Cloud Amount and Daylight Availability

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Abstract

Instrumental measurement of cloud amount was developed and tried with daylight and solar radiation measurement.This paper presents some findings on the relation between cloud amount and daylight availability.

Introduction

Clouds have a great influence on daylight availability. For detailed daylighting designs and other related applications, data on daylight availability should be investigated and arranged by taking the impact of clouds into consideration. Meteorological observations of clouds are made on cloud forms, cloud amount, cloud height and the direction of motion. Among them, cloud amount is considered to be the most dominant factor in fluctuations of daylight. The purpose of this research work is to investigate the relation between cloud amount and variations in daylight availability.

Clouds are observed from both the ground and the air. The ground observation of clouds depends almost on visual means, which tends to cause individual variation in the results. Moreover, the visual observation is inappropriate for long-term continuous measurement at frequent intervals.
Therefore, instrumental observation is necessary for consistent analysis of the results obtained on different sites.

The authors developed a method for instrumental measurement of cloud amount and a prototype instrument in the previous studies [1, 2]. Subsequently, cloud amount measurement was carried out on an experimental basis at the daylight and solar radiation measurement station of Kyushu University in Fukuoka (33°31’N, 130°29’E). This paper shows preliminary findings on the relation between cloud amount and daylight availability as well as an outline of the measuring system.

Measuring system

Cloud amount is defined as a ratio of the sum of the solid angles subtended by clouds to the solid angle of the whole sky (2p). In the developed measuring method, the sky hemisphere is divided into a large number of elements and scanned. Each sky element is judged to be either blue sky or cloud from the correlated colour temperature of skylight. Then, the cloud amount is obtained from the sum of the solid angles subtended by the sky elements judged to be cloud. In order to discriminate between the blue sky and clouds, criteria of correlated colour temperature are decided for solar altitude, altitude of the sky element, and angular distance between the sky element and the sun.

The measuring instrument consists of a luminance colorimeter and a driving unit. The luminance colorimeter (TOPCON BM-5A) measures tristimulus values X, Y and Z, and calculates correlated colour temperature by an internal operation. The driving unit rotates the luminance colorimeter around the vertical axis with varying the angle of elevation. Fig. 1 shows the block diagram of the measuring instrument.

A computer controls the measuring system. The output is recorded automatically and immediately. Scanning patterns and intervals are alterable in the computer program. By the program, the sky scan skips over the sky elements that coincide with obstructions. The computer displays on its screen whether each sky element is blue sky or cloud as the sky scan goes on, and finally the cloud amount.

Measurement and analysis

The cloud amount measurement was carried out for 13 days between 1 December 1998 and 2 February 1999. The scanning pattern was 145 points over the sky hemisphere in accordance with that recommended for sky luminance measurement in the CIE guide to daylight measurement [3]. The sky scan was performed at 15-minute intervals. A standard sky scan took approximately 10 minutes. The angle of view of the luminance colorimeter was 0.2°. 222 sky scans were acquired in total. Fig. 2 shows the frequency distribution of cloud amount.

The measurement station of Kyushu University is collecting data on 14 items of daylight and solar radiation with other related measurement items [4]. The 14 items are global illuminance and irradiance, diffuse illuminance and irradiance, direct solar illuminance and irradiance, and vertical illuminance and irradiance facing North, East, South and West. Data analysis was done on 4 items from among them: global illuminance and irradiance (Evg and Eeg), and diffuse illuminance and irradiance (Evd and Eed). Daylight and solar radiation data are collected at one-minute intervals continuously for 24 hours. Thus, the analysis took data which have been acquired during the corresponding time of each sky scan and used mean values.

The 222 data sets were sorted by solar altitude in 5-degree intervals. The following table shows the number of the data sets by solar altitude.

Table Number of the data sets by solar altitude (S. Alt.)

