



Methane and CO₂ Observations with EMIT, AVIRIS-3, and AVIRIS-5

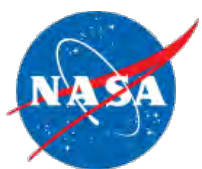


Robert O. Green, Andrew Thorpe, Dana Chadwick, David, R. Thompson, Willow Colman, Philip Brodrick, and Team

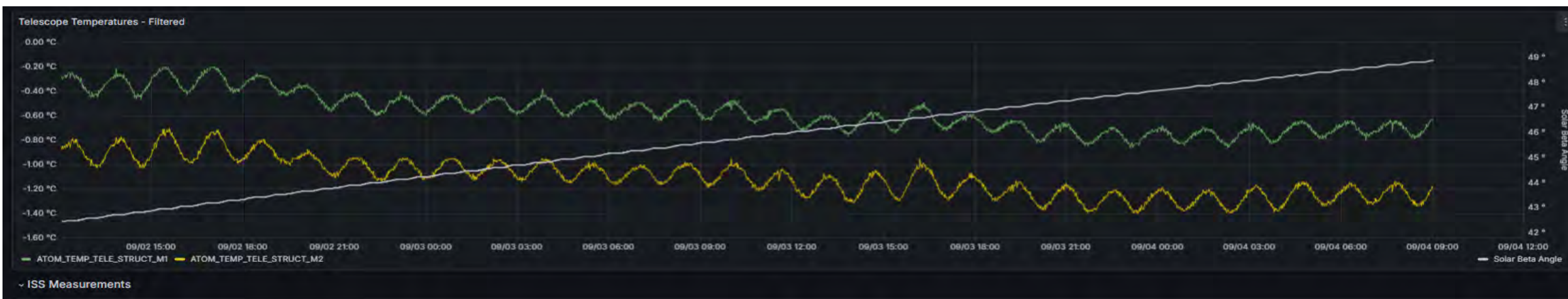
Jet Propulsion Laboratory, California Institute of Technology

<https://earth.jpl.nasa.gov/emit/resources/100/emit-launch-and-post-launch-video/>

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EMIT Today



The Earth has a Mineral Dust Cycle with Impacts throughout the Earth System

Space Imaging Spectroscopy



Particle Emission and Transport



Radiative Forcing



Wet and Dry Deposition



Impacts to the atmosphere oceans, ecosystems, snow/ice, populations, etc.

Earth System Models

Arid Dust Source Regions

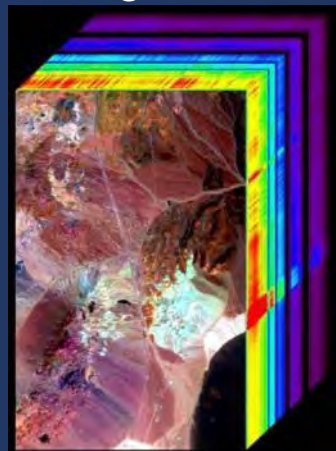
Prior to EMIT
Earth System Models
used arid land mineral maps
traced to **<5000** soil mineral analyses.

EMIT has delivered **>one billion** mineral
composition determinations.

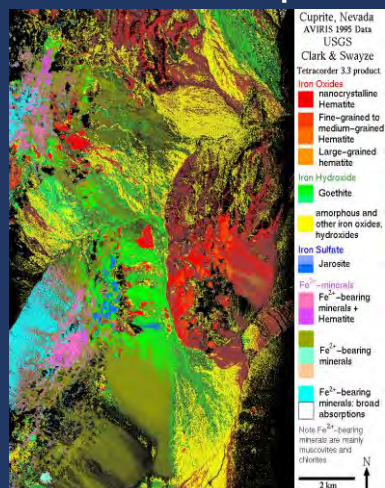


Imaging Spectroscopy Used by NASA Throughout the Solar System

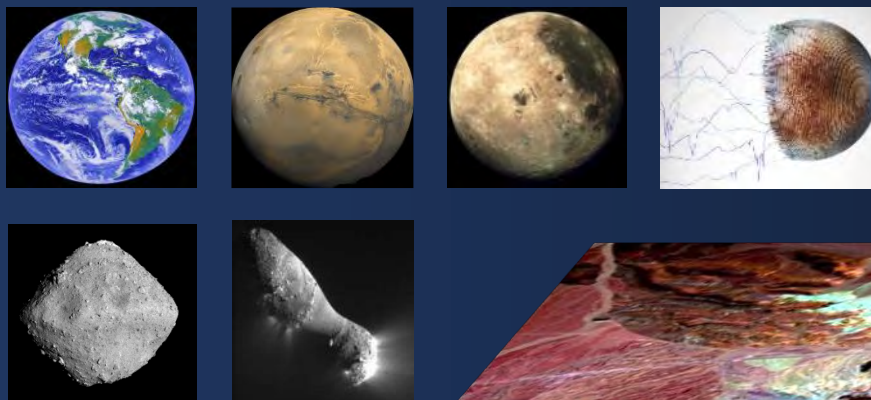
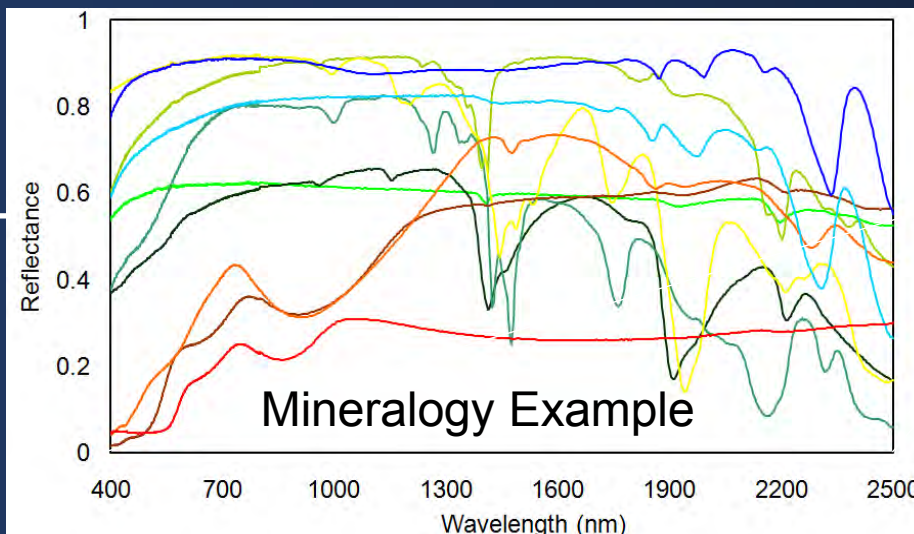
Calibrated
Image Cube



↓
Material Map



Products with Units and Uncertainties:
Actionable Information

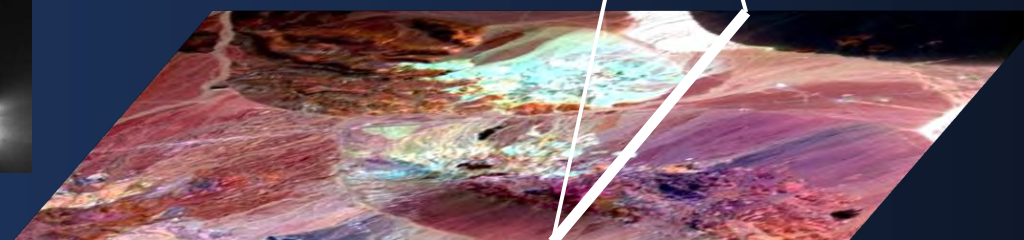


Detector Array

Spectrometer

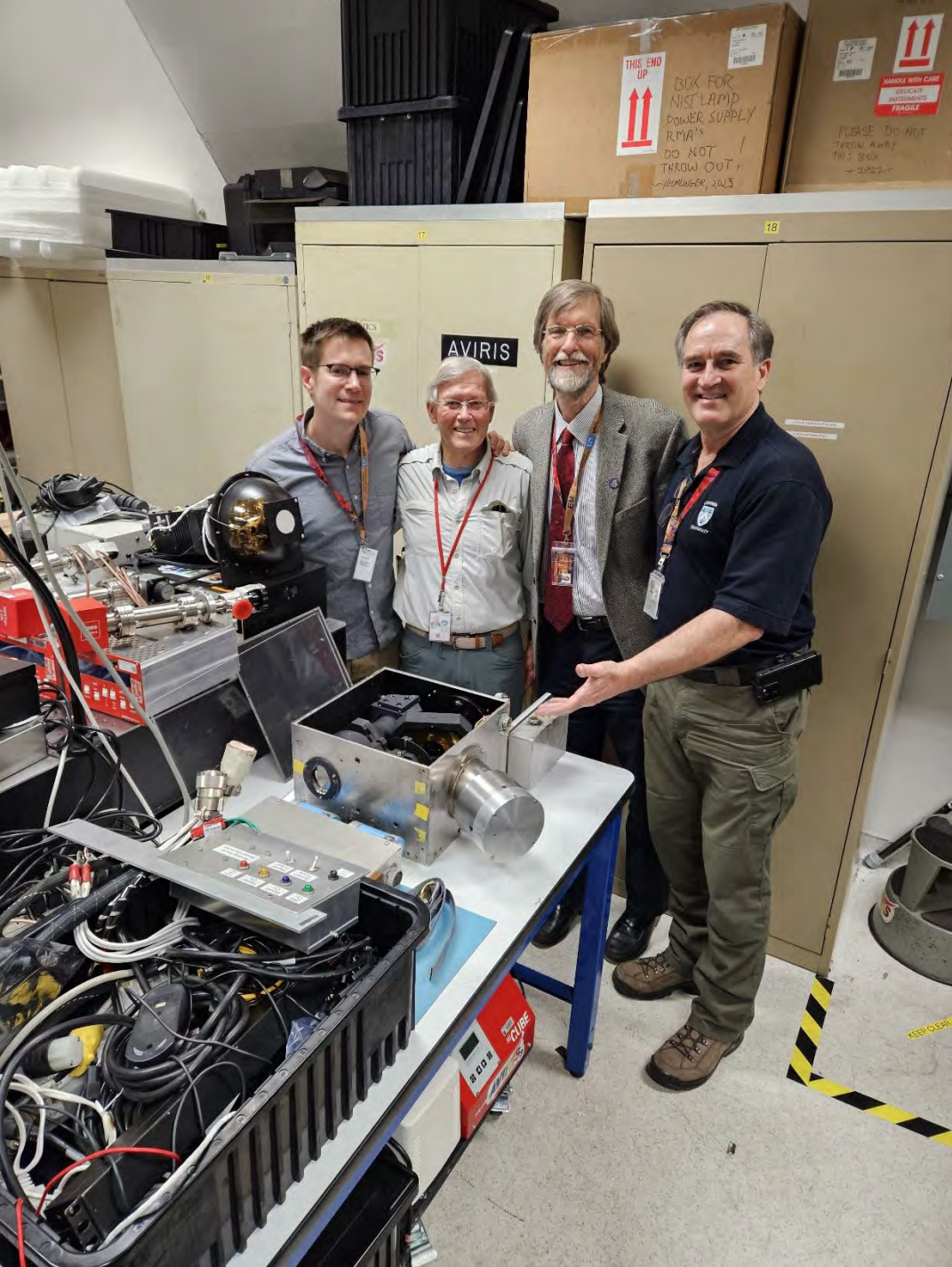
Telescope

Slit



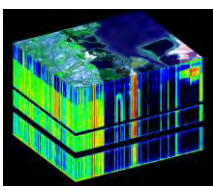
Each imaging spectrometer is different based on requirements and technologies.

AIS Found in 2024

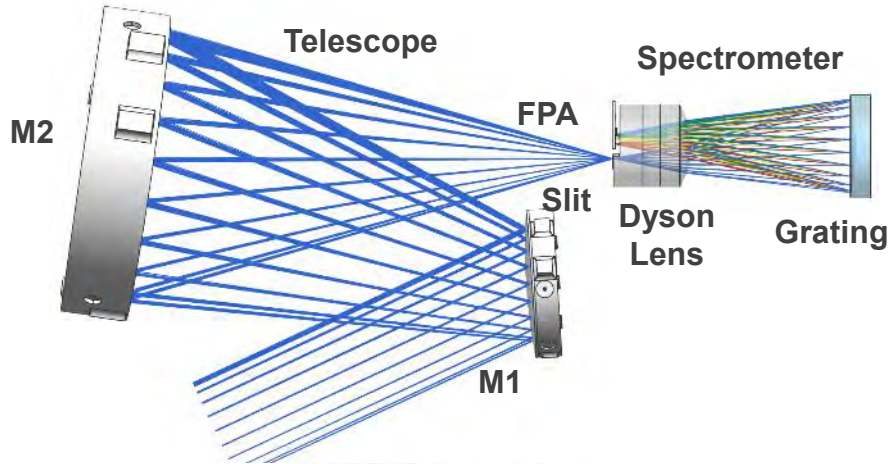




The NASA EMIT Space Imaging Spectrometer is State-of-the-Art (Developed Rapidly through COVID)



Optically Fast F/1.8 Dyson Imaging Spectrometer



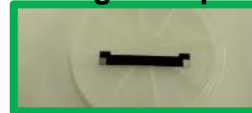
Grating



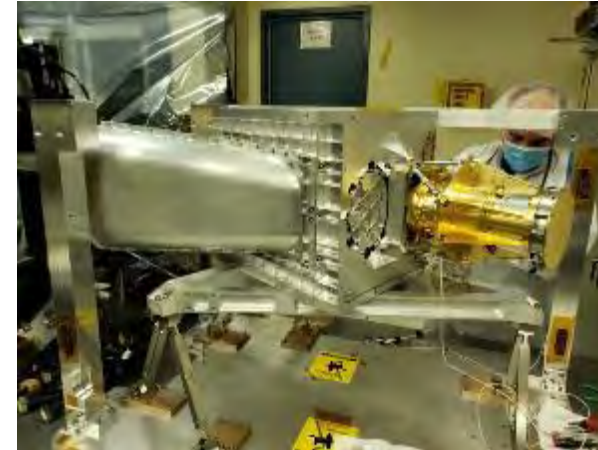
Slit



Light Trap



Optical Bench

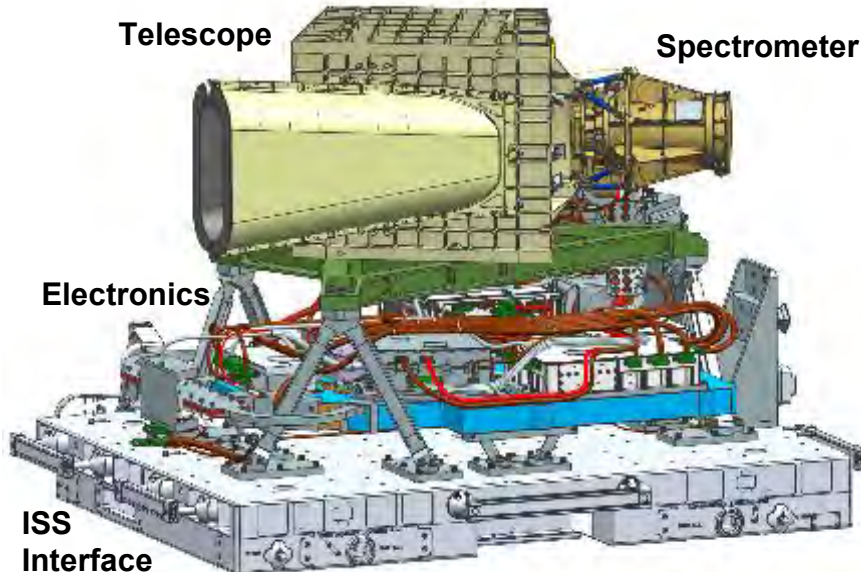


Alignment



Telescope

Spectrometer



Electronics

ISS Interface

On the ISS Interface ExPA



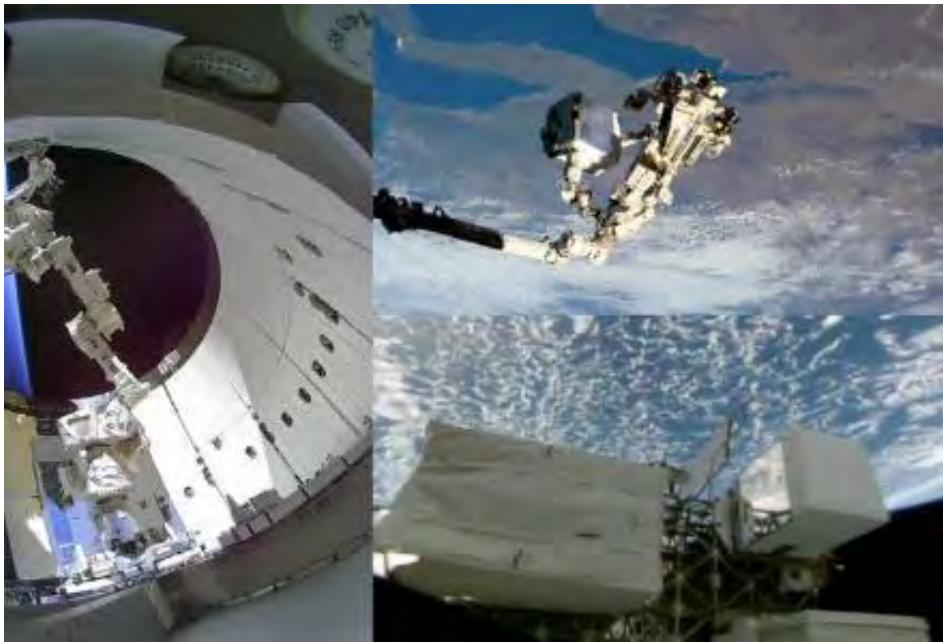
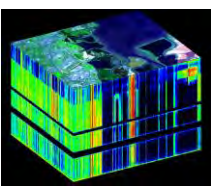
Complete at Preship



Decades of lesson incorporated: signal-to-noise ratio, uniformity, coverage...

