WORLD METEOROLOGICAL ORGANIZATION

INSTRUMENTS AND OBSERVING METHODS

REPORT No. 44

FIRST WMO REGIONAL PYRHELIOMETER COMPARISON OF RA IV

ENSENDA, MEXICO, 20 to 27 April 1989

Final Report
by
I. Galindo

WMO/TD-No. 345

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NOTE

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INTRODUCTION

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

1.2 Considering the importance of Recommendations 10, 11, and 14 (CIMO-IX), which were approved by EC-XXXVIII, Mexico offered to host the First WMO Regional Pyrheliometer Comparison of RA IV. The comparison was carried out from 20 to 27 April 1989 at the Astronomic Observatory of the National Autonomous University of Mexico (UNAM) at Ensenada.

1.3 The International Organizing Committee for the comparison held its first session at Ensenada from 11 to 13 January 1989. The list of participants is given in Appendix A.

1.4 The WMO Secretariat distributed in January 1988 the notification on the comparison. In March 1989, the Secretariat sent the final report of the first session of the International Organizing Committee of 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 at Ensenada on 25 April 1989 (see Appendix A). The Committee analyzed the preliminary results of the comparison including the proposed new WRR reduction factors and calibration factors of the instruments participated in the comparison.

2. PARTICIPATION

2.1 Five Members of RA IV and the WRC Davos participated with 21 experts in the comparison. The list of participants is given in Appendix B.

2.2 15 pyrheliometers (6 Angstrom pyrheliometers, 9 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 7 km northwest of Ensenada at an elevation of 75 m above sea level on the roof of the offices of the National Astronomic Observatory of the National Autonomous University of Mexico (UNAM) at the university complex. This location provided good comparison conditions.

3.2 The pyrheliometeres and pyranometers were mounted on wood benches which were fixed on the roof. The control units of the pyrheliometers were protected from the sun.

3.3 AC power (120 V/60 Hz) was available on the benches. Small data loggers with appropiate software were provided for pyrheliometer operators to storage irradiances during the measurements. The storaged information was brougth through an interface to two personal computers devoted to validation task. Pyranometer outputs were directly delivered to a data logger.

3.4 All participants operated their own pyrheliometers during the period of the Comparison.

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

3.6 Measured data were evaluated on a daily basis. A printout of the series of irradiances measured was provided to each participant.

3.7 Twice a day it was provided the weather forecast for the region. The following meteorological elements were simultaneously measured with the comparison series:

a) Air-temperature;

b) Humidity;

c) Pressure;

d) Wind speed;

e) Wind direction;

f) visibility;

g) atmospheric turbidity.

3.8 The above-mentioned meteorological variables 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 measurements 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 minutes,- 90, and -15 seconds. The buzzer sounds were short pulses -75, -15 and, -5 seconds to indicate data reading. The timing diagrams are shown in Appendix E.

4.2 Operation of instruments

4.2.1 Angstrom Pyrheliometers

Zero adjustments were made before each series. Series started with the right aperture closed. Rightand left aperture were closed alternately every 90 seconds. Twelve observations were thus made in each series. The first readings of each series were discarded.

4.2.2 H-F and TMI absolute radiometers

Zero adjustment and self-calibration were made before each series. Zero-point readings were 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. Twelve values were obtained in each series.

4.2.3 PMO absolute radiometer

Series started with a closed reading, then the PMO radiomewter alternated between open and closed shutters every 90 seconds. Six readings were obtained in each series respectively. The instrument was manually operated.

4.2.4 Thermoelectric pyrheliometers

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.

4.4 The following readings were made:

i) Current/voltage, for PMO absolute radiometer;

ii) Current for Ångström pyrheliometer;

iii) Self-calibration values (current/voltage) and thermopile voltage for TMI/H-F absolute radiometers.

Data formats for mannual records used at the Comparison are attached as Appendix D.

5. COMPARISON REFERENCE

5.1 As Comparison reference, a Regional Standard Group (RSG) was es-- tablished. This group consisted of one instrument of the World Standard Group (PMO-5), two cavity radiometers HF 18747 (RRC Toronto) and the TMI 67502 (RRC Boulder), and the Ångström instrument A 18587 (RRC Mexico). -- PMO-5 acted as the working standard for preliminary data evaluation. PMO-5 provided 6 reference values for each series.

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

$$REF(IV) = \frac{1}{4} (PM05 + HF18747 + TMI67502 + A18587)$$

5.3 The radiometric references of each measurement are listed in - - Appendix G.

6. COMPARISON MEASUREMENTS

6.1 Measurements were taken on 22 and 23 April, 1989 with a total of 80 measurements.

6.2 All the 80 measurements have fullfill the criteria mentioned in paragraph 7.1.

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 Daily data for each instruments are given in Appendix H.

8. COMPARISON RESULTS

8.1 The WRR reduction factor for all pyrheliometers which participating in the Comparison were adopted by the second session of the International Organizing Committee (Ensenada, 24 April 1989) and they are listed in - - Appendix I.

