Study on Solar Spectral Radiation Standard revising Based on Smart

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Abstract: The ISO9845-1-1992(E) standard has been issued for more than 20 years, the various factors that affect the solar spectral radiation have been undergone many changes over the years. The standard data cannot satisfy the current needs. According to the opinions of international experts on the revision of ISO9845-1-1992(E): in the revised standard, the spectral irradiation of different inclined surface should be added, Accordingly, China land center and European land average latitude should be calculated. In this paper, the geometric average latitude and weighted average latitude of China land are calculated respectively. The direct normal irradiance and hemispherical irradiance are calculated by using SMART model at the two tilt angle that corresponding to the latitudes.

Key words: ISO8945; Solar Spectral Irradiation; land Geometry Center; SMART

1 Introduction

The full name of IOS9845-1-1992(E) [1] is solar energy-Reference solar spectral irradiation at the ground at different receiving conditions - Part1: Direct normal and hemispherical solar irradiance for air mass 1.5. There is only one version, that is, the first edition, released in October 15, 1992 (ISO9845-1-1992 for short). This standard has been implemented for more than 20 years. In fact, ISO9845-1-1992 is merged by two standard: ASTME891-87[2] (American Society of Testing Materials) and ASTM E892-87[3]. ASTME891-87 provides standard tables of reference direct normal solar spectral irradiances for air mass 1.5. ASTME892-87 provided standard tables of direct normal solar irradiation on 37° titled surface. ASTME891-87 and ASTME892-87 as the standard of ASTM system in the United States, has undergone many changes over the years. The two standards were revised and promulgated in 1992, ASTME891-87 and ASTME892-87 merged into a standard ASTMG159-98[4]. The ASTMG159-98 standard was revised to ASTMG173-03[5] in 2003, Reapproved and promulgated the ASTMG173-03(R2012) standard[6] in 2012. China´s GBT 17683.1-1999[7] standard (Solar energy - Reference solar spectral irradiation at the ground at different receiving conditions - Part 1: Direct normal and hemispherical solar irradiance for air mass 1.5.) equivalent uses the ISO9845 standard. The relationship between ISO9845-1-1992 and the ASTM series standards is showed in Fig.1.

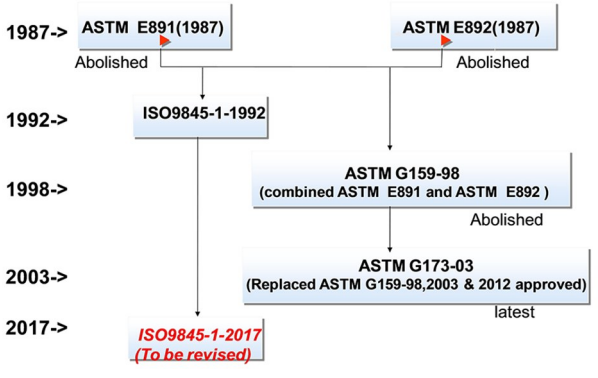

Fig.1 Relationship between ISO9845 standards series and ASTM standard series

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The International Solar Energy Society summoned the Solar Energy Standardization Technical Committee of Climate Measurement and second working group of Data Technology Subcommittee to a seminar from December 7, 2015 to December 8th in Turkey, Istanbul. Discuss the problems of revising ISO9845 international standard, Meteorological Observation Center of China Meteorological Administration researcher LYU Wenhua was invited to attend this seminar as a convener of ISO TC180/SCI/WG2 working group on the revising of the international standard ISO8945-1-1992. The delegates also include solar energy experts from Australia, Germany, Switzerland, Denmark, Morocco, Turkey and other countries. The experts reach agreement over the following aspects:

1) Tilt angle can't be only 37 degrees, as ASTMG173-03 promulgated, it should include more angles.how many angles needed to be include need further discussion.

2) It should include different altitudes data.

3) Different aerosol optical thickness should be calculated differently.

4) It's better to use the direct radiometer data with an open angle of 5° and a tilt angle of 5° given by WMO[8],

5) The solar constant[9,10,11] should be adopted 1361W/m^2 as recommended by WMO .

In this paper, the method of geographical center calculation is mainly introduced.

