SUB-REGIONAL PYRANOMETER INTERCOMPARISON FOR THE SOUTH-EASTERN EUROPE

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ABSTRACT

Knowledge of the solar energy amount at the Earth surface is very important for different purposes especially for all living systems on the Earth. Meteorological and Hydrological Service of Croatia (MHSC) has been modernizing and improving solar radiation measurements in the last four years with the main aim to assure forehand, useful data. Traceability is assured with participation in the International Pyrheliometer Comparison in 2005 at World Radiation Centre in Davos. To assure traceability in the sub-region, in summer 2007 MHSC jointly with World Meteorological Organization (WMO) realized the project "Sub-regional Pyranometer Intercomparison for the South-Eastern Europe" at the Meteorological observatory Split-Marjan, Croatia. Altogether 11 pyranometers from 8 countries participated in the intercomparison. Preliminary results in these papers give an overview of the work already done, and further analyses will provide more helpful and useful data for improving global solar radiation measurement in the sub-region.

1. INTRODUCTION

Following the WMO standards and recommendations regarding measurement, maintenance and calibration of the instruments including their intercomparisons, as well as experiences from the outdoor comparison campaign of pyranometers and sunshine duration recorders in WMO RA VI held in Budapest, Hungary, in 1984 (WMO-TD-No. 146), Meteorological and Hydrological Service of Croatia (MHSC) hosted, with a the great support of WMO Secretariat, "The Sub-Regional Pyranometer Intercomparison for the South-Eastern Europe" in 2007.

Figure 1. Map of the site where the intercomparison took place

The Intercomparison took place on the Adriatic coast in town Split (43° 38' N, 16° 26' E), Croatia (Figure 1), at the Meteorological observatory Split-Marjan. Observatory is situated on the small hill, 122 m above msl, on the west from the town. Intercomparison was held from 20 July through 6 August 2007.

2. PARTICIPATION AND ORGANIZATION

The idea for the intercomparison was suggested by MHSC and accepted by WMO Secretariat in early 2007. With join efforts of WMO and MHSC, member countries from south-eastern part of WMO RA VI were invited to participate in the intercomparison, as well as manufacturers of solar radiation equipment. Great support was got from World Radiation Centre which enabled calibration of two reference pyranometers and sent their own pyranometer for the intercomparison.

Altogether 11 pyranometers from National Meteorological Services from the World Radiation Centre, and from manufacturers of solar radiation instruments participated in the intercomparison, (Table 1). Transportation of the instruments to Croatia was arranged by participating institutes/services via different shipping companies. All instruments were checked in the laboratory under the artificial light source before and after the intercomprison. On site, the instruments were fixed on the same aluminium platform at the flat roof of Meteorological observatory Split-Marjan and levelled properly. As there was no presence of participants, the staff of Meteorological laboratory of MHSC took care about regular and permanent inspection and control of the instruments as well as whole system during the intercomparison.

The signals from the pyranometers were acquired by 12 channel analogue data acquisition system developed by Tritonel-Multimedia (Croatian company specified for meteorological and electronic equipment production). The system was based on amplifiers in front of the AD 12 bits converters and EPROMs, based on 1 second sampling rate. Developed software support assured acquisition of 1-second, 1-minute and 10-minute records on the hard disk of a laptop. The system was calibrated before and checked after the intercomparison with calibrated millivolt source 404S Time Electronics Ltd and digital multimeter Fluke 8841.

Figure 2. Pyranometers on the mounting platform at the roof of Meteorological observatory Split-Marjan

Table 1. Participating instruments

Country	Institute/ Service	Producer	Model	Instrument s/n	Contact person
Bosnia and Herzegovina	Federal Meteorological Institute	Kipp& Zonen	CM 6B	057520	Kemal Sehbarjaktarevic
Israel	Meteorological Service	Kipp& Zonen	CMP 11	060100	Alexander Baskis
Macedonia	Hydrometeoro-logical Service	Kipp& Zonen	CM 11	892422	Vesna Pavlovska
Slovenia	Environmental Agency	Kipp& Zonen	CM 11	861547	Drago Groselj
Slovenia	Environmental Agency	Kipp& Zonen	CM 11	861350	Drago Groselj
Switzerland	World Radiation Centre - PMOD	Kipp& Zonen	CM 21	970401	Wolfgang Finsterle
UK	Delta-T	Delta-T	SPN 1	A-149	Tony Peloe
USA	Davis Inst.	Davis Inst.	PRO 6450	ML98000008	Jason Karvelot
USA	Davis Inst.	Davis Inst.	PRO 6450	ML98000009	Jason Karvelot
Croatia	Meteorological and Hydrological Service	Kipp& Zonen	CM 11	027750	Krunoslav Premec
Croatia	Meteorological and Hydrological Service	Kipp& Zonen	CM 21	950238	Krunoslav Premec

The pyranometers were connected to the system with supplied cables that were less than 10 meters long. All Kipp&Zonen pyranometers were connected direct to the data acquisition system with the 2 wire connection. For the Davis Inc. pyranometers stable 3V DC, and for Delta-T pyranometer, stable 12V DC supply were used, respectively. All instruments were grounded properly.

During the intercomparison auxiliary data were also collected. Meteorological parameters (wind speed and direction, air temperature, relative humidity, atmospheric pressure) as well as global and diffuse solar radiation were measured by the automatic weather station located at the Split Marjan observatory as 10-minute records.

