



ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

April Burn-in Testing Report for Genentech B35, South San Francisco Campus

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Energy Technologies Area
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April Burn-in Testing Report

Genentech B35

June 30, 2015

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Executive Summary

Genentech and Webcor reserved a thirty-day “burn-in” period after completion of the commissioning phase to conduct a detailed evaluation of all systems in the new HTA B35 building prior to occupancy. During this period, LBNL evaluated the automated shading and dimmable indoor lighting control systems to determine whether the systems were working according to design intent. LBNL also evaluated lighting energy use and visual and thermal comfort in the perimeter zones.

LBNL conducted the monitored evaluation in four perimeter zones on the 7th floor from March 25th to May 7th, 2015. The daylight and tuning control functions of the dimmable LED direct-indirect lighting control system were evaluated and then adjusted in collaboration with the electrical contractor (Redwood Electric) during the first three weeks of the evaluation. The lighting controls were then considered to be operating as expected after April 20th and a detailed evaluation of control performance and energy use was conducted thereafter. The automated shading system was assessed over a limited period (April 15-30) on both the 6th and 7th floors to determine whether the controls raised the shade when discomfort glare was imperceptible. After a few days of analysis, changes were made to the settings to admit more daylight by changing both the glare sensor threshold and by increasing the depth of direct sun ingress from 36” to 48” from the façade on all orientations except the east.

Outcomes of this analysis:

Discomfort glare was controlled adequately by the automated shades over the entire monitored period in all four zones. Time-lapsed high dynamic range luminance images captured every 5 min from 6:00 AM to 8:00 PM PDT were used to compute the daylight glare probability (DGP). The cumulative DGP data per day indicated that discomfort glare was adequately controlled (within the “imperceptible glare” range or Class A) for view positions looking toward the computer monitors. For atypical views looking toward the window, the cumulative DGP fell within the perceptible range (Class B) primarily because to the intense luminance of the sun orb that was perceptible through the shade fabric (3% openness factor).

After an adjustment to the sensor threshold, the automated control system raised the shades with a modest degree of conservatism when discomfort glare was imperceptible for typical views looking towards the monitor. In some cases, shades were not raised for several hours after glare had dropped below imperceptible levels. Because view directions produce various degrees of discomfort glare and a single threshold is used for automated control, one can expect some degree of variation in the level of responsiveness. The threshold may need to readjusted during the winter period when sun angles are lower.

Outcomes of this analysis (continued):

The lighting controls were found to maintain adequate minimum illuminance on the workplane in all of the four areas over the course of the day throughout the post-commissioned period (April 21st to May 7th). Control settings derived from prior detailed tests in the LBNL FLEXLAB facility were used to commission the daylighting control system. For the most part, the lighting system was insufficiently dimmed (about 100 lux more than the desired range). This is appropriately conservative and will result in greater energy use but less complaints of inadequate lighting levels. In the east area, the lighting control system did not dim sufficiently but the source of the error was not found.

Daily lighting energy use during the monitored period was reduced by 53% using an enhanced LBNL strategy compared to the default settings implemented by the lighting controls vendor. Over the monitored post-commissioned period, the effective lighting power density due to daylight dimming (8AM-6PM DST) was between 0.15-0.13 W/ft² for the enhanced strategy in the south, west and north areas. For the default strategy, the LPD was between 0.29-0.30 W/ft². The installed load at full output was 0.51 W/ft². During the afternoon when peak demand charges are in effect, LPD levels dropped to 0.05-0.06 W/ft² for the enhanced case, where minimum dim levels were 15% for the downlights and 0% for the uplights. Task level tuning was implemented but then overridden to a higher full output level by the commissioning agent in order to compensate for low illuminance levels in several limited areas on the floor. If task tuning was set to the level advocated by LBNL (nighttime average illuminance of 300 lux), lighting energy savings would be even greater.

Thermal conditions were slightly cool to comfortable in the perimeter zones during the monitored period. Thermal comfort was evaluated at various workstations near the window wall assuming a medium clothing level (clo=0.66, assuming a long sleeve shirt and trousers) and sedentary activity level (met=1.1). Thermal comfort would be affected by the air temperature and velocity of the output from the local overhead diffusers, the radiant temperature of the dark fabric roller shades (when irradiated by the sun) or unshaded glass, and possible convection near the windows due to temperature stratification. Similar to the findings at the FLEXLAB, the conditions were slightly cool on average. The south zone was cold in the morning. The east, west, and north zones were comfortable over the monitored period.

Note: Following the conclusion of our test the enhanced settings for the lighting control system used during the test were rolled out to the rest of the building. When visiting B35 for a follow up meeting we observed that on other floors the lighting control system was improperly commissioned: some uplights were probably reversed with the downlights in the control system. We are still planning to coordinate with Genentech to revise the commissioning of these areas.

1. Test Overview



Study Areas (7th Floor)



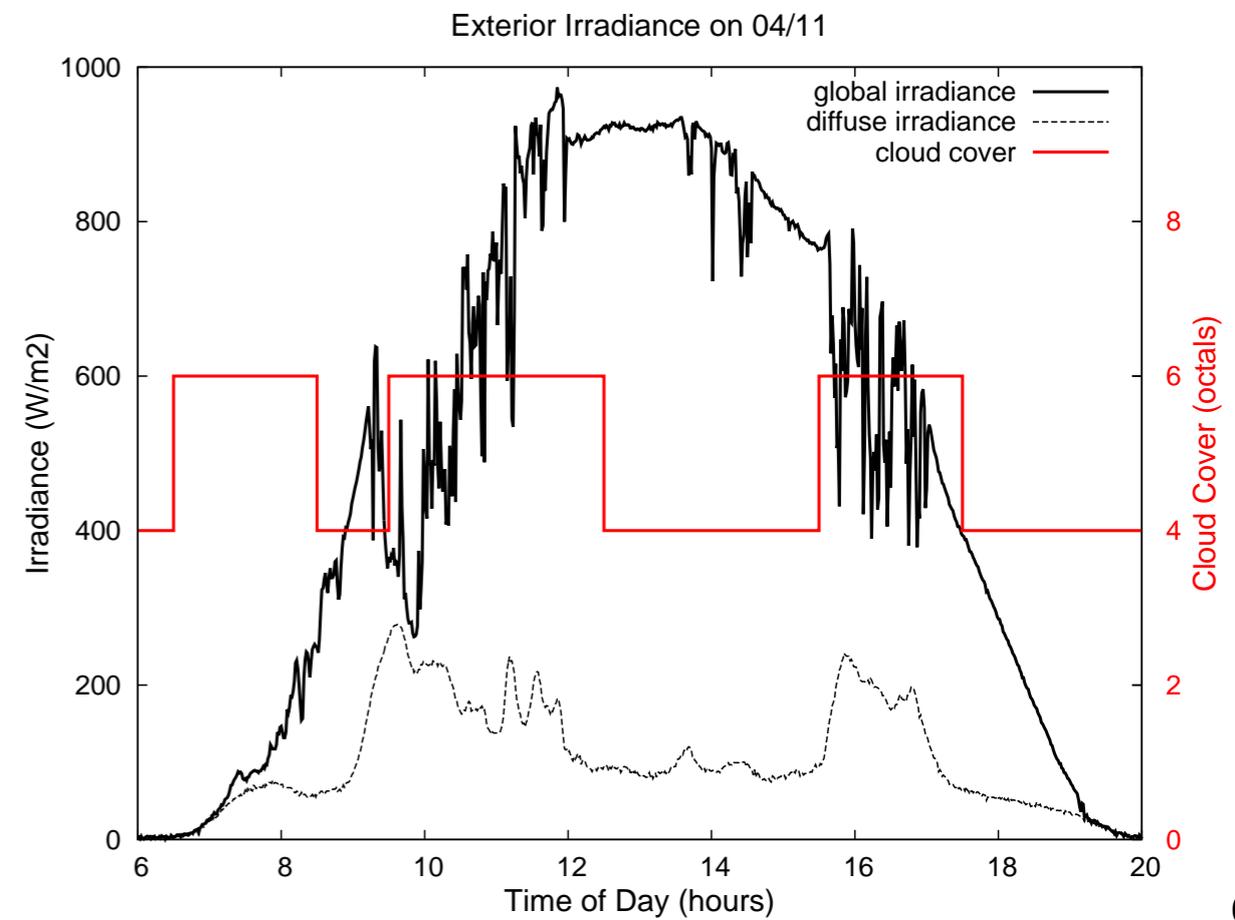
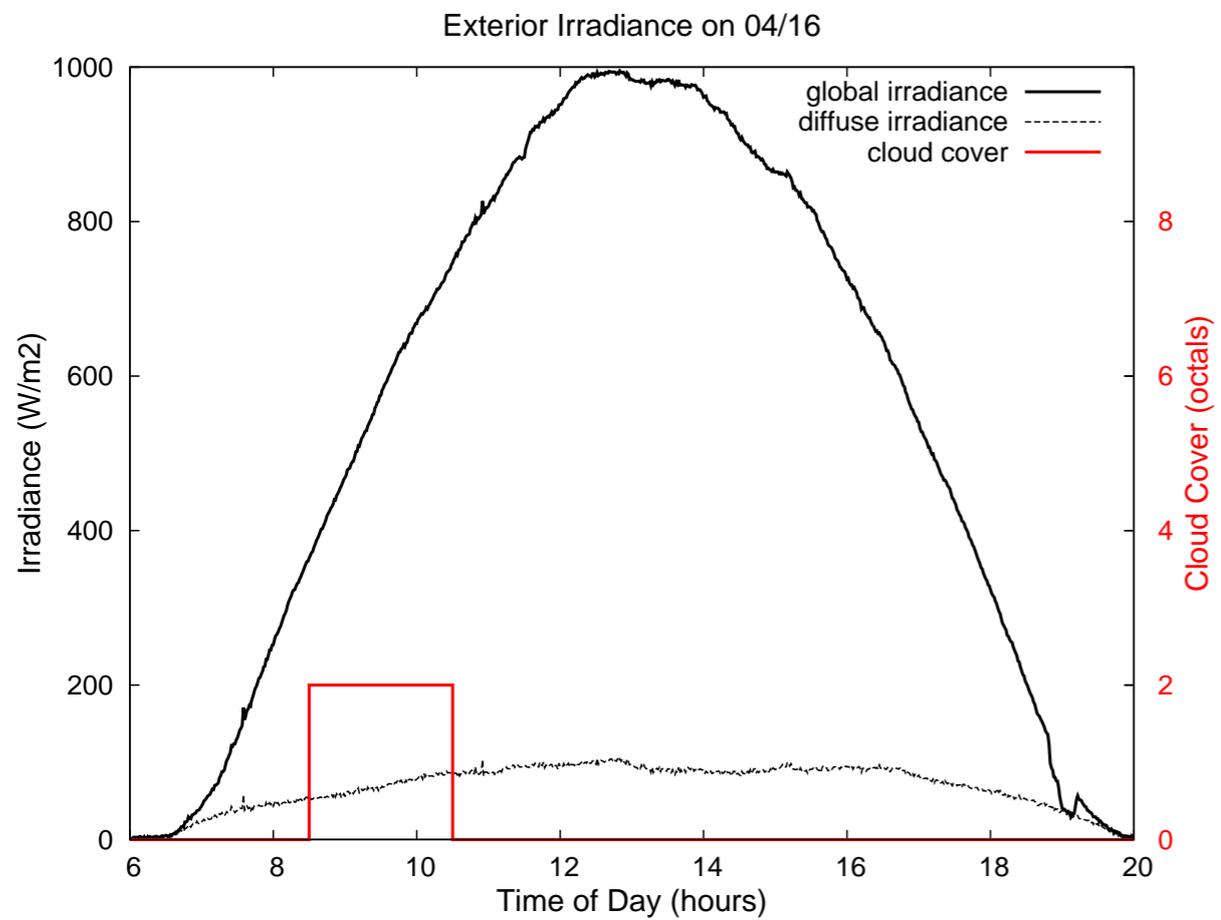
Weather Conditions During Test Period

A sunshine pyranometer (SPN-1 by Delta-T Devices) mounted to the railing on the roof measured exterior irradiance conditions for part of the test period. The SPN-1 measures both global and diffuse horizontal irradiance. These measurements allow us to determine the sky conditions (eg, clear, dynamic, or overcast) during the measurement period.

The sunshine pyranometer was installed on April 10, 2015. Unfortunately a problem with the device recording and storing data prevented data from being collected after April 17, 2015. In order to understand sky conditions during the periods without data collect on site, we used historical Meteorological Terminal Aviation Routine Weather Reports (METAR) from SFO airport, located 2.5 miles south of B35. The reports contain hourly sky cover observations reported in octals (fraction of sky coverage in 1/8 increments). The charts below show measured irradiance and reported cloud cover on a clear day (left) and dynamic day (right). These charts indicate that reported cloud cover at SFO gives a reliable indication of sky conditions at B35.

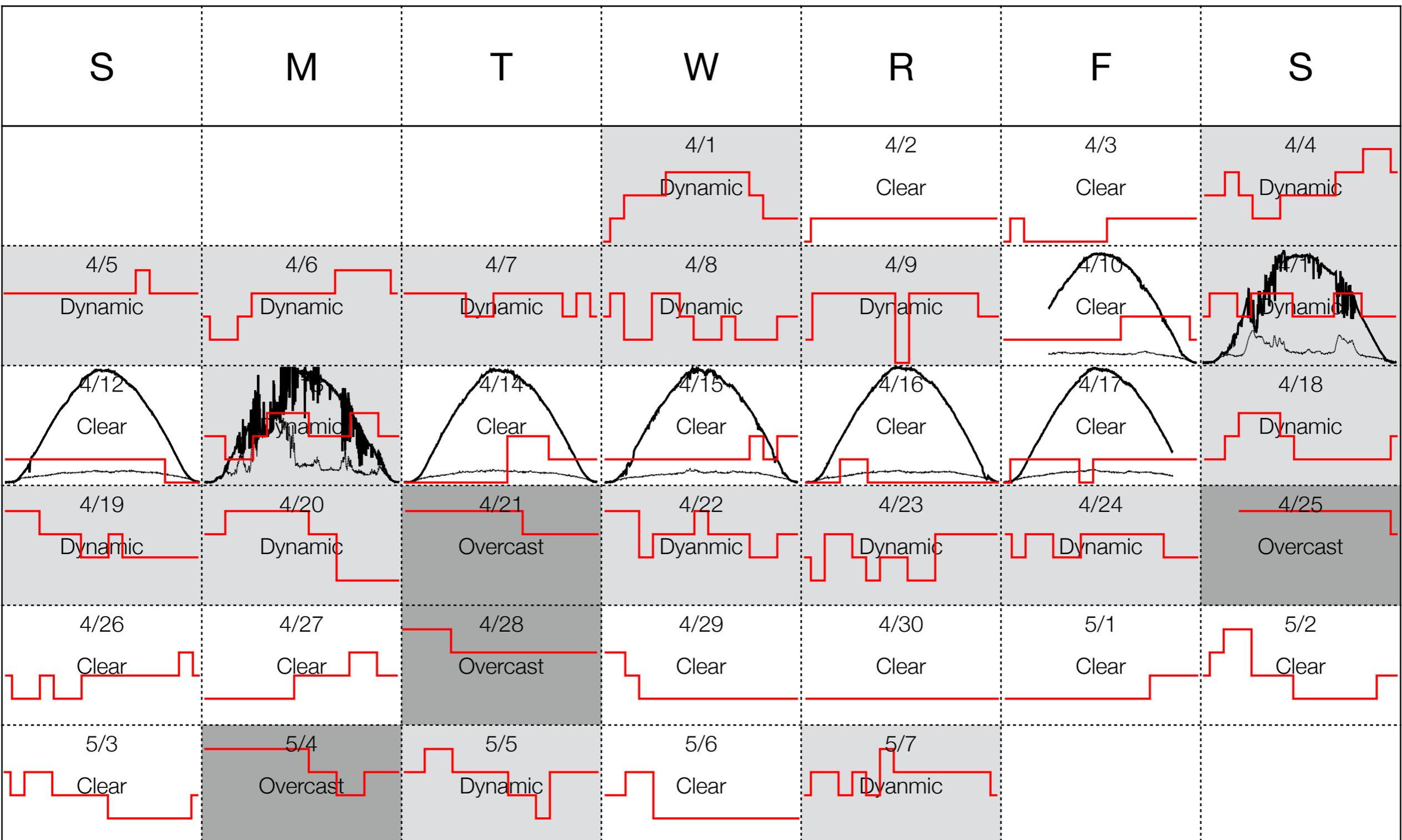


Sunshine Pyranometer installed on the railing of B35 roof.



Weather Conditions During Test Period

Sparklines plotted in the calendar below indicated cloud cover (red), global horizontal irradiance (black) and diffuse horizontal irradiance (gray). The days are coded as clear, dynamic, and overcast based on data presented and HDR photos taken that day.



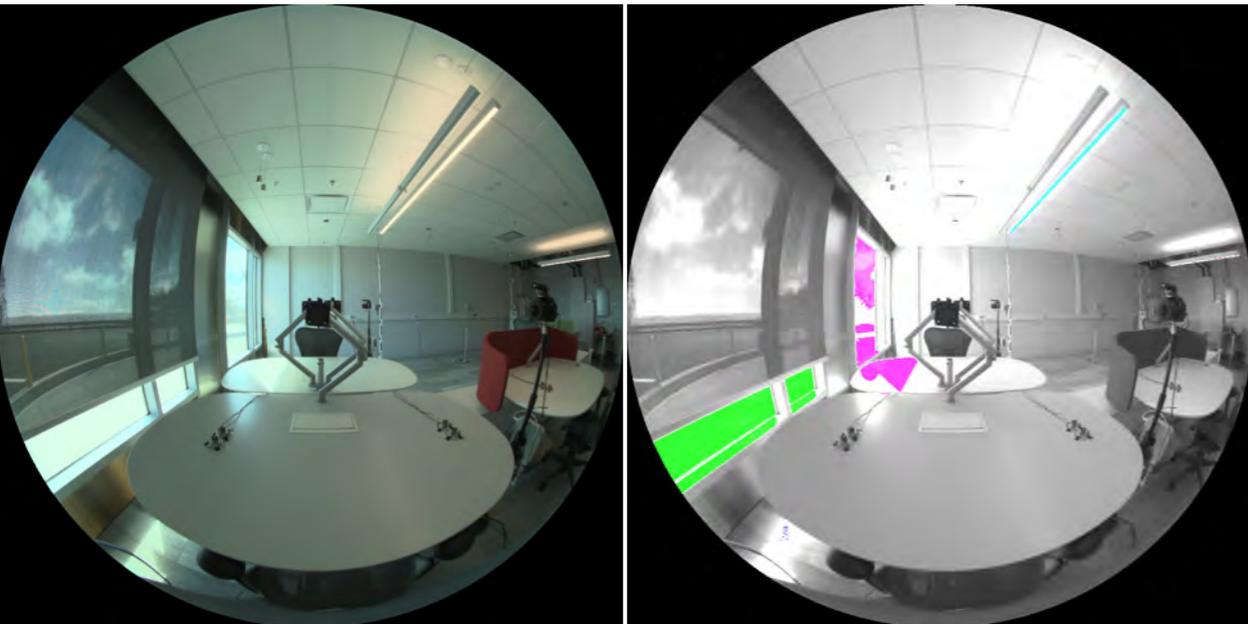
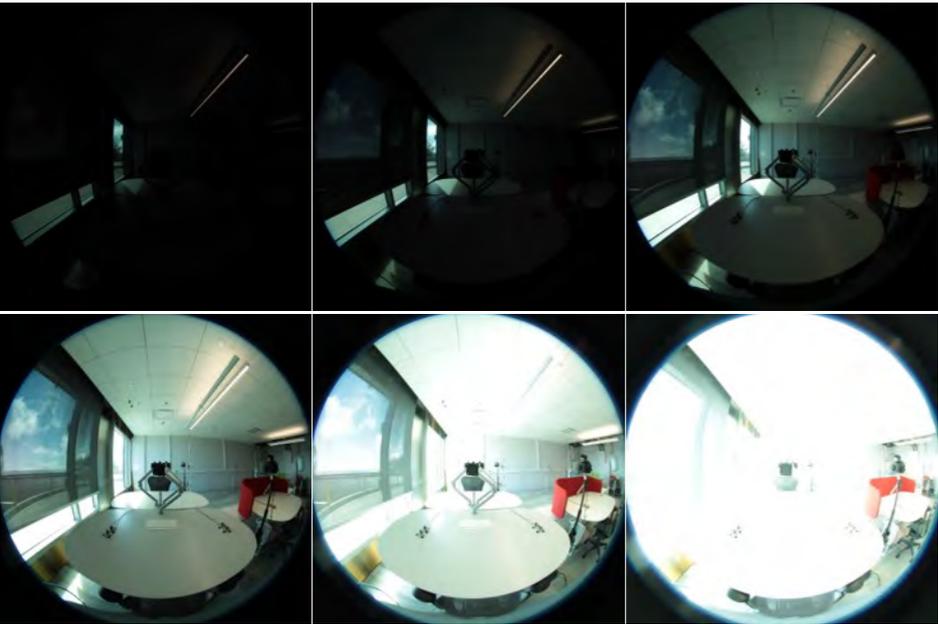
2. Glare Assessment



Glare | Method

Glare evaluation

Luminance maps of the visual environment were captured every 5 minutes between the hours of 6 AM and 8 PM PDT. The luminance maps were analyzed for discomfort glare using Evalglare to compute Daylight Glare Probability (DGP).



Monitoring Hardware

Luminance maps were created using a consumer DSLR camera with 180° fisheye lens attached to a weighted stand (pictured right). The camera was tethered to a computer that automated the capture of six photos with varied shutter speeds. The computer then converted the low dynamic range photos into a high dynamic range (HDR) photo, with absolute luminance value (in cd/m²) for each pixel in the HDR image. The image was calibrated using a photometer mounted to the top of the camera aligned with the front of the lens.

Camera locations

One camera was placed in each of the study areas (four cameras total) during the monitoring period. Because the glare evaluation is only valid for the position of the camera, every few days the cameras were moved to a new desk for evaluation.

Four additional cameras were used on the sixth floor during the shade control evaluation period (April 15 - April 30).



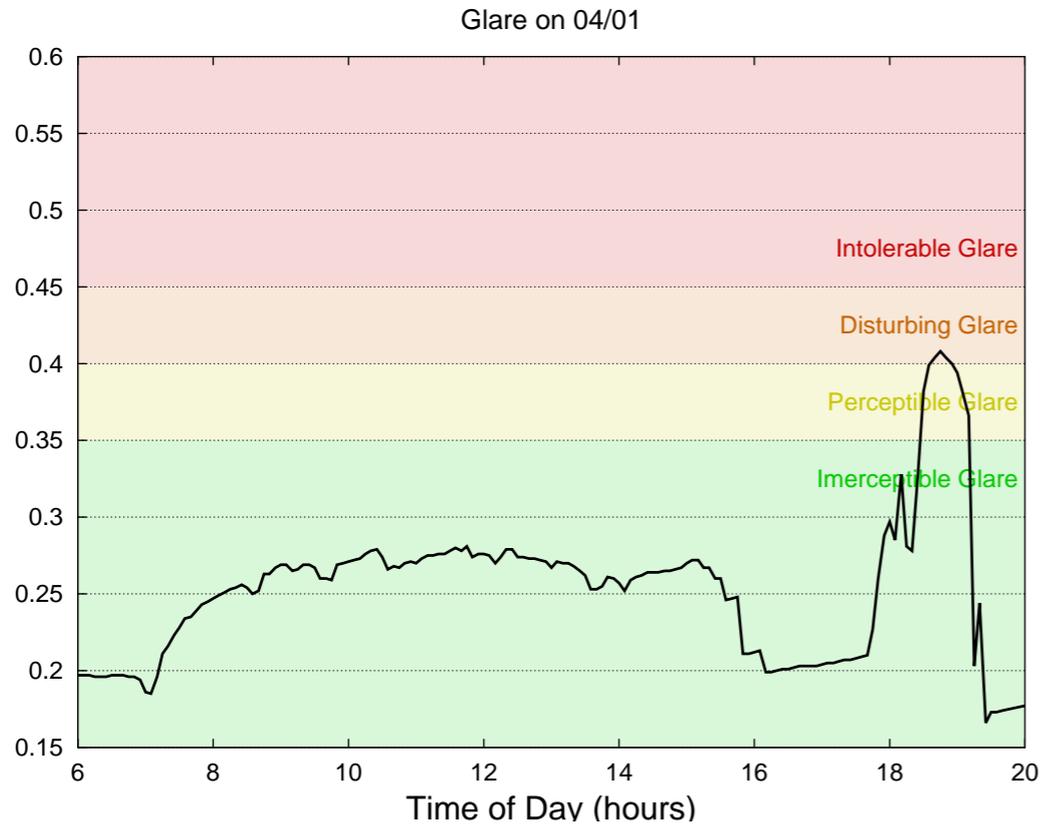
Top, exposure bracketed low dynamic range photos taken in FLEXLAB.

Bottom left, Tone-mapped HDR image generated from LDR photos.

Bottom right, HDR photo with potential glare sources identified as colored regions.

Glare | Metrics

Daily DGP Plot

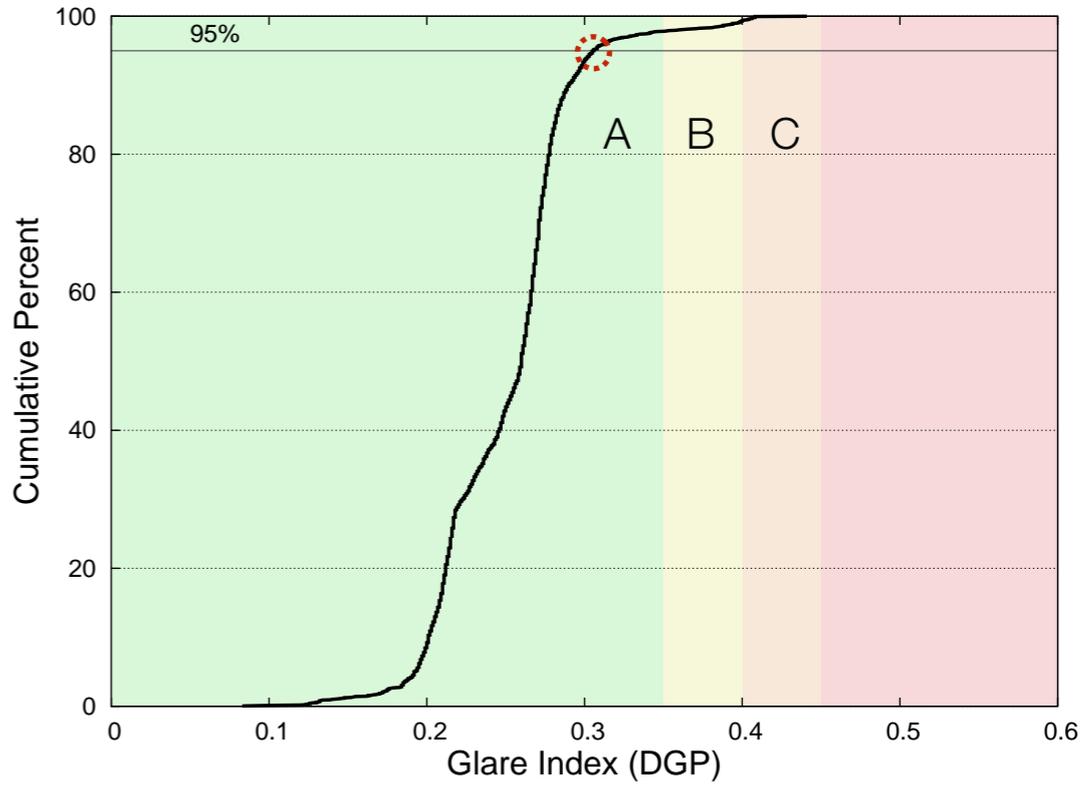


DGP for a particular camera location and facing direction is plotted for an entire day in the “Daily DGP Plots.” The x-axis is hour of the day, in local time time. The y-axis shows DGP, shaded according to correlated subjective response (see table below). One plot is shown for each camera position, typically a sunny day.

DGP correlations to subjective response

SUBJECTIVE RESPONSE	DGP
Imperceptible Glare	< 0.35
Perceptible Glare	0.35 - 0.40
Disturbing Glare	0.40 - 0.45
Intolerable Glare	> 0.45

DGP Cumulative Distribution Plot



The cumulative distribution plot depicts all valid measurements for a particular camera position and facing direction (over several days). Days where shades did not operate (due to power outage or similar) are omitted from these charts. The cumulative distribution is used to calculate the visual comfort class ratings according to Jan Wienold’s recommendations (set table below). The color shading depicts the 95% threshold for each comfort class. The location where the CDF plot crosses the 95% line (circled) corresponds to the 95% DGP limit condition.

Visual comfort class ratings for offices based on cumulative DGP glare index

	A BEST CLASS	B GOOD CLASS	C REASONABLE CLASS
	95% of office time glare is weaker than 'imperceptible'	95% of office time glare is weaker than 'perceptible'	95% of office time glare is weaker than 'disturbing'
DGP Limit (95%)	0.35	0.40	0.45
Average DGP within top 5% band	0.38	0.42	0.53

Source: Wienold, J., 2009. Dynamic Daylight Glare Evaluation. Eleventh International IBPSA Conference, Glasgow Scotland

Glare | Summary

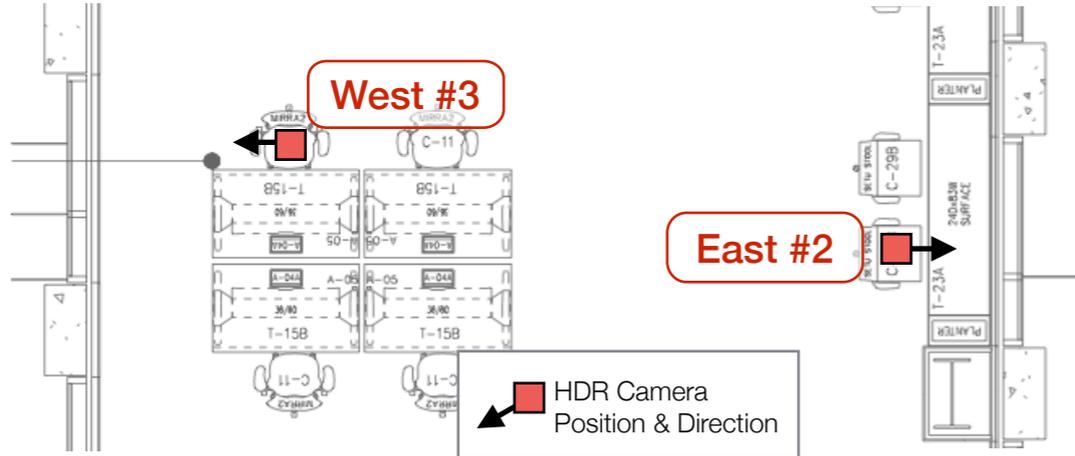
Summary of Results

The table to the right show the statistics and comfort class for all the camera positions. The majority of conditions tested exhibited an ‘A’ class comfort rating. The four ‘B’ class conditions involved unusual cases and are explained below. These results indicate that discomfort glare was minimal between the hours of 7 am and 7pm during the monitoring period (March 25 - May 7).

‘B’ Class Rated Positions

Of the four positions that achieve a ‘B’ class rating, three are instances where the camera was not facing the direction of the desk. Instead, the camera was faced directly towards the window (see diagram below). The cameras were faced towards the window to provide a better indication of shade operation.

The fourth ‘B’ class position (East #2) was a counter seat next to the facade. The camera was raised to the eye height for the taller stool and faced out the window. Occasional glare should be expected when seated at the facade.



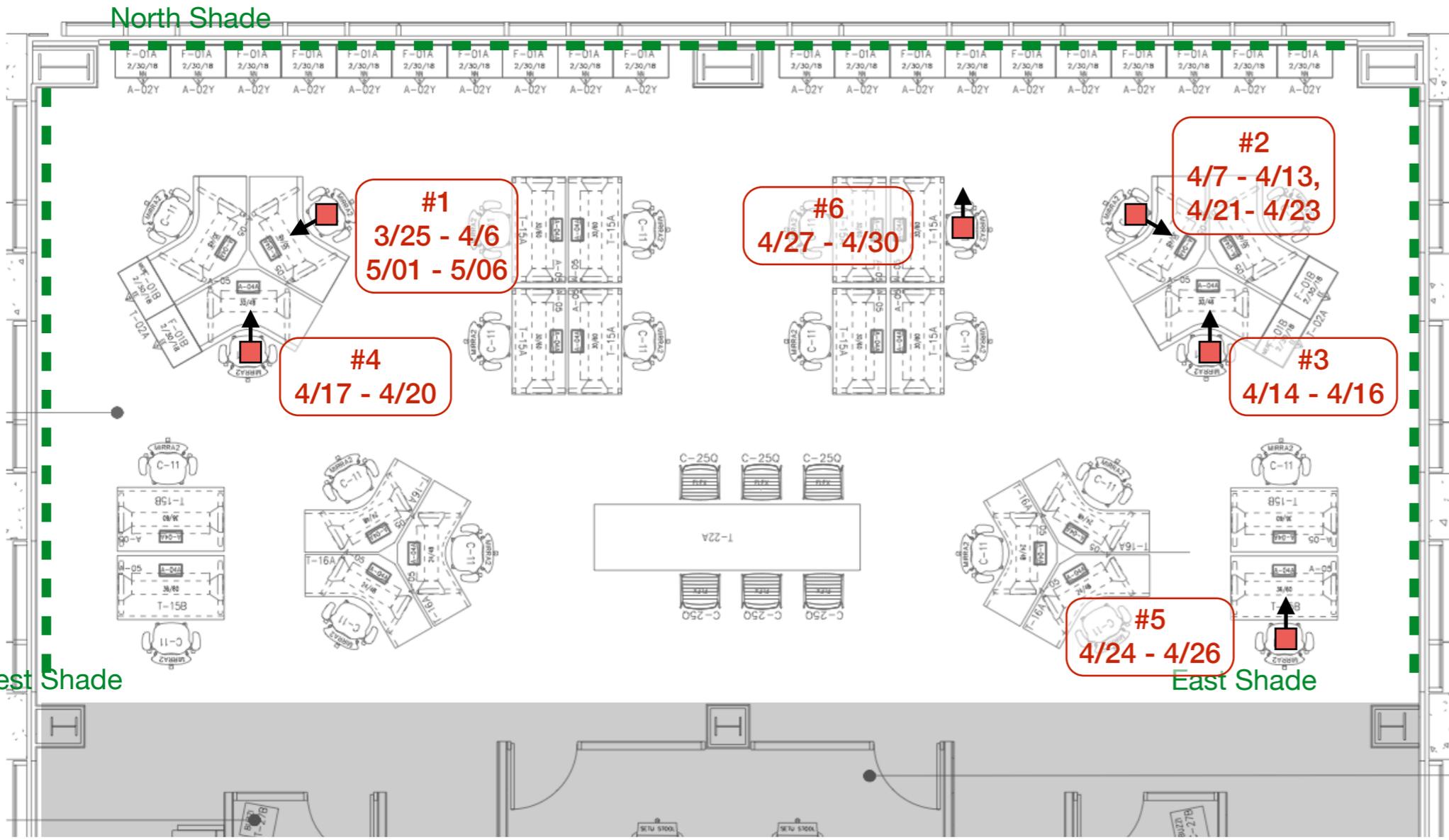
Instead of facing desk, West #3, South #5 and North #6 faced directly towards the window, as indicated by the arrow.

East #2 position is located at the counter seating along the facade.

Cumulative Glare Statistics for HDR measurement Locations

	95% DGP THRESHOLD	AVERAGE DGP WITHIN TOP 5% BAND	COMFORT CLASS RATING
North #1	0.306	0.354	A
North #2	0.276	0.284	A
North #3	0.347	0.367	A
North #4	0.324	0.361	A
North #5	0.279	0.290	A
North #6	0.360	0.372	B
South #1	0.335	0.346	A
South #2	0.320	0.356	A
South #3	0.302	0.322	A
South #4	0.288	0.323	A
South #5	0.386	0.397	B
East #1	0.226	0.236	A
East #2	0.370	0.391	B
East #3	0.237	0.242	A
East #4	0.334	0.345	A
West #1	0.254	0.305	A
West #2	0.239	0.249	A
West #3	0.374	0.417	B

Glare | HDR Camera Locations, North Area

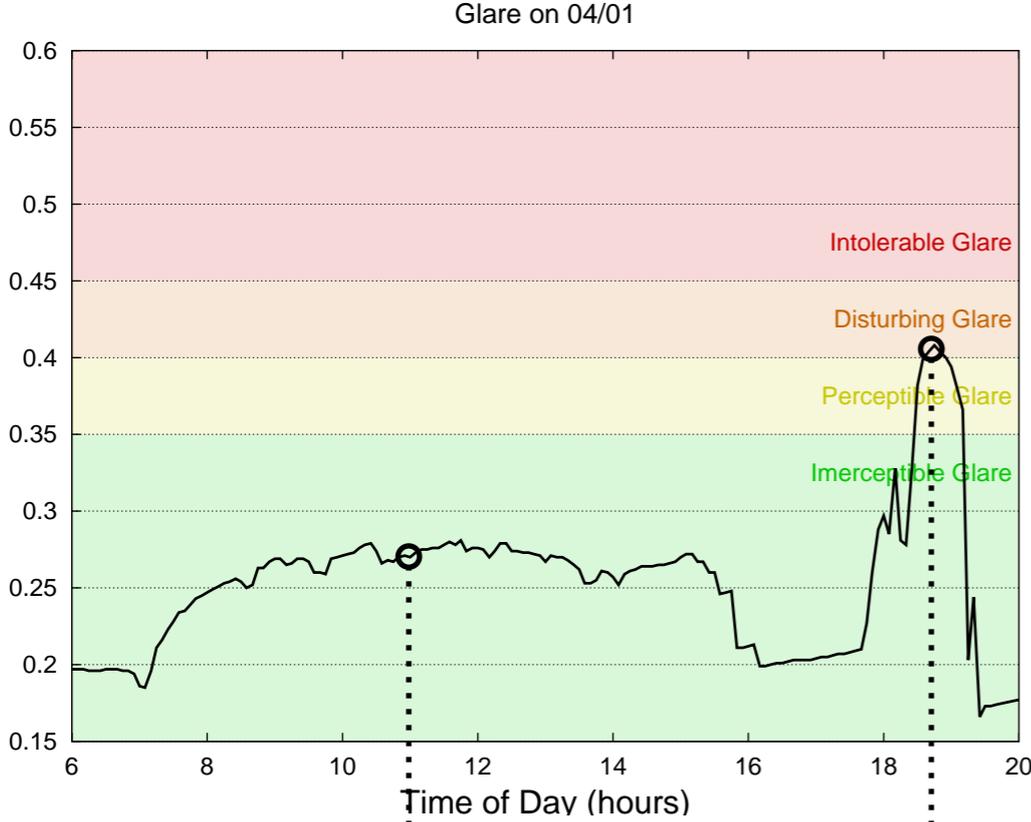


HDR Camera Position & Direction

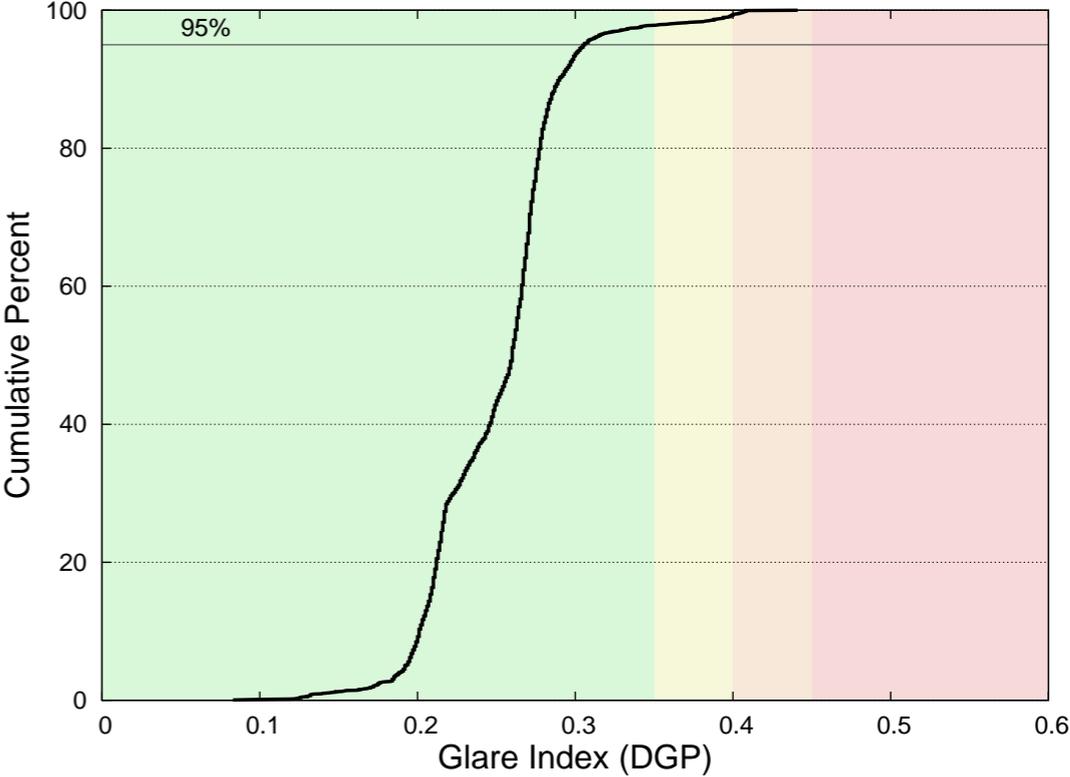
Shade Group

Glare | North #1 3/25-4/4 & 5/1-5/6

Daily Glare Plot for April 1, 2015



Cumulative DGP from 3/25 to 4/4 and 5/1 to 5/6



11:00

18:50

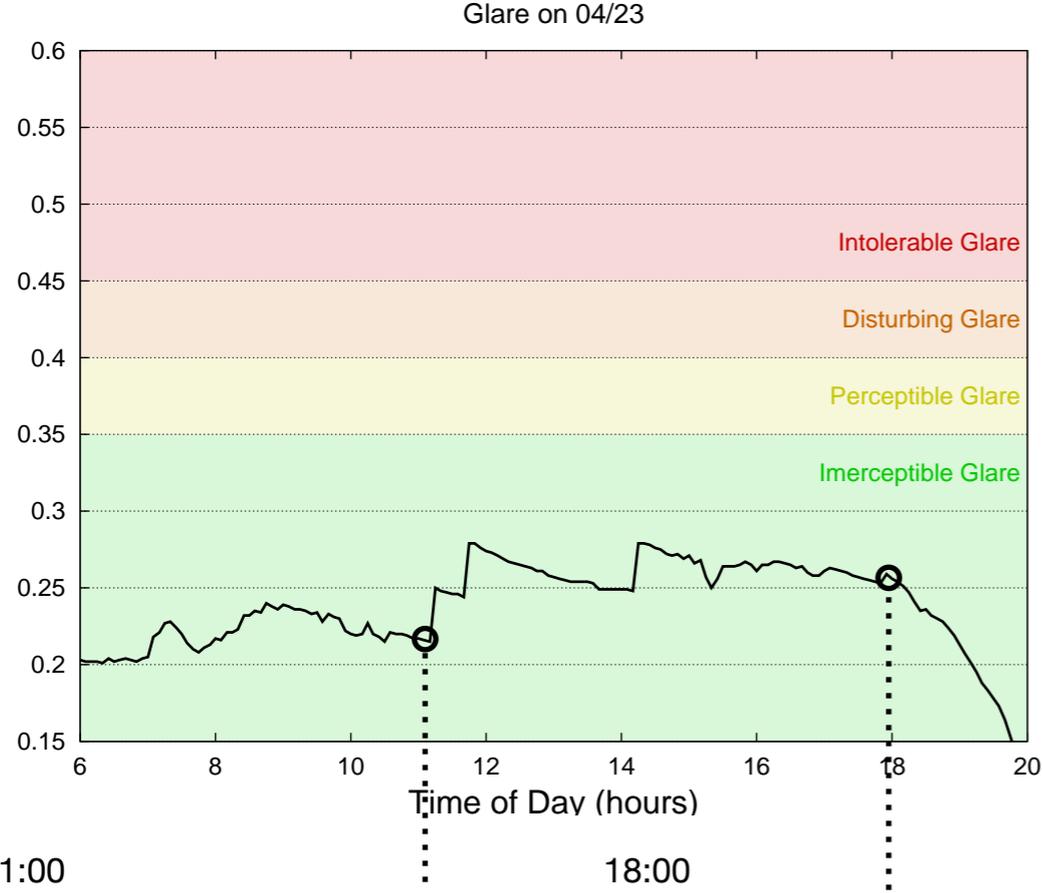


Cumulative DGP Statistics, Position #1, North Area

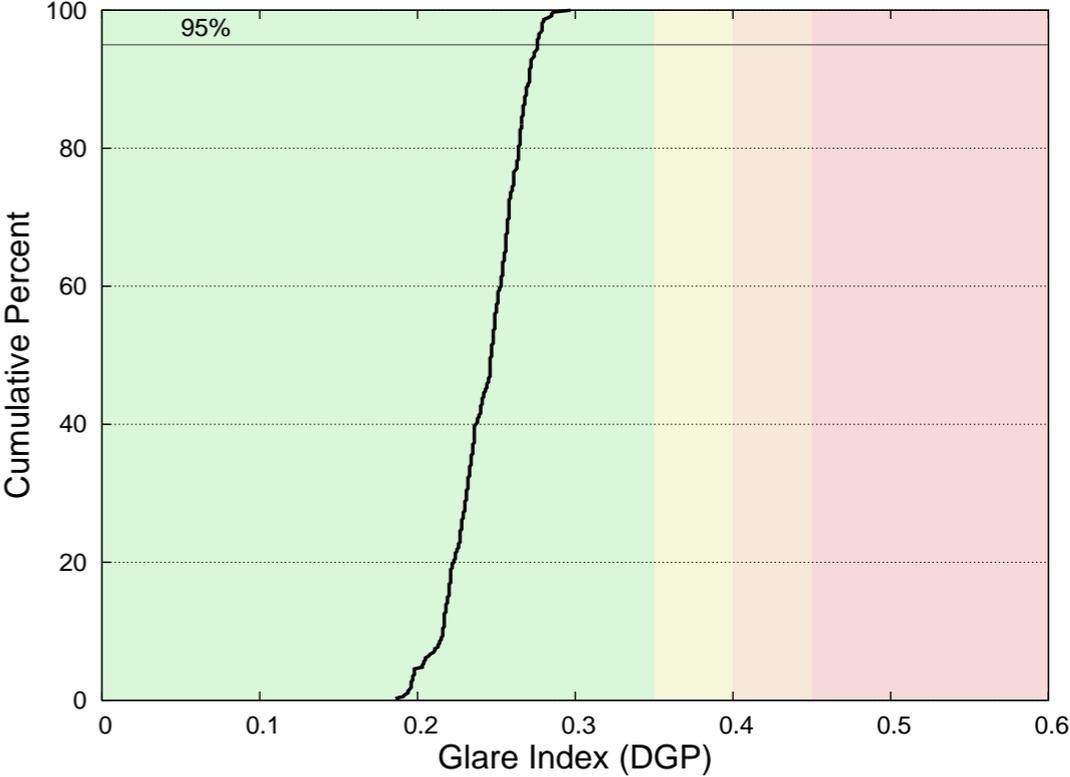
95% DGP Threshold	0.306
Average DGP within top 5% band	0.354
Comfort Class Rating	A

Glare | North #2 4/21-4/23

Daily Glare Plot for April 23, 2015

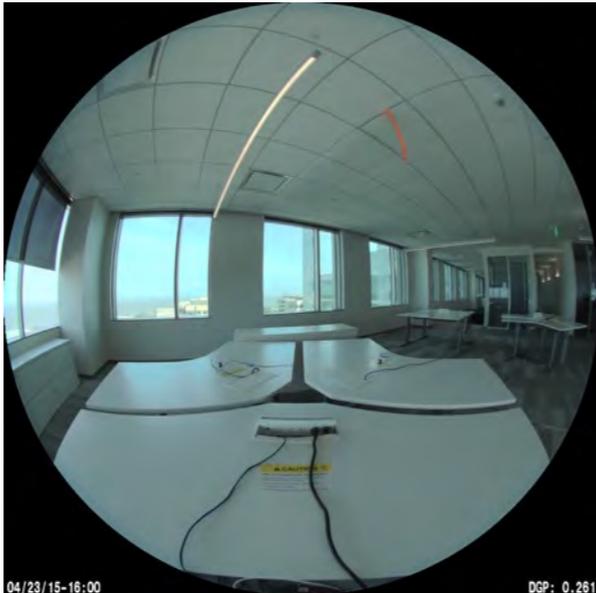
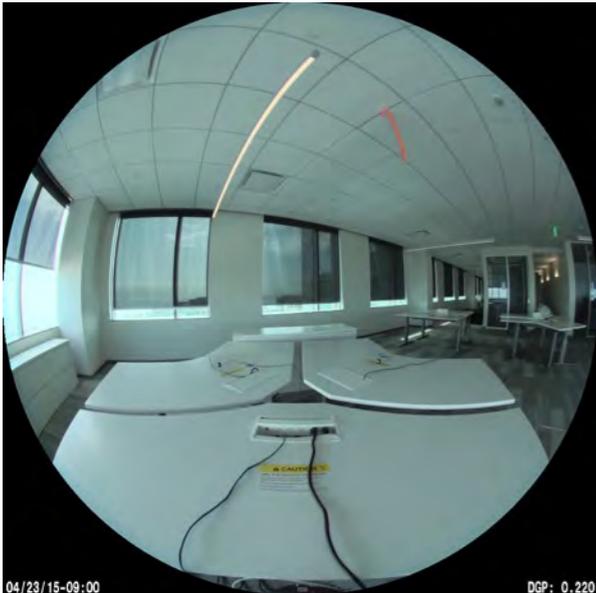