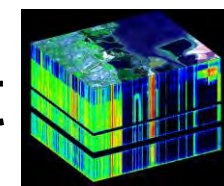


Launch, Docking, and Installation: 14, 16, 24 July 2022

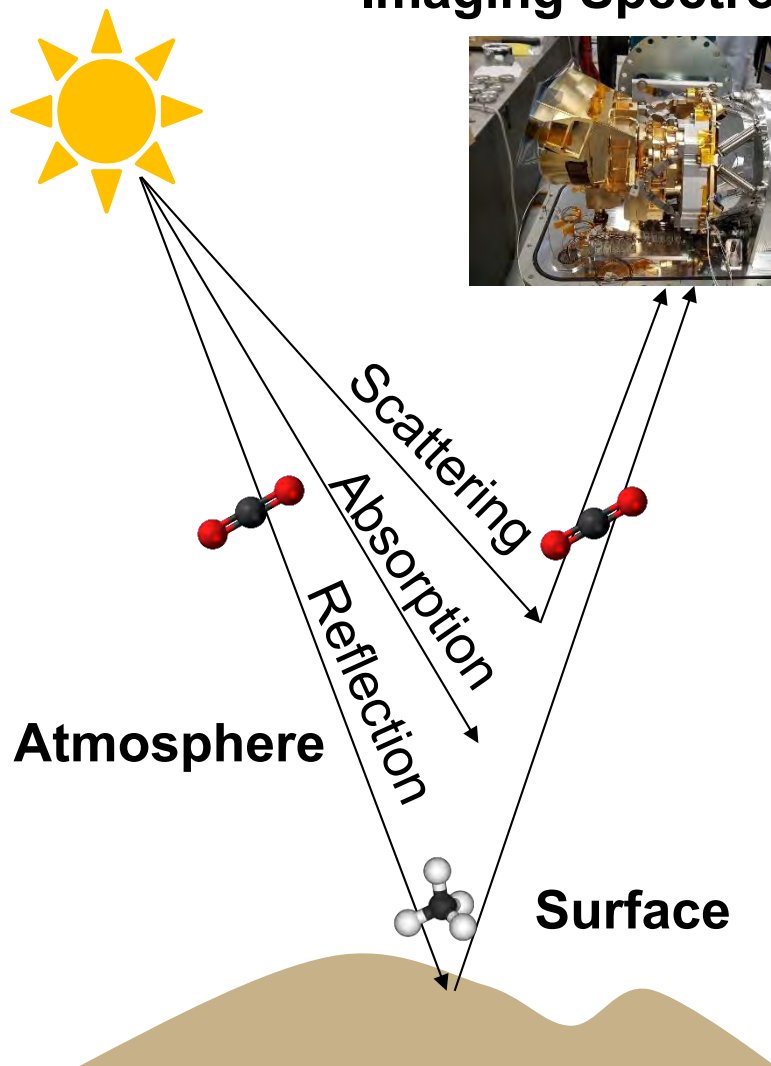
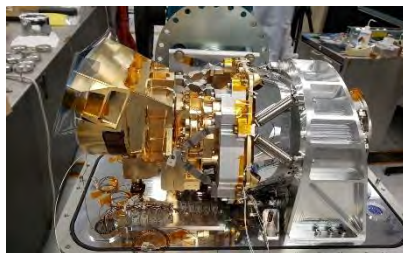




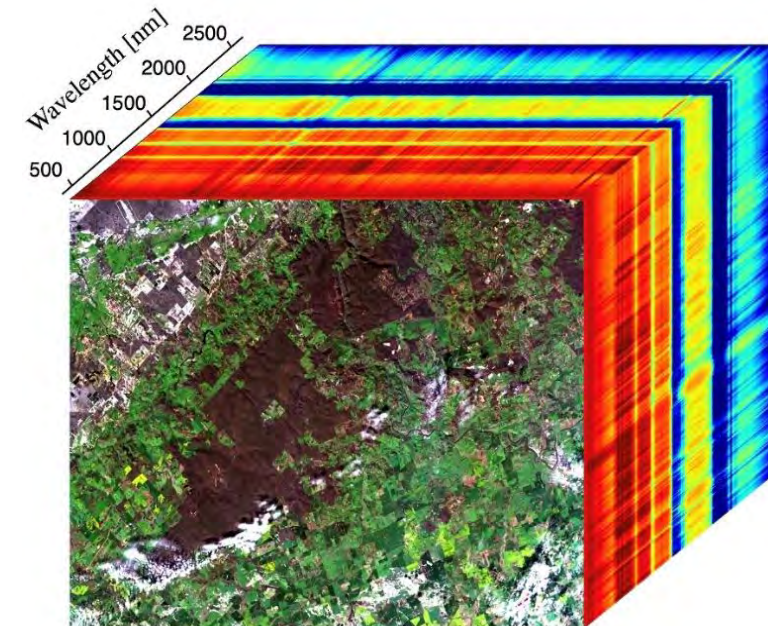
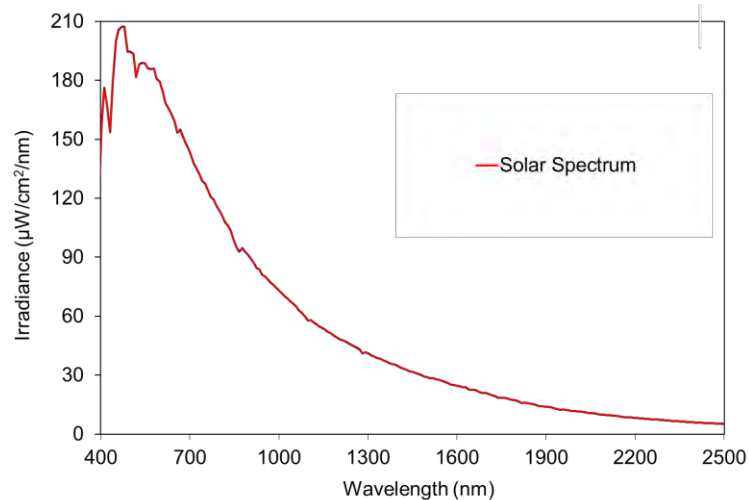
EMIT Imaging Spectroscopy and Remote Measurement



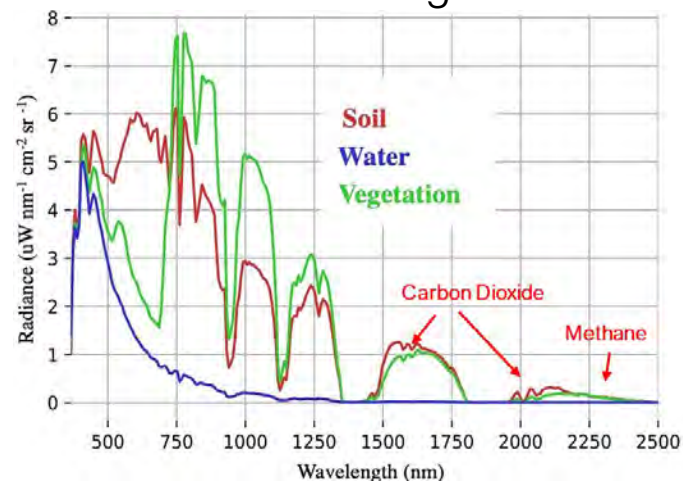
Imaging Spectrometer



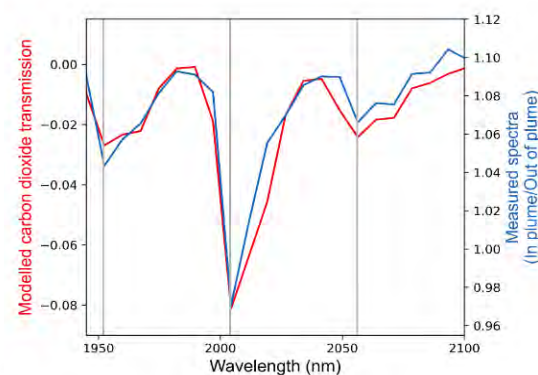
Signal from the Sun



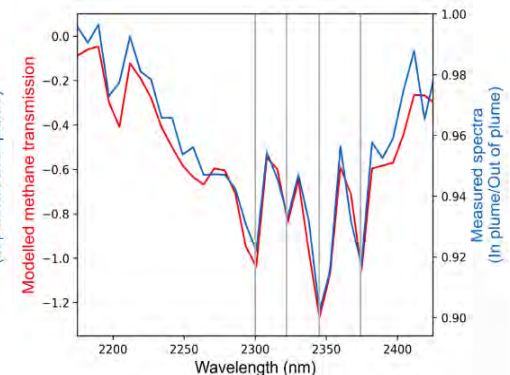
Imaging Spectrometer Measured Signal



Carbon Dioxide

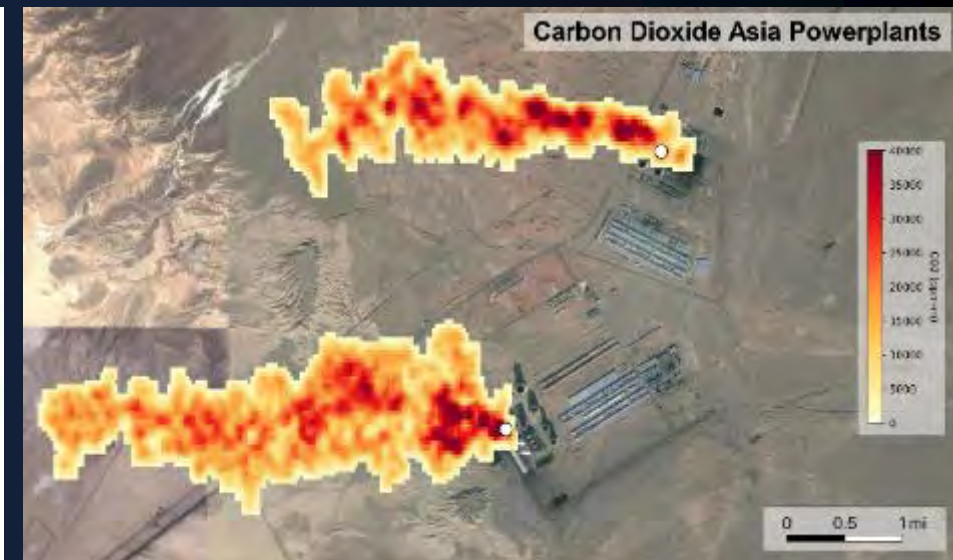
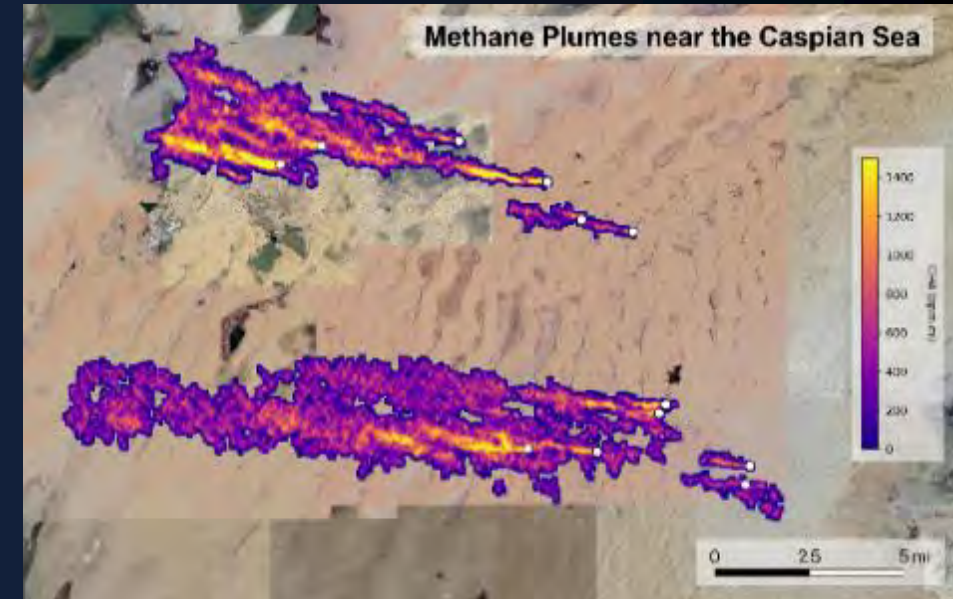
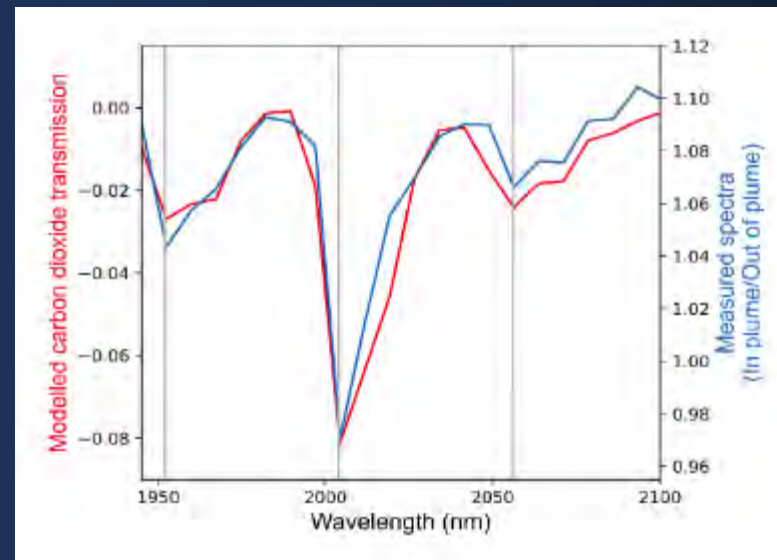
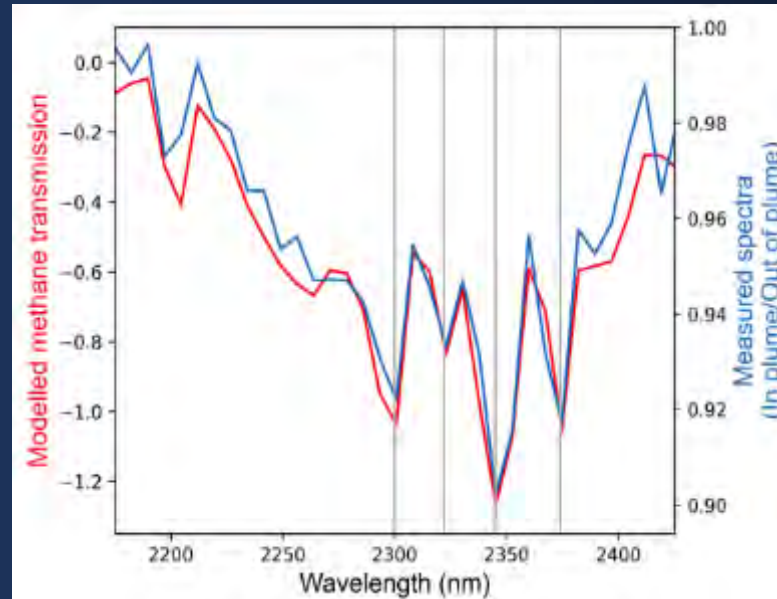
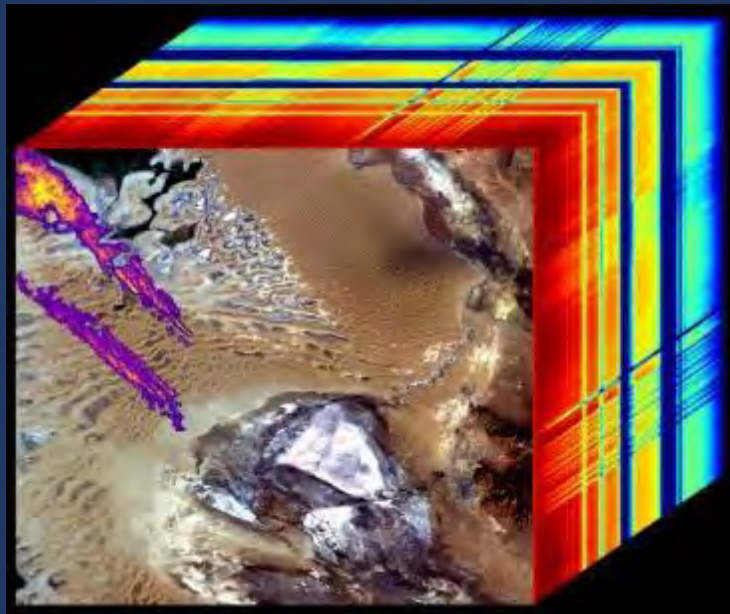


Methane

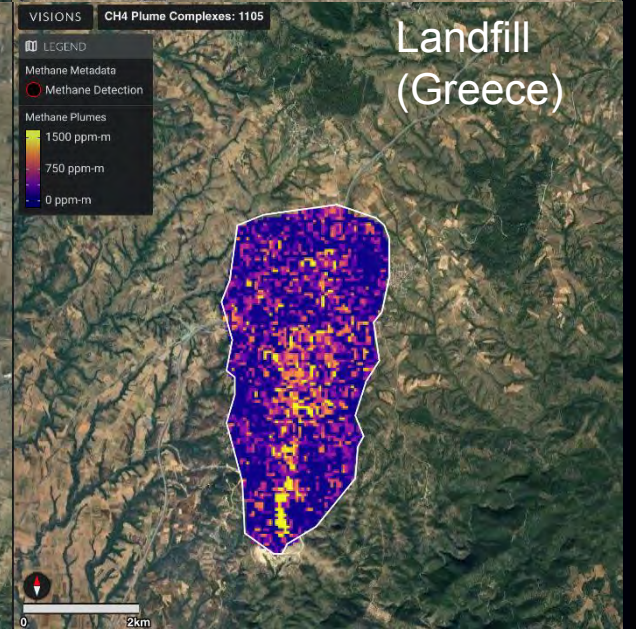
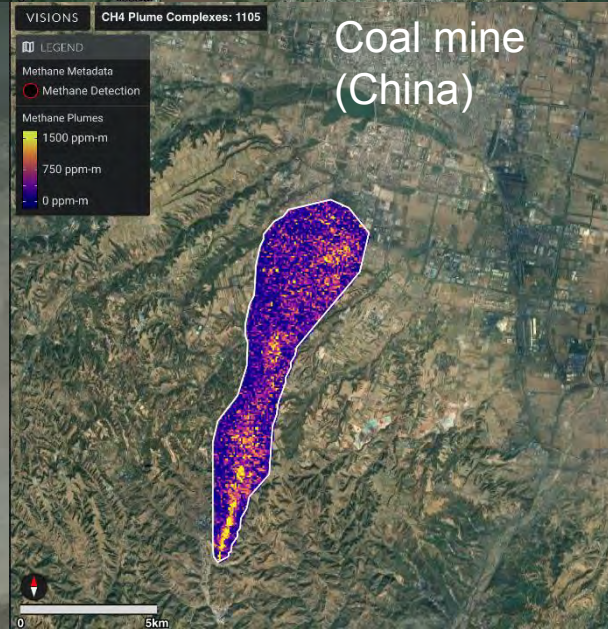
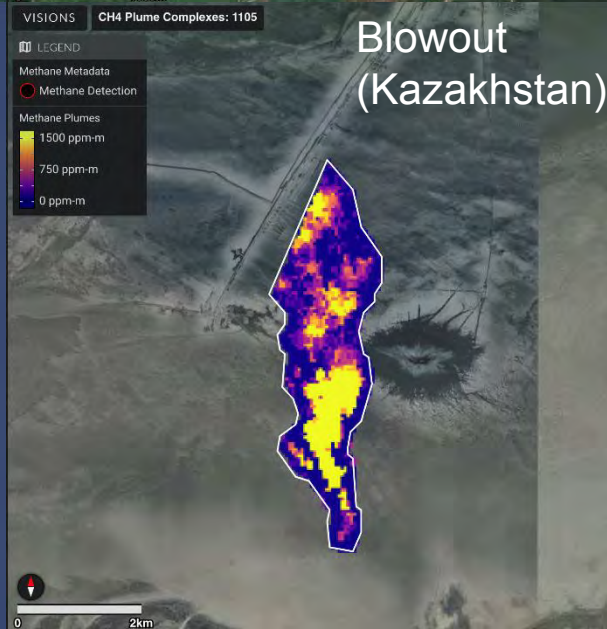
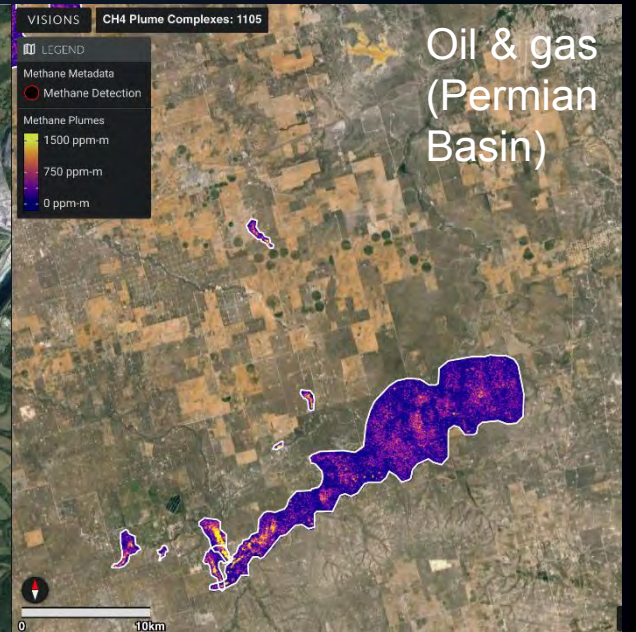
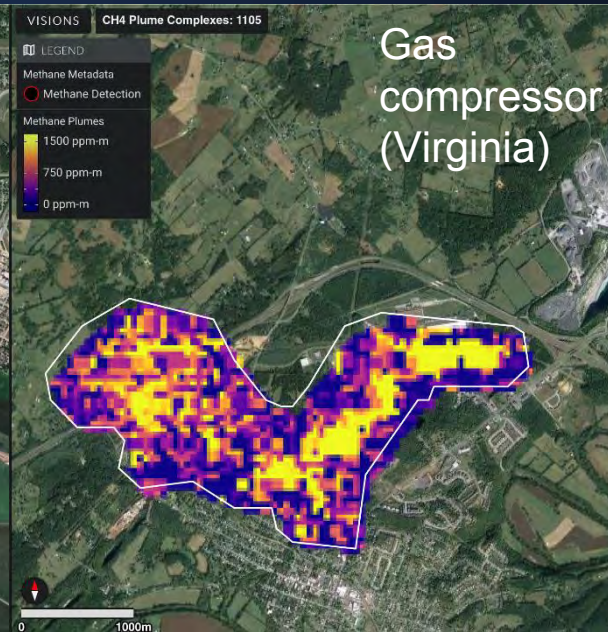
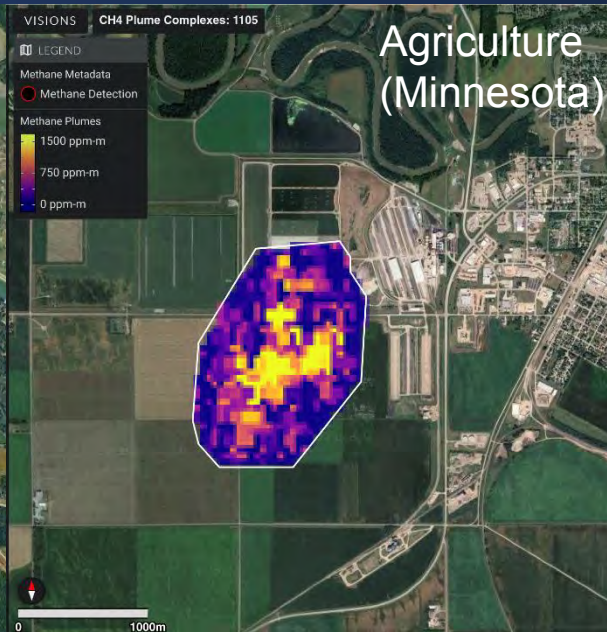
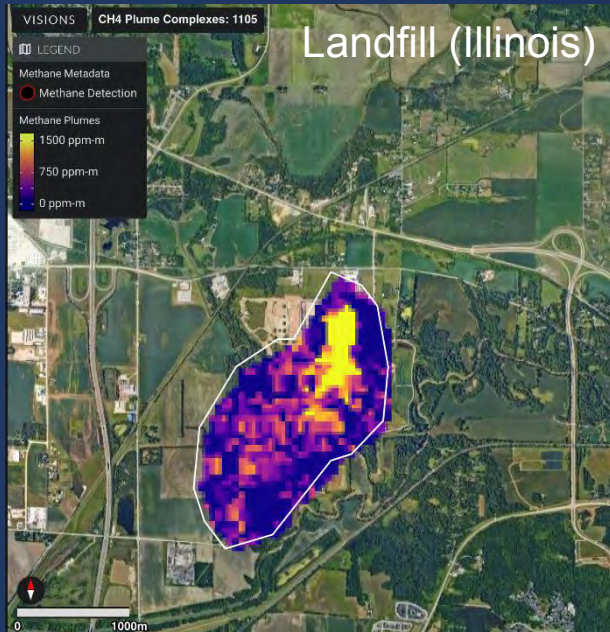