Cloudiness and visibility were observed manually by observer at the Observatory.

Additionally, manual measurement of direct solar radiation was performed every day one hour before and one hour after solar noon with Kipp&Zonen CH1 pyrheliometer that participated in the IPC-X in 2005 in Davos (WMO/TD No. 1320). In the same way aerosol optical depth (AOD) was determined by the Solar Light Co. MICROTOPS II Sunphotometer at 5 wavelengths: 340 nm, 380 nm, 440nm, 500 nm, 675 nm.

All auxiliary data will be used in further analyses of the calibration data.

3. MEASUREMENTS AND PRELIMINARY RESULTS

Although there were almost 60000 data per day per each participating instruments, to avoid the cosine effect only the data between 9 AM and 3 PM local time (local time = GMT+1) were used for calculation. Based on the response time, i.e. thermal relaxation time, all 1-second data were summed over the period of 20 seconds, and for further calculations 20-second sums were used.

3.1. Reference value

For every time interval (20-second sum) the reference value was calculated as the average of 3 Kipp&Zonen instruments using the sensitivity factors achieved by the calibration in Davos in May and July 2007 (table 2):

Table 2. Reference instruments

Model	Instrument s/n	Sensitivity ($\mu V/W/m^2$)	Calibration factor	STDEV (ppm)	N used	N total
CM 21	970401	11,15	1,001049	1755	14904	19436
CM 21	950238	8,64	0,998379	1029	15388	19436
CM 11	027750	5,03	1,000674	1897	16713	19436

STDEV designates standard deviation in parts per million - ppm, N used – number of data used for the calculations, N total – total number of available data.

3.2. Preliminary Results of participating instruments

For the calculations of calibration factors for participating instruments, so called TREFRE(t) was used.

TREFRE(t) represents true reference radiant exposure obtained as the average of:

$$TREFRE(t) = \left\langle CF_1 * RE_1(t), CF_2 * RE_2(t), CF_3 * RE_3(t) \right\rangle,$$

where $RE_i(t)$ represent radiant exposure and CF_i calibration factor of the i-th reference pyranometer at time t.

$\langle\ \rangle$ - denotes average

t – time (20-second interval)

The calibration factors were calculated:

$$CF_i(t) = \frac{TREFRE(t)}{RE_i(t)}, \quad \text{i = (4, 5, 6, 7, 8, 9, 10)}$$

where i – stays for pyranometers other then those used for TREFRE(t) calculations.

In the second iteration all data lying out of ±2σ interval around the average were rejected and the calculations for the $CF_i(t)$ were repeated.

The final calibration factors were calculated as:

$$CF_i = \left\langle CF_i(t) \right\rangle_t \quad \text{i = (4, 5, 6, 7, 8, 9, 10)}$$

where $\langle\ \rangle$ - denotes average over all data remained after first iteration.

Recommended new sensitivity was calculated multiplying previous sensitivity by reciprocal value of calibration factor.

Table 3. Calculated preliminary calibration factors for participating instruments

Country	Instrument s/n	Previous sensitivity ($\mu V/W/m^2$)	Calibration factor	STDEV (ppm)	N used	N total	Recommended new sensitivity ($\mu V/W/m^2$)
Bosnia and Herzegovina	057520	11,88	1,007024	11400	11912	12509	11,80
Israel	060100	10,20	1,027011	778	12088	19436	9,93
Macedonia	892422	4,53	1,013365	794	8789	19436	4,47
Slovenia	861547	5,65	1,010725	1350	9290	19436	5,59
Slovenia	861350	6,94	1,008808	1294	10098	19436	6,88
UK	A-149	1000	1,015036	10339	15288	19436	985,19
USA	ML98000009	1670	0,992848	2535	10915	19436	1682,03

STDEV - designates standard deviation in parts per million - ppm, N used – number of data used for the calculations, N total – total number of available data.

4. CONCLUSIONS

With the great support of WMO Secretariat and World Radiation Centre, MHSC has conducted the first international pyranometer intercomparison in the south-eastern part of Europe.

The favourable, sunny weather enabled to acquire the large amount of data for a reasonable evaluation of the pyranometers participated in the intercomparison.

Reference value obtained by three recently calibrated pyranometers represented a reliable basis for further calculations, although, generally, these preliminary results of participating instruments represent slight underestimation of the global solar radiation. This could be addressed to the degradation of their sensitivity (some of them haven't been calibrated for more than 15 years) or to the different type of sensors, but further detailed analyses with the use of available auxiliary data enable better understandings of the measurement data.

Very helpful and useful comments of the Expert Team on Meteorological Radiation and Atmospheric Composition Measurements constitute a great assistance in preparation of the final report.

Although there were some unexpected organizational and infrastructural irregularities, generally it is believed that the intercomparison provides some useful experiences and results for the participants as well as the community involved in this issue in the sub-region.

5. LITERATURE

1. Guide to Instruments and Methods of Observation, Draft seventh edition (WMO-NO. 8)
2. ISO 9059:1990 - Solar energy - Calibration of field pyanometers by comparison to a reference pyranometer
3. WMO/TD No 146 / IOM Report No. 16: Radiation and Sunshine Duration Measurements, Comparison of Pyranometers and Electronic Sunshine Duration Recorders of RA VI, Budapest, July – December, 1984
4. WMO/TD No. 1320 / IMOP Report No. 91: WMO International Pyrheliometer Comparison IPC-X, 26.9-14.10.2005.