# IMPACT OF THE CLIMATE ON THE DESIGN OF LOW-ENERGY BUILDINGS FOR AUSTRALIA AND REUNION ISLAND

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## ABSTRACT

The work presented in this paper aims to compare two different climates in Australia and Reunion Island and to identify the similarities in terms of bioclimatic design of low energy building. This approach is to perform a real evaluation of the sensation of thermal comfort in the workplace for different climates on the basis of the "bioclimatic chart" developed by Baruch Givoni.

This article discusses the comparison of the thermal comfort levels obtained in the same building located in Australia and Reunion Island for different climatic zones.

Both countries are influenced by the ocean and the altitude but are located at very different latitudes. Australia is a large area with several types of climate: temperate in south-eastern and south-west, desert or semi-arid in most parts of the territory, and tropical climate in the northern zone of the continent. Reunion has a tropical climate that can be affected by the altitude.

Bioclimatic design strategies are different for wet and dry tropical climates, but in terms of targets at low energy, some basic principles can be identical and can be applied around the world.

If a building is well designed and well adapted to its local climate, it is possible to apply the same design rules and standards for all buildings and two for these two different climates.

## INTRODUCTION

This article discusses a comparative study of climate and assessing levels of comfort for two different climates in Australia and Reunion Island. The aim of this work is to highlight the influence of climate on user comfort in a building subject to the two climates. Australia extends its 7,686,850 km2 of the Australian plate. Bordered by the Indian Ocean, Pacific, Australia is separated from Asia by the Arafura Sea and Timor and New Zealand by the Tasman Sea.

The coasts of North and Northeast have a tropical climate. The east coast has a humid subtropical climate and rainfall is abundant throughout the year. The South coast and South West enjoy a Mediterranean climate. The interior has a desert climate. The Australian continent is located between 39 ° S latitude and 153 ° E longitude. Like Australia, Reunion Island is located in the Indian Ocean near the Tropic of Capricorn at 21 ° S and 55 ° E. The island is 70 km long and 50 km wide. The climate is rather humid tropical, but is affected by the altitude that the island has achieved the high mountains. The highest peak is 3,000 meters high.

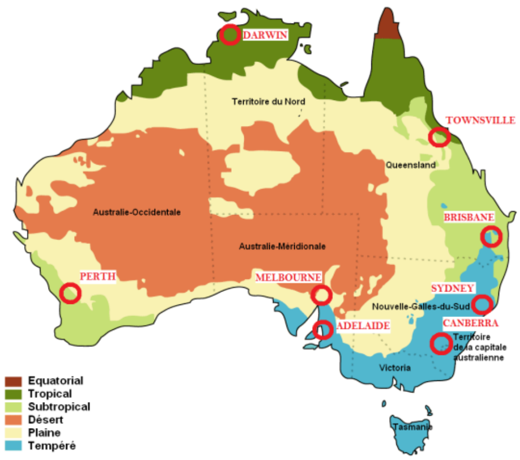


*Figure 1 Map of Australia and climatic zones with cities study*

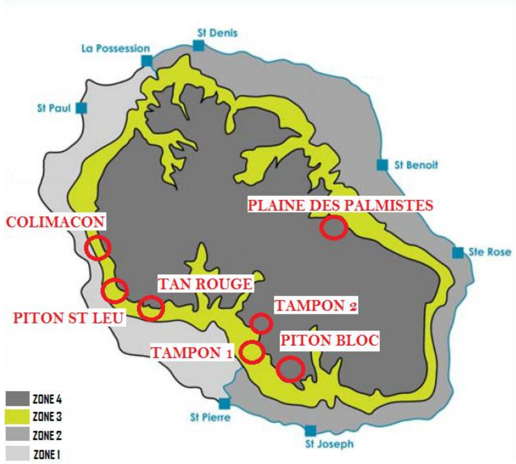


*Figure 2 Map of Reunion Island and climatic zones with cities study*

# METHODOLOGY

The methodology used consists firstly of the study of the climate difference in Australia and Reunion Island. Secondly, we present an advanced building in Reunion Island. The building will be subjected to different climates, allowing us to compare the comfort levels of users in the premises. In this way, we can analyze the influence of climate on the comfort.

Thermal comfort is recognized by the occupants of any building as one of the most important requirements. The level of comfort depends on how the building was designed. The thermal comfort studies were performed on different climates. The simulations for thermal comfort can make coherent choices to design a sustainable building. This setting can give a good indication of how the building will behave before it is built.

