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

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1. The diffusometer: the correcting factors

Diffusometer instruments can be used to estimate the important role of aerosols in attenuating the solar radiation in the slant path of concentrating solar plants (CSP) with tower (***Fig. 1***).

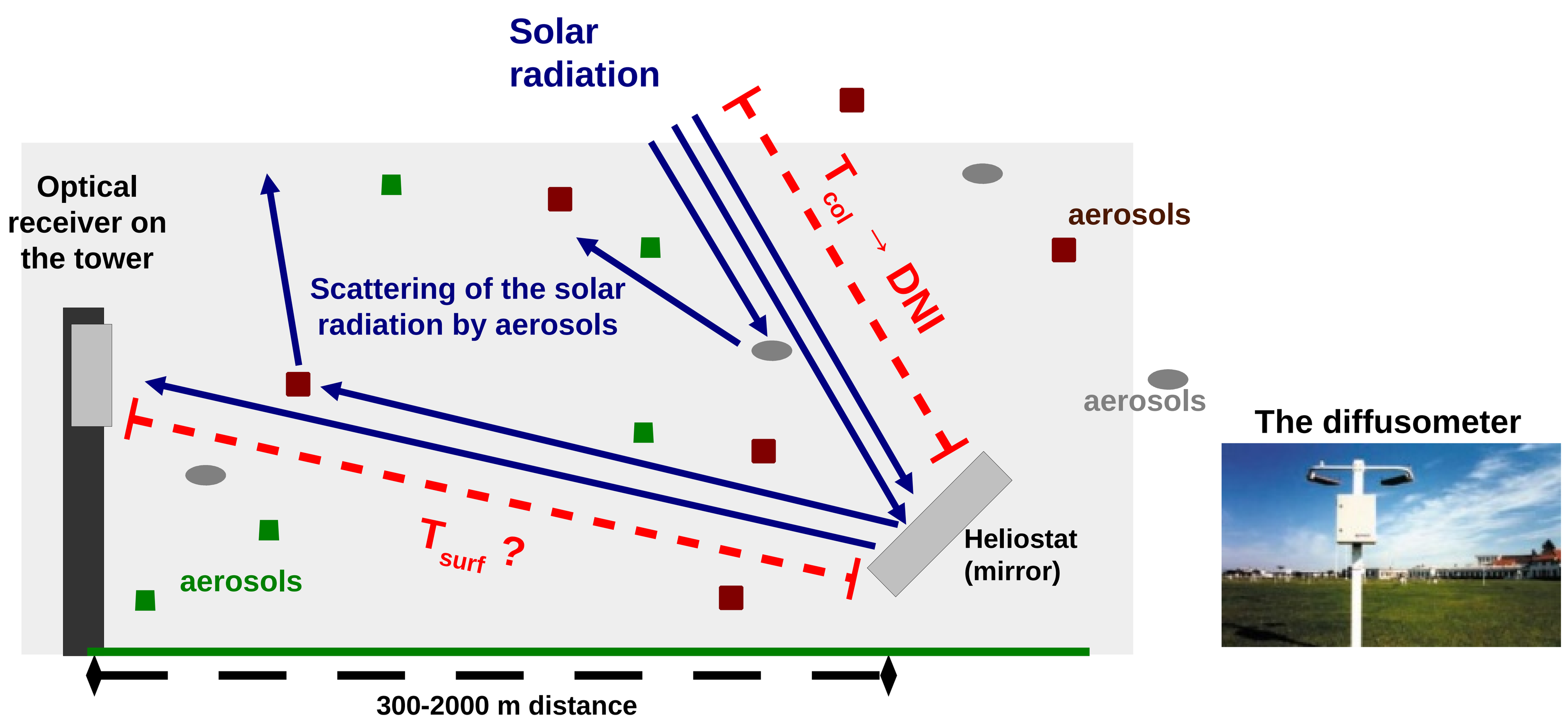

Figure 1. *Schematic view of the two optical pathways in a tower CSP, and the scattering effect by aerosols.*

The measurements (EC_{diff}), made by diffusometers running with a near infra-red light source, need to be corrected, according to the aerosol nature, by three correcting factors: angular (K_Θ), spectral (K_λ), absorption (K_{abs}). Neglecting the Rayleigh scattering at near infra red, the aerosol extinction coefficient (AEC) is:

$$AEC = EC_{diff} \cdot K_\Theta \cdot K_\lambda \cdot K_{abs} \qquad (1)$$

2. The methodology

Figure 2 shows the angular scattering probability of radiation by a fog and a desert dust plume. The diffusometer being initially conceived to monitor mist and fog, the measurement EC_{diff} needs to be converted to the raw measurement (by the $F_{\Theta,fog}$ factor) and back to the aerosol scattering coefficient (ASC) but for desert dust (by $F_{\Theta,dust}$). ASC is then extrapolated at other wavelengths (by K_λ), and then to AEC (by K_{abs}).

