FullView®

SOLAR

Site Climate Variability Analysis

ANALYSIS OF 10-YEAR RECORD

Port Augusta, South Australia

DATE

23 April 2010

FOR

RenewablesSA

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3TIER

1 INTRODUCTION

3TIER has been retained by RenewablesSA to assess the variability and magnitude of solar irradiance, wind speed and temperature at the Port Augusta project site located in South Australia. This report provides a retrospective analysis of the past 10 years of solar irradiance, wind speed and temperature data.

The long-term average global horizontal irradiance value at the Port Augusta site (Latitude: 32.537019°S, Longitude: 137.813373°E) is **5.191** kWh/m^2/day (**216.3** W/m^2). The long-term average direct normal irradiance value is **5.670** kWh/m^2/day (**236.3** W/m^2), and the long-term average diffuse horizontal irradiance value is **1.631** kWh/m^2/day (**67.9** W/m^2).

The long-term average wind speed at 10 meters above ground level (AGL) is **4.22** m/s. The long-term average temperature at 2 meters AGL is **17.8** °C.

This report is accompanied by all the information used in making these summary plots and tables. A time series comma separated value (CSV) file includes hour-ending mean data for: Global Horizontal Irradiance (W/m^2), Direct Normal Irradiance (W/m^2), Diffuse Irradiance (W/m^2), Zenith Angle (degrees), Azimuth Angle (degrees), Wind Speed at 10m (m/s), Wind Direction at 10m (degrees), Air Temperature at 2m (Kelvin), and Relative Humidity at 2m (%). The key variables are also summarised in monthly and hourly diurnal tables, again provided as CSV files.

Typical Meteorological Year (TMY) files have been created in the TMY2 data format for use in existing software that is unable to process the entire time series data set. The TMY files were created using an empirical approach that selects samples from the full time series to create a "typical year" of data with 8760 hours, while preserving the following characteristics of direct normal irradiance: monthly means, monthly cumulative distribution of daily means, diurnal cycle, and the annual mean.

No on-site observations were provided at this project location; thus, all data presented within this report are purely processed satellite output and raw model output. If observational data become available, 3TIER can incorporate the data via additional analysis and provide statistically-corrected results.

Contents

2 EXPLANATION OF IRRADIANCE VALUES

The irradiance values presented in this report are from 3TIER's solar dataset. This dataset is based on the past 10 years (January 1999 – March 2009) of half-hourly high-resolution (roughly 1 km) visible satellite imagery (GMS5, GOES09 and AMTSAT01 using the broad-band visible wavelength channel). The satellite imagery has been processed to create 10 years of hourly values of Global Horizontal Irradiance, Direct Normal Irradiance and Diffuse Horizontal Irradiance at a horizontal resolution of 2 arc minutes. To develop and validate the model, and estimate the error, 3TIER compared the derived irradiance values with observations from the direct surface radiation measurements contained in the Baseline Surface Radiation Network and other sites from the Australian Bureau of Meteorology.

The error estimates were derived comparing the model data with observations that were not used in training or tuning the modelling system. Australia has few available observations, but the indications are that the results in Australia were similar to those in North America (even though the satellites and therefore the tuning algorithms were different). In fact, the Australian results may be marginally more accurate than the North American results, but to provide conservative estimates of accuracy 3TIER has applied the same error estimates to this work as were derived from the larger number of comparisons available in the USA. For more information on 3TIER's validation procedures, including validation white papers, please visit: http://www.3tier.com/en/support/solar-prospecting-tools/what-were-3tiers-solar-prospecting-data-validation-procedures/.

2.1 Global Horizontal Irradiance

Global Horizontal Irradiance is the quantity of the total solar radiation per unit area that is intercepted by a flat, horizontal surface. This value is of particular interest to photovoltaic installations. It includes both direct beam radiation (radiation that comes from the direction of the sun) and diffuse radiation (radiation that has been scattered by the atmosphere and which comes from all directions of the sky). The estimate has a standard error of 10%.

2.2 Direct Normal Irradiance

Direct Normal Irradiance is the quantity of direct beam solar radiation per unit area that is intercepted by a flat surface that is at all times pointed in the direction of the sun. This quantity is of particular interest to concentrating solar installations and installations that track the position of the sun. The estimate has a standard error of 16%.

2.3 Diffuse Horizontal Irradiance

Diffuse Horizontal Irradiance is the quantity of diffuse solar radiation per unit area that is intercepted by a flat, horizontal surface that is not subject to any shade or shadow and does not arrive on a direct path from the sun. The estimate has a standard error of 10%.

3 SOLAR RESOURCE ASSESSMENT

This section provides a retrospective analysis of the past 10 years of solar irradiance data at the Port Augusta project site (Latitude: 32.537019°S, Longitude: 137.813373°E). All irradiance data presented within this section are valid only for this particular location.

3.1 Monthly-mean Variability of Solar Irradiance

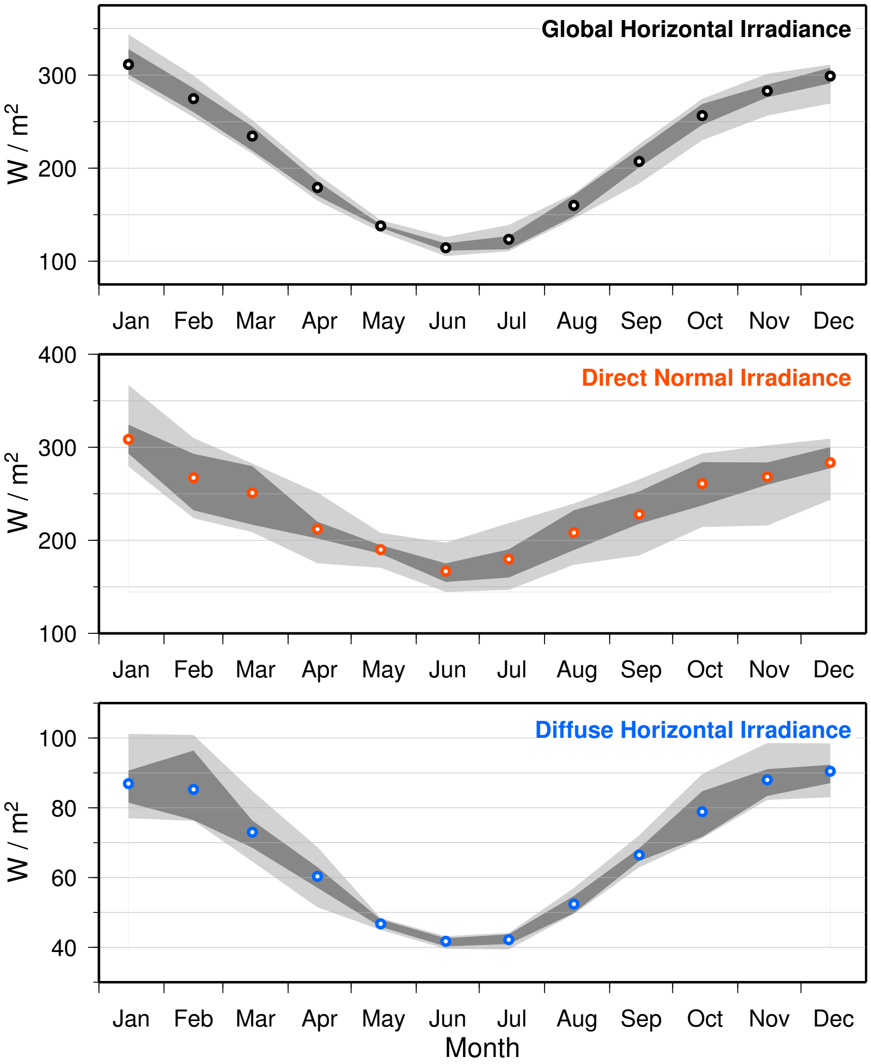


Figure 1: Variability of monthly-mean **Global Horizontal** [top], **Direct Normal** [middle], and **Diffuse Horizontal** [bottom] irradiance. Long-term monthly-mean values are denoted by coloured circles. Upper and lower boundaries of the dark shading correspond to the 75% and 25% quartiles, while the light shading denotes the maximum and minimum monthly-mean irradiance values. Please note that the vertical scale varies between the plots.

