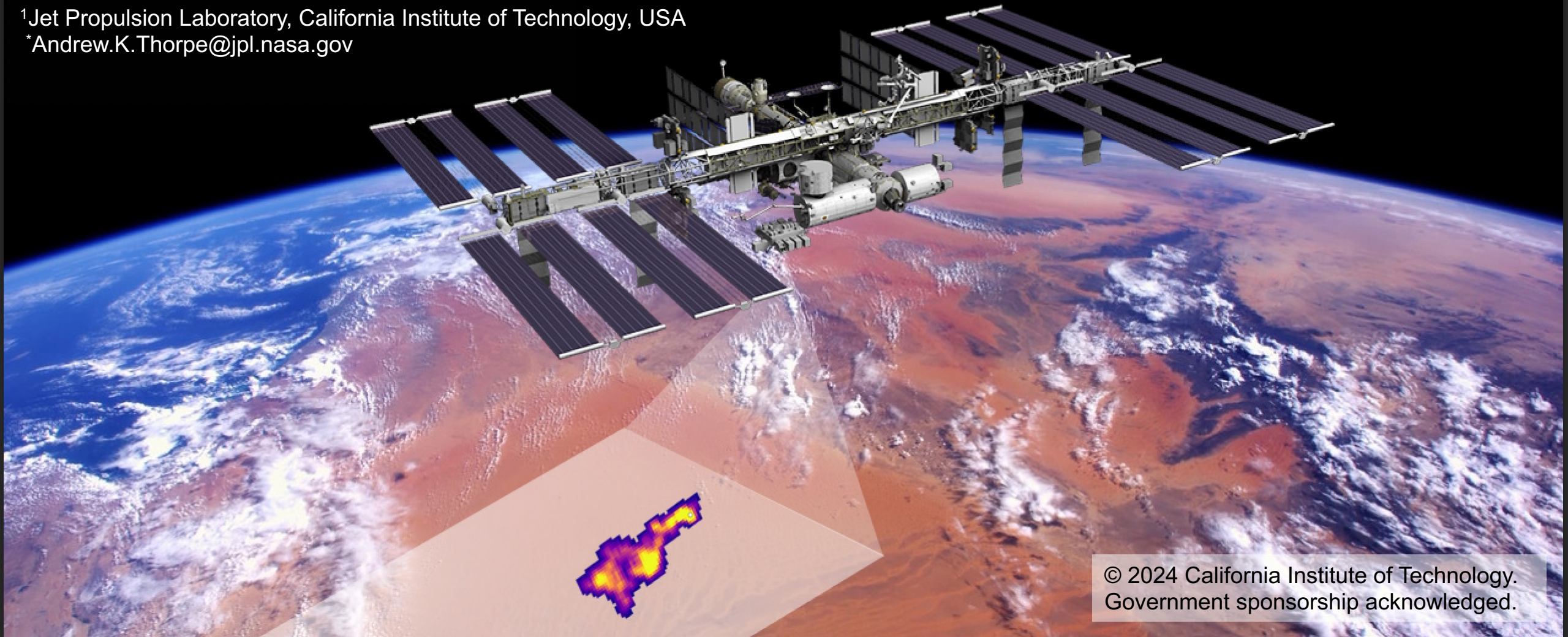
Methane and CO2 emission attribution from space with EMIT and aircraft using AVIRIS-3 for calibration and validation

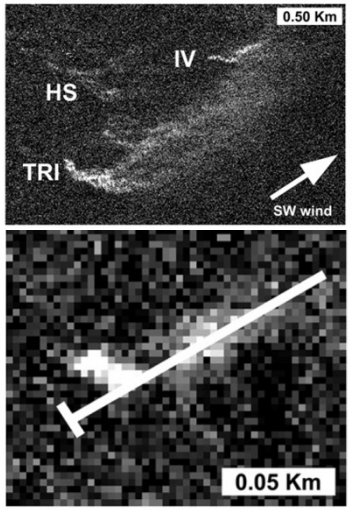
Andrew K. Thorpe[1*], Robert O. Green[1], Philip G. Brodrick[1], Red Willow Coleman[1], Jay E. Fahlen[1], K. Dana Chadwick[1], Adam Chlus[1], David R. Thompson[1], Michael L. Eastwood[1], et al.

[1]Jet Propulsion Laboratory, California Institute of Technology, USA
[*]Andrew.K.Thorpe@jpl.nasa.gov



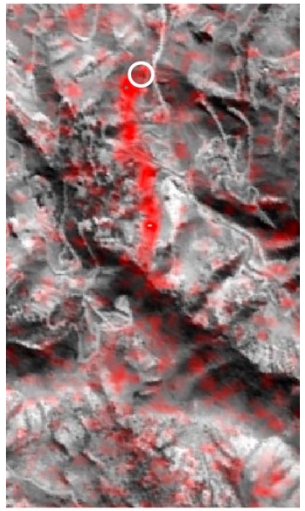
Remote measurement of GHG enhancements using NASA imaging spectrometers has a long track record

Airborne CH_4 observations from AVIRIS, 2008



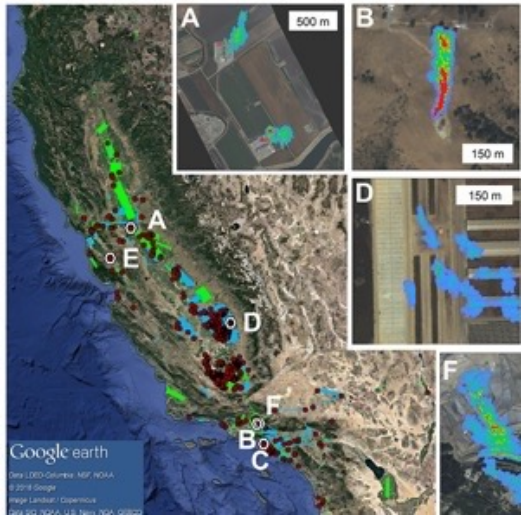
Thorpe et al., 2013

First spaceborne observations from Hyperion, 2016



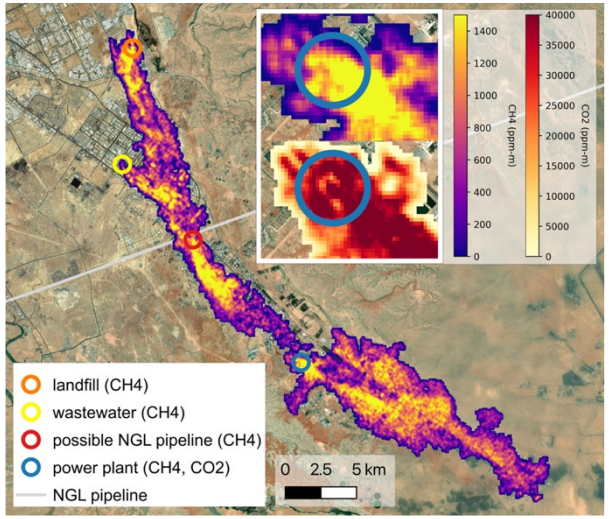
Thompson et al., 2016

Multi-sector methane observations with AVIRIS-NG across California, 2019



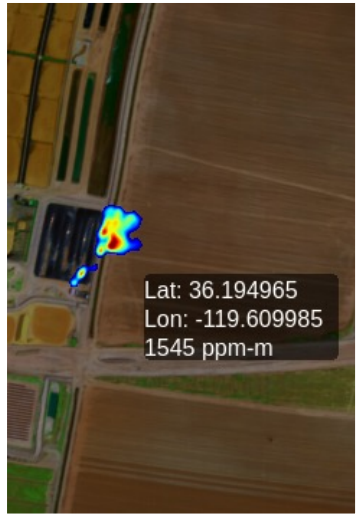
Duren et al., 2019

Observations from EMIT sensor from international space station, starting 2022



Thorpe et al., 2023

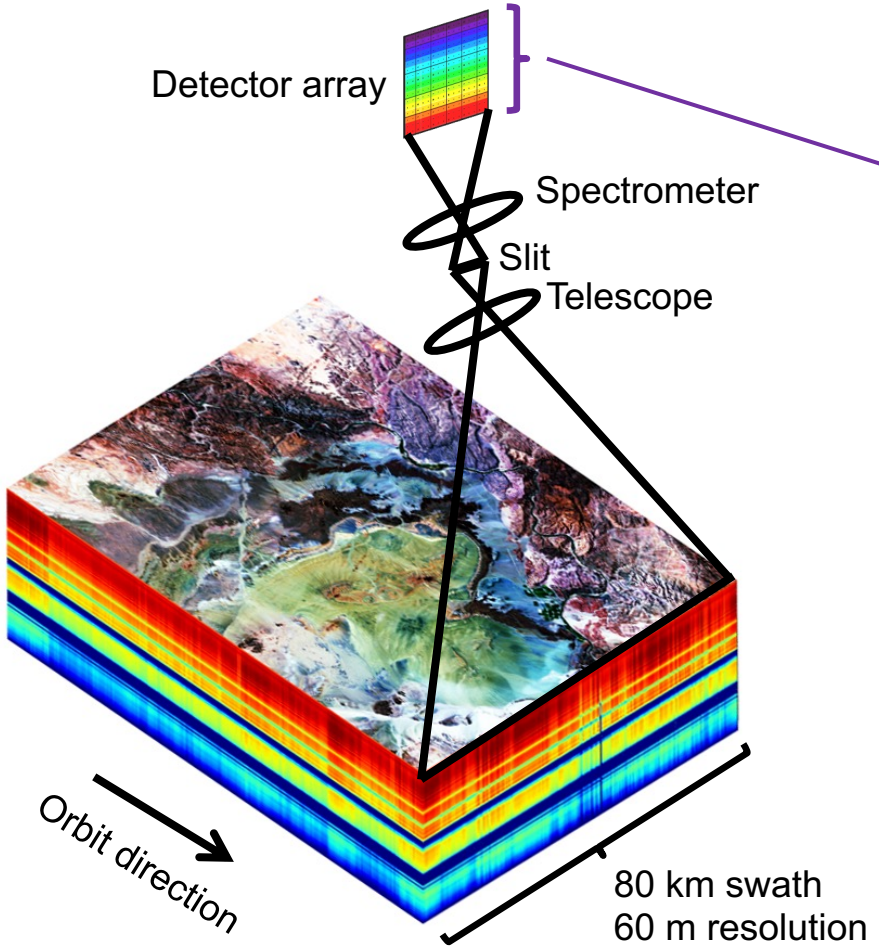
AVIRIS-3 CH_4 observations begin in western US, 2023



