CARBON-I

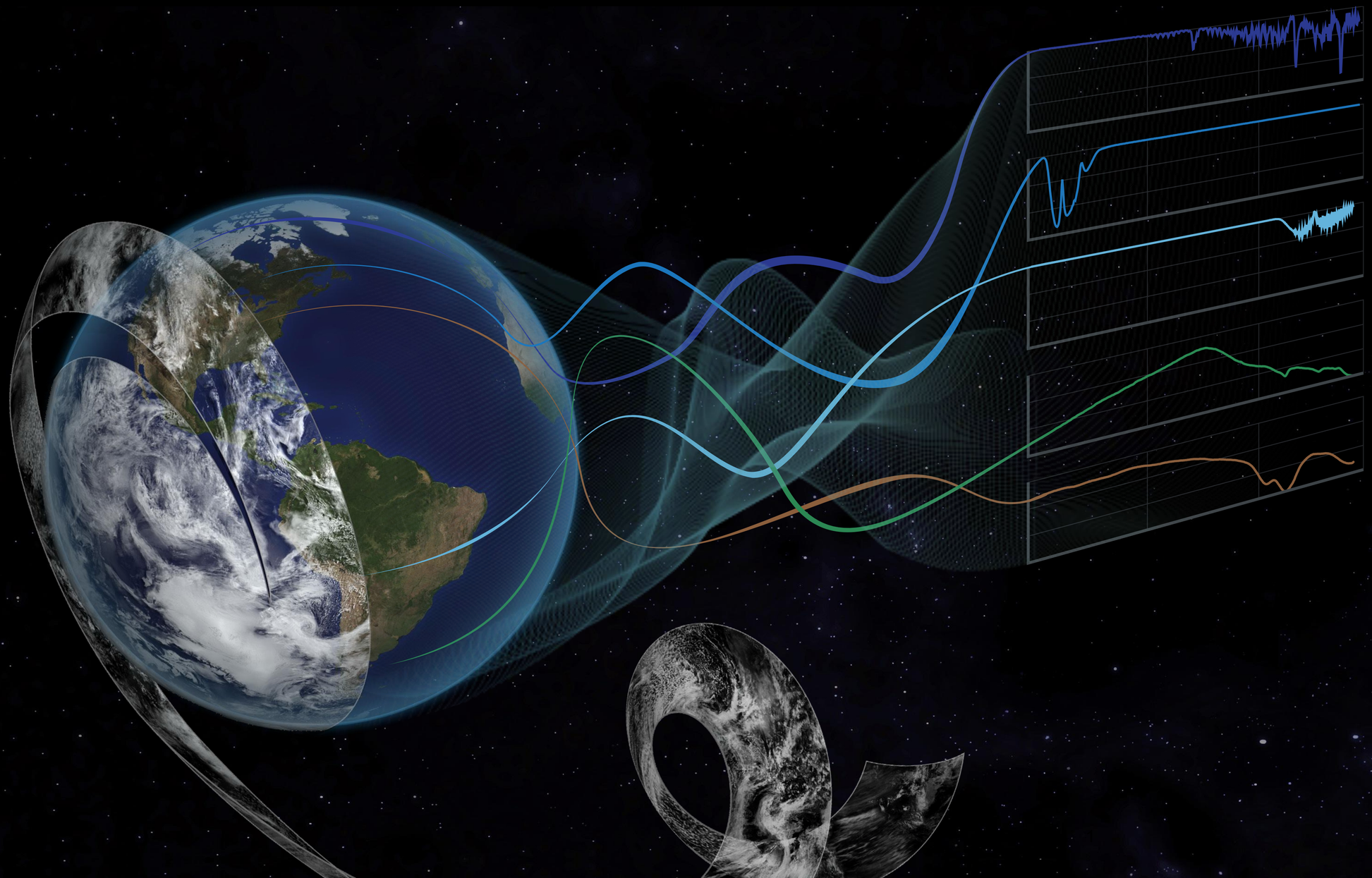
Phase A concept study for NASA's Earth System Explorer call

Christian Frankenberg, Anna Michalak

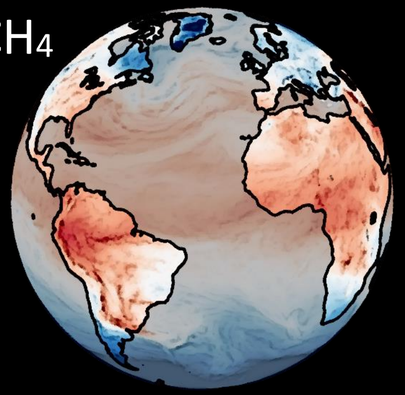
Science team:
Daniel J. Jacob, Andrew K Thorpe, Yi Yin, Lori Bruhwiler, Ermias Kebreab, Alison Hoyt, Alex J Turner, Paul O Wennberg, Robert O Green, Suniti Sanghavi, David R Thompson, Philip G Brodrick and Dana Chadwick

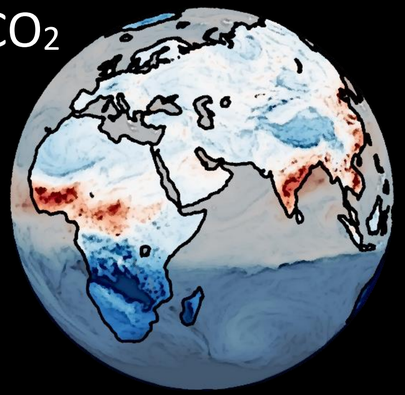
Instrument & Spacecraft teams:
JPL
Lockheed Martin

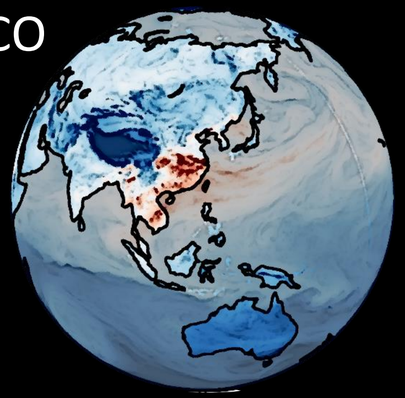
carbon-i.github.io



Carbon-I Mission Goals



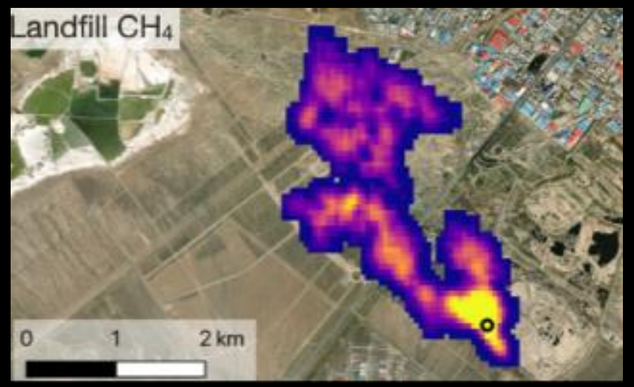




Science Objectives

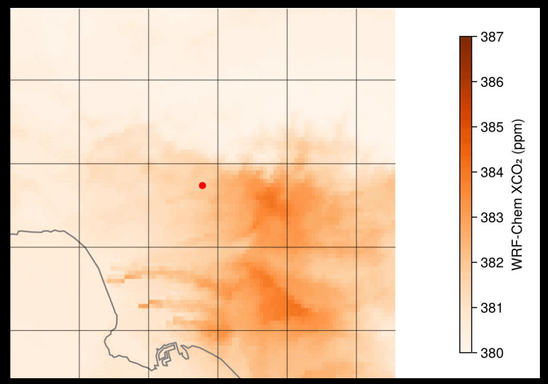
- identify CH_4,CO_2 and CO emission hotspots across the globe.
- quantify global monthly CH_4, CO_2, and CO fluxes at 12–100 km spatial resolution.
- attribute and quantify the processes driving both natural and anthropogenic emissions.

