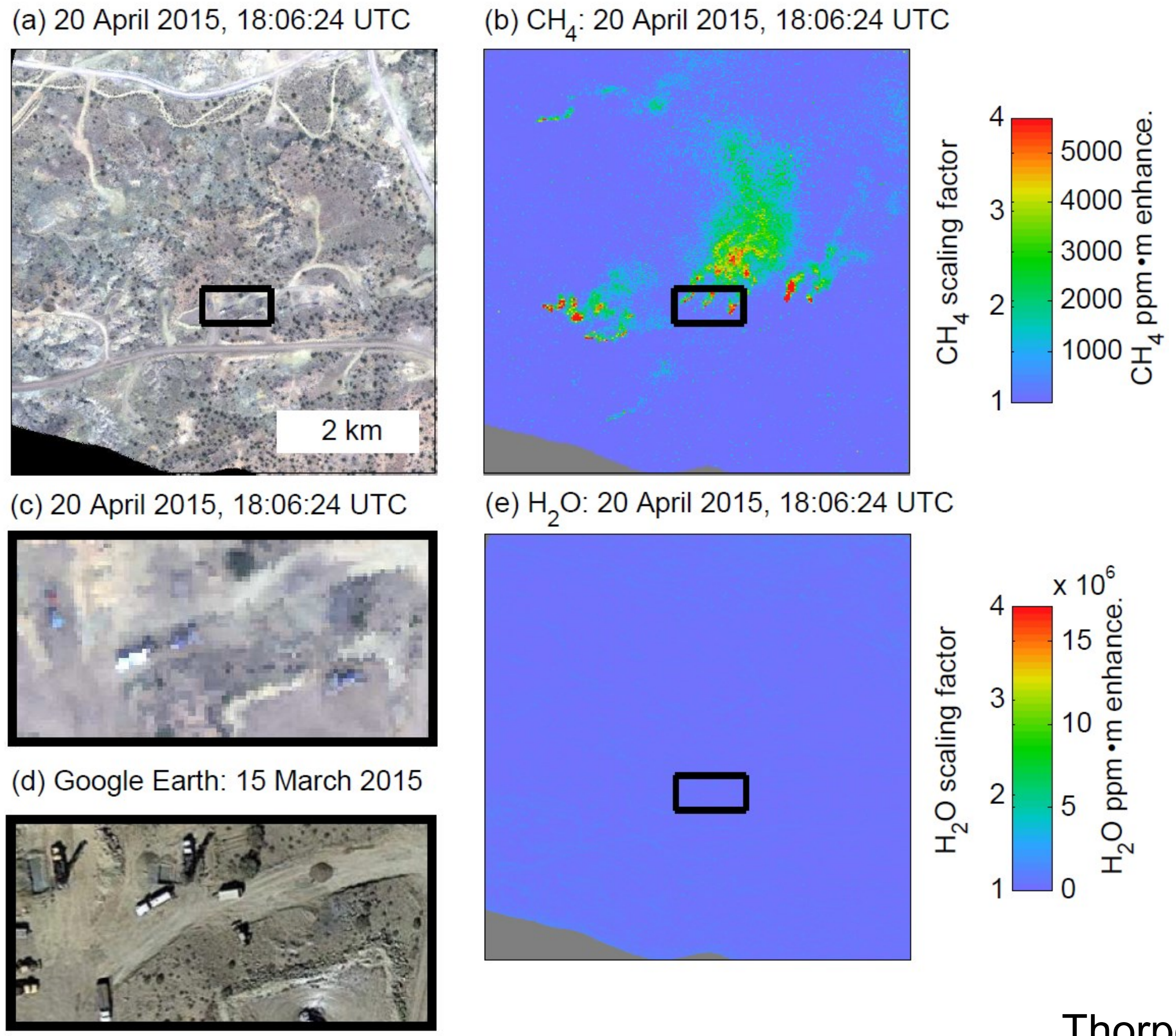
Thorpe et al., 2017

- Coal mine ventilation shaft emissions



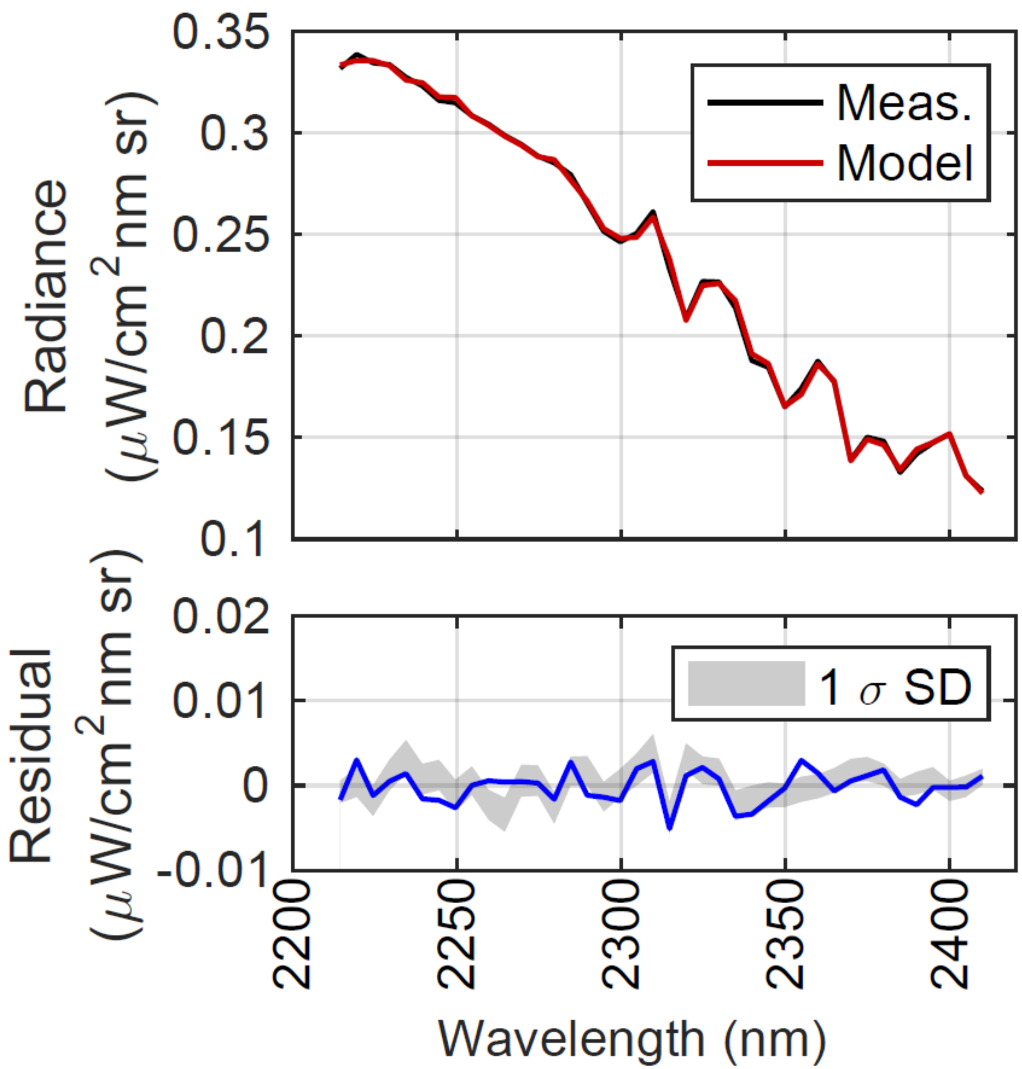
Thorpe et al., 2017

- Coal mine ventilation shaft emissions



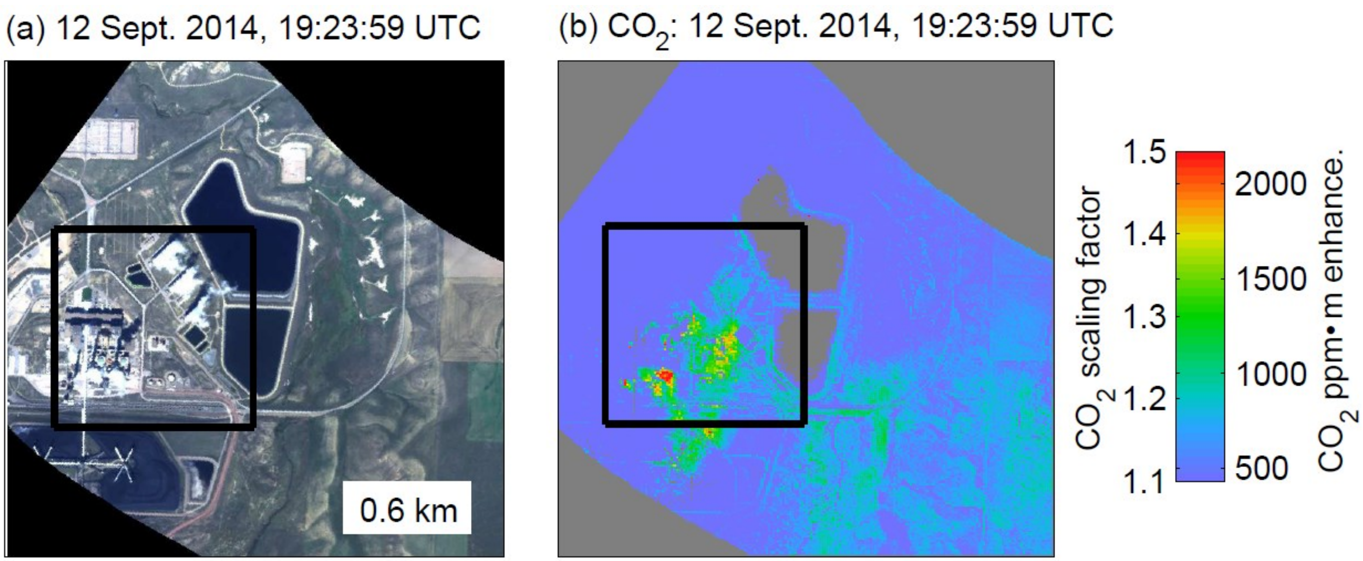
Thorpe et al., 2017

- CH_4 retrieval radiance fits



Thorpe et al., 2017

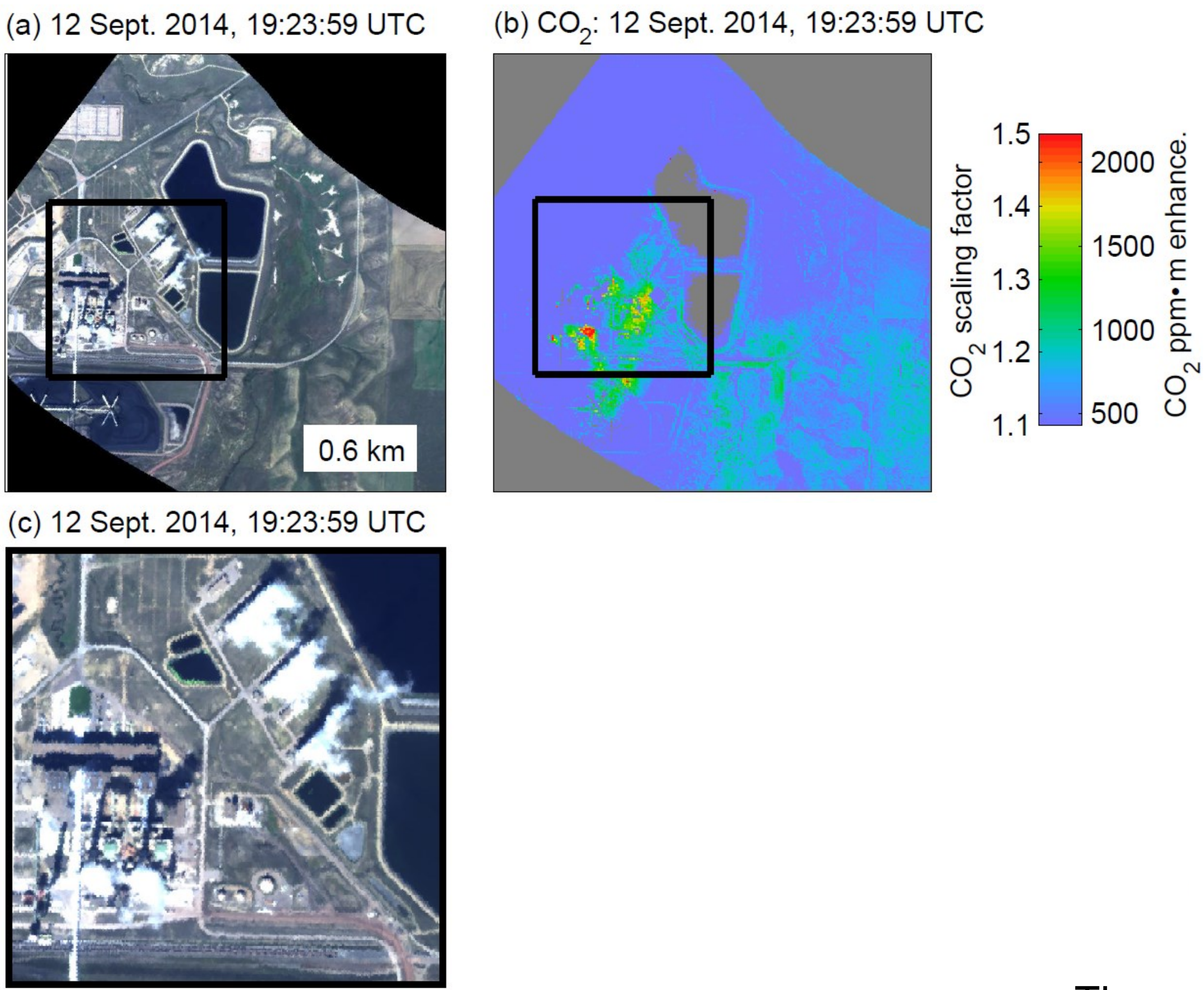
- Power plant



Thorpe et al., 2017

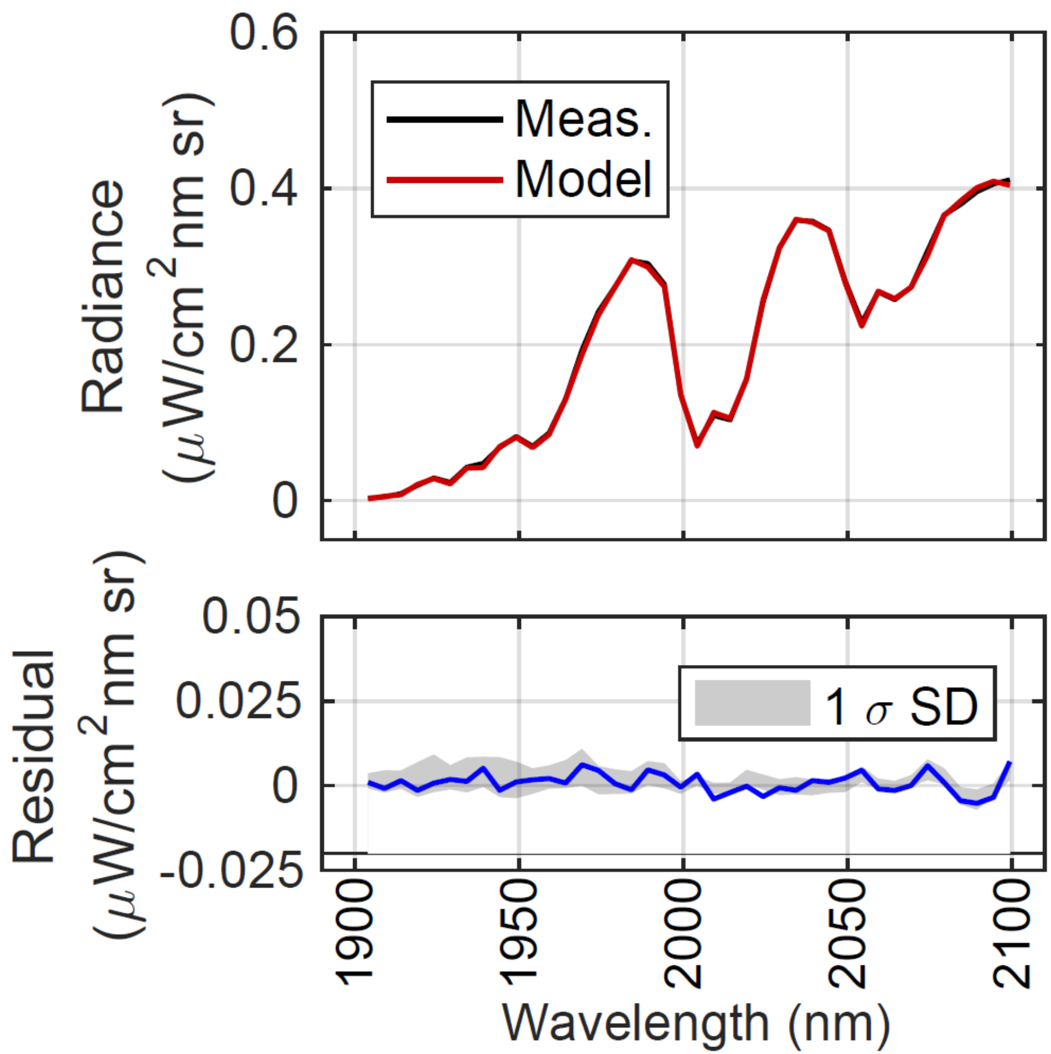
AVIRIS-NG (CO_2)

- Power plant



Thorpe et al., 2017

- CO_2 retrieval radiance fits

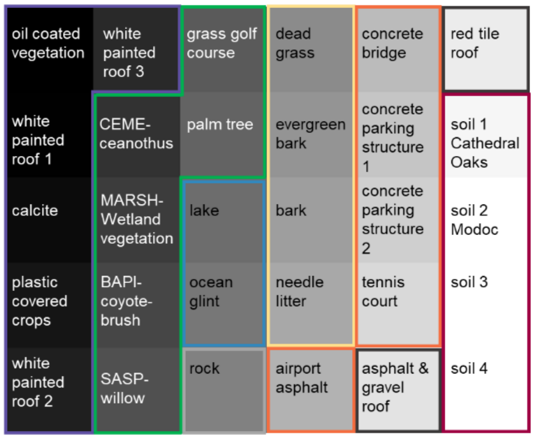


