Diurnal variation of cloud cover on 1996 from GMS-5 images

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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. Final purpose of the present study is to estimate radiative flux at the surface from geostationary meteorological satellite images. Diurnal variation of radiative flux has large amplitude. Hence it is important to make nature of the variation of clouds clear.

In the present study, 1 hourly cloud cover data, which is processed from GMS-5 (Geostationary Meteorological Satellite) of Japan Meteorological Agency, is introduced. As famous cloud data set, ISCCP (International Satellite Cloud Climatology Project) is distributing global 3 hourly data. However it is more valuable to produce 1 hourly data, because incoming solar radiation changes quickly. And the ambiguity of plus minus 1.5 hour is often insufficient for meteorological research on local phenomenon.

2. Data and analysis

GMS-5 image data is received at Institute for Industrial Sciences, University of Tokyo, and is processed by Prof. Kikuchi at Kochi University. Only 10.5 - 11.5 micro meter infrared window channel is used for the present study, though GMS-5 has 3 infrared channels, because this work will be extend to the past data of GMS-3 and GMS-4, which have only one infrared channel.

Two formats for GMS-5 data are used in the present study, because the data had been supplied temporally with different format. One format covers from 70 degree N 70 degree E to 70 degree S 150 degree W (140 square degree), the other is from 60 degree N 80 degree E to 60 degree S 160 degree W (120 square degree). This data also includes some geometrical deformations. These situations will be improved soon. Prof. Kikuchi has released corrected data recently.

NCEP reanalysis data is used for deciding air temperatures at 400 hPa and 700 hPa, that is produced by US National Center for Environment Prediction. It is handled by Mr.Sinpo at University of Tokyo in Japan.

Northern hemisphere weekly snow cover and sea ice extent is also used, that is supplied by US National Snow and Ice Data Center.

As cloud determination method, following procedures are applied. This method is almost same with infrared part of ISCCP cloud detection (Rossow and Garder, 1993). The stages are composed of 3 steps.

a. Picking up clear sky pixels from temporal and spatial variation analysis

The pixel is compared with surrounding pixels in the same day and also compared with same pixel in the day before and after.

b. Screening clear sky pixels and deciding clear sky radiation temperature.

The extremely low values are rejected. If averaged clear sky radiation temperature for some time series is too lower than maxima of them, the average is contaminated by cloud pixels. In such case, maxima is used as clear sky temperature with some negative bias. The biases belongs to surface conditions, open sea, sea ice, high land, snow, and other land covers. The clear sky radiation temperature is decided every 5 days at every hour.

c. Comparing each pixels with the clear sky radiation temperature.

If radiation temperature of a pixel is too lower than the clear sky radiation temperature, it is decided as cloudy pixel. The threshold belongs to surface conditions as above.

3. Results

a. Geographycal distribution of cloud cover and clear sky radiation temperature

Fig. 1 shows that distributions of total cloud cover each season. In South-east Asia, cloud activity is most prominent. ITCZ (Intertropical convergence zones) are also clearly seen. Contrast between summer and winter is remarkable on the Asian continent. Clouds due to cold serge is dominant near Japan islands on winter. Cloud stays on Sichuan basin through the year.

Secondly, cloud pixels are classified by its radiation temperature, although broken cloud, cirrus, òr much water vapor in tropical region may make error. The radiation temperatures are divided into 3 layers; the low layer is below 700 hPa, the middle layer is above 700 hPa and below 400 hPa, and the high layer is above 400 hPa. Air temperature at 400 hPa and 700 hPa are given by climatology of NCEP reanalysis data. The figures of each levels are not shown.

In the high layer, ITCZ and Polar front are shown clearly through the year. Convectional band extends from the Asian Continent to Japan Islands in July. In middle layer, it should noted that some parts of the layer is covered by clouds in the high layer. Therefore, some area looks less cloud cover than real condition. Cloud covers on Sichuan basin are clearly shown through the year. In the low layer, cloud cover shows large contrast between ocean and land. More strict threshold was applied to land area than ocean area, therefore the result shows fewer cloud cover in land area. ISCCP results show very similar pattern. This problem may induce unnatural radiation balance between land and ocean.

