Thermal and Visual Comfort Maximization
of an Unconditioned Space

ANCHORAGE

ALASKA, US

12/11/2015 JEEEUN LEE

Contents

O Overview

A Climate Analysis

B Basecase Assessment

- B1 Well-Daylight
- B2 Visual Comfort
- B3 Thermal Comfort

C Discussion

D Design Proposals

- D1 Orientation
- D2 Natural Ventilation
- D3 Shading

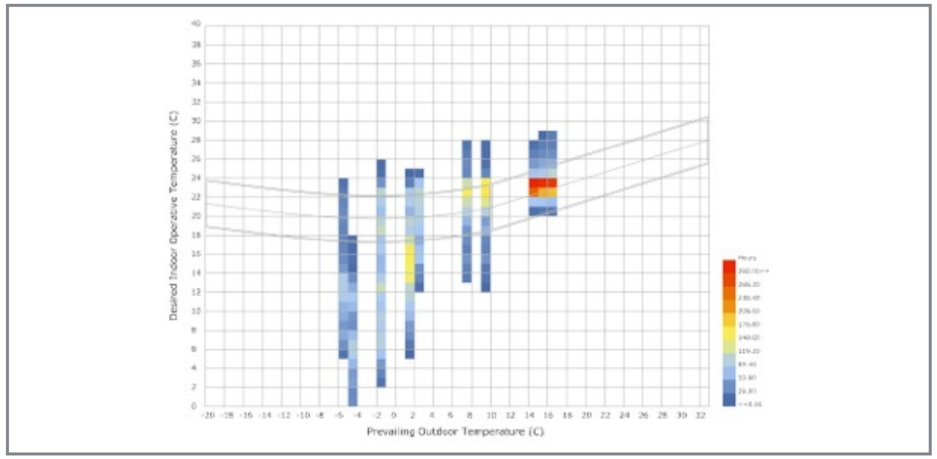
E Final Design Assessment

- E1 Well-Daylight
- E2 Visual Comfort
- E3 Thermal Comfort

F Conclusions

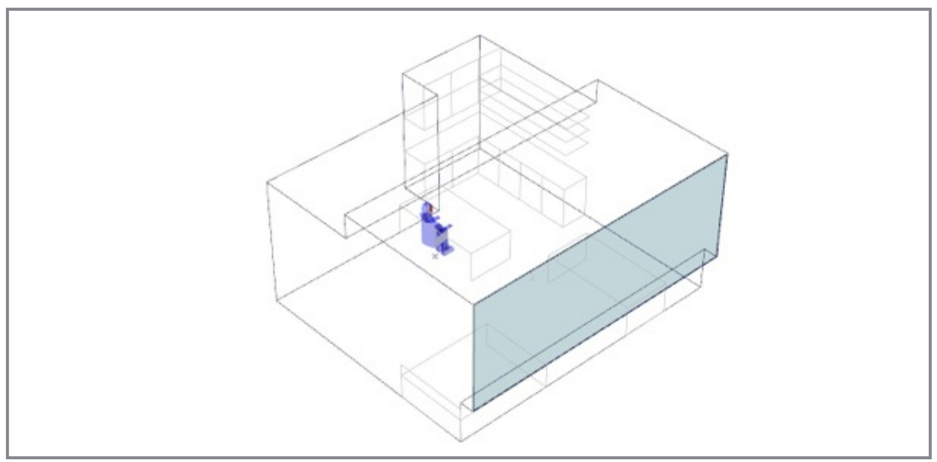
G Appendix

Overview



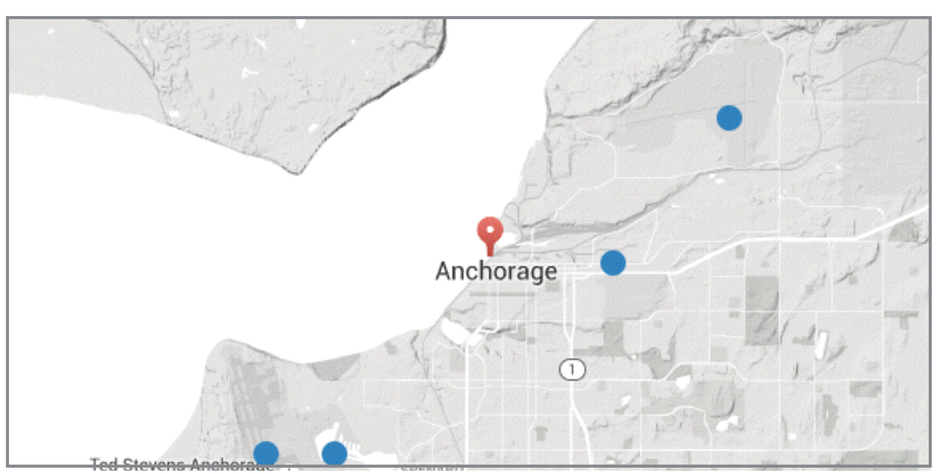
PURPOSE

The purpose of this project is to be **well daylit** and to provide **maximum hours of comfort** for the occupants **during the occupancy of the building** for an indoor space with **no heating and cooling system** by redesigning the façade.



BASE-CASE SPACE

This is a space that will be tested. This is a **detached house** and facing **South-East** in basecase.



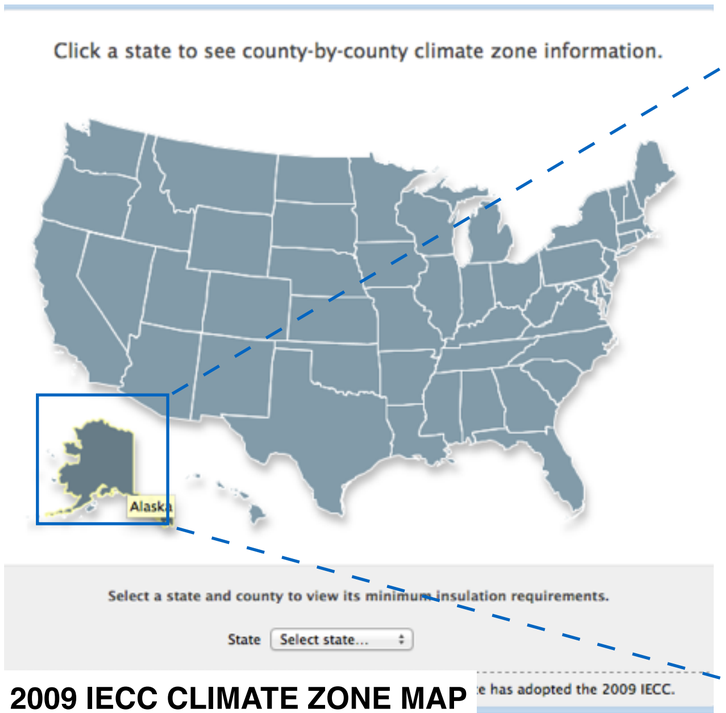
LOCATION

The location for this project is **Anchorage, Alaska, US.**

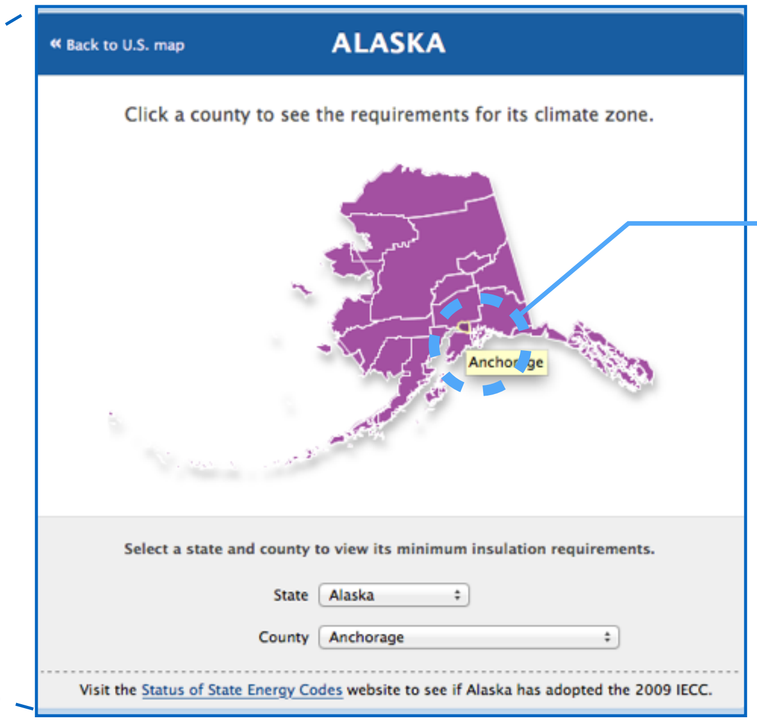
A Climate Analysis

A Climate Analysis

IECC: https://energycode.pnl.gov/EnergyCodeReqs/index.jsp
USDA: http://www.plantmaps.com/interactive-alaska-usda-plant-zone-hardiness-map.php

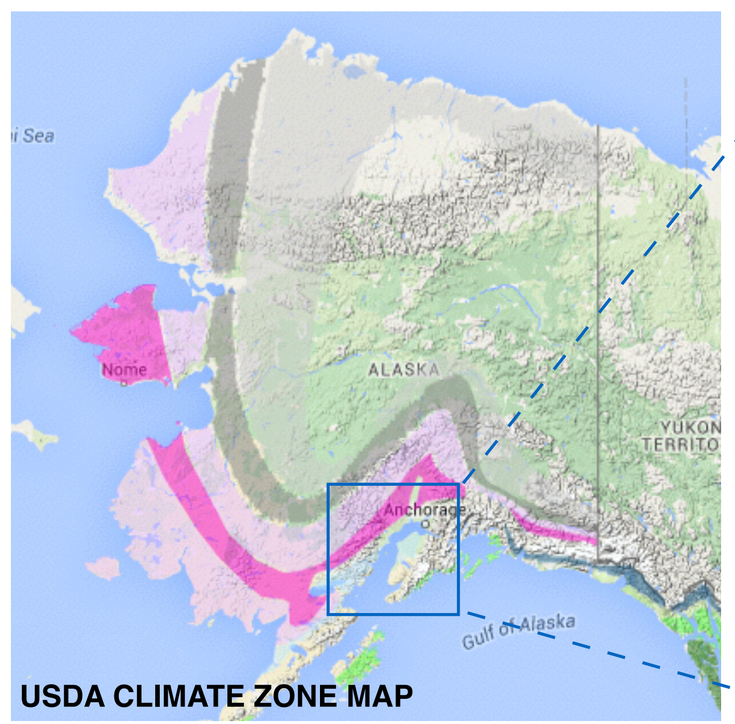


2009 IECC CLIMATE ZONE MAP

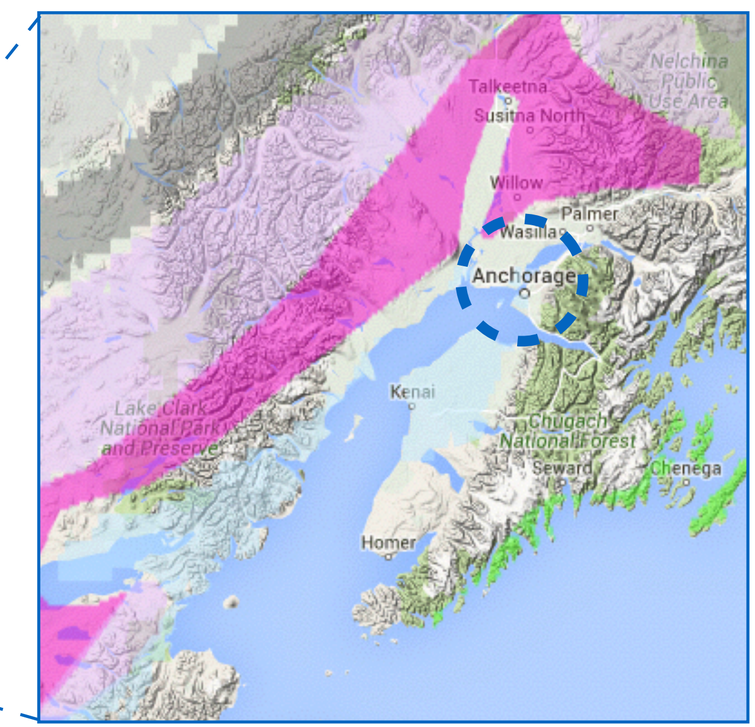


Climate Zone 7 & 8

Ceiling R-value	49
Wood Frame Wall R-value	21
Mass Wall R-value [i]	19/21
Floor R-value	38[g]
Basement Wall R-value [c]	15/19
Slab R-value [d], Depth	10, 4 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



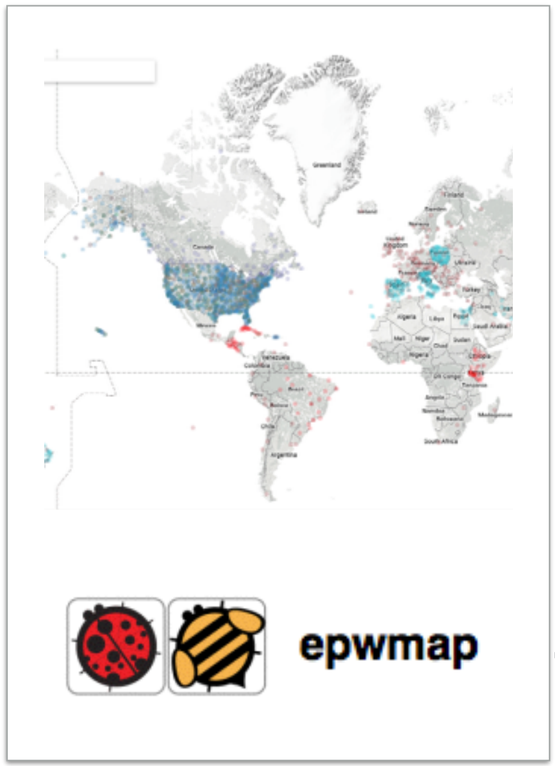
USDA CLIMATE ZONE MAP



LOCATION; ANCHORAGE

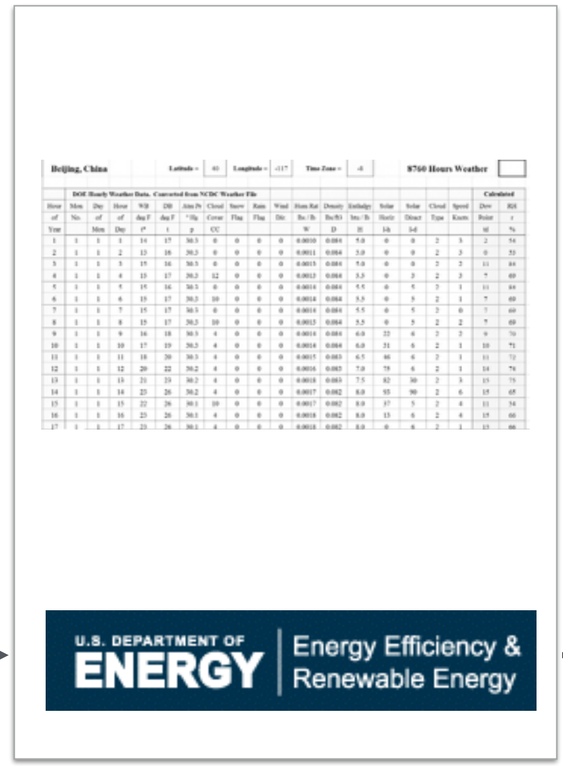
State: Alaska
IECC Climate Zone: 7&8
USDA Climate Zone: 4B
Climate: Subarctic (Short and cool summer)

A Climate Analysis

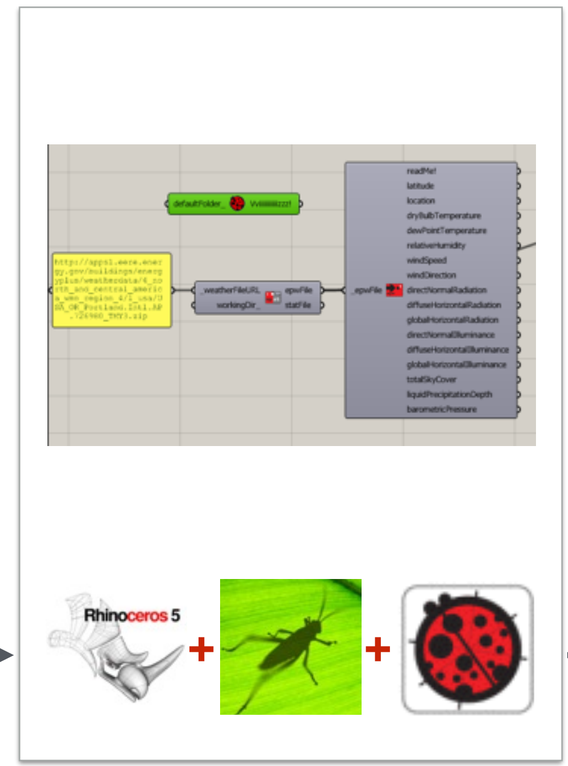


EPW MAP

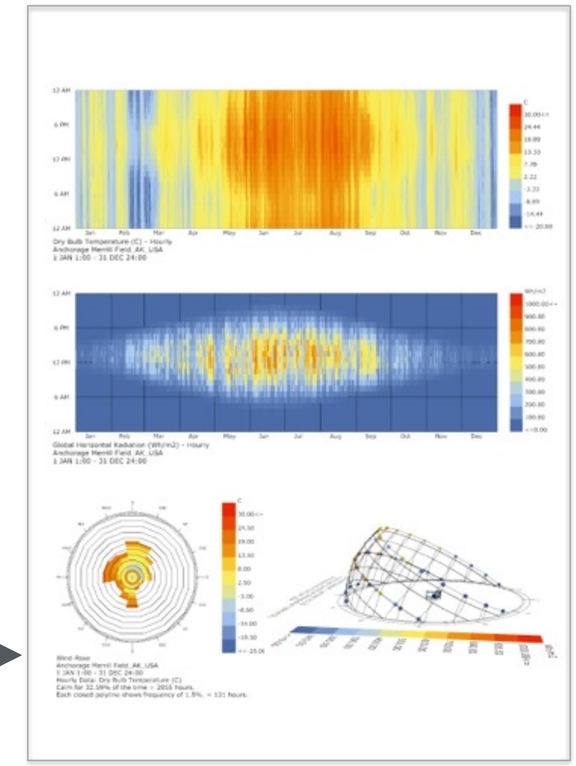
http://mostapharoudsari.github.io/epwmap/



WEATHER DATA
(EPW FILE)



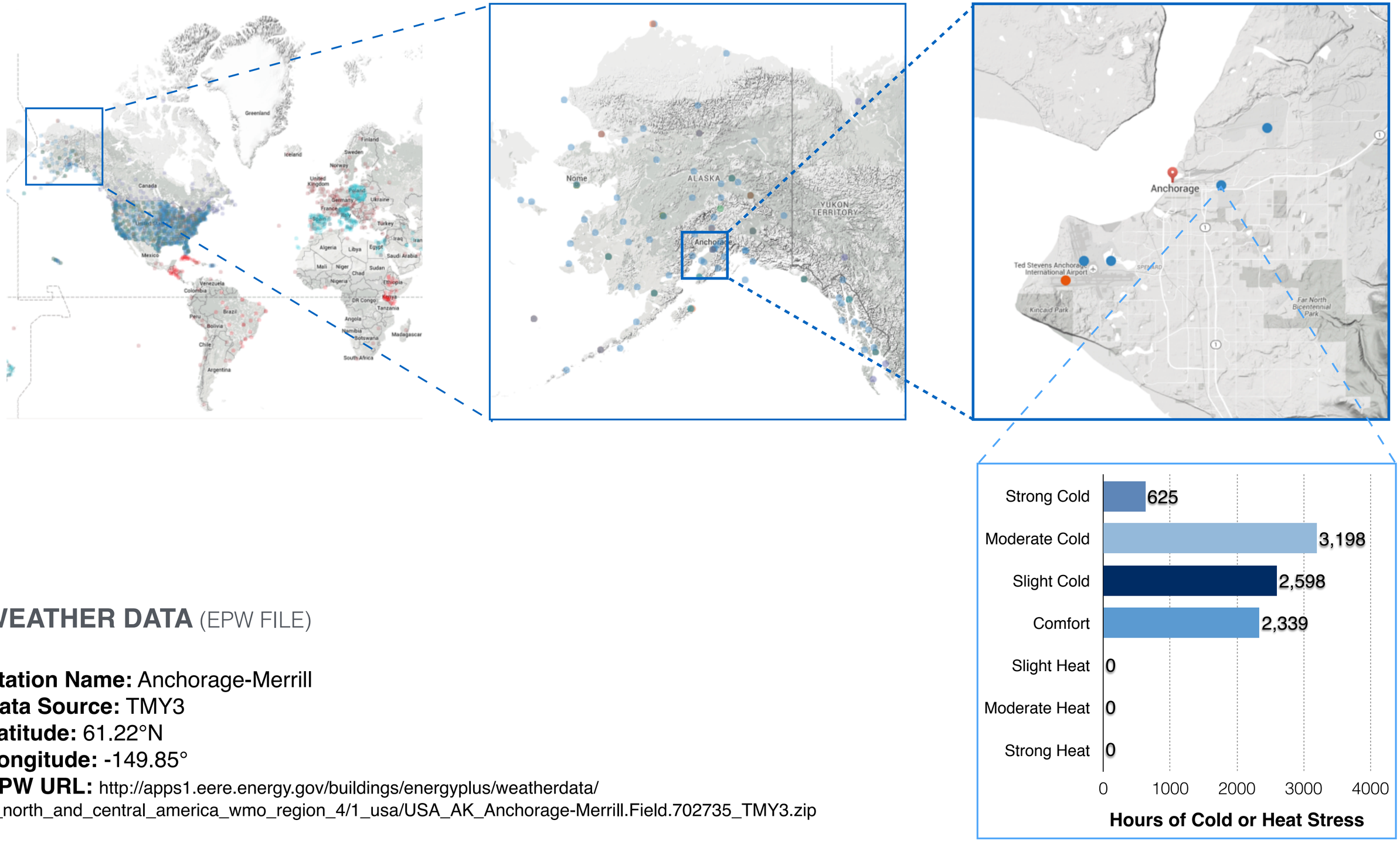
RHINO
+GRASSHOPPER
+LADYBUG



VISUALIZATION

HOW TO VISUALIZE **WEATHER DATA**

A Climate Analysis

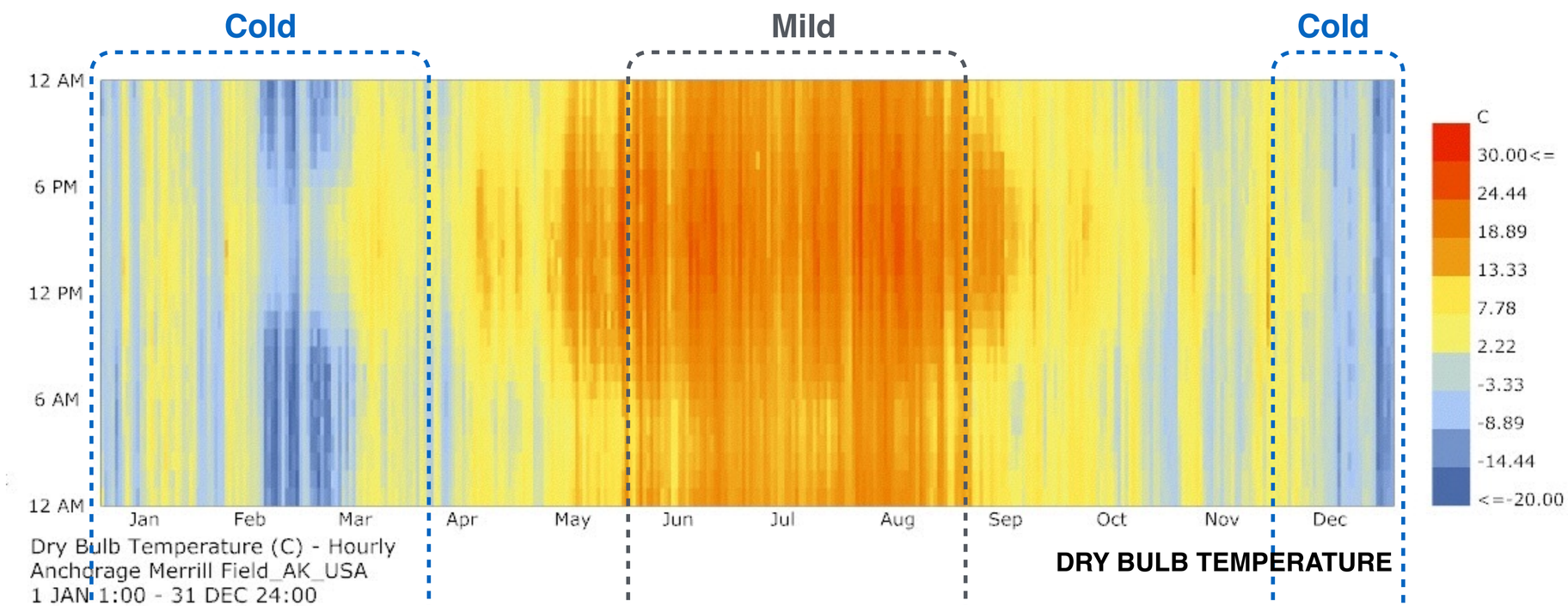


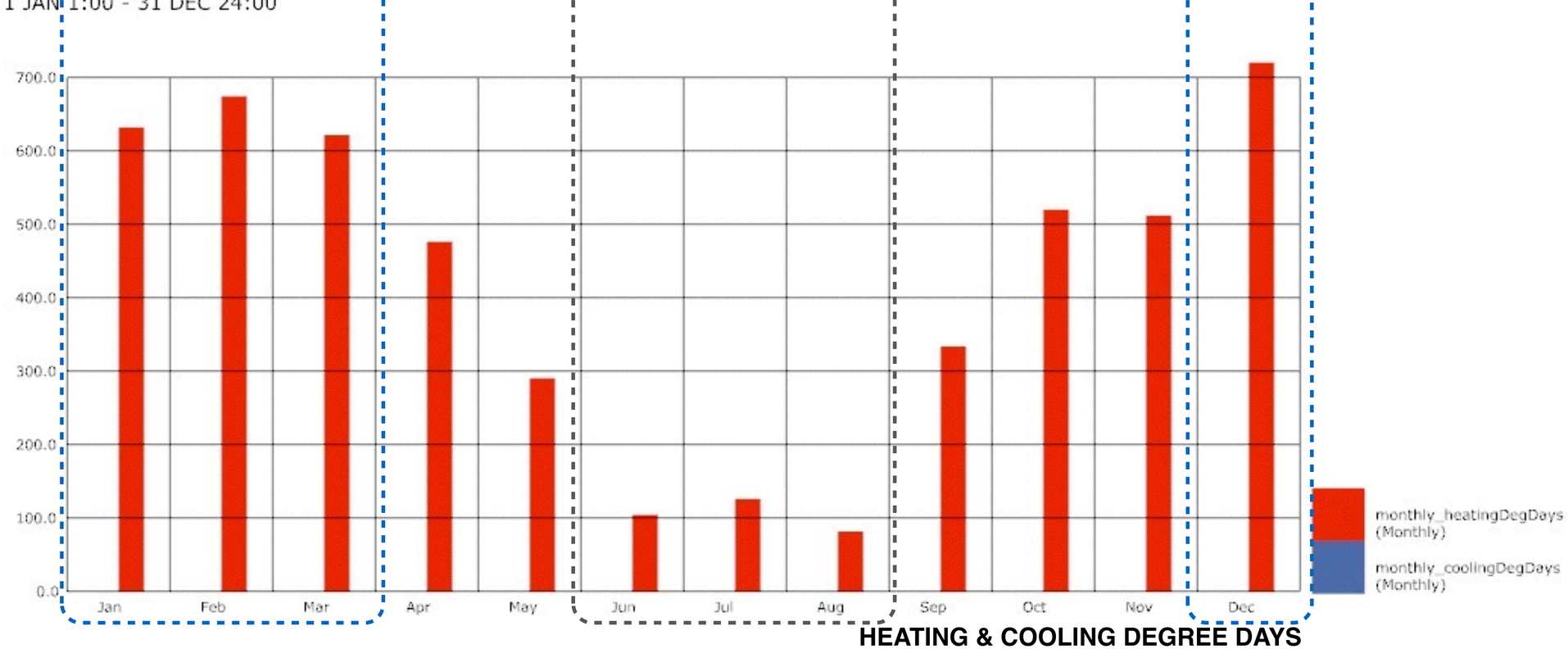
WEATHER DATA (EPW FILE)

Station Name: Anchorage-Merrill
Data Source: TMY3
Latitude: 61.22°N
Longitude: -149.85°
EPW URL: http://apps1.eere.energy.gov/buildings/energyplus/weatherdata/4_north_and_central_america_wmo_region_4/1_usa/USA_AK_Anchorage-Merrill.Field.702735_TMY3.zip

A Climate Analysis

Max: 26.10°C
Min: -20.60°C



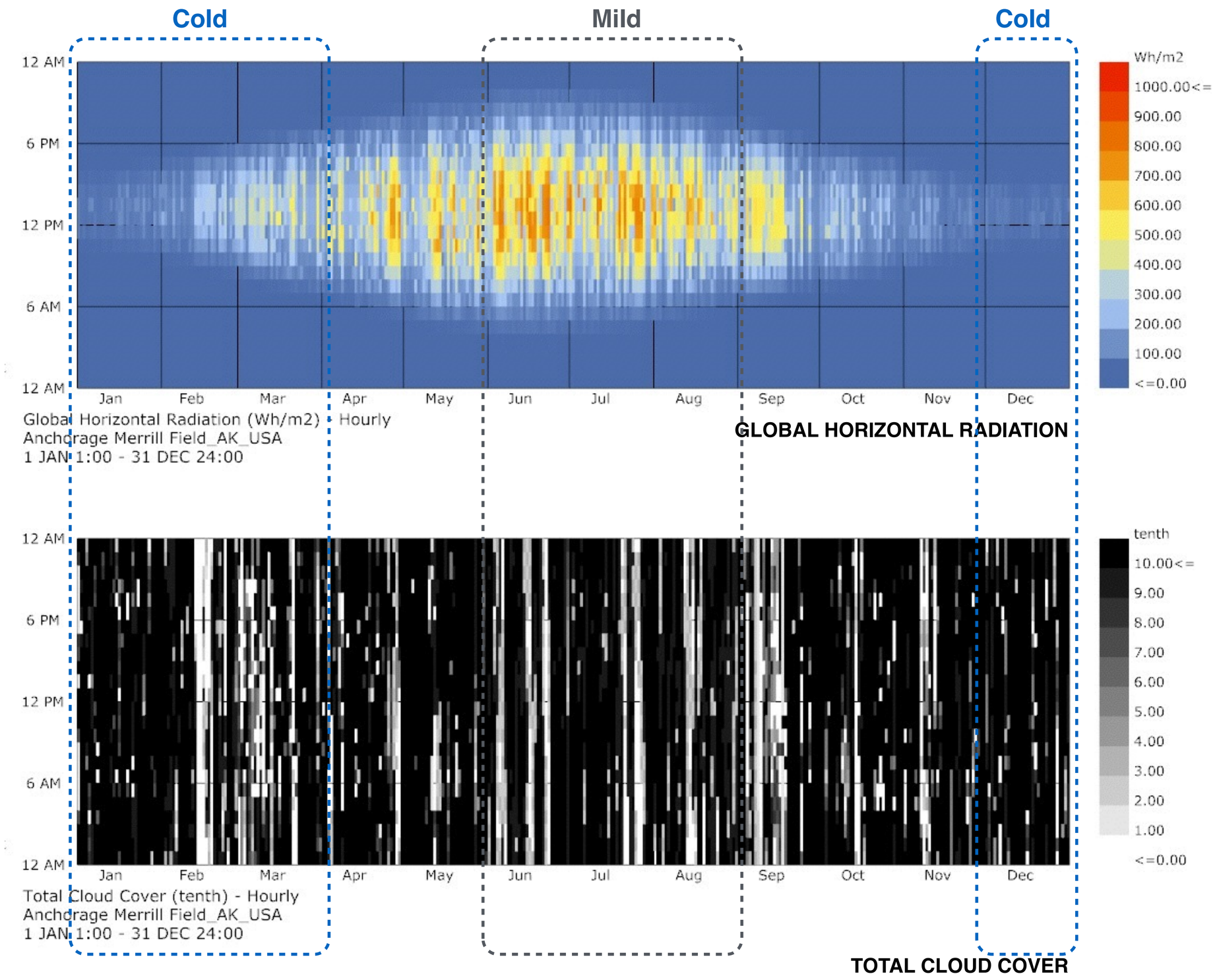


TEMPERATURE

Since this area is on high latitude, the temperature throughout a year is pretty cold, so heating degree days are…

From June to August, the temperature is fairly mild meaning that it requires less heating. From December to March, their monthly heating degree days have the highest values.