3.2 Solar Irradiance Distributions

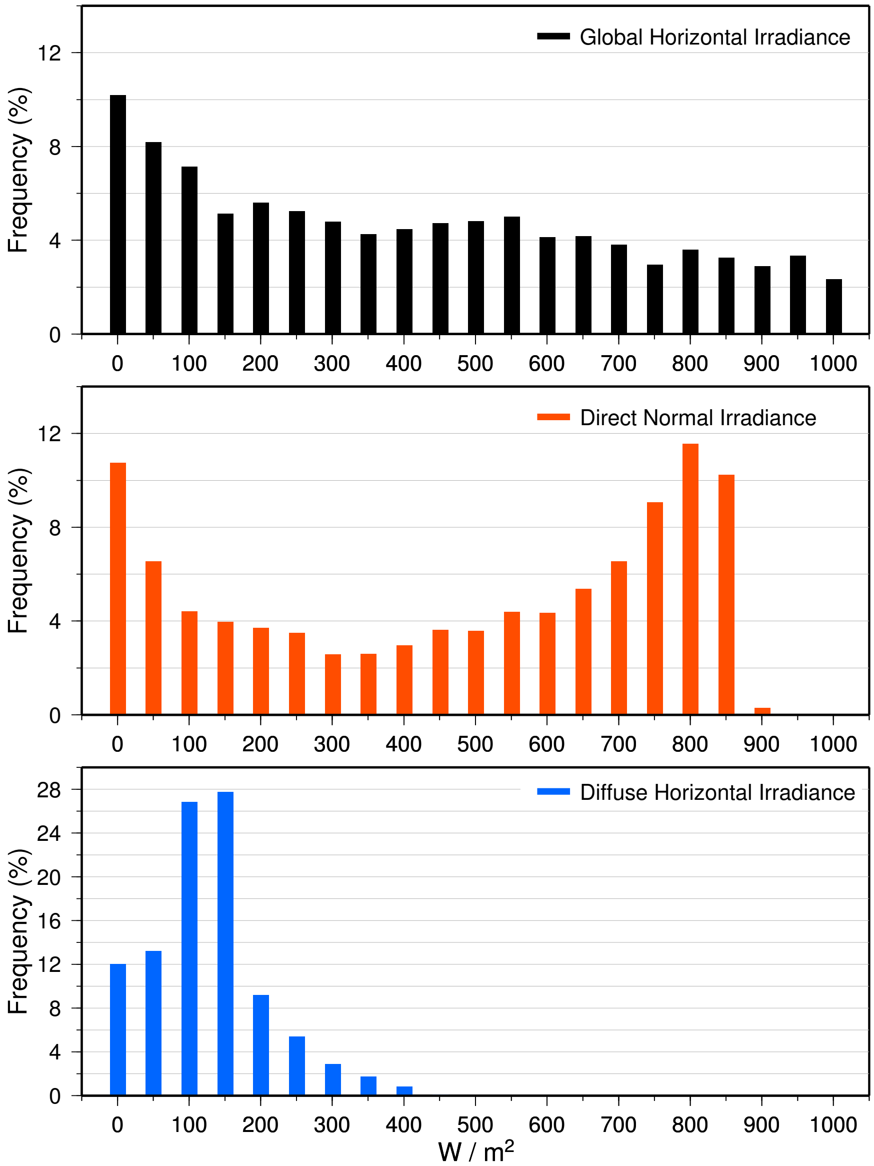


Figure 2: Distribution of hourly **Global Horizontal** [top], **Direct Normal** [middle] and **Diffuse Horizontal** [bottom] daylight irradiance values using 50 W/m^2 bins. (0 W/m^2 bin contains only values ≤ 25.) Each vertical bar represents the frequency of irradiance values occurring within each bin. For example, a vertical bar centered on 200 W/m^2 reaching up to 10% means that one-tenth of all daytime values are between 175 and 225 W/m^2. Please note that the vertical scale varies between the plots.

3.3 Diurnal Variability of Solar Irradiance

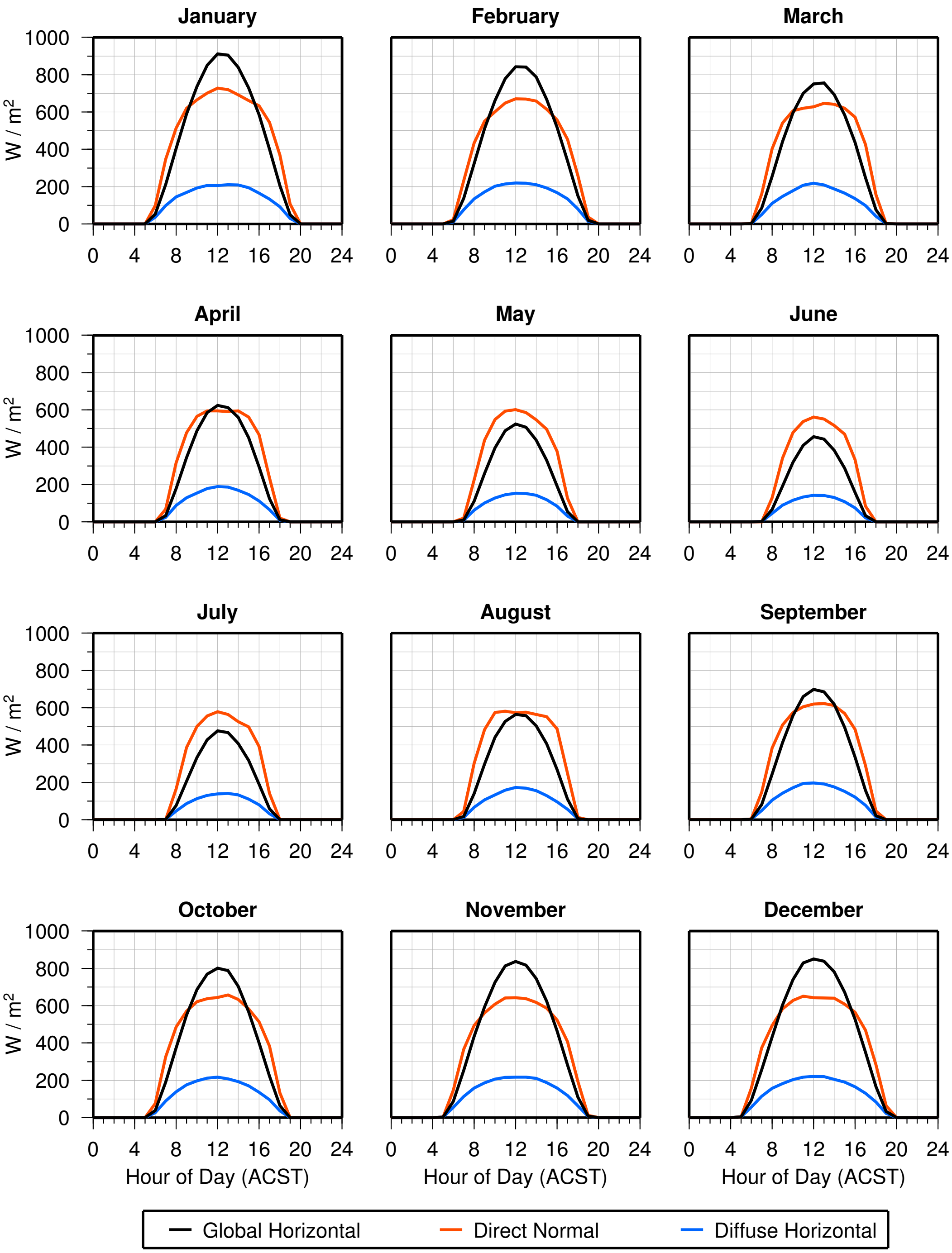
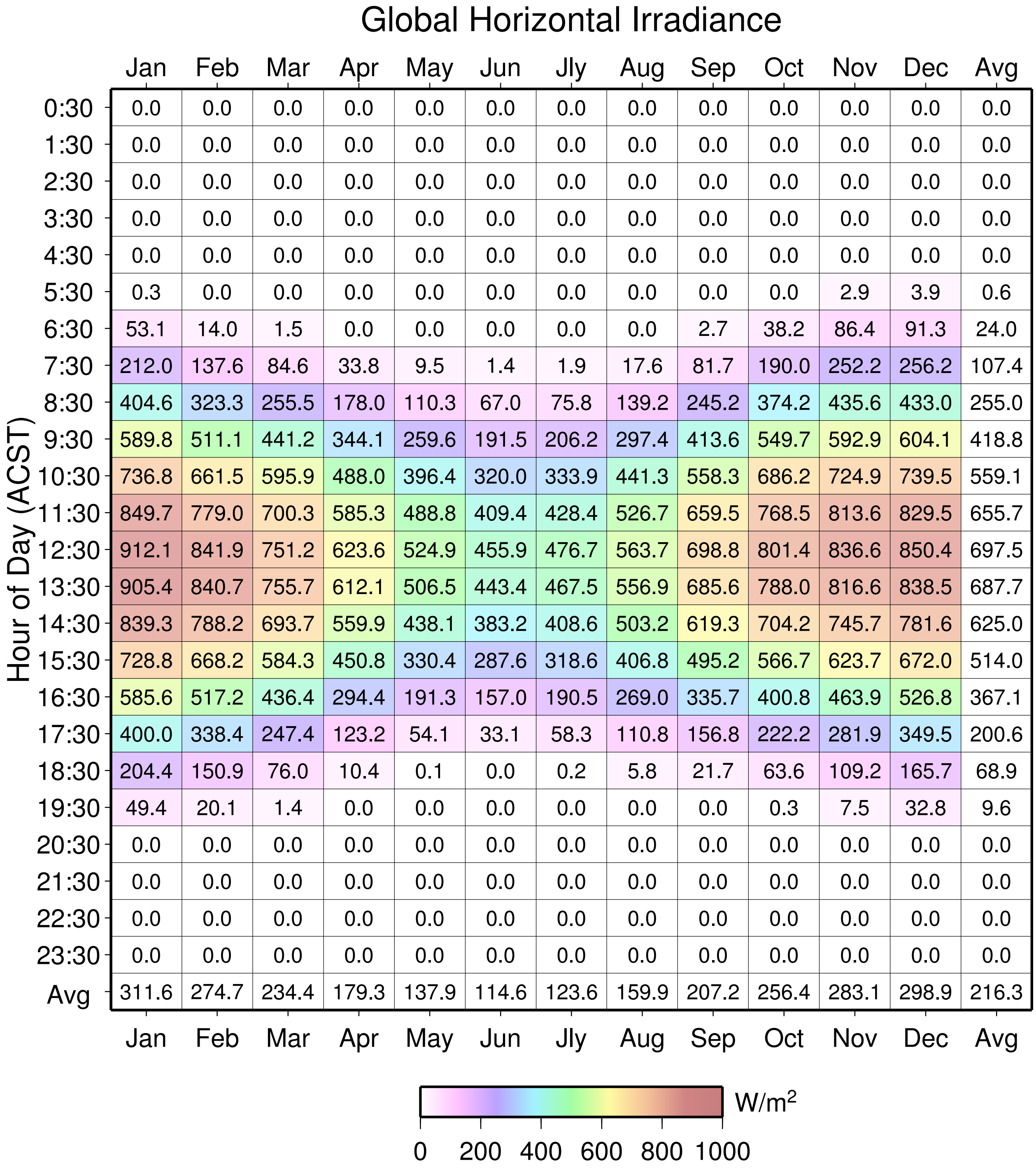


