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Comparison between meteorological re-analyses from ERA-Interim and MERRA and measurements of daily solar irradiation at surface

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ABSTRACT

This paper compares the daily solar irradiation available at surface estimated by the MERRA (Modern-Era Retrospective Analysis for Research and Applications) re-analysis of the NASA and the ERA-Interim re-analysis of the European Center for Medium-range Weather Forecasts (ECMWF) against qualified ground measurements made in stations located in Europe, Africa and Atlantic Ocean. Using the clearness index, also known as atmospheric transmissivity or transmittance, this study evidences that the re-analyses often predict clear sky conditions while actual conditions are cloudy. The opposite is also true though less pronounced: actual clear sky conditions are predicted as cloudy. This overestimation of occurrence of clear sky conditions leads to an overestimation of the irradiation and clearness index by MERRA. The overall overestimation is less pronounced for ERA-Interim because the overestimation observed in clear sky conditions is counter-balanced by underestimation in cloudy conditions. The squared correlation coefficient for clearness index ranges between 0.38 and 0.53, showing that a very large part of the variability in irradiation is not captured by the re-analyses. Within an irradiation homogeneous area, the variability of the bias, root mean square error and correlation coefficient are surprisingly large. MERRA and ERA-Interim should only be used in solar energy with proper understanding of the limitations and uncertainties. In regions where clouds are rare, e.g., North Africa, MERRA or ERA-Interim may be used to provide a gross estimate of monthly or yearly irradiation. Satellite-derived data sets offer less uncertainty and should be preferred.

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1. Introduction

The solar radiation impinging at ground level is an essential variable in solar energy. It is often called surface solar irradiance or irradiation (SSI) in solar energy, solar flux or solar exposure when dealing with measurements, and downwellling shortwave flux, or downwelling surface shortwave flux in numerical weather modelling. The present article deals with the surface daily solar irradiation, i.e., the energy received per surface unit during a day. Applications under concern are construction of time-series or maps for locating favourable areas for solar plants, pre-feasibility studies or monitoring of existing plants.

There are several means to assess the daily irradiation [10]. Ground measuring stations and satellite observations are two of them, sometimes in combination [2,29]. Re-analyses are the third means. Models for weather forecasts are used in a re-analysis mode to reproduce what was effectively observed. The SSI in re-analyses is diagnostic. It is computed by a radiative transfer model and hence depends on the representation of the whole set of radiatively active variables of the atmospheric column above the point. There are several available re-analyses. Of interest here are the MERRA (Modern-Era Retrospective Analysis for Research and Applications) re-analysis proposed by the NASA Global Modeling and Assimilation Office and the ERA-Interim re-analysis of the ECMWF (European Center for Medium-range Weather Forecasts).

Advantages of re-analyses for companies and practitioners in solar energy are the worldwide coverage, the multi-decadal temporal coverage, and their availability at no cost. Re-analysis estimates should not be mistaken with observed data in SSI because while the re-analysis method assimilates state variables such as temperature, moisture and wind, physics variables such as radiation and cloud properties derive from a model and include the uncertainty of this model. However, because of the advantages listed above in coverage, availability and costs, re-analyses are appealing to companies and several are using re-analyses in their daily work. This paper aims at establishing the quality of re-
analyses when compared to qualified ground measurements. Ref. [15] published a similar work using the MERRA re-analysis in order to estimate the climatological variability of the photovoltaic power production over Czech Republic. Our study complements their work and other similar studies in meteorology for limited areas and adds more evidence by comparing MERRA re-analyses to a large number of ground stations located in Europe, Africa and Atlantic Ocean. The limitation in geographical coverage of the present study is explained by the expertise of the authors who are dealing with this area for long. In addition, our study reports on the ERA-interim re-analysis.

To better apprehend the possible benefits of re-analyses, a comparison is also performed with the database HelioClim-1 of daily irradiation created by MINES ParisTech within the HelioClim project [3] and extensively validated against ground measurements. HelioClim-1 is a well-known database of easy access on the Web at no cost with many usages and approximately 400 requests per working day [17]. It will be seen whether the re-analyses offer better accuracy than HelioClim-1.

