Comparison of GOSAT xCH_4 and airborne measurements over Siberia

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1. Introduction

The radiative forcing of methane (CH_4) is estimated as the second largest, after carbon dioxide (CO_2) [IPCC, AR4, 2007]. Despite the importance of atmospheric CH_4 in global warming, however, the strength of individual sources of CH_4 remains highly uncertain [Dlugokencky et al., 2011].

Western Siberia is known to be the largest wetland area in the world [Kremenetski et al., 2003]. The change in CH_4 emissions from the wetlands in this region under climate change may have a substantial impact on the interannual variations in atmospheric CH_4 on a global scale [Morimoto et al., 2006]. Airborne measurements have been carried out by NIES over Novosibirsk and Surgut in western Siberia since 1993 [Umezawa et al., 2012]. GOSAT was launched in January 2009 to measure the column amount of CH_4 globally. GOSAT products are expected to improve the estimates of the CH_4 budget by inverse analysis. To reduce the uncertainty in estimates of CH_4 budget, the precision of the column-averaged volume-mixing ratios of CH_4 observed by satellite is required to be within 1-2 %, without systematic biases [Meirink et al., 2006]. For this purpose, GOSAT must be validated by higher-precision data obtained independently using ground-based or airborne measurements. The results of a validation of GOSAT xCH_4 (NIES ver02.xx) by comparison with TCCON xCH_4 are reported. GOSAT xCH_4 is biased downward by 6.0 ± 12.5 ppb (0.4 ± 0.7%) [Yoshida et al., 2013]. However, all TCCON sites are located in background regions, and validation of GOSAT data over the source regions has not yet been performed.

The purpose of this study is to confirm the quality of the GOSAT xCH_4 dataset obtained from the SWIR band over the CH_4 source region (western Siberia) by comparing GOSAT SWIR data with airborne measurements.

2. Dataset

Period of analysis: 2009-2011

<GOSAT>

- Products by NIES
- TANSO-FTS, SWIR ver.2

<Airborne measurements over Siberia>

- Conducted by NIES
- Novosibirsk (55N, 83E), Surgut (61N, 73E)
- Altitude: 0.5-7.0 km

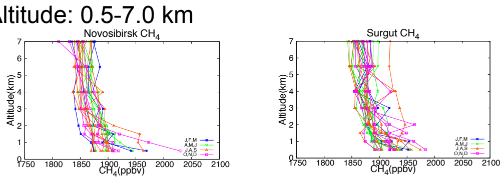

Fig. 1: All profiles observed by the aircraft in 2009-2011

Methane concentration tends to be higher near the ground.

3. Method

We cannot directly compare GOSAT SWIR xCH_4 with CH_4 profiles observed by the aircraft because GOSAT SWIR observes column-averaged dry-air mole fractions (xCH_4). Therefore, we have to convert CH_4 profiles observed by the aircraft into xCH_4 by setting the CH_4 profile at the altitudes where the aircraft does not observe.

<CH_4 profile setting>

<u>0.0~0.5 km (about 950 hPa)</u>

- Methane concentrations below 0.5 km are set to be constant down to the surface.

<u>0.5~7.0 km (about 400 hPa)</u>

- Airborne measurement data

<u>7.0 km~0.1 hPa (about 65 km)</u>

- We use the climatology data of HALOE. This dataset is used by NIES as an *a priori*.

$$xCH_4 = \frac{\text{Total number density of } CH_4}{\text{Total number density of air}}$$

<Meteorological data>

- We use the grid point value (GPV) data that are used by NIES for retrievals.

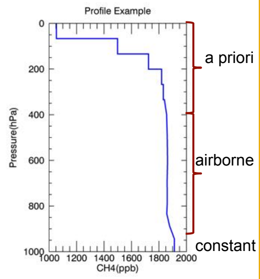

Fig. 2: Example assuming a CH_4 profile from 2010/10/26.

4. Result

$$\text{Diff. (\%)} = \frac{\text{GOSAT } xCH_4 - \text{aircraft } xCH_4}{\text{GOSAT } xCH_4} \times 100$$

The observation method of GOSAT was changed from 5 pointing mode to 3 pointing mode in 2010. After that, GOSAT observed the same (or similar) point three times over a short interval. Therefore, we sometimes obtain three retrieval data at the same (or similar) points.

