Measurements methods for sunshine duration (SD): accuracy evaluation of pyranometric methods and SD measuring instruments Poster#3 (__)

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Introduction and objectives:

- Representative sunshine duration (SD) measurements are typically used for characterizing the climate of a region. However the information about the time amount during which the solar irradiances has been over a specified threshold or, alternatively, the distribution of sunshine hours through seasons still continue to be very important for solar energy usages, for agricultural reasons (such us the selection and the efficiency of specific cultivations in a certain region) and for industrial reasons (solar panels).
- The performance of different SD measurement or calculation methods and their achievable accuracy in operational use are important for the meteorological community.
- In this study (August 2009 - July 2010), a comparison of different algorithms applied for the pyranometric determination of SD is performed in two European locations with different climate (**Vigna di Valle** and **Carpentras**), to assess their achievable accuracy in long-term field measurements and the results are also compared with in-situ SD measuring instruments.

Météo France *– RIC Radiation - Carpentras (FRANCE)*

Italian Met Service *– ReSMA - Vigna di Valle (ITALY)*

METHODS OF MEASUREMENT AND DATA PROCESSING

1) The Pyrheliometric method (WMO no.8 ed.2008 sec. 8.1) It is applied to **1-sec** direct irradiances (**sunshine seconds - SD_{ref} – "Comparison Reference SD"**) or to **1-min average** direct irradiances (**sunshine minutes - $SD_{Pyrh\ 1m}$**).

$I_{1sec} \geq 120 Wm^{-2}$ $SD_{Pyrh} = 1s$ → **$SD_{reference}$**

$I_{1m-avg} \geq 120 Wm^{-2}$ → **SD_{Pyrh}=1min**

2) The Pyranometric method (WMO no.8 ed.2008 sec. 8.1) by means of a Step Algorithm (**SA**) provided by the IMS. It is applied to 1-min average global irradiances (sunshine minutes – **SD_{SA}**). (h: solar elevation)

$G_{THR} = 0.4 G_0 Wm^{-2}$

$G_{1m-avg} \geq G_{THR}$ $h \geq 3°$ → **SD_{SA}=1min**

3) The Pyranometric method (WMO no.8 ed.2008 sec. 8.1) by means of an algorithm developed by Météo France (**MFA, Olivíeri**). It is applied to 1-min average global irradiances (sunshine minutes – **SD_{MFA}**). A, B coefficients are a function of latitude and for comparison sites: A=0,73 B=0,06.

$G_{THR} = Fc \times 1080(\sin h)^{1.25} Wm^{-2}$

$Fc = A + B\cos(\frac{2\pi}{365} d)$ d = daynumber

$G_{1m-avg} \geq G_{THR}$ $h \geq 3°$ → **SD_{MFA}=1min**

4) Evaluation of WMO sunshine threshold accuracy of 20% by means of pyrheliometric method (WMO no.8 ed.2008 sec. 8.1). It is applied to 1-sec direct irradiances (**sunshine seconds – $SD_{Thr\ Tolerance}$**)

$I_{1sec} \geq 144 Wm^{-2}$ → **$SD_{Thr-144}$=1s**

$I_{1sec} \geq 96 Wm^{-2}$ → **SD_{Thr-96}=1s**

5) The Pyranometric method (Annex WMO no.8 ed.2008 sec. 8.1) by means of a Slob and Monna algorithm (**SM**). It is applied to **10-min average, max, min global irradiances $G_{10m\text{-}avg,max,min}$** (sunshine fractions "**f**"of 10-min intervals – **SD_{SM}**). G_0 extra-terrestrial global irradiance; T_L Linke turbidity.

