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A study of Köppen-Geiger system for comfort temperature prediction in Melbourne city

Harimi Djamila **Tay Lee Yong**

The Beginning

Thermal Comfort

RP-884 Database

Melbourne City

Climate

Koppen-Geiger

Adaptive Approach

Wladimir Köppen (1846-1940)

Wladimir Peter Köppen was a geographer, meteorologist, climatologist and botanist

Climate is defined as the long-term prevailing weather conditions

The world meteorological organisation defines climate to be typically a 30-year period

The Köppen approach based on Wladimir Köppen work is the most widely used for climate classification. Köppen’s concept continues to be applicable in almost all scientific disciplines.

This method describes the climate type **at well-defined geographic coordinates of any location.** The Köppen's system is very useful in describing overall climate zone. **The Köppen system can be used for describing climate over various time scales.**

The shortest possible period is one year.

Despite few investigators suggested different approaches to identify the climate type of a location; **Koppen-Geiger is currently the most known and used system for describing climate.** This is **due to its simplicity and the availability of these two parameters worldwide.**

The Köppen-Geiger climate classification according to Kottek, Grieser, Beck, Rudolf, & Rubel (2006)

E / Polar $T_{max}<+10^0C$	ET/ Tundra	EF/ Frost		
B/ Arid $P_{ann}<10P_{th}$	BSh Hot steppe	BSk Cold Steppe		
	BWh Hot desert	BWk cold desert		
A/ Equatorial $T_{min}\geq+18^0C$	Af Equatorial rainforest, fully humid	Am Equatorial monsoon	As Equatorial monsoon with dry summer	Aw Equatorial monsoon with dry winter
C/ Warm-Temperate $-3^0C<T_{min}<+18^0C$	Csa Warm temperate with dry hot summer	Csb Warm temperate with dry warm summer	Csc Warm temperate with dry cool summer and cold winter	
	Cwa Warm temperate with dry winter, hot summer	Cwb Warm temperate with dry winter, warm summer	Cwc Warm temperate with dry winter, cool summer and cold winter	
	Cfa Warm temperate, fully humid, hot summer	Cfb Warm temperate, fully humid, warm summer	Cfc Warm temperate, fully humid, cool summer and cold winter	
D/ Snow climate $T_{min}\leq-3^0C$	Dsa Snow climate with dry hot summer	Dsb Snow climate with dry warm summer	Dsc Snow climate with dry cool summer and cold winter	Dsd Snow climate with dry summer , extremely continental
	Dwa Snow climate with dry winter, hot summer	Dwb Snow climate with dry winter, warm summer	Dwc Snow climate with dry cold winter and cool summer	Dwd Snow climate with dry winter, extremely continental
	Dfa Snow climate, fully humid, hot summer	Dfb Snow climate, fully humid, warm summer	Dfc Snow climate, fully humid, cool summer and cold winter	Dfd Snow climate, fully humid, extremely continental

T_{max} is the maximum air temperature, Pth is a dryness threshold in mm, P_{ann} is the total annual precipitation, T_{min} is the minimum monthly temperature

In recent studies, Köppen's system was used in describing or analyzing thermal comfort according to the adaptive Approach

In the **adaptive comfort approach**, the indoor comfort temperature is described relative to the outdoor climate.

Adaptive approach is **widely accepted** method for predicting comfort temperature or evaluating thermal performance **in naturally ventilated buildings**

The ASHRAE 55 adaptive model is based on the work of de Dear, Brager, & Cooper (1997). The RP-884 database is considerable

In recent years, a few investigators also developed new adaptive models based on Köppen-Geiger system. **However, detailed procedures in identifying climate types at the boundary limits between two climates were not reported.**

Köppen identification may not be an acceptable method for predicting human thermal comfort. Thermal comfort field studies are at finer time scales. It may not be possible to be linked at larger time scales such in Köppen-Geiger system.

?