EMIT Methane and Carbon Dioxide Point Sources Are Measured

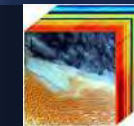
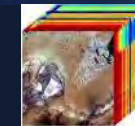
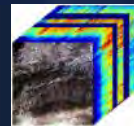
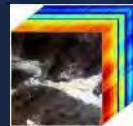
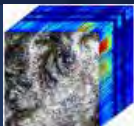


>1000s EMIT CH₄ plumes available through US GHG Center

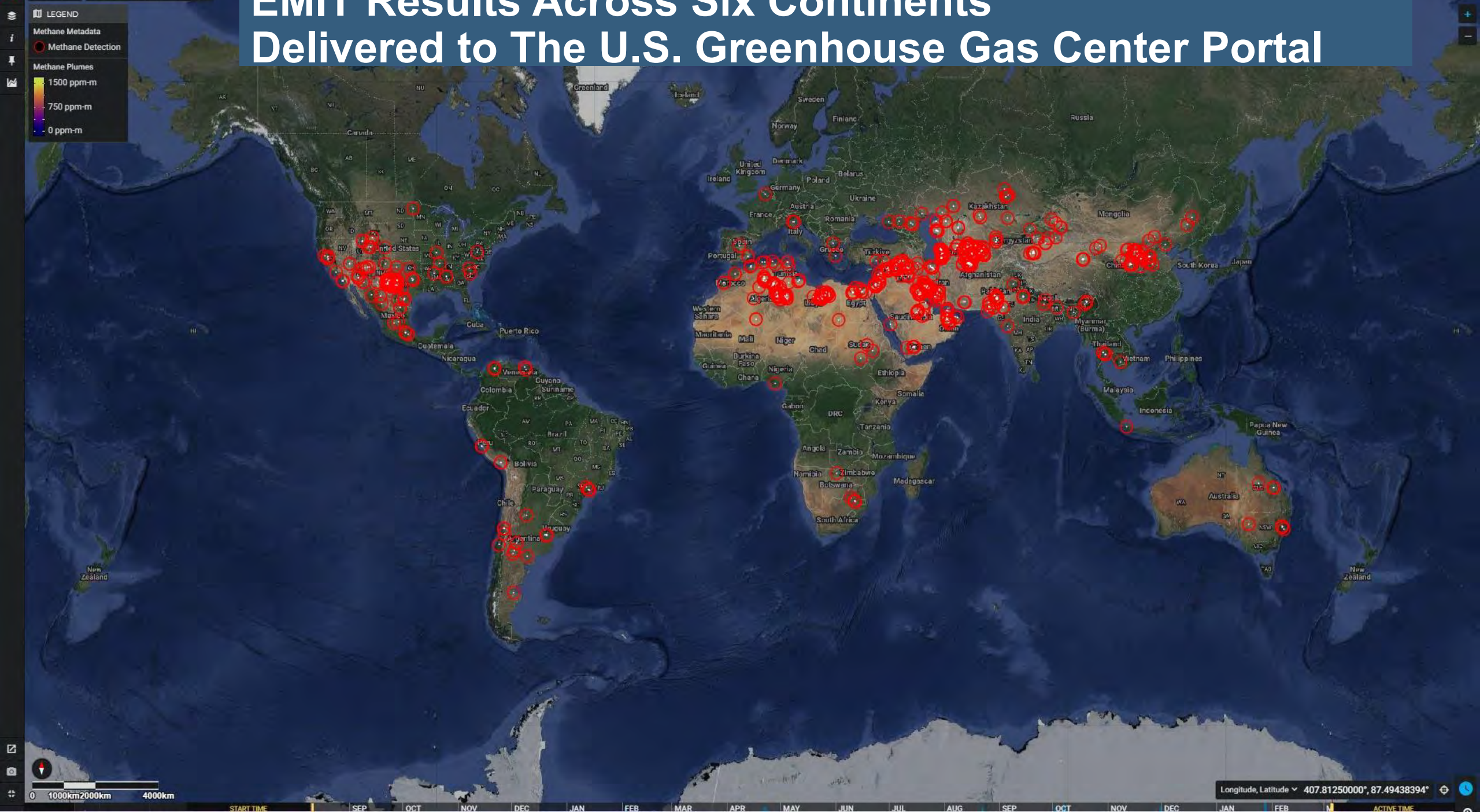


>100,000 Image Cubes Across Six Continents

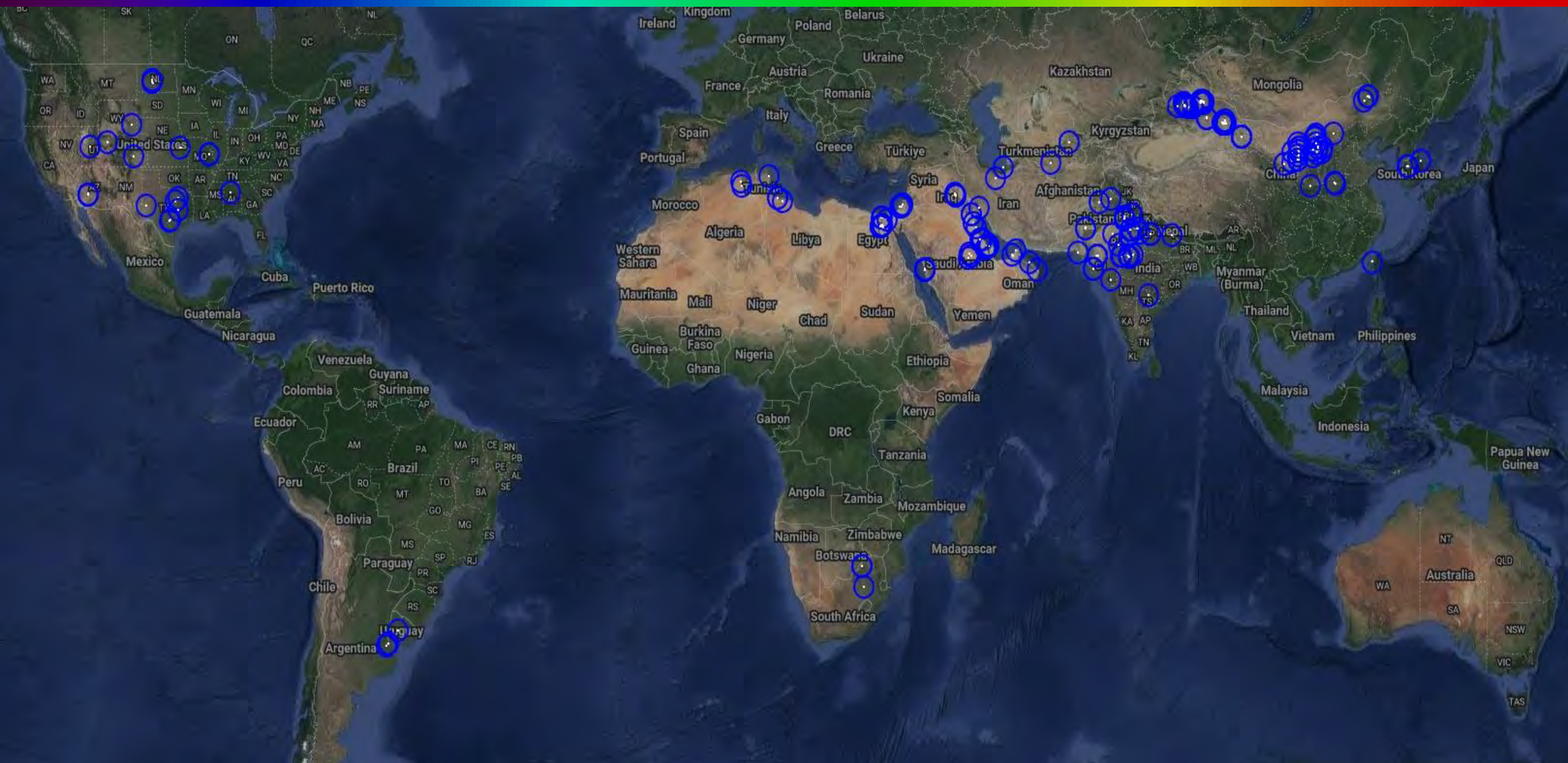
100 Billion Spectra. All available from NASA LP DAAC.



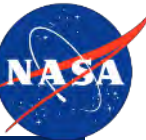
EMIT Results Across Six Continents Delivered to The U.S. Greenhouse Gas Center Portal



EMIT Carbon Dioxide Plumes



Plume information made available through U.S. GHG Center



BETA
U.S. GHG CENTER

DATA CATALOG DATA ANALYSIS DATA INSIGHTS HUB LEARN ABOUT CONTACT US

U.S. Greenhouse Gas Center

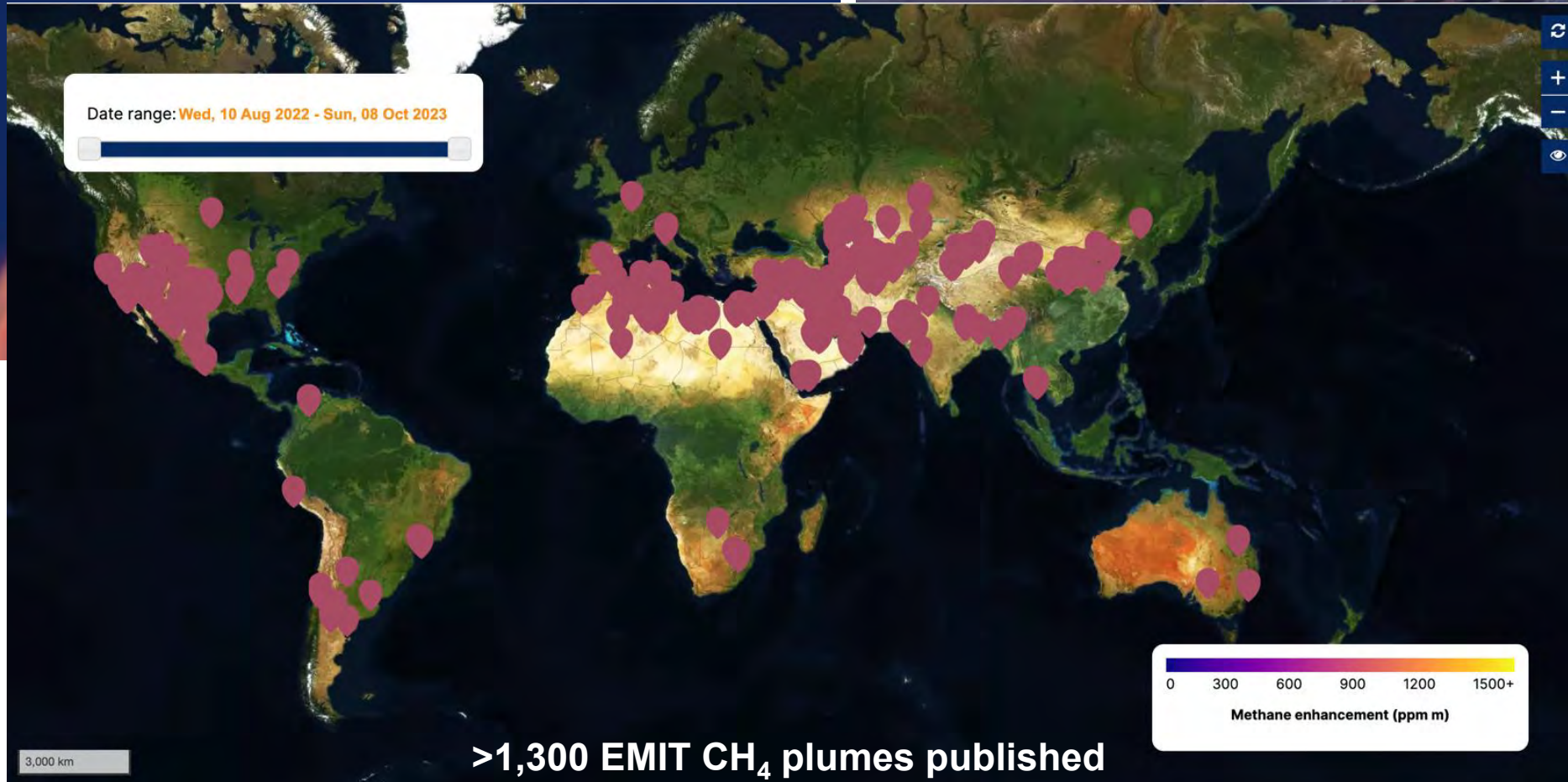
Uniting Data and Technology to Empower Tomorrow's Climate Solutions

BETA
U.S. GHG CENTER

DATA CATALOG DATA ANALYSIS DATA INSIGHTS HUB

PUBLISHED ON AUG 23, 2023

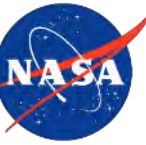
Discovering Large Methane Emission Events with Remote



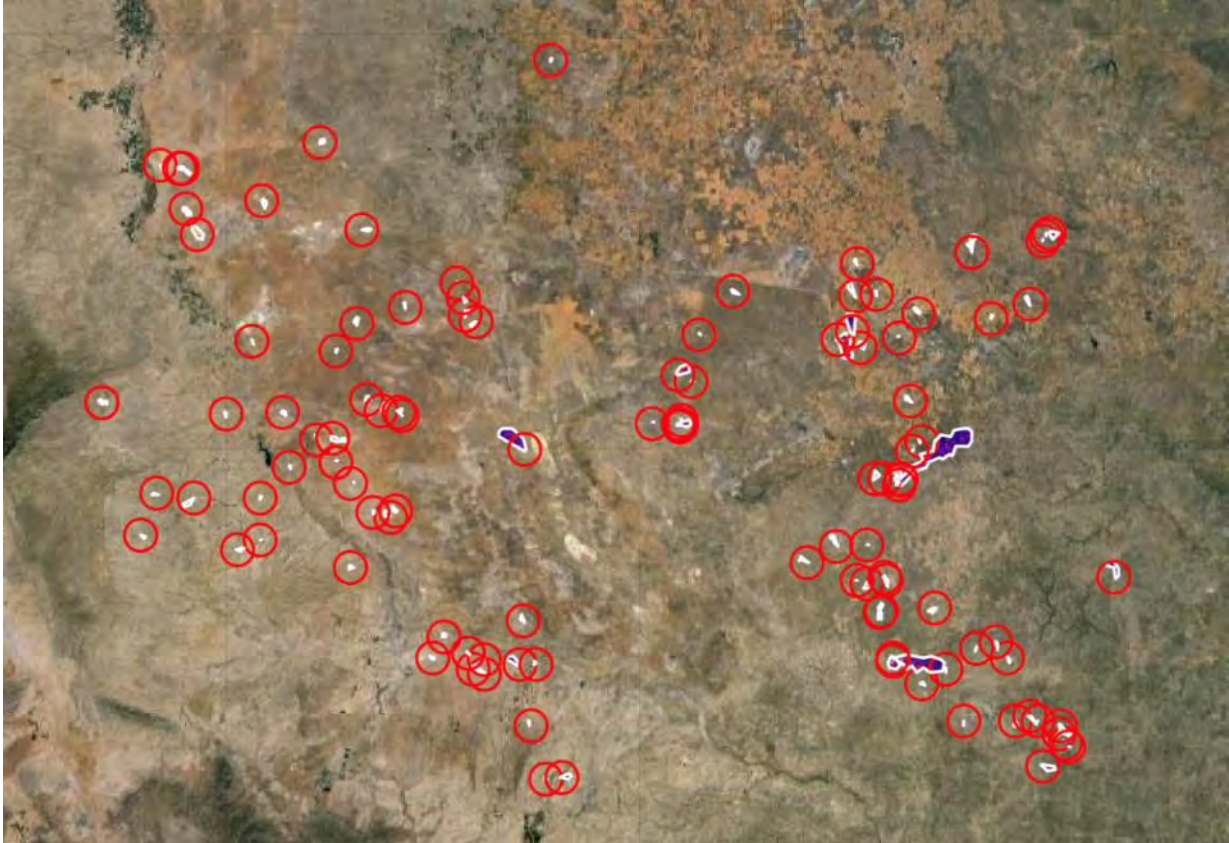
100s EMIT CO₂ plumes identified to date



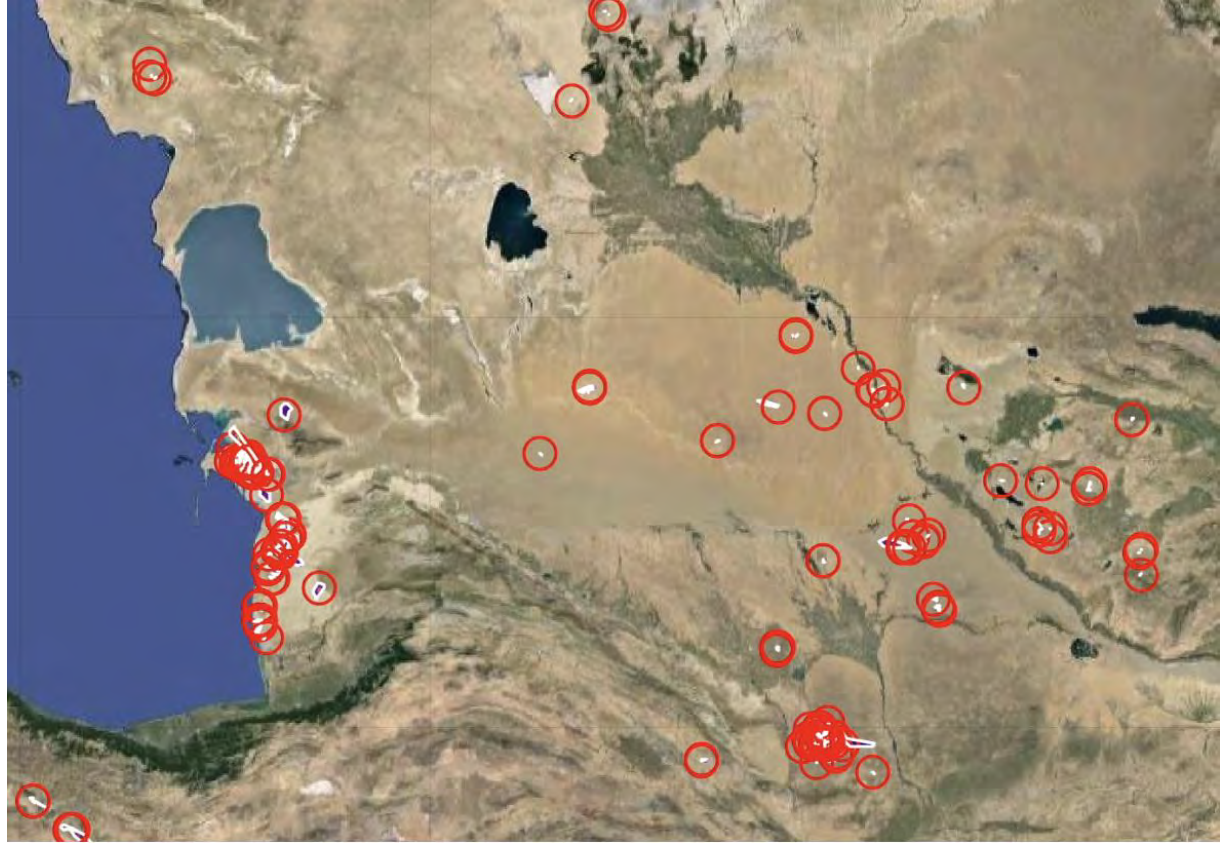
Mitigation activities: Earth Action enabled by EMIT



