SASRAD: An hourly-timestep solar radiation database for South Africa

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Abstract

A methodology is presented for the correction and filling of solar radiation data at sites within South Africa, with the aim of creating a continuous, hourly-timestep dataset for multiple locations. Data from twenty sites, collected by the Agricultural Research Council, are analysed with regard to the amount of data requiring offset or multiplier adjustment, as well as the amount of bad data. A range correction algorithm is implemented based on the 90th percentile (10% exceedance) hourly irradiance, as a function of site latitude and elevation. The resulting, corrected data set is given the title: South African Solar Radiation Database (SASRAD). Comparisons are made with two other solar radiation datasets, the South African Atlas of Agrohydrology and Climatology, and a limited set of older historical data from the South African Weather Service (SAWS).

Results indicate that the SASRAD dataset matches well with other datasets, with major discrepancies apparently due to problems with the other data sets, rather than the SASRAD data. The Coefficient of Multiple Determination (R^2) between the Atlas and SASRAD for monthly radiation is 0.927, and the mean error between three of the SASRAD sites and the corresponding SAWS data is 1.1 MJ m^{-2} d^{-1}. The fraction of data requiring correction varied from 11% to 100%, depending on the site. The range correction algorithm was successful at correcting data that had been subject to incorrect calibration, and did not remove annual trends in mean radiation levels.

Keywords: solar radiation, South Africa, SASRAD, data sets

Introduction

Solar radiation is arguably the primary energy source for the earth, providing radiant and thermal energy to the earth's surface, wind energy through the creation of pressure gradients in the air, and chemical energy via the growth of photosynthetic organisms. Renewable energy technologies typically depend on the availability of solar radiation, either directly (i.e. photovoltaics or solar thermal systems) or indirectly (i.e. biofuels). The performance of these systems at a given location depends on the available insolation as well as other meteorological parameters (primarily temperature and wind), which can affect the performance of the energy utilization systems.

South Africa is fortunate to be located at a latitude and in a climate that is generally well suited for the utilization of solar energy. Early assessments of solar energy availability (i.e. Drummond & Vowinckel, 1957; Schulze & McGee, 1976), indicate that available insolation is as high as 29 MJ m^{-2} d-1. Other more recent assessments of solar radiation in South Africa (i.e. Eberhard et al., 1990; Schulze et al., 1992) have confirmed this general finding. Power and Mills (2004) indicate that these values are not static over time, with global and diffuse irradiance at South African locations changing as much as 1.7 and 2.5% per decade. This suggests that information based on old historical records may not be as valuable as newer data.

Sources of solar radiation data typically report solar radiation values in terms of monthly averages, rather than short timestep values, and tend to provide generalized maps of the region, rather than data for discrete locations. Schulze et al., (1992) provide detailed maps of monthly solar radiation, using a temperature-based algorithm from Clemence (1992). It is important to note that monthly data, while useful for some applications, are not suitable for accurate modelling of solar-driven energy processes. Bekker (2007) found that using monthly average radiation values to model

PV performance in South Africa introduced a mean error of 15.8% at 7 sites, when compared to short timestep (5 minute) values. Hourly radiation data was found to introduce a much smaller error (3.2%).

The availability of solar radiation data in South Africa has been described as quite extensive, relative to other African nations (Bugaje, 2006). Surface meteorological measurements are carried out by several organizations, including the South African Weather Service and the Agricultural Research Council. At many sites, these automated measurements include readings of solar radiation, whose length of record varies from site to site. However, the accuracy of this data is also variable, as found by Bekker (2007). Their approach to the matter was to apply a multiplier to measured data from one site, based on a 30-day running average of data in Eberhard (1990). In addition to apparent multiplier errors, directly measured data often contain periods of bad or missing data. While some researchers have dealt with this problem by simulating irradiance based on other meteorological data (i.e. Maxwell, 1997), the required inputs for such models are not available at many sites.

Successful implementation of energy policies and programmes in South Africa depends on accurate assessment of renewable energy technologies. In turn, the accurate assessment of solar-based renewable energy technologies requires a reliable short-timestep database of radiation values. While measurements of solar radiation are carried out at several sites in South Africa, the reliability of this data is not sufficient for use in careful modelling and feasibility analyses. There is a need for a corrected dataset, ideally consisting of historical solar radiation data at many sites that spans a several-year period. The timestep would ideally be as small as 5-minutes, although hourly data is probably sufficient, and comprise the typical timestep used for many solar radiation data sets (i.e. NREL, 1992). The duration of such a dataset would ideally be 30 years (Jagannathan et al., 1967), although some researchers have suggested that a shorter dataset is sufficient for reliable use (Castellvi & Stöckle, 2001). The dataset should include simultaneous measurements of global horizontal and diffuse horizontal irradiance, as well as air temperature, windspeed and direction.

