WORLD METEOROLOGICAL ORGANIZATION

INSTRUMENTS AND OBSERVING METHODS

REPORT No. 16

RADIATION AND SUNSHINE DURATION MEASUREMENTS

COMPARISON OF PYRANOMETERS AND ELECTRONIC SUNSHINE DURATION RECORDERS OF RA VI BUDAPEST, JULY - DECEMBER 1984

by

G. Major

March 1986

WMO/TD-No. 146

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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C O N T E N T S

PREFACE

One of the physical components of the climate is solar radiation. In meteorology, it has been described for a century or even more in terms of sunshine duration. Recently technical developments have made it possible to construct electronic sunshine duration recorders. To maintain continuity with the previous measurements, the Commission for Instruments and Methods of Observation (CIMO) recommended at CIMO-VIII (1981) the use of 120 W m^2 as a threshold, when using a pyrheliometer as a standard. To what extent are the various electronic sunshine duration recorders capable of fulfilling this recommendation?

In meteorology, the energy aspect of solar radiation is referred to as global radiation, which has been regularly recorded for only half a century. Since 1964 data for global radiation measured by pyranometers, from the whole world have been published by the WMO Radiation Data Centre, the Main Geophysical Observatory in Leningrad. In 1980 the World Meteorological Organization introduced the World Radiometric Reference (WRR) which is accepted as representing the physical unit of total irradiance with an accuracy better than 0.3 per cent. But what accuracy could be expected in the network data?

To obtain some answers to the above questions the WMO Regional Comparison of Pyranometers and Electronic Sunshine Duration Recorders for RA VI was held in Budapest, from July to December 1984. The present report contains the results of this comparison.

1. INTRODUCTION

Regional Association VI (Europe), at its eighth session in Rome in October 1982 accepted the offer of Hungary to undertake in 1984, during a period of six months, a comparison of national reference pyranometers and electronic sunshine recorders.

Members sent 13 instruments to the comparison: 3 sunshine recorders and 10 pyranometers. The list of participating instruments is given in Table 1. Since the various instruments arrived at different times the measurements could only begin on 19 July 1984. The last measurements were made on 16 December 1984. In January 1985, all instruments were returned to their home countries.

2. SUNSHINE RECORDERS

2.1 Short description of instrumentation

According to instruction manuals, the sensor units of the electronic sunshine recorders were fixed on the roof of the radiation pavillion of the Institute of Atmospheric Physics, Budapest, latitude: 47° 26', longitude: 19°11', elevation: 130 m.

The clock of the HAENNI system functions on the main power supply. The electromechanical counter shows the actual value of the sunshine duration in minutes (this unit, rather than seconds, was chosen). The cumulative values were printed at each full hour, from midnight to midnight, when the counter was cleared. Its threshold sensitivity was installed at the factory for 200 W m^{-2}.

The SONI system functions on a quartz clock and a microprocessor. Daily totals and each hourly values were printed with the resolution of one second. Its threshold sensitivity had been installed for 120 W m^{-2}.

The PRECISION MECANIQUE sunshine recorder has a double electro-mechanical counter which automatically changes at midnight. The resolution is 0.01 hour. Its manual does not contain the threshold value, but we can assume it to be 120 W m^{-2}.

A thermocompensated EPPLEY pyrheliometer, NIP-22004E6 served as reference. It was connected to both an electronic counter with 120 W m^{-2} threshold and a strip chart recorder. This was necessary because the sunshine recorders had a different threshold.

More detailed description of the sunshine recorders could be obtained from the respective national meteorological services.

During the comparison, all instruments functioned properly. The main problem was the synchronization of the different clocks and readings.

2.2 Results

Because of the synchronization difficulties, three kinds of data are presented in this report:

- Special observed data: hourly totals when all the three sunshine recorders and pyrheliometer operated synchronously. It is possible that such hours were chosen when there was some sunshine but not the full hour;
- Hourly values: when the three sunshine recorders were read simultaneously. It is possible that such hours were chosen when there was some sunshine but not the full hour;
- Daily and monthly values: daily and monthly totals produced by the three electronic recorders and a Campbell-Stokes recorder as well, during the whole operating period.

The special observed data are presented in Figures 1, 2, 3 and 4. The first three figures characterize the relation between the sunshine measurements and the pyrheliometric sunshine. Because the sensor unit of the PRECISION MECANIQUE has a wide field of view it measures a significant amount of diffuse as well as direct radiation. This situation leads to the high sunshine values when the sun is shining across a fog or transparent cloud layer. Figure 4 presents partial data to demonstrate that all three sunshine recorders measure less than the pyrheliometer, if the solar elevation is low.

The hourly values are shown in Figure 5 as a comparison between the sunshine duration measured by the SONI and by the other two recorders. In each case the HAENNI measured less than the SONI, according to their sensitivity difference. The PRECISION MECANIQUE regularly measures more sunshine than the SONI, but not always. The scattering of the points is mainly due to the difference in time of the direct radiation between the threshold values during the measuring hour.

The daily and monthly values are found in Table 2. The relation between the electronic instruments is the same as that in the case of the hourly values. The comparison with the CAMPBELL-STOKES endorses the choice of the 120 W m^{-2} threshold regarding the continuity of the yearly totals.

2.3 Conclusions

- It would be desirable to compare electronic sunshine recorders when all of them have the same threshold sensitivity.
- At solar elevations less than 10 degrees all three types of sunshine recorders measure less sunshine than the pyrheliometer.
- The role of the circumsolar diffuse radiation in sunshine records should be investigated.

3. PYRANOMETERS

3.1 Description of instrumentation

The pyranometers were fixed on the same roof as the sunshine recorders, the cable output pointing to the North. The CM-11 pyranometer was ventilated. Members sent sensitivity values together with the information on the temperature and directional corrections to be applied to the readings, as is seen in Table 3. The output electromotive force values were collected and measured by a 16-channel data logger made in the Institute of Atmospheric Physics. A measuring cycle lasts 0.6 second. Having finished the readings the data are transferred to a Hewlett-Packard 97-S calculator, which prints the flux densities in W m^{-2} units using the multiplication factors of Table 3. Using the auxiliary information the necessary corrections are made and the final data are punched for further evaluation. Altogether, 544 such measurements have been collected.

3.2 Results

The results of measurements are presented in Table 4. Here all radiation data are expressed in WRR. The auxiliary information consists of,

- true solar time,
- solar elevation,
- solar azimuth angle,
- instrument body temperature,
- wind speed in m/sec.,
- diffuse radiation.

The diffuse radiation was read by the same data collector. The signal was produced by a CM-5 pyranometer shaded by a ring. During the data processing a ring-correction was applied.

Due to the lack of time, a detailed analysis of the collected data was not possible, therefore only some preliminary results of evaluation can be presented here.

In Figure 6 ratios of averages of the different pyranometer data to the mean of their averages are shown. The order of instruments is the same as in Table 4. The averaging was made from all measurements, from the data on page 4 of Table 4 as Summer, page 8 as Autumn and page 17 as Winter. It is seen that the ratios vary strongly with the physical circumstances of the measurements.

It would be desirable if at the same time the pyranometers would produce the same value of global radiation. The variability between the values of different instruments can be characterized by the ratio of the standard deviation to the mean value, that is the relative standard deviation. This deviation varies as a function of the actual physical circumstances of the comparison. To characterize the effect of circumstances some sub-samples have been chosen from the collected data. Sub-sample Summer consists of data on page 4 of Table 4, page 8 of the same table serves as Autumn and page 17 as Winter. In Table 5 the mean values of relative standard deviations are shown for all data and for the sub-samples. For the figures in the first column the original calibration factors were used. The second column shows the results by using corrected calibration factors which were

derived from comparing the pyranometers to each other, that is the average of each instrument for the sample period made to be equal to the mean of averages of all instruments. The comparison of the two columns clearly shows that the unified calibration of pyranometers would decrease the deviations between their measurements.

3.3 Conclusions

- This sample of pyranometers is not representative of the whole territory of RA VI. It is estimated that, the numerical values of deviations of pyranometers given here are somewhat less than they would be on the basis of a full sample.

- Generally, the comparability of instantaneous pyranometric data is about 5 per cent.

- To obtain better agreement between the pyranometers, a standardized calibration procedure is necessary together with the application of corrections due to the actual physical circumstances of the measurement.

4. ACKNOWLEDGEMENT

The author wishes to express his thanks to his colleagues in the Radiation Group of the Institute of Atmospheric Physics, Budapest, for their help in making the measurements and the data handling. Special thanks are due to Mrs. Olga Farkas, who took part in each phase of his work.

Dr. K. Kasten sent valuable comments on the preliminary version of this report.

5. REFERENCE

Ambrosetti P., et al. Results of an Outdoor and Indoor Pyranometer Comparison

International Energy Agency Document No. III.A.3. 1984.

Table 1

PARTICIPATING INSTRUMENTS OF MEMBERS

SUNSHINE RECORDERS

PRECISION MECANIQUE	France
SONI 6.008	Germany, Federal Republic of
HAENNI Solar 112	Switzerland

PYRANOMETERS

Stern - 2223	Austria	(AUS)
Sonntag - 5173/538	German Democratic Republic	(GDR)
CM-11 - 790059	Germany, Federal Republic of	(FRG)
CM-5 - 773876	Hungary	(HUN)
CM-5 - 721995	Norway	(NOR)
CM-5 - 773660	Poland	(PL1)
Sonntag - 2878/882	Poland	(PL2)
CM-5 - 828411	Switzerland	(CH)
Eppley - 2100F3	Turkey	(TUR)
CM-5 - 785140	United Kingdom	(GB)

Table 2

DAILY SUNSHINE

(in minutes)

J U L Y

Date	HAENNI	SONI	PRECISION	CAMPBELL-STOKES
28.		376		384
29.		309		348
30.		669		702
31.	633	744		762

D E C E M B E R

1.	300	331	354	282
2.	245	305	341	186
3.	394	428	421	408
4.	208	251	265	222
5.	365	391	390	312
6.	0	0	0	0
7.	0	0	0	0
8.	0	0	0	0
9.	0	0	0	0
10.	16	21	25	0
11.	76	111	127	180
12.	410	446	430	390
13.	302	359	347	240
14.	71	84	104	42
15.	0	0	0	0
16.	0	0	0	0

Table 2, p. 2

DAILY SUNSHINE

(in minutes)

A U G U S T

Date	HAENNI	SONI	PRECISION	CAMPBELL-STOKES
1.	685	725		738
2.	623	687		774
3.	505	623		672
4.	599	661		684
5.	726	760		774
6.	473	600		678
7.	323	390		408
8.	13	39		36
9.	438	522		334
10.	246	282		306
11.	343	354		396
12.	326	376		450
13.	167	190		234
14.	560	597		654
15.	283	327		378
16.	303	324		324
17.	432	480		516
18.	499	555		576
19.	95	123		150
20.	572	602		702
21.	458	474		522
22.	669	713		720
23.	640	679		708
24.	606	636		654
25.	296	304		300
26.	198	235		264
27.	334	357		432
28.	717	744		732
29.	702	722		714
30.	622	655		666
31.	517	600		624
	13970	15336		16498

Table 2, p. 3

DAILY SUNSHINE

(in minutes)

