Development of the Typical Meteorological Data for Silpakorn University Sanamchandra Palace Campus Zone

Jarut Kunanoppadol[1]

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Abstract

A meteorological database is very important for engineering research and design. Normally, the more specific location design data always give more accuracy in the calculation result. Therefore, this study aims to generate the typical meteorological data for Silpakorn University Sanamchandra Palace Campus zone by the weather data from Nakhon Pathom Meteorological Station (located at latitude 14° 01' 42.5" N, longitude 99° 58' 12.1" E, elevation 7.46 m). We used the method of Sandia Nation Laboratories to generate the typical meteorological year and investigated the typical weather condition. We found that the outdoor design conditions for the zone are found to be 33.07°C, 94.20 %, 2.56 mm, 6.54 hrs, and 3.31 km/hr for maximum dry bulb temperature, maximum relative humidity, rainfall, sunshine duration, and wind speed respectively. We hope that these results for the zone will give advantages for future research, engineering design, business, and other related applications.

Keywords: Typical meteorological data, Finkelstein-Schafer statistics, Outdoor design condition.

Introduction

A meteorological database is very important for many fields of research and design. In general, we do not use the long-term average for engineering calculation but the weather design conditions are normally used (1). A representative database for year duration is known as a typical meteorological year (TMY), mainly used in USA (2), a test reference year (TRY) or a design reference year (DRY), mainly used in Europe (3), or other various types of typical weather design condition (4, 5). A typical outdoor condition consists of individual months of meteorological data sets selected from different years over the available data period. The typical meteorological data have been considered in many fields of research. Some previous studies have been investigated in a design meteorological day (6, 7), outdoor design condition (8), solar heat gain (9), comfortable environment (10), and acceptable wind speed (11) for air-condition and ventilation system design process (12). Some research have been considered in building simulation (13), such as a flow around building (14), an indoor natural ventilation (15), and the effect of wind to building structure (16). There are some previous studies in wind engineering (17, 18) such as optimization for wind system, and other various meteorological conditions (19-21). A typical weather conditions are also beneficial for research in seasonal parameter for electricity demand analysis (22, 23), and agricultural consideration (24). Typical meteorological data have been used in solar application research also (12).

Typical meteorological conditions have been generated in various levels upon the scope and objective of the research study; for a country TMY, such as China (25), Hong Kong (4), and Thailand (26); for a city TMY, such as Athens (Greece) (1), Nicosia (Cyprus) (27), and Damascus (Syria) (2); and for a zone TMY, such as Port Harcourt zone in Nigeria also (28). Basically, the more specific location design data always give more accuracy in the calculation result. Therefore, this study aims to generate the typical meteorological data for Silpakorn University Sanamchandra Palace Campus Zone in Nakhon Pathom, Thailand. We hope that our results will give advantages for future research, engineering design, business, and

[1] *Engineering Business Centre (EBC), Department of Mechanical Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakhon Pathom 73000, Thailand. E-mail: jarut@su.ac.th,*

other related applications. The remaining of the paper is organized as follows; first, we explain the methods used to generate a typical meteorological data; second, we present the results and discussion; and finally, this article concludes with discussion.

Methods

In our study, the meteorological data used to generate the TMY is the secondary data from Nakhon Pathom Meteorological Station with the following geographical data; latitude 14° 01' 42.5" N, longitude 99° 58' 12.1" E, elevation 7.46 m, and 31.4 km from Silpakorn University Sanamchandra Palace Campus as shown in figure 1 (29).

The data were monthly summary reports covering the period of 13 years (1998-2010). The long-term average data are as follows; maximum and minimum dry bulb temperature (°C), maximum and minimum relative humidity (%), rainfall (mm), evaporation (mm), cloud (%), sunshine duration (hrs), and wind speed (km/hr) (30).

In 1978, Hall et al. developed a TMY method that is one of the most commonly accepted methods to generate typical weather years (31, 32). The method of Sandia Nation Laboratories to generate the typical weather condition consisted of two steps; the first step was to select five candidate years, and the second step was to select the typical meteorology month (TMM) from the five candidate years (33).

