Solar Energy Meteorological Research and Training Site - Region 5

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Annual Report Prepared for

Division of Distributed Solar Technology

U.S. Department of Energy

1 October 1978—30 September 1979

By

C. R. Nagaraja Rao and E. Wendoll Howson

MASTER

DEPARTMENT OF ATMOSPHERIC SCIENCES

Oregon State University

Corvallis, Oregon

March 1980

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TABLE OF CONTENTS

	Page
Prefatory Note	i
1. Introduction	1
2. Research and Training.	1
2.1 Research	1
2.1.1 Research Quality Data	1
2.1.2 Sensor Performance	7
2.1.3 Coastal Meteorology.	9
2.2 Training	9
3. Regional Monitoring	16
4. General Activities and Conclusion	16
5. Network Data	17

Prefatory Note

This is the second annual report of work performed under the SEMRTS program essentially during the period 1 October 1978 to 30 September 1979. The field observing facility of the primary research centre located at Oregon State University, Corvallis, is now fully operational, and research quality solar radiation and allied meteorological data have been routinely acquired since February 1979. The five-site, statewide network of solar monitoring stations located at Bend, Coos Bay, Eugene, La Grande, and Whitehorse Ranch has continued to function smoothly under the direction of Prof. McDaniels of the University of Oregon, Eugene, with support from the SEMRTS program under a subcontract.

A fairly detailed study of the response characteristics of radiation sensors, mainly of the thermopile type, has been completed. Also, the dependence of the accuracy of the computed values of irradiation on the sampling rate has been examined.

As part of the training program, two solar energy related courses -- one at the senior level and the other at the advanced graduate level -- were taught by Professor Rao and were received with a fair degree of enthusiasm by the students. The second workshop on 'Solar Energy Measurement and Instrumentation' was conducted during the summer of 1979 (August 27-31). Seminars on different topics in the broad discipline of solar radiation meteorology, catering to both professionals and non-professionals, were arranged during the reporting period.

It is hoped that the data base presently being assembled and research underway will together make it possible to obtain a fairly complete description of the regional solar radiation regime in the not-too-distant future.

Introduction

The Solar Energy Meteorological Research and Training Site (SEMRTS) program was initiated in the fall of 1977 by the U. S. Department of Energy to meet the perceived need for a comprehensive solar radiation and related meteorological data base and for the development of quality educational and training programs in the broad discipline of solar energy in order that future manpower needs could be adequately met. It was decided the country would be divided into eight regions and that the task of setting up the eight regional centres would be entrusted to universities with well-established programs of research and instruction in the atmospheric sciences. Accordingly, Oregon State University, Corvallis, was chosen to administer the program through its Department of Atmospheric Sciences for the region comprising the states of Idaho, Montana, Oregon, Washington, and Wyoming. The University of Oregon would participate in the program as collaborator and subcontractor. Against this background, we shall briefly describe in what follows our performance during the second year of the five-year SEMRTS program under the headings of research and training, regional monitoring, and general activities.

2. Research and Training

2.1 Research

2.1.1 Research Quality Data

The principal functional components of the primary research centre located at Oregon State University, Corvallis, are the off-campus field observing facility and the on-campus teaching and research laboratory. These two have been rendered fully operational during the reporting period.

The field observing facility, where research quality solar radiation and allied meteorological data are routinely acquired, is central to the SEMRTS program. It is located on a university research farm about 2 km east of the main campus and consists of a two-story laboratory and a 48.8m meteorological tower (Fig. 1). Hourly values of the direct (WG295) and global (WG295, GG495, RG630, and RG695) irradiances were measured and re-

Figure 1. The SEMRTS field observing facility at Corvallis.

corded with a six-channel, microprocessor-based data acquisition system from February to July 1979. Since August 1979, when the facility became fully operational, 26 solar radiation and solar-related meteorological measurements are routinely made with sensors mounted on the rooftop of the laboratory and at different levels on the tower. Their average or integrated values, as desired and as often as necessary, are recorded in SI units with a fully automated data acquisition system built around a Hewlett-Packard Model 9825 minicomputer. Generally, one-minute data are recorded on tape and the hourly and daily values, when once they have been computed, are printed out. A printout can be obtained every two minutes, if desired.

The various parameters measured, the sensors and methods used, and the instrument locations are listed in Table 1. Table 2 is a facsimile of a portion of an hourly printout. The following quantities are listed in the printout for any given one-hour period:

A. Measured

1. Global irradiances (G_i)
2. Direct irradiances (S_i)
3. Diffuse irradiation (shadow band)
4. Ultraviolet irradiation (UV)
5. Irradiation on a tilted surface (Lat. Tilt)
6. Global irradiation at 48m (G_{48})
7. Reflected irradiation at 48m (R_{48})
8. Long and short wave atmospheric radiation (LSR)
9. Dewpoint, temperature, wind speed, and direction at 10 and 48m levels
10. The highest and lowest values of temperature (Hi Temp and Lo Temp) recorded up to the end point of the one-hour interval
11. Pressure and precipitation

B. Computed

1. Times of sunrise and sunset on given day
2. Extraterrestrial solar irradiation (ETSR)
3. Diffuse sky irradiation (H_i)
4. Spectral components of global irradiation (G_i - G_j)

Table 1. Measurements made at the SEMRTS field observing facility
(44°35'N, 123°13'W, Elevation: 71.3m)

<u>Parameter</u>	<u>Instrument or Method</u>	<u>Location of Instrument</u>
1. Direct Irradiance (plus circumsolar)	Eppley Normal Incidence Pyrheliometer; WG 295, RG 695 filters	Field Laboratory rooftop; 6.5 m
2. Global Irradiance	Eppley Precision Spectral Pyranometers; WG 295, OG 530, RG 630, RG 695 domes	"
3. Diffuse Irradiance	Eppley Precision Spectral Pyranometers with shadow-band and/or as differences between (2) and the vertical component of (1).	"
4. Irradiance at surface, tilted at latitude, pointed south	Eppley Precision Pyranometer with WG 295 dome	"
5. Global U.V. Irradiance	Eppley U.V. Radiometer	"
6. Sunshine Duration	Campbell-Stokes sunshine recorder	"
7. Downward short and long wave radiations	C.S.I.R.O. Funk type radiometer	"
8. Wind velocity	Cup and vane wind sensor	10 m and 48 m on tower
9. Temperature and lapse rate	Matched thermistors	"
10. Dewpoint	Lithium chloride element (to be supplemented with condensation-type hygrometers at a later date)	"
11. Upward shortwave radiation	Inverted Eppley PSP or equivalent	48 m on tower

Table 1 (Continued)

<u>Parameter</u>	<u>Instrument or Method</u>	<u>Location of Instrument</u>
12. Precipitation	Tipping bucket rain gauge	Field site
13. Pressure	Aneroid sensor	Field laboratory
14. Atmospheric turbidity	Multispectral radiometers (Volz photometer and other instruments)	"

Note 1. There is space on the rooftop platform to mount additional radiation sensors and compare their performance with that of the calibrated Eppley PSP's as and when desired.

