

Thermal comfort analysis: comparison between model and experimental data in tropical climate

Toky Rakotoarivelo, Frédéric Miranville, Claude Gronfier, Bruno

Malet-Damour

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Article ID 209 Thermal comfort analysis: comparison between model and experimental data in tropical climate

Introduction

Thermal Comfort means two things:

- No physiological thermo-regulation
- Hedonic feeling through thermal perception 2.

How do we predict thermal comfort?

By choosing the right model

·.....

By experimental validation

measurements physical analysis field thermal perception evwords intermodal I comfort survey experimental

Methods

For the right people and the right environment

<u>Aim:</u> to show that there is a need to promote the studies of thermal comfort for the Reunion context

Experimental & Numerical set-up

Subjects	Age	Activity	BMI	Clothing
Students	20 to 30 years old	Desk work	16.3 to 32.7	Everyday wear

The highest response rate to the comfort questionnaires was obtained on two particular days:

April 26, 2021	April 29, 2021
Overcast	Clear sky (morning); overcast sky (afternoon)
Light ambiance: intermediate	Light ambiance: bright (morning); intermediate (afternoon)
"Active" porosity: 13%	"Active" porosity: 13%

		Questionnair	e		
	Scale	Thermal sensation	Visual sensation		
	+3	Hot	Glare		
The questionnaire was answered	+2	Warm	Bright		
through online forme according to	+1	Slightly warm	slightly bright	Feeb	Hour
through online forms according to	0	Comfortable, neutral	Comfortable, neutral	Each	Hour

Modeling Indoor thermal comfort models

Identification of models in the literature Implementation of the models in a spreadsheet

Classes	Output type	Designation
	Index	PMV
Apolytical	Rate	PPD
models	Index	TS
	Rate	RSI
	Temperature	T _{sub}
		Tc _{Brager & De Dear}
Empirical	Temperature	TrSI
models	(comfort temperature)	T _{cAuliciems}
		T _{c_{Humphreys}}
		T _{nHumphreys}
Adaptativa	Tomporatura	T _{nAuliciems}
models	(neutrality temperature)	T _{nBrager & de Dear}
		T _{nGriffiths}
		T _{nNicol & Roaf}

Experiment on thermal perception **Measurement & field survey**

Realization of online questionnaires on thermal perception (ASHRAE scale)

Physical measurements of the thermal environment and skin temperatures of the occupants





Tropical climate



Comparative analysis between **Modeling & Experiments results**



Slightly cool

Sensation EXP

——Tc (Auliciems)

33 °C

29 °C

25 °C

21 °C

17 °C

Results

Comfort indexes

Hourly evolution of the average comfort index (over the group)

Experiment analysis

• Sensations between "slightly cold" and "slightly warm"

Indexes analysis

• PMV (Fanger) : inappropriate (temperate climate; AC building) • TS (Rholes and Nevins) : inappropriate (temperate climate; climatic chamber)



Comfort temperatures

Comparative analysis of average results of $T_{c_{\text{average}}}$ with $T_{op_{average}}$ and occupant perception

---Tc (Brager & De Dear)

Time

Experiment analysis

 Neutral situation = thermal comfort • *T_{opneutral}* = 26.3 °C

Comfort temperatures analysis

- Brager and De Dear + Auliciems : inappropriate
 - Humphreys : most efficient, but insufficient

• Possible origins of bias : physical (relative humidity or airspeed) or physiological (clothing, metabolic level, acclimatization) parameters



— EXP (Top)

——Tc (Humphreys)

09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00



-1	Slightly cool	Slightly dark
-2	Cool	Dark
-3	Cold	Very dark

-1	Slightly cool	Slightly dark
-2	Cool	Dark
-3	Cold	Very dark

Measurement		
The apparatus gathered all physical parameters proper to the room and physiological parameters for each participant through sensors	ParametersTaind , RHindT_sk , T_sclTgVaTa , RH	Every

