Inter-comparison campaign of solar UVR instruments at Réunion Island (21.0°S, 55,5°E) : findings and recommendations

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INTER-COMPARISON CAMPAIGN OF SOLAR UVR INSTRUMENTS AT RÉUNION ISLAND (21.0°S, 55,5°E): FINDINGS AND RECOMMENDATIONS

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Introduction

Reunion Island (21.0°S, 55.5°E) is a French and European territory situated in the Indian Ocean in the tropics where solar ultraviolet radiation (UVR) levels are high almost all-year round. This is mainly due to intense incident 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 solar UVR and ozone observations. Continuous UVR measurements require instrument monitoring and calibration processes in terms of wavelength and intensity on regular intervals and made with regular comparison against a reference instrument. Several UV 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 LOA (Laboratoire d'Optique Atmosphérique, University of Lille, France) a Bentham DM300 spectrometer (BT) is operated at Reunion Island. We recently implemented an inter-comparison campaign between the Bentham spectroradiometer and four UV radiometers: a Kipp&Zonen UVS-E-T (KZ), a Solar Light 501 (SL), a SGlux UV COS (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 UV filter Radiometer Comparison in summer 2017 organised 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

Instrument	Type	Date range	Parameters	Uncertainty	Calibration
(BT) Bentham DM300	Spectro radiometer	10/17 to 06/18	15 min, 0.5nm 280-450nm	±5%	Intensity, Wavelength (every 3 months)
(KZ) Kipp&Zonen UVS-E-T	Radiometer	10/17 to 06/18	5 min	±7%	Intensity, SZA, ozone (08/2017)
(SL) Solar light SL501	Radiometer	03/18 to 06/18	1 min	±5%	Intensity, SZA, ozone (08/2017)
(SG) SGLux UV COS	Radiometer	03/18 to 06/18	1 min	±5%	Intensity (12/2017)
(DV) Davis UV sensor	Radiometer	01/18 to 06/18	1 sec	±5%	-
Reuniwatt all-sky camera	Camera	10/17 to 06/18			

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

$$Bias = \frac{1}{n}\sum_{i=1}^{n}\left(UVI_{[X],i} - UVI_{[BT],i}\right)$$

$$RMSE = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(UVI_{[X],i} - UVI_{[BT],i}\right)^2}$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left(100 * \frac{\left|UVI_{[X],i} - UVI_{[BT],i}\right|}{UVI_{[BT],i}}\right)$$

$$r = \frac{\sum_{i=1}^{n}\left(UVI_{[BT],i} - \overline{UVI_{[BT]}}\right)\left(UVI_{[X],i} - \overline{UVI_{[X]}}\right)}{\sqrt{\left(\sum_{i=1}^{n}\left(UVI_{[BT],i} - \overline{UVI_{[BT]}}\right)^2\right)\left(\sum_{i=1}^{n}\left(UVI_{[X],i} - \overline{UVI_{[X]}}\right)^2\right)}}$$