Point Source Scale



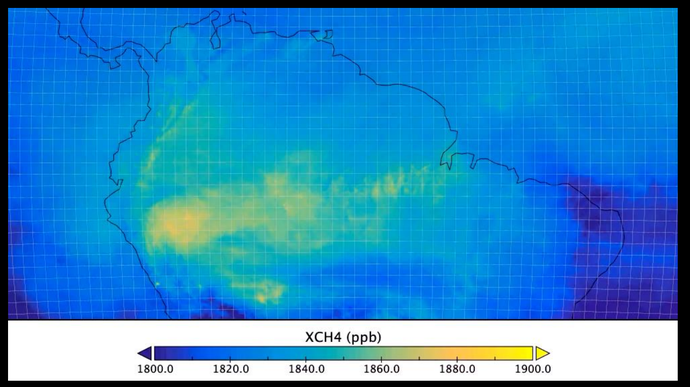
EMIT

Regional Scale



WRF-Chem
from Berkeley

Continental Scale



ECMWF Nature run

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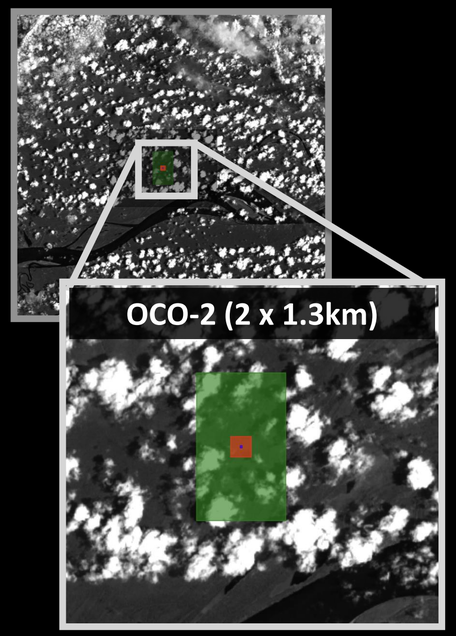
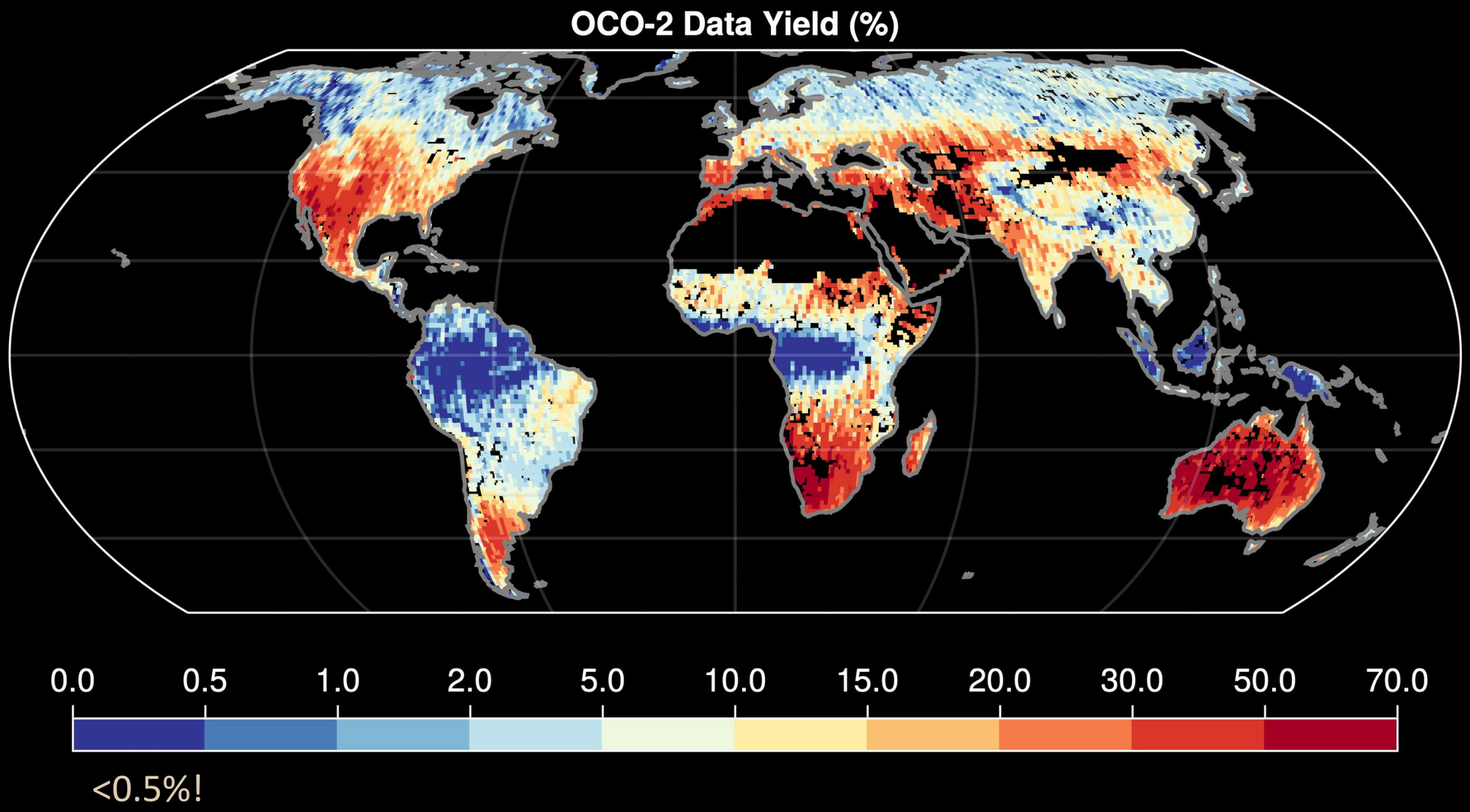
The problem in the humid tropics





Frankenberg, C., Bar-On, Y. M., Yin, Y., Wennberg, P. O., Jacob, D. J., & Michalak, A. M. (2024).
Data drought in the humid tropics: How to overcome the cloud barrier in greenhouse gas remote sensing.
Geophysical Research Letters