Cumulative DGP between 4/21 and 4/23



11:00

18:00

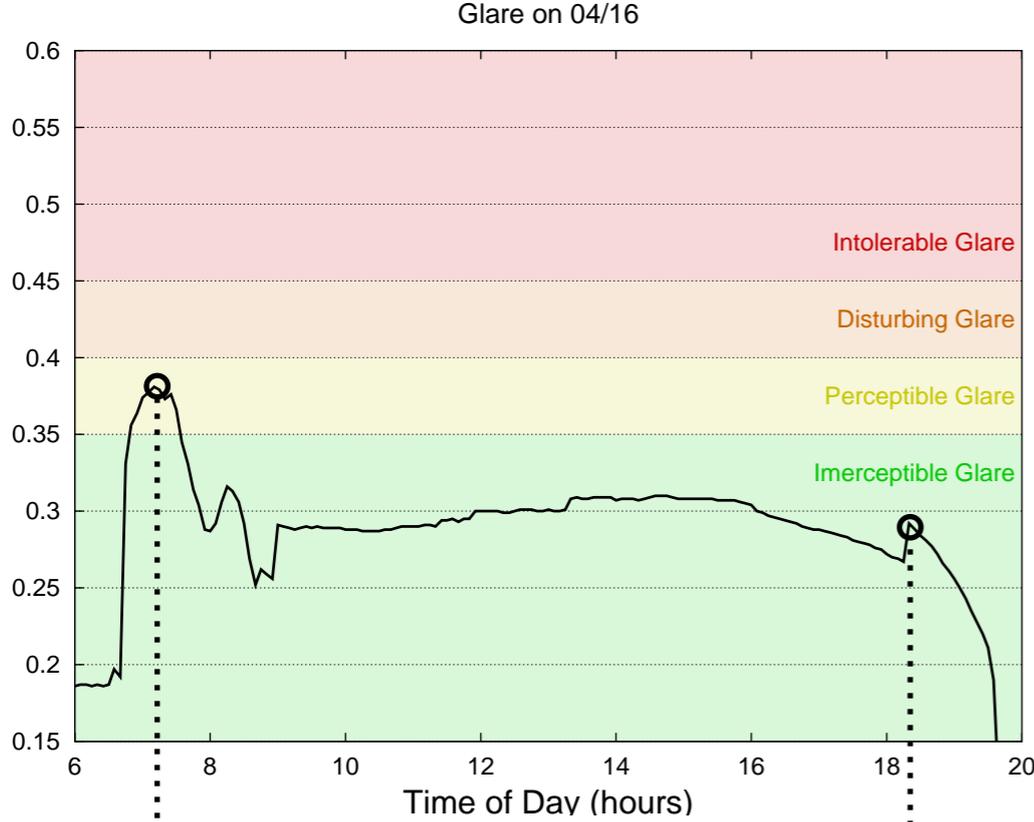


Cumulative DGP Statistics, Position #2, North Area

95% DGP Threshold	0.276
Average DGP within top 5% band	0.284
Comfort Class Rating	A

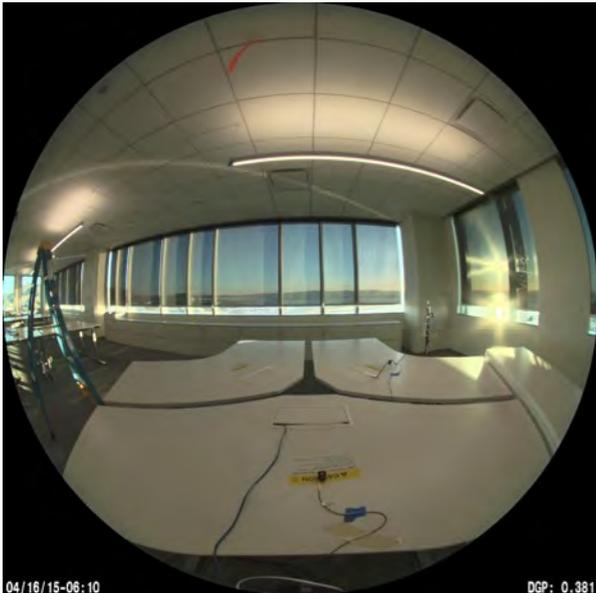
Glare | North #3 4/14-4/16

Daily Glare Plot for April 16, 2015

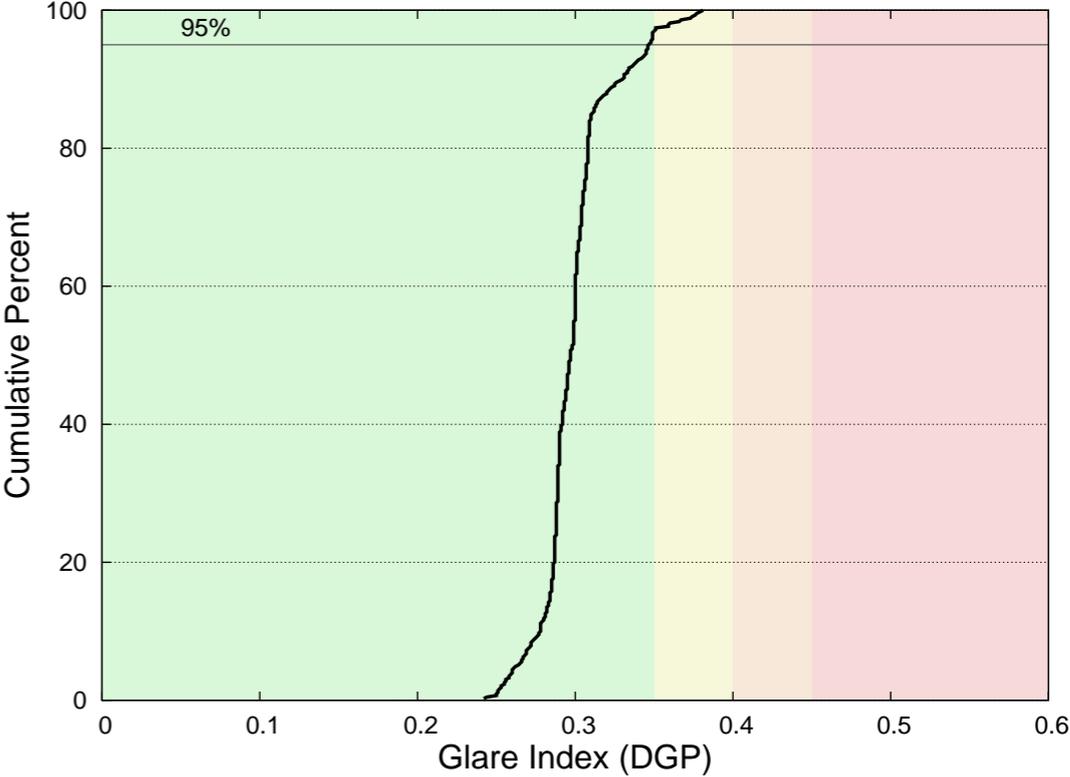


7:10

18:20



Cumulative DGP between 4/14 and 4/16

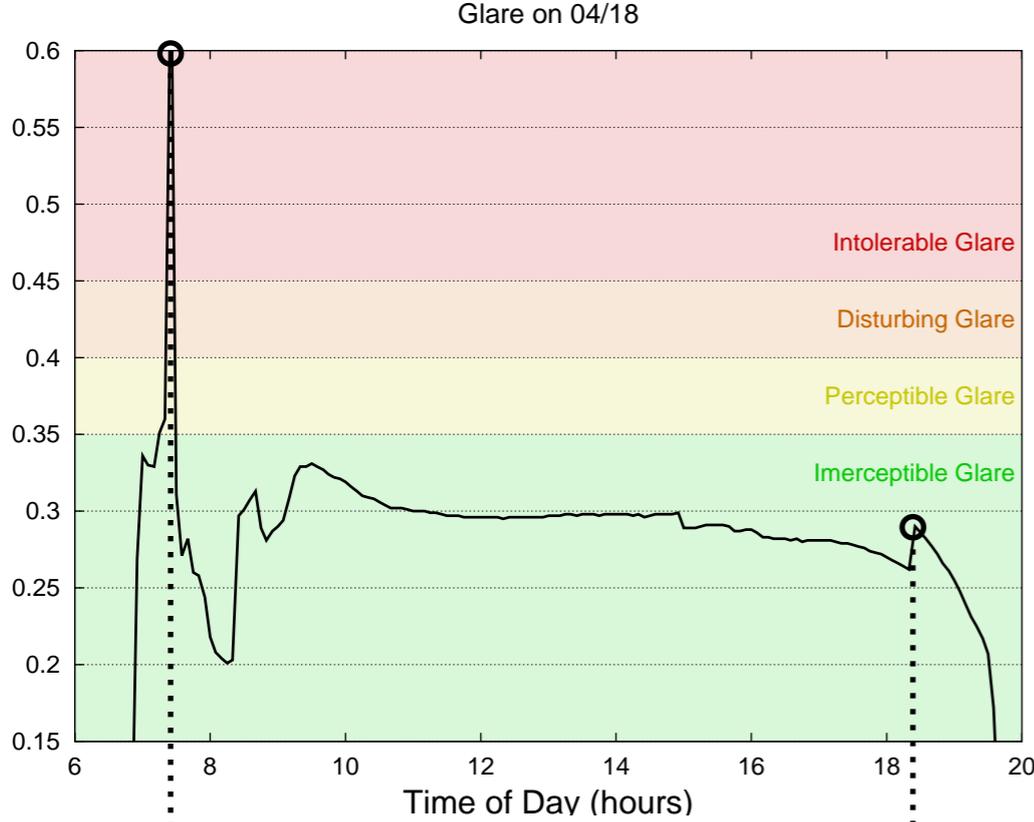


Cumulative DGP Statistics, Position #3, North Area

95% DGP Threshold	0.347
Average DGP within top 5% band	0.367
Comfort Class Rating	A

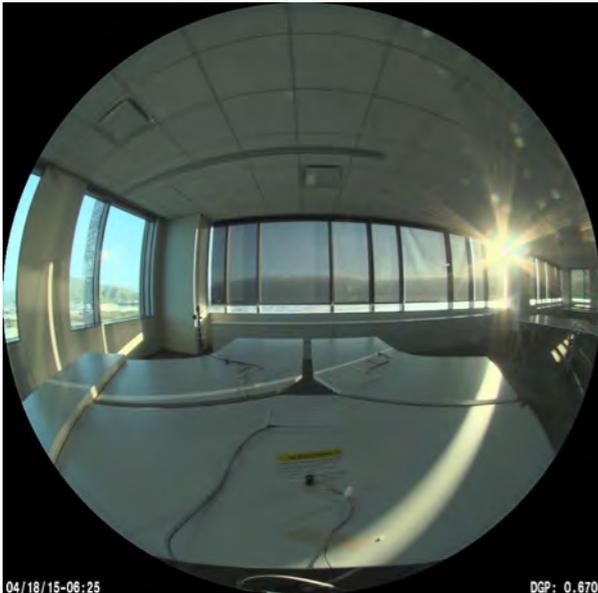
Glare | North #4 4/17-4/20

Daily Glare Plot for April 18, 2015



7:25

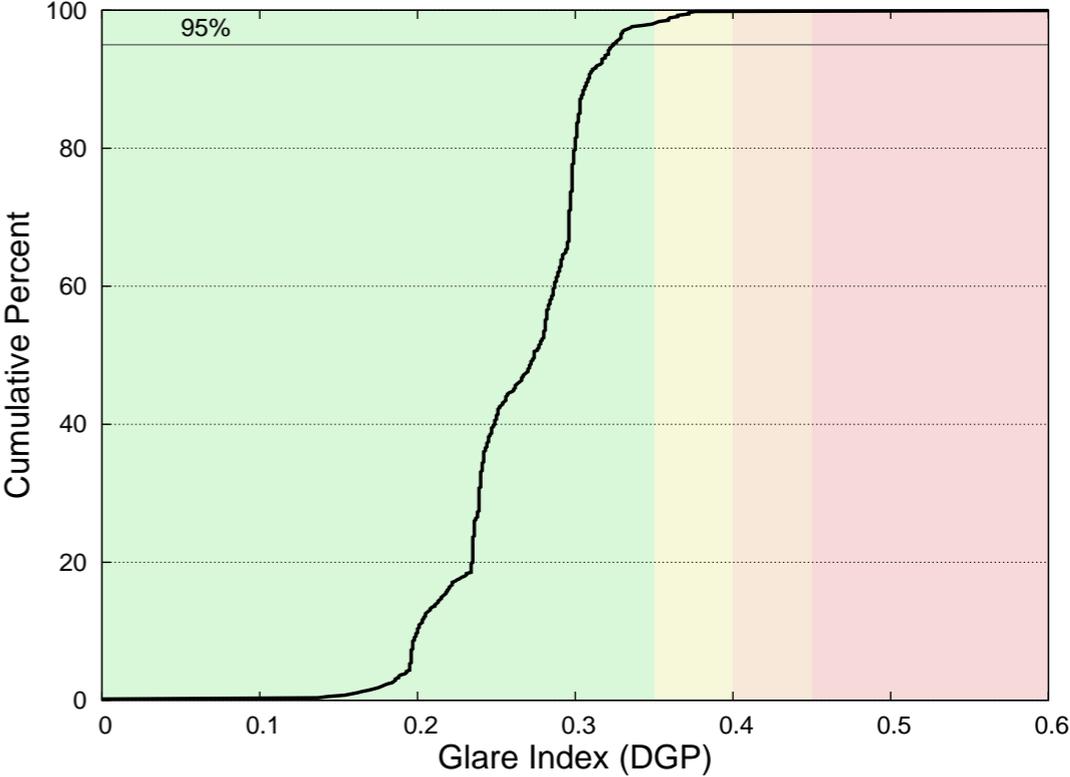
18:25



04/18/15-06:25 DGP: 0.670

04/18/15-17:25 DGP: 0.290

Cumulative DGP between 4/17 and 4/20

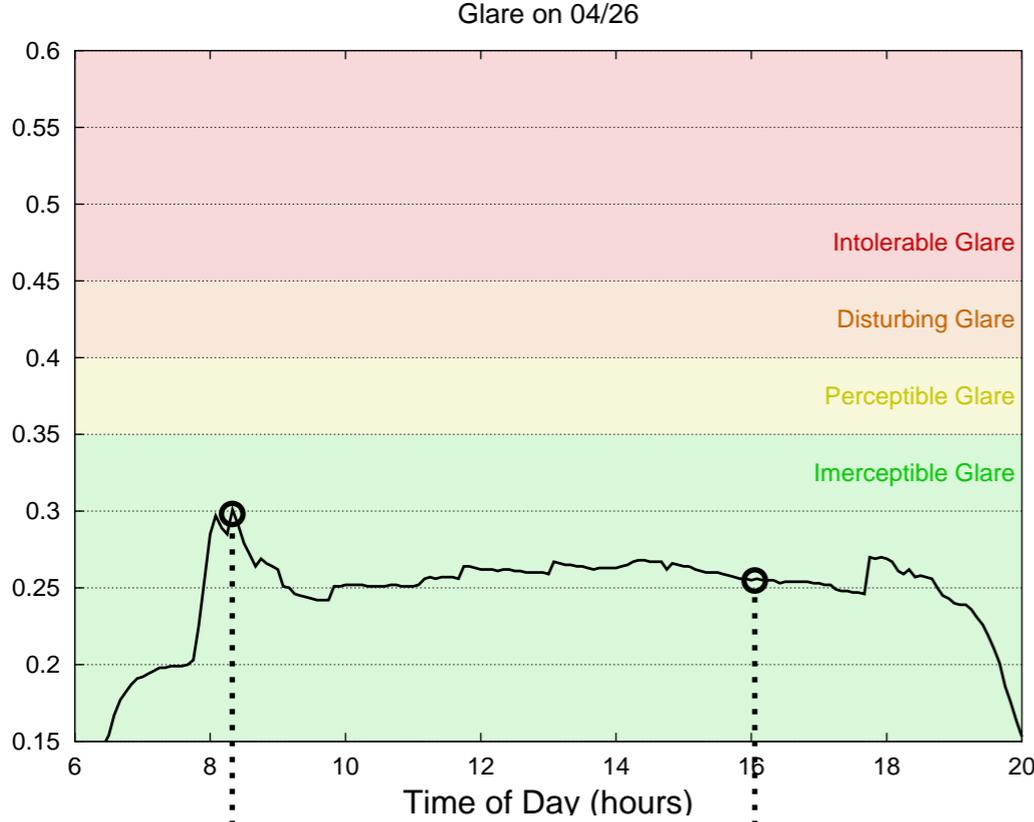


Cumulative DGP Statistics, Position #4, North Area

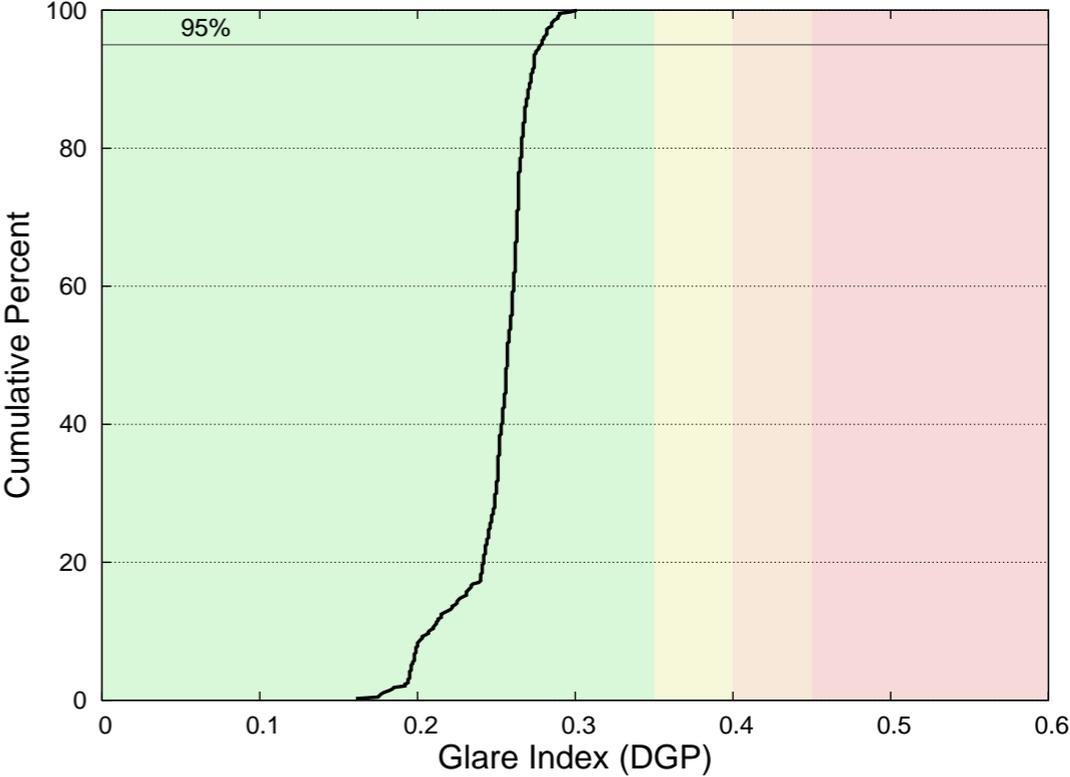
95% DGP Threshold	0.324
Average DGP within top 5% band	0.361
Comfort Class Rating	A

Glare | North #5 4/24-4/26

Daily Glare Plot for April 26, 2015

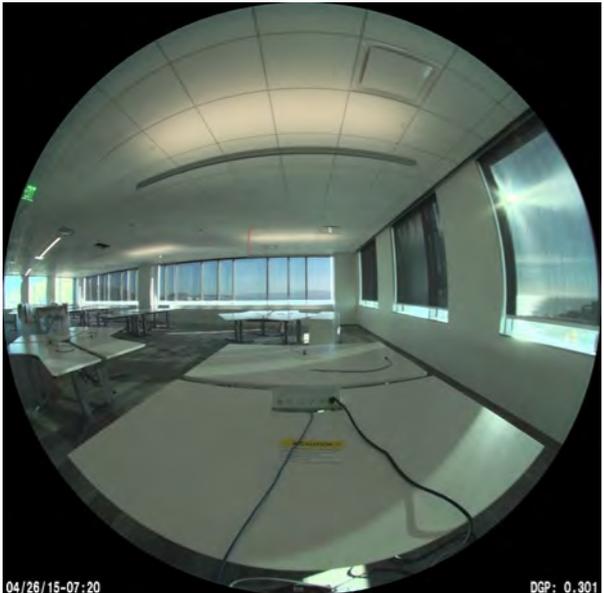


Cumulative DGP between 4/24 and 4/26



8:20

16:00

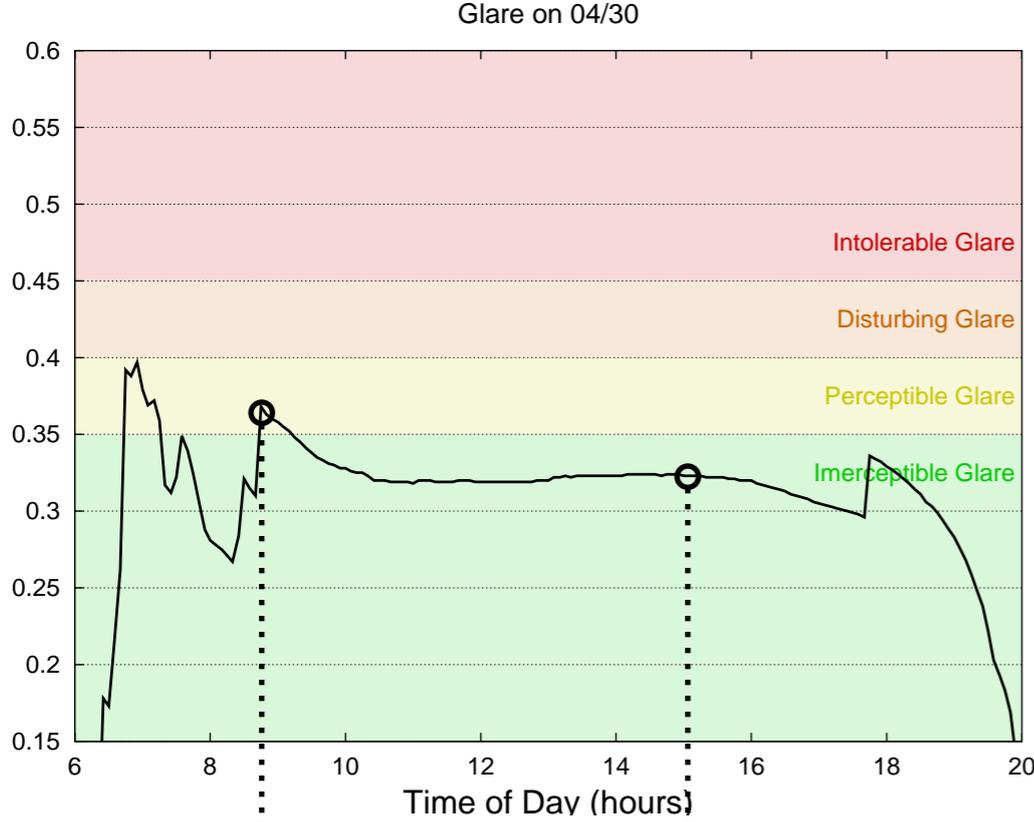


Cumulative DGP Statistics, Position #5, North Area

95% DGP Threshold	0.279
Average DGP within top 5% band	0.290
Comfort Class Rating	A

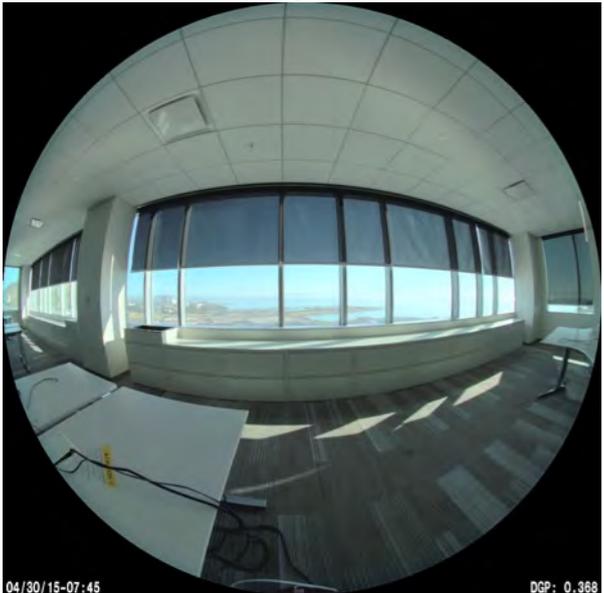
Glare | North #6 4/27-4/30

Daily Glare Plot for April 26, 2015

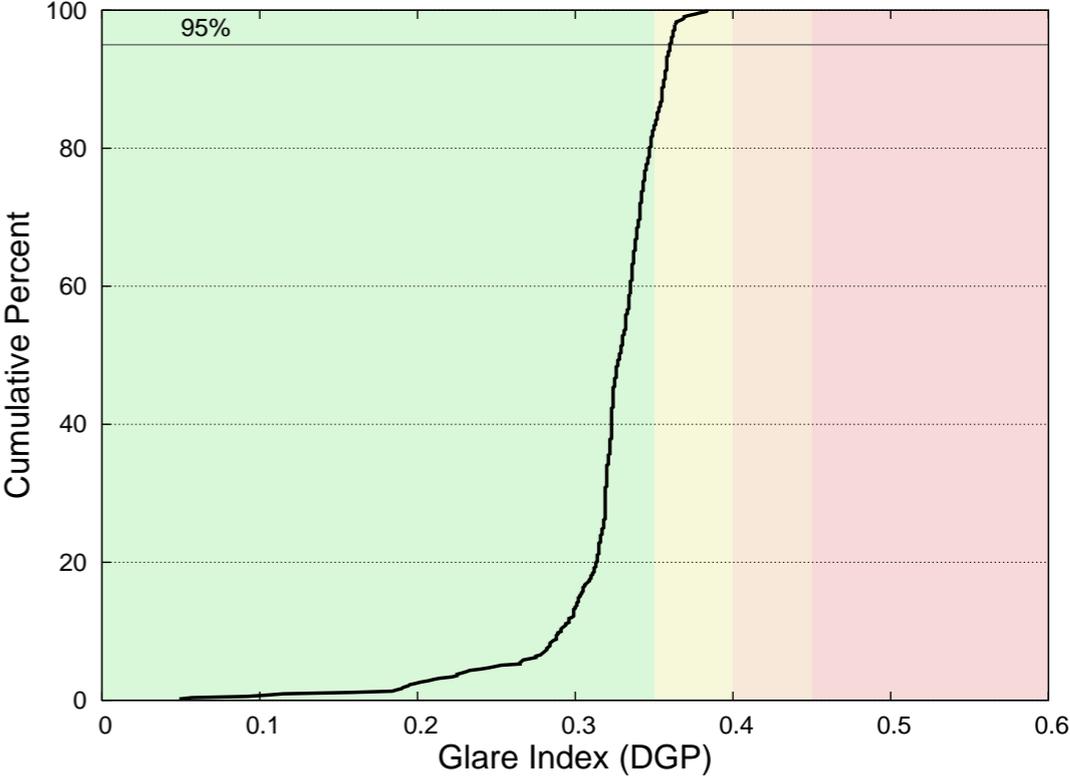


8:20

15:00



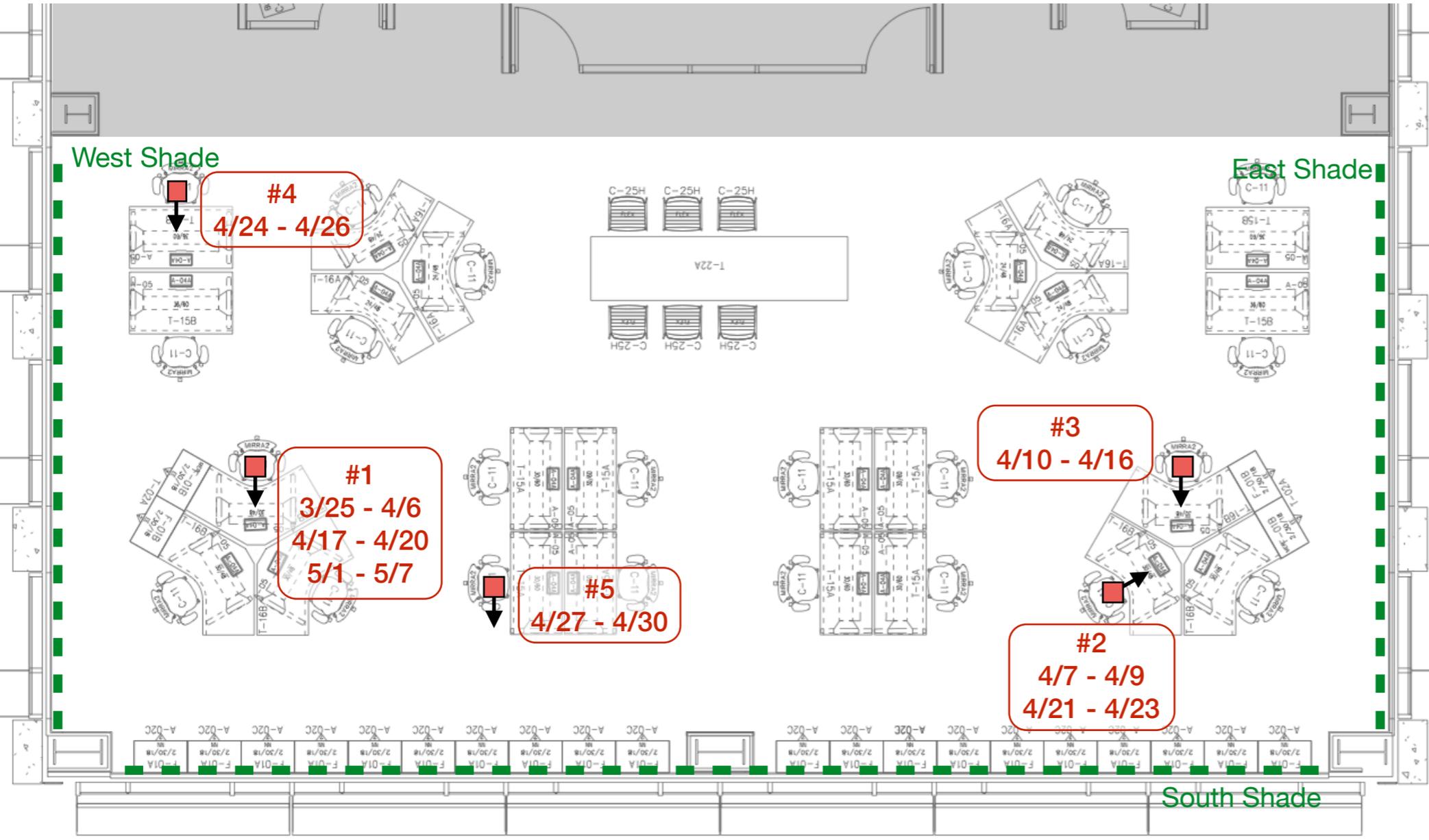
Cumulative DGP between 4/24 and 4/26



Cumulative DGP Statistics, Position #6, North Area

95% DGP Threshold	0.360
Average DGP within top 5% band	0.372
Comfort Class Rating	B

Glare | HDR Camera Locations, South Area



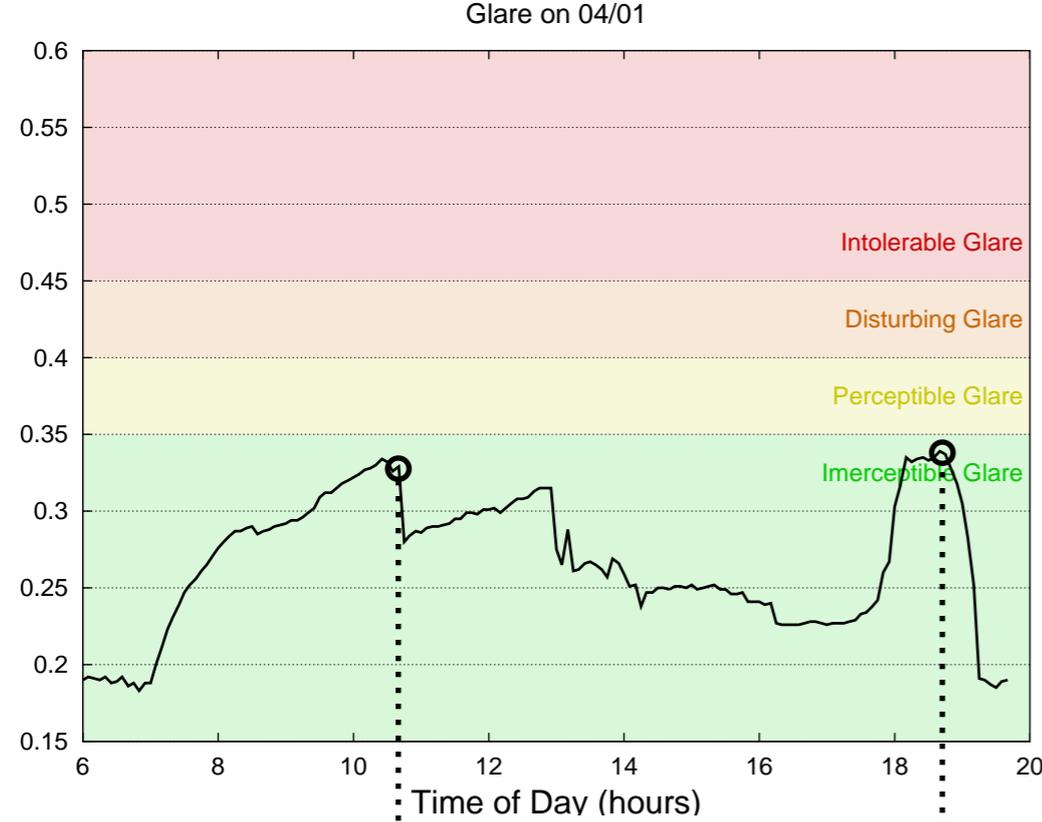
 HDR Camera Position & Direction

 Shade Group

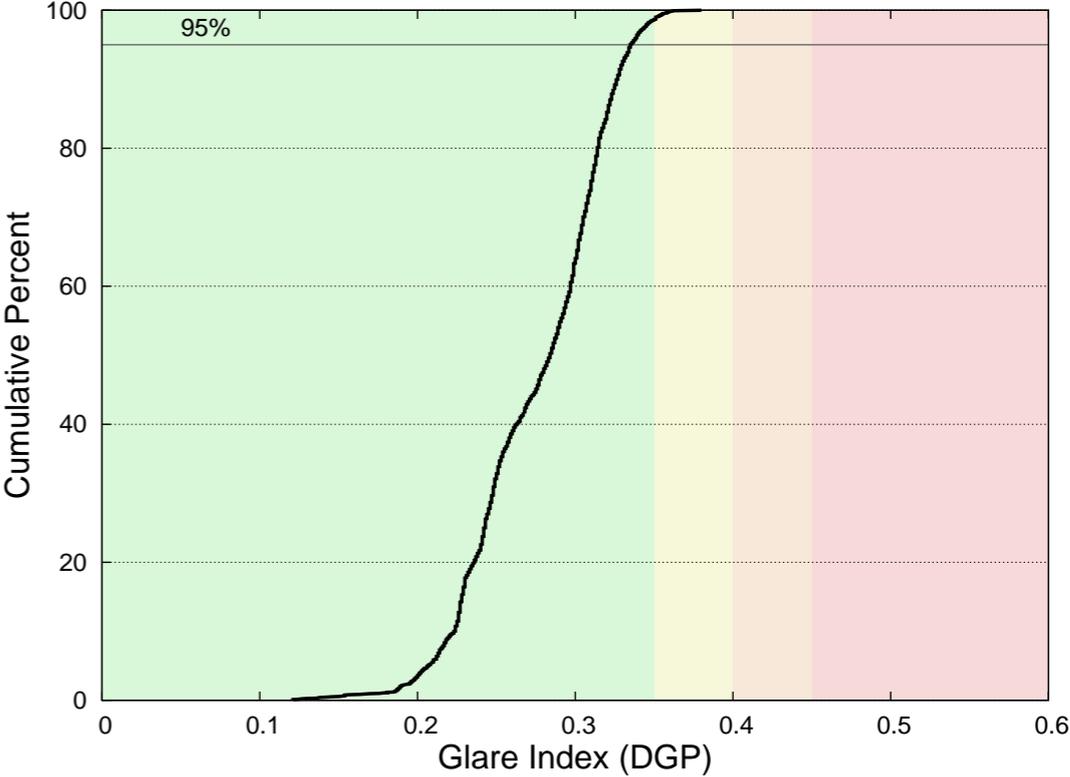


Glare | South #1 3/25-4/3, 4/14-4/20 & 5/1-5/7

Daily Glare Plot for April 1, 2015

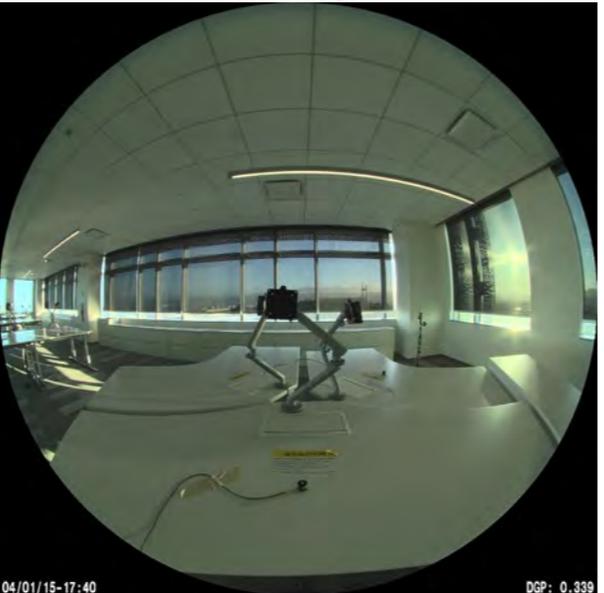


Cumulative DGP 3/25-4/3, 4/14-4/20 & 5/1-5/7



10:40

18:40

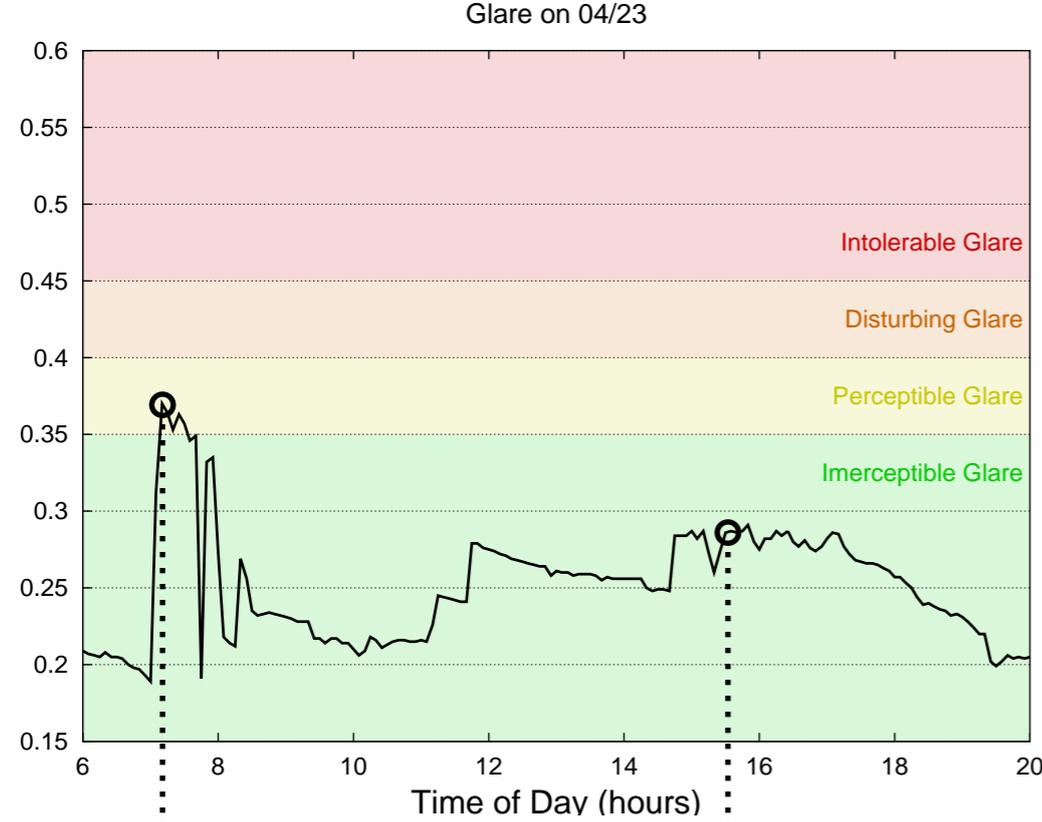


Cumulative DGP Statistics, Position #1, South Area

95% DGP Threshold	0.335
Average DGP within top 5% band	0.346
Comfort Class Rating	A

Glare | South #2 4/7-4/9 & 4/21-4/23

Daily Glare Plot for April 23, 2015

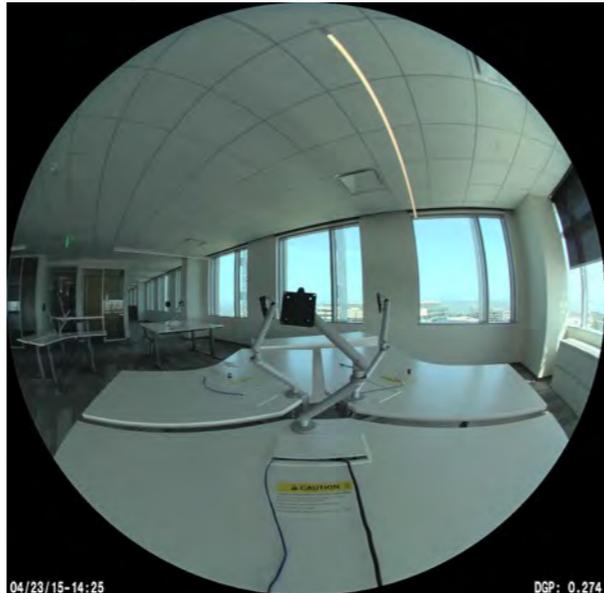


7:05

15:25

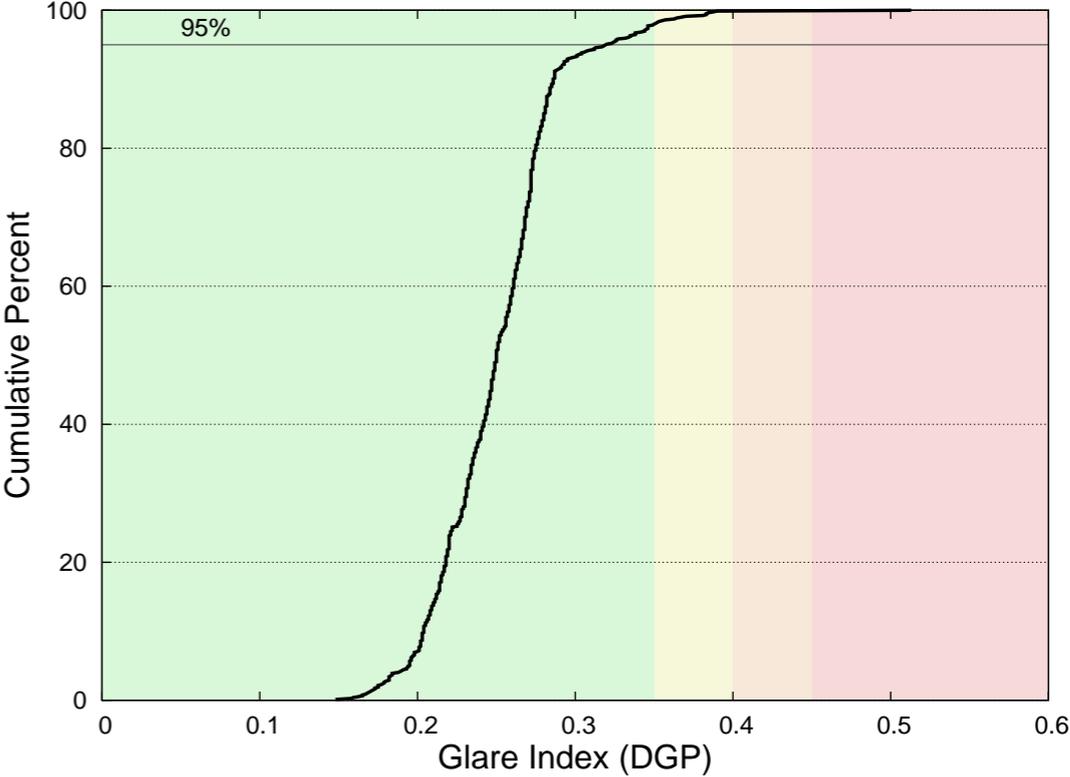


04/23/15-06:05 DGP: 0.312



04/23/15-14:25 DGP: 0.274

Cumulative DGP from 4/7 to 4/9 and 4/21 to 4/23

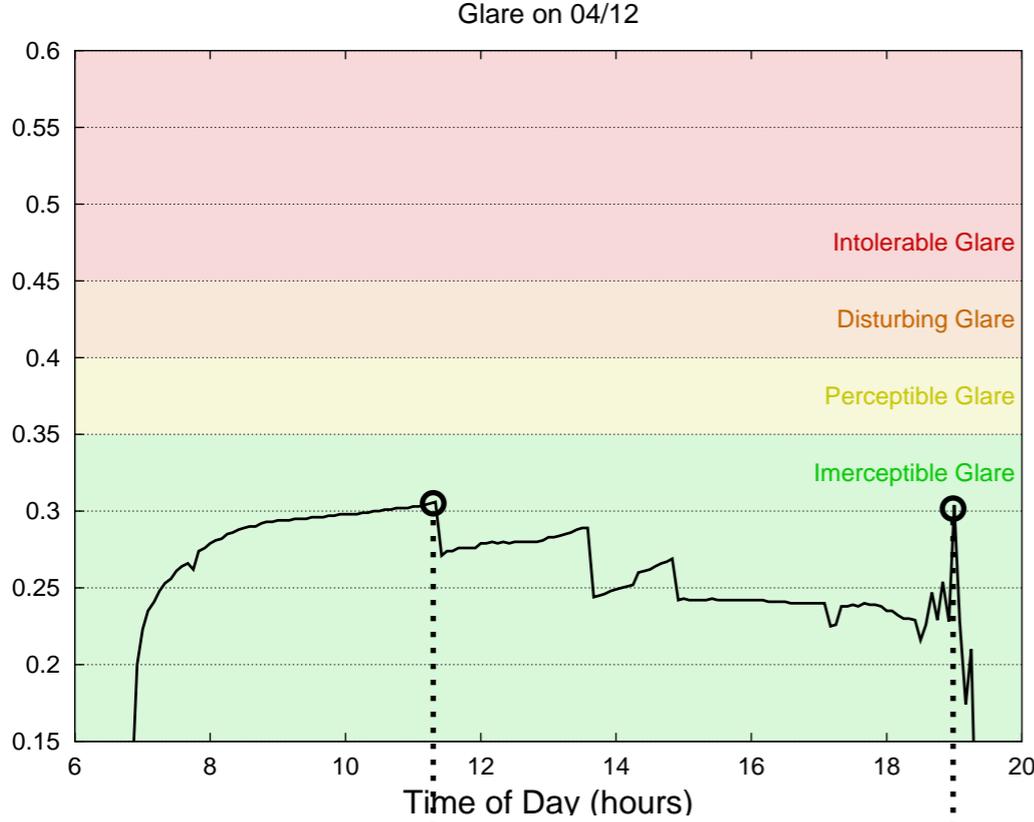


Cumulative DGP Statistics, Position #2, South Area

95% DGP Threshold	0.320
Average DGP within top 5% band	0.356
Comfort Class Rating	A

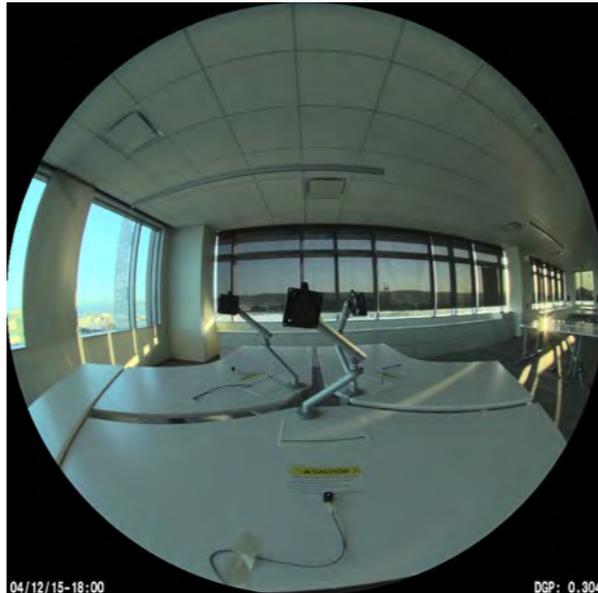
Glare | South #3 4/10-4/16

Daily Glare Plot for April 12, 2015

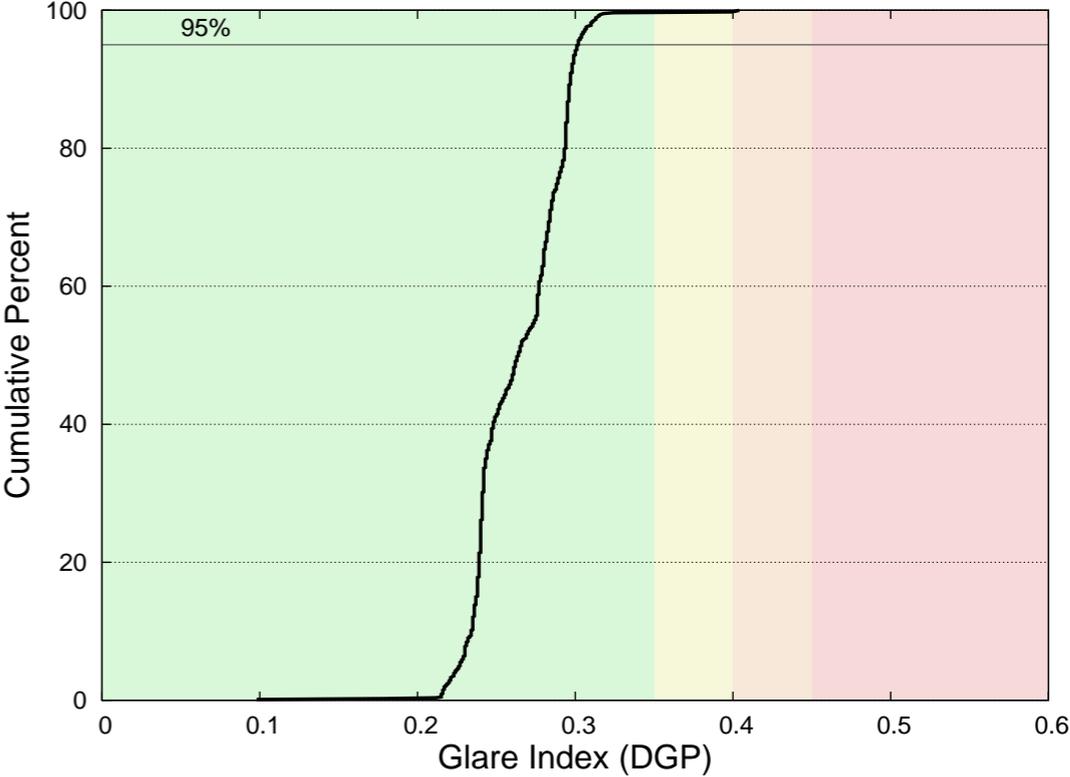


11:20

19:00



Cumulative DGP between 4/10 and 4/16

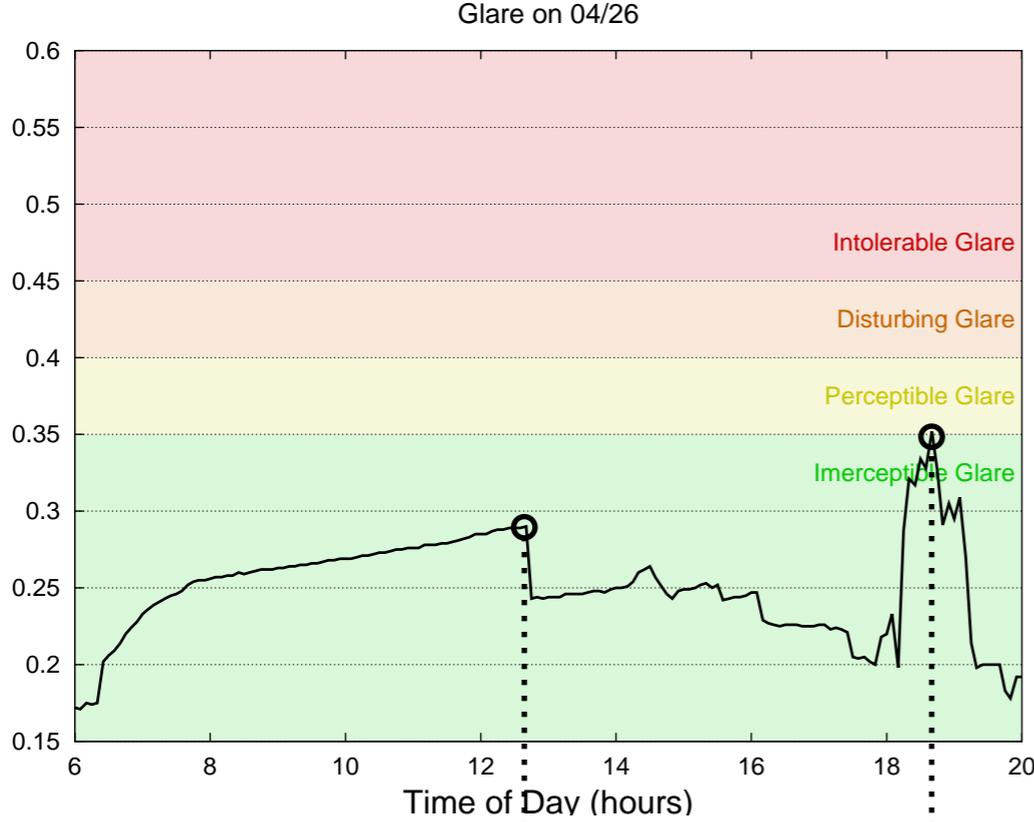


Cumulative DGP Statistics, Position #3, South Area

95% DGP Threshold	0.302
Average DGP within top 5% band	0.322
Comfort Class Rating	A

