Final Project

Building Performance Simulation
Yuchi Wang

.epw file information :
Location : Philadelphia International Airport
Data Type : TWY 3

Climate Analysis

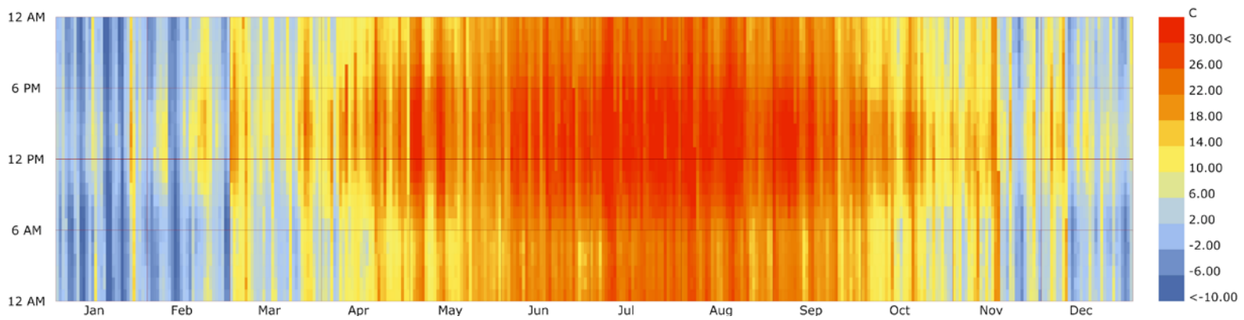
Dry Bulb Temperature / Relative Humidity / UTCI

Philadelphia locates in east coast of United States. Greater Philadelphia lies at the southernmost tip of the humid continental climate zone, with some characteristics of the humid subtropical climate.

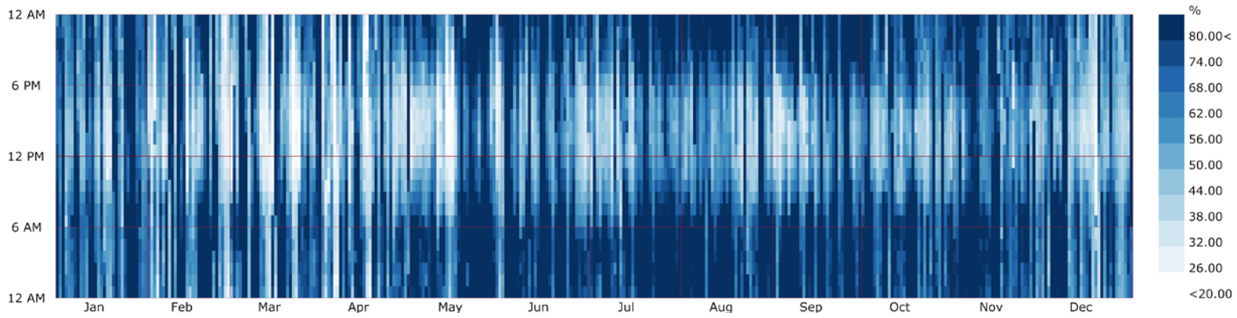
Throughout the year, I found Philadelphia is pretty cold during winter and hot during summer. However, when looking at the relative humidity chart, I found that during the noon time in summer, the relative humidity is not very high, and this provide the possibility of natural ventilation to cool down indoor space.

From the ourdoor comfort chart, after calculation , we can find about 55.84% of the year can be considered comfortable. During the uncomfortable times, we can see that the summer day time and January nights are most discomfortable.

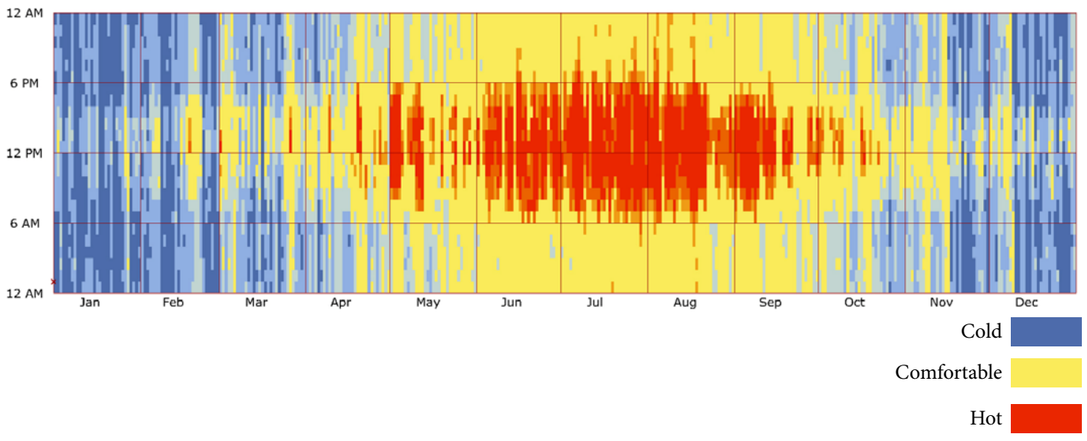
Dry Bulb Temperature



Relative Humidity



Outdoor Comfort



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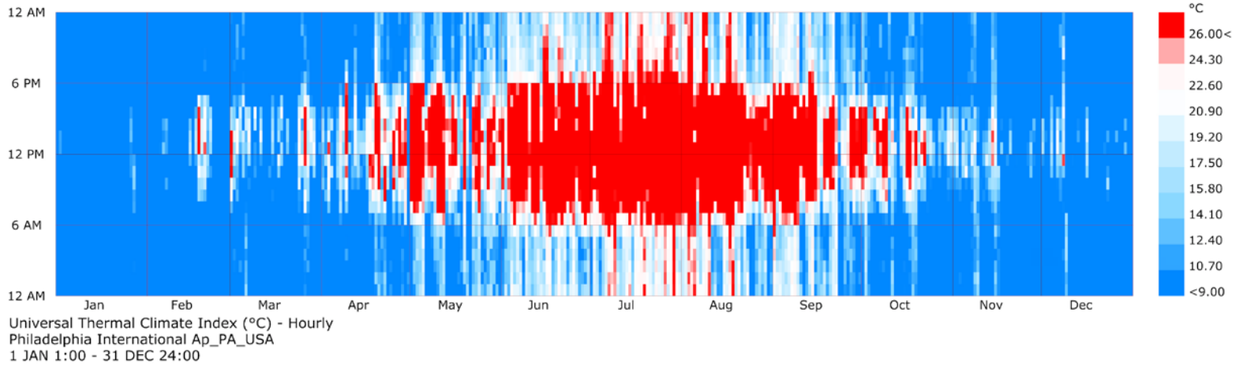


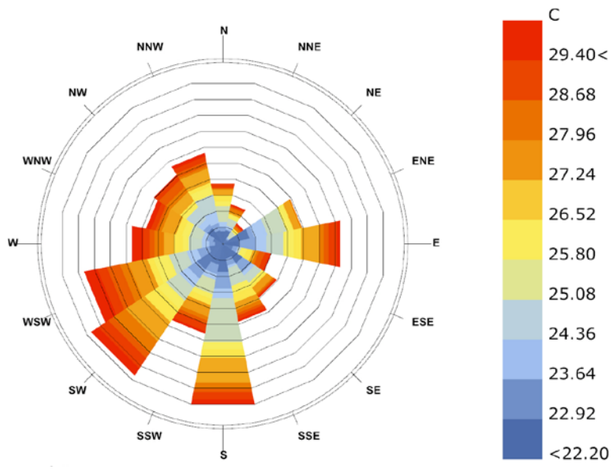
Climate Analysis

Uncomfortable Wind Direction

Normally, the preferred wind speed for good ventilation should between 2m/s and 10m/s. As a result, during the cold seasons, the larger the wind velocity, the more heat a house will lose when there is natural ventilation. During the hot seasons, large wind velocity will help reduce the heat inside but slow wind does no good for heat reducing.

