Balkan Light'99

SATELLIGHT: A WWW SERVER WHICH PROVIDES HIGH QUALITY DAYLIGHT AND SOLAR RADIATION DATA FOR WESTERN AND CENTRAL EUROPE.

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SYNOPSIS: «Satellight» is a web server providing daylight and solar radiation data for Western and Central Europe based on the Meteosat Satellite images. The information consists in maps or in site specific statistics.

ABSTRACT: «Satellight» was a 3 year-European research program (Jan. 1996-March 1999) with the objective of making available on Internet a database of solar radiation and daylight for Western and Central Europe. The data was obtained by processing the information provided by the Meteosat satellite every 30 minutes. We first developed and validated models to derive radiation and daylight data on ground from the satellite measurements. Then we produced two years of data: 1996 and 1997, and made it accessible via a web server. The server is currently in beta testing, its address is http://satel-light.entpe.fr , a page is provided if you want to become a beta tester. It provides statistics on the direct, diffuse and global illuminances or irradiances, on horizontal or tilted plane, for various zones in Europe (including the Balkans) or for specific locations.

1. INTRODUCTION

There is a need today to access rapidly to local climatic data all over Europe, dealing with natural radiation as well as daylight. Optimization of energetic performances of windows and daylighting systems requires at least statistics on horizontal and vertical irradiances and illuminances. Very few measuring stations continuously record these data in Western Europe (about 17). Today, such data are available in climatic atlases such as the European Solar Radiation Atlas [1] and the European Daylighting Atlas [2]. These documents gather very useful information which were derived from meteorological data. However, these data have three major weaknesses: there is a lack of continuity of measurements over Europe (due to the limited number of ground stations in some areas), there are no hourly or 1/2 hourly values except for a few sites, and no information is available regarding the directionality of the diffuse light which is essential for daylighting calculations. Satellite data seem to be a logical approach to answer these problems. The major difficulty stands in the precision of the ground level data derived from the satellite data, using various models. One of our task was to develop and validate such models, the other was to produce a database and make it widely available via an internet web server.

2. THE DATA PROVIDED BY METEOSAT

Since 1977, six Meteosat satellites have been launched. A Meteosat type satellite is a geostationary satellite located on the equatorial plane, at a longitude of 0 degree, and an altitude close to 36,000 km. It sees one half of the earth and measures every half hour, the reflected radiation in three spectral bands: visible (between 0.5 and 0.9 µm), water vapour (between 5.7 and 7.1 µm) and infra red (between 10.5 and 12.5 µm). The images provided by the radiometer have a maximum resolution of 5,000 pixels by 5,000 pixels in the visible. In the other channels, the resolution is 2,500 pixels by 2,500 pixels which leads to a useful number of pixels equal to 6.25 millions. This somewhat lower resolution is also often used for the visible. The satellite takes the complete image of the earth in 25 minutes. This leads to the production every half hour, of about 245,000 pixels useful for western and central Europe. In central Europe, one pixel refers to an area of about 10 km in latitude by 5 km in longitude. The ground data used for the validation of the models were measured every minute, versus 30 minutes for the satellite data. This means that the ground data had to be averaged over a half hour period centered on the time at which the satellite was reading the pixel value. Various tests showed that the best agreement between ground data and satellite data was obtained, not when using one pixel, but when using multiple pixels (3 in latitude by 5 in longitude). This compensates for the unstable situations for which the available irradiation has large variations during the half hour period.

3. DERIVATION OF GLOBAL HORIZONTAL IRRADIANCES

Global horizontal irradiances on ground are estimated from the pixel values in the visible spectrum using the concept of the Heliosat method [3]. This method had been recently modified [4] and we have made further improvements to it. The Heliosat method is based on the assumption that the albedo of a cloudy atmosphere will usually be larger than the albedo of the ocean or the earth surface. Thus, the increase of the albedo gives a measure of the cloud cover.

A relative apparent albedo is estimated from the pixel value of the satellite image. The pixel value depends on the energy radiated by the sun at the time the satellite sees the pixel. The Dumortier [5] cloudless sky model at a turbidity of 3.0, is used to take into account this dependency. For solar elevations below 6°, the satellite radiometer cannot make the difference between a pixel with clouds or without clouds. In that case, we use the pixel value immediately available. From the relative apparent albedo, a cloud index is computed using the following normalization:

$$n = \frac{\rho - \rho_g}{\rho_c - \rho_g}$$

r *relative albedo of the pixel*

r_g *relative albedo of the ground*

r_c *relative albedo of a compact cloud cover*

The relative albedo of a compact cloud cover is obtained from the highest _ value. The relative albedo of the ground is obtained every month for each pixel, from the frequency distribution of albedo values for that pixel. It is the most frequent low value in a series of images [6]. The presence of snow increases significantly the ground albedo, making the detection of clouds harder from the satellite.

The global horizontal irradiance on the ground is then obtained assuming a simple linear relationship between the cloud index n and the clear sky index k c : the ratio of the global irradiance to the global irradiance under cloudless sky conditions:

$$k_c = \frac{Eeg}{Eeg_{clear}}$$

Eeg the global horizontal irradiance

Eeg the global horizontal irradiance under cloudless conditions

n £ -0.2 kc = 1.2

-0.2 £ n £ 0.8 kc = 1 - n

0.8 £ n £ 1.1 kc = 2.0667 - 3.6667n + 1.6667 n^2

n ³ 1.1 kc = 0.05

The Dumortier [5] cloudless sky model is used with monthly values of the turbidity. This has shown to improve the accuracy of the results, over the use of an annual value.

Using this modified Heliosat method and taking no account of snow cover information, the global horizontal irradiances have been produced for various test sites spread across Europe, and compared with ground measurements. Figure 1 shows the results of this comparison in Vaulx-en-Velin (France) and Lisbon (Portugal), on the basis of frequency curves. These results are encouraging.

Figure 1: Probability to exceed a given level of global horizontal irradiance in Vaulx-en-Velin and in Lisbon. Comparison between data measured on ground and data derived from Meteosat.

There is an RMSE of 8 to 13% between modeled and measured values under sunny or quasi sunny conditions. Overcast and quasi overcast conditions lead to larger RMSEs: from 30% to 50%. This is due to the fact that the amount of radiation transmitted by the cloud cover depends on its thickness and its composition. This cannot be derived just from the knowledge of the radiation reflected by the upper surface of the clouds. The group is investigating the use of a database of temperature profiles (ECMWF) to improve this situation.

