Space-Based Observations of CO_2 and Solar-Induced Chlorophyll Fluorescence from the NASA Orbiting Carbon Observatory-2 Mission

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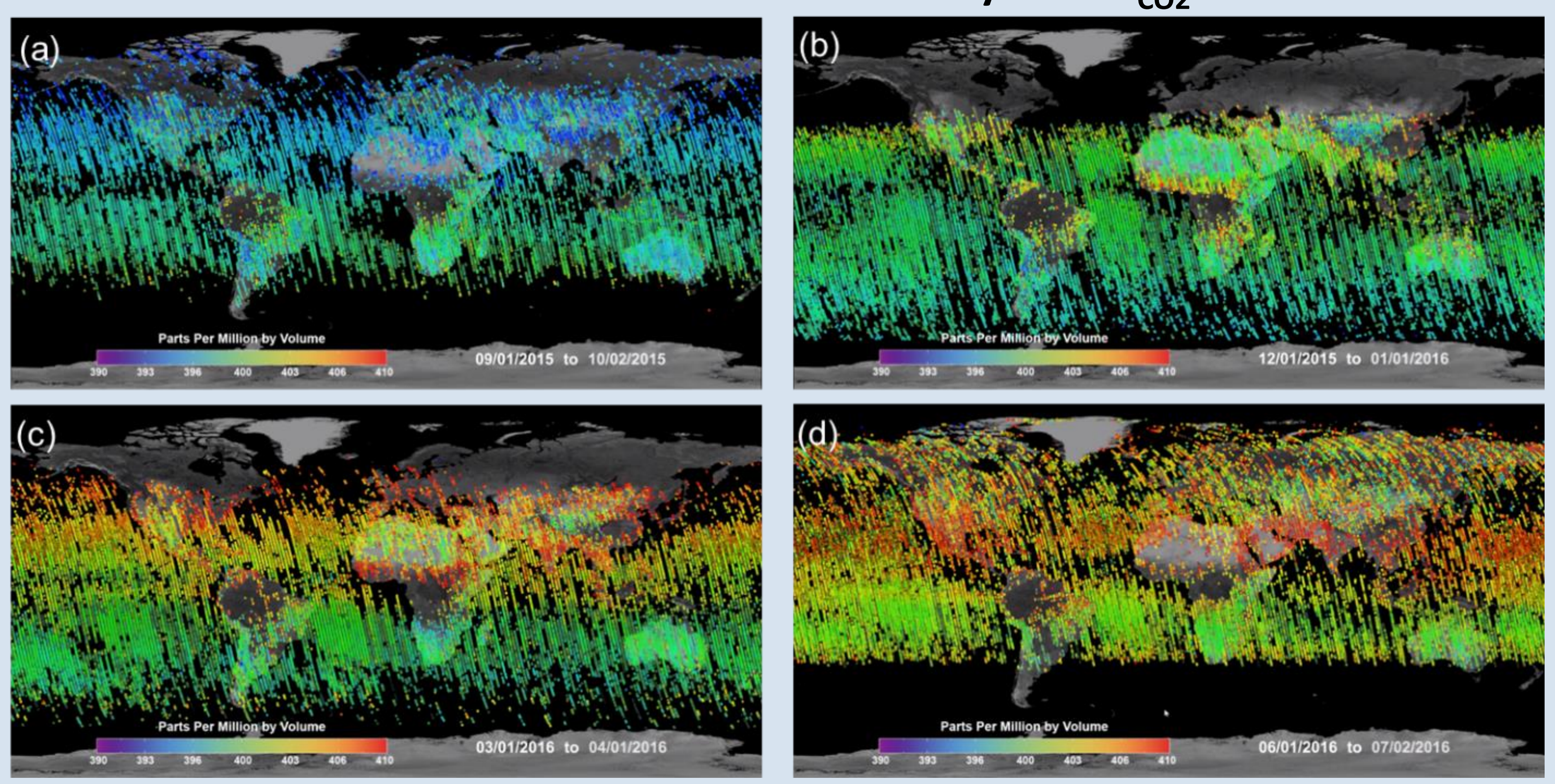
Abstract