Note 2. Surface albedo and skylight polarization measurements will be made at the field site intermittently.

Note 3. Cloud cover will be estimated according to usual NWS practices and/or by analysis of all-sky photographs.

Table 2. Facsimile of Hourly Data Printout
(for illustration purposes only).

Theta (deg)	74.3	4	91 WG-295 (hJ/sqn)	2574.3	0	Tower R48 (hJ/sqn)	121.4	0		Temp 48m (degC)	8.5	0	CH 17 16986F3	951.4	0		
Phi (deg)	147.8	4				Tower G48 (hJ/sqn)	798.9	0		delt T (degC)	1.2	0	CH 18 17518F3	415.8	0		
ETSR (hJ/sqn)	1885.1	4	94 RG-695 (hJ/sqn)	1531.2	0	Lat Tilt (hJ/sqn)	2218.6	0	G4/H4	4.8	0		CH 19 18561F3	927.5	0		
									Tow R48/G48 (Z)	15.3	0						
HiTemp (deg C)	-1.2	0	H1 WG-295 (hJ/sqn)	308.0	0				G48-G18(hJ/sqn)	-157.6	0						
LoTemp (deg C)	-1.2	0															
Precip (mm)	0.1	0															
Sunrise (hr.min)	7.58	4	H4 RG-695 (hJ/sqn)	87.4	0												
Sunset (hr.min)	16.47	4															
SENRIS OSU Corvallis																	
Date 11:06:00	6		G1 WG-295 (hJ/sqn)	758.7	0	Shad Band (hJ/sqn)	484.3	0	Spec G1-G2 (hJ/sqn)	284.5	0	Met WS 10m (m/s)	4.8	0	Comments	0.0	0
Time 11:00-11:00	6s/n		G2 DG-530 (hJ/sqn)	546.2	0	CSIRO Sig (hJ/sqn)	458.6	0	G1-G3 (hJ/sqn)	314.6	0	WS 10m (deg)	23.6	0			
HOURLY RECORD			G3 RG-630 (hJ/sqn)	436.1	0	Tem (deg C)	1.1	0	G1-G4 (hJ/sqn)	388.4	0	WS 48m (m/s)	4.8	0			
			G4 RG-695 (hJ/sqn)	378.2	0	LSR (hJ/sqn)	1616.1	0				WS 48m (deg)	26.2	0			
Theta (deg)	69.5	4	S1 WG-295 (hJ/sqn)	615.2	0	UV Rad (hJ/sqn)	37.7	0	Ratio G1/H1	1.3	0	Temp 10m (degC)	1.9	0	CH 17 16986F3	728.9	0
Phi (deg)	168.7	4				Tower R48 (hJ/sqn)	87.3	0				Temp 48m (degC)	1.8	0	CH 18 17518F3	364.9	0
ETSR (hJ/sqn)	1575.7	4	94 RG-695 (hJ/sqn)	338.7	0	Tower G48 (hJ/sqn)	739.3	0	G4/H4	1.4	0	delt T (degC)	0.3	0	CH 19 18561F3	789.0	0
						Lat Tilt (hJ/sqn)	1192.5	0				Temp 10m (degC)	-8.7	0			
HiTemp (deg C)	-1.2	0	H1 WG-295 (hJ/sqn)	561.4	0				Tow R48/G48 (Z)	11.8	0	Temp 48m (degC)	-7.0	0			
LoTemp (deg C)	-1.2	0							G48-G18(hJ/sqn)	-11.3	0	Pressure (hPa)	101.7	0			
Precip (mm)	0.0	0	H4 RG-695 (hJ/sqn)	266.2	0							Precip (mm)	0.0	0			
Sunrise (hr.min)	7.58	4															
Sunset (hr.min)	16.47	4															
SENRIS OSU Corvallis																	
Date 11:06:00	6		G1 WG-295 (hJ/sqn)	1272.6	0	Shad Band (hJ/sqn)	173.7	0	Spec G1-G2 (hJ/sqn)	298.5	0	Met WS 10m (m/s)	4.2	0	Comments	0.0	0
Time 11:00-12:00	6s/n		G2 DG-530 (hJ/sqn)	974.1	0	CSIRO Sig (hJ/sqn)	866.4	0	G1-G3 (hJ/sqn)	494.2	0	WS 10m (deg)	21.3	0			
HOURLY RECORD			G3 RG-630 (hJ/sqn)	778.3	0	Tem (deg C)	2.8	0	G1-G4 (hJ/sqn)	615.5	0	WS 48m (m/s)	5.0	0			
			G4 RG-695 (hJ/sqn)	657.1	0	LSR (hJ/sqn)	2049.4	0				WS 48m (deg)	24.8	0			
Theta (deg)	67.3	4	91 WG-295 (hJ/sqn)	2916.2	0	UV Rad (hJ/sqn)	56.8	0	Ratio G1/H1	6.8	0	Temp 10m (degC)	1.3	0	CH 17 16986F3	1225.4	0
Phi (deg)	175.1	4				Tower R48 (hJ/sqn)	163.3	0				Temp 48m (degC)	0.8	0	CH 18 17518F3	648.3	0
ETSR (hJ/sqn)	1866.4	4	94 RG-695 (hJ/sqn)	1682.5	0	Tower G48 (hJ/sqn)	1274.1	0	G4/H4	10.9	0	delt T (degC)	0.5	0	CH 19 18561F3	1248.9	0
						Lat Tilt (hJ/sqn)	2926.8	0				Temp 48m (degC)	-8.3	0			
HiTemp (deg C)	1.8	0	H1 WG-295 (hJ/sqn)	186.0	0				Tow R48/G48 (Z)	12.8	0	Temp 48m (degC)	-6.5	0			
LoTemp (deg C)	-1.2	0	H4 RG-695 (hJ/sqn)	68.0	0				G48-G18(hJ/sqn)	1.6	0	Pressure (hPa)	101.7	0			
Precip (mm)	0.1	0										Precip (mm)	0.0	0			
Sunrise (hr.min)	7.54	4															
Sunset (hr.min)	16.47	4															
SENRIS OSU Corvallis																	
Date 11:06:00	6		G1 WG-295 (hJ/sqn)	1389.6	0	Shad Band (hJ/sqn)	162.8	0	Spec G1-G2 (hJ/sqn)	317.4	0	Met WS 10m (m/s)	4.3	0	Comments	0.0	0
Time 12:00-13:00	6s/n		G2 DG-530 (hJ/sqn)	1872.2	0	CSIRO Sig (hJ/sqn)	957.5	0	G1-G3 (hJ/sqn)	522.4	0	WS 10m (deg)	11.3	0			
HOURLY RECORD			G3 RG-630 (hJ/sqn)	867.2	0	Tem (deg C)	4.1	0	G1-G4 (hJ/sqn)	656.5	0	WS 48m (m/s)	5.0	0			
			G4 RG-695 (hJ/sqn)	733.2	0	LSR (hJ/sqn)	2164.4	0				WS 48m (deg)	16.2	0			
Theta (deg)	67.9	4	S1 WG-295 (hJ/sqn)	3231.7	0	UV Rad (hJ/sqn)	61.3	0	Ratio G1/H1	9.6	0	Temp 10m (degC)	1.9	0	CH 17 16986F3	1344.6	0
Phi (deg)	188.4	4				Tower R48 (hJ/sqn)	172.4	0				Temp 48m (degC)	1.4	0	CH 18 17518F3	716.8	0
ETSR (hJ/sqn)	1937.5	4	94 RG-695 (hJ/sqn)	1773.3	0	Tower G48 (hJ/sqn)	1482.9	0	G4/H4	14.6	0	delt T (degC)	0.5	0	CH 19 18561F3	1321.2	0
						Lat Tilt (hJ/sqn)	3175.4	0				Temp 48m (degC)	-7.0	0			
HiTemp (deg C)	2.4	0	H1 WG-295 (hJ/sqn)	145.2	0				Tow R48/G48 (Z)	12.3	0	Temp 48m (degC)	-6.1	0			
LoTemp (deg C)	-1.2	0							G48-G18(hJ/sqn)	13.3	0	Pressure (hPa)	101.6	0			
Precip (mm)	0.1	0	H4 RG-695 (hJ/sqn)	58.3	0							Precip (mm)	0.0	0			
Sunrise (hr.min)	7.58	4															
Sunset (hr.min)	16.47	4															
SENRIS OSU Corvallis																	
Date 11:06:00	6		G1 WG-295 (hJ/sqn)	1231.9	0	Shad Band (hJ/sqn)	157.6	0	Spec G1-G2 (hJ/sqn)	288.8	0	Met WS 10m (m/s)	3.8	0	Comments	0.0	0
Time 13:00-14:00	6s/n		G2 DG-530 (hJ/sqn)	946.1	0	CSIRO Sig (hJ/sqn)	835.2	0	G1-G3 (hJ/sqn)	418.8	0	WS 10m (deg)	16.3	0			
HOURLY RECORD			G3 RG-630 (hJ/sqn)	787.0	0	Tem (deg C)	5.0	0	G1-G4 (hJ/sqn)	566.9	0	WS 48m (m/s)	4.4	0			
			G4 RG-695 (hJ/sqn)	668.1	0	LSR (hJ/sqn)	2857.4	0				WS 48m (deg)	19.7	0			

