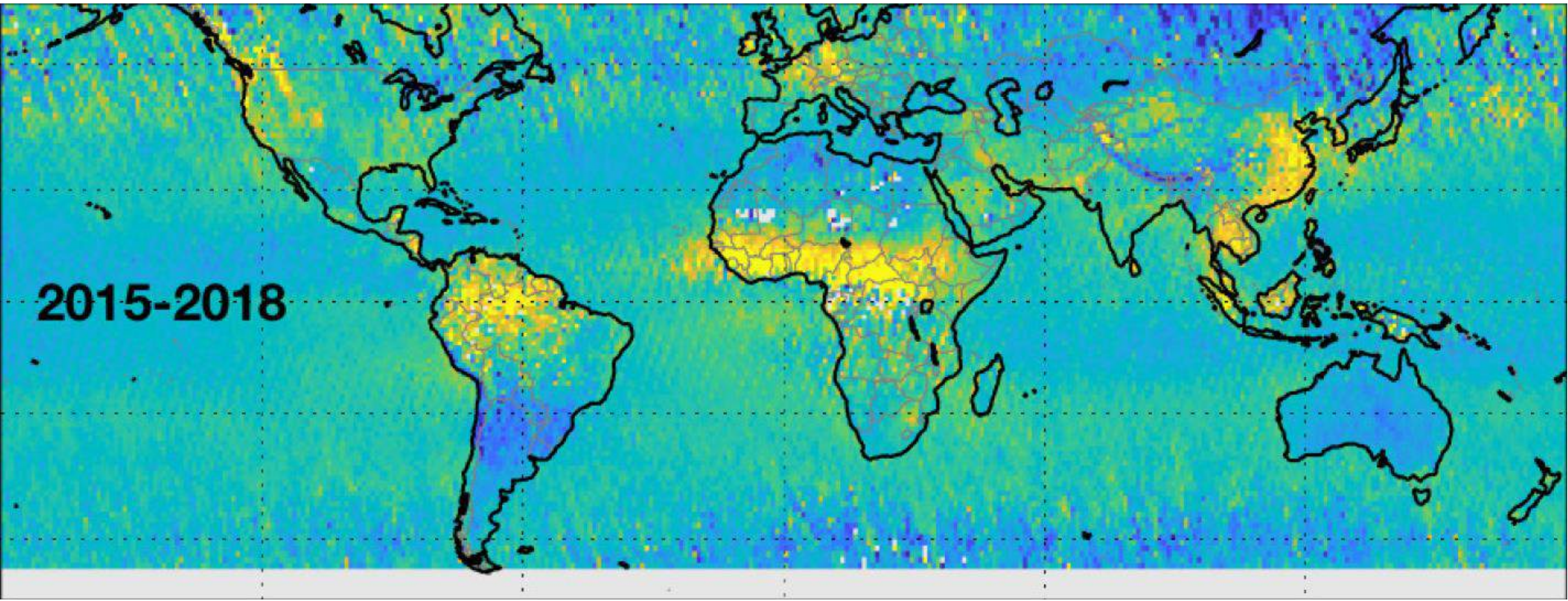


An OCO-2 & OCO-3 Science update

OCO-2 Project Scientist: Michael Gunson, JPL

OCO-3 Project Scientist: Annmarie Eldering, JPL

OCO-2/OCO-3 Scientist Team Lead: Dave Crisp, JPL

OCO-2/OCO-3 Program Scientist**: Ken Jucks, HQ**

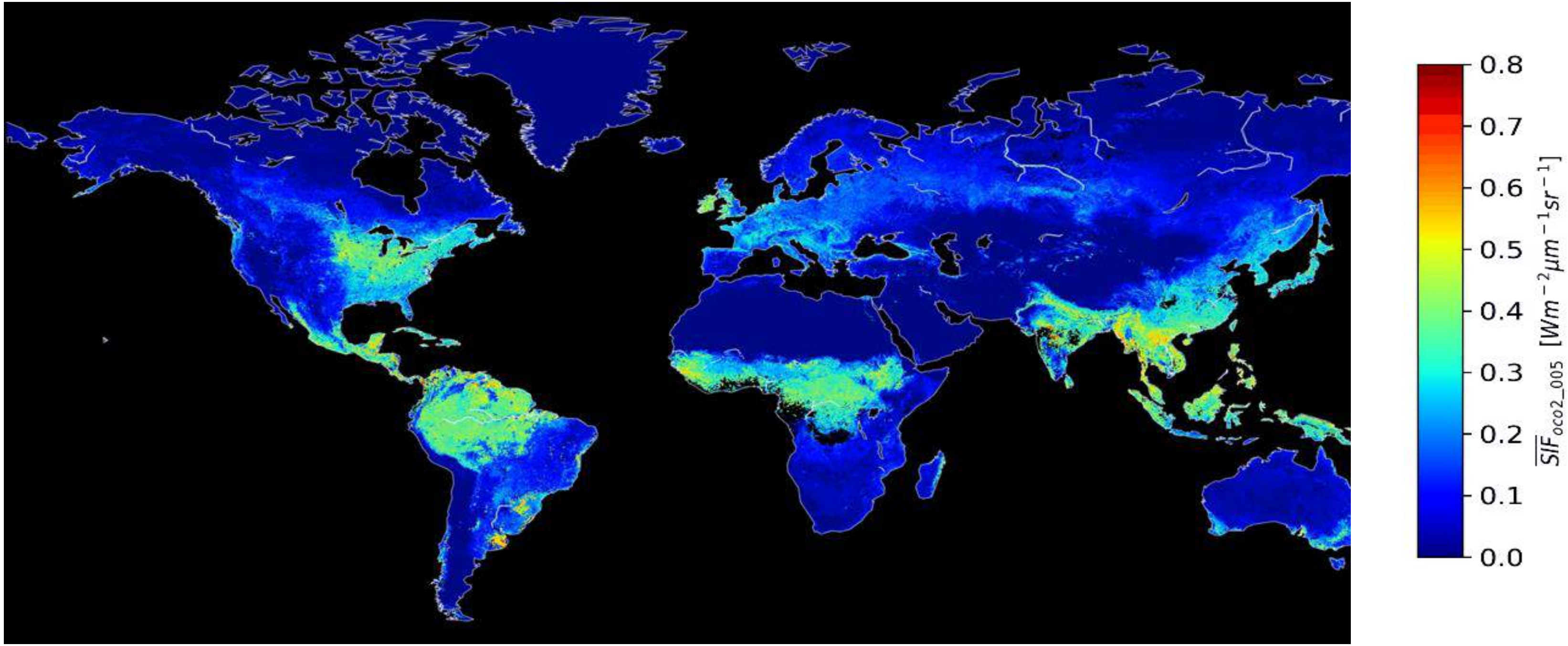
Mission Overview

Watching the Earth Breathe – Measuring CO2 Sources and Sinks from Space

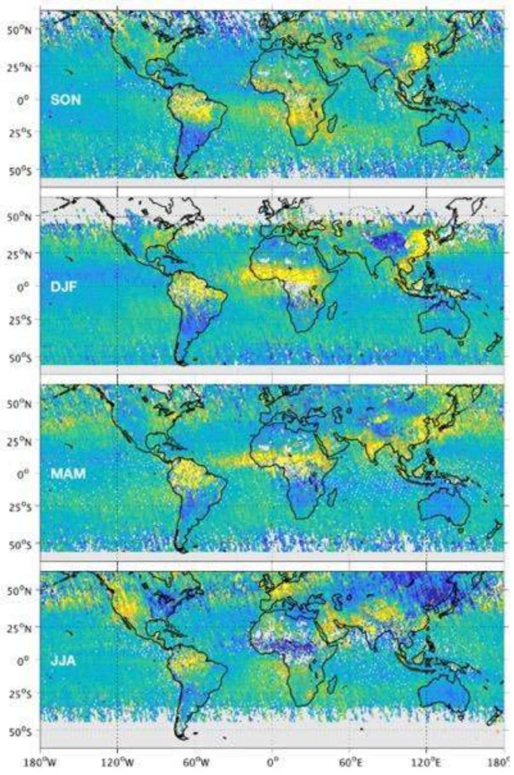
- The OCO-2 mission exploits dedicated spacecraft, a well-calibrated instrument, a state-of-the-art retrieval algorithm, and continuous validation activities to deliver estimates of the column-averaged CO2 dry air