United States (Permian, oil&gas)



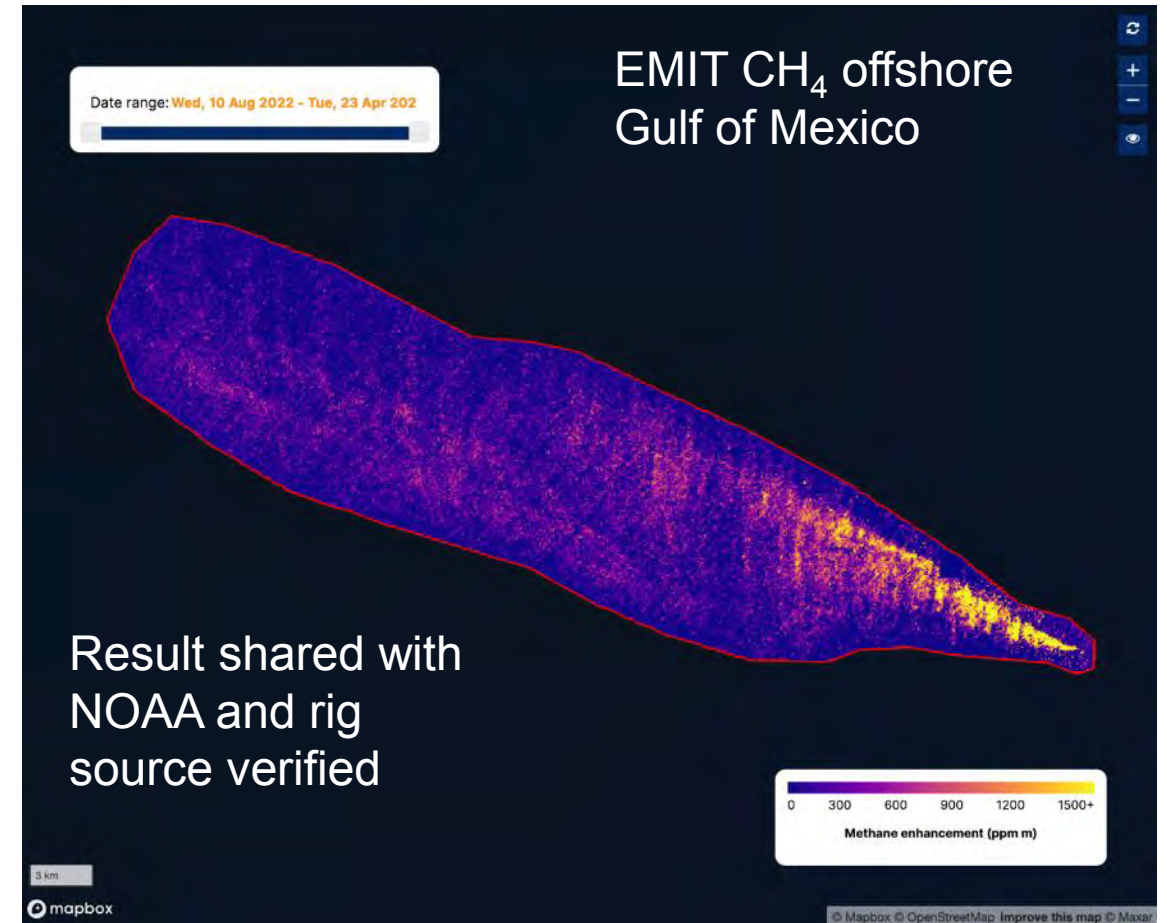
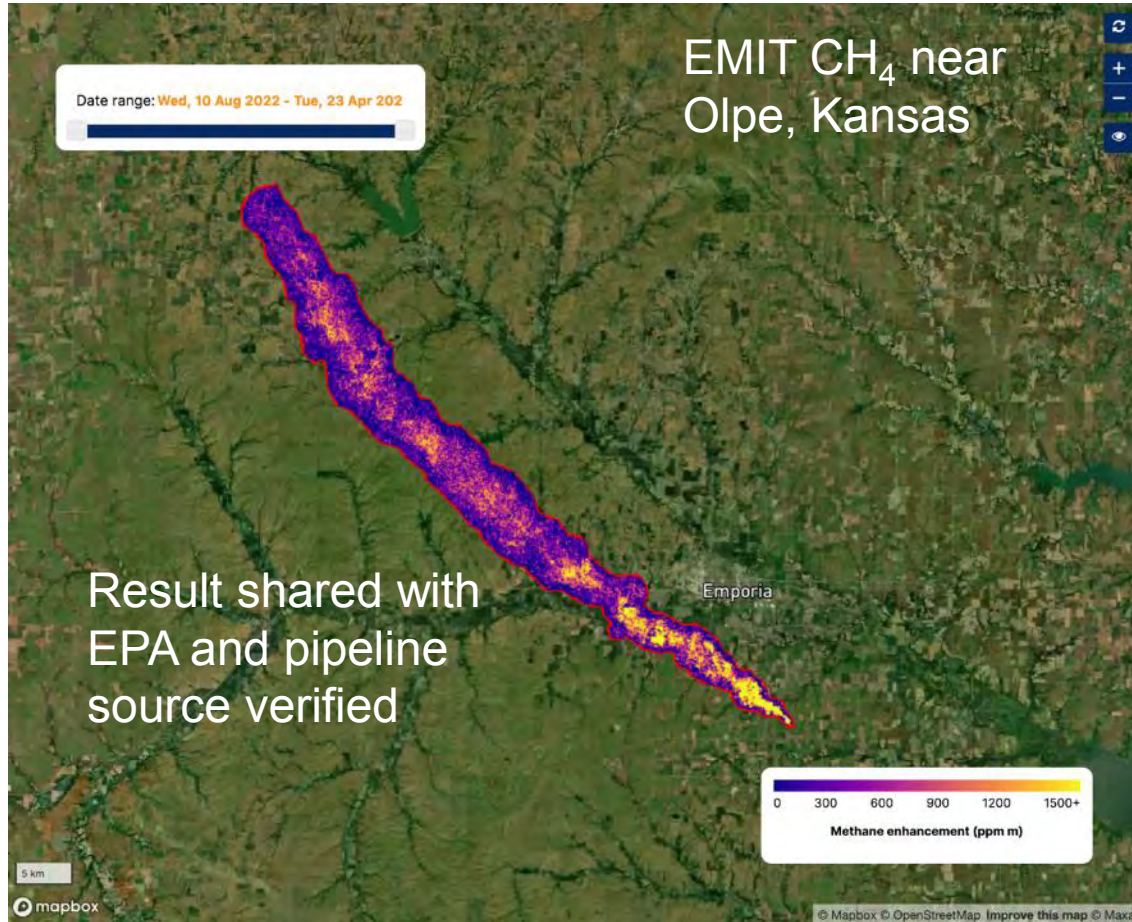
Turkmenistan (oil&gas)



Data in use by:



EMIT CH₄ results can discover unexpected emissions

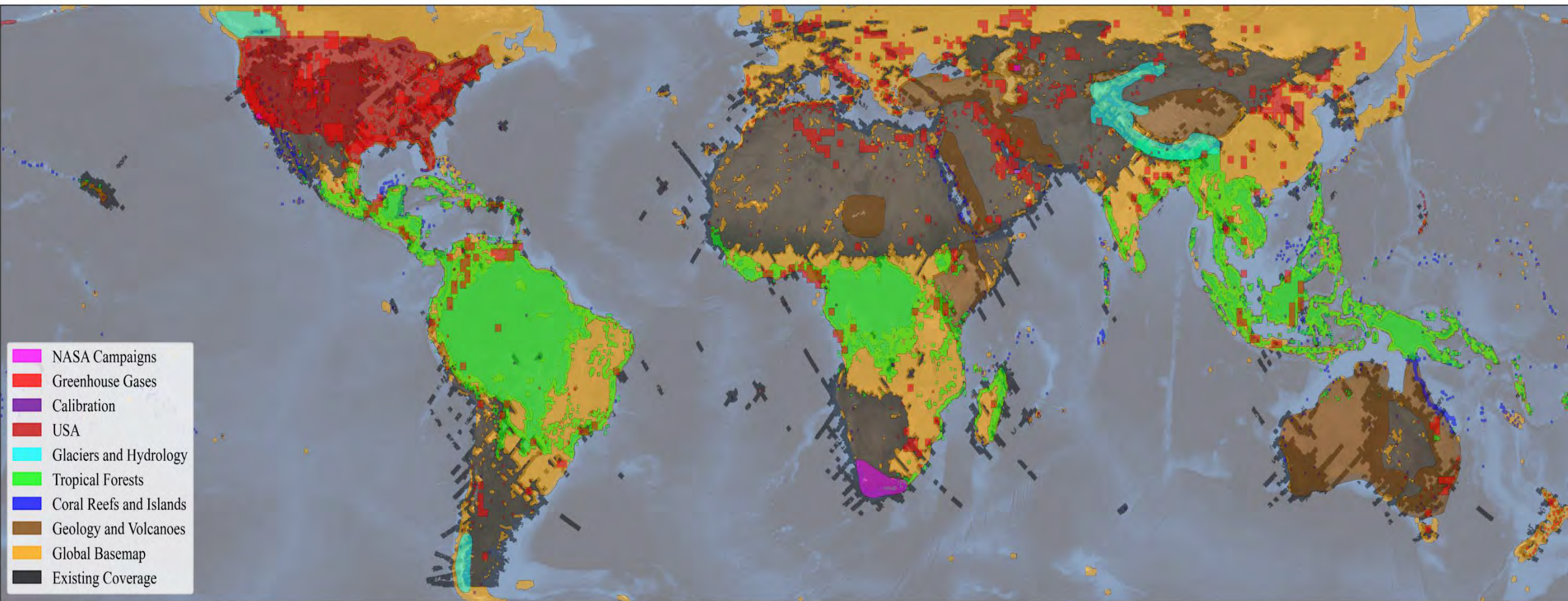


Sources verified by:



80 km Swath EMIT Extended Mission Observation Objectives

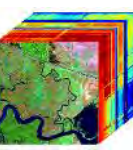
- NASA, SMD, ESD, Decadal Survey, Science, Climate, Action, and National Interests
 - Added value: Moon to Mars, Solar system, Exoplanets
- Objectives: Greenhouse Gases, Decadal SBG, NASA Campaigns, Calibration, USA coverage, Global Basemap



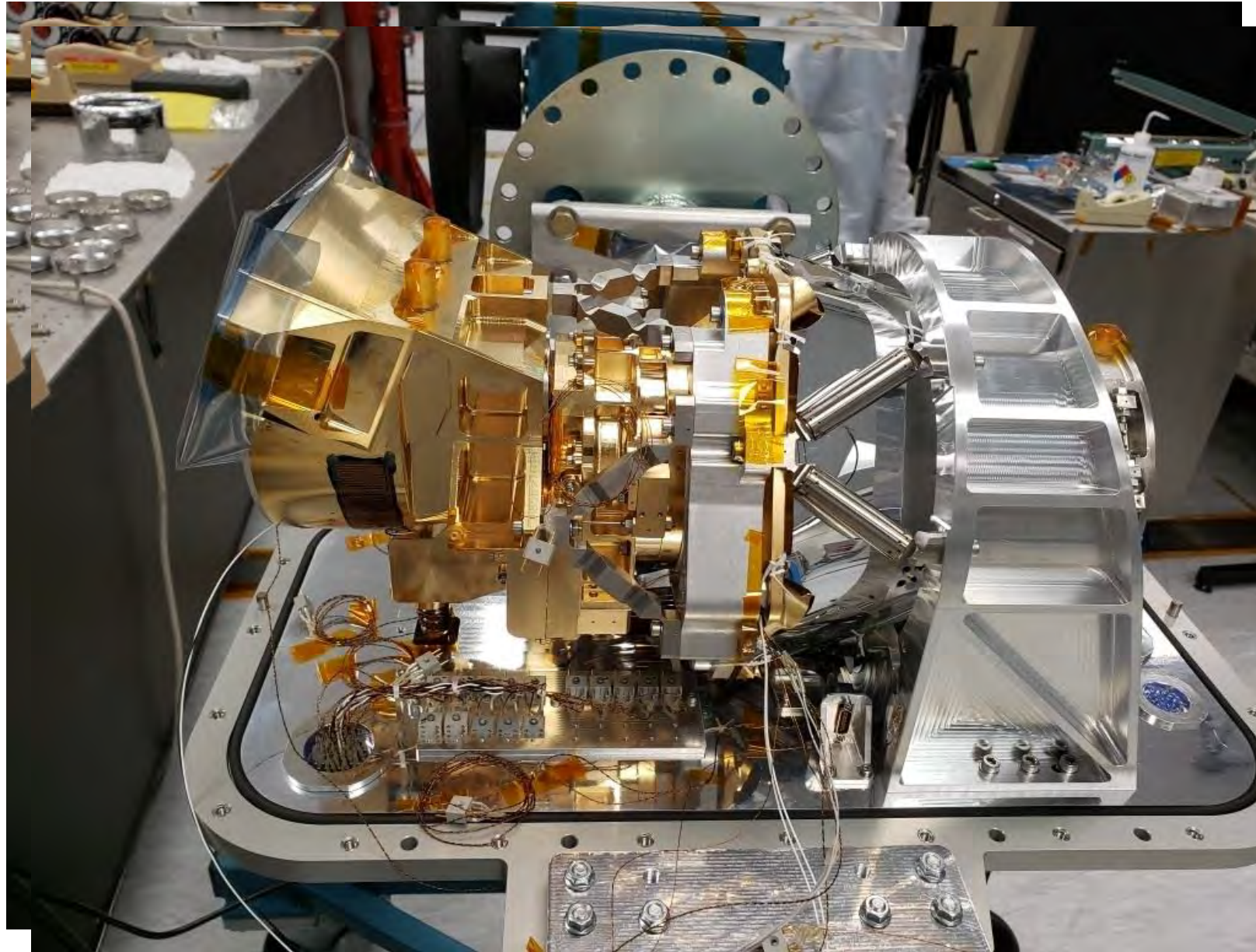
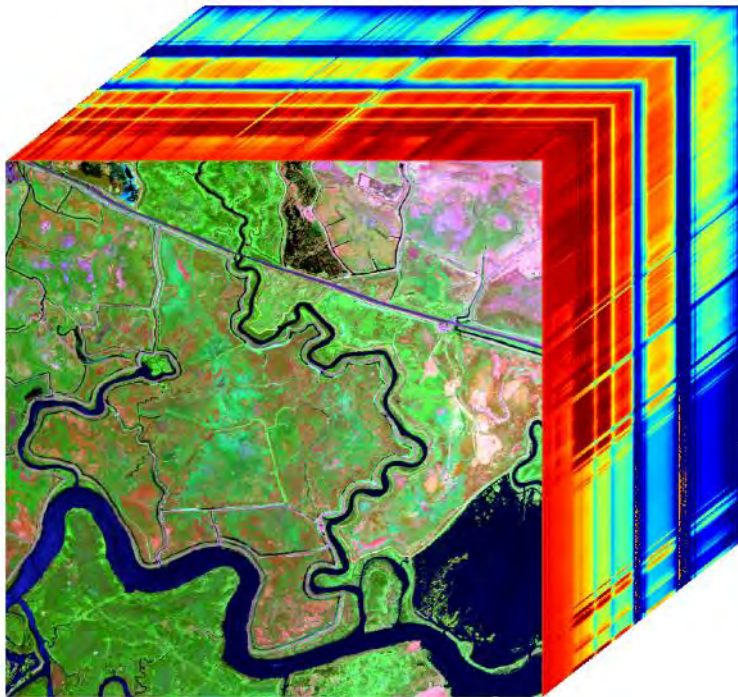


NASA Advancing the State-of the-Art

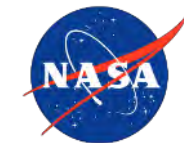
Airborne Visible/Infrared Imaging Spectrometer 3 (AVIRIS-3)



- State-of-the-art imaging spectrometer in the Solar System
- Copy of EMIT imaging spectrometer with airborne telescope.
- > 5x the performance of AVIRIS-NG
- VSWIR spectral range 380 to 2500 nm
- Unmatched signal-to-noise ratio
- 1240 cross-track samples
- 0.56 milliradian spatial sampling: 10 m to 30 cm