5. Surface albedo (R48/G48),
6. The solar azimuth (Φ) and zenith distance (Θ)
corresponding to the endpoint of the one-hour interval

The entries in the 'Comments' column are for purposes of quality control. These sequential one-minute data are then rearranged in the Research Cooperator Format at the main campus computer centre and hourly data tapes generated for transmittal to the National Climatic Centre at Asheville, N.C.

2.1.2 Sensor Performance

The standard (?) UV radiometer (Eppley S.N. 17178) was received from Prof. Coulson of the University of California, Davis, in December 1978. Comparison measurements of the ultraviolet irradiance were made with this standard and with the OSU radiometer (Eppley S.N. 17031) in January and February 1979 under favourable sky conditions. The two instruments appear to agree to within $\pm 3\%$; however, no definite conclusions regarding absolute accuracies can be drawn since facilities for absolute calibration in the ultraviolet (.3 to .38 μ) are hard to come by. It is also observed that the ratio of the irradiance values measured with the two radiometers varies with the level of irradiance as determined with the UCD standard (?). This may be due, in part at least, to the different slewing rates of the two instruments.

The response times of radiation sensors, mainly of the thermopile type, have been studied in the laboratory in detail. The response of an Eppley normal incidence pyrheliometer (NIP) to periodic, square wave illumination is shown in Fig. 2. For the particular instrument studied, it was found that the experimentally determined value of the time constant (~ 1.9 sec) was far in excess of the representative value (~ 1 sec) furnished by the manufacturer. This general trend, albeit to a smaller degree, is noticed with other sensors, too.

A fairly detailed investigation of the dependence of the irradiation values on the frequency of sampling has been made. Typical days with broken clouds were chosen for this study conducted in Corvallis. It is observed that over a seven-minute interval, discrepancies of the order of

Nominal chart speed = 1 mm/sec

Figure 2. Response of the Eppley Normal Incidence Pyrheliometer to Periodic Illumination

The upper and lower dashed lines, respectively, indicate the maximum ($\sim 1.31\text{mV}$) and minimum (0.045mV) values of the NIP signal.

4 to 8% can occur between the computed values based on 6 to 4 samples per minute and those obtained with digitized data 0.8 sec apart. The very obvious fact is also noticed that over shorter time intervals (~ 1 min) these discrepancies are larger.

2.1.3 Coastal Meteorology

An investigation of the incidence and dissipation of fog and stratus along the Pacific Northwest coast has been undertaken. For this purpose, relevant meteorological data from the five coastal stations at Eureka ($40^{\circ}48'N$, $124^{\circ}10'W$, California), Coos Bay ($43^{\circ}21'N$, $124^{\circ}20'W$, Oregon), Newport ($44^{\circ}38'N$, $124^{\circ}03'W$, Oregon), Astoria ($46^{\circ}09'N$, $123^{\circ}53'W$, Oregon), and Quillayute ($47^{\circ}57'N$, $124^{\circ}33'W$, Washington) for the period from 1955 to 1975 are presently being analyzed with nominal support from the present grant. Some of the results of the analyses of the data for 1975 are shown in Figs. 3, 4, 5, and 6.