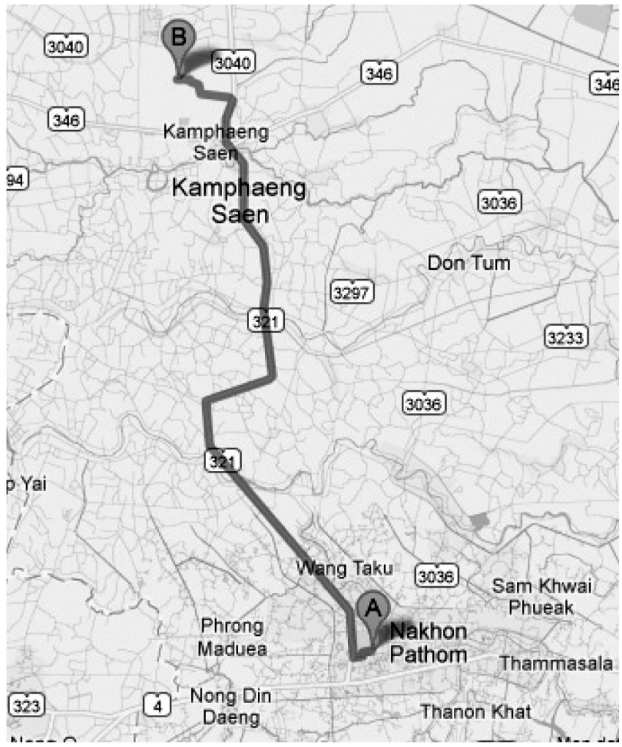

Figure 1: Location of (A) Silpakorn University Sanamchandra Palace Campus and (B) Nakhon Pathom Meteorological Station

Selection of Five Candidate Years

Primarily, the raw meteorological data have to be rearranged for each weather data into calendar months along the thirteen-year periods. The maximum dry bulb temperature data were shown as a sample in table A1. Then, the cumulative distribution function for long-term of all period years (CDF_m) were calculated. The CDF for the variable x was estimated by $S_n(x)$ as shown in equation 1. (31)

$$S_n(x) = \begin{cases} 0 & for\ x \le x_1 \\ (i-0.5)/N & for\ x_i \le x \le x_{i+1} \\ 1 & for\ x \ge x_N \end{cases} \quad (1)$$

Where x_i is the i^{th} order observation (from smallest to largest) and N is the number of observation on the variable. From definition, $S_n(x)$ is a monotonically increasing step function with step of size 1/N occurring at x_i and is bounded by zero and one (2, 31). The CDF_m of maximum dry bulb temperature is plotted for sample in figure A1. Equation 1 was also used to calculate the cumulative distribution function for each year ($CDF_{y,m}$). For each of the twelve calendar month, the procedure involved selecting the five years that were 'closest' to the composite of all thirteen years. This was done by comparing the CDF_m with $CDF_{y,m}$ for each of nine parameters. The statistic selected to measure the closeness of each year's CDF to the long-term composite for a given index was the Finkelstein-Schafer (FS) statistic, following an equation 2 (2, 26). The FS of the maximum dry bulb temperature is shown as a sample in table A2.

$$FS_{y,m}(x) = \frac{1}{N}\sum_{i=1}^{N}\left|CDF_m(x_i) - CDF_{y,m}(x_i)\right| \qquad (2)$$

Then, we calculated the weighted sum (WS) of the nine FS statistics as shown in equation 3 (28, 31). Refer to Hall et al. (1978), choosing the weight factor has not been clear-cut issue but would depend on the ultimate application of the generated typical year. In previous studies, they focused on solar applications, so they weighted solar radiation more than other weather parameters (2, 4, 26, 28). In this study, we would like to develop the typical meteorological data for Silpakorn University Sanamchandra Palace Campus Zone to generate the outdoor design condition for general engineering applications, then, the weighting scheme used for this study is presented in table 1.

$$WS_{y,m} = \frac{1}{M}\sum_{x=1}^{M} WF_x FS_{y,m}(x)$$
$$\sum_{x=1}^{M} WF_x = 1 \qquad (3)$$

The weighted sum of weather variables is shown in table A3. Next, the five years with smallest values of WS were highlighted in table and selected as candidate years for the month.