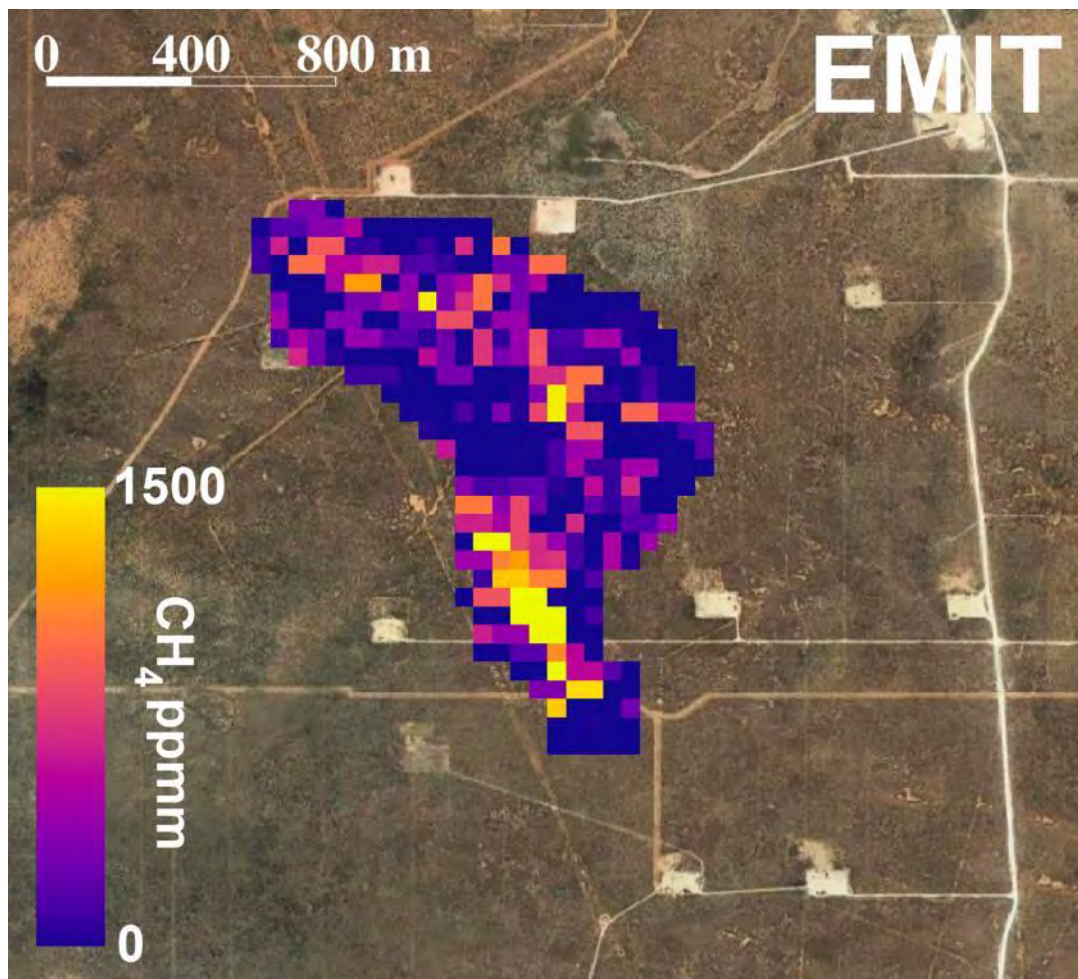
AVIRIS-3 CH₄ observations augment EMIT and other initiatives



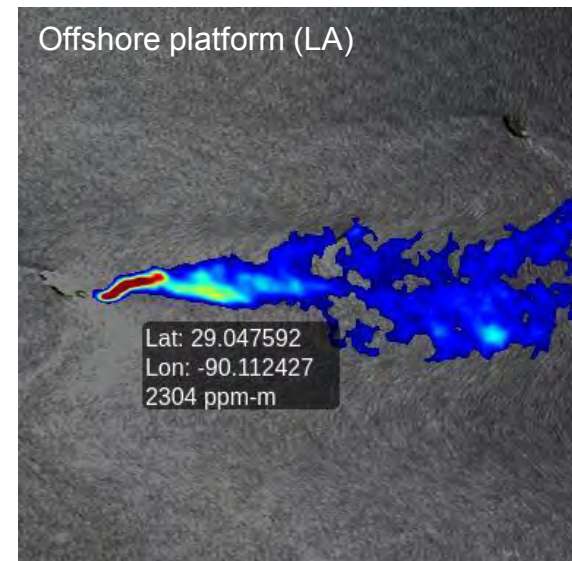
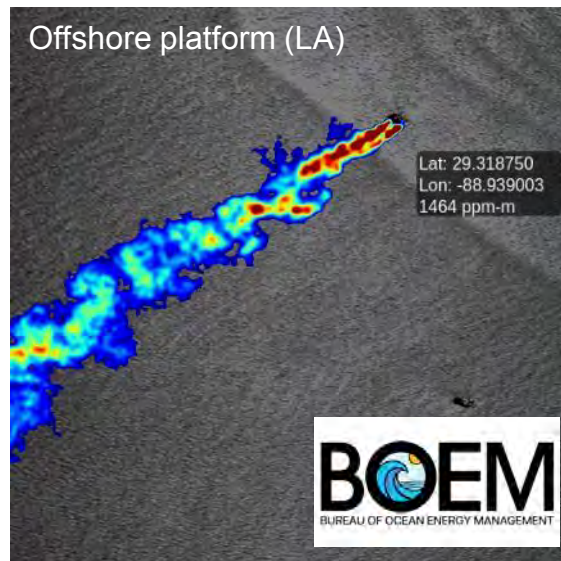
Sensitivity <10 kg/hr

226,000 spectra per second

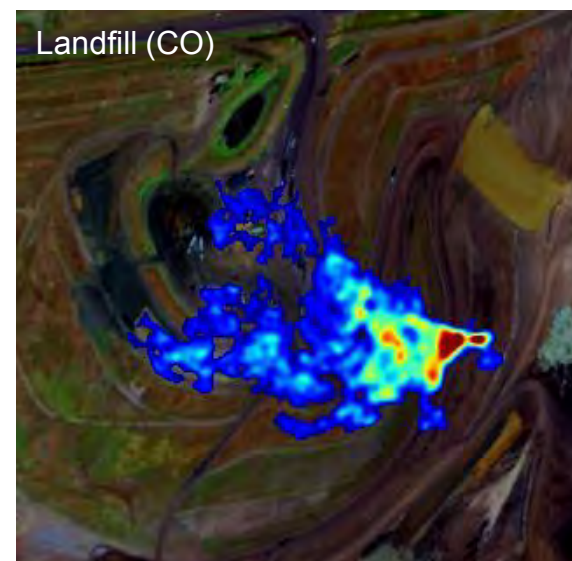
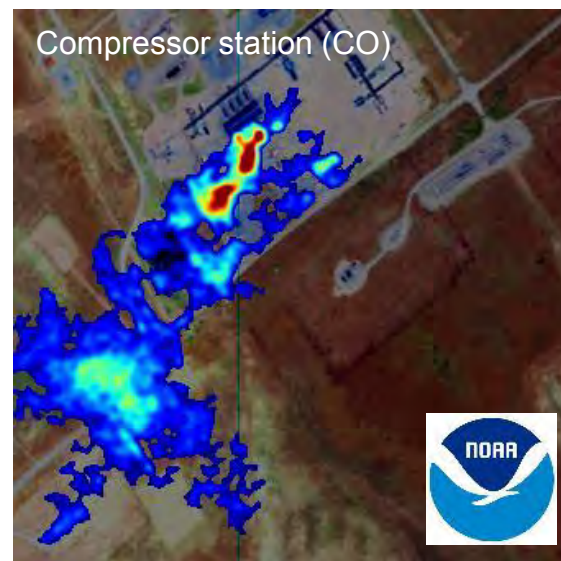
Coincident observations for validation in Permian Basin (NM, TX)



NASA SCOAPE-II mission



NOAA AiRMAPS mission



AV320240603t185822
Seed: 458 ppm-m
Threshold: 78 ppm-m
Detections: 2

Lat: 28.797482
Lon: -89.043655
171 ppm-m

Platform 22178-1,
Cognac (CH4 plume)

AV320240607t161732
Seed: 557 ppm-m
Threshold: 126 ppm-m
Detections: 3

Platform 20390-1

AV320240607t163139
Seed: 1170 ppm-m
Threshold: 76 ppm-m
Detections: 1

Lat: 29.318750
Lon: -88.939003
1484 ppm-m

Platform 928-1



AV320240607t164728
Seed: 3000 ppm-m
Threshold: 88 ppm-m
Detections: 1

Lat: 28.127346
Lon: -88.779373
1950 ppm-m

Platform 20375-1

AV320240607t180116
Seed: 1553 ppm-m
Threshold: 60 ppm-m
Detections: 1

Platform 20575-1

Lat: 29.002893
Lon: -89.853710
1616 ppm-m

AV320240607t180558
Seed: 678 ppm-m
Threshold: 56 ppm-m
Detections: 3

Platform 20046-1

AV320240607t184338
Seed: 1280 ppm-m
Threshold: 53 ppm-m
Detections: 1

Lat: 29.047502
Lon: -90.112427
2304 ppm-m

Platform 20008-1

AV320240607t192528
Seed: 630 ppm-m
Threshold: 43 ppm-m
Detections: 2

Lat: 28.467132
Lon: -91.064720
1341 ppm-m

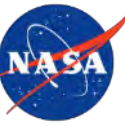
Platform 21429-1

AV320240608t181917
Seed: 1190 ppm-m
Threshold: 63 ppm-m
Detections: 1

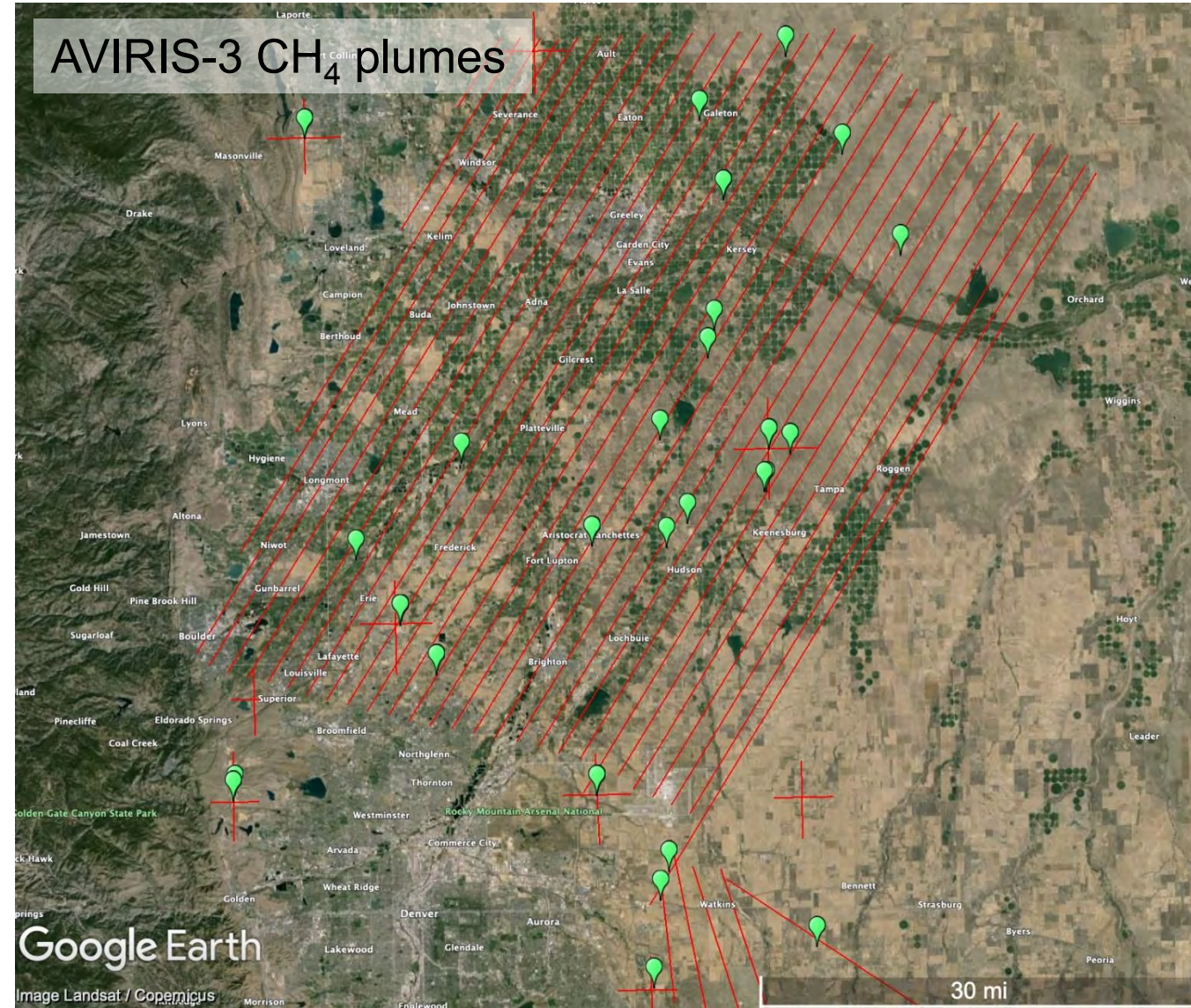
Lat: 29.490819
Lon: -88.015822
1219 ppm-m

Platform 2424-1

Recent campaigns: NOAA AiRMAPS



- Denver Julesburg Basin, July 2024
- Lead by Steven Brown (NOAA), support by Colorado Department of Public Health and Environment
- AVIRIS-3 flights funded by US GHG Center in coordination with NOAA Twin Otter Mass Balance flights
- >40 CH₄ plumes identified with AVIRIS-3

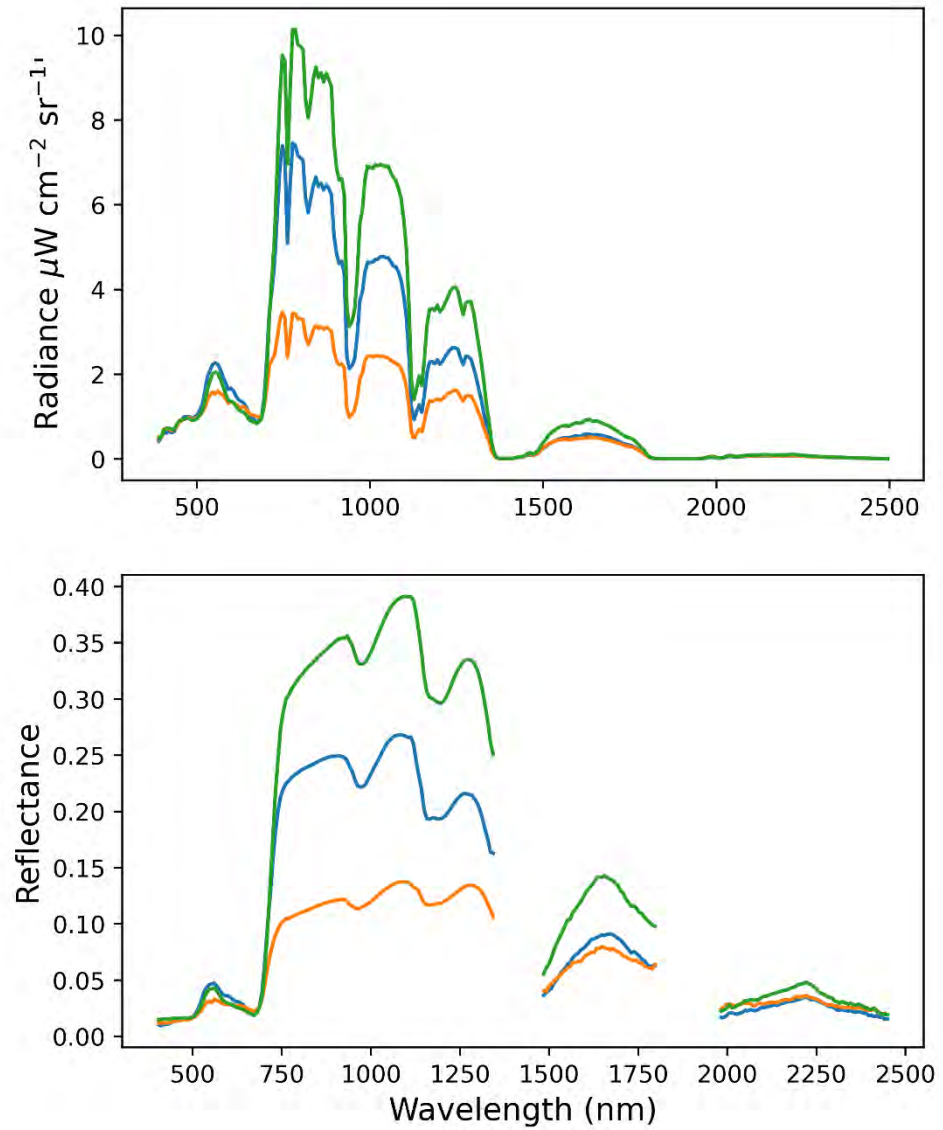


AV320240826t193834

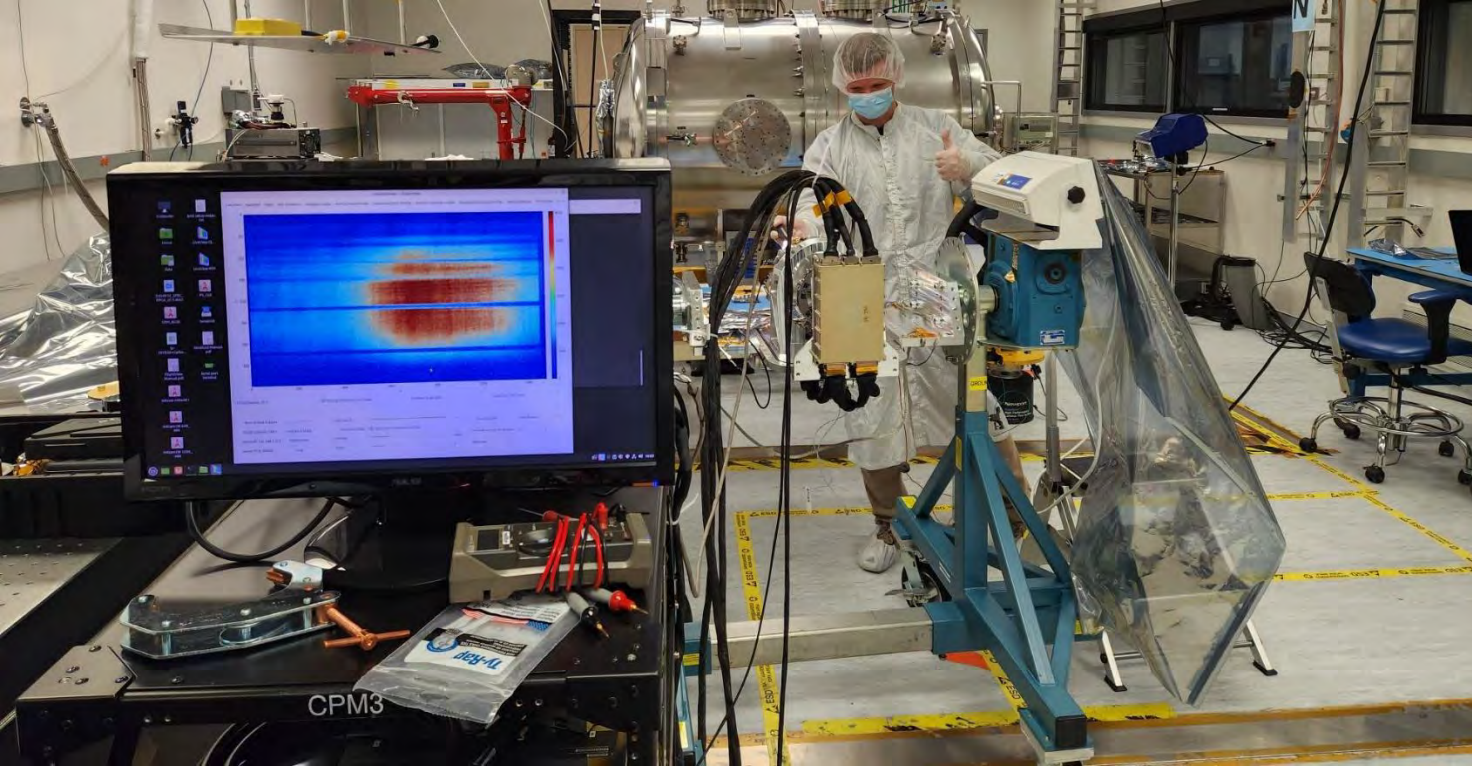
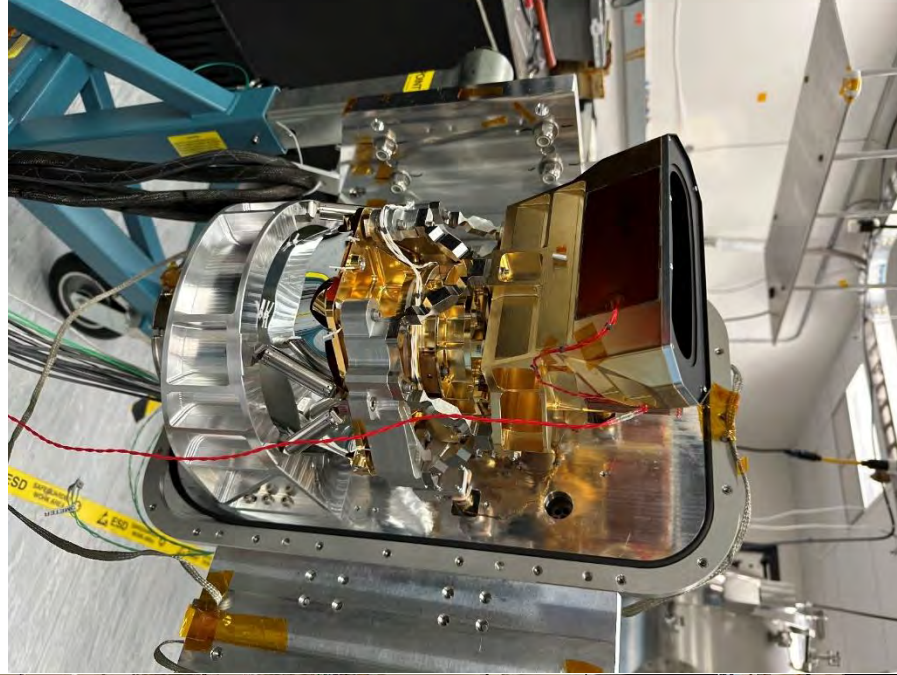
Sedgewick Reserve, CA

