Cloud Detection (CLD)
Algorithm Theoretical Basis Document

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List of Acronyms

AQC	Automatic Quality Control
AVHRR	Advanced Very High Resolution Radiometer
CMDPS	COMS Meteorological Data Processing System
COMS	Communication, Ocean and Meteorological Satellite
CSR	Clear Sky Radiance
EOS	Earth Observation System
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FAR	False Alarm Rate
FOV	Field Of View
GDAPS	Global Data Assimilation and Prediction System
GSFC	Goddard Space Flight Center
HRIT	High-Rate Information Transmission
HSS	Heidke Skill Score
IR	Infrared
LAADS	Level 1 and Atmospheric Archive and Distribution System
MPEF	Meteorological Product Extraction Facility
MODIS	Moderate-resolution Imaging Spectroradiometer
MSG	Meteosat Second Generation
MTSAT-1R	Multi-functional Transport Satellite-1 Replacement
NASA	National Aeronautics and Space Administration
NNCLD	Neural Network Cloud Detection
PC	Proportion Correct
POD	Probability of Detection
PSS	Peirce's Skill Score
RTTOV	Radiative Transfer for the TIROS Operational Vertical Sounder
SAFNWC	Satellite Application Facility Now-Casting
SEVIRI	Spinning Enhanced Visible and Infrared Imager

SWIR	Short-Wave Infrared
WMO	World Meteorological Organization

1. Overview

Cloud Detection (CLD) is the process of determining the existence or non-existence of clouds in each pixel in satellite observed images. It is a very important factor in the satellite data processing field.
It is especially important for building a comprehensive satellite data processing system. Cloud detection is the initial retrieval factor that needs to be performed, because other retrieval factors are determined depending on the existence or non-existence of clouds. For this reason, the accuracy of cloud detection affects the quality of subsequent retrieval data. For example, if cloud contamination is not properly eliminated when retrieving of sea surface temperature, the retrieved temperature will be lower than reality. It is essential to minimize cloud contamination for the retrieval of sea surface temperature.
Accurate cloud detection is also important because the selection of clear sky pixels during quality assessment of raw data such as calibration monitoring and vicarious calibration determines its accuracy. For cloud detection using limited channel data, the possibility of errors is relatively high and the realization of a 100% perfect cloud detection algorithm is difficult to achieve. Therefore, an important consideration in the design process of a cloud detection algorithm is the selection and decision of tolerances for cloud existence and clear decision.
Clouds in the real pixel do not exist, but clouds must decide whether allow the occurred error to judge for existing clouds. In contrast, in spite of ones in pixel exit, ones must decide whether allows the occurred error to judge for non-existing clouds. This has to analyze the effects of clouds on retrieved data in clear sky pixels. Also, the retrieved data in cloudy pixels has to take into account the effects that cloud happen when real clouds are retrieved in non-existing pixels.
If clouds are present, the Communication Ocean and Meteorological Satellite (COMS) Meteorological Data Processing System (CMDPS), retrieves or detects cloud information such as; cloud amount, cloud type, cloud phase, cloud optical thickness, cloud top temperature/height, rainfall intensity, fog, and atmospheric motion vector (except for Atmospheric Motion Vector(AMV) of water vapor). If clouds are not present, CMDPS retrieves data on; land surface temperature, sea surface temperature, total precipitable water, upper tropospheric humidity, and clear sky radiance. If these factors were affected by clouds, but divided into clear pixels, the generated error and this effect are more serious than the inverse case. Therefore, in the CMDPS cloud detection process, in the case of partial cloud or semi-transparent cloud in pixel are included, and is affected indirectly by the surrounding cloud made

it a rule to classify into all cloudy pixel for securing the accuracy of clear sky pixel.

This principle of cloud detection detects clouds as well as factors such as; Asian dust, aerosol, and smoke from forest fires. Even pixels affected by snow cover, hot spots, or sunglint are easy to be judged as cloud pixels. For this reason, factors such as; aerosol detection, aerosol optical thickness, and sea ice/snow cover, etc. products in CMDPS determined using a self-cloud elimination detection algorithm instead of the cloud detection algorithm described in this document.

This document drew upon detailed technology for the purpose of cloud detection applied by CMDPS. Section 2 presents the background and purpose of cloud detection, and briefly explains existing cloud detection algorithm. Section 3 presents the retrieval process and the detailed technology for each cloud detection test with theoretical background of the CMDPS cloud detection algorithm and explains the validation plan to validate the accuracy. Section 4 introduces the interpretation and utilization method of the cloud detection results. Finally, issues and methods for improvement are given in section 5.

2. Background and purpose

Clouds in satellite data generally have a high reflectance and a relatively low brightness temperature for regions with clear sky. Using this feature, we can detect clouds by applying the simple visible (VIS) channel and infrared (IR) channel threshold test. As a result, the method most utilized to detect clouds from satellite data is to test threshold value. This is the way of judging the existence or nonexistence of clouds comparing the fixed threshold value with real channel observation value. If many observation channels are utilized, it performs a variety of tests using a single channel considering the channel properties and using the difference value between two channels. This can detect clouds using a combination of tests.

The most important thing in applying this method is deciding the threshold value used in each test. The threshold value can change depending on the surface and atmospheric conditions such as; water vapor, observation conditions such as sun incident angle and satellite zenith angle. It is very difficult to select one threshold value that can be applied in all conditions. Therefore, it is common to apply different threshold values depending on the conditions. There are many methods for determining threshold value. The analyzer is the empirical method for adjusting as watch real images and the theoretical methods using simulation data calculated by the Radiative Transfer Model. Meanwhile, in order to solve the difficulty for setting of threshold value by change of season in extensive areas uses NWP data. It utilizes the dynamic threshold value technique to determine relative threshold value utilizing theoretically calculated radiance (EUMETSAT, 2004).

Many studies have been performed to develop a cloud detection algorithm for satellite data. The representative examples are the International Satellite Cloud Climatology Project (ISCCP), AVHRR Processing scheme Over cloud Land and Ocean (APOLLO) cloud detection, Cloud Advanced Very High Resolution Radiometer (CLAVR), MODIS cloud mask, and the Meteosat Product Extraction Facility (MPEF) scene analysis algorithm.

The ISCCP Cloud detection algorithm attempts cloud detection using the visible channel and IR channel. It uses a method to compare with clear composition value applicable to each channel values. Threshold value is then set based on the uncertainty for the range of values obtained in clear sky. The ISCCP algorithm consists of five steps; the spatial consistency test for IR channel image, temporal consistency test in the continuous IR image considering the defined daily variation, temporal and combination of spatial statistic value for IR and visible image, production of clear sky composition value using five day satellite data, and threshold value test.

The APOLLO algorithm was introduced by Saunders and Kriebel (1988), Krievel et al. (1989), Gesell (1989) and its algorithm utilizes five channels of the Advanced Very High Resolution Radiometer (AVHRR). The wavelength of the five channels for AVHRR are approximately 0.58~0.68㎛ (channel 1), 0.72~1.10㎛ (channel 2), 3.55~3.93㎛(channel 3), 10.3~11.3㎛ (channel 4), and 11.5~12.5㎛ (channel 5). This algorithm consists of the threshold test for IR channel, the ratio (channel 2/channel 1) test of visible channels, the difference value test of atmospheric window IR channel (channel4-channel5), and the spatial consistency test in the ocean. The results of cloud detection are then classified into; clear and cloudy by ISCCP and Cloud(??), cloud contamination, and clear sky.

