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Comparison of carbon dioxide volume mixing ratios measured by GOSAT TANSO-FTS and TCCON over two sites in East Asia

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Abstract : The comparison between CO_2 volume mixing ratios observed by GOSAT and TCCON from September 2009 through November 2012 was performed at Tsukuba and Saga, two downwind sites in East Asia. The temporal trends of CO_2 values obtained from GOSAT show good agreement with those observed by TCCON at these two by the TCCON, showing a coefficient of determination (R^2) of 0.65. The regression slop we obtained was 0.92, showing a small bias of GOSAT CO_2 values compared to those observed by TCCON. However, we found the higher correlation in fall and winter than that in spring and summer. The CO_2 volume mixing ratios observ sites. The CO_2 volume mixing ratios observed by GOSAT are also in good agreement with those measured ed by GOSAT are in good agreement with those measured by the TCCON at those two sites in fall and winter, showing a coefficient of determination (R^2) of 0.66 where as the correlation of determination obtained between GOSAT and TCCON was only 0.27 in spring and summer.

Key Words : CO_2 remote sensing, GOSAT, FTS, TCCON

1. Introduction

Increase in global average temperatures since the mid-20th century is very likely due to the increase in anthropogenic Green House Gas (GHG) concentrations. The atmospheric CO_2 is known to be one of the most important greenhouse gases that contribute to the enhanced global warming risk. CO_2 is a naturally produced atmospheric species. However, as well known, fossil fuel combustion and deforestation increase carbon dioxide emission into the atmosphere. More than 30 billion tons of CO_2 is released into the atmosphere due to those human activities. In order to quantify the global CO_2 increase and its emissions into the atmosphere, satellite based measurements have recently been utilized (Osawa *et al*., 1999). In recent years, the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) instrument, which is part of the atmospheric chemistry payload of the European Space Agencies (ESA)

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environmental satellite ENVISAT, was launched in March 2002 in order to observe the various atmospheric constituents including CO_2 (Buchwitz *et al*., 2005). The Greenhouse Gases Observing Satellite (GOSAT) was launched on January 23, 2009, to monitor changes in global atmospheric CO_2 mixing ratios from space (Saitoh *et al*., 2009, Yoshida *et al*., 2011). Although these satellite observations provide large spatial coverage in a relatively short measurement time, for understanding and ensuring the quality of the data obtained from the satellites, they often require validations and calibrations of their products via comparison with more accurate measurements, which can be easily maintained for their quality (Parker *et al*., 2011).

In order to carry out such validations of the CO_2 data obtained from the satellite measurements, the Total Carbon Column Observing Network (TCCON) was recently established. TCCON is a global network of ground-based Fourier Transform Spectrometers (FTS) that record direct solar spectra in the near-infrared for atmospheric CO_2 column measurements. Since ground based in-situ measurements of CO_2 can only provide CO_2 mixing ratio at the surface level, which has limitations in representing total CO_2 column amount as well as understanding changes in upper tropospheric CO_2 and that in stratosphere, ground based FTS is thought to be an essential tool for such validation and calibration of CO_2 column densities observed from the space (Toon *et al*., 2009). The previous study (Cogan *et al*., 2012) found that the average correlation (R = 0.84, Bias = -0.04 ppm) between CO_2 volume mixing ratio values retrieved from GOSAT Thermal And Near-infrared Sensor for carbon Observation-Fourier Transform Spectrometer (TANSO-FTS) and ground-based FTS is good at all TCCON sites. However, although those CO_2 volume mixing ratios obtained from GOSAT measurements have been carried out in East Asia where characteristics of atmospheric gases and aerosols vary largely, the investigation needs to be performed to identify the characteristics of GOSAT CO_2 data against those measured by TCCON at East Asia. In this present study, we validated the CO_2 products of GOSAT TANSO-FTS with those obtained from the ground-based FTS measurements at two sites, Tsukuba and Saga in East Asia. The temporal characteristics of CO_2 volume mixing ratios measured by these two different platforms are also discussed.

2. Measurements

The sites of interest in this present study are Tsukuba (36.05˚N, 140.12˚E) and Saga (33.24 ˚N, 130.29˚E), which are located in Japan, downwind sites from Asian continent. For comparison of CO_2 volume mixing ratios, we used TCCON CO_2 data collected sites from September 2009 through November 2012 at these two and level 2 data products in volume mixing ratios that are generated from Short Wavelength Infra-Red (SWIR) data observed by TANSO-FTS onboard GOSAT. The data versions, that are used in this present study includes ver.02.00, v02.09, v2.10, v2.11, v2.19, v.2.20, v2.21, and v2.29. We obtained the TCCON data from https://tccon-wiki.caltech.edu/Network Policy/Data Protocol. Those ground based FTS has high spectral resolution (0.02 cm^{-1}) and high signal-to-noise ratio (SNR) (Washenfelder *et al*., 2006). There are located over 20 TCCON site around the world (Yang *et al*., 2002).