S E P T E M B E R

Date	HAENNI	SONI	PRECISION	CAMPBELL--STOKES
1.	483	619		618
2.	544	584		546
3.	670	695		678
4.	578	617		606
5.	640	668		654
6.	423	447		480
7.	212	246		270
8.	557	586		642
9.	253	290		318
10.	270	307		324
11.	317	348		432
12.	15	26		66
13.	140	164		204
14.	420	442		456
15.	279	315		264
16.	4	5		6
17.	251	279		264
18.	389	411		438
19.	467	512		498
20.	369	390		342
21.	0	0		0
22.	2	6		12
23.	256	272		324
24.	267	237		372
25.	0	0		0
26.	146	156		216
27.	53	55		96
28.	402	411		426
29.	228	222		270
30.	260	280		330
	8895	9590		10150

Table 2, p. 4

DAILY SUNSHINE
(in minutes)

O C T O B E R

Date	HAENNI	SONI	PRECISION	CAMPBELL-STOKES
1.	470	529		486
2.	156	177		192
3.	582	598		582
4.	40	54		72
5.	281	312		324
6.	96	110		108
7.	0	0		0
8.	367	399		456
9.	268	297		282
10.	496	530		486
11.	228	262		246
12.	26	51		0
13.	572	581		558
14.	473	493		492
15.	119	135		150
16.	565	584	568	588
17.	553	575	555	552
18.	546	565	510	546
19.	467	514	479	480
20.	469	484	479	474
21.	1	2	0	6
22.	72	98	85	150
23.	34	59	53	48
24.	107	126	167	126
25.	258	300	334	294
26.	0	3	7	6
27.	18	26	38	48
28.	0	0	0	0
29.	480	499	499	498
30.	107	150	154	144
31.	0	0	0	0
	7851	8513	3928	8394

Table 2, p. 5

DAILY SUNSHINE

(in minutes)

N O V E M B E R

Date	HAENNI	SONI	PRECISION	CAMPBELL-STOKES
1.	0	0	0	0
2.	0	0	0	0
3.	277	299	311	306
4.	437	462	468	438
5.	0	0	0	0
6.	0	0	0	0
7.	302	361	438	354
8.	137	190	217	186
9.	0	0	75	18
10.	30	69	110	84
11.	345	355	370	354
12.	461	481	481	402
13.	0	16	23	18
14.	410	439	440	384
15.	0	0	0	0
16.	0	0	4	0
17.	0	1	0	0
18.	0	0	0	0
19.	0	0	10	0
20.	0	0	0	0
21.	32	47	55	48
22.	259	293	303	294
23.	121	142	138	156
24.	36	46	53	60
25.	307	342	359	240
26.	0	0	0	0
27.	97	116	116	90
28.	324	384	383	306
29.	4	18	68	0
30.	357	393	395	318
	3936	4454	4817	4056

Characteristics of the pyranometers

	Type	Given sensitivity	Multiplication factor $W\ m^{-2}\ mV^{-1}$	Temperature correction	Directional correction
FRG	CM-11	0.065 mV $mW^{-1}cm^2$	176.99	Compensated	
NOR	CM-5	11.19 10^{-6} V $W^{-1}m^2$	89.37		
UK	CM-5	11.05 10^{-6} V $W^{-1}m^2$	90.50		
CH	CM-5	11.26 10^{-6} V $W^{-1}m^2$	88.81	0.15 per cent per ^{o}C	
PL 1	CM-5	11.2 10^{-6} V $W^{-1}m^2$	89.29		
TUR	Eppley	10.24 10^{-6} V $W^{-1}m^2$ IPS	97.66	Compensated	
PL 2	Sonntag	7.3 mV $cal^{-1}cm^2min$ IPS	95.75		
AUS	Stern	2.54 mV J^{-1} cm^2 min	65.62		Azimuth and elevation chart
GDR	Sonntag	9.30 10^{-6} V W^{-1} m^2	107.53		
HUN	CM-5	10.82 10^{-6} V W^{-1} m^2	94.19	0.2 per cent per ^{o}C	

Table 3

TABLE 4

Date	Time	h	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	FUR	PL2	AUS	GDR	HUN
7 19	12.00	63	180	22	7	610	696	691	697	691	673	676	0	0	0	681
7 19	12.04	63	182	23	4	571	732	724	733	725	705	715	0	0	0	726
7 19	12.06	63	183	23	3	561	796	783	775	766	756	755	0	0	0	780
7 19	12.14	63	187	23	4	490	1091	1046	1029	996	991	972	0	0	0	1021
7 19	12.20	63	190	24	3	494	991	962	999	986	949	985	0	0	0	1005
7 19	12.25	63	193	24	2	541	1097	1061	1083	1072	1039	1071	0	0	0	1087
7 19	12.28	63	194	24	3	562	838	810	815	788	783	765	0	0	0	798
7 19	13.17	59	216	24	3	462	555	560	558	554	545	536	0	0	0	548
7 19	13.20	59	218	24	4	460	484	492	489	488	479	466	0	0	0	495
7 19	13.22	59	219	24	3	431	437	438	434	435	429	419	0	0	0	442
7 19	13.24	58	220	24	2	397	401	402	398	406	399	382	0	0	0	407
7 19	13.26	58	220	24	3	375	378	384	383	383	378	360	0	0	0	386
7 19	14.11	53	236	24	2	447	466	468	468	471	458	453	0	0	0	472
7 19	14.13	52	236	24	1	422	513	515	519	515	503	499	0	0	0	517
7 19	14.15	52	237	24	4	406	490	495	492	491	485	472	0	0	0	496
7 20	7.07	26	88	17	0	173	212	220	214	220	214	206	0	0	0	206
7 20	7.14	27	89	18	1	185	212	220	211	217	217	206	0	0	0	212
7 20	7.19	28	90	18	0	206	277	283	284	285	283	273	0	0	0	278
7 20	7.21	29	90	18	0	222	295	298	296	300	298	283	0	0	0	291
7 20	8.21	39	102	18	2	175	171	176	172	178	173	159	0	0	0	177
7 20	9.12	47	114	19	3	394	425	432	431	436	423	416	0	0	0	430
7 20	9.15	47	114	20	3	415	496	497	495	500	488	485	0	0	0	500
7 20	11.01	61	150	20	4	325	319	325	320	323	318	303	0	0	0	325
7 20	11.04	61	152	21	3	321	319	322	317	320	313	303	0	0	0	321
7 20	11.06	61	153	21	5	341	342	346	344	346	339	329	0	0	0	346
7 20	11.58	63	179	26	3	411	944	921	932	919	896	909	0	0	0	937
7 20	11.59	63	180	26	2	414	873	864	875	874	845	862	0	0	0	902
7 20	13.42	56	226	25	3	288	702	709	700	703	688	702	0	0	0	733
7 20	13.45	56	227	25	6	303	861	846	848	838	818	825	0	0	0	854
7 20	14.53	46	248	24	5	228	230	235	229	232	229	220	0	0	0	232
7 20	14.55	46	248	24	3	306	448	450	449	450	440	435	0	0	0	457
7 23	7.06	26	88	21	2	180	336	346	338	340	345	326	0	0	0	333

Table 4

TABLE 4 page: 2

Date	Time	h	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	HUN
7 23	7.09	26	88	21	1	202	354	355	347	352	354	339	0	0	0	345
7 23	7.51	33	96	24	2	250	460	462	459	459	461	446	0	0	0	447
7 23	7.55	34	97	24	0	244	454	450	449	447	446	435	0	0	0	445
7 23	8.38	41	106	26	1	289	466	465	465	464	455	446	0	0	0	472
7 23	8.47	43	108	26	0	293	513	512	504	507	503	490	0	0	0	514
7 23	9.31	49	119	28	0	353	496	497	498	497	488	479	0	0	0	504
7 23	9.34	50	120	28	0	375	572	569	567	564	554	549	0	0	0	575
7 23	11.06	61	154	23	0	422	507	509	510	507	500	490	0	0	0	515
7 23	11.09	61	155	23	0	440	537	539	540	536	524	522	0	0	0	547
7 23	11.59	63	180	31	2	504	761	745	745	731	723	722	0	0	0	766
7 23	12.02	63	181	31	0	489	690	682	679	667	664	655	0	0	0	695
7 23	13.05	60	211	29	4	424	543	536	540	532	527	522	0	0	0	549
7 23	13.09	59	213	29	1	424	572	569	567	560	551	549	0	0	0	574
7 23	14.16	51	237	29	3	364	372	369	365	362	360	353	0	0	0	374
7 23	14.18	51	238	29	0	360	389	387	386	383	378	369	0	0	0	395
7 25	10.04	54	130	21	0	311	319	322	323	323	315	313	339	0	326	316
7 25	10.13	55	133	22	0	354	348	346	350	351	345	339	369	0	358	354
7 25	11.03	60	153	25	1	380	678	682	682	679	661	659	714	0	688	696
7 25	11.06	60	154	25	0	396	690	691	691	688	670	662	721	0	699	705
7 25	11.20	61	160	26	3	415	720	718	721	716	702	695	753	716	731	727
7 25	11.23	61	162	26	3	437	696	697	694	693	676	668	728	690	706	701
7 25	11.27	61	164	26	0	396	661	649	640	630	625	602	676	638	652	643
7 25	11.54	62	177	27	2	432	885	873	881	867	848	855	920	863	900	894
7 25	11.57	62	179	27	1	406	885	876	887	873	857	858	926	856	903	890
7 25	11.59	62	180	26	0	433	873	861	854	836	824	808	884	821	860	854
7 25	12.50	60	204	28	1	496	855	843	845	834	821	819	890	828	867	854
7 25	12.52	60	205	28	1	388	413	426	437	448	429	439	466	437	437	452
7 25	13.32	57	222	27	0	318	307	316	311	313	310	289	323	312	305	318
7 25	14.30	49	241	28	3	335	732	733	733	728	711	712	767	734	746	737
7 25	14.33	48	241	28	3	344	720	727	718	713	699	705	767	722	738	734
7 26	10.26	56	138	22	6	459	484	486	489	486	473	472	515	484	491	489
7 26	11.29	61	165	19	2	134	124	143	136	142	143	130	137	141	129	142

TABLE 4 page: 3

Date	Time	n	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	HUN
7 26	11.33	61	167	19	3	143	142	143	136	142	143	130	137	141	129	143
7 26	11.35	62	168	19	6	142	142	143	142	145	143	130	143	141	136	143
7 26	13.00	59	209	20	3	213	212	214	211	213	208	206	225	213	215	213
7 26	14.16	51	236	21	0	180	180	182	184	187	188	177	196	191	183	191
7 26	14.20	50	238	20	1	185	177	188	181	187	179	170	186	186	183	185
7 26	14.26	49	239	20	2	181	177	182	181	187	179	170	186	184	172	181
7 26	14.30	49	240	20	2	177	177	179	172	178	176	159	176	176	172	178
7 27	10.56	59	150	22	8	346	726	715	706	697	685	672	728	680	699	692
7 27	10.59	59	151	22	11	306	425	435	419	410	414	382	437	409	409	412
7 27	14.19	50	237	22	5	261	307	319	314	316	310	303	329	312	308	321
7 27	14.23	50	238	21	4	302	313	316	311	310	307	299	326	310	308	314
7 30	7.26	28	92	20	2	134	372	378	374	379	378	366	437	378	380	375
7 30	7.30	29	94	21	3	121	401	402	398	400	399	382	460	396	401	387
7 30	7.51	32	98	22	2	153	460	456	453	461	452	439	518	456	466	448
7 30	7.53	33	98	22	1	159	460	462	459	461	458	439	518	459	470	458
7 30	8.17	37	103	23	0	172	513	509	507	513	503	482	567	510	527	503
7 30	8.19	37	103	23	2	181	513	515	513	516	509	490	571	512	527	509
7 30	8.49	42	110	25	2	217	566	563	561	564	554	532	616	564	581	565
7 30	8.51	42	110	25	1	226	555	551	555	553	542	522	603	550	563	551
7 30	9.05	44	114	25	2	238	602	596	597	596	586	556	649	598	609	597
7 30	9.07	45	114	25	0	223	596	593	594	590	580	552	643	592	606	596
7 30	9.23	47	119	26	1	199	684	685	685	681	670	629	741	683	699	688
7 30	9.25	47	119	26	2	208	708	694	700	693	682	636	753	695	713	704
7 30	9.45	50	125	27	1	209	726	706	715	702	696	649	763	707	728	724
7 30	9.47	50	125	27	3	199	732	724	724	720	705	659	773	721	742	731
7 30	10.14	54	134	28	0	246	755	748	751	740	729	682	793	740	756	753
7 30	10.16	54	134	28	2	269	755	748	751	743	729	689	799	744	760	765
7 30	10.59	59	152	29	2	270	796	789	793	785	765	745	805	787	799	796
7 30	11.02	59	153	29	0	270	832	816	818	803	786	765	819	804	810	826
7 30	11.04	59	153	29	0	263	832	816	818	803	789	772	829	804	821	825
7 30	11.24	60	163	28	3	294	808	801	805	793	774	761	809	791	792	816
7 30	11.42	61	174	29	3	270	855	840	848	833	813	808	851	830	839	851