2 Discussion on increasing the tilt surfaces

2.1 Relation between tilt and geography

In the standards of ASTM-E891 and ASTM-G173, the 37° tilt surface represents the average degree of the United States in 48 states[2,5]. In order to make the solar spectral irradiation standard has wider applications, we will calculate China land geometry center and weighted average latitude of China land center. Generally, facing the sun direction when the tilt surface angle is equal to the local latitude, the maximum energy is received throughout the year[8]. In ASTMG173, 37 degrees represents the average latitude of 48 states in the United State. AM (air mass) = 1.5 is calculated from an angle of zenith = 48.19° (Arccos2/3=48.19°) as shown in the Fig.2, the 48.19° is not related to the previous 37°, AM=1.5 is based on the recommendations from NASA's Jet Propulsion laboratory Gonzalez and Ross in the 1980 study[12]: approximately 50% of the solar resources used for photovoltaic products that form the Northeast Maine Caribou (latitude 46°52′) to the Southwest Arizona Phoenix (Latitude 33°26′) are under AM1.5 conditions, In this paper, the geometric center and weighted average latitude center of China Mainland are calculated respectively.

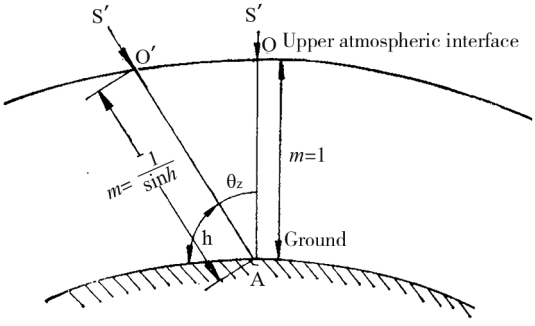

Fig.2 Define of air mass 1.5

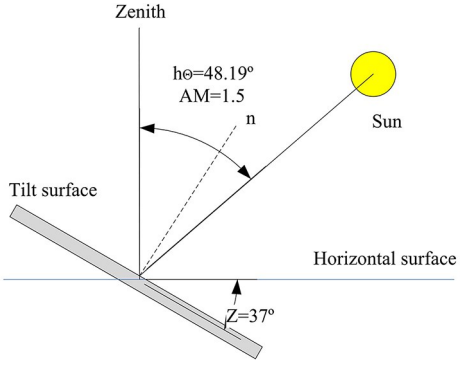

Fig.3 The relation between the tilt and the latitude

2.2 Calculation of China Mainland geometry center

Calculation of land center latitude and longitude in China by using the method of geographical circle coverage, the concrete steps are:

1) Prepare a list coordinates along the border of China Mainland, computing the distance between

coherence points and accumulate them, it is estimated that the total length of the border is 280542.5Km, the construction of the parameterization of the border is shown in Fig.4.

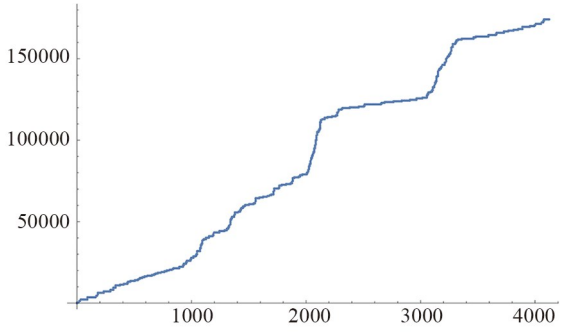

Fig.4 Parameterrization of land boundaries in China

2) Draw1000 geographical disks with radius of 1046Km along the equidistance border. The places that are not covered are 1046 kilometers away from the border to the interior, as shown in Fig.5.

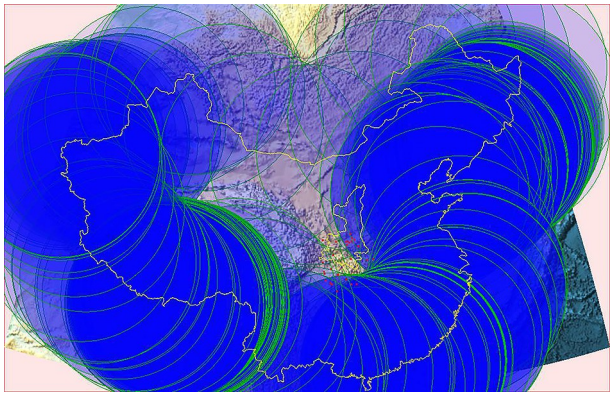

Fig.5 Circular converage along the border line

3) Select a point in the blank space using the coordinate tool, the longitude and latitude are accurate to 1°, the central latitude of China Mainland is 33° and longitude is 108°. Calculate the 30 city points closest to the central points, the cities are: Wanyuan, Ankang, Dazhou, Daxian, Bazhong, Wanxian, Yuxian, Xi´an, Xiangyang, Shanglou, Baoji, Lishan, Guangyuan, Shiyan, Shangping, Taozheng, Liangzhong, Nanlong, Lichuan, Weinan, Guang´an Danjiangkou, Gucheng, Nanchong, Huaying, and Fuling. As shown in Fig.5 the red points.

