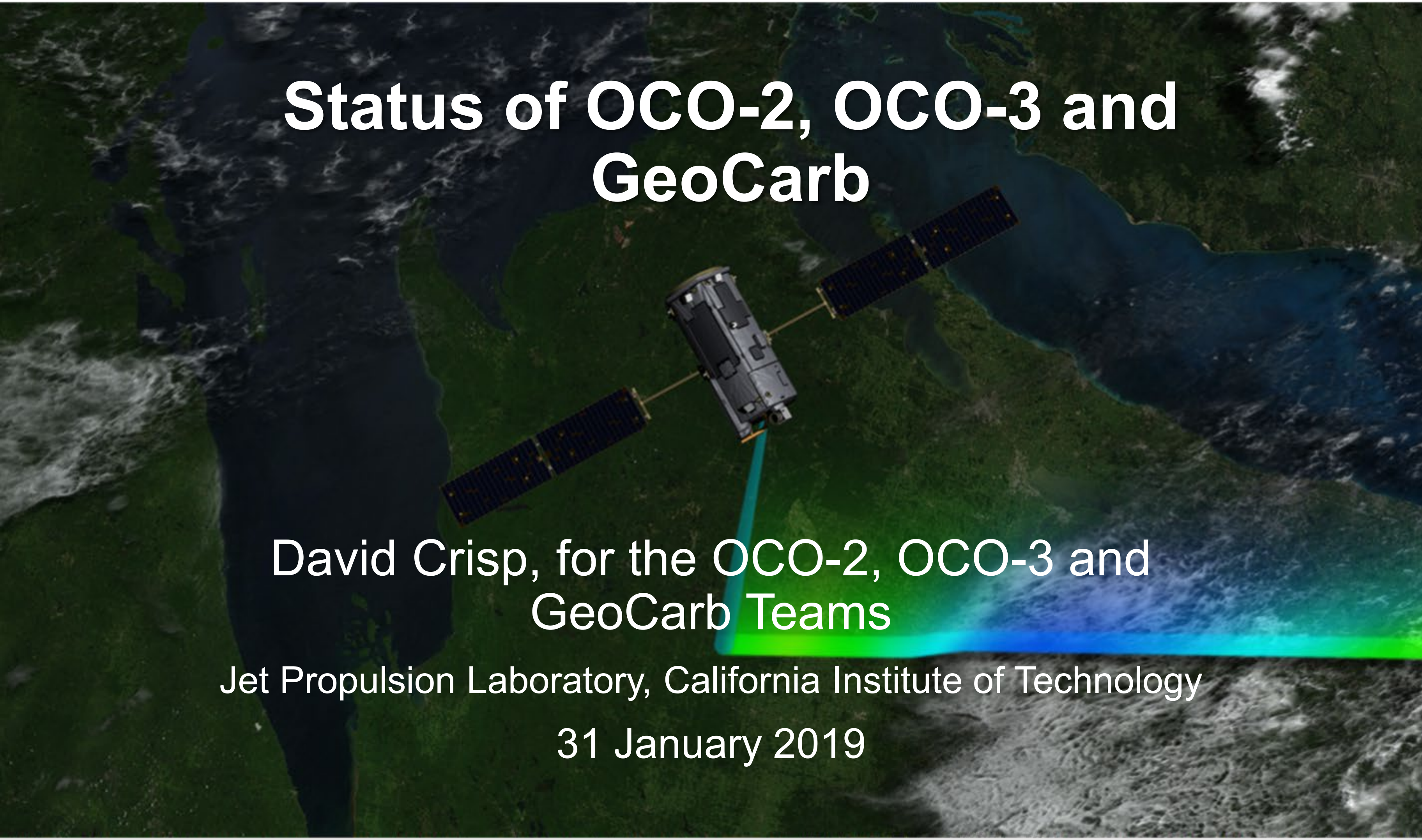


Status of OCO-2, OCO-3 and GeoCarb

David Crisp, for the OCO-2, OCO-3 and GeoCarb Teams

Jet Propulsion Laboratory, California Institute of Technology

31 January 2019

Status Summary

OCO-2 Status

- Observatory Status: Nominal
  - Very close pass (1.3 km) with TanSat on 1 February 2019
- Instrument Status: Nominal
  - Most recent Decon Cycle: 10-17 November 2018
- Science Status: Nominal
  - V8r, V9-Lite products for November and December pending
  - “Build 10” testing initiated

OCO-3 Status

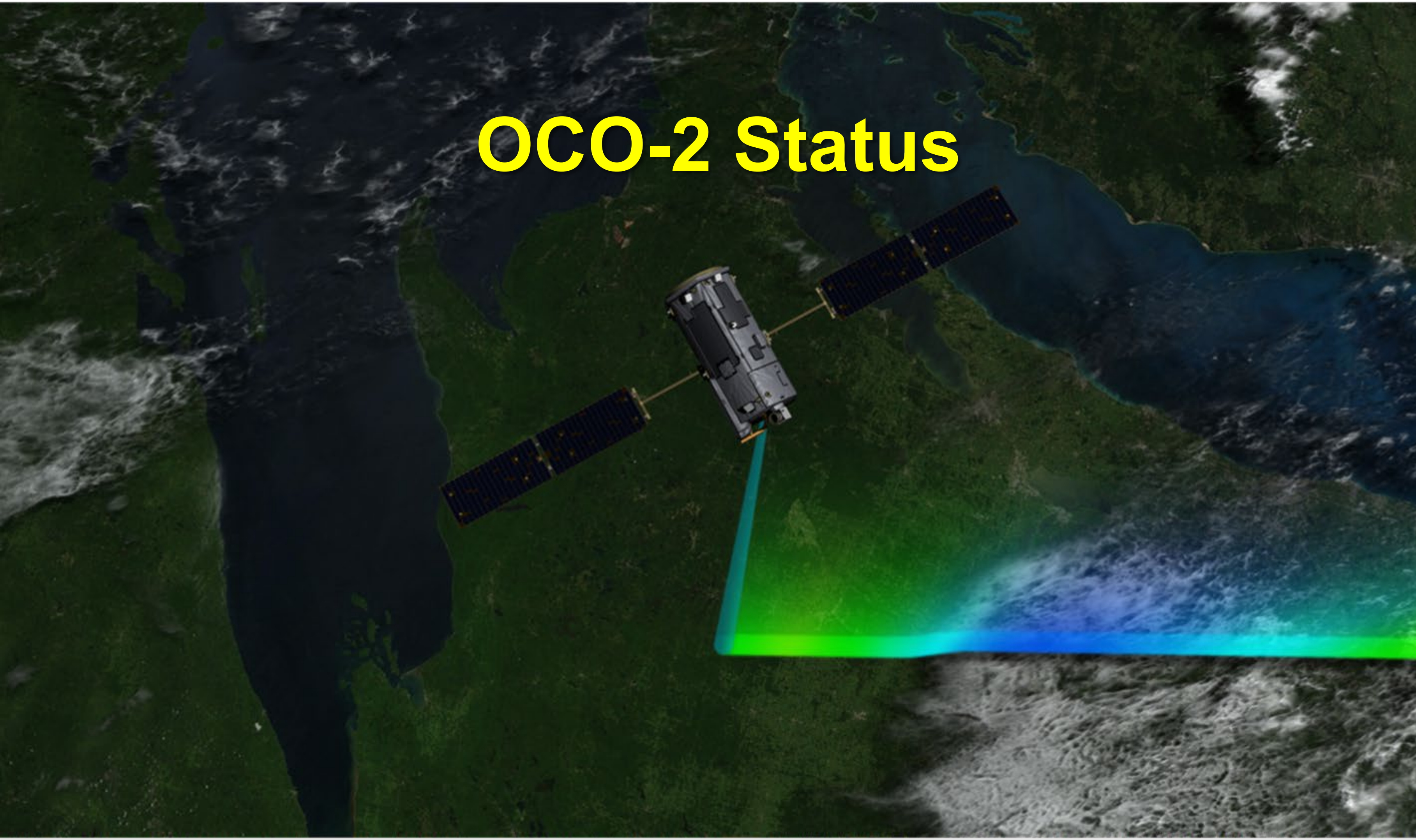
- Launch may slip from 16 to 31 March due to government shutdown

GeoCarb Status

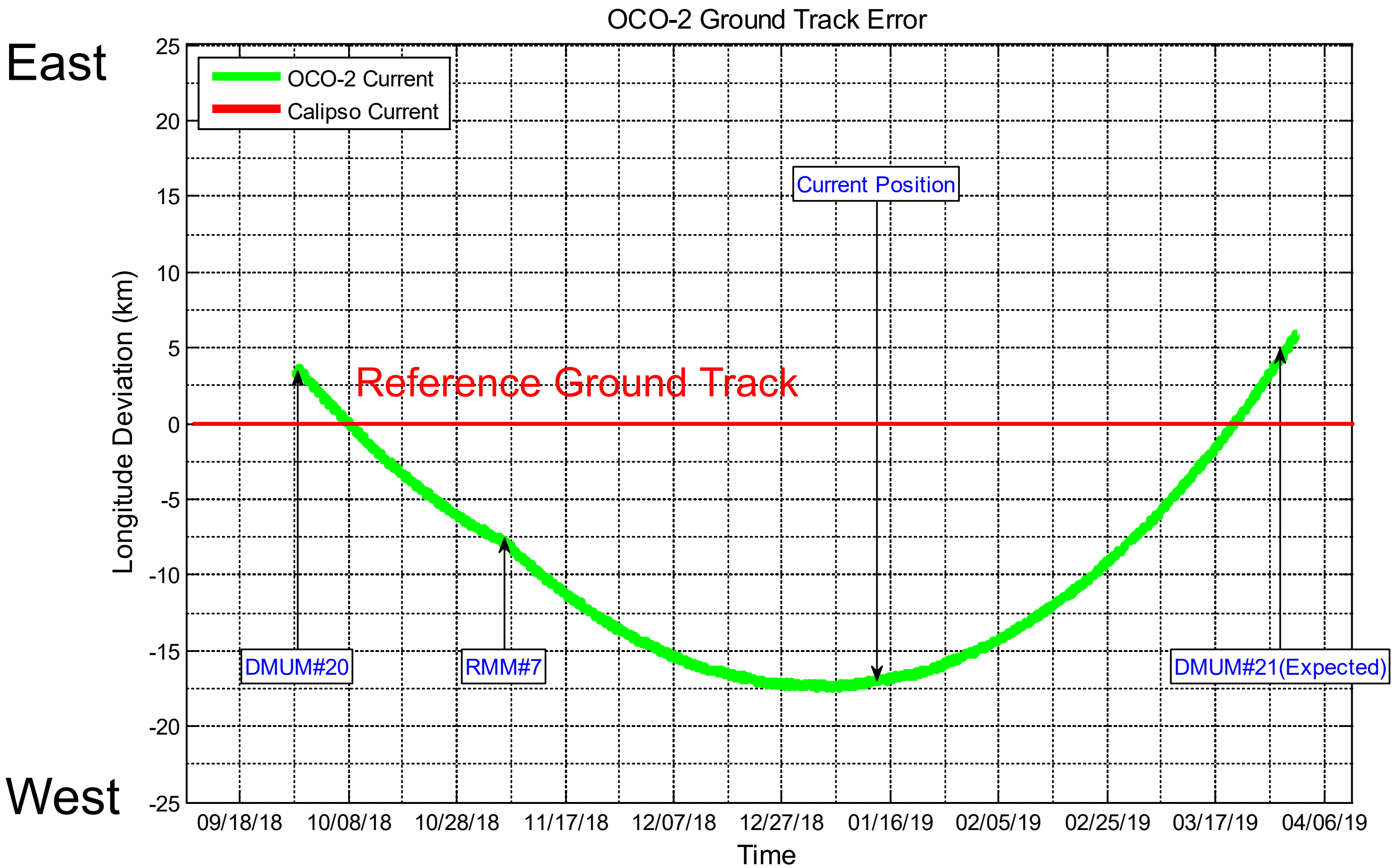
- δ-PDR delayed due to government shutdown

Near Term Activities (IWGGMS-15, CEOS AC-VC)

