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# Cloud-top Height Esimation Method by Geostationary Satellite Split-Window Measurements Trained with CALIPSO data

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We released a database of cloud top height and visible optical thickness (CTOP) with one-hour resolution over the tropical western Pacific and Maritime Continent, by using infrared split-window data of the geostationary satellites (MTSAT) (http://database.rish.kyoto-u.ac.jp/arch/ctop/). We made lookup tables for estimating cloud top height only with geostationary infrared observations by comparing them with the direct cloud observation by CloudSat (Hamada and Nishi, 2010, JAMC). We picked out the same-time observations by MTSAT and CloudSat and regressed the cloud top height observation of CloudSat back onto 11 micro m brightness temperature (Tb) and the difference between the 11 micro m Tb and 12 micro m Tb of MTSAT. The database contains digital data and quick look images from Jul 2005 to real time and the area in 85E-155W (MTSAT2) and 20S-20N.

Though the CTOP dataset is particularly useful for the upper tropospheric clouds, it has one serious problem. The cloud radar onboard CloudSat cannot well detect the optically thin cirrus clouds composed of small ice crystals and misses a certain part of cirriform clouds in the upper troposphere. In order to overcome this weakness, we are now making next version of the CTOP by using the lidar data (CALIOP) onboard CALIPSO satellite. One problem on the use of lidar observation is that they observe very thin cirrus formed around the tropopause. The main purpose of CTOP dataset is to provide the top height of clouds that originate from cloud clusters including cumulonimbus and nimbostratus, not of in-situ cirrus clouds formed near the tropopause. To exclude the very thin tropopause cirrus, we define cloud-top height of CALIOP observation as the height at which the optical depth accumulated from the cloud top is 0.2, instead of the CALIOP cloud top itself. With this criterion we can succeed in estimating the top height of cirruiform clouds, but it has another problem for thick clouds like cumulonimbus. For such clouds, the height of accumulated optical depth 0.2 is considerably lower than the real cloud top, possibly due to rather small number of large cloud particles near the top. Therefore, the estimation using CloudSat data is closer to the real top for the thick clouds, while that using CALIOP data is closer for cirriform clouds. So we are now making a lookup table with using both CloudSat and CALIPSO data to estimate cloud-top heights both for thick and thin clouds seamlessly.

Keywords: cloud top, geostationary satellite, split window, cirrus, tropical meteorology

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# Improvement of GSMaP with multi-channel geostationary meteorological satellite observation for oceanic precipitation

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The Global Satellite Mapping of Precipitation (GSMaP) produces accurate precipitation data with high time and spatial resolution (per 1hour, 0.1 degree) by utilizing the satellite microwave radiometer. At the time and place which all microwave radiometer satellites are not available, the GSMaP estimates where the precipitation area observed before that time will moves by using a cloud moving vector retrieved from the infrared brightness temperature (IR Tb) observed by the geostationary meteorological satellite (GMS). However this method has some possibility of mistaking a destination of precipitating cloud with vertical shear of environmental wind, and uses only IR1 channel of the GMS observation to calculate the cloud moving vector. Therefore, we made a new data which can estimate precipitation probability globally with high temporal and special resolution by using IR1 and water vapor (WV) channel of GMS observation, called precipitation potential map (PPM), and then improved the accuracy of GSMaP precipitation areas by utilizing the PPM (JpGU meeting, 2014).

Since it is difficult to distinguish small precipitating cumulus from non-precipitating stratus only with cloud top height information obtained from IR1 and WV channels, the past PPM has low accuracy of estimating precipitation area for low cloud. Therefore this study first tried to improve the accuracy of PPM for low cloud by adding multi-channel information obtained from Meteosat Second Generation (MSG2). The utilization of GMS multi-channel observation is important from the point of view of preparing next-generation GMS, Himawari-8, Himawari-9, GOES-R series, and Meteosat Third Generation. Next we included the modified PPM into GSMaP precipitation detection algorithm to improve GSMaP precipitation area and precipitation intensity product, and investigated the accuracy of modified GSMaP precipitation product by comparing them with precipitation radar (PR) of Tropical Rainfall Measurement Mission (TRMM) as it is truth. We will intend to explain the result of case study of tracking precipitation system over the ocean under vertical wind shear with modified and non-modified GSMaP. In these areas and conditions, we can expect that the GSMaP estimates the precipitation area more accurately by utilizing the potential map. In these circumstances, we can expect that the GSMaP precipitation estimation becomes more accurate by utilizing the PPM.

