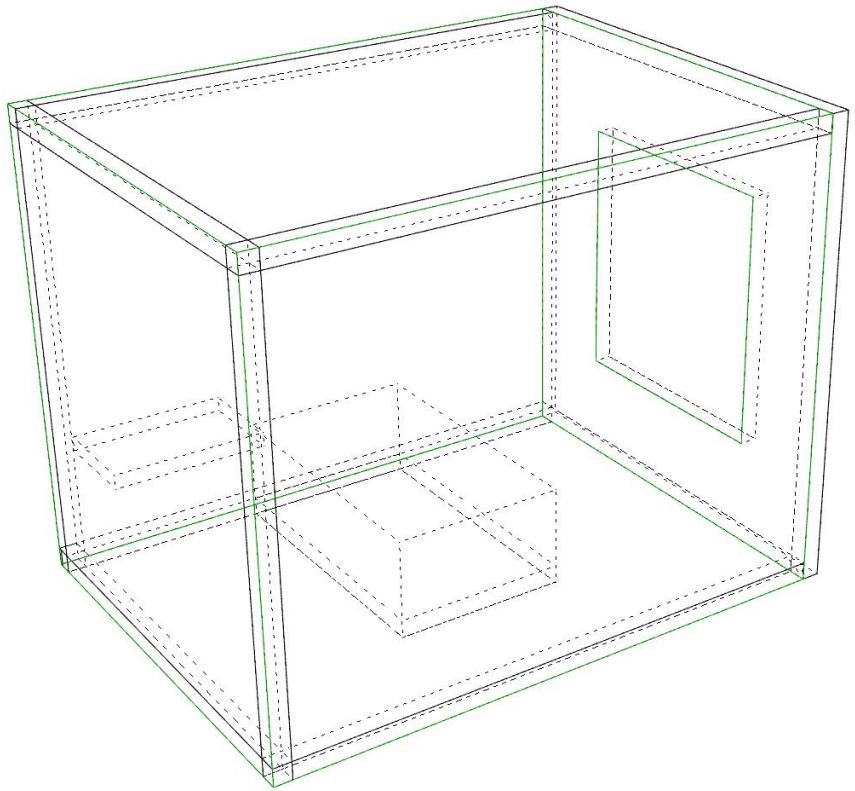
Thermal and Visual Comfort Maximization of an Unconditioned Space

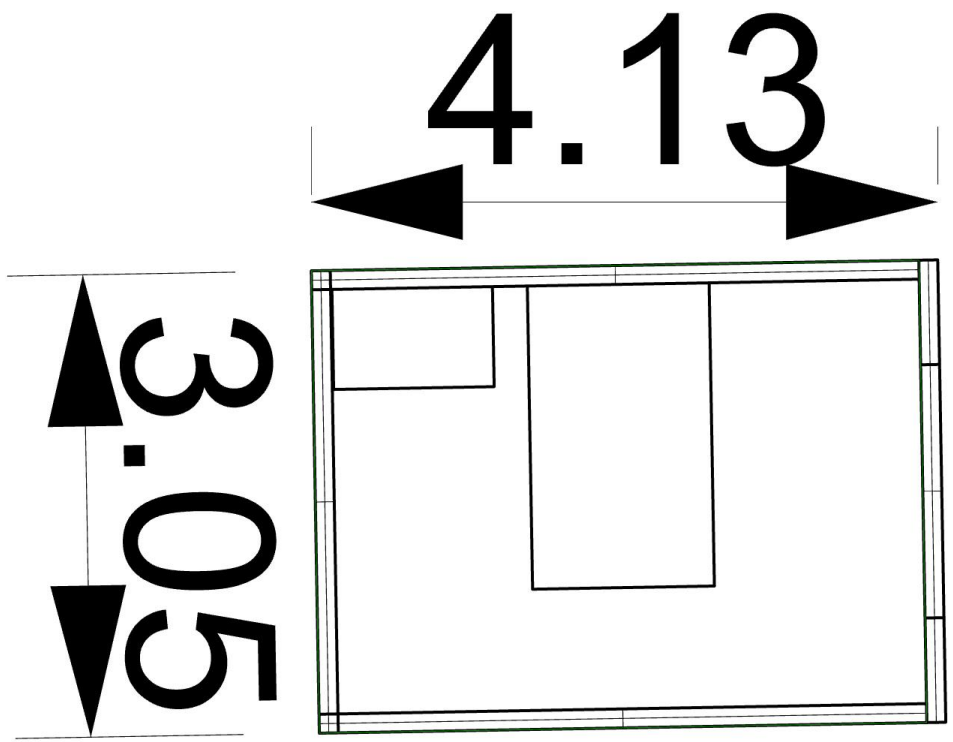
PROJECT GOAL

Maximize hours or percent of comfort.

OBJECTIVES

1. Analyze the climate
2. Analyze Performance of Base Case
3. Devising Design Strategies
4. Evaluating the performance of an improved design proposal





The Geometry into consideration is a single bedroom with east facing window.
Situated : 2930 Chestnut Street Philadelphia.

Climate Analysis

The Climate of Philadelphia comes under zone 4 which has very cold weather as a prominent feature. The main objective would be to tackle the effects of cold weather and create an optimum indoor environment.

Weather Data

Philadelphia

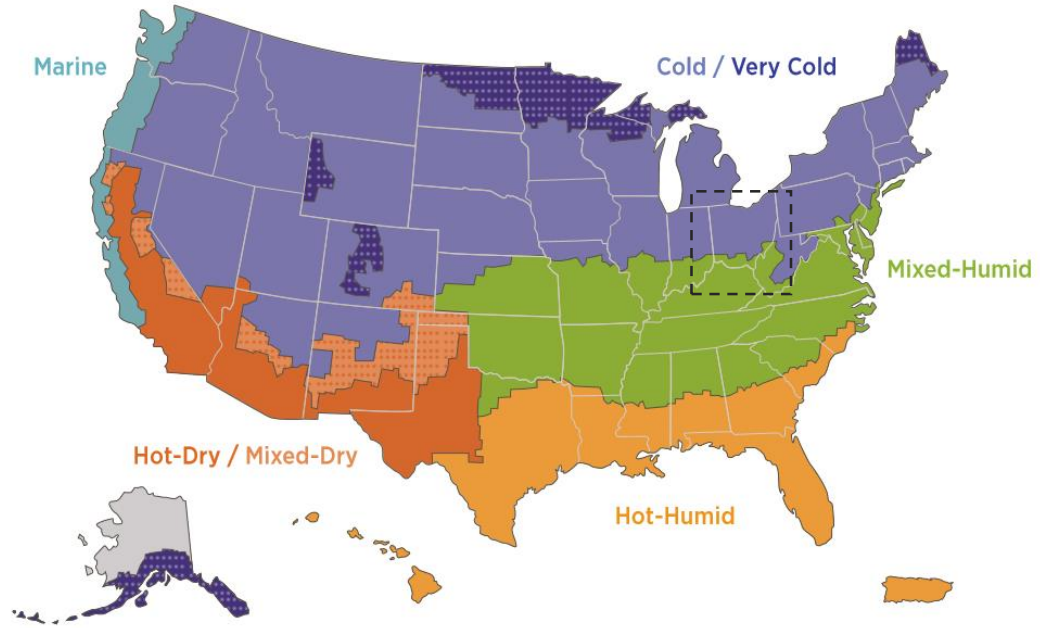
Latitude : 39.57 (north)

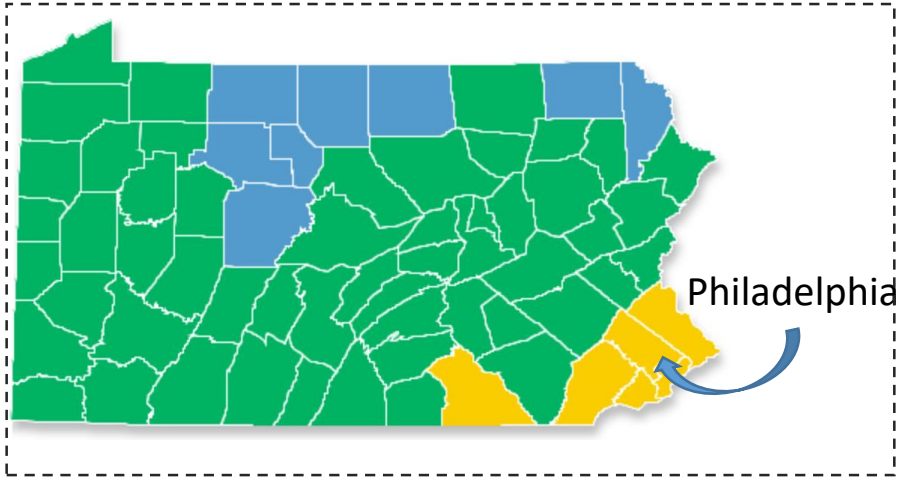
Longitude : 75.10 (west)

Climate Zone : Zone 4 (except marine)

Characteristic : Cold / Very Cold

Building America	IECC
Subarctic	Zone 8 (only found in Alaska)
Very Cold	Zone 7
Cold	Zones 5 and 6
Mixed-Humid	4A and 3A counties above warm-humid line
Mixed-Dry	Zone 4B
Hot-Humid	2A and 3A counties below warm-humid line
Hot-Dry	Zone 3B
Marine	All counties with a "C" moisture regime