4) Strengthen 1000 equal geographical circles to overlay the color, highlight the blank area that is not covered, and select the coordinate value in the blank space by using the coordinate tool, as shown in Fig.6. The latitude and longitude of China mainland geometrycenter is 32.5 °and 108.3°.

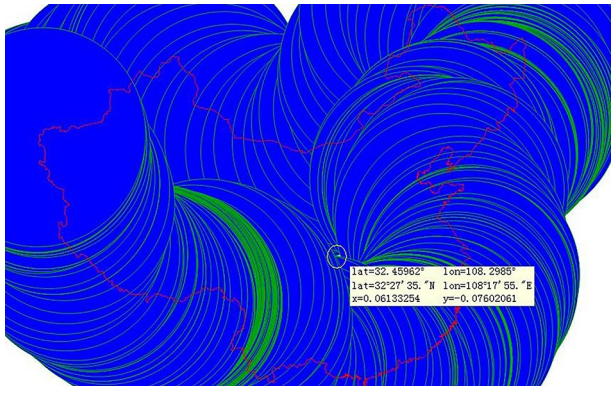

Fig.6 Central point of China mainland

2.3 Calculation of China land latitude weighted average

In order to meet the requirements of solar spectral irradiation calculation, the simplified calculation method can be used to calculate the China mainland weighted latitude center.The concrete method[13] is:

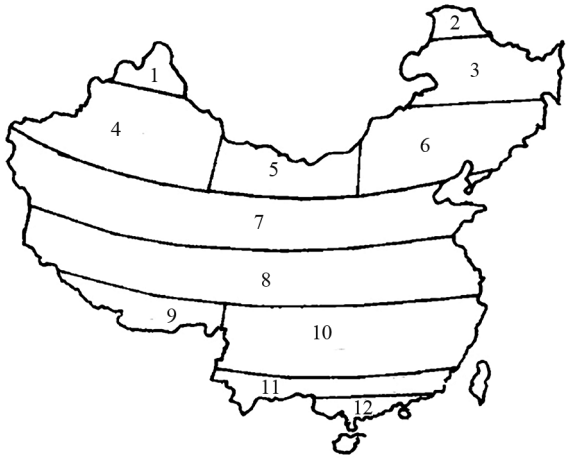

Fig.7 Griding China mainland

Divide the China mainland into 12 Bars and each bar is 5 ° wide, encode these bars as 1,2,3… 12, as shown in Fig.7. The measured data is $\theta_1 = 16.744$, $\varphi_1 = 18.380$. Suppose that the latitude of the

strip i center is θ_i, the longitude is φ_i, the strip area is S_i, the latitude and longitude of the center are θ_c, and φ_c.

We get the latitude and longitude of Mainland China latitude weighted center is $\theta_c = 103.4°$ and $\varphi_c = 35.6°$.

3 Comparison of spectral irradiation of different tilt angles

SMARTS (Simple Model of the Atmospheric Radiative Transfer of Sunshine) is a spectral model and Fortran code to calculate the direct beam, diffuse, and global irradiance incident on surfaces of any geometry at the Earth's surface[14]. It covers the whole shortwave solar spectrum (280 to 4000nm), thus includes the UVA, UVB, Visible and Near-Infrared bands. Besides the regular irradiance predictions needed for many possible applications, it can be used to simulate the spectral or broadband irradiance that would be measured by a radiometer, such as a spectroradiometer, a pyranometer, or a pyrheliometer. It can also predict the illuminance on any surface, the luminous efficacy of direct, diffuse, and global radiation, the UV index, as well as various UV action weighted spectra.

Under cloudless sky conditions, direct beam radiation normally constitutes the major part of the incoming solar shortwave radiation, above about 400 nm. Moreover[11], its measurement can be used to derive information on atmospheric conditions or constituents (e.g. gaseous abundances and aerosol turbidity) by comparison with model calculations smoothed to approximate the instrument spectral response. For these reasons, a major effort is devoted here to obtain individual transmittance functions. All simple parameter models are based on Leckner´s landmark equation[15]:

$$E_\lambda = E_{s\cap\lambda}\tau_{r\lambda}\tau_{OZ\lambda}\tau_{g\lambda}\tau_{w\lambda}\tau_{a\lambda} \quad (1)$$

where E_λ is the dimension of the solar irradiance received on the ground with the wavelength of λ, $E_{s0\lambda}$ is the extraterrestrial spectral irradiance at the average distance between the earth and the sun, and the $\tau_{r\lambda}, \tau_{OZ\lambda}\tau_{g\lambda}, \tau_{r\lambda}, \tau_{w\lambda}, \tau_{a\lambda}$ is respectively Rayleigh scattering, Ozone absorption, mixed gas (Carbon dioxide) absorption, water vapor absorption and spectral transmittance of aerosol attenuation.