2.2 Training

The second week-long workshop on 'Solar Energy Measurement and Instrumentation' was held during the summer of 1979 (August 27-31). Included amongst the guest faculty were Dr. Lufkin (NOAA Headquarters, Washington, D.C.), Mr. Flowers (Environmental Research Laboratories, NOAA, Boulder), and Mr. Whitaker (Solar Energy Research Institute, Golden, Colorado). The distribution of the 30 participants by academic background and training was as follows: Physicists (M.S. and Ph.D.) 6, Atmospheric Scientists (M.S. and Ph.D.) 2, General Science (M.S. and Ph.D.) 2, Engineers (B.S., M.S., and Ph.D.) 5, Chemists (M.S.) 1, Technicians (and others) 14. Twenty-one of the participants came from Oregon, five from Washington, one from Idaho, one from Montana, and two from British Columbia. Thus, there was good academic, professional, and regional representation. The participants were particularly appreciative of the laboratory sessions that formed part of the program. The speakers and the topics covered at the workshop are listed below.

SOLAR ENERGY
MEASUREMENT AND INSTRUMENTATION WORKSHOP
August 27-31, 1979

Oregon State University
Corvallis, Oregon 97331
Program Chairman: Prof. C. R. Nagaraja Rao

MONDAY, AUGUST 27:

Morning

9:00 - 9:20	Introductory Remarks (OSU Staff)	(Rao, Gates)
9:20 - 10:20	Physical Principles of Solar Radiation I	(Rao)
10:20 - 10:30	Discussion	
10:30 - 10:45	Coffee break	
10:45 - 11:45	Physical Principles of Solar Radiation II	(Rao)
11:45 - 12:00	Discussion	

Afternoon

1:30 - 2:30	Solar Radiation Instrumentation I	(Flowers)
2:30 - 2:45	Discussion	
2:45 - 3:00	Coffee break	
3:00 - 4:00	Solar Radiation Instrumentation II	(Flowers)
4:00 - 4:15	Discussion	

TUESDAY, AUGUST 28:

Morning

9:00 - 10:15	Insolation Modelling	(Whitaker)
10:15 - 10:30	Discussion	
10:30 - 10:45	Coffee break	
10:45 - 12:00	Solar Radiation Monitoring in Oregon	(McDaniels)

Afternoon

Laboratory

WEDNESDAY, AUGUST 29:

Morning

9:00 - 10:15	Design and Engineering of Practical Solar Energy Systems I	(Lufkin)
10:15 - 10:30	Discussion	
10:30 - 10:45	Coffee break	
10:45 - 12:00	Design and Engineering of Practical Solar Energy Systems II	(Lufkin)

Afternoon

Laboratory

Evening

7:30 - 8:30	Solar Buildings in Oregon, Public Lecture	(Reynolds)
-------------	--	------------

THURSDAY, AUGUST 30:Morning:

9:00 - 10:15	NOAA-DOE Solar Radiation Monitoring Activities, Data Bases, etc.	(Flowers)
10:15 - 10:30	Discussion	
10:30 - 10:45	Coffee break	
10:45 - 12:00	National Energy Resources Assessment Program at SERI	(Whitaker)

Afternoon

1:30 - 2:30	Insolation on Tilted Surfaces	(Vignola)
2:30 - 2:45	Discussion	
2:45 - 3:00	Coffee break	
3:00 - 4:15	Windpower Potential in the Pacific Northwest	(Hewson, et al.)
4:15 - 4:30	Discussion	

FRIDAY, AUGUST 31:Morning

9:00 - 10:15	Daylight as a National Energy Resource	(Lee)
10:15 - 10:30	Discussion	
10:30 - 10:45	Coffee break	
10:45 - 12:00	Interest-group discussions, audience participation	

Adjourn

Figure 3. Incidence of fog in Astoria.

Figure 4. Surface wind observations in Astoria (wind direction given in degrees, measured clockwise, from geographical north).

Figure 5. Incidence of fog in Coos Bay.

Figure 6. Surface wind observations in Coos Bay (wind direction given in degrees, measured clockwise, from geographical north).

The two courses specially developed as part of the SEMRTS program by Prof. Rao -- 'Solar Radiation and Meteorological Measurements' and 'Atmospheric Radiative Processes' -- have been received with fair enthusiasm by the students. Prof. Rao also gave a seminar entitled 'Transmission Reflection and Absorption of Solar Radiation by Clouds' on 8 March 1979. It was organized jointly by Oregon State University and University of Oregon, Eugene.

3. Regional Monitoring

Special attention was given to updating the five-site statewide network (Fig. 7). Daily values of the global irradiation are obtained with Schenck pyranometers which are, in turn, calibrated against an Eppley precision spectral pyranometer. It is observed that measurements with the Schenck pyranometers are accurate to within $\pm 5\%$. Measured values of the global irradiation for CY 1977 and 1978 are shown in Tables 3-13. Prof. McDaniels of the University of Oregon, Eugene, is directing the operation of this statewide network under a subcontract with the SEMRTS program.

The second Solar Energy Regional Meeting was held in Seattle on 9 August 1979 in conjunction with 'Solar Northwest'. Prof. Leo J. Fritschen of the College of Forest Resources, University of Washington, Seattle, was the host. Ongoing and proposed activities related to solar radiation monitoring were reviewed in the context of the SEMRTS program.

4. General Activities

The University authorities have agreed in principle to underwrite the entire cost of construction of the on-campus Solar and Atmospheric Radiation Laboratory ($\sim 140 \text{ m}^2$) to be built shortly. Prof. Rao attended the program review meeting in Washington, D.C., November 1978. The senior program scientists have given freely of their time to answer inquiries addressed to the University in the area of renewable resource assessment.

Conclusion

It is hoped that one of the more important results of the SEMRTS pro-

would be a complete description of the solar radiation climatology of the region. This would entail investigations of radiative transfer in cloudy, turbid atmospheres, of optical and radiative properties of clouds and fogs, and of insolation modelling from meteorological variables.

Acknowledgment.