Meteorologische Zeitschrift, Vol. 20, No. 3, 351-360 (June 2011) MetZet Classic Papers c by Gebr¨uder Borntraeger 2011

http://koeppen-geiger.vu-wien.ac.at/pdf/Koppen_1884_2.pdf

According to Wladimir Koppen:

" I decided to use daily mean temperatures of 10 and 20 ◦C as threshold values and one and four months as defining time periods, in accordance with the relationship between tree line and oak climate described above. The consideration of the daily temperature variation would indeed be an interesting completion of the picture; however, for a number of reasons it is practical not to complicate the basic characteristics of the picture by doing so"

WLADIMIR KOPPEN

Koppen method was mainly developed to characterize climate types based on plant species

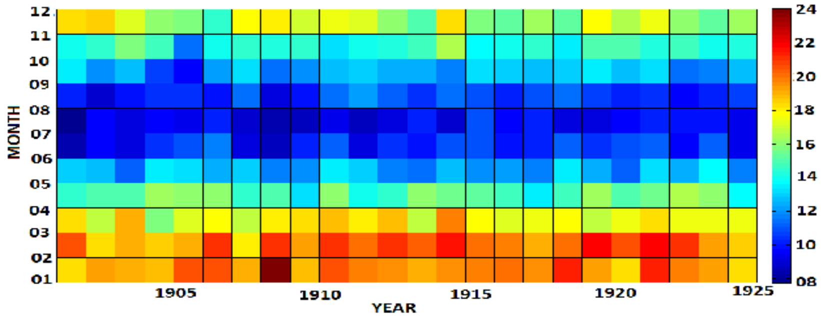
METHODOLOGY

This investigation addressed the Köppen-Geiger method in predicting thermal comfort according to climate types. The Excel file number 16 of the RP-884 database was selected. The origin field study was carried out by de Dear in Melbourne during summer time. The study was conducted in January and February 1983. The office buildings are naturally ventilated. The location was selected due to the availability of long-term quality climatic data.

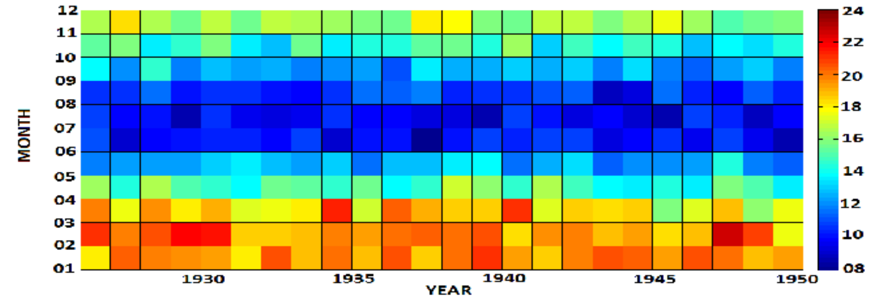
The geographic coordinate of Melbourne regional office station

Station number	Latitude	Longitude	Elevation	Opened	Closed
086071	37.81° S	144.97° E	31 m	1908	06 Jan 2015