Spreadsheet

				-												_						
UAIE	Erudan NS																					
23/04/2021	Pourcentage de person	ine en confort	000	Тетр	erature de cont	or(empingue)		Tempera	ture de neutra	ite (adaptatr)		perature de	conton (phys	dice de contit.	sch Rominia	DO:	Pourcentage de perso	nne en contort	000		E 500	000 100 100
Heuses	EqHal	EqHolinsalistat	PPU	LOBSD	I_o Autoens	I_o Humphreys	I_n No6Hoat	I_n Unitiths	I_n de Llear	I_n Autorems	I_n Humphreys	Trol	L_sub	15	PWV	KSI I	EqHSI	Eq Hol insalista	t PPU	We present dans la salle	bqHolinsabstat.moyen	PPUMUTEN
08:00	100% confortable	0%	5,70%	23,4710	23,4910	212910	23,35 U	218710	23,47 C	23,2110	20670	23,210	27,610	0.075405005	-0,1212	0,02	100% contortable	0%	5,30%	5	0%	10,80 %
03:00	UU% contortable	0%	10,1474	24,10 L	24,05 C	29,55 L	20,00 L	24,12 L	24,10 L	24,50 L	23,32 L	23,00 L	30,50 L	0,1/5425305	-0, 620	0.01	UU% confortable	0%	5,40 %	5	0%	100%
0:00	UU% contortable	0%	5,00%	24,30 C	24,70 L	24,310	25,10 L	24,33 L	24,30 L	24,70 C	24,13 L	24,94 L	32,19 L	0,237611973	0,3336	0,05	UU% confortable	0%	7,40%	3	5%	1,23%
11:00	UU% contortable	0%	1,88%	25,18 L	25,21 L	25,52 L	25,04 L	24,81 L	25,18 L	24,38 L	29,610	25,21 L	31,59 L	0,366562648	0,6150	0,01	UU% confortable	0%	N,57%	5	0%	3,31%
12:00			-													-			-	1	0%	6,19%
13:00																				1	0%	5,00 %
14,00	100% confortable	U%	10,557	25,40°C	25,53°C	26,17°C	26,310	25,16°C	25,4010	25,20°C	24,96°C	2,210	3163 C	0,814607201	0,7510	0,03	1.U.% confortable	U%	6,887	4	0%	10,90 %
15:00	100% confortable	0%	10,797	25,40°C	25,51°C	26,11°C	26,31°C	25,18°C	25,40°C	25,20°C	24,98°C	25,47°C	33,18°C	0,591684003	0,7406	0,09	100% confortable	0%	6,55%	5	0%	10,63 %
16:00	100% confortable	0%	9,06%	24,93°C	25,24 °C	24,39 °C	25,74 °C	24,38 °C	24,93°C	24,73°C	24,18°C	25,35°C	31,33°C	0,452653213	0,6823	0,08	100% confortable	0%	14,79%	2	8%	11,92%
17:00																						
DATE				L							Etu	diant N 5										
30/04/2021	Pourcentage de person	ine en confort		Тетр	érature de conf	ort(empirique)		Tempéra	ture de neutral	ité (adaptatř)		pérature de	confort (phys	dice de conít (ich ASHRA		Pourcentage de perso	nne en confort				
Heures	EqRSI	Eq RSI insatisfait	PPD	T_cB3D	T_c Auliciens	T_c Humphreys	T_n Nic&Roaf	T_n Griffiths	T_n de Dear	T_n Auliciens	T_n Humphreys	TrSI	T_sub	TS	PMV	RSI	EqRSI	Eq RSI insatisfa	PPD	No présent dans la salle	Eq RSI insatisfait moyen	PPO MOYEN
08.00	100% confortable	0%	5,34%	23,47°C	23,49°C	21,29°C	23,95°C	21,87°C	23,47°C	23,27°C	21.67°C	23,21°C	27,61°C		+0,1212	0,02	100% confortable	0%	5,30%	5	0%	11,05%
09.00	100% confortable	0%	6,59%	24,19°C	24,01°C	23,10°C	24,83°C	23,10°C	24,19°C	23,99°C	22,90°C	23,49°C	30,96°C	0,313382028	0,0255	0,03	100% confortable	0%	5,01%	4	0%	11,13 %
10:00	100% confortable	0%	9,48%	24,53°C	24,45°C	23,96 °C	25,25°C	23,69 °C	24,53°C	24,33°C	23,49 °C	24,21°C	30,02 °C	0,225845731	0,2364	0,04	100% confortable	0%	6,16%	4	8%	8,76 %
11:00	100% confortable	0%	19,33 %	25.05°C	25,13°C	25,30 °C	25,89°C	24,60 °C	25.05°C	24,85 C	24,40°C	25,42°C	31,45°C	0,362728758	0.6588	0,07	100% confortable	0%	14,12%	4	4%	13,79%