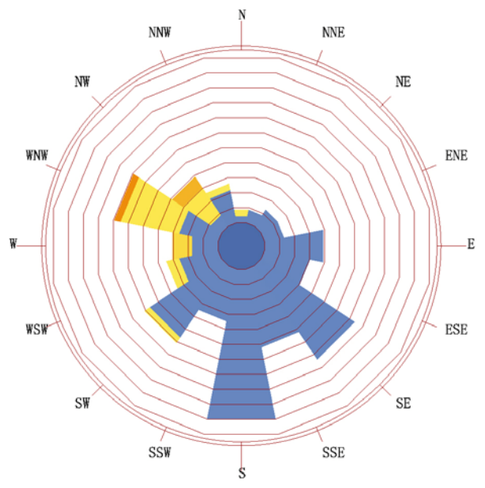
In spring, although there are a lot of slow wind from south, the strong wind are mostly from northwest. During summer, we can see that the overall uncomfortable wind and from south with a low velocity. In autumn, uncomfortable winds are mostly the strong wind, which come from northwest. In winter, the uncomfortable winds are also mostly from northeast, including the strong wind and slow wind.

And from the lower chart, I found during summer, when the dry bulb temperature is between 22 and 30, the wind are mainly from south and south west which I can use for natural ventilation during summer.

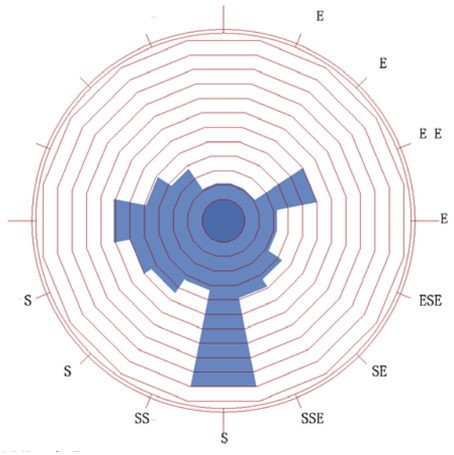


Summer wind frequency when dry bulb temperature is between 22 and 30

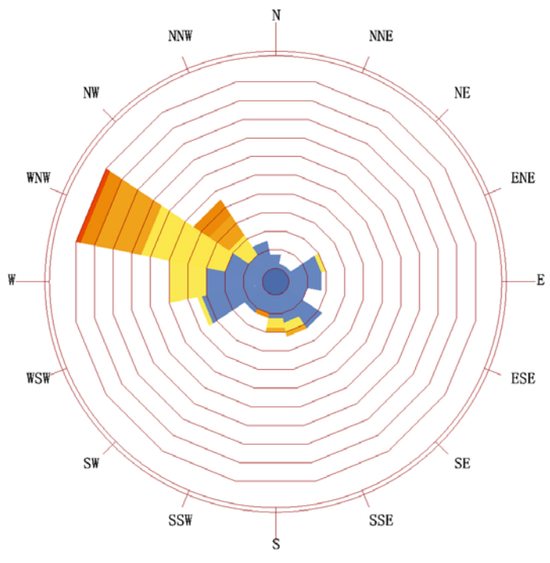
Summer



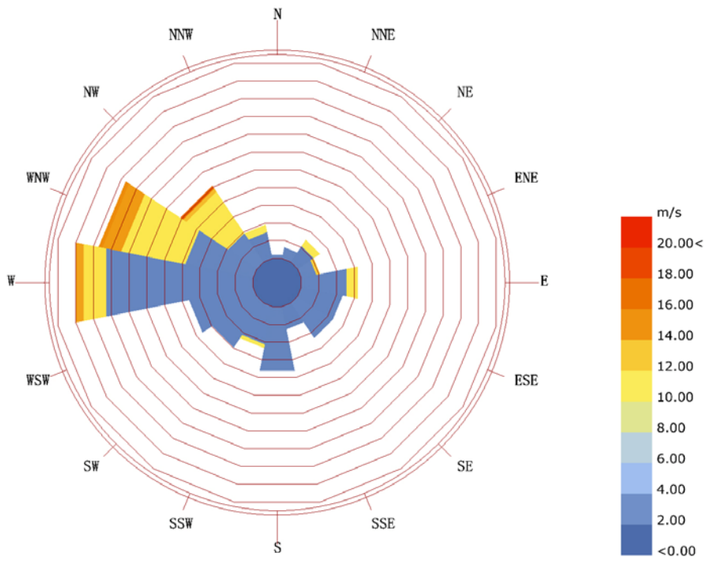
Fall



Winter



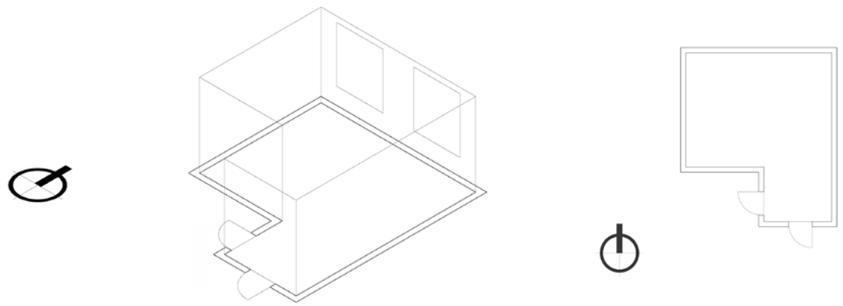
Spring

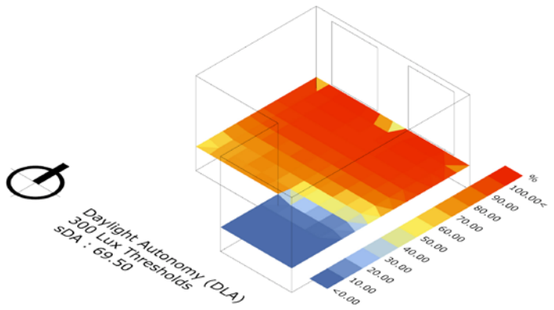


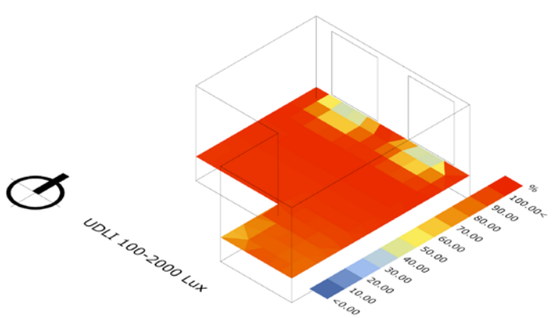
Wind Frequency when the wind speed is less that 2m/s of larger that 10m/s