Date	Time	h	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	HUN
7 30	11.45	61	173	29	5	292	891	873	881	864	842	842	887	863	875	890
7 30	11.58	61	179	29	3	355	796	789	793	779	762	758	799	776	785	805
7 30	12.01	61	181	30	0	359	767	754	757	744	726	722	763	743	749	763
7 30	12.04	61	182	30	4	353	737	733	733	723	705	699	744	724	735	751
7 30	12.07	61	183	30	3	366	820	807	821	805	783	792	825	802	814	829
7 30	12.09	61	184	29	2	365	850	834	839	827	807	805	845	819	835	848
7 30	12.26	61	193	30	4	293	879	864	869	854	836	838	881	850	871	872
7 30	12.28	61	194	30	3	337	867	849	854	843	821	832	868	840	857	860
7 30	12.49	59	203	29	1	320	808	798	799	791	771	775	812	788	799	814
7 30	12.54	59	206	30	3	353	802	789	778	764	759	752	805	778	796	799
7 31	7.16	26	91	23	0	169	319	322	317	318	321	310	342	326	323	314
7 31	7.20	27	92	23	0	169	319	328	323	328	330	316	353	332	333	324
7 31	7.44	31	96	24	0	188	372	378	371	380	375	360	402	379	384	379
7 31	7.46	31	97	24	0	195	378	380	377	383	381	363	405	384	384	383
7 31	8.16	36	103	26	0	199	472	471	465	467	464	449	490	469	473	467
7 31	8.17	36	103	26	0	202	478	477	471	476	473	459	499	477	484	474
7 31	9.08	44	115	29	0	247	608	599	600	596	586	583	619	598	606	609
7 31	9.11	45	116	29	0	247	619	608	606	605	592	589	626	605	613	610
7 31	10.09	53	133	29	3	260	726	715	721	709	696	699	734	708	720	723
7 31	10.13	54	134	30	4	267	726	721	724	717	705	702	744	712	731	735
7 31	10.56	58	150	30	3	276	791	778	778	770	750	758	793	764	774	792
7 31	10.59	58	152	30	4	276	796	778	781	770	753	758	793	763	774	798
7 31	11.29	60	165	31	0	286	808	792	799	783	768	775	805	780	789	816
7 31	11.42	61	171	31	3	283	820	798	805	792	774	782	812	783	799	818
7 31	11.44	61	172	31	3	286	820	804	811	795	780	782	812	787	792	829
7 31	11.48	61	174	31	4	286	814	798	805	789	777	779	805	781	796	823
7 31	11.53	61	177	31	4	293	796	783	784	774	756	761	793	766	781	799
7 31	11.59	61	180	31	4	296	802	789	793	780	762	772	802	773	789	804
7 31	12.01	61	181	32	2	294	814	795	796	785	768	779	802	777	796	813
7 31	12.04	61	182	32	4	297	802	780	787	768	759	758	793	768	785	806
7 31	12.06	61	183	32	0	275	773	754	760	747	732	739	770	742	760	766
8 1	11.51	61	176	32	5	258	808	792	799	779	768	782	805	774	789	819

Date	Time	h	a	T	π/s	DIE	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	HUN
8 1	11.54	61	177	32	0	258	826	807	811	790	780	795	819	784	806	836
8 1	11.57	61	179	32	6	265	820	798	808	789	774	792	816	779	803	834
8 1	12.00	61	180	33	2	269	643	635	630	616	610	612	640	608	617	643
8 1	12.04	61	182	33	5	284	832	810	821	798	783	805	832	795	824	836
8 1	12.06	61	183	33	7	278	814	792	802	783	768	785	812	776	803	816
8 1	12.09	61	184	33	4	284	761	760	769	755	738	755	783	742	767	783
8 10	7.09	23	92	16	3	18	18	18	21	24	21	16	19	20	13	20
8 10	7.32	27	96	16	6	207	206	209	211	211	211	203	219	207	211	207
8 10	7.35	27	97	16	5	207	206	203	205	211	205	199	216	204	211	207
8 10	8.19	35	106	18	3	276	484	480	483	484	470	462	515	475	487	476
8 13	11.07	55	157	17	0	34	35	36	33	36	33	30	33	40	32	35
8 13	11.10	56	158	17	0	34	35	36	36	38	39	30	39	40	32	39
8 13	12.05	57	183	17	0	142	142	146	139	146	146	133	150	145	140	145
8 13	12.51	56	202	20	2	340	584	587	588	595	583	575	603	576	584	589
8 13	12.54	55	203	20	0	248	307	319	320	326	318	306	333	313	319	322
8 15	13.02	54	206	28	3	369	690	697	715	710	686	715	747	709	728	737
8 15	13.07	54	208	28	3	346	596	584	597	591	568	583	610	578	591	603
8 15	13.10	54	209	28	2	372	614	614	615	606	595	596	640	607	624	623
8 15	13.47	50	223	25	3	224	478	471	486	487	464	469	490	474	487	484
8 15	13.50	50	224	25	3	246	378	387	377	376	372	363	394	378	376	381
8 20	12.14	55	186	23	5	174	177	191	184	186	188	173	189	185	172	188
8 20	12.21	55	189	23	8	183	696	694	742	754	693	758	741	710	735	746
8 21	10.39	51	148	27	1	149	726	712	718	706	691	689	728	701	713	719
8 21	10.42	51	149	27	2	149	726	712	718	706	688	692	731	703	724	721
8 21	12.01	55	180	26	0	257	767	760	760	748	726	729	760	740	749	763
8 21	12.03	55	181	26	0	232	242	259	250	253	250	239	258	253	237	260
8 21	12.06	55	183	26	0	242	726	718	721	712	691	692	725	704	717	724
8 21	12.14	55	186	27	3	258	761	754	760	753	729	735	767	736	760	780
8 21	12.19	54	188	27	2	271	785	772	778	768	747	752	789	758	781	785
8 22	10.03	47	136	26	0	162	667	655	661	657	643	639	685	653	667	653
8 22	10.05	47	136	26	2	162	673	661	667	660	646	642	685	653	670	664
8 22	12.02	54	181	29	0	246	743	736	736	730	711	715	747	723	735	741

TABLE 4

Date	Time	b	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	NJN
8 22	12.05	54	182	29	1	240	737	730	727	721	702	702	741	716	728	734
8 23	11.09	52	159	28	2	258	678	673	679	667	652	659	692	661	677	676
8 23	12.04	54	182	29	0	256	696	694	697	684	670	668	701	677	688	699
8 23	12.07	54	183	29	3	259	708	697	697	690	670	679	704	684	692	699
8 27	7.51	26	104	17	0	156	159	173	166	170	170	159	180	171	165	166
8 27	7.55	27	105	17	0	177	342	346	344	348	345	329	369	346	348	333
8 27	9.03	37	120	19	3	326	319	334	329	332	324	316	342	330	333	327
8 27	9.11	38	122	19	0	332	360	360	356	356	348	336	369	350	351	350
8 27	12.08	53	183	22	2	315	850	834	851	850	813	835	865	833	857	842
8 27	12.12	53	185	23	0	335	897	876	890	881	845	865	900	863	889	879
8 27	12.17	52	187	23	0	316	844	828	848	843	807	829	865	827	853	838
8 27	12.50	51	200	23	5	224	820	804	811	804	777	782	822	787	806	804
8 27	12.53	51	201	23	5	227	814	807	818	807	780	785	829	784	810	813
8 28	6.54	16	93	14	0	62	206	217	205	218	220	203	241	212	215	201
8 28	6.58	17	94	14	0	65	206	229	217	227	232	213	251	224	226	207
8 28	7.18	20	98	15	2	75	271	283	272	283	286	266	307	283	280	260
8 28	7.19	20	98	15	2	75	283	295	281	295	298	279	317	291	290	275
8 28	8.09	29	108	17	2	84	425	429	425	431	429	409	463	429	441	416
8 28	8.11	29	109	17	2	87	437	438	431	437	435	419	470	436	448	420
8 28	9.27	40	127	20	3	104	619	620	624	628	610	599	646	612	627	615
8 28	9.30	41	128	20	5	100	637	629	634	634	619	609	656	622	634	628
8 28	10.11	46	140	21	0	110	702	691	697	699	676	668	711	685	699	689
8 28	10.14	46	141	21	2	113	708	703	706	708	688	679	717	692	703	702
8 28	11.13	51	161	22	0	111	761	757	760	759	732	729	763	739	753	755
8 28	11.15	51	162	22	0	107	779	760	769	726	741	739	773	746	753	763
8 28	11.57	52	179	22	3	130	761	754	760	756	729	732	756	738	753	756
8 28	12.01	52	180	22	0	132	767	760	766	759	732	739	763	744	753	770
8 28	12.08	52	183	23	0	126	761	757	760	760	732	732	760	740	753	754
8 28	12.48	51	199	24	0	152	702	697	694	692	667	665	701	677	692	689
8 28	12.50	51	200	25	0	152	714	706	709	703	679	686	717	693	706	700
8 28	14.25	41	231	25	0	133	714	596	594	590	571	572	630	590	602	588
8 28	14.29	41	232	25	0	133	596	590	588	582	563	569	626	588	599	582