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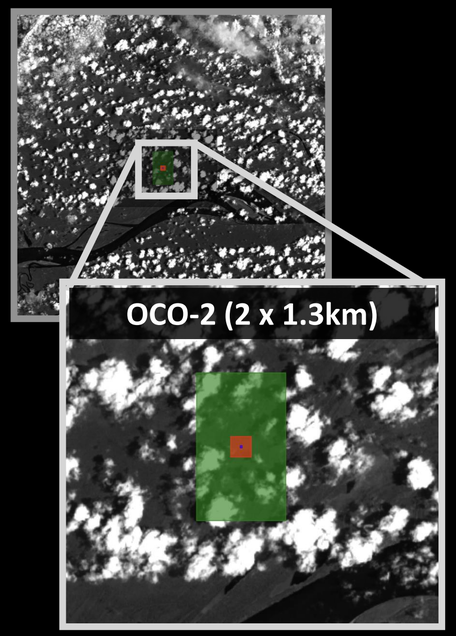
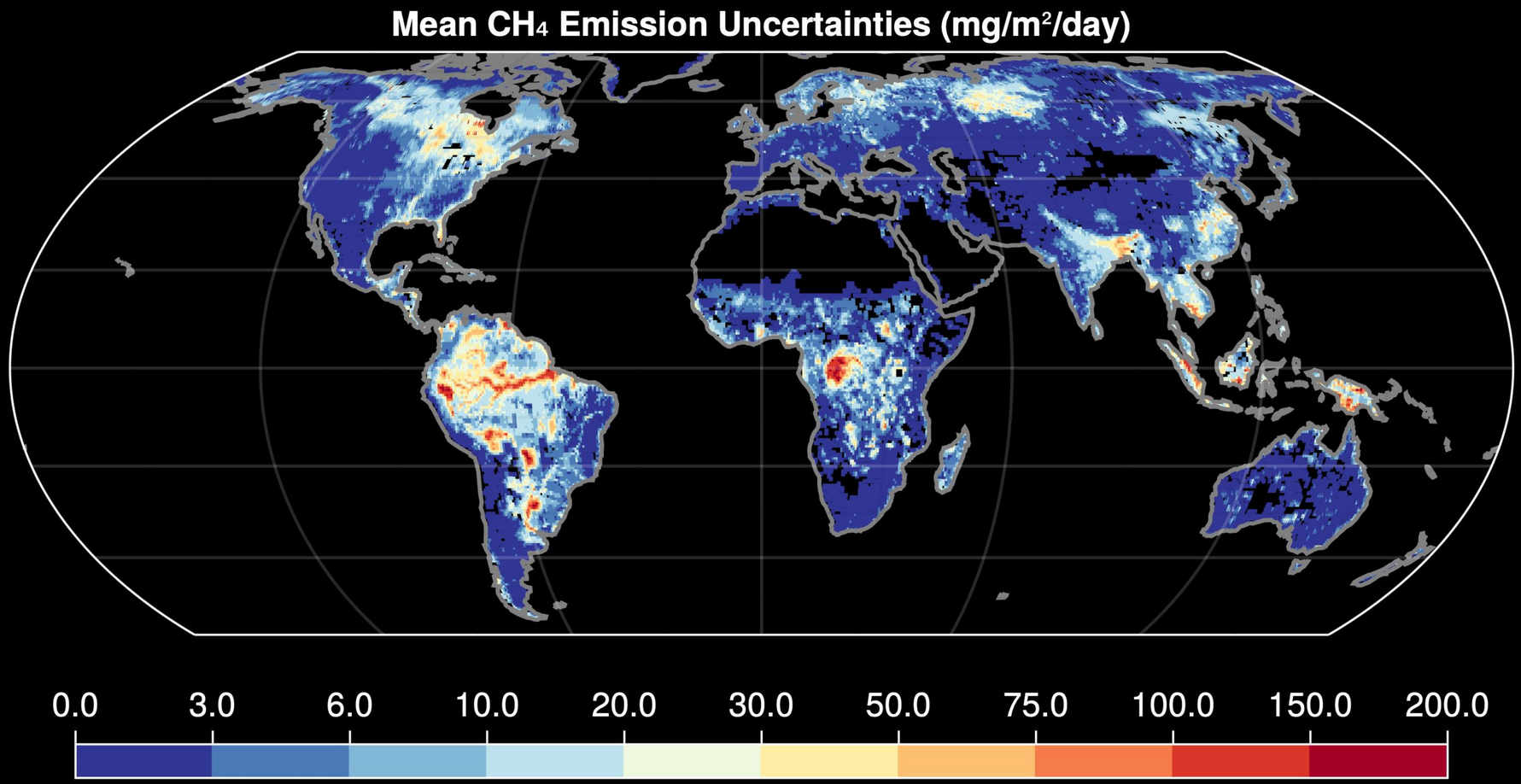
The problem in the humid tropics





Zhu, Qing, et al.
Advancements and opportunities to improve bottom-up estimates of global wetland methane emissions.
Environmental Research Letters (2025).

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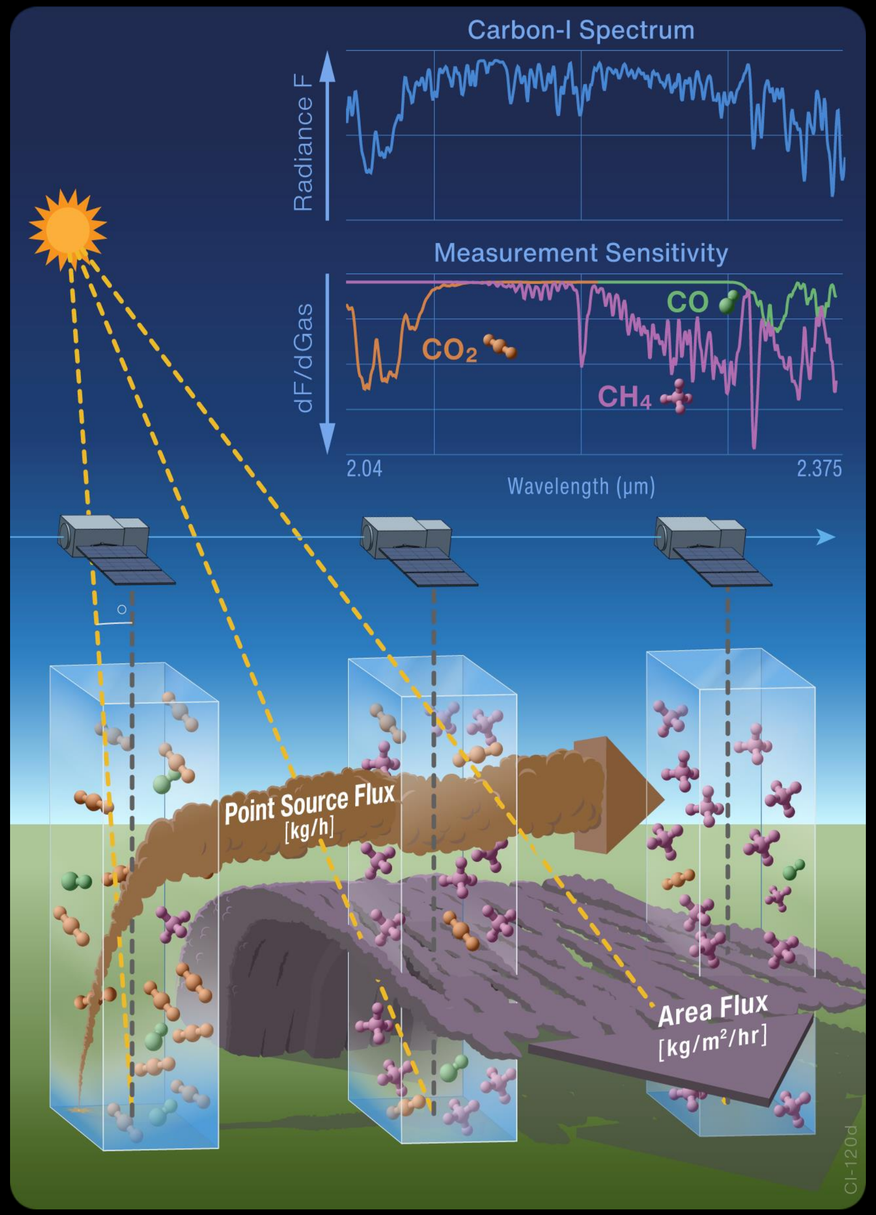
Basic Approach