Glare | South #4 4/24-4/26

Daily Glare Plot for April 26, 2015

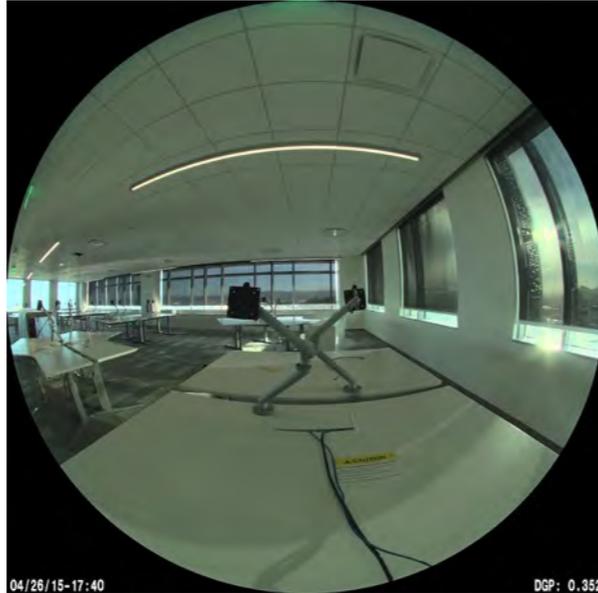


12:40

18:40

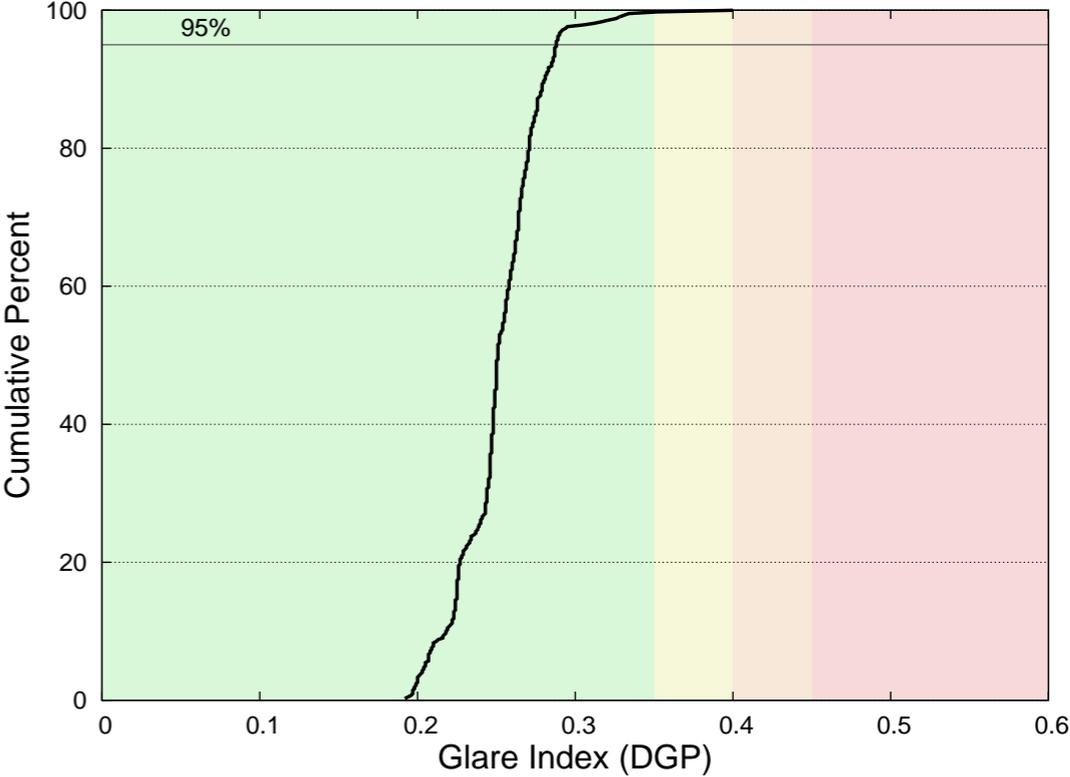


04/12/15-10:20 DGP: 0.306



04/26/15-17:40 DGP: 0.352

Cumulative DGP between 4/10 and 4/16

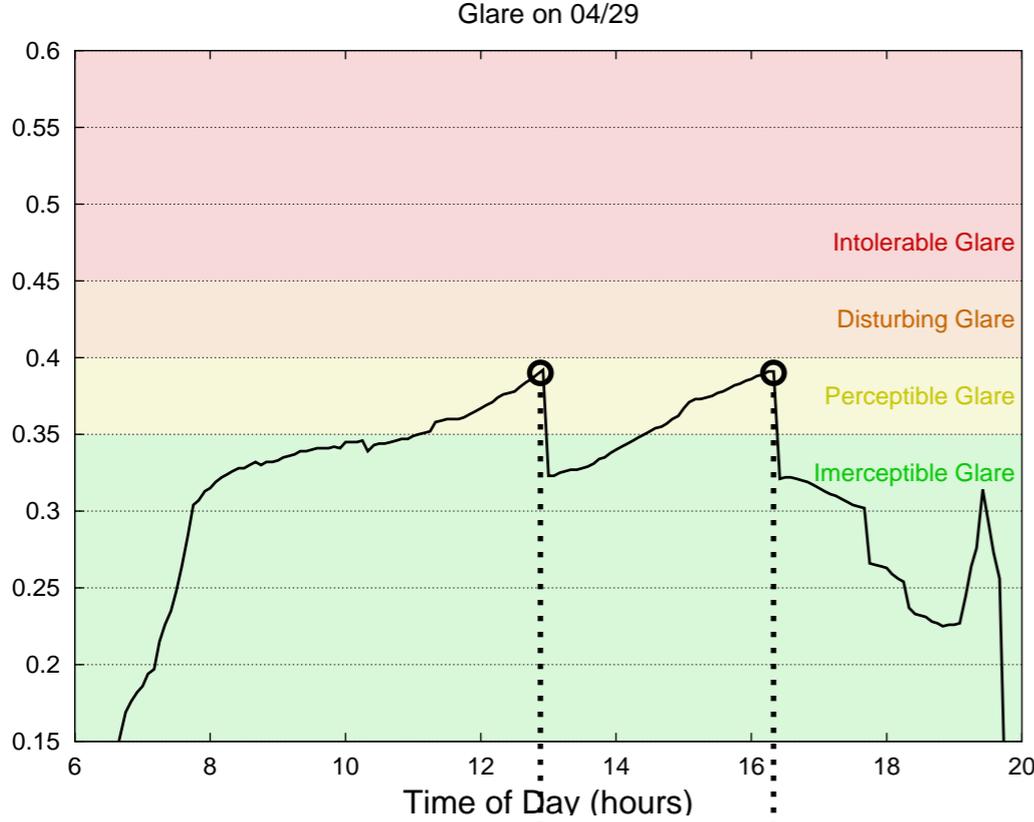


Cumulative DGP Statistics, Position #4, South Area

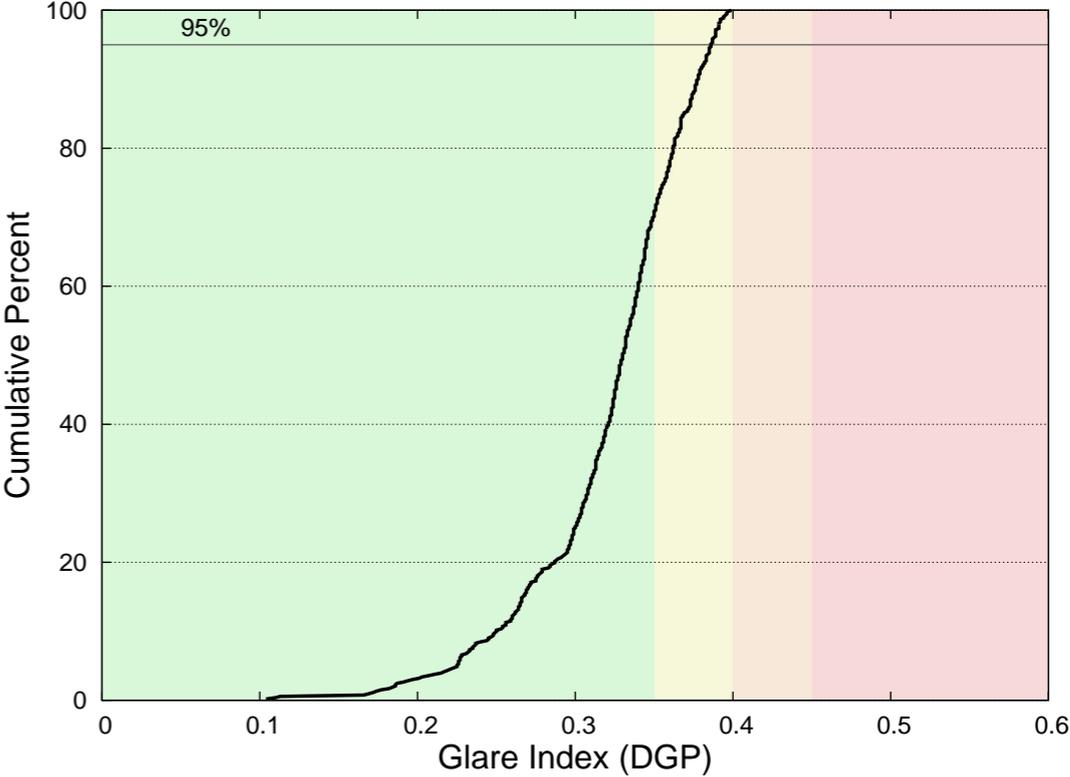
95% DGP Threshold	0.288
Average DGP within top 5% band	0.323
Comfort Class Rating	A

Glare | South #5 4/27-4/30

Daily Glare Plot for April 29, 2015



Cumulative DGP between 4/27 and 4/30



12:55

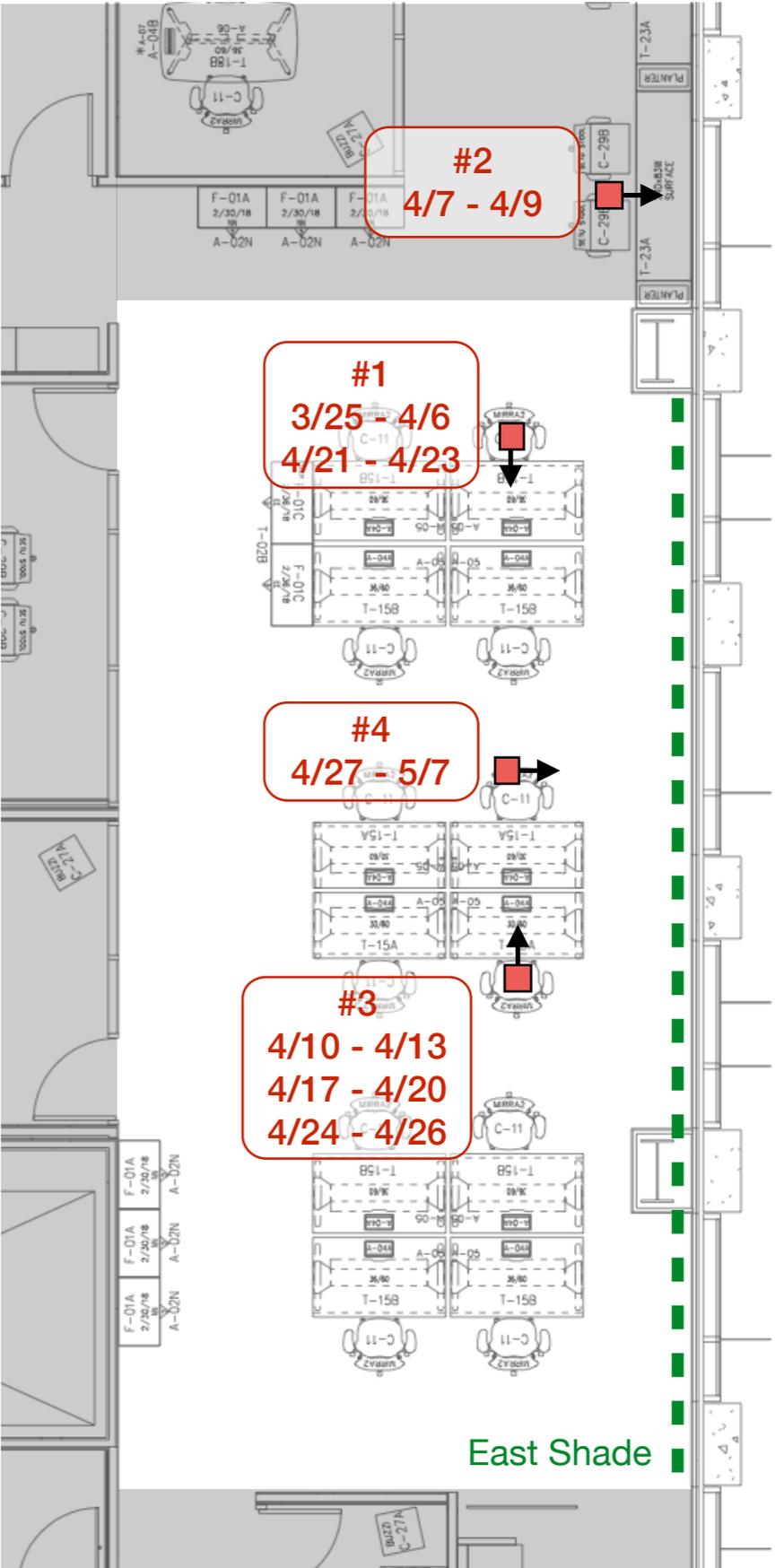
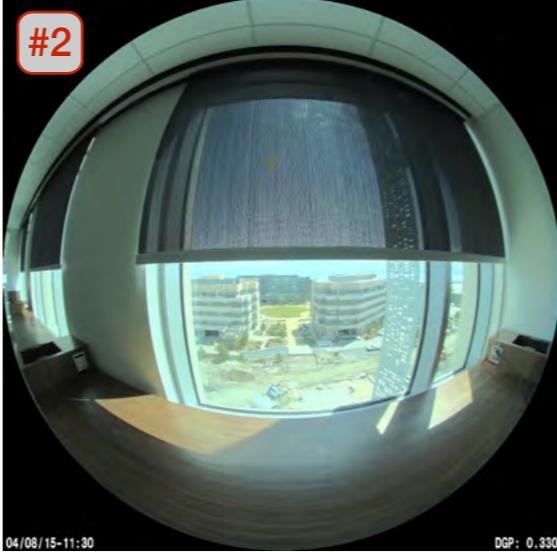
16:20



Cumulative DGP Statistics, Position #5, South Area

95% DGP Threshold	0.386
Average DGP within top 5% band	0.397
Comfort Class Rating	B

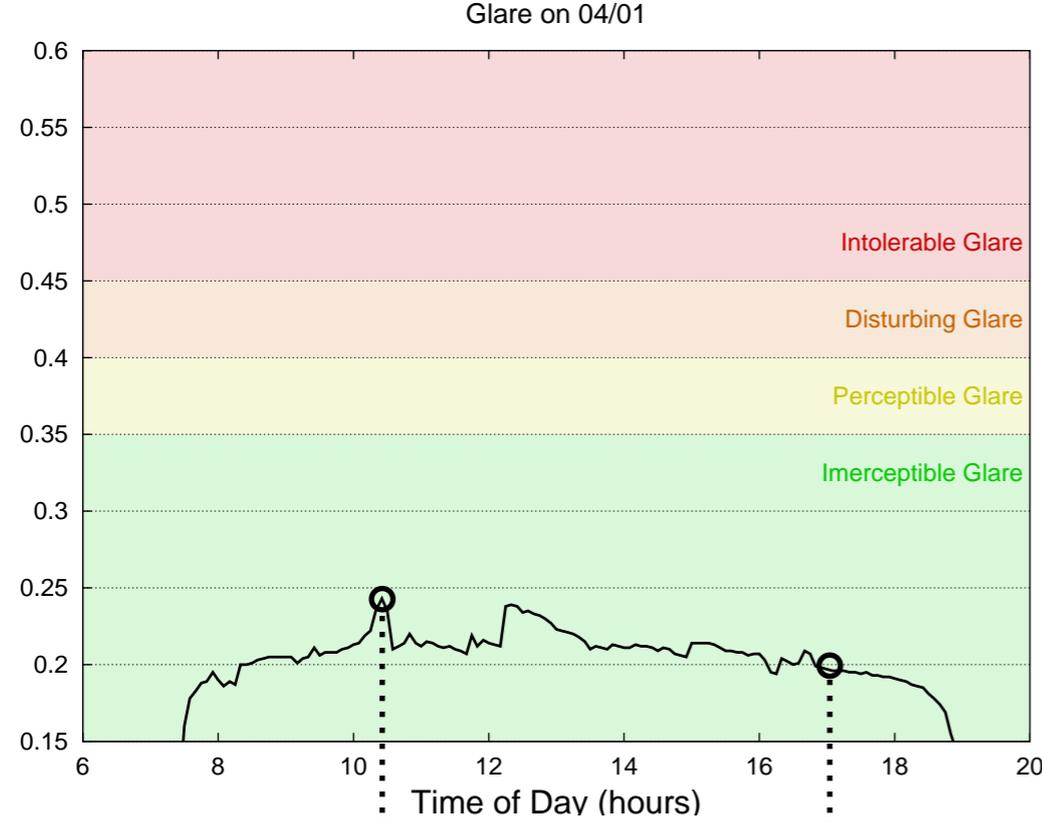
Glare | HDR Camera Locations, East Area



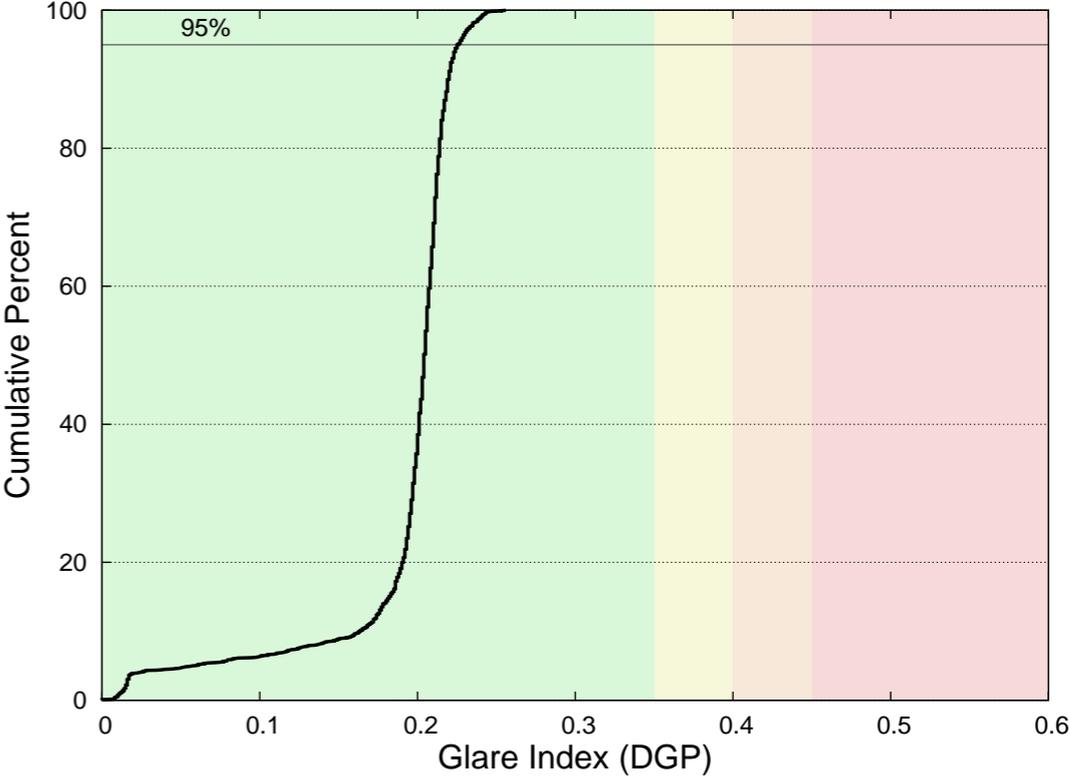
 HDR Camera Position & Direction
 Shade Group

Glare | East #1 3/25-4/6 & 4/21-4/23

Daily Glare Plot for April 29, 2015

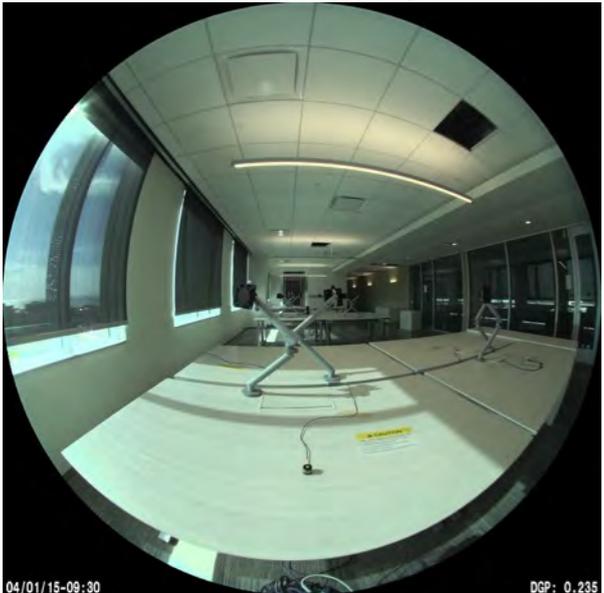


Cumulative DGP between 4/27 and 4/30



10:30

17:00

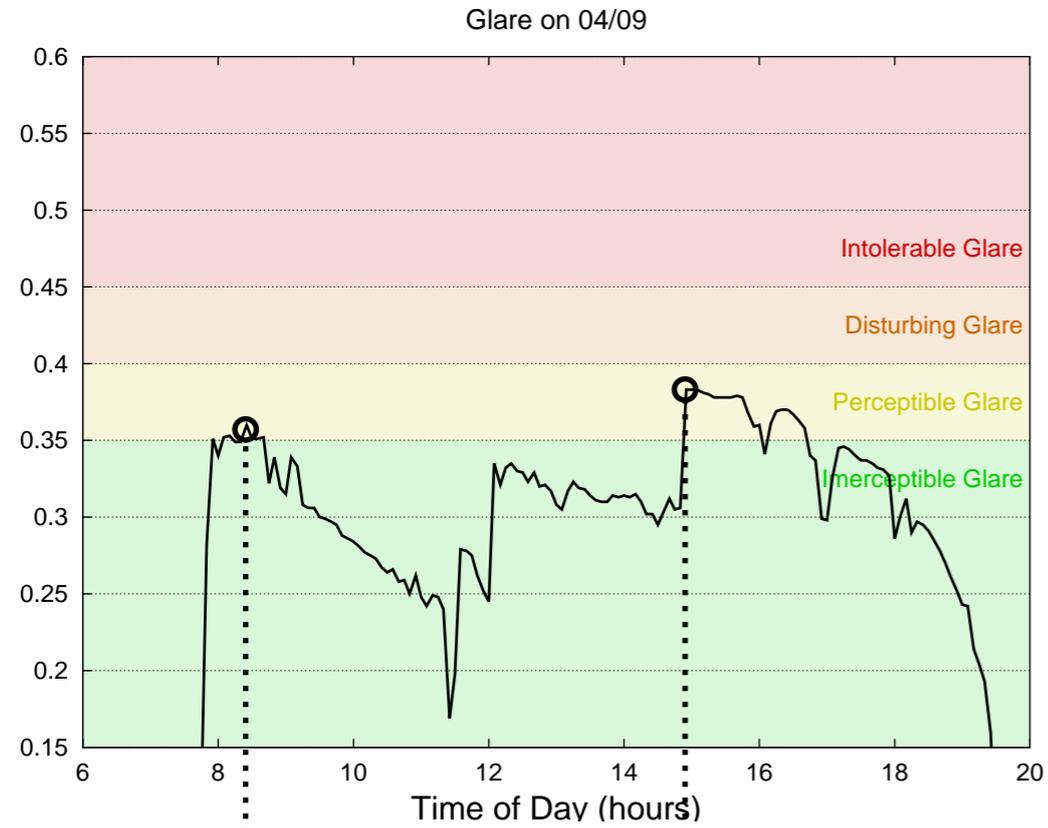


Cumulative DGP Statistics, Position #1, East Area

95% DGP Threshold	0.226
Average DGP within top 5% band	0.236
Comfort Class Rating	A

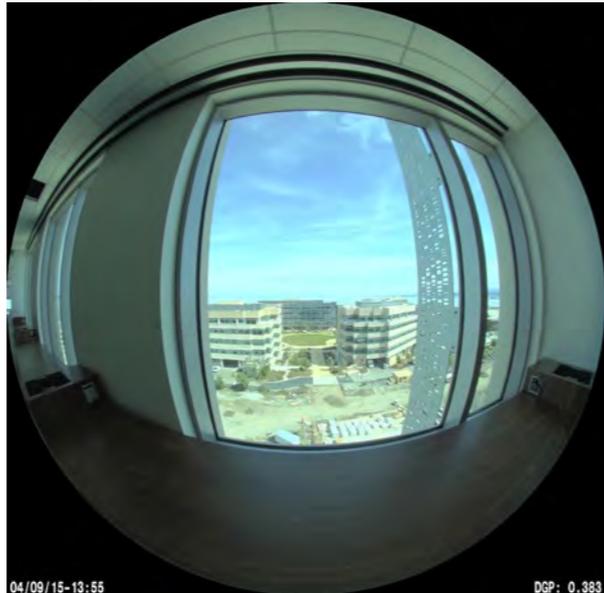
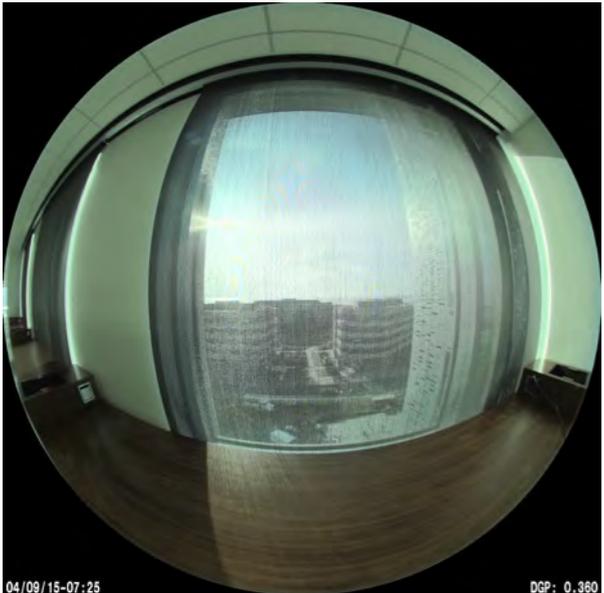
Glare | East #2 4/7-4/9

Daily Glare Plot for April 9, 2015

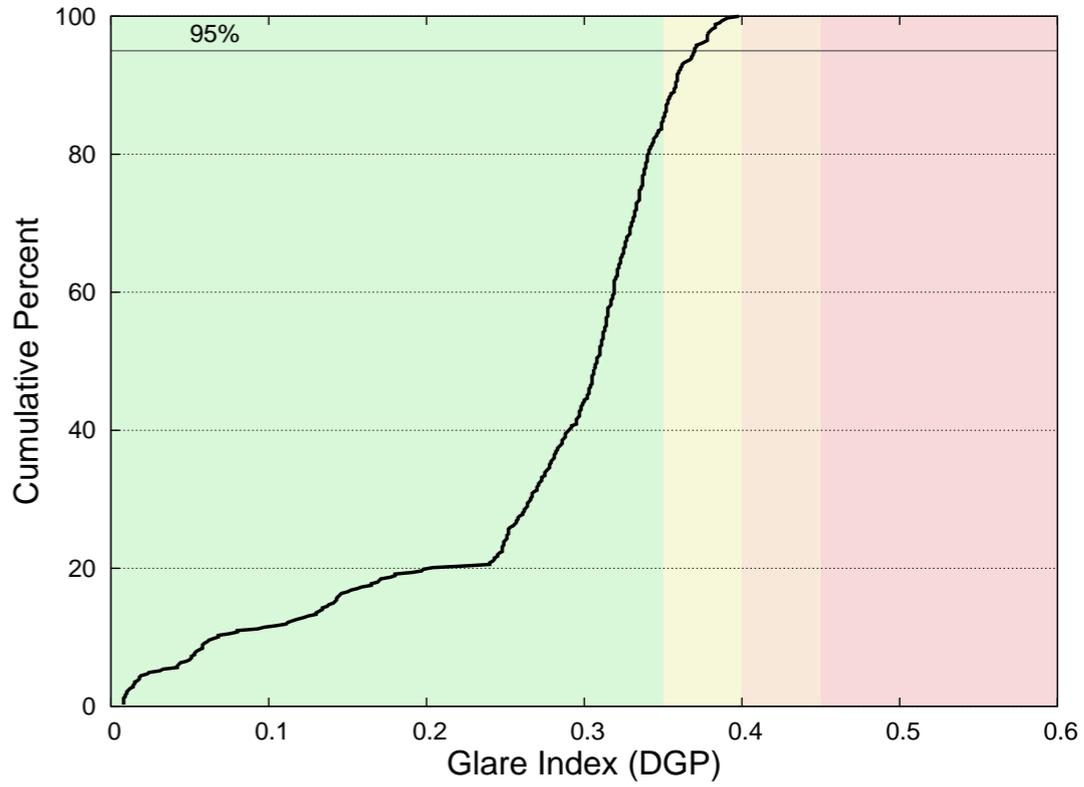


8:25

14:55



Cumulative DGP between 4/7 and 4/9

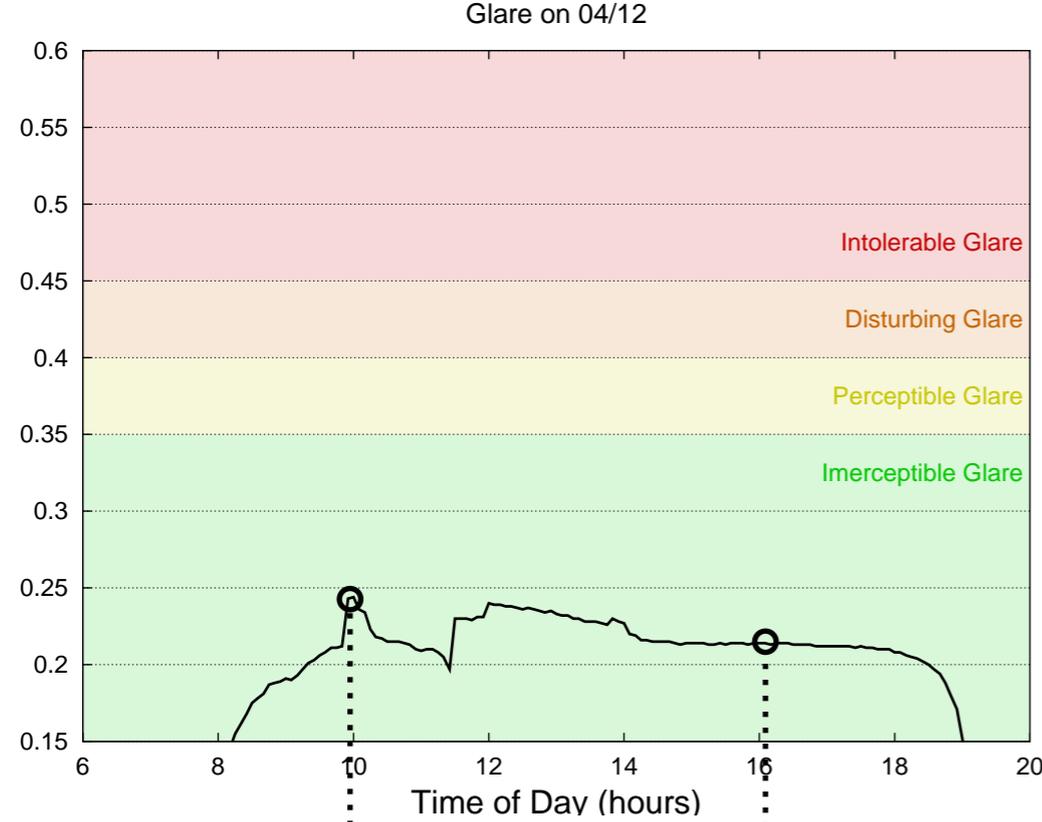


Cumulative DGP Statistics, Position #2, East Area

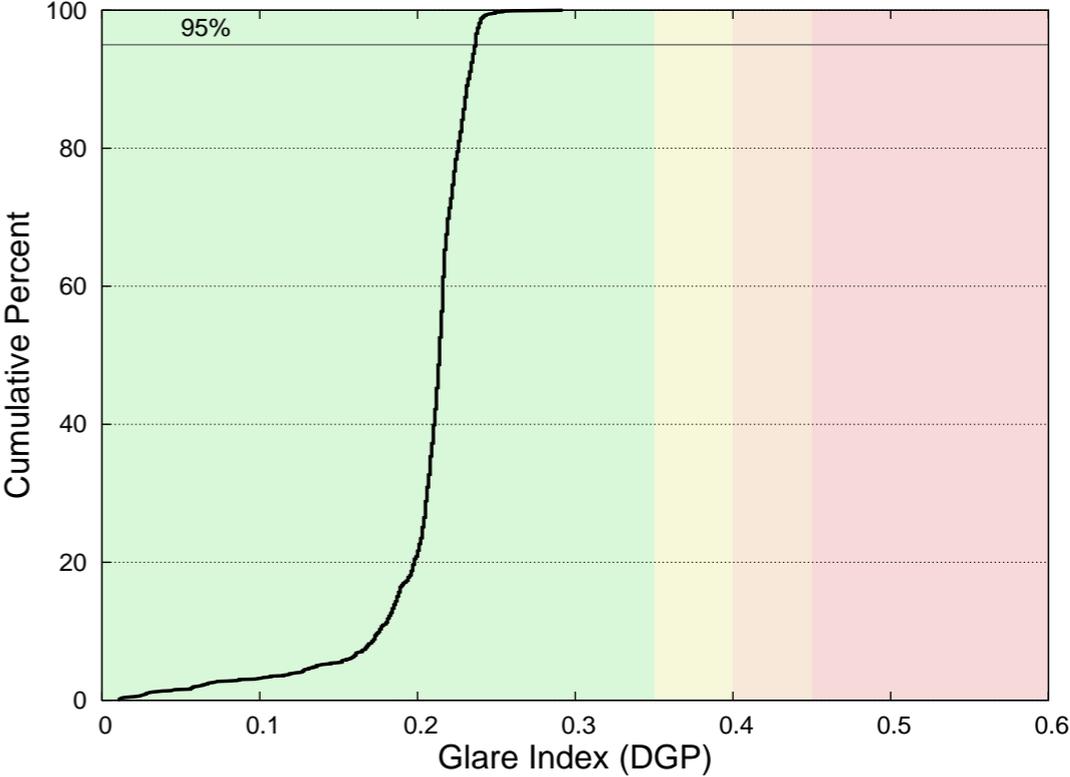
95% DGP Threshold	0.370
Average DGP within top 5% band	0.391
Comfort Class Rating	B

Glare | East #3 4/10-4/13, 4/17-4/20, & 4/24-4/26

Daily Glare Plot for April 12, 2015

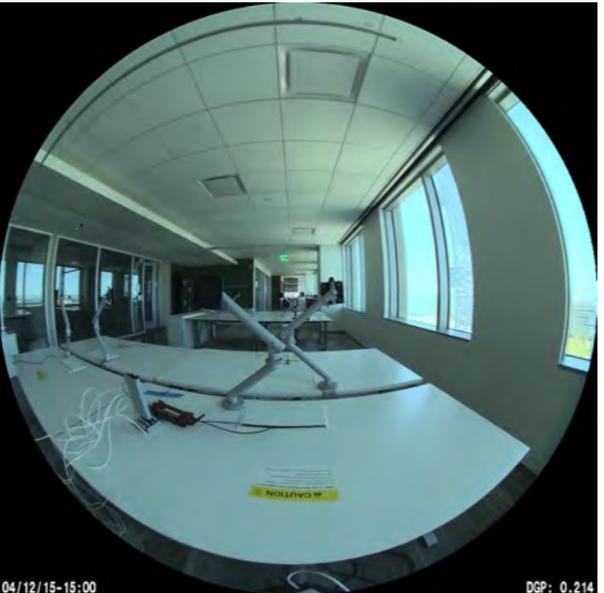
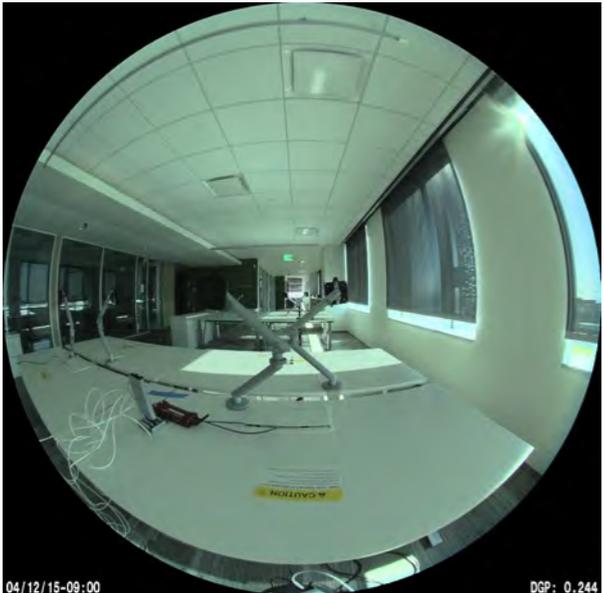


Cumulative DGP during 4/10-4/13, 4/17-4/20, & 4/24-4/26



10:00

16:00

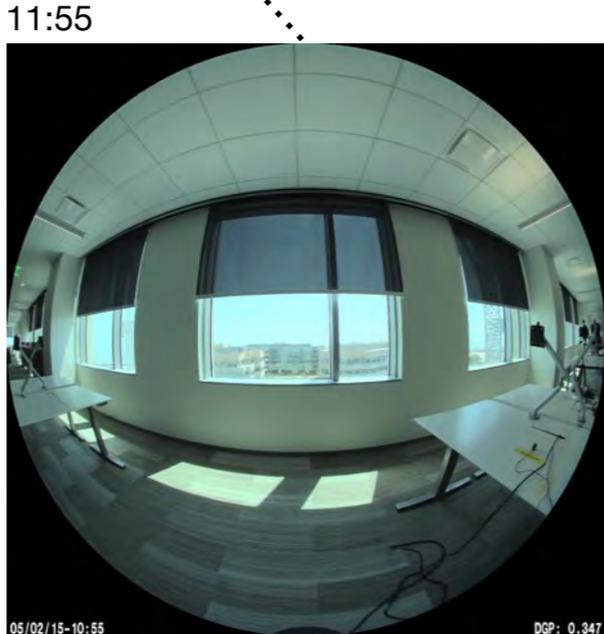
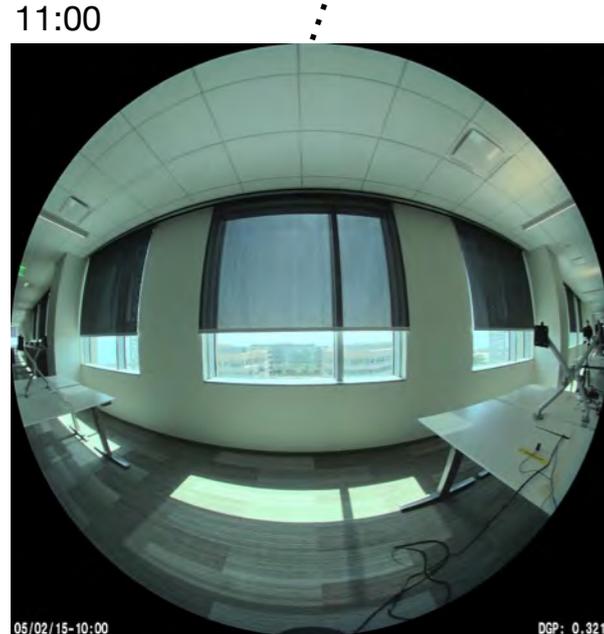
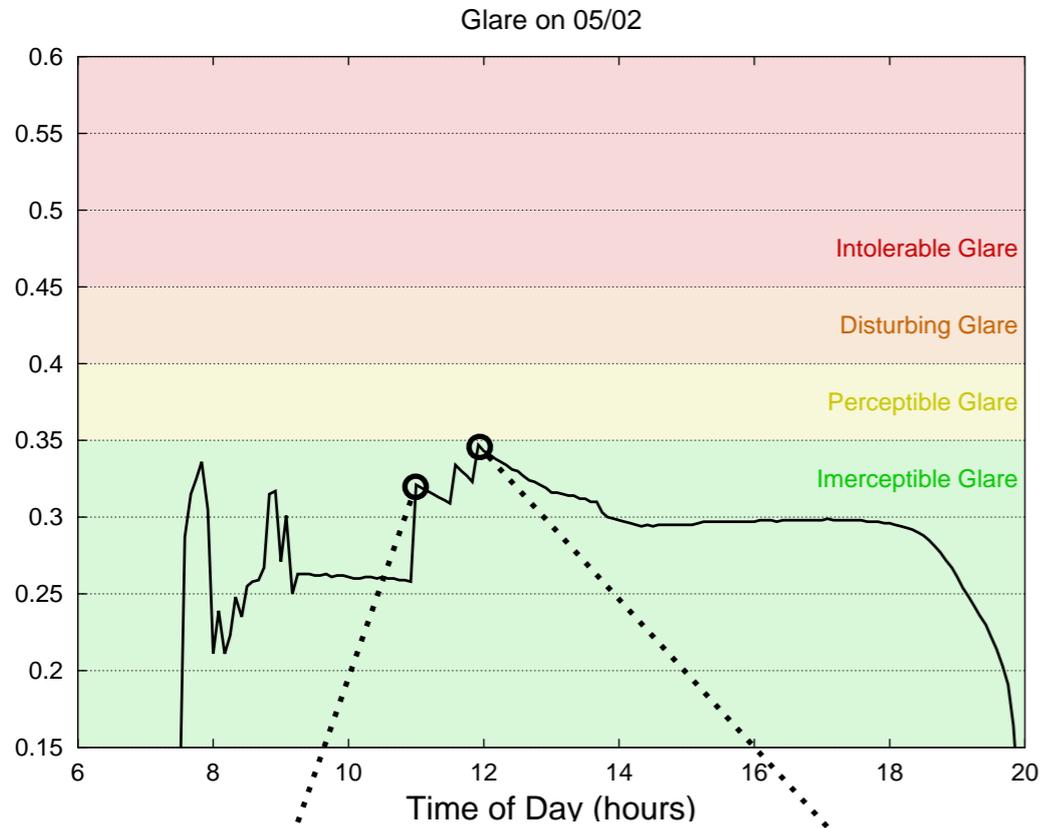


Cumulative DGP Statistics, Position #3, East Area

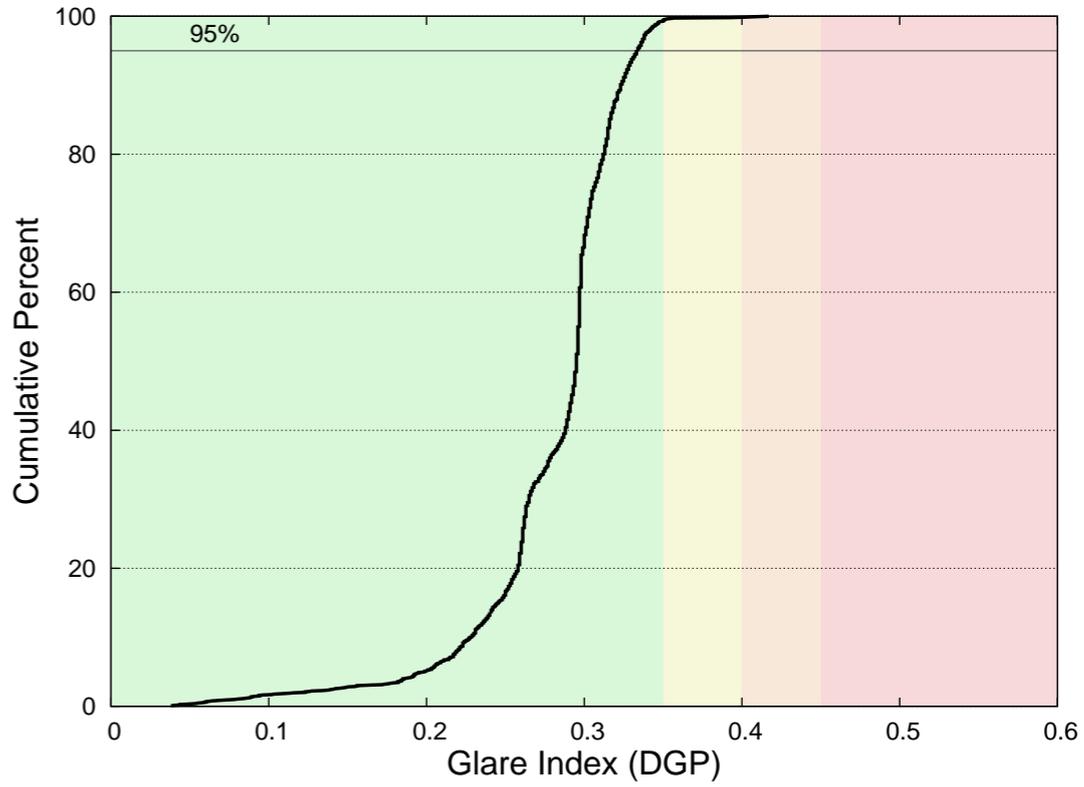
95% DGP Threshold	0.237
Average DGP within top 5% band	0.242
Comfort Class Rating	A

Glare | East #4 4/27-5/7

Daily Glare Plot for May 2, 2015



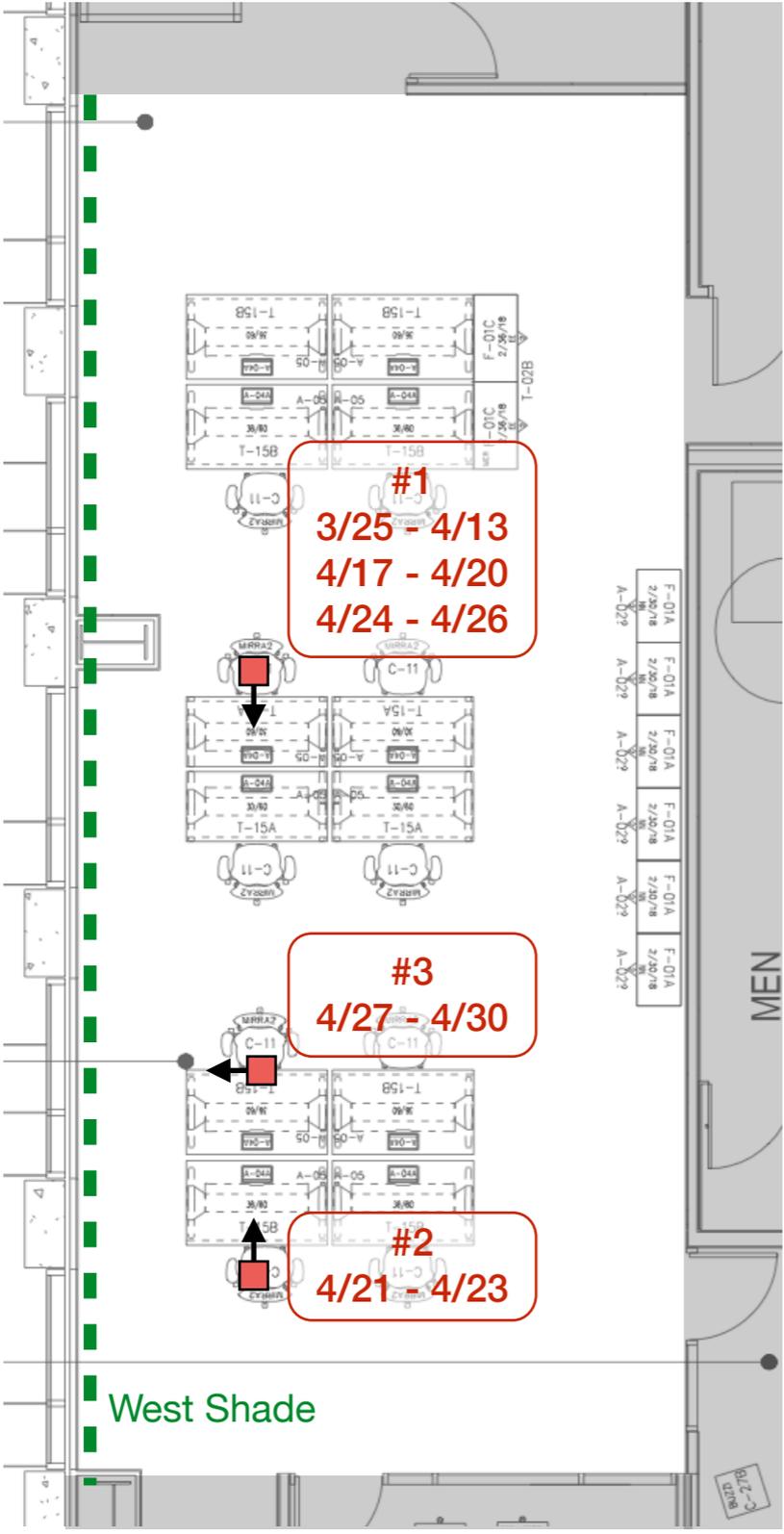
Cumulative DGP between 4/27 and 5/7



Cumulative DGP Statistics, Position #4, East Area

95% DGP Threshold	0.334
Average DGP within top 5% band	0.345
Comfort Class Rating	A