# RESULTS AND DISCUSSION

### Climatic analysis

The first part of this study is to make a comparison between the climates of Australia and Reunion. To do this, we select an arbitrary set of Australian city could be compared to cities Reunion, with climates that may correspond to the area called "upper zone" in Reunion. The cities selected for Australia are:

- Adelaide, located in South Australia at 62m above sea level
- Brisbane, located in east Africa, 30m above sea level
- Canberra, located in the south-eastern Australia, at an altitude of 574 m
- Darwin, located in the north, 30 meters above sea level
- Melbourne, located south at an altitude of 70m
- Perth, located in south-west, 30 meters above sea level
- Sydney, located in east Africa, to 36m above sea level
- Townsville, located in north-eastern Australia, 20m above sea level

The Australian continent is subjected to six different types of climates [Figure 1]. The cities surveyed were relatively varied climates. Adelaide, Canberra, Sydney and Brisbane have a temperate climate. The average annual temperature is 17.1 ° C. Perth and Townsville are subject to a subtropical climate, to achieve an average temperature of 21 ° C. Melbourne is, in turn, influenced by a climate of temperate plains trend with annual average temperature is 15 ° C. And finally, Darwin is subject to a tropical climate, with an annual temperature of 27 ° C.

As shown in figure 2, the climate in Reunion can be divided into four main areas. The first 2 zones correspond to the standard coastal tropical climates. Both are located below 400 meters above sea level and differ mainly by the average wind speed (an area "downwind" area and "wind"). The leeward coast, called Zone 1, is the driest, sunniest and warmest. The windward coast area, called Area 2 is wet because of its exposure to wind. Zone 3 is an area midway between 400 and 800 meters. The average annual temperature is 18.2 ° C. The average solar radiation and humidity is high all year. The highlands, called zone 4, are located above the line of 800 meters. The temperature is cool in summer and cold in winter.

For the island of Reunion, so part of the study interval of our research, we select cities in areas above 400 m altitude. The cities chosen for the Reunion are:

- Colimaçon, located in the west of Reunion Island, at an altitude of 798m
- Piton Bloc, located in the south of the island, at an altitude of 813m
- Piton Saint Leu, located in the west of Reunion Island, at an altitude of 565m
- Plaine des palmistes, located in the center of Reunion Island, at an altitude of 1032 m
- Tampon 1, located in the south / southwest of the island, at an altitude of 789m
- Tampon 2, located in the south / southwest of the island, at an altitude of 860m
- Tan Rouge, located in the west of the island, at an altitude of 750m

Table 1 summarizes the main characteristics of the cities studied. Data were collected from TMY files for Australia. For Reunion, we used files and typical hourly weather generated by David.

The cities studied are compared against the main climatic parameters, namely air temperature, humidity, solar radiation and wind speed. These elements will allow us to highlight the similarities between different climates.

By comparing the climate of fifteen cities, it seems that there are similarities in climate between Sydney and Le Tampon (altitude 860 m). The average temperature in Sydney is 18.6 ° C, which is very close to 18.3 ° C for Le Tampon, and the differences between the daily maxima do not exceed 4 ° C. However the maximum temperatures have a difference of 10 ° C against 1.5 ° C for minimum temperatures.

Figure 3 shows that the model of monthly temperature is almost the same, mostly at the end of the year. The pattern of temperature changes, presented in figure 4 and 5, will highlight the