A Climate Analysis



RADIATION & SKY

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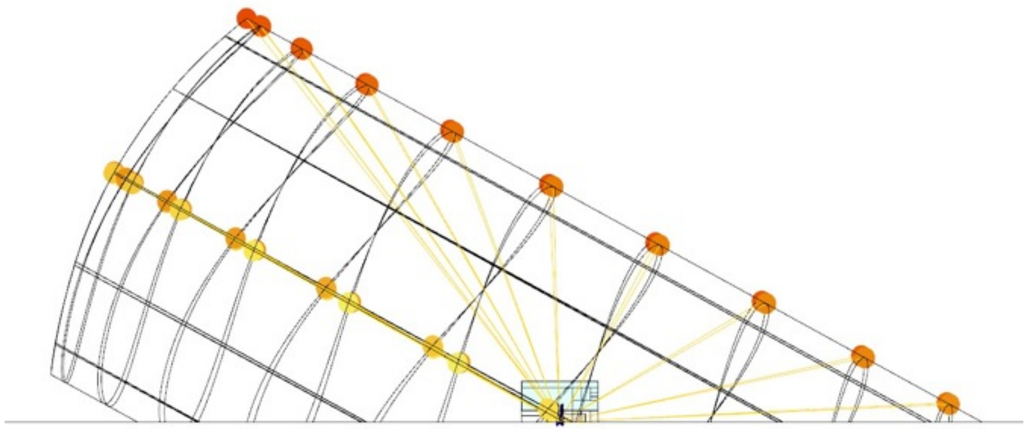
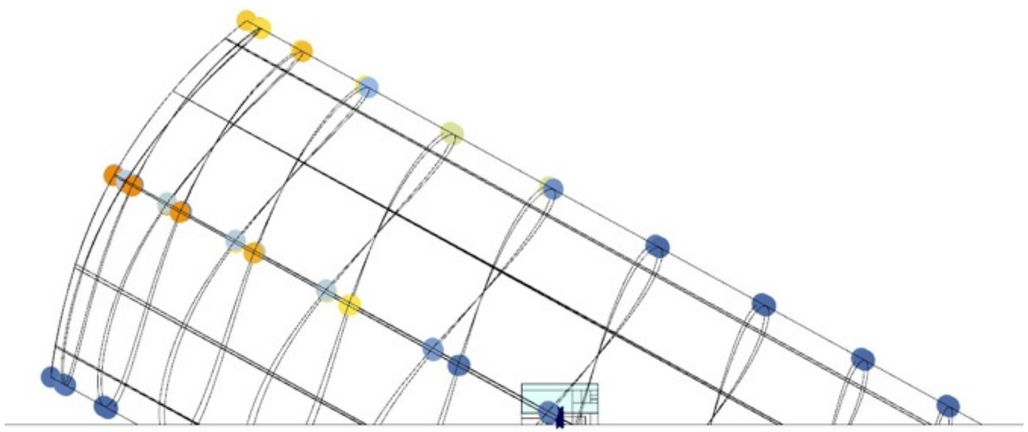
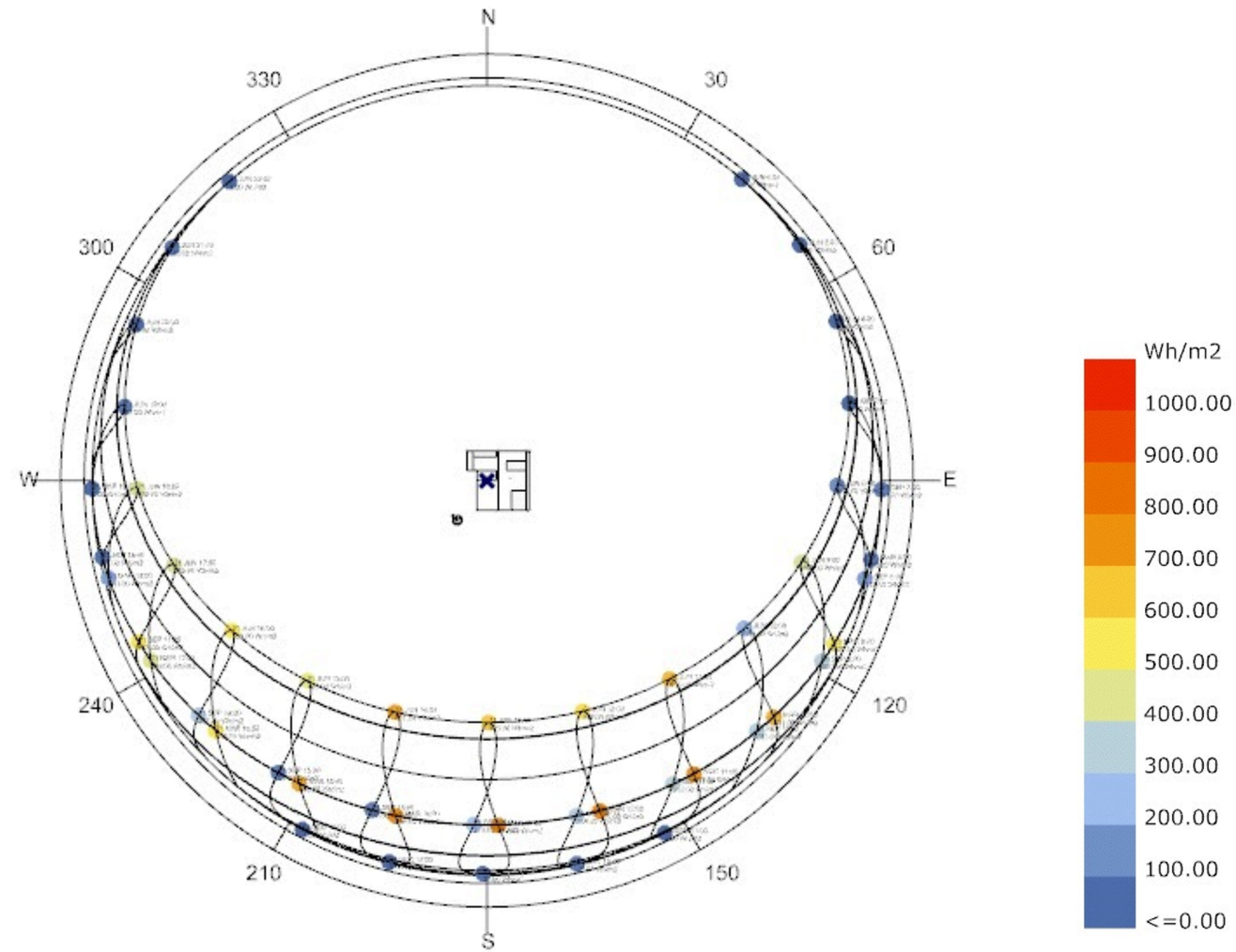
A Climate Analysis



Condition; Dry Bulb Temperature > 0°C



ANNUAL; Direct Normal Radiation

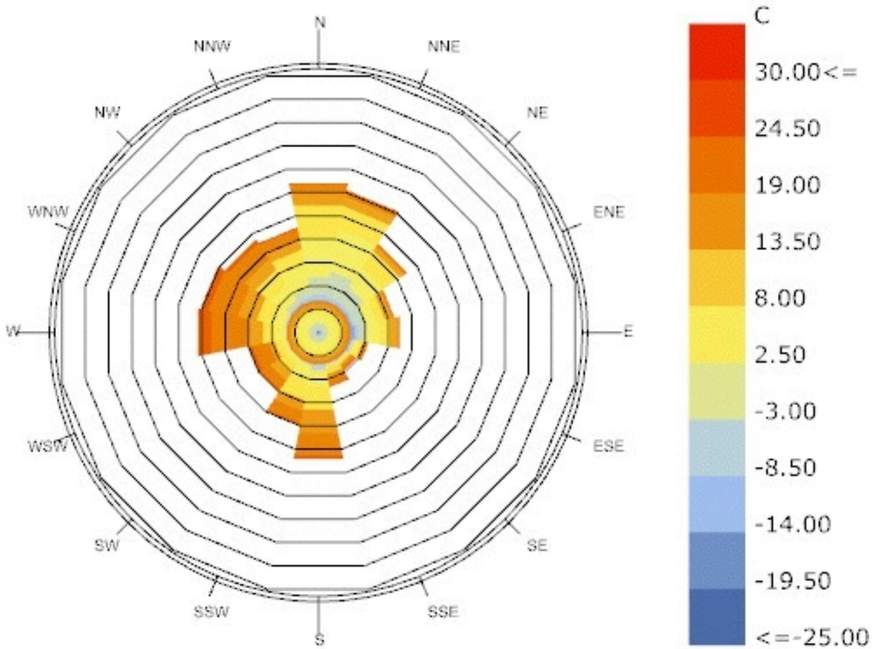


ANNUAL; Direct Normal Radiation

SUNPATH

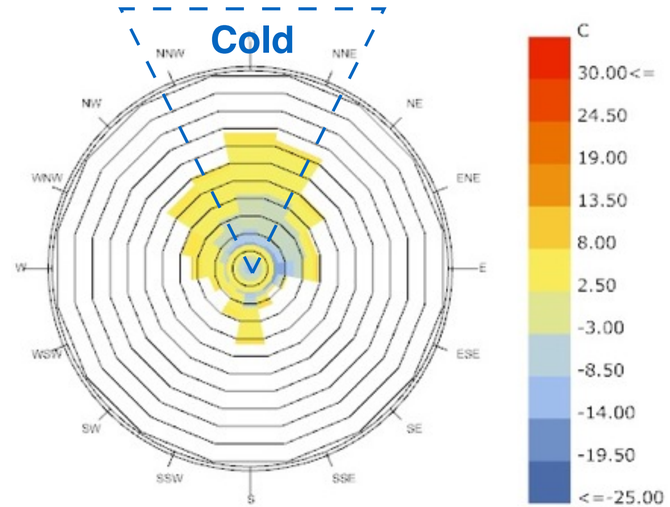
Sun position is compatibly low, especially during winter time that required a lot of sun radiation.

A Climate Analysis



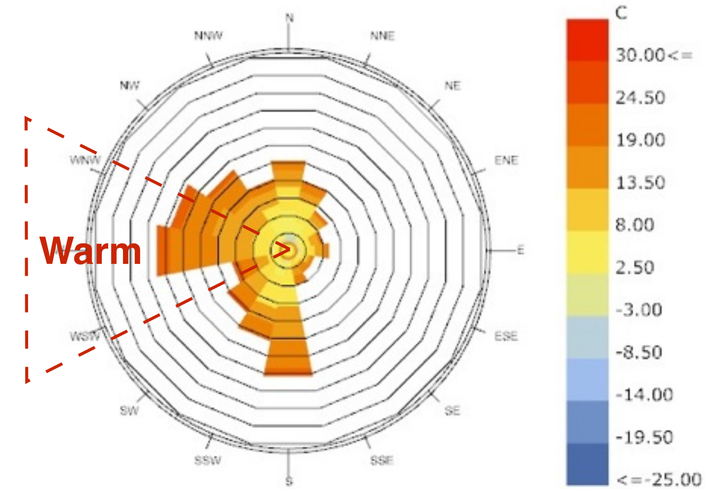
Wind-Rose
Anchorage Merrill Field_AK_USA
1 JAN 1:00 - 31 DEC 24:00
Hourly Data: Dry Bulb Temperature (C)
Calm for 32.59% of the time = 2855 hours.
Each closed polyline shows frequency of 1.5%. = 131 hours.

ANNUAL



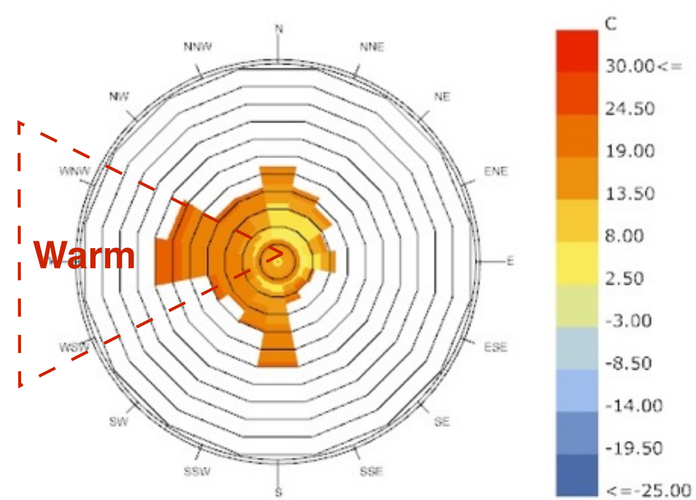
Wind-Rose
Anchorage Merrill Field_AK_USA
1 JAN 1:00 - 31 MAR 24:00
Hourly Data: Dry Bulb Temperature (C)
Calm for 32.45% of the time = 701 hours.
Each closed polyline shows frequency of 1.5%. = 32 hours.

SPRING



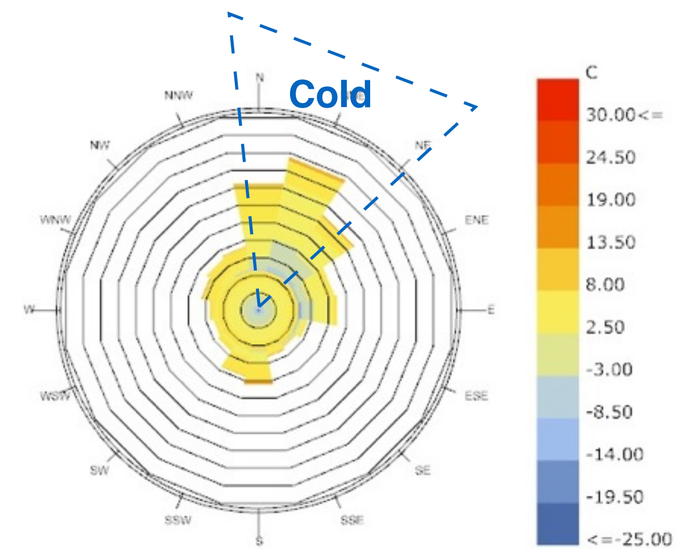
Wind-Rose
Anchorage Merrill Field_AK_USA
1 APR 1:00 - 30 JUN 24:00
Hourly Data: Dry Bulb Temperature (C)
Calm for 12.82% of the time = 280 hours.
Each closed polyline shows frequency of 1.5%. = 32 hours.

SUMMER



Wind-Rose
Anchorage Merrill Field_AK_USA
1 JUL 1:00 - 30 SEP 24:00
Hourly Data: Dry Bulb Temperature (C)
Calm for 30.66% of the time = 677 hours.
Each closed polyline shows frequency of 1.5%. = 33 hours.

FALL



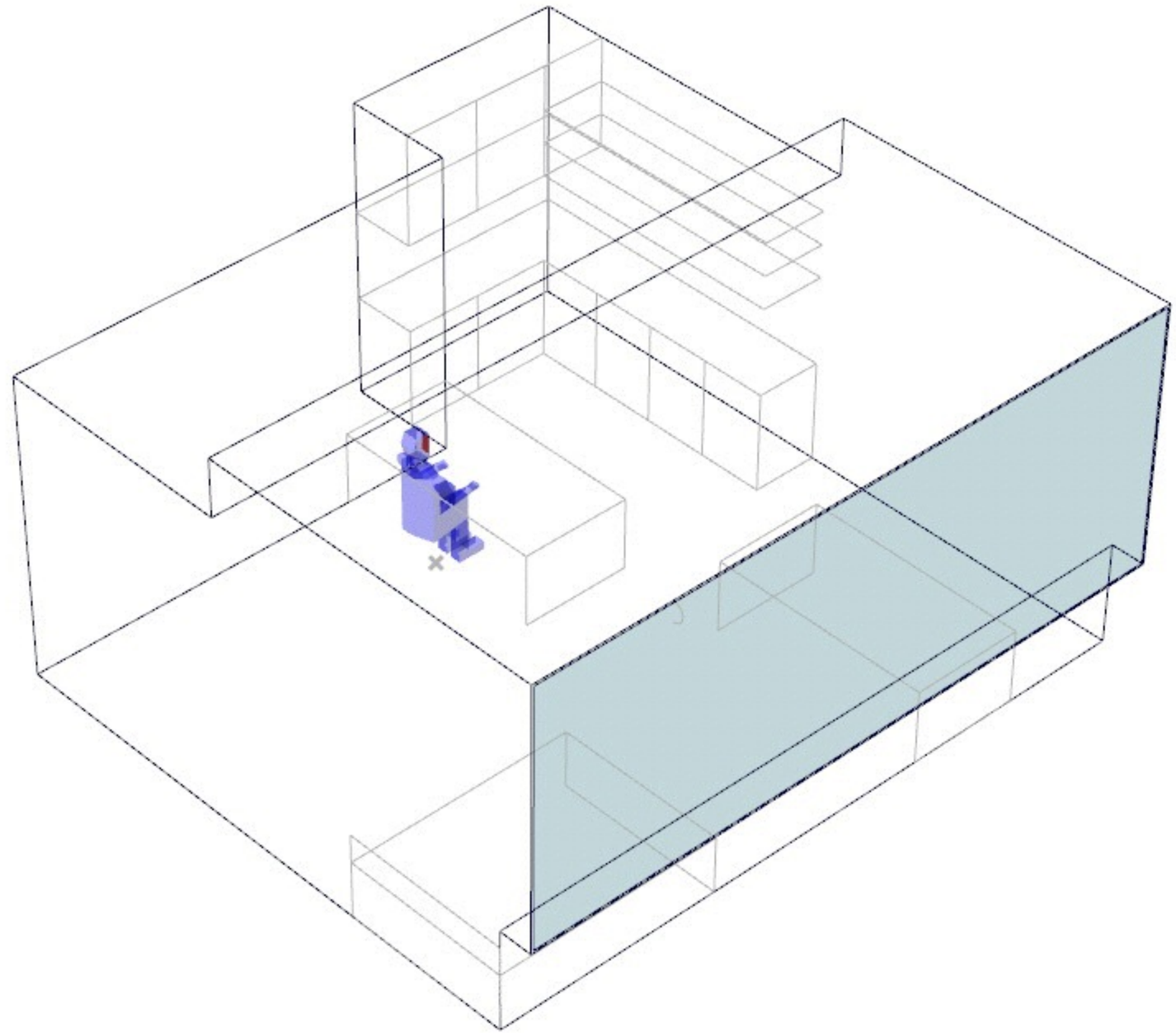
Wind-Rose
Anchorage Merrill Field_AK_USA
1 OCT 1:00 - 31 DEC 24:00
Hourly Data: Dry Bulb Temperature (C)
Calm for 54.21% of the time = 1197 hours.
Each closed polyline shows frequency of 1.5%. = 33 hours.

WINTER

WIND DIRECTION & TEMPERATURE

The wind at Anchorage is mostly from West and North direction. As seasonal wind-rose indicates, most of cold air comes from the North and warmer air is mostly from the West.

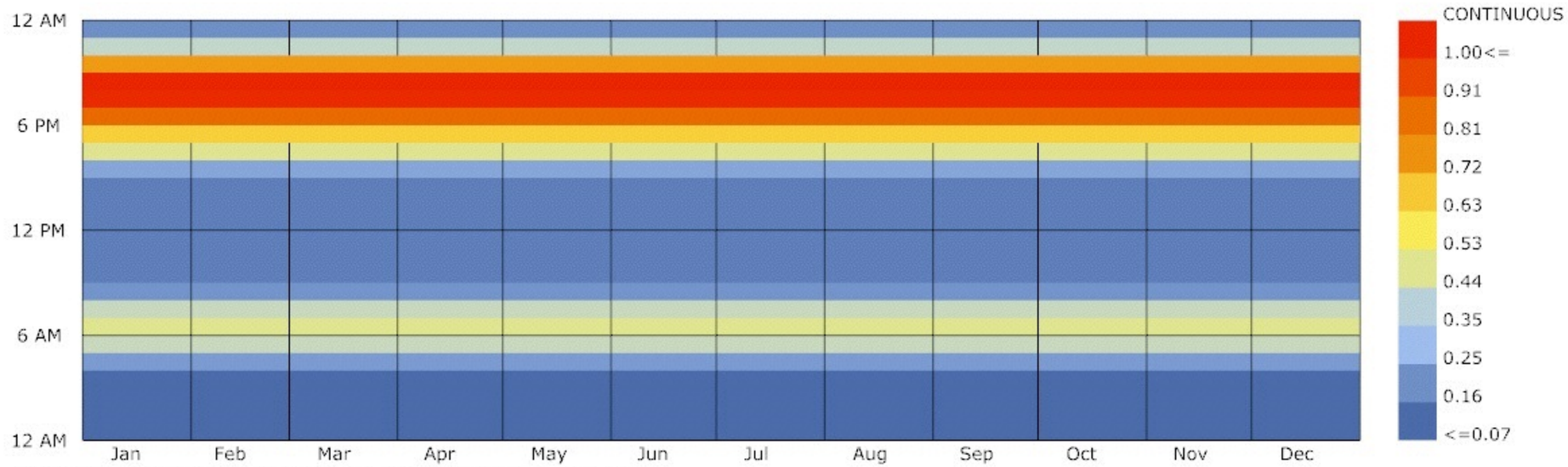
B Basecase Assessment



BASE-CASE SPACE

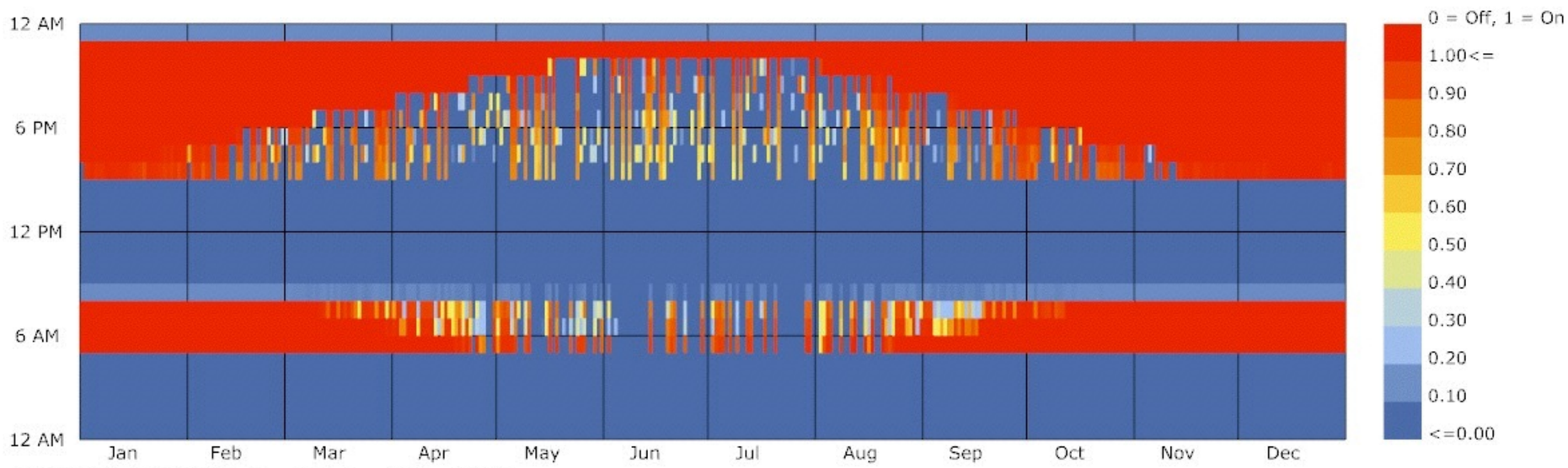
This is a space that will be tested.

This is a detached house and facing South-East in basecase.



MidriseApartment Apartment Light (CONTINUOUS) - Hourly schedule:year

1 JAN 1:00 - 31 DEC 24:00



Lighting Switch Profile (0 = Off, 1 = On) - Hourly

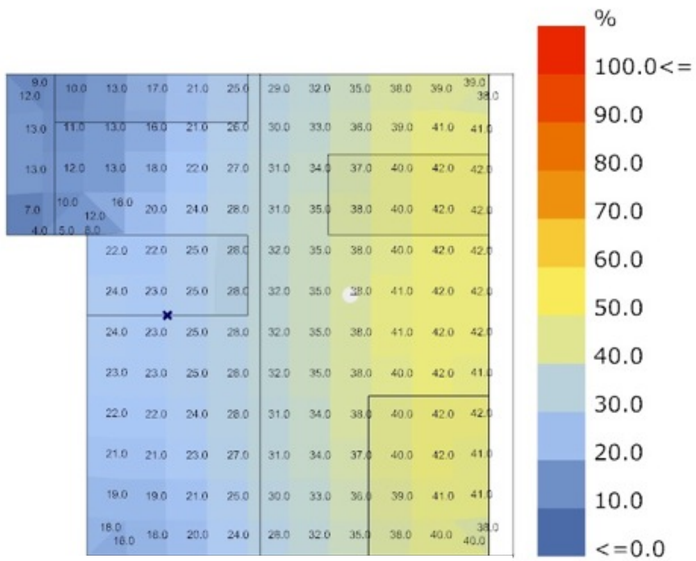
1 JAN 1:00 - 31 DEC 24:00

OCCUPANCY SCHEDULE

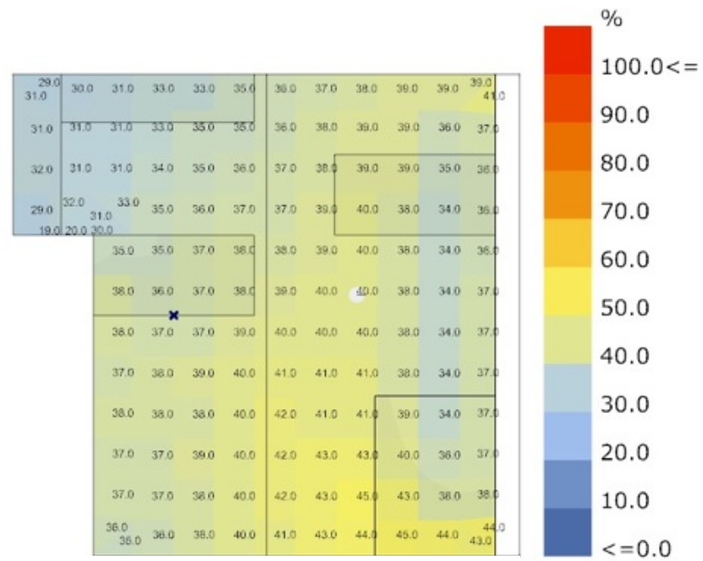
The occupancy time has been regenerated by annual daylighting simulation.