Final Selection of TMM

The final selection of the TMM from five candidate years involved examining statistics of the persistence structure associated with monthly values of five weather parameters that were deemed most important in this research; maximum dry bulb temperature, maximum relative humidity, rainfall, sunshine duration, and wind speed (32). We calculated the root mean square difference (RMSD) of the five using meteorological variables as shown in equation 4 (2, 26).

$$RMSD = \left(\frac{1}{n}\sum_{i=1}^{n} d_i^2\right)^{1/2} \qquad (4)$$

where n is the number of meteorological parameter, d_i is the difference between the monthly values with respect to the long-term average of each meteorological parameter. The RMSD of the five selected meteorological variables for the five candidate years is shown in table A4. The TMMs were selected from the smallest values of RMSD of five candidate years, and were highlighted in table A4 also (31).

Results and Discussion

By applying the method described above, the TMY for Silpakorn University Sanamchandra Palace campus zone was finally formed. Nine meteorological parameters were examined for a period of thirteen years. These parameters were maximum and minimum dry bulb temperature, maximum and minimum relative humidity, rainfall, evaporation, cloud, sunshine duration, and wind speed. The selected month/year combinations from which the TMY was composed are shown in table 2, and the monthly meteorological data obtained by TMY are shown in table 3.

Table 1 Weighting scheme for the TMYs

T_{max}	T_{min}	H_{max}	H_{min}	R	E	C	S_d	W_{spd}
2/14	1/14	2/14	1/14	2/14	1/14	1/14	2/14	2/14

where T_{max} is maximum dry bulb temperature (°C), T_{min} is minimum dry bulb temperature (°C), H_{max} is maximum relative humidity (%), H_{min} is minimum relative humidity (%), R is rainfall (mm), E is evaporation (mm), C is cloud (%), S_d is sunshine duration (hrs), and W_{spd} is wind speed (km/hr).

Table 2 The month/year combinations for the composition of TMY

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Year	2004	2008	2005	2005	2006	2009	2005	2008	2002	2002	2004	2002

Table 3 The monthly meteorological data obtained by TMY

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
T_{max}	31.629	31.883	34.426	36.140	33.958	33.350	33.781	33.681	32.223	32.129	32.357	31.258
T_{min}	19.748	22.410	23.335	25.537	24.810	24.613	24.655	23.574	24.290	23.255	22.423	22.152
H_{max}	94.677	94.483	94.613	94.467	94.484	95.267	93.613	93.710	93.033	93.871	95.100	93.065
H_{min}	48.000	48.379	49.000	49.867	56.387	57.867	57.774	51.000	60.900	57.968	50.100	56.290
R	0.677	1.585	3.481	0.100	3.800	1.597	3.030	4.000	6.200	4.100	0.100	2.000
E	3.294	4.124	5.027	5.257	4.635	3.860	4.394	4.703	3.906	3.710	4.680	3.230
C	25.774	41.552	27.323	38.067	69.710	85.933	83.516	84.323	88.567	61.968	22.667	46.452
S_d	7.513	6.966	8.077	8.257	6.094	4.747	4.706	5.794	4.830	6.700	8.213	6.565
W_{spd}	1.955	2.469	3.035	3.103	2.261	2.837	4.200	4.332	4.267	3.455	5.370	2.448

where T_{max} is maximum dry bulb temperature (°C), T_{min} is minimum dry bulb temperature (°C), H_{max} is maximum relative humidity (%), H_{min} is minimum relative humidity (%), R is rainfall (mm), E is evaporation (mm), C is cloud (%), S_d is sunshine duration (hrs), and W_{spd} is wind speed (km/hr).

The five meteorological annual variations for the selected TMY and for the long-term average are shown in figure 2 to 6 (26).

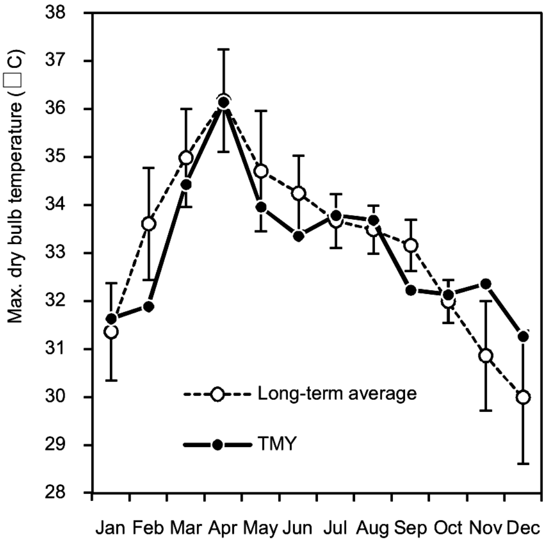

Figure 2 Annual variation of maximum dry bulb temperature for the selected TMY, and long-term average and standard deviation

