A Compilation of Selected Data on Solar Radiation at Sea Level

Assignment 91 195
Technical Memorandum 3/67
February 1967

By
B. H. Morgan

U. S. NAVY

MARINE ENGINEERING LABORATORY

Annapolis, Md.

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ABSTRACT

A spectral distribution curve of solar irradiance at sea level, over the range of 0.3 to 15.0 microns, is presented. This curve was developed from data compiled by Moon in 1940, high altitude solar irradiance measurements reported by Johnson in 1954, and atmosphere transmission measurements reported by Gebbie, et al, in 1951.

ADMINISTRATIVE INFORMATION

The data presented was compiled under MEL Assignment 91 195, Sub-project S-F010 03 01, Task 9292.

TECHNICAL REFERENCES

1 - Moon, P., "Proposed Standard Curve for Engineering Use," J. Franklin Inst. Vol. 230, No. 5, Nov 1940, pp. 583-617
2 - Johnson, F.S., "The Solar Constant," J. Meteor, Vol. 11, No. 6, Dec 1954, pp. 431-439
3 - Gebbie, H.A., W.R. Harding, C. Hilsun, A.W. Pryce, and V. Roberts, "Atmospheric Transmission in the 1 to 14 Micron Region," Proc. Roy. Soc., Vol. A206, London 1951, p. 87

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A COMPILATION OF SELECTED DATA ON SOLAR RADIATION AT SEA LEVEL

1.0 INTRODUCTION

Many investigators have made measurements of solar irradiance outside the earth's atmosphere and at sea level. No one authoritative source of data, however, covers the entire spectral range from 0.3 to 15.0 microns. In order to construct a complete solar irradiance curve for sea level, it was necessary to examine existing data, resolve differences, and correct for revised values of the solar constant and atmosphere transmission factors. This compilation of solar irradiance data is a by-product of a broader study aimed at meeting the U.S. Navy's need for knowledge of the surface characteristics of material and their interaction with electromagnetic radiation. This compilation provides a readily usable basis for calculating solar heating effects on surfaces having different solar absorbing characteristics.

2.0 SOLAR IRRADIANCE

2.1 Moon's Data. In 1940, existing solar irradiance data were correlated in a classic paper by Parry Moon.[1] In his paper, Moon pointed out that the energy received at the earth's surface from the sun is subject to wide variation because of several factors. There is a variation of ±3.5 percent due to the changing distance between the earth and sun, and about ±1.5 percent due to variation in the sun itself. In addition, the degree of atmposheric scattering (by air molecules, water vapor, and dust) and absorption (by molecules of O_2, O_3, H_2O, CO_2, etc) is highly variable. Moon's principal result is a table of spectral solar irradiance at sea level for an air mass of two (m = 2, Zenith distance about 60°). Moon also presented spectral irradiance data at sea level for other zenith distances and for outside the atmosphere.

[1]Superscripts refer to similarly numbered entries in the Technical References at the beginning of this memorandum.

2.2 Johnson's Data. In 1954, F.S. Johnson revised Moon's outside-the-atmosphere data, using new data obtained by the Naval Research Laboratory in the wavelength range from 0.22 to 0.60 micron.[2] Johnson concluded that Moon's data outside-the-atmosphere were still the best available for wavelengths longer than 0.60 micron, but that they should be increased by 2.8 percent because of revision of the basic Smithsonian data used in determining the solar constant (total solar irradiance outside the earth's atmosphere).

2.3 Developed Moon-Johnson Data. For wavelengths shorter than 0.60 micron, Moon's data for spectral irradiance at sea level have been revised to correspond with Johnson's 1954 outside- the -atmosphere data, by multiplying Moon's sea level values for each wavelength by the ratio of the irradiance outside the atmosphere as given by Johnson to that as given by Moon, at the same wavelength.

For wavelengths from 0.6 to 1.8 microns, Moon's sea-level values are increased by 2.8 percent, as suggested by Johnson, to compensate for a revision in the solar constant.

2.4 Developed Johnson-Gebbie Data. For wavelengths greater than 1.8 microns, Johnson's outside-the-atmosphere values (which are those of a 6000 K* gray body) were multiplied by the transmittance of a one-mile path at sea level as measured by Gebbie, et al, in 1951 [3].

3.0 DISCUSSION OF DEVELOPED DATA

3.1 Comparison of Environmental Conditions. The air path used by Gebbie had a visual transmittance, at 0.61 micron, of 60 percent and 17-mm precipitable water vapor, while Moon assumed 20-mm precipitable water vapor. Moon's data indicates a transmittance of 68 percent, at 0.61 micron. The resultant curve for solar spectral irradiance at sea level appears in the following tabulation and is plotted in Figures 1 (0.3 to 1.8 microns) and 2 (1.8 to 15 microns).

