Regional scale variations of atmospheric CO_2 and CH_4 from satellite observation

F Ru[1,2], L Lei[1], R Bu[3], X Guan[1,2] and J Qi[4]
[1]Center for Earth Observation and Digital Earth, Chinese Academy of Sciences, Beijing, China
[2] Graduate University of Chinese Academy of Sciences, Beijing, China
[3]Xian University of Science and Technology, Xian, China
[4]China University of Geosciences, Beijing, China

E-mail: lplei@ceode.ac.cn&fru@ceode.ac.cn

Abstract. To identify the sources, sinks and changes of atmospheric CO_2 and CH_4, this study investigates the spatio-temporal changes of atmospheric CO_2 and CH_4 concentration on the regional scale by the satellite observations. In this paper, choosing the land region of China as the study area, we investigate the spatio-temporal changes of atmospheric CO_2 and CH_4 concentrations using the data of the CO_2 dry air mixing ratio (XCO2), and the CH_4 dry air mixing ratio (XCH4), retrieved by the Greenhouse Gases Observing Satellite (GOSAT) from Jan. 2010 to Dec. 2012. The results show that (1) both XCO2 and XCH4 show higher concentrations in southeastern regions than that in the northwestern, and tend to yearly increasing from 2010 to 2013; (2) XCO2 shows obvious seasonal change with higher values in the spring than that in summer. The seasonal peak-to-peak amplitude is 8 ppm and the annual growth is about 2 ppm. XCH4, however, does not show a seasonal change; (3) With regard to different land-use backgrounds, XCO2 shows larger concentrations over the areas of urban agglomeration than that over the grasslands and deserts, and XCH4 shows lower concentrations over deserts than that over the Yangtze River Delta region and Sichuan Basin.

1. Introduction

The concentration of carbon dioxide (CO_2) has increased from about 280 to 380 ppm over the past century because of the burning of fossil fuels associated with expanding industrial activities [1]. CO_2 absorbs infrared radiation from the Earth's surface and hence an increase in CO_2 concentrations leads to a rise in atmospheric temperature. Methane (CH_4) is the second most significant greenhouse gas after CO_2. The variation of CH_4 concentration has an important role in atmospheric chemistry and climate change [2]. CO_2 and CH_4 account for over 80% of the total anthropogenic warming effect caused by all greenhouse gases, based on estimates of radiative forcing from 1750 to 2005 [1]. To accurately predict the future concentrations of atmospheric CO_2 and CH_4 and their impact on climate, it is first necessary to clarify the distribution and variations of their sources and sinks over the global and regional scales.

Satellite measurement is one of the most effective approaches for monitoring global and regional greenhouse gas distribution. The Japanese Ministry of the Environment (MOE), the National Institute for Environment Studies (NIES), and the Japan Aerospace Exploration Agency (JAXA) have jointly

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developed the Greenhouse Gases Observing Satellite (GOSAT) for monitoring CO_2 and CH_4 distribution [3]. Satellite observation is sensitive to the lower troposphere because it detects light that is reflected from the Earth's surface [4]. In this manuscript, we investigate the spatial and seasonal variations of the CO_2 dry air mixing ratio (XCO2) and the CH_4 dry air mixing ratio (XCH4) from GOSAT data in China.

2. GOSAT data and the study area

We collected the GOSAT Level 2 data in Version 2.xx from Jan. 2010 to Dec. 2012 released for Research Announcement (RA) users, which included the data of XCO2 and XCH4.

GOSAT, which was launched on 23 January 2009, is designed to monitor the global CO_2 and CH_4 distributions from space. It was put into a sun-synchronous orbit at 666-km altitude with 3-day recurrence and descending node at around 13:00 local time [5, 6, 7]. GOSAT carries the Thermal And Near infrared Sensor for carbon Observation (TANSO), which actually are composed of two observational instruments: the TANSO-Fourier Transform Spectrometer (TANSO-FTS) for the observation of greenhouse gases, and the TANSO-Cloud and Aerosol Imager (TANSO-CAI) for the observation of clouds and aerosols [8]. The TANSO-FTS operation pattern is the footprint model.

