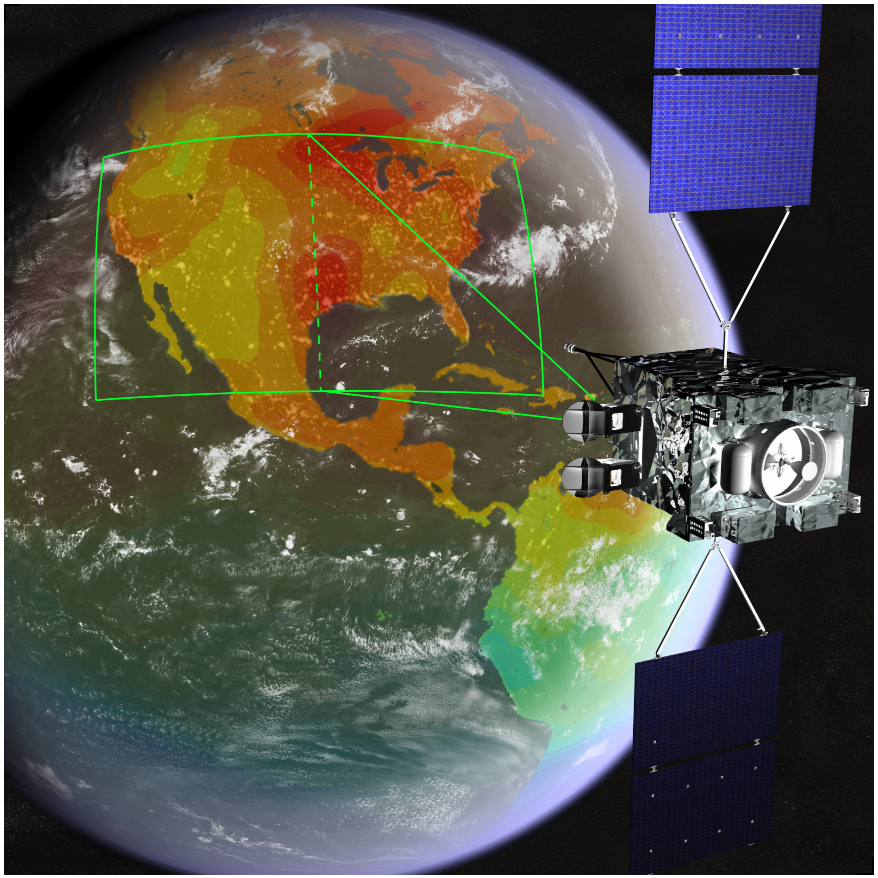
GeoCarb

Mission Status Update

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!

The GeoCarb Mission:

Measuring Carbon Trace Gases and Vegetation Health from Space



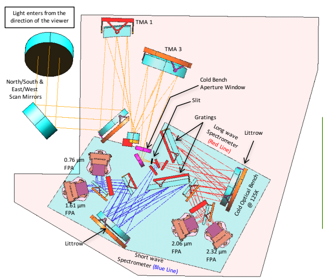
Principal Investigator	Berrien Moore, University of Oklahoma
Technology Development	Lockheed Martin Advanced Technology Center
Host Spacecraft & Mission Ops	SES Government Solutions

Instrument	Single slit, 4-Channel IR Scanning Littrow Spectrometer
Bands	0.76μm, 1.61μm, 2.06μm and 2.32μm
Measurements	O_2, CO_2, CO, CH_4 & Solar Induced Fluorescence
Mass	158 kg (CBE)
Dimensions	1.3 m x 1.14 m x 1.3 m
Power	128W (CBE)
Data Rate	10-100 Mbps
Daily Soundings	~10,000,000 soundings per day

