

Evaluation of the new Design Summer Year weather data using parametrical buildings

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Abstract: The Chartered Institution of Building Services Engineers (CIBSE) updated the near extreme weather (Design Summer Year – DSY) for all 14 locations in the UK in 2016. This new release attempts to address the underlying shortcomings of the previous definition where the averaged dry bulb temperature was the sole metric to choose DSY among source weather years. The aim of this research is to evaluate whether the new definition of the probabilistic DSYs can consistently represent near extreme condition. London historical weather data and their correspondent DSYs were used in this research. Dynamic thermal modelling using EnergyPlus was carried out on large number single zone offices (parametric study) which represent a large portion of cellular offices in the UK. The predicted indoor warmth from the sample building models show that these new definitions are not always able to represent near extreme conditions. Using multiple years as DSY is able to capture different types of summer warmth but how to use one or all of these DSYs to make informed judgement on overheating is rather challenging. The recommended practice from this research is to use more warm years for the evaluation of overheating and choose the near extreme weather from the predicted indoor warmth.

Keywords: Design Summer Year, Overheating, EnergyPlus, Weather data, Parametric study

1. INTRODUCTION

In assessing potential overheating in free running buildings, near-extreme weather data were often used. The Chartered Institution of Building Services Engineers (CIBSE) released standard weather data for three sites (London, Manchester & Edinburgh) since early 2000 (CIBSE Guide J 2002). Later release included 14 cities (16 sites) in total using the same selection criteria – the third warmest year (**near extreme**) among a 20 year source weather datasets, or the mid-year of the upper quartile if more than 20 years (Levermore & Parkinson 2006). The warmth of a weather year was judged by the average Dry Bulb Temperature from April to September. The appropriateness of this averaged Dry Bulb Temperature method was criticised on the fact that at some locations in the UK the predicted indoor warmth using DSY is cooler than its corresponding Test Reference Year (TRY) which represents a typical weather (averaged condition) among the same source weather years (CIBSE TM48 2009; Nicol et al 2009; Smith & Hanby 2012). A detailed analysis on this averaged Dry Bulb Temperature method discovered a number of issues which could cause the chosen DSY less likely being representative as a near-extreme weather (Jentsch et al 2014). The latest release of CIBSE weather data in early 2016 (Virk & Eames 2016) was following the updated method discussed in TM49 – Design Summer Years for London (CIBSE TM49 2014). TM49 uses a definition called “weighted cooling degree hours (WCDH)” to judge the outdoor warmth. And as a result three complete weather years were selected from a much larger source weather datasets (1950 to 2006). The three complete weather years are intended to represent: inner urban (1976 – *a year with a long period of persistent warmth*), rural (2003 – *a year with a more intense single warm spell*) and intermediate urban & sub-urban (1989 – *a moderately warm summer*). WCDH is based on adaptive comfort temperature (CIBSE Guide A 2006; BS EN 15251 2007), and it is closely related to the likelihood of thermal discomfort (Smith & Hanby 2012). However, this Dry Bulb Temperature only selection method and the ‘conceptual free running building’ analogy used in TM49 can be problematic in practices as argued in recent research (Jentsch et al 2015; Ji et al 2016): other weather parameters such as solar radiation and wind should also be included in selecting DSY; also, assuming operative

temperature is the same as outdoor temperature for the ‘conceptual building’ could be unrealistic.

In light of the above, this research aims to evaluate whether the new release of near extreme weather data from CIBSE are fit for purpose. The purpose for developing (or selecting) weather data sets is to analyse building's performance, how various buildings designs respond to weather data is clearly a question in need of answering. For any particular building design in question, it is expected that a warm year should have higher likelihood of causing overheating (in case of free running buildings) or have higher cooling demand (in case of air conditioned buildings). What have been lacking from previous researches are - the use of large number of building models to verify near extreme weather data against their baseline historical weather data; and the appropriate methods for investigating individual weather parameter's contribution on indoor warmth prediction. In this paper a large number of single zone office models were used to examine how these models respond to the near extreme weather conditions.

2. METHODOLOGY

2.1 Historical weather data

London historical weather data from 1976 to 1995 were used in this work. Among these 20 years, the year 1976 and 1989 are the two out of three pDSYs proposed in the CIBSE latest release (CIBSE TM49 2014). The key weather parameters within these source weather years include: global solar irradiation, diffuse solar irradiation, cloud cover, dry-bulb temperature, wet-bulb temperature, atmospheric pressure and wind speed. For free running buildings, dry-bulb temperature (DBT), global solar irradiation (GSR) and wind speed (WS) are thought to have direct influence on indoor operative temperature. Hereinafter, they will be referred as DBT, GSR and WS.

For the purpose of generating standard near extreme weather data, various analyses have been used in ranking the warmth of the historical weather data. Some ranking methods were using on DBT only (CIBSE Guide J 2002; Smith & Hanby 2012; CIBSE TM49 2014), others considered parameters such as GSR and WS in addition to DBT (Jentsch et al 2015; Ji et al 2016). Table 1 shows various warmth rankings for the 20 years historical weather data used in this research where individual column indicates from coolest to warmest (top to bottom). In the table, **HO** stands ‘number of hours over’ a base temperature. **ADH** stands ‘accumulated degree hours’ over a base temperature, it is the sum of the ‘degree hours (d·h)’ over that base temperature. For example, using 21°C as a base temperature, a temperature at 21.2°C has 0.2d·h; a temperature at 28.3°C gives 7.3d·h. ADH is the sum of all these degree hours. It is a metric to indicate the severity of warmth. **AvgDBT** here stands the averaged dry bulb temperature metric used in CIBSE Guide J (2002), **WCDH** is the weighted cooling degree hour metric used in CIBSE TM49 (2014), and t'_{sa} is the sol-air temperature proposed in Ji et al (2016) which takes in to account, DBT, GSR & WS. It is evident in Table 1 that the warmth ranking position for an individual year does vary. The year 1976 was consistently warmer than other years, however, when the base temperatures are less than 17°C, the **HO** metric shows the year 1989 takes the warmest positions.

