An Outdoor Thermal Comfort Index for the Subtropics

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ABSTRACT: This paper presents a research that proposes a thermal comfort index, allowing the verification of the thermal adequacy of outdoor spaces in the subtropics. The method adopted is experimental inductive, by means of field research of a total of ninety-eight micro-climatic situations and over two thousand and five hundred applied questionnaires of thermal sensation perception and preference. Deductive method is also applied, by means of regression analysis, considering seventy-two different micro-climatic conditions. The significance of the results is verified by comparison with the ones obtained by simulation of different predictive models and respective indexes, considering the results from twenty-six different micro-climatic conditions gathered in different urban situations from the previous survey. The results from the proposed equation, compared with those from the others predictive models, showed that, for the specific subtropical microclimatic conditions, they present better correlations with the data gathered. Concluding, the methods used provided a simple, easy-to-use and reliable thermal comfort index to assess outdoor thermal comfort in the subtropical climate.

Keywords: thermal comfort, outdoors, predictive models, equivalent temperature

INTRODUCTION

Thermal comfort assessment in outdoor spaces requires the comprehension of additional factors, which are not taken into account in a typical indoor situation. Short-wave radiation and winds, considerable sweating rates or variable clothing, different human activities and expectations, among other factors, bring more complexity to the analysis. This paper presents a research that proposes a thermal comfort index, allowing the verification of the thermal adequacy of outdoor spaces in the subtropics. The method adopted is experimental inductive, by means of field research of micro-climatic variables and subjective answers, and deductive, by means of regression analysis. The significance of the results is verified by comparison with the ones obtained by simulation of predictive models.

BACKGROUND

This study considered twenty-two predictive models and their indexes. They will be here briefly presented in order to perform later correlation of their results with the results of the empirical research.

Houghten et al. [1], of ASHVE laboratories, propose, in 1923, the Effective Temperature (ET), as determined by dry and wet bulb temperature and wind speed. Vernon & Warner [apud 2], in 1932 propose the Corrected Effective Temperature (CET) substituting dry bulb temperature with globe temperature.

Siple & Passel [3], in 1965, develop the Wind Chill Temperature (WCT) from the data obtained with experiences in Antarctica.

Belding & Hatch [4], in 1965, propose the Heat Stress Index (HSI), relying on a thermal balance model with empirical equations for each exchange.

Yaglou & Minard [5], in 1957, propose the Wet Bulb Globe Temperature (WBGT). ISO 7243:1989 [6] gives an alternate equation for situations under solar radiation.

Gagge [7], in 1967, presents the New Standard Effective Temperature (SET*), defining it as the air temperature in which, in a given reference environment, the person has the same skin temperature (tsk) and wetness (w) as in the real environment.

Givoni [8], in 1969, proposes the Index of Thermal Stress (ITS), which considers the heat exchanges, metabolism and clothes. Originally, it did not consider the radiation exchanges.

Masterton & Richardson [9], in 1979, propose the Humidex, an index calculated based on air temperature and humidity. It is used by the Environment Canada Meteorological Service to alert people of the heat stress danger.

Jendrizky et al. [10], in 1979, developed the Klima Michel Model (KMM). It is an adaptation of Fanger's model [11], with a short wave radiation model, computed in the mean radiant temperature.

Vogt [12], in 1981, proposes the evaluation of thermal stress through the required sweat rate (Swreq). This index was adopted by ISO 7933:1989 [13]. Dominguez et al. [14], in 1992, present the research results of the Termotecnia Group of Seville University, also based on Vogt [12]. The authors accept low sweat rates according to the conditioning required.

Brown & Gillespie [15], in 1995, propose an outdoor Comfort Formula based on thermal budget (S) with some particularities in its terms.

Aroztegui [16], also in 1995, proposes the Outdoor Neutral Temperature (Tne), based on Humphreys [17] and taking into account the solar radiation and air speed.

Blazejczyk [18], in 1996, proposes the Man-Environment Heat Exchange model (Menex), based on thermal balance. The author proposes three criteria, which are supposed to be considered as a whole: Heat Load (HL), Intensity of Radiation Stimuli (R') and Physiological Strain (PhS). He also proposes the Subjective Temperature Index (STI) and the Sensible Perspiration Index (SP). DeFreitas [apud 19], in 1997, presents the Potential Storage Index (PSI) and the Skin Temperature Equilibrating Thermal Balance (STE), both using the Menex Model.

