SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA16202
STSM title: Identification of aerosol model forecast products for soiling forecasting of solar plant components and analysis of the soiling model performance during intense dust events
STSM start and end date: 18/11/2019 to 17/03/2020
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PURPOSE OF THE STSM:

A physical soiling model has been developed previously by DLR to model the loss of reflectivity of solar mirrors in Concentrated Solar Power (CSP) plants. Providing information about the actual soiling state of the solar collectors is crucial for plant operators to optimize the mirror cleaning schedule concerning maintenance costs and water resources. One purpose of the STSM was the analysis of the performance of this soiling model used during intense dust events as those could cause the solar collectors to surpass a critical threshold of cleanliness.

Using the soiling model as well to produce soiling forecasts would enable further cost reductions for the maintenance of CSP plants. The model has been applied so far by using ground-based measurement data of temperature, relative humidity, wind speed and direction and aerosol particle concentrations, but is planned to be run also with dust forecasting products.

The focus of the STSM was: 1. Learn basic concepts about atmospheric models and how to manipulate their outputs (i.e. NetCDF). 2. Analyze the soiling model performance with a particular focus on intense dust events in the Middle East and North Africa (MENA) region and 3. Compare the contribution of all the bulk aerosols (including mineral dust) in the performance of the soiling model.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

During the STSM I learned about the basic concepts of atmospheric aerosol models and how to manipulate their outputs. I performed the evaluation of the operational and a new experimental MONARCH simulations (MONARCH is the in-house full chemistry and aerosol atmospheric model developed in the Earth Sicence Department of BSC) using the measurements for two sites: the Plataforma Solar de Almería (PSA, owned by CIEMAT) in Southern Spain and Missour (MIS) in Morocco (see Fig.1). While PSA is only affected episodically by African dust intrusions (mostly during the summer months), MIS can be considered as a desert site.

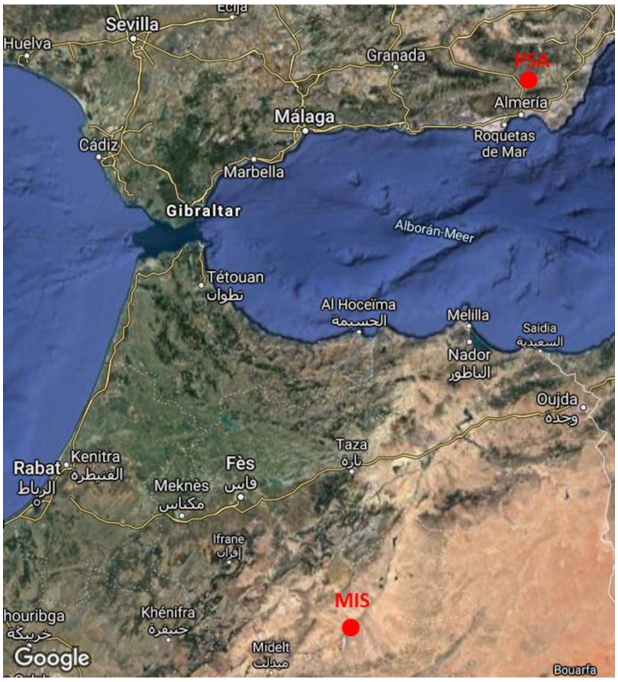

Figure 1: Location of investigated sites.

The validated measurement parameters of the years 2016 and 2017 which are used within the soiling model are ambient temperature, barometric pressure, relative humidity, wind speed and direction and precipitation. Further, the modeled aerosol concentration in the form of PM1 (particulate matter of particles with effective diameters of less than 1µm), PM2.5, PM10 and total suspended particles (TSP) has been compared to ground measurement data of an optical particle counter. Not only instantaneous values, but also moving averages and diurnal behaviours both of the measurement (at 1-minutely basis) and MONARCH model (3-hourly basis) results have been investigated and compared.

A sensitivity analysis of the soiling model concerning its input parameters was performed to estimate the effect on its accuracy dependent on the quality of the input data. Further, it has been investigated if a higher resolved information about the particle size distribution instead of PM and TSP values has an impact on the soiling model performance. The output parameter of the soiling model is the so called "Soiling Rate" which describes the changes in mirror reflectivity from one to the next day. To perform the sensitivity analysis, the measurement data which serve as input for the soiling model have been artificially manipulated and the according deviation of the soiling model results to the measured soiling rates have been analyzed.

