Australian Government
Bureau of Meteorology

Australian one-minute solar radiation data

Product Notes IDCJAC0022 *Version: 1.3 04 March 2014*

Contents

Revision history

Date	Version	Description
26 July 2012	1.1	Version for initial public release
24 August 2012	1.2	Editorial updates
04 March 2014	1.3	Includes file format information

Solar radiation observations - One-minute data - File format

Byte location	Byte size	Explanation
1-2	2	Record identifier - sl
4-9	6	Bureau of Meteorology Station Number.
11-14	4	Year in YYYY format in local standard time
16-17	2	Month in MM format in local standard time
19-20	2	Day in DD format in local standard time
22-23	2	Hours in HH format in local standard time
25-26	2	Minutes in MM format in local standard time
28-34	7	Mean global irradiance (over preceding 1 minute) in W/sq m
36-42	7	Minimum 1 second global irradiance (over preceding 1 minute) in W/sq m
44-50	7	Maximum 1 second global irradiance (over preceding 1 minute) in W/sq m
52-58	7	Standard deviation of global irradiance (over preceding 1 minute) in W/sq m
60-66	7	Uncertainty in mean global irradiance (over preceding 1 minute) in W/sq m
68-74	7	Mean direct irradiance (over preceding 1 minute) in W/sq m
76-82	7	Minimum 1 second direct irradiance (over preceding 1 minute) in W/sq m
84-90	7	Maximum 1 second direct irradiance (over preceding 1 minute) in W/sq m
92-98	7	Standard deviation of direct irradiance (over preceding 1 minute) in W/sq m
100-106	7	Uncertainty in mean direct irradiance (over preceding 1 minute) in W/sq m
108-114	7	Mean diffuse irradiance (over preceding 1 minute) in W/sq m
116-122	7	Minimum 1 second diffuse irradiance (over preceding 1 minute) in W/sq m
124-130	7	Maximum 1 second diffuse irradiance (over preceding 1 minute) in W/sq m
132-138	7	Standard deviation of diffuse irradiance (over preceding 1 minute) in W/sq m
140-146	7	Uncertainty in mean diffuse irradiance (over preceding 1 minute) in W/sq m

148-154	7	Mean terrestrial irradiance (over preceding 1 minute) in W/sq m
156-162	7	Minimum 1 second terrestrial irradiance (over preceding 1 minute) in W/sq m
164-170	7	Maximum 1 second terrestrial irradiance (over preceding 1 minute) in W/sq m
172-178	7	Standard deviation of terrestrial irradiance (over preceding 1 minute) in W/sq m
180-186	7	Uncertainty in mean terrestrial irradiance (over preceding 1 minute) in W/sq m
188-194	7	Mean direct horizontal irradiance (over preceding 1 minute) in W/sq m
196-202	7	Minimum 1 second direct horizontal irradiance (over preceding 1 minute) in W/sq m
204-210	7	Maximum 1 second direct horizontal irradiance (over preceding 1 minute) in W/sq m
212-218	7	Standard deviation of direct horizontal irradiance (over preceding 1 minute) in W/sq m
220-226	7	Uncertainty in mean direct horizontal irradiance (over preceding 1 minute) in W/sq m
228-232	5	Sunshine-seconds-96 (duration of DNI exceeding 96 W/sq m over preceding 1 minute) in seconds
234-238	5	Sunshine-seconds-120 (duration of DNI exceeding 120 W/sq m over preceding 1 minute) in seconds
240-244	5	Sunshine-seconds-144 (duration of DNI exceeding 144 W/sq m over preceding 1 minute) in seconds
246-252	7	Zenith distance in degrees

The first line of each data file are column headings.

Radiation Units

Radiation quantities are generally expressed in terms of either irradiance or radiant exposure. Irradiance is a measure of the rate of radiant energy received per unit area, and has SI units of Watts per square metre (Wm^{-2}), where 1 Watt (W) is equal to 1 Joule (J) per second. Radiant exposure is a time integral (or sum) of irradiance which is the equivalent of the radiant energy received per unit area over the period of interest; the radiant exposure divided by the number of seconds in the period of interest is equivalent to the mean irradiance. Therefore a radiant exposure of 60 Jm^{-2} over 60 seconds = mean irradiance 1 Wm^{-2}.

