Outlined Algorithm Theoretical Basis for MTSAT visible Calibration for GSICS (Liquid cloud method)

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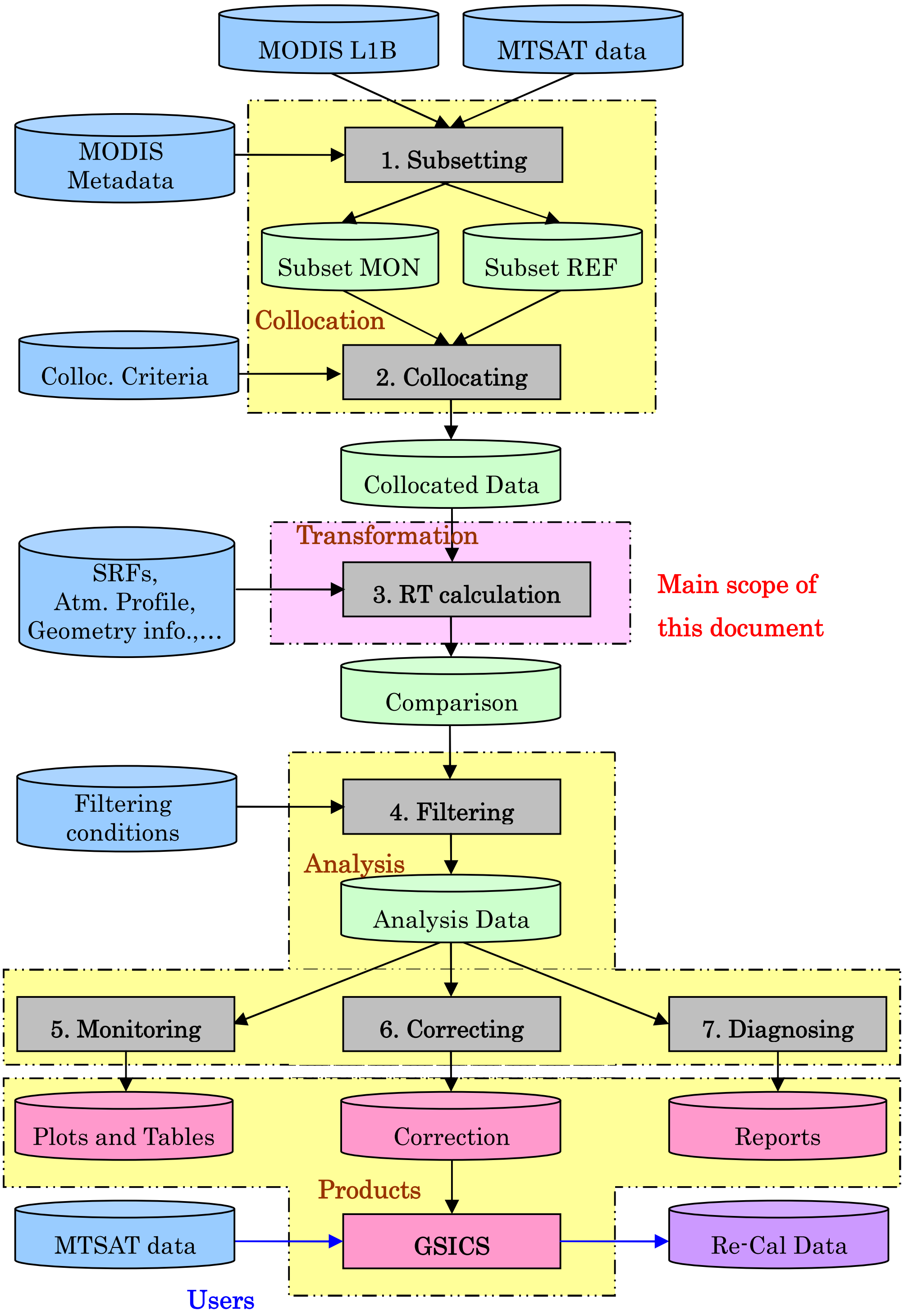
Overview

The Meteorological Satellite Center examines vicarious calibration for geostationary satellite visible channel. This type of calibration is intended to rebuild visible calibration coefficients, and its approach relies on radiative transfer calculation. Reflectivity at each observed location is simulated under atmospheric and geometric conditions corresponding to those of satellite observation. Calibration coefficients are computed using regression analysis for an appropriate number of pairs of observed and simulated reflectivity values.

