Report of the Working Group
“Long-term Analysis of Surface SW Radiation Budget”

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Objectives

• Collection of various types of long-term surface SW radiation data and the related data including proxy-data useful for SW calculations.

• Comprehensive evaluation of the collected data.

• Promotion of the long-term analysis of surface SW radiation and the related data, focusing on their regional properties.
Workshop in Nanjing, China
22 May 2007

• 30 participants from China, Korea and Japan

• The QC procedures have no significant effect on the long-term trend of surface solar radiation over China.
  • 1961 – 1990: Dimming, about 4.61%/10yr.
    – Aerosols? Clouds?
  • 1990 – 2000: Brightening, about 1.76%/10yr.
    – What caused the brightening?
  • 1961 – present: Temperature increasing
    – How can we understand the relation with SW radiation trend? - Evaporation process? Absorbing aerosols? Dynamics? Other climate system?
      \[ F_N^S + F_L^\downarrow = \varepsilon\sigma T_S^4 + H + LE + G \]

• SST might respond to SW radiation trend.
Methods of data quality assessment

• QA1: Physical threshold test
• QA2: Sunshine duration test of global daily irradiation
• QA3: Standard deviation test for annually-averaged global irradiance time series (GEBA: Global Energy Balance Archive)

(Shi et. al, 2008: JAMC, Vol. 47, pp.1006-1016)
Time series of annual mean of global irradiance at all stations
(Shi et al., 2008, JAMC)
Parameterizations for SW radiation

For clear sky condition, downward SW flux is estimated by using basic meteorological data,

\[
\frac{S_{df}}{S_{0d}} = (C_1 + 0.7 \times 10^{-m_d F_1})(1 - i_3)(1 + j_1)
\]

\[
C_1 = \begin{cases} 
0.21 - 0.2 \beta_{DUST}, & \beta_{DUST} < 0.3 \\
0.15, & \beta_{DUST} \geq 0.3 
\end{cases}
\]

\[
F_1 = 0.056 + 0.16(\beta_{DUST})^{0.5}
\]

\[
i_3 = 0.014(m_d + 7 + 2 \log_{10} w) \log_{10} w
\]

\[
j_1 = \left[0.066 + 0.34(\beta_{DUST})^{0.5}\right](\text{ref} - 0.15)
\]

\[S_{df} : \text{average downward SW flux on the Earth’s surface,}\]
\[S_{0d} : \text{SW flux at the top of atmosphere,}\]
\[\beta_{DUST} : \text{turbidity factor,}\]
\[m_d : \text{daily mean optical airmass,}\]
\[w : \text{precipitable water,}\]
\[\text{ref} : \text{surface albedo}\]
Parameterizations for SW radiation (2)

For cloudy sky condition, downward SW flux is estimated from sunshine duration,

$$\frac{S_d}{S_{0d}} = a + b \frac{N + \Delta N}{N_0}$$

for $0 < \frac{N}{N_0} \leq 1$

$$= c$$

for $\frac{N}{N_0} = 0$

$S_d$: average downward SW flux on the Earth’s surface,
$S_{0d}$: SW flux at the top of atmosphere,
$N$: sunshine duration, $N_0$: maximum sunshine duration,
a, b, c, $\Delta N$: parameters depending on the instrument type
Pyranometer Measurements Sites
Comparison of SW radiation among the pyranometer measurement (SPYR), the parameterization (SXU), and the satellite retrieval (SSAT).
Future work

• Collection and archive of radiation data
• Comparison of QA (BSRN, GEBA, satellite data, etc.)
• Assessment of radiation data with related data (clouds, aerosols, etc.)
• Promotion of the long-term analysis of surface SW radiation and the related data.
• Website, workshop or meeting
Report of the WMO Ad-Hoc Group Meeting on Programmatic Gaps Related to the Global Radiation Network Served by the World Radiation Data Centre, MGO, Russia
7-8 June 2006 St. Petersburg Russia

Figure 1 The red points indicate the number of stations in the Global Surface Radiation Network (GSRN) reporting data in 2004 to the WMO-GAW World Data Centre for Radiation. The fainter yellow points represent all other locations that, at some time between 1964 and 2004, have submitted data (courtesy of A. Tsvetkov, head of WRDC)
QA1: Physical threshold test

- **Global radiation, G**
  - Upper limit: The daily solar global radiation in clear sky condition.
  - Lower limit: According to the research of Geiger et al. [2002], the lower limit here is set as 3% of solar radiation at TOA.

