GOBIERNO DE ESPAÑA
MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE
AEMet Agencia Estatal de Meteorología

Solar power forecasting in Spain: users' needs and recent work done in AEMET

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Outline

- Users' needs
- Use of libRadtran to forecast the effect of aerosols in solar radiation

Annual demand coverage of peninsular electricity system

Source	2012	2013
Nuclear	22.1%	21.2%
Wind	18.1%	21.2%
Coal	19.3%	14.6%
Hydro	7.7%	14.2%
Cogeneration and others	12.7%	12.5%
Combined cycle	14.1%	9.5%
Solar photovoltaic	**2.9%**	**3.1%**
Renewable thermal	1.8%	2.0%
Solar thermoelectric	**1.3%**	**1.7%**

Source: the Spanish electricity system, summary 2012, 2013 - Red Eléctrica de España

Users' needs

- The most important parameters for solar power stations are the global horizontal irradiance (GHI) and the direct normal irradiance (DNI). Meteorogical models currently give the GHI and the direct horizontal irradiance (DHI) as direct output, but not the DNI.

Although the DNI can be derived indirectly from the DHI, it would be preferable to have it as part of the output, to avoid unnecessary calculations and errors.

- It is important to increase the frequency of model runs as much as possible, to get updated, more accurate forecasts.

- Including aerosols in models is a must. Errors can be huge some days if they are not predicted.

- Predicting accurately fast fluctuations in cloudiness is not so important as forecasting correctly when big changes in the cloud cover happen.

- Users understand the uncertainty of forecasts at medium range, and they use probabilistic forecasts for planning up to 10 days ahead. Anyway they don't use them yet for the short range.

- It is not essential to get accurate results at a local level, because the prediction for electricity is made at a national level, though it would be better to minimize errors at a regional level to avoid unbalances in the electrical grid.

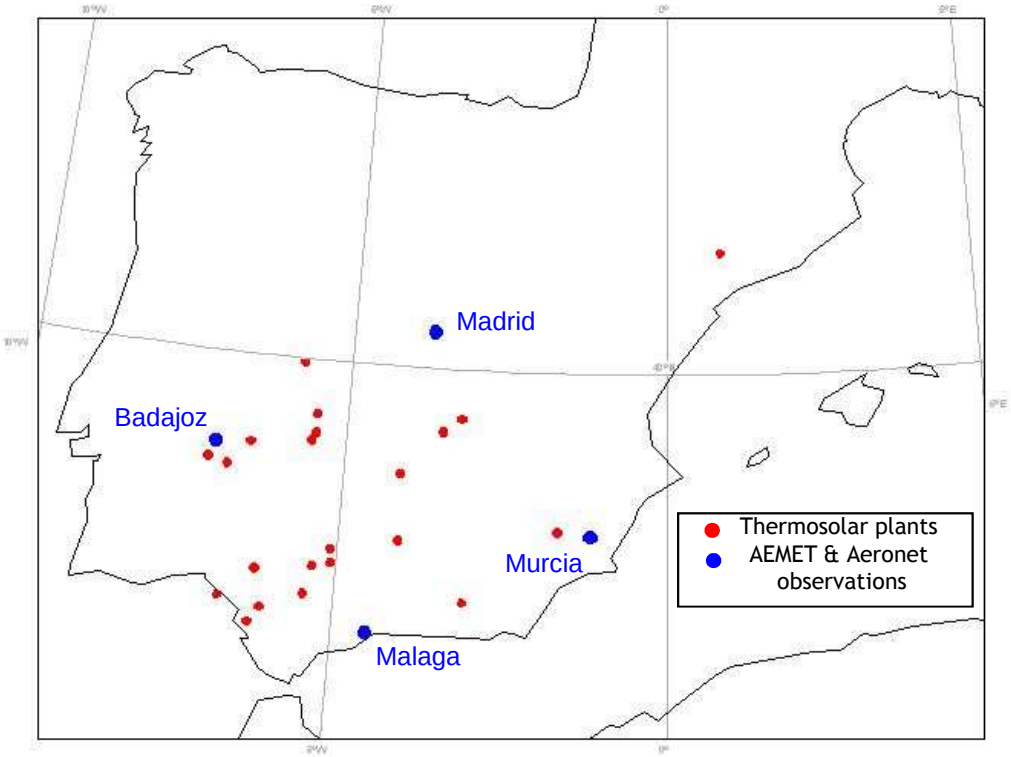
Use of libRadtran to forecast solar radiation

AEMET is currently participating in a project with the Spanish transmission system operator, Red Eléctrica de España, to improve solar radiation forecasts, focusing on the effect of aerosols in solar radiation for clear days.