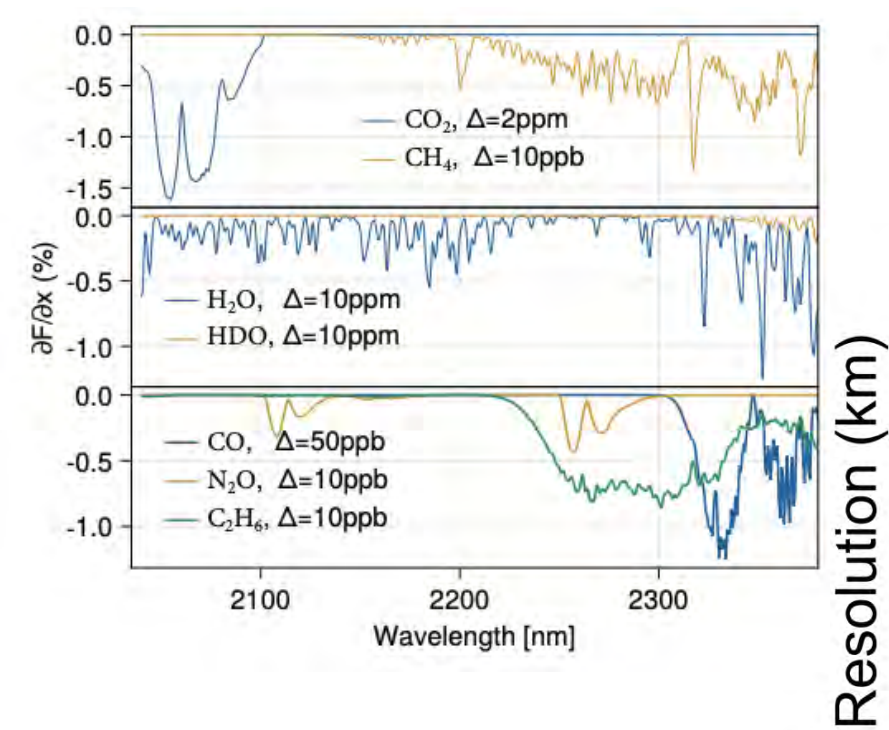
Altitude : 600 m AGL

Pixel size: 0.3 m

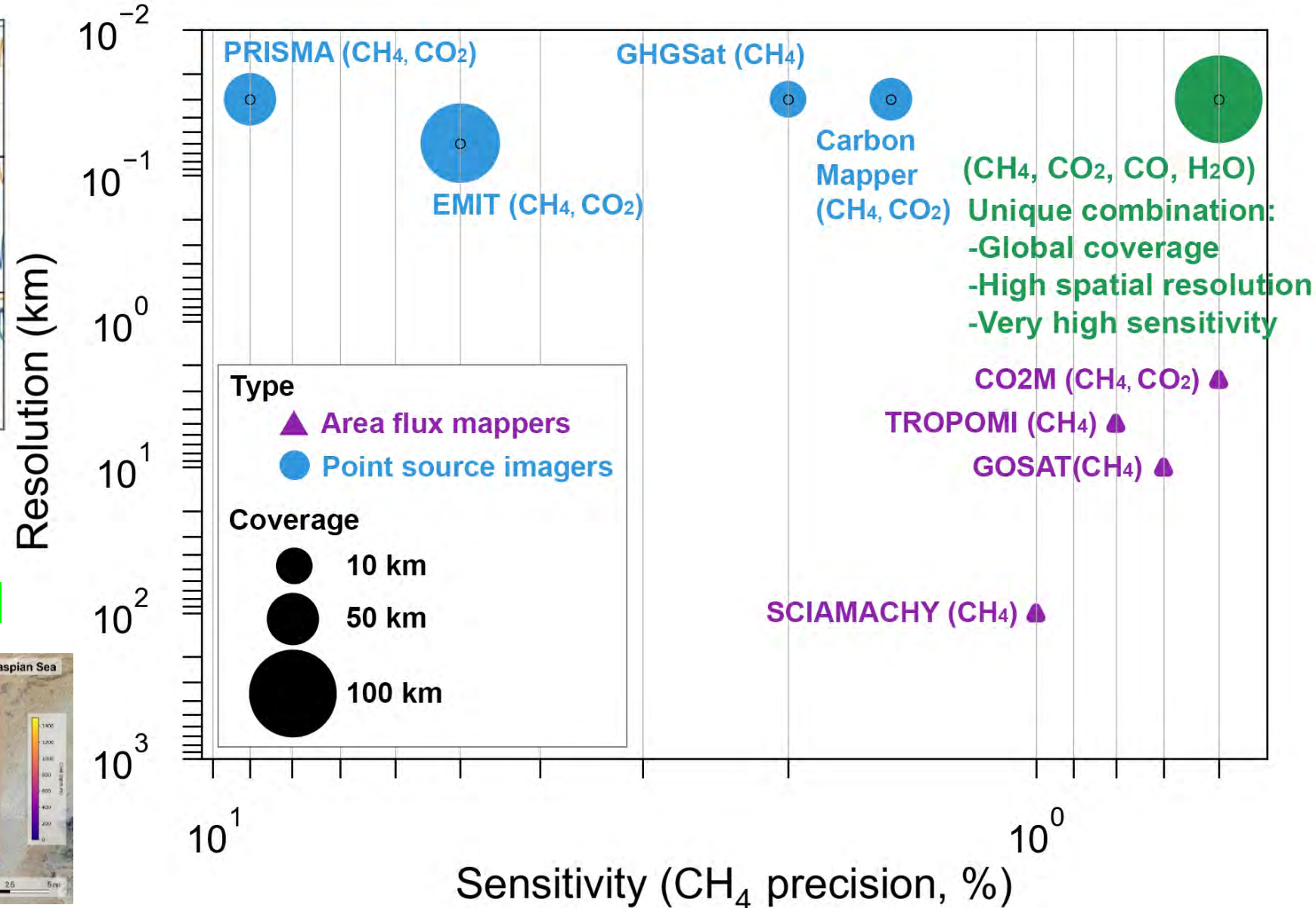
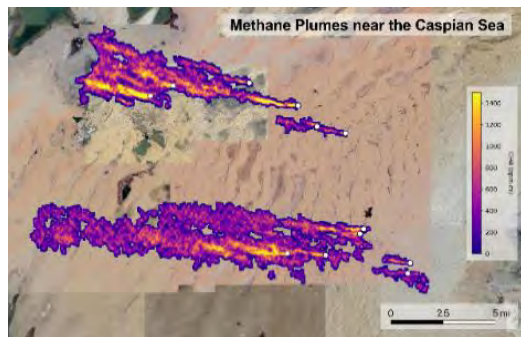
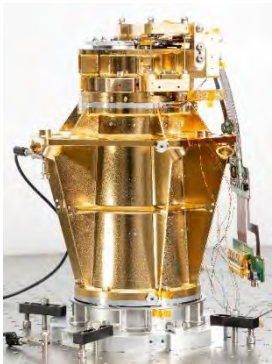


AVIRIS-5 Optical Head 5 nm Spectral Sampling



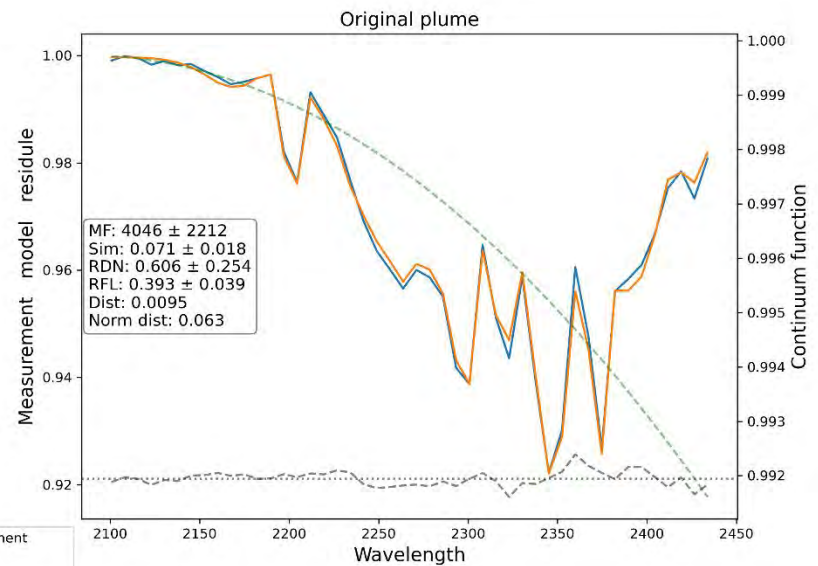
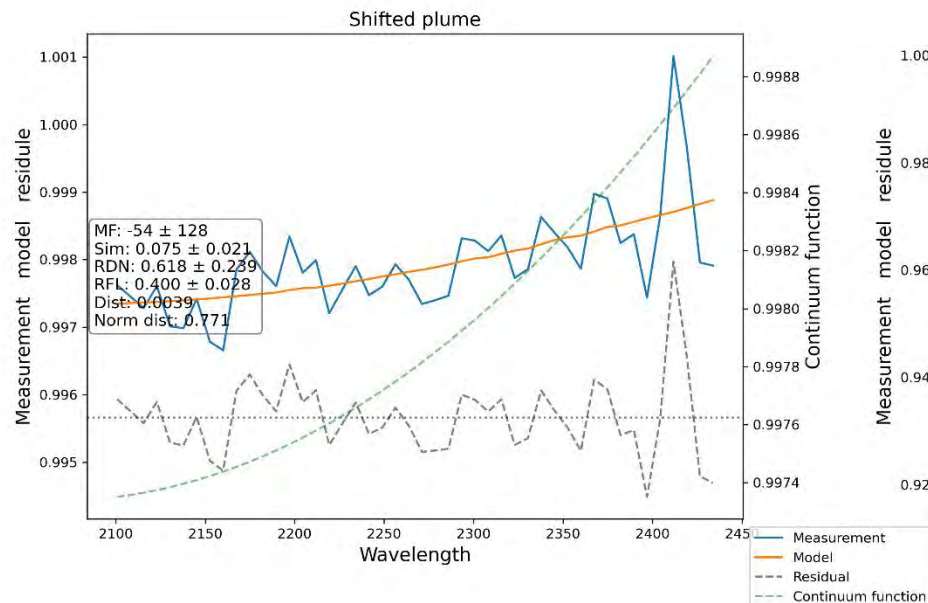
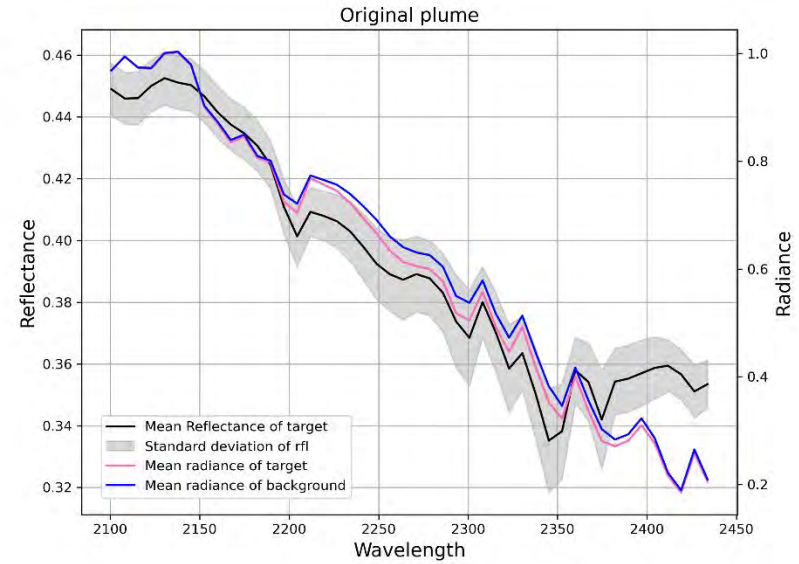
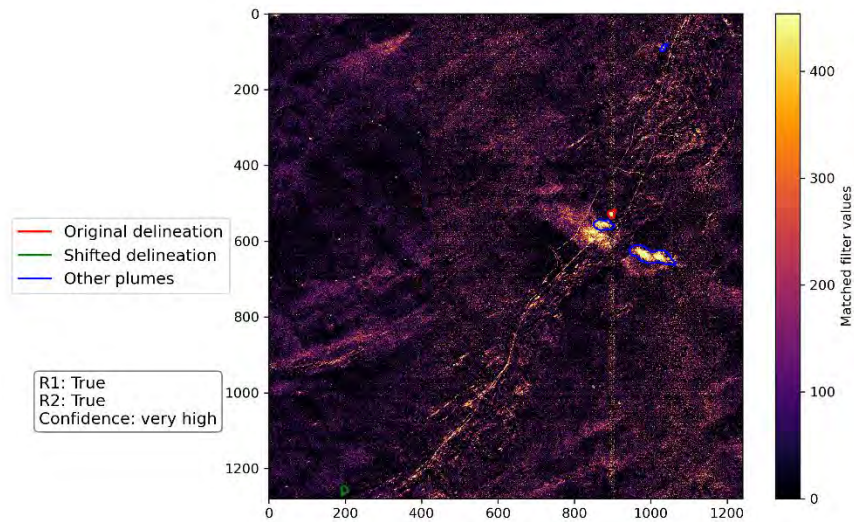


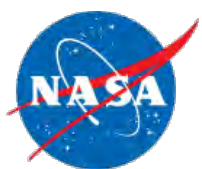
NASA EMIT technology heritage





Advancing Algorithms (Assessing Plume Confidence)

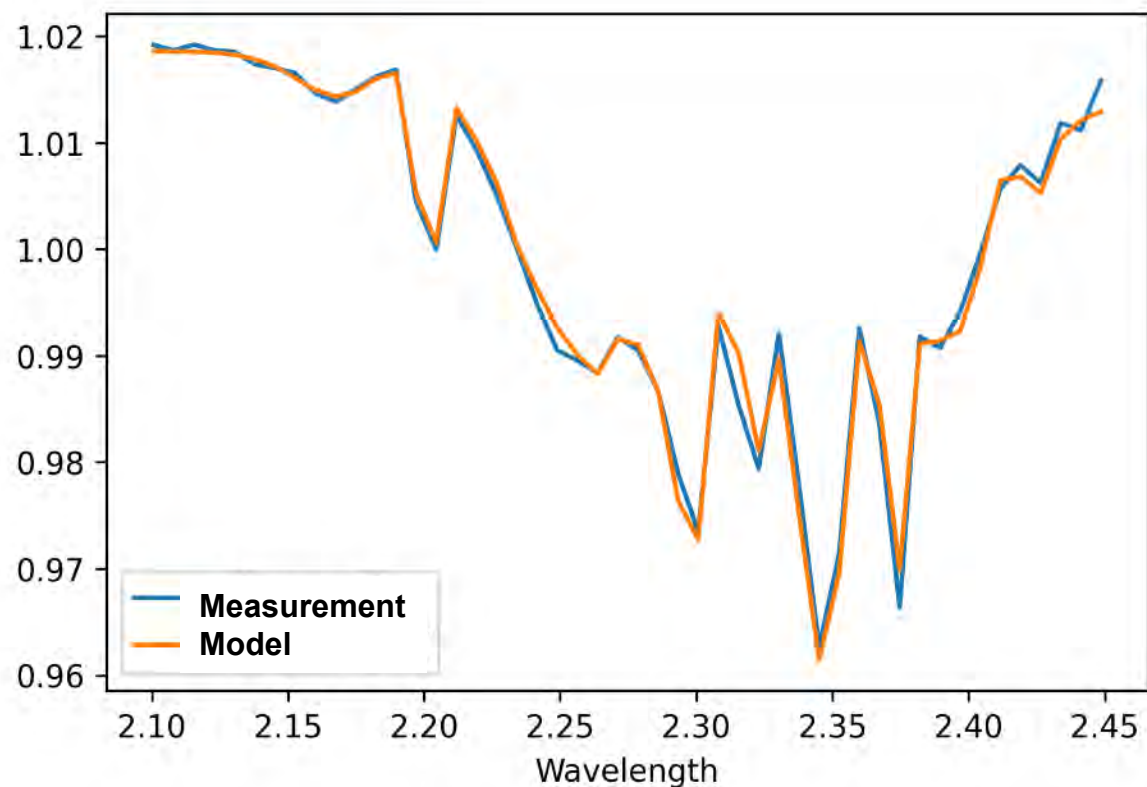




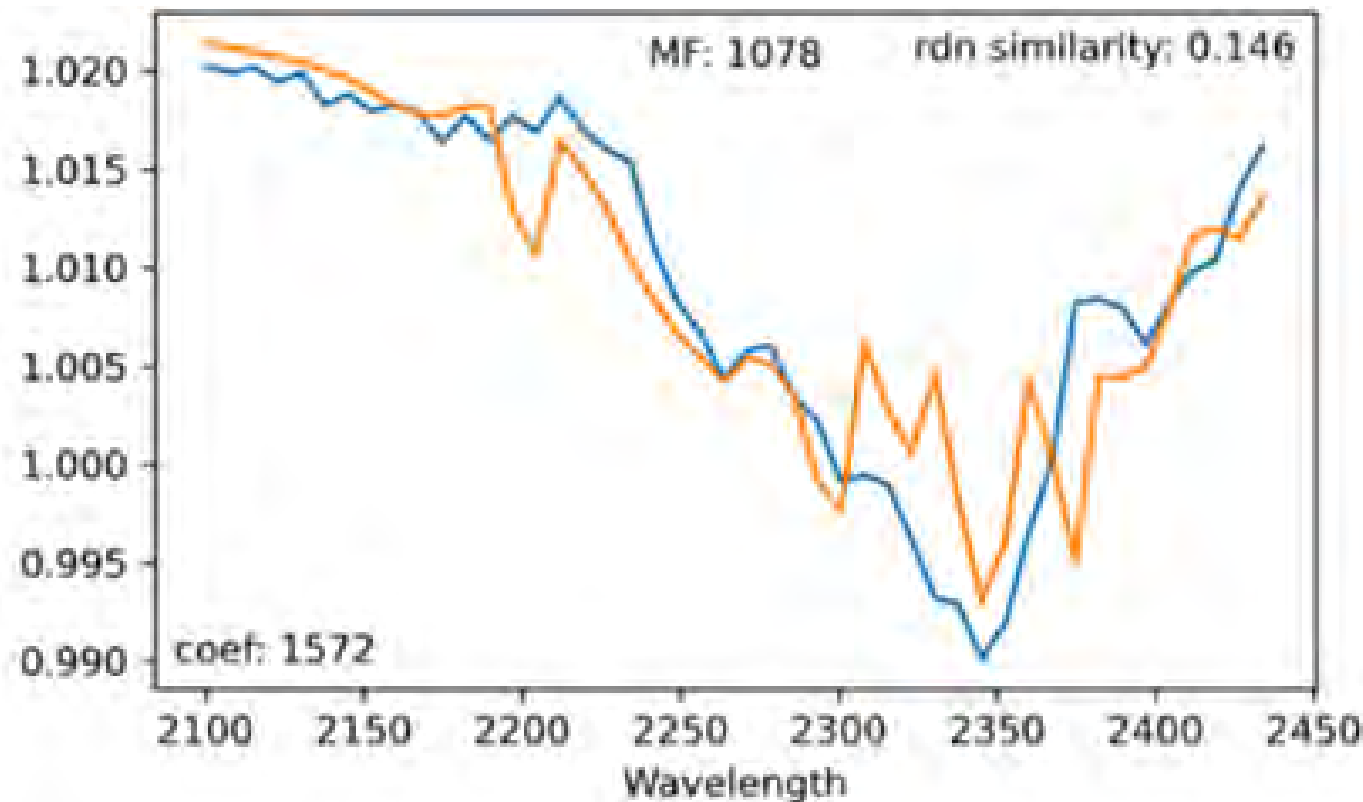
Advancing Algorithms (Assessing Plume Confidence)