If such a dataset was available, it would be extremely useful for modelling of solar energy technologies, as well as other simulation tasks, such as building energy models and agricultural crop models. This paper reports on the generation and testing of such a database, which has been given the acronym SASRAD – South African Solar Radiation Database.

Procedure
Source data – selection and inspection
Hourly meteorological measurements were obtained from the Agricultural Research Council of

Table 1: Site locations and data period of sourcedata

Site #	Location	Lat (deg)	Lon (deg)	Elev (metres)	Start of record (yr)	Length of record (yrs)
30081	Bonfoi Stellenbosch, WC	-33.936	18.782	292	1995	13
30086	Nietvoorbij Stellenbosch, WC	-33.917	18.860	149	1995	13
30087	Ugie, EC	-31.230	28.045	1537	1994	8
30090	Gullenberg, NP	-23.833	28.967	1100	1994	9
30091	Nondweni,,NP	-28.2	30.8	1100	1994	7
30092	Zaaiplaas Middelburg, MP	-25.75	29.9	1500	1994	7
30093	Pretoria Roodeplaat, GT	-25.604	28.354	1229	1999	9
30105	Rustenburg, NW	-25.724	27.291	1170	1997	11
30113	Hluhluwe, KN	-27.920	32.365	95	1999	9
30142	Vaalhartz, NC	-27.950	24.833	1169	1997	11
30144	Glen Bloemfontein, FS	-28.921	26.353	1344	1999	9
30145	Misgund Joubertina, EC	-33.765	23.492	737	1996	12
30149	Funeray, EC	-31.230	28.045	-999	1995	13
30160	Ukulinga, KN	-29.667	30.4	775	1995	13
30173	Kakamas, NC	-28.788	20.655	667	1996	12
30179	Rietrivier PP, NC	-29.096	24.604	1140	1997	11
30180	Upington, NC	-28.464	21.205	793	1996	12
30182	Klaasvoogds Roberston, WC	-33.807	19.989	221	1996	12
30187	Vinkriver Robertson, WC	-33.756	19.776	259	1996	12
30191	Bloukranz Prieska, NC	-29.525	22.973	944	1996	11

South Africa for twenty locations throughout the country. Available measurements included average hourly global horizontal irradiance, dry bulb temperature, relative humidity, windspeed and direction, and precipitation. The sites were chosen based on the maximum available length of record.

This data was reviewed for accuracy and completeness of data. The available length of the dataset varied from 7 years to 13 years. Visual inspection of the data indicated that many of the measurements were either missing or clearly incorrect, and would require careful correction if they were to be useful. Several categories of error were identified in the radiation data, as follows:

1. Missing data points – points at which no measurements were made, represented by -999 values in the dataset.
2. Single points out of range – single points at which the measured value is clearly out of range, relative to points before and after.
3. Periods in which data is out of range – sets of data in which the multiplier for the radiation sensor appears to have been incorrectly applied, resulting in measurements that are correct in form, but are erroneously high or low. This is presumably due to errors in the calibration of the sensors.
4. Data which show a steady increase or decrease with respect to time – occasionally, data was encountered where the measured irradiance value steadily increased or decreased from year to year. This is presumably due to sensor degradation or incorrect application of multipliers.

These errors were identified in each data set using the following approach:

- *Step 1:* Check data against expected minimum and maximum value (0.0 and 1450 W m-2). All points that fall outside these bounds are flagged as 'bad' points.
- *Step 2:* Check to ensure that nighttime irradiance values are zero, and daytime irradiance values are greater than zero. Data that does not meet this criterion are flagged as 'bad' points.

- *Step 3:* Manually examine data set for any additional bad points.
- *Step 4:* Manually inspect and identify points in which an offset or range error exists.

Steps 1 and 2 were automated as part of a computer program, while the 3d and 4th step required manual inspection of the data to identify anomalies.