*Table 1 The main characteristics of the cities studied*

| | Reunion Island | | | | | | | Australia | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zone 3 | | | | Zone 4 | | | | | | | | | | |
| Location | Colimaçon | Piton St Leu | Tan Rouge | Tampon 1 | Piton Bloc | Plaine des palmistes | Tampon 2 | Aelaïde | Brisbane | Canberra | Darwin | Melbourne | Perth | Sydney | Townsville |
| Longitude / Latitude | 55°18'E 21°08'S | 55°20'E 21°13'S | 55°18'E 21°04'S | 55°32'E 21°15'S | 55°34'E 21°19'S | 55°38'E 21°08'S | 55°32'E 21°15'S | 138°59'E 34°93'S | 153°02'E 27°47'S | 149°13'E 35°28'S | 130°84'E 12°46'S | 144°96'E 37°81'S | 115°86'E 31°95'S | 151°21'E 33°86'S | 146°81'E 19°27'S |
| Altitude | 798 | 565 | 750 | 789 | 813 | 1032 | 860 | 61,7 | 28,4 | 574 | 27,8 | 68 | 31,5 | 35,6 | 16,3 |
| Air Temperature | | | | | | | | | | | | | | | |
| Mean | 18,4 | 19,5 | 17,8 | 18,1 | 18,2 | 16,2 | 18,3 | 17,1 | 19,9 | 12,8 | 27,3 | 15 | 18 | 18,6 | 24,1 |
| Mean of daily Max | 24,4 | 25,9 | 25,6 | 24,9 | 24,2 | 23,7 | 25,6 | 31,1 | 28,2 | 25,8 | 34,1 | 27,3 | 32 | 29,3 | 30,8 |
| Mean of daily Min | 13,8 | 14,3 | 12,3 | 14,8 | 15,6 | 13 | 14,5 | 12,5 | 15,5 | 7,1 | 23,7 | 11,2 | 12,6 | 14,9 | 20,3 |
| Absolute Max | 27,4 | 28,1 | 29,7 | 27,9 | 28 | 27,9 | 29,4 | 44 | 32,8 | 39,8 | 35,6 | 38,1 | 40,7 | 40,3 | 33,8 |
| Absolute Min | 10,2 | 10,9 | 9,5 | 9,2 | 9,4 | 7 | 6,8 | 2,1 | 2,1 | -6,2 | 15,5 | 2,5 | 1,2 | 5,3 | 5,3 |
| Mean Global Solar Radiation (Wh/m²/day) | | | | | | | | | | | | | | | |
| Mean | 3811 | 4429 | 3618 | 4959 | 4417 | 3948 | 3609 | 4958 | 4691 | 1615 | 5799 | 4039 | 5245 | 4870 | 5601 |
| Absolute Max | 8770 | 8678 | 7645 | 16082 | 9445 | 8309 | 7120 | 9623 | 8551 | 3199 | 8270 | 9253 | 9248 | 9279 | 9102 |
| Absolute Min | 1372 | 1197 | 647 | 150 | 161 | 458 | 258 | 525 | 767 | 115 | 1319 | 247 | 364 | 1110 | 1110 |
| Relative humidity | | | | | | | | | | | | | | | |
| Mean | 85% | 81% | 91% | 85% | 90% | 92% | 84% | 60% | 70% | 75% | 70% | 68% | 64% | 65% | 69% |
| Mean of daily Max | 95% | 91% | 99% | 95% | 98% | 97% | 96% | 68% | 82% | 87% | 78% | 78% | 74% | 74% | 77% |
| Mean of daily Min | 73% | 68% | 73% | 72% | 76% | 80% | 68% | 47% | 61% | 59% | 58% | 57% | 51% | 54% | 61% |
| Absolute Max | 99% | 99% | 99% | 100% | 99% | 100% | 99% | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| Absolute Min | 39% | 31% | 47% | 53% | 44% | 50% | 32% | 8% | 11% | 6% | 9% | 12% | 9% | 6% | 7% |
| Wind speed (m/s) | | | | | | | | | | | | | | | |
| Mean | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 3,1 | 3,4 | 2,1 | 3,3 | 3,9 | 3 | 2,3 | 3 |
| Mean of daily Max | 5,5 | 5,8 | 4,5 | 3,5 | 3 | 4,1 | 3,4 | 5,5 | 6,2 | 5,4 | 6 | 7,4 | 6,6 | 5,1 | 6,4 |
| Mean of daily Min | 1,8 | 1,1 | 0,7 | 0,4 | 0,6 | 0,8 | 0,2 | 0,9 | 1,1 | 0,2 | 1,1 | 0,9 | 0,3 | 0,3 | 0,5 |
| Absolute Max | 11 | 14 | 10 | 8 | 7 | 10 | 9 | 13,9 | 11,8 | 13,4 | 12,9 | 17 | 16,5 | 15,6 | 13,4 |
| Absolute Min | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

similarities of the season between the two cities. We can even periods when the temperature exceeds 20 ° C. This period is reduced until the middle of the year where we find temperatures between 10 ° C and 20 ° C. We see two important seasons may be associated with winter and summer.