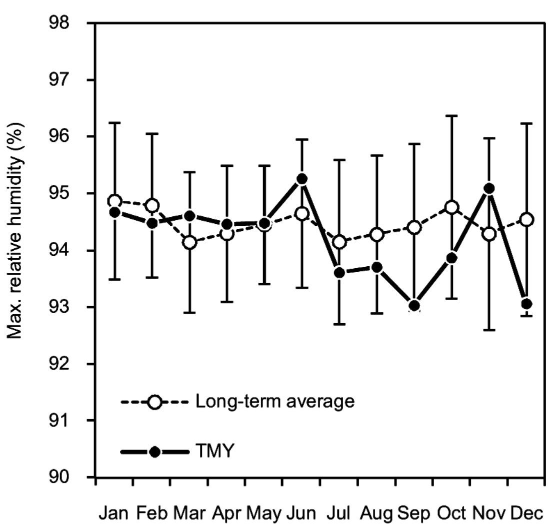

Figure 3 Annual variation of maximum relative humidity for the selected TMY, and long-term average and standard deviation

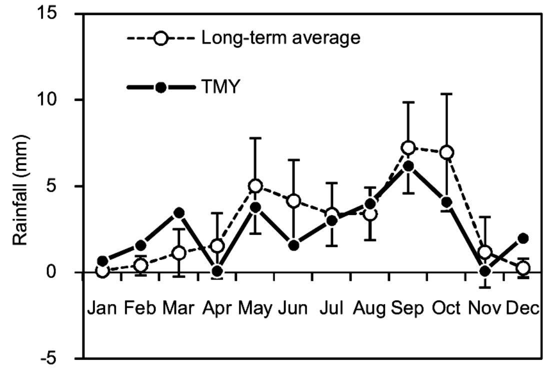

Figure 4 Annual variation of rainfall for the selected TMY, and long-term average and standard deviation

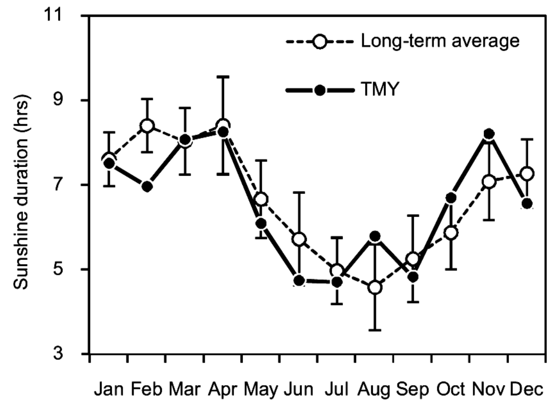

Figure 5 Annual variation of sunshine duration for the selected TMY, and long-term average and standard deviation

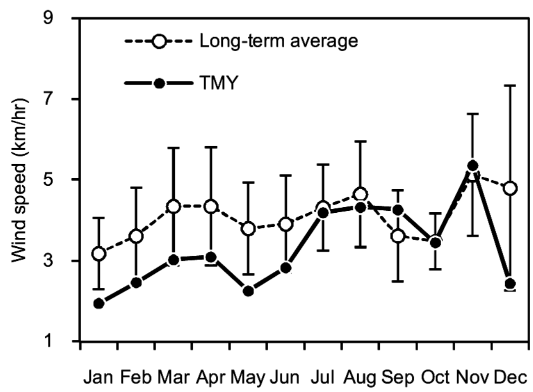

Figure 6 Annual variation of wind speed for the selected TMY, and long-term average and standard deviation

From figures, we found the variance of weather data; therefore, the typical meteorological data have been widely used in engineering design and calculation (1). The outdoor design conditions for Silpakorn University Sanamchandra Palace Campus zone are shown in table 4.