Höppe [20], in 1999, defines the Physiological Equivalent Temperature (PET) of a given environment as the equivalent temperature to air temperature in which, in a reference environment, the thermal balance and the skin and core temperatures are the same of that found in the given environment.

Givoni & Noguchi [21], in 2000, describe an experimental research in a park in Yokohama, Japan, and propose the Thermal Sensation Index (TS).

Bluestein & Osczevski [22], in 2002, propose the New Wind Chill Temperature (NWCT), through a physical modelling of a face exposed to wind.

Nikolopoulou [23], in 2004, presents the works developed by the project Rediscovering the Urban Realm and Open Spaces (RUROS), proposing the actual sensation vote (ASV).

EMPIRICAL DATA

The procedures were done following guidelines and data from [24, 25, 26, 27, 28].

On the field researches, seventy-two different micro-climatic scenarios were considered and one thousand and seven hundred and fifty questionnaires were applied during summer and winter of two consecutive years, in the city of Sao Paulo, Brazil. The procedures are briefly presented in the following paragraphs.

For the measurements and application of questionnaires, three bases were set: the first one under open sky, the second one shaded by trees, and the third one under a tensioned membrane structure. In each one of the three bases, micro-climatic variables (mean radiant temperature, air temperature, air humidity and wind speed) were measured and a hundred and fifty people answered a questionnaire, in six different hours of the day. These people came from different regions of Brazil. Further studies will consider not only the results from acclimatized ones, but also comparatively the results from those who were not acclimatized.

The questionnaire considered questions of personal characteristics (sex, age, weight, height), acclimatization (places of living and duration) and subjective responses (thermal sensation, preference, comfort and tolerance). Pictures were taken of everyone who would answer the questionnaire, in order to identify clothing and activity. A forth base, at 10m high, was set for measuring meteorological parameters (global radiation and wind speed).

The equipment used in each base was the following. Under open sky: meteorological station ELE model EMS, data logger ELE model MM900 EE 475-016. Shaded by trees: meteorological station Huger Eletronics model GmbH WM918 and personal computer for data logging. Under tensioned membrane structure: station Innova 7301, with modules of thermal comfort and stress, and data logger Innova model 1221. At 10m high: meteorological station Huger Eletronics model GmbH WM921 and a piranometer Eppley.

In each base, globe temperature was also measured through 15cm grey globes and semiconductor sensors, storing the data in Hobo data loggers. The measurements were done in intervals of one second, and the storage was done in intervals of one minute, considering the average of measurements.

The limits in which the empirical data were gathered are: air temperature (ta) = 15°C~33°C; mean radiant temperature (mrt) = 15°C~66°C; relative humidity (rh) = 30%~95%; wind speed (va) = 0,1m/s~3,6m/s. It should also be mentioned that, although it is not a limiting factor for normal situations, the maximum and minimum clothing thermal insulation values found were 0,3 and 1,2 clo, with mean values between 0,4 and 0,9 clo.

Considering the Typical Reference Year (TRY) [29] for Sao Paulo, the ranges presented represent 92% of the general climatic situations during day time. On the other hand, if it is necessary to make an extrapolation, it must be done carefully and would better be object of further researches.

MODELLING

The multiple linear regression to be presented was obtained considering the data from the seventy-two microclimatic situations, regarding the application of one thousand and seven hundred and fifty questionnaires.

$$tsp= -3{,}557 + 0{,}0632 \cdot ta + 0{,}0677 \cdot mrt + 0{,}0105 \cdot ur - 0{,}304 \cdot va \quad [1]$$

with: r= 0,936; r^2= 0,875; r^2aj= 0,868; se= 0,315; P< 0,001.

where: tsp= thermal sensation perception [dimensionless], ta = air temperature [ºC], mrt = mean radiant temperature [ºC], rh = relative humidity [%], v = air velocity [m/s]

Considering the thermal sensation perception (tsp), following the categories of the applied questionnaires, result from -0,5 to 0,5 means neutrality; from 0,5 to 1,5 means warm; from 1,5 to 2,5 means hot; above 2,5 means very hot; from -0,5 to -1,5 means cool; from -1,5 to -2,5 means cold; and below -2,5 means very cold.

