

CARBON-I

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

Christian Frankenberg, Anna Michalak

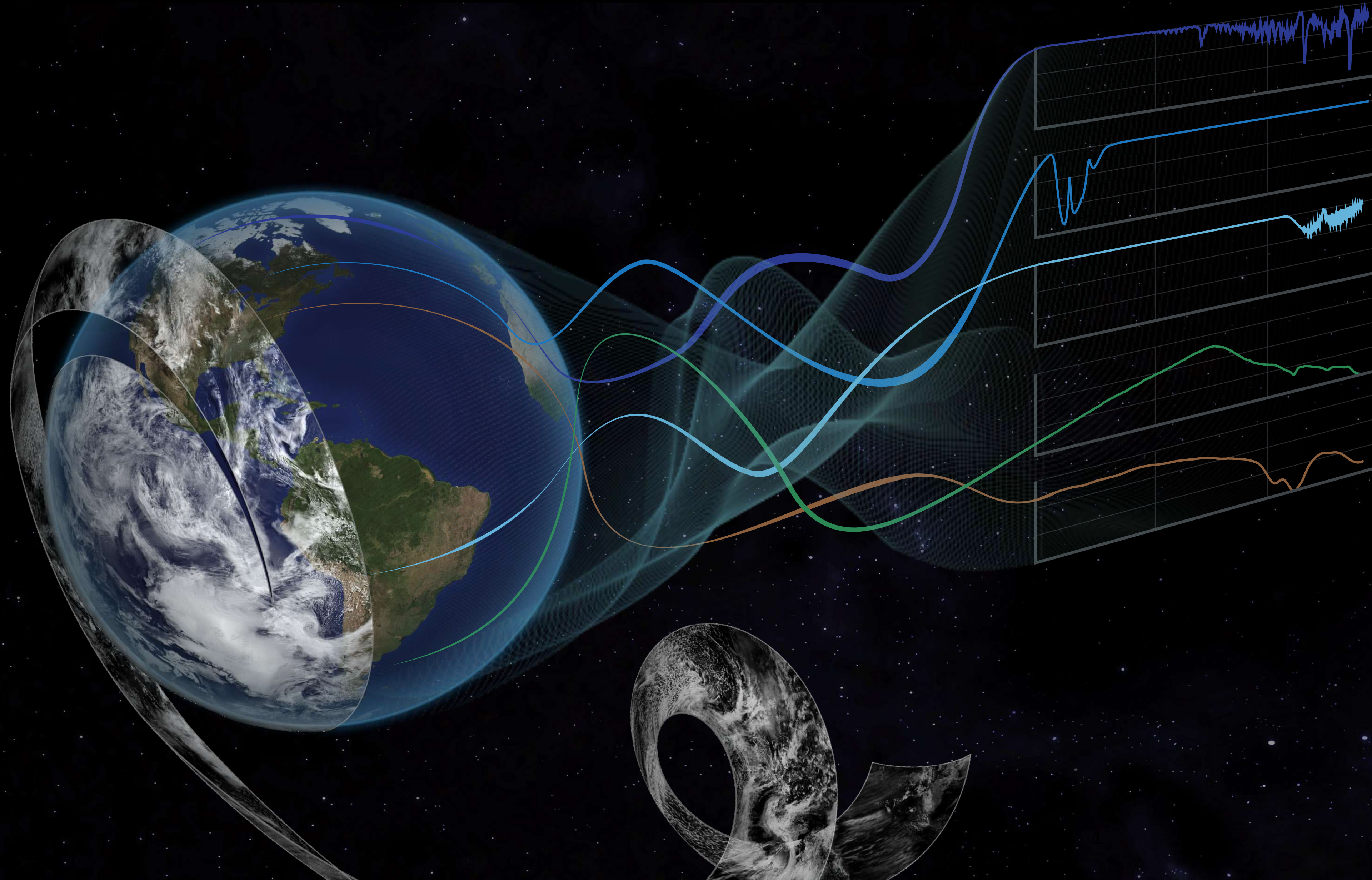
Science team:

Daniel J. Jacob, Andrew K Thorpe,
Yi Yin, Lori Bruhwiler, Ermias Kebeab, 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

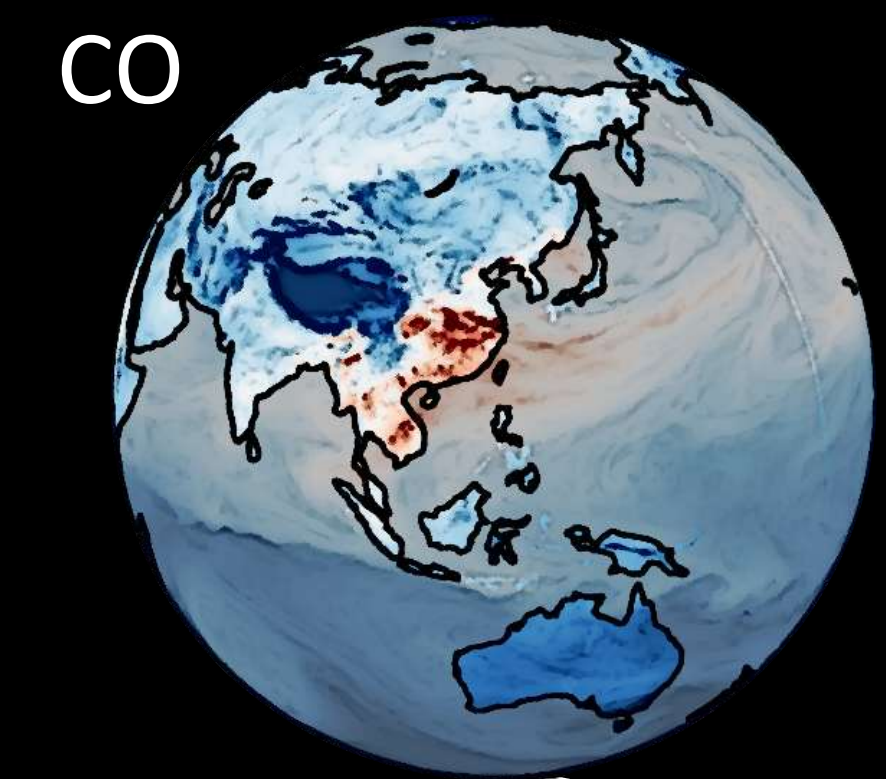
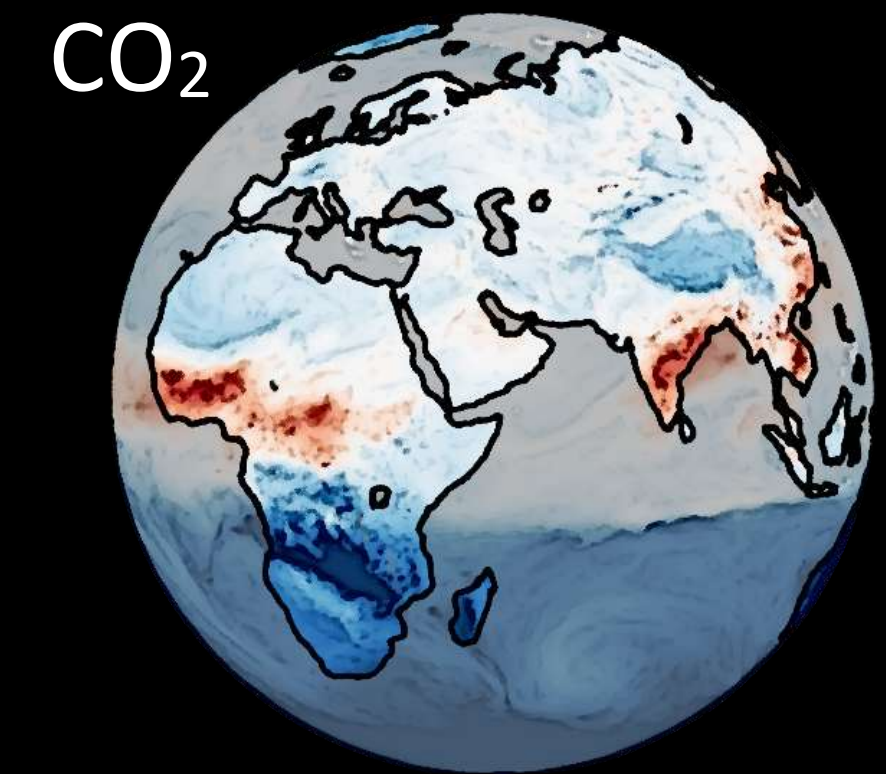
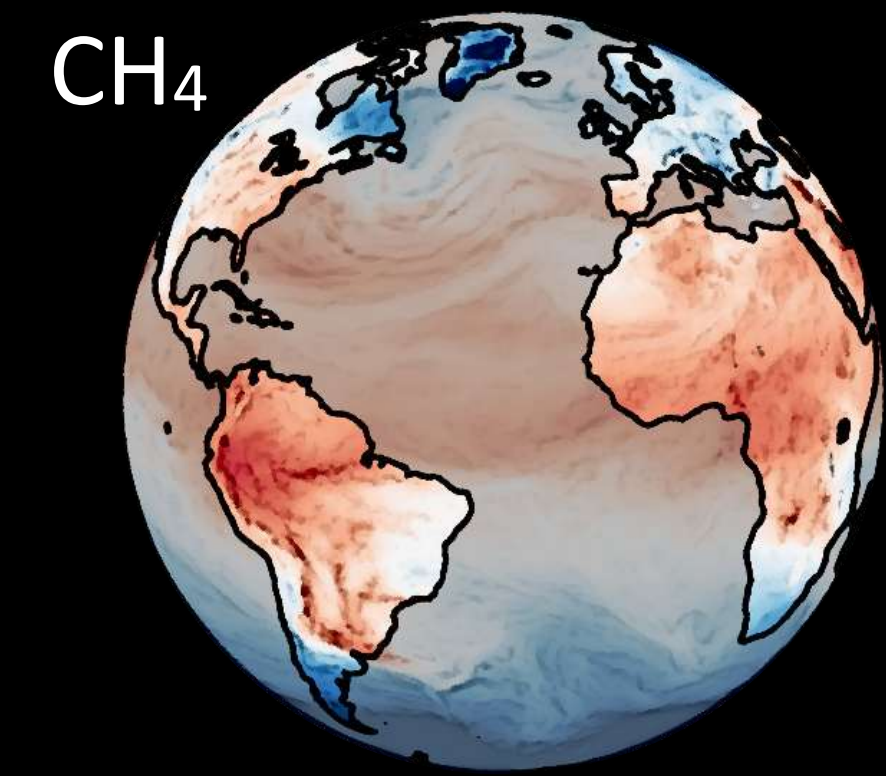
carbon-i.github.io