OCO-2 Status

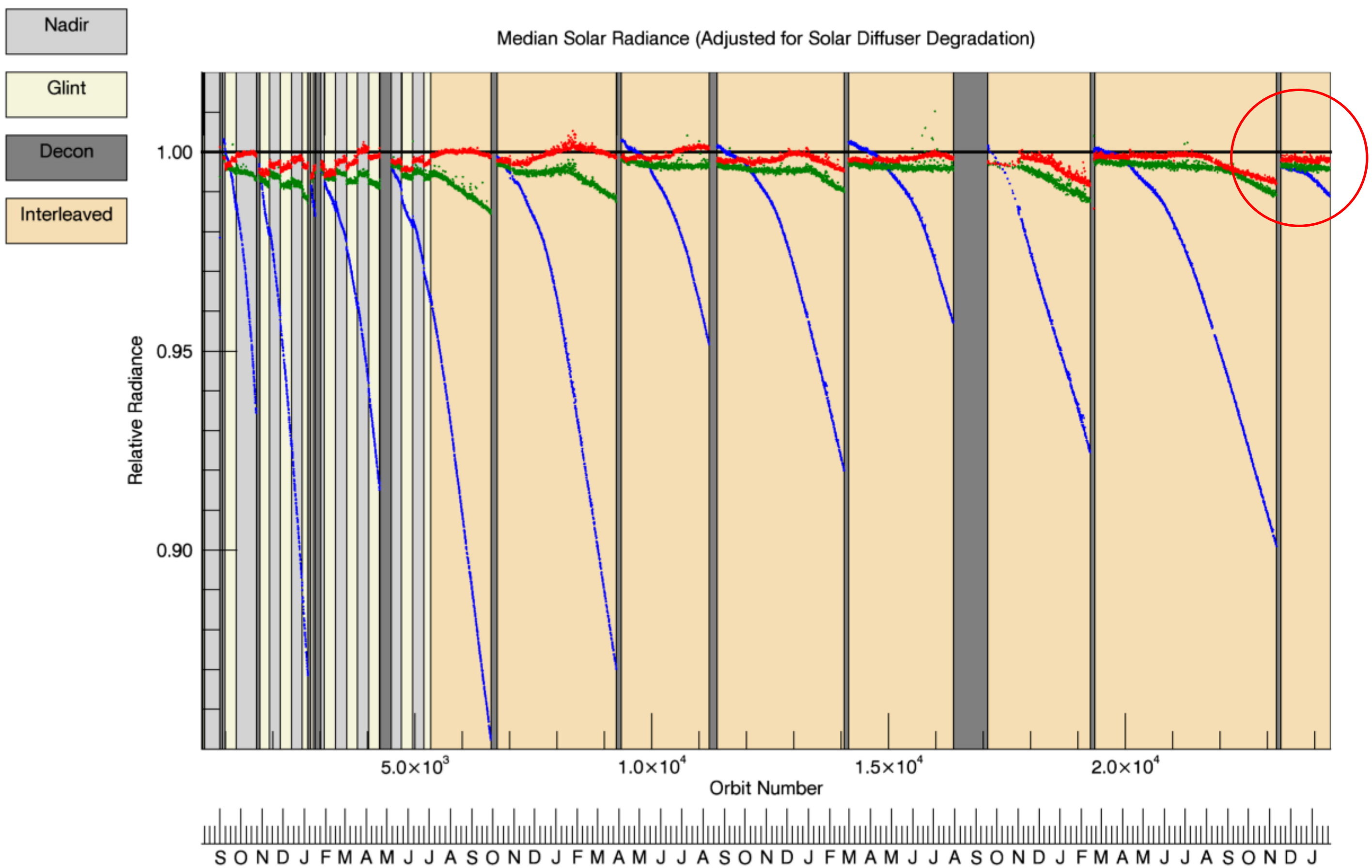


OCO-2 Ground Track



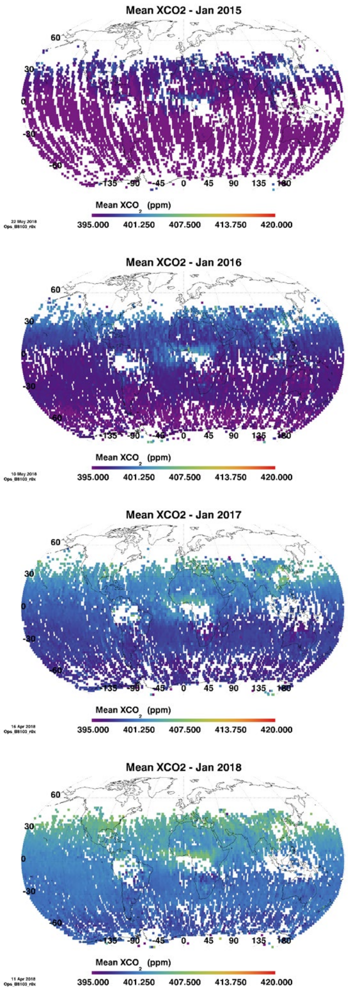
OCO-2 is currently ~17 km west of its reference ground track.
The next drag make-up maneuver is scheduled for 28 March

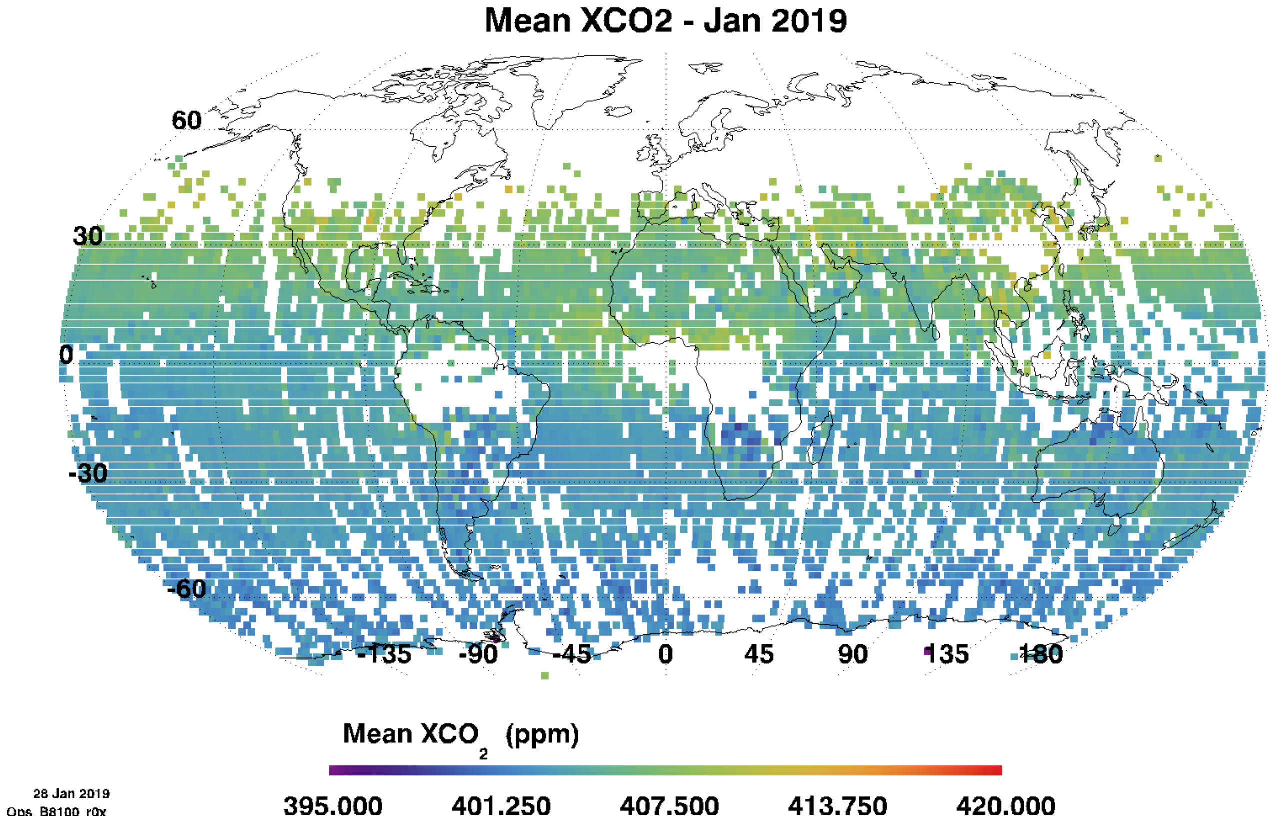
Throughput Trending



November 2018 Decon restored throughput to > 99% in all 3 channels.

L2 V8 Forward Product

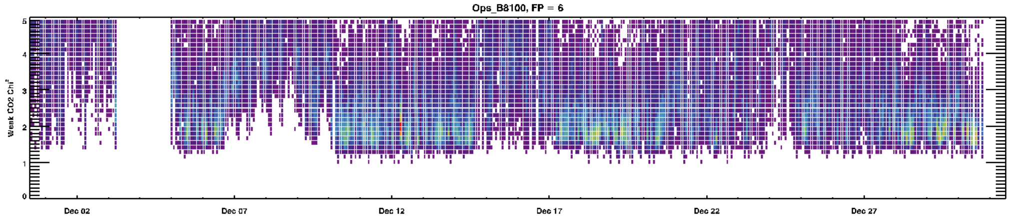




As the January v8 forward product fills in, it is looking a lot like previous years – with more CO2.

Status of the V8r and V9 Lite Products

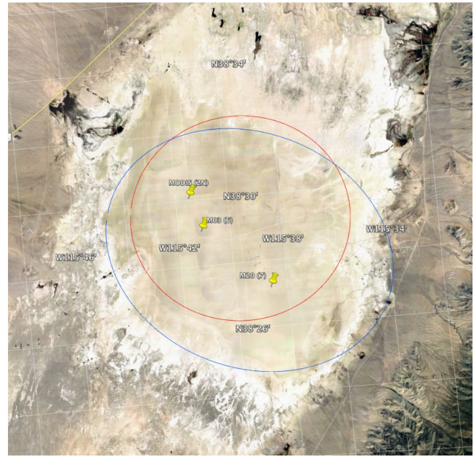
- We have not yet delivered the V8 retrospective product (V8r) or the V9 Lite products for November and December 2018 to the GES-DISC due to 2 factors:
    - We planned to use the NASA Pleiades Cluster to process these data. That cluster has not been available since December 21st, due to the government shutdown.
    - The Calibration Team identified some bad samples in the weak CO_2 band that are producing high χ^2 values in the L2 fits. They requested that we exploit the processing delay to correct these issues for the retrospective November and December products (v8r and v9-Lite)
- The SDOS team now expects to deliver the November and December 2018 retrospective products to the GES-DISC by the following dates:
    - November V8r and V9 Lite files - mid-February
    - December V8r and V9 Lite files - end of February



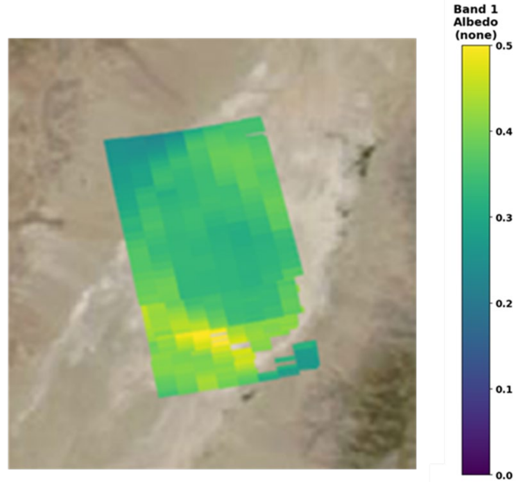
χ^2 values for the weak CO2 footprint 6. The high values are caused by a few bad pixels.

Status and Prospects for Railroad Valley

- The Railroad Valley playa is a critical surface calibration site for several operating and planned Earth Science missions by NASA and its partners.
  - Only instrumented site within the U.S. that is sufficiently homogeneous and undisturbed over a large enough area to enable vicarious calibration of large-footprint instruments, such as OCO-2, OCO-3, GOSAT, GOSAT-2, and GeoCarb.
- Recent mining claims threaten to disrupt the surface of the Railroad Valley playa, rendering it useless for vicarious calibration
- NASA Science Directorate Management has approved the plan to submit a Withdrawal Application that will be submitted to the U.S. Bureau of Land Management to restrict public uses of the RRV playa that disturb the surface
- No progress due to government shutdown



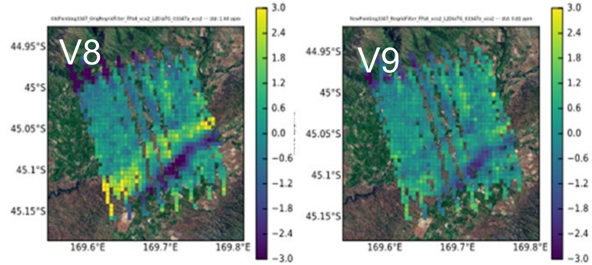
GOSAT footprints on RRV Playa



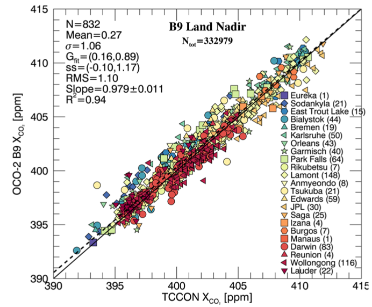
OCO-2 Target Observations over RRV

The OCO-2 V9 Product

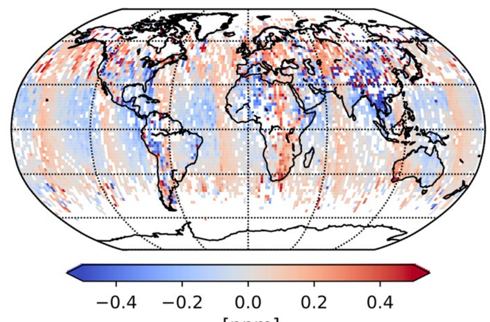
- The OCO-2 Team released the Version 9 (V9) product on 10/15.
    - refined pointing
    - a correction to the prior meteorology
    - updated filtering and bias correction
- These updates
    - reduce bias in the presence of rough topography
    - Provide better sampling over topical and boreal forests with slightly more scatter
- This new dataset is available through the GES-DISC



Pointing Correction Reduces XCO_2 Bias

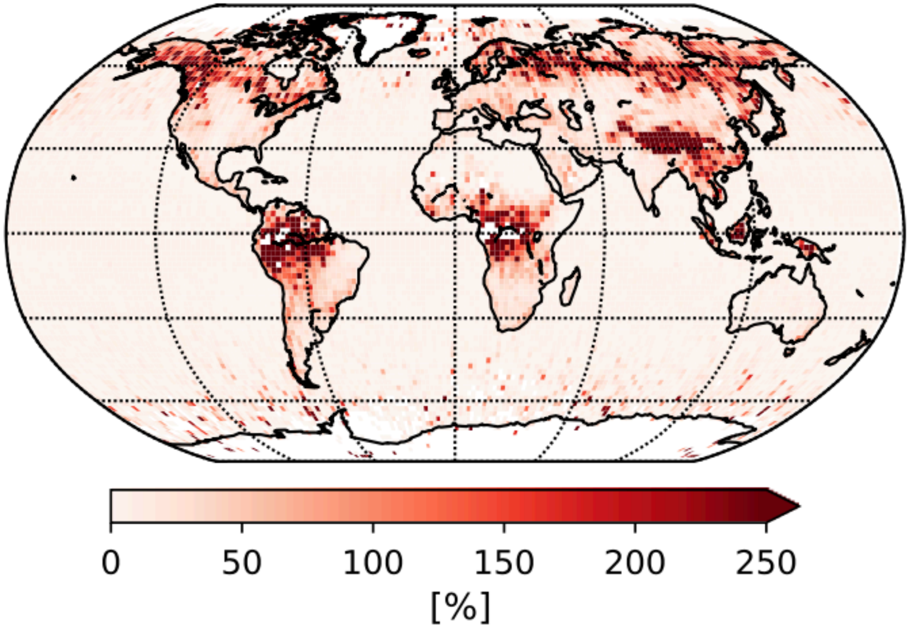


V9 vs TCCON

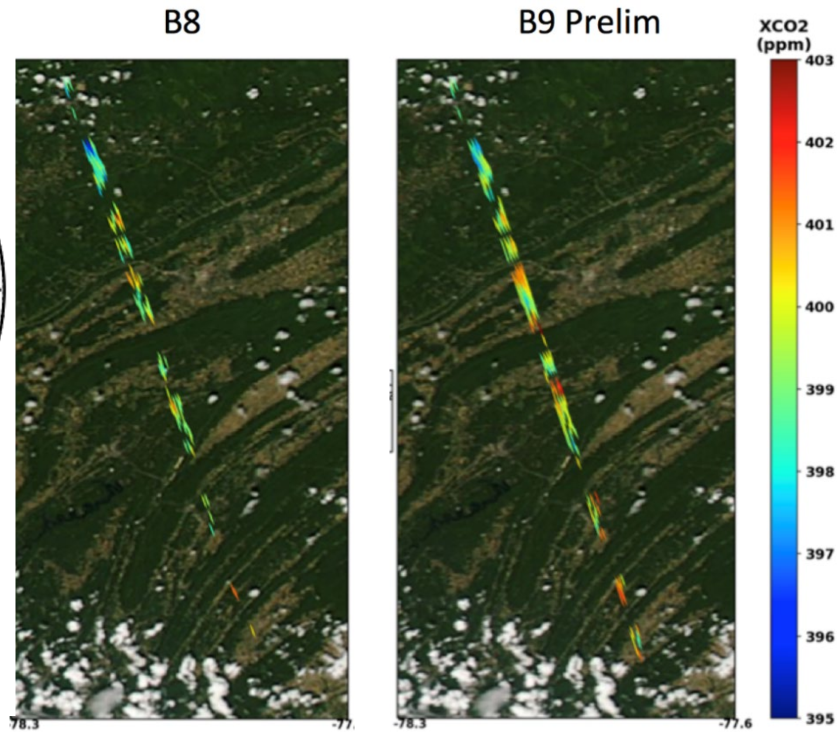


XCO_2 Differences: V8 - V9

Improved Yields for v9-Lite



Matt Kiel et al., AMTD 2018



Emily Bell (CSU)

The pointing correction, combined with re-tuned quality filters improved the yield, especially in regions with rough topography and over dark forested surfaces.