Table 1 Ranking orders of London 1976 to 1995 weather data with various metrics (TRY is added as a reference)

>15 °C		>17 °C		>19 °C		>21 °C		>23 °C		>25 °C		>27 °C		>28 °C		>29 °C		AvgDBT	WCDH	t'_{sa}
HO	ADH	HO	ADH	HO	ADH	HO	ADH	HO	ADH	HO	ADH	HO	ADH	HO	ADH	HO	ADH			
L77	L77	L77	L77	L77	L88	L77	L88	L88	L78	L78	L78	L78	L78	L93	L93	L93	L93	L77	L78	L77
L86	L88	L88	L88	L88	L77	L88	L78	L78	L88	L80	L80	L88	L77	L78	L78	L88	L88	L86	L88	L78
L78	L78	L86	L78	L85	L78	L85	L77	L77	L80	L88	L88	L93	L93	L77	L77	L81	L81	L78	L93	L80
L88	L85	L78	L85	L78	L85	L78	L80	L80	L77	L85	L85	L79	L88	L80	L80	L80	L80	L79	L77	L79
L85	L86	L85	L80	L80	L80	L80	L85	L85	L85	L77	L77	L85	L80	L88	L81	L78	L78	L88	L85	L86
L87	L80	L81	L86	L86	L79	L86	L79	L79	L79	L79	L79	L80	L81	L91	L88	L77	L77	L85	L91	L88
L79	L79	L79	L79	L79	L86	L79	L93	L93	L93	L93	L93	L77	L85	L85	L85	L92	L92	L80	L81	L85
L81	L81	L80	L93	L81	L93	L87	L86	L86	L81	L81	L81	L81	L91	L81	L91	L91	L87	L81	L80	L81
L80	L87	L87	L81	L87	L87	L93	L87	L87	L87	L87	L91	L91	L79	L82	L82	L87	L82	L87	L79	L87
L93	L93	L93	L87	L93	L81	L81	L81	L81	L91	L91	L87	L82	L82	L79	L87	L85	L91	L91	L87	TRY
L91	TRY	TRY	TRY	TRY	TRY	TRY	L91	L82	L86	L86	L82	L92	L92	L92	L92	L82	L85	L93	L82	L93
TRY	L91	L91	L91	L82	L82	L82	L82	L91	L82	L82	L92	L87	L87	L87	L79	L79	L79	TRY	L92	L91
L84	L82	L84	L82	L91	L91	L91	L92	L92	L92	L92	L86	L86	L86	TRY	TRY	L86	L86	L84	L86	L94
L94	L84	L94	L92	L84	L92	L92	TRY	TRY	TRY	TRY	TRY	TRY	TRY	L86	L86	TRY	TRY	L94	TRY	L84
L83	L92	L82	L84	L94	L84	L94	L84	L84	L84	L84	L84	L84	L84	L84	L84	L84	L84	L82	L84	L83
L90	L94	L92	L94	L92	L94	L84	L94	L94	L94	L94	L94	L94	L94	L94	L94	L94	L94	L83	L94	L82
L82	L83	L83	L83	L83	L83	L90	L83	L90	L83	L90	L89	L90	L89	L89	L89	L89	L89	L92	L83	L92
L95	L90	L90	L90	L90	L90	L83	L90	L83	L90	L83	L83	L89	L83	L83	L83	L83	L83	L90	L89	L90
L92	L95	L95	L89	L95	L89	L95	L89	L89	L89	L89	L90	L83	L90	L90	L90	L90	L95	L89	L90	L95
L76	L89	L76	L95	L89	L95	L89	L95	L95	L95	L95	L95	L95	L95	L95	L95	L95	L95	L95	L95	L89
L89	L76	L89	L76	L76	L76	L76	L76	L76	L76	L76	L76	L76	L76	L76	L76	L76	L76	L76	L76	L76