Data processing

The observed errors in the dataset represent a rather formidable set of problems that require significant attention if the measurements are to be used with confidence. Therefore, a careful adjustment of all data was carried out according to the following procedure.

Filling of bad data points

All bad or missing data points were filled, based on the length of the period of the bad data, using the following approach, based on the procedure used in NREL (1992). This process was automated, using data processing routines written in the PV-Wave programming environment (VNI, 2005).

- *Step 1:* Sections of bad data which are less than or equal to 4 hours in duration were filled via linear interpolation, based on the values of the nearest good data points.
- *Step 2:* Sections of bad data whose duration ranges from 5 to 24*7 hours in length were filled with corresponding points from the previous week, following week, previous year, or following year, depending on the availability of good data in that time period.
- *Step 3*: Sections of bad data whose duration is greater than 24*7 hours were filled with corresponding data from the previous year, or the nearest year whose data is good.

Offset adjustment

Data which was in error by an offset value were identified by visually inspecting the dataset, and were corrected by adding or subtracting the appropriate value from the affected data.
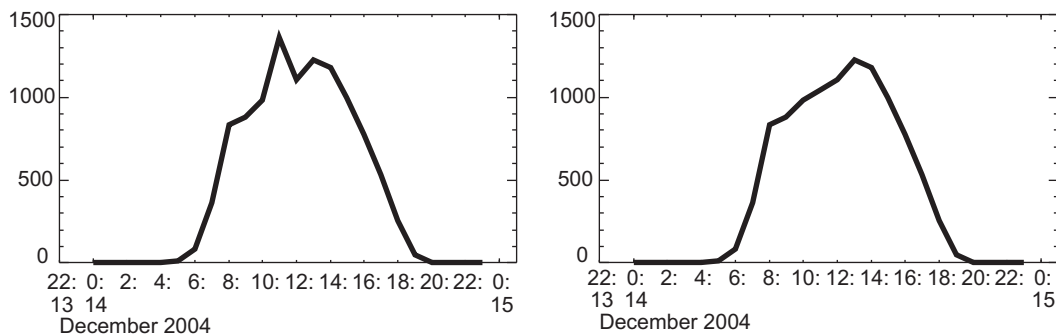

Figure 1: Sample data with single bad point, before and after fill operation
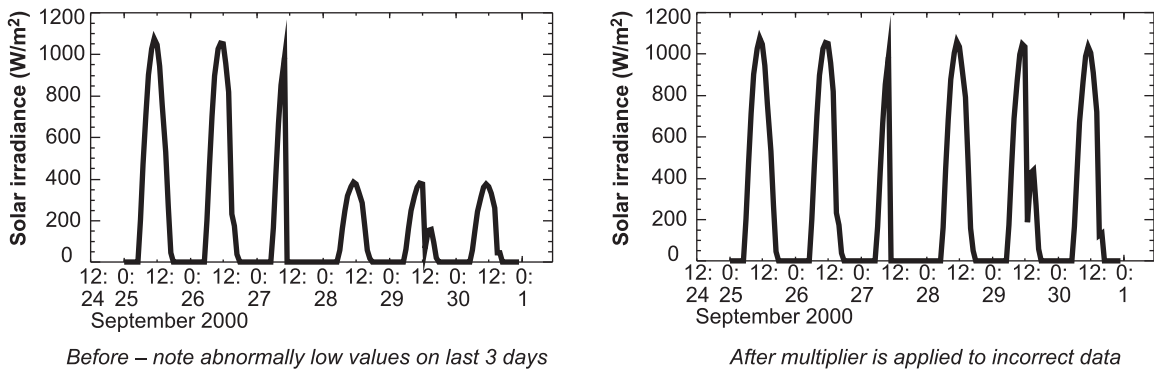*(ARC Site 30081)*

Before – note abnormally low values on last 3 days   *After multiplier is applied to incorrect data*

Figure 2: Example of data before and after multiplier adjustment
(Site #30090)

Multiplier adjustment
Radiation data which was in error due to an incorrect multiplier were adjusted by multiplying those values by an appropriate correction factor. The correction factor was estimated manually and visually confirmed to ensure that the adjusted data match the adjacent, un-adjusted data (see Figure 2). Note that the data for half of the third day is missing, and as such were designated as 'bad points'.