Coming Attractions: Publications in Review

- Ye, X., Lauvaux, T., Kort, E. A., Oda, T., Feng, S., Lin, J. C., Yang, E., and Wu, D., Constraining fossil fuel CO2 emissions from urban area using OCO-2 observations of total column CO2, ATMOSPHERIC CHEMISTRY AND PHYSICS Discussions, 2018.
- Kiel, M., O'Dell, C. W., Fisher, B., Eldering, A., Nassar, R., MacDonald, C. G., and Wennberg, P. O.: How bias correction goes wrong: Measurement of XCO2 affected by erroneous surface pressure estimates, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2018-353, in review, 2018.
- Nelson, R. R. and O'Dell, C. W.: The Impact of Improved Aerosol Priors on Near-Infrared Measurements of Carbon Dioxide, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2018-366, in review, 2018.
- Kulawik, S. S., O'Dell, C., Nelson, R. R., and Taylor, T. E.: Validation of OCO-2 error analysis using simulated retrievals, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2018-368, in review, 2018.
- Eldering, A., Taylor, T. E., O'Dell, C. W., and Pavlick, R.: The OCO-3 mission; measurement objectives and expected performance based on one year of simulated data, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2018-357, in review, 2018.
- Wang, H., Jiang, F., Wang, J., Ju, W., and Chen, J. M.: Differences of the inverted terrestrial ecosystem carbon flux between using GOSAT and OCO-2 XCO2 retrievals, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2018-1175, in review, 2018.

Anthropogenic CO_2 Signatures from OCO-2

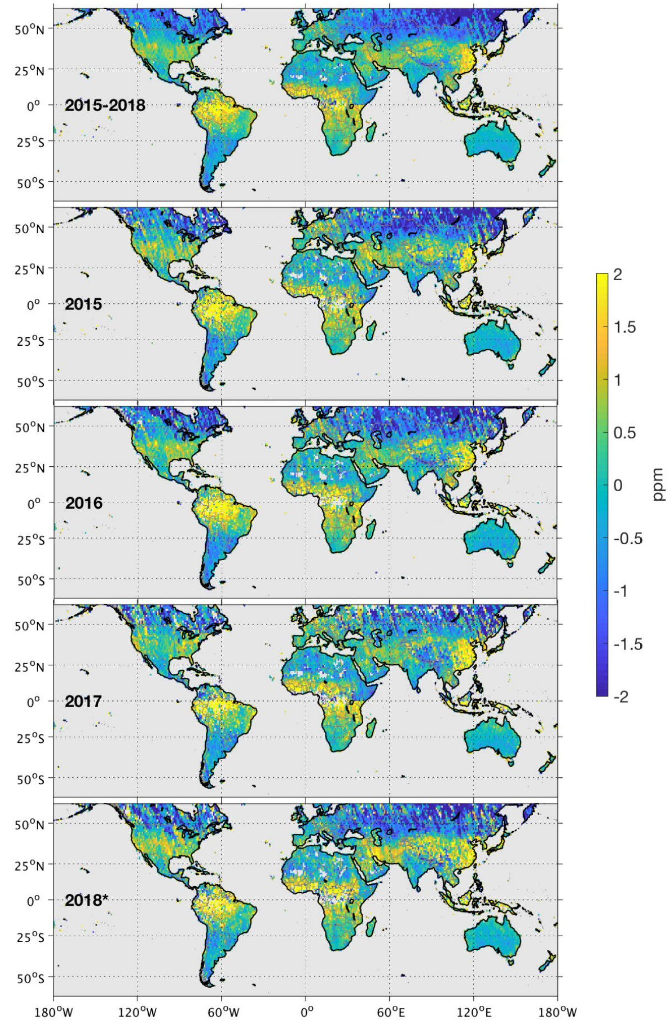
Goal: Understanding Anthropogenic CO_2 signatures on local to global scales

Approach: Identifying persistent XCO_2 anomalies in OCO-2 data

What We Have Learned: OCO-2 XCO_2 anomalies are robust, consistent from year-to-year, and are well correlated with other proxies for high temperature combustion, such as NO_2

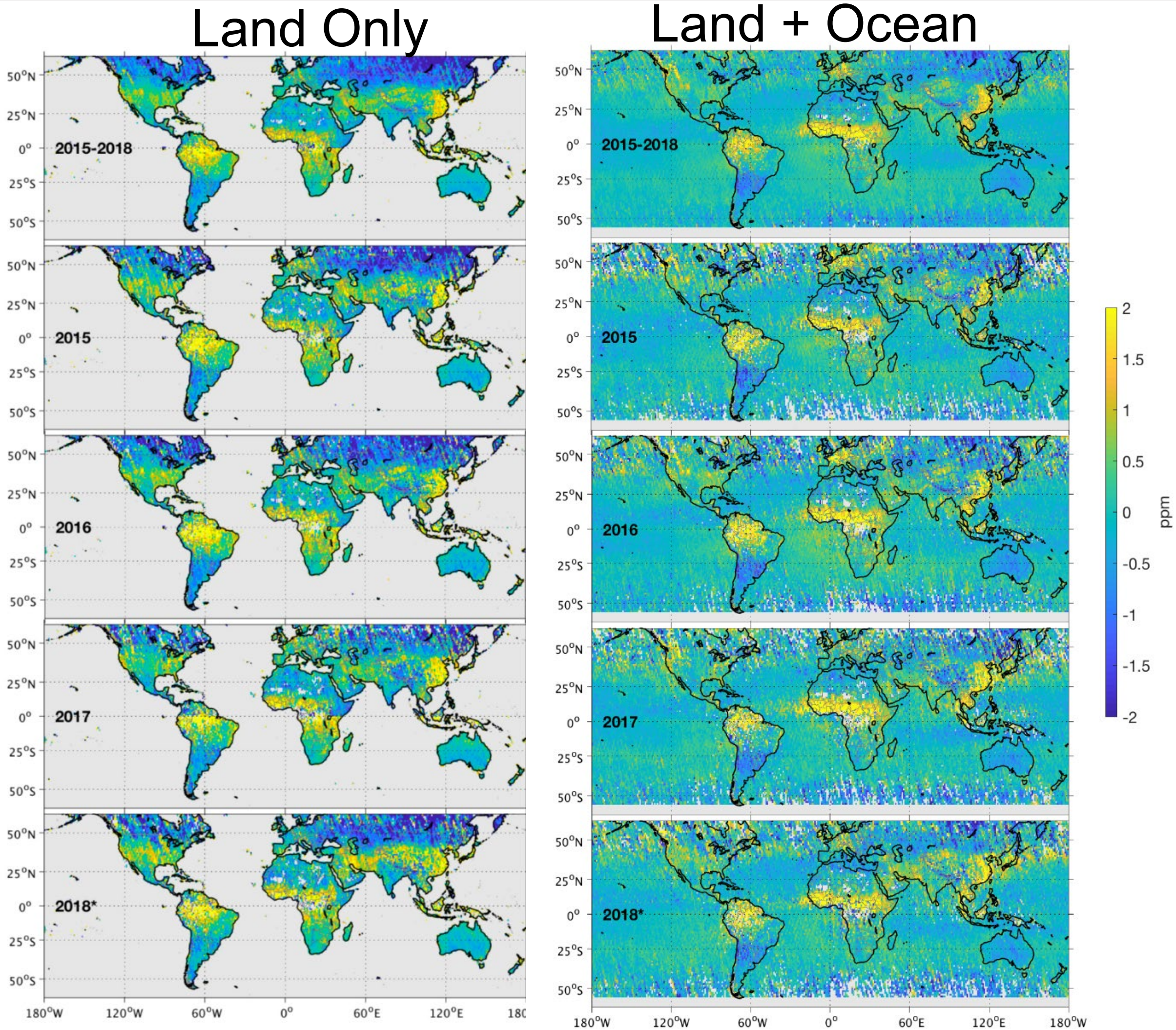
Benefit: These experiments show the intrinsic value of OCO-2 XCO_2 data for tracking anthropogenic CO_2 emissions

Hakkarainen, J., et al., Global XCO_2 anomalies as seen by Orbiting Carbon Observatory-2, Remote Sensing, in review, 2019.



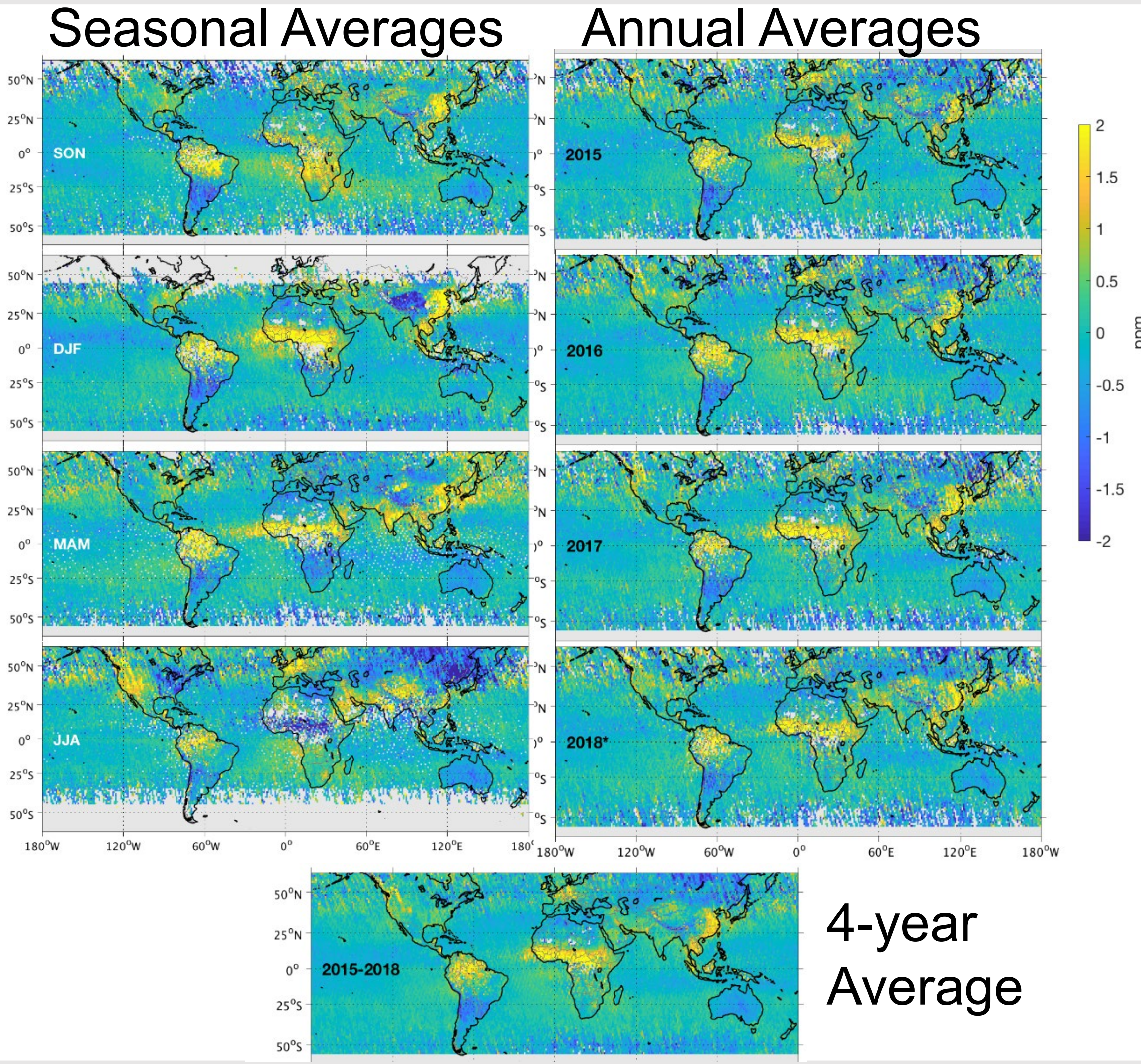
Impact of Including Ocean Observations in Estimates of Land Anomalies

- Anomalies were derived using only land XCO_2 (nadir + glint, left panel) and both land and ocean XCO_2 observations (right)
- The structure and amplitude of most land anomalies is similar with and without ocean XCO_2 measurements
- However, ocean data contributes a small positive anomaly to all land areas because ocean XCO_2 is biased low relative to land XCO_2



Implications of Anomalies

- Seasonal (left) and annual (right) average anomalies were derived for 2015-2018.
- Positive XCO_2 anomalies dominate the tropics, except equatorial Africa during JJA – are the tropics now a net source of CO_2?
- High latitudes land is dominated by negative XCO_2 anomalies, which are strongest during JJA
- Biospheric CO_2 uptake reverses the positive XCO2 anomalies over northeast U.S. and east Asia during JJA

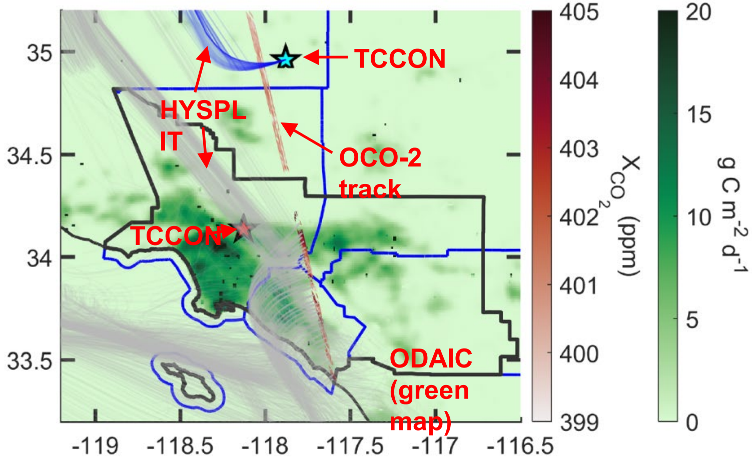


What is the total CO_2 flux from greater Los Angeles?

