The CO_2 slicing algorithm for the TIR cloud/aerosol products of TANSO-FTS2/GOSAT2

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Introduction

Greenhouse gases Observing SATellite 2 (GOSAT-2) is scheduled to be launched in 2018. Although the level 2 products of cloud or aerosol from the thermal infrared (TIR) band (Band 4) of TANSO-FTS/ GOSAT have not been provided, those from TANSO-FTS2/GOSAT2 are planned to be provided. The advantages of TIR band are mainly the abilities to have sensitivity for altitudes and to operate even during nighttime. The accuracy improvements of cloud or aerosol screening with TIR data has large impacts to the TIR gas retrievals during nighttime and also helps to those under cloudy sky conditions. This presentation describes the algorithm for TIR cloud/aerosol level 2 products based on the CO_2 slicing technique to obtain their top heights and effective amounts. In addition, the algorithm was applied to TANSO-FTS/GOSAT data and results were compared CALIPSO observations.

Algorithm description

CO_2 slicing method

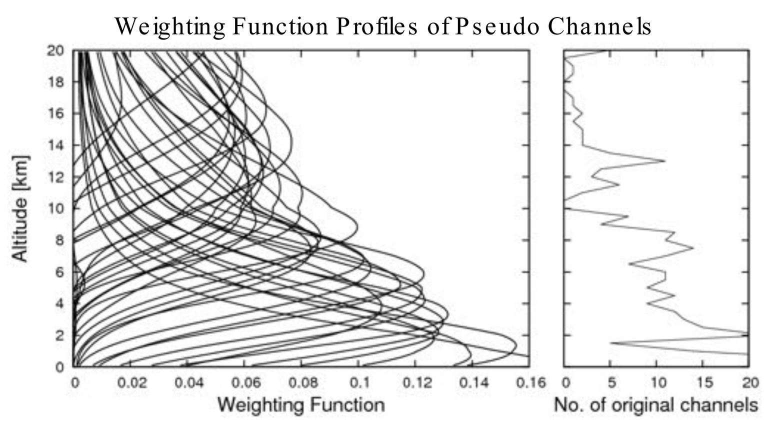
The CO_2 slicing method (Chahine, 1974) was improved for hyperspectral data. This technique was developed for optically thin cloud observation utilizing the difference of CO_2 absorption strength among two channels near 15 µm. The concept of this technique is shown as the following equation.

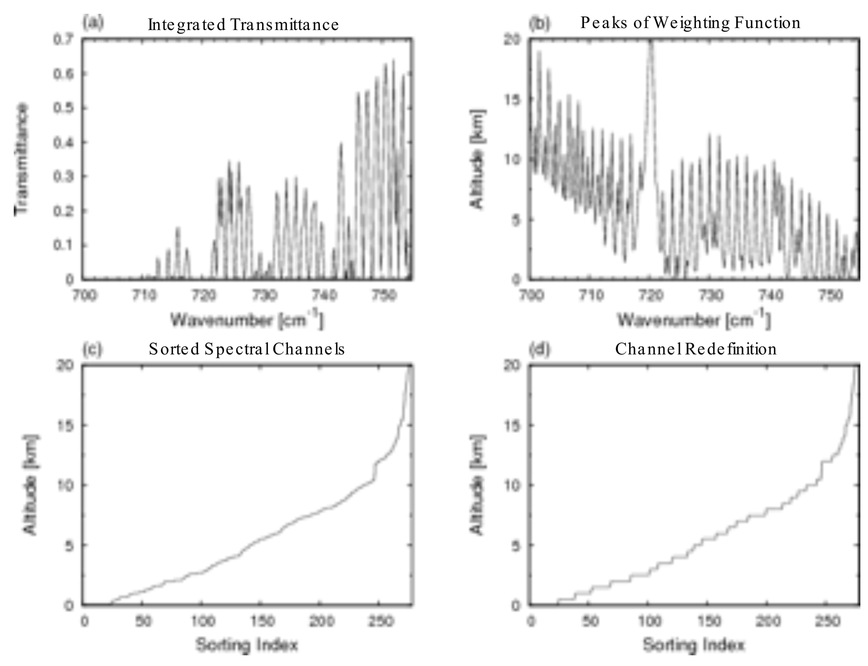
$$\frac{R_{\lambda_1} - R_{\lambda_1}^{clear}}{R_{\lambda_2} - R_{\lambda_2}^{clear}} = \frac{\alpha_1 \epsilon_{\lambda_1} \int_{p_s}^{p_c} T_{\lambda_1}(p) dB_{\lambda_1}}{\alpha_2 \epsilon_{\lambda_2} \int_{p_s}^{p_c} T_{\lambda_2}(p) dB_{\lambda_2}}$$