2.2 Building parametric models

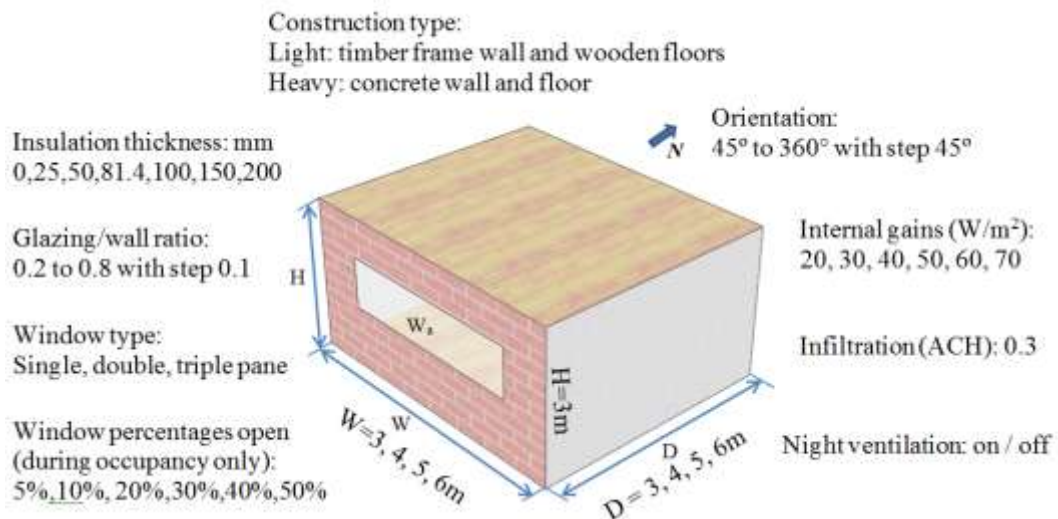


Figure 1 The single zone office model and their varying parameters

Various single zone offices are represented by a single zone dynamic thermal model with a fixed height of 3 metres, and varying widths and depth between 3 and 6 metres, respectively, to represent a wide range of cellular and open-plan office spaces. Deriving from the four towns survey, such side lit spaces may account for over 45% of all offices (Steadman et al 2000a). Figure 1 is the graphic representation of the single zone model. This single zone space is assumed to be taken from a free running office building. Only the façade with a window is exposed to the ambient environment. The rest are either internal roof/ceiling or

partition walls. Adiabatic condition is assumed for these internal surfaces. The cellular office is occupied from 9am to 5pm during which ventilation is provided by opening the window. A fixed night time ventilation schedule may be enabled, so that ventilation is employed when internal temperature is above 22°C between 1am and 8am. The model is created using EnergyPlus. In order to cover the wide variations of office spaces in the UK, parameters including orientation, wall construction, insulation level, window type, window sizes and openable area, internal heat gain, and night ventilation operation are applied to the model. The number of all variations resulted from the combinations of different parameter values are in the order of 10^6 . Modelling the full population of building models is unrealistic therefore sampling is needed.

2.3 Building models sampling conditions

Four building models sampling scenarios are considered. **Sample "i"** examines the combined influence of temperature, solar radiation and wind using complete random building models. **Sample "ii"** is also using the complete random building models but focuses on the sole influence of temperature, excluding the impact of solar radiation and wind completely. For solar, a spectrum filter applied as a shading device that stops all solar irradiance on the facade is employed. This setting prohibits visible light through the window for the whole simulation period. For wind, the weather data is filtered to remove wind speed, so that natural ventilation is only driven by buoyancy. **Sample "iii"** examines the maximum possible impact of solar radiation. The random building models are filtered by the ‘maximum window to wall ratio’ and the ‘south east window’ (315°) where it receives the most solar gains during occupancy period compared with other orientations. Influence of wind is also disabled using the same method as in Sample "ii". **Sample "iv"** assesses the maximum possible wind influence without the presence of solar radiation. By examining London's weather data, the prevailing wind direction is south west. Therefore the random building models have the following fixed conditions: south west facing (45°), maximum window to wall ratio (80%) and maximum openable area (50%), whereas solar is blocked using the shading device. Table 2 is a summary of the sampling conditions.

Table 2 Considered sampling scenarios

Sample index	Descriptions
i	Full parametric building models (complete random sample)
ii	Full parametric building models but the influence of wind and solar is removed
iii	Influence of wind is removed; random models are filtered by maximum glazing and south east facing
iv	Influence of solar is removed; random models are filtered by maximum glazing, maximum opening area, and south west facing

2.4 Overheating criteria

There are various criteria which can be used to assess overheating in buildings. In this study, the single overheating criterion as defined in CIBSE Guide A (2006) and the adaptive overheating criteria from BS EN 15251 (2007) were used. CIBSE single temperature criterion assesses number of hours the indoor operative temperature over 28°C, i.e. for office setting such as this work, overheating is judged if there is more than 1% occupied hours

(which corresponds 20 hours over a year) when operative temperature is over 28°C. Adaptive overheating criteria are based on extensive field studies that examine the relationship between indoor comfort conditions and the outdoor environment (Humphreys & Nicol 1998). The limiting comfort temperature T_{comf} defined as BS EN 15251 by:

$$T_{comf} = 0.33Max(10, T_{rm}) + 18.8 \text{ where} \quad \text{Eq. 01}$$

$$T_{rm} = \alpha T_{rm-1} + (1 - \alpha)T_{dm-1} \quad \text{Eq. 02}$$

(T_{rm-1} and T_{dm-1} are the running mean and daily mean temperature previous day)

T_{comf} , as shown in Eq. 01, is no longer a fixed temperature, it varies with the daily running mean temperature (Figure 2). The overheating limiting temperatures in BS EN 15251 were divided into three categories (Category I, II & III) and the upper limit temperatures for these categories are 2°C, 3°C and 4°C, respectively, above the comfort temperature calculated using Eq. 01. Similarly as CIBSE single temperature criterion, the number of hours over these limiting temperatures can be used as a measure of overheating, i.e. number of hours over these upper limiting temperatures should be no more than 3% of total occupied hours (which corresponds around 61 hours) for that specific category the assessment falls within.

