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Instrumental Set-up to Estimate the Atmospheric Attenuation along the Slant Path of Concentrated Solar Plants

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Abstract. The diffusometer instrument informs about changes in aerosol load affecting the attenuation of the solar radiation along the slant path in central tower concentrated solar thermal plants (CSP). The diffusometer measurements need to be corrected according to the aerosol nature. Three correcting factors are computed by applying the Mie theory on the aerosol microphysical properties retrieved by AERONET. The application concerns the High Atlas chain of Morocco, hosting several CSP projects: a Biral VPF710 diffusometer will be set up at Midelt, and AERONET data are acquired at Ouarzazate. The mean correction factor K_{tot} at Ouarzazate was 0.93 ± 0.10 . K_{tot} is sensitive on the aerosol size and on the refractive index. An empirical relationship with the Ångström exponent α , indicator of the mean aerosol size, shows that K_{tot} was 1.07 ± 0.08 in January 2013 ($\alpha = 1.02 \pm 0.31$), but 0.84 ± 0.03 in July 2013, during the desert dust month ($\alpha = 0.17 \pm 0.11$).

INTRODUCTION

Solar resource estimates are required with high precision and accuracy for solar plant projects. It is especially important to estimate precisely the atmospheric attenuation for large solar plants requiring significant investments, as is the case of the concentrated solar thermal plants designed to generate 100 MW or more. Solar resource depends on the atmospheric attenuation of the solar radiation generated by ozone, water vapor, water droplets, and aerosols. In cloud-free conditions, aerosols are responsible for the largest attenuation and for the largest variability in the collected solar radiation. Moreover, in central tower concentrated solar thermal plants (CSP), aerosols attenuate solar radiation in two optical pathways: not only in the atmospheric column down to the heliostat, but also in the slant path between the heliostat and the tower. With increasing CSP capacities, the heliostat-tower distances also increase, as well as the slant path attenuation. While many authors studied the attenuation across the atmosphere, the estimation of the slant path attenuation needs more effort.

Because of high temporal and spatial variability of aerosol optical properties, in-situ dedicated instrumentation is required. The diffusometer proved to work in operational conditions and to be sensitive to changes in atmospheric attenuation [1]. However corrections are required as the diffusometer is used in the dry conditions of the arid and semi-arid environments as found in Middle East, North Africa, the Atacama desert, ... while it was originally conceived to run in humid conditions to survey mist and fog.

Hanrieder *et al.* [1] proposed a method to correct the diffusometer measurements by the aerosol absorption (ABC method). But no correction of the diffusometer for the aerosol size is proposed, even if Hanrieder *et al.* [2] did mention the hypothesis of “*assuming a scatter function*”. Biral [3] mentioned three corrections: angular, spectral, and absorption. In this paper, we describe the three necessary corrections of the diffusometer measurements (Section

2), the method to compute the correction factors (Section 3), and applications (Section 4 to 6): with a typical aerosol models, for observed varying aerosol nature, and validation of the angular correction factor.

THE CORRECTING FACTORS OF THE DIFFUSOMETER MEASUREMENTS

The Angular Extrapolation of the Diffusometer Measurement

The particle extinction coefficient (PEC) is not directly measured by the diffusometer, as it is more efficient to measure the scattering of emitted light by a small volume of air than its extinction. For technical reasons it is difficult to measure scattering in the entire angular range, and scattering is measured in a limited angular range. Consequently, an angular extrapolation of the measurement is required to reproduce the scattering in the full angular range. The scattering probability at a given angle (the phase function) strongly depends on the aerosol nature, more specifically on the mean aerosol size, shape, and refractive index. The diffusometer being firstly conceived to survey mist and fog, the particle scattering coefficient provided by the manufacturer PSC_{instr} can be written as:

$$PSC_{instr} = \Delta_{\Theta}TSC_{meas} \cdot F_{\Theta, fog} - RSC \quad (1)$$

where $\Delta_{\Theta}TSC_{meas}$ is the effective measurement of total scattering (particles and molecules) in a limited angular interval, RSC is the Rayleigh scattering coefficient, and $F_{\Theta, fog}$ is the phase function correction factor for fog, which can generally be written as:

$$F_{\Theta} = \frac{\int_0^{180^{\circ}} P(\theta) \sin\theta d\theta}{\int_{\Theta_1}^{\Theta_2} P(\theta) \sin\theta d\theta} \quad (2)$$