Cloud top height (CTH) and effective cloud amount (ECA) ca be estimated from this technique. The improvement of the method consists two phases, channel reconstruction and channel optimization (Someya et al., 2016).

Channel reconstruction

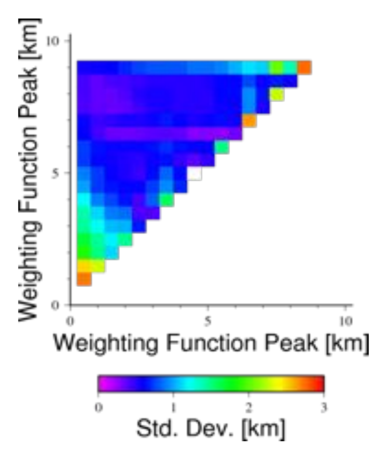
The weighting function ($W = dT/dz$) profiles at each original channel were calculated and the sets of the channels which are most sensitive in the same height range are redefined as "Pseudo channel". The spectral range of 700-750 cm[-1] was used for high and middle level cloud detection and 740-755 cm[-1] was for low clouds.



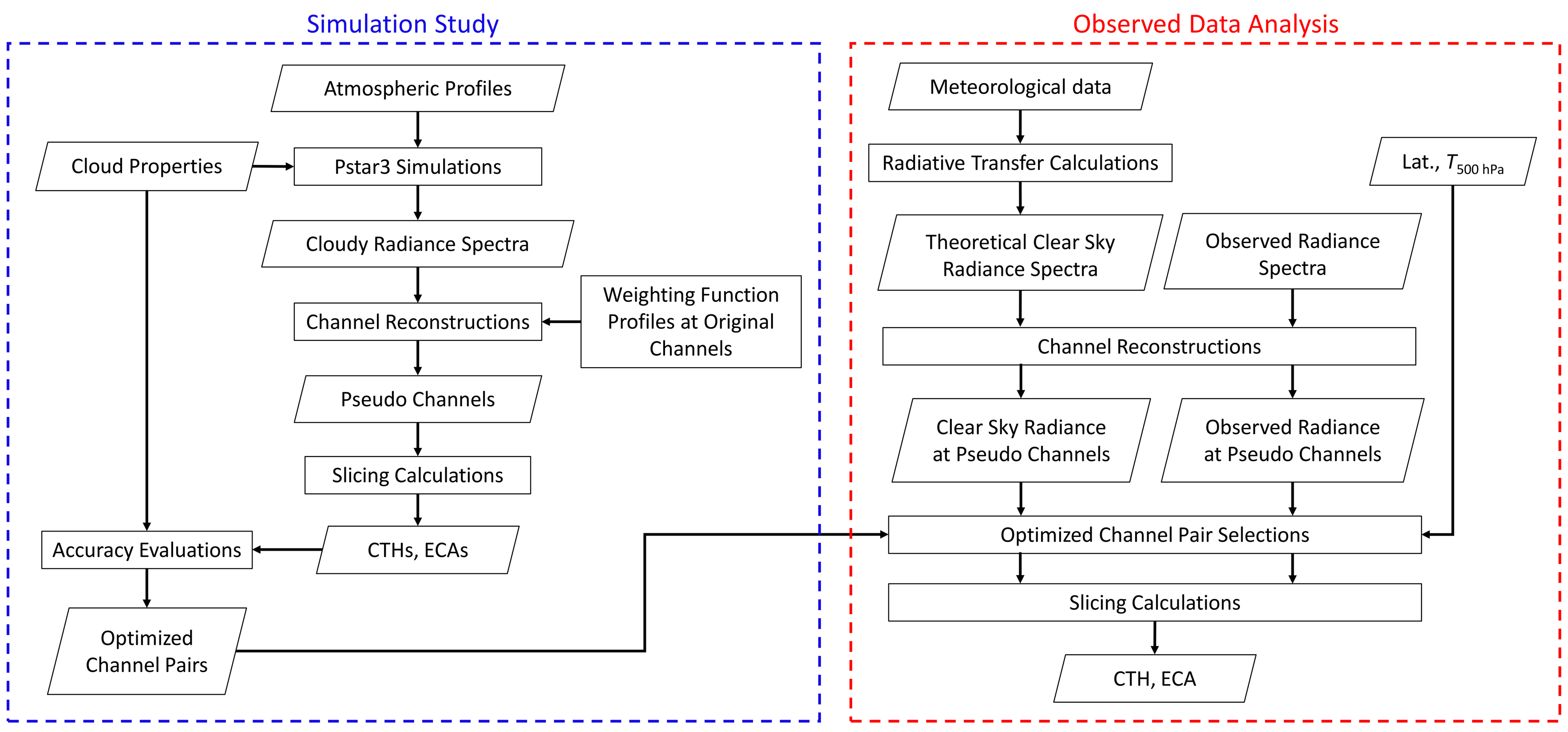


Channel optimization

The accuracy of the slicing algorithm with each pair of the pseudo channels were investigated from the simulation studies. Cloudy radiances were calculated with the radiative transfer code, Pstar3 for typical atmospheric profiles of each 5 K at 500 hPa and latitudes (low, middle, and high in each