Date	Time	n	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	YUG	GDR	HUN
8 28	14.53	38	238	25	0	133	519	518	519	514	500	499	558	519	527	514
8 28	14.56	37	239	25	0	133	513	506	510	505	491	485	542	506	509	504
8 29	7.01	17	95	13	0	65	206	217	208	218	220	206	241	215	215	201
8 29	7.04	18	96	14	0	75	212	226	217	224	232	213	251	225	226	210
8 29	7.30	22	101	15	3	84	295	307	293	307	307	283	326	306	301	287
8 29	7.33	23	101	15	0	84	301	313	299	313	313	292	336	313	312	294
8 29	11.22	51	165	25	2	145	743	730	736	728	711	705	741	716	728	738
9 7	7.08	16	99	16	0	87	71	86	78	86	86	77	85	82	82	87
9 7	7.11	16	99	16	0	91	77	89	81	90	89	80	88	85	86	91
9 7	7.18	18	101	16	0	86	71	86	81	86	86	77	79	84	82	86
9 7	8.11	26	111	16	0	132	124	131	130	137	131	123	134	133	125	132
9 7	8.13	27	112	16	0	152	142	152	148	155	152	143	153	152	147	152
9 7	8.20	28	113	16	0	131	118	131	127	131	131	117	131	129	125	131
9 19	6.55	10	99	11	0	61	88	95	87	93	92	87	101	87	86	85
9 19	6.59	11	100	11	0	64	88	101	97	99	101	90	111	97	97	92
9 19	7.02	12	101	11	2	71	106	107	100	108	107	100	118	101	100	99
9 19	7.05	12	101	12	0	68	106	113	109	116	116	106	127	108	111	104
9 19	7.57	20	112	12	0	117	246	256	244	258	247	239	277	251	251	241
9 19	8.00	21	112	12	0	133	265	271	265	275	271	257	296	267	272	258
9 19	9.53	36	139	18	2	177	519	521	519	526	506	493	545	518	520	516
9 19	9.58	37	141	18	3	180	531	527	531	535	518	506	558	527	534	529
10 2	9.30	29	136	20	4	190	183	197	193	195	190	186	205	192	190	190
10 2	9.35	30	137	20	6	199	195	200	196	201	193	190	205	194	194	199
10 2	10.47	37	157	23	5	163	507	509	510	513	494	493	535	504	509	507
10 2	10.50	37	158	23	7	153	543	533	537	536	524	519	564	534	538	534
10 2	13.30	35	208	25	2	276	614	614	612	608	595	596	656	602	620	607
10 2	13.33	35	209	25	10	271	619	614	615	611	595	602	665	606	624	610
10 2	13.36	35	210	25	2	254	566	569	588	584	560	578	626	568	584	577
10 10	8.10	16	119	10	0	58	142	155	139	147	155	136	167	142	143	133
10 10	8.13	16	120	11	0	58	118	128	112	120	92	103	131	114	115	104
10 10	8.46	21	127	11	0	67	254	265	250	266	271	243	293	255	262	246
10 10	9.24	26	136	11	0	78	295	298	299	309	307	286	323	295	294	292

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Date	Time	h	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	HUN
10 10	10.27	32	152	15	3	109	501	497	501	507	497	472	531	497	502	499
10 10	11.27	35	170	16	2	122	549	539	546	548	521	516	567	539	538	532
10 10	12.23	36	187	18	4	270	454	465	446	445	458	419	479	460	452	450
10 10	13.26	33	206	19	2	267	313	325	320	329	327	313	342	328	315	321
10 10	14.27	27	222	18	4	203	407	411	407	416	417	392	444	407	409	396
10 10	15.29	19	236	20	3	74	242	250	235	249	259	230	274	247	237	239
10 12	13.24	32	205	24	3	171	165	173	169	174	164	164	176	174	168	171
10 12	13.29	32	206	24	2	194	189	194	190	194	188	180	196	194	190	194
10 17	8.27	16	125	3	0	66	212	217	211	218	214	199	248	202	215	195
10 17	8.32	17	126	4	0	60	224	235	229	240	235	217	271	217	229	214
10 17	8.35	17	126	4	0	63	230	244	235	249	244	226	284	227	244	224
10 17	8.37	18	127	4	0	69	236	250	241	255	250	230	287	229	247	228
10 17	8.40	18	127	4	0	72	248	256	250	264	256	236	290	236	254	238
10 17	8.43	18	128	4	0	69	260	265	259	269	265	246	290	243	262	241
10 17	8.47	19	129	5	0	69	265	271	262	278	274	249	296	253	269	247
10 17	8.50	19	130	5	0	69	271	280	272	290	280	260	304	265	280	259
10 17	8.53	20	130	6	0	69	283	286	281	293	286	270	313	271	284	282
10 17	9.02	21	132	6	0	80	301	307	302	320	307	292	336	292	305	286
10 17	9.09	22	134	7	0	78	301	313	308	320	313	289	342	299	312	289
10 17	9.18	23	136	7	0	84	313	322	317	329	324	303	353	314	326	302
10 17	9.34	25	140	9	0	84	360	363	368	379	372	350	398	357	373	349
10 17	9.37	25	141	9	0	81	372	372	371	385	378	353	408	366	380	352
10 17	9.53	27	145	9	0	90	401	405	404	416	414	376	437	401	405	385
10 17	9.57	27	146	9	0	94	395	396	395	407	405	366	427	390	394	382
10 17	10.02	28	147	10	0	100	413	408	413	423	417	386	444	409	416	403
10 17	10.05	28	148	10	1	94	419	420	422	432	429	400	450	420	419	401
10 17	10.40	31	157	11	3	101	466	465	471	480	482	439	493	468	466	452
10 17	10.42	31	158	11	2	97	466	468	468	480	485	443	493	466	466	454
10 17	10.45	31	158	11	3	97	460	463	465	477	485	439	490	463	462	451
10 17	11.35	33	173	13	2	97	507	515	516	523	536	490	539	518	509	494
10 17	11.37	33	173	13	4	97	496	509	507	517	527	479	528	508	495	491
10 17	11.39	33	174	13	4	101	507	509	510	517	530	476	525	506	493	491

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Date	Time	h	a	T	m/s	DiF	PRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	HUN
10 17	12.10	33	183	14	1	145	572	563	570	573	571	546	597	465	570	560
10 17	12.13	33	184	14	2	167	342	352	356	361	354	336	362	348	337	345
10 17	12.16	33	185	14	3	167	578	578	588	594	580	562	610	576	577	565
10 17	12.18	33	185	14	4	148	590	581	582	588	592	556	613	577	581	558
10 17	12.58	32	197	14	3	148	0	545	546	553	560	519	584	544	545	536
10 17	13.01	32	198	14	6	137	549	545	543	556	560	519	584	542	541	533
10 17	13.02	32	198	14	4	118	525	533	531	538	542	506	567	527	530	513
10 18	6.59	3	107	0	0	15	18	27	18	28	27	20	30	26	18	21
10 18	7.03	3	108	0	2	17	29	36	27	37	27	30	39	32	22	25
10 18	7.06	4	109	0	3	17	35	45	33	39	33	37	49	39	32	33
10 18	7.09	4	109	0	3	17	35	45	36	45	36	40	52	42	32	34
10 18	7.14	5	110	0	3	17	24	33	27	34	27	30	36	30	32	25
10 18	7.16	5	111	0	3	17	24	36	30	37	30	30	39	32	32	28
10 18	7.19	6	111	0	4	20	41	48	42	48	42	43	52	42	47	40
10 18	7.22	6	112	0	4	26	53	57	51	54	51	50	65	51	54	48
10 18	7.25	7	112	0	3	26	35	39	39	42	39	34	42	39	36	37
10 18	7.27	7	113	0	3	30	59	69	63	67	63	60	79	61	65	59
10 18	7.31	8	114	0	2	36	71	83	75	82	74	74	91	71	75	68
10 18	7.35	8	114	0	2	36	77	89	81	89	80	80	98	77	86	74
10 18	7.37	9	115	0	3	42	100	110	100	110	98	93	124	96	100	94
10 18	7.40	9	115	0	2	42	106	122	109	118	107	106	137	106	115	102
10 18	7.42	9	116	1	2	39	112	125	115	124	116	109	143	110	118	106
10 18	7.45	10	116	1	2	45	124	134	124	134	122	120	153	117	125	115
10 18	7.48	10	117	1	3	45	124	140	130	143	131	123	159	121	133	122
10 18	7.51	11	117	1	3	47	142	152	139	152	140	130	170	129	140	129
10 18	7.56	12	118	1	2	50	142	158	145	158	149	140	176	138	151	137
10 18	7.59	12	119	2	2	53	142	161	151	164	152	140	176	145	151	139
10 18	8.01	12	119	2	2	53	159	170	157	170	164	146	186	149	161	147
10 18	8.31	17	126	4	3	60	230	241	226	246	250	213	265	219	237	220
10 18	8.34	17	126	4	3	63	230	250	235	255	259	223	274	230	244	230
10 18	8.37	17	127	4	2	63	248	259	244	264	268	230	284	239	251	234
10 18	8.51	19	130	5	2	72	283	292	281	303	307	266	320	272	287	272

Date	Time	h	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	HUN
10 18	9.06	21	133	6	4	69	313	325	317	336	342	299	353	307	323	300
10 18	9.08	21	134	6	4	72	319	331	323	342	348	310	362	314	330	310
10 18	9.11	22	135	6	4	69	319	331	326	347	357	313	365	320	333	314
10 18	9.13	22	135	6	4	69	330	340	335	353	357	320	372	324	341	320
10 18	9.26	23	138	7	5	75	354	344	362	377	384	339	402	349	366	350
10 18	9.28	24	139	7	3	75	354	366	365	380	393	350	402	355	373	348
10 18	9.31	24	139	7	5	78	372	372	371	383	393	350	411	362	376	353
10 18	9.49	26	144	8	2	81	407	411	407	424	438	382	444	406	409	394
10 18	9.52	26	144	8	2	81	407	414	413	428	440	389	450	408	419	402
10 18	9.55	27	145	8	4	81	413	420	416	434	446	392	450	413	419	405
10 18	10.09	28	149	9	7	84	442	438	443	448	464	419	476	434	441	420
10 18	10.12	28	150	9	4	87	442	447	453	460	473	429	479	441	452	436
10 18	10.15	28	150	10	9	84	442	447	453	460	473	429	482	445	452	437
10 18	10.27	29	154	10	6	90	460	462	465	478	485	439	496	461	466	455
10 18	10.29	29	154	10	3	90	460	465	471	478	491	439	499	466	470	451
10 18	10.33	30	155	10	5	87	466	471	474	487	497	446	427	466	444	455
10 18	11.33	33	172	12	4	118	496	495	498	503	485	472	522	493	487	486
10 18	11.36	33	173	12	5	115	501	506	510	515	497	482	531	505	498	490
10 18	11.38	33	174	12	5	118	513	509	516	521	500	485	539	506	505	503
10 19	7.02	3	108	4	0	9	18	18	9	18	18	10	10	16	11	17
10 19	7.06	4	109	4	0	17	18	18	18	18	18	10	19	18	11	17
10 19	7.08	4	109	4	0	17	18	18	18	24	21	20	19	20	22	21
10 19	7.12	4	110	4	0	24	18	27	27	28	27	20	27	24	22	25
10 19	7.15	5	111	4	0	27	24	33	30	37	30	30	33	30	32	34
10 19	7.22	6	112	4	0	36	35	39	45	51	45	40	46	36	43	43
10 19	7.26	7	113	4	0	33	35	45	45	54	45	40	49	42	43	44
10 19	7.32	8	114	4	0	50	53	57	57	66	63	50	65	55	61	59
10 19	7.47	10	117	4	0	72	88	98	91	100	98	87	98	84	97	94
10 19	7.50	10	117	5	0	77	100	107	100	106	107	90	107	90	108	102
10 19	7.53	11	118	5	0	80	106	113	106	109	107	95	107	96	103	106
10 19	7.57	11	119	5	0	80	106	119	112	114	113	100	114	102	115	109
10 19	8.00	12	119	5	0	83	106	125	118	118	116	106	118	110	118	114