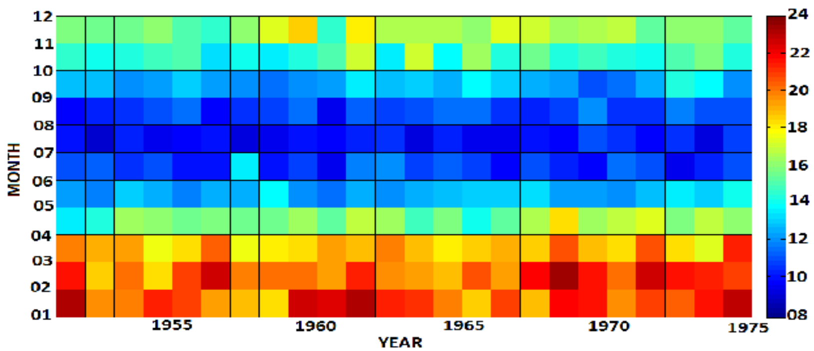
RESULTS & Discussion



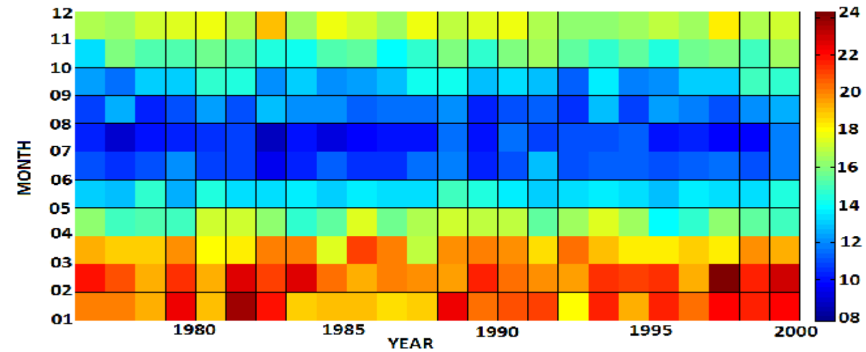
(A) From 1901-1925



(B) From 1926-1950



(C) From 1951-1975

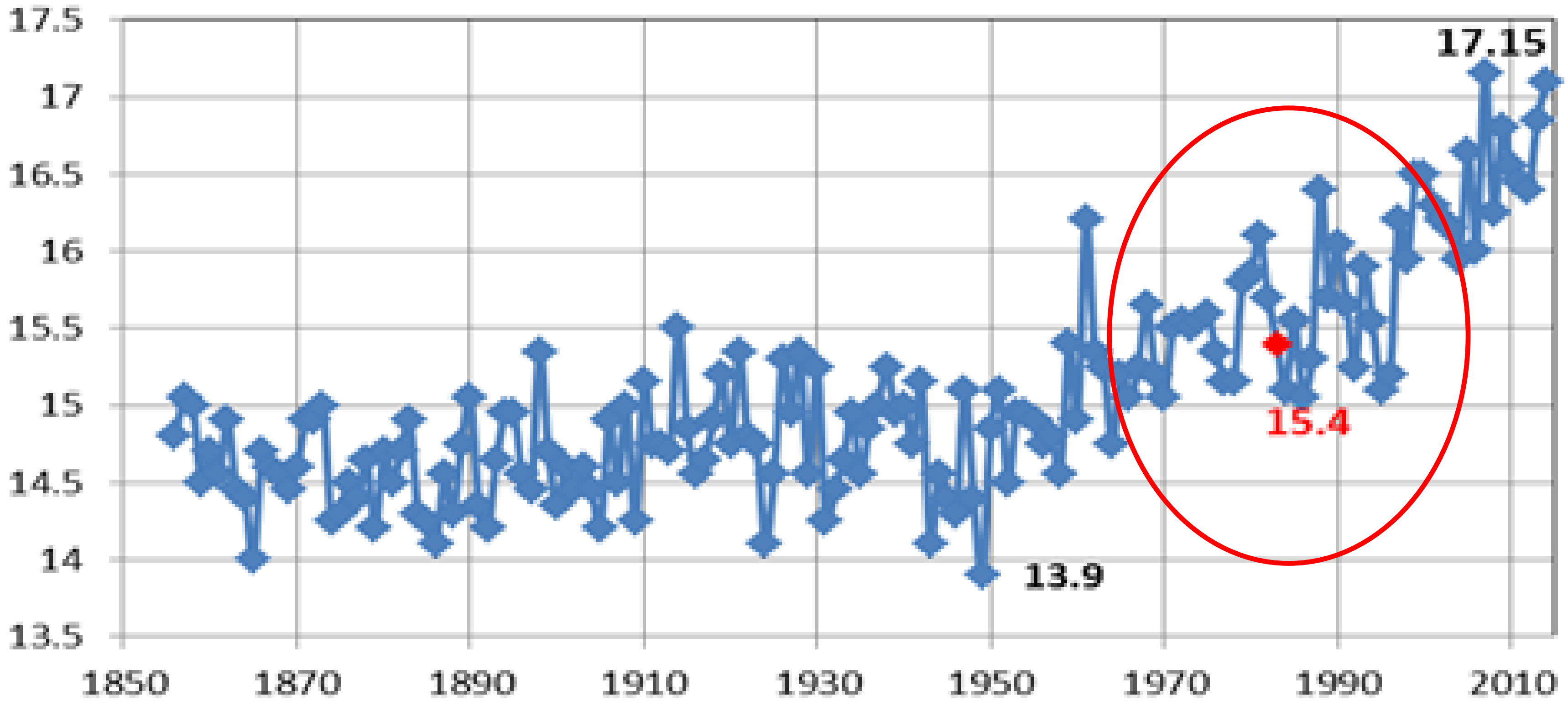


(D) From 1976-2000

Monthly temperature variation for the location