12:00																				1	0%	9,48 %
13:00																				1	15%	12,48 %
14:00																				2	0%	6,83%
15:00	100% confortable	0%	5,58%	25,24°C	25,27°C	25,77°C	26,12°C	24,92 °C	25,24°C	25,04 °C	24,72 °C	25,15°C	24,32 °C	0,746247465	0,4938	0,07	100% confortable	0%	10,10 %	3	0%	7,16%
16:00	35% confortable et 15% chaud	15%	39,12%	24,78°C	24,93°C	24,59 °C	25,55°C	24,12°C	24,78°C	24,58°C	23,92°C	9,02°C	6,36°C	0,457813762	-3,4811	0,09	100% confortable	0%	99,95%	3	5%	39,69%
17:00				1																		
DATE											Etu	diant N 5										
03/05/2021	Pourcentage de person	ine en confort		Тетр	érature de conf	ort(empirique)		Тепре́га	ture de neutsal	ité (adaptatif)		pérature de	confort (phys	dice de confit (Sch ASHRA		Pourcentage de perso	nne en confort				
Heures	EqRSI	Eq RSI insatisfait	PPD	T_oB&D	T_o Auliciens	T_o Humphreys	T_n Nic&Roaf	T_n Gnilliths	T_n de Bear	T_n Auliciens	T_n Humphreys	TrSI	T_sub		PMV	RSI	EgRSI	Eq RSI insatisfa	PPD 1	Nb présent dans la salle	EqRSI insatisfait moyen	PPO MOYEN
Matin	108% confortable	0%	15,06%	24,01 °C	23,50°C	22,65 °C	24,61°C	22,80 °C	24,01°C	23,81 °C	22,60 °C	22,94°C	32,04 °C		-0,2933	0,00	100% confortable	0%	6,79%	5	8%	12,54 %
09.00	100% confortable	0%	11,22%	24,61°C	24,01 °C	24,18°C	25,35°C	23,83 °C	24,61°C	24,41°C	23,63°C	23,11 °C	27,75°C	0,187925032	-0,1275	0,01	100% confortable	0%	5,34%	5	0%	8,77%
				1																		
11:00	100% confortable	0%	6,66%	25,02°C	25,15°C	25,21°C	25,85°C	24,53 °C	25,02°C	24,82°C	24,33°C	25,05°C	30,21°C	0,311313167	0,6426	0,07	100% confortable	0%	13,67%	5	0%	10,49%
				1																		
13:00				1												-				1	0%	5,10%
Après midi	100% confortable	0%	5.02%	24.53°C	24.58°C	23.98°C	25.25°C	23.70°C	24.53°C	24.33°C	23.50°C	24.19°C	28.98°C	Hors portée	0.3298	0.05	100% confortable	0%	7,26%	5	0%	5.62%
15:00	100% confortable	0%	5.05%	24.79°C	24.80°C	24.64 °C	25.57 C	24.15°C	24.79°C	24.59 C	23.95°C	24.34 C	28.10°C	0.548187373	0.3913	0.05	100% confortable	0%	8,19%	5	0%	5.85%
		-	1.000	1														1	1.000	-		
17:00	100% confortable	0%	13.45%	-												-				1	8%	13.45 %

a normalized scale (ASHRAE)

The spreadsheet was used to calculate models results with the	
variables measured in situ. Three types of data were obtained:	

Temperature	Thermal Perception Index	Portion of Populatio
in [°C]	According to ASHRAE scale	in [%]

Conclusion & Perspectives

Neutrality temperatures

Evolution of TrSI, T_{sub} and $T_{op_{average}}$ and occupant perception



09:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00

... more results are available in the article (ID: 209)!

Modeling Experiment Marked discrepancy : unsuitable approaches Identify the least intrusive perception for the survey conditions assessment techniques possible

Consistent results Highlighting the inadequacy of temperate climate studies in the tropical climate context

> Perspectives in modeling Perspective for experiment Develop a field survey combining physics-**Create a generic model Build a numeric model generator** physiology-psychology



Toky Rakotoarivelo Supervised by Dr B. Malet-Damour