Thorpe et al., 2017

AVIRIS-NG (CH_4)

- AVIRIS-NG CH_4 sensitivity study led by Alana Ayasse (University of California, Santa Barbara)

a) Modelled land covers



Ayasse et al., 2018

- AVIRIS-NG CH_4 sensitivity study led by Alana Ayasse (University of California, Santa Barbara)

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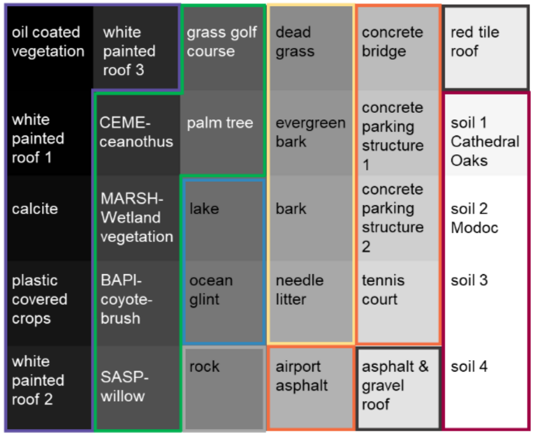
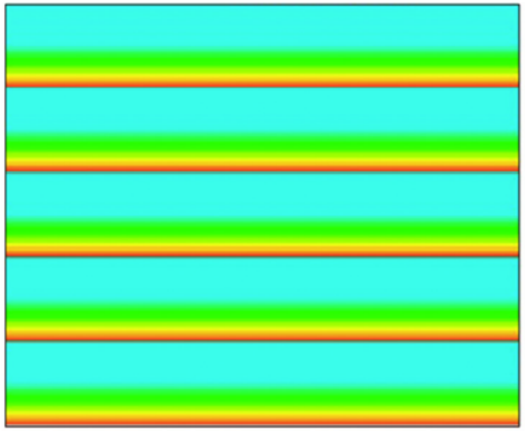


b) Modelled CH_4



Ayasse et al., 2018

AVIRIS-NG (CH_4)

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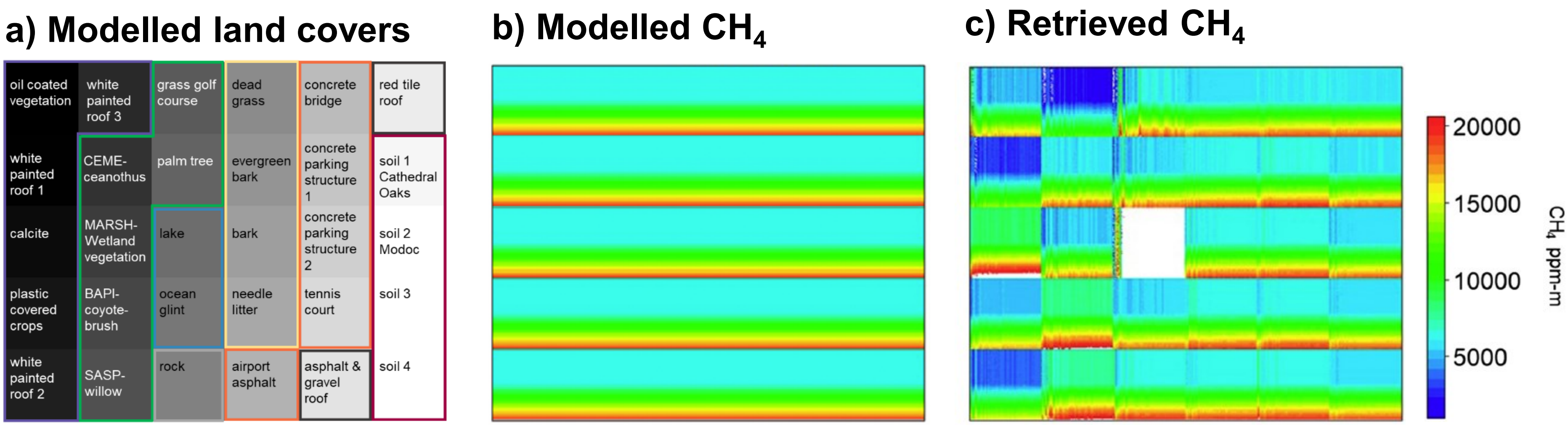