Solar Absorption Spectroscopy
(enables high sensitivity towards the surface)

2-2.4µm spectral range
(enables high precision for CH_4, CO_2, and CO)

Point and Area Fluxes
(Differentiating source types)

Chemical Fingerprinting
(Multiple Gases)



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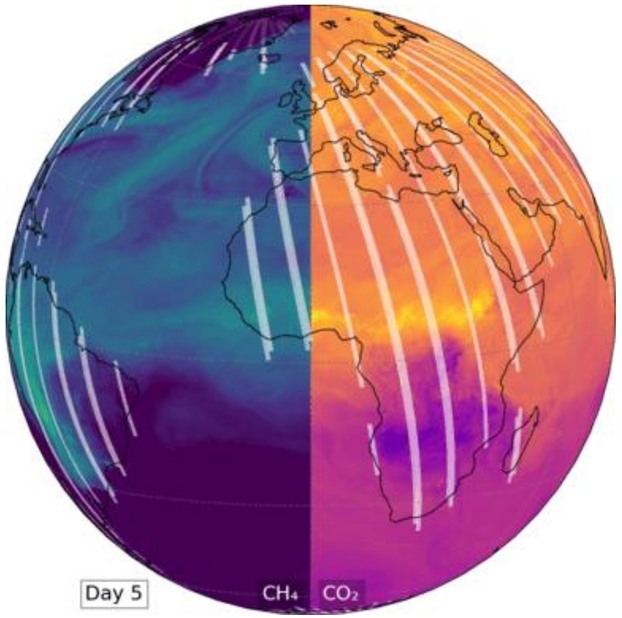
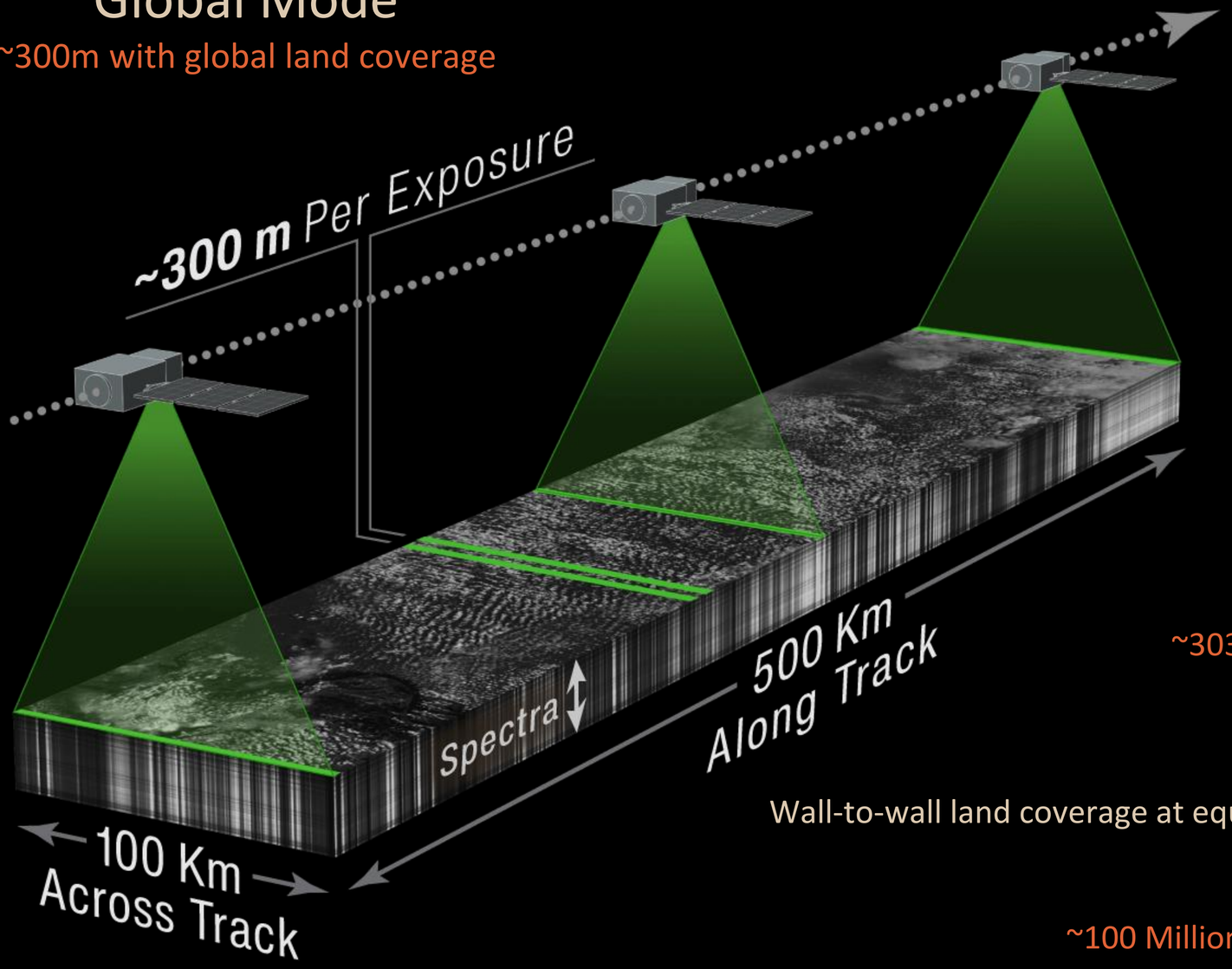
Bringing X_{CH_4}, X_{CO_2}, X_{CO} measurements to the <<1km scale