$P(\Theta)$ is the phase function, which is the probability of light scattering in the direction of the scattering angle Θ , Θ_1 - Θ_2 being the sounded angular range. For other particle types such as desert dust aerosols, the aerosol scattering coefficient (ASC) should be written as:

$$ASC = \Delta_{\Theta}TSC_{meas} \cdot F_{\Theta, aerosols} - RSC \quad (3)$$

In Eq. 3, replacing $\Delta_{\Theta}TSC_{meas}$ defined in Eq. 1 gives:

$$ASC = PSC_{instr} \times \frac{F_{\Theta, aerosols}}{F_{\Theta, fog}} - RSC \times \left(1 - \frac{F_{\Theta, aerosols}}{F_{\Theta, fog}}\right) \quad (4)$$

or

$$ASC = PSC_{instr} \times K_{\Theta} - RSC \times (1 - K_{\Theta}) \quad (5)$$

With the angular correcting factor $K_{\Theta} = F_{\Theta, aerosols} / F_{\Theta, fog}$. In reality not only the particle phase function is measured in the instrument angular interval, but a combination of the particle phase function and the Rayleigh phase function (T meaning 'total' in $\Delta_{\Theta}TSC_{meas}$, for particles and molecules). But we assume that the Rayleigh scattering contribution is negligible and K_{Θ} is computed with only the particle phase functions (Eq. 2). We use PSC for fog which is composed of both aerosols and droplets, and we use ASC when dealing with atmospheric conditions relatively dry.

The Spectral Correction

The manufacturer usually provides the visibility instead of PEC , applying the Koschmeider approximation [e.g. 1]. In such an approximation, PEC is required at around 550 nm while the diffusometer sometimes emits radiation in the near infra red region. In this case, a further spectral correction becomes necessary:

$$ASC(550nm) = ASC(\lambda) \times K_{\lambda} \quad (6)$$

$ASC(\lambda)$ being defined by Eq. 5, Eq. 6 becomes:

$$ASC(550nm) = (PSC_{instr} \times K_{\theta} - RSC \times (1 - K_{\theta})) \times K_{\lambda} \quad (7)$$

The attenuation in fog is almost spectrally neutral ($K_{\lambda, fog} = 1$), and K_{λ} is larger than 1 for aerosols. RSC is only 2 Mm^{-1} at 880 nm for the standard atmospheric pressure and can be neglected for infra red instruments [3].

The Absorption Correction

Eventually, ASC can be converted into the aerosol extinction coefficient (AEC) by assuming aerosol absorption:

$$AEC(550nm) = (PSC_{instr} \times K_{\theta} - RSC \times (1 - K_{\theta})) \times K_{\lambda} \times K_{abs} \quad (8)$$

K_{abs} is computed as the ratio AEC/ASC at 550 nm, which can also be written as:

$$K_{abs} = \frac{1}{\varpi_0} \quad (9)$$

where ϖ_0 is the aerosol single scattering albedo at 550 nm. K_{abs} (or ϖ_0) also varies with the aerosol nature, and specifically with the imaginary part of the refractive index. The difference with the ABC scheme of Hanrieder *et al.* [1] is that we apply the correction on monochromatic extinction and not on broadband attenuation, and we then do not consider gas absorption here.

THE AEROSOL MICROPHYSICAL MODELS AS INPUT PARAMETERS

Mie theory is used to compute the aerosol optical properties as AEC , ϖ_0 , $P(\theta)$, at several wavelengths, assuming spherical aerosols. The aerosol input parameters are the size distribution $n(r)$ as well as the refractive index depending on the mean chemical composition. We present here the particle microphysical models of typical fog, haze and desert dust models, and then we present the generation of aerosol microphysical parameter sets by the AEROSOL ROBOTIC NETWORK (AERONET [4]).

Our Computations for both Haze and Desert Dust

The size distribution of the particle populations can be defined as a sum of log-normal modes. Each mode is defined by three parameters: the mode radius, width and number concentration. Haze (dry) is mostly defined by two modes of ultrafine and Aitken aerosols [5], mist is defined by these two modes and a mode of hydrated aerosols [6] and fog is defined by these three modes and a further mode of droplets [7] (Table 1). Desert dust is defined by four other modes [7]. The refractive index is 1.45-0.01i for haze, mist and dust and depends on the size for fog [6].

TABLE 1. Parameters of the log-normal modes composing the particle size distributions of fog, mist, haze and desert dust.

