

# **Building Simulation Performance**

Bedroom Daylight&Comfort Performance Optimization

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# Climate Analysis

## Identify main environmental factors

### 1. Annual Temperature Analysis

As a bedroom, the occupied time is usually on the morning and during the night, which is from 8pm - 9am. From the chart, we find the temperature in Philadelphia varies from -13.9 to 36.7. 2. During the occupied time, in winter the temperature is usually below 1 C, In summer it is between 24-35 C. So in summer the bedroom needs to be cooled down and in winter, we need to keep it warm.

For me the most comfortable temperature is from 18 - 26, from the chart we can find in spring the temperature is good, but for winter and summer it is not that temperate.

#### Strategy 1:

**To cool down the indoor temperature in summer, we can adjust the orientation and the position of door to get better ventilation.**

**In winter, because the wind is mainly coming from west, we can keep the door closed to prevent the heat loss and the wall on the westside could be thicker.**

### 2. Relative Humidity Analysis

During the occupied time, the humidity is usually more than 70%, which makes the temperature higher, especially in summer.

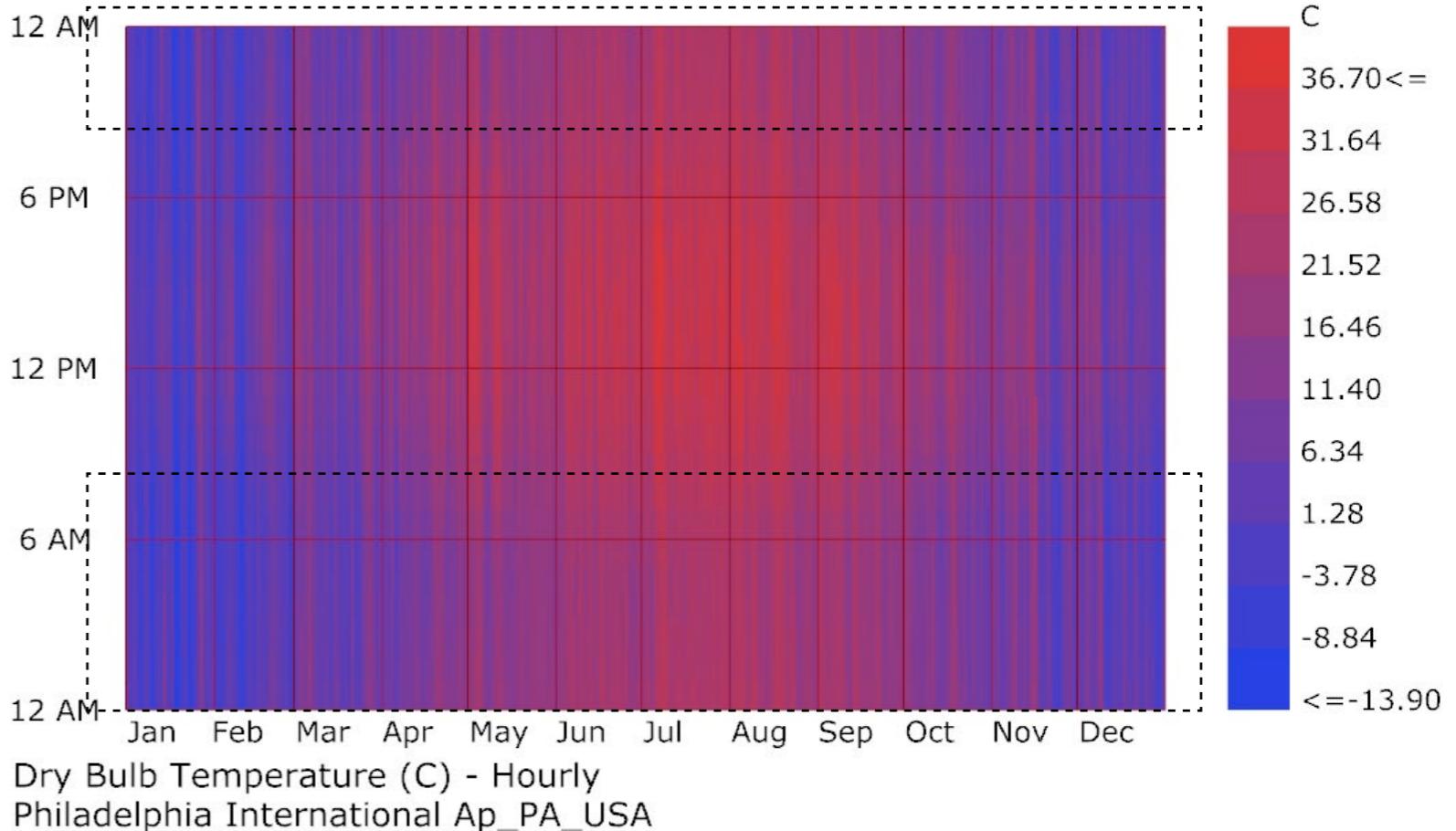
The usual comfort humidity for human indoor is 40% - 60%, from the chart we can find the humidity is good in spring, but for winter and summer it is not that temperate, so we need some improvement.

#### Strategy 2:

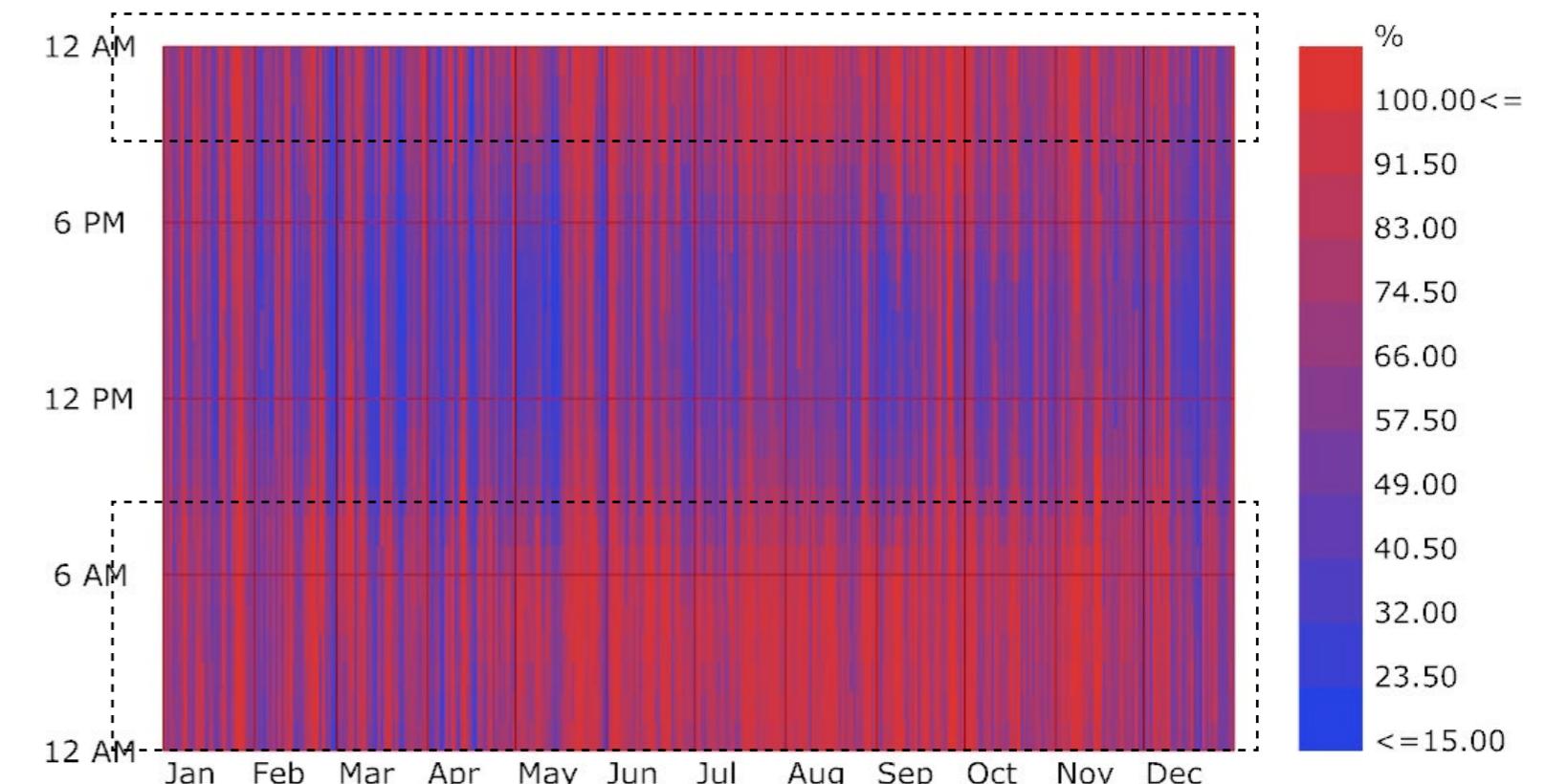
**In summer, to make the interior humidity during the night lower, we could either close the door and window during the night and morning or get a dehumidifier.**

**In winter, to make the interior humidity during the night higher, we could get a humidifier or close the window and door, which keep the bedroom warm.**