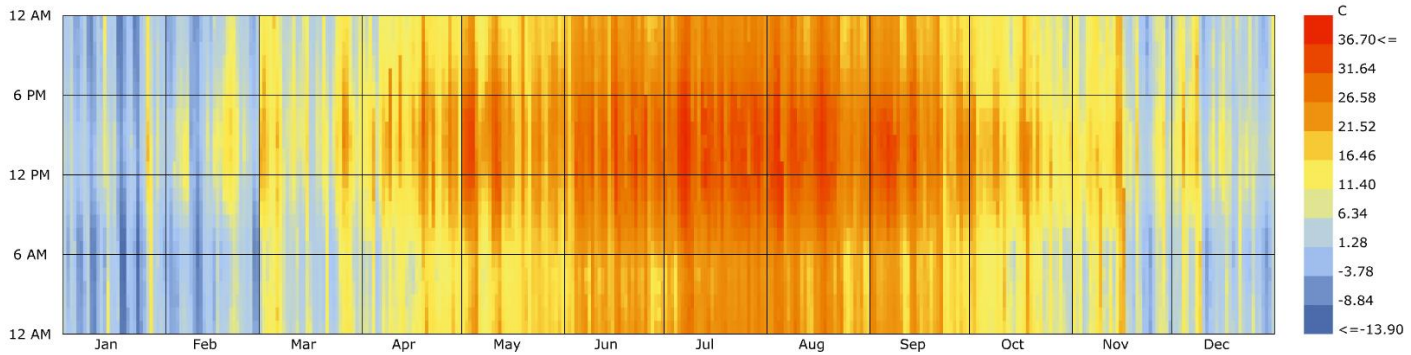




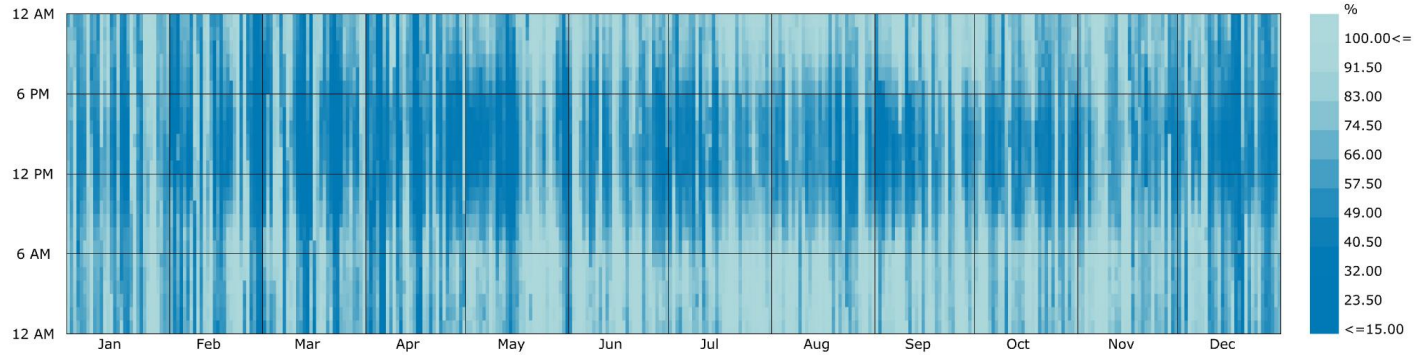
Climate Zone 4 (Except Marine)	
Ceiling R-value	38
Wood Frame Wall R-value	13
Mass Wall R-value [i]	5/10
Floor R-value	19
Basement Wall R-value [c]	10/13
Slab R-value [d], Depth	10, 2 ft
Crawlspace Wall R-value [c]	10/13
Fenestration U-Factor [b]	0.35
Skylight U-Factor [b]	0.60
Glazed fenestration SHGC [b, e]	NR

http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/4_3a_ba_innov_buildingscienceclimatemaps_011713.pdf

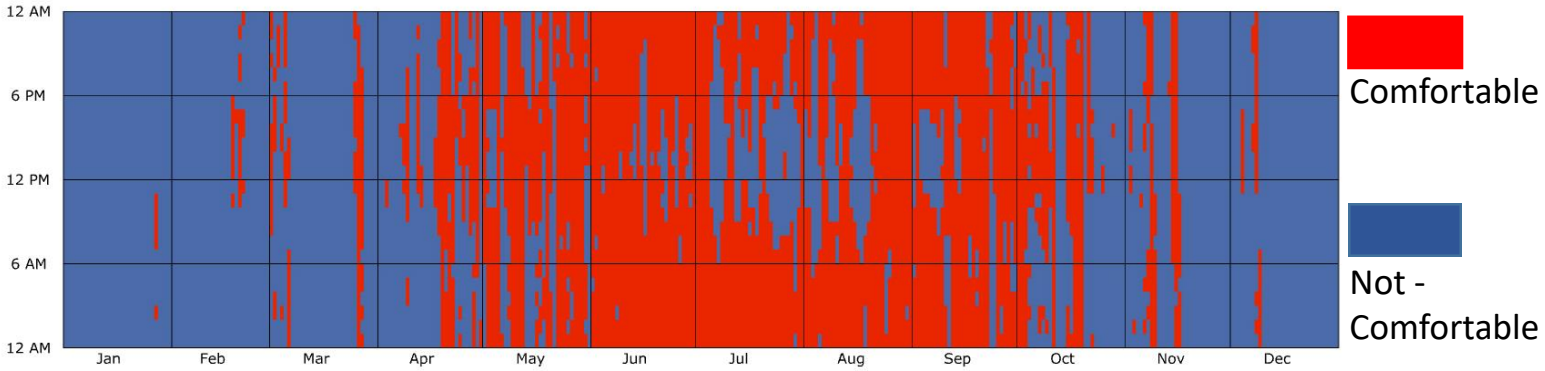
https://energycode.pnl.gov/EnergyCodeReqs/?state=Pennsylvania



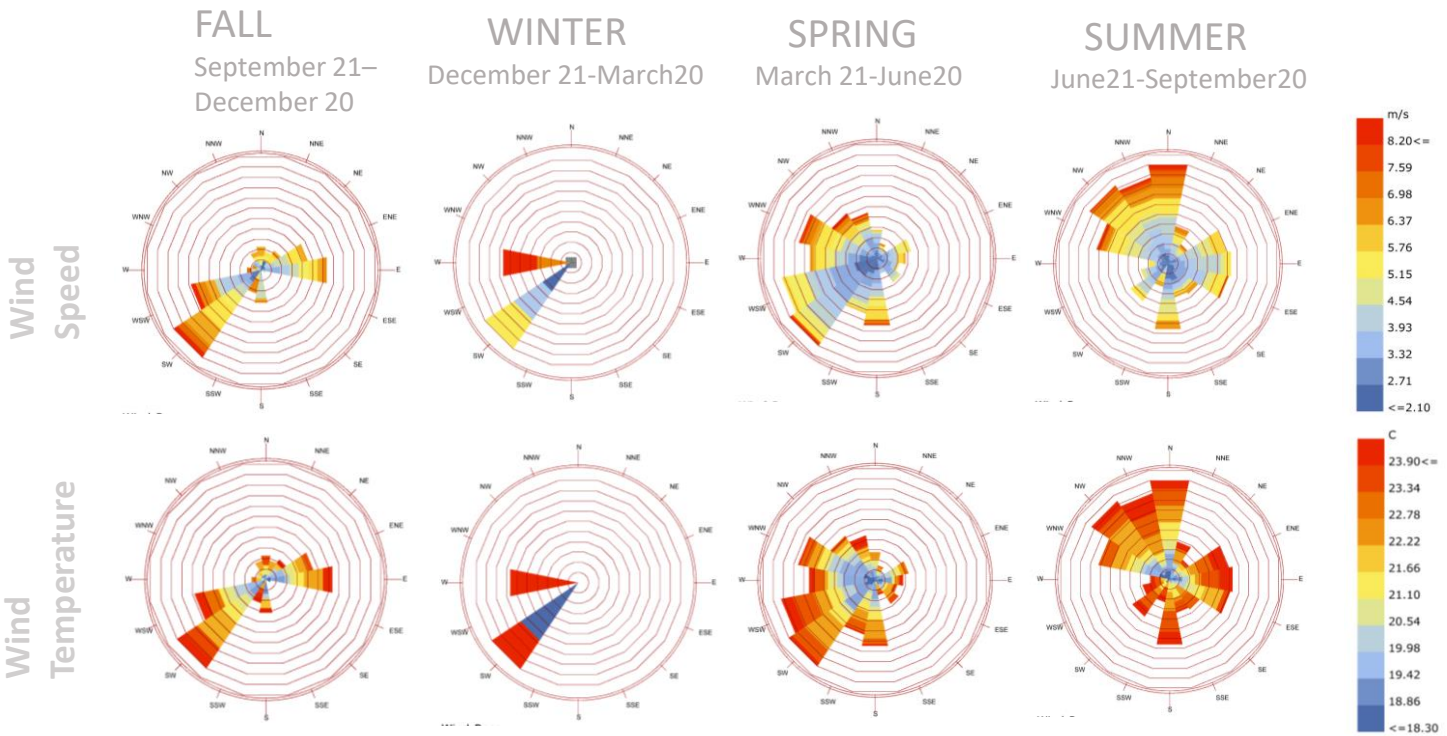
Dry Bulb Temperature in Degree Celsius



Relative Humidity

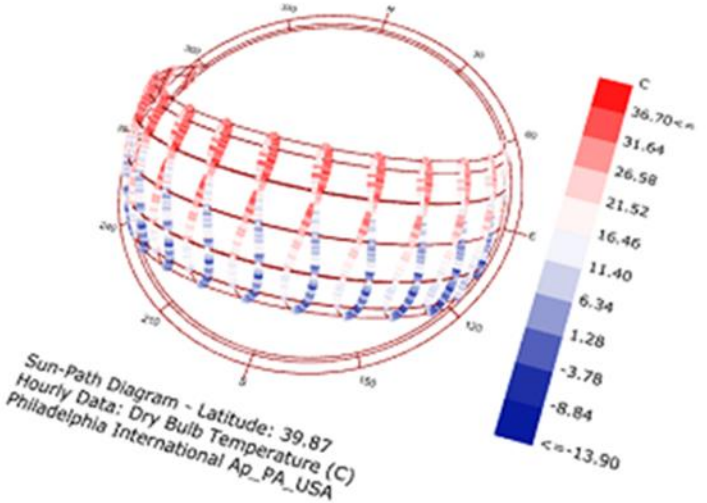


The UTCI, or Universal Thermal Climate Index, meaning temperature of what the weather ‘feels like’. According to the UTCI, Philadelphia has around 41% of comfort, throughout the year. But as seen the crucial cold temperatures may go anywhere from -3 to -20 degree Celsius, between October to April. The humidity is high during the day time.



- North and North-west wind is prevalent in summer, whereas, during the rest of the year it is South-west winds which are prominent.
- The temperature of South-west winds during winter is low and thus, should be avoided.

- For the design of the building thus, a compact design with maximum sealed glass, and minimum openings would be preferred.