*Abbreviations used in this text are from the GPO Style Manual, 1959, unless otherwise noted.

Solar Spectral Irradiance at Sea Level

The mean spectral irradiance, H_λ, for air mass two (corresponding to elevation of the sun above the horizon of about 30°) is given in watts-m^{-2}-$micron^{-1}$ as a function of wavelength, λ, for a surface perpendicular to the sun's rays. Moon-Johnson data is headed M-J: Johnson-Gebbie data is headed J-G.

λ microns	H_λ $W\text{-}m^{-2}\text{-}\mu^{-1}$	λ microns	H_λ $W\text{-}m^{-2}\text{-}\mu^{-1}$
	M-J		M-J
0.30	0.11	0.55	1235
0.31	13.6	0.56	1207
0.32	63.2	0.57	1197
0.33	146	0.58	1201
0.34	196	0.59	1190
0.35	242	0.60	1199
0.36	277	0.61	1201
0.37	355	0.62	1198
0.38	369	0.63	1209
0.39	370	0.64	1208
0.40	555	0.65	1206
0.41	755	0.66	1199
0.42	797	0.67	1192
0.43	783	0.68	1181
0.44	954	0.69	1005
0.45	1087	0.70	1139
0.46	1113	0.71	1100
0.47	1165	0.72	855
0.48	1202	0.73	992
0.49	1145	0.74	1070
0.50	1167	0.75	891
0.51	1182	0.76	582
0.52	1147	0.77	995
0.53	1212	0.78	932
0.54	1252	0.79	949

λ microns	H_λ W-m^{-2}-μ^{-1}	λ microns	H_λ W-m^{-2}-μ^{-1}
	M-J		M-J
0.80	881	1.10	259
0.81	718	1.11	130
0.82	823	1.12	71.8
0.83	887	1.13	101
0.84	882	1.14	169
0.85	862	1.15	222
0.86	836	1.16	279
0.87	820	1.17	337
0.88	631	1.18	356
0.89	531	1.19	354
0.90	493	1.20	383
0.91	386	1.21	413
0.92	265	1.22	443
0.93	174	1.23	432
0.94	286	1.24	398
0.95	501	1.25	337
0.96	600	1.26	320
0.97	651	1.27	392
0.98	663	1.28	393
0.99	661	1.29	356
1.00	648	1.30	271
1.01	637	1.31	214
1.02	627	1.32	173
1.03	618	1.33	118
1.04	609	1.34	59.7
1.05	566	1.35	18.6
1.06	541	1.36	0.68
1.07	534	1.37	0.0
1.08	526	1.38	0.0
1.09	528	1.39	0.0

λ microns	H_λ $W\text{-}m^{-2}\text{-}\mu^{-1}$	λ microns	H_λ $W\text{-}m^{-2}\text{-}\mu^{-1}$
M-J		**M-J**	
1.40	0.0	1.70	136
1.41	1.96	1.71	127
1.42	3.82	1.72	118
1.43	7.74	1.73	108
1.44	14.1	1.74	99.8
1.45	24.5	1.75	82.4
1.46	31.4	1.76	60.5
1.47	46.4	1.77	39.9
1.48	86.0	1.78	18.9
1.49	132	1.79	5.86
1.50	161	1.80	0.95
1.51	192		
1.52	215		
1.53	223	**J-G**	
1.54	232		
1.55	227	1.40	0
1.56	223	1.45	62
1.57	219	1.50	142
1.58	215	1.55	179
1.59	211	1.60	174
1.60	208	1.65	160
1.61	204	1.70	144
1.62	199	1.75	123
1.63	194	1.80	77
1.64	189	1.85	0
1.65	178	1.9	5
1.66	168	2.0	54
1.67	163	2.1	69
1.68	149	2.2	62
1.69	143	2.3	53

λ microns	H_λ W-m^{-2}-μ^{-1}	λ microns	H_λ W-m^{-2}-μ^{-1}
	J-G		J-G
2.4	36	4.9	1.8
2.5	13	5.0	1.13
2.6	0.0	5.1	0.78
2.7	0.0	5.2	0.36
2.8	0.0	5.3	0.14
2.9	3.0	5.4-7.5	0.00
3.0	6.2		
3.1	4.1	7.6	0.06
3.2	8.6	8.0	0.19
3.3	6.3	8.5	0.37
3.4	11.7	9.0	0.33
3.5	13.8	9.5	0.29
3.6	12.2	10.0	0.23
3.7	11.3	10.5	0.18
3.8	10.1	11.0	0.15
3.9	9.6	11.5	0.11
4.0	8.7	12.0	0.10
4.1	7.3	12.5	0.06
4.2	0.8	13.0	0.05
4.3	0.0	13.5	0.02
4.4	0.0	14.0	0.00
4.5	1.8	14.5	0.00
4.6	3.1	15.0	0.00
4.7	3.2		
4.8	2.4		

The values given are for an air mass of two (sun's zenith distance about 60°) and for a surface perpendicular to the sun's rays. Scattered solar-radiation coming from the sky is not included.

