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ABSTRACT

Available quantitative data on solar total and spectral irradiance are examined in the context of utilization of solar irradiance for terrestrial applications of solar energy. A brief review is given on the extraterrestrial solar total and spectral irradiance values. Computed values of solar spectral irradiance at ground level for different air mass values and various levels of atmospheric pollution or turbidity are also presented. Wavelengths are given for computation of solar absorptance, transmittance and reflectance by the 100-selected-ordinate method and by the 50-selected-ordinate method for air mass 1.5 and 2 solar spectral irradiance for the four levels of atmospheric pollution.

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INTRODUCTION

Detailed knowledge of solar irradiance at ground locations is needed in the direct utilization of solar energy for practical applications. Design and stability of terrestrial solar energy collectors, precise prediction of the output of solar cells, performance and degradation of potential coatings, glazings, adhesives and sealants, all require the characterization of the total amount of energy available from the sun, the spectral distribution of this energy and its temporal variations.

Solar total and spectral irradiance at a particular site at ground level depends on several parameters—the geometry of the site (altitude, latitude, and longitude), sun-earth distance, time of the day, season of the year, cloudiness of the atmosphere, orientation of the collector surface, shading, and atmospheric attenuation due to water vapor, ozone, carbon dioxide and aerosols. Measurement of solar spectral irradiance is a complex problem. Precise measurement of the total and spectral irradiance at each location is expensive and not always feasible. Solar irradiance data necessary for terrestrial applications of solar energy can be obtained from a combination of ground measurements and computation based on the extraterrestrial solar spectrum and the atmospheric optical parameters.

This paper will attempt a brief survey of the quantitative data on solar total and spectral irradiance which is currently available. Solar spectral irradiances are presented for air mass values 1, 1.5, 2, 3, 4, 7, and 10 computed from NASA/ASTM standard extraterrestrial solar spectral irradiance and atmospheric optical parameters of 20 mm precipitable water vapor, 3.4 mm ozone and Ångström turbidity coefficients corresponding to four different levels of atmospheric pollution. Wavelengths are given for computation of solar absorptance, transmittance and reflectance by the 50-selected-ordinate method and the 100-selected-ordinate method.

I. EXTRATERRESTRIAL SOLAR TOTAL AND SPECTRAL IRRADIANCE

A. Solar Constant

Solar radiation is usually described in terms of the solar constant and solar spectral irradiance. The solar constant is the amount of total radiant energy received from the sun per unit time, per unit area exposed normal to the sun's rays at the mean sun-earth distance in the absence of the earth's atmosphere. The air mass zero solar spectral irradiance is the distribution of this power (surface) density as a function of wavelength.

Earlier estimates of solar constant and extraterrestrial solar spectral irradiance were based on terrestrial measurements made at different solar zenith angles which were then extrapolated to zero air mass. Ground measurements are limited in accuracy due to the strong and highly variable absorption and scattering properties of the atmosphere. Measurements made from aircraft, balloons, rockets and satellites in recent years have narrowed the wide margin of uncertainty in solar constant and solar spectral irradiance values. An examination of the available literature on the subject shows that there is disagreement among various authors as to the value of the solar constant, but uncertainties in the spectral distribution of solar energy as a function of wavelength are considerably greater than those in the solar constant itself.

The NASA/ASTM standard solar total irradiance value is 1353 $W\ m^{-2}$ with an uncertainty of ± 1.5%. This value was obtained as an average of many series of measurements made from high altitude platforms, ranging in values from 1338 $W\ m^{-2}$ to 1368 $W\ m^{-2}$ (1). According to the authors, the two extreme values are those which claim the least estimated error (2).

In many of the applications of the solar irradiance values, both total and spectral, a question of major concern is the variability of these values. The solar constant is defined for the average sun-earth distance. As the earth moves in its elliptical orbit around the sun the total solar energy received varies by ±3.5%. There are also small and undetermined variations due to cyclic or sporadic changes in the sun itself. These variations are more significant in certain portions of the spectrum than in others.

Current Understanding of the Solar Constant

Several solar constant monitoring programs have been initiated in recent years. Results of the direct measurements of the total solar flux with self-calibrating pyrheliometers from rockets, Nimbus-7 and Solar Maximum Mission (SMM) are listed in Table 1(3), (4) and (5).

Table 1

Solar Constant Measurements from Rockets, Nimbus-7 and SMM

Date	6/29/76	11/16/78	5/22/80
Platform/Sensors	Solar Constant Wm^{-2}		
Rocket/ACRA (Active Cavity Radiometer A)	1368	1373	1372.8
ACRB (Active Cavity Radiometer B)	1368	–	1374.2
PACRAD (Primary Absolute Cavity Radiometer)	1364	1371	1373.1
ESP (Eclectic Satellite Pyrheliometer)	1369	–	1385.1
H-F (Hickey-Frieden Pyrheliometer)	–	–	1378.1
ERB-3 (Earth Radiation Budget Channel 3-painted baffles)	1380	1383	1377
ERB-3A (Earth Radiation Budget Channel 3-anodized baffles)	–	1381	1374
Nimbus-7 Channel 10C (H-F)	–	–	1375.9

SMM/ACRIM 1368 Wm^{-2} since launch in 1980.

The stated uncertainty in these values is about ±0.5 percent.

B. Air Mass Zero Solar Spectral Irradiance

A comparison of air mass zero solar spectral irradiance values that have received a great deal of attention in recent years is given in the wavelength range 0.2–1.7μm in Figure 1 and in the range 1.0μm–4.0μm in Figure 2. The x-axis gives the wavelength in micrometer (μm) and y-axis gives the solar spectral irradiance in Wm^{-2} μm^{-1}. The spectral curves derived by Johnson (6), Moon (7) and Labs and Neckel (8) were based on measurements made from high altitude mountain stations. The spectral curves derived by Thekaekara et al. (9) and Arvesen et al. (10) were based on observations from aircraft at mean altitudes of 11.6–12.5 km. Definitive measurements have not yet been made from space, and the observations made from sea level, mountain tops and even from research aircraft cannot detect a significant amount of solar UV and IR due to atmospheric attenuation and errors inherent in the extrapolation to zero air mass. The best presently available data of solar spectral irradiance in the interval 0.3 μm to 3 μm are those given by Thekaekara et al., Labs and Neckel, and Arvesen et al. (11), (12).

The total irradiance or solar constant values obtained from the integral of the spectral irradiance reported by these authors are very close—Thekaekara 1353 W m^{-2} or 1.940 cal cm^{-2} min^{-1}, Labs and Neckel 1358 W m^{-2} or 1.947 cal cm^{-2} min^{-1}, Arvesen et al. 1390 W m^{-2} or 1.99 cal cm^{-2} min^{-1}. Despite the good agreement in the value of the integrated flux of solar radiation, the spectral irradiance values converge much more poorly. The most significant variations are in the spectral region 0.3 - 1.5 μm in which about 90% of the total flux is generated. The differences among these values can amount to more than 10% at some wavelengths with the largest difference occurring in the important spectral interval 0.5 - 0.7 μm. It is important to note that the 0.3 μm - 0.7 μm range is a region rich in Fraunhofer (solar absorption) structure which each instrument displays in a different way according to the wavelength resolution.

The wavelength range 0.27 μm to 2.6 μm contains over 96% of the sun's energy. Extending the spectral range to 4.0 μm increases the energy content to 99%. This region is responsible for all life processes and for making of weather and climate. The major input into the energy budget of

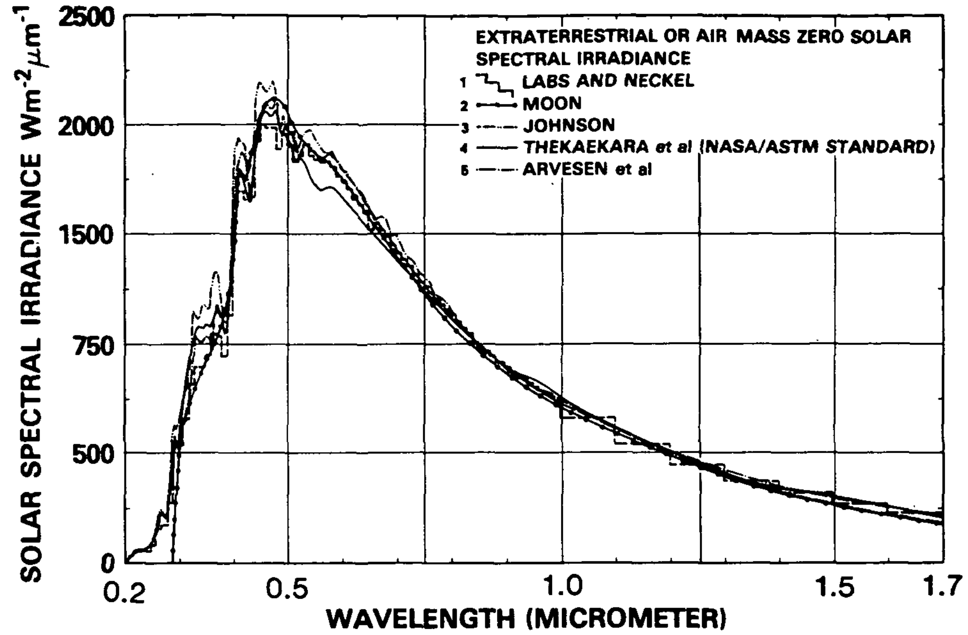


Figure 1. Solar Spectral Irradiance Outside the Atmosphere, 0.2 μm - 1.7 μm reported by: 1. Labs and Neckel, 2. P. Moon, 3. F.S. Johnson, 4. Thekaekara et al (NASA/ASTM Standard), 5. Arvesen et al.

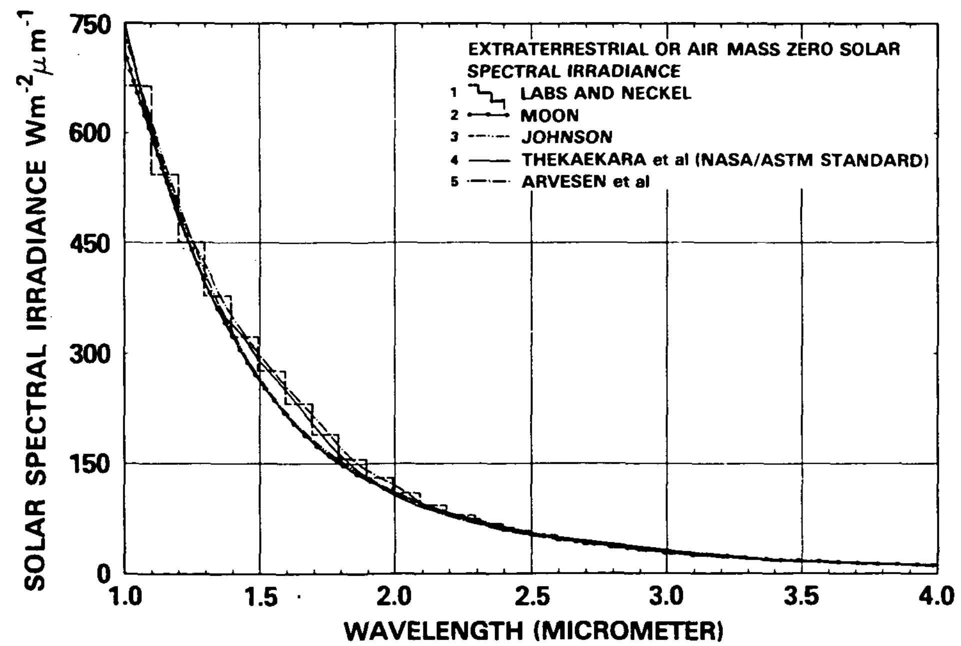


Figure 2. Solar Spectral Irradiance Outside the Atmosphere, 1.0 μm - 4.0 μm reported by: 1. Labs and Neckel, 2. P. Moon, 3. F.S. Johnson, 4. Thekaekara et al (NASA/ ASTM Standard), 5. Arvesen et al.

the earth comes from this region. Photosynthesis essential for all life support is due to wavelength bands centered around 0.44 μm and 0.75 μm. Solar cells are spectrally sensitive and the spectral region 0.4 to 1.1 μm is important for the photovoltaic conversion. The energy distribution in the spectral region 0.3 to 4.0 μm is important for thermal conversion systems.

A conclusion that can be drawn from this survey is that the uncertainty in the solar constant is about ±0.5%. The extraterrestrial solar spectral irradiance on the other hand, is uncertain in as much as 10 to 15% at some wavelengths.

II. SOLAR TOTAL AND SPECTRAL IRRADIANCE AT GROUND LEVEL

A. Atmospheric Attenuation of Solar Radiation

Direct solar radiation reaches the surface of the earth considerably weakened and with its energy distribution greatly changed due to the attenuation along its path through the atmosphere. The attenuation is small in pure air but increases with the amount of contamination or turbidity due to variable components such as dust, aerosol particles and water vapor. The attenuation increases both with the extinction coefficient and the optical absolute air mass. Therefore, the solar radiation is found to vary with time of day, season, geographical latitude and altitude, even when the extinction coefficient remains constant.

The discussion given below is taken from references (13) (14). Throughout most of the solar spectrum the absorption of a monochromatic beam of light is governed by the logarithmic decrement law known as Bouguer's Law.

$$E_\lambda = E^\circ_\lambda e^{-(c_1 + c_2 + c_3)m} \tag{1}$$

where E°_λ and E_λ are spectral irradiance at a given wavelength λ outside the atmosphere and after transmittance through air mass m respectively. The coefficient c_1 is due to Rayleigh scattering, c_2 is due to turbidity, and c_3 is due to ozone optical depth. The air mass is equal to the secant of the solar zenith angle, z. This relationship is not strictly true for large values of solar zenith angles ($z \geqslant 62°$) where account has to be taken for the curvature of the solar rays due to refraction in increasingly denser atmospheric layers. Various approximation formulae are available in the literature for computing air mass for large values of z (13). The zenith angle of the sun can be directly measured with a sextant or can be computed from equation (2)

$$\sec z = (\sin\theta \sin\delta + \cos\theta \cos\delta \cos h)^{-1} \tag{2}$$

where θ is the latitude of the place, δ is the solar declination for the day and h is the hour angle of the sun.

The Rayleigh optical depth c_1 and the ozone optical depth c_3 used in the present computations are based on the data developed by L. Elterman (15). They are valid for the U.S. Standard atmosphere. The total amount of ozone in a vertical path is assumed to be 0.34 cm (at STP). Table 2 lists the values for c_1 and c_3. In Elterman's notation these constants c_1 and c_3 are respectively τ_r', Rayleigh optical thickness (h to ∞) and τ_3', ozone optical thickness (h to ∞). The values for h = 0 (i.e., at sea level) used in the computations are listed in Table 2 for 22 discrete wavelengths. The coefficients at other wavelengths were obtained by linear interpolation of this data. The attenuation coefficient c_2, due to turbidity is given by equation (3),

$$c_2 = \beta\lambda^{-\alpha} \tag{3}$$

where, λ is the wavelength in micrometers, and α and β are Ångström turbidity coefficients related to the size distribution and density of aerosols (16).

In the infrared ($\lambda > 0.69\,\mu$m) there is the selective absorption by the polyatomic gaseous constituents of the atmosphere, mainly water vapor and carbon dioxide, and the continuum attenuation due to scattering and absorption by particulate matter and water droplets. Table 3 lists the wavelength (centroid) for the absorption bands, the wavelength boundaries for the areas of absorption bands, and the constituents of the atmosphere producing them (17).

The selective absorption is characterized by many thousands of lines of the vibration–rotation spectrum of the molecules. The total effect over finite bandwidth is not simple enough to be expressed by equation (1). In the infrared equation (1) has to be modified as

$$E_\lambda = E_\lambda^\circ \cdot e^{-(c_1+c_2+c_3)m} \cdot T_{\lambda i} \tag{4}$$

where $T_{\lambda i}$ is a transmittance factor to account for the molecular absorption bands. No single expression is applicable to all the absorption bands. $T_{\lambda i}$ can have one of the three forms

$$T_{\lambda 1} = e^{-c_4(wm)^{1/2}} \tag{5}$$

$$T_{\lambda 2} = e^{-c_5 wm} \tag{6}$$

$$T_{\lambda 3} = 1 - c_6 m^{1/2} \tag{7}$$

where m is the air mass, w is the amount of precipitable water vapor along the path in millimeters and c_4, c_5 and c_6 are the empirical constants (18).

The expression $T_{\lambda 1}$ is for a strong random model and holds true in the main body of a water-vapor absorption band. The expression $T_{\lambda 2}$ is for the weak random model and holds true for the

Table 2

Atmospheric Extinction Optical Thickness Due to Rayleigh Scattering and Ozone Absorption

Wavelength nm	Rayleigh Optical Thickness c_1	Ozone Optical Thickness c_3
270	1.928	70.956
280	1.645	35.816
300	1.222	3.413
320	0.927	0.303
340	0.717	0.022
360	0.564	0.001
380	0.450	0.000
400	0.364	0.000
450	0.223	0.001
500	0.145	0.012
550	0.098	0.031
600	0.069	0.045
650	0.050	0.021
700	0.037	0.008
800	0.021	0.003
900	0.013	0.000
1060	0.007	0.000
1260	0.003	0.000
1670	0.001	0.000
2170	0.000	0.000
3500	0.000	0.000
4000	0.000	0.000

Table 3

Absorption Bands Produced by Polyatomic Gaseous Constituents of the Atmosphere ($\lambda >$ 0.69 μm)

Wavelength (Centroid) μm	Wavelength boundaries for the areas of absorption band		Atmospheric constituents
	μm	cm^{-1}	
0.69	0.686–0.699	14,300–14,560	oxygen
0.72	0.699–0.739	13,514–14,286	water vapor
0.76	0.755–0.770	12,984–13,236	oxygen
0.81	0.790–0.839	11,905–12,658	water vapor
0.94	0.869–1.031	9,700–11,500	water vapor
1.13	1.031–1,219	8,200–9,700	water vapor
1.25	1.236–1.285	7,782–8,085	oxygen
1.38	1.219–1.612	6,200–8,200	water vapor
1.6	1.526–1.666	6,000–6,550	carbon dioxide
1.87	1.612–2.083	4,800–6,200	water vapor
2.7	2.631–2.873	3,480–3,800	carbon dioxide
2.7 and 3.2	2.772–3.57	2,800–4,400	water vapor
4.3	4.00–4.6296	2,160–2,500	carbon dioxide
6.3	4.629–9.85	1,015–2,160	water vapor

wings of the bands and for small optical depth. The third expression $T_{\lambda 3}$ holds true where the effect of water vapor is negligible, but where other molecular species such as CO_2, O_3 and O_2 in the atmosphere influence the transmission (18). For the present computations the empirical constants c_4, c_5, and c_6 are respectively coefficients $-c_1$, $-c_2$ and c_5 of reference (18) for the wavelength region 1018 nm to 4045 nm.

For the spectral region 700 to 1000nm, the molecular absorption coefficients are computed from the spectral parameters and spectral water vapor transmission data reported by Koepke and Quenzel (19). Table 4 lists the values of c_4, and c_6 for the wavelength region 700 to 1000nm.

Table 4
Molecular Absorption Coefficients for the Wavelength Region
700 to 1000nm (0.72, 0.81 and 0.94 μm bands)

Wavelength (λ)	Coefficient	Coefficient Model
nm	Ci	i
700	0.0	4
710	0.0	4
712	4.5×10^{-4}	4
712.5	6.7×10^{-4}	4
715	6.58×10^{-3}	4
717.5	4.684×10^{-2}	4
720	5.844×10^{-2}	4
722.5	2.035×10^{-2}	4
725	4.247×10^{-2}	4
727.5	3.979×10^{-2}	4
730	3.872×10^{-2}	4
732.5	2.035×10^{-2}	4
735	8.2×10^{-3}	4
740	6.58×10^{-3}	4
742.5	6.58×10^{-3}	4
745	1.8×10^{-3}	4
747.5	0.0	4
760	0.0	4
762.1	2.471×10^{-1}	6
765	0.0	4
785	0.0	4
790	3.61×10^{-3}	4
795	4.29×10^{-3}	4
800	1.03×10^{-2}	4

Table 4 (Continued)

Wavelength (λ)	Coefficient	Coefficient Model
nm	Ci	i
805	5.2×10^{-3}	4
810	1.03×10^{-2}	4
815	4.878×10^{-2}	4
820	3.503×10^{-2}	4
825	3.872×10^{-2}	4
830	3.321×10^{-2}	4
835	1.551×10^{-2}	4
840	5.43×10^{-3}	4
845	3.15×10^{-3}	4
850	0.0	4
890	0.0	4
895	2.06×10^{-2}	4
902	5.243×10^{-2}	4
907	5.613×10^{-2}	4
912	6.225×10^{-2}	4
916	7.690×10^{-2}	4
920	4.032×10^{-2}	4
924	4.437×10^{-2}	4
928	8.330×10^{-2}	4
935	2.4655×10^{-1}	4
943	1.5951×10^{-1}	4
950	1.7315×10^{-1}	4
954	1.8155×10^{-1}	4
957	1.2491×10^{-1}	4
965	8.007×10^{-2}	4
975	4.712×10^{-2}	4
981	2.531×10^{-2}	4
984	1.384×10^{-2}	4
990	2.47×10^{-3}	4
995	0.0	4

Figure 3 shows transmittance as a function of wavelength for the optical parameters of Rayleigh, ozone and turbidity for unit air mass (m = 1). The x-axis gives the wavelength in micrometers (μm) and y-axis gives the transmittance. The Rayleigh optical thickness c_1 and the ozone optical depth c_3 are obtained by linear interpolation of Elterman values given in Table 2.

Figure 4 gives water vapor transmission data for 0.72, 0.81 and 0.94μm bands obtained from equations (5), (6) and (7) by assuming w = 20mm of precipitable water vapor which is a global annual average for mid latitudes, and the coefficients listed in Table 4.

Figure 5 gives a comparison of atmospheric transmittance in the IR as computed from two independent sources of data. The solid line is from Gates and Harrop (reference 18) and shows the effect of both water vapor and carbon dioxide. The transmittance curve is obtained from equations (5), (6) and (7) by assuming w = 20mm of precipitable water vapor. The dashed and dotted lines are based on the data of Wyatt (20). The dashed line is for 20mm of precipitable water vapor and the dotted line is for 200 atm-cm of carbon dioxide. The IR transmittance based on Gates and Harrop is also shown in Figure 6 with different symbols indicating the wavelengths at which the three equations (5), (6) and (7) apply.

B. Computation from Extraterrestrial Solar Spectrum

Solar irradiance received on a surface has two components: (1) that received directly from the sun and (2) that diffused by the sky. Direct solar spectral irradiance at ground level can be computed from the extraterrestrial solar spectrum and the atmospheric optical parameters using equation (4). An example of the results of such computation is given in Figure 7. It shows the NASA/ASTM Standard solar spectral irradiance for air mass zero, that is, irradiance outside the earth's atmosphere at the average sun–earth distance on unit area exposed normal to the sun's rays. It gives the E_λ^o of equation (4). The area under the curve is the solar constant 1353wm^{-2}. The curve with many sharp dips is the solar spectrum for air mass 1.5, that is spectral irradiance on unit area on the ground exposed normal to the sun's rays assuiming relatively clearn air, no clouds and the sun at 48.2 degrees from the vertical. This curve is computed by using equation (4)

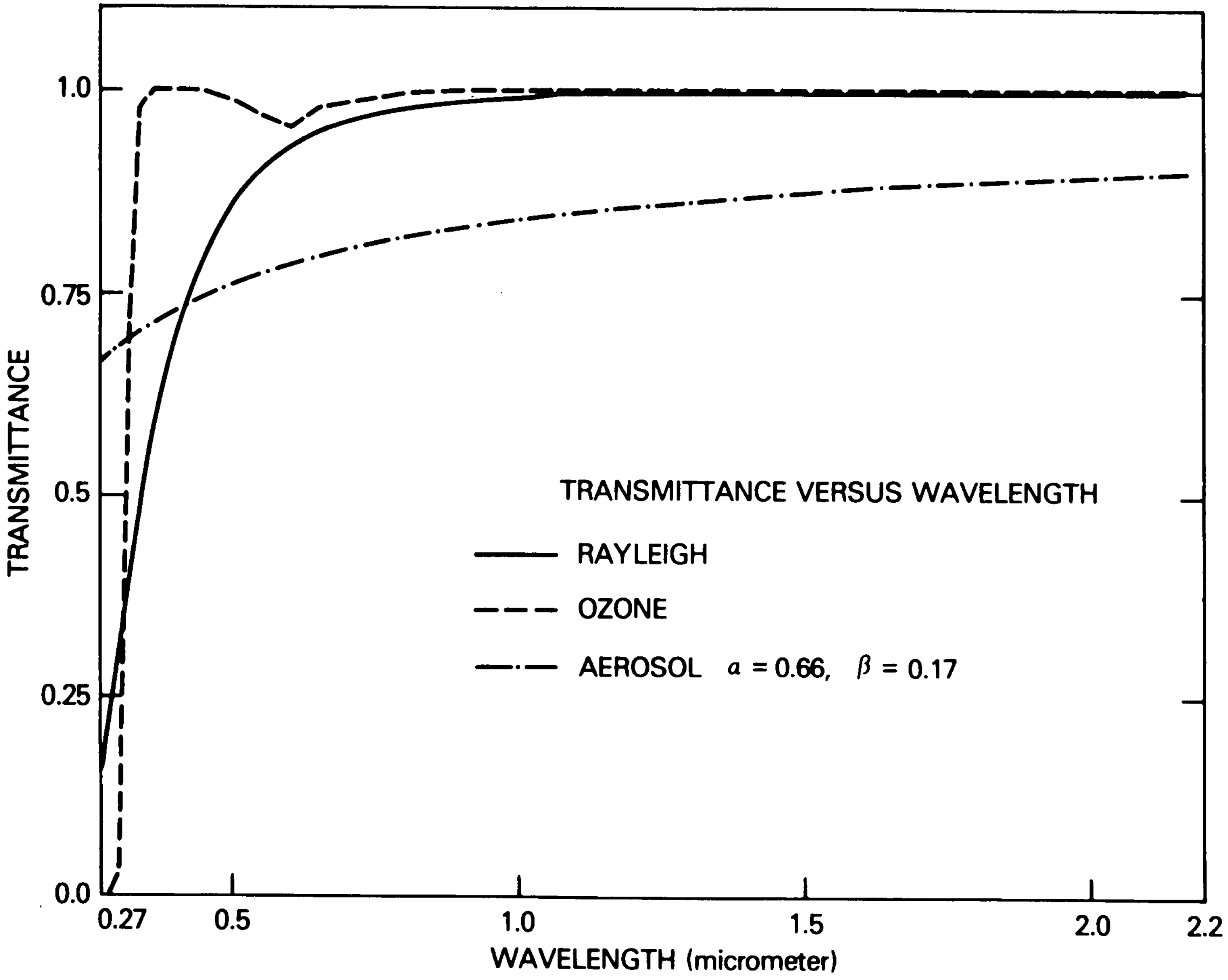


Figure 3. Transmittance vs. Wavelength for Rayleigh (c_1), Ozone (c_3 = 3.4mm) and Aerosol ($c_2 = \beta\lambda^{-\alpha}$, a = 0.66, β = 0.17) Optical Parameters for Air Mass (m = 1)

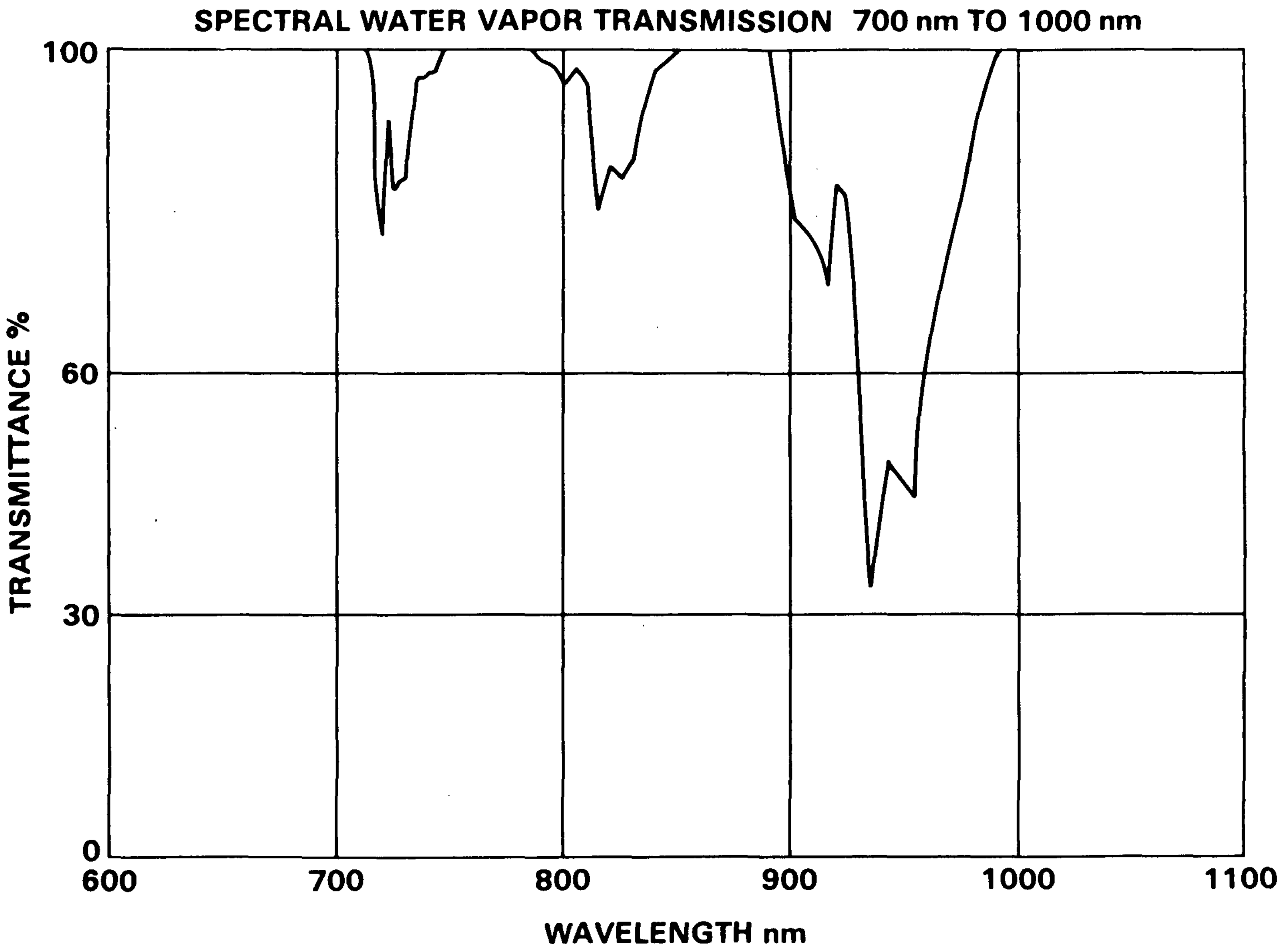


Figure 4. Water Vapor Transmittance for 0.72, 0.81, and 0.94μm Bands
Air Mass (m = 1) and Water Vapor (20mm)