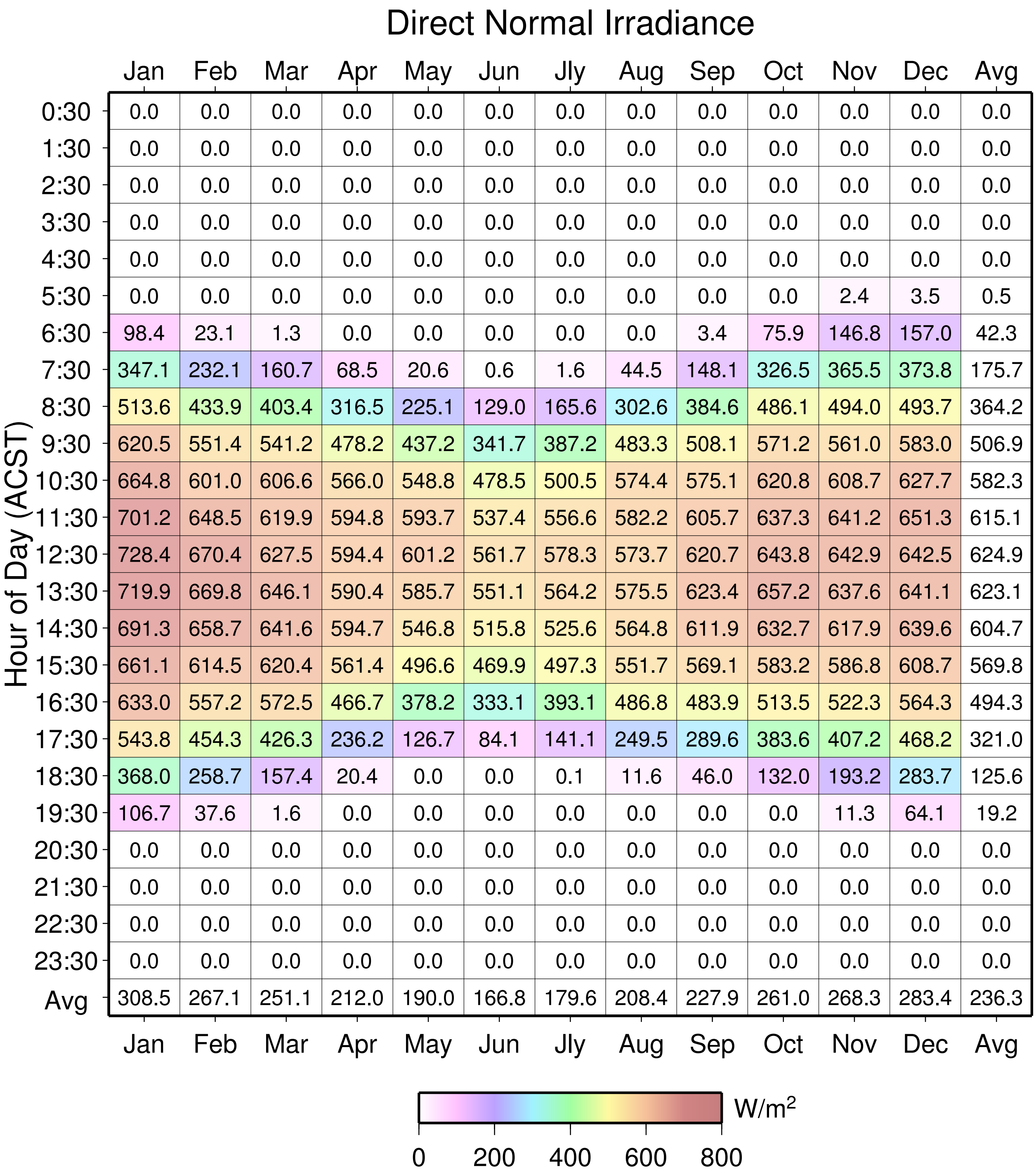
Figure 3: Diurnal cycle of **Global Horizontal** (black), **Direct Normal** (orange) and **Diffuse Horizontal** (blue) irradiance for each month of the year. The horizontal axis is Australian Central Standard Time (ACST). Figures 4, 5, and 6 show the diurnal cycle of Global Horizontal, Direct Normal, and Diffuse Horizontal solar irradiance, respectively, for each calendar month as a "12 X 24" table.