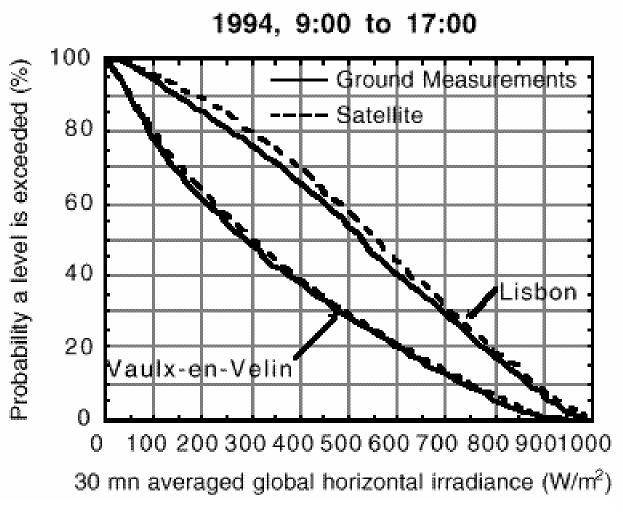


Figure 1

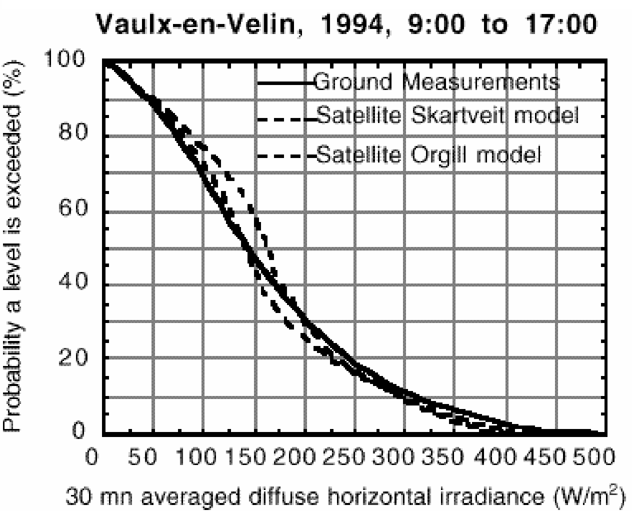


Figure 2

4. CALCULATION OF DIFFUSE HORIZONTAL IRRADIANCES

We have selected an updated version of the Skartveit and Olseth algorithm [7]. One of its interesting features is to prevent situations where the normal beam irradiance become unreasonably high at low solar altitudes. Figure 2 shows the good performance obtained with this model.

Figure 2: Probability to exceed a given level of diffuse horizontal irradiance in Vaulx-en-Velin. Comparison between data measured on ground and data derived from Meteosat using the Orgill&Hollands relationship and the modified Skartveit and Olseth model.

5. CALCULATION OF HORIZONTAL ILLUMINANCES

To derive illuminances, we have selected an indirect route which consists in computing the illuminances from the irradiances using luminous efficacy models. We have selected the luminous efficacy model from Olseth [8]. It has been selected for its capability to adapt to changes in the aerosol/water vapour content and in the depth of the cloud cover using data from Gävle (N), Vaulx-en-Velin (F), Freiburg (G), Lisbon (P) and Geneva (CH), it has been shown to lead to better results than other models.

6. CALCULATION OF VERTICAL ILLUMINANCES

This type of data is essential to assess the performance of daylighting systems, since most apertures of buildings tend to be vertical, at least for residential and office buildings. Vertical windows collect light from the non-zenithal areas of the sky. This leads to a high sensitivity to the specific luminance of the section of the sky seen from the interior of the building. The ideal solution would be to be able to determine, every half hour the sky luminance distribution.

Our first approach dealt with the analysis of the light reflected from various pixels above a site. The University of Geneva tried to relate this information to sky luminance patterns [9]. It compared sky scans taken from the ground in Geneva (145 luminance measurements, every 15 minutes, each of them with an aperture of 10°) and luminances computed from the pixels, assuming clouds to behave as perfect diffusers.

The results were disappointing: (1) because of the size of the pixels, the satellite data can only generate a maximum of 9 luminances, (2) these luminances do not take into account the influence of the circumsolar zone, (3) their position in the sky vault change with the altitude of the cloud layer, (4) the altitude of the cloud layer is difficult to determine. We have reached the conclusion that the satellite information is insufficient to help in finding out the directionality of the light. It is better estimated with sky luminance distribution models using global and diffuse horizontal irradiances and illuminances as an input. Based on earlier studies [10], we have selected the ASRC-CIE Perez model [11].

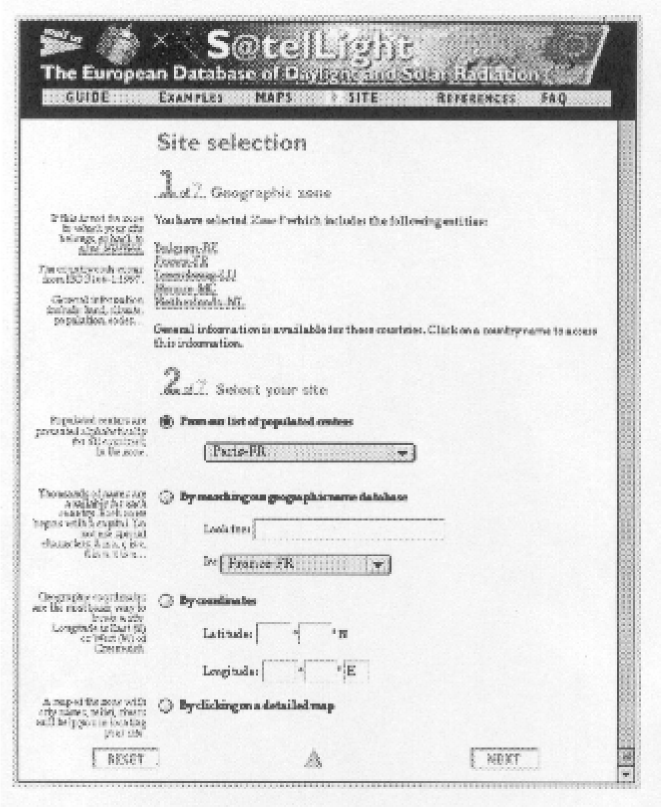
Our second approach was to investigate the use of a model to produce vertical irradiances from horizontal values. Based on earlier studies and further validation in Geneva, a version of the Hay's model [12], modified by Skartveit and Olseth [13], has been selected. Slope irradiance is then transformed into slope illuminance using the luminous efficacy of horizontal irradiance.

When comparing to ground measurements, an albedo of 0.1 was found as representative of the black foreground material placed in front of the vertical sensors. Absolute errors between measured and modelled values were within -5 and +5 klux. The global illuminance on the North surface was slightly overestimated while it was slightly underestimated on the other surfaces.

7. THE WEB SERVER

The final objective of this project was to process and make available two years of satellite derived data: 1996 and 1997. This information is accessible for free on a web server which insures a wide access to the data.

The server is divided into three main sections: «Maps», «Site outdoor» and «Daylighting». The «Maps» section is dedicated to the production of maps for whole Europe or for one of 13 zones in Europe, the «Site outdoor» section, to the production of site (e.g. pixel) specific information, and the «Daylighting» section, to the assessment of the daylighting performance of basic design solutions for a particular location.



Site selection

1 of 2. Geographic zone

You have selected Zone F which includes the following entities:

Belgium-BE
France-FR
Luxembourg-LU
Monaco-MC
Netherlands-NL

General information is available for these countries. Click on a country name to access this information.