S. Alt.	Cloud amount										total
[deg]	0 – **1**	1 – **2**	2 – **3**	3 – **4**	4 – **5**	5 – **6**	6 – **7**	7 – **8**	8 – **9**	9 –**10**	
0 – **5**	0	0	0	0	0	0	0	0	0	0	0
5 – **10**	0	1	1	1	1	0	0	0	0	0	4
10 – **15**	1	4	1	1	0	0	0	0	0	4	11
15 – **20**	7	0	0	1	0	0	0	1	1	7	17
20 – **25**	8	0	1	2	2	1	0	2	2	7	25
25 – **30**	8	6	7	3	4	1	0	0	3	12	44
30 – **35**	9	13	6	5	6	6	3	1	5	32	86
35 – **40**	7	3	5	2	2	1	0	1	3	11	35
total	40	27	21	15	15	9	3	5	14	73	222

Results

In the respective groups sorted by solar altitude, there was a similar tendency between illuminance and irradiance versus cloud amount. The global component appeared to decrease with increasing cloud amount. However, it dispersed for the intermediate range of cloud amount. In that range of cloud amount, the direct solar component fluctuates according to the sun's emergence and consequently influences the global component. When the sky was partly cloudy, the sun sometimes disappeared and soon emerged from behind moving clouds even during one sky scan. The diffuse component seemed to increase slightly with cloud amount. For the cloud amount of 9 - 10, both global and diffuse components dispersed in a somewhat wide range. Cloud form is considered the prime cause. In other words, even when the sky is fully covered with cloud, thin clouds do not weaken daylight and solar radiation so much as thick clouds do. Fig. 3 and Fig. 4 show the relation of cloud amount to illuminance and irradiance respectively for the solar altitude of 30° - 35°.

Then, the global illuminance sorted by cloud amount was investigated. On the whole, the larger was the cloud amount, the lower was the global illuminance. And the global illuminance increased with solar altitude. For the small cloud amount within the range of 0 - 3, there was a linear relationship between the global illuminance and the solar altitude. However, for the larger cloud amount, the global illuminance increased with a range of variation with solar altitude. Fig. 5 shows the global illuminance by cloud amount versus solar altitude.

Cloud Ratio is an index that specifies sky conditions. It is originally defined as a ratio of diffuse irradiance to global irradiance and also applicable to the case of illuminance. The Cloud Ratio is theoretically equal to 1 on both irradiance and illuminance when the sky is completely overcast. It is found from measurements that the Cloud Ratio on illuminance depends on solar altitude and ranges mostly from 0.2 to 0.4 for the clear sky [5].

As the result of comparison between Cloud Ratio on illuminance and cloud amount, the Cloud Ratio ranged roughly from 0.15 to 0.40 for the cloud amount less than 1 (regarded as clear sky). For the cloud amount more than 9 (regarded as overcast sky), the Cloud Ratio was about 1. In general, there seemed to be a correlation between Cloud Ratio and cloud amount. However, the Cloud Ratio varied rather widely for the cloud amount between 1 and 9. Fig. 6 shows the relation between Cloud Ratio on illuminance and cloud amount. The Cloud Ratio is the mean of the values obtained during the time of each sky scan.

The direct solar component dominates the global component, which is the denominator in the definition of Cloud Ratio. Thus, even if the cloud amount is the same, the Cloud Ratio varies according to cloud patterns, that is, proportions of the direct solar component. Therefore, even if the cloud amount is 10, thinner clouds may make the Cloud Ratio smaller than 1.

Conclusions

It is found that cloud forms and patterns cannot be neglected in considering the relation between cloud amount and global illuminance, particularly for the case when the sky is partly cloudy. Further analysis will take a factor of sunshine into consideration.

Additional measurement of cloud amount was carried out between 27 May and 4 June 1999. Follow-up studies are planned on cloud's influences on daylight availability.

Acknowledgments

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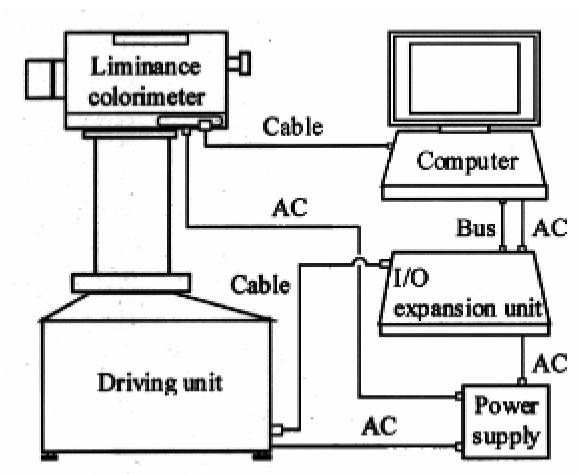