By this process, the heating, cooling and lighting loads can be more precise than without it.

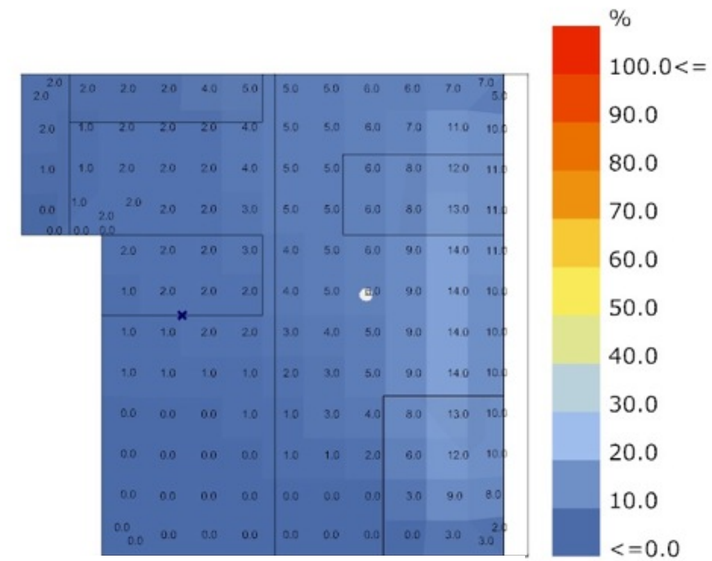
B1 Well Daylit



DLA
Day-Light Autonomy

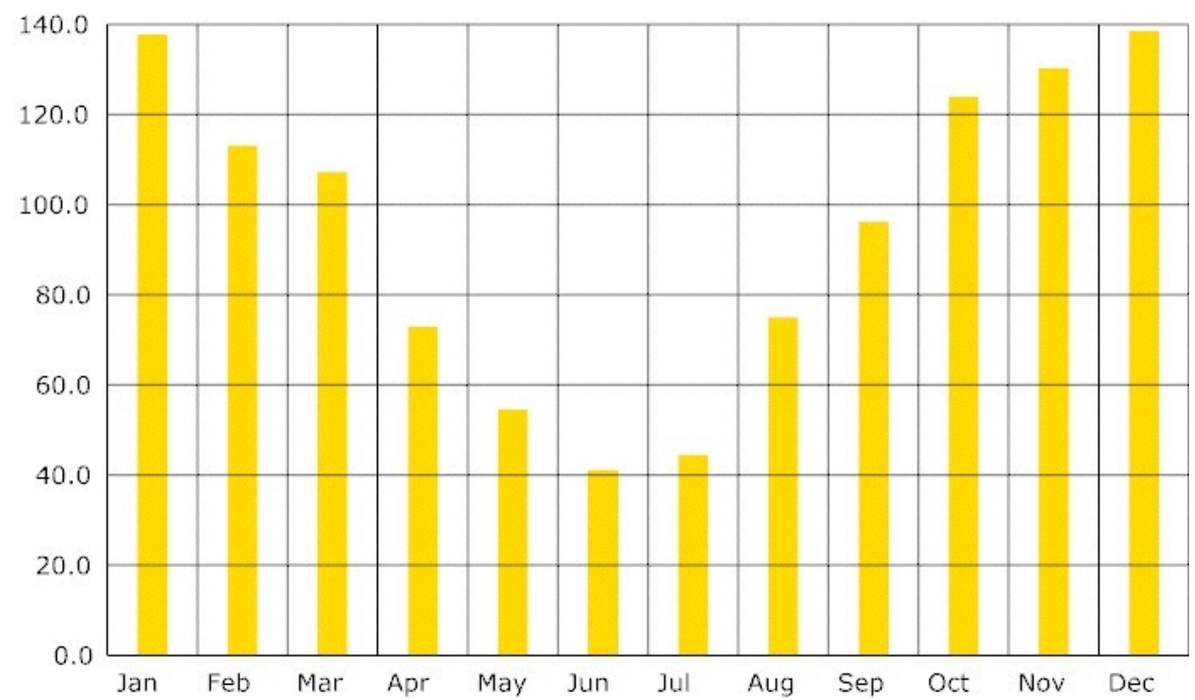


UDLI 100 ~ 2000 lux
Useful Day-Light Illumination



UDLI > 2000 lux
Useful Day-Light Illumination

sDA: 83.09%
Spacial Daylight Autonomy



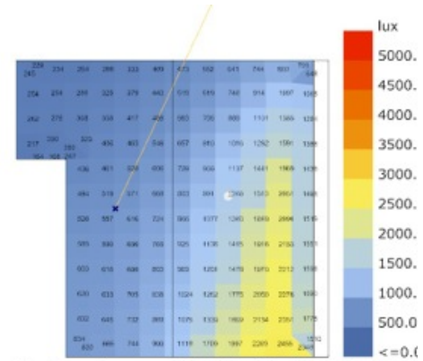
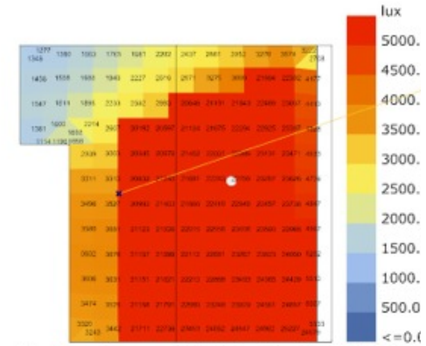
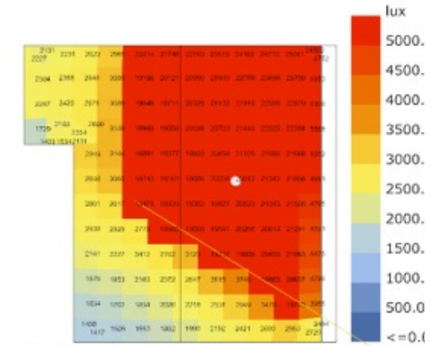
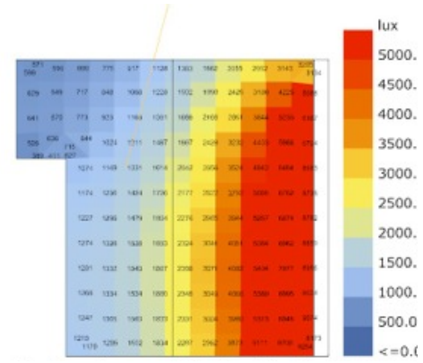
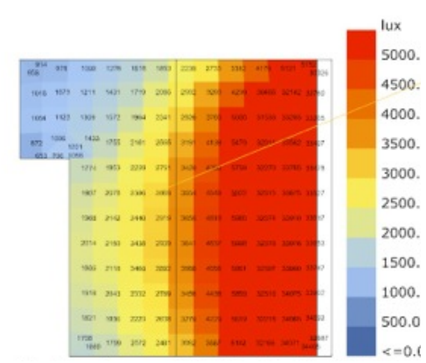
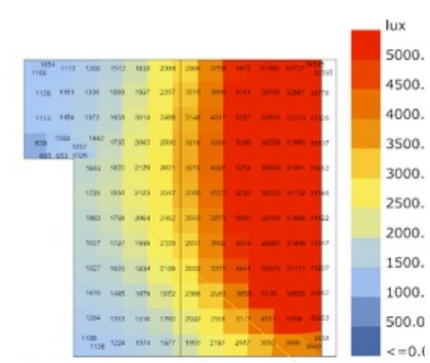
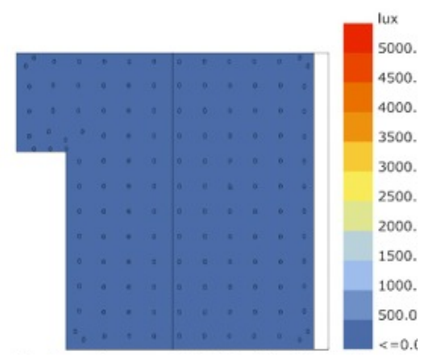
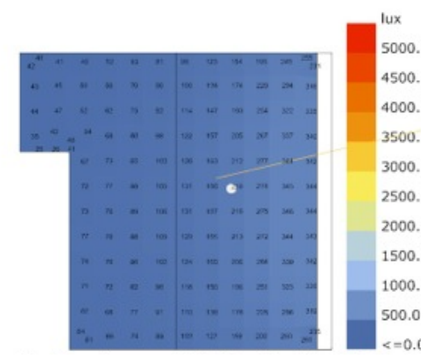
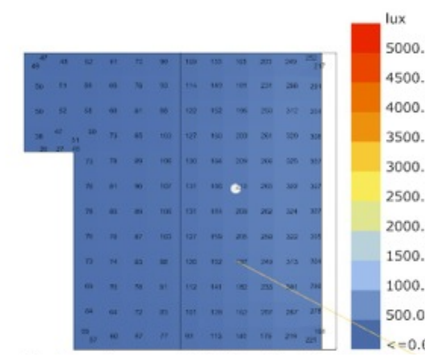
Annual Lighting Loads: 1,135.40

ANNUAL DAYLIGHT ANALYSIS

To allow enough daylight to come inside, sDA should be above 50%. Since the sDA is 83.09%, this room has enough daylight throughout a year.

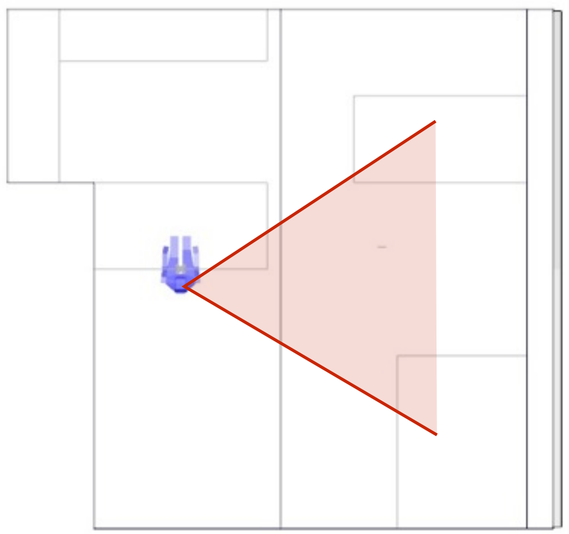
However, according to UDLI images, most of the testing points has less than 100 lux, for more than 50% hours out of a year.

B1 Well Daylit

	9 am	12 pm	3 pm
March			
	Min **164** / Max **2455**	Min **1114** / Max **25227**	Min **1403** / Max **25041**
June			
	Min **389** / Max **9254**	Min **653** / Max **34465**	Min **605** / Max **34515**
December			
	Min **0** / Max **0**	Min **25** / Max **346**	Min **26** / Max **325**

Illuminance

B2 Visual Comfort



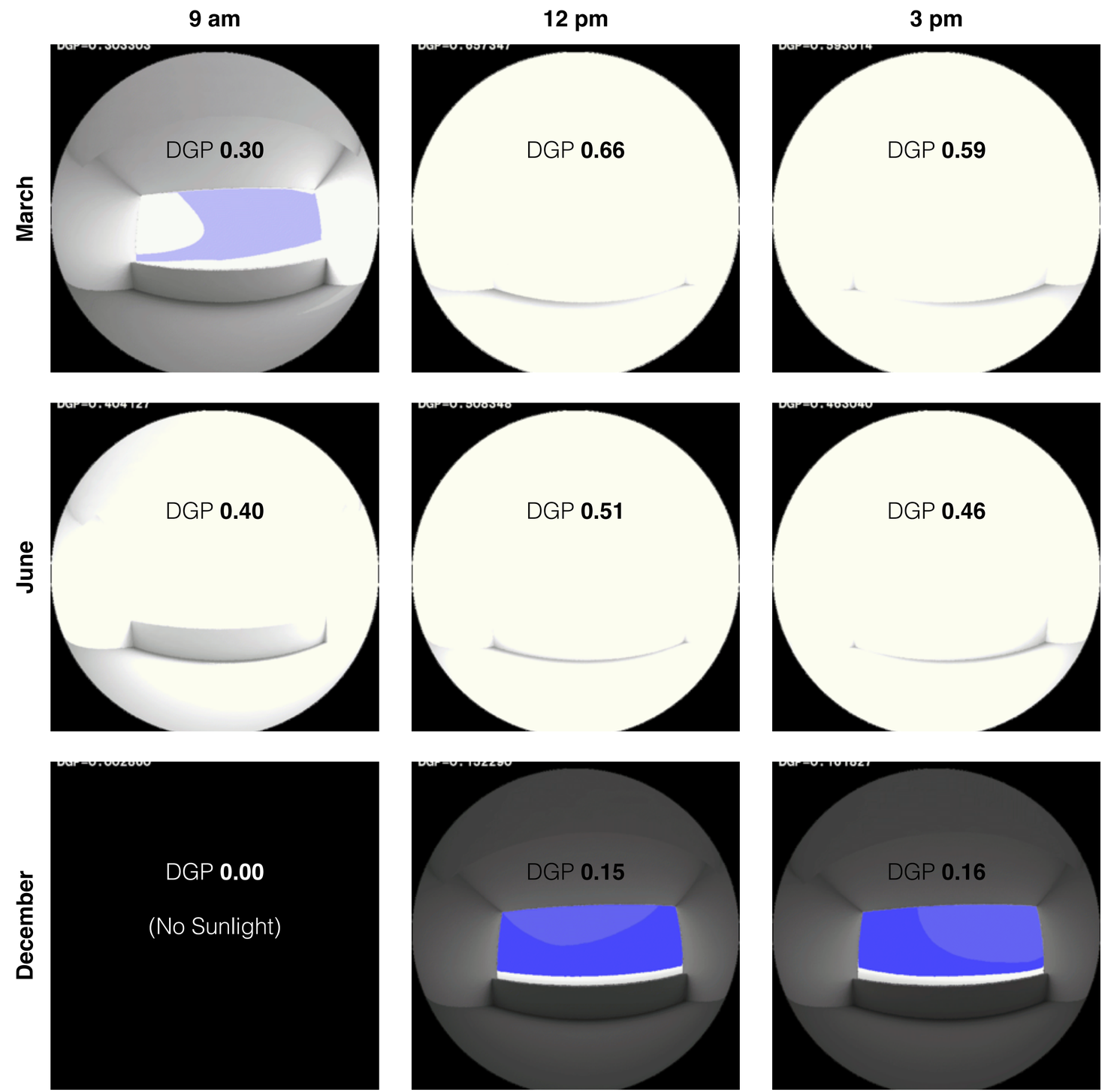
DGP: Daylight Glare Probability

Imperceptible Glare: 0.35 > DGP
Perceptible Glare: 0.4 > DGP>=0.35
Disturbing Glare: 0.45 > DGP >=0.4
Intolerable Glare: DGP >=0.45

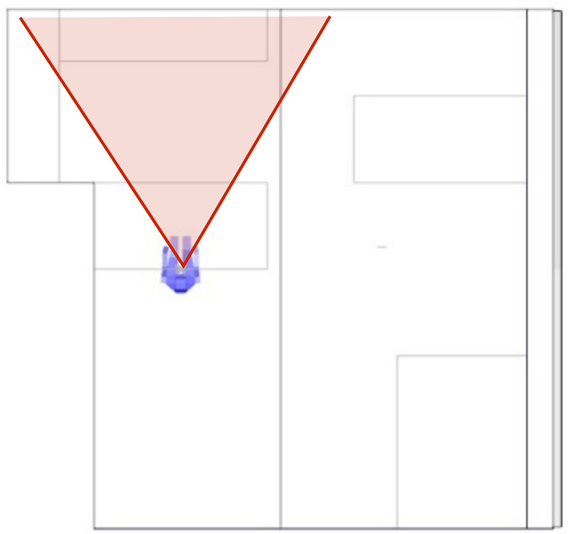
GLARE; Image-based Analysis

To obtain visual comfort, the DGP should be between 0.35~0.40.

When the occupant is facing to the Window, there is glare that can cause visual discomfort, during March and June.



B2 Visual Comfort



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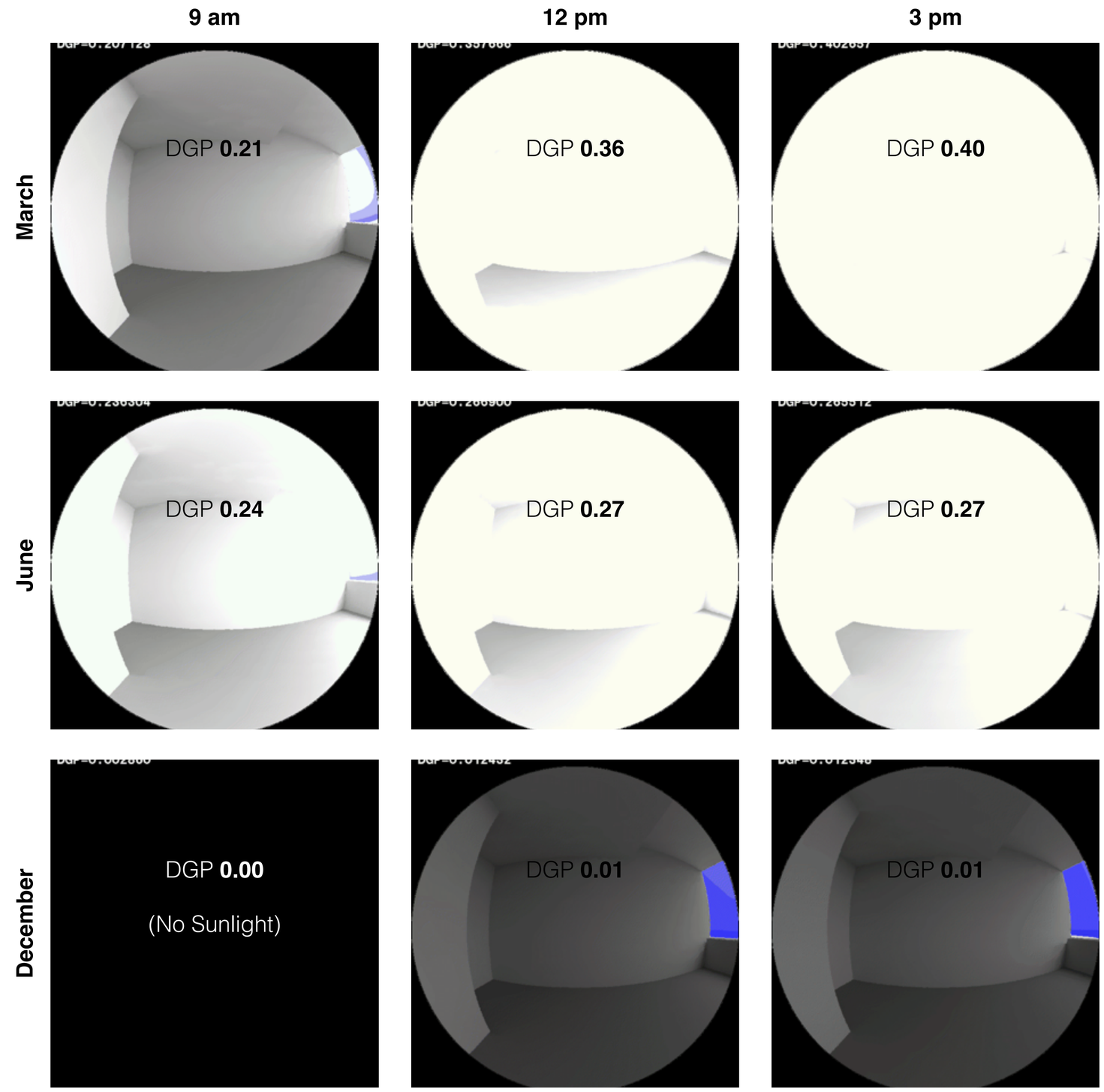
Perceptible Glare: 0.4 > DGP>=0.35
Disturbing Glare: 0.45 > DGP >=0.4
Intolerable Glare: DGP >=0.45

GLARE; Image-based Analysis

To obtain visual comfort, the DGP should be between 0.35~0.40.

When the occupant is facing to the wall, there is no glare that can cause visual discomfort.



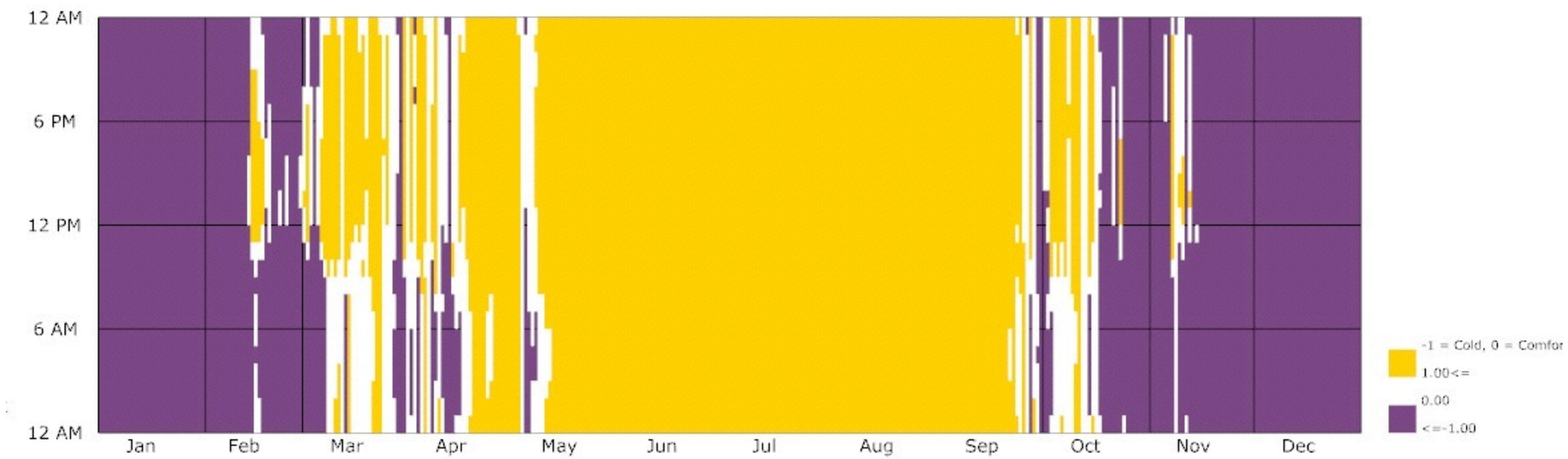
B3 Thermal Comfort

Adaptive Comfort:

11.74%

1028 hours / year

% of Hot: 49.39%
% of Cold: 38.87%



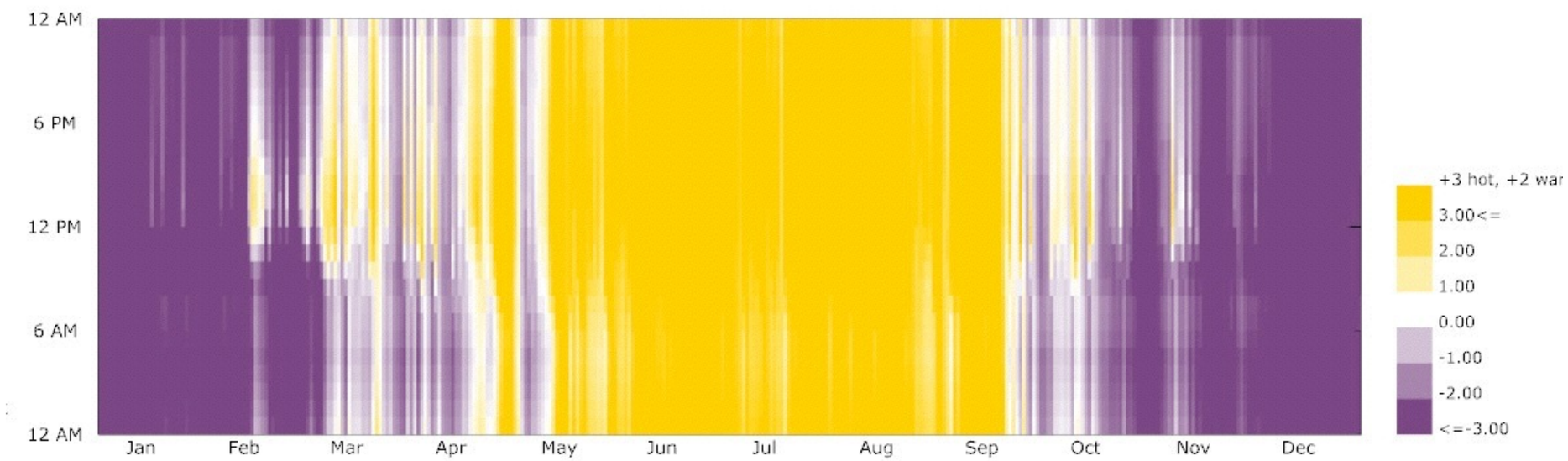
Adaptive Comfort (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Anchorage Merrill Field_AK_USA
1 JAN 1:00 - 31 DEC 24:00

ADAPTIVE COMFORT

PMV Comfort:

7.26%

636 hours / year



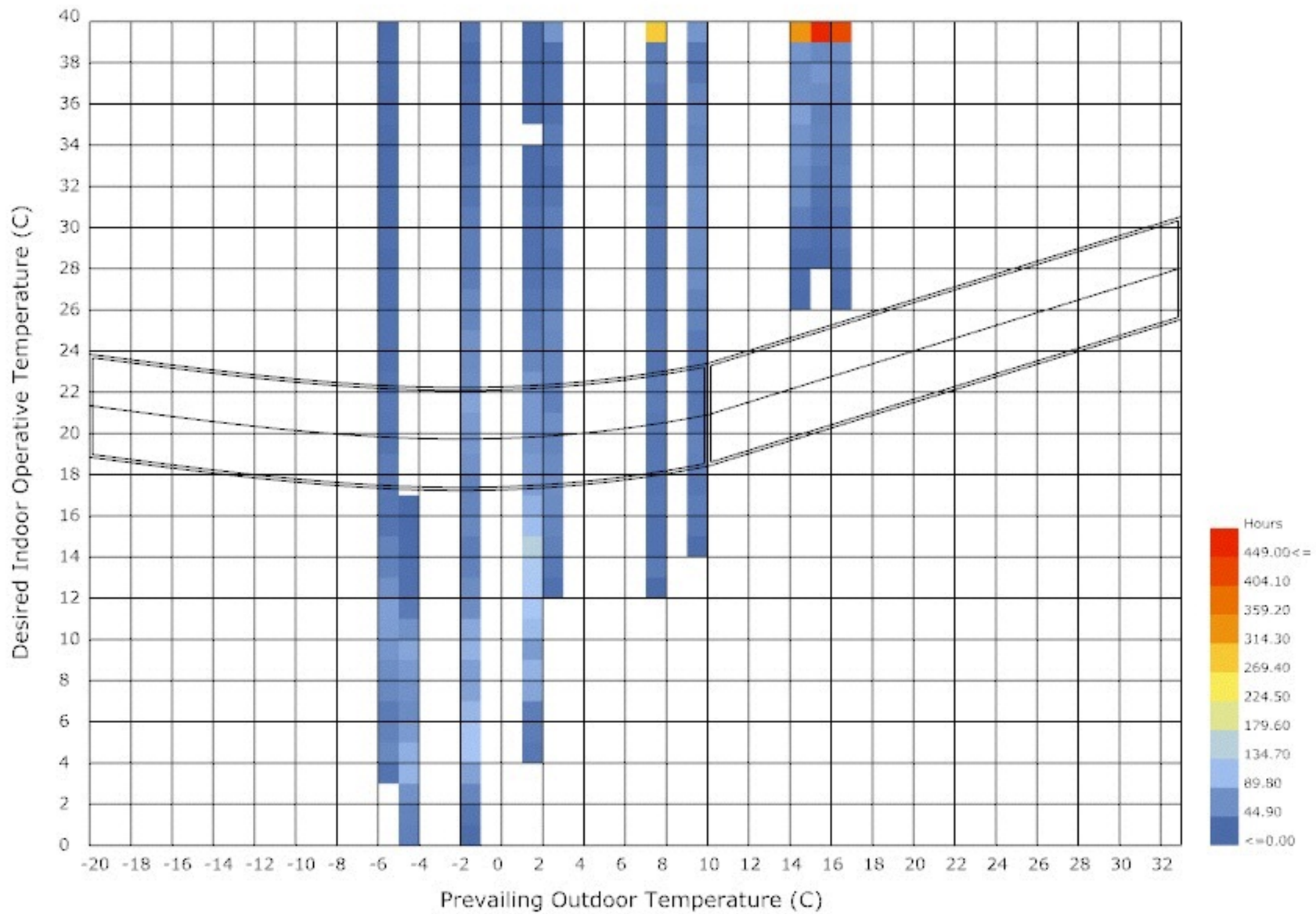
Predicted Mean Vote for TEST_ROOM (+3 hot, +2 warm, +1 slightly warm, 0 neutral, -1 slightly cool, -2 cool, -3 cold) - Hourly
Anchorage Merrill Field AK USA TMY3
1 JAN 1:00 - 31 DEC 24:00

PMV COMFORT
Predicted Mean Vote Comfort

INDOOR COMFORT

Comfort is still fairly low.

