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Classification Standard Skies: The use of horizontal sky illuminance

K.A. Alshaibani

College of Architecture and Planning, University of Dammam, PO Box 2397, Dammam 31451, Saudi Arabia

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ABSTRACT

This paper is about sky models, mathematical models that simulate the luminance distribution of sky. These models are used in building design and computer rendering. The International Commission on illumination (Commission International de l'Eclairage – CIE) has adopted a general sky model in 2003, which known now as the "ISO/CIE Standard General Skies". Such model define the sky types into 15 types that range from cloudy to partly cloudy to clear sky. To classify a sky into one of these types, luminance data of the sky are needed. However, these data are not available in many countries. Therefore, and due to the fact that it is difficult to get accurate luminance measurements near the solar disk and due to the fact that the luminance of a single small patch of sky can fluctuate greatly, other methods that use sky illuminance have been proposed to help to fit a sky in one of the CIE 15 sky types. The goals of this paper is to test one of these methods against real luminance measurements.

1. Introduction

The CIE Standard Skies are quantitative representations of the luminance distribution of the sky. It defines the luminance distribution of the sky into several sky types; cloudy sky, partly cloudy sky to clear sky. Since the introduction of the first sky model by Moon and Spencer in 1942 [1], such models were used in buildings design and computer graphics and renderings. In building design, sky models are used in order to ensure good quality and quantity of internal daylight. Utilizing daylight in buildings vary from one designer to another. From a qualitative point of view, a main reason for using daylight in buildings is its physiological and psychological impact on people and achieving occupant satisfaction [2,3]. From a quantitative point of view, one of the options for reducing the use of electrical lighting is the effective utilization of daylight. In non-residential buildings, a high portion of consumed electricity goes to the provision of lighting. Illuminating such types of buildings generally consume 30–50% of the energy used. This percentage includes energy consumed in providing illumination, and that consumed in removing heat generated by such illumination [4,5]. In an earlier studies the deal with the daylighting, potential energy benefits have been shown. It has also been indicated that good daylighting design is an effective tool for reducing consumption in buildings and therefore requires primary consideration in the initial schematic and preliminary design stages [6–8]. To use daylight effectively in buildings [9], knowledge of the distribution of the luminance of the sky is needed. Accurate sky models is needed in building simulation, where computers are used to simulate the performance of any proposed design. This will help the architects to evaluate their buildings before making the final design. In addition, designers do sometimes test their designs under artificial skies to understand the effect of their decisions on the internal luminous environment of a building. Such artificial skies should represent the luminance distribution of the real sky.

In computer rendering, more accurate and realistic images are becoming more and more important in the business of image rendering. Variation in sky types will affect the quality of images. More accurate sky models are always needed from the computer rendering industry.

To classify a sky into one of these types, luminance data of the sky are needed. However, these data are not available in many countries. It is also difficult to accurate luminance measurements near the solar disk. Therefore, and due to the fact that the luminance of a single small patch of sky can fluctuate greatly, the author have proposed other methods the use sky illuminance for classification a sky into one of the CIE sky types. The goals of this research is to test the one of these method for sky type classification against real luminance measurements.

E-mail address: kshaibani@uod.edu.sa.

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Table 1
Standard sky types and their gradation and indicatrix parameter.

	Type of Sky	gradation		Indicatrix		
		a	b	c	d	e
1	CIE Standard Overcast Sky, steep gradation towards zenith and azimuthal uniformity	4	−0.7	0	−1	0
2	Overcast with a steep gradation and slight brightening toward sun	4	−0.7	2	−1.5	0.15
3	Overcast moderately gradated, azimuthal uniformity	1.1	−0.8	0	−1	0
4	Overcast moderately gradated and slightly brightening toward sun	1.1	−0.8	2	−1.5	0.15
5	Overcast or cloudy with overall uniformity	0	−1	0	−1	0
6	Partly cloudy with a uniform gradation and slight brightening toward sun	0	−1	2	−1.5	0.15
7	Partly cloudy with a brighter circumsolar effect and uniform gradation	0	−1	5	−2.5	0.3
8	Partly cloudy, rather uniform with a clear solar corona	0	−1	10	−3	0.45
9	Partly cloudy with a shaded sun position	−1	−0.55	2	−1.5	0.15
10	Partly cloudy with brighter circumsolar effect	−1	−0.55	5	−2.5	0.3
11	White-blue sky with a clear solar corona	−1	−0.55	10	−3	0.45
12	CIE Standard Clear Sky, Low luminous turbidity	−1	−0.32	10	−3	0.45
13	CIE Standard Clear Sky, polluted atmosphere	−1	−0.32	16	−3	0.3
14	Cloudless turbid with a broader solar corona	−1	−0.15	16	−3	0.3
15	White-blue sky, turbid with broad solar corona	−1	−0.15	24	−2.8	0.15

