Surface climate information from GMS-5 data

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1. Introduction

Cloud is an important component for global and local climate. Its distribution and variation express an integration of atmospheric conditions. Cloud also directly affects to local climate through radiative process. Heat budget at the surface is decided mainly by radiation budget. In daytime, solar radiation dominates the total radiation budget and terrestrial radiation decides it in nighttime. Cloud plays a roll not only on solar radiation but on terrestrial radiation through cloud cover and temperature at cloud bottom. Diurnal change of the radiative flux belongs to the diurnal changes of cloud, atmospheric and surface conditions, and it has large amplitude. The radiative flux at surface is important element for climate condition. Hence it is needed to make properties of the diurnal variation of cloud clear.

In the present study, 1 hourly cloud, clear sky temperature and surface solar radiation data, which are processed from GMS-5 (Geostationary Meteorological Satellite 5), are introduced. Cloud and clear sky radiation temperature data had been stored for 1996. This data covers most of the east Asian continent. Hourly analysis is important because solar radiation changes quickly. Our final purpose is to estimate both of solar and terrestrial radiative fluxes hourly at the surface from geostationary meteorological satellite images. Surface solar radiation for 4 months have been estimated until now, although the research to develop the algorithm for terrestrial radiation is still proceeding.

2. Cloud distribution and clear sky radiation temperature

GMS-5 image data is received at Institute for Industrial Sciences, University of Tokyo, and is processed by Prof. Kikuchi at Kochi University. IR1 (10.5 - 11.5 micro meter), IR2 (11.5 - 12.5 micro meter) and visible channel are used for the present study.

As cloud determination, similar method with infrared analysis part of ISCCP cloud detection (Rossow and Garder, 1993) is applied. The stages are composed of 3 steps.

At first, spatial and temporal variation is analyzed. A pixel is compared with surrounding pixels in the same day and also compared with same pixel (position) in the day before and after. The pixel that has small variation is defined as clear sky. Secondly, clear sky pixels are screened and clear sky radiation temperature for reference is decided. When averaged clear sky radiation temperature for a time series is too lower than maximum among them, the average is assumed to be contaminated by cloud pixels. In such case, maximum is used as clear sky temperature with a negative bias. The biases belongs to surface conditions, open sea, sea ice, high land, snow, and other land covers. The clear sky radiation temperature for reference is decided every 5 days at every hour. Thirdly each pixels are compared with the clear sky radiation temperature. When radiation temperature of a pixel is lower than the clear sky radiation temperature for reference, it is decided as cloudy pixel. The threshold belongs to surface conditions as above.

Detected cloud is classified to cirrus and other cloud. For cirrus detection, the split window method (Inoue, 1987) is applied. When temperature difference between two infrared window channels,

delta T = Brightness temperature (IR1) - Brightness temperature (IR2),

are larger than 1.5 K, the pixel is decided as cirrus.
Then other clouds are classified to 3 layers by its temperature. High layer cloud is defined as that the radiation temperature is lower than atmospheric temperature at 440 hPa. Middle layer is defined between 440 hPa and 680 hPa, and low layer is defined as lower than 680 hPa. ECMWF (European Centre for Medium-range Weather Forecasts) atmospheric data is used for temperature reference. Rest of pixels are classified as clear sky.

The result is stored to 0.5 * 0.5 degree box that has 100 pixels. Hence, cloud amount (%) is expressed as number of pixels in each category. In each box, the median in a category is presented and it is used to calculate cloud optical thickness. The algorithm of estimation for cloud optical thickness in the present study is improved from Nakajima and Nakajima (1995) to adjust for waveband of channels on GMS-5 . Clear sky radiation temperature is also defined as the median in clear sky part in the box.

2-1. Cloud distribution

Fig. 1 shows an example of monthly mean of total cloud amount in July, 1996. It shows very active convection at the Gulf of Bengal, a cloud band from Southern part of China to Japan islands and clear condition over the Australian continent. Similar maps for 4 cloud categories had been produced for each hour.