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, fifth edition, para. 9.4.1.3: "By reference to a standard pyrheliometer and a shaded pyranometer".

9.2 The calibrated pyranometer (Mexico) together with the pyranometers to be calibrated were exposed to the sun. Signals were recorded every 90 seconds by a data logger.

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 fac- - tors. They are given in Appendix K.

10. OTHER ACTIVITIES

10.1 At the end of the Comparison the following presentations were - - made:

- J.R. HICKEY. EPPLEY LAB.: "10 Years of Solar Irradiance Measurements from the ERB Experiment on NIMBUS 7"
- CHESTER V. WELLS. SERI: "Measurement Uncertainty Analysis: I. Principles and Methods"
- CHESTER V. WELLS. SERI: "II Application to Solar Radiation Instruments, Calibration and Measurements"
- DON NELSON. NOAA. ERL: "Current Status on the U.S. Solar Radiation Network"

11. ACKNOWLEDGMENTS

The participants expressed their gratitude to the host country and to the National Astronomical Observatory of UNAM for the excellent organization the Comparison as well as for providing excellent facilities and working conditions for the event. They also expressed their thanks to the Project Leader and participating staff of the National Astronomical Observatory, to WMO, and to the WRC. Hospitality of the host country was highly ap- - preciated.

12. REMARKS

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

LIST OF PARTICIPANTS

I. Galindo	(Chairman) (representing RA IV Regional Radiation Centre Mexico)	Mexico
J. de Luisi	(representing RA IV Regional Radiation Centre Boulder)	USA
D. Wardle	(representing RA IV Regional Radiation Centre Toronto)	Canada
M. Alvarez		Mexico
J.L. Bravo		Mexico
E. Ledesma		Mexico

WMO Secretariat

S. Klemm	Senior Scientific Officer, WWW Department

LIST OF PARTICIPANTS OF THE FIRST REGIONAL PYRHELIOMETER COMPARISON OF RA IV

J. Galindo	Mexico
Agustin Muhlia	Mexico
José Luis Bravo	Mexico
Ernesto Jimenez	Mexico
Jésus Martinez	Mexico
Arturo Mota R.	Mexico
Mauro Valdes B.	Mexico
José Reyes y Martinez	Mexico
D.V. Barton	Canada
Tom Grajnar	Canada
Alfonso Liao Lee	Costa Rica
J. Stallkamp	USA
W. Holman	USA
Eric Laue	USA
Donald W. Nelson	USA
Jean J. Kallis	USA
Chester V. Wells	USA
Jim Huggins	USA
John R. Hickey	USA
César Noguera	Venezuela
C. Wehrli	WRC Davos, Switzerland
S. Klemm	WMO Secretariat

APPENDIX C

List of instruments

(a) Pyrheliometers

		Instrument	Calibration factor
CANADA	AES	H-F 18747	2.0014 cm^{-2}
COSTA RICA	IMN	NIP 18938E6	8.02 $\times 10^{-6}$ V/Wm^{-2}
MEXICO	UNAM	A 166	11101.7 $Wm^{-2}A^{-2}$
	UNAM	A 18587	4516.3 $Wm^{-2}A^{-2}$
	NIP	17579E6	9.31 $\times 10^{-6}$ V/Wm^{-2}
	EQ/II		1108761 $Wm^{-2}A^{-2}$
SWITZERLAND	WRC II	PMO 5	31.638 $Wm^{-2}V^{-2}$
USA	NOAA	TMI MKVI 67502	1.0039 m^{-2}
	EPPLEY	H-F 14915	2.0010 cm^{-2}
	TMI	TMI MKVI 67401	1.0054 m^{-2}
	JPL	TMI MKVI 67702	1.0035 m^{-2}
	SERI	TMI MKVI 68018	1.0046 m^{-2}
	FLA SOLAR	H-F 21182	2.0050 cm^{-2}
	MARIETTA	TMI MKVI 68020	1.0030 m^{-2}
VENEZUELA	MARNR	NIP 23946E6	8.33 $\times 10^{-6}$ V/Wm^{-2}

(b) Pyranometers

MEXICO	UNAM	PSP 17759F3	9.11 $\times 10^{-6}$ V/Wm^{-2}
	UNAM	PSP 17760F3	9.09 $\times 10^{-6}$ V/Wm^{-2}
VENEZUELA	MARNR	PSP 24196F3	9.21 $\times 10^{-6}$ V/Wm^{-2}

APPENDIX D

PRIMERA INTERCOMPARACION PIRHELIOMETRICA REGIONAL (AR-IV)
Ensenada, B. C., México.
Abril de 1989.