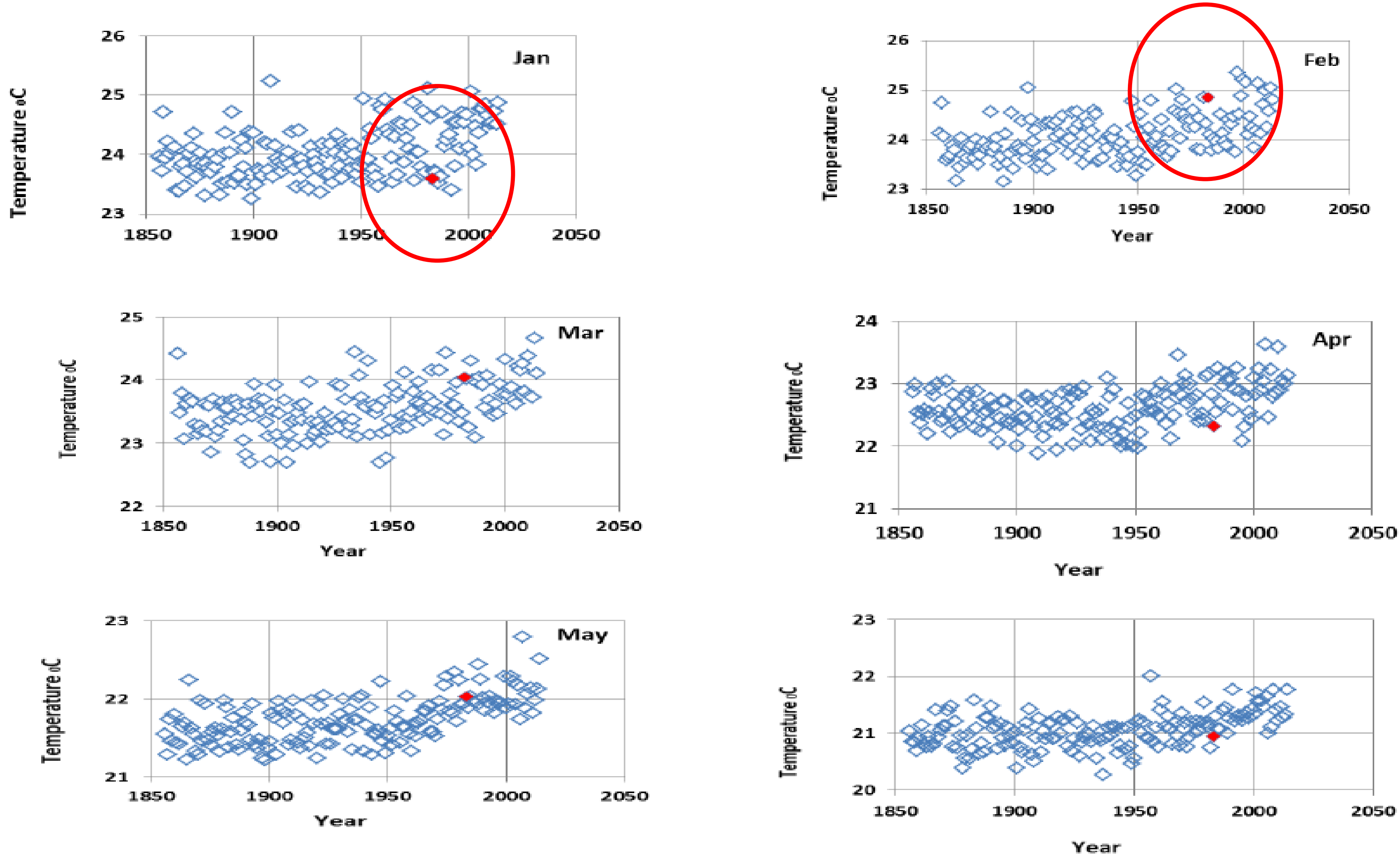
This figure is very useful in identifying the hottest and coldest months of the location. It is apparent that January and February are the hottest months in Melbourne city, June and July are the coldest months