	Number concentration (cm^{-3}) for each mode defined by (r_{mode} (μm), and σ_{mode})				Angstrom exponent
	Ultrafine (0.02, 1.4) [5]	Aitken (0.11, 1.7) [5]	Hydrated aerosol (1.0, 1.4) [6]	Droplets (16.0, 2.0) [7]	
Fog	500	7000	500	15	-0.05
Mist	500	7000	300	0	-0.14
Haze	3000	15 000	5	0	2.06
Other modes [7]	(0.04, 2.24)	(0.14, 1.95)	(0.80, 2.0)	(3.80, 2.15)	
Desert dust	6000	810	90	0.42	0.10

The Microphysical Properties from AERONET

AERONET provides not only raw observation data but also sets of aerosol microphysical properties which can be used to compute all necessary parameters for radiative transfer computations (for satellite validation purposes for example) [4]. These microphysical properties can also be used to compute the correcting factors of the diffusometers. For example, Hanrieder *et al.* [1] showed that correcting the diffusometer data with AERONET providing input data to a radiative transfer code improves significantly the agreement with a reference transmissometer. The AERONET website gives a summary on the version 2 retrieval products (https://aeronet.gsfc.nasa.gov/new_web/Documents/Inversion_products_V2.pdf), with references therein. Only Level 2.0 data are considered.

While more than 10 000 values of the aerosol optical thickness (AOT) per year are provided by AERONET in an arid environment such as Ouarzazate (Morocco), the Level 2.0 size distribution is inverted only 3959 times in 2012-2015 at Ouarzazate, because of constraints such as on the solar position, the cloud cover, the atmosphere homogeneity, Moreover the refractive index and τ_0 are provided only 201 times because of the further constraint of $AOT > 0.40$. Results are presented for the AERONET station of Ouarzazate in Section 5, and Section 6 presents the validation of the angular correcting factor at the other site of SIRTA [8]. Section 4 presents the computations with typical particle models and are compared to the Biral Manual [3].

TABLE 2a. List of the correction factors for several diffusometers in haze conditions. Our computations are given as well as the values given in the Biral Manual [3].

instrument	Computations	F_{θ}		K_{θ}	K_{λ}		$K_{\theta} \cdot K_{\lambda}$	K_{abs}	K_{tot}
		Fog	haze	Haze	fog	haze	Haze	haze	Haze
Biral VPF710	Biral Manual	7.7	4.5	0.58	1	1.85	1.08	1.0	1.08
	Our computations	13.7	6.7	0.49	0.96	2.8	1.37	1.06	1.45
Vaisala FS11		70.5	38.2	0.54	"	"	1.51	"	1.60
Degreane DF20		4.6	2.6	0.57	/	/	/	"	0.60

APPLICATIONS FOR THE BIRAL VPF710 DIFFUSOMETER

We make most computations for the Biral VPF710 diffusometer, as one VPF710 will be set up at Midelt (Morocco), close to several CSP projects. We also make computations for a Degreane DF20+ instrument which run at the SIRTA platform and that we use for validating our angular correction procedure, and for the Vaisala FS11 diffusometer used by Hanrieder *et al.* [1]. For all instruments we rely on the information provided in the manufacturer technical description documents. The VPF710 emits radiation at 880 nm and measures in the 39-51° scattering angular range. The FS11 also runs in near infra red (875 nm) and measures at 42° scattering angle. The DF20+ runs at 550 nm and measures in the 20-50° scattering angular range.