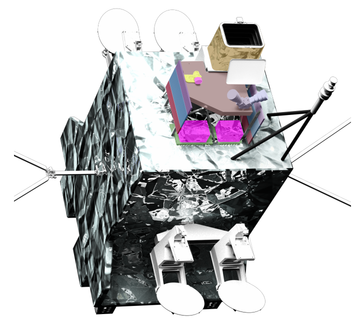
GeoCarb Mission Phasing

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 2020

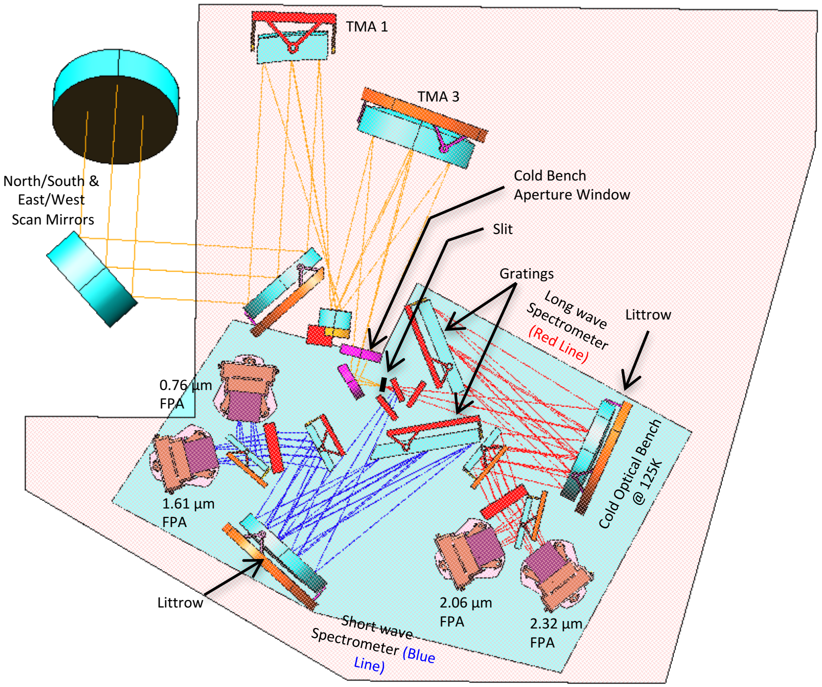
System Integration
Jun 2020 – Jun 2022

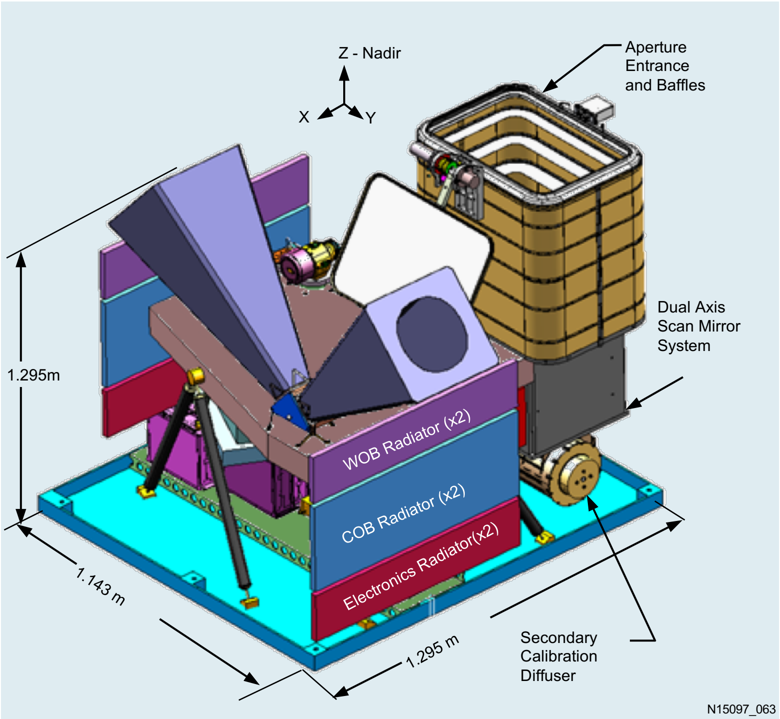
Launch and Orbit Raising
Jun 2022 – Mar 2023