Thirdly, clear sky radiation temperature map was created. This figure is not shown. This map composed of rest of all the pixels without cloudy ones. It does not include only true clear pixel, but may include cloudy pixels which were not discriminated as cloud. For example, convectional area in the bay of Bengal shows too low temperature near 260 K as clear sky. And water vapor absorption and decreasing surface emissivity may make large effects to the temperature. Therefore, edge of the map shows lower value than the center. However it should be noted here that these figures can show large seasonal variations on the continents and small variations on the ocean. It means this map can be used as a kind of index of surface temperature.

b. Diurnal variations of cloud cover and clear sky temperature

Diurnal variations of cloud covers and clear sky radiation temperature are described at 4 regions. These regions are Mongol area as semi-arid surface (38N100E-43N110E), the Northwestern Pacific as ocean surface (35N150E-40N160E), Hua-Bei plane as vegetated surface (32N114E-37N117E), and Australian desert (18S130E-23S140E).

In Mongol area, diurnal variations of total cloud cover show peaks in afternoon in every seasons. These peaks are affected from cloud covers in the low layer. The reason is derived to be effects from diurnal variation of vertical structure of air temperature profile, and the tendency is also certified in ISCCP data. In daytime, the surface temperature is higher than that in night , so it makes cloud detection easier. However, in July, total variation includes cloud in the high layer. The high layer cloud has peak in the evening.

In the Northwestern Pacific, the variations of cloud cover are very stable. In April, cloud in the high layer is decreasing in morning and increasing in afternoon. Summer depression in July may be caused from migration of the extra-tropical high.

Fig. 2 shows the diurnal variations of cloud cover at Hua-Bei plane. The variations are very stable in July. The variations in the low level have maximum in afternoon in the other seasons. These maximum are considered to be same case like Mongol. Diurnal variation of total cloud cover in January is characteristic. The variation in the middle layer leads the total variation. In April, the high layer shows fewer cloud cover in early morning. In October, the total variation increases in afternoon, and more remarkably in evening, while the low layer does not contribute.

In Australian desert, the diurnal variation in January is very remarkable in the low layer. Depression of cloud cover in the middle layer in daytime may emphasis to increase cloud cover in the low layer. In April there is also the depression. While, there looks really no cloud in July.

For clear sky radiation temperature, diurnal variations in each seasons were also described like cloud cover. In the Northwestern Pacific, the diurnal variation of clear sky radiation temperature is very stable. The variation has maximum in early afternoon and stable minimum in 6 - 7 o'clock at local time in Australian Desert through the year. While The variation in Mongol as semi arid area has maximum in early afternoon and minimum through the night. The variation in Hua-Bei plane shows different variations between summer and other seasons. In July it looks stable like that in the ocean, and in other seasons it is like that in Mongol. It is derived that much precipitation in July and vegetation opposed to change the surface temperature quickly.

4. Concluding remarks

Hourly cloud data set from GMS-5 images is produced. This data set shows distribution and variation of cloud cover in the middle layer and the high layer well. The cloud cover in the low layer still remains problem. This problem should be solved in order to use this data for radiation estimation. Hourly changed threshold for cloud determination may improve the problem.

Regional description about diurnal variation of cloud cover and clear sky radiation temperature also shows interesting properties. Physical explanation should be given from further studies.

To extend this analysis to longer term including GMS-3 and GMS-4 will show regional properties of interannual variations of cloud cover.

The product of cloud covers in the present study will open to public in near future.