For the analysis of temporal CO_2 variations, the daily averaged TCCON CO_2 data were employed. For the inter-comparison of GOSAT CO_2 with those measured at Tsukuba and Saga by ground-based FTS, the TCCON data, which were obtained within ± 1˚ of the longitude and latitude where GOSAT CO_2 data were collected, were employed. Additionally, the TCCON data, which were measured within 1 minute before or after the time when GOSAT CO_2 data were observed, were used in order to reduce the errors that can be

caused by possible CO_2 diurnal variations at the sites of interest. When there were more than a single TCCON CO_2 value that satisfies those conditions, the TCCON CO_2 data were averaged for comparison with GOSAT CO_2 data.

3. Results

Fig. 1 shows time series of CO_2 volume mixing ratios measured by TCCON at Tsukuba and Saga and those obtained from GOSAT TANSO-FTS at the same sites. Although it is subject to the further validations, the overall temporal trends of those CO_2 values show good agreement. Due to the lack of either GOSAT or TCCON data, the comparison of temporal CO_2 cycle could be performed only for the year 2012. At Tsukuba in the year 2012, the CO_2 values measured by TCCON range from 386.20 to 397.26 ppmv while those observed from GOSAT range from 380.82 to 402.00 ppmv. At the same year, the CO_2 values measured by TCCON at Saga range from 390.35 to 398.19 ppmv while those observed from GOSAT at Saga range from 391.34 to 401.44 ppmv. The average CO_2 value measured by TCCON was 392.20 ppmv at Tsukuba in 2012 whereas that observed by GOSAT was 394.59 ppmv. The mean CO_2 value measured by TCCON was 394.58 ppmv at Saga in 2012 whereas that observed by GOSAT was 396.13 ppmv.

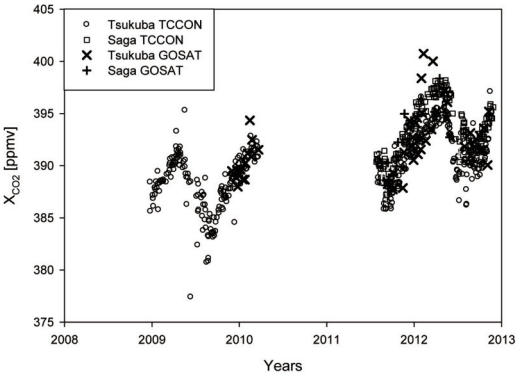

Fig. 1. Time series of CO_2 volume mixing ratios measured by GOSAT and TCCON at Tsukuba and Saga.

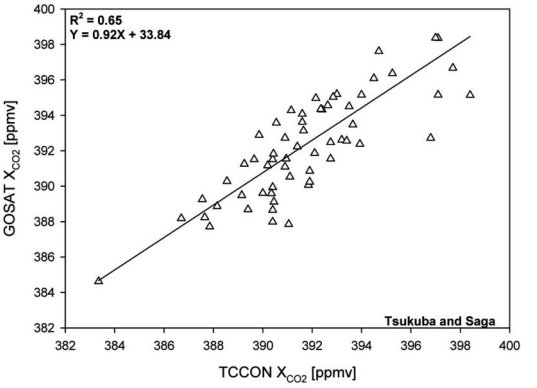

Fig. 2. Correlation between CO_2 volume mixing ratios measured by GOSAT and TCCON at Tsukuba and Saga.

Fig. 2 shows the correlation between CO_2 volume mixing ratios obtained from GOSAT and TCCON at Tsukuba and Saga. The CO_2 volume mixing ratios observed by GOSAT are in good agreement with those measured by the TCCON, yielding a coefficient of determination (R^2) of 0.65 for the measurement period. The regression slop we obtained was 0.92, showing small bias of GOSAT CO_2 values compared to those observed by TCCON at Tsukuba and Saga.

The correlation between CO_2 volume mixing ratios obtained from GOSAT and TCCON at those two sites were further investigated for its seasonal dependency. Fig. 3 shows the seasonal correlation between CO_2 volume mixing ratios measured by GOSAT and TCCON at Tsukuba and Saga. As shown in Fig. 3, we found the higher correlation in fall and winter than that in spring and summer. The CO_2 volume mixing ratios observed by GOSAT are in good agreement with those measured by the TCCON at those two sites in fall and winter, showing a coefficient of determination (R^2) of 0.66 where as the correlation of determination obtained between GOSAT and TCCON was only 0.27 in spring and summer.