2 of 2. Select your site

● From an list of populated centres

Paris-FR

○ By matching on geographic name database

Look for:

In: France-FR

○ By coordinates

Latitude: ° ' N

Longitude: ° ' E

○ By clicking on a detailed map

Figure 3: Site selection on the web server.

The user is requested to answer questions regarding the type of information he desires (see Figure 4): What period of time ? (all year, season, daily schedule), What information ? (solar position, irradiances, illuminances, sky luminances) and for the «Daylighting» section: Which case study ? (type of windows, indoor materials, ground albedo).

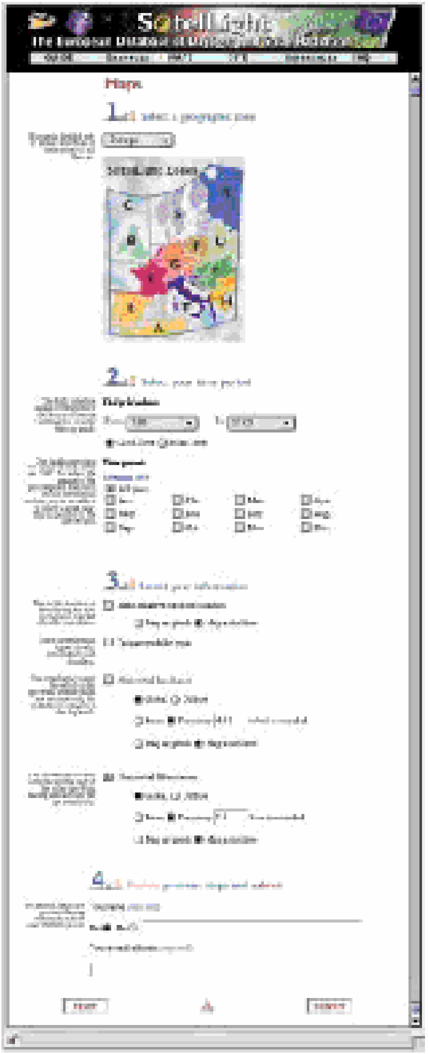


Figure 4: Request form used to select output parameters (production of maps).

The server generates the information on the fly and sends an e-mail to the user when it is ready. Data tables are presented in html tables which can be copied in spreadsheet programs. Figures are presented using the GIF format. Figures 5 to 7 show various examples of the information produced by the server.

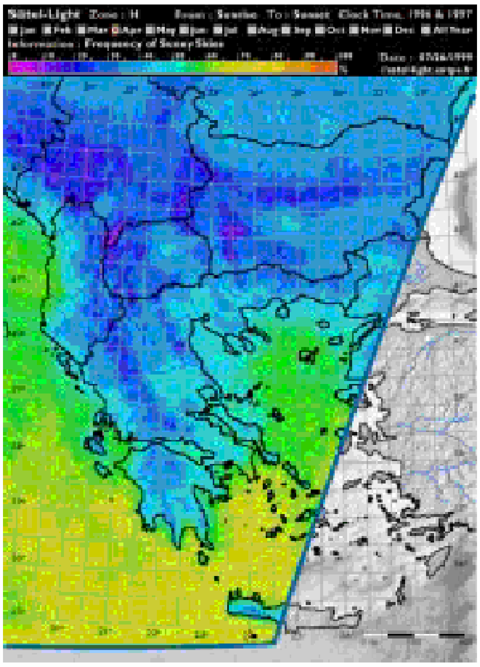


Figure 5: Example of a map. Frequency of sunny skies in April in Greece, Bulgaria…

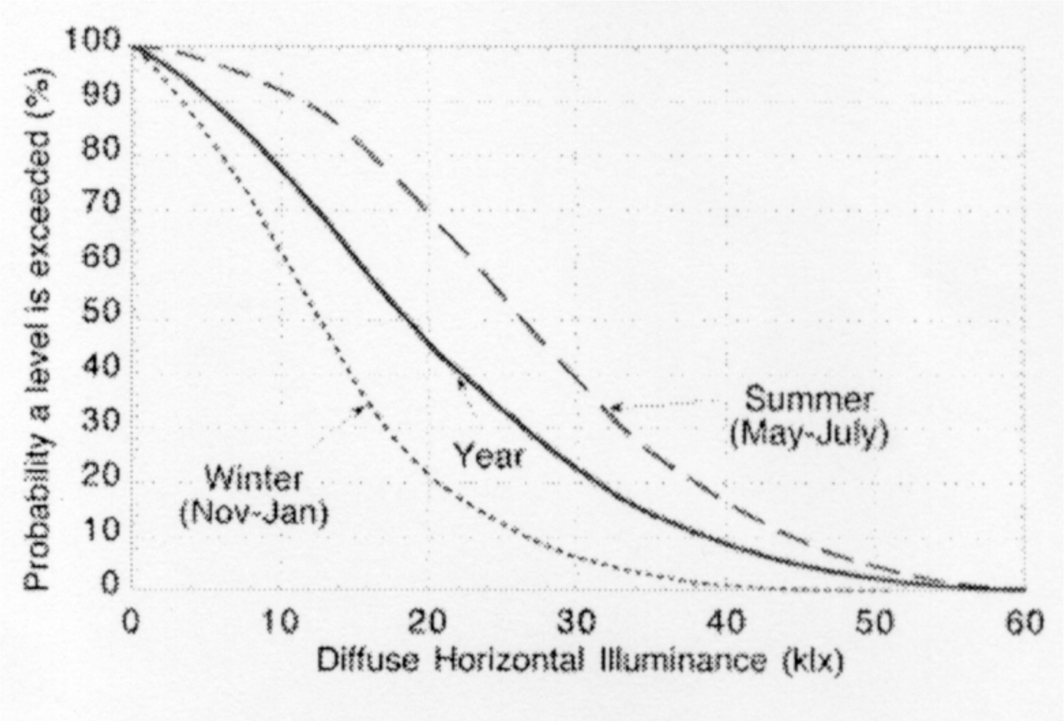


Figure 6: Annual and seasonal probability curve for horizontal illuminance at a site.