Instrumento No.:__________ País:__________ Fecha:__________

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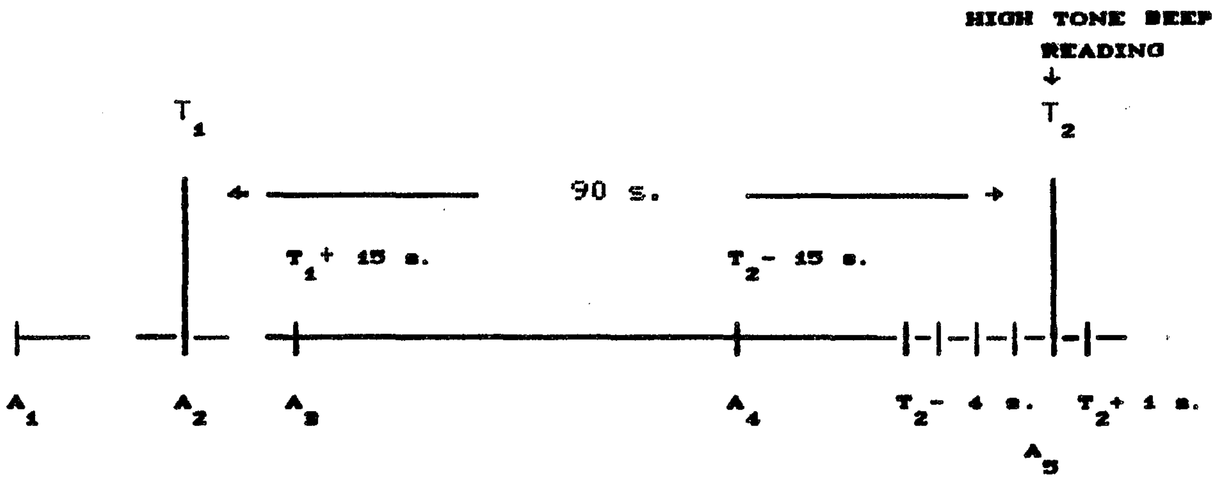
CHRONOLOGY OF THE OBSERVATIONS



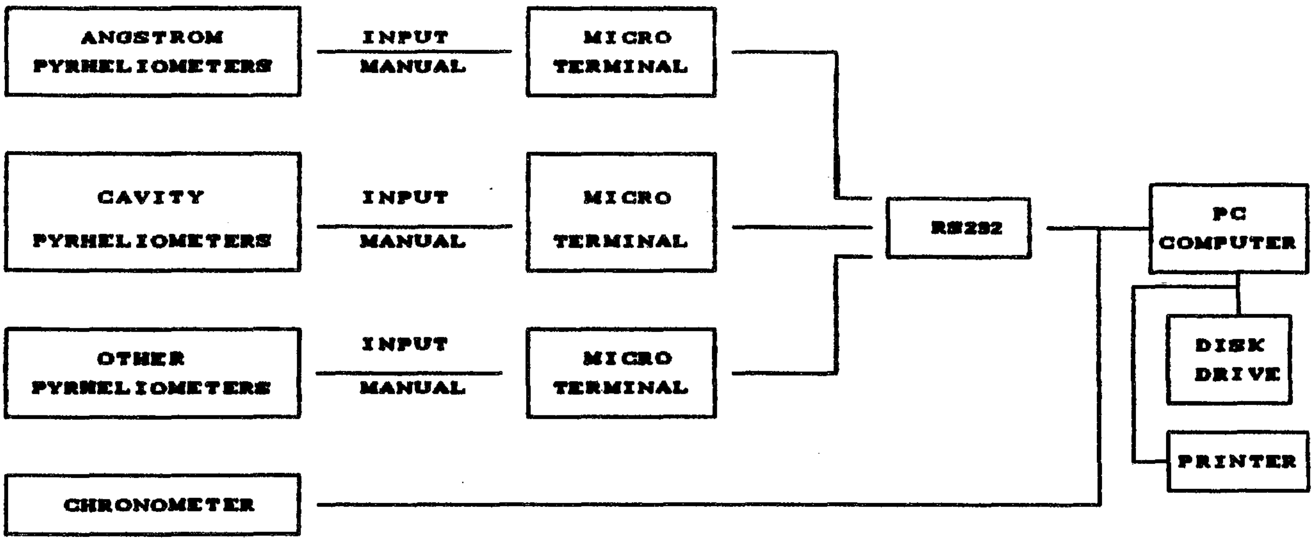
A_1: ANNOUNCE - FIVE MINUTES BEFORE OBSERVATIONS

