Aerosol and Cloud Validation System Based on SKYNET Observations: Estimation of Shortwave Radiation Budget Using ADEOS-II/GLI Data

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Abstract

Using ADEOS-II/GLI aerosol and cloud products, downward and upward solar radiation at the surface and at the top of the atmosphere are estimated to study the Earth radiation budget. There is a good agreement in the main features of the global distribution of radiative fluxes as derived from GLI and from Terra/MODIS, yet, some differences can be noticed and need to be explained. In order to evaluate satellite-retrieved parameters that play a role in the Earth radiation budget, an observational network known as SKYNET has been established in Eastern Asia and it has already been operational during the ADEOS-II/GLI launch. Specifically, observations from the newly developed i-sky radiometer have been used for aerosol and cloud product evaluation. The aerosol products have been found to be in good agreement with observations while the cloud products need further evaluation.

Keywords: GLI, SKYNET, validation, radiation budget

1. Introduction

ADEOS and ADEOS-II are the first Japanese Earth Observing Satellites for collecting global data of the Earth environment including the atmosphere, land, ocean and cryosphere. While the NOAA/AVHRR series have been monitoring the Earth environment using five channels for producing information on aerosols, clouds, vegetation, and SST, ADEOS-II/GLI (Global Imager)1 uses 36 channels in a wavelength range of 0.375 to 12.5µm and allows retrieval of many more products than earlier satellites (http://suzaku.eorc.jaxa.jp/GLI/doc/index.html). ADEOS-II/GLI is similar to the Moderate Resolution Imaging Spectro-radiometer (MODIS) designed and operated by NASA2.

Satellite observations of the Earth environment provide global and periodic data of equal quality, and can also give information on Outgoing Longwave Radiation (OLR) and albedo, which is not directly observed by surface-based observation. For monitoring the Earth environment, ADEOS-II has in addition to the GLI, also the AMSR, ILAS-II, SeaWinds, and POLDER.

Four teams provide standard products from the GLI observations. The atmosphere team provides aerosols and clouds products that serve as inputs to the inference schemes for deriving surface radiation budgets. Therefore, it is important to evaluate such products. The Japan Aerospace Exploration Agency (JAXA) has supported the validation activities of the atmosphere team which operates the SKYNET observational network on aerosol-cloud-radiation in East Asia including the Japanese islands. The brief description of instruments supported by SKYNET can be found in the next section.

The radiation balance of the Earth is a key parameter of the energy budget as discussed in numerous studies (e.g., Zhang et al. 19953, Zhang et al. 20044). Cloud variation and aerosols can strongly affect the Earth climate through modification of...
the energy balance at the top of the atmosphere (TOA) and at the surface, as described in IPCC (2007)\(^1\). In this paper, the validation activity of the GLI atmospheric products is reported on, and results on global scale radiation budgets at the surface and at the TOA, as estimated are presented.

2. SKYNET observational network

2.1 Validation of satellite products

A signal received by a satellite is a radiance scattered, absorbed, and/or reflected by the atmosphere or its boundaries. Atmospheric parameters such as aerosols, clouds, or water vapor can be inferred from the modified signal after interaction with the target material in the atmosphere. Therefore, the retrieval algorithms incorporate a combination of satellite signals/channels, based on the effects of these interactions. The insufficient number of satellite sensor channels required for the retrieval algorithm compels making some assumptions and using ancillary meteorological data which might cause errors in the analysis. Therefore, the retrieved output should be evaluated using reliable information. Such information can also be used for improving the algorithms.

2.2 Validation sites and instruments for GLI atmospheric products

The GLI atmosphere team has analyzed atmospheric parameters of aerosols and clouds, which are affecting the global climate directly and indirectly as pointed out in IPCC (2007)\(^5\). In order to evaluate such parameters, ground-based observations are needed. Several sites have been established in the south-western islands of Japan and Eastern Asia to form a networked known as SKYNET (Fig. 1). The network also monitors atmospheric events in East Asia, such as yellow-sand or anthropogenic aerosols starting from the Asian Continent and transported over the ocean.

