Circumsolar Irradiance Modelling Using LibRadtran and AERONET Data

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Abstract

In this work, the monochromatic circumsolar irradiance (at 675 nm) is modelled using libRadtran and AERONET data at Évora, Portugal, for selected cases representing the 1st, 25th, 50th and 75th percentiles of the aerosol optical depth (AOD) measurements distribution at 675 nm and a maximum value of AOD registered during a Saharan dust outbreak in February 2017. Since there are no measurements of circumsolar irradiance at Évora, the assessment of the model output accuracy was done through a comparison of both the modelled DNI from the solar disk only and the DNI including the circumsolar contribution against measurements from a pyrheliometer included in a meteorological station installed at the same location. The mean bias error and the root mean square error were found to be lower for the DNI with the circumsolar contribution, thus validating the modelling approach of circumsolar irradiance.

Experimental Data and Methodology

The experimental data used in this study are obtained from the AERONET station at Évora, located in the Institute of Earth Sciences (IES), University of Évora (38.5678ºN, 7.9114ºW) and from the meteorological station of IES installed at a few meters from the AERONET station. The list of libRadtran [1] inputs are presented in Table 1. The values of the solar zenith angle (SZA), AOD at 675 nm and total column content in water vapor (H2O) used to determine the solar radiances are given in Table 2.

Table 1. List of libRadtran inputs.

Input	Origin/Value
Spectral range	[670 - 680 nm]
Total column content in water vapor	AERONET
Surface albedo at 440, 675 and 870 nm	AERONET
AOD at 440, 675 and 870 nm	AERONET
Extinction Coefficient at 440, 675 and 870 nm	Derived from AERONET products
Aerosol single scattering albedo at 440, 675 and 870 nm	AERONET
Legendre moments of the aerosol phase function at 440, 675 and 870 nm	Derived from AERONET products
Elevation above mean sea level	0.273 km
Sky element zenith and azimuth angles	Defined to achieve ξ up to 6º
Radiative transfer solver	DISORT2
Number of streams	16

Table 2. SZA, AOD and H2O used for the determination of L_λ of Fig. 1.

Subfigure	AOD Percentile	SZA (°)	$AOD_{675\ nm}$	H2O (cm^{-1})
(a)	P1	75.559	0.011	13.496
(b)	P25	64.648	0.036	13.215
(c)	P50	50.361	0.060	14.480
(d)	P75	75.969	0.100	32.439
(e)	Max	74.741	1.210	15.956

Results and Discussion

To exemplify the impact of the atmospheric conditions on the radiance distribution in the circumsolar region, the diffuse solar radiances L_λ at 675 nm were mapped for an angular region between zenith angles of $\theta \pm 6°$ and azimuth angles $\phi \pm 6°$, as shown in Fig.1.