3.2 Data Consistency. As a test of the consistency of the resulting Johnson-Gebbie data with that from Moon, both curves are plotted together in the range from 1.4 to 1.9 microns, Figure 1. They are reasonably consistent with one another, particularly with respect to their intergrals, the area under the Johnson-Gebbie curve being the larger by about 5 percent. However, at shorter wavelengths not plotted, the Johnson-Gebbie combination falls considerably below the Moon-Johnson curve, at least near the peaks.

The data presented in this memorandum was developed in order that numerical calculations of solar heating effects on surfaces of known radiant characteristics, at sea level, could be carried out. The main purpose was to develop a procedure for performing such calculations, and this was to be done in a rather short period of time. Consequently, sources and methods that were readily available and easily carried out were used to obtain the data presented here, as described in Section 2, and no analysis of its probable accuracy was attemped.

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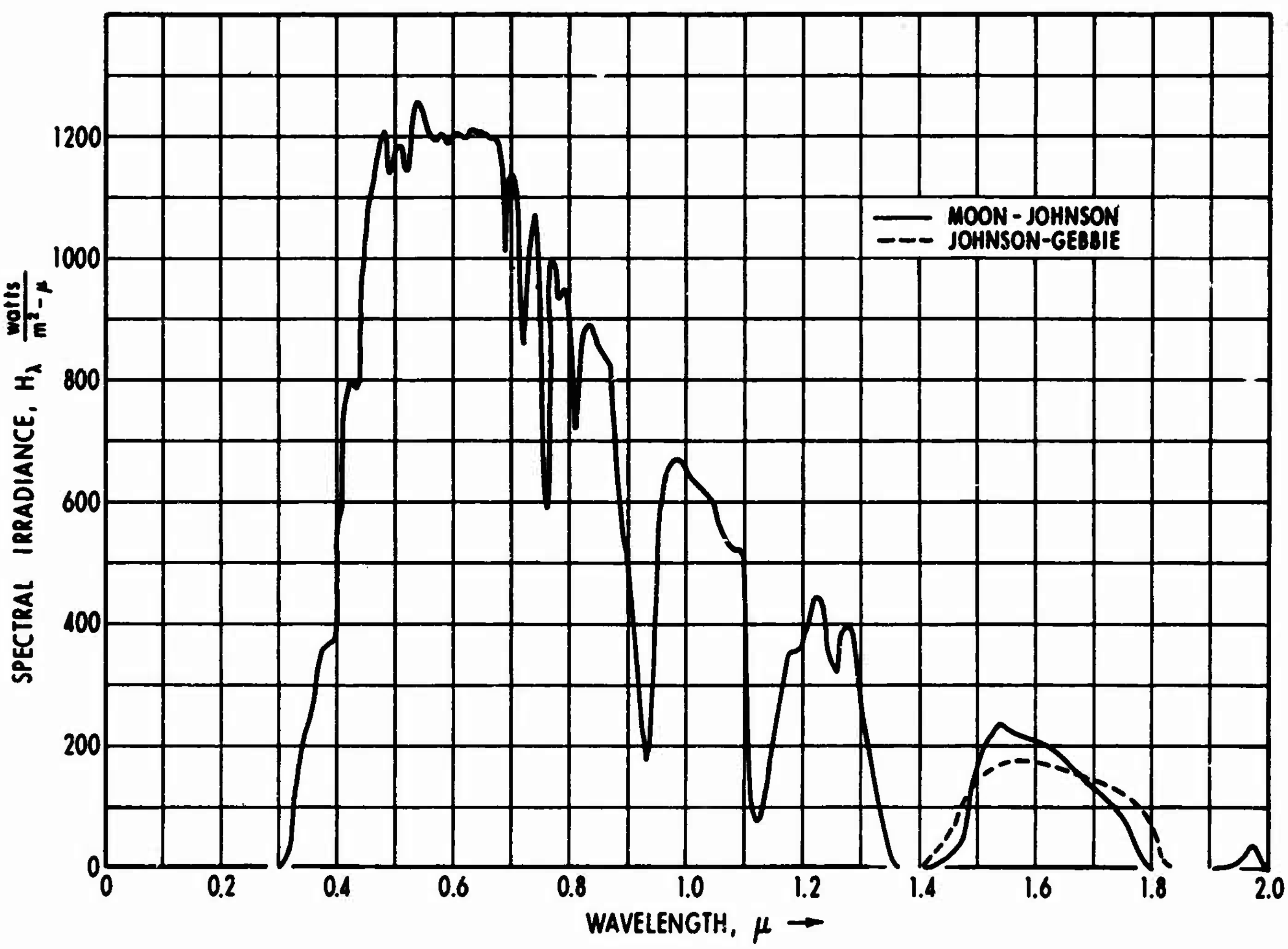