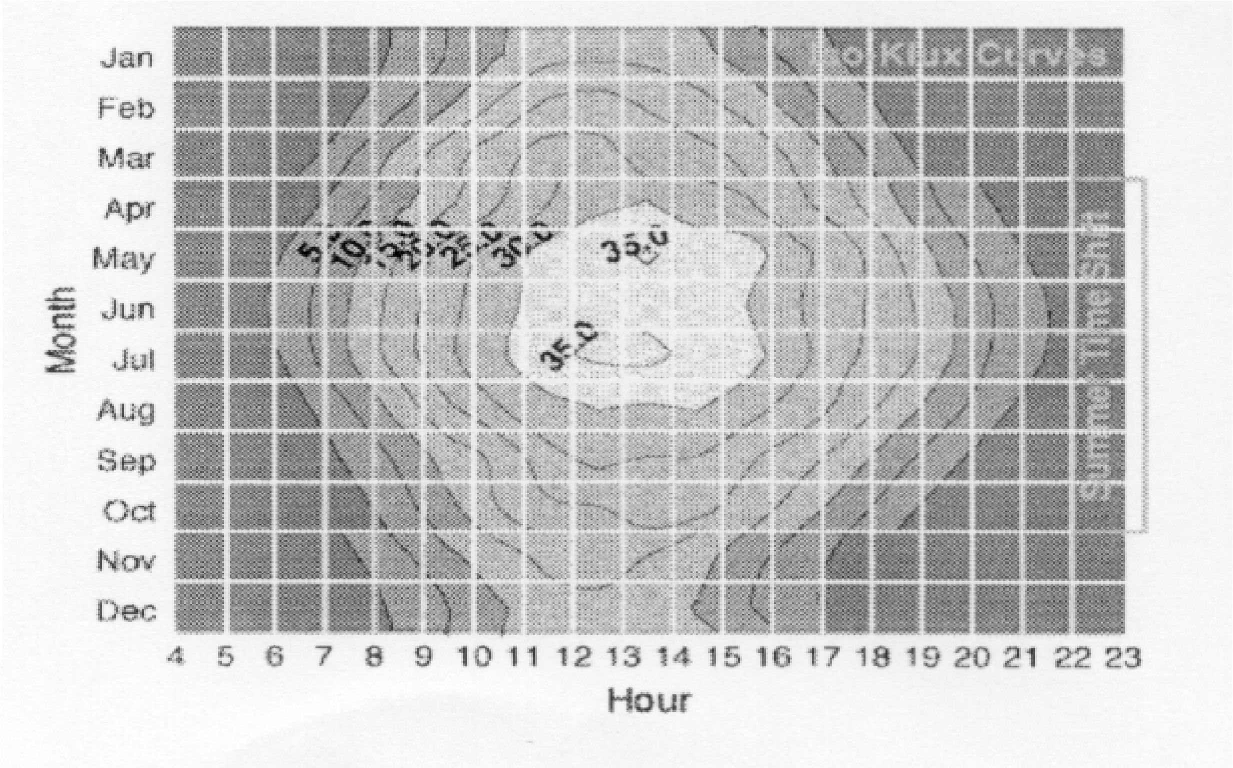


Figure 7: Mean monthly hourly values of diffuse illuminance for a given site.

8. CONCLUSION

The server is currently in beta testing, its address is **http://satel-light.entpe.fr** , a page is provided if you want to become a beta tester.

The information provided by the server should help:

(1) manufacturers to propose optimal solutions for the various European climates;

(2) designers, engineering and marketing firms, to assess and present the performance of their solutions for the client location;

(3) engineering and architecture students.

9. ACKNOWLEDGEMENTS

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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.

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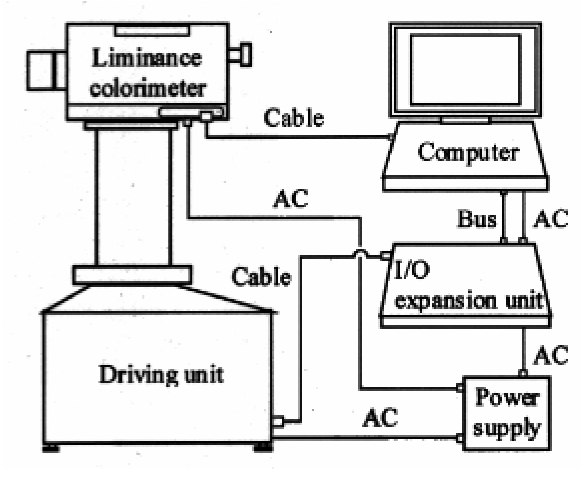

Fig. 1 Block diagram of the measuring instrument

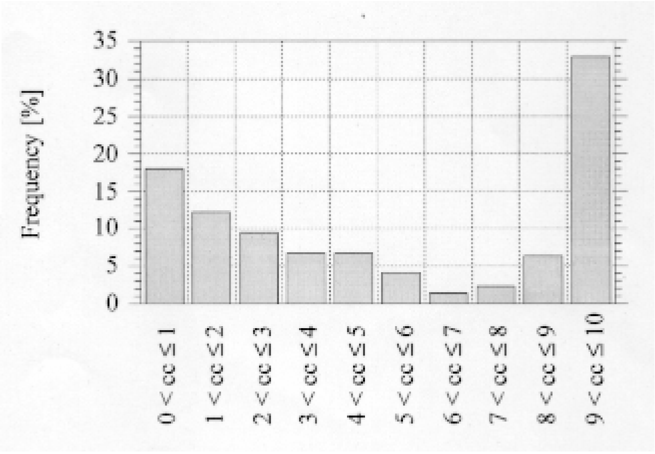

Fig. 2 Frequency distribution of cloud amount (cc)

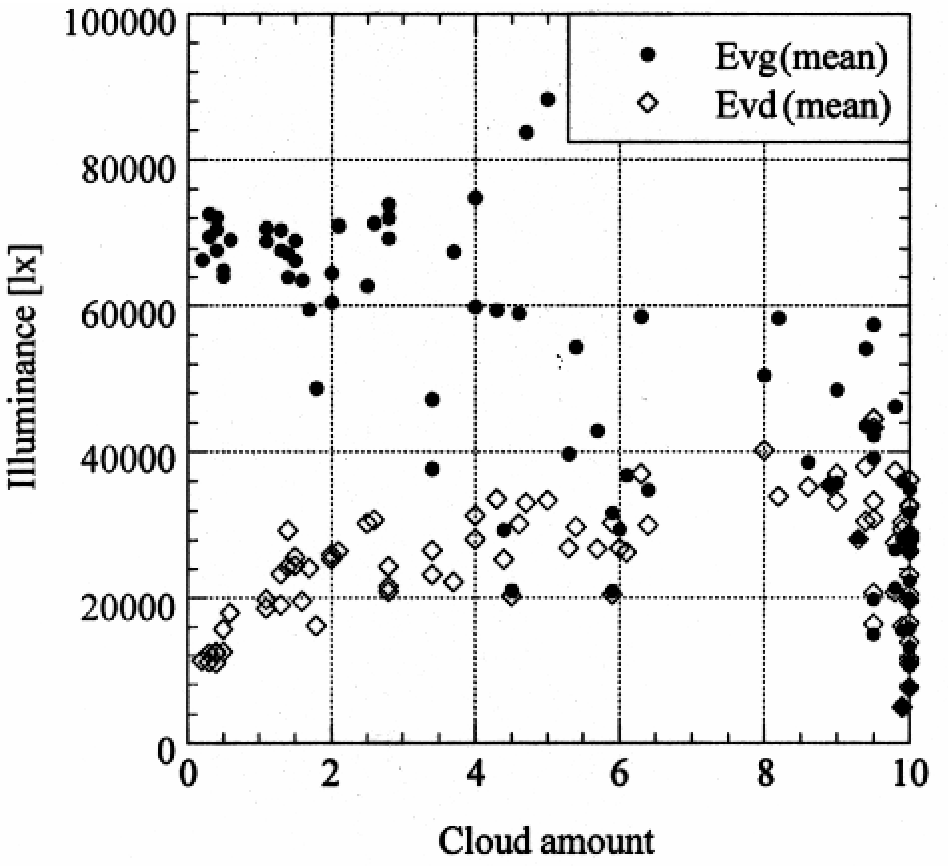

Fig. 3 Global illuminance (Evg) and diffuse illuminance (Evd) versus cloud amount
(Solar altitude: 30° – 35°, Number of the data: 86)