During the summer time, occupants indoor will feel too hot. During the winter time, occupants will feel too cold.



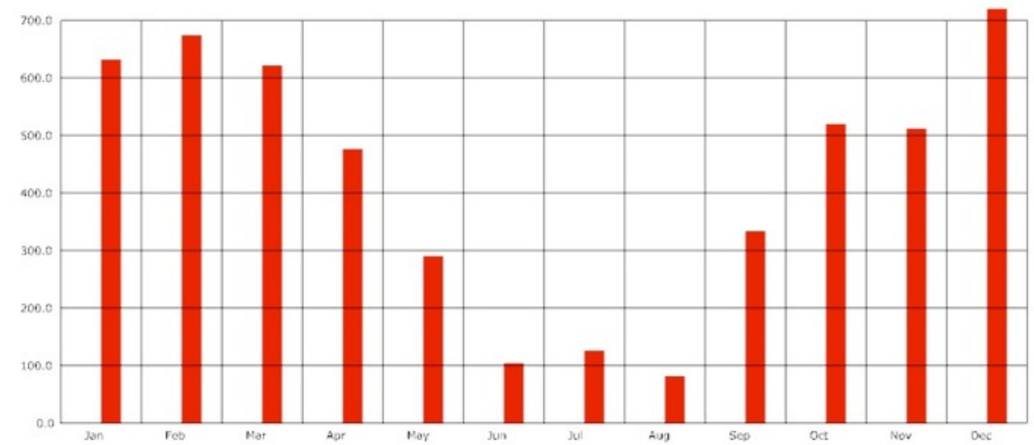
Adaptive Chart
Anchorage Merrill Field_AK_USA
1 JAN 1:00 - 31 DEC 24:00

INDOOR COMFORT

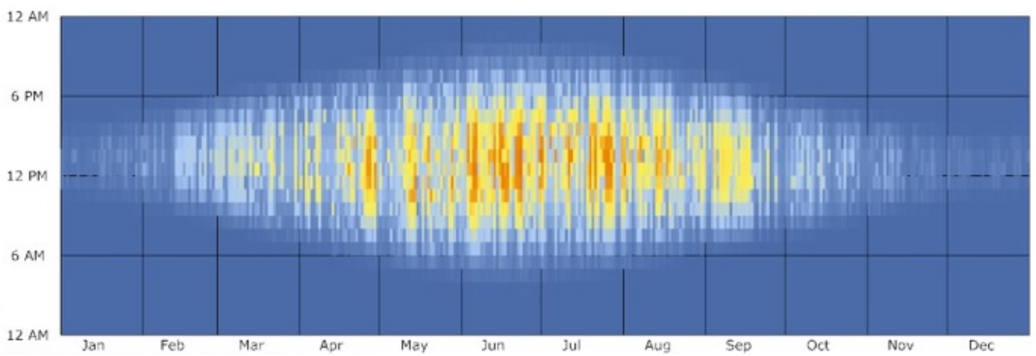
This adaptive chart show most of the time, the indoor temperature is above the desired indoor operative temperature, but still there are some hours has lower indoor temperature than it.

C Discussion

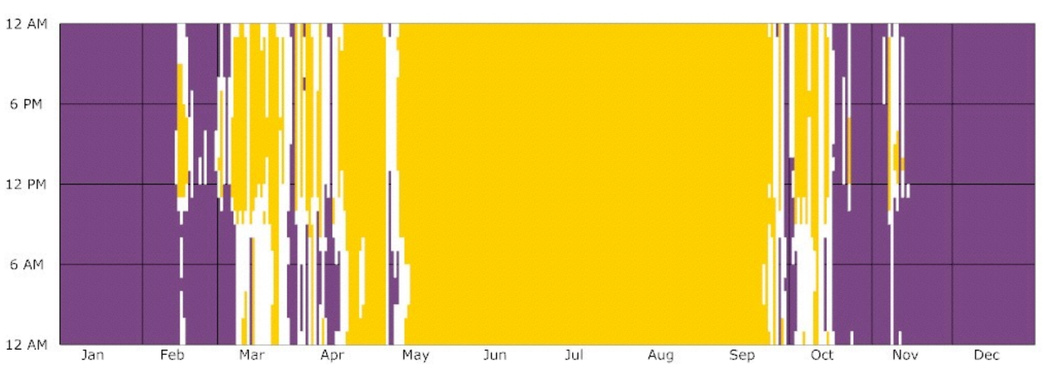
c Discussion



Cold Temperature; only heating degree days exist



Lack OF Solar Radiation



Too much heat in summer indoor

D1 Orientation

To optimize the orientation, energy simulation will be helpful to figure out wichi orientation requires less loads.

The orientation of the lowest values can reflect that there will be less hours of uncomfortable without HVAC.

D2 Natural Ventilation

Without HVAC, natural ventilation is an effective way to emit the collected heat during the summer time.

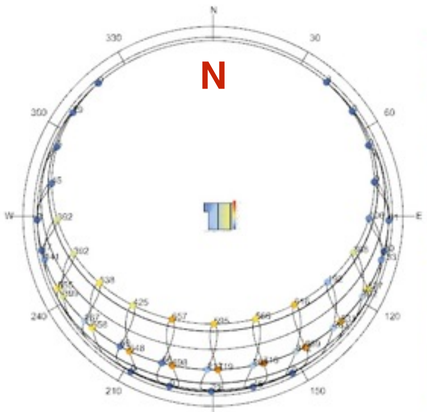
D3 Shading

To reduce radiation in summer and maximize radiation in winter, horizontal shadings with certain angle will be helpful.

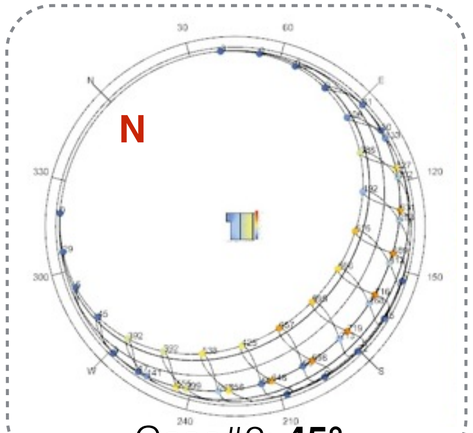
D Design Proposals

D1 Orientation

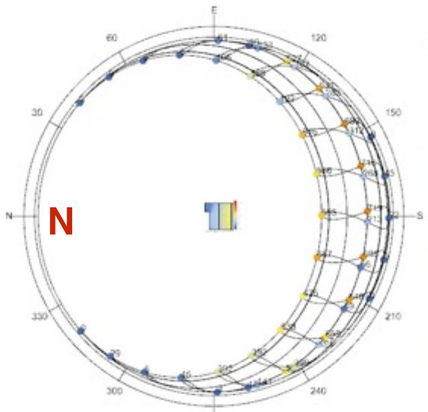
Basecase



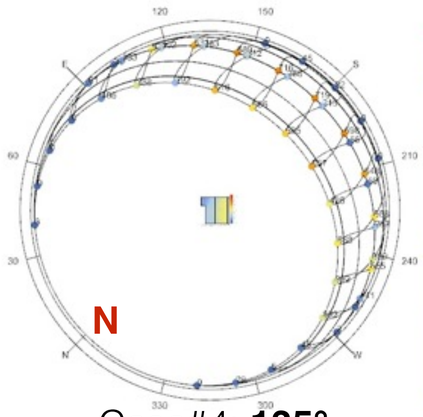
Case#1: **0°**



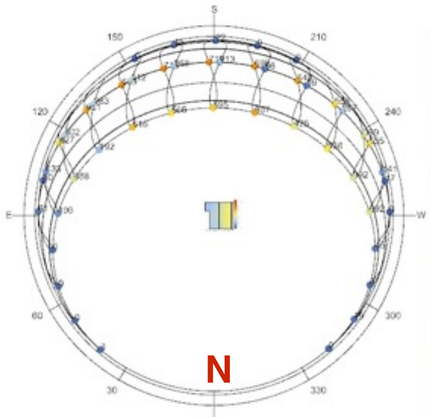
Case#2: **45°**



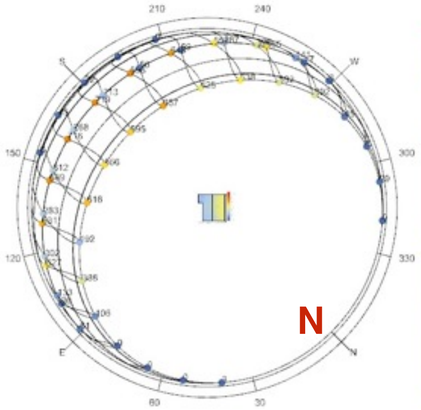
Case#3: **90°**



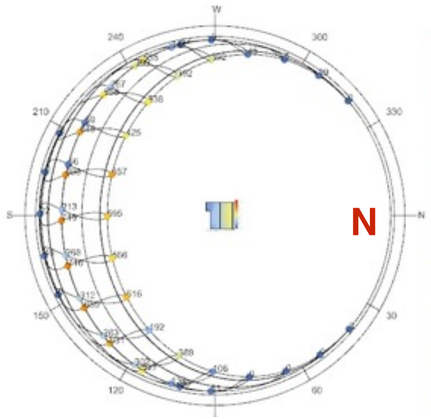
Case#4: **135°**



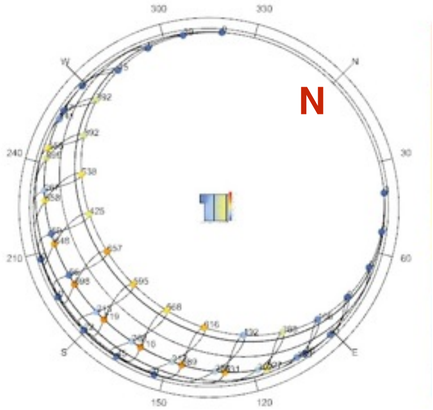
Case#5: **180°**



Case#6: **225°**



Case#7: **270°**



Case#8: **315°**

ANNUAL DAYLIGHT + ENERGY LOAD

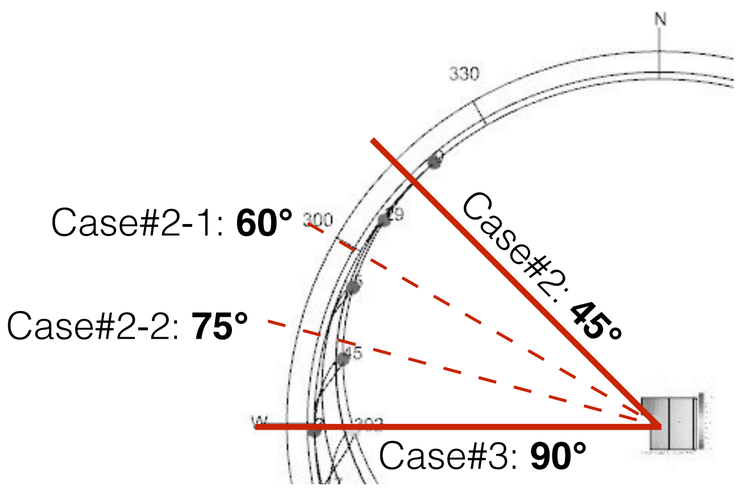
To identify which orientation makes occupants more comfortable, every 45° angle has been tested.

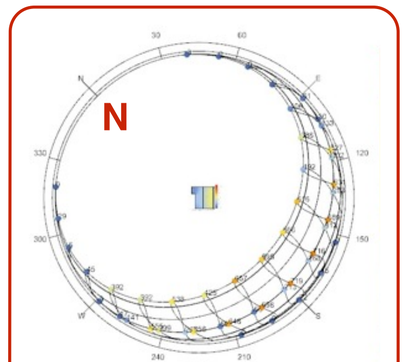
Energy loads doesn't mean this space will have HVAC. Lowest energy loads can reflect the most comfortable space.

* Please refer to **Appendix 1** for details.

D1 Orientation

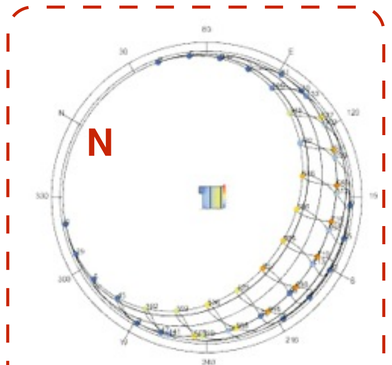
Orientation	#1 0°	#2 45°	#3 90°	#4 135°	#5 180°	#6 225°	#7 270°	#8 315°
Cooling Loads	276.29	438.92	471.21	489.63	315.59	129.9	102.73	192.81
Heating Loads	2389.57	1,878.70	1715.15	1900.15	2334.39	2693.42	2,777.30	2631.69
Lighting Loads	879.59	1,135.40	1157.58	1119.24	1059.22	1066.57	1,099.23	1128.47
Total	**3,545.45**	**3,453.02**	**3,343.94**	**3,509.02**	**3,709.20**	**3,889.89**	**3,979.26**	**3,952.97**
Rank	4	2	1	3	5	6	7	8



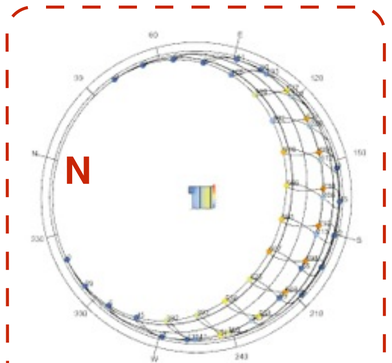


Case#2: **45°**

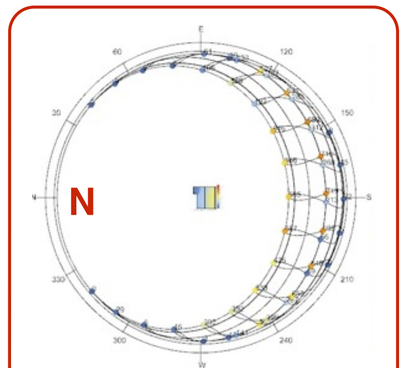
Rank 2



Case#2-1: **60°**



Case#2-2: **75°**



Case#3: **90°**

Rank 1

ANNUAL DAYLIGHT + ENERGY LOAD

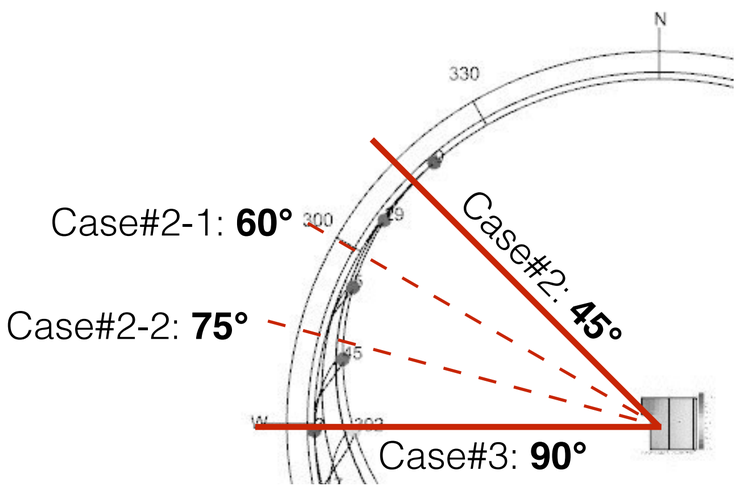
Case#2 and Case#3 have the lowest value of energy loads, so the lower value could exist between that range.

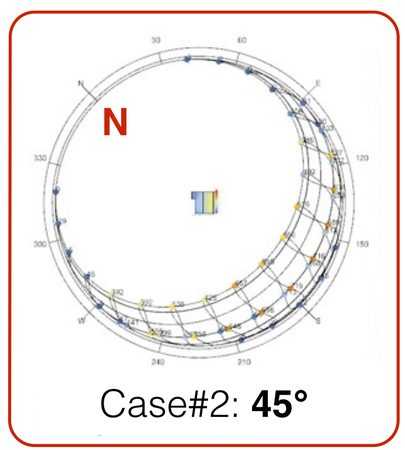
So another round of simulation was conducted for every 15°.

* Please refer to **Appendix 1** for details.

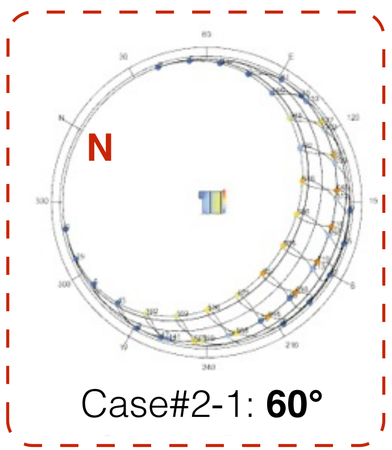
D1 Orientation

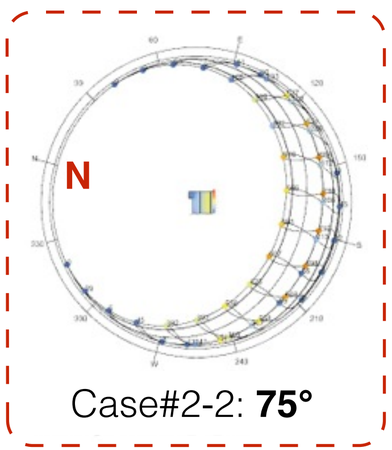
Orientation	#1 0°	#2 45°	#2-1 60°	#2-2 75°	#3 90°	#4 135°	#5 180°	#6 225°	#7 270°	#8 315°
Cooling Loads	276.29	438.92	473.16	468.29	471.21	489.63	315.59	129.9	102.73	192.81
Heating Loads	2389.57	1,878.70	1788.32	1734.16	1715.15	1900.15	2334.39	2693.42	2,777.30	2631.69
Lighting Loads	879.59	1,135.40	1150.07	1151.57	1157.58	1119.24	1059.22	1066.57	1,099.23	1128.47
Total	**3,545.45**	**3,453.02**	**3411.55**	**3354.02**	**3,343.94**	**3,509.02**	**3,709.20**	**3,889.89**	**3,979.26**	**3,952.97**
Rank	4	2			1	3	5	6	7	8

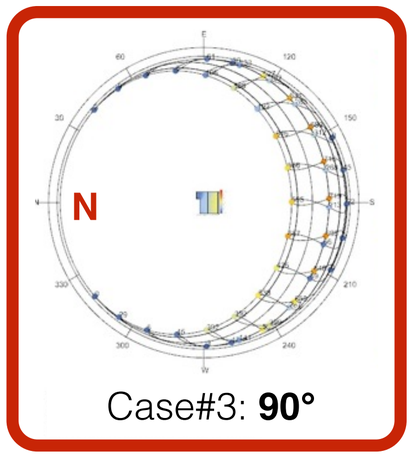




Rank 2







Rank 1

ANNUAL DAYLIGHT + ENERGY LOAD

Even though Case#2-1,2 have been tested, still case#3 (Orientation 90°) has the lowest value of the total energy loads, which includes cooling, heating and lighting loads.

* Please refer to **Appendix 1** for details.

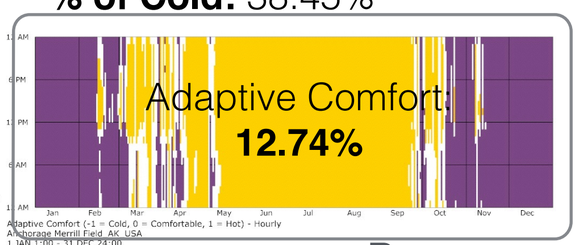
D1 Orientation

Adaptive Comfort:

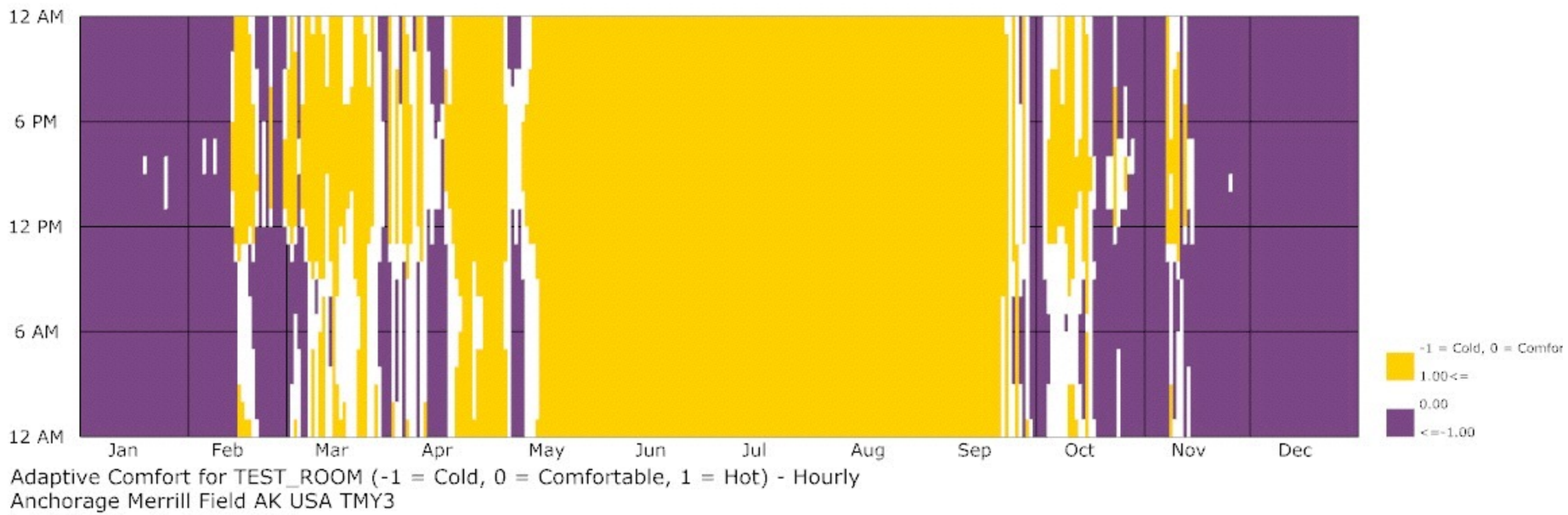
11.58%

1014 hours / year

% of Hot: 49.98%
% of Cold: 38.45%



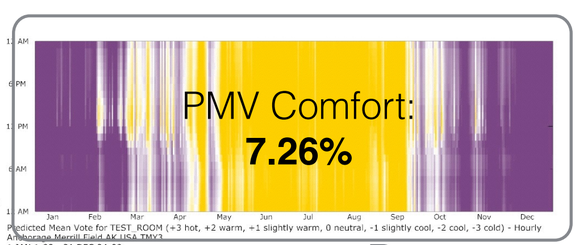
Basecase



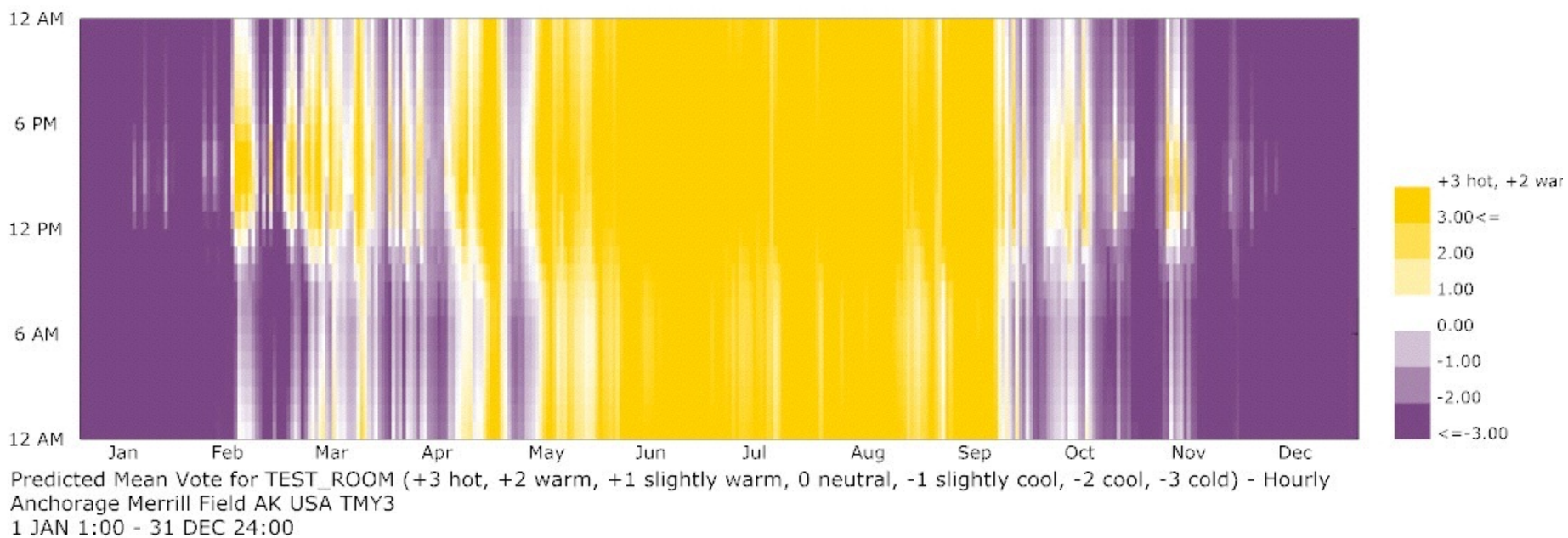
PMV Comfort:

6.99%

612 hours / year



Basecase



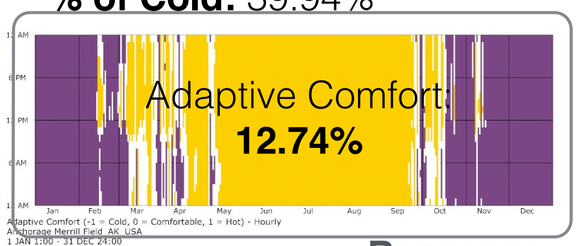
D2 Natural Ventilation

Adaptive Comfort:

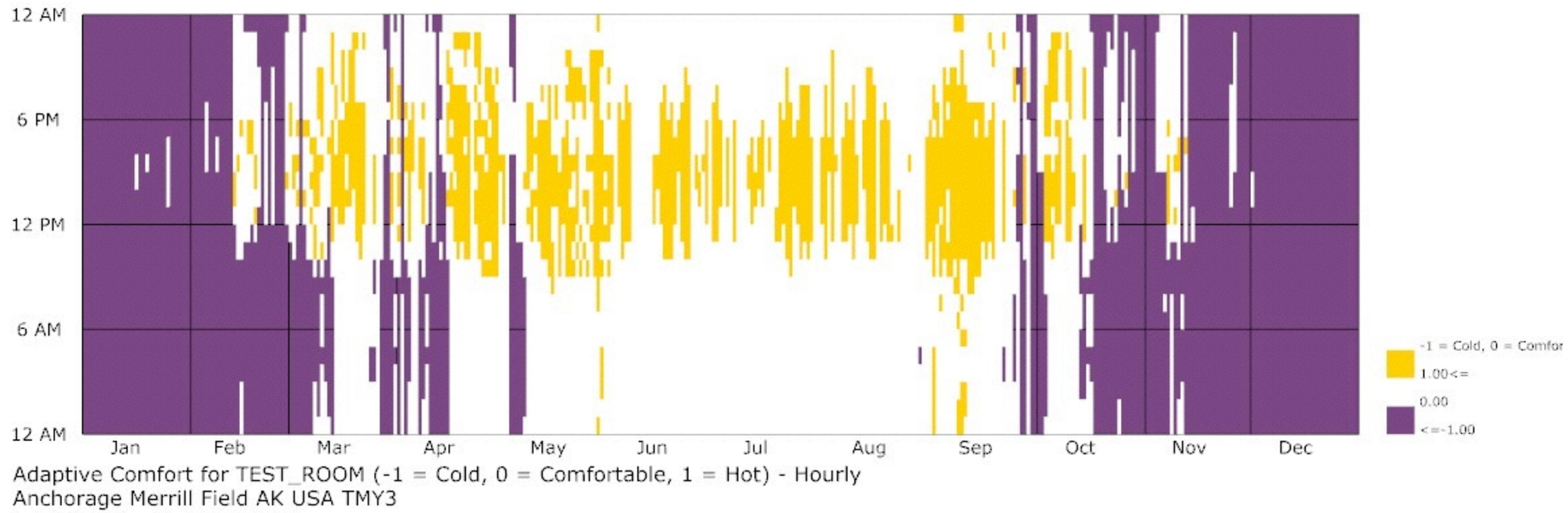
46.74%

4094 hours / year

% of Hot: 13.32%
% of Cold: 39.94%



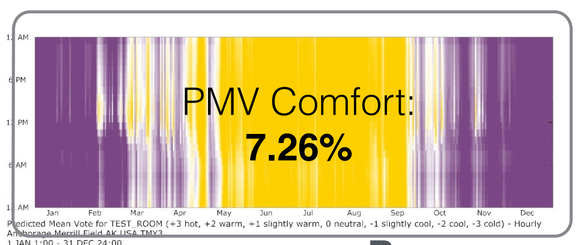
Basecase



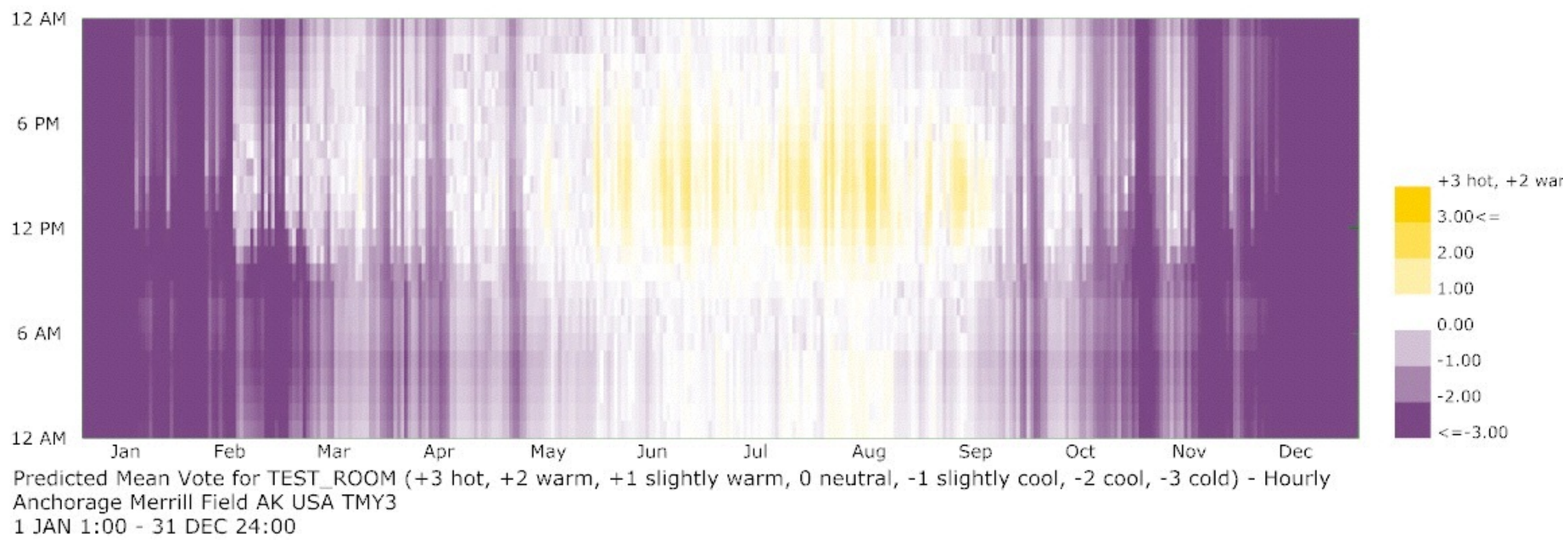
PMV Comfort:

34.24%

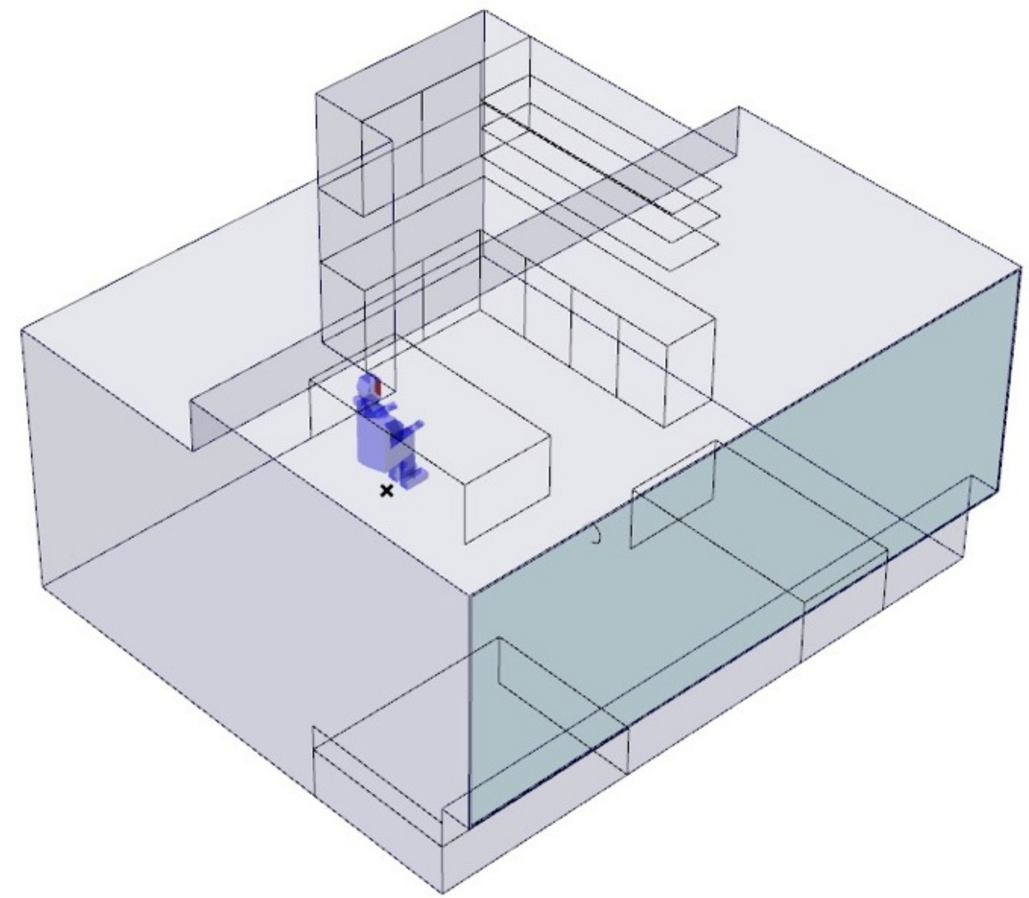
2999 hours / year



Basecase



D3 Shading



27 Shadings = **FACTOR 1** X **FACTOR 2** X **FACTOR 3**

FACTOR 1	FACTOR 2	FACTOR 3
# of Shading **3**	Depth **0.1m**	Angle **-15°**
# of Shading **6**	Depth **0.2m**	Angle **0°**
# of Shading **9**	Depth **0.3m**	Angle **+15°**

INDOOR COMFORT

To compare

* Please refer to **Appendix 2** for details.

D3 Shading

#	Shading Properties			Loads					
	Number	Angle	Depth	Cooling	Rank	Heating	Rank	Total	Rank
1	3	-15	0.1	344.52	27	2035.33	1	2379.85	8
2	3	-15	0.2	225.23	22	2102.21	4	2327.44	**5**
3	3	-15	0.3	139.15	16	2151.12	7	2290.27	**3**
4	3	0	0.1	313.11	26	2083.63	2	2396.74	10
5	3	0	0.2	216.87	20	2201.85	10	2418.72	13
6	3	0	0.3	137.76	15	2284.59	14	2422.35	14
7	3	15	0.1	301.37	25	2105.4	5	2406.77	11
8	3	15	0.2	196.34	19	2324.61	16	2520.95	18
9	3	15	0.3	127.78	14	2447.4	19	2575.18	19
10	6	-15	0.1	243.22	24	2092.82	3	2336.04	6
11	6	-15	0.2	92.57	10	2188.37	9	2280.94	**2**
12	6	-15	0.3	35.92	4	2303.15	15	2339.07	7
13	6	0	0.1	239.49	23	2170.04	8	2409.53	12
14	6	0	0.2	113.98	12	2348.78	17	2462.76	15
15	6	0	0.3	70.28	9	2528.01	22	2598.29	22
16	6	15	0.1	223.02	21	2265.03	12	2488.05	17
17	6	15	0.2	101.44	11	2490.82	21	2592.26	21
18	6	15	0.3	54.77	8	2809.03	24	2863.8	24
19	9	-15	0.1	148.67	18	2117.6	6	2266.27	**1**
20	9	-15	0.2	37.05	5	2260.65	11	2297.7	**4**
21	9	-15	0.3	13.96	1	2451.1	20	2465.06	16
22	9	0	0.1	125.68	13	2269.49	13	2395.17	9
23	9	0	0.2	47.36	7	2578.5	23	2625.86	23
24	9	0	0.3	34.35	2	2862.38	26	2896.73	26
25	9	15	0.1	142.55	17	2437.41	18	2579.96	20
26	9	15	0.2	45.01	6	2837.51	25	2882.52	25
27	9	15	0.3	35.44	3	3162.82	27	3198.26	27

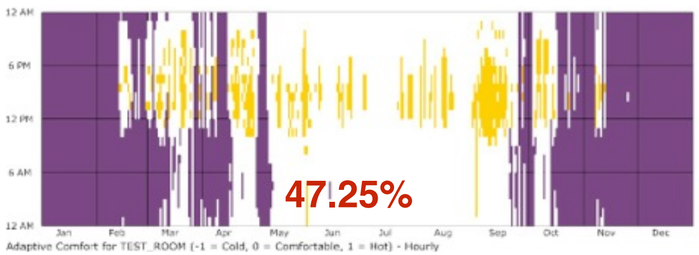
INDOOR COMFORT

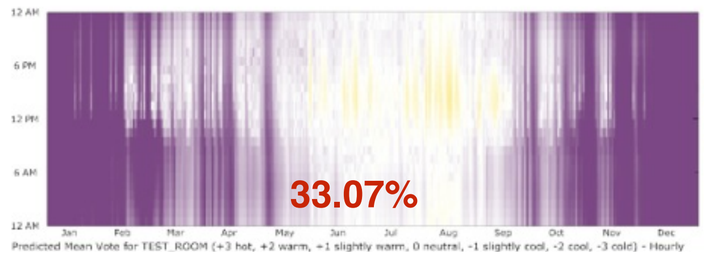
To compare

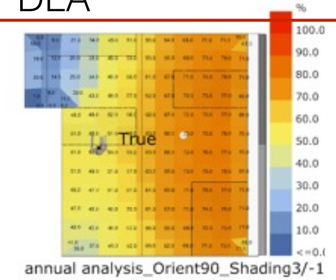
D3 Shading

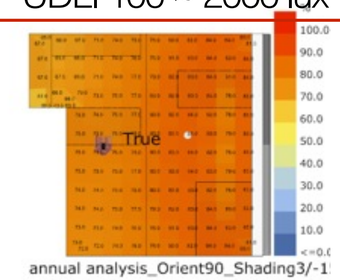
Adaptive Comfort | PMV Comfort | DLA | UDLI 100 ~ 2000 lux | UDLI > 2000 lux

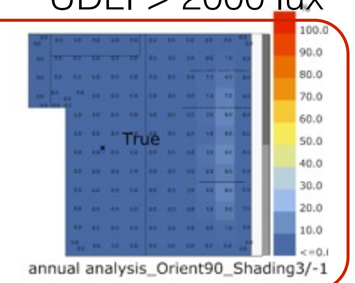
Shading #2



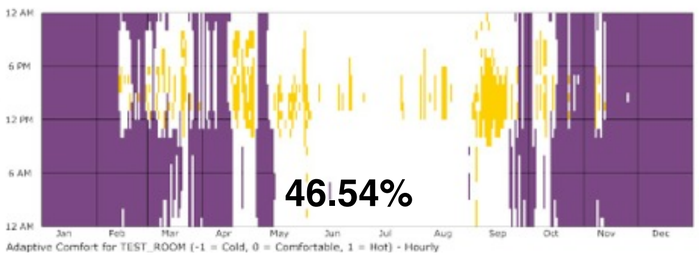


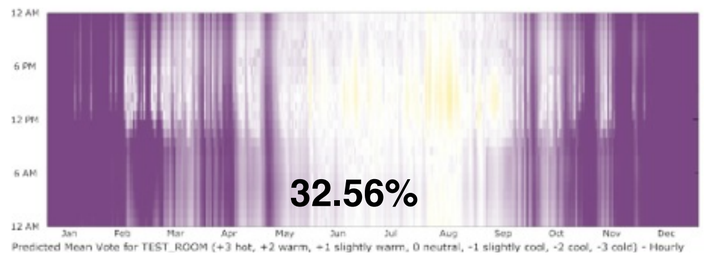


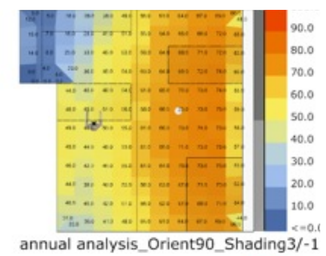


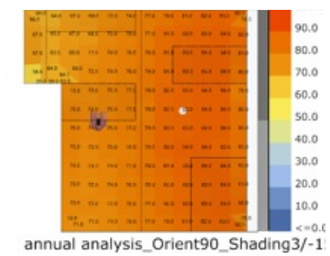


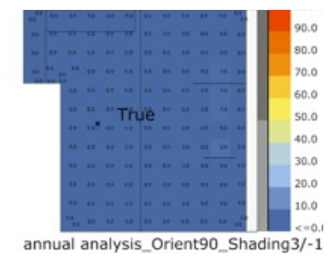
Shading #3











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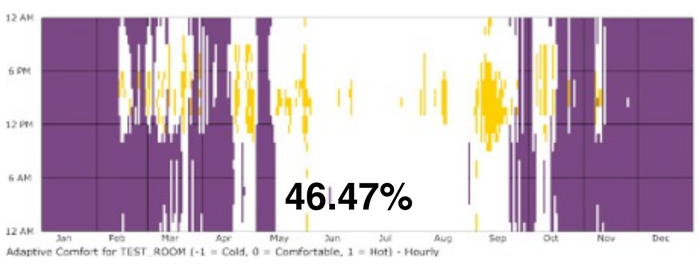

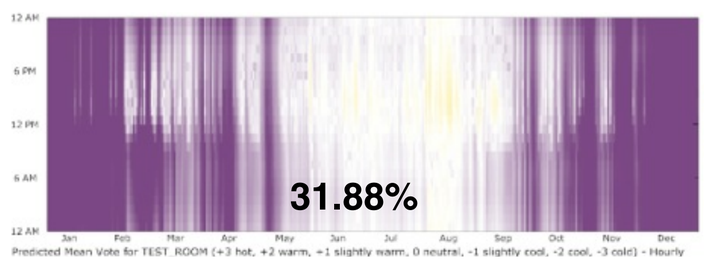

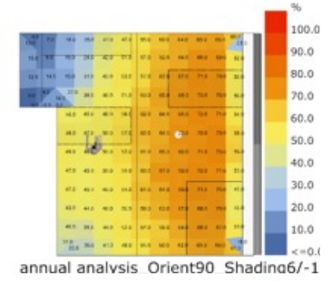

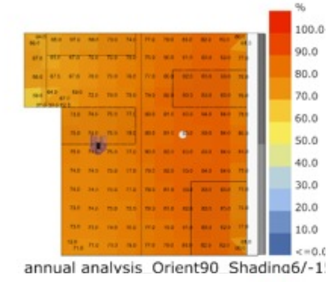

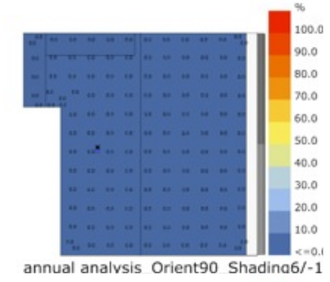

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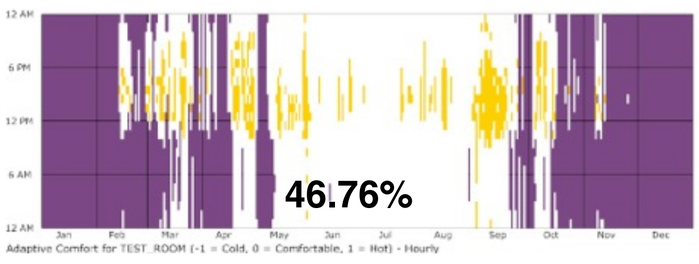
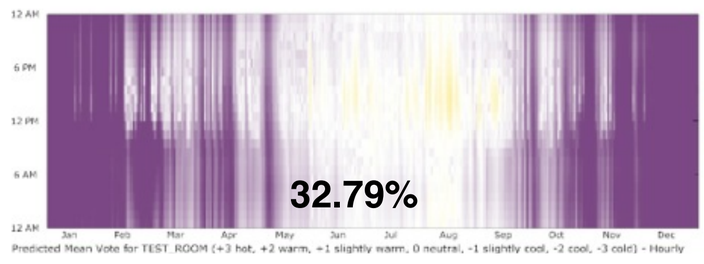
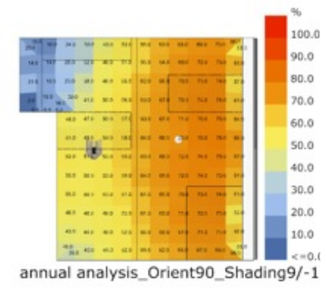
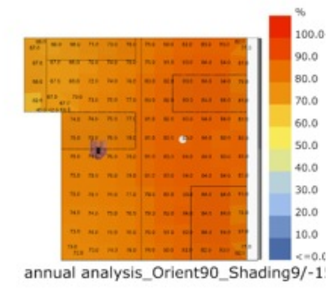
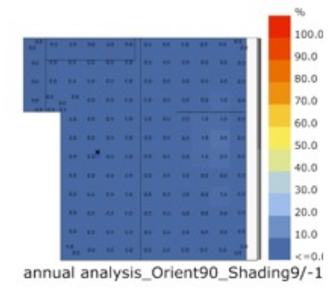


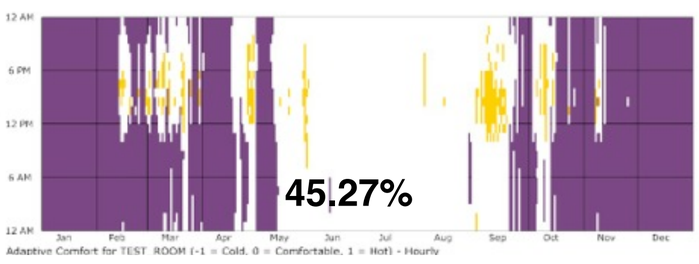


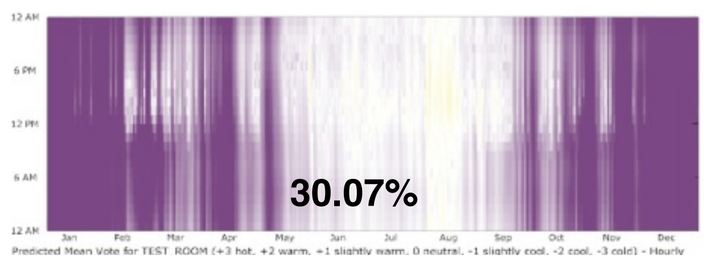


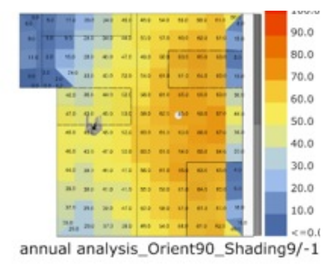


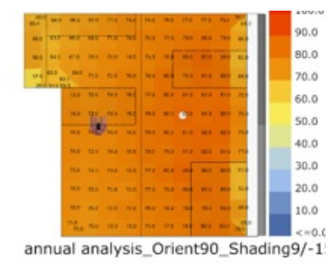


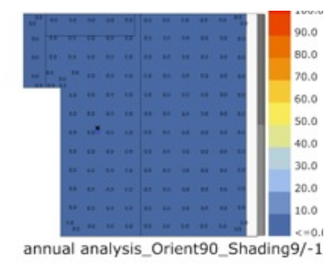
Shading #20







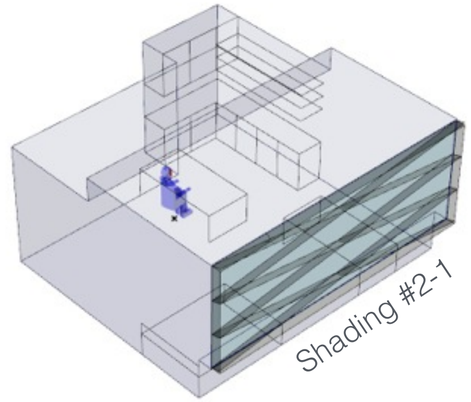


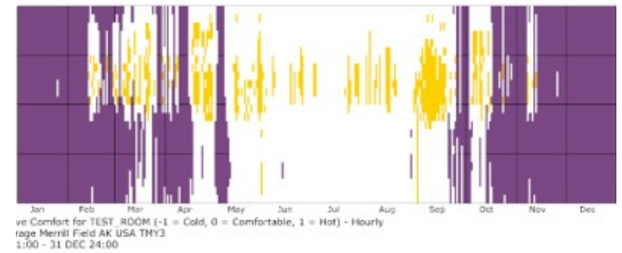


D3 Shading

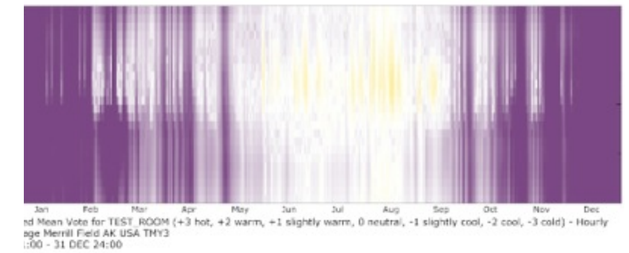
Number of Shading: 3
Depth 0.1m

Angle -10°



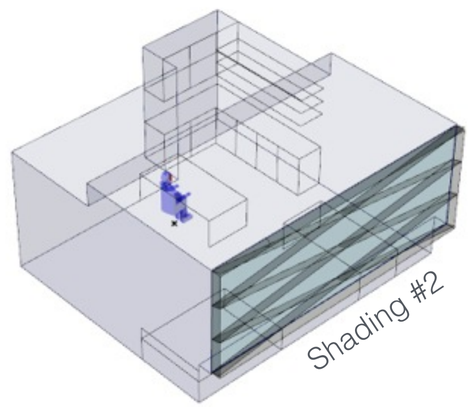


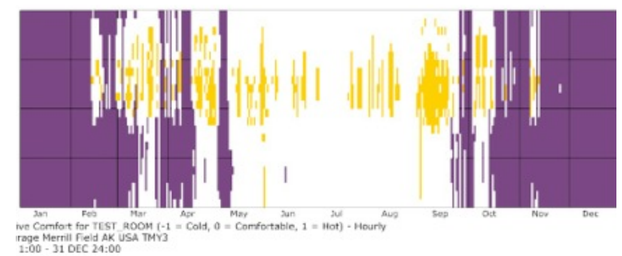
46.77%



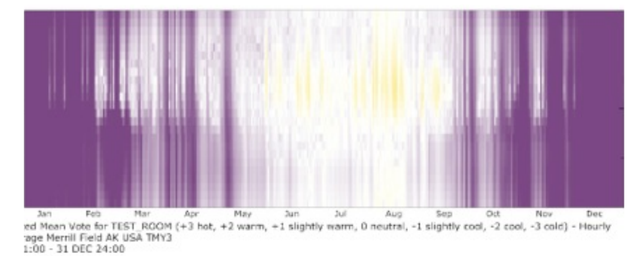
33.06%

Angle -15°



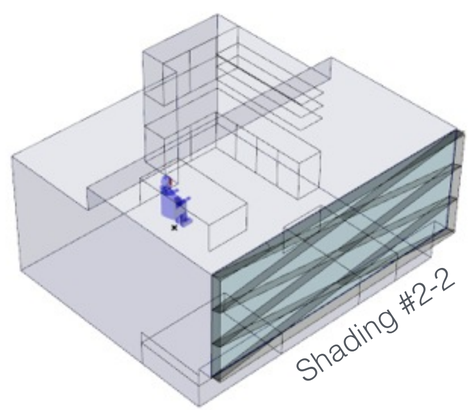


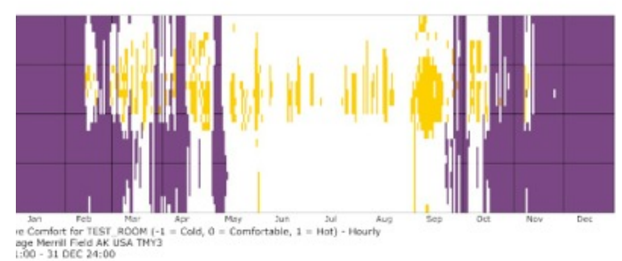
47.25%



33.07%

Angle -20°





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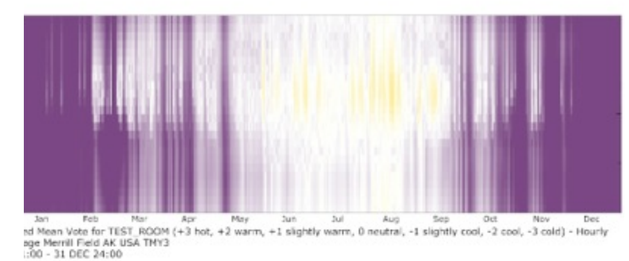


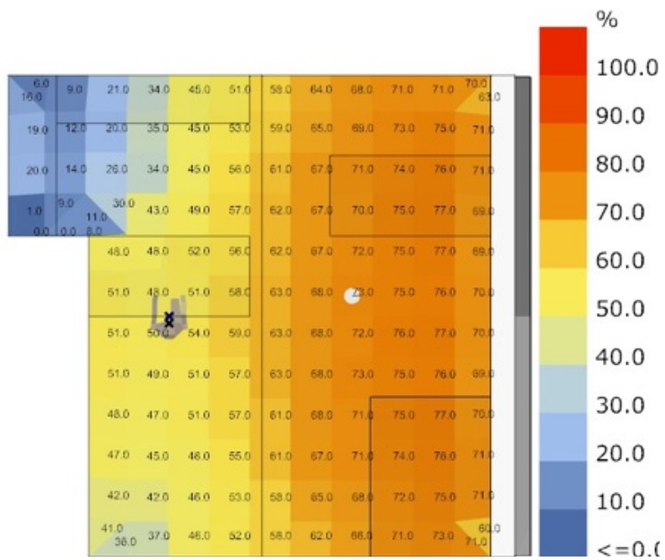
33.10%

Additional Angle Study

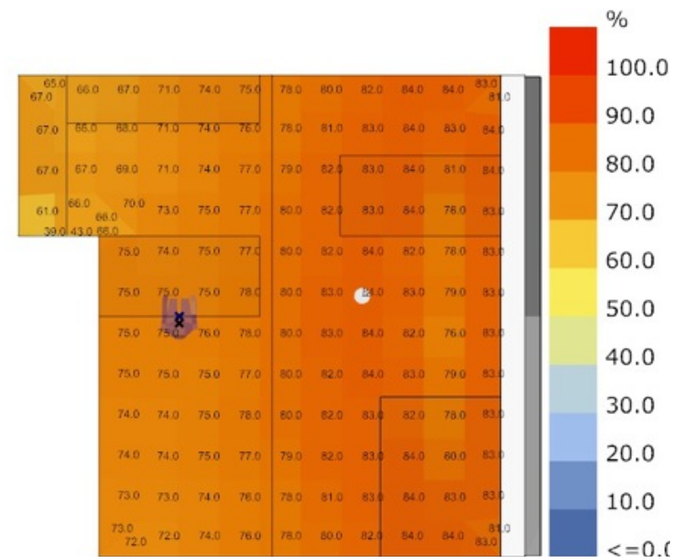
To compare

E Final Design Assessment

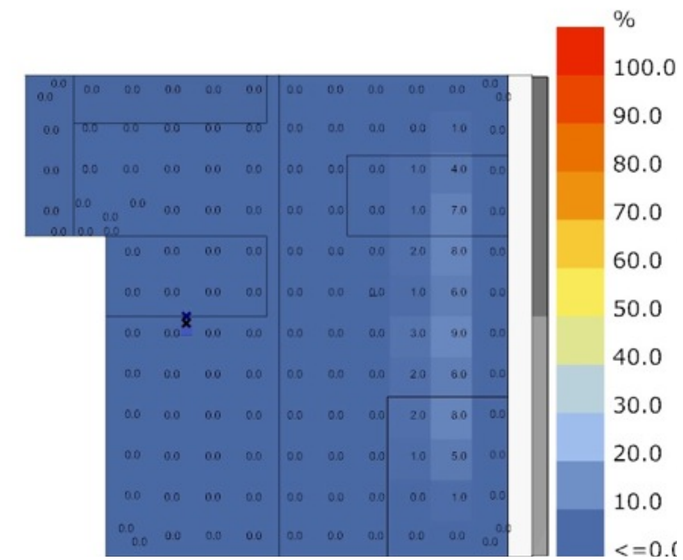
E1 Well Daylit



DLA
Day-Light Autonomy



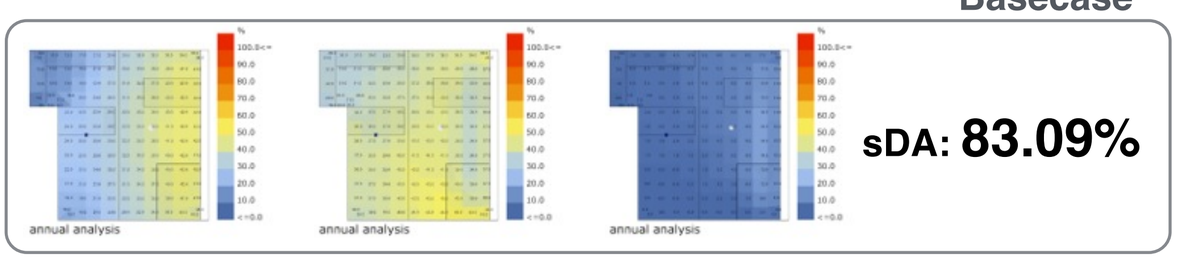
UDLI 100 ~ 2000 lux
Useful Day-Light Illumination