After this 'course' adjustment was made, a more careful adjustment was carried out to ensure that the radiation data was adjusted correctly. This adjustment is based on the assertion that the maximum irradiance at a site will be a function only of site latitude and elevation. A polynomial function was created, based on the National Renewable Energy Laboratory National Solar Radiation Database (NSRDB) dataset for North America (NREL, 1992), which calculates the expected maximum summer irradiance as a function of site latitude and elevation.

$$E_{DM} = 990.274 + 5.867 * L - 0.14927 * L^2 + 0.033639 * E \qquad (1)$$

Where
E_{DM} = Maximum hourly irradiance at a site (W m^{-2}, northern hemisphere)
L = Site latitude (degrees)
E = Site elevation (meters)

This function was then used to correct any datasets that are in error, based on the site's latitude and elevation. The function and the data from which the function are derived are shown in Figure 3. The R^2 value for the equation is 0.947.

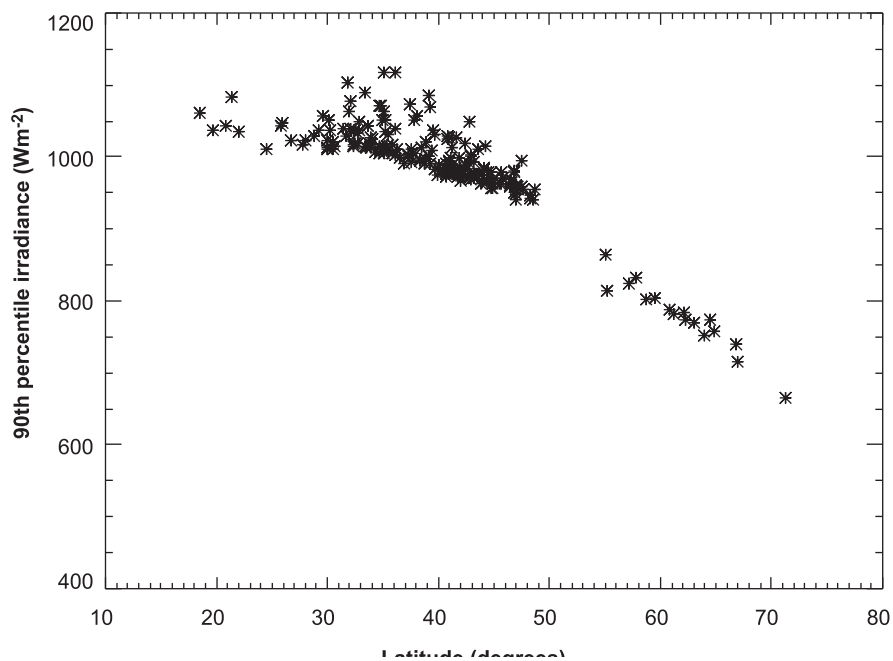Global horizontal radiation values in the dataset were corrected by applying a correction factor

Figure 3: Summer maximum irradiance as a function of latitude

based on the observed and expected maximum summer irradiance values.

$$E_c = 1.07 * E_m * E_{cs} / E_{ms} \qquad (2)$$

Where

E_c = Corrected Irradiance Value (W m^{-2})
E_m = Uncorrected, Measured Irradiance (W m^{-2})
E_{cs} = 90th percentile (summer) irradiance, curve fit value (W m^{-2})
E_{ms} = 90th percentile (summer) irradiance, measured value (W m^{-2})

The multiplier value of 1.07 is included to account for the fact that the sun is closer to the earth during the southern hemisphere summer, resulting in higher irradiance values than those in the northern hemisphere (i.e. Duffie & Beckman, 1974). The 90th percentile was used rather than the absolute maximum in order to reduce the possible effect of outliers in the dataset. In the process of comparing the different percentiles, it was found that the R2 value for the polynomial equation was highest for the 90th percentile.

Flagging of data
In order to allow easy identification of the source of each data point, a 'flag' value was assigned to each value. The 'flag' values are integers that indicate the source and quality of that data point.