The SKYNET observational system (Fig. 2) is of two categories: a basic site and a super site (yellow dots and red dots in Fig. 1). The basic site has only two kinds of measuring instruments, a sky radiometer and radiation instruments (pyranometer and pyrgeometer), which can allow to estimate optical characteristics of aerosols and their radiative effects. The super site has additional instruments, such as a lidar, a microwave radiometer, an integrating nephelometer, and an absorption meter. These instruments can provide additional information on aerosols, clouds and radiation. For example, a combined analysis of aerosols using a lidar and a sky radiometer is a powerful tool for research on long-range transport and its modification of aerosol\(^7\).

The key instrument of the SKYNET is a sky radiometer which can provide information on optical thickness (AOT) and single scattering albedo (SSA) of aerosols by a combined analysis of simultaneous observation of direct and scattered solar radiance. The original type (POM-01) of sky radiometer for aerosol observation has nine channels of 315, 340, 380, 400, 500, 675, 870, 940 and 1020 nm. Unlike a usual sun photometer, a sky radiometer can observe sky brightness in several scattering angles as well as direct solar radiation to provide information on the phase function (scattering pattern) of aerosols. The combined analysis of direct and scattered radiance can give information on the SSA as well as on AOT. The sky radiometer has been installed at all the SKYNET sites, and its enhanced type (POM-02) for cloud observation with two more channels, 1.6 and 2.2 μm at the super sites.

2.3 Validation of aerosols and clouds

Aerosol products are considered as the most important GLI standard products. Figure 3 shows an example of a comparison between the SKYNET estimate of AOT based on the sky radiometer observations and the GLI AOT retrieved using the original standard algorithm ATSK5 (ver.1) (Fig. 3 (a)). The GLI AOT has a bias of more than 0.2 at 500 nm. This difference might be caused by assumptions of the analysis algorithm or the assumed size distribution (i.e., mean radius and standard deviation for log-normal distribution). Therefore, these have been changed with new distribution parameters as derived from the sky radiometer measurements (Fig. 3 (c)). Size distribution of aerosols shows generally wide variation depending on their sources and aging, but there is little information on this parameter from reliable sources, and therefore, the GLI algorithm (ATSK5) assumes the most plausible size distribution parameters. After revising the parameters (ver.2), the agreement has markedly improved, as shown in Fig. 3 (b) however, that is not the case for the
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Sky radiometer
sun photometer
Pyranometer
Pygeometer

Temperature
Humidity

Optical thickness
downward solar radiation
downward terrestrial radiation

single scattering albedo

Angular exponent (Figs. 3 (c) and (d)). This suggests that the satellite estimates of aerosol properties can be affected by additional error sources such as the complex index of refraction and composition and sources of chemical species.

Under this project a new instrument known as i-sky radiometer (POM-02) has been developed for the evaluation of cloud parameters (cloud optical thickness (COT) and effective radius (\( r_e \))). This was accomplished by adding two channels to a traditional sky radiometer (POM-01). The new algorithm exploits the dependence of the difference in optical transmittance between 1.02 \( \mu \)m and 1.6 \( \mu \)m (or 2.2 \( \mu \)m) channels on the cloud optical parameters (COT and \( r_e \)). Therefore, the cloud sensor of the i-sky radiometer points toward the zenith direction for cloud observation after sky scanning for aerosol observation without any dependence on cloud existence.

Figure 4 shows an example of the cloud validation results against the i-sky radiometer (POM-02) observations. The data were collected at the SKYNET Amami-Oshima site during the GLI active period (April to October, 2003) and were synchronized with the GLI over-pass time at the site. Both figures ((a) for COT ; (b) for \( r_e \)) show poor agreement with variations of COT and \( r_e \) for the POM-02 (horizontal axis) being much wider than those from the GLI estimates (vertical axis). The most plausible reason for the discrepancies seems to be the difference of the field of view (FOV) for the two sensors. The minimum size of a GLI pixel is 1 km except for several 250 m channels. The GLI cloud parameters in the standard products are defined as an average over 5 \times 5 pixels (ATSEG : ATmospheric SEGment data). The satellite cloud parameters used in the evaluation are an area-weighted mean of the 3 \times 3 segment data (about 15 km-square region) close to the SKYNET Amami-Oshima validation site, which is.