Direct Solar Irradiance and Horizontal Direct Solar Irradiance

Direct solar irradiance – also known as direct normal irradiance (DNI) - is a measure of the rate of solar energy arriving at the Earth's surface from the Sun's direct beam, on a plane perpendicular to the beam, and is usually measured by a pyrheliometer mounted on a solar tracker. The pyrheliometer has a finite field of view typically with a maximum field of view of 5°. Horizontal direct solar irradiance is the component of direct solar irradiance that would be measured on a horizontal surface, obtained by multiplying the direct solar irradiance by the cosine of the Sun's zenith angle.

Diffuse Solar Irradiance

Diffuse solar irradiance is that component of incoming solar irradiance on a horizontal plane at the Earth's surface resulting from scattering of the Sun's beam due to atmospheric constituents; it does not contain the direct solar irradiance component. Diffuse solar irradiance is measured by a pyranometer, typically with dual glass domes shaded from the Sun's beam. The shading is accomplished either by an occulting disc or a shading arm attached to a solar tracker. The angle subtended by the shading disc of the diffuse pyranometer should be the same as the field of view of the pyrheliometer.

Global Solar Irradiance

Global solar irradiance is a measure of the rate of total incoming solar energy (both direct and diffuse) on a horizontal plane at the Earth's surface. A pyranometer sensor can be used to measure this quantity with limited accuracy. The most accurate measurements are obtained by summing the diffuse solar irradiance and the vertical component of the direct solar irradiance.

Interaction of the Components of Solar Irradiance

As diffuse solar irradiance is a component of global solar irradiance, diffuse solar irradiance should be less than or equal to global irradiance measured at the same time. Global and diffuse irradiance will be equal when the contribution from direct solar irradiance is zero, that is, when the Sun is obscured by thick cloud, or the sun is below the horizon. Measuring each of the three components independently has two clear advantages, namely using an addition of two components to check on the third, and providing redundancy if one of the components can't be measured for a period due to instrument failure.

Downward Infra-Red (Terrestrial/Longwave) Irradiance

Any body with a temperature greater than 0 K (Kelvin) will radiate energy over a range of wavelengths, called the body's radiation spectrum. Most of the Sun's spectrum lies in the wavelength range of 0.25 - 4.0 μm (1 μm (micrometre) = 10^{-6} m), the so-called short wave range. Downward infra-red irradiance is a measurement of the irradiance arriving on a horizontal plane at the Earth's surface, for wavelengths in the range 4 - 100 μm, which corresponds to the wavelength emitted by atmospheric gasses and aerosols. It is related to a "representative atmospheric temperature" of the Earth's atmosphere by the Stefan-Boltzmann Law:

$E = \sigma T^4$

Where:
E = irradiance measured. [Wm^{-2}]
σ = Stefan-Boltzmann constant. [$5.67 \times 10^{-8}\ Wm^{-2}deg^{-4}$]
T = representative atmospheric temperature. [K]

Consequently, this quantity will continue to have a positive value, even at night time, and is measured using a pyrgeometer. As in the case of diffuse solar irradiance measurement, it is required that this instrument is shaded from the direct beam of the Sun during the day, since the Sun's beam can heat the pyrgeometer dome and increase the uncertainty in the measurement. The measured downward infra-red irradiance can be use to derive "representative temperature" of the sky. This derived estimate is dependent on a number of factors, but typically larger values are recorded when middle to low level clouds cover the sky than those recorded during clear skies.

Sunshine Duration

Sunshine duration is defined to be the sum of all time periods during the day when the direct solar irradiance equals or exceeds 120 Wm^{-2} ±20%. The range of irradiance within this definition reflects the variation in response characteristic of the traditional Campbell-Stokes sunshine duration recorder, which uses direct beam sunlight focussed by a glass sphere to burn a trace on a paper chart. Thus, accumulated times within each minute where the direct solar irradiance is above each of the three thresholds – 96 Wm^{-2}, 120 W^{-2}, and 144 Wm^{-2} - are provided in this data product. Where the Bureau has measurements of direct irradiance with a pyrheliometer sunshine duration is calculated for every second of the day.

