Climate and tourism – an Australian perspective

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Abstract

Visitors who come to Australia from cooler countries can experience problems. They are neither adapted to nor prepared for our warmer climates and they often have little information about thermal conditions in Australia. In order to meet tourists' needs for information, a climatology based on thermal comfort considerations has been developed. Because heat stress is the major thermal problem in Australia, we divide the country into three main regions on the basis of January 3 pm temperature and vapour pressure. These zones are subdivided on the basis of summer severity (in the tropical north) or of winter conditions (in the southern and central regions). Climate-based conflict between tour operators and the Commonwealth government can occur. An example of this was when tour operators objected to a walking track in the Uluru - Kata Tjutu National Park (Ayers Rock and the Olgas) being closed by the National Parks and Wildlife Service (NPWS) on hot days, for safety reasons. There was a legal challenge to the track closures by a consortium of tourism operators in 1999. On-site field measurements of heat stress were written into a report for the NPWS, along with an assessment of the risk to tourists from heat stress. The litigation was settled out of court and the policy of track closures based on forecast maximum temperatures remains in place. These case studies from Australia emphasise the point that climate is a resource for the tourism industry, and like any resource, it requires prudent management.

Keywords: thermal comfort • thermal stress • tourism

Introduction

In 1998 more than 600 million people travelled internationally, a figure that is expected to soar to 1.6 billion by 2020. Tourists suffer from a special vulnerability, often unfamiliar with their destination's language, traffic patterns, customs and, of course, its climate (Mieczkowski, 1995). People who come to Australia from cooler countries are no exception. They are neither adapted to nor prepared for our warmer climates, they often have little information about thermal conditions in Australia and they tend to arrive in summer (our most thermally stressful season) in order to escape the Northern Hemisphere winter. Recommendations have been made that improved specific travel information relating to climate and human health should be provided for tourists (WMO, 1995). A climatology for tourists has been developed by the Australian Bureau of Meteorology to provide some much-needed information for our visitors and the tourism industry.

A climatology for tourists

Variables to form basis of classification

Most climate classification systems are based on plant growth factors, usually rainfall and temperature (Stern et al, 2000). What climatic variables are important to tourists? Mieczkowski used a combination of monthly means or totals of air temperature, relative humidity, precipitation, sunshine duration and wind speed in his tourism climate index. The chart presented here is based solely on thermal comfort considerations (disaggregated into temperature and water vapour), which could be a drawback. The classification scheme is not based on an index as such, but rather the overlaying of two fields of spatial climatic data. On the other hand, the chart is equally applicable to building design, urban design and health/quality of life considerations as well as to tourism.

The classification takes no account of rainy days. The major Australian attractions (Uluru, the Great Barrier Reef, Kakadu national park) are in the hot zones: rainy days are more of a problem in cooler climates. Mieczkowski's tourism climate index assumes that rainy days are always unfavorable for tourists. Like much work done in temperate countries, Mieczkowski's work could benefit from consideration of conditions in hotter climates. In the tropics, rain can actually provide *more comfortable conditions* for outdoor activity because of its cooling effect and because rain implies cloud, which means less intense radiation from the sun.

The inclusion of solar radiation was considered, because tourists can suffer serious ill effects from our intense sunshine, but it made the scheme too complex. However, information about radiation is implied in the classification: the arid zones have the greatest solar radiation. The variability of the climate – its day-to-day fluctuations – was another relevant variable which had to be omitted. It is true that information about average conditions is not the whole story: tourists do need to know something about the variability of the climate and the chance of extreme events such as tropical cyclones.

Seasonal conditions used

As Mieczkowski notes, annual climatic averages are of no use to tourists; they are interested in climatic conditions during specific times of the year. In summer, most of Australia is too hot. In the northern tropics and the central arid zone (where our major tourist attractions are found) winter is the most comfortable time of year. Since summer heat stress is our major problem, it was decided to base the climatology largely on summer conditions; on comfortable limits of maximum temperature and 3 pm vapour pressure in January, the southern hemisphere midsummer.

