SOLAR ENERGY IN AEROSOL-INFLUENCED AREAS
Surface solar radiation daily variability

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Target groups

- **Solar Energy**
- **Professional organisations and federations**
- **Regional authorities**

Relevance to the case-study requirements

Solar radiation at the surface is the key climate variable for planning purposes for solar energy power plants. A good knowledge of the statistics of the surface downward shortwave radiation (direct and diffuse) is thus required to anticipate potential energy production or to understand the level of production of existing sites. For a given site, statistics at different temporal scales are needed: long-term averaged values, seasonal cycle, daily to hourly variability and forecasts.

The approach

We propose here to use regional climate modeling tools to provide new climate information related to the needs of the solar energy sector. For a given place at a given time of the year and of the day, two main factors strongly influence the surface downward shortwave radiation: clouds and aerosols (from natural origin such as desert dust particles or from anthropogenic origin such as pollution).

Based on the ALADIN Regional Climate Model (ALADIN RCM, Colin et al., 2010), Météo-France/CNRM developed a new model called (CNRM-RCSM5) able to simulate realistically (1) all the processes leading to the daily variability of the Mediterranean aerosols (emission, transport, deposition) and (2) the high-frequency interaction between the aerosol field and the solar and infra-red radiations. Note in addition that the cloud processes and their interactions with the solar and infra-red radiations were already included.

We illustrate the capacity of the model to reproduce the aerosol field in a given location in Figure 1 (bottom). Period (June-July 2012) and location (Murcià, Spain) were chosen based on stakeholder needs, for observation availability reasons and because Summer is the season when dust aerosols are frequently transported over southwestern Europe. Figure 1 shows that the model is able to reproduce the daily variability of the aerosol field with a weak bias, a good standard deviation and a relatively good temporal correlation. Four major aerosol peaks are identified (around June 18th, June 28th, July 7th-14th and July 25-26th).

The impact for the surface downward shortwave radiation (diffuse + direct) is shown in Figure 1 (top) for the same period in Murcia for which local radiation measurements are available. The ERA-Interim reanalysis and three simulations performed with the CNRM-RCSM5 model and different aerosol representations are compared to the observations.

References:
Colin J., Déqué M., Radu R., Somot S. (2010) Sensitivity study of heavy precipitations in Limited Area Model climate simulation: influence of the size of the domain and the use of the spectral nudging technique. Tellus-A, DOI: 10.1111/j.1600-0870.2010.00467.x

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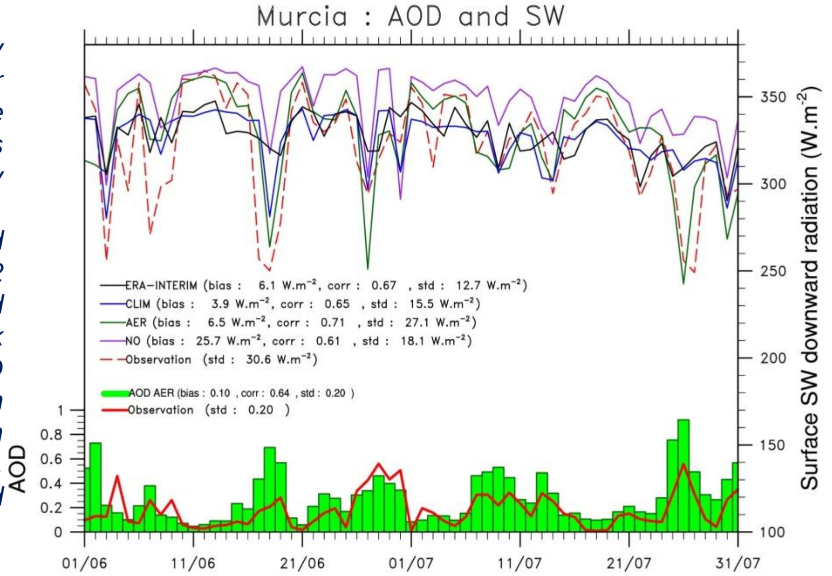
The product

Fig 1 (bottom): Aerosol Optical Depth daily time series in June-July 2012 in Murcia for satellite-based observations in red and for the CNRM-RCSM5 model in green. Statistics (bias, daily temporal correlation and daily standard deviation) are indicated in brackets.
Fig 1 (top): Surface shortwave downward radiation daily time series for June-July 2012 in Murcia for the in-situ observations in dashed red line, the ERA-Interim reanalysis in black and for 3 versions of the CNRM-RCSM5 (NO without aerosol in purple, CLIM with climatologic aerosols in blue and AER with interactive aerosols in green). Statistics (bias, daily temporal correlation and daily standard deviation) are indicated in brakets.*



The first run (NO) was performed without any representation of aerosols in the model. The bias is strong (26 W/m² averaged over 2 months) meaning that too much radiation is reaching the surface if we do not consider the aerosols. The second run (CLIM) was performed with a 2D aerosol monthly climatology. This means that the aerosol load is more realistic but constant within a month. Bias is strongly reduced but the daily temporal correlation is not significantly improved neither the daily standard deviation.
The third simulation (AER) includes the fully interactive scheme for the representation of the aerosols (see section Approach). The bias is slightly increased with respect to the CLIM run but the correlation and the standard deviation (two measures of daily variability) are noticeably improved. Note that the AER run is significantly better than the reanalysis (ERA-Interim) in terms of correlation and standard deviation proving the added-value of this new modeling tool with respect to the classical climate product used for power plant planning.

To illustrate the results, we can use the case of July 25th (a day with a strong aerosol peak), the AER run shows a decrease of the surface solar radiation by 60 W/m² with respect to all the other simulations : CLIM, NO and also ERA-Interim. With this daily lower value, the AER run behavior is clearly more realistic with respect to observations. The comparison of the simulations allows consequently to demonstrate the added-value of using the new tool to simulate of the daily variability of the surface shortwave radiation taking into account the interactive representation of the aerosols.

Making the product usable

Using this new modelling tool developed in CLIM-RUN and illustrated here for Murcia, we can produce time series (from interannual to hourly variability) of surface solar radiation in any Euro-Mediterranean location influenced by aerosols and for any period between 1979 and 2013. We are seeking collaborations to produce indices tailored for solar energy production. In addition to past climate statistics, we may produce in the future real-time forecasts and 21st century climate change projections.

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