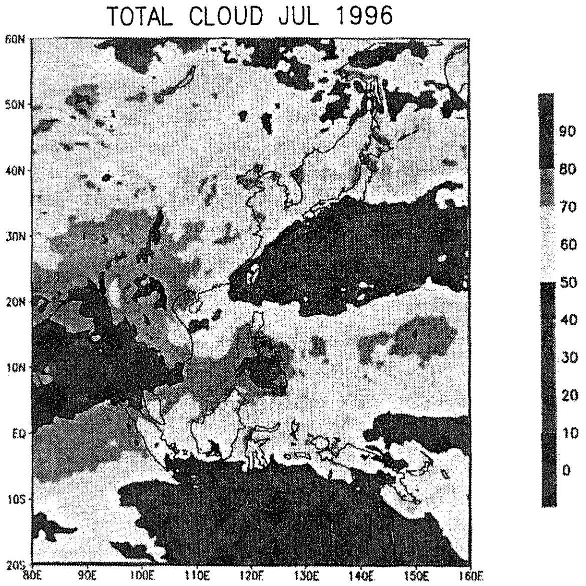

Fig.1. Total cloud cover (%).

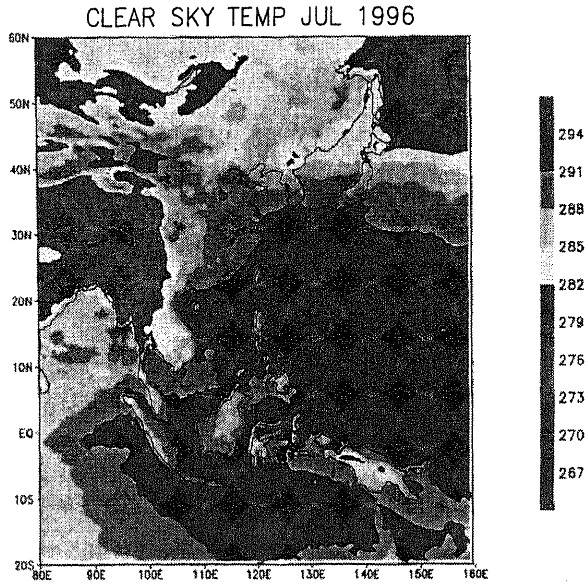

Fig.2. Clear sky radiation temperature (K).

2-2. Clear sky radiation temperature

Fig. 2 shows the monthly averaged clear sky radiation temperature. Water vapor absorption and decreased surface emissivity may make some effects to the radiation temperature. However it should be noted here that the figure can show climatologically reasonable distribution of temperature. It means this map can be used as a kind of index of surface temperature.

Fig. 3 shows diurnal variations in each season in Mongol (38N100E-43N110E) and Hua-Bei plane (32N114E-37N117E). The variation in Mongol as semi arid area has maximum in early afternoon (06Z) and minimum through the night in Fig. 3a. The variation in the Hua-Bei plane shows different variations between summer and other seasons in Fig. 3b. In July it looks stable like that in the ocean, and in other seasons it is like that in Mongol. It is derived that the algorithm picks up intermittent clear sky case in cloudy day in the month, because it is almost cloudy there in this season. Hence the surface appears to be wet and it is difficult to show large amplitude.

Fig. 4 shows seasonal change of clear sky radiation temperature and observational result at Mandalgovi in 1998. In night time (18Z), the observation is closer to the estimation from GMS-5. They will show more agreement after atmospheric correction.