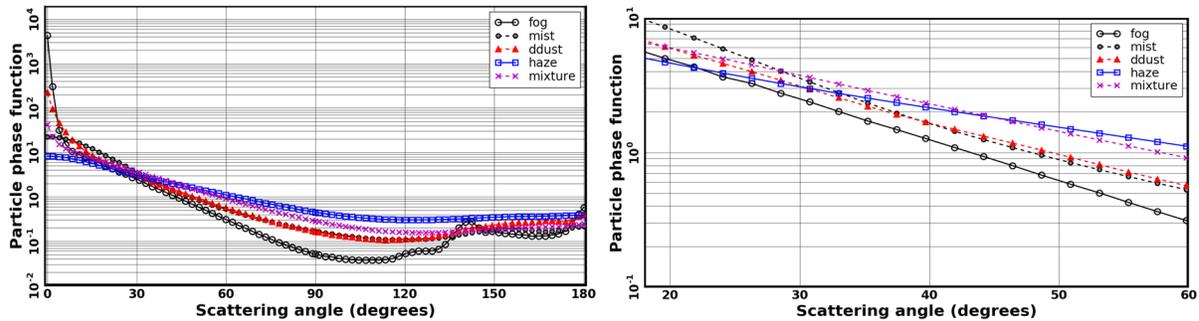


FIGURE 1. Particle phase functions (normalised) computed at 880 nm with Mie theory for haze (composed by 'dry' aerosols), mist (both dry and hydrated aerosols), fog (dry, hydrated aerosols and droplets), and desert dust ('ddust').

The Biral Manual [3] claims that the VPF710 is adapted to estimate the atmospheric extinction of visible light in both fog and haze conditions, thanks to the compensatory spectral and angular corrections (K_{θ} . K_{λ}), which are showed in Table 2a. The angular factor F_{θ} is larger for fog than for haze. Indeed the Mie theory shows that there is more scattering by aerosols than by fog between 39 and 51° (Fig. 1), for equivalent scattering coefficient (phase functions are normalised). Consequently, the angular correction factor K_{θ} is smaller than 1 for haze. On the contrary, haze scatters more efficiently at 550 nm than at 880 nm and the spectral correction factor K_{λ} is larger than 1. Eventually they indeed both partly compensate and the resulting correction factor is close to 1. Biral neglecting the aerosol absorption correcting factor, the correction would be only of 8% for haze.

Such an impact smaller than 10% could be acceptable for airport operations in fog and thick haze conditions, however for solar resource estimate for CSP, better quantitative precision is required and we want to correct the measurements according to variable aerosol conditions. Indeed Biral shows compensatory corrections for only one haze model, while aerosol properties are highly variable on Earth. In CSP environments, aerosols can be mixtures of desert dust of various main size, with local and transported pollution, in various proportions.

The Mie computations with our fog and haze microphysical models give a resulting correcting factor of 45% (Table 2a). Our models may be significantly different to the Biral models, with Mie F_{θ} of 13.7 and 6.7 for fog and haze, resp., instead of 7.7 and 4.5 [3]. However, we agree with Biral for K_{θ} . The largest difference occurs in K_{λ} . We checked that Mie $K_{\lambda}=1.85$ corresponds to a mixture of haze and desert dust (or of haze and mist) generating an Ångström exponent of 1.28. For this mixture, we confirm that Mie shows that K_{θ} . K_{λ} is indeed very close to 1. With our haze model, correction is at least 40% for the three different diffusometers. However the measurement must be increased for the two near infra red diffusometers while it must be decreased for the visible DF20+ (Table 2a).

Moreover, computations for a typical model of desert dust shows that the range of the correcting factor can be large. Indeed K_{tot} is 0.80 for desert dust (Table 2b) and 1.45 for haze. Consequently for solar resource assessment in CSP projects, it is advised to make precise computations of the correcting factor for the varying aerosol nature.

TABLE 2b. As Table 2a but for our computations for desert dust.

instrument	F_{θ}		K_{θ}	K_{λ}		K_{θ} . K_{λ}	K_{abs}	K_{tot}
	fog	desert dust	desert dust	fog	desert dust	desert dust	desert dust	desert dust
Biral VPF710	13.7	9.6	0.70	0.96	1.06	0.74	1.08	0.80
Vaisala FS11	70.5	51.6	0.73	"	"	0.77	"	0.84
Degreane DF	4.6	3.9	0.85	/	/	/	"	0.92

COMPUTATION OF THE CORRECTING FACTORS FOR THE VPF710 DIFFUSOMETER AT OUARZAZATE

The AERONET Data Bases

The closest AERONET station to Midelt, where a Biral VPF710 diffusometer will be set up, is Ouarzazate, which is also at high altitude in the High Atlas chain. Level 2.0 data are available from February 2012 to October 2015, when 3959 size distributions $n(r)$ are inverted but only 201 values of the refractive index are retrieved for the aerosol optical thickness (AOT) > 0.40 (Table 3). Indeed AOT was 0.56 ± 0.34 at 870 nm for the refractive index data base while it was 0.11 ± 0.15 for the larger $n(r)$ data base. Consistently, the Ångström exponent was 0.16 ± 0.07 in the refractive index data base but 0.64 ± 0.34 in the $n(r)$ data base.