Aerosols are not forecasted by models currently, so we are running the libRadtran radiation model to predict GHI and DNI. We are only parameterizing the two most important factors: aerosol optical depth (AOD), and precipitable water.

AOD forecasts are from the BSC-Dream8b model, one of the models which integrate the WMO Sand and Dust Warning Advisory and Assessment System (SDS-WAS). This model has a 0.33º spatial resolution, and produces forecasts every 3 hours.

To verify our forecasts we have chosen 4 places in the south of Spain: Badajoz, Madrid, Murcia and Malaga, where AEMET has installed pyranometers which can measure global, diffuse and direct radiation. In these locations there are also CIMEL photometers which belong to AERONET, the Aerosol Robotic Network, able to measure AOD and precipitable water.

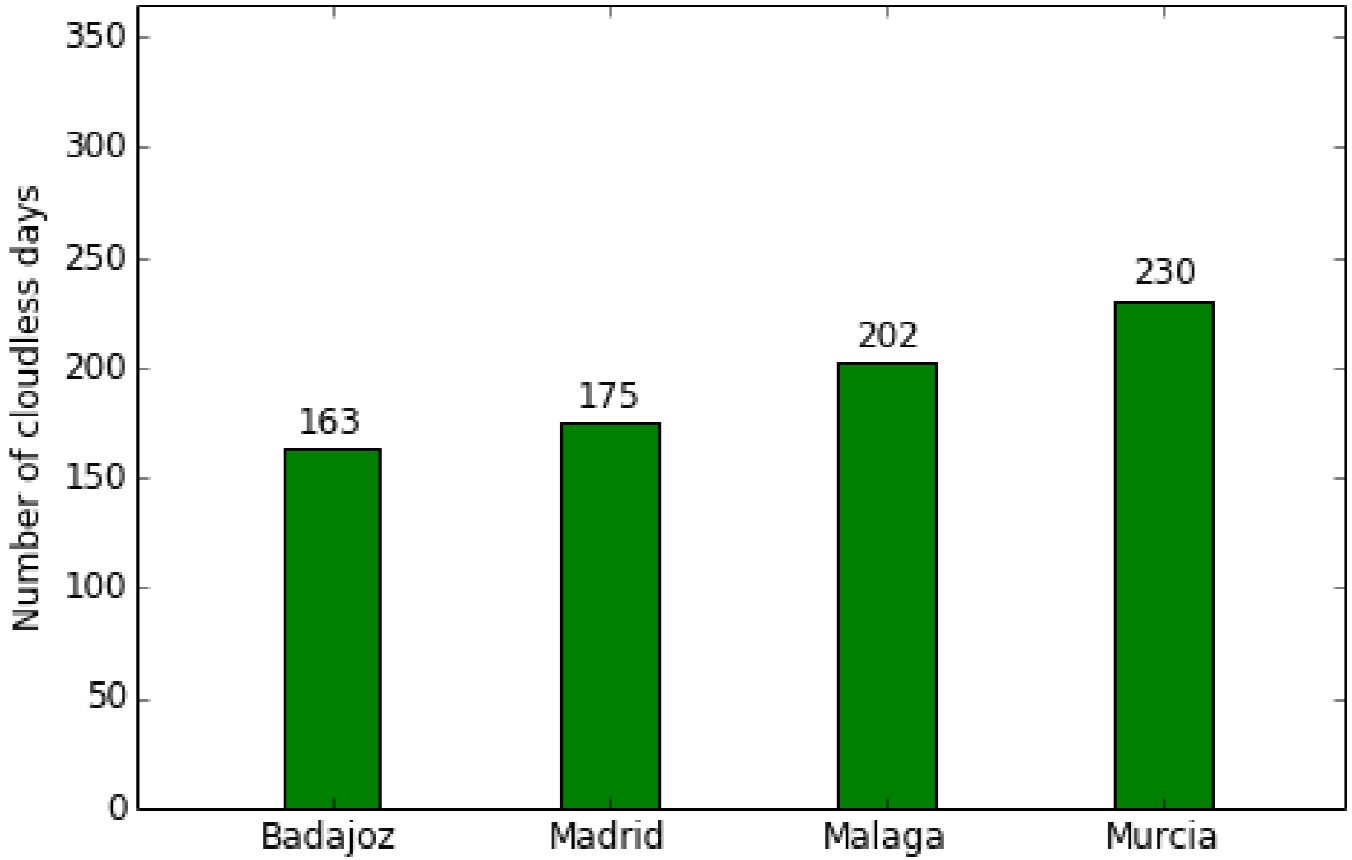


AERONET and SDS-WAS data have been interpolated to get values every hour, to be able to compare them with the other forecasts.