The aerosol microphysical properties provided by the AERONET network [1] for Ouarzazate (Morocco) are used to compute the three correcting factors for a Biral VPF710 diffusometer, measuring in the 39-51° scattering angle interval (according to the technical sheet). K_Θ and K_λ are both correlated to the Ångström exponent α, indicator of the aerosol size, decreasing and increasing with α, resp.

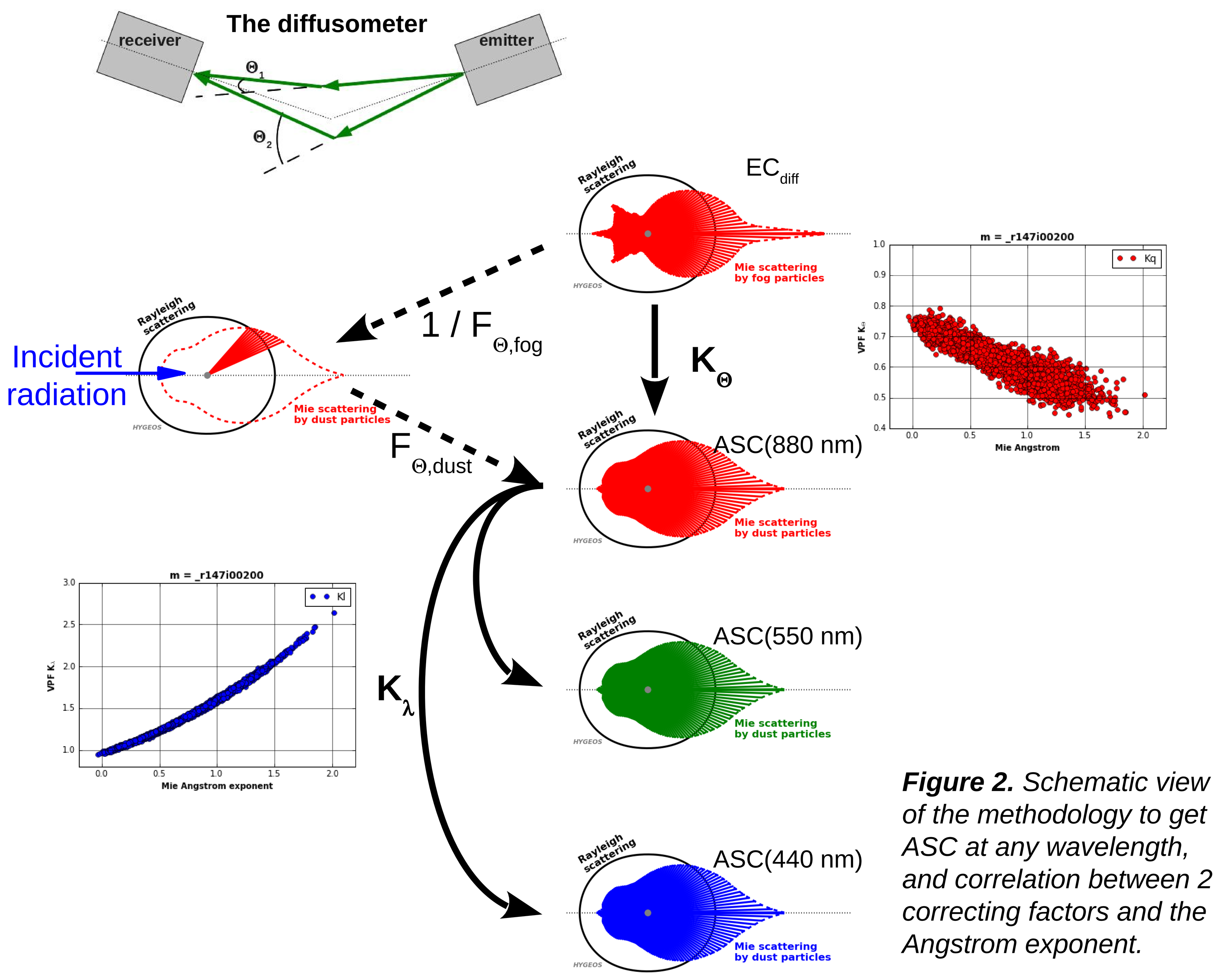

Figure 2. *Schematic view of the methodology to get ASC at any wavelength, and correlation between 2 correcting factors and the Angstrom exponent.*