The POM-02 collects narrow-FOV (e.g., about 2.4 \times 10^{-4} sr) radiances at the zenith direction. To correspond to the satellite resolution, the POM-02 data have been averaged during a period of \(+/-30 \) minutes from the satellite overpass time. The POM-02 observations are every 10 minutes after each aerosol observation, so that the cloud data for comparison are limited. This is a serious drawback for cloud validation because the geometrical and optical characteristics of clouds move and change in time and space and there is a need for rigorously synchronized data in time and space.

Another reason for the discrepancies might be the difference in the estimation principles : the satellite algorithm uses a radiance reflected by clouds, while the ground-based POM-02 uses a radiance transmitted through clouds. For example, when there is a multi-layered cloud including a thin cloud such as cirrus over thick lower clouds, the satellite signal can be partly affected by the top-layered cloud. The ground-based
Both measurements are indirect observation and involve inherent errors originating from the use of different remote sensing techniques. In addition, as pointed out in Dim et al. (2007), horizontal cloud inhomogeneity can also introduce errors in estimation of cloud parameters; the retrieval algorithm for satellite data assumes that clouds are horizontally homogeneous. Because of these reasons, cloud validation poses fundamental issues for ground-based observing systems.

2.4 Summary of validation activity on aerosols and clouds

The SKYNET aerosol-cloud-radiation observation network has been operational during the ADEOS-II/GLI validation period when the GLI was operational. The validation of the GLI aerosol products has been performed using both SKYNET and AERONET data. Consequently, it was possible to improve the retrieval algorithm and achieve better agreement of the retrieved optical thickness with ground measurements.
The cloud validation results are as yet not satisfactory. It is believed that the inhomogeneity of clouds in time and space might be a cause for the disagreement. The cloud validation activity is in its initial stage using the newly developed i-sky radiometer and therefore, there is a need to continue this effort.

3. Estimate of radiation budget using GLI data

3.1 Radiation budget

The radiation budget of the Earth is a key parameter related to climate change. It can be described as a sum of net solar radiation (shortwave) (input to the Earth system) and the terrestrial radiation (longwave) (output from the Earth system). The global mean over many years is considered to be balanced, but to vary with time and space depending on the atmospheric and surface conditions. In particular, the presence of aerosols, clouds and absorptive gases in the atmosphere that varies in time and space can affect the stream of solar and terrestrial radiation. Satellite observations are a powerful tool for estimating such fluxes and therefore, radiation budget has been an important component of the GLI research products.

Using aerosol and cloud products retrieved from GLI an estimate of solar radiation at each level from the TOA to the surface can be obtained, assuming known vertical profiles of these parameters as well as of water vapor, temperature, minor constituents and surface reflectance (yellow boxes in Fig. 5).

Accurate estimates of terrestrial radiation require precise information on clouds, vertical profiles of temperature and humidity, as well as base/top height of clouds (because of thermal emission dependence on temperature). Such information is not available from the GLI, and therefore, the emphasis in this study is on solar radiation.

3.2 Algorithms and data

The radiative transfer calculations for shortwave radiation have been performed with the RSTAR5b radiative transfer code developed by Nakajima and Tanaka (1986)\textsuperscript{10}. Since this code is time-consuming for global scale calculations, the neural network method (NN) is used. Before applying the NN method it is necessary to find the best solution for estimating the solar flux using exact calculation (RSTAR5b) with many combinations of aerosols, cloud parameters, and other auxiliary information. This process corresponds to the traditional lookup table (LUT) approach. Compared to the LUT method, the NN approach is faster, the accuracy is higher and it can be extended to large number of aerosol and cloud parameters. The NN approach requires a large data base on aerosols, clouds and absorbing gases to estimate the radiative fluxes; yet, it is more compact in calculations and executes faster than the LUT approach. The NN-approach has been tested previously using the GMS-5 (Geostationary Meteorological Satellite 5) data over the Chiba University SKYNET site\textsuperscript{11}. For clear sky cases, the surface solar flux estimated with the NN method shows quite good agreement with ground observations. Under cloudy conditions, the agreement is not as good, perhaps because of less accurate information on cloud parameters.