Jacob Hedelius, Junjie Liu, Tomohiro Oda, Shamil Maksyutov, Coleen Roehl, Laura Iraci, James Podolske, Patrick Hillyard, Jianming Liang, Kevin Gurney, Debra Wunch, Paul Wennberg

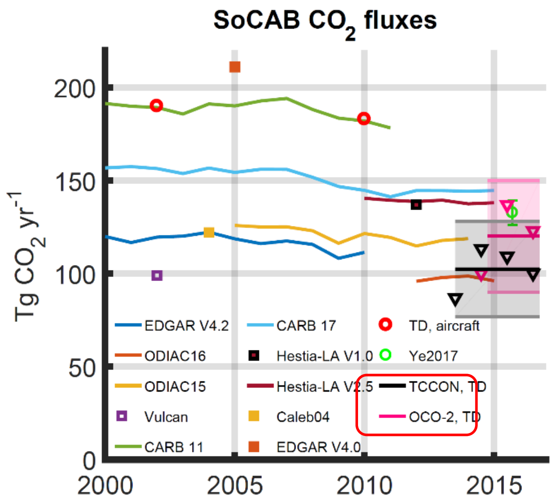
Tools

- OCO-2 satellite data, TCCON ground data
- NOAA meteorology (NAM 12km, HYSPLIT)
- ODIAC and Hestia-LA emissions
- Inversion model that we developed



Results

- Found fluxes in between ODIAC16 and Hestia-LA
- Performed 10 tests to estimate uncertainty, total is 25% - biggest source is meteorology



Significance

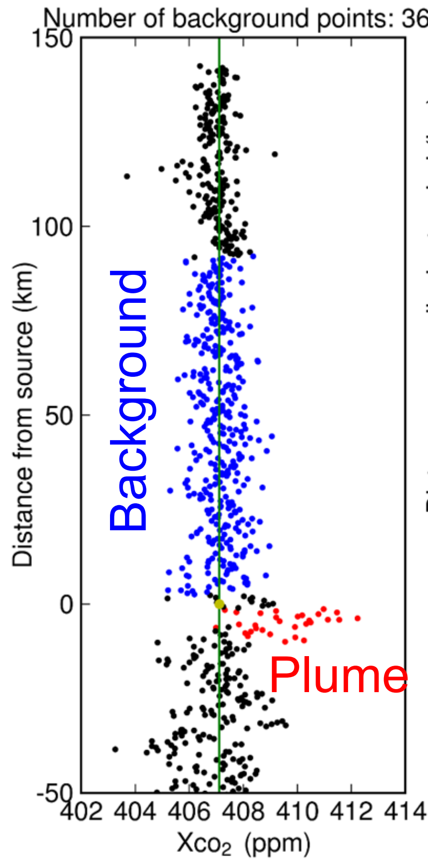
- Demonstrates a method to convert OCO-2 observations to urban emissions in Tg CO_2 yr^{-1}
- Coupled with future studies (e.g., with OCO-3) may help show urban carbon flux trends

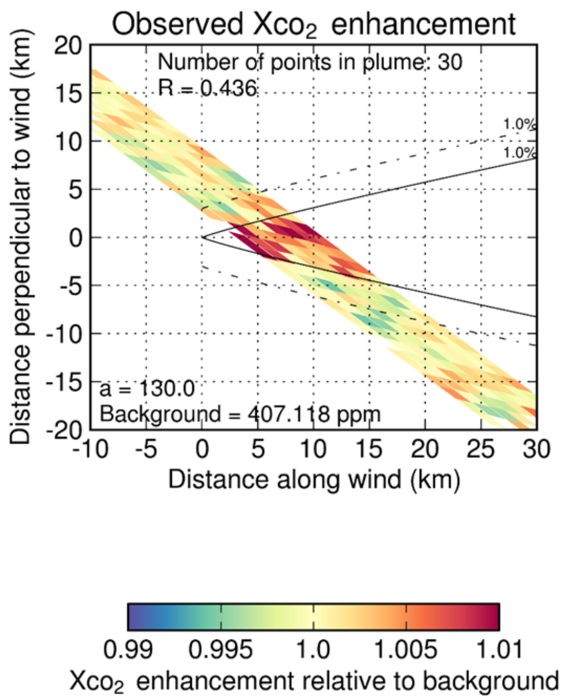
DOI: 10.5194/acp-18-16271-2018

Emissions from Large Power Plants

- **Goal:** Demonstrate that OCO-2 can detect and quantify emission from large power plants
- **Approach:** Quantify emission rates using OCO-2 XCO_2 enhancements and local wind data
- **What we've Learned:** OCO2 data can be used to quantify emissions at the 7 to 20% level in a single overpass
- **Benefit:** Space-based CO_2 measurements will play a critical role in future emissions monitoring

Ray Nassar and Calium McCracken, Remote Sensing, 2019





OCO-2 flew over the Belchatow Power Station in Poland March 28, 2017, detecting 89±12 kilotons of CO_2 per day – consistent with other reports.

Nominal B10 Testing Plan

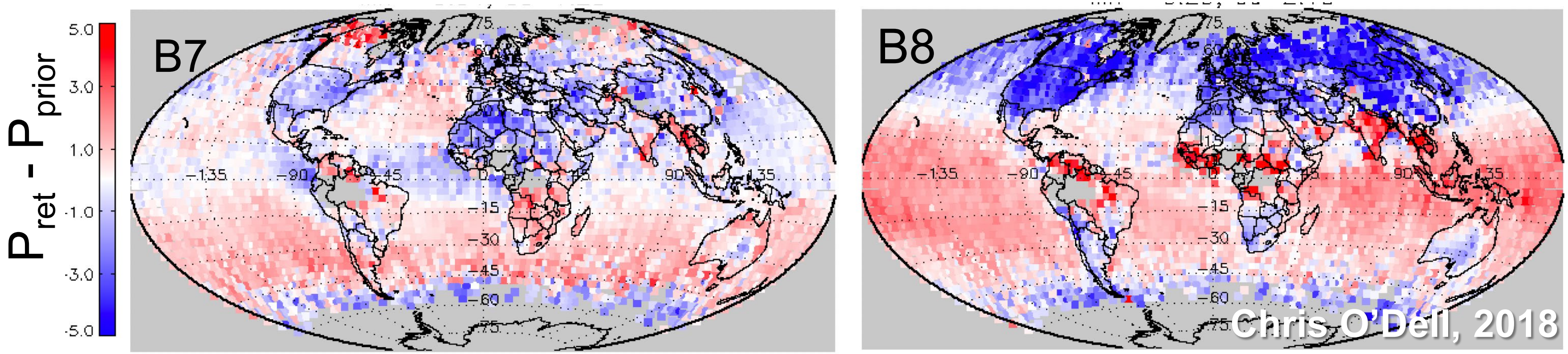
- Solar model update
- ABSCO update

} Progress Report follows

- Test daily aerosol prior
- CO_2 prior update (in coordination with TCCON)
- Assess impact of removing surface pressure from retrieved state vector
- Revise SIF calculation in L2
- Examine processes that affect CO2_grad_del behavior
- Assess value of a CO_2 column (or profile eigenvector) retrieval
- Assess impact of including a non-linear albedo slope
- Investigate including radiance offsets in ABP and in all bands for L2
- Assess convergence criteria and impact of restricting unphysical states
- Include temp profile (or temperature profile eigenvectors) in retrieval
- Assess impact of effort to detect/correct biases due to 3D effects of clouds

Issue: Surface Pressure Biases associated with O_2 A-band Spectroscopy

Differences between the retrieved and prior (ECMWF) surface pressures for ABSCO 4.2 (V7) and ABSCO 5.0 V8) (no EOFs)

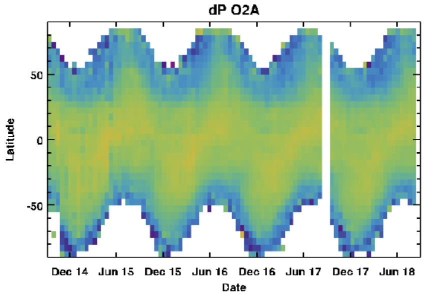


March-April-May seasonal means for B7 (ABSCO 4.2) and B8 (ABSCO 5.0)

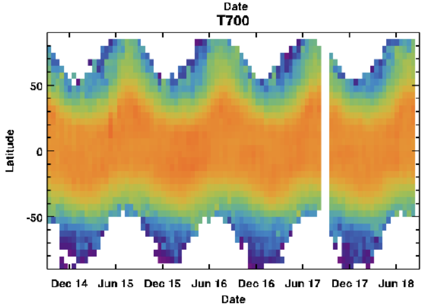
Improvements in the O_2 A-Band spectroscopy reduced spectral residuals and scatter in surface pressure retrievals, but introduced a coherent, pole-to-equator surface pressure bias, and a corresponding inverse pole-to-equator XCO_2 bias.

Lesson Learned: Absorption coefficient CAN produce spatially variable biases

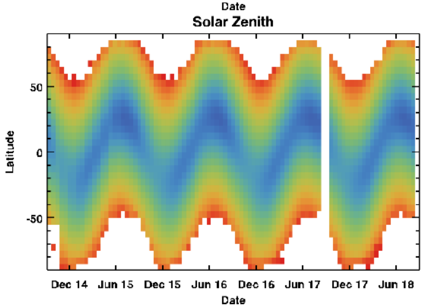
Origin of the Surface Pressure Bias



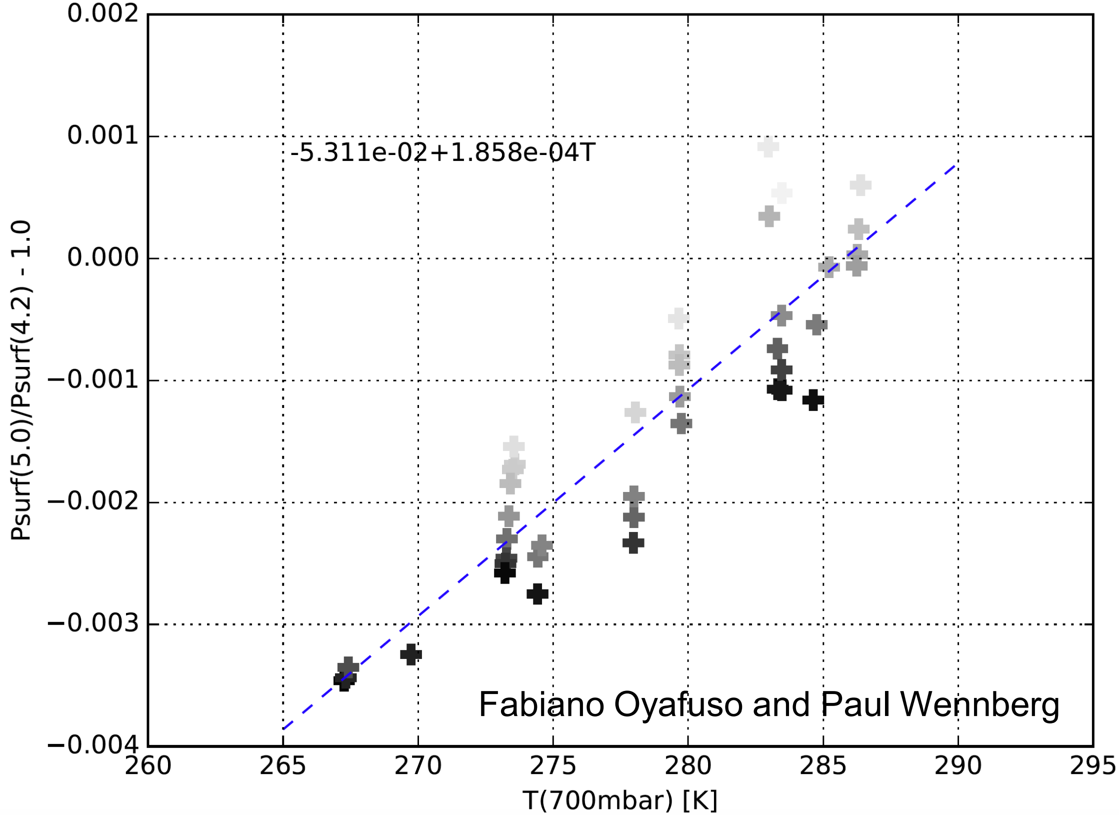
ΔP_{surf}



T(700 hpP)



SZA



The time-dependent amplitude of the surface pressure bias is more strongly correlated with near-surface temperature and/or column water vapor than air mass (note ~1-month lag in ΔP_{surf} and T(700 hP) vs solar zenith angle (SZA)).

