

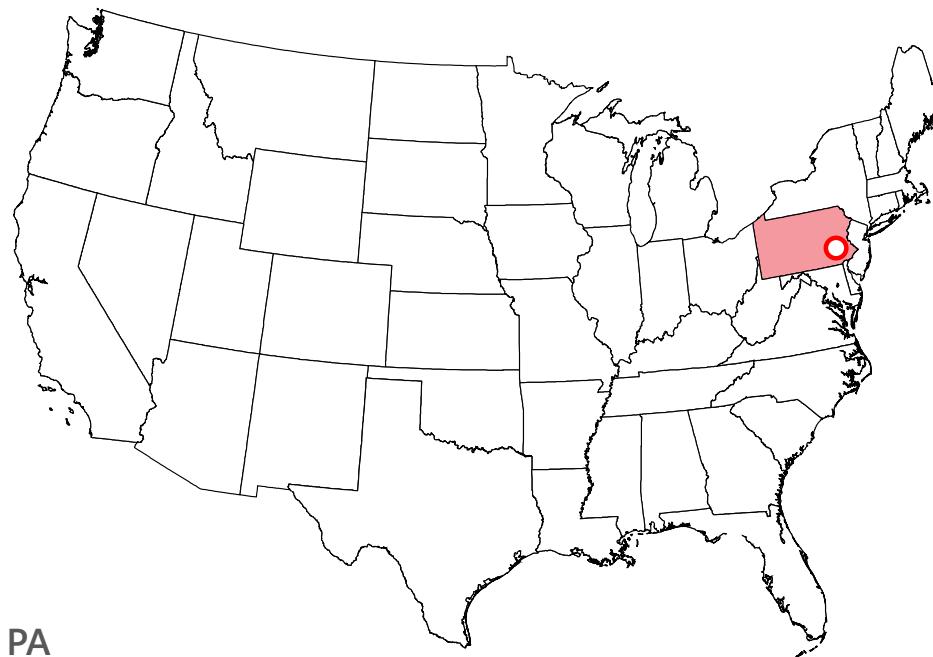
Thermal and Visual Comfort Maximization for an Unconditioned Space

2017 Fall

Building Performance Simulation

Xiaoyu Ma

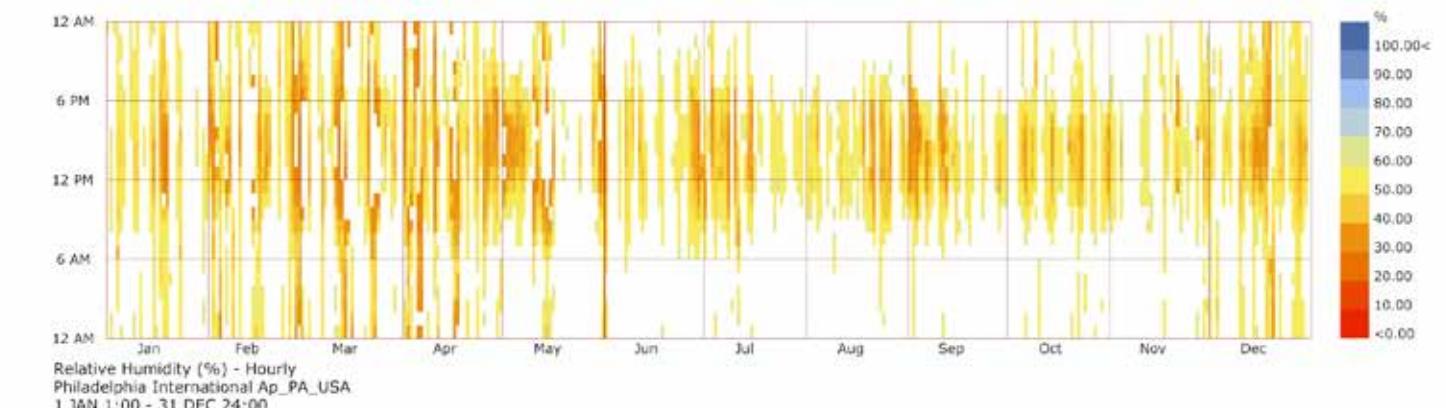
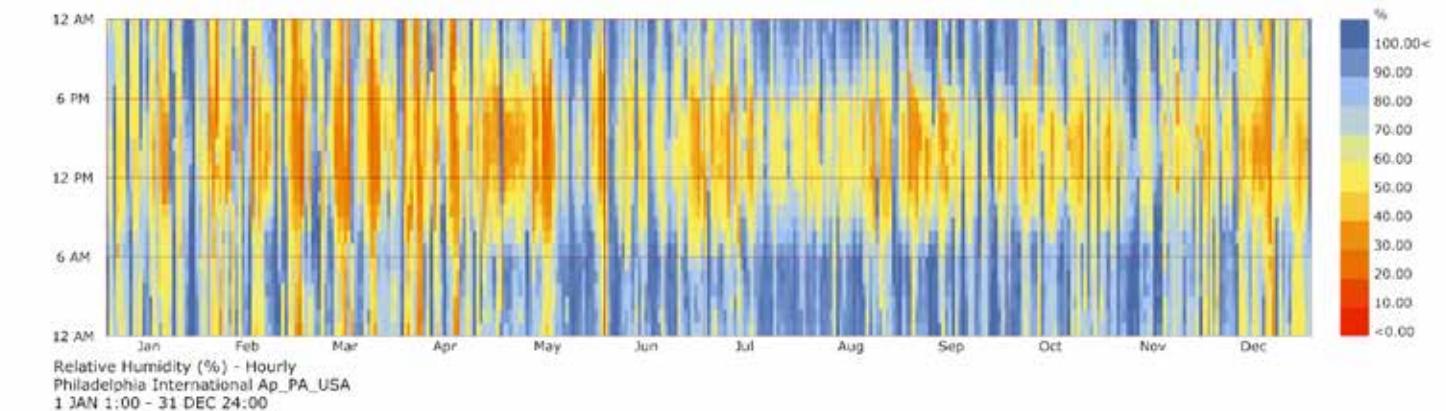
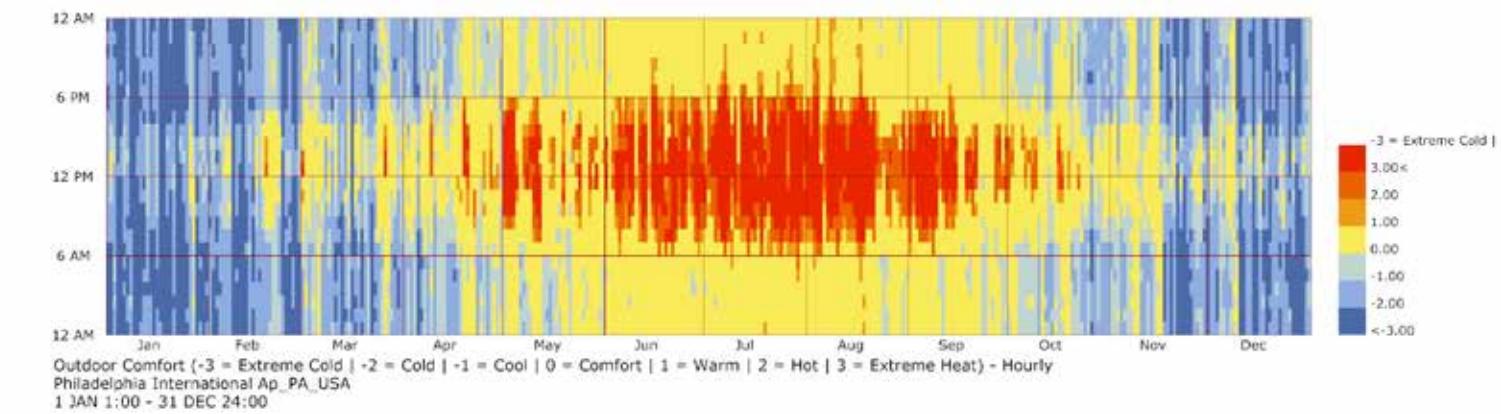
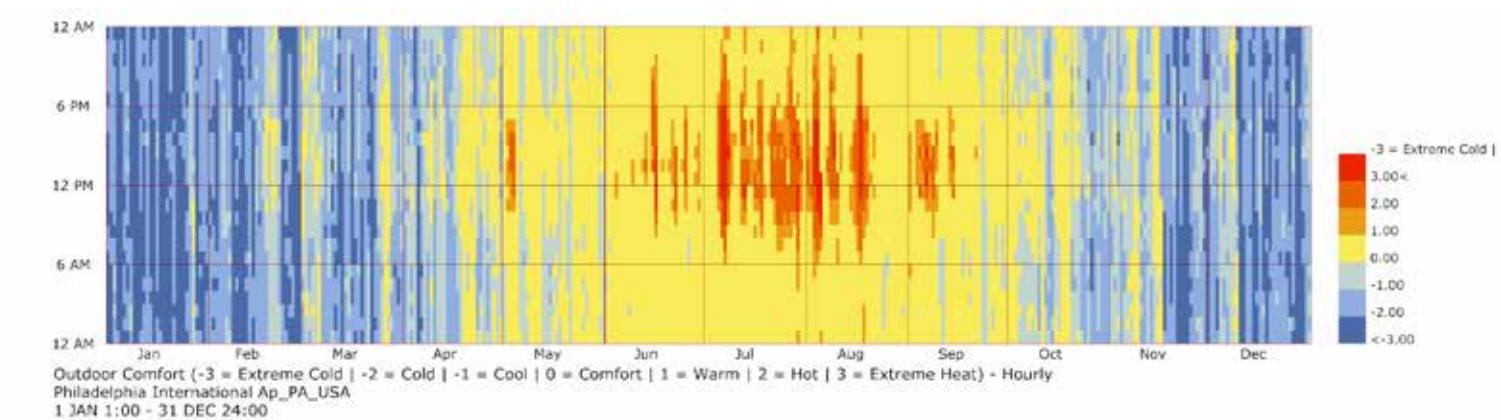
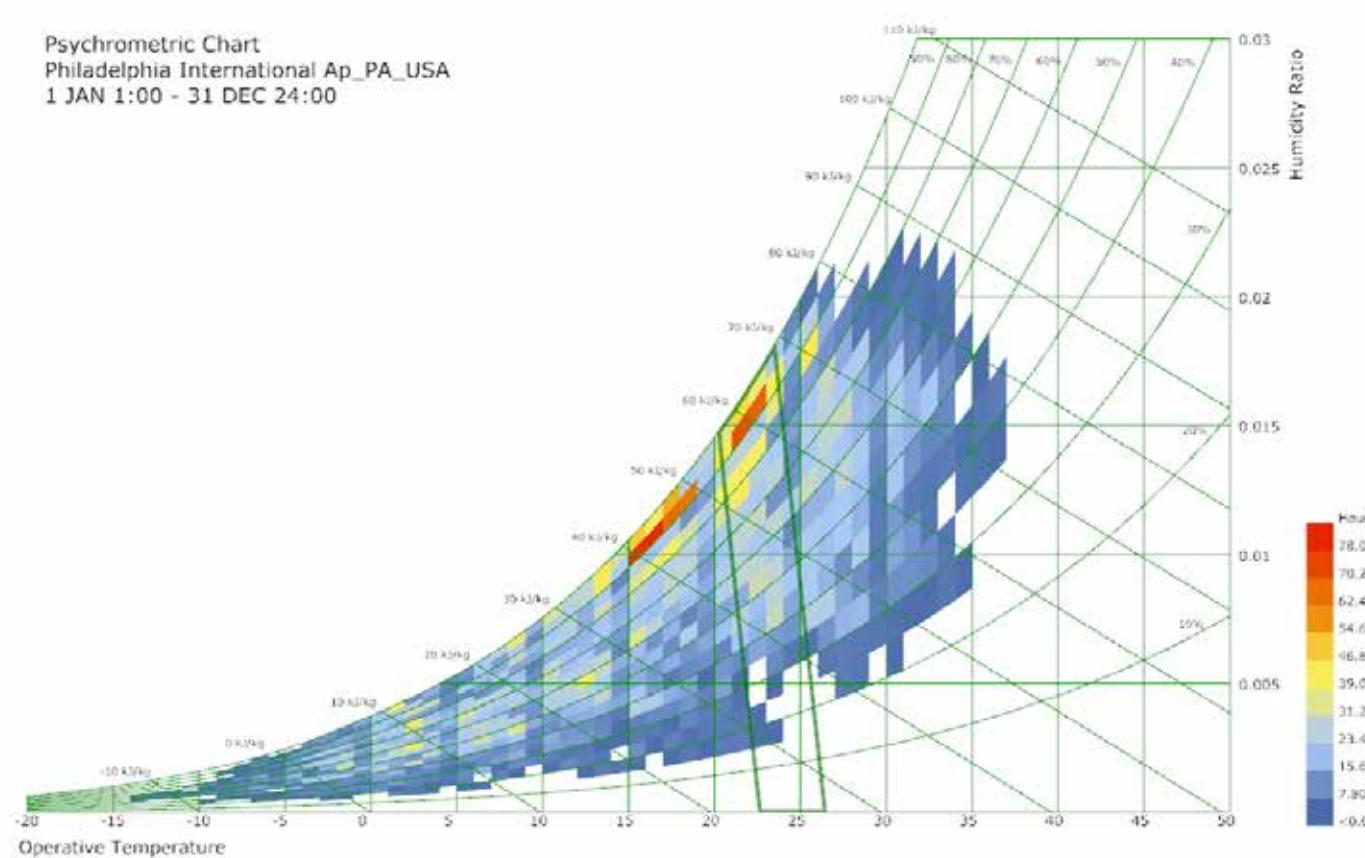
LOCATION



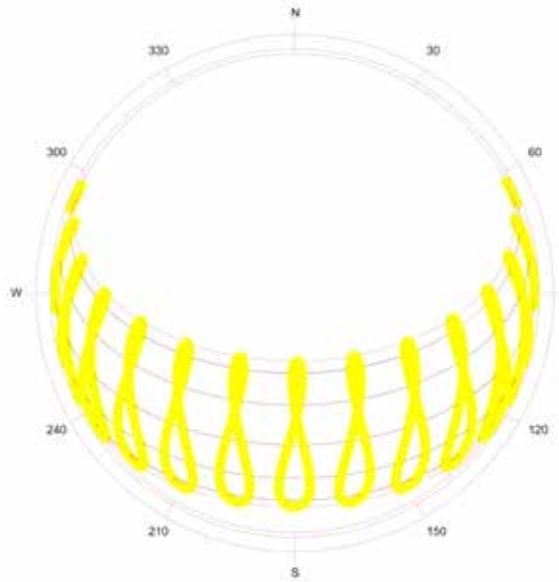
Philadelphia, PA

Philadelphia falls under the northern periphery of the humid subtropical climate zone, whereas according to the Trewartha climate classification, the city has a temperate maritime climate. Summers are typically hot and muggy, fall and spring are generally mild, and winter is cold.