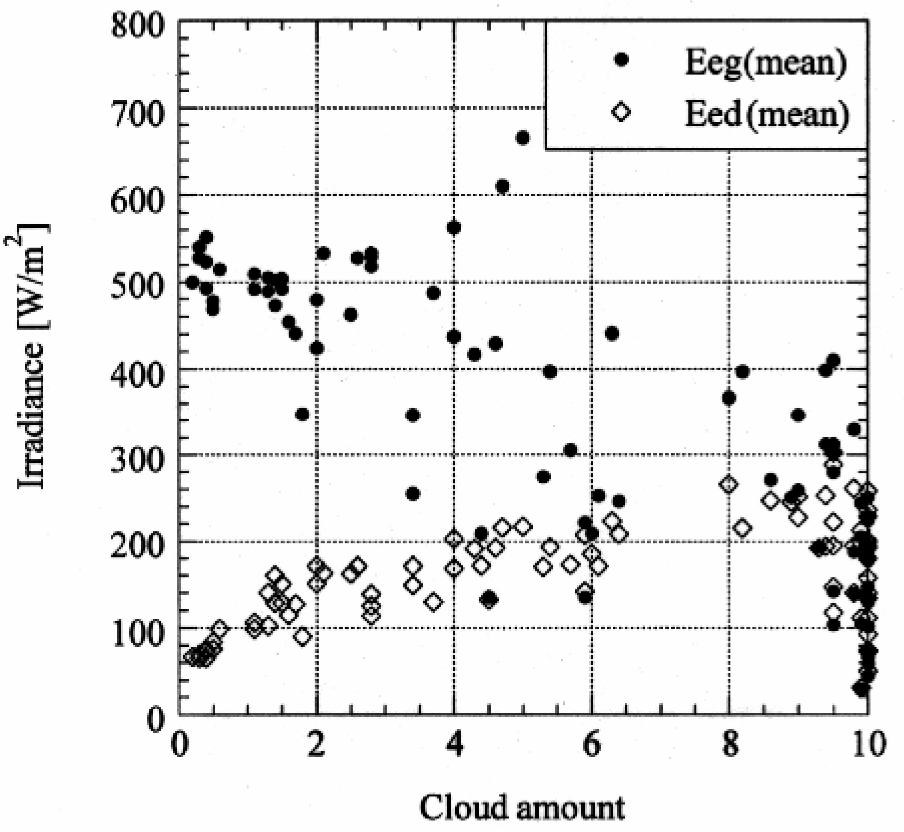

Fig. 4 Global irradiance (Eeg) and diffuse irradiance (Eed) versus cloud amount
(Solar altitude: 30° – 35°, Number of the data: 86)