Figure 1

Solar Irradiance at Sea Level

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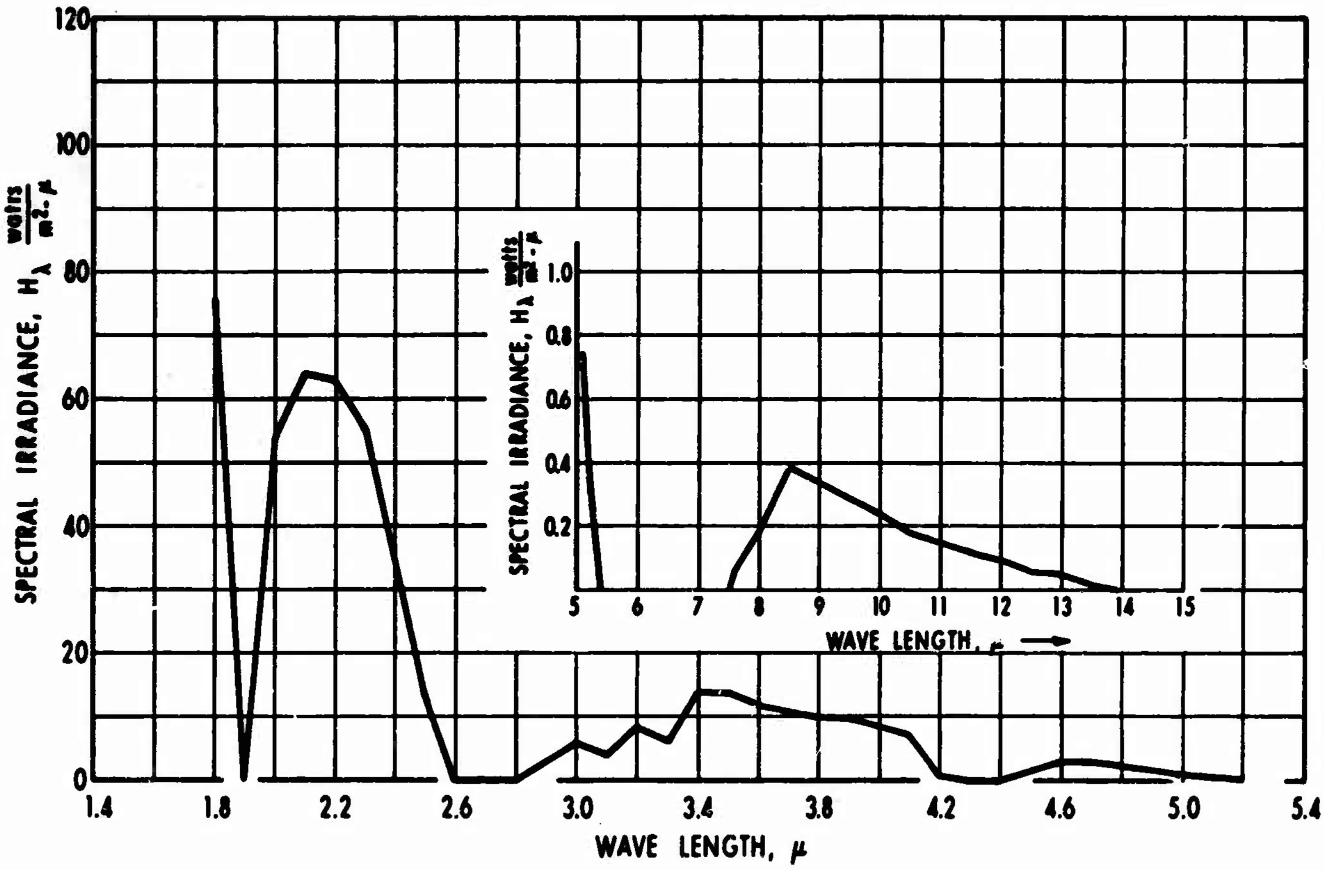

Figure 2

Solar Irradiance at Sea Level

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