This cloud detection algorithm is for global coverage using data from five AVHRR channels the same as the CLAVR algorithm used by the National Oceanic and Atmospheric Administration (NOAA) introduced by Stowe et al. (1991). This algorithm used multichannel information and channel value difference, and spatial consistency, and selected a sequential decision method. If it has 4 pixels of clear sky in 2x2 pixels after performing cloud detection in pixels, it presents clear sky pixels (0% cloudy). In case of having 4 pixels of cloudy, presents cloudy pixels (100% cloudy). For the rest decides on 50% cloudy pixels. For this algorithm, the method restoring into clear sky uses surface information of snow cover/sea ice, sun reflection angle, and desert. Also, the tests applies a different test and threshold value depending on land and sea in daytime, or land and sea in nighttime.

The CLAVR algorithm was consistently improved. The improvements apply different tests for the dynamic threshold value using statistics for nine day clear sky data throughout the day (Stowe et al., 1994). It also classifies clear and cloud contamination pixels, and partial and overcast pixels in cloud contamination. It classifies contaminated clouds by low clouds, cirrus, and developed cumulus system for existing and non-existing clouds. It also attempted classifying transparent clouds using multichannel observation value of additional High-resolution Infrared Radiation Sounder (HIRS). This document will skip the explanation of HIRS, as it does not affect CMDPS development. Based on prior research, the developed algorithm uses multi-channel data from the cloud detection algorithm (Ackerman et al., 1998) of Moderate-resolution Imaging Spectroradiometer (MODIS) sensors on board Terra and Aqua Earth Observing System (EOS) satellites. MODIS has a multichannel imager with 36 channels. 14 channels were used in this algorithm.

MODIS cloud detection tests comprise all five groups. These are; a group of single IR channel threshold value tests ($Tb_{10.8}$, $Tb_{13.9}$, $Tb_{6.7}$ test), multi IR channel brightness temperature difference value tests (Tri-spectral test, $Tb_{10.8}$ - $Tb_{3.9}$, $Tb_{10.8}$ - $Tb_{6.7}$ test), Reflectance tests ($Ref_{0.66}$ or $Ref_{0.87}$, $Ref_{0.87}/Ref_{0.66}$, $Tb_{3.75}$ - $Tb_{3.9}$ test), cirrus detection test using SWIR channel($R_{1.38}$ test), cirrus detection test using IR channels ($Tb_{3.75}$ - Tb_{12}, $Tb_{10.8}$ - Tb_{12} test). Tb is brightness temperature, and Ref is reflectance.

Each individual test uses a fixed threshold value. To compensate drawbacks when it uses a fixed value, it classifies into a reliable clear sky and cloudy applying three threshold values and is designed to determine confidence level of existing cloud. The individual tests are collected with possibility of the maximum cloud existence by each group. As the harmonic average for test results of these groups, it is progressed to determine the final confidence level. Final confidence level is classified into four categories; confident clear, probably clear, undecided, and cloudy.

So far, there mainly described cloud detection algorithm applied polar-orbiting satellite data. A representative cloud detection algorithm using geostationary satellite data is the MPEF scene analysis algorithm of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) using SEVIRI sensor data of Meteosat Second Generation (MGS) in the recent launched European geostationary meteorological satellite. SEVIRI has a sensor to observe 12 multi-channels in a geostationary satellite for the first time.

The MPEF algorithm has the following advantages: First, it does not use regularly a fixed threshold value and estimate radiance or reflectance value in clear sky. By determining threshold value based on this case, it has variable properties to use threshold value. Second, it divides into five steps depending on the confidence level. The final cloud detection results in the process of Automatic Quality Control (AQC) after carrying out cloud detection test using all possible channels. It also uses a threshold test calculating the reflectance value of Short-Wave Infrared (SWIR) channel that is not used much. In the case of the difference comparing the current observation data and the previous time data for saving of calculation time is small, it includes the concept using cloud detection result of the previous time.

Cloud detection algorithm using the threshold value method is widely used in operational algorithms. This is easy to understand in theory as calculation time is relatively low, because it is easy to automate the program.

Traditionally, histograms were used for cloud detection. To explain simply, cold and bright parts using two-dimensional histograms for visible channel reflectance and IR channel brightness temperature are clouds, and dark and warm parts are clear sky. This method is used mainly in cloud classification with the method detecting a cloud depending on latitude distribution. Desbois et al. (1982) is a representative example using this method detected cloud using three channels of visible, IR, water vapor applying in Meteosat image. It performed the studies for automatically classifying the cloud type using the dynamic cluster method. Cloud detection using histograms is appropriate in certain areas, but expanding into global characteristics has difficultly, and the calculations are time consuming. Meanwhile, new studies have been attempted starting in the 1990s. This applied a neural network technique for satellite data processing and cloud detection (Visa et al., 1991; Slawinski et al., 1991; Yhann and Simpson, 1995). A neural network represents a variety of properties depending on temporal and spatial variation. This is the way to compensate for difficulty due to the atmosphere, ocean, and surface conditions. It finds the relationship or pattern between complicated data with statistical and nonlinear properties. The properties for this data are a useful way to predict or classify new data in building the best reflected model. In brief, the procedures prepare training dataset and perform cloud detection using the trained neural network model after training and building one. In applying the neural network technique, the most important step is to build a suitable training dataset. We have to train the model extracting the homogenous data from seasonal, local, optical property of clouds. Also it controls the accuracy of retrieval depending on building any model.

Cloud detection using the observed data from COMS, in other words, cloud detection of CMDPS was developed based on the above-mentioned threshold value test. In the utilization of geostationary satellite data and suitability applying for seasonal and local threshold value using dynamic threshold value, it developed based on MPEF scene analysis algorithm that is operationally utilized in the current EUMETSAT.

COMS consists of 5 channels. All tests used in the MPEF algorithm using 12 channels are unacceptable. Also, since surface information retrieval for snow cover is difficult, we modified this algorithm. If clear sky radiance decides the threshold value, the operational NWP model is used. Reflectance applied the minimum reflectance during the past 15 days. The explanation for the detailed algorithm and retrieval process are described in the next section. The study of cloud detection algorithm using neural network model as part of CMDPS development was additionally progressed. CMDPS software operational algorithm will be applied to threshold value technique. It reviews the application possibility of the neural network model and the study was progressed to compare with the performance. The detailed explanation refers to Neural Network Cloud Detection (NNCLD) ATBD document.

3. Algorithm

3.1. Theoretical background and basis

Cloud detection using threshold value tests is a basic principle to classify clear sky and cloudy using properties of each observed channel and regular threshold value. Cloud detection test methods consist of using a single channel, dual channel difference or ratio tests. Threshold value test of a single channel is simple and detects most thick clouds. This method uses Visible and IR channels at the same time in daytime using Visible and IR channels observed in atmospheric window region. It is only possible to use IR channels at night. We have to understand the properties of this channel in order to perform threshold value test of single channel.

Visible reflectance in clear sky is low and is high when cloudy. Therefore, the test of visible channel reflectance is detected as clouds if it is higher than any threshold value. For oceans, the relative test is easy because the reflectance is very low, but it must pay attention, because reflectance in sunglint regions is high. Relative reflectance on land is also low, but reflectance in the desert is high for general surfaces and is very high in snow covered regions, which makes it hard to distinguish from clouds. When performing Single channel threshold using IR channels, the brightness temperature is high in clear sky pixels, which is the opposite of visible channels, and the brightness temperature is low in cloudy pixels. Because the IR channels of Atmospheric window region in clear sky regions are influenced by Land Surface Temperature (LST) and Cloud Top Temperature (CTT) information in cloudy regions is dominant. Therefore, when cloud detection tests using IR channels is lower than a fixed threshold value, it is determined as cloudy. When it is higher, it is determined as clear sky. Dual channel threshold tests will use the properties that the response appears differently for each wavelength in the case of existing clouds. A representative $Tb_{10.8}$ -Tb_{12} test used in dual channel threshold test uses the feature which is higher than existing thin cirrus, clear sky region, and thick clouds (Saunder and Krieble, 1988; Inoue, 1985). The absorption (emissivity) of ice crystals in IR window region shows a higher value than water drops because the wavelength difference is too large (Ackerman et al. 1990). Therefore, it can be influenced by clouds when the $Tb_{10.8}$ - Tb_{12} value is larger than a specific threshold value.