The soiling model was then applied for 2016 with the regional MONARCH model outputs as input, considering only dust particles and considering desert dust particles together with other aerosol type particles from maritime and anthropogenic sources. The aerosols forecasts have been compared to on-site measurement data of mirror soiling. In a last step, so called "African days" have been examined in detail at PSA. African days are periods during which aerosol particles from Northern African desert regions are assumed to be transported to Southeastern Spain and increase PM2.5, PM10 and TSP values.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The comparison of MONARCH data to ground measurements shows a good agreement for temperature (Fig. 2), relative humidity, barometric pressure and precipitation in 2016 and 2017. Wind speeds are slightly overestimated during the morning hours by the model at PSA which can be observed looking at moving averages (Fig. 3) and the diurnal average.While for MIS, both wind speeds and wind directions show similar averages, mean wind directions at PSA are measured to be dominantly south-east and south-west, while the BSC model shows a dominant north-easterly component instead of south-west. These deviations can be explained by the horizontal resolution of MONARCH data and the topography around the test sites.

The comparison of aerosol concentrations shows that heavy dust events are well captured by MONARCH while the baseline aerosol load contains a large part of sea salt and other aerosol types at PSA and MIS (Fig. 4).

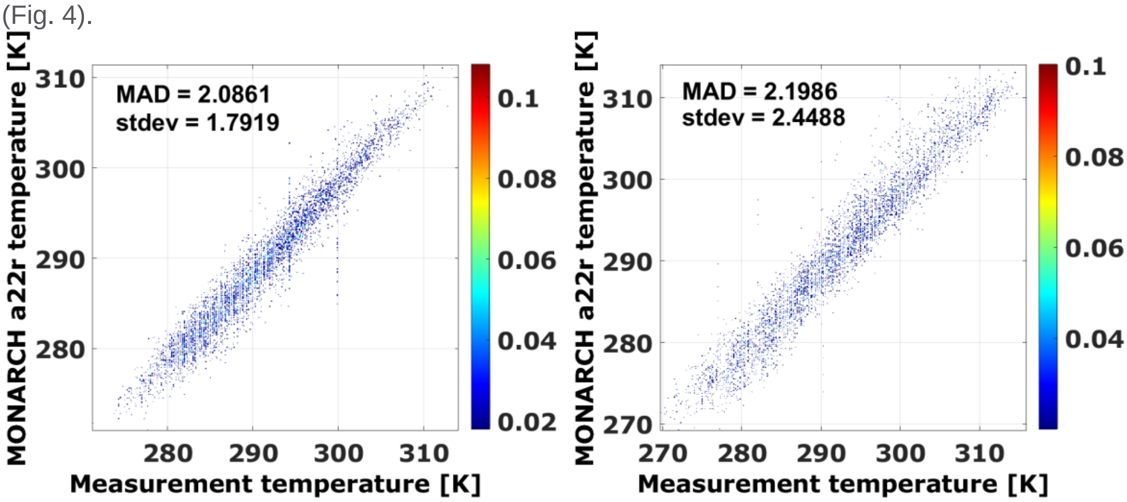

Figure 2: Comparison of measured and modeled (MONARCH a22r) temperature for PSA (right) and MIS (left).

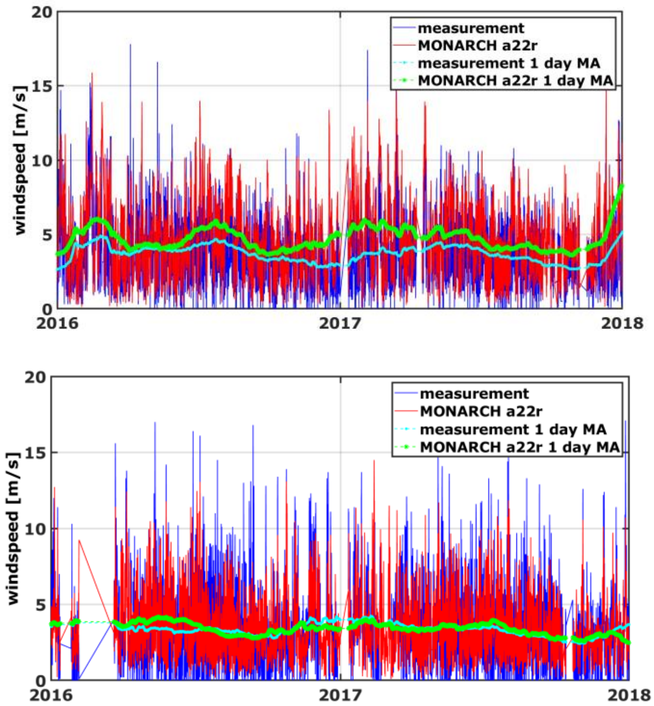

Figure 3: Comparison of wind speed and 1 day moving averages (MA) at PSA (upper plot) and MIS (lower plot).