mole fraction, XCO_2, and solar induced chlorophyll fluorescence (SIF) with an unprecedented combination of precision, accuracy, resolution and coverage.
- The 5+ year XCO_2 & SIF records are providing unique insights into the carbon cycle as it responds to human activities and a changing climate.
- Over the next three years, the OCO-2 team will continue to improve the quality of these products as we use them to quantify CO_2 sources and sinks and the health of the land biosphere.

OCO-2 Observations of SIF

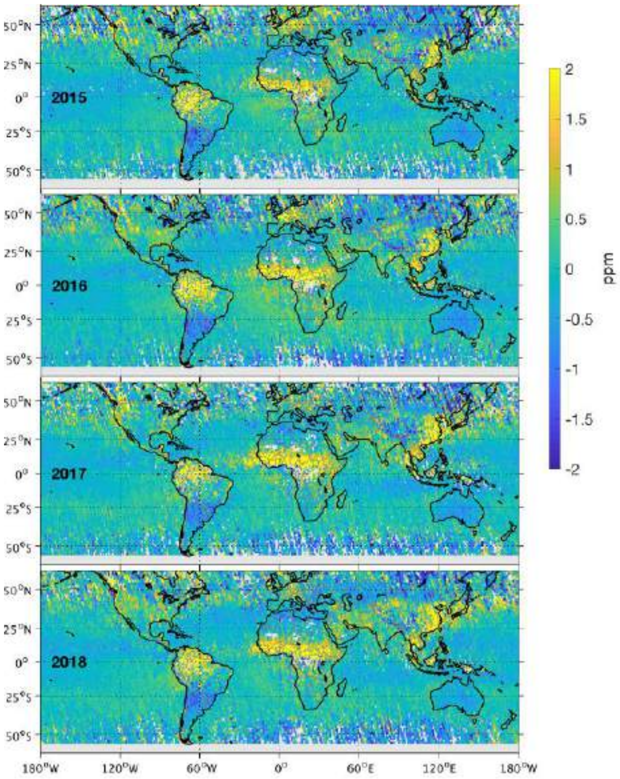
SIF measurements show spatial distribution of photosynthetic activity and its variations over time