hemisphere). For each situations, the most accurate pairs of pseudo-channels for high, middle, and low clouds were selected as the optimized channels.

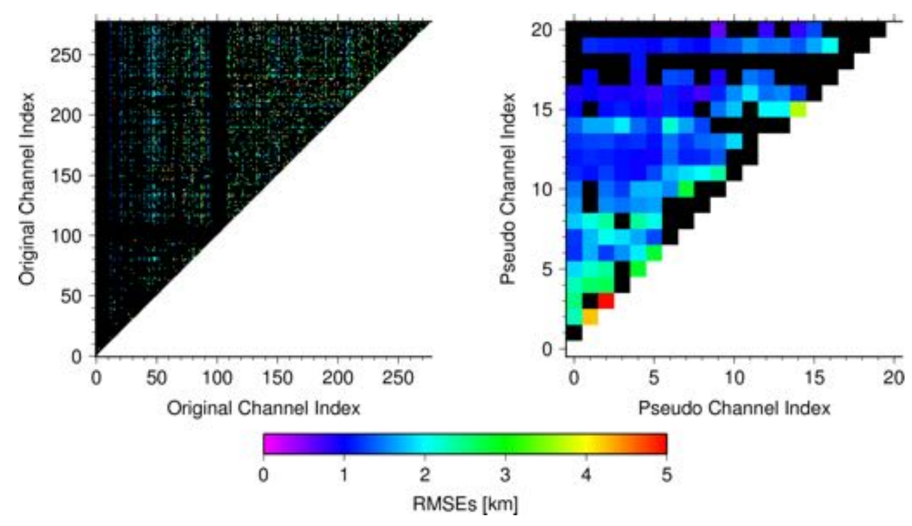


Calculation Flow



Impact of modification

Channel reconstruction is effective to reduce random noises. The right figure shows example of detection accuracy of the slicing algorithm using original channels (left panel) and pseudo channels (right panel) for the several simulated cloudy sky spectra with random noises of 0.5 K in maximum for each original channel. The grids are filled in black if CTH was not appropriately detected by any of analysis. If the original channels are used, many of grids are filled in black or detection errors are large. On the other hand, use of pseudo channels shows that influences of random noises are not so apparent with many of channel pairs. However, the influence of the systematic biases on the spectra can not be reduced by this modification.