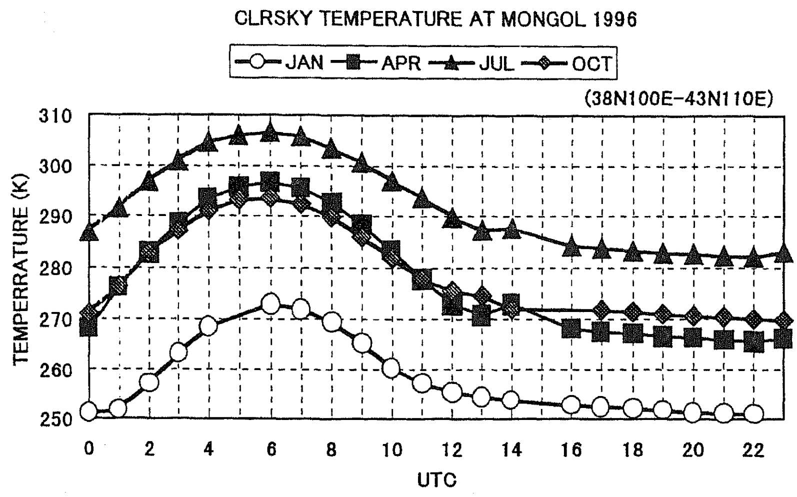

Fig.3a. Diurnal change of clear sky radiation temperature (Mongol).

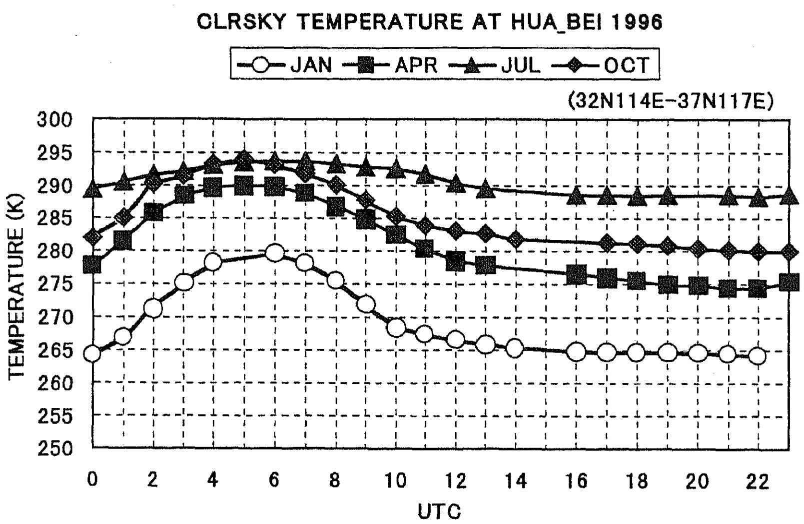

Fig.3b. Diurnal change of clear sky radiation temperature (Hua-Bei plane).

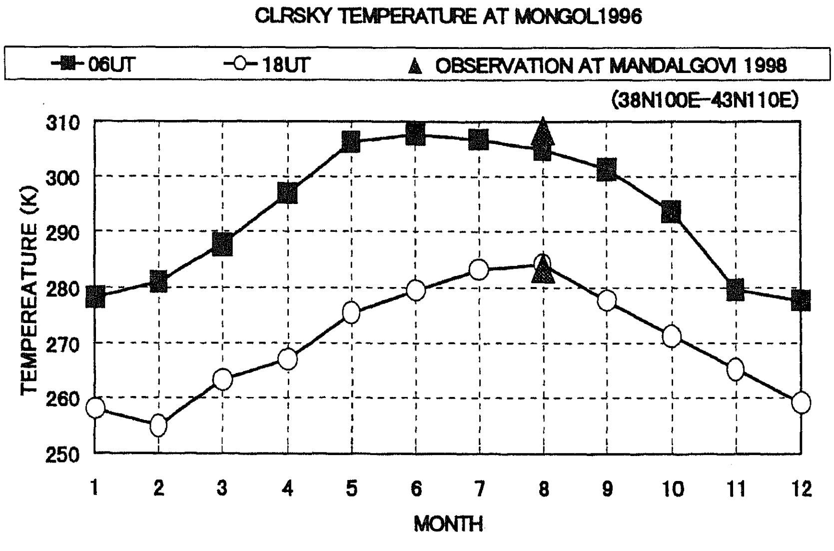

Fig.4. Seasonal change of clear sky radiaiton temperature (Mongol).