Clear sky filtering

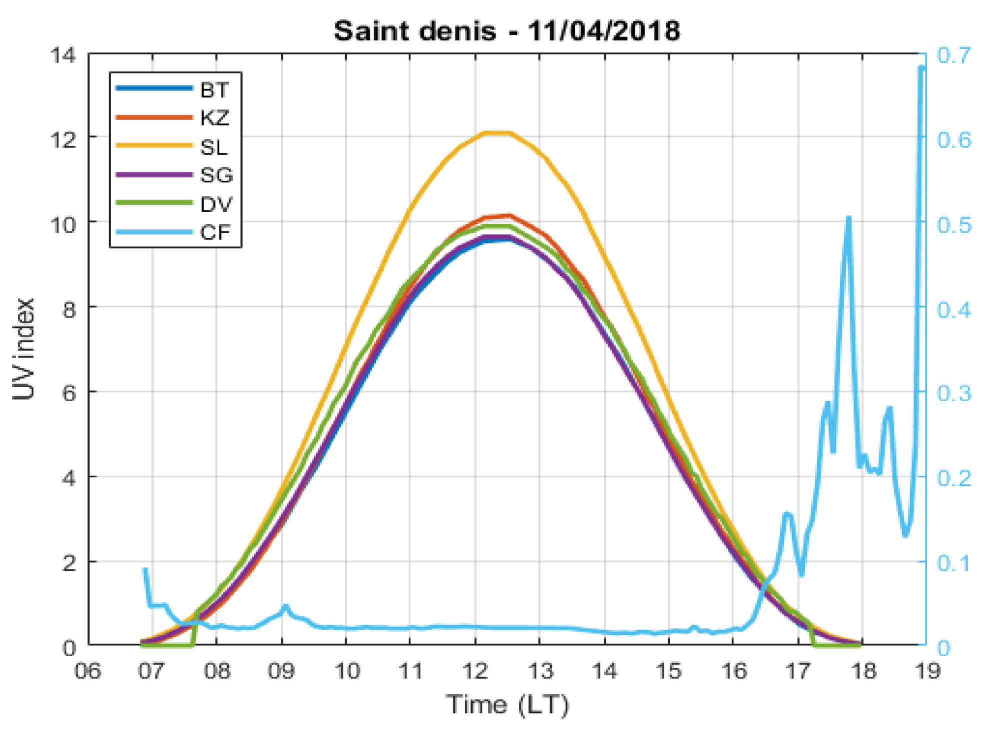

Figure 1: Example of comparison between UV index from ground-based instruments and cloud fraction from all-sky camera at Saint-Denis on 11/04/2018

For manually selected clear sky day, the all sky camera 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 the all sky camera are in good agreement with other clear sky filtering methods **[3]**.

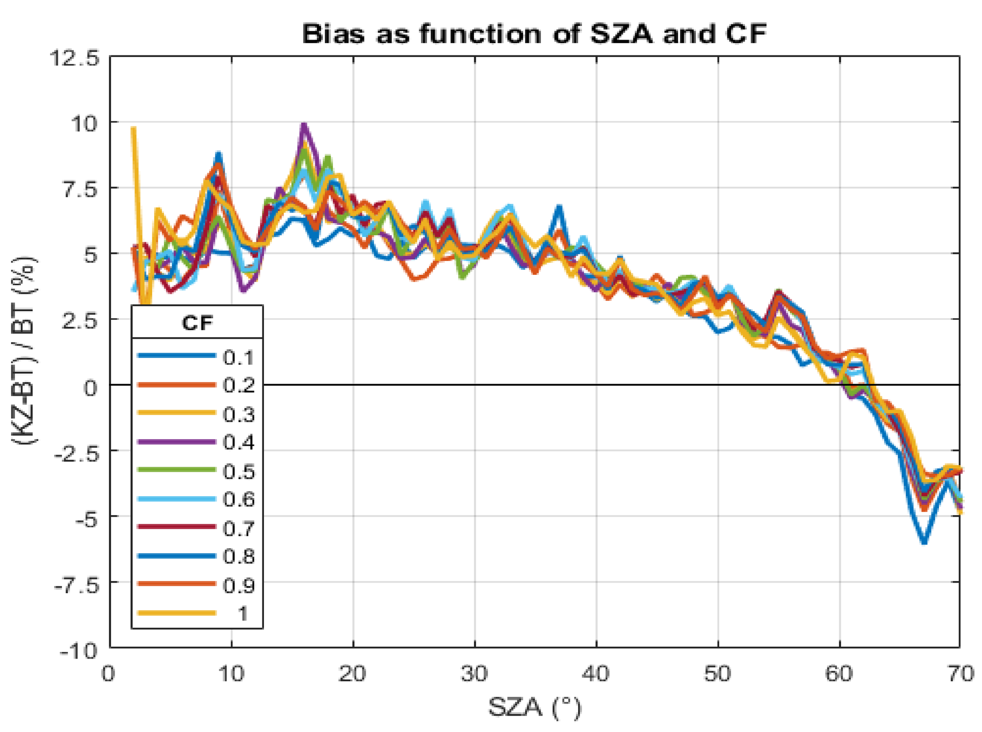

Figure 2: Bias between BT and KZ as function of solar zenith angle and cloud fraction. The legend table indicates the maximum threshold of cloud fraction.