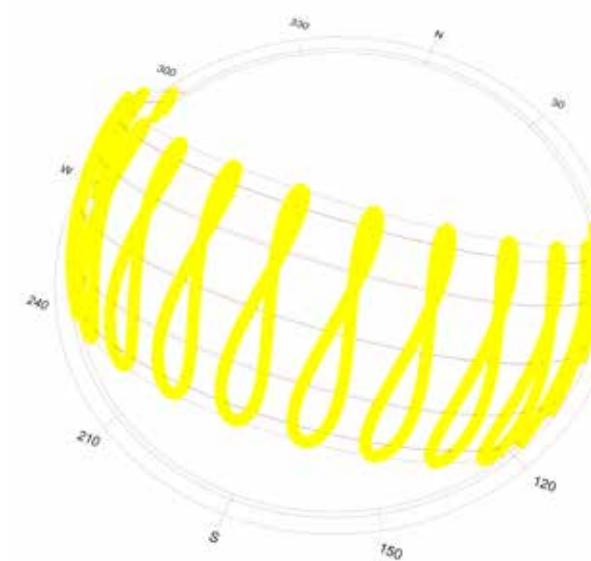
Psychrometric Chart
Philadelphia International Ap_PA_USA
1 JAN 1:00 - 31 DEC 24:00



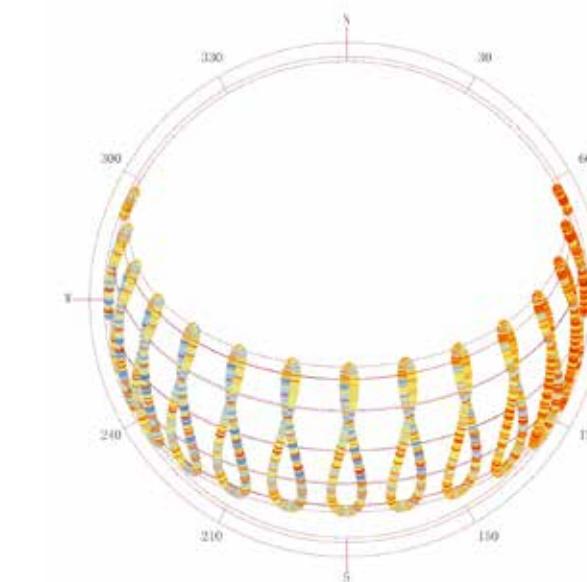
SUN PATH & RADIATION ROSE



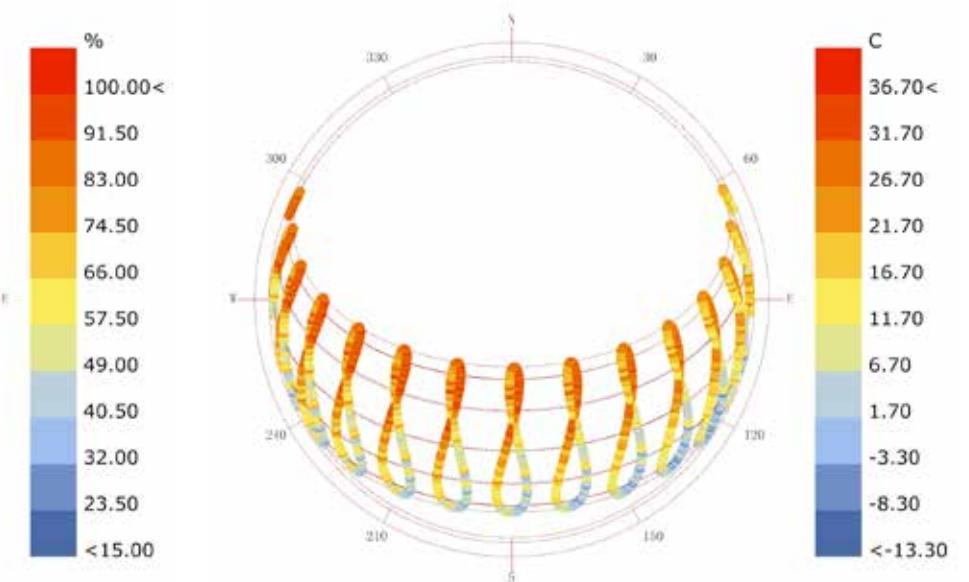
Sun Path



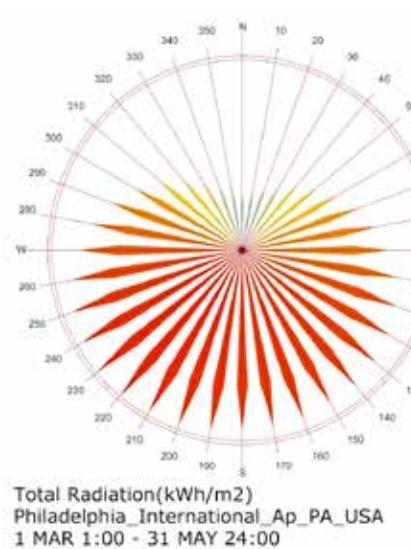
Sun Path



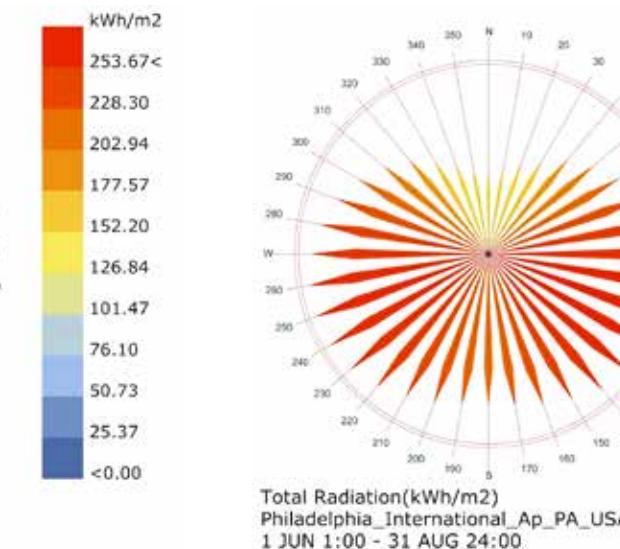
Relative Humidity



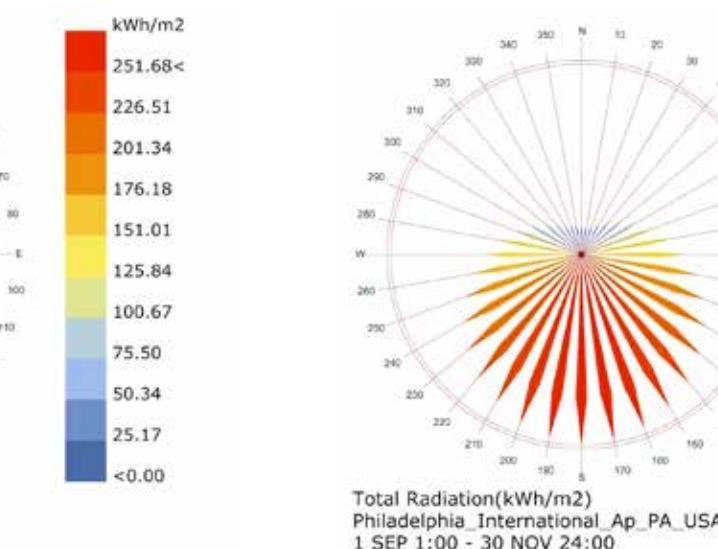
Drybulb Temperature



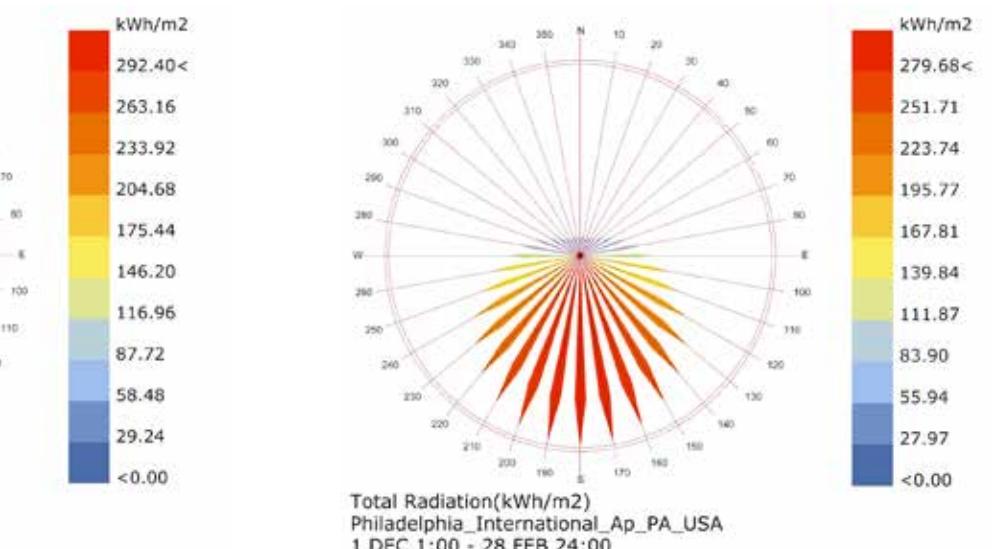
Spring



Summer

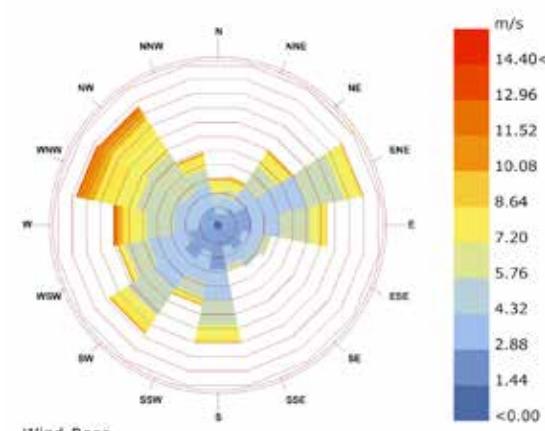


Fall

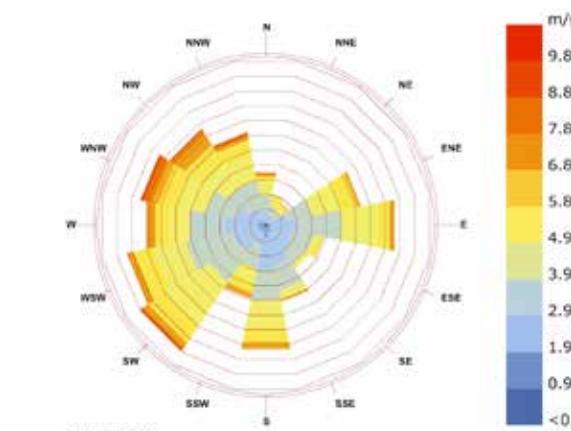


Winter

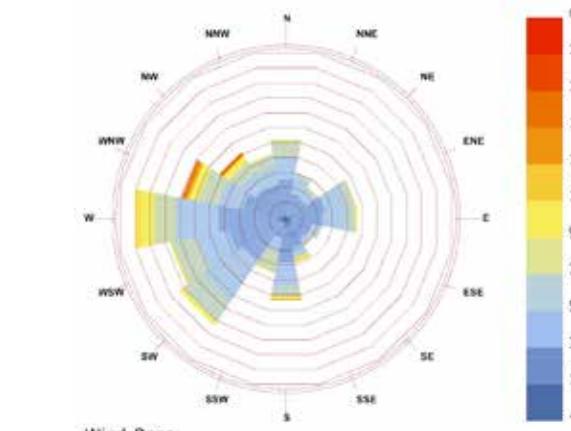
WIND ROSE



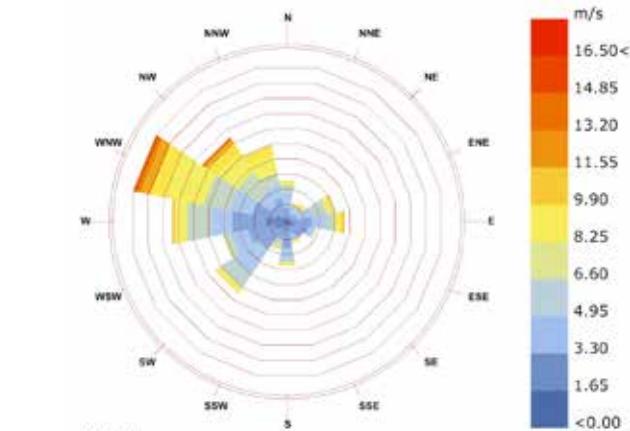
Wind-Rose
Philadelphia International Ap_PA_USA
1 MAR 1:00 - 31 MAY 24:00
Hourly Data: Wind Speed (m/s)
Calm for 3.94% of the time = 87 hours.
Each closed polyline shows frequency of 0.9%. = 20 hours.



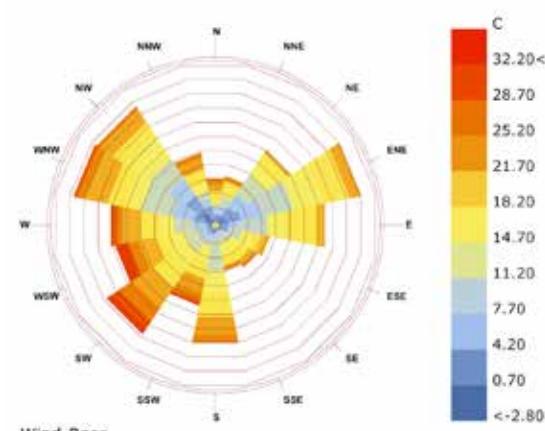
Wind-Rose
Philadelphia International Ap_PA_USA
1 JUN 1:00 - 31 AUG 24:00
Hourly Data: Wind Speed (m/s)
Calm for 1.45% of the time = 32 hours.
Each closed polyline shows frequency of 1.0%. = 21 hours.



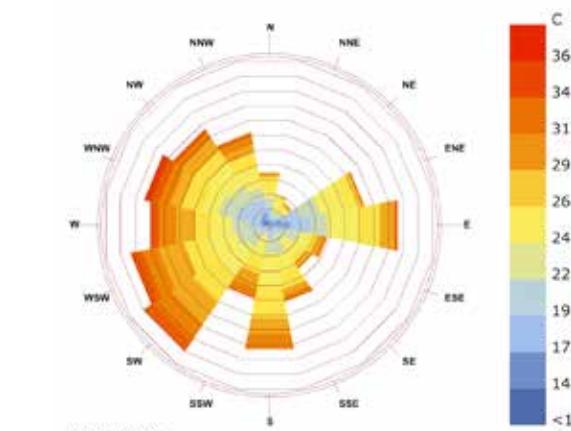
Wind-Rose
Philadelphia International Ap_PA_USA
1 SEP 1:00 - 30 NOV 24:00
Hourly Data: Wind Speed (m/s)
Calm for 2.24% of the time = 49 hours.
Each closed polyline shows frequency of 1.2%. = 26 hours.