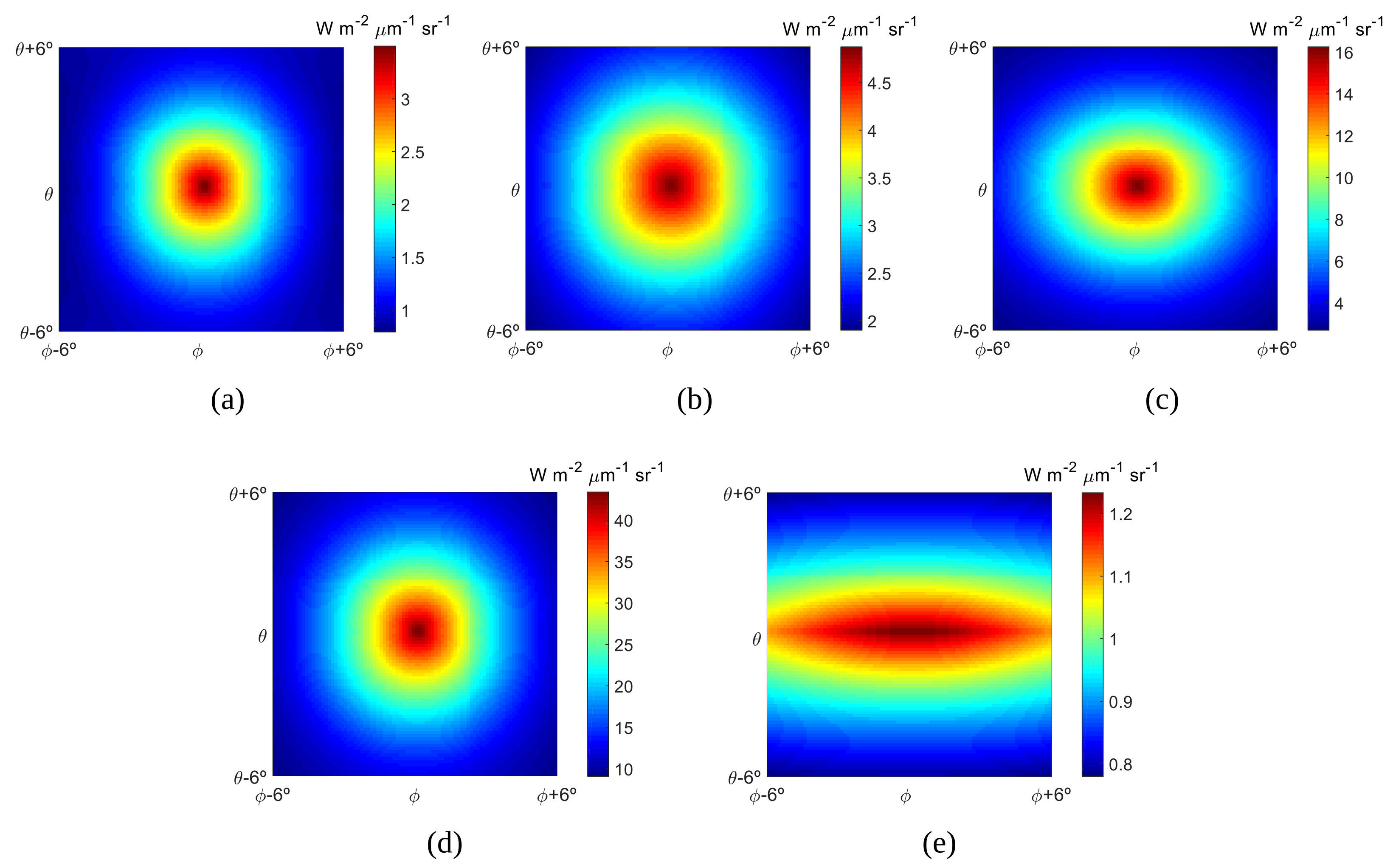

Figure 1. Diffuse L_λ at 675 nm at different θ and ϕ angles (details can be found in Table 2).

The differences between the several diffuse radiances L_λ presented above can be seen in more detail in Fig. 2, where the normalized azimuthally L_λ profile is shown in relation with the scattering angle ξ.

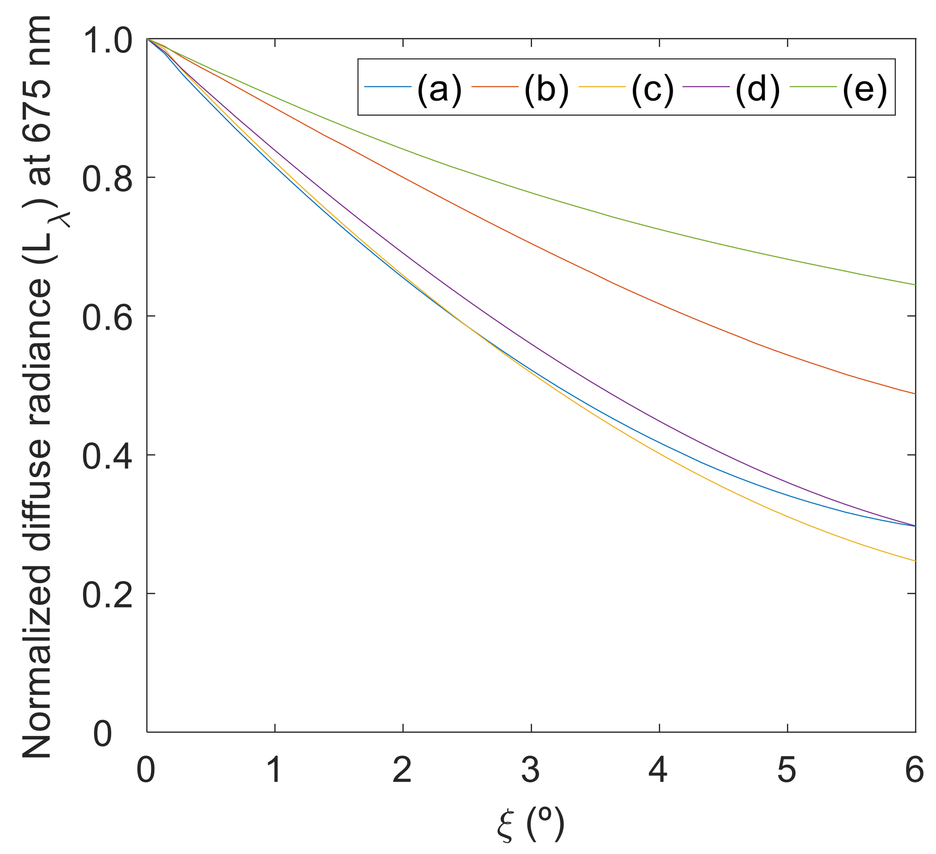

Figure 2. Normalized diffuse radiance profile, L_λ ((a) to (e) correspond to the same cases as in Fig.1 and Table 2).