Fig. 1 Block diagram of the measuring instrument

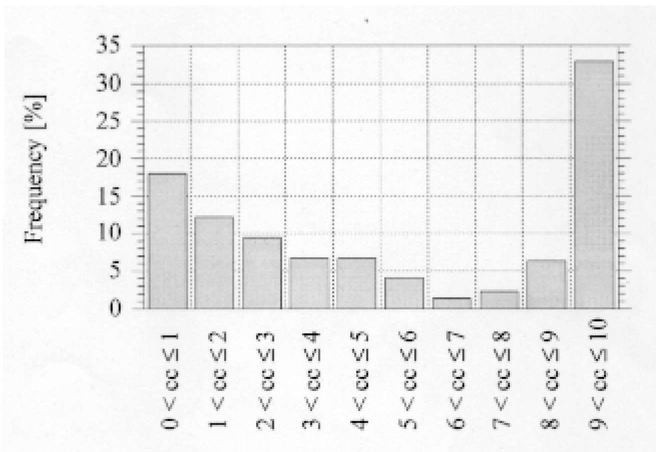

Fig. 2 Frequency distribution of cloud amount (cc)

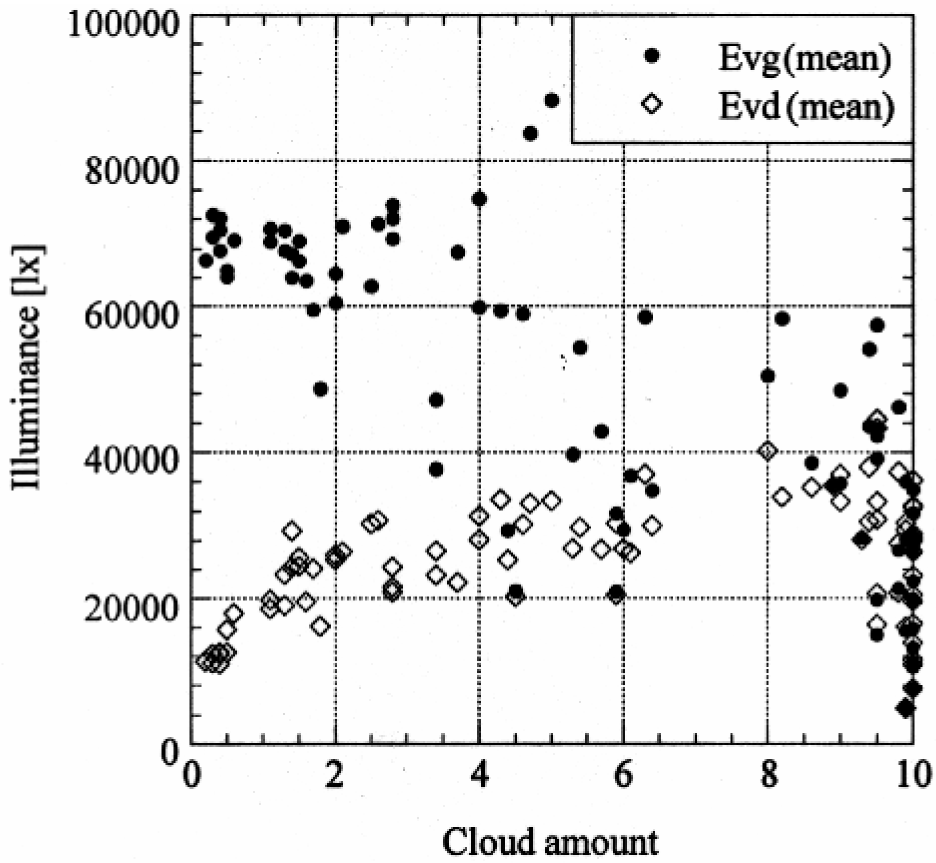

Fig. 3 Global illuminance (Evg) and diffuse illuminance (Evd) versus cloud amount
(Solar altitude: 30° – 35°, Number of the data: 86)

