

**University of Pennsylvania**

ARCH-753-001 Building Performance Simulation

Advisor: Mostapha Sadeghipour Roudsari

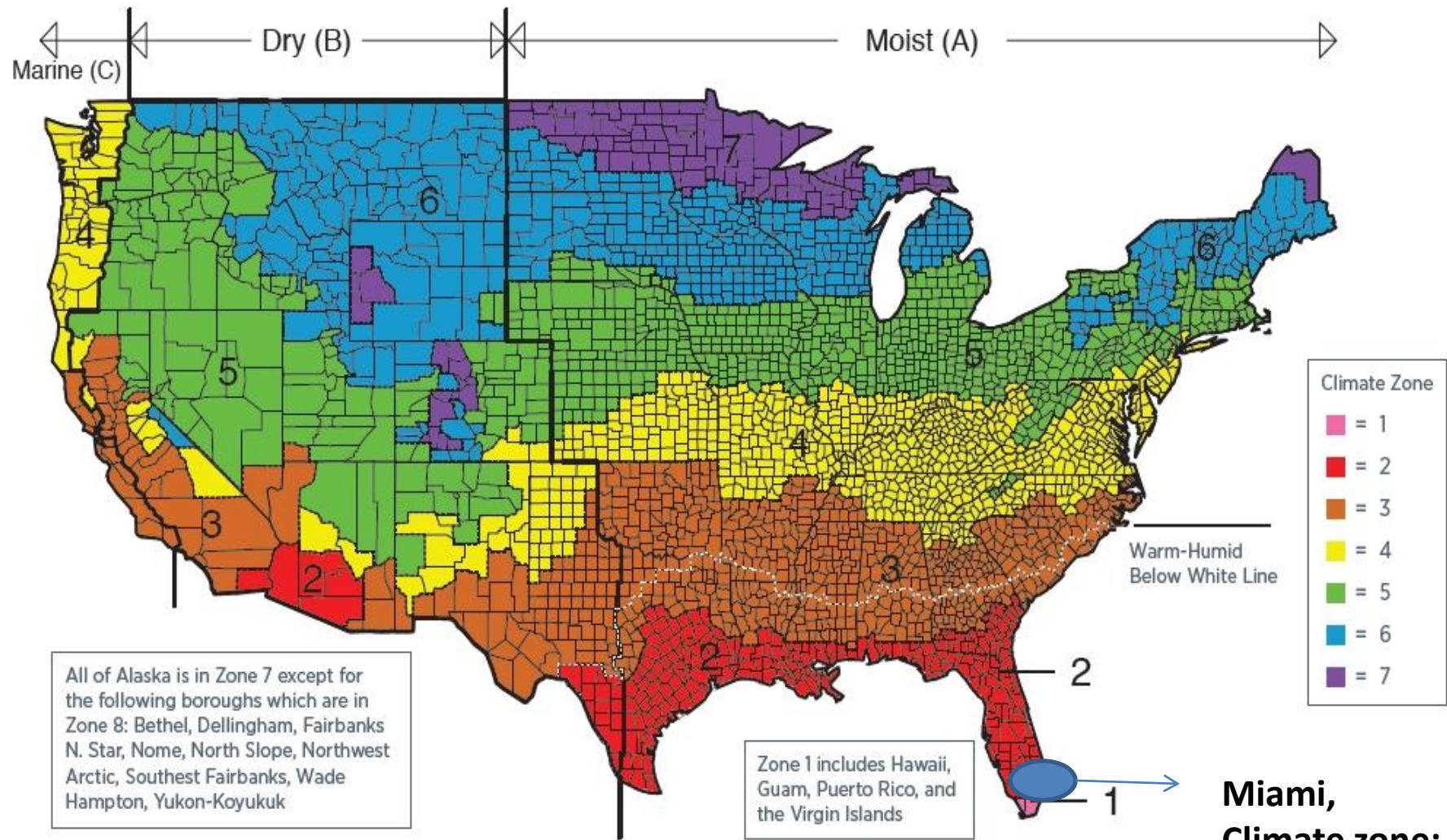
# Final Project Report

## Designing Shade For Miami Climate

**Pegah Mathur**

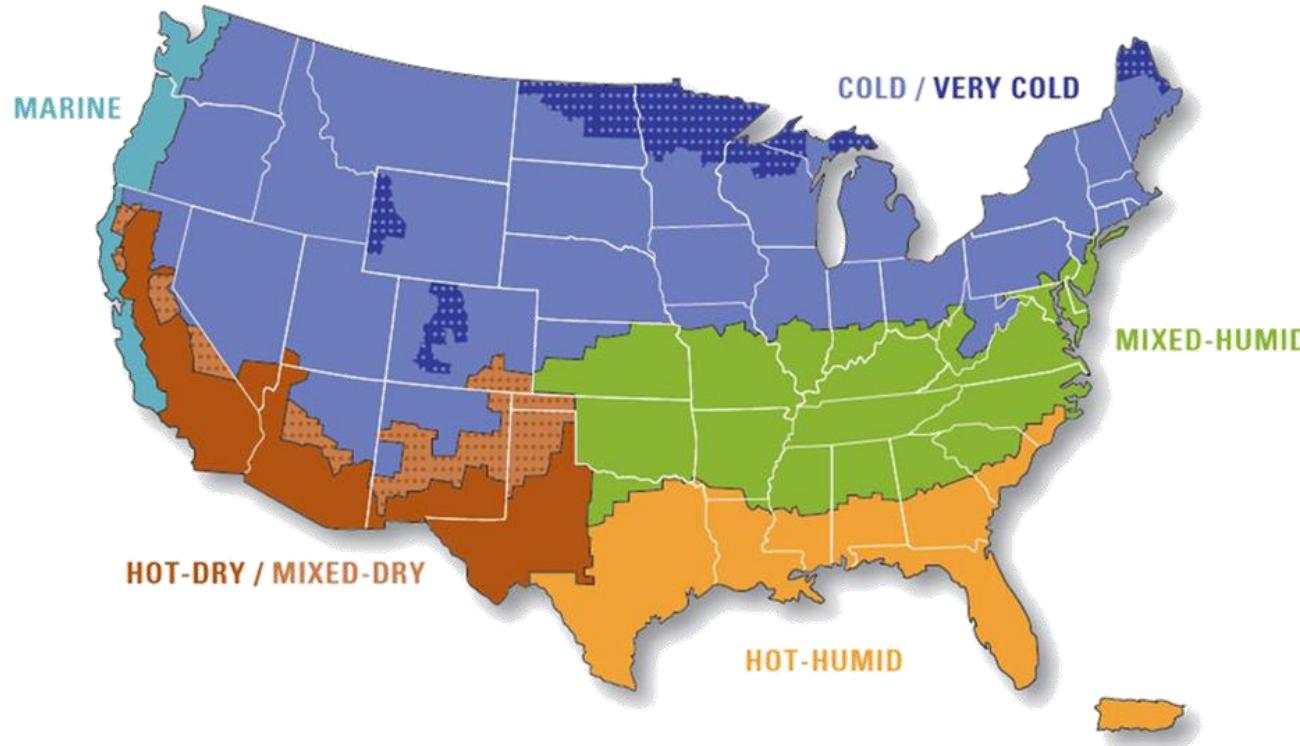
**Winter 2015**

# Miami Climate Report



# Miami Climate

## Hot-Humid



### Hot-Humid Climate

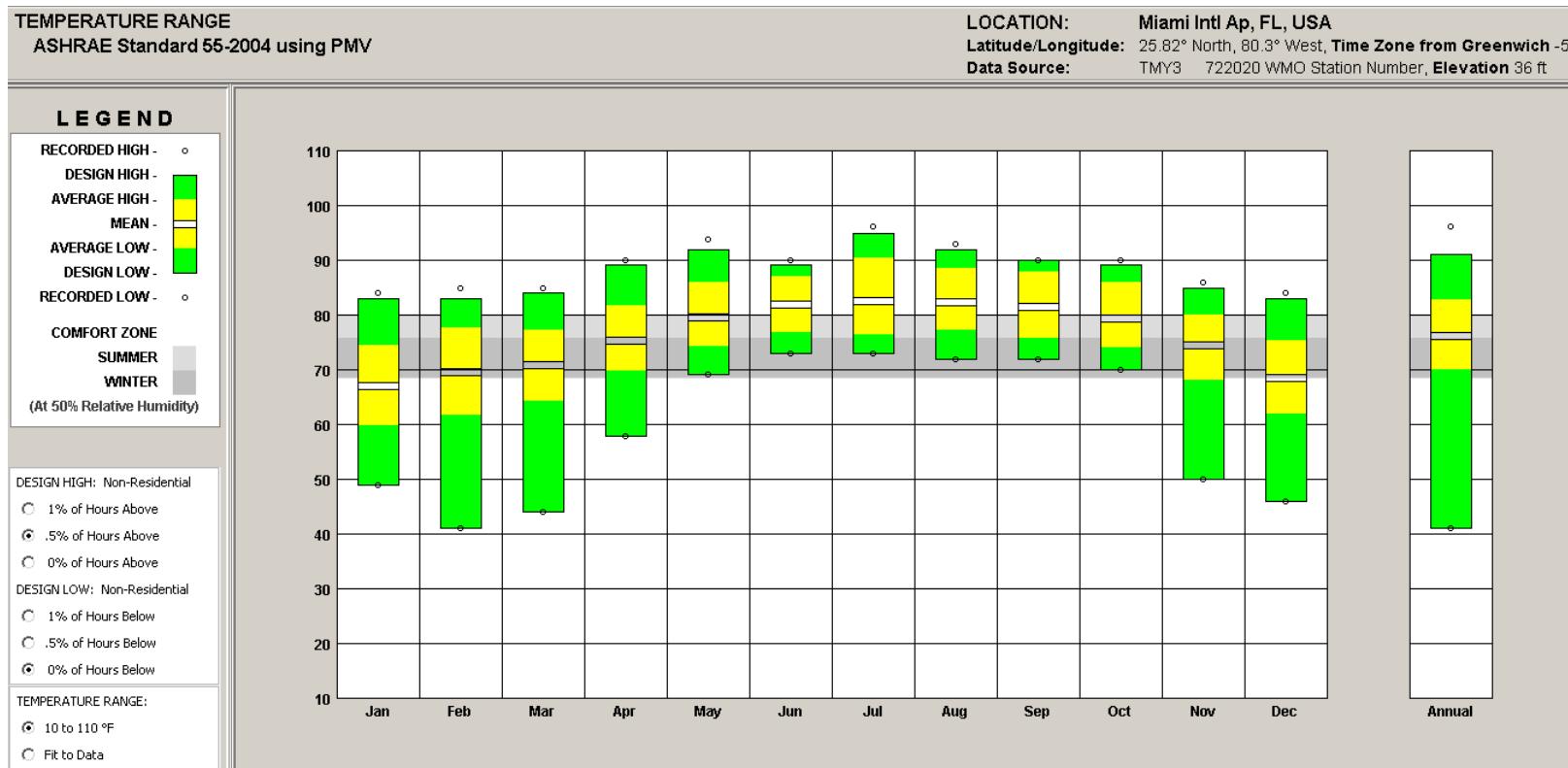
The hot-humid climate is referred to the climate that the annual precipitation is more than and always one of the following condition happens:

The wet bulb temperature is about 67 F (19.5 C) or higher for more than 3000 hours during the six warmest and successive months of the year

The wet bulb temperature is about 73 F (23 C) or higher for more than 1500 hours during the six warmest and successive months of the year

# Miami Climate Temperature

- Temperature Range

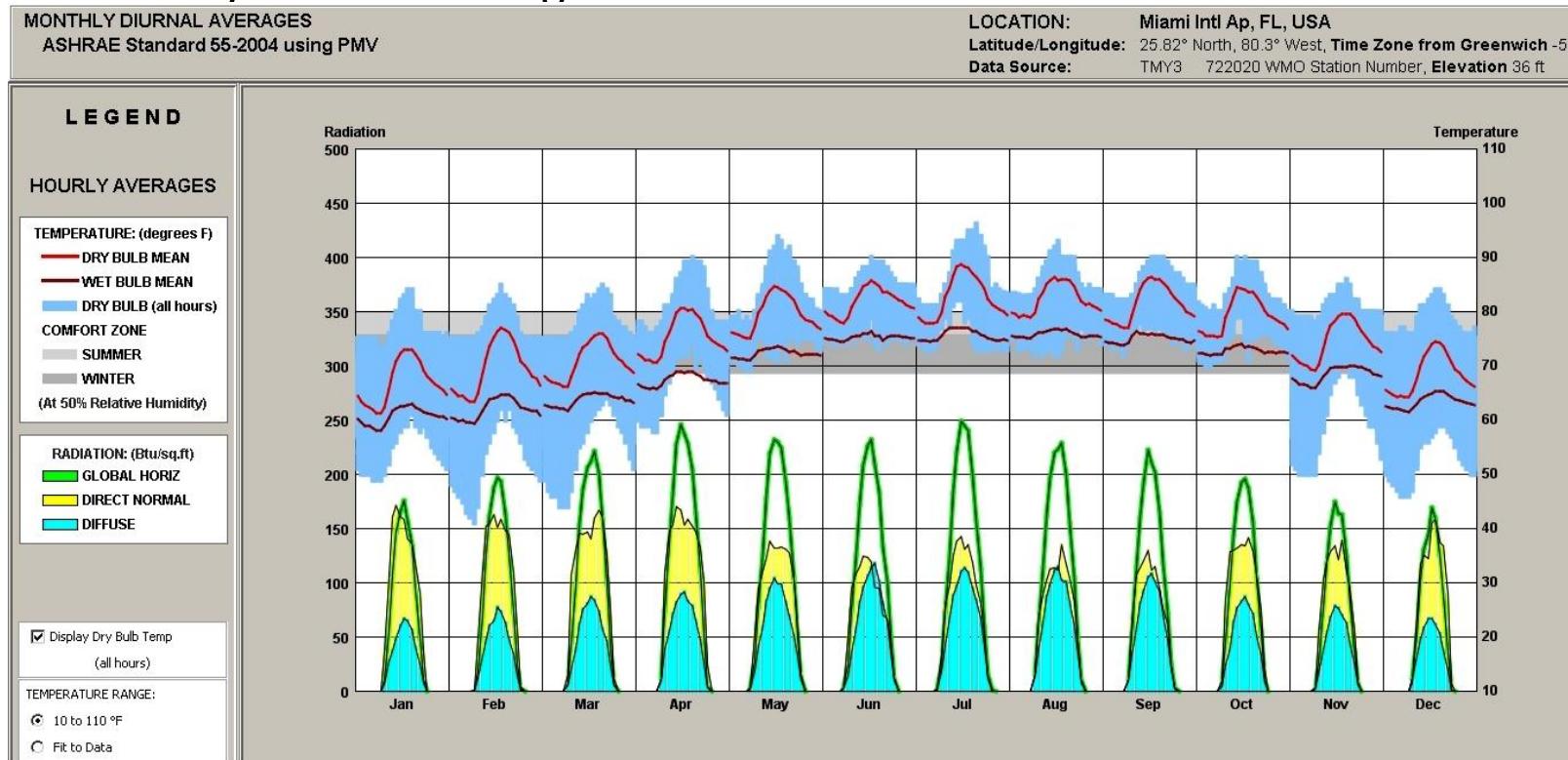


The average annual temperature in Miami is relatively high and between 60-75 F. The highest temperature shown is between May to August which is considerably higher than the average annual temperature (76-88 F).

# Miami Climate

## Temperature

- Monthly Diurnal Average



### Monthly Diurnal Average:

Monthly diurnal average which shows the temperature cycle during the day and also the radiation on the site.

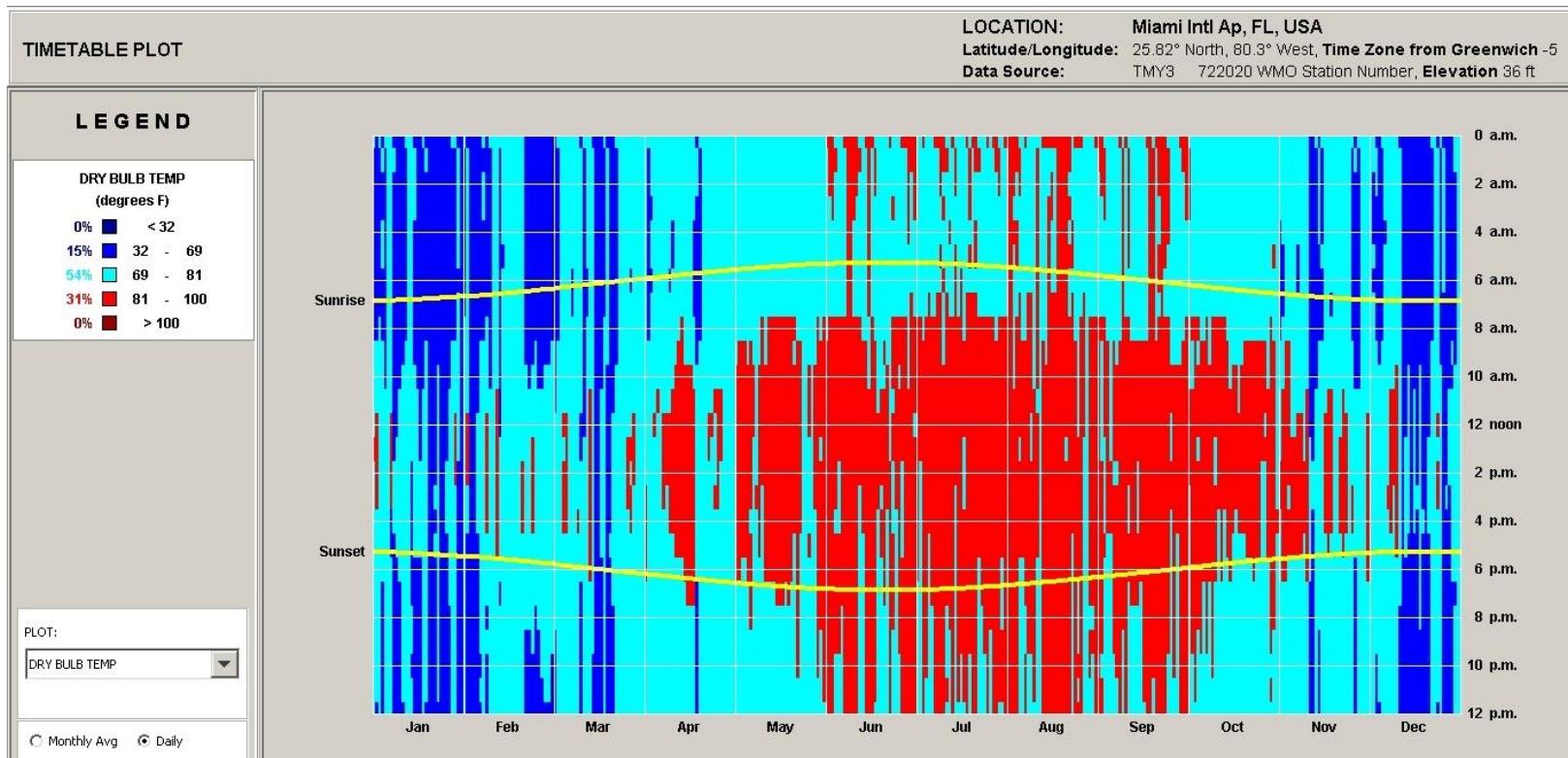
The differences between the average in dry bulb temperature and wet bulb temperature in February and January shows the weather is dryer in these months during the year.

The Time table plot shows the annual temperature during hours in a day.

# Miami Climate

## Temperature

- Annual Temperature



This plot shows that during the daytime in summer and parts of April until late October, the temperature mostly is higher than 81 F , which is above the comfort zone. This happens mostly during the daytime and during the time in which people are at work, offices and educational purpose buildings.