Persistent CO_2 Anomalies seen by OCO-2



Seasonal Anomalies

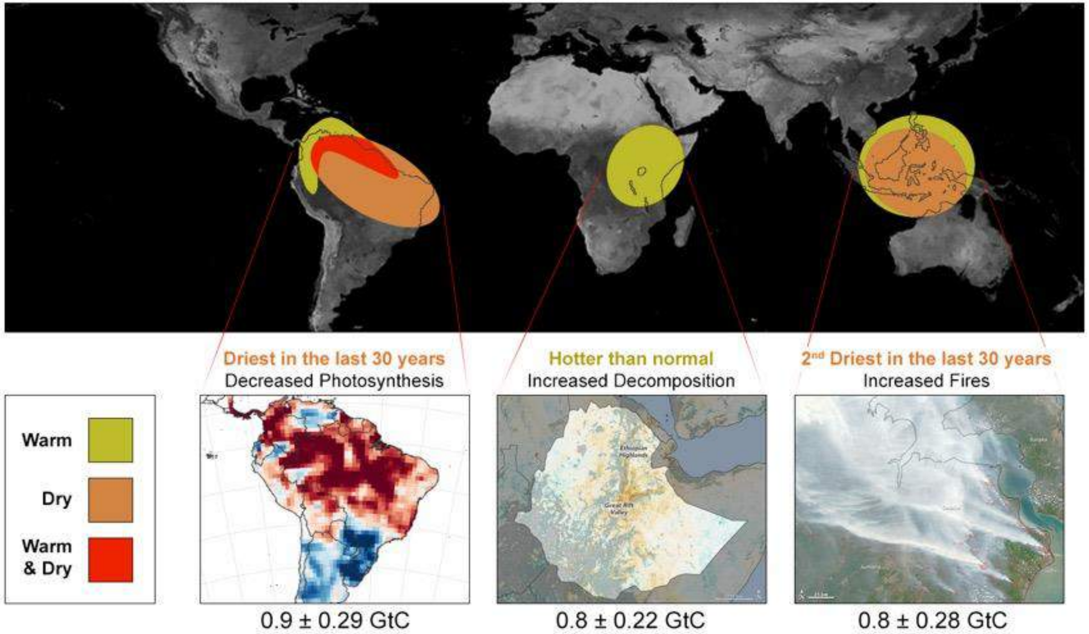


Annual Anomalies

Some regions have persistently high XCO_2 (positive anomalies) and low XCO_2 (negative anomalies) from season to season and from year to year

- Tropical forests exhibit persistent 1-2 ppm positive XCO_2 Anomalies.
- Tropical oceans have persistent 0.5-1.0 ppm negative anomalies.
- Mid- and high latitudes show large variations.

OCO-2 Finds Tropical Forests Were the Main Source of the Record Annual Increase in Carbon Emissions in 2015-2016 El Niño (*Liu et al.)*

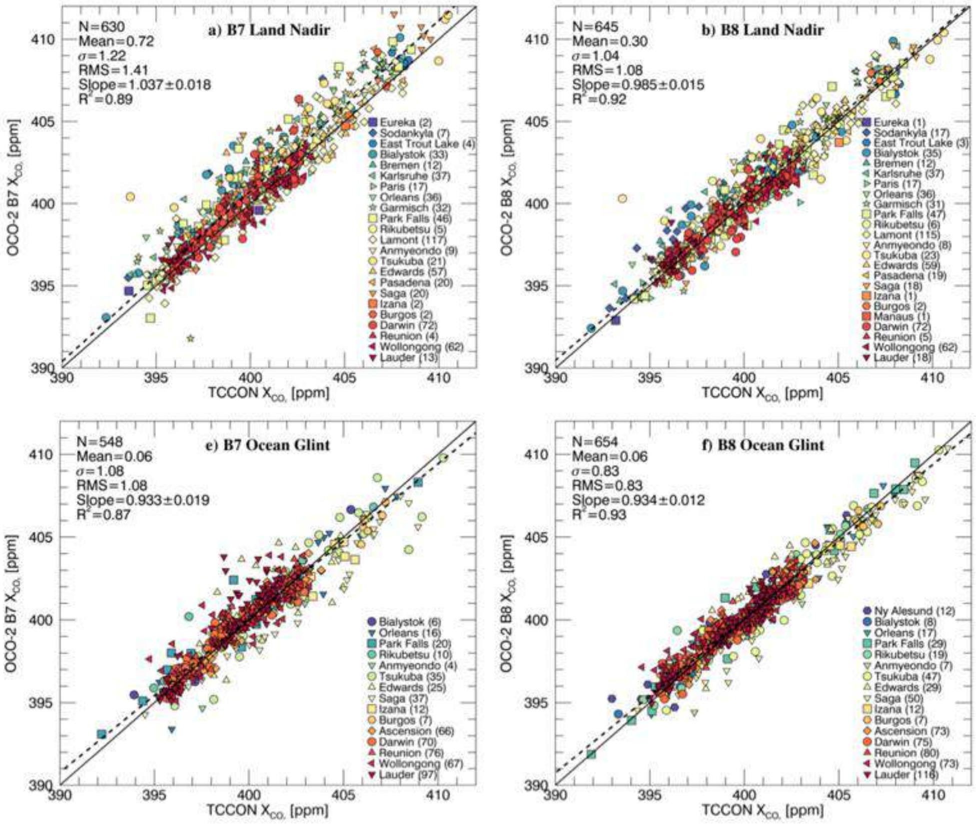


Land masses responsible for the El Niño influenced increases in atmospheric CO_2.

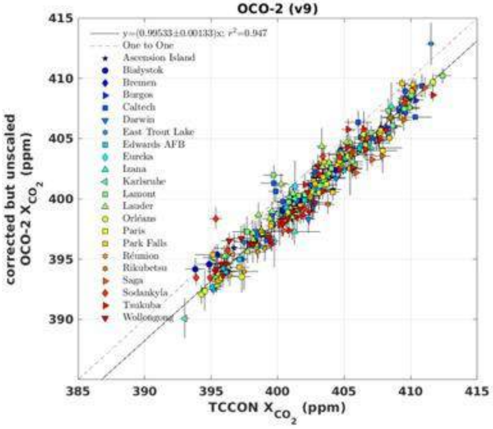
These biospheres are affected by a range of disturbances in tropical biospheres in all major tropical land masses.