XCO2 and XCH4 are retrieved from the Short-Wavelength Infrared (SWIR) observation data of the TANSO-FTS onboard GOSAT [9], which are cloud-free and released as the SWIR Level 2 (L2) products. Figure 1 shows the annual total number of XCO2 retrieval data within a 2.5 ° × 2.5 ° grid from Jan. 2010 to Dec. 2012 for the latest FTS-SWIR L2 products released in Version 2.xx.

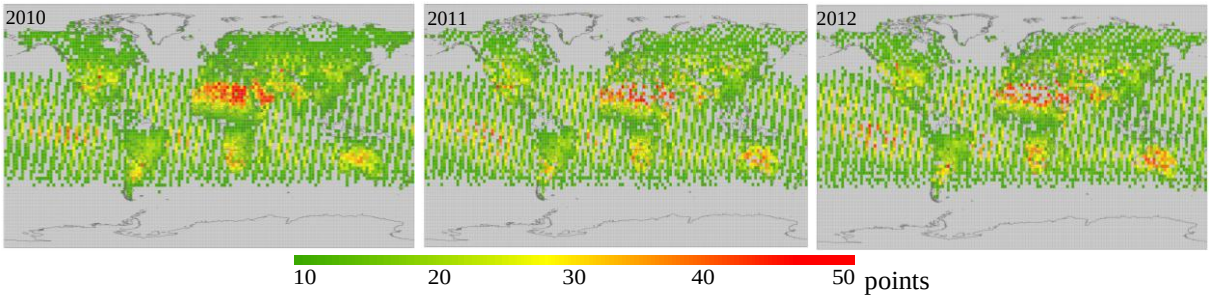


Figure 1. Number of GOSAT SWIR XCO2 data retrieved annually within 2.5 ° × 2.5 ° grid from Jan. 2010 to Dec. 2012.

The study area is located over China. The variations of CO_2 and CH_4 with different land cover located in the six areas in the study area are investigated (see Figure 2).

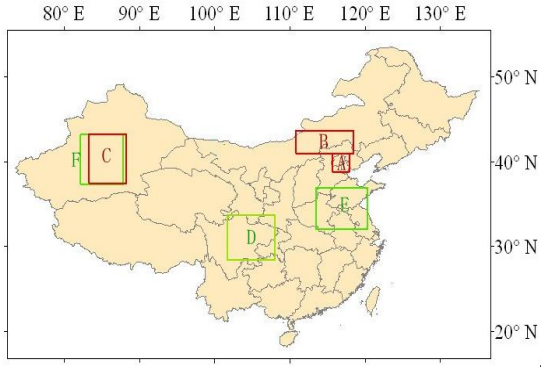
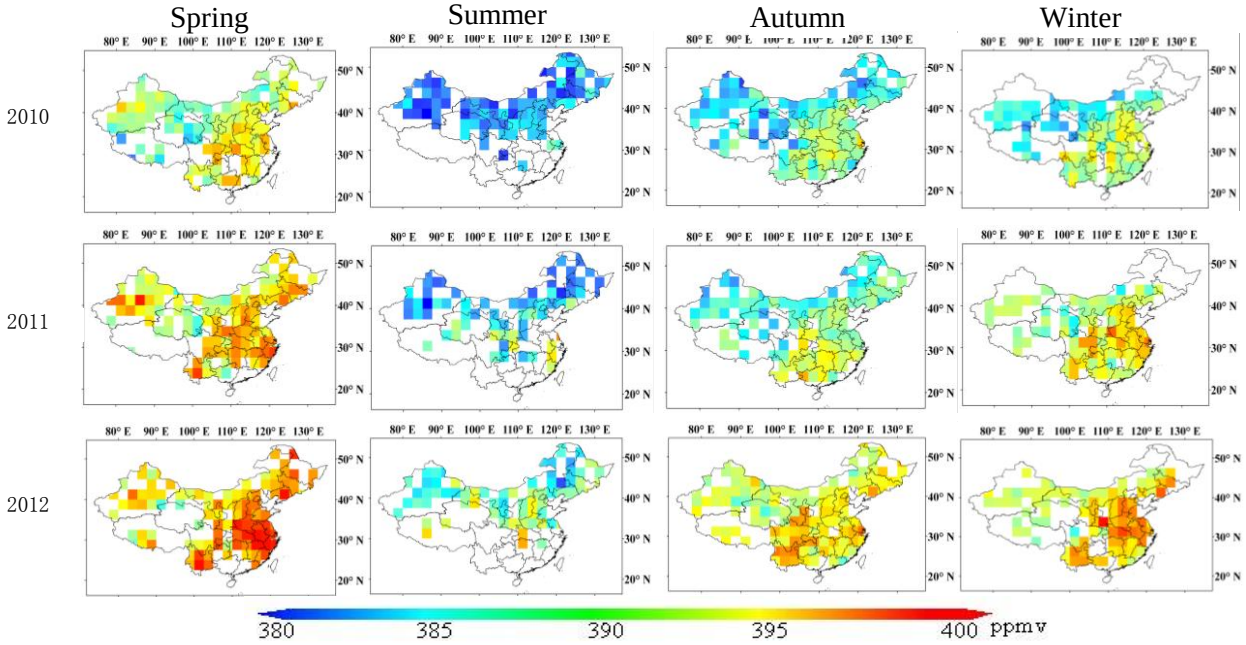