OCO-2 completed its 2-year nominal mission in October 2016 and began its first extended mission. Since September 2014, its 3-channel imaging grating spectrometer has returned high-resolution spectra of reflected sunlight in the 0.765-micron (µm) molecular oxygen (O_2) A-Band and in the 1.61 and 2.06-µm carbon dioxide (CO_2) bands. Typically, between 25,000 and 75,000 soundings each day are sufficiently cloud-free to yield full-column estimates of the column-averaged CO_2 dry air mole fraction, X_{CO2}, with single sounding random errors near 0.5 ppm (0.125%) over most of the globe. Another product derived from the OCO-2 spectra, solar induced chlorophyll fluorescence (SIF), is yielding additional insight into CO_2 uptake by the land biosphere. For example, data collected between March 2015 and June of 2016 provided a unique opportunity to study the carbon-climate response to the intense 2015-2016 El Niño.

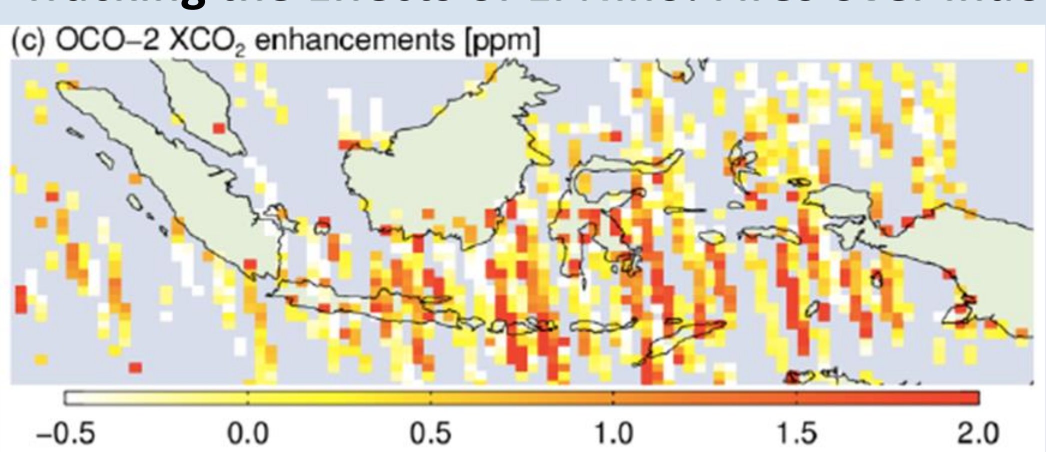
The precision and accuracy of the first, global, OCO-2 X_{CO2} data product, Version 7 (V7), were validated through comparisons with X_{CO2} estimates from the ground-based spectrometers in the Total Carbon Column Observing Network (TCCON) and other standards. After correcting known biases, the median difference between co-located OCO-2 and TCCON X_{CO2} estimates is less than 0.4 ppm and RMS differences are typically less than 1.5 ppm. However, larger biases (~ 3 ppm) are sometimes seen, particularly at high southern latitudes over the ocean during the southern winter. The primary sources of these and other biases have been traced to shortcomings in the instrument calibration, gas absorption coefficients and the retrieval algorithm. These issues are addressed in the Version 8 (V8) algorithm, which has been used to reprocess the entire OCO-2 data record. This poster summarizes recent results, and provides a brief overview of the V8 product.

