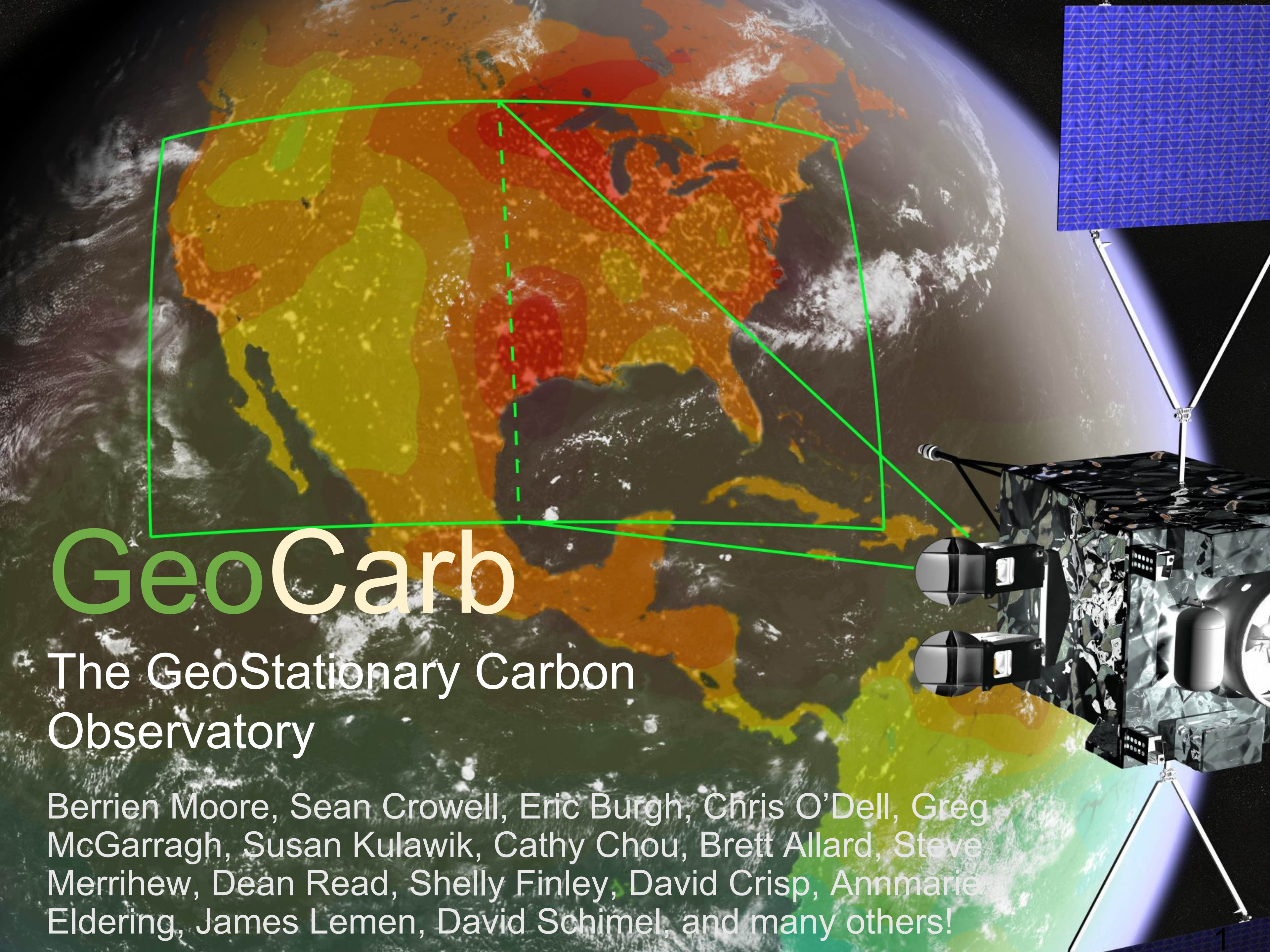


GeoCarb

The GeoStationary Carbon Observatory

Berrien Moore, Sean Crowell, Eric Burgh, Chris O’Dell, Greg McGarragh, Susan Kulawik, Cathy Chou, Brett Allard, Steve Merrihew, Dean Read, Shelly Finley, David Crisp, Annmarie Eldering, James Lemen, David Schimel, and many others!

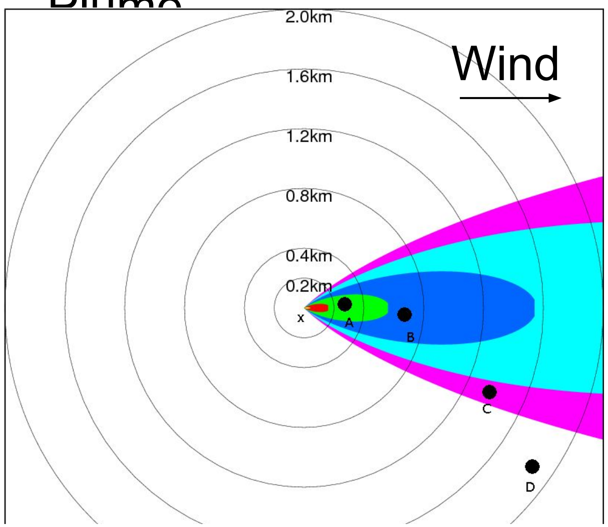
Goals of the Talk

- Introduce the notion of inferring emissions from trace gas observations
- Demonstrate the ability of satellites to make measurements of trace gases from space
- Introduce the GeoCarb mission

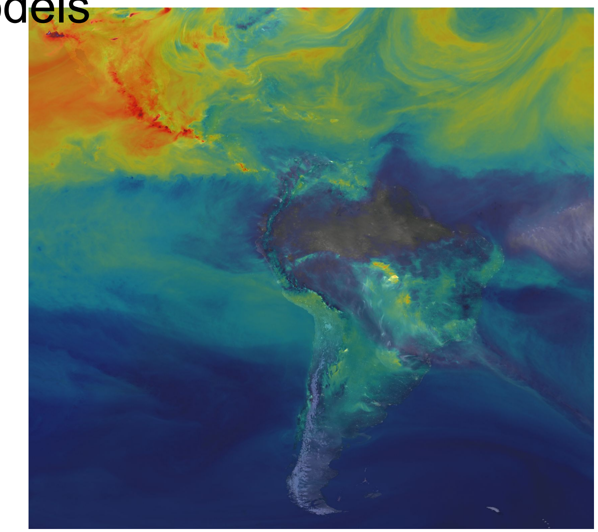
Inferring Emissions from Observations

- Using trace gas measurements and models to infer sources

Locally: "Gaussian Plume"



