Verification of ClimateCypher Climate Data Outputs with System Advisor Model (SAM)

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The P01, P10, P50, P90, and P99 data in statistics refer to a value that is expected to exceed 1%, 10%, 50%, 90%, and 99% of the cases in a given temporal sample respectively and may be done through the process of Monte Carlo simulation (Dobos, Kasberg and Gilman, 2012). We at Exemplary Energy had enabled our in-house software, ClimateCypher, to produce P10 and P90 data based on our last year's analysis (Hameed et al, 2020). Now its capability has been extended to also produce eXtreme Meteorological Year (XMY) data. This data corresponds to hypothetical years with extreme weather conditions which ClimateCypher generates by producing P01 (best) and P99 (worst) year with the help of MSP's (Month Selection Parameters) for weather data of a particular period. The XMYs therefore corresponds to data of worst-case scenarios and would find use in many applications like building simulation or PV power plant design where the design should be conservative enough to handle extreme weather conditions like high temperatures and sustained extremely high or low solar irradiation (occasionally greater than the nominal 1 kW/m² value) (Crawley & Lawrie, 2015). However, it should be noted that the selection algorithm we have used doesn't target extreme hourly values but rather unusually long durations of cloudiness or clear skies.

The concept behind MSP's and how they are used by ClimateCypher can be better understood with the help of the following example: If the MSP for P01 is established to be 0.19, then ClimateCypher iterates the weather dataset (which in this analysis is from 1990 to 2017) in search for individual months that have a probability of occurrence of 19% and then concatenates them to form a synthetic year. This synthetic year would in totality have a 1% chance of occurrence during this particular range of years. A similar process is done for other percentiles like P10, P90, and P99.

The data samples used in this analysis are of two kinds: the weather data of a particular location recorded for 28 years and the energy output obtained from a simulated solar PV generator during these specific years. ClimateCypher is software capable of reading files containing satellite-derived solar data and surface-measured weather data including any ground-measured solar data. It has the capability of producing the weather data for the user's required period of years and also processes the Reference Meteorological Years (RMYs). Both these outputs are provided in the TMY2 (Typical Meteorological Year) and ACDB (Australian Climate Data Bank) formats. RMYs (A, B, or C according to the weighting given to the weather elements, with A having the greatest weighting given to solar irradiation) represent the entire time duration of the weather data in a single synthesized year and provides a convenient way to model building and energy systems (Lee, 2011).

For this analysis, we have simulated a residential PV system using System Advisor Model (SAM). The configuration of the system consists of 3kW solar photovoltaic panels connected to an inverter with a DC to AC conversion ratio of 1.2. Hence the inverter size of the simulation is 2.5 kW_{ac}. The P50/P90 simulate feature of SAM performed the P10, P50, and P90 analysis and gives the 10^{th}, 50^{th} and 90^{th} percentiles along with maximum and minimum energy outputs from the PV system for a minimum of 10 years of single-year weather data (National Renewable Energy Laboratory, 2020).

Furthermore, we have also enhanced the accuracy of our previously established MSPs for P10 and P90 reported in Hameed et al. (2020) by empirically iterating them for more locations that have varying latitudes. Additionally, for this enhancement, we have also considered applying optimum tilt angle while simulating the PV system in SAM. For this, depending on the location, the tilt angle of the PV system is set as per the Australian Solar Radiation Handbook (Australian Solar Energy Society, 2006). It should be noted that the data for optimum tilt angle was absent for some locations like Mackay, Toowoomba, Glen Innes, etc, and was consequently determined with the help of nearby cities that were present in the handbook.

Methodology:

ClimateCypher has been developed to generate P01, P10, P90, and P99 climate files based on MSPs which were established for each of the eight climate zones identified in the National Construction Code (NCC) (Australian Building Codes Board, 2019). These MSPs enable ClimateCypher to indicatively select and concatenate actual months from the historical weather records to form synthesized climate years that closely match 1, 10, 90, and 99 percentile criteria.

These MSPs are empirically iterated in attempts to enable ClimateCypher's outputs to closely match the outputs from SAM (obtained from its P50/P90 feature). It should be noted that while SAM's P50/P90 simulation feature does calculate 10^{th}, 50^{th}, and 90^{th} percentiles based on the inputted weather files, these values are self-generated and do not precisely correspond to energy output from an actual year. Thus, for ease of further analysis, energy outputs of a calendar year with a minimum difference to SAM generated P10 and P90 values were taken as the new SAM P10 and P90 energy outputs. Also the maximum and minimum energy outputs generated in the above-mentioned feature are taken as SAM P01 (clearest actual year) and SAM P99 (cloudiest actual year) energy outputs.

This analysis was performed for all eight Australian capital cities and 10 other locations. The locations are listed in Table I.