A_2: BEEP AND ANNOUNCE - TIME ZERO

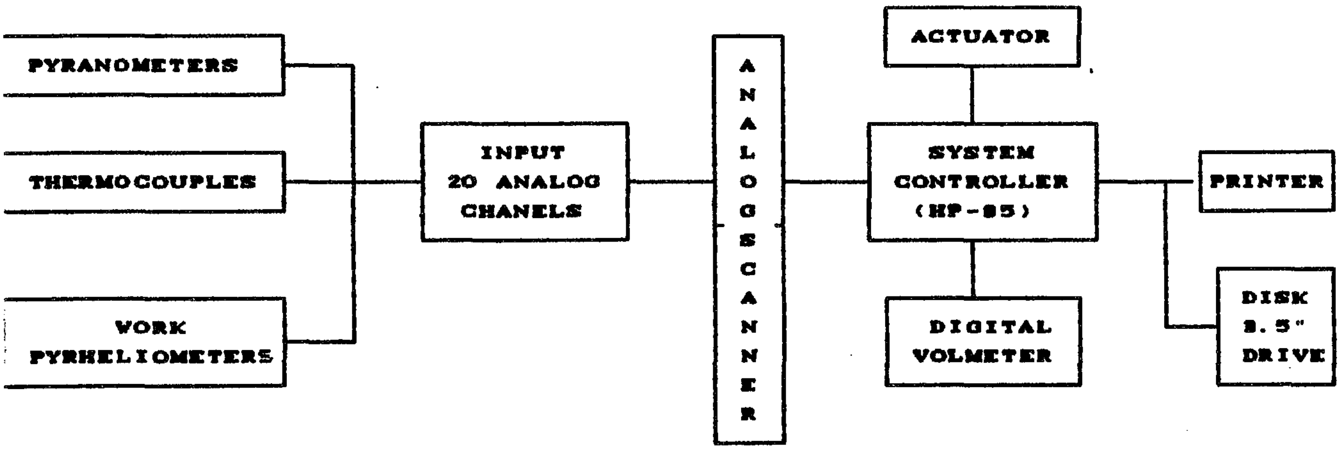
A_3: BUZZER AND ANNOUNCE - SHADE THE LEFT (OR RIGHT) HAND STRIP

A_4: BEEP AND ANNOUNCE - FIFTEEN SECONDS BEFORE MEASURENENT

A_5: FOUR BEEPS (EACH SECOND) BEFORE HIGH TONE BEEP FOR READING



BLOCK DIAGRAM OF THE DATA ACQUISITION AND PROCESSING SYSTEM FOR PYRHELIOMETERS



BLOCK DIAGRAM OF THE DATA ACQUISITION AND PROCESSING SYSTEM

FOR PYRANOMETERS

Pyranometer Comparison during the First Regional Pyrheliometer Comparison (RPC) of RA-IV

The Pyranometers were compared in the same way as described the "WMO GUIDE TO METEOROLOGICAL INSTRUMENTS AND METHODS OF OBSERVATION: 9.4.1.3 By reference to a standard pyrheliometer".

1) The comparison of pyranometer was carried out parallel at the same place (see Appendix E) and during the same period as the RPC.

2) The participating pyranometer was installed and maintained by the staff of the host country.

3) The pyranometer was leveled horizontally to measure global radiation G.

4) All data were acquired, processed and evaluated by the data acquisition system of the RPC (see 2.5.2 and 2.5.3).

5) Data reports are included as Appendix K.

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 (IRRADIANCE) 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 electrical-power is diminished by the amount of radiative power absorbed by the cavity. The intensity is calculated accodring 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 Ångström 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 irradiance 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.

PRIMERA INTERCOMPARACION PIRHELIOMETRICA AR-IV
Ensenada, B. C.
MEXICO

SUMMARY OF DAILY IRRADIANCE VALUES

Fecha: 04-22-1989
Instrumento: Eppley H-F No. 18747
Constante de Instrumento: 1
Terminal No. 01 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10	11	12
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30	15:16:30	15:50:30	16:25:30
Razon Media	******	******	1.0017	1.0010	1.0007	1.0011	1.0000	1.0004	1.0010	1.0010	1.0004	1.0005
D. E.	******	******	0.0006	0.0009	0.0008	0.0001	0.0003	0.0008	0.0004	0.0003	0.0005	0.0010
No. de Datos	0	0	4	4	4	3	4	4	4	4	4	4

Fecha: 04-22-1989
Instrumento: MK-VI No. 67502
Constante de Instrumento: 1
Terminal No. 02 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10	11	12
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30	15:16:30	15:50:30	16:25:30
Razon Media	******	******	1.0001	1.0001	1.0003	1.0006	1.0006	1.0003	1.0014	1.0001	1.0016	1.0002
D. E.	******	******	0.0005	0.0003	0.0005	0.0006	0.0006	0.0002	0.0008	0.0005	0.0009	0.0008
No. de Datos	0	0	4	4	4	3	4	4	4	4	4	4

Fecha: 04-22-1989
Instrumento: MK-VI No. 68020
Constante de Instrumento: 1
Terminal No. 02 (2)

Serie No.	1	2	3	4	5	6	7	8	9	10	11	12
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30	15:16:30	15:50:30	16:25:30
Razon Media	******	******	1.0017	1.0001	1.0014	1.0013	1.0010	1.0022	1.0013	1.0016	1.0016	1.0018
D. E.	******	******	0.0005	0.0002	0.0003	0.0007	0.0005	0.0003	0.0009	0.0004	0.0005	0.0004
No. de Datos	0	0	4	4	4	3	4	4	4	4	4	4

