WORLD METEOROLOGICAL ORGANIZATION

INSTRUMENTS AND OBSERVING METHODS

REPORT No. 43

FIRST WMO REGIONAL PYRHELIOMETER COMPARISON OF RA II AND RA V

(Tokyo, 23 January–4 February 1989)]

by
Y. SANO

WMO TD No 308

1989

W O R L D M E T E O R O L O G I C A L O R G A N I Z A T I O N

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WITH THE COMPLIMENTS

of
Mr. Klemm
Senior Scientific Officer
World Weather Watch Department

WORLD METEOROLOGICAL
ORGANIZATION
GENEVE

NOTE

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1. INTRODUCTION

1.1 The Executive Council at its thirty-ninth session approved the regional comparison of national standard pyrheliometers of RA II and RA V.

1.2 Considering the importance of Recommendations 10, 11, and 14 of CIMO-IX, which were approved by the EC-XXXVIII, the Japan Meteorological Agency (JMA) agreed, at the request of WMO, to host the First WMO Regional Pyrheliometer Comparison of RA II and RA V. The Comparison was carried out from 23 January to 4 February 1989 at the Regional Radiation Center Tokyo (Tsukuba).

1.3 The International Organizing Committee for the Comparison held its first session at the Regional Radiation Center Tokyo and the JMA Headquarters from 31 October to 2 November 1988. The list of participants is given in Appendix A. The Committee prepared the detailed procedures for the Comparison and visited the Comparison site in Tsukuba.

1.4 The WMO Secretariat distributed in March 1988 the notification on the Comparison and in August 1988 the invitation to the Comparison. In November 1988, the Secretariat sent the final report of the first session of the International Organizing Committee for the Comparison to Members who had indicated their intention to participate in the Comparison.

1.5 The International Organizing Committee held its second session at the Comparison site of the Regional Radiation Center Tokyo (Tsukuba) from 2 to 4 February 1989. The list of participants is attached in Appendix A. The Committee analyzed and approved the final results of the Comparison including the WRR reduction factors and new calibration factors of the instruments participated in the Comparison.

1.6 Members of the second session of the Committee,

including the Project Leader and the representatives of: WRC Davos, RRC Melbourne, RRC Tokyo, and the Secretariats of WMO and JMA, met in Tokyo (JMA Headquarters) between 4 and 7 February 1989. They discussed and improved on the draft final report of the Comparison.

2. PARTICIPATION

2.1 Ten Members of RA II and RA V, and the WRC Davos participated with 23 experts in the Comparison. The list of participants is given in Appendix B.

2.2 Seventeen pyrheliometers (9 Angstrom pyrheliometers, 6 absolute radiometers, including one of the World Standard Group, and 2 thermoelectric pyrheliometers), and eight pyranometers participated in the Comparison. The list of instruments is attached in Appendix C.

3. DATA ACQUISITION AND EVALUATION

3.1 The Comparison was carried out 70 km north of Tokyo at an elevation of 560 m above sea level, half way up to the Mt. Tsukuba on the roof of the Tsukubasan Keisei Hotel. This location provided good comparison conditions.

3.2 The pyrheliometers and pyranometers were mounted on iron benches which were fixed on the hotel roof. The control units of the pyrheliometers were protected from the sun and wind. Some movable wind shields were used in order to enlarge the wind-protected area on the roof.

3.3 AC power (220V/50Hz and 100V/50Hz) was available on the benches. Push-button switches (for sending validation signals to the computer) and terminal boards (for relaying pyrheliometer output to the data logger) were provided.

3.4 All participants operated their own pyrheliometers during the period of the Comparison. The JMA staff operated the pyrheliometer of New Zealand.

3.5 The operation of the radiation measuring instruments including PMO-6 (Japan), PMO-5 (WRC),and PACRAD (India) was done manually. Some of the instruments signals were recorded automatically by a data logger, but all participants kept manual records for control purposes as shown in Appendix D.

3.6 Measured data were evaluated on a daily basis.

3.7 The following meteorological variables were measured simultaneously with the comparison series:

(i) Air-temperature;
(ii) Humidity;
(iii) Pressure;
(iv) Wind speed;
(v) Wind direction;
(vi) Atmospheric ozone concentration; and
(vii) Aerosol optical depth.

3.8 The meteorological variables mentioned-above are given in Appendix L with global/diffuse radiation, solar elevation, and relative air-mass.

4. PROCEDURES

4.1 Timing

The duration of one series of measurement was 18 minutes. This period was divided into 12 intervals of 90 seconds so that 6, 10 or 12 readings were obtained by individual instruments in one series. The synchronization of measurements was achieved by voice announcement and buzzer from the computer system each 90 seconds. Voice

announcements were made at -5, -3 minutes, -1 minute, and -15 seconds. The buzzer sounds were: short pulses -5, -4 and -3 seconds, continuous sound between -2 and 3 seconds indicating data reading. The timing diagrams are shown in Appendix E.

4.2 Operation of instruments

4.2.1 Angstrom pyrheliometer

Cold-zero-adjustment was made before each series. Series started with the right aperture closed. Right and left aperture were closed alternately every 90 seconds. Twelve observations were thus made during 18 minutes: The first reading of each series were not used.

4.2.2 PACRAD/H-F absolute radiometer

Zero-adjustment and self-calibration were made before each series. Zero-point reading was taken first, then the heater current was turned on, and heater voltage/current and thermopile output were read. After this calibration, the heater was turned off and the sensor exposed to the sun. The thermopile output was read every 90 seconds from then on. Twelve values were obtained in each series.

4.2.3 PMO absolute radiometer

Series started with a closed reading, then the PMO radiometers alternated between open and closed shutters every 45 seconds in case of the PMO-6 (Japan, working reference), and every 90 seconds for the PMO-5 (WRC, WSG). Twelve or six readings were obtained in each series respectively. The signals from both instruments were acquired automatically, but their shutters were operated manually.

4.2.4 Thermoelectric pyrheliometer

The thermopile output was read automatically every 90

seconds. Twelve values were obtained in each series.

4.3 The radiation data were evaluated using the equations shown in Appendix F. For PACRAD 13219 (India), 0.834 W/m2 was added to the right-hand side of Formula A.

4.4 The following readings were made:

(i) Current/voltage, for PMO absolute radiometer;
(ii) Current for Angstrom pyrheliometer;
(iii) Thermopile voltage for thermoelectric pyrheliometer;
(iv) Self-calibration values (current/voltage) and thermopile voltage for PACRAD/H-F absolute radiometer.

Data formats for manual records used at the Comparison are attached as Appendix G.

