INTER-COMPARISON CAMPAIGN OF SOLAR UVR INSTRUMENTS
AT RÉUNION ISLAND (21.0ºS, 55.5ºE):
FINDINGS AND RECOMMENDATIONS


Introduction

Reunion Island (21.0ºS, 55.5ºE) is a French and European territory situated in the Indian Ocean in the tropics where solar ultraviolet radiation (UVF) levels are high almost all year round. This is mainly due to intense solar radiation combined with weak stratospheric ozone columns. Yet, very few UVR and ozone measurements are available or operational in these regions, especially in the south-west Indian Ocean countries. Since 2009, the Reunion University, a French and European university, started a research program based on ground-based UVR and ozone observations. Continuous UVR measurements require instrument monitoring and calibration processes in terms of wavelength and intensity on regular intervals and with regular comparison against a reference instrument. Several UVF instruments comparison has already been done [1], but a comparison at high UV level can highlight a different instrument trend. In the framework of the NDACC (Network for the Detection of Atmospheric Composition Change) and in collaboration with the IUPA (Laboratoire d’Optique Atmosphérique, Université de Lille, Lille, France) a Bentham DM6300 spectrometer (BT) is operated at Reunion Island. We recently implemented an inter-comparison campaign between the Bentham spectrometer and four UVF radiometers: a Kipp&Zonen (DV) SOL-T KZ, a Solar light 501 SL, a Solux UV-CDS (SG) and a Davis radiometer (DV), with the Bentham spectrometer as a reference. It should be noted that the Kipp&Zonen and Solar light 501 radiometers were calibrated during the International UVF Radiometer Comparison in summer 2017 organized by PMOD/WRC at the WCC-UV in Davos [2]. In order to identify clear sky conditions, an all-sky camera recording cloud fraction (CF) has been operating at the observation site.

Materials

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Type</th>
<th>Date range</th>
<th>Parameters</th>
<th>Uncertainty</th>
<th>Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>(BT) Bentham DM6300</td>
<td>Spectroradiometer</td>
<td>10/17 to 06/18</td>
<td>±5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(KZ) Kipp&amp;Zonen</td>
<td>Radiometer</td>
<td>10/17 to 06/18</td>
<td>5 min, 0.5 km</td>
<td>±7%</td>
<td></td>
</tr>
<tr>
<td>(DV) Solar light</td>
<td>Radiometer</td>
<td>03/18 to 06/18</td>
<td>1 min, 0.5 km</td>
<td>±5%</td>
<td></td>
</tr>
<tr>
<td>(SG) Solux UV-CDS</td>
<td>Radiometer</td>
<td>03/18 to 06/18</td>
<td>1 sec, 0.5 km</td>
<td>±5%</td>
<td></td>
</tr>
<tr>
<td>(DV) Davis all-sky camera</td>
<td>Camera</td>
<td>10/17 to 06/18</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Methods of comparison

All data are interpolated on a 1 degree grid of solar zenith angle. The comparison is performed by calculating bias per SZA, MAPE, correlation and RMSE:

\[
\text{Bias} = \frac{1}{n} \sum_{i=1}^{n} (\text{Instrument}_i - \text{Reference}_i),
\]

\[
\text{MAPE} = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{\text{Instrument}_i - \text{Reference}_i}{\text{Reference}_i} \right| \times 100,
\]

\[
\text{R} = \frac{\sum_{i=1}^{n} (\text{Instrument}_i - \text{Reference}_i)(\text{Reference}_i - \text{Mean}_i)}{\sqrt{\sum_{i=1}^{n} (\text{Instrument}_i - \text{Mean}_i)^2 \sum_{i=1}^{n} (\text{Reference}_i - \text{Mean}_i)^2}}
\]

\[
\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (\text{Instrument}_i - \text{Reference}_i)^2}
\]

Clear sky filtering

For manually selected clear sky day, all the sky index values are between 2 and 10. Figure 1 shows an example of clear sky day at La Réunion on 11/04/2018 with a constant cloud fraction of 2%.

Cloud fraction data from all the sky camera are in good agreement with other clear sky filtering methods [3].

Figure 2 shows no significant difference as function of cloud fraction. Indeed, the bias is the same from clear sky condition (CF=0,3) to overcast sky condition (CF=10).

Same results are found for the other instruments: SL, SG and DV.

Comparison

Figure 3 and 4 show a good agreement between the KZ and the SG to the BT. The bias is similar to the instrument accuracy, within ±5%.

A slight dependence on SZA is identified on KZ data, from ±5% at low SZA to ±5% at high SZA.

The SL underestimates the UVI about 30% to the BT. This bias does not depend on SZA.

Figure 4 highlights a strong solar zenith angle dependence on the DV data, but the bias is low for solar zenith angle (0 to 30°).

Conclusion

The cloud condition doesn’t affect the bias between the instruments. The effect of the cloud cover on the UVI is the same on all the co-localised instruments.

KZ: Good coherence with BT. KZ measurements seem to be SZA-dependent but overall bias remain below ±7%, as stated in the specification. Nevertheless, the reason of this SZA dependency have to be clarified.

SL: There is no SZA dependency as the SL was calibrated in order to take into account effects of SZA and ozone absorption during Davos inter-comparison campaign [2]. However there is a constant positive bias of 30%. This shift can be corrected by using a lower calibration factor.

SG: Good agreement with the BT; low and constant bias.

DV: The UVI are clearly function of SZA. The bias is low, within 5% for low solar zenith angle.

Recommandations

The SL501 shift can be corrected by using a new calibration factor according to the bias founded, 0.69 Wm-2m-2 instead of 0.8686 Wm-2m-2. A new calibration can also be performed to solve this issue.

Reference