Glare | HDR Camera Locations, West Area



#1
 3/25 - 4/13
 4/17 - 4/20
 4/24 - 4/26

#3
 4/27 - 4/30

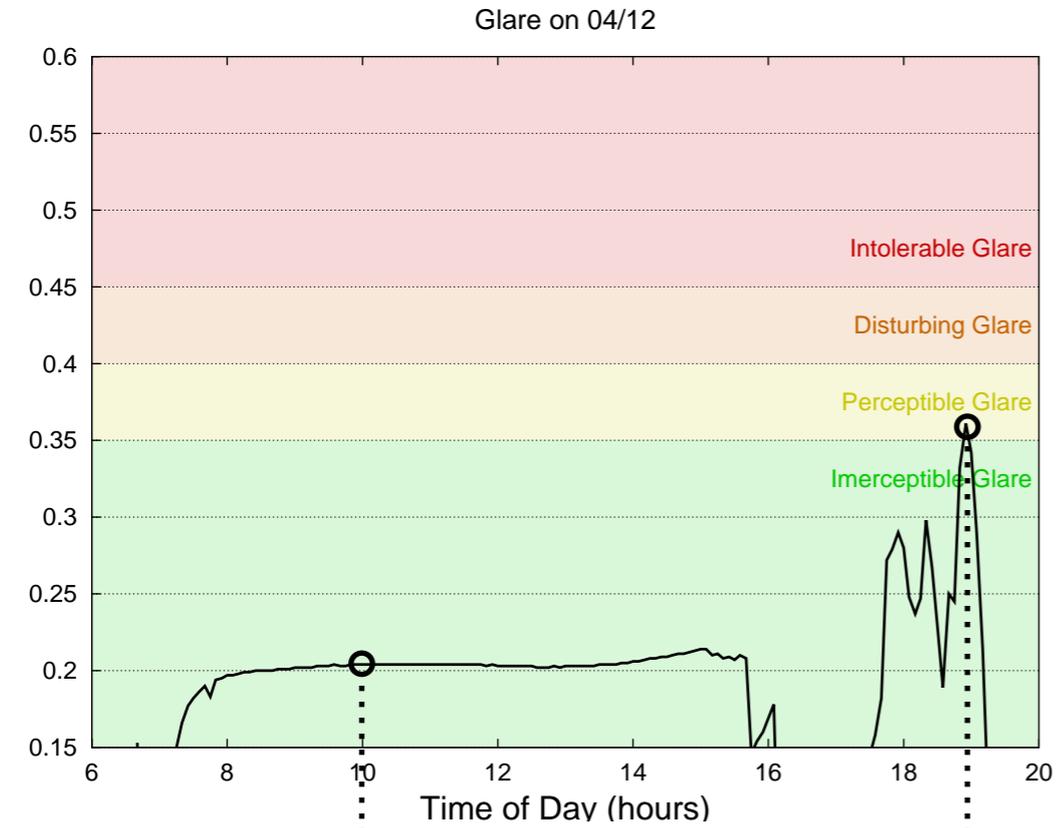
#2
 4/21 - 4/23



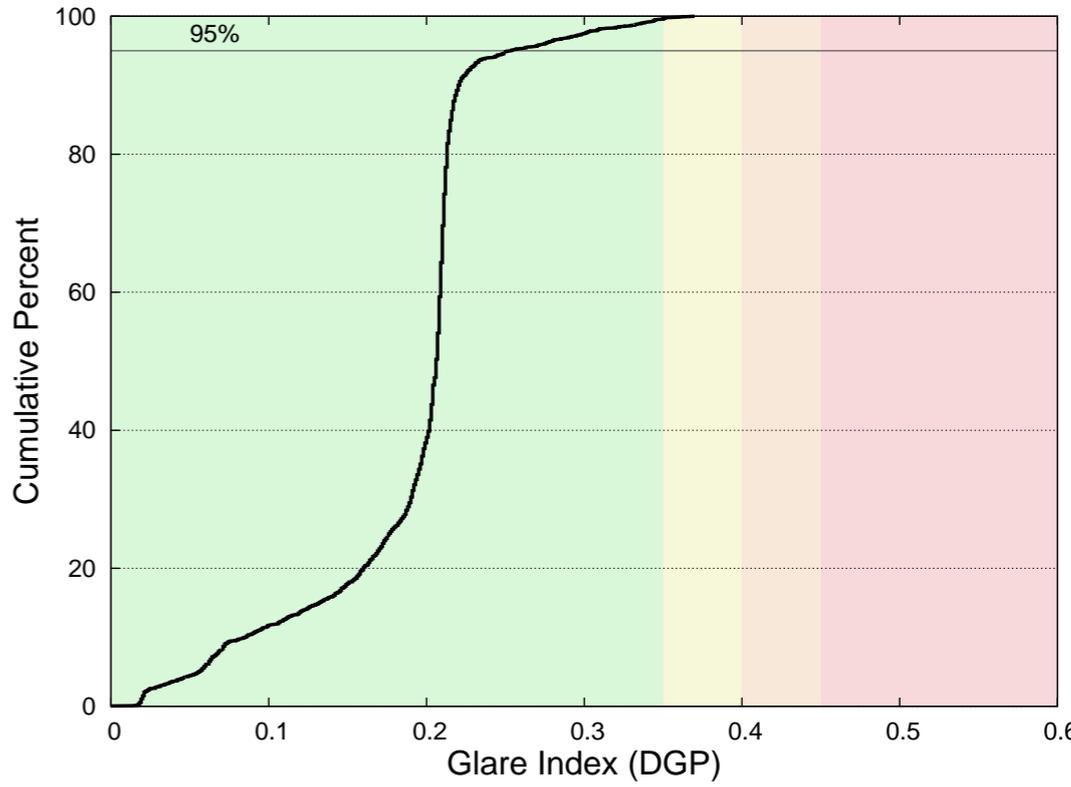
-  HDR Camera Position & Direction
-  Shade Group

Glare | West #1 3/25-4/13, 4/17-4/20 & 4/24-4/26

Daily Glare Plot for April 12, 2015

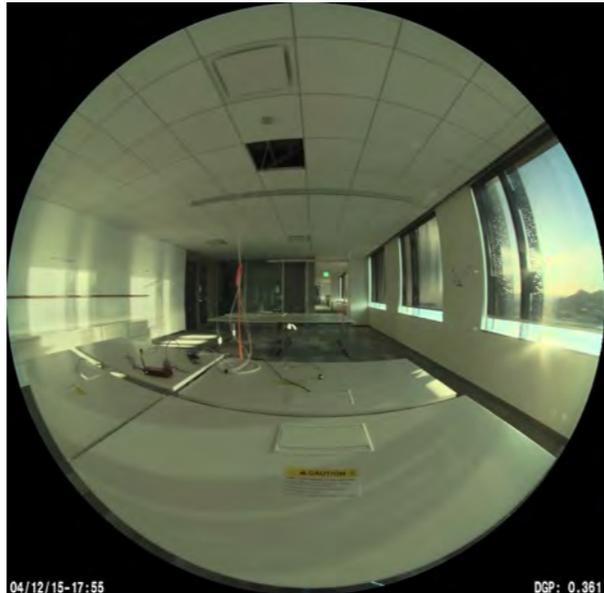


Cumulative DGP for 3/25-4/13, 4/17-4/20 & 4/24-4/26



10:00

18:55

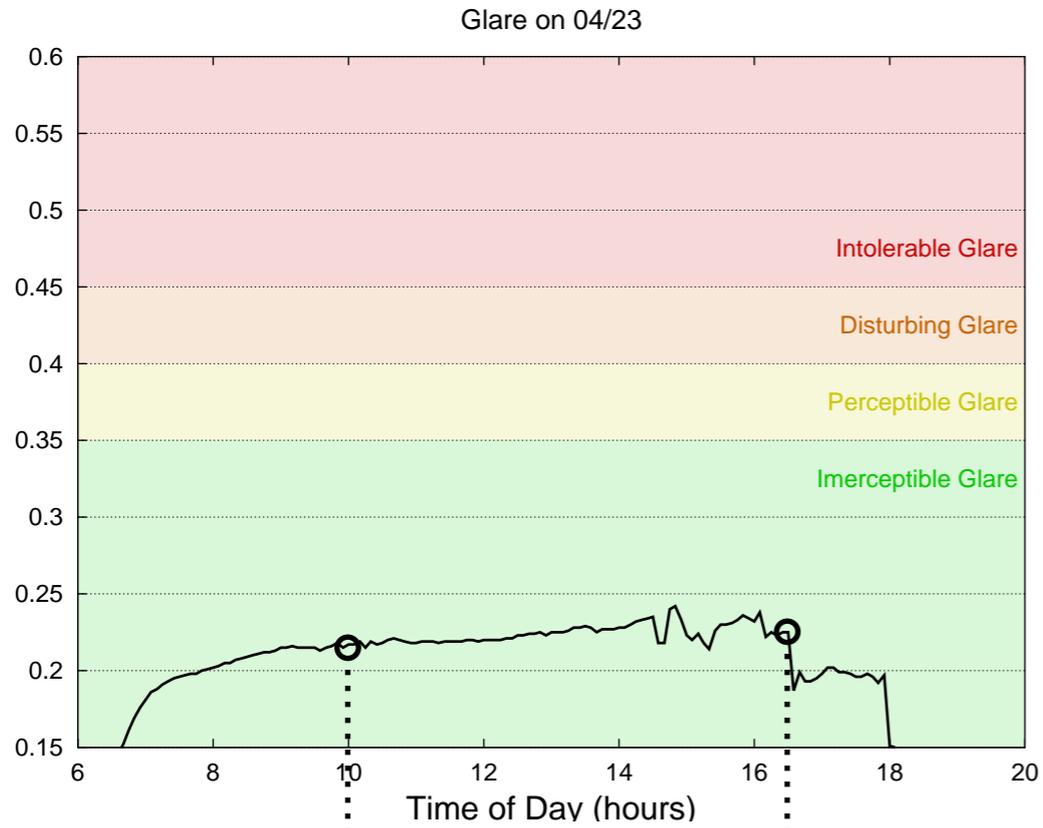


Cumulative DGP Statistics, Position #1, West Area

95% DGP Threshold	0.254
Average DGP within top 5% band	0.305
Comfort Class Rating	A

Glare | West #2 4/21-4/23

Daily Glare Plot for April 23, 2015

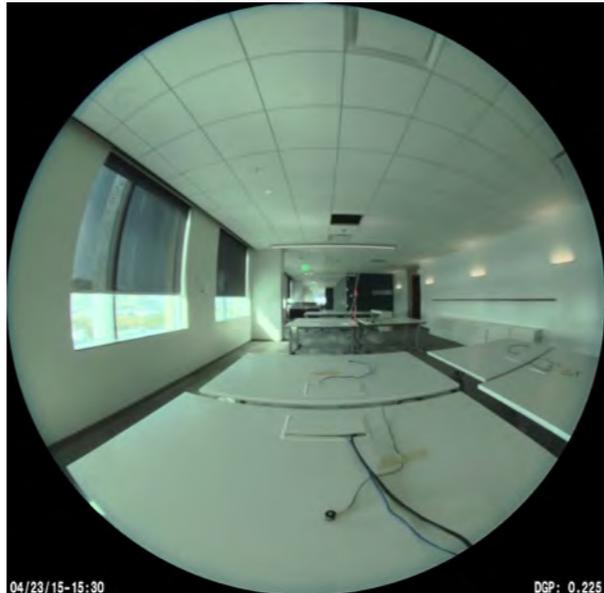


10:00

16:30

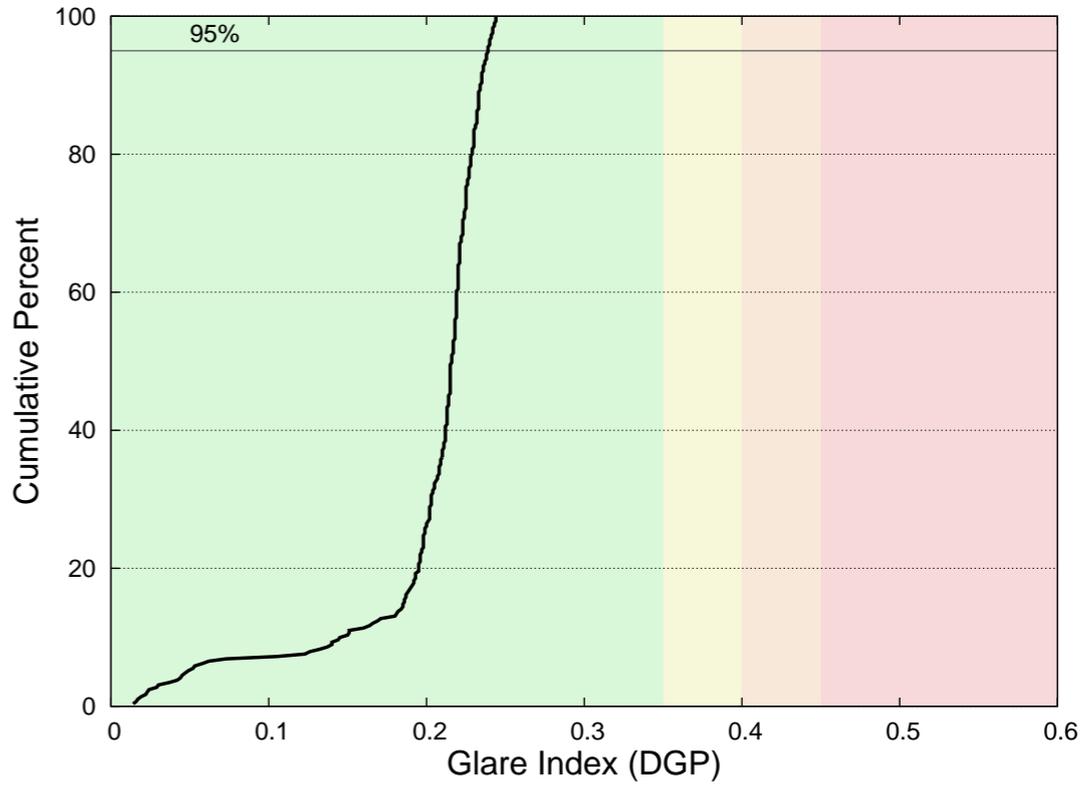


04/23/15-09:00 DGP: 0.217



04/23/15-15:30 DGP: 0.225

Cumulative DGP between 4/21-4/23

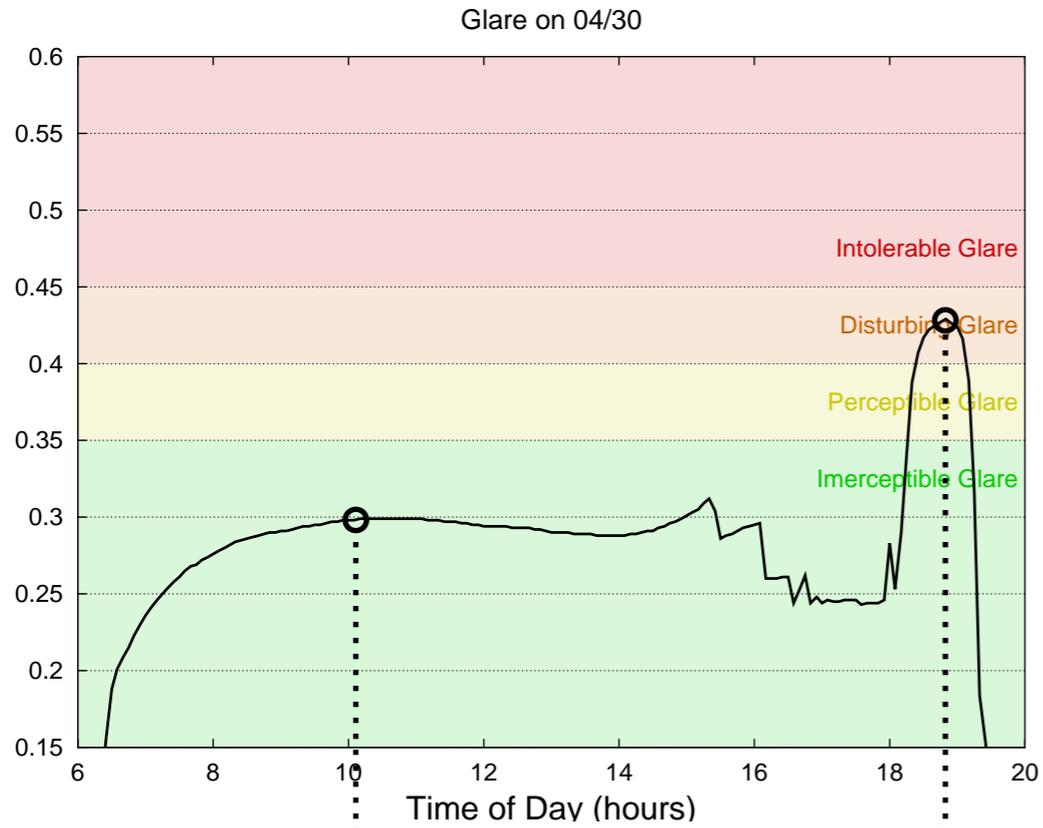


Cumulative DGP Statistics, Position #1, West Area

95% DGP Threshold	0.239
Average DGP within top 5% band	0.249
Comfort Class Rating	A

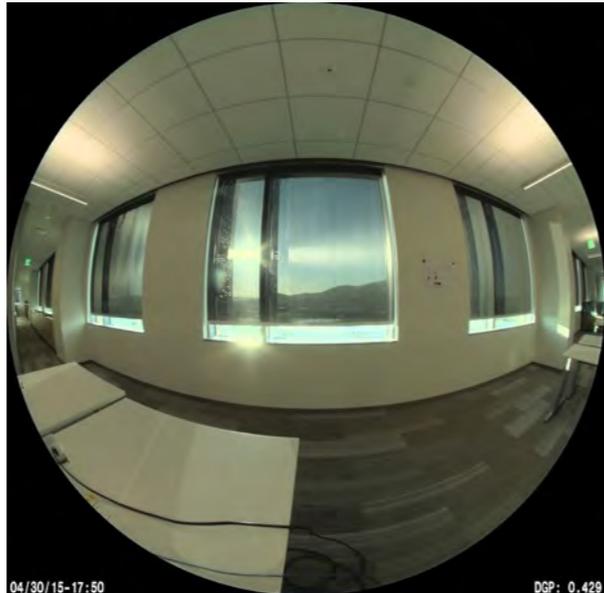
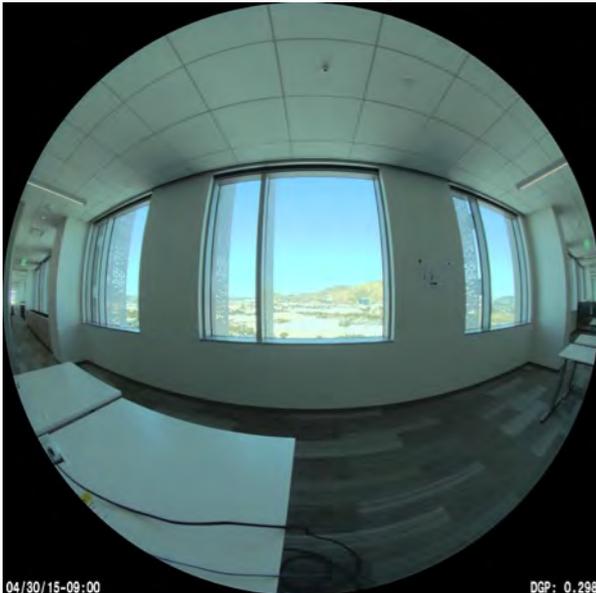
Glare | West #3 4/27-4/30

Daily Glare Plot for April 23, 2015

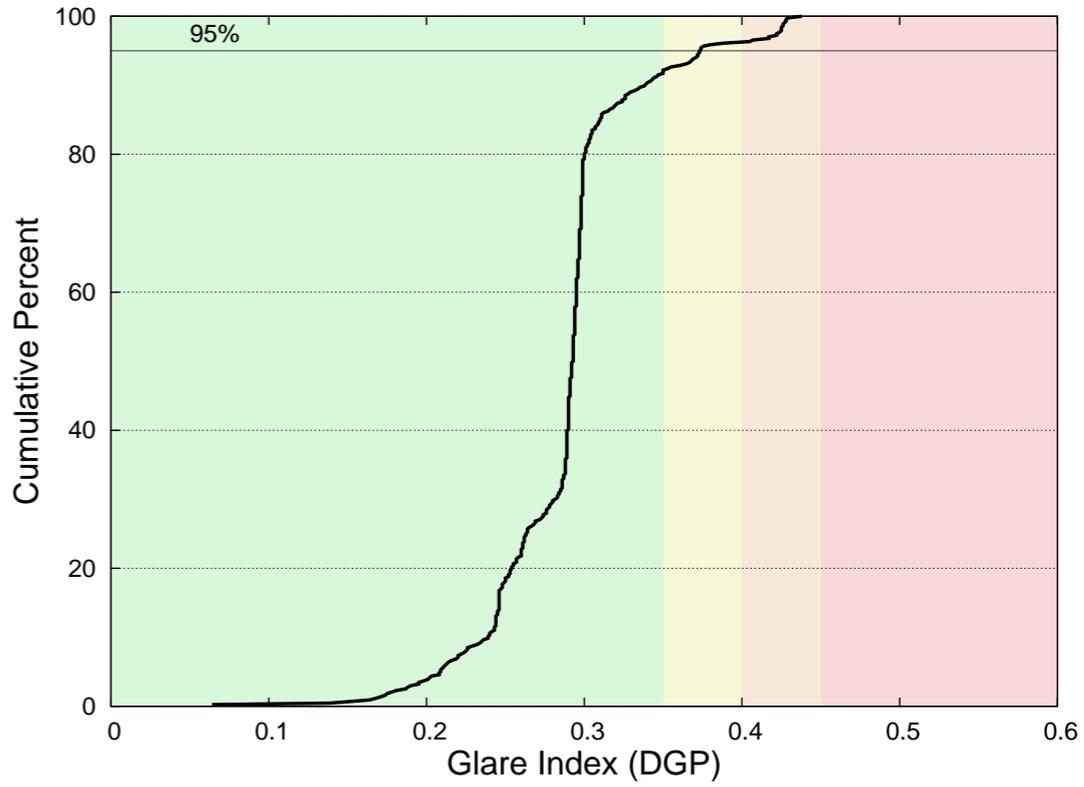


10:00

18:50



Cumulative DGP between 4/21-4/23



Cumulative DGP Statistics, Position #1, West Area

95% DGP Threshold	0.374
Average DGP within top 5% band	0.417
Comfort Class Rating	B

3. Automated Shade Operation

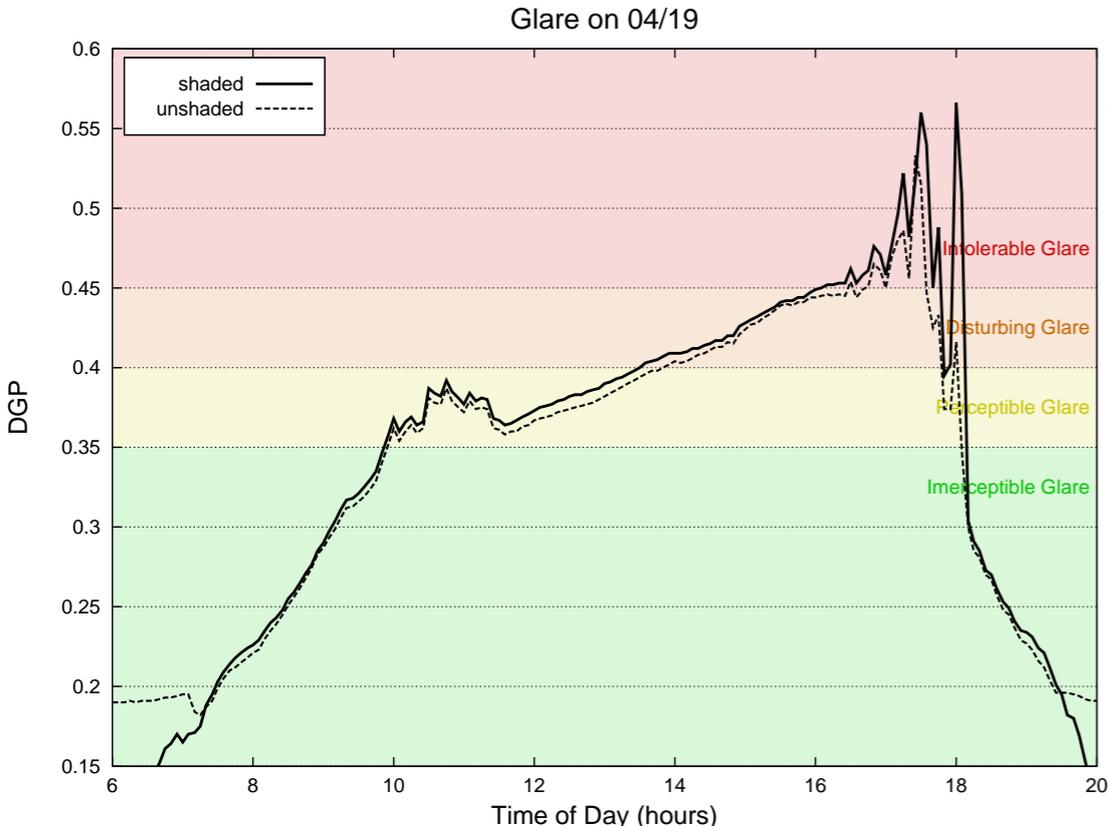


Shade Operation | Method

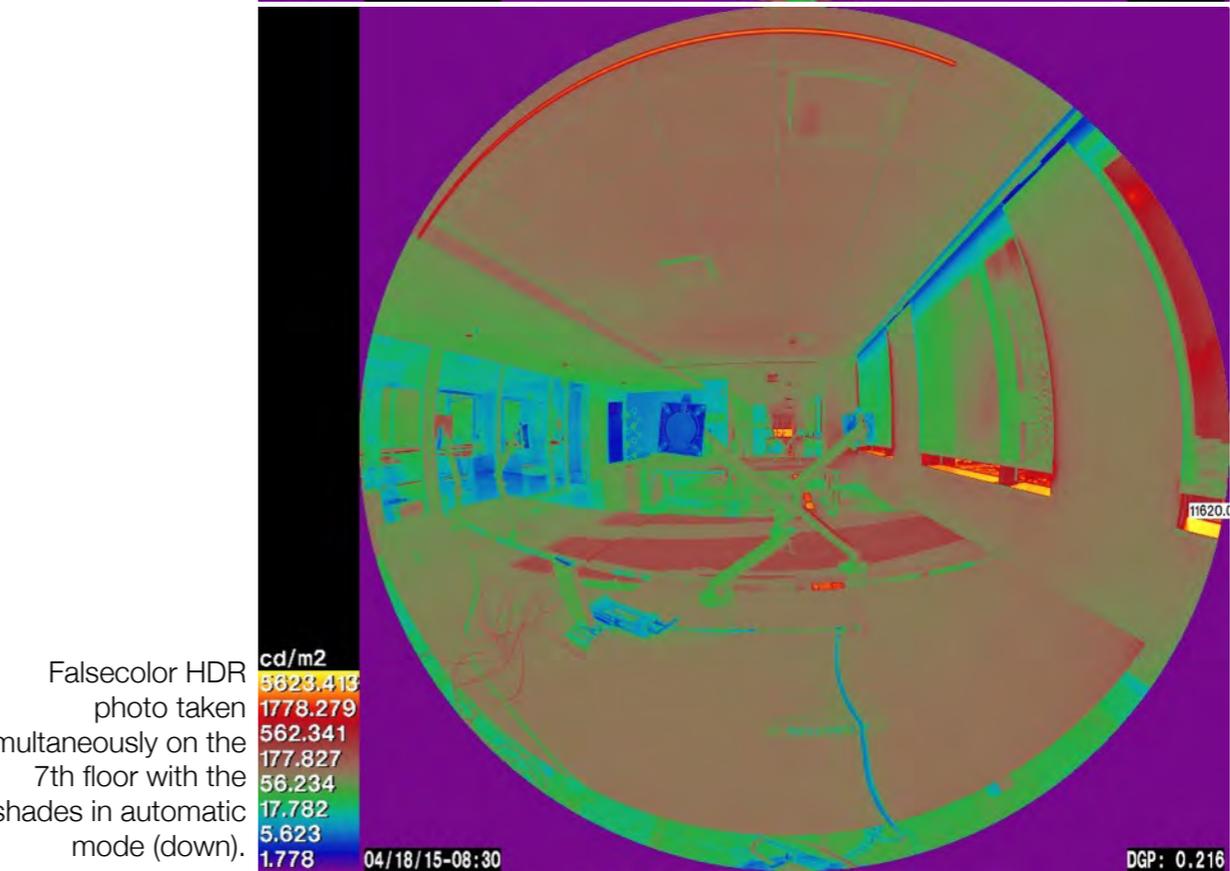
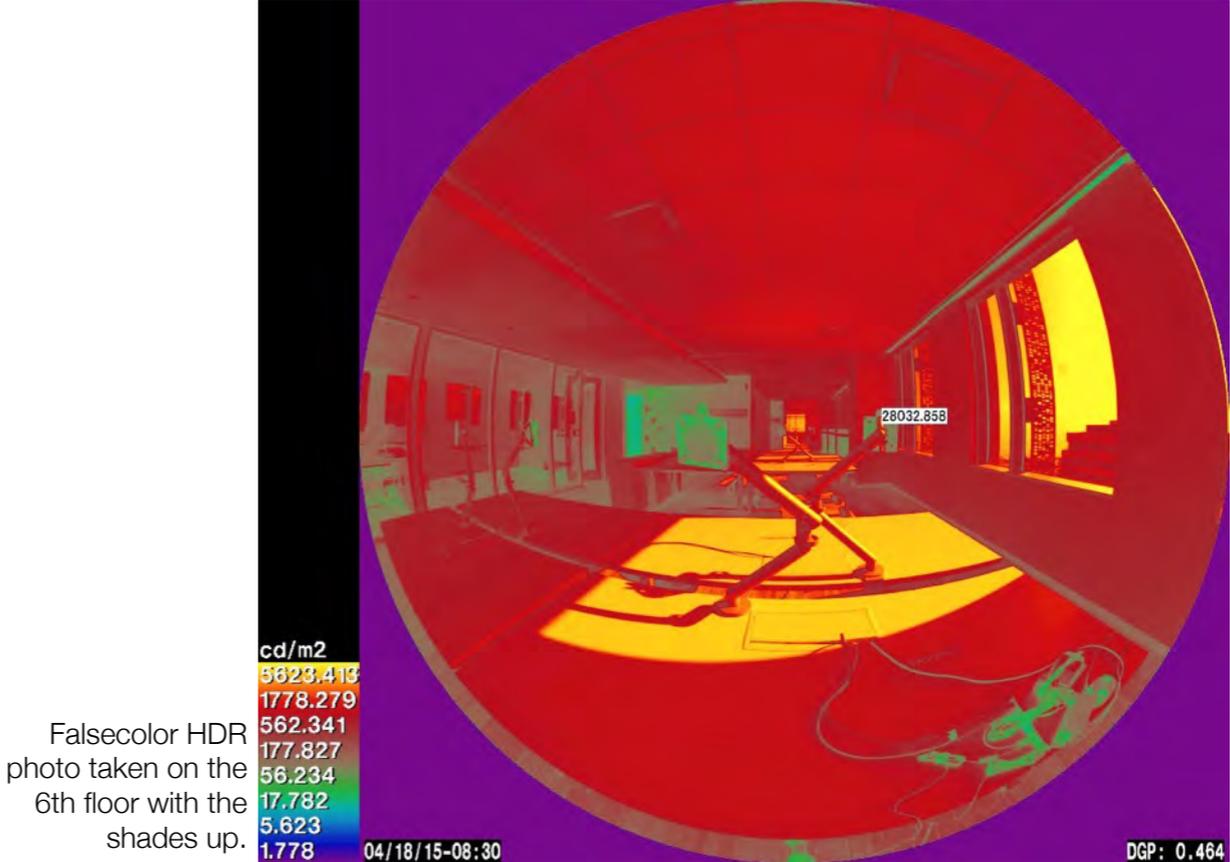
Glare Comparisons

Shade controls on the 6th floor were overridden so that the shades remained up during the second half of April (15th - 30th). Four additional HDR cameras were placed on the 6th floor in the same location as the cameras on the 7th floor (where the shades were operating as normal). With HDR images from essentially the same position able to compare DGP between shaded and unshaded cases. With the comparison we can tell if the shade could have remained up longer.

The falsecolor images on the right show a comparison between daylight conditions on the 6th floor (unshaded) and 7th floor (shaded). The plot below shows DGP recorded on a day when shades were raised on both the 6th and 7th floors. The DGP between two floors tracked very closely, demonstrating that the two conditions are comparable.



DGP plot on a day when shades were raised on both the 6th and 7th floor.



Shade Operation | Summary

Shade Operation

The shade controller was initially commissioned to operate as follows:

- When Sunny: Limit sun ingress into the building to 36" from the facade on the floor.
- When Cloudy: Raise the shades to admit more daylight. The controller will wait 10 minutes after the sky changes from sunny to cloudy to limit cycling on dynamic days.
- When Luminance of the sky causes glare (regardless of sky condition): Lower the shade to cover half of the window. The in window glare sensor has a threshold of 7000 for lowering the shade.

In Test Modifications

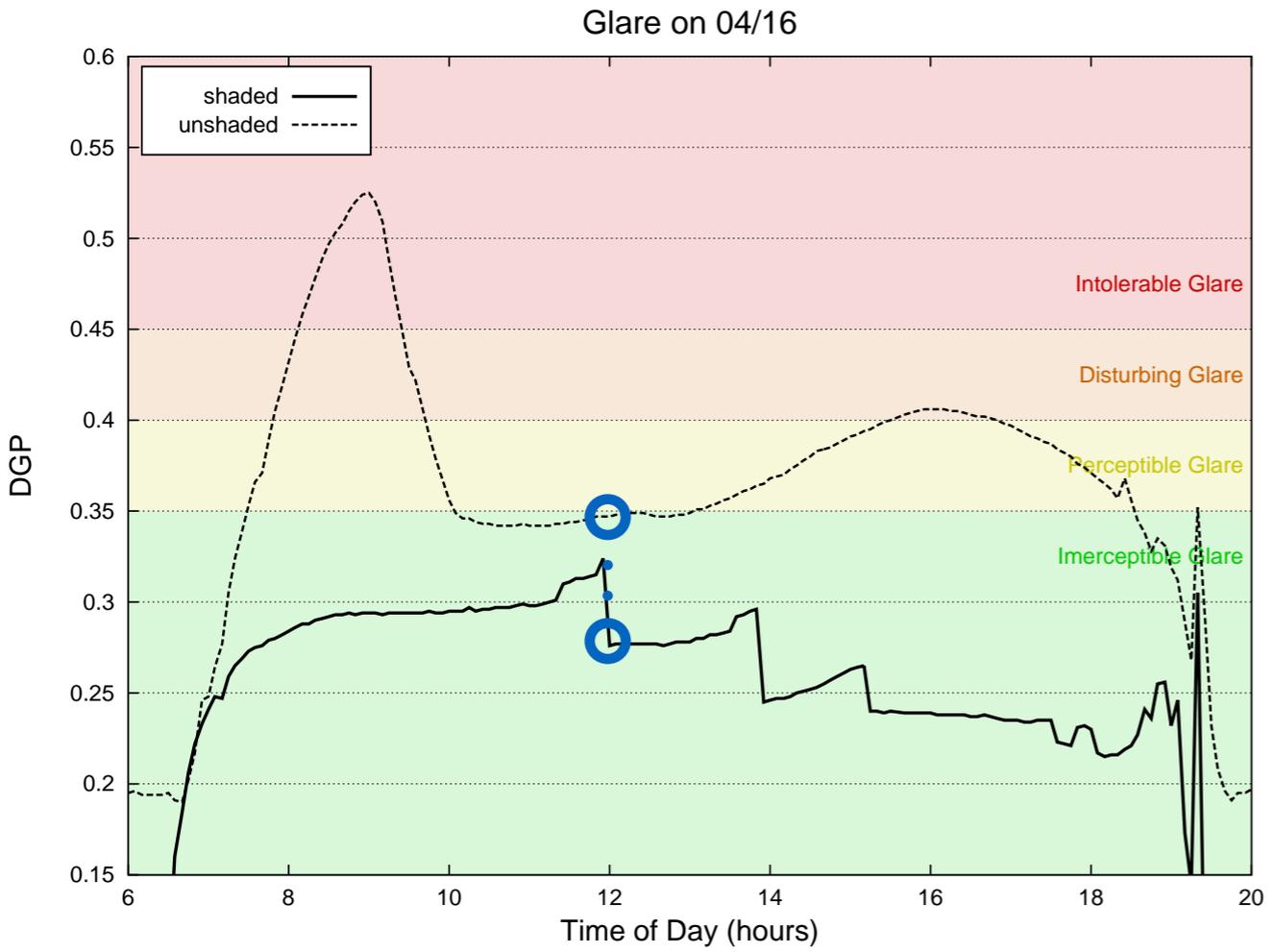
After a few days of comparative DGP measurements, we determined that the threshold for the glare sensor could be increased by 25% (from 7000 to 8750). Additionally, furniture locations would permit than 48" of direct sun ingress at the North, South and West facades. Furniture is located closer to the window on the East facade, so the ingress limit remained at 36".

These changes were implemented on April 23rd.

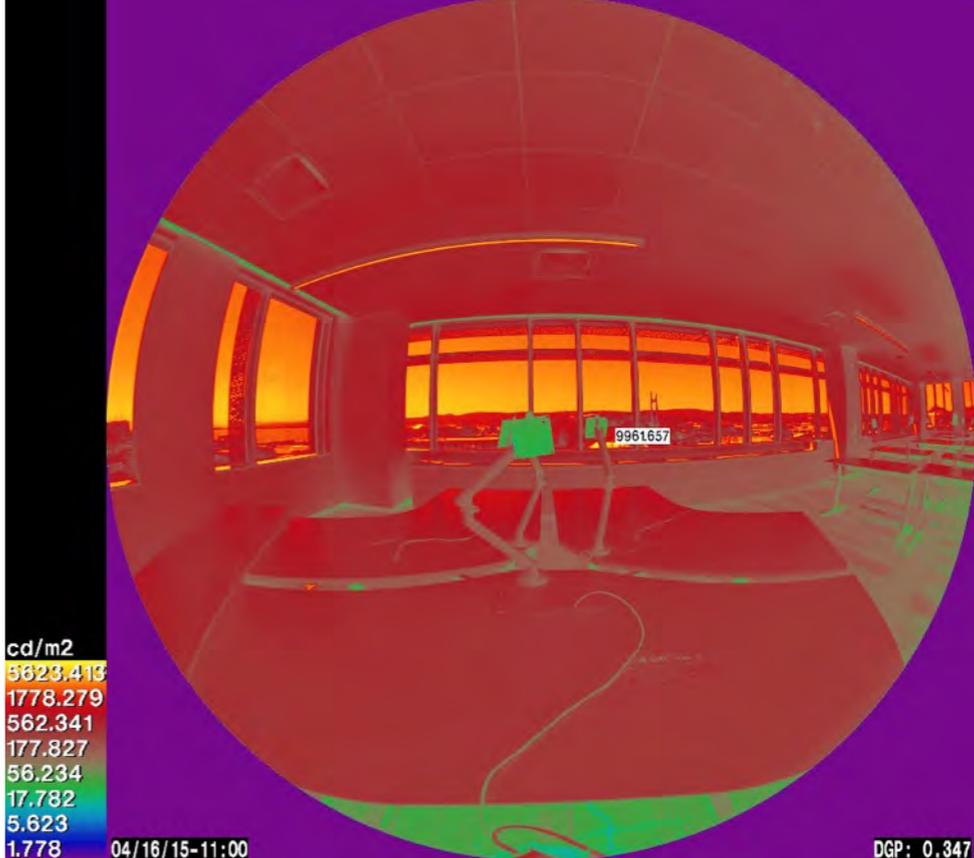
Shade Operation | South Facade

In this south facing view the shades on the east window (left in view) are deployed early in the day to prevent glare from the east. Around noon the South shades lower to mid-window to prevent glare from the bright sky. Around 2 PM the south shade lowers further to prevent direct sun ingress. At 3:15 the south shade closes to the lowest position to prevent sun ingress.

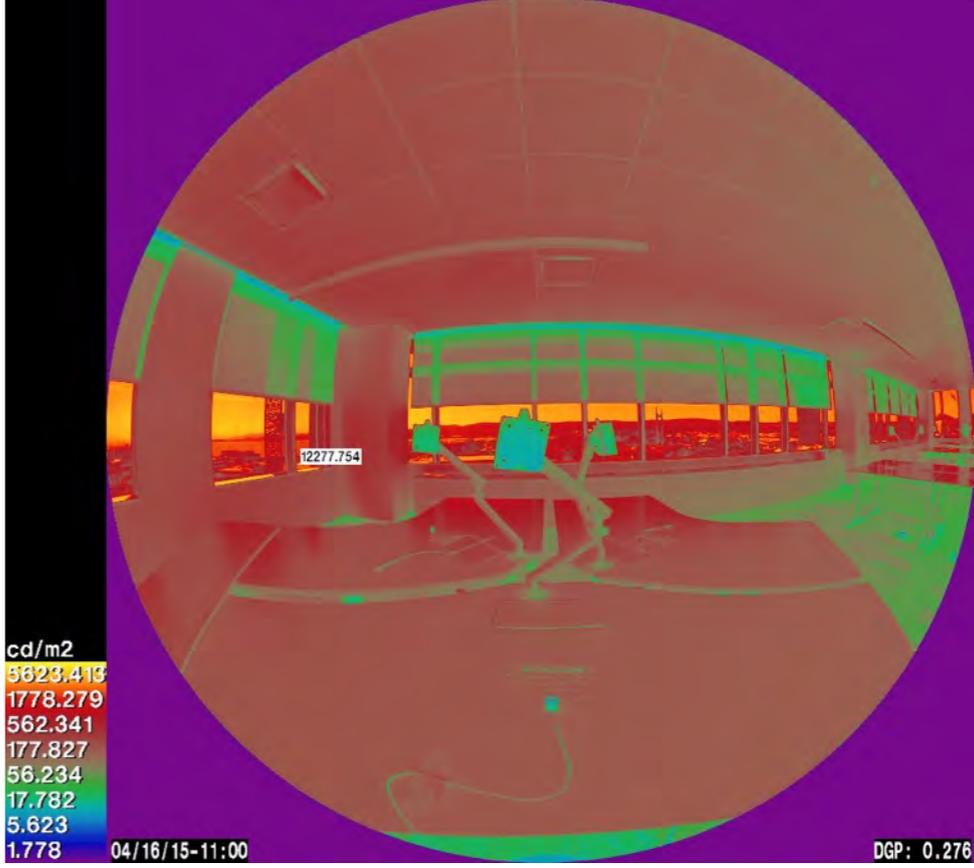
The images to the right show the moment just after the shades on the south facade move to mid-window to prevent sky glare. DGP on the unshaded floor is 0.347, just at the threshold of “perceptible glare.” This demonstrates that south and east shades were appropriately deployed to prevent discomfort glare despite neither east nor south shade needing to be down to limit sun ingress. Though perhaps the one of either the south or east shades could have remained up longer (but not both).



April 16, 12:00
Unshaded Condition



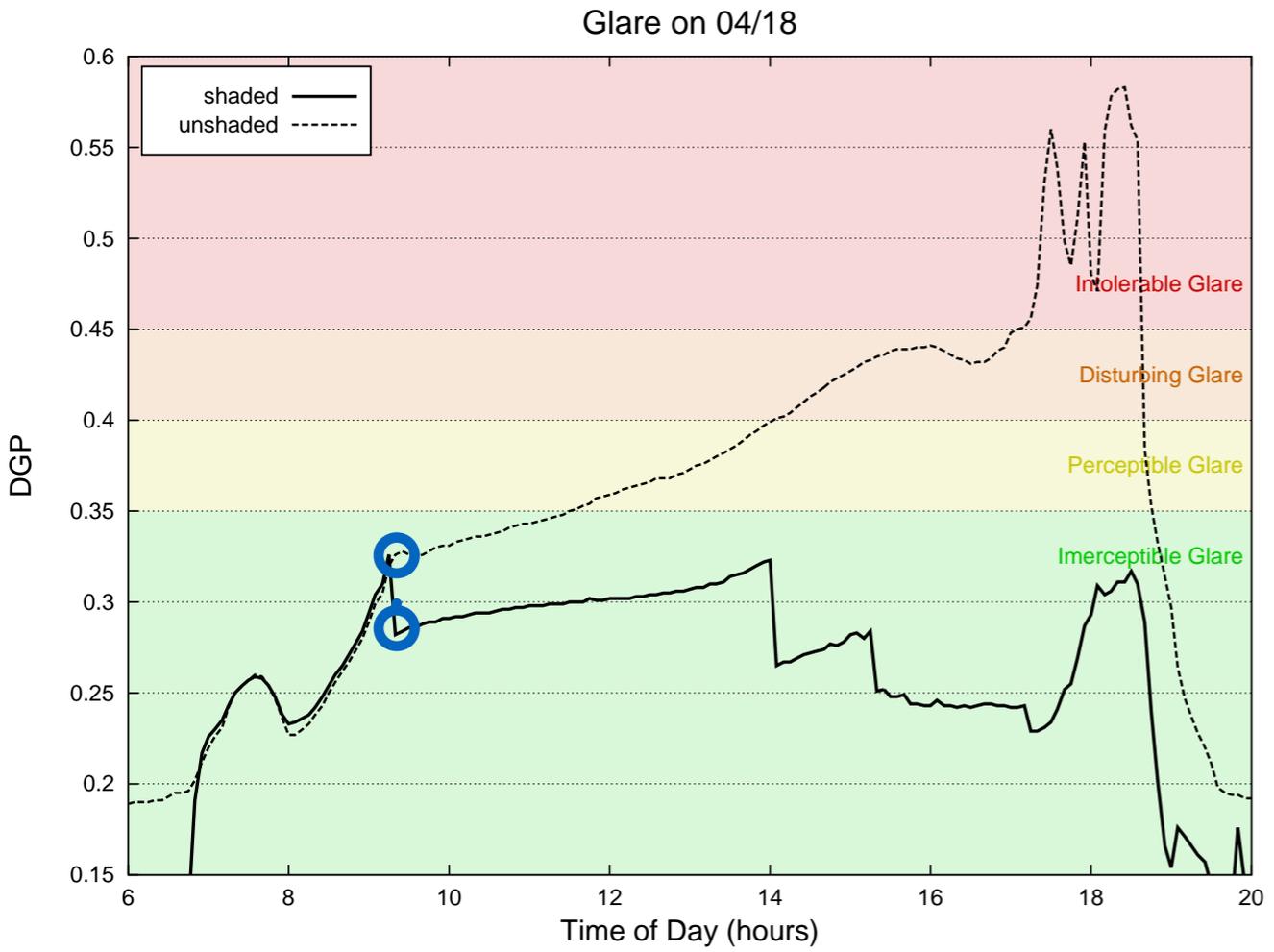
April 16, 12:00
Shaded Condition



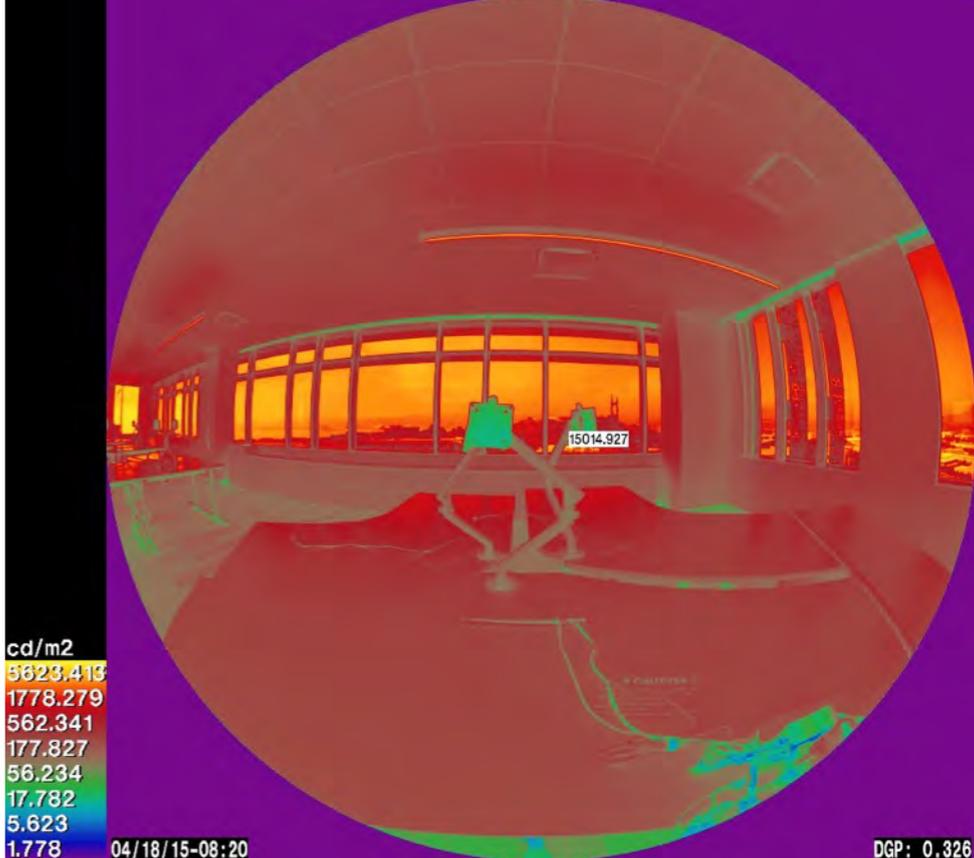
Shade Operation | South Facade

In this south facing view the shades on the south and west (on the right in the view) windows are raised in the morning. The south shade deploys to mid-window height at 9:20 AM to mitigate glare from the sky. Then at 2:05 PM the south shade lowers to limit sun ingress into the space. At 3:20 PM the south shade moves to the lowest level. The west shade remains up until 3:00 PM. Then between 3:00 and 4:00 the west shade progressively lowers to limit sun ingress.