OCO-2 Observes the Seasonal Cycle in X_{CO2}



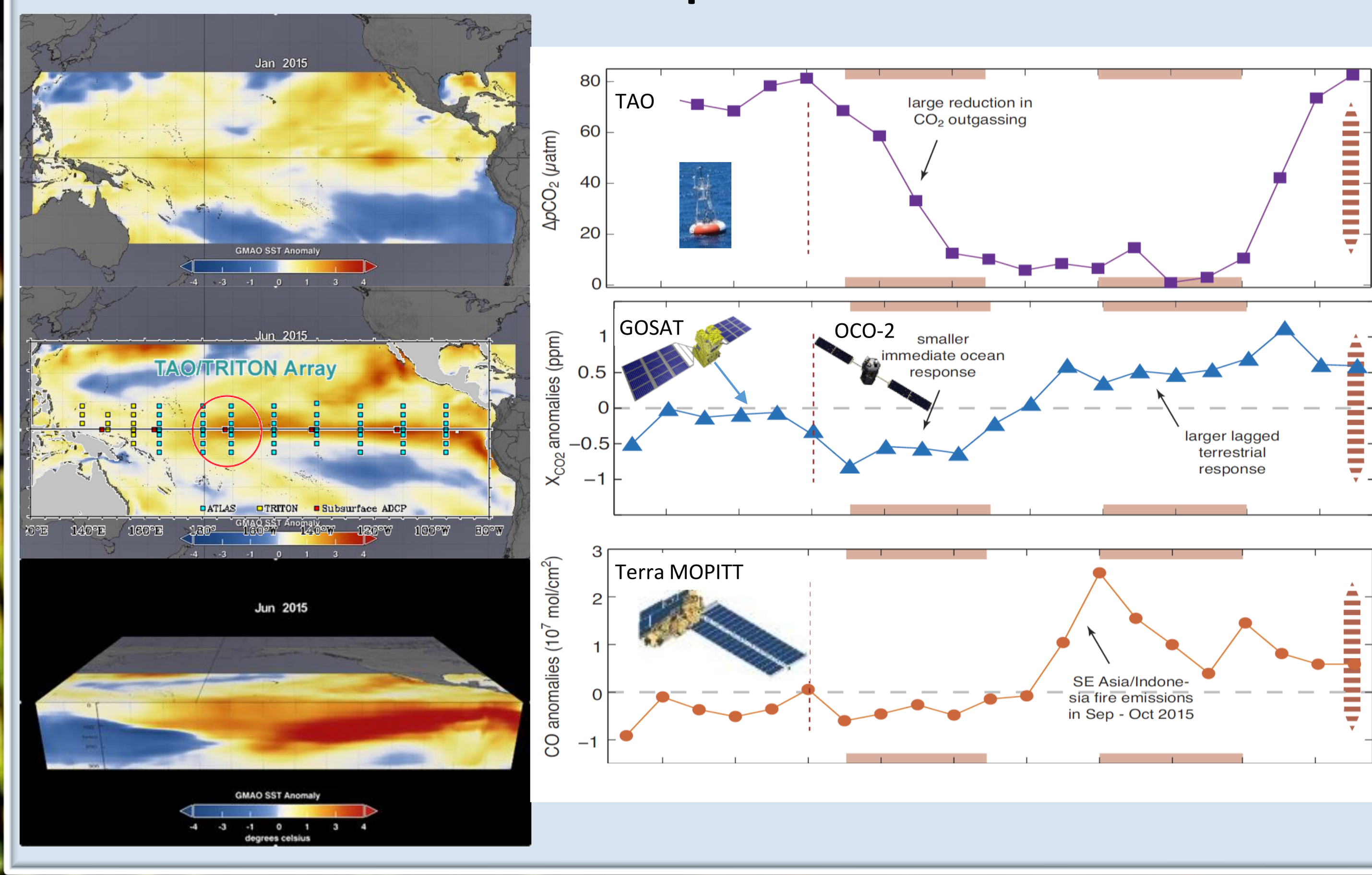
OCO-2 X_{CO2} soundings collected during (a) Sep 2015, (b) Dec 2015, (c) Mar 2016, and (d) Apr 2016 illustrate the coverage and spatial resolution of the Version 7 product at monthly intervals. Optically thick clouds often preclude observations at high latitudes in the winter hemisphere and over the tropics, but these data still provide high resolution, global description of the CO_2 cycle.