Ayasse et al., 2018

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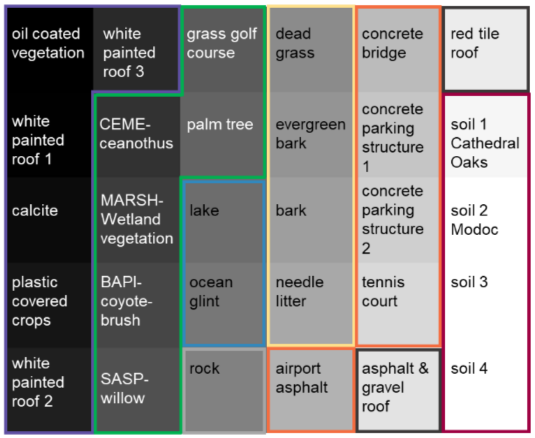
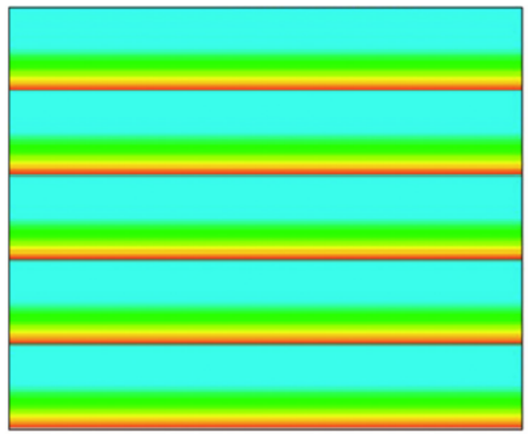
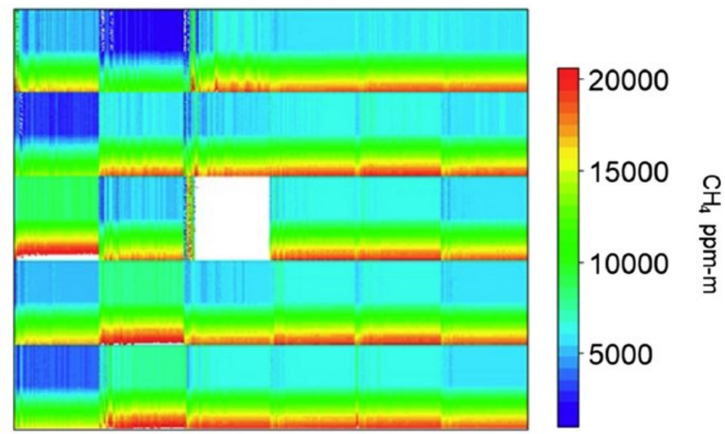


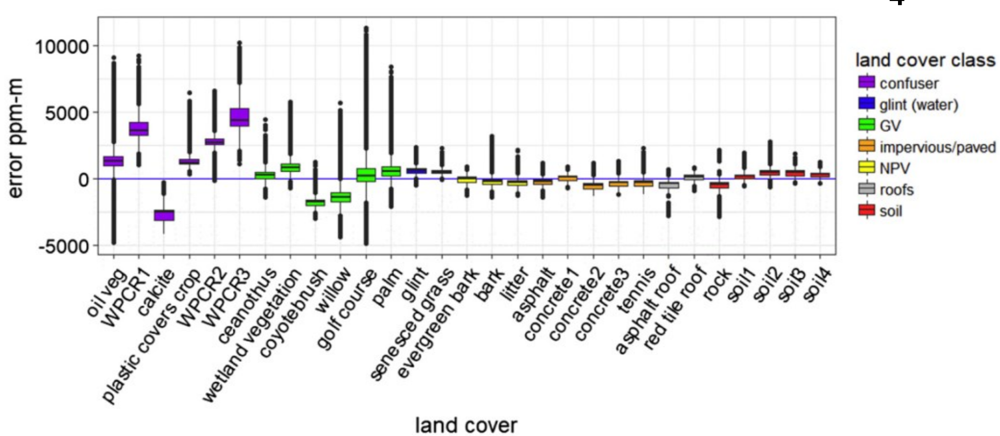
b) Modelled CH_4



c) Retrieved CH_4



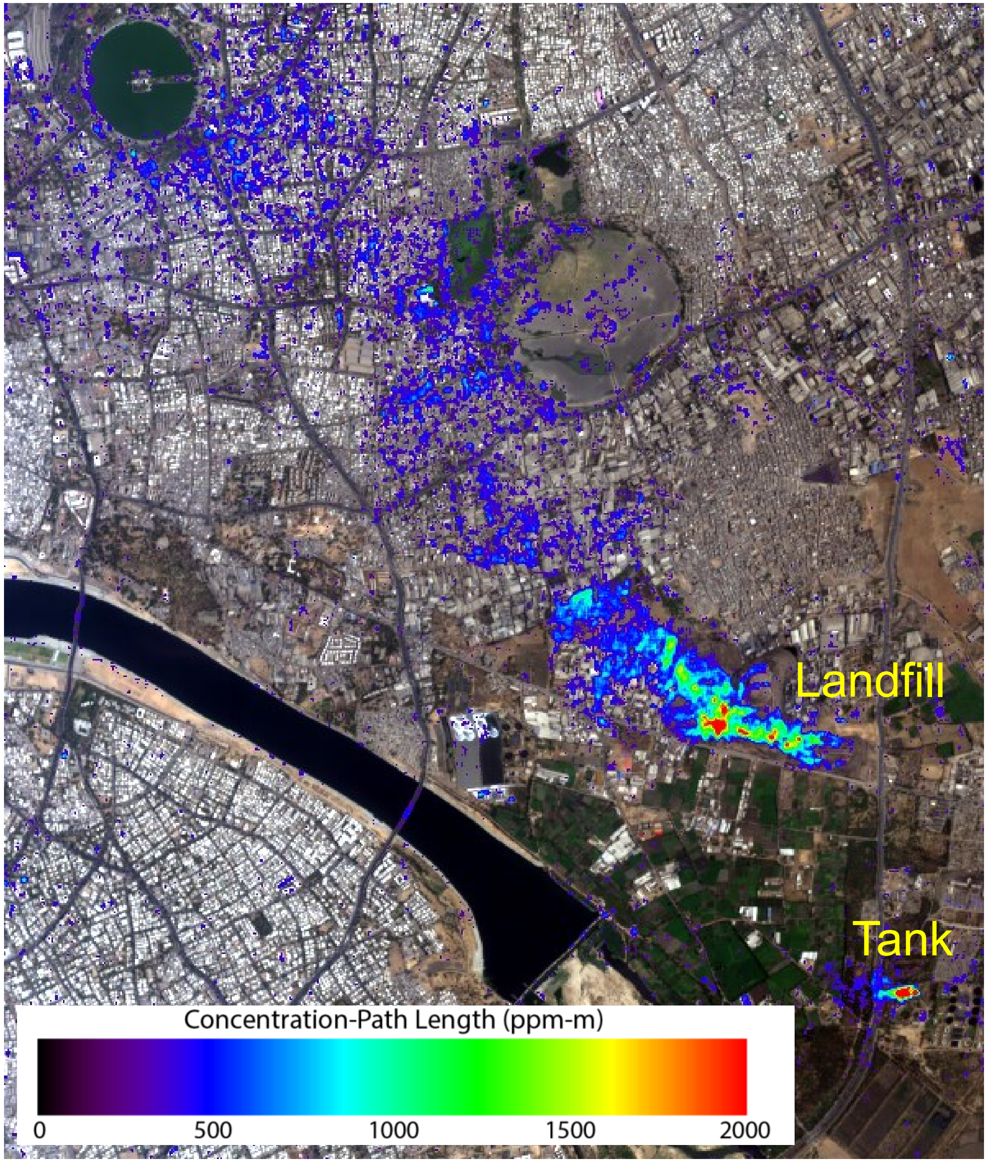
d) Characterized uncertainties in retrieved CH_4



Ayasse et al., 2018

AVIRIS-NG (CH_4)

- 2016 Ahmedabad India plumes (8.1 m spatial resolution)

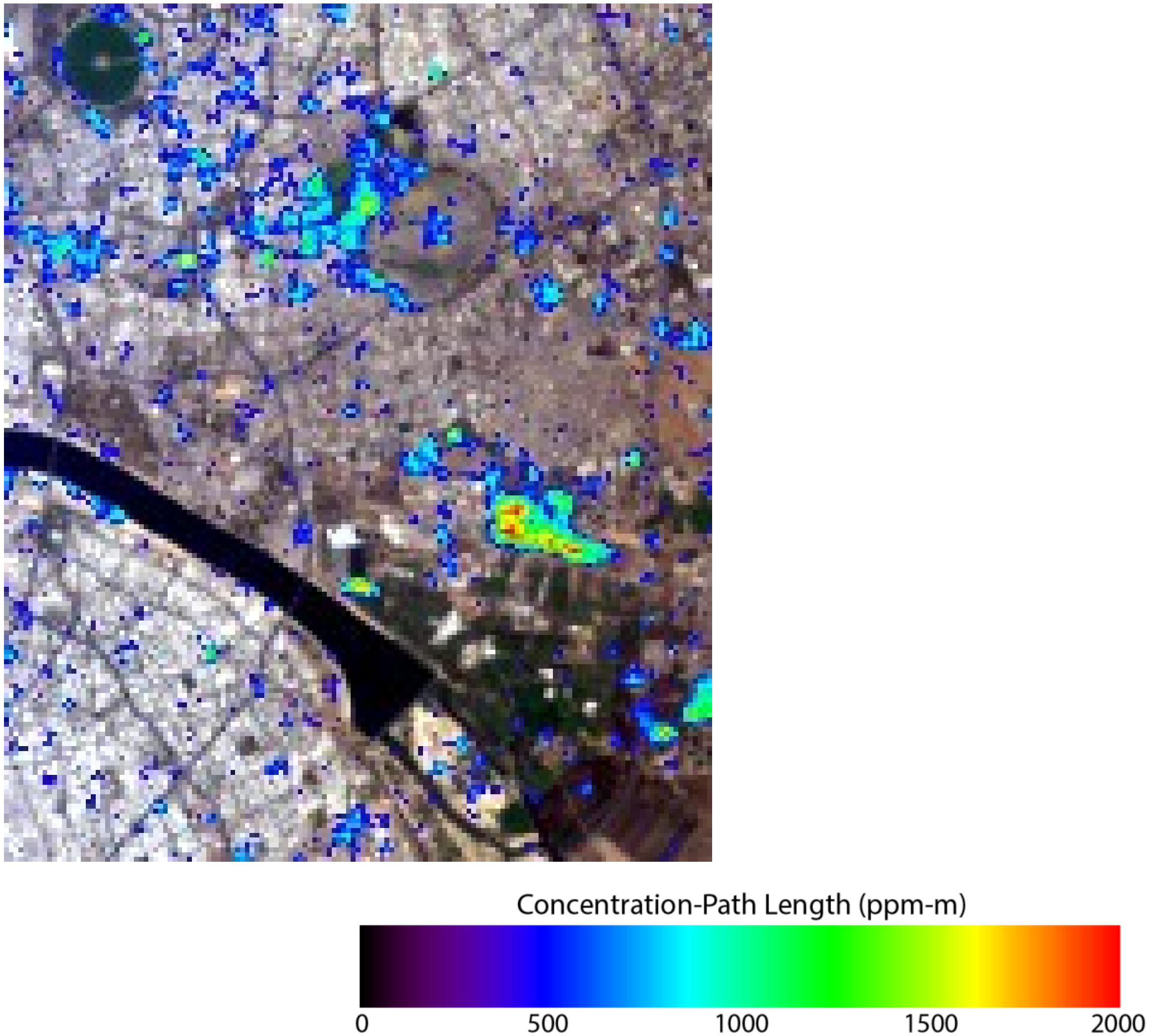


Dennison et al., in prep

SBG-like observables (CH_4)