Generated by Matlab



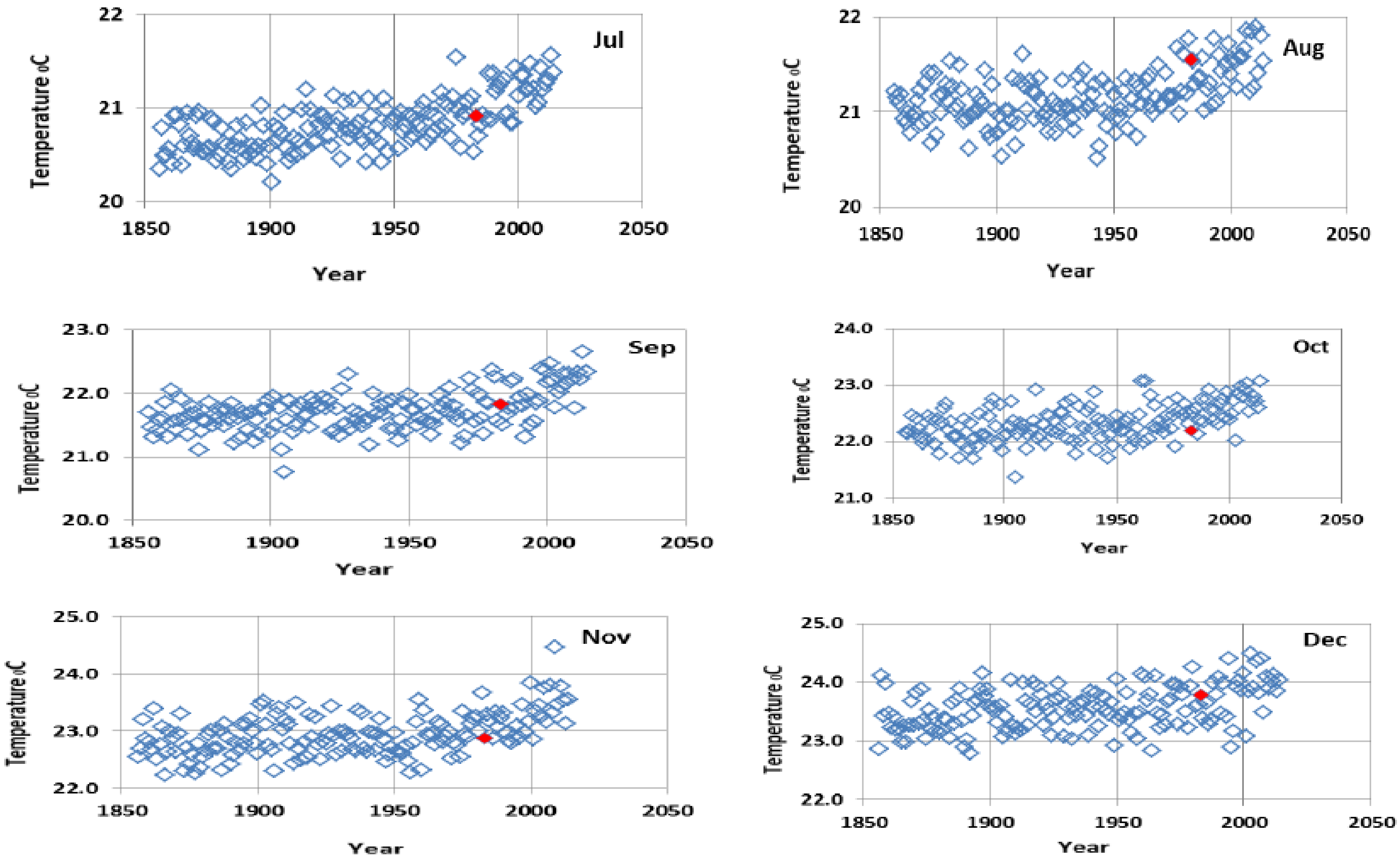
Mean yearly temperatures variation in Melbourne regional office