Tracking the Effects of El Niño: Fires over Indonesia



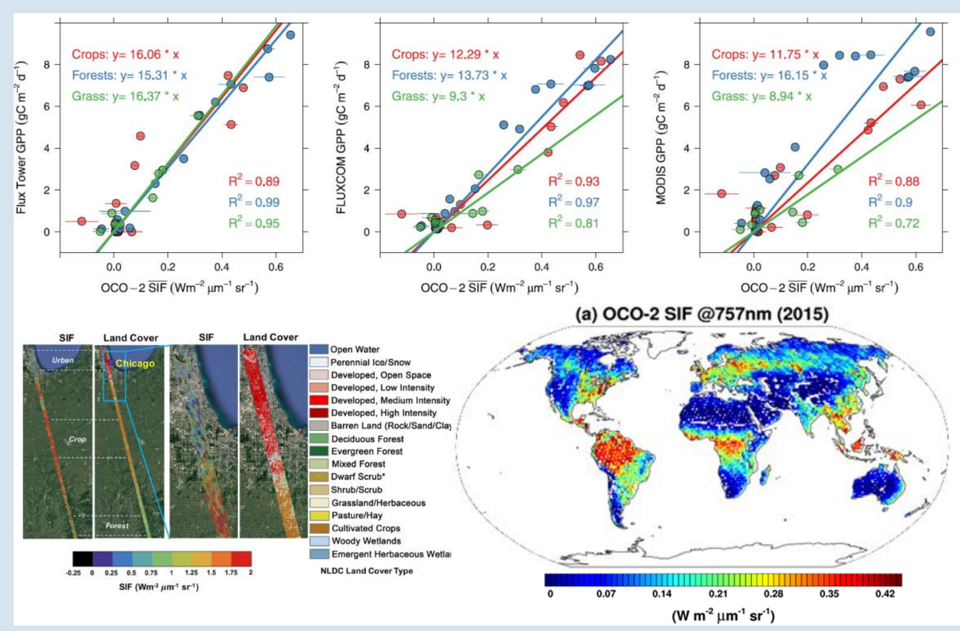
OCO-2 recorded enhanced X_{CO2} over Indonesia between Jul and Nov 2015, while MODIS and MOPITT recorded fire activity. However, Heymann et al. (GRL, 2017) found that emission estimates based on OCO-2 X_{CO2} anomalies are less than 70% as large as those in the GFAS and GFED inventories.

2015-2016 El Niño: Ocean Response



Chatterjee et al. (Science, 2017; GC14A-03) find that X_{CO2} was reduced by 0.5 ppm in the central equatorial Pacific (Nino 3.4 region) between March and July of 2015, consistent with TAO buoy measurements of reduced ocean outgassing. By August 2015, emissions from the land biosphere produce elevated X_{CO2} in this area.

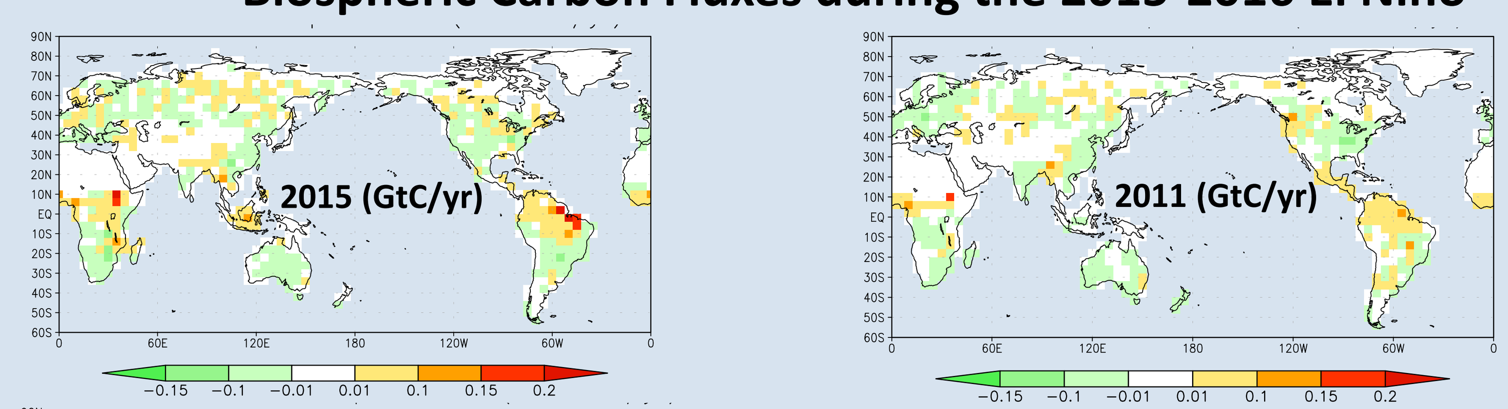
Solar Induced Chlorophyll Fluorescence (SIF)