5. COMPARISON REFERENCE

5.1 As comparison reference, a Regional Standard Group (RSG) was established. This group consisted of one instrument of the World Standard Group (PMO-5) and two Regional Standards (PMO-6, Japan and PACRAD, India). PMO-6 served as the working standard for preliminary data evaluation. PMO-6 and PACRAD provided 12 reference values and PMO-5 provided 6 reference values for each series.

5.2 The determination of regional radiometric reference was made according to the following table:

SEQ#	STANDARD 1 (WORKING)	STANDARD 2	STANDARD 3	REFERENCE
1	PMO-6(1)	PMO-5(1)	PACRAD(1)	REF(1)
2	PMO-6(2)	-	PACRAD(2)	REF(2)
3	PMO-6(3)	PMO-5(2)	PACRAD(3)	REF(3)
		¦		
11	PMO-6(11)	PMO-5(6)	PACRAD(11)	REF(11)
12	PMO-6(12)	-	PACRAD(12)	REF(12)

REF(1)= 1/3 x (PMO-6(1)+PMO-5(1)+PACRAD(1))
REF(2)= C1 x PMO-6(2);
C1=1/2 x (REF(1)/PMO-6(1)+REF(3)/PMO-6(3))
REF(3)= 1/3 x (PMO-6(3)+PMO-5(2)+PACRAD(3))
¦
REF(11)= 1/3 x (PMO-6(11)+PMO-5(6)+PACRAD(11))
REF(12)= C6 x PMO-6(12);
C6= REF(11)/PMO-6(11)

5.3 Radiometric references of each measurement are listed in Appendix H.

6. COMPARISON MEASUREMENTS

6.1 Measurements were taken on 25, 27, 28, 29, 30 and 31 January 1989 with a total of 41 series.

6.2 From the total number of 41 series, 13 series of measurements were selected using criteria mentioned in para.7.

7. REFERENCE EVALUATION

7.1 A 2 % criterion was applied to the selection of individual values.

7.2 A 0.25 % criterion was applied to the mean values of series to be included in the final evaluation.

7.3 Series selected can be found in Appendix I.

8. COMPARISON RESULTS

8.1 The WRR reduction factors for all pyrheliometers which participated in the Comparison were adopted by the second session of the International Organizing Committee (Tsukuba, 2 - 3 February 1989) and they are listed in Appendix J.

9. CALIBRATION OF PYRANOMETERS

9.1 Calibration of the pyranometers was made according to the WMO publication No.8, WMO GUIDE TO METEOROLOGICAL INSTRUMENTS AND METHODS OF OBSERVATION, fithth edition, para. 9.4.1.2: "By reference to a standard pyrheliometer and a shaded pyranometer".

9.2 The calibrated pyranometer (MS-801, JAPAN) with a shading disk and pyranometers to be calibrated were exposed to the sun. Signals were recorded every 90 seconds by the data logger. The sum of direct and diffuse radiation was used as the reference (G_{ref}) for the calibration according to:

$$G_{ref} = I \times \cos Z + D,$$

where I is the direct solar irradiation at normal incidence determined by the regional reference (see para.5). D is the diffuse radiation measured by the shaded pyranometer (MS-801). For each measurement, the calibration factor (K) was

calculated as follows:

$$K = G_{ref}/V,$$

where V is the output voltage of the pyranometer to be calibrated.

9.3 The mean values of K were adopted as the final calibration factors. They are given in Appendix K.

9.4 It is emphasized that calibration was performed at temperature around 7°C. For non-compensated pyranometers (CM 5 and MS-801), these values may only be used after temperature correction.

10. OTHER ACTIVITIES

10.1 During the Comparison, days with atmospheric condition unsuitable for measurements were utilized for training in radiation measurements and for lectures on:

(i) Sunphotometers calibration - Dr. T. Ito, Dr.M. Shiobara, Mr.C. Wehrli, and Mr.Y. Miyake (EKO Co.,Ltd.);

(ii) Solar trajectory and radiation - Mr. T.Yamauchi;

(iii) Activities of the WRC/PMOD - Mr. C. Wehrli;

(iv) Evolution of pyrheliometry - Mr. C. Wehrli and Dr. V.A. Klevantsova;

10.2 The participants also visited the Meteorological Research Institute and Meisei Electric Co., Ltd.

11. ACKNOWLEDGMENTS

The participants expressed their gratitude to the host

country and to the JMA for smooth organization and good preparation of the Comparison as well as for providing excellent facilities and working conditions for the Comparison. They also expressed their thanks to the Project Leader and participating staff of the JMA, to WMO, and to the WRC. Hospitality of the host country was highly appreciated.

12. REMARKS

The final results of the Comparison will be submitted to the presidents of CIMO, RA II, and RA V for approval, and they will be included as a recommendation of the next session of RA II and RA V.

List of participants

International Organizing Committee

First session (Tokyo, 31 October - 2 November 1988)

K. Dehne	(Chairman)	Germany, Fed. Rep. of
Y. Sano	(Project Leader)	Japan
H. Shimura	(representing RRC Tokyo)	Japan
M. Saito	(representing RRC Tokyo)	Japan
Y. Hirose	(representing RRC Tokyo)	Japan

S. Klemm	(WMO Secretariat)	
K. Nagasaka	(JMA Secretariat)	

Second session (Tsukuba, 2 - 3 February 1989)

Y. Sano	(Chairman/Project Leader)	Japan
V. Desikan	(representing RRC Puna)	India
P. Novotny	(representing RRC Melbourne)	Australia
C. Wehrli	(representing WRC Davos)	Switzerland
A. Klevantsova	(representing WRDC Leningrad)	USSR
H. Shimura	(representing RRC Tokyo)	Japan
M. Saito	(representing RRC Tokyo)	Japan
Y. Hirose	(representing RRC Tokyo)	Japan

S. Klemm	(WMO Secretariat)	
H. Ohno	(JMA Secretariat)	

In addition, the following experts also participated in the second session:

Lin Yiqiu	China
Lu Wenhua	China
Cheuk-ming Tam	Hong-Kong
T. Ito	Japan
M. Shiobara	Japan
Chan Ah Kee	Malaysia
Ibrahim Mat Tahir	Malaysia
Lee Bu-yong	Rep. of Korea

List of participants
First WMO Regional Pyrheliometer Comparison of RA II and RA V