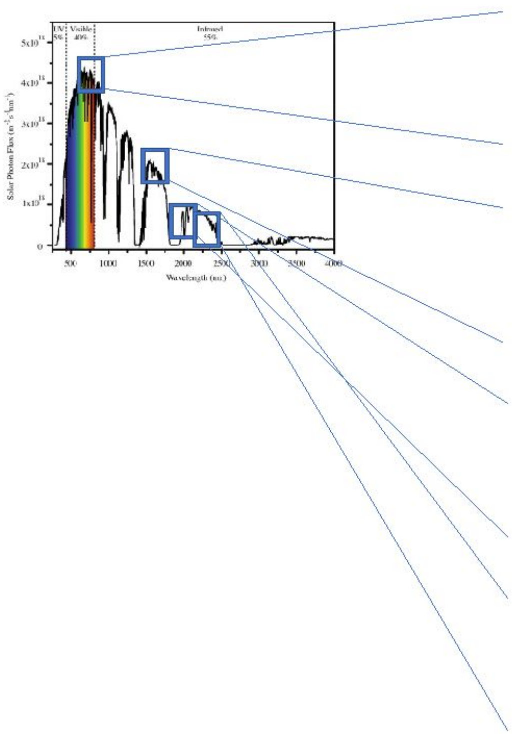
Regionally: Chemical Transport Models

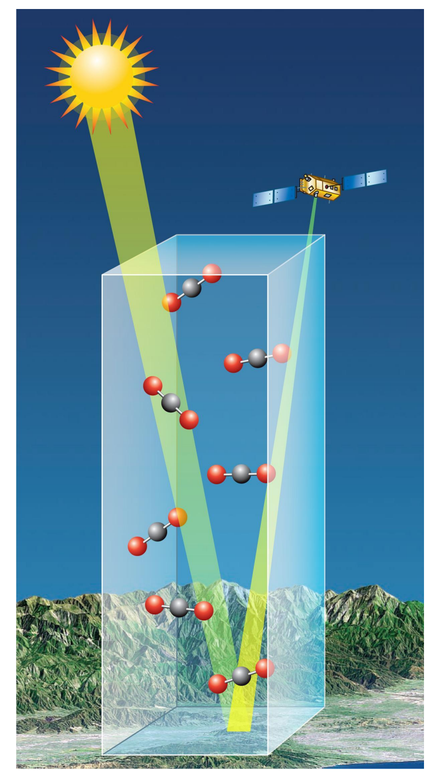


- In situ measurements are regionally sparse and their interpretation is highly dependent on estimates of atmospheric transport, which makes emissions estimates uncertain
- Satellites provide another data source that has global coverage at moderate spatial resolution and lower precision/accuracy and is somewhat less sensitive to transport

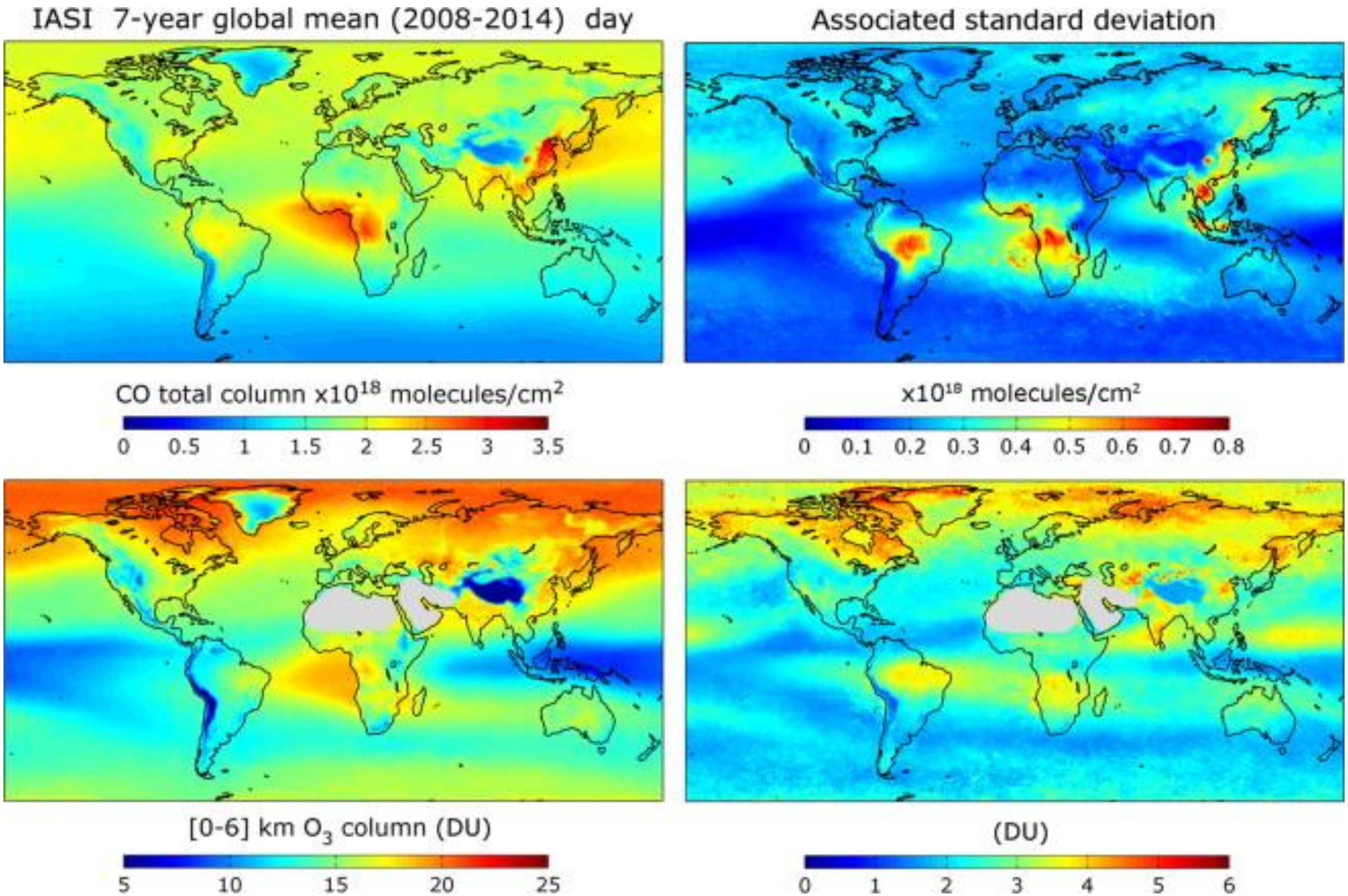
How do remote sensors make obs?