3. Impact on the slant path transmittance

The slant path transmittance T is computed using the Beer-Lambert-Bouguer law for the two AERONET sites of Ouarzazate and Masdar Institute (UAE). The correction $\Delta T = T_{diff} - T_{corr}$ is showed in ***Figure 3*** for different initial estimates of T_{diff} and Ångström exponent α. $\alpha < 0.5$ indicates large desert dust aerosols, $\alpha > 1.5$ smaller pollution aerosols and $\alpha \sim 1$ mixture of desert and pollution aerosols.

The impact of the diffusometer measurement correction on the transmittance varies from 0 to +4% for desert dust, according to the desert dust plume density, from 0 to -4% for pollution, and is close to 0 for desert dust-pollution mixture.

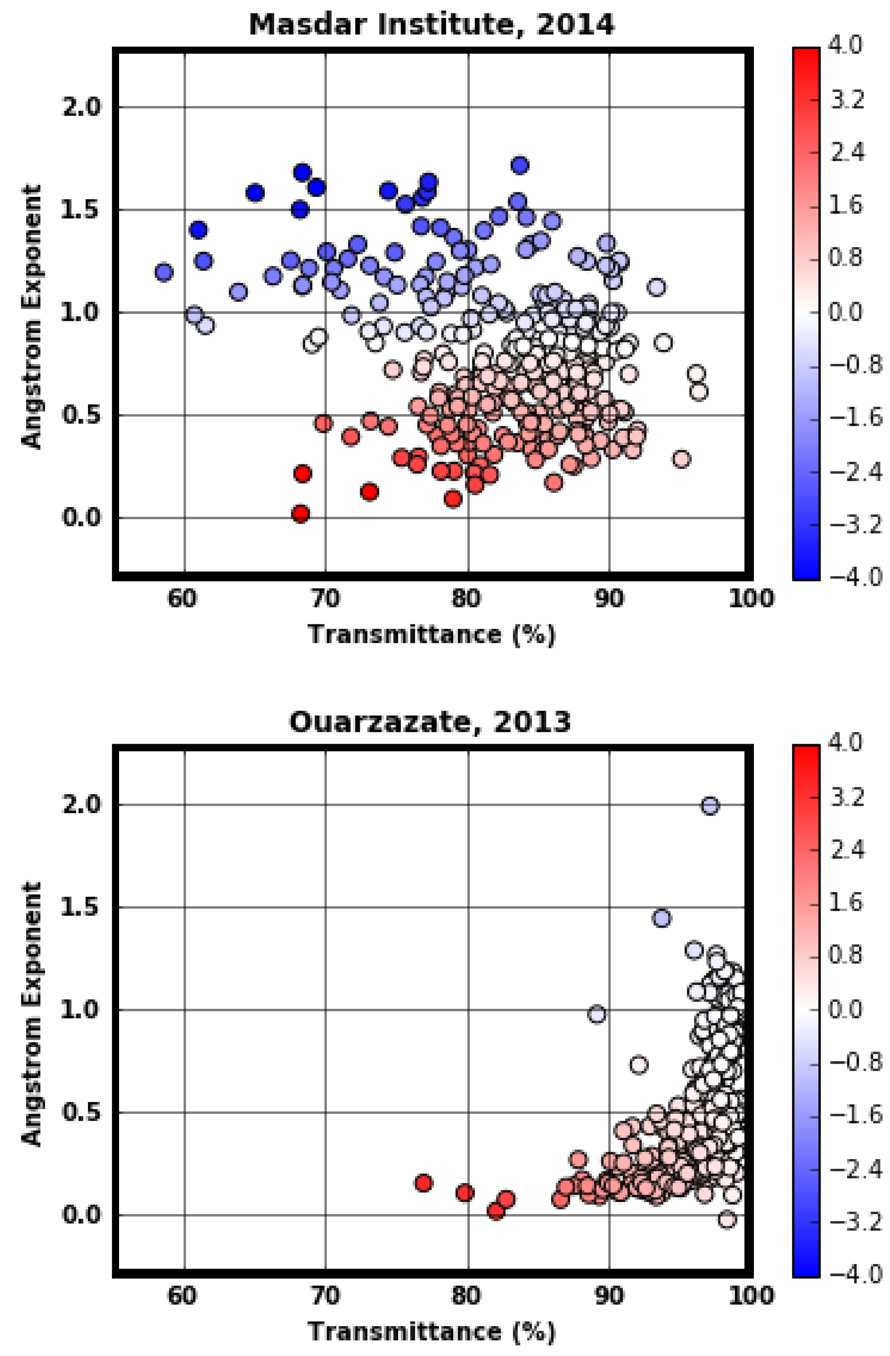

Figure 3. *Impact on transmittance, ΔT, of the correction applied on the diffusometer measurements, in function of the aerosol plume density and nature, for Ouarzazate in 2013 (top) and for Masdar Institute in 2014 (bottom).*