.

Sequence of ABSCO tests

- **Test 0: B9 baseline (absco v5.0)**
- **Test 1: B9 no-EOF baseline (absco v5.0)**
- **Test 2: Update to water vapor continuum (from "custom" to MT_CKD v3.2)**
- Test 3: Update to both water vapor continuum and water vapor lines (H16)
  - Ground-based testing suggested not the way we would go, but test for completeness
- **Test 4: O2 A-band: v180916 line contribution + 181031 Mlawer empirical CIA**
- Test 5: O_2 A-band: v180916 line contribution + 181019 Mlawer empirical CIA
  - Previous iteration of CIA. Asked for this mainly for purposes of a sensitivity test.

New Updates to the ABO2 Cross Sections

- A substantial amount of efforts has been devoted to collecting and fitting laboratory measurements to identify/correct the air mass bias
- Fits have improved, but "Sawtooth" residuals indicate outstanding issues with line mixing

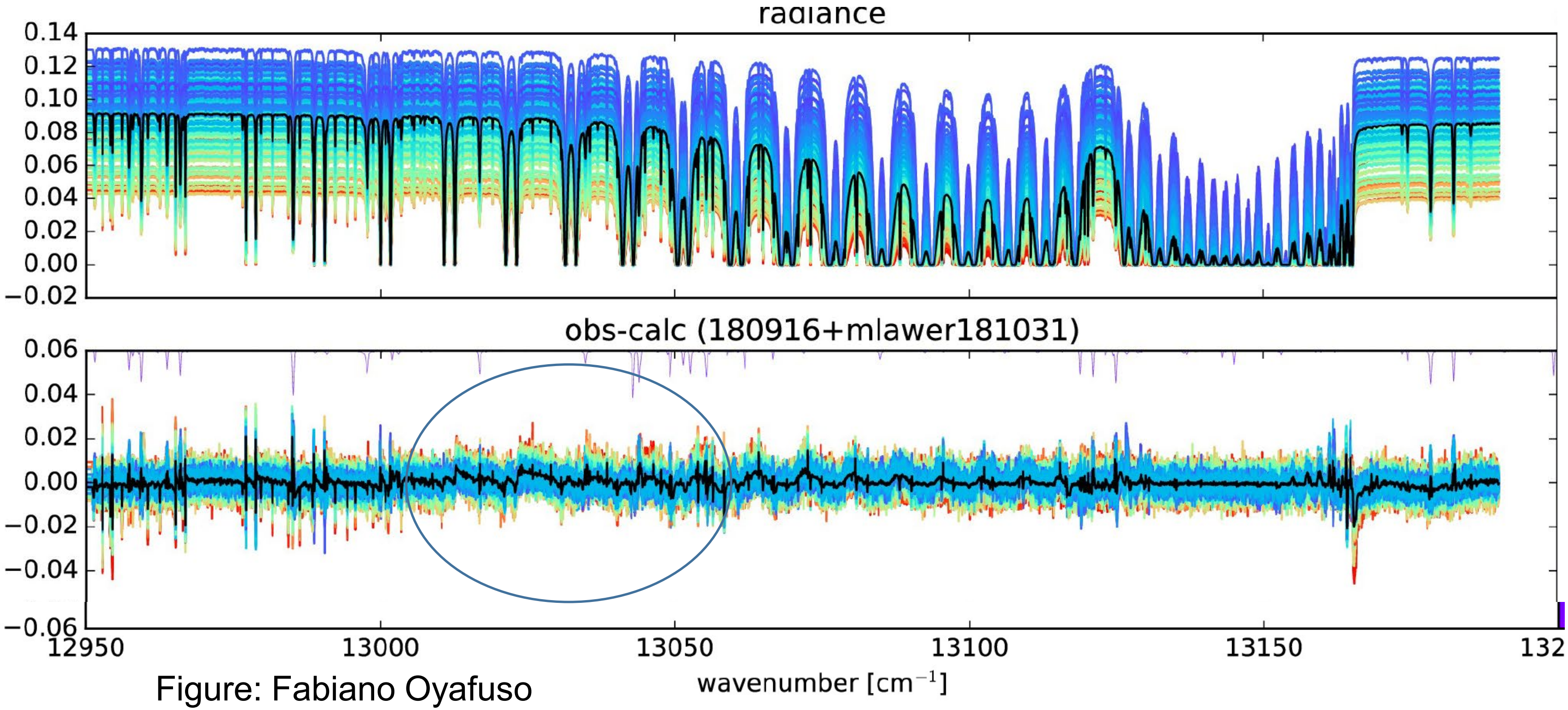
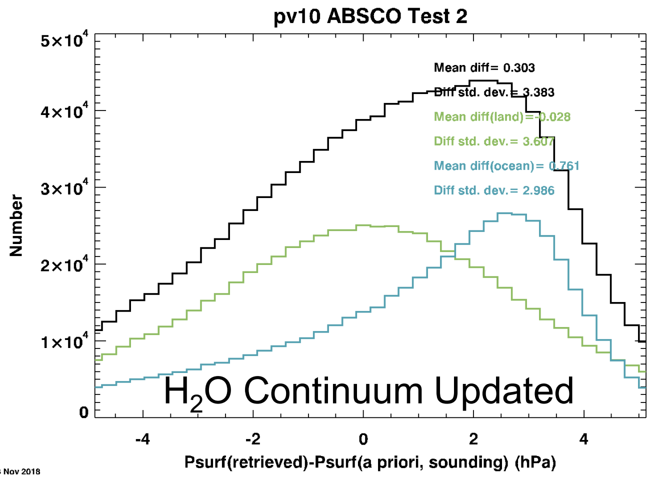
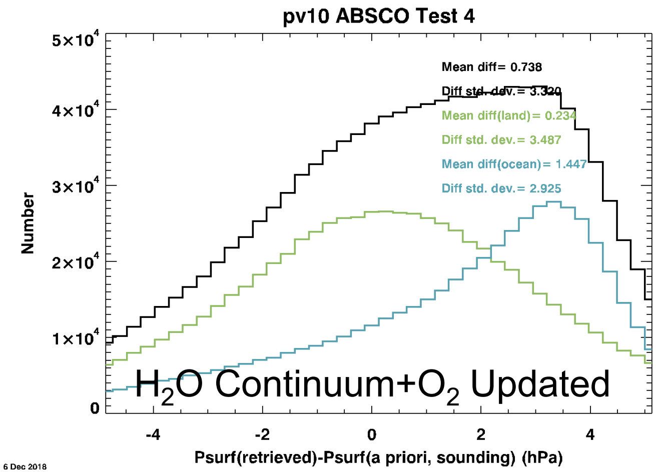


Figure: Fabiano Oyafuso

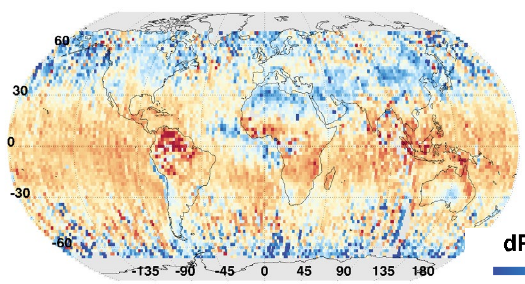
Preliminary Tests of New ABSCO Tables

- H_2O continuum update reduces water vapor dependence
- O_2 ABSCO update reduces spectral residuals and p_surf temperature dependence, but has an overall high bias similar latitude dependent biases – WORK IN PROGRESS

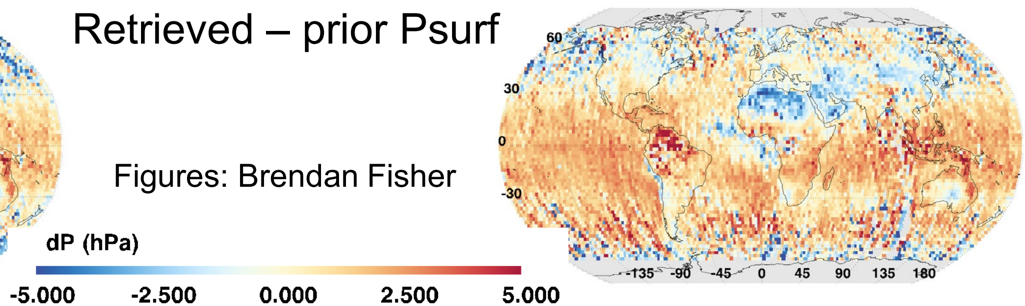




Retrieved – prior Psurf



Figures: Brendan Fisher



Overall structure and latitude dependence of the surface pressure histograms is not changed with the introduction of the revised ABSCO coefficients (using mlawer20181031 CIA)

O_2-O_2 Collision-Induced Absorption

- Residuals can be reduced by fitting an empirical O_2-O_2 continuum
- This continuum can introduced biases in the surface pressure

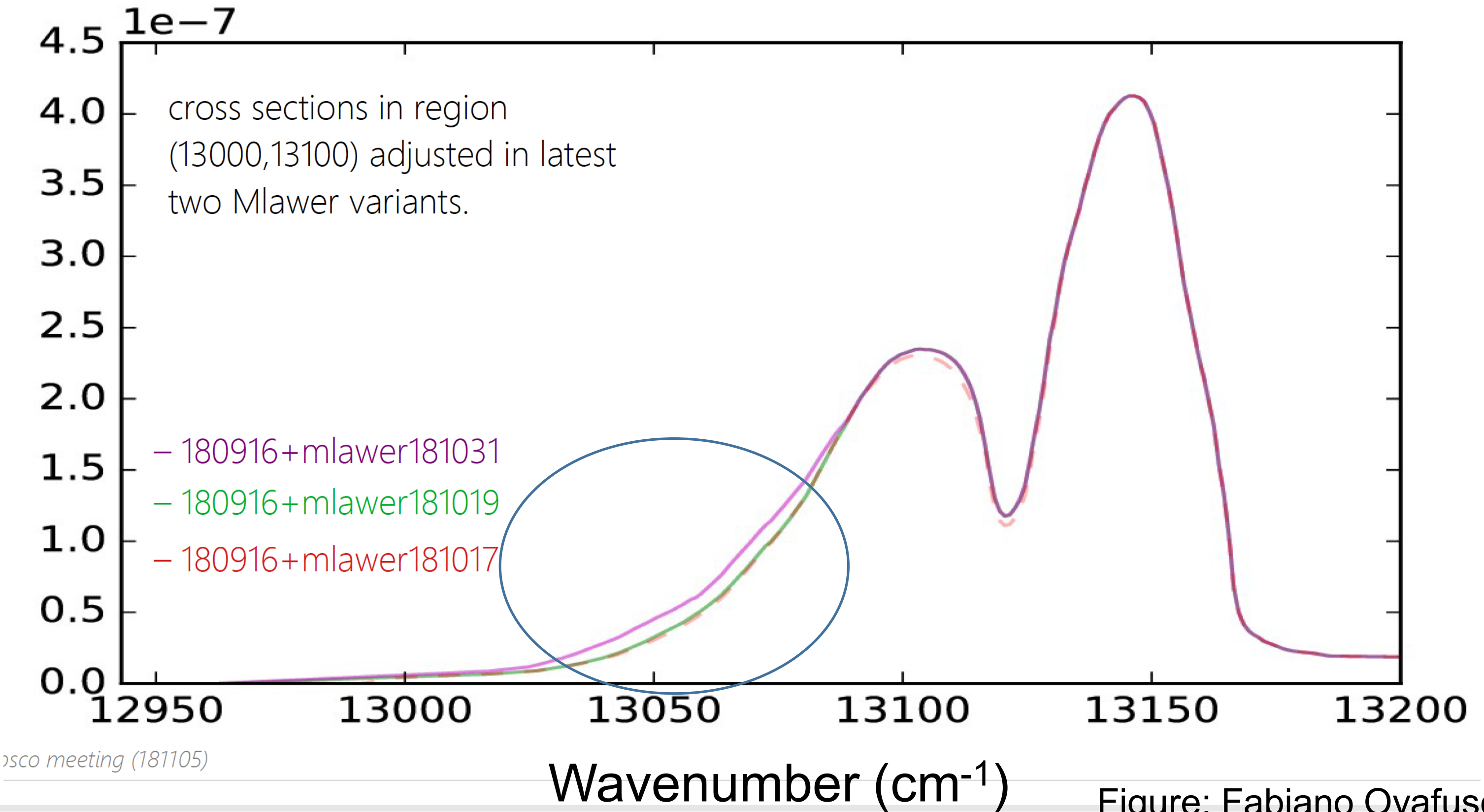
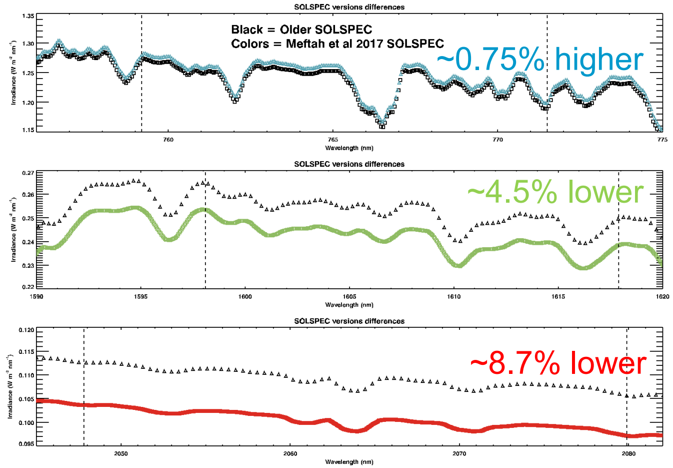


Figure: Fabiano Oyafuso

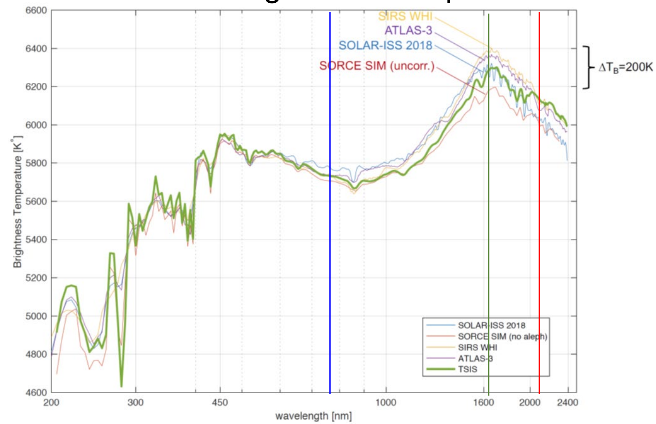
Updates to the Top of Atmosphere Solar Flux