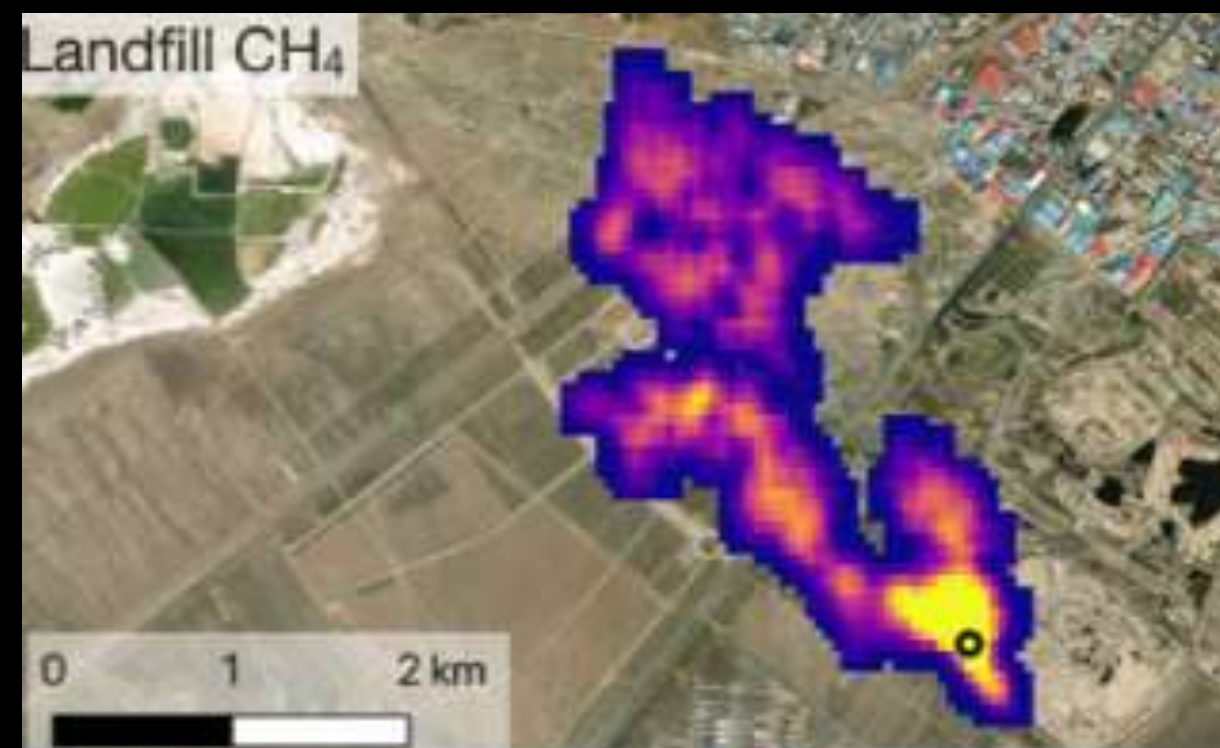
Carbon-I Mission Goals

Science Objectives

- identify CH₄, CO₂ and CO emission hotspots across the globe.
- quantify global monthly CH₄, CO₂, and CO fluxes at 12–100 km spatial resolution.
- attribute and quantify the processes driving both natural and anthropogenic emissions.

