Objective and about GOSAT

Greenhouse gases observation Satelllite (GOSAT) was launched in 2009 and has been operating normally. However, the areas where the greenhouse gases can be retrieved are still limited especially in high and middle latitudes. That is mainly because Cloud and Aerosol Imager (CAI) onboard GOSAT, which is used for cloud screening, covers only reflected sunlight ranged from ultraviolet to near infrared, and has relatively low sensitivity to optically thin clouds such as cirrus clouds. On the other hand, Thermal And Near infrared Sensor for carbon Observation – Fourier Transform Spectrometer (TANSO-FTS) which is the main sensor of GOSAT has a thermal infrared band and expected to have ability to detect optically thin clouds. However, the cloud detection in high latitudes is not easy even thermal infrared band data are combined to CAI images because of lower surface and atmospheric temperature in this region. Furthermore, the situation is more complicated if the polar stratospheric clouds (PSCs), whose optical thickness is thinner than cirrus clouds, exist in the lower atmosphere. In this study, we improvised cirrus detection method using thermal infrared spectra and tried to detect clouds globally involving high latitude winter.

CO2 slicing method

Usage of spectral pseudo channels

In this study, CO2 slicing method which was developed for cirrus detection was applied. The equation of this method is written as

\[ r^c - r^b = \sum_{j=1}^{c} \left( u_j \ln \left( \frac{b_j}{R} \right) \right) \]

where \( R \) is the observed radiance by the sensor, \( B \) is the calculated radiance for clear sky, \( r \) is function which is assumed to be a line-by-line radiative transfer code, LBLRTM (Clough et al., 2005), was used. According to this formula, \( r \) is determined so that as difference between left hand and right hand is minimum.

It is reported from the GOSAT project office that wavelength position of each spectral channel of TANSO-FTS slightly fluctuate because of instability of sampling laser, which causes random shifting of weighting function peak of each spectral channel. In order to increase the robustness against this effect, we use the spectral pseudo channels which consist of real channels having weighting function peaks in the same height range. The pseudo channels were set for each 0.5 km height range of weighting function peak as shown in Figure 5. Most of pseudo channels were consisted of 5 through 50 real channels depending on atmospheric condition in a spectral range from 700 to 750 cm⁻¹.

Channel optimization

Once the pseudo channels were set, the optimal combination of them was determined based on simulation studies using a multi-scattering radiative transfer code, Polarization Radiance System for Transfer of Atmospheric Radiation (PuRa). This optimization was carried out for various latitudinal zone and temperature profile patterns based on the meteorological analysis data provided from meteorological agency (JMA-GPV). The classification was made according to temperature range at 500Pa height level. For each profile, the clouds were assumed with changing optical thickness and cloud top height (CTH) by following in PuRa calculations and investigated the accuracy with each channel combination.

- Latitudinal zone and temperature profile patterns classified:
  - Magnetic pole: north, south, middle
  - Temperature profiles: each 5K bins between min. - max. for each latitudinal zone
  - Cloud parameters changed in the simulations:
    - Optical thickness: 0.1-5.0
    - Cloud top height (CTH): 1-3km (low altitude), 3-12km (middle altitude), 3-12km (high altitude winter)

Figure 6 shows an example of the accuracy of CTH detection defined as the standard deviation of retrieval error for each pseudo channel combination. This figure was made for all temperature profile patterns, and the optimal channel combinations were determined so as to have minimum standard deviation of retrieval error.

Results

Antarctic (PSCs)

The slicing method algorithm was applied to the analysis of GOSAT data observed in August 19-21, 2010. Retrieved CTH distribution was compared with that from Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) (Winker et al., 2003) observations as shown in Figure 6. In this figure, high level clouds, which can be recognized as PSCs, retrieved from both of data particularly over an area 0-40 W and 70-90 S affected to gravity waves.

Figure 10 is latitude-altitude distribution of retrieved CTH. There are tendency that CTH goes down with latitude in most of height levels as expected. However, some unrealistic feature can be seen around 1Km level in low latitudes showing an uniform level of cloud top. This height is nearly equal to inflection point of temperature profiles, and the strange feature may be caused by unrealistic setting of the surface temperature, but it is still under investigation.

Figure 11 is comparison between cloud top temperature estimated with slicing method and single channel cloud screening described in the first section. On this scatter map, various types of cloud are identified according to the temperature ranges for both methods (SL: slicing, SC: single channel) as follows:

- Clouds: SL ~190-300K, SC ~180-250K

- PSCs: SL ~180-195K, SC ~200-250K


Figure 12 shows latitude-altitude distribution of retrieved CTH. In this figure, low clouds which is detected by slicing method is fairly similar to that from CALIPSO except an longitudinal region in 90W - 0W. When high level clouds or PSCs exist, lower clouds were generally not detected because the slicing method has sensitivity only to the first layer of cloud. On the other hand, CALIPSO can detect lower clouds if the upper level clouds is not so thick.

Figure 13 is comparison between cloud top temperature retrieved with the slicing method and single channel cloud screening.

Summary

- Key technology of this study is that Slicing method was modified for usage of spectral pseudo channels and channel optimization.
- High clouds recomposed as PSCs were detected by this algorithm.
- The area of PSCs were retrieved almost coincident with that by CALIPSO but there were some differences with height.

Reference