References

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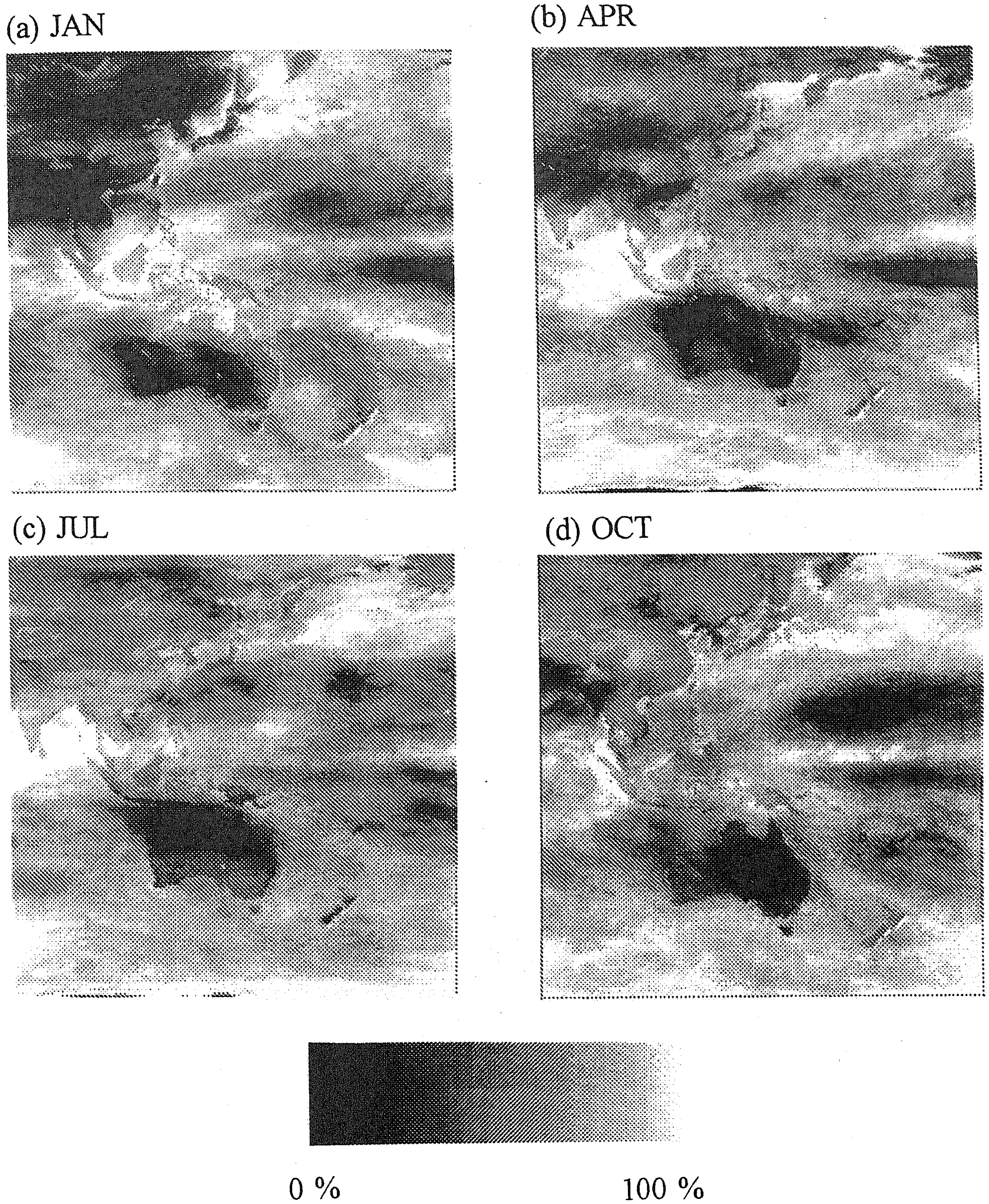

Fig. 1. Total cloud cover of (a) January, (b) Feburary, (c) July, and (d) October.