Operations
Mar 2023 – Mar 2026*

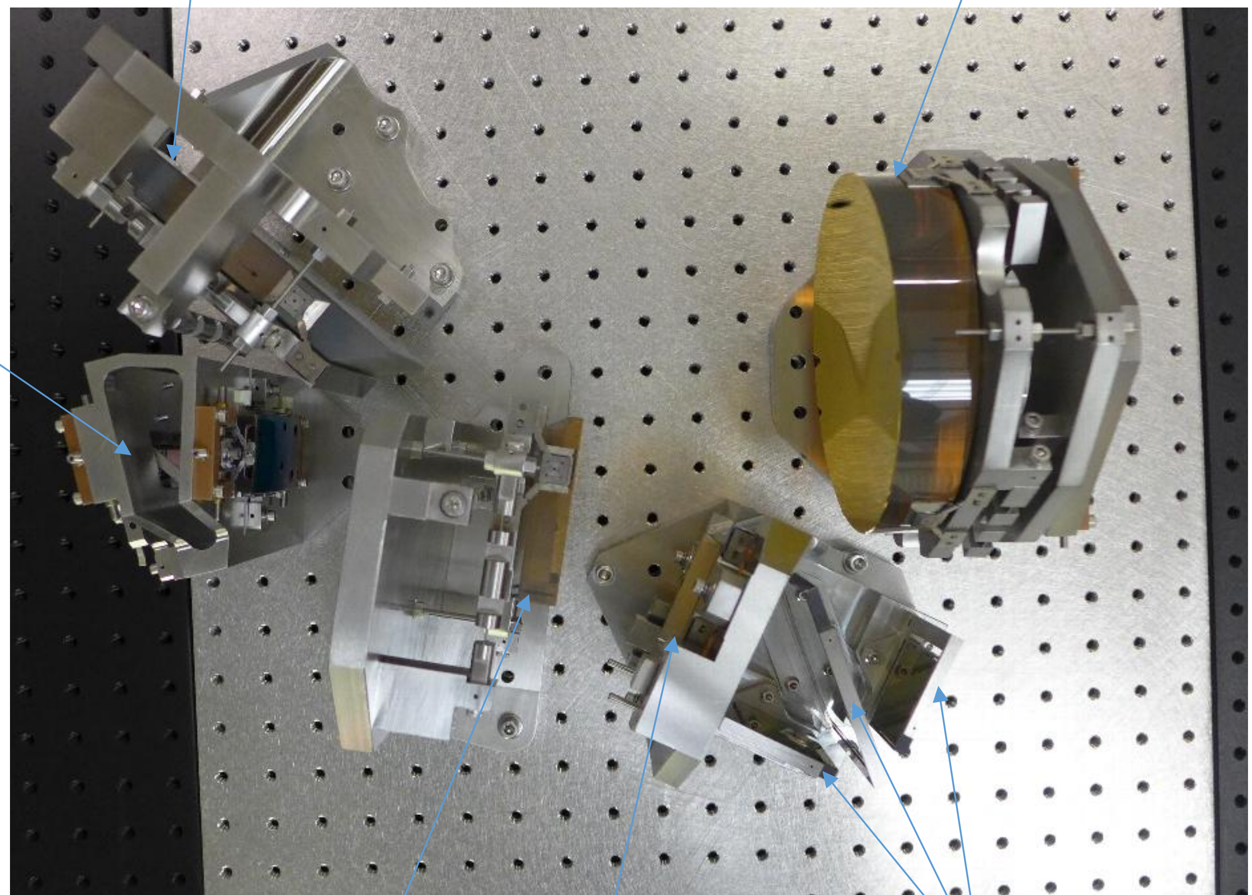
GeoCarb Instrument

Light enters from the direction of the viewer

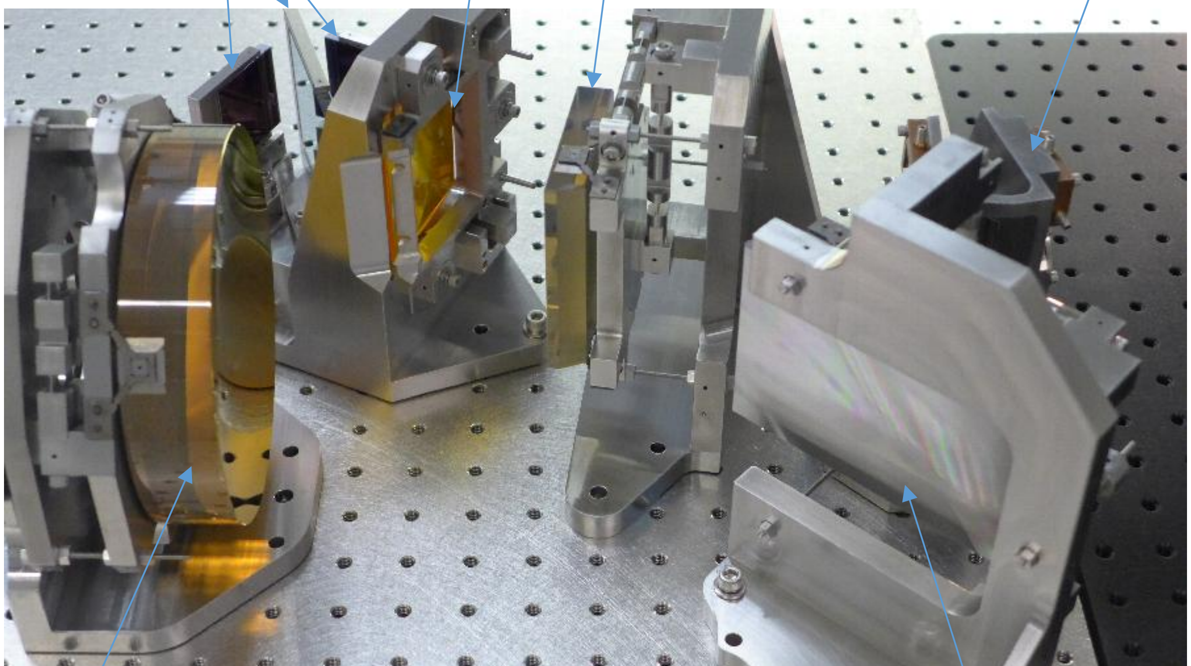




Testbed Optics

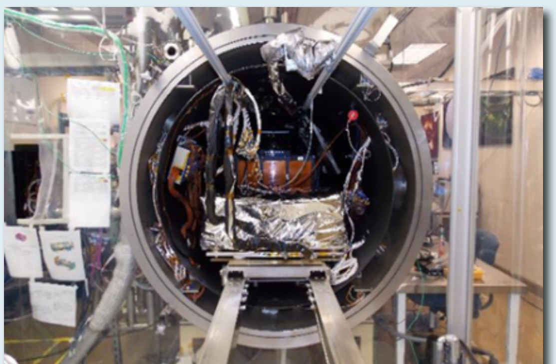


Testbed Optics



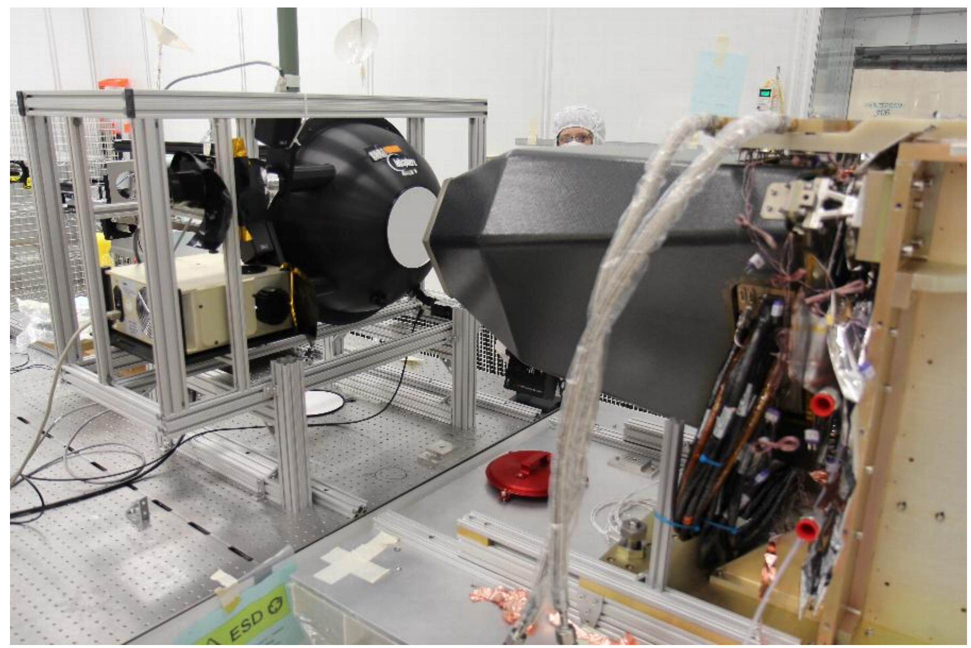
Pre-flight Calibration

- Many of the pre-flight calibration and characterization activities for GeoCarb will be similar to what was performed for OCO-2
  - E.g., ILS, gain and offset, integrated radiometric efficiency similar to OCO-2
- The LMATC thermal vacuum chamber is located next to a heliostat
  - Has been used to test IRIS, HMI, SUVI



- 5 foot ID X 18 foot length chamber
- Gaseous helium (Ghe) shroud
- Liquid Nitrogen (l, N_2) Continuous flooded shroud at 80K
- Closed loop GHe refrigerator of 250 Watts at 20K
- 18 foot 30 inch wide rail system
- 12 inch port can be window, 5 inch window, five 7 inch windows, 16 inch window
- Controlled heating hot box and panels to +100 C
- Class 1000 clean room surrounding the Rocket Chamber

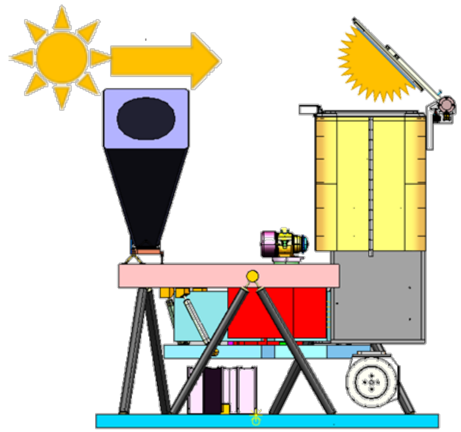
N15097_084



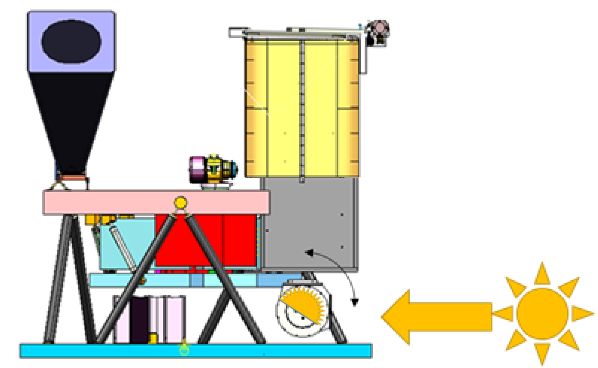
Integrating sphere with Geostationary Lightning Mapper at LMSAL