Marked Red represents year of the survey



Variation of the monthly mean neutral temperature (1850 to 2010)

Marked Red represents year of the survey



Variation of the monthly mean neutral temperature (1850 to 2010)

Marked Red represents year of the survey

The red colour represents the predicted neutral temperature during the year of the survey (1983).

It is apparent that the neutral temperature is subjected to time scale.

Therefore, consideration of the year of the survey for comparison among studies is important.

The average monthly temperature is not necessary the most frequent temperature of the month or of the day.

Statistical description of the selected data

	A_{sh}	T_a	T_{op}	V_a	RH
Mean	0.7	24.3	24.5	0.2	39.2
Median	0.5	23.2	23.5	0.1	39.0
Sample standard deviation	1.1	3.1	3.0	0.1	6.6
Minimum	-3.0	19.2	19.1	0.0	18.4
Maximum	3.0	33.2	32.7	1.0	56.7
Lower confidence interval 95%	0.5	24.0	24.2	0.2	38.7
Upper confidence interval 95%	0.8	24.6	24.8	0.2	39.8

$A_{sh:}$ Subjects votes on ASHRAE scale (Cold:-3, cool: -2, slightly cool: -1, neutral: 0, slightly warm: 1, warm: 2, hot: 3), $T_{am:}$ Air temperature (^{0}C), $T_{op:}$ Operative temperature (^{0}C), $V_{a:Velocity}$(m/s), RH: Relative humidity (%)

Köppen-Geiger predictions and projections for the location

Period	Predicted	Projections			
		A1	A2	B1	B2
1901-1925	Cfb	-	-	-	-
1926-1950	Cfb	-	-	-	-
1951-1975	Cfb	-	-	-	-
1976-2000	Cfb	-	-	-	-
2001-2025	-	Cfb	Cfb	Cfb	Cfb
2026-2050	-	Cfb	Cfb	Cfb	Cfb
2051-2075	-	Cfa	Cfa	Cfb	Cfb
2076-2100	-	Cfa	Cfa	Cfa	Cfa

Köppen-Geiger predictions and projections for the location

Koppen-Geiger classification for the location

Years	Climate Type									
1901-1910	Csb	Csb	Csb	Cwb	Cfb	Cwb	Csb	Csa	Cfb	Cwb
1911-1920	Csb	Cfb	Cfb	Cwb	Bsk	Csb	Cfb	Cfb	Csb	Cfb
1921-1930	Csb	Cfb	Csb	Csb	Cfb	Cwb	Csb	Csb	Csb	Cwb
1931-1940	Cfb	Cwb	Cwb	Cwb	Cfb	Cfb	Cfb	Cfb	Cwb	Cfb
1941-1950	Cfb	Csb	Cfb	Cwb	Cfb	Csb	Csa	Cwb	Csb	Cfb
1951-1960	Cwa	Cfb	Cfb	Cfb	Cfb	Cwa	Cwb	Cfb	Cfa	Cwa
1961-1970	Cfa	Cwb	Csb	Cwb	Cwb	Cfb	Bsk	Cwa	Csb	Cfb
1971-1960	Cfa	Cwb	Csb	Csa	Cwb	Csb	Cfb	Csb	Csa	Cfb
1981-1900	Csa	Bsk	Cwa	Csb	Cwb	Cfb	Csb	Csa	Cfb	Cwb
1991-2000	Cwb	Csb	Csb	Csb	Cfb	Cfb	Bsk	Cfb	Csa	Cfa

The dominant climate type is not necessary the climate type of the location at a particular year. Climate type and subtype of a location are subjected to variation over years.

