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Impact of aerosols and cirrus clouds on the GOSAT-observed CO_2 and CH_4 inferred from ground-based lidar, skyradiometer and FTS data at prioritized observation sites

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Abstract

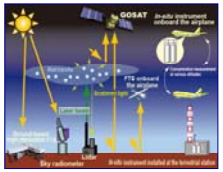
We study the impact of aerosols and cirrus on the Greenhouse gases Observing SATellite (GOSAT) products of the column-averaged dry-air mole fraction of carbon dioxide (XCO_2) and methane (XCH_4) (Ver. 02.xx) using ground-based lidar, skyradiometer, and Fourier Transform Spectrometer (FTS) data at prioritized observation sites of Tsukuba (36.1°N, 140.1°E), Moshiri (44.4°N, 142.3°E), Saga (33.2° N, 130.3° E) and Lauder (45.0°S, 169.7°E).

We focus on the following topics:
◆**Cirrus clouds screening**
◆**Lower tropospheric aerosols**
◆**Stratospheric aerosols**

Introduction

A revised version of the TANSO-FTS SWIR retrieval algorithm (ver. 02.xx) shows much smaller biases and standard deviations (-1.48 ppm and 2.09 ppm for XCO_2 and -5.9 ppb and 12.6 ppb for XCH_4, respectively) than those of the ver. 01.xx. (Yoshida et al., 2013).

To improve the accuracy of the retrieval results:
◆Specify the causes of biases (systematic errors)
◆Assessment of the impact of aerosols and thin cirrus clouds on the GOSAT data are important to improve further the retrieval algorithm.



Schematic illustration of validation experiment

Methods

Dataset and Instrumentations

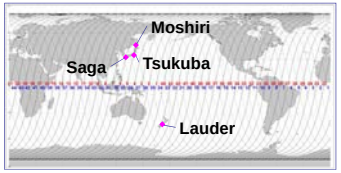
GOSAT: Ver. 02.xx (land only, +/- 0.5 degree latitude / longitude box centered at each TCCON site) (Yoshida et al., 2013)

FTS: TCCON processed by GGG 2012, mean values within +/- 30 min of GOSAT overpass time (Wunch et al., 2011)

Lidar: Rayleigh-Mie polarization sensitive, 532 and 1064 nm (Uchino et al., 2012a,b)

Skyradiometer: POM (Prede Co. Ltd.) 340, 360, 400, 500, 675, 870 and 1020 nm (Uchiyama et al., 2005; Kobayashi et al., 2010)

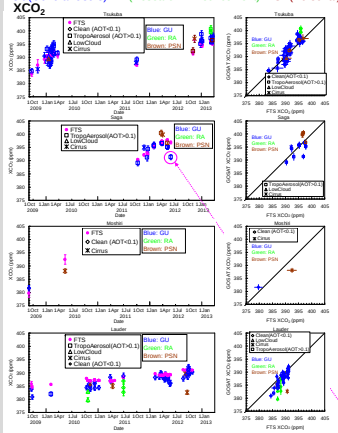
Observation sites

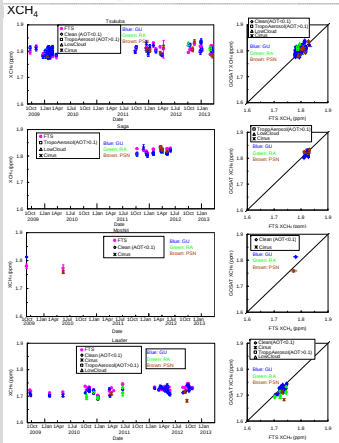


Results

XCO_2 and XCH_4 between GOSAT and FTS

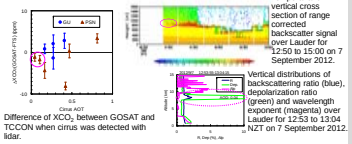
GOSAT screening level:
GU(General Users)>RA(Research Announcement)>PSN(Personal)





Screening works well with a few exceptions.

Cirrus clouds screening

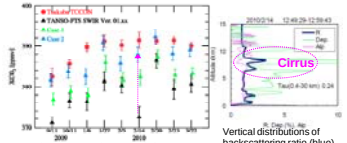


Difference of XCO_2 between GOSAT and TCCON when cirrus was detected with lidar.

Temporal and vertical cross section of range corrected backscatter signal over Lauder for 12:50 to 15:00 on 7 September 2012.

Vertical distributions of backscattering ratio (blue), depolarization ratio (green) and wavelength exponent (magenta) over Lauder for 12:53 to 13:04 NZT on 7 September 2012.

