Estimate of downward solar flux from GMS-5 clouds (Session 1: Radiation studies)

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Estimate of downward solar flux from GMS-5 clouds

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1. Introduction

Climate system is characterized by many parts of the heat exchange processes, especially energy transfer and water budget in the surface-atmosphere system. As for the energy budget, incoming solar radiation heats the surface up first through the relatively transparent atmosphere, and then the surface emits the radiation to the atmosphere as well as sensible and latent heat. The net amount of surface solar radiation is strongly dependent on atmospheric constituents, such as clouds, aerosols and absorption gases, through light scattering and absorption.

In order to make clear the climate system, the first step is to know the characteristics of each process in the Earth-atmosphere system. Asian continent is one of huge thermal sources, and it can play a great role on seasonal and interannual variations in the regional scale, resulting in the global change. Therefore, it is valuable to estimate the surface solar radiation as a fundamental energy source. A estimation from satellite data is very effective because of the wide area coverage, while the ground measurements are limited due to economy and technical reasons. However, satellite derivation has some errors coming from some ambiguities of atmospheric components.

In the present study, the downward surface solar radiation can be estimated by GMS-5 visible and thermal infrared image data. The result is compared with the ground-based measurements at GAME observation sites.

2. Data and analysis

2-1. Estimate of surface downward solar radiation

For computation of surface solar radiation, the atmosphere including clouds and aerosols is assumed to be plane parallel. RSTAR5 code, developed by Nakajima et al.(1983, 1986 and 1988), is used for computation. Lookup table for surface solar flux is set for parameters of optical thickness of cloud, ratio of water cloud to ice cloud, optical thickness of aerosol, effective water vapor, solar zenith angle, and surface reflectance. Cloud type, convective or stratus, is also distinguished by the imhomogeneity index, which means variance of infrared thermal temperature in the unit area except the gap between cloud top and the surface. Higher index shows convective type, otherwise stratus. Cloud overlapping model is introduced such that maximum overlapping is used for convective cloud and random overlapping for stratus.

The representative optical characteristic of cloud can be determined from statistics of all pixel data considering the overlapping model. The surface radiation for each unit area can be derived from the lookup table using the parameters. The atmospheric profile is selected from ECMWF data day by day and every 12-hour. Global Aerosol Data Set (GADS, Kopke et al., 1997) developed by the Max Planck Institute is adopted for aerosol data because of no information over land.

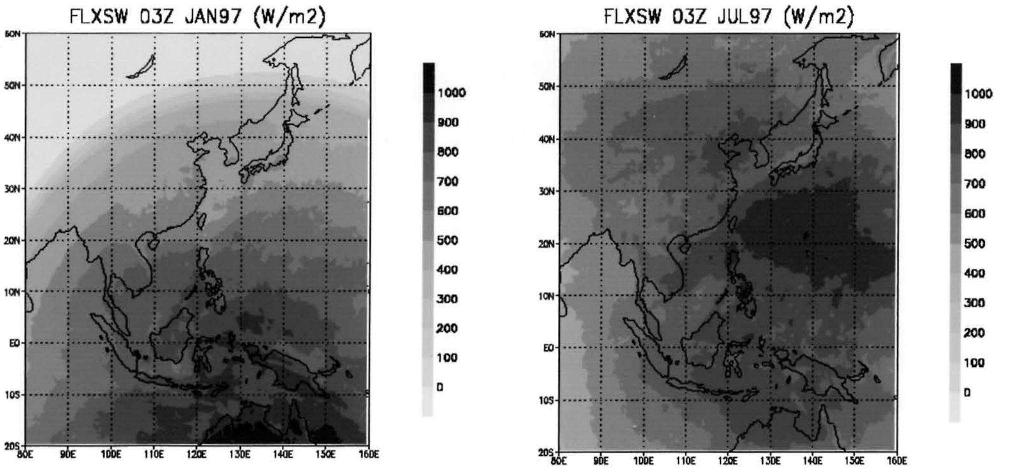

Fig.1. Monthly averaged solar flux at 03Z in January and July.

Fig.1 shows monthly mean surface solar flux map at 03Z in northern summer (July) and winter (January). The surface solar flux in Fig.1 can reflect the variation of cloud and aerosol existence, while radiation map for the Rayleigh atmosphere must show the concentric pattern with a center of solar position on the Earth. For example, there is the lower part of the solar energy over the Japan islands due to the stational front.

However, it should be noted that integration for daily data can be obtained within less than 70 degrees in solar zenith angle due to limitation of retrieval of cloud optical thickness.

2-2 Observational data

Ground observation of the solar global flux at Si-Samrong (17.17 ° N, 99.87 ° E) in Thailand, Shouxian (32.55 ° N, 116.78 ° E) in China are running under support of related universities, istitutes and funding agencies. At both sites, a standard pyranometer, Kipp and Zonen CM21F and a pyrheliometer, EKO MS-53A, are used for diffuse flux and direct radiance, respectively. It is available for validation of the surface solar radiation derived from GMS-5. Monthly mean daily data is valid for usable ten days or more in a month.