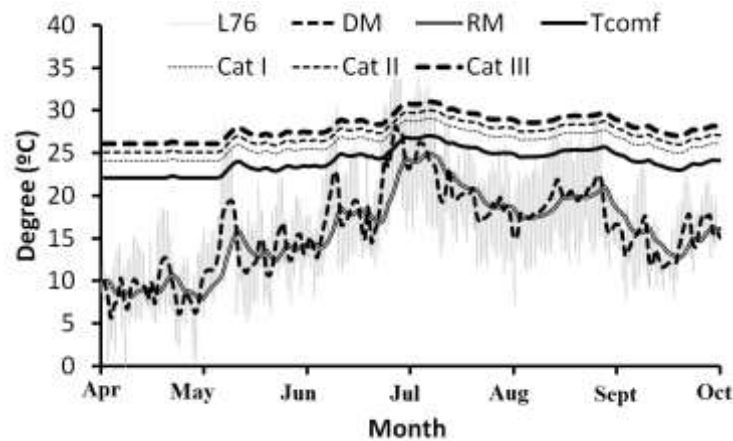


Figure 2 The limiting comfort temperature for the year of 1976 using Eq. 01 for April to September (the upper limits of Category I, II & III would be a parallel shift of T_{comf} by 2, 3 & 4 degree Celsius).

Table 3 Overheating assessment criteria

Index	Description	Unit
c0	Number of hours over 28C during occupancy	[hrs]
c1	adh over 28C during occupancy	[deg.hrs]
c2	BS EN 15251 Category I exceeded during occupancy	[hrs]
c3	adh over Category I during occupancy	[deg.hrs]
c4	BS EN 15251 Category II exceeded during occupancy	[hrs]
c5	adh over Category II during occupancy	[deg.hrs]
c6	BS EN 15251 Category III exceeded during occupancy	[hrs]
c7	adh over Category I during occupancy	[deg.hrs]

As discussed in CIBSE TM52 (2013), overheating occurrence does not always reflect the actual overheating severity which is the accumulated degree hours over limiting temperatures (either a fixed temperature as CIBSE Guide A or varying ones as BS EN 15251). In this work the accumulated degree hours (adh) is calculated the same as CIBSE TM52. The predicted indoor warmth (including both overheating occurrence and severity) is ranked for each individual parametric model from the intended sampling conditions (i to iv in Table 2). A criteria index list is made to facilitate the indoor warmth assessment (Table 3 above).

2.5 Statistical ranking on predicted indoor warmth & sampling

The method for analysing the data is statistical ranking, i.e. to use statistics on the ranking orders of the results. The statistical ranking process is following the method used in Ji et al (2016):

- 1) A random sample of simulation cases is generated from the parametric model.
- 2) Simulations are carried out on the set of sample cases, with each of the 20 London weather years (1976-1995) and the Test Reference Year, respectively.
- 3) Using the results of each simulated case, the 20 weather years are ranked by the predicted indoor warmth using the overheating criteria defined in Table 3.
- 4) The ranks of the weather years of each simulation case, according to each criterion, are collated, so that for each weather year, frequency histograms of the ranks are calculated.

In this work, the Latin Hypercube Sampling (LHS) method is used (Stein 1987). With LHS, a sample size of normally 10 times of the number of variables is sufficient for estimating mean values of the population (*ref* Figure 1, there are 10 varying parameters). As a result, 100 random building models for each weather year will be enough for producing reliable estimation of the average overheating profiles. For the analysis where statistical ranking of the weather years is of interest, the relationship between building characters and their overheating risks under different climatic conditions need to be examined, a larger sample is therefore required. After experimenting, a Quasi-Monte Carlo sample of 2,000 designs for each weather year, generated using the Sobol sequence, was used. Sampling and simulation of the parametric model is managed using the jEPlus tool (Zhang 2009). In total, 42,000 simulations have been performed for the years 1976-1995 plus TRY weather data.

3. RESULTS & DISCUSSIONS

Histograms were produced to illustrate the ranking probability of predicted indoor warmth for each weather year. With 20 years historical weather data, 32 of these graphs were made based on the 4 sets of samples and 8 overheating criteria (Tables 2 & 3). In this work, the analysis is primarily carried out against those warm weather years of interests: the top 6 warmer years (*ref*: Table 1, these years are: 76, 83, 89, 90, 94, 95), with the assumption that one of these weathers will be able to represent the ‘near-extreme’ weather, i.e. being the third warmest.

3.1 The ranking probability of the warmer years

In Figure 3, i to iv + c0 are the ranking probabilities of the 4 sample sets in Table 2 by the number of hours over 28°C for the single zone office space during occupancy. For the year 1976, the probability of being the warmest in terms predicted indoor warmth is only about 32% for the full parametric **Sample "i"**; while this probability increases to 48% when

excluding influences of both solar radiation and wind condition (**Sample "ii"** – only dry bulb temperature is the key driver for possible overheating), and to 74% for **Sample "iv"** where the random models have a maximum possible influence of wind speed and direction on top of **Sample "ii"**. There seems to be a tendency that the probability of being the warmest for 1976 increases when the sampling conditions can lead to less number of hours over the limiting temperature. On the contrary, significantly less probability (6%) of being the warmest for the year 1976 was resulted by **Sample "iii"** where the solar radiation is maximized as well as removing the influence of the counter factor of wind in terms of predicted indoor warmth. The year 1989 does not seem to sustain a ranking position with statistical significance apart from for **Sampling "iii"** where its probability of being the warmest is over 80%. For the c0 criterion, it is more likely for the year 1990, 1983 & 1994 to be in the 4th, 5th & 6th ranking position and same is true for the year of 1995 to be in the 2nd ranking position although this is less obvious and with the exception of **Sample "iii"**. For all those concerned years **Sample "iii"** creates a more random order in terms of their ranking probabilities.