It is difficult to detect low clouds at night compared with daytime using the visible channel. The temperature in low clouds compared with clear sky is not low, so the shape of clouds doesn't appear in IR channels. The IR and SWIR channels difference tests are mainly used to detect low clouds at night. The $Tb_{10.8}$ - $Tb_{3.75}$ value for existing clear sky or thick clouds is close to the imaginary value, but existing low clouds have the positive value over a certain value. This cloud emissivity in SWIR channel wavelength is lower than IR channels, because the brightness temperature of SWIR channel is lower than IR channels. Meanwhile the $Tb_{10.8}$ - $Tb_{3.75}$ test is used to detect thin cirrus clouds. When the emitted radiation from the surface penetrates cirrus clouds, the transmittance in the SWIR channel is higher than the IR channel's wavelength. If thin cirrus clouds exist, the SWIR value is relatively high, so $Tb_{10.8}$ - $Tb_{3.75}$ uses the properties to obtain the negative value. However, using the SWIR channel in the daytime is difficult, including both the emitted component from earth radiation and reflected solar component.

The test in sunglint regions uses this feature. When it analyzes satellite images, we can know that sunglint appear in the equator or ocean region within global visible images The SWIR channel is uncertain for the value including the reflected component of solar energy, but this influence appears. While sunglint regions do not appear in IR channel images, it clearly appears in the $Tb_{3.75}$ - $Tb_{10.8}$ channel difference value. Sunglint regions use this feature to test.

If the spatial resolution such as geostationary satellite is low satellite, single cloud within Field Of View (FOV) is included a partial cloud or the information is weak, so cloud detection by single channel or dual channels can be difficult. The cloud detection method mainly used to complement this point is the spatial consistency test. For example, the standard deviation of observed value within 3x3 pixels is small for homogeneous clouds or clear sky regions, but the value including both cloud contaminated pixels and non-existing cloud pixel is large. If it uses this feature, cloud detection for the edge of the cloud is possible. To determine the existing cloud and non-existing cloud from satellite data is performed by using that it analyze he information included each channel of pixels based on understanding of properties for observation channel.

The COMS project carried forward a securement of multichannel image above 10 channels. The analysis of cloud detection in this background used 12 channel MSG sensors and 36 channel MODIS sensors. The MSG algorithm, the cloud detection algorithm of the latest operational geostationary satellite basically selected to designing cloud detection algorithm in CMDPS. The MSG scene analysis algorithm removes clouds using the partial representative channels for specific retrieval. The algorithm processes the overall data against an existing algorithm. It performs a variety of tests using as many channels as possible, and retrieves the results of cloud detection. It estimates the comparison value in the case of clear sky for Full disk area. Selecting the dynamic threshold value using this and performing the tests, the explanation for algorithm has many advantages that are arranged in detail. The static threshold value uses binary data. For clear sky, the process estimates reflectance of visible and SWIR channels and IR brightness temperature by the Radiative Transfer Model. The prediction field of the NWP model is required as additional input data, so this algorithm has become more complex and difficult, requiring attention in operation tests. Especially, as mentioned above the processing for estimating clear sky radiance of IR channel, the prediction accuracy of NWP plays the main role in the process to decide the accuracy of cloud detection

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3.2. Retrieval process

The CMDPS cloud detection algorithm performs in pixel units based on the threshold value test. The performance steps are as follows:

a. Step 1: Clear sky reflectance and brightness temperature estimation. This estimates Clear sky reflectance (CSRef) and clear sky brightness temperature (CSTb) using the previous observed data and RTM simulated data.
b. Step 2: Sun zenith angle test. This performs a sun zenith angle test to determine day, night, and dawn/twilight regions in each pixel unit. Test results to determine the threshold value used in the channel and each test in the next step.

c. Step 3: Use test and data quality of each channel observed data. It uses the information obtained in the previous steps, which the channel determines to use in cloud detection. Also, it performs the quality test and use of the channel observation data in each pixel unit.

d. Step 4 : threshold value determination. The threshold value is used differently depending on the fixed threshold value and observation conditions in each threshold value test applied in cloud detection.

e. Step 5 : cloud detection and automatic quality test. It performs each individual test determined In Day/night, dawn/twilight. After performing automatic quality test using individual results, it produces the final cloud detection result.

As the basic concept of threshold test divides using threshold value test for physical signals (brightness, temperature and reflectance) of pixels including clear sky and cloudy pixel, it will judge the existence and non-existence of clouds in the observation data. The threshold value test method not only uses data observed in all COMS channels and possible channel information in each pixel, but also utilizes observation information (standard deviation) of neighboring regions. The threshold value test applied to detect clouds is as follows:

A. Test 1 : Threshold value test of single channel reflectance

- Test 1a — Reflectance test using VIS 0.6㎛ channel
- Test 1b — Reflectance test using daytime SWIR3.75_sol

B. Test 2 : dual channel reflectance difference value test

- Test 2 — VIS0.6㎛ - SWIR3.75_sol reflectance difference value test

C. Test 3 : Threshold value test of single channel brightness temperature

- Test 3a — SWIR3.75㎛ Single channel brightness temperature test
- Test 3b — IR10.8㎛ single channel brightness temperature test
- Test 3d — IR12.0㎛ single channel brightness temperature test

D. Test 4

- Test 4a — IR10.8㎛ - SWIR3.75㎛ dual channel brightness temperature difference value test
- Test 4b — IR10.8㎛ – WV6.75㎛ dual channel brightness temperature difference value test
- Test 4c — IR10.8㎛ - IR12.0㎛ dual channel

- Test 4d IR12.0㎛ – SWIR3.75㎛ dual channel brightness temperature difference value test
- Test 4e IR12.0㎛ – WV6.75㎛ dual channel brightness temperature difference test

E. TEST 5

- Test 5a VIS0.6㎛channel standard deviation for 3x3 pixels
- Test 5b SWIR3.75㎛channel standard deviation for 3x3 pixels
- Test 5c IR10.8㎛channel standard deviation for 3x3 pixels
- Test 5d IR12.0㎛channel standard deviation for 3x3 pixels