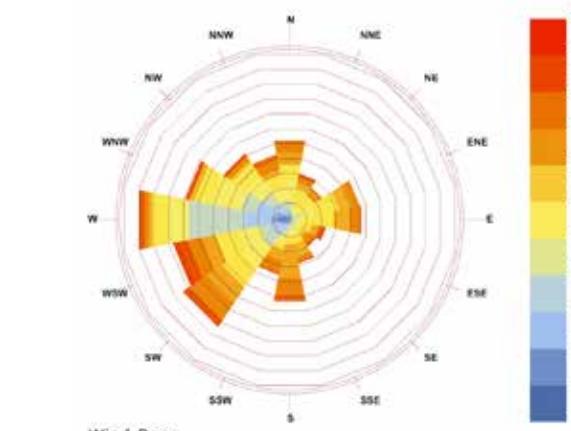
Wind-Rose
Philadelphia International Ap_PA_USA
1 DEC 1:00 - 28 FEB 24:00
Hourly Data: Wind Speed (m/s)
Calm for 3.61% of the time = 78 hours.
Each closed polyline shows frequency of 1.6%. = 34 hours.



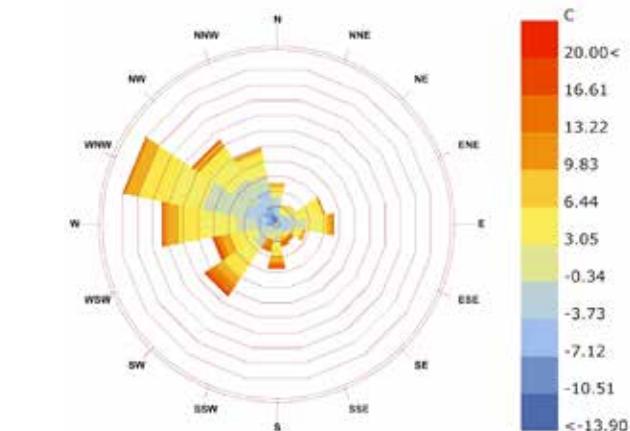
Wind-Rose
Philadelphia International Ap_PA_USA
1 MAR 1:00 - 31 MAY 24:00
Hourly Data: Dry Bulb Temperature (C)
Calm for 3.94% of the time = 87 hours.
Each closed polyline shows frequency of 0.9%. = 20 hours.



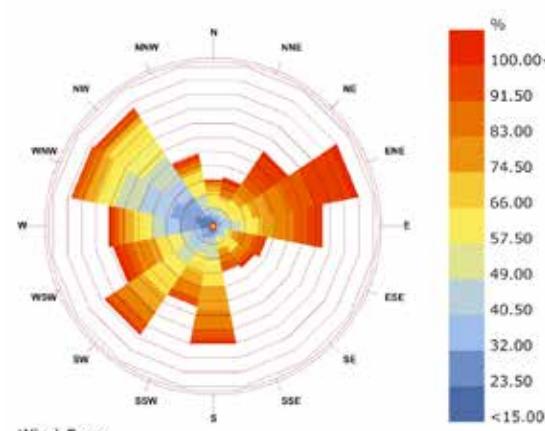
Wind-Rose
Philadelphia International Ap_PA_USA
1 JUN 1:00 - 31 AUG 24:00
Hourly Data: Dry Bulb Temperature (C)
Calm for 1.45% of the time = 32 hours.
Each closed polyline shows frequency of 1.0%. = 21 hours.



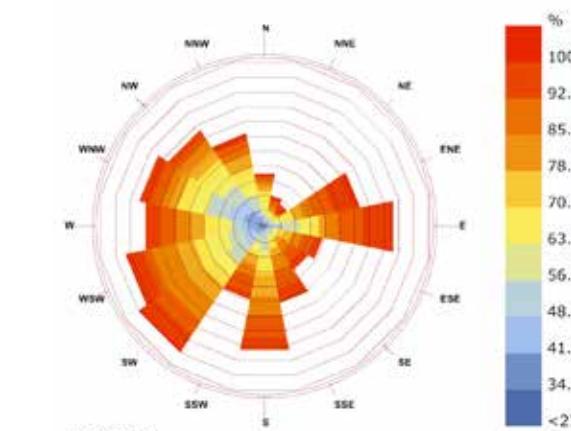
Wind-Rose
Philadelphia International Ap_PA_USA
1 SEP 1:00 - 30 NOV 24:00
Hourly Data: Dry Bulb Temperature (C)
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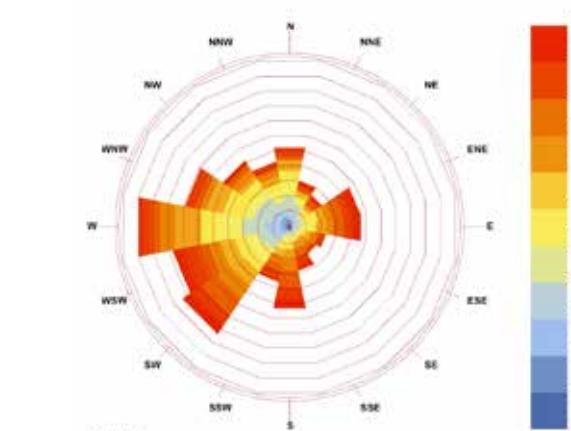
Wind-Rose
Philadelphia International Ap_PA_USA
1 DEC 1:00 - 28 FEB 24:00
Hourly Data: Dry Bulb Temperature (C)
Calm for 3.61% of the time = 78 hours.
Each closed polyline shows frequency of 1.6%. = 34 hours.



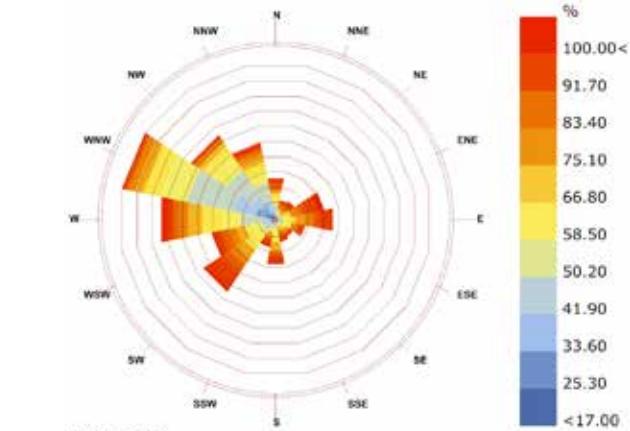
Wind-Rose
Philadelphia International Ap_PA_USA
1 MAR 1:00 - 31 MAY 24:00
Hourly Data: Relative Humidity (%)
Calm for 3.94% of the time = 87 hours.
Each closed polyline shows frequency of 0.9%. = 20 hours.



Wind-Rose
Philadelphia International Ap_PA_USA
1 JUN 1:00 - 31 AUG 24:00
Hourly Data: Relative Humidity (%)
Calm for 1.45% of the time = 32 hours.
Each closed polyline shows frequency of 1.0%. = 21 hours.

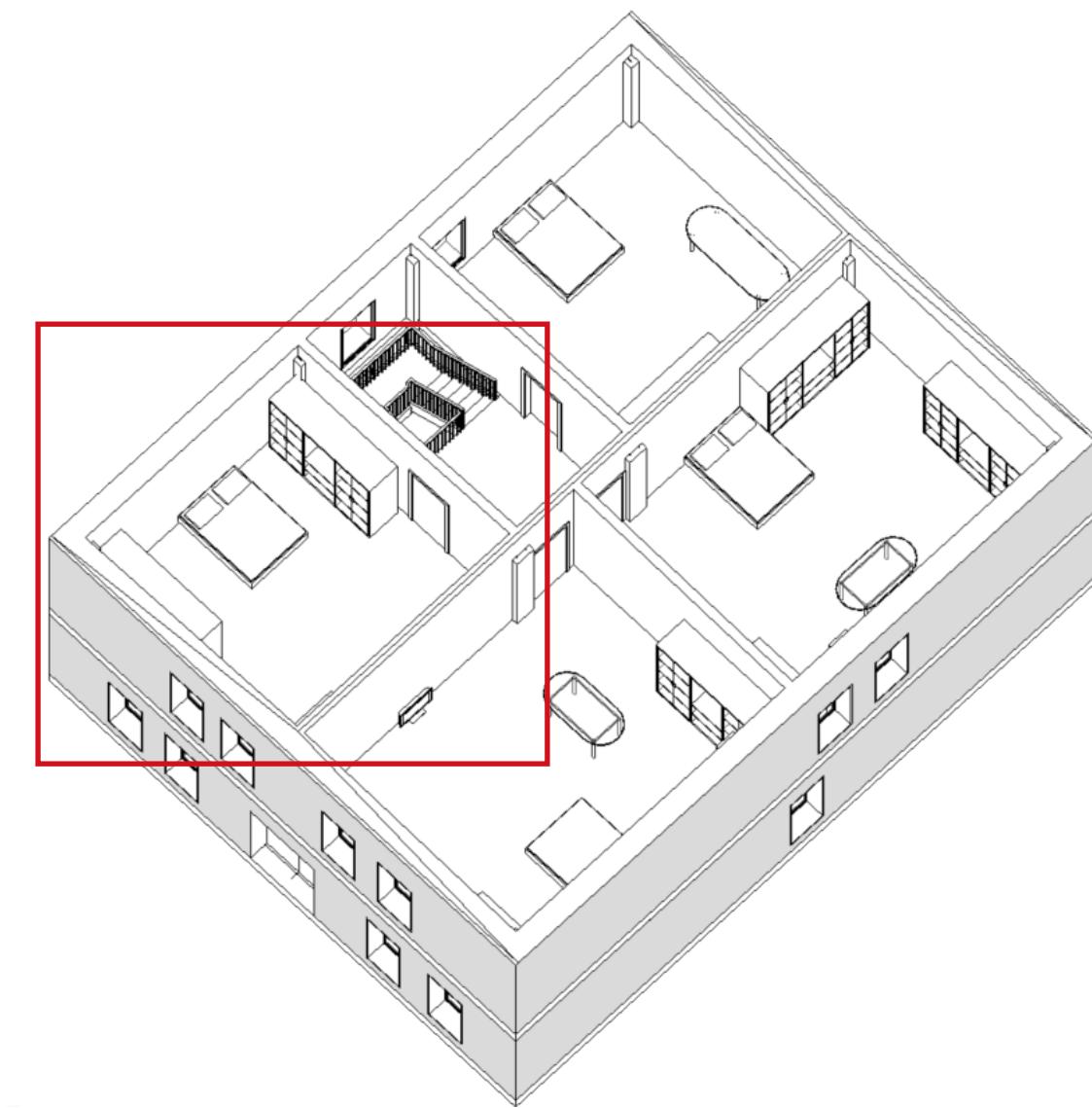
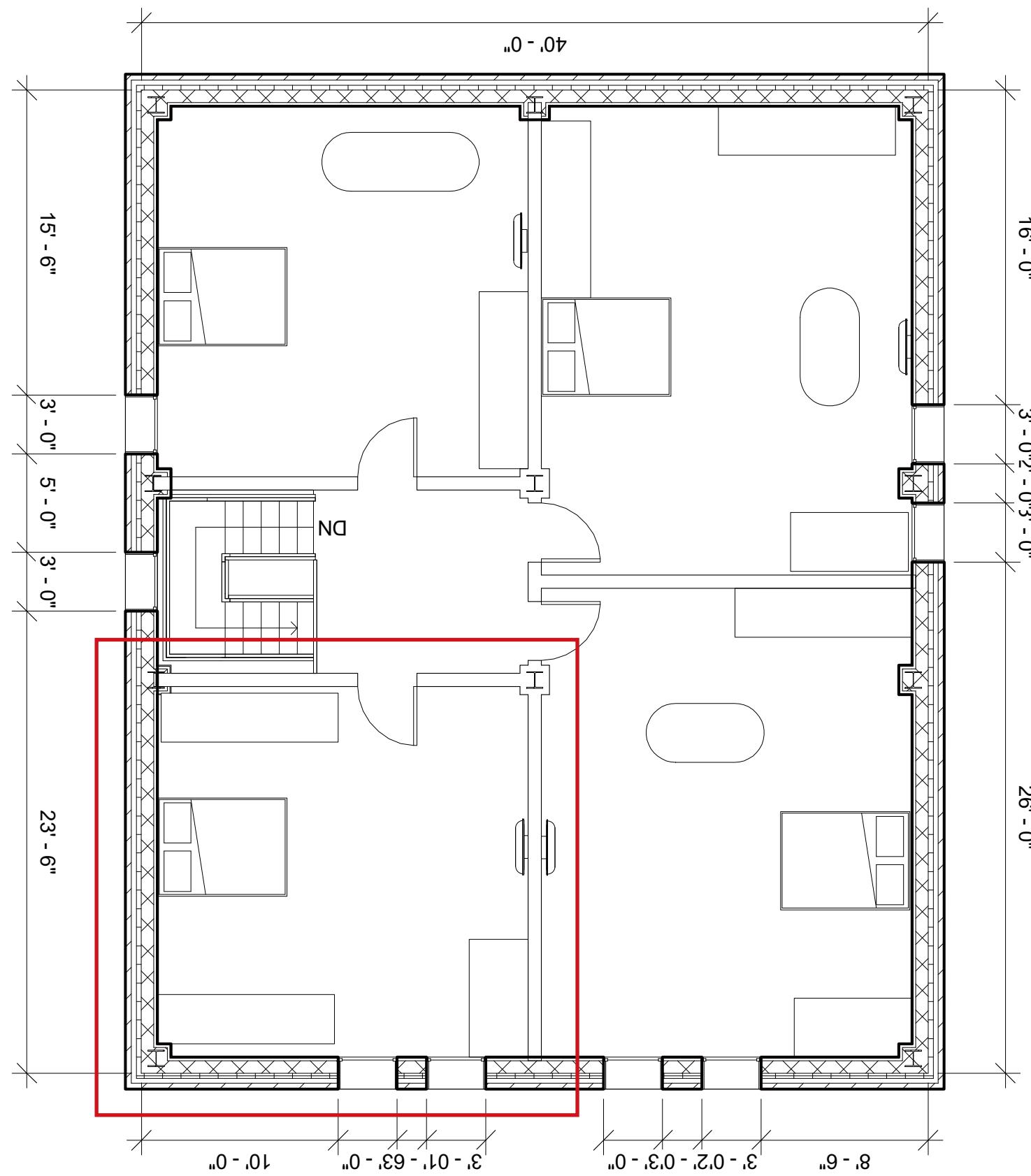


Wind-Rose
Philadelphia International Ap_PA_USA
1 SEP 1:00 - 30 NOV 24:00
Hourly Data: Relative Humidity (%)
Calm for 2.24% of the time = 49 hours.
Each closed polyline shows frequency of 1.2%. = 26 hours.