- Accurate estimates of the top-of-atmosphere solar flux are critical to X_{CO2} retrievals
- For OCO-2, we construct the solar spectrum by combining a high resolution solar "transmission spectrum" (provided by Geoff Toon) and a continuum derived from the ATLAS 3 SOLSPEC experiment
- Two recent studies have identified biases in the ATLAS 3 SOLSPEC fluxes
  - Reanalysis of the ISS SOLar SOLSPEC observations (Meftah et al. 2018)
  - New data from the ISS TSIS SSI instrument (Richard et al. 2018)
- Both studies show the largest differences in the CO_2 channels

Solar ISS values are:



TSIS-SIM Brightness Temperatures

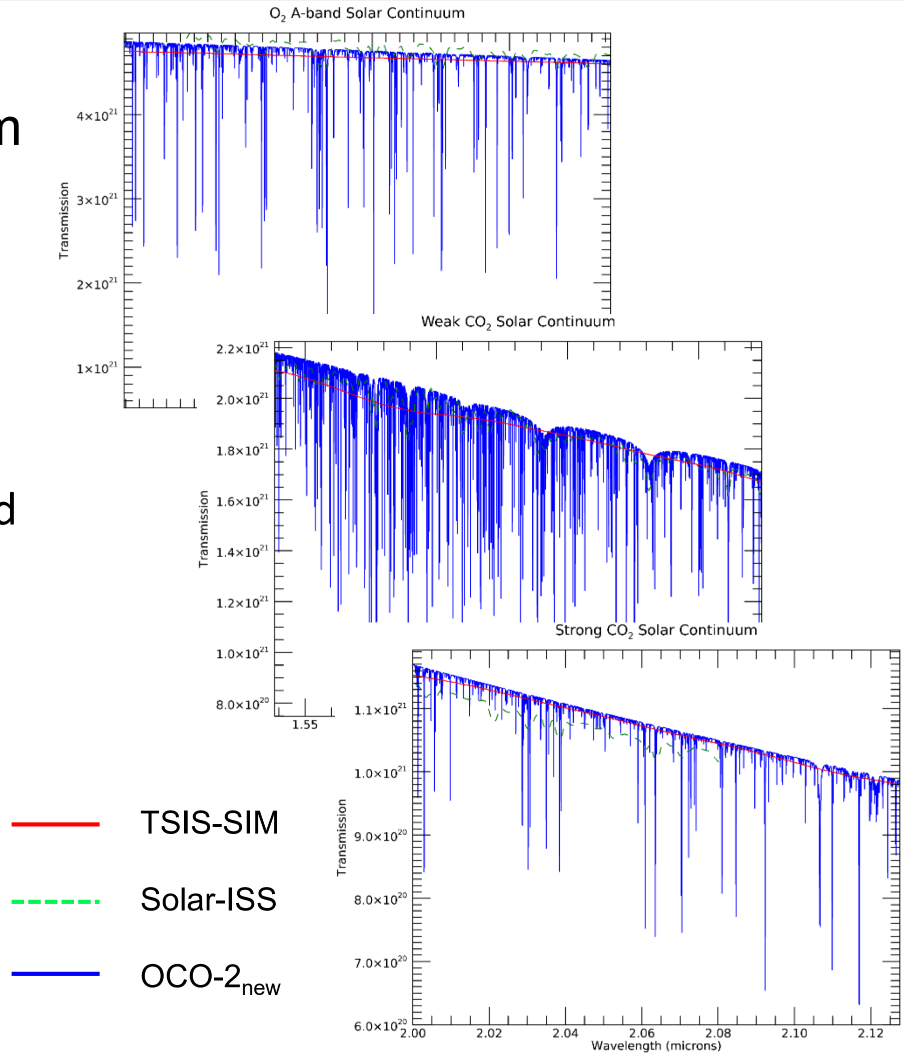


Largest Differences seen in the SWIR

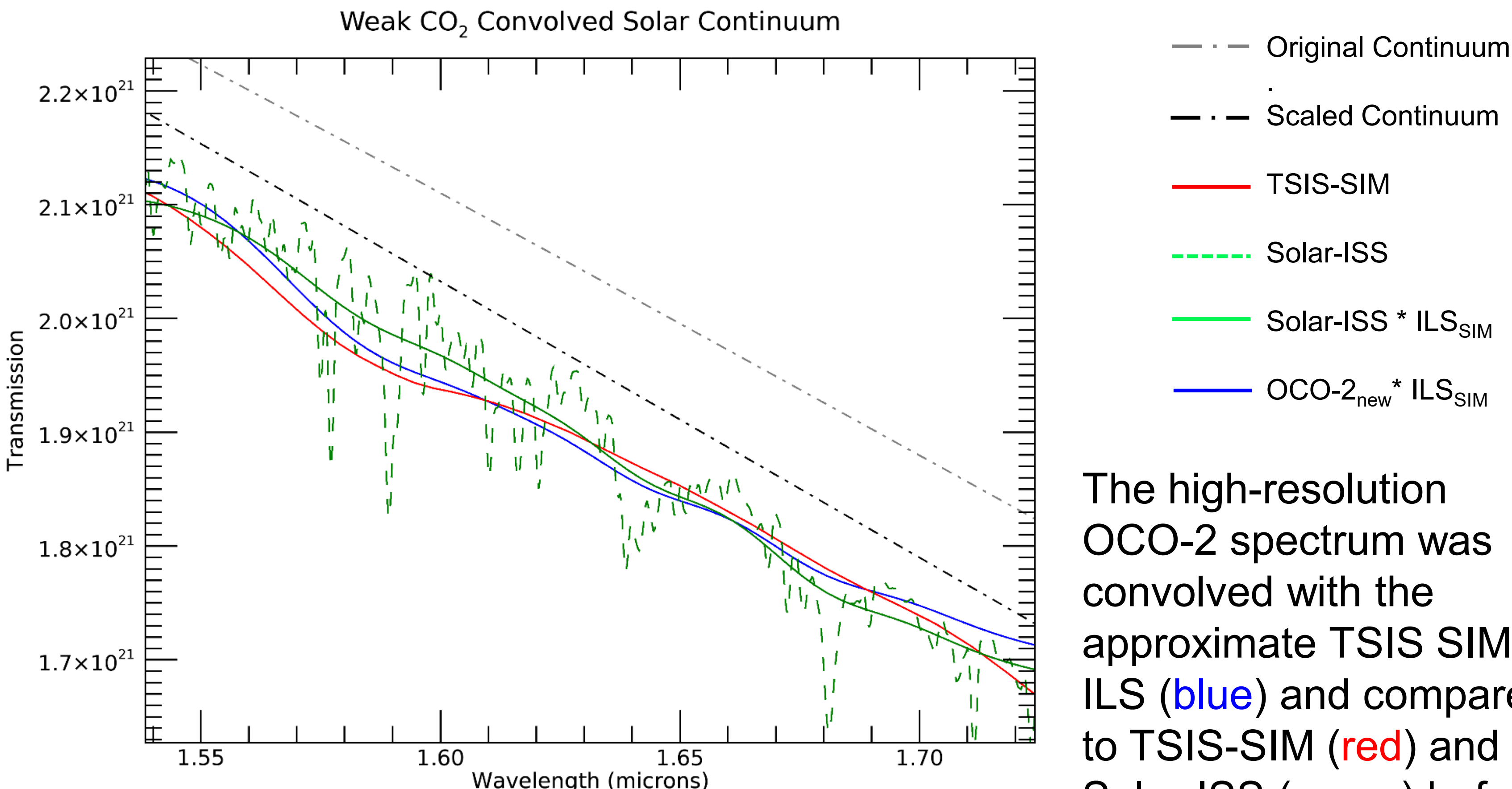
Adjusting the OCO-2 Solar Continuum

Approach:

- Current OCO-2 spectral continuum in each channel (v6/v7/v8) was compared to the solar spectra recently received from Solar-ISS and TSIS-SIM teams
- OCO-2 continuum values were:
  - Scaled by a multiplicative offset and slope (offset + slope*(λ-λ_{min})),
  - Multiplied by the high resolution transmission spectrum
  - Convolved with an approximate TSIS-SIM ILS
  - Compared to TSIS-SIM (red) and Solar ISS (green)



Spectrally-convolved Results – Example SCO2



SCO2 Scaling: $0.935 \times F_{c(old)}$

- No slope correction needed

The high-resolution OCO-2 spectrum was convolved with the approximate TSIS SIM ILS (blue) and compared to TSIS-SIM (red) and Solar-ISS (green) before (dashed) and after (solid) convolution with SIM ILS.

Call for Contributions to a Special Issue of Remote Sensing on Calibration/Validation of Hyperspectral Imagery

remote sensing

IMPACT FACTOR 3.406

Special Issue

Calibration/Validation of Hyperspectral Imagery

Guest Editors:

Dr. Aaron Pearlman
GeoThinkTank LLC / NASA Goddard Space Flight Center Biospheric Sciences Lab

Dr. Shihyan Lee
SAIC / NASA Ocean Biological Processing Group

Deadline for manuscript submissions: 30 April 2019

Website:www.mdpi.com/journal/remotesensing/special_issues/calibration_validation_Hyperimage

The issue will cover a broad range of areas of the calibration and validation of space-based, aircraft-based, or unmanned aircraft-based hyperspectral sensors used in remote sensing. These topics include but are not limited to the following:

- Pre-launch calibration—radiometric, spectral, spatial
- Post-launch vicarious validation field campaigns
- Hyperspectral imagery artefact identification and mitigation
- Cross-comparison of hyperspectral imagers with
- other satellite sensors

Call for Contributions to a Special Issue of Remote Sensing on CO_2 and CH_4

remote sensing

Special Issue

Remote Sensing of Carbon Dioxide and Methane in Earth's Atmosphere

IMPACT FACTOR 3.406

***Special Issue* Editor:**

Dr. Prabir K. Patra
Japan Agency for Marine-Earth Science and Technology
Dr. David Crisp
Jet Propulsion Laboratory, California Institute of Technology
Dr. Thomas Lauvaux
Pennsylvania State University

Website: www.mdpi.com/si/18603
Submission Deadline: 31 May 2019

Carbon dioxide (CO_2) and methane (CH_4) are the two most important greenhouse gases that have led to a significant fraction of the increase in earth's surface temperature in the past 100 years. This Special is dedicated to the past progress and new developments in satellite remote sensing of long-lived greenhouse gases, with a focus on CO and CH_4.

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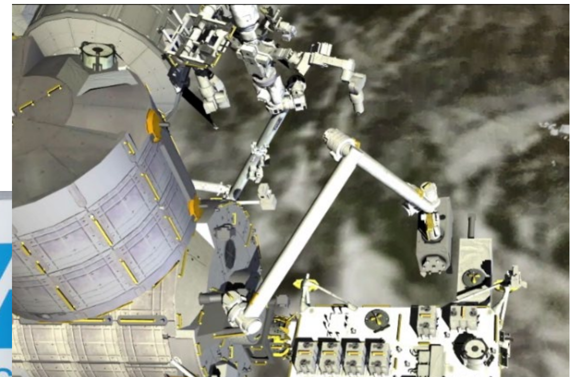
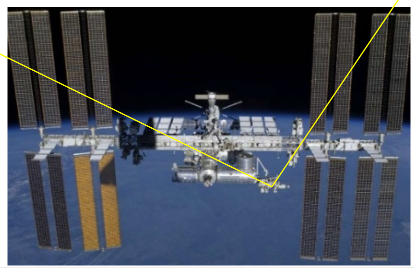
OCO-3 Status

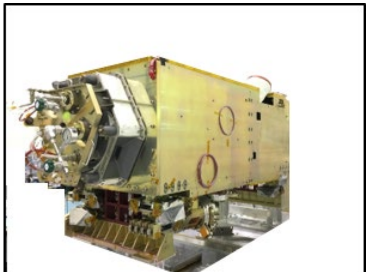
OCO-3 Status Summary

- OCO-3 is currently in storage at Cape Canaveral
  - February 8 transfer to Dragonland for integration into the Dragon trunk and deployment on the Falcon 9 launch vehicle.
  - Current launch date: Currently under revision
  - Impact of partial Government shutdown unknown