Fecha: 04-22-1989
Instrumento: MK-VI No. 67401
Constante de Instrumento: 1
Terminal No. 03 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10	11	12
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30	15:16:30	15:50:30	16:25:30
Razon Media	******	******	1.0007	0.9999	0.9999	1.0007	1.0001	1.0005	1.0017	1.0011	1.0011	1.0010
D. E.	******	******	0.0006	0.0002	0.0002	0.0009	0.0006	0.0006	0.0003	0.0009	0.0006	0.0004
No. de Datos	0	0	4	4	4	3	4	4	4	4	4	4

Fecha: 04-22-1989
Instrumento: MK-VI No. 68018
Constante de Instrumento: 1
Terminal No. 03 (2)

Serie No.	1	2	3	4	5	6	7	8	9	10	11	12
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30	15:16:30	15:50:30	16:25:30
Razon Media	******	******	1.0025	1.0021	1.0022	1.0021	1.0013	1.0021	1.0028	1.0025	1.0026	1.0025
D. E.	******	******	0.0004	0.0001	0.0003	0.0007	0.0006	0.0004	0.0009	0.0004	0.0005	0.0004
No. de Datos	0	0	4	4	4	3	4	4	4	4	4	4

Fecha: 04-22-1989
Instrumento: MK-VI No. 67702
Constante de Instrumento: 1
Terminal No. 04 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10	11	12
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30	15:16:30	15:50:30	16:25:30
Razon Media	******	******	1.0025	1.0022	1.0024	1.0021	1.0022	1.0026	1.0034	1.0032	1.0034	1.0028
D. E.	******	******	0.0005	0.0003	0.0002	0.0009	0.0006	0.0006	0.0008	0.0009	0.0006	0.0002
No. de Datos	0	0	4	4	4	3	4	4	4	4	4	4

Fecha: 04-22-1989
Instrumento: Eppley H-F No. 21182
Constante de Instrumento: 1
Terminal No. 05 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10	11	12
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30	15:16:30	15:50:30	16:25:30
Razon Media	******	******	1.0036	1.0019	1.0037	1.0022	1.0020	1.0030	1.0040	1.0039	1.0039	1.0030
D. E.	******	******	0.0003	0.0014	0.0007	0.0010	0.0005	0.0007	0.0011	0.0002	0.0004	0.0007
No. de Datos	0	0	4	4	4	3	4	4	4	4	4	4

Fecha: 04-22-1989
Instrumento: Eppley H-F No. 14915
Constante de Instrumento: 1
Terminal No. 05 (2)

Serie No.	1	2	3	4	5	6	7	8	9	10	11	12
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30	15:16:30	15:50:30	16:25:30
Razon Media	******	******	1.0018	1.0001	1.0012	1.0004	1.0005	1.0000	1.0011	1.0025	1.0004	1.0014
D. E.	******	******	0.0009	0.0014	0.0005	0.0010	0.0005	0.0008	0.0006	0.0002	0.0010	0.0012
No. de Datos	0	0	4	4	4	2	4	4	4	4	4	4

Fecha: 04-22-1989
Instrumento: Angstrom Eppley No. 18587
Constante de Instrumento: 4516.3
Terminal No. 06 (1)

Serie No.	1	2	3	4	5	6	7	8	9
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30
Razon Media	******	******	0.9994	0.9996	0.9995	0.9989	0.9993	0.9988	0.9991
D. E.	******	******	0.0014	0.0007	0.0009	0.0010	0.0016	0.0005	0.0004
No. de Datos	0	0	4	4	4	3	4	4	4

	10	11	12
	15:16:30	15:50:30	16:25:30
	0.9997	0.9992	1.0013
	0.0008	0.0007	0.0008
	4	4	4

Fecha: 04-22-1989
Instrumento: PMO 5
Constante de Instrumento: 1
Terminal No. 07 (1)

Serie No.	1	2	3	4	5	6	7	8	9
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30
Razon Media	******	******	0.9988	0.9993	0.9994	0.9994	1.0000	1.0004	0.9985
D. E.	******	******	0.0009	0.0005	0.0006	0.0006	0.0009	0.0004	0.0006
No. de Datos	0	0	4	4	4	3	4	4	4

	10	11	12
	15:16:30	15:50:30	16:25:30
	0.9992	0.9988	0.9979
	0.0010	0.0012	0.0005
	4	4	4

Fecha: 04-22-1989
Instrumento: Eppley Nip No. 18938E6
Constante de Instrumento: 8.33
Terminal No. 08 (1)

Serie No.	1	2	3	4	5	6	7	8	9
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30
Razon Media	******	******	0.9563	0.9541	0.9535	0.9518	0.9510	0.9500	0.9501
D. E.	******	******	0.0010	0.0008	0.0013	0.0011	0.0010	0.0006	0.0016
No. de Datos	0	0	4	4	4	3	4	4	4

	10	11	12
	15:16:30	15:50:30	16:25:30
	0.9505	0.9500	0.9495
	0.0017	0.0008	0.0015
	4	4	4

Fecha: 04-22-1989
Instrumento: Eppley Nip No. 23946E6
Constante de Instrumento: 8.33
Terminal No. 08 (2)