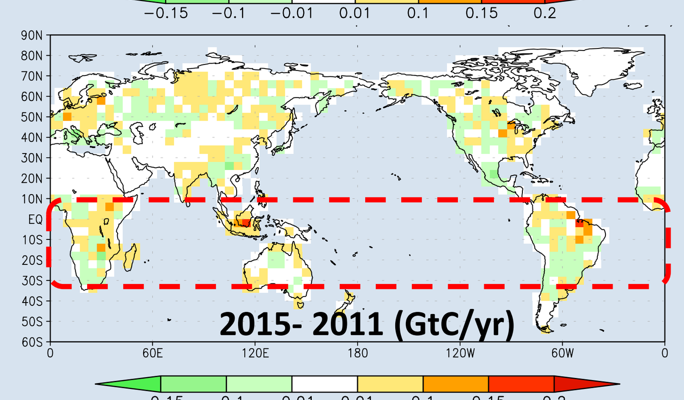


Sun et al. (Science, 2017), Verma et al. (JGR BioGeosciences, 2017), and Wood et al. (GRL, 2017) demonstrated a consistent, global, spatiotemporal correspondence between OCO-2 SIF observations and gross primary production (GPP).

Global SIF maps derived from OCO-2, GOSAT and GOME-2 observations were then combined with X_{CO2} observations to track changes in the GPP associated with the 2015-2016 El Niño.

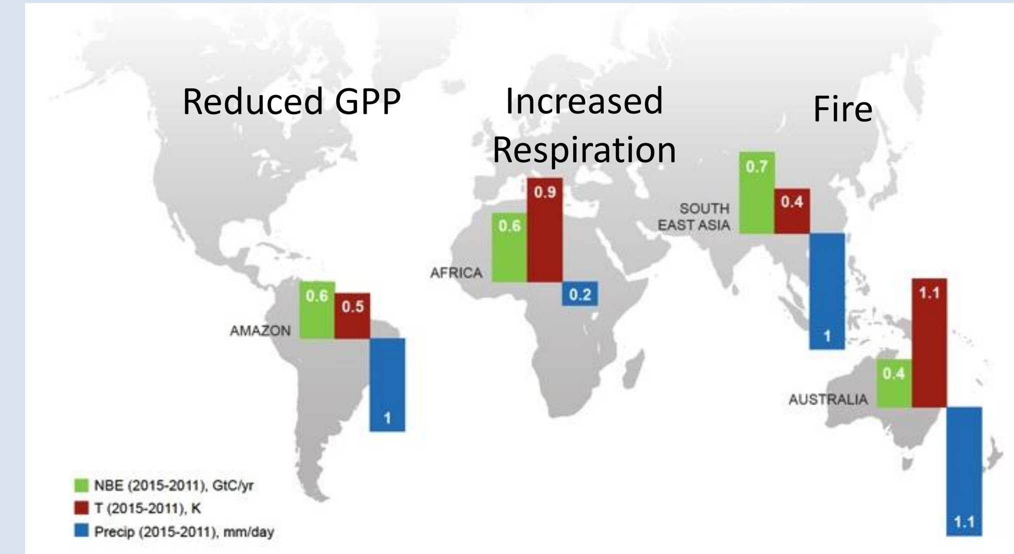
Biospheric Carbon Fluxes during the 2015-2016 El Niño