Calculated by the Smart model[16,17,18], Some of the main parameters values are: site pressure = 1013.25hPa, Carbon Dioxide Concentration = 370ppmv, Aerosol Optical Depth at 500nm = 0.084 etc. Other parameters remain the same with ASTM G173 standard table except for the tilt angle.

Change the tilt angle parameter at each calculation, the tilt angle is , 33°, 35° and 37°, then we can obtain the solar normal irradiance and hemispherical spectral irradiance, as show in Fig.7 and Fig.8.

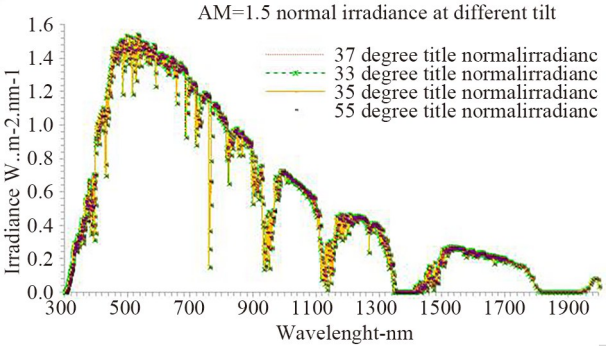

Fig.7 Wavelengh by wavelengh normal irradiation at the tilts of 33°, 35°, 37° and 55° (AM = 1.5) by SMARTS

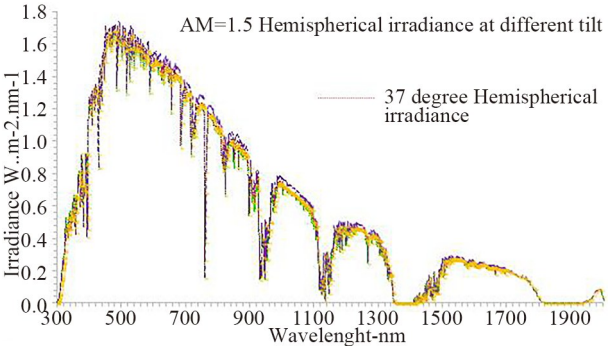

Fig.8 Wavelengh by wavelengh hemispherical irradiation at the tilts of 33°, 35°, 37° and 55° (AM = 1.5) by SMARTS

4 Conclusion

The integral value of solar irradiance is calculated by trapezoidal area method[5]:

$$E_{0\to\lambda i} = E_{0\to\lambda 1} + \sum_{j=1}^{i-1} \left(\frac{E_{\lambda j+1} + E_{\lambda j}}{2}\right)\Delta\lambda_j \quad (2)$$

where $\Delta\lambda_j = \lambda_{j+1} - \lambda_j$ (3)

$E_{0\to\lambda 1}$ is the base value before the first wave in the table, the value is estimated by half of the first trapezoid area, thus

$$E_{0\to\lambda 1} = \frac{1}{2}\left(\frac{E\lambda_2 + E\lambda_1}{2}\right)(\lambda_2 - \lambda_1) \quad (4)$$

Similarly, the total irradiance $E\lambda_{N\to\infty}$ outside λ_N wavelength is estimated by the function:

$$E\lambda_{N\to\infty} = \frac{1}{2}\left(\frac{E\lambda_N + E_{\lambda_{N-1}}}{2}\right)(\lambda_N - \lambda_{N-1}) \quad (5)$$

Then the function of solar irradiance is

$$E_{0\to\infty} = E\,0 \to \lambda N + E_{\lambda N\to\infty} \quad (6)$$

Use the data calculated by SMART at the tilt parameters of 33° and 35°, the hemispherical irradiance integral value at 33° is 997.2 W · m^{-2}, 35° is 1006.9 W · m^{-2}.

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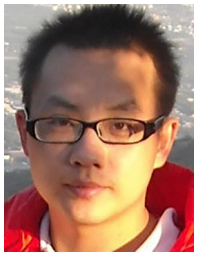

Zhou Xuhui, born in 1984, graduated from Nanjing University of Information Science and Technology, He received his Master Degree in 2011. Now is an engineer of Hunan meteorological technology equipment center, His main research direction is the atmospheric detection technology research and application.

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