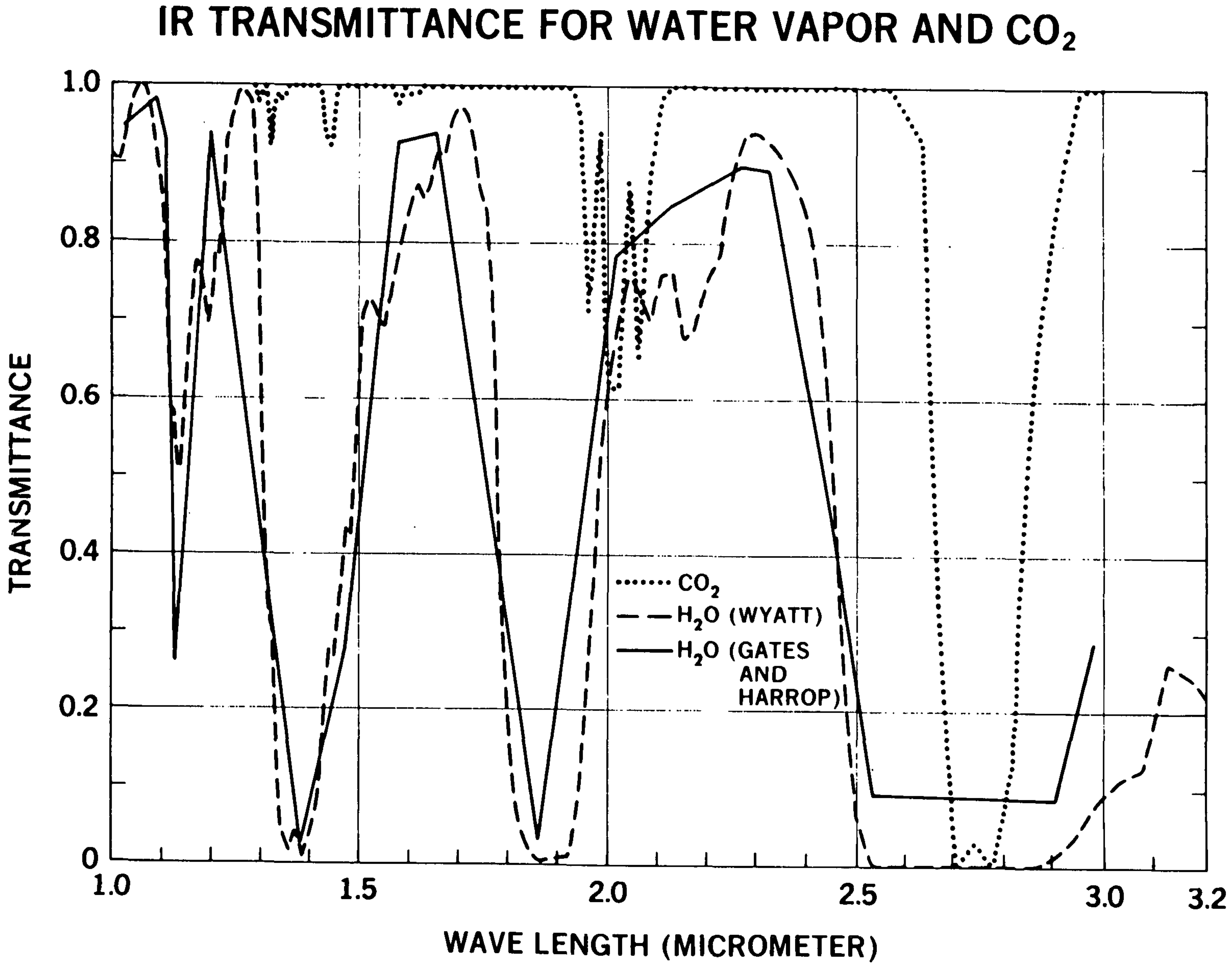
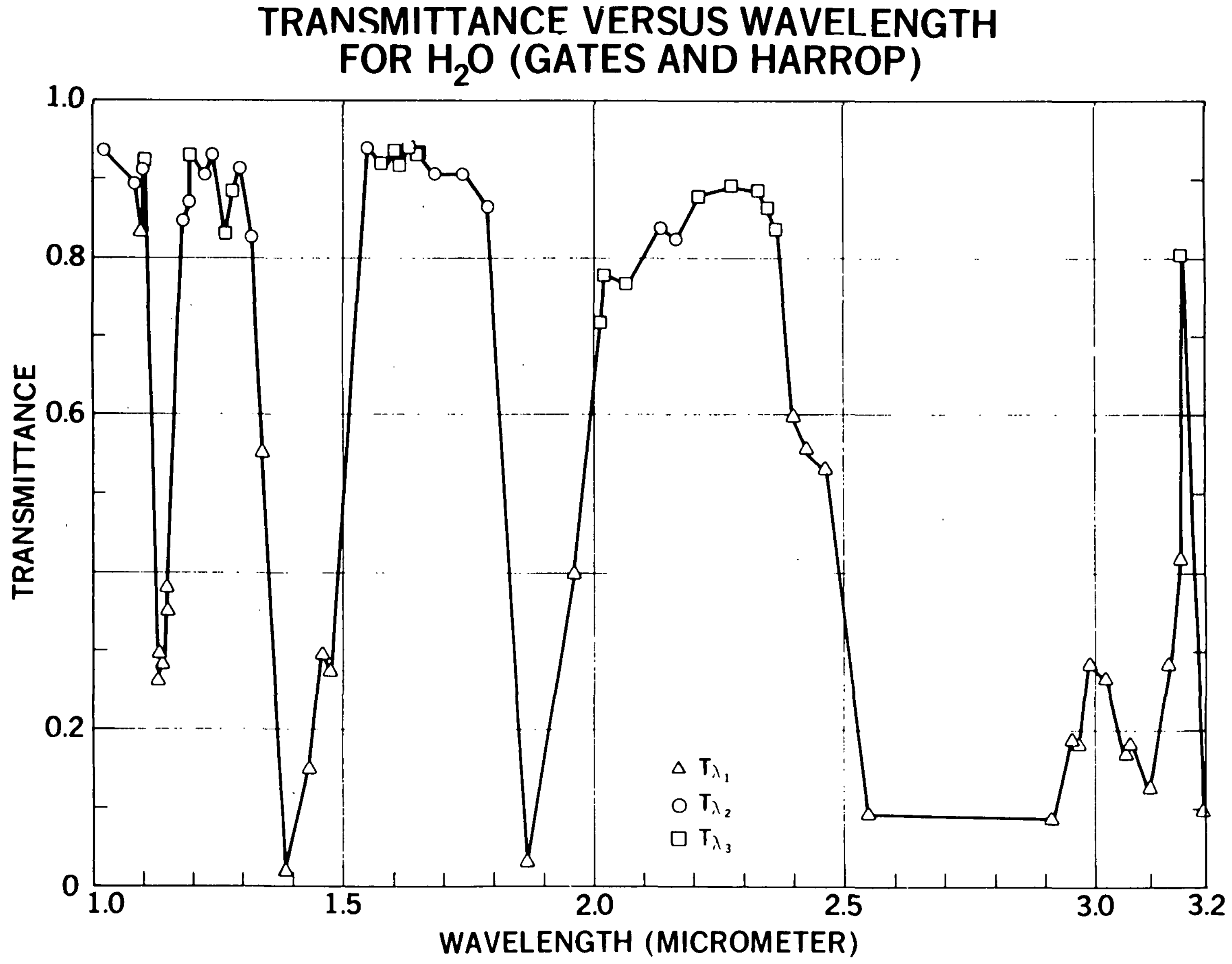


Figure 5. Transmittance vs. Wavelength for Water Vapor (20mm) and Carbon Dioxide (200 atm-cm)



TRANSMITTANCE VERSUS WAVELENGTH FOR H_2O (GATES AND HARROP)

Figure 6. IR Transmittance vs. Wavelength for Water Vapor and Carbon Dioxide

$T_{\lambda 1} = e^{-c_4 (Wm)^{1/2}}$, $T_{\lambda 2} = e^{-c_5 Wm}$, $T_{\lambda 3} = 1 - c_6 \sqrt{m}$

W = 20mm

m (Air Mass = 1)

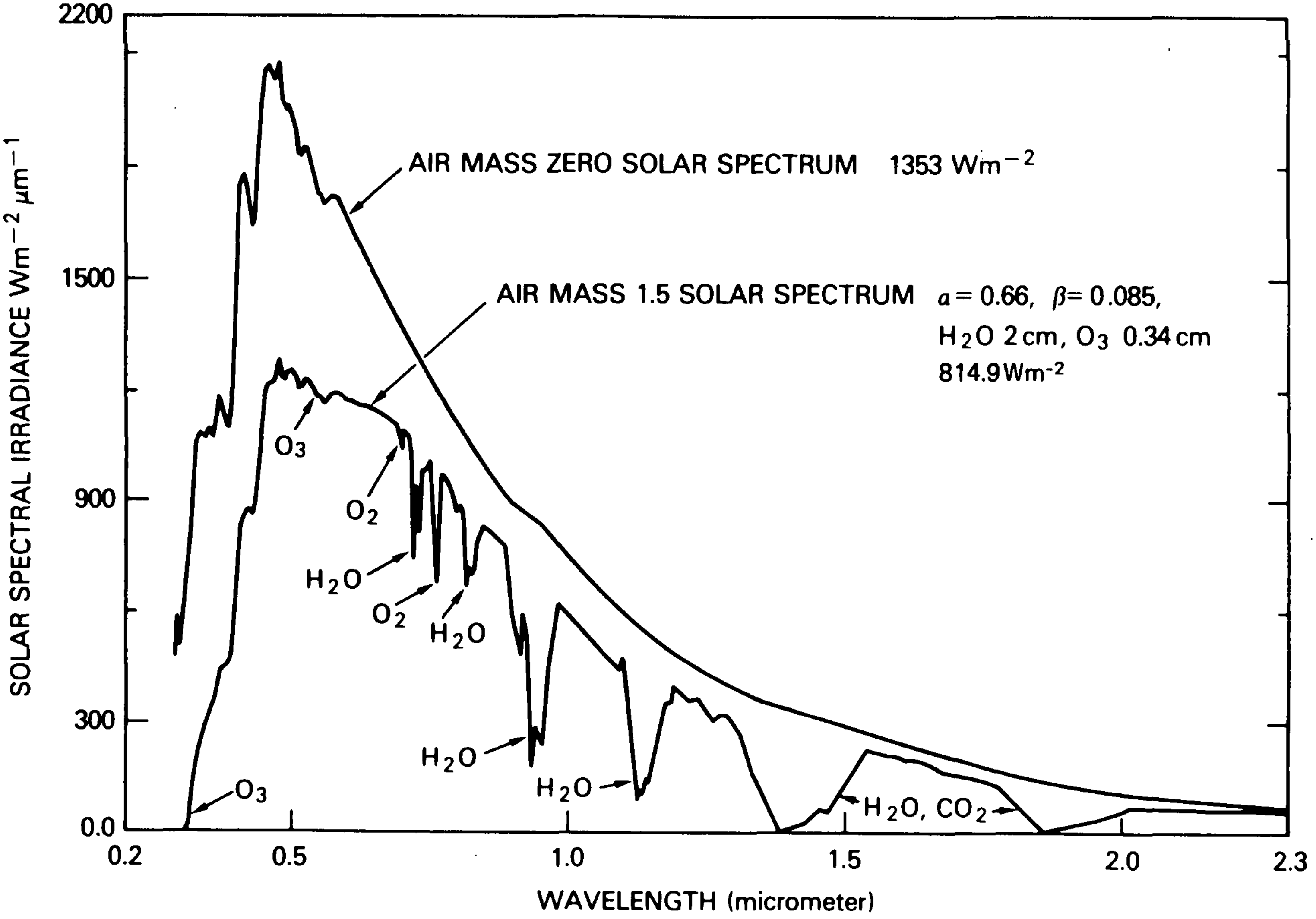


Figure 7. Extraterrestrial Solar Spectrum and That Received at Ground Surface for Air Mass 1.5, H_2O 2cm, O_3 0.34cm and $\alpha = 0.66$, $\beta = 0.085$

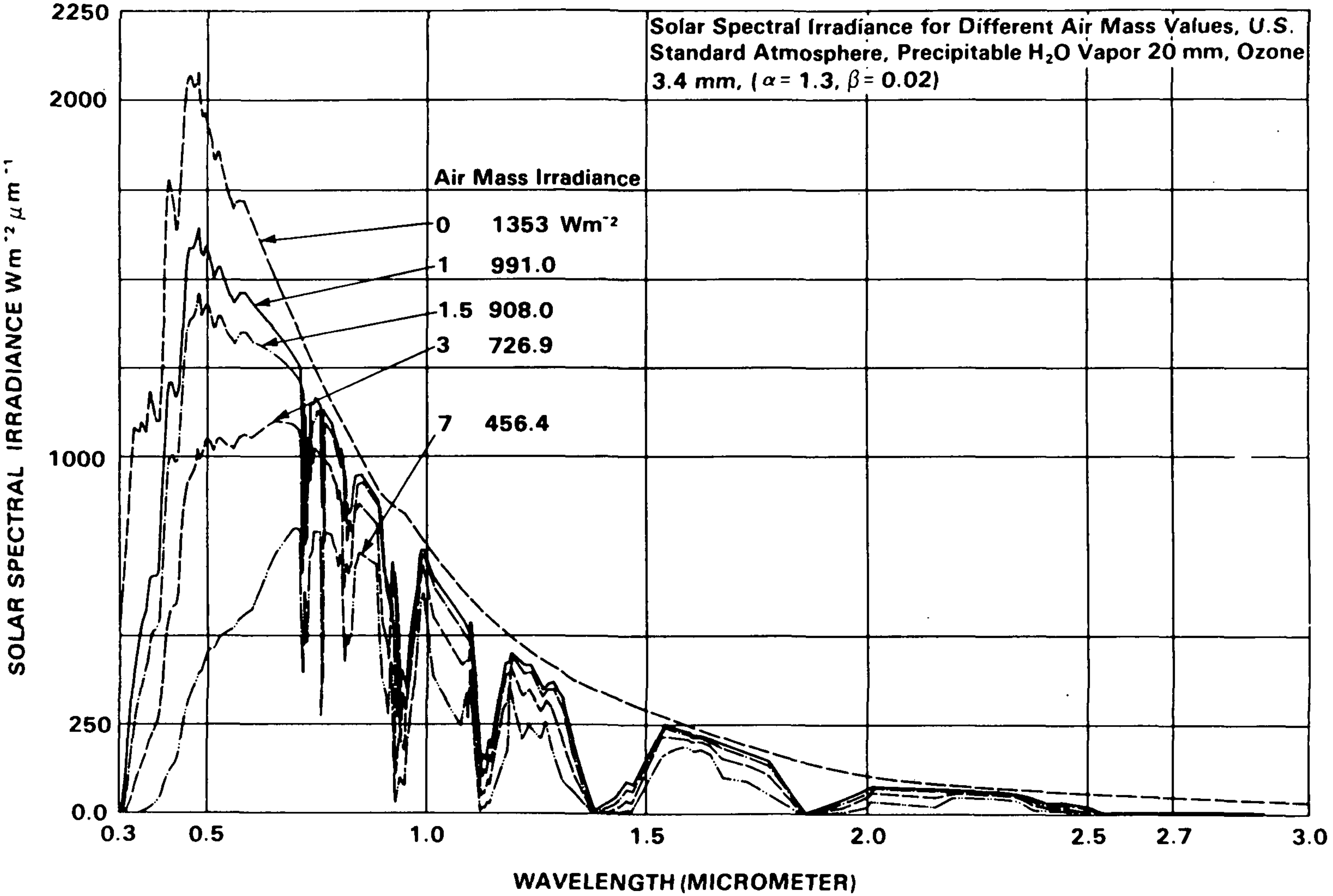


Figure 8. Solar Spectral Irradiance for Different Air Mass Values, Assuming U.S. Standard Atmosphere, Precipitable H_2O Vapor 20mm, Ozone 3.4mm, Very Clear Atmosphere (α = 1.3, β = 0.02)

from the air mass zero curve for atmospheric parameters, 20mm of precipitable water vapor, 3.4mm of ozone, and turbidity coefficients $\alpha = 0.66$, $\beta = 0.085$. The total direct solar energy transmitted by the atmosphere in this case is obtained by integrating the area under the curve and it is found to be 814.9wm^{-2} or 60.2 percent of that received above the atmosphere.

Spectral irradiance values for air mass 1, 1.5, 2, 3, 4, 7 and 10 computed from NASA/ASTM standard solar spectral irradiance outside the atmosphere (E_λ^o) and for U.S. Standard atmosphere 20mm of precipitable water vapor, 3.4mm of ozone from equation (4) are given in Figures 7-10 and Tables 4 and 5 in the wavelength range 300nm–4045nm. As the solar zenith angle increases the transmitted energy decreases.

Solar spectral irradiance values given for $\alpha = 1.3$, $\beta = 0.02$ in Figure 8 and Table 4 correspond to a very clear atmosphere. A higher value of β corresponds to a more turbid atmosphere. Spectral irradiance values given for $\alpha = 1.3$ and $\beta = 0.085$ in Figure 9 and Table 4 represent a rather clear atmosphere. As turbidity increases the transmitted energy decreases.

It has been discussed earlier that the α, β Ångström turbidity coefficients are related to the size distribution and density of aerosols. The wavelength exponent α generally is within the range from 0.5 to 2.5 and according to Ångström (1929) has a mean value of 1.3. An α value of 0.5 indicates a greater than average proportion of large particles while an α value of 2.5 indicates a less than average proportion of large particles (21). Considerably higher levels of pollution typical of large cities and industrial centers are represented by $\alpha = 0.66$, $\beta = 0.085$ and $\alpha = 0.66$, $\beta = 0.17$ in Table 5 and Figures 10 and 11 respectively (13). Total irradiance at ground level is obtained by integration of the area under the spectral irradiance curves. It is significant that as air-mass increases or as turbidity increases, the amount of energy in the infrared relative to the total increases and that in the uv and visible decreases.

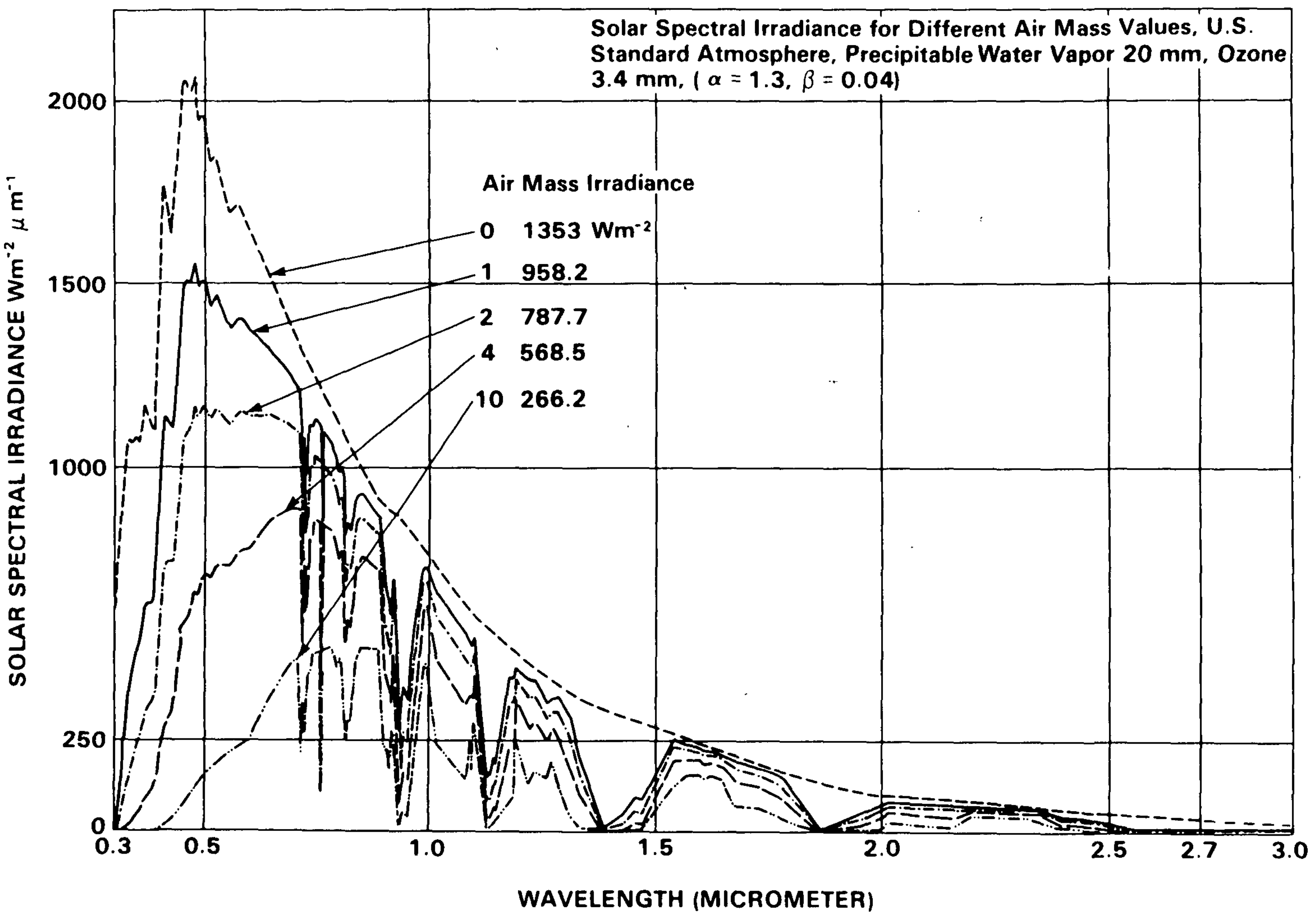


Figure 9. Solar Spectral Irradiance for Different Air Mass Values, Assuming U.S. Standard Atmosphere, Precipitable Water Vapor 20mm, Ozone 3.4mm, Clear Atmosphere (α = 1.3, β = 0.04)

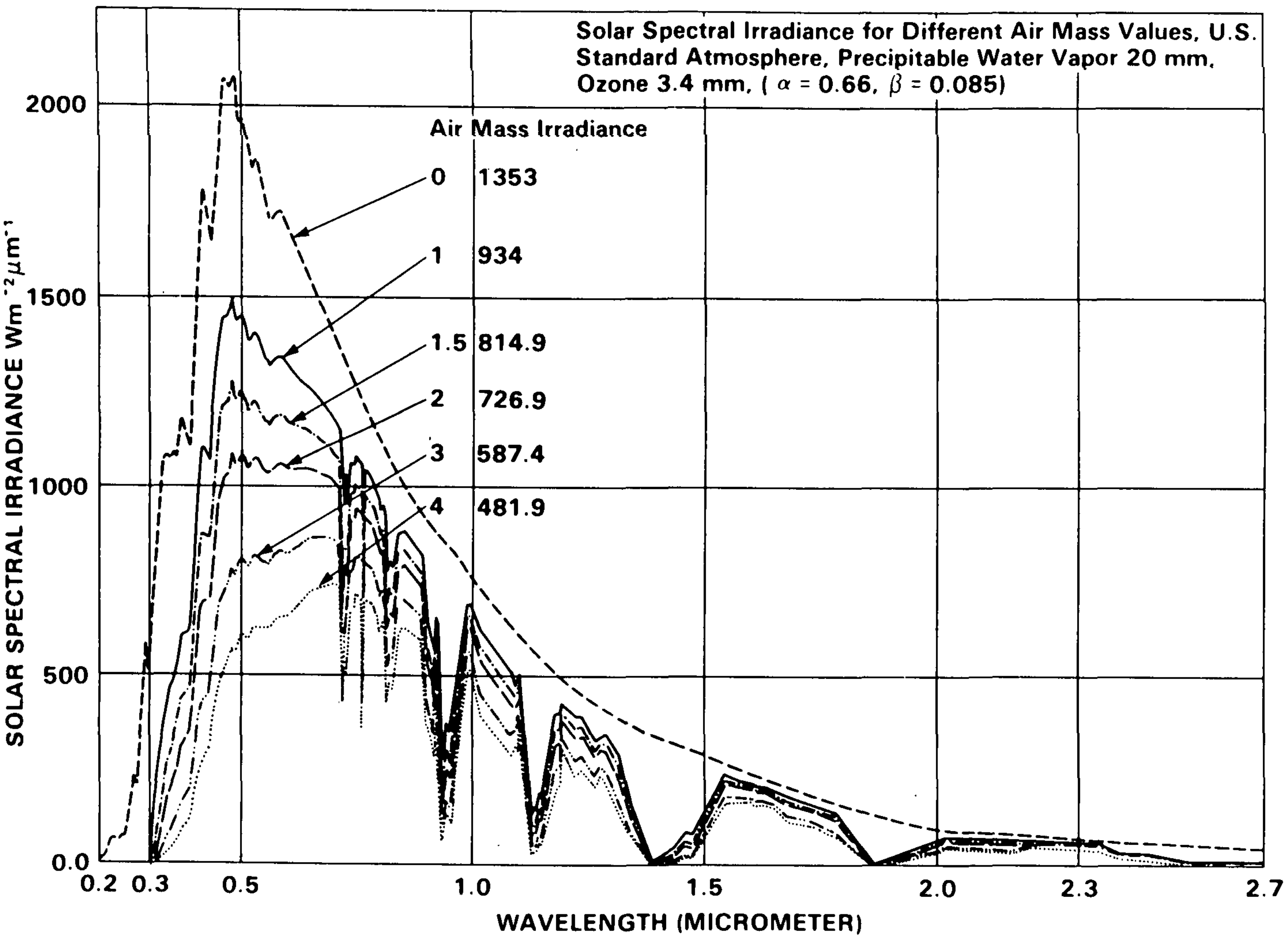


Figure 10. Solar Spectral Irradiance for Different Air Mass Values, Assuming U.S. Standard Atmosphere, Precipitable Water Vapor 20mm, Ozone 3.4mm, Turbid Atmosphere ($\alpha = 0.66$, $\beta = 0.085$)

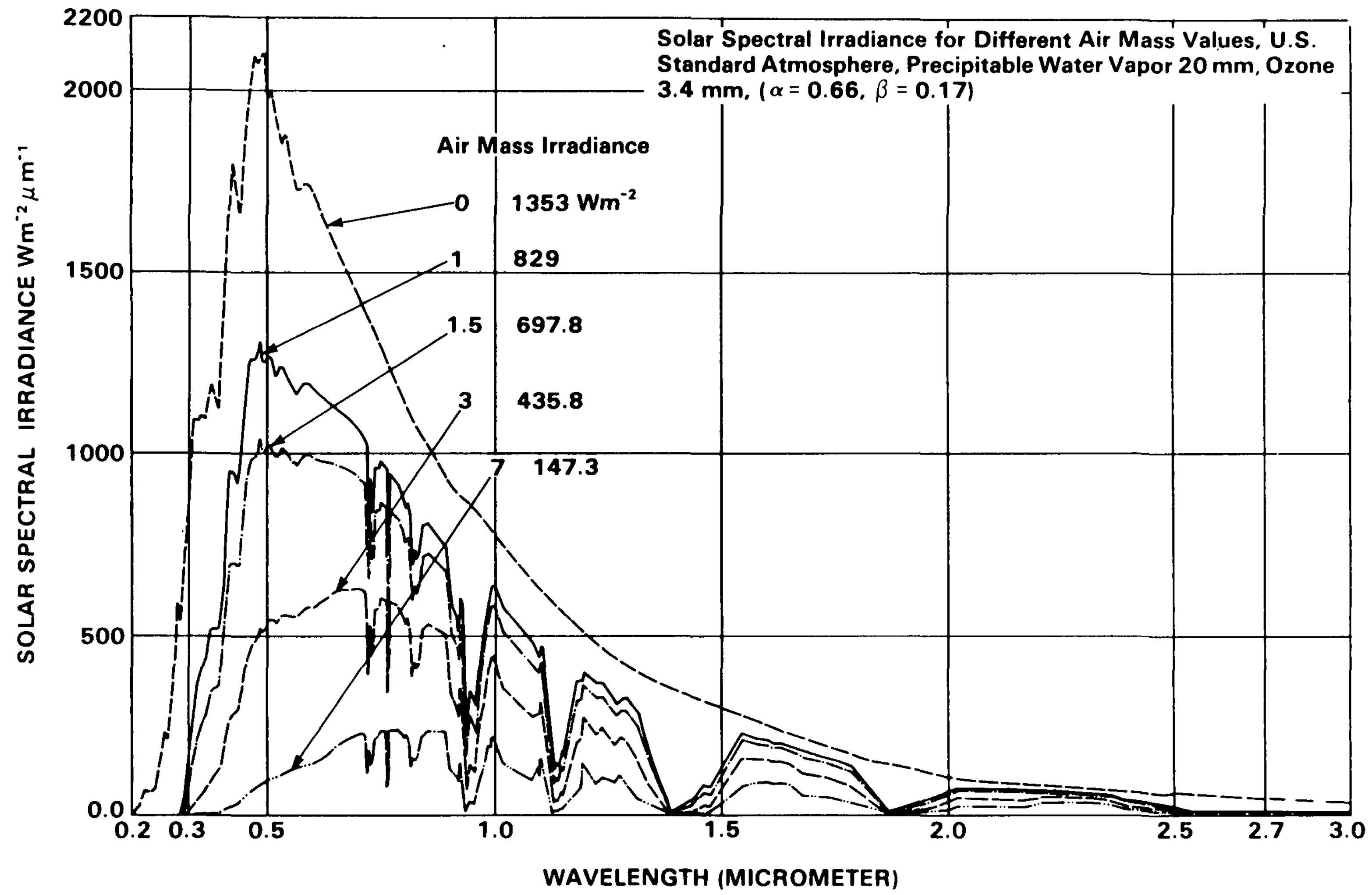


Figure 11. Solar Spectral Irradiance for Air Mass Values, Assuming U.S. Standard Atmosphere, Precipitable Water Vapor 20mm, Ozone 3.4mm, Very Turbid Atmosphere (α = 0.66, β = 0.17)

Table 4. Solar Spectral Irradiance for Different Air Masses, $Wm^{-2}\ \mu m^{-1}$

H_2O 20mm, O_3 3.4mm, a, β, Ångström Turbidity Coefficients $\alpha = 1.3$, $\beta = 0.02$ and $\alpha = 1.3$, $\beta = 0.04$

Air Mass / Wave Length, nm		$a = 1.3$ $\beta = 0.02$							$a = 1.3$ $\beta = 0.04$						
	0	1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
290	482.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
295	584.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	514.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0
305	603.0	12.5	2.0	0.0	0.0	0.0	0.0	0.0	11.4	2.0	0.0	0.0	0.0	0.0	0.0
310	689.0	33.5	7.0	2.0	0.0	0.0	0.0	0.0	30.6	6.0	1.0	0.0	0.0	0.0	0.0
315	764.0	87.1	29.0	10.0	1.0	0.1	0.0	0.0	79.7	26.0	8.0	1.0	0.1	0.0	0.0
320	830.0	222.2	115.0	59.0	16.0	4.3	0.1	0.0	203.5	101.0	50.0	12.0	3.0	0.0	0.0
325	975.0	295.6	163.0	90.0	27.0	8.2	0.2	0.0	271.2	143.0	75.0	21.0	5.8	0.1	0.0
330	1059.0	363.6	213.0	125.0	43.0	14.7	0.6	0.0	334.1	188.0	105.0	33.0	10.5	0.3	0.0
335	1081.0	420.3	262.0	163.0	64.0	24.7	1.5	0.1	386.9	231.0	138.0	50.0	17.7	0.8	0.0
340	1074.0	472.9	314.0	208.0	92.0	40.4	3.4	0.3	436.0	278.0	177.0	72.0	29.2	2.0	0.1
345	1069.0	492.4	334.0	227.0	104.0	48.1	4.7	0.5	454.6	296.0	193.0	82.0	35.0	2.7	0.2
350	1093.0	526.6	365.0	254.0	122.0	58.9	6.6	0.7	486.9	325.0	217.0	97.0	43.0	3.8	0.3
355	1083.0	545.7	387.0	275.0	139.0	69.8	8.9	1.1	505.4	345.0	236.0	110.0	51.3	5.2	0.5
360	1068.0	562.9	409.0	297.0	156.0	82.4	12.1	1.8	522.0	365.0	255.0	125.0	60.9	7.1	0.8
365	1132.0	614.8	453.0	334.0	181.0	98.5	15.8	2.5	570.9	405.0	288.0	145.0	73.2	9.4	1.2
370	1181.0	661.0	495.0	370.0	207.0	115.9	20.3	3.6	614.6	443.0	320.0	166.0	86.6	12.2	1.7
375	1157.0	667.3	507.0	385.0	222.0	128.0	24.6	4.7	621.2	455.0	334.0	179.0	96.2	14.9	2.3
380	1120.0	665.6	513.0	395.0	235.0	139.7	29.3	6.2	620.4	462.0	344.0	190.0	105.4	17.9	3.0
385	1098.0	667.5	520.0	406.0	247.0	150.0	33.7	7.6	622.9	469.0	353.0	200.0	113.7	20.8	3.8
390	1098.0	682.8	538.0	425.0	264.0	164.2	39.5	9.5	638.0	486.0	371.0	215.0	125.1	24.5	4.8
395	1189.0	756.3	603.0	481.0	306.0	194.7	50.1	12.9	707.4	546.0	421.0	250.0	149.0	31.4	6.6
400	1429.0	929.7	750.0	605.0	394.0	256.1	70.5	19.4	870.5	679.0	530.0	323.0	196.8	44.5	10.1
405	1644.0	1085.9	882.0	717.0	474.0	312.9	90.2	26.0	1017.8	801.0	630.0	390.0	241.5	57.3	13.6
410	1751.0	1174.0	961.0	787.0	528.0	353.9	106.7	32.2	1101.5	874.0	693.0	436.0	274.2	68.3	17.0
415	1774.0	1207.4	996.0	822.0	559.0	380.7	120.0	37.8	1134.0	907.0	725.0	463.0	296.2	77.4	20.2
420	1747.0	1207.0	1003.0	834.0	576.0	398.0	131.3	43.3	1134.7	914.0	737.0	479.0	310.9	85.2	23.2
425	1693.0	1187.3	994.0	833.0	584.0	409.5	141.2	48.7	1117.2	908.0	737.0	487.0	321.1	92.3	26.5
430	1639.0	1166.7	984.0	830.0	591.0	420.8	151.8	54.7	1098.8	900.0	737.0	494.0	331.1	99.8	30.1
435	1663.0	1201.5	1021.0	868.0	627.0	453.2	170.9	64.5	1132.7	935.0	771.0	525.0	357.9	113.1	35.7

Table 4 (Continued)