The mean refractive index at Ouarzazate was $1.45 \pm 0.03 - 0.005 \pm 0.002i$ at 440 nm, and $1.47 \pm 0.03 - 0.002 \pm 0.001i$ at 670-870 nm (Table 3). The spectral dependence of the aerosol single scattering albedo is strong between 440 and 670 nm according to AERONET: ω_0 was 0.89 ± 0.02 at 440 nm and 0.96 ± 0.02 at 670-1020 nm.

The correcting factors at Ouarzazate are computed for the VPF710 ($\lambda=880$ nm and $\Theta=39-51^\circ$), K_{λ} for the conversion to 550 nm, and K_{abs} at 550 nm, with the refractive index m of $1.45 - 0.005i$ and $1.47 - 0.002i$ (Table 3). It is considered that m does not depend on the aerosol size. Also, the spectral dependence of the real part of m being small, we use a constant value at all wavelengths to compute both K_{θ} and K_{λ} . Moreover, as we do not know the changes in m for the $n(r)$ data base, we consider a constant refractive index with time. We also provide a sensitivity

study with other values of m : 1.40-0.005i, 1.50-0.005i, 1.45-0.001i and 1.45-0.010i. As a constant value of m with time is used, we can not compute K_{abs} for the $n(r)$ data base. We consequently compute K_{abs} using the AERONET estimate of $\tau_0(440-670 \text{ nm})$ available in the restricted m data base (Table 3).

Validation of the Computations

We checked that our computations with the Mie theory could reproduce AERONET AOT , α and τ_0 . The root mean square (RMS) difference in AOT between AERONET observation and Mie computations was only 0.013 for mean AOT of 0.11-0.14. Little variations of AOT can have strong impact on α and the RMS difference reached 0.18 in α but the agreement is nevertheless satisfying in terms of average (Table 3). The large RMS difference can be partly caused by the approximation of a constant value of the refractive index.

Since the imaginary part of the refractive index is constant, Mie-computed τ_0 is little varying in time, with ~ 0.01 standard deviation. Also, the mean Mie-computed τ_0 in the refractive index data base was close to observations at 440 nm with $m=1.45-0.005i$ and at 670 nm with $m=1.47-0.002i$ (Table 3).

TABLE 3. Aerosol optical properties at Ouarzazate in 2012-2015, according to Level 2.0 AERONET, for the aerosol size distribution $n(r)$ data base (3959 inversions), and the refractive index m data base (201 retrievals for $AOT > 0.40$), and for two values of m . The correcting factors are also given for the $n(r)$ data base and the Biral VPF710 instrument.

	AERONET data bases	Mie-computations	
		1.45-0.005i	1.47-0.002i
Value of m for computations		1.45-0.005i	1.47-0.002i
Number of inverted $n(r)$	3959		
$AOT(440 \text{ nm}) / AOT(870 \text{ nm})$	0.14±0.15 / 0.11±0.15	0.14±0.15 / 0.10±0.14	0.14±0.15 / 0.10±0.14
α	0.64±0.34	0.66±0.36	0.68±0.38
$\tau_0(440 \text{ nm}) / \tau_0(670-1020 \text{ nm})$	/	0.91±0.02 / 0.91±0.02	0.96±0.01 / 0.96±0.01
$\tau_0(550 \text{ nm})$	/	0.91±0.02	0.96±0.01
$K_\theta(880 \text{ nm})$	/	0.65±0.07	0.64±0.06
K_λ	/	1.37±0.29	1.38±0.28
$K_{abs}(550 \text{ nm})$	/	1.10±0.02	1.04±0.01
K_{tot}	/	0.96±0.10	0.90±0.10
Number of m retrievals	201		
$AOT(870 \text{ nm})$	0.56±0.34	0.53±0.33	0.54±0.33
α	0.16±0.07	0.15±0.08	0.15±0.08
$\tau_0(440 \text{ nm}) / \tau_0(670-1020 \text{ nm})$	0.89±0.02 / 0.96±0.02	0.88±0.01 / 0.91±0.01	0.94±0.01 / 0.96±0.01
$m_R(440 \text{ nm}) / m_R(670 \text{ nm})$	1.45±0.03 / 1.47±0.03		
$m_I(440 \text{ nm}) / m_I(670 \text{ nm})$	0.0052±0.0016 / 0.0023±0.0013		

Averaged Values of the Correcting Factors

A sensitivity study shows that the correcting factors are sensitive to both the real m_R and imaginary parts m_I of the refractive index. For m_R decreasing from 1.50 to 1.40, the mean K_θ is increased by 0.05, K_{abs} by 0.01, K_λ is on the contrary decreased by 0.05, and eventually K_{tot} is increased by 0.04. For m_I increasing from 0.001 to 0.010, K_θ is increased by 0.03, K_{abs} by 0.16, K_λ is unchanged, and eventually K_{tot} is also increased by 0.18.