Thermal comfort definition used

Various definitions of thermal comfort were considered. Mieczkowski considered that sunshine was undesirable once the temperature reached 33ºC, implying that temperatures above 33ºC are too great for comfort. An earlier ASHRAE Standard set the upper limit of summer comfort indoors at 26.1ºC and vapour pressure of 1.9 kPa. The current ASHRAE Standard 55-92 (ASHRAE, 1992, 1995) sets the upper summer indoor comfort limit at an Effective Temperature (Gagge et al, 1986) value of 26 ºC and wet bulb temperature of 20ºC.

We have adopted a less stringent definition of thermal comfort. Visitors come to Australia for our scenery and climate rather than the art, architecture and history: they will be outdoors much of the time. It has been shown (Nikolopoulou, 2001) that people have lower expectations of comfort when outdoors, so the upper comfort limit can be set higher than for indoor conditions. Accordingly, we set the upper comfort limit at a mean January max temperature of 30 ºC and mean 3 pm January vapour pressure of 2.1 kPa.

How do these conditions rate on a thermal comfort scale? If clothing is set at 0.3 clo (shorts and singlet) and activity level at 115 W/sq m (walking at 0.89 m/sec), then air and radiant temperatures of 30 deg C combined with a vapour pressure of 2.1 kPa lead to an Effective Temperature of 29.96 ºC. This is well above the current ASHRAE standard for indoor comfort mentioned above. The value of the Predicted Mean Vote thermal index (Fanger 1970) for these conditions is 1.83, indicating that 69% of people would be dissatisfied. Outdoors in daytime, the mean radiant temperature would obviously be greater than air temperature, so the level of discomfort here is an under-estimate. It should be remembered that Fanger's index was derived from samples of college age subjects sitting inside climate chambers.

Results

The temperate zone is defined as the region where summer temperature and vapour pressure are both below the upper comfort limits described above. The hot dry zone is defined as the area where summer maximum temperature is above the upper limit for comfort, but summer water vapour pressure is below its upper comfort limit. In the warm/hot humid zone, water vapour pressure is above the comfort limit. Each of these zones is subdivided on the basis of summer severity (in the tropical north) or of cool annual or winter conditions (in the southern and central regions).

Fig. 1 Mild temperate zone

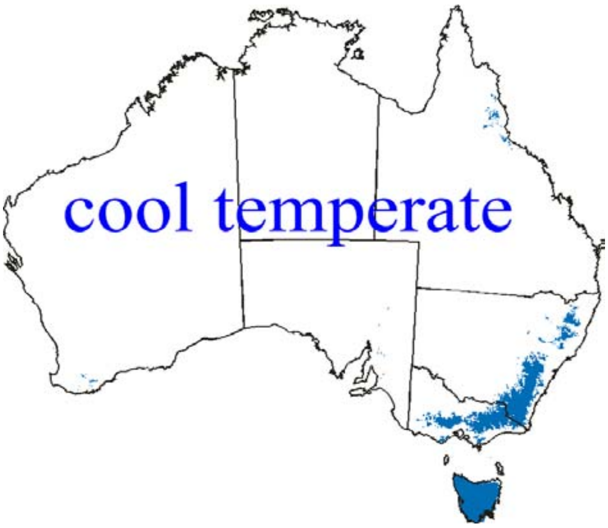

Fig. 2 Cool temperate zone

Parts of the temperate zone can be cold, especially in the mountains in the southeast of the mainland and in Tasmania. This zone is subdivided into mild temperate (Fig. 1) and cool temperate zones (Fig.2) by home heating needs (annual heating degree days[1] greater than 2000). This is the thresh-hold where edge insulation of concrete slabs becomes cost-effective.

[1] The HDD figure (base 18 deg C) for each day is the difference between 18 and the day's mean temperature. For example, if the mean temperature for the day is 11 deg C, that day contributes 7 HDDs to the annual total. For days over 18 deg C, the HDD figure is zero.

Fig. 3 Hot dry zone with cold winter

In the hot dry zone, winter nights can be very cold. Accordingly, the zone is subdivided by winter temperature (July mean temperature less than 14º**C**) into a zone with cold winter (Fig. 3) and a zone with mild winter (Figure 4).

Fig. 4 Hot dry zone with mild winter

The warm/hot humid zone, where uncomfortable summer conditions are the dominant consideration, is subdivided by summer maximum temperature into a warm humid zone and a hot humid zone (mean January maximum temperature greater than 30ºC). Note that the hot humid zone fails *both* the summer water vapour and temperature criteria!

