CLASSIFICATION OF THE IDMP DATA OF KYOTO INTO KITTLER-PEREZ MODEL OF SKY LUMINANCE DISTRIBUTION

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ABSTRACT

The purpose of this paper is to validate Kittler-Perez model of classification of sky luminance distribution about the IDMP data in Kyoto Japan. Data were classified by the nearest centroid sorting method on the combination of nine indices of insolation condition. The indices are, 1) cloud ratio, 2) sky clearness index, 3) ratio of zenith luminance to diffuse illuminance, 4) standardized diffuse illuminance, 5) brightness, 6) standardized global illuminance, 7) standardized direct illuminance, 8) permeability, and 9) turbidity. Data measured every minute for a year over five degree of solar altitude were used to calculate these indices. Parameters of the types of K-P model in the relationship between solar altitude and ratio of zenith luminance to diffuse illuminance were estimated by non-linear regression. Classified cases were matched to the nearest types of the model by parameter comparison. Almost classified groups could be matched to the types of K-P model except for the type of turbid sky condition and the types of non-homogeneous gradation. This fact shows that the classification of the model is valid and the method of sorting classification works effective to some extent. But it is notable that the types of non-homogeneous gradation were found or could not be separated for the data of Kyoto.

KEYWORDS

Sky luminance distribution, Insolation condition, Classification, Kittler-Perez model

INTRODUCTION

As a sky luminance distribution model for intermediate sky, Kittler and Perez introduced a set of fifteen standard skies formed from combinations of six types of gradation function and six types of scattering indicatrix function. The model can be given by five parameters for sky luminance distribution. On the other hand, Nakamura and Igawa introduced All Weather Sky Model which standardized global illuminance gives the sky luminance distribution.

K-P model gives typical standard skies but we have no immediate way to estimate to which type the sky corresponds, even with the referred ranges of indices such as turbidity and standardized diffuse illuminance. It is an advantage of N-I model that the sky luminance distribution is determined directly by global illuminance measurement. All Weather Sky Model was made, however, by least squared method on the measurements in Tokyo and might be effected by the weather characteristics of the site.

In this study K-P model is applied to the measurements in Kyoto. This paper introduces a new method to estimate sky types without sky luminance distribution measurements. Measurements are classified by the nearest centroid sorting method about their combination of nine insolation indices. Parameters of each classified case in the relationship between solar altitude and ratio of zenith luminance to diffuse illuminance are estimated by non-linear regression. The cases are compared and matched to the types of K-P model by considering the parameters or indices.

METHODS

Data

Daylight measurements at the IDMP station in Kyoto in 1998 since January to December were used. In 1998 the measuring equipments were adjusted successfully and the measurements continued smoothly except for the duration of power failure one or two days in a month due to thunder lighting or remodeling of the building. Data of solar altitude under five degree were not used. Total number of 15,107 measurements for the year was analyzed.

Method of classification

Data for a year was classified by the nearest centroid sorting method about nine insolation indices. Measured direct, diffuse, global illuminance/ irradiance and zenith luminance were used to calculate the indices. The indices were, 1) cloud ratio (CLDV), 2) sky clearness index (CLER), 3) ratio of zenith luminance to diffuse illuminance (LERT), 4) standardized diffuse illuminance(KITL), 5) brightness (BRGT), 6) standardized global illuminance (EVGM), 7) standardized direct illuminance (EVSM), 8) permeability(PERM), and 9) turbidity (TURV) as shown in Figure 1. A measurement was expressed as a set of nine indices. In the sorting method the mutual distance in a ninth dimension among measurements were compared each other and the nearer measurements were gathered in a given number of cases. The number of cases was specified fifteen in this study in accordance with the number of types of K-P model of sky luminance distribution.

Estimation of the types of K-P model

Kittler et al mentioned that the ratio of zenith luminance to diffuse illuminance (LERT) is a function of solar altitude as the following equation.

$$L_Z / E_{vd} = \frac{B(\sin\gamma_s)^C / (\cos\gamma_s)^D + E\sin\gamma_s}{133.8\sin\gamma_s} \qquad \textbf{(1)}$$

Fifteen types of K-P model can be characterized with parameters B, C, D, and E in the equation. Parameters of the classified cases were estimated by iteration method with initially assigned range of parameters. In this study the nearest types of K-P model were matched to the classified cases by referring parameters.