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Date	Time	h	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TJR	PL2	AUS	GDR	HUN
10 19	8.13	14	122	6	0	96	136	149	142	151	140	133	143	134	147	142
10 19	8.17	14	123	6	0	99	147	161	145	160	152	143	156	144	158	150
10 19	8.21	15	124	6	0	102	159	167	154	166	161	149	167	149	161	156
10 19	8.27	16	125	6	0	102	159	170	163	176	170	159	183	159	172	163
10 19	8.30	16	126	6	0	107	159	179	163	182	179	167	189	161	172	167
10 19	8.32	16	126	6	0	107	159	173	169	182	179	164	189	161	172	167
10 19	8.44	18	129	6	0	126	195	209	205	214	211	196	235	195	204	198
10 19	8.47	18	129	7	0	126	195	206	205	217	214	196	232	195	204	197
10 19	8.50	19	130	7	0	129	206	220	220	229	226	210	248	211	219	210
10 19	8.53	19	131	7	0	132	212	229	226	236	232	213	254	216	226	215
10 19	8.57	20	132	7	0	135	224	229	229	238	238	217	251	221	229	221
10 19	9.02	20	133	8	0	136	230	241	241	253	250	230	265	232	240	233
10 19	9.05	21	133	8	0	141	242	250	247	260	259	239	268	242	247	243
10 19	9.07	21	134	8	0	136	230	244	244	253	253	230	265	237	247	236
10 19	9.22	23	137	9	0	154	265	277	278	289	286	260	293	270	280	269
10 19	9.25	23	138	9	0	154	265	277	281	289	283	263	300	272	280	273
10 19	9.28	23	139	9	0	154	265	280	281	289	280	263	296	274	280	272
10 19	9.44	25	143	10	0	163	319	325	326	337	333	296	350	324	330	318
10 19	9.47	25	143	10	0	163	330	331	335	342	339	306	359	335	333	325
10 19	9.50	26	144	10	0	160	336	343	344	351	351	320	369	345	344	332
10 19	10.01	27	147	11	0	164	360	366	371	378	375	339	391	365	369	355
10 19	10.04	27	148	11	2	164	372	375	374	384	384	350	402	372	379	366
10 19	10.07	27	148	11	0	164	372	375	380	387	384	350	402	378	376	372
10 19	10.17	28	151	12	0	172	389	393	398	408	402	369	427	397	405	393
10 19	10.22	29	152	12	0	172	395	399	404	411	405	369	430	401	405	394
10 19	10.25	29	153	12	0	172	407	402	407	414	408	369	430	407	409	399
10 19	10.29	29	154	12	1	167	407	402	407	414	411	379	430	407	409	397
10 19	10.32	29	155	12	0	172	407	405	410	416	411	376	433	409	409	402
10 19	10.35	30	156	12	0	172	407	402	407	414	411	369	430	402	409	397
10 19	11.32	32	172	15	0	173	442	444	443	447	455	419	466	446	441	437
10 19	11.35	32	173	15	2	176	448	447	453	456	464	429	470	452	452	450
10 19	11.38	32	174	15	2	173	442	447	453	456	455	429	470	448	452	444

Date	Time	h	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	HUN
10 19	11.57	33	179	15	2	183	442	441	446	450	438	419	470	448	441	442
10 19	12.00	33	180	16	0	183	460	456	459	462	452	432	482	457	455	455
10 19	12.03	33	181	16	0	183	454	453	456	459	446	429	479	452	452	451
10 30	8.24	12	127	3	0	25	18	27	27	28	27	20	30	25	22	25
10 30	8.28	13	127	3	0	25	18	27	27	28	27	20	30	30	22	25
10 30	8.59	17	134	3	0	65	53	66	66	70	65	60	68	62	65	66
10 30	9.14	18	137	3	0	69	71	72	72	76	71	66	72	70	72	69
10 30	9.39	21	143	3	0	68	71	80	72	82	80	69	79	80	75	79
10 30	9.41	21	144	4	0	73	65	74	75	79	77	63	72	75	68	74
10 30	10.21	25	153	5	0	110	106	116	115	118	116	100	114	115	108	113
10 30	10.23	25	154	5	0	119	106	122	118	127	116	109	121	122	118	119
10 30	10.33	26	157	5	0	110	106	116	118	118	116	106	118	116	115	110
10 30	10.36	26	157	5	0	116	106	119	118	127	116	109	124	120	118	116
10 30	11.31	28	172	6	0	128	118	134	127	136	134	117	127	131	122	128
10 30	11.34	28	173	6	0	123	118	131	124	133	131	113	127	126	122	123
10 30	12.35	28	190	7	0	165	159	170	172	178	170	156	176	173	161	165
10 30	12.38	28	191	7	0	171	165	179	175	184	179	164	180	178	172	173
10 30	13.04	27	198	8	0	209	230	238	235	244	232	217	238	230	222	229
10 30	13.07	27	198	8	0	223	242	256	253	262	253	236	261	251	247	247
10 30	13.18	26	201	8	0	209	277	292	290	301	280	273	304	289	283	281
10 30	13.21	26	202	8	0	220	301	316	311	323	301	289	333	312	312	299
10 30	14.32	20	220	10	0	112	212	232	220	234	223	210	244	228	215	216
10 30	14.34	20	220	10	0	109	212	223	214	225	217	199	241	222	215	204
10 30	15.06	16	227	11	0	92	159	164	154	168	170	146	176	161	158	156
10 30	15.09	16	228	11	0	89	153	161	151	162	164	140	167	154	151	150
10 30	15.35	12	233	10	0	57	65	98	100	99	107	90	104	94	97	97
10 30	15.48	10	236	10	0	54	83	89	81	90	89	77	88	80	82	82
10 30	16.03	8	239	9	0	40	53	54	54	57	63	40	49	55	50	54
10 30	16.06	8	240	9	0	38	47	54	48	54	57	40	46	48	43	50
10 30	16.25	5	243	8	0	16	18	27	18	27	27	10	10	22	11	24
11 8	10.22	22	155	9	2	196	201	203	205	210	208	193	212	205	201	196
11 8	10.26	23	156	9	3	221	230	241	244	247	241	230	251	239	237	232

Date		Time	h	a	T	m/s	Dif	FRG	NOR	GB	SW	PL1	PUR	PL2	AUS	GDR	HUN
11	8	11.37	26	174	10	2	208	230	247	247	259	253	236	258	251	247	244
11	8	11.40	26	175	11	2	192	177	197	187	194	196	167	212	205	197	192
11	8	11.43	26	177	11	2	216	248	253	250	273	274	252	290	278	276	269
11	8	12.01	26	180	12	3	240	354	357	359	371	363	336	378	361	362	356
11	8	12.04	26	181	12	2	237	348	349	350	356	351	326	372	350	351	341
11	8	13.05	24	197	13	3	181	295	304	305	311	304	286	329	310	305	298
11	8	13.06	24	197	13	4	147	212	217	220	224	217	203	228	219	211	214
11	8	13.37	22	205	13	3	138	248	259	253	264	259	239	280	264	258	251
11	8	13.39	22	206	13	4	153	248	259	253	261	256	239	284	264	258	252
11	8	14.25	18	217	12	4	125	195	197	190	197	196	180	216	199	194	189
11	8	14.29	18	218	12	3	119	189	194	190	197	196	177	208	193	186	185
11	8	15.06	14	226	12	3	89	124	131	124	132	134	109	137	130	122	120
11	8	15.13	13	227	12	3	77	106	116	109	119	125	100	127	116	108	113
11	8	15.21	12	229	12	2	72	106	107	100	111	113	93	111	103	100	105
11	8	15.26	11	230	12	4	62	88	98	91	99	98	80	98	88	86	89
11	8	15.29	11	230	12	4	62	88	98	91	99	98	80	98	90	86	90
11	8	15.33	10	231	12	6	62	83	89	81	90	89	69	88	80	79	82
11	8	15.37	10	232	12	3	53	71	74	66	75	74	60	72	70	65	70
11	8	15.41	9	233	12	4	42	53	63	54	63	63	50	55	55	54	58
11	8	15.45	9	234	12	6	42	53	54	48	54	63	40	49	49	47	54
11	8	15.51	8	235	11	3	33	35	45	36	44	45	30	39	43	32	43
11	8	15.55	7	236	11	4	33	35	45	45	44	54	40	39	43	43	46
11	8	16.02	6	237	11	3	26	35	36	36	36	45	30	30	36	32	38
11	8	16.06	6	238	11	3	26	35	36	33	36	42	30	30	34	32	35
11	8	16.10	5	239	11	3	23	24	30	27	36	36	20	22	30	22	32
11	8	16.13	5	239	11	3	20	18	27	21	27	30	20	19	24	22	26
11	8	16.15	4	240	11	3	17	18	24	18	27	27	16	16	24	22	26
11	8	16.21	3	241	10	2	9	18	18	12	18	18	10	10	18	11	17
11	12	8.36	10	131	0	2	54	124	134	130	140	134	120	156	124	125	119
11	12	8.42	11	132	1	3	61	136	152	145	158	152	133	176	138	143	136
11	12	9.03	14	137	2	3	70	177	212	193	216	202	193	222	184	194	185
11	12	9.07	14	138	2	3	67	195	220	199	225	205	199	232	192	201	192

Date	Time	h	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	MUN
11 12	9.29	17	143	4	2	73	230	268	244	272	256	239	274	243	247	236
11 12	9.32	17	143	4	2	75	230	268	250	272	259	246	274	243	247	240
11 12	10.17	21	154	6	2	78	301	313	317	327	321	292	345	320	312	297
11 12	10.19	21	154	6	2	78	313	325	323	339	333	303	356	328	323	310
11 12	10.36	22	158	6	3	93	336	343	344	359	342	320	381	345	344	333
11 12	10.39	22	159	6	2	93	336	346	344	359	345	320	381	350	341	331
11 12	11.01	24	165	7	3	105	324	334	332	344	330	310	362	338	326	317
11 12	11.03	24	165	7	3	100	342	352	347	356	348	323	378	354	341	336
11 12	11.29	24	172	8	2	94	407	408	407	418	408	379	450	408	398	398
11 12	11.33	25	173	7	5	94	407	408	407	417	408	379	447	410	401	396
11 12	12.26	25	187	7	4	85	372	375	371	383	375	350	414	375	369	350
11 12	12.28	25	187	7	5	85	360	366	362	371	366	339	402	365	358	337
11 13	8.35	10	131	-3	3	16	18	18	18	19	18	13	19	19	22	17
11 13	8.38	10	132	-3	2	16	18	18	18	19	18	20	19	19	22	17
11 13	9.31	17	143	-2	3	38	35	45	42	45	45	37	39	44	43	38
11 13	9.33	17	144	-2	2	38	35	45	45	45	45	40	49	46	43	42
11 13	10.15	20	153	-1	2	68	71	77	81	82	80	69	79	74	75	74
11 13	10.21	21	155	-1	2	75	71	80	81	82	83	69	79	81	79	75
11 13	10.51	23	162	0	3	65	71	74	72	79	74	63	68	74	65	70
11 13	10.54	23	163	0	1	65	65	71	72	79	77	63	68	74	65	68
11 13	12.21	24	186	2	0	91	88	101	100	104	101	90	101	104	97	91
11 13	12.23	24	186	2	0	94	88	98	100	101	98	90	98	101	97	94
11 13	13.43	21	206	3	0	164	159	179	175	186	179	164	180	180	172	165
11 13	13.47	20	207	2	0	147	153	164	160	174	167	149	167	169	158	154
11 13	15.13	12	226	2	0	70	106	116	109	118	116	100	114	114	108	106
11 13	15.16	11	227	2	0	63	100	107	100	110	107	90	101	103	97	92
11 13	15.26	10	229	1	2	60	88	89	81	91	89	69	82	87	79	80
11 13	15.28	10	230	1	0	57	71	83	78	85	86	69	79	80	75	72
11 13	15.36	9	231	1	0	43	53	63	63	67	71	50	53	62	57	62
11 13	15.58	6	235	0	0	33	35	45	36	45	45	30	33	42	32	38
11 13	16.01	5	236	-1	0	27	35	42	36	45	45	30	30	39	32	39
11 13	16.12	4	238	-1	1	16	18	27	18	28	27	10	16	24	13	23