- Photons get emitted, absorbed and scattered by the atmosphere.
- We can model these processes and estimate gas concentrations that provide the best match for the measured radiances.
- This process has inherent uncertainties that make remotely sensed measurements less precise and less accurate



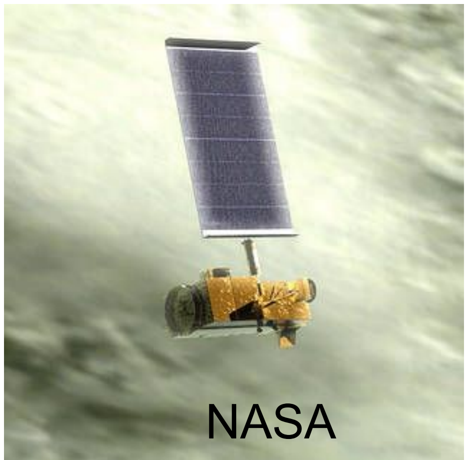


Example Satellite Observing Systems

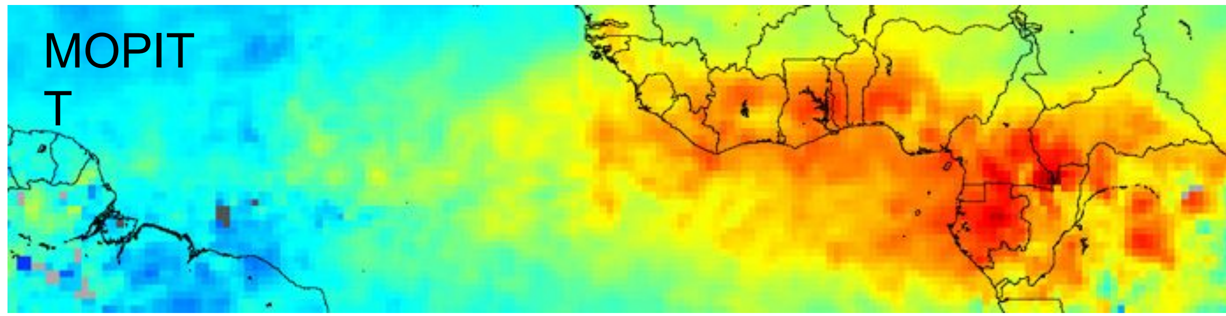


Clerbaux et al (2015)