# Miami Climate

## Temperature

- Heating Degree days and cooling degree days

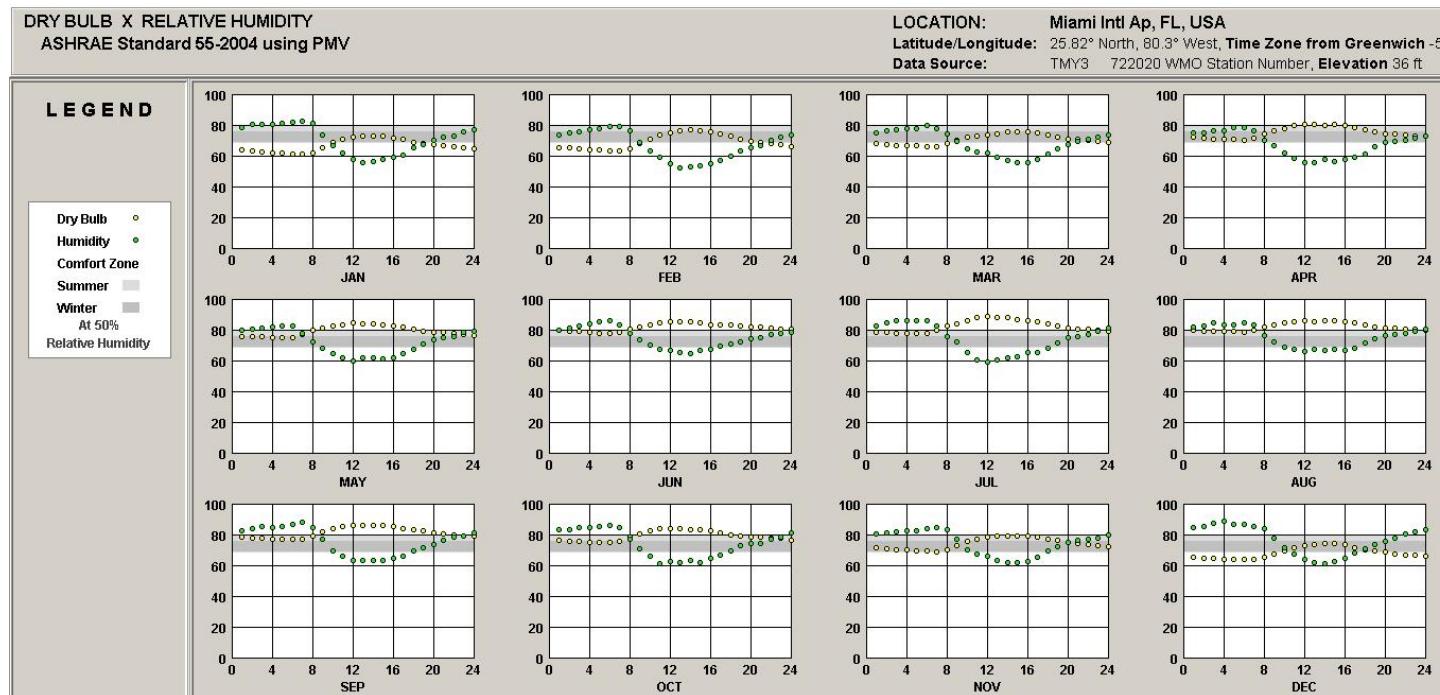
Miami Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Temperature	67.2	68.5	71.7	75.2	78.7	81.4	82.6	82.8	81.9	78.3	73.6	69.1	75.9
Avg. Max Temperature	75.2	76.5	79.1	82.4	85.3	87.6	89.0	89.0	87.8	84.5	80.4	76.7	82.8
Avg. Min Temperature	59.2	60.4	64.2	67.8	72.1	75.1	76.2	76.7	75.9	72.1	66.7	61.5	69.0
Days with Max Temp of 90 F or Higher	0.0	0.0	< 0.5	1.0	4.0	10.0	16.0	16.0	10.0	2.0	0.0	0.0	61.0
Days with Min Temp Below Freezing	< 0.5	0.0	< 0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	< 0.5	0.0

Miami Heating and Cooling	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Heating Degree Days	88.0	51.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	41.0	200
Cooling Degree Days	156	149	221	306	425	492	546	552	507	412	264	168	4198

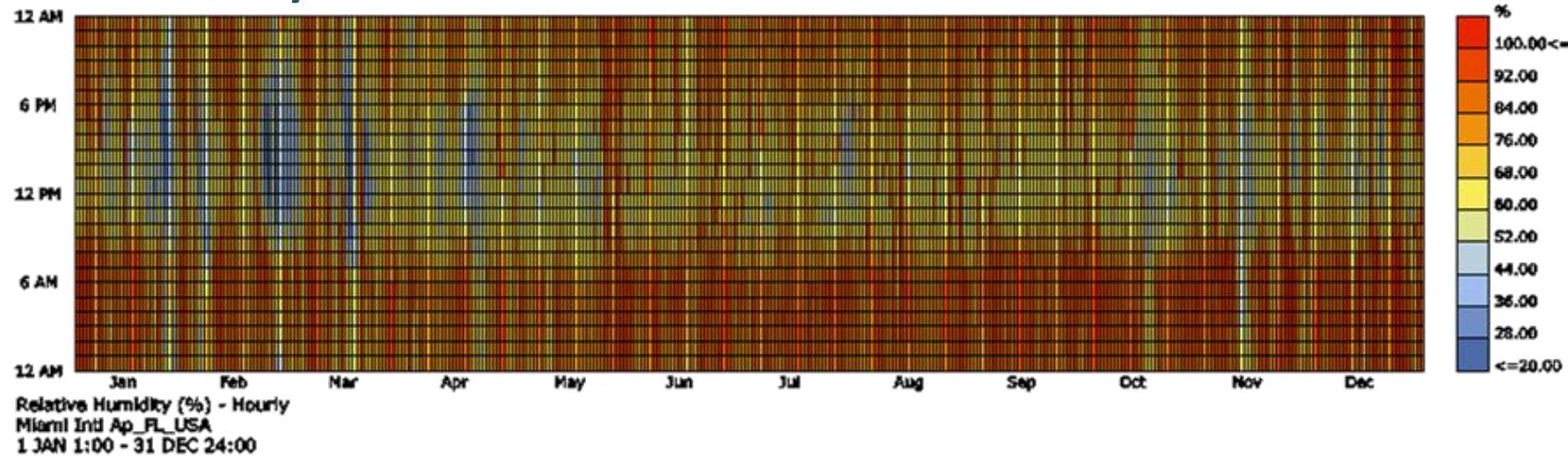
Looking at Miami Heating degree days, indicates that generally, heating is not needed seriously in this climate as even in January as coldest month as shown in the chart, the heating degree days are only 88 days (night time)which would be about 2.5 C/F heating day degree needed, while it is also stated that the cooling degree days (daytime) are more (mostly double times) in winter , in January.

# Miami Climate Humidity

- Humidity is identified as important as temperature in terms of the comfort definition. Low percent of humidity will result in dry air, while too much humid weather would make occupants feel muggy and uncomfortable.
- Miami, as stated in the climate zone, is considered as Hot and humid and as showing in the dry bulb and relative humidity chart, and also the psychometric chart below the average percent of relative humidity is between 60% to 85% during the whole year. In the other words, humidity never goes below 58% even in coldest months of the winter on January and February.

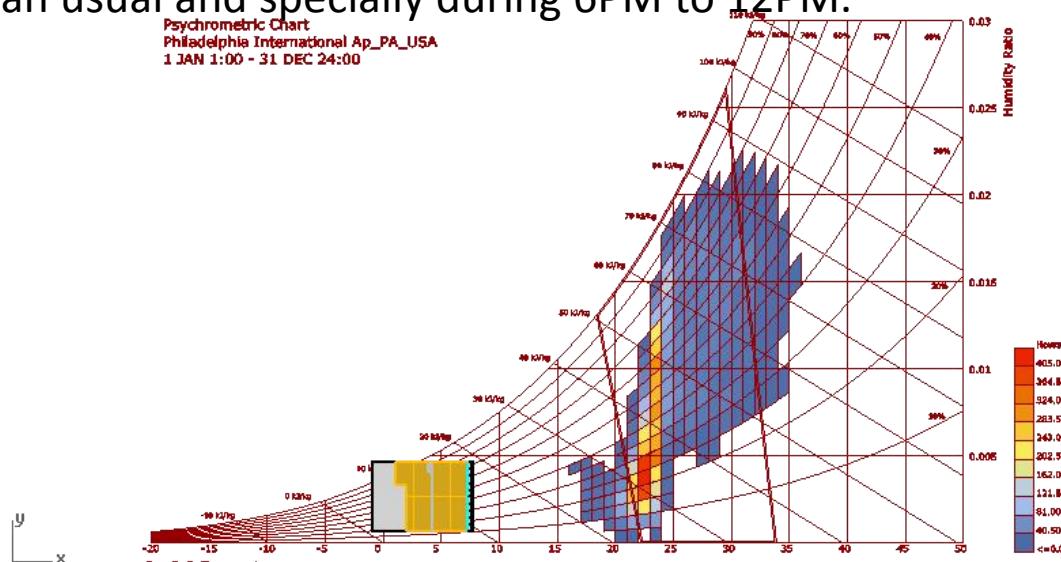


# Miami Climate Humidity



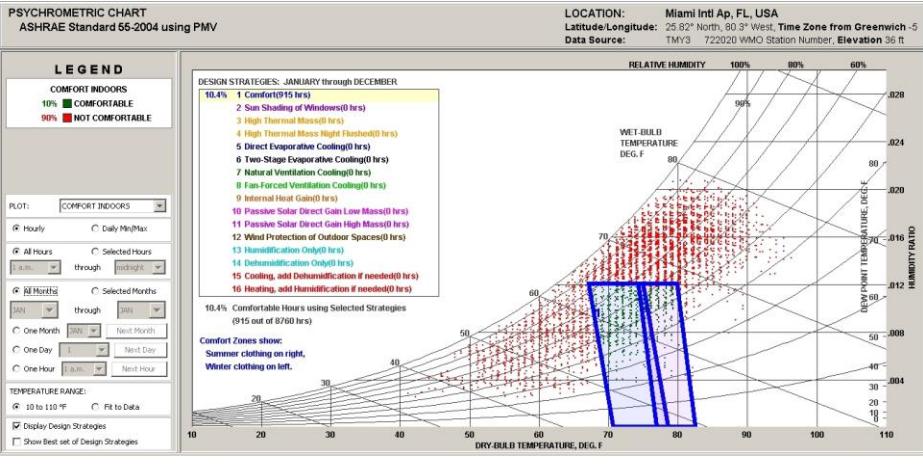
Relative humidity in the chart above indicates that approximately most of the year the humidity is higher than 75% and only in months of Jan and Feb it is lower than usual and specially during 6PM to 12PM.

Psychrometric Chart  
Philadelphia International Ap\_PA\_USA  
1 JAN 1:00 - 31 DEC 24:00

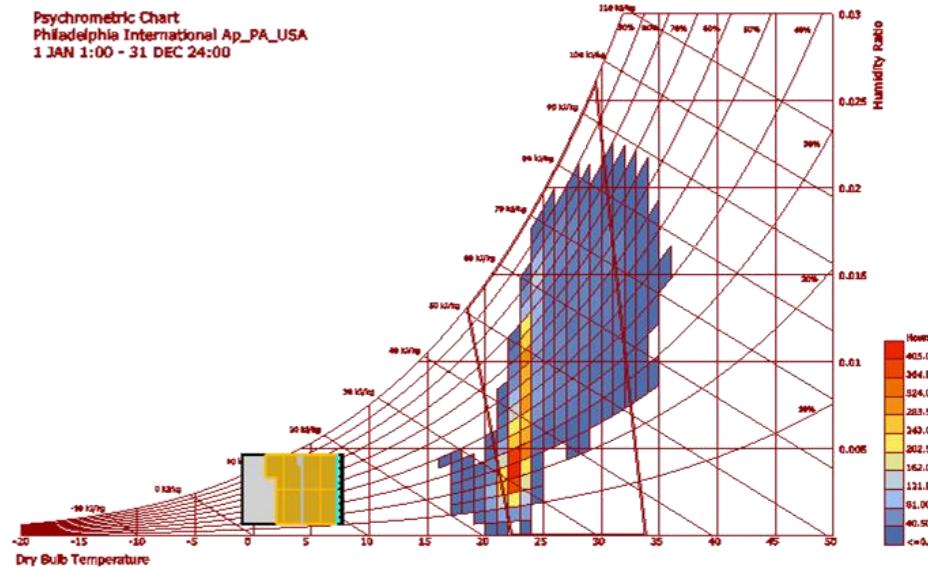


# Miami Climate

## Humidity



**Psychrometric Chart**  
Philadelphia International Ap\_PA\_USA  
1 JAN 1:00 - 31 DEC 24:00



Data shown on psychometric chart includes the temperature (dry bulb and wet bulb) and also the Humidity (Relative and absolute). Psychometric chart can be used to identify the occupant comfort zone in the area and design necessary passive design strategies to raise the comfort level.

(<http://sustainabilityworkshop.autodesk.com>, 2015)

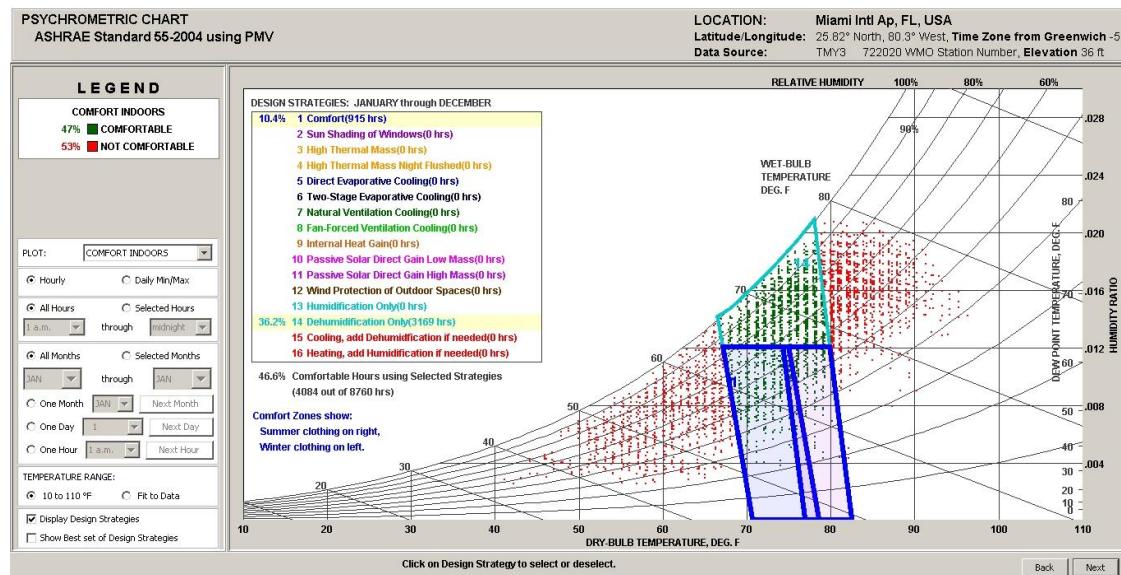
At very first we can see the most weather through the year in Miami is hot and moist. It is shown in the psychometric chart that the humidity through the whole year is high and in all months is between the range of 60% to 100%.

It is understood from the psychometric chart above that without any strategy applied into the building design, the occupants' comfort in this building with use of summer or winter clothing is only about 10.5% of times, which is a very low rate.

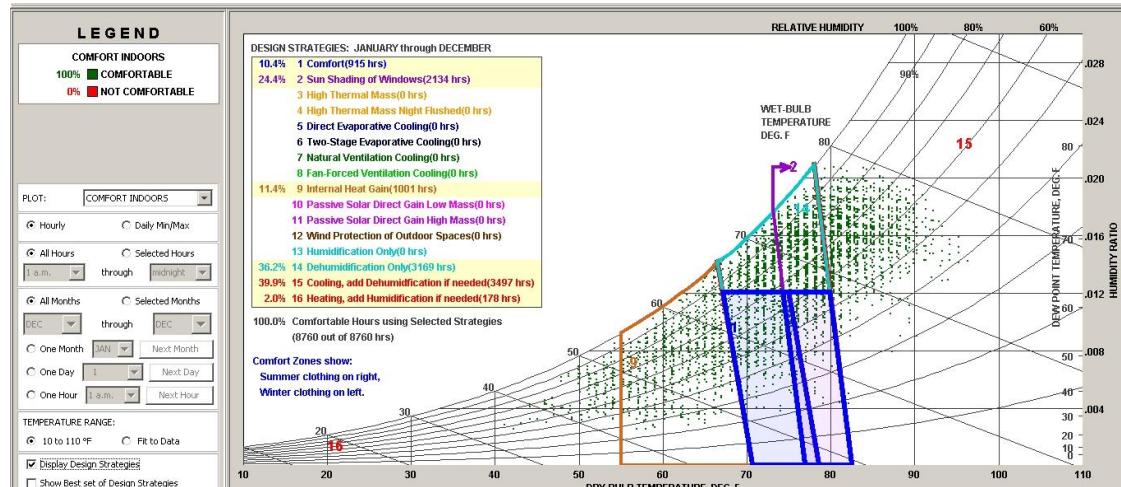
# Miami Climate

## Humidity

Adding dehumidification as a strategy to decrease the raises the comfort zone up to 36% which proves that the main issue in Miami climate is about the high level of humidity through the whole year.



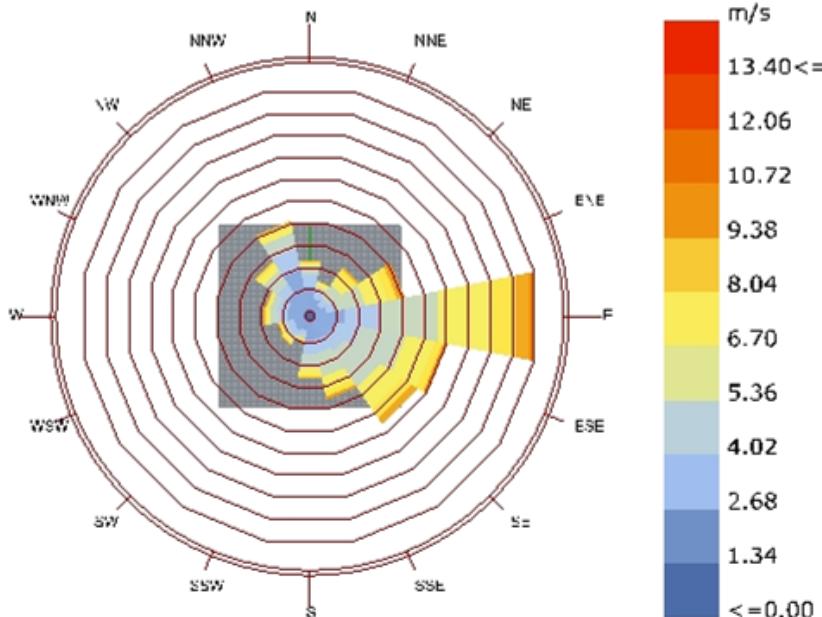
As shown in Psychometric chart, the most important issue in the hot and humid climate of Miami which is confronting the comfort, is humidity. As the higher temperature gets, the more humidity it can hold, the high temperature of the area increases the feeling of humidity and eventually muggy.



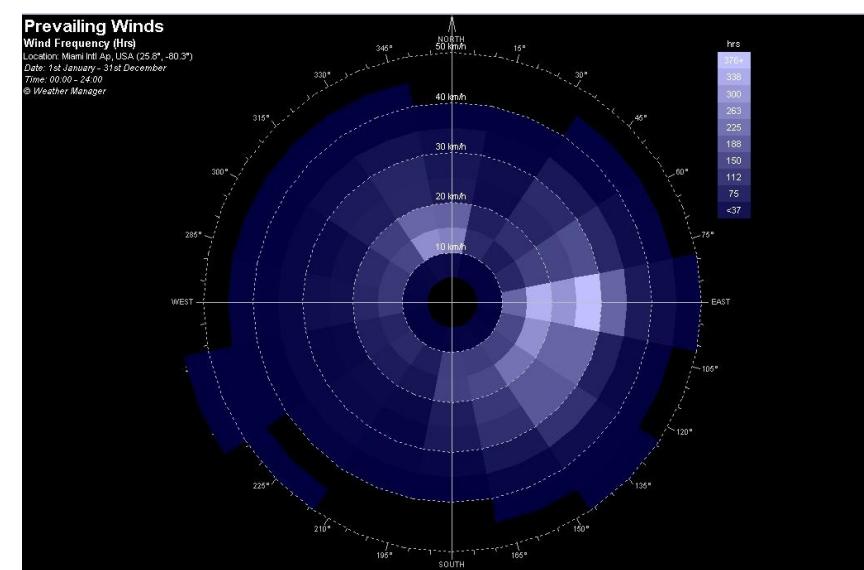
# Miami Climate

## Wind-Rose

The wind rose diagram below shows the frequency, direction and also the speed of the wind in hours during the whole year. It is shown that the wind with a speed in comfort zone mostly is from east and north west and in early hours of the day. Totally, the comfort area of wind rose is very small percent of the whole year and about 150 hours. The wind-rose here is showing the frequency of the wind through the whole year. Circles here indicates the wind speed and the radials show the wind direction the colored parts of each spoke represents the hours of wind rose on that direction and speed.



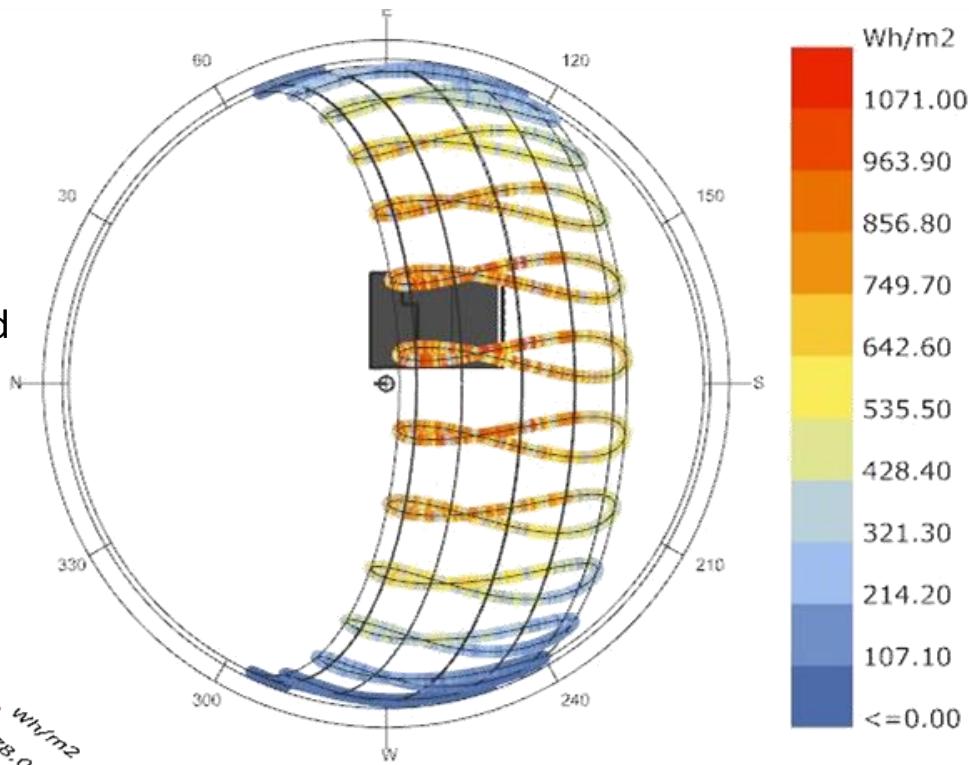
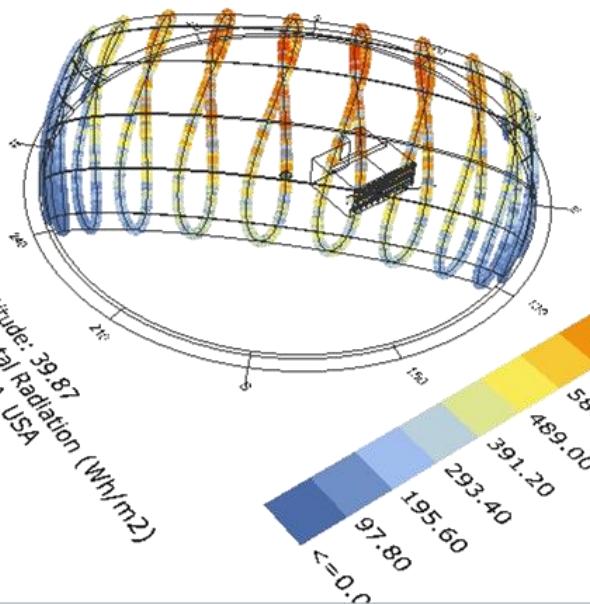
Wind-Rose  
Miami Intl Ap\_FL\_USA  
1 JAN 1:00 - 31 DEC 24:00  
Hourly Data: Wind Speed (m/s)  
Calm for 5.84% of the time = 512 hours.  
Each closed polyline shows frequency of 1.7%. = 150 hours.