Figure 2. Study area and the investigated areas with the different land covers. The red frames are for XCO2: A-Urban agglomeration located in Beijing-Tianjin-Hebei region with high population density, B-Grassland in northern Inner Mongolia, C-Desert in Xinjiang; the green frames are for XCH4: D-Rice fields in Sichuan Basin, E-Rice fields in Yangtze River Delta region, F-Desert in Xinjiang.

3. Results and discussion

3.1. Spatio-temporal variation of XCO2 and XCH4 in China

(a) XCO2



(b) XCH4

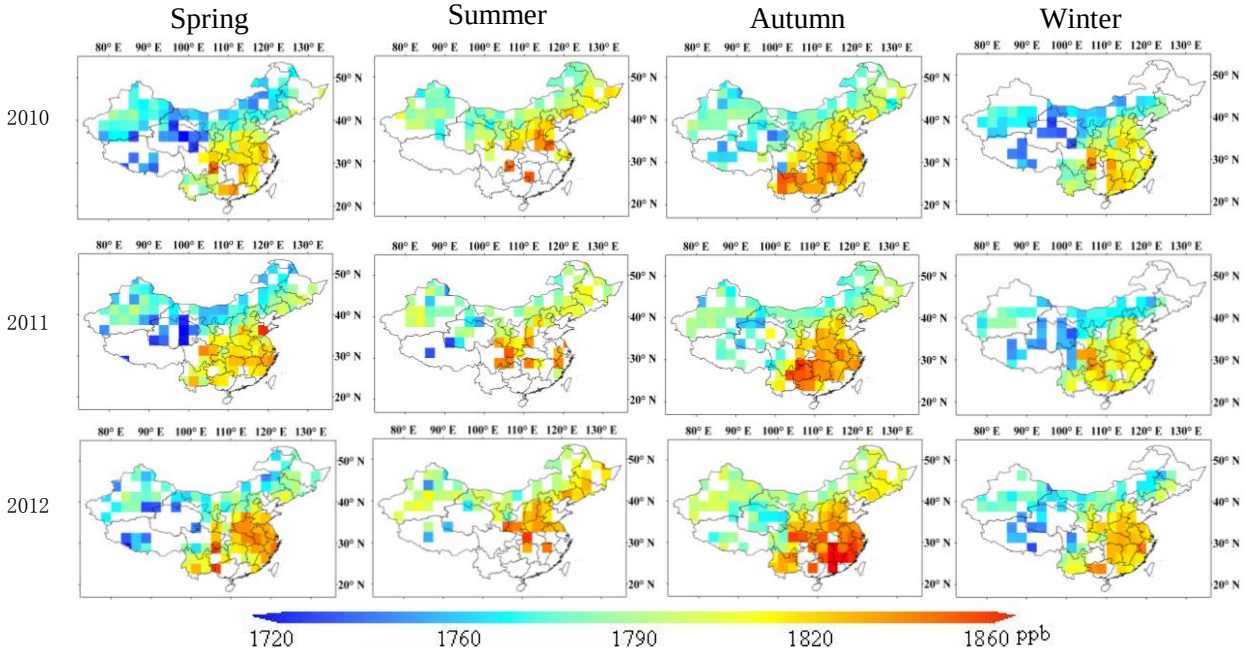


Figure 3. Spatio-temporal changes of (a) XCO2 and (b) XCH4 from 2010 to 2012.