- Simulated 30 m data using SBG-like point spread function and noise

10 nm spectral resolution

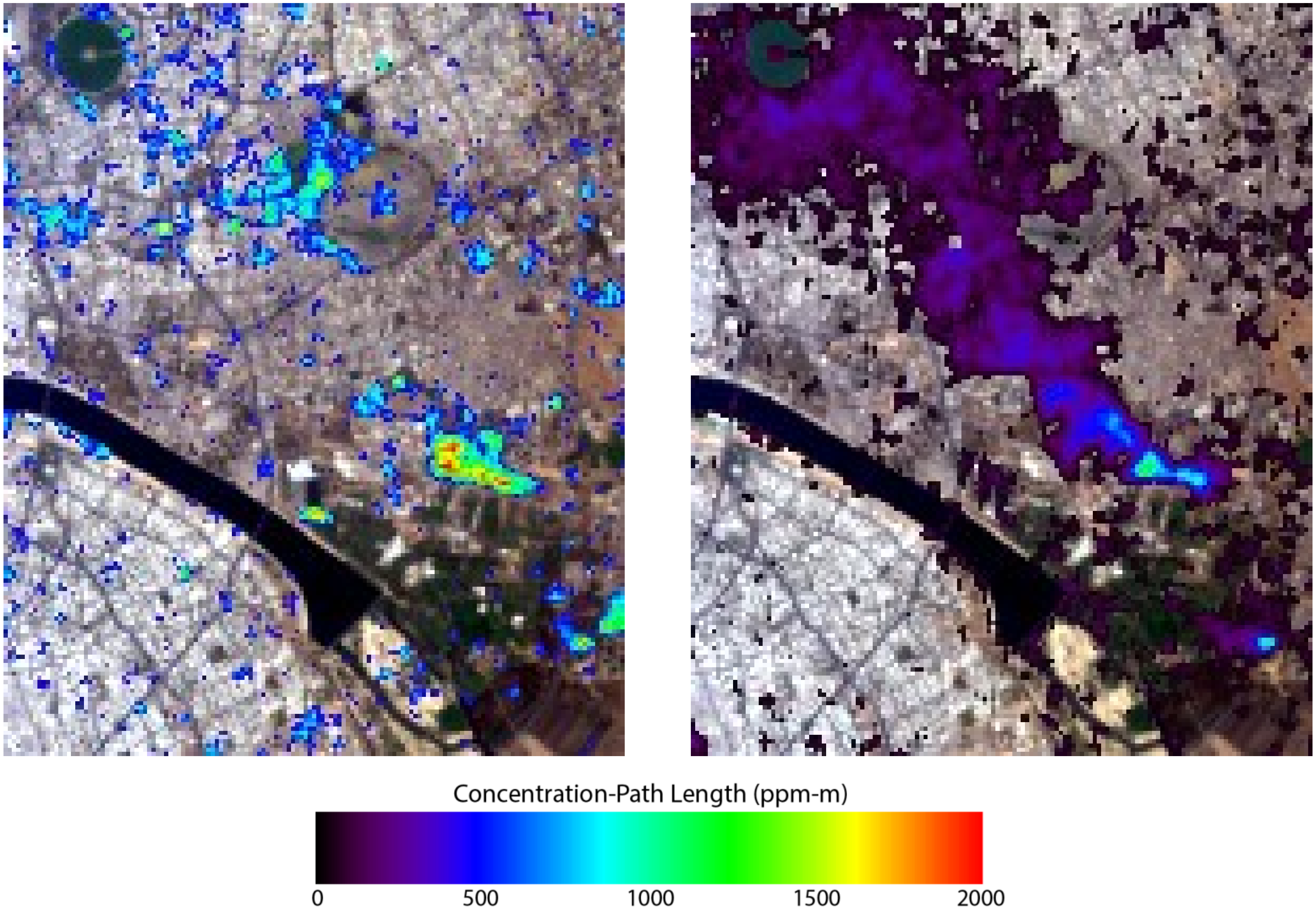


Dennison et al., in prep

SBG-like observables (CH_4)

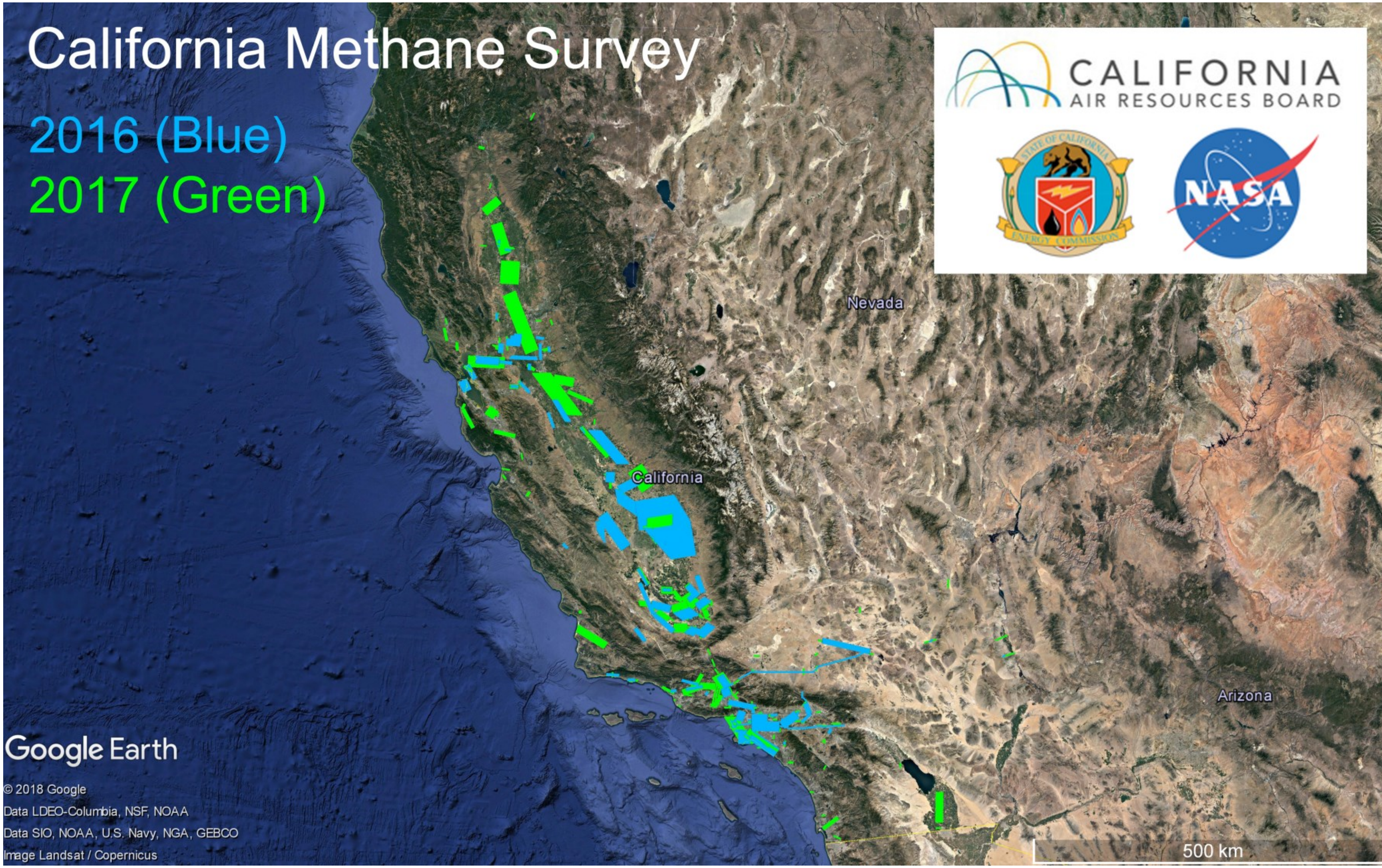
- Simulated 30 m data using SBG-like point spread function and noise