In the prevailing wing graph above, this also can be seen.

# Miami Climate Sunpath

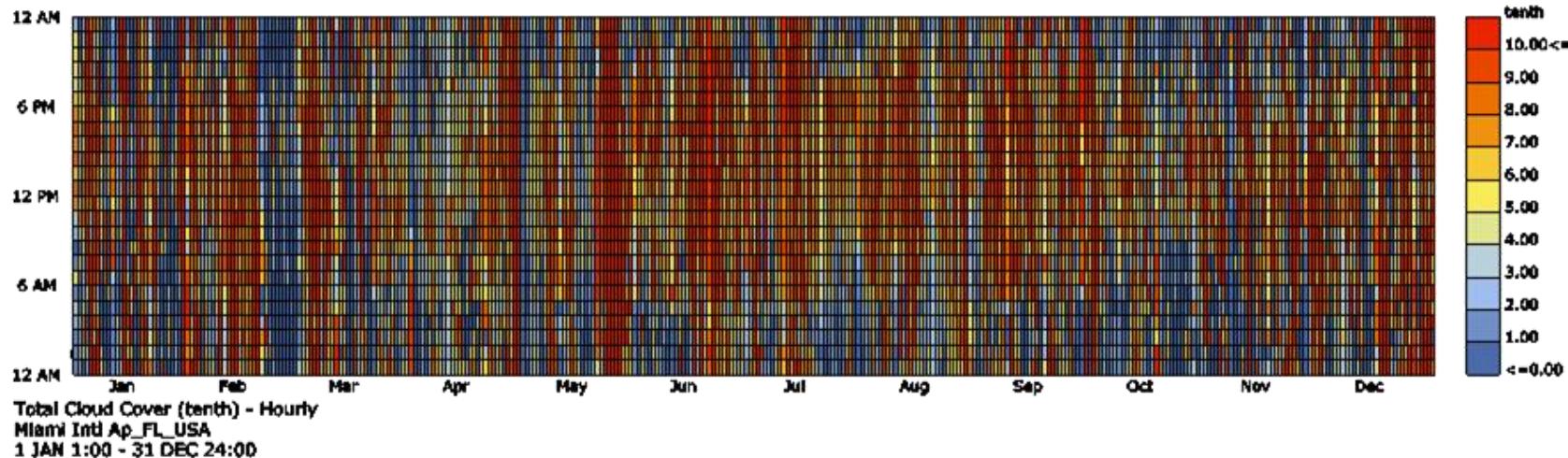
Sunpath of Miami in compared with Philadelphia sunpath shows much stronger values . The high bound in Philadelphia legend is 100WH/sqm more less than Miami.



Relative humidity in the chart above indicates that approximately most of the year the humidity is higher than 75% and only in months of Jan and Feb it is lower than usual and specially during 6PM to 12PM.

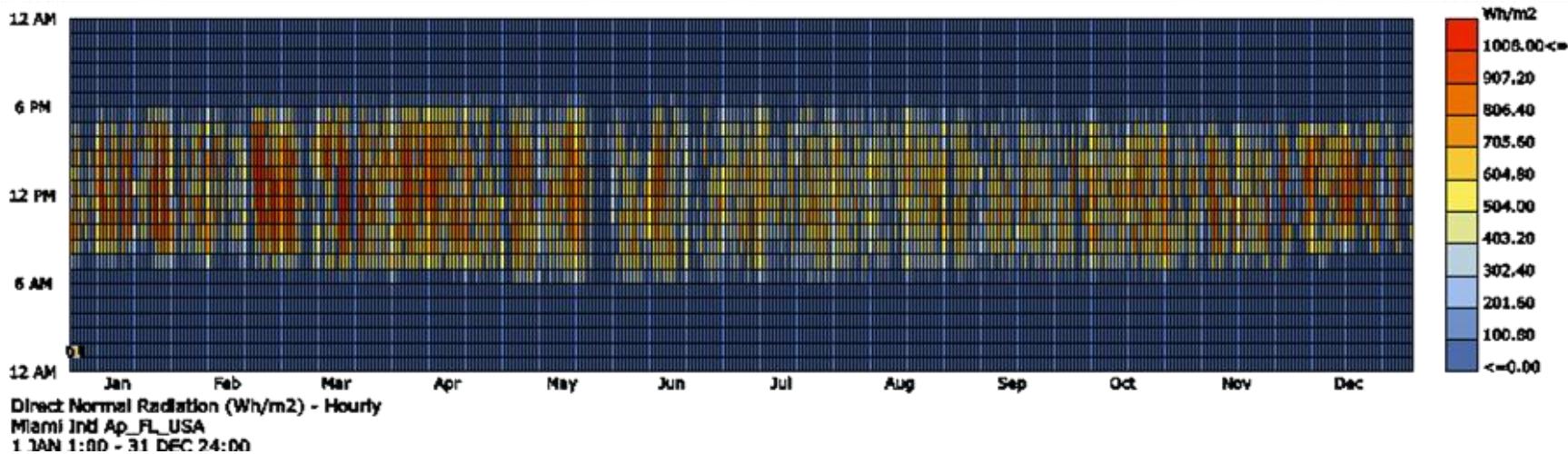
# Miami Climate

## Cloud Cover/ Annual Radiation



Cloud cover chart of Miami shows that on May, parts of June, Aug and Dec, the sky is covered by clouds mostly.

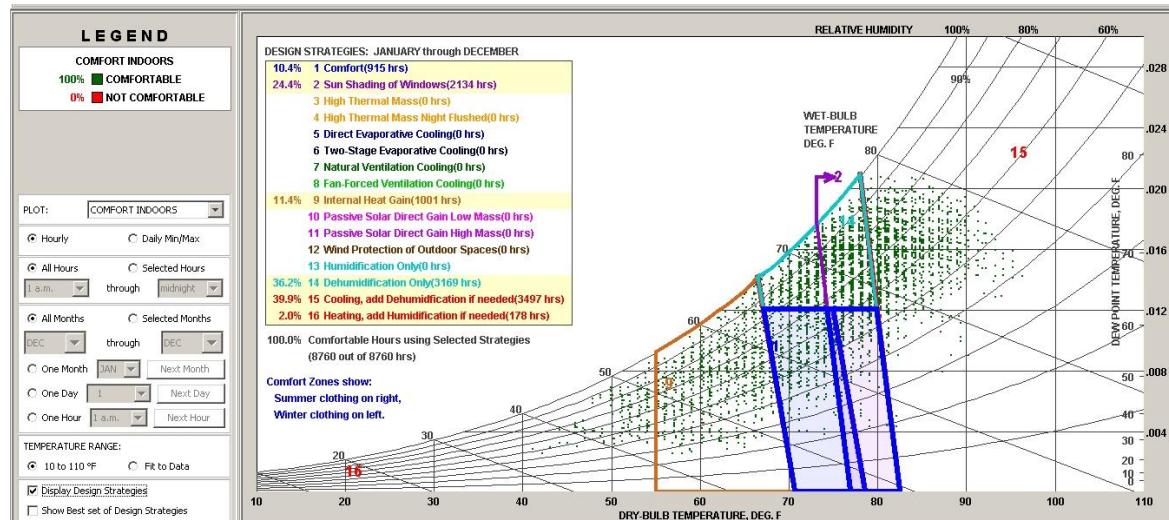
The annual radiation also verifies this assumption as in those months stated above the radiation is less.



# Miami Climate Strategies

## Recommended Strategies for design in Miami Climate

As shown in Psychometric chart, the most important issue in the hot and humid climate of Miami which is confronting the comfort, is humidity. As the higher temperature gets, the more humidity it can hold, the high temperature of the area increases the feeling of humidity and eventually muggy.



### Active Strategies for Design in hot and humid climate:

**Dehumidification:** The first and the most crucial strategy recommended to be applied in this climate is dehumidification. decreasing the percentage of humidity in the air will result in more comfort feeling during the day and the night.

**Cooling:** As the temperature mostly does not go below 68 F during the year in Miami, cooling seems to be inevitable and very much important in creating more comfort hours during the day.

# Miami Climate Strategies

**Passive strategies for design in hot and humid climate :**

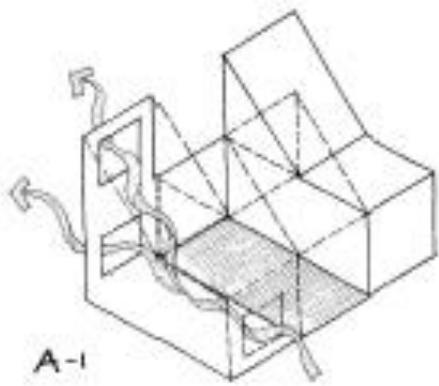
**Natural Ventilation:** In this climate the only ventilation which would perform is **central stack ventilation** combined with cross-ventilation, which is designed by openings in opposite directions in tall ceilings. In this way, stack ventilation bunches the rooms to use central stack ventilation and the outside to form a cross-ventilated breeze way through the entire building.



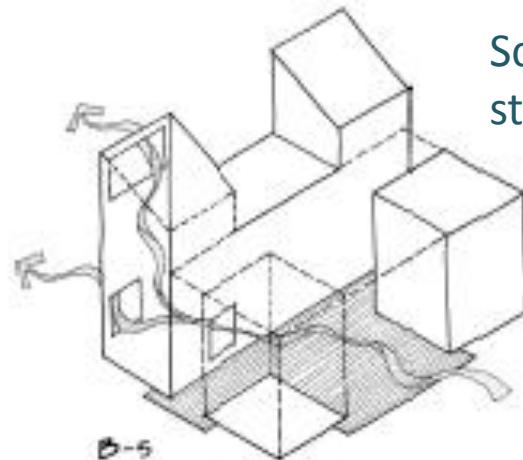
Logan House, Tomba, Miami, FL

**Shading:** First passive strategy is to prevent the sun radiation come in. It is showed clearly in psychometric charts that proper Shading has a great influence on decreasing the daytime high temperature in this climate.

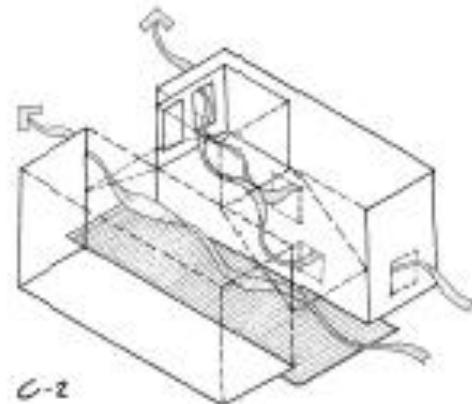
Scheme of Natural ventilation  
strategies



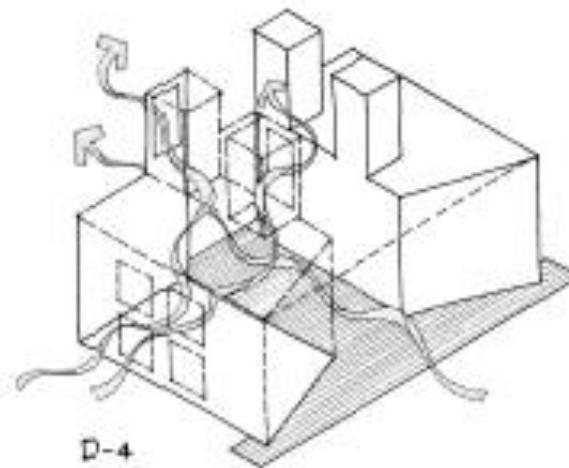
A-1



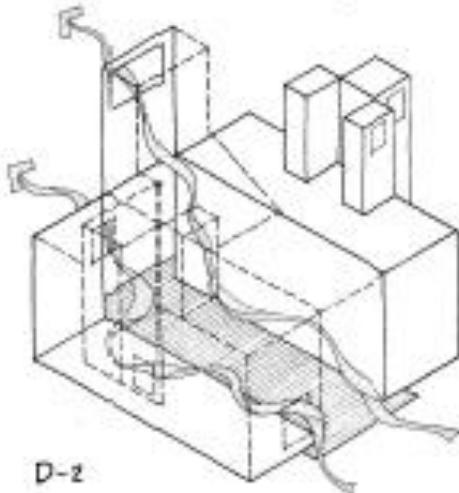
B-5



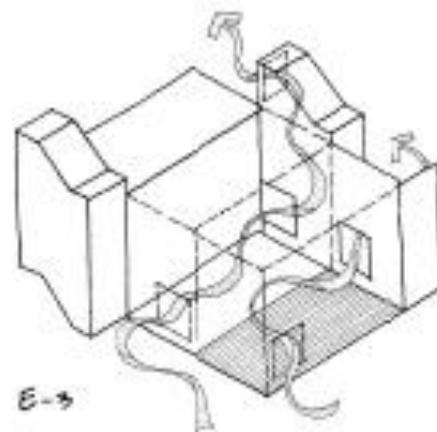
C-2



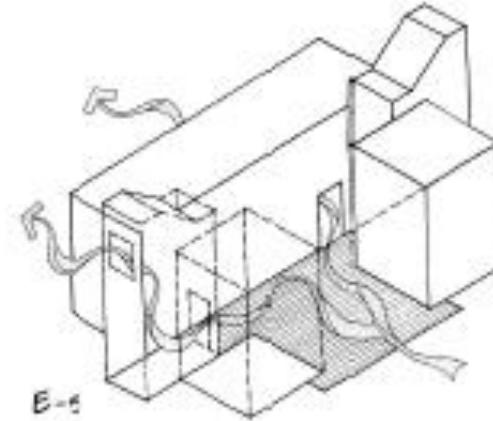
D-4



D-2



E-3

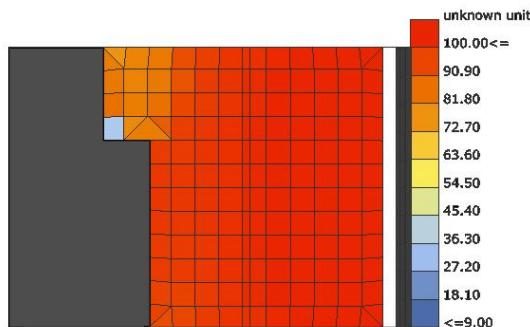


E-5

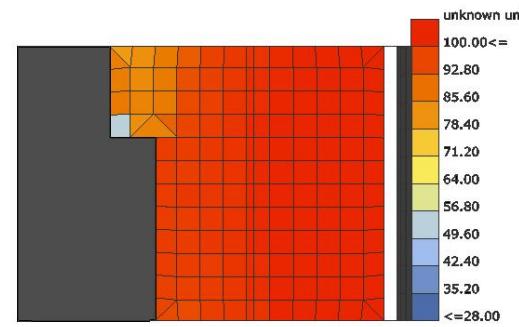
# Base Case

## Orientation \_ Annual Daylighting

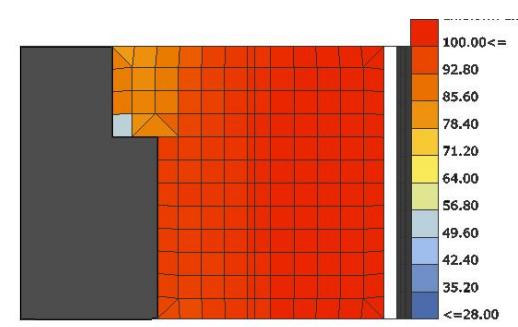
- Orientation of the room is being assessed for finding the best orientation for daylighting.



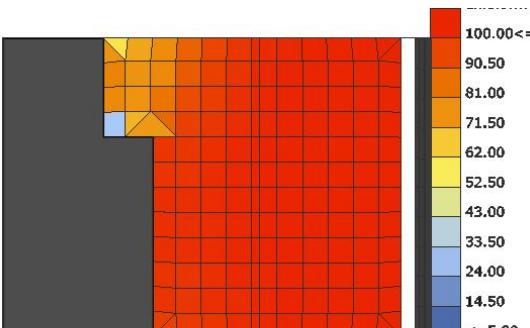
45  
no title



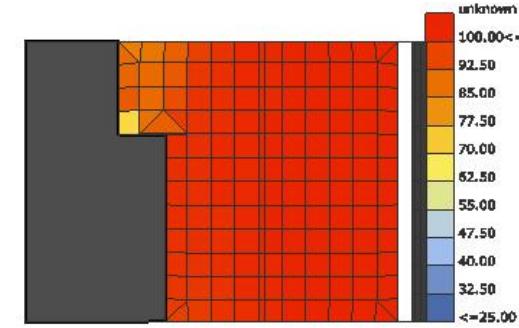
90  
no title



0  
no title



135  
no title



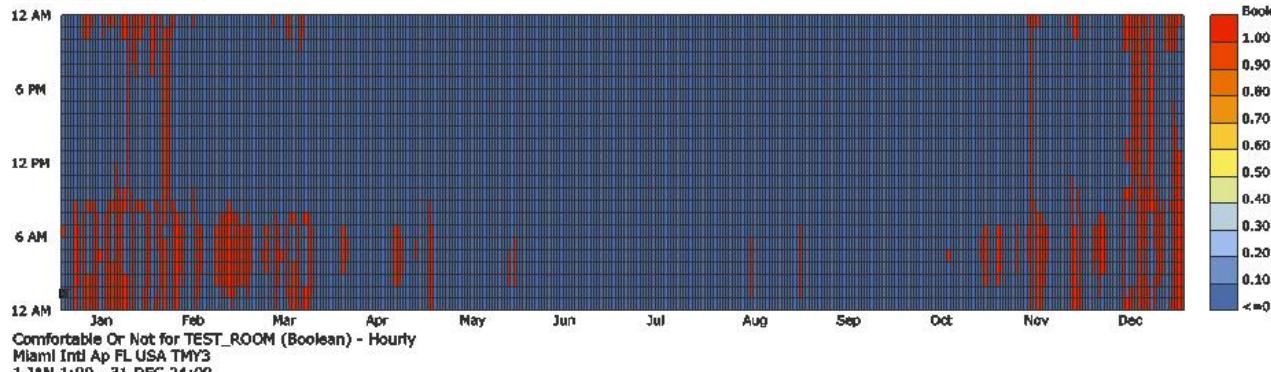
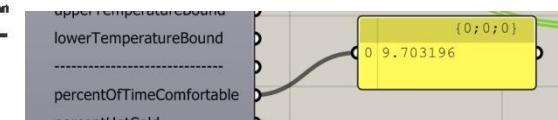
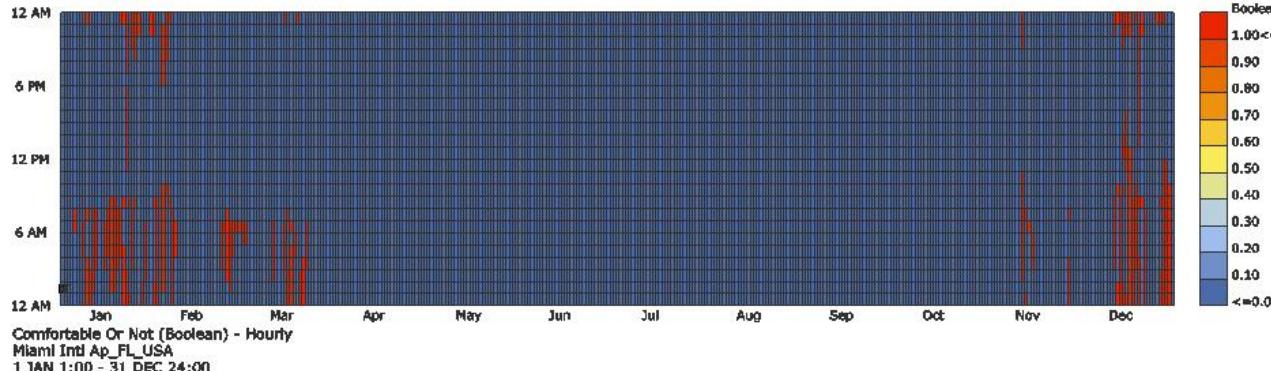
270  
no title

0/ SDA:98.53  
45/SDA:97.79  
90/SDA:  
135/SDA:97.79  
270/SDA: 98.53

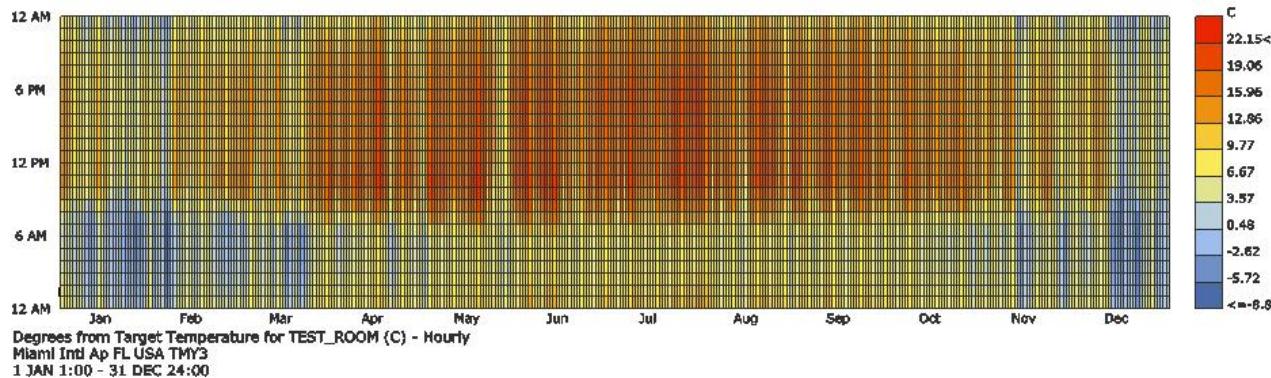
# Base Case

## Orientation \_ Comfort

- Orientation of the room is being assessed for finding the best orientation for most comfort.