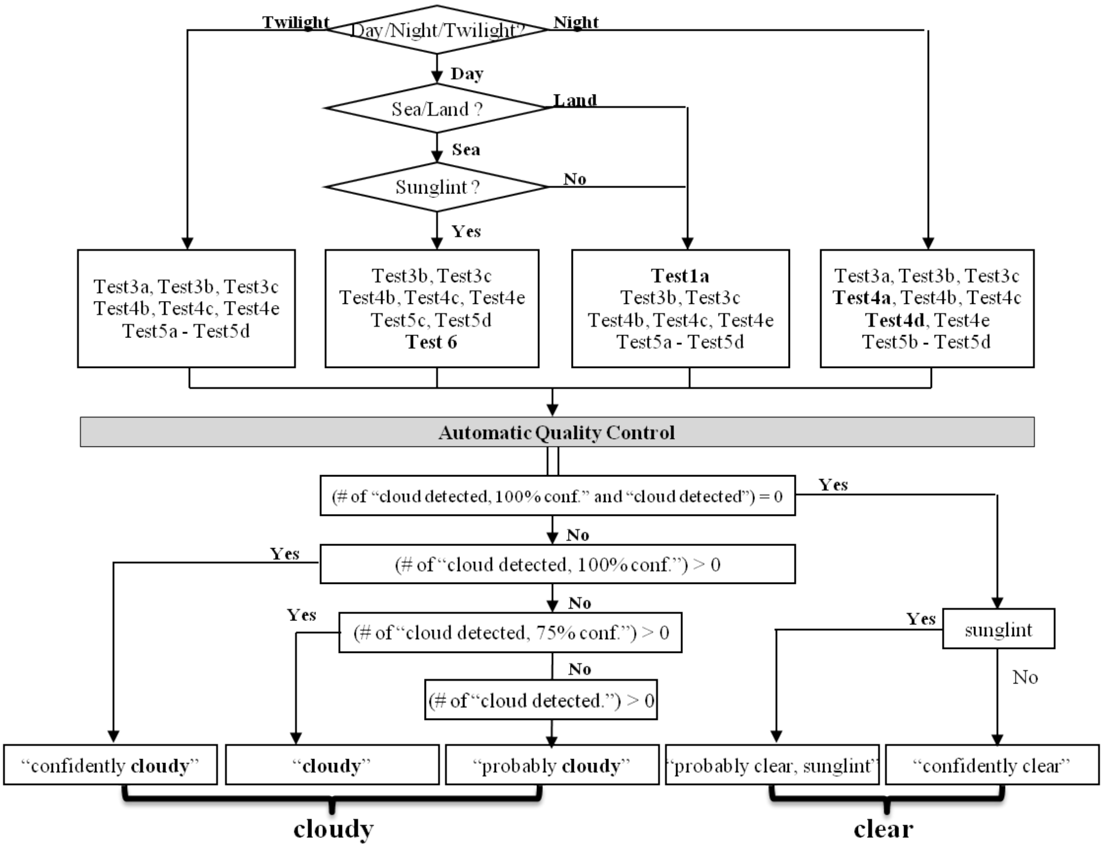
F. TEST 6

- Test 6 sunglint region test using SWIR3.75㎛ and IR10.8㎛

The cloud detection algorithm during the satellite operation period was improved through the addition and deletion of many spectrum tests or the insertion of the existing threshold vale test. The algorithm is simply geared to perform this process. Also, the results of cloud detection have to perform the quality test for all cloud contamination pixels.

3.3. Detailed explanation of the cloud detection process

As mentioned above, a 6 step cloud detection algorithm is performed. Each step is applied for each pixel and all static input data, i.e. threshold value, variable, constant. can be modified. The test results of steps 3 and 5 express whether it passes as flag and later it defines as test flag. Test flags of test 1a to test 1b and test 3a to test 3c are classified as 'test failed', 'cloud detected, 100 % confidence', 'clear scene, 100 % confidence'. Test flags for the other all tests are classified as 'test failed' and 'cloud detected'.



Test1a if $Ref_{0.6}$ > THR_MAX : "CLD(100%)" else if $R_{0.6}$ < THR_MIN : "CLR" else : "test failed"	**Test1b** if $Ref_{3.75}$ > THR_MAX : "CLD(100%)" else if $R_{3.75}$ < THR_MIN : "CLR" else : "test failed"	
Test2 if $Ref_{0.6}$ - $Ref_{3.75}$ > THR : "CLD" else : "test failed"		
Test3a if $Tb_{3.75}$ > THR_MAX : "CLR" else if $Tb_{3.75}$ < THR_MIN : "CLD(100%)" else : "test failed"	**Test3b** if $Tb_{10.8}$ > THR_MAX : "CLR" else if $Tb_{10.8}$ < THR_MIN : "CLD(100%)" else : "test failed"	**Test3c** if $Tb_{12.0}$ > THR_MAX : "CLR" else if $Tb_{12.0}$ < THR_MIN : "CLD(100%)" else : "test failed"
Test4a if $Tb_{10.8}$ - $Tb_{3.75}$ > THR_MAX or $Tb_{10.8}$ - $Tb_{3.75}$ < THR_MIN : "CLD" else : "test failed"	**Test4b** if $Tb_{10.8}$ - $Tb_{6.75}$ < THR : "CLD" else : "test failed"	**Test4c** if $Tb_{10.8}$ - $Tb_{12.0}$ > THR : "CLD" else : "test failed"
Test4d if $Tb_{12.0}$ - $Tb_{3.75}$ > THR_MAX or $Tb_{12.0}$ - $Tb_{3.75}$ < THR_MIN : "CLD" else : "test failed"	**Test4e** if $Tb_{12.0}$ - $Tb_{6.75}$ < THR : "CLD" else : "test failed"	

Test5a if std_$Ref_{0.6}$ > THR and $R_{0.6}$ > mean_$R_{0.6}$: "CLD" else : "test failed"	**Test5b** if std_$Tb_{3.75}$ > THR and $Tb_{3.75}$ < mean_$Tb_{3.75}$: "CLD" else : "test failed"	**Test5c** if std_$Tb_{10.8}$ > THR and $Tb_{10.8}$ < mean_$Tb_{10.8}$: "CLD" else : "test failed"	**Test5d** if std_$Tb_{12.0}$ > THR and $Tb_{12.0}$ < mean_$Tb_{12.0}$: "CLD" else : "test failed"

Test6
if $Tb_{3.75}$ - $Tb_{10.8}$> THR : "CLD"
else : "test failed"

Fig. 1.Detailed schematic diagram for cloud detection tests and automatic quality control procedure.

3.3.1. Step 1: clear sky reflectance and brightness temperature estimation

Test 1's Single channel reflectance threshold test performance and single channel brightness temperature test used the dynamic threshold value. This dynamic threshold value determines the threshold value for leaving margin of a certain amount using the value in clear sky conditions. Therefore, the estimating process requires reflectance and brightness temperature of clear sky. First, clear sky reflectance obtains the minimum reflectance using the same observation time data of previous 15 days and uses the reflectance. This process is performed by the post-processing of CMDPS. The cloud detection module was developed to use the data in post-processing.

Meanwhile, the clear sky radiance for IR channels is used as simulation data by the Radiative Transfer Model. RTM simulation uses the current Global Data Assimilation and Prediction System (GDAPS) prediction fields in CMDPS pre-processing. The pre-processing module is retrieved every 3 hours using the latest input GDAPS prediction fields. It performs temporal and spatial interpolation for time fitted with processing data depending on regular schedule and processing of the pixel data. In this step, the estimated reference value in clear sky directly affects determination of threshold value of cloud detection test. The accuracy of the estimated value is affected the largest cloud detection. The study of cloud detection will improve accuracy studies retrieved in clear sky conditions. The management for binary data and RTM performing process in the operation is required.

3.3.2. Step 2 : Sun zenith angle test

Cloud detection tests depend on the existence and non-existence of clouds using visible rays. The existence and non-existence of clouds is tested using sun zenith angle of test pixels. We classify the local time Of Each pixel using Sun zenith angle as follows.

a. Day : sun zenith angle is smaller than 85° or is equal

b. Night : sun zenith angle is bigger than 85° or is equal

c. dawn or twilight : sun zenith angle exist between two threshold values.

The sun zenith angle test was implemented using the same day/night test results in the previous CMDPS data processing module.

3.3.3. Step 3 : Channel use possibility test and data quality test

Cloud detection is required to assure accuracy of input data in CMDPS products. The problem for COMS Level 1B data can happen that is suspended by error for the performance in the whole CMDPS data processing flow in the case of problem of one pixel. First, it performs the test for channel value to prevent the problem. It performs several tests to determine channel availability. Channel values are tested to be within the maximum and minimum value and consist of five channels in daytime and four channels at night, maintaining for the consistency of neighboring pixels. This was also included within the cloud detection module in the first development step, but was separated to affect the whole data processing. In the first part of CMDPS data processing is modified to jointly use for processing.

3.3.4. Step 4 : Threshold value determination

The determination process of threshold value is important, because cloud detection in CMDPS is performed through the threshold test. Using a regular threshold value without observation conditions depends on the properties of the test to improve the threshold value test (static threshold) and change with observation conditions. For static threshold value, applying physical value does not change during the satellite's operation period. On the other hand, dynamic threshold value changes all the time depending on observation frequency during the operation period. Therefore, dynamic threshold value must be adjusted to fit in observation conditions.

