The retrieval of Surface Solar Insolation using SMAC code with GMS-5 satellite data

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Abstract

Surface Solar Insolation is important for vegetation productivity, hydrology, crop growth, etc. However, ground base measurement stations installed pyranometer are often sparsely distributed, especially over oceans. In this study, Surface Solar Insolation is estimated using the visible and infrared spin scan radiometer(VISSR) data on board Geostationary Meteorological Satellite (GMS)-5 covering from March 2001 to December 2001 in clear and cloudy conditions. To retrieve atmospheric factor, such as, optical depth, the amount of ozone, H_2O, and aerosol, SMAC (Simplified Method for Atmospheric Correction) code, is adopted. The hourly Surface Solar Insolation is estimated with a spatial resolution of 5km × 5km grid. The daily Surface Solar Insolation is derived from the available hourly Surface solar irradiance, independently for every pixel. The pyranometer by the Korea Meteorological Agency (KMA) is used to validate the estimated Surface Solar Insolation with a spatial resolution of 3 × 3Pixels.

KEY WORDS: Insolation, GMS-5, SMAC

1. INTRODUCTION

In many application of solar energy, the Surface Solar Insolation at the location of interest is one of the important products to energy-water model, vegetation productivity, crop growth, global climate change studies, and meteorological predict model. Nevertheless, in many countries, the available information on the solar insolation is rather limited, which fail to capture its spatial variability. For the retrieval Surface Insolation, we used the visible and infrared spin scan radiometer(VISSR) data on board Geostationary meteorological Satellite (GMS-5) producing products with high spatial and temporal resolation for any within the sensor coverage.

In this study, Surface Solar Insolation estimation is based on the works by Gautier, Diak, and Masse(1980) and Kizu(1995); and Kawamura(1998). The Kawamura' simple physical model is used for atmospheric factor, such as, optical depth, the amount of ozone, H_2O and aerosol, simply and empirically. Most of Surface Solar Insolation retrieval models using satellite data use the atmospheric factors depending on constant or empirical value (e.g., it can induce the estimation error). SMAC code is based on a set of equations with coefficients which are provided according to the spectral bands of the various satellite sensors. So it can be rapidly implemented and applied in operational preprocessing system. The purpose of the present study is to derive the Surface Solar Insolation using atmospheric factor from SMAC code.

2. DATA AND METHOD

2.1 VISSR aboard GMS-5 and Pyranometer data sets

The Japanese GMS-5 satellite was launched in March 1995 into geostationary orbit, located at nominal geodetic coordinates of 0° latitude and 140° E longitude. Full disk images are relayed to ground receiving stations approximately 25–28 times per day, providing up to half-hourly temporal coverage during some periods of the day. Table.1 summarizes some important information about the VISSR on GMS-5. There are four channels: one visible, two thermal infrared channels (8-14 μm), and a channel sensing thermal radiation emitted by the strong water vapor rotation band at 6.3 μm. The nominal spatial resolution of the visible channel is 1.25 km, while the infrared channels have a reduced resolution of 5 km.

In this study, we utilized 3 hourly interval reflectance data of visible channel 1 (VIS) for the period from March 1, 2001, to November 31, 2001 It has 0.05° × 0.05° spatial resolution for the domain of 10–40°N and 80–170°E.

A match-up data set is defined as a pair of the pyranometer measurement data that is obtained from the Korea Meteorological Agency(KMA) and the satellite data. Fig. 1 shows the location of the 22 pyranometer observation sites that were used in this study. But validation data set in ocean almost not exist around the Korean peninsula. So Matching-up the ground-based true data and the satellite data in ocean will perform in the future work.

Table 1. Characteristics of VISSR/GMS-5.

	Visible	Infrared		
		Band1	Band2	Band3
Spectral band	0.55~0.90μm	10.5~11.5μm	11.5~12.5μm	6.5~7.0μm
Channels	4	1	1	1
Spatial resolution	1.25km	5.0km	5.0km	5.0km

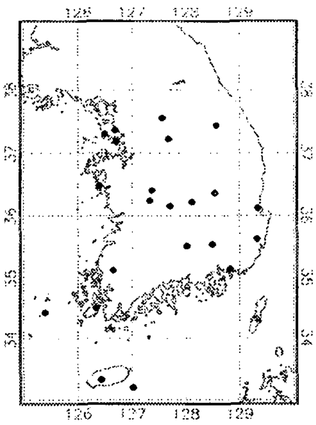

Figure 1. Location of observation stations

2.2 Algorithm to estimate the Surface Solar Insolation

The Surface Solar Insolation retrieval algorithm is based on works by Gautier, Diak, and Masse(1980) and Kizu(1995), and Kawamura(1998). The algorithm used in this study to retrieve the Surface Solar Insolation is represented in fig.2. First, the VISSR image pixels are classified as cloudy or clear sky pixel using VISSR visible and infrared channels. Then, the clear sky model or the cloudy sky model is applied to produce the Surface Solar Insolation. Finally, we used observation data to validate estimated Surface Solar Insolation.