Figure 3 show the seasonal changes, for spring from March to May, summer from June to August, fall from September to November and winter from December to February in the following year. It can be

seen from Figure 3 that XCO2 shows obvious seasonal change that the concentration is the highest in spring and the lowest in the summer. Both XCO2 and XCH4 are obviously higher in the southeastern region with high population density than that in the sparsely populated northwestern region [10].

The monthly variation of XCO2 and XCH4 averaged for the whole of land area from Jan 2010 to Dec 2012 is shown in Figure 4.

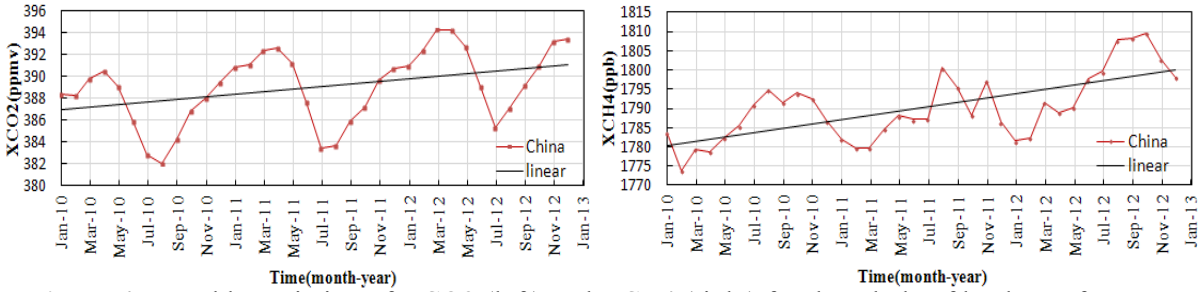


Figure 4. Monthly variation of XCO2 (left) and XCH4 (right) for the whole of land area from Jan. 2010 to Dec. 2012.

As shown in Figures 3 and Figure 4, XCO2 demonstrates a clear seasonal change. The annual maximum values, which are 390ppm, 392ppm and 394ppm for the 3 years of 2010 to 2012 respectively, are all around April. The annual minimum values, which are 382ppm, 384ppm and 386 ppm respectively, are all around July. The seasonal change of the peak-to-peak amplitude is 8ppm. The annual growth is 1.75ppmv from 2010 to 2011 and 2.21 ppm from 2011 to 2012. The annual mean growth is 2ppm during the 3 years.

XCH4, however, does not present seasonal change like XCO2 which is inconsistency to ground-based measurements. It is known from ground-based measurements that global atmospheric CH_4 concentration demonstrates seasonal variations [11, 12]. This inconsistency of the XCH4 retrieved data from GOSAT is necessarily investigated further.

3.2. Seasonal variation of XCO2 and XCH4 in the different land use

Figures 5 and Figure 6 show the variation of XCO2 and XCH4 retrieval footprints, respectively, from Jan. 2010 to Dec. 2012 over the six areas as shown in Figure 2.