Monthly mean temperature in Melbourne ^{0}C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Long-Term	20.1	20.2	18.6	15.6	12.7	10.5	9.8	10.9	12.6	14.6	16.6	18.6
Year 1984	**19.2**	**21.3**	18.6	14.7	12.7	10.7	9.6	12.1	12.5	14.2	16.8	18.4
Δt	0.9	-1.0	-0.1	0.9	0.0	-0.2	0.2	-1.2	0.1	0.4	-0.1	0.2

Monthly mean neutral temperature variation over years (1980-2000)

Year	Jan	Feb	Mac	April	May	Jun	Jul	Agst	Sept	Oct	Nov	Dec	Mean	SD	Climate
1980	**23.7**	**23.8**	**23.3**	**23.1**	**22.2**	**21.2**	**21.1**	**21.6**	**22.4**	**22.7**	**23.3**	**24.2**	**22.7**	**1.0**	**Cfb**
1981	25.1	24.9	23.5	23.2	21.9	21.1	21.1	21.2	22.3	22.5	23.0	23.6	22.8	1.4	Csa
1982	24.6	24.3	24.0	22.8	21.9	20.7	20.5	21.8	21.6	22.3	23.7	23.6	22.7	1.4	Bsk
1983	23.6	24.9	24.0	22.3	22.0	20.9	20.9	21.6	21.8	22.2	22.9	23.8	22.6	1.3	Cwa
1984	23.7	24.1	23.3	22.5	21.9	21.3	20.7	21.5	21.5	22.5	23.3	23.4	22.5	1.1	Csb
1985	23.7	23.8	24.3	23.3	22.0	21.1	20.8	21.3	21.7	22.6	23.2	23.6	22.6	1.2	Cwb
1986	23.5	24.0	24.0	22.7	22.0	21.1	20.9	21.3	21.8	22.1	22.9	23.3	22.5	1.1	Cfb
1987	23.6	24.0	23.1	23.0	22.0	21.4	20.9	21.4	22.2	22.4	23.3	23.3	22.5	1.0	Csb
1988	24.7	23.8	24.0	23.2	22.4	21.4	21.4	21.6	22.2	22.7	23.1	24.0	22.9	1.1	Csa
1989	**24.1**	**24.5**	**24.0**	**23.1**	**23.2**	**21.0**	**20.9**	**21.0**	**21.8**	**22.3**	**23.2**	**23.8**	**22.7**	**1.3**	**Cfb**
1990	24.2	24.1	23.9	23.1	22.0	21.3	21.4	21.2	21.9	22.7	23.3	24.1	22.8	1.2	Cwb
1991	24.3	24.0	23.6	22.6	21.8	21.8	21.2	21.3	21.8	22.9	23.0	23.5	22.6	1.1	Cwb
1992	23.4	23.9	24.1	22.9	22.0	21.2	21.2	21.1	21.3	22.6	22.8	24.0	22.5	1.2	Csb
1993	**24.5**	**24.4**	23.7	23.3	22.0	21.3	21.3	21.8	22.0	22.4	22.8	23.4	22.7	1.1	**Csb**
1994	23.8	24.3	23.5	22.9	21.9	21.3	21.3	21.1	21.5	22.6	22.9	24.4	22.6	1.2	Csb
1995	**24.5**	**24.5**	**23.4**	**22.1**	**21.8**	**21.2**	**20.9**	**21.6**	**21.6**	**22.3**	**23.1**	**22.9**	**22.5**	**1.2**	**Cfb**
1996	**24.1**	**23.8**	**23.6**	**22.3**	**22.0**	**21.3**	**20.9**	**21.4**	**21.8**	**22.7**	**22.9**	**23.2**	**22.5**	**1.0**	**Cfb**
1997	24.7	25.3	23.5	22.8	21.9	21.4	20.8	21.2	21.9	22.7	23.5	23.9	22.8	1.4	Bsk
1998	24.5	24.5	23.9	22.5	22.0	21.3	20.8	21.5	22.4	22.4	23.0	24.0	22.7	1.3	Cfb
1999	24.7	24.9	23.8	22.4	22.3	21.4	21.4	21.7	22.4	22.9	23.2	23.9	22.9	1.2	Csa
2000	**24.1**	**25.2**	**24.3**	**23.1**	**21.9**	**21.3**	**21.1**	**21.4**	**22.2**	**22.4**	**23.8**	**24.2**	**22.9**	**1.4**	**Cfa**
Mean	24.2	24.3	23.8	22.8	22.0	21.2	21.0	21.4	21.9	22.5	23.1	23.7	22.7	1.2	
SD	0.5	0.5	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.4	0.1	0.1	

