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Solar Radiometric Activities at De Aar, South Africa

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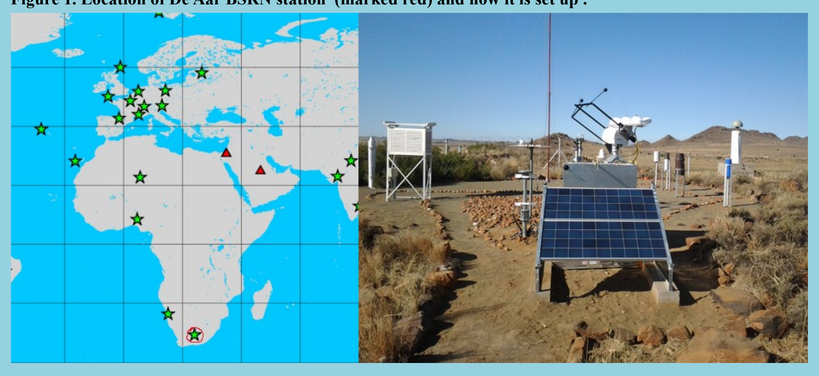
Introduction

De Aar Baseline Solar Radiation Network (BSRN) station (latitude: -30.67; longitude: 23.99; altitude: 1287 m) is located in the cold interior climatic zone in the Northern Cape province of South Africa. The open bare-area De Aar is characterized by insignificant urban development and it is thus a very clean site with an annual average diffuse fraction of 0.2 and an annual clearness index of 0.75. The area has an annual humidity of less than 45 % while mean monthly temperature ranges between 10 to 25 °C. The most dominant wind speed velocity is between 3.6 -5.7 m/s blowing from South-East direction and the sunshine duration is slightly less than 10 hours in winter and autumn and slightly above 10 hours in summer and spring. The De Aar station undergoes regular maintenance and the data is quality controlled according to (Long & Dutton, 2000) methodology. To date 40 monthly files have been submitted to the World Radiation Monitoring Center (WRMC) of which 97.8%, 97.68%, 97.72% and 98.38% for GHI, DIF, DNI and LWD respectively . These data sets exhibits a flag value of 0 therefore are of good quality.

Figure 1. Location of De Aar BSRN station (marked red) and how it is set up .



Instrumentation

Table 1: Instruments that are used to measure solar radiation parameters at De Aar .

Measurements	
Solar Radiation Parameter	**Instrument**
Direct Normal Irradiance (DNI)	Kipp & Zonen Pyrheliometer (CHP1)
Global Horizontal Irradiance (GHI)	Kipp & Zonen pyranometer (CMP21)
Diffuse Horizontal Irradiance (DIF)	Shaded Kipp & Zonen pyranometer (CMP21)
Longwave Downward radiation (LWD)	Kipp & Zonen Pyrgeometer (CGR4)
UVA & B	Kipp & Zonen UV-S AB-T

BSRN QC Analysis Results

Following the BSRN QC procedures Table 2 summarises the performance of the De Aar BRSN station

Table 2. Weighted monthly De Aar BSRN station BSRN quality check results from May 2014 to May 2018.

BSRN CODE	0	5	8	10	16	32	40
GHI	97.80	1.28	0.01	0.00	0.56	0.35	0
DIF	97.68	1.28	0.08	0.05	0.34	0.55	0
DNI	97.72	1.25	0.15	0.00	0.46	0.44	0
LWD	98.38	1.61	0.00	0.00	0.00	0.00	0
OVERALL	97.90	1.36	0.06	0.01	0.34	0.34	0

Data Validation

Daily mean observation data from De Aar was used to validate CMSAF EDR dataset as shown in Table 3

Table 3. Observation and CMSAF dataset that were compared against each other.