$CrIn(h, T_L) = \exp(-\frac{T_L}{0{,}9 + 9{,}4\sin h}) + 0{,}2 + \frac{\sin h}{0{,}3}$

$(G_{10m-avg,\max,\min} / G_0)$ is compared to CrIn

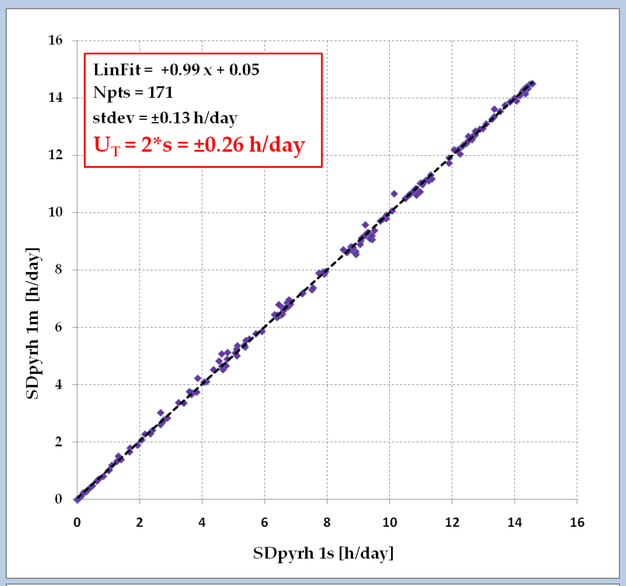
$\forall h \leq 5{,}7° \Rightarrow f = 0$ → **SD_{SM}=f·10m**

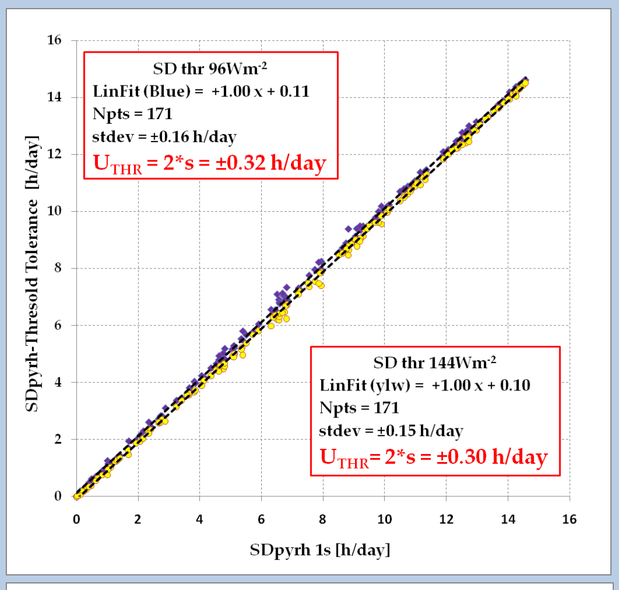
6) Daily sunshine duration by means of SD measuring instruments (**daily sunshine – SD_{SENSOR}**) → **SD_{SENSOR}[h/day]**