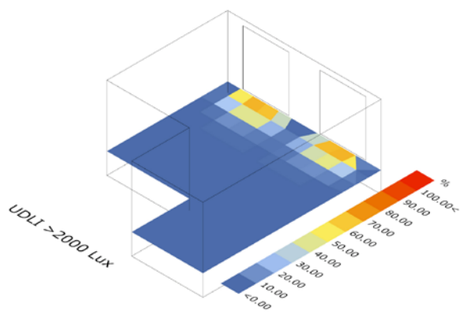
Baseline Analysis

Daylighting







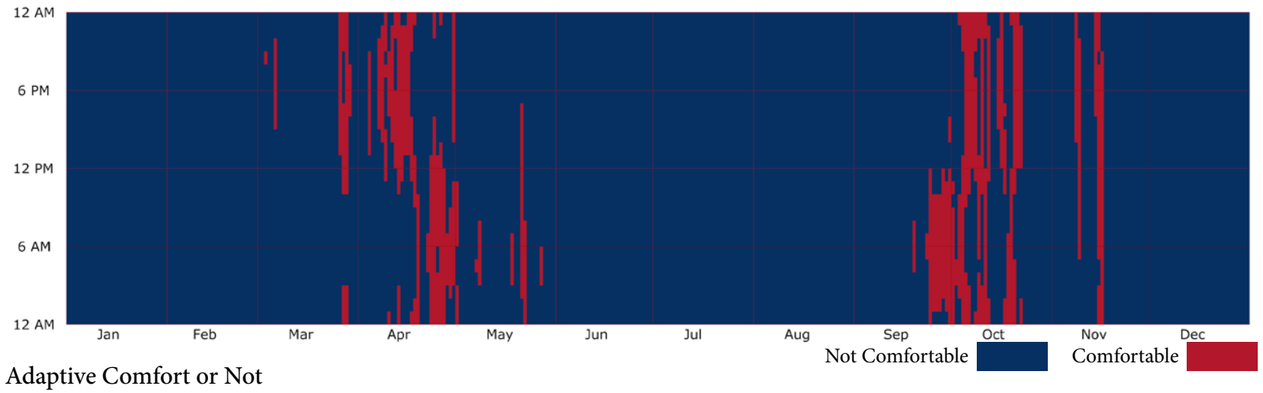


From the daylighting chart on the right, I found even the house is north facing, the daylighting is not a big issue because of the space is not that deep. So the main concern for the exploration should focus on the thermal comfort.

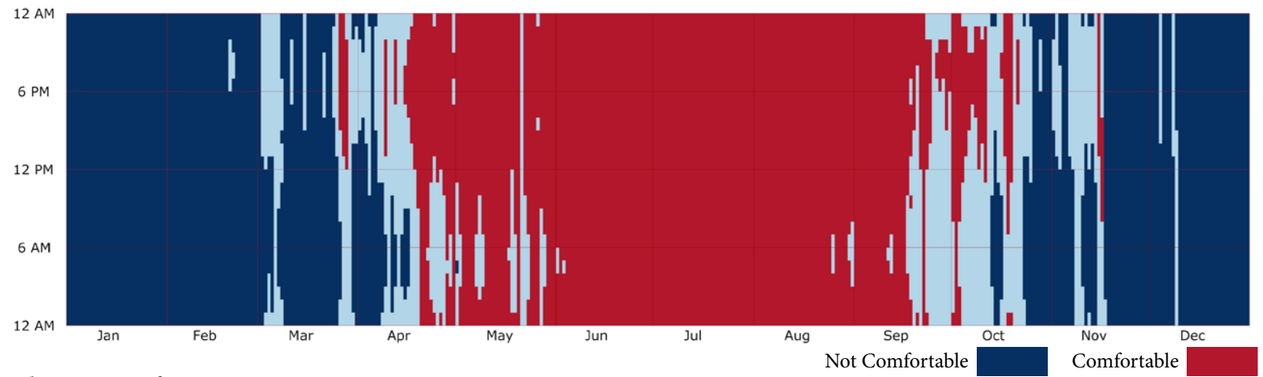
Thermal Comfort

For the indoor comfort, we can find the main issue is the over heat during summer time and too cold during winter.

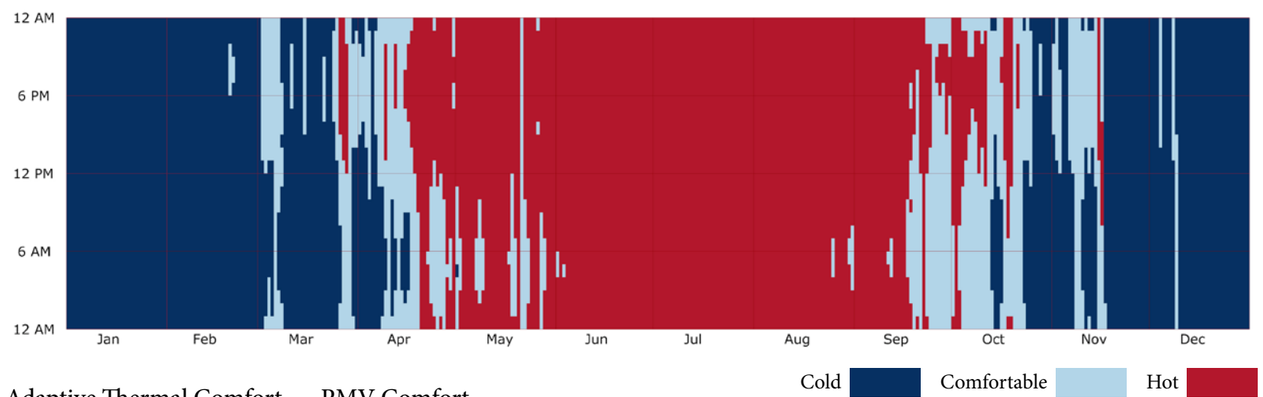
PMV Comfort or Not



Adaptive Comfort or Not



Adaptive Comfort Situation



Adaptive Thermal Comfort	PMV Comfort
16.37	8.37

Exploration Direction

About Daylighting

From the baseline analysis, even the main facade orientation is north, the daylighting situation is not a big issue. The exploration should focus more on improving thermal comfort. However, if changing orientation is taken into consideration, after changing the orientation, a daylighting simulation should be run aagain to double check the daylighting situation.

Issues 1 - Too Cold During Winter

During winter time, the indoor is extremely cold. Changing the orientation to introduce more solar radiation can work as one apporach to improve. But after changing the orientation, daylighting need to be double check if a shader is needed

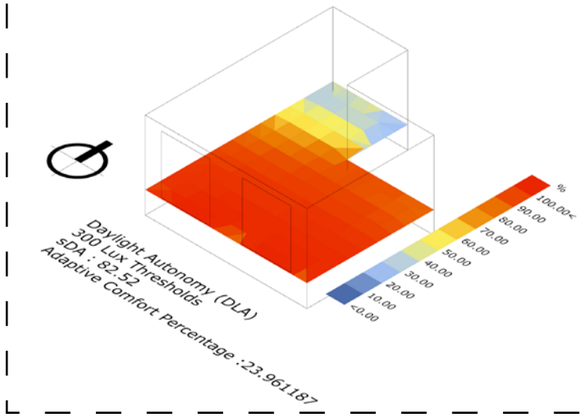
Issues 2 - Too Hot During Summer

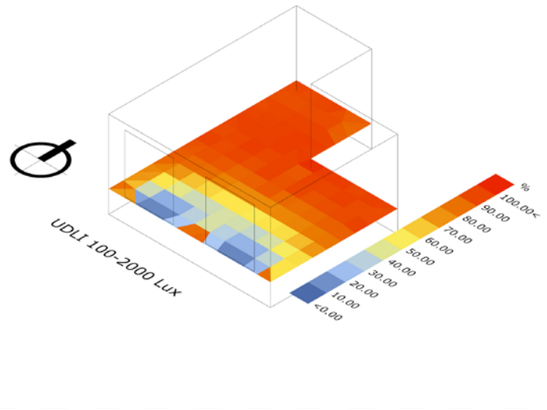
During summer, the indoor is extremely hot. Considering the cold issue during winter, enlarge the window is not a proper strategy in this case. As a result, changing the natrual ventilation strategy is a reasonable approach.