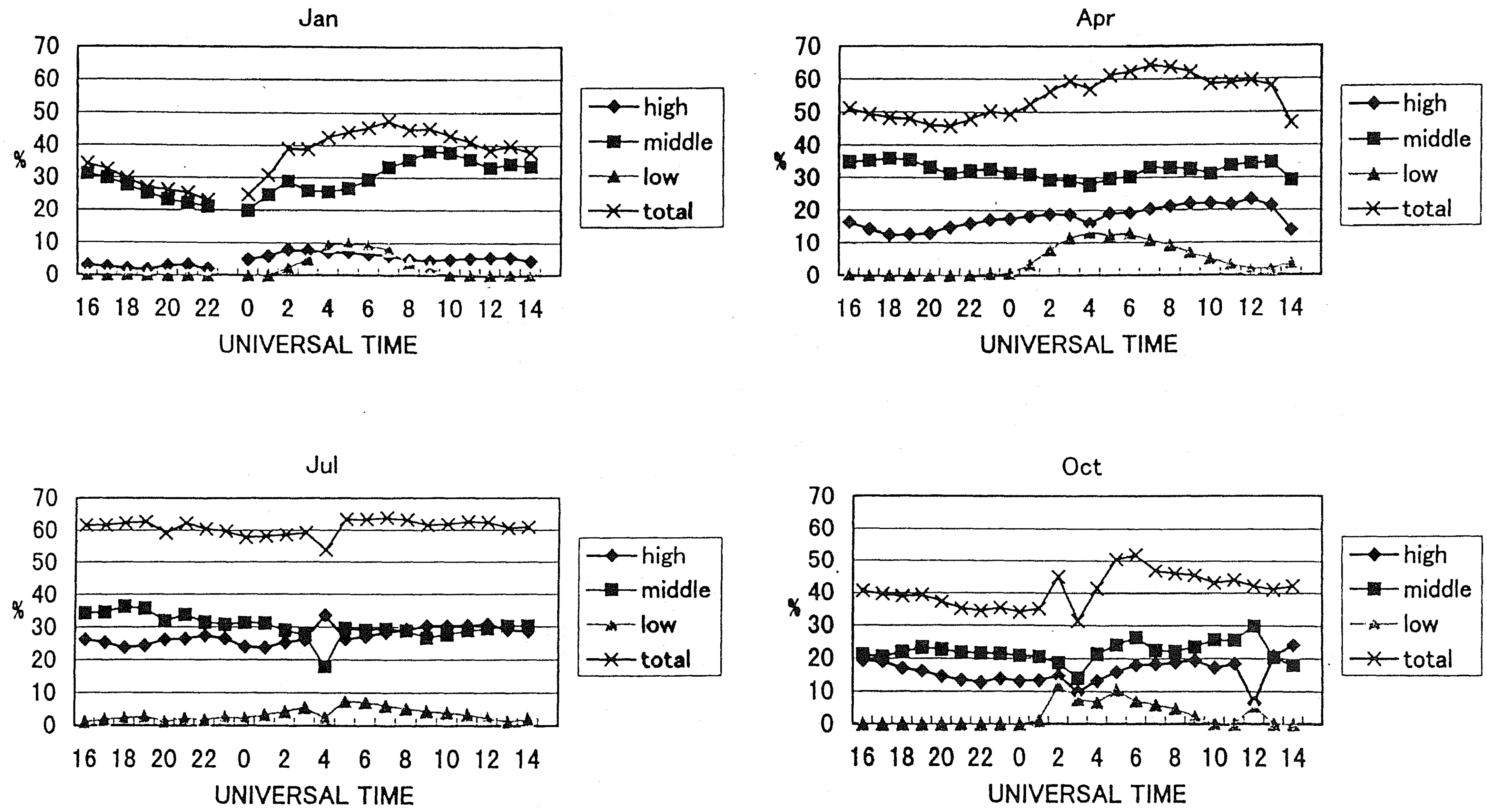

Fig.2. Diurnal variation of cloud cover in Hua-Bei plane (32N114E - 37N117E). Time series start from 0 hour at local time.