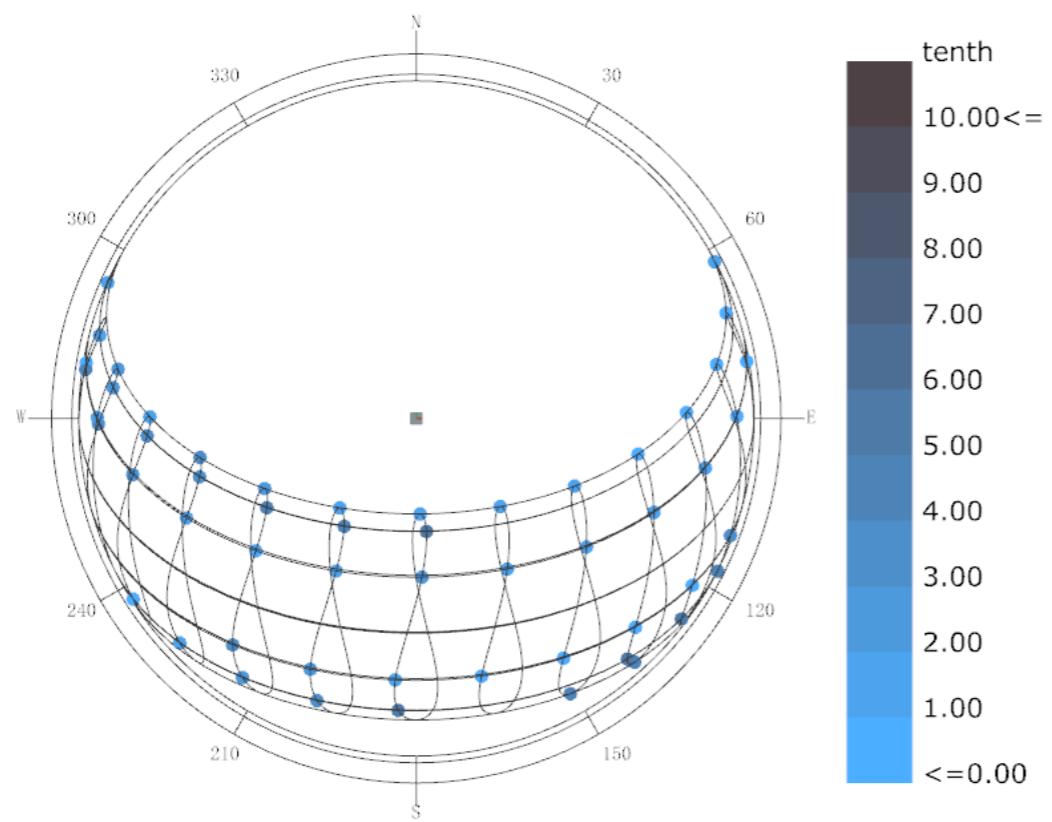
Annual Temperature



Annual Relative Humidity

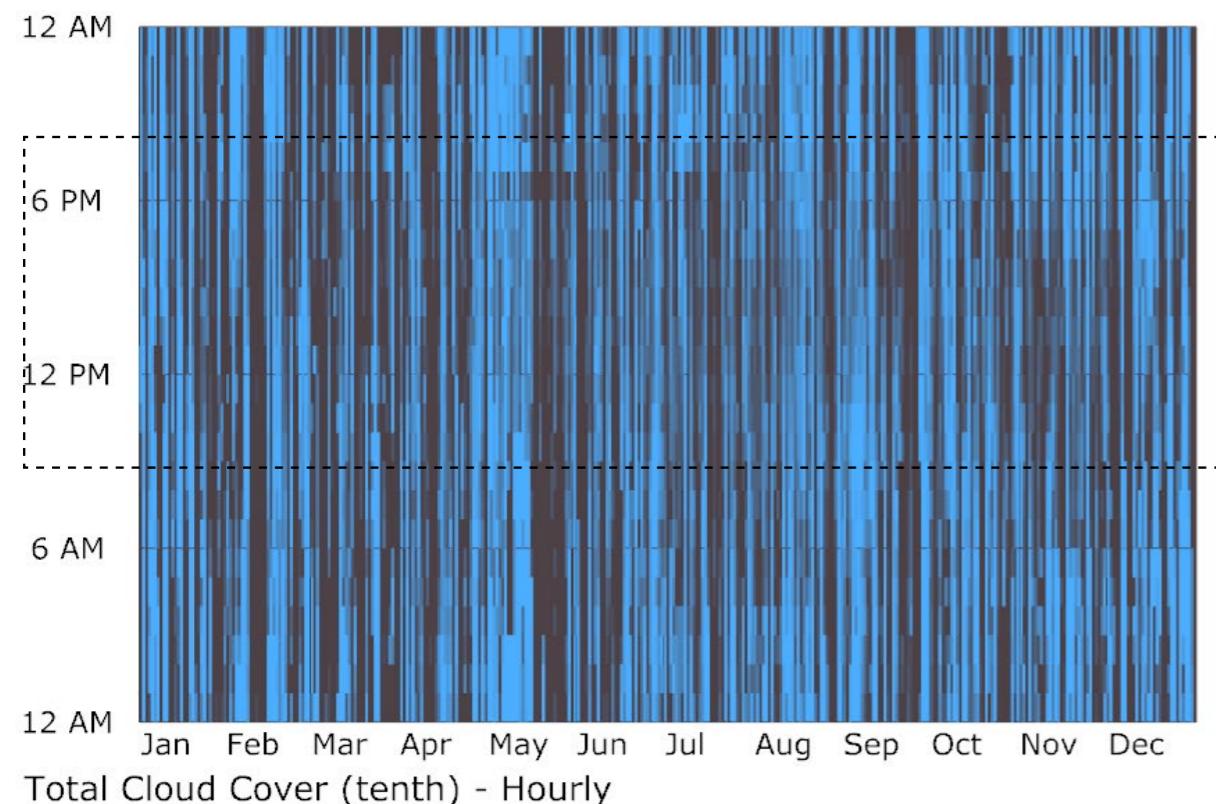


## Annual Sky Cover Analysis

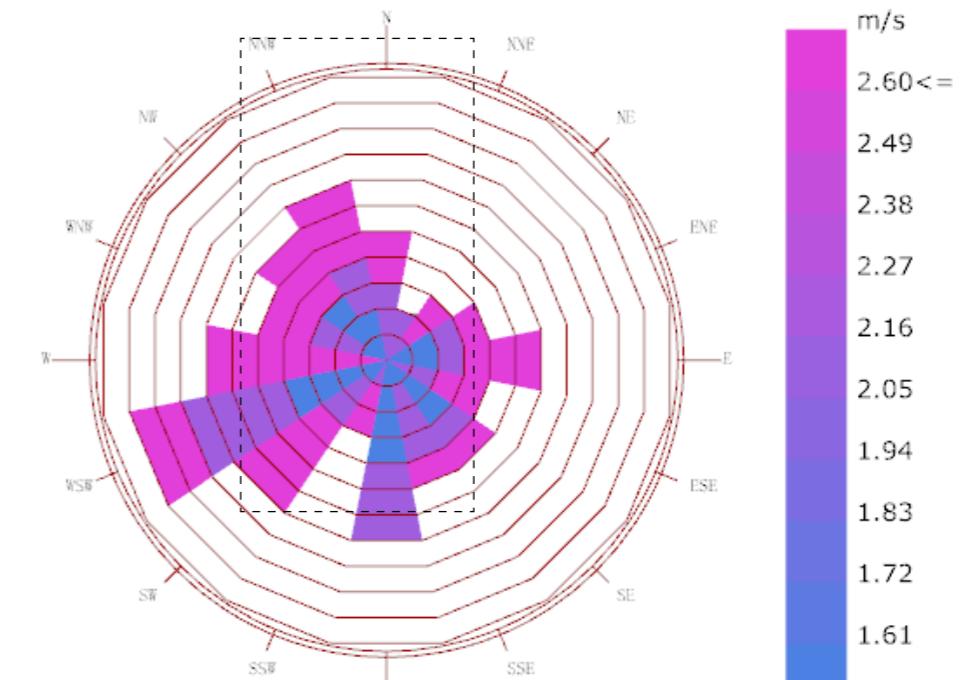
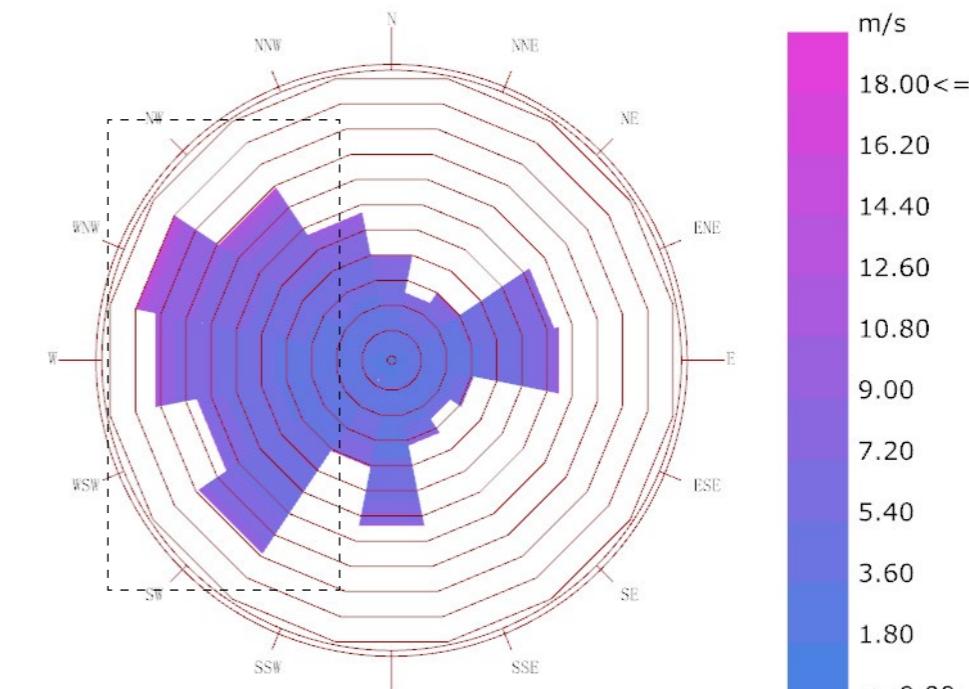


During the occupied time, from these two charts, the annual sky cover is not changing very much, the fall season and winter season has more chance to be covered. This indicates the orientation of bedroom should be properly set to get more sunlight in winter.

## Annual Sky Cover



## Wind Speed and Direction



Wind Speed between 1- 3 m/s

The comfort wind is between 1- 3m/s, which is also mainly coming from west and southwest.

## Strategies based on the location.

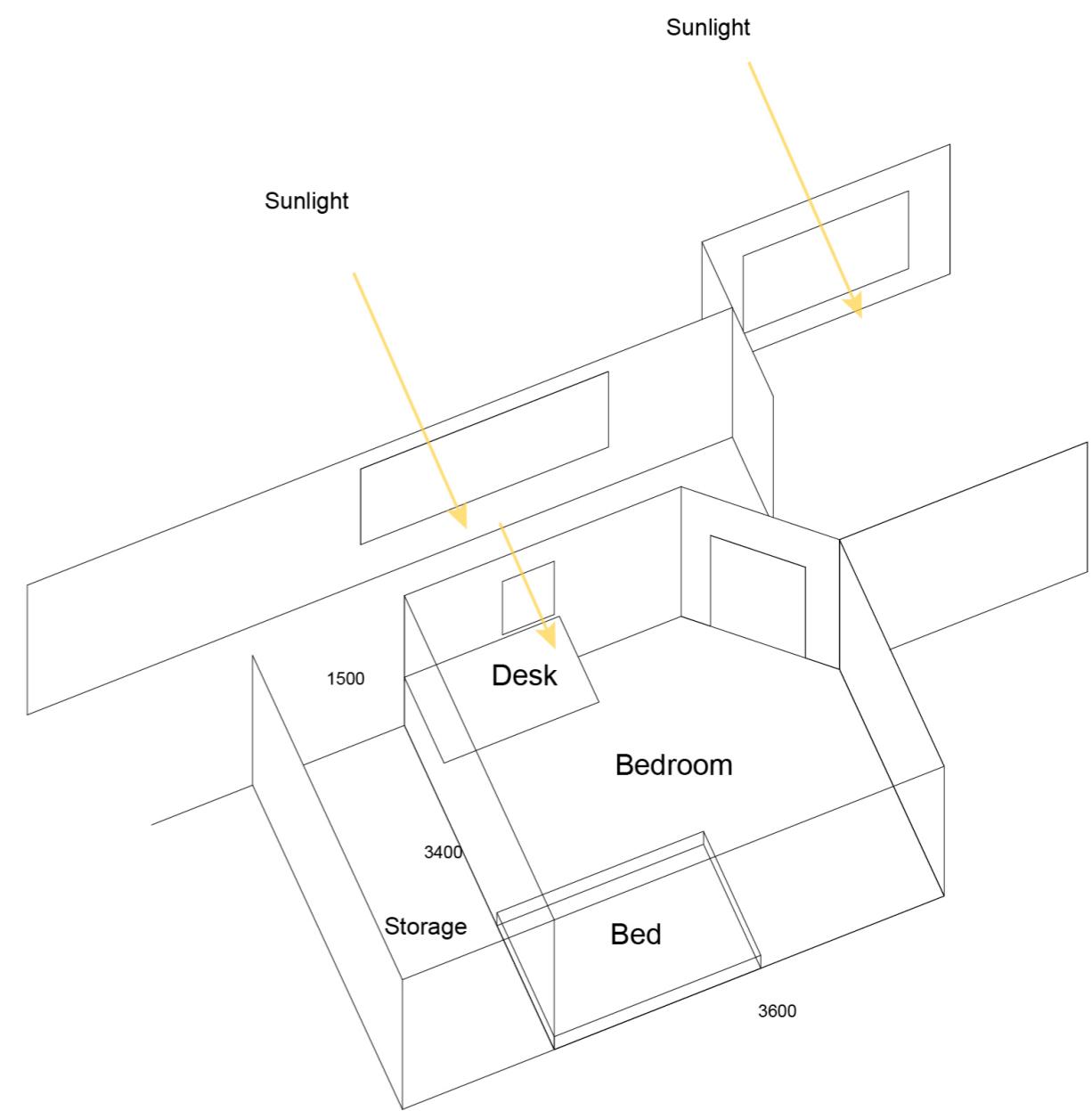
## Base Bedroom Model

### Strategy 1: Adjust and Add openings

In summer, adjust the orientation and the location of door to get better ventilation.  
In winter, because the wind is mainly coming from west, we can keep the door closed to prevent the heat loss and the wall on the westside could be thicker.

### Strategy 2: Natural Ventilation

In summer, close the door and window during the night and morning to make the interior humidity during the night lower  
In winter, close the window and door to make the interior humidity during the night.



### Strategy 3: Change the Materiality

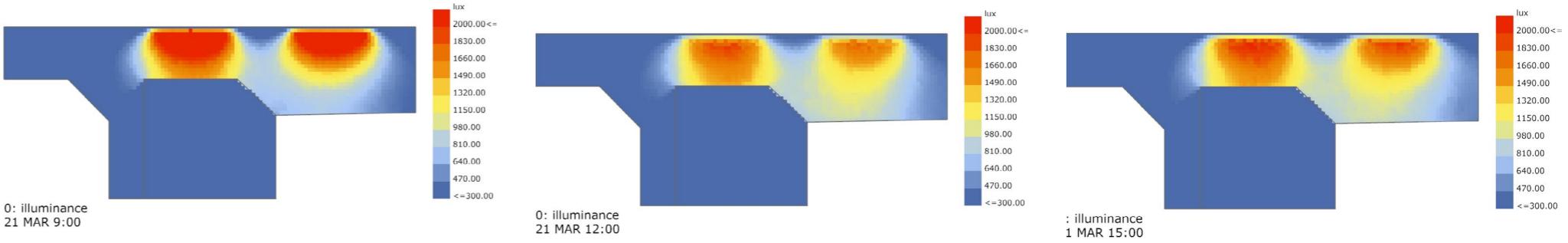
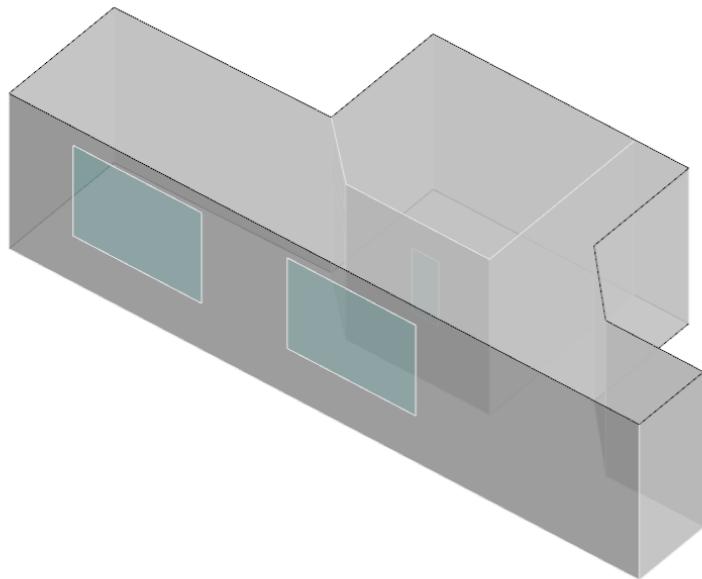
By changing the materiality of envelope and interior wall, the energy flow can be controlled which affects daylight and comfort performance

Major Problem:  
1.No direct sunlight: Dark room  
2.Bad Ventilation  
3.The location of door is not good for good ventilation

Adjustable parameter:  
1.Dimension of window  
2.Add one more window for ventilation  
3.Material