Mr. Kenneth True, who is responsible for the installation, operation, and maintenance of the equipment at the field observing facility and for the presentation of the data in the Research Cooperator Format, deserves special thanks. Messrs. William Bradley and Glenn Dorsch have ably assisted him in this task. Mr. Mai-Kun Wai is responsible for the detailed analysis of the coastal meteorological data.

5. Network Data:
Tables 3-12.

Figure 7. Solar radiation monitoring stations
(Oregon and vicinity)

- (●) : U. of G. station; ● : Others in Oregon; ▲ : Others in the vicinity
 (*): SEMRTS, Corvallis

TABLE 3. GLOBAL RADIATION (SOLAR RADIATION ON A HORIZONTAL SURFACE)
IN LANGLEYS/DAY FOR 1977

Station: Bend, Oregon Latitude: 44°04'N Longitude: 121°17'W
Elevation: ~4000' (~1219m)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	261	0	493	160	544	593	598	550	413	238	155
2	0	66	0	493	462	656	719	435	372	405	0	132
3	0	263	299	536	585	312	502	660	329	394	0	169
4	0	266	400	559	444	560	429	652	482	382	114	156
5	0	95	392	491	313	707	422	608	0	297	199	161
6	0	224	281	546	485	426	736	593	529	187	198	188
7	0	95	270	545	325	396	719	431	523	256	225	203
8	0	186	310	529	636	727	581	596	540	395	274	190
9	0	268	421	341	171	657	588	649	526	368	123	0
10	0	288	443	527	149	690	698	574	519	366	134	148
11	0	241	374	558	274	300	594	614	513	366	99	51
12	0	242	356	520	548	603	700	603	501	330	204	75
13	0	279	376	489	500	444	702	405	487	246	242	63
14	0	304	360	597	587	616	699	401	370	325	139	63
15	0	283	420	446	294	692	685	532	302	338	193	81
16	0	255	0	514	587	740	623	512	312	337	199	39
17	0	312	0	606	348	601	439	537	248	333	175	71
18	0	330	0	0	536	682	433	472	173	330	132	207
19	205	316	262	0	714	611	673	540	379	247	74	171
20	0	174	327	0	598	351	614	488	485	295	108	114
21	0	285	282	357	408	713	474	430	322	320	32	102
22	28	277	297	346	343	670	611	574	463	226	53	176
23	163	116	84	368	331	717	460	495	205	0	68	147
24	237	320	129	402	505	699	358	363	354	298	58	120
25	82	163	442	0	543	716	519	158	338	123	75	181
26	255	211	0	0	487	704	664	362	407	202	135	31
27	249	226	475	0	585	713	608	208	63	232	172	29
28	247	226	503	0	688	725	684	197	76	96	57	70
29	248		368	375	739	714	661	471	286	133	140	52
30	0		494	304	304	643	668	555	322	253	146	142
31	148		137		547		659	366		169		59
AVG	186	235	340	476	458	611	597	486	378	289	143	118
MAX	255	330	503	606	739	740	736	660	550	413	274	207
MIN	28	66	84	304	149	300	358	158	63	96	32	29

0 = MISSING DATA

TABLE 4. GLOBAL RADIATION (SOLAR RADIATION ON A HORIZONTAL SURFACE)
IN LANGLEYS/DAY FOR 1978

Station: Bend, Oregon		Latitude: 44°04'N		Longitude: 121°17'W		Elevation: ~4000' (~1219m)						
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	75	139	272	254	611	668	536	654	528	423	280	176
2	30	66	62	506	578	692	434	643	460	410	204	180
3	159	151	216	305	598	684	134	625	483	408	164	155
4	112	75	68	429	630	689	575	480	284	396	272	83
5	128	83	187	399	560	671	614	638	160	391	249	135
6	164	93	304	224	640	603	634	545	351	381	263	87
7	58	144	240	348	639	662	330	585	149	343	136	201
8	157	83	191	484	460	669	684	521	341	367	122	110
9	34	201	284	549	331	500	658	623	236	347	195	96
10	23	133	387	539	404	464	662	624	293	363	245	75
11	69	307	189	581	574	694	667	577	323	334	257	123
12	138	55	432	584	296	484	621	231	510	***	239	197
13	30	65	363	409	529	595	662	390	127	***	243	186
14	26	190	441	411	281	***	577	589	404	***	248	105
15	150	249	338	272	492	615	574	176	398	***	82	188
16	154	126	417	447	683	705	568	325	447	315	119	94
17	134	117	418	480	661	668	***	572	418	334	***	66
18	36	280	421	447	614	577	***	589	424	336	***	113
19	168	318	439	335	489	699	651	441	475	305	***	205
20	204	305	448	380	298	603	675	***	448	271	***	48
21	102	310	334	512	637	528	674	***	252	323	***	166
22	205	332	339	494	519	527	655	***	361	321	***	***
23	241	138	250	278	638	435	608	***	441	252	***	***
24	223	145	176	316	367	325	624	394	380	313	***	***
25	71	161	356	110	522	468	510	551	338	324	***	***
26	220	196	383	122	325	567	255	483	441	306	***	***
27	220	372	476	613	520	694	***	547	334	251	***	***
28	128	382	406	432	692	445	***	544	386	309	***	***
29	70		289	599	704	393	***	505	416	251	***	***
30	77		250	301	708	529	645	224	393	285	***	***
31	138		148		560		660	297		237		***
AVG	121	186	307	405	534	581	573	495	367	329	207	133
MAX	241	382	476	613	708	705	684	654	528	423	280	205
MIN	23	55	62	110	281	325	134	176	127	237	82	48

*** = MISSING DATA

Multiply all irradiation values by 1.02.