Example Satellite Observing Systems

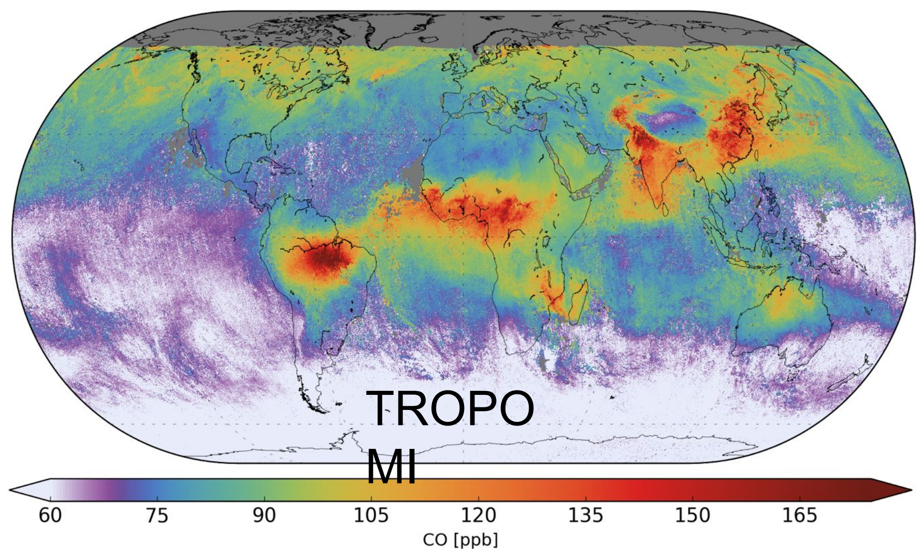


NASA
Terra



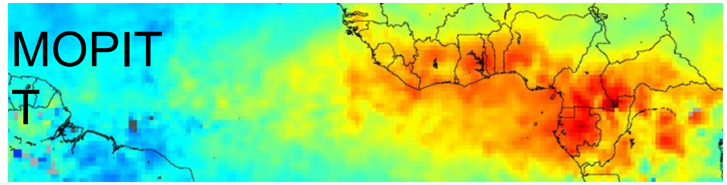
MOPIT
T

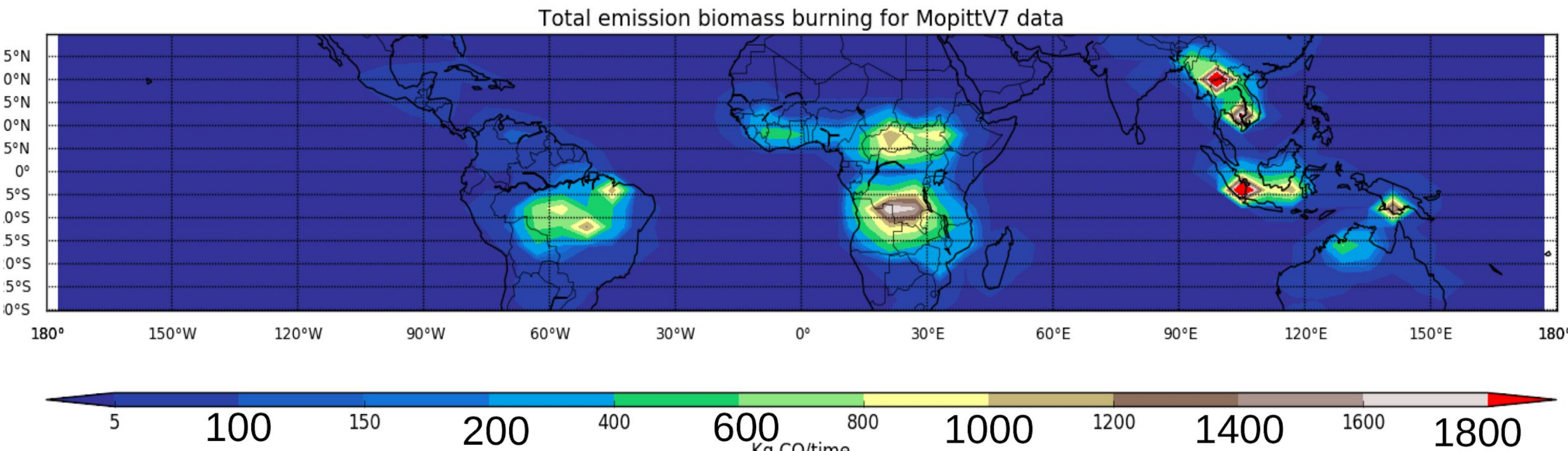
Sentinel-5
p

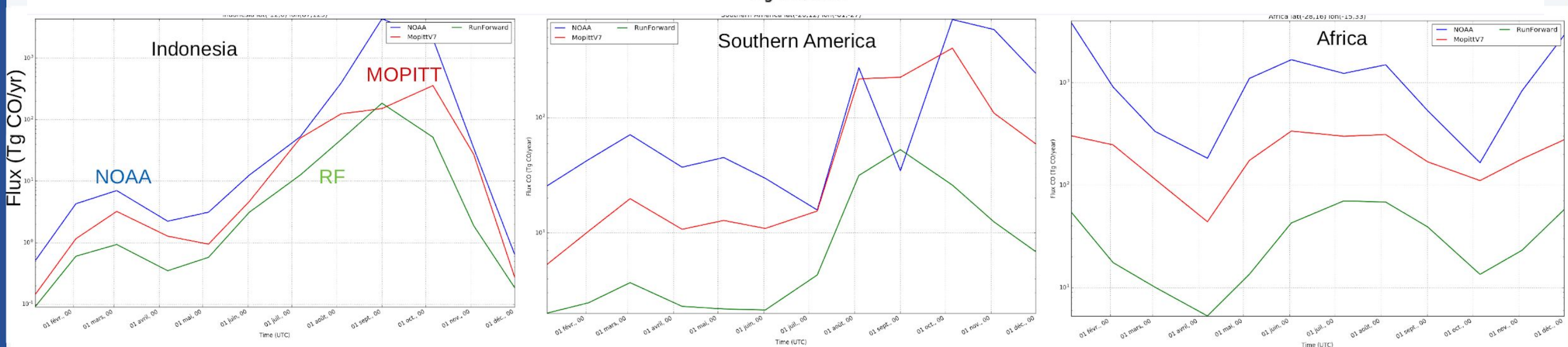


TROPO
MI

CO Surface Emissions from MOPITT





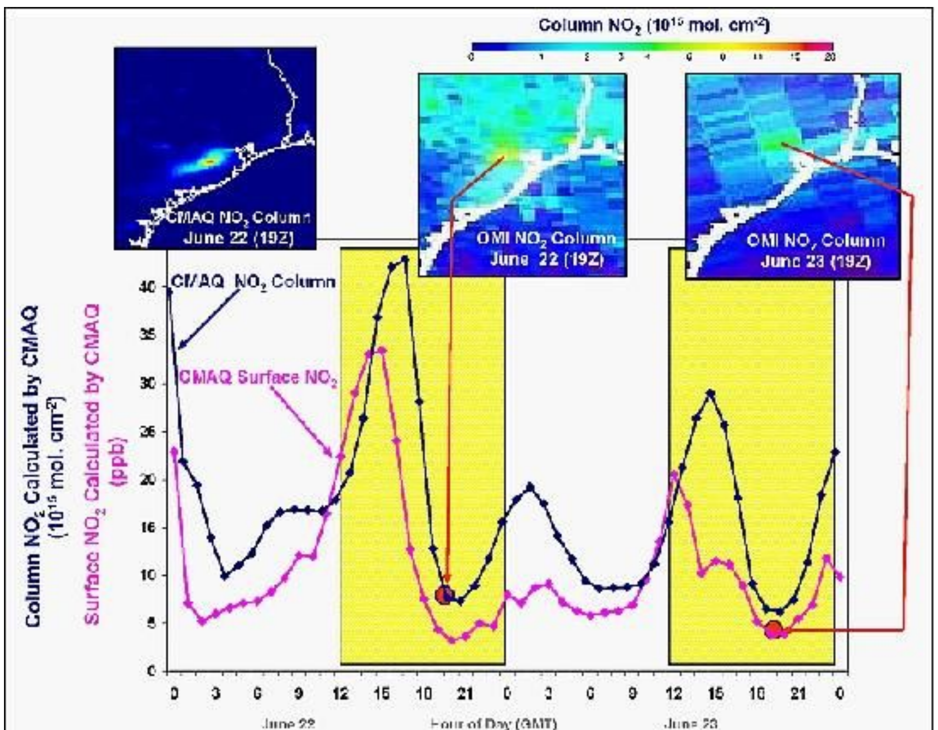


The Difficulty with Low Earth Orbit

- Fixed overpass time – not much information on diurnal cycle of constituents with a single satellite
- Revisit cycle can convolve sources and transport (though to a lesser extent than in situ measurements) without a sufficiently wide swath

Tropospheric Emissions: Monitoring of Pollution

TEMPO is a **geostationary** air quality monitoring mission that will return high resolution, high precision measurements of a large complement of tropospheric pollutants, including aerosols, O3, NO2, and others.



