Australian Government
Bureau of Meteorology

Gridded Hourly Solar Direct Normal Irradiance Metadata

Dataset

Title	Hourly solar direct normal irradiance

Custodian

Custodian	Bureau of Meteorology
Jurisdiction	Australia

Description

Abstract	Solar direct normal irradiance (DNI) is the instantaneous intensity of solar direct beam radiation falling on a surface normal to the beam. This product is derived from global horizontal irradiance that is in turn derived from hourly satellite data. It gives a single instantaneous DNI value for every hour, at the time of the satellite observation. Typical values for DNI are up to around 1000 W/m2 (watts per square metre). The values are usually highest in cloud-free conditions away from the ends of the day. Localised variations are caused mainly by variations in atmospheric conditions, primarily cloudiness. See LINEAGE below for more information.
Purpose	Created for renewable energy applications but expected to be used for a broad range of applications including ecosystem modelling and building thermal design.
Descriptive key words	Gridded, satellite, solar, radiation, irradiance, direct, beam, DNI, meteorology
Geographic Extent Names(s)	Australia
General Category	Gridded data
General Custodian Jurisdiction	Australian Government Australia
Geographic Extent Polygon	Not applicable
Geographic Bounding Box	See below
North Bounding Latitude	-10.05
South Bounding Latitude	-43.95
East Bounding Longitude	153.95
West Bounding Longitude	112.05
Beginning Date	1 January 1990
Ending Date	31 October 2016

Dataset Status

Progress	Completed
Maintenance and Update frequency	As required

Access

Stored Data Format	Arc/Info grids – all Australia
Available Format Type	ASCII row major.
Access Constraint	Satellite-derived solar direct normal irradiance estimates are based on images from the Geostationary Meteorological Satellites GMS-4 and GMS-5, Geostationary Operational Environmental Satellite (GOES-9), the MTSAT-1R and MTSAT-2 satellites, and the Himawari-8 satellite, which are provided with permission of the Japan Meteorological Agency (JMA) and the United States National Oceanic & Atmospheric Administration (NOAA). Any use of products from this imagery requires acknowledgement of the satellites of JMA and NOAA as the original source of the satellite data, and acknowledgement of the Commonwealth of Australia (Bureau of Meteorology) which received and processed the images. Acknowledgement should be in the form: "*Solar radiation data derived from satellite imagery processed by the Bureau of Meteorology from the Geostationary Meteorological Satellite, MTSAT and Himawari-8 series operated by Japan Meteorological Agency and from GOES-9 operated by the National Oceanographic & Atmospheric Administration (NOAA) for the Japan Meteorological Agency"* Please contact us (see details below) for more information.

Metadata constraints

Use limitation	Use of these data should be acknowledged to the Bureau of Meteorology. Apart from the purposes of study, research, criticism and review, no part of these data may be reproduced, or redistributed for any commercial purposes, or distributed to a third party for such purpose, without written permission from the Director of Meteorology.
Other constraints	These products are made available under the Bureau's default terms of use (noted at http://www.bom.gov.au/other/copyright.shtml)
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Data Quality

Lineage

The Bureau of Meteorology's computer radiation model uses hourly visible images from geostationary meteorological satellites to estimate hourly instantaneous solar global horizontal irradiance (GHI) at ground level. Each GHI value is converted to a direct normal irradiance (DNI) value by applying a conversion algorithm which depends on the GHI values and the sun position. The following paragraphs describe these steps in detail.

For each satellite acquired image, the brightnesses are averaged within each grid cell and used to estimate GHI at the ground. Essentially, the GHI at the ground can be calculated from the GHI at the top of the earth's atmosphere, the amount absorbed in the atmosphere (dependant on the amount of water vapour present), the amount reflected from the surface (surface albedo) and the amount reflected from clouds (cloud albedo). The two-band physical model (Weymouth and Le Marshall, 2001) that has been the basis of the Bureau of Meteorology's satellite solar radiation system since 2000 was used. Thumbnail images of all GHI grids were inspected and anomalous grids, due to satellite images that were noisy or otherwise anomalous, were rejected. The satellite model is invalid for solar zenith angles between 83 and 90 degrees; for these cases the GHI value is estimated from an adjacent hour by assuming that the ratio of GHI to a modelled clear-sky GHI value is constant.

The GHI bias is reduced using a bias model derived from comparisons of the satellite estimates with ground-based radiation observations from the Bureau of Meteorology's radiation monitoring network. The bias model is a function of the cosine of the solar zenith angle and the atmospheric transmittance (also known as clearness index), and is fitted separately to the three intervals 1990-01-01 to 2005-10-31 (GMS-4, GMS-5 and GOES-9), 2005-11-01 to 2016-03-21 (MTSAT series), and 2016-03-22 onwards (Himawari-8).