10 nm spectral resolution **5 nm spectral resolution**

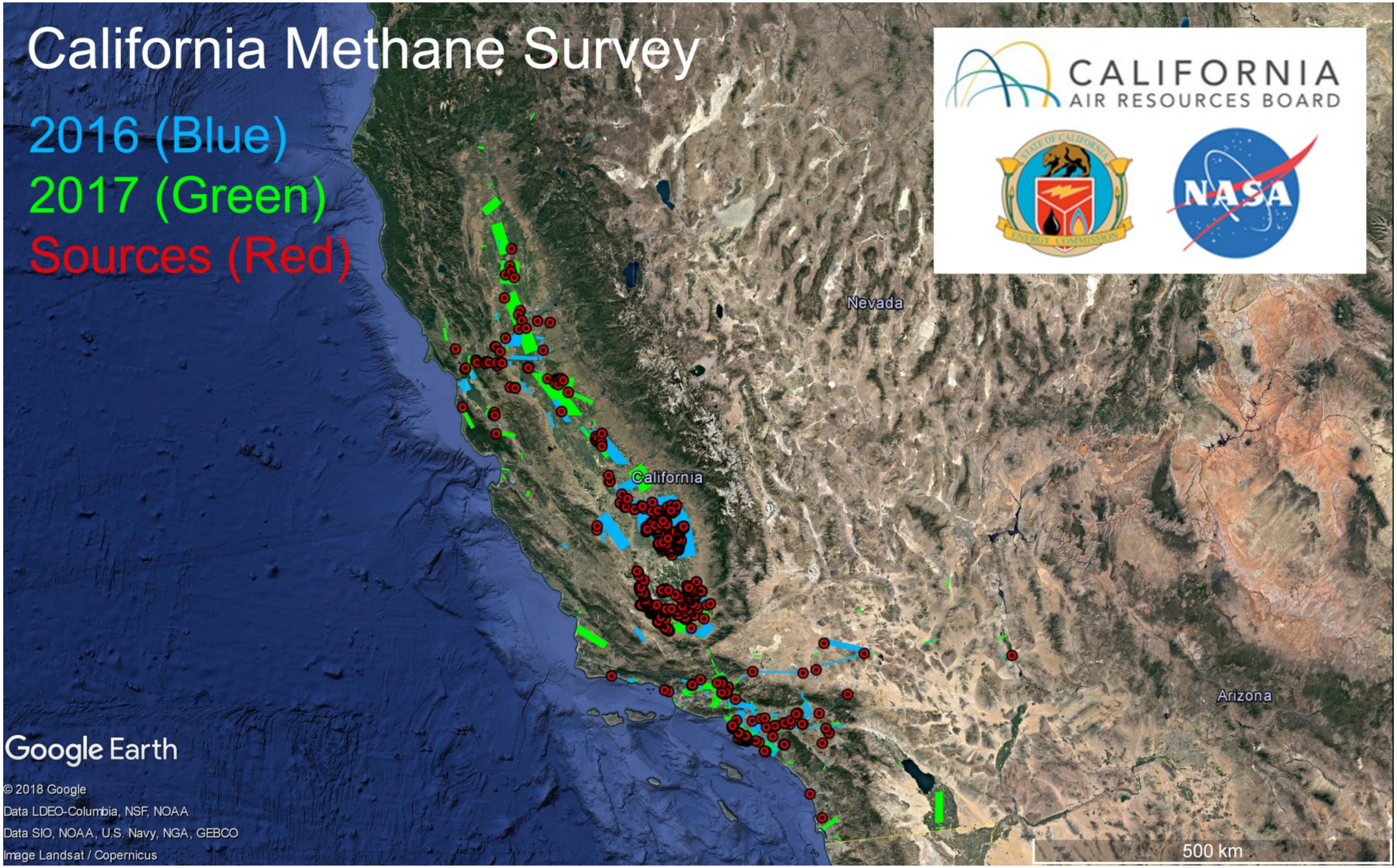


Dennison et al., in prep

California Baseline Methane Survey

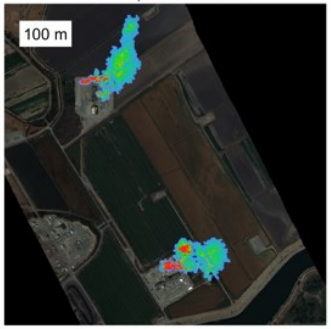


Duren et al., in prep

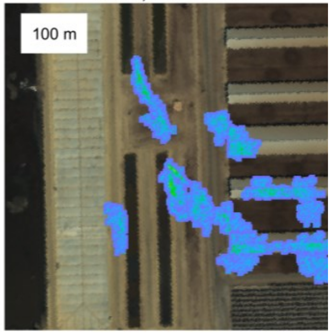


Duren et al., in prep

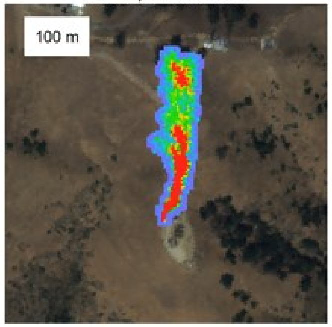
AIRIS-NG CH_4 plumes



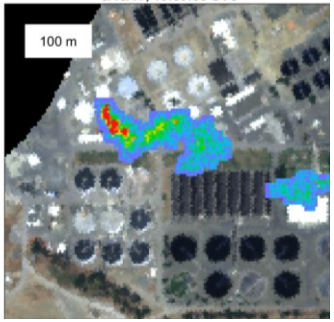
Natural Gas Compressor



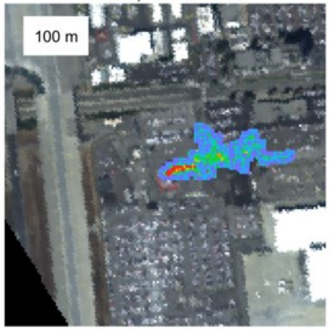
Dairy (manure lagoon)



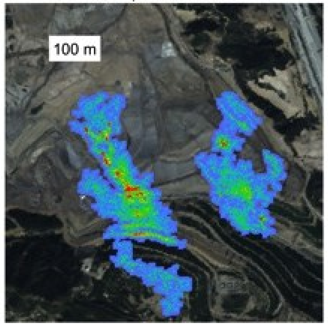
Oil well



Waste Water Treatment



Leaking LNG tank (airport)

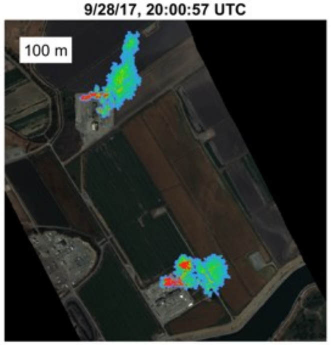


Landfill

California Baseline Methane Survey

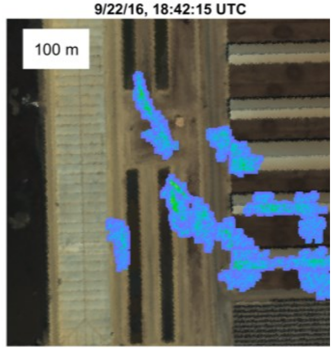
AVIRIS-NG CH_4 plumes

9/28/17, 20:00:57 UTC



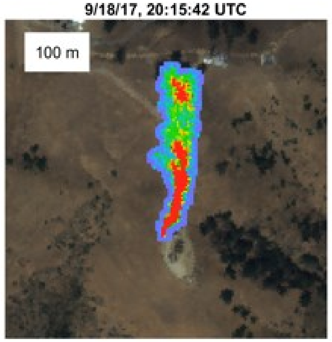
Natural Gas Compressor

9/22/16, 18:42:15 UTC



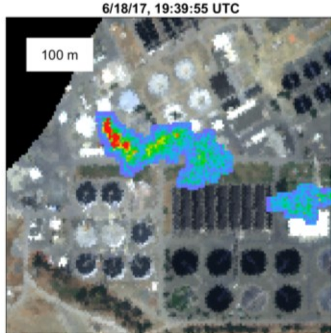
Dairy (manure lagoon)

9/18/17, 20:15:42 UTC



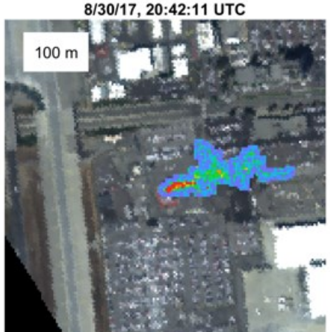
Oil well

6/18/17, 19:39:55 UTC



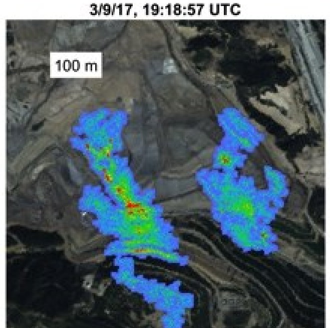
Waste Water Treatment

8/30/17, 20:42:11 UTC



Leaking LNG tank (airport)

3/9/17, 19:18:57 UTC



Landfill

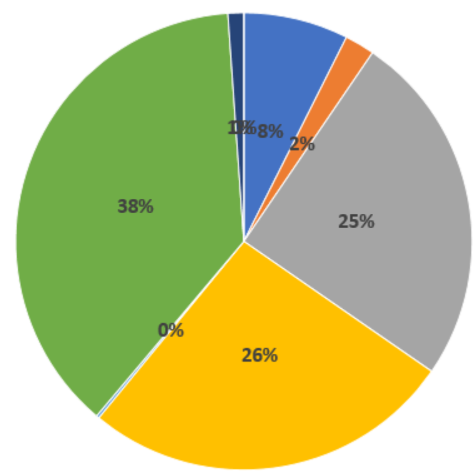
Wind speed (HRRR reanalysis)

Instantaneous emission flux (kg/hr)

Annual emission flux (kg/hr)

Source apportionment

By IPCC sector (Duren et al., in prep)



California Baseline Methane Survey

- Phase 1 report: http://bit.ly/BaselineMethaneSurvey
- Phase 2 analysis ongoing

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Monday, November 27, 2017

UP LINKS

- Reducing Air Pollution - ARB Programs
  - Research Activities
    - **Methane Research Program**

PROGRAM LINKS

- AB 1496 Methane Research
- Statewide GHG Monitoring Network
- Statewide Natural Gas Storage Facility Survey

RELATED LINKS

- Megacities Carbon Project (NASA)
- California Greenhouse Gas Emissions Measurement Project (LBNL)

RESOURCES

- Contact Us
- Join Any Research Email List(s)
- Library Catalog
- RSS / Newsfeed

AB 1496 Research Program

This page last was reviewed on October 30, 2017

Assembly Bill No. 1496, Chapter 604, Section 39731 (Thurmond, 2015)

In 2015, the Governor approved Assembly Bill 1496 (AB 1496) which requires ARB to do the following:

- Undertake monitoring and measurements of high emission methane "hot spots"
- Life-cycle greenhouse gas emissions analysis of natural gas produced and imported into California
- Review and assess the atmospheric reactivity of methane as a precursor to the formation of photochemical oxidant
- Update relevant policies and programs to incorporate new information

AB 1496 Research Efforts

Statewide Methane Survey

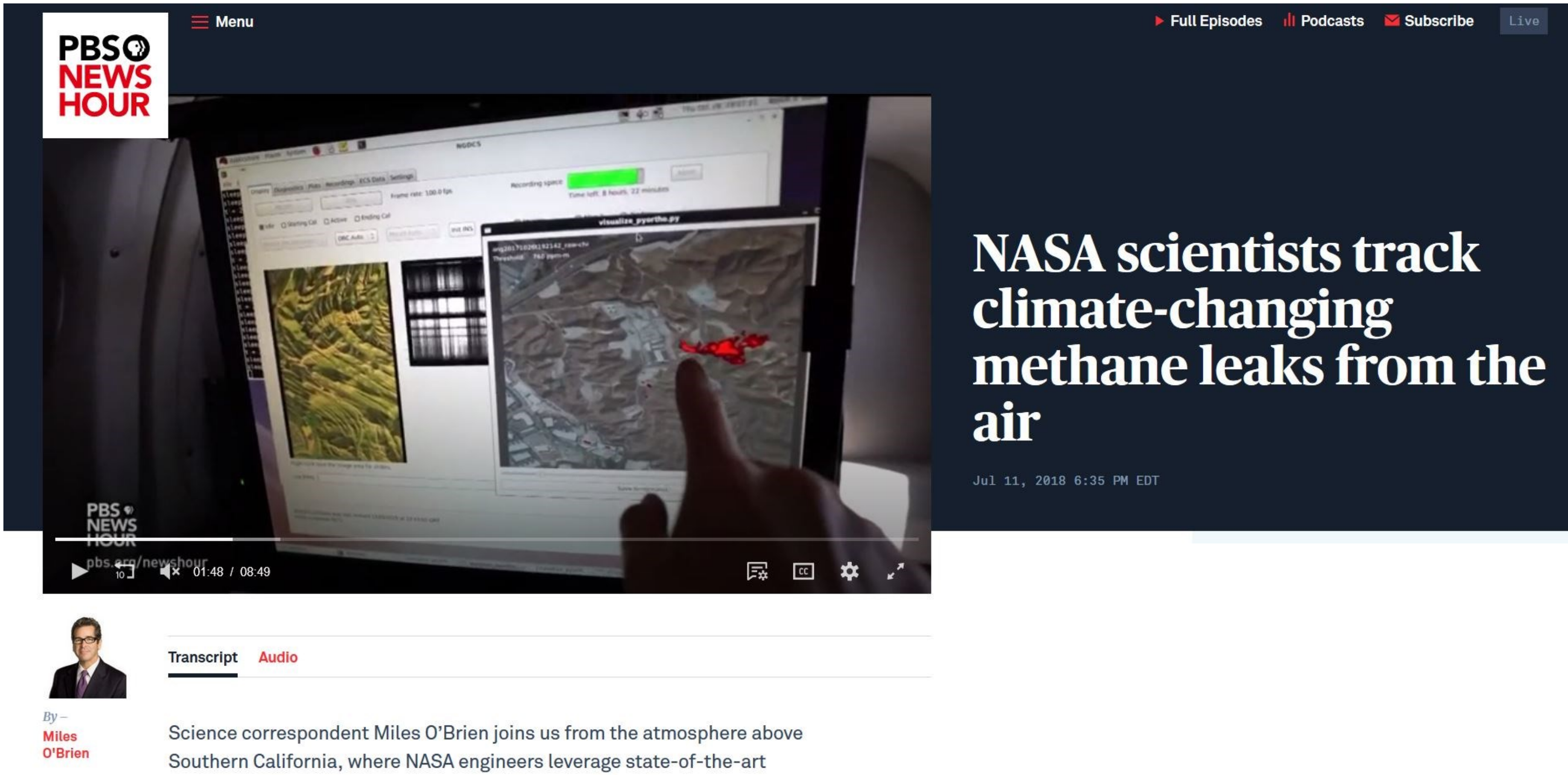
A key component of ARB's research effort is a large-scale statewide aerial methane survey being conducted by NASA Jet Propulsion Laboratory (JPL), through funding from ARB and CEC. The project focuses on identifying and mitigating methane "super emitters", and utilized an imaging camera capable of seeing methane to visually identify large methane plumes throughout the State. The first comprehensive survey was conducted during the Fall of 2016, and covered approximately 30,000 square kilometers, and identified many of the largest methane "super-emitters" in the State. A second field campaign will occur in the Fall of 2017. The survey will capture sources in all important methane source sectors, including:

- Oil and Gas - production/processing, storage, transmission, distribution
- Agriculture - dairies, manure, rice fields
- Waste - landfills, waste water

Resources:

- California Methane Survey - Phase I Interim Report NEW!
  - Phase I Report - Source List NEW!
- Staff Presentation to the Board on California Statewide Methane Survey (September 2017)

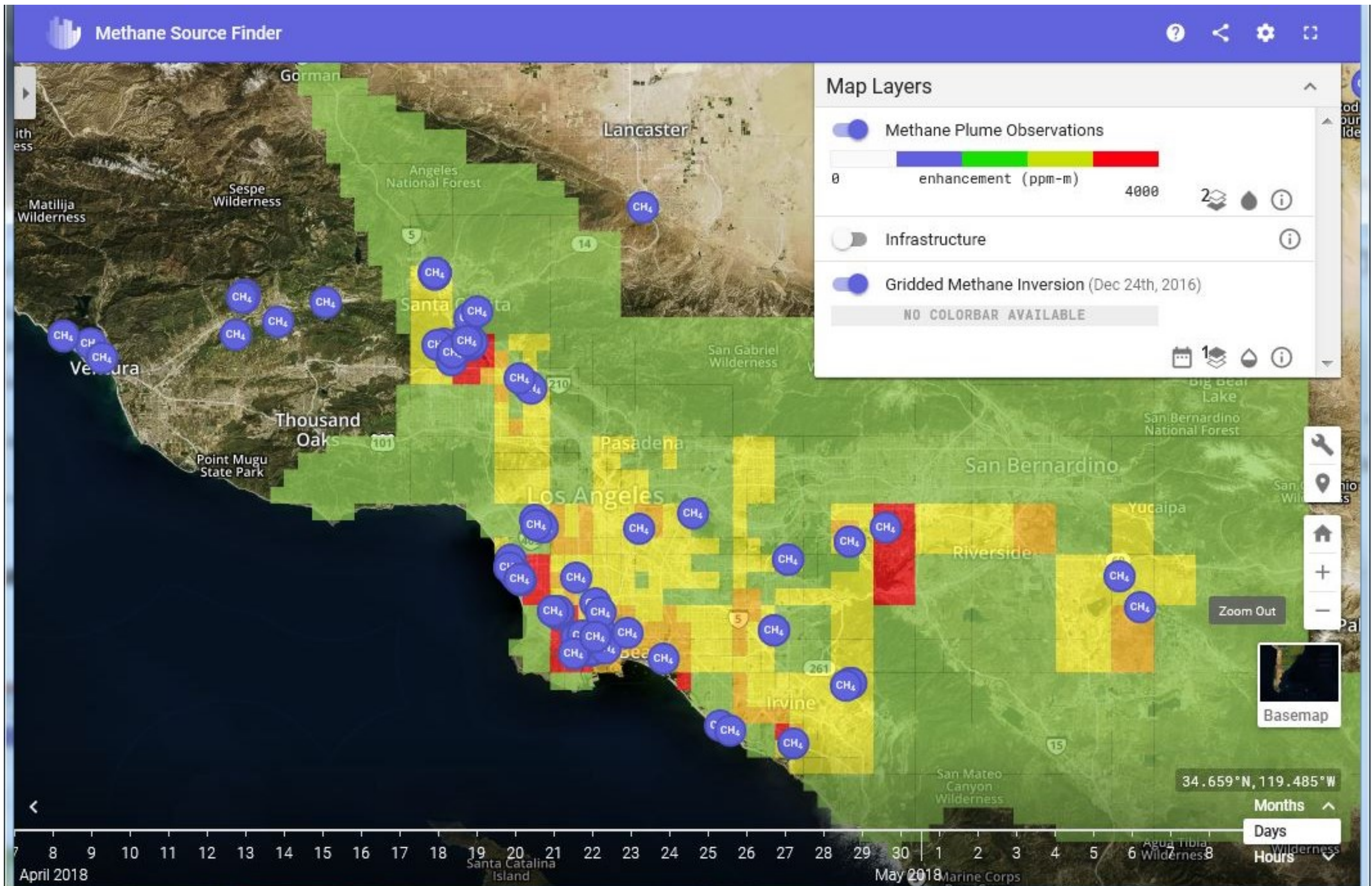
- PBS NewsHour story: http://bit.ly/PBSMethaneSurvey



Methane Source Finder

- NASA funded web based data portal including methane data at different spatial/temporal resolution (gridded emissions data, plumes from imaging spectrometers, infrastructure layers)

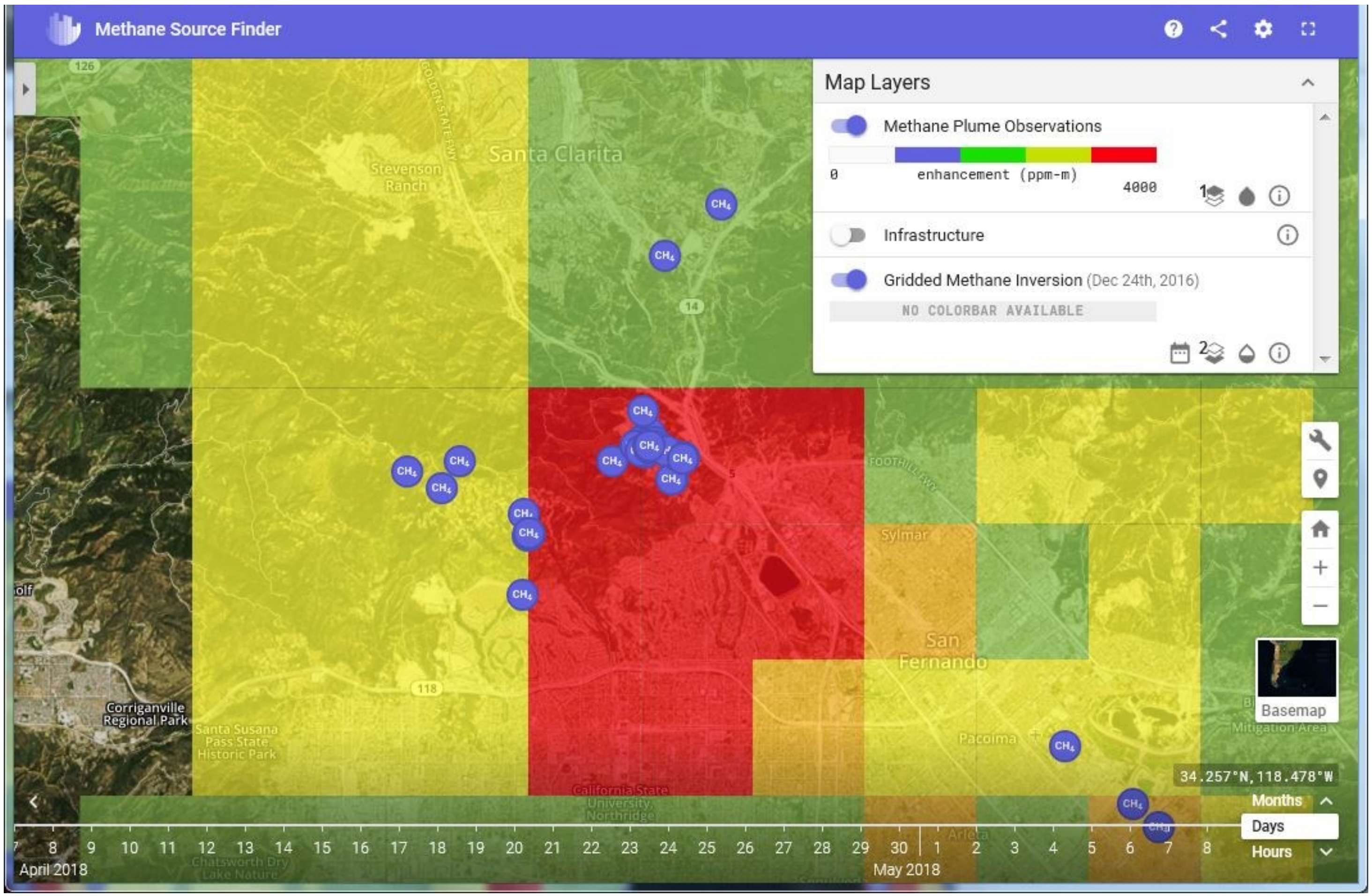
LA Basin regional analysis



Methane Source Finder

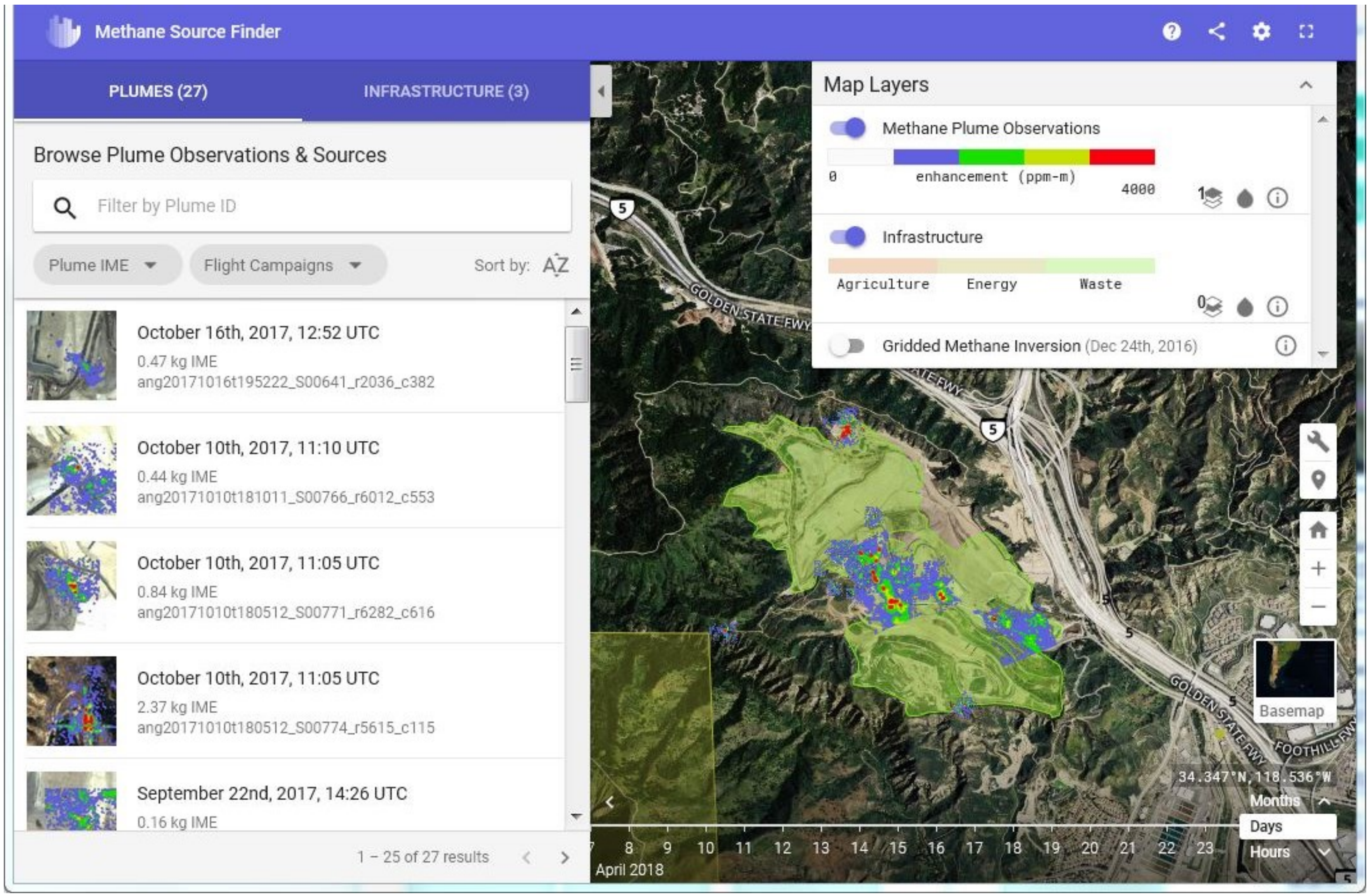
- NASA funded web based data portal including methane data at different spatial/temporal resolution (gridded emissions data, plumes from imaging spectrometers, infrastructure layers)