Table 1 presents a statistic resume of the constant and the four dependent variables and Table 2 presents the analysis of variance.

Table 1: Statistic summary of the constant and the four dependent variables

	c	se	t	p	VIF
ct	-3,557	0,249	-11,17	<0,001	
ta	0,0632	0,0143	3,796	<0,001	2,101
mrt	0,0677	0,011	-2,803	<0,001	1,135
rh	0,0105	0,00305	2,220	<0,001	2,089
va	-0,304	0,0053	12,861	<0,001	1,915

where: ct= constant, c = coefficient, se= standard error, t= statistical test t, p= significance, VIF= variance inflation factor.

Table 2: Analysis of variance

	DF	SS	MS	F	p
Regression	4	46,667	11,667	117,44	<0,001
Residual	67	6,656	0,0993		
Total	71	53,323	0,751		

where: DF= degrees of freedom, SS= sum of squares, MS= mean square, F= statistical test F, p= significance.

Monteiro & Alucci [30], reviewing the state of the art of outdoor thermal comfort modelling researches, observe that there is a tendency to use equivalent temperatures instead of interpretative ranges, since an equivalent temperature itself, without an interpretative range, would give a notion of the thermal sensation, taking into account a reference environment.

In this research, in order to propose an equivalent temperature model, the following assumptions to the reference environment where done: mrt = ta; rh=50% and va=0 m/s. Considering these assumptions, the relationship between the air temperature of the reference environment and the thermal sensation perception is the following:

$$ta{,}re = 23{,}395 + 7{,}639 \cdot tsp \quad [2]$$

where: ta,re = air temperature of the reference environment [ºC], tsp = thermal sensation perception [dimensionless].

By equations 1 and 2, the following equation is proposed, where TEP stands for the proposed Temperature of Equivalent Perception, in ºC.

$$TEP = -3{,}777 + 0{,}4828 \cdot ta + 0{,}5172 \cdot mrt + 0{,}0802 \cdot rh - 2{,}322 \cdot va \quad [3]$$

The Temperature of Equivalent Perception (TEP) of a given environment can be defined as a thermal sensation scale which presents values numerically equivalent to those of the air temperature of a reference environment (mrt=ta, rh=50%, and va=0) in which the thermal sensation perception is the same to the one verified in the given environment.

Following equation 2, one may observe that the air temperature of neutrality, in the case of a reference environment, is approximately equal to 23,4°C. Yet the advantage of equivalent temperatures is the intuitive interpretation of their values, it is also interesting to provide a interpretative range, since the intuitive interpretation is only possible after the exposition to several environments and their respective equivalent temperatures. In the *Discussion* topic of this paper interpretative ranges for the Temperature of Equivalent Perception (TEP) will be proposed.

Considering the applicability of the proposed equation, the limits in which the Temperature of Equivalent Perception (TEP) is valid are the ones verified for the empirical research. Table 3 presents the limits of the microclimatic variables, in which TEP is based. Further studies to be developed, with more comprehensive empirical data, would test the validity of the results beyond those limits.

Table 3: Limit values for microclimatic variables

variable	min	max
ta (ºC)	15,1	33,1
mrt (ºC)	15,5	65,5
rh (%)	30,9	94,7
va (m/s)	0,1	3,6
TEP (ºC)	13,7	45,3

VERIFICATION

Three criteria were established for comparing the simulation results with the field research results aiming to verify the significance of the results provided by the new proposed predictive model. The first criterion is the correlation between the results of the model parameter and the results of the thermal sensation responses obtained in the field study. The second criterion is the correlation between the results of the index and the results of the thermal sensation responses obtained in the field study. The last one is the percentage of correct predictions.

Concerning the indexes based on equivalent temperatures, the criterion for interpretation of the indexes used was the one by De Freitas [19]. Yet the author proposes this one only for effective temperatures, it was used for other equivalent temperatures because no other references were found; except for STI, for which was used Blazejczyk [18].

All the criteria are based on results concerning new empirical field researches, performed during summer and winter, in three different locations, in another neighbourhood of Sao Paulo, using the same procedures established before, and considering twenty-six new micro-climatic scenarios and the mean thermal sensation responses for each one of this scenarios (eight hundred and fifty eight applied questionnaires).