Fig. 5 Warm humid zone

Fig. 6 Hot humid zone

Discussion

Caveat and drawbacks of the chart

As Pontius Pilate nearly said: "what is comfort?" It depends on individual perceptions and on what climate you are used to, in other words, on acclimatisation (de Dear and Brager, 1998). This climatology takes no account of acclimatisation, as tourists are not acclimatised, unless they come from a region with a climate similar to that of their destination.

Another issue worth noting is that climate classifications are simplified views of complex reality: unfortunately Australia does not divide neatly into 6 separate and homogeneous zones. The very act of drawing a boundary on a chart is rather misleading: there is no sharp demarcation of climate, but just a gradual change as one climate merges into another. Within each zone, there are variations, too, depending on elevation, distance from the coast and land use effects.

Need for standardised information provision practices

Bushwalker alerts (warnings of dangerous weather conditions for walkers) are issued by the Australian Bureau of Meteorology's Tasmanian Regional Office, but not by other state forecasting offices. If walkers from Tasmania are visiting another part of Australia and don't hear a walker alert, then they may incorrectly assume that conditions are safe, with adverse consequences. This illustrates the need for consistent information provision practices within a country.

Internationally standardised information for tourists is also desirable. Is this an impossible dream? Mieczkowski's tourism climate index requires only information which all national meteorological services can provide: with minor modifications, it could be applied internationally.

Ethical dilemmas for government services

Understandably, tourism organizations are keen to promote their country and seldom mention problems which the unfortunate traveller may encounter. The problem is not confined to the private sector. Many national economies depend on income generated by tourism. Not surprisingly, government officials seldom, if ever, warn in-bound tourists of health, safety, or other issues (Richter and Richter, 1999).

Australia is no exception to this pressure; we don't want to discourage tourists. However, some of Australia's most famous tourist attractions are located in quite hostile climate zones: we need to strike a balance between promoting tourism and warning tourists of the dangers they face.

The Australian Bureau of Meteorology has experienced pressure to encourage tourism. For example, a number of local councils in the cooler parts of the country have asked us to take temperature readings in urban areas rather than at the nearby airports where our observations are often made. They have noticed that the temperature in town is usually warmer than at the exposed airport site we use. It would appear that if reported temperatures were a degree or two warmer, then tourists would flock to the particular city/town!

Possible conflict with tour operators – a case study

Climate-based conflict between tour operators and the Commonwealth government can occur. An example of this was when tour operators objected to a walking track in the Uluru - Kata Tjutu National Park (Ayers Rock and the Olgas) being closed by the National Parks and Wildlife Service (NPWS) for heat-safety reasons. There was a legal challenge to the track closures by a consortium of tourism operators in 1999.

The Uluru-Kata Tjutu National Park stands as one of Australia's most significant tourist attractions, particularly with international visitors. A busy local airport and several resort facilities within the park enable hundreds of thousands of visitors per year (ca 400,000 in 1996/7) to enjoy some of the most spectacular and dramatic desert scenery on the planet.

While the landscape and ecology that attracts so many tourists owe their unique character largely to Central Australia's arid climate, the climatic context of these attractions poses significant risks to the health of visitors. Many tourists arrive unacclimatised from a Northern hemisphere winter. They are greeted by very high summer temperatures, some of the most intense solar radiation on record, and heavy infrared radiation fluxes from the denuded lithospheric environment that is completely unshaded by vegetation. Some visitors are elderly and physically unfit to perform the relatively strenuous exercise that these attractions demand. Even young and fit visitors to the park can expose themselves to considerable risks through their alcohol intake the night before, and their unsuitable clothing and inadequate fluid intake on the day.

In the context of these risk factors it is perhaps not surprising that the NPWS, who manage the park on behalf of the indigenous landowners (the local Aboriginal tribes), typically attend a few dozen incidents of heat-related illness each summer (e.g. over 20 separate rescue operations were logged in the summer of 1996/7). Apart from the undesirable implications for the actual victims, these cases are the cause of extreme anxiety for the traditional owners of the park whose ancient culture places on them a responsibility of care far exceeding levels normally found in Western cultures.

These heat-related illness cases within the park raise legal concerns as well. The NPWS owes a common law duty of care for all visitors to the park, although this duty has yet to be tested in court.