AERONET data is also used to filter out the times when it is cloudy. By using Level 1.5 AERONET data we can select just the periods with a clear sky.

Furthermore, we have added some additional filters to make sure the verification makes sense. For example, a particular day is included in our verification scheme only if there have been at least 4 hours without clouds during that day.

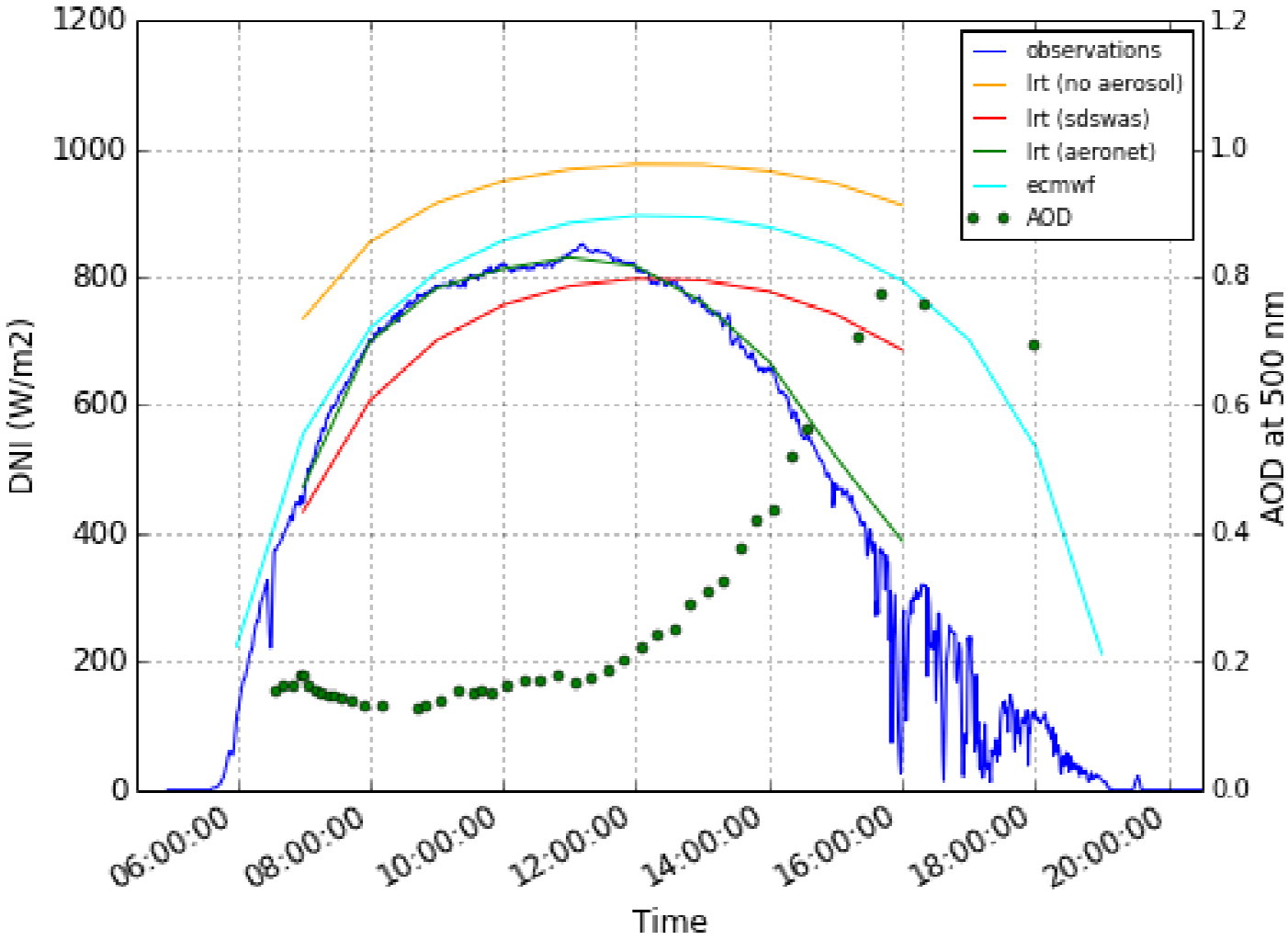
Number of days with at least 4 hours without clouds:



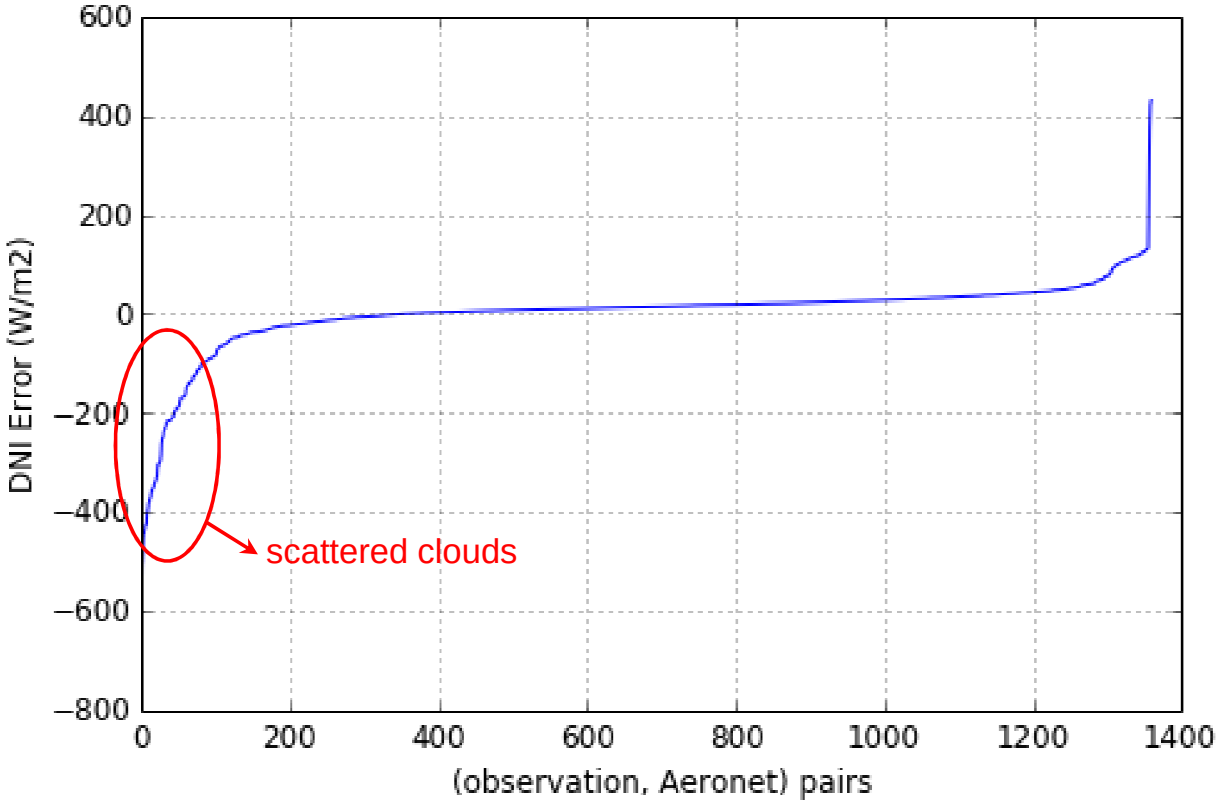
We have compared the DNI from several sources for the year 2013:

- Observations from AEMET pyranometers
- “Perfect forecasts” by libRadtran, taking the precipitable water and AOD (at 500 nm) from Aeronet observations
- Forecasts by libRadtran, taking the precipitable water from the ECMWF model, and supposing there are no aerosols at all.
- Forecasts by libRadtran, taking the precipitable water from the ECMWF model, and AOD (at 550 nm) from the SDS-WAS model.
- Forecasts by the ECMWF model (calculating the DNI from the DHI)