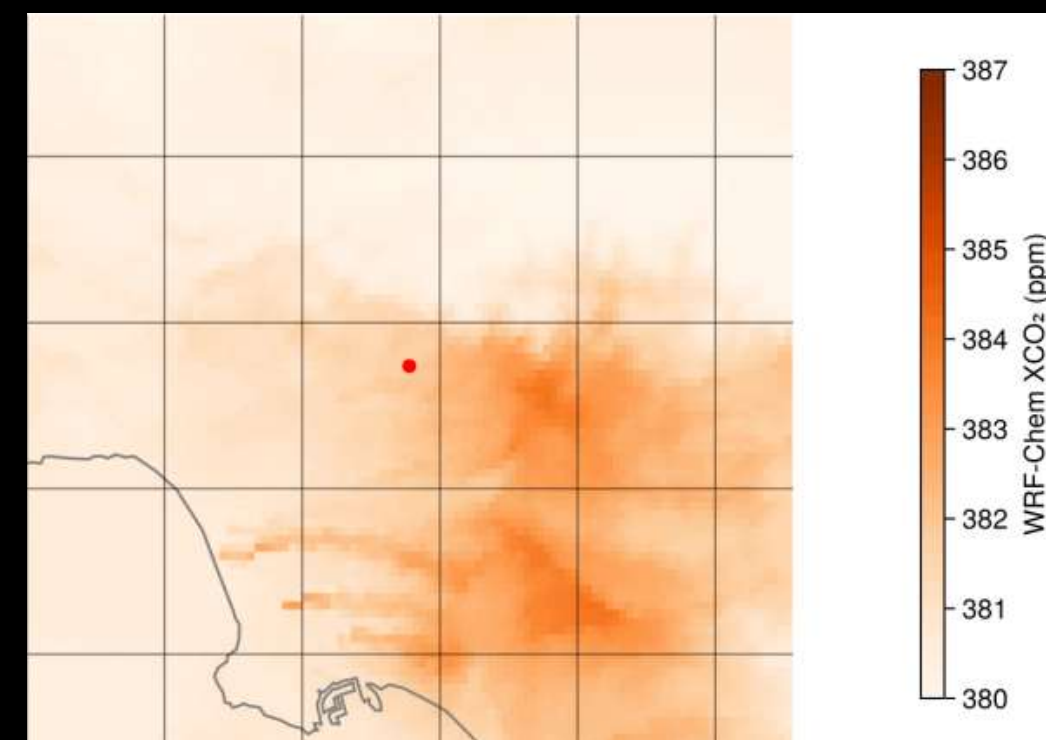


Point Source Scale



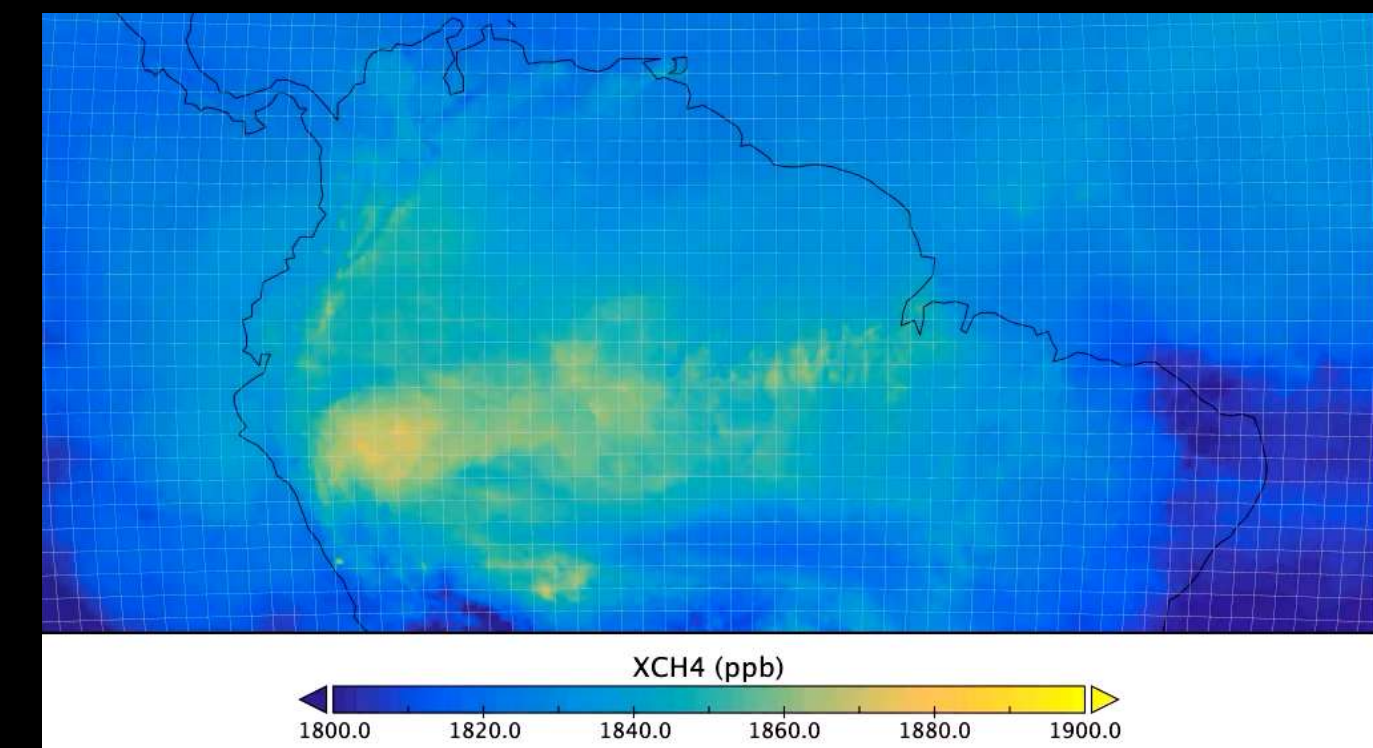
EMIT

Regional Scale



WRF-Chem
from Berkeley

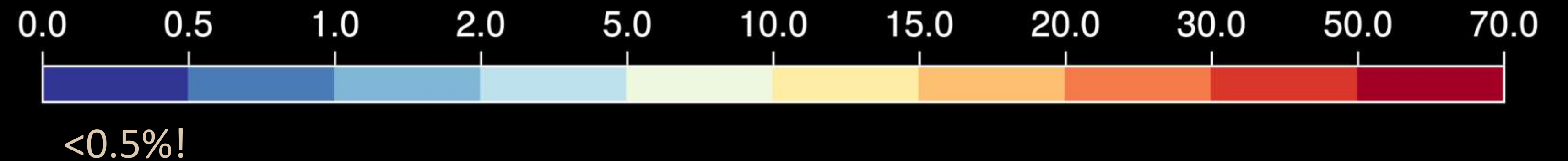
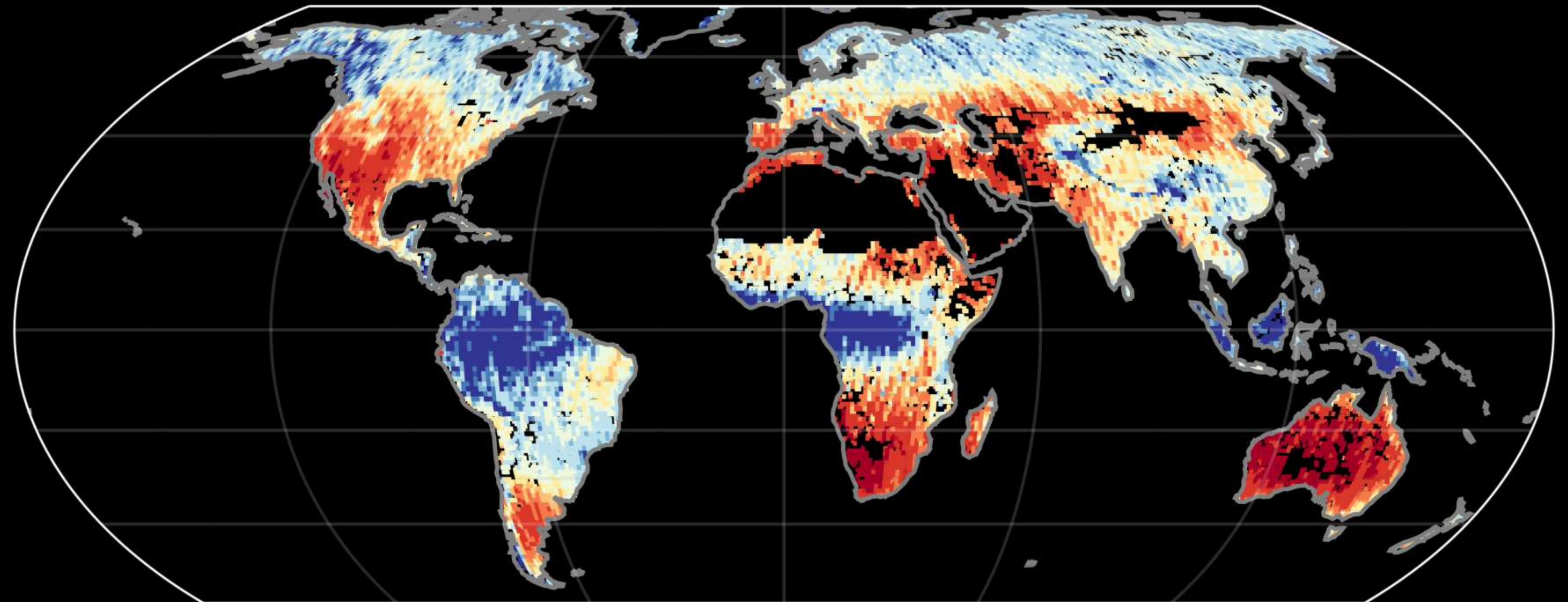
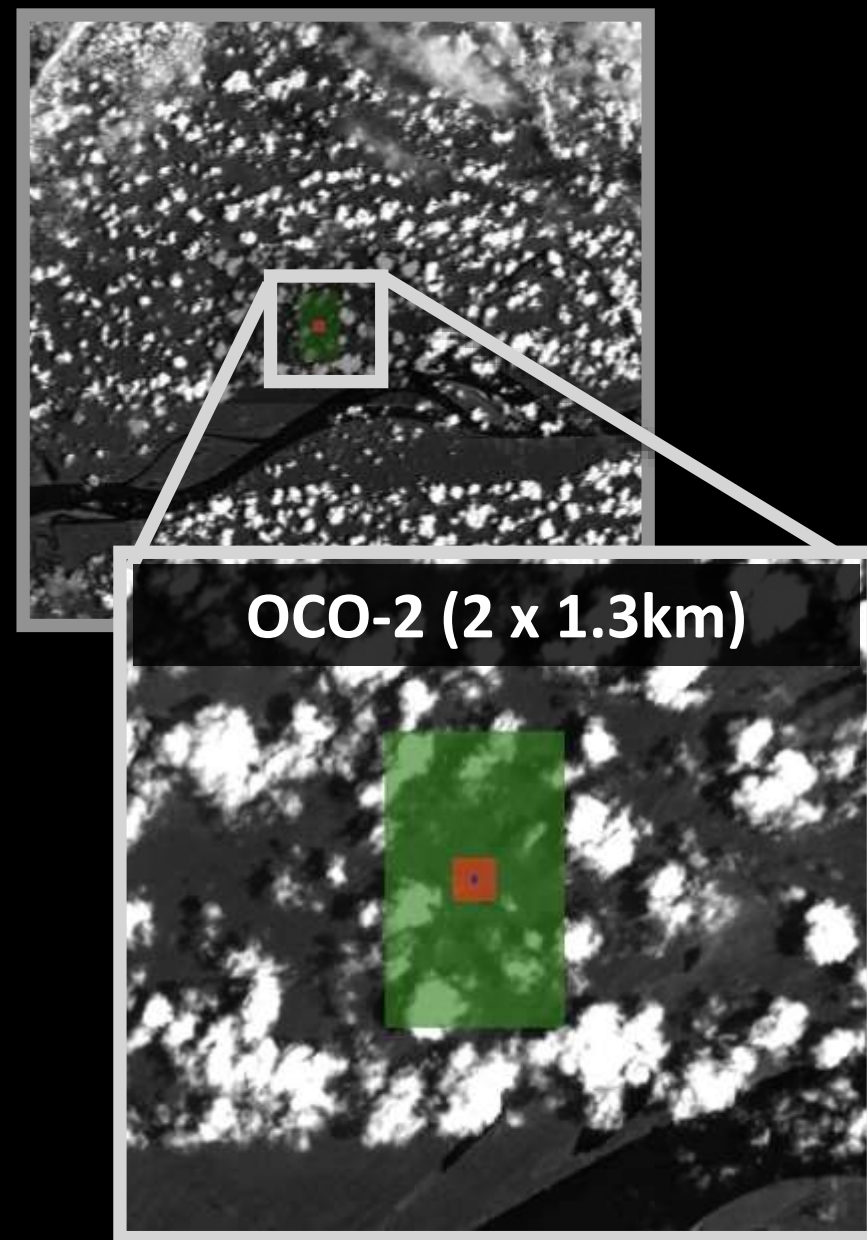
Continental Scale



ECMWF Nature run

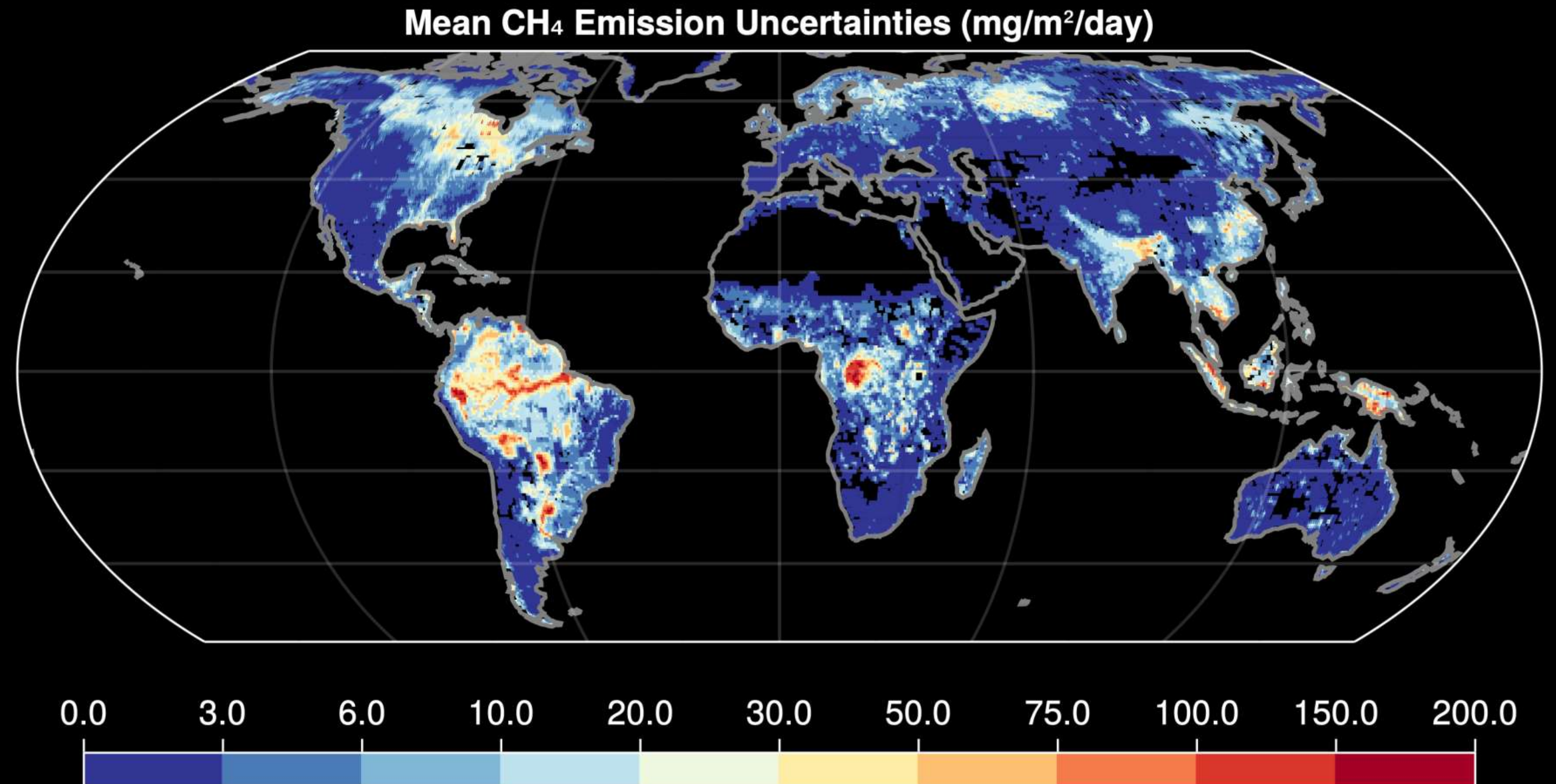
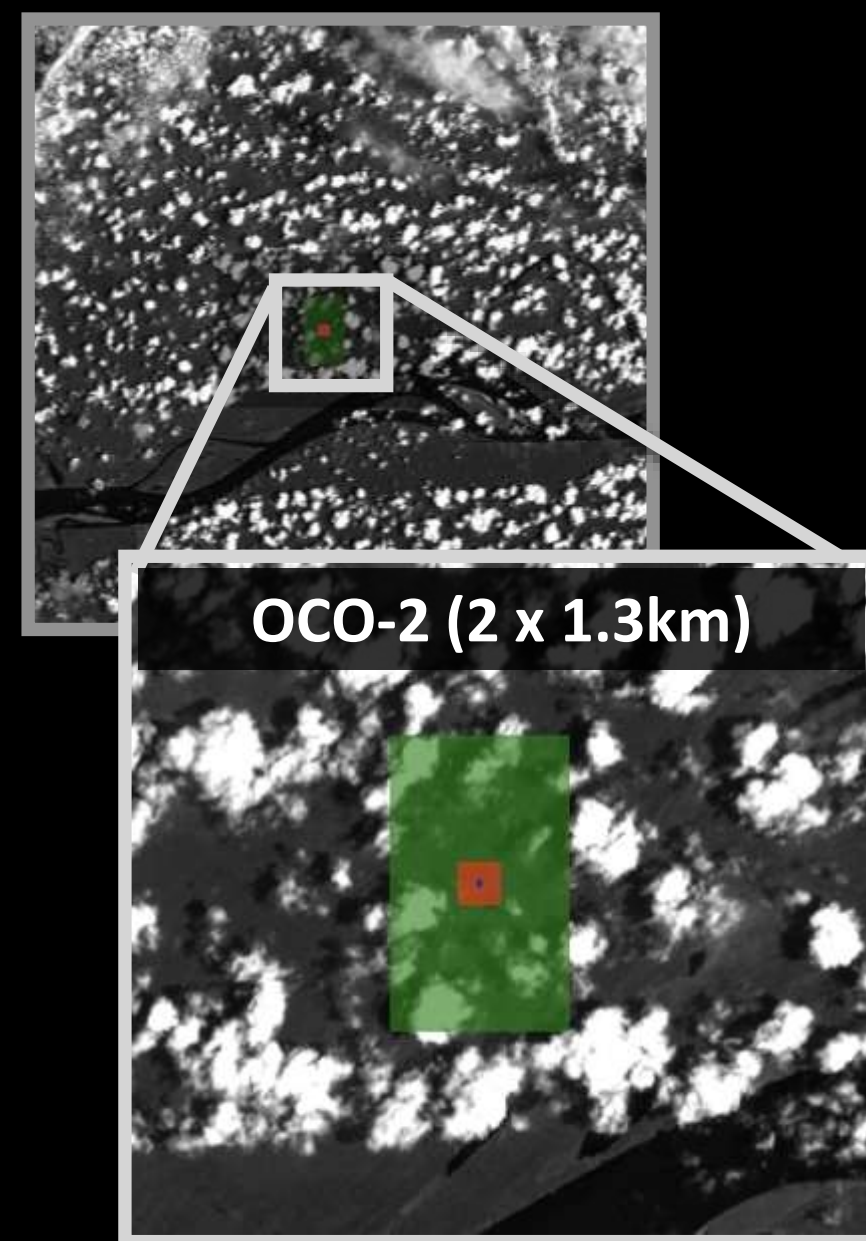
The problem in the humid tropics