Sun's (or Solar) Zenith Distance

The solar zenith distance is the angular distance from directly overhead (i.e. the zenith) measured in degrees, and is sometimes used instead of solar altitude or solar elevation within calculations based on the horizontal coordinate system. The zenith distance is the complement of solar altitude (i.e. 90°- altitude).

Uncertainty

The uncertainty associated with each solar statistic has been calculated using ISO guidelines (ISO/IEC, 2008). All the solar measurements are traceable to the World Radiometric Reference for solar components, and the World Infrared Standard Group for terrestrial/longwave, and hence are linked to SI units. Processes for site visits and data reduction are based on the Global Climate Observing System (GCOS) radiation program led by the Baseline Surface Radiation Network (BSRN) protocols.

Data quality control and assurance of the new network stations is such that the 95% uncertainty for any quantity measured is well within the original network targets of 3% or 15 Wm^{-2} (whichever is the greater) after the post measurement verification is completed.

Instrument Calibration

The Bureau uses matched sensors for diffuse and global pyranometry, and instruments are chosen such that there is a 95% confidence that there will be < 1% change in sensitivity over 12 months due to sensor degradation. However, pyranometer sensitivity may change with time and exposure to radiation, mainly due to the deterioration of the sensor.

Within the current network each site which forms part of the BSRN/GCOS is visited every six months, and every 18 months for other sites. The primary purpose of these visits is to calibrate the pyrheliometers, pyrgeometers and the data acquisition systems as per the BSRN/CGOS protocols.

Calibration of the pyranometer equipment is achieved using the “Alternate Method” (Forgan, 1996) that only requires the routinely corrected data; that is every day’s data can be used to ensure the pyranometers are in calibration. Between visits the pyranometer being used to measure global irradiance operates over a wide range of conditions, prior to it being swapped for use as a diffuse pyranometer. As a result, the sum of pyrheliometer direct irradiance measurements and the well-calibrated diffuse pyranometer provide the most accurate measurement of the global irradiance.

Location of stations

The location of stations at which the Bureau has made one minute observations of various solar parameters is shown in Figure 1. The classification of stations can be interpreted as follows:

1. Open – Station was operating at the beginning of the 2011-12 financial year.
2. Re-opened – The station was re-opened during the 2011-12 financial year;
3. Closed – Station no longer operating;
4. New – A new station established in the second half of the 2011-12 financial year;
5. SECVI network – A previous solar resource monitoring station open between 1993/4 and 1995/6.

Data from a number of stations, in particular those part of the SECVI network, are presently not available. These data need to be reprocessed before being suitable for inclusion in this product. When they are included will depend on the availability of Bureau resources.