A. Threshold value determination for Test1a, Test1b.

The reflectance tests (test1a~b) compare with reflectance and threshold value of the pixel unit of $VIS_{0.6과}$ $TB_{3.75\_sol}$ (the derived value of converting radiance to reflectance of the observed SWIR3.75㎛ in existing solar effect). The process estimates the SWIR channel solar reflected component using the method of Setvak and Doswell (1991). When the earth's surface temperature in the SWIR channel is the same as IR channel $Tb_{10.8,}$ It induces the emitted component using an assumption of emitting energy. Clear sky reflectance information updates using clear sky reflectance in the pixel unit of two channels. It obtains the clear sky reflectance (CSref) value extracting the minimum value for pixels using relevant observation time and the same prior 15 days data. Clear sky reflectance is usually determined by surface properties. It is supposed that the change of surface properties is not big during a 15 days period. In the case of the spring and fall season, errors around twilight zone is the possibility, because sun zenith angle changes in the same pixel. Also, reflectance value is affected by sun zenith angle. It is used to correct for sun zenith angle in both channel and clear sky reflectance value in order to apply to cloud detection test. Threshold value using reflectance test adds the constant margin with previous clear sky reflectance.

(1) $THR\_Test1a\_MAX_{vis} = CSRef_{vis} \times refl\_test1a\_add\_max$

(2) $THR\_Test1a\_MIN_{vis} = CSRef_{vis} \times refl\_test1a\_add\_min$

(3) $THR\_Test1b\_MAX_{swir} = CSRef_{swir} \times refl\_test1b\_add\_max$

(4) $THR\_Test1b\_MIN_{swir} = CSRef_{swir} \times refl\_test1b\_add\_min$

B. Threshold value determination for Test 2

Threshold value is induced as following equation:

$$THR\_Test2 = a_{0,2} + Ref_{vis} \times a_{1,2} \quad (4.5)$$

Where, Ref_{vis} is reflectance in visible channel, the coefficients $a_{0,2}$ and $a_{1,2}$ have different values for ocean and land.

C. Threshold value determination for Test 3a – Test 3c

Single channel brightness temperature test from Test 3a to Test 3c uses clear sky brightness temperature for SWIR3.75㎛, IR10.8㎛, IR12.0㎛ channel. Threshold value is determined from Tb obtained in step 1.

The final threshold value is induced as follows.

(1) Oceans

$THR\_Test3a\_MAX = CSTb_{3.75} - temp3a\_sea\_max$

$THR\_Test3a\_MIN = CSTb_{3.75} - temp3a\_sea\_min$

$THR\_Test3b\_MAX = CSTb_{10.8} - temp3b\_sea\_max$

$THR\_Test3b\_MIN = CSTb_{10.8} - temp3b\_sea\_min$

$THR\_Test3c\_MAX = CSTb_{12.0} - temp3c\_sea\_max$

$THR\_Test3c\_MIN = CSTb_{12.0} - temp3c\_sea\_min$

(2) Land

$THR\_Test3a\_MAX = CSTb_{3.75} - temp3a\_land\_max$

$THR\_Test3a\_MIN = CSTb_{3.75} - temp3a\_land\_min$

$THR\_Test3b\_MAX = CSTb_{10.8}$ - temp3b_land_max

$THR\_Test3b\_MIN = CSTb_{10.8}$ - temp3b_land_min

$THR\_Test3c\_MAX = CSTb_{12.0}$ - temp3c_land_max

$THR\_Test3c\_MIN = CSTb_{12.0}$ - temp3c_land_min

D. Threshold determination from Test 4a to Test 4d

Threshold value test of Dual channel brightness temperature from Test 4a to Test 4d use the fixed threshold value as follows:

(1) $THR\_Test4a\_MAX = a_{0,4a} + CSTb_{10.8} \times a_{1,4a} + CSTb_{3.75} \times a_{2,4a}$

(2) $THR\_Test4a\_MIN = b_{0,4a} + CSTb_{10.8} \times b_{1,4a} + CSTb_{3.75} \times b_{2,4a}$

(3) $THR\_Test4b = a_{0,4b} + CSTb_{10.8} \times a_{1,4b} + CSTb_{6.75} \times a_{2,4b}$

(6) $THR\_Test4c = a_{0,4c} + CSTb_{10.8} \times a_{1,4c} + CSTb_{12.0} \times a_{2,4c}$

(8) $THR\_Test4d\_MAX = a_{0,4d} + CSTb_{12.0} \times a_{1,4d} + CSTb_{3.75} \times a_{2,4d}$

(9) $THR\_Test4d\_MIN = b_{0,4d} + CSTb_{12.0} \times b_{1,4d} + CSTb_{3.75} \times b_{2,4d}$

(10)$THR\_Test4e = a_{0,4e} + CSTb_{12.0} \times a_{1,4e} + CSTb_{6.75} \times a_{2,4e}$

Where, CSTb is clear sky brightness temperature estimated for relevant channels obtained in Step 1. The coefficients a0, a1, a2, b0, b1, b2 have different values depending on day/night, land/ocean, day/ocean, day/land, night/ocean, night/land, etc.

E. Threshold value determination from Test 5a to Test 5d

Threshold value of the standard deviation from Test5a to Test5b is arranged into fixed value as follows:

(1) Oceans

THR_Test5a = test5a_sea

THR_Test5b = test5b_sea

THR_Test5c = test5c_sea

THR_Test5d = test5d_sea

(2) Land

THR_Test5a = test5a_land

THR_Test5b = test5b_land

THR_Test5c = test5c_land

THR_Test5d = test5d_land

F. Threshold value determination of Test 6

Threshold value of Test 6 for sunglint regions is induced with related function of Equation (4.6)

$$THR\_Test6 = \max(c_1, c_1 \times CSRef_{vis}/c_2) \quad (4.6)$$

Where, $CSRef_{vis}$ is clear sky reflectance of VIS0.65㎛ of % units. $c_1$and c_2 are parameters to determine threshold value.

3.3.5. Step 5 : Cloud detection and automatic quality test

The test for each time in day/night and dawn/twilight, etc. is performed independently. Each test decides the performance possibility or impossibility depending on the fixed determination factor. The threshold test is performed as follows:

A. Detailed explanation of threshold value tests.

(1) Test 1

If the reflectance of the VIS 0.65㎛ channel corrected sun zenith angle is larger than THR_Test1a_MAX, it classifies as cloud pixels, it is flagged as ‘cloud detected, 100 % confidence'. The same rule is applied for Test1b. If the reflectance of VIS 0.65㎛ channel corrected sun zenith angle is smaller than THR_Test1a_MIN, it classifies as clear sky pixels, it is flagged as ‘clear scene, 100 % confidence'.

(2) Test 2

If VIS 0.65㎛ - SWIR 3.75㎛ reflectance difference value is larger than THR_Test2, it classifies as cloud sky. It is flagged as ‘cloud detected'.

(3) Test 3

If the brightness temperature of SWIR 3.75㎛ is larger than THR_Test3a_MAX, it classifies as clear sky. It is flagged as ‘clear scene, 100% confidence’, Test 3b and Test 3c have the same rule applied. If the brightness temperature of SWIR 3.75㎛ is smaller than THR_Test3a_Min, it classifies as cloud. It is flagged as ‘cloud detected, 100% confidence’, Test 3b and Test 3c have the same rule applied.

(4) Test 4

If the Brightness temperature difference of IR 10.8㎛ and SWIR 3.75㎛ in Test 4a is larger than THR_Test4a_MAX or smaller than THR_Test4a_MIN, it classifies as cloud. It is flagged as 'cloud detected'. Test4d is has the same rule applied. If brightness temperature difference of IR 10.8㎛ - WV.75㎛ in Test 4b is smaller than THR_Test4b, it is flagged as 'cloud detected'. Test 4e has the same rule applied. If brightness temperature difference of IR 10.8㎛–IR 12.0㎛ in Test 4c is larger than THR_Test4c, it is flagged as 'cloud detected'.