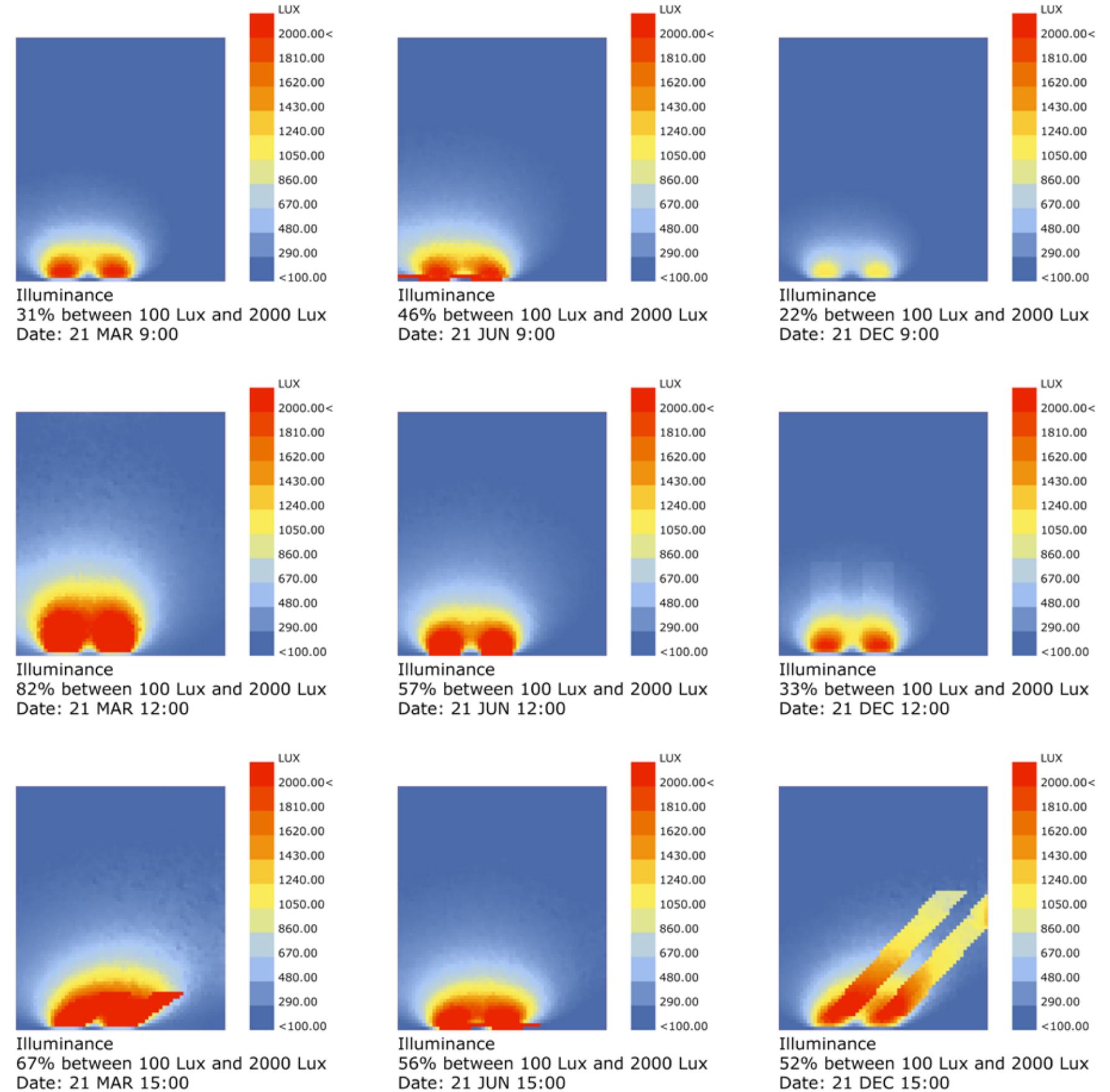
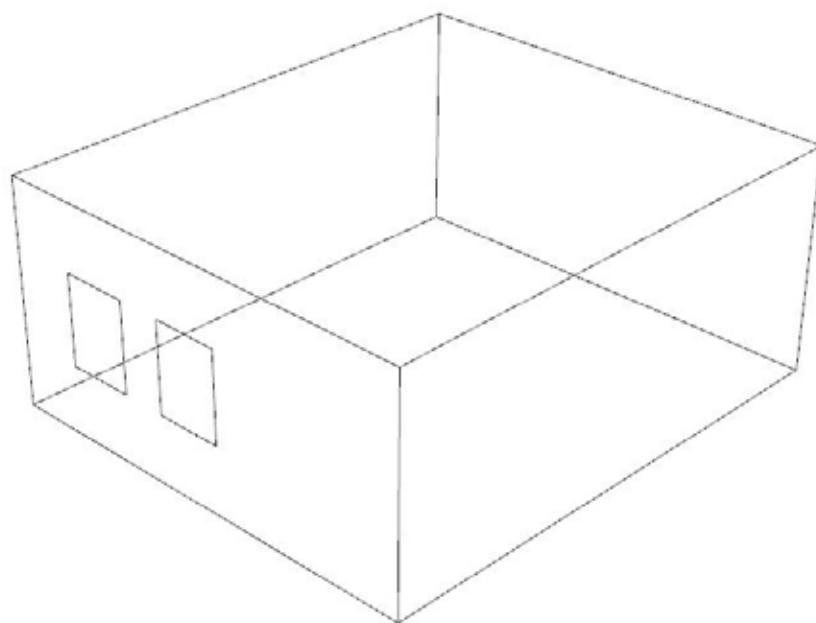


Wind-Rose
Philadelphia International Ap_PA_USA
1 DEC 1:00 - 28 FEB 24:00
Hourly Data: Relative Humidity (%)
Calm for 3.61% of the time = 78 hours.
Each closed polyline shows frequency of 1.6%. = 34 hours.

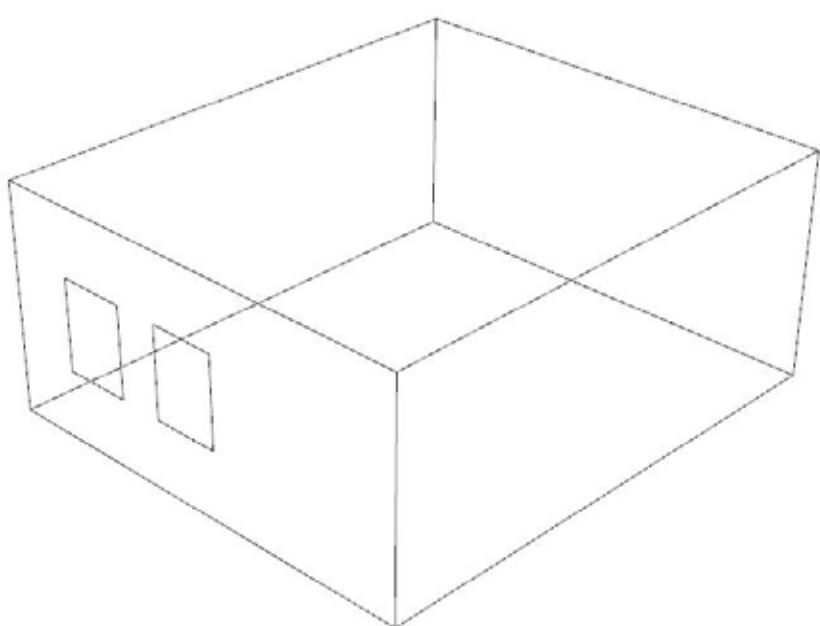
TEST ROOM



BASELINE-DAYLIGHTING



BASELINE-GLARE ANALYSIS



MARCH 21 9:00



MARCH 21 12:00



MARCH 21 15:00



JUNE 21 9:00



JUNE 21 12:00



JUNE 21 15:00



DECEMBER 21 9:00

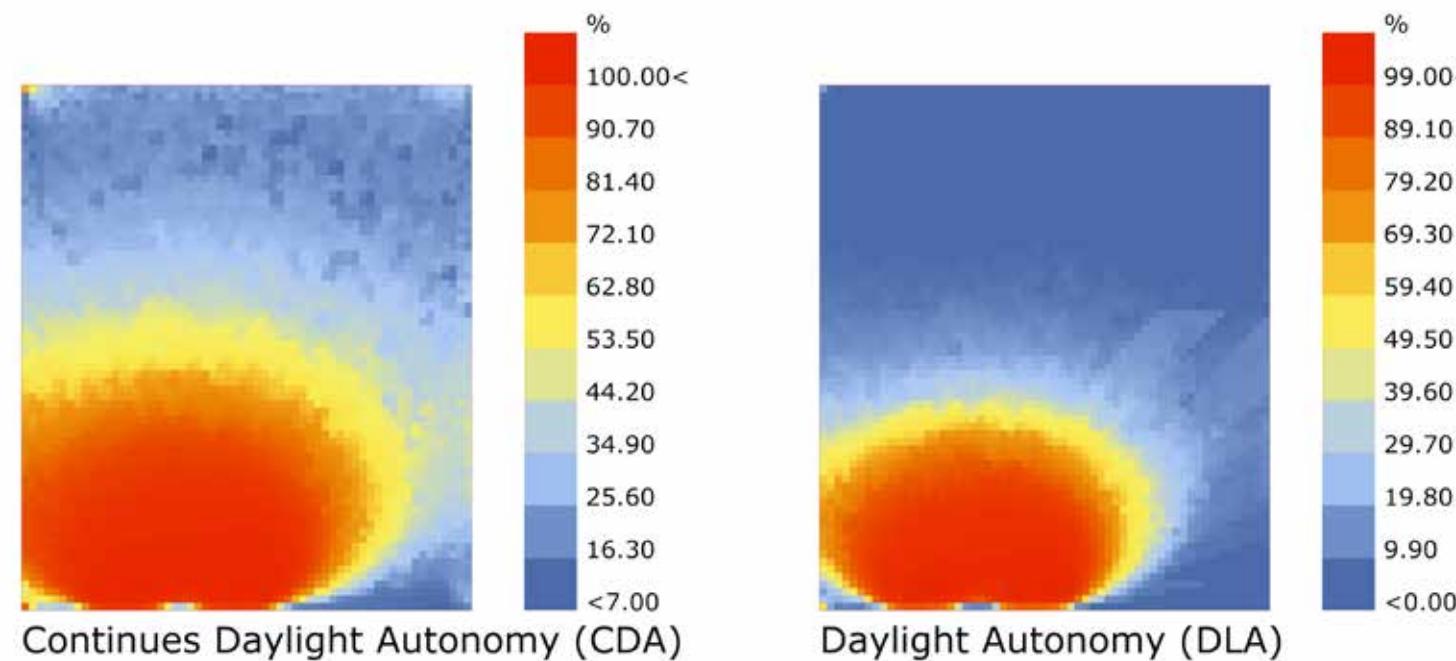
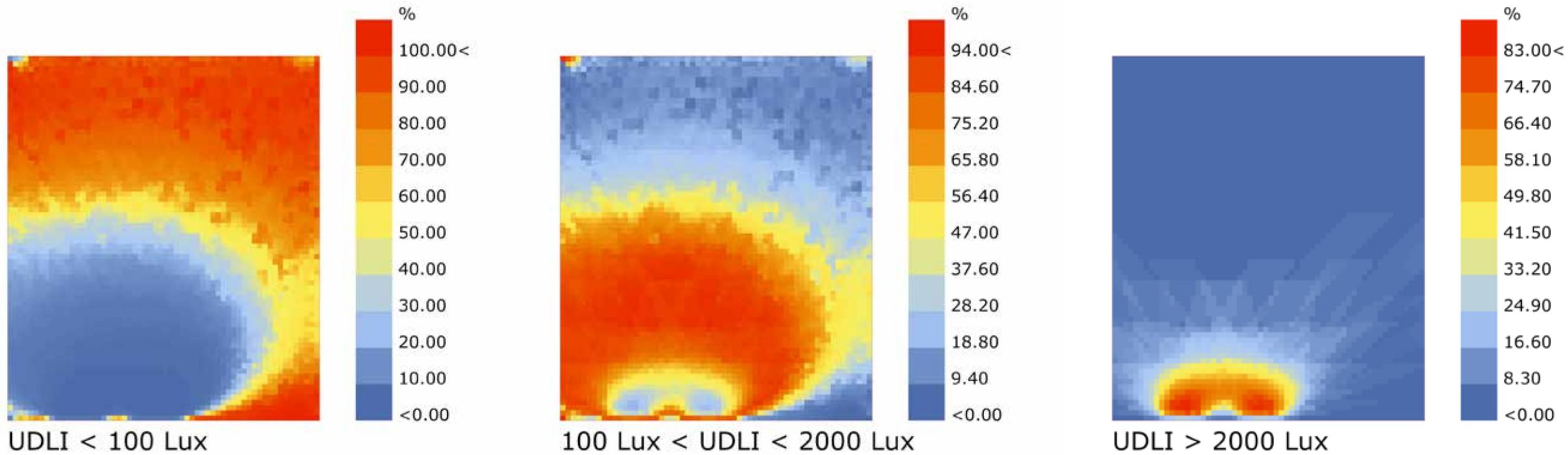


DECEMBER 21 12:00



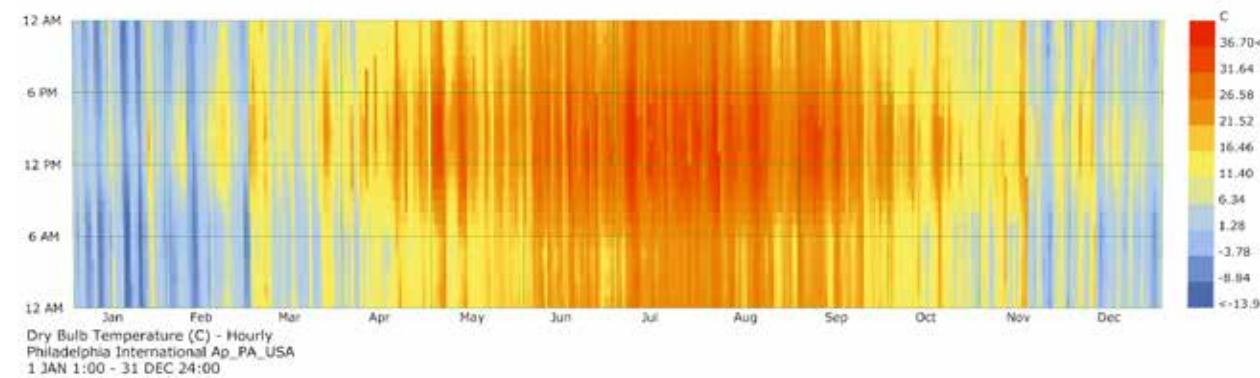
DECEMBER 21 15:00

BASELINE-ANNUAL DAYLIGHT ANALYSIS (UDLA, DLA, CDA)