  - More as we know it

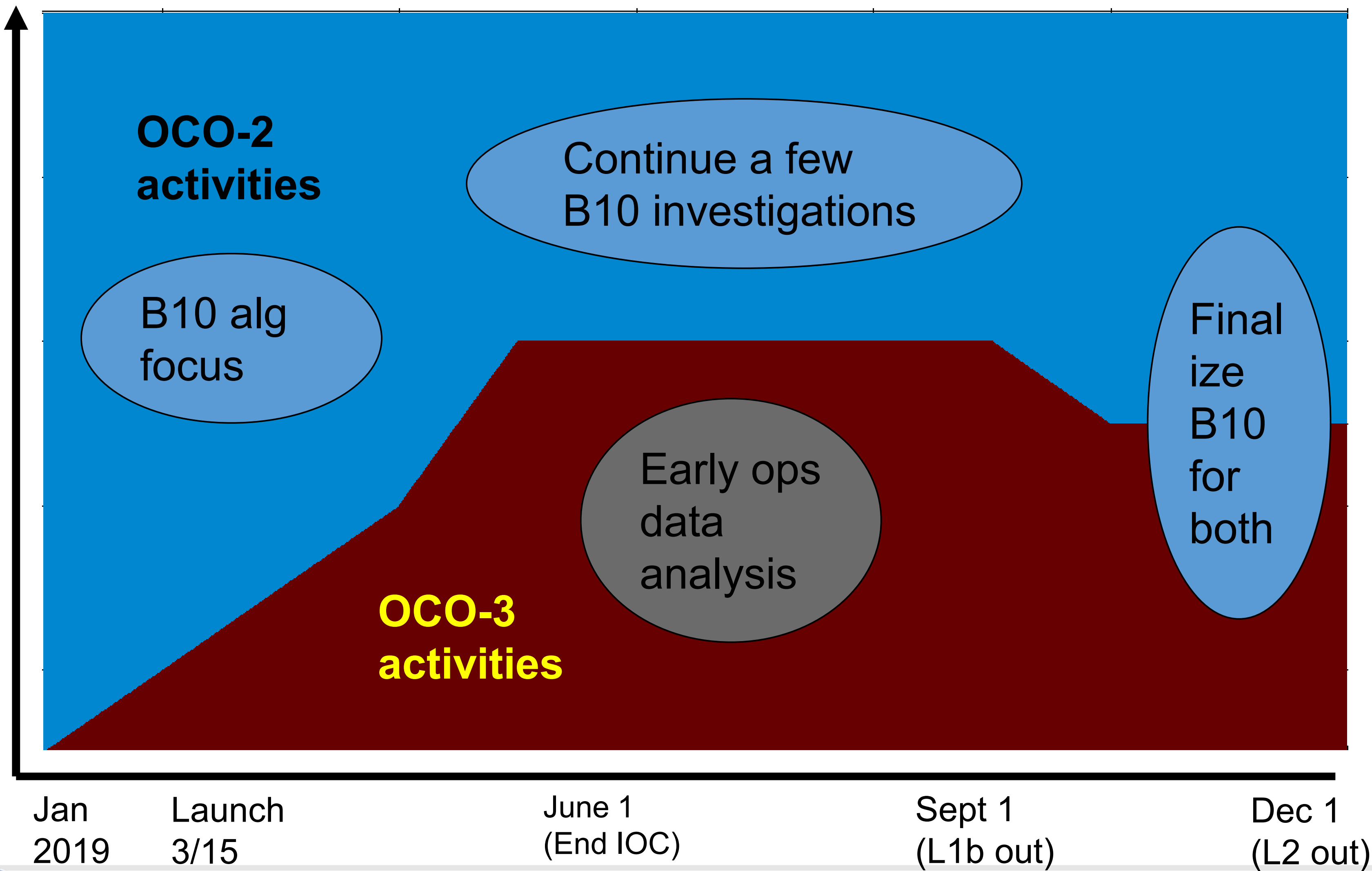




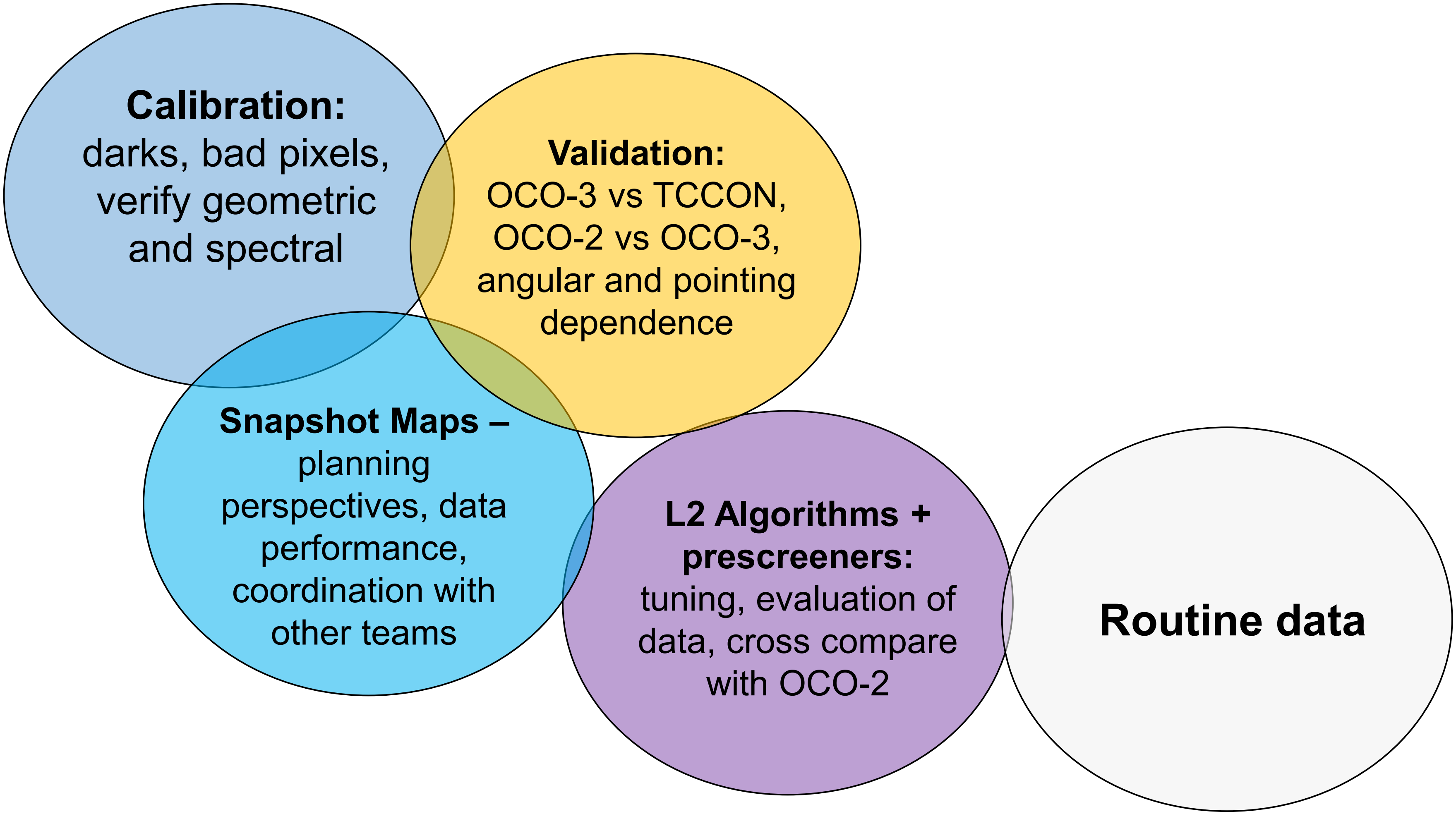


The OCO-3 Team

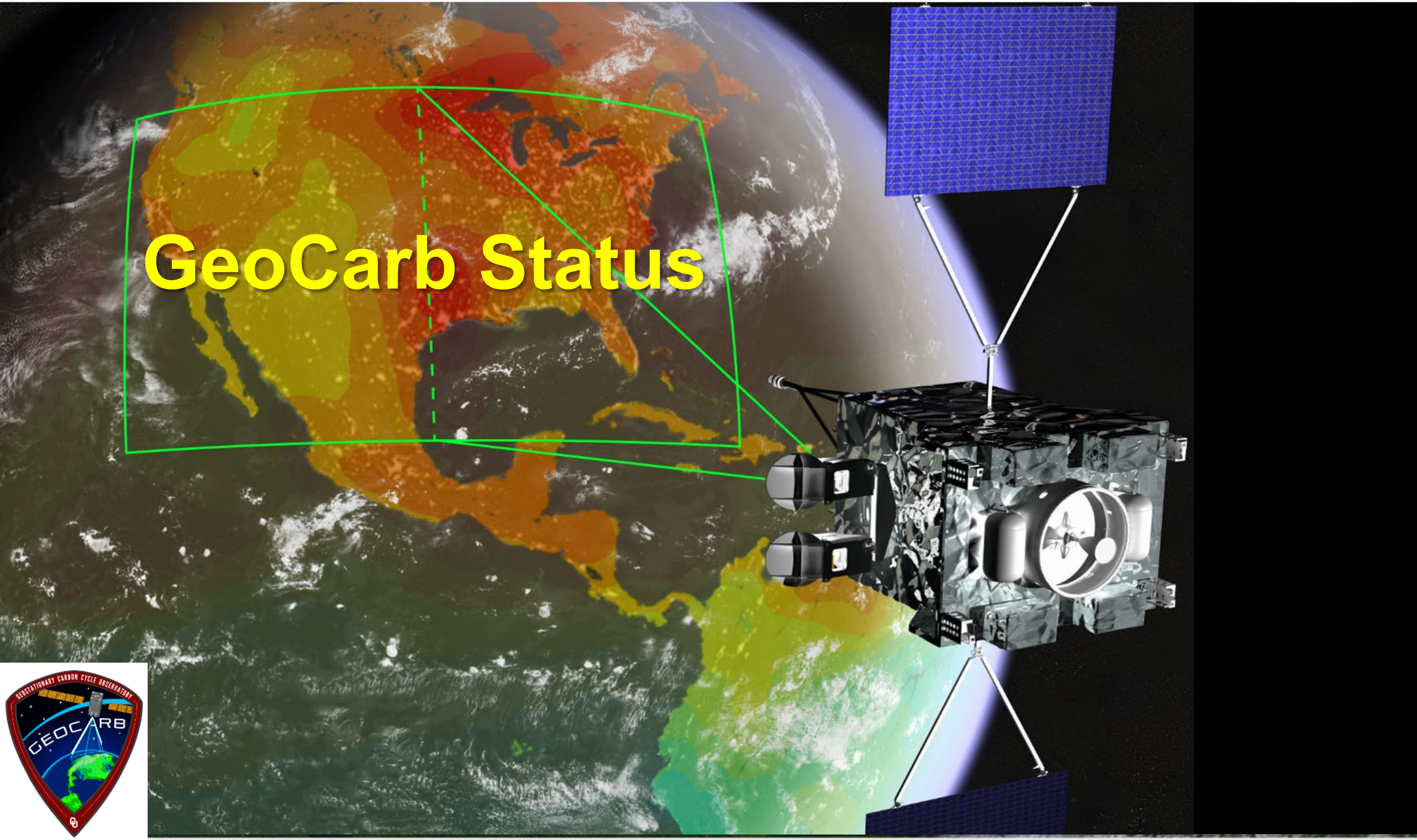
Integrating OCO-2 and OCO-3 Activities



Snapshot of Early Ops Activities



GeoCarb Status

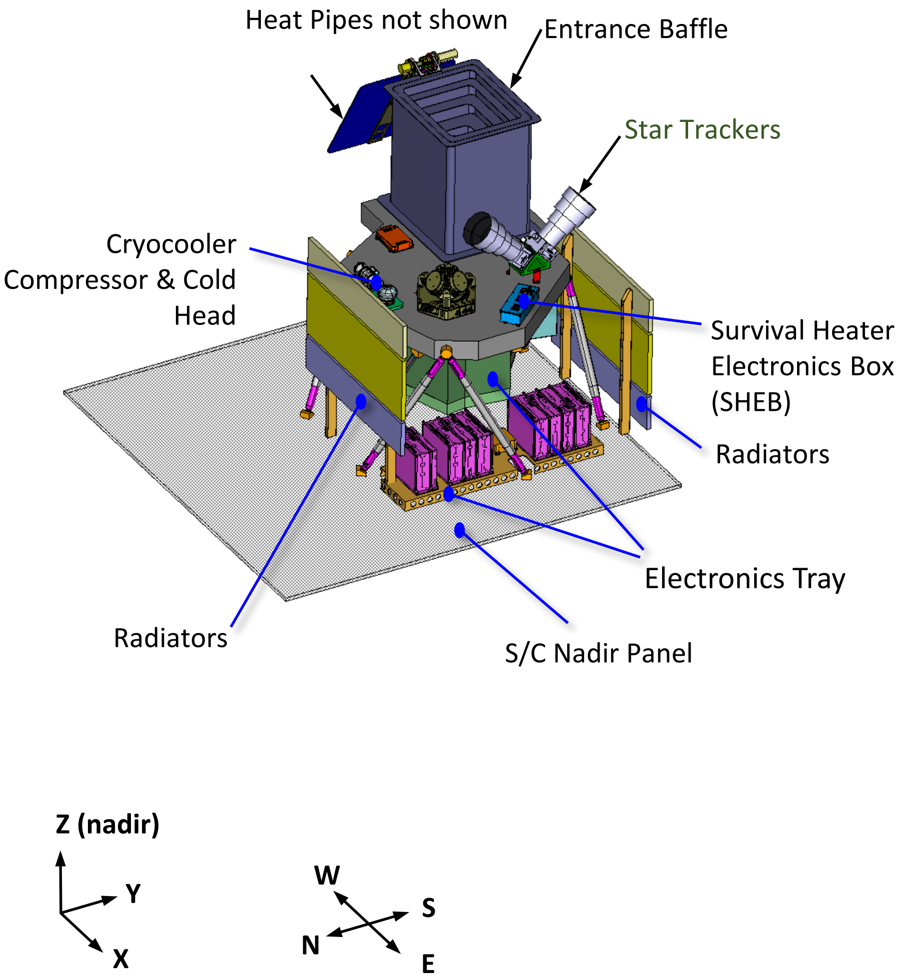


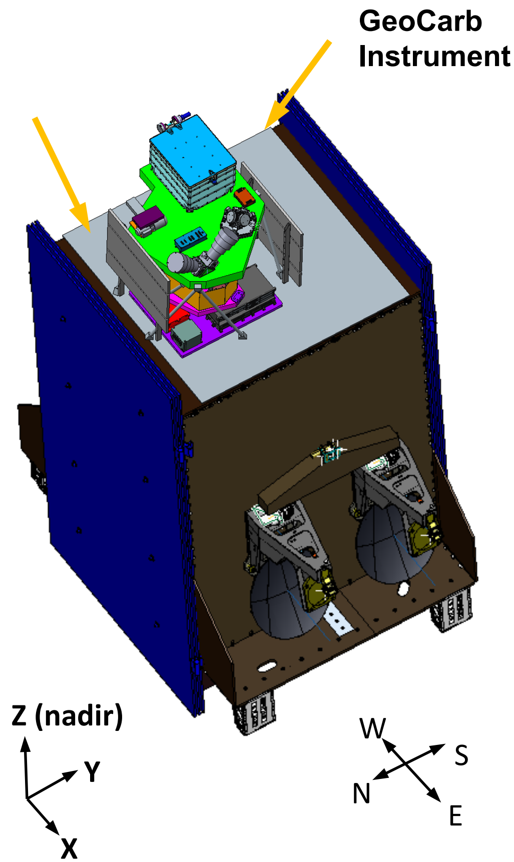
GeoCarb Status

- At August 2018 PDR, the Standing Review Board recommended that the GeoCarb Mission hold a δ-PDR to address:
  - Cost growth in Host spacecraft and instrument mass growth
  - 25% Reserve threshold for remaining budget not met.
- GeoCarb Instrument team identified a series of instrument descopes that save approximately 30kg of mass and 3 million dollars in costs
  - Redesign focuses on decreasing the optics size by ½ and removing non-critical components such as the IMU and calibration drum.
- All project areas, including science, were asked to identify budget reductions to compensate for increase host spacecraft costs.
- The GeoCarb Project is also exploring other hosting options to further reduce cost and increase reserves