The Reunion sky brings solar radiation less than in Sydney with a difference on the average of 1.26 kWh / m² / day. The maxima can get slight variations of the order of 0.9 kWh / m² / day for solar minimum and 2.1 kWh / m² / day for the maxima.

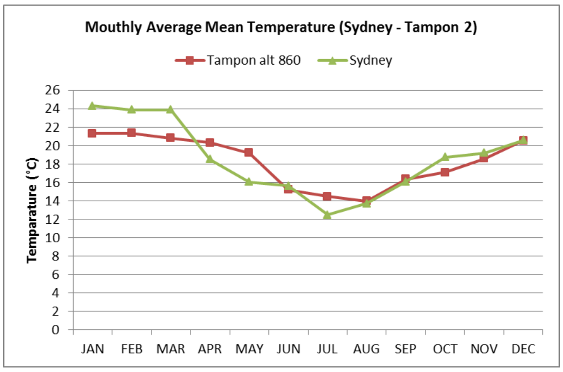


*Figure 3 Comparison of the monthly temperature for Sydney and Le Tampon*

The humidity is a parameter for its complete differentiation Reunion cities Australian cities. Indeed, Reunion is under the influence of a humid tropical climate marked by annual humidity around 90% in contrast to Australia where the climate is drier with a maximum annual average humidity of 75% (Canberra). On Sydney and Tampon, we see a deviation from the average of about 20%.

In other words, humidity is not a parameter of similarity between the two countries. Reunion climate is much wetter than the Australian climate

On wind speeds, Sydney is under the influence of strong wind can expect 15.6 m / s cons 9m / s for Tampon. The difference on the average wind speed is low (1.7 m / s).

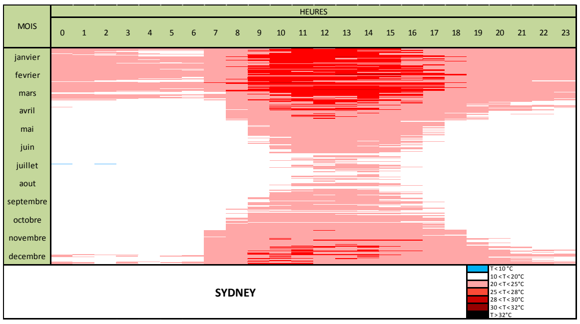


*Figure 4 Hourly temperature distributions throughout the year for Sydney*

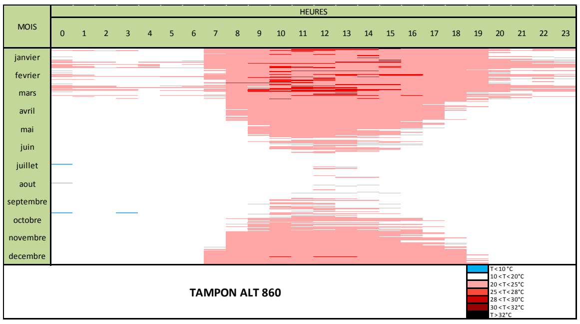


*Figure 5 Hourly temperature distributions throughout the year for Le Tampon*

**Definition of building study**

The second part of the study is to submit a building to Australian climates and Reunion closest. We try to evaluate the influence of climate on user comfort by using as reference the comfort chart of Baruch Givoni (also called bioclimatic diagram). We can account for the variation in the number of hours of discomfort depending on where the building is situated.

*Figure 6 Perspective of the building studied - ENERPOS*

To do this, we use an existing building in Reunion Island: Enerpos. This project applies to the construction of commercial buildings in hot climates.

Completion of this building has been submitted to this repository to Reunion Island, the tool called PERENE (Energy Performance of Buildings Reunion). This document is based on experience gained during recent years in the field of residential and commercial buildings, either through energy audits, either by the feedback ECODOM or by expert reports conducted in the area of senior Reunion. It aims to keep pace with the draft decree of French thermal regulation DOM - Overseas Department- (called RT2ADOM).

ENERPOS, as we can see in figure 6, is one of the 11 research projects that have been selected by the French National Research Agency.

The project is composed of two small parallel buildings respectively named Building A (South Side) and Building B (North Side). The main facades are north and south orientated. Each building has two storeys. The room types are: Laboratory research on the ground floor of the southern building, five classrooms (respectively numbered 1 to 5), two computer rooms (respectively numbered 1 and 2).