Orbit Simulations



Global Mode

~300m with global land coverage



~303m x 345m pixels

~103km swath

Wall-to-wall land coverage at equator with revisit every 28 days

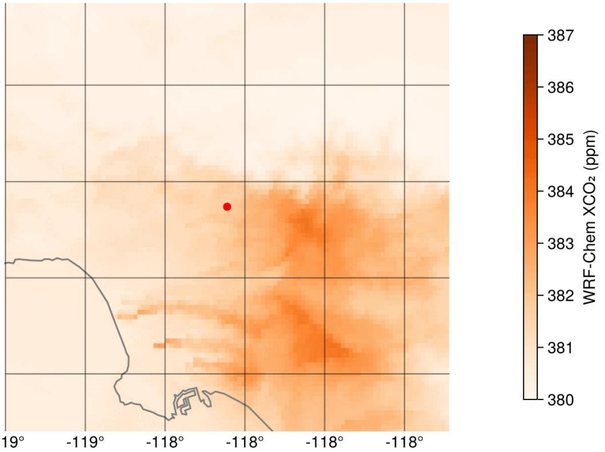
~100 Million spectra per day

CARBON-I

Bringing X_{CH_4}, X_{CO_2}, X_{CO} measurements to the <<100m scale

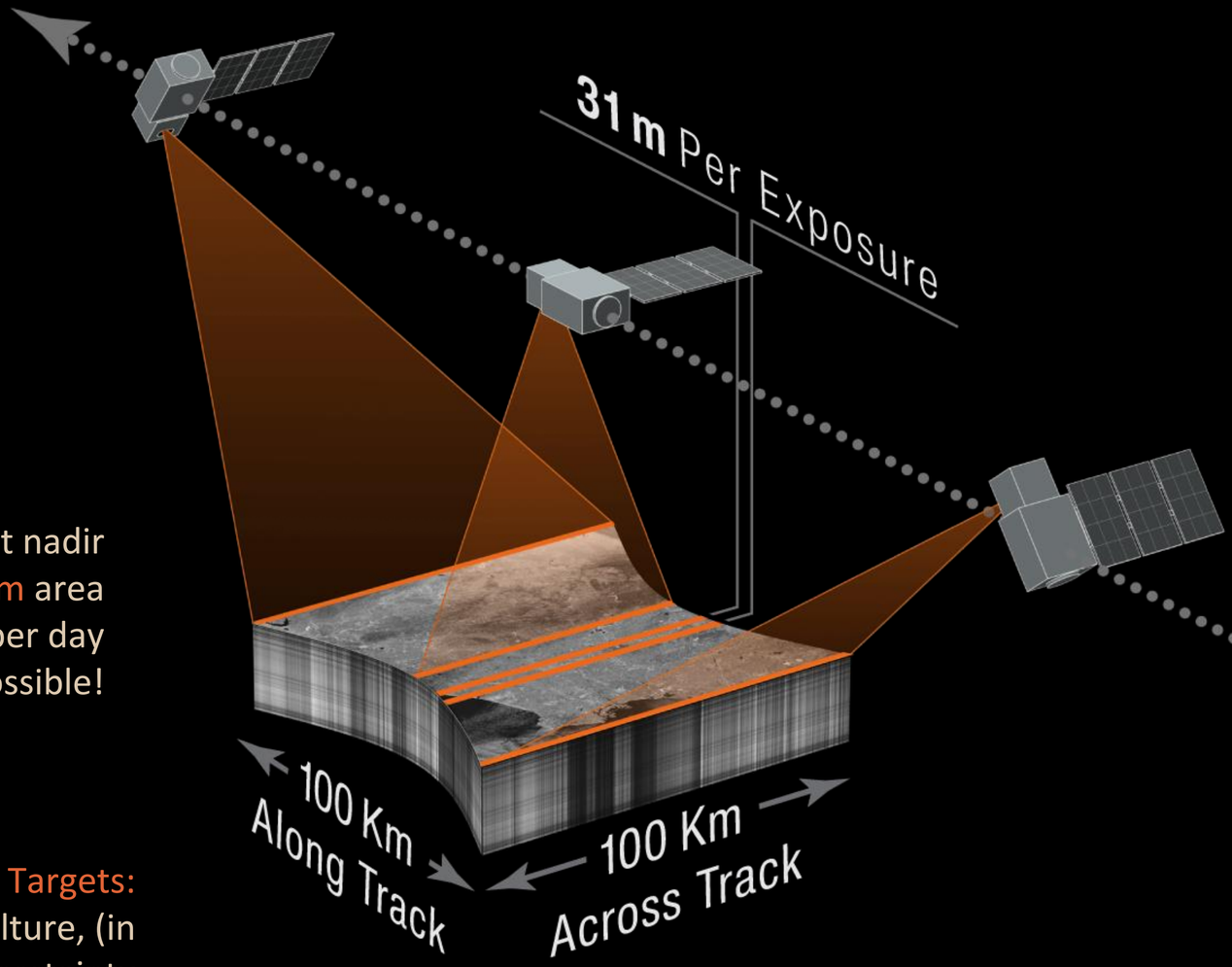
Los Angeles

1km simulations



Target Mode

<50m for regions of interest



~35m x 30m pixels at nadir
100km x 100km area
3 targets per day
Weekly revisits possible!

Representative Targets:
Wetlands, megacities, agriculture, (in general regions of highest uncertainty