Serie No.	1	2	3	4	5	6	7	8	9
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30
Razon Media	******	******	0.9782	0.9768	0.9736	0.9703	0.9673	0.9667	0.9654
D. E.	******	******	0.0016	0.0006	0.0012	0.0006	0.0005	0.0004	0.0010
No. de Datos	0	0	4	4	4	3	4	4	4

	10	11	12
	15:16:30	15:50:30	16:25:30
	0.9620	0.9623	0.9589
	0.0014	0.0013	0.0010
	4	4	4

Fecha: 04-22-1989
Instrumento: Angstrom No. 166
Constante de Instrumento: 11101.7
Terminal No. 09 (1)

Serie No.	1	2	3	4	5	6	7	8	9
Hora Inicial	9:44:30	10:16:30	10:50:30	11:24:30	11:57:30	12:31:30	13: 5:30	13:39:30	14:41:30
Razon Media	******	******	0.9895	0.9912	0.9954	1.0232	1.0173	0.9997	0.9943
D. E.	******	******	0.0076	0.0035	0.0112	0.0133	0.0140	0.0100	0.0083
No. de Datos	0	0	4	4	4	3	2	4	4

10	11	12
15:16:30	15:50:30	16:25:30
1.0023	1.0024	1.0066
0.0057	0.0183	0.0074
4	4	4

PRIMERA INTERCOMPARACION PIRHELIOMETRICA AR-IV
Ensenada, B. C.
MEXICO

SUMMARY OF DAILY IRRADIANCE VALUES

Fecha: 04-23-1989
Instrumento: Eppley H-F No. 18747
Constante de Instrumento: 1
Terminal No. 01 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	1.0007	1.0006	1.0007	1.0008	0.9999	0.9997	1.0006	1.0008	0.9991	0.9989
D. E.	0.0005	0.0008	0.0006	0.0007	0.0019	0.0007	0.0001	0.0005	0.0015	0.0018
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: MK-VI No. 67502
Constante de Instrumento: 1
Terminal No. 02 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	1.0008	1.0005	1.0004	1.0007	1.0002	0.9998	1.0010	1.0004	1.0009	1.0011
D. E.	0.0005	0.0006	0.0006	0.0006	0.0010	0.0003	0.0005	0.0003	0.0011	0.0006
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: MK-VI No. 68020
Constante de Instrumento: 1
Terminal No. 02 (2)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	1.0043	1.0010	1.0005	1.0002	1.0018	1.0006	1.0003	1.0019	1.0007	1.0009
D. E.	0.0050	0.0004	0.0005	0.0004	0.0008	0.0007	0.0002	0.0001	0.0009	0.0007
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: MK-VI No. 67401
Constante de Instrumento: 1
Terminal No. 03 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	1.0005	0.9998	1.0005	1.0005	1.0025	1.0015	0.9996	1.0022	1.0012	1.0016
D. E.	0.0006	0.0007	0.0004	0.0004	0.0012	0.0005	0.0004	0.0004	0.0007	0.0007
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: MK-VI No. 68018
Constante de Instrumento: 1
Terminal No. 03 (2)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	1.0020	1.0019	1.0020	1.0020	1.0029	1.0014	1.0016	1.0026	1.0012	1.0022
D. E.	0.0004	0.0005	0.0006	0.0004	0.0008	0.0006	0.0003	0.0002	0.0007	0.0006
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: MK-VI No. 67702
Constante de Instrumento: 1
Terminal No. 04 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	1.0029	1.0019	1.0020	1.0023	1.0022	1.0019	1.0018	1.0041	1.0025	1.0027
D. E.	0.0004	0.0007	0.0003	0.0004	0.0010	0.0006	0.0006	0.0006	0.0008	0.0006
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: Eppley H-F No. 21182
Constante de Instrumento: 1
Terminal No. 05 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	1.0037	1.0033	1.0023	1.0026	1.0028	1.0028	1.0029	1.0036	1.0028	1.0032
D. E.	0.0009	0.0005	0.0006	0.0008	0.0008	0.0007	0.0005	0.0005	0.0009	0.0012
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: Eppley H-F No. 14915
Constante de Instrumento: 1
Terminal No. 05 (2)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	1.0019	1.0027	1.0007	1.0005	1.0013	1.0017	1.0006	1.0015	1.0002	1.0006
D. E.	0.0006	0.0006	0.0014	0.0011	0.0004	0.0011	0.0011	0.0005	0.0014	0.0020
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: Angstrom Eppley No. 18587
Constante de Instrumento: 4516.3
Terminal No. 06 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	1.0000	0.9997	1.0007	0.9999	1.0007	1.0020	1.0002	0.9987	1.0005	1.0015
D. E.	0.0008	0.0009	0.0014	0.0019	0.0008	0.0010	0.0010	0.0014	0.0014	0.0015
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: PMO 5
Constante de Instrumento: 1
Terminal No. 07 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	0.9985	0.9991	0.9982	0.9985	0.9992	0.9984	0.9982	1.0001	0.9996	0.9985
D. E.	0.0006	0.0007	0.0006	0.0007	0.0012	0.0005	0.0005	0.0011	0.0009	0.0008
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: Eppley Nip No. 18938E6
Constante de Instrumento: 8.33
Terminal No. 08 (1)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	0.9459	0.9428	0.9414	0.9412	0.9411	0.9394	0.9512	0.9514	0.9514	0.9505
D. E.	0.0004	0.0005	0.0005	0.0015	0.0012	0.0005	0.0008	0.0012	0.0013	0.0011
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: Eppley Nip No. 23946E6
Constante de Instrumento: 8.33
Terminal No. 08 (2)