Figure 2 shows no significant difference as function of cloud fraction. Indeed, the bias is the same from clear sky condition (CF=0,1) to overcast sky condition (CF=1)

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

Comparison

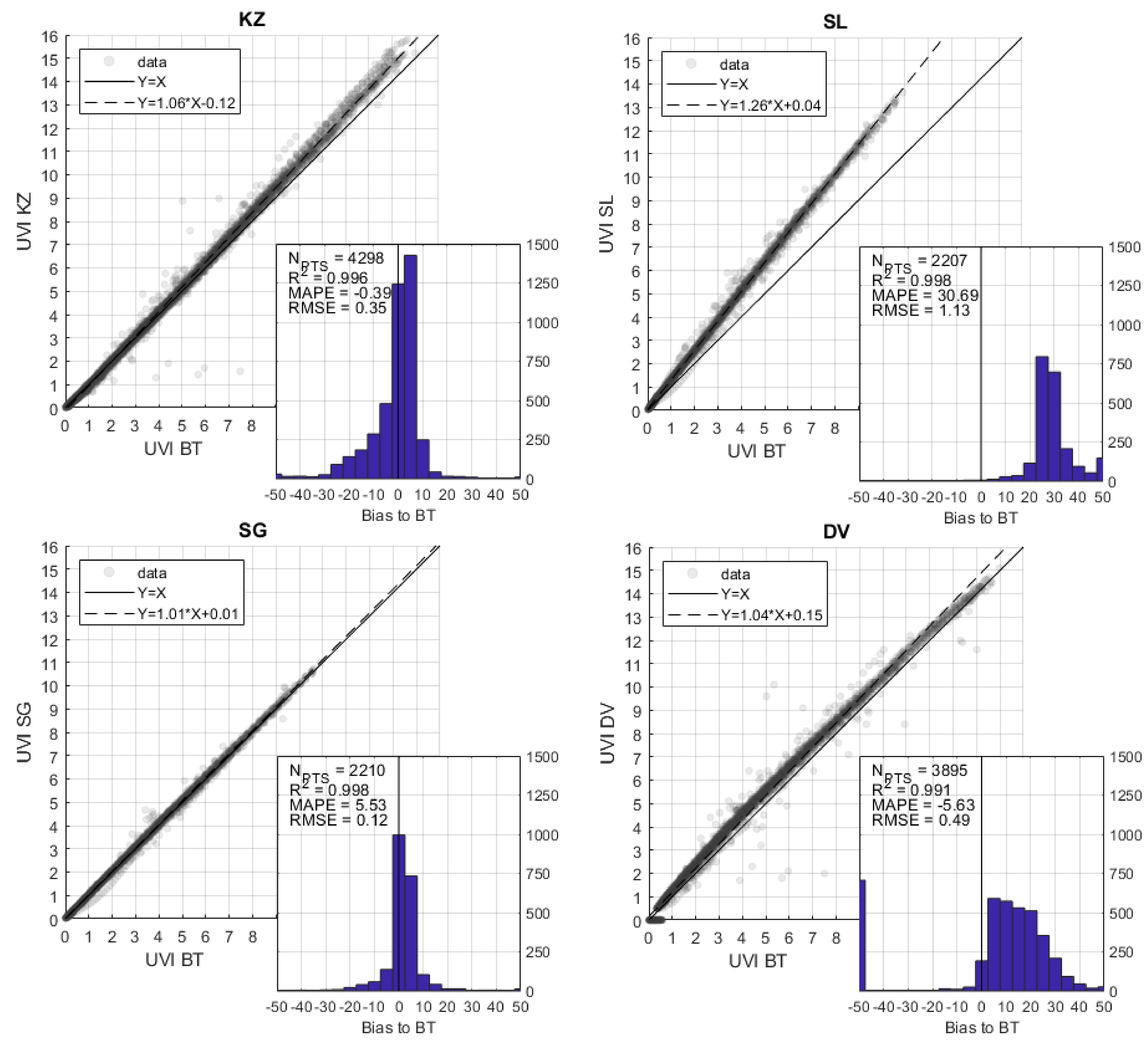

Figure 3: Correlation with BT and the compared instruments. The inserted histograms show the relative difference between BT and the compared instruments with the number of points, correlation, MAPE and RMSE. These comparisons are performed for clear sky UV index, with a maximum threshold of 10% of cloud fraction.