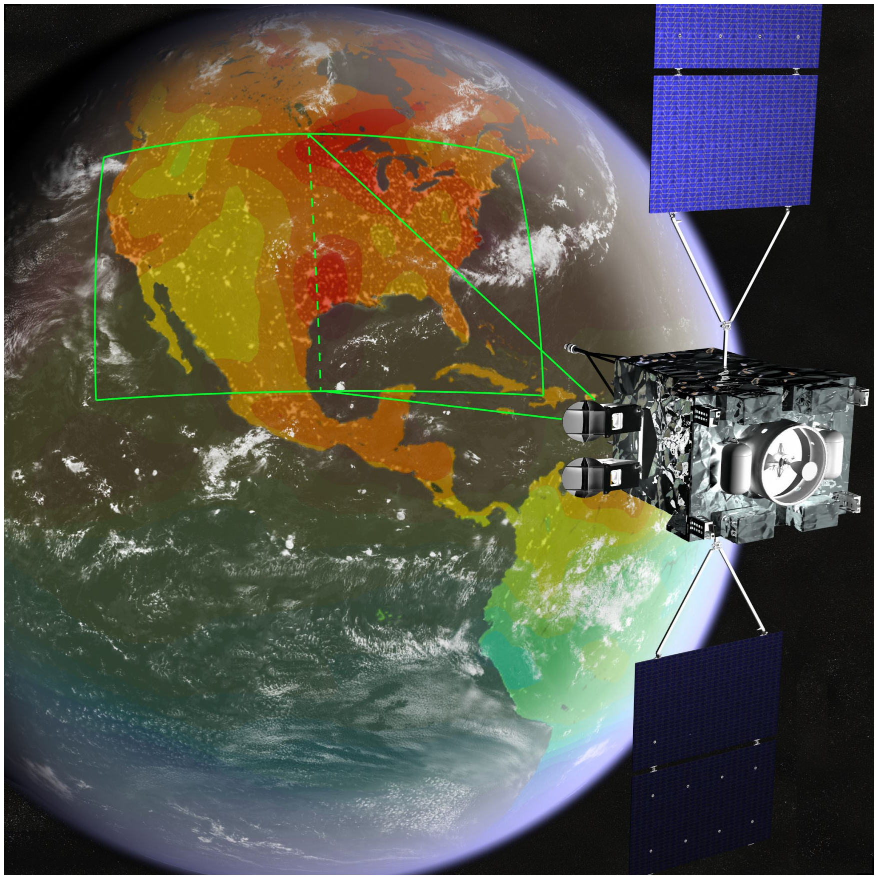
Species/Products		Typical value[2]	Required Precision	Expected Precision[3]	
				Worst	Nominal
O_3 Profile	0-2 km (ppb)	40	10	9.15	9.00
	FT (ppb) [4]	50	10	5.03	4.95
	SOC [4]	8×10^3	5%	0.81%	0.76%
Total O_3		9×10^3	3%	1.54%	1.47%
NO_2*		6	1.00	0.65	0.45
H_2CO* (3/day)		10	10.0	2.30	1.95
SO_2* (3/day)		10	10.0	8.54	5.70
$C_2H_2O_2$* (3/day)		0.2	0.40	0.23	0.17
AOD		0.1 – 1	0.05	0.041	0.034
AAOD		0 – 0.05	0.03	0.025	0.020
Aerosol Index (AI)		-1 – +5	0.2	0.16	0.13
CF [4]		0 - 1	0.05	0.015	0.011
CTP (hPa) [4]		200–900	100	85.0	60.0

[1] Spatial Resolution: 8×4.5 km^2 at the center of the domain. Time resolution: Hourly, unless noted.
[2] Typical values. Units are 10^{15} molecules•cm^{-2} for gases and unitless for aerosols/clouds, unless specified.
[3] Expected precision is viewing condition dependent; results for worst and nominal cases.
[4] FT, free troposphere: 2 km-tropopause, SOC: stratospheric O_3 column, CF: cloud fraction, CTP: cloud top pressure.
* = background value. Pollution is higher, and in starred constituents, the precision is applied to polluted cases.

Threshold products at 8×9km^2 at 80 min. time resolution.

The GeoCarb Mission:

Measuring Carbon Trace Gases and Vegetation Health from Space



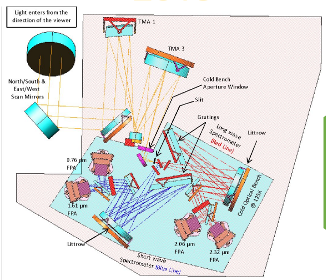
Principal Investigator	Berrien Moore, University of Oklahoma
Technology Development	Lockheed Martin Advanced Technology Center
Host Spacecraft & Mission Ops	SES Government Solutions

Instrument	Single slit, 4-Channel IR Scanning Littrow Spectrometer
Bands	
Measurements	O_2, CO_2, <u>CO</u>, CH_4 & Solar Induced Fluorescence
Mass	158 kg (CBE)
Dimensions	1.3 m x 1.14 m x 1.3 m
Power	400W (CBE)
Data Rate	10-100 Mbps
Daily Soundings	~5,000,000 soundings per day

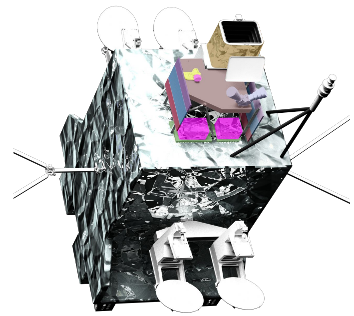
GeoCarb Mission Phasing

Passed into Phase B in November 2017!