3.4 Tabular Data



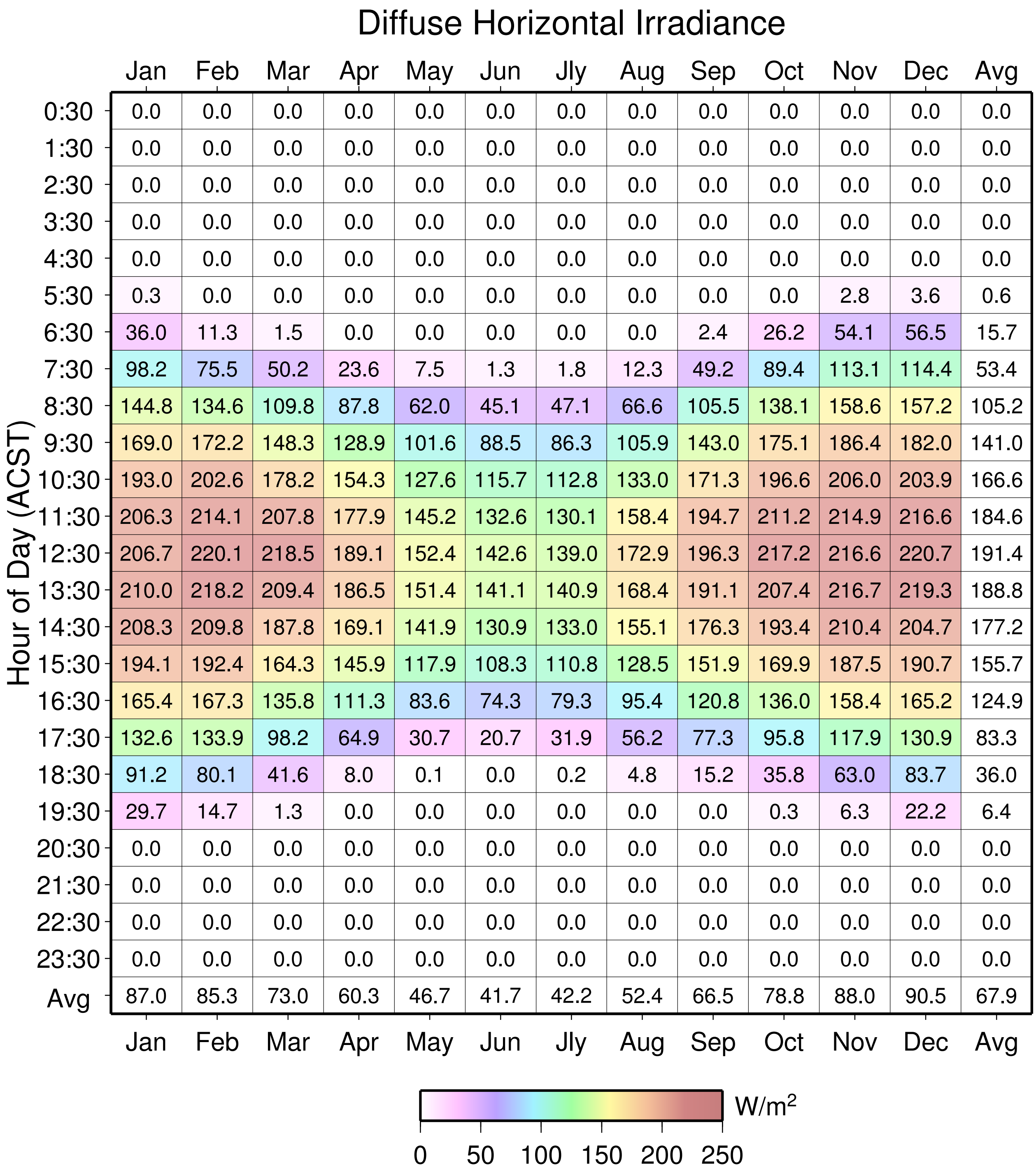
Hour of Day (ACST)	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Avg
0:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5:30	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	3.9	0.6
6:30	53.1	14.0	1.5	0.0	0.0	0.0	0.0	0.0	2.7	38.2	86.4	91.3	24.0
7:30	212.0	137.6	84.6	33.8	9.5	1.4	1.9	17.6	81.7	190.0	252.2	256.2	107.4
8:30	404.6	323.3	255.5	178.0	110.3	67.0	75.8	139.2	245.2	374.2	435.6	433.0	255.0
9:30	589.8	511.1	441.2	344.1	259.6	191.5	206.2	297.4	413.6	549.7	592.9	604.1	418.8
10:30	736.8	661.5	595.9	488.0	396.4	320.0	333.9	441.3	558.3	686.2	724.9	739.5	559.1
11:30	849.7	779.0	700.3	585.3	488.8	409.4	428.4	526.7	659.5	768.5	813.6	829.5	655.7
12:30	912.1	841.9	751.2	623.6	524.9	455.9	476.7	563.7	698.8	801.4	836.6	850.4	697.5
13:30	905.4	840.7	755.7	612.1	506.5	443.4	467.5	556.9	685.6	788.0	816.6	838.5	687.7
14:30	839.3	788.2	693.7	559.9	438.1	383.2	408.6	503.2	619.3	704.2	745.7	781.6	625.0
15:30	728.8	668.2	584.3	450.8	330.4	287.6	318.6	406.8	495.2	566.7	623.7	672.0	514.0
16:30	585.6	517.2	436.4	294.4	191.3	157.0	190.5	269.0	335.7	400.8	463.9	526.8	367.1
17:30	400.0	338.4	247.4	123.2	54.1	33.1	58.3	110.8	156.8	222.2	281.9	349.5	200.6
18:30	204.4	150.9	76.0	10.4	0.1	0.0	0.2	5.8	21.7	63.6	109.2	165.7	68.9
19:30	49.4	20.1	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3	7.5	32.8	9.6
20:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avg	311.6	274.7	234.4	179.3	137.9	114.6	123.6	159.9	207.2	256.4	283.1	298.9	216.3
	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Avg

Figure 4: Hourly-mean **Global Horizontal Irradiance** values in W/m^2. The vertical axis is Australian Central Standard Time (ACST). Time series graph of the diurnal variability is shown in Figure 3.



	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Avg
0:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	3.5	0.5
6:30	98.4	23.1	1.3	0.0	0.0	0.0	0.0	0.0	3.4	75.9	146.8	157.0	42.3
7:30	347.1	232.1	160.7	68.5	20.6	0.6	1.6	44.5	148.1	326.5	365.5	373.8	175.7
8:30	513.6	433.9	403.4	316.5	225.1	129.0	165.6	302.6	384.6	486.1	494.0	493.7	364.2
9:30	620.5	551.4	541.2	478.2	437.2	341.7	387.2	483.3	508.1	571.2	561.0	583.0	506.9
10:30	664.8	601.0	606.6	566.0	548.8	478.5	500.5	574.4	575.1	620.8	608.7	627.7	582.3
11:30	701.2	648.5	619.9	594.8	593.7	537.4	556.6	582.2	605.7	637.3	641.2	651.3	615.1
12:30	728.4	670.4	627.5	594.4	601.2	561.7	578.3	573.7	620.7	643.8	642.9	642.5	624.9
13:30	719.9	669.8	646.1	590.4	585.7	551.1	564.2	575.5	623.4	657.2	637.6	641.1	623.1
14:30	691.3	658.7	641.6	594.7	546.8	515.8	525.6	564.8	611.9	632.7	617.9	639.6	604.7
15:30	661.1	614.5	620.4	561.4	496.6	469.9	497.3	551.7	569.1	583.2	586.8	608.7	569.8
16:30	633.0	557.2	572.5	466.7	378.2	333.1	393.1	486.8	483.9	513.5	522.3	564.3	494.3
17:30	543.8	454.3	426.3	236.2	126.7	84.1	141.1	249.5	289.6	383.6	407.2	468.2	321.0
18:30	368.0	258.7	157.4	20.4	0.0	0.0	0.1	11.6	46.0	132.0	193.2	283.7	125.6
19:30	106.7	37.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.3	64.1	19.2
20:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avg	308.5	267.1	251.1	212.0	190.0	166.8	179.6	208.4	227.9	261.0	268.3	283.4	236.3

Figure 5: Hourly-mean **Direct Normal Irradiance** values in W/m^2. The vertical axis is Australian Central Standard Time (ACST). Time series graph of the diurnal variability is shown in Figure 3.