The bias corrected GHI is converted to DNI via the diffuse fraction estimated by applying a modified form of the Ridley et al. (2010) model. The model estimates the diffuse fraction (ratio of diffuse irradiance to GHI) from the instantaneous clearness index (ratio of GHI to extraterrestrial irradiance), daily mean clearness index, solar elevation, apparent solar time, and a measure of temporal variability that is the root mean squared difference between the clearness index for the current hour and those for one hour before and after. This variability parameter is used instead of the "persistence" parameter adopted by Ridley et al. because it gave lower uncertainties (median absolute percentage error of 16%, compared with 20% obtained by Ridley et al. for southern hemisphere stations). The model coefficients were established by fitting the model to observations of GHI and DNI from the Bureau's surface radiation network, which were 1-minute observations taken at 1-hour intervals to simulate the satellite sampling.

The satellite data were acquired from the following satellites and instruments.

Start date	End date	Satellite	Instrument
1990-01-01	1995-06-10	GMS-4	VISSR
1995-06-11	2003-05-20	GMS-5	VISSR
2003-05-21	2005-10-31	GOES-9	GOES I-M Imager
2005-11-01	2010-06-30	MTSAT-1R	JAMI
2010-07-01	2016-03-21	MTSAT-2	JAMI
2016-03-22	Ongoing	Himawari-8	AHI

GMS is the Geostationary Meteorological Satellite series operated by the Japan Meteorological Agency.
GOES is the Geostationary Operational Environmental Satellite system operated by the US National Oceanic and Atmospheric Administration.
MTSAT is the Multi-Functional Transport Satellite series operated by the Japan Meteorological Agency.
VISSR is the Visible and Infrared Spin Scan Radiometer.
JAMI is the Japanese Advanced Meteorological Imager.
AHI is the Advanced Himawari Imager.

The hourly irradiance gridded dataset covers Australia with a resolution of 0.05 degrees in latitude and longitude. The grid file names include the UT date and hour (without minutes) of the observation time. Note that the grids for the early part of a particular local date fall into the preceding UT date. The irradiance units are watts per square metre (W/m^2).

The number of minutes of the observation time after the start of the hour varies smoothly with latitude in a manner that is fixed for each satellite and hour of the day, but which differs between satellites, and for some satellites between hours of the day (columns A and B in the tables below). The number of minutes after the hour for each satellite and hour of the day is given by the following table at 5-degree latitude increments. For GMS-4 (first table) separate observation times apply to three different date ranges. For Himawari-8 the observation times follow a less regular progression with latitude and have a typical uncertainty of up to 0.5 minutes due to the satellite imaging the Earth in broad swaths, the fact that these swaths follow a complex pattern that is generally the same between images but can differ for some images, and the limited information on times available in the satellite data stream.

Table of number of minutes of the observation time after the start of the hour for GMS-4.

Start date	1990-01-01		1993-01-01		1994-07-01	
End date	1992-12-31		1994-06-30		1995-06-10	
Latitude	GMS-4 A	GMS-4 B	GMS-4 A	GMS-4 B	GMS-4 A	GMS-4 B
-10.0	45.7	38.7	47.2	40.7	46.7	40.5
-15.0	46.7	39.7	48.2	41.7	47.7	41.5
-20.0	47.7	40.7	49.3	42.8	48.8	42.6
-25.0	48.7	41.7	50.2	43.7	49.7	43.5
-30.0	49.6	42.6	51.1	44.6	50.6	44.4
-35.0	50.5	43.5	52.0	45.5	51.5	45.3
-40.0	51.2	44.2	52.7	46.2	52.2	46.0
-44.0	51.8	44.8	53.3	46.8	52.8	46.6

A columns: UT hours 18 19 20 21 23 00 01 02 03 05 06 07 08 09 11
B columns: UT hours 22 04 10

Table of number of minutes of the observation time after the start of the hour for GMS-5 and GOES-9.

Start date	1995-06-11		2003-05-21	
End date	2003-05-20		2005-10-31	
Latitude	GMS-5 A	GMS-5 B	GOES-9 A	GOES-9 B
-10.0	46.7	39.7	39.9	27.9
-15.0	47.7	40.7	41.0	29.0
-20.0	48.8	41.8	42.0	30.0
-25.0	49.7	42.7	43.0	31.0
-30.0	50.6	43.6	43.9	31.9
-35.0	51.5	44.5	44.7	32.7
-40.0	52.2	45.2	45.5	33.5
-44.0	52.8	45.8	46.0	34.0

A columns: UT hours 18 19 20 21 23 00 01 02 03 05 06 07 08 09 11
B columns: UT hours 22 04 10

Table of number of minutes of the observation time after the start of the hour for MTSAT-1R, MTSAT-2 and Himawari-8.