Tokyo (Tsukuba), Japan, 23 January - 4 February 1989

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Appendix C

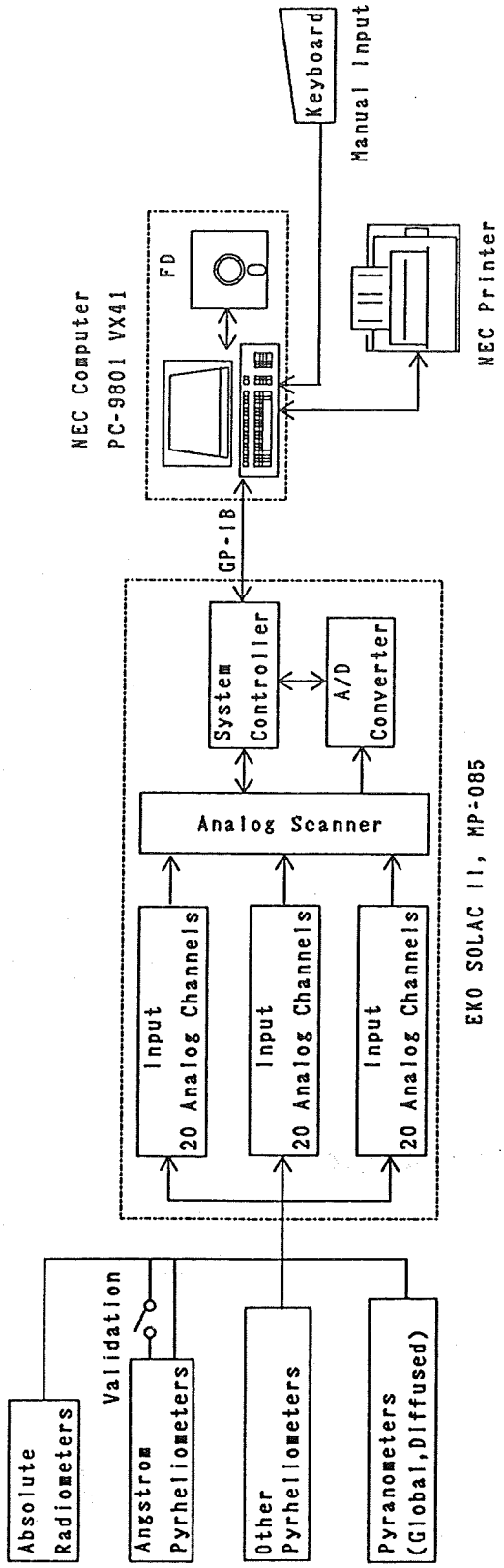
List of Instruments

(a) Pyrheliometer

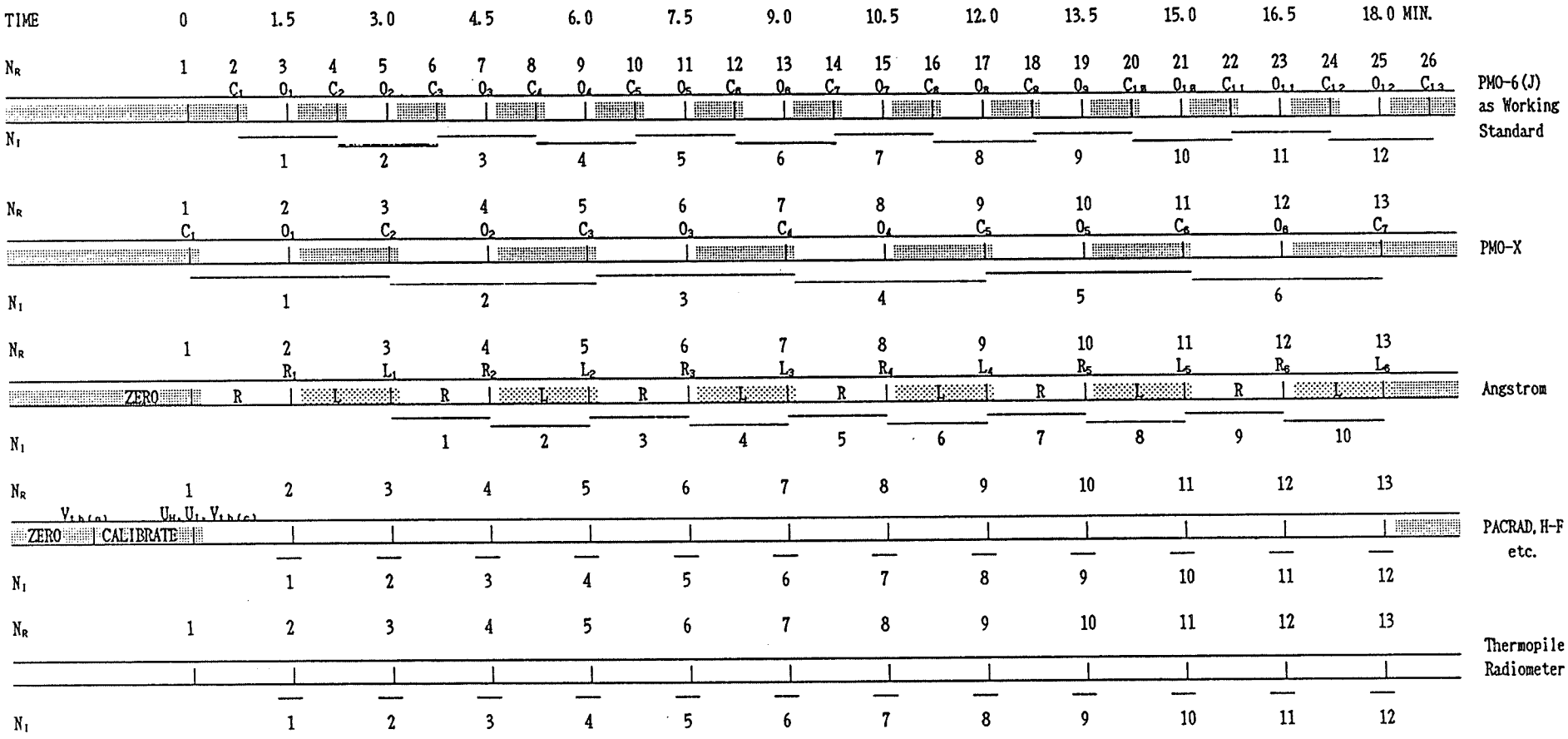
	INSTRUMENT	CALIBRATION FACTOR IN USE
AUSTRALIA	A 578	6237.3 $W \cdot m^{-2} \cdot A^{-2}$
CHINA	H-F 20294	20030.0 m^{-2}
	H-F 19743	20030.0 m^{-2}
HONG KONG	A 17864	4697 $W \cdot m^{-2} \cdot A^{-2}$
INDIA	PACRAD 13219	10079 m^{-2}
IRAN	A 12579	4344.4 $W \cdot m^{-2} \cdot A^{-2}$
JAPAN	PMO-6 811107	23.984 $W \cdot m^{-2} \cdot V^{-2}$
	H-F 23738	20040 m^{-2}
	A 26043	4831.1 $W \cdot m^{-2} \cdot A^{-2}$
	A 26044	4870.2 $W \cdot m^{-2} \cdot A^{-2}$
	NIP 10816E6	127.37 $W \cdot m^{-2} \cdot mV^{-1}$
	NIP 25677E6	127.21 $W \cdot m^{-2} \cdot mV^{-1}$
MALAYSIA	A 23628	4550.5 $W \cdot m^{-2} \cdot A^{-2}$
NEW ZEALAND	A 13591	4200 $W \cdot m^{-2} \cdot A^{-2}$
REPUBLIC OF KOREA	A 703	5954.3 $W \cdot m^{-2} \cdot A^{-2}$
USSR	A 212	10535 $W \cdot m^{-2} \cdot A^{-2}$
WRC DAVOS	PMO-5	31.638 $W \cdot m^{-2} \cdot V^{-2}$