Thermal injuries can range from mild heat exhaustion to serious heat stress, heat-stroke and, in some cases, death. These incidents clearly indicate a need for some rational risk management and safety strategies. In response, in 1988 the NPWS implemented a policy of park closures at 11:00 hrs on days when the Australian Bureau of Meteorology forecasts maximum temperature at the nearby Yulara aerodrome to exceed 36^{o}C. This threshold emerged from a review of NPWS's log of heat-related incidents. The closure policy was applied specifically to a walking track known locally as "The Valley of the Winds" within the Olgas (Kata Tjutu). Commercial sensitivity of the tourism sector to such a policy prompted the peak industry body in Australia, the Tourism Council, to launch complex litigation against the NPWS. The matter was heard by the Australian Administrative Appeals Tribunal. The ultimate resolution of that dispute relied heavily on scientific expert evidence relating to heat stress assessments on the Valley of the Winds (VOW) walking track during >36^{o}C days, as described below.

Assessment of thermal stress - general

There is no heat stress index developed to date which provides the true answer to the evaluation of heat stress in all situations. When all factors that influence man's response to heat are considered, there will always be a certain degree of inaccuracy when predicting individual situations (ISO, 1989). Nevertheless the Wet Bulb Globe Temperature (*WBGT*) index stands out as the most widely used and well-documented index of heat stress, especially within occupational health and hygiene circles. Industrial standards used in the management of hot workplaces are based on the concepts of permissible heat exposures and Threshold Limit Values (TLV) of *WBGT*, (ACGH, 1992; ISO, 1989). The standards have been derived from extensive laboratory and field experience with heat, and therefore represent a rational basis for assessing heat stress on the VOW walking track. The ACGIH heat exposure TLVs listed below are based on the assumption that nearly all individuals wearing light summer clothing (0.6 clo units), with adequate water and salt intake should be able to function effectively under the given thermal conditions without exceeding a deep body temperature of 38°C.

Table 1 Permissible heat exposure threshold limit values (source: ACGH, 1992)

Work/rest regimen	*Light Work Load*	*Moderate Work Load*	*Heavy Work Load*
Continuous work	30.0 °C	26.7 °C	25.0 °C
75% Work, 25% rest each hour	30.6 °C	28.0 °C	25.9 °C
50% Work, 50% rest each hour	31.4 °C	29.4 °C	27.9 °C
25% Work, 75% rest each hour	32.3 °C	31.1 °C	30.0 °C

Thermal stress assessment on the VOW walking track

Tourists walking the VOW track were estimated to have a metabolic rate falling within the "moderate" work-load category, mainly on the basis of gradients throughout the terrain. If sustained continuously from start-to-finish of the walking track (2~3 hours) the appropriate TLV in Table 1 would therefore be 26.7°C *WBGT*. However, there are climbs along the VOW track where the TLV for "heavy" work-loads (25°C *WBGT*) would be more appropriate.

Direct measurements of all the relevant thermal environmental parameters were made on the VOW walking track during a day that was forecast by the Australian Bureau of Meteorology to reach maximum air temperatures in excess of 40^{o}C at the nearby Yulara aerodrome. The NPWS policy of VOW walking track closure was in place on the day in question. A tripod with various sensors for WBGT and other basic microclimatic measurements was installed in a representative site and left in place for the entire day. Figure 7 illustrates the equipment used in the field tests.

