Measuring Atmospheric Carbon Dioxide from the NASA Orbiting Carbon Observatory-2 (OCO-2)

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Abstract: NASA's OCO-2 spacecraft has returned observations of atmospheric carbon dioxide (CO_2) since September 2014. These data are being used to study the processes emitting CO_2 into the atmosphere and those absorbing it at the surface.
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1. Introduction

Fossil fuel combustion, deforestation, and other human activities are now adding almost 40 billion tons of carbon dioxide (CO_2) to the atmosphere each year. These emissions are superimposed on an active natural carbon cycle that adds about 20 times as much CO_2 to the atmosphere annually, and then reabsorbs a comparable amount, along with over half of the CO_2 contributed by human activities. Interestingly, the identity and location of the natural "sinks" in the land biosphere and ocean that are responsible for absorbing this anthropogenic CO_2 are still poorly understood. Because of this, it is impossible to accurately predict how these sinks will respond to a warming climate. Space based remote sensing provides new tools for studying the sources and sinks of CO_2. The NASA Orbiting Carbon Observatory-2 (OCO-2) was launched in July 2014 and was inserted at the head of the 705-km Afternoon Constellation (A-Train) a month later.

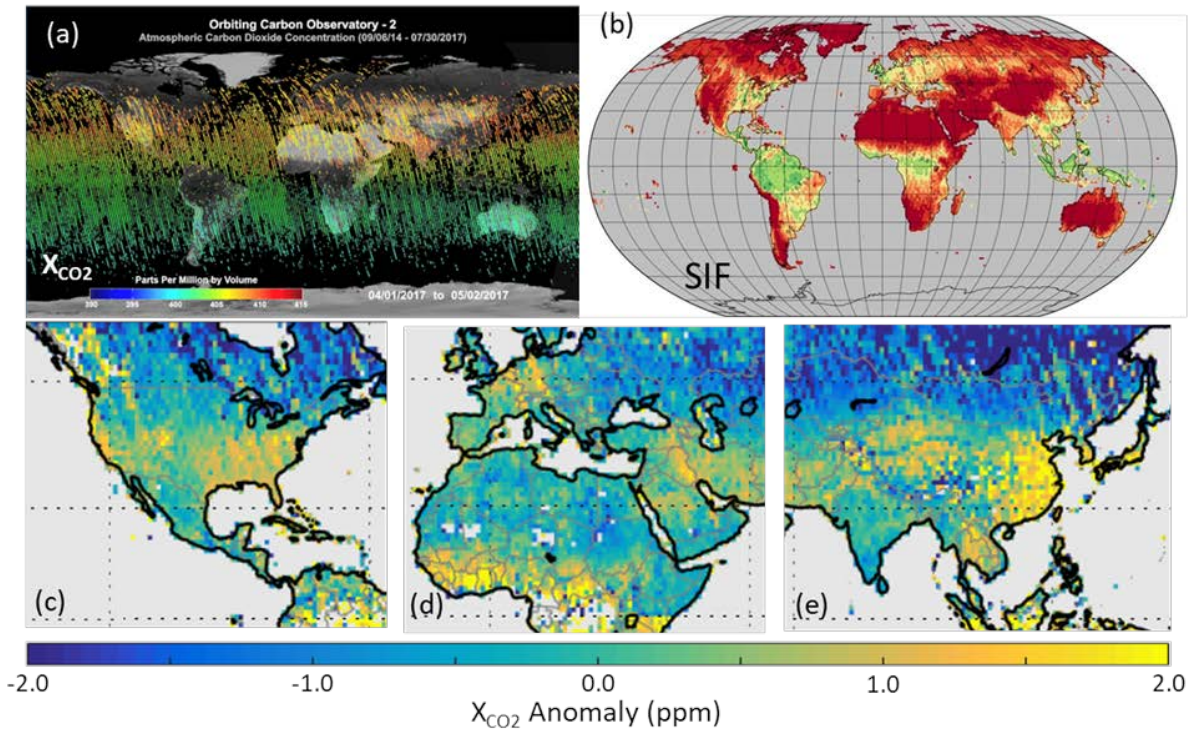
2. The OCO-2 products

Since early September of 2014, its 3-channel imaging grating spectrometer has returned over one million high-resolution spectra of reflected sunlight in the 0.765 microns (µm) molecular oxygen (O_2) A-Band and in the 1.61 and 2.06 µm CO_2 bands each day. These spectra are combined into soundings that are analyzed with state-of-the-art remote sensing retrieval algorithms produce spatially-resolved estimates of the column-averaged CO_2 dry air mole fraction, X_{CO2}. Each day, between 25,000 and 85,000 of these soundings are sufficiently cloud-free to yield full-column X_{CO2} estimates with single sounding random errors near 0.5 ppm (0.125%) at solar zenith angles as large as 70 degrees (Figure 1a) [1].

Another product derived from the OCO-2 spectra, solar induced chlorophyll fluorescence, SIF (Figure 1b). As plants perform photosynthesis, up to 2% of the sunlight used for photosynthesis is re-emitted at red and infrared wavelengths. This fluorescence can be detected by monitoring the filling of solar Fraunhofer lines in the O_2 A-band channel. Members of the OCO-2 science team and others in the carbon cycle community are using these observations to provide additional insight into gross primary productivity and CO_2 uptake by plants on land [2]. OCO-2 also returns estimates of the total column water vapor, which are sufficiently accurate to be of interest to the meteorological community [3]. OCO-2 completed its nominal 2-year mission in October 2016, and began its first extended mission.

3. Results

OCO-2 observations returned during its first 4 years in orbit clearly show the most robust features of the atmospheric carbon cycle including the intense northern hemisphere spring drawdown, as land plants rapidly absorb atmospheric CO_2 to form new leaves, stems, and roots. They show enhanced CO_2 over regions with intense fossil fuel combustion, such as the Western Europe and the east coasts of China and the U.S. [4]. They also show high CO_2 in regions of intense biomass burning over central Africa, the Amazon, and Southeast Asia (Figures 1c-e). Data collected between March 2015 and June of 2016 provide a high resolution global description of the atmospheric CO_2 response to the intense 2015-2016 El Niño [5, 6]. As these data are analyzed by the science community, they are expected to reveal far more information about the processes controlling the atmospheric CO_2 buildup. They are also providing insight into methods for collecting and analyzing space-based atmospheric CO_2 data as part of a global atmospheric CO_2 monitoring system.



(a) Global maps of the spatial coverage, resolution, and amplitude of the OCO-2 X_{CO2} estimates for April 2017. The X_{CO2} amplitudes vary from 390 (blue) to 415 parts per million (ppm) red). (b) Annual average SIF. Green indicates areas of higher gross primary production. (c) X_{CO2} anomalies over North and Central America. (b) X_{CO2} anomalies over Europe and North Africa. (e) X_{CO2} anomalies over Asia.

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5. References

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