Table 2: Flag values for data points

Flag value	Meaning
-9	Data missing / not available
-8	Data bad – removed but not filled
-5	Data modelled based on other measurements
-4	Data adjusted by an offset
-3	Data adjusted by a multiplier
-2	Data filled from adjacent week
-1	Data filled from adjacent points
1	Data not altered
year (i.e. 2002)	Data filled from that year

Addition of diffuse irradiance data
The measured solar radiation data in this study consisted only of global horizontal irradiance values. Because of the importance of separating diffuse from total irradiance when simulating the performance of solar technologies, it was deemed necessary to include values of diffuse horizontal irradiance as well. These values were calculated (rather than being measured) using the procedure of Erbs et al. (1982) as outlined in Battles et al. (2000). Briefly, this consists of calculating the diffuse fraction based on the clearness index (Kt) as follows:

$$k_t = E_{gh} / E_{xt} \qquad (3)$$

$$E_{gd} = E_{gh} * K \qquad (4)$$

$$K = 1.0 - 0.09\, k \quad \text{when } k_t < 0.22 \qquad (5a)$$

$$K = 0.9511 - 0.1604\, k_t + 4.388\, k_t^2 - 16.638\, k_t^3 + 12.336\, k_t^4$$
$$\text{when } 0.22 < kt < 0.8 \qquad (5b)$$

$$K = 0.165 \qquad \text{when } k_t > 0.8 \qquad (5c)$$

Where

K_t = Clearness index, dimensionless
E_{gh} = Global horizontal irradiance, w m^{-2}
E_{xh} = Extra terrestrial horizontal irradiance, w m^{-2}
E_{gd} = Global diffuse irradiance, w m^{-2}
K = diffuse fraction, dimensionless

Similar data review and correction procedures were carried out on the other meteorological data (temperature, humidity, wind and precipitation) – full details can be found in Ciolkosz (2008).

Testing of data
Since the only comparable data available is aggregated daily or monthly, the data in this study was tested by calculating monthly values and comparing them to those reported in the *South African Atlas of Hydrology and Agroclimatology* (Schulze et al., 1997). This source was chosen because of its representation of solar radiation at all locations within South Africa, as well as its thorough presentation of temperature and humidity data. The monthly mean daily radiation for each site was calculated both from the SASRAD dataset and from the information in the atlas, and the values were compared by calculating the mean difference and R^2 for the data.

File format
Data is saved in a series of formatted ASCII text files, with separate files for each location and year of data. The file name is formatted as follows: SSSSS_YYYY.srd where SSSSS = site number, and YYYY = year of data. The first line of data in each file is a header, containing site information. Subsequent lines consist of hourly readings – one line for each hour of the year. The format of the file is as in Tables 3 and 4.

Results
Visual inspection of the datasets indicated values that appear reasonable in magnitude for the locations in question. The fraction of radiation data which required some sort of adjustment varied from 11.1% to 100%, as per Table 5. Information on the correction of the other meteorological data can be found in Ciolkosz (2008).

Global horizontal irradiance values for all sites

<p style="text-align:center">**Table 3: Header format**</p>

Position	Name	Units
1-5	Site Code	as given by ARC
7-30	City	or town or farm name
32-33	Province	EC = Eastern Cape, FS = Free State, GT = Gauteng, KN = KwaZulu-Natal LP = Limpopo, MP = Mapumalanga, NC = Northern Cape, NW = Northwest Province, C = Western Cape
35-39	Latitude	decimal degrees
41-45	Longitude	decimal degrees
47-50	Elevation	meters above sea level
52	Source	'A' = ARC
54-55	Version	01 = first release, 2007, 02 = current release (2008)

<p style="text-align:center">**Table 4: Format of data lines**</p>

Position	Name	Units
1-4	Year	AD
6-7	Month	1-12
9-10	Day	1-31
12-13	Hour	0-23
15-18	Global Horizontal Radiation	W m^{-2}
20-23	Radiation Flag	see Table 2
25-28	Diffuse Horizontal Radiation	W m^{-2}
30-33	Diffuse Radiation Flag	see Table 2
35-39	Dry Bulb Temperature	°C
41-44	Temperature Flag	see Table 2
46-49	Relative Humidity	Percent
51-54	Humidity Flag	see Table 2
56-59	Windspeed	m s^{-1}
61-64	Windspeed Flag	see Table 2
66-69	Wind Direction	Degrees
71-74	Wind Direction Flag	see Table 2
76-79	Precipitation	mm hr^{-1}
81-84	Precip Flag	see Table 2