TABLE 5. GLOBAL RADIATION (SOLAR RADIATION ON A HORIZONTAL SURFACE)
IN LANGLEYS/DAY FOR 1977

Station: Coos Bay, Oregon Latitude: 43°22'N Longitude: 124°14'W
Elevation: ~100' (~30m)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	0	265	341	214	0	543	518	0	381	138	2
2	0	267	66	385	392	641	0	654	356	392	211	0
3	0	226	251	547	443	234	495	537	258	361	217	37
4	0	224	381	514	384	431	669	401	234	320	68	80
5	0	79	362	267	477	708	479	199	368	302	139	111
6	0	241	121	397	609	694	721	324	499	181	148	59
7	0	153	65	311	483	189	642	170	456	228	177	102
8	0	213	111	319	676	712	456	533	516	341	239	147
9	0	198	218	392	142	675	533	588	503	353	153	65
10	0	81	349	287	193	205	694	587	469	335	129	112
11	0	189	321	513	0	286	673	626	492	319	52	66
12	0	153	236	484	649	616	431	462	457	0	168	45
13	0	293	276	363	405	528	689	240	124	282	161	27
14	0	313	190	600	318	553	690	292	93	277	60	26
15	0	292	177	276	487	631	653	468	198	272	111	131
16	0	207	473	537	293	663	888	560	206	302	160	18
17	0	191	276	609	376	130	561	285	193	310	188	131
18	0	332	146	578	457	0	441	313	88	148	0	96
19	0	205	0	609	0	424	682	514	153	265	188	131
20	0	137	411	446	405	214	669	185	350	71	84	44
21	0	207	452	294	391	638	676	415	400	297	33	62
22	0	263	234	428	168	530	636	536	359	133	79	98
23	0	114	261	348	282	684	579	0	109	214	28	15
24	0	88	292	384	631	708	188	357	266	88	25	113
25	0	99	395	239	271	637	189	157	227	139	23	158
26	0	166	284	501	508	716	418	365	333	272	89	109
27	0	101	347	0	460	716	525	253	83	201	61	33
28	0	122	363	0	648	708	580	215	212	67	68	67
29	0		361	0	705	716	643	492	315	85	41	42
30	0		504	0	329	650	650	480	283	166	89	136
31	0		127		262		0	0		153		171
AVG	0	191	277	422	416	544	564	404	295	242	114	84
MAX	0	332	504	609	705	716	721	654	516	392	239	171
MIN	0	79	65	239	142	130	188	157	83	67	23	15

0 = MISSING DATA

TABLE 6. GLOBAL RADIATION (SOLAR RADIATION ON A HORIZONTAL SURFACE)
IN LANGLEYS/DAY FOR 1978

Station: Coos Bay, Oregon		Latitude: 43°22'N		Longitude: 124°14'W		Elevation: ~100' (~30m)						
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	52	82	***	205	530	681	194	***	***	***	259	103
2	36	22	***	294	375	500	354	***	***	***	203	81
3	38	75	***	224	576	522	275	***	***	***	107	85
4	56	117	***	311	***	598	532	***	***	***	224	19
5	30	68	***	325	614	630	678	***	***	***	249	147
6	89	73	***	541	643	621	594	***	***	***	248	173
7	48	91	***	372	629	573	395	***	***	***	253	171
8	71	55	***	504	587	536	511	***	***	***	82	112
9	81	151	***	538	190	411	***	***	***	***	215	29
10	147	265	***	517	226	357	581	***	***	***	246	57
11	34	264	156	556	441	683	656	***	***	***	247	73
12	71	119	297	555	196	243	651	***	***	***	198	165
13	43	182	333	240	131	567	404	***	***	***	234	166
14	43	77	***	120	94	479	431	***	***	***	232	68
15	83	233	370	190	323	546	128	***	***	***	***	161
16	73	117	389	290	583	594	478	***	***	***	***	69
17	130	75	400	116	648	687	646	***	***	***	***	71
18	34	107	504	266	648	224	629	***	***	***	***	162
19	58	283	408	234	659	678	564	***	***	***	***	169
20	82	***	425	381	551	179	633	***	***	***	***	44
21	107	***	328	356	518	412	***	***	***	***	***	76
22	***	***	103	280	596	261	***	***	***	***	***	43
23	193	***	174	277	354	277	***	***	***	***	128	42
24	201	***	177	237	401	505	***	***	***	***	195	79
25	87	***	395	176	323	320	***	***	***	***	176	166
26	180	***	352	270	194	559	***	***	***	***	193	97
27	204	***	215	235	162	667	***	***	***	***	125	93
28	62	***	227	358	577	311	***	***	***	115	23	168
29	223		131	532	694	194	***	***	***	145	31	163
30	153		285	328	682	199	***	***	***	280	23	171
31	120		265		686		***	***		289		122
	94	129	297	328	461	467	491	0	0	207	177	108
	223	283	504	556	694	687	678	0	0	289	259	173
	30	22	103	116	94	179	128	0	0	115	23	19

*** = Missing Data

Multiply all irradiation values by 1.02.

TABLE 7. GLOBAL RADIATION (SOLAR RADIATION ON A HORIZONTAL SURFACE)
IN LANGLEYS/DAY FOR 1977

Station: Eugene, Oregon Latitude: 44°03'N Longitude: 123°04'W
Elevation: 500' (~152m)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	103	187	248	144	388	526	605	520	240	150	61
2	0	63	69	368	427	971	615	605	281	216	166	38
3	0	153	183	491	344	197	344	611	228	209	78	49
4	0	205	346	526	337	329	570	603	331	357	40	59
5	0	86	337	529	357	612	499	517	302	315	101	126
6	0	71	180	519	528	559	720	535	494	136	160	63
7	0	169	172	512	315	596	714	533	480	208	164	110
8	0	168	130	285	602	714	695	598	520	186	159	156
9	0	228	174	355	519	653	230	600	480	274	138	41
10	0	120	298	360	242	600	702	602	464	323	183	78
11	0	106	348	406	465	312	659	563	478	327	76	99
12	0	126	259	497	502	531	270	570	463	282	124	42
13	0	103	301	362	496	621	703	555	439	158	131	24
14	0	212	261	548	363	460	650	548	98	158	34	435
15	0	250	371	204	360	428	652	575	231	255	67	60
16	0	239	380	393	349	636	624	561	294	246	111	24
17	0	280	213	560	438	559	0	539	290	179	133	106
18	0	238	126	476	392	377	360	444	112	144	112	98
19	0	285	210	589	665	489	640	510	173	247	102	98
20	0	105	354	411	432	204	656	129	274	39	166	69
21	0	173	434	263	480	621	650	134	301	274	71	102
22	0	165	409	368	248	471	666	482	392	168	76	54
23	0	81	265	443	253	738	638	405	79	236	27	24
24	0	76	330	387	0	727	610	293	320	167	25	54
25	0	86	426	222	0	506	324	154	252	113	21	56
26	0	115	246	510	0	686	0	327	296	130	95	111
27	0	133	326	563	357	688	525	288	70	127	57	70
28	0	155	296	398	490	675	573	292	119	73	56	72
29	0		364	362	684	692	619	356	196	109	62	55
30	0		497	321	318	651	638	493	224	124	64	76
31	0		133		423		650	456		86		143
AVG	0	153	278	416	412	556	576	467	307	197	98	86
MAX	0	285	497	589	684	738	720	611	520	357	183	435
MIN	0	63	69	204	144	197	230	129	70	39	21	24