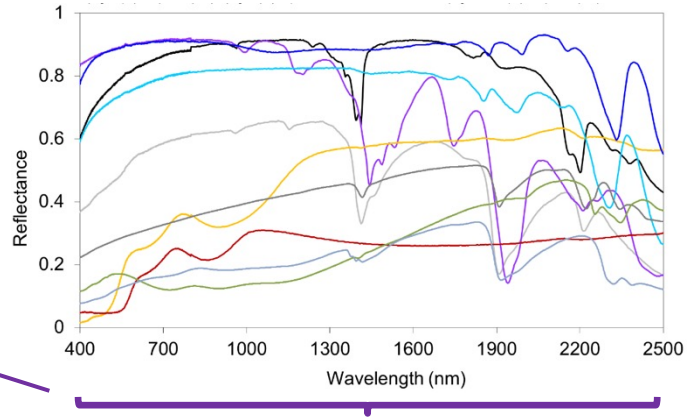
Coleman et al., in prep.

EMIT measures mineral spectral fingerprints

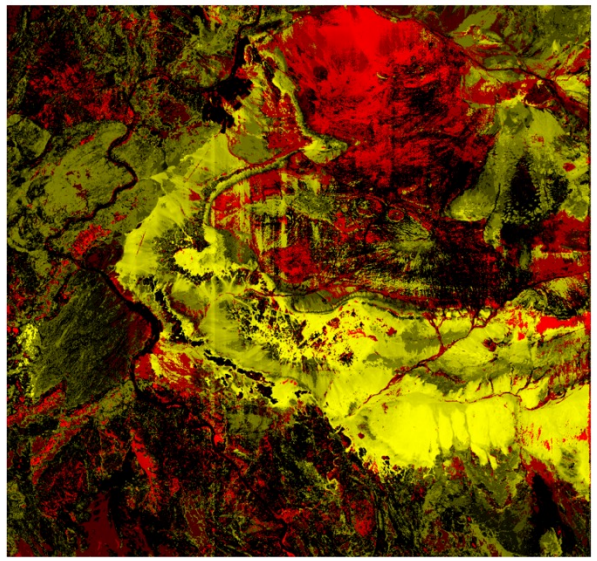
EMIT on the ISS measures radiance



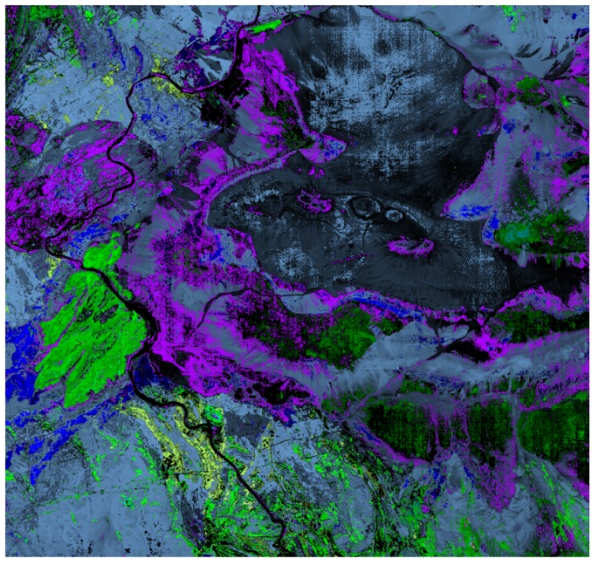
Mineral spectral signatures
(7.4 nm spectral resolution)

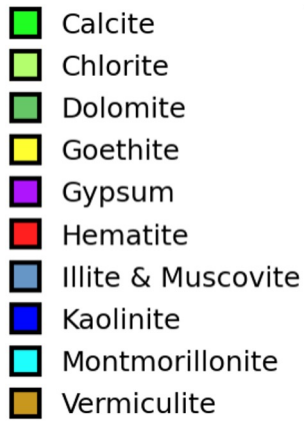


Dominant Mineral Abundances - Iron Oxides

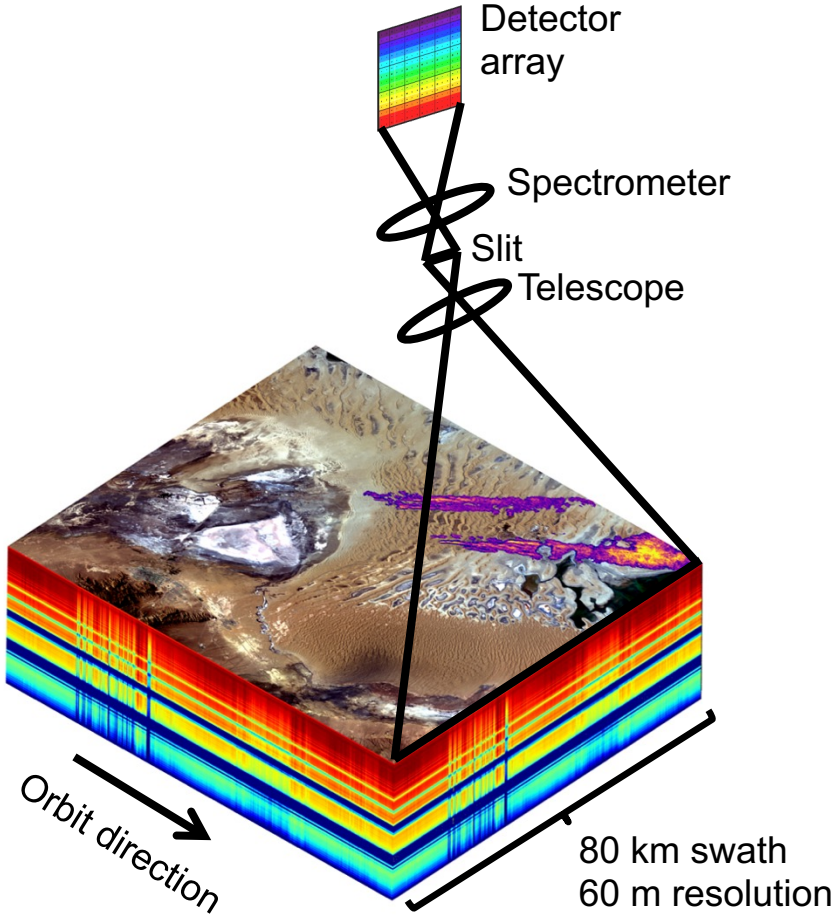


Dominant Mineral Abundances - 2μm



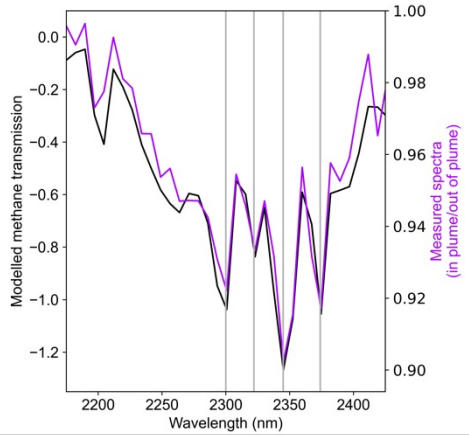


EMIT also measures CH_4 and CO_2 spectral fingerprints!

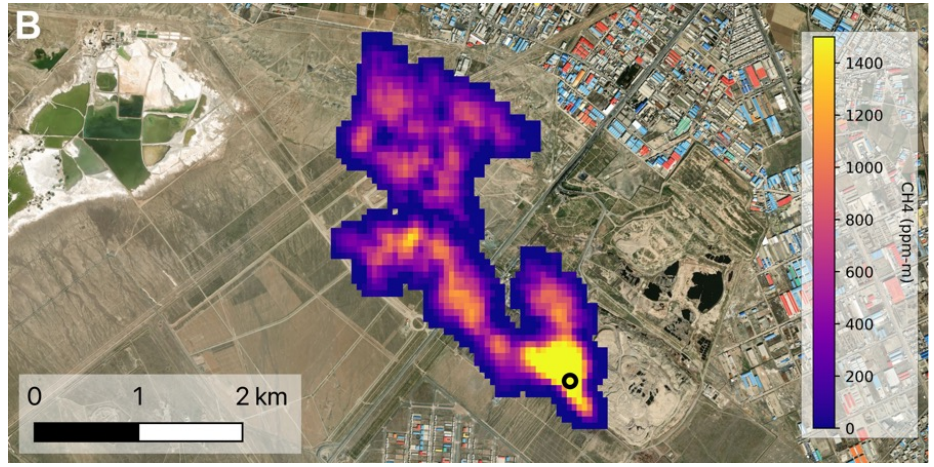


- Daily coverage varies (~1,300,000 km^2)