Start date	2005-11-01	2010-07-01	2016-03-22	
End date	2010-06-30	2016-03-21	Ongoing	
Latitude	MTSAT-1R	MTSAT-2	Himawari-8	
-10.0	46.2	44.7	36.0	
-15.0	47.2	45.7	36.9	
-20.0	48.3	46.8	37.0	
-25.0	49.2	47.7	37.9	
-30.0	50.1	48.6	38.4	
-35.0	51.0	49.5	38.6	
-40.0	51.7	50.2	38.9	
-44.0	52.3	50.8	39.1	

Differences from previous release (with metadata dated 28 February 2013)

- Files are supplied for 24 hours of each day. Previously files were supplied only for the 18 hours of a day for which some region of Australia is in daytime at some time of the year.
- Nighttime values are given as zero rather than as missing data. Missing values will remain when a daytime value can't be produced because, for instance, input data are missing or rejected or model limitations are exceeded.
- Values for which the solar zenith angle is between 83 and 90 degrees, for which cases the satellite GHI model is not valid, and corresponding to the period of up to approximately one hour after sunrise or before sunset, are filled by adjusting the satellite GHI value from an adjacent hour. The fill method assumes that the clear-sky index is the same as that of the next (for morning) or previous (for afternoon) hour, where the clear-sky index is the ratio of the GHI to the clear-sky GHI predicted for the same solar zenith angle by a simple model.
- If the satellite data for an hour are missing then a file is supplied which contains missing or zero values for daytime or nighttime respectively.
- The above changes, taken together, result in this dataset being a complete hourly time series, with values given as missing only for daytime cases of missing or rejected satellite data.
- The Bureau of Meteorology ground network used for bias modelling and uncertainty estimation includes the eight stations that operated for approximately two years during 2012-2014 under the Solar Resource Mapping Project sponsored by the Australian Renewable Energy Agency.
- The bias model has an improved functional form and is based on the expanded station network.
- The uncertainty estimates are based on 25-minute averages of the surface observations, rather than the 1-minute averages used previously, to better recognise the spatial averaging inherent in the satellite data.

Differences from previous version of metadata (dated 15 March 2016)

- From 22 March 2016 the data are derived from the Himawari-8 satellite. While Himawari-8 provides data every 10 minutes, compared to hourly for the earlier satellites, this solar irradiance dataset currently continues to be hourly.
- The observation times for the Himawari-8 period fall in the range 30 to 40 minutes into the hour, even though the following satellite scan (40 to 50 minutes into the hour) would better match the previous satellites, in order to avoid data gaps caused by the daily absence of a satellite scan starting at 02:40 UTC due to satellite housekeeping.

	References Ridley B., Boland J. and Lauret P. (2010). Modelling of diffuse solar fraction with multiple predictors. Ren. Energy, 35, 478-483. Weymouth G.T. and Le Marshall J.F. 2001. Estimate of daily surface solar exposure using GMS-5 stretched-VISSR observations. The system and basic results. Aust. Meteor. Mag., 50, 263-278.
Positional Accuracy	The satellite data on which the analyses were based have an associated resolution and typical accuracy of 0.01 degrees, although some individual images have errors of several times that.
Attribute Accuracy	The accuracy of the satellite-based DNI values is estimated by comparison with 25-minute averaged DNI measurements from Bureau of Meteorology surface-based instruments. The mean bias difference (average of the satellite - surface difference), calculated for the entire record and across all surface sites, is -3 W/m^2. The root mean square difference, calculated on a similar basis, is 172 W/m^2. The source of uncertainties associated with calculation of DNI includes uncertainties in: • limitations and approximations in the physical satellite model used to estimate GHI; • anisotropy of cloud-top reflectance; • water vapour in the atmosphere; • satellite calibration; and • the GHI-to-DNI conversion model. It should be noted that a particular DNI value may not be representative of a 1-hour period, due to variations in the solar zenith angle during the hour, and most significantly because of variations in atmospheric conditions such as cloudiness. For more information (metadata) please contact us.

Logical Consistency	Not applicable
Completeness	The temporal coverage is not complete. A grid cell may contain a missing value for a particular time if the time is between sunrise and sunset and no satellite image was available, the image was not processed, or the image was rejected by quality control. Notably: • No values are reported for hours early and late in the day for the period up until 1994-06-30, due to the absence of satellite images at these times during the initial period of operation of GMS4. • The values are sparser during the period July 2001 to June 2003, which spans the period of reduced imaging frequency at the end of the life of GMS-5, and the initial few weeks of operation of GOES-9 in the Australian region.

Metadata date

Metadata date	15 November 2016

Contact Information

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