De Aar Observation	CMSAF EDR Satellite
Daily GHI	Daily SIS
Daily DNI	Daily SID /Cos(SZA)
Daily DIF	Daily SIS - Daily SID

The Mean Absolute Bias Error (MABE) from May 2014 to December 2017 were:

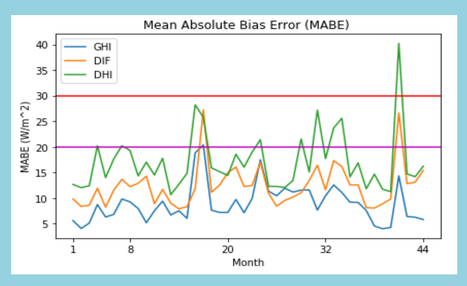
a) GHI was 8.66 W/m^2,

b) DIF was 12.12 W/m^2 and

c) DNI was 16.89 W/m^2,

Overall GHI, DIF and DHI were all below the optimal accuracy of 15 W/m^2 for GHI and DIF and 20 W/m^2 for DNI. As shown in Figure 2, the validation threshold for DHI is 30 W/m^2 while those both DHI and DIF is 20 W/m^2

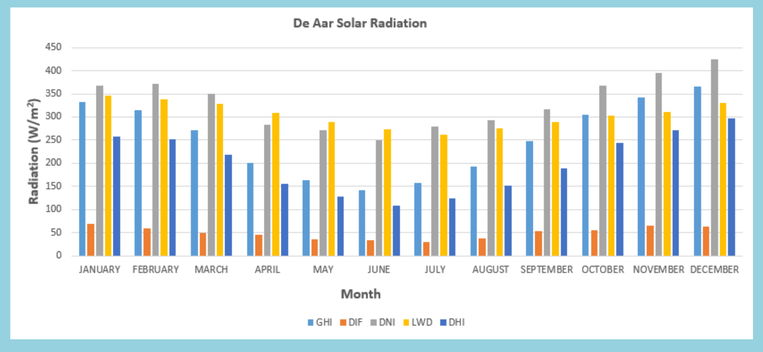
Figure 2. Validation results, Mean Absolute Bias Error (MABE) between De Aar daily mean observation and CMSAF satellite mean daily values (Month 1= May 2014, Month 44=December 2017.



Mean monthly solar radiation at De Aar

The bars in Figure 3 show a monthly variation of solar radiation parameters at De Aar. Radiation parameters peaks in December and minimum in June . The mean monthly radiation values are up there with the sites that receives high solar radiation amounts in the world .

Figure 3. Mean monthly solar radiation at De Aar from May 2014 to December 2017



Mean seasonal solar radiation and Meteorological parameters at De Aar

Table 4 show a seasonal variation of solar radiation parameters and meteorological parameters at De Aar. Summer and spring seasons are characterised by higher radiation amounts, lower humidity, higher sunshine duration and lower clearness index while winter and autumn are characterised by lower radiation amounts, higher humidity, higher sunshine duration and lower clearness index . Diffuse fraction did not show any seasonal variation.

Table 4. Seasonal monthly mean Solar Radiation in (W/m^2) and meteorological parameters from May 2014 to May 2018.

SEASON	GHI	DIF	DNI	LWD	DHI	TEMP	HUMIDITY	SUNSHINE	DF	CI
DJF	349.194	66.153	396.988	338.600	276.380	24.41	41.37	11.17	0.19	0.87
MAM	211.818	43.049	301.477	308.862	167.528	17.44	48.09	9.45	0.20	0.70
JJA	163.734	33.444	273.684	269.750	127.679	10.34	48.84	8.62	0.20	0.60
SON	298.178	57.680	359.842	301.122	234.700	18.55	34.71	10.66	0.20	0.83
ANNUAL	255.731	50.081	332.998	304.583	201.572	17.69	43.25	9.97	0.20	0.75

Mean seasonal Total solar radiation at De Aar

Table 5 show the seasonal total irradiance at De Aar in (W/m^2) with all solar radiation parameters dominating in summer (DJF) season followed by spring (SON) and low radiation amount are recorded in winter (JJA) followed by autumn (MAM) . The seasonal mean monthly and seasonal total monthly solar radiation follows the same pattern.