4. Validation

Data were collected at the SIRTA platform [2] during the 2011-2012 winter, by a TSI-3550 nephelometer, considered as the reference, and by a Degreane DF20+ diffusometer, measuring in the scattering angular range of 20-50°, as mentioned in the Degreane technical sheets. As too few size distributions are inverted during winter at SIRTA, we defined an empirical relationship of K_Θ in function of the Angstrom exponent. ***Figure 4*** shows that the angular correction significantly improves the agreement between the diffusometer and the nephelometer measurements.

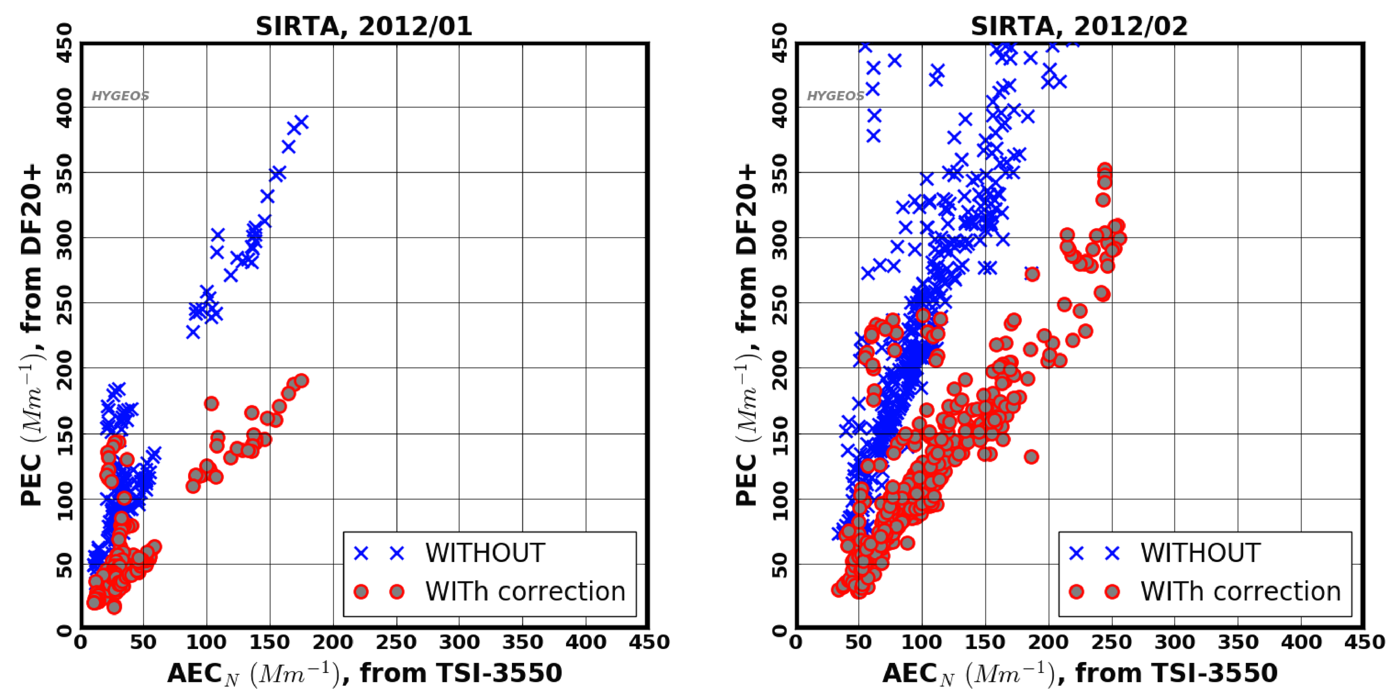

Figure 4. *Impact of the angular correction of the diffusometer measurements (PEC) acquired at SIRTA in January (left) and February 2012 (right), plotted versus nephelometer measurements (AEC_N), before (blue crosses) and after correction (red circles).*

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References

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2. M. Haeffelin et al., *Ann. Geophysic.*, 23, 253-275 (2005).