- The Amazon was much drier than normal, curbing the rate of photosynthesis, reducing CO_2 uptake.
- Africa was hotter than normal, with normal rainfall. This increased decomposition of dead biomass, increasing CO_2 release.
- SE Asia was dry, which spurred more fires, increasing CO_2 release.

Biases relative to TCCON decreasing with time



Currently, there is no evidence for biases in the XCO2 product that could explain the observed anomalies However, additional validation is needed over the centers of action

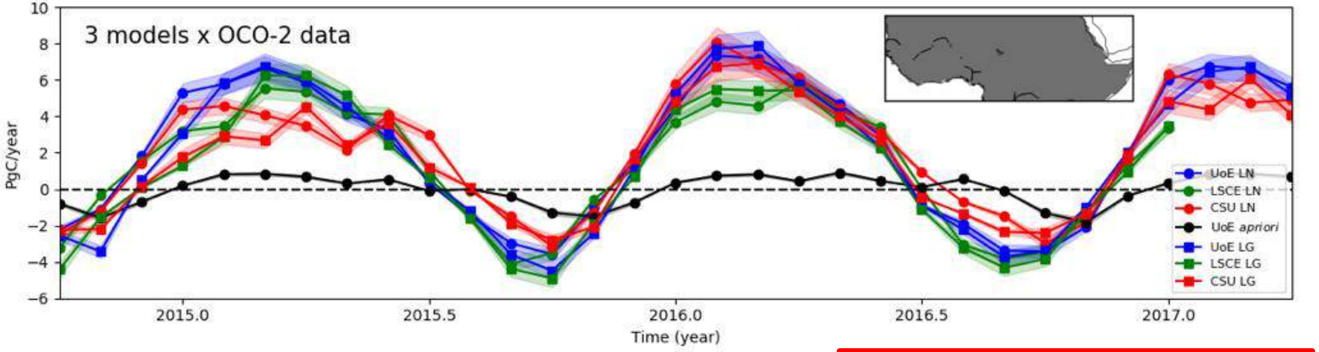


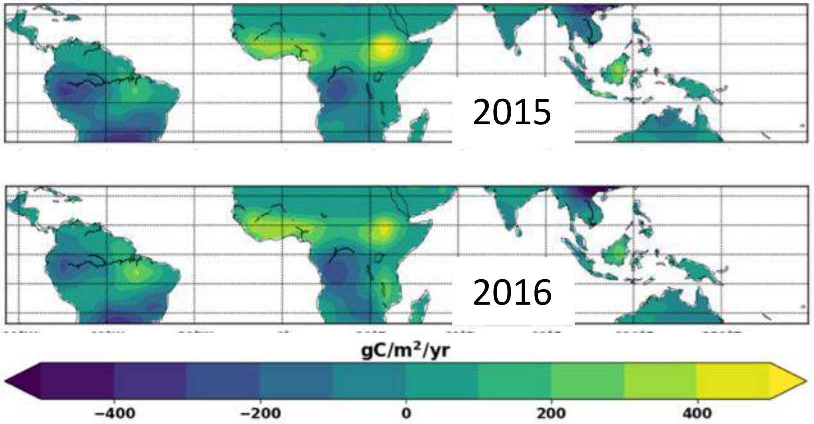
Could the earlier carbon cycle models be wrong?

- The ongoing OCO-2 multi-model intercomparison shows that carbon cycle models can produce regional scale flux biases driven by
  - Uncertainties and/or limitations in the input wind fields
  - Differences in the a priori constraints on land and ocean
  - Spatial resolution of the input meteorology or flux inversion
- However, the biggest flux differences are still driven by
  - Differences in spatial coverage repeat frequency of the CO_2 or XCO_2 data
  - Large-scale biases, (e.g. land/ocean biases in the OCO-2 v7 product)
- OCO-2 measurement precision is adequate, but improvements in accuracy and coverage are needed to retrieve reliable fluxes
- A global level 4 OCO-2 CO_2 flux product will be a major focus of future research.

Net C emissions from African land biosphere dominate pan-tropical atmospheric CO_2 signal

First time we have a consensus of tropical land CO_2 fluxes with different models.



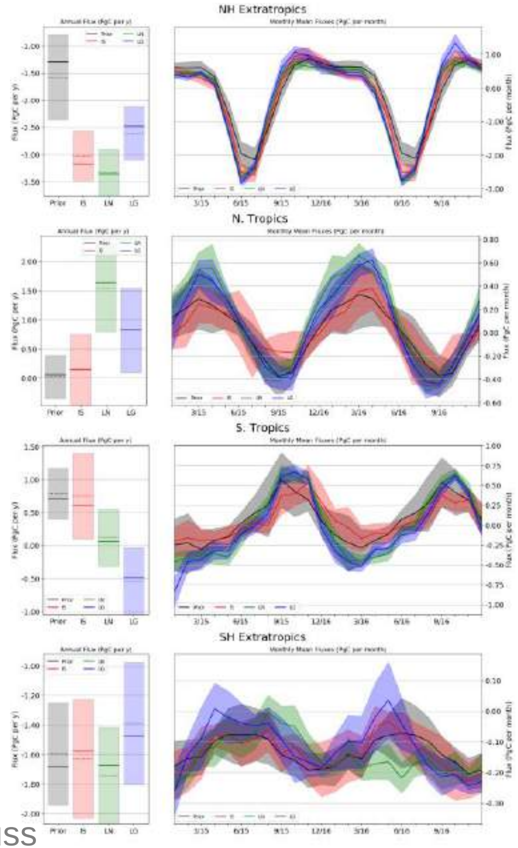


- Qualitatively consistent with other NASA products, e.g. GRACE, OCO-2 SIF, Aura OMI
- GOSAT puts OCO-2 into longer context.
- Will re-prioritize tropical research agenda