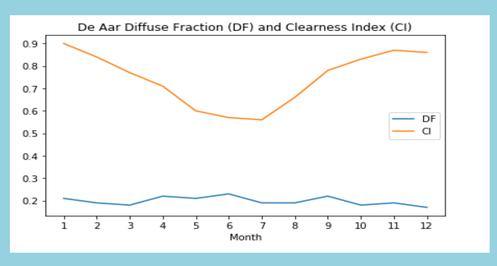
Table 5. Seasonal monthly total Solar Radiation from May 2014 to May 2018

SEASON	GHI	DIF	DNI	LWD	DHI
DJF	8093.049	1534.737	9326.011	8104.105	6430.193
MAM	5078.828	1032.024	7227.687	7352.500	4016.909
JJA	3870.418	786.664	6479.883	6237.429	3022.752
SON	7143.377	1384.215	8588.165	7194.183	5604.290
ANNUAL	6046.418	1184.410	7905.437	7222.054	4768.536

De Aar Site Cleanliness

The monthly mean ratio of DIF to GHI a diffuse fraction (DF) which is an indicative of site clearness was calculated, it is clear from the graph that De Aar is a very clean site (DF was less than 0.3 through out the year) this indicates low aerosol loading and clear skies which is indicates that the site is location is very suitable for solar energy projects. The monthly ratio of GHI to DNI a clearness index (CI) was also calculated from the graph the values were high in summer (DJF) and spring (SON) , this indicates that the site is more clear during those seasons and high solar radiation amounts are recorded.

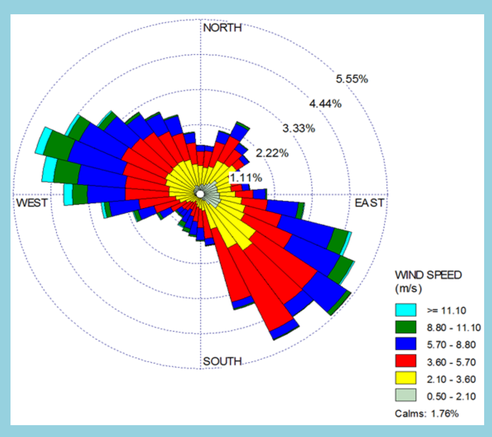
Figure 4. De Aar monthly DF (Diffuse Fraction) and CI (Clearness Index)



De Aar Wind Speed and Wind Direction

Frequency distribution analysis of wind direction revealed a prevailing south easterly wind direction while wind speed frequency was maximum between 3.6 and 5.7 m/s. Based on the moderately high wind speed this location is very suitable for solar energy projects.

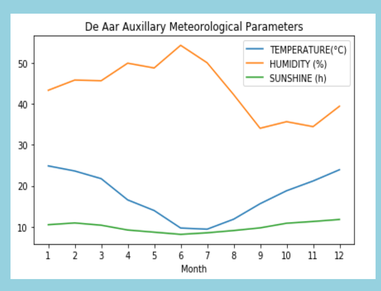
Figure 5. Wind rose of wind speed and wind direction at De Aar.



De Aar Monthly Auxillary Meteorological Pattern

The plots in Figure 6 show a monthly variation of meteorological parameters at De Aar in summer and spring mean monthly sunshine duration is slightly higher than 10 hours, mean monthly temperature is in around 25 degrees Celsius and humidity is less than 45 % while in winter and autumn mean monthly temperature is less slightly greater than 10 degrees Celsius , humidity is slightly above 45 % and sunshine duration is slightly less than 10 hours. The mean annual humidity is less than 50 % , mean annual temperature is high but less than 30 degrees Celsius sunshine duration close to 10 hours , these conditions in addition to high solar radiation amounts makes De Aar one of very suitable sites for solar radiation energy projects in the world.

Figure 6. De Aar monthly mean auxiliary meteorological parameters (Temperature, Humidity and sunshine duration) from May 2014 to May 2018.



Concluding remarks

The utility of ground solar radiation measurements is highly dependent on the assessment of uncertainties in the measured data, continuous monitoring of the health status of the radiometric station and the status of the solar radiation resource database. In this contribution, De Aar BSRN station monitoring, data quality control and the validation results have been elucidated. Our results show that the most dominant source of solar radiation data bias is operational in nature i.e., the missing data due to power and vandalism. Notwithstanding this operational challenges, the overall quality of solar radiation data in the database good. The available minute dataset can therefore be used with confidence to validate global models and satellites observations. SAWS is expected to continue to maintain the solar radiation network as well as utilize the solar radiation resource to advance applications research.

Acknowledgements

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