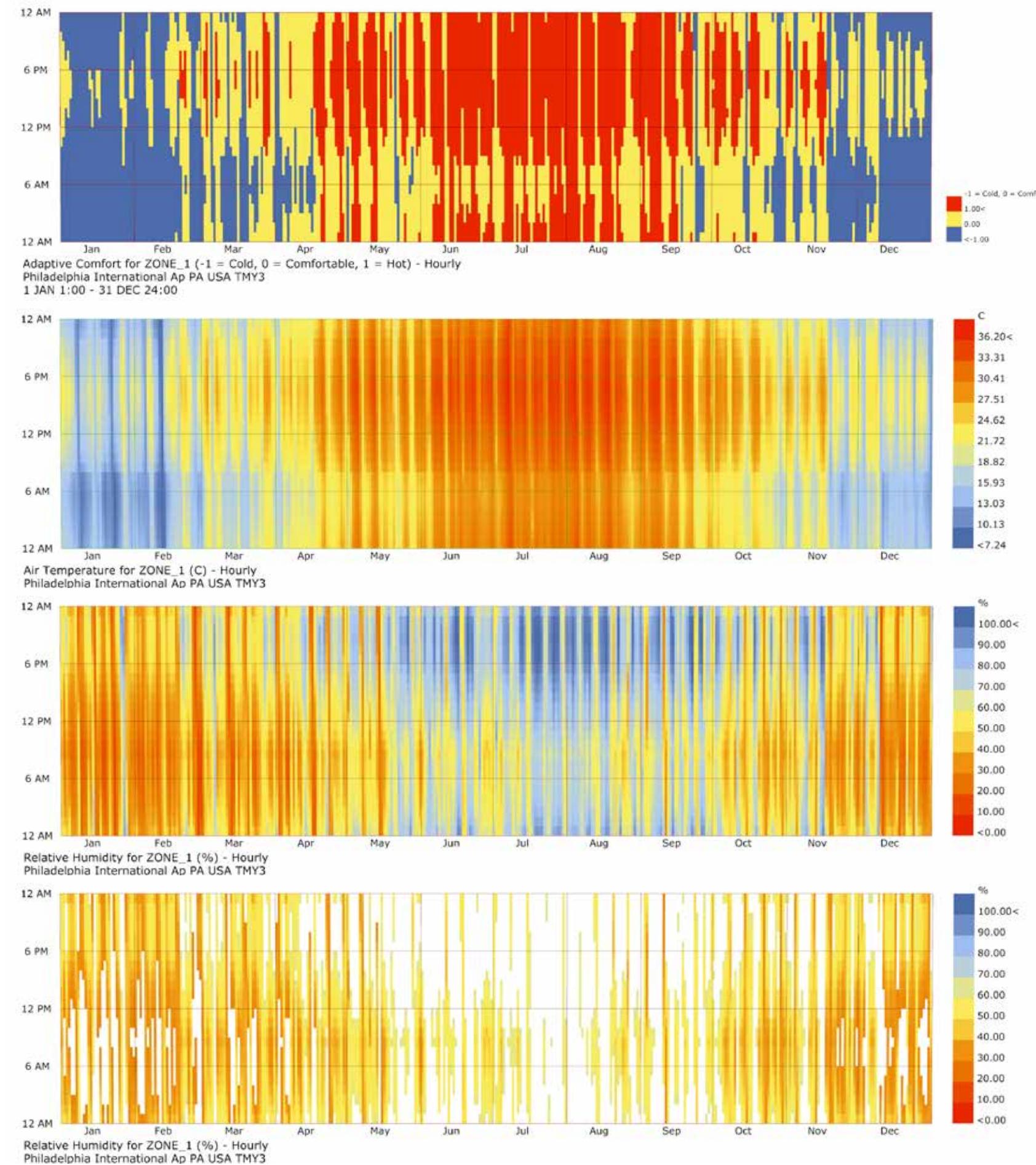
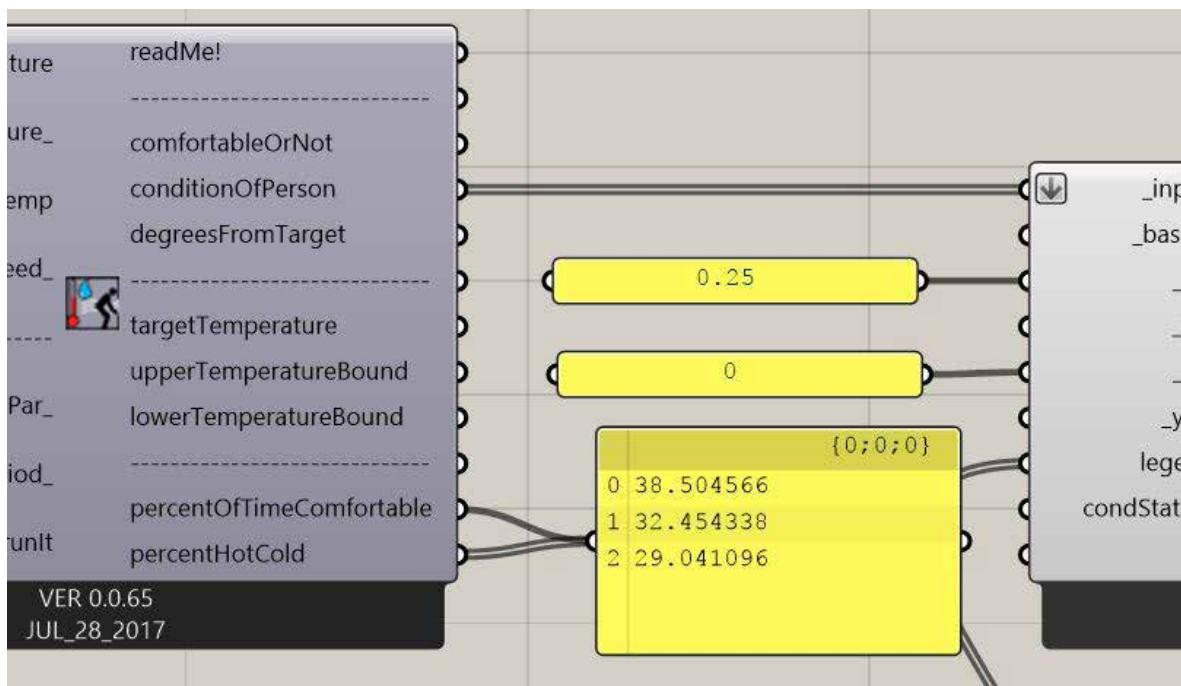
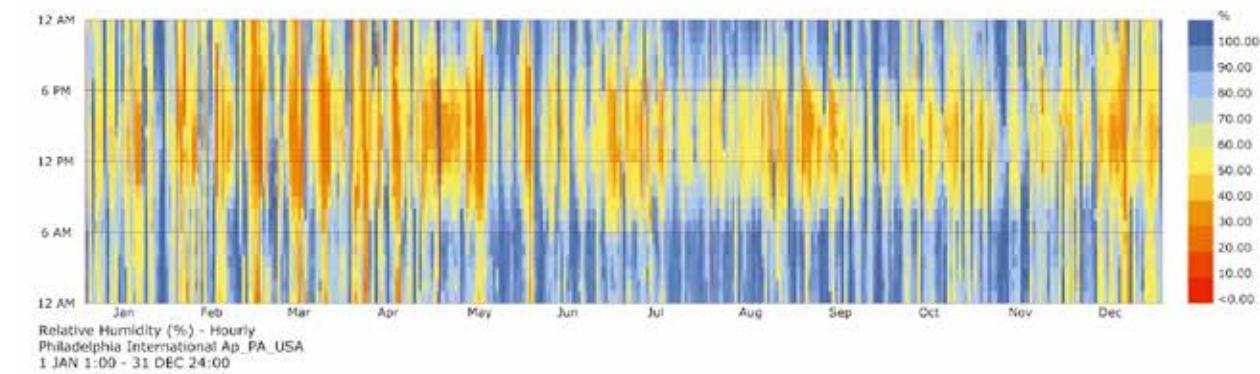


INDOOR FACTORS

Outdoor Temperature



Outdoor Relative Humidity

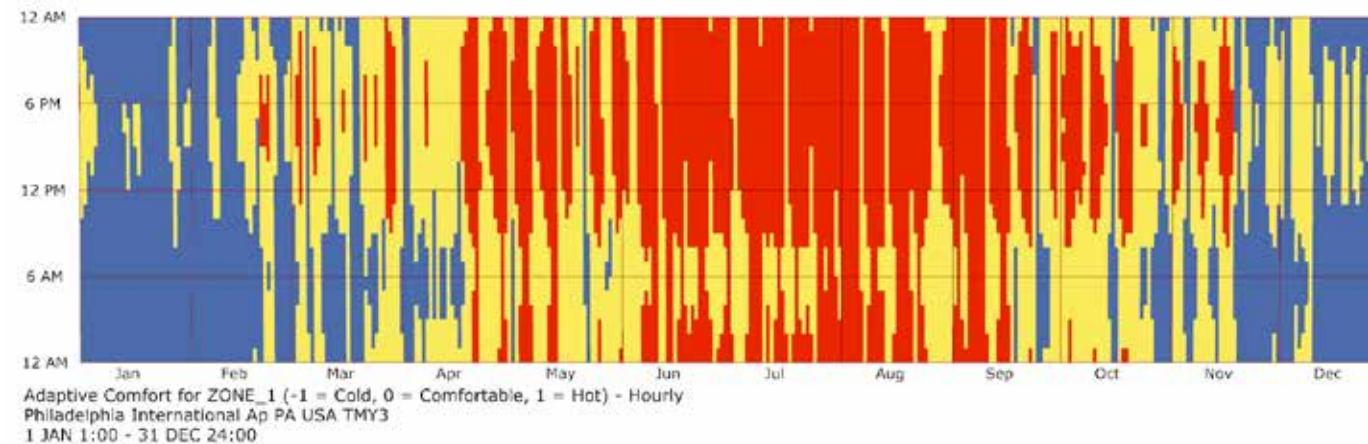


ORIENTATION TEST

Improve thermal comfort

Change the window facing direction and find the best window direction for thermal comfort. (Originally facing south, Glazing ratio = 0.1)

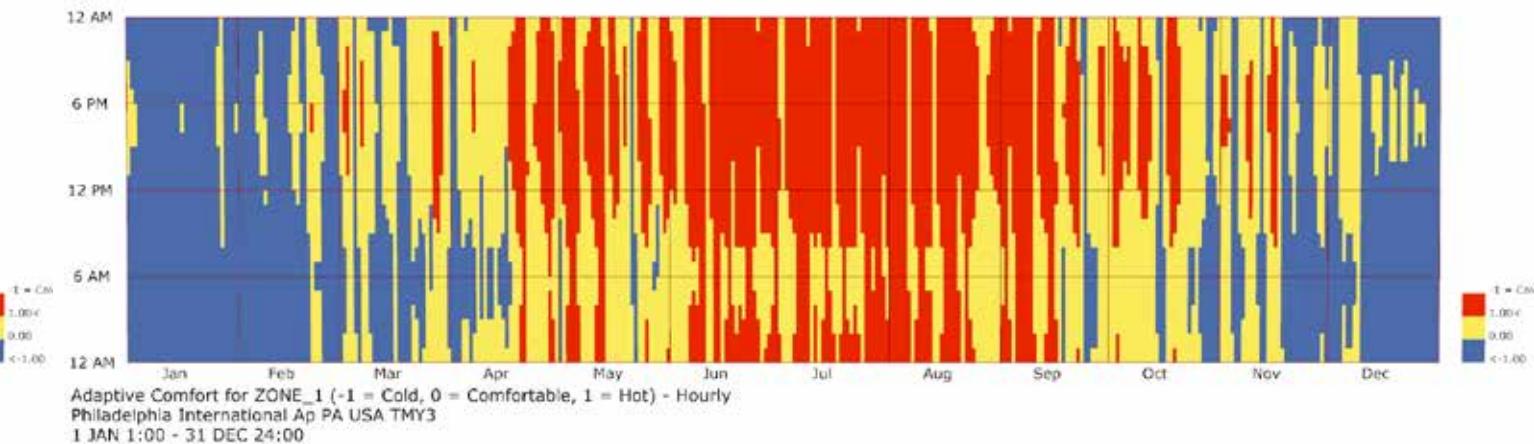
After testing simulation in 4 directions, I found that the Original direction (facing south) has the highest percent of comfortable time(38.49%), so I won't change the direction of window.