Palmer et al, Nature Comms., 2019

2015-2016 Fluxes as seen by OCO-2 and the Global in situ Network

- The OCO-2 team has been running a global multi-model intercomparison to improve our ability to retrieve CO_2 sources and sinks on regional scales from in situ and OCO-2 observations
  - Current experiments using only OCO-2 version 7 data over land
- Results
  - OCO-2 and in situ data indicate a global annual carbon sink of 3.7±0.5 PgC
    - Land contribution is 1.5±0.6 PgC
  - Agreement is best in northern hemisphere extratropics, which are well sampled by the surface networks
  - The largest difference occur over tropical Africa where there are few in situ measurements



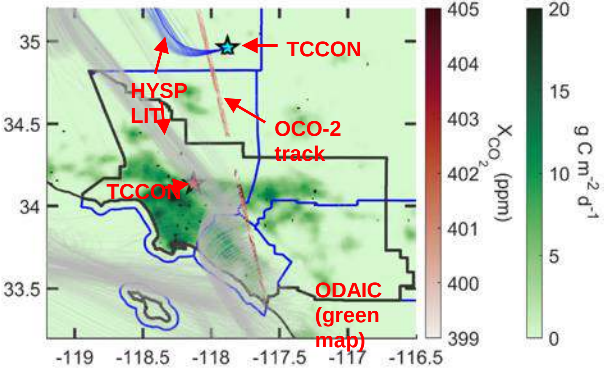
Crowell et al. Atmos. Chem. Phys. Discuss

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

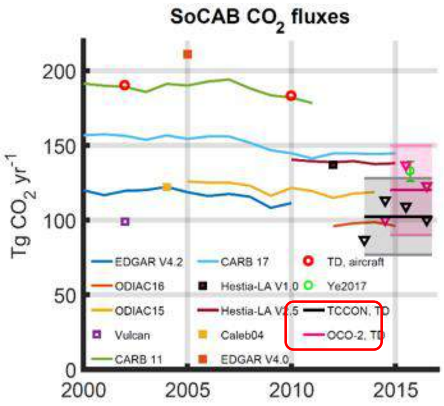
Tools

- 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

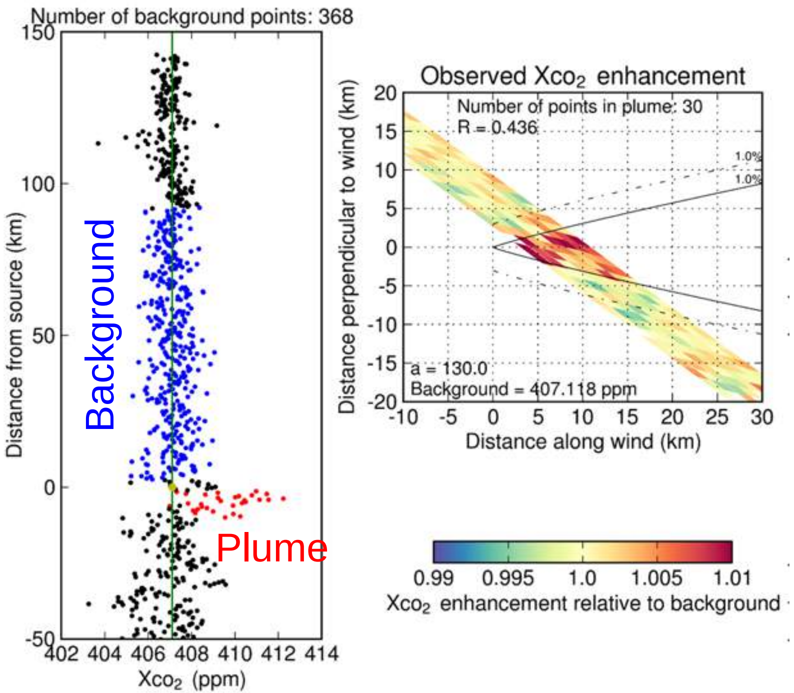
- Demonstrates a method to convert OCO-2 observations to urban emissions in Tg CO_2 yr^{-1}
- Coupled with future studies (e.g., with OCO-3) may help show urban carbon flux trends

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:** OCO-2 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

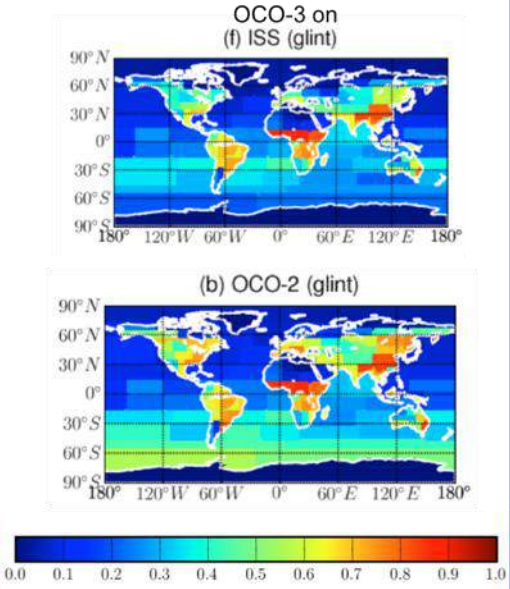
Ray Nassar and Calium McCracken, Remote Sensing, 2019



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.