Aiming better results to the specific evaluation of open spaces of Sao Paulo, a calibration was performed in order to fit the results from the simulations to the results found in the empirical researches. In order to do so, each index was linguistically compared to seven values (the same used in the field researches): three positive ones (warm, hot, very hot), three negative ones (cool, cold, very cold) and one of neutrality (negative values do not apply for models that consider only hot environments).

The calibration was done through iterative method, changing the range limits of each index in order to maximize the correlation between its results and those found in the empirical researches. The calibration could be done, also iteratively, to maximize the percentage of correct predictions. However, it was assumed that is more important to assure the maximization of the correlation between the results of the index and those from empirical data, once this correlation expresses the tendency of correctly predicting other situations.

RESULTS

Table 4 presents the final results considering the comparison criteria presented. This table presents the correlation modules between field study results and simulation results, without and with the calibration process presented.

Table 4: Correlation between field study and simulation results

Index	C	Co	Po	Cc	Pc
ET*	0,73	0,59	44%	0,71	72%
CET*	0,89	0,77	11%	0,85	81%
OT	0,72	0,69	47%	0,72	75%
EOT*	0,70	0,66	42%	0,73	75%
WCTI	0,69	0,64	31%	0,74	78%
HSI	0,83	0,72	68%	0,89	81%
WBGT	0,86	-	-	0,86	89%
SET*	0,89	0,84	28%	0,86	86%
ITS	0,84	0,75	62%	0,89	86%
HU	0,74	0,70	69%	0,78	81%
PMV	0,87	0,82	65%	0,83	86%
Swreq	0,87	-	-	0,86	83%
W	0,86	-	-	0,86	83%
Swreq’	0,89	0,83	72%	0,89	86%
S’	0,89	0,65	61%	0,87	83%
Tne	0,88	0,70	33%	0,89	86%
HL	0,89	0,76	62%	0,88	86%
PhS	0,81	0,71	28%	0,89	86%
R’	0,86	0,76	69%	0,86	83%
STI	0,87	0,79	53%	0,82	78%
SP	0,89	0,82	78%	0,89	86%
ECI	0,78	0,72	42%	0,80	81%
PSI	0,89	0,86	78%	0,88	83%
STE	0,79	0,71	58%	0,81	83%
PET	0,89	0,78	31%	0,89	86%
TS	0,87	0,84	78%	0,89	89%
NWCTI	0,62	0,60	22%	0,71	72%
ASV	0,85	0,77	76%	0,89	86%
TEP	0,94	-	-	0,94	96%

where: C= Correlation with the model parameter; Co= Correlation with the original index without calibration; Po= Percentage of correct predictions without calibration; Cc= Correlation with the index with calibration; and Pc= Percentage of correct predictions with calibration.

DISCUSSION

Considering Table 4, one may observe that the best results without calibration are provided by the Potential Storage Index (PSI), calculated using the MENEX model proposed by Blazejczyk [18]. This index presented correlations of 0,89 and 0,86; respectively for its model parameter and its original index. The percentage of correct predictions, also without calibration was one of 78%, one of the highest among the original indexes. Table 5 shows PSI interpretative ranges, which is originally presented by [18].

Table 5: Potential Storage Index (PSI)

PSI (W/m^2)	Interpretation
< -184	very hot
-184 ~ -111	hot
-110 ~ -50	warm
-49 ~ 16	neutral
17 ~ 83	cool
84 ~161	cold
> 162	very cold

Following Table 4, one may affirm that, before the proposal of the Temperature of Equivalent Perception (TEP), for the specific case of evaluating outdoor spaces on the subtropics, the best index would be the Perceived Equivalent Tempeature, calculated using the MEMI model proposed by Hoppe [20]. Although it provided poorer results considering the first interpretative ranges, with the calibration process the new ranges provided the best results among the studied indexes: correlations of 0,89 and 0,89; respectively for the model parameter and the calibrated index. The percentage of correct predictions, with calibration, was 86%. Table 6 presents the calibrated ranges proposed by this research to interpretation of the Physiological Equivalent Temperature (PET), by [20].

Table 6: Physiological Equivalent Temperature (PET)

PET (ºC)	Interpretation
> 43,0	very hot
31,0 ~ 43,0	hot
26,0 ~ 31,0	warm
18,0 ~ 26,0	neutral
12,0 ~ 18,0	cool
4,0 ~ 12,0	cold
< 4,0	very cold

Keep on following Table 4, one may observe that the results of the proposed Temperature of Equivalent Perception (TEP) provides better results than all the other indexes, even when compared with the results form the calibrated indexes. Its correlations are of 0,94 for the model parameter and 0,94 for the index. The percentage of correct predictions achieved 96%, the highest among all the results.