Application to GOSAT data

The algorithm was applied to TANSO-FTS/GOSAT data and results were compared to those from CALIPSO. Only the uppermost cloud data of CALIPSO were used. The characteristics of the results compared to CALIPSO are listed as below.

- The spatial distributions and seasonal variations are generally well agreed
- Cloud amounts are overestimated over the lands
- CTHs are estimated as lower level especially in the Tropics

Data and period

GOSAT: TANSO-FTS Level 1B V150.151 (Jan. – Dec. 2010)

CALIPSO: Lidar Level2 5km Cloud Layer products (Jan. – Dec. 2010)

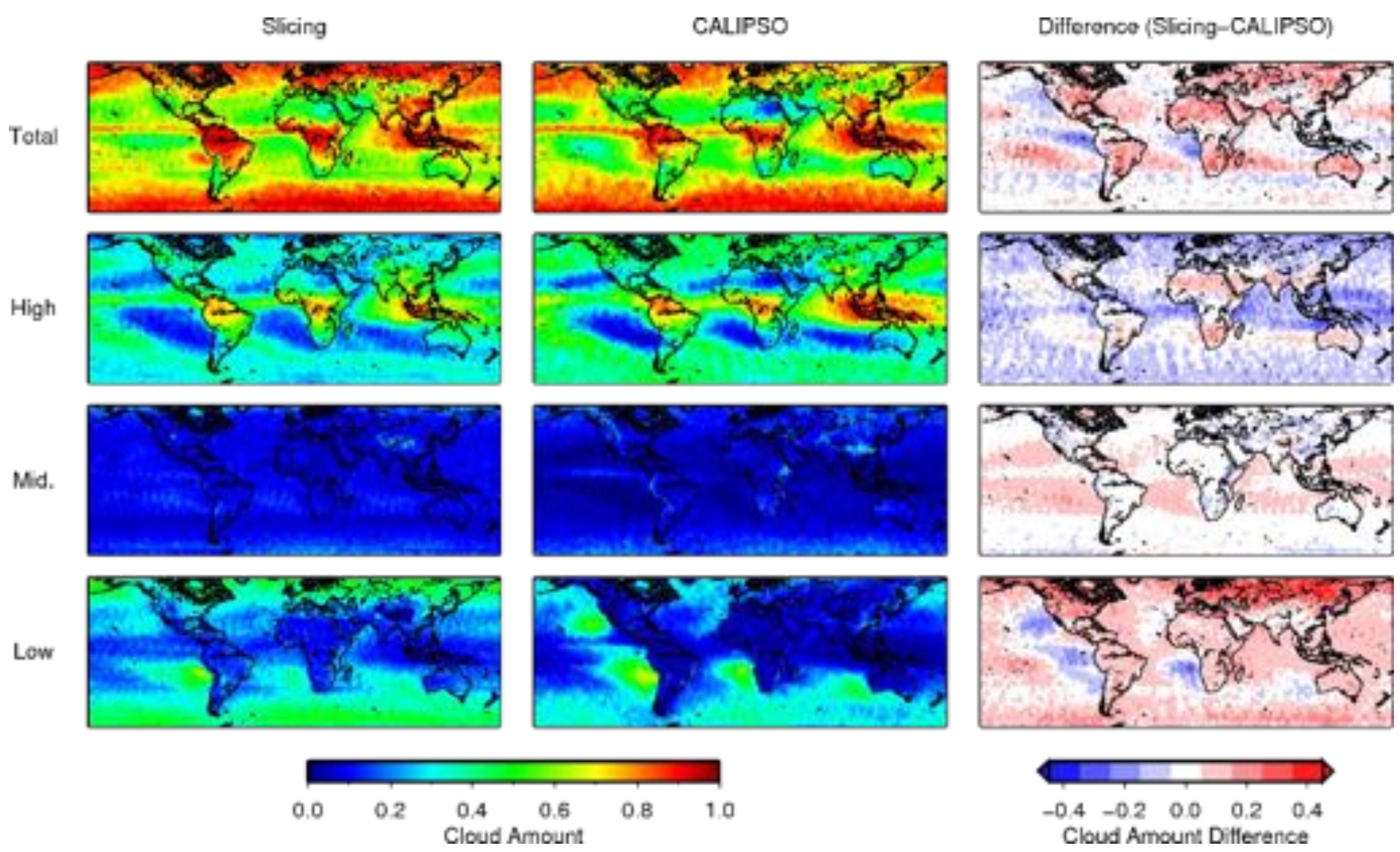
Horizontal distributions of cloud amounts