(b) Pyranometer

	INSTRUMENT	CALIBRATION FACTOR IN USE ($W \cdot m^{-2} \cdot mV^{-1}$)
CHINA	PSP 20463F3	95.97
HONG KONG	CM 5 784530	87.22
IRAN	CM 5 752820	84.10
JAPAN	MS-801 F83006	139.99
	MS-801 F85035	157.58
	PSP 25918F3	103.32
MALAYSIA	CM 5 881454	88.89
REPUBLIC OF KOREA	SCP 23208	890.47



BLOCK DIAGRAM OF THE DATA ACQUISITION AND PROCESSING SYSTEM



▒ and Ci : CLOSE
▒ and Li : LEFT
i : Reading

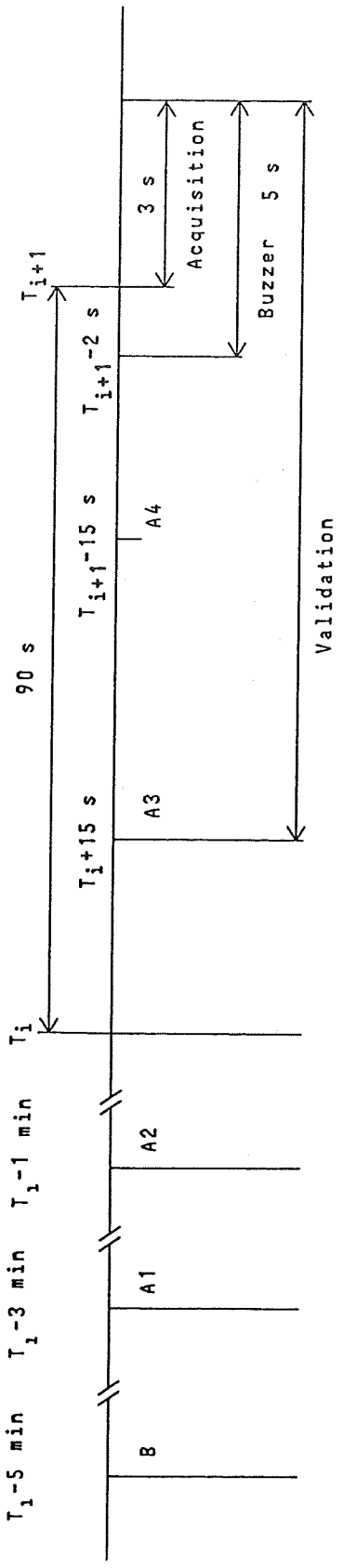
Oi : OPEN
Ri : RIGHT (shaded strip of Angstrom Pyrheliometer)
——— : Interval containing readings which are used for calculation of irradiance values

N_R : Running number of reading

N_I : Running number of calculable irradiance values

TIMING DIAGRAM

Appendix E, p.1



B Buzzer : five beeps
A1 Announce : "Three minutes before measurement"
A2 Announce : "One minute before measurement"
A3 Announce : "Please shade the left(or right) hand strip"
A4 Announce : "Fifteen seconds before measurement"

CHRONOLOGY OF ACQUISITION

CALCULATION OF DIRECT SOLAR IRRADIANCES

With the following notations:

I	direct solar irradiance
Vth	output of thermopile
U_H or U_R	voltage across heater (U_H) or standard resistor (U_R)
i_H	current through heater
R_N	standard resistor
K	calibration factor
R_L	resistance of heater leads

1. THE (IRRADIANCES) ABSOLUTE RADIOMETERS OF PACRAD TYPE ARE CALCULATED ACCORDING TO:

An irradiance measurement consists of the reading of the thermopile output Vth(irrad.) produced by the irradiated receiver. During the calibration period the shaded cavity is heated electrically and the voltage U_H across the heater, the voltage U_R across a standard resistor R_N and the corresponding thermopile output Vth (cal.) are measured. Further, the null of the thermopile Vth(null) is determined with the detector shaded and with no electrical power. The irradiance is determined by the following equation:

$$I = K \cdot \frac{Vth(irrad) - Vth(null)}{Vth(cal) - Vth(null)} \cdot \frac{U_R}{R_N} \cdot \left\{ U_H - \frac{U_R}{R_N} \cdot R_L \right\} \qquad \text{Formula A}$$

The TMI are calibrated directly by the user, so that only one value is read which is scaled and zeroed during the calibration period in such a way, that a 100 mV reading corresponds to 100 $mWcm^{-2}$, hence the irradiance formula is very simple:

$$I = K \cdot U \qquad \text{Formula B}$$

with:

$K = 10{,}000 Wm^{-2}V^{-1}$

2. ACTIVE ABSOLUTE RADIOMETERS

These radiometers are operated actively, which means that the temperature difference across the thermal resistor is maintained constant by heating the cavity electrically. During the shutter open period, the electricalpower is diminished by the amount of radiative power absorbed by the cavity. The intensity is calculated according to the following formulas, depending on how the electrical power is measured:

$$I = K \cdot [P_{(closed)} - P_{(open)}] \qquad \text{Formula C}$$

with:

$$P = U_H \cdot i_H \qquad \text{Formula D}$$

$$P = U_H \cdot \frac{U_R}{R_N} \qquad \text{Formula E}$$

$P_{(close)}$ is linearly interpolated for the instant of the open reading from the closed values before and after the open reading.

3. ANGSTROM PYRHELIOMETERS

The current through the left or right strip of the Angstrom pyrheliometer is measured as voltage drop across a standard resistor. The irradiance is calculated by the formula:

$$I = K \cdot \frac{U_R(right) \cdot U_R(left)}{R_N^2} \qquad \text{Formula F}$$

As this irradiance is the geometric mean between the irradiances prevailing at the time of the left and right reading respectively, the ratio to the reference is calculated using the geometric mean of the corresponding reference irradiances.