<p style="text-align:center">**Table 6: Sample data file**</p>

```
****************** SASRAD SOLAR RADIATION DATABASE FOR SOUTH AFRICA ****************
30081 Bonfoi Stellenbosch WC -33.935 18.7817 292 A 02
year mo dy hr    rad flag diff flag    tdb flag    rh flag    wsp flag    wdr flag prcp flag
1995  1  1  0      0 2003    0   -5   18.9 1996    63 2003    0.6 2003    345 2003    0 2003
1995  1  1  1      0 2003    0   -5   18.9 1996    66 2003    0.6 2003    347 2003    0 2003
1995  1  1  2      0 2003    0   -5   18.6 1996    69 2003    0.8 2003    318 2003    0 2003
1995  1  1  3      0 2003    0   -5   18.5 1996    59 2003    0.7 2003     50 2003    0 2003
1995  1  1  4      0 2003    0   -5   18.6 1996    65 2003    0.9 2003    329 2003    0 2003
1995  1  1  5      0 2003    0   -5   18.7 1996    57 2003    0.6 2003    338 2003    0 2003
1995  1  1  6    180 2003  160   -5   19.1 1996    53 2003    0.5 2003    335 2003    0 2003
1995  1  1  7    399 2003  243   -5   20.6 1996    58 2003    0.3 2003    161 2003    0 2003
1995  1  1  8    616 2003  246   -5   22.7 1996    52 2003    0.5 2003    180 2003    0 2003
1995  1  1  9    840 2003  192   -5   24.3 1996    42 2003    0.7 2003    192 2003    0 2003
1995  1  1 10    993 2003  175   -5   26.0 1996    32 2003    1.0 2003    231 2003    0 2003
1995  1  1 11   1081 2003  178   -5   26.6 1996    23 2003    2.0 2003    270 2003    0 2003
1995  1  1 12   1113 2003  184   -5   27.6 1996    20 2003    3.3 2003    249 2003    0 2003
1995  1  1 13   1090 2003  180   -5   27.7 1996    19 2003    3.3 2003    239 2003    0 2003
1995  1  1 14   1000 2003  165   -5   27.3 1996    23 2003    2.6 2003    220 2003    0 2003
1995  1  1 15    849 2003  140   -5   26.5 1996    25 2003    3.2 2003    225 2003    0 2003
1995  1  1 16    651 2003  107   -5   26.4 1996    39 2003    1.7 2003    210 2003    0 2003
1995  1  1 17    436 2003   72   -5   26.3 1996    40 2003    1.8 2003    189 2003    0 2003
1995  1  1 18    216 2003   36   -5   25.9 1996    53 2003    2.1 2003    218 2003    0 2003
1995  1  1 19     38 2003    6   -5   24.6 1996    80 2003    1.8 2003    210 2003    0 2003
```

Table 5: Summary of radiation data correction

Site #	Location	Length of record (yrs)	% good	% filled	% mult	% bad
30081	Bonfoi Stellenbosch, WC	13	13.8	69.9	16.3	0
30086	Nietvoorbij Stellenbosch, WC	13	63.3	9.7	27.0	0
30087	Ugie, EC	8	0	79.0	21.0	0.0014
30090	Gullenberg, NP	9	40.7	26.6	32.7	0
30091	Nondweni,,NP	7	42.8	50.1	7.1	0
30092	Zaaiplaas Middelburg	7	82.3	17.7	0	0
30093	Pretoria Roodeplaat, GT	9	79.1	19.3	1.6	0
30105	Rustenburg, NW	11	83.8	16.2	0	0
30113	Hluhluwe, KN	9	88.9	11.1	0	0
30142	Vaalhartz, NC	11	36.4	9.7	53.9	0
30144	Glen Bloemfontein, FS	9	83.7	16.0	0.3	0
30145	Misgund Joubertina, EC	12	73.9	11.0	15.1	0
30149	Funeray, EC	13	22.7	55.4	21.9	0.0008
30160	Ukulinga, KN	13	40.1	48.7	11.2	0
30173	Kakamas, NC	12	86.7	13.3	0	0
30179	Rietrivier PP, NC	11	65.9	19.9	14.2	0
30180	Upington, NC	12	41.5	11.6	46.9	0
30182	Klaasvoogds Roberston, WC	12	29.1	17.4	53.5	0
30187	Vinkriver Robertson, WC	12	76.2	22.4	1.4	0
30191	Bloukranz Prieska, NC	11	0	21.6	78.4	0

Table 7: Annual trends in daily radiation

Site no.	Annual trend (MJ m^{-2}d^{-1} per year)
30081	0.0155
30086	-0.0224
30087	-0.0473
30090	-0.0289
30091	-0.0329
30092	-0.0426
30093	0.1735
30105	0.0603
30113	-0.0056
30142	0.0651
30144	0.1847
30145	0.0378
30149	0.1141
30160	0.0550
30173	0.0066
30179	-0.0086
30180	0.0581
30182	0.1055
30187	0.0846
30191	-0.0382
average	0.0367

and times averaged 235.1 w m-2, which corresponds to 20.3 MJ m-2 d-1. A sample of a SASRAD data file is shown in Table 6.