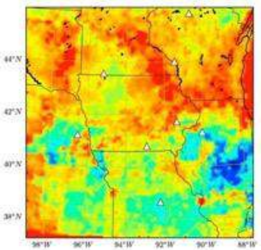
OCO-3 Science Overview

Global Flux Estimates: OCO-2 and OCO-3 impacts (simulated)



Flux error improvement for January
Palmer et al., 2011

Unique Science Opportunities with OCO-3



Midwest Carbon Flux
From Schuh et al., 2013

Terrestrial Carbon Cycle

Process studies enabled by measurements at all sunlit hours, including SIF. ISS will contain complementary instrumentation.

Snapshot Maps

Enabled by enhanced target mode using pointing mirror assembly

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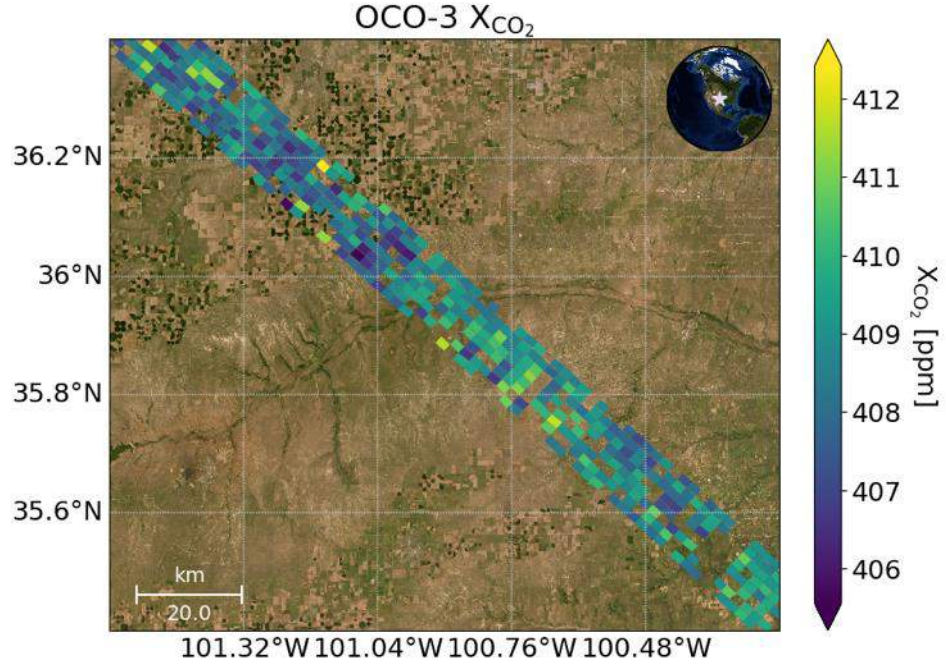
Orbiting Carbon Observatory-3 (OCO-3)
-- EARLY SET OF XCO2 RETRIEVALS –

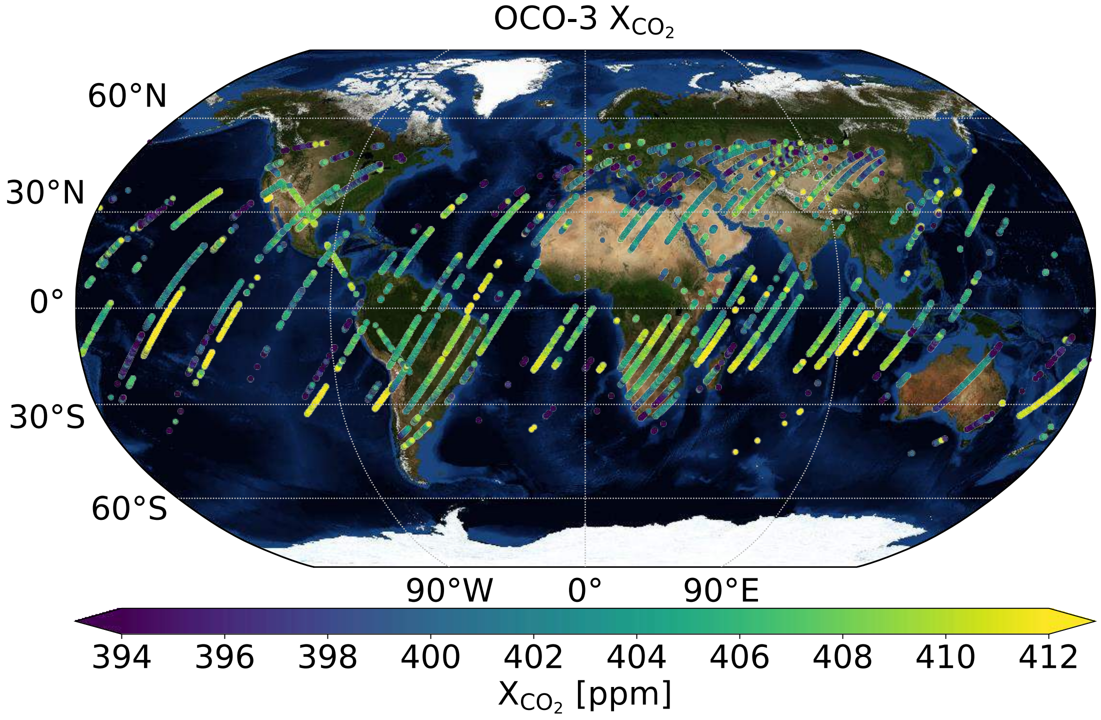
The inherited algorithms work out of the box. Data quality will improve as calibration improves