We used five geostationary satellites, MSG2, METEOSAT, GOES-West, GOES-East, and MTSAT-1R. All geostationary satellite data is released from the Center for Environmental Remote Sensing, Chiba University (CEReS). Global Satellite Mapping of Precipitation (GSMaP)_MVK and GSMaP_NRT (v6.000.0) was used as satellite observation of precipitation with the microwave sensor. The GSMaP products are produced by Earth Observation Research Center (EORC) in Japan Aerospace Exploration Agency (JAXA). We used near surface rain observed by the precipitation radar of the Tropical Rainfall Measurement Mission (TRMM PR; 2A25, V7) as truth.

Keywords: geostationary meteorological satellite, precipitation, GSMaP

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# A greenhouse gas retrieval algorithm for GOSAT TANSO-FTS SWIR using polarization information

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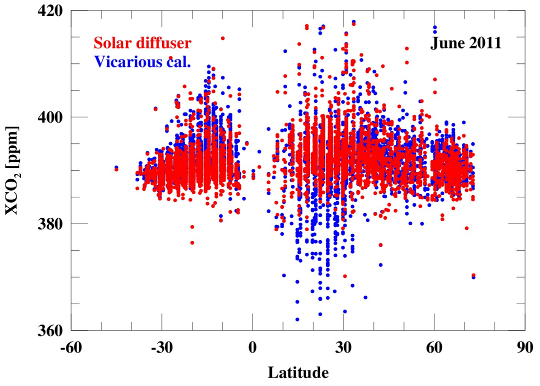
TANSO FTS is a Fourier transform spectrometer onboard the Greenhouse Gases Observing Satellite (GOSAT), which is in orbit after the launch in January 2009. TANSO-FTS measures two orthogonal polarizations of solar backscattered spectra at three narrow bands in the short wave infrared (SWIR). It is expected that by using the polarization information, undesirable effects of cloud and aerosols on greenhouse gas retrievals are corrected more effectively, and the accuracy of the retrievals is improved. So far, no retrieval algorithm has been realized which uses polarization information of TANSO-FTS. In this study, for the first time, we present retrieval results of column-averaged concentrations of carbon dioxide ($XCO_2$) from polarized TANSO-FTS SWIR spectra.

Accurate radiometric calibration of the two polarized spectra is one of the most crucial factors for successful retrievals from TANSO-FTS spectra. With a simulation study conducted under the idealized situation that there is no calibration error in calibration coefficients of TANSO-FTS, we showed that the polarization information increases the information content of the aerosols and reduces retrieval errors in $XCO_2$. In fact, degradation of the sensor is not avoidable. Unless the calibration coefficients are evaluated after the launch with sufficient accuracy, polarization information of TANSO-FTS will not improve the $XCO_2$ retrievals.

In this study, retrievals of $XCO_2$ were compared using several calibration coefficients evaluated in different methods. The figure shows $XCO_2$retrievals from TANSO-FTS measurements over land in June 2011. Blue dots in the figure are results obtained with calibration coefficients evaluated from vicarious calibration reported by Kuze et al. (TGRS, 2014). We also tried to evaluate calibration coefficients from the solar calibration data by analyzing polarization properties of the solar diffuser panel. Retrievals of $XCO_2$ with the solar diffuser calibration are plotted by red dots in the same figure. Comparing these results obtained with two different calibration coefficients, we found that the values of $XCO_2$ with the vicarious calibration tend to scatter toward a low concentration in the Sahara desert. On the other hand, this tendency is hardly seen in $XCO_2$ retrievals with the solar diffuser calibration. Also, some high $XCO_2$ regions are observed in South America and Southern Africa in the retrievals with the vicarious calibration, which are not seen in the retrievals with the solar diffuser calibration.

Our result indicates that the calibration coefficients make a marked difference in retrieved $XCO_2$ if the polarization information is used. We plan to analyze more observations, and to try another calibration technique, such as ocean glint observations.