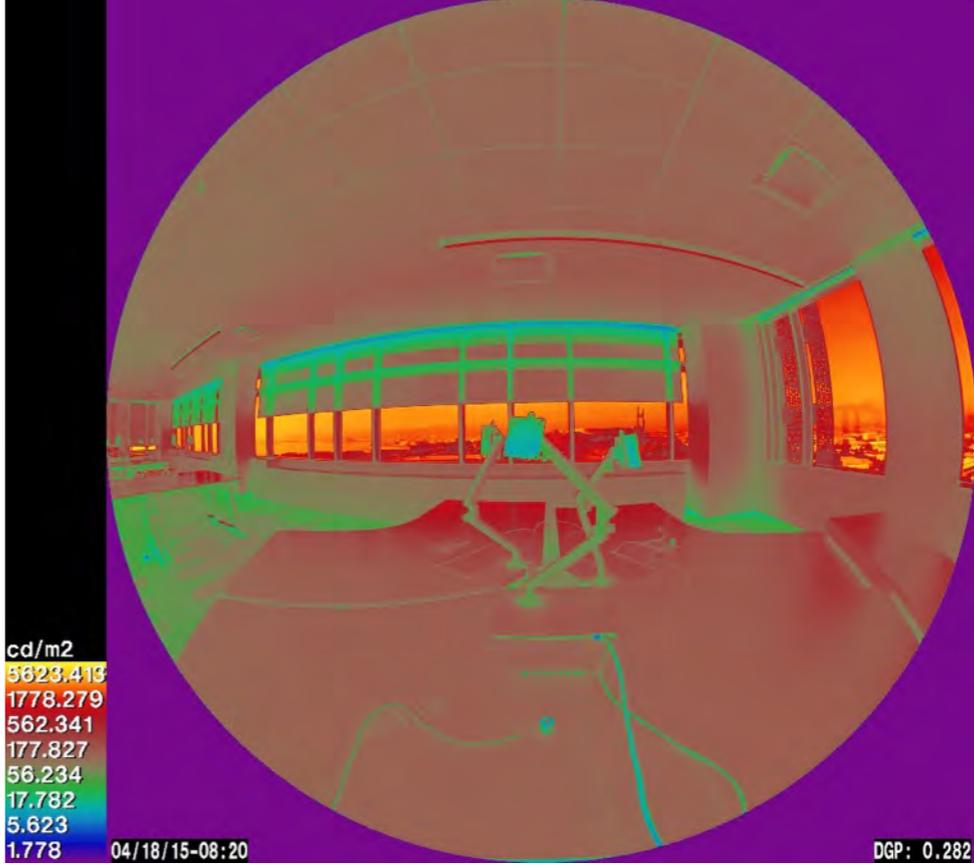
The images to the right show the moment just after the shades on the south facade move to mid-window to prevent sky glare. DGP on the unshaded floor is 0.326, in the “imperceptible glare” range. In this case the DGP from the south facade doesn’t cross into the “perceptible glare” range until 11:30, three hours later. This occurred before the MechoSystems glare sensor threshold was raised by 25%.



April 18, 9:20
Unshaded Condition



April 18, 9:20
Shaded Condition

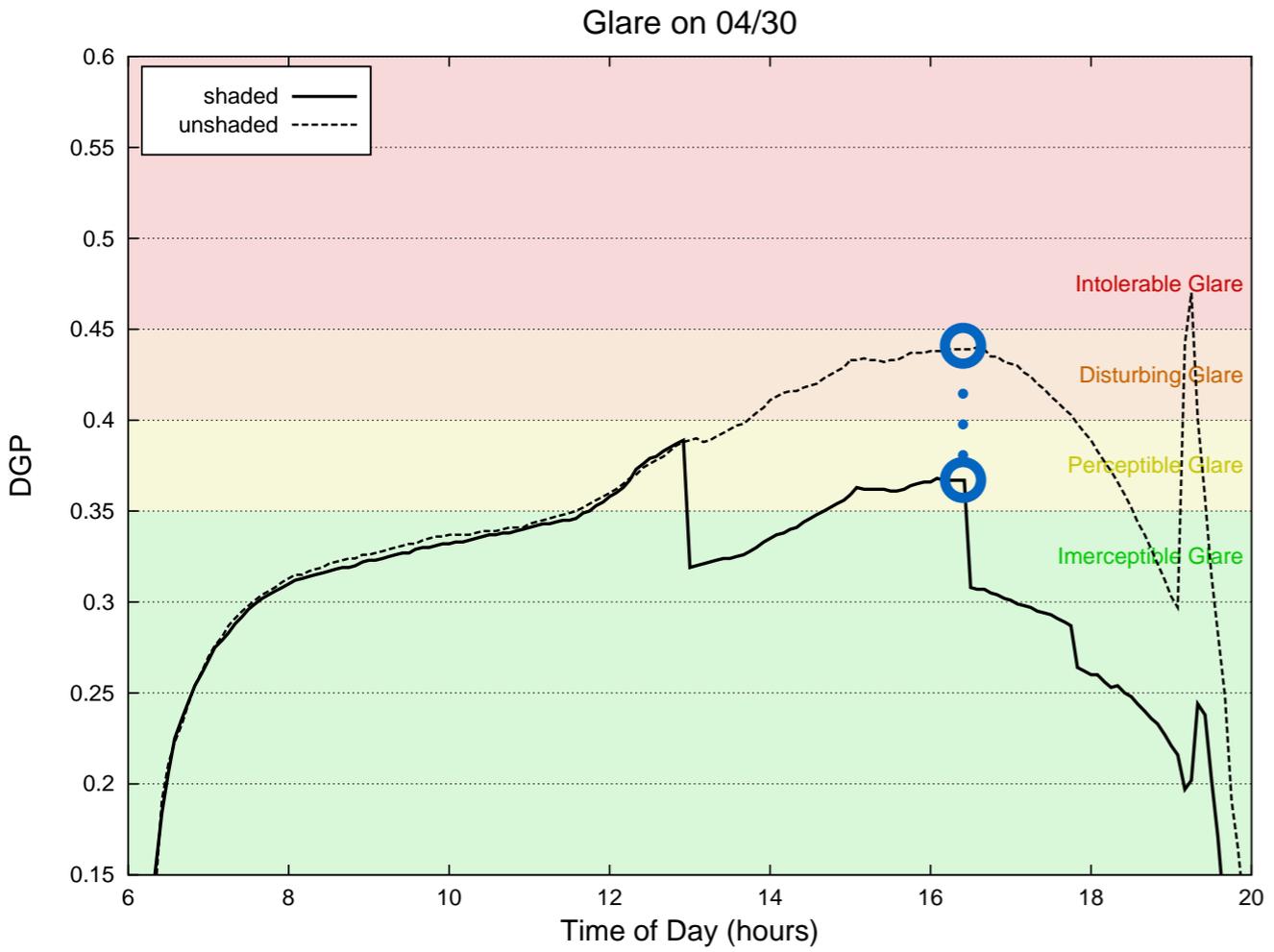


Shade Operation | South Facade

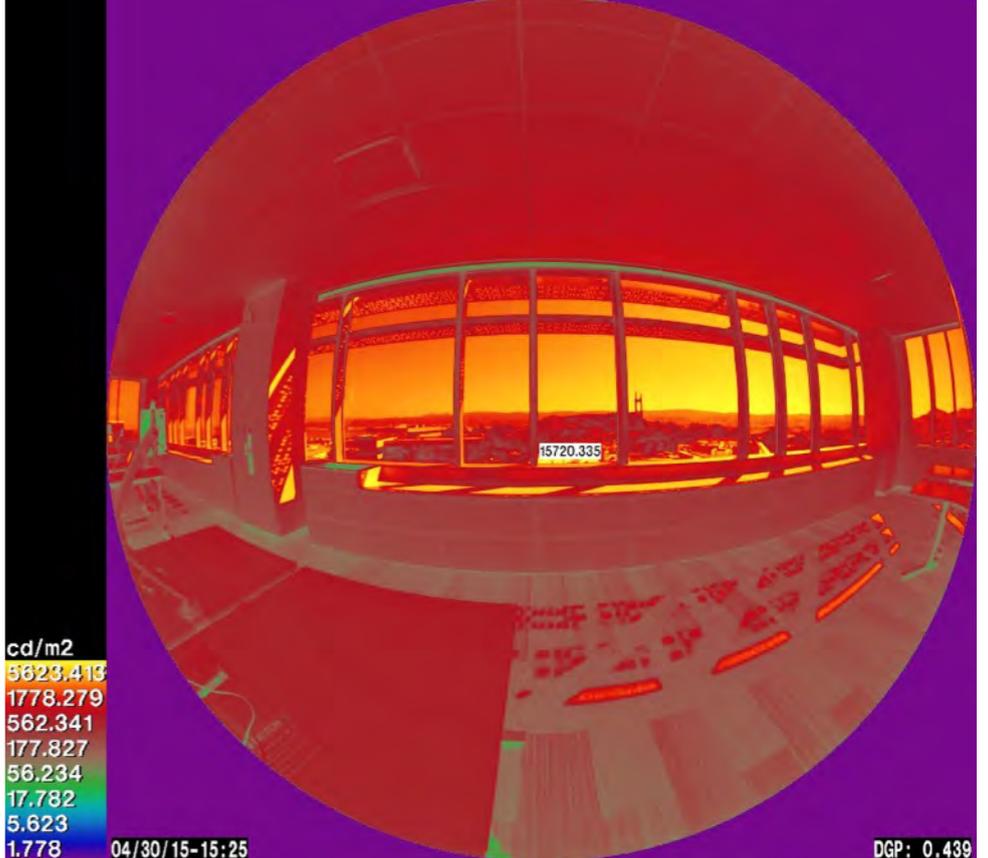
This view is atypical because the camera faces 90° to the desk, directly facing the window. In the glare assessment section this view was rated class 'B.' This view was taken to understand worst case condition on the south facade.

The south shade lowers to mid-window height at 1 PM to prevent sky glare, an appropriate time for typical desk views. However, for a view facing the window such, it should have occurred an hour earlier for DGP to remain below 0.35. Then at 4:30 PM the shade begins to lower to limit sun ingress. For this view, DGP crosses into "perceptible glare" peaking at 0.367 prior to lowering the shade.

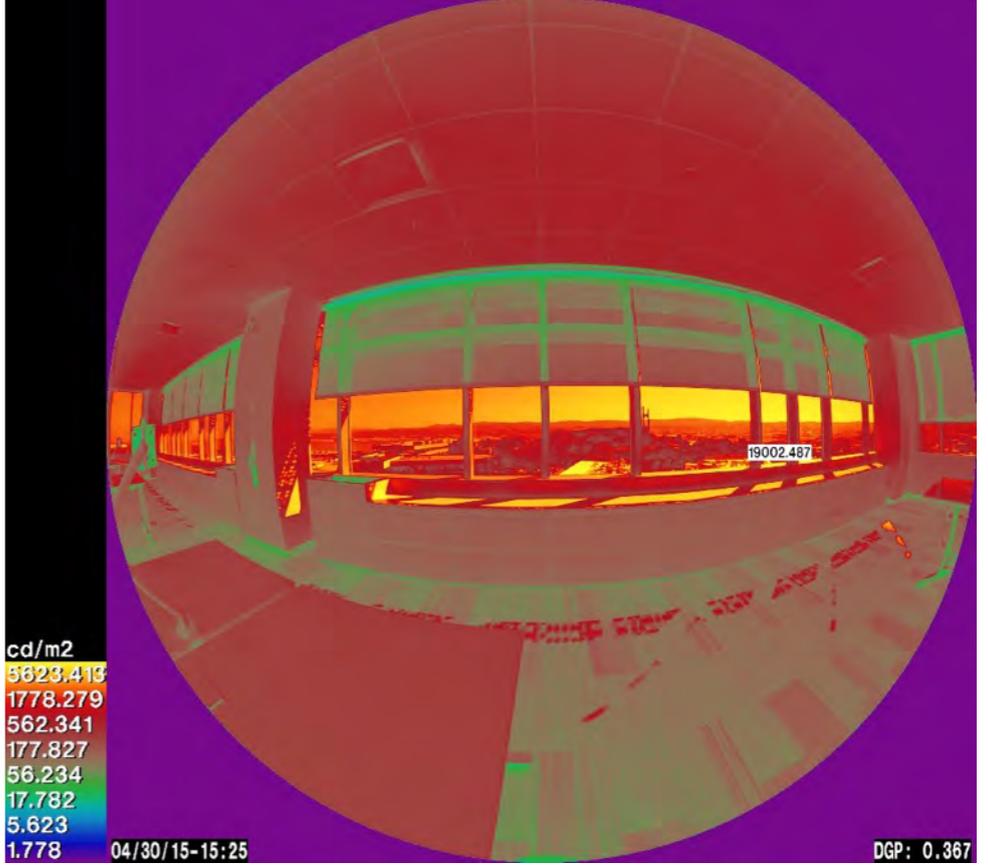
If the occupant faces the direction of the desk (as is expected) DGP will be lower than is shown in the chart below and should be in acceptable range. This demonstrates that the shade controls are optimized tuned for the current furniture arrangement, however if desks are moved the glare sensor threshold may need to be lowered.



April 30, 16:25
Unshaded Condition



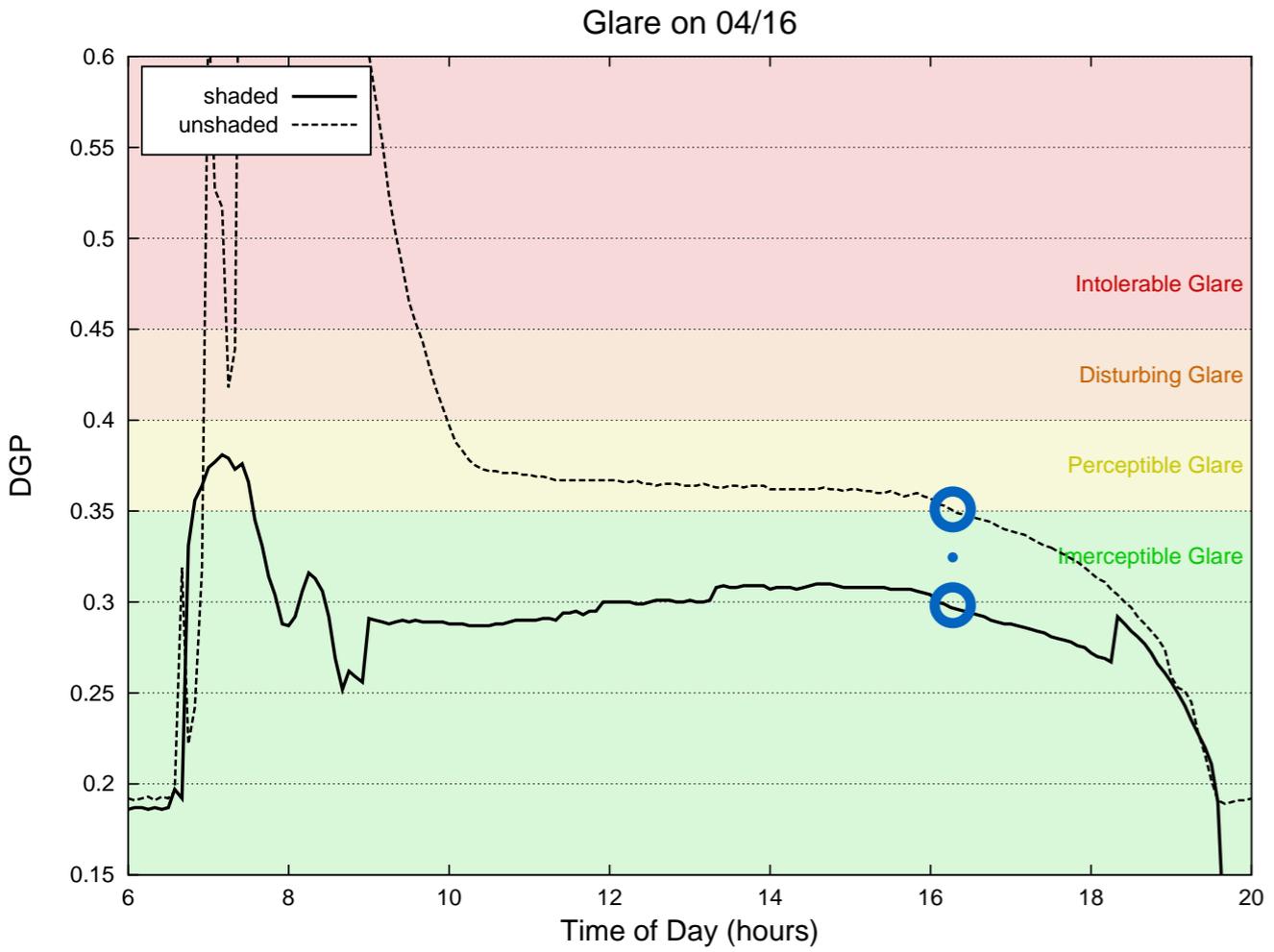
April 30, 16:25
Shaded Condition



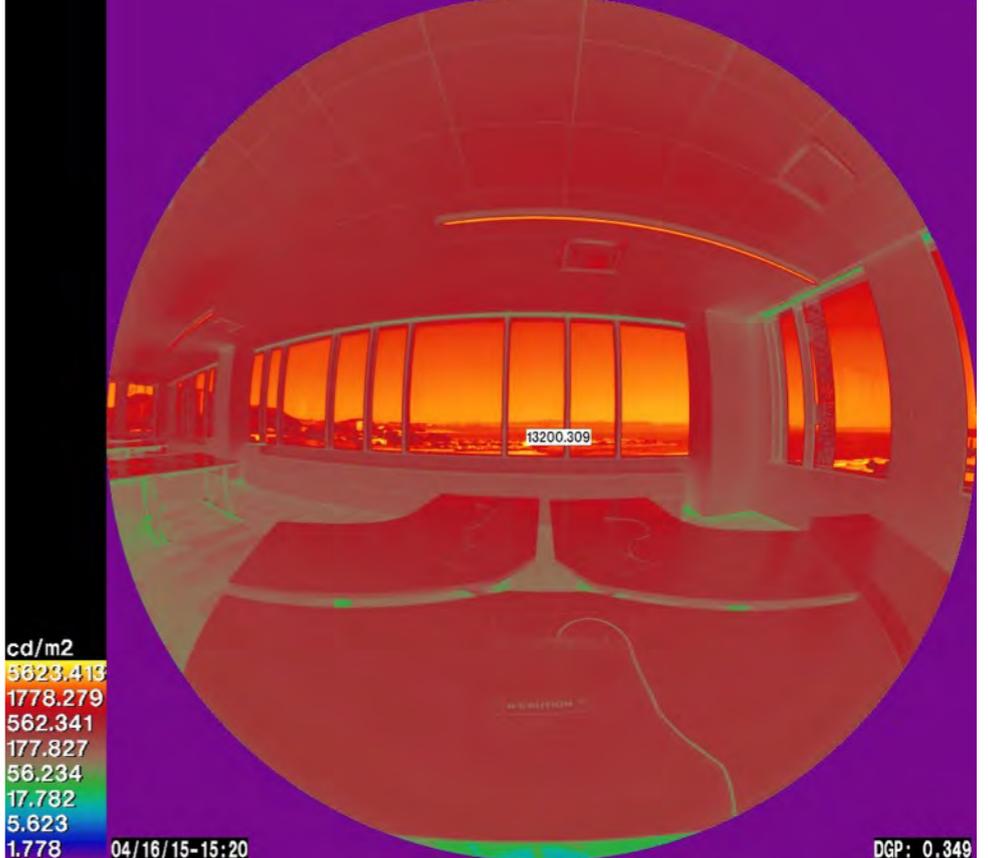
Shade Operation | North Facade

In this north facing view the shades on the north (straight ahead in view) and east (to the right in view) start the day in a fully lowered position to prevent limit direct sun ingress. The north shade begins to raise at 8:45 AM and by 9:00 the shade is at the mid-window position. The north shade remains in the mid-window position due the sky brightness until 6:20 PM. The east window shade at the lowest position until 10:20 to limit direct solar ingress, it raises gradually until it is fully raised at 1:20 pm.

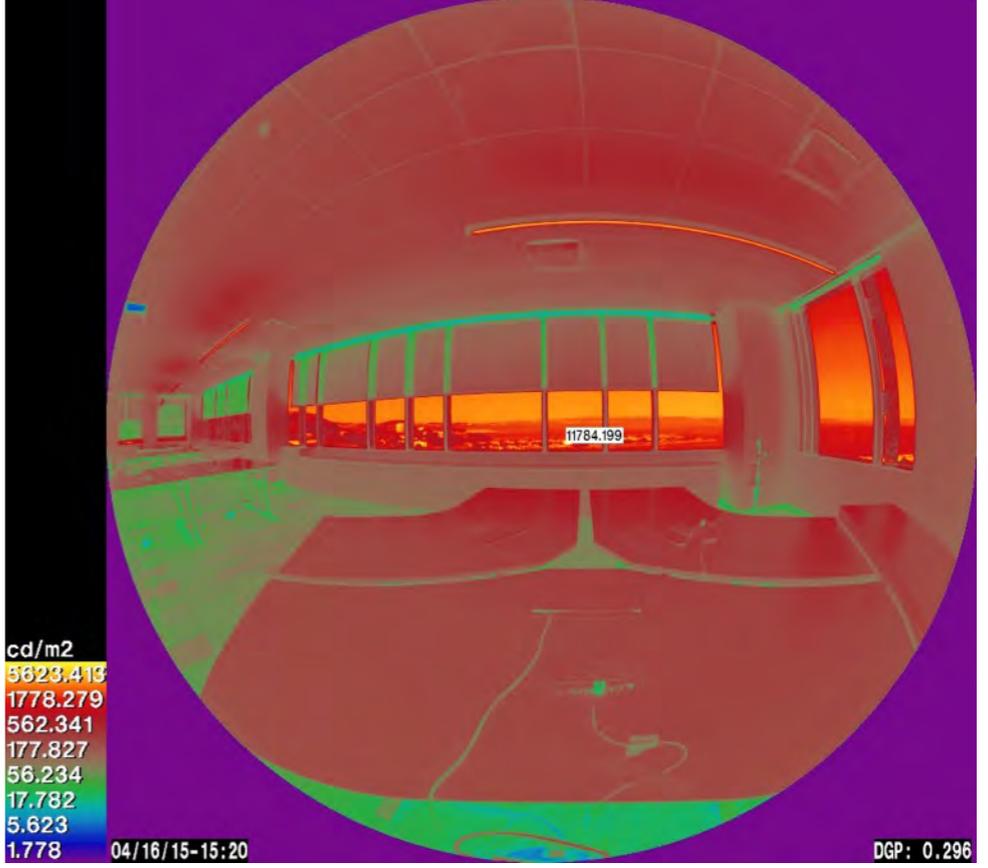
The DGP plot below shows that for this view, the north shade could have been fully raised at 4:20 PM, when DGP on the unshaded floor was 0.349, two hours earlier than when the shade actually raised. These conditions occurred before the glare sensor threshold was raised.



April 16, 16:20
Unshaded Condition



April 16, 16:20
Shaded Condition

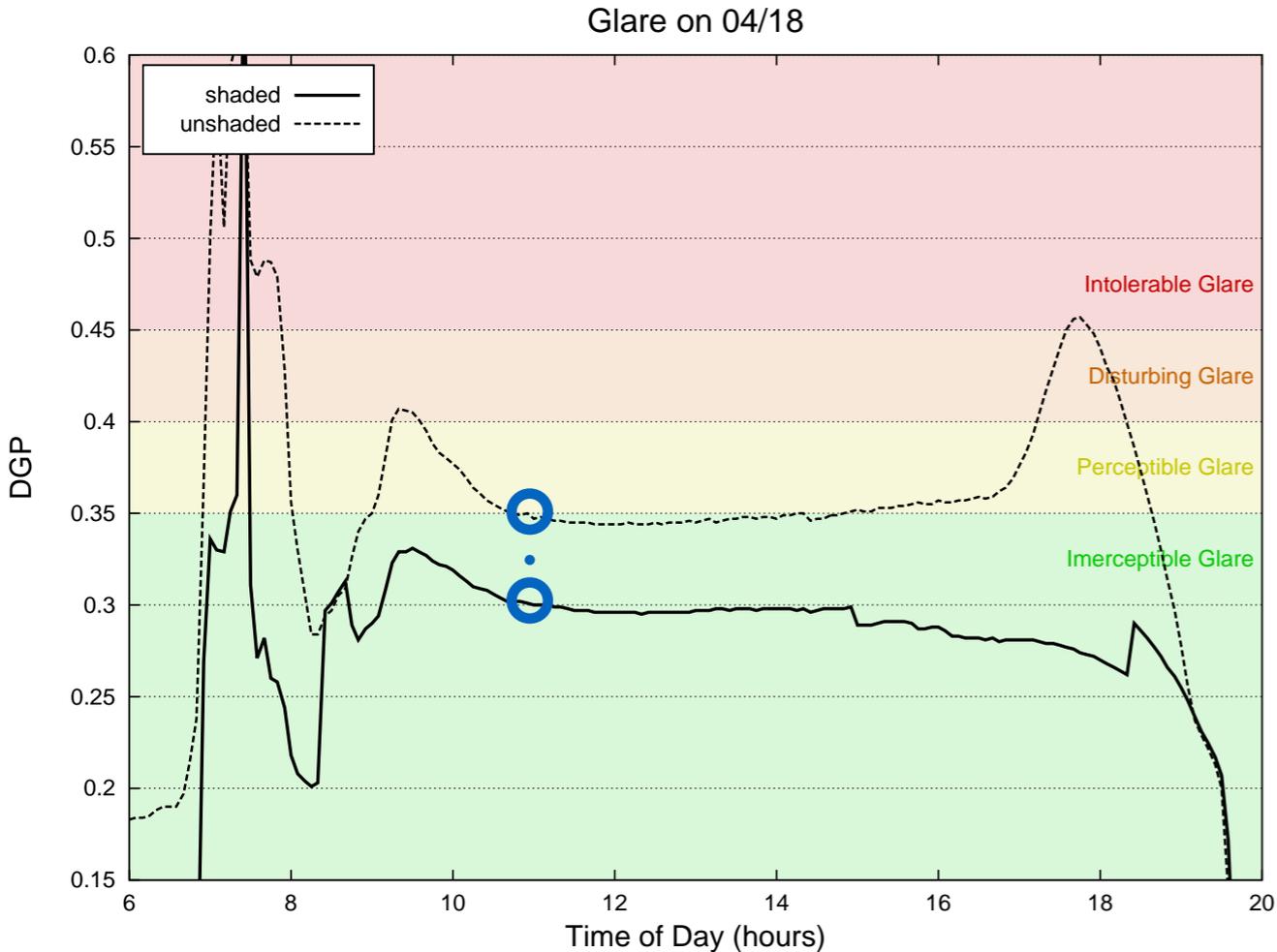


Shade Operation | North Facade

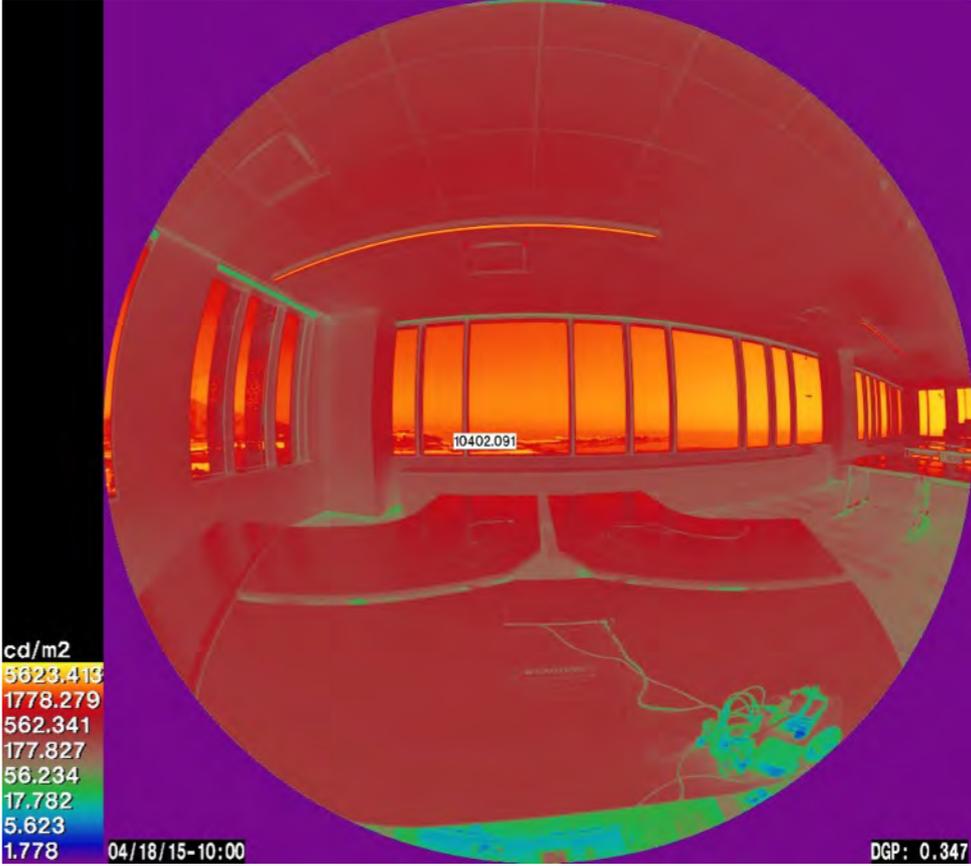
The west shades (left) in this north facing view remain fully open until 3:00 PM at which point they begin to deploy to limit sun ingress. The west shades are at the lowest level by 4:05 PM.

The north shades (straight ahead) begin the day at the lowest level to limit ingress of low angle sun. At 7:25, DGP spikes in the shaded condition because the sun shines through a small gap between the shade and the column. The north shade raises completely at 8:25 AM, when clouds obscure the sun. At 8:45 as the clouds begin to thin, the glare sensor triggers the shades to lower to mid-window height to prevent glare from the bright sky. The north shades remain at mid-window until 6:20 at which point they are fully raised.

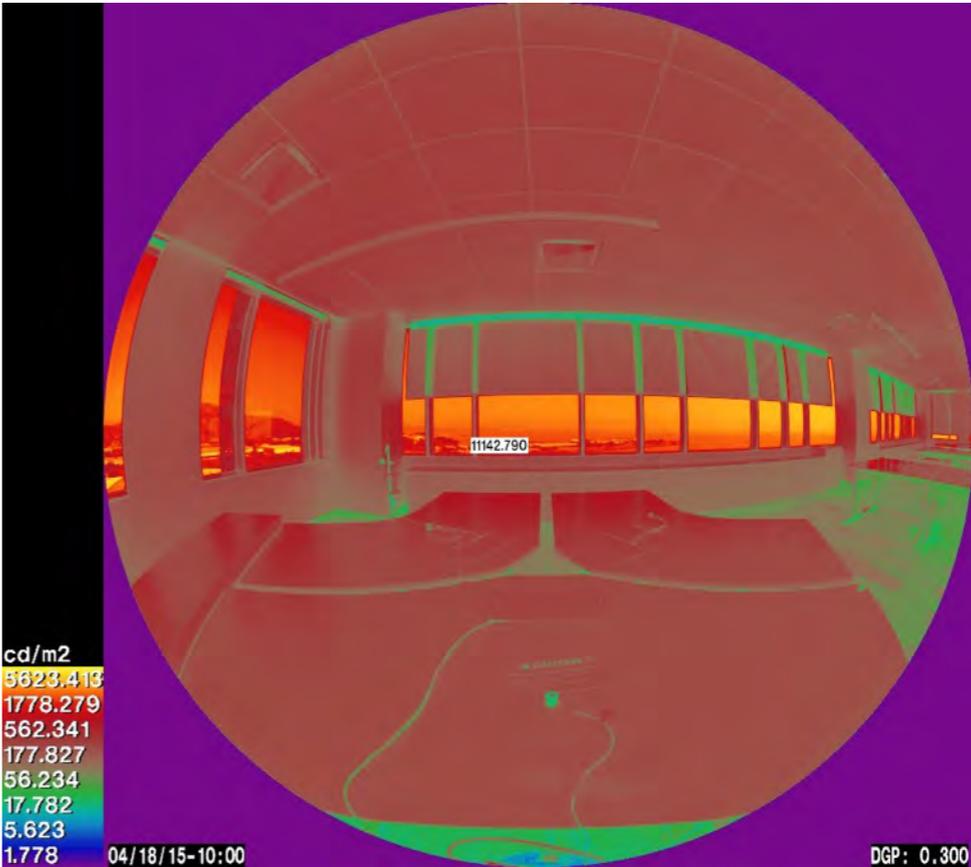
The images to the right from 11:00 AM show the time when the DGP on the unshaded floor crosses below the 0.35 threshold and the north shades could have been raised, though DGP remains near the threshold until it cross back above around 3:00 PM.



April 18, 11:00
Unshaded Condition



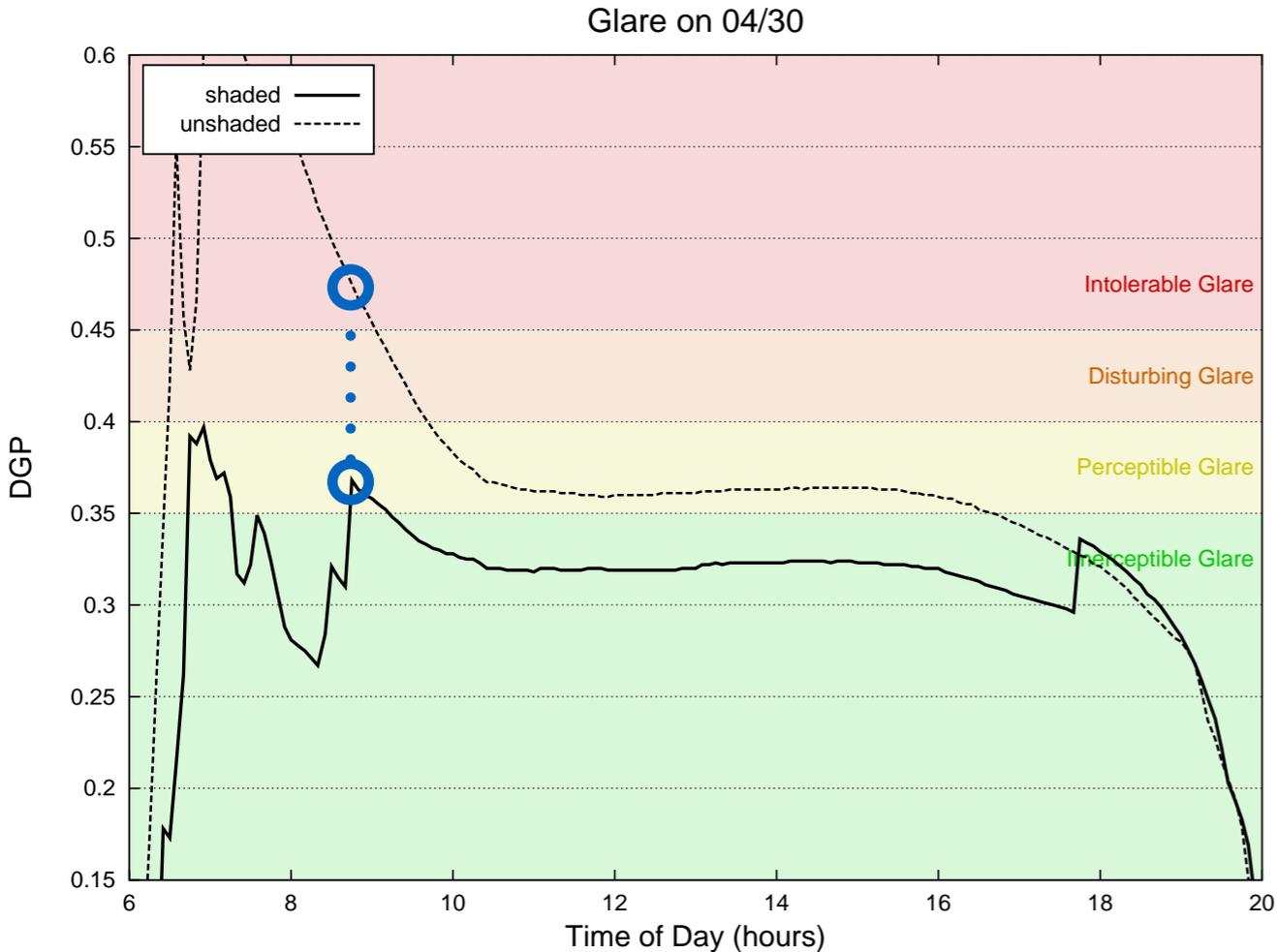
April 18, 11:00
Shaded Condition



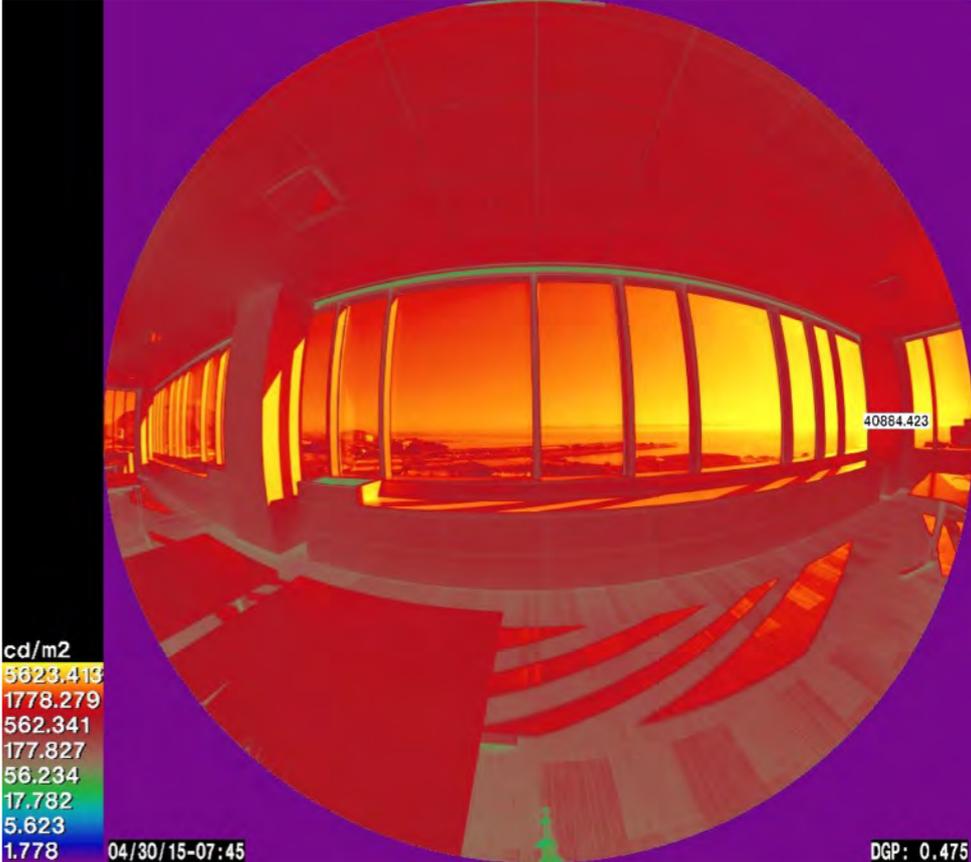
Shade Operation | North Facade

This atypical north view faces 90° to the desk, to look directly at the north window. The shades begin the day at the lowest level to limit direct sun ingress. The orb of the sun is visible through the shade, and so the DGP is in the “perceptible glare” range between 6:40 and 7:10 AM. The shade begins to raise at 8:30. The shade remains at the mid-height level from 8:45 AM until 5:40 PM to prevent glare from the bright sky. The diagram below shows that DGP would be in the perceptible range during much of the time that the shade was at mid-height. These conditions occurred after the glare sensor threshold was increased.

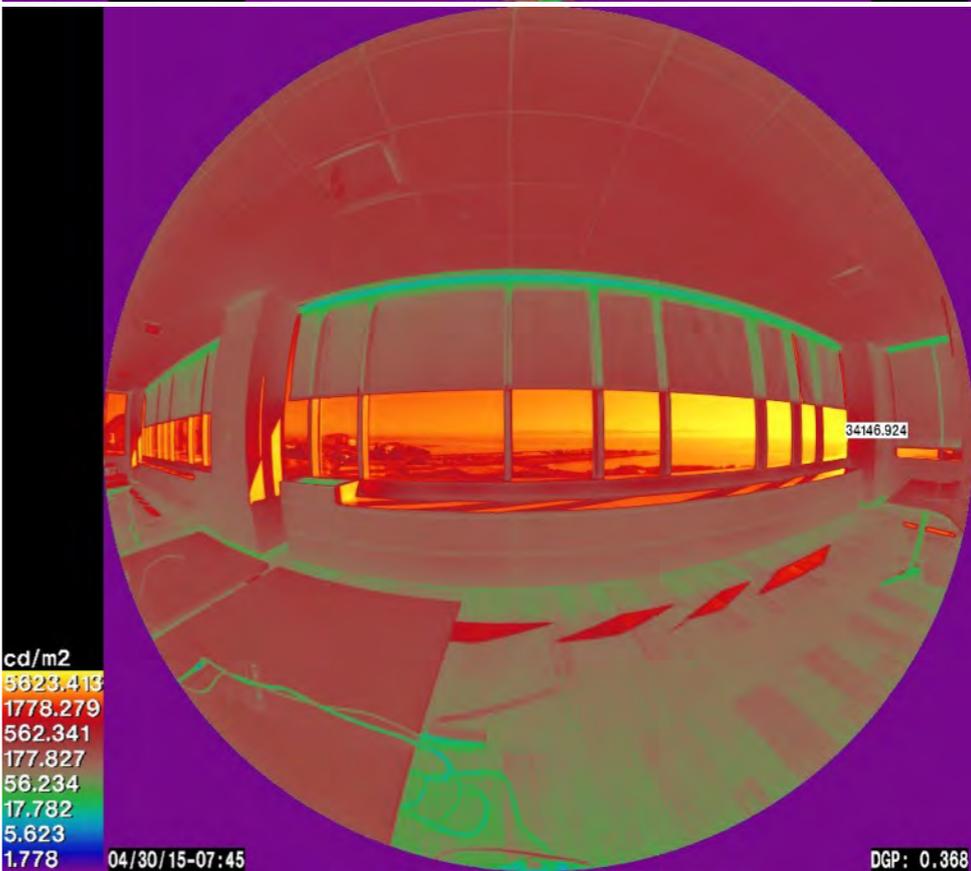
The images to the right show a moment just after the shade raised as direct sun ingress receded at 8:45 AM. At this moment the DGP in the shaded condition spikes to 0.368 (in the perceptible glare range). DGP in the unshaded condition is 0.475 (intolerable glare). For this view, the shade should have remained down longer to limit DGP, however since this view isn’t aligned with the desk, the situation is permissible.



April 30, 8:45
Unshaded Condition



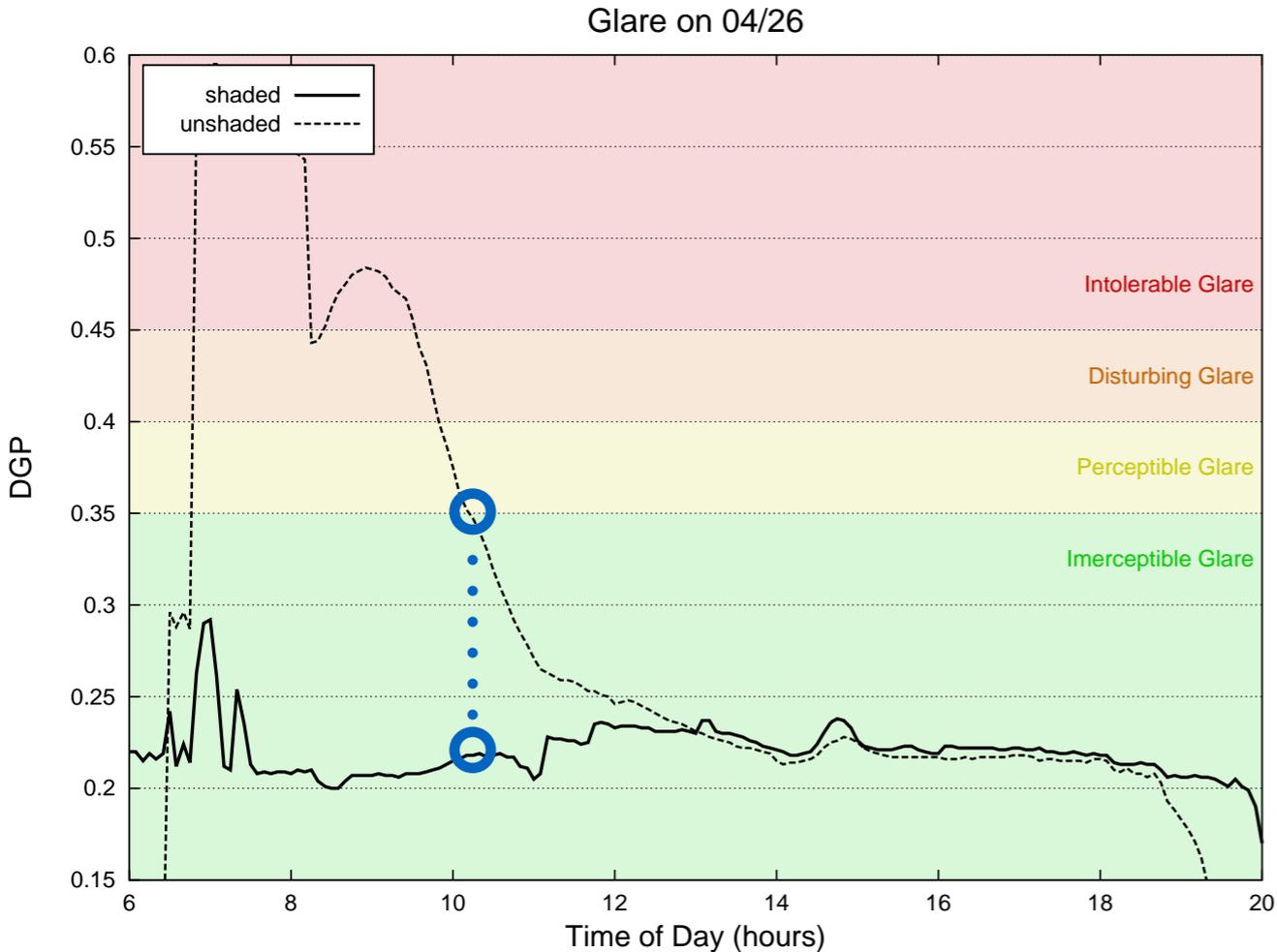
April 30, 8:45
Shaded Condition



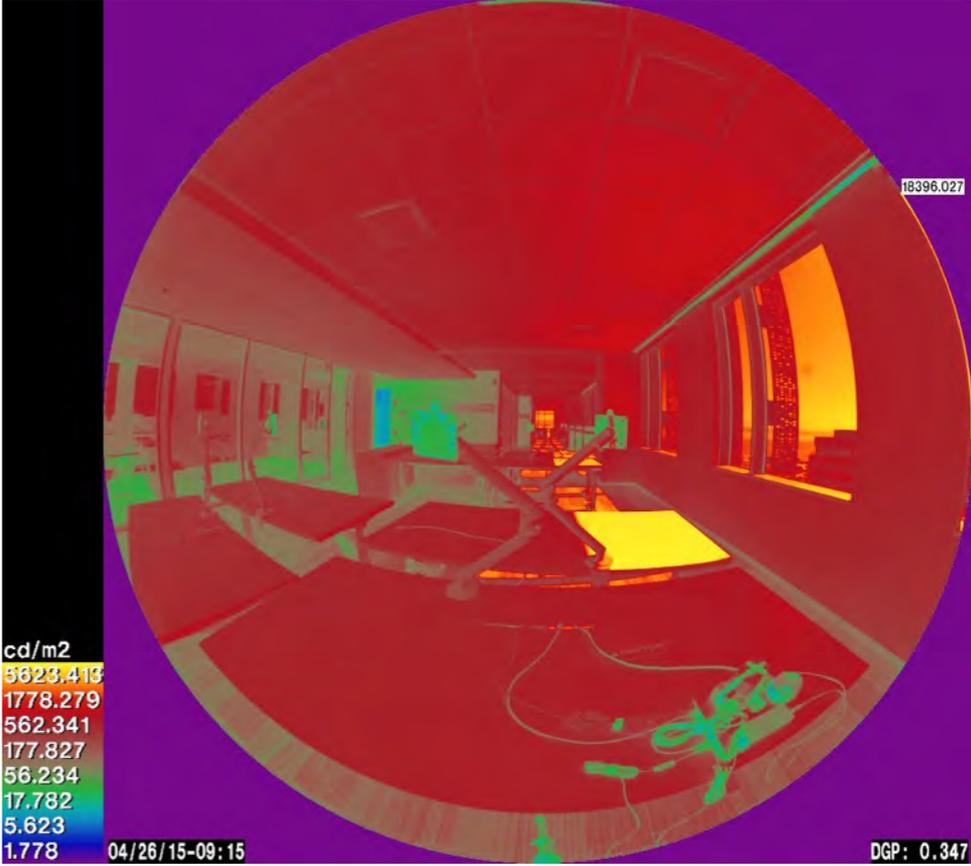
Shade Operation | East Facade

In this view at the east facade, the shade begins the day in a fully lowered position to prevent direct sun ingress. The shade begins to raise at 11:10 AM and is fully raised by 1:05 PM. The shade remains up for the remainder of the day.

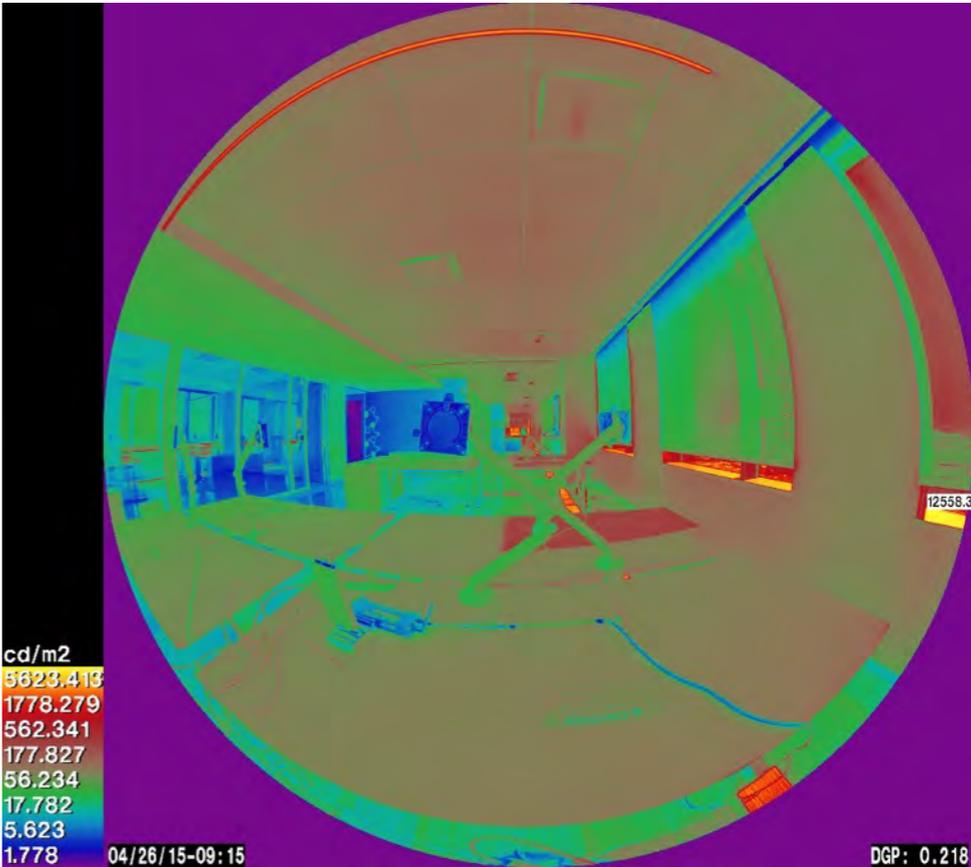
The chart below shows that DGP falls into the acceptable range shortly after 10:00 though the shades on the shaded floor remain down until 11:10. The images to the right show the time that DGP falls below the 0.35 threshold on the unshaded floor. In these images we see that the sun is shining directly onto the desk. The automated shades remained down at this time to limit direct sun ingress (not to control glare).