South (Original)

Glazing Ratio = 0.1

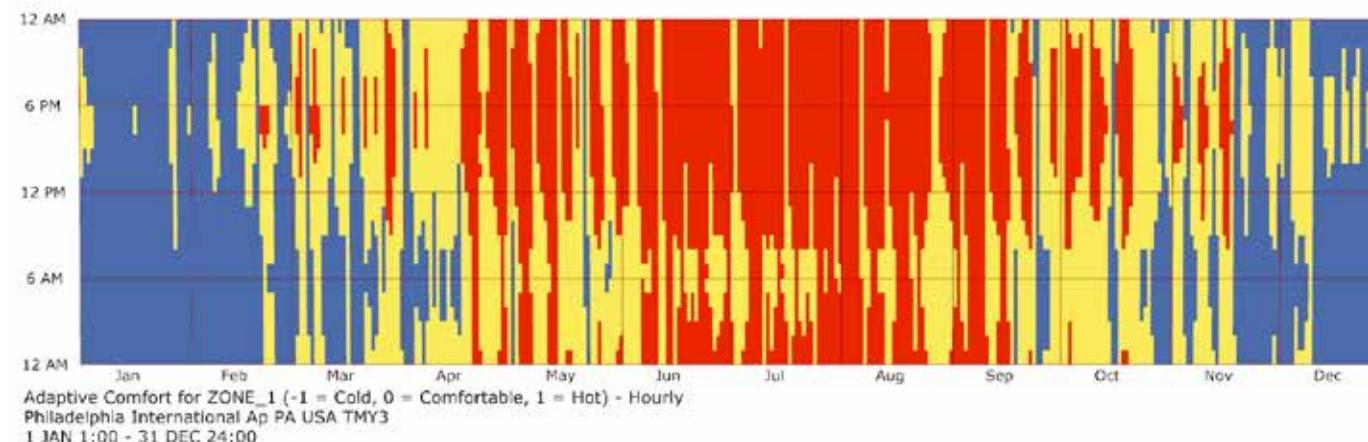
Percent of Comfortable time = **38.49%**



North

Glazing Ratio = 0.1

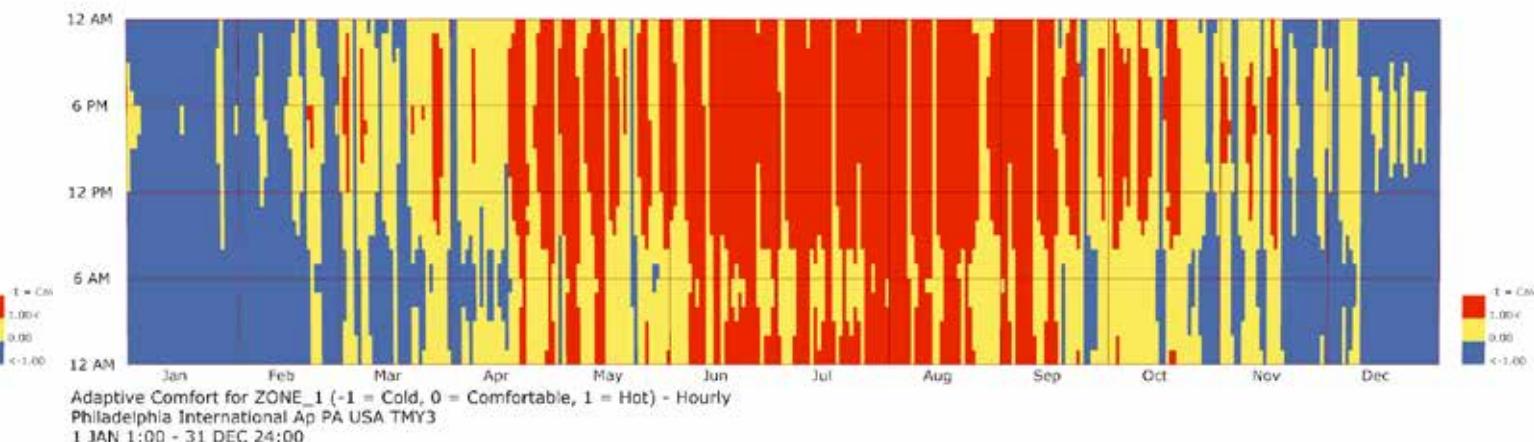
Percent of Comfortable time = **37.39%**



West

Glazing Ratio = 0.1

Percent of Comfortable time = **36.43%**



East

Glazing Ratio = 0.1

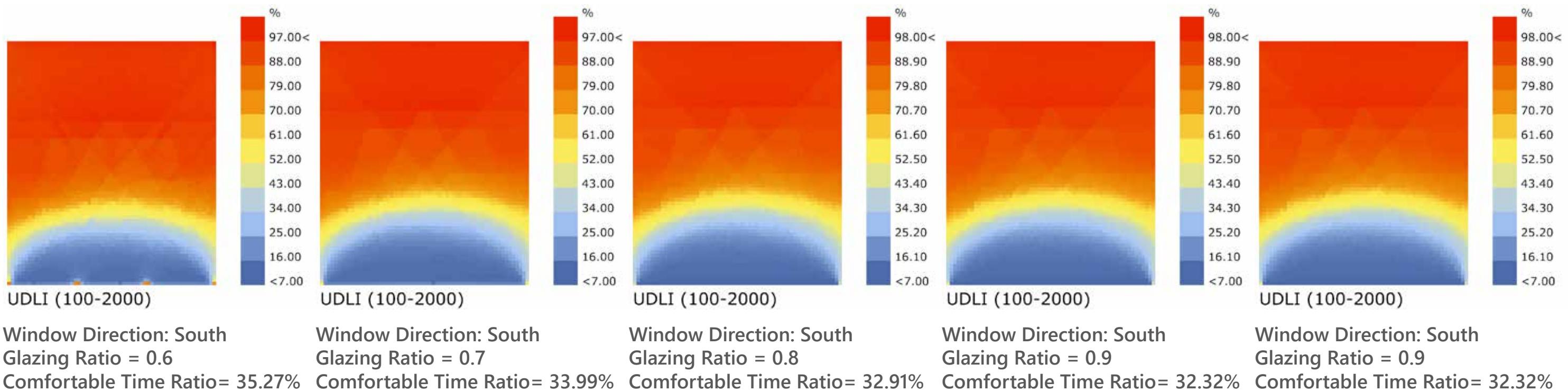
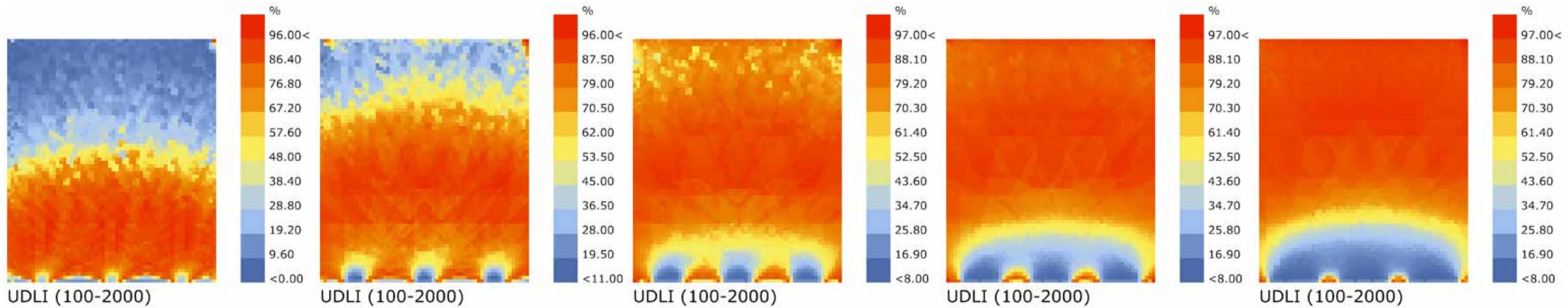
Percent of Comfortable time = **35.98%**

GLAZING RATIO TEST

Improve indoor daylight environment

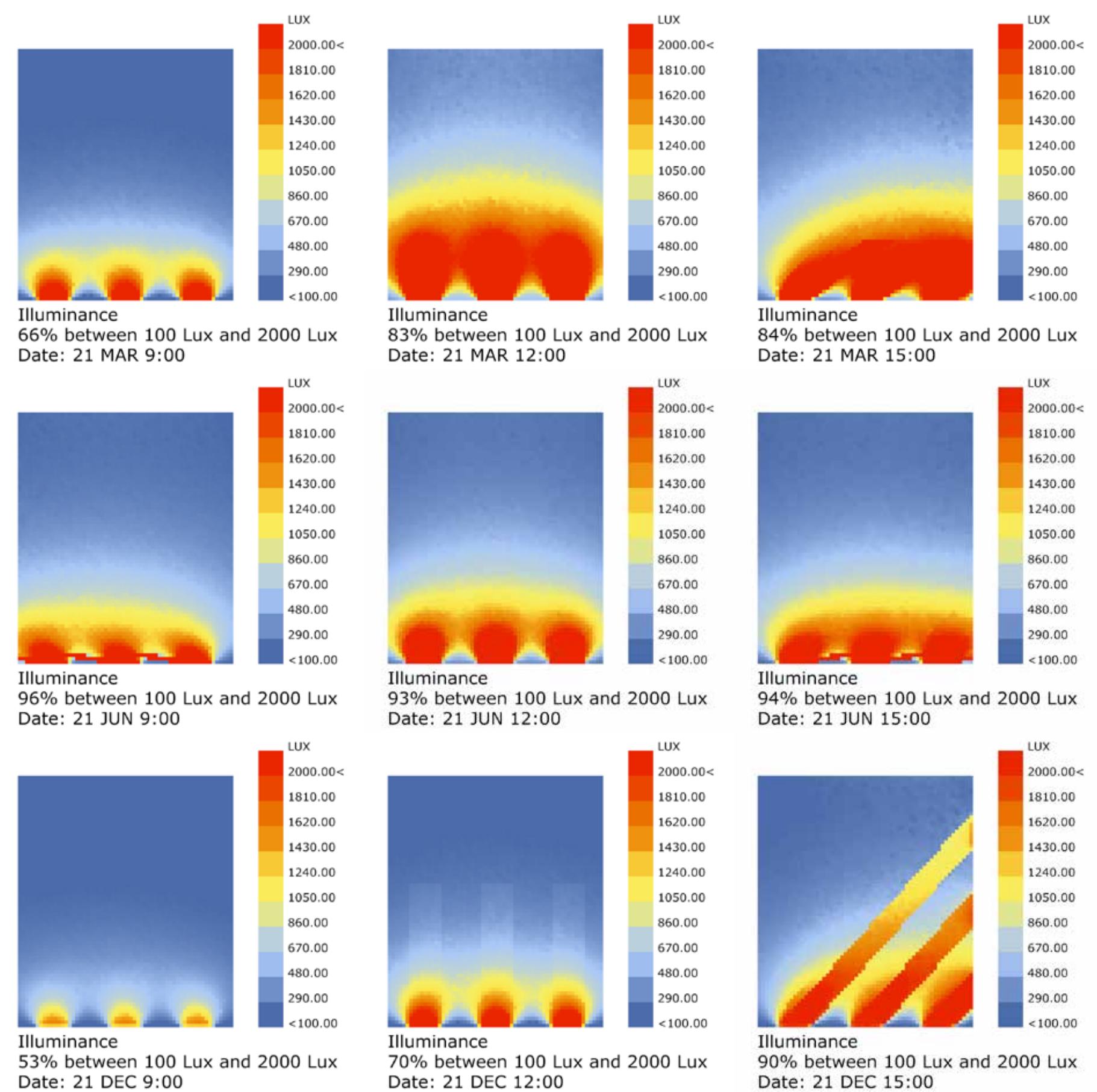
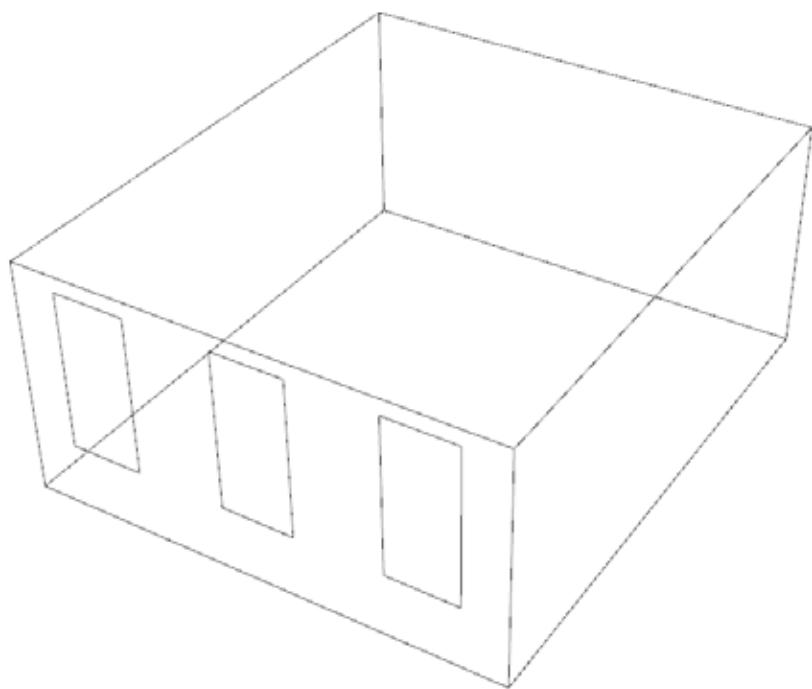
Change the glazing ratio and find the best glazing ratio for indoor daylight environment. (Original Glazing ratio = 0.1)

After testing simulation in different glazing ratio, I found that when glazing ratio is 0.3, the room will get the better daylight compared to other glazing ratio. At the same time, I also tested the comfortable time ratio for each glazing ratio, and found that 0.2, 0.3, 0.4 has higher comfortable ratio compared to others. So according these two results, I would make glazing ratio 0.3 on the south wall.



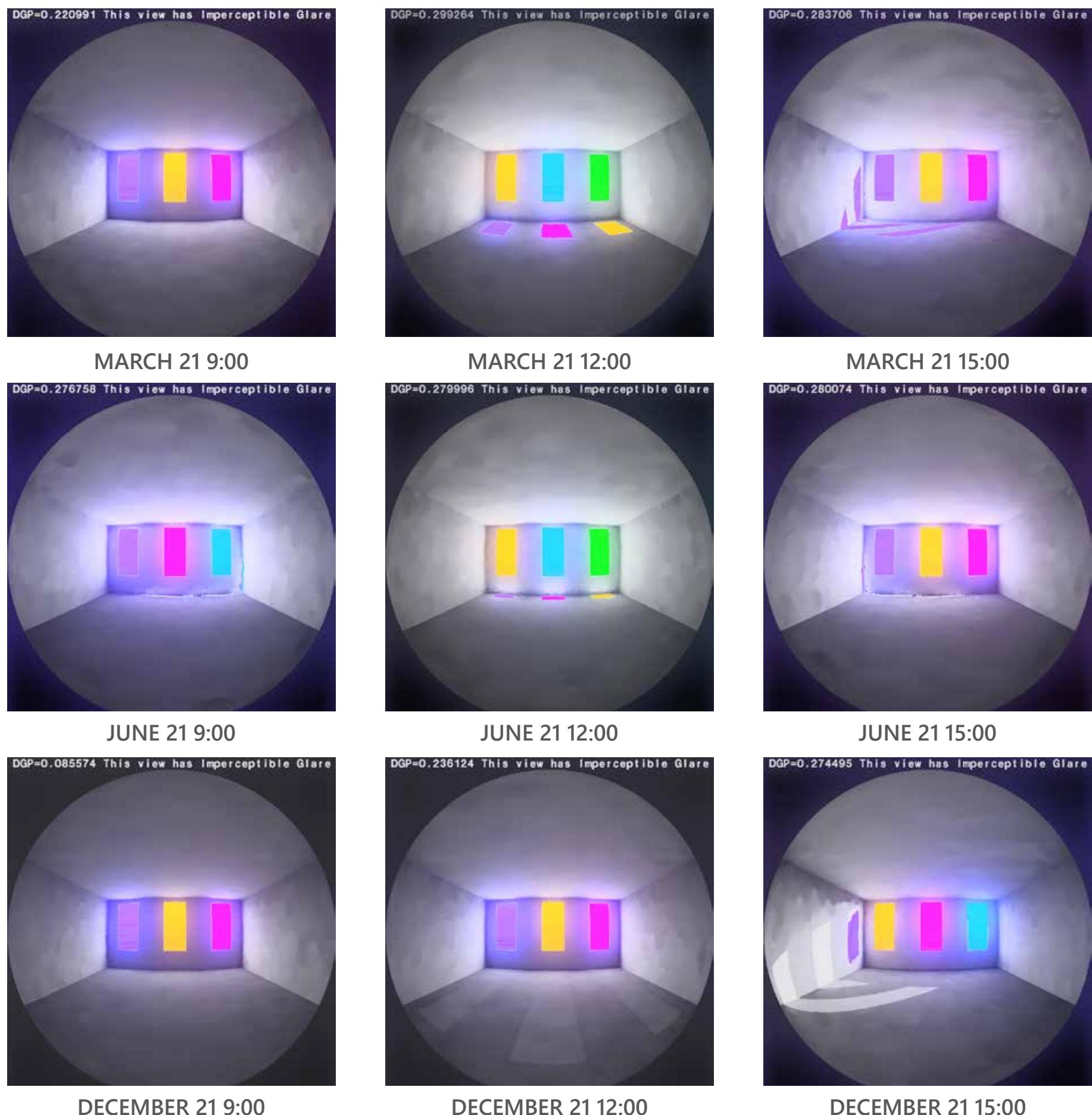
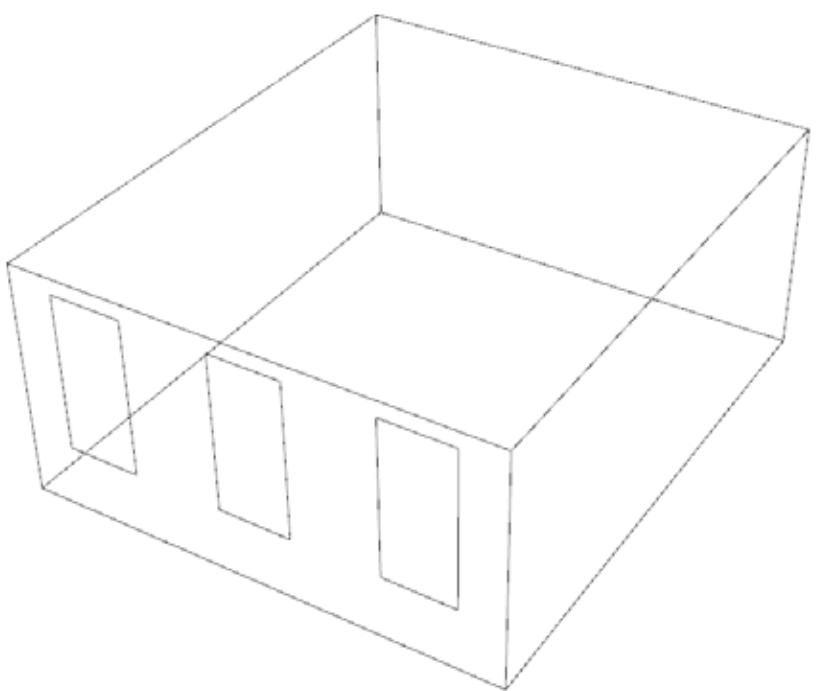
TYPICAL DAYLIGHT TEST FOR MODIFIED ROOM