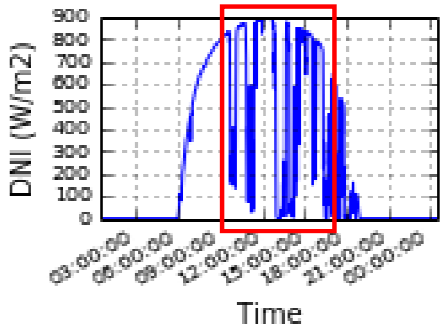
DNI curves for Badajoz station for 1st Aug 2013:

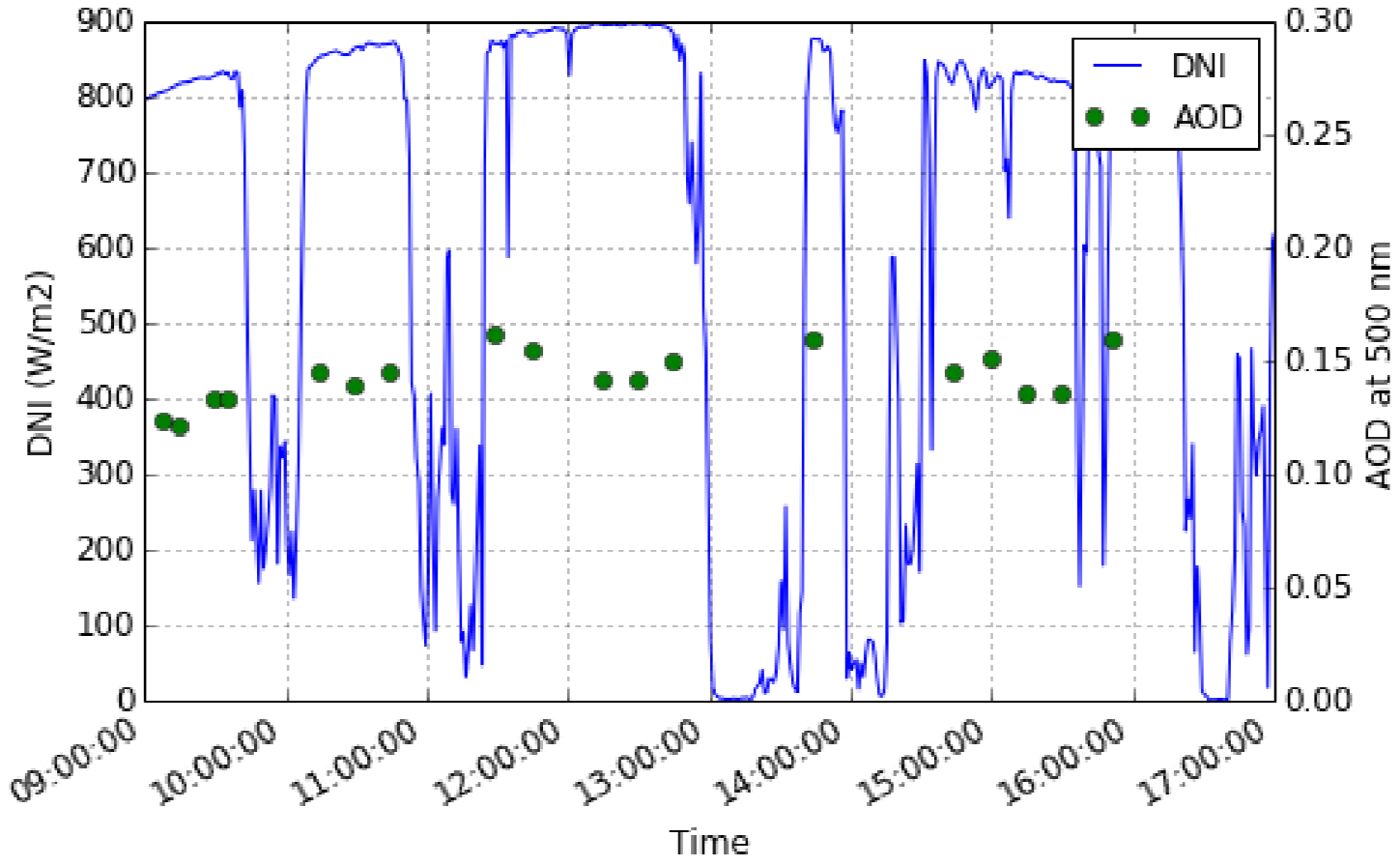


DNI error when comparing observations vs. AERONET forecasts in Badajoz, ordered by error:

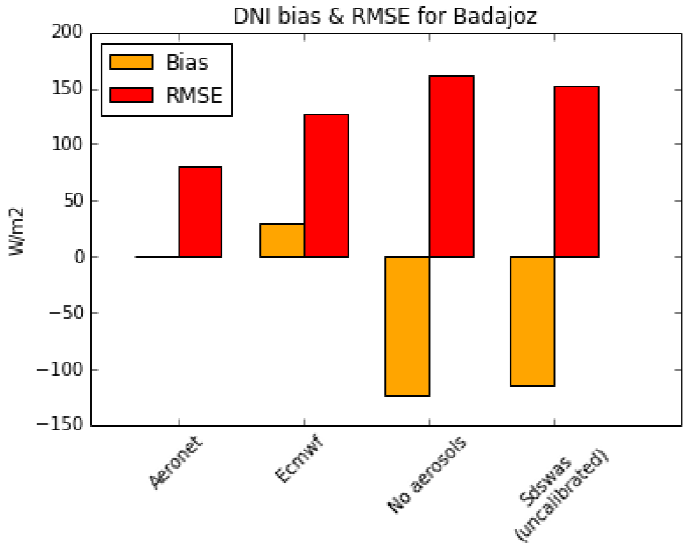


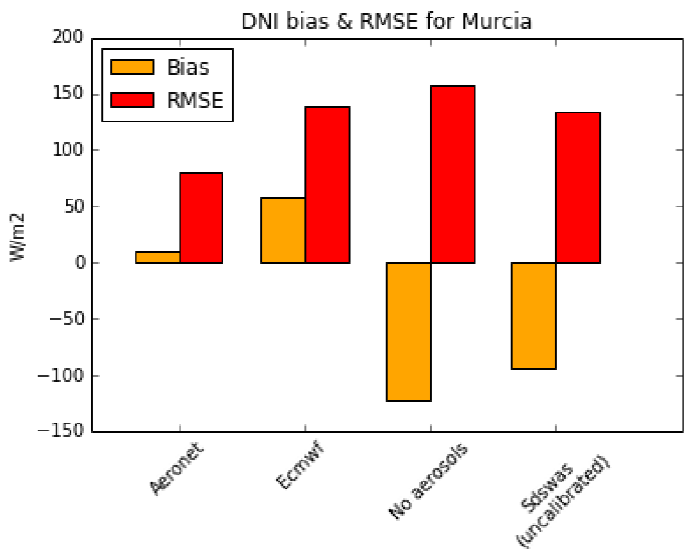
Comparison of DNI observations and AERONET AOD observations on 14th April 2013 in Badajoz:

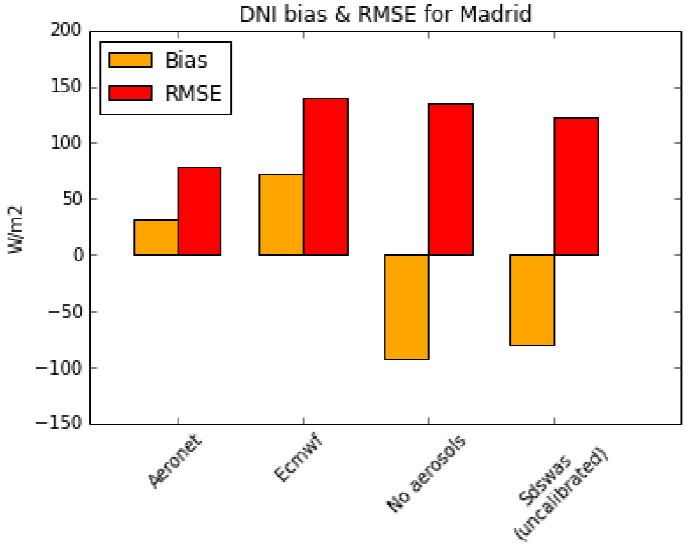




Preliminary results for the year 2013:







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Summary:

- We have developed a program based on libRadtran radiation model to forecast solar radiation for clear days. It takes into account aerosols from external sources, forecasted by dust models such as Bsc-Dream4b.

- Preliminary results seem to indicate there is some skill in this method, though more work needs to be done to confirm it.

- We still need to solve some issues related to the filters we are using to select the cloudless days, and to reduce the systematic errors which still remain.