Atmospheric extinction in CSP tower plants in Morocco and Spain

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Fig.1: CESA1 tower plant on typical clear (left) and hazy day (right) at PSA, Spain.

Motivation

In solar tower plants, reflected radiation is partially lost on its way to the receiver due to atmospheric extinction. This plant yield reduction is influenced strongly by the actual aerosol and water vapor load at a certain site. It is still common to choose one of two cases representing clear and hazy conditions for yield calculations (see e.g. Fig.1) which can lead to an under- or overestimation of the expected annual plant yield of several percent [1].

Methodology + Results

1. ABC corrected MOR measurements

Extinction measurements at 3 sites in Morocco and Spain (two of enerMENA network [2]) are investigated. The ABC method of [3] has been applied to scatterometer measurements (Fig. 2). More than 3 years of 1 minute resolved data in Missour, Morocco (MIS), 2 years in Zagora, Morocco (ZAG) and 4 years at the Plataforma Solar de Almería, Spain (PSA) have been investigated.

Fig. 2: FS11 Vaisala scatterometer (left), CHP1 Kipp & Zonen pyrheliometer for direct normal irradiance (DNI) measurements (right).

Fig. 3 shows a histogram of the raw, uncorrected and the ABC corrected T_{1km} (transmittance for 1km slant range). The mean ABC corrected T_{1km} lies around 0.85 at all sites, but MIS and ZAG show a larger spread during the year around the average caused by e.g. frequent Saharan dust outbreaks reach less frequent the Iberian peninsula