# Original Base Model

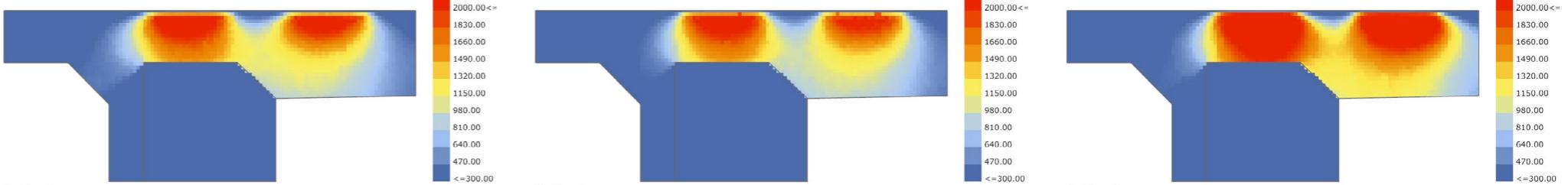
## Point-in time Illuminance



9AM, MAR 21

12PM, MAR 21

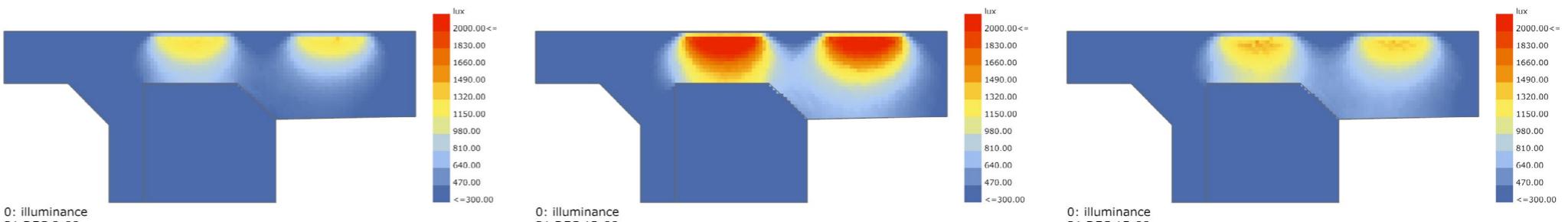
15PM, MAR 21



9AM, JUN 21

12PM, JUN 21

15PM, JUN 21



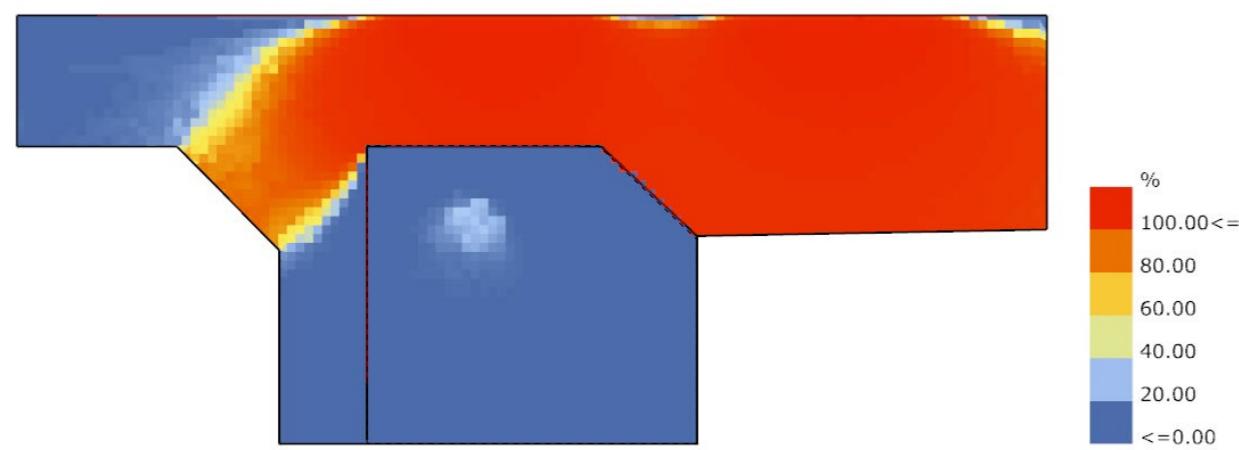
9AM, DEC 21

12PM, DEC 21

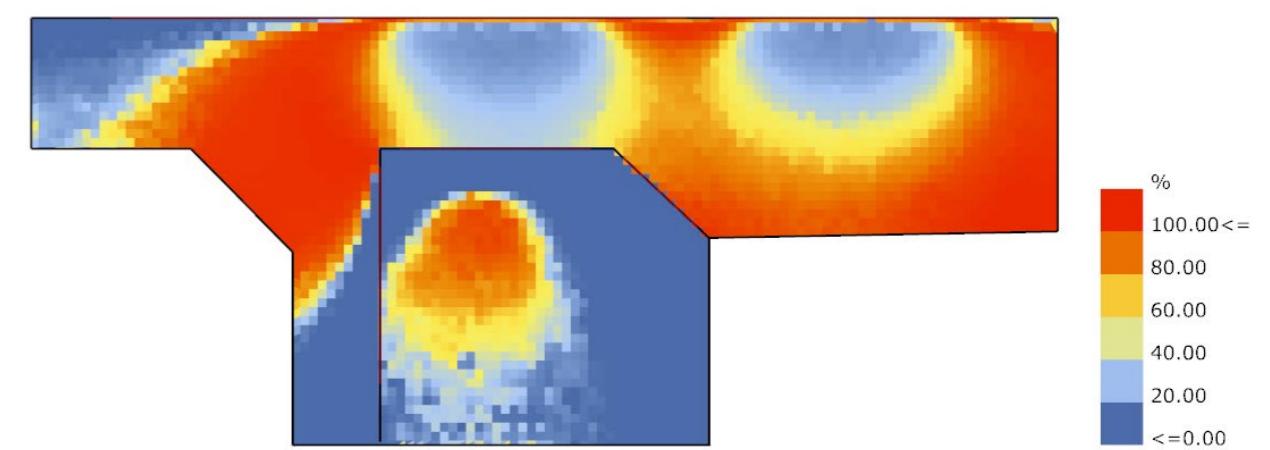
15PM, DEC 21

## Original Base Model

### Daylight Autonomy&Useful Daylight Illuminance



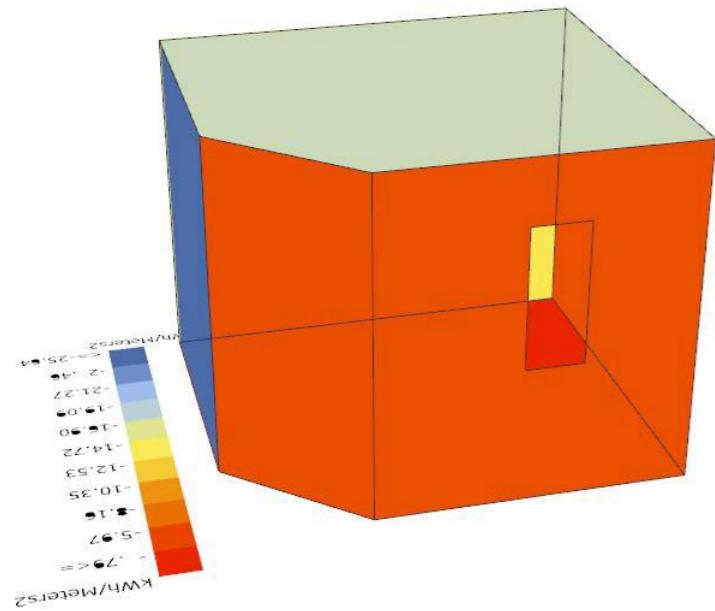
**Daylight Autonomy: 48%**



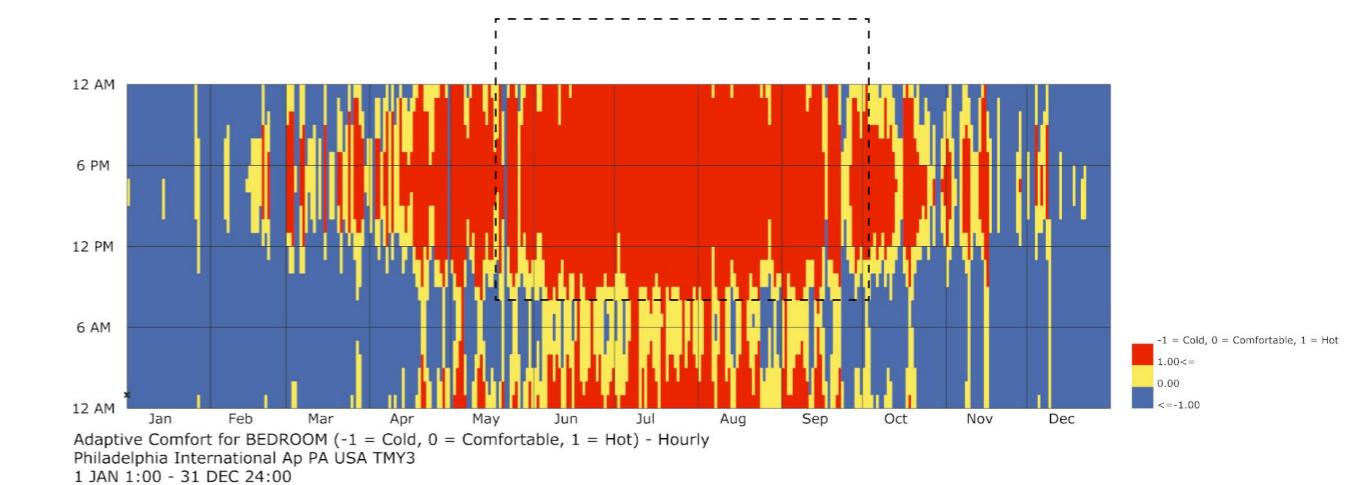
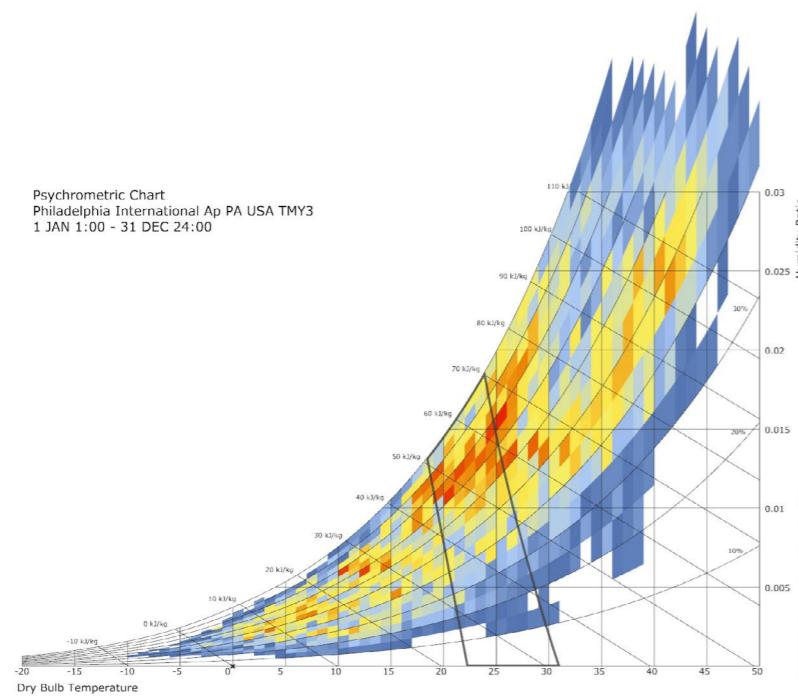
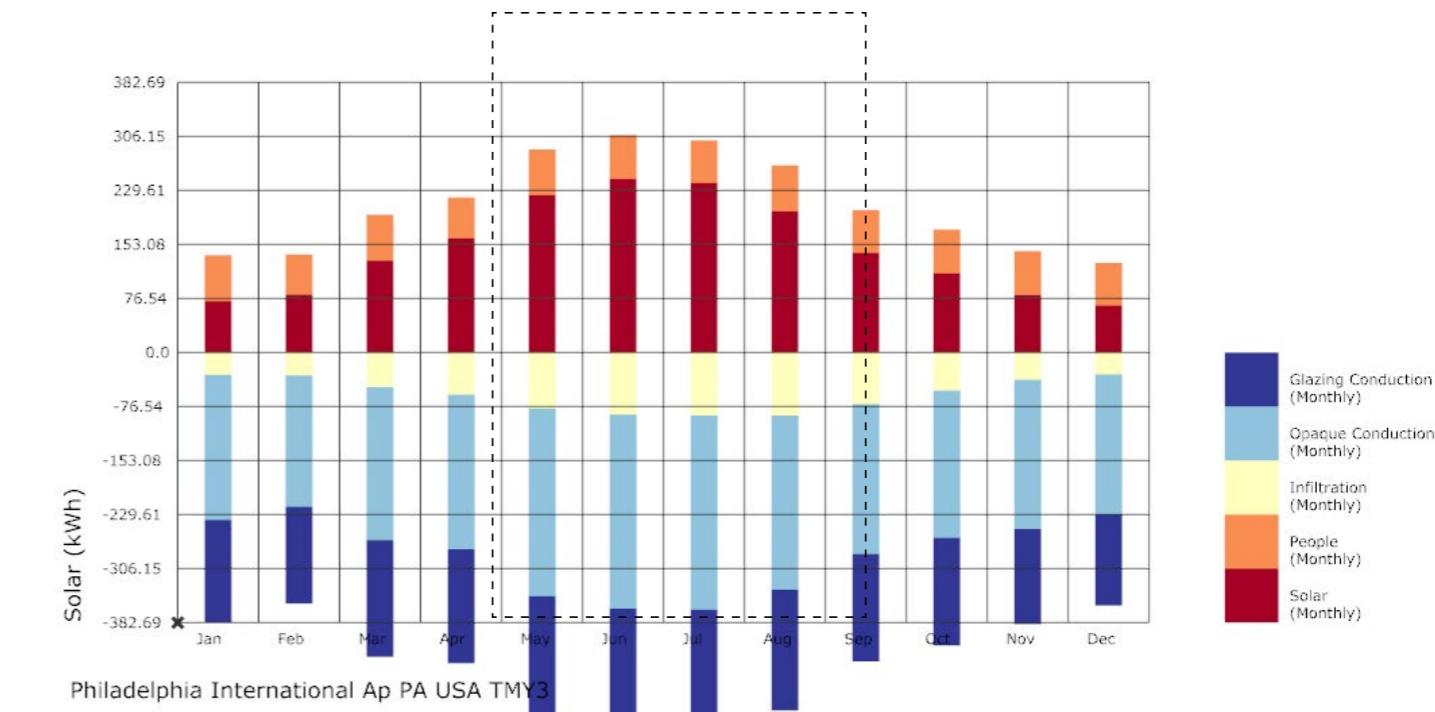
**Useful Daylight Illuminance(100-2000lux): 45%**

# Original Base Model

## Comfort Simulation



**Comfort: 19.69%**  
**Hot: 34.42%**  
**Cold: 45.89%**



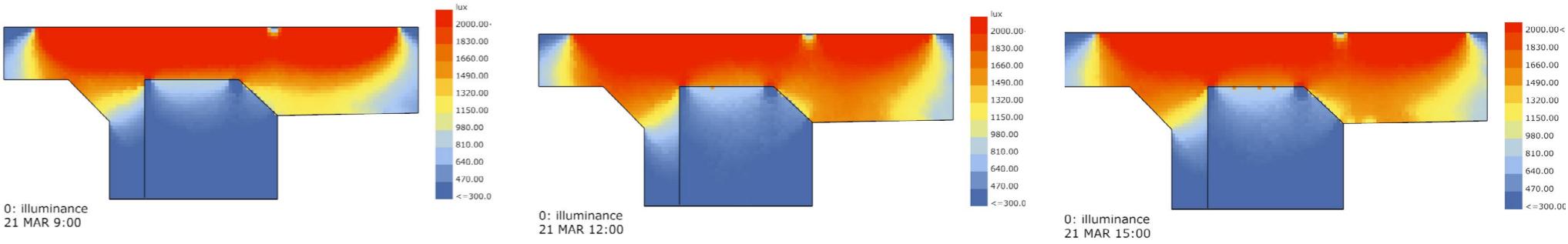
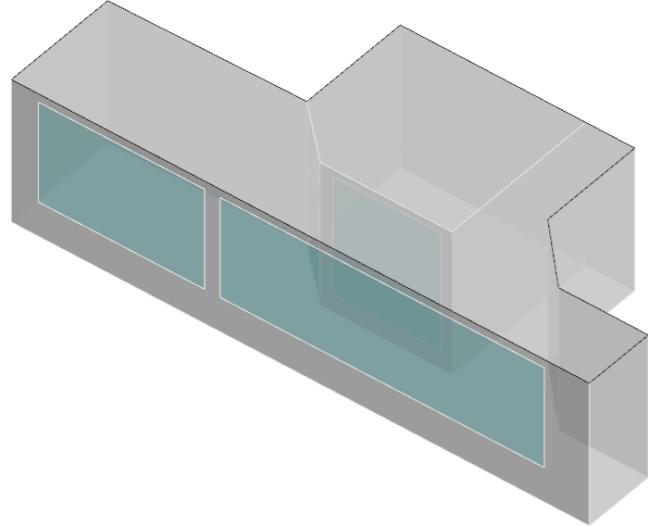
## Conclusion

Based on the comfort simulation result, it can be identified that during summer which is from June to September, people inside feel hot from noon to midnight. During winter from November to February people inside feel cold.

From the chart, it can be conclude that opaque conduction, glazing conduction and solar radiation contributes more on energy flow.

# 1ST Modified Model

## Point-in time Illuminance



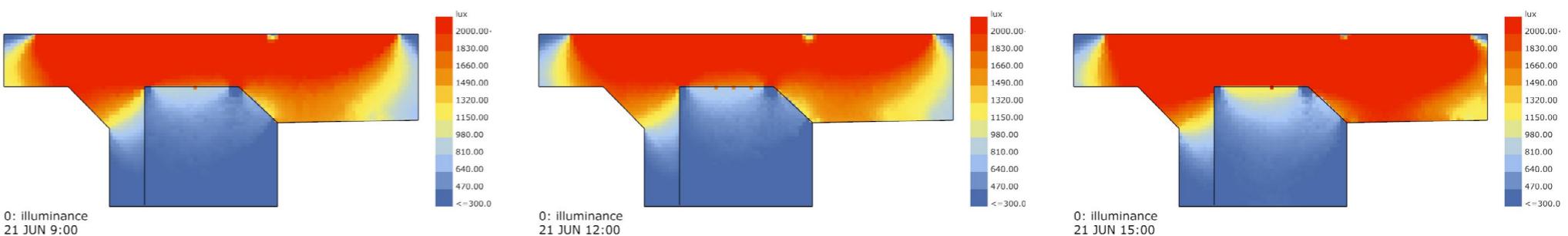
9AM, MAR 21

12PM, MAR 21

15PM, MAR 21

## Strategy:

Enlarge the size of Window.



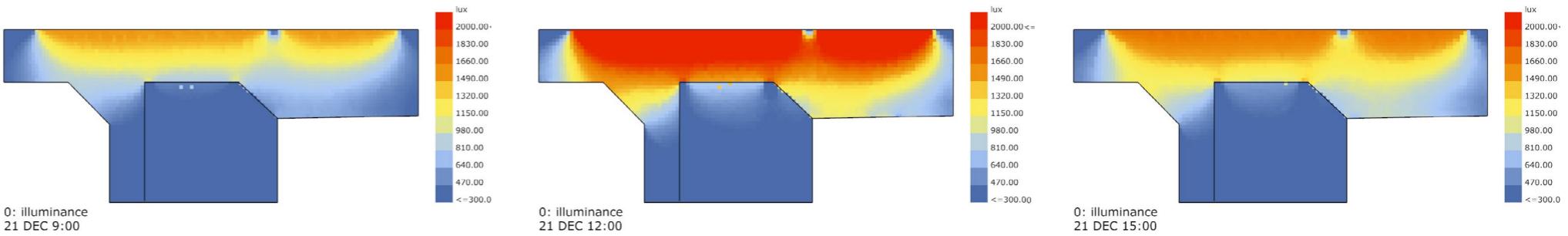
9AM, JUN 21

12PM, JUN 21

15PM, JUN 21

## Result:

The indoor daylight quality is partly improved, but still most area has no sufficient illuminance.