Sample "iii" random models emphasize the maximum influence of solar radiation and in the meanwhile excluding wind. This would result the highest level of overheating (by the number of hours over limiting temperatures) among the 4 sampling sets i to iv. The year of 1989 has the highest probability of being the warmest (slightly over 80%). This is ‘unusual’ as the year of 1989 has long been used as a near extreme year, never been deemed the warmest by any of the previous analysis (CIBSE Guide J 2002; Jetsch et al 2014; CIBSE TM49 2014; Ji et al 2016). In Table 1, when varying the base temperatures, the year 1989 has the highest number of hours over 15 °C and 17°C. The random models from **Sample "iii"** have the largest glazing ratio, facing south east (the highest solar gain orientation during occupancy), and no wind. These models may have caused overheating (i.e. indoor operative temperatures are higher than 28°C or the upper limits of the adaptive comfort criteria) when outdoor temperature is below 17°C and this could be the reason why the year 1989 has the highest probability of being the warmest in terms of the predicted indoor warmth.

Similarly as observed in Figure 3 above, when examining the overheating severity (accumulated degree hours over 28°C) in Figure 4, the 4 sampling sets i to iv + c1 show better consistency in terms of predicted indoor warmth ranking probability. The year 1976 is consistently the warmest. Even with Sample "iii", its ranking probability of being the warmest is still as high as 90%. The ranking probability of the year 1989 spreads over 4 or 5 positions in Figure 4. Other years maintain their ranking position well with relatively higher percentage probabilities, in particular for sampling sets i, ii & iv. Unlike the other three sampling sets, the years 1990 & 1995 behave differently for **Sample "iii"**, i.e. the year 1990 stands in the 4th position and the year 1995 has nearly 60% chance in the 3rd position. For all 4 sampling sets in Figure 4, the highest probability ranking position for the years 1983 and 1994 remain unchanged (5th and 6th in ranking). The above observations could be explained by Table 1 where the accumulated degree hours over various base temperatures for these 20 year historical weathers. In Table 1, the year 1976 is consistently the warmest with ADH, while the year 1989 moving from the 5th to the second warmest when the base temperature is 15 °C. The year 1995 is consistently the second warmest in Table 1 and Figure 4 with the exception of **Sample "iii"** where the parametric models of this sample group are prone to cause large number of overheating hours, i.e. when outdoor temperature is 15°C the single zone office space may be already overheated due to maximum possible solar gain, internal heat gains and windless condition. In summary, to some extent Figure 4 does correspond Table 1 reasonably well.

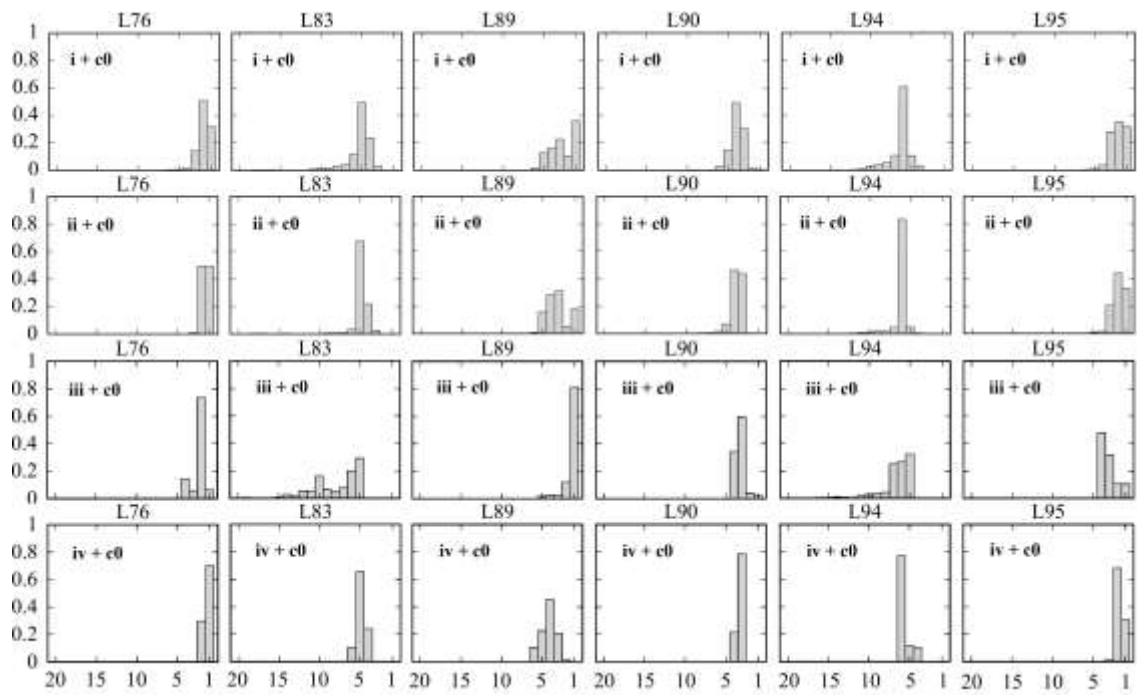


Figure 3 [samples i to iv + c0] Ranking probabilities by the ‘number of hours over’ 28°C (ref: Table 2 & 3) for the single zone office space during occupancy.