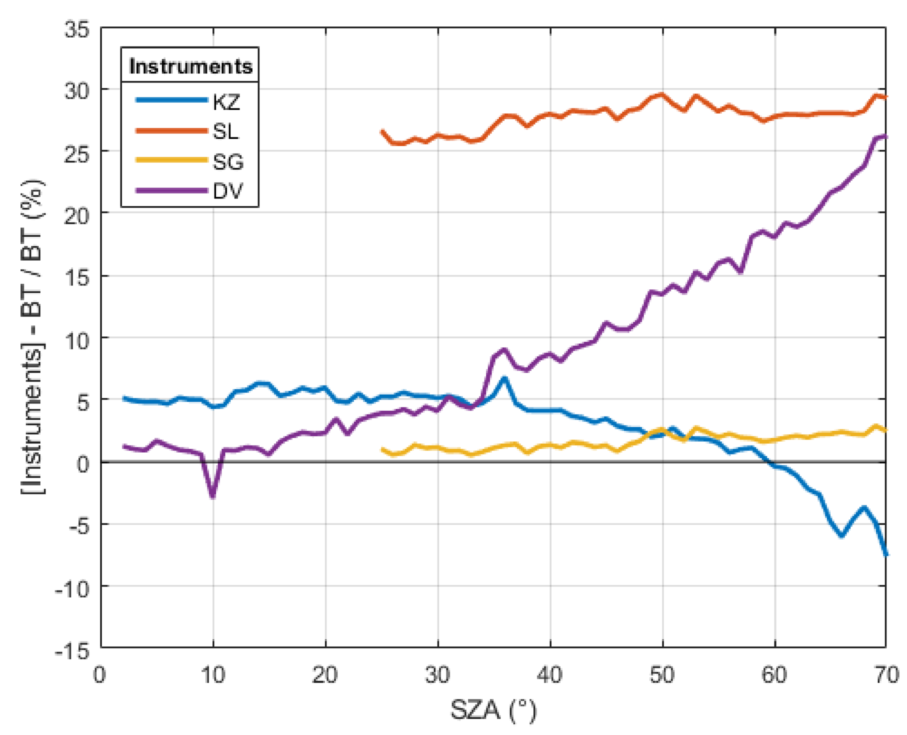

Figure 4: Bias as function of solar zenith angle. Bias computed with clear sky data by using a maximum threshold of 10% of cloud fraction.

- Figures 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 over estimates 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 low 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 $W.m^{-2}.V^{-1}$ instead of 0,8686 $W.m^{-2}.V^{-1}$. A new calibration can also be performed to solve this issue.

Reference

[1] de Paula Corrêa, M., Godin-Beekmann, S., Haeffelin, M., Brogniez, C., Verschaeve, F., Saiag, P., Pazmino, A. & Mahé, E. (2010). Comparison between UV index measurements performed by research-grade and consumer-products instruments. *Photochemical & Photobiological Sciences*, *9*(4), 459-463.

[2] International UV Filter Radiometer Comparison PMOD/WCC-UV, Davos, Switzerland, Summer 2017 http://projects.pmodwrc.ch/bb2017/media/UVC-II_report.pdf

[3] Lamy, K., Portafaix, T., Brogniez, C., Godin-Beekmann, S., Bencherif, H., Morel, B., Pazmino, A., Metzger, J.-M., Auriol, F., Deroo, C., Duflot, V., Goloub, P. & Long, C. N. (2018). Ultraviolet radiation modelling from ground-based and satellite measurements on Reunion Island, southern tropics. *Atmospheric Chemistry and Physics*, *18*(1), 227-246.