On Orbit Calibration

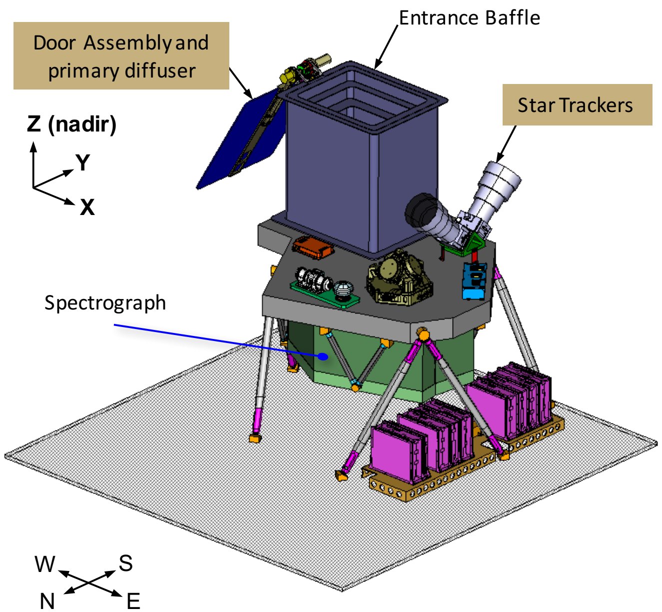
GeoCarb will maintain a primary radiometric calibration via solar measurements through a diffuser. We will also view the moon ~8 times per year, and use lamps for flat fields.



6AM viewing with Primary Diffuser



6PM viewing with Secondary Diffuser



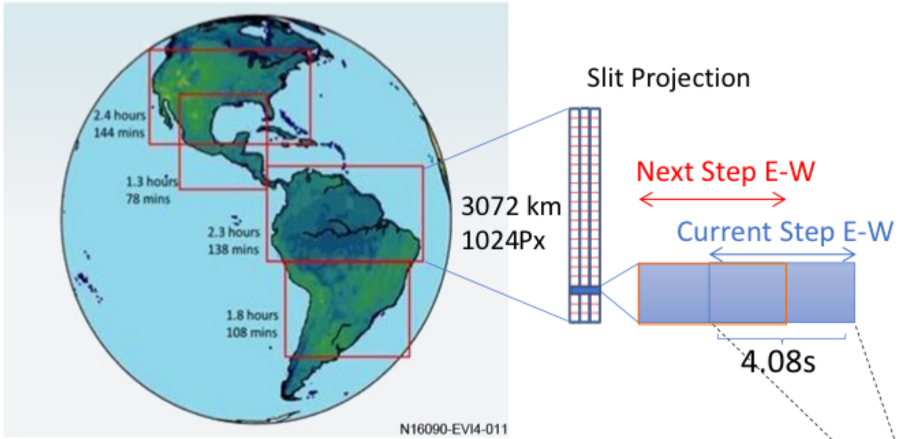
Geometric calibration will use star observations from the slit to calibrate the scan mirror positions relative to the star tracker observations on the instrument.

Polarization will be monitored using sun glint measurements taken at various solar zenith angles.