RESULTS

Classification

Nine indices were calculated for total 15107 measurements and the measurements were classified into fifteen cases as noted before. Figure2 shows the range of the nine indices for the classified cases. In the figure, horizontal axes show the range of the value of indices. The values of clearness index and turbidity in the figure are multiplied by 0.1 and 0.01 respectively for the sake of convenience of display.

The sample sizes of fifteen cases are 3332, 816, 879, 422, 663, 115, 50, 1509, 827, 4334, 19, 5, 1511, 291, 334. Case-11 of 19 measurements and Case-12 of 5 measurements are small sized, where Case-1 and Case-10 have large sizes more than 3000 measurements. Except for these cases, the measurements are classified rather evenly in number.

Figure2 shows that each case tends to have individual ranges of nine indices. For instance, the range of indices in Case-3 and Case-9 resembles one another at first glance, but their ranges of cloud ratio are quite different, that is, from about 0.2 to 0.5 in Case-3 and from about 0.4 to 1.0 in Case-9. So we can distinguish them by the value of cloud ratio. It can be said that the insolation conditions are classified successfully by means of the nearest centroid sorting method about daylight measurements without using sky luminance distribution data.

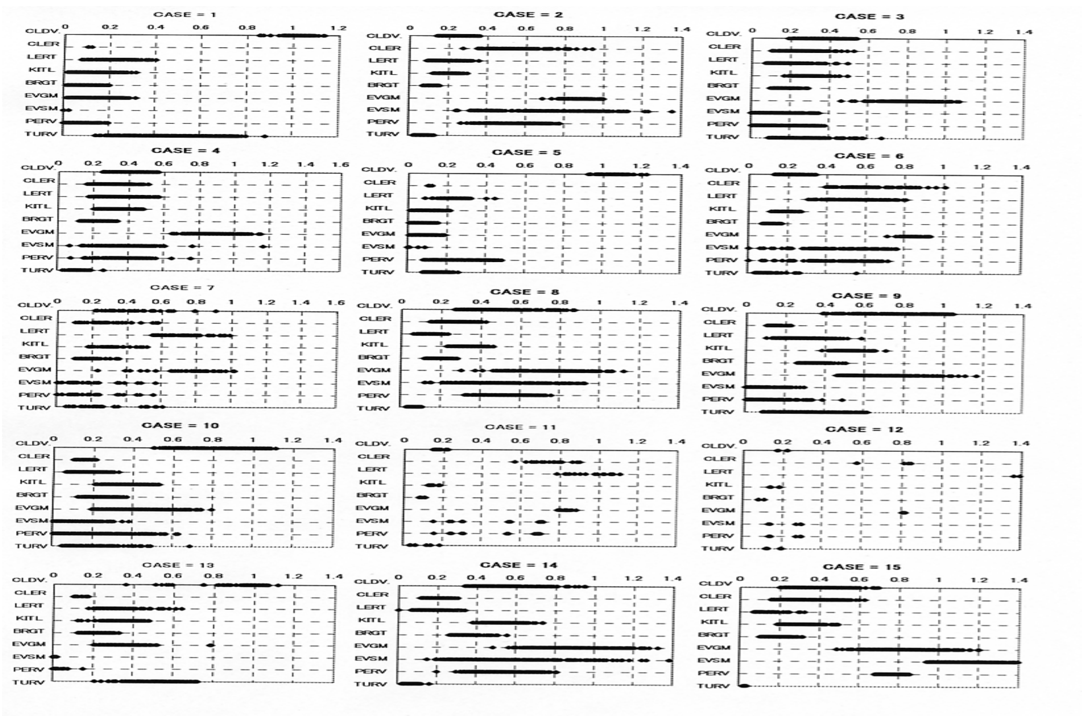

Figure2: Ranges of indices by cases

Figure3 shows the relationships between the solar altitude and the ratio of zenith luminance to diffuse illuminance for fifteen classified cases. This figure indicates individuality of the cases, although some cases resemble each other in the relationships. Parameter B, C, D, and E in Eqn.1 for these cases were estimated. These cases were matched to the types of K-P model by comparing the estimated parameters with help of the ranges of indices shown in Figure2.