Table I. List of locations for which analysis is performed and their details

Location	State	Climate Zone	Climate Zone Description	Longitude (°E)	Latitude (°N)	Elevation (m)	Tilt Angle (°S)
Darwin	NT	1	High humidity summer and warm winter	130.9	-12.4	30.4	20
Townsville	QLD			146.77	-19.25	4.3	20
Mackay	QLD	2	Warm humid summer and mild winter	149.22	-21.12	30.3	30
Brisbane	QLD			153.1	-27.4	4	30
Tennant Creek	NT	3	Hot dry summer and warm winter	134.1	-19.6	376	20
Alice Springs	NT	3 and 4	Hot dry summer and warm / cool winter	133.9	-23.8	546	30
Oodnadatta	SA	4	Hot dry summer and cool winter	135.5	-27.6	117	30

Toowoomba	QLD	5	Warm temperate	151.91	-27.54	691.0	30
Perth	WA			116.0	-31.9	15.4	30
Swanbourne	WA			115.76	-31.96	41.0	30
Richmond	NSW			150.78	-33.60	19	30
Sydney	NSW			151.2	-33.9	6	30
Adelaide	SA			138.6	-34.9	48	30
Glen Innes	NSW	6	Mild temperate	151.75	-29.73	1045	30
Melbourne	VIC			145.0	-37.8	31.2	30
Armidale	NSW	7	Cool Temperate	151.62	-30.53	1079	30
Canberra	ACT			149.2	-35.3	578.4	30
Hobart	TAS			147.3	-42.9	4	40
Cabramurra	NSW	8	Alpine	148.4	-35.9	1482.4	30
Mount Buller	VIC			146.43	-37.15	1707	30

Results:
For each of the NCC climate zones, after iterative analysis, each month selection parameter (MSP) was empirically determined and are shown in Table II. It also shows the percentage difference between percentile energy outputs from SAM (obtained with the help from P50/P90 simulation) and the yearly energy output obtained by inputting P01, P10, P90, and P99 year data produced by ClimateCypher (using MSPs) in SAM:

Table II. List of Climate Zones, locations their MSPs and the percentage difference between the SAM calculated energy outputs and the same obtained from ClimateCypher

Climate Zone	Location	MSP (P01 P10 P90 P99)	Percentage difference between the SAM calculated energy outputs and the same obtained via ClimateCypher			
			P01	P10	P90	P99
1	Darwin	0.20 0.35 0.75 0.93	1.52%	0.91%	0.27%	-2.47%
	Townsville		0.20%	-0.13%	0.90%	0.56%
2	Mackay	0.20 0.35 0.80 0.95	0.54%	0.07%	-0.40%	-0.97%
	Brisbane		-0.08%	0.92%	0.59%	-1.20%
3	Tennant Creek	0.25 0.36 0.81 0.85	-0.09%	0.71%	-0.67%	0.53%
	Alice Springs		1.37%	0.67%	-1.69%	2.19%
4	Alice Springs	0.25 0.36 0.81 0.90	0.33%	0.62%	-1.24%	0.47%
	Oodnadatta		-1.69%	-0.25%	-0.54%	1.40%
5	Toowoomba	0.23 0.36 0.76 0.90	1.01%	1.15%	2.31%	2.43%
	Perth		-1.69%	-0.25%	-0.54%	1.40%
	Swanbourne		0.18%	0.07%	-1.65%	1.62%
	Richmond		1.23%	-0.42%	-1.97%	-2.17%
	Sydney		0.69%	0.17%	1.37%	0.40%
	Adelaide		1.12%	-0.42%	0.23%	0.23%

6	Glen Innes	0.15 0.25 0.75 0.90	0.54%	1.80%	0.57%	-0.24%
	Melbourne		1.38%	1.26%	-1.22%	-1.96%
7	Armidale	0.19 0.31 0.76 0.87	0.94%	-0.57%	1.47%	-1.38%
	Canberra		0.22%	-0.02%	-1.48%	-1.19%
	Hobart		0.39%	0.10%	1.53%	2.40%
8	Cabramurra	0.20 0.35 0.70 0.85	-0.29%	-0.42%	-1.61%	-0.13%
	Mount Buller		-0.33%	-1.48%	-0.65%	1.43%

In Table II the percentage difference is marked in 3 distinct colours, green when the percentage difference is within ± 2%, yellow for ± 2-2.2%, amber for ± 2.2-2.4%, and red for exceeding ± 2.4%.

Conclusion:

It can be seen from Table II that almost all the percentage differences between the SAM and ClimateCypher outputs are within ± 2%. All high-sun years (P01 and P10) fall within that tolerance as do all but Toowoomba for the P90 values. For the P99 extreme low sun years only Darwin, Alice Springs (in climate zone 3), Toowoomba, Richmond, and Hobart fall outside that measure.

Work yet to be done:

Exemplary Energy is awaiting BOM dissemination of solar irradiation data of the latest few years which is foreshadowed as occurring in September or October this year. With this, we will verify our above results and/or improve upon them. We aim to present these updated and enhanced findings at the Conference.

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