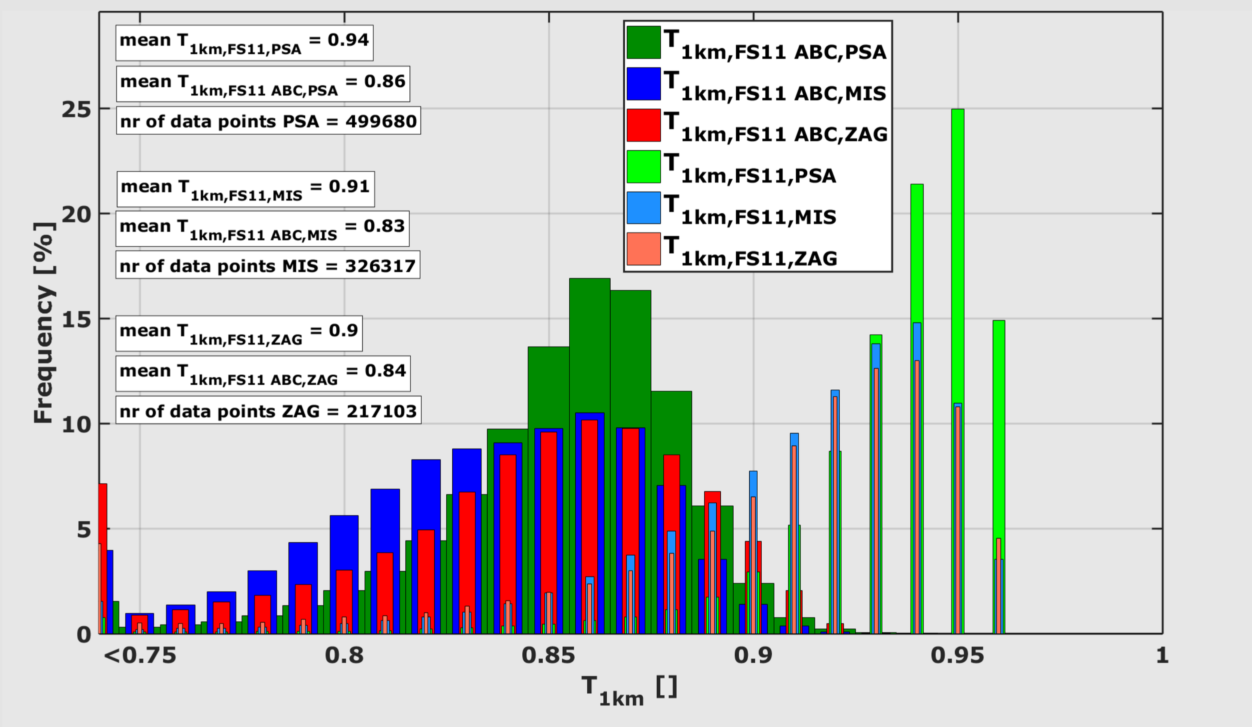


Fig.3: Histogram of all available data points of raw, uncorrected T_{1km} and ABC corrected T_{1km} for PSA, MIS and ZAG between May 2013 and August 2017. T_{1km} is the transmittance for 1km slant range.

2. Transmittance model validation

The T_{1km} from ABC corrected MOR measurements is compared to T_{1km} derived with the DNI measurement based model of [4] for MIS, ZAG and PSA. The extinction height profile is the crucial assumption of the model approach. Therefore, 3 height extinction profiles have been tested:

1. constant profile in the 1st km over ground and no aerosol particles above ("1km")
2. LIVAS profile [5] for each specific site (see Fig.4). The profiles for PSA and MIS are similar in their shape with a maximal extinction coefficient close to ground, while in ZAG a second maximum can be found in ~3.5km height . ("LIVAS")
3. constant profile below the ECWMF ERA-Interim [6] boundary layer height (BLH). Averaged grid points can be seen in Fig. 5. ("BLH")

The MBE of T_{1km} for the simple option "1km" lies between +0.013 and -0.03 and RMSEs are about 0.06 (Fig. 6). With LIVAS profiles negative MBE (-0.05 -to 0.083) are found and also the RMSEs are higher.

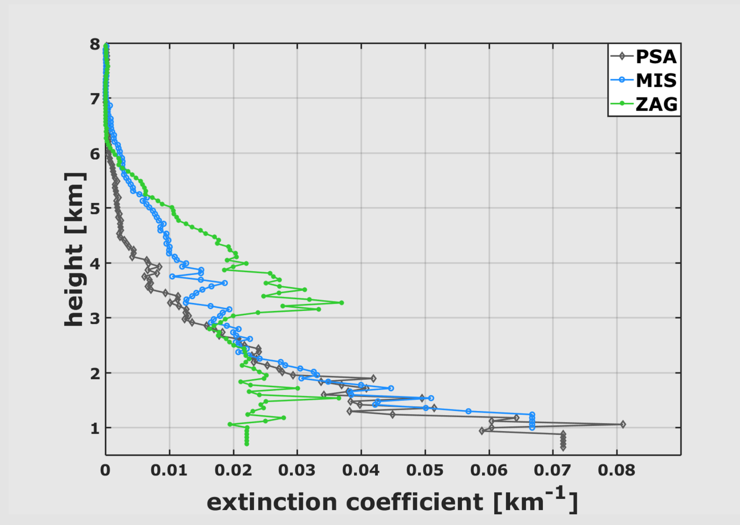


Fig.4: LIVAS extinction profiles (532nm) for PSA, MIS and ZAG.