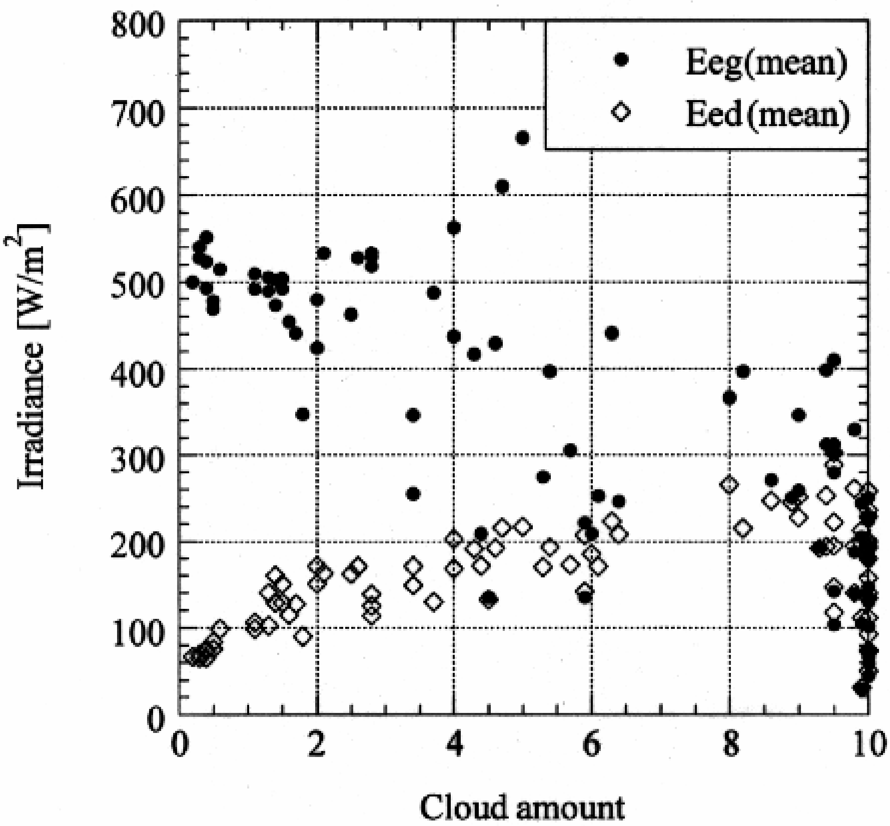

Fig. 4 Global irradiance (Eeg) and diffuse irradiance (Eed) versus cloud amount
(Solar altitude: 30° – 35°, Number of the data: 86)