Cloud amount (CA) = (Cloud detected observations) / (All observations) within 2.5° × 2.5° grids

High cloud : cloud top pressure (CTP) < 440 hPa

Middle cloud : 440 hPa ≤ CTP < 680 hPa

Low cloud : 680 hPa ≤ CTP



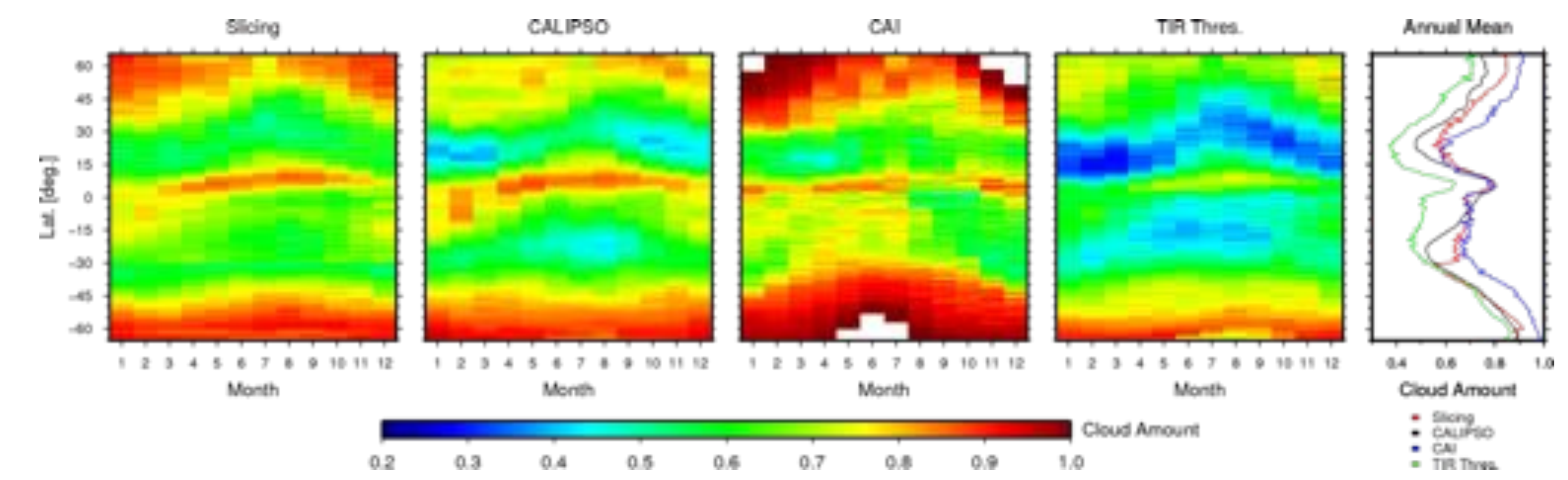
Cloud amount statistics

	GOSAT slicing				CALIPSO			
	CA	CAHR(%)	CAMR(%)	CALR(%)	CA	CAHR(%)	CAMR(%)	CALR(%)
Global	0.72	49	13	38	0.68	61	12	27
Over water	0.71	46	14	41	0.70	58	10	32
Over land	0.73	57	12	32	0.64	69	16	14