Adaptive Comfort:  
9.7%

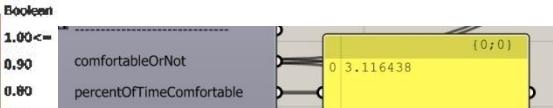
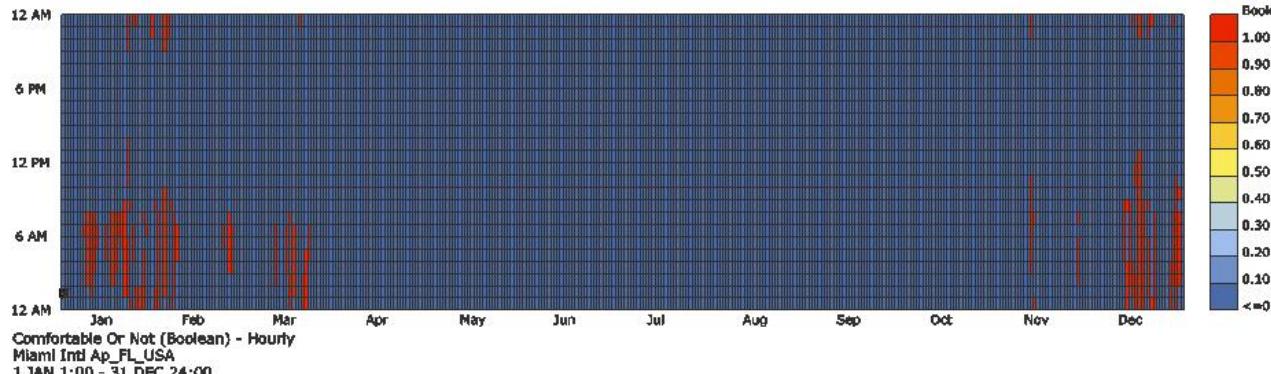


Degrees from target

# Base Case

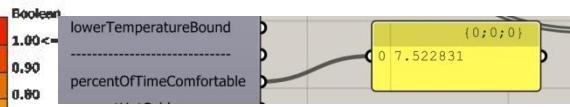
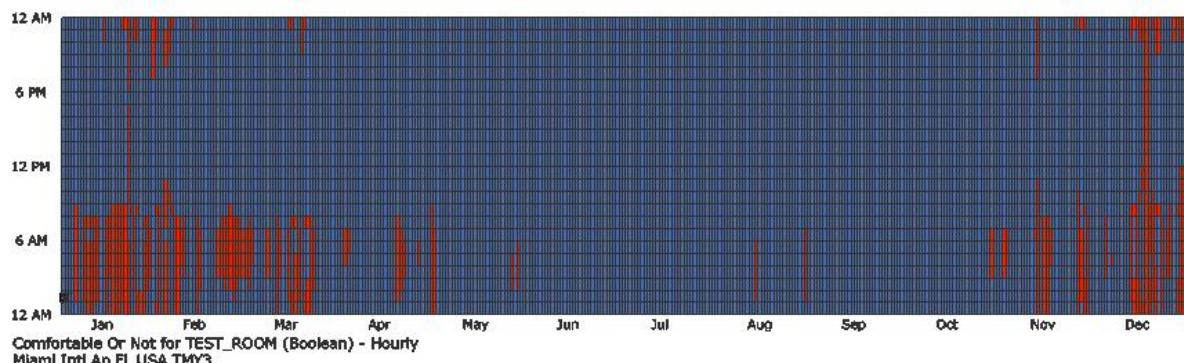
## Orientation \_ Comfort

- Orientation of the room is being assessed for finding the best orientation for most comfort.

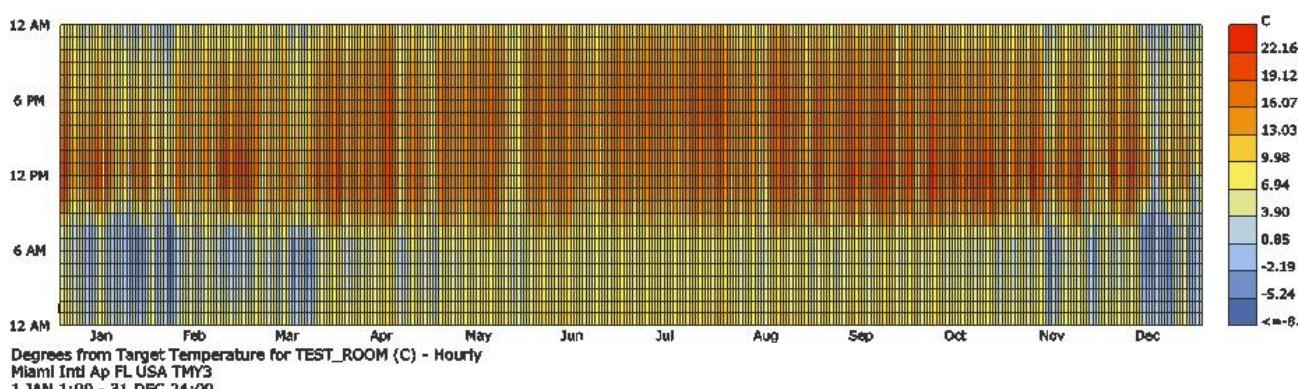


Base/ Orientation: 45

PMV: 3.15%



Adaptive Comfort:  
7.52%

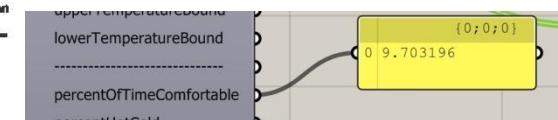
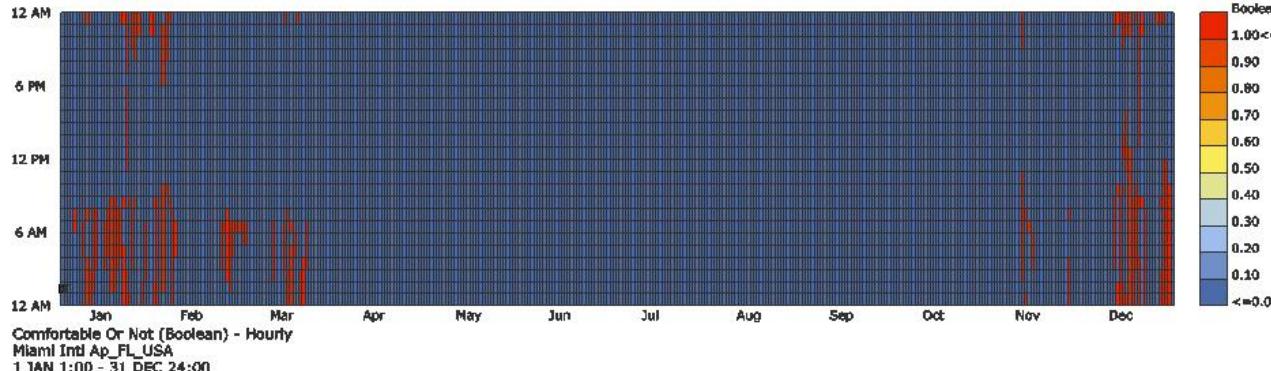


Degrees from target

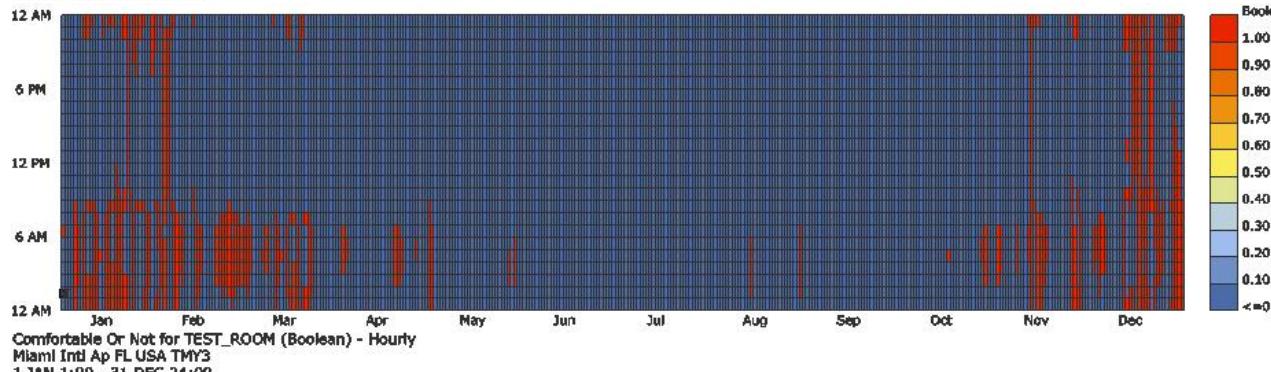
# Base Case

## Orientation \_ Comfort

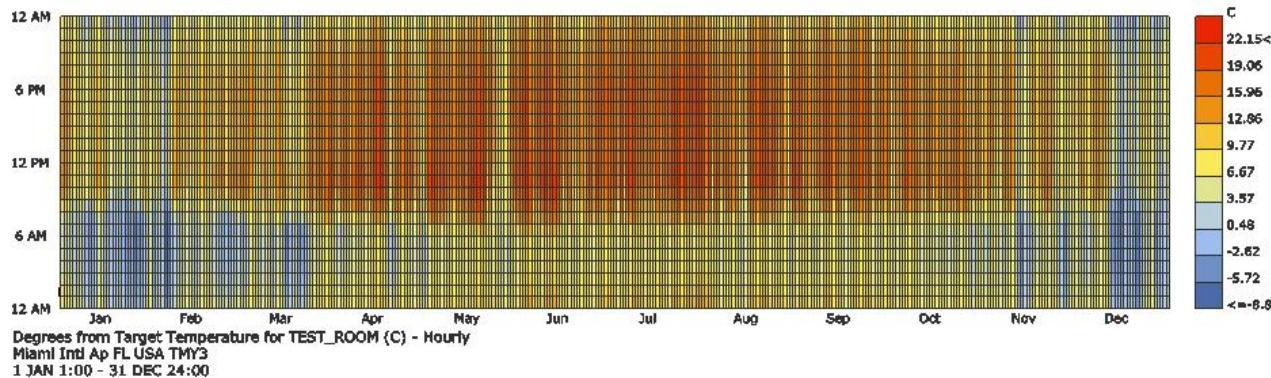
- Orientation of the room is being assessed for finding the best orientation for most comfort.



Base/ Orientation: 90  
PMV



Adaptive Comfort:  
16.4%

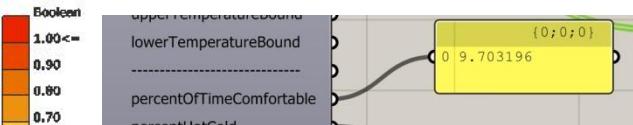
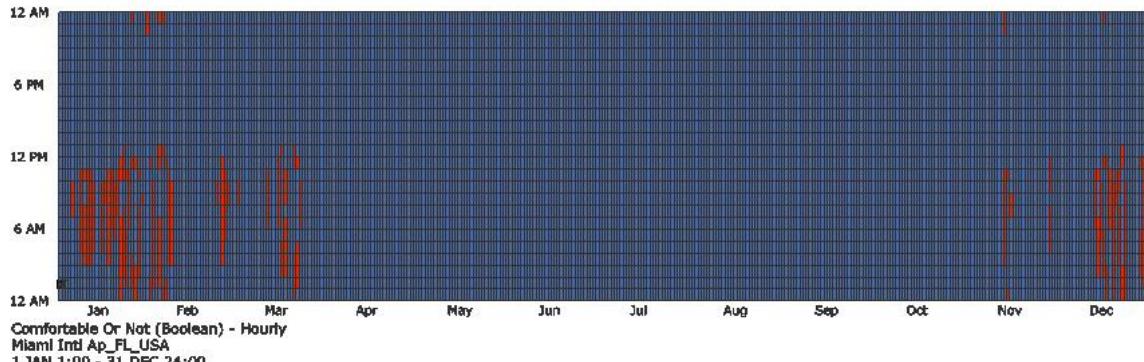


Degrees from target

# Base Case

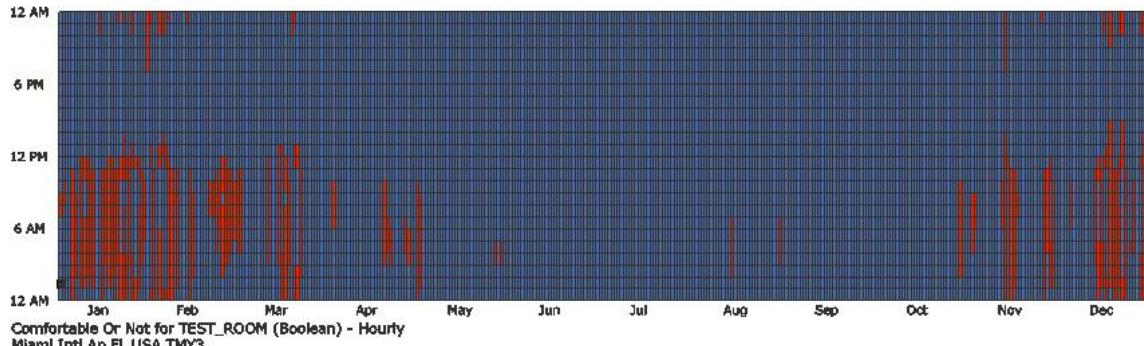
## Orientation \_ Comfort

- Orientation of the room is being assessed for finding the best orientation for most comfort.

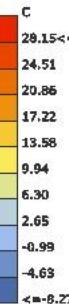
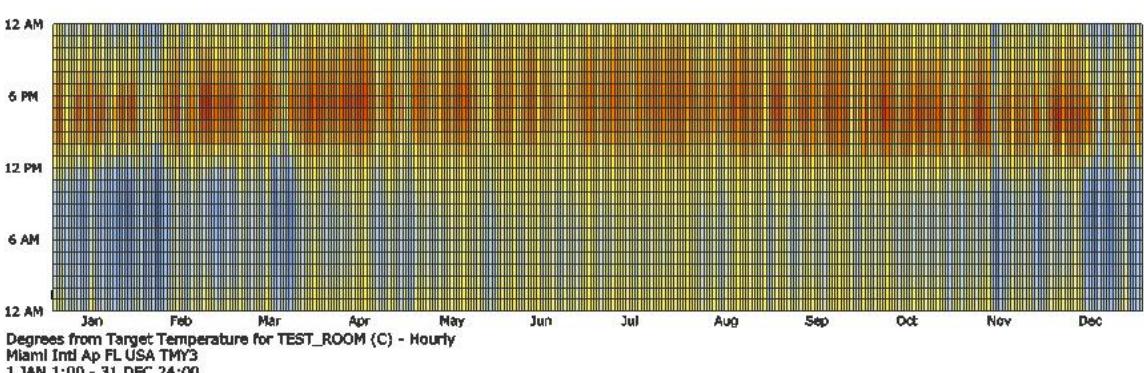


Base/ Orientation: 135

PMV



Adaptive Comfort:  
9.7%

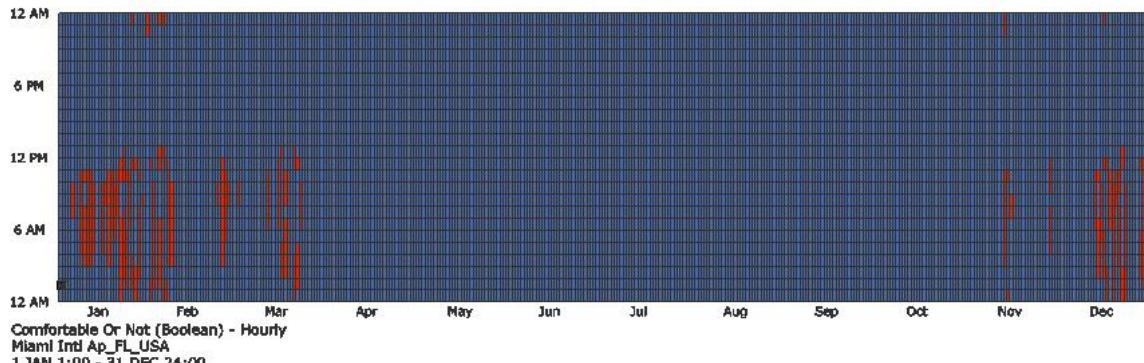


Degrees from target

# Base Case

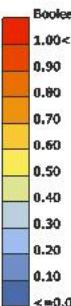
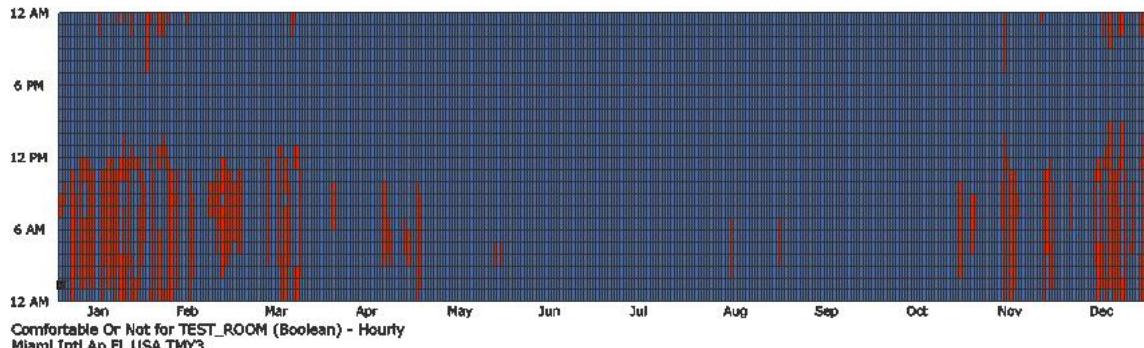
## Orientation \_ Comfort

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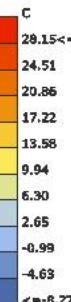
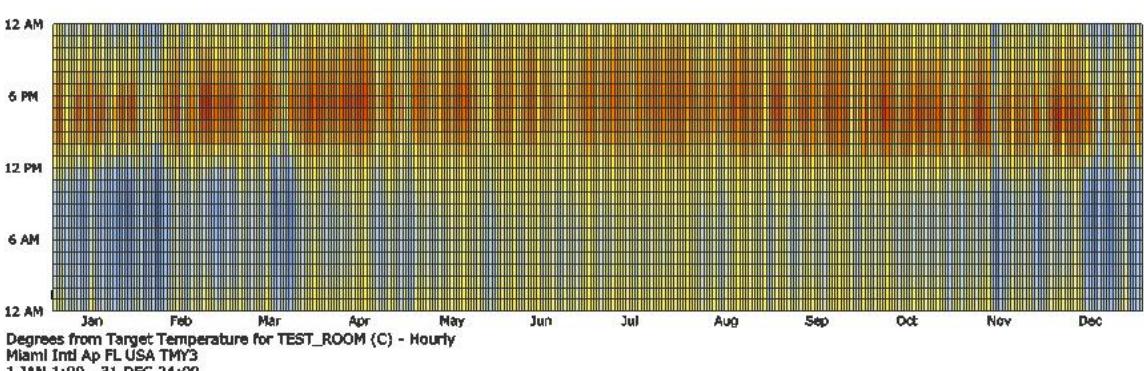


Base/ Orientation: 135

PMV



Adaptive Comfort:  
9.7%



Degrees from target

# Problem solving process

Here it is aimed to reach an acceptable level of comfort and daylighting by designing the shade. Three different shading design proposals are being designed and simulated to figure out the best result.

Other factors being assessed in this study are:

- Orientation
- The ratio of glazing area
- The material of the glass and walls
- And schedule

All parameters stated above are being applied, changed and assessed to see the influence of each parameter and to reach the best result.

# Problem solving process

## Orientation

### Orientation

Orientation of the room in 5 different angles is simulated both for daylighting and comfort and as a result, the best orientation which is providing the most comfort with enough daylighting is façade being designed facing north.

As showing on charts, the most level of comfort is occurring when the room is facing north and Least amount of solar radiation is getting into the space.

As a result there is approximately very little need for heat gain in this climate and the only problem is the daylighting. In this orientation providing enough daylight is the challenge as well as level of comfort.