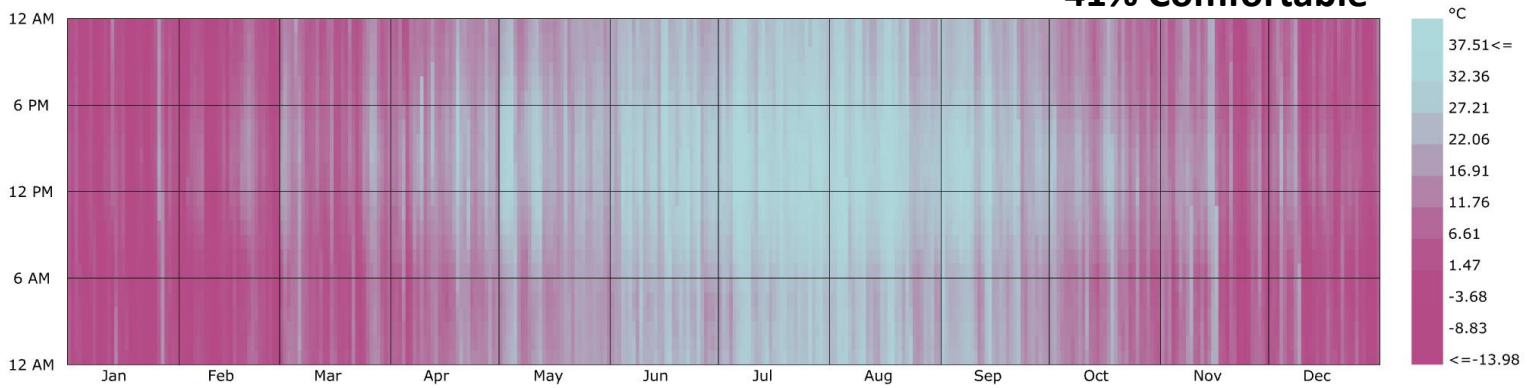


- The solar exposure needs to be capitalized during winter, whereas the exposure to direct sunlight needs to be reduced during winter.

- Design of the shading devices to be done, keeping the above point in mind.

- The direct sun exposure needs to be avoided whereas the inclined sun during the colder seasons helps in forming a relief. (reducing cold stress)

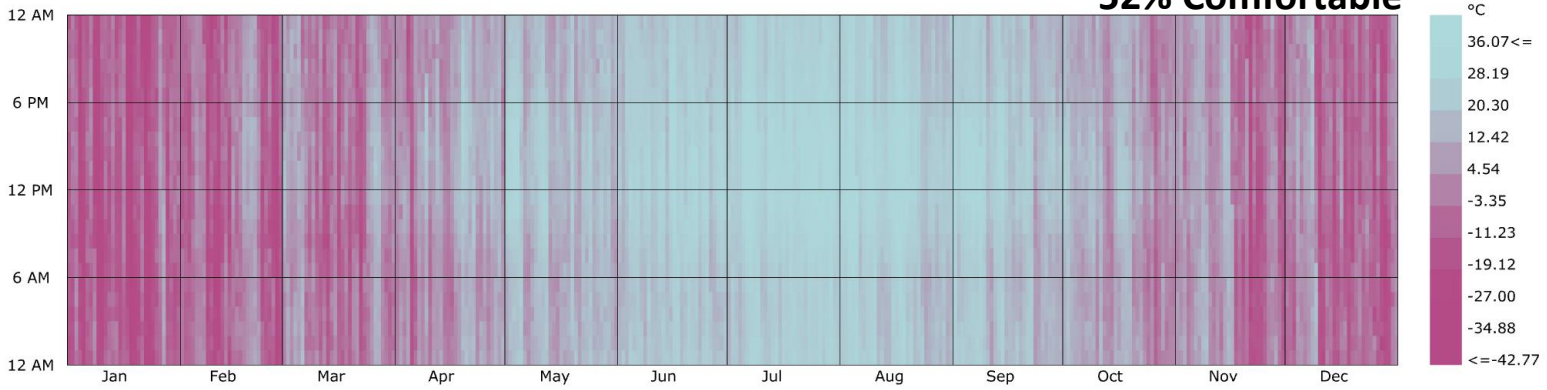
41% Comfortable



With Wind Speed

Universal Thermal Climate Index (UTCI) in Degree Celsius (9-26 degree Celsius)

52% Comfortable



Without Wind Speed

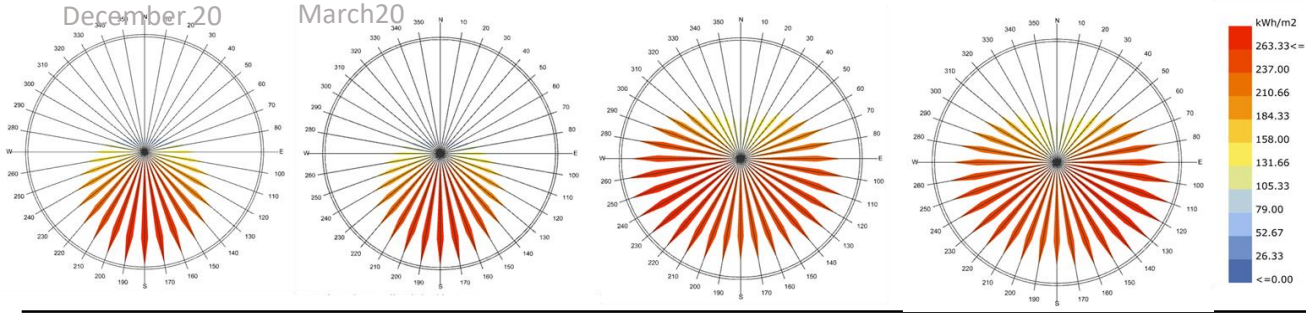
Universal Thermal Climate Index (UTCI) in Degree Celsius (9-26 degree Celsius)

FALL
September 21–December 20

WINTER
December 21-March20

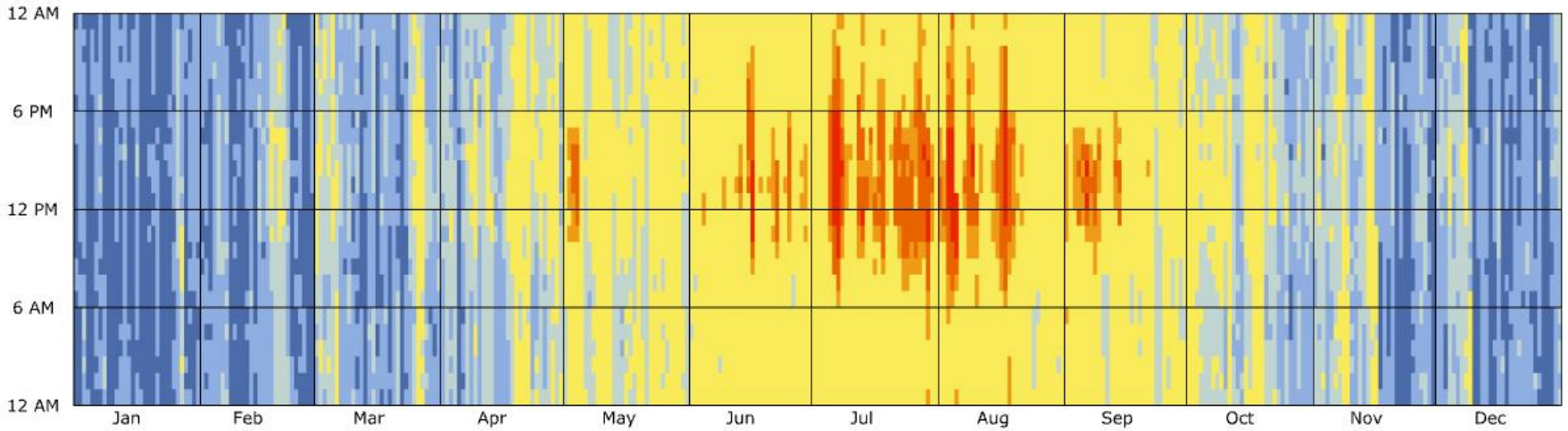
SPRING
March 21-June20

SUMMER
June21-September20

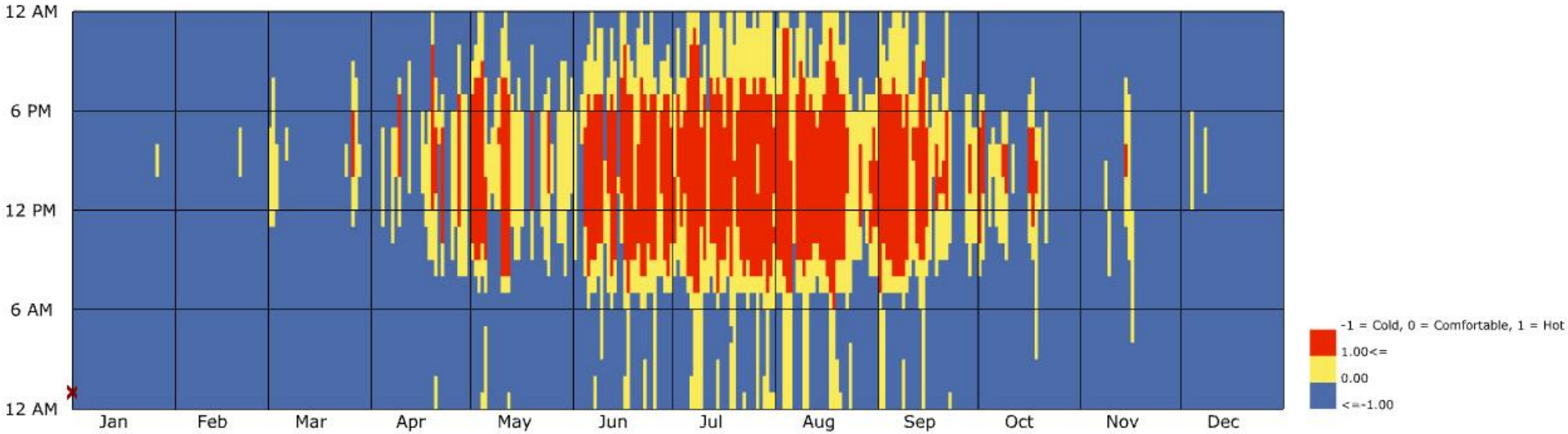


The two UTCI mappings, show the difference in level of comfort with and without wind speed. The comfort level drops from 52 to 41 percent with the introduction of wind speed.