High Matched Filter Value Methane Match

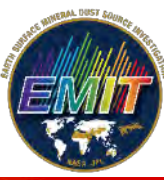


High Matched Filter Value False Positive





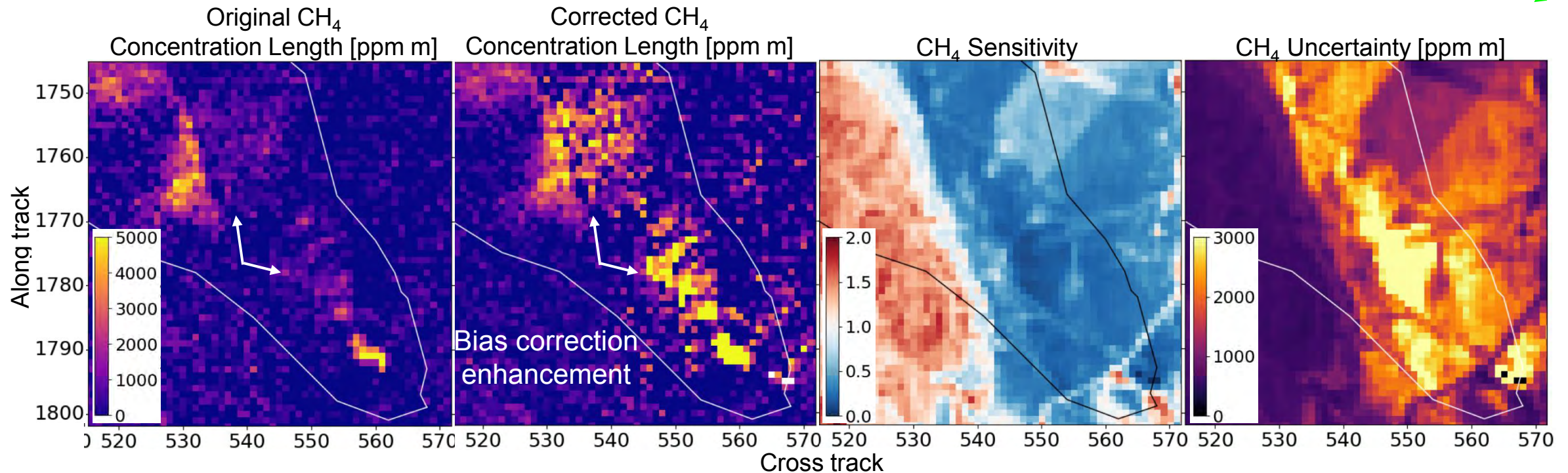
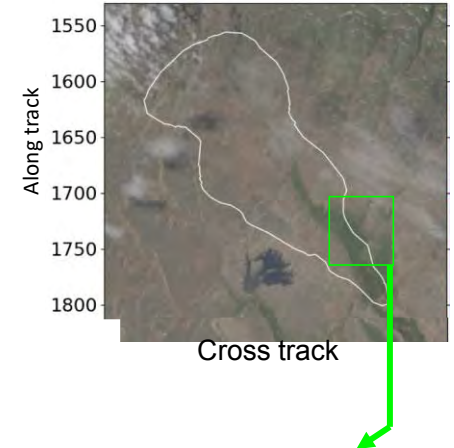
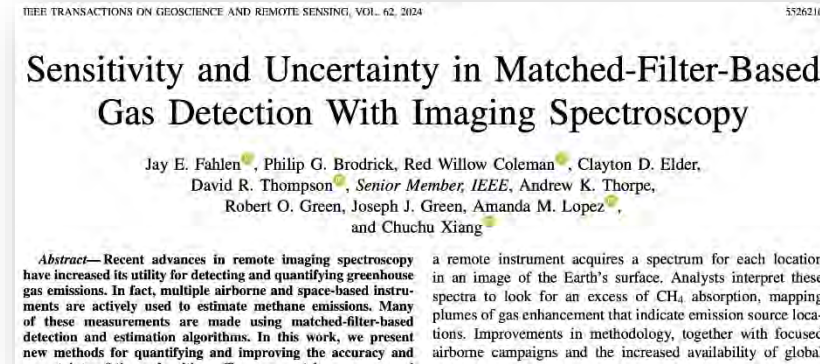
Bias and Uncertainty estimates reveal weaker plumes in difficult environments



Dim surface backgrounds degrade detection sensitivity

New bias and uncertainty calculations:

- reveal plumes in challenging viewing conditions
- quantify concentration estimate accuracy



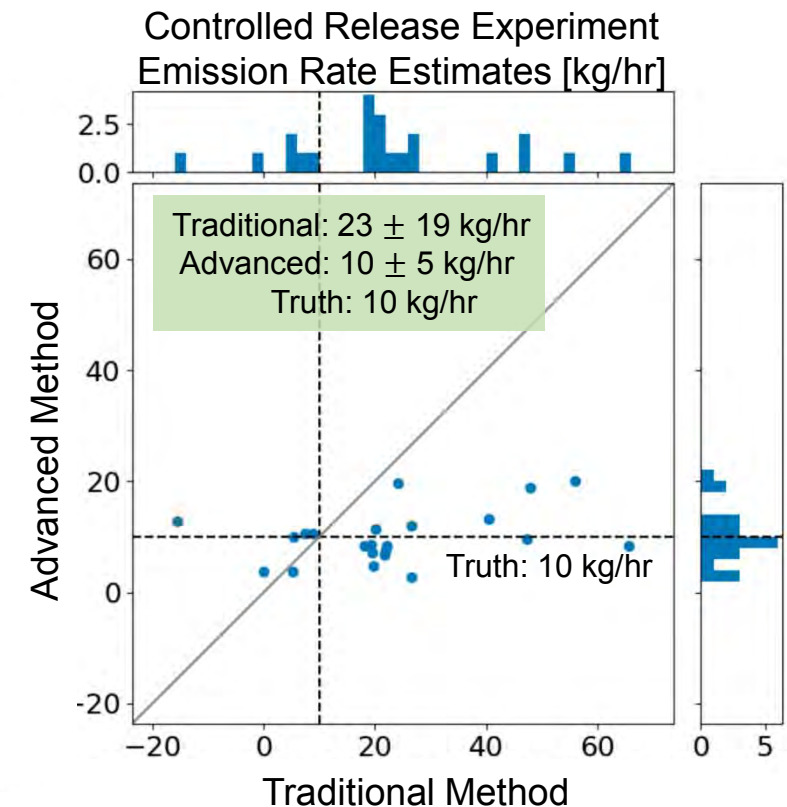
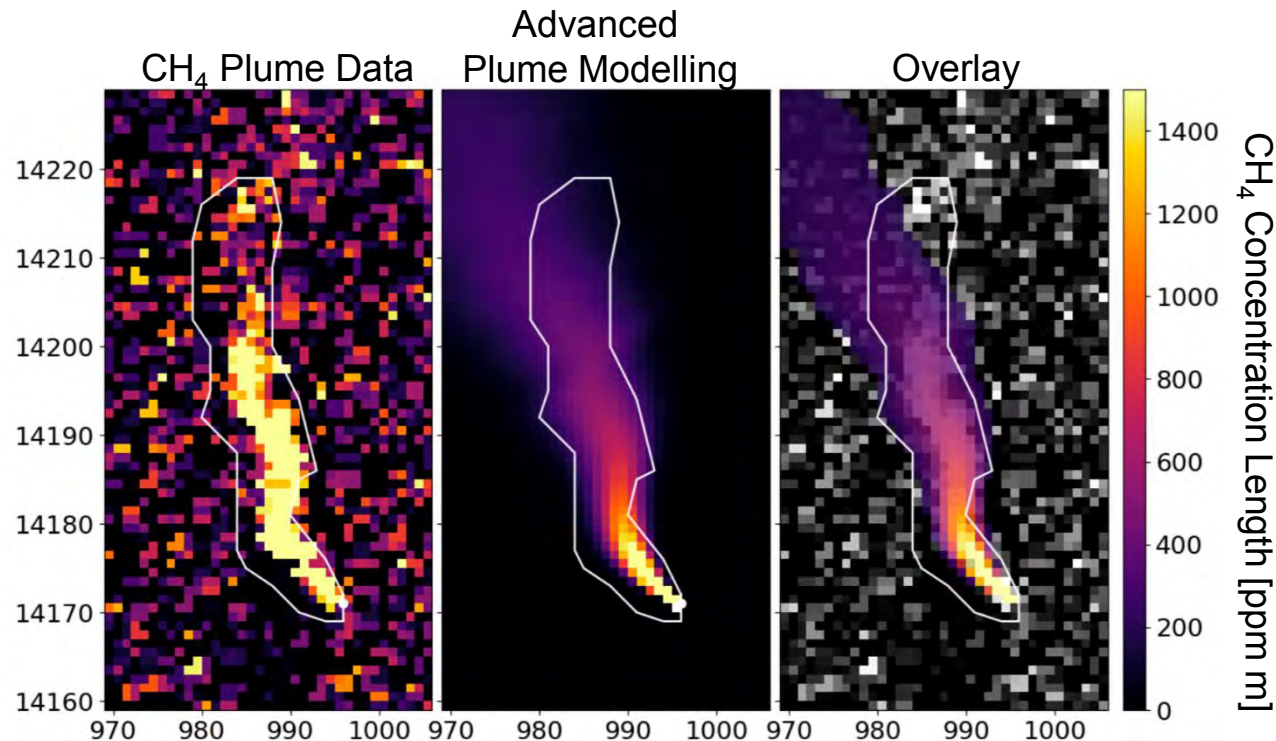
Advanced Emission Rate Estimation Improves Accuracy



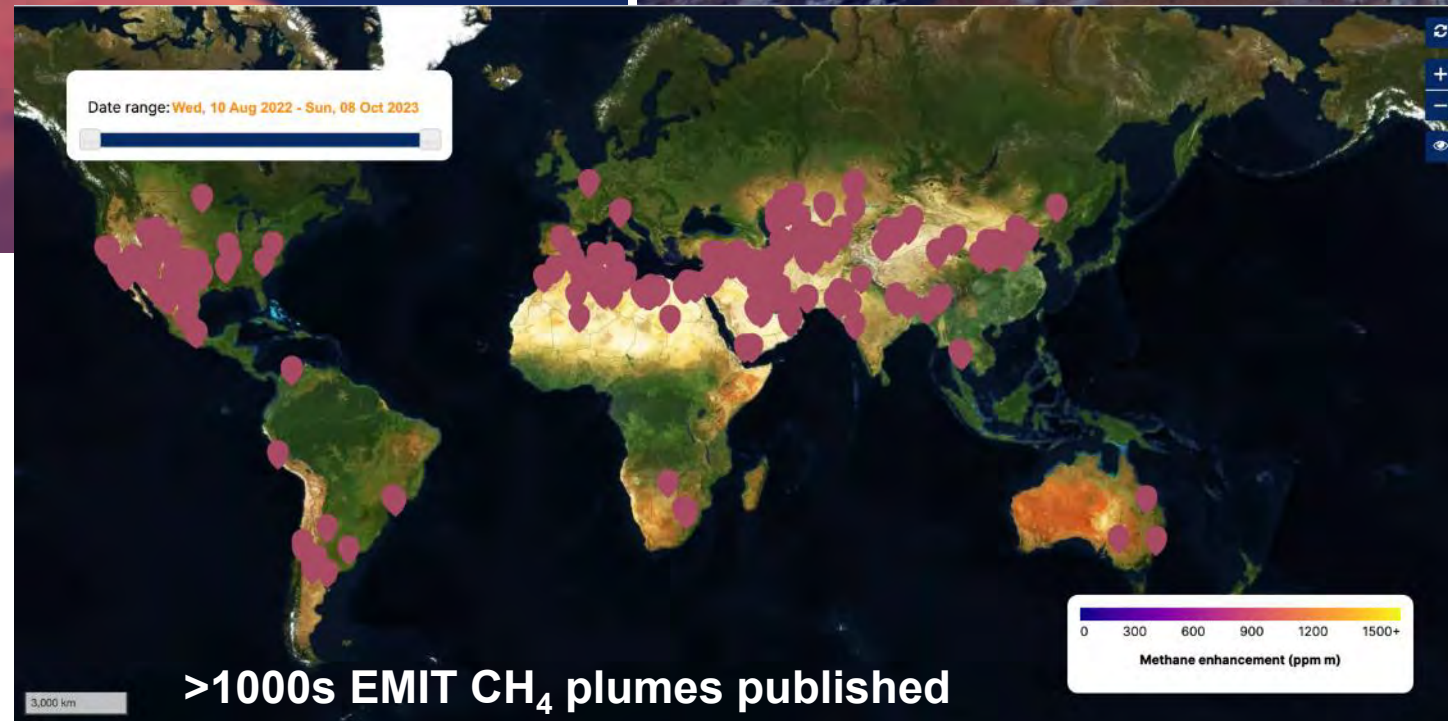
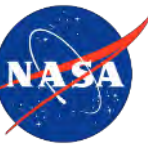
Traditional emission quantification relied on coarse summing across the plume

Advanced methods reduce bias and uncertainty by 2x and 4x, respectively, incorporating:

- Full statistical 2D inversion of new plume models
- Compensation for bias due to surface brightness variation
- Compensation for pixel-to-pixel uncertainty
- Changing winds



Supporting the U.S. GHG Center

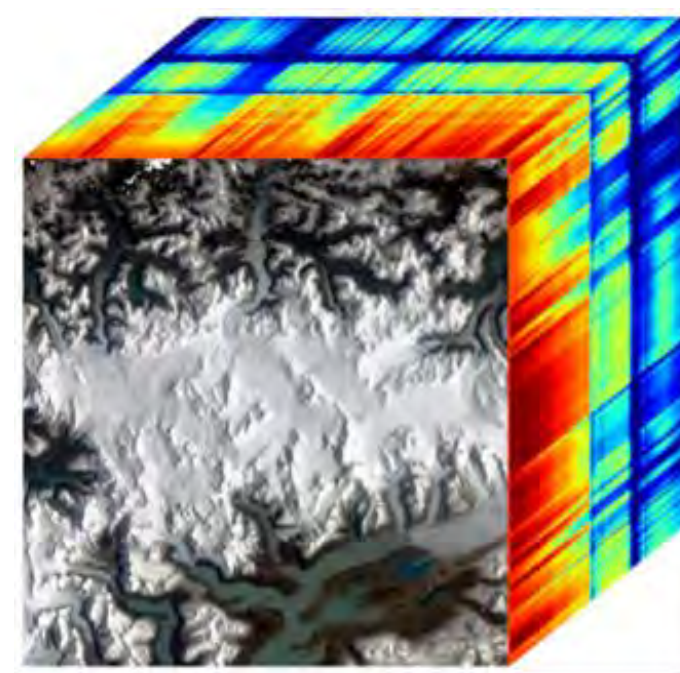
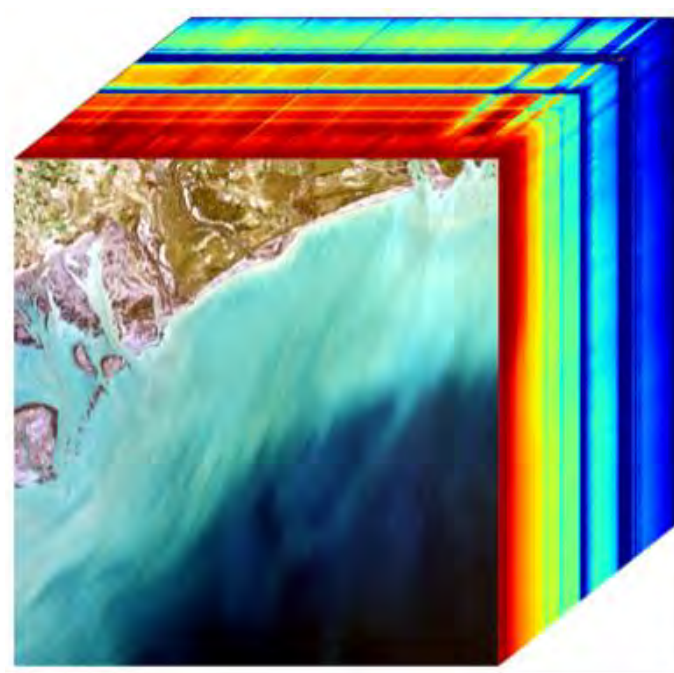
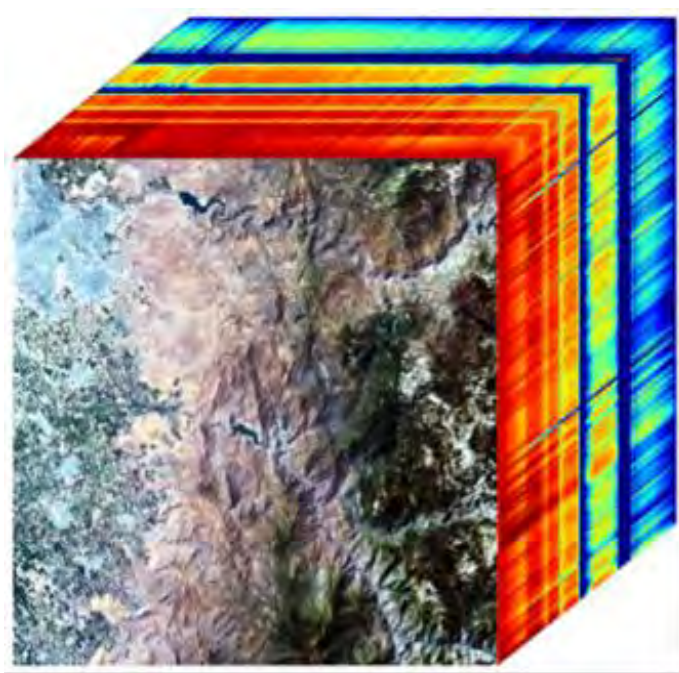
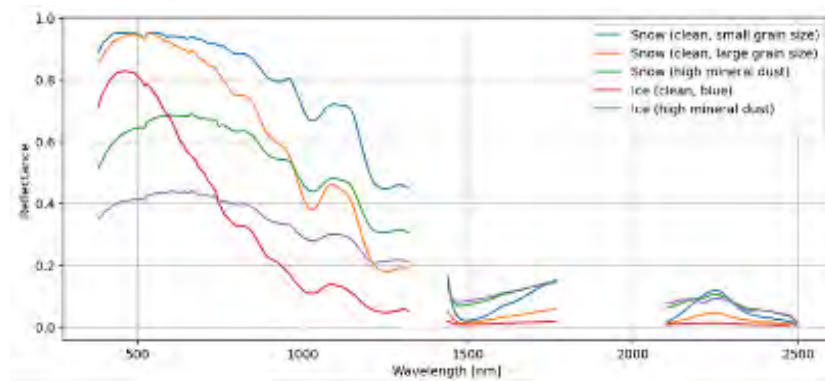
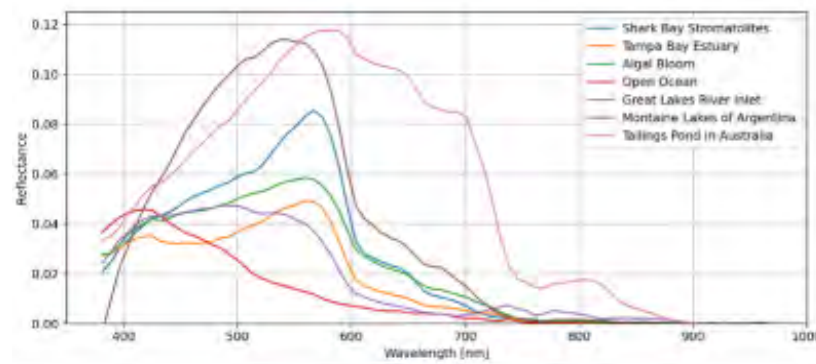
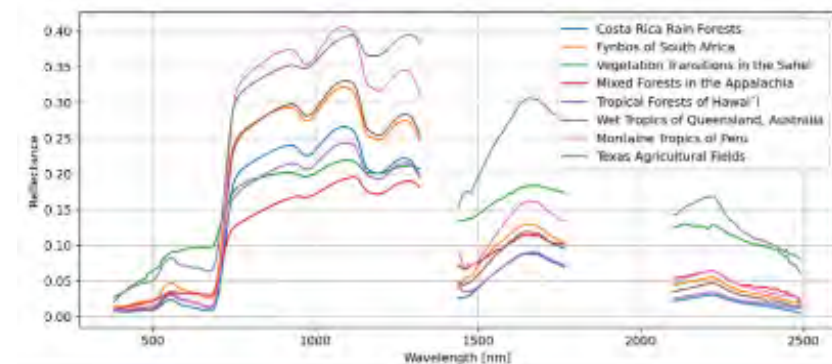