- Update: The GeoCarb δ-PDR was delayed due to U.S. Government shutdown and is currently being rescheduled

GeoCarb Instrument Overview





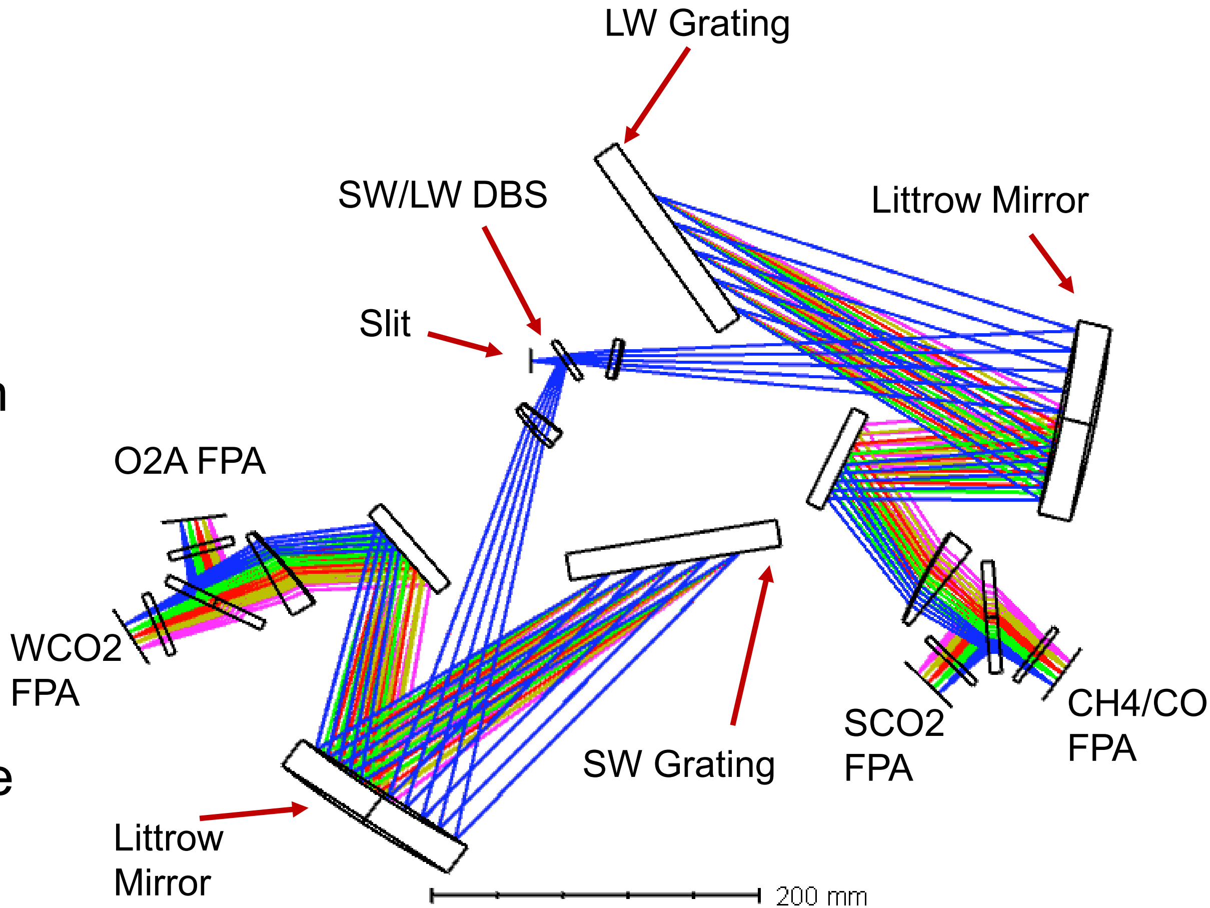
GeoCarb Instrument Optical Design

4-Channel spectrographs split between

- ABO2 +WCO2
- SCO2+CH4/CO

Echelle gratings used in multiple orders with beam splitters and blocking filters to isolate bandpasses.

Four (1024^2) HgCdTe H1RG detectors



GeoCarb Resource Budgets

Item	CBE	Contin-gency	MEV	NTE (SC alloc)	Margin
Mass	155.3 kg[5]	14.9%	178.4 kg[5]	219 kg	19%[1]
Envelope	N-S = 1.78m, E-W = 2.0m, Height = 1.5m				SC provide >2.5 cm clearance
Operational Power[3]	380 W[5]	26%	478 W[5]	630 W[4]	24%
Survival Heater Power[3]	53 W	28%	87 W	160 W	46%
Decontamination Heater Power[3]	2.6 W	26%	3.5 W	8 W	56%
Tlm & Cmd HW Channels (critical temp sensors)	8	N/A	8	15	47%
Low-Rate (Housekeeping) Telemetry	Nom: 128 bps Diag: 4096 bps	N/A	Nom: 128 bps Diag: 4096 bps	Nom: 128 bps Diag: 4096 bps	N/A[2]
High Rate (Science and Engineering) Telemetry	9.3 Mbps	N/A	9.3 Mbps	10 Mbps	6.5%[2]

Science Impacts of Instrument De-scope

Primary descope - reduce aperture area by half

- Reduce diameter from 75mm to 53mm

Science impacts can be accommodated through changes to observation strategy (con ops) and calibration planning

- Sampling rate is reduced by a factor of two
- Changes in air mass during longer dwell times assessed with OSSEs

Other descopes:

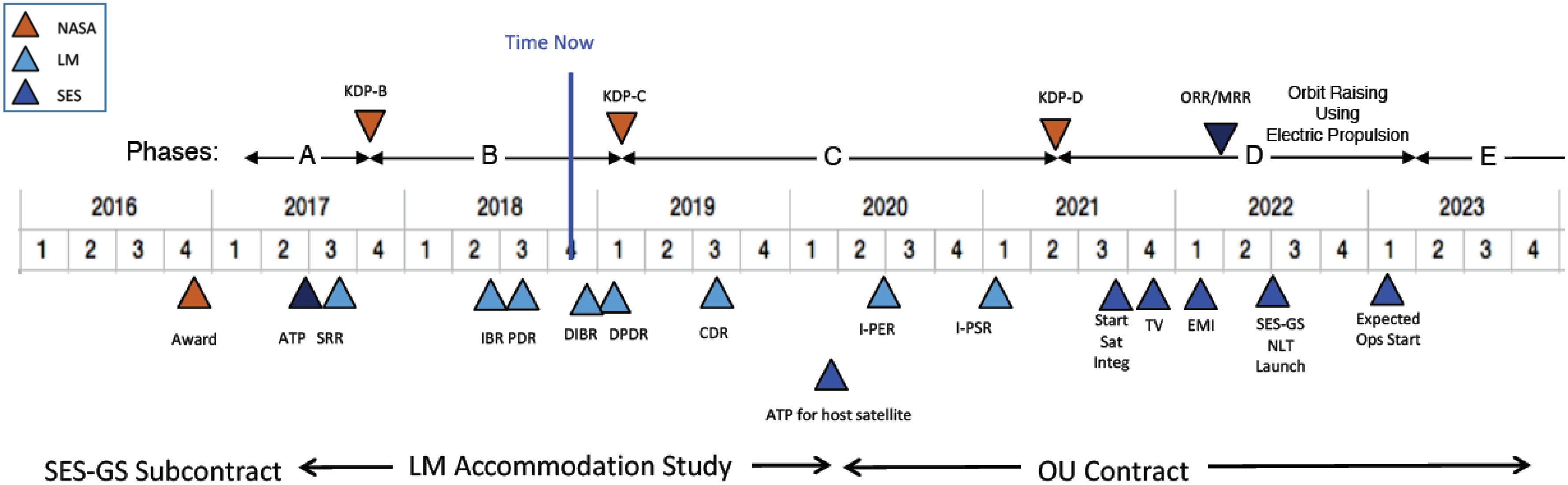
- ISS/IMU: baseline pointing knowledge is slightly reduced
  - Still within requirements. Previous experiments indicate that this change will only reduce the number of soundings available in the vicinity of sharp topography
- Secondary Solar Calibration: redundancy to assess changes in primary diffuser removed.
  - Looking into the options of incorporating a second diffuser into the scan mechanism
  - Also considering more frequent lunar observations, which will be used to assess changes in the calibration over time in conjunction with on board lamps

Instrument Performance Requirements

Species	Band (nm)	Threshold Spectral Resolution Δλ (nm)	Baseline Spectral Resolution Δλ (nm)	Resolving Power
O_2A /SIF	760	0.0479	0.0474	16034
WCO_2	1610	0.102	0.101	15941
SCO_2	2060	0.138	0.136	15147
CH_4/CO	2320	0.155	0.153	15163

Species	Band	Threshold Requirement	Baseline Requirement	Reference Condition		
				Intensity	F_{sun}/π	a_E
	(nm)	SNR	SNR	nW / (cm^2 sr cm)	nW / (cm^2 sr cm)	
O_2A /SIF	760	382	395	416.2	2378	0.175
WCO_2	1610	376	389	362.8	2073	0.175
SCO_2	2060	293	302	213.7	1474	0.145
CH_4/CO	2320	246	254	146.6	1173	0.125

GeoCarb Schedule Status



- Mission authorization (Key Decision Point-C, KDP-C) moved to Feb-2019
- SES launch opportunities are:
  - 103 W – launch in Q1 2023
  - 87 W – launch in Q4 2024
- Plan supports a 1-Jul-2022 launch to insure instrument is available if an earlier date become available
  - Current estimate for instrument completion is May/Jun 2021

Ongoing Accommodation Studies

- Hosting spacecraft - SES:
  - Reviewed updated opportunities and hosting cost estimates
  - 103 W: Launch estimated to be in 1st quarter 2023. SES board
    - approval anticipated in early 2020
  - 87 W: Launch estimated to be in 3rd or 4th quarter 2024. SES
    - board approval anticipated in mid to late 2021

- Other options – GEOshare (a Lockheed Martin ride share activity):
  - Continuing programmatic and technical discussions with GEOshare
  - Discussed electrical, C&DH and mechanical interfaces in support of GEOshare's accommodation study

- Short Term Outlook: Continuing to interact with host spacecraft as we prepare for delta PDR

GeoCarb Summary

- GeoCarb has implemented an instrument de-scope
  - Saves mass
  - Saves money
  - Simplifies design
  - Still enables the project to meet the science objectives of the mission
- Preparing now for Preliminary Design Review and passage into Phase C in the next few months
- Algorithms are mature and will meet our measurement requirements
- Scene inhomogeneity identified as a potential driver of bias
  - We have baselined a 1D slit homogenizer, similar to the on used on S5 UVNS, to mitigate this issue
- Next steps - δ-PDR, KDP-C and start of Phase C

Key Near Term Activities

Planned Date	Activity Description
TBD	GeoCarb δ-PDR, Palo Alto, CA
End of Mar (TBC)	OCO-3 Launch, Cape Canaveral, FL
End of Mar (TBC)	OCO-2/OCO-3 Spring Science Team Meeting, Coco Beach, FL
7-12 Apr	EGU General Assembly, Vienna
13-17 May	ESA Living Planet Symposium, Milan, Italy
21-22 May	NOAA ESRL GMD Annual Conference, Boulder
4-6 Jun	IWGGMS-15, Sapporo, Hokkaido
10-12 Jun	CEOS AC-VC Annual Meeting, Tokyo/Tsukuba (TBD)
17-20 Jun	CALCON - Characterization and Radiometric Calibration for Remote Sensing, Logan Utah
7-18 Jul	27th IUGG General Assembly 8-18 July, Montreal, Canada
30 Jun-5 July	2019 RRV Campaign
26-29 Aug 2019	Chapman Conference: Carbon-Climate Feedbacks, San Diego

Red text indicates that there may be a changes.

IWGGMS and CEOS AC-VC Meetings

IWGGMS-15, (M-W) June 3-5, 2019, Sapporo, Hokkaido, Japan

- NIES posted a webpage for the meeting here:

  https://www.nies.go.jp/soc/en/events/iwggms15/

  This page includes the following deadlines:
  - **Workshop Dates:** June 3 (Mon) - June 5 (Wed), 2019
  - **Abstract submission:** January 22 (Tue) - April 1 (Mon), 2019
  - **Registration:** January 22 (Tue) - April 26 (Fri), 2019 **(those who need visa to enter Japan should register** before March 28, 2019)

The GOSAT RA PI meeting will be held on Thursday 6 June at the same venue

- See https://www.nies.go.jp/soc/en/ra/meeting01/

IWGGMS and CEOS AC-VC Meetings

The CEOS AC-VC-14 will be held on 10-12 June in either Tokyo or Tsukuba

- Hosted by JAXA. Venue to be announced
  - Looking for a venue in Tokyo
  - A conference room at Tsukuba Space Center has been reserved for back-up
- Status of White Paper actions
  - White Paper Publication
    - CEOS SIT Chair, Steve Volz, encouraged the publication of the white paper to facilitate citations and efforts to build on its contents
    - The WMO and Copernicus Program initiated an MOU to produce a joint publication
  - Integration of White Paper Actions into CEOS and CGMS Work Plans
    - The CEOS AC-VC is working with WG-Climate and WG-Cal/Val to define the distribution of effort and define the interfaces
  - Upcoming meetings
    - WG-Cal/Val and AC-VC - Global Space-based Inter-Calibration System (GSICS) Annual Meeting, 04-08 March 2019 at ESA-ESRIN in Frascati, Italy
    - CEOS/CGMS WGClimate joint meeting with all GCOS Panels and the WCRP-DAC in Marrakech, Morocco on 18-22 March 2018