Exploring local CH_4 hotspots



- NASA funded web based data portal including methane data at different spatial/temporal resolution (gridded emissions data, plumes from imaging spectrometers, infrastructure layers)

Sunshine Canyon Landfill source attribution



NRC Decadal Survey RFI 2

Remote Sensing of Environment 114 (2010) 592–606

Mapping methane emissions from a marine geological seep source using imaging spectrometry

Dar A. Roberts, Eliza S. Bradley, Ross Cheung, Ira Leifer, Philip E. Dennison, Jack S. Margolis

GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L10702, doi:10.1029/2011GL046729, 2011

Detection of marine methane emissions with AVIRIS band ratios

Eliza S. Bradley, Ira Leifer, Dar A. Roberts, Philip E. Dennison, and Libe Washburn

Remote Sensing of Environment 134 (2013) 305–318

High resolution mapping of methane emissions from marine and terrestrial sources using a Cluster-Tuned Matched Filter technique and imaging spectrometry

Andrew K. Thorpe, Dar A. Roberts, Eliza S. Bradley, Christopher C. Funk, Philip E. Dennison, Ira Leifer

Atmos. Meas. Tech., 7, 491–506, 2014

Retrieval techniques for airborne imaging of methane concentrations using high spatial and moderate spectral resolution: application to AVIRIS

A. K. Thorpe, C. Frankenberg, and D. A. Roberts

Remote Sensing of Environment 179 (2016) 104–115

Mapping methane concentrations from a controlled release experiment using the next generation airborne visible/infrared imaging spectrometer (AVIRIS-NG)

A.K. Thorpe, C. Frankenberg, A.D. Aubrey, D.A. Roberts, A.A. Nottrott, T.A. Rahn, J.A. Sauer, M.K. Dubey, K.R. Costigan, C. Arata, A.M. Steffke, S. Hills, C. Haselwimmer, D. Charlesworth, C.C. Funk, R.O. Green, S.R. Lundeen, J.W. Boardman, M.L. Eastwood, C.M. Sarture, S.H. Nolte, I.B. Mccubbin, D.R. Thompson, J.P. McFadden

The Airborne Methane Plume Spectrometer (AMPS): Quantitative Imaging of Methane Plumes in Real Time

Andrew K. Thorpe, Christian Frankenberg, Robert O. Green, David R. Thompson, Andrew D. Aubrey, Pantazis Mouroulis, Michael L. Eastwood, Georgios Matheou

Atmos. Meas. Tech., 8, 4383–4397, 2015

Real-time remote detection and measurement for airborne imaging spectroscopy: a case study with methane

D. R. Thompson, I. Leifer, H. Bovensmann, M. Eastwood, M. Fladeland, C. Frankenberg, K. Gerilowski, R. O. Green, S. Kratwurst, T. Krings, B. Luna, and A. K. Thorpe

OTC-25984-MS

Crosscutting Airborne Remote Sensing Technologies for Oil and Gas and Earth Science Applications

A.D. Aubrey, C. Frankenberg, R.O. Green, M.L. Eastwood, D.R. Thompson - NASA Jet Propulsion Laboratory, California Institute of Technology; A.K. Thorpe, University of California, Santa Barbara

AGU PUBLICATIONS
Geophysical Research Letters
RESEARCH LETTER 10.1002/2016GL069079

Space-based remote imaging spectroscopy of the Aliso Canyon CH_4 superemitter

D. R. Thompson, A. K. Thorpe, C. Frankenberg, R. O. Green, R. Duren, L. Guanter, A. Hollstein, E. Middleton, L. Ong, and S. Ungar

PNAS

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

Christian Frankenberg, Andrew K. Thorpe, David R. Thompson, Glynn Hulley, Eric Adam Kort, Nick Vance, Jakob Borchardt, Thomas Krings, Konstantin Gerilowski, Colm Sweeney, Stephen Conley, Brian D. Bue, Andrew D. Aubrey, Simon Hook, and Robert O. Green

Atmos. Meas. Tech., 10, 3833–3850, 2017

Airborne DOAS retrievals of methane, carbon dioxide, and water vapor concentrations at high spatial resolution: application to AVIRIS-NG

Andrew K. Thorpe, Christian Frankenberg, David R. Thompson, Riley M. Duren, Andrew D. Aubrey, Brian D. Bue, Robert O. Green, Konstantin Gerilowski, Thomas Krings, Jakob Borchardt, Eric A. Kort, Colm Sweeney, Stephen Conley, Dar A. Roberts, and Philip E. Dennison

Remote Sensing of Environment 215 (2018) 386–397

Evaluating the effects of surface properties on methane retrievals using a synthetic airborne visible/infrared imaging spectrometer next generation (AVIRIS-NG) image

Alana K. Ayasse, Andrew K. Thorpe, Dar A. Roberts, Christopher C. Funk, Philip E. Dennison, Christian Frankenberg, Andrea Steffke, Andrew D. Aubrey

EARTH SCIENCE AND APPLICATIONS FROM SPACE RFI#2 15 MAY 2016

Understanding anthropogenic methane and carbon dioxide point source emissions

Riley M. Duren[1], Andrew K. Thorpe[1], Robert O. Green[1], Christian Frankenberg[2], David R. Thompson[1], Andrew D. Aubrey[1], Charles E. Miller[1], Kevin R. Gurney[3], Luis Guanter[4], Heinrich Bovensman[5], Konstantin Gerilowski[5], Ilse Aben[6], Andre Butz[7], Colm Sweeney[8], Eric A. Kort[9]

[1]Jet Propulsion Laboratory, California Institute of Technology

[2]California Institute of Technology

[3]Arizona State University

[4]Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum

[5]University of Bremen

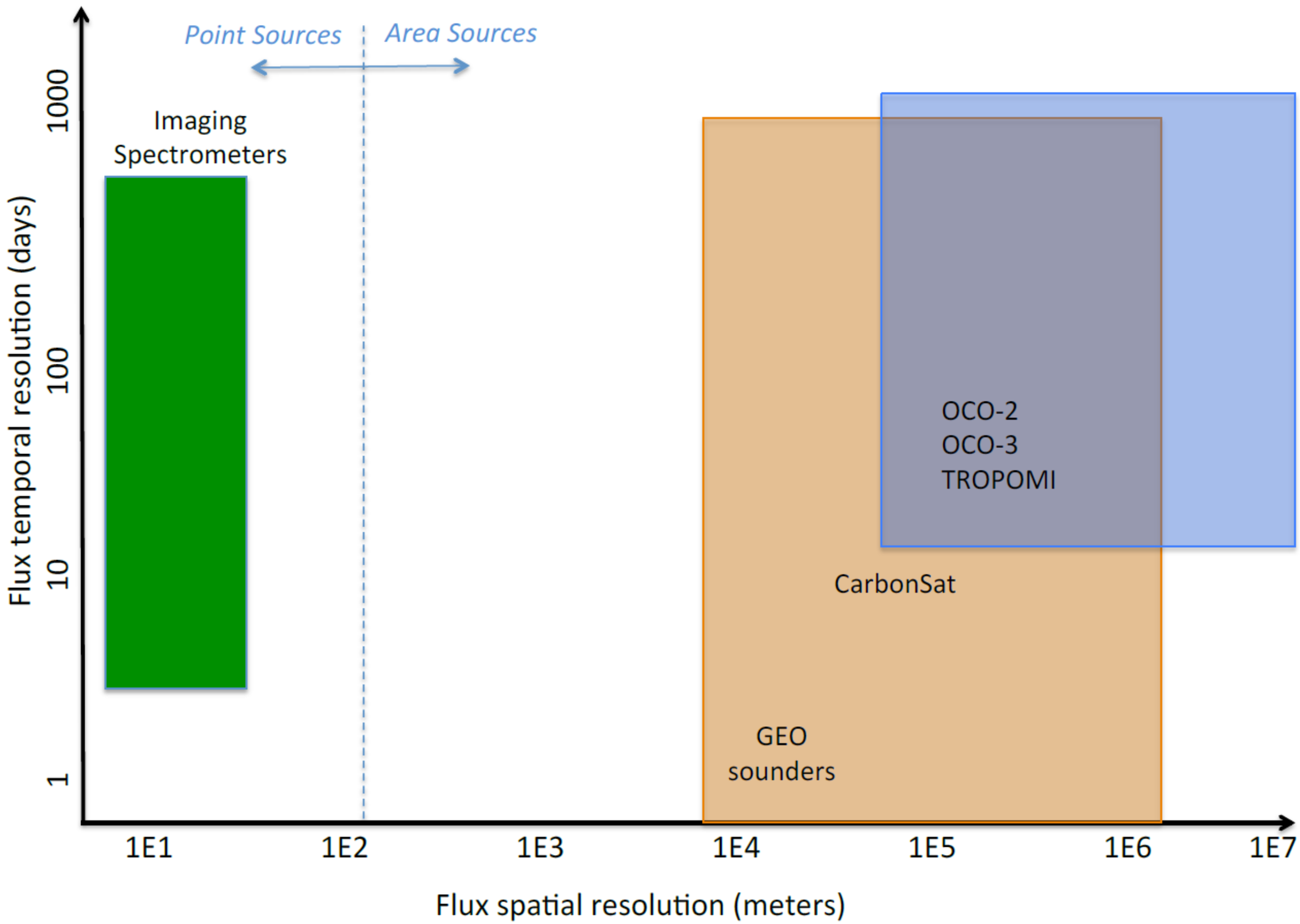
[6]SRON Netherlands Institute for Space Research

[7]Karlsruhe Institute of Technology

[8]NOAA/CU Boulder

[9]University of Michigan

- Imaging spectrometer for gas mapping provides unique capabilities that compliment existing measurements



Duren et al., 2016

NRC Decadal Survey RFI 2

- Imaging spectrometer design for gas mapping reflect balance between
  - Detection threshold (spectral resolution, spatial resolution)
  - Coverage (swath)