Outdoor
41% Comfortable



Adaptive Indoor
15.58% Comfortable
12% Heat Stress
72% Cold Stress



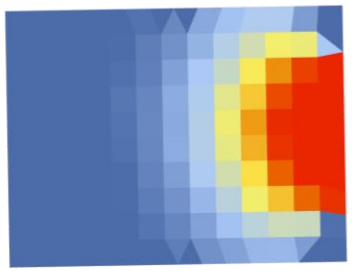
Adaptive Comfort for ZONE_6_T (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Philadelphia International Ap PA USA TMY3
1 JAN 1:00 - 31 DEC 24:00

9 A.M

12 Noon

3 P.M

MARCH



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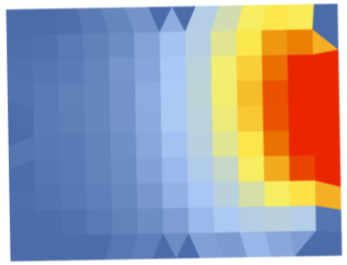

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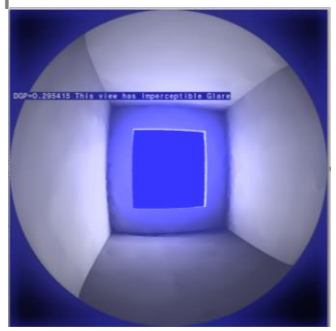

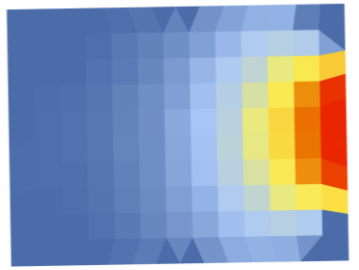

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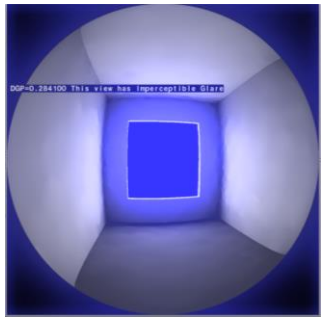
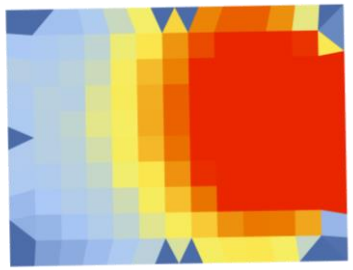


JUNE



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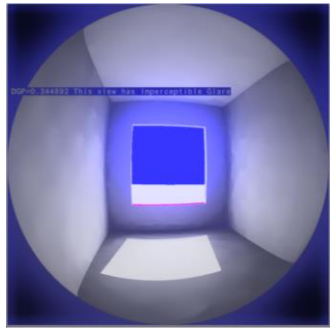

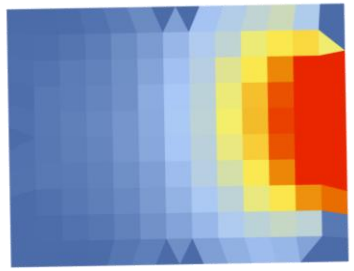

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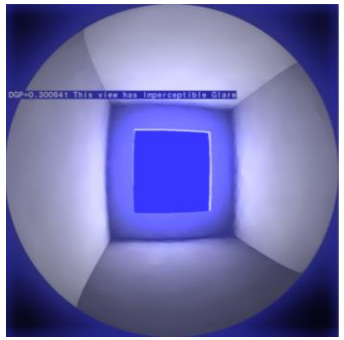

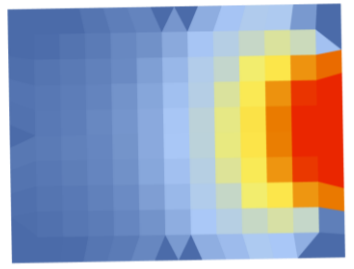

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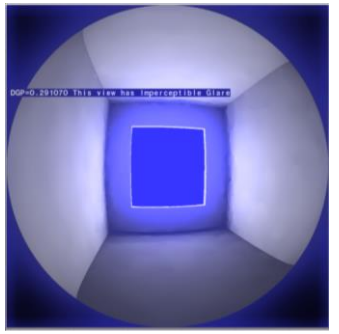
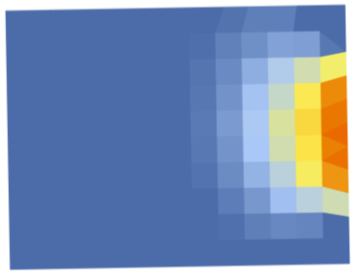


DECEMBER



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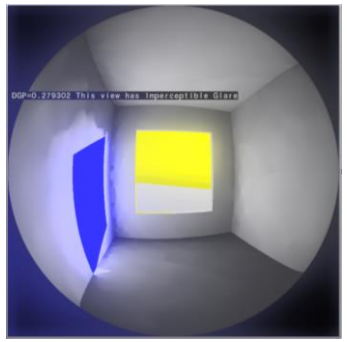

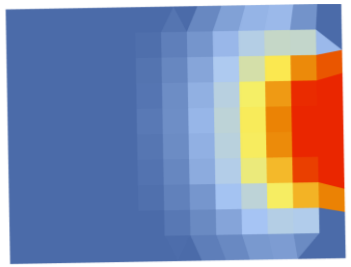

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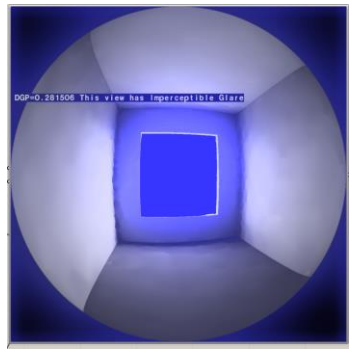

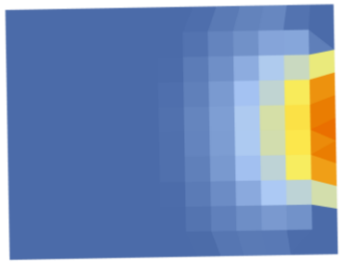

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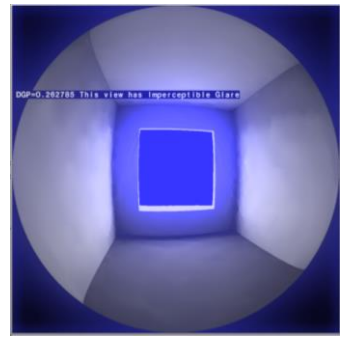
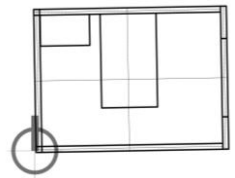


Spatial Daylight Autonomy (sDA) – 65.96

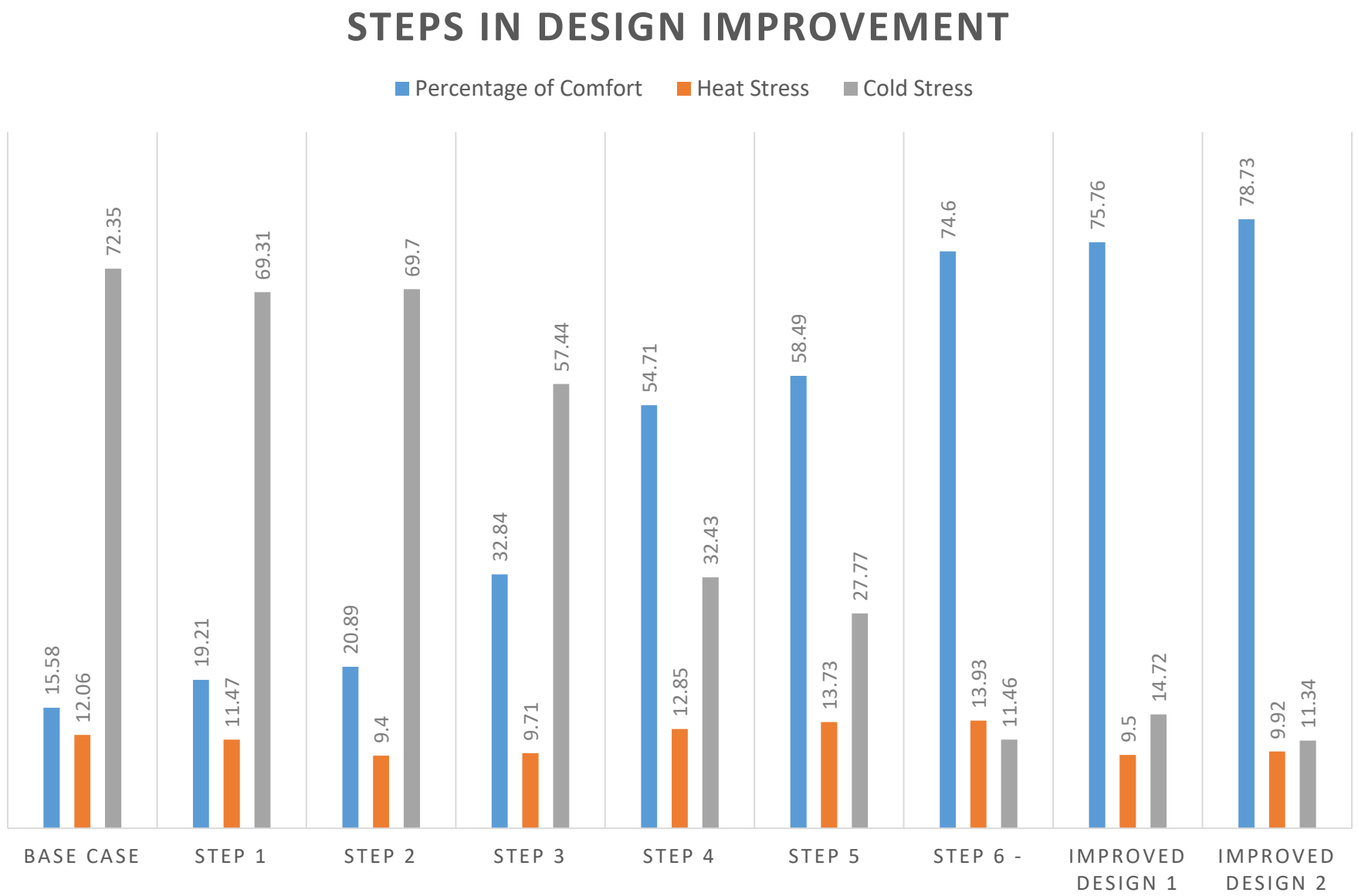


The percentage of Comfort drops from 41% for outdoors to just 15% indoor.

- Thus, to increase the temperature indoors, solar gains need to be maximized during the morning time, with hybrid methods (screens to keep the sun out during summers).
- As seen from the radiation rose, larger glass windows on South side can benefit from receiving the heat, but east and west sides need to be protected from sun penetration, as this can lead to uncomfortable environment during summer and spring.