The GLI aerosol parameters used in the transfer calculations are based on the Higurashi and Nakajima (1999)\textsuperscript{12} algorithm for ocean areas and on the new algorithm developed by Fukuda et al. (2008)\textsuperscript{13} over land areas. The cloud parameters based on Nakajima and Nakajima (1995)\textsuperscript{14} (the GLI standard products) are used for cloudy segments. The surface reflectance is also derived from GLI data, as developed by Cui et al. (2009)\textsuperscript{15} with correction for a bi-directional reflectance...
Fig. 5 Solar (left part) and terrestrial radiation (right part) flow and atmospheric parameters. Yellow color boxes show radiation products derived from the GLI data. Shortwave radiation budget is focused in this paper because of the insufficient information derived from the GLI for terrestrial radiation.

The spatial resolution of these parameters is 0.25 × 0.25 deg (ATSEG data). The cloud parameters of optical thickness and effective radius used in the algorithm are averaged over 5 × 5 pixels of each ATSEG data

The radiative transfer calculations require information on water vapor and temperature profiles as well as other minor constituents. These basic parameters are obtained from the JRA-25 re-analysis product with an original 1.25° grid resolution (http://jra.kishou.go.jp/AboutJRA_en.html) and are linearly interpolated from each hourly data onto a 0.25° GLI standard product grid in space and into the target observing time. The monthly means of the radiation products have been calculated by integration of each instantaneous satellite path observation. It should be noted that the data are instantaneous, not daily means.

3.3 Results and discussion

Figure 6 shows the global distribution of the monthly mean of (a) downward solar radiation at the surface (SFC) and (b) the upward radiation at the TOA, respectively. The right column in each map shows the GLI product, and for comparison, Terra/MODIS data are shown in the left column. The lines along 180 deg in longitude in the GLI maps are due to the lack of retrieved data from the ATSEG data.

Since the solar radiation at the SFC and the TOA depend mainly on cloud characteristics, the SFC and TOA radiation are inversely related, namely, areas with lower SFC radiation correspond to areas with higher reflected radiation at the TOA. The radiation maps also show that desert areas of the Middle-East to northern Africa receive larger solar radiation and lose more radiation to space than in other regions. This is due to the relatively higher reflectance than that of surrounding areas including ocean surfaces.

The comparison with MODIS products is shown in the same figures. Time difference between both satellites is roughly 30 minutes, so that both radiation patterns are expected to be similar. However, the GLI estimate of the surface radiation is higher than that of MODIS. Corresponding to this tendency, the TOA radiation of the GLI is lower than that of MODIS, namely, the Earth from GLI might seem a little darker. For example, the cloud bands in May at the south of the Japanese islands can be seen in the MODIS results, but are not clearly seen in the GLI products.

In order to better illustrate this difference, the zonal mean values for each sensor are shown in Fig. 7. Roughly speaking, the agreement is relatively good for the surface radiation (Fig. 7 (a)), but somewhat worse for the TOA radiation (Fig. 7 (b)). The downward solar radiation in the southern hemisphere shows good agreement between the two products.

Surface solar radiation in the northern hemisphere is overestimated by the GLI in the lower latitudes and underestimated in the higher latitudes during April to July when compared with MODIS. From August to October the difference is quite small, especially in the mid-latitudes, and the differences in both estimates disappear at about 60 deg. This suggests that the optical characteristics of clouds may change statistically with time.

The zonal patterns for the solar radiation reflected at the TOA are in good agreement between GLI and MODIS, but
Fig. 6 (a) Downward solar radiation at the surface derived from the Terra/MODIS (left) and ADEOS-II/GLI (right).
Fig. 6 (b) Same as Fig. 6 (a) except for upward solar radiation at the TOA.
Fig. 7  (a) Zonal means of downward solar radiation at the surface (SFC). Solid and dotted lines are for ADEOS-II/GLI and Terra/MODIS, respectively.
Fig. 7 (b) Same as Fig. 7 (a) except for upward radiation at the TOA.
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Fig. 8 Global distribution of cloud parameters, (a) COT (only for water cloud) and (b) $r_e$ (only for water cloud), for the ADEOS-II/GLI and the Terra/MODIS in April 2003. The lowest panels show the zonal mean of each (c) COT and (d) $r_e$.

throughout the observation period, the GLI-estimates are lower than the MODIS-estimates except for higher latitudes. The solar radiation at the TOA reflects on the cloud state, which may suggest that the GLI clouds may be thinner and/or smaller in amount than those from MODIS.