In the topic about modelling, it was argued that the advantage of equivalent temperatures is the intuitive interpretation of their values. On the other hand, it is also interesting to provide an interpretative range, since the intuitive interpretation is only possible after the exposition to several environments and their respective equivalent temperatures. Thus, Table 7 presents the interpretative ranges for the Temperature of Equivalent Perception (TEP), considering the results found in the empirical researches.

Table 7: Temperature of Equivalent Perception (TEP)

TEP (ºC)	Sensation
> 42,5	very hot
34,9 ~ 42,4	hot
27,3 ~ 34,8	warm
19,6 ~ 27,2	neutrality
12,0 ~ 19,5	cool
4,4 ~ 11,9	cold
< 4,3	very cold

One may observe that the criteria used to evaluate the model predictions allow successive verifications. The first correlation verifies the possible potential of the model. In other words, it verifies the sensibility of the model, showing how well the model parameter results vary in function to variations of thermal responses. The second correlation does the same, but specifically with the interpretation criteria of the indexes. The final criterion gives the percentage of correct predictions, telling how well the model is performing.

Considering the calibration, we can observe that it provides better correlation with the new empirical data gathered and consequently greater percentage of correct predictions. Considering the results found, it is more interesting to use a model with a better first correlation (the correlation between the model parameter and the field subject responses) than a one with a greater percentage of correct predictions but with a poor first correlation, because a good first correlation means that the models, once calibrated with empirical data, has a good potential to correctly predict the thermal sensations.

As one may see, the Temperature of Equivalent Perception (TEP), proposed in this work, presents the highest correlation between the model parameter and the field subject responses, leading also to the highest correlation between the index and the field subject responses. Finally, it presents also the best results in term of percentage of correct predictions. One may also notice that, before proposing the Temperature of Equivalent Perception, the best results would be given by the Potential Storage Index (PSI), calculated using the MENEX model proposed by Blazejczyk [18], or by the Physiological Equivalent Temperature (PET), calculated using the MEMI model proposed by Hoppe [18].

One may see that both indexes are estimated by means of a thermo-physiological balance model, which needs several iterations to provide reliable results. The Temperature of Equivalent Perception (TEP) not only presented better results compared to the empirical data gathered, but also provides a simpler model to estimate outdoor thermal comfort, since it relies on only one multiple linear equation.

FINAL CONSIDERATION

The contribution of this paper is to provide a thermal comfort index which can be properly used for predicting thermal comfort in outdoor spaces in a subtropical climate. The experimental comparative study of different outdoor thermal comfort predictive models allowed the verification of the results. Comparing the results from the equation generated from multiple linear regression analysis to the ones from the predictive models (even from the calibrated ones), one may observe that the equation found, which culminated in the proposal of the Temperature of Equivalent Perception (TEP), presents better correlations with the data gathered in new scenarios. Concluding, the research provided a simple, easy-to-use and reliable index to assess thermal comfort in outdoor spaces in a subtropical climate.