Compared to the original room, the daylight environment in modified room become much better.

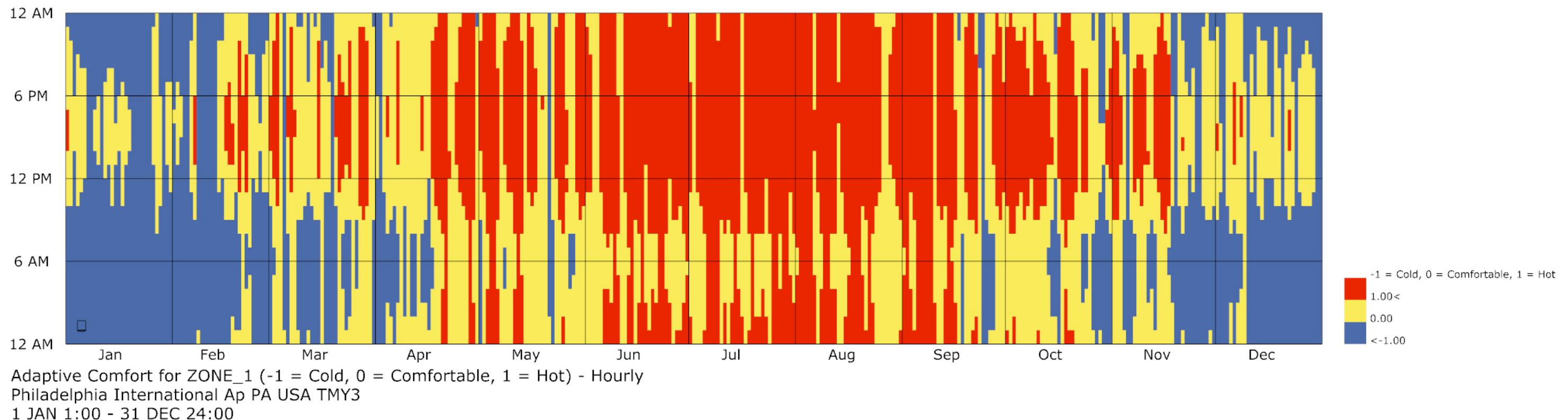


GLARE ANALYSIS FOR MODIFIED ROOM

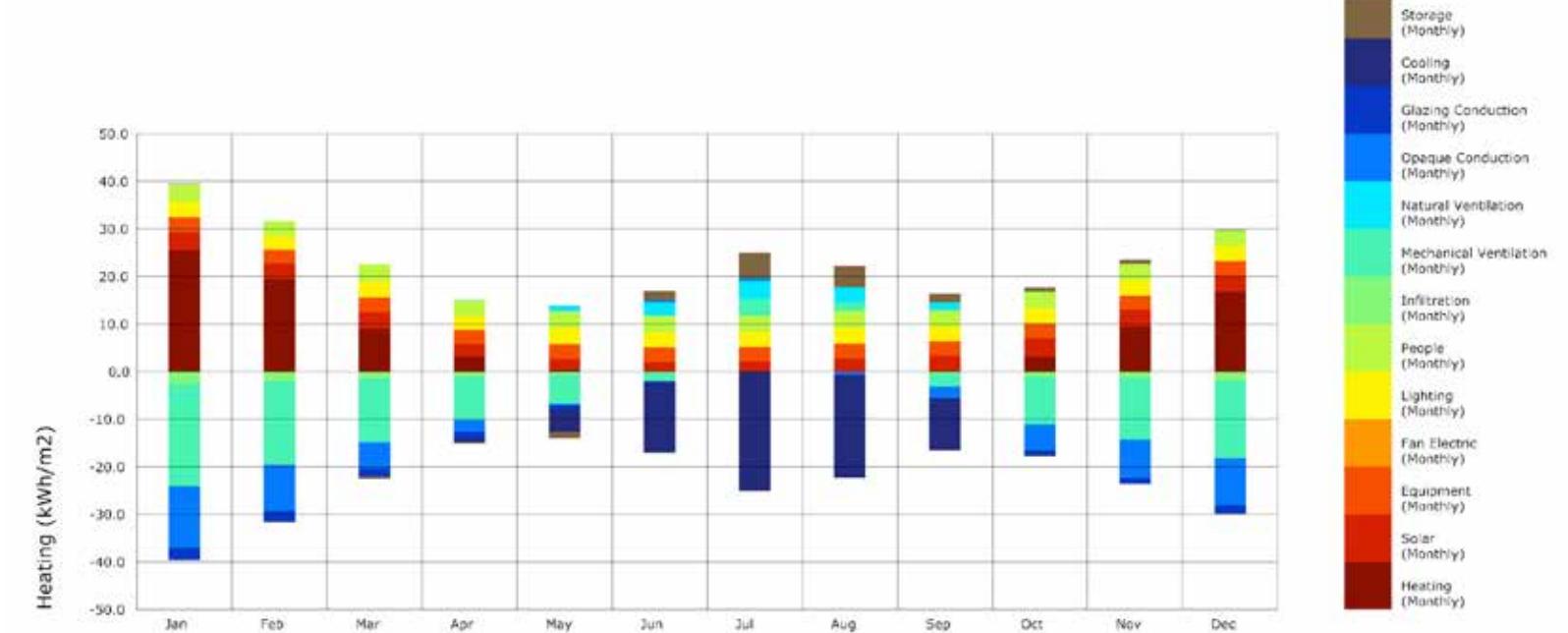
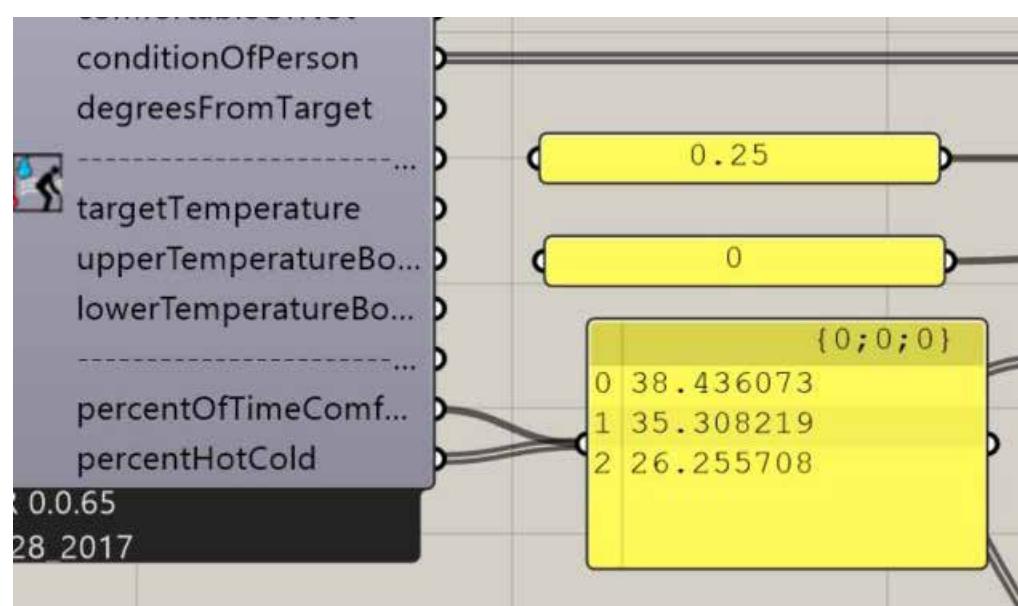
According to the glare analysis for modified room, I found that the glare status was slightly higher, but still imperceptible in all the test days. So I keep it as it is.



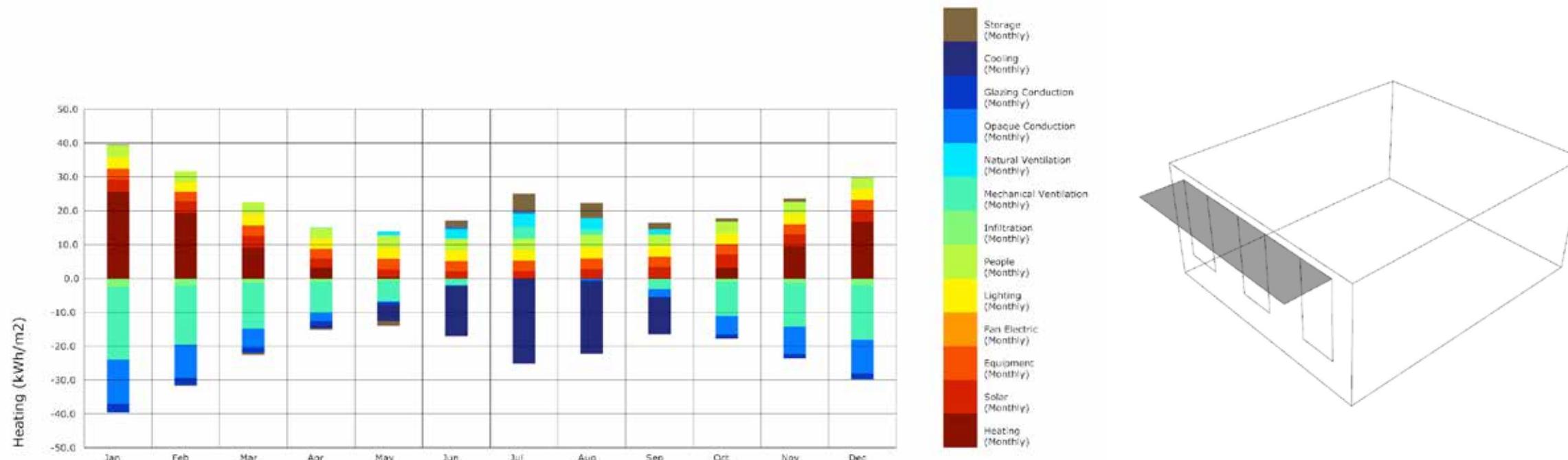
INDOOR COMFORT TEST



We could see that hot time is more than cold time, so I tried to add shade to the window in order to reduce the heat and increase the comfortable time.