Refs. [4,24] have compared measurements made at several ground stations located in the same area: Mozambique, to HelioClim-1 and have found that though Mozambique is fairly homogeneous regarding SSI, the differences between HelioClim-1 and ground measurements are spatially variable. Similar conclusions were reported by Ref. [1] for North Africa (Algeria, Egypt and Tunisia) and Ref. [20] for Southern Africa. This paper examines whether re-analyses exhibit less variable errors in homogeneous climatic areas.

2. Material and methods

2.1. MERRA re-analysis

The MERRA data set [22] has a resolution of 0.5° × 0.65° with 72 vertical levels from ground to 0.01 hPa. The radiative transfer model for shortwave radiation (CLIRAD-SW) is described in Ref. [9]. MERRA includes an odd-oxygen family transport model providing the ozone concentration necessary for solar absorption. Production and loss of ozone as well as other optically active species are specified from climatology of the Goddard two-dimensional chemistry and transport model [12]. The hourly SSI estimates are horizontally interpolated using a bilinear interpolation technique, to the measurement site from the closest four surrounding grid cells with a weighting factor that is inversely proportional to the distance. Daily irradiation is computed by summing the hourly SSI estimates after multiplying them by the number of seconds in 1 h.

2.2. ERA-interim re-analysis

The ERA-Interim data set [11] has a resolution of 0.75° × 0.75° and counts 60 vertical levels from ground to 0.1 hPa. Ref. [11] noted an overestimation of 2 W m−2 of the incoming radiation at the top of the atmosphere. The radiative transfer model uses the prognostic water vapour and cloud variables (cloud cover, cloud condensed water) from the meteorological model and climatologic values for aerosols, carbon dioxide, trace gases and ozone. The SSI is estimated every 3 h. Similarly to MERRA, the SSI is bi-linearly interpolated to the measurement site. Daily irradiation is computed by summing the eight available SSI estimates after multiplying them by the number of seconds in 3 h.

2.3. HelioClim-1 database

The HelioClim Project is an ambitious initiative of MINES ParisTech launched in 1997 after preliminary works in 80’s [3] to increase knowledge on the SSI and to offer SSI values for any site, any instant over a large geographical area and long period of time, to a wide audience. The project comprises several databases that cover Europe, Africa and the Atlantic Ocean. These databases use satellite images as inputs for their creation and updating. The HelioClim-1 database offers daily means of the SSI for the period 1985–2005.

The accuracy of the HelioClim-1 database has been assessed by comparison with ground measurements made by high-quality pyranometers on a daily basis. If well-calibrated and well-maintained, these pyranometers exhibit a relative uncertainty of 10% of the daily mean of SSI at a 95 per cent confidence level [27]. Ref. [18] compared 55 sites in Europe for the period June 1994–July 1995 and 35 sites in Africa for the period 1994–1997. Ref. [1] compared HelioClim-1 data with ground measurements in Algeria, Egypt, and Tunisia. Refs. [4,24] performed a similar study for Mozambique, while Ref. [20] focused on Southern Africa. These works demonstrated that the HelioClim-1 database offers good quality for Africa, the Mediterranean Basin, and more generally for latitudes comprised between −45° and +45°. Outside these limits, the quality may decrease because of the characteristics of the satellite images used for the construction of HelioClim-1 [3] though this is not a systematic effect and local conditions may prevail. The HelioClim-1 has many usages as illustrated by published works in various domains: oceanography, climate, energy production, life cycle analysis, agriculture, ecology, human health, and air quality [17].

The Global Earth Observation System of Systems (GEOSS) is a project aiming at proactively linking together existing and planned observing systems around the world and supporting the development of new systems where gaps currently exist. The GEOSS Data-CORE (GEOSS Data Collection of Open Resources for Everyone) is a distributed pool of documented data sets with full, open and unrestricted access at no more than the cost of reproduction and distribution. The HelioClim-1 database has been identified as a Data-CORE by the GEOSS in November 2011 [14]. Previously, HelioClim-1 was open to researchers and students at no cost on a case-by-case basis. HelioClim-1 can easily be accessed at no cost on the Web (www.soda-is.com).

2.4. Ground measurements

National meteorological services (NMS) usually measure solar radiation at a few sites. Data are sent to the World Radiation Data Center (WRDC), a laboratory of the Voeikov Main Geophysical Observatory in Saint-Petersburg, Russia, under the control of the World Meteorological Organization (WMO). There, the data are archived and published. They are available only for research and educational communities of the countries participating to WMO for non-commercial activities. Quality of measurement is difficult to assess from the WRDC archives. All data are scrutinized at WRDC and quality-flagged before entering archives. No information on uncertainty other than the flag is provided with the radiation data. It is considered that these data meet the requirements set by WMO for international exchange: relative uncertainty is 5%–10% for good to moderate quality [27].