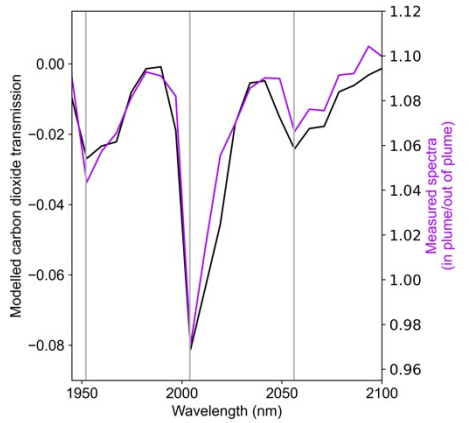
CH_4 spectral fingerprint from EMIT radiance data



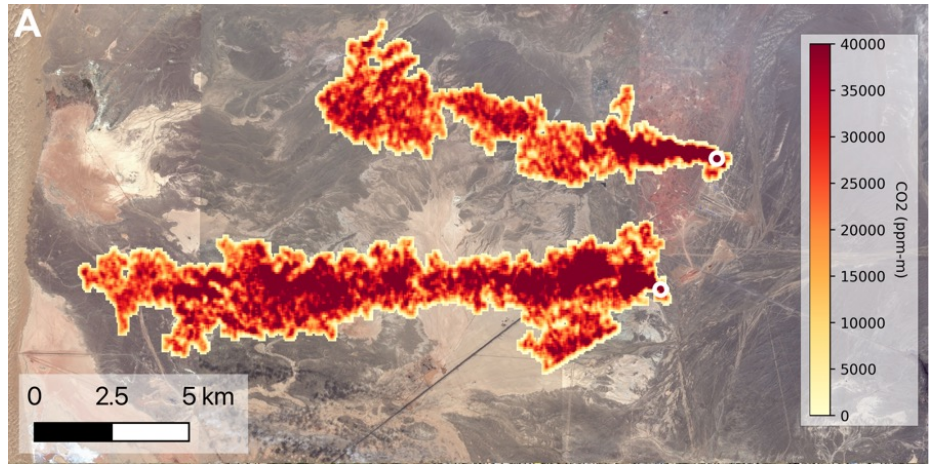
CH_4 from landfill (Iran)



CO_2 spectral fingerprint



CO_2 from power plants (China)



Sciences Advances publication: EMIT methane and CO2

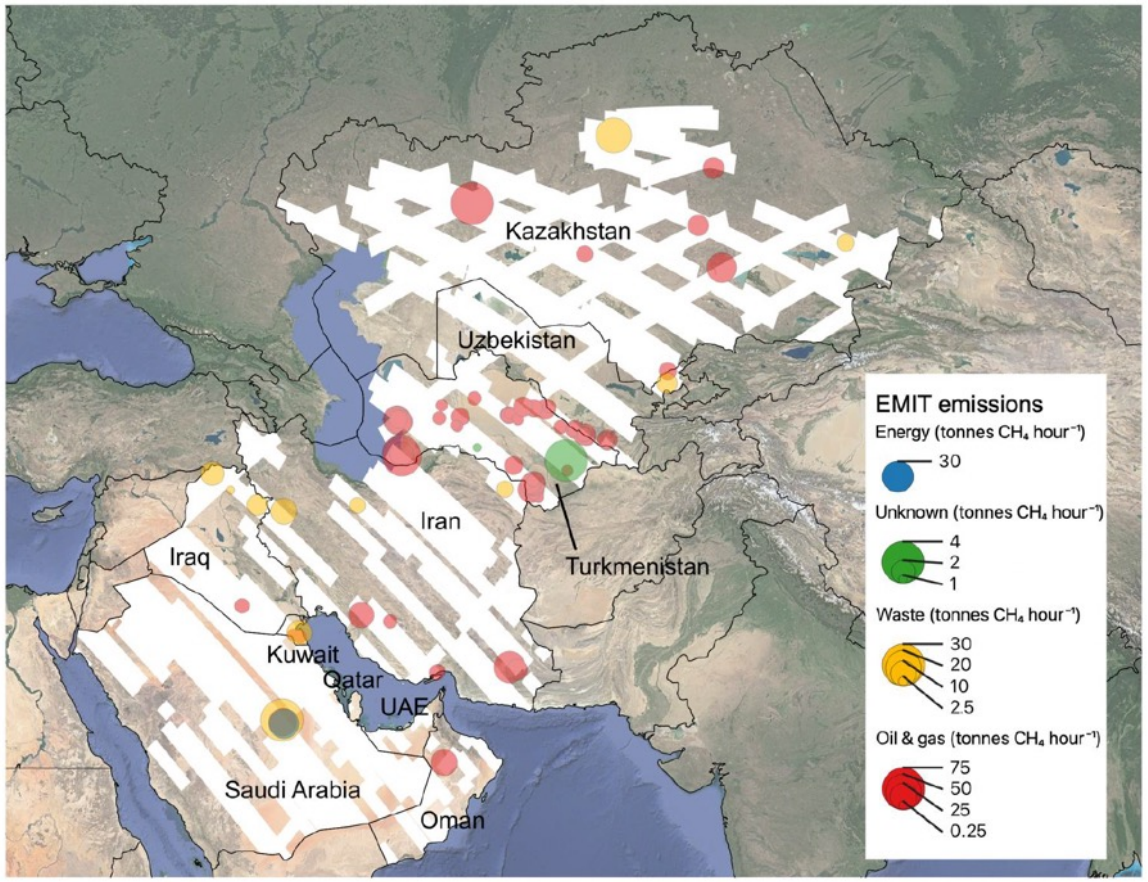
SCIENCE ADVANCES | RESEARCH ARTICLE

ATMOSPHERIC SCIENCE

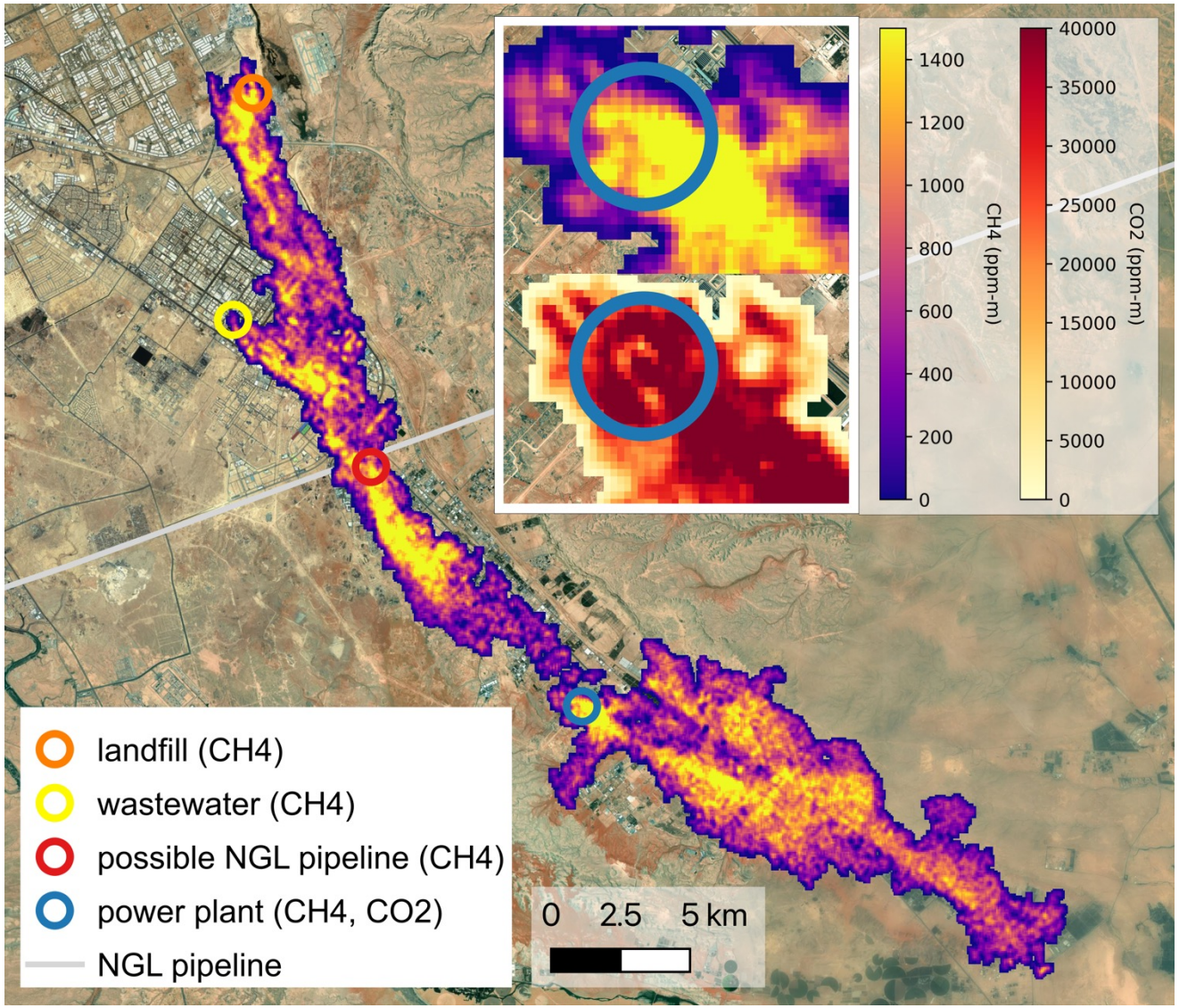
Attribution of individual methane and carbon dioxide emission sources using EMIT observations from space

Andrew K. Thorpe[1]*, Robert O. Green[1], David R. Thompson[1], Philip G. Brodrick[1], John W. Chapman[1], Clayton D. Elder[1], Itziar Irakulis-Loitxate[2,3], Daniel H. Cusworth[4,5], Alana K. Ayasse[4,5], Riley M. Duren[1,4,5], Christian Frankenberg[6], Luis Guanter[2,7], John R. Worden[1], Philip E. Dennison[8], Dar A. Roberts[9], K. Dana Chadwick[1], Michael L. Eastwood[1], Jay E. Fahlen[1], Charles E. Miller[1]

Carbon dioxide and methane emissions are the two primary anthropogenic climate-forcing agents and an important source of uncertainty in the global carbon budget. Uncertainties are further magnified when emissions occur at fine spatial scales (<1 km), making attribution challenging. We present the first observations from NASA's Earth Surface Mineral Dust Source Investigation (EMIT) imaging spectrometer showing quantification and attribution of fine-scale methane (0.3 to 73 tonnes CH_4 hour^{-1}) and carbon dioxide sources (1571 to 3511 tonnes CO_2 hour^{-1}) spanning the oil and gas, waste, and energy sectors. For selected countries observed during the first 30 days of EMIT operations, methane emissions varied at a regional scale, with the largest total emissions observed for Turkmenistan (731 ± 148 tonnes CH_4 hour^{-1}). These results highlight the contributions of current and planned point source imagers in closing global carbon budgets.