Acquired During the 25 June to 03 July 2019 Timeframe; Swath in Oklahoma
[Ref: Data produced by SDOS Team and graphics by R. Nelson]

Orbiting Carbon Observatory-3 (OCO-3)
-- Global XCO2 data collected to date –

Using nadir and glint data for oceans

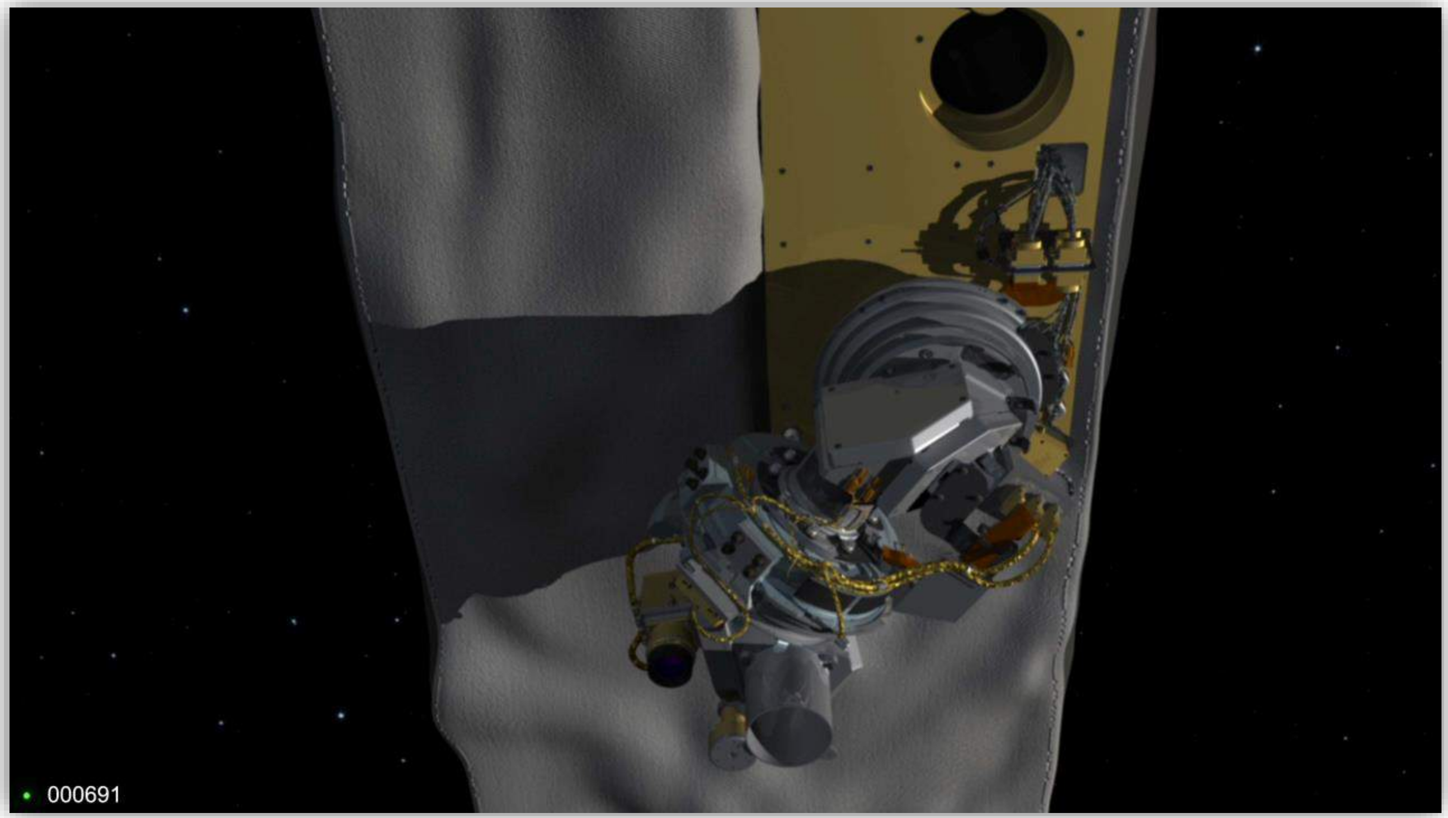


Calibration updates and data screening not complete, but now collecting a dense enough data set for those steps.

[Ref: Data produced by the SDOS team and graphics by R. Nelson]
Simple screening applied, no bias correction.

OCO-3 ON the ISS

PMA during snapshot maps



Figures by John Howard

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Footprints sketched for snapshot over LA