The broadband DNI measurements were multiplied by the fraction corresponding to the considered wavelength interval ($B_{n\lambda}^{exp}$) and compared against the modelled DNI values from the solar disk only ($B_{n\lambda}^{Sun}$) and against the modelled DNI values from the solar disk plus the circumsolar irradiance ($B_{n\lambda}$), following Eissa et al. [2] approach. Figure 3 presents this comparison together with the mean bias error (MBE) and the root mean square error (RMSE) for each case.

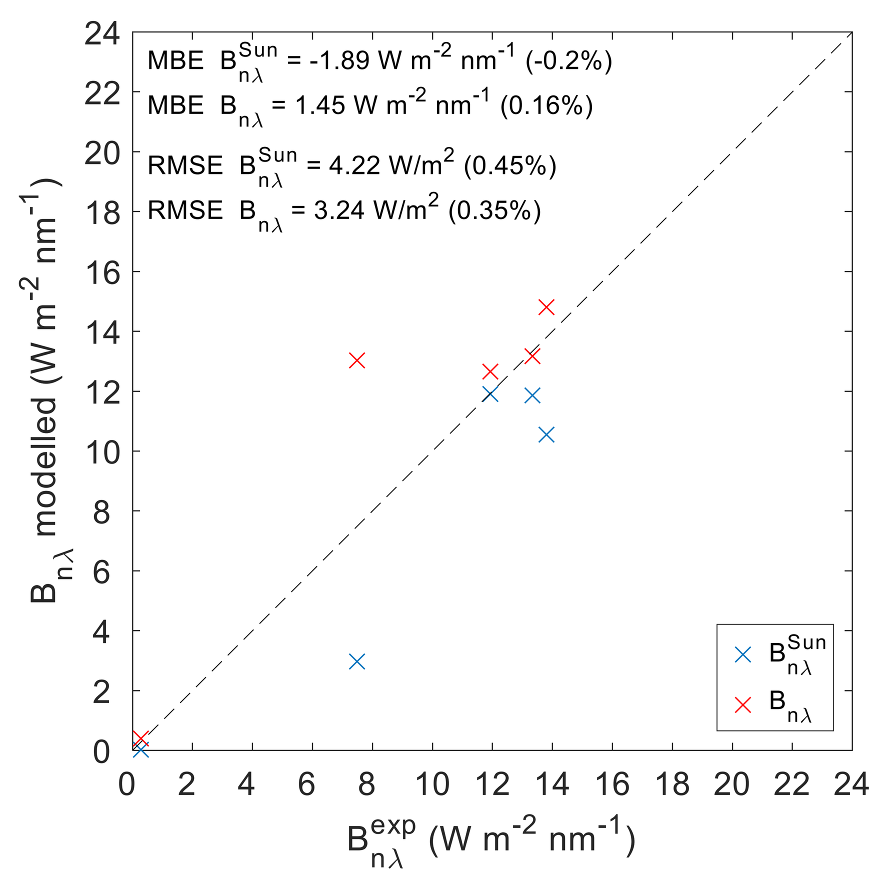

Figure 3. Comparison of $B_{n\lambda}^{Sun}$ (blue symbols) and $B_{n\lambda}$ (red symbols) against $B_{n\lambda}^{exp}$.

Conclusions

In this work, the radiative transfer code libRadtran was used to determine the monochromatic circumsolar radiation for selected cases representing the 1st, 25th, 50th and 75th percentiles of the aerosol optical depth (AOD) measurements distribution at 675 nm and a maximum value of AOD registered during a Saharan dust outbreak in February 2017 in Portugal. The accuracy of the modelled values was found through the comparison of the modelled DNI values for the solar disk only ($B_{n\lambda}^{Sun}$) and the modelled DNI values including the circumsolar radiation ($B_{n\lambda}$) against the measured broadband DNI values from a pyrheliometer downscaled for the same spectral range of simulations ($B_{n\lambda}^{exp}$), located in the same location of the AERONET station. The $B_{n\lambda}$ presented a lower MBE and RMSE, which show that the inclusion of the circumsolar radiation $CS_{n\lambda}$ improves the results obtained from libRadtran.

Acknowledgments

Edgar F.M. Abreu thanks the Fundação para a Ciência e Tecnologia (FCT), Portugal for the Ph.D. Grant SFRH/BD/136433/2018. The work was supported by the European Union through the European Regional Development Fund, included in the COMPETE 2020 (Operational Program Competitiveness and Internationalization) through the ICT project (UID/GEO/04683/2013) with the reference POCI-01-0145-FEDER-007690 and also through the DNI-A (ALT20-03-0145-FEDER-000011) project. The authors also acknowledge AERONET / PHOTONS and RIMA networks for the scientific and technical support and Samuel Bárias for maintaining instrumentation used in this work.

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