OCO-2 Data Yield (%)



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

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).

Basic Approach

Solar Absorption Spectroscopy

(enables high sensitivity towards the surface)

2-2.4 μm spectral range

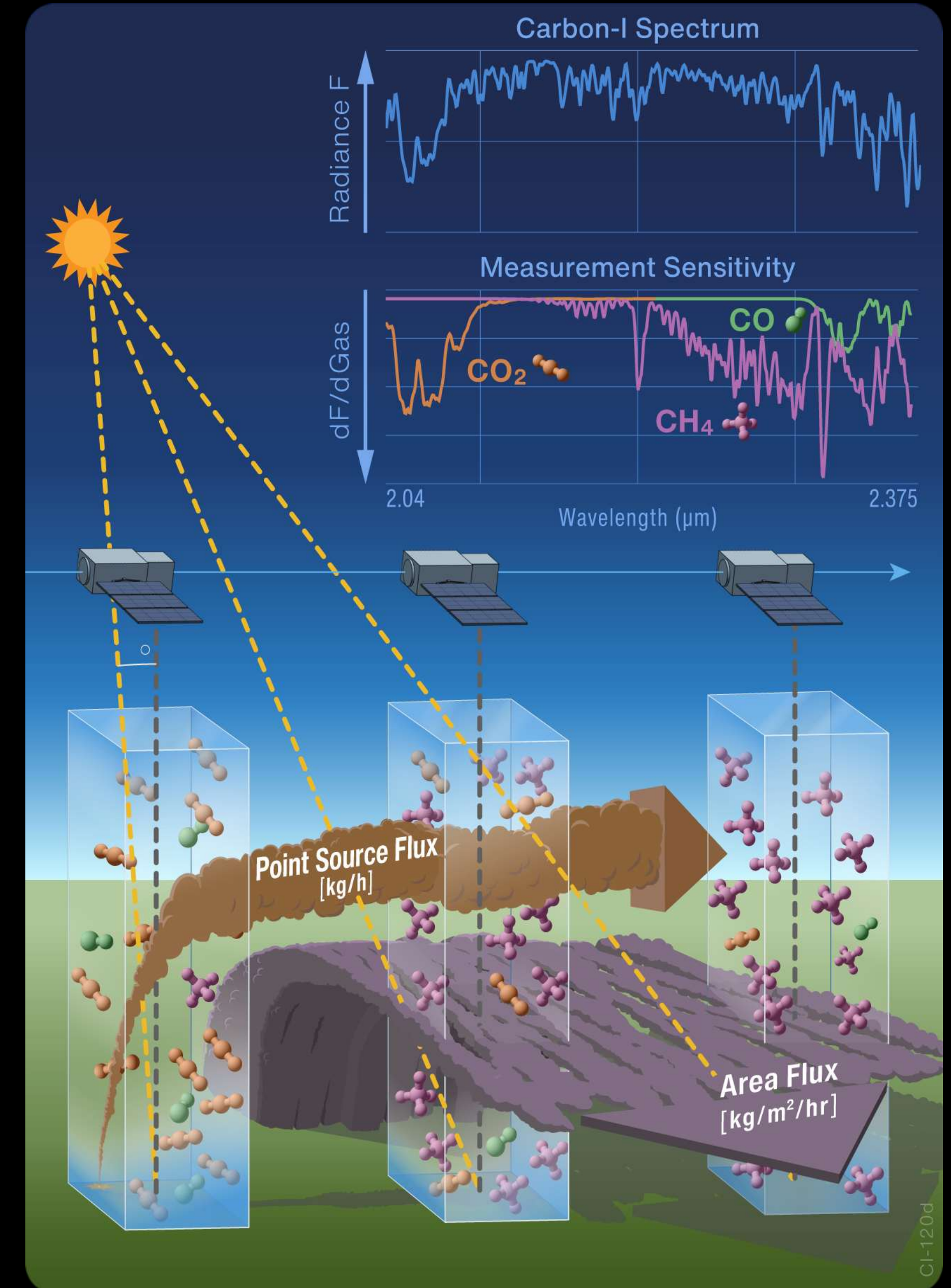
(enables high precision for CH_4 , CO_2 , and CO)

Point and Area Fluxes

(Differentiating source types)