Diffuse Horizontal Irradiance

	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Avg
0:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5:30	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	3.6	0.6
6:30	36.0	11.3	1.5	0.0	0.0	0.0	0.0	0.0	2.4	26.2	54.1	56.5	15.7
7:30	98.2	75.5	50.2	23.6	7.5	1.3	1.8	12.3	49.2	89.4	113.1	114.4	53.4
8:30	144.8	134.6	109.8	87.8	62.0	45.1	47.1	66.6	105.5	138.1	158.6	157.2	105.2
9:30	169.0	172.2	148.3	128.9	101.6	88.5	86.3	105.9	143.0	175.1	186.4	182.0	141.0
10:30	193.0	202.6	178.2	154.3	127.6	115.7	112.8	133.0	171.3	196.6	206.0	203.9	166.6
11:30	206.3	214.1	207.8	177.9	145.2	132.6	130.1	158.4	194.7	211.2	214.9	216.6	184.6
12:30	206.7	220.1	218.5	189.1	152.4	142.6	139.0	172.9	196.3	217.2	216.6	220.7	191.4
13:30	210.0	218.2	209.4	186.5	151.4	141.1	140.9	168.4	191.1	207.4	216.7	219.3	188.8
14:30	208.3	209.8	187.8	169.1	141.9	130.9	133.0	155.1	176.3	193.4	210.4	204.7	177.2
15:30	194.1	192.4	164.3	145.9	117.9	108.3	110.8	128.5	151.9	169.9	187.5	190.7	155.7
16:30	165.4	167.3	135.8	111.3	83.6	74.3	79.3	95.4	120.8	136.0	158.4	165.2	124.9
17:30	132.6	133.9	98.2	64.9	30.7	20.7	31.9	56.2	77.3	95.8	117.9	130.9	83.3
18:30	91.2	80.1	41.6	8.0	0.1	0.0	0.2	4.8	15.2	35.8	63.0	83.7	36.0
19:30	29.7	14.7	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	6.3	22.2	6.4
20:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23:30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avg	87.0	85.3	73.0	60.3	46.7	41.7	42.2	52.4	66.5	78.8	88.0	90.5	67.9

Figure 6: Hourly-mean **Diffuse Horizontal Irradiance** values in W/m^2. The vertical axis is Australian Central Standard Time (ACST). Time series graph of the diurnal variability is shown in Figure 3.

4 MODEL SIMULATIONS BY 3TIER

The assessment of the wind resource at the Port Augusta project site presented in this report is based on 10+ years of simulated data (January 1999 – March 2009). The simulated data set is constructed using a state-of-the-art Numerical Weather Prediction (NWP) model that processes coarse-resolution historic gridded data and high resolution topographical and surface data to generate the meteorological time series data.

The NWP model simulated data set is constructed from two separate model runs: a 10+ year 15km resolution simulation and a 1-year 5km resolution simulation. Some details of the NWP model configuration are shown below in Table 1. The extent of the coarsest grid was selected to capture the effect of synoptic weather events on the wind resource at the site, as well as to allow the model to develop regional, thermally-driven circulations. The increasingly fine 45km, 15km, and 5km grids were selected to model the effect of local terrain and local scale atmospheric circulations.

Parameter	Value
Mesoscale numerical weather prediction model	WRF
Horizontal resolution of valid study area	5.0km
Number of vertical levels	31
Elevation data base	3 second SRTM
Vegetation data base	30 second USGS
Surface parameterisation	Monin-Obukhov similarity model
Boundary layer parameterisation	YSU model (MRF with entrainment)
Land surface scheme	5-layer soil diffusivity model

Table 1: Numerical weather prediction model configuration.

5 WIND AND TEMPERATURE RESOURCE ASSESSMENT

This section provides a retrospective analysis of the past 10 years of wind and temperature data, derived from the NWP model, at the Port Augusta project site (Latitude: 32.537019°S, Longitude: 137.813373°E). All data presented within this section are valid only for this particular location.

5.1 Monthly-Mean Variability

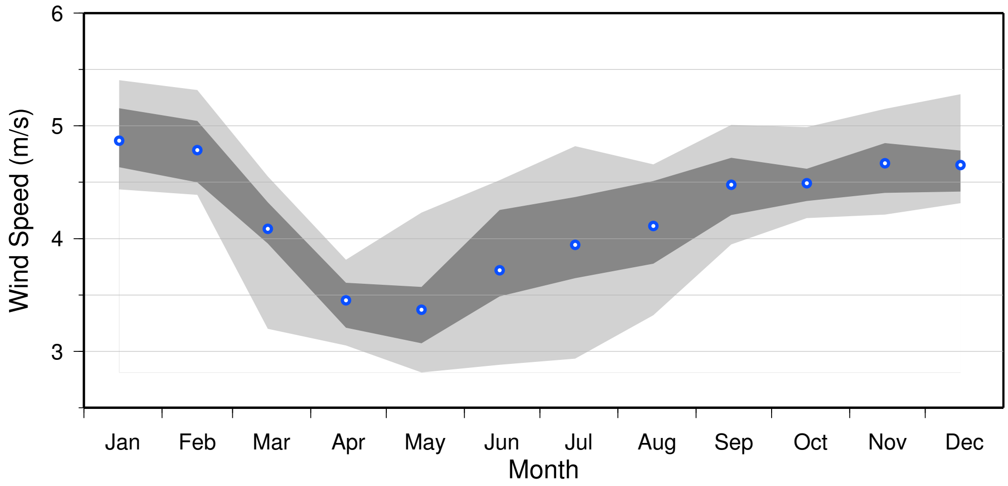


Figure 7: Variability of monthly-mean wind speed at $10m$ AGL at Port Augusta. Long-term monthly-mean values are denoted by coloured circles. Upper and lower boundaries of the dark shading correspond to the 75% and 25% quartiles, while the light shading denotes the maximum and minimum monthly-mean wind speeds.

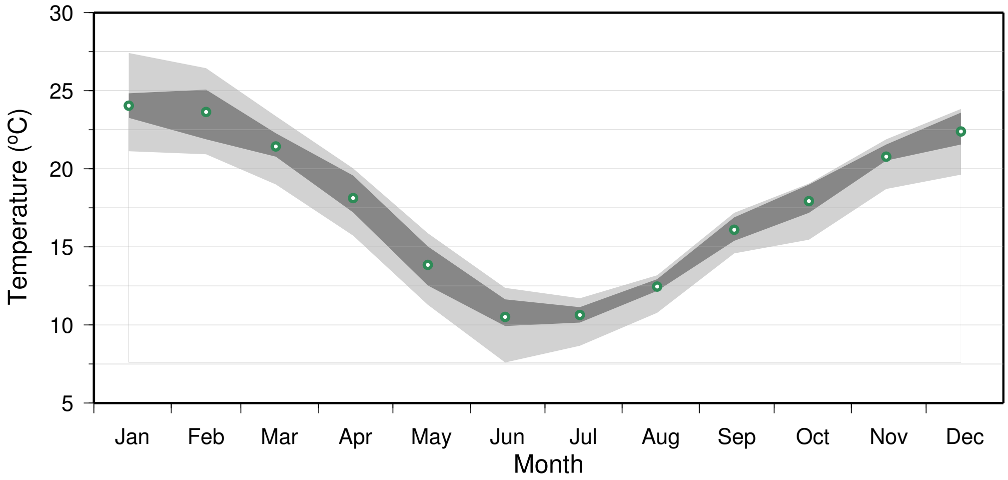


Figure 8: Variability of monthly-mean temperature at $2m$ AGL at Port Augusta. Long-term monthly-mean values are denoted by coloured circles. Upper and lower boundaries of the dark shading correspond to the 75% and 25% quartiles, while the light shading denotes the maximum and minimum monthly-mean temperature.