As the strong seasonal dependency of the correlation between CO_2 measured by GOSAT and TCCON was observed at these two sites in East Asia, it was important to understand the sources for such seasonal

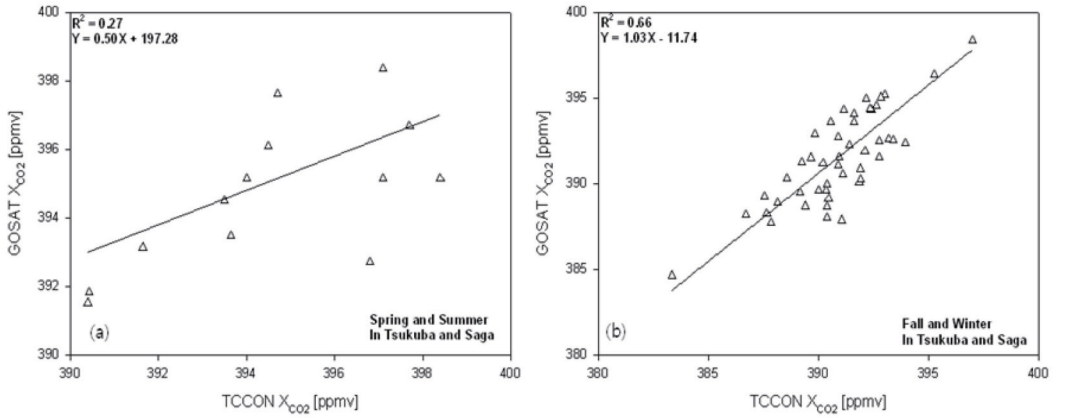

Fig. 3. Seasonal correlation between CO_2 volume mixing ratios measured by GOSAT and TCCON at Tsukuba and Saga.

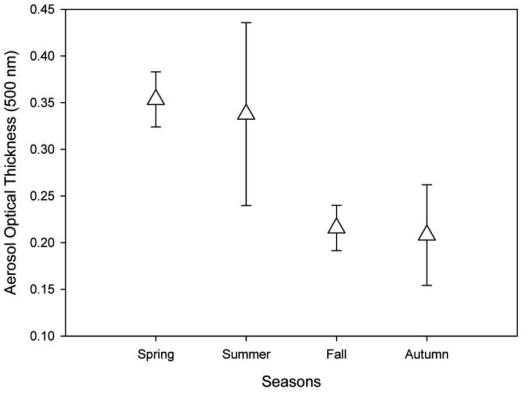

Fig. 4. Seasonal mean Aerosol Optical Thickness (AOT) at 550 nm observed by AERONET at Osaka, located between Tsukuba and Saga.

discrepancy. Since it is known that aerosols are critical sources of uncertainties that increase errors in CO_2 retrieval from GOSAT measurement data, the aerosol loads at these two sites were examined. Aerosol Optical Thickness (AOT) obtained from Aerosol Robotic NETwork (AERONET) level 2.0 data sets were employed to quantify seasonal variations in aerosol loads since availability of the AERONET data is better than that of satellite data in general. In addition, AERONET AOT data is known to be much accurate than the satellite data. However, there was no such aerosol data were available, we used the AERONET data measured at Osaka (34.65˚N, 135.59˚E), which is located between Tsukuba and Saga. It was revealed that mean AOTs were found to be larger in spring and summer than those in fall and winter. The mean AOTs were 0.35 ± 0.03 and 0.34 ± 0.10 in spring and summer, respectively whereas they were 0.22 ± 0.02 and 0.28 ± 0.05 in fall and winter, respectively. When aerosol load was high, the correlation between CO_2 measured by GOSAT and TCCON was smaller. In spring and summer, the long range transport of Asian dust and pollutant plume from Asian continent is thought to contribute to those enhancements in AOTs in spring and summer. Since aerosol are one of the causes for large errors in CO_2 retrieval using GOSAT data, these poor correlation in spring and summer can be associated with those enhanced aerosols in East Asia in these seasons.

4. Summary and Conclusion

The comparison between CO_2 volume mixing ratios observed by GOSAT and TCCON from September 2009 through November 2012 was carried out for Tsukuba and Saga in Japan. The overall temporal trends of those CO_2 values obtained from GOSAT show good agreement with those observed by TCCON. The CO_2 volume mixing ratios observed by GOSAT are also in good agreement with those measured by the TCCON. However, we found the higher correlation in

fall and winter than that in spring and summer. Since aerosol is known to be the largest source of CO_2 retrieval using GOSAT data, the enhanced aerosol load in spring and summer is thought to contribute to the decrease in the correlation between CO_2 measured by GOSAT and TCCON at Tsukuba and Saga. For future studies, the correlation between aerosol load and correlations between CO_2 measured by GOSAT and TCCON needs to be investigated at other sites as well.

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