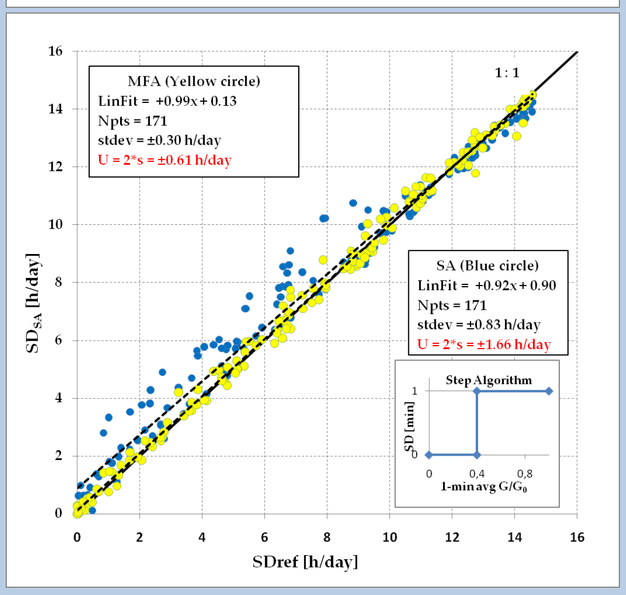
DATA ANALYSIS AND RESULTS

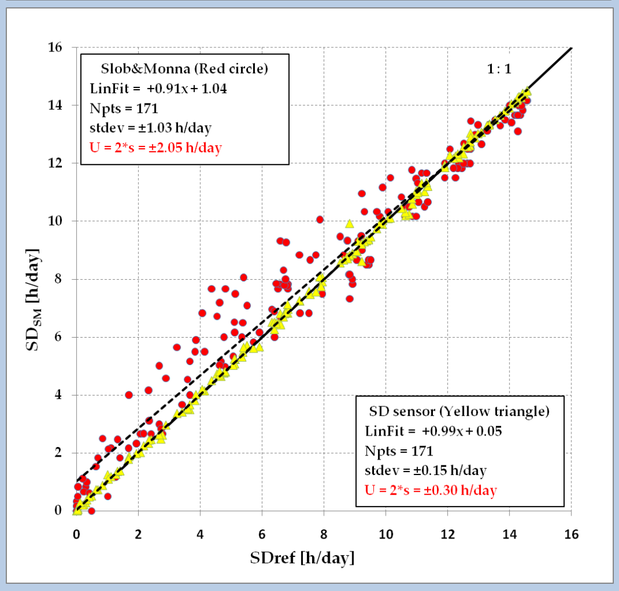
The data analysis is performed by plotting the **daily SD totals** calculated from different methods and versus the **SD Reference** (SD_{ref}). The relevant statistic values, derived from plots and dataset, are summarized in a table for each comparison site, including the **measurement uncertainties** (U_M).

The uncertainty (U_T) of SD calculated by means of 1-min average direct irradiance and the uncertainty (U_{THR}) derived from SD threshold accuracy of 20% (96-144Wm^{-2}) are firstly evaluated and reported on the corresponding plots for both comparison sites.