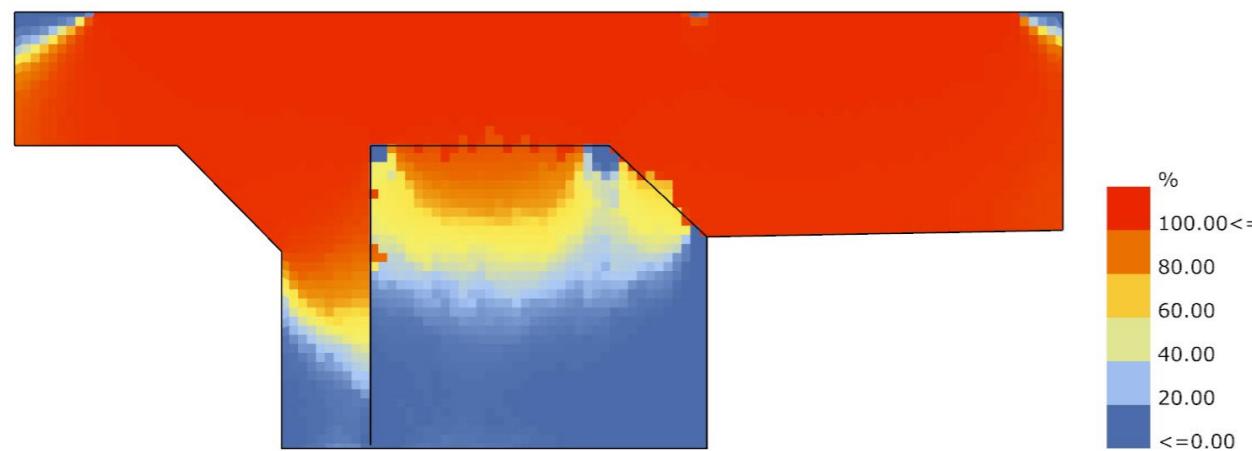
9AM, DEC 21

12PM, DEC 21

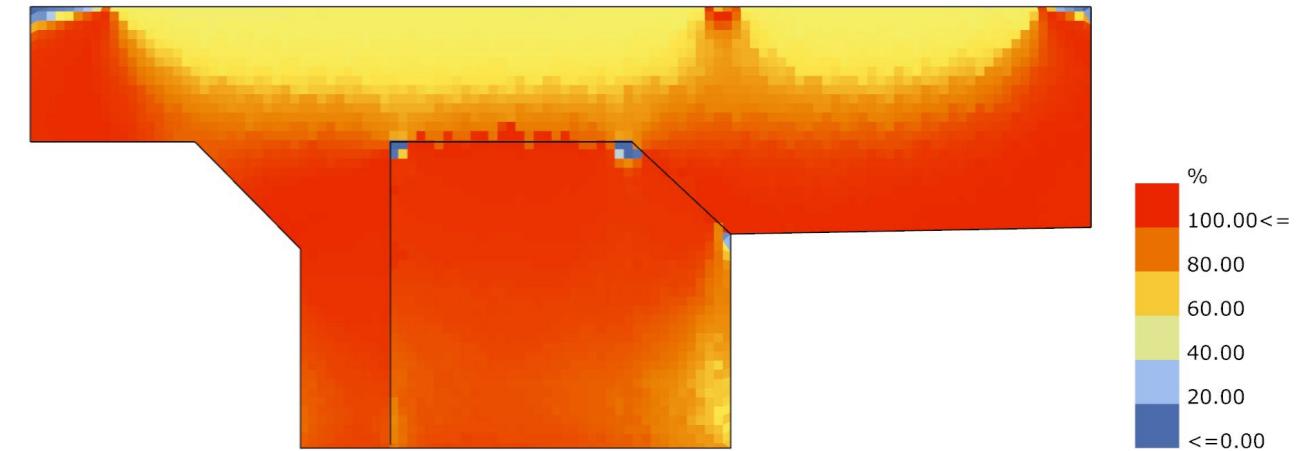
15PM, DEC 21

## 1st Modified Model

### Daylight Autonomy&Useful Daylight Illuminance



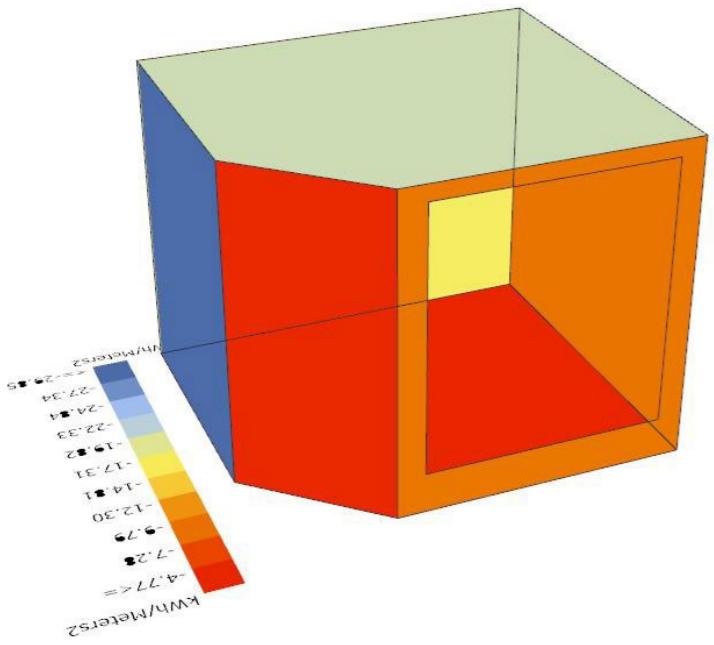
**Daylight Autonomy: 69.61%**



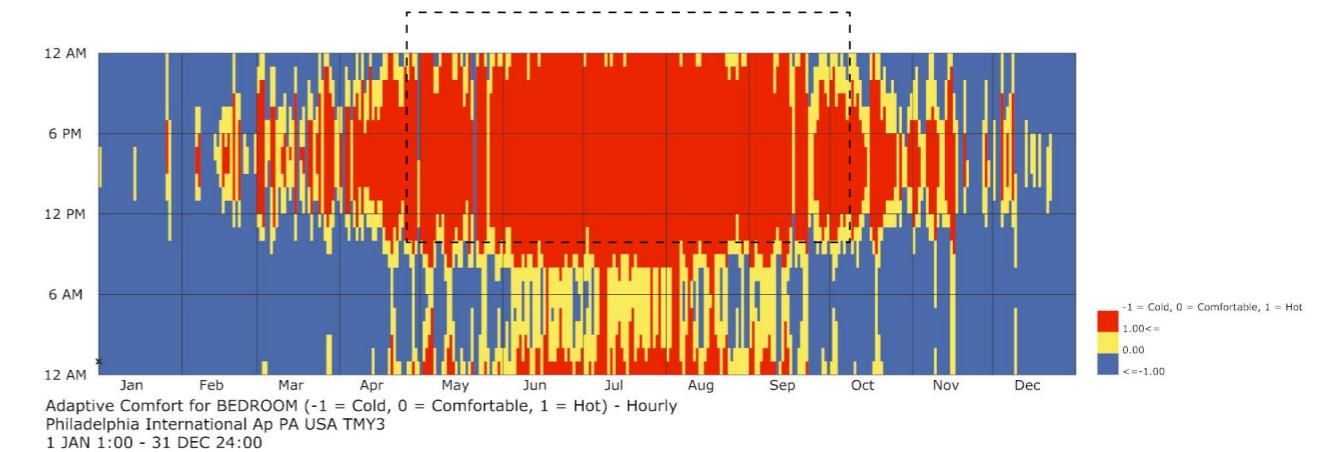
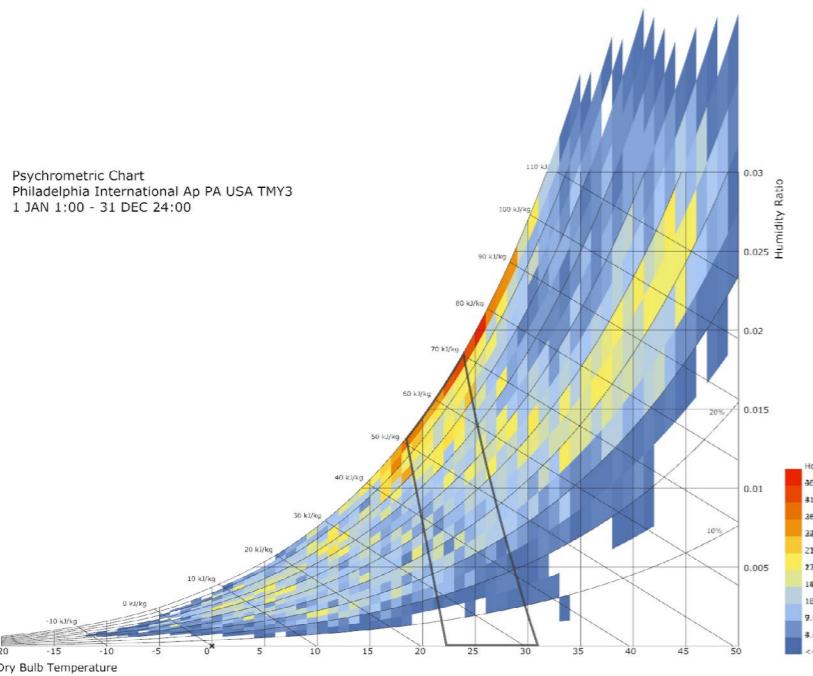
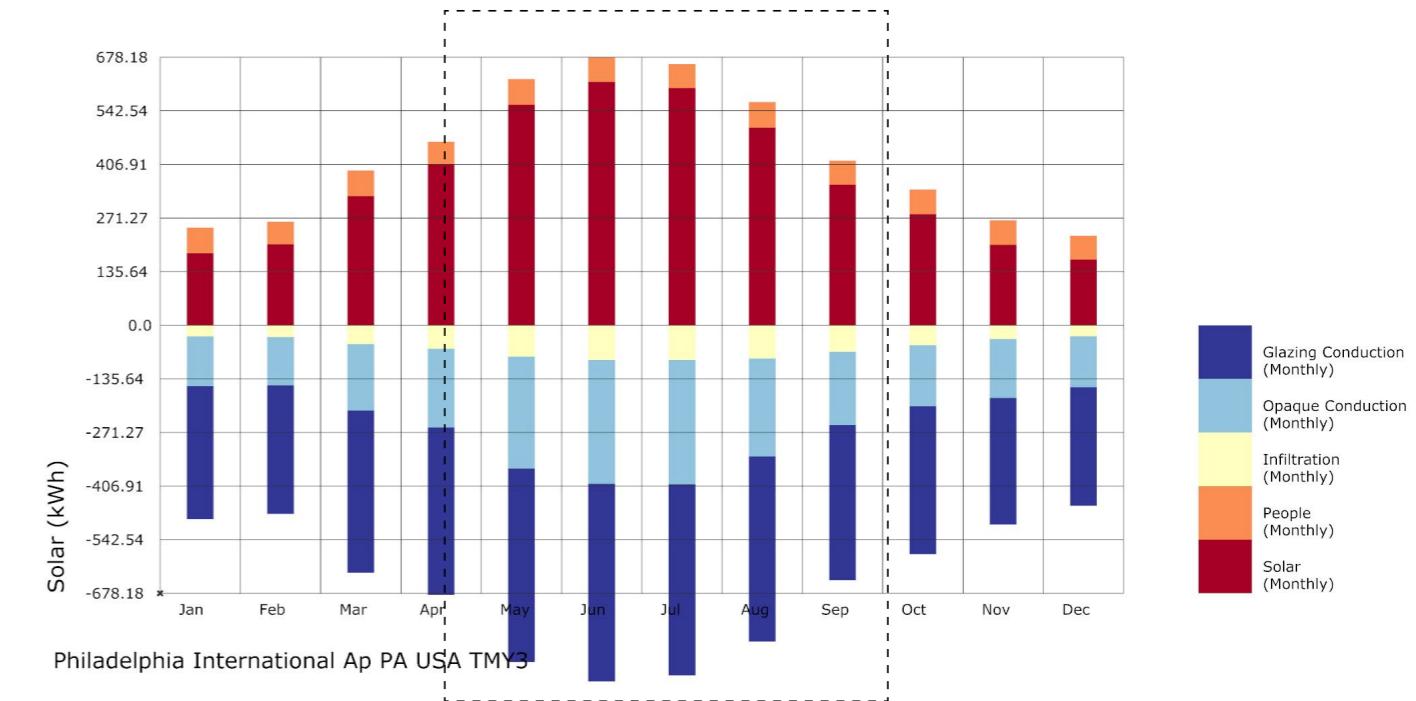
**Useful Daylight Illuminance(100-2000lux): 60%**

# 1st Modified Model

## Comfort Simulation



**Comfort: 18.21%**  
**Hot: 35.72%**  
**Cold: 46.07%**

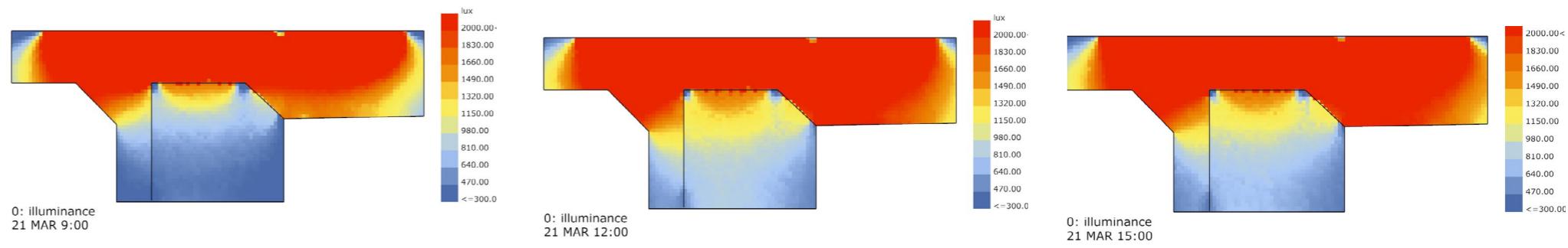
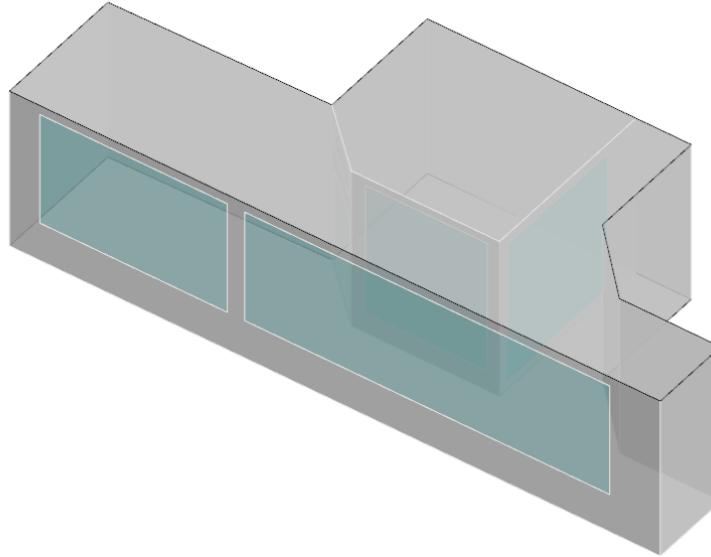


## Conclusion

Based on the comfort simulation result, this room has more daylight illuminance because the window area increased. However, the comfort value decreased, the reason could be when increasing the window area, the energy get through the windows more easily. As a result, the room becomes easier to loses heat during winter and gain heat during summer.