4. ACTINOMETERS (NORMAL INCIDENCE PYRHELIOMETERS)

The irradiance is directly calculated from the thermopile output. At the start of a measuring series, a reading of the zero with the detector shaded is performed. The irradiance amounts to:

$$I = K \cdot [V_{th(open)} - V_{th(closed)}] \qquad \text{Formula G}$$

ABSOLUTE RADIOMETER (ACTIVE CAVITY TYPE)

DATE : _____ RUN No. : _____
STARTING TIME : _____
MEMBER COUNTRY : _____
INSTRUMENT No. : _____ CODE : _____
CALIBRATION FACTOR:
K = _____ UNIT : _____
R_N = _____ UNIT : _____

TIME (MIN.)	SEQ. No.	DATA	TIME (MIN.)	SEQ. No.	DATA
-0.75	(1)	ZERO _____	9.75	(15)	P (0) _____
0.0	(2)	P (C) _____	10.5	(16)	P (C) _____
0.75	(3)	P (0) _____	11.25	(17)	P (0) _____
1.5	(4)	P (C) _____	12.0	(18)	P (C) _____
2.25	(5)	P (0) _____	12.75	(19)	P (0) _____
3.0	(6)	P (C) _____	13.5	(20)	P (C) _____
3.75	(7)	P (0) _____	14.25	(21)	P (0) _____
4.5	(8)	P (C) _____	15.0	(22)	P (C) _____
5.25	(9)	P (0) _____	15.75	(23)	P (0) _____
6.0	(10)	P (C) _____	16.5	(24)	P (C) _____
6.75	(11)	P (0) _____	17.25	(25)	P (0) _____
7.5	(12)	P (C) _____	18.0	(26)	P (C) _____
8.25	(13)	P (0) _____		(27)	ZERO _____
9.0	(14)	P (C) _____			

Note: Subscript (C) and (0) indicates "CLOSE" and "OPEN" respectively.
Please hand over a copy of this data sheet to us for the data processing.

REMARKS: _____

ABSOLUTE RADIOMETER (PACRAD TYPE)

DATE : _____ RUN No. : _____
STARTING TIME : _____
MEMBER COUNTRY : _____
INSTRUMENT No. : _____ CODE : _____
CALIBRATION FACTOR:
K = _____ UNIT : _____
R_L = _____ UNIT : _____
R_N = _____ UNIT : _____

TIME (MIN.)	SEQ. No.	DATA	TIME (MIN.)	SEQ. No.	DATA
-1.5	(1)	V_{th} (zero) _____	7.5	(7)	V_{th} _____
0.0	(2)	U_H _____	9.0	(8)	V_{th} _____
		U_R _____	10.5	(9)	V_{th} _____
		V_{th} (cal) _____	12.0	(10)	V_{th} _____
1.5	(3)	V_{th} _____	13.5	(11)	V_{th} _____
3.0	(4)	V_{th} _____	15.0	(12)	V_{th} _____
4.5	(5)	V_{th} _____	16.5	(13)	V_{th} _____
6.0	(6)	V_{th} _____	18.0	(14)	V_{th} _____

Please hand over a copy of this data sheet to us for the data processing.

REMARKS: _____

PYRHELIOMETER (ANGSTROM TYPE)

DATE : _____ RUN No. : _____
STARTING TIME : _____
MEMBER COUNTRY : _____
INSTRUMENT No. : _____ CODE : _____
CALIBRATION FACTOR :
K = _____ UNIT : _____
NORMAL RESISTOR : R_N= _____ UNIT : _____

TIME (MIN.)	SEQ. No.	DATA		TIME (MIN.)	SEQ. No.	DATA	
0.0	(1)	ZERO		10.5	(8)	U_R (R)	
1.5	(2)	U_R (R)		12.0	(9)	U_R (L)	
3.0	(3)	U_R (L)		13.5	(10)	U_R (R)	
4.5	(4)	U_R (R)		15.0	(11)	U_R (L)	
6.0	(5)	U_R (L)		16.5	(12)	U_R (R)	
7.5	(6)	U_R (R)		18.0	(13)	U_R (L)	
9.0	(7)	U_R (L)			(14)	ZERO	

Note: (R) and (L) indicates "RIGHT HAND STRIP SHADED" and "LEFT HAND STRIP SHADED" respectively.

Please hand over a copy of this data sheet to us for the data processing.

REMARKS: _____

SUMMARY OF REGIONAL RADIOMETRIC REFERENCE VALUES
FIRST WMO REGIONAL PYRHELIOMETER COMPARISON
OF
RA II AND RA V
TOKYO(TSUKUBA) JAPAN 1989

DATE	STARTING TIME	IRRADIANCE [W·m^{-2}]						MEAN [W·m^{-2}]	STANDARD DEVIATION [W·m^{-2}]	N
27-JAN.	10:59:45	763.7	764.1	780.1	759.8	754.6	754.1			
		760.5	774.5	763.4	782.3	783.2	784.2	768.69	11.41	12
	11:32:45	******	802.4	783.4	786.7	813.3	790.6			
		796.0	806.4	824.1	822.9	817.8	823.9	806.14	15.34	11
29-JAN.	09:47:45	945.7	948.2	947.8	944.9	946.8	950.1			
		950.4	950.0	952.6	948.7	954.7	965.3	950.44	5.42	12
30-JAN.	10:00:45	959.9	962.3	964.9	968.8	969.8	970.9			
		972.1	969.9	972.5	974.4	973.7	973.9	969.42	4.70	12
	10:30:45	979.2	975.2	975.8	977.6	978.2	978.0			
		979.9	984.3	984.9	984.3	986.0	989.0	981.02	4.48	12
	11:00:45	983.2	981.2	981.2	978.8	980.6	979.5			
		980.4	982.1	979.4	970.7	970.3	975.6	978.57	4.22	12
	12:00:45	932.6	940.3	939.4	943.1	940.9	936.6			
		942.3	941.6	941.8	939.4	945.3	941.8	940.43	3.26	12
	12:30:45	946.0	934.3	930.0	938.8	940.2	936.2			
		917.3	909.2	892.9	906.5	904.2	904.3	921.66	17.86	12
	13:00:45	925.6	914.6	917.7	915.6	909.2	899.5			
		877.3	878.5	853.6	862.4	864.1	849.4	888.96	27.69	12
	13:30:45	861.3	864.8	858.6	851.9	850.1	853.6			
		846.5	847.4	842.1	839.9	840.7	842.3	849.94	8.35	12
31-JAN.	10:00:45	809.4	809.7	812.7	817.9	815.5	817.8			
		824.6	824.5	822.6	823.9	822.5	840.2	820.11	8.41	12
	10:30:45	839.8	844.1	844.3	838.9	851.3	855.6			
		856.1	854.8	856.2	854.3	854.3	859.5	850.76	7.05	12
	11:00:45	852.8	855.4	856.5	843.4	853.3	861.4			
		856.4	856.5	849.8	851.6	850.6	835.1	851.91	6.92	12