Some data points with good agreement were rejected when cirrus was present. It might be possible to Increase data points by improving screening algorithm.



Comparison of XCO_2 (Ver. 01.xx) data. Case 1 and Case 2 XCO_2 are retrieved using Kurucz's and Toon's solar irradiance data, respectively. Both cases are taking into account the vertical profiles of two types of aerosols and cirrus clouds determined from lidar and sky radiometer.

Vertical distributions of backscattering ratio (blue), depolarization ratio (green) and wavelength exponent (magenta) over Tsukuba for 12:49 to 12:59 JST on 14 February 2010.

Uchino et al., *ACP* (2012a)

Taking the vertical profiles of aerosol and cirrus into retrieval reduces the negative bias of GOSAT data.

Lower tropospheric aerosols

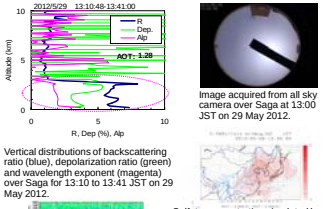


Image acquired from all sky camera over Saga at 13:00 JST on 29 May 2012.

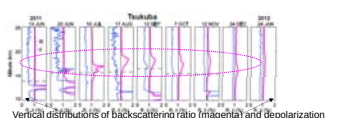
Vertical distributions of backscattering ratio (blue), depolarization ratio (green) and wavelength exponent (magenta) over Saga for 13:10 to 13:41 JST on 29 May 2012.

Range corrected backscatter signal at 1064nm over Saga from 11:00 to 16:00 JST on 29 May 2012.

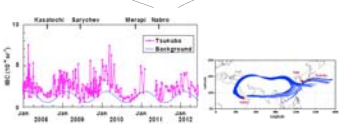
Sulfate concentration simulated by Chemical Weather FORecasting System (Uno et al., JGR 2003). http://www-cfors.nies.go.jp/~cfors/researchIndex-j.html

GOSAT XCO_2 was 5.54 ppm lower than TCCON XCO_2 when high concentration of aerosols was present below 3 km in altitude.
・AOT at 550 nm = 1.33 (Skyradiometer) / 0.32(GOSAT).
・High Alp and low Dep. suggest presence of small and near-spherical particles.
・These particles were transported from the Asian mainland.
・Surface Pressure = 1013.15 hPa (Amedas) / 1010.59 hPa (GOSAT)

Stratospheric aerosols



Vertical distributions of backscattering ratio (magenta) and depolarization ratio (blue) over Tsukuba from 13 Jun 2011 to 24 Jan 2012.

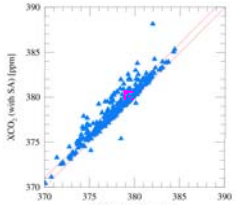


Temporal variation of vertically integrated backscattering coefficient (IBC) over Tsukuba (magenta) from 2008 to 2012. The blue line shows the background values estimated from 1997 to 2001.

10-day isentropic forward trajectories of air parcels initially at an altitude of 17 km over Mt. Nabro.

Uchino et al., *ACP* (2012b)

Increase of stratospheric aerosol by recent volcanic eruptions causes negative bias of 1 ppm in XCO_2 assuming AOT=0.02, Albedo=0.1 (Ota et al., 2008)



Comparison of GOSAT-derived XCO_2 with and without stratospheric aerosol on July 2009. The vertical and horizontal axes are the values with and without stratospheric aerosol (AOT=0.01) in the retrieval.

Neglecting background stratospheric aerosol (AOT=0.01) causes negative bias of 0.5 ppm of XCO_2.

Suggestion for improving retrieval algorithm:
・A priori AOT from OSIRIS & vertical distribution from lidar
・Limit SPRINTARS model data to troposphere

Conclusion

The main findings are as follows:

1) The screening of the GOSAT products by scattering in 2-micron band has eliminated most of the data points when cirrus clouds were detected with the lidar. However, it eliminated some data points showing good agreement with ground-based FTS data when thin cirrus clouds were present, suggesting that number of GOSAT data could be increased by taking thin cirrus clouds into the retrieval algorithm.
2) A large difference was found between GOSAT and ground-based FTS data when dense aerosol layer was present in the atmospheric boundary layer over Saga on May 29, 2012.
3) The stratospheric aerosol increase after 2008 by volcanic eruptions with a Volcanic Explosivity Index (VEI) of 4 has non-negligible impact on the GOSAT products.

Further validation is necessary to improve the quality of GOSAT retrievals.

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