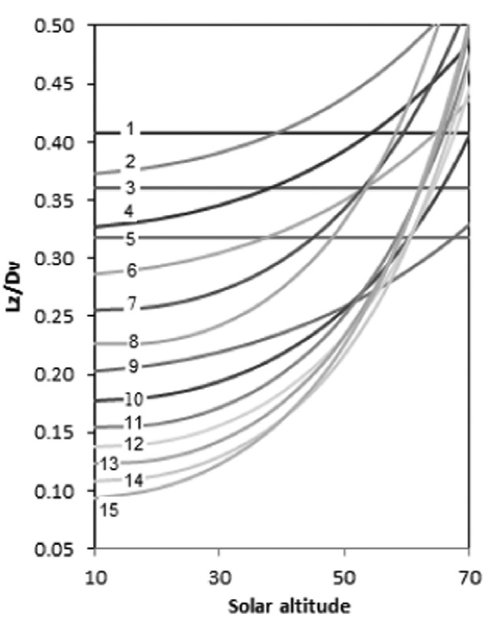

Fig. 1. Determination of standard skies from the Lz/Dv ratio.

2. The luminance distribution of the ISO/CIE Standard General Skies

In order to find the best numerical description of the luminance of the International Commission on illumination (Commission International de l'Eclairage – CIE) has adopted in 2003 a general sky model which was proposed by Kittler and others [10,11]. Later such model was adopted by the International Standard Organisation [12]. This sky model is known now as the "ISO/CIE Standard General Skies". It describe the luminance distribution of the sky into fifteen conditions that range from cloudy to partly cloudy to clear sky. The luminance of a sky element of the ISO/CIE Standard General Sky is given by:

$$L/Lz = \frac{f(\chi)\varphi(Z)}{f(Zs)\varphi(0^O)} \tag{1}$$

$$\frac{f(\chi)}{f(Zs)} = \frac{1 + c[\exp(d\,\chi) - \exp(d\pi/2)] + e\cos^2\chi}{1 + c[\exp(d\,Zs) - \exp(d\pi/2)] + e\cos^2 Zs} \tag{2}$$

$$\frac{\varphi(Z)}{\varphi(0^O)} = \frac{1 + a\exp(b/\cos Z)}{1 + a\exp b} \tag{3}$$

where:

L=The luminance of a sky point
Lz=The zenith luminance
χ=the angle between the sky element and the sun
Z=the angle between the sky element and the zenith
Zs=the angle between the sun and the zenith

a, b, c, d and e are values of six groups of the gradation function (φ) and indicatrix function (f) (Table 1).

3. Identifying ISO/CIE Standard General Skies

The main methods for fitting a sky into one of the fifteen ISO/CIE skies as proposed earlier [11]:

1. Normalizing the luminance of a sky element to the zenith luminance (L/Lz).
2. Normalizing the zenith luminance to the horizontal sky illuminance (Lz/Dv), Fig. 1.

In order to use one of the above two methods, luminance data are needed. However due to the fact that these data are not available in many countries and due to the fact that it is difficult to accurate luminance measurements [13]. The author has proposed earlier other methods that can help to fit a sky in one of the CIE fifteen sky types including the use of sky illuminance [14–17].

These are:

1. The use of the ratio of the sky illuminance received on a vertical surface to either another sky illuminance received on another vertical surface or sky illuminance received on the horizontal. This ratio can help in selecting the best-fit sky [14,15], Fig. 2.
2. The use of the ratio of sky illuminance received from certain portion of the sky dome to the total sky illuminance received on the horizontal [17]. Such ratio can be used in finding the type of a sky, figs. 3and 4.

This paper investigate in the use of the ratio of horizontal sky illuminance received from a give portion of the sky dome to the sky illuminance on the horizontal can be used to find the best fit sky.