Chemical Fingerprinting

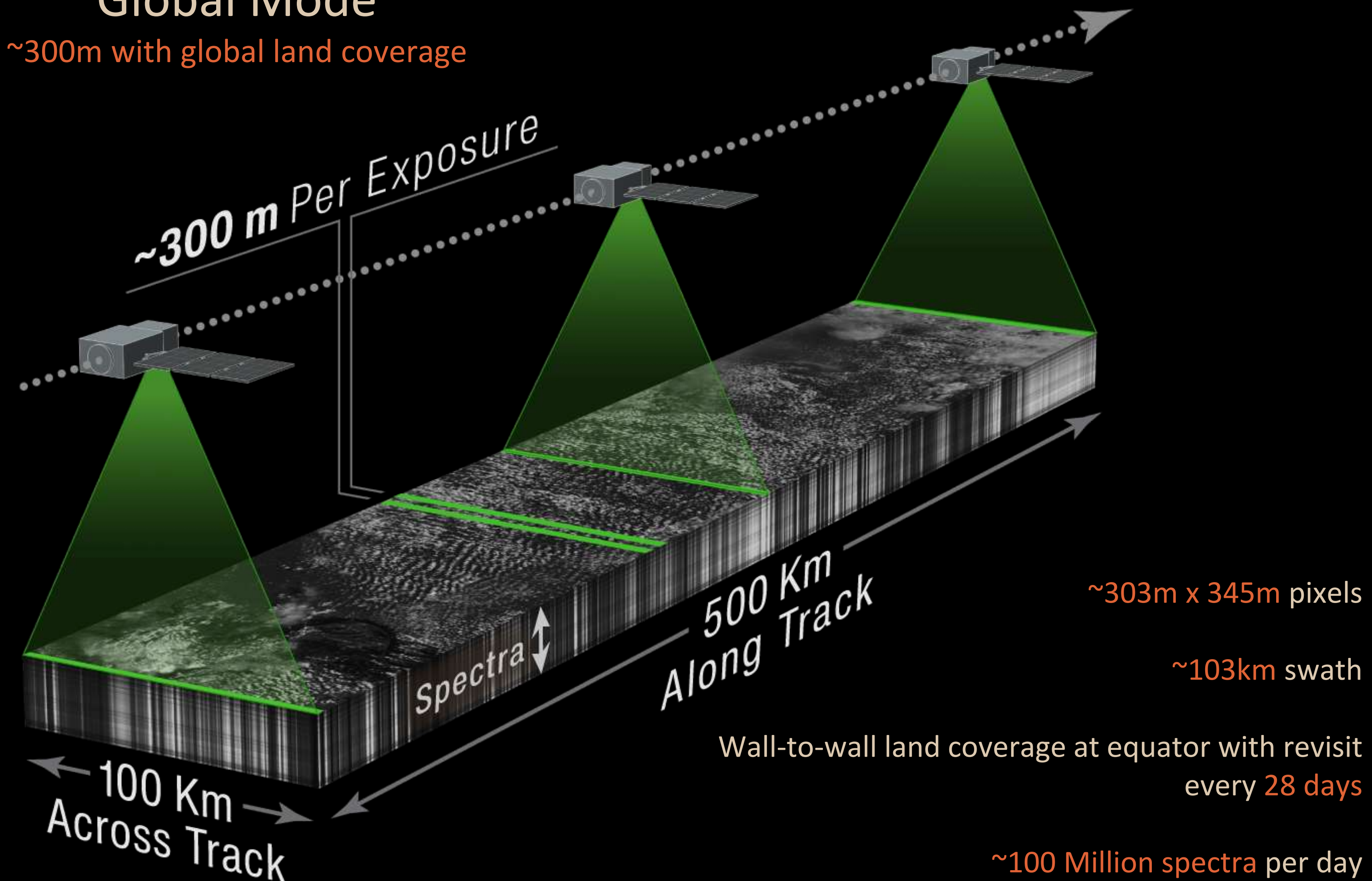
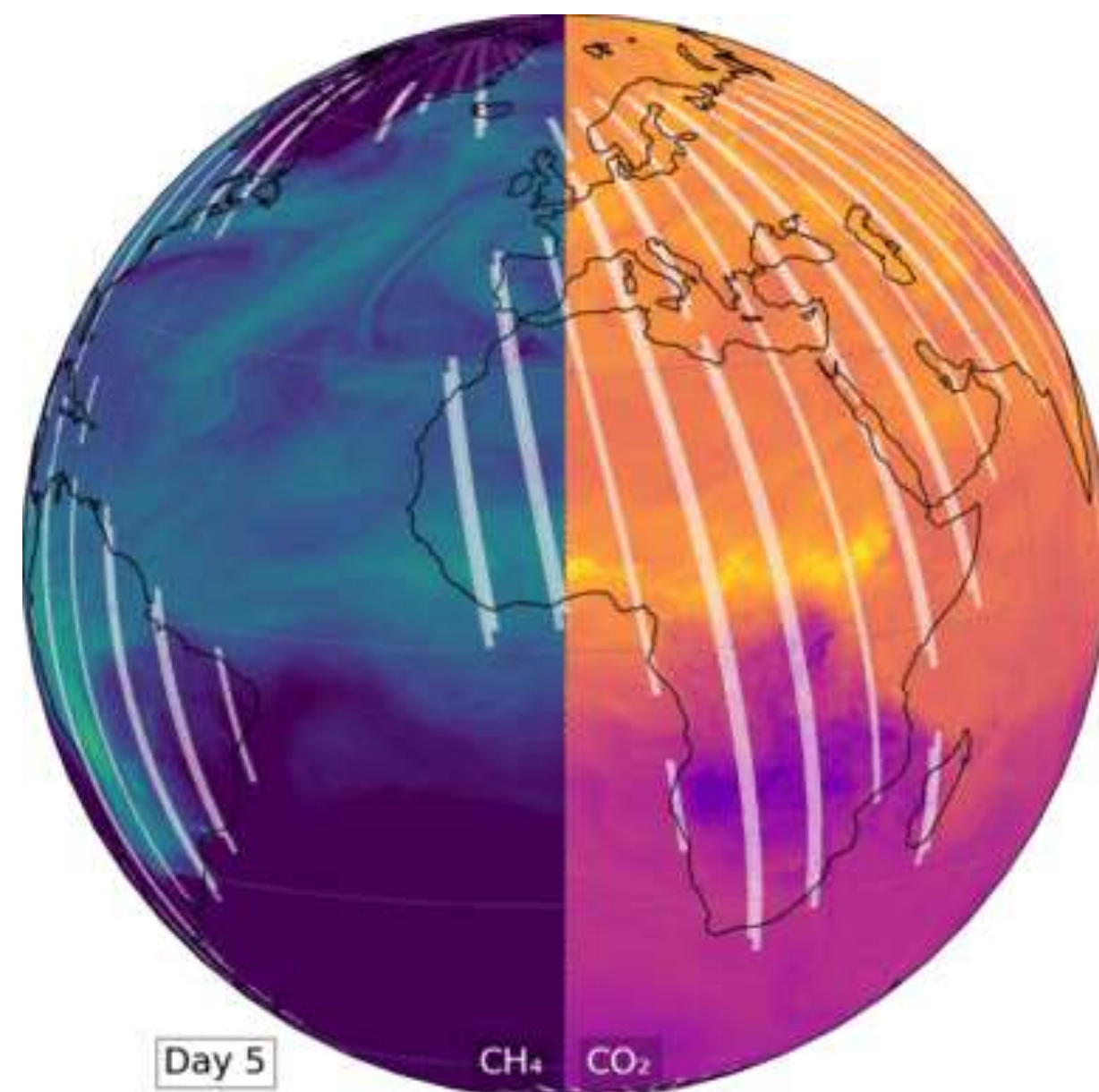
(Multiple Gases)



Global Mode

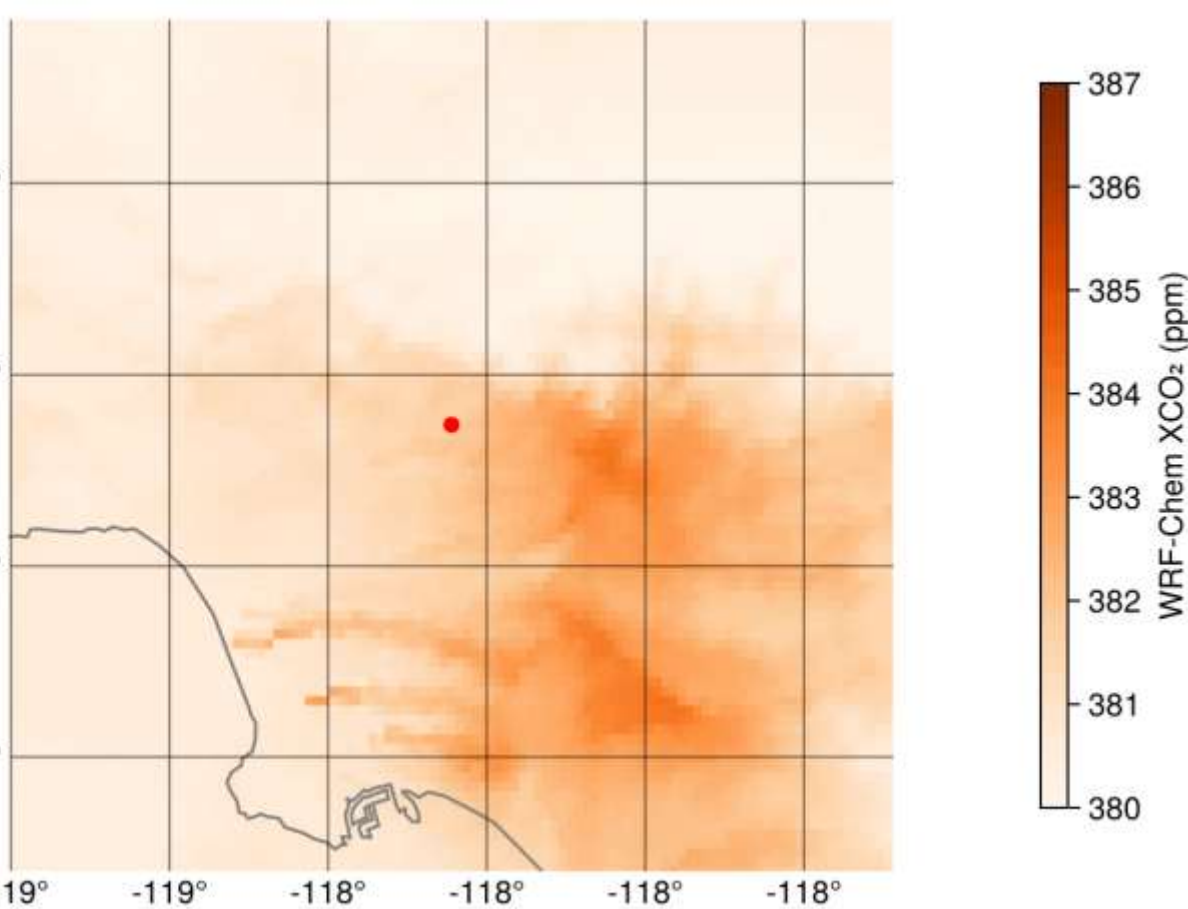
$\sim 300\text{m}$ with global land coverage