Efforts were made and are being made by the WRDC to publish data on the Web. For data prior to 1994, a joint effort by the WRDC and the National Renewable Energy Laboratory (NREL) of the USA resulted in an automatic delivery system based on e-mail (wrducible@nrel.gov). This system is very convenient though it has a few drawbacks. The major one deals with the format of data which are not always compatible with data from other sources. Refs. [19,24] have compared measurements made at several ground stations located in the same area: Mozambique, to HelioClim-1 and have found that though Mozambique is fairly homogeneous regarding SSI, the differences between HelioClim-1 and ground measurements are spatially variable. Similar conclusions were reported by Ref. [1] for North Africa (Algeria, Egypt and Tunisia) and Ref. [20] for Southern Africa. This paper examines whether re-analyses exhibit less variable errors in homogeneous climatic areas.
data returned by the automatic system to detect these cases and correct them. This may be an additional cause of error in data. For data in 1994 and after, the WRDC has set up a Java-based interface (wrdc.mgo.rssi.ru) which is very convenient to display the data but does not allow downloading data. Consequently, data have to be copied by hand or other solutions such as optical character recognition which are not fully satisfactory. Whatever the solution, it requests manual handling of numbers which may be another source of error. Getting data from the WRDC has some risk and burden. However, it is a much better situation than if one has to request data separately to each NMS.

Several stations belong to the Global Atmosphere Watch (GAW) program of the WMO and exhibit good quality, including a quality flag. Data may be downloaded from the Web site (wrdc.mgo.rssi.ru) in HTML format. Other stations belong to the Baseline Solar Radiation Network (BSRN) and exhibit high to good quality, including quality flags. Data may be downloaded from the Web site (wrdc.mgo.rssi.ru).

In the present work, only ground stations that are known to the authors for the reliability of their measurements were kept. In addition, the authors have also collected data set from the PIRATA network of buoys in the Tropical Atlantic Ocean [7]. These sites do not suffer any orographic effect and have been selected for the sake of the demonstration. Corrections are brought to measurements to take into account exposure of instruments to elements such as sea-spray, natural and anthropogenic aerosols. The corrected PIRATA data sets have been downloaded from the Pacific Marine Environmental Laboratory (PMEL) of the National Oceanic and Atmospheric Administration (NOAA) of the USA (www.pmel.noaa.gov/tao/data_deliv). Pyranometers installed on the buoys may experience accumulation of African dust, potentially leading to significant underestimation of the SSI [13]. These authors indicate that good quality is offered by buoys located in the area $-10^\circ$ to $4^\circ$. Only these buoys were kept in this study.

Only stations having more than 1000 days of valid measurements were kept in this study. 135 stations were studied.

2.5. Method for comparison

Comparison was carried on the SSI and the clearness index (KT). If $E$ denotes the daily SSI and $E_0$ denotes the daily irradiation received on a horizontal surface at the top of atmosphere, KT is defined as:

$$KT = \frac{E}{E_0}$$ (1)

The clearness index is also called global transmissivity of the atmosphere, or atmospheric transmittance, or atmospheric transmission. The greater KT, the clearer the atmosphere. Values of KT around 0.7 denote clear sky conditions. The changes in solar radiation at the top of the atmosphere due to changes in geometry, namely the daily course of the sun and seasonal effects, are usually well reproduced by models and lead to a de facto correlation between observations and estimates hiding potential weakness of a model. KT is a stricter indicator of the performances of a model regarding its ability to estimate the optical state of the atmosphere. $E_0$ is a function of the day in the year and of the solar constant which is the mean yearly value of the solar radiation received by a plane normal to the sun rays located at the top of atmosphere. $E_0$ in Eq. (1) is estimated by the model of Ref. [5]. The solar constant in this model is 1367 W m$^{-2}$, equal to that used in HelioClim-1 and very close to those in MERRA (1365 W m$^{-2}$) and ERA-Interim (1370 W m$^{-2}$).