5.2 Diurnal Variability of Wind Speed

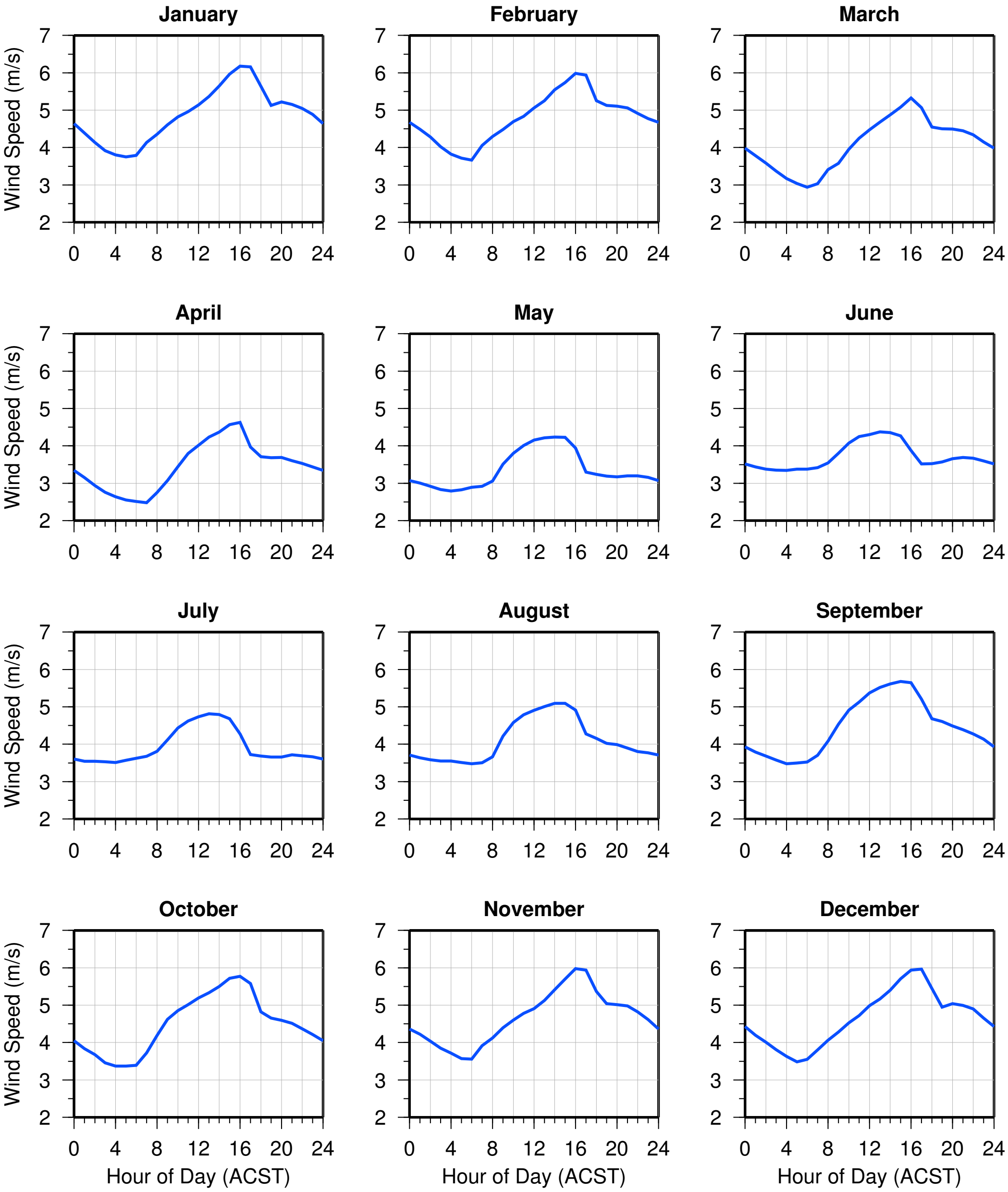


Figure 9: Diurnal cycle of wind speed at $10m$ AGL for each month of the year. The horizontal axis is in Australian Central Standard Time (ACST). Figure 11 shows the diurnal cycle of wind speed for each calendar month as a '12 X 24' table.

5.3 Diurnal Variability of Temperature

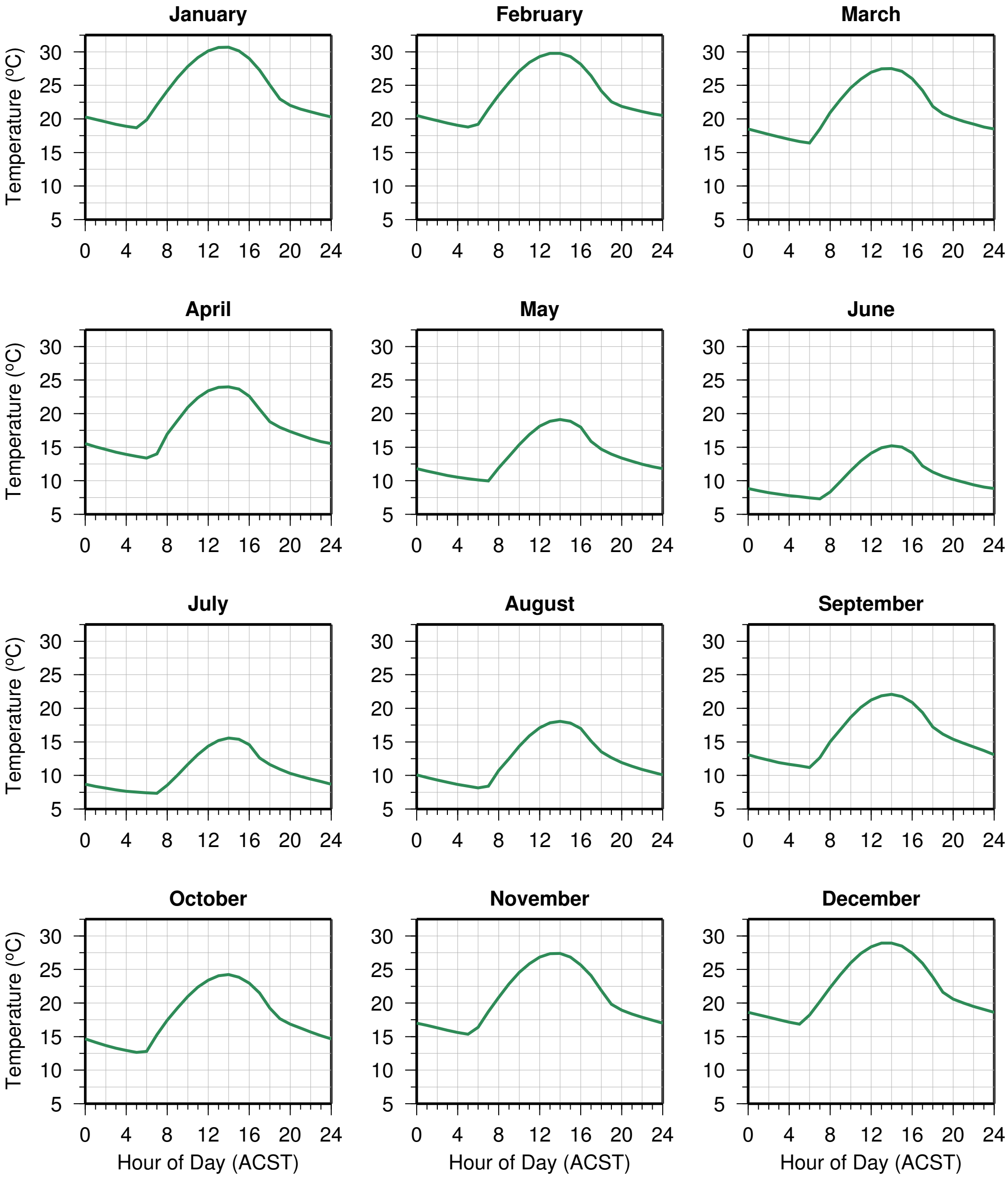
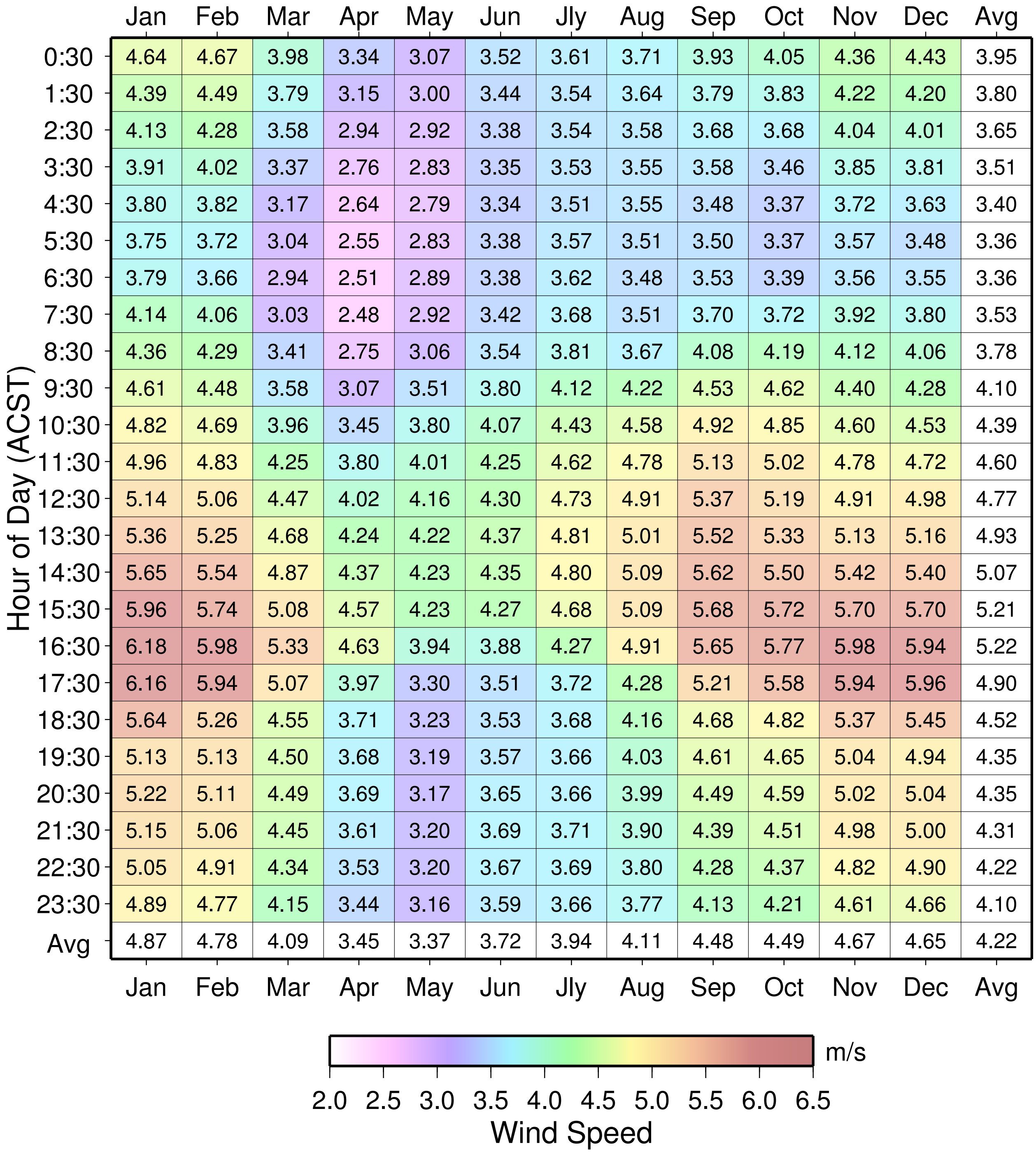