3. Surface solar radiation

Surface solar radiation is estimated from cloud information that are described at former chapter, ECMWF atmospheric data and GADS aerosol model. Radiation transfer model assumes plane parallel atmosphere and cloud. The RSTAR program package that was developed by Nakajima et al. is used for the two-stream calculation.

Optical thickness of cloud, ratio of ice cloud to water cloud, optical thickness of aerosol, effective water vapor amount, solar zenith angle and surface reflectance / ocean surface wind speed are adopted for parameters. Table of solar radiative flux is estimated from them, because too much time is needed to calculate the flux at each box.

Fig.5 shows an example of solar radiative flux at 03Z, July, 1996. This map is averaged at 03Z for all of days in the month. The fluxes in January, April, July and October in 1996 had been estimated. Fig.6 shows comparison of the estimations with observation in August 1998 at Mandalgovi, Mongol. Observation case appears to be consistent with seasonal change of the estimations from GMS-5.

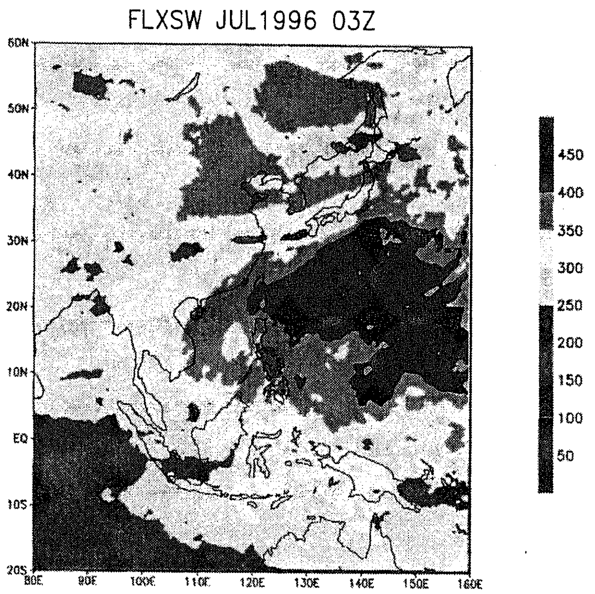

Fig.5. Surface solar radiative flux (W/m2).

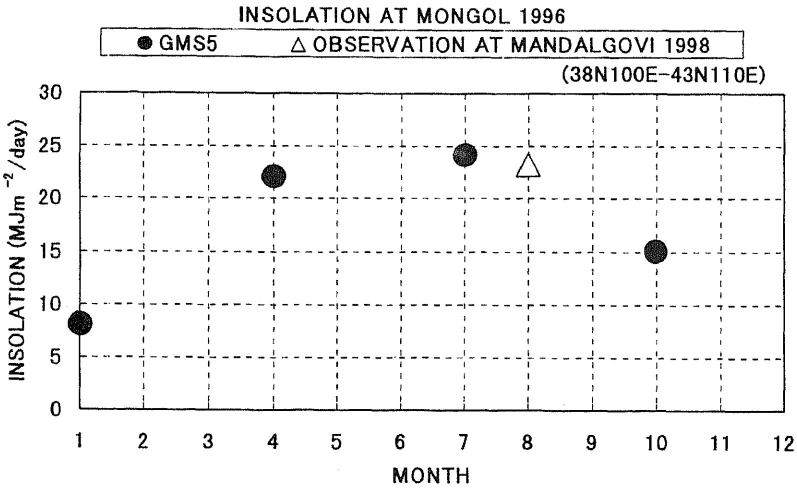

Fig.6. Seasonal change of daily accumulated surface solar radiation (Mongol).

More observation data are needed to compare with the estimation from GMS-5. The comparison makes disagreements between observation and estimation clear for various conditions. After the comparison, threshold of cloud detection, aerosol data, surface reflectance and assumptions for cloud properties should be discussed again. Change of sensitivity of the visible sensor is also one of problems. For this issue, longterm variability of output level from the visible sensor should be estimated exactly.

References

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