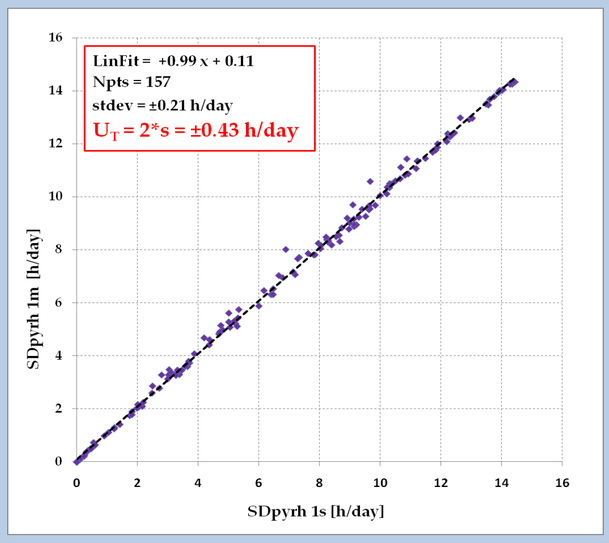


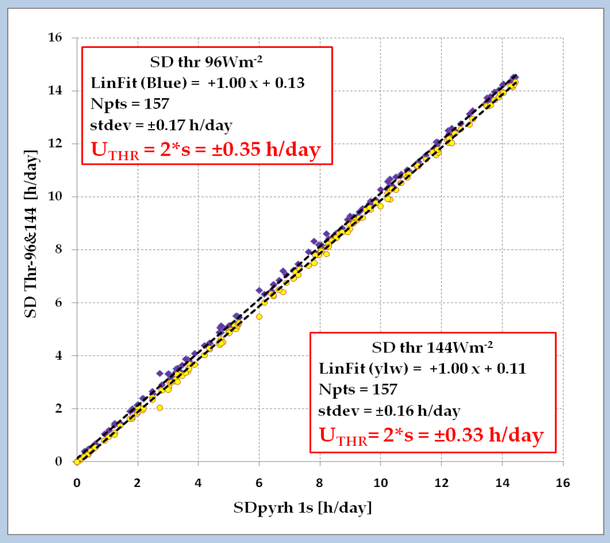


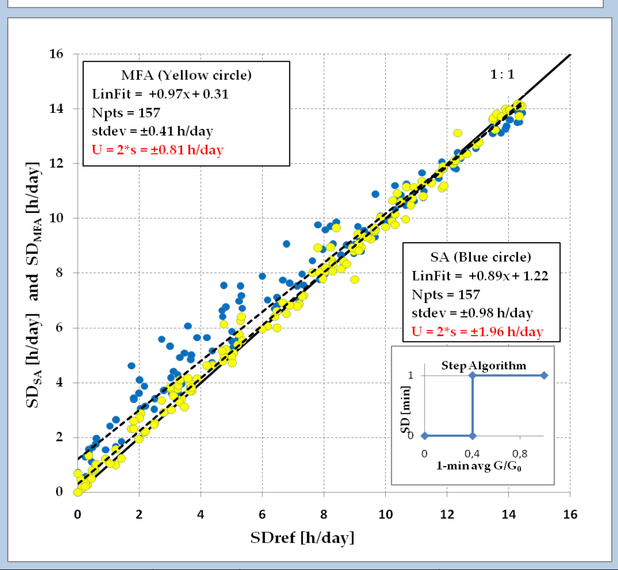


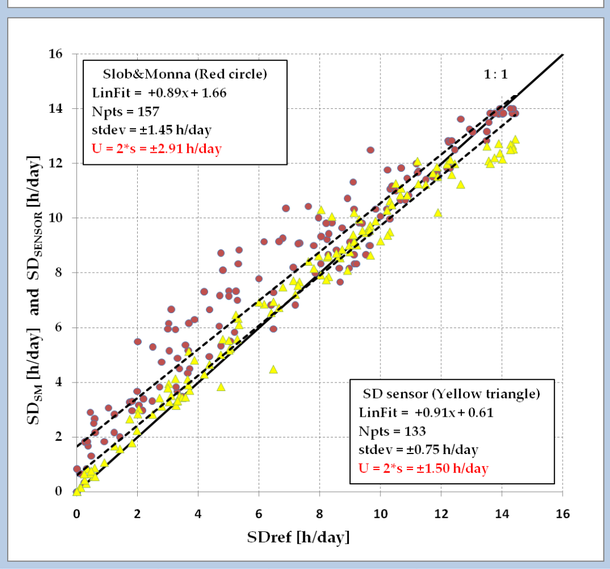


CARPENTRAS *FRANCE*	Npts (days)	Measurement Uncertainty U_M =2*stdev [h/d]	Daily Mean diff SD_x-SD_{REF} [h/day]	Stand. Error of mean diff [h/day]	U_{DIFF} (2*SE) [h/day]	Diff (Totals) SD_x-SD_{REF} [h]	U_{TOTALS} (100*Diff/Totals) [%]
SD_{SA}	171	±1.66	+0.35	±0.06	±0.11	+60.56	+4.7
SD_{MFA}	171	±0.61	+0.04	±0.02	±0.05	+6.01	+0.5
SD_{SM}	171	±2.05	+0.40	±0.07	±0.14	+69.2	+5.3
SD_{SENSOR}	171	±0.30	+0.01	±0.01	±0.02	+2.2	+0.2