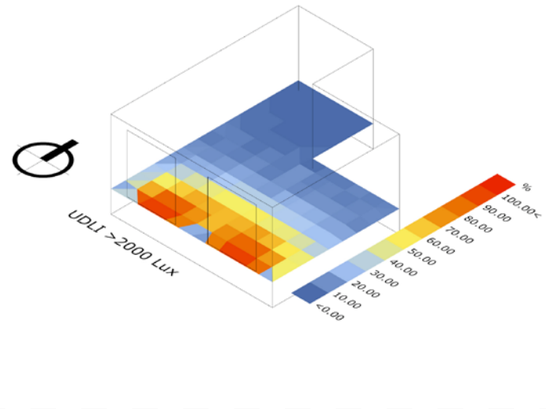
Exploration

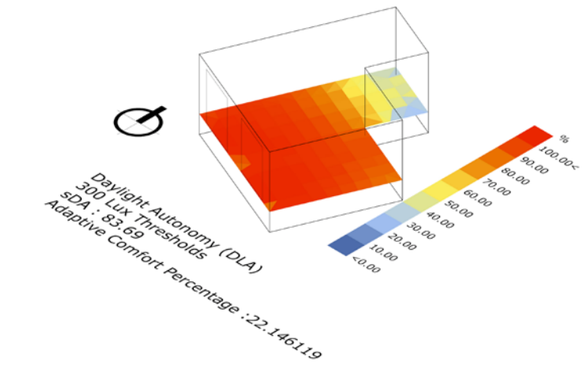
Change the Orientation

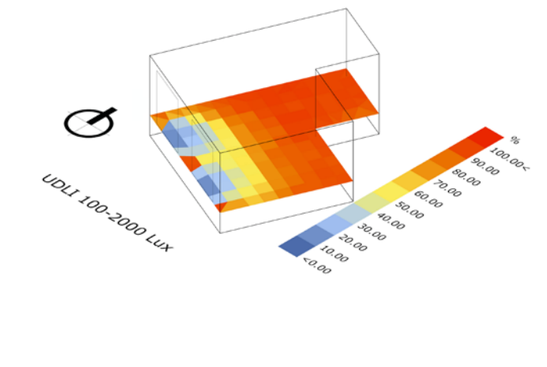
From the wind rose chart with comfort wind, I found during summer, the wind used for natural ventilation mostly come from south. In order to take advantage of natural ventilation later, I change the orientation of the building from facing north to south. I took several orientation test and calculated the adaptive comfort and found south orientation works best and there was no issue about lacking of daylighting. So next step is to design a shader that improve the indoor daylighting environment.

