The enerMENA Meteorological Network – Solar Radiation Measurements in the MENA Region

Fig. 1. Overview of the enerMENA stations situated in Morocco, Algeria, Tunisia, Egypt and Jordan.

Introduction

Solar irradiance and ancillary meteorological data are needed for solar resource assessment. Accurate measurements are required for comparison and adjustment of long-term satellite data. Furthermore, reliable irradiance measurements are needed to validate Direct Normal Irradiance (DNI) forecasting methods. Starting in 2010, ten meteorological stations have been installed in the Middle East and Northern Africa (MENA) within the enerMENA project (see Fig. 1, Tab. 1).

Fig. 2. Station with thermal sensors in Missour, Morocco.

Fig. 3. RSI station in Erfoud, Morocco.

Site	Country	Local partner	Station type	Altitude (m)	Lat. (°N)	Lon. (°E)	Activation
Tataouine	Tunisia	CRTEn	TS	210	32.974	10.485	Dec. 13th, 2010
Ma'an	Jordan	University of Jordan	TS	1012	30.172	35.818	Jan. 11th, 2011
Oujda	Morocco	University of Oujda	TS	617	34.650	-1.900	Aug. 18th, 2011
Cairo	Egypt	Cairo University	TS	104	30.036	31.009	June 6th, 2012
Ghardaia	Algeria	CDER	TS	463	33.465	3.780	Sep. 30th, 2012
Adrar	Algeria	CDER	TS	262	27.880	-0.274	Sep. 27th, 2012
Missour	Morocco	IRESEN	TS	1107	32.860	-4.107	May 27th, 2013
Tan-Tan	Morocco	IRESEN	TS	75	28.498	-11.322	June 5th, 2013
Erfoud	Morocco	IRESEN	RSI	859	31.491	-4.218	May 30th, 2013
Zagora	Morocco	IRESEN	RSI	783	30.272	-5.852	May 31th, 2013

Tab. 1. List of enerMENA stations sorted by their activation date. TS refers to 'Thermal Sensors' stations whereas RSI refers to 'Rotating Shadowband Irradiometer' stations.

Measurement equipment

Most of the enerMENA stations use pyrheliometers for DNI and thermal pyranometers for DHI and GHI measurement, being referred to as 'Thermal Sensors' stations (Fig. 2). The stations Erfoud and Zagora in Morocco use Rotating Shadowband Irradiometers (RSI) to derive GHI, DHI and DNI (Fig. 3). All stations measure wind speed and direction at 10 m height, temperature, relative humidity and air pressure. Data are available with up to 1 min resolution. Several stations have been and are being upgraded with enhanced instrumentation for CSP relevant parameters such as soiling, ageing, circumsolar radiation and atmospheric attenuation in tower plants.

Data quality control

Several error sources can cause reduced data quality and completeness. Common examples are broken sensors, sensor soiling, shading by surrounding objects (Fig. 4) or animals and power outages. Corresponding corrections are applied whenever possible.