## 2nd Modified Model

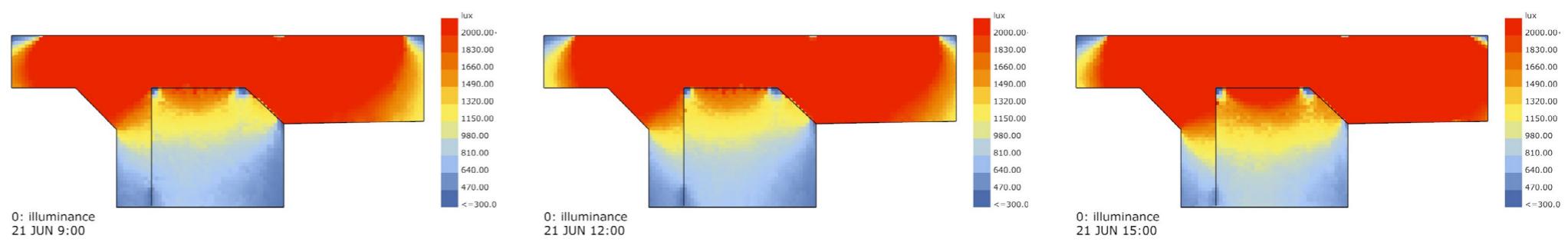
### Point-in time Illuminance



9AM, MAR 21

12PM, MAR 21

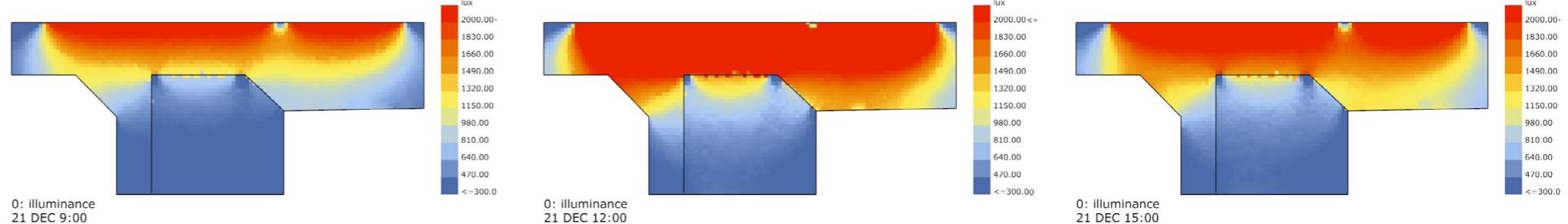
15PM, MAR 21



9AM, JUN 21

12PM, JUN 21

15PM, JUN 21



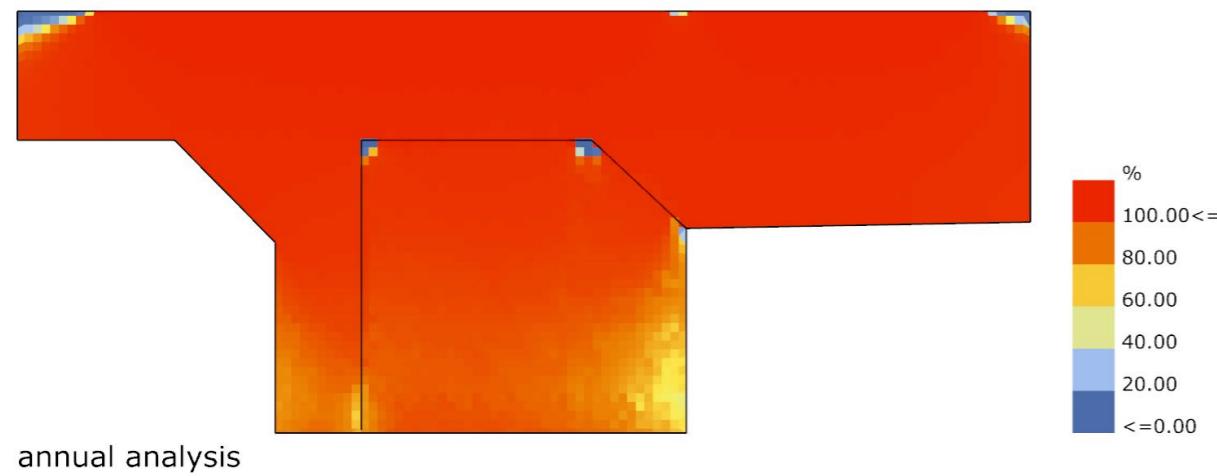
9AM, DEC 21

12PM, DEC 21

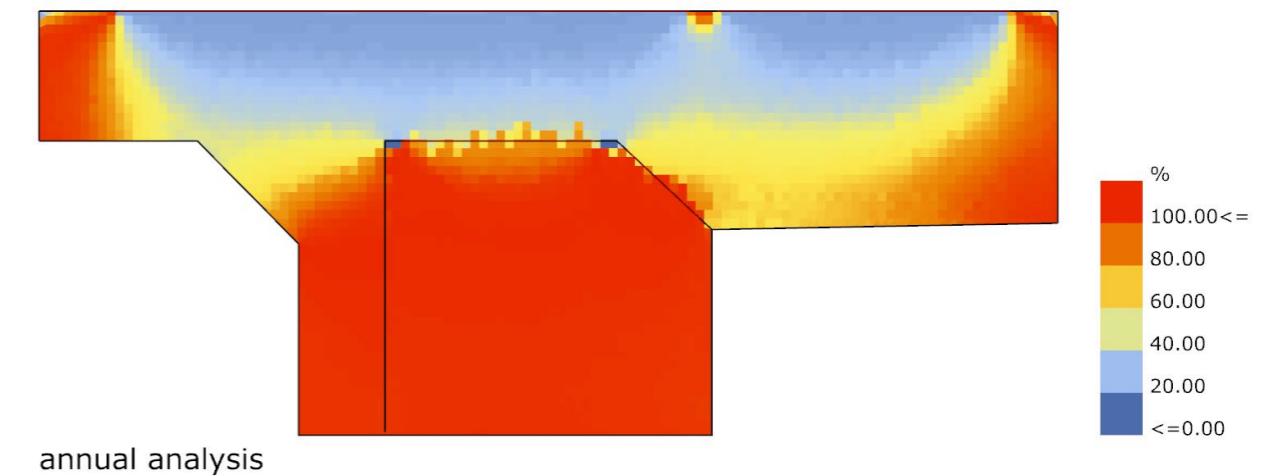
15PM, DEC 21

## 2nd Modified Model

### Daylight Autonomy&Useful Daylight Illuminance



**Daylight Autonomy: 93%**

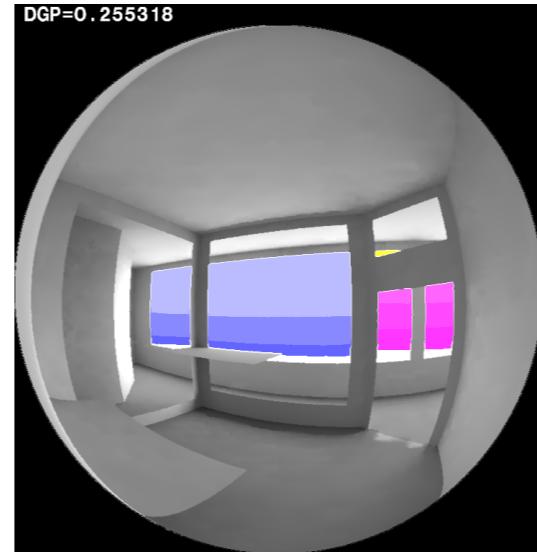


**Useful Daylight Illuminance(100-2000lux): 60%**

## 2nd Modified Model

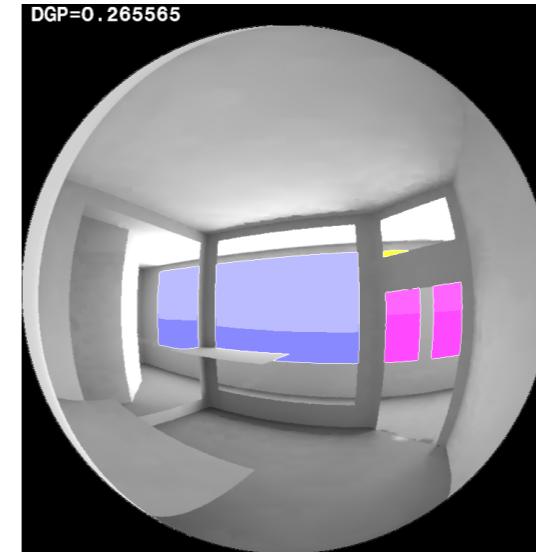
### Glare Analysis

Based on the simulation result of 2nd modified model, the DGP is below 0.35, which means the glare is imperceptible.