<Novosibirsk>

The distance between the airborne and GOSAT measurement locations is less than 300 km.

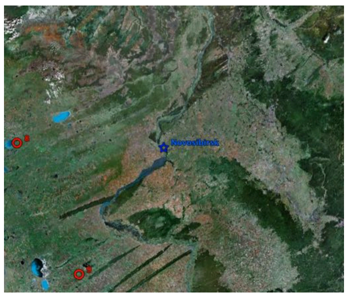

Fig. 3: When the measurement dates match, 'O' indicates the GOSAT locations, and '☆' indicates the airborne measurement locations. The measurement point number of GOSAT is noted as the order of the distance from Novosibirsk.

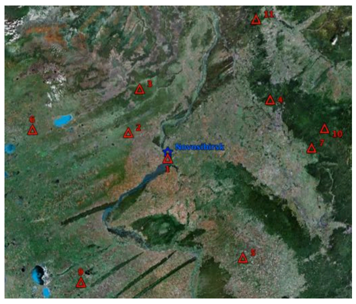

Fig. 4: When the GOSAT measurement date is one day after or one day before the date of airborne measurements, '△' indicates the GOSAT locations and '☆' indicates the airborne measurement location. The measurement point number of GOSAT is noted as the order of the distance from Novosibirsk.

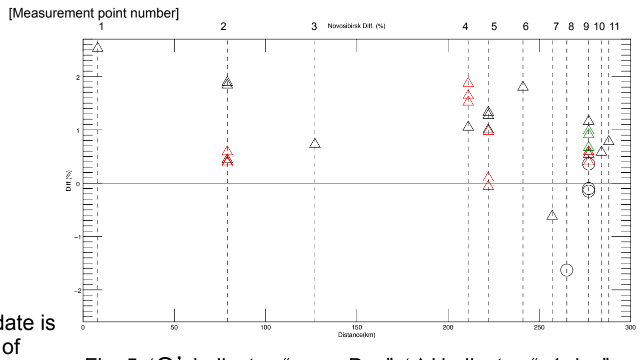

Fig. 5: 'O' indicates "same Day", '△' indicates "±1 day". The point color and number match the list of measurement points in Table 1.

Table 1: The list of the matching data for airborne and GOSAT measurements. The colors and symbols indicated in Table 1 are the same as the data points in Fig. 5.

Measurement point	Aircraft Day yyyy/mm/dd	GOSAT Day Time (UT) yyyy/mm/dd hh/mm/ss
1△	2011/09/28	2011/09/27 08:09:18
2△	2010/08/26	2010/08/27 08:06:42~08:06:51
2△	2011/09/28	2011/09/27 08:09:41~08:09:50
3△	2010/07/26	2010/07/25 08:06:24
4△	2011/09/28	2011/09/29 07:37:19
4△	2011/06/06	2011/06/07 07:37:02~07:37:11
5 △	2011/09/28	2011/09/29 07:37:24~07:37:33
5△	2010/10/26	2010/10/25 07:34:51~07:35:00
6△	2010/07/26	2010/07/25 08:06:51
7△	2010/06/14	2010/06/13 08:06:22
8 ○	2010/06/14	2010/06/14 08:39:06
9 ○	2010/10/26	2010/10/2608:07:49~08:07:58
9 △	2011/09/28	2011/09/27 08:10:22~08:10:32
9△	2010/08/26	2010/08/27 08:07:23~08:07:32
9△	2011/07/08	2011/07/07 08:10:41~08:10:50
10△	2010/06/14	2010/06/15 07:33:56
11△	2010/07/26	2010/07/25 08:05:57

<Surgut>

The distance between the airborne and GOSAT measurement locations is less than 300 km.