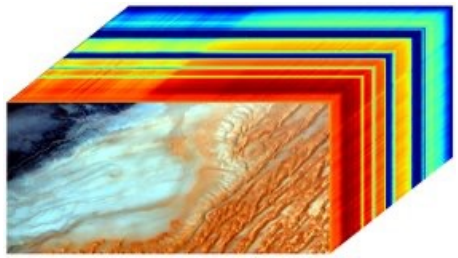
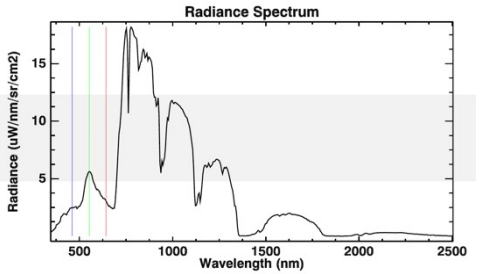
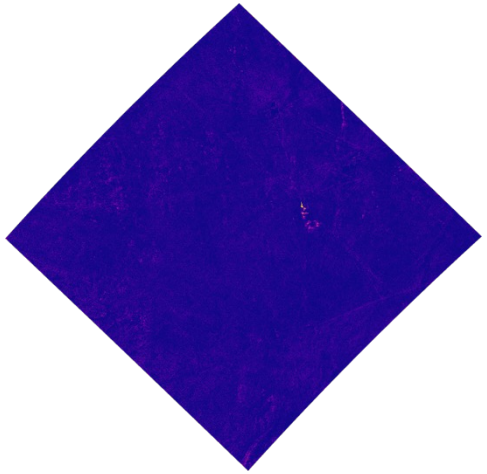
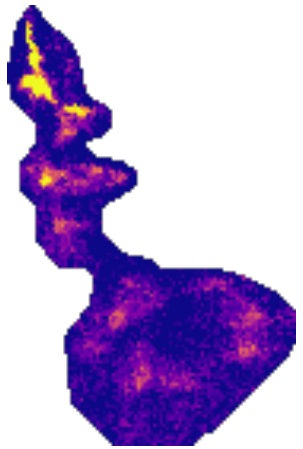
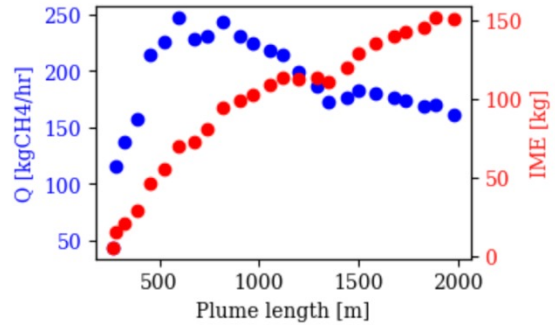


Attribution of CH_4 (and CO_2) emissions to different emission sectors



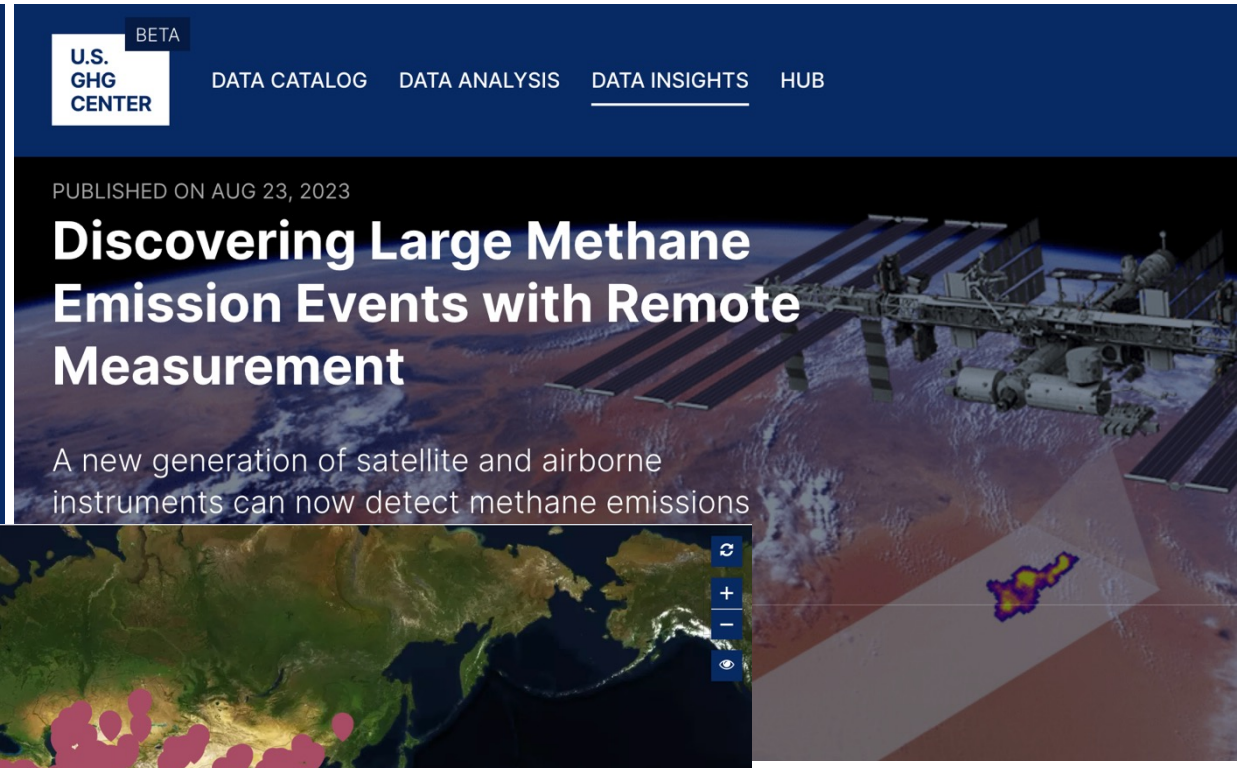
Thorpe et al., 2023

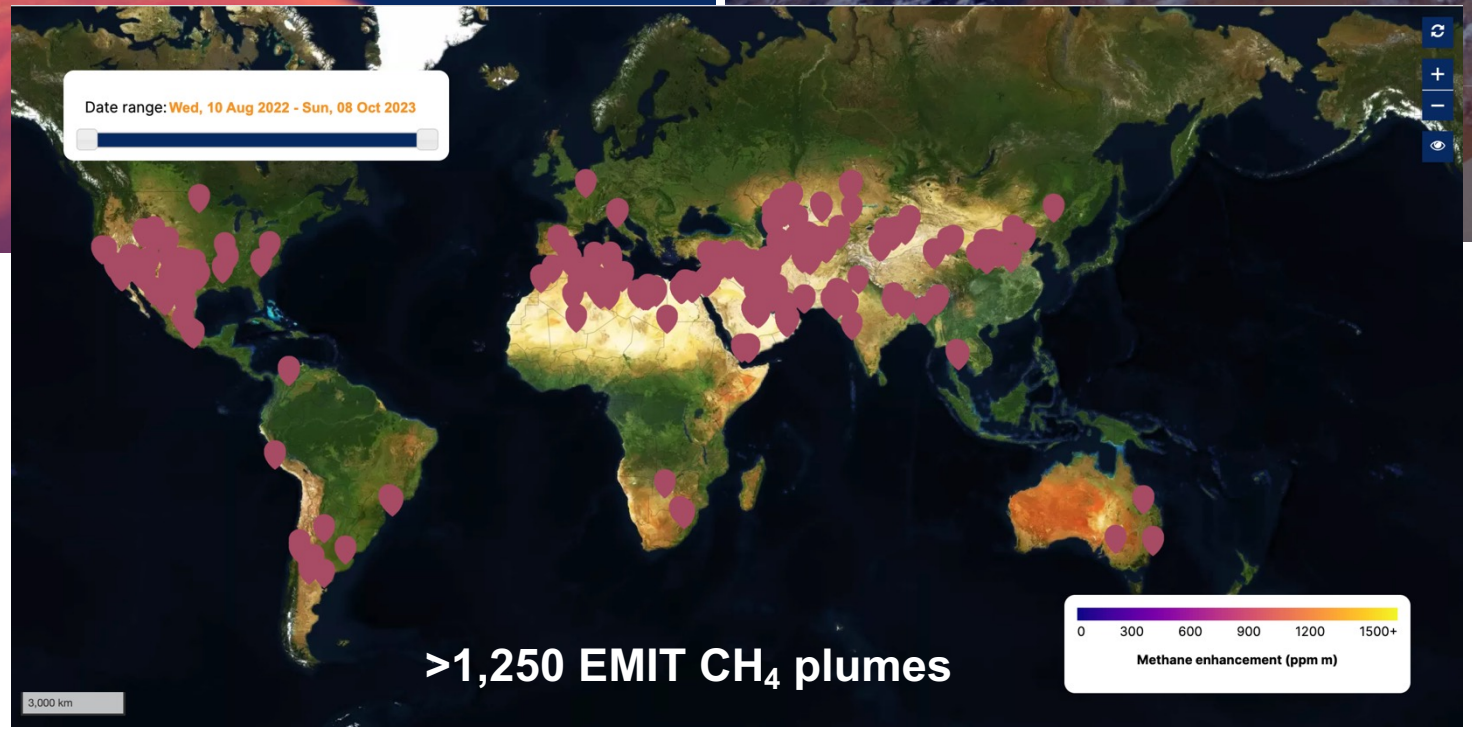
Data products relevant to super-emitters