SUMMARY OF ALL DAILY RESULTS
FIRST WMO REGIONAL PYRHELIOMETER COMPARISON
OF
RA II AND RA V
TOKYO(TSUKUBA) JAPAN 1989

PMO6 811107 K=23.984 $W \cdot m^{-2} \cdot y^{-2}$			JAPAN								
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	ALL
MEAN	0.9995	1.0023	0.9992	0.9998	1.0014	0.9996	0.9988	1.0001	1.0002	0.9999	
STDEV	0.0031	0.0018	0.0031	0.0009	0.0007	0.0004	0.0004	0.0016	0.0006	0.0006	
N	12	11	12	12	12	12	12	12	12	12	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	1.0008	1.0014	1.0038								
STDEV	0.0024	0.0016	0.0020								1.00051
N	12	12	12								0.00215
											155

PMO5 K=31.638 $W \cdot m^{-2} \cdot y^{-2}$			WRC/DAVOS								
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	ALL
MEAN	1.0004	0.9986	0.9958	0.9994	1.0006	0.9993	0.9990	1.0006	0.9996	1.0002	
STDEV	0.0042	0.0028	0.0035	0.0007	0.0004	0.0012	0.0007	0.0010	0.0009	0.0011	
N	6	5	6	6	6	6	6	6	6	6	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	0.9999	0.9988	1.0009								
STDEV	0.0016	0.0019	0.0020								0.99946
N	6	6	6								0.00224
											77

PACRAD 13219 K=10079 m^{-2}			INDIA								
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	ALL
MEAN	0.9947	1.0004	1.0018	1.0009	0.9983	1.0020	1.0025	0.9987	1.0005	0.9994	
STDEV	0.0062	0.0027	0.0052	0.0018	0.0011	0.0018	0.0010	0.0022	0.0019	0.0021	
N	12	11	12	12	12	12	12	12	12	12	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	0.9983	0.9965	1.0001								
STDEV	0.0038	0.0034	0.0025								0.99955
N	12	12	12								0.00370
											155

H-F 20294 K=20030.0 m^{-2}			CHINA								
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	ALL
MEAN	1.0015	1.0055	0.9971	1.0012	1.0030	0.9998	0.9973	1.0003	1.0009	1.0001	
STDEV	0.0069	0.0064	0.0039	0.0027	0.0023	0.0015	0.0014	0.0024	0.0021	0.0028	
N	12	11	12	12	12	12	12	12	12	12	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	1.0015	0.9999	1.0025								
STDEV	0.0039	0.0049	0.0042								1.00079
N	12	12	12								0.00427
											155

H-F 19743 K=20030.0 m^{-2}			CHINA								
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	ALL
MEAN	1.0023	1.0019	1.0011	1.0018	1.0001	1.0005	0.9991	1.0006	1.0004	0.9996	
STDEV	0.0150	0.0028	0.0035	0.0012	0.0012	0.0007	0.0015	0.0015	0.0013	0.0013	
N	12	11	12	12	12	12	12	12	12	12	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	1.0015	0.9999	1.0032								
STDEV	0.0040	0.0042	0.0035								1.00092
N	12	12	12								0.00476
											155

SUMMARY OF ALL DAILY RESULTS
FIRST WMO REGIONAL PYRHELIOMETER COMPARISON
OF
RA II AND RA V
TOKYO(TSUKUBA) JAPAN 1989

H-F 23738	K=20040 m^{-2}		JAPAN							
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330
MEAN	******	******	1.0004	1.0003	1.0028	1.0028	1.0014	1.0026	1.0032	1.0024
STDEV	******	******	0.0040	0.0012	0.0013	0.0010	0.0008	0.0011	0.0013	0.0009
N	**	**	12	12	12	12	12	12	11	12
RUN	3101-1000	3101-1030	3101-1100							
MEAN	1.0040	1.0030	1.0030							
STDEV	0.0037	0.0035	0.0043							
N	12	12	12							

ALL: 1.00235 / 0.00268 / 131

A 212	K=10535 $W \cdot m^{-2} \cdot A^{-2}$		USSR							
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330
MEAN	******	******	1.0010	1.0032	0.9981	0.9980	1.0017	1.0055	1.0012	1.0045
STDEV	******	******	0.0042	0.0022	0.0064	0.0023	0.0014	0.0023	0.0023	0.0023
N	**	**	10	10	10	10	10	10	10	10
RUN	3101-1000	3101-1030	3101-1100							
MEAN	1.0054	1.0066	1.0083							
STDEV	0.0027	0.0035	0.0030							
N	10	10	10							

ALL: 1.00303 / 0.00447 / 110

A 578	K=6237.3 $W \cdot m^{-2} \cdot A^{-2}$		AUSTRALIA							
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330
MEAN	0.9999	1.0046	0.9966	0.9986	1.0026	0.9989	1.0000	1.0003	1.0000	1.0001
STDEV	0.0030	0.0007	0.0023	0.0018	0.0064	0.0013	0.0040	0.0012	0.0025	0.0013
N	10	10	10	10	10	10	10	10	10	10
RUN	3101-1000	3101-1030	3101-1100							
MEAN	1.0025	1.0012	1.0030							
STDEV	0.0025	0.0032	0.0022							
N	10	10	10							

ALL: 1.00062 / 0.00342 / 130

A 12579	K=4344.4 $W \cdot m^{-2} \cdot A^{-2}$		IRAN							
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330
MEAN	1.0081	1.0036	1.0091	1.0152	1.0148	1.0159	******	1.0029	1.0135	1.0104
STDEV	0.0027	0.0135	0.0034	0.0051	0.0022	0.0044	******	0.0212	0.0020	0.0037
N	7	10	9	8	10	10	**	10	8	10
RUN	3101-1000	3101-1030	3101-1100							
MEAN	1.0147	1.0142	1.0152							
STDEV	0.0031	0.0041	0.0033							
N	10	10	10							

ALL: 1.01149 / 0.00900 / 112

A 17864	K=4697 $W \cdot m^{-2} \cdot A^{-2}$		HONG KONG							
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330
MEAN	0.9895	0.9967	0.9950	0.9934	0.9946	0.9932	0.9919	0.9919	0.9904	0.9894
STDEV	0.0046	0.0024	0.0021	0.0010	0.0011	0.0010	0.0009	0.0016	0.0009	0.0009
N	10	10	10	10	10	10	10	10	10	10
RUN	3101-1000	3101-1030	3101-1100							
MEAN	0.9942	0.9931	0.9945							
STDEV	0.0022	0.0035	0.0024							
N	10	10	10							