The deviations were computed by subtracting measurements from re-analyses estimations and HelioClim-1. These deviations are summarized by the bias, i.e. the mean value of the deviations, the standard-deviation, the root mean square error (RMSE), and the correlation coefficient. Relative bias and RMSE are also computed by dividing the bias and the RMSE by the mean value of the observations for the station under concern. The deviations are computed separately for each re-analysis and HelioClim-1. Consequently, the number of samples and the mean of the observations may vary slightly.

3. Results

Figs. 1—4 are examples of scatter density plots between the in situ measurements and the re-analyses estimates for the SSI and KT, respectively, for Mersa Matruh in Egypt and Maputo in Mozambique. These stations were selected for their contrast in climate. Mersa Matruh is on the Mediterranean coast and experiences a rather Mediterranean climate with a mild rainy boreal winter and a dry, warm and rainless summer. The soil is generally sandy. The sky is very clear in boreal summer: KT is larger than 0.65. Maputo (Mozambique) is located on the Southeast coast of Africa, in the Limpopo plain. The climate is
rainy with no winter and the driest months are in austral winter (June–August). It is characterized by KT almost constant during the year, ranging between 0.53 and 0.59, with a maximum in austral winter.

In Fig. 1 (left), the cloud of points for the daily irradiation is elongated along a line which is fairly close to the 1:1 line. The correlation coefficient is large: 0.95. Most of the points lie above the 1:1 line, denoting an overestimation of SSI by MERRA. Bias is 150 J cm$^{-2}$, i.e. 8% of the mean observed value. The cloud of points is scattered. The standard-deviation is large: 225 J cm$^{-2}$, i.e. 12% of the mean observed value. One notes that the extreme irradiation for clear sky is not accurately reproduced.

Fig. 1 (right) for daily clearness index clearly shows a large discrepancy between MERRA and the measurements. The cloud of points does not follow the 1:1 line. The correlation coefficient is 0.68, meaning that only 46% of the variance, i.e. the quantity of information contained in observations, is explained by MERRA. MERRA overestimates KT with a bias of 0.05 (8%). MERRA overestimates KT for almost all values of KT but underestimates the greatest KT. The occurrence of KT comprised between 0.6 and 0.7 is much greater in MERRA than in observations; MERRA overestimates the frequency of clear sky conditions. The standard deviation is large: 0.08 (13%).

The performance of MERRA is worse for Maputo (Fig. 2) than for Mersa Matruh. The points are not elongated along the 1:1 line. There is a clear overestimation of both the daily irradiation (Fig. 2 left) and the clearness index (Fig. 2 right) though highest values in SSI and KT are underestimated. The bias is respectively 192 J cm$^{-2}$, i.e. 10% of the mean observed value, and 0.06 (10%). The standard-deviation is respectively 486 J cm$^{-2}$ (26%) and 0.13 (22%), denoting the large scattering of the points. The correlation coefficient is low: 0.71 and 0.58. It means that MERRA explains only 50% and 34% of the variance in respectively daily irradiation and clearness index. Fig. 2 (right) shows that MERRA exhibits very often KT equal to 0.7 while observed KT are less than 0.6. MERRA often predicts clear sky conditions while actual conditions are cloudy. The opposite is also true though less pronounced: actual clear sky conditions are predicted as cloudy by MERRA.

Fig. 3 (left) exhibits the SSI for Mersa Matruh and ERA-Interim. The cloud of points for the daily irradiation in is elongated along a line which is very close to the 1:1 line. The correlation coefficient is large: 0.92. Many points lie above the 1:1 line, denoting an
overestimation. Bias is 82 J cm\(^{-2}\), i.e. 4% of the mean observed value. The cloud of points is scattered with a large standard-deviation: 273 J cm\(^{-2}\), i.e. 14% of the mean observed value. The greatest irradiations for clear sky are not accurately estimated by ERA-Interim. There is a large discrepancy in daily clearness index between ERA-Interim and the measurements (Fig. 3 right). Points are not located along the 1:1 line. The correlation coefficient is low: 0.56, meaning that only 31% of the variance is explained by ERA-Interim. ERA-Interim overestimates KT as a whole though it underestimates the greatest KT. The bias is 0.03 (5%). The standard deviation is large: 0.10 (17%). A striking feature in this graph is that ERA-Interim predicts clear sky conditions while actual conditions are cloudy or cloudy conditions while the sky is clear. This overestimation in cloudy conditions compensates the underestimation in clear sky conditions, yielding a small bias overall.