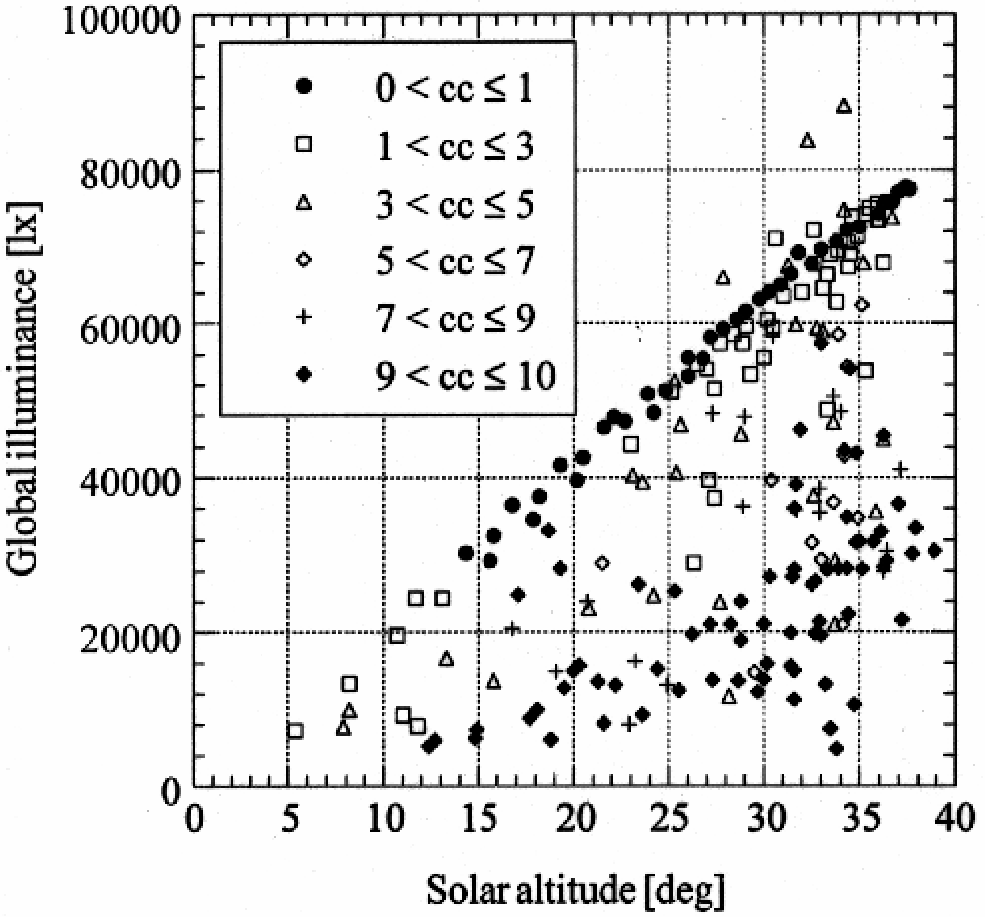

Fig. 5 Global illuminance by cloud amount (cc) versus solar altitude

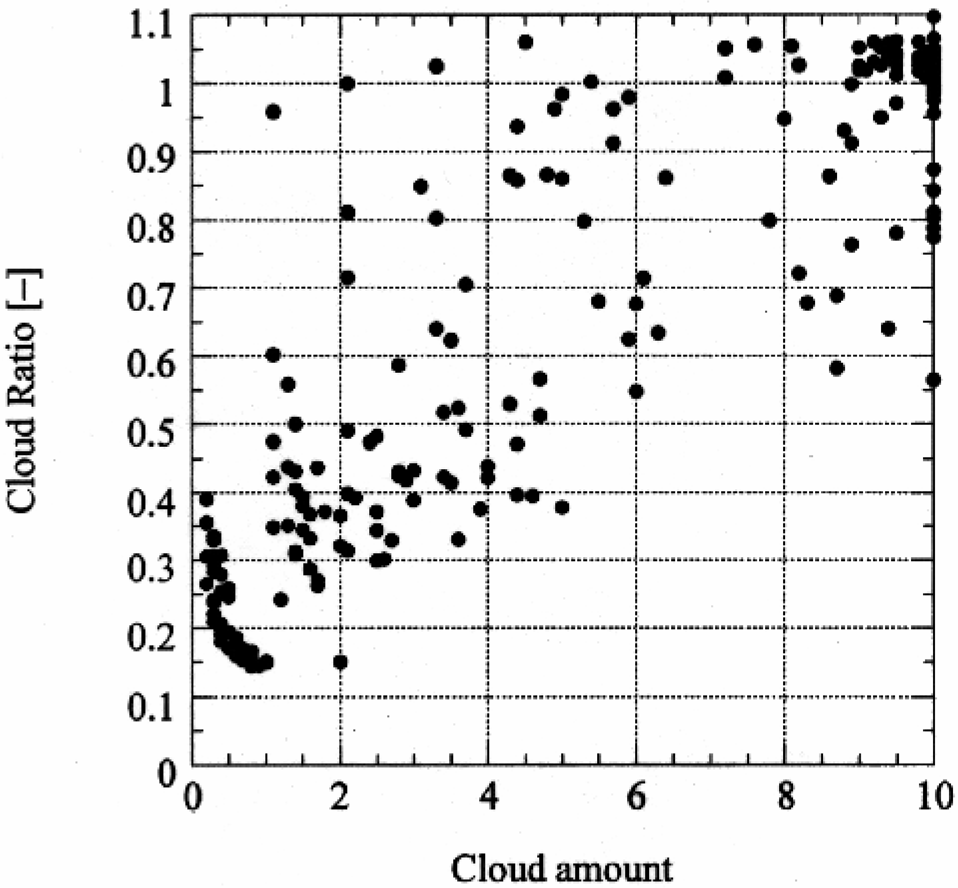

Fig. 6 Relation between Cloud Ratio on illuminance and cloud amount

DAYLIGHT AS CLIMATE FACTOR

ЕСТЕСТВЕНОТО ОСВЕТЛЕНИЕ КАТО КЛИМАТИЧЕН ФАКТОР

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The natural lighting is presented as climate norm for a given territory, necessary for the planing of electricity consumption for lighting. For the real presentation of it's spatial and time structure are used the continuous actinometric measurements of the sun radiation in Bulgaria. In the paper is described the daily and yearly available amount of daylight, the influence of different factors applying an accepted lighting equivalent.

1. Увод

Естественото осветление, свързано с енергетиката, светлотехниката, строителството и др., като характеристика на радиационния режим, е и важен климатичен фактор. Изучаването на светлинния режим на страната е свързано и с използване на природните ресурси от светлинна енергия, което е с голям икономически ефект с оглед спестяването на електроенергия. Разходът на произведената електроенергия и превърната в топлинна, светлинна и механична се определя не само от производствените условия, но съществено зависи и от метеорологичните фактори, включващи и радиационните в това число и естественото осветление. Ето защо при планиране на разход на електроенергия за осветление трябва да се разполага и с климатична норма на естественото осветление за дадена територия. Съществуващите обаче (предимно епизодични и само в отделни случаи регулярни) измервания, за сравнително кратък период (отличаващи се от значително от средните многогодишни стойности на естественото осветление) са недостатъчни за изследване неговата пространствена и временна структура. Това налага за изследване на светлинния климат на даден район да се използват многогодишни данни от актинометричните измервания, които се провеждат в повече места. За тази цел е необходимо определянето на светлинния еквивалент на слънчевата радиация, неговата зависимост от височината на Слънцето, облачността и прозрачността на атмосферата.

2. Светлинен еквивалент на слънчевата радиация

Светлинният еквивалент на слънчевата радиация представлява отношението на осветлението в **klx** към едновременните стойности на интензивността на слънчевата радиация в **kW/m^2**.

Изследвания [3] показват, че стойностите на светлинния еквивалент, определени за места с различни метеорологични условия са близки поради което за различни географски райони може да се използва един и същи светлинен еквивалент. Различни автори отбелязват постоянство на светлинния еквивалент на сумарна слънчева радиация - 70 klx/kWm^{-2} с граници на колебание ±5%. По наши изследвания същият за София при средни условия на облачността и при височина на София 65° той е 71-72 klx/kWm^{-2}. В много по-широки граници се изменя светлинният еквивалент на разсеяната радиация, което се обяснява с по-тясната й зависимост от съдържанието на аерозоли в атмосферата.

3. Определяне на естественото осветление чрез данните от актинометричните наблюдения в България

Чрез светлинния еквивалент и актинометричните измервания сме определили естественото осветление по методика, разработена в Главна Геофизическа Обсерватория в Санкт Петербург. Като изходни данни са използвани ежечасните актинометрични измервания за височина на Слънцето по голяма от 5°.

При определяне на сумарното естествено осветление актинометричните наблюдения през отделните часове са разпределени за сумарната радиация **Q** на две групи - в първата при открит слънчев диск **Q_1** и при Слънце просветващо през облаци - **Q_2**. Във втората група - при слабо просветващо през слой плътни облаци Слънце **Q_3** и при мрачно небе, когато Слънцето е покрито с облаци **Q_4**. Данните за разсеяната радиация са разделени на три групи: - при открит слънчев диск - **Q_1**, при Слънце просветващо през облаци **Q_2**, и при мрачно небе - **Q_3**.Чрез така групираните ежедневни стойности са определени съответните средни за сумарната и разсеяна слънчева радиация по часове. За получаване на естественото осветление, средните са умножени със съответния светлинен еквивалент. За да се получат средните месечни стойности на сумарното осветление **E_Q**, средните часови стойности се умножават със съответния брой на случаите, т.е - **n_1** и **n_2** и сумата от произведенията се дели на общия брой на случаите т.е.:

$$E_Q = \frac{E_{Q1,2}.n_1 + E_{Q2,3}.n_2}{n_1 + n_2}$$

По същия начин за получаване на средната месечна стойност на разсеяното осветление **E_D** средните значения на разсеяното осветление по часове, групирани при различни условия на облачността се умножават по съответния брой на случаите и сумата от произведенията се дели на сумата от броя на случаите или т.е.:

$$E_D = \frac{E_{D_1} + E_{D_2} + E_{D_3}}{n_1 + n_2 + n_3},$$

където n_1, n_2, n_3 са броят на случаите през месеца при съответните условия на естественото осветление.

Чрез така получените данни за отделните години са определени средните многогодишни стойности на сумарното и разсеяно осветление за всеки срок на даден месец.

4. Зависимост на естественото осветление от астрономичните и метеорологични фактори

Основната характеристика на светлинния режим на дадено място е осветлението на хоризонталната повърхност , т.е светлинният поток падащ на единица повърхност.