9AM, MAR 21

DGP:0.255318



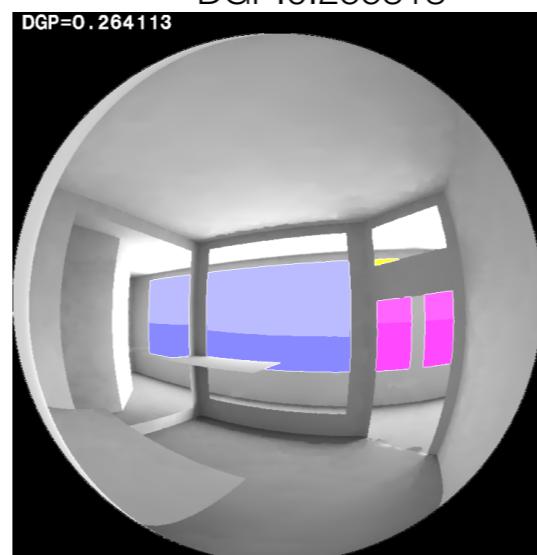
12PM, MAR 21

DGP:0.265565



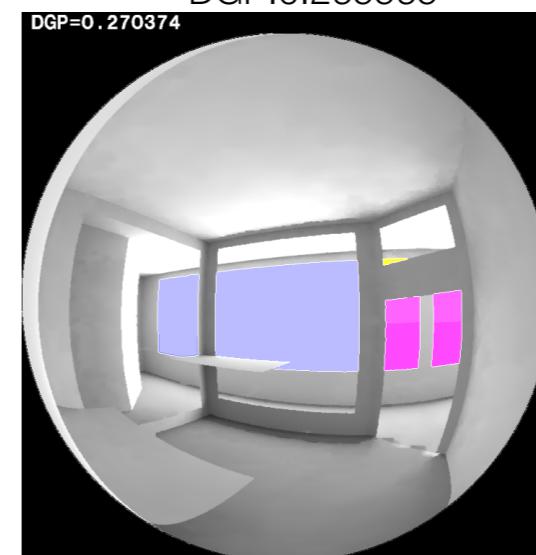
15PM, MAR 21

DGP:0.265898



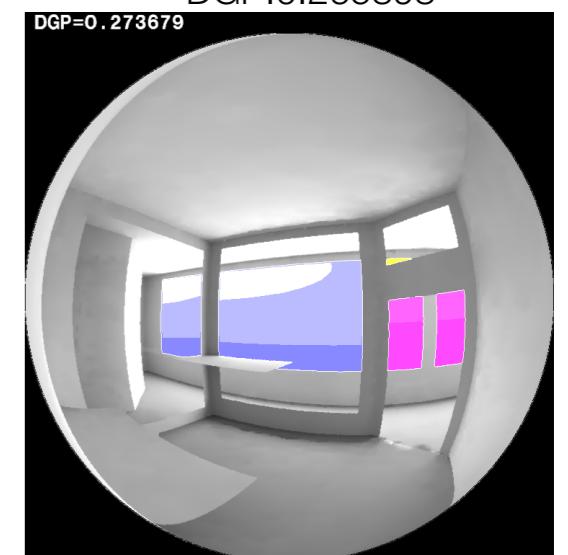
9AM, JUN 21

DGP:0.264113



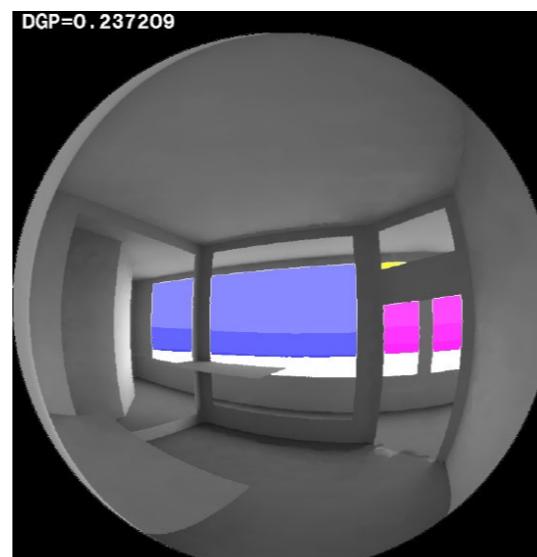
12PM, JUN 21

DGP:0.270374



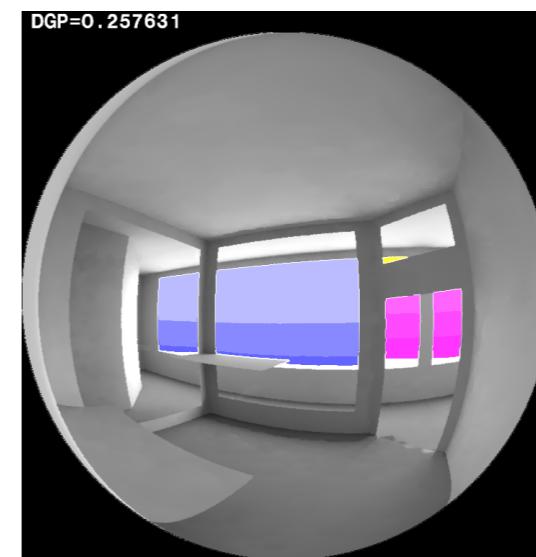
15PM, JUN 21

DGP:0.273679



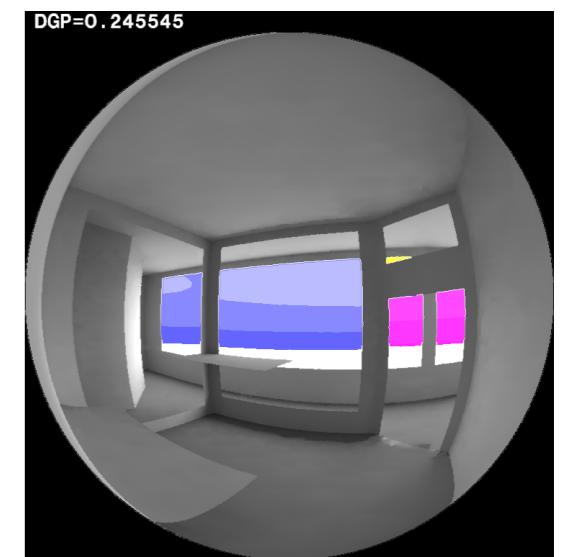
9AM, DEC 21

DGP:0.237209



12PM, DEC 21

DGP:0.257631

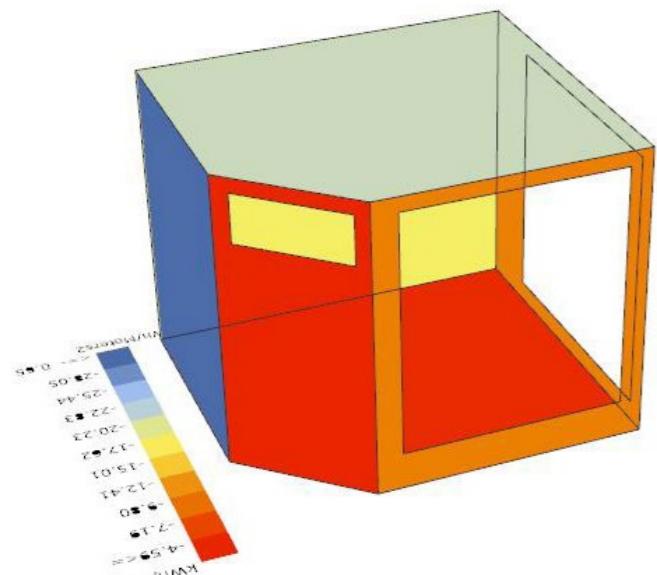


15PM, DEC 21

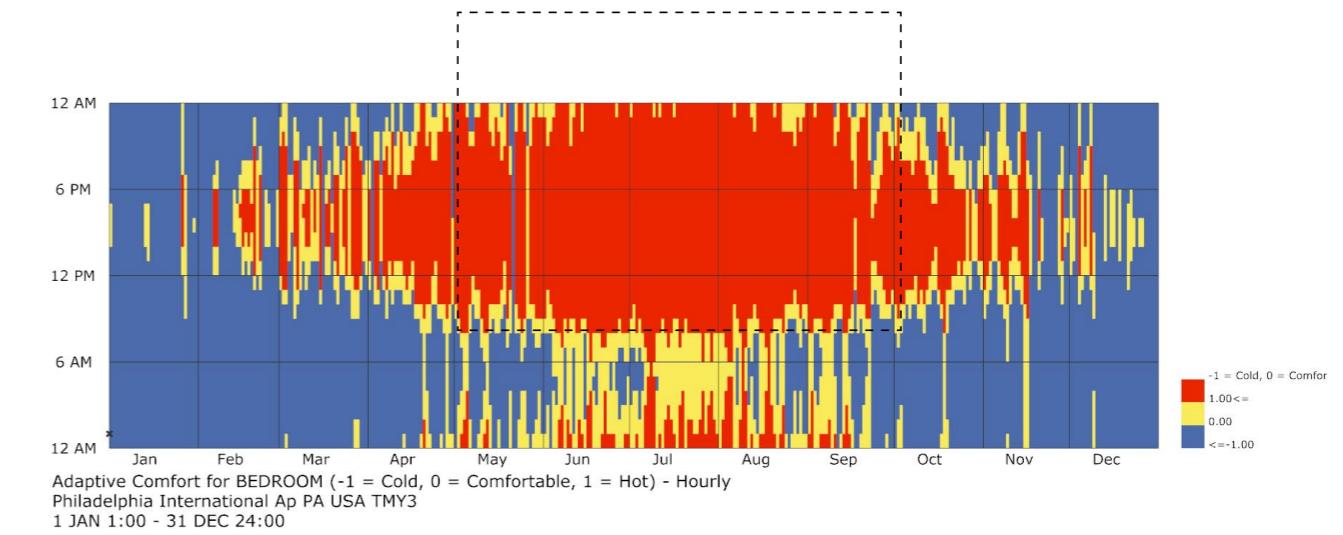
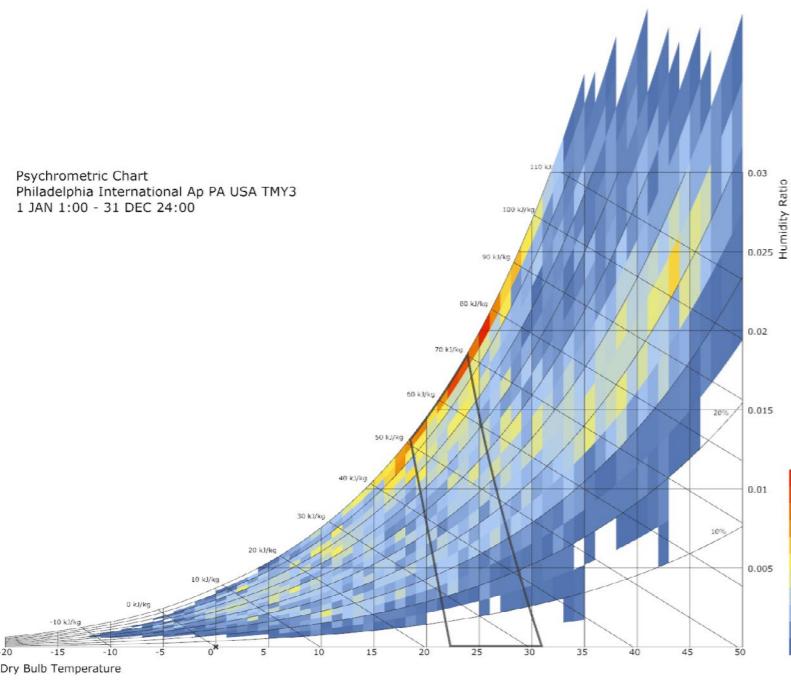
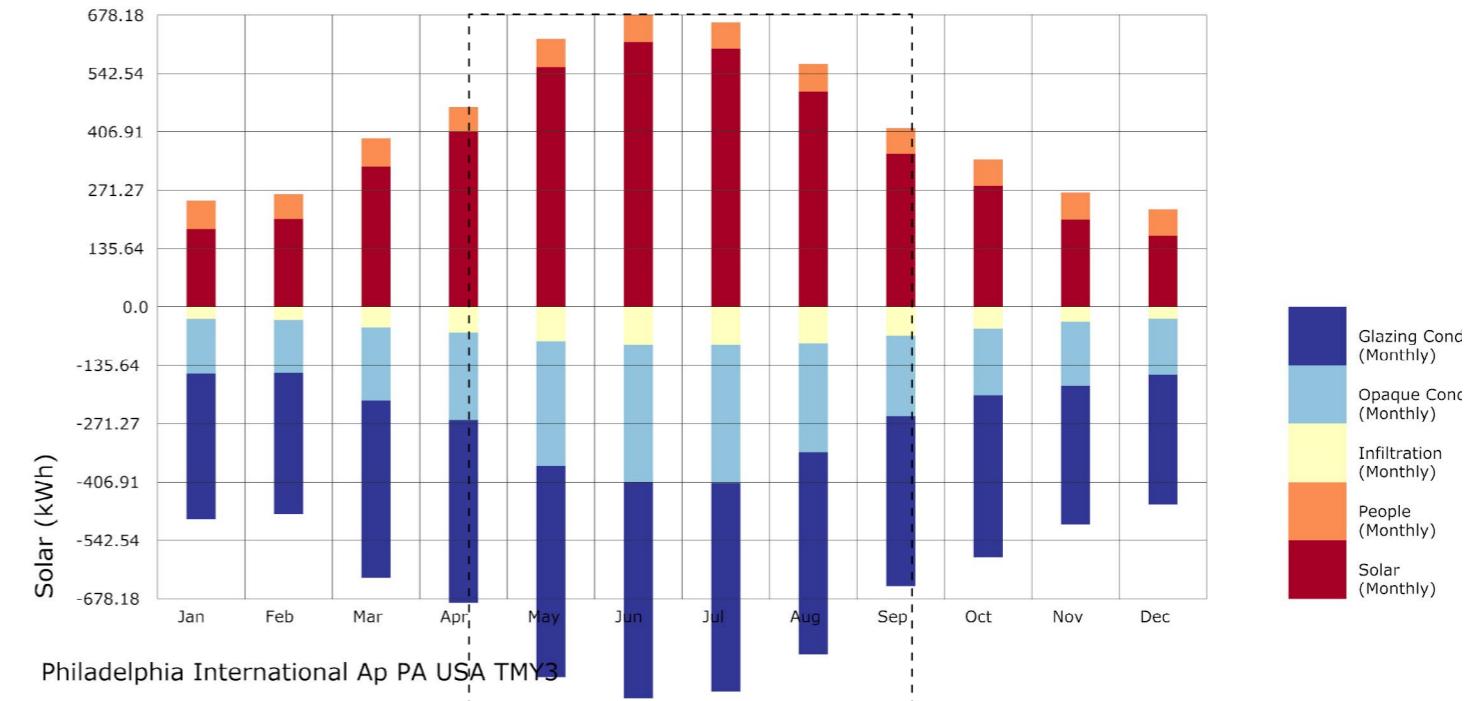
DGP:0.245545

## 2nd Modified Model

### Comfort Simulation



**Comfort: 17.76%**  
**Hot: 35.58%**  
**Cold: 46.66%**



### Conclusion

Based on the daylight simulation result, the daylight performance of this room has been improved. However, the comfort simulation shows poor performance when simply increasing the window area.