Wave Length, nm / Air Mass		$\alpha = 1.3$			$\beta = 0.02$				$\alpha = 1.3$			$\beta = 0.04$			
	0	1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
440	1810.0	1327.3	1137.0	973.0	714.0	523.5	206.4	81.4	1252.4	1042.0	867.0	600.0	414.8	137.4	45.5
445	1922.0	1430.6	1234.0	1065.0	793.0	589.9	243.2	100.3	1350.9	1133.0	949.0	667.0	469.1	162.9	56.5
450	2006.0	1515.4	1317.0	1145.0	865.0	653.3	281.6	121.4	1432.2	1210.0	1022.0	730.0	521.2	189.7	69.0
455	2057.0	1565.6	1366.0	1192.0	907.0	690.3	304.4	134.2	1480.8	1256.0	1066.0	767.0	552.5	206.1	76.9
460	2066.0	1584.3	1387.0	1215.0	932.0	714.4	322.1	145.3	1499.7	1278.0	1089.0	790.0	573.6	219.4	83.9
465	2048.0	1582.2	1391.0	1222.0	944.0	729.6	336.5	155.2	1498.9	1282.0	1097.0	803.0	587.6	230.4	90.3
470	2033.0	1582.4	1396.0	1232.0	959.0	746.2	351.9	165.9	1500.2	1289.0	1107.0	817.0	602.7	242.2	97.3
475	2044.0	1602.8	1419.0	1257.0	986.0	772.9	372.7	179.7	1520.6	1312.0	1131.0	842.0	626.1	257.8	106.1
480	2074.0	1638.4	1456.0	1294.0	1023.0	807.8	398.3	196.4	1555.5	1347.0	1167.0	875.0	656.3	276.9	116.8
485	1976.0	1572.6	1403.0	1252.0	996.0	792.7	399.6	201.4	1494.1	1299.0	1130.0	854.0	645.8	279.2	120.7
490	1950.0	1563.4	1400.0	1253.0	1005.0	805.7	415.3	214.0	1486.3	1298.0	1133.0	864.0	658.2	291.5	129.1
495	1960.0	1583.0	1423.0	1279.0	1033.0	834.1	439.5	231.5	1506.0	1320.0	1157.0	889.0	683.2	310.0	140.6
500	1942.0	1580.1	1425.0	1286.0	1046.0	851.1	458.4	246.9	1504.1	1324.0	1165.0	902.0	698.9	324.7	150.9
505	1920.0	1567.5	1416.0	1280.0	1045.0	853.1	464.2	252.6	1493.2	1317.0	1161.0	903.0	702.3	330.3	155.4
510	1882.0	1541.8	1395.0	1263.0	1035.0	847.7	466.1	256.2	1469.5	1299.0	1147.0	896.0	699.6	333.1	158.6
515	1833.0	1506.8	1366.0	1239.0	1018.0	836.9	464.9	258.2	1437.0	1272.0	1127.0	883.0	692.4	333.6	160.8
520	1833.0	1511.9	1373.0	1247.0	1029.0	848.4	476.1	267.1	1442.8	1280.0	1136.0	894.0	703.5	343.1	167.3
525	1852.0	1532.7	1394.0	1268.0	1050.0	868.8	492.5	279.2	1463.5	1301.0	1156.0	914.0	722.2	356.4	175.9
530	1842.0	1529.6	1394.0	1270.0	1055.0	875.8	501.5	287.2	1461.3	1302.0	1159.0	920.0	729.7	364.3	181.9
535	1818.0	1514.7	1383.0	1262.0	1052.0	876.1	506.7	293.1	1447.9	1292.0	1153.0	918.0	731.5	369.6	186.7
540	1783.0	1490.5	1363.0	1246.0	1042.0	870.8	508.7	297.2	1425.6	1275.0	1140.0	911.0	728.7	372.4	190.4
545	1754.0	1471.2	1347.0	1234.0	1035.0	868.1	512.3	302.3	1408.0	1261.0	1130.0	907.0	728.0	376.4	194.6
550	1725.0	1451.7	1332.0	1222.0	1028.0	865.2	515.7	307.3	1389.9	1248.0	1120.0	902.0	727.0	380.3	198.9
555	1720.0	1450.4	1332.0	1223.0	1031.0	869.6	521.4	312.7	1389.3	1249.0	1122.0	907.0	732.2	385.9	203.4
560	1695.0	1432.2	1316.0	1210.0	1022.0	863.9	521.1	314.3	1372.6	1235.0	1111.0	900.0	728.8	387.0	205.5
565	1705.0	1443.0	1328.0	1222.0	1035.0	875.9	531.5	322.5	1384.1	1247.0	1124.0	912.0	740.4	396.1	211.9
570	1712.0	1452.3	1338.0	1232.0	1045.0	886.5	541.1	330.3	1393.2	1257.0	1134.0	923.0	750.8	404.6	218.0
575	1719.0	1461.1	1347.0	1242.0	1056.0	897.2	550.9	338.3	1402.3	1267.0	1144.0	933.0	761.3	413.3	224.4
580	1715.0	1460.5	1348.0	1244.0	1059.0	902.1	557.2	344.2	1402.4	1268.0	1147.0	938.0	766.9	419.4	229.3
585	1712.0	1460.8	1349.0	1247.0	1064.0	907.6	563.9	350.3	1403.3	1271.0	1150.0	943.0	772.9	425.7	234.5

Table 4 (Continued)

Wave Length, nm \ Air 'Mass	0	$a = 1.3$			$\beta = 0.02$				$a = 1.3$			$\beta = 0.04$			
		1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
590	1700.0	1453.4	1344.0	1243.0	1062.0	908.3	567.6	354.7	1396.8	1266.0	1148.0	943.0	774.9	429.8	238.4
595	1682.0	1440.8	1334.0	1234.0	1057.0	905.6	569.2	357.8	1385.3	1257.0	1141.0	940.0	774.0	432.4	241.6
600	1666.0	1429.9	1325.0	1227.0	1053.0	903.9	571.5	361.3	1375.4	1250.0	1135.0	937.0	773.8	435.4	245.0
605	1647.0	1420.2	1319.0	1225.0	1056.0	910.7	583.9	374.4	1366.7	1245.0	1134.0	941.0	780.9	446.2	254.9
610	1635.0	1416.5	1319.0	1227.0	1063.0	921.2	599.1	389.6	1363.7	1245.0	1137.0	949.0	791.2	459.1	266.4
620	1602.0	1401.0	1310.0	1225.0	1072.0	937.2	626.9	419.3	1349.8	1239.0	1137.0	958.0	807.5	483.1	289.0
630	1570.0	1386.0	1302.0	1224.0	1080.0	953.5	656.0	451.3	1336.4	1233.0	1137.0	968.0	824.1	508.2	313.4
640	1544.0	1375.8	1299.0	1226.0	1092.0	973.4	688.7	487.3	1327.5	1231.0	1141.0	981.0	843.8	536.3	340.9
650	1511.0	1359.0	1289.0	1222.0	1099.0	988.8	719.4	523.4	1312.3	1223.0	1140.0	990.0	859.6	563.0	369.0
660	1486.0	1344.0	1279.0	1216.0	1100.0	995.6	737.3	546.0	1299.1	1215.0	1136.0	993.0	867.9	579.8	387.3
670	1456.0	1325.0	1264.0	1206.0	1097.0	998.6	752.7	567.3	1281.2	1202.0	1127.0	992.0	872.8	594.7	405.1
680	1427.0	1306.2	1250.0	1196.0	1095.0	1001.9	768.5	589.4	1263.8	1189.0	1119.0	991.0	877.9	609.9	423.7
690	1402.0	1290.9	1239.0	1189.0	1094.0	1007.5	786.4	613.8	1249.7	1180.0	1114.0	993.0	885.1	626.8	443.9
700	1369.0	1267.8	1220.0	1174.1	1087.3	1006.9	799.7	635.1	1228.1	1163.2	1101.7	988.3	886.6	640.1	462.1
710	1344.0	1248.0	1202.6	1158.9	1076.1	999.3	800.1	640.6	1209.7	1147.6	1088.8	980.0	882.0	643.1	468.9
712	1338.0	1240.6	1195.2	1151.6	1069.2	992.8	795.1	636.9	1202.6	1140.7	1082.1	973.9	876.6	639.5	466.6
715	1329.0	1199.9	1149.3	1102.1	1015.2	936.5	738.6	584.7	1163.2	1097.1	1035.8	925.0	827.3	594.5	428.9
717.5	1321.5	997.2	917.7	850.7	740.6	651.4	458.3	331.3	967.0	876.2	799.9	675.2	575.9	369.4	243.5
720	1314.0	942.0	857.0	787.0	674.3	585.3	399.0	281.3	913.0	817.9	739.4	614.0	516.6	320.7	205.9
722.5	1308.0	1112.6	1052.2	998.2	903.5	821.4	626.3	483.2	1079.2	1005.1	939.1	824.5	727.0	505.9	356.2
725	1302.0	1003.8	928.7	864.9	759.1	672.5	481.9	353.9	973.7	887.3	813.9	692.9	595.5	389.5	261.1
727.5	1296.0	1012.0	939.2	877.0	773.3	687.8	497.9	368.8	981.8	897.4	825.5	706.1	609.3	402.8	272.4
730	1290.0	1012.8	941.2	880.0	777.5	692.9	504.0	375.0	982.7	899.6	828.6	710.4	614.3	408.3	277.5
732.5	1282.5	1093.7	1035.7	983.8	892.8	813.8	625.4	486.3	1061.4	990.1	926.5	815.9	721.8	506.9	360.2
735	1275.0	1148.9	1101.6	1057.7	977.2	904.5	721.4	578.1	1115.0	1053.3	996.3	893.4	802.5	585.2	428.7
737.5	1267.5	1142.9	1096.3	1052.9	973.5	901.7	720.7	578.7	1109.5	1048.5	992.2	890.5	800.7	585.4	430.0
740	1260.0	1145.1	1100.5	1058.8	981.7	911.6	733.3	592.2	1111.7	1052.7	997.9	898.3	809.8	596.1	440.5
742.5	1253.7	1141.3	1097.4	1056.3	980.3	911.1	734.8	594.7	1108.2	1050.1	996.0	897.6	810.1	598.1	443.2
745	1247.5	1159.7	1120.7	1083.2	1012.6	946.9	775.3	635.5	1126.2	1072.5	1021.6	927.4	842.2	631.6	474.1
747.5	1241.2	1164.1	1127.3	1091.7	1023.8	960.1	791.9	653.2	1130.6	1079.0	1029.7	937.9	854.3	645.5	487.8

Table 4 (Continued)

Wave Length nm \ Air Mass		$a = 1.3$			$\beta = 0.02$				$a = 1.3$			$\beta = 0.04$			
	0	1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
760	1211.0	1139.3	1105.1	1071.9	1008.5	948.8	790.1	658.0	1107.3	1058.9	1012.5	925.8	846.6	647.2	494.8
762.1	1205.5	854.2	767.6	694.7	574.9	478.5	273.1	143.7	830.3	735.6	656.4	528.0	427.1	223.9	108.2
765	1198.0	1128.6	1095.4	1063.2	1001.6	943.5	789.8	659.5	1097.0	1049.7	1004.5	919.8	842.2	646.6	496.4
785	1146.5	1085.6	1056.3	1027.9	973.2	921.6	782.3	664.1	1056.2	1013.8	973.1	896.5	825.9	645.8	505.0
790	1134.0	1057.9	1026.4	996.3	939.8	887.2	748.2	632.4	1029.6	985.5	943.8	866.4	796.0	618.9	482.2
795	1121.5	1044.4	1013.3	983.7	928.1	876.6	740.7	627.5	1016.6	973.0	932.0	856.0	786.9	613.1	479.0
800	1109.0	1006.7	971.4	938.9	879.5	825.7	688.5	577.4	980.1	933.1	889.9	811.5	741.8	570.7	441.7
805	1097.0	1019.5	989.2	960.5	906.9	857.3	726.9	618.2	992.8	950.6	910.9	837.6	771.1	603.8	474.2
810	1085.0	986.4	952.5	921.3	864.3	812.7	680.7	573.5	960.8	915.7	874.1	798.8	731.6	566.2	440.8
815	1072.5	821.5	763.4	715.0	635.5	571.0	428.8	331.3	800.3	734.1	678.6	587.6	514.4	357.2	255.2
820	1060.0	864.1	814.5	772.1	700.4	640.3	501.5	400.9	842.0	783.5	733.1	648.0	577.3	418.4	309.4
825	1048.0	840.9	790.0	746.8	674.3	614.2	477.0	378.8	819.6	760.1	709.4	624.3	554.2	398.5	293.0
830	1036.0	852.7	805.9	765.6	697.3	639.9	506.1	408.1	831.2	775.6	727.6	646.0	577.3	423.4	316.2
835	1024.5	913.3	879.0	848.0	792.6	743.4	620.1	522.0	890.5	846.2	806.1	734.7	671.8	519.5	405.3
840	1013.0	945.5	919.5	895.1	849.4	807.0	694.7	600.0	922.0	885.6	851.3	787.8	729.9	582.8	466.8
845	1001.5	945.0	921.5	899.0	856.5	816.5	709.1	616.9	921.7	887.7	855.4	794.9	739.1	595.7	480.9
850	990.0	948.1	927.9	908.0	869.7	832.9	731.7	642.7	925.0	894.1	864.3	807.5	754.5	615.5	502.0
890	908.0	874.7	858.5	842.6	811.6	781.8	698.9	624.7	854.6	829.1	804.3	757.0	712.5	594.1	495.3
895	899.5	790.8	760.5	733.7	686.9	646.0	545.2	465.7	772.7	734.6	700.6	641.0	589.0	463.8	369.6
902	888.8	678.3	632.0	593.9	531.8	481.9	372.0	296.0	663.0	610.8	567.4	496.7	439.9	317.1	235.7
907	883.3	663.3	615.9	577.0	514.2	464.0	354.9	280.3	648.4	595.3	551.4	480.4	423.8	302.7	223.4
912	877.8	641.6	592.1	552.0	487.8	437.1	328.7	256.2	627.2	572.4	527.6	455.8	399.3	280.6	204.4
916	873.4	598.1	544.0	500.9	433.7	382.0	275.6	207.9	584.8	526.0	479.0	405.5	349.2	235.6	166.1
920	869.0	700.9	661.6	628.4	573.2	527.6	423.3	347.6	685.5	639.8	601.0	536.1	482.6	362.1	278.1
924	864.6	685.0	644.0	609.7	553.2	506.8	402.3	327.6	670.1	623.0	583.4	517.7	464.0	344.6	262.6
928	860.2	572.9	518.0	474.5	407.5	356.4	253.0	188.5	560.3	501.0	454.0	381.3	326.3	216.8	151.1
935	852.5	273.7	210.0	167.6	114.2	82.2	36.5	18.7	267.8	203.3	160.5	106.9	75.3	31.3	15.0
943	844.0	400.1	335.3	288.1	222.2	177.6	101.5	63.6	391.6	324.6	276.0	208.3	162.9	87.2	51.2
950	837.0	373.5	308.8	262.4	198.6	156.2	85.9	52.3	365.6	299.0	251.4	186.2	143.4	74.0	42.2
954	830.2	356.9	292.6	246.9	184.7	143.8	77.3	46.1	349.4	283.4	236.6	173.2	132.1	66.6	37.3

Table 4 (Continued)

Air Mass / Wave Length nm		$a = 1.3$			$\beta = 0.02$				$a = 1.3$			$\beta = 0.04$			
	0	1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
957	825.1	457.0	396.7	351.2	284.8	237.4	150.3	102.3	447.5	384.3	336.6	269.2	218.1	129.6	82.8
965	811.5	549.7	499.2	459.2	397.1	349.6	252.4	190.9	538.2	483.8	440.3	372.8	321.4	217.9	154.7
975	794.0	623.6	585.6	554.0	502.4	460.4	366.2	299.4	610.9	567.8	531.7	472.3	424.0	317.0	243.6
981	783.2	678.4	651.3	627.9	587.5	552.8	468.9	403.6	664.6	631.6	602.6	552.4	509.3	406.2	328.8
984	777.8	709.3	689.0	670.7	638.0	608.8	534.1	472.4	695.0	668.2	643.9	600.1	561.0	463.0	385.2
990	767.0	736.2	723.5	711.3	687.9	665.7	604.2	549.3	721.5	701.9	683.1	647.5	614.0	524.6	448.8
995	757.0	735.0	724.2	713.6	692.9	672.7	615.8	563.6	720.3	702.6	685.4	652.1	620.5	534.6	460.5
1018	719.2	657.9	629.2	601.8	550.5	503.6	385.5	295.0	645.1	611.0	578.7	519.1	465.6	336.0	242.5
1082	620.0	544.0	509.7	477.4	418.9	367.6	248.3	167.8	534.3	496.0	460.5	396.9	342.0	218.9	140.2
1094	602.0	505.7	483.0	463.9	431.7	404.8	341.7	294.2	496.8	470.3	447.6	409.2	377.0	301.7	246.2
1098	596.0	534.3	505.9	479.0	429.4	384.9	277.3	199.8	524.9	492.6	462.3	407.2	358.6	245.0	167.4
1101	591.8	535.4	519.6	505.6	480.9	459.0	408.6	358.0	526.0	506.0	488.0	456.0	427.6	356.5	300.0
1128	560.5	143.2	104.8	80.3	51.3	35.0	13.7	6.4	140.8	102.1	77.6	48.7	32.7	12.2	5.4
1131	557.0	161.3	121.4	95.3	63.3	44.7	19.0	9.5	158.6	118.3	92.1	60.1	41.7	16.9	8.0
1137	550.1	151.7	112.9	87.8	57.4	40.0	16.5	8.0	149.2	110.0	84.9	54.6	37.4	14.7	6.8
1144	542.0	202.7	161.5	133.1	95.9	72.5	36.5	20.8	199.3	157.5	128.7	91.2	67.8	32.4	17.6
1147	538.5	185.0	144.6	117.3	82.3	60.8	29.0	15.8	181.9	141.0	113.4	78.2	56.9	25.8	13.4
1178	507.0	423.2	386.7	353.3	294.9	246.2	143.2	83.3	416.5	377.4	342.1	281.0	230.8	127.9	70.9
1189	496.0	426.2	395.1	366.3	314.7	270.5	171.6	108.9	419.5	385.8	354.8	300.1	253.8	153.6	92.9
1193	492.0	449.3	437.5	427.0	408.4	392.0	350.2	315.4	442.2	427.2	413.6	389.4	367.8	313.3	269.1
1222	464.3	415.0	392.4	371.0	331.6	296.4	211.7	151.2	408.7	383.4	359.7	316.6	278.7	190.1	129.6
1236	451.2	414.1	396.7	380.0	348.7	320.4	247.3	191.1	407.8	387.7	368.6	333.2	301.1	222.3	164.2
1264	426.5	348.6	329.8	313.9	286.8	263.8	209.3	167.5	343.5	322.6	304.7	274.3	248.7	188.7	144.4
1276	416.7	362.8	349.2	337.5	317.3	299.9	257.5	223.7	357.6	341.7	327.9	303.8	283.0	232.6	193.5
1288	406.8	367.6	349.5	332.2	300.2	271.3	200.2	147.7	362.4	342.0	322.8	287.5	256.1	181.0	127.9
1314	386.1	315.6	285.4	258.0	210.9	172.4	94.2	51.5	311.2	279.4	250.9	202.3	163.1	85.4	44.8
1335	369.7	201.6	175.1	155.3	126.6	106.4	69.2	48.6	198.8	171.5	151.1	121.5	100.6	62.8	42.3
1384	343.7	6.0	2.4	1.1	0.3	0.1	0.0	0.0	6.0	2.4	1.1	0.3	0.1	0.0	0.0
1432	321.0	47.1	30.5	21.1	11.3	6.7	1.9	0.7	46.5	30.4	20.5	10.9	6.4	1.7	0.6
1457	308.6	90.1	68.1	53.7	36.0	25.6	11.2	5.7	89.0	67.0	52.4	34.7	24.4	10.3	5.1

Table 4 (Continued)

Wave Length, nm / Air Mass	0	α = 1.3		β = 0.02					α = 1.3		β = 0.04				
		1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
1472	301.4	81.6	61.0	47.1	30.8	21.5	8.9	4.4	80.6	60.0	46.0	29.7	20.5	8.2	3.9
1542	270.4	252.2	243.5	235.2	219.3	204.5	165.9	134.5	249.3	239.0	229.9	211.9	195.4	153.2	120.0
1572	257.3	234.5	229.0	223.5	214.6	206.8	187.4	171.4	231.9	225.0	218.6	207.6	197.8	173.4	153.4
1599	245.4	227.5	223.0	219.0	211.0	204.8	188.5	174.8	225.0	219.0	214.0	204.0	196.1	174.7	156.8
1608	241.5	219.5	214.0	209.0	201.0	193.3	174.9	159.9	217.0	210.0	205.0	194.0	185.1	162.2	143.5
1626	233.6	217.5	213.0	210.0	203.0	197.1	182.2	169.7	215.2	210.0	205.0	197.0	188.9	169.2	152.6
1644	225.6	208.2	204.0	200.0	193.0	186.7	171.4	158.6	206.0	200.0	196.0	187.0	179.0	159.2	142.8
1650	223.0	205.9	201.0	198.0	191.0	184.8	169.7	157.2	204.0	198.0	193.0	185.0	177.2	157.8	141.6
1676	212.1	191.3	182.0	173.0	156.0	140.3	103.0	75.6	189.3	179.2	169.0	151.0	134.7	95.9	68.2
1732	187.9	169.7	161.0	153.0	138.0	124.9	92.0	67.7	168.0	159.0	150.0	134.0	120.1	85.9	61.4
1782	166.6	143.5	133.0	124.0	107.0	91.8	58.8	37.6	142.2	131.3	121.0	104.0	88.4	55.0	34.2
1862	138.2	4.2	2.0	1.0	0.3	0.1	0.0	0.0	4.1	2.0	1.0	0.3	0.1	0.0	0.0
1955	112.9	44.7	36.0	30.0	22.0	17.4	9.4	5.7	44.4	36.0	30.0	22.0	16.8	8.9	5.2
2008	102.0	72.6	66.0	60.0	51.0	43.0	24.4	10.1	72.0	65.0	59.0	50.0	41.6	23.1	9.4
2014	101.2	78.2	73.0	68.0	61.0	54.6	39.6	28.0	78.0	72.0	67.0	59.0	52.9	37.5	25.9
2057	95.6	72.7	67.0	63.0	56.0	49.4	34.7	23.2	72.0	67.0	62.0	54.0	47.9	32.8	21.5
2124	87.4	73.1	67.0	61.0	51.0	42.9	25.1	14.7	72.6	66.0	60.0	50.0	41.6	23.8	13.7
2156	83.8	69.0	63.0	57.0	47.0	38.5	21.4	12.0	68.5	62.0	56.0	46.0	37.3	20.4	11.1
2201	78.9	69.0	67.0	65.0	61.0	58.4	51.4	45.8	68.5	66.0	64.0	60.0	56.8	48.9	42.6
2266	72.4	64.3	62.0	61.0	58.0	55.5	49.6	44.9	63.8	62.0	60.0	57.0	54.0	47.3	41.9
2320	67.6	59.6	58.0	56.0	53.0	51.1	45.4	40.8	59.2	57.0	55.0	52.0	49.7	43.3	38.2
2338	66.3	57.0	55.0	53.0	50.0	47.2	40.7	35.6	56.6	54.0	52.0	49.0	45.9	38.9	33.3
2356	65.1	54.2	52.0	50.0	46.0	42.9	35.5	29.7	53.8	51.0	49.0	45.0	41.7	33.9	27.8
2388	62.8	37.5	33.0	30.0	25.0	22.1	15.6	11.8	37.3	33.0	30.0	25.0	21.5	14.9	11.0
2415	61.0	33.9	30.0	26.0	22.0	18.6	12.5	9.1	33.6	29.0	26.0	21.0	18.1	12.0	8.5
2453	58.3	31.0	27.0	24.0	19.0	16.1	10.5	7.5	30.6	26.0	23.0	19.0	15.7	10.1	7.0
2494	55.4	21.2	17.0	14.0	10.0	8.0	4.2	2.5	21.0	17.0	14.0	10.0	7.8	4.0	2.4
2537	52.4	4.8	3.0	2.0	1.0	0.4	0.1	0.0	4.8	3.0	2.0	1.0	0.4	0.1	0.0
2900	35.0	3.0	2.0	1.0	0.3	0.1	0.0	0.0	3.0	2.0	1.0	0.3	0.1	0.0	0.0
2941	33.4	6.2	4.0	3.0	2.0	1.1	0.4	0.2	6.2	4.0	3.0	2.0	1.1	0.4	0.2

Table 4 (Continued)

Wave Length, nm \ Air Mass		$a = 1.3$ $\beta = 0.02$							$a = 1.3$ $\beta = 0.04$						
	0	1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
2954	32.8	5.9	4.0	3.0	2.0	1.1	0.3	0.1	5.9	4.0	3.0	2.0	1.0	0.3	0.1
2973	32.1	9.0	7.0	5.0	4.0	2.5	1.1	0.6	9.0	7.0	5.0	4.0	2.5	1.1	0.5
3005	30.8	8.1	6.0	5.0	3.0	2.1	0.9	0.4	8.1	6.0	5.0	3.0	2.1	0.9	0.4
3045	28.8	4.8	3.0	2.0	1.0	0.8	0.3	0.1	4.8	3.0	2.0	1.0	0.8	0.2	0.1
3056	28.2	5.1	3.0	3.0	1.0	0.9	0.3	0.1	5.1	3.0	2.0	1.0	0.9	0.3	0.1
3097	26.2	3.3	2.0	1.0	1.0	0.4	0.1	0.0	3.3	2.0	1.0	1.0	0.4	0.1	0.0
3132	24.9	7.1	5.0	4.0	3.0	2.0	0.9	0.4	7.0	5.0	4.0	3.0	1.9	0.8	0.4
3156	24.1	19.3	18.0	17.0	16.0	14.5	11.4	8.9	19.2	18.0	17.0	16.0	14.2	11.0	8.5
3204	22.5	2.2	1.2	1.0	0.2	0.0	0.0	0.0	2.2	1.2	1.0	0.3	0.1	0.0	0.0
3214	22.1	3.5	2.3	2.0	1.0	0.6	0.2	0.1	3.5	2.2	2.0	1.0	0.5	0.2	0.1
3245	21.1	4.1	3.0	2.0	1.0	0.8	0.3	0.1	4.1	3.0	2.0	1.0	0.8	0.3	0.1
3260	20.6	3.3	3.0	2.0	1.0	0.7	0.2	0.1	3.8	3.0	2.0	1.0	0.7	0.2	0.1
3285	19.7	14.7	14.0	13.0	11.0	9.7	6.5	4.0	14.7	14.0	13.0	11.0	9.6	6.3	3.8
3317	18.8	13.4	12.0	11.0	9.0	7.9	4.5	1.8	13.3	12.0	11.0	9.0	7.8	4.3	1.7
3344	18.1	4.4	3.0	2.0	2.0	1.0	0.4	0.2	4.3	3.0	2.0	2.0	1.0	0.4	0.2
3403	16.5	12.7	12.0	11.0	10.0	8.9	6.5	4.5	12.7	12.0	11.0	10.0	8.8	6.3	4.4
3450	15.6	13.0	12.2	12.0	11.0	10.2	8.4	7.0	12.9	12.1	12.0	11.0	10.0	8.2	6.8
3507	14.5	12.9	12.5	12.0	12.0	11.3	10.2	9.3	12.9	12.2	12.0	12.0	11.1	9.9	8.9
3538	14.2	12.1	12.0	11.0	11.0	10.1	8.7	7.6	12.1	12.0	11.0	10.0	9.9	8.5	7.3
3573	13.8	11.3	11.0	9.0	7.0	6.1	3.3	1.8	11.2	10.0	9.0	7.0	6.0	3.0	1.7
3633	13.1	11.1	11.0	10.0	10.0	9.4	8.4	7.7	11.1	11.0	10.0	10.0	9.3	8.2	7.4
3673	12.6	9.4	9.0	8.2	8.0	7.0	5.7	4.9	9.4	9.0	8.0	7.0	6.9	5.6	4.7
3696	12.3	10.8	10.3	10.0	10.0	9.3	8.4	7.8	10.7	10.2	10.0	10.0	9.2	8.2	7.5
3712	12.2	11.2	11.0	11.0	11.0	10.2	9.6	9.0	11.2	11.0	11.0	10.0	10.0	9.3	8.7
3765	11.5	9.8	9.0	9.0	9.0	8.2	7.3	6.7	9.7	9.0	9.0	9.0	8.1	7.1	6.4
3812	11.0	9.2	9.0	8.0	8.0	7.6	6.7	6.0	9.1	9.0	8.0	8.0	7.5	6.5	5.8
3888	10.4	8.4	8.0	8.0	7.0	6.3	5.0	3.9	8.3	8.0	7.0	7.0	6.2	4.8	3.8
3923	10.1	8.3	8.0	7.0	7.0	6.4	5.2	4.2	8.2	8.0	7.0	7.0	6.3	5.1	4.1
3948	9.9	8.1	8.0	7.0	7.0	6.2	5.0	4.0	8.0	7.9	7.0	7.0	6.1	4.9	3.9
4045	9.1	6.9	6.1	6.0	5.0	4.7	3.2	2.1	6.9	6.0	6.0	5.0	4.6	3.1	2.0
Total Irradiance W m^{-2}	1353	991.0	908.0	838.8	726.9	638.7	456.4	342.3	958.2	865.3	787.7	663.2	568.5	378.2	266.2

Table 5. Solar Spectral Irradiance for Different Air Masses

H_2O 20mm, O_3 3.4mm, α, β, Ångstrom Turbidity Coefficients $\alpha = 0.66$, $\beta = 0.085$ and $\alpha = 0.66$, $\beta = 0.17$

Air Mass / Wave Length, nm		$\alpha = 0.66$ $\beta = 0.085$							$\alpha = 0.66$ $\beta = 0.170$						
	0	1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
290	482.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
295	584.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	514.0	4.1	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0
305	603.0	11.4	2.0	0.0	0.0	0.0	0.0	0.0	9.4	1.0	0.0	0.0	0.0	0.0	0.0
310	689.0	30.5	6.3	1.0	0.0	0.0	0.0	0.0	25.4	5.0	1.0	0.0	0.0	0.0	0.0
315	764.0	79.4	26.0	8.0	1.0	0.1	0.0	0.0	66.2	19.0	6.0	0.0	0.0	0.0	0.0
320	830.0	202.6	100.2	49.0	12.0	2.9	0.0	0.0	169.2	76.0	34.0	7.0	1.4	0.0	0.0
325	975.0	269.5	142.0	75.0	21.0	5.7	0.1	0.0	225.5	108.0	52.0	12.0	2.8	0.0	0.0
330	1059.0	331.6	186.0	104.0	33.0	10.2	0.3	0.0	277.9	142.0	73.0	19.0	5.0	0.1	0.0
335	1081.0	383.4	228.0	136.0	48.0	17.1	0.8	0.0	321.8	176.0	96.0	29.0	8.5	0.2	0.0
340	1074.0	431.3	273.0	173.0	70.0	27.9	1.8	0.1	362.7	211.0	123.0	41.0	14.0	0.5	0.0
345	1069.0	449.2	291.0	189.0	79.0	33.3	2.5	0.2	378.4	225.0	134.0	47.0	16.8	0.7	0.0
350	1093.0	480.5	319.0	211.0	93.0	40.8	3.5	0.3	405.4	247.0	150.0	56.0	20.7	1.1	0.1
355	1083.0	498.0	338.0	229.0	105.0	48.4	4.7	0.5	420.8	262.0	164.0	64.0	24.7	1.4	0.1
360	1068.0	513.7	356.0	247.0	119.0	57.2	6.4	0.7	434.8	277.0	177.0	72.0	29.3	2.0	0.1
365	1132.0	561.3	395.0	278.0	138.0	68.4	8.3	1.0	475.7	308.0	200.0	84.0	35.3	2.6	0.2
370	1181.0	603.5	431.0	308.0	158.0	80.5	10.7	1.4	512.3	337.0	222.0	96.0	41.8	3.4	0.3
375	1157.0	609.4	442.0	321.0	169.0	89.0	13.0	1.9	518.0	347.0	232.0	104.0	46.5	4.2	0.4
380	1120.0	608.0	448.0	330.0	179.0	97.2	15.6	2.5	517.6	352.0	239.0	111.0	51.1	5.0	0.5
385	1098.0	609.8	454.0	339.0	188.0	104.5	17.9	3.1	519.9	358.0	246.0	117.0	55.2	5.9	0.6
390	1098.0	623.9	470.0	355.0	201.0	114.5	21.0	3.9	532.6	371.0	258.0	125.0	60.8	6.9	0.8
395	1189.0	691.2	527.0	402.0	234.0	135.8	26.7	5.2	590.8	416.0	294.0	146.0	72.5	8.9	1.1
400	1429.0	849.9	655.0	505.0	301.0	178.8	37.6	7.9	727.4	519.0	370.0	188.0	95.9	12.7	1.7
405	1644.0	992.8	772.0	600.0	362.0	218.7	48.2	10.6	850.8	612.0	440.0	228.0	117.9	16.3	2.3
410	1751.0	1073.7	841.0	658.0	404.0	247.5	57.1	13.2	921.3	668.0	485.0	255.0	134.2	19.5	2.8
415	1774.0	1104.5	871.0	688.0	428.0	266.5	64.3	15.5	948.8	694.0	507.0	271.0	145.2	22.2	3.4
420	1747.0	1104.3	878.0	698.0	441.0	278.9	70.4	17.8	949.8	700.0	516.0	281.0	152.7	24.5	3.9
425	1693.0	1086.5	870.0	697.0	448.0	287.2	75.9	20.1	935.6	696.0	517.0	286.0	157.9	26.7	4.5
430	1639.0	1067.9	862.0	696.0	453.0	295.4	81.7	22.6	920.7	690.0	517.0	291.0	163.2	28.9	5.1
435	1663.0	1100.1	895.0	728.0	481.0	318.4	92.2	26.7	949.5	717.0	542.0	310.0	176.7	32.9	6.1