As a whole, the re-analyses for the 135 stations exhibit similar behaviour with respect to ground measurements than the two examples of Mersa Matruh and Maputo, especially in clearness index. To better illustrate the findings and for the sake of clarity, a limited number of stations is discussed from now on. Six homogeneous climatic areas have been selected that offer a variety of the conditions encountered in Europe and Africa. Each contains a sufficient number of stations to assess whether the variability in error is less than that observed in HelioClim-1. These six climatic areas are: 1) Baltic Area, 2) France, 3) Eastern Europe, 4) North Africa, 5) Mozambique, and 6) Equatorial Atlantic Ocean. The 42 stations retained are listed in Table 1.

Tables 2 and 3 present the statistical results for MERRA and ERA-Interim for respectively the SSI and KT for the six areas. The results for HelioClim-1 have been added. For each climatic area, each table reports the mean of the observations for this area, the ranges of bias, relative bias, RMSE, relative RMSE and correlation coefficient observed for the set of stations located in the area. Figs. 5 and 6 exhibit the relative bias and relative RMSE for respectively the SSI and KT for the six areas and permit a visualisation of the differences between the data sets and the variability of performances within an area.

Except in few occasions, MERRA overestimates the SSI and KT. The RMSE is large in all cases, except for desert areas, when clear sky conditions prevail and as a consequence, the influence of false prediction of clear sky conditions by MERRA is of lesser importance. The correlation coefficient for daily irradiation is usually large and greater than 0.85. This is not the case at all for Mozambique or the Equatorial Atlantic where the correlation coefficient is much lower and the RMSE much greater. One may suspect the measurements. However, results of HelioClim-1 for these two areas are similar to the others. Consequently, there are other reasons for the large uncertainty of MERRA in these areas. MERRA often exhibits correlation coefficient less than 0.7 in KT (Table 3). This means that MERRA explains less than 50% of the variance in atmospheric transmissivity. A striking feature is the variability of the bias, RMSE and correlation coefficient within each homogeneous area. The worst cases are Mozambique and Equatorial Atlantic among those presented.

ERA-Interim tends also to overestimate the SSI and KT in a less pronounced manner than MERRA. The same features than those mentioned for MERRA can be observed for ERA-Interim. However, as a whole, the RMSE is greater for ERA-Interim than for MERRA (Fig. 6) and the correlation coefficient is lower. The errors in predicting cloudy situations are greater for ERA-Interim than for MERRA.

Finally, these tables report the performance for HelioClim-1 in order to situate those of MERRA and ERA-Interim. This is well illustrated in Figs. 5 and 6. Looking at these figures and Tables 2 and 3, one may observe that as a whole, HelioClim-1 exhibits less bias, less RMSE and greater correlation coefficient than MERRA and ERA-Interim. In addition, HelioClim-1 offers less variability in uncertainty than MERRA and ERA-Interim within a given area. There are exceptions, such as Equatorial Tropical Ocean (area 6) where HelioClim-1 exhibits more bias than MERRA and ERA but less RMSE.
is less for arid sites, i.e. where clear sky conditions prevail, than skies. These results are similar to the present sky conditions. The bias is larger for cloudy skies than for clear (respectively 0.04 and 0.02 for KT in Table 3). If only the

and greater correlation coefficient. The variability in bias within an area is quite often greater for HelioClim-1 than for MERRA and ERA-Interim. This is not the case for RMSE, where there is no “best” data set.

4. Discussion

The overestimation of the SSI by re-analyses has been already documented. Refs. [25,26] found a tendency of a majority of re-analyses to overestimate the SSI and wrote that deficiencies in clear-sky radiative transfer calculations are major contributors to the excessive SSI.