GeoCarb Sampling

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

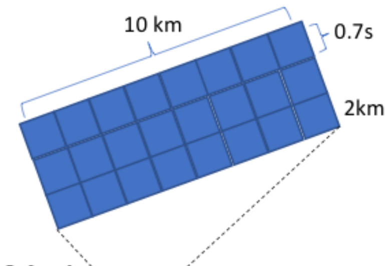
Fixed FOV
Land only

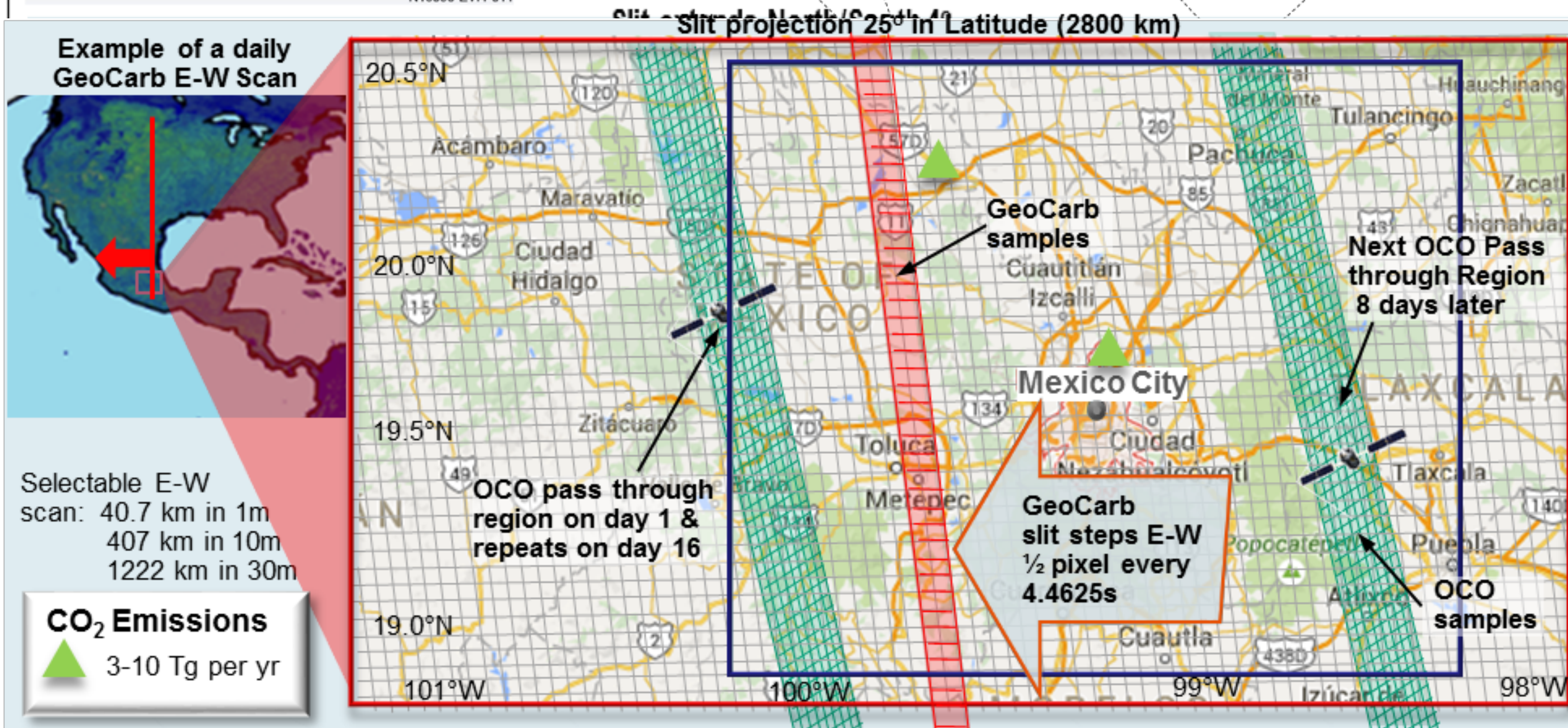


OCO-2 Sampling

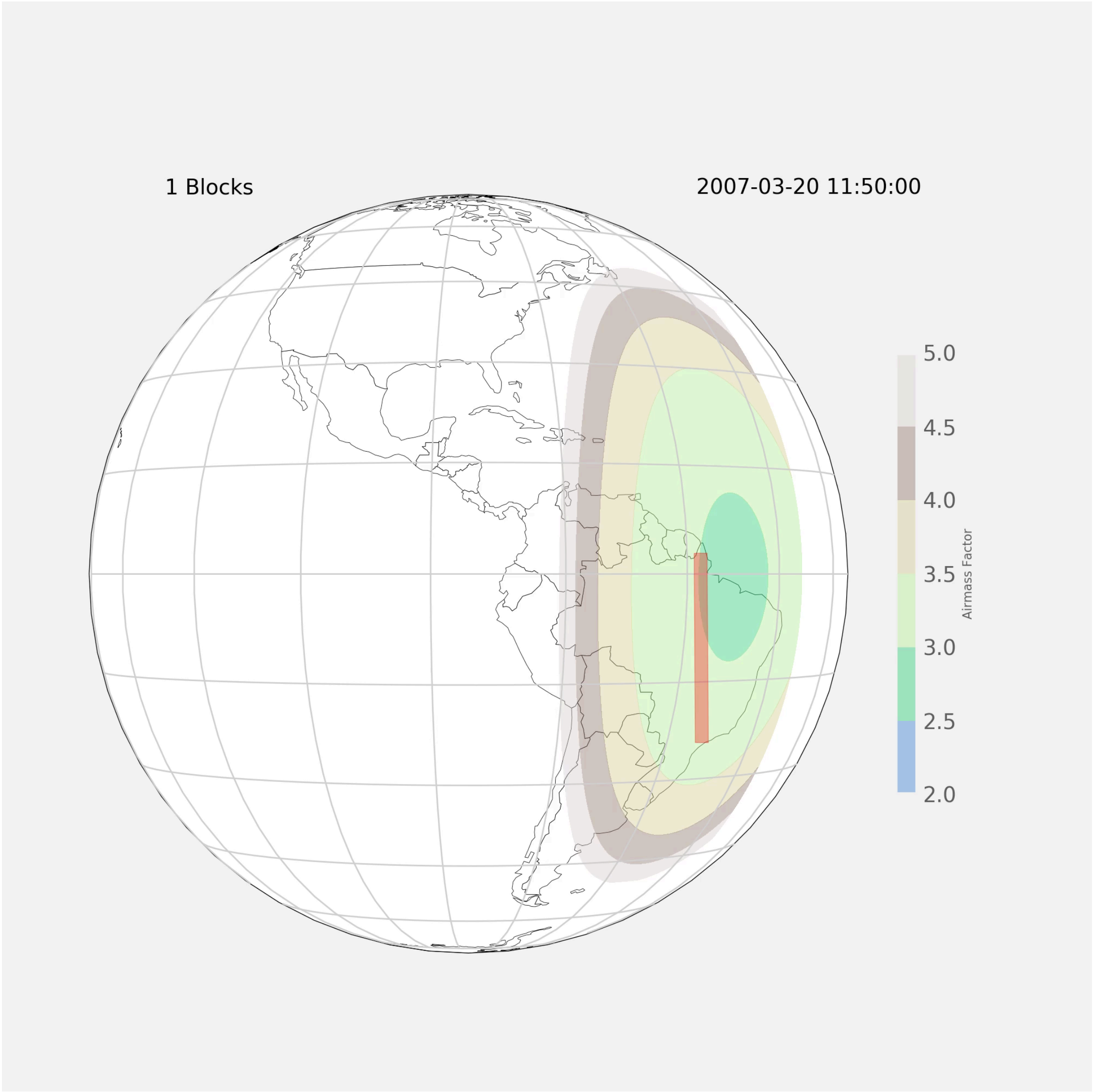
High Spatial Resolution Along Track
8 Footprints for Small Scale Variability
Global Land/Ocean Coverage