Design Strategies Suggestions based on the climate analysis:

1. Compact planning of the building for minimizing heat loss.
2. Windows to be sealed majorly, partial openings to be provided on North and North west side to use ventilation during Summer.
3. Orientation – longer side preferably parallel to North – South direction, so as to increase direct solar heat gain during winter.
4. Horizontal shading on South façade, in the form of brise-soleil, light shelves and overhangs would contribute to building heating in winter.
5. Louvers, screens and blinds on East and west Façade to avoid afternoon Sun during Summer, these shouldn’t be fixed rather adjustable by users, as in Spring the radiation can be used for increase in comfort levels.



The steps in design improvement have been aimed prominently at reducing the cold stress. The process and learnings are further described.

Step 1 – GLAZING 20% WINDOW TO WALL RATIO, SOUTH ORIENTATION

Glazing changed from East to South, also now having an opening on the longer side of the plan. A seemingly moderate reduction in cold stress is observed as the southern glazing would directly allow the winter inclined sun to penetrate, thus causing heat gain during the day, keeping the room pleasant.

Step 2 – CONSTRUCTION CHANGE FOCUS GLASS

Changes in construction material, for example making the glass having a Solar Heat Gain Coefficient of 65% (as compared to the least value 7%). In this step a reduction in heat stress is observed.

Step 3 – CONSTRUCTION CHANGE FOCUS THERMAL MASS

Continuing with the change in construction, as the wall, roof and floor materials are made heavier, a significant drop in cold stress is observed (69.70 to 57.44), as the thermal mass would help trap heat the building is subjected to in the day time and radiate this later in the day.

Step 5 –
INCREASE IN GLAZING AREA

In a bid to utilize the solar heat in an advantageous manner, the opening on south side is increased from 20 to 40% (doubled) which brings the cold stress down from 32% to 27%.

Step 4 – NATURAL VENTILATION RANGE OF OPERATION

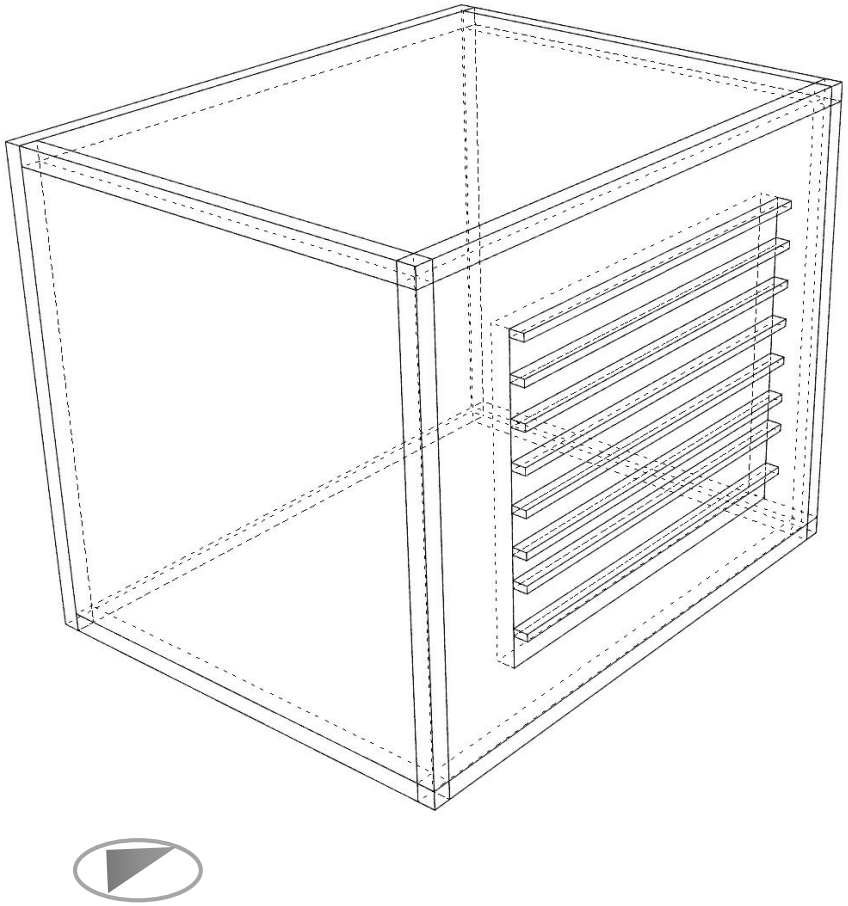
Introducing range for the Natural Ventilation to work within gave a great rise in comfort % and again a loft decrease in cold stress (from 57 to 32%) . A slight rise in heat stress is observed 9 % to 12%) as the range would result in lesser time for the structure to be naturally ventilated. This range when worked with Building systems can be used for operable windows for desired thermal comfort

Step 6 – INFILTRATION & BLINDS

Came in as a very surprising result to a very simple solution. T he infiltration when curbed to almost 0, made the cold stress down to 15%. Although infiltration 0 is a very ambitious aspect in structures, yet this fluctuation helped me understand the effect of a sealed structure in climate like Philly. In addition, introduction to blinds, further improved the case by reducing the heat stress caused by direct sunlight.

Improved Designs

After trying and working these steps, a point was reached where a number of iterations could be tried for the combination of the opening, shading devices and working on even more improved design.

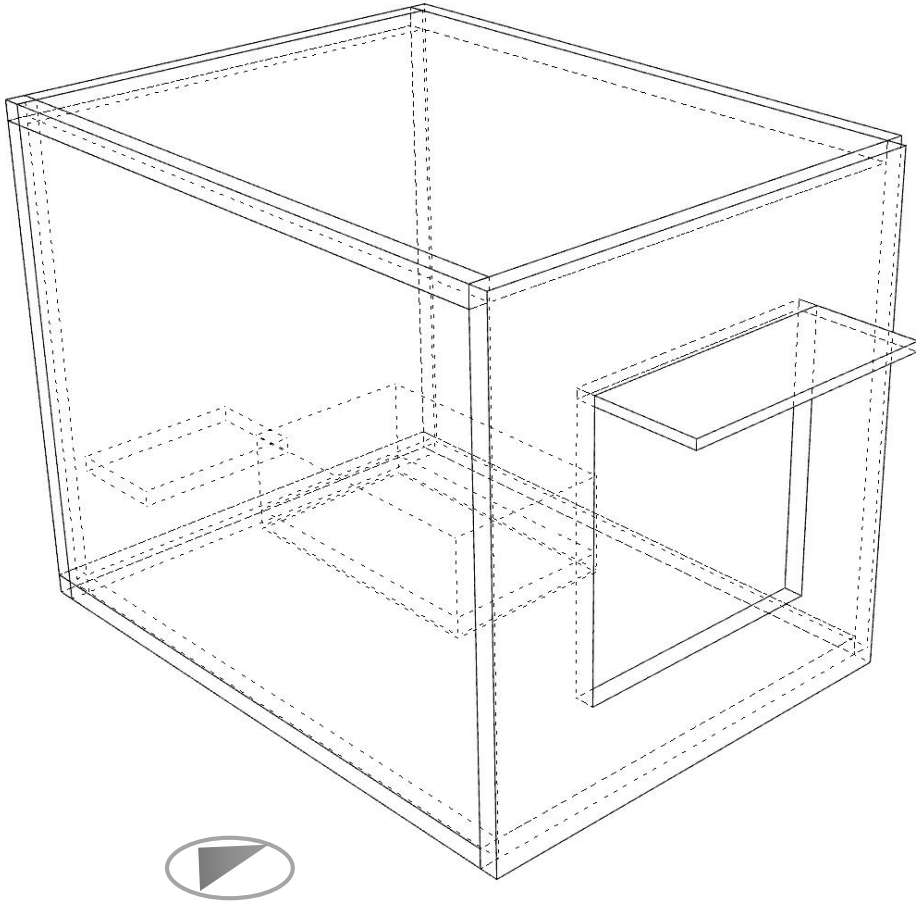


Improved Case 1

- South Glazing 40%
- Orientation 20 degree
- Longer face has the opening
- Different shading iterations tried ahead.

Improved Case 2

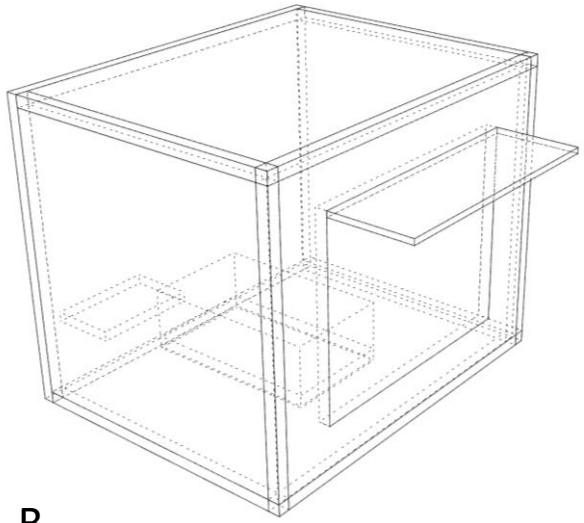
- East Glazing 40%
- Orientation 280 degree, which basically makes it a south window.
- Shorter face has the opening
- Different shading iterations tried ahead.



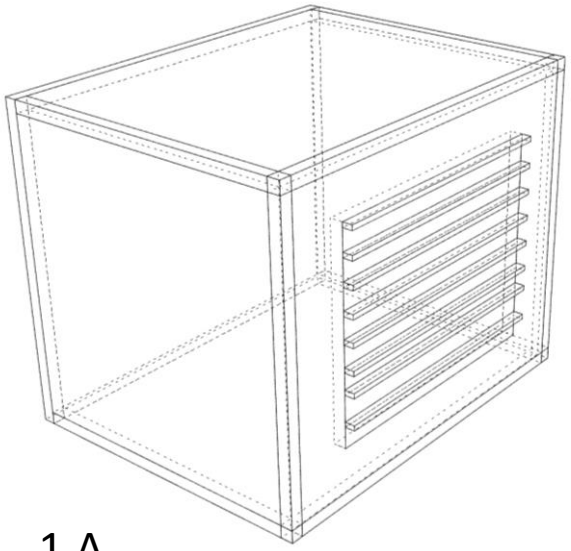
The Design strategies suggested earlier proved helpful in increasing the comfort percent but the learning here is the extent to which each factor affects this process.
Controlling infiltration and thermal mass proved to be two predominant factors, next orientation, glazing percentage and shading as well helped further the goal.