Figure 8 shows comparison of cloud parameters for April 2003, (a) COT and (b) $r_e$, between GLI and MODIS at global scale (upper two panels for GLI and middle panels for MODIS) and the zonal means ((c) for COT and (d) for $r_e$). The zonal mean of the COT is in good agreement for a region of about $-45$ to $30$ deg in latitude, but the difference becomes bigger for regions southward of $-45$ deg and northward of $30$ deg. In general, the reliability of optical thickness estimated by the reflectance method is decreasing with increase in the solar zenith angle (Dim et al., 2007)\(^1\). For these reasons, the COT for the higher latitude regions may have larger errors. In the GLI cloud algorithm, the analysis is limited to pixels with solar zenith angle less than 75 deg. This might be a possible reason for the difference between GLI and MODIS southward of $-45$ deg. Northward of $30$ deg there is a large difference between the COTs the COT for MODIS northward of about 30 deg up to 60 deg in latitude is much larger than that for the GLI. The mean COT from GLI above 60 deg latitude is higher than MODIS COT. This may be due to a rapid increase in COT at northern Canada and Alaska, where the MODIS shows smaller COT.

The effective cloud radius can also affect the upward and downward solar radiation through differences in the asymmetry factor, but this effect is less pronounced than that of the COT. The bottom panel of Fig. 8 (d) shows interesting zonal
mean patterns of both effective radii, where the MODIS \( r_e \) is somewhat larger than the GLI except northward of 50 deg latitude. Interestingly, differences of both COTs and effective radii are distinguishable in the northern hemisphere. This may reflect differences of the retrieval algorithms between the GLI and the MODIS\(^7\), because both algorithms give independent products of aerosols and clouds. In particular, the algorithms might be sensitive to the specific atmospheric and surface conditions in the northern hemisphere. These differences in COT and \( r_e \) between both satellite sensors are discussed by Nakajima et al. (2009)\(^8\).

Another source of differences in radiation estimation is cloud fraction, depending on cloud detection algorithms. The agreement of cloud fraction is quite good except for southward of about –60 deg latitude, despite of difference in the detection algorithm, as shown in Fig. 9. The GLI cloud fraction is slightly larger than the MODIS one in the middle latitudes of the northern hemisphere, but it does not affect estimates of downward solar radiation, as compared to the differences in COT. In Fig. 9, the cloud fraction from ISCCP shows differences from the GLI/MODIS one, including an overlapping effect of multi-layered clouds.

4. Summary

GLI validation activities and radiation budget studies using the GLI data can be summarized as follows:

1. The SKYNET observation network has been established and maintained throughout the GLI operation. The SKYNET operation continues beyond the operational period of the GLI and data are open to the research community. The data serve for support of algorithm improvement activity and to meet the need for validation of future satellite sensors, such as GOSAT/CAI.

2. The downward solar radiation at the surface and the upward solar radiation at the TOA have been estimated using a new estimation scheme with cloud/aerosol parameters derived from GLI.

3. The solar radiation derived from the GLI data is compared with Terra/MODIS ones. The agreements in global scale distribution patterns and zonal means are quite good, in particular for the downward solar radiation at the surface in the southern hemisphere. In the northern hemisphere, the difference between them is more complicated than in the southern hemisphere, which suggests that the cloud characteristics might be different. The GLI-values at the TOA are underestimated as compared to MODIS due to underestimate of clouds.

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References


7) A. Shimizu, N. Sugimoto, I. Matsui, K. A., I. Uno, T. Murayama, N. Kagawa, K. Aoki, A. Uchiyama, and A.

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