ALL: 0.99291 / 0.00298 / 130

SUMMARY OF ALL DAILY RESULTS
FIRST WMO REGIONAL PYRHELIOMETER COMPARISON
OF
RA II AND RA V
TOKYO(TSUKUBA) JAPAN 1989

A 26043	K=4831.1 $W \cdot m^{-2} \cdot A^{-2}$		JAPAN								ALL
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	
MEAN	0.9986	0.9988	0.9959	0.9965	0.9984	0.9971	0.9970	0.9972	0.9963	0.9955	
STDEV	0.0059	0.0041	0.0025	0.0012	0.0012	0.0007	0.0008	0.0015	0.0018	0.0010	
N	8	8	10	10	10	10	10	8	10	10	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	1.0020	0.9986	0.9980								
STDEV	0.0042	0.0031	0.0036								0.99765
N	10	9	10								0.00313
											123
A 26044	K=4870.2 $W \cdot m^{-2} \cdot A^{-2}$		JAPAN								ALL
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	
MEAN	0.9992	0.9955	0.9912	0.9935	0.9936	0.9966	0.9927	0.9945	0.9935	0.9915	
STDEV	0.0119	0.0030	0.0039	0.0011	0.0017	0.0068	0.0007	0.0031	0.0017	0.0017	
N	5	10	10	8	10	10	10	10	10	10	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	0.9940	0.9949	0.9974								
STDEV	0.0020	0.0035	0.0036								0.99430
N	10	10	10								0.00420
											123
A 703	K=5954.3 $W \cdot m^{-2} \cdot A^{-2}$		KOREA								ALL
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	
MEAN	1.0057	1.0108	0.9985	0.9981	0.9983	0.9982	0.9974	0.9995	0.9964	0.9961	
STDEV	0.0037	0.0095	0.0042	0.0056	0.0016	0.0016	0.0018	0.0031	0.0043	0.0025	
N	10	10	10	8	10	10	10	10	8	10	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	1.0060	1.0067	1.0089								
STDEV	0.0053	0.0058	0.0039								1.00159
N	10	8	9								0.00661
											123
A 23628	K=4550.5 $W \cdot m^{-2} \cdot A^{-2}$		MALAYSIA								ALL
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	
MEAN	0.9888	0.9938	0.9887	0.9902	0.9913	0.9906	0.9896	0.9908	0.9899	0.9891	
STDEV	0.0037	0.0011	0.0018	0.0013	0.0008	0.0007	0.0010	0.0014	0.0012	0.0012	
N	10	10	10	9	10	10	10	10	10	10	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	0.9911	0.9910	0.9926								
STDEV	0.0031	0.0039	0.0021								0.99057
N	10	10	10								0.00245
											129
A 13591	K=4200 $W \cdot m^{-2} \cdot A^{-2}$		NEW ZEALAND								ALL
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	
MEAN	0.9985	1.0001	0.9961	0.9982	0.9997	0.9979	0.9979	0.9979	0.9968	0.9959	
STDEV	0.0065	0.0055	0.0030	0.0015	0.0008	0.0004	0.0011	0.0010	0.0010	0.0011	
N	10	10	10	10	10	10	10	10	8	10	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	0.9994	0.9986	1.0000								
STDEV	0.0021	0.0034	0.0026								0.99826
N	10	10	10								0.00311
											128

SUMMARY OF ALL DAILY RESULTS
FIRST WMO REGIONAL PYRHELIOMETER COMPARISON
OF
RA II AND RA V
TOKYO(TSUKUBA) JAPAN 1989

NIP 10816E6 K=127.37 $W \cdot m^{-2} \cdot mV^{-1}$ JAPAN

											ALL
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	
MEAN	0.9953	******	0.9968	0.9996	0.9994	0.9977	0.9985	0.9985	0.9968	0.9978	
STDEV	0.0073	******	0.0031	0.0017	0.0016	0.0019	0.0021	0.0025	0.0027	0.0015	
N	12	**	12	12	12	12	12	12	12	12	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	0.9994	0.9977	0.9999								0.99812
STDEV	0.0047	0.0037	0.0036								0.00356
N	12	12	12								144

NIP 25677E6 K=127.21 $W \cdot m^{-2} \cdot mV^{-1}$ JAPAN

											ALL
RUN	2701-1059	2701-1132	2901-0947	3001-1000	3001-1030	3001-1100	3001-1200	3001-1230	3001-1300	3001-1330	
MEAN	******	******	0.9974	0.9956	0.9959	0.9942	0.9959	0.9965	0.9931	0.9971	
STDEV	******	******	0.0037	0.0022	0.0018	0.0015	0.0026	0.0030	0.0033	0.0028	
N	**	**	12	12	12	12	12	12	12	12	
RUN	3101-1000	3101-1030	3101-1100								
MEAN	0.9912	0.9881	0.9894								0.99404
STDEV	0.0050	0.0046	0.0046								0.00446
N	12	12	12								132

LIST OF
WRR REDUCTION FACTORS AND
NEW CALIBRATION FACTORS RECOMMENDED
FOR PYRHELIOMETERS

INSTRUMENT	OLD CALIBRATION FACTOR	WRR REDUCTION FACTOR	σ_c	N	$\sigma_c/\sqrt{N}$	NEW CALIBRATION FACTOR RECOMMENDED
PMO-5	31.638 $W \cdot m^{-2} \cdot V^{-2}$	0.99946	0.00224	77	0.00026	
PACRAD 13219	10079 m^{-2}	0.99955	0.00370	155	0.00030	
PMO-6 811107	23.984 $W \cdot m^{-2} \cdot V^{-2}$	1.00051	0.00215	155	0.00017	
H-F 19743	20030.0 m^{-2}	1.00092	0.00476	155	0.00038	20012 m^{-2}
H-F 20294	20030.0 m^{-2}	1.00079	0.00427	155	0.00034	20014 m^{-2}
H-F 23738	20040 m^{-2}	1.00235	0.00268	131	0.00023	19993 m^{-2}
A 212	10535 $W \cdot m^{-2} \cdot A^{-2}$	1.00303	0.00447	110	0.00043	
A 578	6237.3 $W \cdot m^{-2} \cdot A^{-2}$	1.00062	0.00342	130	0.00030	
A 703	5954.3 $W \cdot m^{-2} \cdot A^{-2}$	1.00159	0.00661	123	0.00060	5945 $W \cdot m^{-2} \cdot A^{-2}$
A 12579	4344.4 $W \cdot m^{-2} \cdot A^{-2}$	1.01149	0.00900	112	0.00085	4295 $W \cdot m^{-2} \cdot A^{-2}$
A 13591	4200 $W \cdot m^{-2} \cdot A^{-2}$	0.99826	0.00311	128	0.00027	4207 $W \cdot m^{-2} \cdot A^{-2}$
A 17864	4697 $W \cdot m^{-2} \cdot A^{-2}$	0.99291	0.00298	130	0.00026	4731 $W \cdot m^{-2} \cdot A^{-2}$
A 23628	4550.5 $W \cdot m^{-2} \cdot A^{-2}$	0.99057	0.00245	129	0.00022	4594 $W \cdot m^{-2} \cdot A^{-2}$
A 26043	4831.1 $W \cdot m^{-2} \cdot A^{-2}$	0.99765	0.00313	123	0.00028	4843 $W \cdot m^{-2} \cdot A^{-2}$
A 26044	4870.2 $W \cdot m^{-2} \cdot A^{-2}$	0.99430	0.00420	123	0.00038	4898 $W \cdot m^{-2} \cdot A^{-2}$
NIP 10816E6	127.37 $W \cdot m^{-2} \cdot mV^{-1}$	0.99812	0.00356	144	0.00030	127.6 $W \cdot m^{-2} \cdot mV^{-1}$
NIP 25677E6	127.21 $W \cdot m^{-2} \cdot mV^{-1}$	.0.99404	0.00446	132	0.00039	128.0 $W \cdot m^{-2} \cdot mV^{-1}$