Annual trends

Annual trends in the SASRAD data are summarised in Table 7. Of the 20 sites, 11 show an increase in solar radiation, with 9 showing a decrease. The maximum increase is for site 30144 (Glen Bloemfontein), and the greatest decrease is at site 30087 (Ugie). On average, the solar radiation data are increasing in magnitude at an annual rate of 0.037 MJ m^{-2} d^{-1}.

Sample plots are given in Figure 4 for two representative sites, showing the variation in daily radiation from year to year. While an overall trend is apparent, the variation from year to year is quite noticeable as well.

Comparison to other datasets

Comparison of the mean of the monthly radiation data from the SASRAD dataset to the South African Atlas of Hydrology and Agro-Climatology (Schulze et al., 1997) showed good agreement, with an R^2 of 0.927. The mean difference between the two datasets is 3.72 MJ m^{-2} d^{-1}. Typically, the two datasets agree most closely at midwinter, with SASRAD giving lower values during summer months (see Figure 6). This discrepancy is most likely due to problems with the radiation-prediction algorithm
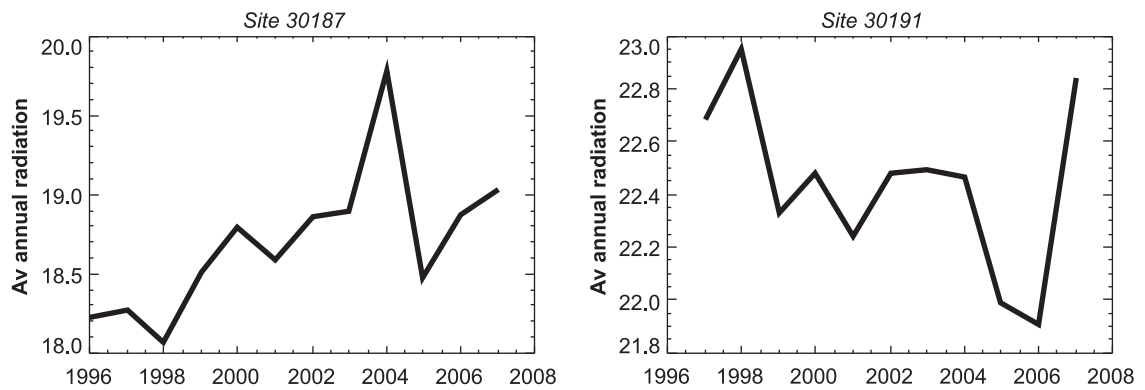
Figure 4: Annual variation in daily radiation for two sites (MJ m⁻² d⁻¹)

used in the atlas, as the algorithm is best suited only for clear sky conditions, and is not as accurate under the cloudy conditions typically found in summer months over most of South Africa (Horan, 2008).
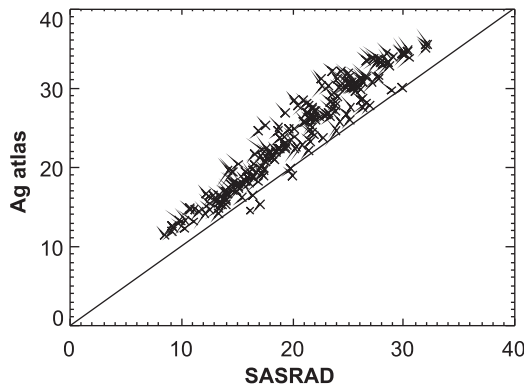

Figure 5: SASRAD vs. Ag Atlas daily radiation (MJ m⁻² d⁻¹)

Comparison of the SASRAD data for three sites (Upington, Glen, and Pretoria) to a rather old set of South African Weather Service data for nearby locations (1957-1997) indicates a much closer agreement to the SASRAD data than to those from the Ag Atlas (results not shown). Therefore, the differences between SASRAD and the Ag Atlas do not appear to be indicative of any systematic error in the SASRAD data. Note that revisions are underway for the next release of the atlas, in which these deficiencies are corrected (Horan, 2008).