(5) Test 5

This test is applied in 3x3 pixel region, but in case of including the boundary of land and ocean do not perform this test. If the standard deviation for reflectance of VIS 0.65 is larger than THR_Test5a, the observed reflectance is larger than the average of 3x3 pixels. It is flagged as 'cloud detected'. If the standard deviation for reflectance of SWIR 3.75 is larger than THR_Test5a, the observed reflectance is smaller than the average of n x n pixel region. It is flagged as 'cloud detected'. Test 5c has the same rule applied.

(6) Test 6

If the standard deviation for reflectance of SWIR 3.75㎛ - IR 10.8㎛ is larger than THR_Test6b, it is a cloud pixel. It is flagged as 'cloud detected'

A. Application of threshold test

As described above, each threshold test is performed independently. First cloud detection is initialized It perform differently the application in the observation times.

(1) daytime

(a) sunglint region classification

The relevant pixel locates above surface of water such as lake or ocean.

ABS($\cos^{-1}$(cos(sol_zenith)×cos(sat_zenith)-sin(sol_zenith)×sin(sat_zenith)×cos(relative_azimuth)))value is smaller than sgl criteria threshold value. The current threshold value uses 15^{o}.

In the case of classified with sunglint performs Test2, Test3b, Test3c, Test4b, Test4c, Test4e, Test5c, Test5d, Test6.

(b) In the case of non-sunglint region performs Test1a, Test1b, Test2, Test3a-Test3c, Test4a-Test4e, Test5a-Test5d.

(c) Test1b, Test2, Test3a, Test4a, Test4d use reflectance and solar emitted components of the dual SWIR 3.75㎛ channel, sun zenith angle above 60°. It has rather high reflectance in process of component analysis. For this reason, it has a relatively low brightness temperature. This does not apply for the region above 60°and below 80°. The Reflected component in the process of Multi-functional Transport Satellite-1 Replacement(MTSAT-1R) High-Rate Information Transmission (HRIT) data is almost 0 of decreasing around sun zenith angle 70°. In the case of dawn/twilight set up that do not perform the test for Test1a, Test1.

(3) In the case of nighttime performs Test3a-Test3c, Test4a-Test4e, Test5b-Test5d using IR channels. Therefore the flags of each threshold value test for cloud detection are determined to designate whether the test performs due to use possibility of observation data or data result use of the previous observation time, each test performance.

If the test is performed, test flag know that clouds are detected by some test. If it uses the result of the previous observation time, test flag is determined in the same with the previous time. This flag test is newly added and can reflect later improvements. The automatic quality test is applied to identify cloud pixels, because cloud detection algorithm was designed to emphasis on whether clear sky test pixels exist. The test for the next test flag applies to all pixels.

a. If the 'cloud detected, 100 % confidence' or 'cloud detected' test flags are not identified, and not in a sunglint region with a 'confidently clear' quality flag, the cloud detection results represent clear pixels.

b. If the 'cloud detected, 100 % confidence' or 'cloud detected' test flags are not identified, and not in a sunglint region with a 'probably clear, sunglint' quality flag, cloud detection results represent ‘clear’.

c. If there is at least one 'cloud detected, 100 % confidence' test flag, it determines a quality flag with 'confidently cloudy', and cloud detection results represent ‘cloudy’.

d. If there is at least one 'cloud detected, 75 % confidence', and there are no 'cloud detected, 100 % confidence' test flags, it determines a quality flag with 'cloudy' or the cloud detection results represent ‘cloudy’.

e. If there are no with 'cloud detected' or 'cloud detected, 75% confidence' or 'cloud detected, 100 % confidence' test flags, it determines a quality flag with 'probably cloudy', represented by 'cloudy'

This algorithm determines cloud detection results and quality flags through the Automatic Quality Control (AQC) process. AQC is the process of gathering performance results of other tests according to time. The relevant condition and threshold value tests have a complex relationship with each cloud detection result used by it. Therefore, it exactly understands to the basic concept of AQC process and threshold value is determined. Later products need to adjust the AQC process in order to retrieve significant quality flags to use.

To determine threshold value, accurately collocated cloud training data is required. This data analyzes real images in the image analyzer. The data judging the existence or non-existence of clouds will be very useful. It will be able to use MODIS cloud detection data, and temporal and spatial collocation data.

As described above, training data must be included to calculate the threshold value for each test. For example, using channel reflectance and single channel brightness temperature tests must include clear sky reflectance and brightness temperature.

For example, the parameter (refl_test1a_add_max) deciding threshold value of Test1a is decided to judge for 100% contaminated clouds using whether clear sky reflectance $CSRef_{vis}$ and pixel reflectance, and the pixel contaminated or not. The other way, refl_test1a_add_min is 100% clear sky.

3.4. Validation

3.4.1. Validation method

To validate the cloud detection results, it applies the statistic validation technique proposed by the validation technique of binary variables in CMDPS. The true value of cloud detection to compare with CMDPS cloud detection results are classified in Table 1. These obtain the validation score for POD, FAR, PSS, and HSS. Using the true value of cloud detection is the result of MODIS cloud detection and is explained in detail in the next section.

Table 1. Contingency table for validation of cloud detection result.

MODIS / CMDPS	Cloudy	Clear	TOTAL
Cloudy	A	b	a+b

Clear	C	d	c+d
TOTAL	a+c	b+d	a+b+c+d=n

① PC (Proportion Correct, Accuracy) = $\frac{a+d}{n}$

② POD (Probability of Detection) = $\frac{a}{a+c}$

③ FAR (False Alarm Rate) = $\frac{b}{a+b}$

④ PSS (Peirce's Skill Score, true skill statistic, Hanssen and Kuipers discriminant)= $\frac{ad-bc}{(a+c)(b+d)}$

⑤ HSS (Heidke Skill Score, Cohen's k)

$$= \frac{PC-E}{1-E}, \quad \text{where} \quad E=\left(\frac{a+c}{n}\right)\left(\frac{a+b}{n}\right)+\left(\frac{b+d}{n}\right)\left(\frac{c+d}{n}\right)$$

3.4.2. Validation data

The validation for cloud detection is generally not easy (Ackerman and Cox, 1981; Rossow and Gander, 1993). There are two types of cloud detection validation using image interpretation and quantitative analysis. Image interpretation uses the image analysis method and composite images for the channel and temporal and spatial properties. Cloud detection data will constantly be retrieved. Images are analyzed based on knowledge and experience of the cloud and surface channel properties. This visual image interpretation has difficulty providing quantitative assessment.

Quantitative validation can be done by comparing cloud detection results and direct pixel units obtained in ground observation such as Lidar or sensors on board other satellite. This validation method can provide the quantitative accuracy. However, the two types of observation data have different observation properties for cloud. Problems include the uncertainty in process of generating temporal and spatial collocation data (Baum et al., 1995). Despite this limitation, the validation method for monitoring CMDPS cloud detection accuracy is compared with cloud detection results retrieved in MODIS data. The MODIS group officially provides cloud detection results. The result using Terra/MODIS(Aqua/MODIS) data is MOD35 (MYD35). This study acquires data from Level 1, Atmospheric Archive, and the Distribution System (LAAD) webpage of the Goddard Space Flight Center (GSFC) at the National Aeronautics and Space Administration (NASA) to acquire near real time data.