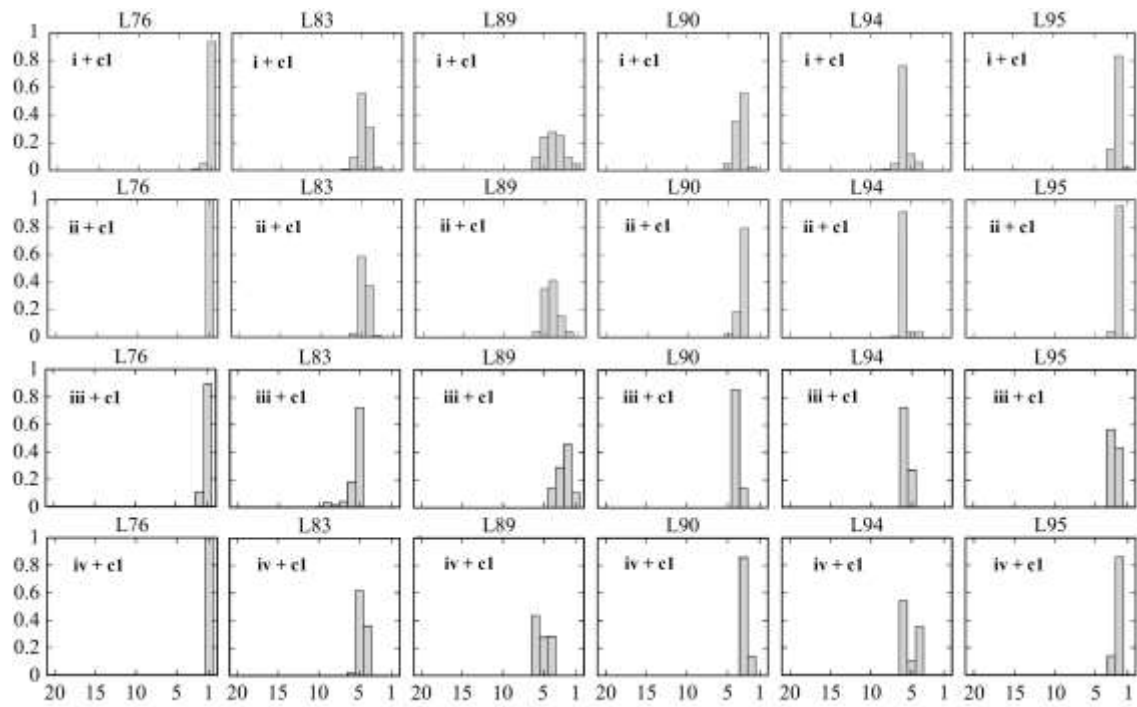


Figure 4 [samples i to iv + c1] Ranking probabilities by both ‘the accumulated degree hours (adh) over’ 28°C (ref: Table 2&3) for the single zone office space during occupancy.

To a great extent, the ranking probabilities of the six warmer years using the adaptive overheating criteria from BS EN 15251 (Table 3) do behave similarly as those using the CIBSE fixed temperature criterion. What has been discussed in Figures 3 & 4 can also be said for the adaptive criteria although variations do exist. Overall, the year 1976 tends to have higher probability of being the warmest where sampling sets cause less number of hours over, i.e. Samples "ii" & "iv". **Sample "iii"** is still an ‘outlier’ as the year 1989 has the highest probability of being the warmest within this group of random models. No strict correlation

between any of the discussed outdoor ranking methods (this work and existing literature such as CIBSE Guide J 2002; Nicol et al 2009; Jetsch et al 2014; CIBSE TM49 2014) and the predicted indoor warmth probability ranking was observed. It is clear that thermal responses of various building designs can be very different against the tested 20 years historical weather data in terms of predicted indoor warmth. Judging by the probability ranking of the predicted indoor warmth it is unlikely possible to choose a complete year which can always represent the ‘near extreme’ or being the third warmest.

3.2 TRY ranking probability

By definition TRY represents an averaged weather condition of the historical weather data from which it is generated. The 11th ranking position in Figure 5 with a higher probability is where ideally it should be. It is clearly not the case. For random model **Sample "i"**, TRY is more likely being 7th warmest based on its highest probability ranking with the 20 source weather years, although for cases ‘i + c0’ (53%) and ‘i + c2’ (35%) the highest probabilities are not statistically significant. With the adh over ‘i + c1’ & ‘i + c3’, its probabilities of being the 7th warmest are both higher (around 60%). **Sample "iv"** shows more consistent high ranking probability of being the 7th warmest position for all criteria (c0 to c3, table 3). TRY’s probability ranking positions vary for random models in sampling sets ii & iii, changing from the 5th warmest position (iii + c2, c3), the 6th warmest position (iii + c0) to the 7th warmest position for remaining cases with the case ‘ii+c1’ show 90% probability in Figure 5. The above observations on the probability ranking of the predicted indoor warmth for TRY do not correlate well with Table 1 – the highest ranking position for TRY is the 8th warmest in terms of outdoor warmth. With lower base temperatures, the TRY tends to move the middle. The above observation shows that the probability ranking of the predicted indoor warmth for TRY does indicate that TRY is warmer than expected.