Ref. [28] report on MERRA compared to ground daily irradiation measurements made in the U.S.A. MERRA exhibits a positive bias of 143 J cm\(^{-2}\) and a RMSE of 400 J cm\(^{-2}\). The uncertainty is less for arid sites, i.e. where clear sky conditions prevail, than in northern sites; the bias is 20–100 J cm\(^{-2}\) and 30–150 J cm\(^{-2}\) respectively, and the RMSE is 400–500 J cm\(^{-2}\) and 300–700 J cm\(^{-2}\). Ref. [30] compare MERRA against the FLUXNET measurements in Canada and U.S.A. for monthly averages of daily irradiation. They report an overestimation of 175 J cm\(^{-2}\) for all sky conditions. The bias is larger for cloudy skies than for clear skies. These results are similar to the present findings. If all stations are merged for all sky conditions (Table 2), the overall bias is 119 J cm\(^{-2}\) for MERRA and 57 J cm\(^{-2}\) for ERA-Interim (respectively 0.04 and 0.02 for KT in Table 3). If only the

Table I

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<th>Longitude E (deg)</th>
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<td>Pirata1</td>
<td>00.00</td>
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</tr>
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<td>Pirata2</td>
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<td>1999–2011</td>
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<td>–</td>
<td>Pirata3</td>
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<td>-23.00</td>
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<tr>
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<td>Pirata14</td>
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correlation coefficient in KT and the high bias and RMSE in both SSI and KT.

Ref. [31] focus on the Arctic region where very few measuring stations are available. They report that ERA-Interim has a low bias. They found that the bias in MERRA is positive in one BSRN station (415 J cm$^{-2}$) and negative in the other one (−85 J cm$^{-2}$). No other work was found documenting the variability of the bias, root mean square error and correlation coefficient within an irradiation homogeneous area. The present study finds large variability in these quantities. Practically, it means that a post-processing correction of MERRA or ERA-Interim may not be simple. Ref. [30]. propose an empirical model exploiting 14 stations in Canada and U.S.A. for monthly averages of daily irradiation. This post-processing algorithm consists of empirical relationships between model bias, clearness index, and site elevation. Ten other stations in the same region are used for validation. As a whole, the bias is strongly reduced as well as the RMSE, without a degradation of the correlation coefficient. The two sites in Florida used for calibration exhibit a large increase in RMSE and a large decrease in correlation coefficient after correction. When dealing with annual mean of SSI, Ref. [30] reports correlation coefficient between MERRA and observations ranging from −0.50 to 0.95 before correction. The empirical correction has a tendency to improve them.

5. Conclusion

The major finding in this study is that the MERRA and ERA-Interim re-analyses often predict clear sky conditions while actual conditions are cloudy. The opposite is also true though less pronounced: actual clear sky conditions are predicted as cloudy. This overestimation of occurrence of clear sky conditions leads to an overestimation of the SSI in the Baltic Area. Finally, a striking feature is the variability of the bias, RMSE and correlation coefficient within a same area though each area is fairly homogeneous for the SSI.

The present results bring more evidence on the overestimation observed in several re-analyses as discussed in the previous section, the dependency of this overestimation with the frequency of cloudy sky conditions.
clear-sky conditions, and the necessity to take into account the
dynamics of the aerosols. Cases such as Mozambique and Equato-
rial Atlantic Ocean have not been studied in literature relating to
MERRA or ERA-Interim. The present study shows that these re-
analyses present serious drawbacks for these areas in tropical hu-
mid climate. It is further observed that stations in Ghana and in
Guiana also located in tropical humid climate exhibit similar results
than those in Mozambique. The BSNR site at De Aar in South Africa
is located in a dry climate and has similar results that those found in
Northern Africa. The number of reliable data from stations collected
in the present study is very limited in the tropical humid climate
affecting Central Africa, Equatorial Atlantic Ocean, and Northern
South America and no clear explanation may be provided on why
these areas exhibit greater uncertainty that the areas in dry climate
or rainy climate with mild winters.

To conclude, MERRA and ERA-Interim should only be used in
solar energy with proper understanding of the limitations and
uncertainties. In regions where clouds are rare, e.g. North Africa,
MERRA or ERA-Interim may be used to provide a gross estimate of
monthly or yearly irradiation. In all cases, a correction of MERRA
or ERA-Interim by a function fitted on available ground mea-
surements as shown in Figs. 1–4 will reduce the bias but not
significantly the scattering of the estimates, i.e. the standard-
deviation of the errors, and will not increase the correlation co-
efficient. There is no simple means to correct a posteriori for the
errors made in MERRA or ERA-Interim mistaking cloudy hours as
cloud-free ones. Uncertainty in MERRA or ERA-Interim is greater
than that observed in HelioClim-1. If Europe or Africa is at stake,
HelioClim-1 should be preferred to ERA-Interim and MERRA,
though limited to the period 1985–2005.

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