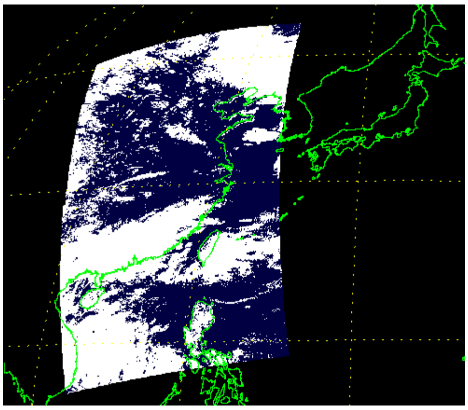
3.4.3. Temporal and spatial collocation method

MODIS provides data with 5 minutes observation units (granule). The horizontal resolution of cloud detection data is 1km. Cloud detection results are divided into four steps (confident clear, probably clear, undecided, cloudy). The First step for validation of cloud detection is temporal and spatial processing. Cloud consider for shape relatively changing a great for short time. It selects MODIS data observed within 10 minutes based on COMS observation time. COMS observation resolution is 4km. The spatial collocation uses the neighboring 5x5 pixels in selecting the nearest MODIS pixel in latitude and longitude positions of COMS observation pixel.

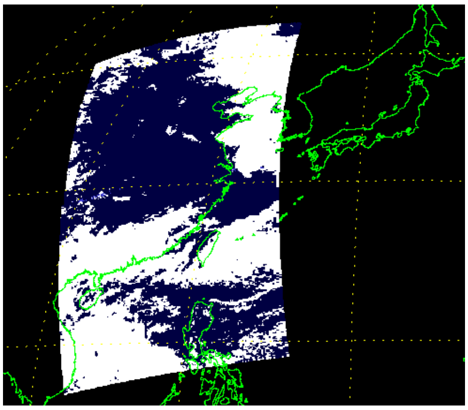
MODIS data strictly judges the clouds. This study classified 4 steps for cloud detection. The first step present as cloud for pixel decided into cloudy. Confident clear, probably clear, and undecided classify with clear sky. If the cloud pixel ratio within the relevant 5x5 pixels accounts for more than 50%, the true value of the pixel is defined as cloud pixel, the other way it performed the comparison that determines as clear pixel. This temporal and spatial collocation data is used for validation to generate within SZA 60°.

3.4.4. Validation result analysis

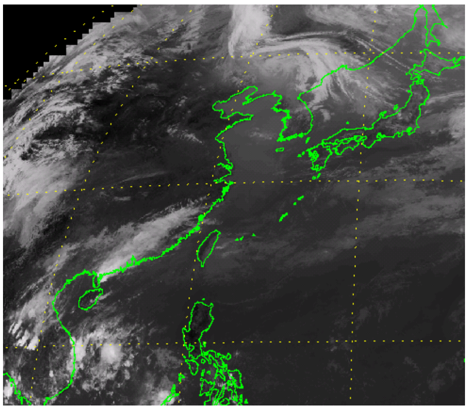
Fig.2 shows the result for 0533UTC on April 7, 2006 and 0033UTC on August, 8, 2006 using the described validation method. First of all, Fig.2 on April 7, 2006. Fig.2-a) is the result of CMDPS cloud detection applying 0533 UTC MTSAT-1R data. Fig.2 c) and d) are IR and VIS channel image of MTSAT at the same time. Fig. 2 b) shows that 0530 UTC and 0535 UTC before and after 0533UTC in MTSAT-1R observation time composes two MODIS cloud detection (granule) data of 5 minute intervals in initial observation time. The CMDPS cloud detection algorithm relatively detects many clouds in the China inland areas, but MODIS presents that generally detect many clouds in the ocean. Also, In the case of CMDPS algorithm, Luzon islands in the Philippine mostly show that cloud are overestimated.



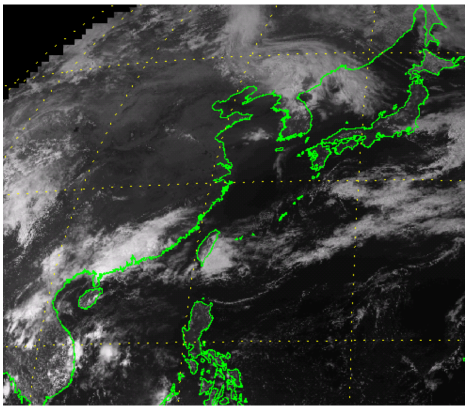
a) CMDPS CLD



b) MODIS CLD

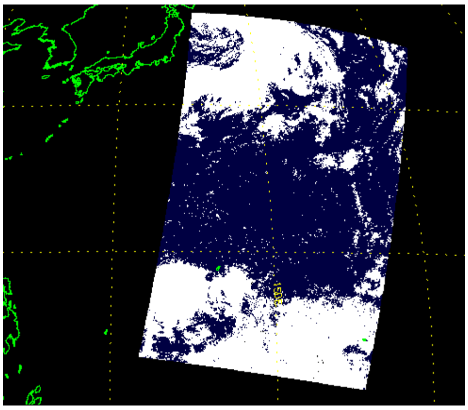


c) MTSAT-1R IR channel imagery

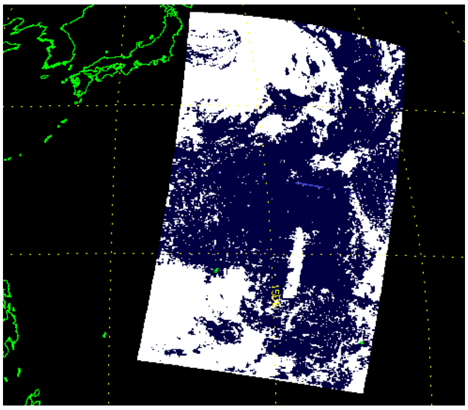


d) MTSAT-1R Visible channel imagery

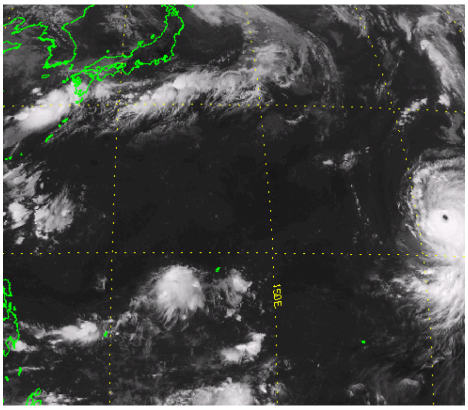
Fig. 2. Comparison of cloud detection results between the CMDPS algorithm using MTSAT-1R (0533UTC on April 7, 2006) and MODIS (0555UTC on the same day) (a and b, upper panel). c and d represent infrared and visible imagery of MTSAT-1R, respectively.



a) CMDPS CLD



b) MODIS CLD



c) MTSAT-1R IR channel imagery

d) MTSAT-1R Visible channel imagery

Fig. 3. Same as Fig. 2, except for 0033 UTC on August 31, 2006.

Fig. 3 shows the comparison of images for 0033UTC on August 31, 2006. This is the marine region southeast of Japan. The overall cloud detection pattern is similar. CMDPS algorithm for 0033UTC on August 31 underestimates a little more the clouds than MODIS algorithm. The region showed the difference of the obvious cloud detection is cloud detection region of CMDPS algorithm for long stretches of cloud region to north-south direction of MODIS cloud detection middle portion right-hand corner region.

Clouds detected by sunglint in both CMDPS and MODIS are different for the observation location properties of the two satellites. In most MODIS observation, sunglint presents in the central part of the observation path in the daytime ocean. In geostationary satellite data, sunglint regions are present around the equator.

The retrieved validation score for the two cases is shown in Table 2. If we look at the results, PC meaning the overall cloud detection accuracy shows detection rate about 80% in the two cases. Meanwhile, about 21% of FAR in pixels was detected from clouds. If this numerical value considers the properties of cloud detection, accuracy is not high. The image with the error of pure cloud detection algorithm will be analyzed for the error effects according to the observation property of two satellites.