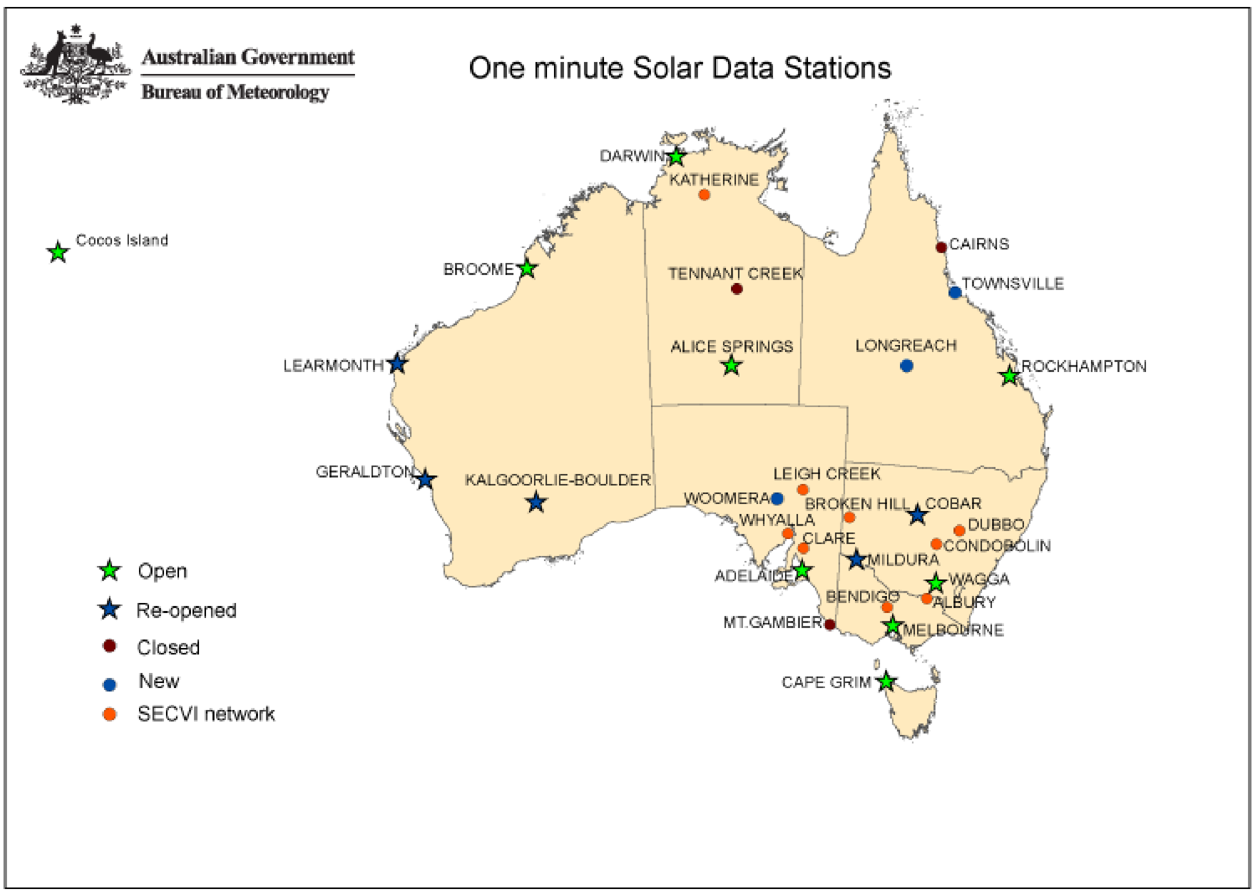

Figure 1. Location of stations where one minute solar data have been recorded.

Missing data

The majority (if not all) stations will have some periods for which data are not available. Causes for missing data vary, but are typically due to an equipment fault or a site closure for a period of time.

The completeness of records varies between stations and depending on the solar parameter. For the stations that have already been loaded into Bureau's database ADAM, the last 6 months of data were analysed for their completeness to give an indication of the likely overall completeness of 1-min solar data:

- For global irradiance no station had more than 10% of data missing and typically less than 5% of data are missing.

The completeness for measurements of direct and diffuse irradiance is only marginally lower, although in one case 18% of measurements (over the 6-month period) are missing.

Instruments and observational practices

Historically a nearby site (within about 1 mile in earlier days) may have used the same site number. There may have been changes in instrumentation and/or observing practices over the period included in a dataset, which may have an effect on the long-term record. In recent years many sites have had observers replaced by Automatic Weather Stations, either completely or at certain times of the day.

References

World Meteorological Organization, 2008, WMO Guide to meteorological instruments and methods of observation, WMO-No. 8 (Seventh edition), (6 August 2008)

Forgan, B.W., 1996, A new method for calibrating reference and field pyranometers. Journal of Atmospheric and Oceanic Technology, 13, pp. 638–645.

International Organization for Standardization/ International Electrotechnical Commission, 2008, ISO/IEC Guide 98-3:2008 Uncertainty of measurement -- Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)

Acknowledgement

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If data is not as requested

If the data provided are not as requested, the data will be repeated at no extra cost, provided that:
a) the Bureau is notified within 60 days.
b) the printout/disc/data file is returned to the Bureau for checking.
c) there has been a fault or error in providing the data.

Where there has been no fault or error of provision, the cost involved in requested corrective action such as re-sending the data or providing alternative sites will be charged for as necessary.

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