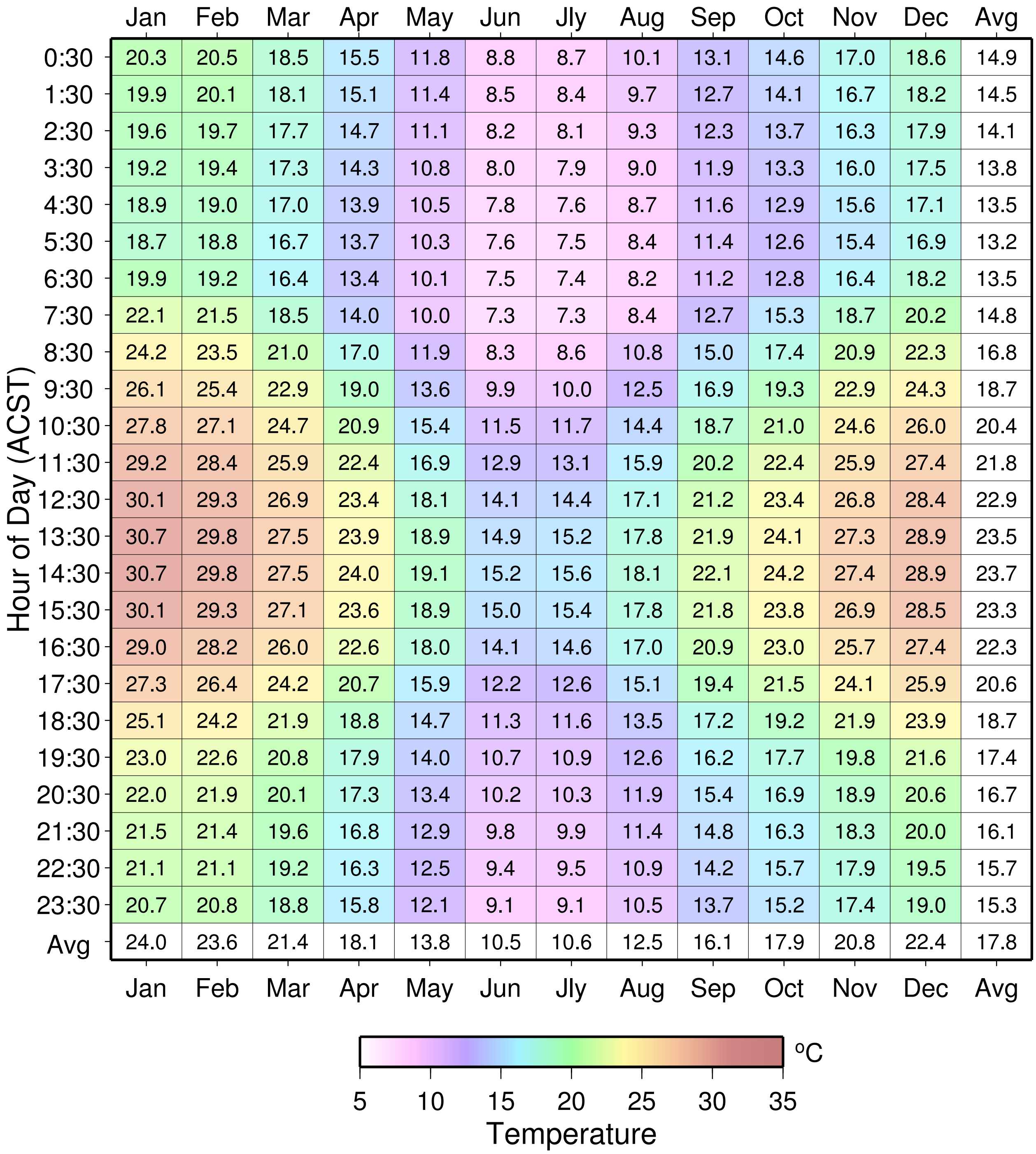
Figure 10: Diurnal cycle of temperature at $2m$ AGL for each month of the year. The horizontal axis is in Australian Central Standard Time (ACST). Figure 12 shows the diurnal cycle of temperature for each calendar month as a '12 X 24' table.

5.4 Tabular Data



	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Avg
0:30	4.64	4.67	3.98	3.34	3.07	3.52	3.61	3.71	3.93	4.05	4.36	4.43	3.95
1:30	4.39	4.49	3.79	3.15	3.00	3.44	3.54	3.64	3.79	3.83	4.22	4.20	3.80
2:30	4.13	4.28	3.58	2.94	2.92	3.38	3.54	3.58	3.68	3.68	4.04	4.01	3.65
3:30	3.91	4.02	3.37	2.76	2.83	3.35	3.53	3.55	3.58	3.46	3.85	3.81	3.51
4:30	3.80	3.82	3.17	2.64	2.79	3.34	3.51	3.55	3.48	3.37	3.72	3.63	3.40
5:30	3.75	3.72	3.04	2.55	2.83	3.38	3.57	3.51	3.50	3.37	3.57	3.48	3.36
6:30	3.79	3.66	2.94	2.51	2.89	3.38	3.62	3.48	3.53	3.39	3.56	3.55	3.36
7:30	4.14	4.06	3.03	2.48	2.92	3.42	3.68	3.51	3.70	3.72	3.92	3.80	3.53
8:30	4.36	4.29	3.41	2.75	3.06	3.54	3.81	3.67	4.08	4.19	4.12	4.06	3.78
9:30	4.61	4.48	3.58	3.07	3.51	3.80	4.12	4.22	4.53	4.62	4.40	4.28	4.10
10:30	4.82	4.69	3.96	3.45	3.80	4.07	4.43	4.58	4.92	4.85	4.60	4.53	4.39
11:30	4.96	4.83	4.25	3.80	4.01	4.25	4.62	4.78	5.13	5.02	4.78	4.72	4.60
12:30	5.14	5.06	4.47	4.02	4.16	4.30	4.73	4.91	5.37	5.19	4.91	4.98	4.77
13:30	5.36	5.25	4.68	4.24	4.22	4.37	4.81	5.01	5.52	5.33	5.13	5.16	4.93
14:30	5.65	5.54	4.87	4.37	4.23	4.35	4.80	5.09	5.62	5.50	5.42	5.40	5.07
15:30	5.96	5.74	5.08	4.57	4.23	4.27	4.68	5.09	5.68	5.72	5.70	5.70	5.21
16:30	6.18	5.98	5.33	4.63	3.94	3.88	4.27	4.91	5.65	5.77	5.98	5.94	5.22
17:30	6.16	5.94	5.07	3.97	3.30	3.51	3.72	4.28	5.21	5.58	5.94	5.96	4.90
18:30	5.64	5.26	4.55	3.71	3.23	3.53	3.68	4.16	4.68	4.82	5.37	5.45	4.52
19:30	5.13	5.13	4.50	3.68	3.19	3.57	3.66	4.03	4.61	4.65	5.04	4.94	4.35
20:30	5.22	5.11	4.49	3.69	3.17	3.65	3.66	3.99	4.49	4.59	5.02	5.04	4.35
21:30	5.15	5.06	4.45	3.61	3.20	3.69	3.71	3.90	4.39	4.51	4.98	5.00	4.31
22:30	5.05	4.91	4.34	3.53	3.20	3.67	3.69	3.80	4.28	4.37	4.82	4.90	4.22
23:30	4.89	4.77	4.15	3.44	3.16	3.59	3.66	3.77	4.13	4.21	4.61	4.66	4.10
Avg	4.87	4.78	4.09	3.45	3.37	3.72	3.94	4.11	4.48	4.49	4.67	4.65	4.22

Figure 11: Hourly-mean wind speed values at $10m$ AGL in m/s. The vertical axis is in Australian Central Standard Time (ACST). Time series graph of the diurnal variability for each month is shown in Figure 9.