Table 5 (Continued)

Air Mass / Wave Length, nm	0	$\alpha = 0.66$ $\beta = 0.085$							$\alpha = 0.66$ $\beta = 0.170$						
	0	1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
440	1810.0	1215.5	996.0	816.0	548.0	368.2	111.5	33.8	1050.3	800.0	609.0	354.0	205.2	40.1	7.8
445	1922.0	1310.0	1082.0	893.0	609.0	415.3	131.6	41.7	1133.5	870.0	668.0	394.0	232.5	47.7	9.8
450	2006.0	1388.4	1155.0	961.0	665.0	460.3	152.6	50.6	1202.2	931.0	721.0	432.0	258.8	55.7	12.0
455	2057.0	1434.8	1198.0	1001.0	698.0	486.9	165.2	56.1	1243.7	967.0	752.0	455.0	274.9	60.8	13.4
460	2066.0	1452.2	1218.0	1021.0	718.0	504.4	175.2	60.8	1260.1	984.0	769.0	469.0	285.9	64.9	14.7
465	2048.0	1450.7	1221.0	1028.0	728.0	515.7	183.3	65.1	1260.1	988.0	775.0	477.0	293.5	68.4	15.9
470	2033.0	1451.2	1226.0	1036.0	739.0	527.9	192.0	69.8	1261.8	994.0	783.0	486.0	301.6	72.1	17.2
475	2044.0	1470.3	1247.0	1058.0	761.0	547.3	203.7	75.8	1279.6	1012.0	801.0	501.0	313.9	77.0	18.9
480	2074.0	1503.4	1280.0	1090.1	790.0	572.6	218.1	83.1	1309.6	1041.0	827.0	522.0	329.7	83.0	20.9
485	1976.0	1443.3	1234.0	1054.0	770.0	562.4	219.2	85.4	1258.5	1004.0	802.0	510.0	325.1	84.0	21.7
490	1950.0	1435.2	1231.0	1056.0	777.0	572.2	228.2	91.0	1252.6	1004.0	805.0	517.0	332.0	88.0	23.3
495	1960.0	1453.6	1252.0	1078.0	800.0	592.9	241.9	98.7	1269.8	1022.0	823.0	533.0	345.3	93.9	25.5
500	1942.0	1451.2	1255.0	1084.0	810.0	605.6	252.7	105.5	1268.8	1026.0	829.0	542.0	353.9	98.7	27.5
505	1920.0	1440.0	1247.0	1080.0	810.0	607.6	256.4	108.2	1260.2	1021.0	827.0	543.0	356.3	100.8	28.5
510	1882.0	1416.8	1229.0	1067.0	803.0	604.4	257.8	110.0	1240.9	1008.0	818.0	539.0	355.7	101.9	29.2
515	1833.0	1384.9	1204.0	1046.0	791.0	597.3	257.6	111.1	1214.0	988.0	804.0	533.0	352.7	102.5	29.8
520	1833.0	1390.0	1210.0	1054.0	799.0	606.1	264.3	115.2	1219.5	995.0	811.0	540.0	359.1	105.7	31.1
525	1852.0	1409.5	1230.0	1073.0	816.0	621.3	273.9	120.7	1237.6	1012.0	827.0	553.0	369.3	110.2	32.9
530	1842.0	1406.9	1230.0	1075.0	821.0	626.9	279.4	124.5	1236.4	1013.0	830.0	557.0	373.9	113.1	34.2
535	1818.0	1393.6	1220.0	1068.0	819.0	627.7	282.8	127.4	1225.6	1006.0	826.0	557.0	375.5	115.1	35.3
540	1783.0	1371.7	1203.0	1055.0	812.0	624.5	284.4	129.5	1207.3	993.0	817.0	554.0	374.8	116.4	36.1
545	1754.0	1354.2	1190.0	1046.0	807.0	623.2	286.8	132.0	1192.8	984.0	811.0	552.0	375.2	118.0	37.1
550	1725.0	1336.6	1177.0	1036.0	802.0	621.7	289.2	134.5	1178.2	974.0	805.0	550.0	375.4	119.6	38.1
555	1720.0	1335.7	1177.0	1037.0	806.0	625.5	293.0	137.2	1178.3	975.0	807.0	553.0	378.8	121.8	39.2
560	1695.0	1319.2	1164.0	1027.0	799.0	622.0	293.3	138.3	1164.7	965.0	800.0	550.0	377.8	122.6	39.8
565	1705.0	1330.0	1175.0	1037.0	809.0	631.3	299.6	142.2	1175.0	975.0	810.0	558.0	384.6	125.9	41.2
570	1712.0	1338.4	1183.0	1046.0	818.0	639.5	305.6	146.0	1183.3	984.0	818.0	565.0	390.7	129.0	42.6
575	1719.0	1346.9	1192.0	1055.0	827.0	647.8	311.6	149.9	1191.6	992.0	826.0	573.0	396.9	132.2	44.0
580	1715.0	1346.7	1193.0	1057.0	830.0	652.0	315.7	152.8	1192.3	994.0	829.0	576.0	400.6	134.6	45.2
585	1712.0	1347.3	1195.0	1060.0	834.0	656.6	320.0	156.0	1193.6	997.0	832.0	580.0	404.5	137.1	46.5

Table 5 (Continued)

Air Mass / Wave Length, nm	0	$a = 0.66$			$\beta = 0.085$				$a = 0.66$				$\beta = 0.170$		
		1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
590	1700.0	1340.7	1191.0	1057.0	834.0	657.7	322.6	158.3	1188.6	994.0	831.0	581.0	406.3	138.9	47.5
595	1682.0	1329.4	1182.0	1051.0	830.0	656.4	324.1	160.0	1179.4	988.0	827.0	580.0	406.6	140.2	48.3
600	1666.0	1319.6	1174.0	1045.0	828.0	655.8	325.9	162.0	1171.5	982.0	824.0	579.0	407.3	141.6	49.2
605	1647.0	1311.0	1170.0	1044.0	831.0	661.3	333.6	168.2	1164.5	979.0	824.0	582.0	411.8	145.6	51.5
610	1635.0	1307.9	1170.0	1046.0	837.0	669.6	342.8	175.5	1162.6	980.0	827.0	588.0	418.0	150.3	54.0
620	1602.0	1294.2	1163.0	1046.0	845.0	682.4	359.9	189.7	1151.9	977.0	828.0	596.0	428.2	159.2	59.2
630	1570.0	1280.9	1157.0	1045.0	853.0	695.6	377.8	205.2	1141.4	973.0	830.0	603.0	438.6	168.5	64.8
640	1544.0	1272.1	1155.0	1048.0	863.0	711.4	397.9	222.5	1134.9	973.0	834.0	613.0	450.7	179.0	71.1
650	1511.0	1257.1	1147.0	1046.0	870.0	723.9	416.9	240.1	1122.8	968.0	834.0	620.0	460.8	189.1	77.6
660	1486.0	1244.2	1138.0	1042.0	872.0	730.2	428.6	251.6	1112.5	963.0	833.0	624.0	466.9	195.9	82.2
670	1456.0	1226.8	1126.0	1034.0	871.0	733.8	438.9	262.5	1098.2	954.0	828.0	625.0	471.2	202.2	86.8
680	1427.0	1209.9	1114.0	1026.0	870.0	737.4	449.5	273.9	1084.3	945.0	824.0	626.0	475.6	208.6	91.5
690	1402.0	1196.2	1105.0	1021.0	871.0	742.9	461.3	286.5	1073.1	939.0	821.0	629.0	481.1	215.7	96.7
700	1369	1175.2	1088.9	1008.9	866.1	743.5	470.4	297.6	1055.5	926.8	313.7	627.4	483.7	221.7	101.6
710	1344	1157.4	1074.0	996.7	858.3	739.1	472.0	301.4	1040.4	915.4	805.5	623.5	482.7	223.9	103.9
712	1338	1150.6	1067.5	990.6	853.0	734.6	469.3	300.0	1034.5	910.2	800.9	620.1	480.2	223.0	103.6
715	1329	1112.9	1026.7	948.2	810.1	693.2	436.3	275.6	1001.0	875.8	767.0	589.5	453.7	207.7	95.5
717.5	1321.5	925.1	820.0	732.2	591.3	482.6	271.1	156.5	832.3	699.7	592.6	430.5	316.0	129.3	54.3
720	1314	874.0	766.0	677.5	538.6	433.8	236.2	133.0	786.4	653.8	548.5	392.4	284.3	112.8	46.3
722.5	1308	1032.4	940.5	859.5	721.9	609.0	371.0	228.7	929.1	803.0	696.1	526.1	399.5	177.4	79.7
725	1302	931.5	830.2	744.9	606.7	498.8	285.7	167.7	838.6	709.1	603.7	442.6	327.6	136.9	58.6
727.5	1296	939.2	839.6	755.4	618.0	510.2	295.2	174.7	845.7	717.4	612.5	451.3	335.5	141.7	61.3
730	1290	940.0	841.6	758.2	621.8	514.3	299.2	178.0	846.7	719.4	615.0	454.3	338.5	143.9	62.5
732.5	1282.5	1015.3	926.3	847.8	714.2	604.3	371.5	231.0	914.7	792.0	688.0	522.1	398.0	178.9	81.4
735	1275	1066.5	985.3	911.5	781.7	671.7	428.5	274.7	961.0	842.8	740.1	572.0	442.9	206.8	97.0
737.5	1267.5	1061.2	980.8	907.7	779.2	670.1	428.7	275.6	956.5	839.3	737.4	570.5	442.2	207.2	97.5
740	1260	1063.3	984.7	912.9	786.0	677.8	436.6	282.3	958.6	842.9	741.9	575.9	447.7	211.2	100.0
742.5	1253.7	1059.9	982.1	911.0	785.2	677.7	437.7	283.7	955.7	844.0	740.8	575.8	448.1	212.2	100.9
745	1247.5	1077.1	1003.1	934.4	811.2	704.6	462.2	303.5	971.4	859.1	760.0	595.1	466.1	224.3	108.0
747.5	1241.2	1081.3	1009.2	941.9	820.5	714.7	472.4	312.3	975.4	864.7	766.5	602.4	473.4	229.7	111.5

Table 5 (Continued)

Wave Length, nm \ Air Mass	0	$\alpha = 0.66$			$\beta = 0.085$				$\alpha = 0.66$				$\beta = 0.170$		
		1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
760	1211.0	1058.8	990.0	925.7	809.4	707.7	473.0	316.1	956.2	849.7	755.0	596.2	470.8	231.8	114.1
762.1	1205.5	794.0	687.8	600.1	461.6	357.0	163.6	69.1	717.2	590.5	489.7	340.2	237.7	80.3	25.0
765	1198.0	1049.0	981.6	918.5	804.3	704.3	472.9	317.5	947.8	843.0	749.8	593.2	469.3	232.4	115.0
785	1146.5	1009.9	947.8	889.5	783.5	690.1	471.6	322.3	913.9	816.0	728.6	580.8	463.0	234.5	118.8
790	1134.0	984.3	921.2	862.5	757.0	664.9	451.7	307.5	891.3	793.7	707.2	562.0	446.9	225.4	113.9
795	1121.5	971.9	909.5	851.7	747.8	657.2	447.5	305.4	880.4	784.1	698.9	555.8	442.5	223.9	113.6
800	1109.0	937.0	872.2	813.3	709.0	619.6	416.5	281.6	849.1	752.4	667.9	527.6	417.8	209.0	105.2
805	1097.0	949.0	888.4	832.3	731.6	643.8	440.4	302.1	860.4	766.9	684.0	545.1	434.9	221.6	113.3
810	1085.0	918.4	855.8	798.7	697.7	610.8	412.9	280.8	832.9	739.1	656.9	520.4	413.2	208.4	105.7
815	1072.5	765.0	686.1	620.0	513.3	429.5	260.5	162.5	694.1	592.9	510.4	383.3	291.0	131.8	61.4
820	1060.0	804.9	732.2	669.9	566.0	482.0	305.1	197.0	730.5	633.2	551.8	423.2	327.1	154.8	74.8
825	1048.0	783.4	710.4	648.2	545.3	462.7	290.6	186.6	711.4	614.7	534.4	408.2	314.5	147.9	71.1
830	1036.0	794.6	724.9	664.8	564.2	482.5	308.8	201.4	721.8	627.6	548.6	422.9	328.5	157.6	77.1
835	1024.5	851.2	790.9	736.6	641.7	561.0	378.9	258.2	773.5	685.0	608.2	481.4	382.4	193.7	99.0
840	1013.0	881.3	827.5	777.7	687.9	609.2	424.7	297.0	801.2	717.3	642.7	516.8	416.1	218.0	114.5
845	1001.5	881.0	829.5	781.4	694.1	616.9	434.1	306.0	801.1	719.4	646.2	521.9	421.9	223.2	118.4
850	990.0	884.1	835.5	789.6	705.1	629.7	448.5	319.5	804.3	725.0	653.5	530.9	431.3	231.3	124.0
890	908.0	816.8	774.6	734.7	660.9	594.5	432.7	314.9	745.1	675.0	611.5	501.8	411.8	227.5	125.7
895	899.5	738.5	686.3	639.9	559.5	491.4	337.8	235.0	674.0	598.4	533.0	425.3	340.9	178.1	94.2
902	888.8	633.7	570.7	518.3	433.6	367.0	231.0	149.8	578.8	498.2	432.5	330.5	255.5	122.6	60.6
907	883.3	619.7	556.2	503.6	419.3	353.5	220.5	142.0	566.0	485.5	420.2	319.5	246.1	116.9	57.4
912	877.8	599.5	534.9	482.0	398.0	333.3	204.5	130.1	547.7	467.1	402.3	303.5	232.2	108.6	52.7
916	873.4	558.9	491.5	437.5	354.0	291.4	171.6	105.6	510.8	429.4	365.4	270.2	203.3	91.4	42.9
920	869.0	655.2	597.9	549.0	468.1	402.7	263.9	177.0	598.9	522.5	458.8	357.6	281.2	140.7	72.1
924	864.6	640.4	582.1	532.9	451.9	387.1	251.0	167.0	585.6	509.0	445.5	345.5	270.6	134.1	68.2
928	860.2	535.6	468.2	414.8	333.0	272.3	158.0	96.2	489.8	409.5	346.9	254.7	190.5	84.6	39.4
935	852.5	255.9	190.0	146.6	93.4	62.8	22.8	9.5	234.2	166.3	122.7	71.5	44.1	12.2	3.9
943	844.0	374.3	303.3	252.1	181.9	135.9	63.8	32.6	342.6	265.7	211.3	139.5	95.5	34.3	13.5
950	837.0	349.5	279.5	229.7	162.7	119.7	54.0	26.9	320.0	244.9	192.6	124.9	84.2	29.1	11.1
954	830.2	334.0	264.9	216.2	151.3	110.3	48.6	23.7	305.9	232.2	181.4	116.3	77.7	26.3	9.9

Table 5 (Continued)

Wave Length, nm \ Air Mass	0	$a = 0.66$		$\beta = 0.085$					$a = 0.66$		β 0.170				
		1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
957	825.1	427.7	359.1	307.6	233.4	182.1	94.5	52.7	391.9	315.0	258.2	179.5	128.3	51.2	22.0
965	811.5	514.5	452.1	402.3	325.7	268.4	158.9	98.5	471.6	396.8	338.1	250.9	189.5	86.4	41.3
975	794.0	583.9	530.6	485.8	412.5	354.0	231.2	155.2	535.5	466.1	408.7	318.2	250.4	126.2	65.3
981	783.2	635.3	590.3	550.7	482.5	425.2	296.2	209.4	582.9	518.8	463.5	372.7	301.3	162.1	88.5
984	777.8	664.3	624.5	588.4	524.2	468.5	337.7	245.4	609.6	549.0	495.5	405.1	332.2	185.1	103.9
990	767.0	689.7	656.0	624.2	565.5	512.7	382.6	285.9	633.2	577.0	526.0	437.6	364.2	210.3	121.6
995	757.0	688.6	656.8	626.4	569.8	518.3	390.1	293.6	632.3	577.9	528.1	441.1	368.5	214.7	125.1
1018	719.2	616.8	571.2	529.0	453.7	389.1	245.4	154.8	567.1	504.0	447.2	352.6	278.0	136.3	66.8
1082	620.0	511.0	464.0	421.2	347.2	286.2	160.2	89.7	471.4	411.0	358.4	272.5	207.2	91.1	40.0
1094	602.0	475.1	439.9	409.5	358.1	315.5	220.9	157.8	438.6	390.1	348.9	281.6	229.0	126.1	70.8
1098	596.0	502.1	461.0	422.9	356.3	300.1	179.4	107.3	463.5	409.0	360.5	280.4	218.0	102.6	48.2
1101	591.8	503.1	473.0	446.5	399.0	357.9	261.1	192.2	464.6	420.0	380.7	314.2	260.2	149.5	86.6
1128	560.5	134.7	96.0	71.0	42.6	27.4	8.9	3.5	124.5	85.0	60.7	33.7	20.0	5.2	1.6
1131	557.0	151.7	111.0	84.3	52.6	34.9	12.4	5.1	140.3	99.0	72.1	41.6	25.5	7.2	2.3
1137	550.1	142.7	103.0	77.7	47.8	31.3	10.8	4.4	132.0	92.0	66.5	37.8	22.9	6.2	2.0
1144	542.0	190.7	148.0	117.8	79.9	56.8	23.8	11.3	176.4	132.0	100.9	63.3	41.6	13.8	5.2
1147	538.5	174.1	132.0	103.9	68.5	47.7	18.9	8.6	161.0	118.0	88.9	54.3	34.9	11.0	3.9
1178	507.0	398.5	353.0	313.3	246.3	193.6	94.0	45.7	369.3	315.0	268.9	195.9	142.7	55.1	21.3
1189	496.0	401.5	361.0	325.0	263.1	212.9	112.9	59.9	372.2	322.3	279.3	209.6	157.2	66.4	28.1
1193	492.0	423.2	400.0	378.9	341.4	308.6	230.4	173.5	392.4	357.0	325.7	272.1	228.1	135.7	81.4
1222	464.3	391.2	359.0	329.6	277.7	234.0	140.0	83.7	363.2	321.0	284.0	222.2	173.8	83.1	39.8
1236	451.2	390.5	363.0	337.9	292.4	253.0	164.0	106.3	362.6	325.0	291.5	234.3	188.3	97.7	50.7
1264	426.5	328.9	302.0	279.4	240.9	209.1	139.4	93.7	305.8	271.0	241.6	193.6	156.3	83.7	45.2
1276	416.7	342.4	321.0	300.7	266.8	238.0	171.8	125.5	318.5	287.0	260.2	214.8	178.3	103.6	60.9
1288	406.8	347.1	321.0	296.1	252.6	215.5	133.9	83.1	323.0	288.0	256.4	203.6	161.7	80.9	40.5
1314	386.1	298.1	262.0	230.2	177.8	137.3	63.2	29.1	277.7	236.0	199.8	143.7	103.3	38.5	14.3
1335	369.7	190.5	161.0	138.7	106.9	84.8	46.6	27.6	177.6	145.0	120.5	86.6	64.0	28.5	13.7
1384	343.7	5.7	2.0	1.0	0.3	0.1	0.0	0.0	5.3	2.0	0.9	0.2	0.1	0.0	0.0
1432	321.0	44.6	28.0	18.9	9.6	5.4	1.3	0.4	41.7	25.0	16.5	7.9	4.1	0.8	0.2
1457	308.6	85.4	63.0	48.2	30.6	20.6	7.7	3.3	79.9	57.0	42.2	25.1	15.8	4.8	1.7

Table 5 (Continued)

Air Mass / Wave Length, nm		$\alpha = 0.66$ $\beta = 0.085$							$\alpha = 0.66$ $\beta = 0.170$						
	0	1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
1472	301.4	77.3	56.0	42.3	26.2	17.3	6.1	2.6	72.4	51.0	37.1	21.5	13.3	3.9	1.3
1542	270.4	239.3	225.0	211.7	187.4	165.8	114.9	79.6	224.5	205.0	186.4	154.7	128.4	73.5	42.1
1572	257.3	222.6	212.0	201.4	183.0	168.0	130.2	101.9	209.0	192.0	177.6	152.0	130.6	83.8	54.3
1599	245.4	216.0	206.0	197.0	181.0	166.7	131.5	104.5	203.0	188.0	174.0	150.0	129.9	85.0	56.0
1608	241.5	208.5	198.0	189.0	172.0	157.4	122.1	95.7	195.9	180.0	167.0	143.0	122.7	79.1	51.4
1626	233.6	206.7	198.0	189.0	174.0	160.7	127.5	101.9	194.3	180.0	167.0	145.0	125.6	82.8	55.0
1644	225.6	197.9	189.0	180.0	166.0	152.4	120.1	95.5	186.4	172.0	160.0	138.0	119.3	78.3	51.8
1650	223.0	195.7	187.0	178.0	164.0	150.9	119.1	94.7	184.1	170.0	158.0	136.0	118.2	77.6	51.4
1676	212.1	181.9	168.0	156.0	134.0	114.8	72.4	45.7	171.2	154.0	138.0	112.0	90.1	47.5	25.0
1732	187.9	161.5	150.0	139.0	119.0	102.5	65.1	41.3	152.2	137.0	123.0	100.0	80.9	43.0	22.9
1782	166.6	136.7	124.0	112.0	92.0	75.6	41.8	23.1	129.0	114.0	100.0	77.0	59.9	27.9	12.9
1862	138.2	4.0	2.0	1.0	0.3	0.1	0.0	0.0	3.8	2.0	1.0	1.0	0.1	0.0	0.0
1955	112.9	42.7	34.0	28.0	20.0	14.5	6.8	3.6	40.5	31.0	25.0	17.0	11.6	4.6	2.1
2008	102.0	69.4	62.0	55.0	44.0	35.8	17.7	6.4	65.7	57.0	49.0	38.0	28.9	12.2	3.8
2014	101.2	74.7	68.0	62.0	53.0	45.5	28.8	17.8	70.8	63.0	56.0	45.0	36.7	19.8	10.4
2057	95.6	69.5	63.0	58.0	49.0	41.3	25.3	14.8	66.0	58.0	52.0	42.0	33.4	17.5	8.7
2124	87.4	70.0	63.0	56.0	45.0	35.9	18.4	9.5	66.4	58.0	51.0	38.0	29.2	12.8	5.6
2156	83.8	66.0	59.0	52.0	41.0	32.3	15.8	7.7	62.7	54.0	47.0	35.0	26.3	11.0	4.6
2201	78.9	66.1	62.0	59.0	54.0	49.1	38.0	29.7	62.8	58.0	54.0	46.0	40.1	26.7	17.9
2266	72.4	61.6	58.0	56.0	51.0	46.8	36.8	29.3	58.6	54.0	50.0	44.0	38.4	26.0	17.9
2320	67.6	57.2	54.0	52.0	47.0	43.2	33.8	26.8	54.4	50.0	47.0	41.0	35.5	24.0	16.5
2338	66.3	54.7	51.0	49.0	44.0	39.9	30.4	23.4	52.1	48.0	44.0	38.0	32.8	21.6	14.4
2356	65.1	52.0	49.0	46.0	41.0	36.3	26.5	19.6	49.5	45.0	41.0	35.0	29.9	18.9	12.1
2388	62.8	36.0	31.0	28.0	23.0	18.7	11.7	7.8	34.3	29.0	25.0	20.0	15.5	8.3	4.8
2415	61.0	32.5	28.0	24.0	19.0	15.8	9.4	6.0	31.0	26.0	22.0	17.0	13.0	6.7	3.7
2453	58.3	29.6	25.0	22.0	17.0	13.7	7.9	5.0	28.0	23.0	20.0	15.0	11.3	5.7	3.1
2494	55.4	20.3	16.0	13.0	9.0	6.8	3.2	1.7	19.4	15.0	12.0	8.0	5.6	2.3	1.1
2537	52.4	4.6	3.0	2.0	1.0	0.4	0.1	0.0	4.4	2.0	1.0	1.0	0.3	0.1	0.0
2900	35.0	2.9	2.0	1.0	0.3	0.2	0.0	0.0	2.8	2.0	1.0	0.3	0.2	0.0	0.0
2941	33.4	6.0	4.0	3.0	2.0	1.0	0.3	0.1	5.7	4.0	3.0	1.0	0.8	0.2	0.1

Table 5 (Continued)

Wave Length, nm \ Air Mass		$a = 0.66$	$\beta = 0.085$						$a = 0.66$	$\beta = 0.170$					
	0	1	1.5	2	3	4	7	10	1	1.5	2	3	4	7	10
2954	32.8	6.0	4.0	3.0	2.0	0.9	0.3	0.1	5.5	4.0	2.0	1.0	0.8	0.2	0.1
2973	32.1	8.7	6.0	5.0	3.0	2.2	0.9	0.4	8.4	6.0	5.0	3.0	1.8	0.6	0.3
3005	30.8	8.0	6.0	4.0	3.0	1.8	0.7	0.3	7.5	5.0	4.0	2.0	1.6	0.5	0.2
3045	28.8	4.7	3.0	2.0	1.0	0.7	0.2	0.1	4.5	3.0	2.0	1.0	0.6	0.1	0.0
3056	28.2	4.9	3.0	2.0	1.0	0.8	0.2	0.1	4.7	3.0	2.0	1.0	0.7	0.2	0.1
3097	26.2	3.2	2.0	1.0	1.0	0.4	0.1	0.0	3.1	2.0	1.0	1.0	0.3	0.1	0.0
3132	24.9	6.8	5.0	4.0	3.0	1.7	0.7	0.3	6.5	5.0	4.0	2.0	1.5	0.5	0.2
3156	24.1	18.7	17.0	16.0	14.0	12.6	8.9	0.3	17.9	16.0	15.0	13.0	10.7	6.7	4.2
3204	22.5	2.1	1.2	1.0	0.3	0.2	0.0	0.0	2.0	1.2	1.0	0.4	0.2	0.0	0.0
3214	22.1	3.4	2.2	2.0	1.0	0.5	0.1	0.0	3.3	2.0	1.0	1.0	0.4	0.1	0.0
3245	21.1	3.9	3.0	2.0	1.0	0.7	0.2	0.1	3.8	3.0	2.0	1.0	0.6	0.2	0.1
3260	20.6	3.7	2.2	2.0	1.0	0.6	0.2	0.1	3.5	2.3	2.0	1.0	0.5	0.1	0.0
3285	19.7	14.2	13.0	12.0	10.0	8.5	5.1	2.8	13.7	12.0	11.0	9.0	7.3	3.9	1.9
3317	18.8	12.9	12.0	10.0	8.0	6.9	3.5	1.3	12.4	11.0	10.0	8.0	5.9	2.7	0.9
3344	18.1	4.2	3.0	2.0	1.0	0.9	0.3	0.1	4.1	3.0	2.0	1.0	0.8	0.2	0.1
3403	16.5	12.3	11.0	10.0	9.0	7.8	5.1	3.2	11.9	11.0	10.0	8.0	6.7	3.9	2.2
3450	15.6	12.5	12.0	11.0	10.0	8.9	6.7	5.0	12.0	12.0	10.0	9.0	7.7	5.1	3.5
3507	14.5	12.5	12.0	11.0	11.0	9.9	8.1	6.7	12.1	11.2	11.0	9.0	8.5	6.2	4.6
3538	14.2	11.8	11.1	11.0	10.0	8.8	6.9	5.5	11.3	11.0	10.0	9.0	7.6	5.3	3.8
3573	13.8	10.9	10.0	9.0	7.0	5.4	2.6	1.3	10.5	9.0	8.0	6.0	4.6	2.0	0.9
3633	13.1	10.8	10.0	10.0	9.0	8.3	6.7	5.5	10.4	10.0	9.0	8.0	7.1	5.2	3.8
3673	12.6	9.1	8.0	8.0	7.0	6.1	4.6	3.5	8.8	8.0	7.0	6.0	5.3	3.5	2.5
3696	12.3	10.4	10.0	10.0	9.0	8.2	6.7	5.6	10.0	9.3	9.0	8.0	7.1	5.2	3.9
3712	12.2	10.9	10.3	10.0	10.0	9.0	7.6	6.5	10.5	10.0	9.0	9.0	7.8	5.9	4.6
3765	11.5	9.5	9.0	9.0	8.0	7.2	5.9	4.8	9.1	8.3	8.0	7.0	6.3	4.6	3.4
3812	11.0	8.9	8.2	8.0	7.0	6.7	5.4	4.4	8.6	8.0	7.0	7.0	5.8	4.2	3.1
3888	10.4	8.1	8.0	7.0	6.0	5.6	4.0	2.9	7.8	7.1	7.0	6.0	4.8	3.1	2.0
3923	10.1	8.0	7.0	7.0	6.0	5.6	4.2	3.1	7.7	7.0	7.0	6.0	4.9	3.3	2.2
3948	9.9	7.8	7.0	7.0	6.0	5.5	4.0	3.0	7.6	7.0	6.0	6.0	4.8	3.2	2.1
4045	9.1	6.7	6.0	6.0	5.0	4.1	2.6	1.5	6.5	6.0	5.0	4.0	3.6	2.0	1.1
Total Irradiance W m^{-2}	1353	934	814.9	726.9	587.4	481.9	281.7	174	829	697.8	592.4	435.8	325	147.3	71.6

III. DISCUSSION

The spectral composition of solar radiation varies with atmospheric transparency and different solar zenith angles. Under natural conditions molecular and aerosol scattering always occur together with molecular absorption. In computing the transmission in narrow spectral regions,, the starting point is the theory of a model representation of the spectrum. This results in analytical expressions for the transmission functions which are rather complicated and difficult to apply to real atmospheres. Therefore, some authors have tried either to simplify the results of the theory of model spectra or derive empirical relationships. Both require experimental data with adequate resolution. In the present computations empirical relationships are used to derive spectral transmission data.

A. Spectral Water Vapor Transmission of the Bands Between 0.7μm and 1.0μm

Table 3 lists the principal absorption bands produced by water vapor in the infrared portion of the spectrum. At wavelengths shorter than 1μm there exist three water vapor bands:

1. "*a*," 0.7–0.74μm Centroid 0.72μm
2. "0.8μm," 0.790–0.8398μm Centroid 0.81μm
3. "$\rho\sigma\tau$," 0.8695–1.0309μm Centroid 0.94μm

The absorption due to 0.72μm and 0.81μm bands is low as shown in Figure 4 and therefore the determination of spectral transmission values requires a high concentration of water vapor in the optical path. However, the contribution to the absorption of solar radiation from these bands cannot be neglected because of the large solar irradiance in this region (22).

For wavelengths longer than 1μm, spectral water vapor transmission values applicable to real atmospheres can be obtained from the data published by Gates and Harrop (18), Wyatt et al. (20), Moskalenko (23), and McClatchey et al. (24). For wavelengths shorter than 1μm, there is a scarcity of experimental data that can be applied to real atmospheres. Spectral water vapor transmission values for 0.72μm, 0.81μm and 0.94μm bands have been reported by Moskalenko (23), Koepke and Quenzel (19), and Burch and Gryvnak (25). Spectral parameters reported by Moskalenko were obtained from laboratory measurements of the absolute spectral transmission of water vapor for large absorber thickness up to 12 g cm^{-2}. No temperature dependence was reported. The data reported by Burch and Gryvnak were based on measurements made at a temperature of 443°K to get water vapor content up to 3 g cm^{-2}. Koepke and Quenzel data were based on ground based measurements of direct solar radiation with a high resolution grating spectrometer. The optical paths in these observations were sufficiently long (air mass 7.7 and 12.6) to get remarkable absorption in the bands below 1 μm. The water vapor content in the slant path of the solar radiation, determined from radiosonde ascents was between 4.44 g cm^{-2} and 7.29 g cm^{-2}.

In reference 19, Koepke and Quenzel made a comparative study of their data with that of Moskalenko and Burch and Gryvnak. Koepke and Quenzel observed good agreement in the spectral behavior of their data and that of Burch and Gryvnak; but significant differences were observed with that of Moskalenko.

Molecular absorption coefficient is a function of not only the amount of absorbing material, but also the local temperature and pressure of the absorbing gas. Spectral water vapor data obtained at high temperatures as in Burch and Gryvnak are not applicable to real atmospheres without corrections for temperature effects. The effects of temperature on water vapor transmission for 0.72 μm, 0.81 and 0.94 μm bands are not known.

Therefore, in the present computations, Koepke and Quenzel spectral parameters reported in reference 19 are used in computing the spectral transmission for the bands below 1 μm.

B. Scattering

The scattering produced by a scattering center (molecule or aerosol particle) is a function of both the size of the particle and its index of refraction. The scattering molecules, primarily oxygen and nitrogen, are so small relative to most aerosol particles that they should be discussed separately. For molecules the scattering is Rayleigh scattering, which is essentially isotropic and affects blue light. This scattering accounts for the blue color of the daylight sky. The much larger aerosol particles produce Mie scattering, which is sometimes called small angle scattering.

For an aerosol particle the relative index of refraction, the ratio of the index of the particle to that of the medium surrounding it, determines the amount of scattering. For a particle of a given size and shape, the size of the particle, and particularly its surface area, in relation to the wavelength of the incident flux, affects the amount of scattering and determines the geometrical distribution of the scattered flux. Most aerosol particles are considered to be spherical for purposes of theoretical treatment, and a parameter A* is used to express the relative size of the particle. A is defined as the ratio of the circumference of the particle to the wavelength of the incident flux in reference 26.