Discussion

The SASRAD database presented here represents a consistent, continuous set of hourly radiation data for multiple sites in South Africa that can be used for evaluation of a variety of solar technologies. The locations of the 20 sites were chosen as a function of the available data records, and as such do not cover all areas in South Africa. As the data originates from the Agricultural Research Council, the sites are also generally not within the major population centres of South Africa. Coincident values for temperature, humidity, wind speed and precipitation are also provided, which makes the data set especially valuable for modelling purposes.

The correction procedures applied to the data are quite extensive, but the resulting values appear to correlate well to existing aggregated data, with any discrepancies accountable to problems with the reference data set, rather than the SASRAD data. As with any data set, the major concern is for the
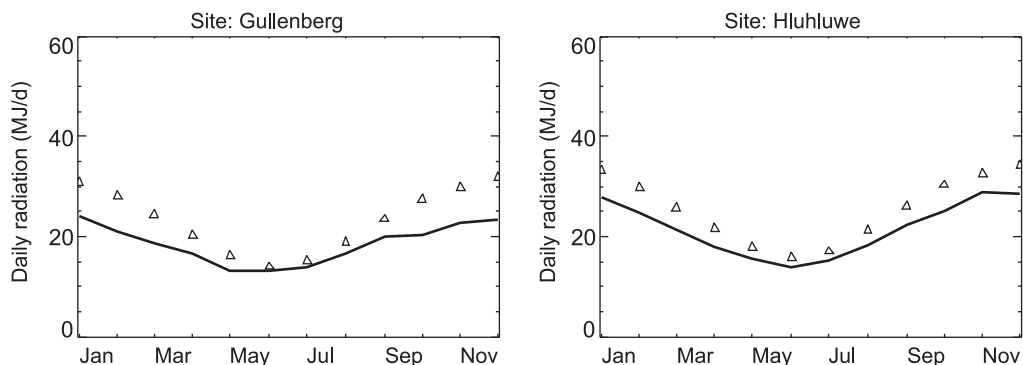

Figure 6: Annual Variation in SASRAD and Ag Atlas daily radiation for two typical sites (MJ m⁻² d⁻¹)

accuracy of the data. While it is not possible to rigorously test the SASRAD data on an hour-by-hour basis, the results presented here suggest that the corrected SASRAD dataset can be used with good confidence.

The range correction appears to be successful at correcting the radiation values without 'erasing' any year-to-year differences, as the annual trends are of the same magnitude as those reported in Power and Mills (2004). However, annual trends are not expected to be accurate at locations in which extensive data filling was utilised. The range correction algorithm is a vital step in the processing of the data, as without it the radiation data would not be expected to exhibit reliable values from year to year. Corrections based on the average radiation value (rather than the maximum) are less valuable for this purpose, as they would tend to normalise radiation values to an overall mean, which should be expected to vary from year to year, due to long term trends in climate (principally cloud cover).

The range correction algorithm does not make allowances for annual variation in sky clearness, as could be caused by large volcanic eruptions, such as the Mt. Pinatubo eruption in 1992 (Power & Mills, 2004). However, the period in which the dataset was collected was not subjected to large-scale volcanic activity. If need be, a correction factor could be applied to data in future years if this becomes an issue.

Future enhancements to the SASRAD database could include inclusion of additional sites, expansion of the length of data record, and further refinement to the data correction algorithm. Originally, the SASRAD database was intended for the investigation of energy and environmental performance of agricultural and rural structures, hence the use of the ARC dataset with its focus on rural locations. However, the potential uses for this dataset are much broader, including the modelling of solar energy technologies, modelling of building performance, development of engineering design data, and creation of 'typical year' climate files. Many of these tasks have already been carried out for some sites by others, but the SASRAD dataset affords the opportunity to extend these efforts to a wider array of locations within South Africa.

Conclusions

The following conclusions can be drawn from the generation and testing of the SASRAD data set.
- A significant degree of correction and filling of data is required in order to render useful the currently available measured radiation data for South Africa.
- The use of automated and manual identification of bad data, coupled with a range correction algorithm, results in radiation data that agrees with earlier datasets for the region.

- The range correction algorithm is successful at normalizing the radiation data without removing annual trends in radiation values.

References
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