UDLI > 2000 lux
Useful Day-Light Illumination

sDA: 69.85%
Spacial Daylight Autonomy

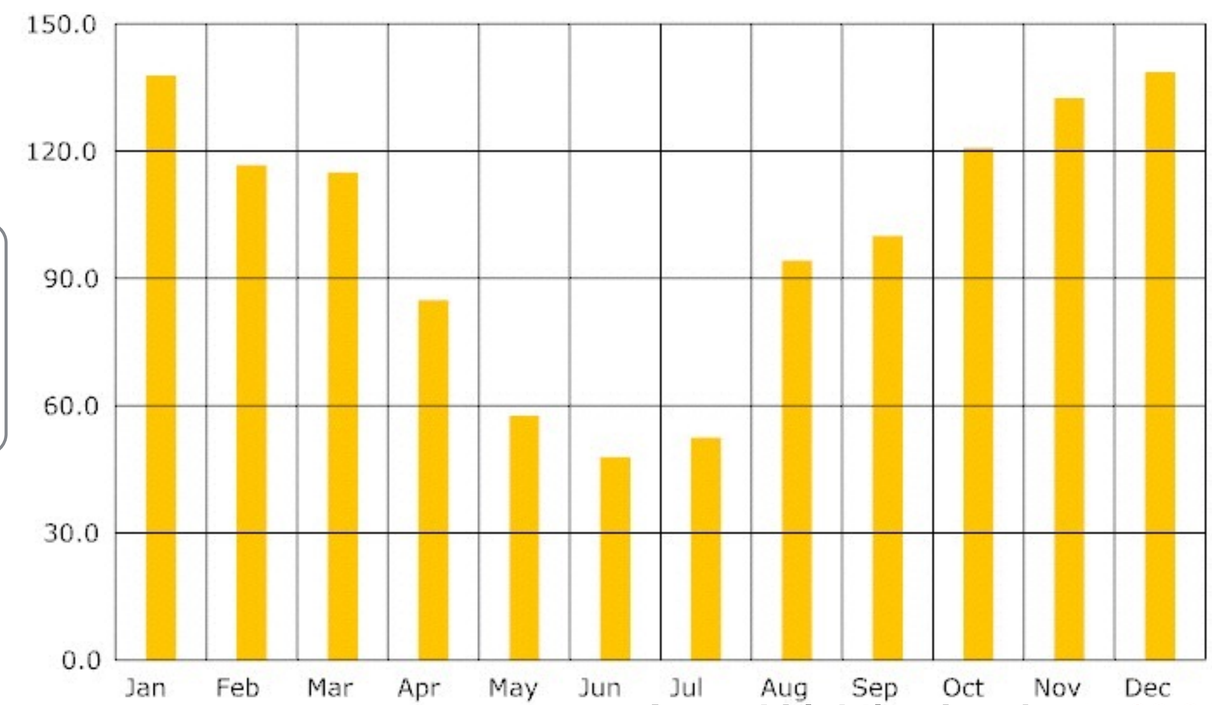
Basecase



sDA: 83.09%

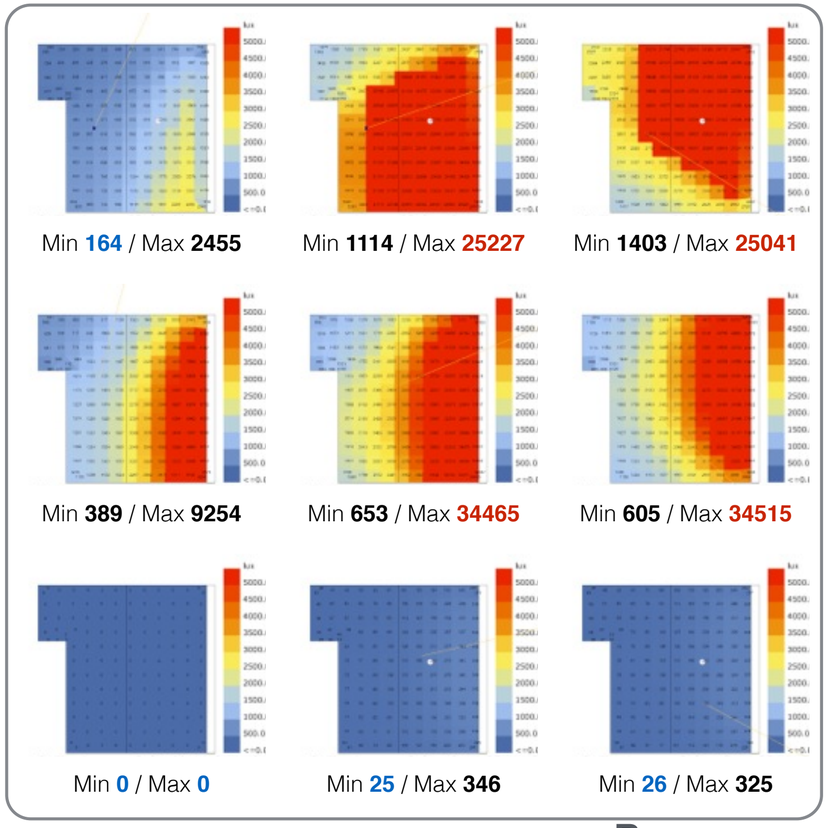
ANNUAL DAYLIGHT ANALYSIS

The wind at Anchorage is mostly from West and North direction. As seasonal wind-rose indicates, most of cold air comes from the North and warmer air is mostly from the West.

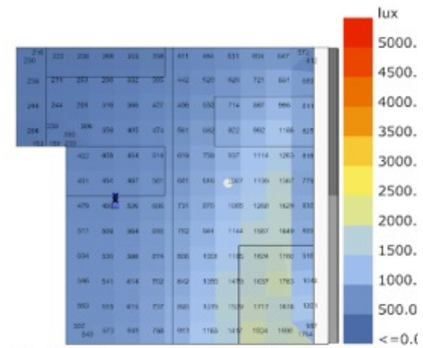
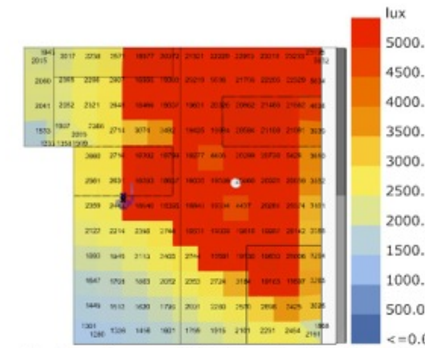
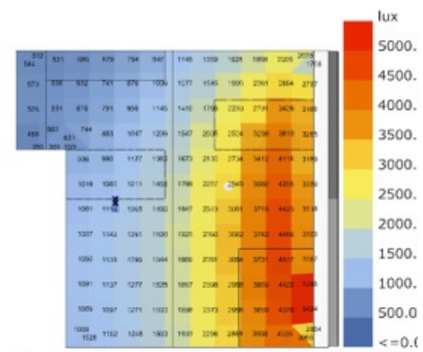
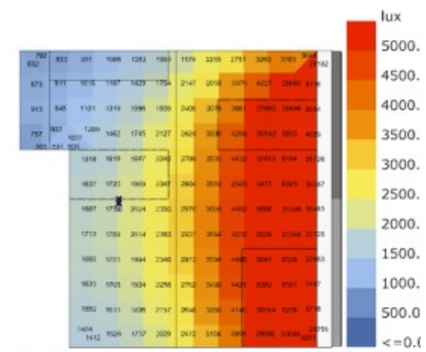
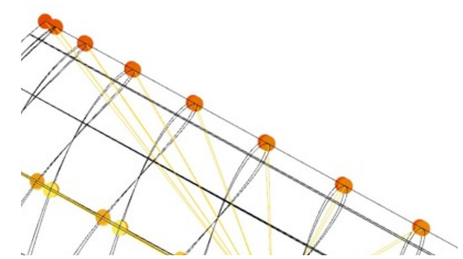
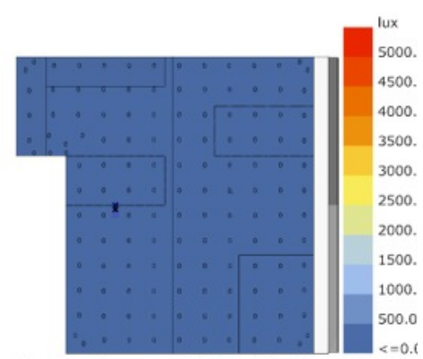
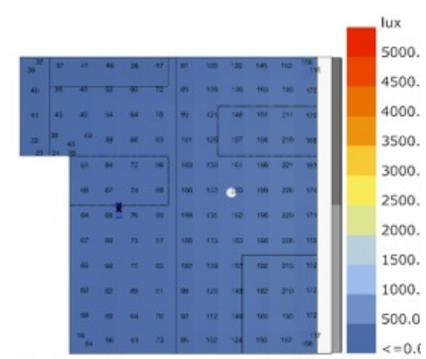
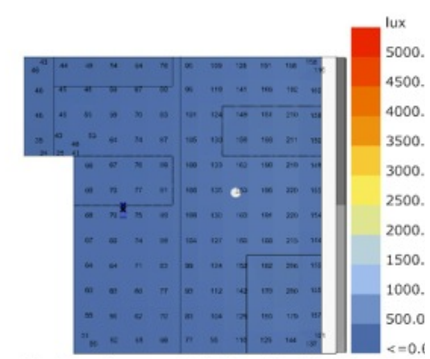


Annual Lighting Loads: 1,198.84

E1 Well Daylit



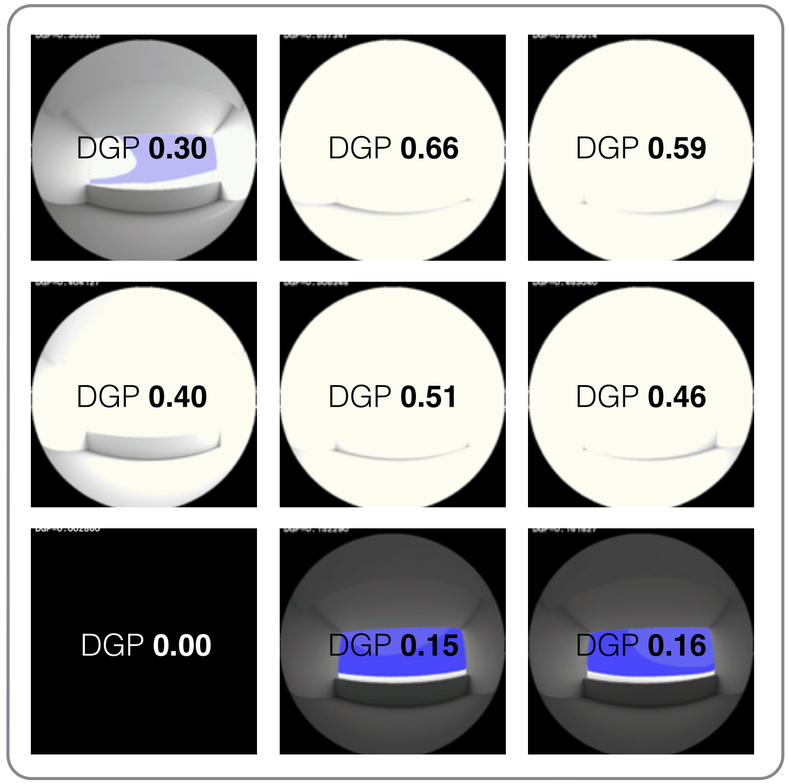
Basecase

	9 am	12 pm	3 pm
March	 Min 153 / Max 1824	Min 958 / Max 23848	 Min 1233 / Max 23233
June	 Min 350 / Max 5424	 Min 565 / Max 31288	 Min 491 / Max 29518
December	 Min 0 / Max 0	 Min 23 / Max 229	 Min 24 / Max 220

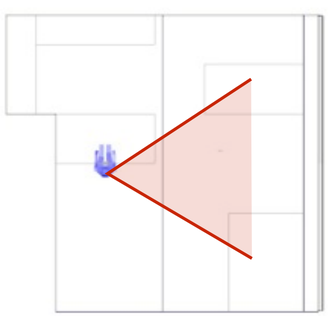
Illuminance

As the shading was added, the maximum value of illuminance could be reduced.

E2 Visual Comfort

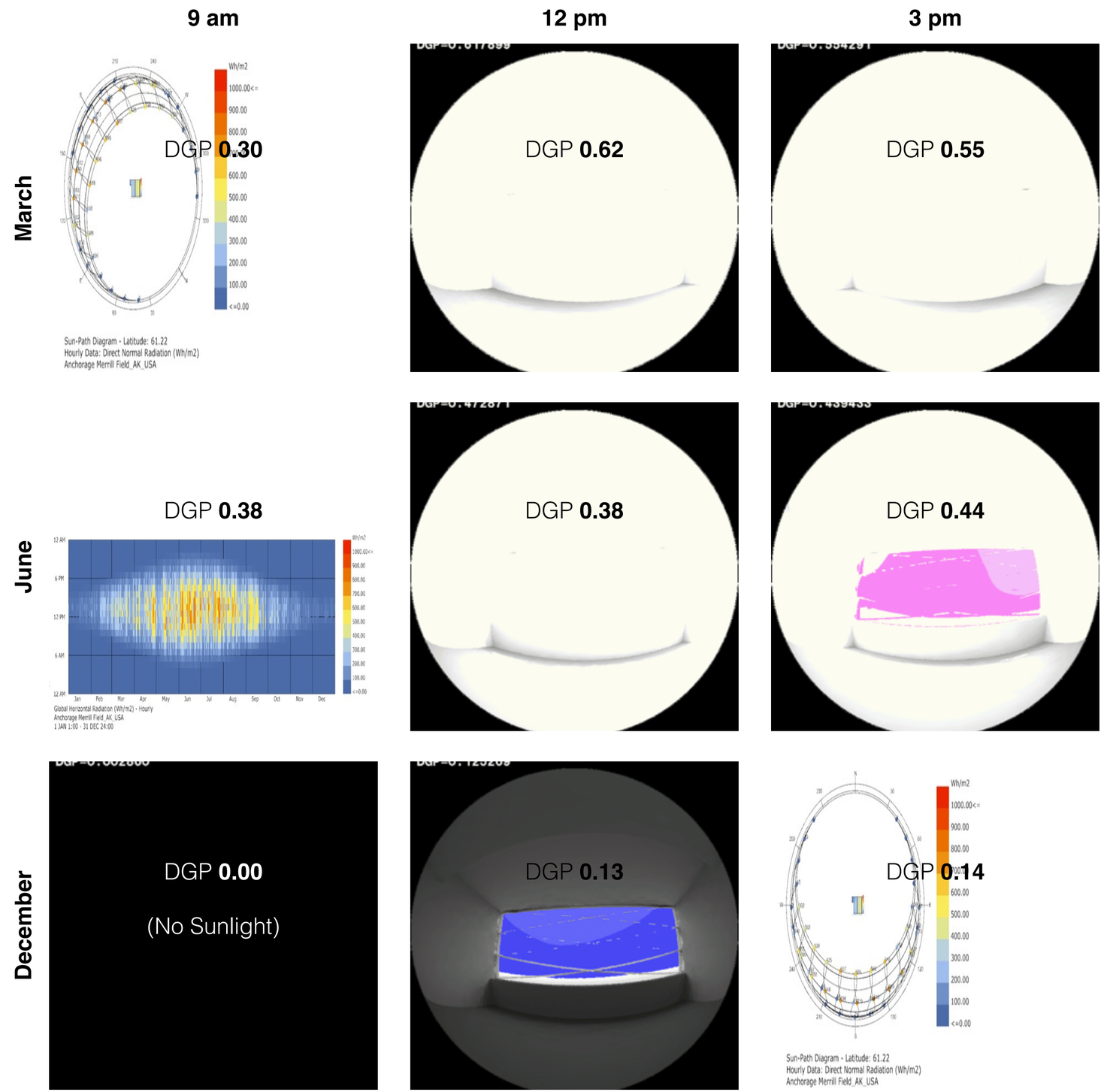


Basecase

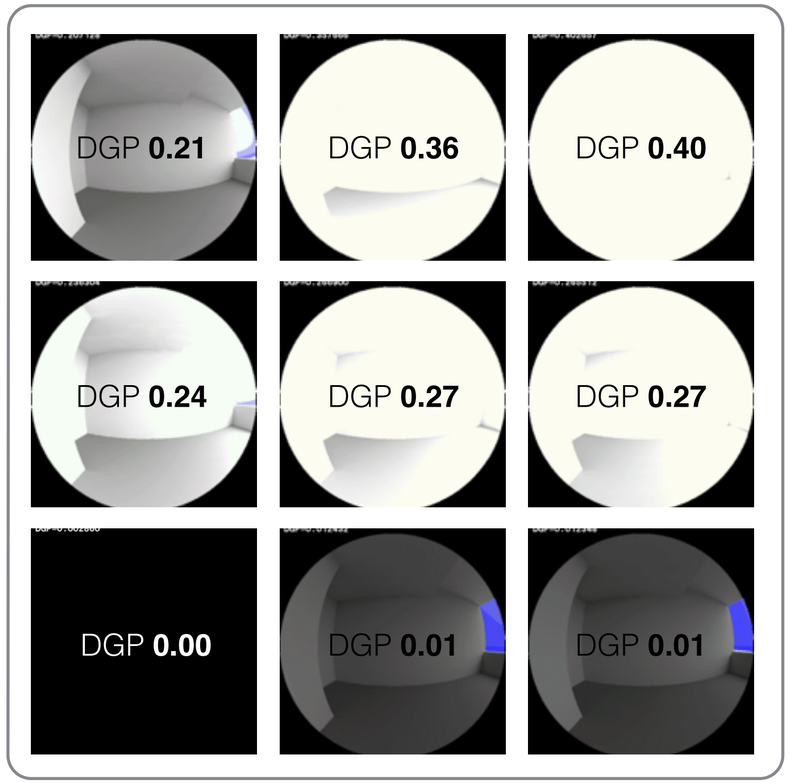


GLARE; Image-based Analysis

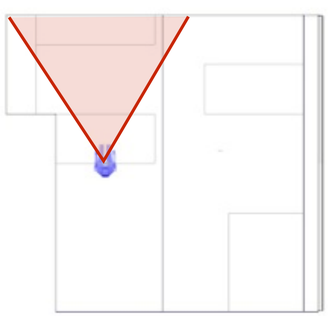
Some of the period still has DGP value more than 0.40, but this direction is not that occupants usually face. By the reason it wouldn't disturb them.



E2 Visual Comfort

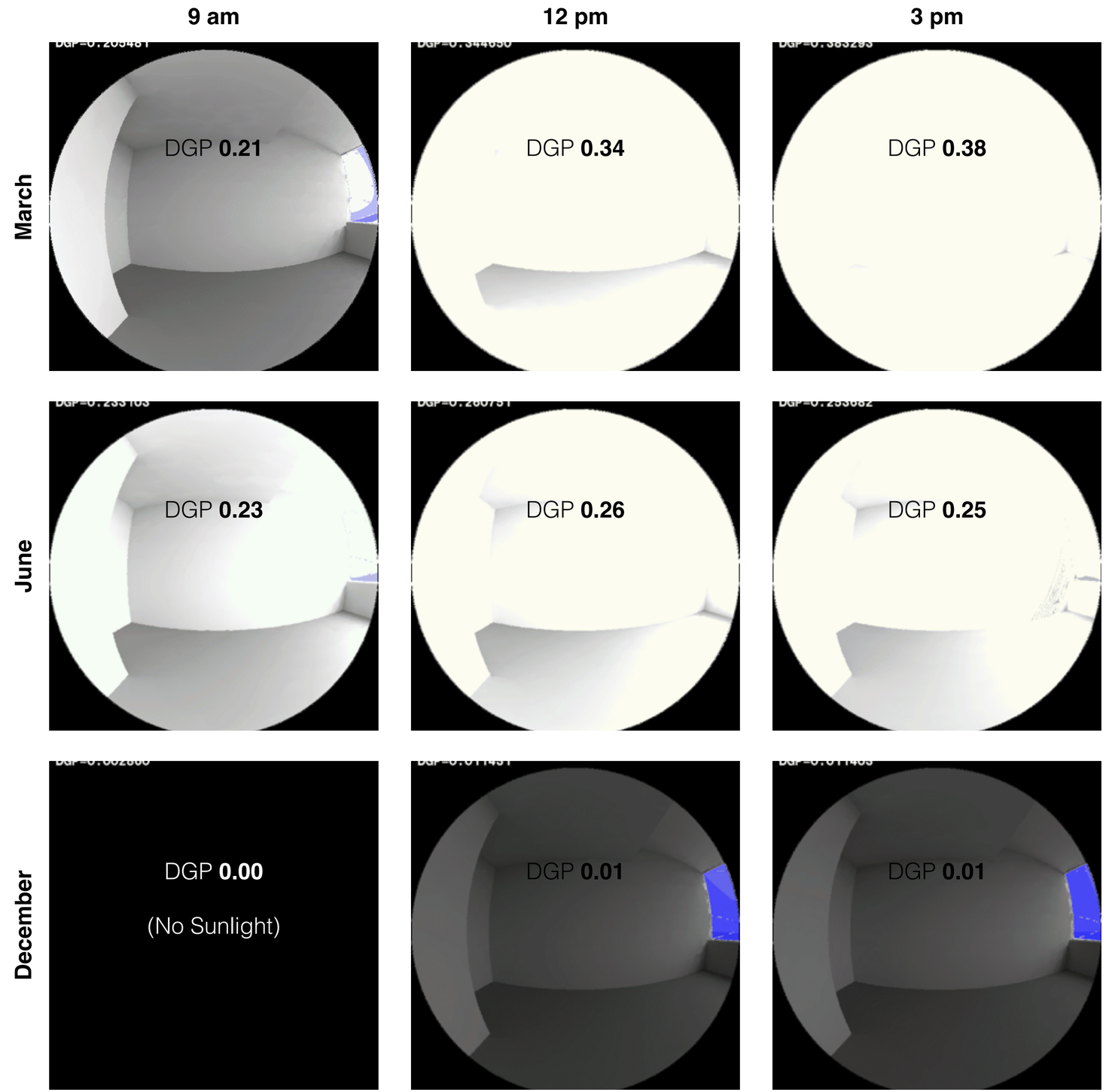


Basecase



GLARE; Image-based Analysis

As basecase, all the time DGP are lower than 0.40, meaning visual comfort. The lack of light has to be solved with artificial light.



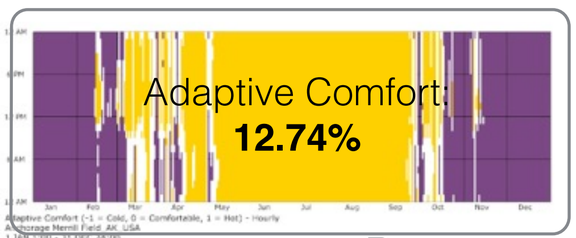
E3 Thermal Comfort

Adaptive Comfort:

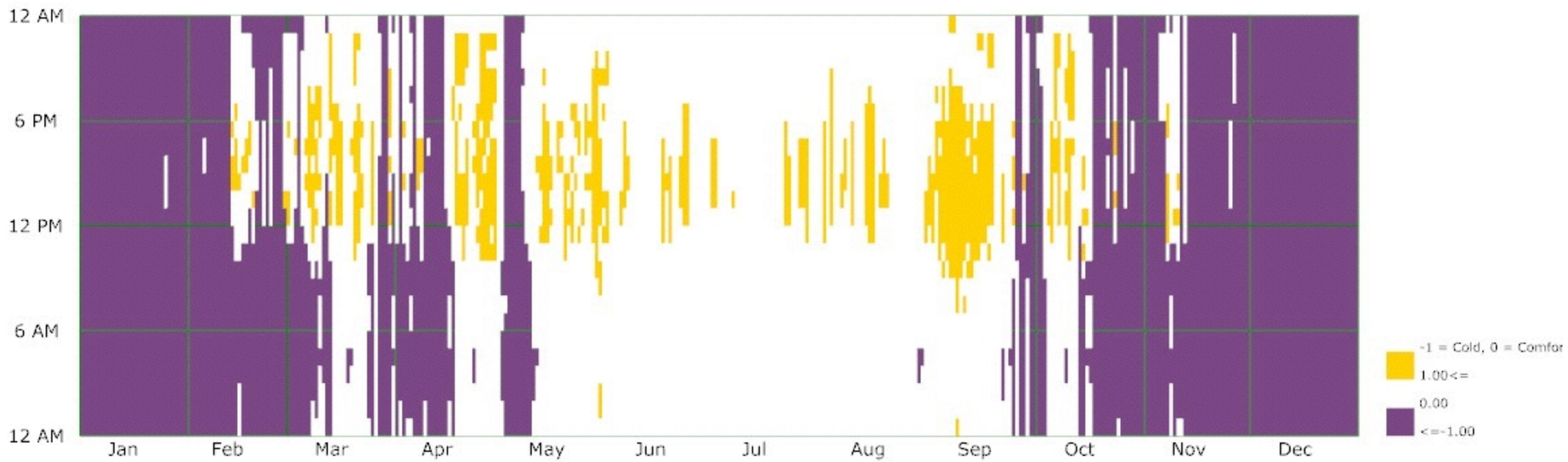
47.74%

4182 hours / year

% of Hot: 7.68%
% of Cold: 44.58%



Basecase

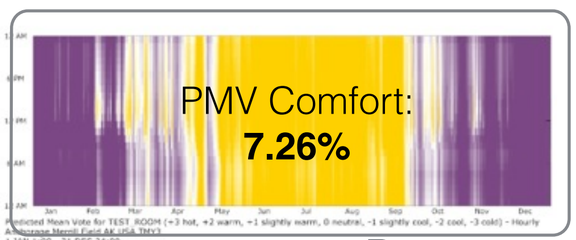


Adaptive Comfort for TEST_ROOM (-1 = Cold, 0 = Comfortable, 1 = Hot) - Hourly
Anchorage Merrill Field AK USA TMY3
1 JAN 1:00 - 31 DEC 24:00

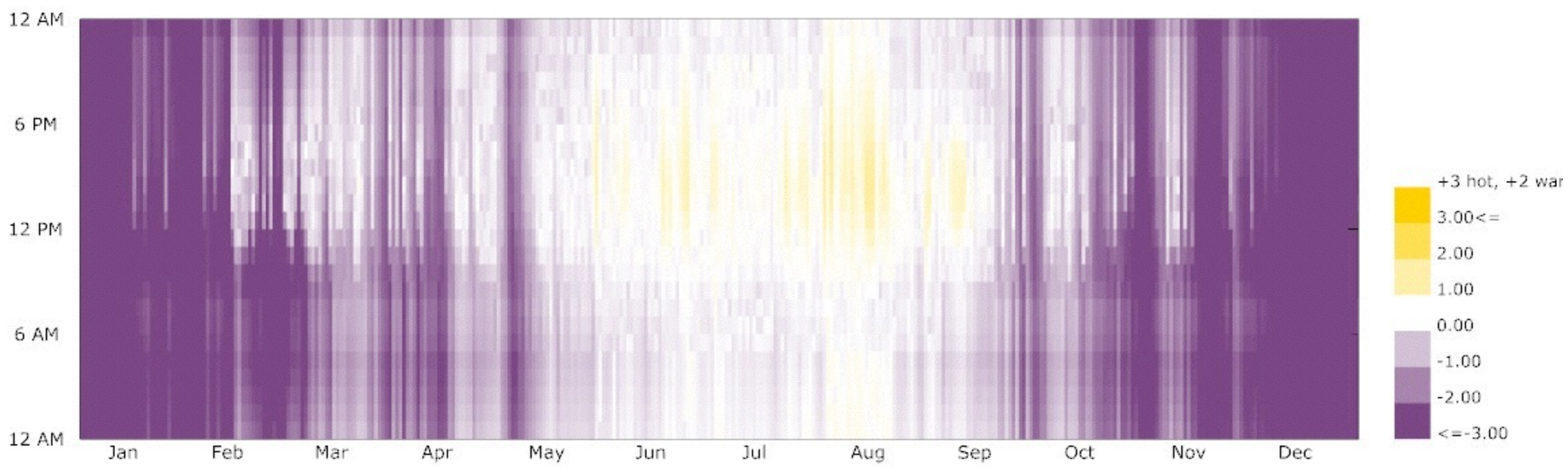
PMV Comfort:

33.40%

2926 hours / year

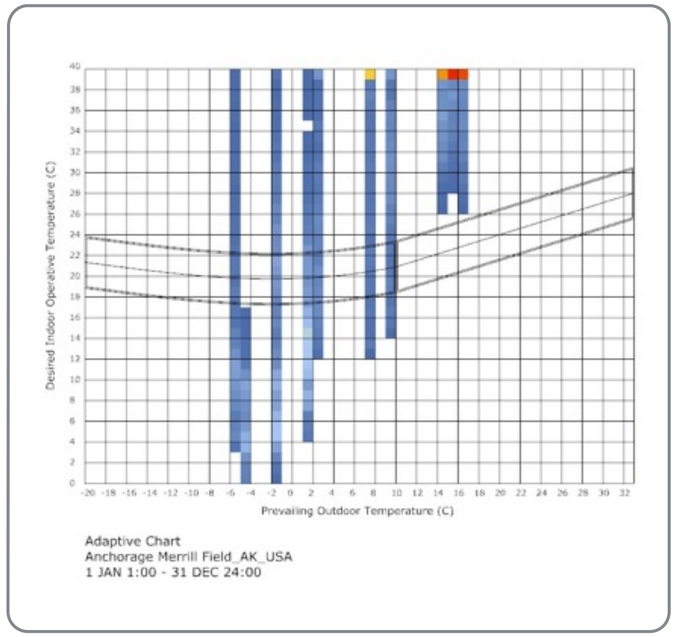


Basecase

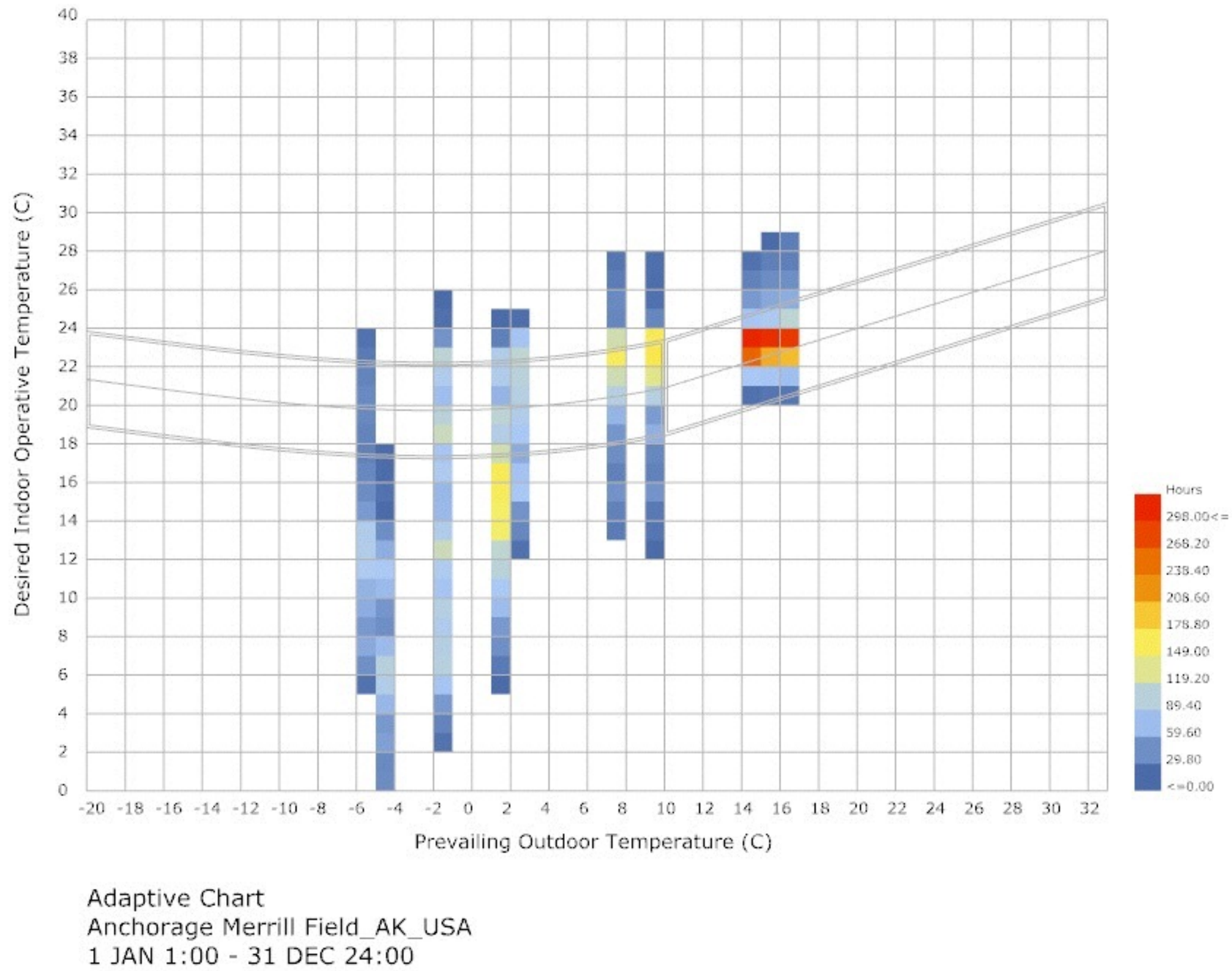


Predicted Mean Vote for TEST_ROOM (+3 hot, +2 warm, +1 slightly warm, 0 neutral, -1 slightly cool, -2 cool, -3 cold) - Hourly
Anchorage Merrill Field AK USA TMY3
1 JAN 1:00 - 31 DEC 24:00

E3 Thermal Comfort



Basecase



Adaptive Comfort

F Conclusion

F Conclusions

Basecase

Adaptive Comfort:

11.74%

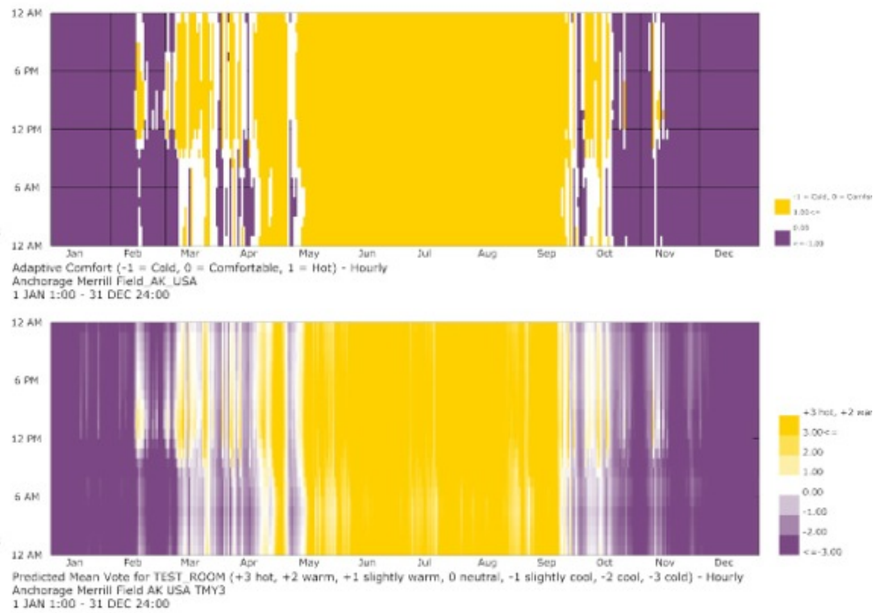
1028 hours / year

% of Hot: 49.39%
% of Cold: 38.87%

PMV Comfort:

7.26%

636 hours / year



Adaptive	PMV	Design Proposals	
11.58	6.99	D1	Orientation
46.74	34.24	D2	Natural Ventilation
47.25	33.07	D3	Shading

Final Design

Adaptive Comfort:

47.25%

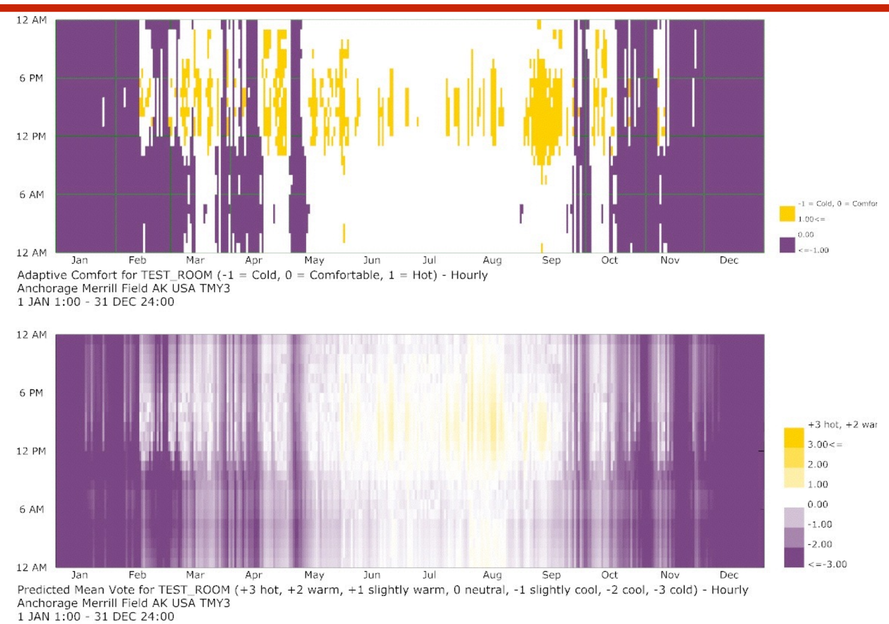
4139 hours / year

% of Hot: 6.90%
% of Cold: 45.84%

PMV Comfort:

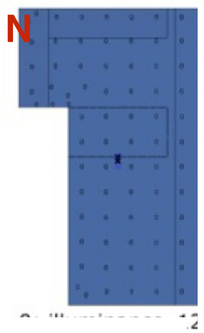
33.07%

2897 hours / year



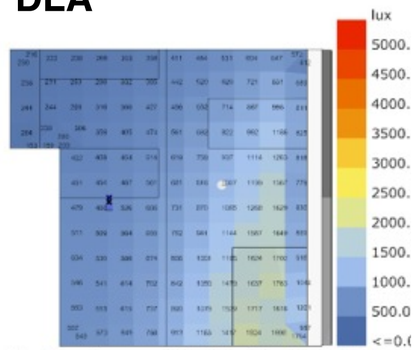
G Appendix

G Appendix 1 - **D1** Orientation

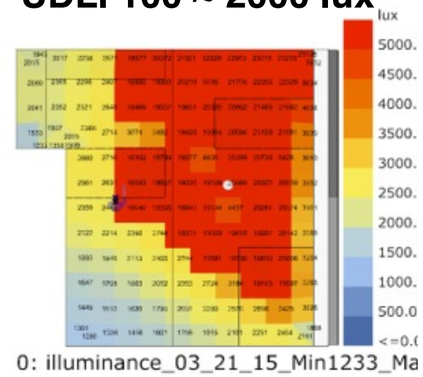


Case#1: **0°**

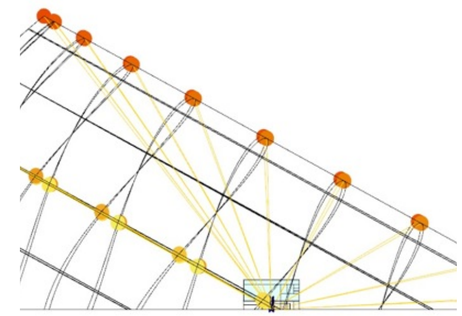
DLA



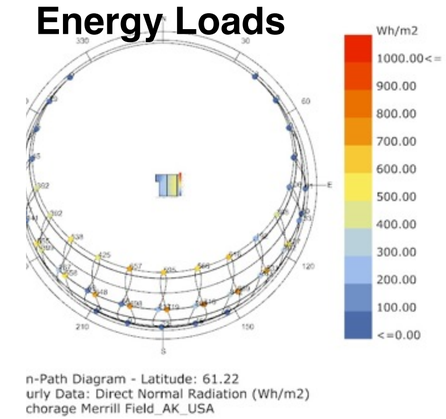
UDLI 100 ~ 2000 lux

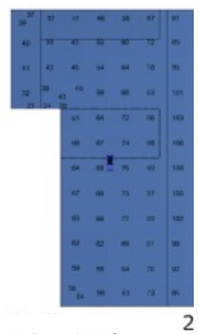


UDLI > 2000 lux

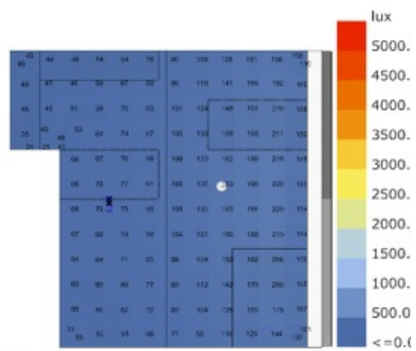


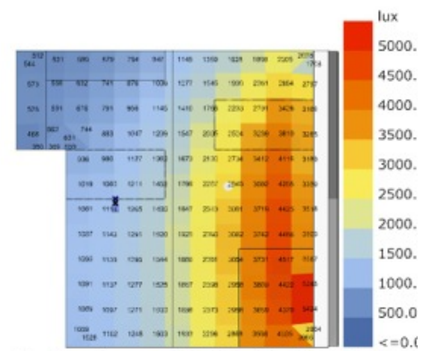
Energy Loads

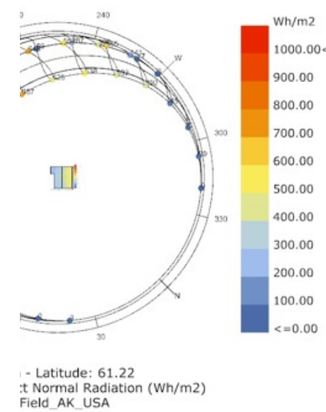


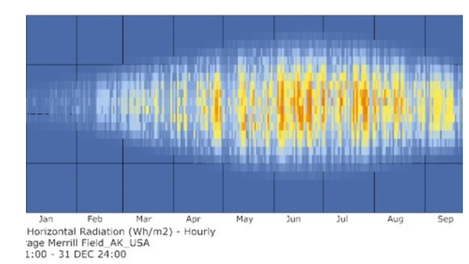


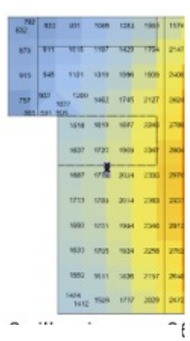
Case#2: **45°**



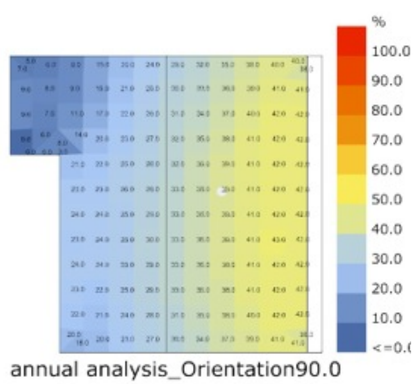


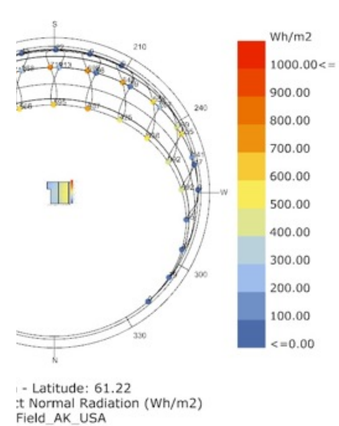


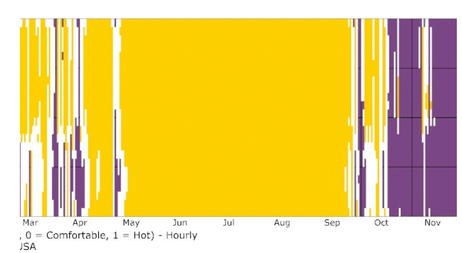


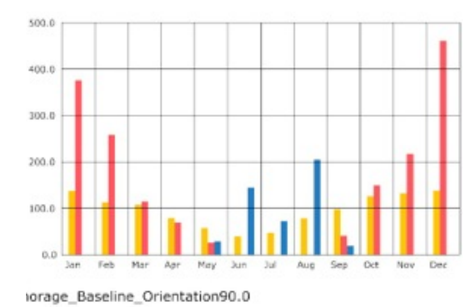


Case#3: **90°**



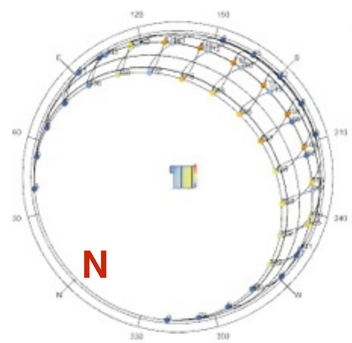




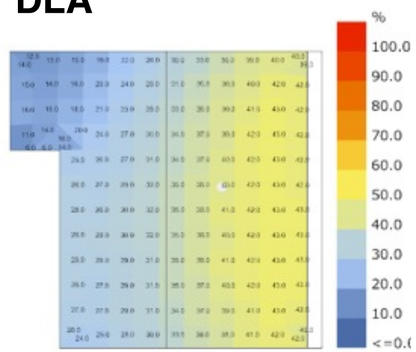


G Appendix 1 - **D1** Orientation

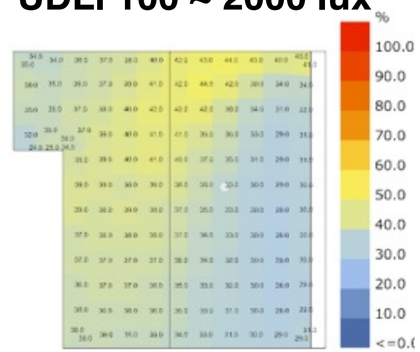
DLA | **UDLI 100 ~ 2000 lux** | **UDLI > 2000 lux** | **Energy Loads**