	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Avg
0:30	20.3	20.5	18.5	15.5	11.8	8.8	8.7	10.1	13.1	14.6	17.0	18.6	14.9
1:30	19.9	20.1	18.1	15.1	11.4	8.5	8.4	9.7	12.7	14.1	16.7	18.2	14.5
2:30	19.6	19.7	17.7	14.7	11.1	8.2	8.1	9.3	12.3	13.7	16.3	17.9	14.1
3:30	19.2	19.4	17.3	14.3	10.8	8.0	7.9	9.0	11.9	13.3	16.0	17.5	13.8
4:30	18.9	19.0	17.0	13.9	10.5	7.8	7.6	8.7	11.6	12.9	15.6	17.1	13.5
5:30	18.7	18.8	16.7	13.7	10.3	7.6	7.5	8.4	11.4	12.6	15.4	16.9	13.2
6:30	19.9	19.2	16.4	13.4	10.1	7.5	7.4	8.2	11.2	12.8	16.4	18.2	13.5
7:30	22.1	21.5	18.5	14.0	10.0	7.3	7.3	8.4	12.7	15.3	18.7	20.2	14.8
8:30	24.2	23.5	21.0	17.0	11.9	8.3	8.6	10.8	15.0	17.4	20.9	22.3	16.8
9:30	26.1	25.4	22.9	19.0	13.6	9.9	10.0	12.5	16.9	19.3	22.9	24.3	18.7
10:30	27.8	27.1	24.7	20.9	15.4	11.5	11.7	14.4	18.7	21.0	24.6	26.0	20.4
11:30	29.2	28.4	25.9	22.4	16.9	12.9	13.1	15.9	20.2	22.4	25.9	27.4	21.8
12:30	30.1	29.3	26.9	23.4	18.1	14.1	14.4	17.1	21.2	23.4	26.8	28.4	22.9
13:30	30.7	29.8	27.5	23.9	18.9	14.9	15.2	17.8	21.9	24.1	27.3	28.9	23.5
14:30	30.7	29.8	27.5	24.0	19.1	15.2	15.6	18.1	22.1	24.2	27.4	28.9	23.7
15:30	30.1	29.3	27.1	23.6	18.9	15.0	15.4	17.8	21.8	23.8	26.9	28.5	23.3
16:30	29.0	28.2	26.0	22.6	18.0	14.1	14.6	17.0	20.9	23.0	25.7	27.4	22.3
17:30	27.3	26.4	24.2	20.7	15.9	12.2	12.6	15.1	19.4	21.5	24.1	25.9	20.6
18:30	25.1	24.2	21.9	18.8	14.7	11.3	11.6	13.5	17.2	19.2	21.9	23.9	18.7
19:30	23.0	22.6	20.8	17.9	14.0	10.7	10.9	12.6	16.2	17.7	19.8	21.6	17.4
20:30	22.0	21.9	20.1	17.3	13.4	10.2	10.3	11.9	15.4	16.9	18.9	20.6	16.7
21:30	21.5	21.4	19.6	16.8	12.9	9.8	9.9	11.4	14.8	16.3	18.3	20.0	16.1
22:30	21.1	21.1	19.2	16.3	12.5	9.4	9.5	10.9	14.2	15.7	17.9	19.5	15.7
23:30	20.7	20.8	18.8	15.8	12.1	9.1	9.1	10.5	13.7	15.2	17.4	19.0	15.3
Avg	24.0	23.6	21.4	18.1	13.8	10.5	10.6	12.5	16.1	17.9	20.8	22.4	17.8

Figure 12: Hourly-mean temperature values at $2m$ AGL in degrees Celsius. The vertical axis is in Australian Central Standard Time (ACST). Time series graph of the diurnal variability for each month is shown in Figure 10.

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ADDENDUM ON MODELLING APPROACH AND POTENTIAL SOURCES OF DIFFERENCE

There may be differences in the modelling results between 3TIER and alternative information providers. This statement underlines some of the potential sources of difference.

General Modelling Approach

There are several methods to achieve solar modelling. Some approaches rely primarily on interpolation between ground-based observations, although this is impractical in locations where the observations are sparse. Although other approaches exist, it has been found that modelling from satellite-based observations is the most accurate approach to obtaining solar information beyond ~25km from a well-maintained observation station. 3TIER uses satellite-based modelling to produce its solar data. However, there are also variations in the satellite modelling approach that may cause differences in the modelled irradiance.

3TIER's Modelling Approach

3TIER uses satellite imagery to determine the cloud index for each hour. This is combined with turbidity information, terrain data and snow cover information to calculate the Global Horizontal Irradiance (GHI). After calculating the GHI, the Direct Normal Irradiance (DNI) and Diffuse Irradiance (DIF) are calculated using a methodology based upon the work of Richard Perez at the State University of New York (SUNY).

Some of the features of 3TIER's modelling which may be different to other approaches include:

Turbidity Index

3TIER understands that the conversion from GHI to DNI and DIF is very sensitive to the turbidity index. After considering several approaches, 3TIER has decided that the best approach available at this stage is to use the Linke Turbidity Index with the monthly values calculated using from J. Remund et al[1].

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[1] Remund J., Wald L., Lefevre M., Ranchin T., Page J., 2003. Worldwide Linke turbidity information. Proceedings of ISES Solar World Congress, 16-19 June 2003, Göteborg, Sweden. Also described at: http://www.helioclim.net/linke/linke_helioserve.html

This data set is not ideal over Australia and has some spatial anomalies. For this reason 3TIER are very careful in checking the turbidity index in all locations where our data is applied to ensure that it is not in a region affected by the unusual spatial effects in the turbidity index. To date 3TIER has not received a request that fell in a region where the Linke Turbidity Index did not seem reliable. The approach has been validated against on-ground observations.
The Turbidity Index values used were:

Site name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Neuroodla	4.25	4.35	3.8	3.85	3.45	3.3	3.25	3.15	3.8	3.85	4.05	4.2
Northwest Bend	3.3	3.5	3.25	3.05	3.15	3.1	2.75	3.1	3.45	3.25	3.4	3.5
Pimba	4.35	4.35	3.95	3.9	3.4	3.35	3.3	3.1	3.8	3.95	4.15	4.3
Pt Augusta	3.85	3.95	3.55	3.6	3.25	3.25	3.05	3.1	3.75	3.55	3.85	3.95

Note that the Turbidity Index values for Northwest Bend are the lowest of all sites, meaning that given similar GHI values, it would be expected to have the highest DNI. Not all providers of solar information use turbidity information and instead may try to adjust the end results to observations rather than including the information in the initial processing.

Application of the GHI>DNI and GHI>DIF Conversion
There are different ways of calculating DNI and DIF from GHI. 3TIER uses the work[2] of Richard Perez from SUNY. 3TIER has implemented the work from section 3.3 of this paper as it provides better information on a global scale.

There are other potential sources of difference in approach and model tuning as well – but the most likely sources of difference have been covered in the above statements.

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[2] Perez, R., P. Ineichen, K. Moore, M. Kmiecik, C. Chain, R. George, and F. Vignola, 2002: A new operational model for satellite-derived irradiances: Description and validation. Solar Energy, 73, 307-317