The purpose of this building is to achieve a visual and thermal comfort with only passive means. It is passing through, thus the natural ventilation is possible. It includes numerous openings been done with "jealousy". It is at the forefront of new technologies on the construction methods in tropical climate. It is oriented North - North / East.

We will study a class on the ground floor of Building B. The floor plan is shown in Figure 7 and the 3D model is used to display the position of this room in the building (Figure 8). The front display is oriented North - North / East.

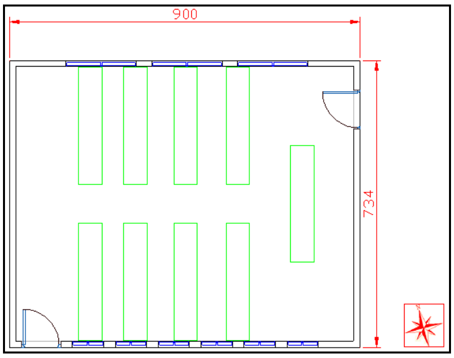


*Figure 7 View room plan studied*

The building is designed for hot climates instead. The front display has a sun protection type "fixed shading." The construction method is typical : heavy inertia (concrete structure 16 cm thick) for facades protected (case study) and an external insulation with polyethylene and wood siding for the façades most at risk.

Our study room is made of concrete 16cm. The openness index (opening area divided by total floor area) is 0.24. We believe that our room does load internal variables (presence of computer, projector, etc.). The room has an installed capacity of lighting 8W / m². We use a standard schedule for the classroom: students are in the room Monday through Friday from 8 am to 12 pm and 13 pm to 17 pm. We do not vacation during our simulation period.

The building has a cooling system designed for computer rooms. For the rest rooms, thermal comfort is achieved with natural ventilation and ceiling fans.

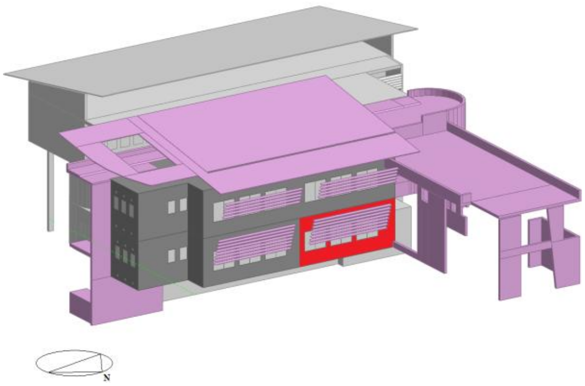

*Figure 8: 3D model study of the building - in red, the study room*

**Analysis of simulation results**

We perform simulations using the software Design Builder based on the dynamic thermal computer EnergyPlus.

The simulations are carried out on the two configurations. The first is to leave the closed room (no natural ventilation) and to implement a basic configuration for the classroom: twenty-five students write their progress (or 0.4 people / m²  with a metabolic level 1). The second case study is to open the opening of the room occupied and operate the ceiling fan. The table 2 summarizes simulations for the two cities studied.

*Table 2 Summary of simulations*

| CASE STUDY | OCCUPATION | STATE OPENINGS |
|---|---|---|
| Case 1 | Occupation : 0.4 pers/m² | Closed room |
| Case 2 | Occupation : 0.4 pers/m² | Open room |

We use the diagram of Givoni, otherwise known as bioclimatic diagram, to highlight the influence of climate on user comfort.

The diagram of Givoni assesses the comfort of summer (summer cladding) of an individual subjected to different thermal environments and different air velocities. The parameters involved are temperature, humidity and air velocity. We note 3 comfort zones, materialized on the diagram of humid air by three parallelograms, distinguished by the thresholds of discomfort based on air velocities [Figure 8]:

- Comfort Zone 1: temperature ranging from 20 to 27 ° C, humidity between 20 and 80% for air velocity zero
- Comfort Zone 2: temperature ranging from 20 to 30 ° C, humidity between 20 and 90% for an air velocity of 0.5 m / s (naturally ventilated)
- Comfort Zone 3: temperature ranging from 20 to 32 ° C, humidity between 20 and 95% for an air velocity of 1 m / s (natural ventilation + ceiling fans)