Radiative transfer calculation requires atmospheric profiles, aerosol and cloud optical parameters, and observation geometry information. The input data are created from JMA's NWP model (JCDAS: JMA Climate Data Assimilation System) data, Total Ozone Mapping Spectrometer (TOMS) ozone amount data, and Moderate Resolution Imaging Spectroradiometer (MODIS) L1B data.

The calibration approach utilizes three types of targets, cloud-free ocean surface, cloud-free land surface and spatially uniform liquid cloud top as dark, medium and bright targets, respectively. This document mainly focuses on outline of the radiative transfer calculation step for liquid cloud top target. Brief methodology and preliminary uncertainty analysis are shown in the following sections.


MODIS L1B
MTSAT data
MODIS Metadata
1. Subsetting
Subset MON
Subset REF
Collocation
Colloc. Criteria
2. Collocating
Collocated Data
Transformation
SRFs, Atm. Profile, Geometry info.,...
3. RT calculation
Main scope of this document
Comparison
Filtering conditions
4. Filtering
Analysis
Analysis Data
5. Monitoring
6. Correcting
7. Diagnosing
Plots and Tables
Correction
Reports
Products
MTSAT data
GSICS
Re-Cal Data
Users

Methodology for liquid cloud target

Target selection

To reduce the uncertainty of the vicarious calibration, radiative transfer calculation should be performed for a spatially uniform and temporally stable area. An observed image is separated into grids of 0.05 by 0.05 degrees, and simulation is examined only for uniform and stable grids. Such grids are referred to as "targets" here, and should cover a wide range of radiances to obtain a reliable regression line. Targets are limited only over ocean area.

If solar or satellite zenith angle is less than pre-determined thresholds in a grid, the grid is included in further analysis. Likewise, cloud optical thickness check and cloud top temperature check are examined for each grid to find target.

Simulation

Radiative Transfer Code

RSTAR, developed by the Atmosphere and Ocean Research Institute at the University of Tokyo (Nakajima and Tanaka, 1988), is employed as the radiative transfer code. It requires information on atmospheric profiles, total column ozone amount, surface reflectivity, optical parameters of scattering particles and viewing geometry. The inputs for radiative transfer calculation should be independent of the monitored satellite data. In this approach, therefore, the atmospheric profile and ozone amount are based on JMA NWP model data and Earthprobe/TOMS data, respectively. Scattering objects are cloud particles. The optical parameters of scattering particles are retrieved from MODIS L1B data. For cloud target, no aerosol is assumed. Simulation conditions are shown on Table.1.

Table 1. Input factors to radiative transfer calculation for liquid cloud target

Input factors	Source
Atmospheric profile - temperature - pressure - water vapor - sea surface wind speed	JMA NWP data (JCDAS)
Ozone amount	NASA Earthprobe/TOMS product
Cloud optical parameters - Optical thickness - Effective radius	Retrieved from MODIS L1B by a cloud analysis package

Cloud optical parameters retrieval

Cloud parameters such as optical thickness and effective radius are dominant factors for liquid cloud target. These parameters are retrieved from Terra/MODIS L1B data using a cloud analysis package, CAPCOM (Nakajima and Nakajima, 1995). CAPCOM computes cloud optical parameters from three channels of satellite data — visible, near-infrared and infrared. This approach utilizes MODIS bands 1, 20 and 31.

NASA's MODIS cloud products (e.g. known as MOD06) are alternatives to CAPCOM- retrieved cloud parameters as simulation input data. However, the radiative transfer code used to retrieve the cloud properties from MODIS L1B and that used to calculate simulated radiance should be consistent to ensure accurate simulation. As the radiative transfer algorithm included in CAPCOM is the same as that of RSTAR, this calibration approach adopts CAPCOM-retrieved cloud parameters instead of NASA's MODIS cloud product.