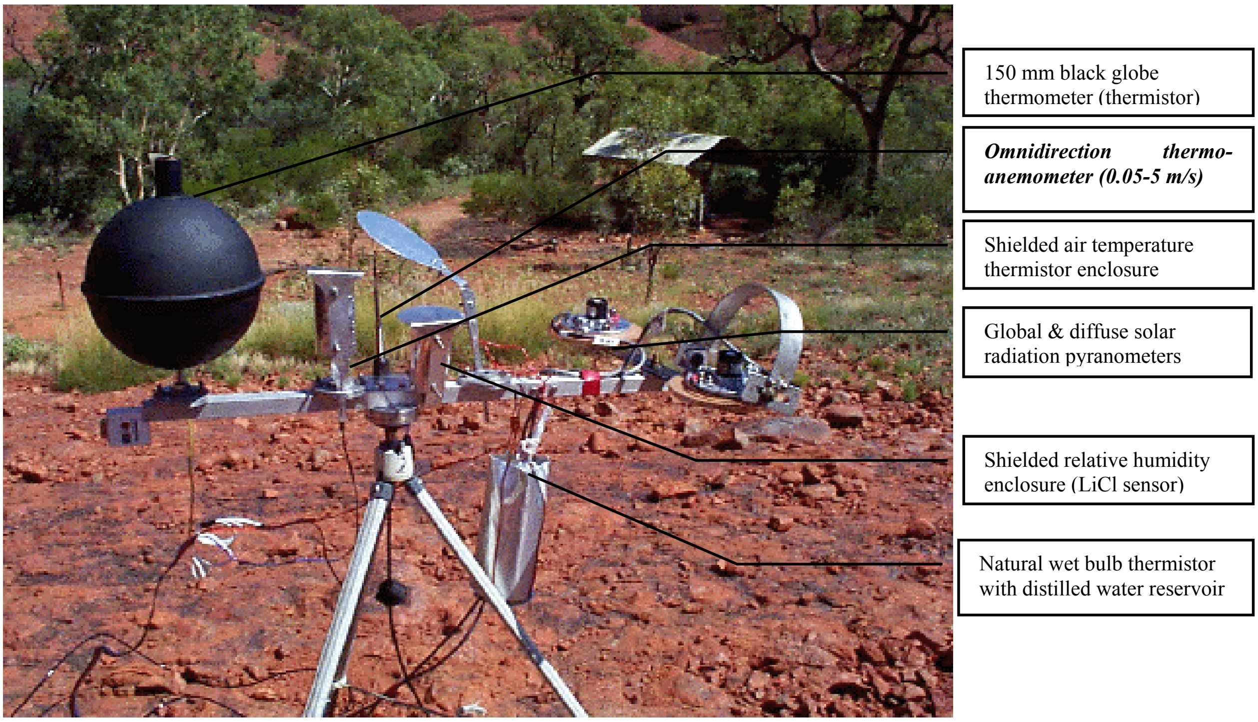

Fig. 7 The tripod with sensors measuring all relevant heat balance variables as well as WBGT parameters.

The tripod supported all sensors at a height of 1m above ground level, corresponding to waist height of a walking subject. Sensors were connected to a Campbell Scientific 21X datalogger that scanned its input channels once every 10 seconds, then archived an average of 60 measurements every 10 minutes. All sensors were exposed according to the guidelines listed in ISO Standard (ISO, 1989). Note that the black globe and natural wet-bulb sensors were exposed to direct solar radiation in accordance to accepted international standards (ISO, 1989) while the air temperature sensor was not. Readings from these three sensors were combined using the outdoor version of the index equation, $WBGT_{outdoor}$, as listed in ISO 7243 (1989):

$$WBGT_{outdoor} = 0.7\ t_{nw} + 0.2\ t_g + 0.1\ t_a \qquad \text{(eq. 1)}$$

where t_{nw} is natural wet bulb temperature (°C)

t_g is equilibrium black globe temperature (°C), and

t_a is air temperature (°C)

The inclusion of air temperature in this form of the equation is intended to reduce *WBGT* values below those that would result from the more familiar indoor version of the WBGT equation being applied in situations where the black globe thermometer is directly exposed to solar radiation:

$$WBGT_{indoor} = 0.7\ t_{nw} + 0.3\ t_g \qquad \text{(eq. 2)}$$

Time series of various thermal stress index calculations are plotted in Figure 8 below, starting at 0930 hrs and finishing at 1800 hrs. Plotted along with *WBGT* are values of the OUTdoor Mean Radiant Temperature *OUT_MRT* and the OUTdoor Standard Effective Temperature, *OUT_SET** (Pickup and de Dear, 2000). *OUT_SET** is the outdoor adaptation of the classic indoor climate index by Gagge *et al.* and can be defined as the temperature of a hypothetical isothermal, reference environment where air temperature ($t_{a)}$ *is equal to mean radiant temperature,* (t_{mrt},) relative humidity (*rh) of* 50 %, wind speed (v) of 0.15 ms^{-1}, such that a person in the reference environment, wearing 0.6 clo and standing quietly with a metabolic rate of 1.2 mets, has the same mean skin temperature (t_{sk}) and skin wettedness (w) as the person in the actual complex environment (Gagge *et al.*, 1971; Gagge *et al.*, 1986; Pickup and de Dear, 2000).