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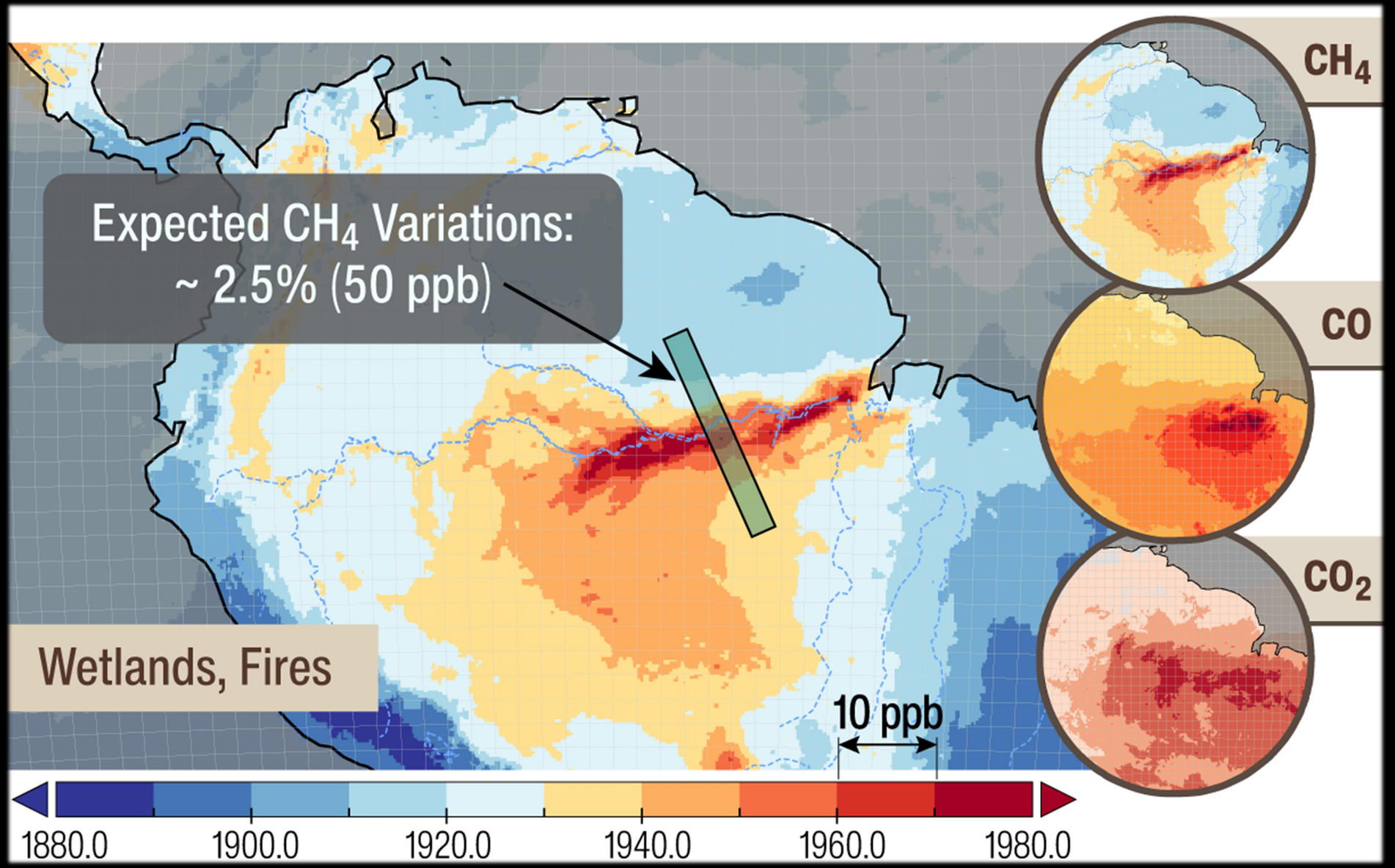
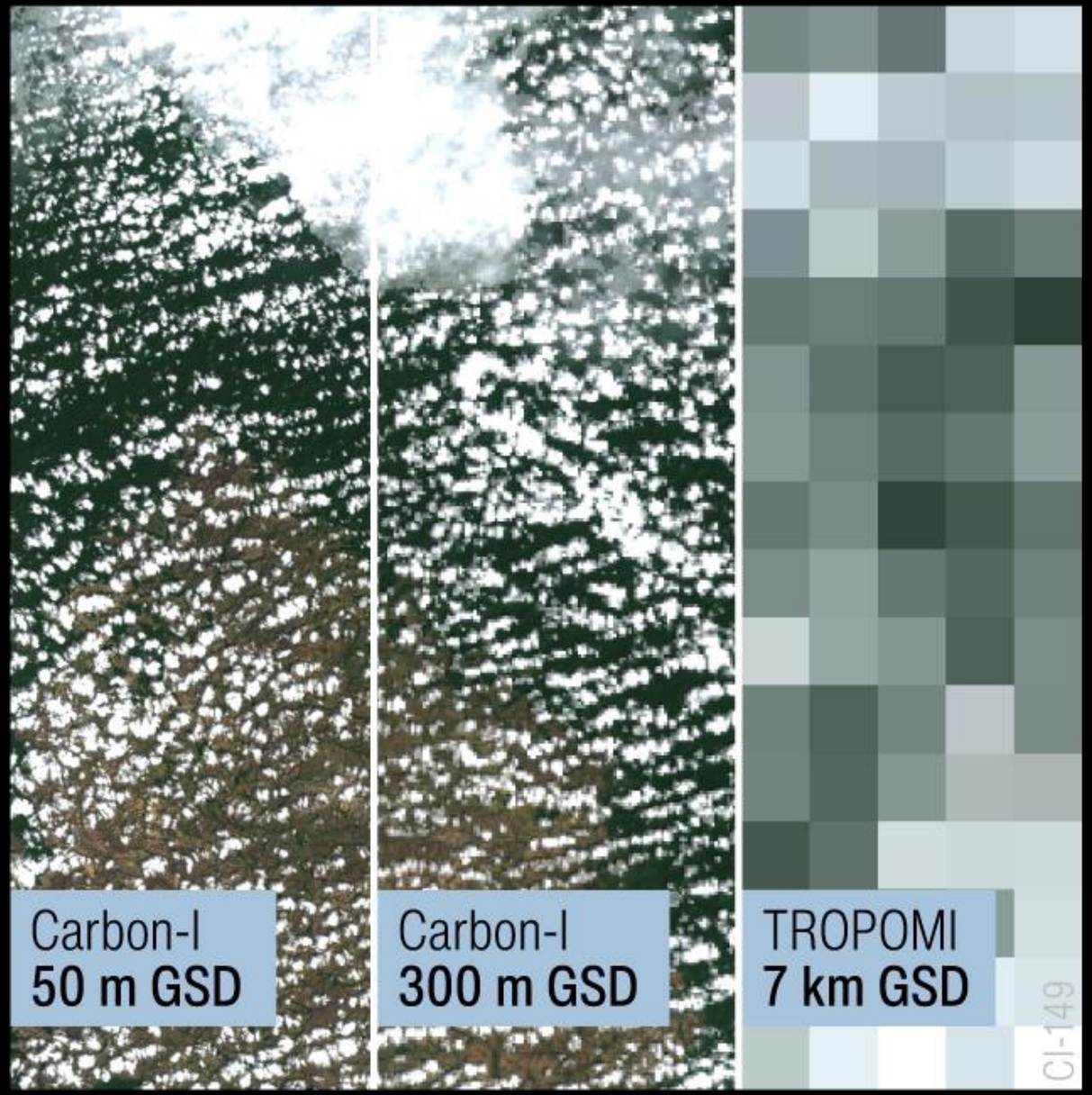
Global Fluxes

Tropical Wetlands — The Elephant in the room



Global Fluxes

Tropical Wetlands — The Elephant in the room



CARBON-I


Agricultural Fire in the Amazon
RGB Satellite Image
0
10
20
30
Kilometers
C1-004F

Closer to Home
Palisades and Eaton Fires

The Carbon-I Demonstrator Unit (CIDU)

- A functioning imaging spectrometer (in vacuum and temperature as in flight)
- Delivered under an aggressive schedule (October to February)
- Leveraged Additive Manufacturing/3D printing metal

Team

Christine Bradley, Adam Duran, Sven Geier, Michael Eastwood, Lucas Shaw, David Aldrich, Peter Sullivan, Quentin Vinckier, Tomas Seager, Mauricio Zuleta, Samad Firdosy… many more