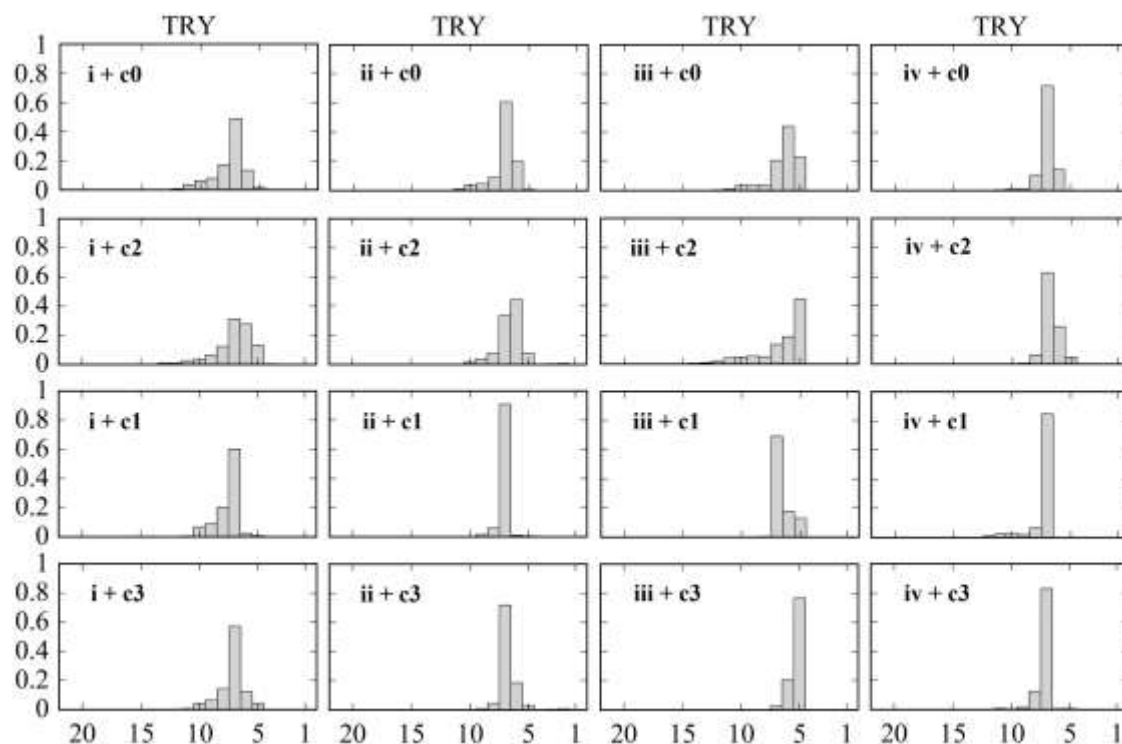


Figure 5 Ranking probabilities for TRY (21 ranking positions) by both ‘the number of hours over’ and ‘adh over’ CIBSE Guide A single temperature criterion 28°C and BS EN 15251 Category I upper limit (ref: Table 6) for the single zone office space during occupancy.

3.3 The averaged overheating occurrence and severity

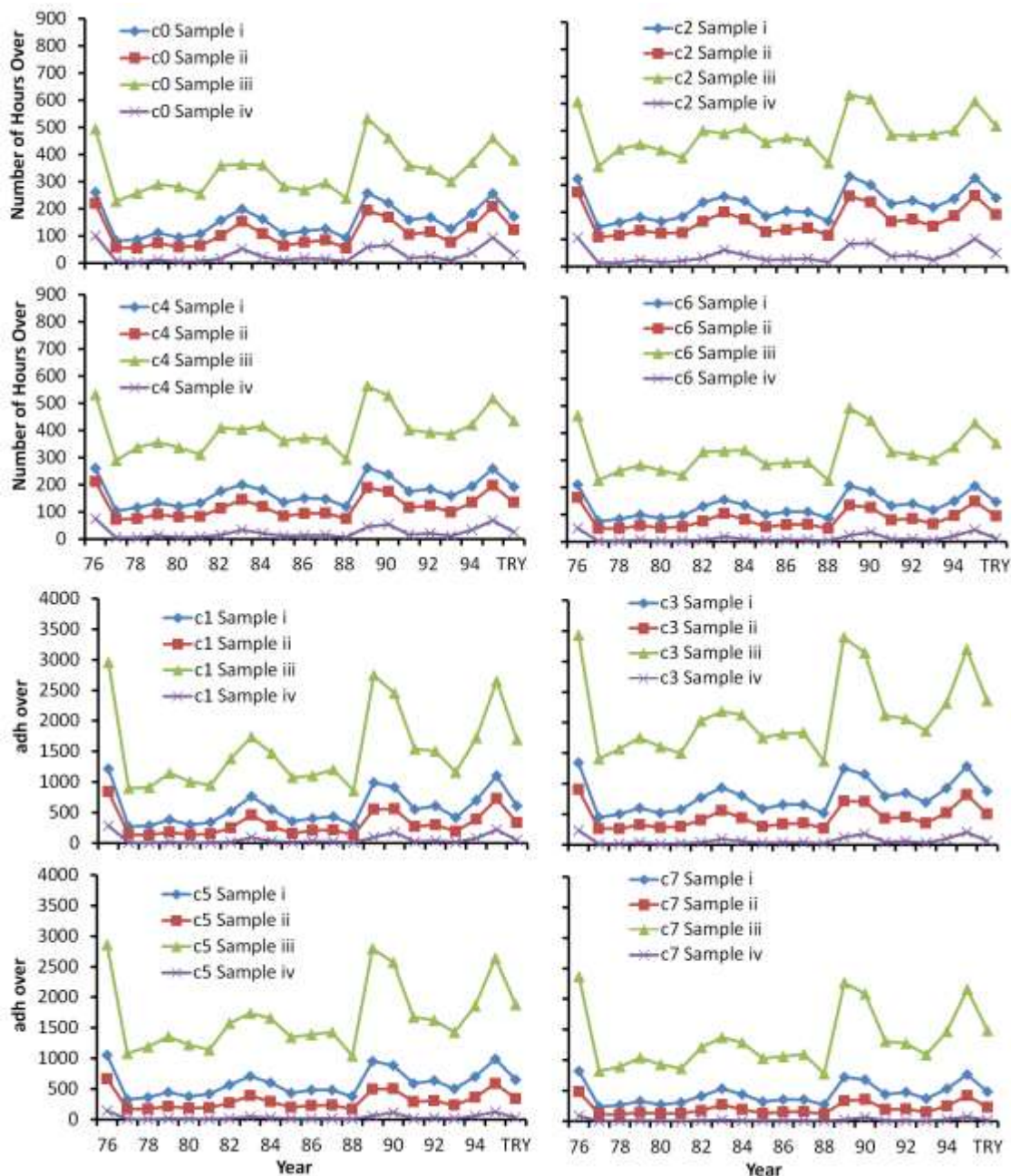


Figure 6 **Averaged** 'number of hours over' and 'adh over' for all 4 sampling sets of random building models (Table 2) against the 8 criteria (Table3)