# Ventilation

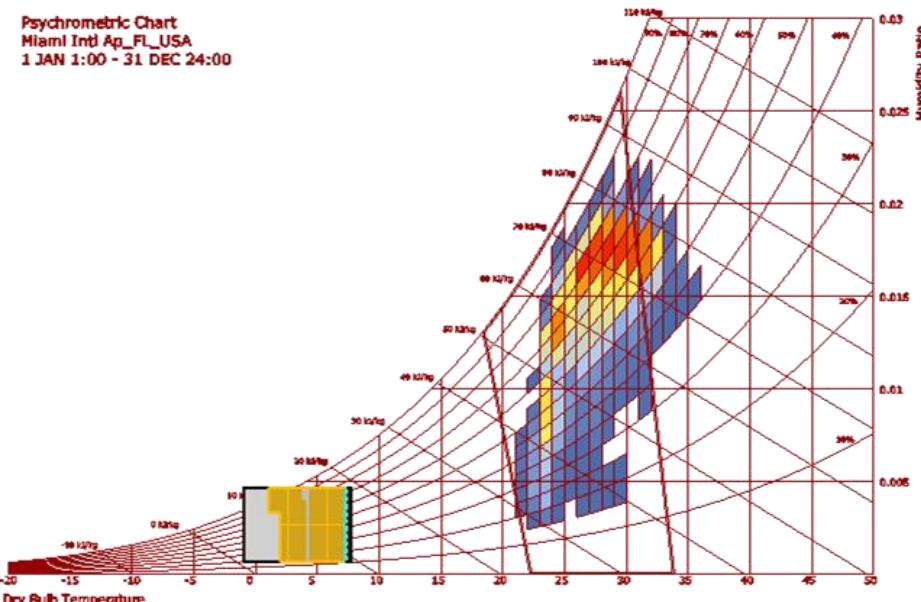
Since Miami climate as stated before is located in zone 1a which is the hot and humid weather, ventilation and dehumidification has a great effect on increasing the comfort level and percentage.

The base case without ventilation with same other parameters is showing about 16% of adaptive comfort which is quite low.

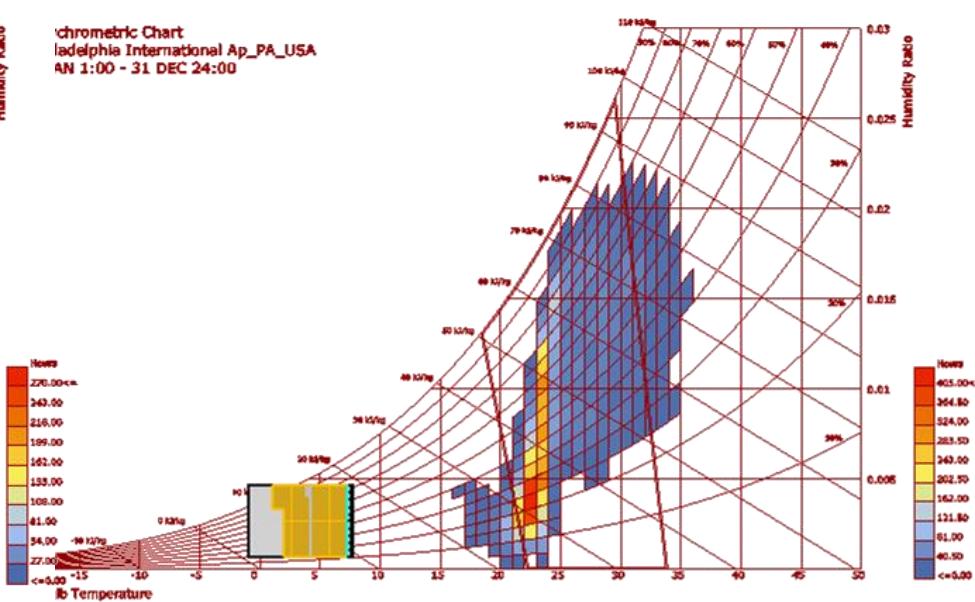
This difference is happening due to the reason that in the cold weather of Philadelphia the more solar radiation gets into the room, which will cause heating, the higher level of comfort it reaches.

Conversely, simulations showed that in Miami, due to hot and humidity, the strategy should follow, least solar radiation in plus ventilation and dehumidification.

Psychrometric Chart  
Miami Intl Ap\_FL\_USA  
1 JAN 1:00 - 31 DEC 24:00



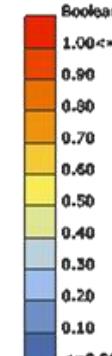
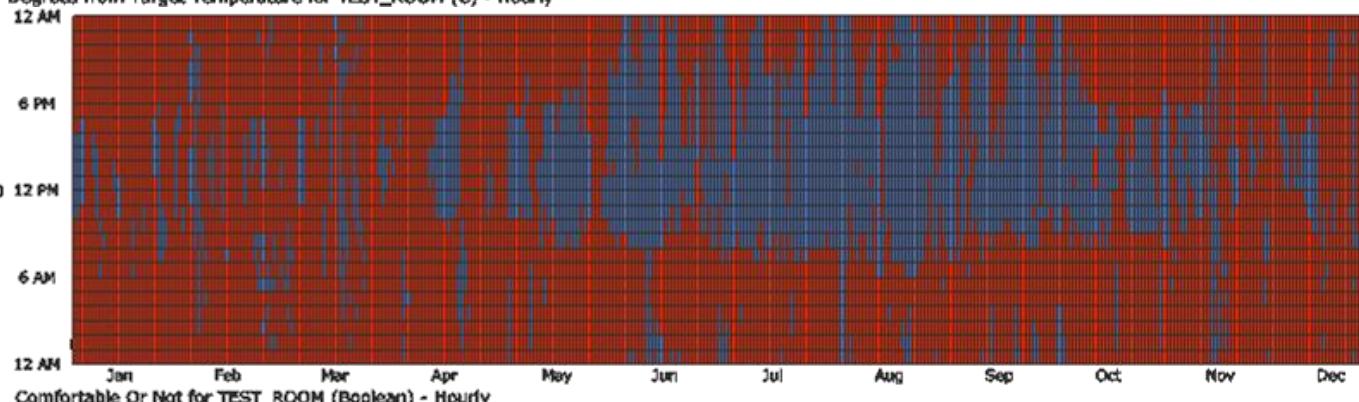
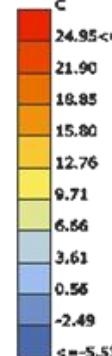
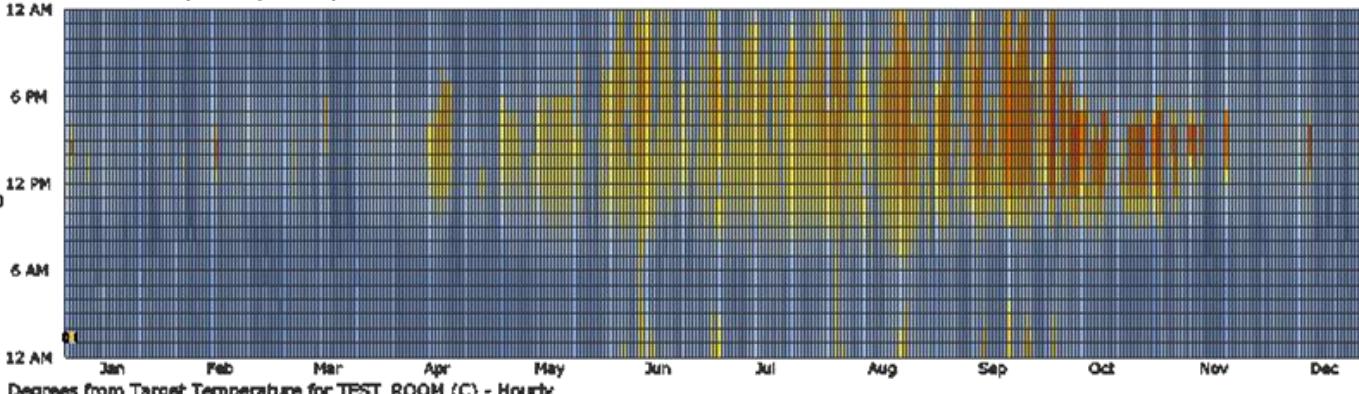
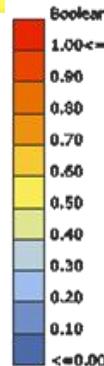
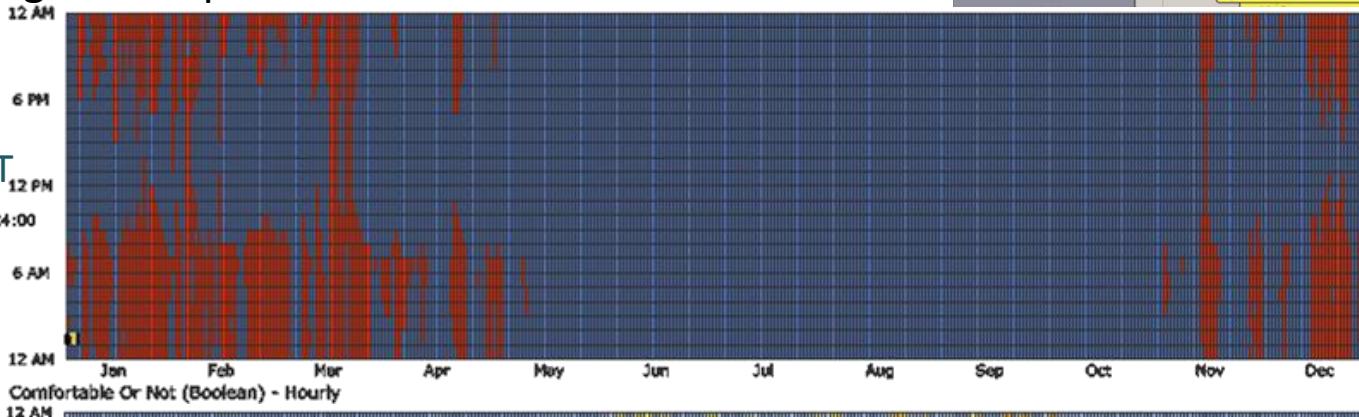
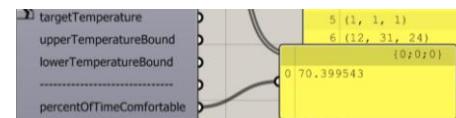
Psychrometric Chart  
Philadelphia International Ap\_PA\_USA  
1 JAN 1:00 - 31 DEC 24:00



# Base case with Ventilation

- Base case without shading and with ventilation

Percentage of adaptive comfort :70.39%



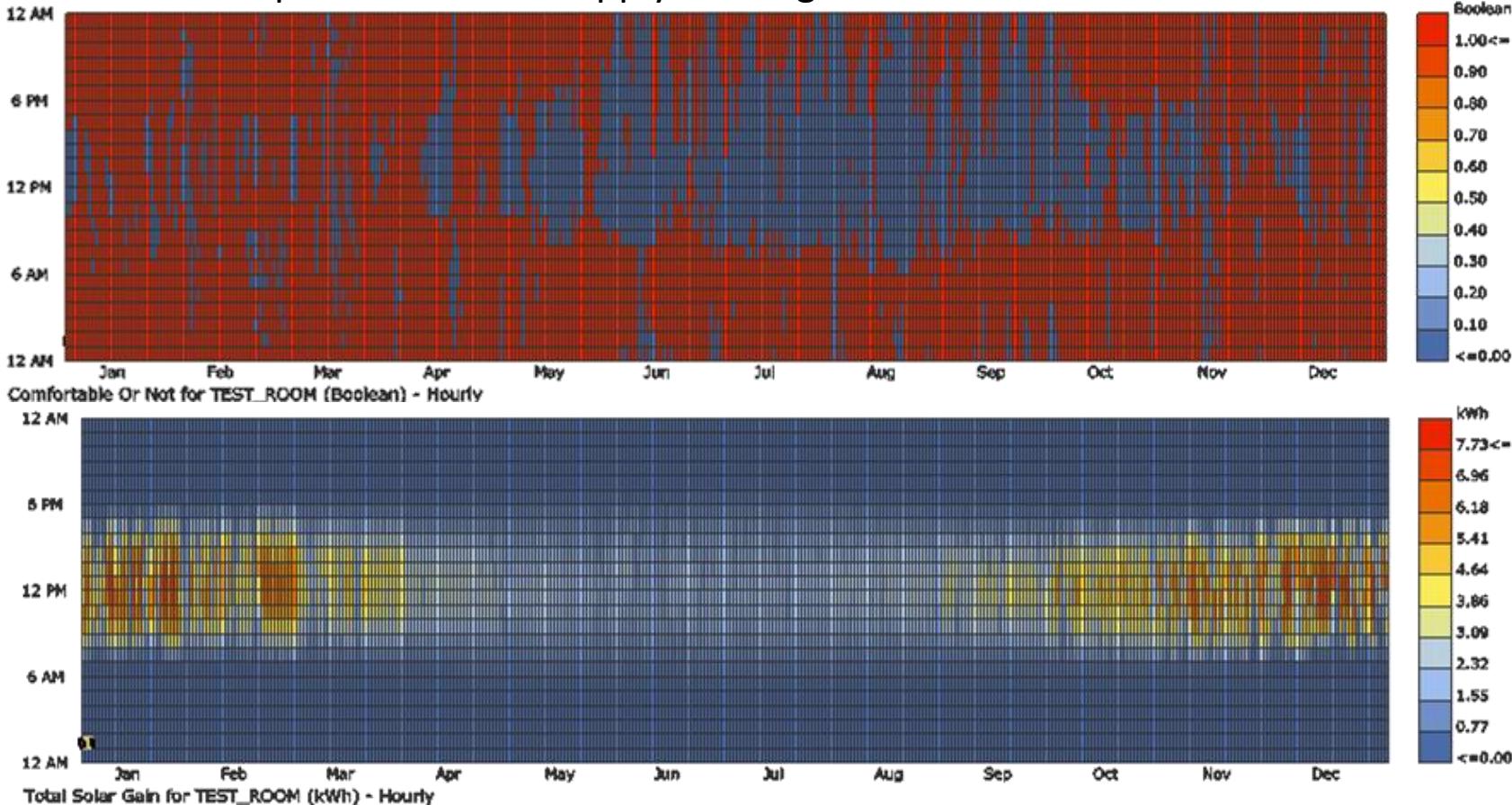
# Base case with Ventilation

Percentage of adaptive comfort :70.39%

- Base case without shading and with ventilation

PMV chart and adaptive comfort shows that the base case which is being conditioned by ventilation without any shading is having serious problem in 9 months of the year from march to November from 11am to 4 pm.

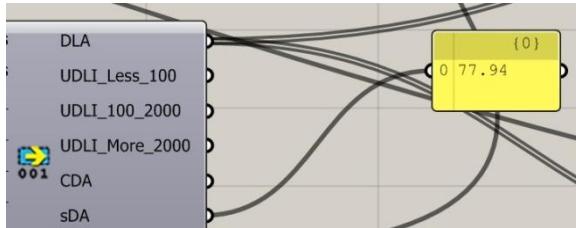
Here at this point we start to apply shading to increase the level of comfort.



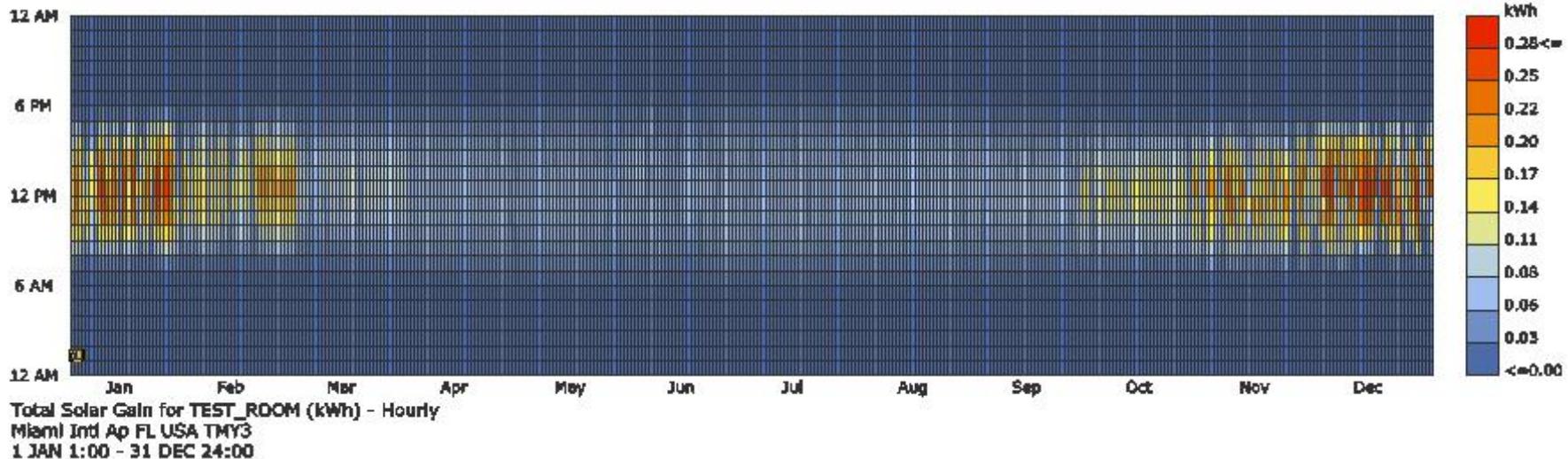
# Shading Design Proposal I

## Daylighting

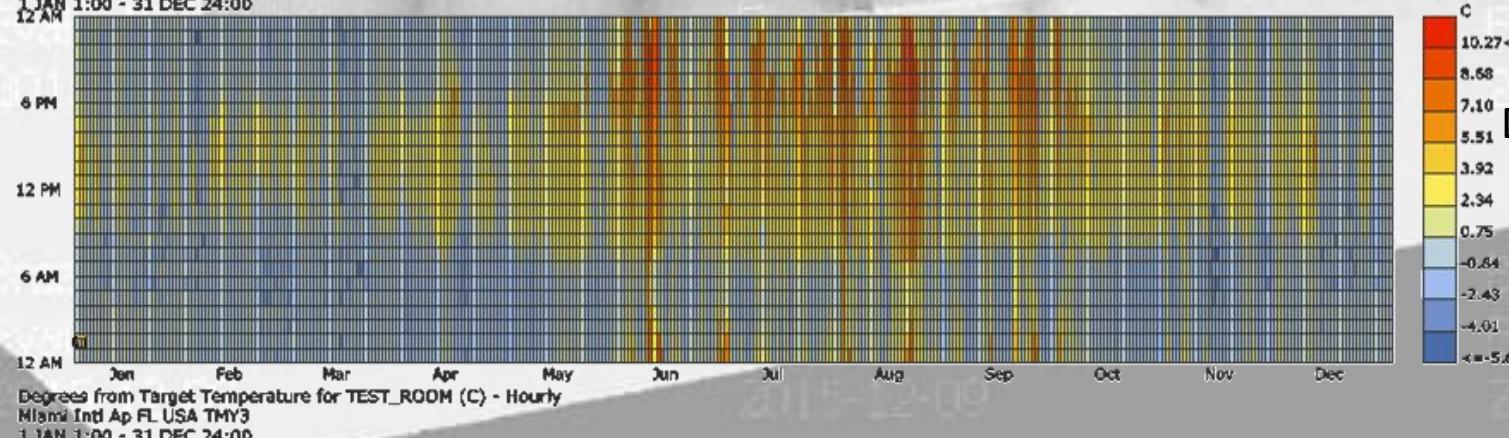
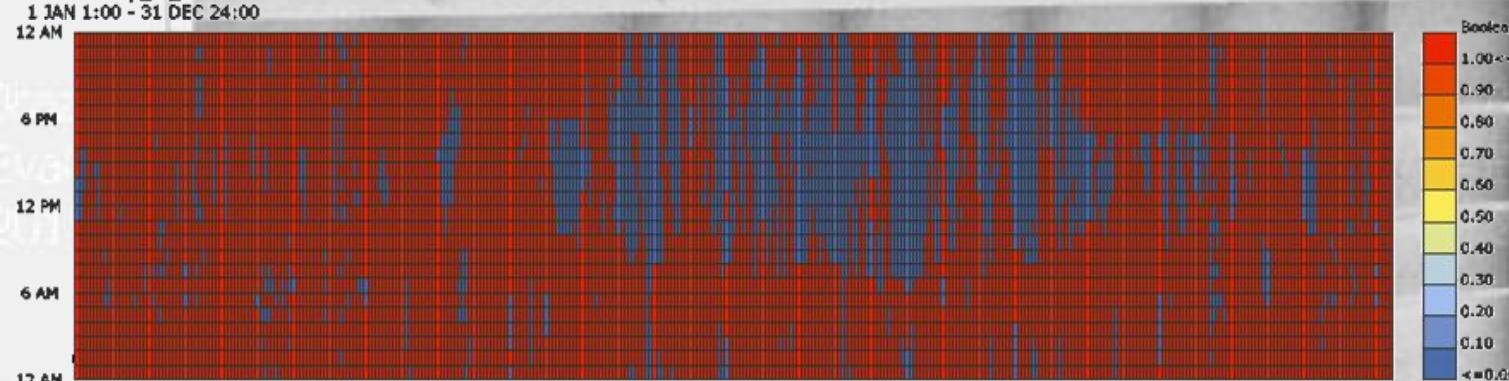
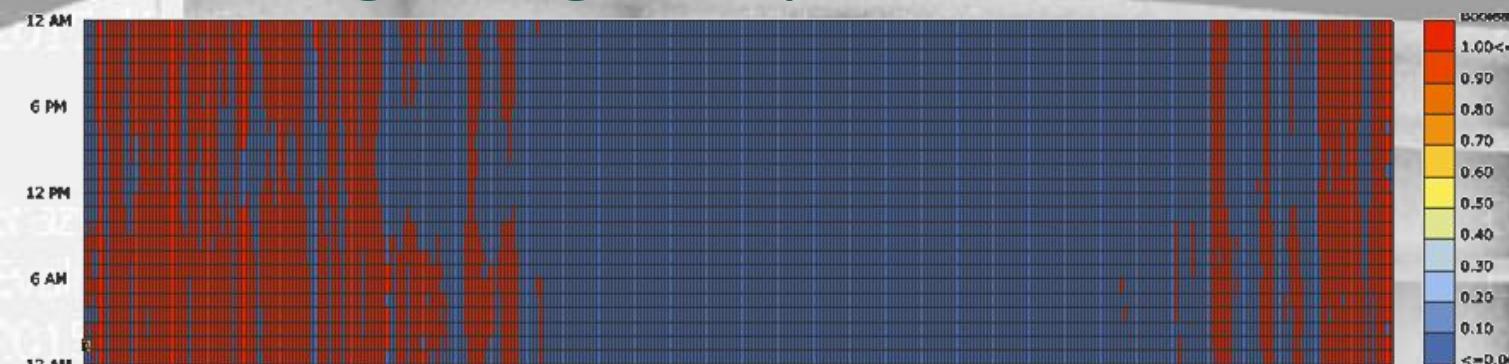
First shade design is facing north and providing  
SDA: 77.94