According to reference 26, the scattered flux is always axially symmetrical about the incident ray. There is always some fraction of the incident flux scattered into all possible directions from the center of the particle, and in this sense the scattering is diffuse, but not istropically diffuse. If the amount of scattered light is plotted in polar coordinates about the scattering center, the surface joining the points will form a dumbell shaped solid, with forward and backward lobes. If the figure is bisected by a plane through the center normal to the incident ray, scattering on the side of incidence is called backscattering, and that on the opposite side forward scattering. The relative sizes of the forward and backward lobes of the solid, is a function of the parameter A, as shown in Figures 12 a, b and c (27).

When A is less than 0.1, the flux is scattered symmetrically about the bisecting plane, with maxima in the forward and backward directions, and a minimum in the bisecting plane, as shown in Figure 12 a. The amplitude of the scattered flux in the forward and backward directions along the incident ray is about triple that of the minimum in directions normal to that ray. When A is about 0.25, the amplitude of the maximum in the forward direction is about double that in the backward direction, which in turn is about triple that normal to the incident ray, as shown in Figure 12 b. When A increases to 1.0, scattering is predominately forward scattering, with a ratio

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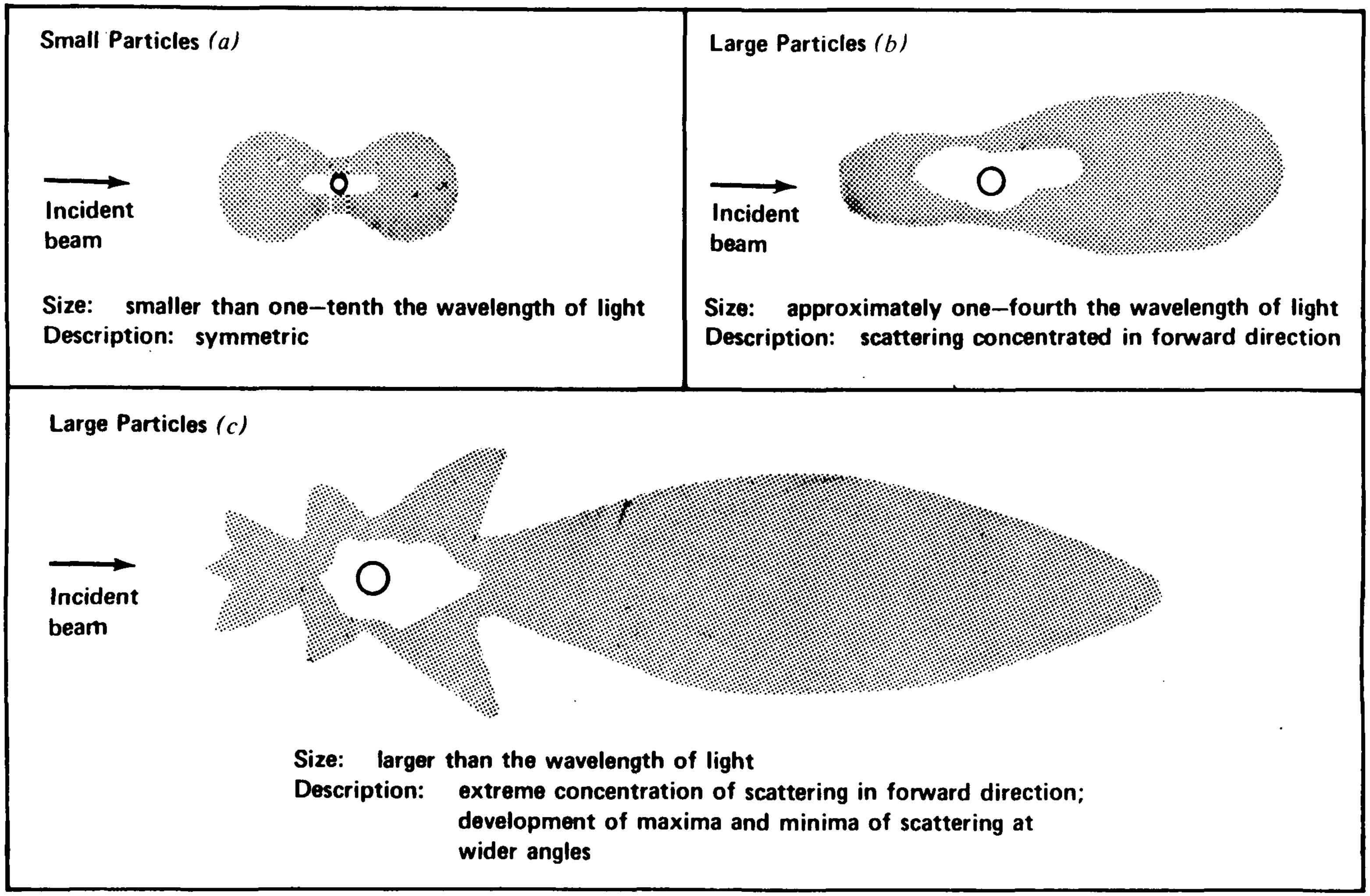
*A is used here instead of the α of Ref. 16 to avoid confusion with the Angstrom α used in the tables as an aerosol parameter.



Size: smaller than one–tenth the wavelength of light
Description: symmetric

Size: approximately one–fourth the wavelength of light
Description: scattering concentrated in forward direction

Size: larger than the wavelength of light
Description: extreme concentration of scattering in forward direction; development of maxima and minima of scattering at wider angles

Figure 12. Angular Patterns of Scattered Intensity From Particles of Three Sizes: (a) Small Particles, (b) Large Particles, (c) Larger Particles

ratio of the forward to backward amplitudes of about five, and side lobes develop, which peak at angles of about 20° and 57° and 135° to the incident ray, as shown in Figure 12 c.

The direct radiance from the sun is significantly reduced by atmospheric scattering, and the forward scattered flux is spread over the entire sky. At least two models have been used to compute the spectrally total sky radiance as a function of the angle from the sun and atmospheric parameters. Bossy and Pastiels (28) made a correction to the empirical model proposed by Linke and Umlitz, to derive the equation

$$L_s(x) = K\ 10^{-\gamma x} \tag{9}$$

where K is a constant, γ has values in the range of 0.15 to 0.60 for different atmospheric conditions that are reasonable for solar irradiance measurements, and x is the angular distance from the sun, in degrees. Grassl (29) computed the circumsolar flux as a fraction of the incoming flux at the top of the atmosphere as a function of projected solid angle, from the exact single scattering function of Diermendjian for both continental and maritime aerosols, with results that agree qualitatively with those of Bossey and Pastiels. The conclusion is that in general the spectrally total sky radiance decreases exponentially with distance from the sun, for a cloudless sky. When clouds are present, the sky radiance will vary over the sky, with the type, size and distribution of the clouds.

There is need for accurate data on the measured spectrally total radiance of the sky as a function of distance from the sun, air mass and atmospheric composition.

The energy distribution in the scattered sky radiation depends on the angular distance from the sun, the state of the atmosphere, the sun's elevation in the sky and the degree of cloudiness. Computed values of the energy distribution in the scattered radiation spectrum for various model atmospheres have been reported by Dave et al. (30). The ratio of the diffuse to direct solar radiation is very high in the UV and drops rapidly in the visible and IR. Representative values of this ratio based on Dave Atmospheric model C1 (O_3 = 3.18mm, H_2O = 29.25mm, particles 19.7×10^6 in one sq. cm column) for air mass two are: 151% at 350nm, 54% at 435nm, 46% at 455nm, 28% at 555nm, 22% at 655nm, 18% at 750nm, 15% at 910nm and 13% at 1000nm.

A flat–plate receiver, either photovoltaic or thermal, will receive flux from the entire hemisphere above it, which usually includes most of the sky, hence most of the forward scattered solar flux will be received. The irradiance for flux from a given direction is reduced by the cosine of the angle of incidence, and the solar absorptance of nearly all materials decreases with an increase in the angle of incidence, particularly at angles of incidence greater than 50 to 60 degrees. The net effect is that the efficiency of the collector is lower for scattered flux than for direct flux. Even so, under ideal conditions, half or more of the total scattered flux may be effective. On the other hand, for a collector with a concentration ratio of 1000, flux is received from only 0.1% of the sky, and most of the scattered flux is lost.

Even in the case of a flat-plate collector, while the inclusion of the scattered flux will increase the fraction of the extraterrestrial irradiance received by the collector, it will have only a small effect on the relative spectral distribution, particularly when compared to the changes in spectral distribution produced by changes in atmospheric composition and air mass which are also rather small.

The data reported in this Technical Memorandum are for direct solar irradiance, and do not include scattered flux.

IV. COMPUTATION OF SOLAR ABSORPTANCE, REFLECTANCE AND TRANSMITTANCE

The spectral irradiances are listed in Tables 4 and 5 in units of watts per square meter and micrometer of spectral wavelength interval. The wavelengths in the first column are in units of nanometers to give values in convenient whole numbers. (Note that different length units are used deliberately for area and wavelength in order to avoid the confusingly misleading appearance of a volume unit when the unit dimensions of spectral irradiance are given in the standard SI form of $W \cdot m^{-3}$, which is not watts per cubic meter, but rather watts per square meter per meter of wavelength interval.)

Each spectral irradiance, in units of $W \cdot m^{-2} \cdot \mu m^{-1}$, in Tables 4 and 5 must be multiplied by a wavelength interval in μm to convert the spectral irradiance to irradiance in $W \cdot m^{-2}$. The choice of the size of the interval associated with each wavelength λ in the tables is somewhat arbitrary. In essence, the area under the spectral irradiance curve is being divided into as many areas as there are λ's in the table, by vertical lines, and the spacing between the lines for any one wavelength is equal to the wavelength interval assigned to that wavelength. In order to evaluate the total area under the curve, the areas for adjacent wavelengths must have a common border, with no overlap and no gap.

The spacing between the λ's in column one is not uniform. In regions where the Fraunhofer lines or atmospheric absorption peaks occur, and where the spectral irradiance is changing rapidly with λ, the wavelengths are closely spaced to adequately describe the shape of the curve. In other regions, where the spectral irradiance is changing slowly and there are no peaks or valleys, the points are spaced farther apart to reduce the size of the tables, which are quite voluminous.

In reducing the spectral data for AM 1.5 and 2.0 the boundary between the wavelength intervals assigned to adjacent wavelengths was taken as the average of the two adjacent wavelengths. In Tables 6, 7, 8 and 9 the first column with the heading λ is the wavelength, in nm, for the spectral irradiance E_λ, in $W \cdot m^{-2} \cdot \mu m^{-1}$, in the fourth column. The second column headed λ_m is the average, in nm, of the λ in column one and the next larger λ, and is the upper boundary of the wavelength interval $\Delta\lambda$ in column three, which is in units of nm. The $\Delta\lambda$ for wavelength λ is the difference between the λ_m's for that wavelength and the next smaller wavelength. If λ_1, λ_2 and λ_3 are three successive wavelengths, in nm, then λ_m for λ_2 is $(\lambda_2 + \lambda_3)/2$, and $\Delta\lambda$ is $0.001 \cdot (\lambda_3 - \lambda_1)/2$, in μm.

The value of ΔE, in $W \cdot m^{-2}$, in column five is the product of $\Delta\lambda$ in column three and E_λ in column four. The value of $E(0 - \lambda_m)$ is the cumulative sum of all the ΔE's up to and including that for the λ in column one.

The value for $E(0 - \lambda_m)/E(0 - \infty)$ in column seven is the ratio of $E(0 - \lambda_m)$ in column 6 to the $E(0 - \lambda_m)$ at λ_m = 4071.5nm, the last value in the table, and is expressed as a dimensionless decimal fraction. The value of $E(0 - \lambda_m)$ at 4071.5nm is smaller than the total solar irradiance by a small unknown amount. For the extraterrestrial solar spectrum, the difference is about 0.88%. The differences for the terrestrial solar irradiances is expected to be about the same, but the atmospheric absorptance beyond 4045nm was not computed in this study.

The solar properties (reflectance, absorptance and transmittance) are each the weighted average of the spectral property, in which the solar spectral irradiance is the weighting function. Several different procedures can be used for computing the weighted average. The ideal equation for computing a solar property, X_s, from the measured spectral property, $X(\lambda)$, is

$$X_s = \frac{\int_0^\infty X(\lambda) \cdot E_\lambda(\lambda) \cdot d\lambda}{\int_0^\infty E_\lambda(\lambda) \cdot d\lambda}$$

where $E_\lambda(\lambda)$ is the terrestrial solar spectral irradiance at wavelength λ, and $X(\lambda)$ may be spectral reflectance, $\rho(\lambda)$, spectral absorptance, $\alpha(\lambda)$ or spectral transmittance, $\tau(\lambda)$, each at wavelength λ. Neither $X(\lambda)$ or E_λ are known as algebraic functions, and the integration must be approximated by a summation. The limits of integration are normally between 300 and 4045nm, and in some cases 300 to 2500nm. Less than 1% of extraterrestrial solar irradiance is at wavelengths longer than 4045nm, and less than 3.7% is at wavelengths longer than 2500nm. There is essentially no terrestrial solar irradiance at wavelengths below 300nm.

There are two widely used summation processes. The most accurate procedure is known as the weighted ordinate method. In this method the spectral property, $X(\lambda)$, at each wavelength is multiplied by the solar spectral irradiance, $E_\lambda(\lambda)$, at that wavelength and the wavelength interval, $\Delta\lambda(\lambda)$ for that wavelength, and the products for all wavelengths are summed. The solar spectral irradiance $E_\lambda(\lambda)$ at wavelength λ is multiplied by the wavelength interval, $\Delta\lambda(\lambda)$ for that wavelength, and the products are summed. The ratio of the first sum to the second sum is then the desired solar property, X_s. The equation is

$$X_s = \frac{\sum_{\lambda=300\mathrm{nm}}^{\lambda=4045\mathrm{nm}} X(\lambda) \cdot E_\lambda(\lambda) \cdot \Delta\lambda(\lambda)}{\sum_{\lambda = 300\mathrm{nm}}^{\lambda=4045\mathrm{nm}} E_\lambda(\lambda) \cdot \Delta\lambda(\lambda)}$$

The values for the product $E_\lambda(\lambda) \cdot \Delta\lambda(\lambda)$ are given in Tables 6, 7, 8 and 9 as ΔE, and the sums of all $E_\lambda(\lambda) \cdot \Delta\lambda(\lambda)$'s are given as $E(0 - \lambda_m)$ for $\lambda = 4045$nm. The equation then becomes,

$$X_s = 1/E(0 - \infty) \cdot \sum_{\lambda=300\mathrm{nm}}^{\lambda=4045\mathrm{nm}} X(\lambda) \cdot \Delta E(\lambda),$$

remembering that $E(0 - \lambda_m)$ at $\lambda = 4045$nm has been taken as $E(0 - \infty)$. Solar properties can easily be evaluated by the weighted ordinate method by use of a computer, in which both the spectral property values and spectral irradiance values are entered into the computer memory. The procedure is rather tedious for hand computation, since it involves over 200 multiplications and additions.

An alternative procedure is called the selected ordinate method. In this procedure tha area under the terrestrial solar irradiance curve is divided into N equal areas by vertical lines which represent wavelengths, and the centroid wavelength for each area is computed. The desired property is then computed as 1/N times the sum of the values of the spectral property at each of the N wavelengths. The equation is

$$X_s = 1/N \sum_{i=0}^{i=N} X(\lambda_i).$$

If 100 selected ordinates (wavelengths) are used, the difference between the values computed by the weighted ordinate method and the selected ordinate method will almost never exceed 1%, and will rarely exceed 1/2%, even for spectrally selective materials. If 50 selected ordinates are used, the difference between the values for spectrally non-selective materials will be about the same as for the 100 selected ordinate method, but for spectrally selective materials the difference may exceed 1% of the computed value.

For hand computations, the use of the selected ordinate method instead of the weighted ordinate method will reduce the number of operations from over 200 multiplications and additions to 100 additions. The use of the 50 selected ordinate method will further reduce the operations to 50 additions.

The 100 selected ordinate method is recommended for evaluating solar properties of spectrally selective materials, and the 50 selected ordinate method is recommended for evaluating solar properties of spectrally nonselective materials, if hand computations are used.

The wavelengths for use with the 100 selected ordinate method are given in Table 10, and those for the 50 selected ordinate method are given in Table 11. The wavelengths for the 100 selected ordinate method were taken as the wavelengths at which $E(0 - \lambda_m)/E(0 - \infty)$ had values at intervals of 0.01 from 0.005 to 0.995. These wavelengths were computed by linear interpolation between the values for $E(0 - \lambda_m)/E(0 - \infty)$ and λ_m on each side of the desired value. The wavelengths for the 50 selected ordinate method were taken as the wavelengths at which $E(0 - \lambda_m)/E(0 - \infty)$ had values at intervals of 0.02 from 0.01 to 0.99, and were similarly computed.

The extraterrestrial solar spectrum extends beyond the terrestrial solar spectrum in both the ultraviolet and infrared. Table 4 shows only the extraterrestrial solar irradiance from 290 to 4045 nm.

The Standard Solar Constant and Air Mass Zero Solar Spectral Irradiance Tables (1) give the extraterrestrial solar irradiance from 115nm to 40,000 nm. This latter table was used to compute the wavelengths for the 100 selected ordinate and 50 selected ordinate methods of computing extraterrestrial solar properties, as shown in Tables 10 and 11.

Table 6. Terrestrial Irradiance for Air Mass 1.5 Computed from the Spectral Data in Table 4

AM 1.5		$a = 1.3$			$\beta = 0.02$		$a = 1.3$			$\beta = 0.04$
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ $W\,m^{-2}$ μm^{-1}	ΔE $W\,m^{-2}$	E $(0\text{-}\lambda_m)$ $W\,m^{-2}$	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ $W\,m^{-2}$ μm^{-1}	ΔE $W\,m^{-2}$	E $(0\text{-}\lambda_m)$ $W\,m^{-2}$	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
300	302.5	5	0	0	0	0.00	0	0	0	0.00
305	307.5	5	2.0	0.01	0.01	0.00	2.0	0.01	.01	0.00
310	312.5	5	7.0	.035	.045	0.00	6.0	.03	.04	0.00
315	317.5	5	29.0	.145	.19	0.02	26.0	.13	.17	0.02
320	322.5	5	115.0	.575	.765	0.08	101.0	.505	.675	0.08
325	327.5	5	163.0	.815	1.58	0.17	143.0	.715	1.39	0.16
330	332.5	5	213.0	1.065	2.645	0.29	188.0	.94	2.33	0.27
335	337.5	5	262.0	1.31	3.955	0.44	231.0	1.155	3.485	0.40
340	342.5	5	314.0	1.57	5.525	0.61	278.0	1.39	4.875	0.56
345	347.5	5	334.0	1.67	7.195	0.79	296.0	1.48	6.355	0.73
350	352.5	5	365.0	1.825	9.02	0.99	325.0	1.625	7.98	0.92
355	357.5	5	387.0	1.935	10.955	1.21	345.0	1.725	9.705	1.12
360	362.5	5	409.0	2.045	13.	1.43	365.0	1.825	11.53	1.33
365	367.5	5	453.0	2.265	15.265	1.68	405.0	2.025	13.555	1.57
370	372.5	5	495.0	2.475	17.74	1.95	443.0	2.215	15.77	1.82
375	377.5	5	507.0	2.535	20.275	2.23	455.0	2.275	18.045	2.09
380	382.5	5	513.0	2.565	22.84	2.52	462.0	2.31	20.355	2.35
385	387.5	5	520.0	2.6	25.44	2.80	469.0	2.345	22.7	2.62
390	392.5	5	538.0	2.69	28.13	3.10	486.0	2.43	25.13	2.90
395	397.5	5	603.0	3.015	31.145	3.43	546.0	2.73	27.86	3.22
400	402.5	5	750.0	3.75	34.895	3.84	679.0	3.395	31.255	3.61
405	407.5	5	882.0	4.41	39.305	4.33	801.0	4.005	35.26	4.08
410	412.5	5	961.0	4.805	44.11	4.58	874.0	4.37	39.63	4.58
415	417.5	5	996.0	4.98	49.09	5.41	907.0	4.535	44.165	5.10
420	422.5	5	1003.0	5.015	54.105	5.96	914.0	4.57	48.735	5.63
425	427.5	5	994.0	4.97	59.075	6.51	908.0	4.54	53.275	6.16
430	432.5	5	984.0	4.92	63.995	7.05	900.0	4.5	57.775	6.68
435	437.5	5	1021.0	5.105	69.1	7.61	935.0	4.675	62.45	7.22
440	442.5	5	1137.0	5.685	74.785	8.24	1042.0	5.21	67.66	7.82
445	447.5	5	1234.0	6.17	80.955	8.92	1133.0	5.665	73.325	8.48

Table 6 (Continued)

AM 1.5			$\alpha = 1.3$		$\beta = 0.02$		$\alpha = 1.3$		$\beta = 0.04$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
450	452.5	5	1317.0	6.586	87.54	9.64	1210.0	6.05	79.375	9.17
455	457.5	5	1366.0	6.83	94.37	10.34	1256.0	6.28	85.655	9.9
460	462.5	5	1387.0	6.935	101.305	11.16	1278.0	6.39	92.045	10.64
465	467.5	5	1391.0	6.955	108.26	11.92	1282.0	6.41	98.455	11.38
470	472.5	5	1396.0	6.98	115.24	12.69	1289.0	6.445	104.9	12.12
475	477.5	5	1419.0	7.095	122.355	13.47	1312.0	6.56	111.46	12.88
480	482.5	5	1456.0	7.28	129.615	14.28	1347.0	6.735	118.195	13.66
485	487.5	5	1403.0	7.015	136.63	15.05	1299.0	6.495	124.69	14.41
490	492.5	5	1400.0	7.0	143.63	15.82	1298.0	6.49	131.18	15.16
495	497.5	5	1423.0	7.115	150.745	16.60	1320.0	6.6	137.78	15.93
500	502.5	5	1425.0	7.125	157.87	17.39	1324.0	6.62	144.4	16.69
505	507.5	5	1416.0	7.08	164.95	18.17	1317.0	6.585	150.985	17.45
510	512.5	5	1395.0	6.975	171.925	18.94	1299.0	6.495	157.48	18.20
515	517.5	5	1366.0	6.83	178.755	19.69	1272.0	6.36	163.84	18.94
520	522.5	5	1373.0	6.865	185.62	20.45	1280.0	6.4	170.24	19.68
525	527.5	5	1394.0	6.97	192.59	21.21	1301.0	6.505	176.745	20.43
530	532.5	5	1394.0	6.97	199.56	21.98	1302.0	6.51	183.255	21.18
535	537.5	5	1383.0	6.915	206.475	22.74	1292.0	6.46	189.715	21.93
540	542.5	5	1363.0	6.815	213.29	23.49	1275.0	6.375	196.09	22.67
545	547.5	5	1347.0	6.735	220.02	242.3	1261.0	6.305	202.395	23.39
550	552.5	5	1332.0	6.66	226.685	24.97	1248.0	6.24	208.635	24.12
555	557.5	5	1332.0	6.66	233.345	25.70	1249.0	6.245	214.88	24.84
560	562.5	5	1316.0	6.58	239.925	26.43	1235.0	6.175	221.055	25.55
565	567.5	5	1328.0	6.64	246.565	27.16	1247.0	6.235	227.29	26.27
570	572.5	5	1338.0	6.69	253.255	27.89	1257.0	6.285	233.575	27.00
575	577.5	5	1347.0	6.735	259.99	28.64	1267.0	6.335	239.91	27.73
580	582.5	5	1348.0	6.74	266.73	29.38	1268.0	6.34	246.25	28.46
585	587.5	5	1349.0	6.745	273.475	30.12	1271.0	6.355	252.605	29.20
590	592.5	5	1344.0	6.72	280.195	30.86	1266.0	6.33	258.935	29.90
595	597.5	5	1334.0	6.67	286.865	31.60	1257.0	6.285	265.22	30.66

Table 6 (Continued)

AM 1.5		a = 1.3		β = 0.02			a = 1.3		β = 0.04	
λ nm	λm nm	Δλ nm	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ_m) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ_m) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %
600	602.5	5	1325.0	6.625	293.49	32.33	1250.0	6.25	271.47	31.38
605	607.5	5	1319.0	6.595	300.085	33.05	1245.0	6.225	277.695	32.10
610	615	7.5	1319.0	9.8925	309.9775	34.14	1245.0	9.3375	287.0325	33.18
620	625	10	1310.0	13.1	323.0775	35.59	1239.0	12.39	299.4225	34.61
630	635	10	1302.0	13.02	336.0975	37.02	1233.0	12.33	311.7525	36.03
640	645	10	1299.0	12.99	349.0875	38.45	1231.0	12.31	324.0625	37.46
650	655	10	1289.0	12.89	361.9775	39.87	1223.0	12.23	336.2925	38.87
660	665	10	1279.0	12.79	374.7675	41.28	1215.0	12.15	348.4425	40.28
670	675	10	1264.0	12.64	387.4075	42.67	1202.0	12.02	360.4625	41.67
680	685	10	1250.0	12.5	399.9075	44.05	1189.0	11.89	372.3525	43.04
690	695	10	1239.0	12.39	412.2975	45.41	1180.0	11.800	384.1575	44.03
700	705	10	1220.0	12.20	424.4975	46.76	1163.2	11.6320	395.7895	45.75
710	711	6	1202.6	7.2156	431.7131	47.55	1147.6	6.8856	402.6751	46.54
712	713.5	2.5	1195.2	2.988	434.701	47.88	1140.7	2.8518	405.5268	46.87
715	716.2	2.75	1149.3	3.1606	437.8617	48.23	1097.1	3.0170	408.5439	47.22
717.5	718.75	2.5	917.6	2.2940	440.1557	48.48	876.2	2.1905	410.7344	47.48
720	721.25	2.5	857.0	2.1425	442.2982	48.72	817.8	2.0445	412.7789	47.71
722.5	723.75	2.5	1052.2	2.6305	444.9287	48.96	1005.1	2.5128	415.2916	48.00
725	726.25	2.5	928.6	2.3215	447.2502	49.26	887.2	2.2180	417.5096	48.26
727.5	728.75	2.5	939.2	2.3480	449.5982	49.52	897.4	2.2435	419.7531	48.52
730	731.25	2.5	941.1	2.3528	451.9509	49.78	899.6	2.2490	422.0021	48.78
732.5	733.75	2.5	1035.7	2.5892	454.5402	50.07	990.1	2.4752	424.4774	49.06
735	736.25	2.5	1101.6	2.7540	457.2942	50.37	1053.3	2.6332	427.1106	49.37
737.5	738.75	2.5	1096.3	2.7408	460.0349	50.67	1048.5	2.6212	429.7319	49.67
740	741.25	2.5	1100.5	2.7512	462.7862	50.97	1052.7	2.6318	432.3636	49.98
742.5	743.75	2.5	1097.4	2.7435	465.5297	51.28	1050.0	2.6250	434.9886	50.28
745	746.25	2.5	1120.7	2.8018	468.3314	51.58	1072.5	2.6812	437.6699	50.59
747.5	753.75	7.5	1127.3	8.4548	476.7862	52.47	1078.9	8.0918	445.7616	51.52
760	761.05	7.3	1105.1	8.0672	484.8534	53.40	1058.9	7.7300	453.4916	52.42
762.1	763.55	2.5	767.6	1.9190	486.7724	53.61	735.6	1.8390	455.3306	52.63

Table 6 (Continued)

AM 1.5										
λ nm	λm nm	$E\lambda$ $\Delta\lambda$ nm	W m^{-2} μm^{-1}	ΔE Wm^{-2}	E $(0 - \lambda m)$ W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %	$E\lambda$ Wm^{-2} μm^{-1}	ΔE W m^{-2}	E $(0-\lambda_m)$ W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %
765	775	11.45	1095.4	12.5423	499.3147	55.00	1049.7	12.0191	467.3497	54.02
785	787.5	12.5	1056.3	13.2038	512.5185	56.45	1013.8	12.6725	480.0222	55.48
790	792.5	5.0	1026.4	5.1320	517.5850	57.01	985.5	4.9275	484.9497	56.05
795	797.5	5.0	1013.3	5.0665	522.7170	57.57	973.0	4.8650	489.8147	56.62
800	802.5	5.0	971.4	4.875	527.5740	58.11	933.1	4.6655	494.4802	57.16
805	807.5	5.0	989.1	4.9455	532.5195	58.65	950.6	4.753	499.2332	57.70
810	812.5	5.0	952.5	4.7625	537.2820	59.18	915.7	4.5785	503.8117	58.23
815	817.5	5.0	763.4	3.8170	541.0990	59.60	734.1	3.6705	507.4822	58.66
820	822.5	5.0	814.5	4.0725	545.1715	60.05	783.5	3.9175	511.3997	59.11
825	827.5	5.0	790.0	3.9500	549.1215	60.48	760.1	3.8005	515.2002	59.55
830	832.5	5.0	805.9	4.0295	553.1510	60.93	775.6	3.8780	519.0782	60.00
835	837.5	5.0	879.0	4.3950	557.5460	61.41	846.2	4.2310	523.3092	60.49
840	842.5	5.0	919.5	4.5975	562.1435	61.92	885.6	4.4280	527.7372	61.00
845	847.5	5.0	921.5	4.6075	566.7510	62.42	877.7	4.3885	532.1257	61.52
850	870	22.5	927.9	20.8778	587.6287	64.72	894.1	20.1172	552.2429	63.83
890	892.5	22.5	858.5	19.3162	606.9450	66.85	829.1	18.6548	570.8977	65.99
895	898.5	6.0	760.5	4.5630	611.5080	67.35	734.6	4.4076	575.3053	66.50
902	904.5	6.0	632.1	3.7926	615.3006	67.77	610.8	3.6648	578.9701	66.92
907	909.5	5.0	615.9	3.0795	618.3801	68.11	595.3	2.9765	581.9646	67.27
912	914	4.5	592.2	2.6648	621.0450	68.40	572.4	2.5758	584.5224	67.56
916	918	4.0	544.0	2.1760	623.2210	68.64	526.0	2.1040	586.6264	67.81
920	922	4.0	661.6	2.6464	625.8674	68.94	639.8	2.5592	589.1856	68.10
924	926	4.0	644.0	2.5760	628.4434	68.22	623.0	2.4920	591.6776	68.39
928	931.5	5.5	518.0	2.8490	631.2924	69.53	501.1	2.7560	594.4336	686.2
935	939	7.5	210.0	1.575	632.8674	69.71	203.3	1.5248	595.9584	68.88
943	946.5	7.5	335.3	2.5148	635.3821	69.98	324.6	2.4345	598.3929	69.17
950	952	5.5	308.8	1.6984	637.0805	70.17	299.0	1.6445	600.0374	69.36
954	955.5	3.5	292.6	1.0241	638.1046	70.28	283.4	0.9919	601.0293	69.47
957	961	5.5	396.7	2.1818	640.2865	70.52	384.3	2.1136	603.1429	69.72
965	970	9.0	499.2	4.4928	644.7793	71.02	483.8	4.3542	607.4671	70.22

Table 6 (Continued)

AM 1.5		$a = 1.3$			$\beta = 0.02$		$a = 1.3$		$\beta = 0.04$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
975	978	8.0	585.6	4.6848	649.4641	71.54	567.8	4.5424	612.0395	70.74
981	982.5	4.5	651.3	2.9308	652.3949	71.86	631.6	2.8422	614.8817	71.07
984	987	4.5	689.0	3.1005	655.4954	72.20	668.2	3.0069	617.8886	71.42
990	992.5	5.5	723.5	3.9792	659.4747	72.64	701.9	3.8604	621.7491	71.87
995	1006.5	14.0	724.2	10.1388	669.6135	73.75	702.6	7.8364	631.5855	73.00
1018	1050	43.5	629.2	23.3702	696.9837	76.77	611.0	26.5785	658.1640	76.07
1082	1088	38.0	509.7	19.3686	716.3523	78.90	496.0	18.8480	677.012	78.25
1094	1096	8.0	483.0	3.864	720.2163	79.33	470.3	3.7624	680.7744	78.69
1098	1099.5	3.5	505.9	1.7706	721.9869	79.52	492.6	1.7241	682.4985	78.89
1101	1114.5	15.0	519.6	7.7940	729.7809	80.38	506.0	7.5900	690.0885	79.76
1128	1129.5	0.015	104.8	1.5720	731.3529	80.55	102.1	1.5315	691.6200	79.94
1131	1134	4.5	121.4	0.5463	731.8992	80.61	118.3	0.5324	692.1523	80.00
1137	1140.5	6.5	112.9	0.73384	732.6331	80.70	110.0	0.7156	692.8680	80.09
1144	1145.5	5	161.5	0.8075	733.4406	80.78	157.5	0.7875	693.6555	80.18
1147	1162.5	17	144.6	2.4582	735.8988	81.06	141.0	2.397	696.0525	80.45
1178	1183.5	21	386.7	8.1207	744.0195	81.95	377.4	7.9254	703.9779	81.37
1189	1191	7.5	395.1	2.96325	746.9827	82.28	385.5	2.8935	706.8715	81.70
1193	1207.5	16.5	437.5	7.21875	754.2015	83.07	426.2	7.0488	713.9202	82.52
1222	1229	21.5	392.4	8.4366	762.6381	84.00	383.4	8.2431	722.1633	83.47
1236	1250	21	396.7	8.3307	770.9688	84.91	387.7	8.1417	730.3050	84.41
1264	1270	20	329.8	6.596	777.5548	85.64	322.6	6.452	736.7570	85.16
1276	1282	12	349.2	4.1906	781.7452	86.11	341.7	4.1004	740.8471	85.63
1288	1301	19	349.5	6.6405	788.3857	86.84	342.0	6.498	747.3554	86.38
1314	1324.5	23.5	285.4	6.7069	795.0926	87.58	279.4	6.5659	753.9213	87.14
1335	1359.5	35	175.1	6.1285	801.2211	88.25	171.5	6.0025	759.9238	87.84
1384	1408	48.5	2.4	0.1164	801.3375	88.26	2.4	0.1164	760.0402	87.85
1432	1444.4	36.5	30.5	1.11325	802.4507	88.39	30.4	1.1096	761.1498	87.98
1457	1464.5	20	68.1	1.362	803.8127	88.54	67.0	1.34	762.4898	88.13
1472	1507	42.5	61.0	2.5925	806.4052	88.82	60.0	2.55	765.0398	88.43
1542	1557	50	243.5	12.175	818.5802	90.16	239.0	11.95	776.9898	89.81