April 26, 10:15
Unshaded Condition



April 26, 10:15
Shaded Condition

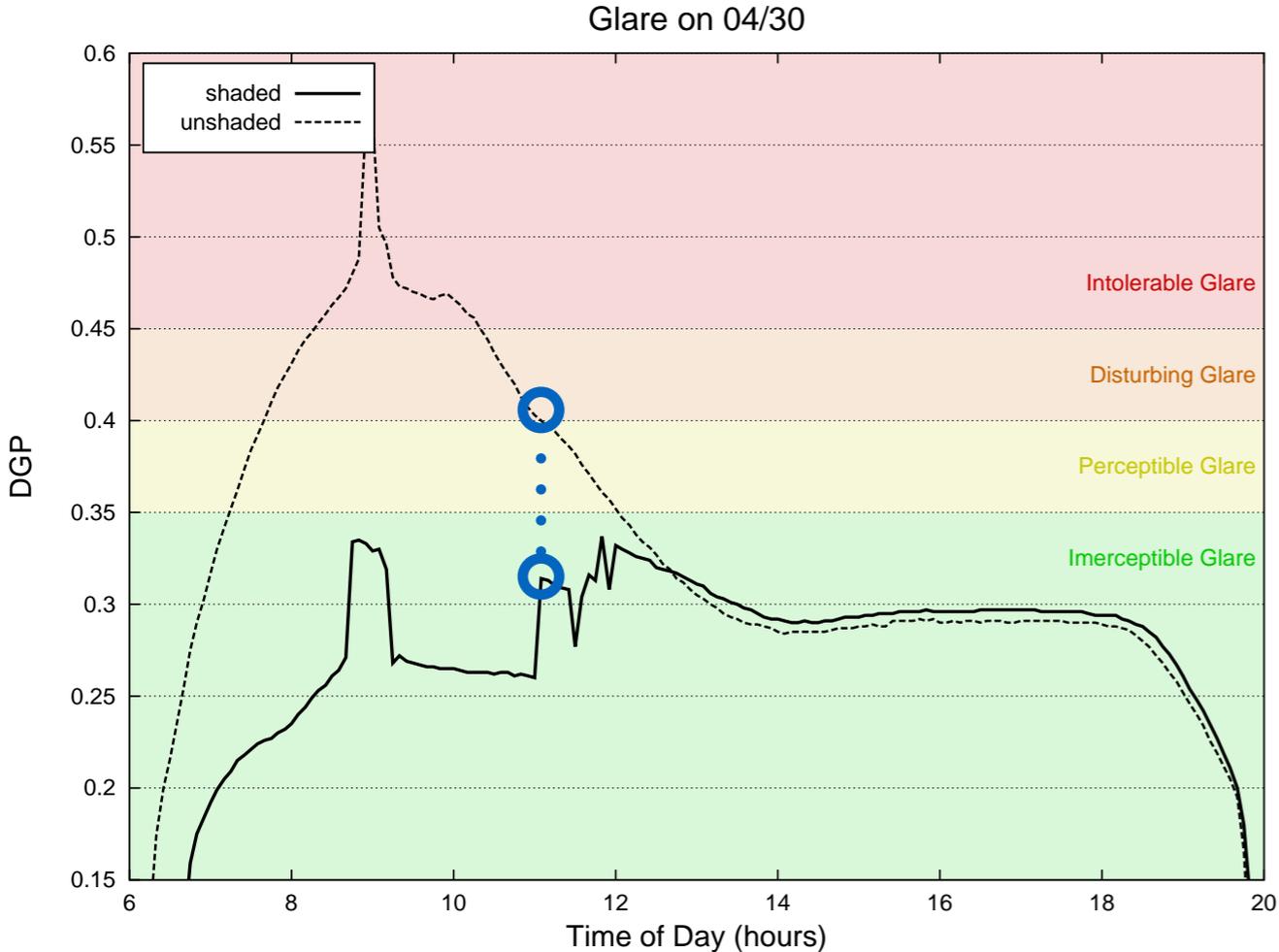


Shade Operation | East Facade

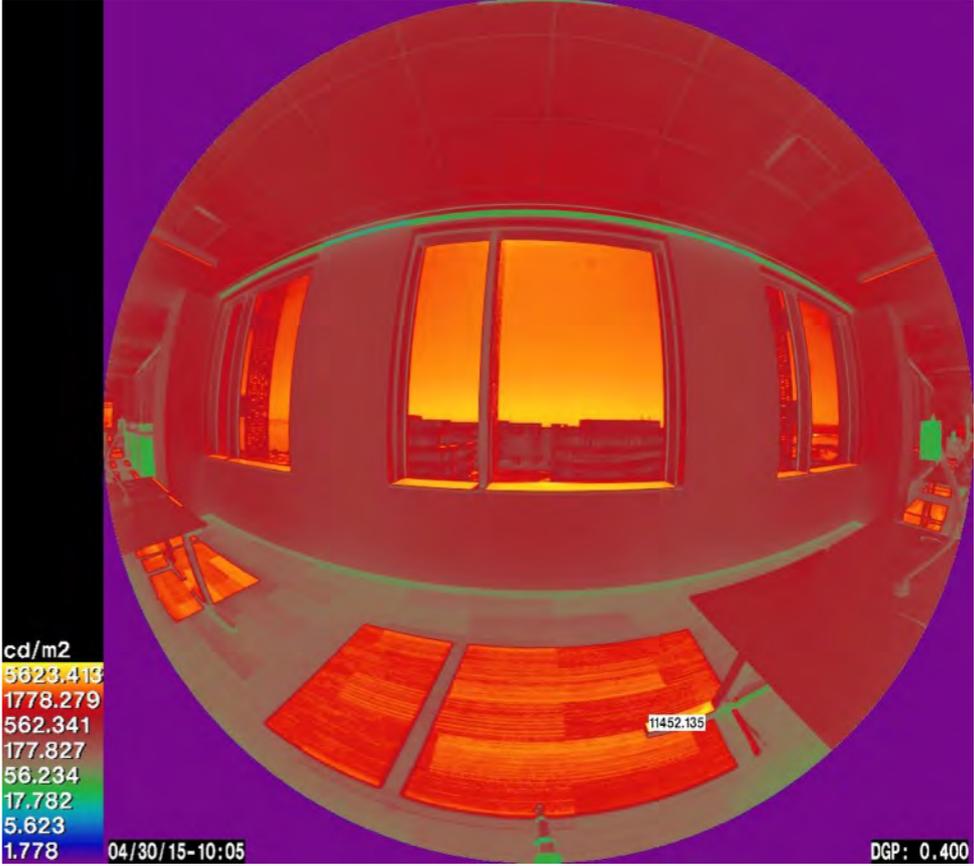
This is another one of the atypical views where the camera is facing the window directly, 90° from the orientation of the desk. The east shades begin the day at the lowest level to prevent sun ingress. Between 8:45 and 9:10 the sun is in view through the window. The shade effectively mitigates glare from the sun as DGP remains below 0.35 during this time. The shade begins to rise at 11:05 AM and is completely up by 1:00 PM.

The chart below shows the moment just after the shade begins to rise. The unshaded sun patch on the floor stops at the leg of the desk, which is approximately 36" from the facade, the distance of ingress permitted by the shade.

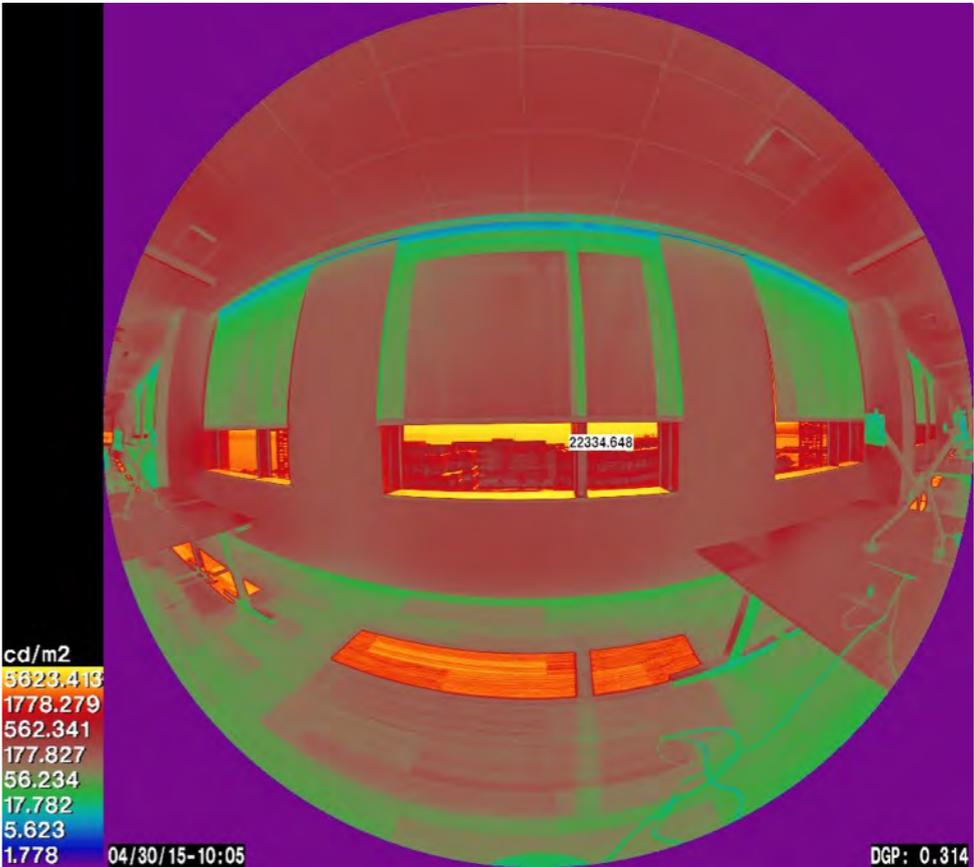
The chart below shows that the shade is fully raised near the time that the DGP drops below the 0.35 threshold on the unshaded floor, indicating that the shade operates effectively even for this more onerous view direction.



April 30, 11:05
Unshaded Condition



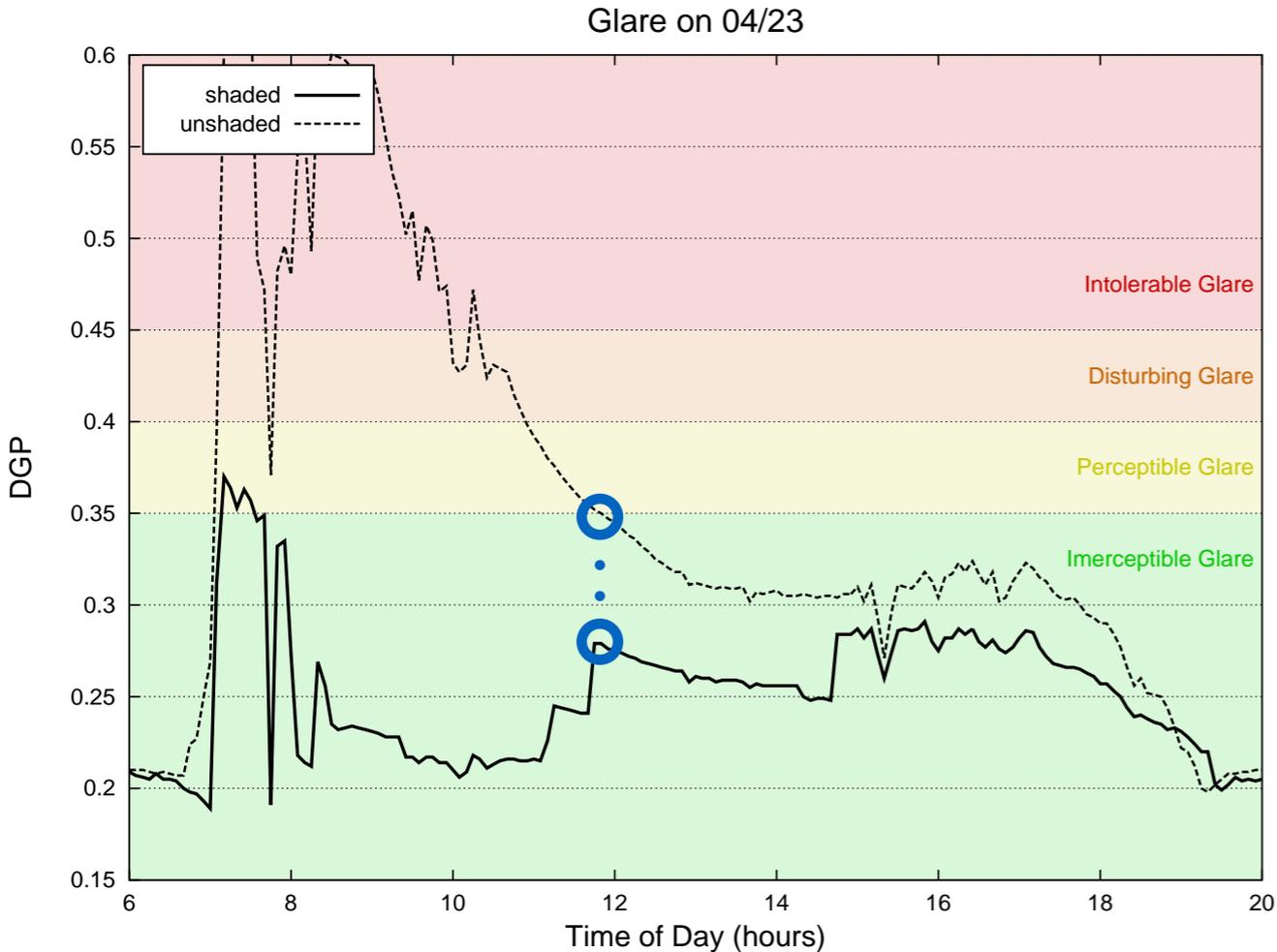
April 30, 11:05
Shaded Condition



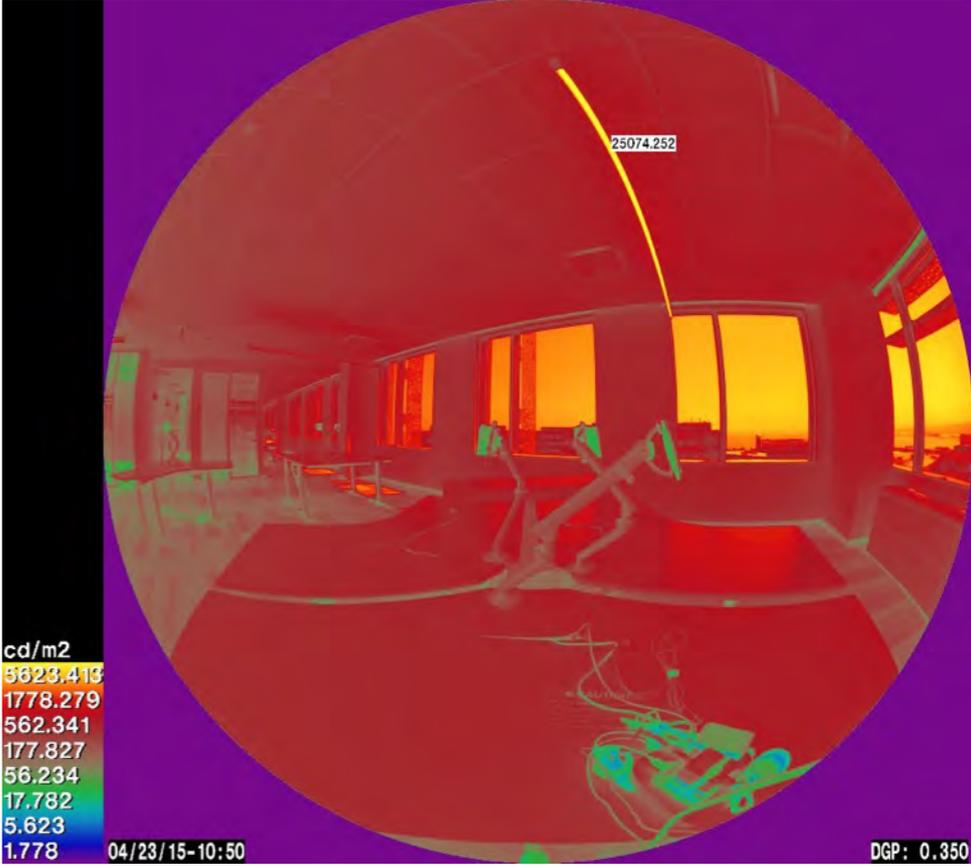
Shade Operation | East Facade

This view is taken from the south test area, but faces the east facade. The east shade begins the day at the lowest level to prevent solar ingress. The shade begins to raise at 11:20 AM. The shade remains at the mid-height level between 11:40 AM and 4:45 PM to prevent glare from the bright sky.

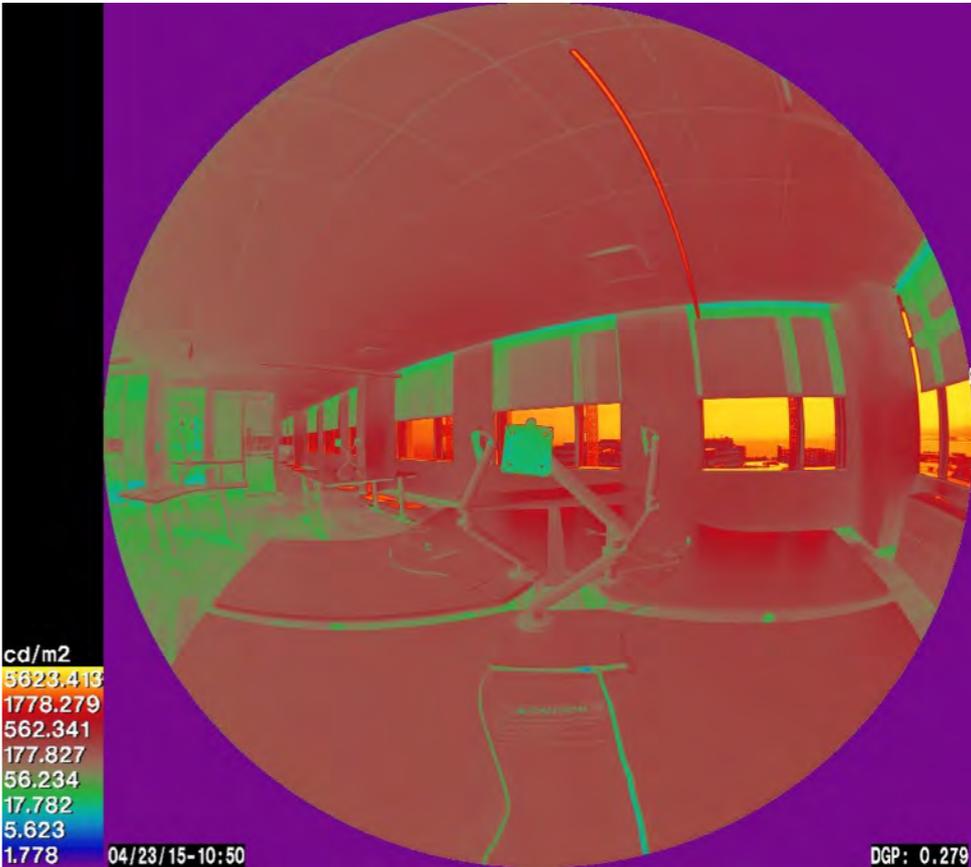
The chart below shows DGP on the unshaded floor dropping below the 0.35 threshold at 11:50, though the shades remained at the mid-height level until 2:45 PM, nearly 3 hours longer than necessary for this view. However this view faces a north-east direction, and another view facing south-east towards the brighter half of the sky would likely have a higher DGP during this time, so it is likely that the shade operated effectively when considering other views.



April 23, 11:50
Unshaded Condition



April 23, 11:50
Shaded Condition

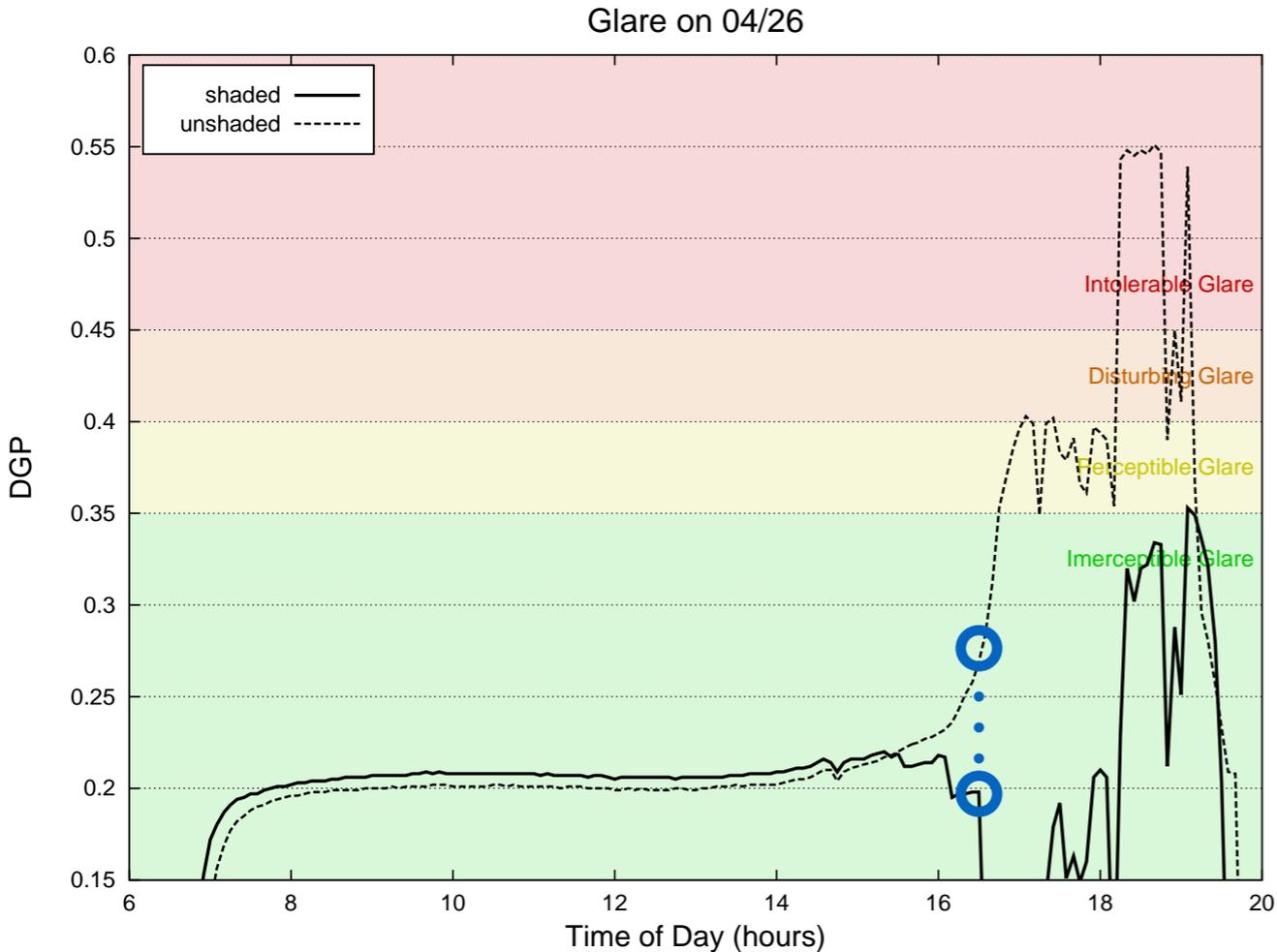


Shade Operation | West Facade

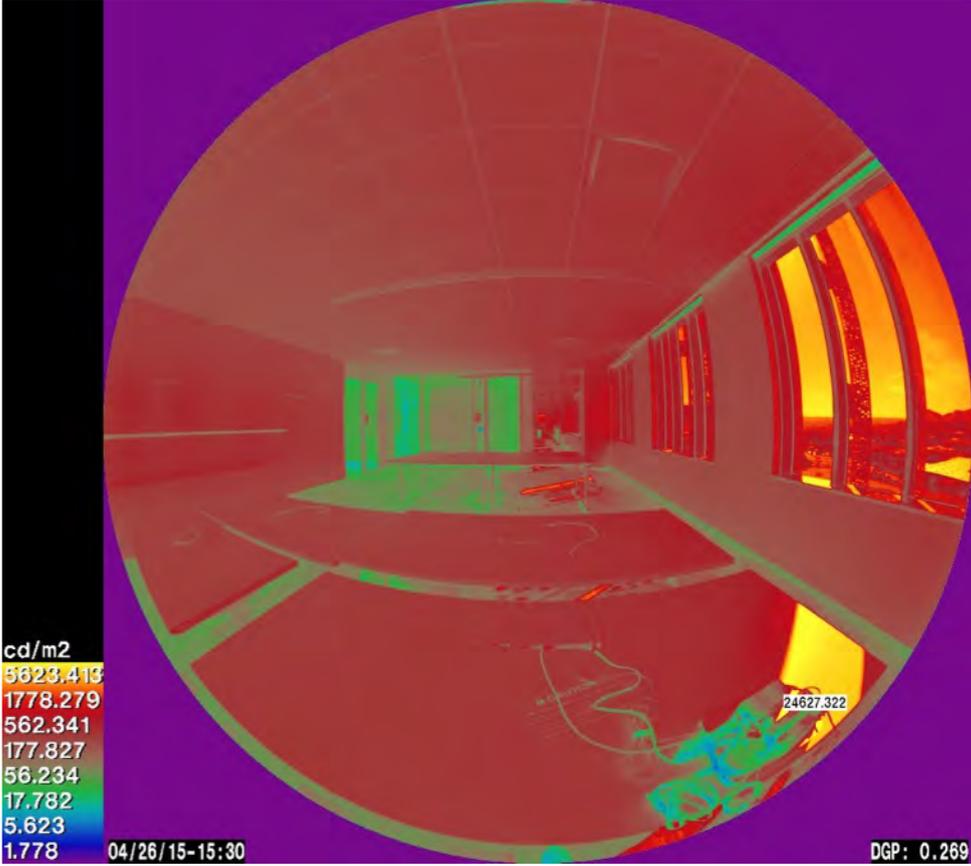
This view near the west facade faces south with west windows on the right. The west shades begin the day up, and remain up until 3:25 PM when they begin to lower to limit sun ingress. The shades are at the lowest level by 4:35 and remain down until sunset.

The photos to the right show the time just before the shade moves to the lowest level. The DGP on the unshaded floor is below the critical threshold, however sun ingress would be further than desired. The shade lowered to limit sun ingress, not to control glare.

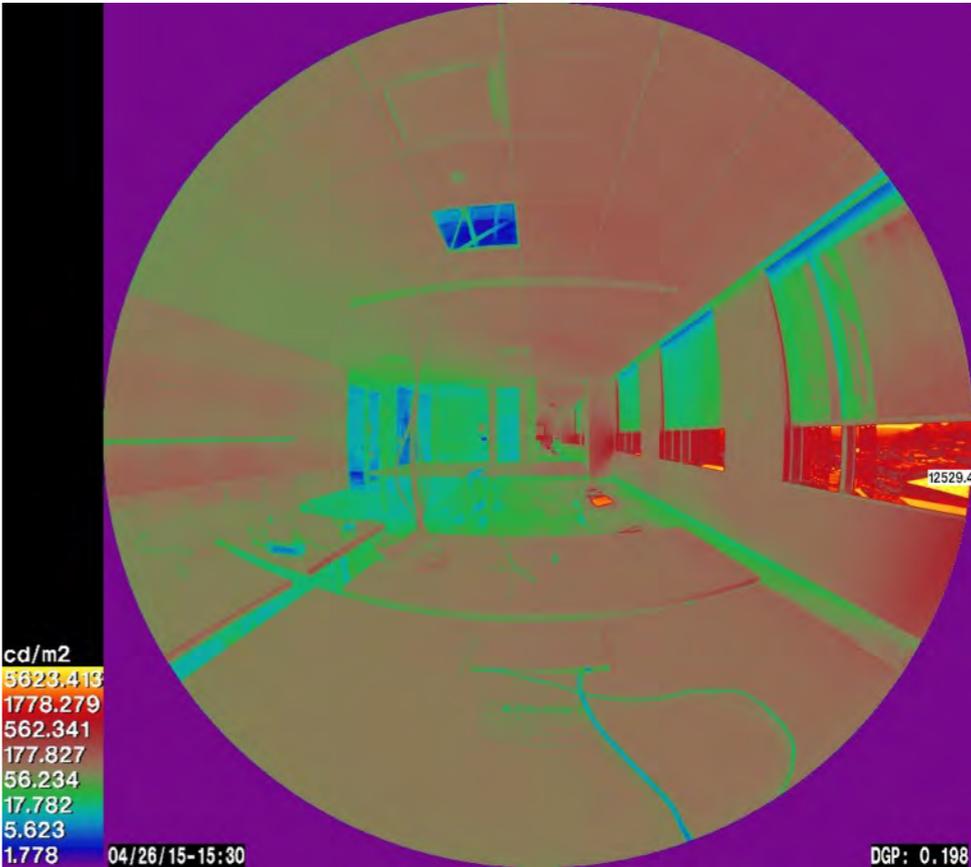
The chart below shows that the DGP on the unshaded floor passes above the 0.35 threshold at 4:40 PM. The shade effectively maintains DGP below the critical threshold, even when the sun is visible through the window from 5:20 until 7:40 PM.



April 26, 16:30
Unshaded Condition



April 26, 16:30
Shaded Condition

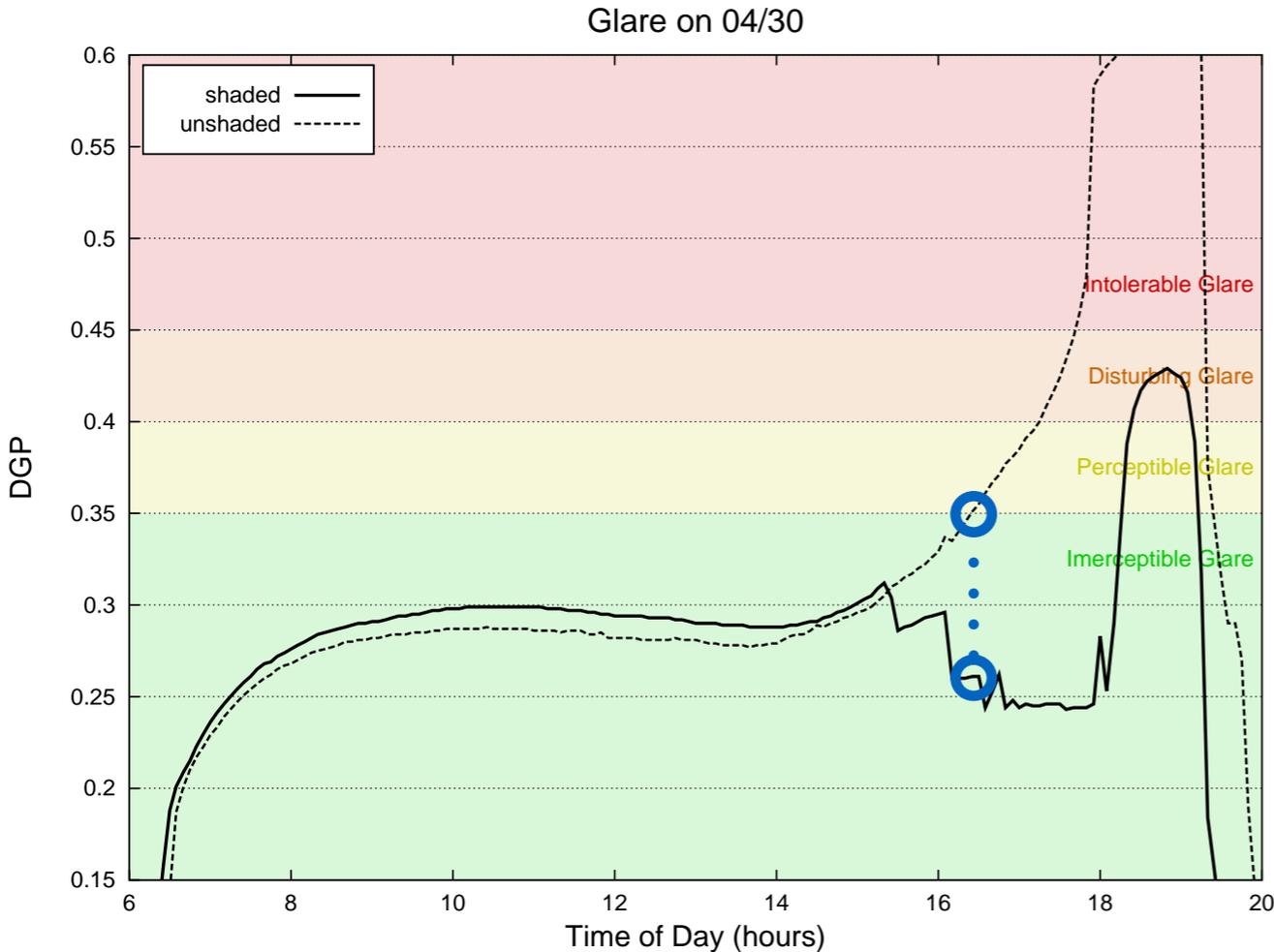


Shade Operation | West Facade

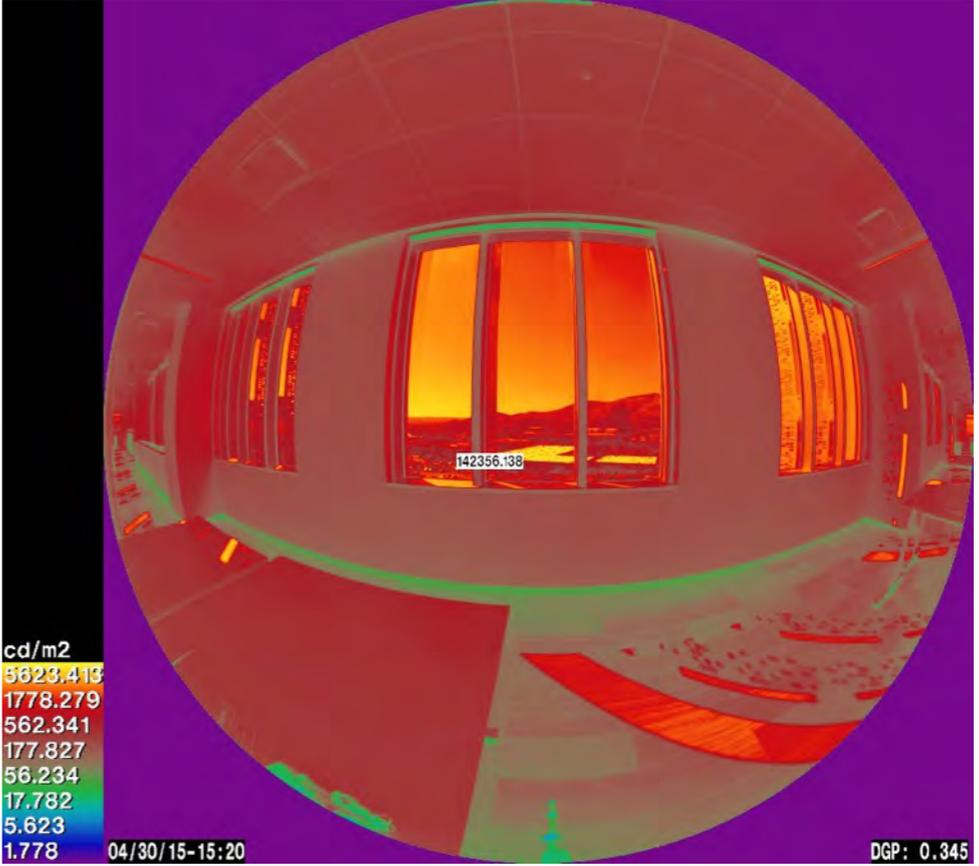
This west facing view is atypical because the camera faces the window directly, 90° from the direction of the desk. The shade on the west facade is up until 3:25 PM, when the sun starts to shine too far into the building. The shade lowers progressively from 3:25 to 4:35 PM to limit sun ingress. At 4:35 PM the shade is at its lowest position.

The images to the right show the conditions just before DGP on the unshaded floor crosses into the “perceptible glare” range. While DGP is acceptable up to this point, the sun is shining too far into the building so the shade is down.

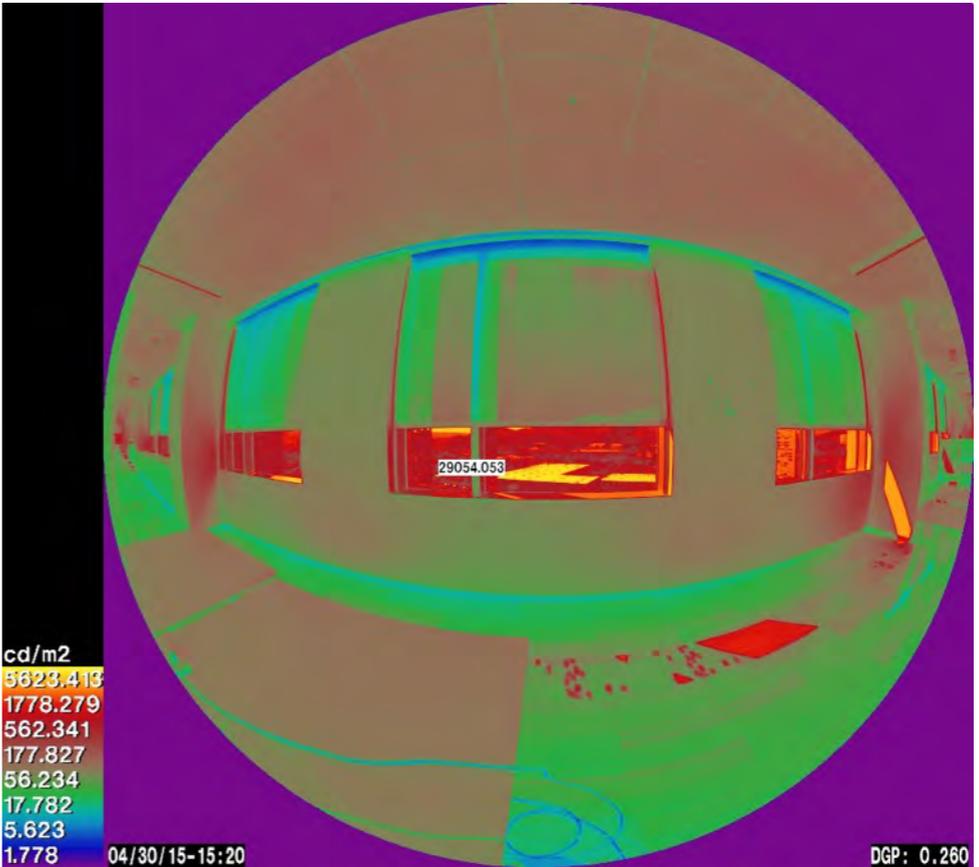
The chart below shows that the DGP crosses into the “disturbing glare” range for 40 minutes. During this time the sun is visible in the window, and is near the center of view. This condition would be problematic if the desk faced this direction, however the view parallel to the facade has much lower glare at this time (see previous page) so the condition is less concerning.



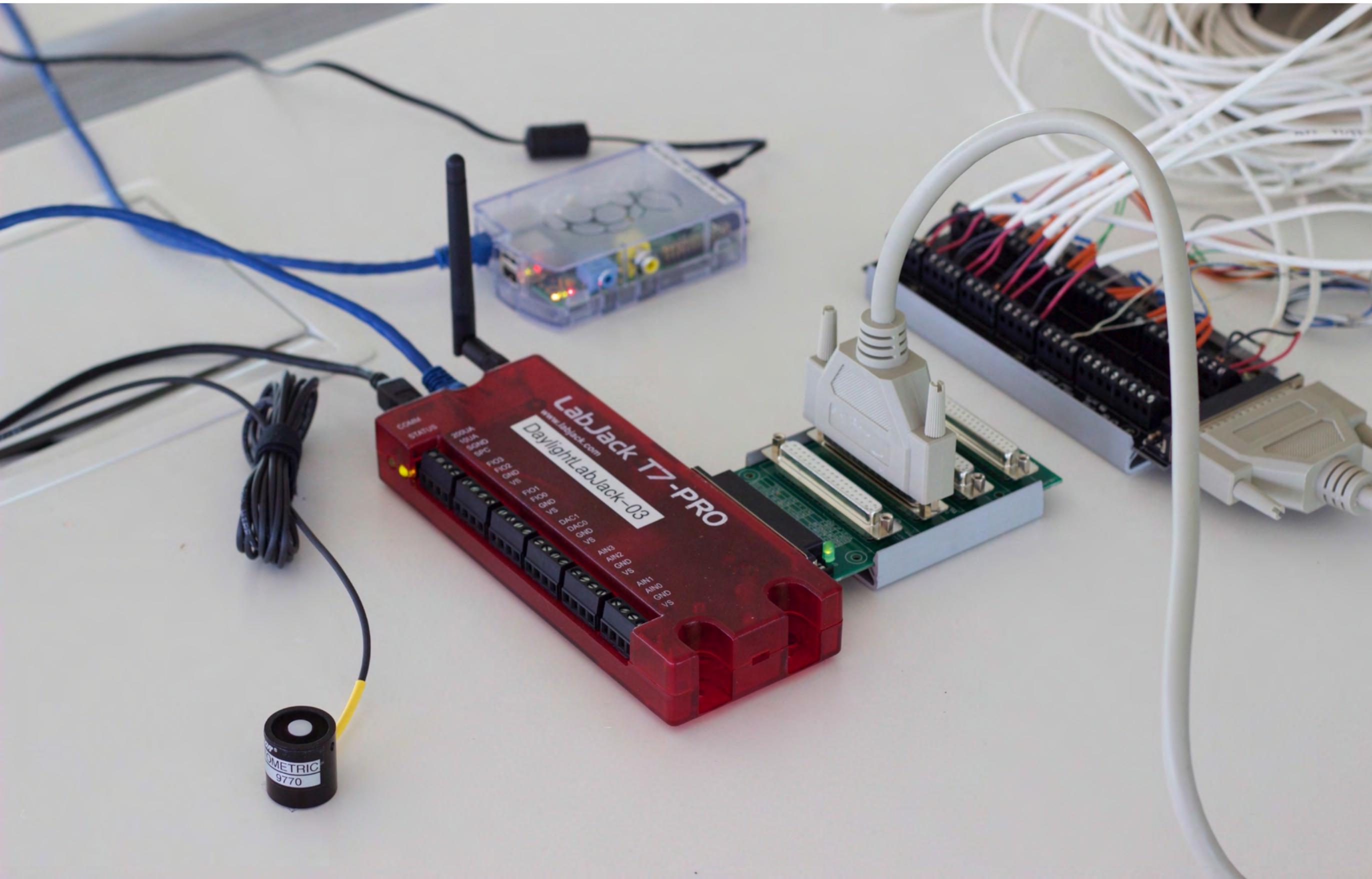
April 30, 16:20
Unshaded Condition



April 30, 16:20
Shaded Condition



4. Lighting Control Operation



Lighting Control Operation | Method

Workplane Illuminance Sensors

Several illuminance sensors were affixed to the center of desks in each test area (the desktops were 30" above the floor). There were not enough sensors available to cover every desk, so representative sampling (one-third to one-half) of desks were selected for illuminance measurements. Diagrams showing the locations of sensors are provided later in this section.

The illuminance sensors were Li-cor LI-210 photometers. All the sensors in a test area were connected to LabJack T7-Pro data acquisition devices (with a LabJack Mux80 multiplexor to increase the number of analogue inputs). A 1 kΩ resistors were connected in parallel with the sensor feeds so that the current output of the sensor could be read as a voltage by the LabJack's analog inputs. The gain on the illuminance sensor inputs was set to 1000, giving a measurement range of 0 - 0.01 V. The LabJack resolution index was set to 12, giving a measurement time of 159 milliseconds and a 16.4 bit effective resolution. This corresponds to an illuminance range of 0 - 30,000 lux with 0.35 lux resolution.

Illuminance was recorded in one minute intervals, 24 hours a day during the monitoring period.

Illuminance measurement characteristic calculations		
Resistance	1,000	Ω
Maximum measurable voltage	0.01	V
Voltage measurement resolution	0.12	μV
Maximum measurable current	10	μA
Current measurement resolution	0.00012	μA
Photometer calibration constant	0.333	μA/kLux
Maximum measurable illuminance	30,000	Lux
Illuminance measurement resolution	0.35	Lux

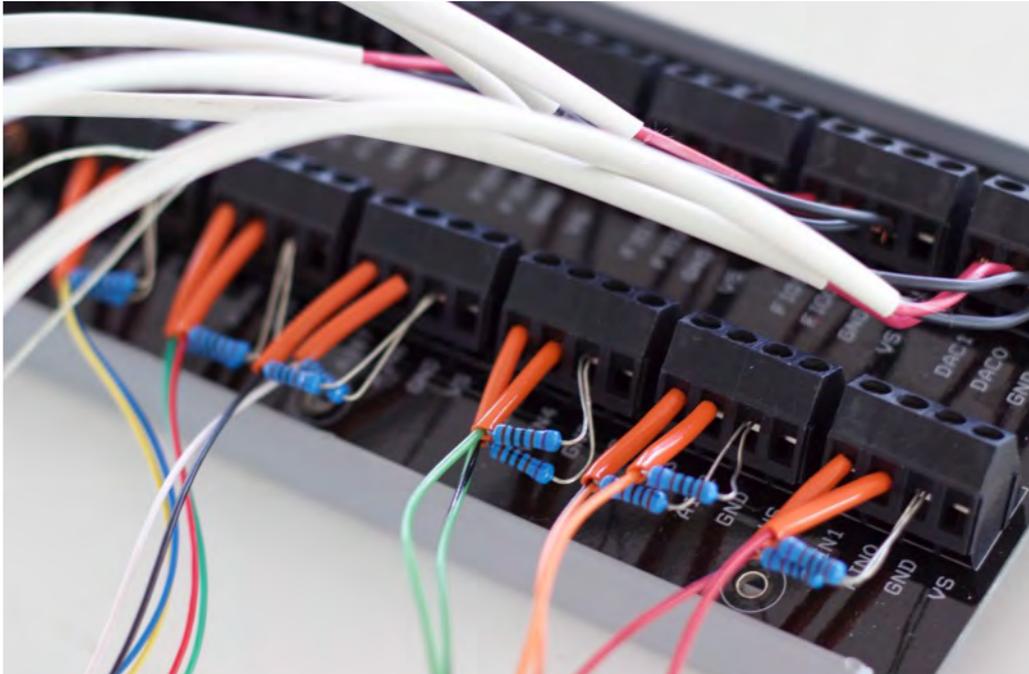
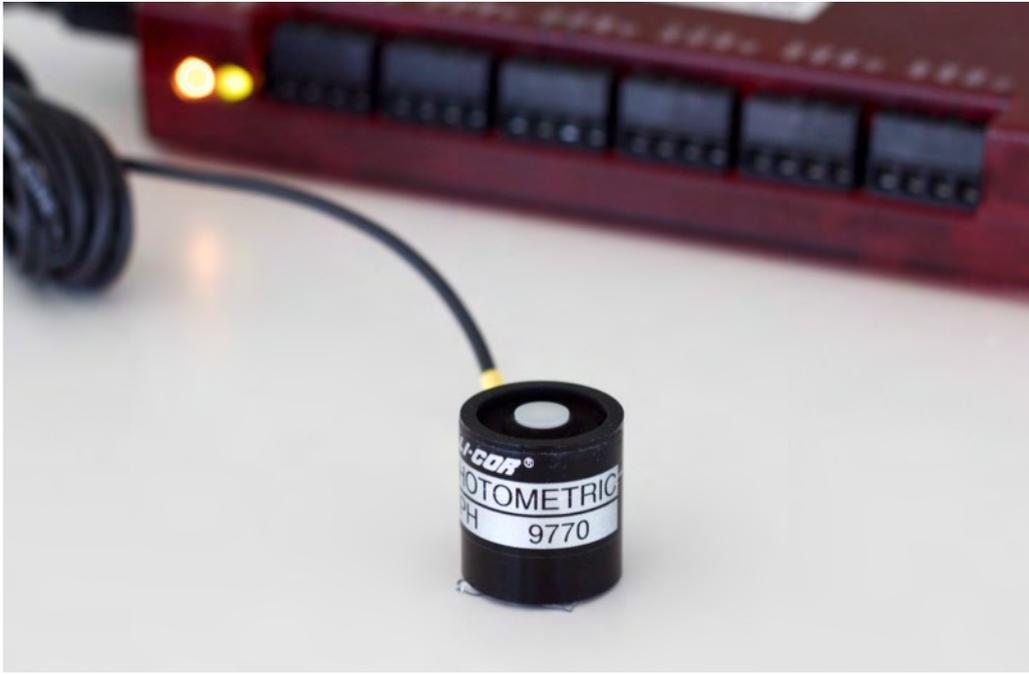


Photo of resistors connected in parallel across the illuminance sensor inputs.



Li-cor photometer affixed to the center of a desk (with LabJack T7-Pro in the background).

Lighting Control Operation | Method

Fixture dimming levels

A sensing line was spliced into the 0-10V signal between the Encelium lighting control module (LCM) and LED driver at each fixture in the test areas. The LabJack measured and recorded the voltage of the dimming signal every minute.

Reporting Period

The Encelium system was programmed using the settings recommended based on FLEXLAB testing. Troubleshooting of the lighting control system took the first three weeks of the April test period. For the metrics in this section we consider only April 21 - May 7, after the lighting control system was operating largely as expected.

The reporting hours are from 6am - 6pm local time.