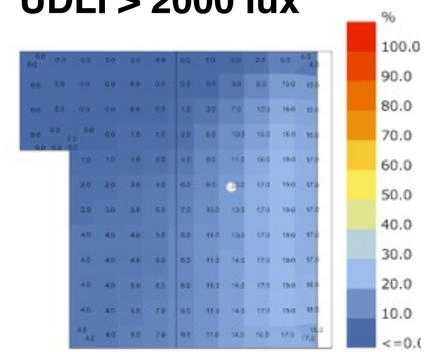
Case#4: **135°**



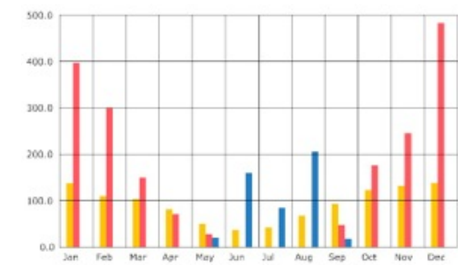
annual analysis_Orientation135.0



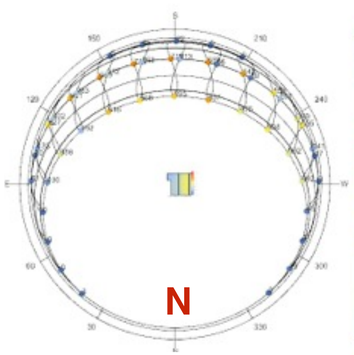
annual analysis_Orientation135.0



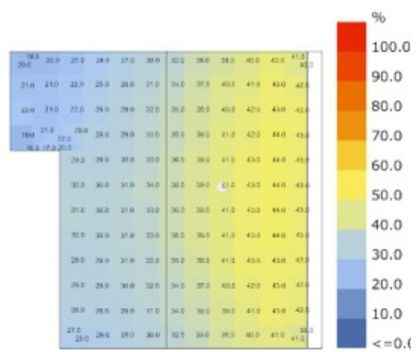
annual analysis_Orientation135.0



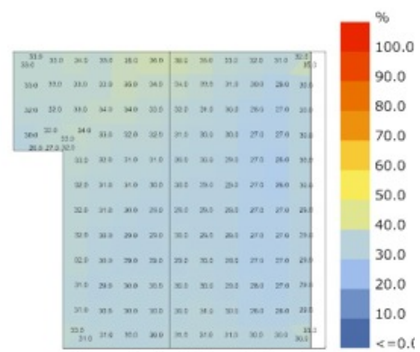
horage_Baseline_Orientation135.0



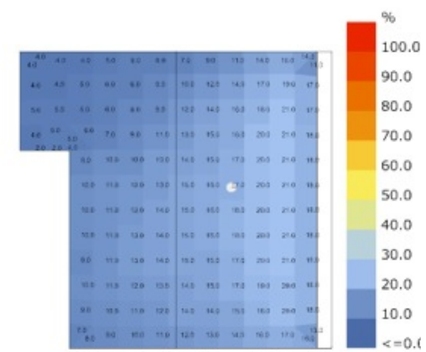
Case#5: **180°**



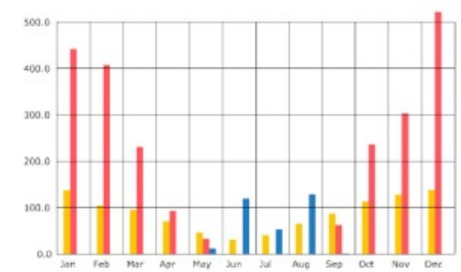
annual analysis_Orientation180



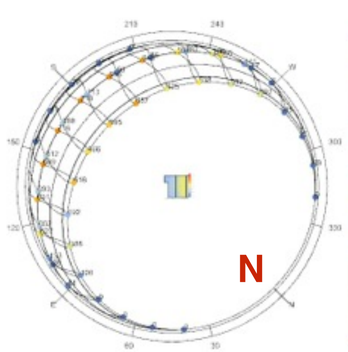
annual analysis_Orientation180



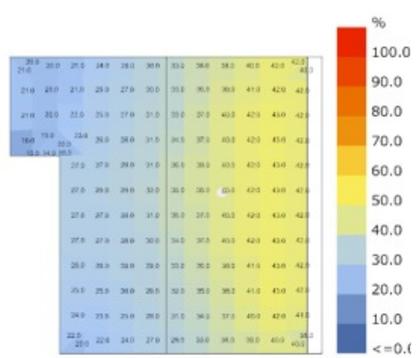
annual analysis_Orientation180



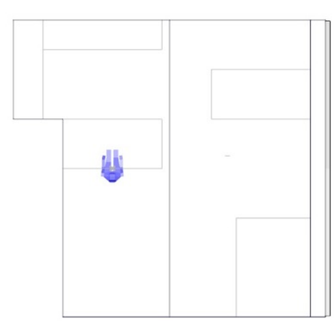
horage_Baseline_Orientation180

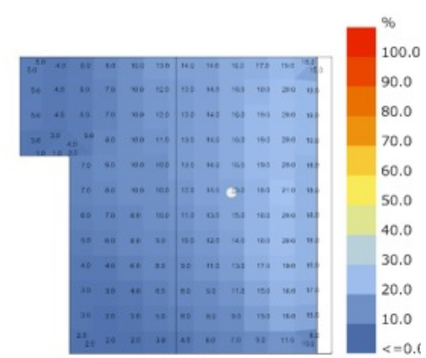


Case#6: **225°**

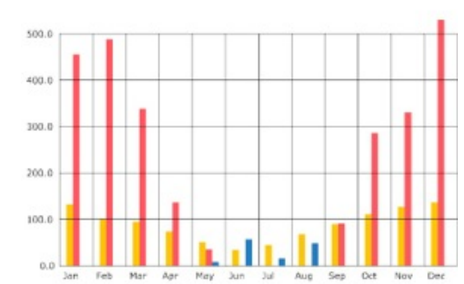


annual analysis_Orientation225



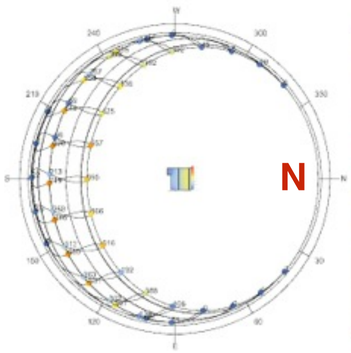


annual analysis_Orientation225



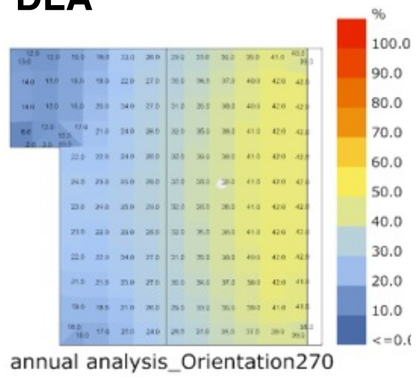
horage_Baseline_Orientation225

G Appendix 1 - **D1** Orientation

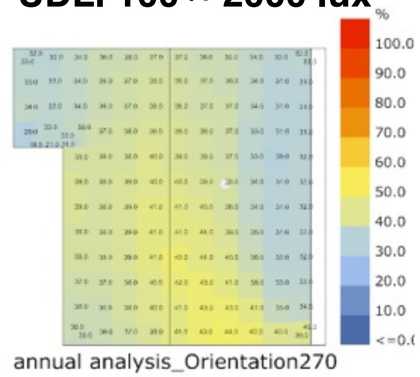


Case#7: **270°**

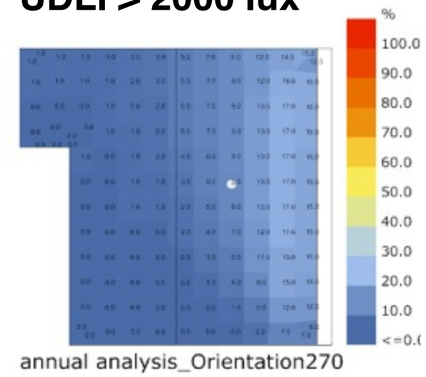
DLA



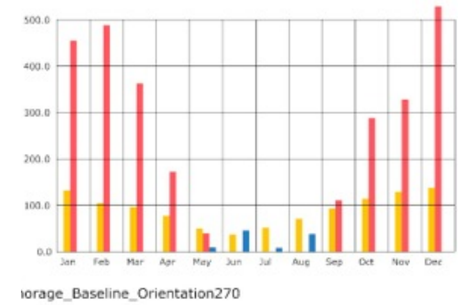
UDLI 100 ~ 2000 lux

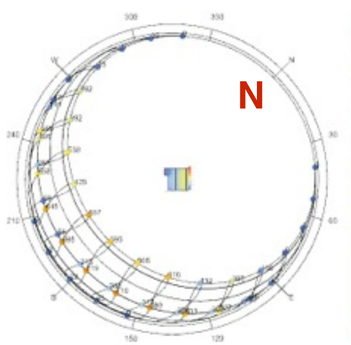


UDLI > 2000 lux

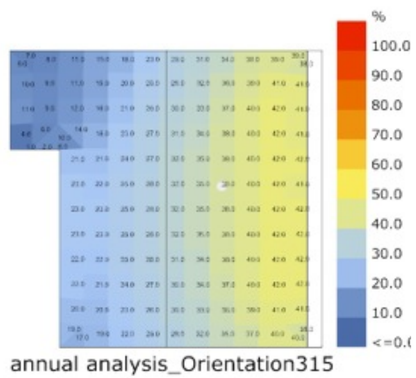


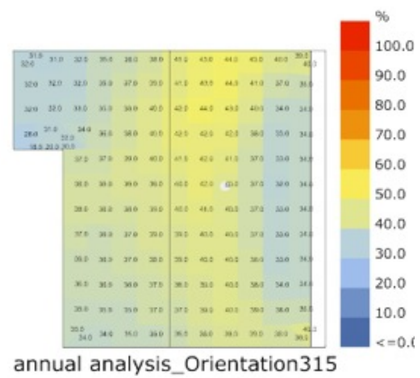
Energy Loads

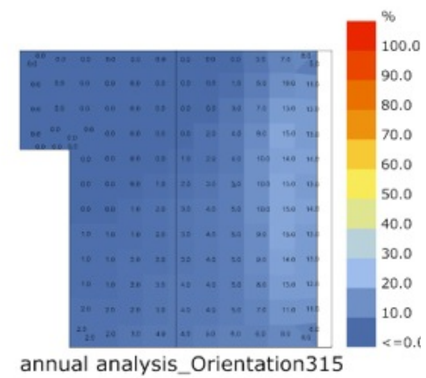


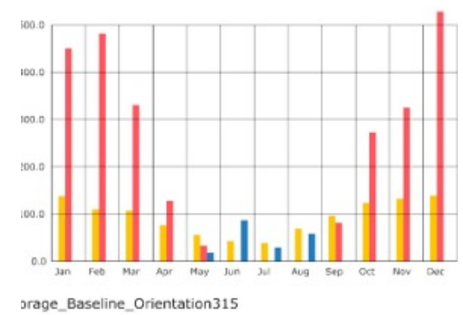


Case#8: **315°**

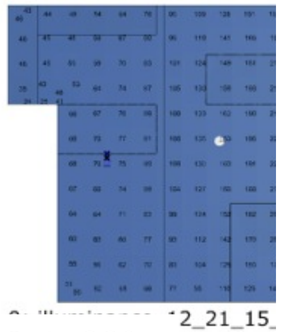


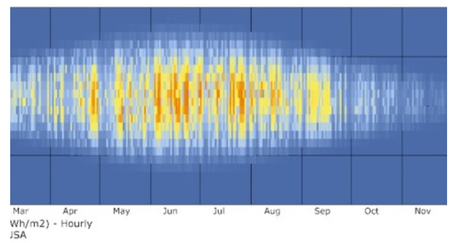




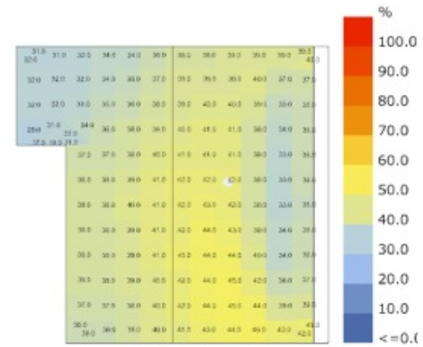


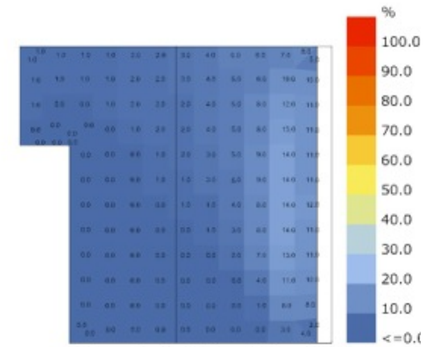
G Appendix 1 - **D1** Orientation

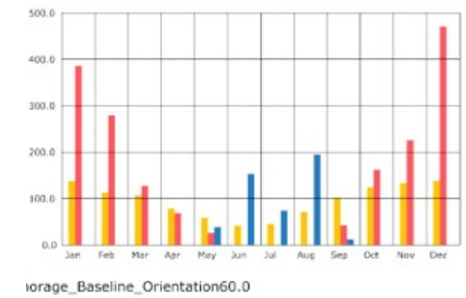


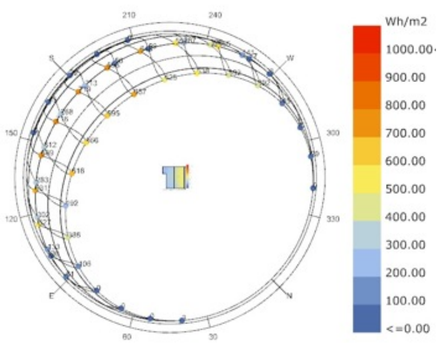


Case#2-1: **60°**

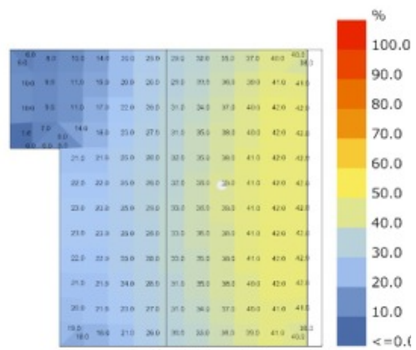


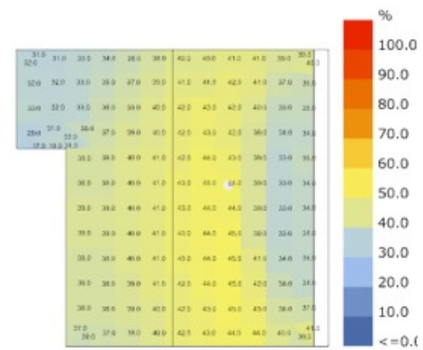


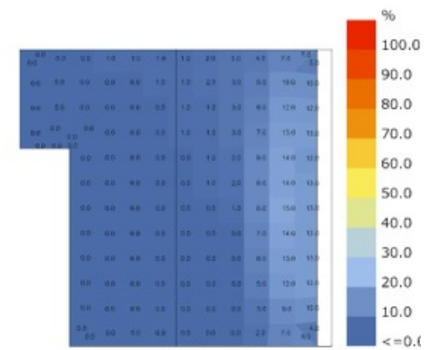


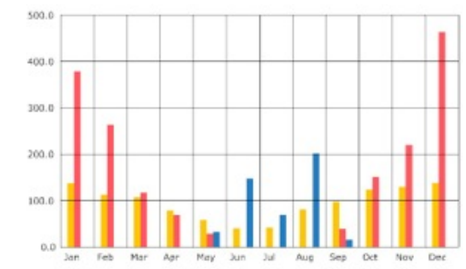


Case#2-2: **75°**



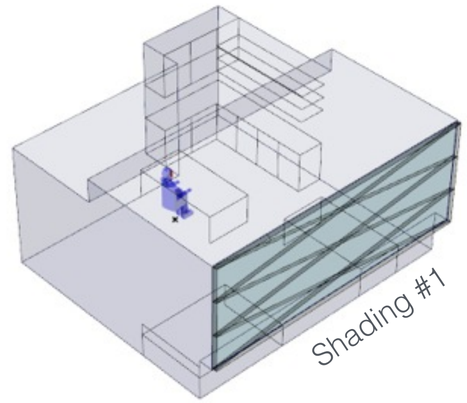


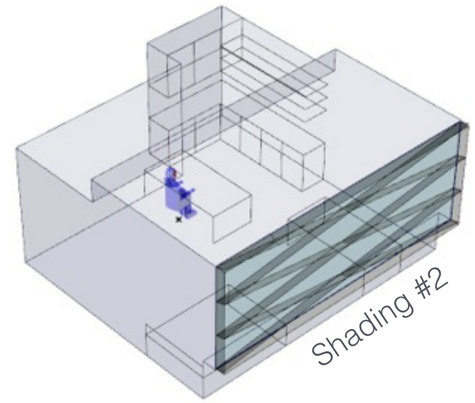


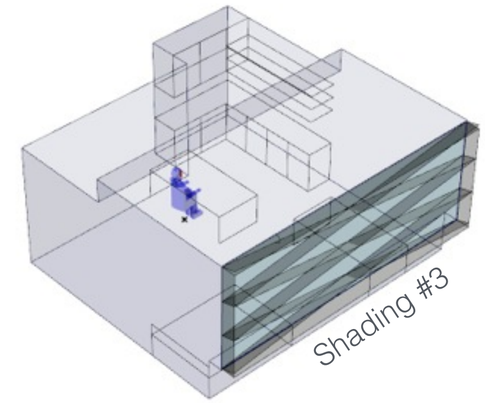


Depth 0.1m | **Depth 0.2m** | **Depth 0.3m**

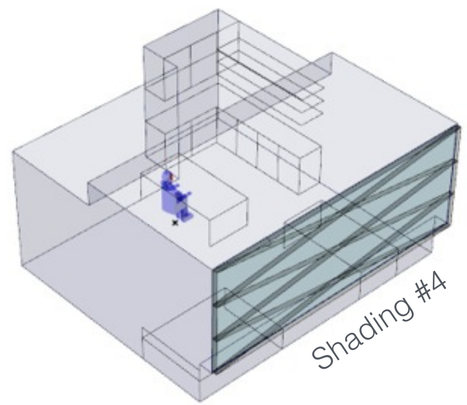
Angle -15°

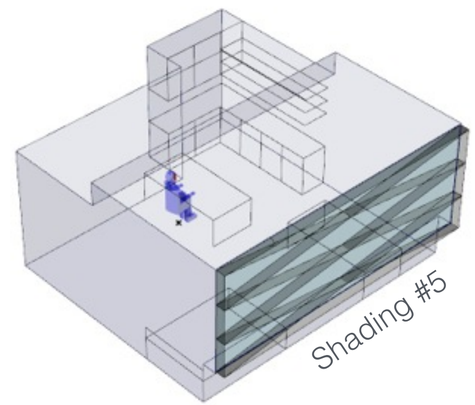


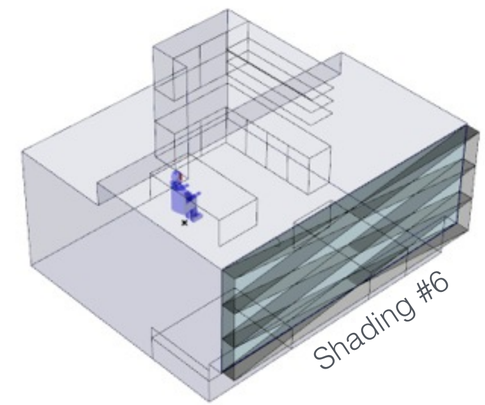




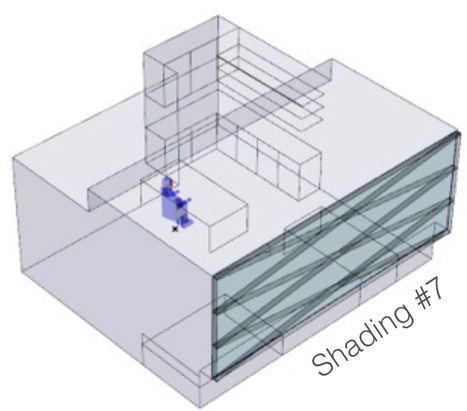
Angle 0°

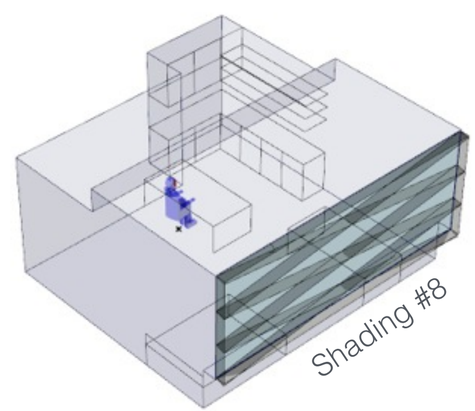


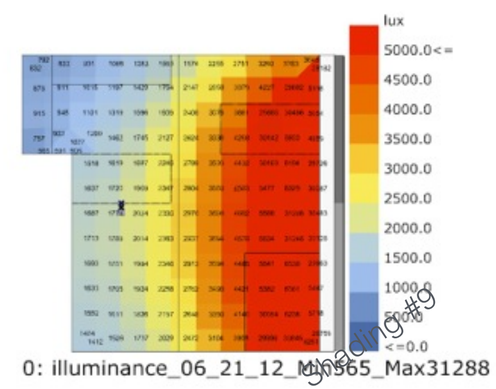




Angle +15°



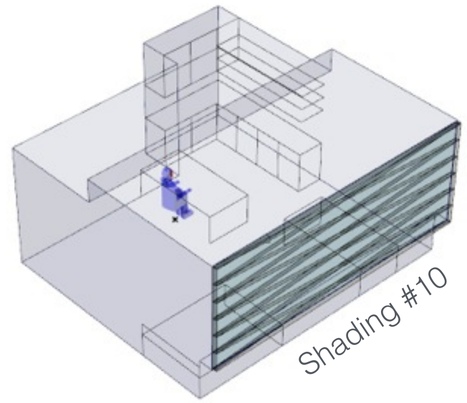


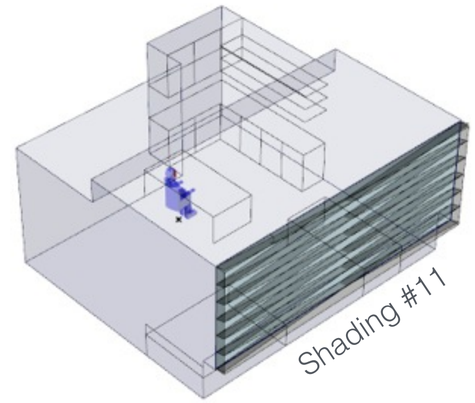


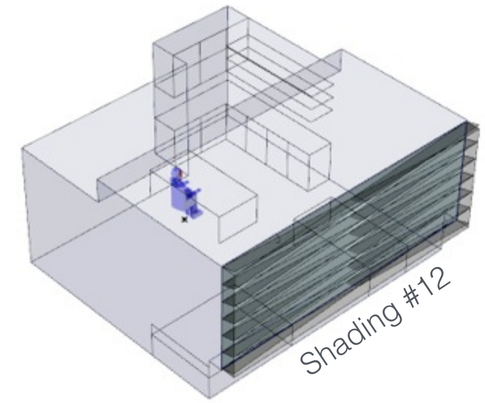
Number of Shading: 3

Depth 0.1m | **Depth 0.2m** | **Depth 0.3m**

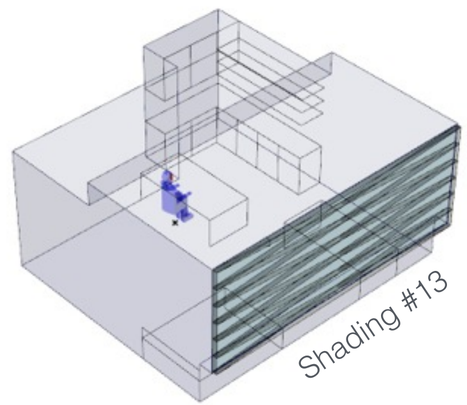
Angle -15°

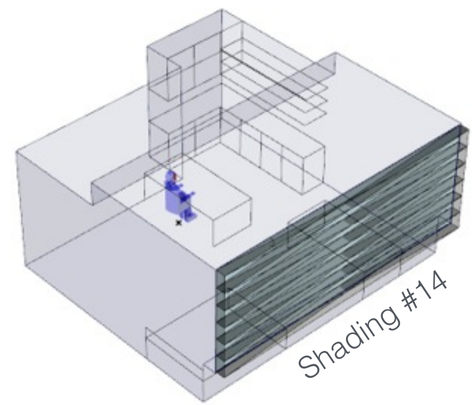


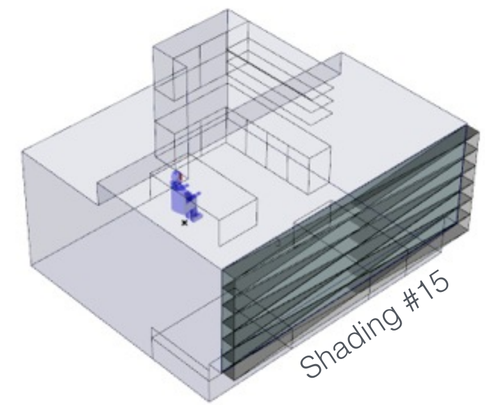




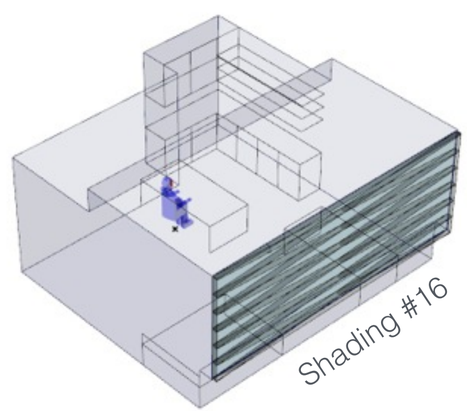
Angle 0°

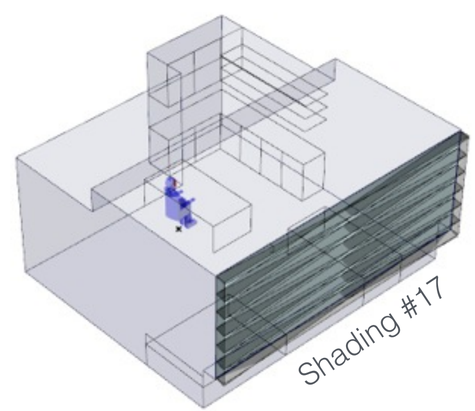


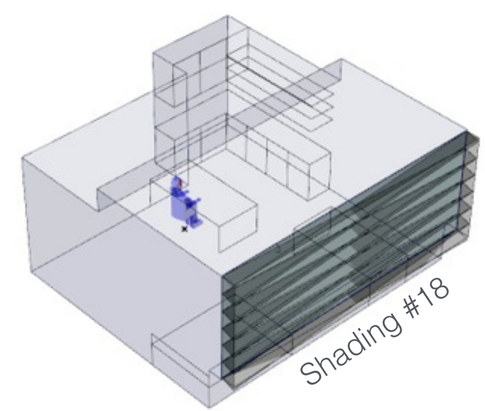




Angle +15°



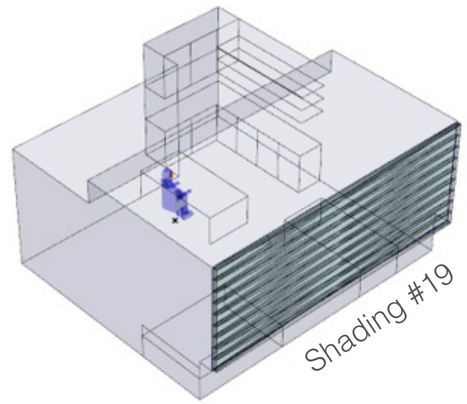


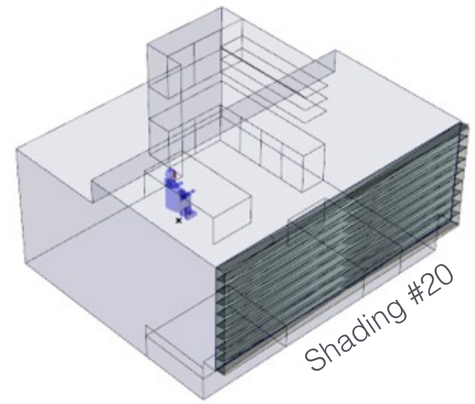


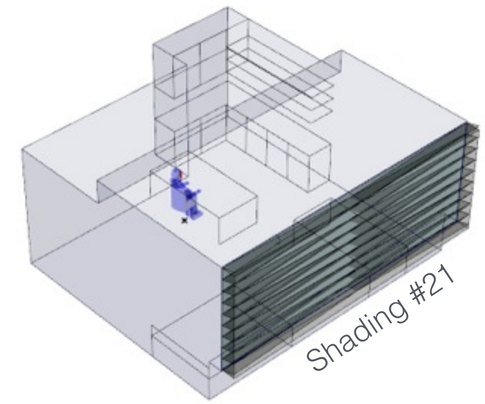
Number of Shading: 6

Depth 0.1m | **Depth 0.2m** | **Depth 0.3m**

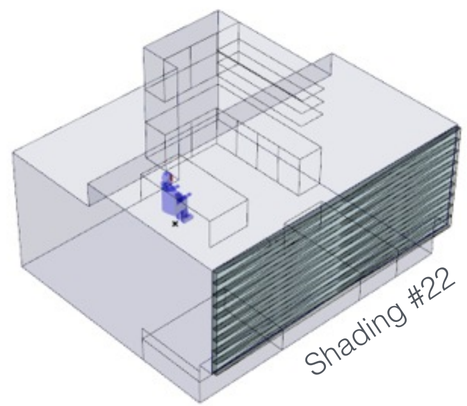
Angle -15°

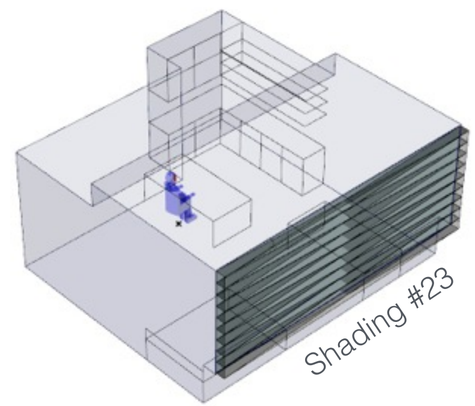


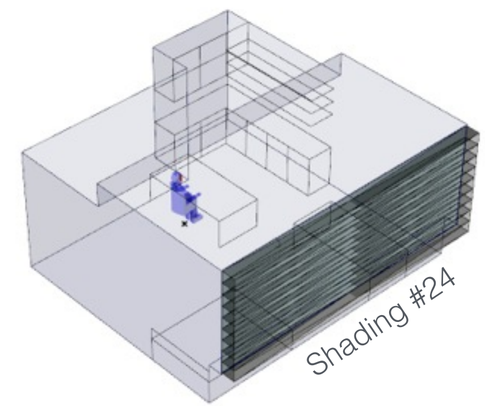




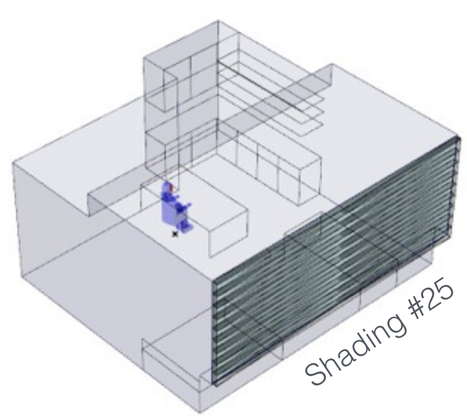
Angle 0°

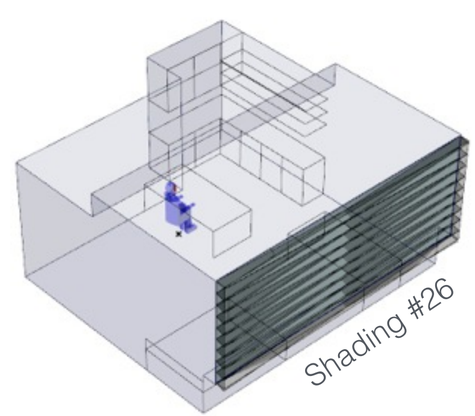


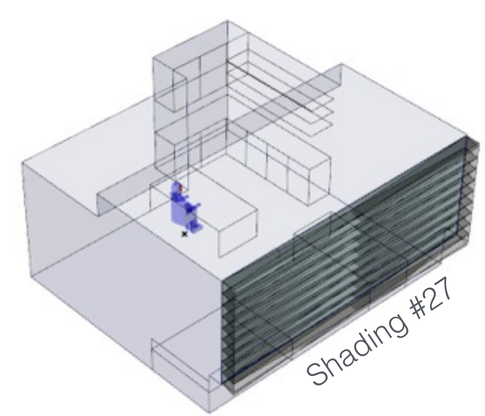




Angle +15°



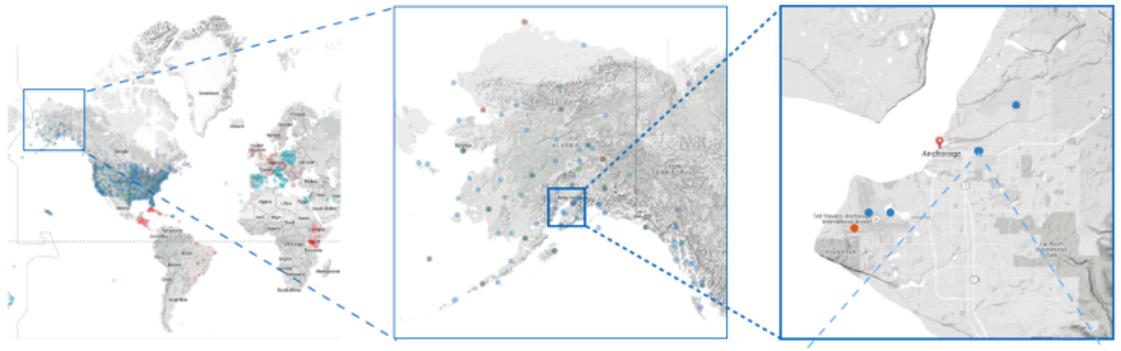


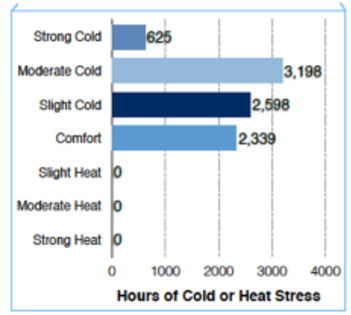


Number of Shading: 9

ARCH753 Building Performance Simulation / Final Project

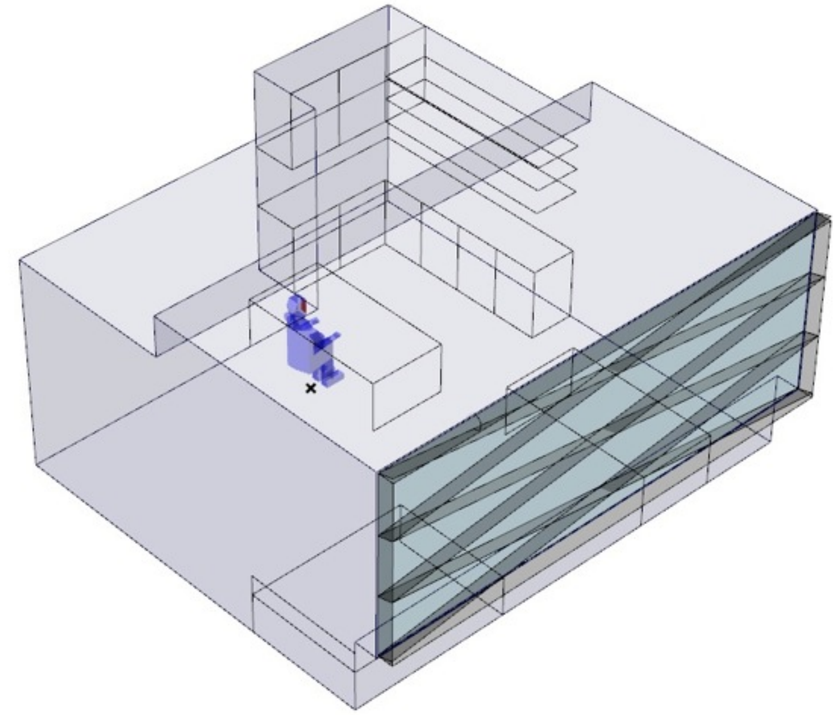
JEEEUN LEE

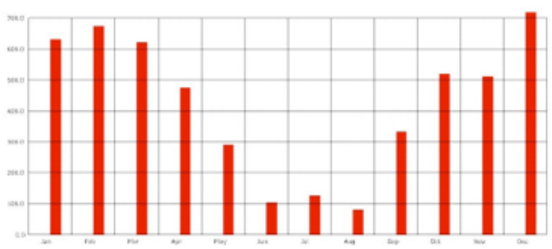




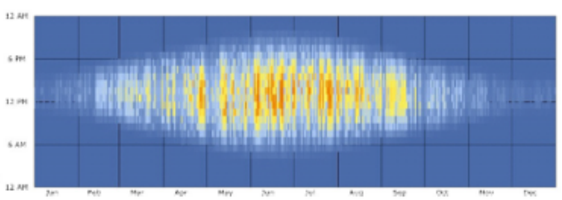
WEATHER DATA (EPW FILE)

Station Name: Anchorage-Merrill
Data Source: TMY3
Latitude: 61.22°N
Longitude: -149.85°
EPW URL: http://apps1.eere.energy.gov/buildings/energyplus/weatherdata/4_north_and_central_america_wmo_region_4/1_usa/USA_AK_Anchorage-Merrill.Field.702735_TMY3.zip

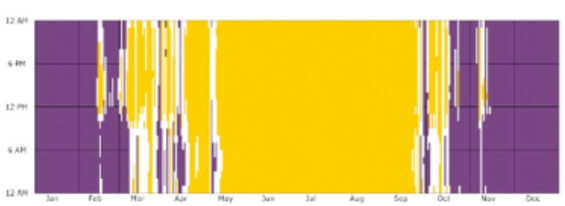




Cold Temperature; only heating degree days exist



Lack OF Solar Radiation



Too much heat in summer indoor

D1 Orientation

To optimize the orientation, energy simulation will be helpful to figure out wichi orientation requires less loads.

The orientation of the lowest values can reflect that there will be less hours of uncomfortable without HVAC.

D2 Natural Ventilation

Without HVAC, natural ventilation is an effective way to emit the collected heat during the summer time.

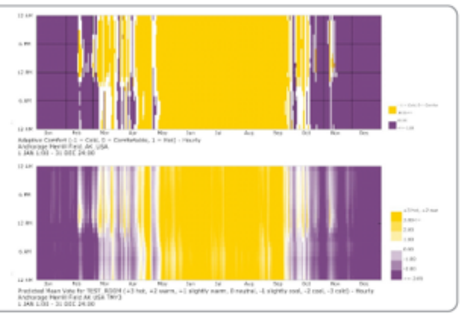
D3 Shading

To reduce radiation in summer and maximize radiation in winter, horizontal shadings with certain angle will be helpful.

Adaptive Comfort:
11.74%
1028 hours / year

% of Hot: 49.39%
% of Cold: 38.87%

PMV Comfort:
7.26%
636 hours / year

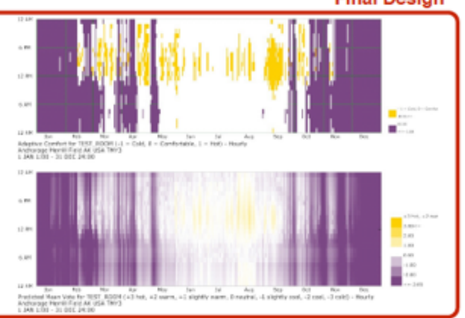


Final Design

Adaptive Comfort:
47.25%
4139 hours / year

% of Hot: 6.90%
% of Cold: 45.84%

PMV Comfort:
33.07%
2897 hours / year



Adaptive	PMV	Design Proposals
11.58	6.99	D1 Orientation
46.74	34.24	D2 Natural Ventilation
47.25	33.07	D3 Shading