Orbit Simulations



Los Angeles

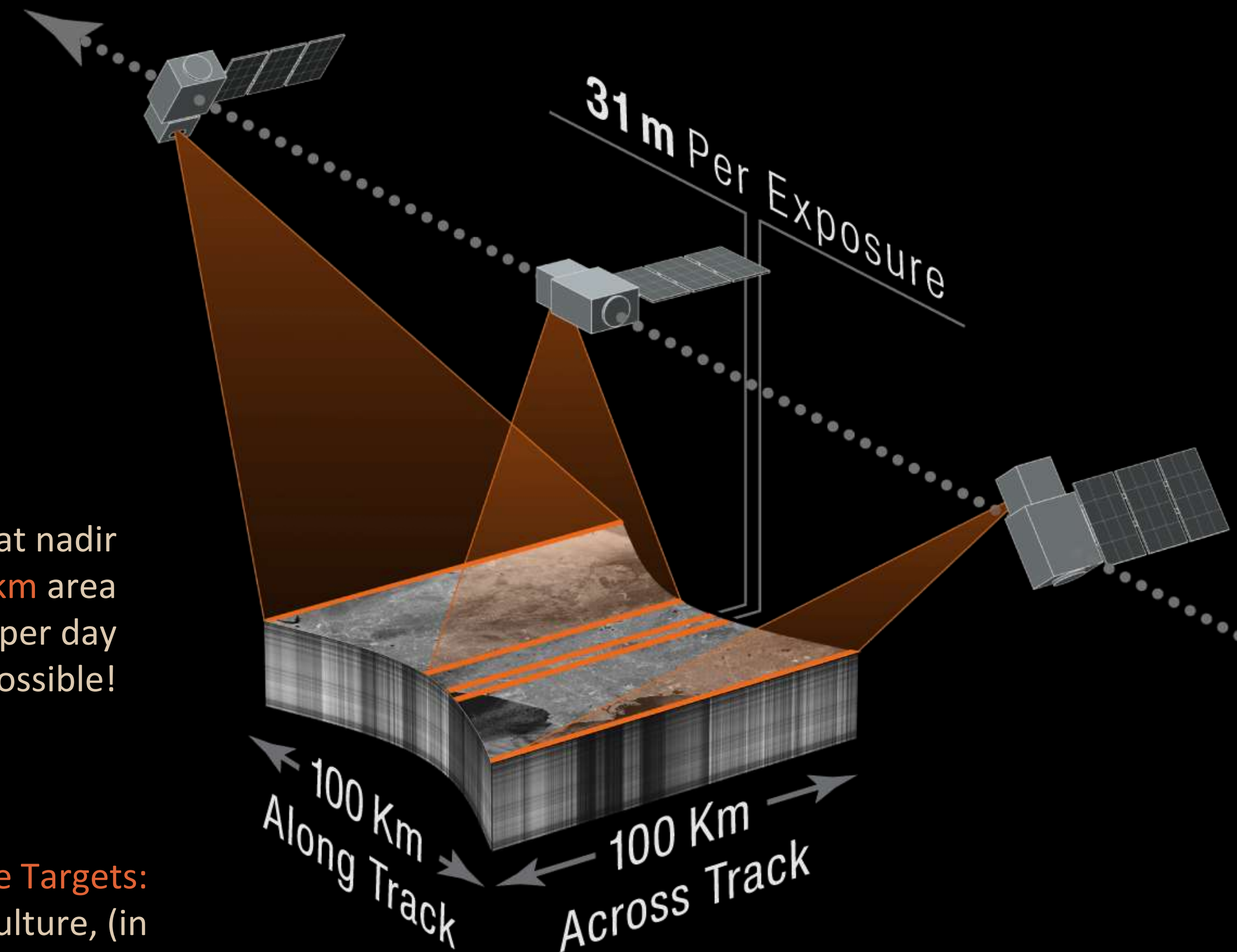
1km simulations

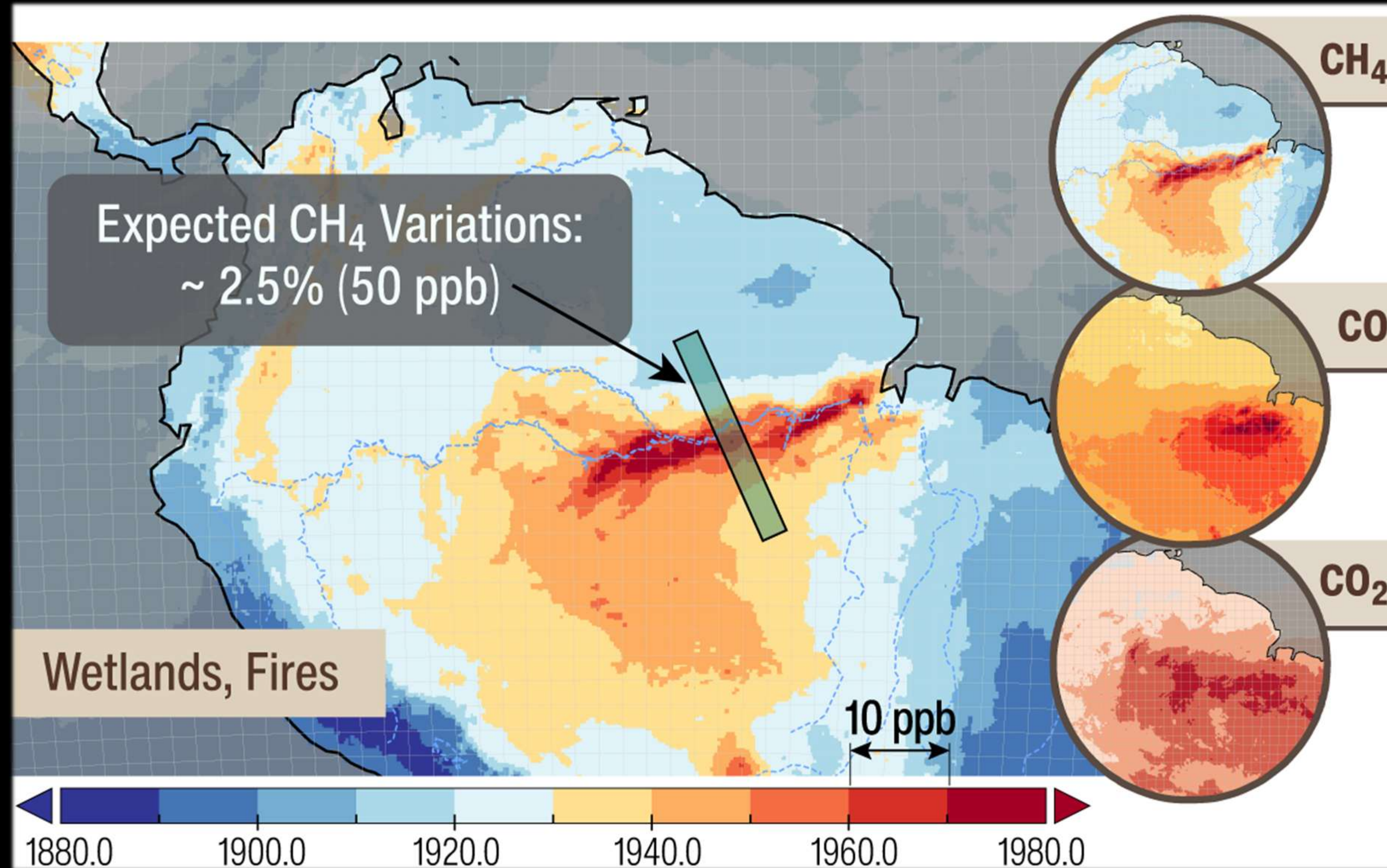


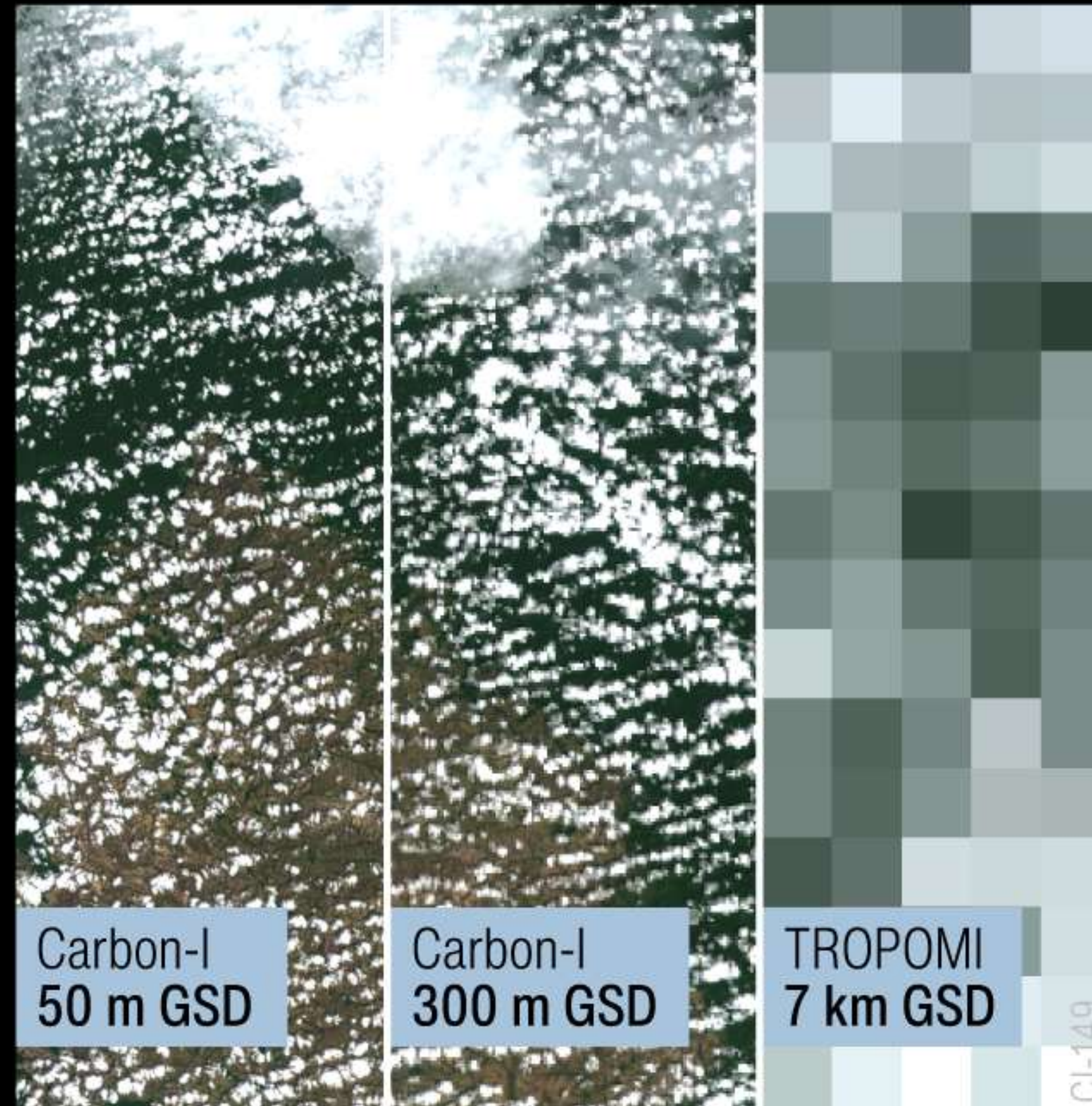
Target Mode
<50m for regions of interest