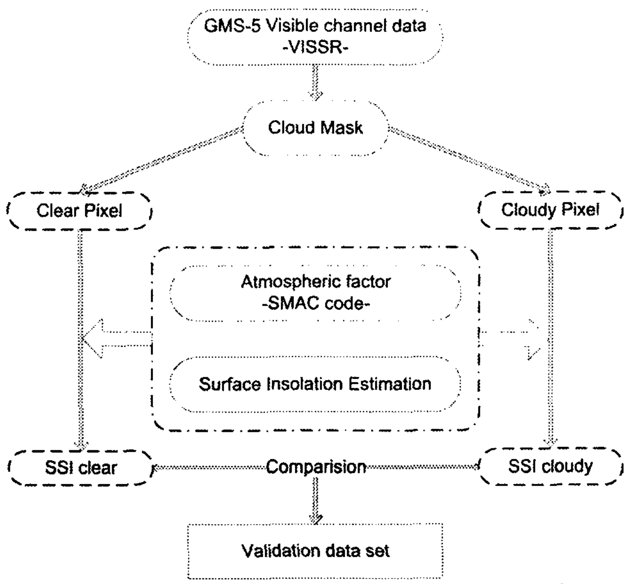

Figure 2. Algorithm for the Surface Solar Insolation

In the clear sky conditions, the Surface Solar Insolation can be obtained through the following equations;

$$S_s = S_I + S_R + S_A \quad (1)$$

$$S_I = S \cdot \tau_0 \cdot \tau_R \cdot (1-\alpha_W) \cdot \tau_A, \quad (2)$$

$$S_R = S \cdot \tau_0 \cdot (0.5 \cdot (1-\tau_R)) \cdot \tau_A, \quad (3)$$

$$S_A = S \cdot \tau_0 \cdot \tau_R \cdot (1-\alpha) F_c \cdot \omega_0 \cdot (1-\tau_A), \quad (4)$$

$$S = I \cdot (d_M / d)^2 \cdot \cos\theta. \quad (5)$$

In these formulas, S_S is the total insolation, S_I the direct irradiance, S_R the diffuse irradiance due to Rayleigh scattering and S_A the diffuse irradiance due to scattering by aerosols.

In the cloudy sky case, the surface insolation is estimated by taking account of the effects of reflection and absorption by the cloud.

$$S_s = (S_I + S_R + S_A) \cdot (1 - a \cdot A). \quad (6)$$

The parameters used in the equations are utilized atmospheric factor from SMAC code which has been depended on constant or empirical value. SMAC code is based on a set of equations with coefficient, which is determined using a best fit technique against the computations of the 6S code (Second Simulation of satellite Signal in the Solar Spectrum Tanre et al. 1990), according to the spectral bands of the various satellite sensors. So it can easily be implemented in operational data preprocessing system.

The transmittance due to attenuation by ozone is estimated as,

$$\tau_o(\theta_s,\theta_v) = \exp(a(mU_{O_3})^n))$$
$$m = 1/\cos(\theta_s) + 1/\cos(\theta_v) \quad (7)$$

M is the airmass, U_{O3} is amount of ozone.

For a molecular atmosphere, The Transmittance due to Rayleigh scattering is given by

$$\tau_r = \tau_m \cdot p_r(\xi)/4\cos(\theta_s)\cos(\theta_v) \quad (8)$$
$$\tau_m(P) = \tau_m(P_0)\cdot P/P_0$$
$$P_r(\xi) = 1\cdot 5\frac{(1-\delta)}{2+\delta}(1+\cos^2(\xi)) + 3\frac{\delta}{2+\delta}$$
$$\cos(\xi) = -[u_s \cdot u_v + \sqrt{(1-u_s^2)(1-u_v^2)}\cdot\cos(\Delta\Phi)]$$

τ_m is molecular optical depth, ξ is the scattering angle, δ is the depolarisation factor (δ =0.0139).

Transmittance due to attenuation by aerosols can be written as follows:

$$\tau_A = a_0 + a_1\tau_{550} \quad (9)$$
$$p_p(\xi) = a_0 + a_1\xi + a_2\xi^2$$

a_0 and a_1 are the coefficients

The Absorptance of water vapor can be given as follow:

$$\alpha_w(\theta_s,\theta_v) = \exp(a(mU_{H_2O})^n) \quad (10)$$

In these formula, To estimate of the absorptance of water vapor, α_W, ozone transmission, τ_O, Rayleigh optical depth, τ_R, aerosol transmission, τ_A, requires the coefficients, which is derived using the SMAC code
So, each parameter can be fast and easily calculated when the Surface Solar Insolation is applied

It is known that designation and classification of the clouds are critical for the retrieval if Surface Solar Insolation using clear sky and cloudy sky condition. In the present scheme, the successive physical processing steps were operated to the image on a per-pixel basis to classify cloudy pixels. For the cloudy pixel, the value of the Surface Solar Insolation attenuation coefficient by cloud has been assigned according to the type of cloud.