Table 6 (Continued)

AM 1.5		α = 1.3			β = 0.02		α = 1.3		β = 0.04	
λ nm	λm nm	Δλ nm	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ$_m$) W m^{-2}	E(0-λ$_m$) / E(0-∞) %	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ$_m$) W m^{-2}	E(0-λ$_m$) / E(0-∞) %
1572	1585.5	28.5	229.0	6.5265	825.1067	90.88	225.0	6.4125	783.4023	90.55
1599	1603.5	18	223.0	4.014	829.1207	91.32	219.0	3.942	787.3443	91.01
1608	1617	13.5	214.0	2.889	832.0097	91.64	210.0	2.835	790.1793	91.33
1626	1635	18	213.0	3.834	835.8437	92.06	210.0	3.78	793.9593	91.77
1644	1647	12	204.0	2.448	838.2917	92.33	200.0	2.4	796.3593	92.05
1650	1663	16	201.0	3.216	841.5077	92.69	198.0	3.168	799.5273	92.41
1676	1704	41	182.0	7.462	848.9697	93.51	179.2	7.3472	806.8745	93.26
1732	1757	53	161.0	8.533	857.5027	94.45	159.0	8.427	815.3015	94.24
1782	1822	65	133.0	8.645	866.1477	95.40	131.3	8.5345	823.8360	95.22
1862	1908.5	86.5	2.0	.173	866.3207	95.42	2.0	.173	824.0090	95.24
1955	1981.5	73	36.0	2.628	868.9487	95.71	36.0	2.628	826.6370	95.55
2008	2011	29.5	66.0	1.947	870.8957	95.92	65.0	1.9175	828.5545	95.77
2014	2035.5	24.5	73.0	1.7885	872.6842	96.12	72.0	1.764	830.3185	95.97
2057	2090.5	55	67.0	3.685	876.3692	96.53	67.0	3.685	834.0035	96.40
2124	2140	49.5	67.0	3.3165	879.6857	96.89	66.0	3.267	837.2705	96.78
2156	2178.5	38.5	63.0	2.4255	882.1112	97.16	62.0	2.387	839.6575	97.05
2201	2233.5	55	67.0	3.685	885.7963	97.55	66.0	3.63	843.2875	97.45
2266	2293	59.5	62.0	3.689	889.4853	97.95	62.0	3.689	846.9765	98.88
2320	2329	36	58.0	2.088	891.5732	98.18	57.0	2.052	849.0285	98.12
2338	2347	18	55.0	.99	892.5632	98.29	54.0	.972	850.0005	98.23
2356	2372	25	52.0	1.3	893.8632	98.43	51.0	1.275	851.2755	98.38
2388	2401.5	29.5	33.0	.9735	894.8367	98.51	33.0	.9735	852.2490	98.49
2415	2434	32.5	30.0	.975	895.8117	98.65	29.0	.9425	853.1915	98.60
2453	2473.5	39.5	27.0	1.0665	896.8782	98.77	26.0	1.027	854.2185	98.72
2494	2515.5	42	17.0	.714	897.5922	98.85	17.0	.714	854.9325	98.80
2537	2718.5	203	3.0	.609	898.2012	98.91	3.0	.609	855.5415	98.87
2900	2920.5	202	2.0	.404	898.6052	98.96	2.0	.404	855.9455	98.92
2941	2947.5	27	4.0	.108	898.7132	98.97	4.0	.108	856.0535	98.93
2954	2963.5	16	4.0	.064	898.7772	98.98	4.0	.064	856.1175	98.94
2973	2989	25.5	7.0	.1785	898.9557	99.00	7.0	.1785	856.2960	98.96

Table 6 (Continued)

AM 1.5		$a = 1.3$			$\beta = 0.02$		$a = 1.3$		$\beta = 0.04$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{(E\ 0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
3005	3025	36	6.0	.216	899.1717	99.02	6.0	.216	856.5120	98.98
3045	3050.5	25.5	3.0	.0765	899.2482	99.03	3.0	.0765	856.5883	98.99
3056	3076.5	26	3.0	.078	899.3262	99.04	3.0	.078	856.6655	99.50
3097	3114.5	38	2.0	.076	899.4022	99.04	2.0	.076	856.7425	99.01
3132	3144	29.5	5.0	.1475	899.5497	99.06	5.0	.1475	856.8900	99.02
3156	3180	36	18.0	.648	900.1977	99.13	18.0	.648	857.5380	99.10
3204	3209	29	1.2	.0348	900.2325	99.14	1.2	.0348	857.5729	99.10
3214	3229.5	20.5	2.3	.04715	900.2796	99.14	2.2	.0451	857.6179	99.11
3245	3252.5	23	3.0	.069	900.3486	99.15	3.0	.069	857.6869	99.12
3260	3272.5	20	3.0	.06	900.4086	99.16	3.0	.06	857.7469	99.12
3285	3301	28.5	14.0	.399	900.8077	99.20	14.0	.399	858.1459	99.17
3317	3330.5	29.5	12.0	.354	901.1617	99.24	12.0	.354	858.4999	99.21
3344	3373.5	43	3.0	.129	901.2907	99.25	3.0	.129	858.5289	99.23
3403	3426.5	53	12.0	.636	901.9267	99.32	12.0	.636	859.2649	99.30
3450	3478.5	52	12.2	.6344	902.5611	99.39	12.1	.6292	859.8941	99.37
3507	3522.5	44	12.5	.55625	903.1108	99.45	12.2	.5368	860.4309	99.43
3538	3555.5	33	12.0	.396	903.5071	99.50	12.0	.396	860.8269	99.48
3573	3603	47.5	11.0	.5225	904.0295	99.55	10.0	.475	861.3019	99.53
3633	3653	50	11.0	.55	904.5695	99.61	11.0	.55	861.8519	99.60
3673	3684.5	31.5	9.0	.2835	904.8631	99.65	9.0	.2835	862.1354	99.63
3696	3704	19.5	10.3	.20085	905.0639	99.67	10.2	.1989	862.3343	99.65
3712	3738.5	34.5	11.0	.3795	905.4434	99.71	11.0	.3795	862.7138	99.70
3765	3788.5	50	9.0	.45	905.8934	99.76	9.0	.45	863.1638	99.75
3812	3850	61.5	9.0	.5535	906.4469	99.82	9.0	.5535	863.7173	99.81
3888	3905.3	55.5	8.0	.444	906.8909	99.87	8.0	.444	864.1613	99.86
3923	3935.5	30	8.0	.24	907.1309	99.90	8.0	.24	864.4013	99.89
3948	3996.5	61	8.0	.488	907.6189	99.95	7.9	.4819	864.8832	99.95
4045	4071.5	75	6.1	.4575	908.0764	100.00	6.0	.450	865.3332	100.00

Table 7. Terrestrial Irradiance for Air Mass 1.5 Computed from the Spectral Data in Table 5

AM 1.5		a = 0.66		β = 0.085			a = 0.66			β = 0.17
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0-\lambda_m)$ W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0-\lambda_m)$ W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %
300	302.5	5	0	0	0	0.00	0	0	0	0.00
305	307.5	5	2.0	.01	.01	0.00	1.0	.005	.005	0.00
310	312.5	5	6.3	.0315	.0415	0.01	5.0	.025	.03	0.00
315	317.5	5	26.0	.13	.1715	0.02	19.0	.095	.125	0.02
320	322.5	5	100.2	.501	.6725	0.08	76.0	.38	.505	0.07
325	327.5	5	142.0	.71	1.3825	0.17	108.0	.54	1.045	0.15
330	332.5	5	186.0	.93	2.3125	0.28	142.0	.71	1.755	0.25
335	337.5	5	228.0	1.14	3.4525	0.42	176.0	.88	2.635	0.38
340	342.5	5	273.0	1.365	4.8175	0.51	211.0	1.055	3.69	0.53
345	347.5	5	291.0	1.455	6.2725	0.77	225.0	1.125	4.815	0.69
350	352.5	5	319.0	1.595	7.8675	0.97	247.0	1.235	6.05	0.87
355	357.5	5	338.0	1.69	9.5575	1.17	262.0	1.31	7.36	1.05
360	362.5	5	356.0	1.78	11.3375	1.39	277.0	1.385	8.745	1.25
365	367.5	5	395.0	1.975	13.3125	1.63	308.0	1.54	10.285	1.47
370	372.5	5	431.0	2.155	15.4675	1.90	337.0	1.685	11.97	1.72
375	377.5	5	442.0	2.21	17.6775	2.17	347.0	1.735	13.705	1.96
380	382.5	5	448.0	2.24	19.9175	2.44	352.0	1.76	15.465	2.22
385	387.5	5	454.0	2.27	22.1875	2.72	358.0	1.79	17.255	2.47
390	392.5	5	470.0	2.35	24.5375	3.01	371.0	1.855	19.11	2.74
395	397.5	5	527.0	2.635	27.1725	3.34	416.0	2.08	21.19	3.04
400	402.5	5	655.0	3.275	30.4475	3.74	519.0	2.595	23.785	3.41
405	407.5	5	772.0	3.86	34.3075	4.21	612.0	3.06	26.845	3.85
410	412.5	5	841.0	4.205	38.5125	4.73	668.0	3.34	30.185	4.33
415	417.5	5	871.0	4.355	42.8675	5.26	694.0	3.47	33.655	4.82
420	422.5	5	878.0	4.39	47.2575	5.80	700.0	3.5	37.155	5.33
425	427.5	5	870.0	4.35	51.6075	6.34	696.0	3.48	40.635	5.82
430	432.5	5	862.0	4.31	55.9175	6.86	690.0	3.45	44.085	6.32
435	437.5	5	895.0	4.475	60.3925	7.41	717.0	3.585	47.67	6.83
440	442.5	5	996.0	4.98	65.3725	8.02	800.0	4.	51.67	7.41
445	447.5	5	1082.0	5.41	70.7825	8.69	870.0	4.35	56.02	8.03

Table 7 (Continued)

AM 1.5		$a = 0.66$			$\beta = 0.085$		a 0.66		$\beta = 0.17$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0-\lambda_m)$ W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0-\lambda_m)$ W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %
450	452.5	5	1155.0	5.775	76.5525	9.40	931.0	4.655	60.675	8.70
455	457.5	5	1198.0	5.99	82.5475	10.13	967.0	4.835	65.51	9.40
460	462.5	5	1218.0	6.09	88.6375	10.88	984.0	4.92	70.43	10.10
465	467.5	5	1221.0	6.105	94.7425	11.63	988.0	4.94	75.37	10.80
470	472.5	5	1226.0	6.13	100.8725	12.38	994.0	4.97	80.34	11.52
475	477.5	5	1247.0	6.235	107.1075	13.15	1012.0	5.06	85.4	12.24
480	482.5	5	1280.0	6.4	113.5075	13.93	1041.0	5.205	90.605	12.99
485	487.5	5	1234.0	6.17	119.6775	14.69	1004.0	5.02	95.625	13.71
490	492.5	5	1231.0	6.155	125.8325	15.44	1004.0	5.02	100.645	14.42
495	497.5	5	1252.0	6.26	132.0925	16.21	1022.0	5.11	105.755	15.16
500	502.5	5	1255.0	6.275	138.3675	16.98	1026.0	5.13	110.885	15.89
505	507.5	5	1247.0	6.235	144.6025	17.75	1021.0	5.105	115.99	16.63
510	512.5	5	1229.0	6.145	150.7475	18.50	1008.0	5.04	121.03	17.35
515	517.5	5	1204.0	6.02	156.7675	19.24	988.0	4.94	125.92	18.06
520	522.5	5	1210.0	6.05	162.8175	19.98	995.0	4.975	130.945	18.77
525	527.5	5	1230.0	6.15	168.9675	20.74	1012.0	5.06	136.005	19.49
530	532.5	5	1230.0	6.15	175.1175	21.49	1013.0	5.065	141.07	20.22
535	537.5	5	1220.0	6.1	181.2175	22.24	1006.0	5.03	146.1	20.94
540	542.5	5	1203.0	6.015	187.2325	22.98	993.0	4.965	151.065	21.65
545	547.5	5	1190.0	5.95	193.1825	23.71	984.0	4.92	155.985	22.36
550	552.5	5	1177.0	5.885	199.0675	24.43	974.0	4.87	160.855	23.06
555	557.5	5	1177.0	5.885	204.9525	25.15	975.0	4.875	165.73	23.75
560	562.5	5	1164.0	5.82	210.7725	25.87	965.0	4.825	170.555	24.45
565	567.5	5	1175.0	5.875	216.6475	26.59	975.0	4.875	175.43	25.15
570	572.5	5	1183.0	5.915	222.5625	27.32	984.0	4.92	180.35	25.85
575	574.5	5	1192.0	5.96	228.5225	28.05	992.0	4.96	185.31	26.56
580	582.5	5	1193.0	5.965	234.4875	28.78	994.0	4.97	190.28	27.27
585	587.5	5	1195.0	5.975	240.4625	29.51	997.0	4.985	195.265	27.99
590	592.5	5	1191.0	5.955	246.4175	30.24	994.0	4.97	200.235	28.70
595	597.5	5	1182.0	5.91	252.3275	30.97	988.0	4.94	205.175	29.41

Table 7 (Continied)

AM 1.5		$\alpha = 0.66$			$\beta = 0.085$			$\alpha = 0.66$	$\beta = 0.17$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
600	602.5	5	1174.0	5.87	258.1975	31.69	982.0	4.91	210.085	30.11
605	607.5	5	1170.0	5.85	264.0475	32.41	979.0	4.895	214.98	30.81
610	615	7.5	1170.0	8.775	272.8225	33.48	980.0	7.35	222.33	31.87
620	625	10	1163.0	11.63	284.4525	34.91	977.0	9.77	232.1	33.27
630	635	10	1157.0	11.57	296.0225	36.33	973.0	9.73	241.83	34.66
640	645	10	1155.0	11.55	307.5725	37.75	973.0	9.73	251.56	36.06
650	655	10	1147.0	11.47	319.0425	39.16	968.0	9.68	261.24	37.44
660	665	10	1138.0	11.38	330.4225	40.55	963.0	9.63	270.87	38.82
670	675	10	1126.0	11.26	341.6825	41.94	954.0	9.54	280.41	40.19
680	685	10	1114.0	11.14	352.8225	43.30	945.0	9.45	289.86	41.55
690	695	10	1105.0	11.05	363.8725	44.66	939.0	9.39	299.25	42.89
700	705	10	1088.9	10.889	374.7615	46.00	926.7	9.2670	308.5170	44.22
710	711	6	1074.0	6.444	381.2055	46.79	915.4	5.4924	314.0094	45.01
712	713.5	2.5	1067.5	2.6688	383.8742	47.11	910.2	2.2755	316.2849	45.33
715	716.25	2.75	1026.7	2.8234	386.6977	47.46	875.8	2.4084	318.6934	45.68
717.5	718.75	2.5	820.0	2.0500	388.7477	47.71	699.7	1.7492	320.4426	45.93
720	721.25	2.5	766.0	1.9150	390.6627	47.98	653.8	1.6345	322.0771	46.16
722.5	723.75	2.5	940.5	2.3512	393.0139	48.24	803.0	2.0075	324.0846	46.45
725	725.25	2.5	830.2	2.0755	395.0894	48.49	709.1	1.7728	325.8574	46.71
727.5	728.75	2.5	839.6	2.0990	397.1884	48.75	717.5	1.7938	327.6511	46.96
730	731.25	2.5	841.6	2.1040	399.2924	49.01	719.4	1.7985	329.4496	47.22
732.5	733.75	2.5	926.3	2.3158	401.6082	49.29	792.0	1.9800	331.4296	47.51
735	736.25	2.5	985.3	2.4632	404.0714	49.59	842.8	2.1070	333.5366	47.81
737.5	738.75	2.5	980.8	2.4520	406.5234	49.89	839.2	2.0980	335.6346	48.11
740	741.25	2.5	984.7	2.4618	408.9852	50.20	842.9	2.1072	337.7418	48.41
742.5	743.75	2.5	982.1	2.4522	411.4404	50.50	841.0	2.1025	339.8444	48.71
745	746.25	2.5	10031.1	2.5078	313.9482	50.81	859.1	2.1298	341.9741	49.02
747.5	753.75	7.5	1009.1	7.5682	421.5164	51.73	864.7	6.4852	348.4594	49.94
760	761.05	7.3	990.0	7.2270	428.7434	52.62	849.7	6.2028	354.6622	50.84
762.1	763.55	2.5	687.8	1.7195	430.4629	52.83	590.5	1.4762	356.1384	51.05

Table 7 (Continued)

AM 1.5		$\alpha = 0.66$			$\beta = 0.085$		$\alpha = 0.66$		$\beta = 0.17$	
λ nm	λm nm	Δλ nm	Eλ W m^{-2} µm^{-1}	ΔE W m^{-2}	E (0- λ_m) W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	Eλ W m^{-2} µm^{-1}	ΔE W m^{-2}	E (0- λ_m) W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
765	775	11.45	981.6	11.2393	441.7022	54.21	843.0	9.6524	365.7908	52.43
785	787.5	12.5	947.8	11.8475	453.5497	55.66	816.0	10.2000	375.9908	53.89
790	792.5	5.0	921.1	4.6055	458.1552	56.23	793.7	3.9685	379.9593	54.46
795	797.5	5.0	909.5	4.5475	462.7027	56.79	784.1	3.9205	383.8798	55.02
800	802.5	5.0	872.2	4.3610	467.0637	57.32	752.4	3.7620	387.6418	55.56
805	807.5	5.0	888.4	4.4420	471.5057	57.87	766.9	3.8345	392.4763	56.11
810	812.5	5.0	844.8	4.2790	475.7847	58.40	739.1	3.6955	395.1718	56.64
815	817.5	5.0	686.1	3.4305	479.2152	58.82	592.9	2.9645	398.1363	57.07
820	822.5	5.0	732.2	3.6610	482.8762	59.27	633.2	3.1660	401.3023	57.52
825	827.5	5.0	710.4	3.5520	486.4282	59.70	614.7	3.0735	404.3758	57.96
830	832.5	5.0	724.9	3.6245	490.0527	60.15	627.6	3.1380	407.5138	58.41
835	837.5	5.0	790.9	3.9545	494.0072	60.63	685.0	3.4250	410.9388	58.90
840	842.5	5.0	826.5	4.1375	498.1447	61.14	717.3	3.5865	414.5253	59.42
845	847.5	5.0	829.5	4.1475	502.2922	61.65	719.4	3.5970	418.1223	59.93
850	870	22.5	835.5	18.7988	521.0910	63.96	725.0	16.2125	434.4348	62.27
890	892.5	22.5	774.6	17.4285	538.5195	66.10	675.0	15.1875	449.6223	64.45
895	898.5	6.0	686.3	4.1178	542.6373	66.60	598.4	3.5904	453.2127	64.96
902	904.5	6.0	570.7	3.4242	546.0615	67.02	498.2	2.9892	456.2019	65.39
907	909.5	5.0	556.2	2.7810	548.8425	67.36	485.5	2.4275	458.6294	65.74
912	914	4.5	534.9	2.4070	551.2495	67.66	467.0	2.1015	460.7309	66.04
916	918	4.0	491.5	1.9660	553.2155	67.90	429.4	1.7176	462.4485	66.28
920	922	4.0	597.9	2.3916	555.6071	68.19	522.5	2.0900	464.5385	66.58
924	926	4.0	582.1	2.3284	557.9355	68.48	509.0	2.0360	466.5745	66.88
928	931.5	5.5	468.2	2.5751	560.5106	68.79	409.5	2.2522	468.8267	67.20
935	939	7.5	190.0	1.4250	561.9356	68.97	166.3	1.2472	470.0740	67.38
943	946.5	7.5	303.3	2.2748	564.2104	69.25	265.7	1.9928	472.0667	67.66
950	952	5.5	279.5	1.3572	565.7476	69.44	244.9	1.3470	473.4137	67.86
954	955.5	3.5	264.9	0.9272	566.6748	69.44	232.2	0,8127	474.2264	67.97
957	961	5.5	359.2	1.9756	568.6504	69.79	315.0	1.7325	475.9589	68.22
965	970	9.0	452.1	4.0689	572.7193	70.29	396.8	3.5712	479.5301	68.73

Table 7 (Continued)

AM 1.5		α = 0.66		β = 0.085			α = 0.66		β = 0.17	
λ nm	λm nm	Δλ nm	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0- λ_m) W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0- λ_m) W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
975	978	8.0	530.6	4.2448	576.9647	70.81	466.0	3.7280	483.2581	69.27
981	982.5	4.5	590.3	2.6564	579.6204	71.14	518.8	2.3346	485.5927	69.60
984	987	4.5	624.5	2.8102	582.4307	71.48	549.0	2.4705	488.0632	69.96
990	992.5	5.5	656.0	3.6080	586.0387	71.93	577.0	3.1735	491.2347	70.41
995	1006.5	14	656.8	9.1952	595.2339	73.06	577.9	8.0906	499.3273	71.57
1018	1050	43.5	571.2	24.8472	620.0811	76.11	504.0	21.9240	521.2513	74.71
1082	1088	38	464.0	17.6320	637.7171	78.27	411.0	15.6180	536.8693	76.95
1094	1096	8	439.9	3.5192	641.2323	78.70	390.1	3.1208	539.9901	77.40
1098	1099.5	3.5	461.0	1.6135	642.8458	78.90	409.0	1.4315	541.4216	77.60
1101	1114.5	15	473.0	7.0950	649.9408	79.77	420.0	6.3000	547.7216	78.50
1128	1129.5	15	96.0	1.440	651.3808	79.95	85.0	1.2750	548.9966	78.69
1131	1134	4.5	111.0	0.4995	651.8803	80.01	99.0	0.4455	549.4421	78.75
1137	1140.5	6.5	103.0	0.6695	652.5498	80.09	92.0	0.598	550.0401	78.84
1144	1145.5	5	148.0	0.74	653.2898	80.18	132.0	0.66	550.7001	78.93
1147	1162.5	17	132.0	2.244	655.5338	80.46	118.0	2.006	552.7001	79.22
1178	1183.5	21	353.0	7.413	662.9468	81.37	315.0	6.615	559.3211	80.17
1189	1191	7.5	361.0	2.7075	665.6543	81.70	322.3	2.41725	561.7381	80.52
1193	1207.5	16.5	400.0	6.6	672.2543	82.51	357.0	5.8905	567.6288	81.36
1222	1229	21.5	359.0	7.7185	679.9728	83.46	321.0	6.9105	574.5302	82.35
1236	1250	21	363.0	7.623	687.5958	84.39	325.0	6.825	581.3553	83.33
1264	1270	20	302.0	6.04	693.6358	85.13	271.0	5.42	586.7753	84.10
1276	1282	12	321.0	3.852	697.4878	85.61	287.0	3.4560	590.2313	84.60
1288	1301	19	321.0	6.099	703.5868	86.35	288.0	5.472	595.7033	85.38
1314	1324.5	23.5	262.0	6.157	709.7438	87.11	236.0	5.546	601.2493	86.18
1335	1359.5	35	161.0	5.635	715.3788	87.80	145.0	5.075	606.3243	86.91
1384	1408	48.5	2.0	0.097	715.4758	87.81	2.0	0.097	505.4213	86.92
1432	1444.5	36.5	28.0	1.022	716.4978	87.92	25.0	0.9125	607.3338	87.05
1457	1464.5	20	63.0	1.26	717.7578	88.09	57.0	1.14	608.4738	87.22
1472	1507	42.5	56.0	2.38	720.1378	88.39	51.0	2.1675	610.5413	87.53
1542	1557	50	225.0	11.25	731.3878	89.77	205.0	10.25	620.8913	88.99

Table 7 (Continued)

AM 1.5		$a = 0.66$		$\beta = 0.085$			$a = 0.66$		$\beta = 0.17$	
λ nm	λm nm	Δλ nm	Eλ W m^{-2} µm^{-1}	ΔE W m^{-2}	E (0- λ_m) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %	Eλ W m^{-2} µm^{-1}	ΔE W m^{-2}	E (0- λ_m) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %
1572	1585.5	28.5	212.0	6.042	737.4298	90.51	192.0	5.472	626.3633	89.78
1599	1603.5	18	206.0	3.708	741.1378	90.96	188.0	3.384	629.7473	90.26
1608	1617	13.5	198.0	2.673	743.8108	91.29	180.0	2.43	632,1773	90.61
1626	1635	18	198.0	3.564	747.3748	91.73	180.0	3.24	635.4173	91.08
1644	1647	12	189.0	2.268	749.6428	92.01	172.0	2.064	637.4813	91.37
1650	1663	16	187.0	2.992	752.6348	92.37	170.0	2.72	640.2013	91.76
1676	1704	41	168.0	6.888	759.5228	93.22	154.0	6.314	646.5153	92.67
1732	1757	53	150.0	7.95	767.4728	94.20	137.0	7.261	653.7763	93.71
1782	1822	65	124.0	8.06	775.538	95.18	114.0	7.41	661.1863	94.77
1862	1908.5	86.5	2.0	.173	775.7058	95.21	2.0	.173	661.3593	94.80
1955	1981.5	73	34.0	2.482	778.1878	95.51	31.0	2.263	663.6223	95.12
2008	2011	29.5	62.0	1.829	780.0168	95.74	57.0	1.6815	665.3038	95.36
2014	2035.5	24.5	68.0	1.666	781.6828	95.94	63.0	1.5435	666.8473	95.58
2057	2090.5	55	63.0	3.465	786.1478	96.36	58.0	3.19	670.0373	96.04
2124	2140	49.5	63.0	3.1185	788.2663	96.75	58.0	2.871	672.9083	96.45
2156	2178.5	38.5	59.0	2.2715	790.5378	97.02	54.0	2.079	674.9873	96.75
2201	2233.5	55	62.0	3.41	793.9478	97.43	58.0	3.19	678.1773	97.18
2266	2293	59.5	58.0	3.451	797.3988	97.85	54.0	3.213	681.3903	97.64
2320	2329	36	54.0	1.944	799.3428	98.09	50.0	1.8	683.1903	97.90
2338	2347	18	51.0	.918	800.2608	98.20	48.0	.864	684.0543	98.03
2356	2372	25	49.0	1.225	801.4858	98.35	45.0	1.125	685.1793	98.19
2388	2401.5	29.5	31.0	.9145	802.4003	98.46	29.0	.8555	686.0348	98.31
2415	2434	32.5	28.0	.91	803.3103	98.57	26.0	.845	686.8798	98.43
2453	2473.5	39.5	25.0	.9875	804.2978	98.70	23.0	.9085	687.78831	98.56
2494	2515.5	42	16.0	.672	804.9698	98.78	15.0	.63	688.4183	98.65
2537	2718.5	203	3.0	.609	805.5788	98.85	2.0	.406	688.8243	98.71
2900	2920.5	202	2.0	.404	805.9828	98.90	2.0	.404	689.2283	98.77
2941	2947.5	27	4.0	.108	806.0908	98.92	4.0	.108	689.3363	98.78
2954	2963.5	16	4.0	.064	806.1548	98.92	4.0	.064	689.4003	98.79
2973	2989	25.5	6.0	.153	806.3078	98.94	6.0	.153	689.5533	98.81

Table 7 (Continued)

AM 1.5		$\alpha = 0.66$			$\beta = 0.085$		$\alpha = 0.66$		$\beta = 0.17$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
3005	3025	36	6.0	.216	806.5238	98.97	5.0	.18	689.7331	98.84
3045	3050.5	25.5	3.0	.0765	806.6003	98.98	3.0	.0765	689.8098	98.85
3056	3076.5	26	3.0	.078	806.6783	98.99	3.0	.078	689.8878	98.86
3097	3114.5	38	2.0	.076	806.7543	99.00	2.0	.076	689.9638	98.87
3132	3144	29.5	5.0	.1475	806.9018	99.02	5.0	.1475	690.1113	98.89
3156	3180	36	17.0	.612	807.5138	99.09	16.0	.576	690.6873	98.98
3204	3209	29	1.2	.0348	807.5486	99.09	1.2	.0348	690.7221	98.98
3214	3229.5	20.5	2.2	.0451	807.5937	99.10	2.0	.041	690.7631	98.99
3245	3252.5	23	3.0	.069	807.6627	99.11	3.0	.069	690.8321	99.00
3260	3272.5	20	2.2	.044	807.7067	99.11	2.3	.046	690.8781	99.00
3285	3301	28.5	13.0	.3705	808.0772	99.16	12.0	.342	691.2201	99.05
3317	3330.5	29.5	12.0	.354	808.4312	99.20	11.0	.3245	691.5446	99.10
3344	3373.5	43	3.0	.129	808.5602	99.22	3.0	.129	691.6735	99.12
3403	3426.5	53	11.0	.583	809.1432	99.29	11.0	.583	692.2566	99.20
3450	3478.5	52	12.0	.624	809.7672	99.37	11.0	.624	692.8806	99.29
3507	3522.5	44	12.0	.528	810.2952	99.43	11.2	.4928	693.3734	99.36
3538	3555.5	33	11.1	.3663	810.6615	99.48	11.0	.363	693.7364	99.41
3573	3603	47.5	10.0	.475	811.1365	99.54	9.0	.4275	694.1639	99.47
3633	3653	50	10.0	.5	811.6365	99.60	10.0	.5	694.6639	99.55
3673	3684.5	31.5	8.0	.252	811.8884	99.63	8.0	.252	694.9159	99.58
3696	3704	19.5	10.0	.195	812.0835	99.65	9.3	.18135	695.0973	99.61
3712	3738.5	34.5	10.3	0.35535	812.4388	99.70	10.0	.345	695.4423	99.66
3765	3788.5	50	9.0	.45	812.8888	99.75	8.3	.415	695.8573	99.72
3812	3850	61.5	8.2	.5043	813.3931	99.81	8.0	.492	696.3493	99.78
3888	3905.5	55.5	8.0	.444	813.8371	99.87	7.1	.394	696.7433	99.84
3923	3935.5	30	7.0	.21	814.0471	99.89	7.0	.21	696.9533	99.87
3948	3996.5	61	7.0	.427	814.4741	99.94	7.0	.427	697.3903	99.94
4045	4071.5	75	6.0	0.450	814.9241	100.00	6.0	.456	697.8303	100.00

Table 8. Terrestrial Irradiance for Air Mass 2 Computed from the Spectral Data in Table 4

AM 2		$\alpha = 1.3$		$\beta = 0.02$			$\alpha = 1.3$		$\beta = 0.04$	
λ nm	λm nm	Δλ nm	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ_m) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ_m) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %
300	302.5	5	0	0	0	0.00	0	0	0	0.00
305	307.5	5	0	0	0	0.00	0	0	0	0.00
310	312.5	5	2.0	0.01	0.01	0.00	1.0	0.005	0.005	0.00
315	317.5	5	10.0	0.05	0.06	0.01	8.0	0.04	0.045	0.01
320	322.5	5	59.0	0.295	0.355	0.04	50.0	0.25	0.295	0.04
325	327.5	5	90.0	0.45	0.805	0.10	75.0	0.375	0.67	0.09
330	332.5	5	125.0	0.625	1.43	0.17	105.0	0.525	1.195	0.15
335	337.5	5	163.0	.815	2.245	0.27	138.0	0.69	1.885	0.24
340	342.5	5	208.0	1.04	3.285	0.39	177.0	0.885	2.77	0.35
345	347.5	5	227.0	1.135	4.42	0.53	193.0	0.965	3.735	0.47
350	352.5	5	254.0	1.27	5.69	0.68	217.0	1.085	4.82	0.61
355	357.5	5	275.0	1.375	7.065	0.84	236.0	1.18	6.	0.76
360	362.5	5	297.0	1.485	8.55	1.02	255.0	1.275	7.275	0.92
365	367.5	5	334.0	1.67	10.22	1.22	288.0	1.44	8.715	1.11
370	372.5	5	370.0	1.85	12.07	1.44	320.0	1.6	10.315	1.31
375	377.5	5	385.0	1.925	13.995	1.67	334.0	1.67	11.985	1.52
380	382.5	5	396.0	1.98	15.975	1.90	344.0	1.72	13.705	1.74
385	387.5	5	406.0	2.03	18.005	2.15	353.0	1.765	15.47	1.96
390	392.5	5	425.0	2.125	20.13	2.40	371.0	1.855	17.325	2.20
395	397.5	5	481.0	2.405	22.535	2.69	421.0	2.105	19.43	2.47
400	402.5	5	605.0	3.025	25.56	3.05	530.0	2.65	22.08	2.80
405	407.5	5	717.0	3.585	29.145	3.48	630.0	3.15	25.23	3.20
410	412.5	5	787.0	3.935	33.08	3.94	693.0	3.465	28.695	3.64
415	417.5	5	822.0	4.11	37.19	4.43	725.0	3.625	32.32	4.10
420	422.5	5	834.0	4.17	41.36	4.93	737.0	3.685	36.005	4.57
425	427.5	5	833.0	4.165	45.525	4.53	737.0	3.685	39.69	5.04
430	432.5	5	830.0	4.15	49.675	5.92	737.0	3.685	43.375	5.51
435	437.5	5	868.0	4.34	54.015	6.44	771.0	3.855	47.23	6.00
440	442.5	5	973.0	4.865	58.88	7.02	867.0	4.335	51.565	6.55
445	447.5	5	1065.0	5.325	64.205	7.66	949.0	4.745	56.31	7.15