EMIT Level 1B: Calibrated radiance & geolocation **LP DAAC**  	**Level 2B: Methane enhancement maps** 	**Level 2B: Methane plumes** 	**Level 3: Methane emission rates with uncertainties (planned)** 
	Level 2B: CO2 enhancement maps (planned)	**Level 2B: CO2 plumes (planned)**	**Level 3: CO2 emission rates with uncertainties (planned)**
AVIRIS-3 Level 1B: Calibrated radiance & geolocation (planned) **ORNL DAAC**	**Level 2B: Methane enhancement maps (planned)**	**Level 2B: Methane plumes (planned)**	**Level 3: Methane emission rates with uncertainties (planned)**
	Level 2B: CO2 enhancement maps (planned)	**Level 2B: CO2 plumes (planned)**	**Level 3: CO2 emission rates with uncertainties (planned)**

Open science repositories: [1]https://github.co/emit-sds [2]https://github.com/emit-sds/emit-ghg

Data visualization through U.S. GHG Center



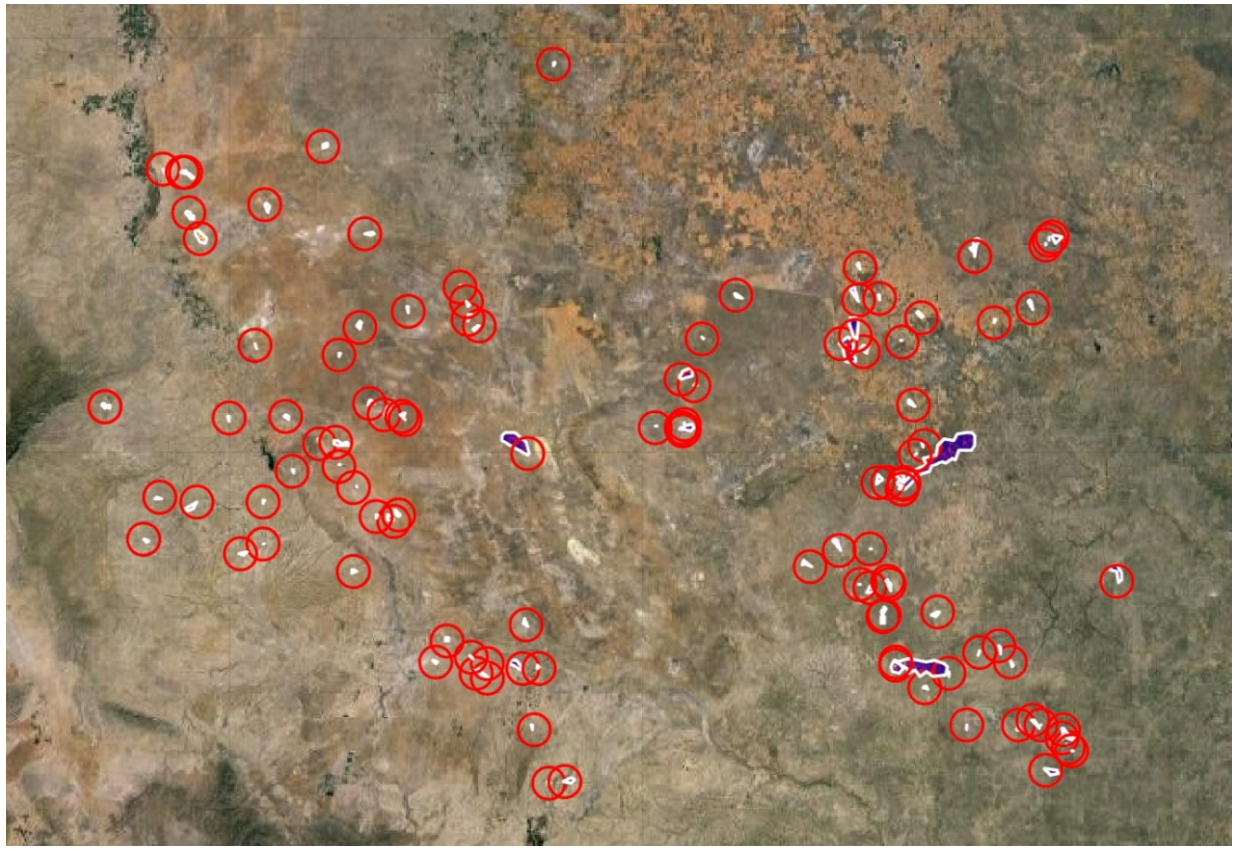


>1,250 EMIT CH_4 plumes

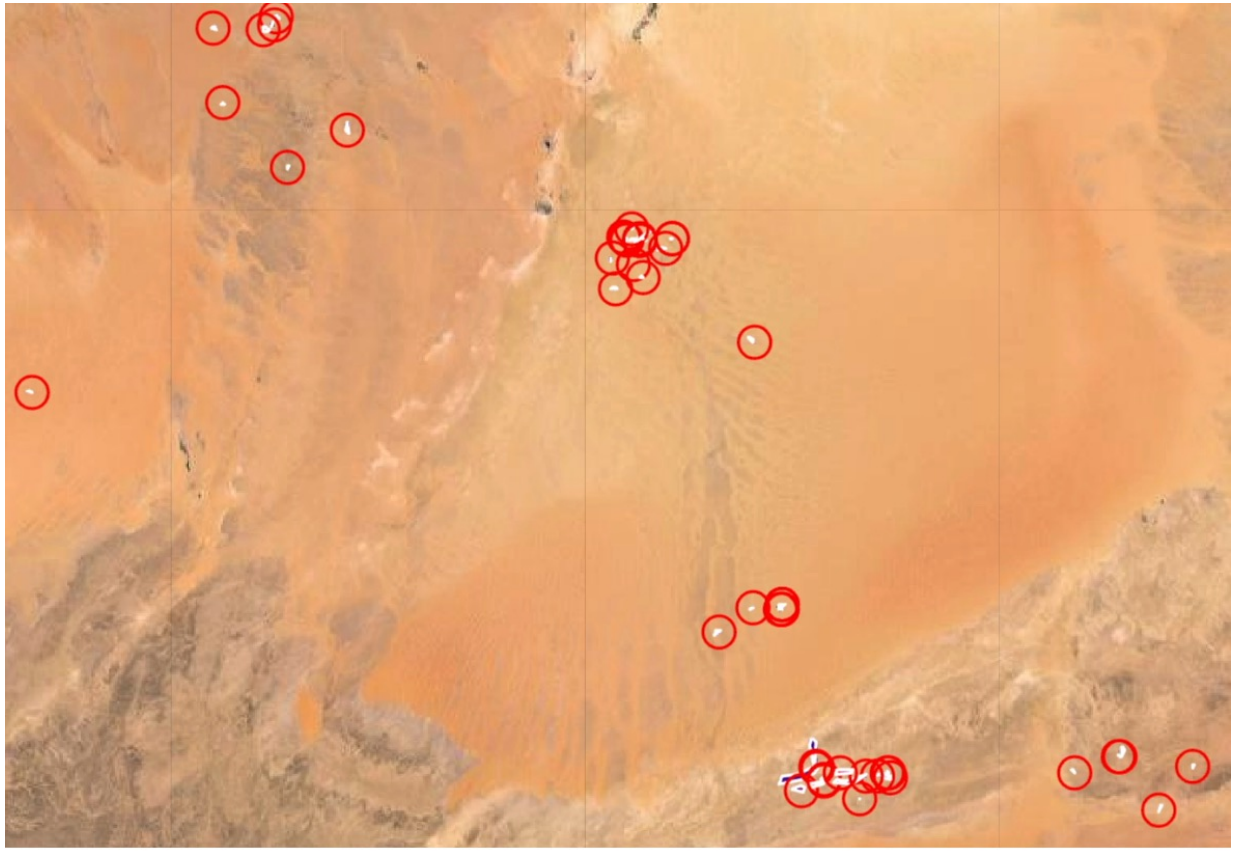
>150 EMIT CO_2 plumes identified to date, but not yet published

EMIT identifies CH_4 emissions from energy sector

United States (Permian, oil&gas)