TABLE 4

Date	Time	h	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	HUN
11 13	16.15	3	239	-1	0	16	18	21	18	28	27	10	10	22	11	20
11 14	8.30	9	130	-6	1	68	88	104	100	102	98	90	107	92	90	81
11 14	8.40	10	132	-5	0	76	106	134	127	129	116	109	127	112	118	109
11 14	9.25	16	142	-4	2	105	183	232	220	211	205	183	216	188	194	191
11 14	9.27	16	142	-3	1	105	195	238	232	217	211	190	228	197	201	193
11 14	9.38	17	145	-3	3	120	230	247	250	258	256	230	271	242	247	229
11 14	9.40	17	145	-2	2	129	230	250	253	257	259	230	274	244	247	227
11 14	10.10	20	152	-1	0	101	265	283	281	292	286	257	304	276	272	260
11 14	10.13	20	153	-1	0	111	265	286	281	292	295	260	304	284	280	258
11 14	10.32	21	158	0	0	112	301	307	308	320	307	279	326	304	301	276
11 14	10.36	22	158	0	0	121	289	304	302	320	304	279	323	304	294	284
11 14	11.30	24	173	3	2	121	348	357	353	364	357	329	381	352	344	328
11 14	11.37	24	174	3	3	116	342	349	347	364	348	323	381	352	344	326
11 14	12.28	24	187	3	3	121	336	346	344	355	348	320	378	345	337	310
11 14	12.32	24	188	4	0	119	336	343	341	354	345	320	375	342	333	316
11 14	14.12	18	213	5	6	84	224	223	226	233	232	210	265	230	226	214
11 14	14.15	18	214	5	5	84	212	223	223	227	232	206	254	227	219	214
11 14	15.32	9	230	4	4	44	71	80	78	85	89	69	65	63	75	78
11 14	15.36	8	231	4	4	44	71	80	72	82	80	63	58	72	65	70
11 14	15.47	7	233	3	3	35	53	57	54	60	63	40	39	48	47	48
11 14	15.50	7	234	3	3	29	35	54	45	54	54	40	39	44	43	45
11 14	15.54	6	235	3	5	29	35	45	45	48	54	37	33	43	32	44
11 27	9.27	13	144	9	5	36	35	36	36	37	39	34	39	38	32	36
11 27	9.32	14	145	9	5	41	35	45	45	45	45	40	39	48	43	43
11 27	9.46	15	148	9	4	62	53	63	63	66	63	60	68	66	65	62
11 27	9.53	16	149	9	5	65	65	69	69	72	71	60	68	66	65	66
11 27	10.05	17	152	9	7	66	65	69	69	72	71	60	68	67	68	66
11 27	10.15	17	154	9	8	51	53	54	54	54	57	50	58	52	54	52
11 27	10.25	18	157	9	8	54	53	54	54	63	63	50	49	53	54	55
11 30	8.30	6	132	-2	4	40	47	54	51	55	51	47	55	48	43	48
11 30	8.40	8	134	-2	3	56	53	69	63	73	71	60	68	62	65	62
11 30	9.01	10	138	-1	3	65	88	107	100	110	107	90	107	90	97	95

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Date	Time	h	a	T	m/s	Dif	FRG	NOR	GB	CH	PL1	TUR	PL2	AUS	GDR	HUN
11 30	9.04	10	139	-1	3	68	88	98	91	101	98	87	101	88	90	91
11 30	9.23	12	143	0	5	79	124	143	136	156	143	120	147	130	129	128
11 30	9.27	13	144	0	6	82	130	152	139	156	143	127	150	134	136	139
11 30	9.39	14	146	0	4	97	165	191	181	201	185	164	199	171	172	172
11 30	9.41	14	147	0	4	97	177	200	187	210	190	177	208	177	183	184
11 30	9.53	15	150	1	3	100	190	206	205	213	205	173	228	197	204	190
11 30	9.56	15	150	1	3	111	195	206	205	216	205	180	235	197	204	188
11 30	10.29	18	158	3	2	105	248	250	247	262	253	273	284	252	247	233
11 30	10.31	18	158	3	2	100	248	256	253	268	259	283	290	257	251	242
11 30	11.09	20	167	4	4	108	301	304	305	315	304	283	342	301	301	285
11 30	11.12	20	168	4	3	111	301	304	308	318	304	289	350	307	301	282
11 30	12.09	21	182	5	7	112	319	313	317	327	318	299	362	316	312	308
11 30	12.11	21	183	5	4	112	319	319	320	327	321	299	369	317	312	304
11 30	13.29	18	202	6	4	89	248	250	250	263	250	230	304	254	247	234
11 30	13.33	18	203	6	5	95	236	244	241	251	247	220	296	242	237	231
12 11	12.12	20	183	9	17	130	247	247	235	232	229	210	268	237	244	216
12 11	12.15	20	184	9	14	147	248	256	244	247	250	223	274	246	244	232
12 11	12.18	19	184	9	19	158	277	277	281	289	271	266	300	266	272	257
12 11	12.44	19	191	9	16	153	307	307	314	328	310	299	342	308	312	295
12 11	12.49	19	192	9	14	111	230	232	226	238	238	213	254	228	226	217
12 11	12.51	19	192	9	15	130	242	244	244	250	244	226	268	244	244	234
12 11	13.04	18	196	10	16	217	271	289	278	291	295	266	313	287	287	266
12 11	13.08	18	196	10	17	186	307	313	299	306	315	276	336	304	308	286
12 11	13.16	18	198	9	15	181	289	298	293	301	304	270	317	288	294	279
12 11	13.19	17	199	9	17	167	260	268	268	286	274	257	290	268	269	260
12 11	13.54	15	207	9	17	133	136	149	145	156	149	143	159	152	147	147
12 11	14.06	14	210	9	18	158	183	194	190	201	196	180	199	189	190	187
12 12	8.28	5	133	3	6	15	35	48	36	45	36	34	55	43	36	35
12 12	8.32	5	133	3	8	20	47	57	48	57	48	43	68	51	47	42
12 12	9.18	11	143	4	4	34	106	113	109	118	110	93	127	105	103	99
12 12	9.20	11	143	4	4	37	106	122	112	121	116	100	137	111	108	107
12 12	9.59	14	151	5	7	51	190	197	193	199	193	177	225	190	194	181

Date	Time	n	a	T	m/s	Dif	PRG	NOR	GR	Cu	PL1	TUR	PL2	AUS	GDR	AUT
12 12	10.02	15	152	5	6	51	195	206	205	215	205	190	241	203	204	191
12 12	11.04	18	166	6	6	51	271	283	281	290	280	257	317	282	275	264
12 12	11.07	19	167	6	7	51	277	283	278	287	280	257	320	284	276	269
12 12	11.59	20	180	7	7	60	301	304	302	317	304	279	342	306	301	294
12 12	12.02	20	181	7	4	57	301	304	299	308	304	279	342	301	301	289
12 12	13.22	17	200	8	5	72	348	360	350	364	360	323	402	357	348	335
12 12	13.26	17	201	8	2	51	243	250	244	253	250	230	284	254	247	240
12 12	13.34	16	203	8	4	48	230	232	229	241	238	210	265	234	229	226
12 12	13.38	16	203	8	3	51	230	232	226	235	235	210	265	234	226	219
12 12	14.40	11	217	7	2	43	106	107	100	109	116	90	127	109	97	103
12 12	14.47	10	219	7	2	29	59	63	60	66	68	53	72	60	57	65
12 12	14.51	10	219	7	2	43	88	86	81	94	92	74	101	90	86	84
12 12	14.59	9	221	7	2	34	71	77	69	78	83	63	82	74	68	73
12 12	15.27	6	227	6	2	23	35	36	36	37	45	30	39	36	32	33
12 12	15.30	5	227	6	2	23	35	36	36	37	36	30	39	36	32	31
12 12	15.32	5	228	5	2	23	35	36	27	37	36	27	30	34	22	30
12 12	15.34	5	228	5	2	17	35	27	27	28	36	20	30	30	22	25
12 12	15.36	4	228	5	2	17	24	27	27	28	33	20	30	30	22	25
12 12	15.39	4	229	5	2	17	12	27	24	28	27	20	22	24	22	22
12 12	15.42	4	229	5	2	17	18	24	18	28	27	20	19	22	18	21
12 13	8.16	3	130	-4	2	16	18	24	18	19	18	20	19	22	18	17
12 13	8.20	4	131	-4	2	16	18	30	24	28	27	24	30	29	25	23
12 13	8.36	6	134	-4	2	34	53	71	54	64	65	50	68	59	54	55
12 13	8.45	7	136	-3	2	42	71	54	63	73	77	60	82	65	65	68
12 13	8.48	7	137	-3	2	42	71	89	72	83	83	66	88	72	75	73
12 13	9.13	10	142	-2	2	65	106	125	127	128	134	120	134	106	111	115
12 13	9.17	10	142	-2	2	68	106	134	133	131	140	130	137	112	118	121
12 13	9.46	13	149	-1	2	87	142	179	190	184	188	159	176	162	161	156
12 13	9.51	14	150	-1	2	93	142	185	193	190	193	159	186	164	172	157
12 13	9.53	14	150	-1	2	93	159	197	208	201	205	170	196	177	183	171
12 13	10.21	16	156	0	2	107	165	209	220	213	208	183	205	186	197	183
12 13	10.24	16	157	0	2	110	177	223	235	226	223	199	216	197	215	188

Table 5

Sample	Original calibration factor (in per cent)	Corrected calibration factor (in per cent)
All data	5.1	4.9
Summer	2.0	0.8
Autumn	4.1	1.9
Winter	9.5	6.6

The mean values of relative standard deviation for different data samples by using the original calibration factors and using corrected calibration factors which were derived from comparing the pyranometers to each other.

LEGENDS OF FIGURES

Fig. 1 Comparison of SONI sunshine data to the sunshine derived from pyrheliometer measurements.

Fig. 2 Comparison of HAENNI sunshine data to the sunshine derived from pyrheliometer measurements.

Fig. 3 Comparison of PRECISION MECANIQUE sunshine data to the sunshine derived from pyrheliometer measurements.

Fig. 4 Ratio of hourly pyrheliometric sunshine to the hourly sunshine measured by different electronic sunshine recorders as function of solar elevation.

Fig. 5 Comparison of hourly sunshine values.

Fig. 6 Ratio of average value of global radiation to the mean average for 3 samples and for all data. The order of pyranometers is the same as in Table 4.