Regression

The simulated radiance is compared with the MTSAT nominal radiance. When calibration coefficients, C_0 and C_1, are defined in equation (1), linear regression coefficients by the comparison of simulated and nominal radiances give calibration coefficients.

$$\text{Radiance (calculated)} = C_0 + C_1 * \text{Radiance (nominal)} \qquad (1)$$

Validation

Accuracy of the radiative transfer calculation

To estimate the accuracy of this approach, the simulated radiance are compared not with MTSAT observed radiance but with Terra/MODIS radiance. MODIS carries onboard calibrators, which makes the observation data well calibrated and reliable. The input factors for the radiative transfer calculation are the same as those for the simulation for MTSAT, e.g., aerosol and cloud optical parameters retrieved from MODIS L1B.

Figure 1 shows a match-up between the MODIS band 1 observed radiance and the simulated radiance. In addition to the result for liquid cloud target, other two targets, cloud-free ocean and land are plotted just for reference. The error between the both radiances is less than 1% in average, which indicats that the methodology is sufficiently reliable.

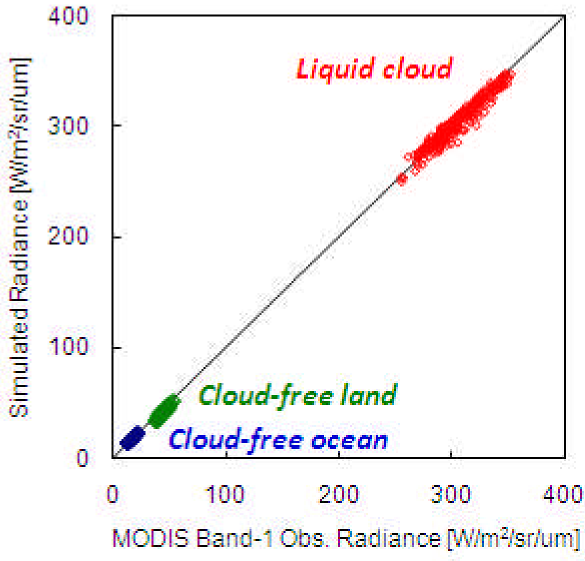


Fig.1 Match-up between simulated radiance and Terra/MODIS band 1 observed radiance. The slope of the regression line is 1.00 and the bias is almost zero. The radiative transfer code can simulate MODIS observed radiance with an error margin of less than 1%.

Error budget of simulation

Separately of the last section, simulated radiance uncertainty is estimated based on random error of input factors to radiative transfer calculation. Table 2 shows an error budget for a month. We can find that the dominant factor is the retrieved cloud optical parameters.

Table 2 Random error uncertainty of input parameters to radiative transfer calculation and simulated radiance. These figures are based on a case of January 2011.

Factor	RTM input parameter	Typical uncertainty	Radiance uncertainty [%]
Solar and sensor geometry	Sat zenith angle	0.2 deg	0.2
	Solar zenith angle	~ 0 deg	~ 0
	Relative azimuth ang.	0.2 deg	0.2
Atmospheric profile	Ozone	2 %	0.1
	Water vapor	Assumed 30 %	0.2
Surface	Sea surf. wind speed	Assumed 30 %	~ 0
Cloud parameters	Optical thickness	8%	3.8
	Effective radius	4%	
Total			(RSS) 3.8

Reference

Okuyama, A., Toru Hashimoto, Ryuichiro Nakayama, Yoshihiko Tahara, Toshiyuki Kurino, Hideaki Takenaka, Satoru Fukuda, Takashi Y. Nakajima, Akiko Higurashi, Miho Sekiguchi, Tamio Takamura, Teruyuki Nakajima, "Geostationary Imager Visible Channel Recalibration", 2009 EUMETSAT METEOROLOGICAL SATELLITE CONFERENCE, SESSION 6. Monitoring climate and understanding climate processes with satellites

(RSTAR)

Nakajima, T., and M. Tanaka, (1988) Algorithms for radiative intensity calculations in moderately thick atmospheres using a truncation approximation., J. Quant. Spec. Rad. Trans., 40, pp 51-69

(CAPCOM)

Nakajima, T.Y., and T. Nakajima, (1995) Wide area determination of cloud microphysical properties from NOAA AVHRR measurement for FIRE and ASTEX region., J. Atmos. Sci., 52, pp 4043-4059

The RSTAR and CAPCOM tools are available on the following website of the Atmosphere and Ocean Research Institute at the University of Tokyo.
http://www.ccsr.u-tokyo.ac.jp/~clastr/