Table 2. Preliminary validation results for the CMDPS cloud detection algorithm. For calculation of validation scores in this table, MODIS cloud detection output is considered as an true value.

a) 0533 UTC, April 7, 2006 Case	b) 0033 UTC, August 31, 2006 Case

CMDPS / MODIS	Cloudy	Clear	TOTAL
Cloudy	92931	24931	117863
Clear	26570	98561	125131
TOTAL	119502	123492	242994

CMDPS / MODIS	Cloudy	Clear	TOTAL
Cloudy	105142	28868	134010
Clear	31094	146931	178025
TOTAL	136236	175799	312035

DATE	PC	POD	FAR	PSS	HSS
20060407 0533 UTC	0.7881	0.7777	0.2115	0.5758	0.5759
20060831 0033 UTC	0.8078	0.7718	0.2152	0.6076	0.6087

In order to see the validation results for long periods, it showed using the primary test operation result of CMDPS on November, 2007 performed in CMDPS pre-processing, post-processing and the interface development process (Table 3). The test operation period is the result of 24 days from November 1 to November 24, 2007. MTSAT-1R HRIT data was used. The accuracy of the developed CMDPS cloud detection algorithm is greater than 80%. POD of the detection performance in real cloud pixels presents more than 83%, FAR in clear sky present is about 13%. Additional analysis results of daily validation score was able to recognize that the sable validation score was stably retrieved.

Table 3. Validation result for cloud detection during CMDPS pre- and post-processing and interface development program first operation test period (Nov. 1 - 24, 2007)

Reference data	Validation result (period : November 1 - 24, 2007)				
	PC	POD	FAR	PSS	HSS
MOD35	0.820	0.852	0.137	0.614	0.608
MYD35	0.805	0.819	0.133	0.592	0.579

The validation consistently adjusted the algorithm and threshold value based on this result. It showed for the test operation of three times and the validation result of final near real time operation in Table 2.3.8. In the case of secondary test operation, hit rate results weakly adjusted threshold value in order to reduce False Alarm by overestimated detection caused from falling result. Finally, the cloud detection hit rate of performed results applying quality information described by current algorithm for the final operation test improved more that 88%, and False Alarm improved until 12~13% level.

Table 4. Validation results for cloud detection during CMDPS operation test periods.

	1st Ops. Test		2nd Ops. Test		3rd Ops. Test		Final Ops. Test	
ref. data / score	PC	POD	PC	POD	PC	POD	PC	POD
PC	0.820	0.805	0.784	0.788	0.809	0.804	0.839	0.822
POD	0.852	0.819	0.755	0.777	0.839	0.838	0.880	0.881
FAR	0.137	0.133	0.090	0.093	0.116	0.122	0.124	0.127

4. Interpretation method of retrieval results

if we look at the accuracy of other satellite and cloud detection accuracy of algorithm in order to interpretation and improvement purpose setting of results for CMDPS cloud detection accuracy, in the case of MODIS cloud detection, PC is 83%, POD 80,9%, FAR 14.3%. It obtained similar accuracy to CMDPS. Dybbroe, et.al (2005) showed that cloud detection accuracy by using Advanced Very High Resolution Radiometer (AVHRR) of EUMETSAT Satellite Application Facility NoW-Casting (SAF) is 94.2% of POD and 28.5 of FAR. The performance detected from real clouds is 94.2%, but False Alarm ratio with the number of real clear sky pixels in pixels detected from real cloud is 28.5%, it can estimate that is excessively detected the clouds. Meanwhile, SAFNW suggested data validation results for a year produced using the MSG Spinning Enhanced Visible and Infrared Imager (SEVIRI) (EUMETSAT, 2005). The data used for validation retrieved 708,797 collocation data on 5x5 pixels average for satellite data of the nearest time and location using hourly data of the synoptic observation area of World Meteorological Organization (WMO) ground observation data.

The validation results were compared with the cloud detection algorithm of SAFNWC and the EUMETSAT Meteorological Product Extraction Facility (MPEF). The proposed results showed the that PC, POD, FAR values in the SAFNW algorithm are 95.0%, 95.0%, and 5.0%, and 90.2%, 88.4%, and 6.2% in the MPEF algorithm, respectively. This value was retrieved using 12 channels of SEVIRI data. It is possible of attainment for the accuracy in satellite with five channels such as COMS, but we will have to exert to have the retrieval accuracy above. Meanwhile satellite zenith angle is retrieved average value of global image within 60° in order to retrieve the quantitative validation score in CMDPS. The validation score has meaning in terms of quantitative value. Image analysis procedure for detail analysis and improvement of algorithm is certainly required. The region mainly generated the error will be reinforce the individual test method and improvement of automatic quality test routine of cloud detection through analysis whether detected low cloud area and cirrus area, located in land and ocean, day and night.

5. Problems and possibilities for improvement

CMDPS cloud detection data is consisted of the algorithm suitable to MTSAT-1R HRIT data. The main data used for estimating Clear sky radiance is retrieved to perform Radiative Transfer for the TIROS Operational Vertical Sounder (RTTOV) RTM as input data GDAPS data. Clear sky radiance estimated in this process is affected greatly by land surface temperature of NWP prediction fields. In the case of GDAPS, the accuracy of its information does not show satisfactory results. For example, climate values for snow covered regions in NWP in winter input regular as each month. As a result, in the boundary of snow covered regions consistently shows a tendency to represent the discontinuity for clear sky radiance. Simulated value in the plateau and Australia desert regions has a relatively large error compared with real satellite observation values. The clear sky radiance estimating process error can induce a fatal error detecting cloud pixels. Using previous observation data or clear sky radiance (CSR) products to complement it is comprised in program development. The composition for the larger time to reduce missing value needs to give attention to happen for change of season with spring, autumn. Because the clear sky reference value is possible to happen that it does not represent the current properties. Use of RTM and clear sky radiance observed in satellite apply the pros and cons, the optimal solution plan remains a take of one leave in the future. The regions with the highest errors in the developed CMDPS cloud detection data are the Australian desert, snow cover in high latitudes, and plateau regions. The errors occur in estimating clear sky radiance by RTM. In the Australia region, the detection error was due to high reflectance. Clear sky reflectance using the single channel reflectance test does not use RTM. It uses the minimum reflectance value in observation data of the same time during the previous 15 days. It theoretically expects that does not have a large error. If we look at performance results of cloud detection, it can often look the detected result as 50 % cloudy. This problem is somewhat remediable through continuous studies, but in the case of performing for

CMDPS cloud detection, stable security of the previous 15 days data must be guaranteed. In the study, Data utilization for the previous 15 days is operated in real time using algorithm of cloud amount retrieval of the whole sky using MTSAT-1R, but in this case, an hour's error have experienced, is the chief factor in the error in the 15 day retrieval results.

Cloud detection discontinuity is another error in the boundary point between day/night, dawn regions. It applies for adjusting threshold value into a way minimizing the discontinuity of day and night cloud detection results. The discontinuity in cloud quality information of the automatic quality performance results by the difference of individual tests performed by each condition still exists. In future, the effort of solving for the discontinuity to utilize primarily the quality information of cloud detection will be progressed. In spite of the studies of many years and effort of COMS prelaunch accuracy improvement, the worst region for cloud detection performance is the dawn region In twilight regions, it is limited to utilizing solar light channels of visible and SWIR channel. Low cloud and fog detection is very difficult. It is difficult to detect cirrus with thin optical thickness using five channels. Cirrus greatly affect the energy budget of earth and it is very important in the climate research field. Thin cirrus does not clearly present in the visible channel. In spite of the very low temperature, emitted energy in a lower surface is transmitted in IR channels. This often happen that cloud detection fails due to the relative brightness temperature. The channels used to complement the difficulty are water vapor absorption bands of 1.38㎛ or 1.83㎛ in daytime. The channel used both in the daytime and nighttime is 8.7㎛. This channel uses the properties of the different reflective index in water and ice phases. In the future, for the improvement of cloud detection in the satellite development, the satellites on board additional channels are acutely required.

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Appendix :

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