Preliminary Design
Nov 2017 – August 2018



Spacecraft Build and Test
Oct 2018 – Jun 2020



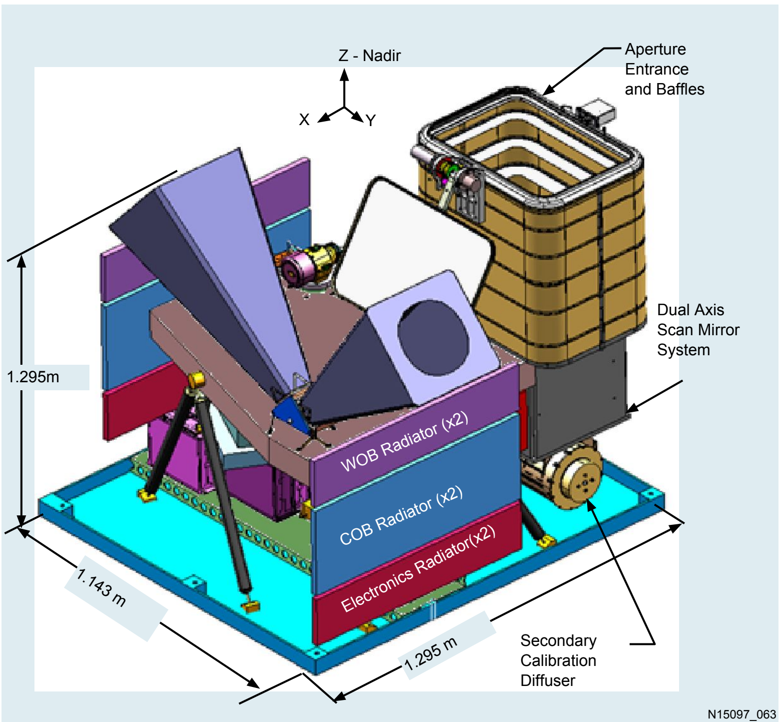
Instrument Build/Test
Sept 2018 – Jun

System Integration
Jun 2020 – Jun

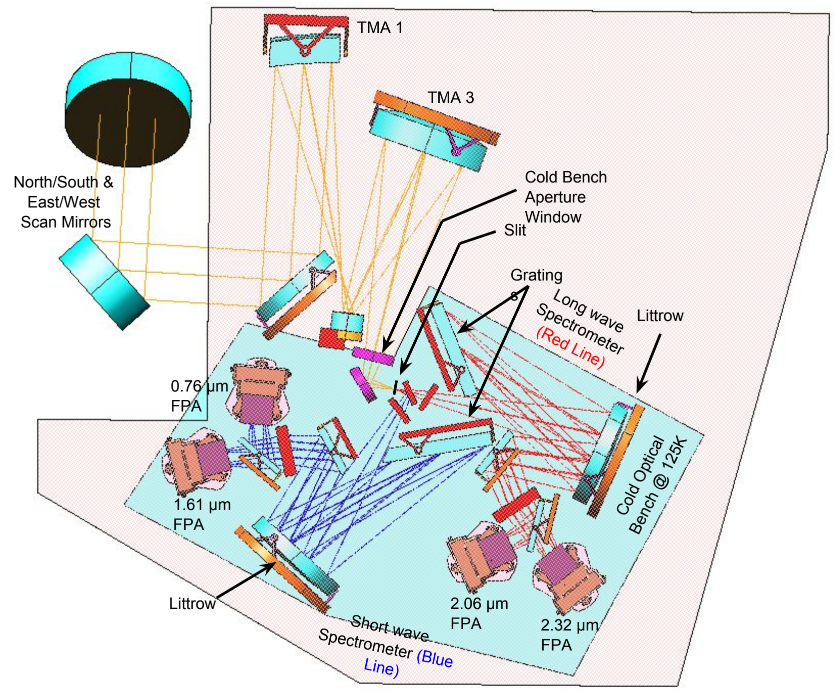
Launch and Orbit Raising
Jun 2022 – Mar 2023

Operations
Mar 2023 – Mar 2026*

GeoCarb Instrument



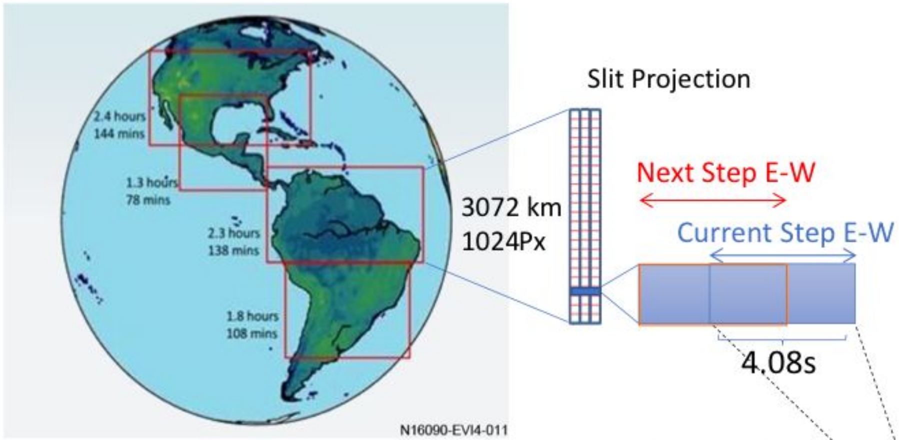
Light enters from the direction of the viewer



GeoCarb Sampling

High Spatiotemporal Resolution
Daily/Sub-daily Revisits
Flexible Scanning Strategies