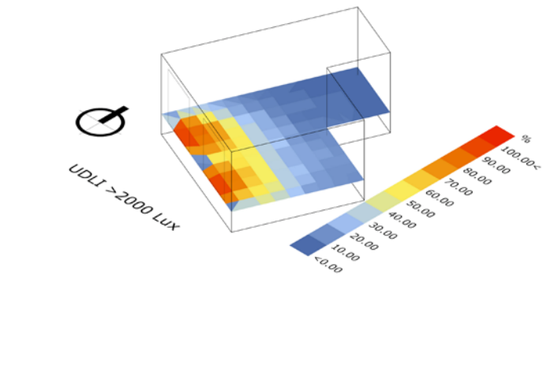


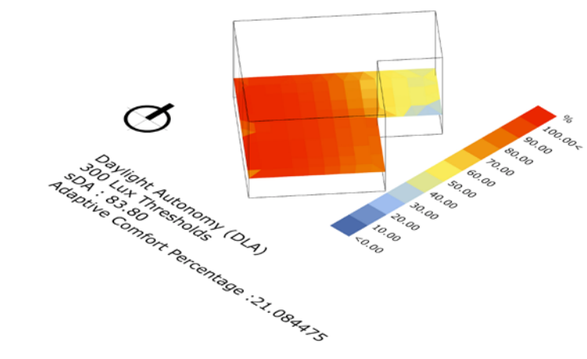


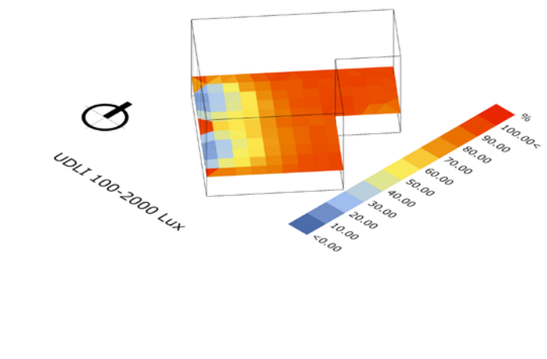


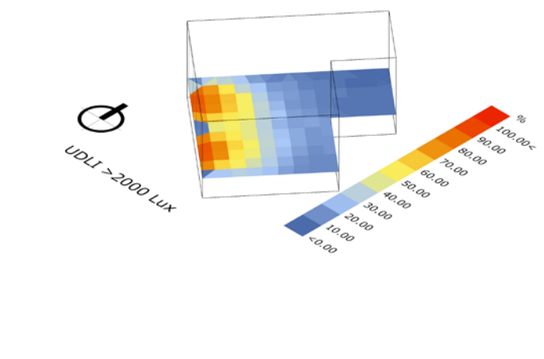








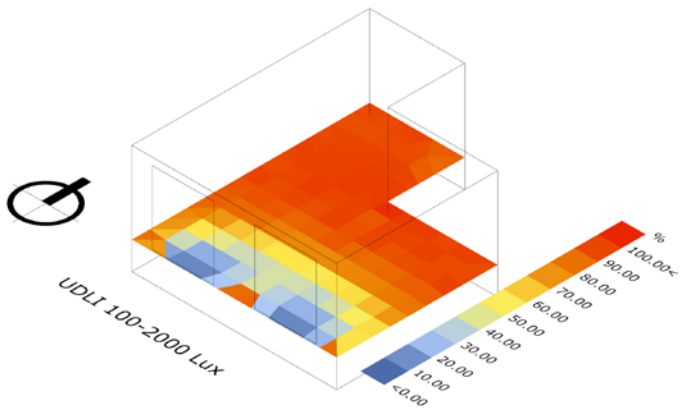




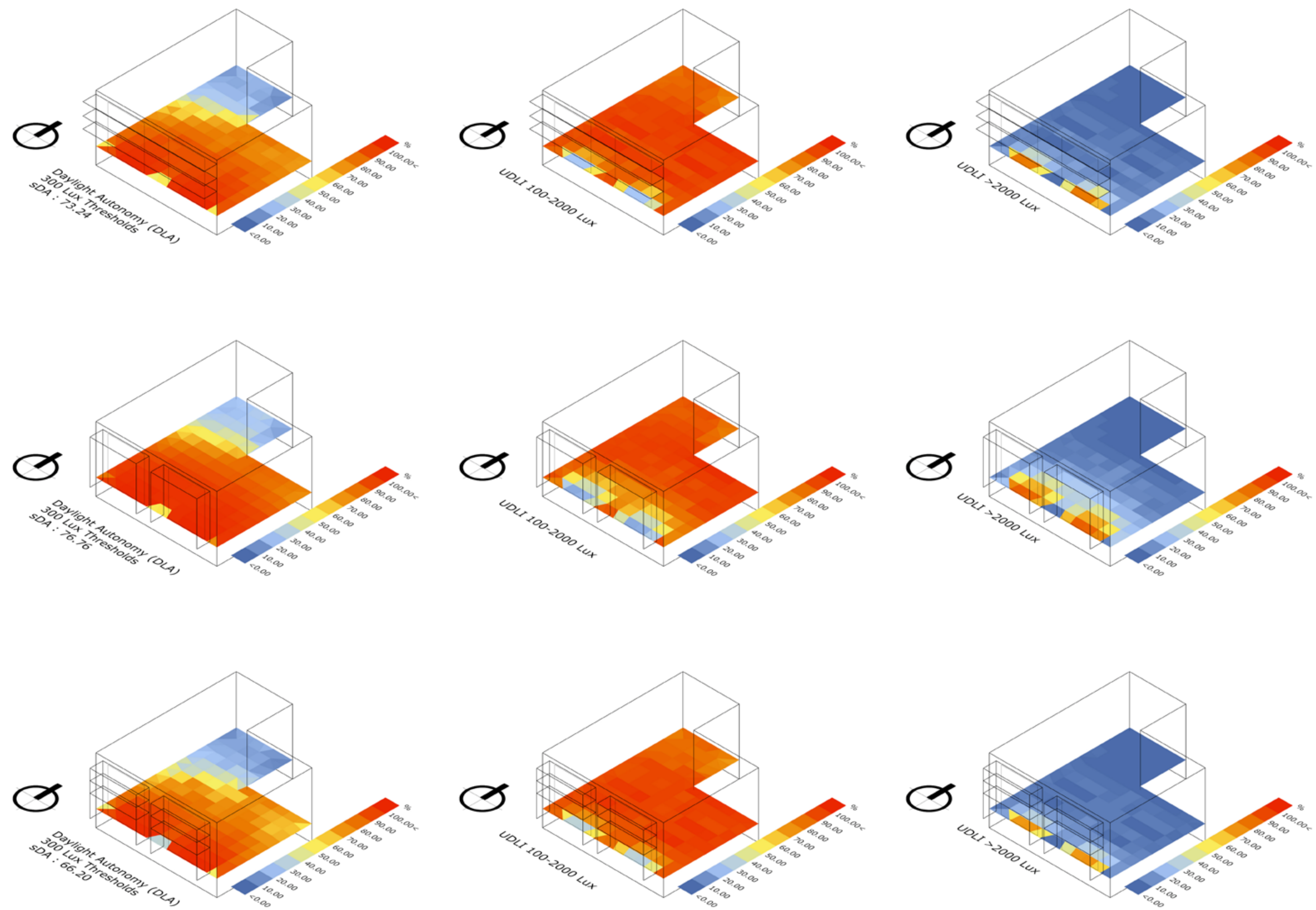
Exploration

Adding Window Shader

Starting Point



Daylight Autonomy | UDLI 100-2000 | UDLI >2000

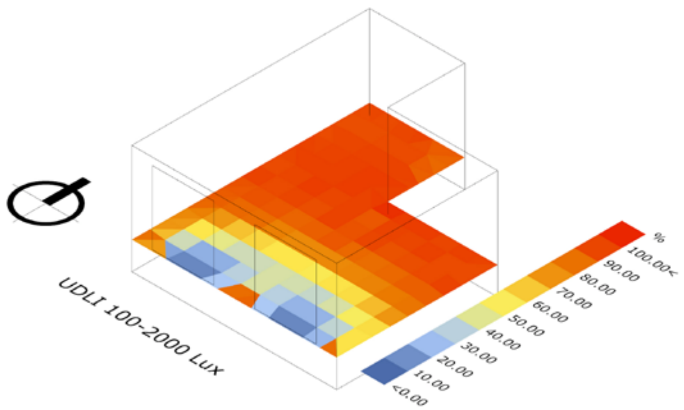


From the UDLI diagram, I found the main daylighting issue for this case is the over-lightened near the south window. So I designed a shader to improve the daylighting environment near the window but maintain the deep inner space still lightened.