Естественото сумарно осветление представлява сума от естественото осветление създадено от непосредствените слънчеви лъчи и разсеяното – определящо се от разсеяното осветление от атмосферата и отразеното от земната повърхност. То зависи от астрономичните фактори, т.е. положението на Слънцето на небосвода – неговата височина и азимут и от метеорологичните фактори – количество, форма и разположение на облаците по небосвода, прозрачността на атмосферата, албедото на активната повърхност.

Естественото осветление при безоблачно небе се определя предимно от височината на Слънцето. Така за София от около 42klx на пладне през зимата, сумарното осветление през лятото нараства повече от два пъти и достига до 93klx, а съответните стойности на разсеяното осветление са 10klx и 16klx. Значително по-силно е осветлението от пряка слънчева радиация върху перпендикулярна повърхност. Различието между осветлението на двете повърхности намалява с нарастване височината на Слънцето. Така през зимата осветлението върху хоризонтална повърхност представлява 40% от това върху перпендикулярна повърхност, а през лятото то нараства до 90%.

За редица отрасли от стопанската дейност на човека е необходимо естественото осветление за ден или месец. За определяне на дневните му суми е приложена методиката за намиране същите на слънчевата радиация [1]. Чрез така определените дневни суми на сумарното и разсеяно осветление и съответните за сумарната и разсеяна радиация са построени графични зависимости (фиг.1), по които са определени дневните суми на естественото осветление в различни места

Естественото осветление се изменя в твърде широки граници в зависимост от облачността, като при мрачно небе и ниски облаци намалява значително. При наличие на облаци обаче и при открит слънчев диск сумарното осветление може да превиши това при безоблачно небе до 10-20% (фиг.2).

Степента на влияние на отражателните свойства на активната повърхност върху сумарното осветление се определя от височината на Слънцето и вида на облачността. Влиянието на снежната повърхност при безоблачно небе е по-осезателно при малки височини на Слънцето и обратно – при облачно небе е най-значително при най-големите височини на Слънцето. Това добре се илюстрира със фиг.3. Увеличението на дневното осветление вследствие на отражение от снега и вторично отражение от облаците в отделни части от деня може да достигне до десетина процента.

Прозрачността на атмосферата се отразява слабо върху сумарното осветление, тъй като с увеличаване на помътняването и естественото осветление от пряка слънчева радиация намалява, но нараства разсеяното осветление. Това добре се илюстрира от проведените актинометрични наблюдения в един от най-замърсените райони на гр. Перник – кв. Мошино и незамърсения район – гр. Брезник (фиг.4.).

Основните фактори, определящи разсеяното осветление при безоблачно небе са височината на Слънцето и прозрачността на атмосферата. То нараства с намаляване на прозрачността на атмосферата (особено при по-големи височини на Слънцето) и съществено зависи от отражателните свойства на активната повърхност. Наличието на облаци довежда обикновено до намаляване на естественото осветление. В отделни случаи , в зависимост от вида на облаците и тяхното разположение по небосвода, сумарното осветление сумарното осветление може да бъде и по-голямо от същото при безоблачно небе. В средни обаче сумарното осветление при наличие на облаци е по-малко от същото при безоблачно небе. При мрачно небе (облачност ≥ 8) естественото осветление намалява повече от половината в сравнение с осветлението при безоблачно небе [2].

Важна климатична характеристика представлява съотношението между разсеяното и сумарното осветление. При малки височини на Слънцето то се определя от разсеяното осветление. С нарастване на височината на Слънцето доминираща роля започва да играе осветлението от пряка слънчева радиация. Дневния ход на съотношението между разсеяното и сумарно осветление в София през лятото се вижда от фиг. 5.

5. Годишен ход и пространствено разпределение на естественото осветление на територията на България

Годишният ход на сумарното осветление се определя както от радиационния режим включващ астрономичните и метеорологични фактори, така и от състоянието на отражателната повърхност. За цялата страна максималните му стойности са през юли, а минималните през месец декември. През зимата за значителна част от страната то е между 6-7.10^3 klx. През пролетта сумарното дневно осветление почти за цялата страна достига 27-28. 10^3 klx. Пространственото разпределение на сумарното осветление през лятото наподобява това на сумарната слънчева радиация – то се изменя в границите 36-42 10^3 klx, а в най-южните части от страната и над 42. 10^3 klx. Значително по-неблагоприятни за сумарното осветление през лятото са местата в котловинните полета на Западна България.

Съществена е ролята на разсеяното осветление през зимата и в мрачни дни, както и в часовете близки до изгрев и залез Слънце. Колебанията на разсеяното осветление от промените в облачността са по-големи в сравнение с тези, предизвикани от прозрачността на атмосферата и височината на Слънцето. Месечните суми на разсеяното осветление са с изразен годишен ход – минимални през декември и максимални за повечето места през май. Почти за цялата страна през зимата то е около 5-6. 10^3 klx. Годишният максимум на разсеяното осветление през май за по-голямата част от страната е 18-19. 10^3 klx. На ден.

Съотношението между разсеяно и сумарно осветление е с ясно изразен годишен ход – с максимум през зимата (60-70%) и минимум през лятото, когато решаваща роля играе осветлението от пряка слънчева радиация.