Table 8 (Continued)

AM 2		$a = 1.3$			$\beta = 0.02$		$a = 1.3$		$\beta = 0.04$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
450	452.5	5	1145.0	5.725	69.94	8.34	1022.0	5.11	61.42	7.80
455	457.5	5	1192.0	5.96	75.89	9.50	1066.0	5.33	66.75	8.48
460	462.5	5	1215.0	6.075	81.965	9.77	1089.0	5.445	72.195	9.17
465	467.5	5	1222.0	6.11	88.075	10.5	1097.0	5.485	77.68	9.86
470	472.5	5	1232.0	6.16	94.235	11.24	1107.0	5.535	83.215	10.57
475	477.5	5	1257.0	6.285	100.52	11.99	1131.0	5.655	88.87	11.29
480	482.5	5	1294.0	6.47	106.99	12.75	1167.0	5.835	94.705	12.03
485	487.5	5	1252.0	6.26	113.25	13.50	1130.0	5.65	100.355	12.74
490	492.5	5	1253.0	6.265	119.515	14.25	1133.0	5.665	106.02	13.46
495	497.5	5	1279.0	6.395	125.91	15.01	1157.0	5.785	111.805	14.20
500	502.5	5	1286.0	6.43	132.34	15.78	1165.0	5.825	117.63	14.94
505	507.5	5	1280.0	6.40	138.74	16.54	1161.0	5.805	123.435	15.67
510	512.5	5	1263.0	6.315	145.055	17.30	1147.0	5.735	129.17	16.40
515	517.5	5	1239.0	6.195	151.25	18.04	1127.0	5.635	134.805	17.12
520	522.5	5	1247.0	6.235	157.485	18.78	1136.0	5.68	140.485	17.84
525	527.5	5	1268.0	6.34	163.825	19.53	1156.0	5.78	146.265	18.57
530	532.5	5	1270.0	6.35	170.175	20.29	1159.0	5.795	152.06	19.31
535	537.5	5	1262.0	6.31	176.485	21.04	1153.0	5.765	157.825	20.04
540	542.5	5	1246.0	6.23	182.715	21.79	1140.0	5.7	163.525	20.77
545	547.5	5	1234.0	6.17	188.885	22.52	1130.0	5.65	169.175	21.48
550	552.5	5	1222.0	6.11	194.995	23.25	1120.0	5.6	174.775	22.19
555	557.5	5	1223.0	6.115	201.11	23.98	1122.0	5.61	180.385	22.91
560	562.5	5	1210.0	6.05	207.16	24.70	1111.0	5.555	185.94	23.61
565	567.5	5	1222.0	6.11	213.27	25.43	1124.0	5.62	191.56	24.33
570	572.5	5	1232.0	6.16	219.43	26.16	1134.0	5.67	197.23	25.05
575	577.5	5	1242.0	6.21	225.64	26.91	1144.0	5.72	202.95	25.77
580	582.5	5	1244.0	6.22	231.86	27.65	1147.0	5.735	208.685	26.50
585	587.5	5	1247.0	6.235	238.095	28.39	1150.0	5.75	214.435	27.23
590	592.5	5	1243.0	6.215	244.31	29.13	1148.0	5.74	220.175	27.96
595	592.5	5	1234.0	6.17	250.48	29.87	1141.0	5.705	225.88	28.68

Table 8 (Continued)

AM 2		$a = 1.3$			$\beta = 0.02$		$a = 1.3$		$\beta = 0.04$	
λ nm	λm nm	Δλ nm	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ$_m$) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ$_m$) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %
600	602.5	5	1227.0	6.135	256.614	30.60	1135.0	5.675	231.5550	29.40
605	607.5	5	1225.0	6.125	262.74	31.33	1134.0	5.67	237.2250	30.12
610	615	7.5	1227.0	9.2025	271.9425	32.43	1137.0	8.5275	245.7525	31.21
620	625	10	1225.0	12.25	284.1925	33.89	1137.0	11.37	257.1225	32.65
630	635	10	1224.0	12.24	296.4325	35.35	1137.0	11.37	268.4925	34.10
640	645	10	1226.0	12.26	308.6925	36.81	1141.0	11.41	279.9025	35.54
650	655	10	1222.0	12.22	320.9125	38.27	1140.0	11.4	291.3025	36.99
660	665	10	1216.0	12.16	333.0725	39.72	1136.0	11.36	302.6625	38.43
670	675	10	1206.0	12.06	345.1325	41.15	1127.0	11.27	313.9325	39.87
680	685	10	1196.0	11.96	357.0925	42.58	1119.0	11.19	325.1225	41.29
690	694	10	1189.0	11.890	368.9825	44.00	1144.0	11.14	336.2625	42.70
700	705	10	1174.0	11.740	380.7225	45.40	1101.7	11.0170	347.2795	44.10
710	711	6	1158.9	6.9480	387.6705	46.23	1088.8	6.5328	353.8123	44.93
712	713.5	2.5	1151.6	2.8790	390.5495	46.57	1082.1	2.7052	356.5176	45.27
715	716.25	2.75	1102.1	3.0308	393.5803	46.93	1035.8	2.8484	359.3650	45.63
717.5	718.75	2.5	850.7	2.1268	395.7070	47.18	799.9	1.9998	361.3658	45.89
720	721.25	2.5	787.0	1.9675	397.6745	47.42	739.4	1.8485	363.2142	46.12
722.5	723.75	2.5	998.2	2.4705	400.1450	47.71	939.1	2.3478	365.5620	46.42
725	726.25	2.5	864.9	2.1622	402.3073	47.97	813.9	2.0438	367.5968	46.68
727.5	728.75	2.5	877.0	2.1925	404.4998	48.23	825.5	2.0638	369.6605	46.94
730	731.25	2.5	880.0	2.200	406.6998	48.49	828.6	2.0715	371.732	47.21
732.5	733.75	2.5	983.8	2.4595	409.1593	48.79	926.5	2.3162	374.0482	47.50
735	736.25	2.5	1057.9	2.6442	411.8035	49.10	996.3	2.4908	376.5390	47.82
737.5	738.75	2.5	1052.9	2.6322	414.4358	49.42	992.2	2.4805	379.0195	48.13
740	741.75	2.5	1058.8	2.6470	417.0828	49.73	997.9	2.4948	381.5142	48.45
742.5	743.75	2.5	1056.3	2.6408	419.7325	50.05	996.0	2.490	384.0042	48.76
745	746.25	2.5	1083.2	2.7080	422.4315	50.37	1021.6	2.5540	386.4582	49.09
747.5	753.75	7.5	1091.7	8.1878	430.6193	51.35	1029.7	7.2275	394.2810	50.07
760	761.05	7.3	1071.9	7.8249	438.4441	52.28	1012.5	7.3912	401.6722	51.01
762.4	763.55	2.5	694.7	1.7368	440.1809	52.49	656.4	1.6410	403.3132	51.22

Table 8 (Continued)

AM 2		$\alpha = 1.3$			$\beta = 0.02$		$\alpha = 1.3$		$\beta = 0.04$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
765	775	11.45	1063.2	12.1736	452.3545	53.94	1004.5	11.5015	414.8148	52.68
785	787.5	12.5	1027.9	12.8488	465.2033	55.47	973.1	12.1638	426.9785	54.22
790	792.5	5.0	996.3	4.9815	470.1848	56.06	943.7	4.7185	431.6970	54.82
795	797.5	5.0	983.7	4.9185	475.1033	56.65	932.0	4.6600	436.3570	55.41
800	802.5	5.0	938.9	4.6945	479.7978	57.21	889.9	4.4495	440.8065	55.98
805	807.5	5.0	960.5	4.8025	484.6003	57.78	910.9	4.5545	445.3610	56.55
810	812.5	5.0	921.3	4.6065	489.2068	58.33	874.1	4.3705	449.7315	57.11
815	817.5	5.0	715.0	3.5750	492.7818	58.76	678.6	3.3930	453.1245	57.54
820	822.5	5.0	772.1	3.8605	496.6423	59.22	733.1	3.6655	456.790	58.01
825	827.5	5.0	746.8	3.7340	500.3763	59.66	709.3	3.5465	460.3365	58.46
830	832.5	5.0	765.5	3.8280	504.2043	60.12	727.6	3.6380	463.9745	58.92
835	837.5	5.0	848.0	4.240	508.4443	60.63	806.1	4.0305	468.0050	59.43
840	842.5	5.0	895.1	4.4755	512.9198	61.16	851.2	4.2560	472.2610	59.97
845	847.5	5.0	899.0	4.4950	517.4148	61.70	855.4	4.2770	476.5380	60.51
850	870	22.5	908.0	20.4300	537.8448	64.13	864.3	19.4468	495.9848	62.98
890	892.5	22.5	842.6	18.9585	556.8033	66.39	804.4	18.0990	514.0838	65.28
895	898.5	6.0	733.7	4.4022	561.2055	66.92	700.6	4.2036	518.2874	65.82
902	904.5	6.0	593.9	3.5634	564.7689	67.34	567.4	3.4044	521.6918	66.25
907	909.5	5.0	577.0	2.8850	567.6539	67.69	551.4	2.7570	524.4488	66.60
912	914	4.5	552.0	2.4840	570.1379	67.98	527.6	2.3742	526.8230	66.90
916	918	4.0	500.9	2.0036	572.1415	68.22	479.0	1.9160	528.7390	67.14
920	922	4.0	628.4	2.5136	574.6551	68.52	601.0	2.4040	531.1430	67.45
924	926	4.0	609.7	2.4338	577.0939	68.81	583.4	2.3336	533.4766	67.74
928	931.5	5.5	474.5	2.6098	579.7036	69.12	454.0	2.4970	535.9736	68.06
935	939	7.5	167.6	1.2570	580.9606	69.27	160.4	1.2030	537.1766	68.21
943	946.5	7.5	288.1	2.1608	583.1214	69.53	275.9	2.0692	539.2458	68.48
950	952	5.5	262.3	1.4426	584.5640	69.70	251.3	1.3822	540.6280	68.65
954	955.5	3.5	246.9	0.8642	585.4282	69.81	236.6	0.8281	541.4561	68.76
957	961	5.5	351.2	1.9316	587.3598	70.04	336.6	1.8513	543.3074	68.99
965	970	9.0	459.2	4.1328	591.4926	70.53	440.3	3.9627	547.2701	69.50

Table 8 (Continued)

AM 2		$\alpha = 1.3$			$\beta = 0.02$		$\alpha = 1.3$		$\beta = 0.04$	
λ	λm	$\Delta\lambda$	$E\lambda$ W m^{-2}	ΔE	E $(0\text{-}\lambda_m)$	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$	$E\lambda$ W m^{-2}	ΔE	E $(0\text{-}\lambda_m)$	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$
nm	nm	nm	μm^{-1}	W m^{-2}	W m^{-2}	%	μm^{-1}	W m^{-2}	W m^{-2}	%
975	978	8.0	554.0	4.4320	595.9246	71.06	531.7	4.2536	551.5237	70.04
981	982.5	4.5	627.9	2.8256	598.7501	71.39	602.6	2.7117	554.2354	70.38
984	987	4.5	670.7	3.0182	601.7683	71.75	643.9	2.8976	557.1329	70.75
990	992.5	5.5	711.3	3.9122	605.6804	72.22	683.1	3.7570	560.8900	71.23
995	1006.5	14.0	713.6	9.9904	515.6708	73.41	685.3	9.5942	570.4842	72.44
1018	1050	43.5	601.8	26.1783	641.8491	76.53	578.7	25.1734	595.6576	75.64
1082	1088	38	477.4	18.1412	659.9903	78.70	460.5	17.4990	613.1566	77.86
1094	1096	8.0	463.9	3.7112	663.7015	79.14	447.6	3.5808	616.7374	78.31
1098	1099.5	3.5	479.0	1.6765	665.3780	79.34	462.3	1.6180	618.3555	78.52
1101	1114.5	15	505.6	7.5840	672.9620	80.24	488.0	7.3200	625.6755	79.45
1128	1129.5	15	80.3	1.2045	674.1665	80.38	77.6	1.1640	626.8395	79.60
1131	1134	4.5	95.3	.42885	674.5954	80.44	92.1	.41445	627.2539	79.65
1137	1140.5	6.5	87.8	.5707	675.1661	80.51	84.9	.55185	627.8058	79.72
1144	1145.5	5	133.1	.6655	675.8316	80.59	128.7	.6435	628.4493	79.80
1147	1162.5	17	117.3	1.9941	677.8257	80.82	113.4	1.9278	630.3771	80.05
1178	1183.5	21	353.3	7.4193	685.2450	81.71	342.1	7.1841	637.5612	80.96
1189	1191	7.5	366.3	2.74725	687.9922	82.04	354.8	2.661	640.2222	81.30
1193	1207.5	16.5	427.0	7.0455	695.0377	82.88	413.6	6.8244	647.0466	82.17
1222	1229	21.5	371.0	7.9765	703.0142	83.83	359.7	7.73355	654.7801	83.15
1236	1250	21	380.0	7.98	710.9942	84.78	368.6	7.7406	662.5207	84.13
1264	1270	20	313.9	6.278	717.2722	85.53	304.7	6.094	668.6147	84.91
1276	1282	12	337.5	4.05	721.3222	86.01	327.9	3.9348	672.5495	85.40
1288	1301	19	332.2	6.3118	727.6340	86.75	322.8	6.1332	678.6827	86.18
1314	1324.5	23.5	258.0	6.063	733.6970	87.49	250.9	5.89615	684.5784	86.93
1335	1359.5	35	155.3	5.4355	739.1325	88.13	151.1	5.2885	689.8674	87.60
1384	1408	48.5	1.1	.05335	739.1859	88.14	1.1	.05335	689.9207	87.61
1432	1444.5	36.5	21.1	.77015	739.9560	88.23	20.5	.74825	690.6690	87.71
1457	1464.5	20	53.7	1.074	741.0300	88.36	52.4	1.048	691.7170	87.84
1472	1507	42.5	47.1	2.0018	743.0318	88.60	46.0	1.955	693.6720	88.09
1542	1557	50	235.2	11.76	754.7918	90.00	229.9	11.495	705.1670	89.55

Table 8 (Continued)

AM 2		$\alpha = 1.3$			$\beta = 0.02$			$\alpha = 1.3$	$\beta = 0.04$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
1572	1585.5	28.5	223.5	6.3698	761.1615	90.76	218.6	6.2301	716.3971	90.34
1599	1603.5	18	219.0	3.942	765.1035	91.23	214.0	3.852	715.2491	90.83
1608	1617	13.5	209.0	2.8215	767.9250	91.57	205.0	2.7675	718.0166	91.18
1626	1635	18	210.0	3.78	771.7050	92.02	205.0	3.69	721.7066	91.65
1644	1647	12	200.0	2.4	774.1050	92.30	196.0	2.352	724.0586	91.95
1650	1663	16	198.0	3.168	777.2730	92.68	193.0	3.088	727.1466	92.34
1676	1704	41	173.0	7.093	784.3660	93.53	169.0	6.929	734.0756	93.22
1732	1757	53	153.0	8.109	792.4650	94.49	150.0	7.95	742.0256	94.23
1782	1822	65	124.0	8.06	800.5350	95.46	121.0	7.865	749.89-6	95.23
1862	1908.5	86.5	1.0	.0865	800.6215	95.47	1.0	.0865	749.9771	95.24
1955	1981.5	73	30.0	2.19	802.8115	95.73	30.0	2.19	752.1671	95.52
2008	2011	29.5	60.0	1.77	804.5815	95.94	59.0	1.7405	753.9076	95.74
2014	2035.5	24.5	68.0	1.666	806.7125	96.55	67.0	1.6415	755.5491	95.94
2057	2090.5	55	63.0	3.465	809.7125	96.55	62.0	3.41	758.9591	96.38
2124	2140	49.5	61.0	3.0195	812.7365	96.90	60.0	2.97	761.9290	96.73
2156	2178.5	38.5	57.0	2.1945	814.9310	97.15	56.0	2.156	764.0850	97.01
2201	2233.5	55	65.0	3.575	818.5060	97.58	64.0	3.52	767.6050	97.45
2266	2293	59.5	61.0	3.6295	822.1355	98.01	60.0	2.24	771.1750	97.91
2320	2329	36	56.0	2.016	824.1515	98.25	55.0	1.98	773.1550	98.16
2338	2347	18	53.0	.954	825.1055	98.36	52.0	.936	774.0910	98.28
2356	2372	25	50.0	1.25	826.3555	98.51	49.0	1.225	775.3160	98.43
2388	2401.5	29.5	30.0	.885	827.2405	98.62	30.0	.885	776.2011	98.54
2415	2434	32.5	26.0	.845	828.0855	98.72	26.0	.845	777.0461	98.65
2453	2473.5	39.5	24.0	.948	829.0335	98.83	23.0	.9085	777.9546	98.77
2494	2515.5	42	14.0	.588	829.6215	98.90	14.0	.588	778.5426	98.84
2537	2718.5	203	2.0	.406	830.0275	98.95	2.0	.406	778.9486	98.89
2900	2920.5	202	1.0	.202	830.2295	98.97	1.0	.202	779.1506	98.92
2941	2947.5	27	3.0	.081	830.3105	98.98	3.0	.081	779.2316	98.93
2954	2963.5	16	3.0	.048	830.3585	98.99	3.0	.048	779.2796	98.94
2973	2989	25.5	5.0	.1275	830.4860	99.01	5.0	.1275	779.4070	98.95

Table 8 (Continued)

AM 2		α = 1.3			β = 0.02		α = 1.3		β = 0.04	
λ nm	λm nm	Δλ nm	Eλ W m^{-2} µm^{-1}	ΔE W m^{-2}	E (0-λ_m) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %	Eλ W m^{-2} µm^{-1}	ΔE W m^{-2}	E (0-λ_m) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %
3005	3025	36	5.0	.18	830.6660	99.03	5.0	.18	779.5871	98.97
3045	3050.5	25.5	2.0	.051	830.7170	99.03	2.0	.051	779.6381	98.98
3056	3076.5	26	3.0	.078	830.7950	99.04	2.0	.052	779.6901	98.99
3097	3114.5	38	1.0	.038	830.8330	99.05	1.0	.038	779.7281	98.99
3132	3144	29.5	4.0	.118	830.9510	99.06	4.0	.118	779.8461	99.01
3156	3180	36	17.0	.612	831.4630	99.13	17.0	.612	780.4581	99.09
3204	3209	29	1.0	.029	831.5920	99.14	1.0	.029	780.4871	99.09
3214	3229.5	20.5	2.0	.041	831.6330	99.14	2.0	.041	780.5281	99.09
3245	3252.5	23	2.0	.046	831.6790	99.15	2.0	.046	780.5741	99.10
3260	3272.5	20	2.0	.04	831.71904	99.15	2.0	.04	780.6141	99.10
3285	3301	28.5	13.0	.3705	832.0895	99.20	13.0	.3705	780.9845	99.15
3317	3330.5	29.5	11.0	.3245	832.4140	99.24	11.0	.3245	781.3091	99.19
3344	3373.5	43	2.0	.086	832.5000	99.25	2.0	.086	781.3951	99.21
3403	3426.5	53	11.0	.583	833.0830	99.31	11.0	.583	781.9780	99.28
3450	3478.5	52	12.0	.624	833.7070	99.39	12.0	.624	782.6020	99.36
3507	3522.5	44	12.0	.528	834.2350	99.45	12.0	.528	783.1301	99.42
3538	3555.5	33	11.0	.363	834.5980	99.50	11.0	.363	783.9931	99.47
3573	3603	47.5	9.0	.4275	835.0255	99.55	9.0	.4275	783.9205	99.52
3633	3653	50	10.0	.5	835.5255	99.61	10.0	.5	784.4206	99.59
3673	3684.5	31.5	8.2	.2583	835.7838	99.64	8.0	.252	789.6726	99.62
3696	3704	19.5	10.0	.195	835.9788	99.66	10.0	.195	784.8676	99.64
3712	3738.5	34.5	11.0	.3795	836.3583	99.71	11.0	.3795	785.2471	99.69
3765	3788.5	50	9.0	.45	836.8083	99.76	9.0	.45	785.6971	99.75
3812	3850	61.5	8.0	.492	837.3003	99.82	8.0	.492	786.1891	99.81
3888	3905.5	55.5	8.0	.444	837.7443	99.87	7.0	.3885	786.5775	99.86
3923	3935.5	30	7.0	.21	837.9543	99.90	7.0	.21	786.7876	99.89
3948	3996.5	61	7.0	.427	838.3813	99.95	7.0	.427	787.2146	99.94
4045	4071.5	75	6.0	.450	838.8313	100.00	6.0	.450	787.6646	100.00

Table 9. Terrestrial Irradiance for Air Mass 2 Computed from the Spectral Data in Table 5

AM 2			$\alpha = 0.66$		$\beta = 0.085$		$\alpha = 0.66$		$\beta = 0.17$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
300	302.5	5	0	0	0	0.00	0	0	0	0.00
305	307.5	5	0	0	0	0.00	0	0	0	0.00
310	312.5	5	1.0	.005	.005	0.00	1.0	.005	.005	0.00
315	317.5	5	8.0	.04	.045	0.01	6.0	.03	.035	0.01
320	322.5	5	49.0	.245	.29	0.04	34.0	.17	.205	0.03
325	327.5	5	75.0	.375	.665	0.09	52.0	.26	.465	0.08
330	332.5	5	104.0	.52	1.185	0.16	73.0	.365	.83	0.14
335	337.5	5	136.0	.68	1.865	0.26	96.0	.48	1.31	0.22
340	342.5	5	173.0	.865	2.73	0.38	123.0	.615	1.925	0.32
345	347.5	5	189.0	.945	3.675	0.51	134.0	.67	2.595	0.44
350	352.5	5	211.0	1.055	4.73	0.65	150.0	.75	3.345	0.56
355	357.5	5	229.0	1.145	5.875	0.81	164.0	.82	4.165	0.70
360	362.5	5	247.0	1.235	7.11	0.98	177.0	.885	5.05	0.85
365	367.5	5	278.0	1.39	8.5	1.17	200.0	1.0	6.05	1.02
370	372.5	5	308.0	1.54	10.04	1.38	222.0	1.11	7.16	1.21
375	377.5	5	321.0	1.605	11.645	1.60	232.0	1.16	8.32	1.40
380	382.5	5	330.0	1.65	13.295	1.83	239.0	1.195	9.515	1.61
385	387.5	5	339.0	1.695	14.99	2.06	246.0	1.23	10.745	1.81
390	392.5	5	355.0	1.775	16.765	2.31	258.0	1.29	12.035	2.03
395	397.5	5	402.0	2.01	18.775	2.58	294.0	1.47	13.505	2.28
400	402.5	5	505.0	2.525	21.3	2.93	370.0	1.85	15.355	2.59
405	407.5	5	600.0	3.	24.3	3.34	440.0	2.2	17.555	2.96
410	412.5	5	658.0	3.29	27.59	3.80	485.0	2.425	19.98	3.37
415	417.5	5	688.0	3.44	31.03	4.27	507.0	2.535	22.515	3.80
420	422.5	5	698.0	3.49	34.52	4.75	516.0	2.58	25.095	4.23
425	427.5	5	697.0	3.485	38.005	5.23	517.0	2.585	27.68	4.69
430	432.5	5	696.0	3.48	41.485	5.71	517.0	2.585	30.265	5.11
435	437.5	5	728.0	3.64	45.125	6.12	542.0	2.71	32.975	5.57
440	442.5	5	816.0	4.08	49.205	6.77	609.0	3.045	36.02	6.08
445	447.5	5	893.0	4.465	53.67	7.39	668.0	3.34	39.36	6.65

Table 9 (Continued)

AM 2		$a = 0.66$			$\beta = 0.085$		$a = 0.66$		$\beta = 0.17$	
			Eλ		E	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$	Eλ		E	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$
λ	λm	Δλ	W m^{-2}	ΔE	(0-λm)		W m^{-2}	ΔE	(0-λ_m)	
nm	nm	nm	μm^{-1}	W m^{-2}	W m^{-2}	%	μm^{-1}	W m^{-2}	W m^{-2}	%
450	452.5	5	961.0	4.805	58.475	8.05	721.0	3.605	42.965	7.25
455	457.5	5	1001.0	5.005	63.48	8.74	752.0	3.76	46.725	7.89
460	462.5	5	1021.0	5.105	68.585	9.44	769.0	3.845	50.57	8.54
465	467.5	5	1028.0	5.14	73.725	10.14	775.0	3.875	54.445	9.19
470	472.5	5	1036.0	5.18	78.905	10.86	783.0	3.915	58.36	9.85
475	477.5	5	1058.0	5.29	84.195	11.59	801.0	4.005	62.365	10.53
480	482.5	5	1090.1	5.4505	89.6455	12.34	827.0	4.135	66.5	11.23
485	487.5	5	1054.0	5.27	94.9155	13.06	802.0	4.01	70.51	11.90
490	492.5	5	1056.0	5.28	100.1955	13.78	805.0	4.025	74.535	12.58
495	497.5	5	1078.0	5.39	105.5855	14.53	823.0	4.115	78.65	13.28
500	502.5	5	1084.0	5.42	111.0055	15.27	829.0	4.145	82.795	13.98
505	507.5	5	1080.0	5.4	116.4055	16.02	827.0	4.135	86.93	14.68
510	512.5	5	1067.0	5.335	121.7405	16.75	818.0	4.09	91.02	15.37
515	517.5	5	1046.0	5.23	126.9705	17.47	804.0	4.02	95.04	16.05
520	522.5	5	1054.0	5.27	132.2405	18.20	811.0	4.055	99.095	16.73
525	527.5	5	1073.0	5.365	137.6055	18.94	827.0	4.135	103.23	17.29
530	532.5	5	1075.0	5.375	142.9805	19.67	830.0	4.15	107.38	18.13
535	537.5	5	1068.0	5.34	148.3205	20.41	826.0	4.13	111.51	18.83
540	542.5	5	1055.0	5.275	153.5955	21.14	817.0	4.085	115.595	19.52
545	547.5	5	1046.0	5.23	158.8255	21.86	811.0	4.055	119.65	20.20
550	552.5	5	1036.0	5.18	164.0055	22.57	805.0	4.025	123.675	20.88
555	557.5	5	1037.0	5.185	169.1905	23.28	807.0	4.035	127.71	21.56
560	562.5	5	1027.0	5.135	174.3255	23.99	800.0	4.	131.71	22.24
565	567.5	5	1037.0	5.185	179.5105	24.70	810.0	4.05	135.76	22.92
570	572.5	5	1046.0	5.23	184.7405	25.42	818.0	4.09	139.85	23.61
575	577.5	5	1055.0	5.275	190.0155	26.15	826.0	4.13	143.98	24.31
580	582.5	5	1057.0	5.285	195.3005	26.87	829.0	4.145	148.125	25.01
585	587.5	5	1060.0	5.3	200.6005	27.60	832.0	4.16	152.285	25.71
590	592.5	5	1057.0	5.285	205.8855	28.33	831.0	4.155	156.44	26.41
595	597.5	5	1051.0	5.255	211.1405	29.05	827.0	4.135	160.575	27.11

Table 9 (Continued)

AM 2		a = 0.66			β = 0.085		a = 0.66		β = 0.17	
			Eλ		E	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$	Eλ		E	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$
λ	λm	Δλ	W m^{-2}	ΔE	(0-λ_m)		W m^{-2}	ΔE	(0-λ_m)	
nm	nm	nm	μm^{-1}	W m^{-2}	W m^{-2}	%	μm^{-1}	W m^{-2}	W m^{-2}	%
600	602.5	5	1045.0	5.225	216.3655	29.77	824.0	4.12	164.695	27.81
605	607.5	5	1044.0	5.22	221.5855	30.49	824.0	4.12	168.815	28.50
610	615	7.5	1046.0	7.845	229.4305	31.57	827.0	6.2025	175.0175	29.55
620	625	10	1046.0	10.46	239.8905	33.01	828.0	8.28	183.2975	30.95
630	635	10	1045.0	10.45	250.3405	34.45	830.0	8.3	191.5975	32.35
640	645	10	1048.0	10.48	260.8205	35.89	834.0	8.34	199.9375	33.76
650	655	10	1046.0	10.46	271.2805	37.33	834.0	8.34	208.2775	35.16
660	665	10	1042.0	10.42	281.7005	38.76	833.0	8.33	216.6075	36.57
670	675	10	1034.0	10.34	292.0405	40.19	828.0	8.28	224.8875	37.97
680	685	10	1026.0	10.26	302.3005	41.60	824.0	8.24	233.1275	39.36
690	695	10	1021.0	10.21	312.5100	43.00	821.0	8.21	241.3	40.75
700	705	10	1008.9	10.0890	322.5990	44.39	813.7	8.1370	249.4745	42.12
710	711	6	996.6	5.9796	328.5786	45.21	805.54	4.833	254.3075	42.94
712	713.5	2.5	990.6	2.4765	331.0551	45.56	800.9	2.0022	256.3097	43.27
715	716.25	2.75	948.2	2.6076	333.6626	45.91	767.0	2.1092	258.4190	43.63
717.5	718.75	2.5	732.2	1.8305	335.4932	46.17	592.6	1.4815	259.9005	43.88
720	721.25	2.5	677.5	1.6938	337.1869	46.40	548.5	1.3712	261.2718	44.11
722.5	723.75	2.5	859.5	2.1488	339.3356	46.69	696.1	1.7401	263.0120	44.41
725	726.25	2.5	744.9	1.8622	341.1979	46.95	603.7	1.5092	264.5212	44.66
727.5	728.75	2.5	755.4	1.8885	343.0864	47.21	612.5	1.5312	266.0525	44.92
730	731.25	2.5	758.1	1.8952	344.9816	47.42	615.0	1.5375	267.5900	45.18
732.5	733.75	2.5	847.8	2.1195	347.1012	47.76	688.0	1.7200	269.3100	45.46
735	736.25	2.5	911.5	2.8788	349.3799	48.08	740.1	1.8502	271.1602	45.78
737.5	738.75	2.5	907.2	2.2692	351.6492	48.39	737.4	1.8435	273.0038	46.09
740	741.25	2.5	912.9	2.2822	353.9314	48.70	741.9	1.8548	274.0585	46.41
742.5	743.75	2.5	911.0	2.2775	356.2089	49.02	740.8	1.8520	276.7105	46.72
745	746.25	2.5	934.4	2.3360	358.5449	49.34	760.0	1.9000	278.6105	47.04
747.5	753.75	7.5	941.9	7.0642	365.6092	50.31	766.5	5.7488	284.3952	48.01
760	761.05	7.3	925.6	6.7576	372.3668	51.24	755.0	5.5115	289.8708	48.94
762.1	763.55	2.5	600.1	1.5002	373.8670	51.45	489.7	1.2242	291.0950	49.15

Table 9 (Continued)