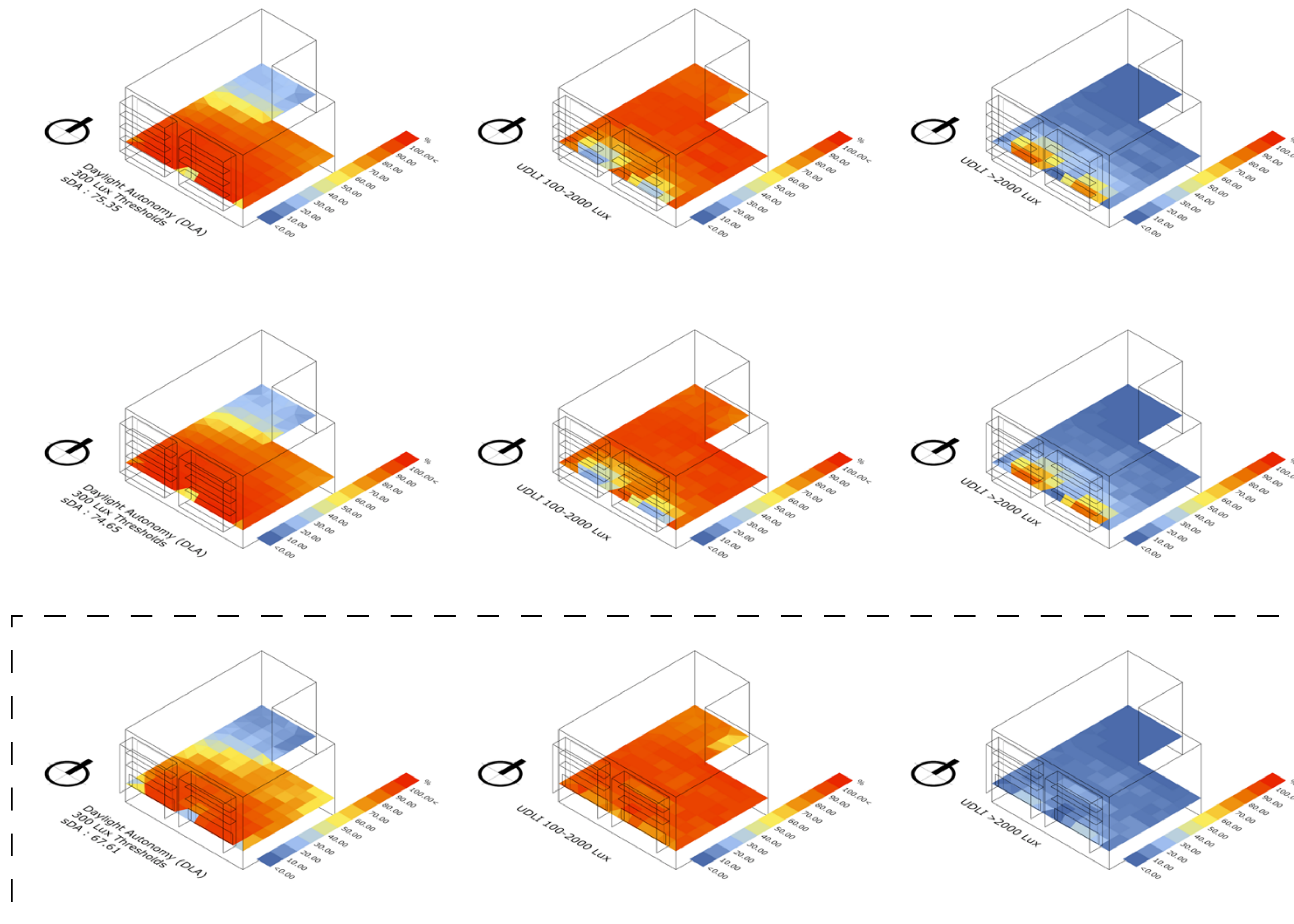
Exploration

Adding Window Shader

Starting Point



Daylight Autonomy | UDLI 100-2000 | UDLI >2000

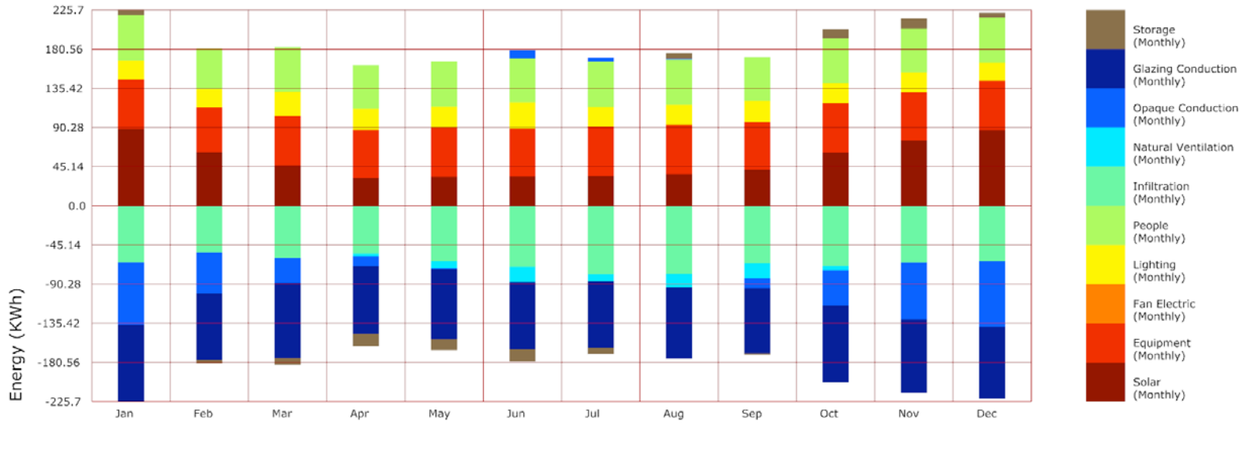


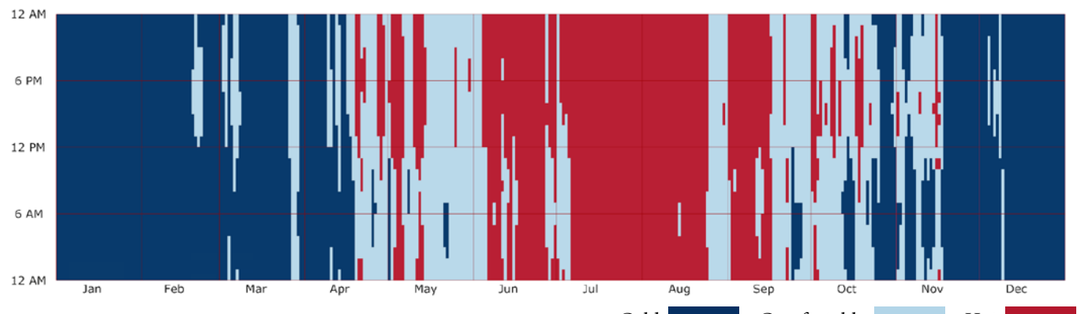
From the UDLI diagram, I found the main daylighting issue for this case is the over-lightened near the south window. So I designed a shader to improve the daylighting environment near the window but maintain the deep inner space still lightened.

Finally, a combination shading system is selected, which includes the vertical shading blocking east and west sunlight, a vertical shading at the bottom blocking over-light near window, and horizental shading.

Exploration

Double Check Energy Chart





After the sun shader design, I took a look at the indoor comfort situation and the energy balance chart. From the indoor comfort chart, I found the overheat during summer and cold during winter is till the main issue. And from the energy balance chart, possible steps to improve the situation should include:

Adding R value for wall and window construction to reduce heat loss during winter,

Change natural ventilation strategy to reduce heat inside the house

Adaptive Thermal Comfort

28.13

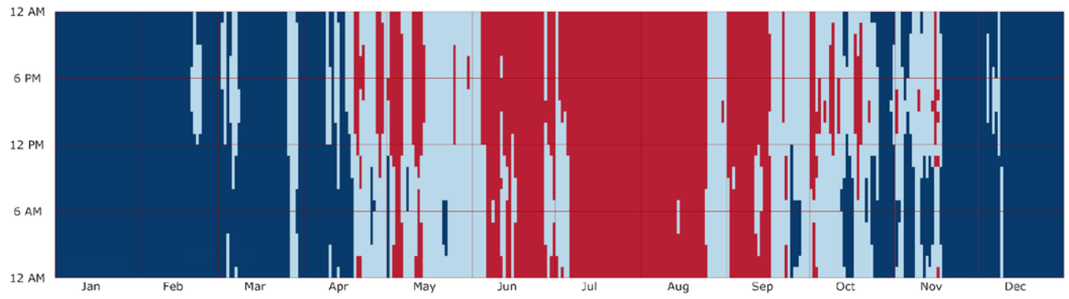
Exploration

Increase R value for wall construction and Windows

Wall R Value IP	8.76
Window U Value IP	0.55
Roof R Value IP	17.40
Floor R Value IP	35.97

Adaptive Thermal Comfort

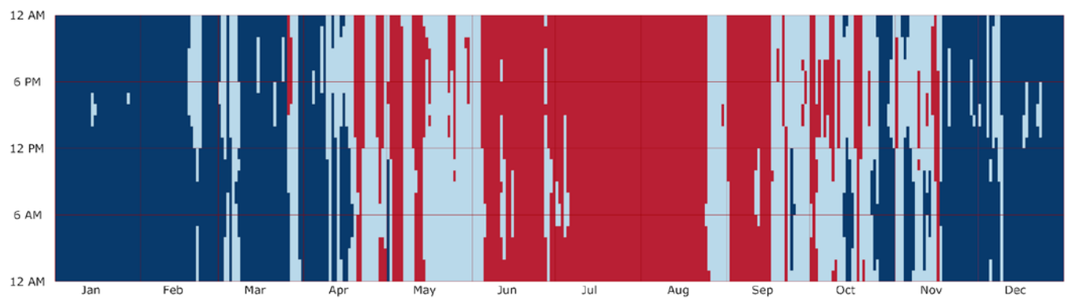
28.13



Wall R Value IP	14.78
Window U Value IP	0.4
Roof R Value IP	20.05
Floor R Value IP	35.97