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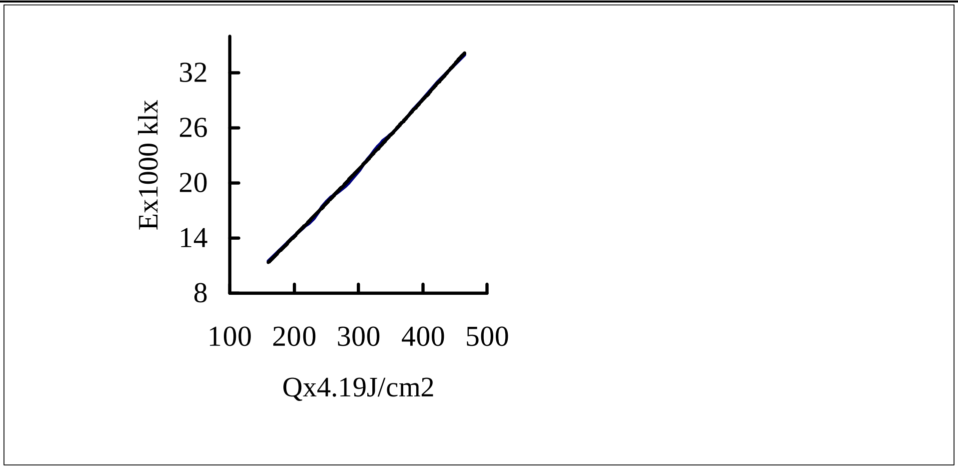
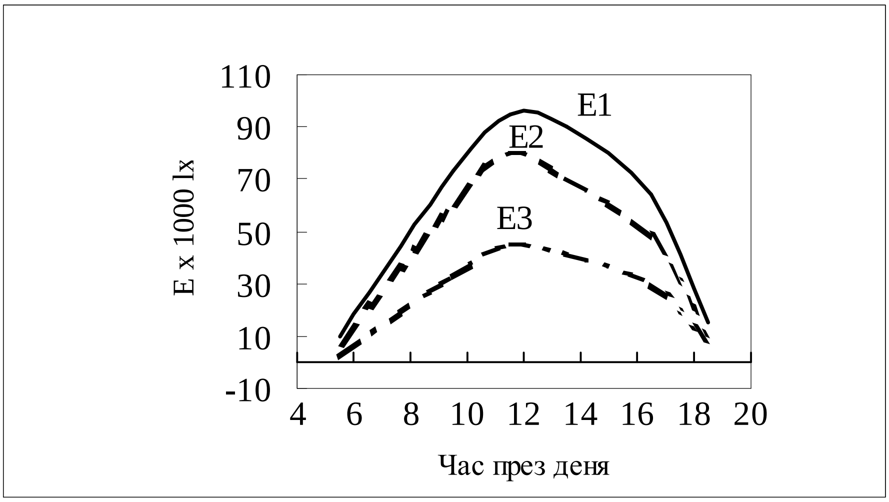
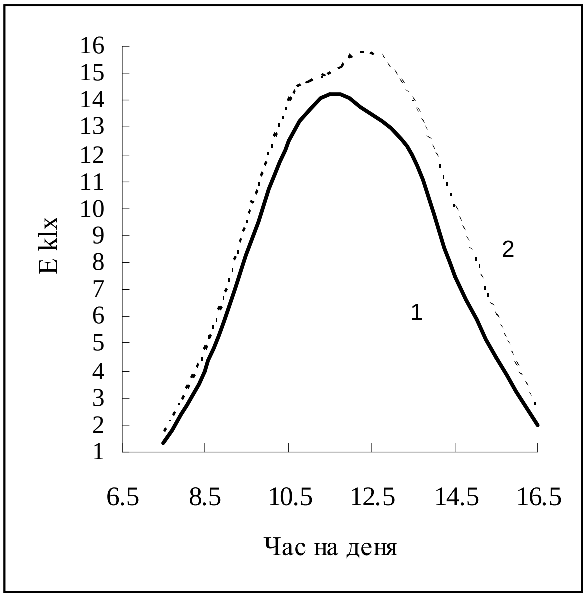


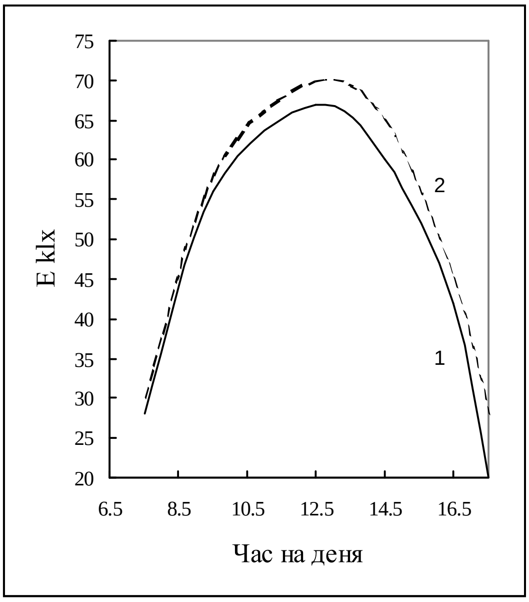
Фиг.1 Зависимост между дневните суми на сумарната радиация и сумарното осветление



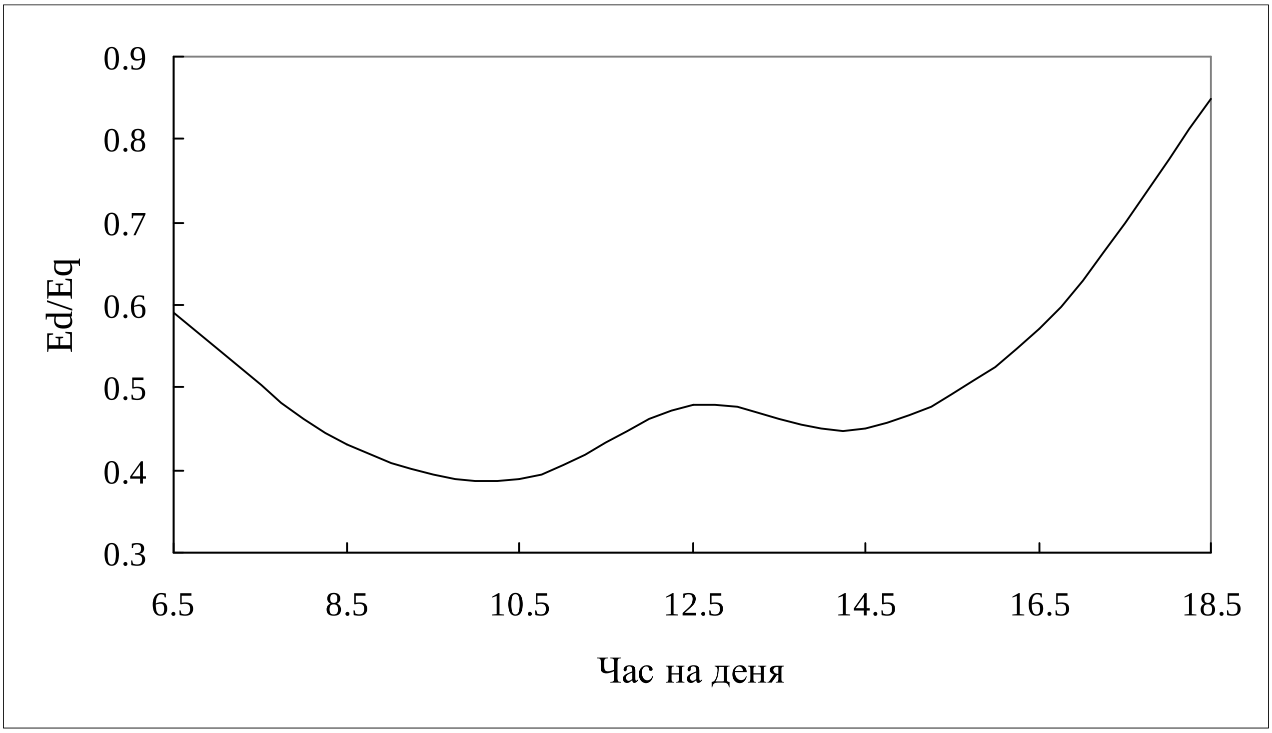
Фиг. 2 София-Юли. Дневен ход на сумарното осветление при безоблачно небе E_1, средни условия на облачността E_2, мрачно небе E_3.



Фиг. 3 София-Дневен ход на сумарното осветление при мрачно небе 1 – без снежна покривка, 2 – със снежна покривка



Фиг. 4 Дневен ход на осветлението от пряка слънчева радиация в Перник (1) и Брезник (2)



MODEL OF CLOUDY SKY FOR THE CONDITIONS IN BULGARIA

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МОДЕЛ НА ОБЛАЧНОТО НЕБЕ В УСЛОВИЯТА НА БЪЛГАРИЯ

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К. Бианчи, А. Джеорджеску, Румъния