### 3rd Modified Model: Blinds&Material

#### Comfort Simulation

##### Reduce Hot Hours

###### Add Blinds

Depth: 0.5m  
Number of Blinds: 3

###### Add Blinds

Depth: 0.5m  
Number of Blinds: 8

**Comfort: 19.25%**  
**Hot: 31.67%**  
**Cold: 49.09%**

##### Reduce Cold Hours

###### Change material Construction

Exterior Wall:  
Before: 5.5, After: 34.4  
  
Exterior Roof:  
Before: 9.2, After: 34.4  
  
Exterior Window:  
Before: R1.0, SHGC 0.7  
After: R1.9, SHGC 0.39

**Comfort: 22.80%**  
**Hot: 35.64%**  
**Cold: 41.56%**

##### Reduce Hot Hours

###### Add Blinds

Depth: 0.3m  
Number of Blinds: 15

###### Add Blinds

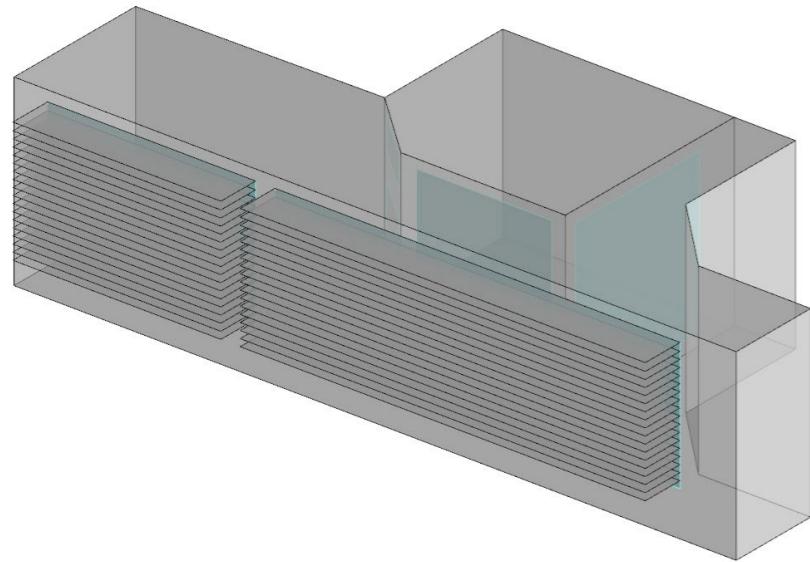
Depth: 0.5m  
Number of Blinds: 18

**Comfort: 23.72%**  
**Hot: 33.84%**  
**Cold: 42.44%**

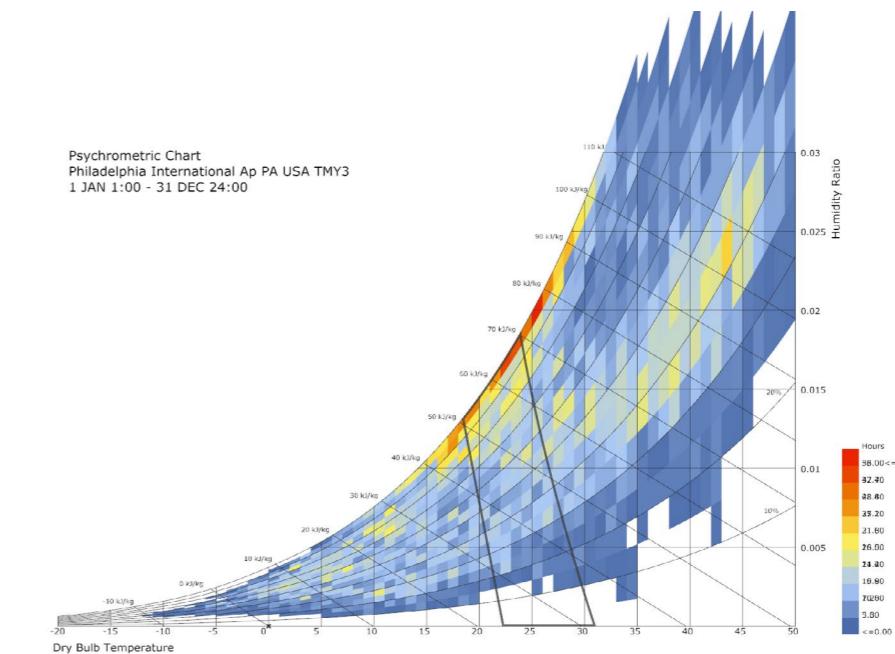
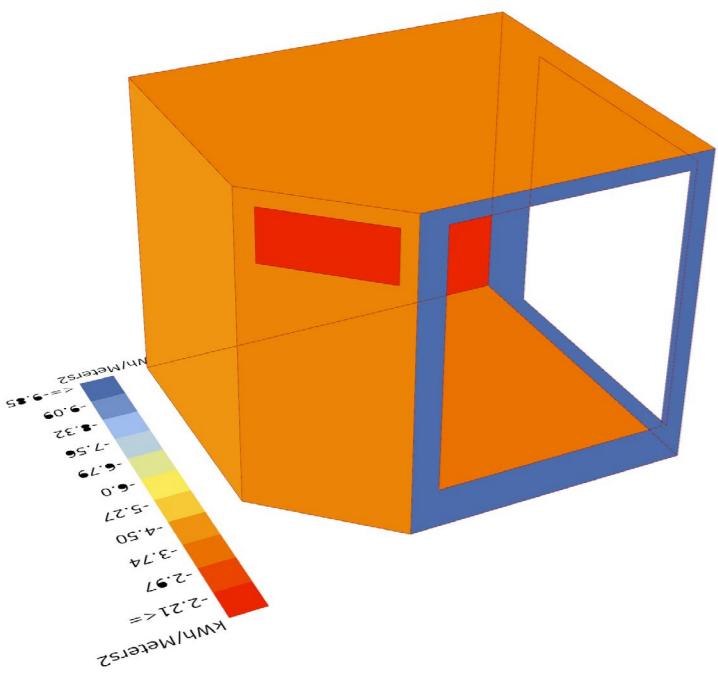
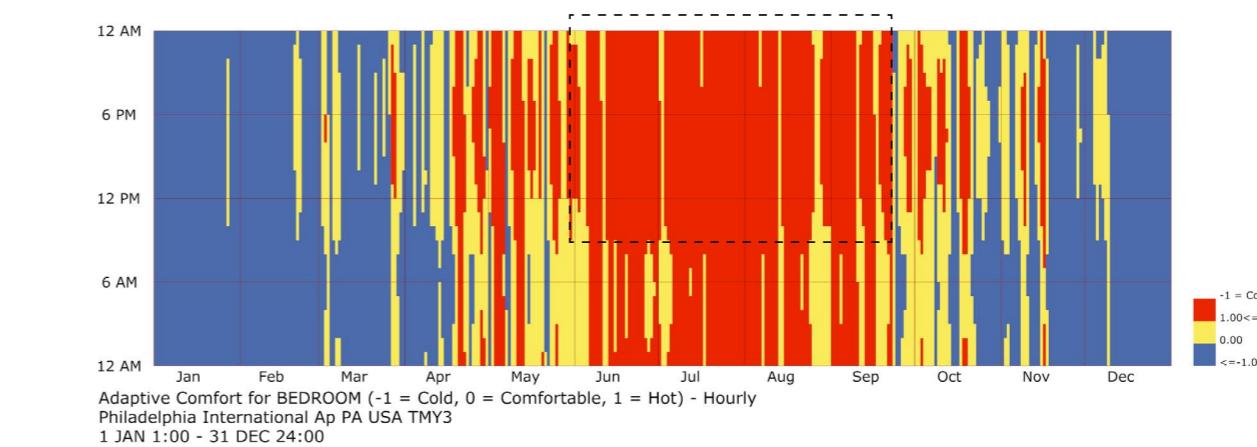
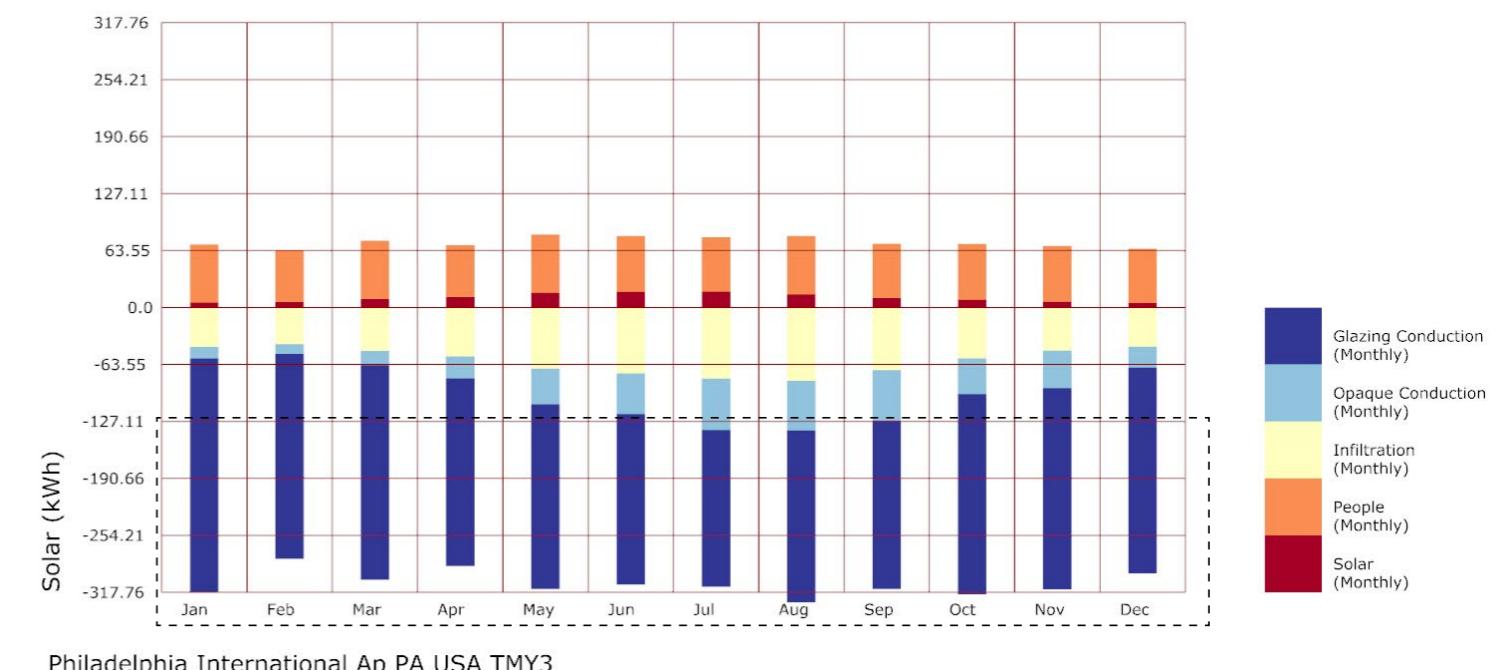
**Comfort: 24.01%**  
**Hot: 33.23%**  
**Cold: 42.76%**

## 3rd Modified Model

### Comfort Simulation

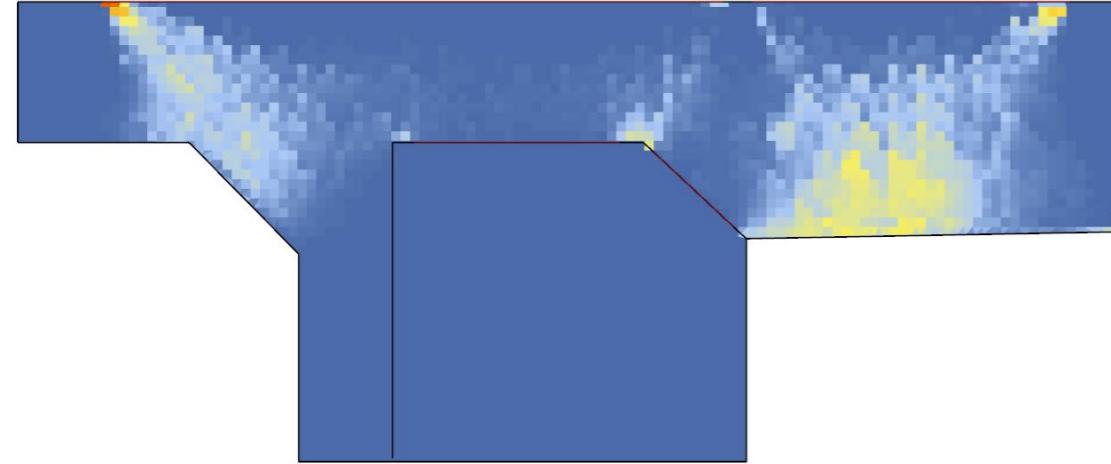


**Comfort: 24.01%**  
**Hot: 33.23%**  
**Cold: 42.76%**

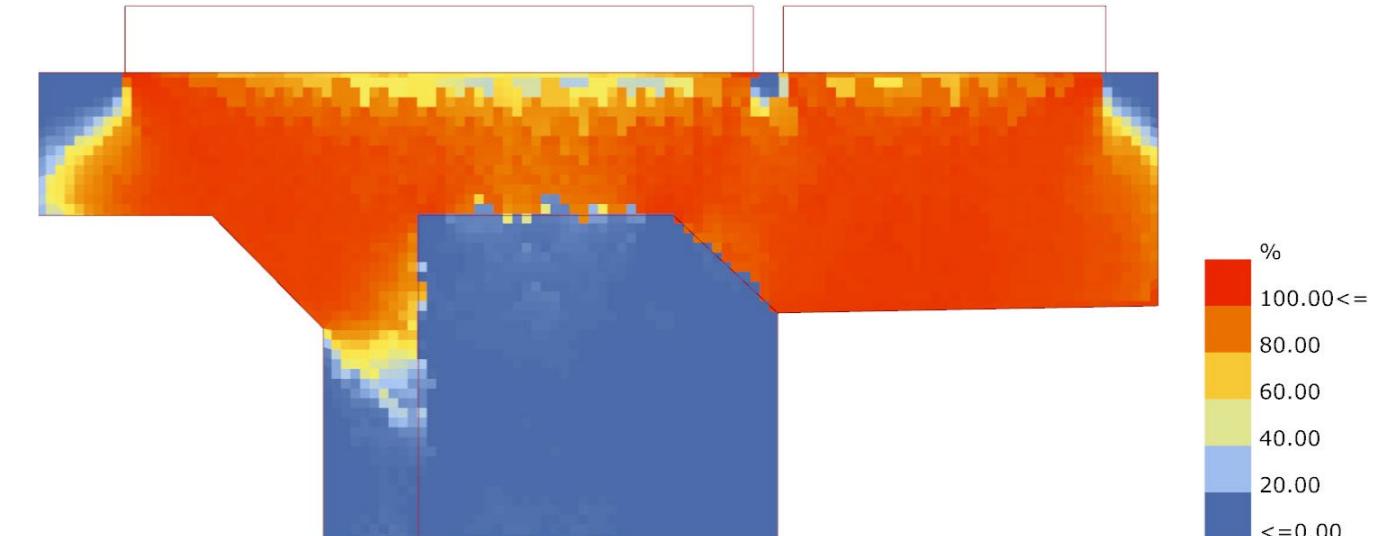


## 3rd Modified Model

### Useful Daylight Illuminance



**Daylight Autonomy: 6%**



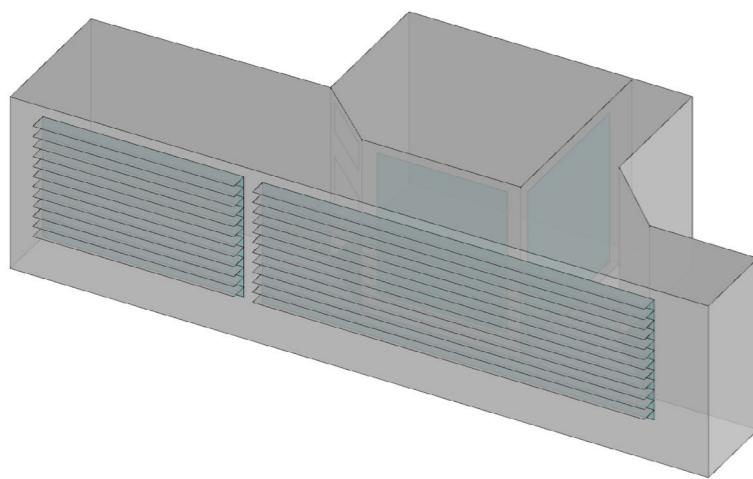
**Useful Daylight Illuminance(100-2000lux): 58%**

### Conclusion

From the result of thermal comfort simulation, when adding shading on the window and change the materiality, the comfortable hours increased because it prevent the sunlight from heating the room during summer and reduce heat lose in winter. However, the shading also has negative affect on the daylight performance since daylight is blocked.

## Final option: Change the material, depth and number of shading

### Comfort Simulation



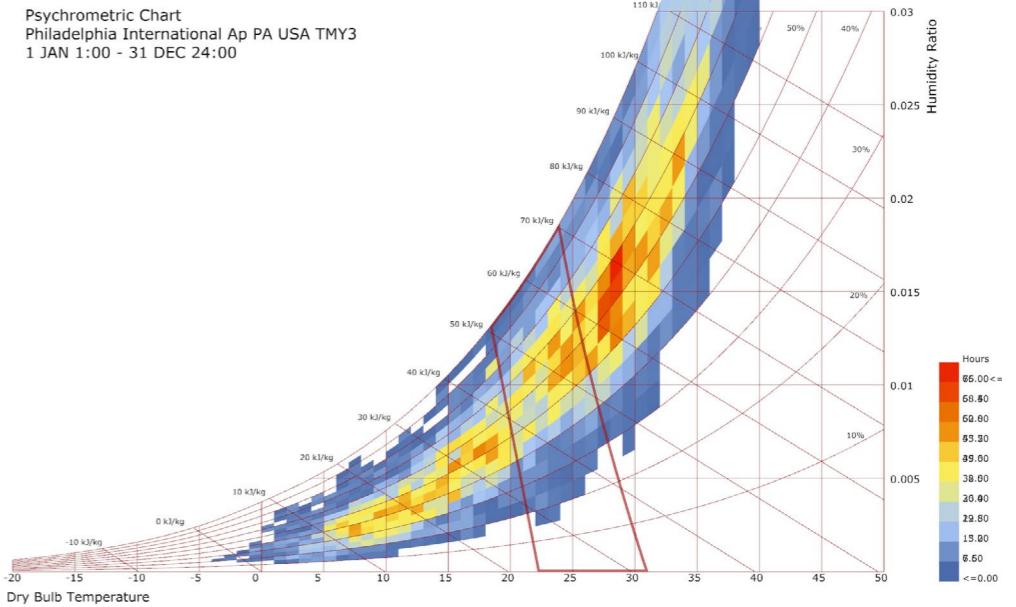
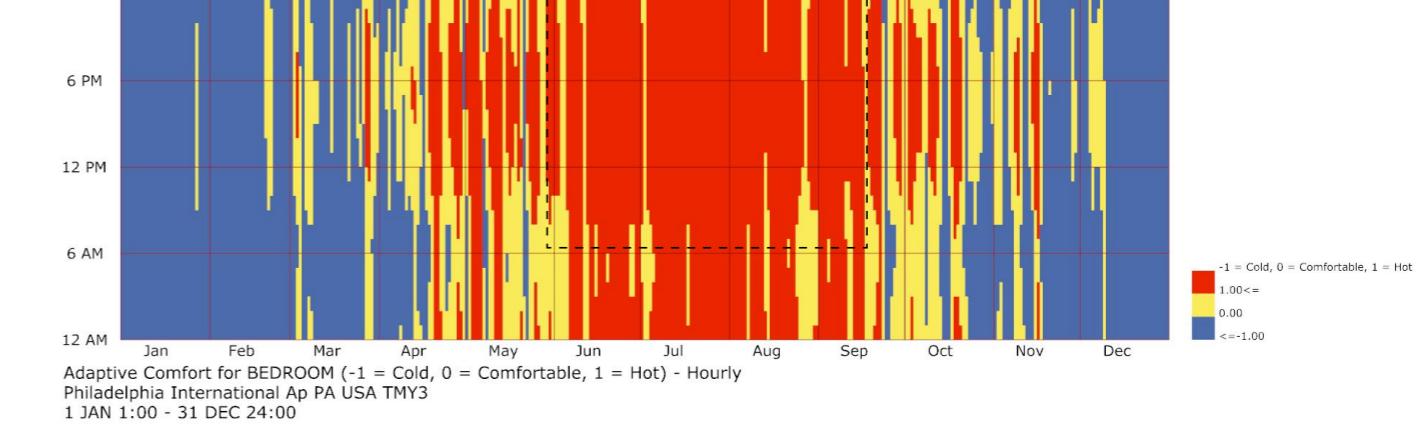
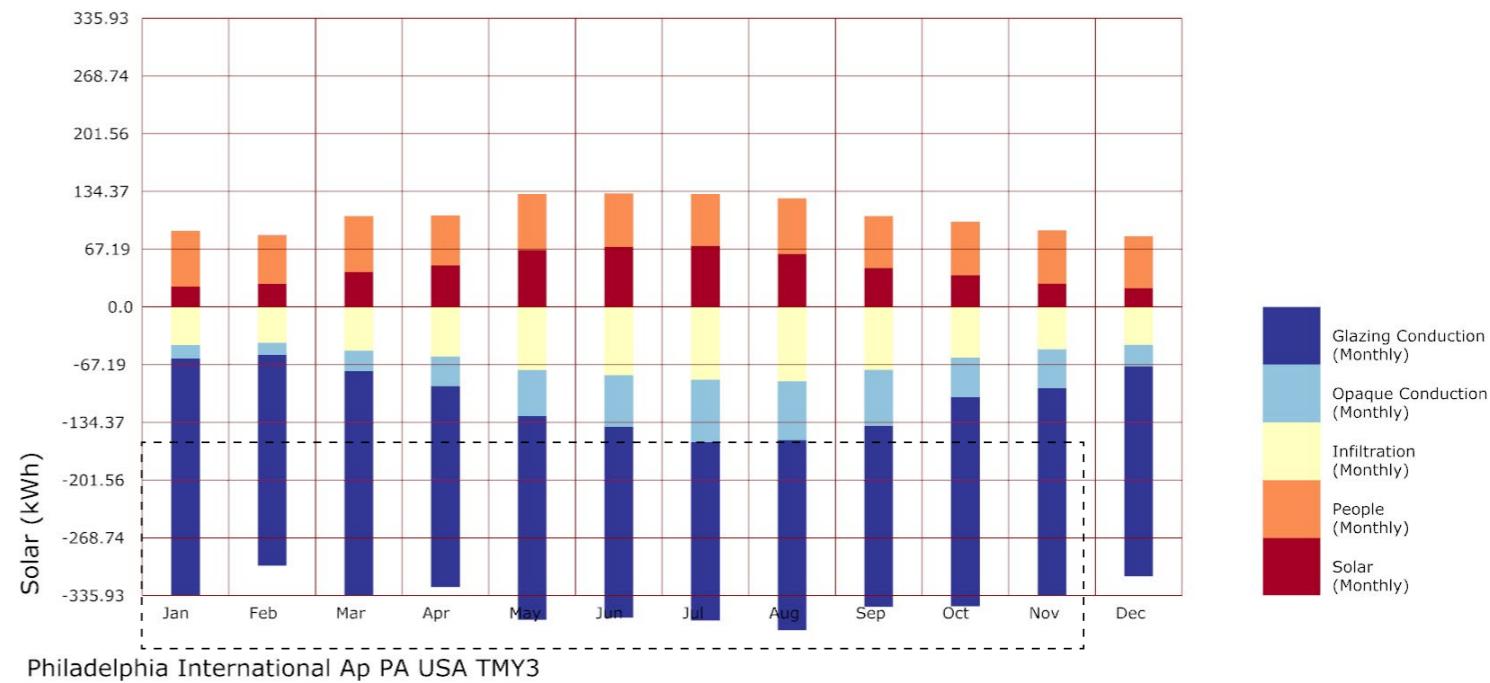
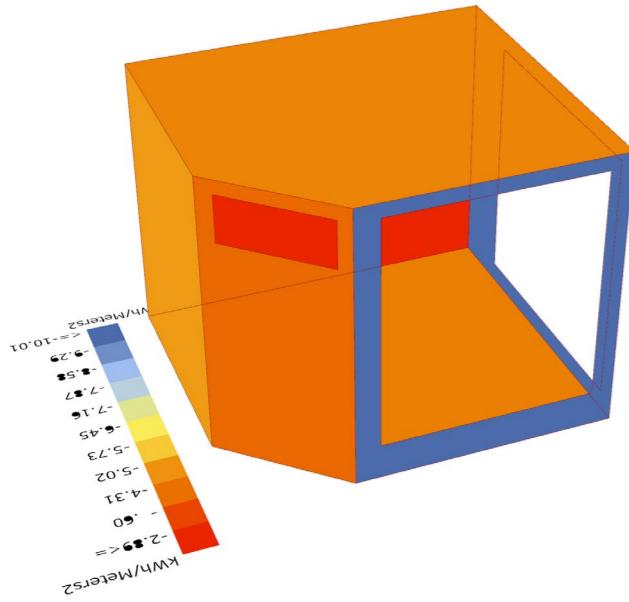
**Comfort: 22.83%**  
**Hot: 35.75%**  
**Cold: 41.42%**