Figure 1

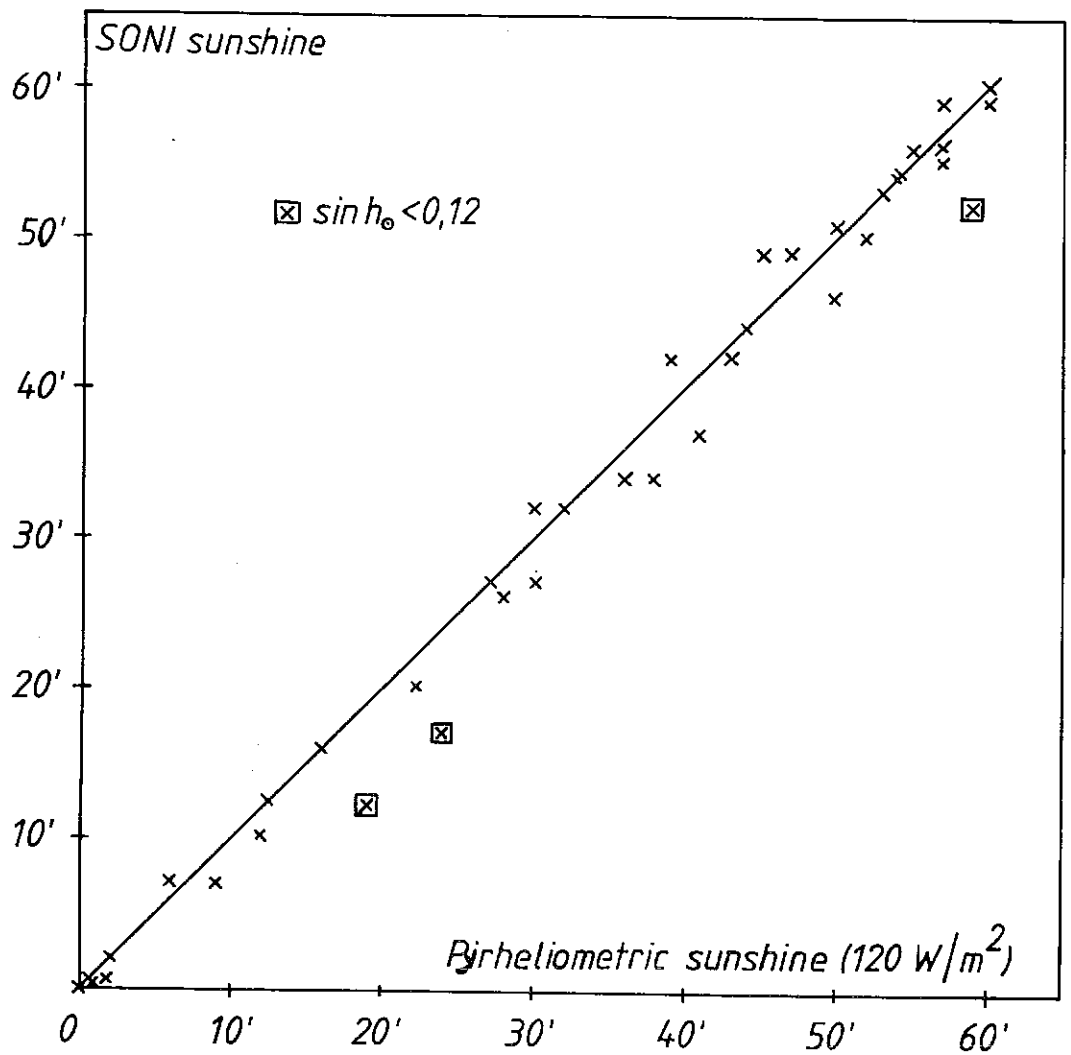

SONI sunshine
⊠ sin h⊙ <0,12
Pyrheliometric sunshine (120 W/m²)
0
10'
20'
30'
40'
50'
60'

Figure 2

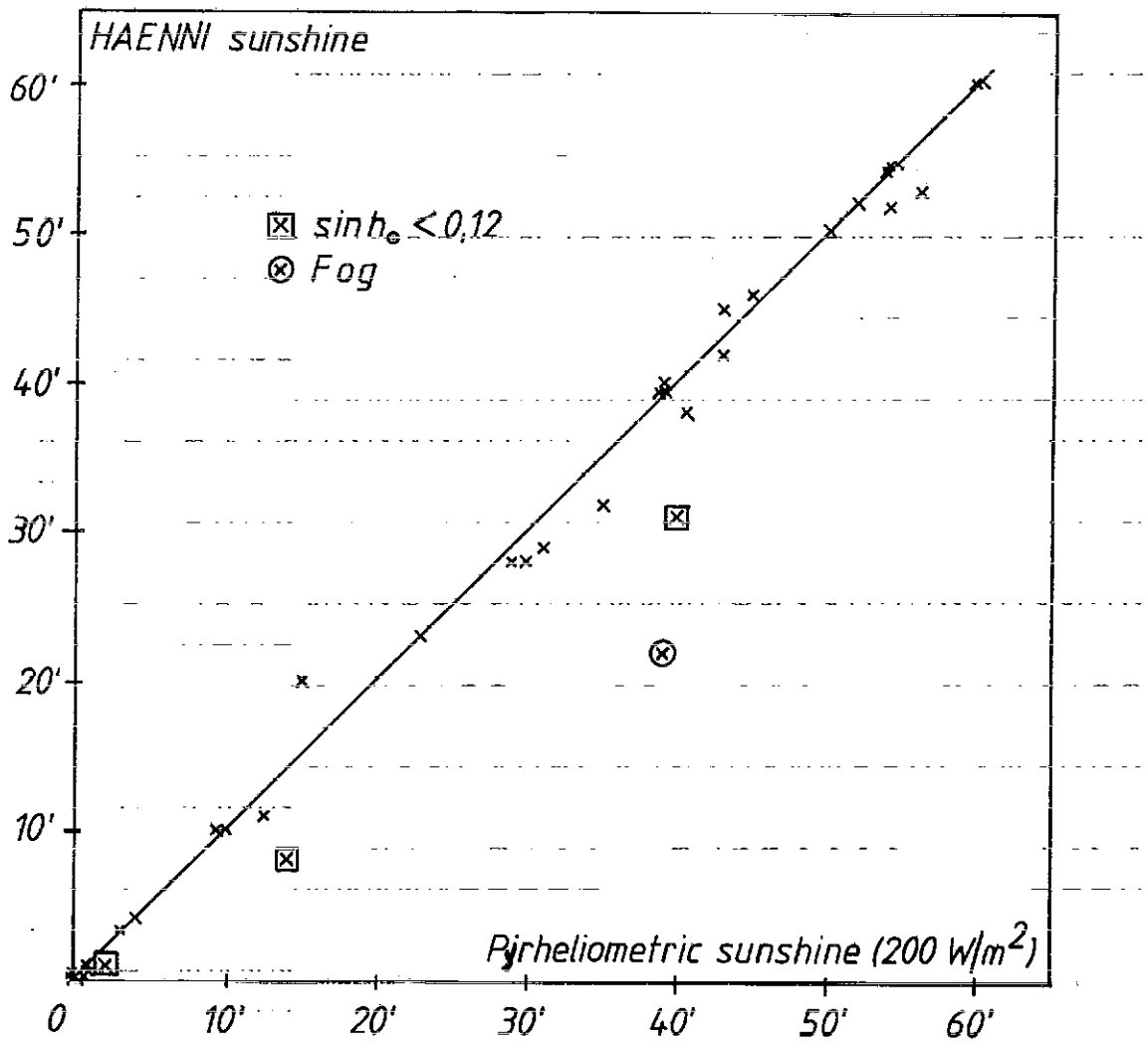

HAENNI sunshine
60'
50'
40'
30'
20'
10'
0
10'
20'
30'
40'
50'
60'
⊠ sin h_e < 0,12
⊗ Fog
Pyrheliometric sunshine (200 W/m²)

Figure 3

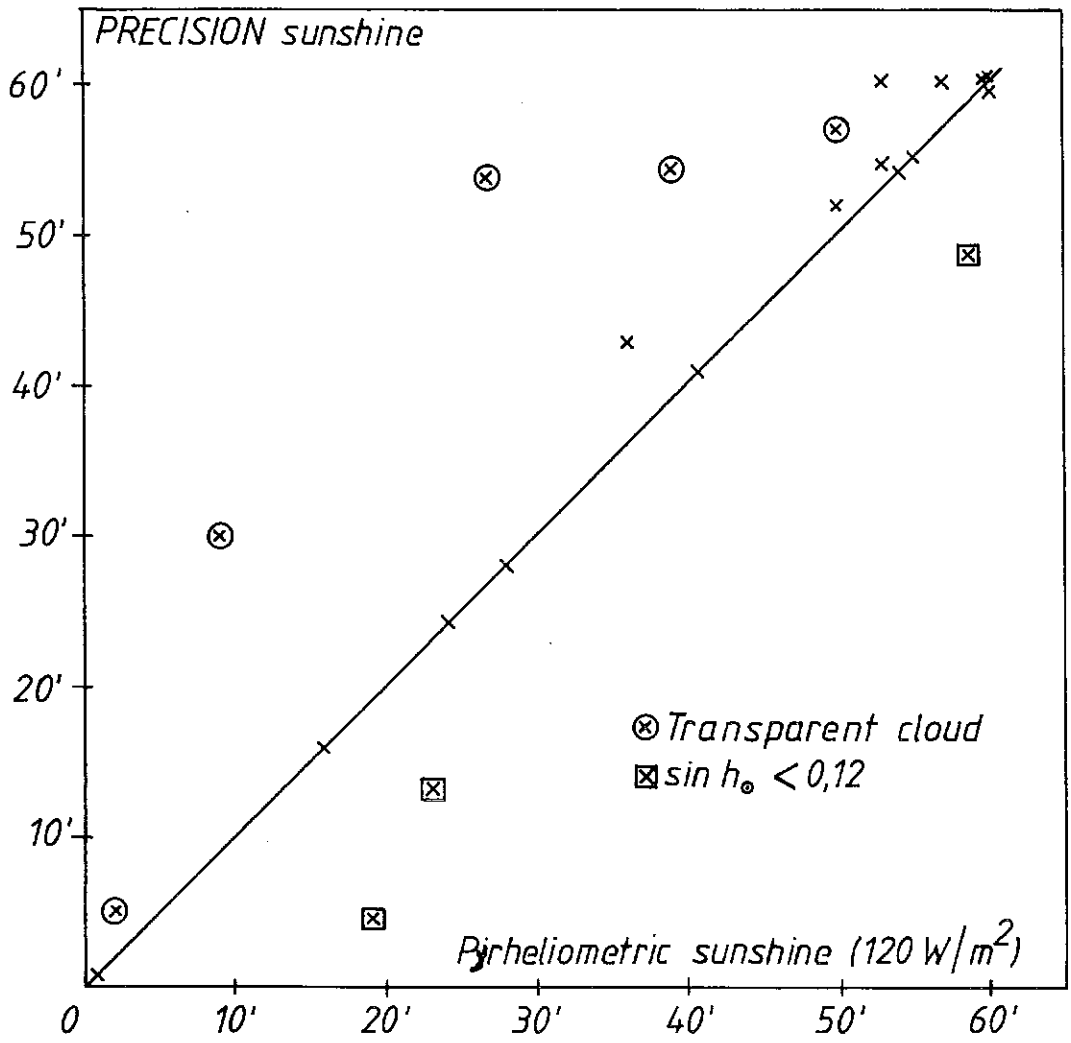

PRECISION sunshine
60'
50'
40'
30'
20'
10'
0
10'
20'
30'
40'
50'
60'
⊗ Transparent cloud
⊠ sin h⊙ < 0,12
Pyrheliometric sunshine (120 W/m²)