Total solar gain chart shows that during March and April total solar gain has been reduced by this shade and the percentage of comfort has been increased to 72.68



# Shading Design Proposal I



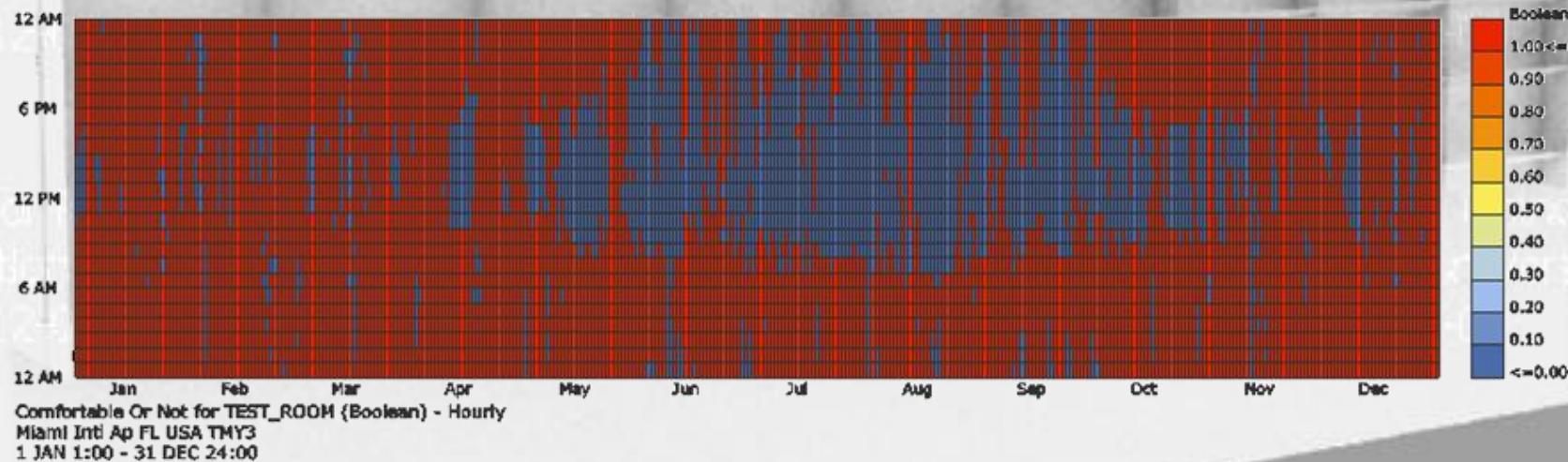
# Shading Design Proposal I

- Adaptive comfort and comfort charts show that shade I is not a very helpful device for level of comfort.
- And also the days hot or cold also shows that there are still many days very hot in this room which means a lot of radiation coming into the room which should be blocked in order to prevent heat gain.
- On this design proposal, we start to change other parameters.

## 1. Glazing Ratio:

By adding a glazing ratio of 0.7%, the adaptive comfort level is increased to 74.32%.

This increase shows that decreasing the glass surface to 70% which is causing less radiation getting into the room is working better in this climate.



As it is seen in the adaptive comfort chart the after adding glazing ration, there is still a lot of discomfort specially during March to November from 10AM to 4PM.

# Shading Design Proposal I

## Changing other parameters and applying new ones

### 2.Material:

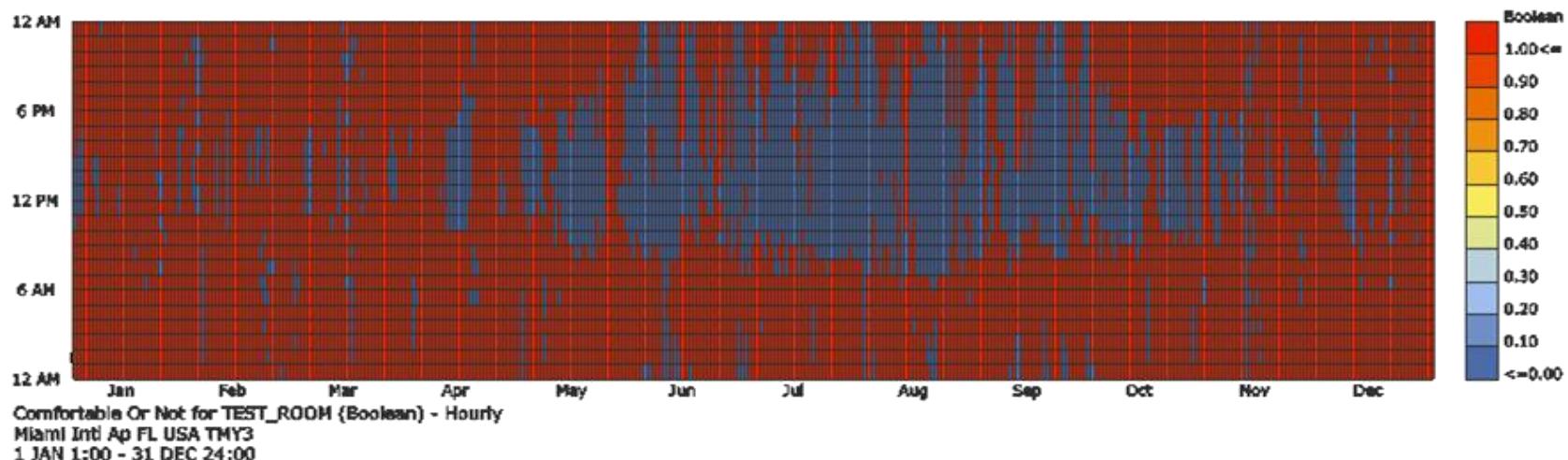
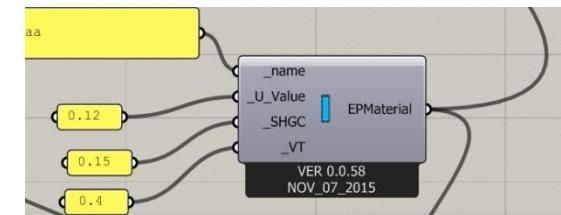
For the glass material, a new glass type description is defined to the window construction component to be tested for the level of comfort.

Instead of a single glazed window, a double glazed window, high performance called “Low SHGC Thermotec” with the following configuration has been added to the window component:

U value: 0.12

SHGC :0.15

VT: 0.4



As it is seen in the adaptive comfort chart the after adding high performance glazing material, is increased to 79.88%.

All, parameters which had positive effect on the increasing of the comfort level will be applied to all design proposals after this as well.

# Shading Design Proposal II

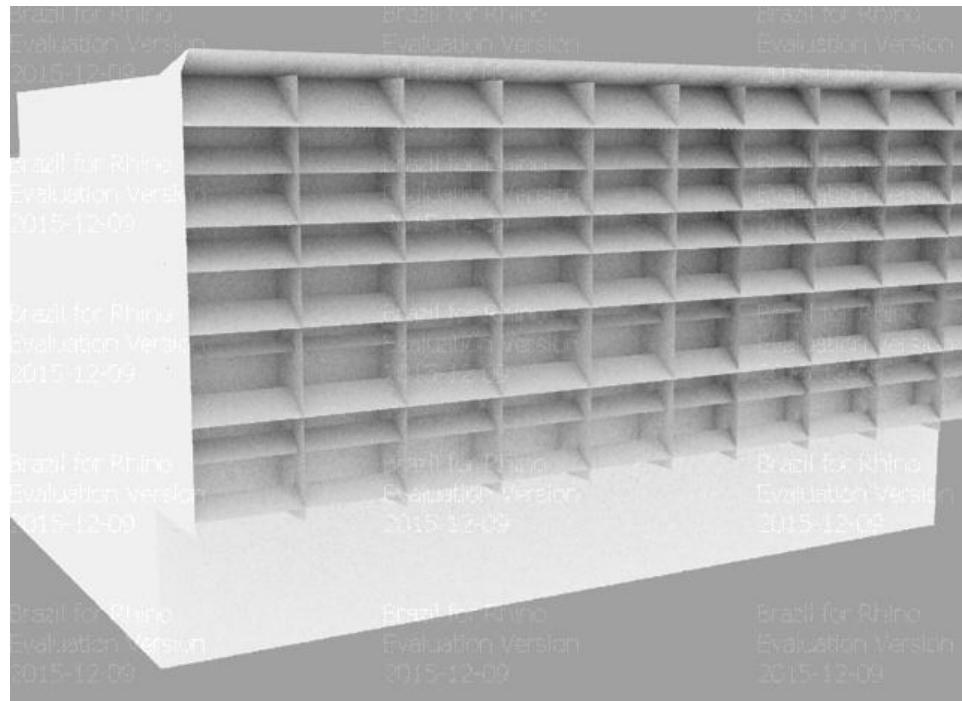
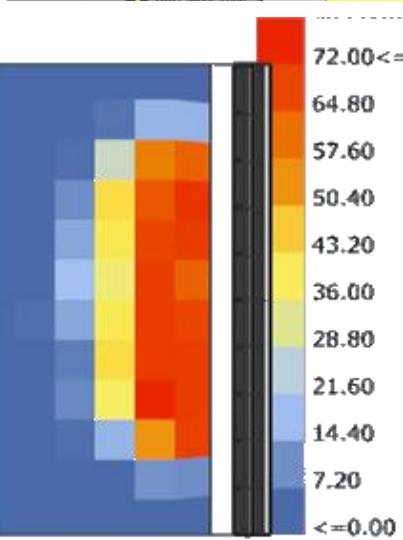
## Daylighting

Second shade design is facing north and providing

SDA: 11.76%

### lighting Schedule

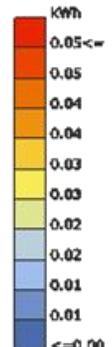
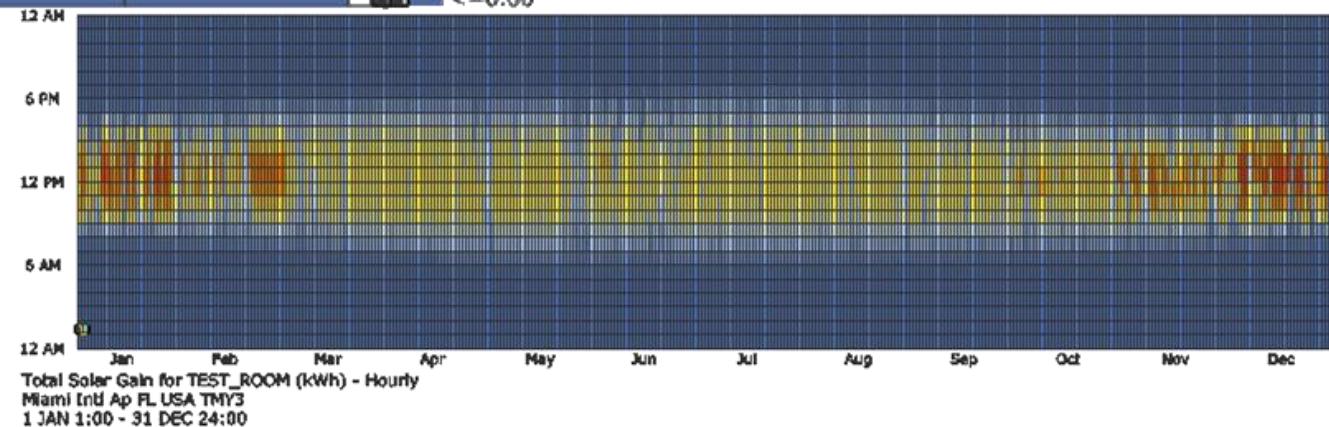
```
_illFilesAddress DLA  
_testPoints UDU_Less_100  
ptsVectors_ UDU_100_2000  
occupancyFiles_ UDU1_More_2000
```



As it is shown on the daylighting grid there is not enough daylighting in the space with this shade and also the solar gain is quite low during May to October.



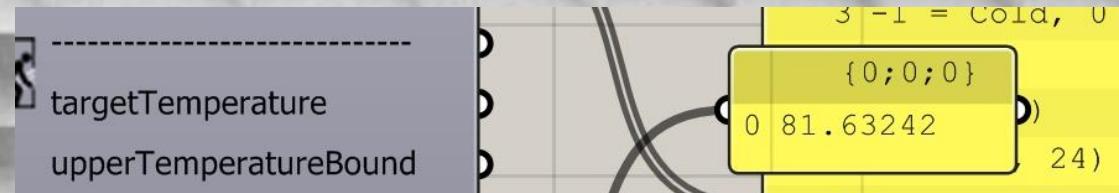
no title



# Shading Design Proposal II

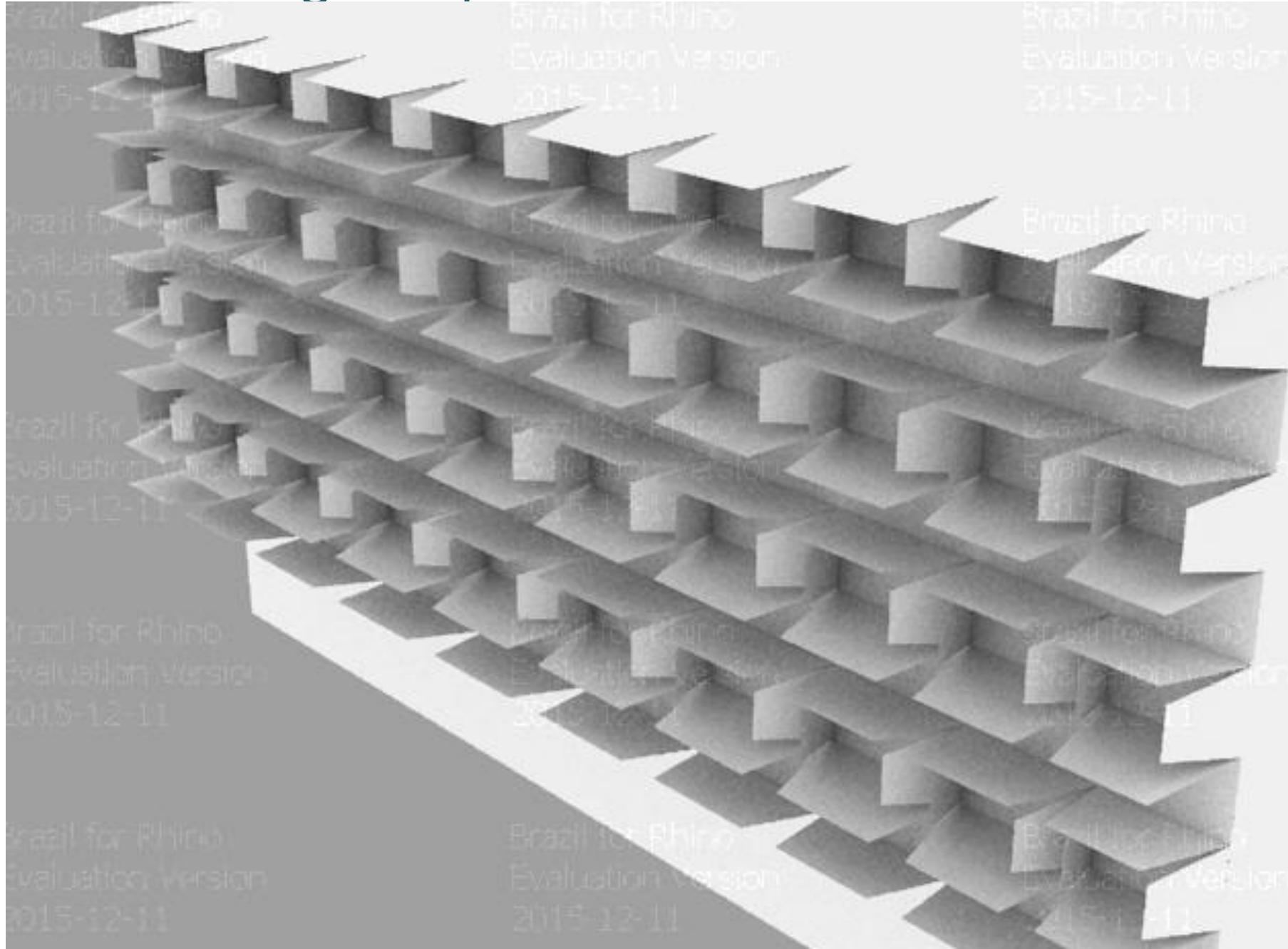
## Changing other parameters and applying new ones

Adaptive comfort:  
81.63%



As SDA is quite low in this design proposal, which is showing there is not enough daylighting entering into the space, the acceptable comfort level is not reliable.

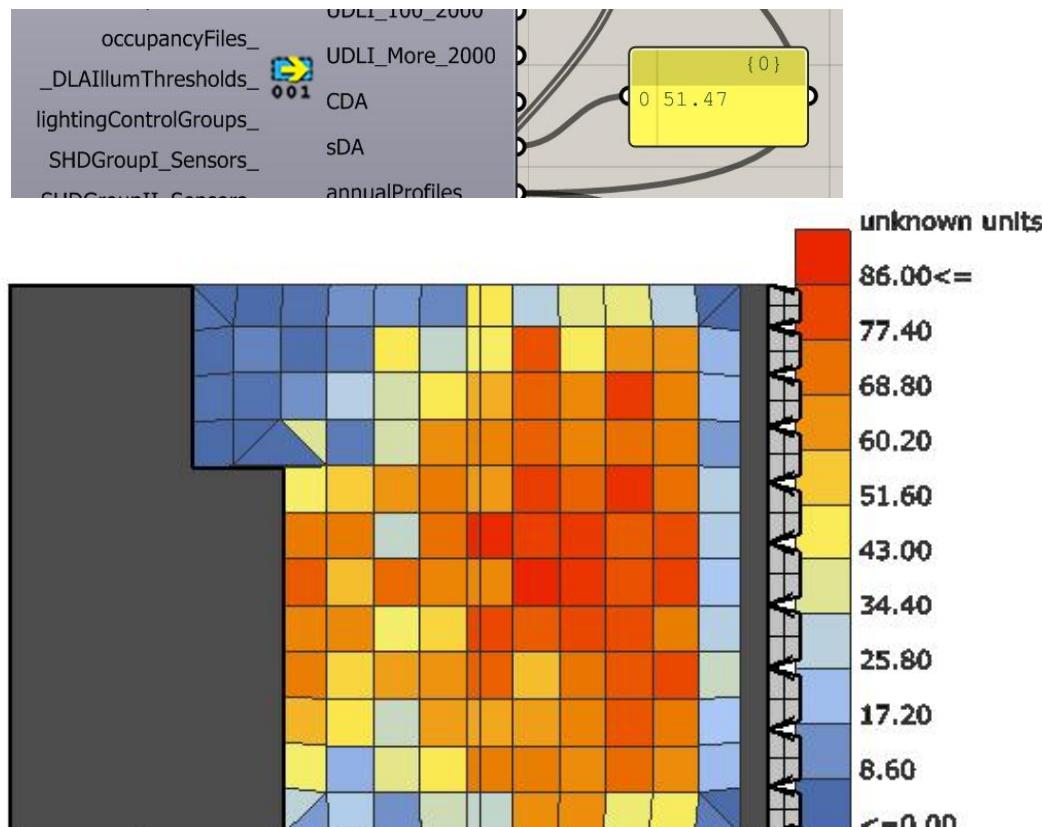
# Shade Design Proposal III



# Shade Design Proposal III

## Daylighting

SDA: 51.47%



This proposal is providing 51.47% SDA which shows that enough daylighting is being provided in the interior space of the room.