According to observations at Ouarzazate, K_θ was $\sim 0.65 \pm 0.07$ for the $n(r)$ data base, and K_λ was $\sim 1.37 \pm 0.29$, for both 1.45-0.005i and 1.47-0.002i. AERONET suggests that m_I changed by a factor larger than 2 from 440 to 670

nm, but we don't know what is the refractive index at 550 nm. We could provide the average as being the most probable case: $K_{abs} = 1.07 \pm 0.02$ and $K_{tot} = 0.93 \pm 0.10$. Similar computations were done for a Vaisala FS11 diffusometer, and $K_{tot,FS11}$ was 1.00 ± 0.11 .

Correlation with the Ångström Exponent

Figure 2 shows a satisfying correlation between K_{θ} , K_{λ} , K_{tot} and the Ångström exponent α . Expectedly, K_{λ} and α are nicely correlated, with $K_{\lambda}=1$ for $\alpha=0$, increasing up to ~ 2.6 for $\alpha=2.0$. For the typical haze model described in Section 3, K_{λ} was indeed 2.8 for $\alpha=2.06$. Also the values for the typical aerosol models are consistent with the values for the AERONET-inverted size distributions, as $\sim 20\%$ correction for $\alpha=0$ and $\sim 40\%$ for $\alpha=2$.

The spread around the linear fit of K_{λ} and K_{θ} is caused by changes in the size distribution which affect the phase function but not α . The refractive index being considered constant with time, K_{abs} is not dependent on α .

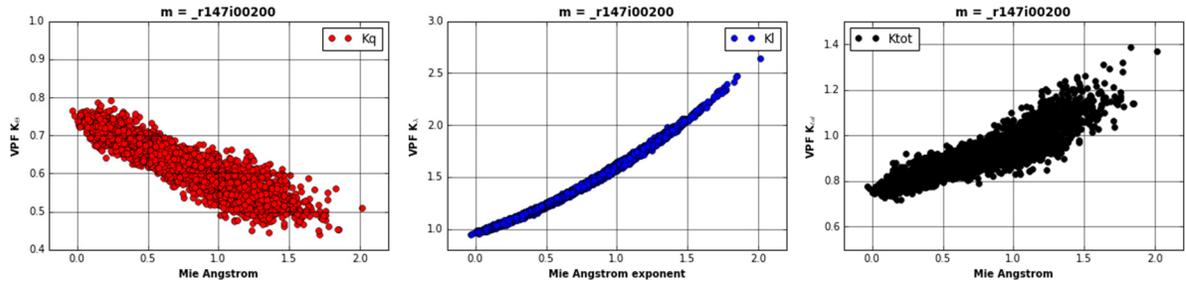


FIGURE 2. Correlation between the correcting factors and the Ångström exponent, all computed with Mie theory for $m=1.47-0.002i$ and the Biral VPF710: K_{θ} (left) at 880 nm, K_{λ} (center) and K_{tot} (right).

Both K_{θ} and K_{tot} can be approximated by a linear relationship as:

$$K_{\theta} = 0.80 - 0.17 \alpha \quad (10)$$

$$K_{tot} = 0.80 + 0.27 \alpha \quad (11)$$

The parameterisation of Eq. 11 is tested. $K_{tot,VPF710,param}$ was 0.97 ± 0.10 for the $n(r)$ data base, with $\alpha=0.63 \pm 0.36$, close to the Mie computed K_{tot} (Table 3). For the original Level 2.0 AERONET AOT data base ("440-870Ångstrom", 14 000 values), $K_{tot,VPF710,param}$ was 0.93 ± 0.10 and $\alpha=0.48 \pm 0.34$. An annual cycle of α was observed. $K_{tot,VPF710,param}$ was 1.07 ± 0.08 and $\alpha=1.02 \pm 0.31$ in January 2013, and $K_{tot,VPF710,param}$ was 0.84 ± 0.03 and $\alpha=0.17 \pm 0.11$ during the desert dust month of July 2013. The slant path transmittance, computed with the Beer-Lambert-Bougly law [e.g. 9], could be affected by up to $\pm 4\%$ according to the aerosol nature and the aerosol plume density.