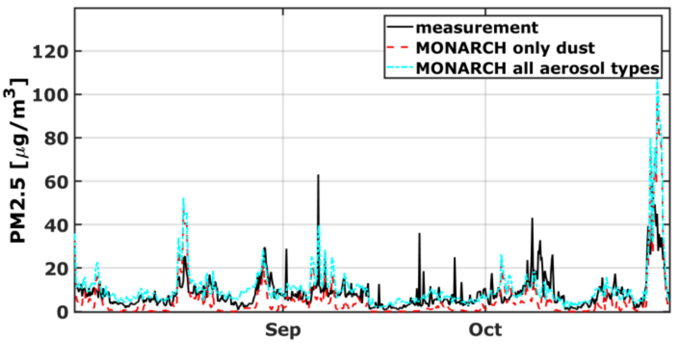

Figure 4: Comparison of measured PM2.5 (black line), modeled PM2.5 considering only desert dust (red broken line) and modeled PM2.5 considering all aerosol type (cian dotted line) at PSA for autumn 2016.

The sensitivity analysis of the soiling model results showed that the soiling model is most sensitive to the correct input of the amount of aerosol particles with effective diameters between 2.5 and 10µm (PSA) and diameters larger than 10µm (MIS). Further, the reduction of particle size resolution from 31 size bins (as in the ground measurements) to 4 size bins (PM1, PM2.5, PM10 and TSP as in the MONARCH output examined here) result in larger uncertainties of the soiling model. Therefore, it can be concluded that a higher size bin resolution of the MONARCH particle data will be used within the soiling model for future purposes.

The usage of MONARCH outputs within the soiling model shows a satisfying coincidence with measured soiling rates (mean absolute deviation (MAD) of 0.48% at PSA, Table 1). If only dust particles are considered and other aerosol types are ignored, the soiling model still performs within the expected uncertainty limits (MAD=0.49% at PSA). Also for MIS, **no considerable difference in the soiling model performance has been noticed by only considering dust particles instead of all aerosol types**. During 2016, on 146 days aerosol particle transports from Northern Africa to Southeast Spain are reported by the Spanish research institutions CSIC and CIEMAT. On 61 of these here called “African days”, daily soiling rate measurements are available. It has been found that the soiling model performance is slighty reduced if only these “african days” are considered (Table 1). This might be mainly caused by the reduced data sample size. Using the MONARCH output which only includes dust particles result in a better performance of the soiling model for African days. This result has been expected as particle transports to Spain from Northern Africa usually mainly consists of dust particles.

Table 1: Mean absolute deviation (MAD) of the modeled daily soiling rate using MONARCH output of 2016 at PSA and MIS in comparison to the measured soiling rate.

	MAD (PSA)	**Nr data points (PSA)**	**MAD (MIS)**	**Nr data points (MIS)**
2016, all days	0.48%	150	1.06%	158
2016, only „African days“	0.60%	61	-	-
2016, all days, only dust particles of MONARCH output considered	0.49%	150	1.07%	158
2016, only “African days”, only dust particles of MONARCH output considered	0.55%	61	-	-

The performed work is therefore within the following inDUST COST objectives:

- Identify and exploit dust forecast products best suited to be transferred/tailored to the needs of end-users. These findings show that daily dust forecasts can be exploited to model daily mirror soiling rates which is an important parameter needed by CSP plant operators.
- Coordinate the current R&D activities and enhance the availability of appropriate products to assist the diverse socio-economic sectors affected by the presence of airborne mineral dust. The performed study serves therefore ongoing R&D activities concerning the reduction of water usage within CSP plants. This is especially important in the MENA region with high solar energy potential, high presence of airborne mineral dust, but low water resources as dust forecasts can be used to optimize mirror cleaning strategies. Moreover, in solar plants in Southern Europe, desert dust is the most important contributor to the soiling.

FUTURE COLLABORATIONS (if applicable)

A joint publication including the results of the STSM of DLR together with BSC is planned in the future. Further, already existing collaborations within H2020 EU projects will be maintained as well as follow-up projects concerning dust products and its usage within the Solar Energy industry are targeted in the future.