# RETRIEVAL ALGORITHM OF $CO_2$ COLUMN DENSITY BY USING SIMULATION DATA OF THE 'GOSAT' SWIR FTS UNDER THE CIRRUS-EXISTING CONDITION

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## ABSTRACT

Greenhouse gases Observing SATellite (GOSAT) of Japan is planned to be launched in 2008. GOSAT will be equipped with a FTS to monitor $CO_2$ column density globally. The FTS has three near infrared bands which cover 0.76 µm, 1.6 µm, and 2.0 µm spectral regions, respectively. Retrieval algorithms to estimate $CO_2$ and $CH_4$ column densities from these bands data are now being developed. We have investigated retrieval algorithms under the non-clear sky conditions. As one of these cases, a cirrus cloud parameter estimation was researched. The cirrus vertical profile (i.e., existing height) is estimated from the 0.76 µm band data. Strong water vapor absorption area is included in the 2.0 µm spectral band, so that the reflected radiance from a ground surface is absorbed completely by $H_2O$ in this area. Thus the signal in this area is considered as path radiance caused by the cirrus clouds reflection, because there is little water vapor above the cirrus cloud top. By using this signal, the cirrus optical depth can be estimated, and then column densities of $CO_2$, $CH_4$ and $H_2O$ are retrieved precisely.

## A STEPWISE ESTIMATION METHOD UNDER THE CIRUUS-EXISTING CONDITION

Spectral regions of the GOSAT FTS measurements cover 1.6 µm and 2.0 µm bands to monitor $CO_2$, $CH_4$, and $H_2O$ [*Hamazaki et al.*, 2004]. An oxygen *A*-band in the 0.76 µm region was also measured to monitor air mass and to identify cloud effects. It was confirmed that the retrieval error of column density from the observation data taken under the clear sky condition is much less than 1% [*Yokota et al.*, 2004]. The major error sources of this spectral region are clouds (cirrus) and aerosols at that time (see Fig.1). According to our simulation, removal of aerosol effects on $CO_2$ column density estimation is difficult because aerosols exist at lower atmosphere in the planetary boundary layer, and the effects of the aerosols are very similar to the variation of the ground surface reflection (albedo). Therefore, to distinguish them from the observed spectral data is difficult.

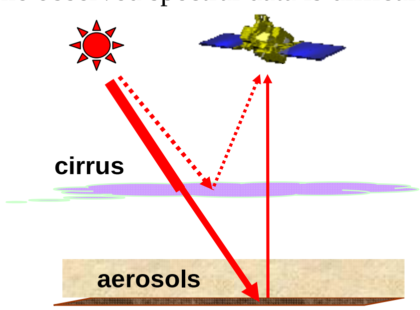


Fig. 1. Nadir-looking satellite measurement for detection of column density of Green-house gases ($CO_2$, $CH_4$) with the short-wavelength infrared sensor under cirrus/ aerosol conditions.

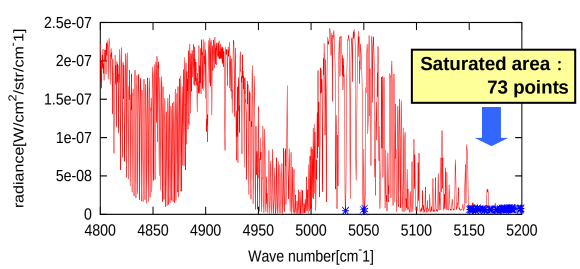


Fig. 2. Radiance spectra of 2.0 µm band. The saturated area of $H_2O$, seen at the right-hand side of this figure, is used for cirrus estimation.

We developed a stepwise estimation method to correct cirrus effects on $CO_2$ column density retrieval. The outline of the methods is:

- Step 1: The cirrus optical thickness ($\tau$) estimation from $H_2O$ saturated spectral region of the 2.0 µm band (see Fig. 2).
- Step 2: The estimation of cloud height distribution (h) and ground surface albedo ($\alpha$) from 0.76 µm band with a constraint of non-negative value of $\alpha$.

- Step 3: Simultaneous retrieval of column densities of the three gases ($CO_2$, $CH_4$, and $H_2O$), cirrus optical thickness ($\tau$'), and ground surface albedo ($\alpha$') from 1.6 μm and 2.0 μm bands.

## NUMERICAL SIMULATION CONDITIONS

This method was tested by the simulation. Input parameters (initial values) for the simulation are: $CO_2$, $CH_4$ and $H_2O$ profiles, cirrus cloud height, optical depth of cirrus cloud, surface albedo, temperature and pressure profiles. The radiance spectra are calculated by using them. In the spectrum calculation, a radiative transfer calculation code HSTAR, based on RSTAR code developed by T. Nakajima's group at CCSR of Univ. of Tokyo, is utilized. The HSTAR simulates total radiance with high spectral resolution by line-by-line calculation including Rayleigh scattering, the path-radiance, and the multiple-scattering effects caused by aerosols and clouds. The HITRAN 2000 line parameter database is used for calculating gas cross-sections. Other conditions for the simulation are shown in Table1.

**Table 1.** Conditions of the numerical simulation

| Items | Conditions |
|---|---|
| Measurement geometry | Solar zenith angle: 30º, scan angle: 0º, azimuth: 0º（scatt. angle: 30º） |
| Calculation step | 0.01 [$cm^{-1}$] |
| Spectral resolution and signal to noise ratio (SNR) of the FTS | 0.76 μm band: resolution = 0.5 [$cm^{-1}$], SNR=600<br>1.6 μm band: resolution = 0.2 [$cm^{-1}$], SNR=300<br>2.0 μm band: resolution = 0.2 [$cm^{-1}$], SNR=300 |
| Atmospheric model | US Standard, ($CO_2$: 380 [ppmv] constant) |
| Ground surface albedo | Initial: 0.3, True: 0.2 (assumed to be constant for all bands) |
| Cirrus cloud | Initial: 10-11 km, True: 7-8 km, Optical thickness: $\tau$ = 0.2 @0.55 μm |
| Retrieval trials | 12 times |

## SIMULATION RESULTS

AS a result of numerical simulations and in case of cirrus clouds with an optical thickness t of 0.2 exist at the altitude of 7 - 8 km, $CO_2$ column density was retrieved within 0.2 % error by the stepwise estimation even when the cirrus initial height was estimated to be 3 km incorrectly (Table 2). Therefore, it was confirmed that the stepwise method will be useful for the cirrus contaminated measurement condition under a simple assumption of a constant ground surface albedo among the three bands. More complex cases are now under study.

**Table 2.** An Example of the Estimation Error (%) of the Step 3 result
(This is a case that the initial guess of the cirrus height was misestimated 3 km higher.)

| Parameter | mean | S.D. | Min. | Max. | Total |
|---|---|---|---|---|---|
| $CO_2$ column | 0.14 | 0.14 | -0.05 | 0.40 | 0.20 |
| $CH_4$ column | -0.21 | 0.10 | -0.41 | -0.06 | 0.23 |
| $H_2O$ column | -0.26 | 0.24 | -0.60 | 0.11 | 0.35 |
| Opt. thick. $\tau$ | -0.96 | 0.35 | -1.48 | 1.18 | 1.02 |
| S. albedo $\alpha$ | 0.01 | 0.01 | -0.01 | 0.03 | 0.01 |

## REFERENCES

Hamazaki, T., A. Kuze, and K. Kondo (2004), Mission Sensor System for Greenhouse Gas Observing Satellite (GOSAT), *SPIE* 5543, 275-282.

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