Opto-mechanical team

–Jeff Wang, Daniel Millsaps, Pedro Moreira, Dustin Crumb

The Optical Design of the Carbon Investigation (Carbon-I) Imaging Spectrometer

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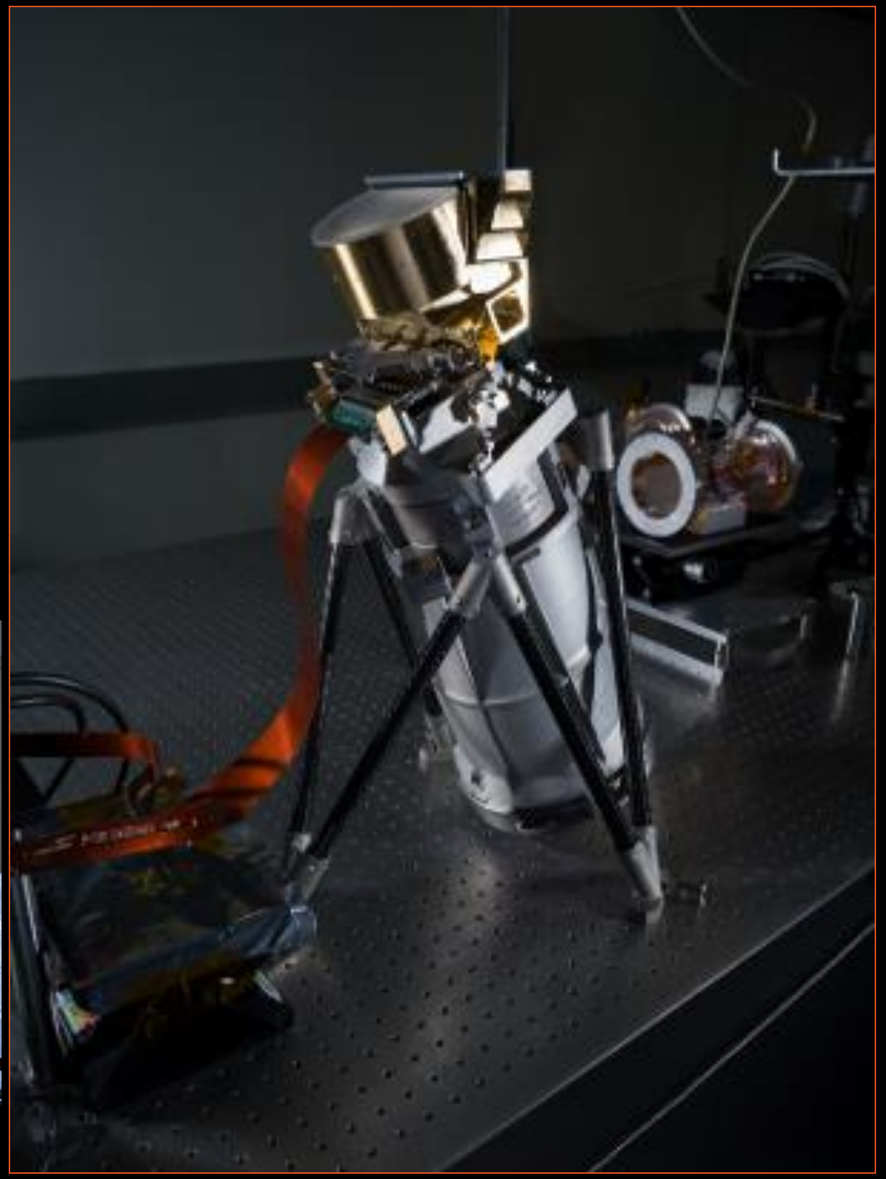
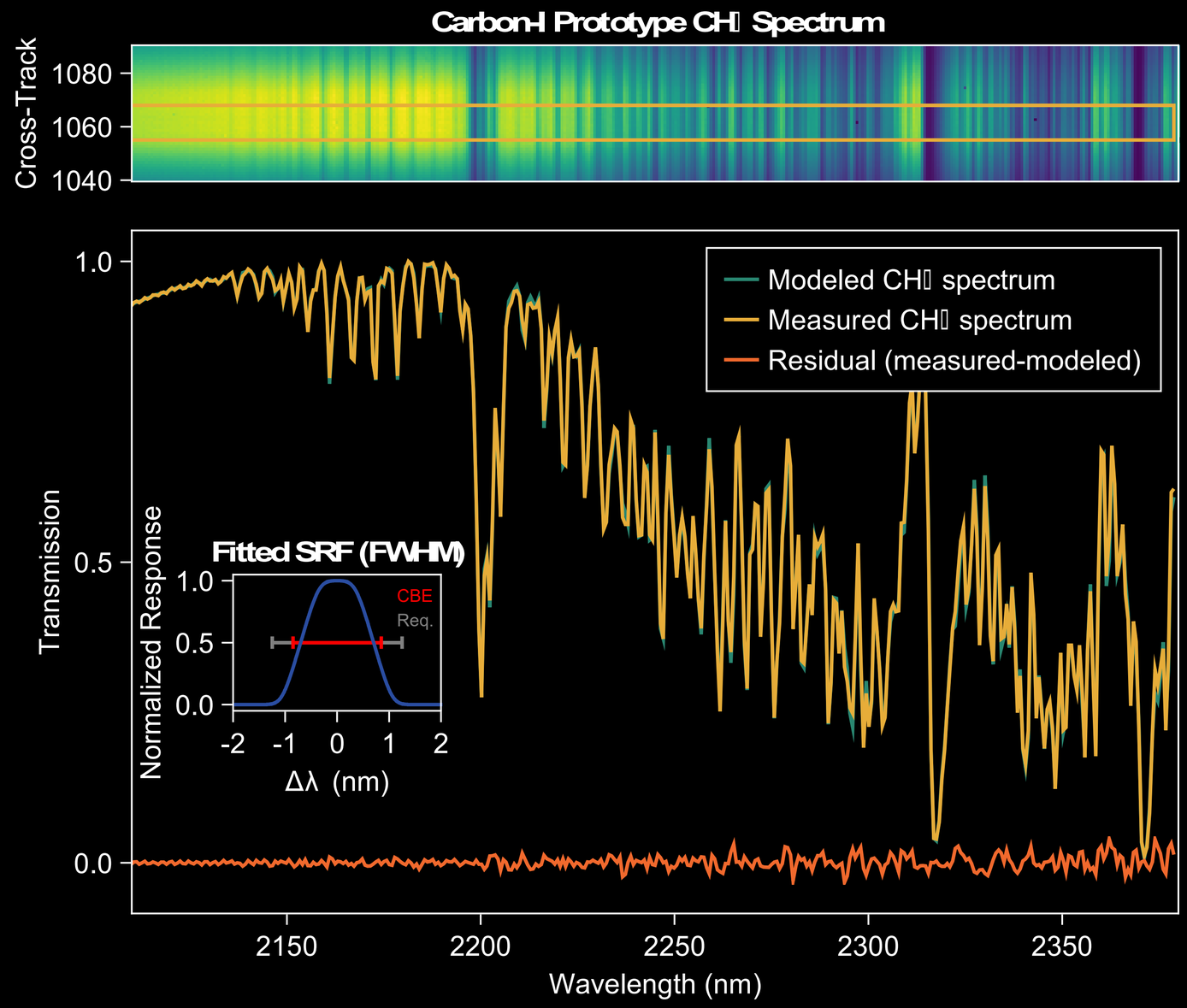


Bradley et al, IEEE 2025 Best Paper Award (https://doi.org/10.48550/arXiv.2505.22545 preprint)

Fitting a CIDU methane spectrum

- Methane gas cell in between light source and CIDU
- Fit of methane column and spectral calibration