Different Iterations of shading devices have been tried on both the improved cases. Changing the depth and number of these blinds or shades, comfort percentage, heat stress and cold stress are accounted for. Also for better visual comfort, daylight analysis is made to improve further.

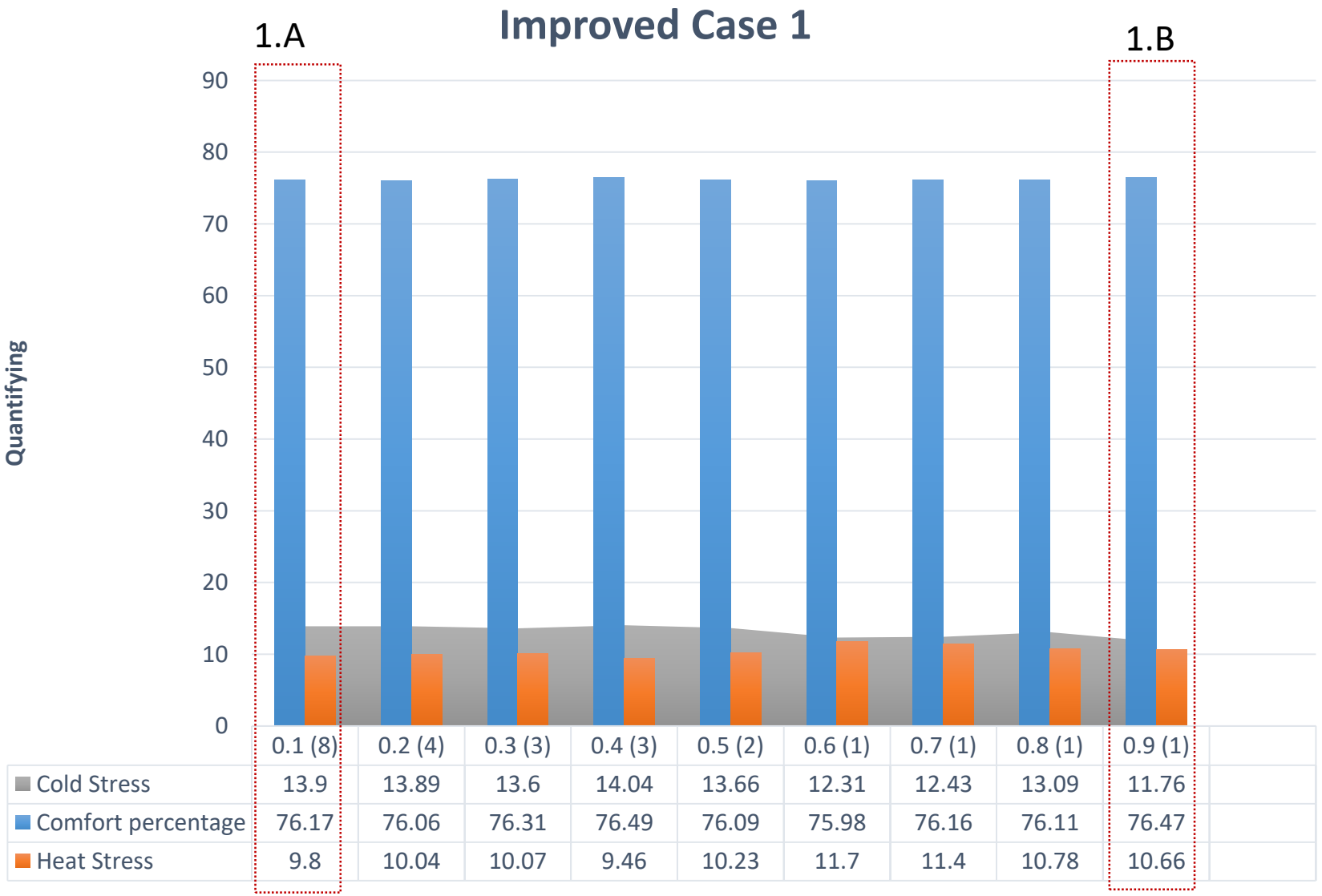
DGP: Daylight glare probability:
Imperceptible Glare [0.35 > DGP]
Perceptible Glare [0.4 > DGP >= 0.35]
Disturbing Glare [0.45 > DGP >= 0.4]
Intolerable Glare [DGP >= 0.45]



1.B

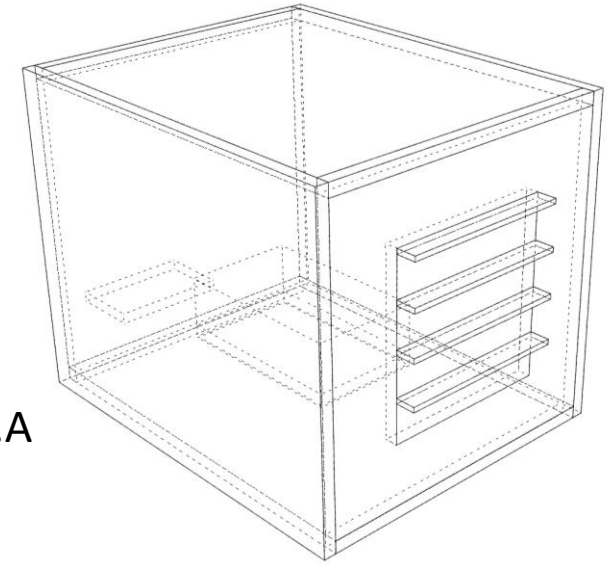


1.A

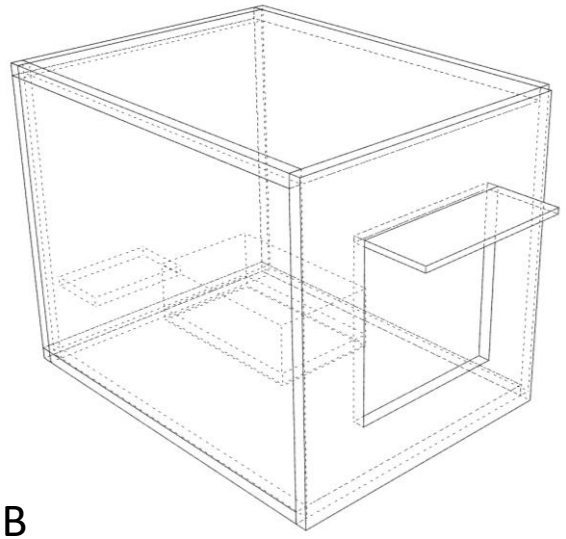


	0.1 (8)	0.2 (4)	0.3 (3)	0.4 (3)	0.5 (2)	0.6 (1)	0.7 (1)	0.8 (1)	0.9 (1)
Cold Stress	13.9	13.89	13.6	14.04	13.66	12.31	12.43	13.09	11.76
Comfort percentage	76.17	76.06	76.31	76.49	76.09	75.98	76.16	76.11	76.47
Heat Stress	9.8	10.04	10.07	9.46	10.23	11.7	11.4	10.78	10.66

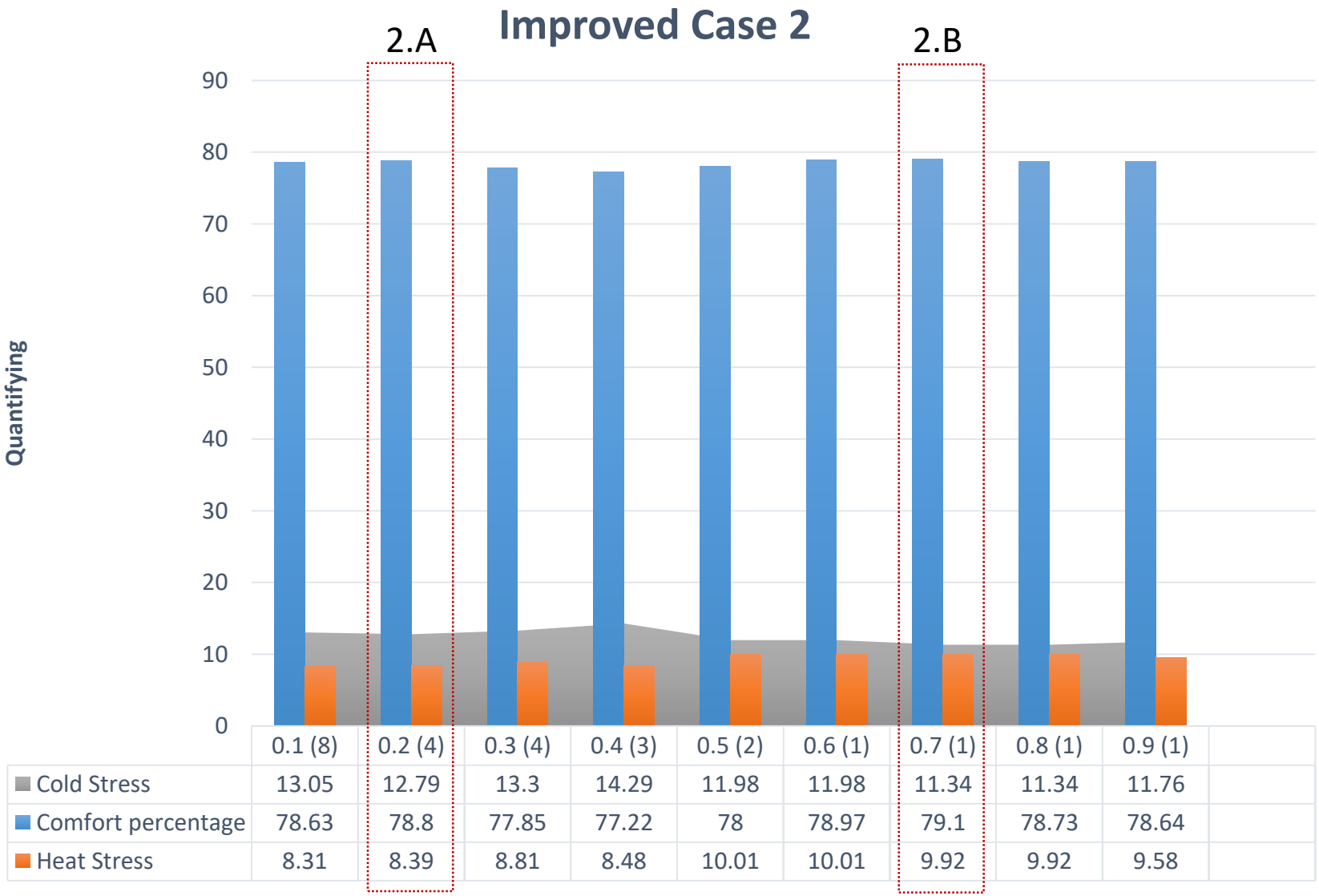
Here the quantities 0.1, 0.2, 0.3, etc depict the depth whereas the nos. inside parenthesis (1,2,3,etc.) stand for the nos. of shades or blinds.