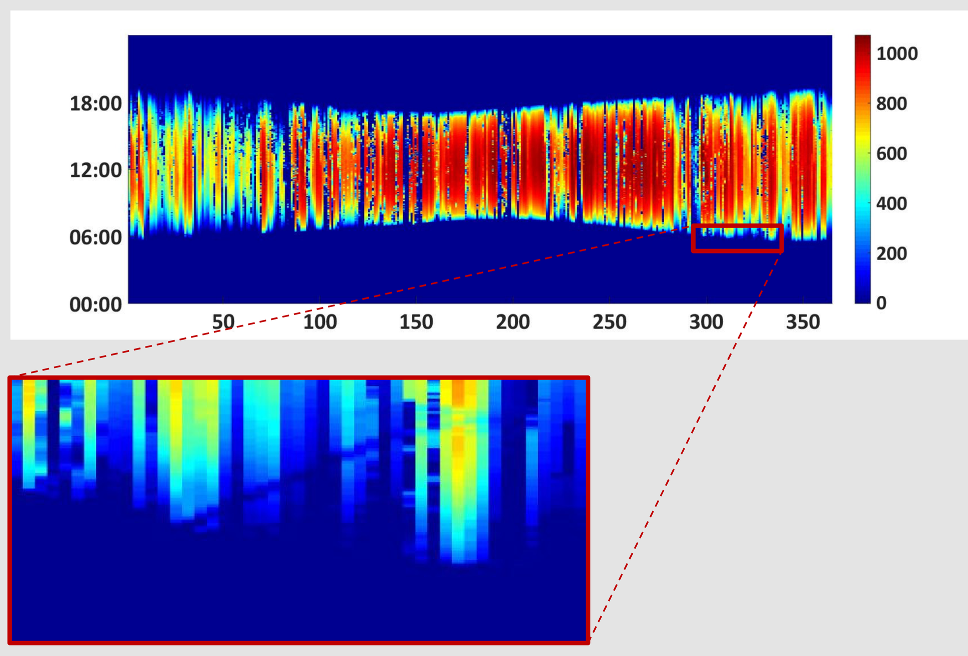
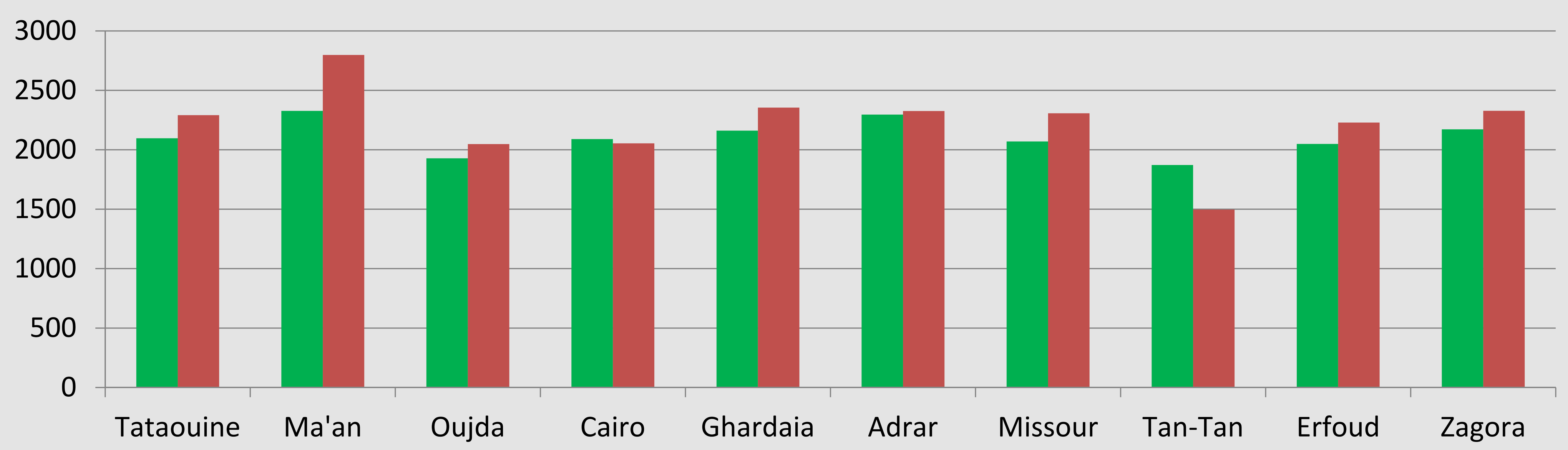


Fig. 4. Example of sensor shading in Zagora during the month May of 2015. DNI is plotted in W/m² over the day number on the x-axis and hour of day on the y-axis.

Fig. 7. Bar plot of the annual GHI (green) and DNI (red) sums in kWh/m²/year of the enerMENA stations. For every station the largest interval covering complete years has been evaluated.