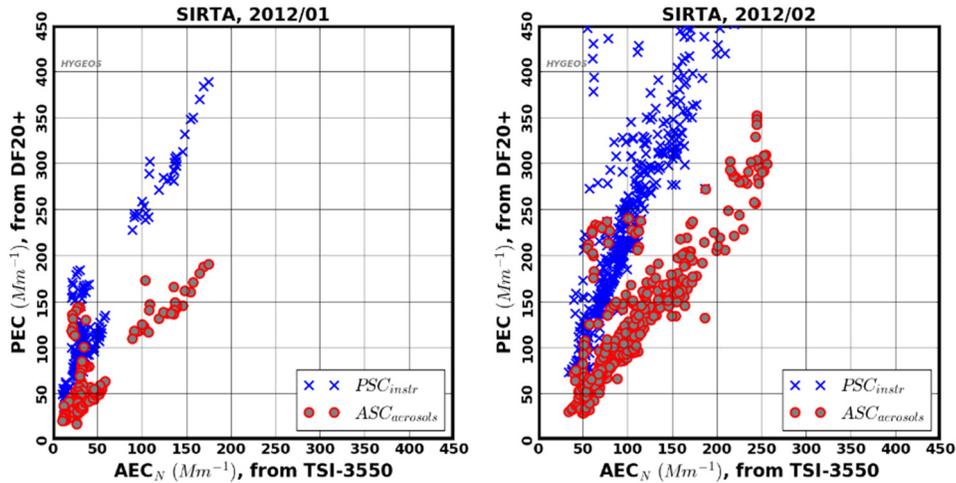


FIGURE 3. Impact of the angular correction of the diffusometer measurements acquired at SIRTA in 2012 January (left) and February (right), versus nephelometer measurements, before (PSC_{instr}) and after correction (ASC).

VALIDATION OF THE ANGULAR CORRECTION

Data were collected at the SARTA platform [8] during the 2011-2012 winter, by a TSI-3550 nephelometer, considered as the reference, and by a Degreane DF20+ diffusometer. For measurement in a scattering angular range of 20-50°, as mentioned in the Degreane technical sheets, the angular correction K_θ is 0.57 for haze and 0.85 for desert dust (Tables 2a and 2b). As too few size distributions are inverted during winter at SARTA, we need to use the empirical relationship of K_θ in function of α (Eq. 10). Figure 3 shows that the angular correction significantly improves the agreement between the diffusometer and the nephelometer measurements.

CONCLUSIONS

A Biral VPF710 diffusometer will be set up at Midelt (Morocco) close to CSP projects to get in situ proofs of the aerosol impact on the solar radiation attenuation along the slant path. We demonstrated that the measurements need to be corrected according to the aerosol nature as size and chemical composition defined by the refractive index. Three correcting factors were identified: the angular K_θ , the spectral K_λ and the absorption correcting factor K_{abs} , which are multiplied together to provide K_{tot} . They were computed with the Mie theory applied on the aerosol microphysical properties delivered by AERONET.

The mean VPF710 K_{tot} was close to 1.0 at Ouarzazate, but with large variability. The observed satisfying correlation with the Ångström exponent α shows that K_{tot} was 1.07 ± 0.08 in January 2013 ($\alpha = 1.02 \pm 0.31$), but 0.84 ± 0.03 in July 2013, during the desert dust month ($\alpha = 0.17 \pm 0.11$). The slant path transmittance could be affected by up to +/-4% according to the aerosol nature and the aerosol plume density. α is efficiently measured by a sunphotometer (e.g. AERONET) which will be also set up at Midelt to provide precise correction of the diffusometer measurements. Though, the spread in the correlation K_{tot} versus α are caused by the size distribution, then in situ measurements of the size distribution will also be performed at Midelt, with a ground-based optical particle counter.

The computations also show a significant sensitivity of K_{tot} to the refractive index, which is however difficult to observe in situ. Retrievals from the sun/sky-photometer will be used. At Ouarzazate, the refractive index was $1.45 - 0.005i$ at 440 nm and $1.47 - 0.002i$ at 670-1020 nm according to AERONET. We however do not know the mean value at 550 nm.

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