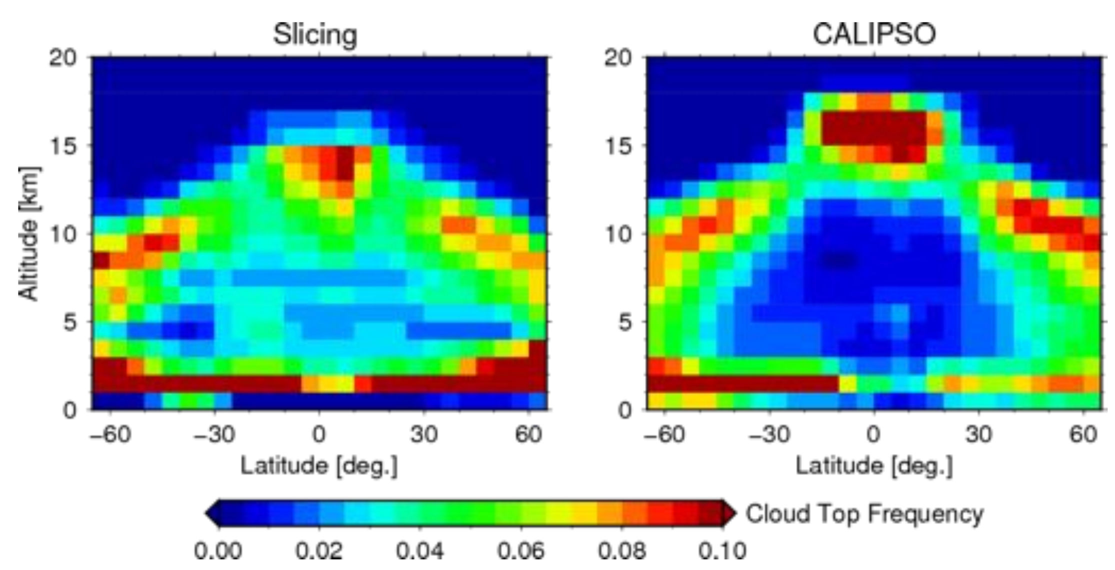
Seasonal variations of cloud amounts

Slicing, CALIPSO, TIR threshold : both day and night

CAI : daytime only

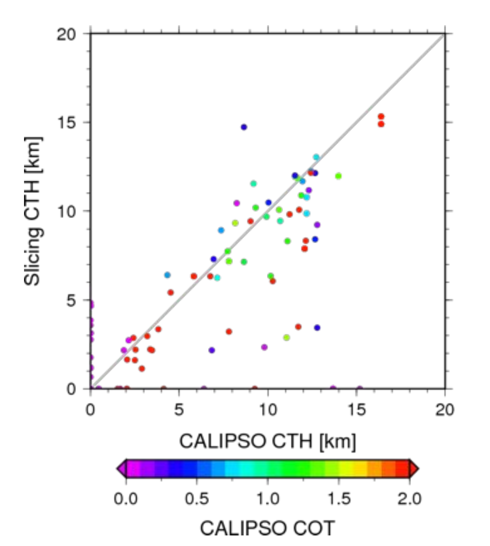


Zonally averaged vertical distributions of cloud top frequency



CTHs from collocated observations

Match up condition : 5 km and 2 min.



Summary

The algorithm for cloud/aerosol level2 products of TANSO-FTS2/GOSAT2 were developed based on CO_2 slicing technique. The original spectral channels were reconstructed in the range of 700-755 cm[-1] and their pairs used for calculations were optimized as indicators of temperature at 500 hPa and latitudes based on the simulation studies using Pstar3. The modification was effective to reduce the random noises on the observed radiance spectra.

The algorithm was applied to GOSAT data. Their characteristics such as the horizontal distributions or seasonal variations were generally agreed to those from CALPSO observations. It was revealed that the slicing tends to overestimate cloud amounts over lands and to estimate CTH lower than CALIPSO. It seems that optically very thin clouds in the tropics and extremely low clouds with inversion layer in the west coast of continents are difficult to detect by this method.

We are analyzing L1B V160.161 obtained from 2009 to 2014. The results are planned to be compared with ground-based lidar observation data to evaluate dust detection performances.

Reference

Chahine, J. Atmos. Sci., 1974

Someya et al., Atmos. Meas. Tech., 2016