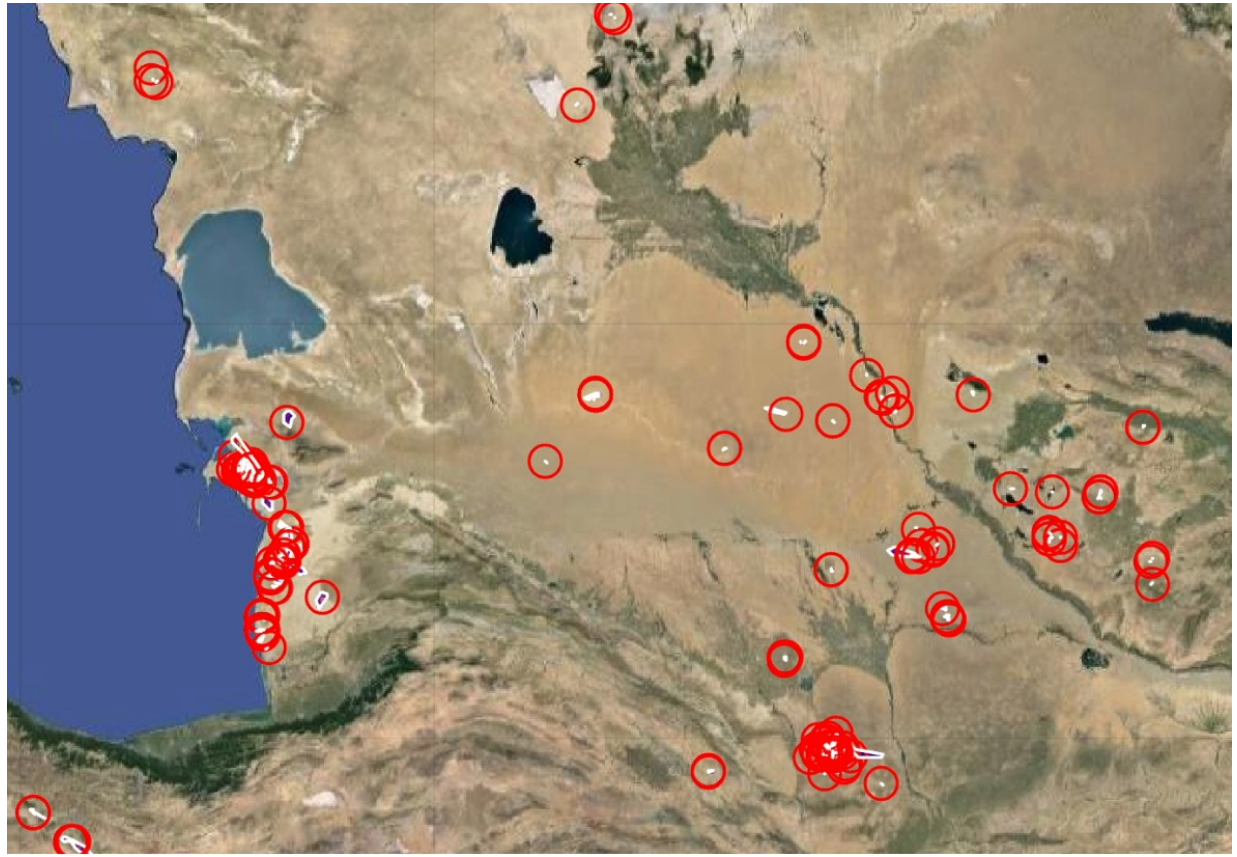


Algeria (oil&gas)

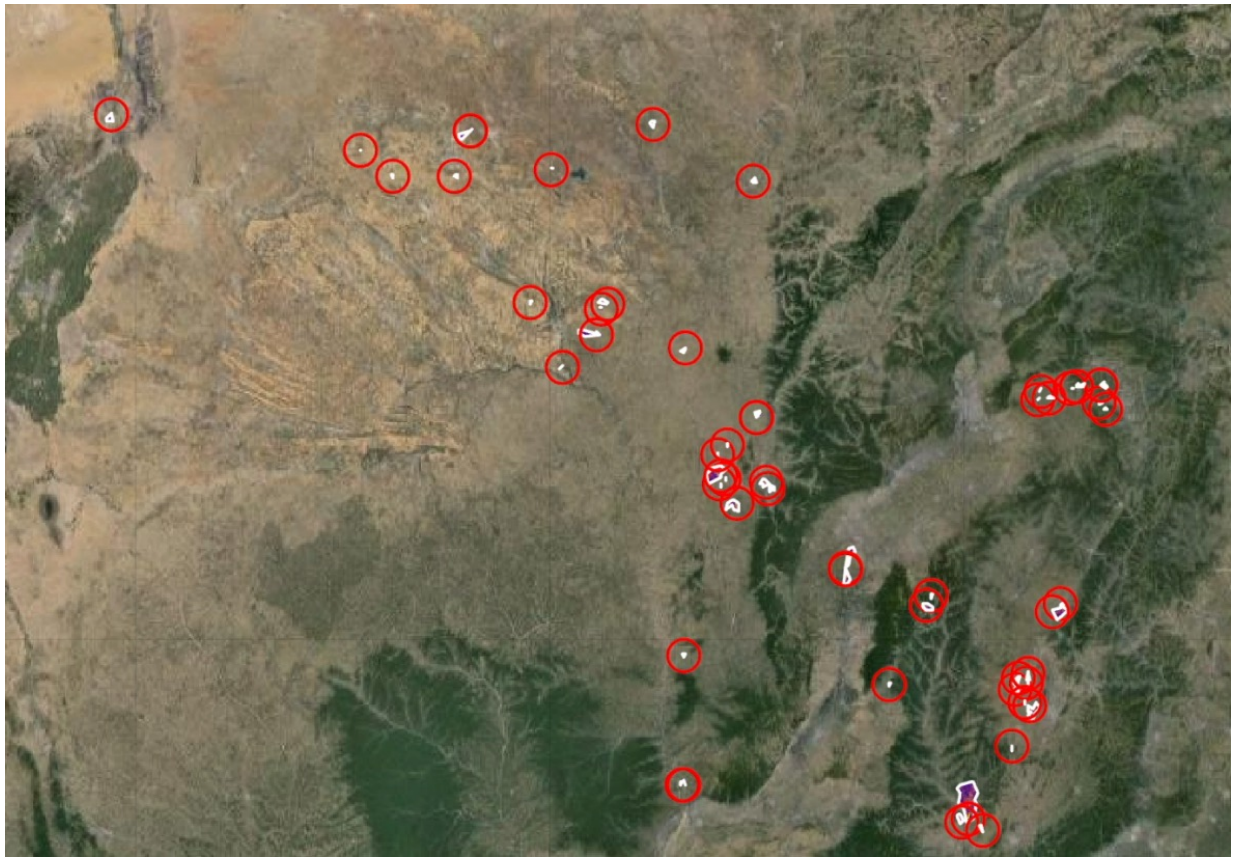


EMIT identifies CH_4 emissions from energy sector

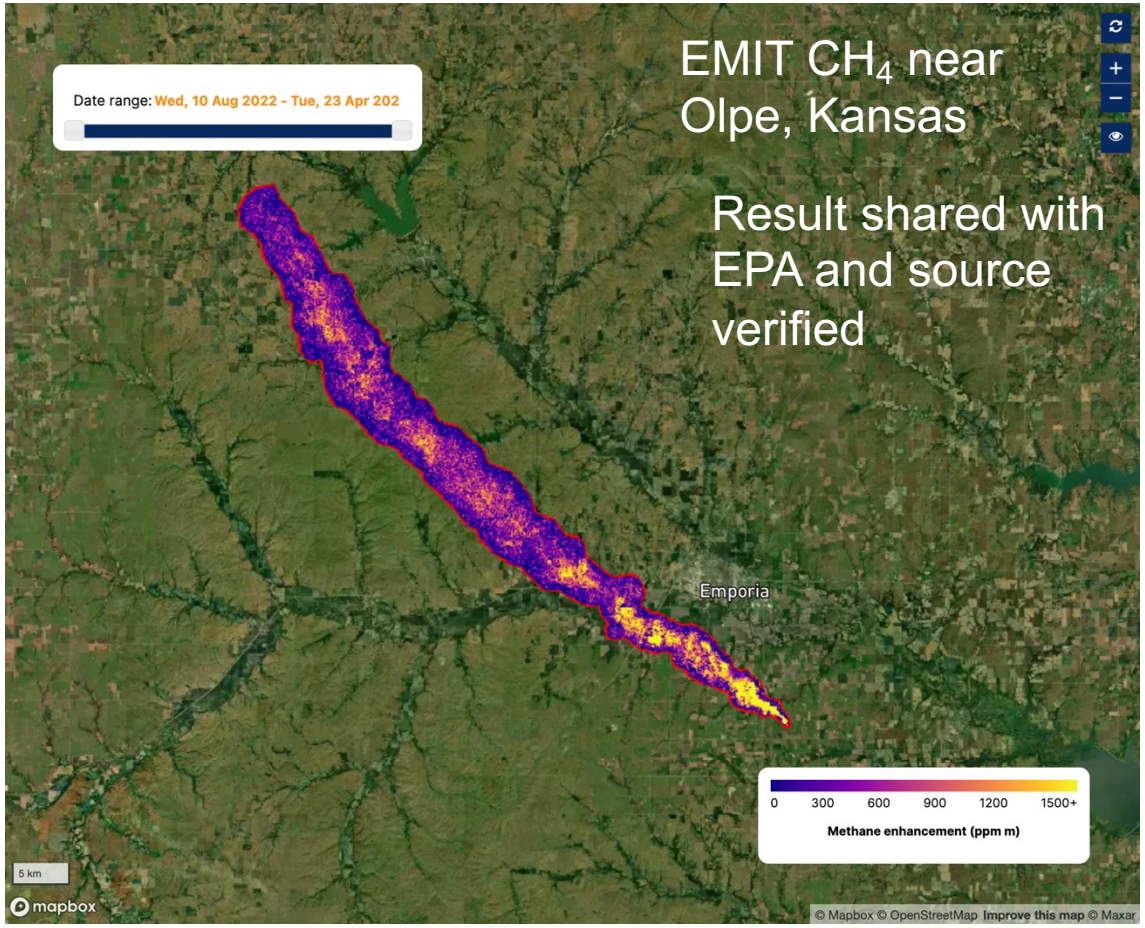
Turkmenistan (oil&gas)