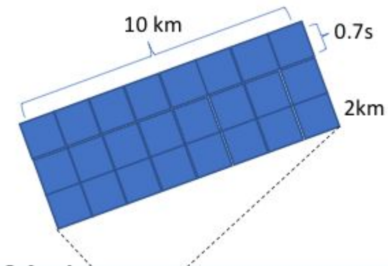
Fixed FOV
Land only

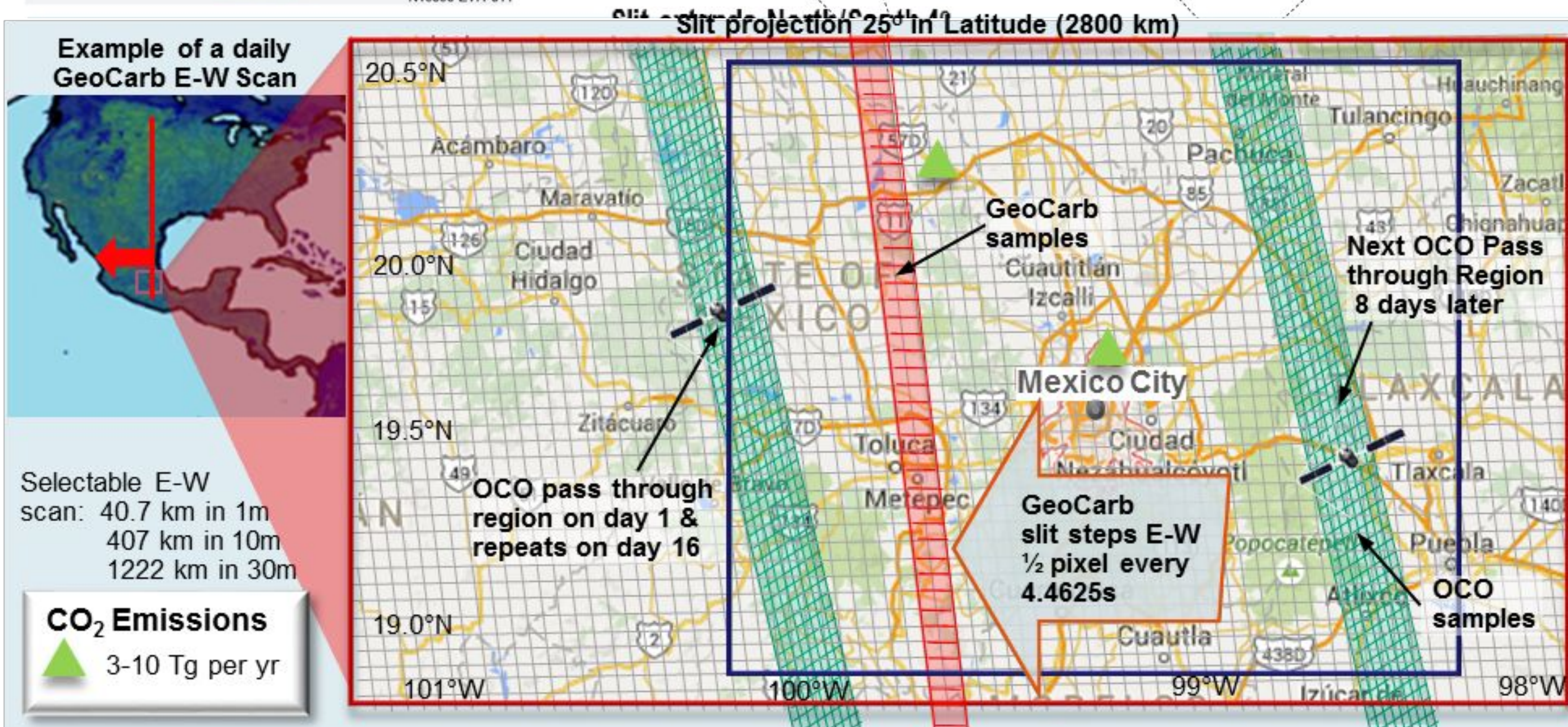


OCO-2 Sampling

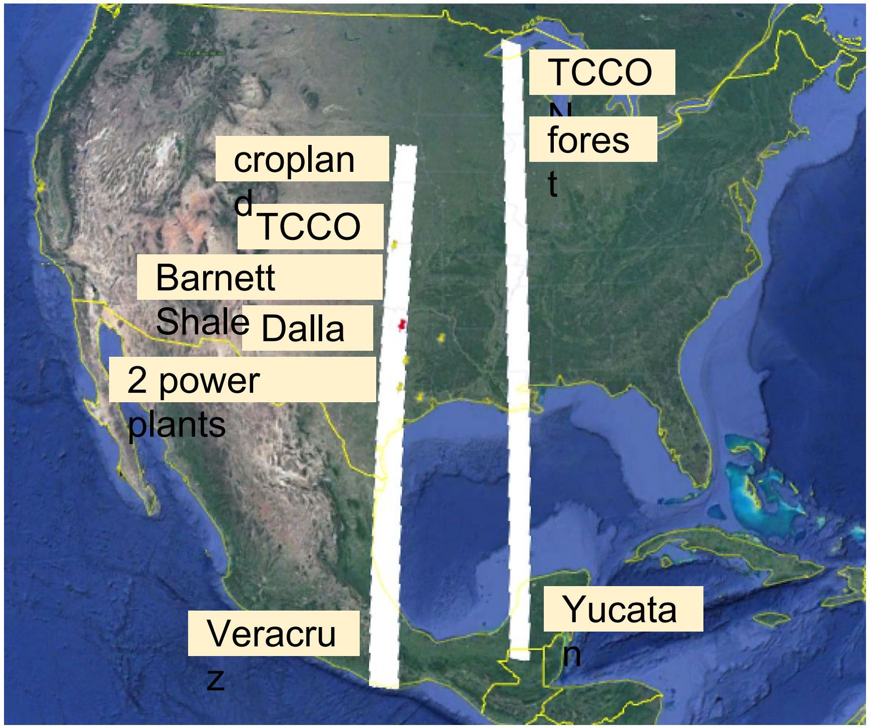
High Spatial Resolution Along Track
8 Footprints for Small Scale Variability
Global Land/Ocean Coverage

16 Day Revisit Cycle
Large Gaps Between Tracks





Intensive Scans Multiple Times per Day



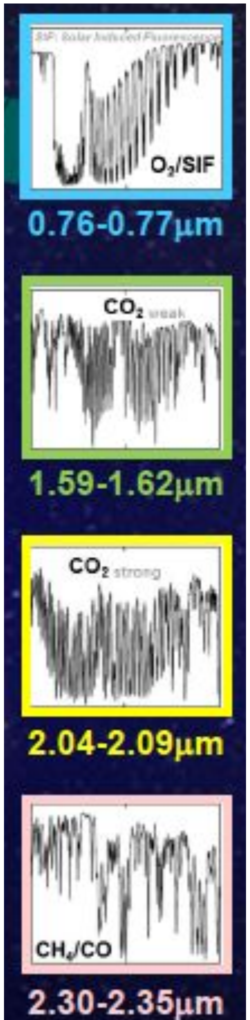
Varying size cities:
Oklahoma City, OK
Wichita, Kansas
Dallas , Texas
Corpus Christi, Texas

Varying size cities:
Lake Parchartrain, LA
Jackson, MI
Memphis, TN
St. Louis, MO
Davenport, IA
Dubuque, IA