- **Diffuse radiation, D**
  - Upper limit: The daily solar global radiation in clear sky condition.
  - Lower limit: The daily surface diffuse radiation under clear sky condition.

- **Direct radiation, B**
  - Upper limit: The daily surface direct solar radiation under clear sky condition.
  - Lower limit: Zero.
QA2: Sunshine duration test of global radiation

- The monthly percentage of sunshine duration (MPSD) of each station is calculated according to monthly sunshine duration data. The MPSD is the ratio of monthly observed sunshine duration $S$ to the monthly available sunshine duration $L$.

- To compare sunshine duration percentage with surface global radiation, we need to calculate a ‘clearness index, $K$’, from radiation data. Monthly averaged $K$ is calculated by $K = G/G_0$, where $G_0$ is the incident irradiance at TOA.
As the result of QA2 test, the ESD is different from the site to site and its range varies from 0 to 2.35%. The geographic distribution of the ESD is relatively uniform and among all of 27196 monthly data tested, 210 did not pass through QA2 tests, which is about 0.77%.
QA3: Standard deviation test of time series for annual averaged global radiation

For the time series of the annual averaged values \( Y \) of solar global radiation, \( Y(t) \), its average \( m_Y \), and standard deviation \( S_Y \) can be calculated by

\[
m_Y = \frac{1}{N} \sum_t Y(t),
\]

and

\[
s_Y^2 = \frac{1}{N-1} \sum_t [Y(t) - m_Y]^2,
\]

where \( N \) is the observation period with a unit of year.
Global solar radiation trend (%/10yr)

-15 to -9
-9 to -6
-6 to -3
-3 to 0
0 to 3
3 to 6
Long-term variations of annual mean of direct and diffuse irradiance.
Aerosol Optical Thickness in China

From Qiu et al. (2000), Luo et al. (2001), Chu et al. (2003)
## Results of QA1

Table 1 Test thresholds and results of three variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Measurement Days</th>
<th>Error days</th>
<th>Percent of error days</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G$</td>
<td>$0.03G_0$</td>
<td>$G_c$</td>
<td>1220107</td>
<td>37466</td>
<td>3.07</td>
</tr>
<tr>
<td>$B$</td>
<td>0</td>
<td>$B_c$</td>
<td>813929</td>
<td>117</td>
<td>0.01</td>
</tr>
<tr>
<td>$D$</td>
<td>$D_c$</td>
<td>$G_c$</td>
<td>813943</td>
<td>20479</td>
<td>2.52</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>2847979</td>
<td>58062</td>
<td>2.04</td>
</tr>
</tbody>
</table>

Table 2 Monthly distributions of error days

<table>
<thead>
<tr>
<th>Variables</th>
<th>Error days (upper limit error days /lower limit error days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>$G$</td>
<td>885/3542</td>
</tr>
<tr>
<td>$D$</td>
<td>0/3542</td>
</tr>
<tr>
<td>$B$</td>
<td>26/0</td>
</tr>
</tbody>
</table>
Table 3 Regional averages of global solar radiation $m(m_Y, Z)$ and standard deviation $m(s_Y, Z)$ and $s(s_Y, Z)$

<table>
<thead>
<tr>
<th>Region</th>
<th>$m(m_Y, Z)$</th>
<th>$m(s_Y, Z)$</th>
<th>$s(s_Y, Z)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>50°-60°N</td>
<td>119</td>
<td>6.4</td>
<td>1.14</td>
</tr>
<tr>
<td>40°-50°N</td>
<td>154</td>
<td>9.38</td>
<td>4.45</td>
</tr>
<tr>
<td>30°-40°N</td>
<td>196</td>
<td>12.27</td>
<td>3.94</td>
</tr>
<tr>
<td>20°-30°N</td>
<td>213</td>
<td>10.00</td>
<td>2.75</td>
</tr>
</tbody>
</table>

GEBA: $m(s_Y, Z) + 2s(s_Y, Z)$ is used.

Among 3068 year-station data tested by QC3, 15 have been identified to be the ESD which is about 0.49% of the total.
ISCCP–FD - Pyranometer data

Fig. 3
GEWEX–SRB - Pyranometer data

Fig. 2