SEASONAL CHANGING TREND OF CO_2 CONCENTRATION RESPONSING TO CARBON ABSORPTION OF VEGETAION OBSERVED BY SATELLITES

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ABSTRACT:
It is not exactly known how the seasonal variations of CO_2 concentration such as its seasonal peak and amplitude etc., are influenced by vegetation carbon absorption. This paper presents the seasonal changing trend of CO_2 concentration affected by the seasonal activity of vegetation carbon absorption observed by Greenhouse Gases Observing Satellite (GOSAT). We extracted the seasonal changing characteristic values of CO_2 concentration using the global mapping of column-averaged CO_2 dry-air mole fraction (XCO_2) retrievals from GOSAT observing data during June 2009 to May 2014. The seasonal changing characteristic values of CO_2 concentration mainly include the amplitudes, the peak and its time of XCO_2 seasonal variations. As a result, it is found that the amplitude of XCO_2 seasonal variation is spatially corresponding to that of the normalized difference vegetation index (NDVI) from Moderate Resolution Imaging Spectroradiometer (MODIS) which could indicate the magnitude of vegetation carbon absorption. Additionally the seasonal variation of XCO_2 is strongly correlated with the seasonal variation of NDVI over vegetation covers in the northern hemisphere.

1. INTRODUCITION

Satellite observation of atmospheric CO_2 such as Greenhouse Gases Observing Satellite (GOSAT) and Obit Carbon Observation (OCO-2) offers us new opportunities to know the mechanism of land biosphere absorption for CO_2 as its advantage of global coverage and high measurement density comparing to in-site measurements (Buchwitz et al, 2015, Hungershoefer et al., 2010, Crisp et al.,2004; Yokota et al., 2004). The patterns of XCO_2 distribution averaged over a long period of several years are mostly affected by distribution of the underlying surface fluxes (Schneising et al., 2011). It is not completely clear what is the spatial differences of seasonal variation of CO_2 concentration in a global scale although we know that the seasonal cycle of CO_2 is mainly induced by the seasonal activities of biosphere absorption for CO_2 [Zeng et al., 2014; Schimel at al., 2015].

In this paper we applied the global XCO_2 mapped from GOSAT XCO_2 data to extract the seasonal changing characteristics of XCO_2 and analyze these characteristics related with the vegetation absorptive strength using NDVI data.

2. USED DATA AND PROCESSING

2.1 Raw XCO_2 data

We collected the raw XCO_2 data (ACOS-GOSAT v3.3, http://co2web.jpl.nasa.gov) produced by the Atmospheric CO_2 Observations from Space (ACOS) project from applying the Orbiting Carbon Observatory (OCO) calibration, validation, and remote sensing retrieval algorithm to the GOSAT spectral measurements spanning from June 2009 through May 2013 (O'Dell et al., 2012; Wunch et al., 2011). We extracted those land-only data with high gain flag from those raw ACOS-GOSAT v3.3 XCO_2 retrievals. The data is first filtered using the advanced screening criteria to extract the good soundings, and then bias-corrected to remove the systematic bias in the XCO_2 retrievals, as recommended by ACOS data users' guide (Wunch et al., 2011, Crisp et al., 2012). The filtered and bias-corrected data are referred to as ACOS-XCO_2 hereafter. It is reported that the bias-corrected data is uncertain to ~0.3 ppm when compared with data from Total Carbon Column Observing Network (TCCON) (ACOS User Guide, 2014), and ACOS datasets show more stable performance comparing with the other several individual satellite retrieval algorithms (Buchwitz et al., 2015). Additionally we collected the simulation XCO_2 data by Carbon-Tracker model from June 2009 to May 2014 for comparing with ACOS-XCO_2 (http://www.esrl.noaa.gov/gmd/ccgg/carbontracker).