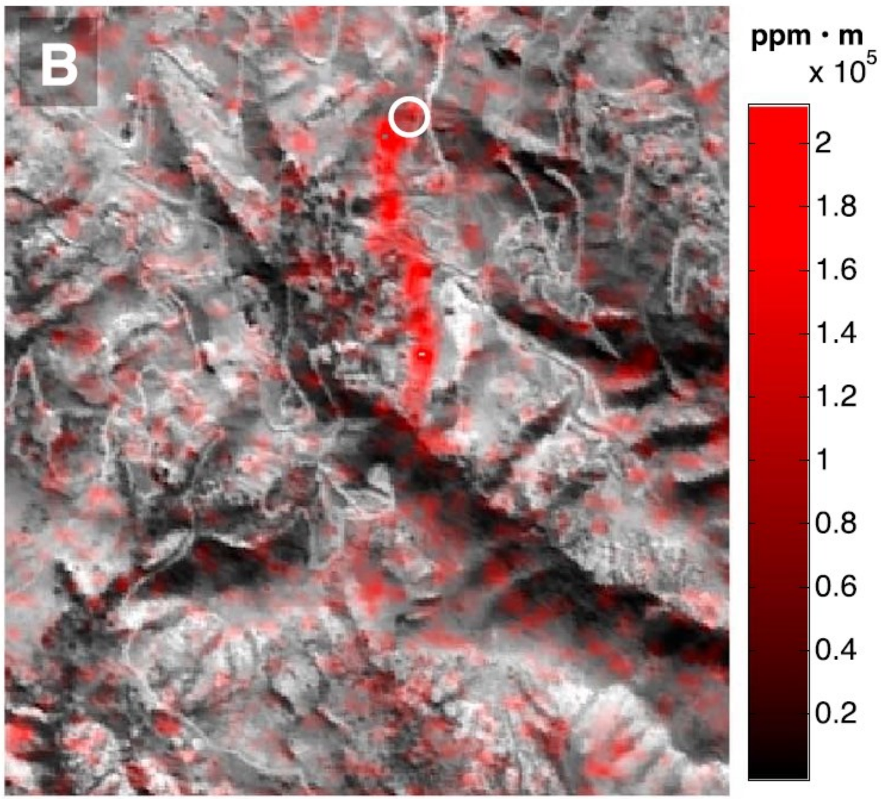
Observing System	Imaging spectrometer specifications	Source population	Fraction of population sampled	Fraction of total emissions from sampled population (for the given detection threshold)	Detection threshold (kg/hr)	Spatial resolution (m)*	Sample interval** (days)
Tier A	Platform: single satellite Spatial resolution: 30 m Swath width: 180 km Spectral resolution: **5 nm** Wavelength: 1.9 - 2.5 micron	CH_4: 10,000,000 facilities[1b] (global)	99%	30%	1,000	30	30
		CO_2: tens of thousands of facilities (global)[1a]	99%	>80%	200,000	30	30
Tier B	Platform: Smallsat constellation Spatial resolution: 10 m Spectral resolution: 10 m Daily sampling: 250,000 km^2 (target mode) FWHM: **1 nm** Wavelength: 1.9 - 2.5 micron	CH_4: 10,000,000 facilities (global)[2]	>50%	50-90%[3]	50	10	15
		CO_2: tens of thousands of facilities[1a] (global)	>50%	>90%	20,000	10	15

[1a] Of 21,000 large power plants in the CARMA database, 30% (~7000 plants) are responsible for 99% of CO_2 emissions from that sector; there are also thousands of other industrial facilities that are large CO_2 emitters
[1b] An estimated 10,000,000 facilities globally; only ~100,000 facilities contribute 30% of methane point source emissions (scaled from US GHGRP)
[2] Assume super-emitter distribution (scaled from US EIA data and Zavala-Araiza et al, 2015; Lyon et al, 2015; Frankenberg et al, 2016)
[3] Predict 50-90% completeness with the cited detection threshold (varies by sector)
*Native resolution of the instrument (pixel size) - not necessarily flux estimate resolution (which is often larger for area source sounders)
**Rough estimate of sample interval based on orbit/campaign driven revisit interval and the impact of clouds, northern hemisphere summer

Duren et al., 2016

- Orbital Hyperion instrument and AVIRIS also observed CH_4 plume

Hyperion (10 nm): 1/1/16, 16:39 UTC
Low Earth orbit

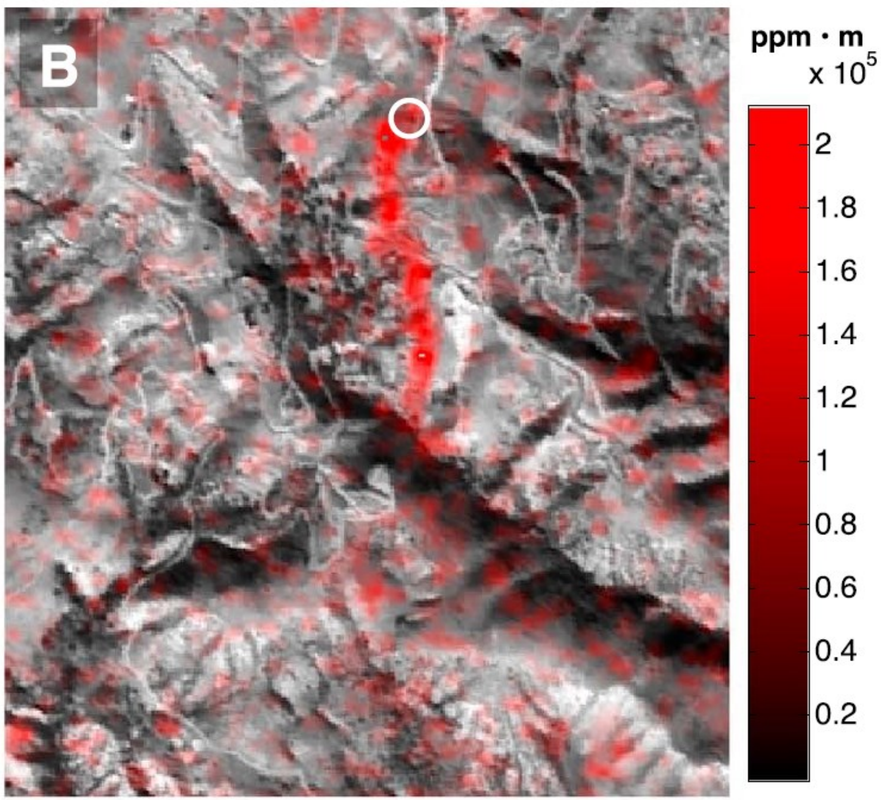


Thompson et al., 2016

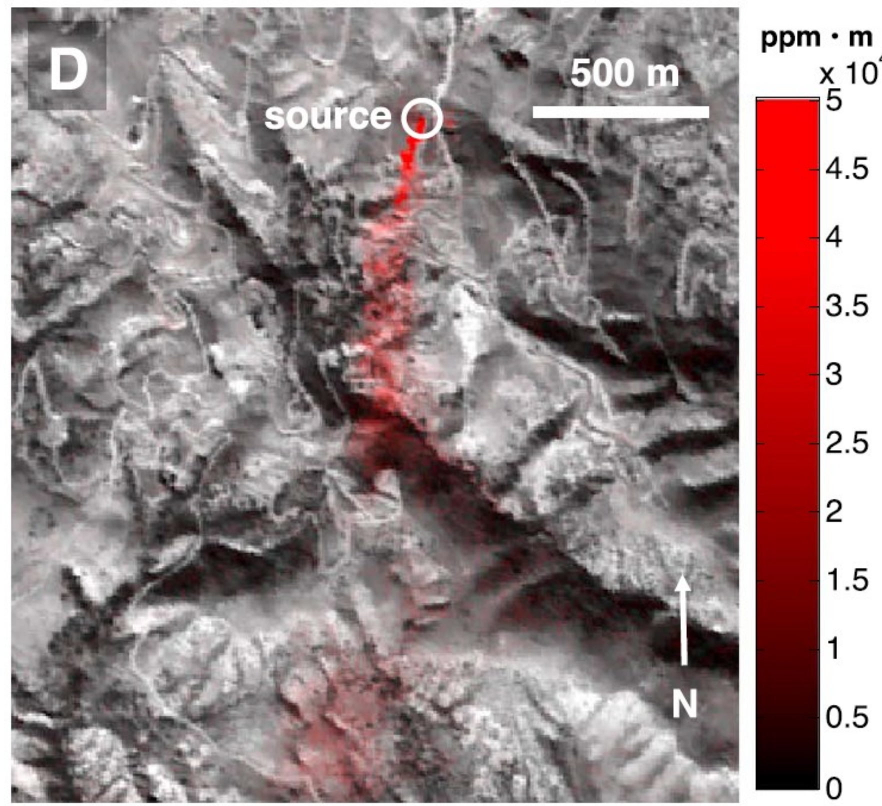
NRC Decadal Survey RFI 2

- Orbital Hyperion instrument and AVIRIS also observed CH_4 plume

Hyperion (10 nm): 1/1/16, 16:39 UTC
Low Earth orbit

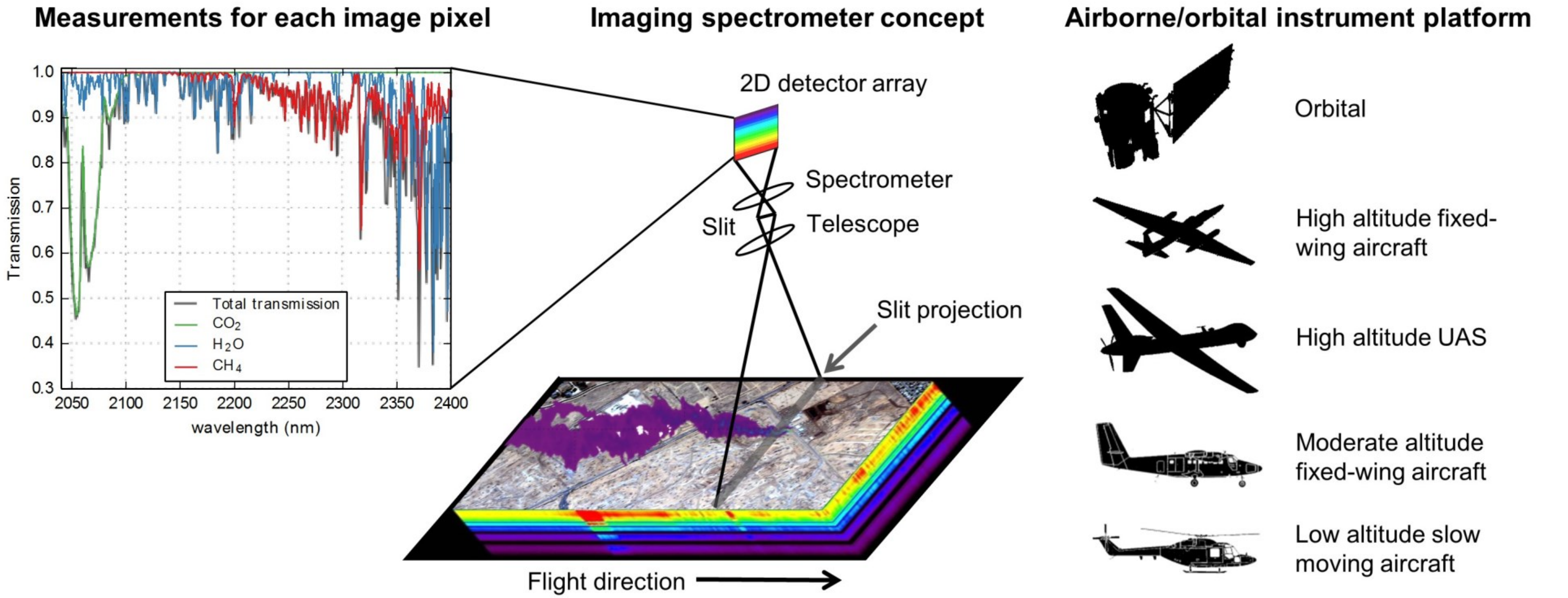


AVIRIS (10 nm): 1/12/16, 20:25 UTC
6.6 km above ground level



Thompson et al., 2016

- Earth System Explorer-Targeted Observable: Greenhouse Gases
  - "Low Earth Orbit observation of [CH4 and CO2] plumes from point sources using SWIR spectrometers with very high spatial resolution (less than 50 m) over limited viewing domains." (NRC, 2018)



Thorpe et al., 2016

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