The averaged 'number of hours over' 28°C and the upper limiting temperatures from the adaptive Categories I, II & III for each sampling set (Table 2) are shown in Figure 6. In Figure 6, the averaged 'number of hours over' for **Sample "i"** is consistently higher than **Sampling "ii"** which indicates that the combined influence of wind and solar tends to increase the level of overheating. Solar gain is a contributing factor for overheating but for free running buildings wind is a counter factor. This increase of overheating level means solar radiation plays a more significant role to push the indoor temperature up than wind which tends to cool the indoor temperature down through ventilation. Although the exact quantity of overheating hours for each individual random model is arbitrary the general trend in average term is obvious. It is evident in from Figure 6 that the level of increase in

overheating hours for **Sample "iii"** is higher than the level of decrease in overheating hours for **Sample "iv"** when using **Sample "ii"** as a baseline (see table 2). This also confirms the stronger influence on overheating hours from solar than from wind. When examining the averaged 'accumulated degree hours (adh) over' in Figure 6, the observation on the relative influences of solar and wind in overheating prediction is the same. For absolute quantities of the averaged adh over 28°C and adaptive Category I to III limiting temperatures, the year 1989 becomes the second warmest for **Sample "iii"** which is consistent with Figures 3 & 4. Similarly for the averaged 'number of hours over' of **Sample "iii"** in Figure 6, the year 1989 becomes the warmest (as in Figures 3).

4. CONCLUSIONS

This paper sets out to assess the existing definition of standard near extreme weather data. The parametric model was made by a single zone office setting through which both physical changes (size, orientation, glazing, insulation, etc) and operational changes (window opening percentage, internal gains, with or without shading, etc) were randomly modified. The LHS sampling technique was used to generate 4 sampling sets and the building models from these sampling sets were used to examine the impact of building models on overheating assessments. The 20 years historical weather data of London as well as their corresponding TRY were simulated on the sample models of each sampling set. Both single temperature overheating criteria from CIBSE Guide A and adaptive criteria from BS EN 15251 were used to assess overheating in these sample building models. By using a statistical voting procedure, the ranking probability of each weather year on their predicted indoor warmth is presented against both overheating occurrence and severity.

The ranking probabilities of predicted indoor warmth for source weather years show no strict correlation with any existing ranking metrics discussed in this paper. The general observation of warmth from the examined weather years shows that the year 1976 is not always the warmest when using the 'number of hours over' criteria. There is a clear ranking position swap between 1976 and 1989 when the sampling models emphasize the maximized solar radiation scenarios, i.e. the year 1989 has highest probability of being the warmest for **Sample "iii"**. This observation conflicts with most of the existing outdoor warmth definitions apart from the 'number of hours' over lower based temperatures of existing weather data (Table 1). For the 'accumulated degree hours (adh) over' criteria, the year 1976 has been largely consistent of being the warmest with higher ranking probability of predicted indoor warmth. For **Sample "iii"** the year 1989 can become the warmest with the adh over but its probability is much lower than the overheating occurrence cases. Other examined weather years such as 1983, 1990, 1994 & 1995 could not hold any particular ranking position either, but relatively, they are more chances for them to appear in the 5th, 3rd, 6th & 2nd position although they do swap positions with different sampling sets and different criteria used to judge overheating.

For all 4 sampling sets the averaged 'number of hours' and 'adh' over clearly indicates the strong influences from solar radiation and wind speed on the indoor thermal responses. Although the exact 'number of hours' over (for both overheating occurrence and severity) contributed by solar and wind could be random for single zone office models, the averaged 'number of hours' over shows that the influence from solar radiation does outweigh the counter influence from wind induced space conditioning through ventilation. The ranking probabilities of predicted indoor warmth for TRY show that TRY is warmer than expected as its highest ranking probability happens most likely in the 7th position when compared with its

20 source weather years. Even with this 7th position, the statistical significance is not always maintained as for some cases the probability of being the 7th warmest is less than 40%.

It is evident from this research that buildings themselves have significant influences on indoor overheating and the near extreme definitions using historical weather data do not always correlate with the predicted indoor warmth. As shown in this work, it is true that warmer years defined from historical weather data using various methods (i.e. averaged DBT, WCDH, SWCDH, TWCDH, FS statistics on DBT & Solar radiation, etc) are also warmer years based on their predicted indoor warmth ranking probability (1976, 1983, 1989, 1990, 1994 & 1995). However, the exact ranking sequence is not often maintained, i.e. which year is the warmest and which year is the near extreme for individual buildings. This supports the notion of the CIBSE latest release of using pDSYs where multiple weather years are used to cover various types of warmth of historical weather. It is therefore sensible to suggest that more warmer years should be included to make sure one of which can always represent 'near extreme' weather for any individual building design.

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