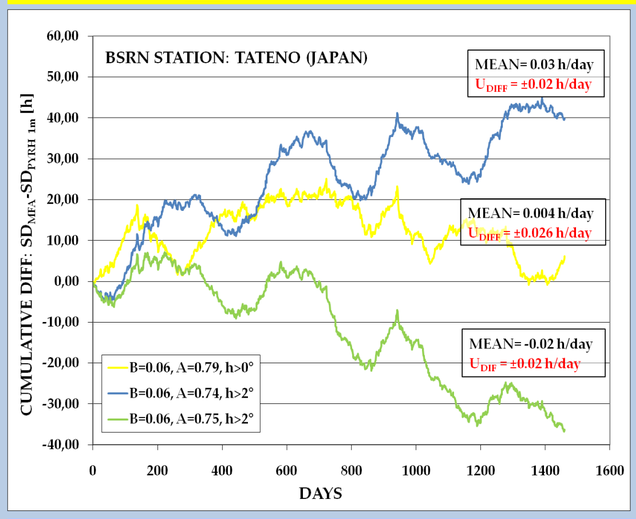


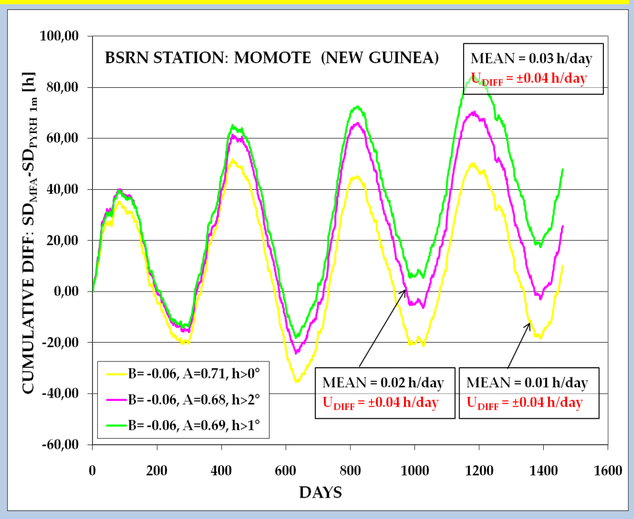




VIGNA DI VALLE *ITALY*	Npts (days)	Measurement Uncertainty U_M =2*stdev [h/d]	Daily Mean diff SD_x-SD_{REF} [h/day]	Stand. Error of mean diff [h/day]	U_{DIFF} (2*SE) [h/day]	Diff (Totals) SD_x-SD_{REF} [h]	U_{TOTALS} (100*Diff/Totals) [%]
SD_{SA}	157	±1.96	+0.52	±0.07	±0.13	+81.42	+7.1
SD_{MFA}	157	±0.81	+0.08	±0.03	±0.06	+13.03	+1.2
SD_{SM}	157	±2.91	+0.91	±0.09	±0.18	+142.29	+11.8
SD_{SENSOR}	133	±1.50	+0.01	±0.06	±0.13	+1.89	+0.2

The evaluation of the performance of the MFA algorithm is also extended to two BSRN stations by using 1-min average global and direct irradiances for the period 2005-2008 (1470 Npts). Results are optimized by selecting the 3 best sets of A, B and h algorithm's values. Cumulative differences of SD_{MFA} and $SD_{PYRHELIOMETER\ 1m}$ are plotted versus time. The corresponding mean daily differences and the related uncertainty (U_{DIFF}=2 * stdev / √Npts) are displayed in each plot for comparison.





- CONCLUSIONS -

- **Uncertainty** due to **1-min averaged** direct irradiances instead of 1-sec data: **±0.26 – 0.43 h day^{-1}**
- The **threshold tolerance** of 20% corresponds to an uncertainty **±0.30 – 0.35 h day^{-1}**
- **The achieved uncertainties of pyranometric methods seems not comparable to the CIMO guide required uncertainty ± 0,1h (U_{95})** (*WMO, 2008*)
- The **MFA algorithm** (SD from 1-min averaged global irradiances) **provides better results** than the others with **measurement uncertainty ± 0.61 – 0.81 h day^{-1}**; moreover, **its optimization,** through the use of 1-min averaged **BSRN data, provides a method to improve the daily mean differences (0.04 – 0.08 h day^{-1}) and their uncertainty (± 0.05 – 0.06 h day^{-1})**

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