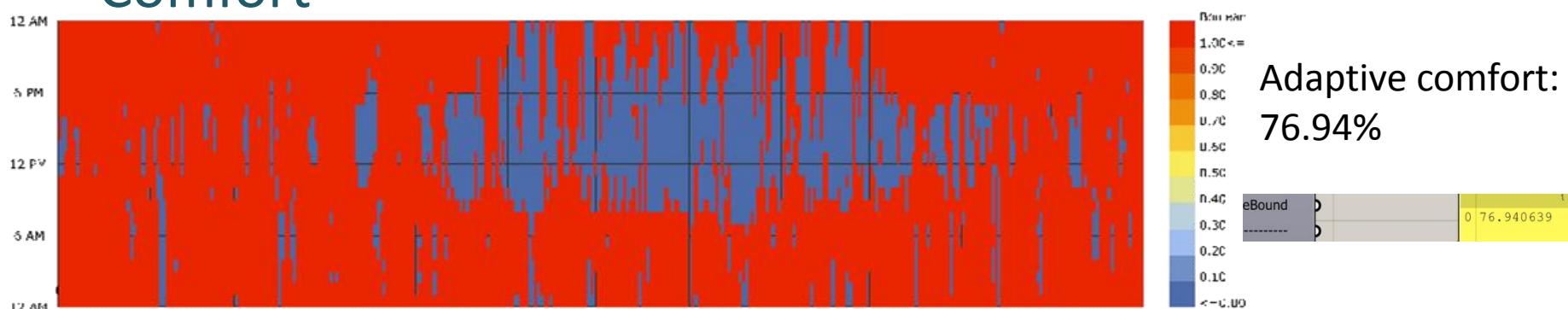
Glazing Ratio: 0.8



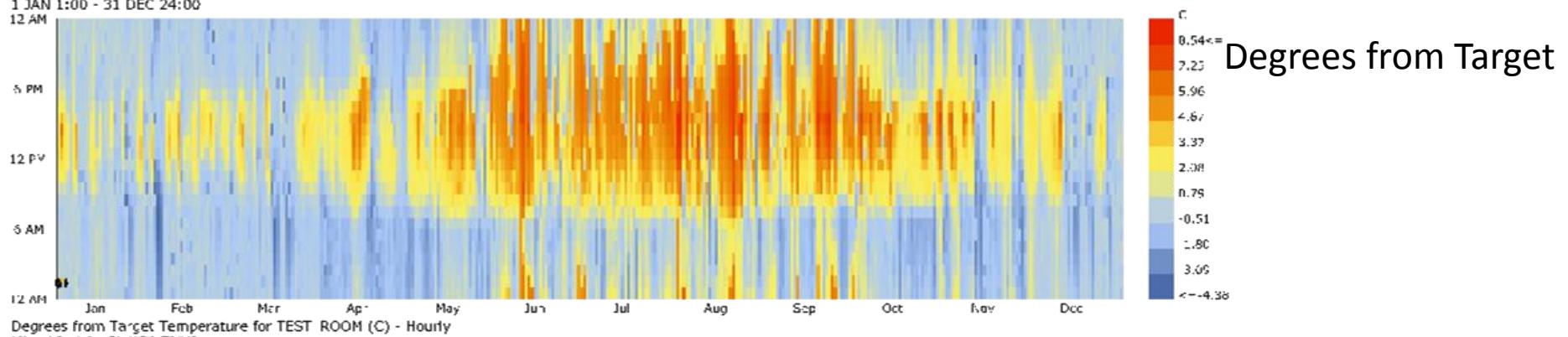
no title

# Shade Design Proposal III

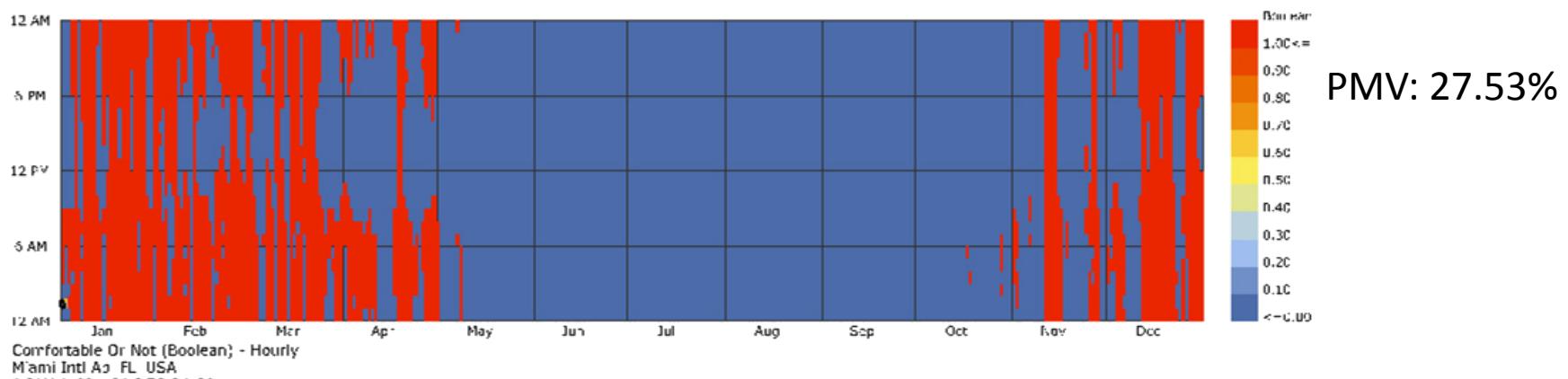
## Comfort



Comfortable Or Not for TEST ROOM (Boolean) - Hourly  
Miami Intl Ap FL USA TMY3  
1 JAN 1:00 - 31 DEC 24:00



Degrees from Target Temperature for TEST ROOM (C) - Hourly  
Miami Intl Ap FL USA TMY3  
1 JAN 1:00 - 31 DEC 24:00



PMV: 27.53%

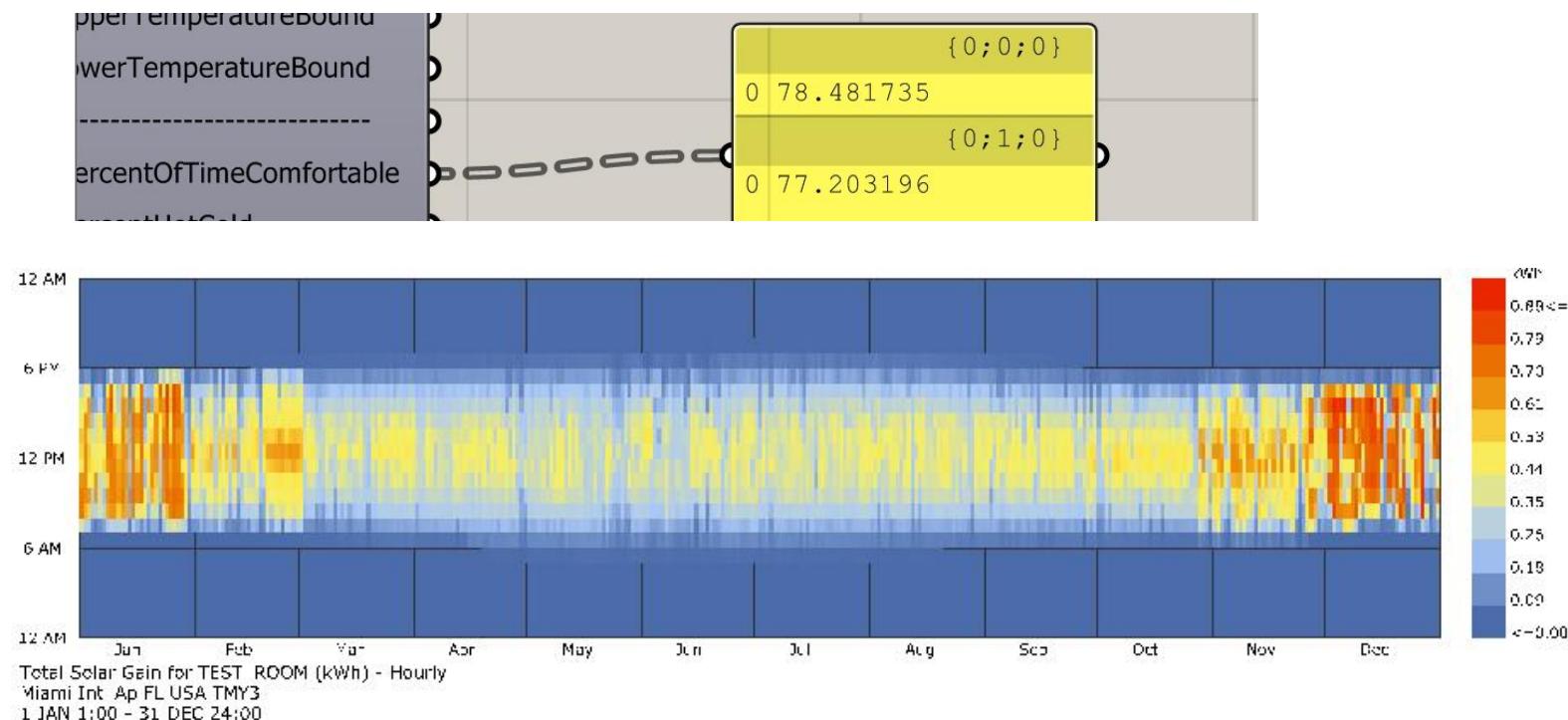
# Shade Design Proposal III

## Comfort

- Since the shading is providing enough and proper daylighting into the room, to increase the level of comfort there are few options that do not influence the daylighting level, which should be other than increasing the shade or decreasing the glazing ratio.

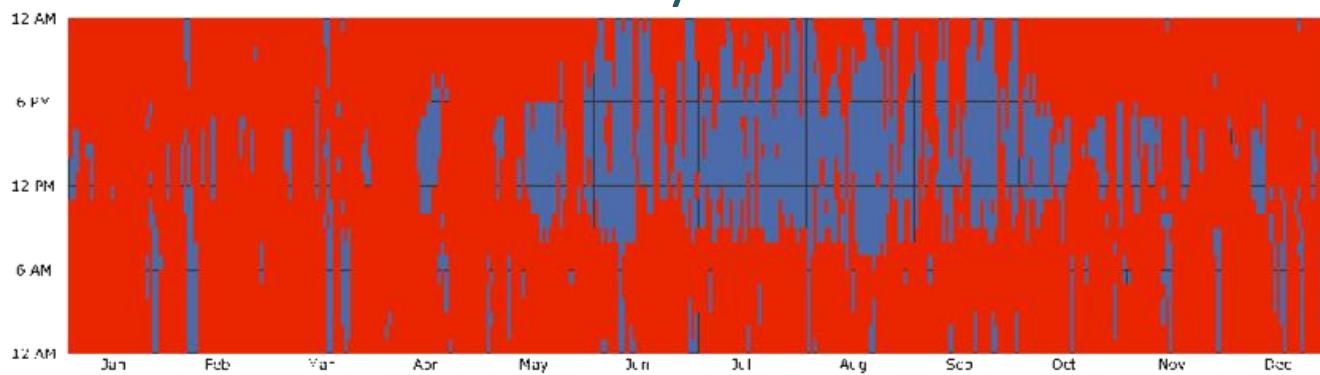
### 1. Adding a hallway to the room:

Adding a hallway to the room by making less heat transfer into the space from one side increased the comfort level to **78.48%**.



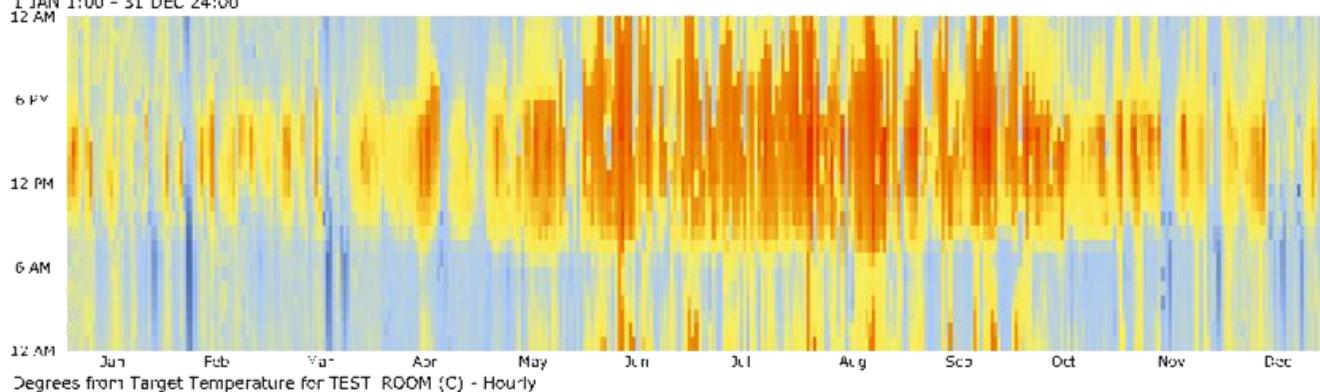
# Shade Design Proposal III

## Comfort-With Hallway

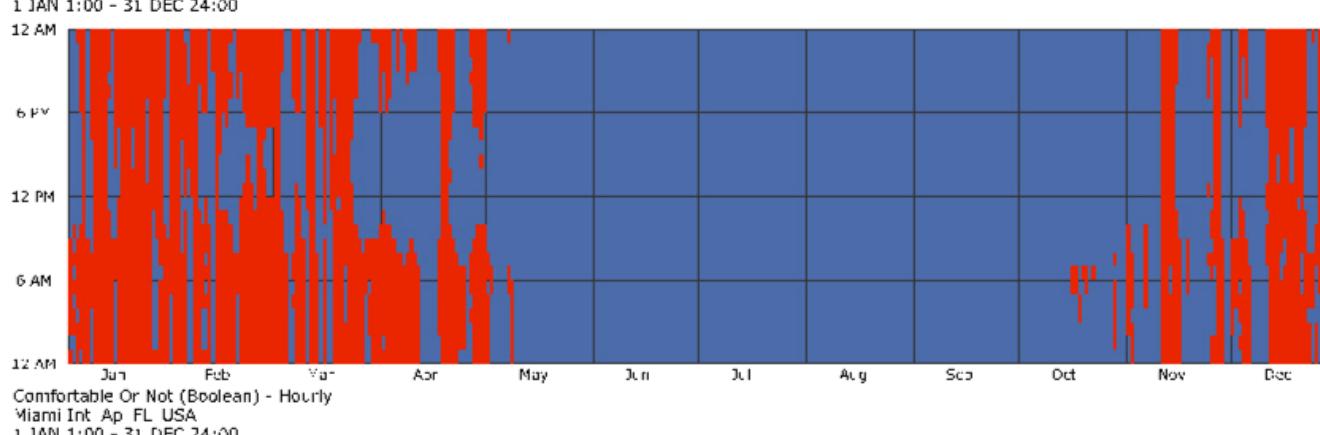


Adaptive comfort:  
78.48%

Adaptive comfort chart shows that the discomfort which was observing between 10 AM to 4 PM during Mar to Oct has been decreased considerably.



Degrees from Target



PMV: 31.65%

# Shade Design Proposal III

## Comfort\_ Construction Material

- Since the shading is providing enough and proper daylighting into the room, to increase the level of comfort there are few options that do not influence the daylighting level, which should be other than increasing the shade or decreasing the glazing ratio.

### 2. Construction Material:

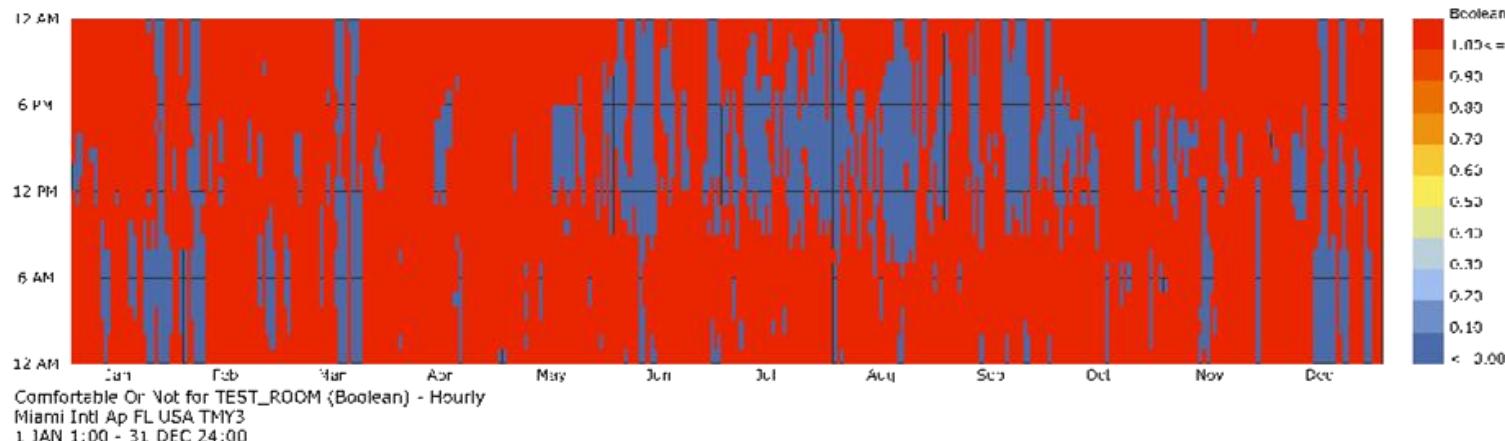
Changing the construction material is another option which might be effective on comfort level while does not affect daylighting level.

Materials improved include:

#### 1. Window: ASHRAE 189.1-2009 EXTWINDOW CLIMATE ZONE 2

After trying one custom window material, and many more material from library, the best level of comfort was obtaining by this material for window.

Adaptive Comfort: 76.76%



# Shade Design Proposal III

## Comfort\_ Construction Material

- Since the shading is providing enough and proper daylighting into the room, to increase the level of comfort there are few options that do not influence the daylighting level, which should be other than increasing the shade or decreasing the glazing ratio.

### 2. Construction Material:

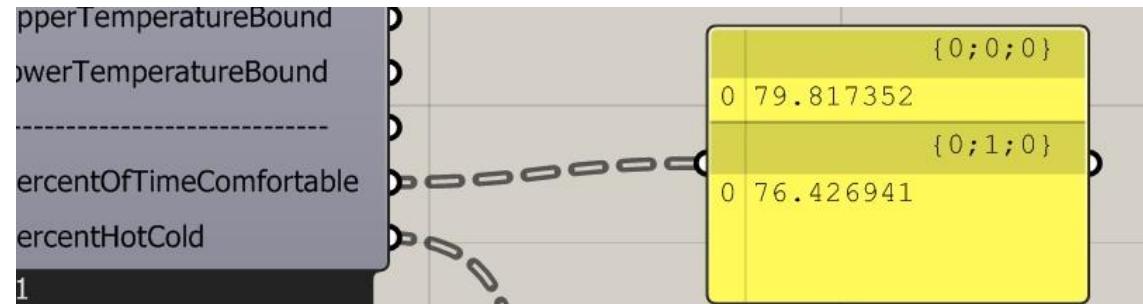
Changing the construction material is another option which might be effective on comfort level while does not affect daylighting level.

Materials improved include:

### 2. Wall: ASHRAE 189.1-2009 EXTWALL MASS CLIMATE ZONE 4

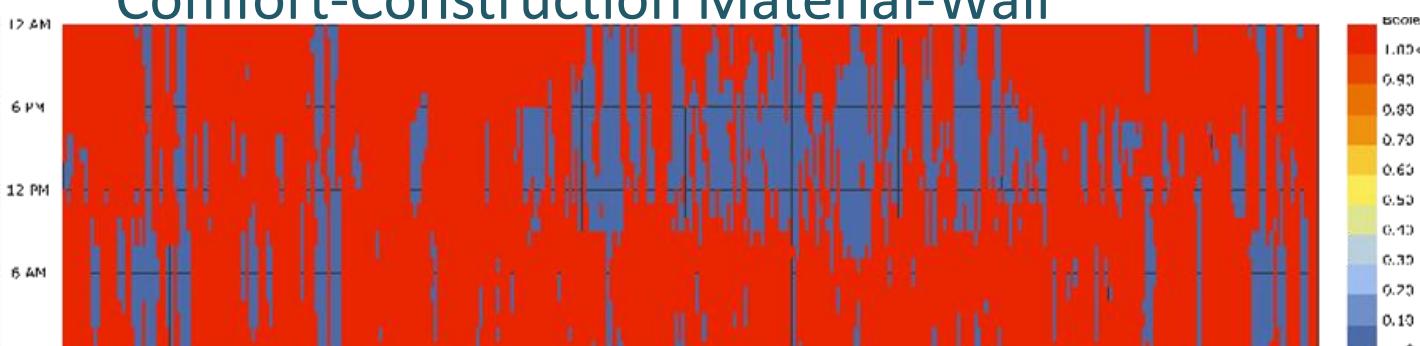
After trying one custom wall material as thermal mass (the material which had been used for Philadelphia weather and was failed for Miami) and many more material from library, the highest level of comfort was obtaining by this material for window.