NOTE: σ_c = STANDARD DEVIATION OF WRR REDUCTION FACTOR
N = NUMBER OF MEASUREMENTS
$\sigma_c/\sqrt{N}$ = STANDARD ERROR OF MEAN

LIST OF
NEW CALIBRATION FACTOR RECOMMENDED
FOR PYRANOMETERS

INSTRUMENT	OLD CALIBRATION FACTOR	NEW CALIBRATION FACTOR RECOMMENDED	σ_c	$\sigma_c/\sqrt{N}$	N
	[$W \cdot m^{-2} \cdot mV^{-1}$]				
PSP 20463F3	95.97	101.8	0.8	0.07	120
*CM 5 784530	87.22	90.6	0.8	0.07	120
*CM 5 752820	84.10	90.1	0.4	0.04	120
*MS-801 F83006	139.99	142.6	0.7	0.07	120
PSP 25918F3	103.32	104.1	0.6	0.06	120
*CM 5 881454	88.89	91.1	0.4	0.04	120
SCP 23208	890.47	927.8	12.1	1.11	120

NOTE: σ_c = STANDARD DEVIATION
N = NUMBER OF MEASUREMENTS
$\sigma_c/\sqrt{N}$ = STANDARD ERROR OF MEAN

* The calibration was performed at temperature around 7 °C.
For non-compensated pyranometers (CM 5 and MS-801),
these values may only be used after temperature correction.

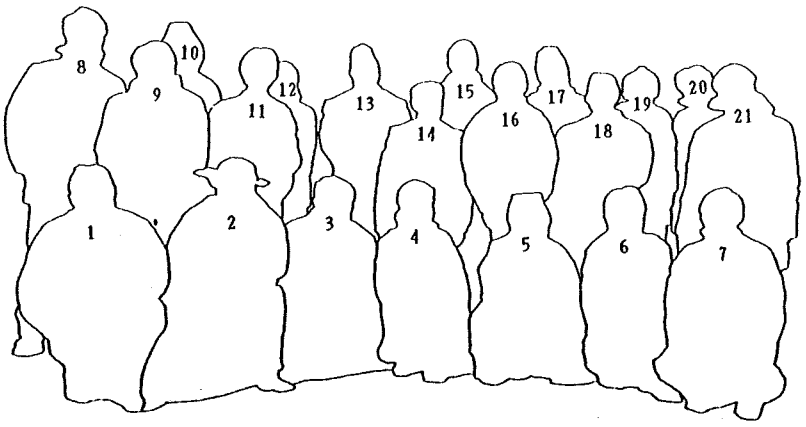
SUMMARY OF METEOROLOGICAL DATA
FIRST WMO REGIONAL PYRHELIOMETER COMPARISON
OF
RA II AND RA V
TOKYO(TSUKUBA) JAPAN 1989

MEAN VALUES FOR EACH RUN

DATE	START TIME	REL AIR MASS	SOLAR ELEVA	AEROSOL OPTICAL DEPTH 368 nm	500 nm	675 nm	RADIATION GLOBAL	DIFFUSE	AIR TEMP	REL HUM	PRESSURE	WIND SPEED	WIND DIRECT	TOTAL OZONE 12JST
			DEG				W/m^2	W/m^2	°C	%	hPa	m/s		cm(NTP)
27-JAN.	10:59	1.705	34.32	0.290	0.231	0.179	-	-	7.8	75	939.7	2.7	N	0.306
27-JAN.	11:32	1.667	35.24	0.259	0.205	0.160	-	-	8.6	69	939.0	1.1	NNW	0.306
29-JAN.	09:47	1.952	29.27	0.107	0.076	0.049	-	-	-1.0	68	955.6	1.6	NE	0.314
30-JAN.	10:00	1.867	30.82	0.075	0.061	0.042	569.2	72.5	5.3	39	959.8	0.0	CALM	0.288
30-JAN.	10:30	1.745	33.37	0.106	0.081	0.059	614.6	75.0	6.5	34	959.9	0.0	CALM	0.288
30-JAN.	11:00	1.672	35.12	0.101	0.079	0.055	643.2	80.2	6.8	31	959.5	0.0	CALM	0.288
30-JAN.	12:00	1.641	35.93	0.151	0.113	0.078	642.9	91.0	7.2	-	959.0	0.0	CALM	0.288
30-JAN.	12:30	1.679	34.96	0.172	0.126	0.088	620.7	92.6	8.3	43	959.2	0.0	CALM	0.288
30-JAN.	13:00	1.757	33.11	0.194	0.140	0.094	579.6	93.9	7.8	43	959.3	0.0	CALM	0.288
30-JAN.	13:30	1.886	30.47	0.223	0.156	0.103	524.6	93.6	8.7	39	959.3	0.0	CALM	0.288
31-JAN.	10:00	1.856	31.06	0.213	0.157	0.115	537.8	114.6	7.0	54	956.2	1.7	NE	0.291
31-JAN.	10:30	1.734	33.62	0.195	0.144	0.106	586.4	115.3	7.6	58	956.2	1.7	N	0.291
31-JAN.	11:00	1.662	35.39	0.195	0.147	0.105	614.4	121.1	8.0	63	955.2	1.6	N	0.291

The First WMO Regional Pyrheliometer Comparison
of RA II and RA V

Tsukuba, Jan. 30, 1989



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