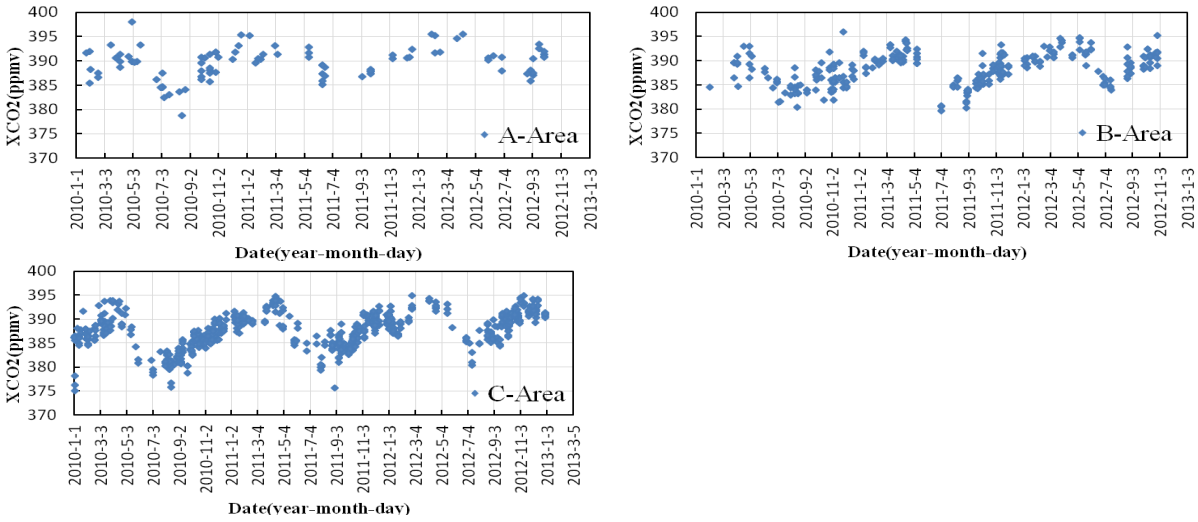


Figure 5. Temporal variations of retrieved XCO2 in the three areas as shown in Figure 2.

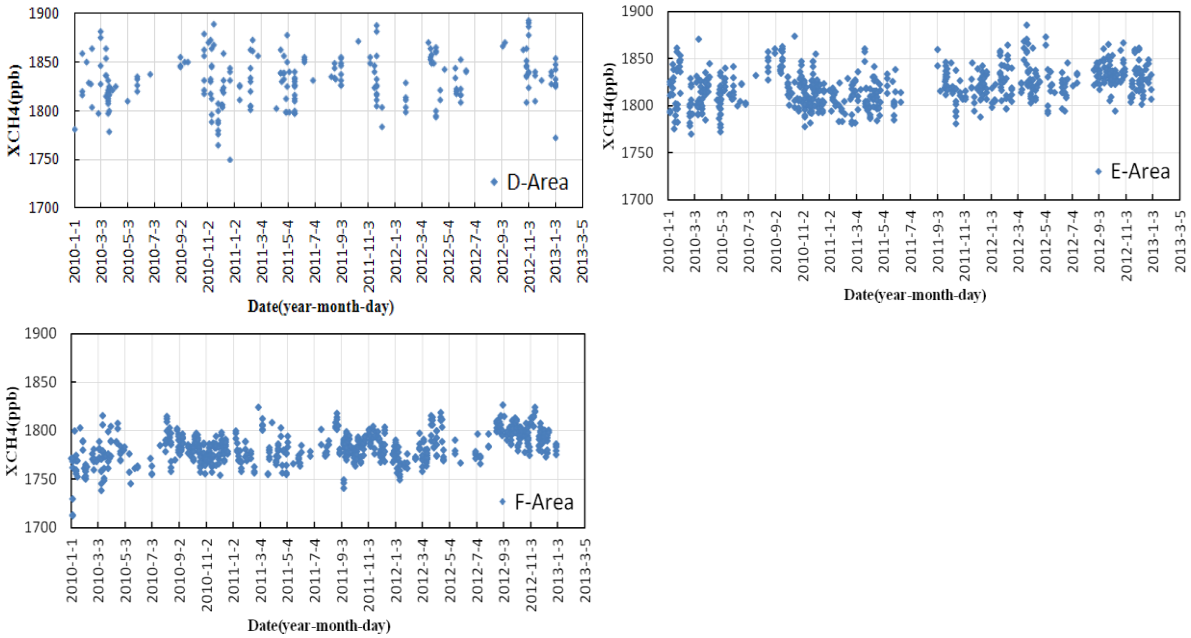


Figure 6. Temporal variations of retrieved XCH4 in the three areas shown in Figure 2.