The classification used in this study is based on (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006) works

A close observation in the Table listed in the previous slide showed <u>that the shift of the main climate from (C) to (B) did not affect the neutral temperature.</u> This is well depicted in 1982 and 1989. The predicted monthly neutral temperatures of the selected case study was 24.5^{0}C in January and 24.4^{0}C in February.

Climate main type (B) is identified only based on precipitation. The situation is different for other main climate types

Subjects votes according to buildings

N^0 of Records	B-Code	ASHRAE Votes	T_{OP} Average
1	1	-2	Only 1 vote
14	1	-1	21.7
43	1	0	**22.7**
25	1	1	23.6
15	1	2	26.1
4	1	3	Only 4 votes
2	2	-3	Only 2 votes
7	2	-2	Only 7 votes
45	2	-1	22.5
100	2	0	**22.9**
117	2	1	24.5
60	2	2	27.2
38	2	3	29.3

ASHRAE Votes is referred to subjects' votes on seven points scale: Cold, cool, slightly cool, neutral, slightly warm, warm and hot
B-Code is refereed to building code

Köppen-Geiger may not be the appropriate method for predicting neutral temperatures according to climate types. This is because the classification is not strictly defined according to the elevation of air temperature by range. For instance, the monthly minimum temperature for (**Af**) should be more than 18^{0}C. However, the maximum monthly temperature for (**Cfa**) should be at least 22^{0}C (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006). *Further the description of the climate as fully humid is not directly linked to relative humidity. For instance, the second letters in (**Cfa**) and (**Af**) are not about relative humidity (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006). Interestingly, the mean relative humidity level of the selected case study is 39.2%. This is considered dry environment in thermal comfort studies. However, the climate of the location is warm temperate, fully humid, warm summer (**Cfb**).*


Conclusion

The development of any adaptive thermal comfort model from Köppen-Geiger according to climate types may lead to erroneous predictions

The climate of the location was categorised (Cfb). However, the subjects were mostly exposed to dry environment with an average relative humidity of 39.2%. The analysed results showed that the description of the outdoor climate according to Köppen-Geiger method did not reflect the indoor relative humidity. Similar observation was made with air temperature.

Despite the wide range of the recorded indoor temperatures, the shift from neutrality to slightly cool or slightly warm was very narrow.

The climate of any location requires information about latitude, longitude, elevation and time/year. This approach helps in providing knowledge on the impact of climate on thermal comfort.

This will certainly provide better information on the available strategies for overcoming the overheating issue due to climate variation and climate change.

GIS helps in the interpretation of thermal comfort data with relation to space and time. **The exact site location and time are two important variables in monitoring the impact of climate variation and climate change on thermal comfort.**

THANK YOU

The END…