Table 4 The outdoor design conditions

Dry bulb temperature		
- maximum	33.07 ± 1.41	°C
- minimum	23.40 ± 1.57	°C
Relative humidity		
- maximum	94.20 ± 0.73	%
- minimum	53.63 ± 4.63	%
Rainfall	2.56 ± 1.86	mm
Evaporation	4.23 ± 0.65	mm
Cloud	56.32 ± 25.60	%
Sunshine duration	6.54 ± 1.33	hrs
Wind speed	3.31 ± 1.03	km/hr

Conclusion

To develop the typical meteorological data for Silpakorn University Sanamchandra Palace Campus Zone, we used the weather data from Nakhon Pathom Meteorological Station (located at latitude 14° 01' 42.5" N, longitude 99° 58' 12.1" E, elevation 7.46 m, and 31.4 km from Silpakorn University) (29, 30). We used the method of Sandia Nation Laboratories consisted two steps to generate the typical weather condition (31, 33). First, we rearranged the raw data into twelve calendar months along the thirteen-year periods from 1998 to 2010. The cumulative distribution function for long-term and for each year were calculated and compared together by the Finkelstein-Schafer (FS) statistic (2, 26). Then, we calculated the weighted sum (WS) of the nine FS statistics by our weighting scheme (31) and the five years with smallest values of WS were selected as candidate years for the month. Second, we calculated the root mean square difference (RMSD) of the five using meteorological parameters that were deemed most important in this research; maximum dry bulb temperature, maximum relative humidity, rainfall, sunshine duration, and wind speed (32). The typical meteorological months (TMMs) were selected from the smallest values of RMSD of five candidate years (31). The monthly meteorological data obtained by TMY are shown in table 3. Finally, the outdoor design conditions for the zone are found to be 33.07°C, 94.20 %, 2.56 mm, 6.54 hrs, and 3.31 km/hr for maximum dry bulb temperature, maximum relative humidity, rainfall, sunshine duration, and wind speed. We hope that these results for the zone will give advantages for future research, engineering design, business, and other related applications.

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Appendix

Table A1 The maximum dry bulb temperature data (°C) (30)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	33.381	35.454	36.548	37.467	36.971	35.643	34.490	33.955	32.887	32.039	30.400	29.655
1999	30.784	32.196	35.584	34.323	33.500	33.247	33.626	33.123	33.383	31.323	30.323	26.726
2000	31.571	32.559	34.600	34.207	34.490	33.543	33.632	34.123	32.967	32.513	30.060	30.784
2001	32.487	33.707	32.594	36.973	34.323	33.767	33.706	33.042	34.070	31.629	29.277	29.877
2002	30.761	33.622	34.339	36.663	33.868	34.257	33.687	33.055	32.223	32.129	30.780	31.258
2003	30.461	33.711	34.297	36.753	35.152	34.107	32.726	33.577	32.873	31.703	32.513	29.635
2004	31.629	32.562	35.424	37.297	34.310	34.113	34.684	33.668	32.680	32.429	32.357	30.613
2005	31.555	34.825	34.426	36.140	36.106	34.740	33.781	33.735	32.890	31.765	31.060	28.603
2006	31.806	33.196	35.210	35.927	33.958	33.887	33.526	32.777	33.353	32.332	32.800	29.910
2007	30.555	33.282	36.203	35.937	33.513	34.877	33.335	32.877	33.247	31.474	29.560	31.819
2008	31.435	31.883	34.484	35.297	33.939	33.987	33.400	33.681	32.763	32.423	29.857	28.765
2009	29.319	34.539	35.474	35.913	33.945	33.350	32.865	34.374	33.877	32.632	31.533	31.548
2010	31.948	35.357	35.597	37.337	37.116	35.663	34.229	33.345	33.827	31.487	30.640	30.703

Table A2 The FS of the maximum dry bulb temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	0.205	0.321	0.231	0.000	0.167	0.263	0.327	0.288	0.199	0.135	0.038	0.042
1999	0.006	0.019	0.125	0.045	0.109	0.006	0.154	0.064	0.038	0.051	0.032	0.000
2000	0.077	0.038	0.202	0.000	0.013	0.077	0.019	0.077	0.045	0.109	0.067	0.096
2001	0.103	0.051	0.051	0.035	0.051	0.013	0.128	0.051	0.026	0.090	0.016	0.013
2002	0.119	0.090	0.038	0.054	0.006	0.013	0.038	0.058	0.013	0.058	0.083	0.026
2003	0.045	0.058	0.019	0.048	0.038	0.064	0.071	0.083	0.019	0.096	0.115	0.035
2004	0.167	0.045	0.064	0.022	0.109	0.154	0.096	0.109	0.019	0.096	0.167	0.099
2005	0.071	0.109	0.224	0.074	0.128	0.186	0.160	0.231	0.122	0.019	0.103	0.003
2006	0.192	0.071	0.045	0.093	0.038	0.019	0.013	0.167	0.032	0.160	0.090	0.061
2007	0.051	0.006	0.067	0.122	0.103	0.115	0.071	0.109	0.083	0.045	0.029	0.032
2008	0.038	0.038	0.019	0.157	0.026	0.032	0.051	0.032	0.006	0.006	0.006	0.010
2009	0.022	0.083	0.077	0.099	0.115	0.109	0.096	0.135	0.179	0.141	0.141	0.064
2010	0.045	0.308	0.256	0.016	0.179	0.186	0.256	0.186	0.250	0.051	0.106	0.071