2.2 Mapping XCO_2 data from ACOS-GOSAT retrievals

XCO_2 data from ACOS-GOSAT retrievals are irregularly distributed and have many gaps in space and time mainly due to cloud coverage and the observation mode of GOSAT-FTS (Zeng et al., 2014), which make it difficult to directly interpret the detailed spatio-temporal variations of CO_2 concentration. The mapping method to fill the gaps between ACOS-GOSAT XCO_2 data is therefore applied to the ACOS- XCO_2 data. The method is based on the spatio-temporal geo-statistical estimation approach, which first quantify and model the spatio-temporal correlation structure in the data and then make optimal estimations of XCO_2 in the gaps using spatio-temporal kriging (Zeng et al., 2014). The mapping method and the resulted mapping XCO_2 data, which are used in this study, are described and assessed in Zeng et al. (2013) and Guo et al. (2015). Using the mapping method, we obtained the mapped ACOS-XCO_2 dataset and the corresponding estimation standard deviation, a measurement of estimation uncertainty, in 1°×1° grids in space and 3 days interval in time from June 2009 to May 2014.

2.3 NDVI data

The data of the normalized difference vegetation index (NDVI) from Moderate Resolution Imaging Spectroradiometer (MODIS) is collected as well in the same period as XCO_2 dataset released from USGS (http://e4ftl01.cr.usgs.gov). All of these data is resampled in 1°×1° grids matching with the grid size of XCO_2 data.

2.4 Fitting of XCO_2 seasonal cycle

The temporal variation of CO_2 concentration could be divided into two parts for annual growth and seasonal cycle mainly affected by the anthropogenic fossil fuel emissions and biosphere activities. The classical formula, a skewed sine wave, can be used to fit the temporal variation of CO_2 concentration [Vettr et al., 2015; Lindqvist et al., 2015]. We fitted an monthly seasonal cycle to the mapping XCO_2 and daily Carbon-Tracker simulating data using the harmonic functions [Lindqvist et al., 2015].

3. RESULTS AN D DISCUSSION

The amplitude of XCO_2 seasonal variation, which is the difference between the maximum and the minimum XCO_2, is extracted using fitting XCO_2 seasonal cycle from the temporal variation of mapping ACOS-XCO_2 data, and is shown in Figure 1. Similarly Figure 2 demonstrates the amplitude of XCO_2 seasonal variation using fitting XCO_2 seasonal cycle from the temporal variation of simulated XCO_2 data by Carbon-Tracker.

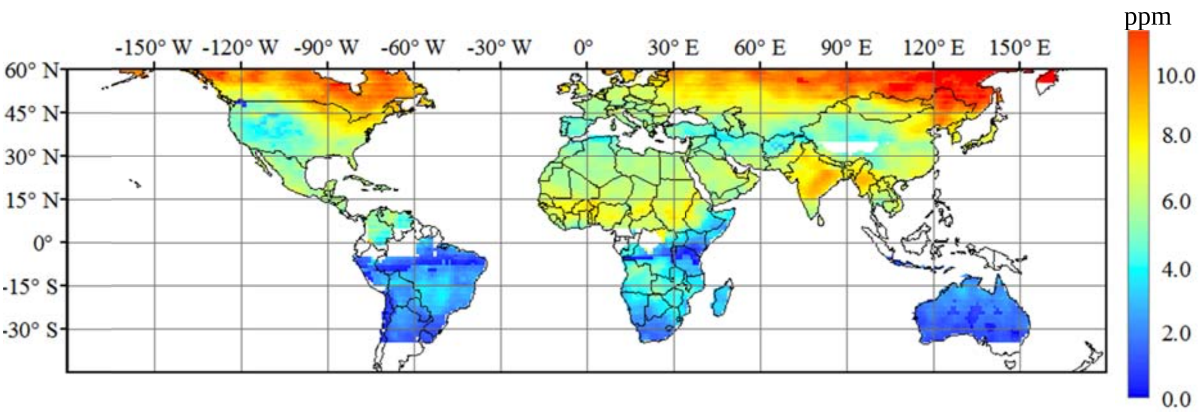

Figure 1. The amplitude of XCO_2 seasonal variation from fitting seasonal cycle of mapping XCO_2 derived from GOSAT ACOS v3.5 data from June 1 2009 to May 30 2014 with 3 day time resolution.

We can find from Figure 1 that the amplitude of XCO_2 seasonal variation observed by GOSAT clearly changes with the latitudinal band and responding to the border of high latitudinal forest in the northern hemisphere. Comparing with the amplitude of XCO_2 seasonal variation from simulated $XCO_2$by Carbon-Tracker 2015 as shown in Figure 2, they demonstrated very similar spatial distribution whereas that of ACOS-XCO_2 presented slightly higher value than that of simulating XCO_2.