Table1 shows the results of matching of the classified cases of measurement in Kyoto to the types of K-P model. Typical types are easier to be applied. Case-1 in Kyoto data (n=3332) corresponds to Type III.3 of uniform sky, and Case-2 (n=816) to TypeV.4 of CIE Clear

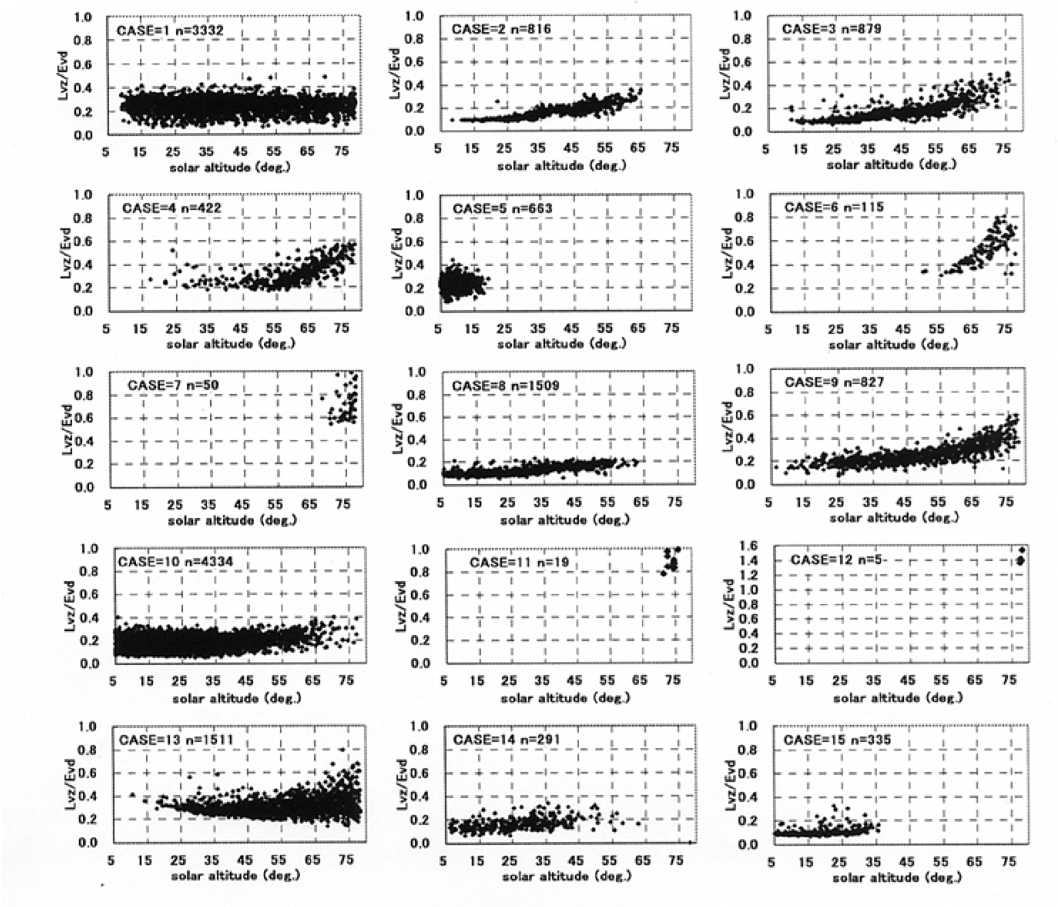

Figure3: Relationships between solar altitude and ratio of zenith luminance to diffuse illuminance by cases

