CO$_2$ and CH$_4$ concentrations in the middle and upper troposphere from GOSAT/TANSO-FTS TIR

N. Saitoh$^1$, R. Imasu$^2$, K. Shiomi$^3$, Y. Nasu$^4$, M. Touno$^4$, S. Hayashida$^4$

$^1$CEReS, Chiba Univ.; $^2$AORI, Univ. Tokyo; $^3$EORC/JAXA; $^4$Nara Women’s Univ.
Outline

1. Retrieval method

2. Results for CO$_2$

3. Results for CH$_4$

4. Validation of CH$_4$ profiles using CONTRAIL (aircraft) data and comparison with AIRS retrieval
Greenhouse Gases Observing Satellite; GOSAT

Target: column amounts (SWIR) and profiles (TIR) of CO₂ and CH₄

Obs.: 56,000 ground points / 3 days

FOV: 10.5 km (diameter)

Period: 5 years scheduled

Sensors:
- Thermal and Near Infrared Sensor for Carbon Observation (TANSO)-FTS
- TANSO-Cloud and Aerosol Imager (CAI)

TANSO-FTS:
- SWIR (Band 1: 0.75-0.78 μm, Band 2: 1.56-1.72 μm, Band 3: 1.92-2.08 μm)
- TIR (Band 4: 5.5-14.3 μm, 0.2 cm⁻¹)

http://www.gosat.nies.go.jp/

Launched on 23 January, 2009

Five cross track patterns of GOSAT observation.
Retrieval grid setting

\[
AK = (K^T S^{-1}_\xi K + S_a^{-1})^{-1} K^T S^{-1}_\xi K
\]

\[
\hat{x} = (I - A)x_a + Ax' + G \epsilon
\]

\[
G = S_a K^T (KS_a K^T + S_\epsilon)^{-1}
\]

AK area = How much of retrievals comes from measurements.

[Rodgers, 2000]

Full grid layers merged until sum of AK areas exceeds 1.

Channel selection

- Retrieval channels are selected on the basis of CO₂ and CH₄ information content.
- Channels with large “bias”, judging from the differences between observed and forward radiances, are excluded even if they have much information.

See Saitoh et al., JGR, 2009 for more details
GOSAT/TANSO-FTS TIR L2 data status

- GOSAT/TANSO-FTS TIR L2 data have been processed operationally at NIES.
- Since May 16th 2011, TIR L2 data of CO₂ and CH₄ profiles have been released to GOSAT RA researchers.
- In a short time, the TIR L2 data will be open to the public.

- In the daytime data processing, TANSO-CAI L2 cloud flag information is used for the assessment of cloudiness.
- In the nighttime data processing, information on cloudiness is derived from the TIR spectra themselves.
TIR CO$_2$ concentrations (day & night)

April 2010, 700 hPa

Low CO$_2$ bias seen in over land, especially over the Sahara.

reasonable latitudinal gradients

April 2010, 500 hPa

April 2010, 300 hPa

High CO$_2$ bias seen in the tropics.

April 2010, 100 hPa

Courtesy to NIES/GOSAT DHF
TIR L2 CO$_2$ data summary

- TIR L2 CO$_2$ distributions show reasonable latitudinal gradients.

- In the tropics, TIR L2 CO$_2$ data have high biases. “High CO$_2$ orbits” are occasionally seen in the daytime data. There is few data in the tropics in the nighttime data.
  - The fewer number of nighttime data is attributable to the determination of cloud based on the TIR spectra?

- CO$_2$ data over the Sahara have low biases. This is probably due to the uncertainties in the determination of surface temperature and surface emissivity.
TIR CH$_4$ concentrations (day & night)

April 2010, 700 hPa

Slightly low CH$_4$ bias seen over the Sahara.

April 2010, 500 hPa

Low CH$_4$ values originated from stratospheric air in high latitudes.

April 2010, 300 hPa

Reasonable latitudinal gradients

April 2010, 100 hPa

Courtesy to NIES/GOSAT DHF
TIR L2 CH$_4$ data validation

**CONTRAIL** (Comprehensive Observation Network for Trace gases by Air Liner): See Matsueda et al., [2008] for CONTRAIL project.
- CH$_4$ data obtained with ASE (Automatic air Sampling Equipment) on the flight between Japan and Guam once a month from April 2009 to March 2010.
- CH$_4$ data obtained on April 21$^{th}$, June 9$^{th}$, and March 15$^{th}$ were used for comparison.

**AIRS** (Atmospheric Infrared Sounder):
- AIRS L2 CH$_4$ products (version 5.2), except data with “QF = 2”.
- Comparison criteria:
  - Measurement locations < 50 km; under the criterion, their measurement time differences were almost within 1.5 hour.
- 7 pressure levels (794, 525, 407, 307, 206, 79.9, 3.68 hPa)
  Averaging kernel matrices of AIRS and GOSAT were not considered. Just compared at the nearest pressure levels.
CH$_4$ data obtained during descent are regarded as a “single CH$_4$ profile”. 

April 21$^{th}$, 2009
CONTRAIL CH$_4$ vs. TIR L2 CH$_4$

CONTRAIL CH$_4$ profiles directly compared with TIR L2 CH$_4$ profiles by applying TIR averaging kernel (AK).

$$X_{\text{obs-expected}} = X_a + A \left( X_{\text{CONTRAIL}} - X_a \right)$$

Here, $X_a$ is a priori vector used in TIR CH$_4$ retrieval, CH$_4$ profile from the NIES transport model [Maksyutov et al., 2008]. $A$ is a AK matrix.

April 21$^{\text{th}}$, 2009
7 profiles comparison
CONTRAIL CH$_4$ vs. TIR L2 CH$_4$

June 9$^{th}$, 2009
3 profiles comparison

March 15$^{th}$, 2010
5 profiles comparison

Averaged TIR CH$_4$ profiles show better agreements with CONTRAIL CH$_4$ data than the a priori.
AIRS CH$_4$ vs. GOSAT L2 CH$_4$ (April)

~780 hPa

LAND

SEA

~410 hPa

LAND

SEA

a priori (NIES TM)
AIRS CH$_4$ vs. GOSAT L2 CH$_4$ (August)

~780 hPa

AIRS
GOSAT

a priori (NIES TM)

~410 hPa

LAND
SEA
AIRS CH$_4$ vs. GOSAT L2 CH$_4$ in UT

April, ~210 hPa

AIRS
GOSAT
a priori (NIES TM)

August, ~210 hPa

LAND
SEA
GOSAT-AIRS Comparison

(CCSR-L1B(type2-nb_-1.3) ← AIRS Ver.5): 680-820 cm$^{-1}$

Mean rad. in $\Delta v=20$ cm$^{-1}$

2009.4.7 (night) [680-820 (dv=20) cm$^{-1}$] (ang.diff.<45 degree)
TIR L2 CH$_4$ data summary

- TIR L2 CH$_4$ distributions show reasonable latitudinal gradients.
- TIR L2 CH$_4$ data have some characteristics similar to L2 CO$_2$ data: “occasional high concentration orbits” in the tropics, slightly low bias over the Sahara, and the fewer number of nighttime data.

Comparison with CONTRAIL:
- Although the range of the variability in each TIR CH$_4$ profile is large, the averaged CH$_4$ profiles show better agreements with CONTRAIL CH$_4$ data than the a priori CH$_4$.

Comparison with AIRS:
- About 70% of coincident GOSAT/TIR and AIRS CH$_4$ data agree to each other within ±2% at 780 hPa.
- GOSAT/TIR CH$_4$ data have high biases against AIRS CH$_4$ data in mid-troposphere.