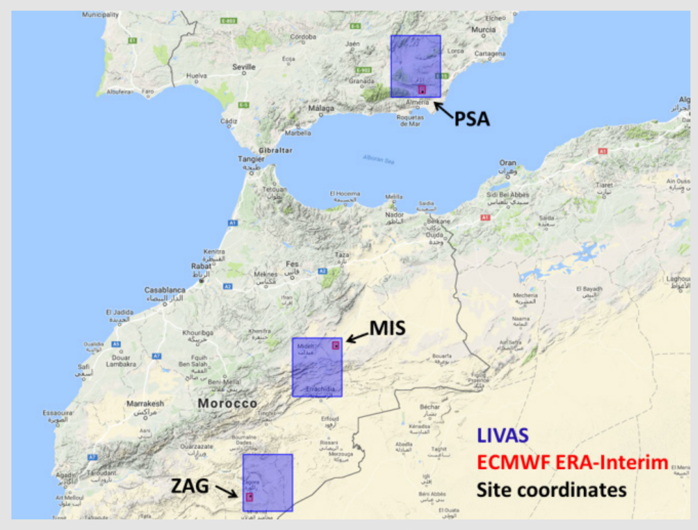
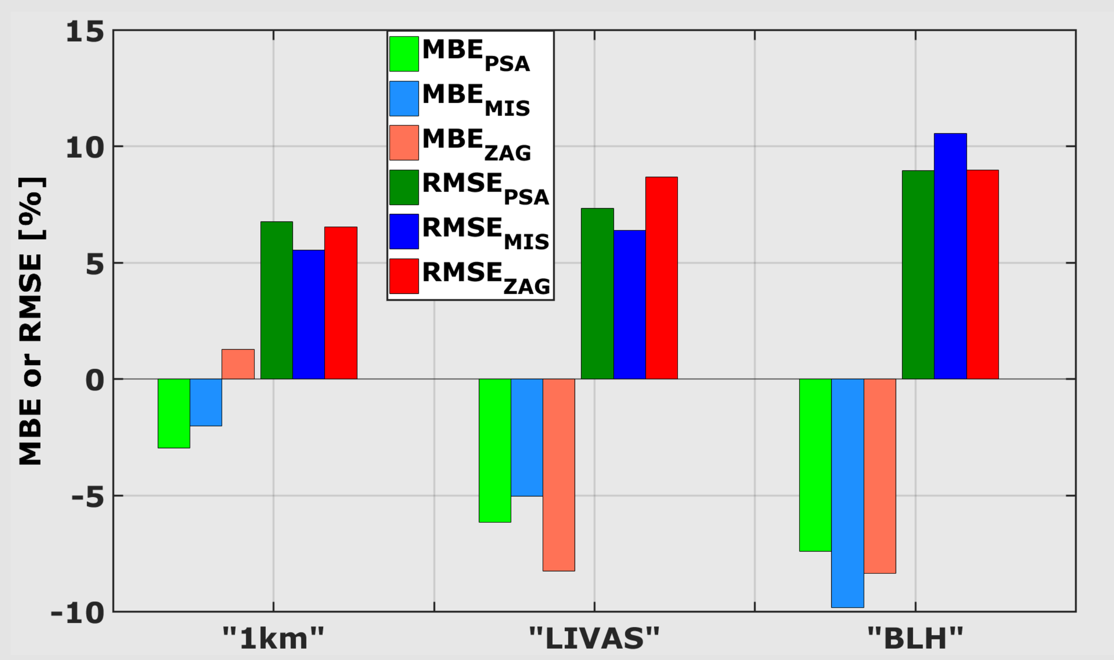


Fig.5: ECMWF BLH grid, LIVAS extinction profile grid and location of PSA, MIS and ZAG.

Fig.6: MBE (mean bias error) and RMSE (root mean square error) for the validation of the transmittance model for different assumptions for the extinction height profile. Only data points available at all sites at the same time have been evaluated.



Conclusions

- ABC corrected T_{1km} measurements show a more pronounced annual variation of atmospheric extinction at the semi-desert sites of Morocco compared to PSA.
- The validation of the transmittance model showed its applicability at various sites with T_{1km} of about 0.85. The RMSEs are around 0.06 and low MBEs between -0.02 and 0.013 for the constant profile in the 1st km over ground.
- Using LIVAS or ECMWF BLH to estimate an extinction height profile results in higher uncertainties which indicates the restricted applicability and/or accuracy of the BLH and LIVAS data.
- At clear sites with T_{1km} of ≥ 0.8 the transmittance model is considered sufficient for resource assessment. Hazy sites can be identified with the model but there additional ground measurements of T_{1km} are recommended (e.g. ABC corrected MOR measurements).

References

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