SHADE TEST



Window Direction: South
 Glazing Ratio = 0.3
 Comfortable Time Ratio = 40.32%
 Hot Time Ratio = 30.16%
 Cold Time Ratio = 29.52%

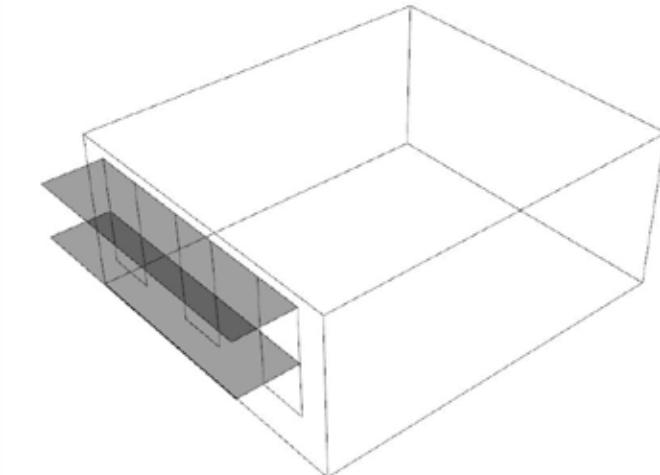
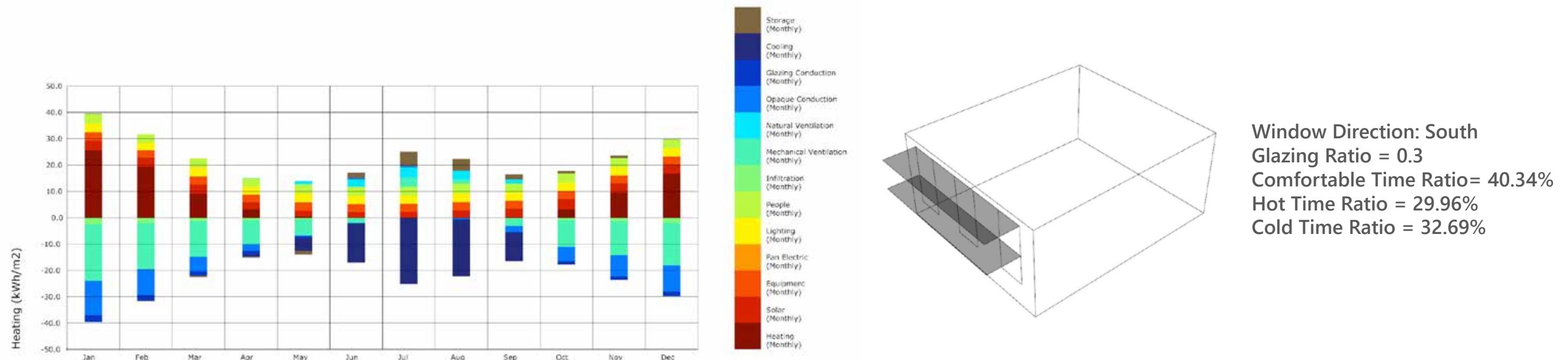


Adaptive Comfort for ZONE_1 (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly

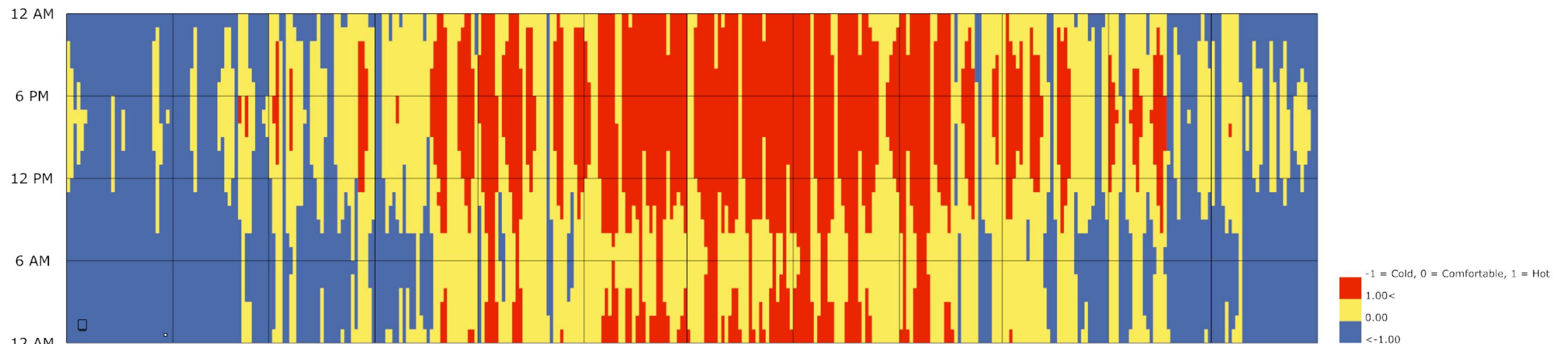
Philadelphia International Ap PA USA TMY3

1 JAN 1:00 - 31 DEC 24:00

SHADE TEST

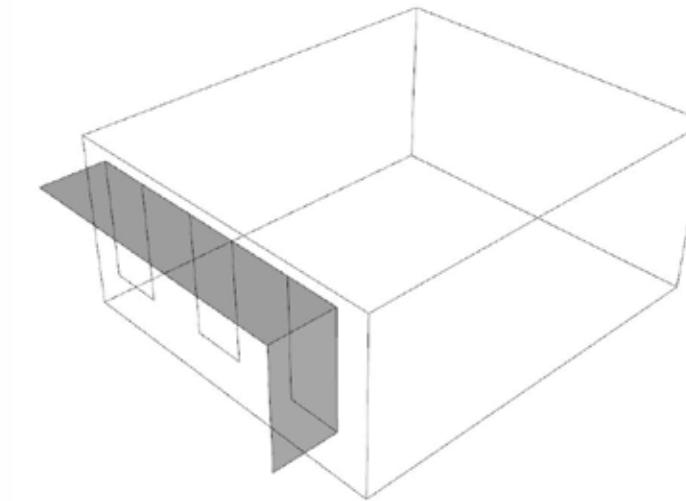
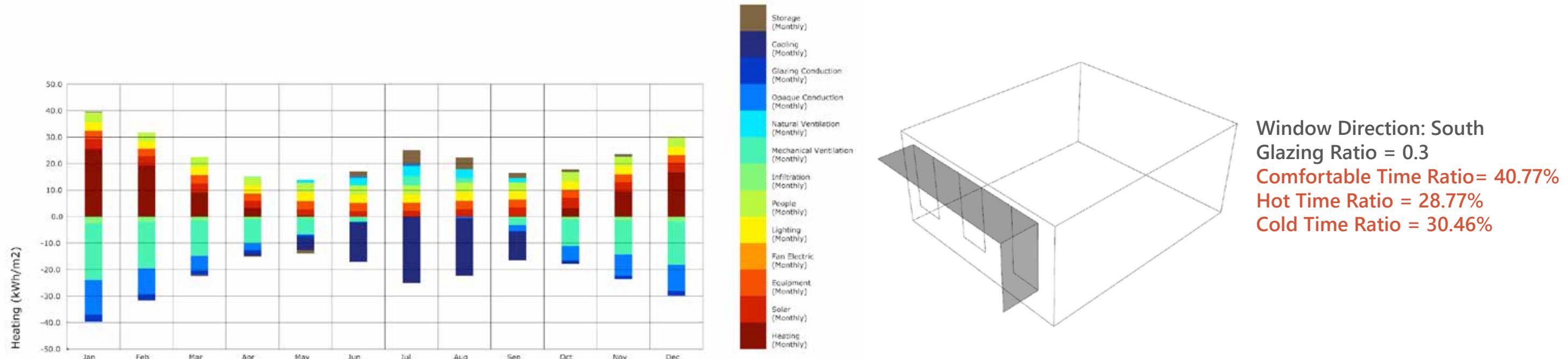


Window Direction: South
 Glazing Ratio = 0.3
 Comfortable Time Ratio = 40.34%
 Hot Time Ratio = 29.96%
 Cold Time Ratio = 32.69%

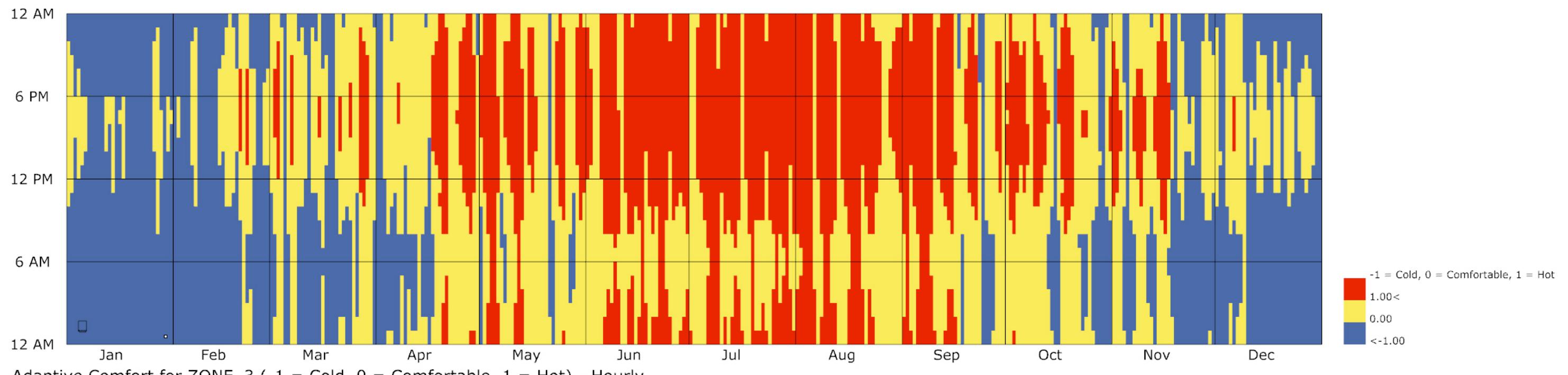


Adaptive Comfort for ZONE_3 (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
 Philadelphia International Ap PA USA TMY3
 1 JAN 1:00 - 31 DEC 24:00

SHADE TEST

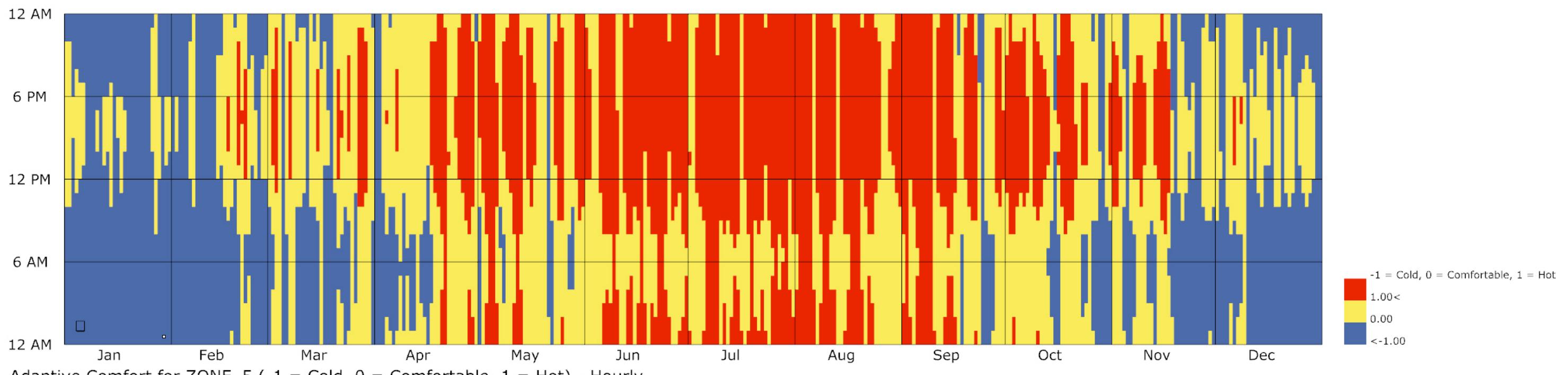
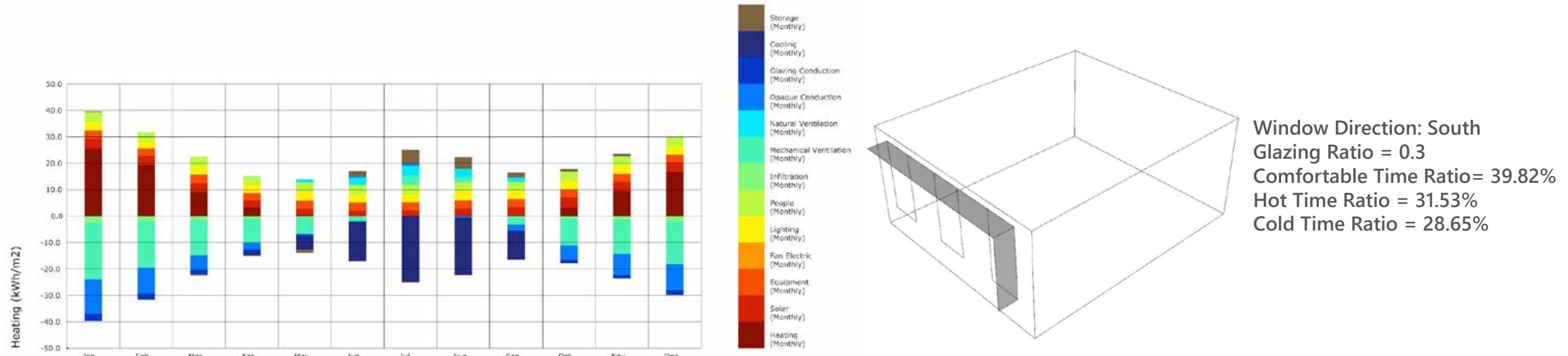


Window Direction: South
Glazing Ratio = 0.3
Comfortable Time Ratio= 40.77%
Hot Time Ratio = 28.77%
Cold Time Ratio = 30.46%



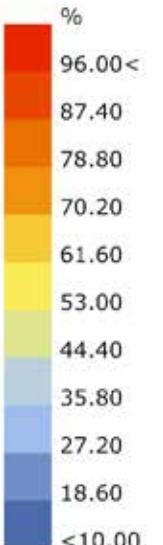
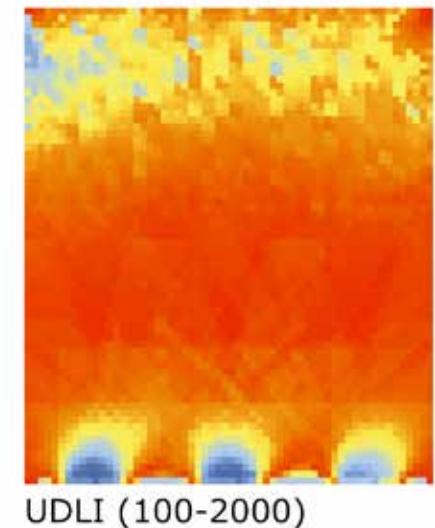
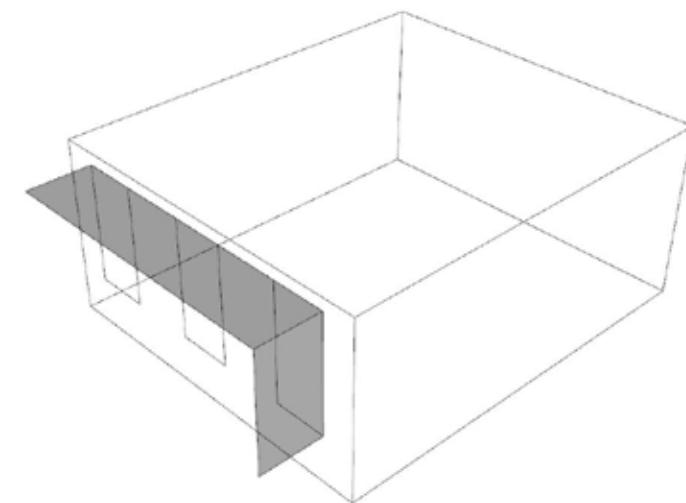
Adaptive Comfort for ZONE_3 (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

SHADE TEST



FINAL DESIGN

Window Direction: South
Glazing Ratio = 0.3 (original = 0.1)
Comfortable Time Ratio= 40.77%
Hot Time Ratio = 28.77%
Cold Time Ratio = 30.46%



Strategies:

1. Test 4 window direction, find the one with highest comfort time ratio. After testing, keep south facing.
2. Test glazing ratio, find the one provide best daylight environment.
3. Test comfort time ratio with different glazing ratio, find the better one to fit both daylighting and indoor comfort. after testing, change glazing ratio to 0.3 (original = 0.1)
4. Check glare status
5. Check indoor comfort, found that hot time is more than cold time, add shades to the window to reduce heat from radiation.
6. Test different shades, find the best one.