Liu et al. (Science 2017) analyzed GOSAT and OCO-2 X_{CO2} and SIF data with the CMS Flux Model. They found that during 2015-2016 El Niño, the pan-tropical biosphere released an additional 2.36± 0.34 billion tons of carbon (GtC) into the atmosphere (~78% of the global total) relative to the reference year, 2011 (a La Niña year).

The Biospheric Response to the 2015-2016 El Niño: 3 Continents, 3 Stories

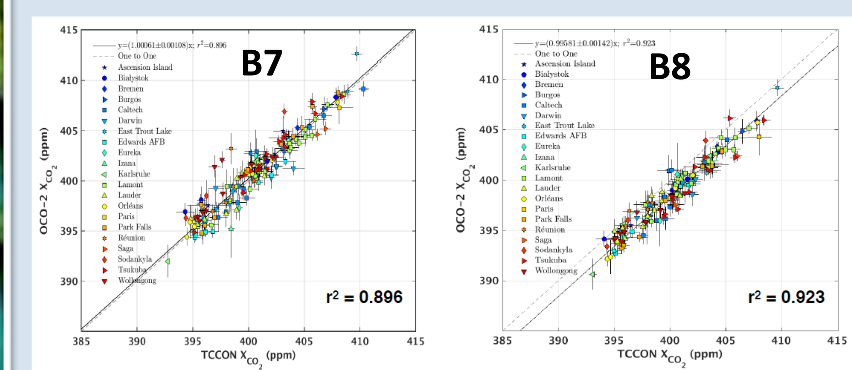


Liu et al. (Science, 2017; A51M-07) find that while the enhanced emissions from tropical South America, Africa, and Asia, were comparable, different processes dominated in each region.

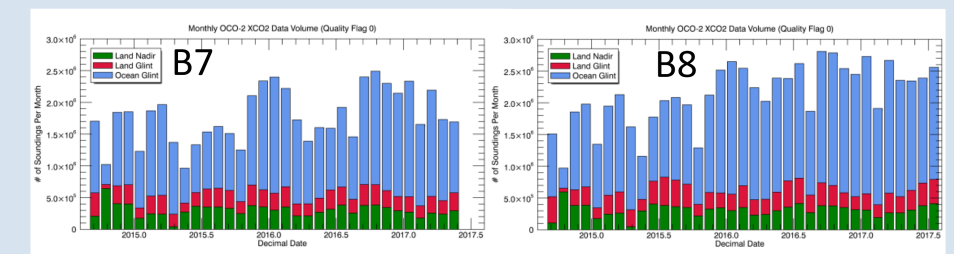
- In the Amazon, GPP was reduced due to intense drought.
- In tropical Africa, rainfall was nominal but high temperatures increased emissions from fires and respiration.
- Fire emissions were the dominant source of CO_2 over tropical Asia.