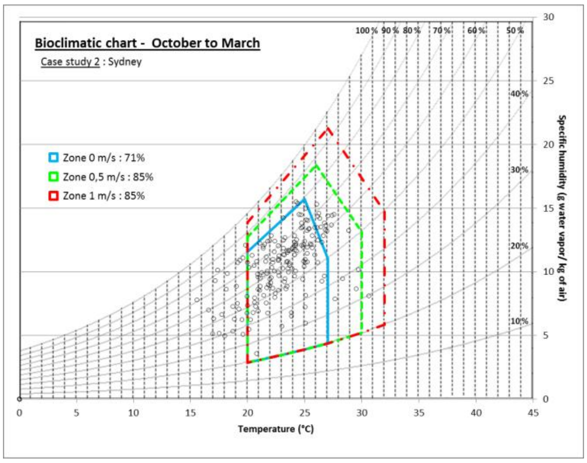


*Figure 9 Example of a diagram of Givoni - Case Study2 for Sydney*

This diagram is adapted for climate zones 1 and 2 of Reunion. We also use it in zone 3 because it is common for a slight cladding is used in blast during the summer. That is why the simulations are done only warm season for both countries, either from October to March.

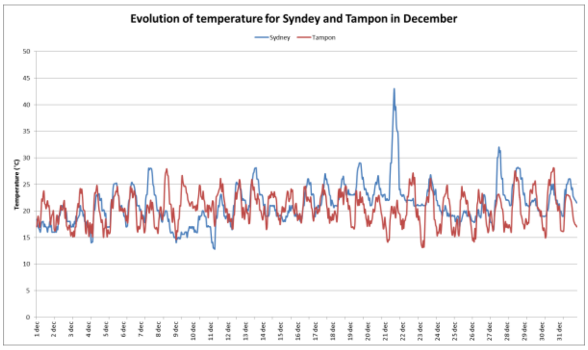


*Figure 10 Comparison of temperature during the month of December*

Comparing closer daily temperatures between Sydney and Le Tampon, we find that real similarities appear in December [Figure 9]. As shown in this figure 10 this similarity is important on December 5. In the first part we highlight the differences between the various simulations on the entire warm season (October to March). Then, in order to refine the results, we show the evolution of the level of comfort after a day on each climate where the temperature profile in Sydney is almost the same as Tampon.

When we perform simulations on the summer period, we find that the number of hours of discomfort (at zero air velocity) is higher than in Sydney in Tampon with a standard max 432h when the room is closed [Table 3]. The building responds to its environment and causes higher levels of discomfort for the city in Reunion. When the air speed above zero, the Australian climate is becoming less uncomfortable.

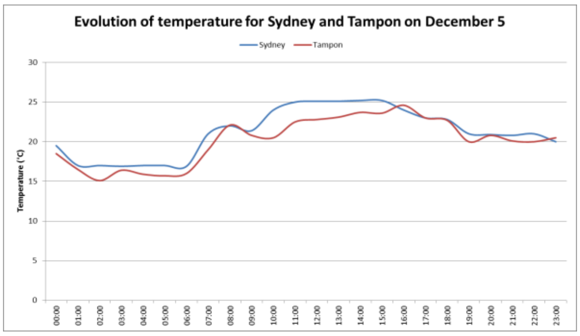


*Figure 11 Comparison of temperature during the day on December 5*

Then we find a maximum deviation of 384h when the room is closed for an air velocity of 0.5 m / s. The climate has an indirect impact on the user. Tampon time is less discomfort than Sydney. We note that the same building located in the same conditions in both countries can prevent 20% of the time of discomfort if it is located in Sydney when the air velocities are zero. Conversely, the building located in Reunion, to an air speed equal to 0, we can prevent up to 50% of the time of discomfort.

*Table 3 Comparison of the number of hours of discomfort between Sydney and Tampon for December*

| SUMMER | | SYDNEY | TAMPON | DEVIATION |
|---|---|---|---|---|
| 1 | 0 m/s | 2016 | 2448 | -432 |
| | 0.5 m/s | 816 | 432 | 384 |
| | 1 m/s | 432 | 312 | 120 |
| 2 | 0 m/s | 1248 | 1584 | -336 |
| | 0.5 m/s | 672 | 552 | 120 |
| | 1 m/s | 648 | 528 | 120 |

Givoni diagram is provided of the three zones of comfort that varies with wind speed. The points used are located within the parameters temperature and humidity. Sydney, and Tampon have the same temperature profile but the distinction is mainly on moisture. With average differences of about 25%, the annual profile of moisture for these two cities is different. Therefore, we can highlight the influence of this parameter to user comfort. To do this, we highlight the results of the comfort levels for the day on 5 December when the temperatures of the two cities are roughly the same way [Table 4].