0 = MISSING DATA

TABLE 8. GLOBAL RADIATION (SOLAR RADIATION ON A HORIZONTAL SURFACE)
IN LANGLEYS/DAY FOR 1978

Station: Eugene, Oregon Latitude: 44°03'N Longitude: 123°04'W
Elevation: 500' (~152m)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	138	***	202	181	435	678	143	626	490	323	251	114
2	27	***	235	280	396	673	238	617	428	332	189	97
3	***	***	219	302	469	653	159	587	139	376	153	68
4	***	***	97	***	464	663	332	551	91	310	188	23
5	***	***	131	***	464	646	607	***	124	353	218	132
6	***	***	173	***	638	***	656	***	226	280	238	36
7	***	***	100	***	622	***	589	585	282	218	171	166
8	***	***	84	***	576	***	393	***	152	345	30	97
9	***	***	283	***	184	354	269	***	125	122	185	22
10	***	***	146	506	212	277	631	***	231	271	241	61
11	***	***	137	***	384	676	671	***	357	323	243	51
12	***	***	279	***	211	315	615	***	***	332	217	46
13	***	***	301	***	163	459	626	***	89	331	222	156
14	***	***	374	***	172	443	631	***	326	326	216	36
15	***	***	357	***	410	435	88	256	346	119	46	126
16	***	***	386	***	465	604	312	304	389	172	67	61
17	***	***	396	***	557	688	644	475	251	273	68	56
18	***	***	403	339	657	133	588	547	385	291	94	35
19	***	***	412	250	555	616	640	273	***	294	44	140
20	***	***	***	***	628	502	641	237	***	71	70	35
21	***	***	***	***	***	312	657	147	303	297	130	107
22	***	72	225	188	***	335	602	276	241	290	96	62
23	***	148	228	267	***	219	625	277	402	236	126	39
24	***	162	***	291	***	476	635	126	354	238	27	89
25	***	172	403	***	334	222	599	367	266	256	32	42
26	***	180	290	***	179	635	542	486	303	***	34	113
27	***	264	***	***	211	671	469	527	305	109	117	81
28	***	334	163	362	363	598	483	522	372	99	24	144
29	***		152	504	***	179	624	488	378	161	31	150
30	***		197	185	***	327	632	133	170	104	26	159
31	***		256		***		***	223		244		73
AVG	83	190	246	305	406	474	511	392	279	250	126	84
MAX	138	334	412	506	657	688	671	626	490	376	251	166
MIN	27	72	84	181	163	133	88	126	89	71	24	22

*** = MISSING DATA

Multiply all irradiation values by 1.02.

TABLE 9. GLOBAL RADIATION (SOLAR RADIATION ON A HORIZONTAL SURFACE)
IN LANGLEYS/DAY FOR 1977

Station: La Grande, Oregon Latitude: 45°20'N Longitude: 118°05'W
Elevation: 2900' (884m)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	127	191	303	316	369	419	628	506	372	73	44
2	0	234	233	318	277	635	695	282	318	352	219	13
3	0	237	151	421	160	429	586	593	356	386	164	80
4	2	235	358	508	350	610	201	600	413	365	196	23
5	0	196	356	516	447	675	414	574	468	245	103	122
6	0	244	163	506	256	386	685	425	477	169	161	58
7	0	224	87	511	416	448	694	540	481	89	146	63
8	0	0	180	321	513	701	597	511	505	309	228	57
9	0	173	188	507	238	609	454	592	500	320	162	49
10	0	204	370	513	208	598	695	586	469	338	183	93
11	0	273	324	398	493	399	535	631	443	321	102	42
12	0	196	167	530	350	558	626	575	442	326	179	41
13	0	282	284	349	544	277	670	574	445	185	76	14
14	0	284	263	573	394	436	647	275	419	290	26	19
15	0	250	255	379	357	607	655	577	288	298	56	35
16	0	218	266	368	301	690	656	562	114	308	92	130
17	0	211	374	564	240	696	404	551	287	288	91	30
18	0	279	218	519	227	597	246	545	179	292	92	80
19	0	302	166	474	567	447	663	358	93	173	96	164
20	0	116	221	498	572	448	617	512	348	255	171	140
21	0	74	259	197	530	690	469	318	204	257	56	17
22	0	200	447	468	511	544	439	506	267	265	51	6
23	0	303	123	563	249	650	565	392	44	92	59	0
24	0	307	355	596	412	690	128	208	298	255	21	0
25	162	160	0	440	463	665	511	210	201	43	33	0
26	190	196	107	567	100	678	589	287	418	182	75	51
27	226	106	162	598	481	659	618	244	143	15	51	43
28	207	62	251	531	517	681	547	111	58	86	109	122
29	106		230	450	700	674	605	205	271	131	99	43
30	238		488	371	458	691	632	307	252	136	126	115
31	83		115		591		630	245		96		169
AVG	173	211	245	462	395	575	545	436	324	233	110	67
MAX	238	307	488	598	700	701	695	631	506	386	228	169
MIN	83	62	87	197	100	277	128	111	44	15	21	6