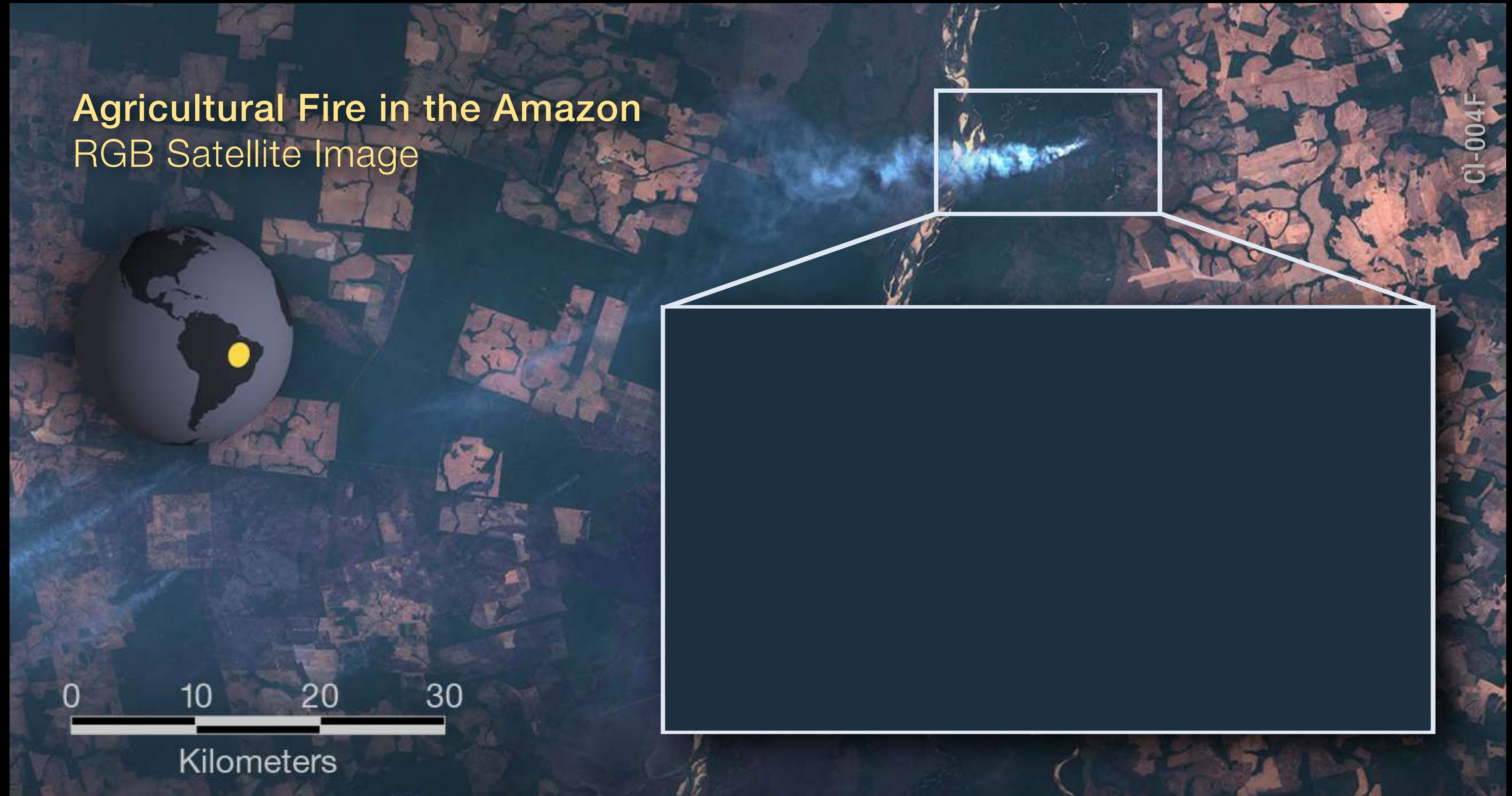
~35m x 30m pixels at nadir
100km x 100km area
3 targets per day
Weekly revisits possible!

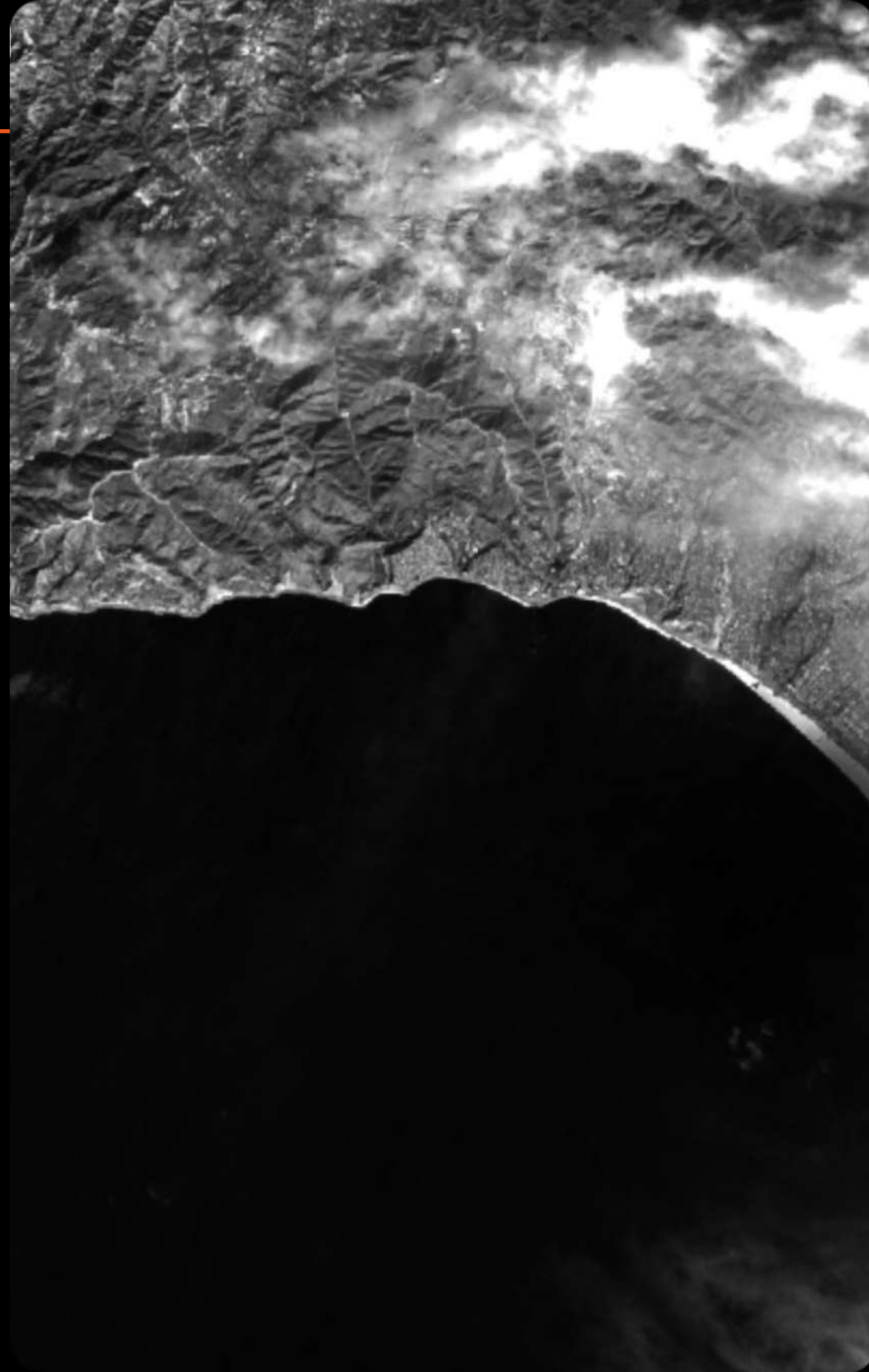
Representative Targets:
Wetlands, megacities, agriculture, (in
general regions of highest uncertainty











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

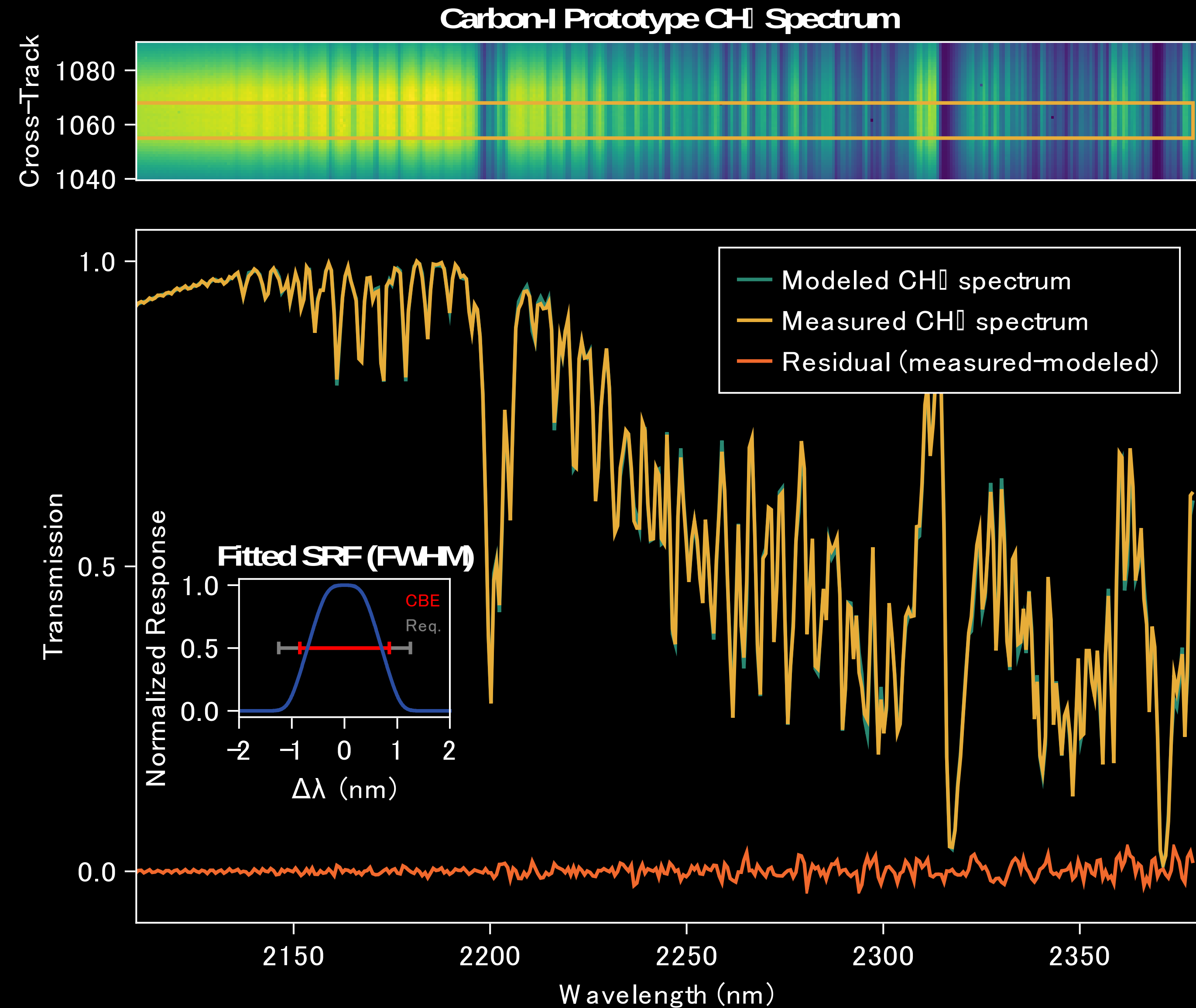
Christine L. Bradley, Rami W. Wehbe, Matthew Smith, Sharmila Padmanabhan,
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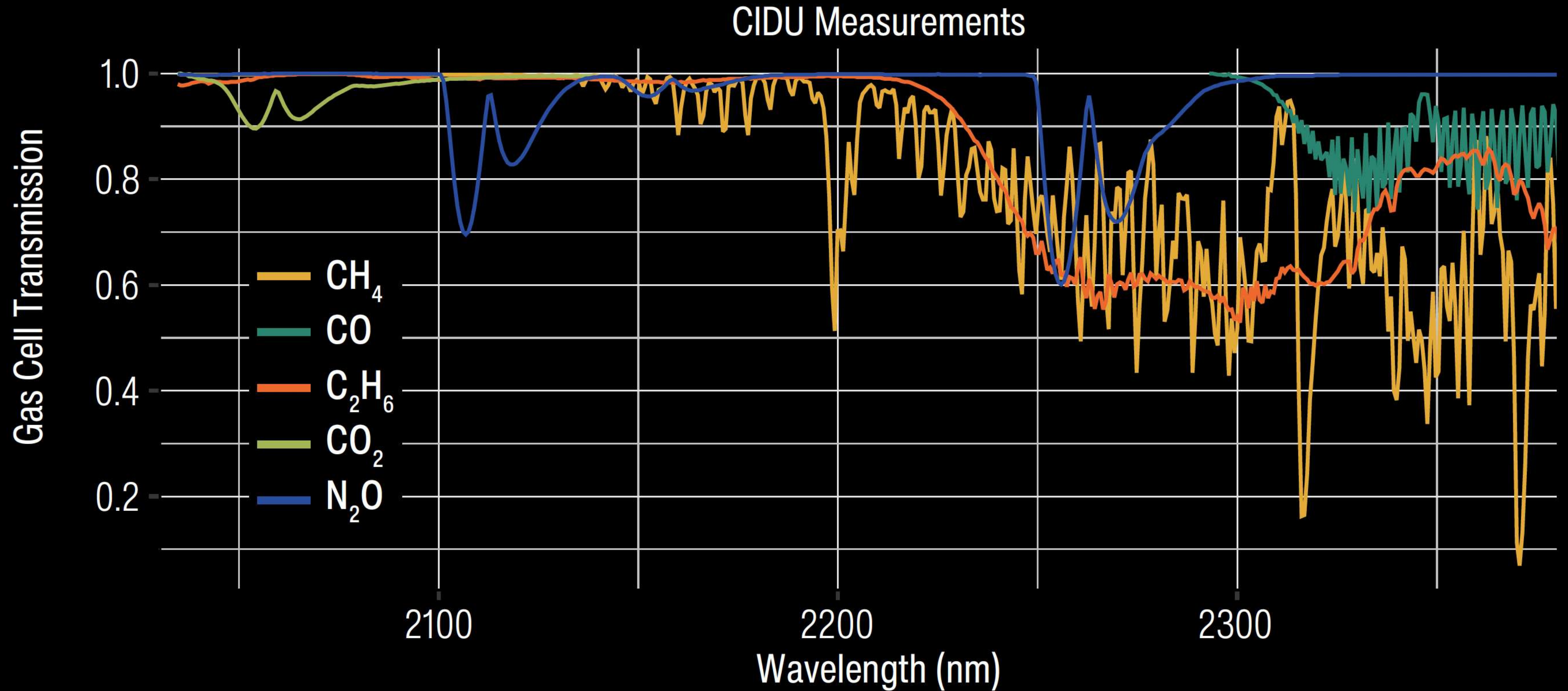
Bradley et al, IEEE 2025 Best Paper Award (<https://doi.org/10.48550/arXiv.2505.22545> preprint)