Adaptive Comfort: 79.81%

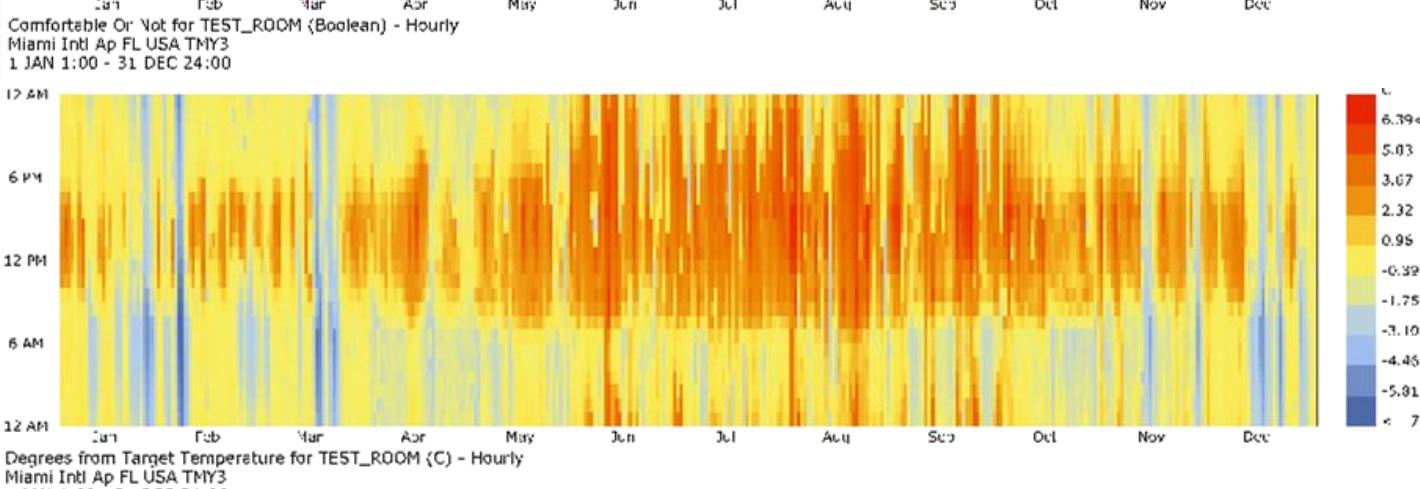


# Shade Design Proposal III

## Comfort-Construction Material-Wall

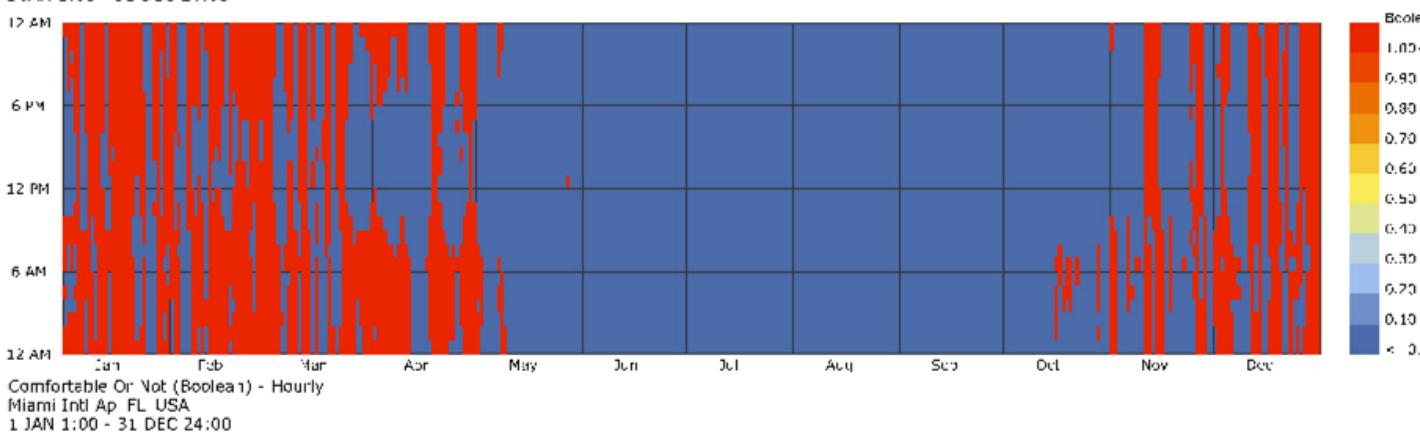


Adaptive comfort:  
79.81%



Adaptive comfort chart shows that the discomfort which was observing between 12AM to 2PM during Jul to Aug has been decreased.

Degrees from Target



PMV: 29.44%

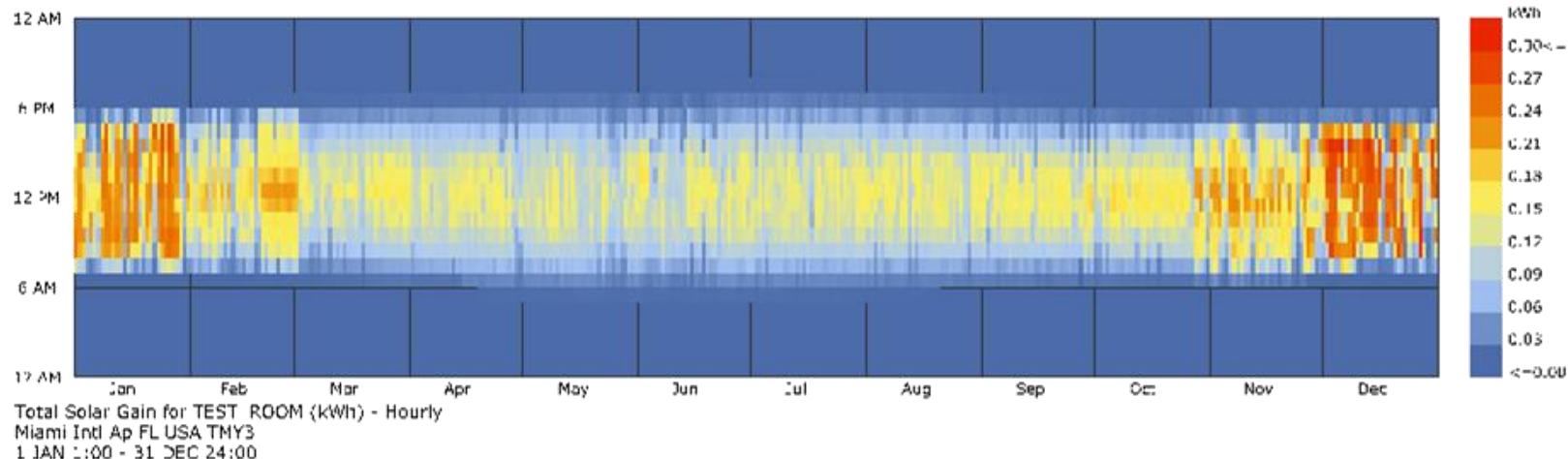
# Shade Design Proposal III

## Comfort\_ Construction Material

### 3. Roof : ASHRAE 189.1-2009 EXTROOF IEAD CLIMATE ZONE 2-5

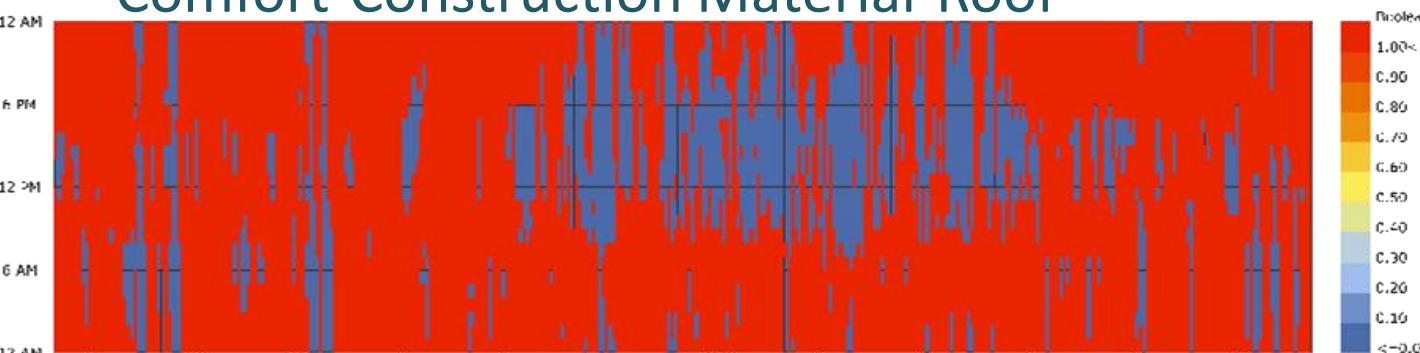
This material also is selected based on the trial and error running simulation with few others and finding this for the best result.

**Adaptive Comfort: 85.13%**



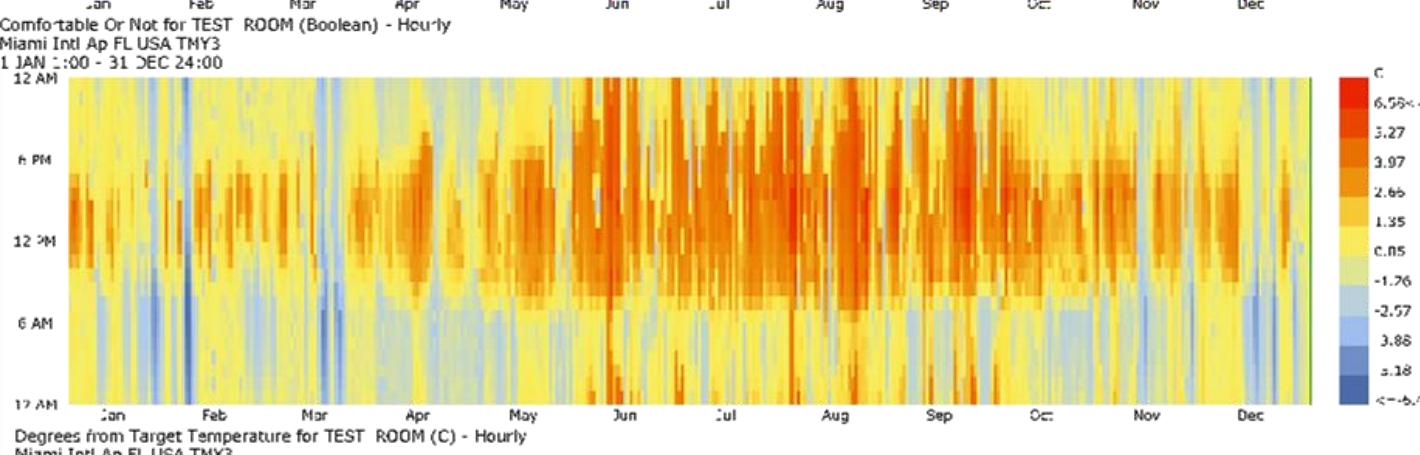
# Shade Design Proposal III

## Comfort-Construction Material-Roof

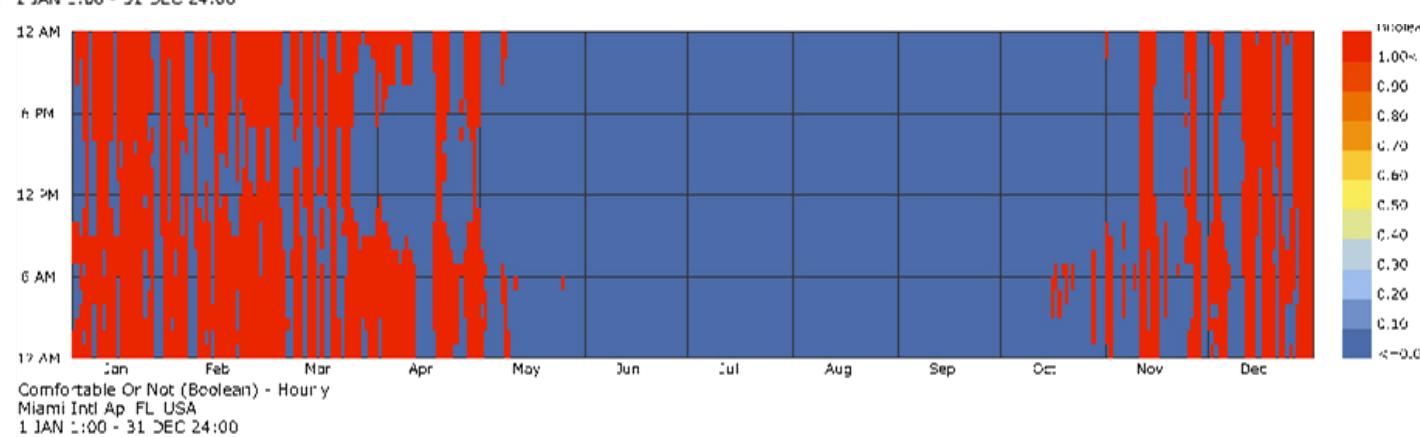


Adaptive comfort:  
85.13%

Adaptive comfort chart shows that the discomfort which was observing between 10AM to 3PM on March and April has been moved o comfort area.



Degrees from Target



PMV: 24.44%

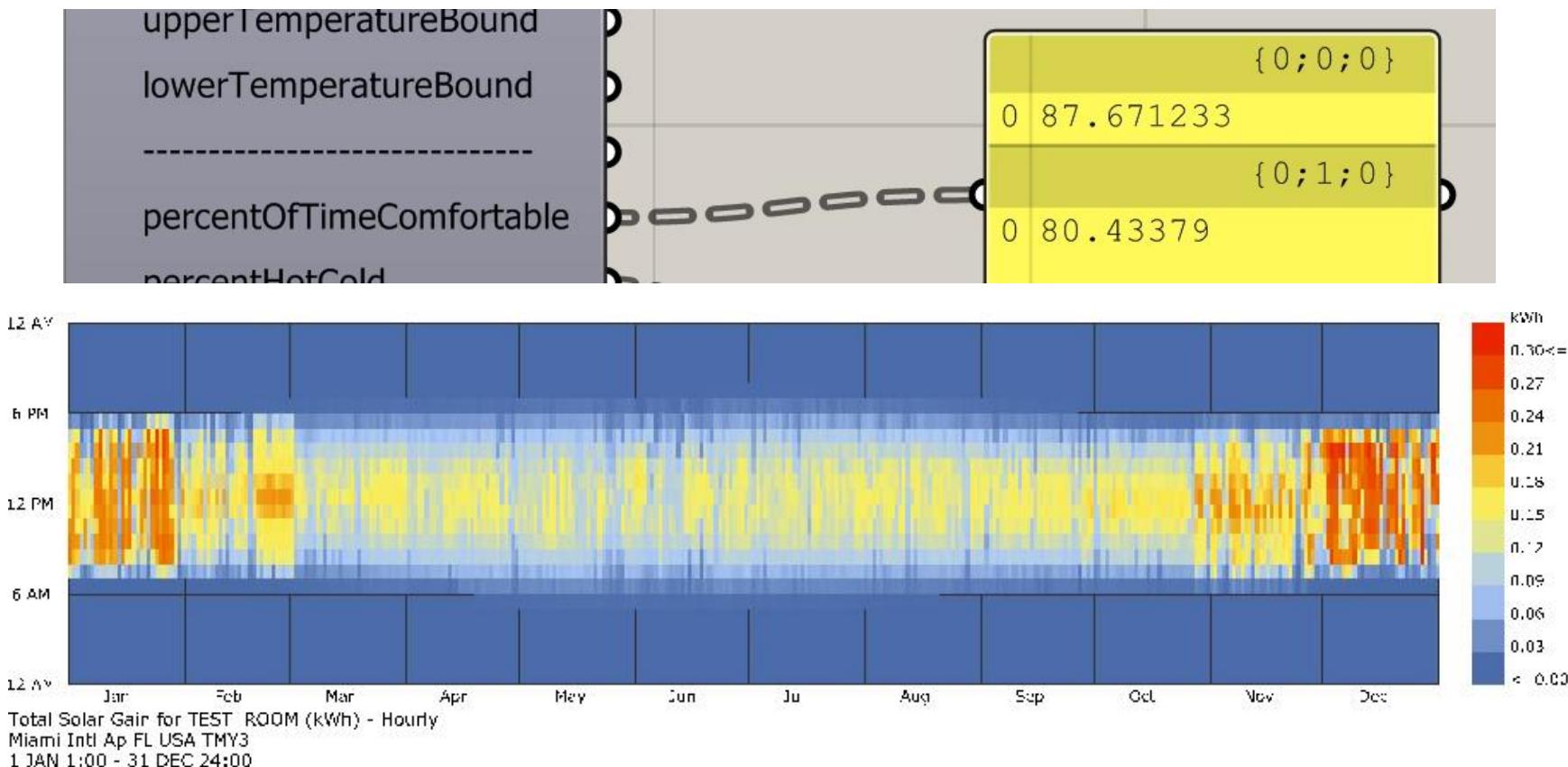
# Shade Design Proposal III

## Comfort\_ Construction Material

### 4. Floor: EXERIOR FLOOR

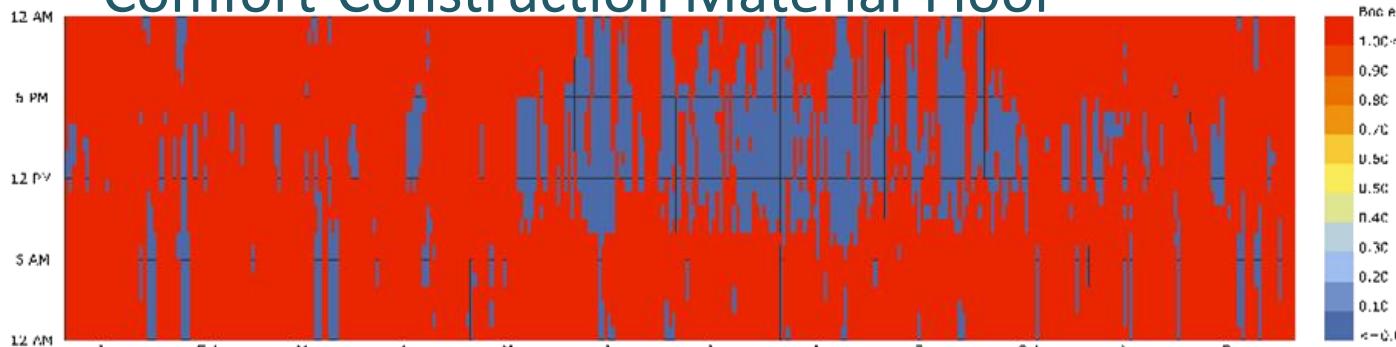
This material also is selected based on the trial and error running simulation with few others and finding this for the best result.

**Adaptive Comfort: 87.67%**



# Shade Design Proposal III

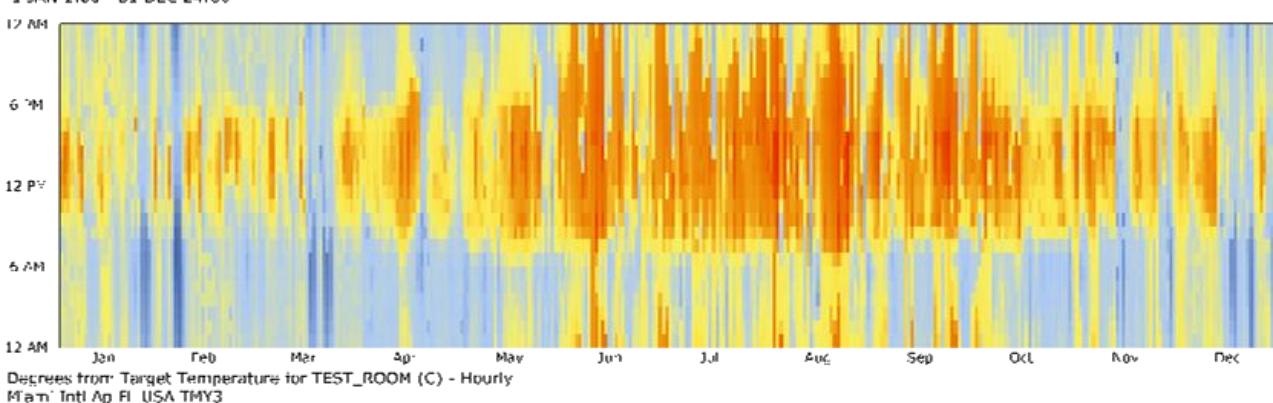
## Comfort-Construction Material-Floor



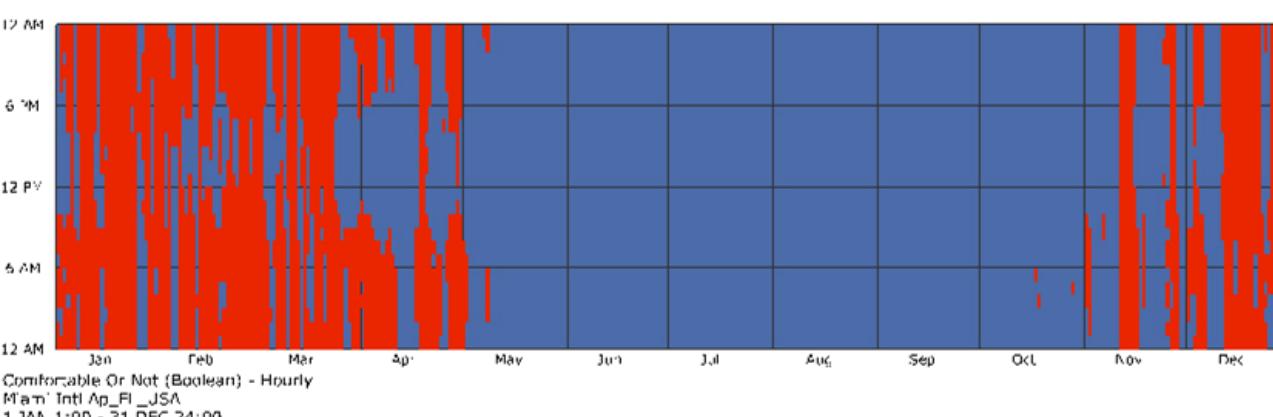
Adaptive comfort:  
87.67%

Here in this best result achieved it is observed that the uncomfortable hours on the chart has been reduced to it's lowest part on the chart. Specially in April and Aug and also in Nov and December.

Degrees from Target



Degrees from Target



PMV: 25.70%

# Conclusion

Three shade proposals were designed, simulated and tested on this room in the climate of Miami to reach the highest possible level of comfort with enough daylighting as well.

The first proposal was giving very high level of daylighting, while the comfort level low and mostly close to the base case. To increase the level of comfort glazing ratio was applied and slight improvement was observed though not enough.

The second proposal was designed based on the first one which was showing too much solar radiation and daylight is entering the space, so the horizontal and vertical shade according to the VSA became Longer and provided a very good level of comfort (about 81%) while the in the daylighting simulation the SDA was about 12% which was showing less than 12% of the area of the room is being provided enough daylight.

Consequently, it was understood both from climate study and proposals simulations that, the high temperature in Miami has caused many hot days and approximately in this climate there is not serious need for heating even during winter and the best way to provide comfort is firstly to block the irritating radiation and prevent the heat to get in.

The design approach after many trial and errors between too much daylight , less comfort and not enough daylight and more comfort reached to the final shade proposal III which is giving 51.47% SDA and 87.67% level of adaptive comfort.

After finalizing the shade design by reaching an acceptable level in both of daylighting and comfort, to increase the level of comfort other options including: glazing ratio and construction material were changed and tested and best material were found, and applied to reach the final and highest level of adaptive comfort.