0 = MISSING DATA

TABLE 10. GLOBAL RADIATION (SOLAR RADIATION ON A HORIZONTAL SURFACE)
IN LANGLEYS/DAY FOR 1978

Station:	La Grande, Oregon				Latitude:		45°20'N		Longitude:		118°05'W	
	Elevation: 2900' (≈884m)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	102	60	329	115	450	652	***	***	502	378	233	58
2	86	87	295	388	518	600	370	***	422	367	207	86
3	81	198	117	356	497	627	345	***	410	354	80	47
4	160	92	40	141	287	642	158	***	438	357	234	14
5	44	33	95	170	361	638	462	***	95	355	203	186
6	112	159	339	113	398	610	607	***	103	334	207	133
7	102	65	81	137	615	584	346	***	45	285	184	179
8	27	227	90	444	584	624	581	***	407	267	26	144
9	36	102	238	526	207	459	536	***	191	320	149	26
10	61	174	321	490	287	325	618	***	277	267	224	81
11	124	100	144	557	441	662	***	***	226	321	201	21
12	75	265	183	525	400	231	***	***	300	293	46	158
13	41	107	242	432	270	417	***	***	230	311	133	171
14	114	168	318	361	144	331	***	***	361	316	215	94
15	114	108	422	412	358	579	***	***	324	228	178	177
16	60	247	406	304	509	***	***	***	435	234	89	82
17	78	95	387	424	428	***	***	***	297	275	35	101
18	93	94	420	519	436	***	***	***	285	292	94	122
19	66	127	365	391	610	***	***	***	370	281	34	153
20	70	86	413	171	351	***	***	***	346	255	79	117
21	120	296	388	331	376	***	***	***	217	283	72	64
22	155	307	400	253	515	***	***	***	231	274	98	52
23	207	198	80	540	276	***	***	***	396	255	89	47
24	119	48	275	309	367	***	***	***	371	189	45	130
25	88	118	336	198	408	***	***	***	385	271	68	150
26	216	172	382	104	350	***	***	***	383	277	92	158
27	210	144	451	92	442	***	***	***	247	196	115	58
28	53	323	376	393	587	***	***	***	318	210	101	92
29	151		410	562	583	***	***	***	374	132	36	161
30	126		274	562	666	***	***	***	222	115	18	166
31	74		364		623		***	***		254		169
AVG	102	150	290	344	430	532	447	0	307	276	120	110
MAX	216	323	451	562	666	662	618	0	502	378	234	186
MIN	27	33	40	92	144	231	158	0	45	115	18	14

*** = MISSING DATA

Multiply all irradiation values by 1.02.

TABLE 11. GLOBAL RADIATION (SOLAR RADIATION ON A HORIZONTAL SURFACE)
IN LANGLEYS/DAY FOR 1977

Station: Whitehorse Ranch Latitude: 42°20'N Longitude: 118°14'W
Elevation: 4350' (~1325m)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	180	270	310	329	639	335	563	545	427	159	0
2	0	293	382	497	535	633	342	438	546	418	171	0
3	0	284	270	438	241	625	434	349	528	403	280	63
4	0	303	415	553	596	684	661	467	522	409	254	160
5	0	260	414	502	271	599	713	490	508	347	176	0
6	0	302	0	561	404	576	522	413	502	163	280	98
7	0	297	136	561	343	356	669	216	509	386	233	164
8	0	139	345	0	508	516	682	596	0	394	271	185
9	0	299	254	219	0	237	493	592	514	373	264	111
10	0	222	426	589	296	364	712	584	504	373	238	188
11	0	319	358	554	343	597	700	606	510	369	109	55
12	0	0	227	573	434	586	663	524	502	344	237	153
13	0	0	349	198	545	470	703	471	432	328	149	45
14	0	319	362	612	549	380	671	410	277	349	101	50
15	0	279	372	517	238	658	576	470	465	351	203	159
16	0	287	389	533	473	0	659	541	140	351	236	70
17	0	324	390	616	373	505	621	244	426	344	167	60
18	0	351	305	620	497	496	658	347	376	335	176	204
19	0	330	249	620	592	494	550	423	220	268	0	208
20	107	163	442	541	663	394	671	469	233	283	0	156
21	181	187	492	439	495	704	595	523	358	300	29	118
22	181	252	488	539	457	611	464	531	404	300	179	149
23	240	106	227	617	312	698	0	0	277	101	116	159
24	172	363	0	621	373	697	0	128	430	311	38	121
25	59	258	452	503	503	697	547	101	424	277	141	185
26	159	301	472	626	447	696	653	0	405	126	179	105
27	267	370	376	535	653	699	382	265	359	227	148	22
28	292	286	377	503	684	712	668	379	212	153	173	25
29	282		260	0	720	710	662	556	140	158	0	49
30	284		317	0	607	606	0	526	301	218	0	158
31	192		276		701		650	531		192		0
AVG	201	272	348	518	473	574	595	440	399	302	181	119
MAX	292	370	492	626	720	712	713	606	546	427	280	208
MIN	59	106	136	198	238	237	335	101	140	101	29	22

0 = Missing Data

TABLE 12. GLOBAL RADIATION (SOLAR RADIATION ON A HORIZONTAL SURFACE)
IN LANGLEYS/DAY FOR 1978

Station: Whitehorse Ranch Latitude: 42°20'N Longitude: 118°14'W
Elevation: 4350' (~1325m)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	135	113	365	201	431	536	530	625	534	399	263	145
2	101	81	190	426	605	443	595	626	451	413	277	139
3	143	197	281	405	607	495	278	609	472	422	270	198
4	126	126	84	320	566	483	***	404	393	404	150	113
5	92	139	257	356	430	667	***	386	147	***	249	151
6	121	73	372	159	313	606	***	536	110	383	269	***
7	193	69	205	250	571	630	390	566	144	373	229	***
8	74	145	110	399	621	682	644	524	496	378	253	***
9	41	169	229	554	447	622	608	474	***	375	242	***
10	105	99	413	546	455	252	652	567	286	373	***	***
11	113	267	195	***	520	***	645	590	331	364	149	72
12	178	214	367	565	642	537	***	***	511	368	147	152
13	85	157	180	405	531	603	560	***	233	371	274	209
14	80	323	450	411	579	588	***	607	358	367	262	217
15	184	273	451	292	381	***	650	483	472	243	251	186
16	83	253	448	378	559	690	659	466	473	309	182	179
17	92	269	375	426	649	701	667	481	345	339	235	85
18	106	272	407	550	342	443	660	595	302	346	219	***
19	85	251	370	496	516	689	653	577	461	301	162	223
20	138	***	462	318	569	657	585	586	462	319	103	182
21	193	309	297	538	600	642	668	504	380	321	47	164
22	126	158	187	382	579	691	647	***	454	342	118	97
23	240	302	226	511	260	692	602	520	444	327	190	141
24	240	163	478	308	340	314	606	542	434	267	76	187
25	119	321	462	161	411	603	631	561	426	327	39	208
26	175	156	397	114	482	529	406	337	290	322	214	193
27	250	295	489	366	557	476	586	549	378	310	197	97
28	217	391	494	329	675	522	616	542	422	300	61	206
29	218		371	610	689	571	638	515	388	***	40	198
30	58		253	241	687	670	621	403	399	296	40	207
31	148		147		686		612	529		282		163
AVG	137	207	323	380	526	573	593	525	379	343	180	164
MAX	250	391	494	610	689	701	668	626	534	422	277	223
MIN	41	69	84	114	260	252	278	337	110	243	39	72

*** = MISSING DATA

Multiply all irradiation values by 1.02.