16 Day Revisit Cycle
Large Gaps Between Tracks

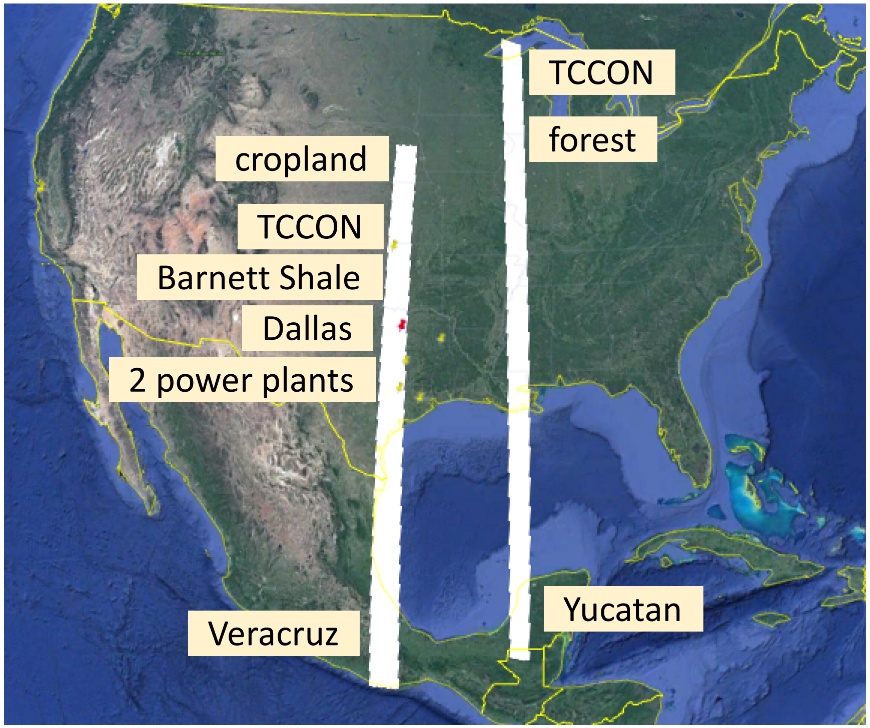




Automating Scanning Strategies



Intensive Scans Multiple Times per Day



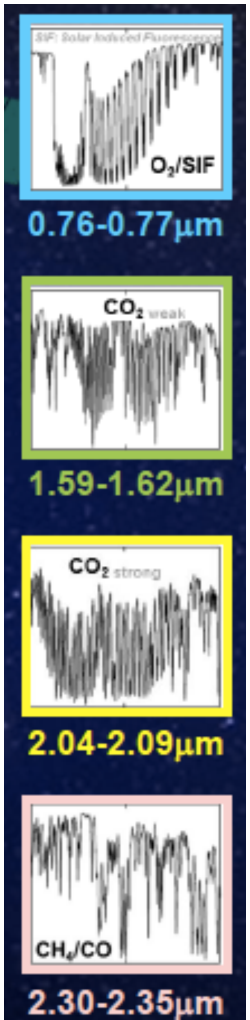
Varying size cities:
Oklahoma City, OK
Wichita, Kansas
Dallas , Texas
Corpus Christi, Texas

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 & PLRA L1 Requirements



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

CO_2

CO_2, H_2O, Clouds, Aerosol

CH_4, CO, H_2O

<u>Multi-Sounding Accuracy</u>

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

<u>Single-Sounding Precision</u>

- 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]

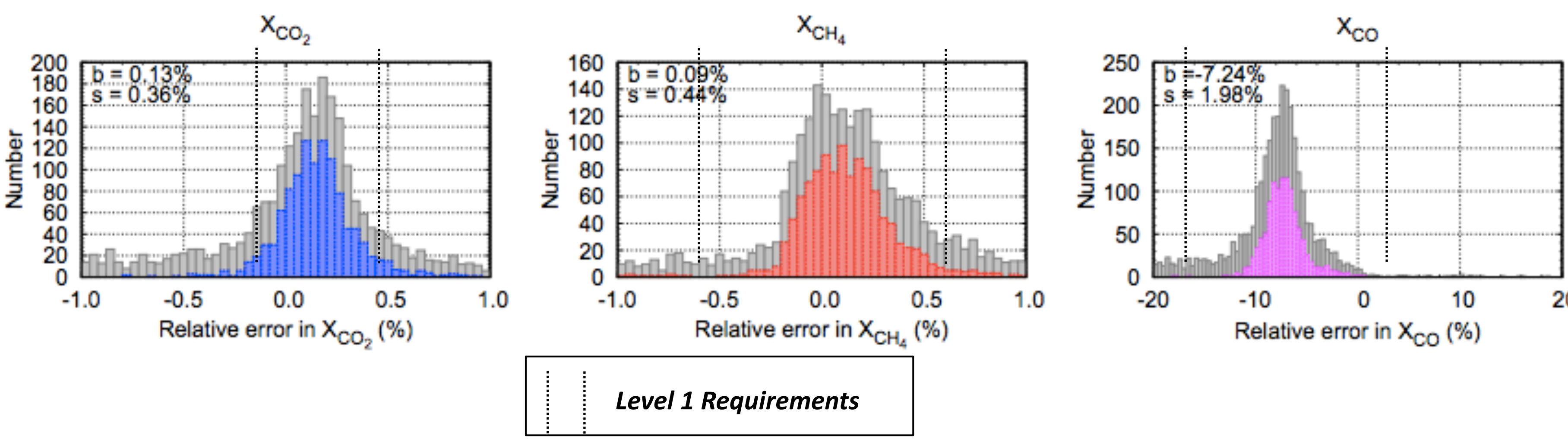
Atmos. Meas. Tech., 9, 4633–4654, 2016
www.atmos-meas-tech.net/9/4633/2016/
doi:10.5194/amt-9-4633-2016

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**



GeoCarb is an International Partnership!