100s EMIT CO₂ plumes identified to date



EMIT Spectra are High Quality

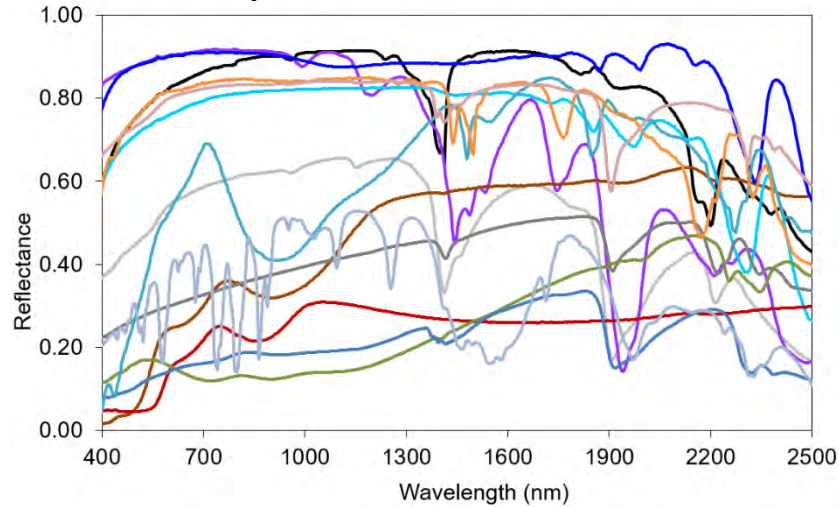
All EMIT measurements and Algorithms are Freely Available



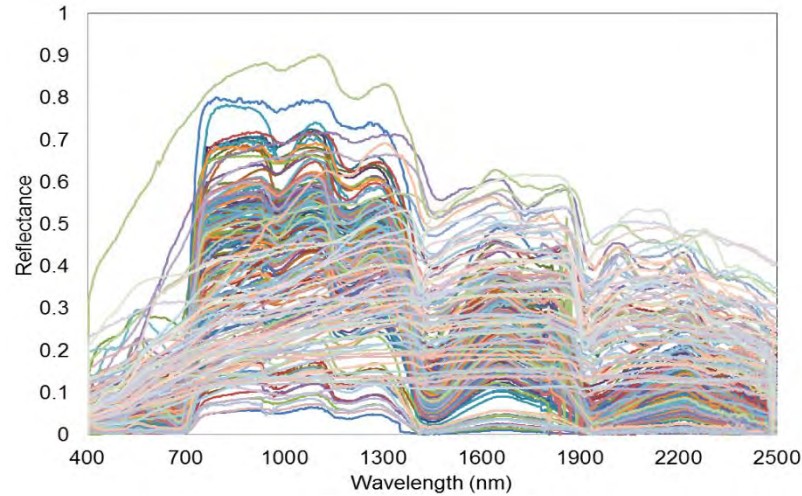


The Earth System is Rich with VSWIR Spectroscopic Signatures to Close Critical Knowledge Gaps

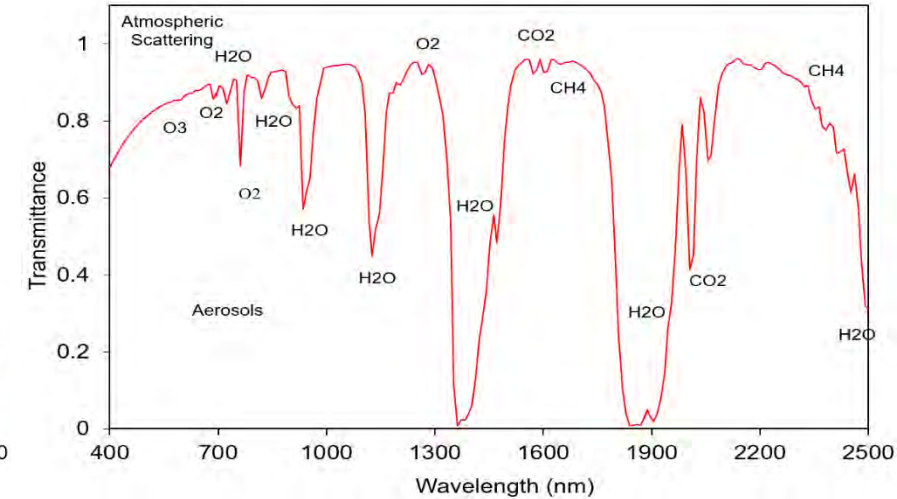
Geology: Broad Diversity of Mineral Spectra



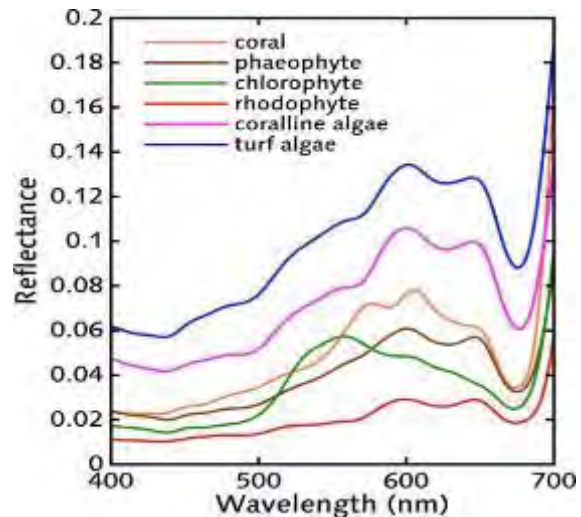
Ecosystems: Diversity of Signatures



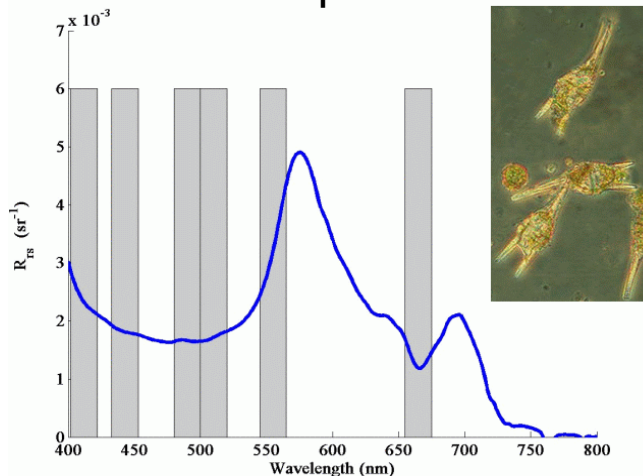
Atmosphere: Gases, Aerosols, Clouds



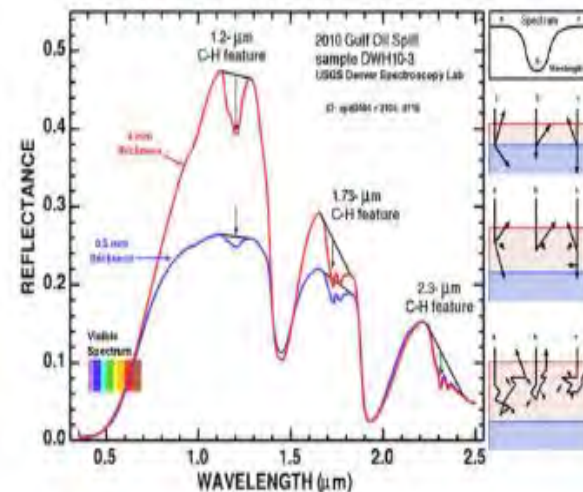
Aquatic: Benthic Materials



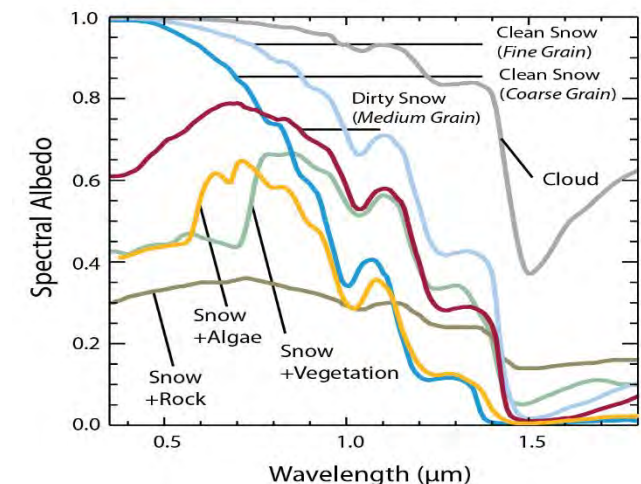
Aquatic: Algal Biomass and Composition



Oil Spill



Snow/ice: Grain size, Dust, Albedo and Melt

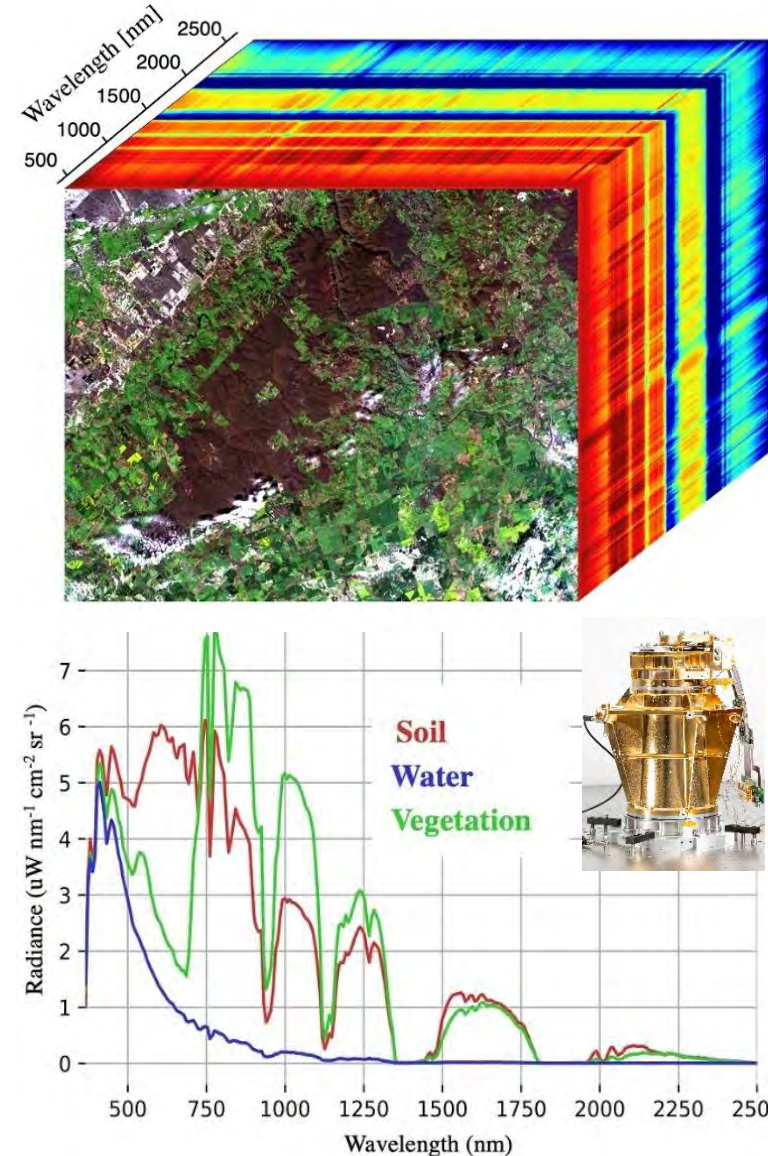




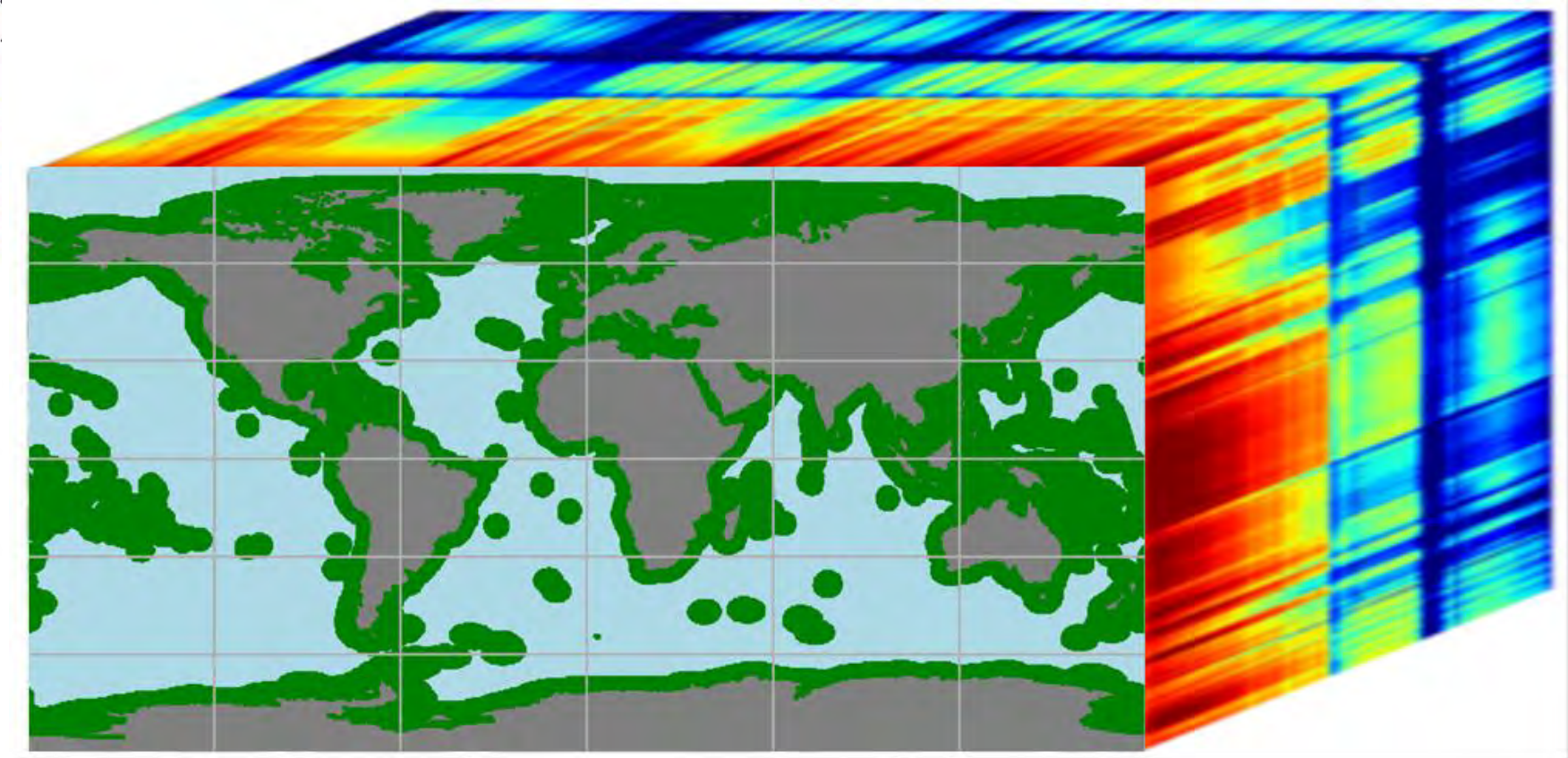
Global VSWIR Imaging Spectroscopy with SBG



EMIT Provides the Basis for SBG VSWIR



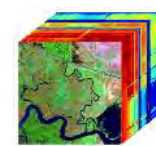
NASA Decadal SBG VSWIR, **in development**, observes the Earth from pole to pole every 16 days with 30 m spatial sampling.



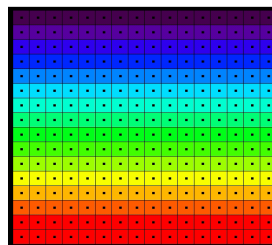
SBG VSWIR has > 20X the capability of EMIT



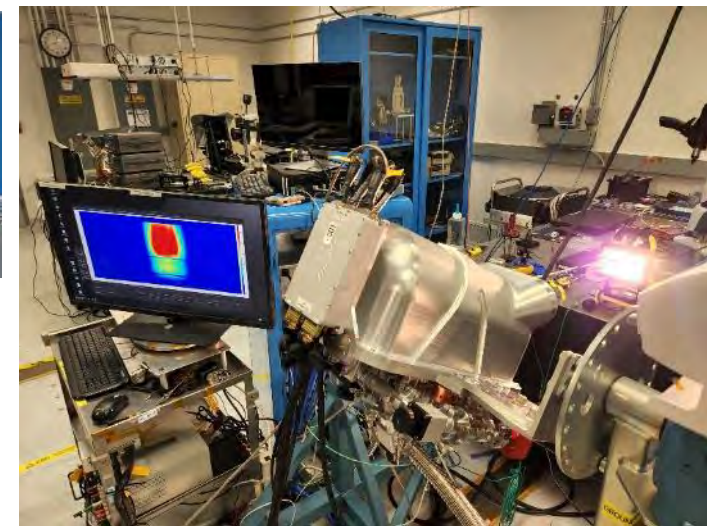
AVIRIS-3 is Ready to Support AirMAP via NASA and US GHGC



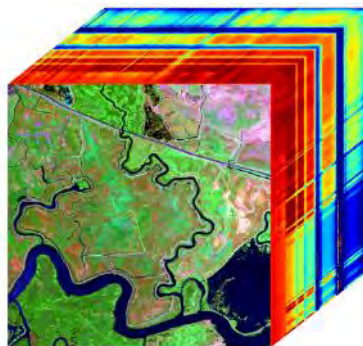
- *Imaging Spectroscopy: Ecosystems, Aquatic, Geology, Hydrology, Atmosphere, Anthropogenic, etc.*
 - Highest AVIRIS type SNR, Calibration, Full VSWIR (380 2500 nm @ 7.5 nm)
 - 40° Swath, 1240 samples at 0.5 milliradian
 - 0.5 to 13 m ground sampling
 - Exceptional measurement quality for science



- Exceptional uniformity
- EMIT spectrometer



- *AVIRIS-3 is flying in 2023 and planned to be compatible w/ B200, G-3/5, ER-2, and other platforms*



- *Basic products available: Radiance and reflectance*
- *Science product algorithms for: ecosystem, aquatic, geology, hydrology, greenhouse gases, ...*
- *POC: Robert.O.Green@jpl.nasa.gov*