*Table 4 Comparison of the number of hours of discomfort between Sydney and Tampon during December, 5*

| SUMMER | | SYDNEY | TAMPON | DEVIATION |
|---|---|---|---|---|
| 1 | 0 m/s | 9 | 10 | -1 |
| | 0.5 m/s | 3 | 9 | -6 |
| | 1 m/s | 1 | 4 | -3 |
| 2 | 0 m/s | 0 | 4 | -4 |
| | 0.5 m/s | 0 | 0 | 0 |
| | 1 m/s | 0 | 0 | 0 |

A temperature profile substantially similar, we find that the building subject to the Australian climate allows for better comfort conditions for users with a maximum deviation on the number of hours of discomfort from 6h when the room is closed and that the air velocities do not exceed 0.5 m / s. The parameter shown here is the humidity. It is obvious that contributes to user comfort.

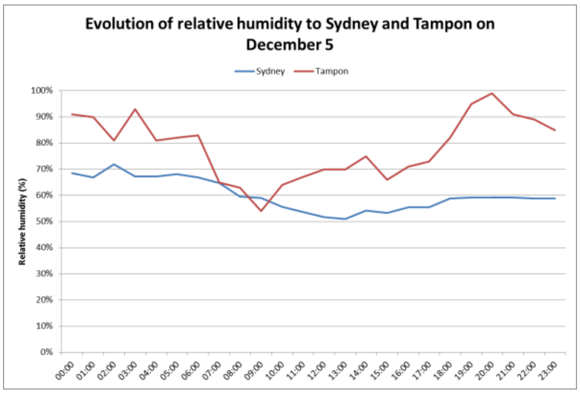


*Figure 12 Comparison of moisture during the day on December 5*

Figure 11 gives an overview of the evolution of daily moisture for December 5. We see that the moisture profile of Sydney and Le Tampon is completely different. This information validates the hypothesis that moisture can have an influence on user comfort. At larger scales, the classification of a climatic environment takes into account a number of key parameters which are temperature, humidity, air velocity and solar radiation, common parameters to evaluate the comfort users. Moisture, such as temperature, can put a person in a situation of discomfort. For simple relationship, we can infer that the climate has an impact on user comfort.

## CONCLUSION

Comparative studies climate helped to highlight the similarities between Sydney, located in eastern Australia to 36 m, and Le Tampon is located in the southern of Reunion Island to 860m above sea level. Sydney is subjected to a temperate climate while Tampon is facing a humid tropical climate. Only the moisture of the two cities highlights a difference of about 20%, showing that the climate is more humid Reunion that the Australian climate. The simulations were performed on a building present in Reunion. We have studied two configurations for a room of this building. The first case study consisted of placing twenty-five students in this room closed. Then we open the room with the windows it contains. We compared the two cases for the hot season in Sydney and Le Tampon (summer). The results showed that when the room is open, and that exchanges between the exterior and the interior was caused (opening windows, activation of ceiling fans), comfort conditions are met for a Reunion climate. In order to highlight the impact of humidity on the results and show that this parameter can influence the level of comfort, we focused on a day when both cities had a temperature profile substantially similar. Sydney, drier climate, ensuring comfort conditions greater than that of the same building in Tampon. The results of these simulations show that moisture cannot reach or comfort conditions. The climate is defined by a set of parameters, including moisture. We deduce that a building subject to the same Australian climates and Reunion acts differently on the comfort of its users. The climate has a significant impact on user comfort and consequently on the construction methods to achieve a proper level of comfort. In our case, solutions to climate Reunion dehumidification would achieve the same performance as similar buildings located in Sydney.

## REFERENCES

David, M., Adelard, L., Garde, F., et al. 2005. Weather data analysis based on typical weather sequences. In Proceedings of IBPSA World Congress, Montreal.

A. Lenoir, F. Garde, L. Adelard, M. David, et al Presentation of the experimental deedback of a French net zero energy building under tropical climate

Garde, F. et al. 2005. Elaboration of thermal standards for french tropical islands. Presentation of the PERENE Project. In Proceedings of Clima2005, Lausanne.

F. Wang, F. Garde, M. Donn : A comparative study in the architectural design of low energy apartments for two climates: New Zealand and Reunion Island.