Keywords: satellite observation, carbon dioxide, GOSAT



ACG09-P04 Room:Convention Hall Time:May 27 18:15-19:30

# Evaluation of Satellite-Borne Radar, Lidar, and Imager Algorithm for Retrieval of Cloud Microphysical Properties

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We developed algorithm for the retrieval of effective radius (R$_{eff}$) and cloud water content (CWC) of clouds by using collocated CloudSat 94 GHz cloud radar, CALIPSO lidar and MODIS imager. Main aim of the study is to evaluate uncertainties of the algorithm. The radar and lidar retrieval algorithm was initially developed by Okamoto et al., (2010) for ice cloud region detected by radar and lidar. And Sato and Okamoto (2011) extended the range of applicability to the ice regions detected radar or lidar. Then Okamoto et al., (2014) further extended the algorithm by introducing optical thickness ($\tau_{vis}$) information from MODIS that can be applicable to both ice and water clouds, and rainy regions detected radar or lidar. Here RL and RLI denote radar or lidar algorithm and radar/lidar with $\tau_{vis}$ algorithm from imager (RLI). Major source of uncertainties in the RL is the treatment of radar only detected clouds and precipitation where lidar signal is totally attenuated and we introduced empirical formula in radar-only region derived from ground-based Doppler cloud radar observations.

In this presentation, cloud microphysics of convective clouds was analysed in September 10, 2006 over the Pacific Ocean. We examined the vertical distribution of R$_{eff}$, CWC, $\tau_{vis}$ as well as cloud water path (CWP). By using $\tau_{vis}$ as a constraint, R$_{eff}$ is ~ 50 $\mu$m smaller than RL results and ~ 300 $\mu$m smaller than RL results in the water cloud region below ~ 5 km. Responding to this trend, IWC was 0.5 g/m$^3$ larger and LWC was 0.01 g/m$^3$ larger compare to the RL ones. We also compared $\tau_{vis}$ and CWP between from MODIS, RL, and RLI.

Instead of retrieved $\tau_{vis}$, MODIS reflectance was also combined with RL and we examined the uncertainties in the both versions of RLI algorithms, due to the possible variability of ice particle shape and orientations.

In 2017, the joint European and Japanese satellite mission EarthCARE, which will carry a Doppler cloud radar, high-spectral resolution lidar, multi-spectral imager, and broadband radiometer, is scheduled to launch. We discuss how to use Doppler information to reduce the retrieval errors. The algorithm described above will be adapted to the standard algorithm.

Keywords: synergy, radar, lidar, imager, cloud microphysics

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# Current status and development of Cloud analysis algorithms based on EarthCARE/MSI observation

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Clouds and aerosols are the major uncertainty in the understanding of the Earth's climate system. An improvement of understanding and better modeling of the relationship of clouds, aerosols and radiation are therefore prominent part in climate research and weather prediction. It is important to obtain the global data of clouds and aerosols occurrence, structure and physical properties that are derived from measurements of solar and thermal radiation.

EarthCARE (Earth Clouds, Aerosols and Radiation Explorer) is one of the future earth observation mission of ESA and JAXA. This mission aims at understanding of the role that clouds and aerosols play in reflecting incident solar radiation back into space and trapping infrared radiation emitted from Earth's surface. These observations are needed to improve the precision of climate variability prediction.

The mission will achieve the objectives by measuring the vertical structure and horizontal distribution of clouds and aerosols globally. The satellite will carry four instruments for observations of clouds and aerosols; Atmospheric Lidar (ATLID), Cloud Profiling Rader (CPR), Multi-Spectral Imager (MSI) and Broad-Band Radiometer (BBR). MSI provides across-track information on clouds and aerosols with channels in the visible, near infrared, shortwave and thermal infrared. Two products based on CLAUDIA [Ishida and Nakajima, 2009] and CAPCOM [Nakajima and Nakajima, 1995; Kawamoto et al., 2001] are advanced in this study. In this presentation, current status and development of algorithms will be introduced.