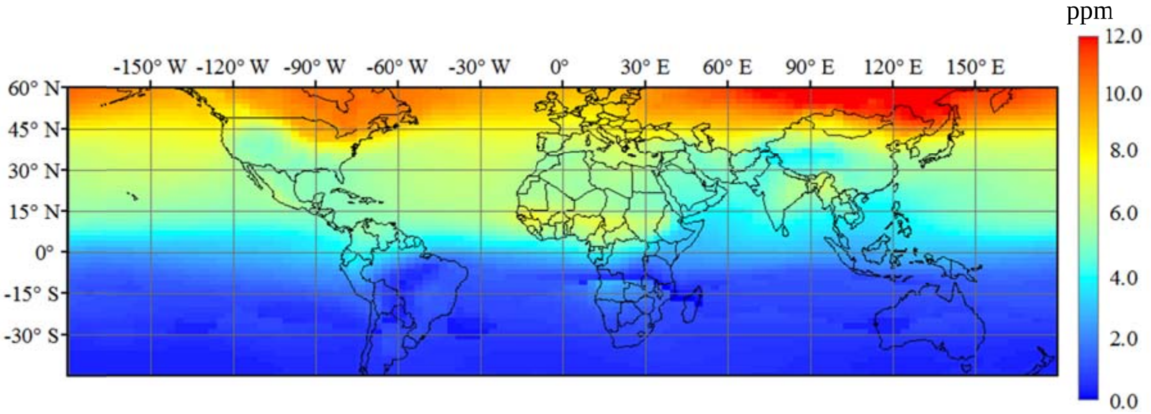

Figure 2. The amplitude of XCO_2 seasonal variation from fitting seasonal cycle of simulating daily XCO_2 derived from Carbon-Tracker 2015 from June 1 2009 to May 30 2014 with 3 day time resolution.

The month of minimum XCO_2 and the month of maximum in XCO_2 seasonal variation, which is extracted using fitting XCO_2 seasonal cycle from the temporal variation of mapping ACOS-XCO_2 data, are shown in Figure 3. It can be seen from Figure 3 that both of the month of maximum XCO_2 and minimum XCO_2 changed with the latitudinal band in the northern hemisphere.