- There will be footprint rotation – not yet in these simulations

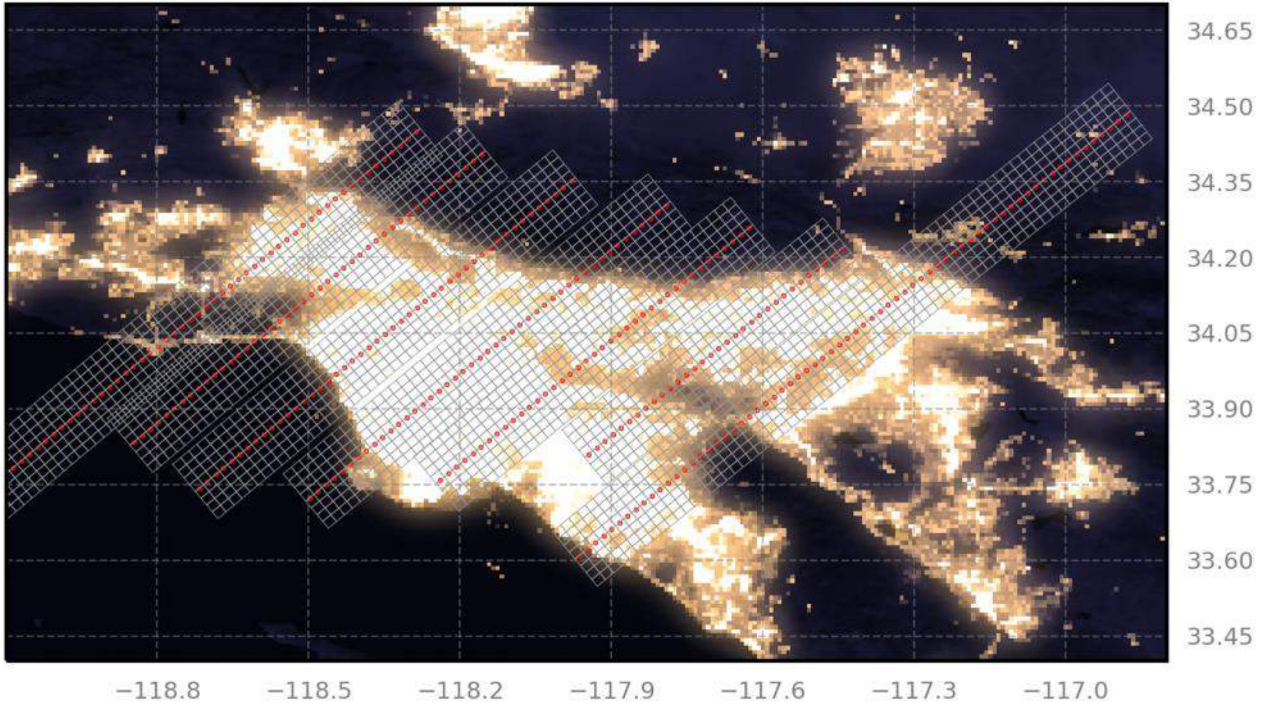

Figure Thomas Kurosu

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Revisits over a year

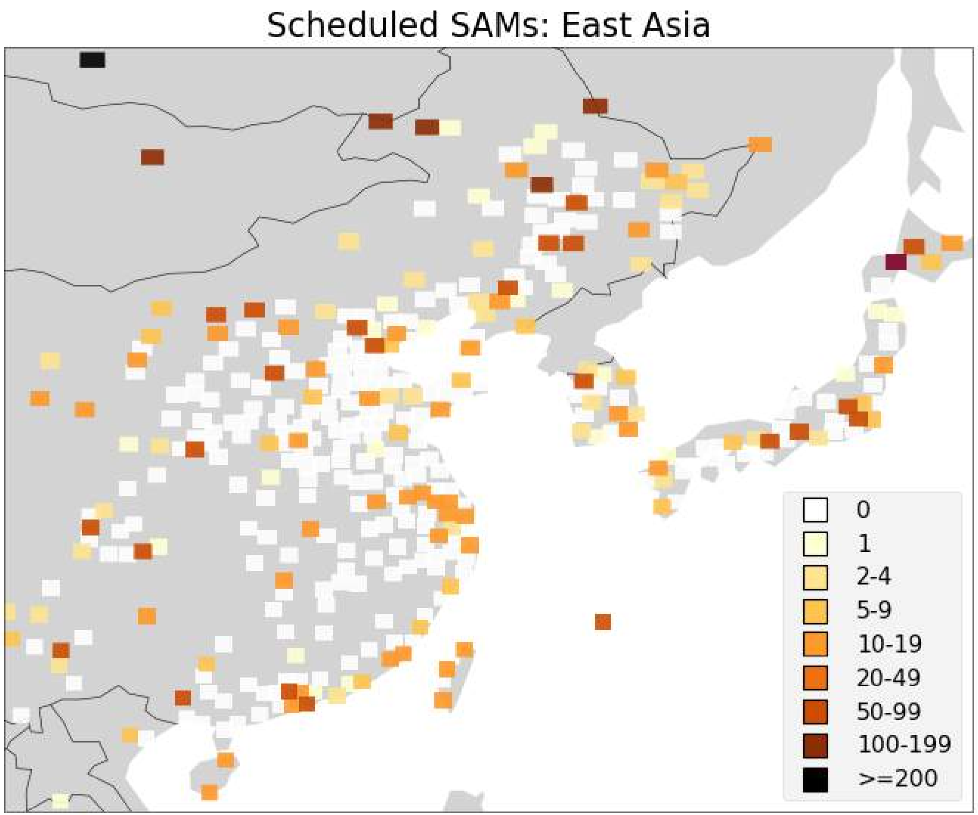

Figure by Ryan Pavlick

Conclusions

- OCO-3 builds on and extends OCO-2 measurements, adding time of day information and new types of data collects with flexible pointing system
- Payload is at Kennedy Space Center – will be in storage there by end of week
- Launch date is March 16, 2019 on Dragon Capsule on Space-X Falcon-9
- Calibration team is completing analysis of pre-launch characterization
- Missions ops and science team finalizing planning tools
- SDOS and algorithm team stepping through simulations with operational algorithms
- **Team is excited and ready to get to operations!**

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