Serie No.	1	2	3	4	5	6	7	8	9	10
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30	15:45:30
Razon Media	0.9629	0.9602	0.9567	0.9598	0.9573	0.9543	0.9534	0.9540	0.9519	0.9475
D. E.	0.0005	0.0007	0.0014	0.0013	0.0010	0.0005	0.0006	0.0010	0.0010	0.0016
No. de Datos	4	5	4	4	4	4	4	4	4	4

Fecha: 04-23-1989
Instrumento: Angstrom No. 166
Constante de Instrumento: 11101.7
Terminal No. 09 (1)

Serie No.	1	2	3	4	5	6	7	8	9
Hora Inicial	10:11:30	10:45:30	11:19:30	11:53:30	12:27:30	13: 1:30	13:35:30	14:39:30	15:12:30
Razon Media	0.9910	1.0033	0.9932	0.9931	0.9927	0.9925	0.9936	0.9899	0.9921
D. E.	0.0006	0.0111	0.0080	0.0070	0.0054	0.0071	0.0064	0.0075	0.0069
No. de Datos	4	5	4	4	4	4	4	4	4

Serie No.	10
Hora Inicial	15:45:30
Razon Media	0.9977
D. E.	0.0077
No. de Datos	4

SUMMARY OF REGIONAL REFERENCE VALUES
FIRST WMO REGIONAL PYRHELIOMETER COMPARISON
OF RA-IV
ENSENADA, MEXICO 1989

DATE	STARTING TIME	IRRADIANCE [W m^{-2}]					MEAN [W.m^{-2}]	STANDARD DEVIATION [W.m^{-2}]	N
22-IV	9:44:30	-	-	-	-	-	-	-	-
	10:16:30	-	-	-	-	-	-	-	-
	10:50:30	-	-	903.97	-	909.05	-		
		-	907.23	-	908.76	-	907.25	2.02	4
	11:24:30	-	-	926.33	-	927.65			
		-	924.31	-	927.20	-	926.37	1.28	4
	11:57:30	-	-	938.71	-	938.88			
		-	941.40	-	941.83	-	940.20	1.42	4
	12:31:30	-	-	-	-	952.22			
		-	954.60	-	956.16	-	954.33	1.62	3
	13: 5:30	-	-	957.51	-	962.75			
		-	958.52	-	964.90	-	960.92	3.02	4
	13:39:30	-	-	957.51	-	962.75			
		-	968.35	-	969.36	-	969.52	0.85	4
	14:41:30	-	-	939.98	-	942.24			
		-	940.17	-	937.87	-	940.07	1.55	4
	15:16:30	-	-	913.16	-	914.33			
		-	911.85	-	907.14	-	911.62	2.73	4
	15:50:30	-	-	885.37	-	881.52			
		-	881.98	-	876.70	-	881.39	3.09	4
	16:25:30	-	-	838.42	-	832.68			
		-	827.70	-	822.47	-	830.32	5.91	4
23-IV	10:11:30	-	-	883.86	-	883.26			
		-	884.20	-	888.28	-	884.90	1.98	4
	10:45:30	-	909.14	-	913.31	-			
		917.80	-	917.24	-	920.58	915.47	3.91	5
	11:19:30	-	-	928.89	-	926.19			
		-	928.90	-	926.68	-	927.66	1.24	4
	11:53:30	-	-	934.73	-	935.33			
		-	937.77	-	938.17	-	936.50	1.49	4
	12:27:30	-	-	941.79	-	944.33			
		-	944.11	-	944.51	-	943.68	1.10	4
	13: 1:30	-	-	950.25	-	947.72			
		-	947.04	-	945.20	-	947.55	1.81	4
	13:35:30	-	-	950.37	-	950.39			
		-	947.44	-	948.01	-	949.05	1.34	4
	14:39:30	-	-	924.84	-	923.43			
		-	924.14	-	923.40	-	923.95	0.59	4
	15:12:30	-	-	909.85	-	907.48			
		-	903.98	-	902.52	-	905.96	2.88	4
	15:45:30	-	-	886.70	-	882.67			
		-	883.05	-	881.39	-	883.45	1.97	4