Table A3 The WS of the meteorological data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	0.141	0.209	0.139	0.070	0.154	0.222	0.202	0.231	0.226	0.164	0.159	0.099
1999	0.173	0.211	0.120	0.151	0.218	0.218	0.207	0.136	0.167	0.147	0.104	0.121
2000	0.156	0.175	0.136	0.109	0.132	0.127	0.103	0.115	0.138	0.156	0.095	0.136
2001	0.121	0.120	0.125	0.127	0.141	0.074	0.142	0.065	0.122	0.122	0.098	0.119
2002	0.135	0.136	0.124	0.088	0.094	0.109	0.092	0.062	0.091	0.093	0.089	0.092
2003	0.151	0.146	0.170	0.114	0.046	0.119	0.065	0.109	0.113	0.088	0.063	0.115
2004	0.105	0.073	0.109	0.080	0.092	0.099	0.120	0.094	0.071	0.113	0.086	0.077
2005	0.095	0.093	0.095	0.089	0.053	0.093	0.093	0.100	0.097	0.052	0.103	0.084
2006	0.110	0.099	0.128	0.116	0.085	0.138	0.114	0.082	0.092	0.135	0.139	0.110
2007	0.152	0.056	0.129	0.143	0.120	0.083	0.136	0.117	0.108	0.093	0.083	0.107
2008	0.064	0.079	0.055	0.102	0.100	0.087	0.122	0.088	0.098	0.101	0.084	0.050
2009	0.038	0.084	0.079	0.081	0.061	0.067	0.062	0.077	0.076	0.081	0.104	0.056
2010	0.076	0.109	0.194	0.137	0.190	0.157	0.125	0.178	0.173	0.169	0.174	0.108

Table A4 The RMSD of the five using meteorological variables

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998				2.775								
1999			2.218									
2000							1.812					
2001						1.494		2.418				
2002				2.302			1.124	1.443	1.852	0.814	2.519	1.363
2003					1.564		1.266			1.151	2.009	
2004	1.602	1.126	1.851	2.562	1.503				2.392		1.614	2.486
2005	1.936	1.762	1.005	2.011	1.440	0.927	0.991		3.409	2.724		2.633
2006					1.010			1.888	3.874			
2007		1.732				1.458				1.651	1.973	
2008	1.825	1.118	1.863			1.805		0.748			2.082	2.612
2009	2.319	1.810	1.591	2.085	3.758	1.237	1.440	0.810	2.061	3.392		1.944
2010	1.840			2.775								

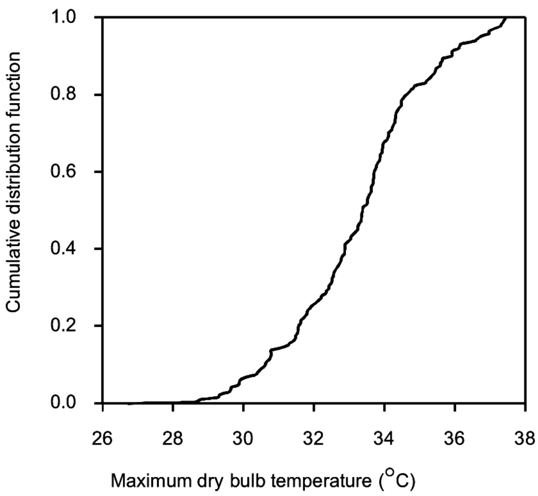

Figure A1 The CDF_m of the maximum dry bulb temperature

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