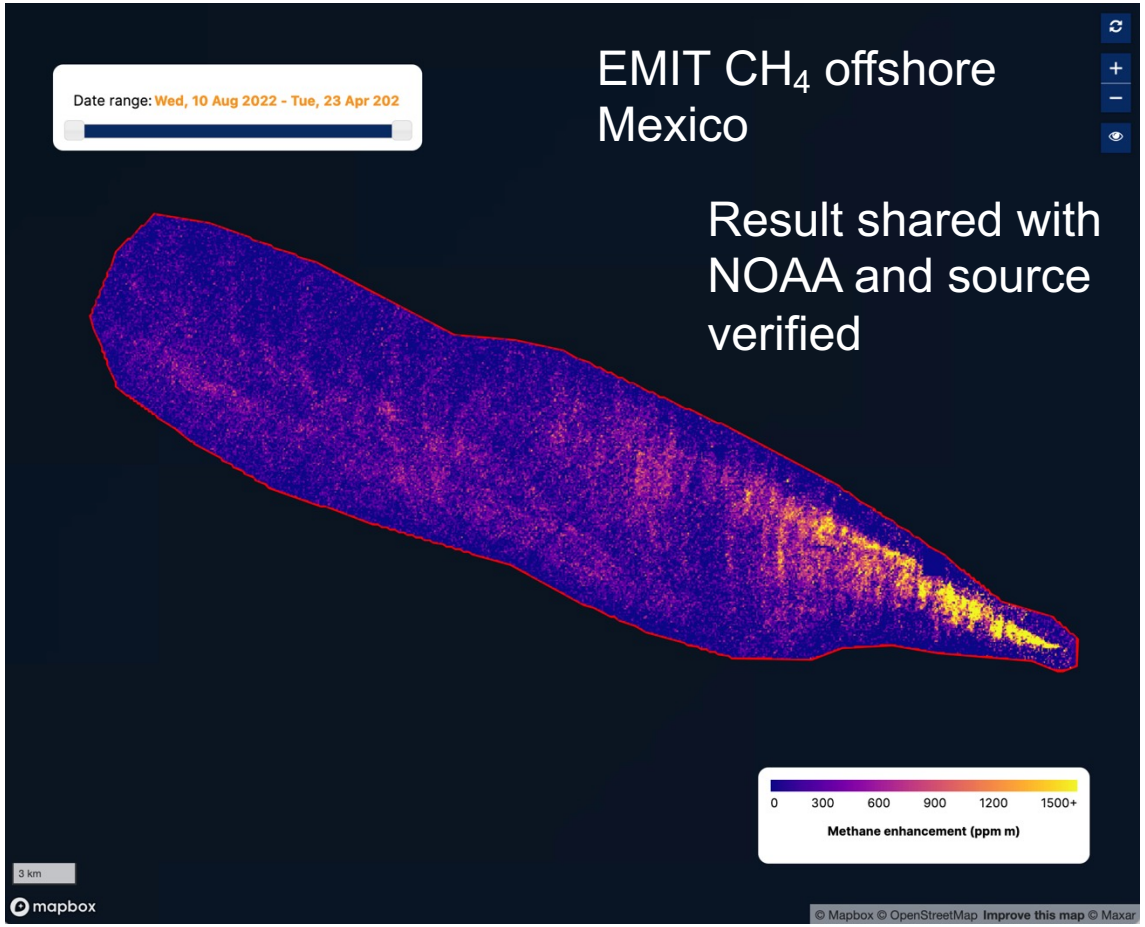


China (coal mines)



EMIT CH_4 results can be unexpected



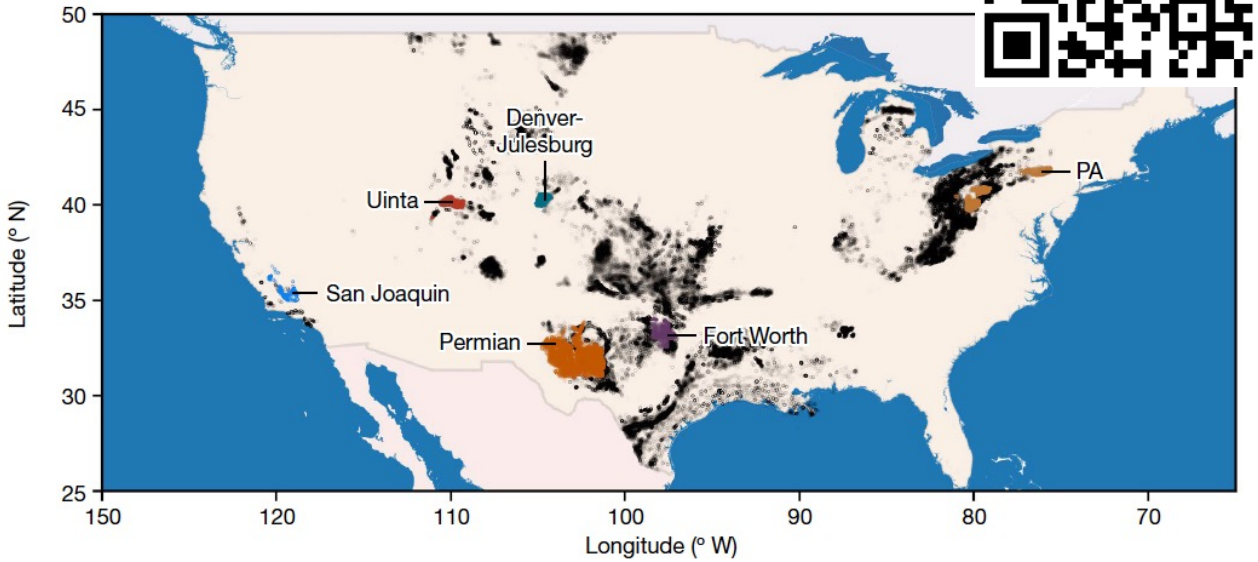


Continued need for aircraft studies (AVIRIS-NG, GAO)

nature

US oil and gas system emissions from nearly one million aerial site measurements

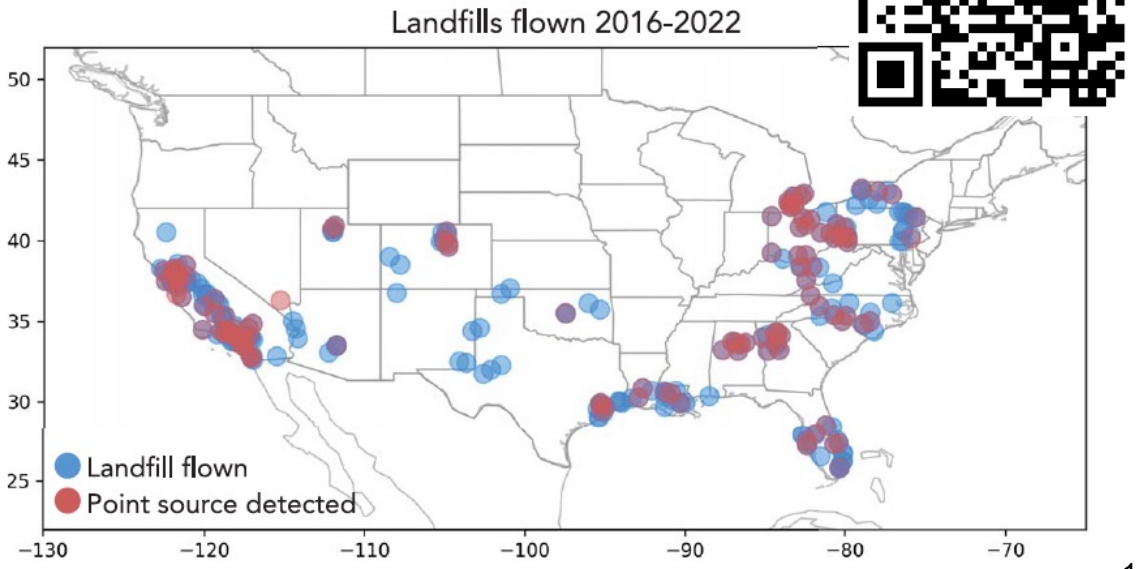
Evan D. Sherwin[1,6]✉, Jeffrey S. Rutherford[1,7], Zhan Zhang[1], Yuanlei Chen[1], Erin B. Wetherley[2], Petr V. Yakovlev[2], Elena S. F. Berman[2], Brian B. Jones[2], Daniel H. Cusworth[3], Andrew K. Thorpe[4], Alana K. Ayasse[3], Riley M. Duren[3,4,5] & Adam R. Brandt[1]



Science

Quantifying methane emissions from United States landfills

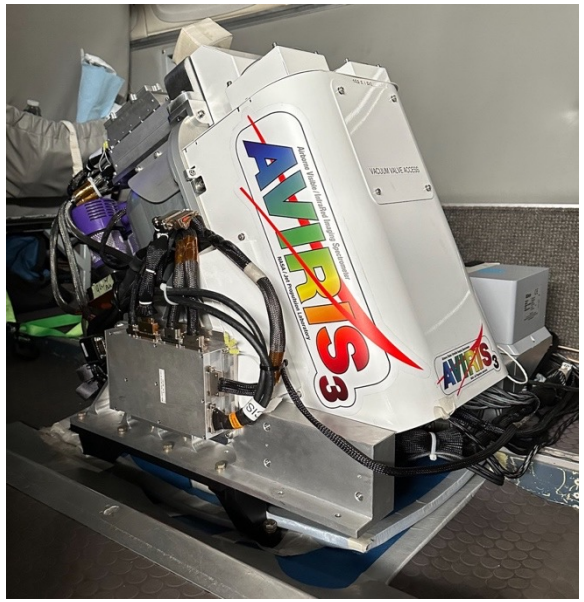
Daniel H. Cusworth[1,2]*, Riley M. Duren[1,2,3], Alana K. Ayasse[1], Ralph Jiorle[1], Katherine Howell[1], Andrew Aubrey[1], Robert O. Green[3], Michael L. Eastwood[3], John W. Chapman[3], Andrew K. Thorpe[3], Joseph Heckler[4], Gregory P. Asner[4], Mackenzie L. Smith[5], Eben Thoma[6], Max J. Krause[6], Daniel Heins[6], Susan Thorneloe[6]