OU

Colorado State University

NASA

LOCKHEED MARTIN

Ames Research Center

SES

JPL

Goddard SPACE FLIGHT CENTER

AEXA AGENCIA ESPACIAL MEXICANA

POSTERA CRESCAM LAUDE
THE UNIVERSITY OF MELBOURNE

LSCE LABORATOIRE DES SCIENCES DU CLIMAT & DE L'ENVIRONNEMENT

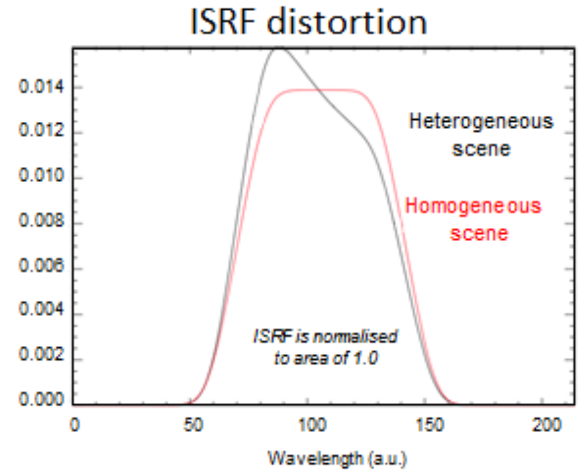
LMD

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

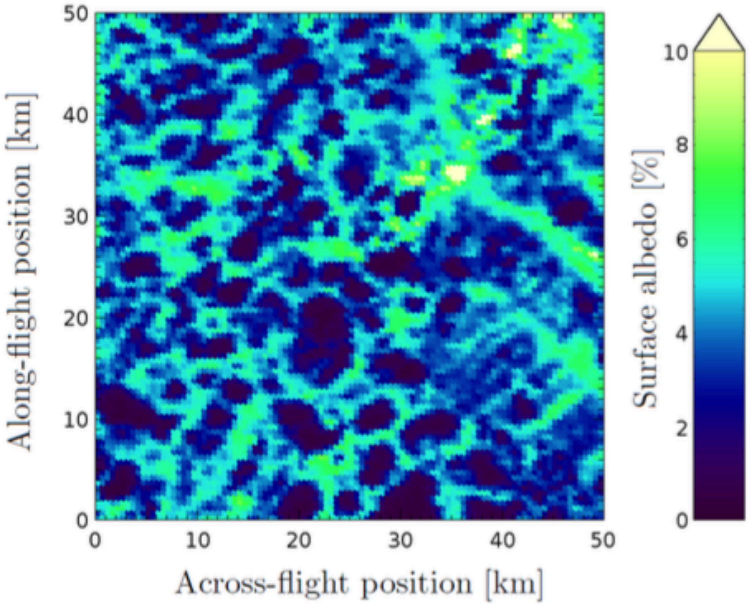
Scene Inhomogeneity Induced Error

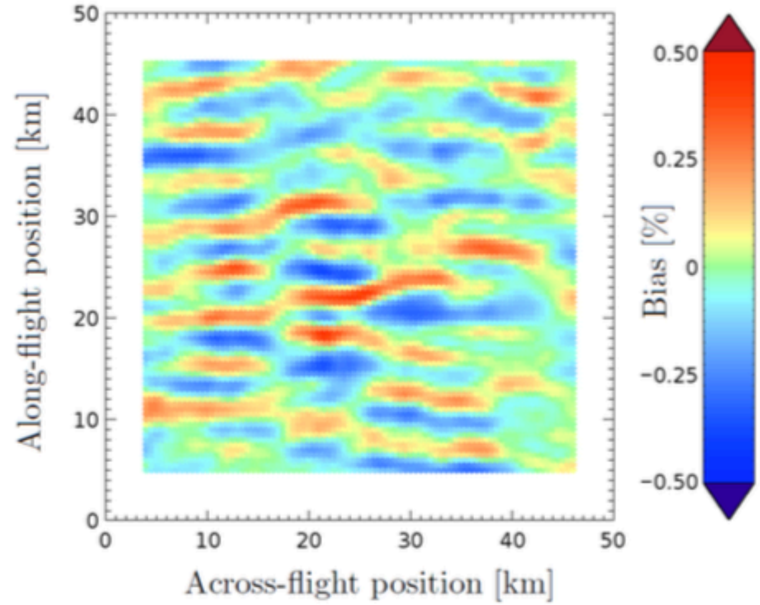
Sentinel 5 found significant retrieval bias resulting brightness variations smaller than the slit width.

(and Bernd Sierk)



Hu et al.: The operational methane retrieval algorithm for TROPOMI, Atmos. Meas. Tech., 9, 5423-5440, 2016