2.A

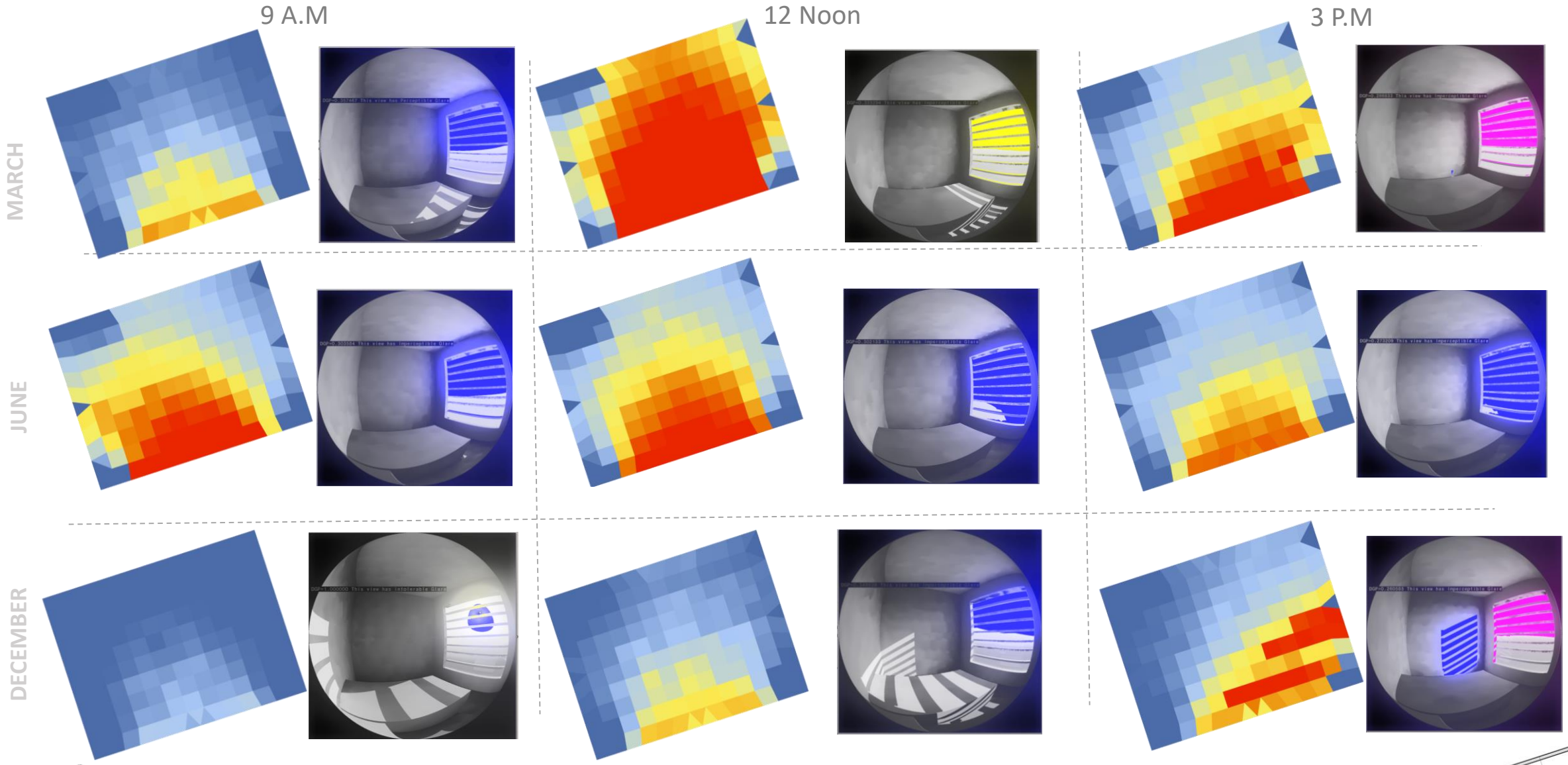


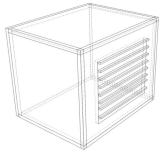
2.B



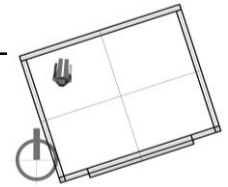
	0.1 (8)	0.2 (4)	0.3 (4)	0.4 (3)	0.5 (2)	0.6 (1)	0.7 (1)	0.8 (1)	0.9 (1)
Cold Stress	13.05	12.79	13.3	14.29	11.98	11.98	11.34	11.34	11.76
Comfort percentage	78.63	78.8	77.85	77.22	78	78.97	79.1	78.73	78.64
Heat Stress	8.31	8.39	8.81	8.48	10.01	10.01	9.92	9.92	9.58

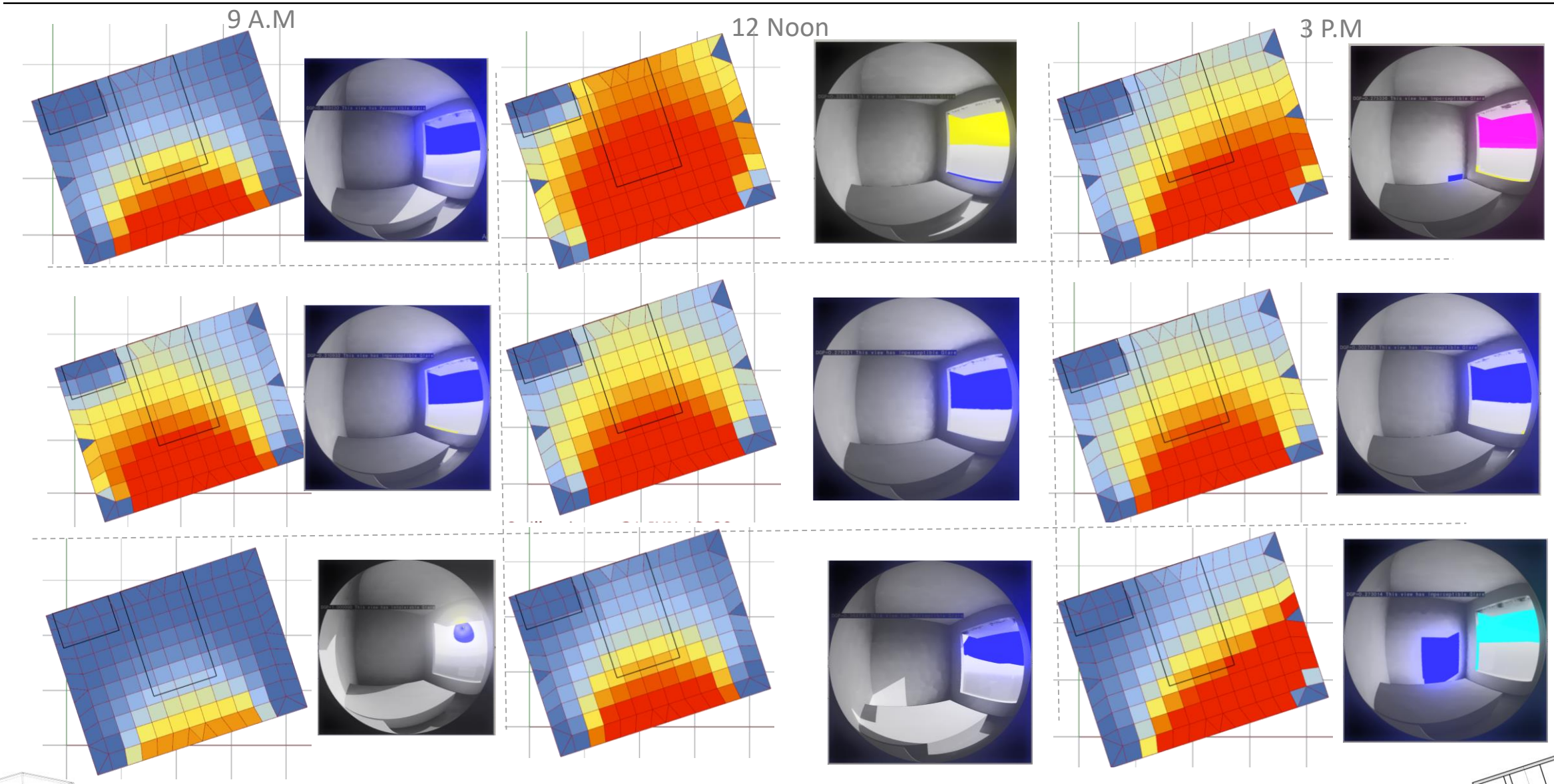
Here the quantities 0.1, 0.2, 0.3, etc depict the depth whereas the nos. inside parenthesis (1,2,3,etc.) stand for the nos. of shades or blinds.