It can be seen from Figure 5 that XCO2 demonstrates larger concentrations over urban areas than that over grassland and desert, and the amplitude of XCO2 seasonal variation is larger over grassland than that over other areas. It can be found from Figure 6 that XCH4 shows clearly larger values over rice fields than that over desert, which indicate the affection of XCH4 emission from rice fields. XCH4, however, does not show seasonal variation in any area like XCO2.

4. Conclusions

In this paper, we used the GOSAT-L2 data to investigate the spatio-temporal variations of XCO2 and XCH4 over the land area of China from Jan. 2010 to Dec. 2012. The results show that
(1) Both XCO2 and XCH4 tend to increase spatially from the northwestern to the southeastern region, which are responding to the variations of population density from low to high.
(2) XCO2 observed from GOSAT data shows clear seasonal variation, and XCO2 is the highest in spring and the minimum in summer; the peak-to-peak amplitude is 8ppm and the annual mean growth is 2ppm for the whole land area of China. XCH4 shows irregular seasonal variation.
(3) Over the different land-use backgrounds, XCO2 over urban agglomerations is larger concentrations than that over grassland and desert; XCH4 shows lower concentrations over desert than over the Yangtze Delta and Sichuan Basin.

Our results indicate that XCO2 data obtained from GOSAT demonstrate reasonable temporal and spatial variations of atmospheric CO_2 on a regional scale, which implies that GOSAT could be applied in potential to the quantitative monitoring of anthropogenic emissions. However, XCH4 data from GOSAT do not show reasonable seasonal variation, which needs further investigation and verification.

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References

[1] Solomon, S., et al. "Climate change 2007: The physical science basis, contribution of working group 1 to the fourth assessment report of the Intergovernmental Panel on Climate Change." (2007).
[2] Gunter W D, Wong S, Cheel D B. Slowing down of the global accumulation of atmospheric methane during 1980s. Nature, 1992, **358** 313-316.
[3] Hamazaki, Takashi, et al. "Fourier transform spectrometer for greenhouse gases observing satellite (GOSAT)." Fourth International Asia-Pacific Environmental Remote Sensing Symposium 2004: Remote Sensing of the Atmosphere, Ocean, Environment, and Space. International Society for Optics and Photonics, 2005.
[4] Barkley, Michael P., et al. "Assessing the near surface sensitivity of SCIAMACHY atmospheric CO2 retrieved using (FSI) WFM-DOAS." Atmos. Chem. Phys **7** 3597-3619.
[5] Hamazaki, Takashi, Akihiko Kuze, and Kayoko Kondo. "Sensor system for greenhouse gas observing satellite (GOSAT)." Optical Science and Technology, the SPIE 49th Annual Meeting. International Society for Optics and Photonics, 2004.
[6] GOSAT http://www.gosat.nies.go.jp/index_e.htm .
[7] Hamazaki, T., Y. Kaneko, and A. Kuze. "Carbon dioxide monitoring from the GOSAT satellite." Proceedings XXth ISPRS conference, Istanbul, Turkey. **1223**. 2004.
[8] Kuze, Akihiko, et al. "Thermal and near infrared sensor for carbon observation Fourier-transform spectrometer on the Greenhouse Gases Observing Satellite for greenhouse gases monitoring." Applied Optics **48** 6716-6733.
[9] Yoshida, Y., et al. "Retrieval algorithm for CO2 and CH4 column abundances from short-wavelength infrared spectral observations by the Greenhouse Gases Observing Satellite." Meas. Tech **4** 717-734.
[10] Lei, Liping, et al. "A preliminary investigation of CO< inf> 2</inf> and CH< inf> 4</inf> concentration variations with the land use in Northern China by GOSAT." Geoscience and Remote Sensing Symposium (IGARSS), 2010 IEEE International. IEEE, 2010.
[11] World Meteorological Organization. WMO Greenhouse Gas Bulletin，2009.
[12] Zhou, L. X., et al. "Characteristics of atmospheric methane concentration variation at Mt. Waliguan." QJ Appli. Meteorol **9** 385-391.