At Si-Samrong, a multi-channel sky radiometer, Prede POM-01 with an automatic solar tracking system has been operating to derive aesorol optical chracteristics.

3. Comparison of estimated solar flux with observational data

Fig.2 shows the comparison of the satellite solar flux with the observed one. Fig.2a shows the cases in clear sky days which were decided by diurnal variation of surface observed solar flux. The data at Si-samrong in October 1997 shows smaller variability of the satellite solar flux than that of the observe one. The data at Si-samrong in January 1998 shows the similar property, and shows underestimate. The satellite solar flux under clear sky condition has a variation due to changes of the water vapor and aerosol. The observed flux is widely changeable in time and space rather than the estimated flux, because the latter one is used with a representative aerosol model and water vapor from the objective analysis data. Further analyses using in situ aerosol time series data will solve the distinction between the satellite estimate and the observed solar flux.

Fig.2b shows the comparison of the estimated solar flux with the observation for cloudy days. The surface observed data at Shouxian in July,1998 show wide variation from 46 to 312 W/m2, but the satellite solar flux varies from 162 to 301 W/m2. The largest data for each site are near the condition of a few cloudy sky. The lower data tend to be more overestimate. The absolute value of difference tends to increase with decrease of the daily solar flux. This suggests the cloud optical thickness is underestimate. The scale of the difference is almost 116 W/m2 at maximum, which is much larger than the difference on clear days.

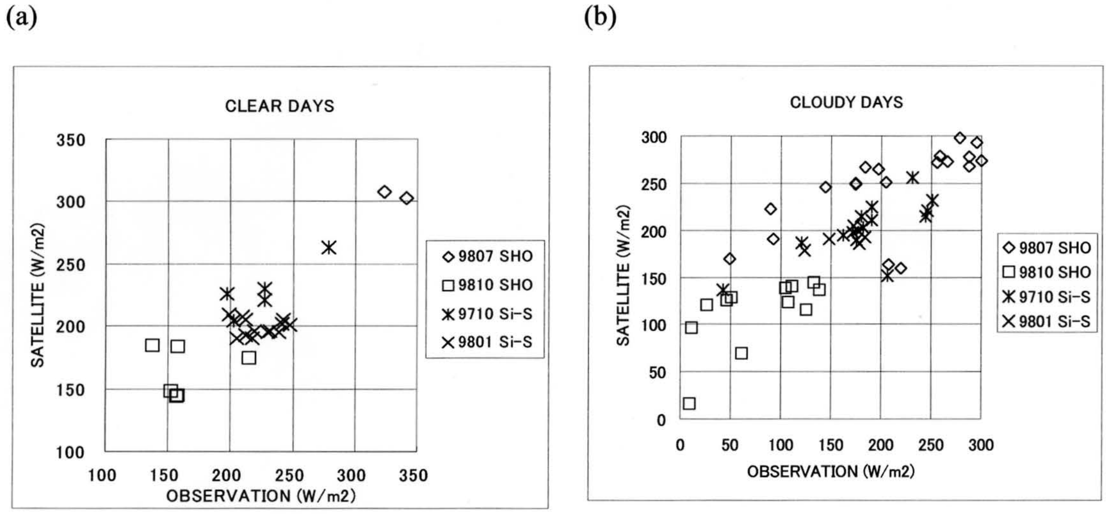

Fig.2. comparison of estimate of downward solar flux with the observational data.

In the algorithm to infer the surface solar flux, an optical thickness at a cloudy pixel has been decided by choosing the statistical median of thermal infrared brightness temperature in a unit area (0.5 deg. x 0.5 deg.) for each cloud layer. The pixel can present the typical cloud top brightness temperature, however the statistical median is no physical reason for the retrieve of the optical thickness. Then more examination for comparison of the infrared brightness temperature with the optical thickness is needed to establish statistical relationship. Another possibility of underestimation of cloud optical thickness is inhomogeneity. The rough surface of cloud top can make a shadow to a neighboring cloud and affect the estimate of cloud optical thickness to be smaller.

Averaged differences between the satellite estimate and the surface observation during 2 months are 0.4% and 8.4% at Si-samrong and Shouxian, recpectively. However, averaged r.m.s. differences are 16.2% and 35.1% at Si-samrong and Shouxian, respectively. The r.m.s. difference is quite larger than other studies (e.g., Pinker and Ewing, 1985).

4. Summary

The downward surface solar flux was estimated hourly from GMS-5 infrared and visible data. The method of the estimation includes theoretical transfer model. The radiation data from GAME sites was used for comparison with the satellite estimate. For clear day, the satellite estimate shows less variation than the observed data. For cloudy day, the satellite estimate tends to be larger than measurement. Retrieval of cloud optical thickness should be improved. Monthly averaged bias error (r.m.s. error) are 0.4% (16.2 %) and 8.4% (35.1%) at Si-samrong and Shouxian, respectively.

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