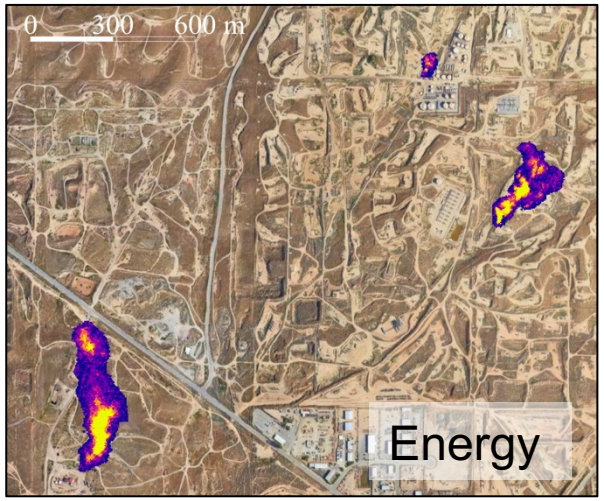


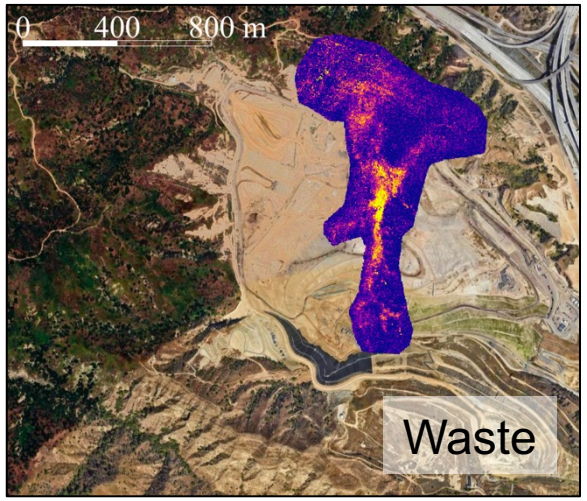
AVIRIS-3 for improved CH_4 and CO_2 mapping from aircraft

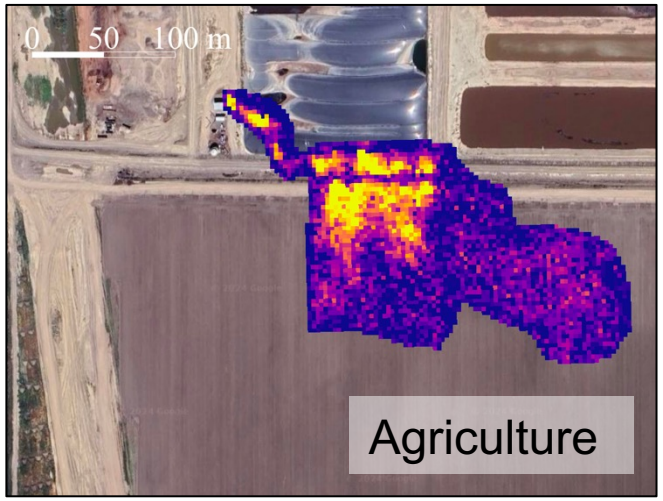
Parameter	AVIRIS-NG		AVIRIS-3	Improved capability
Swath samples	600	→	1240	Wider coverage
Swath angle	34° FOV		40° FOV	
Ground sample distance (GSD)	0.3-20 m	→	0.3-20 m	Smaller GSD for same altitude
SNR @ 2200 nm	>1000	→	>1200	Increased signal

First flights began in July 2023; Greenhouse gas plumes observed across emission sectors





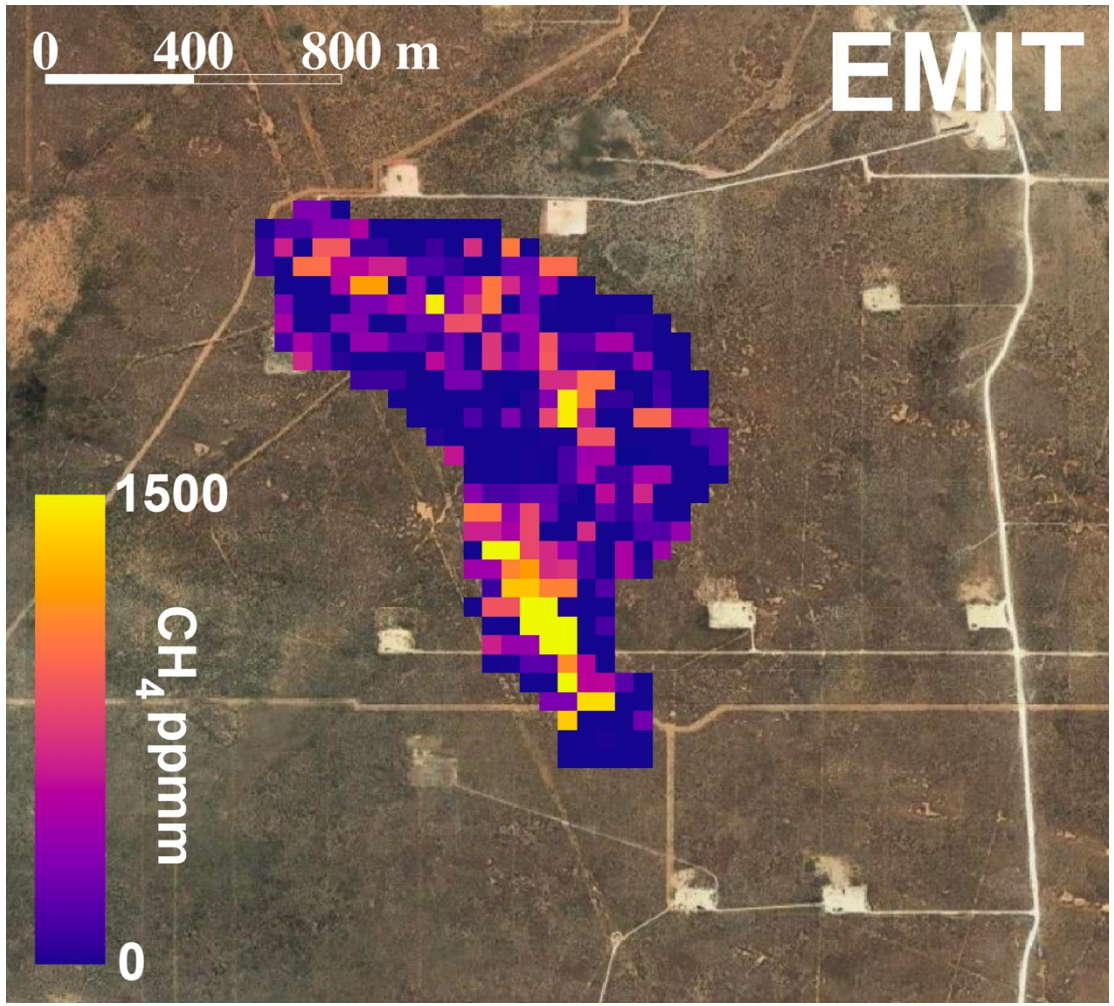




Ongoing work by Willow Coleman

EMIT and AVIRIS-3 cal/val

Coincident observations

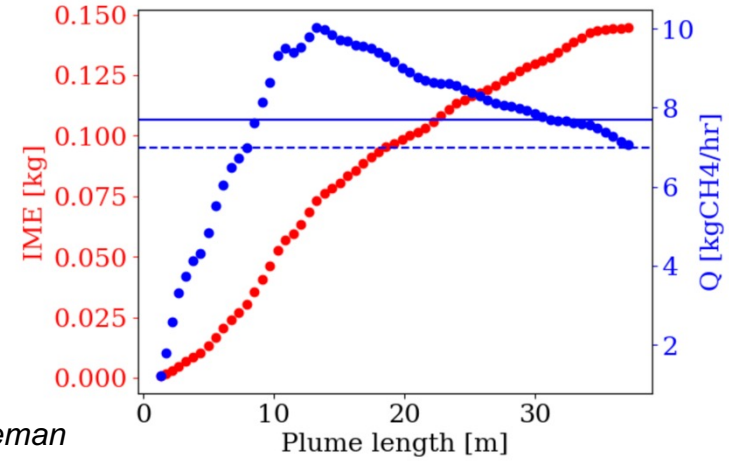


Controlled release experiments

AVIRIS-3:

- Multiple flow rates (1, 4, 7, 10 kg CH_4 hr^{-1})
- Multiple ground sampling distance (0.5, 1.0, 2.5, 4.0 m pixels)

7 kg CH_4 hr^{-1}



Ongoing work by Willow Coleman

EMIT: planned Stanford controlled releases starting in Sep. 2024

Expanding use of EMIT greenhouse gas data

Current

U.S. GHG CENTER

CARBON MAPPER

UN environment programme | International Methane Emissions Observatory

KAYRROS

Planned

- ESA MEDUSA (Methane Emission Detection Using Satellites Assessment) project
- U.S. EPA Super Emitter Program (pending technology approval)

Thank you!