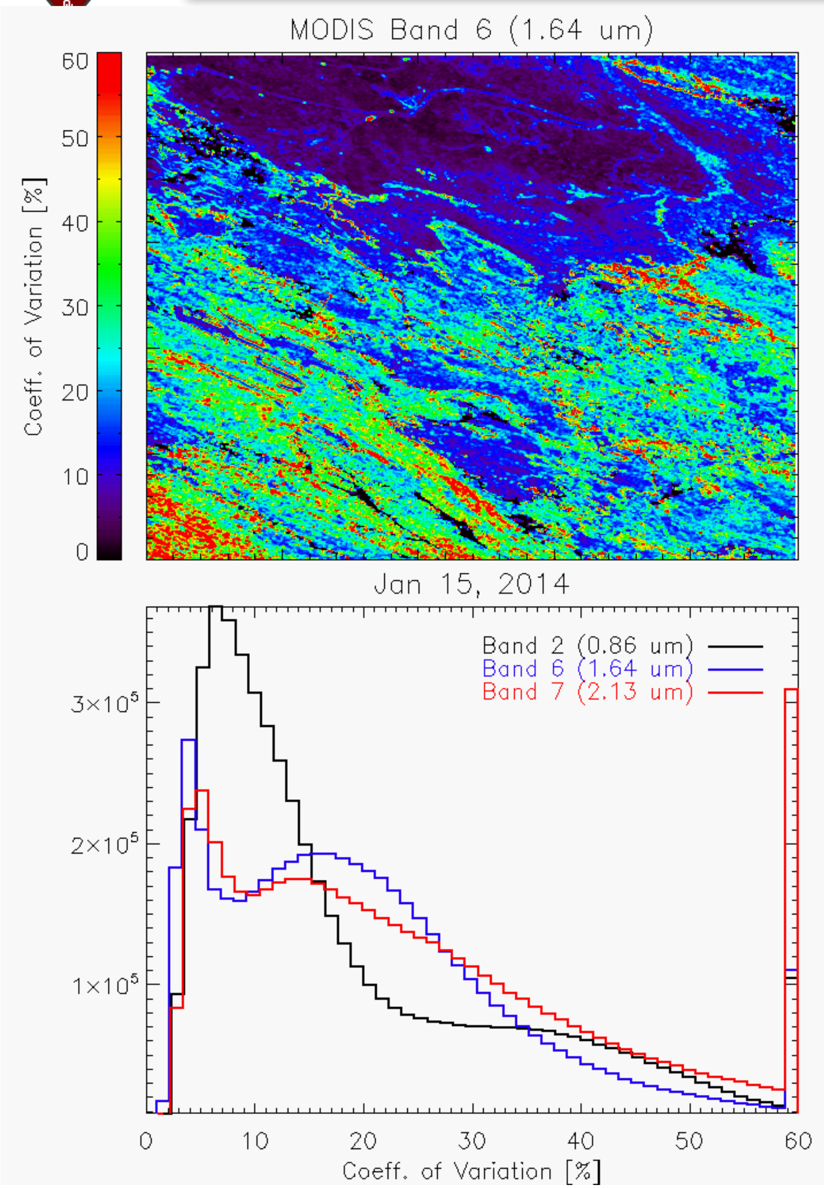


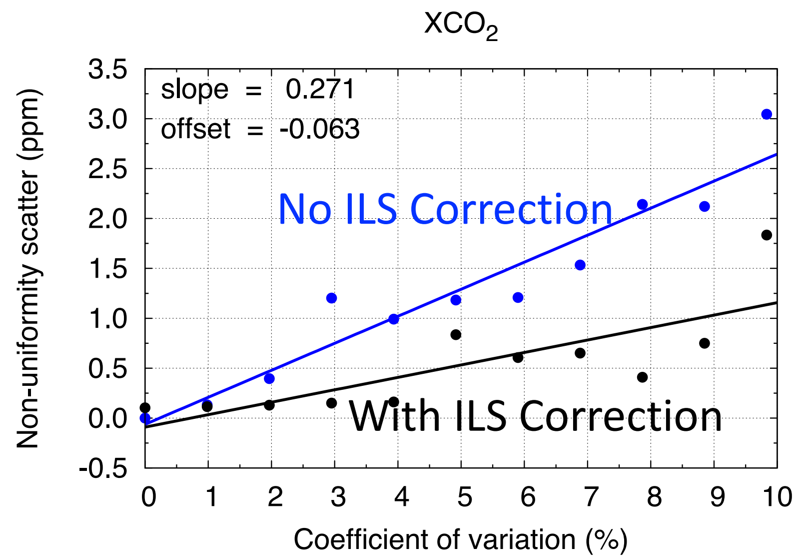
Summary

- GeoCarb is the first Earth Science hosted payload making carbon gas measurements from GEO
- GeoCarb is in Preliminary Design, preparing for PDR in August and Confirmation in October.
- 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
- Resolving known sources of bias (e.g. non-uniform slit illumination)
- We are working closely with the OCO-2 applications lead to develop stakeholder input for SIF data usage
- We'd love to collaborate: urban scale modeling, multi-tracer studies, validation opportunities, ...

Backup

Mitigating Inhomogeneity Induced Errors



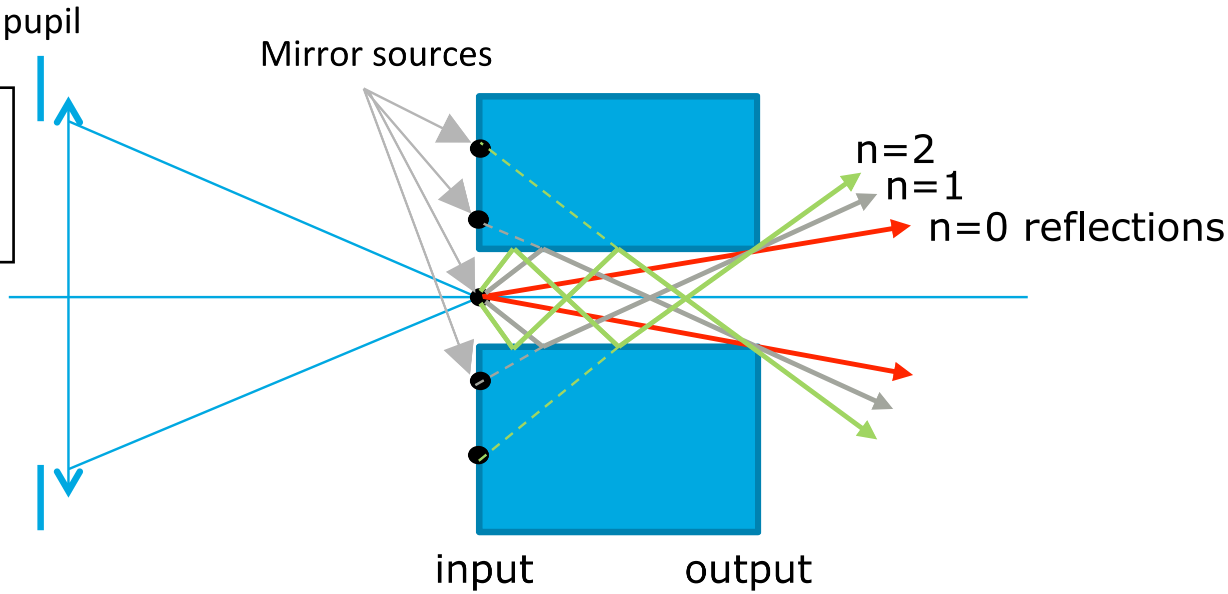


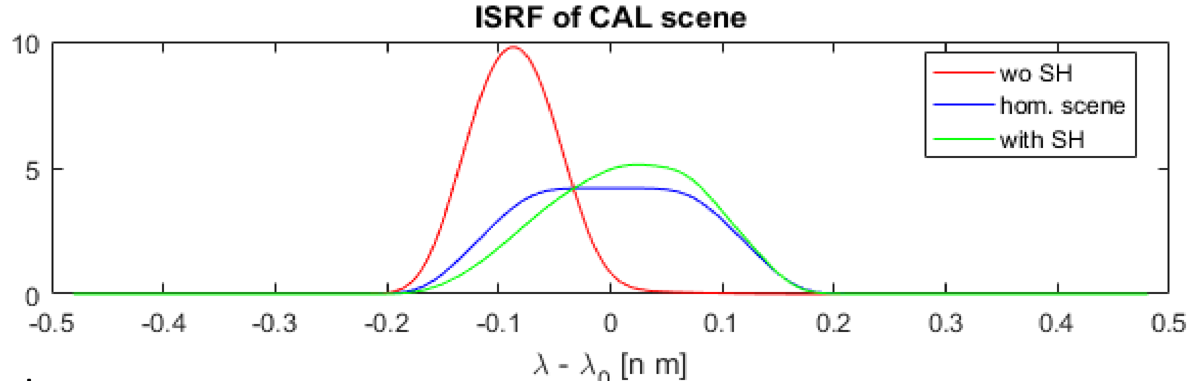
Courtesy: Denis O'Brien

With a continuous scan and downloading multiple frames (rather than the co-added data), we might be able to estimate the distorted ILS function using a weighting of sub-slit ILS functions measured during thermal vacuum testing.

Mitigating Inhomogeneity Induced Errors

1D Slit Homogenizer





Courtesy: Bernd Sierk

Pursuing Both Avenues Will Yield the Lowest Bias