Outdoor mean radiant temperature *OUT_MRT* is the temperature of a hypothetical isothermal, reference environment ($t_a = t_{mrt}$, $rh = 50$ %, $v = 0.15$ ms^{-1}) such that a person in the reference environment has the same net radiation exchange as the person in the actual, complex radiative field. In effect, short and long-wave radiative exchanges between the subject and the real environment are measured, and then equated to the longwave exchanges in the isothermal reference environment with a temperature of *OUT_MRT*.

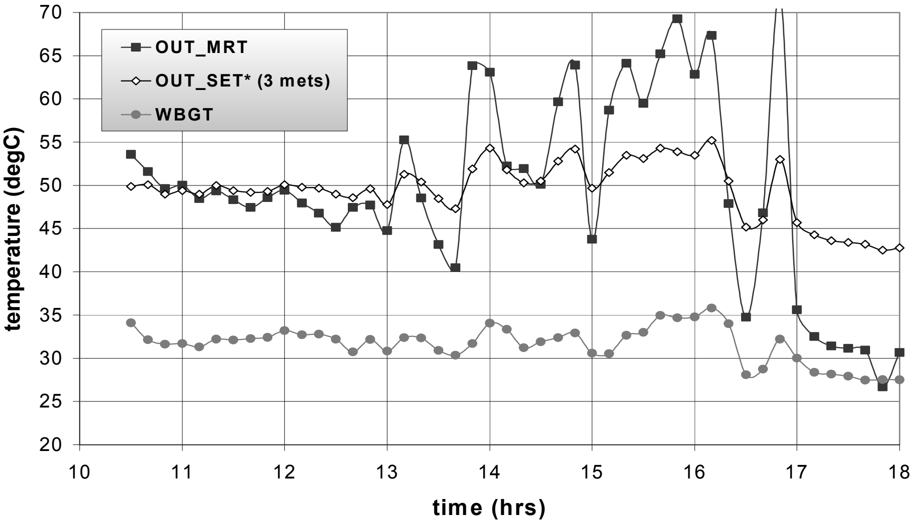

Fig. 8 Observed levels of Mean Radiant Temperature (OUT_MRT), Standard Effective Temperature (OUT_SET*) and Wet Bulb Globe Temperature (WBGT) on the Valley of the Winds walking track during a day with a maximum air temperature of 44^{o}C.

Mean radiant temperature (*OUT_MRT*) records in Figure 8 show the significant effects of intense solar radiation and long-wave (infrared) radiation loads from the bare rock surfaces of the walking track. The latter recorded maximum surface temperatures in excess of 70^{o}C and these are responsible for some of the extreme values of *OUT_MRT* in Figure 8. The *OUT_SET** values in Figure 8 were calculated with an assumed metabolic rate of three met units (176 W/m^{2}), corresponding to a steady walk of about 3 to 4 km/h with some gentle climbing. In Figure 8 it can be seen that, from the start of measurements mid-morning until the sun disappeared behind the western canyon wall at about 17:00hrs, the *OUT_SET** index registered temperatures at about 50^{o}C or above, except for a very brief late afternoon storm. The *WBGT* values derived from the technique described earlier in this paper exceeded the TLV for moderate workloads (26.7^{o}C in Table 1) throughout the entire period of observation. It seems highly likely that this TLV of 26.7^{o}C would still be exceeded by WBGT measurements on a milder day with maximum air temperature of only 36^{o}C (the NPWS threshold for park closure). Even if the tourists were required to take the walk much more easily, resting for 30 minutes in every hour, the corresponding TLV of 29.4°C would still have been exceeded from 9:00 through 17:00 hrs on the day plotted in Figure 8. These findings lent strong support to the NPWS policy of walking track closure on days with a high likelihood of heat stress (forecast T_{max} >36). The litigation was settled out of court and the policy of track closures based on forecast maximum temperatures remains in place.