AM 2		$\alpha = 0.66$			$\beta = 0.085$		$\alpha = 0.66$		$\beta = 0.17$	
λ nm	λm nm	$\Delta\lambda$ nm	Eλ $\mathrm{W\,m^{-2}}$ $\mathrm{\mu m^{-1}}$	ΔE $\mathrm{W\,m^{-2}}$	E $(0\text{-}\lambda_m)$ $\mathrm{W\,m^{-2}}$	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	Eλ $\mathrm{W\,m^{-2}}$ $\mathrm{\mu m^{-1}}$	ΔE $\mathrm{W\,m^{-2}}$	E $(0\text{-}\lambda_m)$ $\mathrm{W\,m^{-2}}$	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
765	775	11.45	918.6	10.5180	384.3850	52.89	489.7	1.2242	291.6802	50.60
785	787.5	12.5	899.5	11.1188	395.5037	54.42	728.6	9.1080	308.7877	52.13
790	792.5	5.0	862.5	4.3125	399.8162	55.02	707.2	3.5360	312.3237	52.73
795	797.5	5.0	851.7	4.2585	404.0747	55.60	698.4	3.4945	315.8182	53.32
800	802.5	5.0	813.2	4.0660	408.1407	56.16	667.8	3.3390	319.1572	53.88
805	807.5	5.0	832.3	4.1615	412.3002	56.74	684.0	3.4200	322.5772	54.66
810	812.5	5.0	798.7	3.9935	416.2957	57.28	656.9	3.2845	325.8617	55.02
815	817.5	5.0	620.1	3.1005	419.3962	57.71	510.4	2.5520	328.4137	55.45
820	822.5	5.0	669.9	3.3495	422.7457	58.17	551.8	2.7590	331.1727	55.91
825	827.5	5.0	648.1	3.2405	425.9862	58.62	534.4	2.6720	333.8447	56.36
830	832.5	5.0	664.8	3.3240	429.3102	59.08	548.62	2.7430	336.5877	56.83
835	837.5	5.0	736.6	3.6830	432.9932	59.58	608.2	3.0410	339.6287	57.34
840	842.5	5.0	777.7	3.8885	436.8817	60.12	642.7	3.2135	342.8422	57.88
845	847.5	5.0	781.4	3.9070	440.7887	60.66	646.2	3.2310	346.0732	58.43
850	870	22.5	789.6	17.766	458.5547	63.10	753.2	14.7038	360.7770	60.91
890	892.5	22.5	734.7	16.5308	475.0855	65.37	611.5	13.7588	374.5357	63.23
895	898.5	6.0	639.9	3.8394	478.9249	65.90	533.0	3.1980	377.7337	63.77
902	904.5	6.0	518.3	3.1098	482.0347	66.33	432.4	2.5944	380.3281	64.21
907	909.5	5.0	503.6	2.5180	484.5527	66.68	420.2	2.1010	382.4291	64.57
912	914	4.5	482.0	2.1690	486.7217	66.97	402.3	1.8104	384.3295	64.87
916	918	4.0	437.5	1.7500	488.4717	67.22	365.4	1.4616	385.7011	65.12
920	922	4.0	549.0	2.1960	490.6677	67.52	458.8	1.8352	387.5363	65.43
924	926	4.0	532.9	2.1316	492.7993	67.87	445.5	1.7820	389.3183	65.73
928	931.6	5.5	414.8	2.2814	495.0807	68.13	346.9	1.9080	391.2262	66.05
935	939	7.5	146.6	1.0995	496.1802	68.23	122.7	0.9202	392.1465	66.21
943	946.5	7.5	252.0	1.8900	498.0702	68.54	211.1	1.5840	393.7305	66.48
950	952	5.5	229.7	1.2634	499.3335	68.71	192.6	1.0593	394.7898	66.55
954	955.5	3.5	216.2	0.7567	500.0902	68.82	181.4	0.6349	395.4247	66.76
957	961	5.5	307.6	1.6918	501.7820	69.05	258.2	1.4201	396.8448	67.00
965	970	9.0	402.3	3.6207	505.4027	69.55	338.1	3.0429	399.8877	67.51

Table 9 (Continued)

AM 2		$\alpha = 0.66$			$\beta = 0.085$		$\alpha = 0.66$		$\beta = 0.17$	
λ nm	λm nm	$\Delta\lambda$ nm	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	$E\lambda$ W m^{-2} μm^{-1}	ΔE W m^{-2}	E $(0\text{-}\lambda_m)$ W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
975	978	8.0	485.8	3.8864	509.2891	70.08	408.7	3.2696	403.1573	68.067
981	982.5	4.5	550.7	2.4782	511.7673	70.42	463.5	2.0858	405.2430	68.419
984	987	4.5	588.3	2.6474	514.4146	70.79	495.5	2.2298	407.4728	68.795
990	992.5	5.5	624.2	3.4331	517.8477	71.26	526.0	2.8930	410.3658	69.28
995	1006.5	14.0	626.2	8.7696	526.6173	72.47	528.1	7.3934	417.7592	70.53
1018	1050	43.5	529.0	23.0115	549.6288	75.63	447.2	19.4532	437.2124	73.82
1082	1088	38.0	421.2	16.0056	565.6344	77.83	358.4	13.6192	450.8316	76.116
1094	1096	8.0	409.5	3.2760	568.9104	78.29	348.9	2.7912	453.6228	76.59
1098	1099.5	3.5	422.9	1.4802	570.3906	78.49	360.5	1.2618	454.8845	76.80
1101	1114.5	15.0	446.5	6.6975	577.1114	79.41	380.7	5.7105	460.5950	77.77
1128	1129.5	15	71.0	1.0650	578.1130	79.56	60.7	0.9105	461.5055	77.92
1131	1134	4.5	84.3	0.3794	578.5324	79.61	72.1	0.3244	461.8300	77.97
1137	1140.5	6.5	77.7	0.5050	579.0375	79.68	66.5	0.4322	462.2622	78.05
1144	1145.5	5.0	117.8	0.5890	579.6265	79.76	100.9	0.5045	462.7667	78.13
1147	1162.5	17.0	103.9	1.7663	581.3928	80.00	88.9	1.5113	464.2780	78.39
1178	1183.5	21.0	313.3	6.5793	687.9721	80.91	268.9	5.6469	469.9249	79.34
1189	1191.0	7.5	325.0	2.4375	590.4096	81.24	279.3	2.0948	472.0197	79.69
1193	1207.5	16.5	378.9	6.25185	596.6614	82.10	325.7	5.37405	447.3937	80.60
1222	1229	21.5	329.6	7.0864	603.7478	83.05	284.0	6.106	483.4997	81.63
1236	1250	21	337.9	7.0959	610.8437	84.06	291.5	6.1215	489.642	82.67
1264	1270	20	279.4	5.588	616.4317	84.82	241.6	4.832	494.4532	83.48
1276	1282	12	300.7	3.6084	620.0401	85.32	260.2	3.1224	497.5756	84.00
1288	1301	19	296.1	5.6259	625.6660	86.10	256.4	4.8716	502.4472	84.83
1314	1324.5	23.5	230.2	5.4097	631.8684	86.84	199.8	4.6953	507.1425	85.62
1335	1359.5	35	138.7	4.8545	635.9302	87.51	120.5	4.2175	511.3600	86.34
1384	1408	48.5	1.0	.0485	635.9787	87.51	0.9	.04365	511.4037	86.34
1432	1444.5	36.5	18.9	.68985	636.6686	87.61	16.5	.60225	512.5009	86.44
1457	1464.5	20	48.2	.964	637.6326	87.74	42.2	.844	512.8499	86.586
1472	1507	42.5	42.3	1.79775	639.4303	87.99	37.1	1.5678	514.4267	86.85
1542	1557	50	211.7	10.585	650.0153	89.45	186.4	9.32	523.7467	88.43

Table 9 (Continued)

AM 2		α = 0.66		β = 0.085			α = 0.66		β = 0.17	
λ nm	λm nm	Δλ nm	Eλ W m^{-2} μm^{-2}	ΔE W m^{-2}	E (0-λ$_m$) W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ$_m$) W m^{-2}	$\frac{E(0\text{-}\lambda_m)}{E(0\text{-}\infty)}$ %
1572	1585.5	28.5	201.4	5.7399	655.7552	90.24	177.6	5.0616	528.8083	89.28
1599	1603.5	18	197.0	3.546	659.3012	90.72	174.0	3.132	531.9403	89.81
1608	1617	13.5	189.0	2.5515	661.8527	91.07	167.0	2.2545	534.1948	90.19
1626	1635	18	189.0	3.402	665.2547	91.54	167.0	3.006	537.2008	90.70
1644	1647	12	180.0	2.16	667.4147	91.84	160.0	1.92	539.1208	91.02
1650	1663	16	178.0	2.848	670.2627	92.23	158.0	2.528	541.6488	91.45
1676	1704	41	156.0	6.396	676.6587	93.11	138.0	5.658	547.3068	92.40
1732	1757	53	139.0	7.367	684.0257	94.13	123.0	6.519	553.8258	93.50
1782	1822	65	112.0	7.28	691.3057	95.13	100.0	6.5	560.3258	94.60
1862	1908.5	86.5	1.0	.0865	691.3922	95.14	1.0	.0865	560.4123	94.62
1955	1981.5	73	28.0	2.044	693.4362	95.42	25.0	1.825	562.2373	94.92
2008	2011	29.5	55.0	1.6225	695.0587	95.64	49.0	1.4455	563.6828	95.17
2014	2035.5	24.5	62.0	1.519	696.5777	95.85	56.0	1.3272	565.0548	95.40
2057	2090.5	55	58.0	3.19	699.7677	96.29	52.0	2.86	567.9148	95.88
2124	2140	49.5	56.0	2.772	702.5397	96.67	51.0	2.5245	570.4393	96.31
2156	2178.5	38.5	52.0	2.002	704.5417	96.93	47.0	1.8095	572.2488	96.59
2201	2233.5	55	59.0	3.245	707.7867	97.38	54.0	2.97	575.2188	97.09
2266	2293	59.5	56.0	3.332	711.1187	97.84	50.0	2.975	578.1938	97.60
2320	2329	36	52.0	1.872	712.9907	98.09	47.0	1.692	579.8858	97.88
2338	2347	18	49.0	.882	713.8727	98.21	44.0	.792	580.6778	98.01
2356	2372	25	46.0	1.15	715.0227	98.37	41.0	1.025	581.7028	98.19
2388	2401.5	29.5	28.0	.826	715.8487	98.49	25.0	.7375	582.4402	98.31
2415	2434	32.5	24.0	.78	716.6287	98.59	22.0	.715	583.1553	98.43
2453	2473.5	39.5	22.0	.869	717.4979	98.71	20.0	.79	583.9453	98.57
2494	2515.5	42	13.0	.546	718.0437	98.79	12.0	.504	584.4493	98.65
2537	2718.5	203	2.0	.406	718.4497	98.84	1.0	.203	584.6523	98.69
2900	2920.5	202	1.0	.202	718.6517	98.87	1.0	.202	584.8543	98.72
2941	2947.5	27	3.0	.081	718.7327	98.88	3.0	.081	584.9353	98.73
2954	2963.5	16	3.0	.048	718.7807	98.89	2.0	.032	584.9673	98.74
2973	2989	25.5	5.0	.1275	718.9082	98.91	5.0	.1275	585.0948	98.76

Table 9 (Continued)

AM 2		α = 0.66			β = 0.085		α = 0.66		β = 0.17	
λ nm	λm nm	Δλ nm	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ$_m$) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %	Eλ W m^{-2} μm^{-1}	ΔE W m^{-2}	E (0-λ$_m$) W m^{-2}	$\frac{E(0-\lambda_m)}{E(0-\infty)}$ %
3005	3025	36	4.0	.144	719.0522	98.93	4.0	.144	585.2388	98.78
3045	3050.5	25.5	2.0	.051	719.1032	98.93	2.0	.051	585.2898	98.79
3056	3076.5	26	2.0	.052	719.1552	98.94	2.0	.052	585.3418	98.80
3097	3114.5	38	1.0	.038	719.1932	98.95	1.0	.038	585.3798	98.81
3132	3144	29.5	4.0	.118	719.3112	98.96	4.0	.118	585.4978	98.83
3156	3180	36	16.0	.576	719.8872	99.04	15.0	.54	586.0378	98.92
3204	3209	29	1.0	.029	719.9162	99.05	1.0	.029	586.0668	98.92
3214	3229.5	20.5	2.0	.041	719.9572	99.05	1.0	.0205	586.0873	98.93
3245	3252.5	23	2.0	.046	720.0032	99.06	2.0	.046	586.1333	98.94
3260	3272.5	20	2.0	.04	720.0432	99.06	2.0	.04	586.1733	98.94
3285	3301	28.5	12.0	.342	720.3852	99.11	11.0	.3135	586.4868	99.00
3317	3330.5	29.5	10.0	.295	720.6802	99.15	10.0	.295	586.7818	99.05
3344	3373.5	43	2.0	.086	720.7662	99.16	2.0	.086	586.8678	99.06
3403	3426.5	53	10.0	.53	721.2962	99.24	10.0	.53	587.3978	99.15
3450	3478.5	52	11.0	.572	721.8682	99.31	10.0	.52	587.9178	99.24
3507	3522.5	44	11.0	.484	722.3522	99.38	11.0	.484	588.4018	99.32
3538	3555.5	33	11.0	.363	722.7152	99.43	10.0	.33	588.7318	99.37
3573	3603	47.5	9.0	.4275	723.1427	99.49	8.0	.38	589.1118	99.44
3633	3653	50	10.0	.5	723.5427	99.56	9.0	.45	589.5618	99.51
3673	3684.5	31.5	8.0	.252	723.8947	99.59	7.0	.2205	589.7823	99.55
3696	3704	19.5	10.0	.195	724.0897	99.62	9.0	.1755	589.9578	99.58
3712	3738.5	34.5	10.0	.345	724.4347	99.67	9.0	.3105	590.2683	99.63
3765	3788.5	50	9.0	.45	724.8847	99.73	8.0	.4	590.6683	99.70
3812	3850	61.5	8.0	.492	725.3767	99.80	7.0	.4305	591.0988	99.77
3888	3905.3	55.5	7.0	.3885	725.7652	99.85	7.0	.3885	591.4873	99.84
3923	3935.5	30	7.0	.21	725.9752	99.88	7.0	.21	591.7973	99.87
3948	3996.5	61	7.0	.427	726.4022	99.93	6.0	.366	592.0633	99.94
4045	4071.5	75	6.0	0.450	726.8522	100.00	5.0	0.375	592.4383	100.00

Table 10. Wavelengths in Nanometers, for the 100 Selected Ordinate Method of Computing Solar Properties

No.	$\frac{E(0-\lambda)}{E(0-\infty)}$	α=1.3	β=.02	α=1.3	β=.04	α=.66	β=.085	α=.66	β=.17
		AM1.5	AM2	AM1.5	AM2	AM1.6	AM2	AM1.5	AM2
		nm	nm	nm	nm	nm	nm	nm	nm
1	0.005	339.4	346.5	340.5	348.4	341.9	347.3	341.8	349.9
2	0.015	363.9	373.8	366.1	377.0	364.7	375.2	368.0	379.9
3	0.025	382.2	394.2	385.2	398.0	383.5	396.0	388.0	401.0
4	0.035	398.3	407.8	401.1	410.9	399.6	409.2	403.5	414.0
5	0.045	411.2	418.2	411.7	421.7	410.3	419.9	414.2	425.5
6	0.055	418.3	428.2	421.2	432.4	419.7	430.3	422.5	436.8
7	0.065	427.4	438.0	430.8	442.1	429.0	440.1	434.3	446.2
8	0.075	436.5	446.3	439.8	450.2	438.2	448.4	433.3	454.4
9	0.085	444.4	453.6	444.7	457.7	446.1	455.8	451.0	462.2
10	0.095	451.6	460.6	454.7	464.9	453.2	462.9	458.2	469.8
11	0.105	458.2	467.5	461.6	472.0	460.0	470.0	465.4	477.3
12	0.115	464.7	474.3	468.3	478.9	466.6	476.9	472.4	484.5
13	0.125	471.2	480.8	475.0	485.8	473.3	483.6	479.2	491.9
14	0.135	477.7	487.5	481.5	492.8	479.8	490.5	486.1	499.1
15	0.145	483.9	494.1	488.1	499.5	486.3	497.3	493.0	506.2
16	0.155	490.4	500.7	494.7	506.3	492.9	504.0	499.8	513.5
17	0.165	496.8	507.2	501.2	513.2	499.4	510.8	506.6	520.8
18	0.175	503.2	513.9	507.8	520.1	505.9	517.7	513.6	528.0
19	0.185	509.7	520.6	515.5	527.0	512.5	524.6	520.6	535.2
20	0.195	516.2	527.3	521.9	533.8	519.2	531.3	527.5	542.4
21	0.205	522.9	533.9	528.0	540.7	525.9	538.1	534.4	549.7
22	0.215	529.4	540.6	534.6	547.6	532.5	545.0	541.4	557.0
23	0.225	535.9	547.3	541.4	554.6	539.3	552.0	548.5	564.4
24	0.235	542.5	554.2	548.2	561.7	546.1	559.0	555.7	571.7
25	0.245	549.3	561.1	555.2	568.7	553.0	566.1	562.9	578.9

Table 10 (Continued)

No.	E(0 − λ) / E(0 − ∞)	α=1.3	β=.02	α=1.3	β=.04	α=.66	β=.085	α=.66	β=.17
		AM1.5	AM2	AM1.5	AM2	AM1.5	AM2	AM1.5	AM2
		nm	nm	nm	nm	nm	nm	nm	nm
26	0.255	556.1	567.5	555.2	575.6	559.9	573.0	570.0	586.0
27	0.265	563.0	577.6	562.1	582.5	566.9	579.9	577.1	593.1
28	0.275	569.8	581.5	569.1	589.3	573.8	586.8	584.1	600.3
29	0.285	576.6	588.2	575.9	596.2	580.6	593.7	591.1	607.5
30	0.295	583.3	595.0	582.7	603.2	587.4	600.6	598.1	614.6
31	0.305	590.1	601.8	589.6	610.1	594.3	607.6	605.3	621.8
32	0.315	596.6	608.7	596.4	617.0	601.2	614.5	612.4	628.9
33	0.325	603.7	615.5	603.3	624.0	608.1	621.5	619.5	636.1
34	0.335	610.6	622.4	617.3	630.9	615.8	628.4	626.7	643.2
35	0.345	617.5	629.2	624.2	637.8	622.1	635.4	633.8	650.3
36	0.355	624.4	636.1	631.2	644.7	629.1	642.3	641.0	657.4
37	0.365	631.4	642.9	638.3	651.6	636.2	649.2	648.2	664.5
38	0.375	638.4	649.7	645.3	658.5	643.2	656.2	655.4	671.6
39	0.385	645.4	656.6	652.4	655.5	650.3	663.2	662.6	678.8
40	0.395	652.4	663.5	659.5	672.4	657.5	670.2	669.9	686.0
41	0.405	659.5	670.5	666.6	679.5	664.6	677.2	677.3	693.2
42	0.415	666.6	677.4	673.8	686.5	671.8	684.3	684.7	700.5
43	0.425	673.7	684.4	681.1	693.6	679.1	691.4	692.1	707.8
44	0.435	681.0	691.5	689.6	700.7	686.4	698.6	699.6	715.2
45	0.445	688.3	698.6	697.7	707.9	693.8	705.8	707.1	724.7
46	0.455	695.1	705.7	703.6	715.2	701.3	713.1	714.8	733.6
47	0.465	703.1	713.0	710.7	724.5	708.8	722.1	724.2	742.0
48	0.475	710.6	721.9	719.0	733.8	716.6	731.9	733.7	749.8
49	0.485	718.9	731.3	728.6	741.7	726.3	739.6	742.0	757.6
50	0.495	728.9	739.4	737.3	749.4	735.5	747.5	750.2	767.8

Table 10 (Continued)

No.	$\frac{E(0-\lambda)}{E(0-\infty)}$	α=1.3	β=.02	α=1.3	β=.04	α=.66	β=.085	α=.66	β=.17
		AM1.5	AM2	AM1.5	AM2	AM1.5	AM2	AM1.5	AM2
		nm	nm	nm	nm	nm	nm	nm	nm
51	0.505	737.3	747.2	745.4	757.1	743.8	755.2	758.2	779.9
52	0.515	745.6	754.9	753.6	765.8	751.9	764.0	767.3	782.3
53	0.525	753.6	763.2	762.0	773.6	760.0	771.9	775.6	790.6
54	0.535	762.2	771.5	776.7	781.7	769.1	780.0	784.1	799.1
55	0.545	770.9	779.6	779.1	789.9	777.5	788.1	792.8	807.8
56	0.555	779.3	787.7	787.6	798.2	786.1	796.6	801.9	818.1
57	0.565	787.9	796.2	796.5	807.0	794.9	805.4	811.2	829.0
58	0.575	796.8	805.0	805.6	817.0	804.1	815.0	822.3	839.0
59	0.585	806.1	814.5	811.7	828.0	813.7	826.2	833.4	848.1
60	0.595	816.3	825.7	826.9	838.1	825.2	836.7	843.3	857.2
61	0.605	827.7	832.8	837.6	847.4	836.1	846.1	853.0	866.3
62	0.615	838.4	845.7	847.3	856.5	846.0	855.3	862.6	875.7
63	0.625	848.2	854.9	857.0	865.6	855.8	864.5	872.4	885.4
64	0.635	858.0	864.2	866.8	875.1	865.6	874.0	882.7	895.5
65	0.645	867.8	873.7	877.0	884.8	875.7	883.8	893.1	908.6
66	0.655	878.2	883.6	887.4	895.0	886.2	893.9	906.1	922.9
67	0.665	888.8	893.7	989.5	908.1	897.3	906.9	920.9	947.3
68	0.675	900.6	906.8	913.0	922.7	911.6	921.8	942.2	969.7
69	0.685	915.6	921.7	927.4	947.2	930.1	945.4	965.9	983.5
70	0.695	930.9	945.6	956.2	970.1	953.9	969.2	981.1	995.0
71	0.705	960.4	969.6	974.3	984.0	973.2	982.5	993.6	1006.1
72	0.715	977.5	983.8	988.0	995.7	987.2	995.3	1005.6	1019.3
73	0.725	990.8	995.8	1000.3	1007.3	999.6	1007.0	1019.4	1032.6
74	0.735	1003.3	1407.7	1013.5	1020.9	1012.8	1020.7	1033.2	1045.8
75	0.745	1017.3	1021.7	1027.7	1034.5	1027.1	1034.4	1047.1	1061.3

Table 10 (Continued)

No.	$\frac{E(0-\lambda)}{E(0-\infty)}$	$\alpha=1.3$	$\beta=.02$	$\alpha=1.3$	$\beta=.04$	$\alpha=.66$	$\beta=.085$	$\alpha=.66$	$\beta=.17$
		AM1.5	AM2	AM1.5	AM2	AM1.5	AM2	AM1.5	AM2
		nm	nm	nm	nm	nm	nm	nm	nm
76	0.755	1031.7	1035.6	1041.9	1048.1	1041.4	1048.2	1063.4	1077.8
77	0.765	1046.1	1049.5	1057.4	1064.7	1056.9	1065.0	1080.3	1094.5
78	0.775	1063.0	1067.0	1094.9	1081.8	1674.5	1082.2	1097.7	1110.4
79	0.785	1080.8	1084.5	1092.5	1099.1	1092.3	1099.7	1114.4	1165.0
80	0.795	1099.1	1102.2	1110.0	1119.3	1109.8	1123.6	1168.7	1186.9
81	0.805	1124.8	1139.9	1163.5	1172.9	1163.5	1174.0	1190.6	1205.7
82	0.815	1172.9	1178.6	1186.5	1194.8	1186.5	1195.9	1210.5	1226.3
83	0.825	1195.6	1200.1	1207.1	1214.8	1207.3	1216.2	1232.2	1246.7
84	0.835	1217.4	1221.6	1242.9	1236.5	1230.0	1238.0	1254.4	1270.4
85	0.845	1240.4	1243.8	1252.4	1259.5	1252.9	1261.6	1279.6	1293.4
86	0.855	1266.0	1269.3	1278.6	1284.3	1279.3	1286.4	1304.4	1320.9
87	0.865	1292.3	1294.5	1304.6	1310.9	1305.5	1313.8	1339.9	1452.4
88	0.875	1322.1	1325.3	1342.5	1354.1	1344.2	1359.1	1503.5	1527.6
89	0.885	1459.7	1489.4	1509.6	1521.1	1511.1	1524.5	1540.2	1559.5
90	0.895	1532.3	1539.1	1545.8	1555.4	1547.3	1558.9	1575.4	1593.0
91	0.905	1570.4	1575.7	1583.6	1591.5	1585.2	1596.2	1612.6	1628.0
92	0.915	1611.0	1614.3	1623.8	1629.3	1625.6	1633.3	1652.2	1665.2
93	0.925	1654.5	1655.3	1667.1	1670.6	1669.1	1675.5	1696.4	1708.6
94	0.935	1703.5	1702.7	1716.9	1718.8	1719.2	1724.3	1746.4	1756.8
95	0.945	1760.5	1757.4	1774.3	1774.7	1777.0	1781.3	1805.4	1816.0
96	0.955	1928.5	1918.0	1969.8	1977.5	1978.9	1991.9	2026.4	2046.5
97	0.965	2086.8	2083.6	2103.7	2106.6	2108.0	2117.5	2146.4	2172.4
98	0.975	2225.5	2221.4	2238.6	2238.0	2242.6	2248.1	2272.9	2281.0
99	0.985	2390.0	2369.9	2405.5	2389.9	2412.4	2405.8	2455.1	2453.9
100	0.995	3558.2	3560.0	3573.6	3581.1	3574.4	3608.5	3630.4	3643.6

Table 11. Wavelengths, in Nanometers, for the 50 Selected Ordinate Method of Computing Solar Properties

No.	$\frac{E(0-\lambda)}{E(0-\infty)}$	$\alpha=1.3$	$\beta=.02$	$\alpha=1.3$	$\beta=.04$	$\alpha=.66$	$\beta=.085$	$\alpha=.66$	$\beta=.17$
		AM1.5	AM2	AM1.5	AM2	AM1.5	AM2	AM1.5	AM2
		nm	nm	nm	nm	nm	nm	nm	nm
1	0.01	352.7	361.9	354.4	364.5	353.3	363.1	354.0	366.9
2	0.03	390.8	401.8	393.9	404.7	392.3	403.3	396.9	408.3
3	0.05	413.8	423.2	416.5	427.1	415.1	425.1	419.3	431.2
4	07	432.1	442.3	435.5	446.2	432.5	444.4	439.0	450.4
5	0.09	448.1	457.2	451.3	461.3	449.7	459.4	454.7	466.0
6	0.11	461.5	470.7	464.9	475.5	463.3	473.5	468.9	480.9
7	0.13	474.5	484.1	478.2	489.3	476.5	487.1	482.6	495.5
8	0.15	487.2	497.4	491.4	502.9	489.6	500.7	496.4	507.8
9	0.17	500.0	510.5	504.5	516.7	502.6	514.2	510.1	524.4
10	0.19	512.9	524.0	517.9	530.4	515.9	527.9	524.1	538.8
11	0.21								
11	0.21	526.1	537.2	531.3	544.1	529.2	541.6	537.9	553.4
12	0.23	539.2	550.8	544.8	558.2	542.7	555.5	552.1	568.1
13	0.25	552.7	564.5	558.6	577.2	556.4	569.6	566.5	582.4
14	0.27	566.4	578.1	572.5	585.9	570.3	583.4	580.6	596.7
15	0.29	579.9	591.6	586.2	599.7	584.0	597.1	594.6	611.1
16	0.31	593.4	605.2	602.5	613.6	597.7	611.0	608.8	625.4
17	0.33	607.1	618.9	613.8	627.4	611.6	624.9	623.1	639.6
18	0.35	620.9	632.6	627.7	641.2	625.6	638.8	637.4	653.8
19	0.37	634.9	646.3	641.8	655.1	639.7	652.7	651.8	668.1
20	0.39	648.9	660.1	655.9	669.0	653.9	666.7	666.3	682.4
21	0.41	663.0	673.9	670.2	683.0	668.2	680.8	681.0	696.8
22	0.43	677.4	688.0	684.7	697.1	682.8	695.0	695.8	711.5
23	0.45	692.0	702.2	700.6	711.5	697.5	709.4	710.9	729.5
24	0.47	706.8	716.9	714.5	729.3	712.6	726.7	728.7	745.9
25	0.49	723.7	735.4	733.2	745.6	731.2	743.6	746.1	761.8

Table 11 (Continued)

No.	$\frac{E(0-\lambda)}{E(0-\infty)}$	α=1.3	β=.02	α=1.3	β=.04	α=.66	β=.085	α=.66	β=.17
		AM1.5	AM2	AM1.5	AM2	AM1.5	AM2	AM1.5	AM2
		nm	nm	nm	nm	nm	nm	nm	nm
26	0.51	741.5	751.1	749.5	761.0	747.8	759.2	763.0	778.3
27	0.53	757.7	767.6	766.6	777.6	764.9	775.9	779.9	794.8
28	0.55	775.0	783.7	783.4	794.0	780.7	792.4	797.3	812.4
29	0.57	792.4	800.1	801.1	811.5	799.5	809.9	816.7	834.2
30	0.59	810.8	819.9	821.3	833.3	819.5	831.7	838.5	852.7
31	0.61	833.3	841.0	842.5	851.9	841.1	850.7	857.8	870.7
32	0.63	853.1	859.5	861.9	870.2	860.7	869.1	877.6	890.2
33	0.65	872.9	878.6	882.2	889.7	881.0	888.8	899.0	916.1
34	0.67	894.3	899.7	905.6	915.7	904.2	914.4	928.1	961.0
35	0.69	922.9	929.3	941.1	961.1	939.8	959.9	974.0	989.3
36	0.71	969.7	977.1	981.5	989.9	980.6	989.5	999.6	1012.7
37	0.73	997.0	1001.6	1006.5	1014.1	1005.8	1013.8	1026.3	1039.1
38	0.75	1024.5	1028.6	1034.8	1041.3	1034.2	1041.3	1054.9	1069.6
39	0.77	1054.1	1058.2	1066.1	1073.2	1065.7	1073.6	1088.9	1102.6
40	0.79	1089.8	1093.5	1101.4	1107.2	1101.2	1107.8	1149.4	1176.0
41	0.81	1159.0	1166.7	1175.0	1184.4	1175.0	1185.5	1200.5	1215.8
42	0.83	1206.0	1210.5	1218.3	1225.8	1218.6	1227.2	1242.9	1258.2
43	0.85	1252.3	1255.9	1265.7	1272.3	1266.4	1274.2	1291.7	1306.0
44	0.87	1306.2	1308.9	1320.1	1328.0	1321.1	1332.9	1430.1	1511.7
45	0.89	1513.7	1521.3	1527.7	1538.3	1529.2	1542.5	1557.2	1576.1
46	0.91	1590.3	1594.7	1603.3	1610.7	1606.7	1614.1	1632.0	1646.2
47	0.93	1678.6	1678.4	1691.3	1693.9	1693.3	1698.8	1720.9	1372.7
48	0.95	1794.6	1791.2	1806.1	1807.3	1809.9	1813.7	1954.5	1990.6
49	0.97	2155.5	2153.3	2171.1	2174.5	2174.8	2184.8	2208.7	3177.0
50	0.98	2996.0	2180.8	3083.9	3129.5	3118.9	3161.1	3261.9	3303.8

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FIGURE CAPTIONS

Figure 1. Solar Spectral Irradiance Outside the Atmosphere, 0.2μm–1.7μm reported by: 1. Labs and Neckel, 2. P. Moon, e. F. S. Johnson, 4. Thekaekara et al. (NASA/ASTM Standard), 5. Arvensen et al.

Figure 2. Solar Spectral Irradiance Outside the Atmosphere, 1.0μm–4.0μm reported by: 1. Labs and Neckel, 2. P. Moon, 3. F. S. Johnson, 4. Thekaekara et al. (NASA/ASTM Standard), 5. Arvensen et al.

Figure 3. Transmittance vs. Wavelength for Rayleigh (c_1), Ozone ($c_3 = 3.4$mm) and Aerosol ($c_2 = \beta\lambda^{-\alpha}$, $\alpha = 0.66$, $\beta = 0.17$) Optical Parameters for Air Mass ($m = 1$)

Figure 4. Water Vapor Transmittance for 0.72, 0.81 and 0.94μm Bands

Figure 5. Transmittance vs. Wavelength for Water Vapor (20mm) and Carbon Dioxide (200 at m - cm)

Figure 6. IR Transmittance vs. Wavelength for Water Vapor and Carbon Dioxide

Figure 7. Extraterrestrial Solar Spectrum and That Received at Ground Surface for Air Mass 1.5, H_2) 2cm, O_3 0.34cm and $\alpha = 0.66$, $\beta = 0.085$

Figure 8. Solar Spectral Irradiance for Different Air Mass Values, Assuming U.S. Standard Atmosphere, Precipitable H_2O Vapor 20mm, Ozone 3.4mm, Very Clear Atmosphere ($\alpha = 1.3$, $\beta = 0.02$)

Figure 9. Solar Spectral Irradiance for Different Air Mass Values, Assuming U.S. Standard Atmosphere, Precipitable Water Vapor 20mm, Ozone 3.4mm, Clear Atmosphere ($\alpha = 1.3$, $\beta = 0.04$)

Figure 10. Solar Spectral Irradiance for Different Air Mass Values, Assuming U.S. Standard Atmosphere, Precipitable Water Vapor 20mm, Ozone 3.4mm, Turbid Atmosphere ($\alpha = 0.66$, $\beta = 0.085$)

Figure 11. Solar Spectral Irradiance for Air Mass Values, Assuming U.S. Standard Atmosphere, Precipitable Water Vapor 20mm, Ozone 3.4mm, Very Turbid Atmosphere ($\alpha = 0.66$, $\beta = 0.17$)

Figure 12. Angular Patterns of Scattered Intensity From Particles of Three Sizes: (a) Small Particles, (b) Large Particles, (c) Larger Particles, From Brumberger et al. (1968)

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16. Abstract

Available quantitative data on solar total and spectral irradiance are examined in the context of utilization of solar irradiance for terrestrial applications of solar energy. A brief review is given on the extraterrestrial solar total and spectral irradiance values. Computed values of solar spectral irradiance at ground level for different air mass values and various levels of atmospheric pollution or turbidity are also presented. Wavelengths are given for computation of solar absorptance, transmittance and reflectance by the 100-selected-ordinate method and by the 50-selected-ordinate method for air mass 1.5 and 2 solar spectral irradiance for the four levels of atmospheric pollution.

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