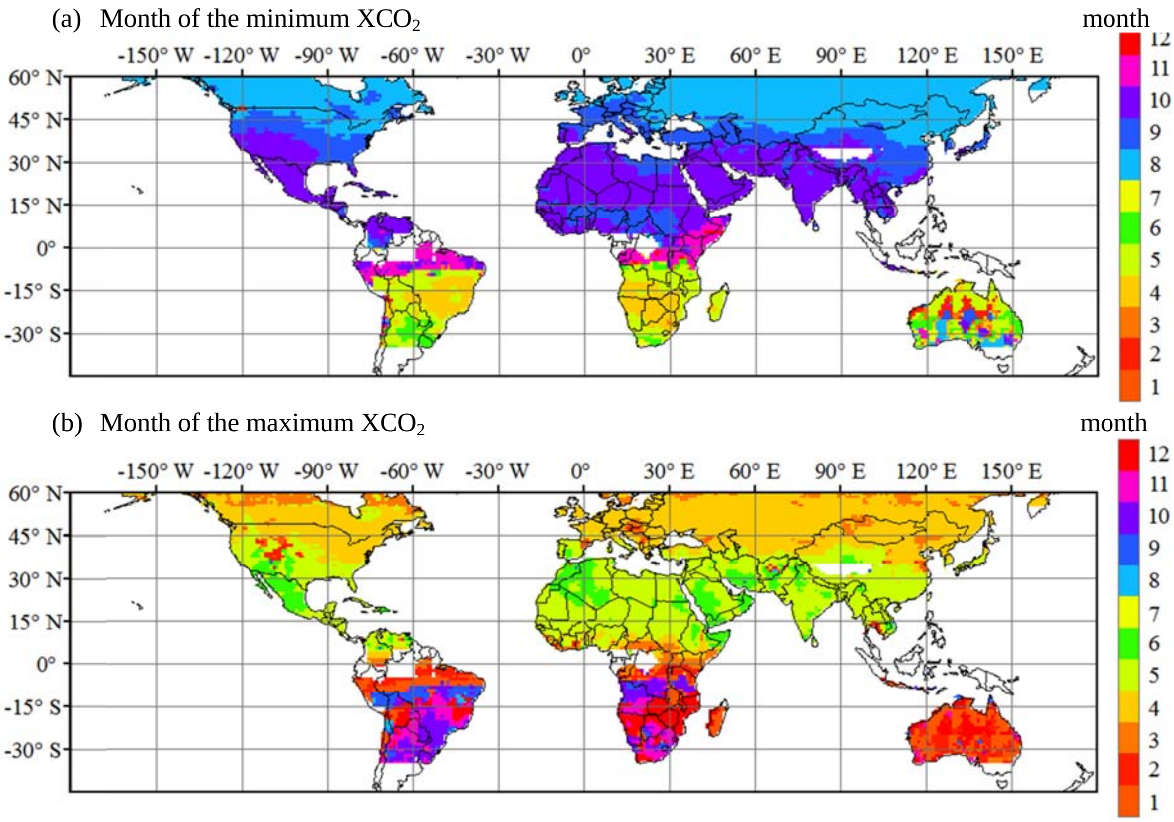

Figure 3. The month of peak in XCO_2 seasonal variation is extracted from fitting seasonal cycle of mapping ACOS-XCO_2 observed by GOSAT from June 1 2009 to May 30 2014 with 3 day time resolution, (a) the month of minimum XCO_2; (b) the month of maximum XCO_2.

Moreover the amplitude magnitude of ACOS-XCO_2 is agreement with the amplitude contour of ACOS-XCO_2 8 ppm (Figure 4).

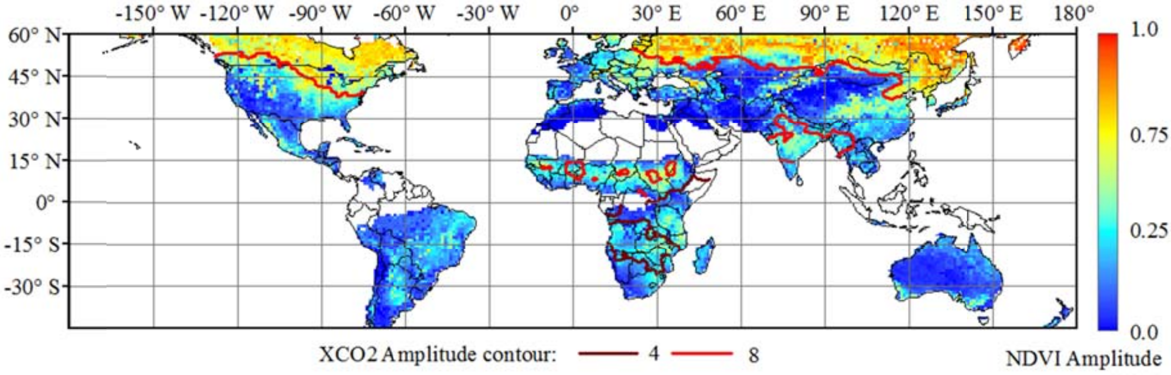

Figure 4. The amplitude of NDVI seasonal variation is extracted from fitting seasonal cycle of MODIS NDVI from June 1 2009 to May 30 2014 with 8 day time resolution which is overlapped with the amplitude contour ofACOS-XCO_2 seasonal variation in 4 ppm and 8 ppm.

4. CONCLUSION

This study probed the potential application of ACOS-GOSAT XCO_2 retrievals for assessment of vegetation absorption of atmospheric CO_2. In order to study the continued variations of XCO_2 in space and time, a mapped XCO_2 dataset, generated by applying a geostatistical estimation method of spatio-temporal data to fill the gaps in original ACOS-GOSAT XCO_2 data, is used in this study. As a result, the mapped XCO_2 dataset captures the spatio-temporal variations of XCO_2 and the seasonal cycle of CO_2 concentration in space in good detail which is related with the absorption of vegetation for atmospheric CO_2.

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