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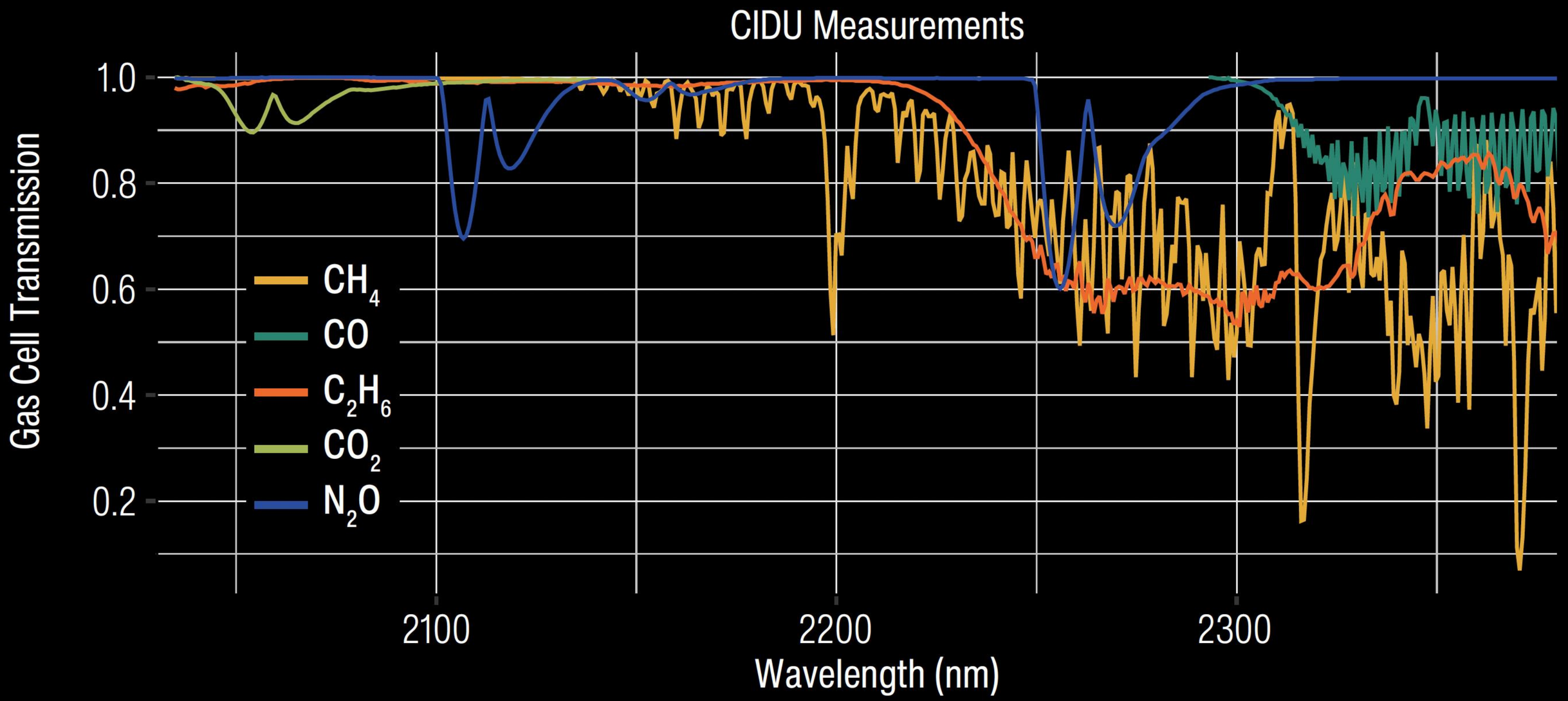
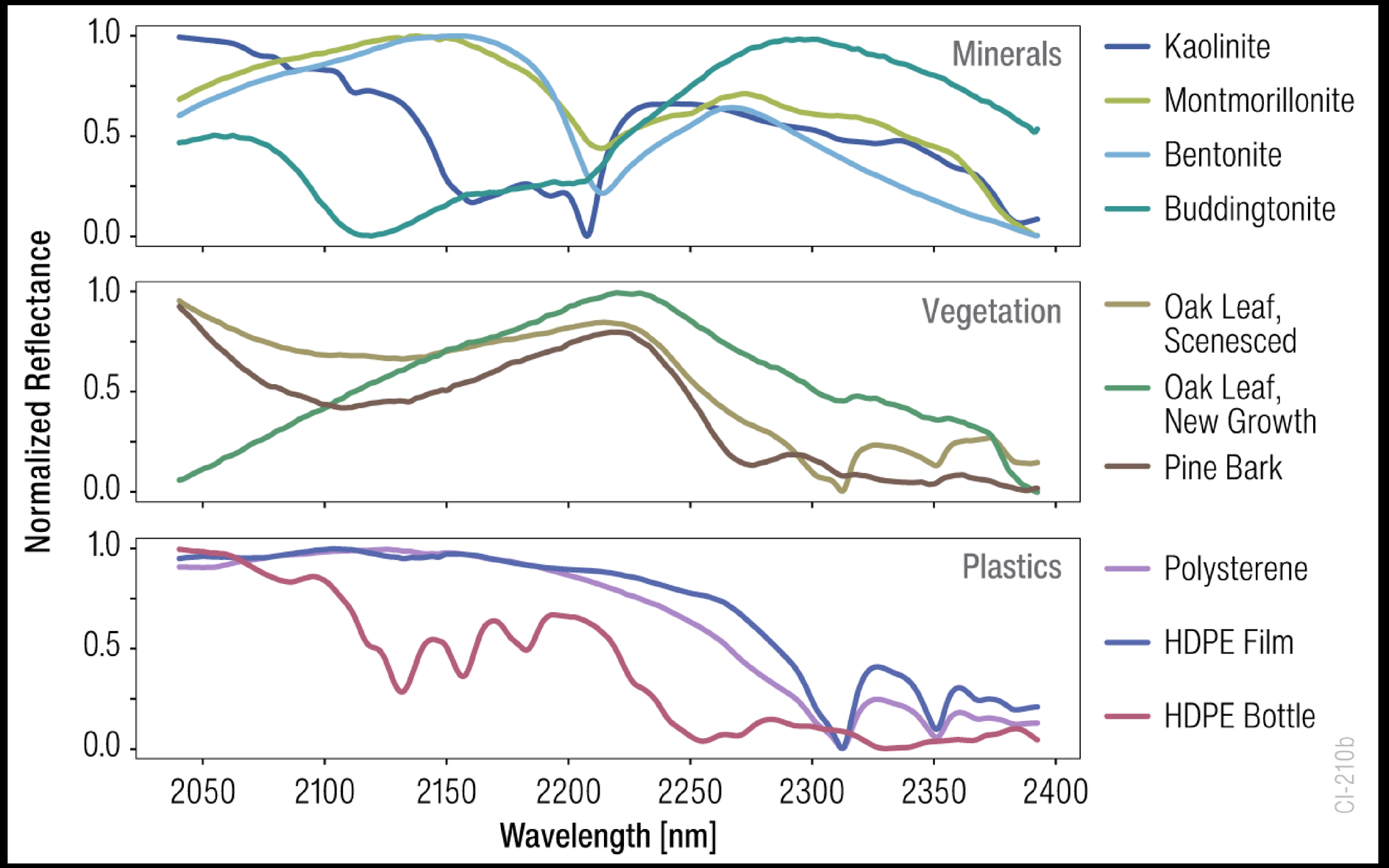
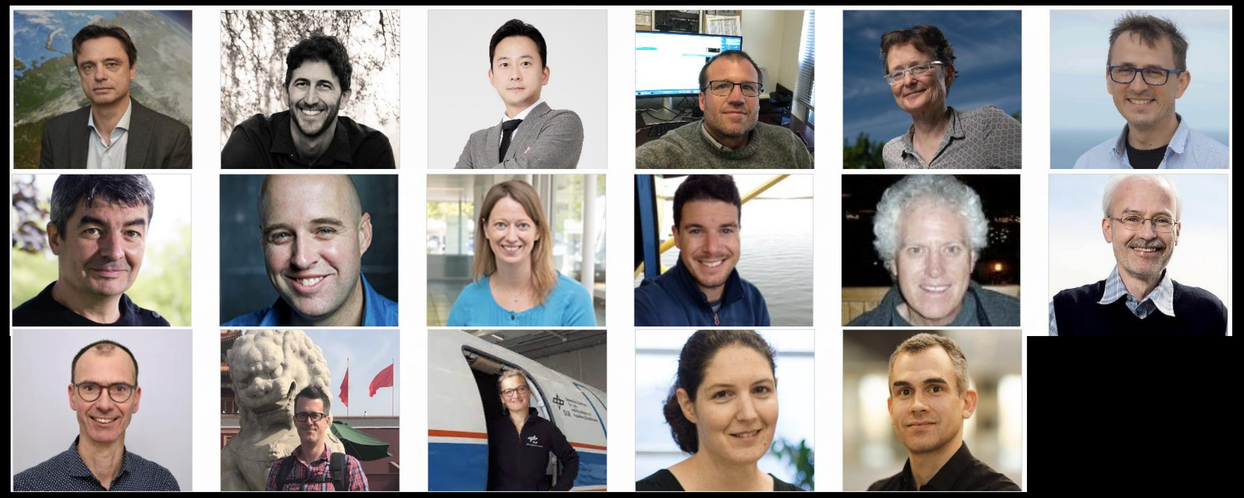
More CIDU Spectra



More than just trace gases (also measured by CIDU)



Questions?



And many more!!!