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REFERENCES

1. Houghten, F.C.; Yaglou, C.P. Determining lines of equal comfort. *ASHVE Transactions*, 29, 1923.
2. Williamson, S. P. (coord.). *Report on wind chill temperature and extreme heat indices*: evaluation and improvement projects. Washington: OFCMS Supporting Research, 2003.
3. Siple, P. A.; Passel C. F. Measurements of dry atmospheric cooling in subfreezing temperatures. *Proceedings of the American Philosophical Society*, 89 (1), p.177-199, 1945.
4. Belding, H. S.; Hatch, T. F. Index for evaluating heat stress in terms of resulting physiological strain. *Heating, Piping, Air Conditioning,* 27, p.129-42, 1955.
5. Yaglou, C. P.; Minard, D. Control of heat casualties at military training centers. A.M.A. *Archives of Industrial Health*, 16, p. 302-16, 1957.
6. International Organization Standardization. *ISO 7243*. Hot environments: estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature). Genève: ISO, 1989.
7. Gagge, A. P.; Stolwijk J. A. J.; Hardy, J. D. Comfort and thermal sensations and associated physiological responses at various ambient temperatures. *Environ. Res*., 1, p. 1-20, 1967.
8. Givoni, Baruch. *Man, climate and architecture*. New York: John Wiley & Sons, 1969.
9. Masterton, J. M.; Richardson, F. A. Humidex: a method of quantifying human discomfort. *Environment Canada*, CLI 1-79. Ontario, Downsview: Atmospheric Environment Service, 1979.
10. Jendritzky, Gerd et al. *Klimatologische Probleme* – ein einfaches Verfahren zur Vorhersage der Wärmebelastung, in Zeitschrift für angewandte Bäder und Klimaheilkunde. Freiburg, 1979.
11. Fanger, P. O. *Thermal comfort:* analysis and application in environment engineering. New York: McGraw Hill, 1970.
12. Vogt, J.J. Ambiances thermiques. In: Scherrer, J. et al. *Précis de physiologie du travail, notions d'ergonomie*, Masson, 2ème édition, 217-263 1981.
13. ISO. *ISO 7933*. Hot environments: analytical determination and interpretation of thermal stress using calculation of required sweat rate. Genève: ISO, 1989.
14. Dominguez et al. *Control climatico en espacios abiertos*: el proyecto Expo'92. Sevilla: Universidad de Sevilla, 1992.
15. Brown, Robert D.; Gillespie, Terry J. *Microclimatic landscape design:* creating thermal comfort and energy efficiency. New York: John Wiley & Sons, 1995.
16. Aroztegui, José Miguel. Índice de Temperatura Neutra Exterior. In: Encontro Nacional Sobre Conforto No Ambiente Construído (ENCAC), 3, 1995, Gramado. *Anais*... Gramado: ENCAC, 1995.
17. Humphreys, Michael A. Field studies of thermal comfort compared and applied. *BRE Current Paper*, 75/76, London, 1975.
18. Blazejczyk, Krysztof. *Menex 2002*. http://www.igipz.pan.pl/klimat/blaz/menex.htm. 2002. Visited in 24/04/2004.
19. Blazejczyk, Krysztof; Tokura, Hiromi; Bortkwcz, Alicja; Szymczak, W. Solar radiation and thermal physiology in man. In: International Congress of Biometeorology & International Conference on Urban Climatology, 15, 1999, Sydney. *Selected Papers from the Conference*... Geneva: World Meteorological Organization, p. 267-272, 2000.
20. Höppe, Peter R. The physiological equivalent temperature: a universal index for the biometeorological assessment of the thermal environment. *Int. J. Biomet*., 43, p. 71-75, 1999.
21. Givoni, Baruch; Noguchi, Mikiko. Issues in outdoor comfort research. In: Passive And Low Energy Architecture, 17, 2000, Cambridge. *Proceedings*... London: J&J, p. 562-565, 2002.
22. Bluestein, M.; Osczevski, R. Wind chill and the development of frostbite in the face. Preprints, *15th Conference on Biometeorology and Aerobiology*, Kansas City, MO: Amer. Met. Soc., p. 168-171, 2002.
23. Nikolopoulou, Marialena (org). *Designing Open Spaces in the Urban Environment*: a Bioclimatic Approach. Atenas: CRES, 2004.
24. ASHRAE. *Handbook of fundamentals*. Atlanta: ASHRAE, 2005.
25. ISO. *ISO 7726*. Ergonomics: instruments for measuring physical quantities. ISO: Genève, 1998.
26. ISO. *ISO 9920*. Ergonomics of the thermal environment: estimation of the thermal insulation and evaporative resistance of a clothing ensemble. ISO: Genève, 1995.
27. ISO. *ISO 10551*. Ergonomics of the thermal environment: assessment of the influence of the thermal environment using subjective judgment scales. ISO: Genève, 1995.
28. ISO. *ISO 8996*. Ergonomics: metabolic heat production. ISO: Genève, 1990.
29. Goulart, S. et al. *Climatic data for energetic evaluation of buildings in fourteen Brazilian cities*. Florianópolis: UFSC, 1998.
30. Monteiro, L.M.; Alucci, M.P. Outdoor thermal comfort: numerical modelling approaches and new perspectives. In: Passive And Low Energy Architecture, 22, 2005, Beirut. *Proceedings*... 2005.