Keywords: EarthCARE, MSI, cloud, aerosol

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# Early phase retrieval of aerosol optical characteristics by Himawari-8

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Himawari-8 is a geostationary meteorological satellite launched in October 2014 by. It equips an imager, called Advanced Himawari Imager (AHI). Himawari-8/AHI is a latest imager as a geostationary satellite. For example, AHI has 16 bands from visible (0.47um) to thermal infrared (13.3um) Moreover, AHI can observe East Asia, South-East Asia, Oceania, and West Pacific area as often as 10 min. The resolutions of sensors are as fine as 0.5km for 0.64um, 1.0km for 0.47um, 0.51um, and 0.86um, and 2.0km for 1.6um to 13.3um. These high resolution and high frequent observation are very unique for geostationary satellite. We are selected as ”Himawari-8’s data quality evaluator” by JMA, and now JAXA is receiving Himawari-8’s data.

In this study, we have retrieved aerosol characteristics from Himwari-8’s data. As a package of aerosol retrieval, we used REAP (Higurashi and Nakajima, 1999), and retrieved aerosol optical thickness and Angstrom Exponent over the ocean. We need to assume some of the parameters of aerosol in the satellite remote sensing when we make Look Up Table. We have assumed bimodal-lognormal distribution as a size distribution. Mode radii and standard deviations are cited by Fukuda et al (2013)’s value. mode radius for coarse mode is 3.86um and that for fine mode is 0.148um. Standard deviation for coarse mode is 2.0 and that for fine mode is 1.56. Complex refractive indexes are calculated from AERONET (Aerosol Robotic Network) observations. We used AERONET data in Anmyon (126.330E, 36.539N), Baengnyeong (124.630E, 37.966N), Fukuoka (130.475E, 33.524N), Gangneung WNU (128.867E, 37.771N), Shirahama (135.357E, 33.697N), and Yonsei University (126.935E, 37.564N), and we calculated the average value; $1.51 + i*0.0226$ for 0.64um and $1.53 + i*0.0233$ for 0.86um. As a threshold of cloudiness, we applied CLAUDIA’s threshold test concept. (Ishida et al., 2009) However, some of the thresholds are tuned for Himawari-8. We will also compare our result with ground truth obtained by AERONET.

Keywords: Himawari-8, aerosol

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# Cloud detection algorithm using TIR spectra for improving gas retrievals from GOSAT data

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Thermal And Near-infrared Sensor for Observation (TANSO) onboard Greenhouse gases Observing SATellite (GOSAT) consists of Fourier Transform Spectrometer (FTS) and Cloud and Aerosol Imager (CAI). Greenhouse gas concentrations are retrieved from the shortwave infrared (SWIR) bands and the thermal infrared (TIR) for scenes judged to be cloud and aerosol free through the cloud screening procedure with CAI observations. However, CAI does not operate during nighttime although TIR data can be obtained. Moreover, it has no sensitivity for cloud and aerosol heights which must be measured to decrease the currently reported gas concentration biases. Therefore, we developed an algorithm to detect optically thin clouds and dust aerosols with their heights from TIR data. The algorithm used in this study was based on a cirrus detection technique called CO2 slicing method, modified as described below. The weighting functions which represent sensitivity profiles were calculated at each channel in the TIR band of GOSAT. The channels were reconstructed as sets of several spectral channels for each height level based on the peak heights of the weighting functions. Subsequently, the channel combinations were optimized based on simulation studies for several temperature profile patterns for each latitude and temperature at 500 hPa. The observed data were analyzed using these optimized channels. Global tropospheric cloud amounts and cloud properties such as cloud top heights and optical thickness were validated using CALIPSO data.

Monthly mean cloud amounts from GOSAT data were compared with those from CALIPSO. Results show some differences of cloud amounts and heights between GOSAT and CALIPSO, which might be caused by surface temperature biases, the difference of sensitivity of sensors, the inverse layer, and marine stratocumulus clouds. However, the horizontal distributions of clouds derived using the slicing method resembled those obtained from CALIPSO and it was revealed that the slicing method algorithm has high sensitivity compared with TIR threshold cloud screening which is currently adopted as the cloud screening method for GOSAT data in nighttime. Cloud properties were also compared for coincident observation between GOSAT and CALISPO and the results showed that the accuracy of cloud detection is improved drastically by the new approach presented in this study. Clouds with optical thickness less than 0.1 are detectable using this method. Based on these results, the slicing method algorithm developed for this study seems to be useful for cloud screening. It is expected to improve the accuracy of greenhouse gas observations.

Keywords: satellite remote sensing, greenhouse gas, cirrus