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

INSTRUMENT	OLD CALIBRATION FACTOR	WRR REDUCTION FACTOR	σ	N	$\sigma/\sqrt{N}$	NEW CALIBRATION FACTOR RECOMMENDED
H-F 18747	2.0014 cm^{-2}	1.00048	0.00048	80	0.00005	
MK-VI 67502	1.0039 m^{-2}	1.00055	0.00078	80	0.00009	
PMO5	31.638 $Wm^{-2}V^{-2}$	0.99901	0.00102	80	0.00011	
A-18587	4516.3 $Wm^{-2}A^{-2}$	0.99995	0.00144	80	0.00016	
MK-VI 68020	1.0030 m^{-2}	1.00131	0.00153	80	0.00017	1.0017 m^{-2}
MK-VI 67401	1.0054 m^{-2}	1.00082	0.00100	80	0.00011	1.0046 m^{-2}
MK-VI 68018	1.0046 m^{-2}	1.00212	0.00070	80	0.00008	1.0025 m^{-2}
MK-VI 67702	1.0035 m^{-2}	1.00255	0.00086	80	0.00010	1.0009 m^{-2}
HF 21182	2.0050 cm^{-2}	1.00309	0.00099	80	0.00010	1.9988 cm^{-2}
HF 14915	2.0010 cm^{-2}	1.00110	0.00127	79	0.00014	1.9988 cm^{-2}
NIP 18938E6	8.33 $\mu V/Wm^{-2}$	0.94856	0.00492	80	0.00055	7.90 $\mu V/Wm^{-2}$
NIP 23946E6	8.33 $\mu V/Wm^{-2}$	0.96188	0.00818	80	0.00091	8.01 $\mu V/Wm^{-2}$
SMHI A-166	11101.7 $Wm^{-2}A^{-2}$	0.99730	0.01195	78	0.00135	11131.8 $Wm^{-2}A$

LIST OF NEW CALIBRATION FACTOR

RECOMMENDED FOR PYRANOMETERS

INSTRUMENT	OLD CALIBRATION FACTOR $\mu V/Wm^{-2}$	+MEAN RATIO	σ	N	$\sigma/\sqrt{N}$	NEW CALIBRATION FACTOR RECOMMENDED $\mu V/Wm^{-2}$
*PSP-17759F3	9.11					
PSP-24196F3	9.21	1.01120	0.01242	2781	0.00024	9.31
PSP-17760F3	9.09	-	-	-	-	

* MEXICAN NATIONAL REFERENCE PYRANOMETER COMPARED AGAINST EPPLEY A-18587

\+ MEAN RATIO = MEAN [PYRAN. IRRADIAN./REFERENCE PYRAN. IRRADIAN.]

SUMMARY OF METEOROLOGICAL DATA
FIRST WMO REGIONAL PYRHELIOMETER COMPARISON
OF RA-IV
ENSENADA, MEXICO 1989

MEAN VALUES FOR EACH RUN

DATE	START TIME	REL AIR MASS	SOLAR ANG ELEV	AIR TEMP	REL HUM	PRESSURE	WATER VAP PRES	WIND SPEED	WIND DIRC
22-IV	9:44	1.4114	45.02	16.5	63.3	1009.1	11.9	5	W
	10:16	1.2774	51.43	17.2	60.2	1009.1	11.8	10	W
	10:50	1.1799	57.85	17.1	58.2	1009.0	11.3	5	W
	11:24	1.1161	63.54	17.6	55.1	1008.9	11.1	10	W
	11:57	1.0793	67.79	18.1	54.0	1008.7	11.2	10	W
	12:31	1.0634	70.00	18.0	53.8	1008.5	11.1	10	W
	13:05	1.0684	69.27	18.8	54.0	1008.2	11.7	12	W
	13.39	1.0948	65.88	18.8	54.1	1007.9	11.7	12	W
	14:41	1.2084	55.76	19.5	49.0	1007.6	11.1	7	W
	15:16	1.3236	48.98	19.8	48.6	1007.6	11.2	7	W
	15:50	1.4899	42.06	20.1	49.9	1007.9	11.7	10	NNW
	16:25	1.7494	34.76	19.0	56.1	1007.3	12.3	10	NNW
23-IV	10:11	1.2908	50.69	16.6	53.6	1009.6	10.1	5	W
	10:45	1.1884	57.20	17.2	52.6	1009.6	10.3	4	W
	11:19	1.1208	63.05	17.4	49.2	1009.6	9.9	5	W
	11:53	1.0801	67.69	17.8	50.8	1009.6	10.3	5	W
.....	.12:27	1.0619	70.22	17.8	52.6	1009.4	10.7	5	W
	13:01	1.0646	69.82	18.0	52.9	1009.4	10.9	6	W
	13:35	1.0883	66.65	18.8	50.5	1009.5	11.0	4	W
	14:39	1.2003	56.31	19.2	51.1	1009.3	11.4	6	NE
	15:12	1.3049	49.93	19.0	54.3	1009.1	11.9	6	NE
	15:45	1.4573	43.24	19.0	54.3	1008.4	11.9	6	NE