### Strategy:

By changing the density, depth and material of shading, the idea is to create balance between daylight performance as well as thermal comfort.

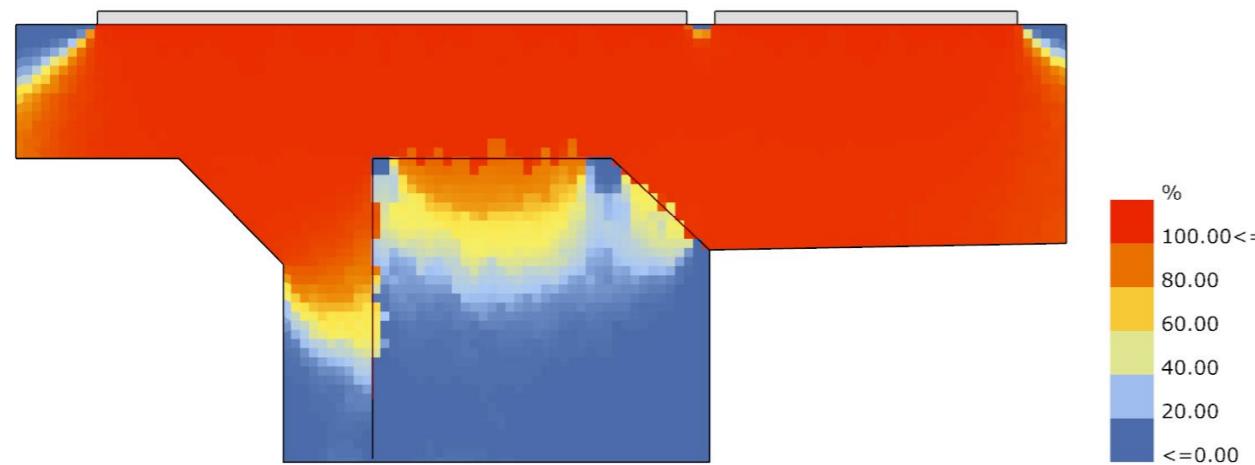
### Result:

The DA and UDI are improved. Meanwhile, the thermal comfort value didn't change much.

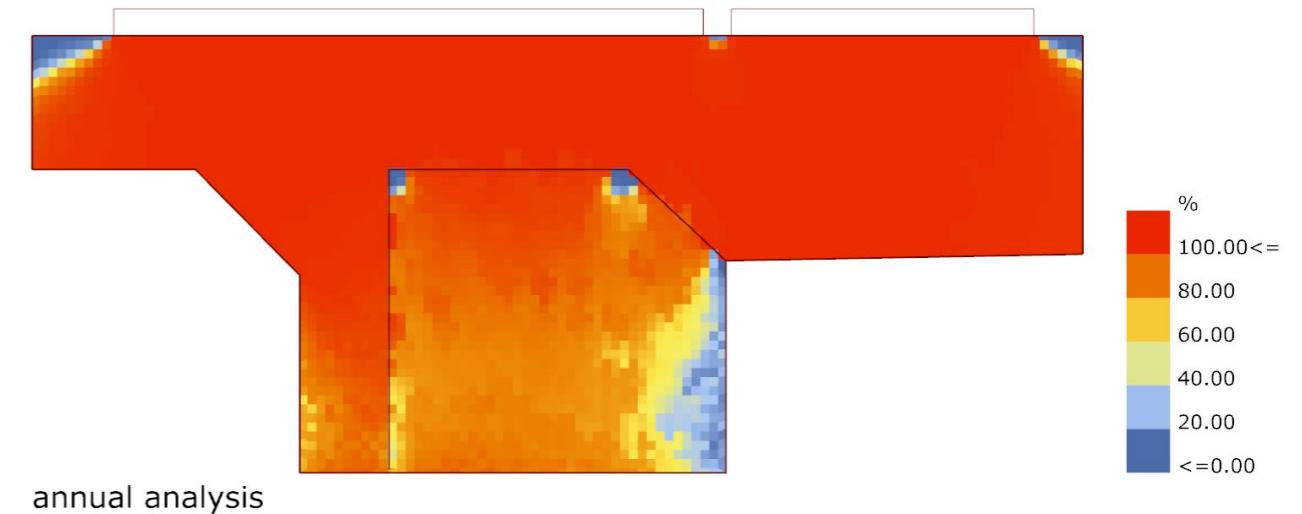


## Final option: Change the material, depth and number of shading

### Useful Daylight Illuminance

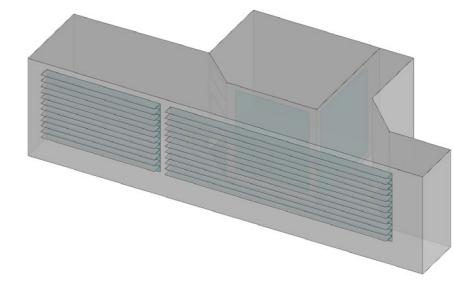
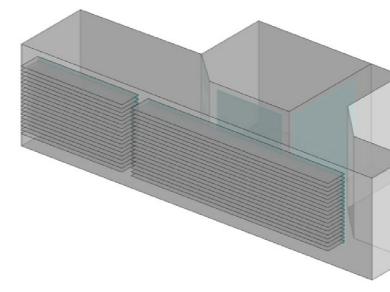
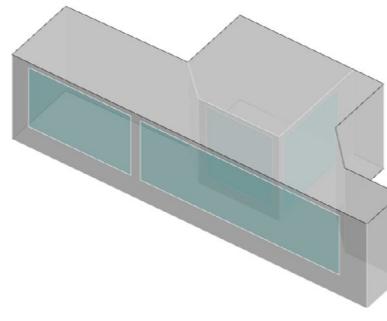
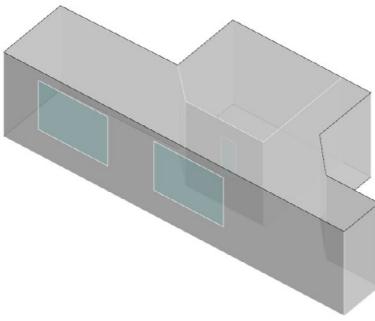


**Daylight Autonomy: 67.06%**

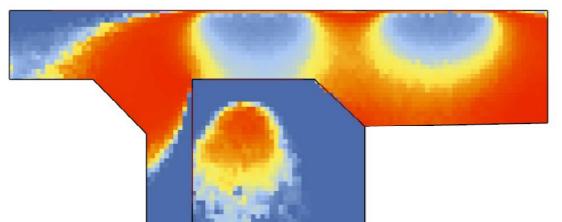


**Useful Daylight Illuminance(100-2000lux): 99%**

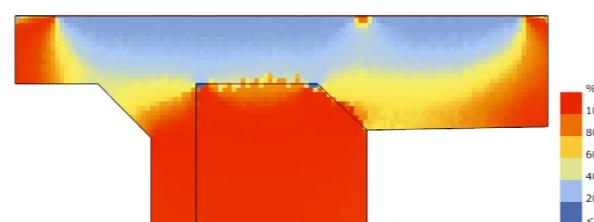
## Model



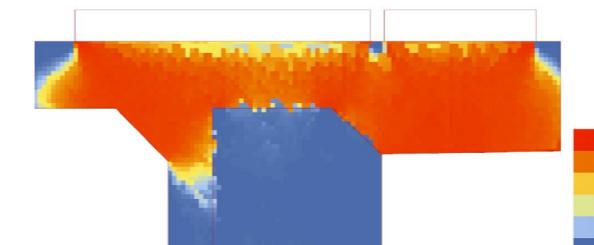
## UDI



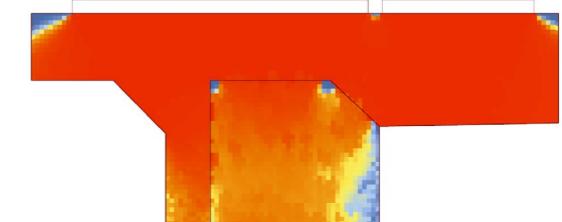
45%



60%

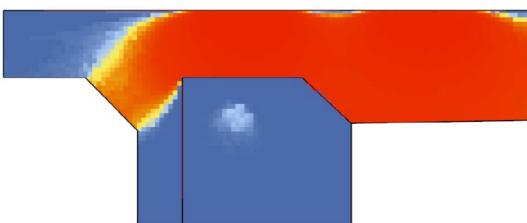


58%

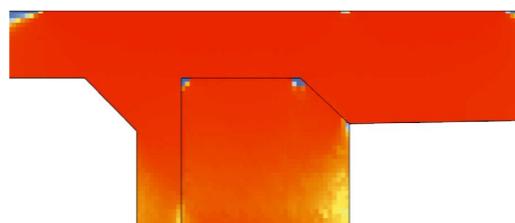


99%

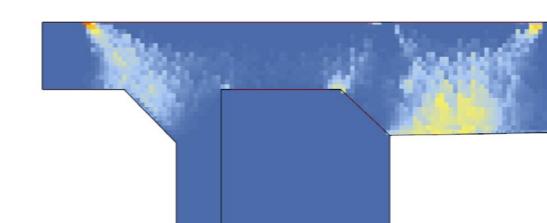
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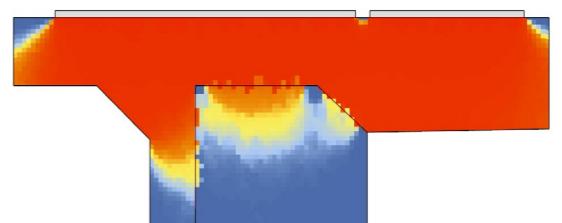
48%



93%

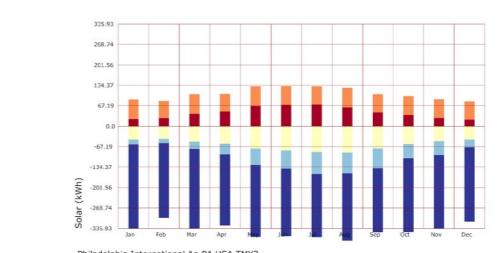
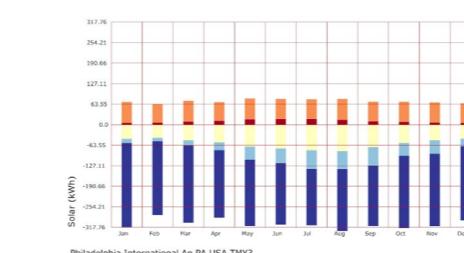
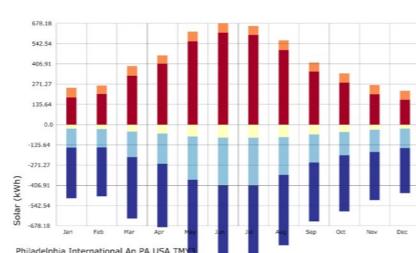
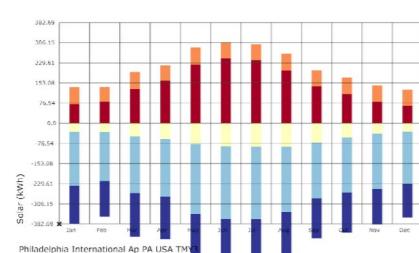


6%



67.06%

## Energy Balance



**Base Model**

**Comfort: 18.66%**

**3rd Option**

**Comfort: 17.76%**

**4th Option**

**Comfort: 24.01%**

**Final option**

**Comfort: 22.83%**

## Conclusion& Further Proposal

### Conclusion

The process of building performance optimization is about creating a logic that:

1. Find issues from a macro-scale to a micro-scale
2. Possible Proposals.
3. Test different options, then compare and analyze the results.
4. Redevelop the design idea
5. Make balance between different ideas.

### Further Proposal

1. Build up a sloping window that connects with outside to get direct sunlight.



2. Since the room is inside a house, the influence of the space that surrounds the bedroom may need to be further considered for daylight and thermal comfort performance.

3. Potential influence of ventilation needs to be further developed to improve the comfort value.