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

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Single slit, 4-Channel IR Scanning Littrow Spectrometer</th>
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<tbody>
<tr>
<td>Bands</td>
<td>0.76μm, 1.61μm, 2.06μm and 2.32μm</td>
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<tr>
<td>Measurements</td>
<td>O₂, CO₂, CO, CH₄ &amp; Solar Induced Fluorescence</td>
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<tr>
<td>Mass</td>
<td>158 kg (CBE)</td>
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<tr>
<td>Dimensions</td>
<td>1.3 m x 1.14 m x 1.3 m</td>
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<tr>
<td>Power</td>
<td>128W (CBE)</td>
</tr>
<tr>
<td>Data Rate</td>
<td>10-100 Mbps</td>
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<tr>
<td>Daily Soundings</td>
<td>~10,000,000 soundings per day</td>
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</table>
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*
Light enters from the direction of the viewer
Testbed Optics

Slit, DBS, and LW Lens 1

LW Grating

LW Littrow

LW Fold Mirror

LW Lens 2

LW DBS and Filters
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

Integrating sphere with Geostationary Lightning Mapper at LMSAL
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.

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

POCO-2 Sampling

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

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Example of a daily GeoCarb E-W Scan

- Selectable E-W scan: 40.7 km in 1m, 407 km in 10m, 1222 km in 30m

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CO₂ Emissions

- ▲ 3-10 Tg per yr
Automating Scanning Strategies
Intensive Scans Multiple Times per Day

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

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), O₂, Clouds, Aerosol

CO₂

CO₂, H₂O, Clouds, Aerosol

CH₄, CO, H₂O

Multi-Sounding Accuracy
- CO₂ : 0.3% (1.2 ppm)
- CH₄ : 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

Performance of a geostationary mission, geoCARB, to measure CO2, CH4 and CO column-averaged concentrations

I. N. Polonsky1, D. M. O’Brien2, J. B. Kumer3, C. W. O’Dell4, and the geoCARB Team5

Potential of a geostationary geoCARB mission to estimate surface emissions of CO2, CH4 and CO in a polluted urban environment: case study Shanghai

- 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!

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.


ISRF distortion

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

(and Bernd Sierk)
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

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

Again the smaller the wavelength the better the ability to homogenize. It should be noted that a real input scene observed by the satellite is by far not as heterogeneous as the CAL scene. A high contrast on Earth ground is softened by atmosphere and is smeared by time since the satellite's swath moves across the Earth with a speed of $6.7 \text{ km/s}$. Quantitatively speaking the few current known real scenes from Earth behave roughly 97% as a homogeneous scene and only 3% as the CAL scene above.

For the last result we come back to formula (1). Because of the simple derivation it is not obvious that this formula shall hold when diffusion is considered. Fixing $l$ and $b$ as above the formula states that the design is optimal if

$$F# = \frac{l}{(2^bn)_{n=1,2,...}},$$

i.e. $F# = 19.98, 9.99, 6.66, ...$. A simulation of ISRF shape error under

1D Slit Homogenizer

Telescope pupil

Mirror sources

input

output

n=0 reflections

n=1

n=2

n=0 reflections

ISRF of CAL scene

wo SH

hom. scene

with SH

Pursuing Both Avenues Will Yield the Lowest Bias