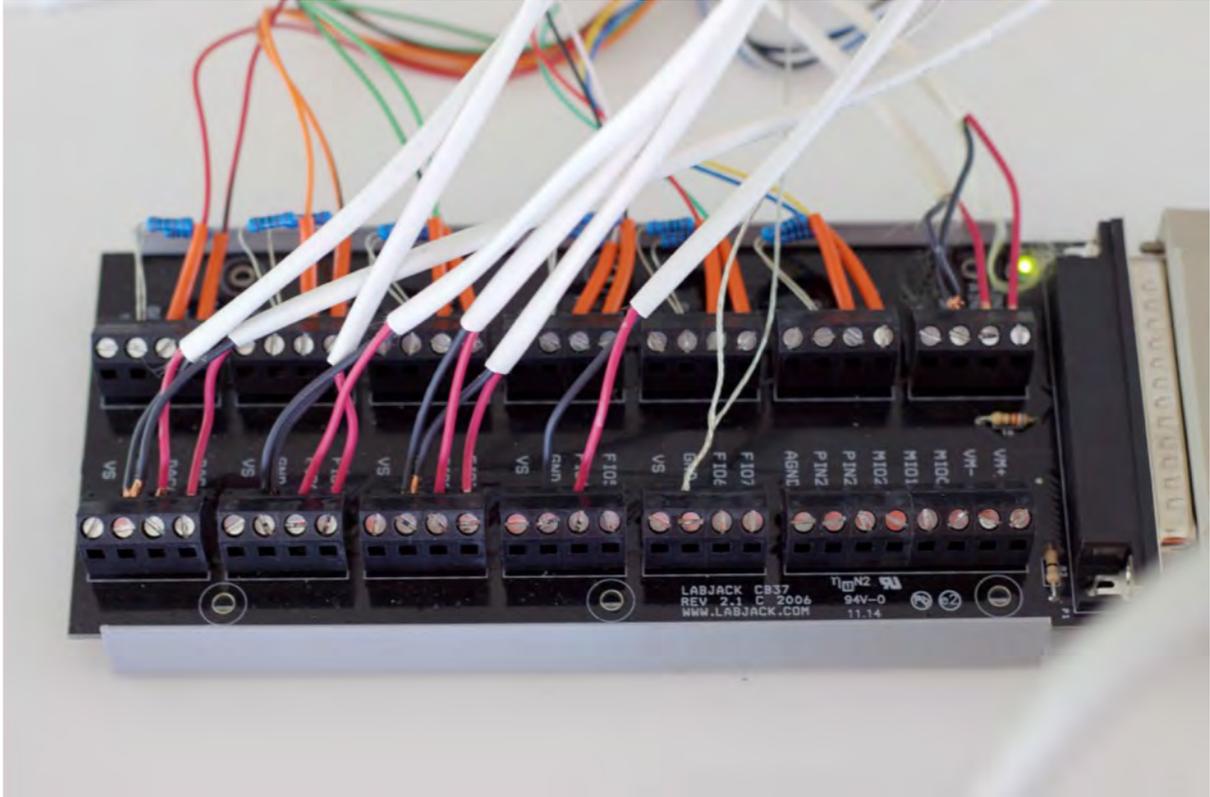
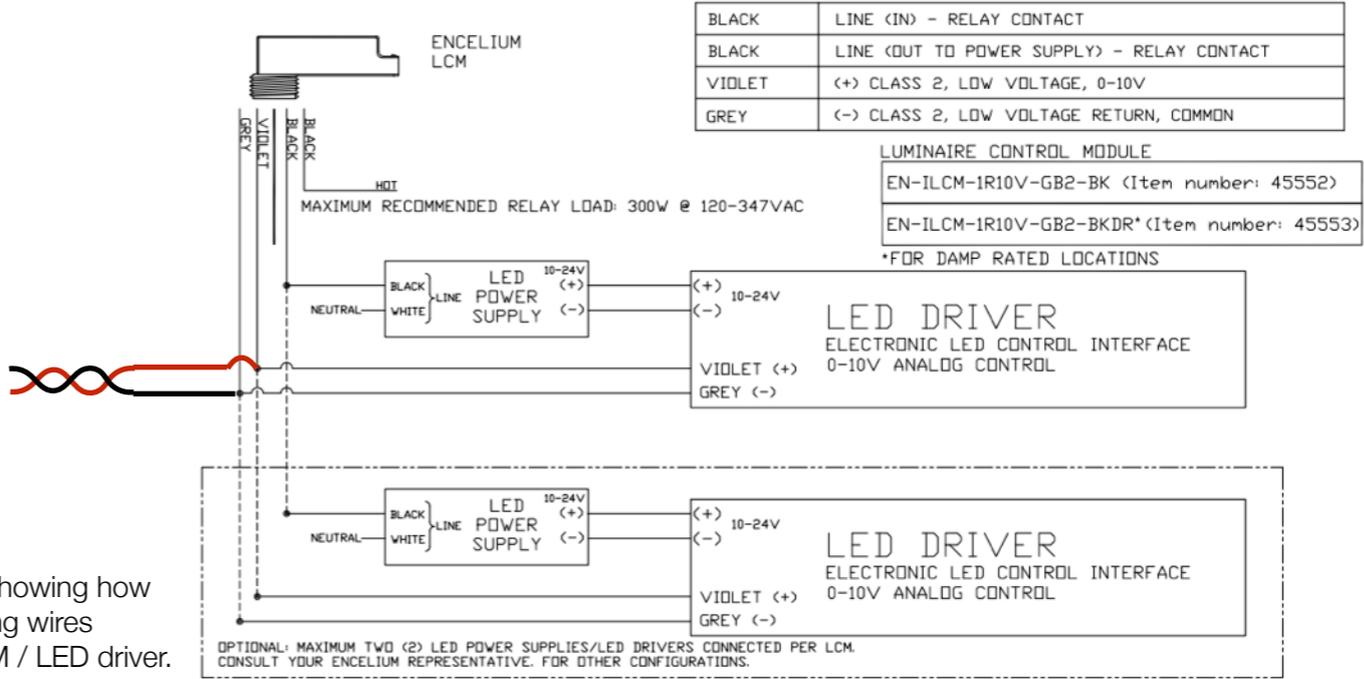
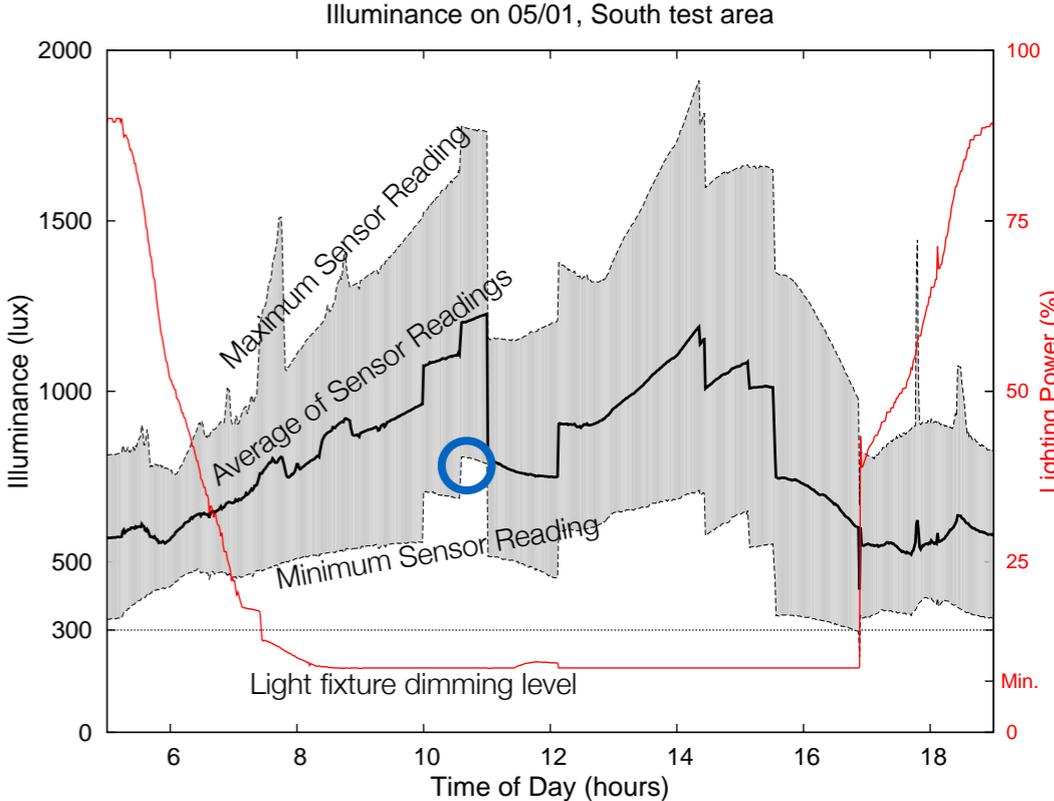


Photo of the dimming sensing wires (red and black conductors in white sheathing) connecting to the LabJack.

Lighting Control Operation | Metrics

Daily Illuminance Plot

The daily illuminance plot shows measured illuminance (from combined daylight and electric light) in a test area during a specific day. The thick black line is the average of all sensor measurements in an area. The gray shaded area is the range between the minimum sensor reading and maximum sensor reading at a particular time. The red line shows the assumed lighting power use (based on dimming signal) as a percent of total installed power for the area. In this chart 7.5% is labeled as the minimum lighting power because for that particular day that was the minimum power permitted (downlights at 15% uplights at 0%). Including lighting power allows us to understand how the lighting might influence the illuminance measurements. For example, in this chart during the middle of the day the lighting is at minimum power, so we know that the lighting isn't over-providing at 11 AM, when the minimum illuminance exceeds 500 lux (circled in blue).



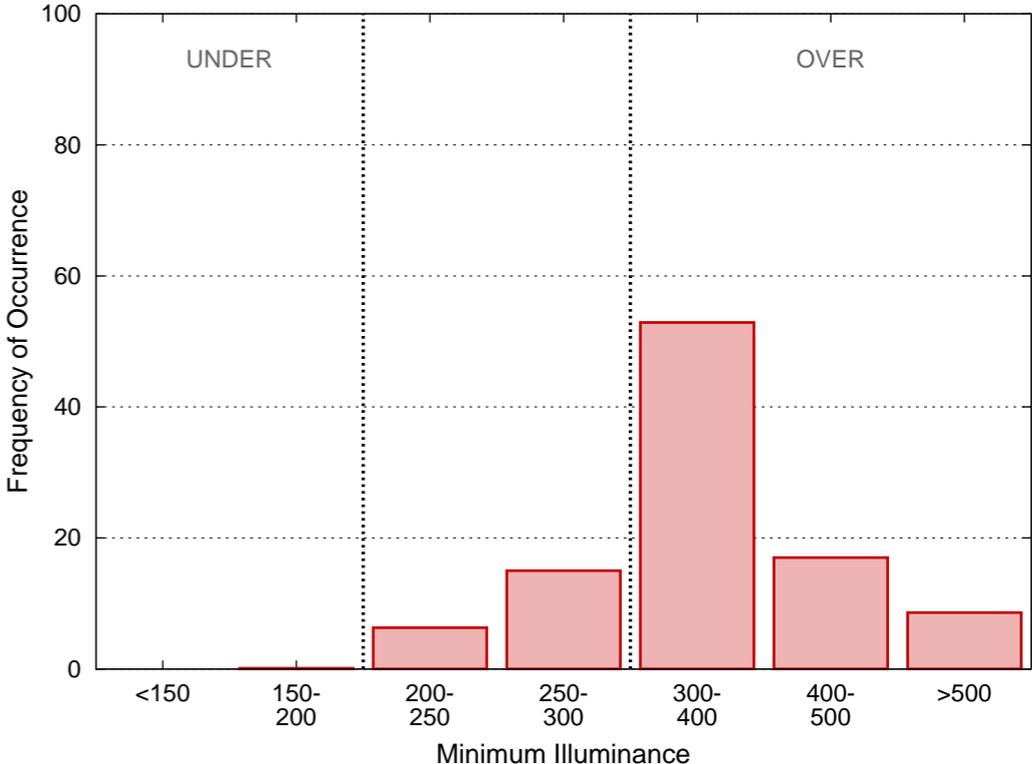
Minimum Illuminance

We use minimum illuminance to judge the ability of the lighting control system to provide adequate illumination for the space. Average illuminance is avoided because often times high illuminance levels near the window skew the average well above the design criteria while areas further from the window may be below the target criteria, which isn't apparent in the average illuminance value.

The design illuminance criteria for B35 is a 300 lux average on the work plane, which is consistent with current guidance from the Illuminating Engineering Society of North America (IESNA). IESNA also recommends a work plane uniformity ratio (average to minimum) of no more than 1.5:1 for office spaces, allowing for a minimum work plane illuminance of 200 lux.

We categorize times when the minimum illuminance on the workplane falls below 200 lux as times that the control system under provides electric lighting. And times when the minimum illuminance is above 300 lux we deem as times that the lighting control system over provides electric lighting.

The histogram to the right shows, for a specific test area, the relative frequency minimum illuminance falls into each range. These charts only consider times when the lighting is dimmed above minimum power settings. Times when the lights are dimmed to the lowest permitted power setting, illuminance from daylight may exceed design criteria.



Lighting Control Operation

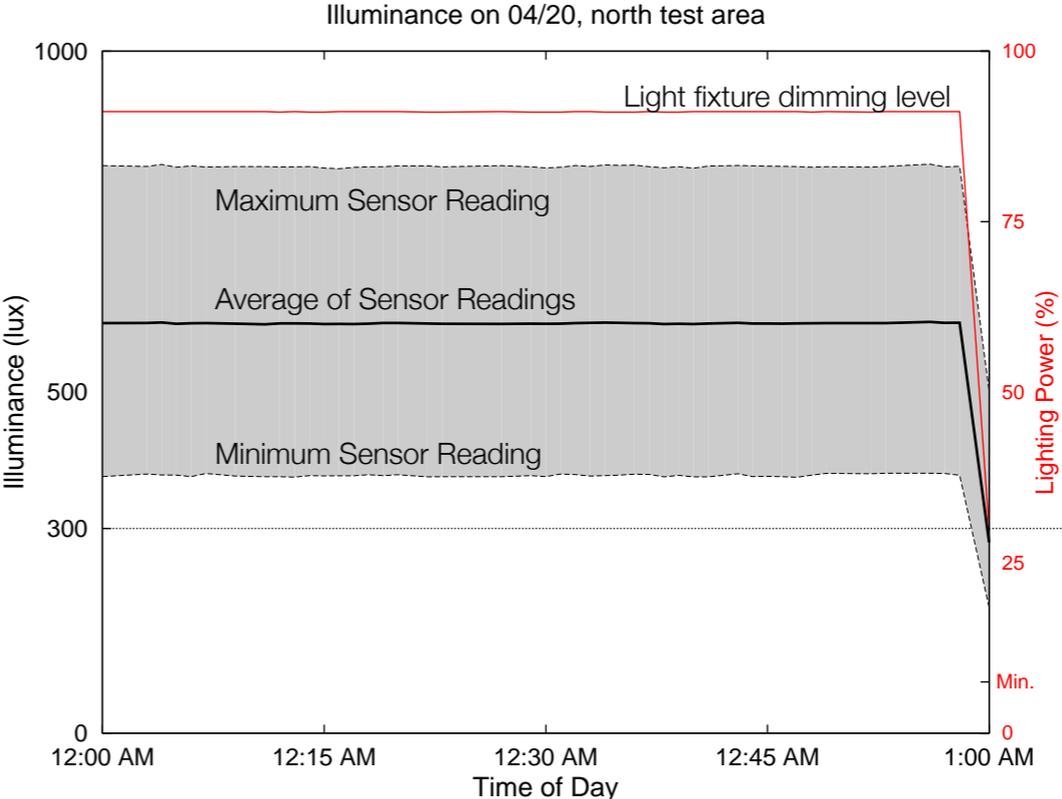
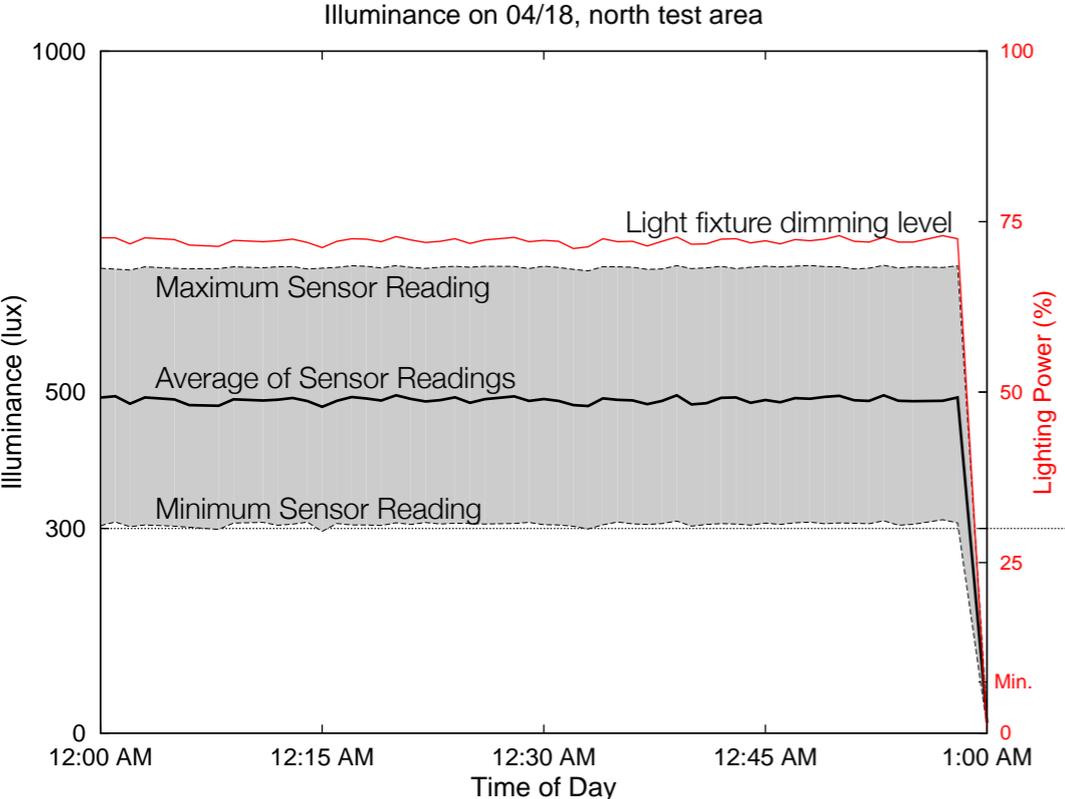
Task Level Tuning

Task Level Tuning

Task level tuning is an overall reduction in light fixture output so that the electric lighting provides what is required and no more. The initial setting for task level tuning at B35 limited fixture output to 72%. However the commissioning agent found that average illuminance fell below 300 lux in localized areas, so task level tuning was disabled and light fixture output was increased to 90% of full output (against LBNL's recommendation).

Night Time Illuminance

Light fixtures in open office areas turned on for a couple of hours in the middle of each night. During this time we can see the workplane illuminance from electric lighting without daylight contribution. The charts below show the workplane illuminance with the light fixtures at 72% output (left) and with 90% output (right). As you can see the average illuminance measured by the sensors is above 500 lux in both cases. In the 72% output scenario, the minimum illuminance is at 300 lux, while the minimum illuminance is 375 in the 90% output. For this reason, LBNL recommends reinstating the task level tuning for all areas, with the exception of the specific locations identified by the commissioning agent. The tuning level remains at 90%, waiting for information regarding specific locations of under illuminance from the commissioning agent.



Workplane illuminance measured at night with task tuning (left) and without task tuning (right).

Lighting Control Operation | North Area

Daily Illuminance Plot

The chart shown to the right shows illuminance in the north test area on April 30, after troubleshooting and tuning the dimming system to operate as desired.

Note: As described previously, task tuning was disabled during this time so the illuminance maintained by the dimming system is 20% more than desired.

While the lights are on in the morning (6:00 to 8:30 AM), the minimum illuminance in the north test area tracks the 360 lux (300 lux design criteria +20%) rather closely. During the middle of the day the electric lighting is effectively at the minimum output and the illuminance goes above design criteria of 300 lux.

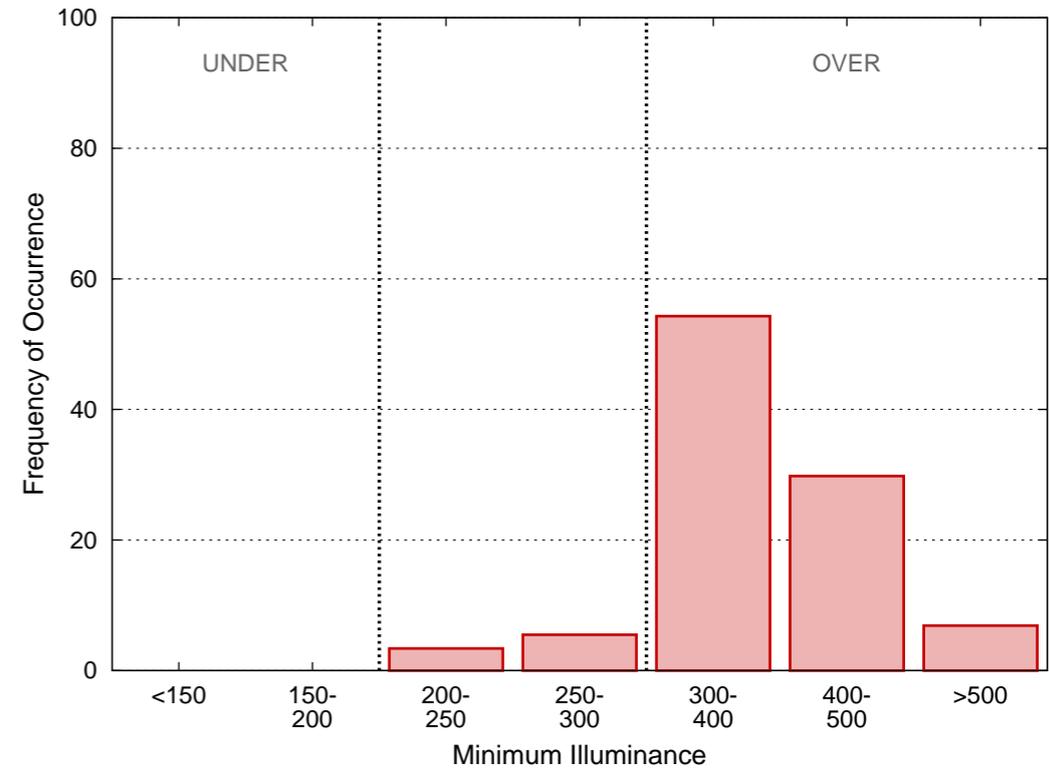
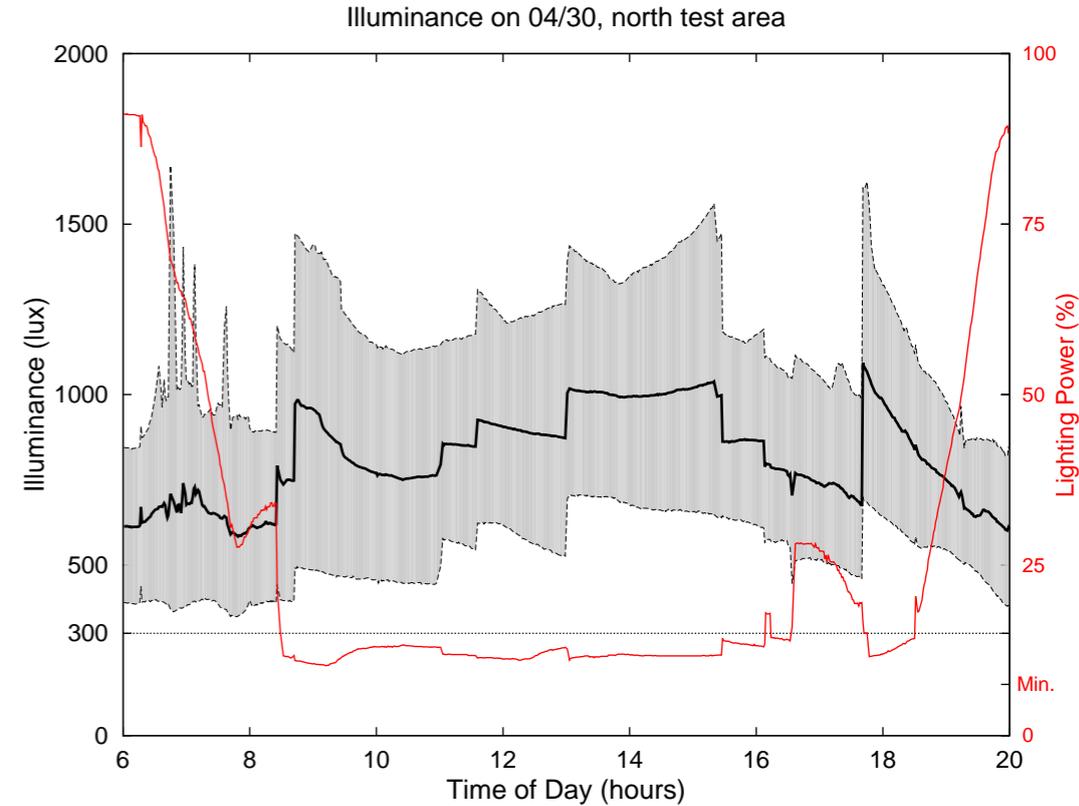
Around 4:30 PM the west shades close, and the lights increase output to compensate, though based on illuminance readings the lights could have mostly stayed off.

At about 5:30 PM the north shades went up, because the glare sensors were below the sky glare threshold. The illuminance jumps accordingly and the lights dimmed to off.

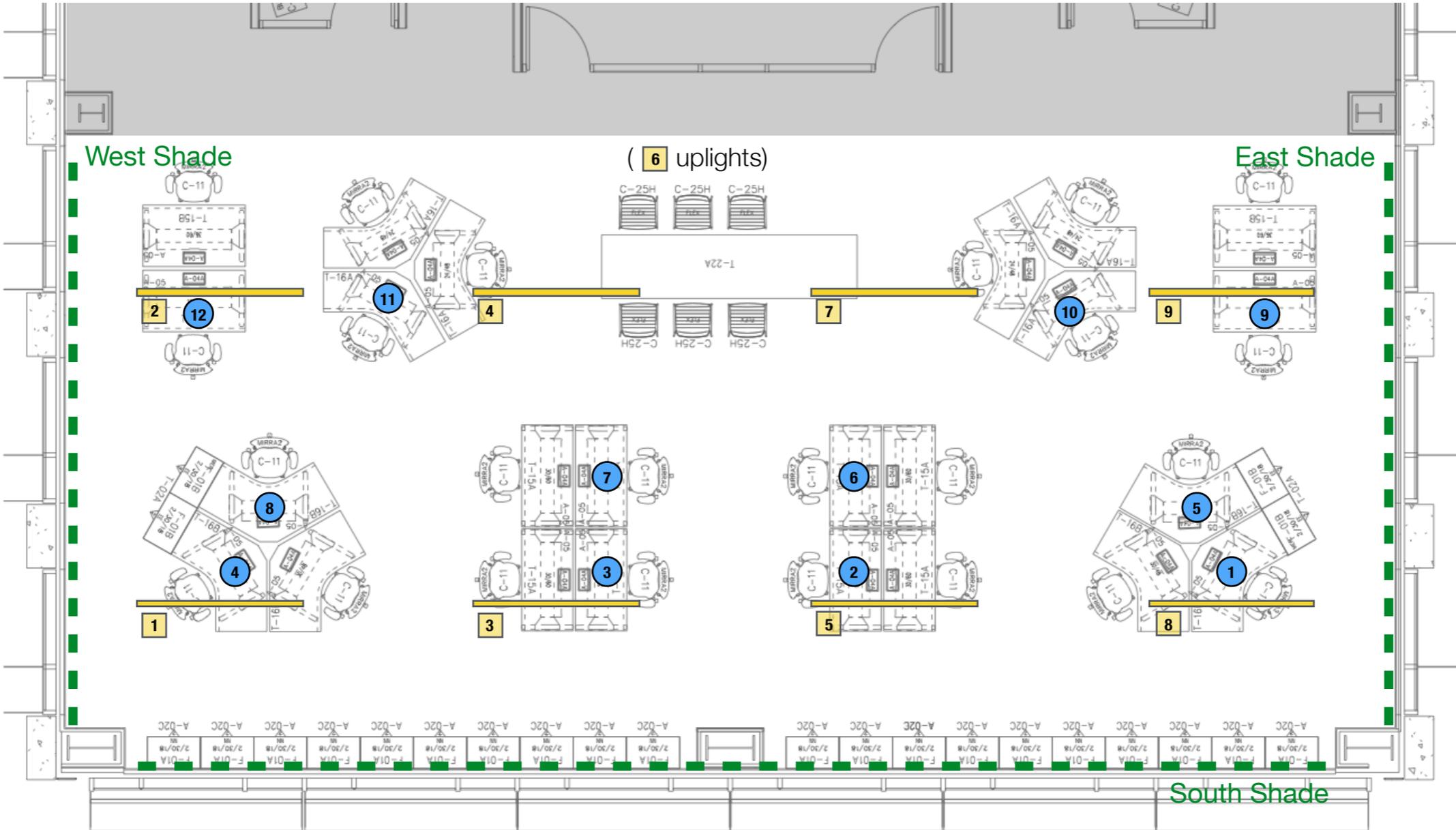
At 6:30 daylight illuminance began to fade, and the lights came on to compensate.

Minimum Illuminance

The minimum illuminance histogram shows that the minimum illuminance is in the 300-400 lux range 54% of the time, and above 300 lux 91% of the time. The minimum illuminance measured at a sensor never falls below 200 lux during the study period.



Lighting Control Operation | South Area



① Li-cor Photometer (w/ ID #)

① Pendant Light Fixture (w/ ID# for downlight)

■ ■ ■ ■ ■ Shade Group

Lighting Control Operation | South Area

Daily Illuminance

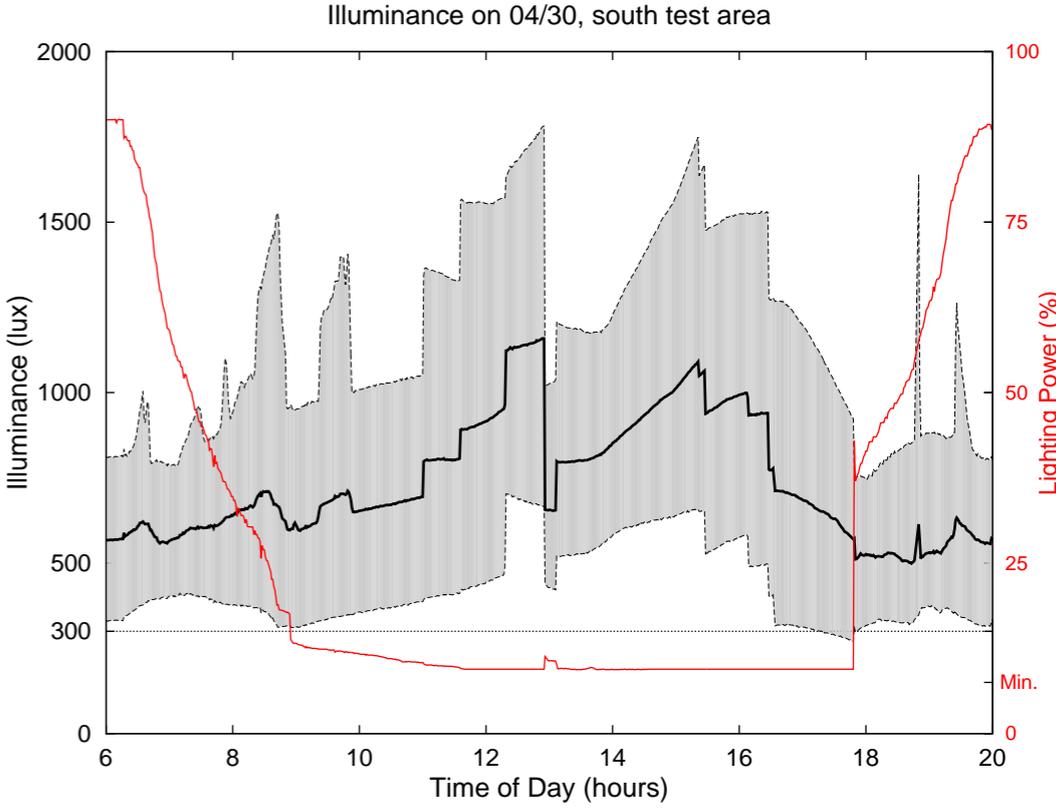
The chart shown to the right shows illuminance in the south test area on April 30, after troubleshooting and tuning the dimming system to operate as desired.

Note: As described previously, task tuning was disabled during this time so the illuminance maintained by the dimming system is 20% more than desired.

While the lights are on in the morning (6:00 to 9:00 AM), the minimum illuminance in the north test area tracks the 360 lux (300 lux design criteria +20%) rather closely.

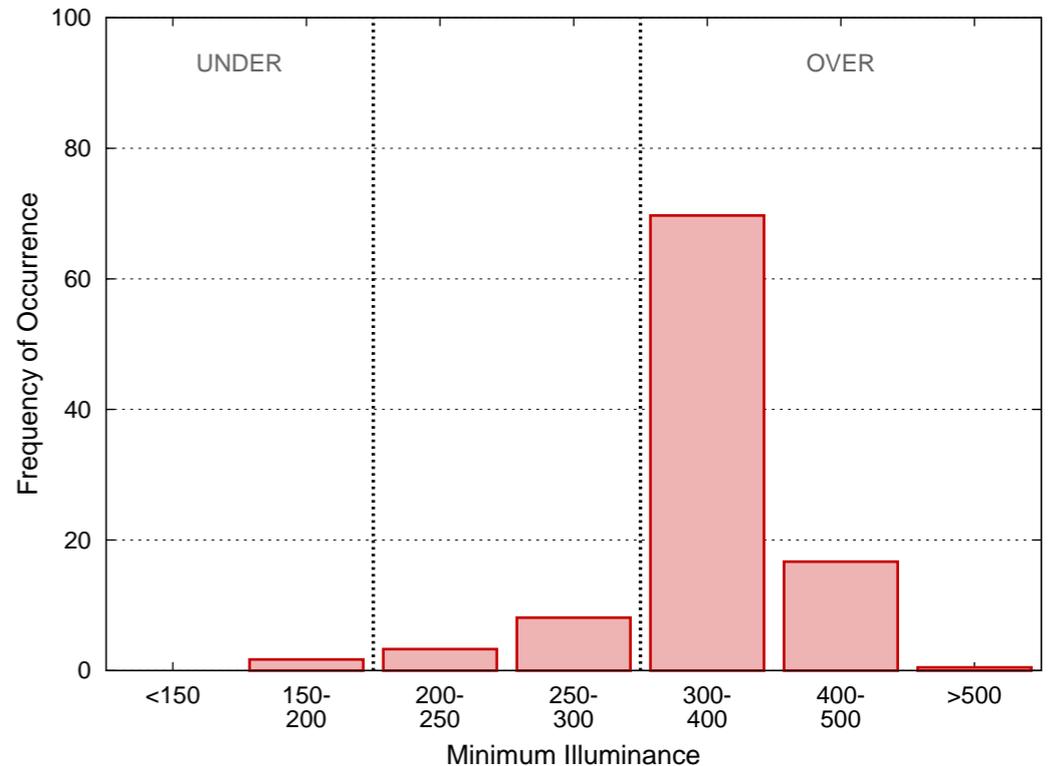
During the middle of the day (9:00 AM to 4:30 PM) the electric lighting is effectively at the minimum output and the illuminance exceeds design criteria.

Around 5:50 PM the south and west shades move to the lowest position, and the lights come on some to compensate. For the remainder of the day, the minimum illuminance tracks the design criteria closely.

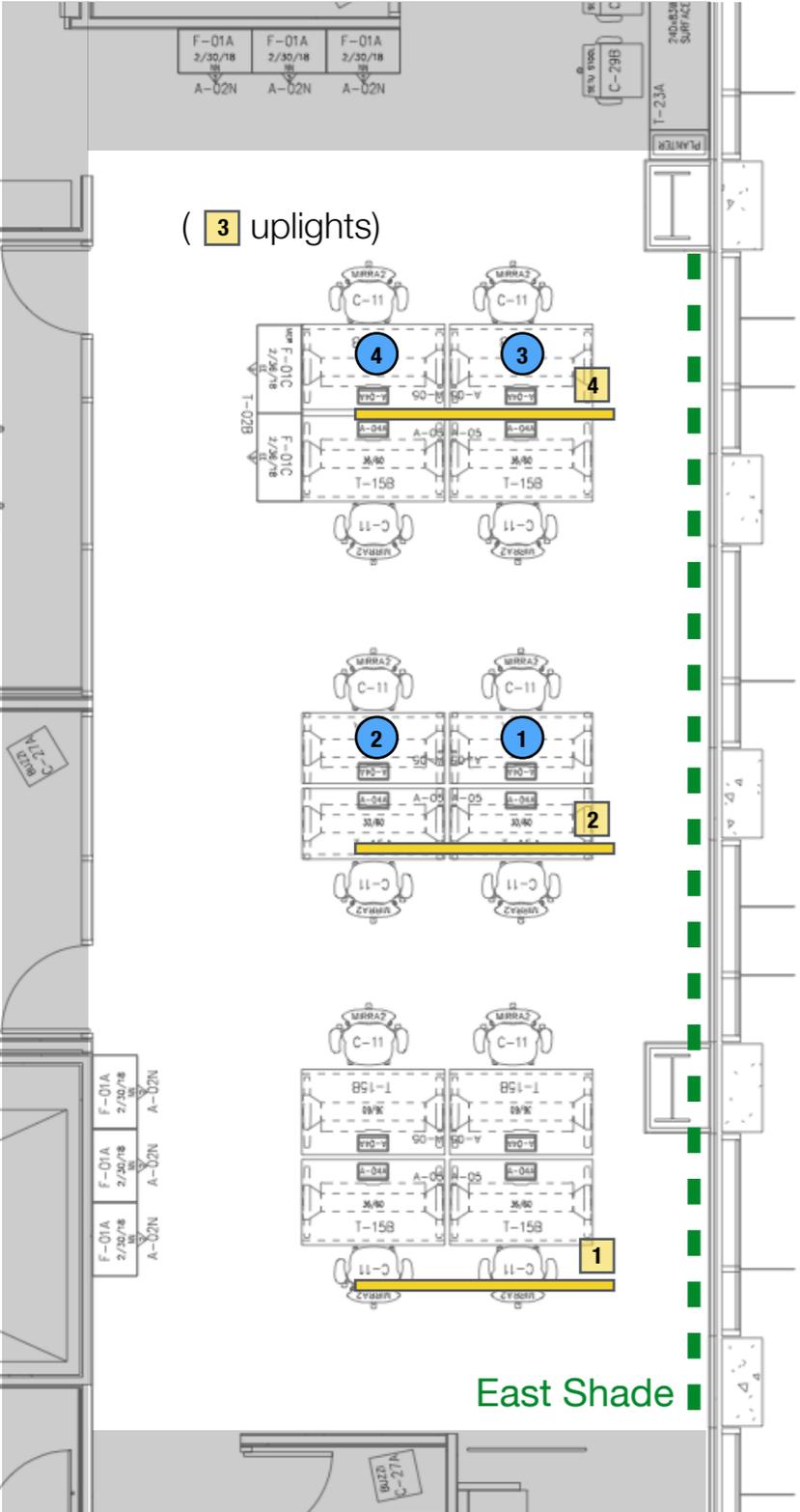


Minimum Illuminance

The minimum illuminance histogram shows that the minimum illuminance measured at a workplane sensor (when lights are above minimum output) is in the 300-400 lux range about 70% of the time. Minimum illuminance is below 200 lux 1.7% of the time. Often this minimum illuminance falls below 200 because of latency between the shades lowering and the lighting controls adjusting.



Lighting Control Operation | East Area

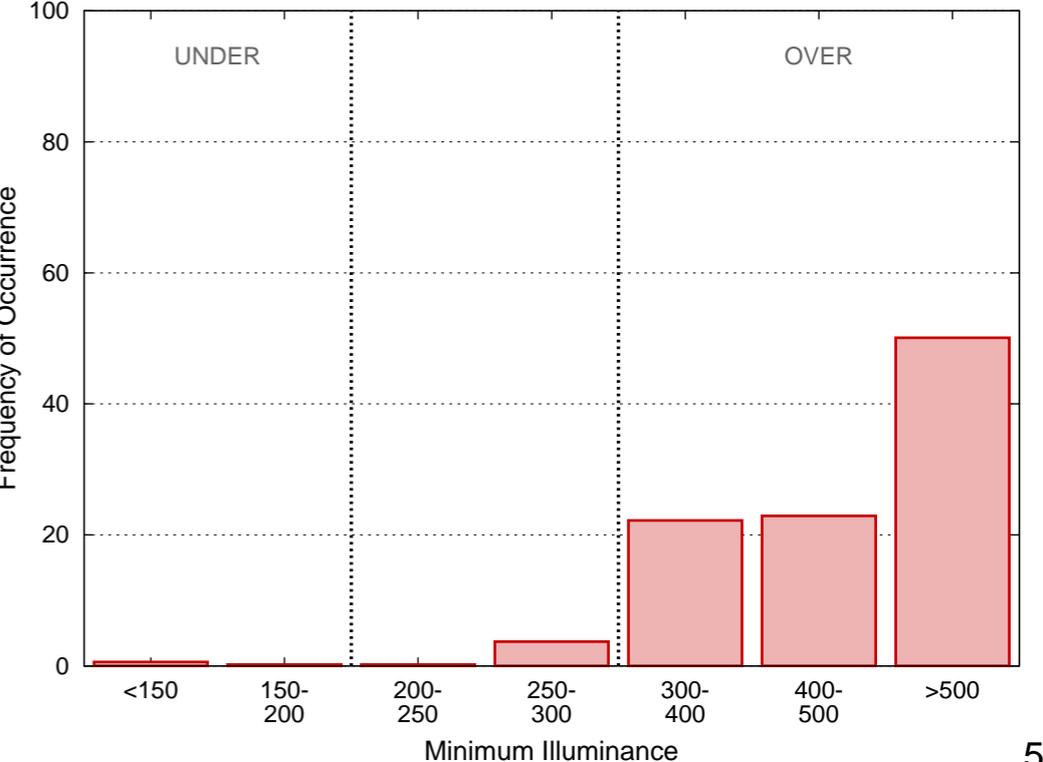
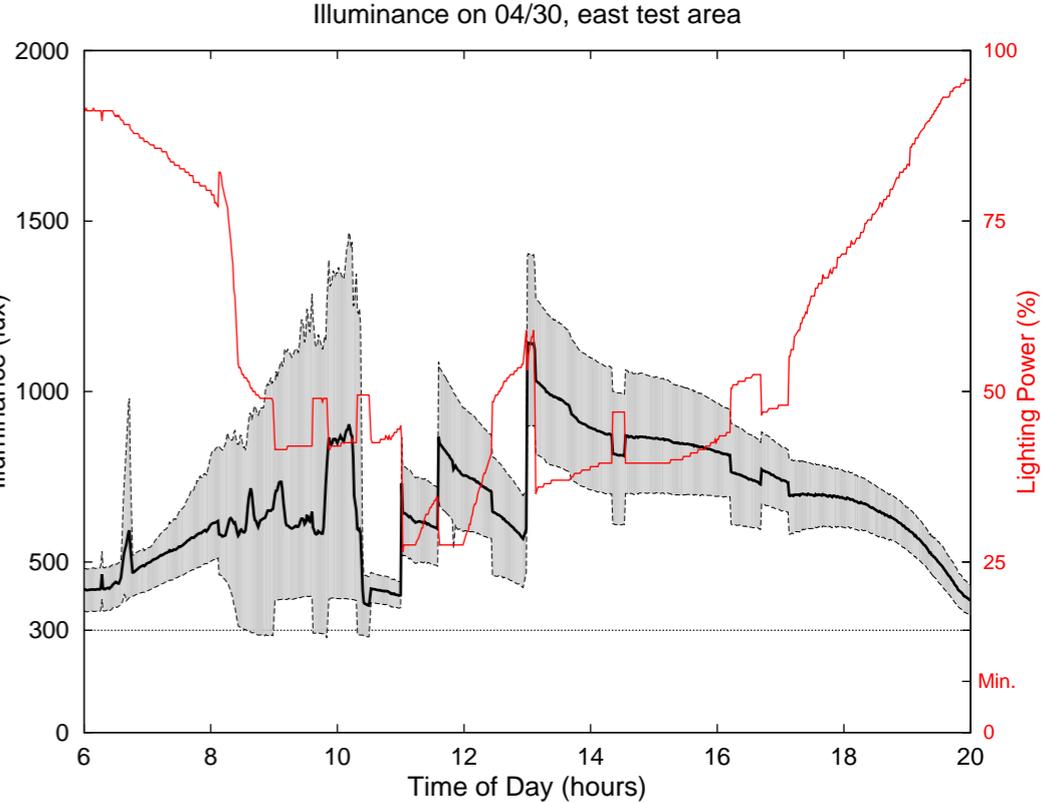


Daily Illuminance

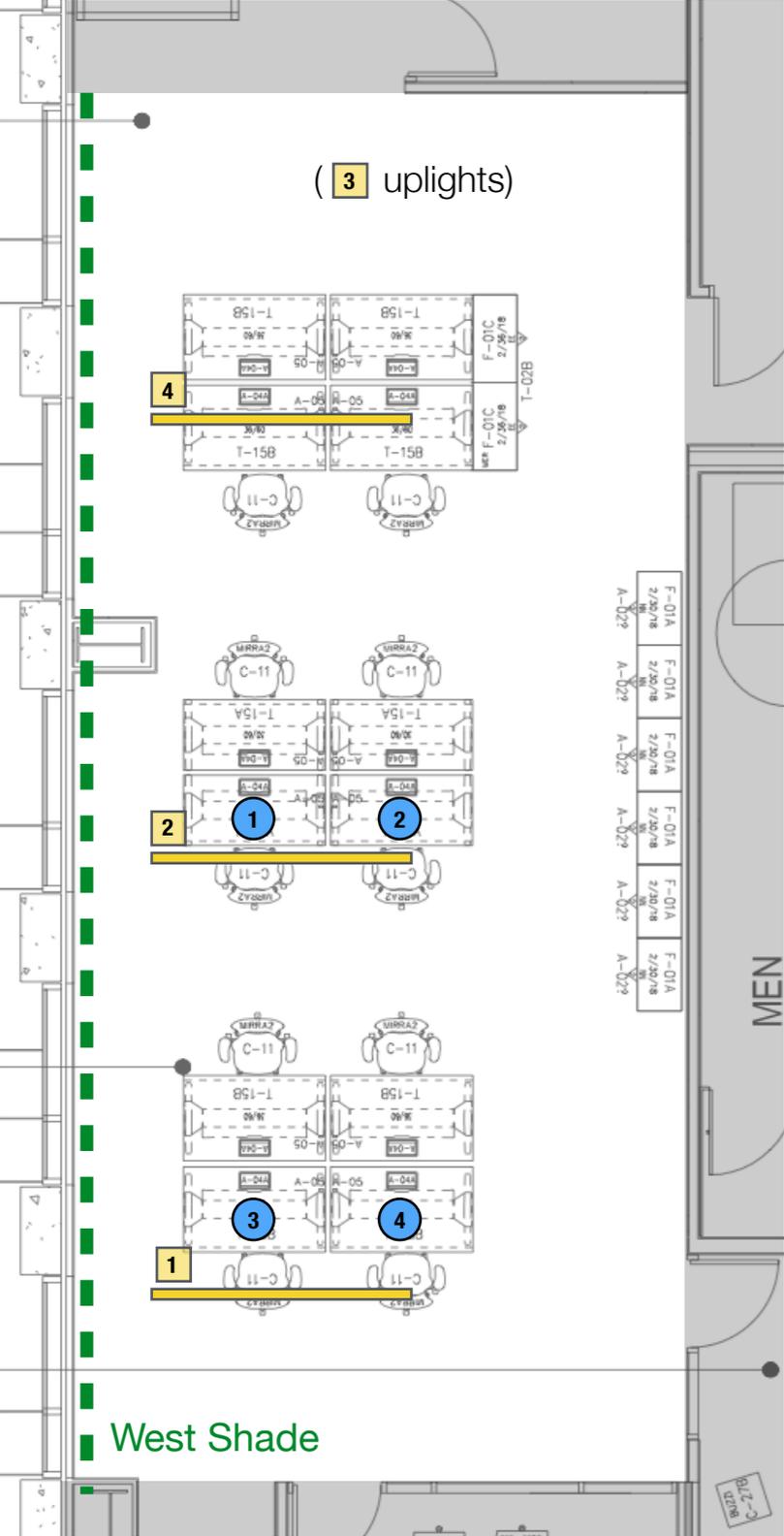
In the east test area minimum illuminance tracked the design criteria closely in the morning, when the shade was deployed. In the afternoons, however the illuminance measured at sensor locations often exceeded the design criteria. This is likely a result of the change in distribution of light coming through the window when the shade is up. During this time correlation between the amount of light on the photocell and light on the workplane changes.

Minimum Illuminance

The minimum illuminance histogram illustrates the persistent over illumination in the afternoon. 50% of the time minimum illuminance was above 500 lux.