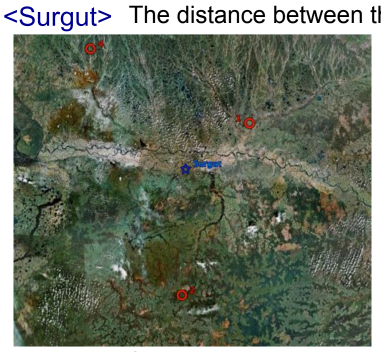

Fig. 6: Same as in Fig. 3

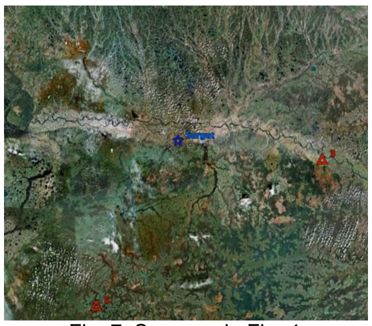

Fig. 7: Same as in Fig. 4

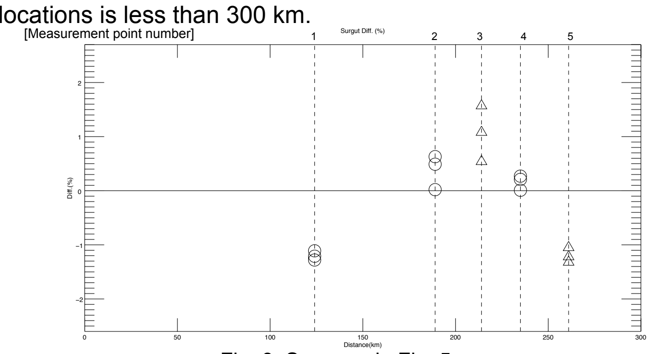

Fig. 8: Same as in Fig. 5

Table 2: Same as in Table1

Measurement point	Aircraft Day yyyy/mm/dd	GOSAT Day Time (UT) yyyy/mm/dd hh/mm/ss
1 ○	2011/05/26	2011/05/26 09:12:59~09:13:08
2 ○	2011/05/26	2011/05/26 09:13:13~09:13:22
3△	2011/09/23	2011/09/22 08:40:55~08:41:04
4 ○	2011/05/26	2011/05/26 09:12:45~09:12:54
5△	2011/05/26	2011/05/25 08:41:00~08:41:10

Table 3: Relative difference

Diff. (%)	Same day	±1 day
Novosibirsk	-0.9 ± 1.1 (%)	0.9 ± 0.8 (%)
Surgut	-0.2 ± 0.9(%)	-0.3 ± 1.2(%)

- The Diff. (%) value is small (<1%) enough to assure high-quality GOSAT products. However, the standard deviation of Diff. (%) values is not negligible (~1%).
- The three retrieval data obtained at the same (or similar) target points have significant variability.

5. Summary

We compared GOSAT data with airborne measurement data over west Siberia to confirm the quality of the GOSAT xCH_4 dataset obtained from the SWIR band over Siberia (Novosibirsk, Surgut). To compare GOSAT xCH_4 with the CH_4 profiles observed by aircraft, we set the distribution of CH_4 concentrations at the altitudes where the aircraft did not observe. The xCH_4 values corresponding to the aircraft measurements were then calculated. We used climatology data from the HALOE satellite to set the distribution of CH_4 concentrations in the stratosphere. The GPV dataset was used to calculate the air density and the dry air column.

The Diff. (%) values between the GOSAT and airborne measurements shown in Table 3 are smaller than the difference reported by validation with TCCON [Yoshida et al., 2013]. Therefore, the presented results demonstrate that the GOSAT SWIR dataset had enough reliability to be used for inverse analysis of the CH_4 budget over Siberia. When the gap between the dates of GOSAT and the airborne measurements is one day, Diff. (%) is larger than for the comparison on the same day. The Diff. (%) values seem to depend on the measurement time rather than the distance.

<Uncertainty factors>

- Climatology data of HALOE in the stratosphere
- Heterogeneity of land cover
- Suitability of the distance (300 km)
- Meteorological data to determine air and column density

<Future topics>

- We will compare the TIR (vertical profile) with airborne measurements and SWIR data.
- Meteorological Data
  Temperature profile: GPV → GPS

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