TABLE_

Application of the cases to types of K-P model

Code	Code	CIE	Type of sky					Parameter				E_{edn}	
grad.	scat.	sky	cloud	gradation	az.uniform	around sun	turbidity	B	C	D	E	$/E_{so}$	Tv
I	1	O.C.	over cast	steep	uniform	—		54.63	1.00	0.00	0.00	.10	--
I	2	—	over cast	steep	non-uniform	sl. bright		12.35	3.68	0.59	50.47	.18	--
II	1	—	over cast	moderate	uniform	—		48.30	1	0.00	0.00	.15	--
II	2	—	over cast	moderate	non-uniform	sl. bright		12.23	3.57	0.57	44.27	.22	--
III	1	—	over cast	uniform	uniform	—		42.59	1.00	0.00	0.00	.20	--
①	(n=3332)							3.58	0.67	0.07	27.86	.16	45.7
III	2	—	cloudy	uniform	non-uniform	sl. bright		11.84	3.53	0.55	38.78	.38	--
III	3	—	cl/ sl. o.c.	uniform	non-uniform	bright		21.72	4.52	0.63	34.56	.42	12.0
⑩—	(4)	(n=788)						21.18	4.80	0.71	19.75	.44	16.0
III	4	—	cloudy	uniform	uniform	very brgt.		29.35	4.94	0.70	30.41	.41	10.0
⑭	(n=291)							15.16	3.34	0.79	26.90	.51	6.5
IV	2	—	partly cloud.	uniform	non-uniform	shaded		10.34	3.45	0.50	27.47	.40	12.0
③	(n=879)							21.74	4.36	0.59	12.97	.30	23.8
IV	3	—	cloudy	uniform	non-uniform	bright		18.41	4.27	0.63	24.04	.36	10.0
⑨	(n=827)							15.97	4.49	0.60	24.00	.51	31.8
IV	4	—	partly cloud.	uniform	non-uniform	very brgt.		24.41	4.60	0.72	20.76	.23	4.0
⑧	(n=1509)							21.87	5.02	0.71	12.98	.34	6.5
V	4	Clear	clear	uniform	non-uniform	very brgt.	unturb.	23.00	4.43	0.74	18.52	.18	2.5
②	(n=788)							22.1	3.90	0.71	13.83	.21	6.5
V	5	—	clear	uniform	non-uniform	bright	pollut.	27.45	4.61	0.76	16.59	.28	4.5
VI	5	—	clear	uniform	non-uniform	bright	turbid	25.54	4.40	0.79	14.56	.28	5.0
VI	6	—	sl. cloudy	uniform	non-uniform	very brgt.	turbid	28.08	4.13	0.79	13.00	.30	4.0
④	(n=422)							18.79	4.20	0.62	21.87	.34	10.3

Code I.1 ~ VI.6 ; Types of K-P model

Case ①~⑭ ; Cases by the nearest centroid sorting (data measured in Kyoto)

Sky. Case-3 to TypeIV.2 of partly overcast sky with shaded sun, Case-4 to V.5~VI.6 of clear but turbid skies, Case-8 to TypeIV.4 of partly cloudy with a clear solar corona, Case-9 to TypeIV.3 of partly cloudy sky with brighter circumsolar effect and Case-14 to TypeIII.4 of partly cloudy and uniform with a clear solar corona. The largest case of Case-10 (n=4334) cannot be applied as it is but a part of the case (Case-10.4, n=788) corresponds to TypeIII.3 when classified again into five sub-cases within the case.

DISCUSSION

Cases corresponded to no types of K-P model

Some cases do not correspond to any types of K-P model. Case-5 is supposed to be the case when the shadow band failed to be adjusted because the CLDV is extremely high for the lower solar altitude. Some cases do not converge in regression. Case-6 is supposed to be quasi-clear sky because EVDM is higher than in Case-2 (CIE clear sky) in addition to extremely high PERM. The steep rate of rising of LERT suggests of the case correspond to Type6 in indicatrix function. EVSM in Case-15 is extremely high although solar altitude is low. Reflected direct light is assumed to incident. Other sub-cases of Case-10 than Case-10.4 cannot find any matched types.

Absence of the types with gradation in Kyoto data

As Table1 shows, none of the type I / II of gradation function find the matched cases in Kyoto. It can be thought that skies with gradation rarely appeared in Kyoto, otherwise the method of the classification, particularly in choosing the set of indices, fails to express the gradation function. According to the range of indices shown in K-P model, four types with gradation in the model were extracted from the Kyoto data. They were supposed to be a part of Case-1 or Case-13 but the relationships between solar altitude and LERT were different from the model except for TypeII.1.

CONCLUSIONS

K-P model can be applied to the measurements in Kyoto because some classified cases correspond to the types of the model except for the types with gradation.

REFERENCES

Kittler, R. (1999). Spatial distribution of daylight – CIE standard universal skies, *CIE TC3-15 Draft Standard (tentative-KP).*

Matsuura, K. (1999). Spatial distribution of daylight – CIE standard all weather skies, *CIE TC3-15 Draft Standard (tentative-NI).*