Spatial Daylight Autonomy (sDA) – 87.14





Spatial Daylight Autonomy (sDA) – 90

9 A.M

12 Noon

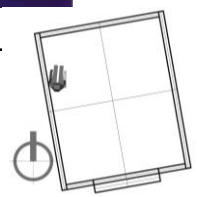
3 P.M

MARCH

JUNE

DECEMBER

Spatial Daylight Autonomy (sDA) – 72.86



9 A.M

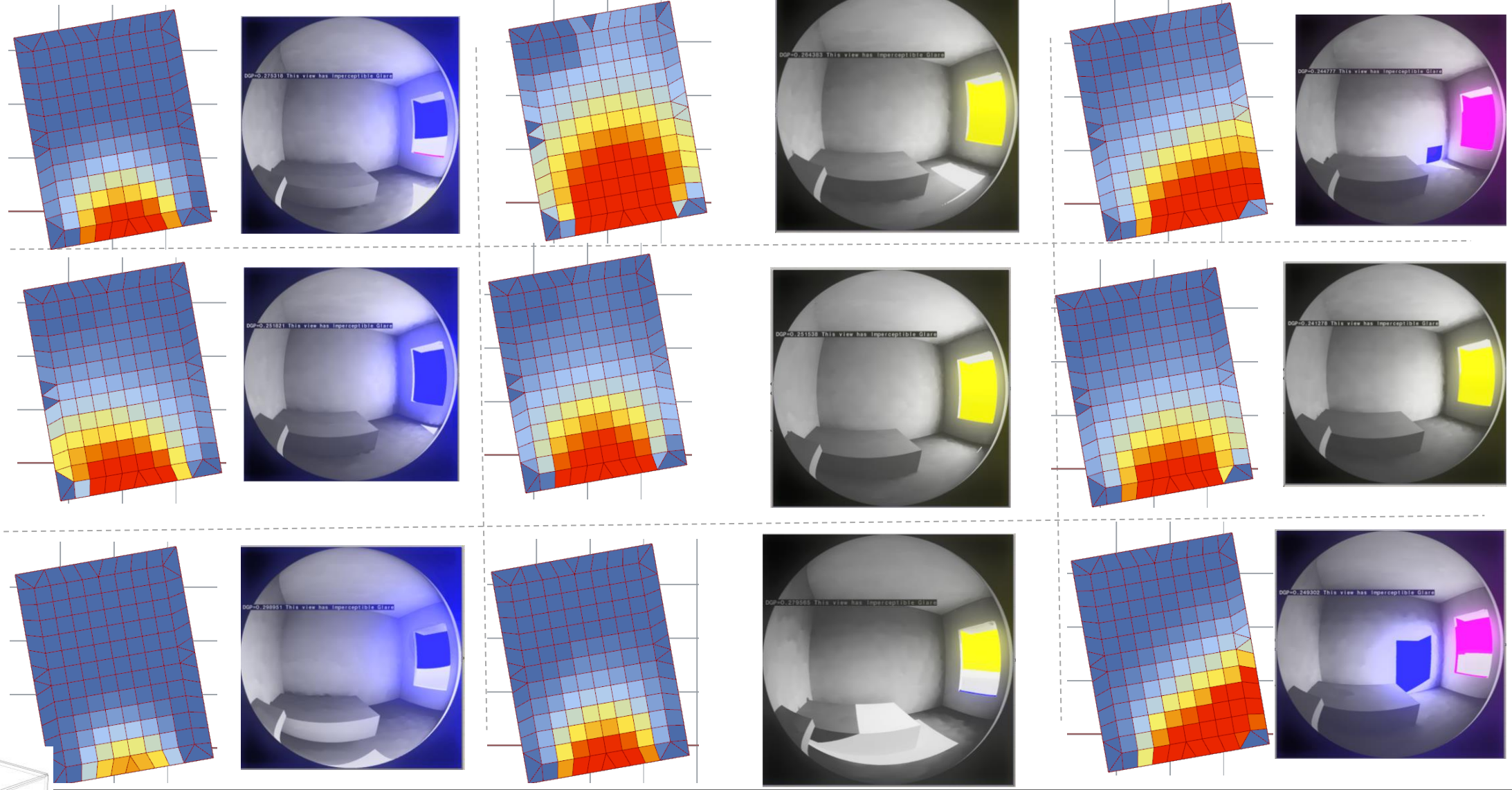
12 Noon

3 P.M

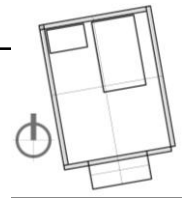
MARCH

JUNE

DECEMBER



Spatial Daylight Autonomy (sDA) – 67.14



Design Iterations	Comfort %	sDA	March (DGP)			June (DGP)			December (DGP)		
			9A.M	12 Noon	3 P.M	9A.M	12 Noon	3 P.M	9A.M	12 Noon	3 P.M
Base Design	15.58	65.96	0.35	0.29	0.28	0.34	0.3	0.29	0.27	0.28	0.26
1.A	76.17	87.14	0.35	0.32	0.26	0.3	0.3	0.27	1.0	0.34	0.26
1.B	76.47	90	0.36	0.32	0.27	0.31	0.3	0.27	1.0	0.36	0.27
2.A	78.8	72.86	0.28	0.27	0.24	0.25	0.25	0.24	1.0	0.28	0.24
2.B	79.1	67.14	0.27	0.26	0.24	0.25	0.25	0.24	0.29	0.28	0.24

What is the take away after the daylight and glare analysis?

Iterations 2.A & 2.B seemed to be the best options of improvement based on the increase in comfort percentage over the base design. But as Daylighting gave the nos. for sDA, these iterations fail to prove best solutions for visual comfort.

Thus, this whole study incorporating the steps to achieve an improved iteration proves that more than 1 factor affects the comfort achievement of a structure.

The steps taken to maximize the comfort percentage helped in understanding and defining thumb rules for a particular climatic and contextual setting.

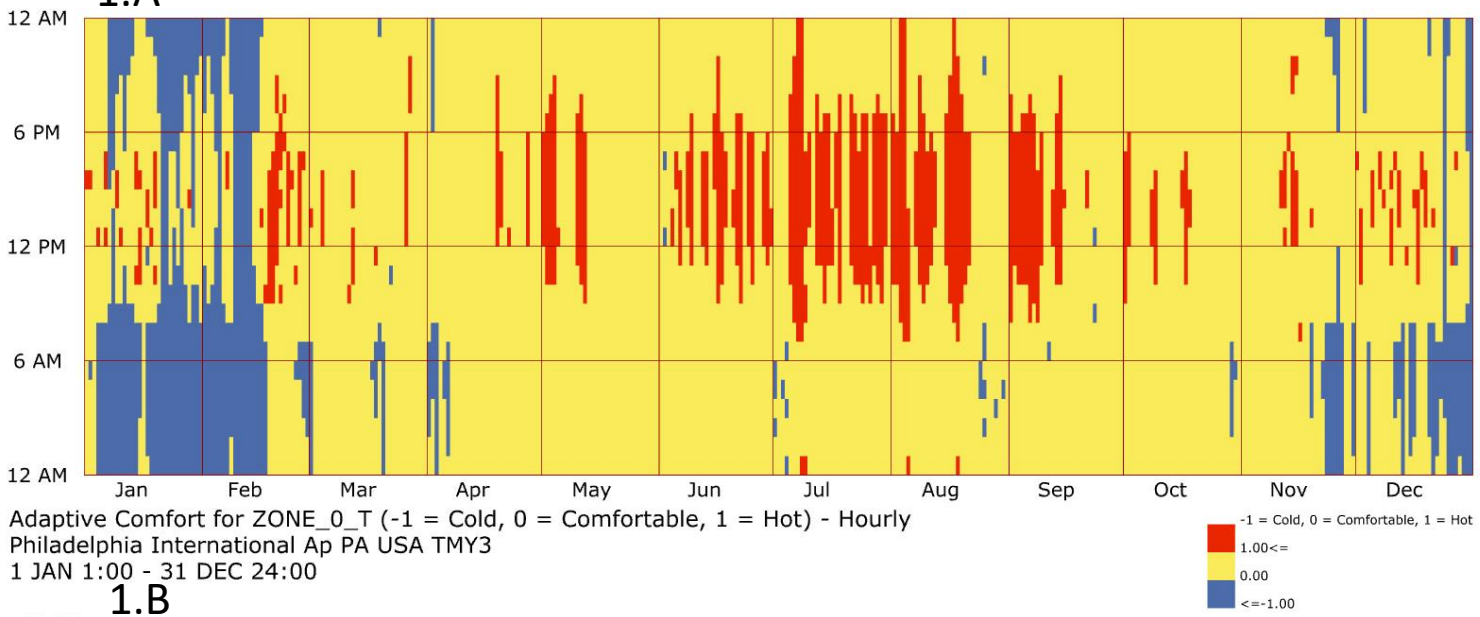
It helped in busting a number of myths and also provide a quantitative proof as to what works the better.

The Comfort percentage has not reached to 100% and various reasons for that:

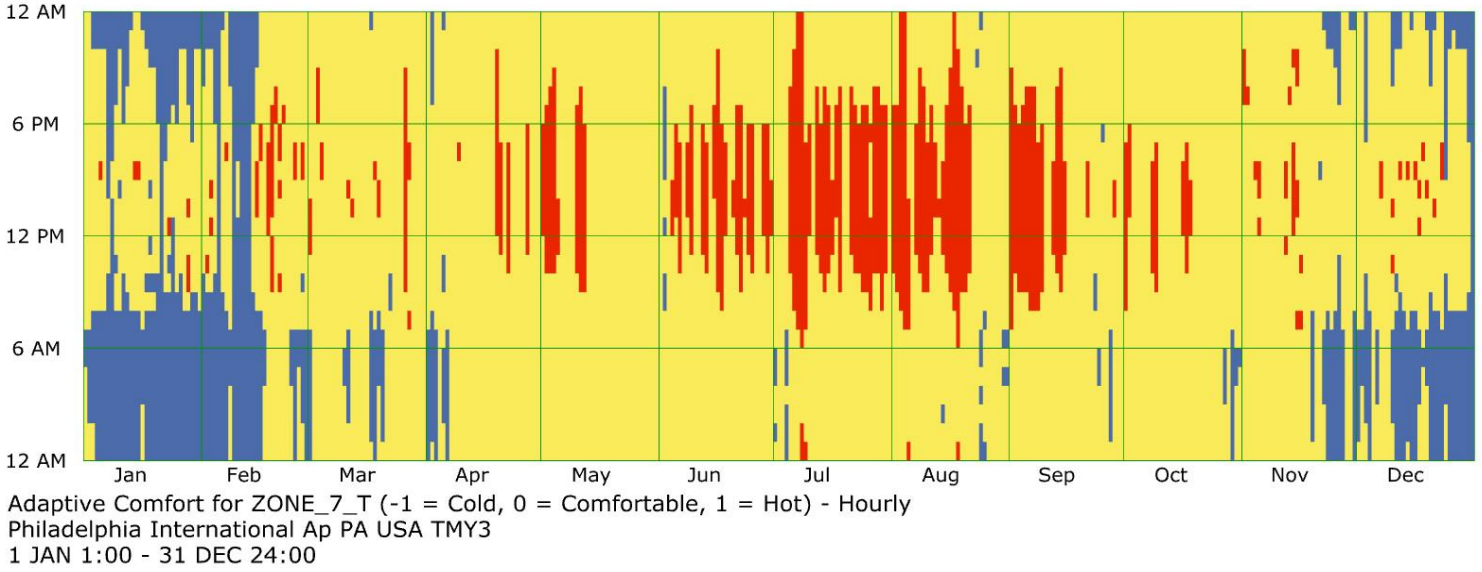
Adaptive shading could improve the percentage significantly.

Different kinds of Smart glasses could help in further achieving comfort.

1.A



1.B



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