Figure 4

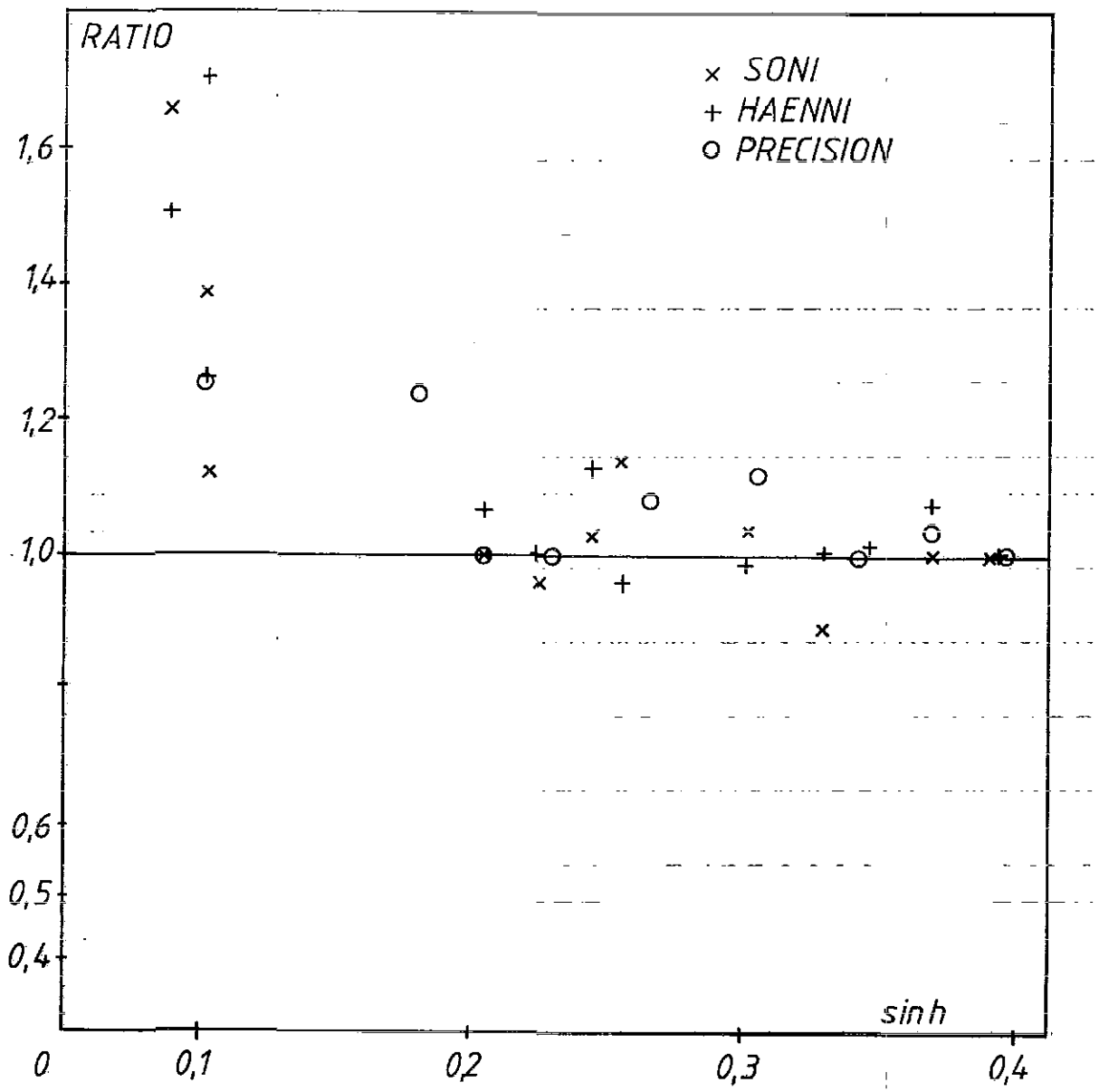

RATIO
× SONI
+ HAENNI
o PRECISION
1,6
1,4
1,2
1,0
0,6
0,5
0,4
sin h
0
0,1
0,2
0,3
0,4

Figure 5

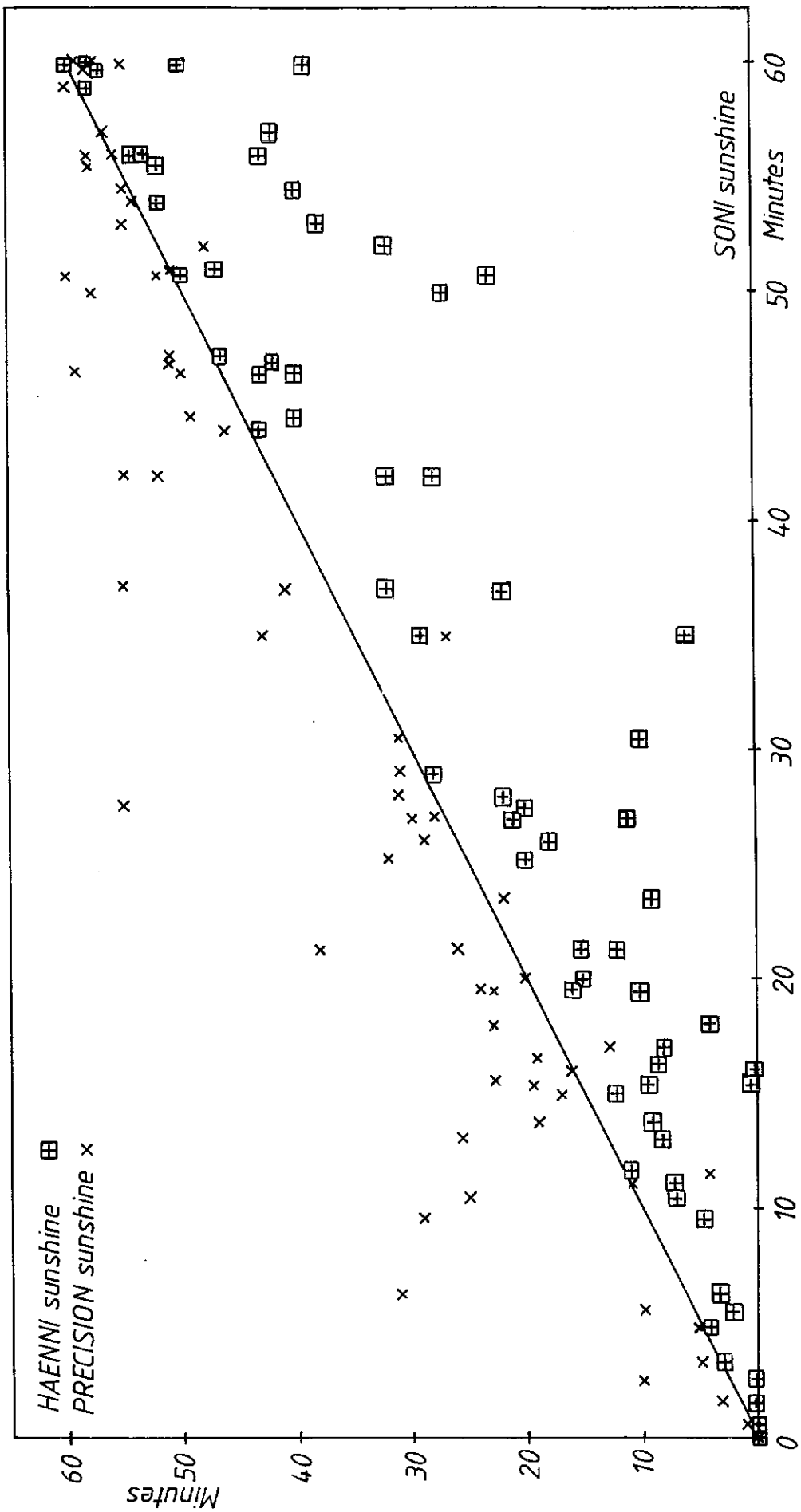
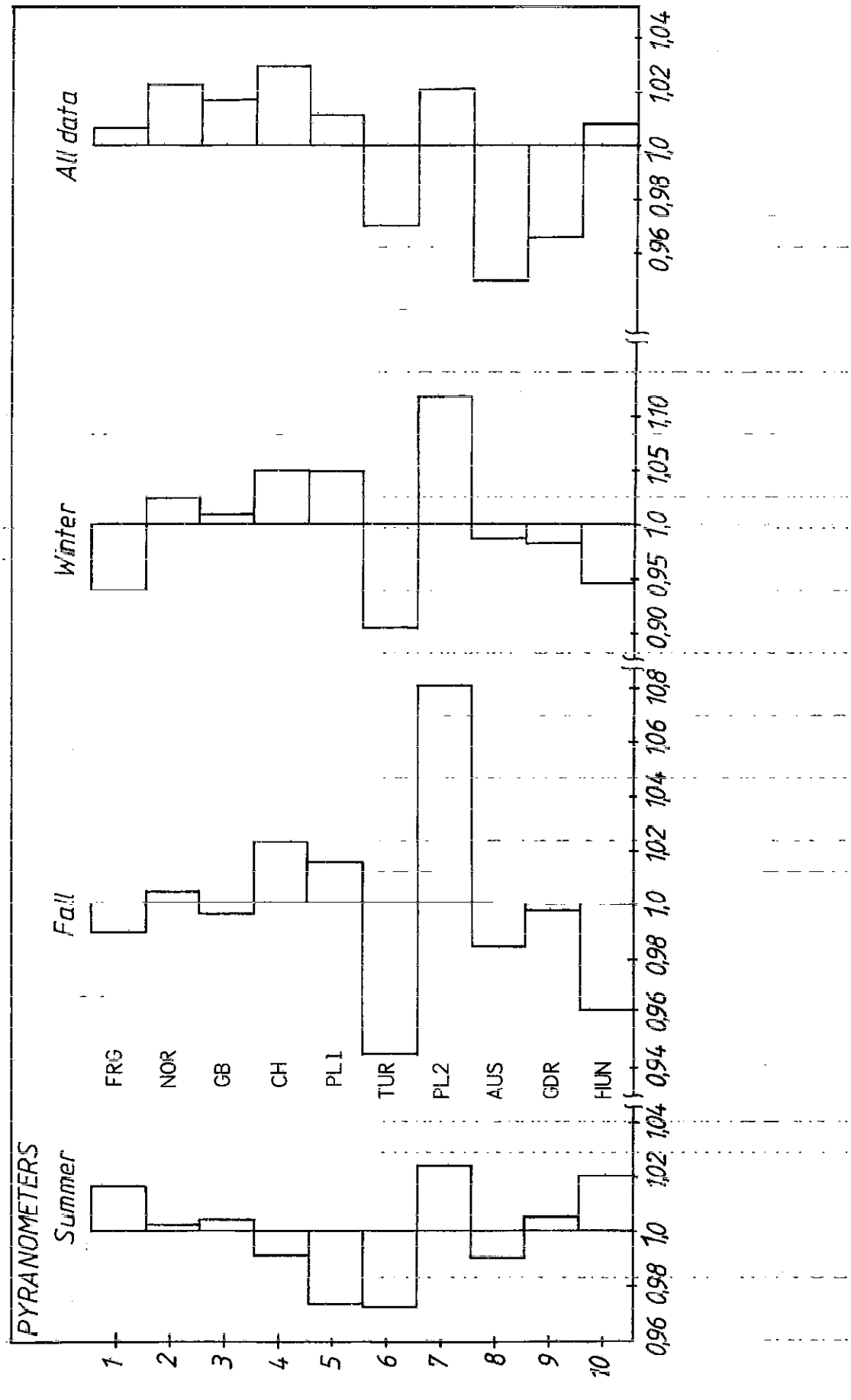

HAENNI sunshine
PRECISION sunshine
SONI sunshine Minutes
Minutes
0
10
20
30
40
50
60

Figure 6


PYRANOMETERS
Summer
Fall
Winter
All data
FRG
NOR
GB
CH
PL1
TUR
PL2
AUS
GDR
HUN
1
2
3
4
5
6
7
8
9
10
0,96
0,98
1,0
1,02
1,04
0,94
0,96
0,98
1,0
1,02
1,04
1,06
1,08
0,90
0,95
1,0
1,05
1,10
0,96
0,98
1,0
1,02
1,04