3. RESULT

The present study has generated hourly, daily, and monthly Surface Solar Insolation over Korean peninsula for ten months(March 2001 through December 2001). The image in Figure 3 represents the output data file of the Surface Solar Insolation product for GMS-5 scene of 20/04/2001 at 0230 UTC. The Figure 4 represents the output data file of the Surface Solar Insolation product at 20/04/2001, 0230 UTC. It totally depends on the solar position via a factor of cosine of the solar zenith angle. The clouds systematically affect the values of Surface Solar Insolation. The Surface Solar Insolation values for cloudy pixels are lower then clear pixel values. The hourly estimates with 3×3 pixels were validated against one point measurement. Figure 4 shows the scatter plot of situation in the collocation files regardless of cloud cover. Using averaged value for 3×3 pixels, drifting clouds from adjacent pixels across the ground station during the averaging interval of 1 hour are taken into account. The standard deviation error is 9.45. In the validation work, this statistical result doesn't represent the accuracy of the estimated values. Now, validation work is processing and is going to be analyzed further.

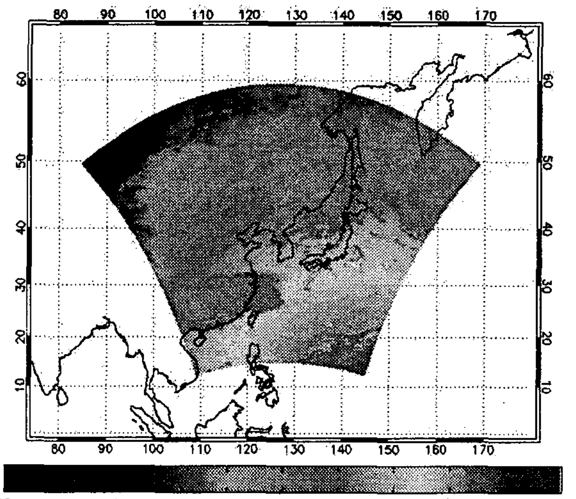

Fig. 3 Surface Solar Insolation from GMS-5 at 20, April. 2001.

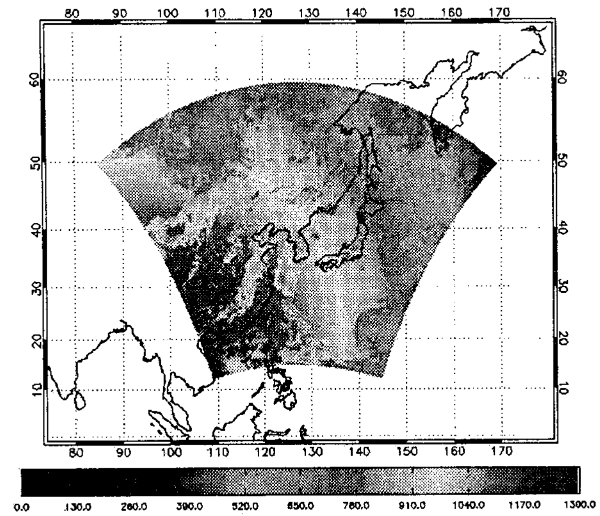

Fig. 3 Surface Solar Insolation from GMS-5 at 15, Aug. 2001.

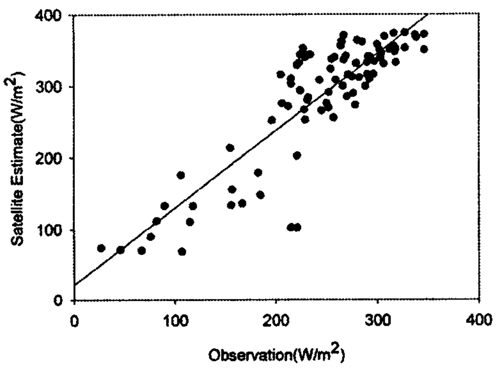

Fig. 4 Validation of hourly insolation over the Korean peninsula

4. CONCLUSION

We used the GMS-5 satellite data to retrieve Surface Solar Insolation over Korean peninsula for 10 months(March 2001 through December 2001). The estimate of Surface Solar Insolation has been improved using atmospheric factor which is retrieved by SMAC code. By using SMAC code, it can easily be produced and applied in operational preprocessing system.

The estimated values are validated by the in situ measurement and shown to have a standard deviation error of 9.45 for the hourly product.

It could form the input a number of applications, such as use of meteorological predicts model, vegetation productivity, hydrology, crop-simulation model for yield forecasting. There is a need to analysis output data and to validate the estimated value in the ocean.

5. ACKNOWLAGE

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