Stripes are (left to right):
1.4, 1, 1, 1.2 degrees wide

Total time for observing above: 10.33 minutes
3 extra times per day: 33 minutes

GeoCarb Bands & Requirements



Solar Induced Fluorescence (SIF), O_2, Clouds, Aerosol

CO_2

CO_2, H_2O, Clouds, Aerosol

CH_4, CO, H_2O

Multi-Sounding Precision

- CO_2 : 0.3% (1.2 ppm)
- CH_4 : 0.6% (10 ppb)
- CO : 10% or 12 ppb, *whichever is greater*

Single-Sounding Precision

- SIF : 0.75 W m^{-2} μm^{-1} sr^{-1}

Retrieval of XCO2, XCH4, and XCO

Atmos. Meas. Tech., 7, 959–981, 2014
www.atmos-meas-tech.net/7/959/2014/
doi:10.5194/amt-7-959-2014

Atmospheric Measurement Techniques
Open Access

Performance of a geostationary mission, geoCARB, to measure CO_2, CH_4 and CO column-averaged concentrations

I. N. Polonsky[1], D. M. O'Brien[2], J. B. Kumer[3], C. W. O'Dell[4], and the geoCARB Team[5]

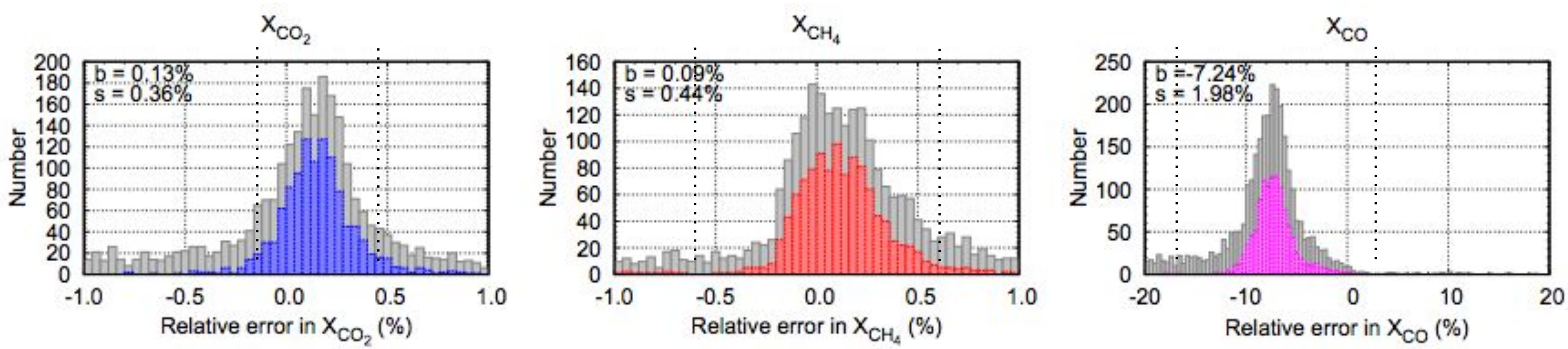
Atmos. Meas. Tech., 9, 4633–4654, 2016
www.atmos-meas-tech.net/9/4633/2016/
doi:10.5194/amt-9-4633-2016

Atmospheric Measurement Techniques
Open Access

Potential of a geostationary geoCARB mission to estimate surface emissions of CO_2, CH_4 and CO in a polluted urban environment: case study Shanghai

Denis M. O'Brien[1], Igor N. Polonsky[2], Steven R. Utembe[3], and Peter J. Rayner[3]

- **From Polonsky et al. 2014 and O'Brien et al, 2016, synthetic retrievals showed good performance for all gases in clear and polluted atmospheres**
- **Accuracy requirements met or nearly met for CO2, CH4 and CO**
- **In addition, ability to capture power-plant plumes in the presence of imperfect aerosols**



Level 1 Requirements

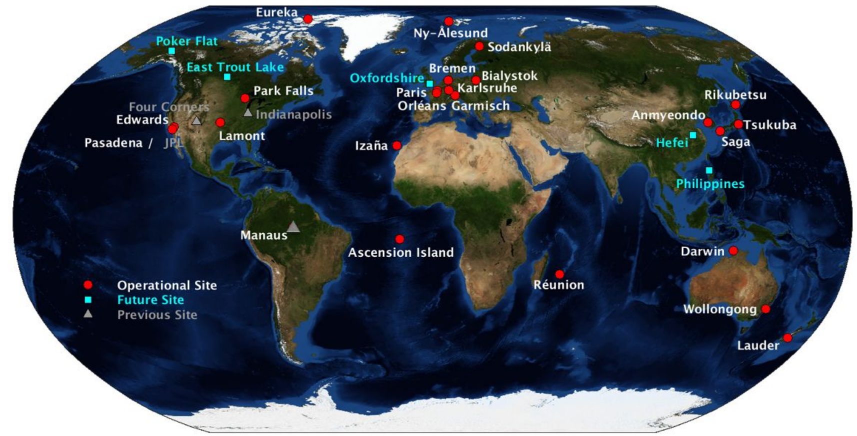
CO Can Also Help Interpret CO_2

- CO and CO_2 are co-emitted during combustion – and so we can use the correlations between them to improve CO_2 emissions in urban regions.
- The figure below shows the ability of GeoCarb data to constrain weekly emissions at 5km scales with CO_2 alone (left) and including CO (right).

GeoCarb is an International Partnership!

We'd love to collaborate! berrien@ou.edu (or

Collaboration with AEM/UNAM



- Remote sensors must be calibrated, and the resulting retrievals must be validated against independent data and/or models to remove bias.
- GeoCarb, like OCO-2/3 and GOSAT, will be validated against TCCON, which is in turn validated against in situ observations.

Summary

- GeoCarb is the first Earth Science hosted payload to make carbon gas measurements from GEO
- GeoCarb is in Preliminary Design, preparing for Confirmation in February.
- GeoCarb instrument design, calibration planning, algorithms, and validation strongly leverage OCO-2 experience, with appropriate modifications
- Scanning strategies to balance minimizing sampling bias for regional flux estimation and targeting point sources
- We'd love to collaborate: urban scale modeling, multi-tracer studies, validation opportunities, ...