Sensor soiling analysis and correction

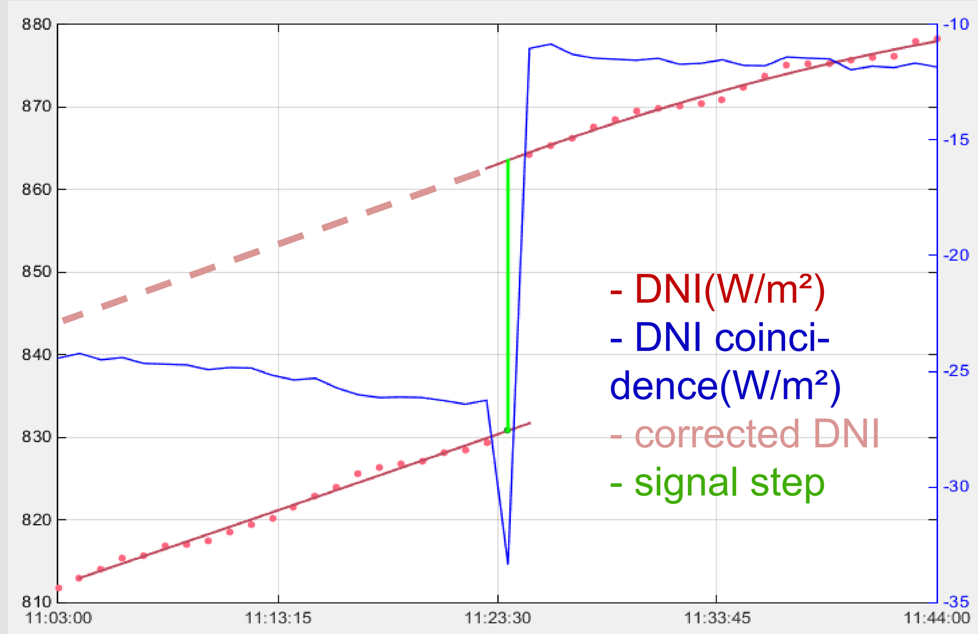


Fig. 5. Exemplary sensor soiling analysis. The DNI coincidence is the difference between measured DNI and DNI calculated from GHI and DHI.

Sensor cleaning is crucial for the data quality. The recommendation for thermal sensors was to clean them every week day. For RSIs only weekly cleaning was recommended. Errors due to soiling can be corrected assuming a linear cleanliness reduction between two cleaning events (Fig. 5). A mean cleanliness averaged over all stations with thermal sensors of 99.2 % and 99.3 % for RSI stations can be reached; however RSIs need 5 times less cleaning efforts to achieve a slightly better cleanliness as for thermal sensors, which can be of advantage at remote sites.

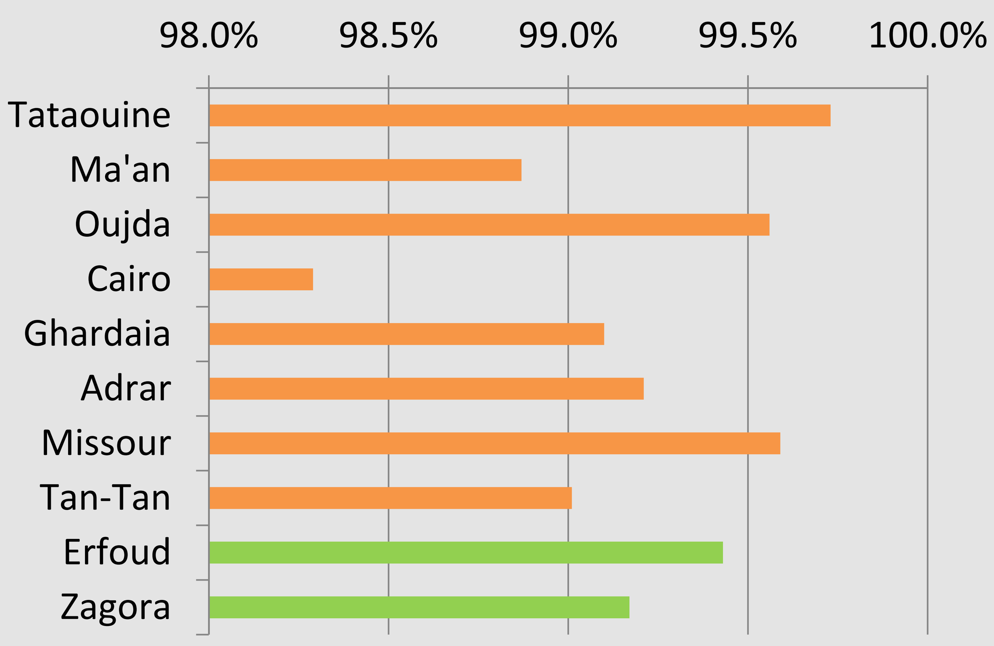


Fig. 6. Average DNI sensor cleanliness over one year (thermal sensors stations orange; RSIs green).

Annual irradiation

Average annual GHI and DNI sums have been calculated from the available measurement data (Fig. 7). Data gaps have been filled by interpolation or data from neighboring days or stations depending of the gap length following [Hoyer Klick et al., 2009]. Intervals of maximal four years have been evaluated, but for a representative analysis long term data of several decades is necessary. A site of high annual DNI sum of 2798 kWh/m² is Ma'an. The comparably low annual DNI sum of 1497 kWh/m² for Tan-Tan in Morocco is due to clouds and frequently reported fog.

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Auswärtiges Amt

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