Adaptive Thermal Comfort

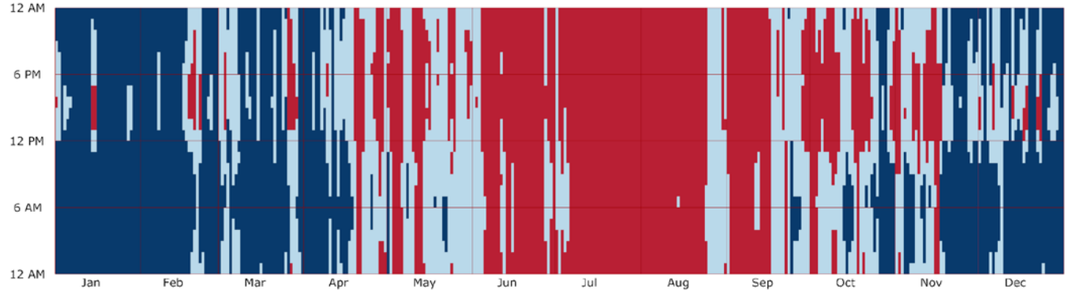
28.15



Wall R Value IP	14.78
Window U Value IP	0.7
Roof R Value IP	20.05
Floor R Value IP	35.97

Adaptive Thermal Comfort

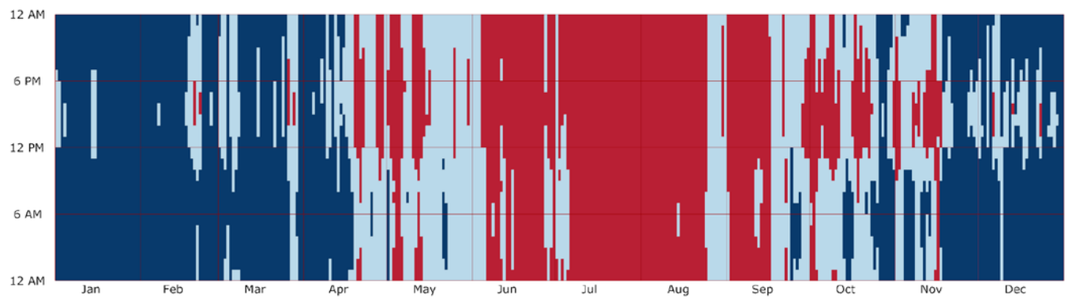
29.24



Wall R Value IP	14.78
Window U Value IP	0.9
Roof R Value IP	20.05
Floor R Value IP	35.97

Adaptive Thermal Comfort

29.62



Cold Comfortable Hot

Adaptive Thermal Comfort

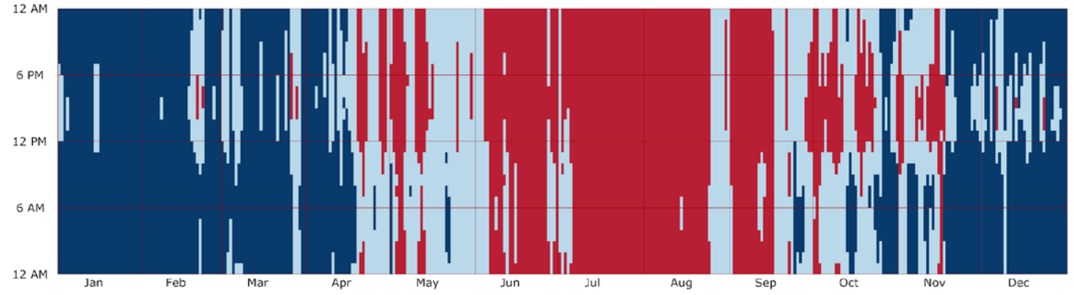
29.62

Exploration

Change Natural Ventilation Strategy

Adaptive Thermal Comfort

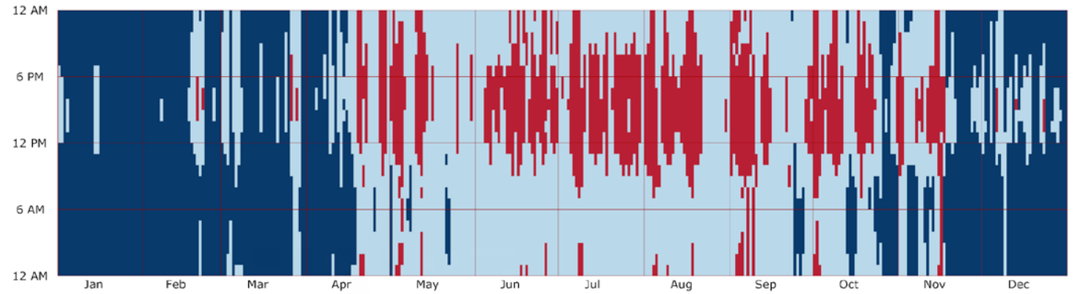
29.62



The next step is to change the natural ventilation strategy.
In this case, when the temperature is over 22 degree, and the outdoor dry bulb temperature is between 22 degree and 30 degree, the natural ventilation is introduced to improve cool indoor down. And I found the effect is pretty obvious, raising the adaptive comfort from 29.62 to 45.24