Looking Forward – The OCO-2 Build 8 (B8) Data Product

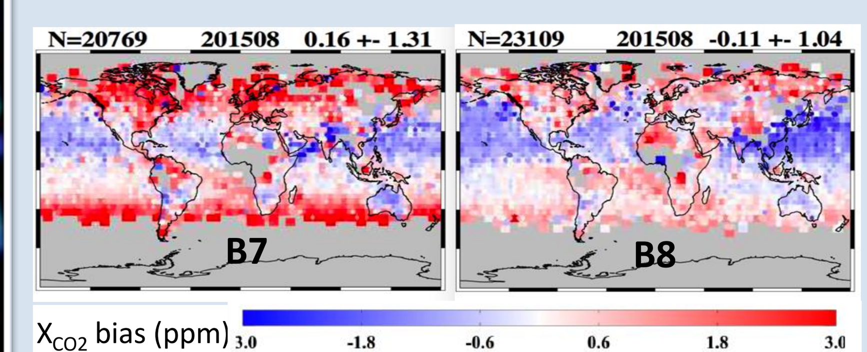
The results summarized above were generated using the OCO-2 Build 7 (B7) product. In general, B7 was a good product, but its accuracy and coverage were compromised in some regions by issues that have been traced to shortcomings in the instrument calibration, pre-screening methods, gas absorption coefficients and the retrieval algorithm implementation. These issues have been addressed by the B8 product. This product has reduced X_{CO2} bias compared to TCCON and other truth metrics. The B8 X_{CO2} product also has better yields and better coverage than B7, especially at high latitudes of the winter hemisphere (see **O'Dell et al. A32D-08**).



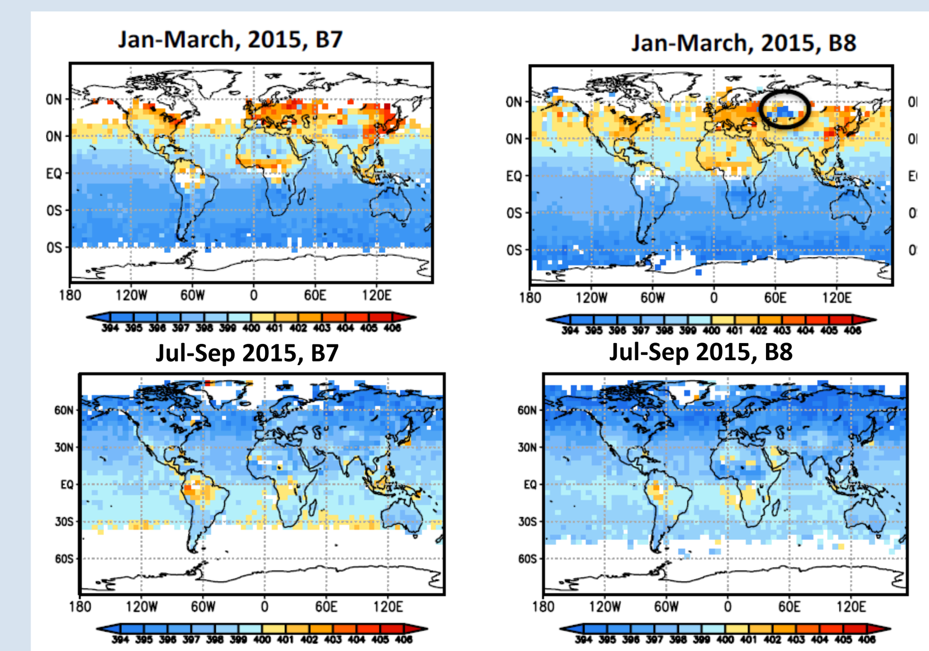
The B8 X_{CO2} product (right) shows substantially better agreement with TCCON than the B7 product (left).



Improvements in the B8 data screening algorithms increased the yield of the X_{CO2} product, especially over the ocean at high latitudes and over South America.



The largest improvements were produced by including the scattering by optically-thin (τ<0.01) stratospheric aerosols that produced large (3 ppm) biases in the southern hemisphere over the ocean. Including this aerosol layer also reduced biases over land and over high latitude oceans in the northern hemisphere.



The improved coverage of the B8 X_{CO2} product (right) is most obvious at high latitudes in the winter hemisphere over the ocean.

The OCO-2 B7 products are now being combined with other space- and ground-based data to provide new insights into the atmospheric carbon cycle. The improved B8 products are expected to continue progress. These products can be obtained through the GES-DISC at the site:

https://disc.gsfc.nasa.gov/datasets?page=1&source=OCO-2%20OCO%20SPECTROMETERS