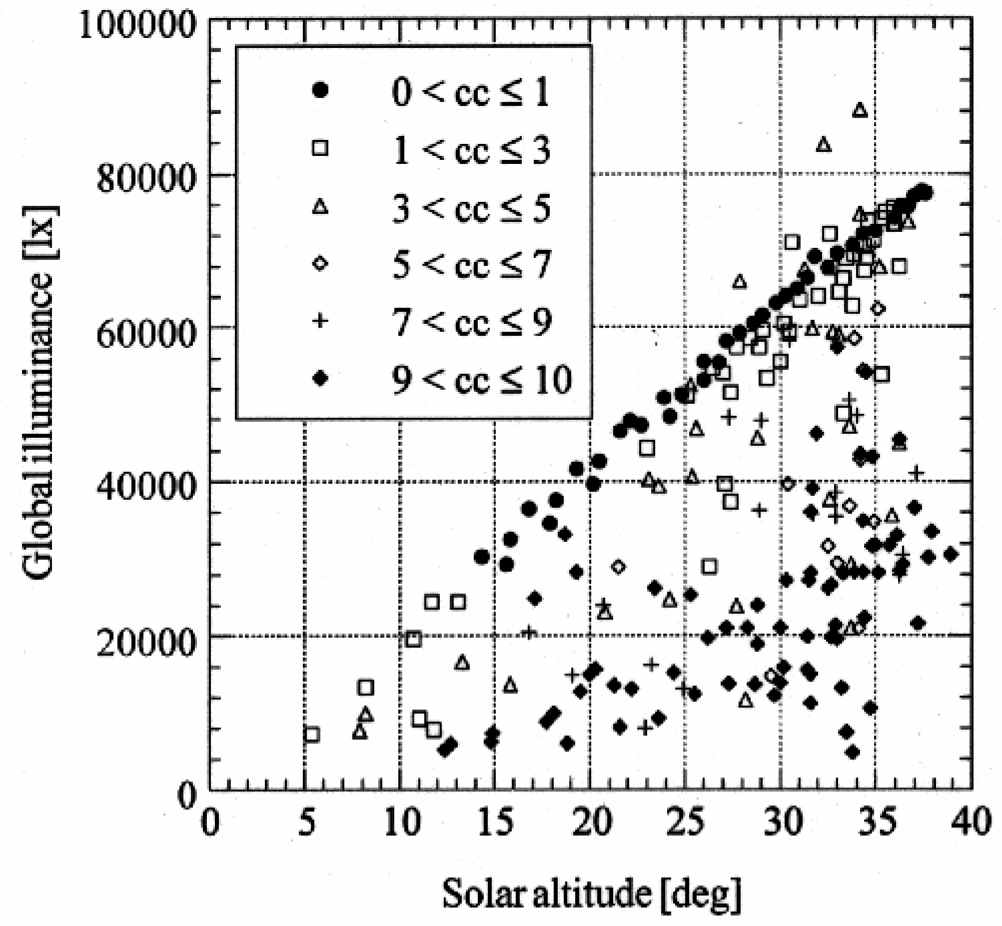

Fig. 5 Global illuminance by cloud amount (cc) versus solar altitude

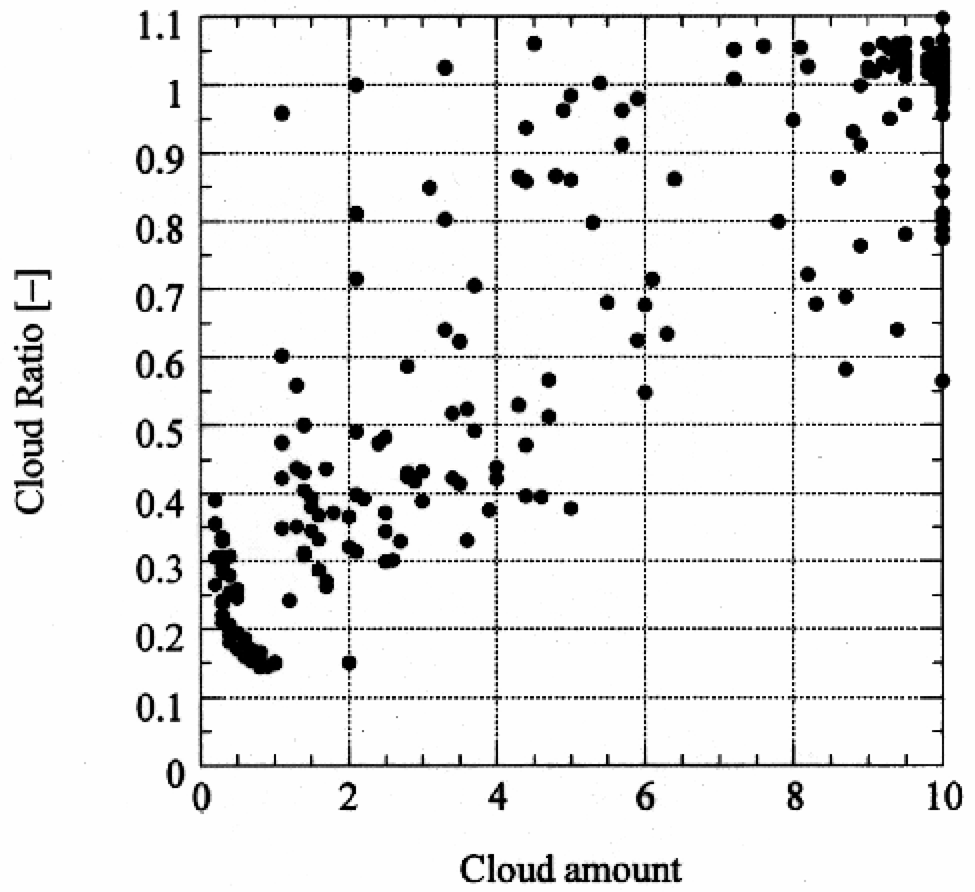

Fig. 6 Relation between Cloud Ratio on illuminance and cloud amount