Adaptive Thermal Comfort

45.24



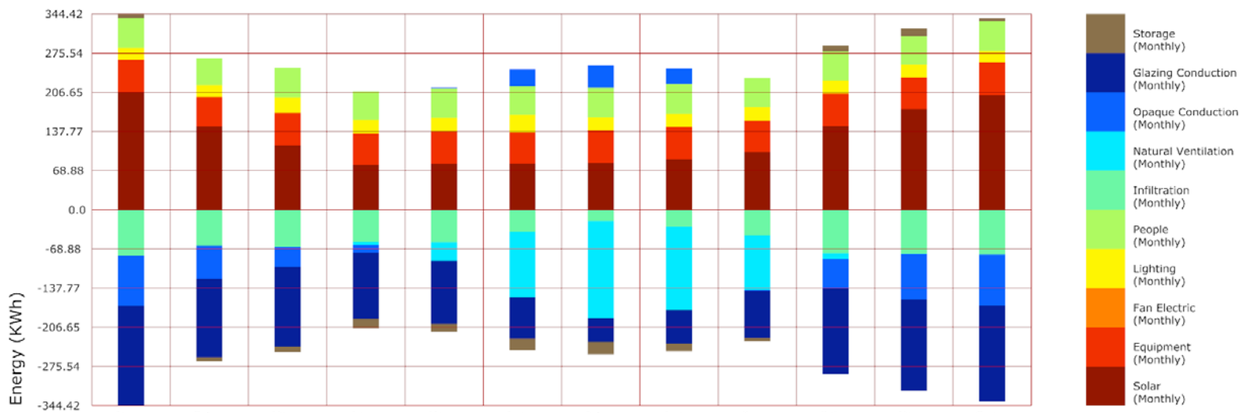
Cold Comfortable Hot

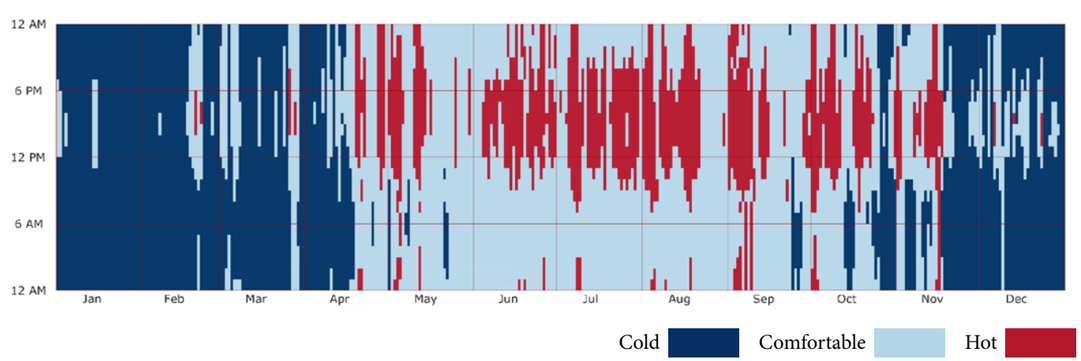
Adaptive Thermal Comfort

45.24

Exploration

Double Check Energy Chart





After these steps of exploration, the adaptive thermal comfort raised to 45.24. The reason why it cannot go further are as follows:

The house has context boundary in the south and north, so the side walls are adiobatic which reduce the possible heat transfer during summer,

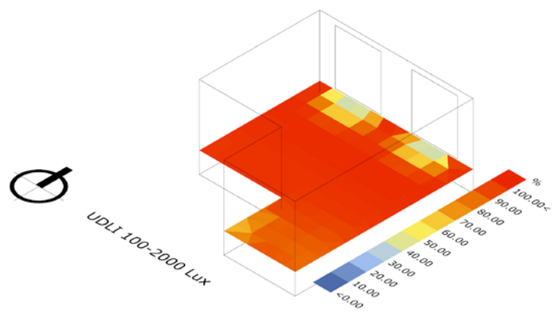
From the climate report, we find that during winter, the weather is so cold that the solar radiation itself cannot provide enough heat to indoor and keep cold weather keeps the heat loss during winter pretty high.

Adaptive Thermal Comfort

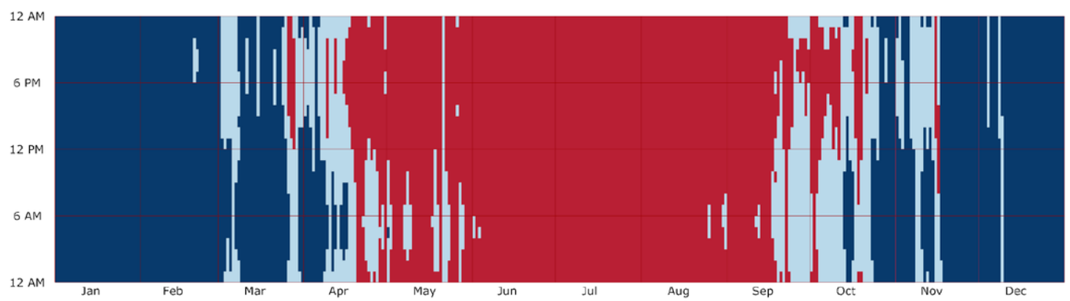
45.24

Comparison

Baseline



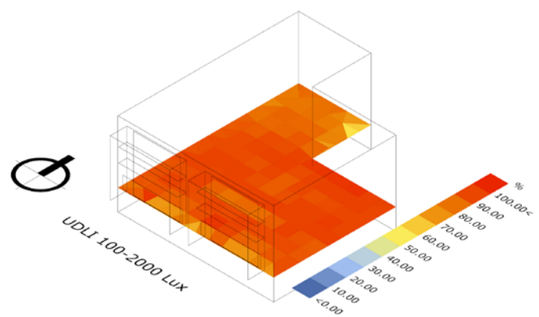
Daylighting



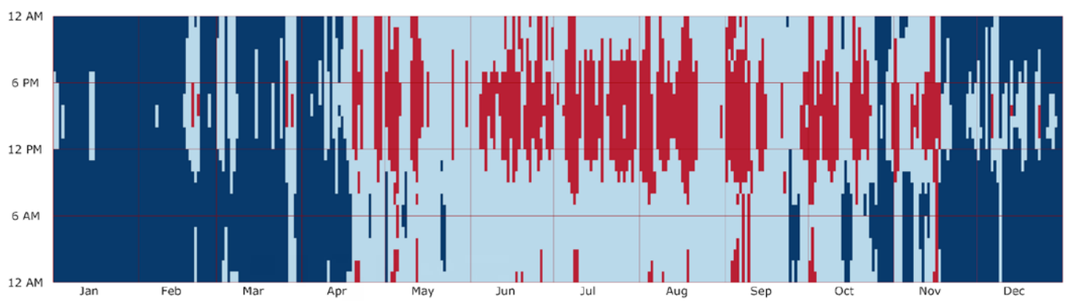
Adaptive Comfort

16.37

Exploration Result

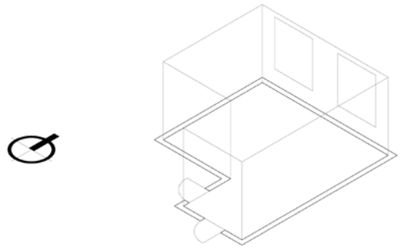
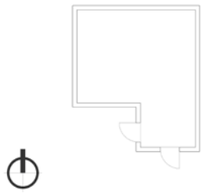
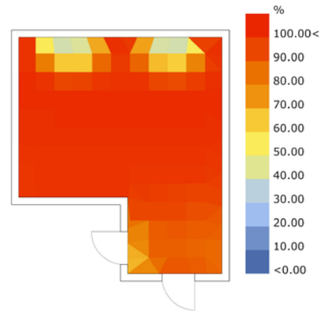
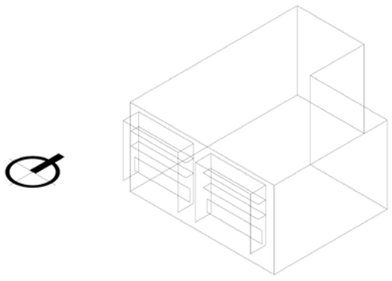
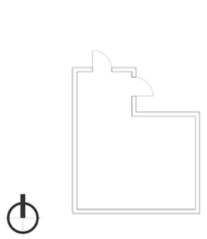
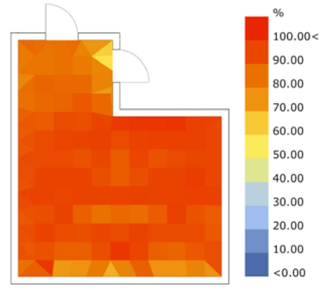


Daylighting



Adaptive Comfort

45.24

Geometry	Strategies				Result	
	Daylighting		Thermal Comfort		Daylighting	Adaptive Comfort
	Orientation	Shading	Ventilation	Infiltration		
		None				16.37
			Change the natural ventilation strategy. When the indoor temperature is over 24 degree, open the window to introduce natural ventilation	Add R vlaue to building materials to improve performance during winter		45.24

After these steps of exploration, the adaptive thermal comfort raised to 45.24. The reason why it cannot go further are as follows:

The house has context boundary in the south and north, so the side walls are adiobatic which reduce the possible heat transfer during summer,

From the climate report, we find that during winter, the weather is so cold that the solar radiation itself cannot provide enough heat to indoor and keep cold weather keeps the heat loss during winter pretty high.