Fitting a CIDU methane spectrum

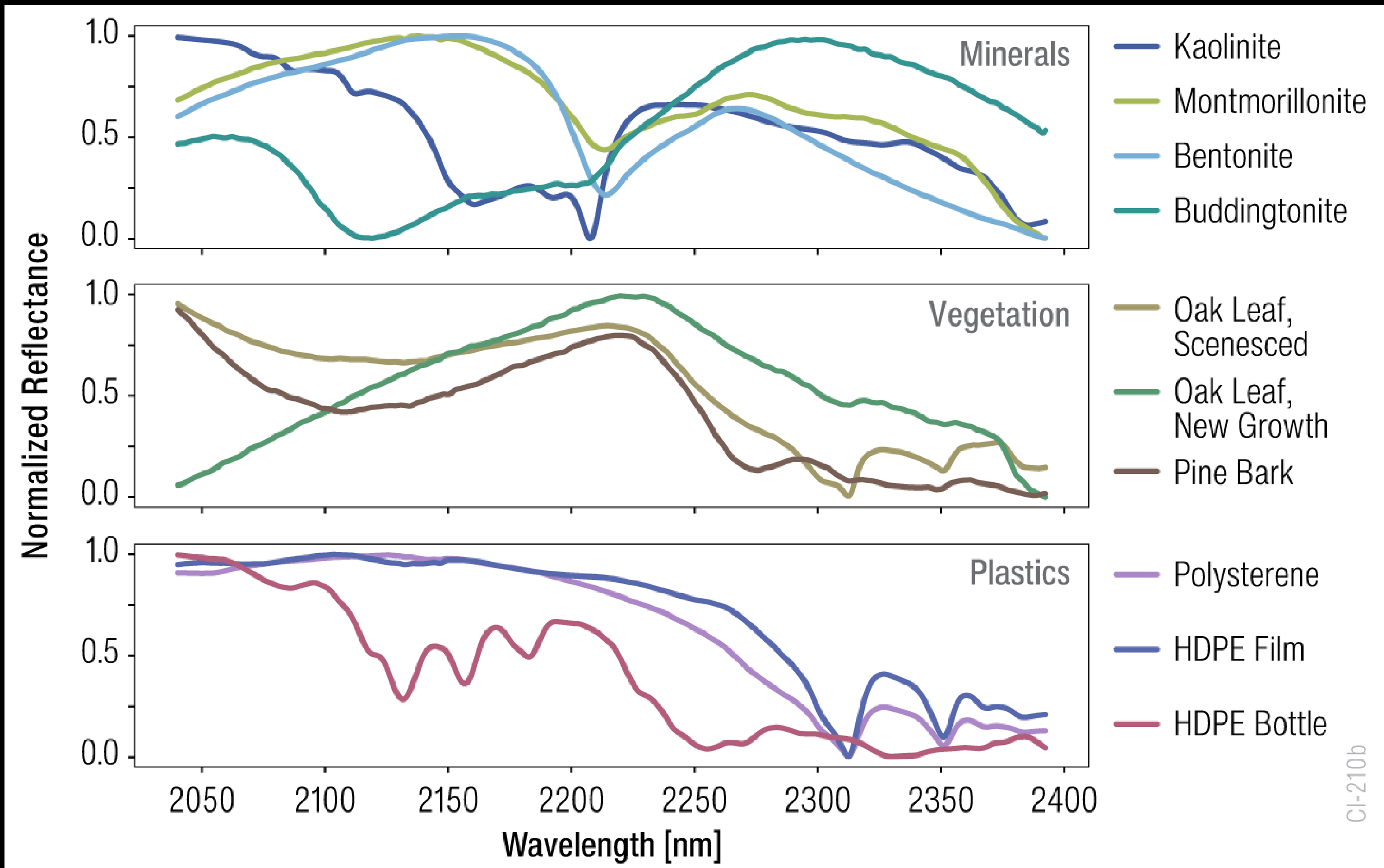


- Methane gas cell in between light source and CIDU
- Fit of methane column and spectral calibration

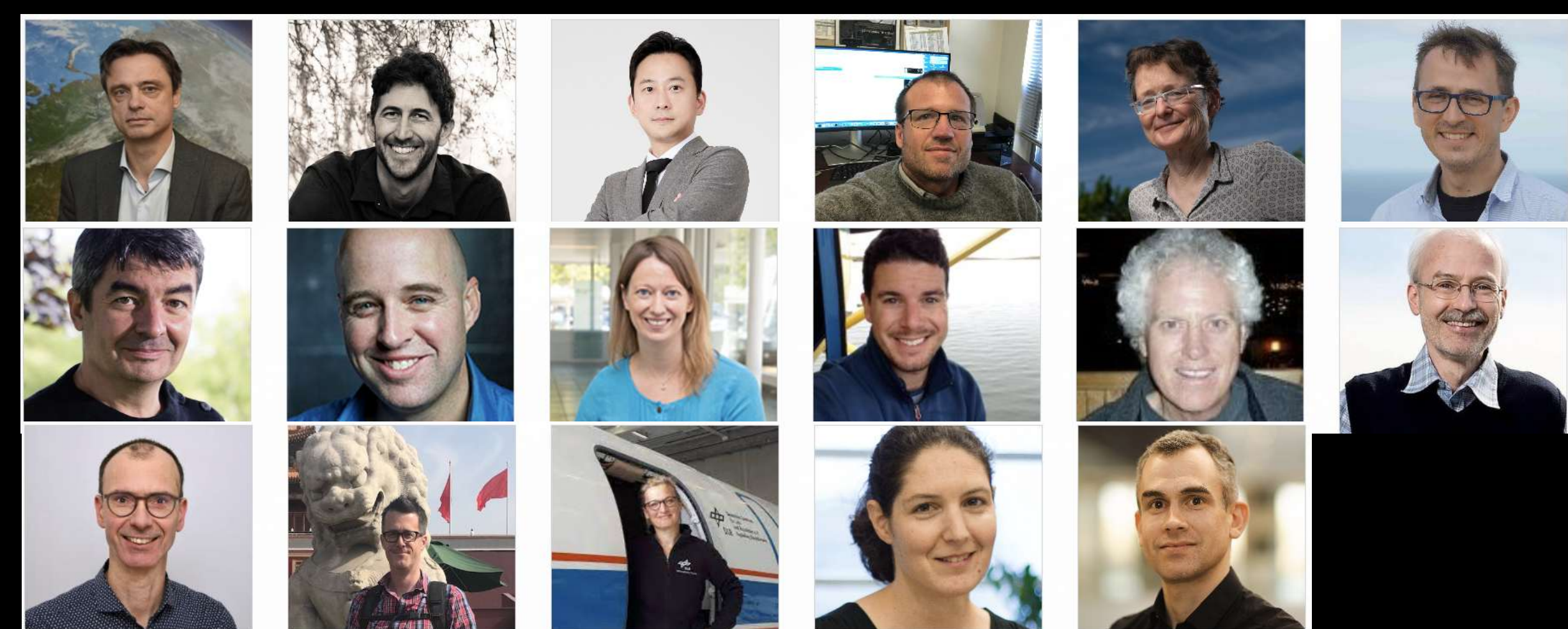
More CIDU Spectra



More than just trace gases (also measured by CIDU)



Questions?



And many more!!!