OUT-SET – an index of outdoor thermal stress

Plenty of ***outdoor*** thermal indices exist but to date, the most sophisticated and thoroughly researched indices come from indoor applications, largely as a result of the air conditioning industry's sponsorship of thermal comfort research programs. The International Society of Biometeorology has recently become aware of the need to bring outdoor indices up to or beyond the standards set by the air conditioning industry for indoor applications, and has formed a Working Group to develop a Universal Index of Thermal Climate (UTCI). The Working Group's deliberations to date have focused on enumeration of the end-users and applications envisaged for the UTCI, and also the minimum requirements of the UTCI. The previous section of this paper described a very common end-use for the UTCI - namely provision of thermal comfort forecasts or heat stress warnings to the public and other weather-sensitive and weather-information sensitive end-users. For example, the Australian National Rugby League is being pressed by commercial/media interests to begin their season at the height of summer, and in so doing, are at risk of exposing players to significant risks of heat-related illness.

Until the UTCI Working Group has finished its job, outdoor thermal comfort researchers are required to choose from numerous options that are available in the public domain (or a few that are commercially available). A recent example of the former is *OUT-SET**, as mentioned in the previous section. This index is not particularly new index in that it is based on Gagge *et al.*'s 2-node model & the **S**tandard **E**ffective **T**emperature (indoors). Inputs include t_a, t_{mrt}, *v, rh, clo* and *met.* Other researchers have adapted indoor thermal comfort indices to outdoor contexts - for example, Jendritzky's (1981) modification of Fanger's (1970) Predicted Mean Vote (PMV) which is widely acknowledged in thermal comfort research circles as being satisfactory in near-neutral thermal environments but grossly inaccurate in conditions beyond moderately warm or cool.

Conversion of OUT_SET* into WBGT

Indices such as *PMV* or *SET** (and their outdoor versions) can provide information on the impacts of changes in any one of the six basic input parameters on overall thermal discomfort, but much more field experience with two- or three-parameter indices such as *WBGT* has been built up over the last several decades. For example, the occupational health and safety guidelines for heat exposure are specified in terms of threshold limiting values for *WBGT*, not *OUT_SET**, simply because the former has been in widespread use for so much longer. This indicates a need for new and more sophisticated outdoor thermal climate indices, such as OUT_SET*, or indeed, the anticipated UTCI to have transfer functions for mapping back to the vast body of knowledge we have built up over the years with older indices such as WBGT.

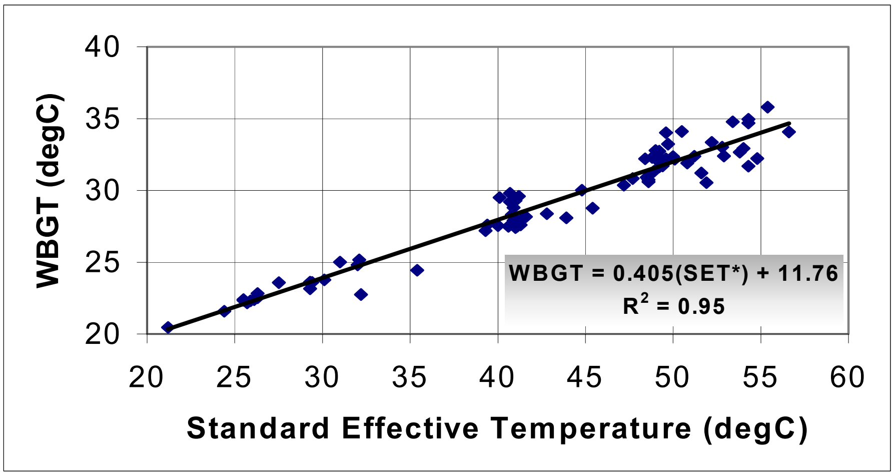

Fig. 9 Linear relationship between WBGT and OUT_SET* indices measured side-by-side in moderate through to extreme thermal conditions.

To achieve this for *OUT_SET** with respect to *WBGT*, a simple linear regression equation was fitted between simultaneous measurements of both indices across a sample of over 70 thermal environments of varying levels of heat stress. This enables an *OUT_SET** measurement to be translated back to its equivalent *WBGT* index value which can then be compared to the relevant threshold limit values of the type listed in Table 1 above.

Conclusions

An Australian climatic classification scheme directed at the needs of tourists was developed, based on thermal comfort considerations. A case study was presented, showing how the outdoor version of the Standard Effective Temperature, *OUT_SET**, can be used in the management of tourism and recreation in the potentially dangerous climate of Australia's interior. Both studies illustrate ways in which climatic resources can and should be managed for the benefit of the weather sensitive tourism industry.

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