Lighting Control Operation | West Area

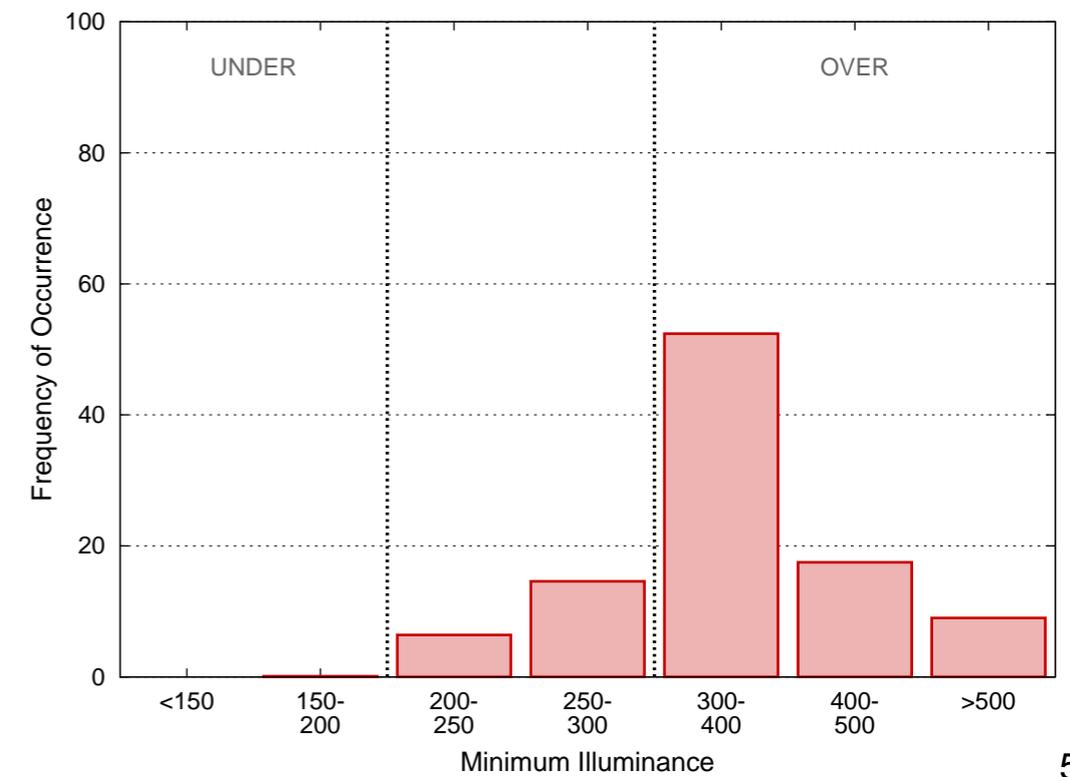
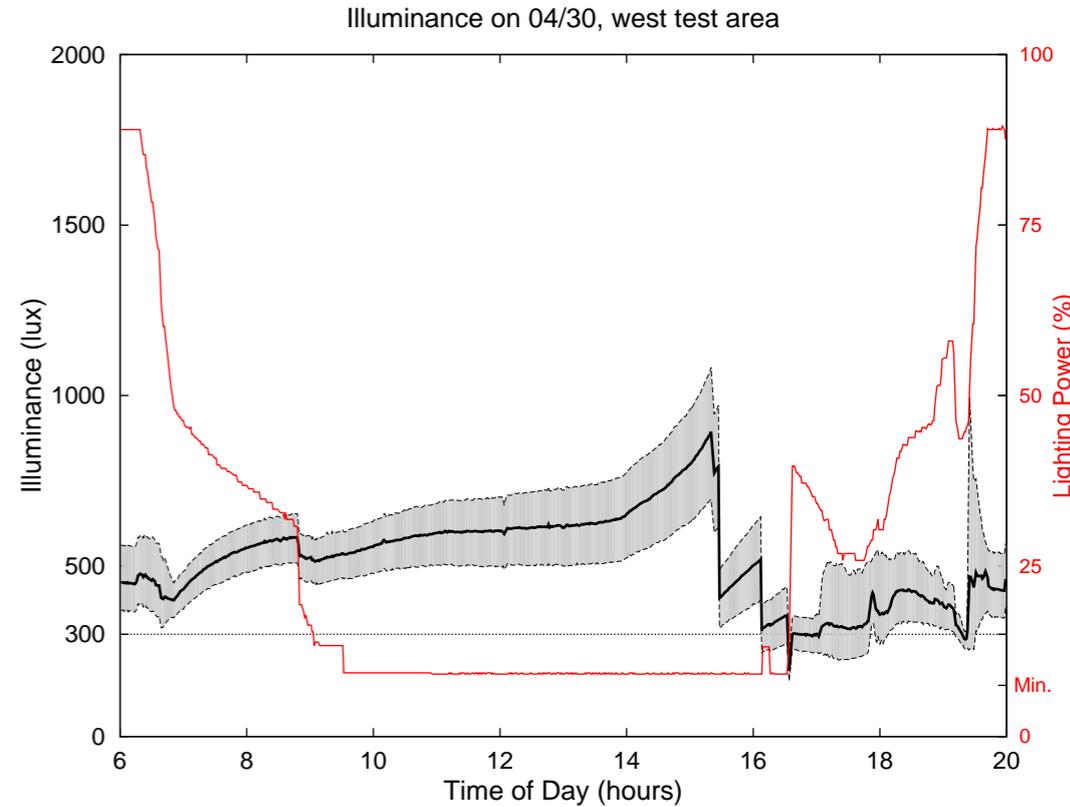


Daily Illuminance

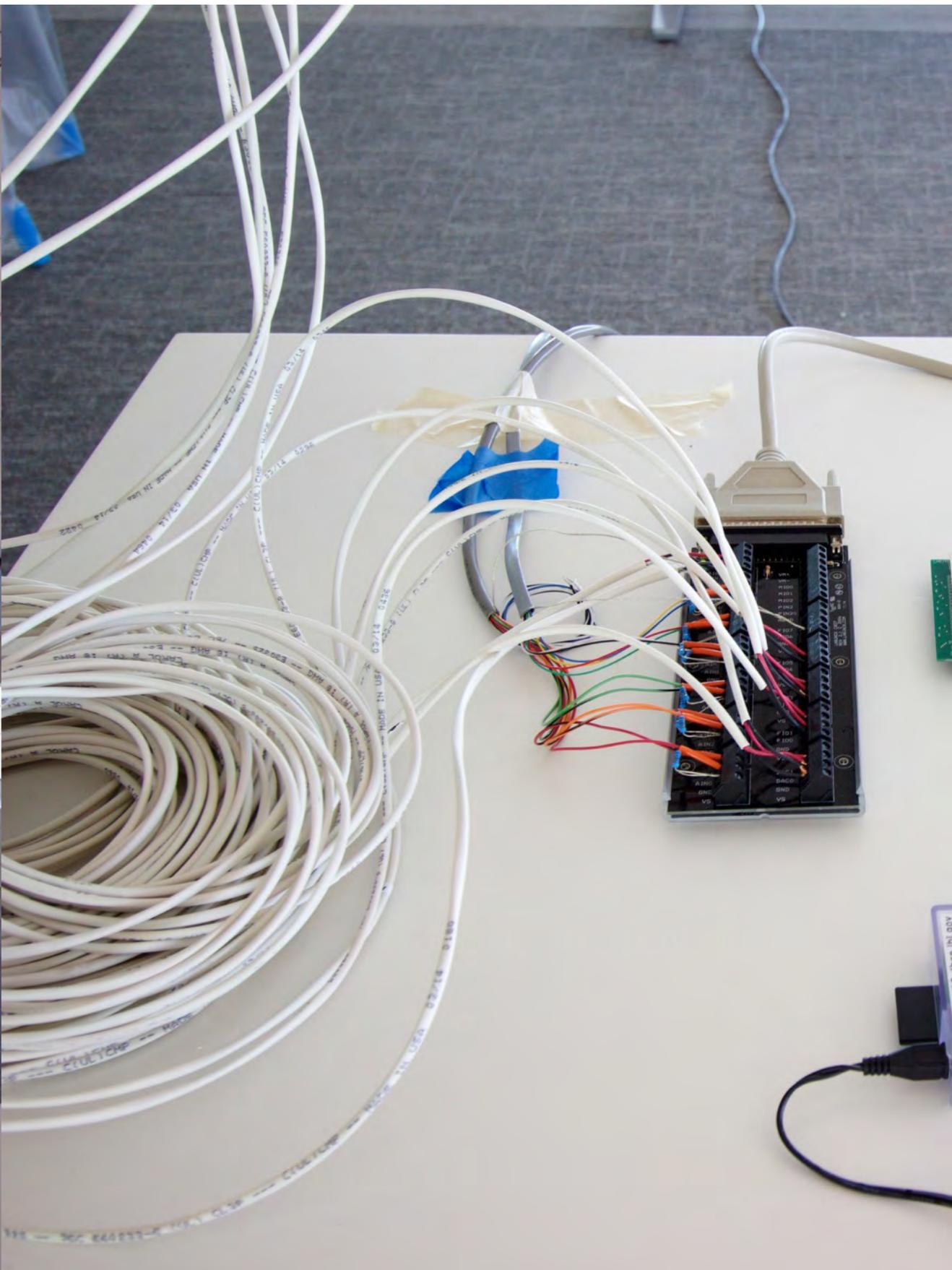
In the west test area, illuminance creeps upward in the morning as the daylight increases and lights dim until 9:30 AM when the lights are at minimum output. Later in the day when the shades begin to drop, illuminance drops as well until the lights ramp up at 4:45 PM. After 4:45 illuminance tracks target illumination closely.

Minimum Illuminance

The minimum illuminance histogram illustrates the persistent over illumination in the morning. 52% of the time minimum illuminance was between 300 & 400 lux. During the study period minimum illuminance was above 200 lux 99.9% of the time.



5. Lighting Energy Use



Lighting Energy Use | Metrics

Daylight Dimming Strategy

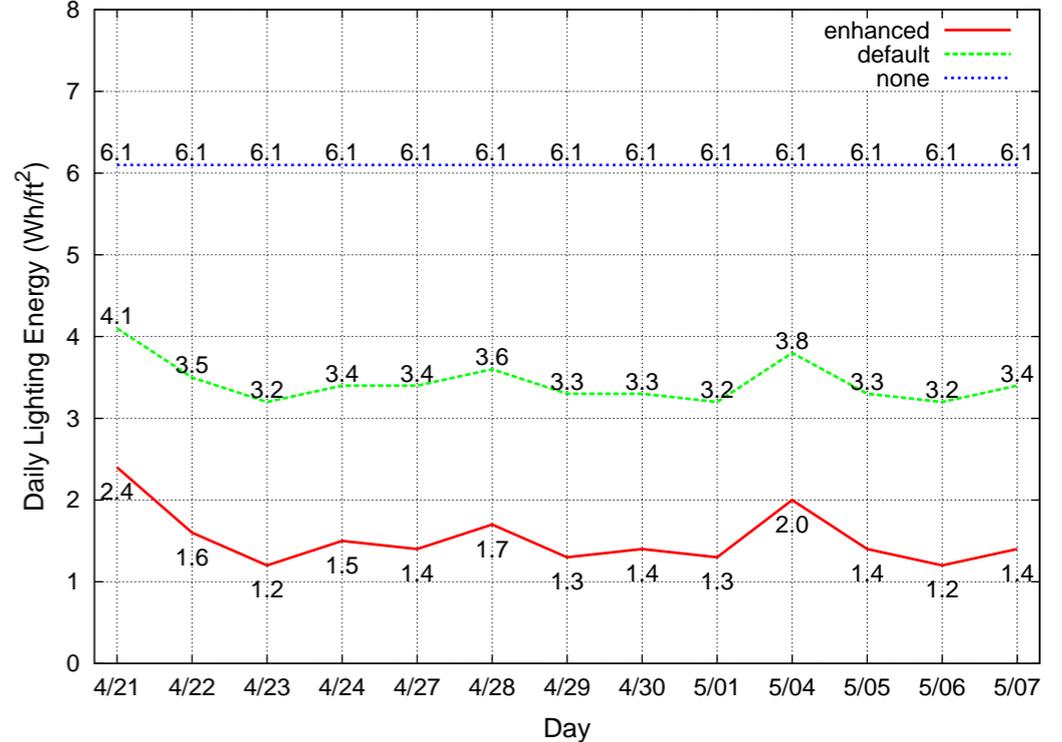
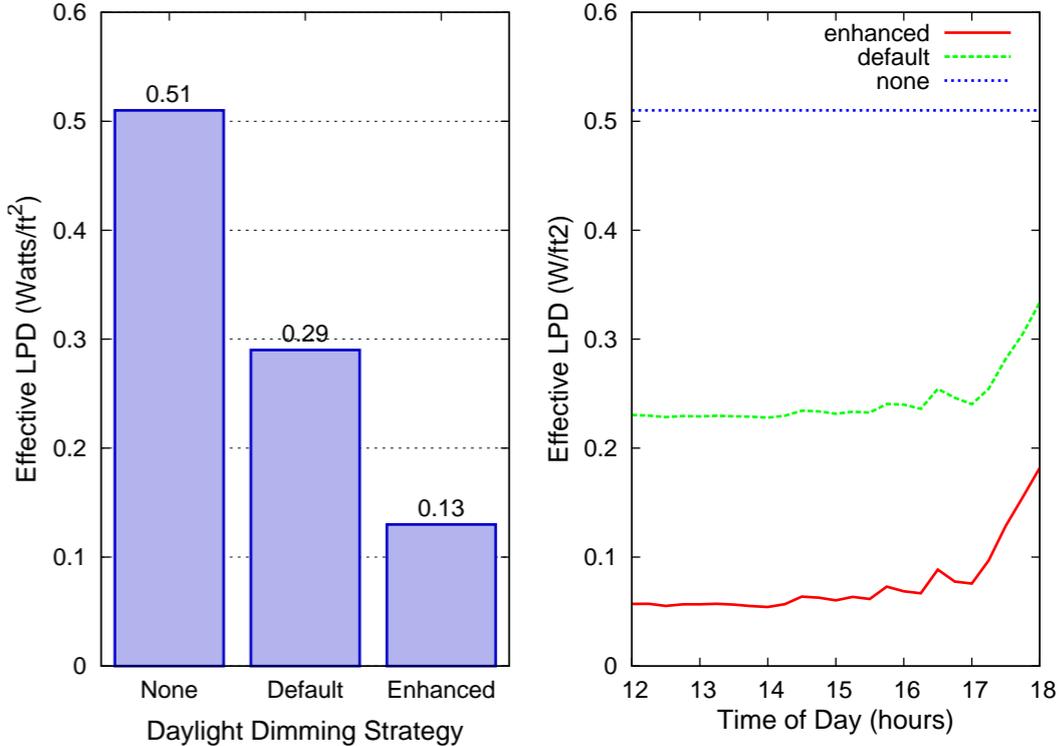
We report lighting energy savings for default and enhanced dimming strategies. The 'default' dimming strategy is the default commissioning performed by the controls vendor, including a 40% minimum dim setting for both up and down lights. The 'enhanced' dimming strategy is the modified settings provided by LBNL, including a 15% minimum dim for the downlight and 0% minimum dim setting for the uplights.

Effective LPD

Effective LPD is the measured instantaneous light power divided by floor area (using an area of 2000 square feet for the north and south areas, and 750 square feet for the east and west areas). It is different from (installed) LPD in that it includes reduction based on daylight dimming. The blue bar chart in the upper left illustrates the average LPD between the hours of 6 AM and 6 PM local time during the study period. The chart on the upper right shows the hourly LPD during the afternoon peak demand period.

Daily Lighting EUI

We are unable to accurately extrapolate annual energy use intensity (EUI) from data measured during this study. Instead we provide daily energy use divided by floor area, or Daily EUI, for each test area.

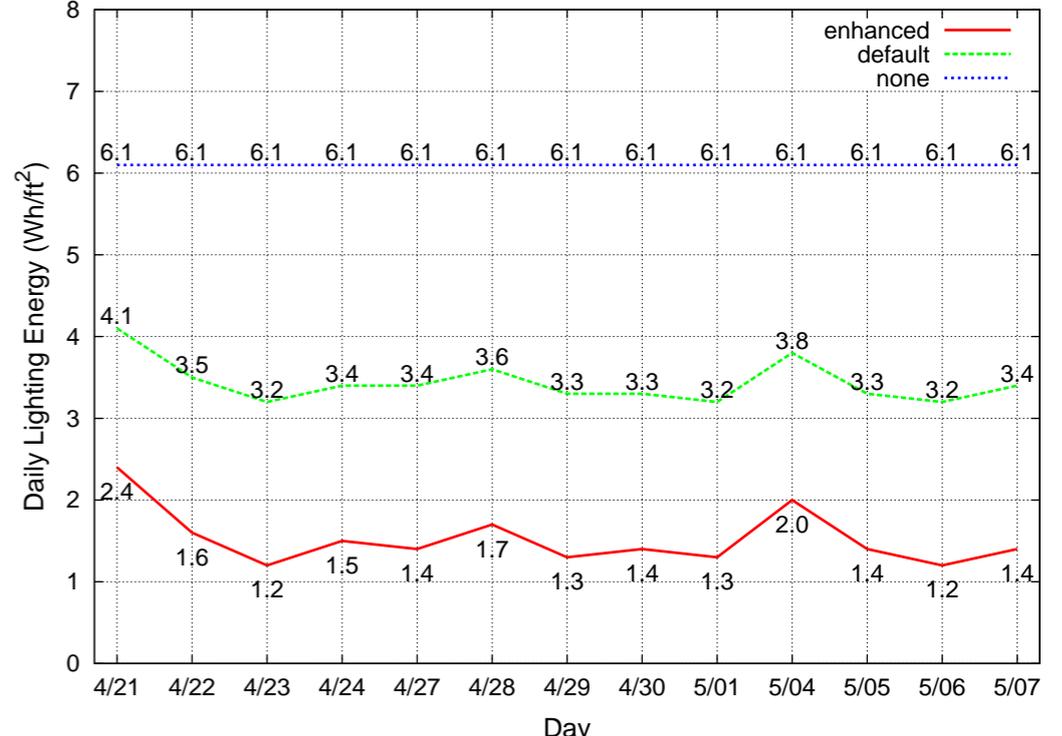
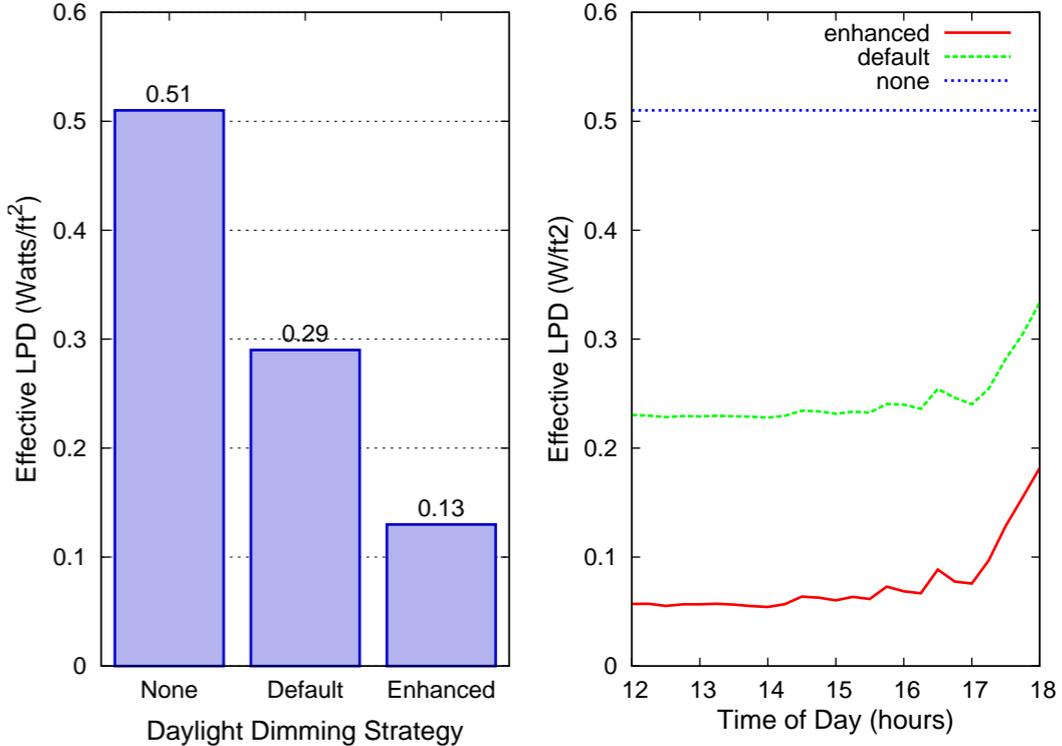


Lighting Energy Use | South Test Area

Effective LPD

In the south test area effective LPD for the enhanced daylight dimming strategy is 55% less than the default daylight dimming settings.

During the afternoon peak period the load reduction is even more pronounced. For example, at 4 PM the load with enhanced daylight dimming is 71% less than the load with default daylight dimming.

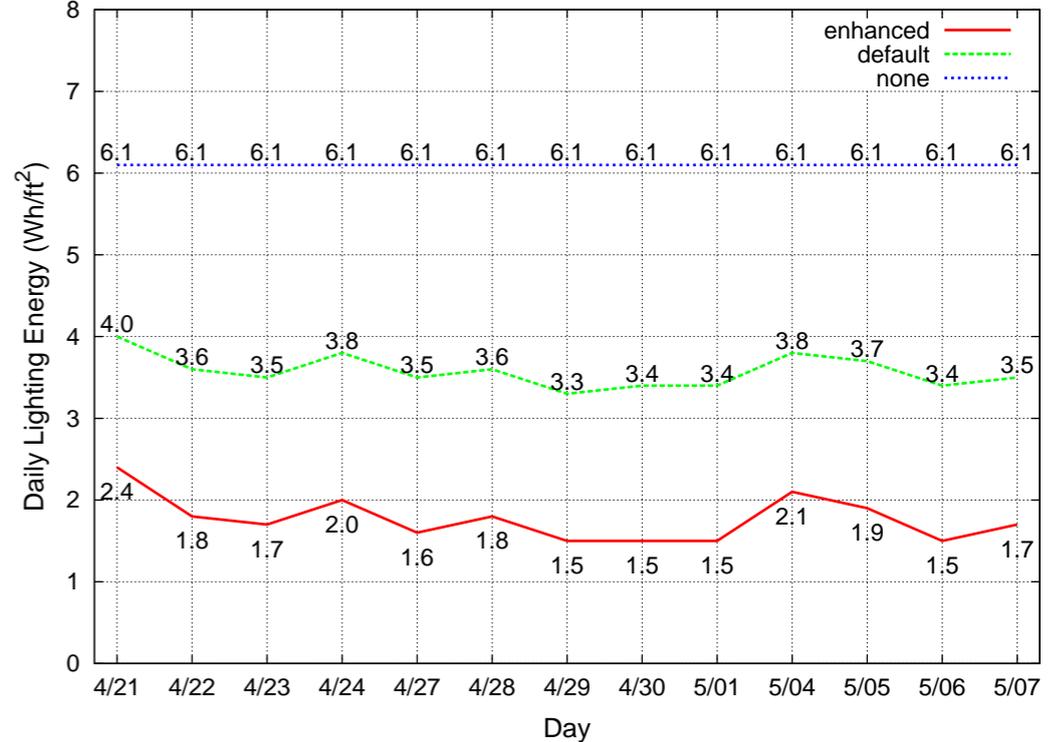
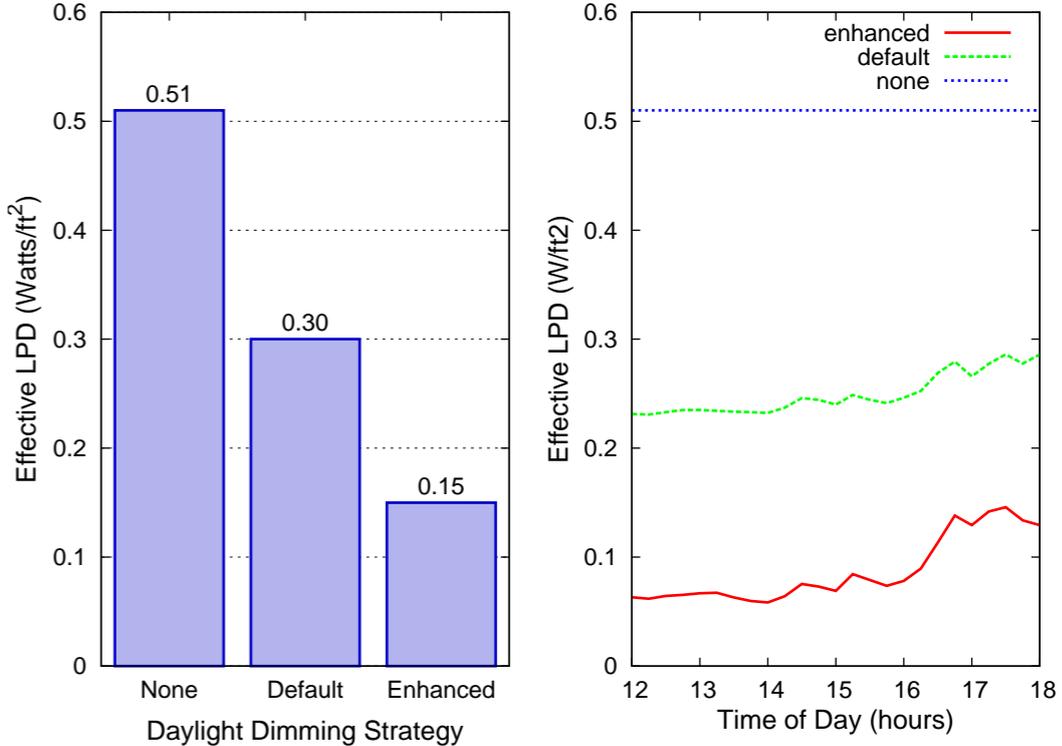


Lighting Energy Use | North Test Area

Effective LPD

In the north test area effective LPD for the enhanced daylight dimming strategy is 50% less than the default daylight dimming settings.

During the afternoon peak period the load reduction is even more pronounced. For example, at 4 PM the load with enhanced daylight dimming is 68% less than the load with default daylight dimming.

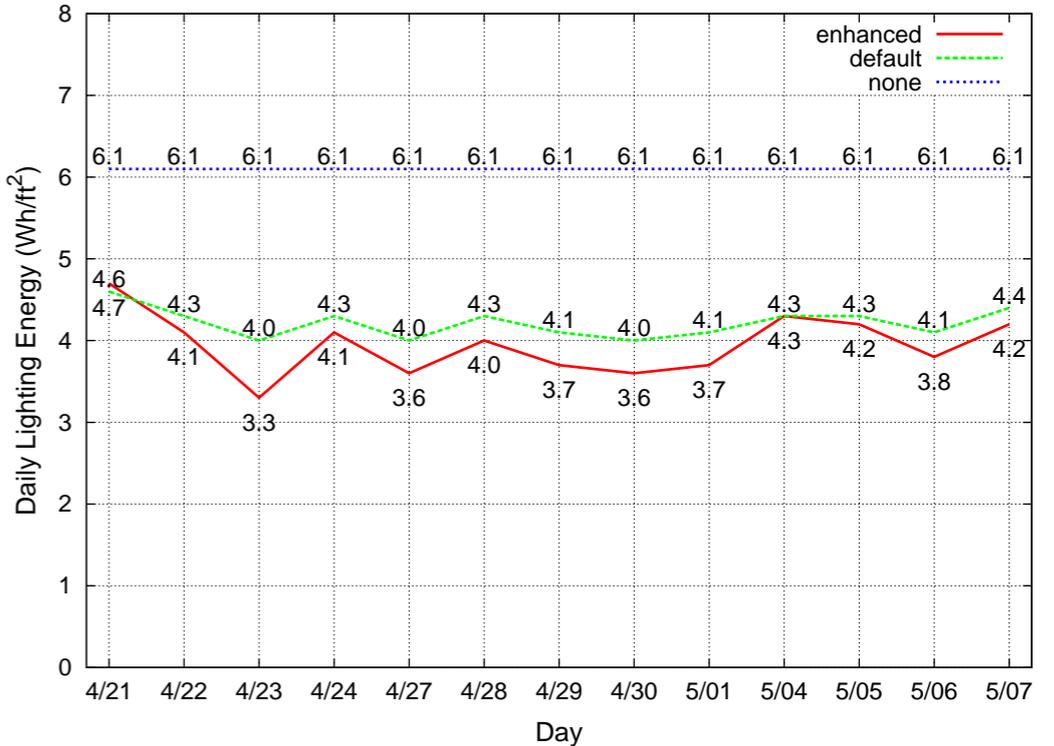
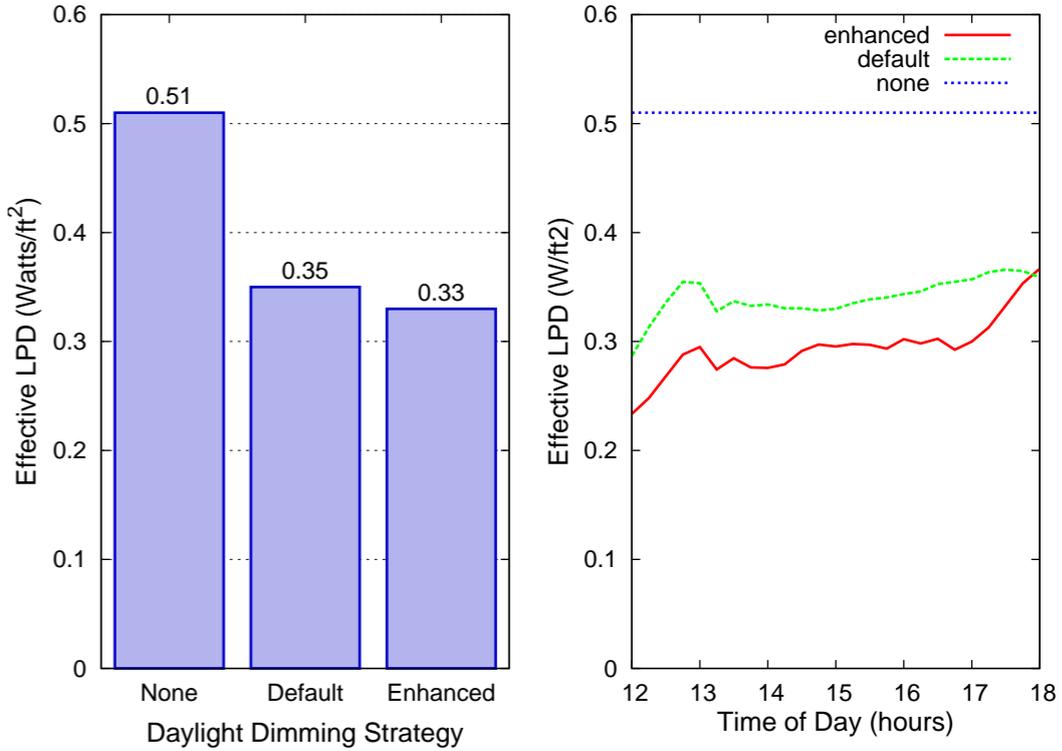


Lighting Energy Use | East Test Area

Effective LPD

The east test area is where, despite repeated efforts at troubleshooting, the daylight dimming response never worked as expected. This resulted in marginal savings from enhanced daylight dimming compared to default daylight dimming. LPD for the enhanced daylight dimming strategy is 6% less than the default daylight dimming settings.

During the afternoon peak period the load reduction is somewhat more pronounced. For example, at 4 PM the load with enhanced daylight dimming is 12% less than the load with default daylight dimming.

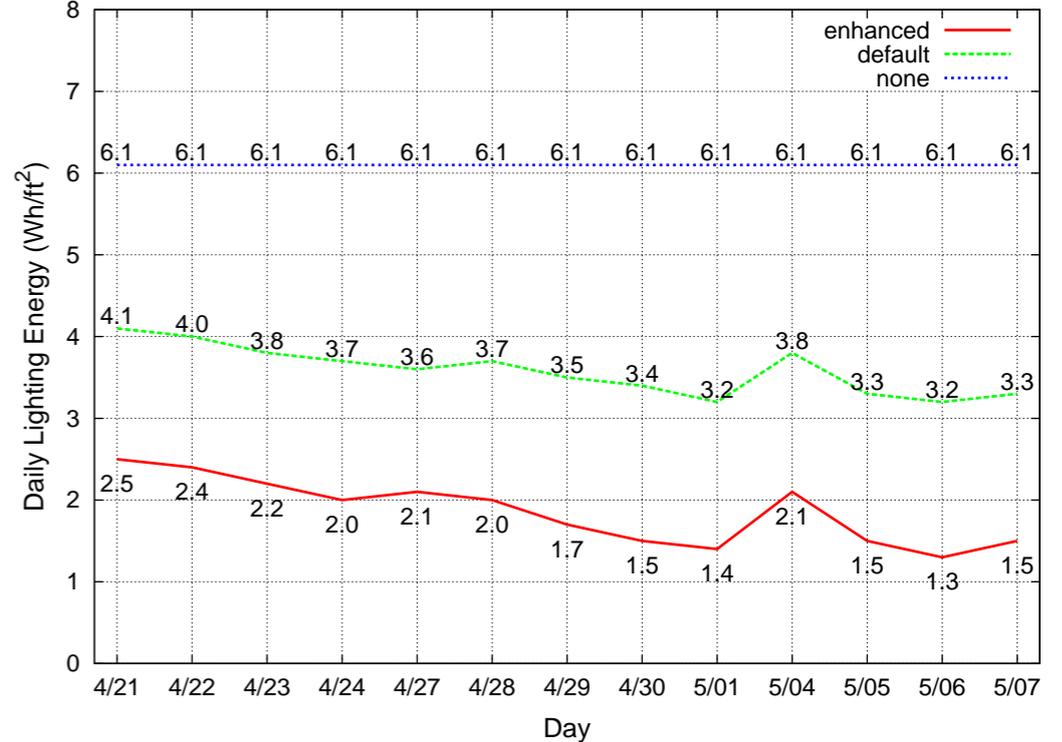
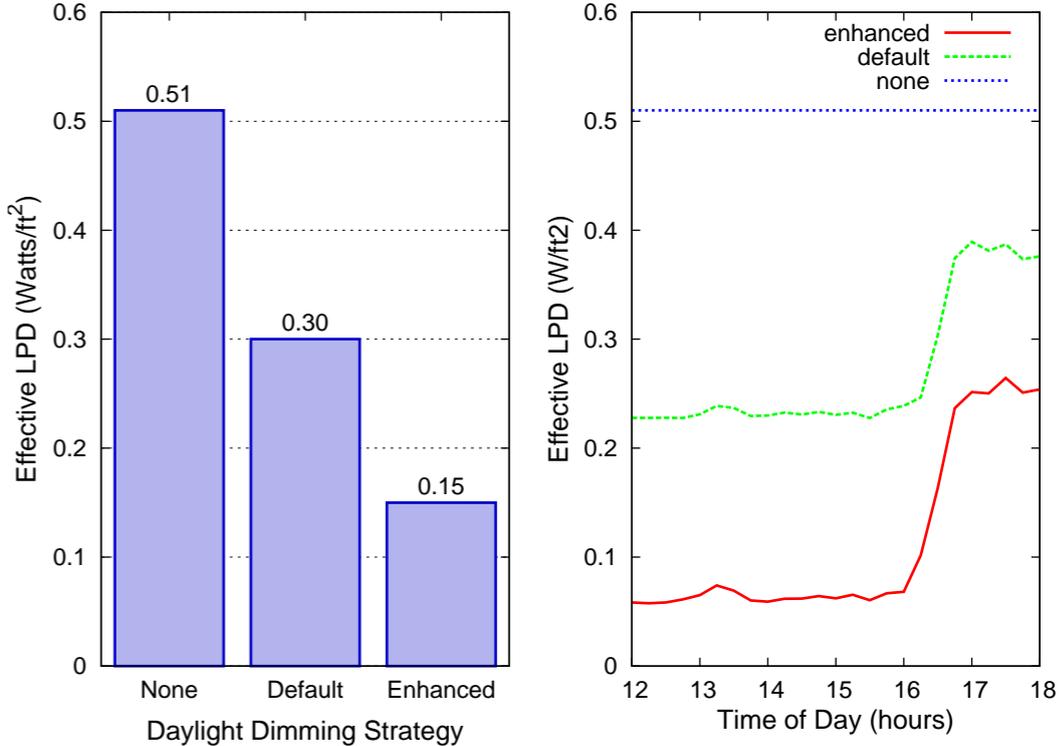


Lighting Energy Use | West Test Area

Effective LPD

In the south test area effective LPD for the enhanced daylight dimming strategy is 50% less than the default daylight dimming settings.

During the afternoon peak period the load reduction is even more pronounced. For example, at 4 PM the load with enhanced daylight dimming is 71% less than the load with default daylight dimming. But as the shades close to mitigate afternoon sun, the lighting power increases.



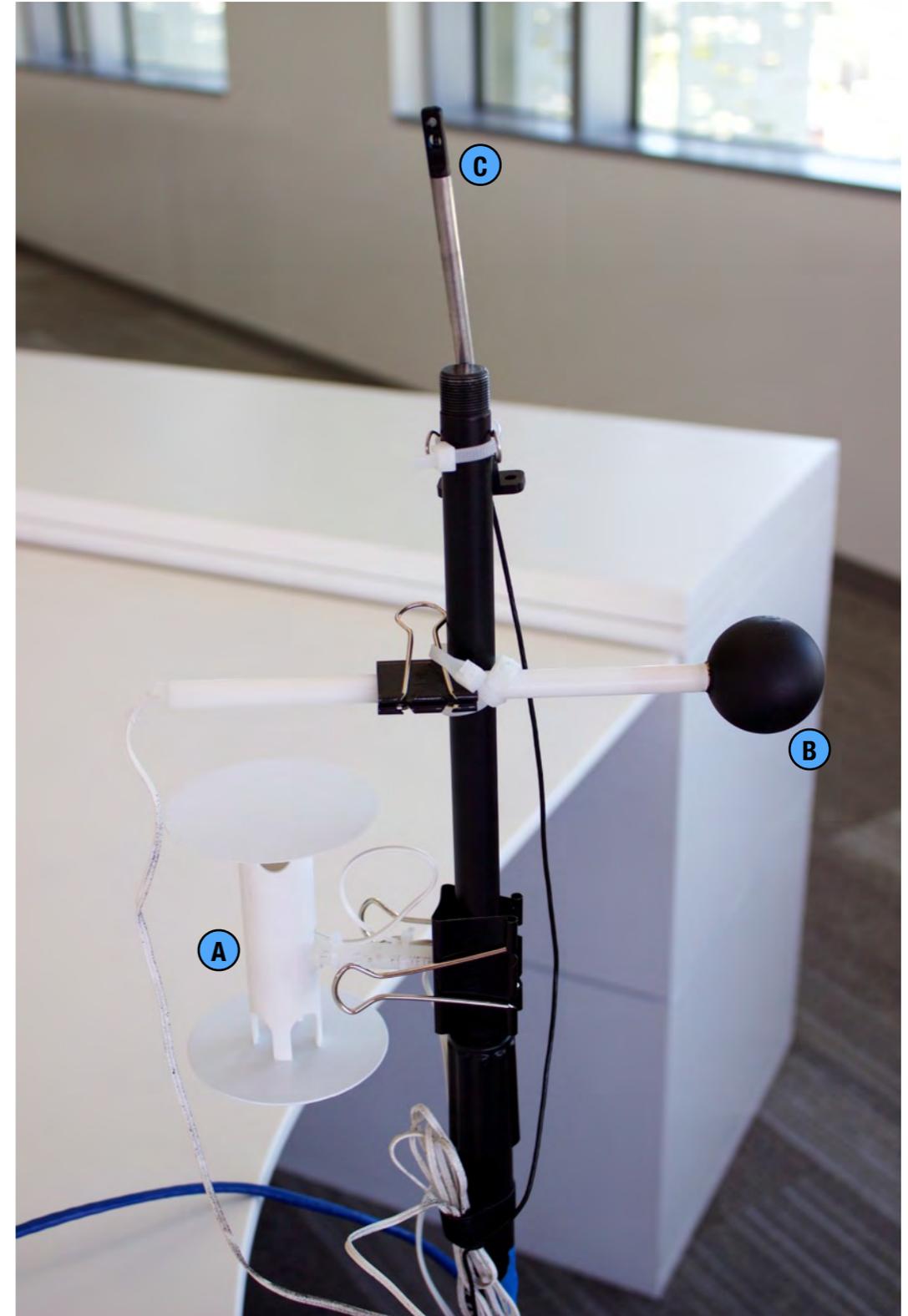
6. Thermal Comfort



Thermal Comfort | Methods

Sensors

The thermal comfort monitoring station (pictured right) consists of a shielded temperature sensor (A), a globe temperature sensor (B) and a hot wire anemometer (C). The shielded temperature sensor provides dry-bulb temperature and the shield prevents direct radiation from affecting the reading. The globe temperature sensor is used to approximate mean radiant temperature (with a correction for dry-bulb temperature and air velocity). The anemometer measures air velocity, though the particular sensor used has directional sensitivity. We assumed relative humidity of 40% at all times.



Thermal Comfort | Metrics

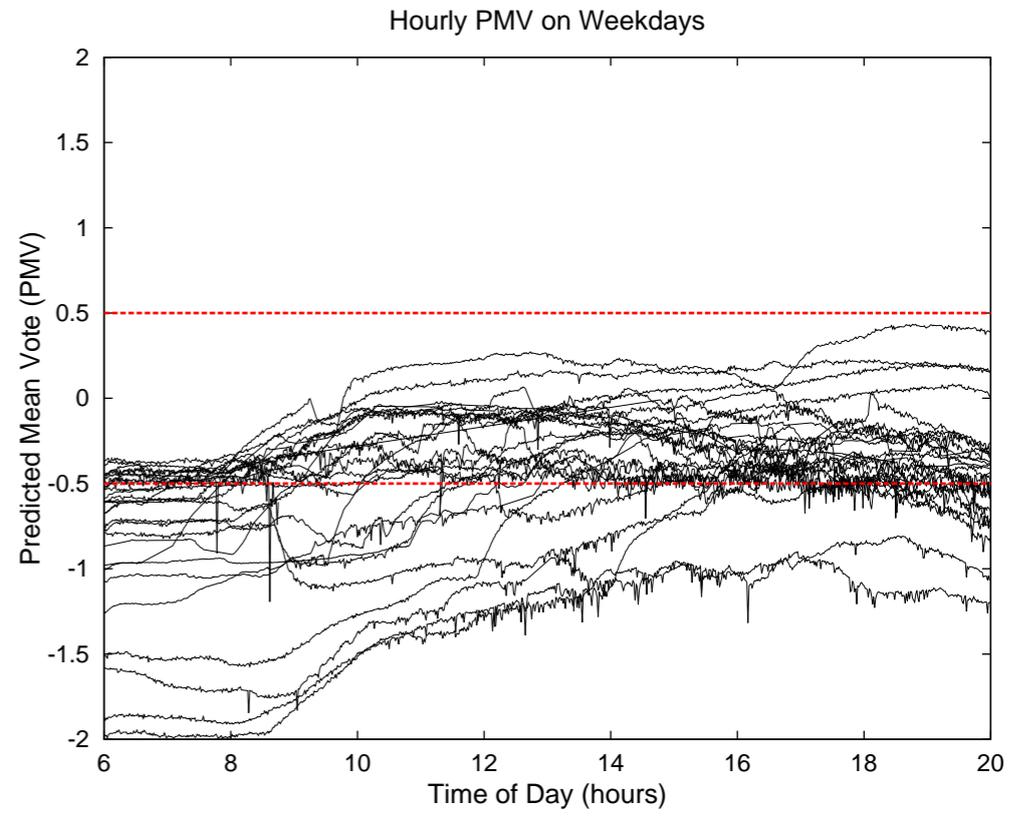
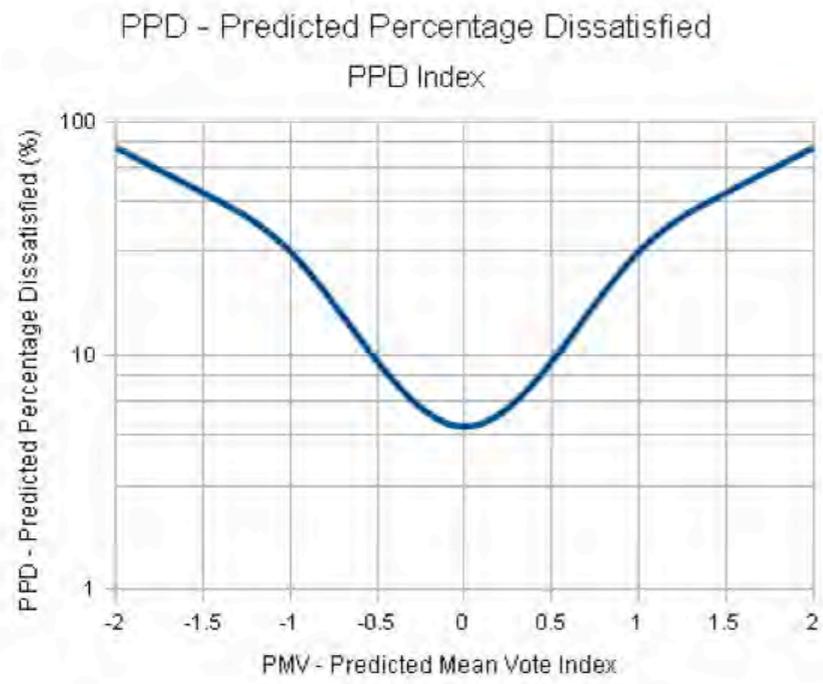
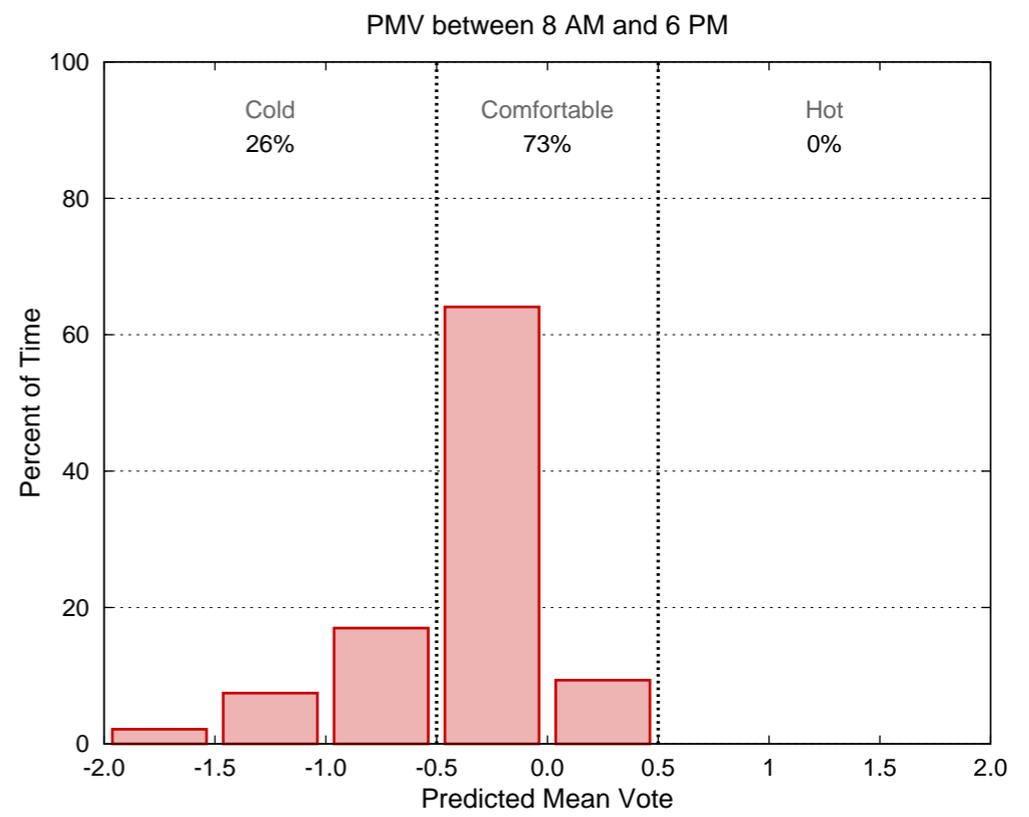
Predicted Mean Vote (PMV)

Thermal comfort was evaluated using the Predicted Mean Vote (PMV) method, developed by Fanger, which forms the basis for ASHRAE Standard 55-2010 “Thermal Environmental Conditions for Human Occupancy”. Calculations were performed using the UC Berkeley Center for the Built Environment Thermal Comfort Tool (<http://smap.cbe.berkeley.edu/comforttool>). PMV values range from +3 (hot sensation for occupants) to -3 (cold sensation for occupants). A PMV of +1 indicates a slightly warm thermal sensation and -1 slightly cold. ASHRAE Standard 55 specifies that the PMV should be between -0.5 and +0.5 to meet the standard for comfort. Another indicator is the Predicted Percent Dissatisfied (PPD) which is a quantitative measure of the thermal comfort of a group of people at a particular thermal environment.

Our analysis assumed typical clothing for Genentech employees consisted of underwear, t-shirt, calf-length socks, shoes, long-sleeve dress shirt, straight thick trousers, (a clo value of 0.66). This matches well with a female outfit of knee-length skirt, long-sleeve shirt, full slip (clo=0.67)

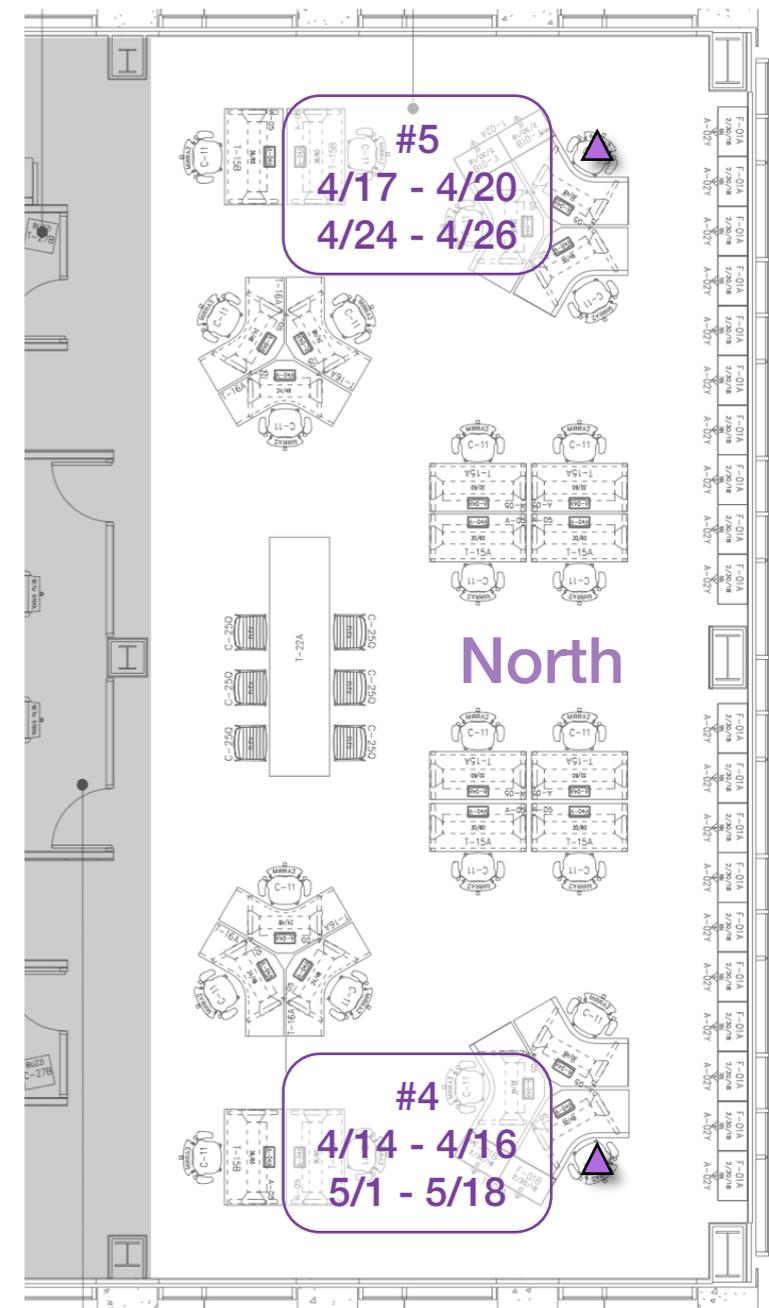
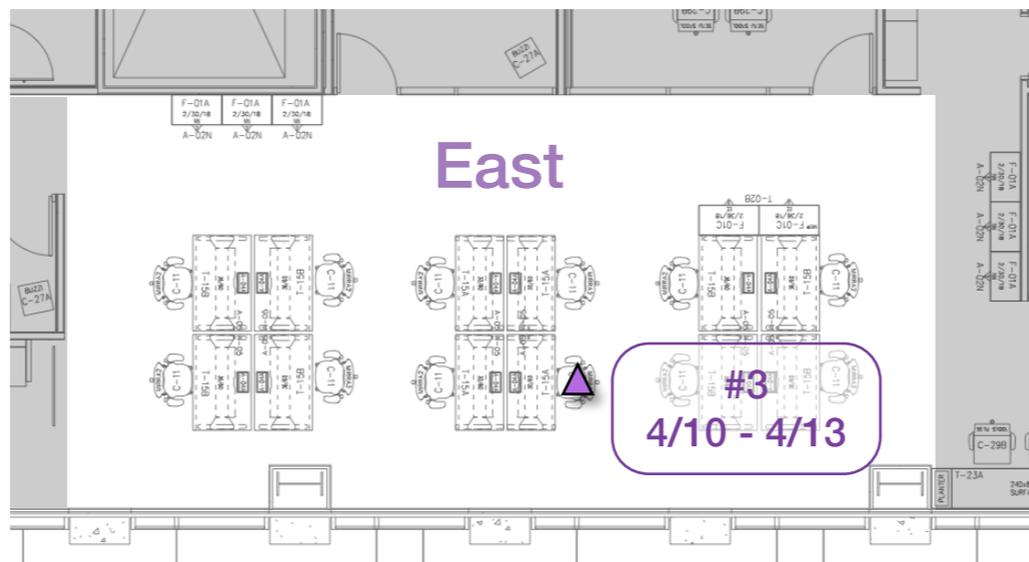
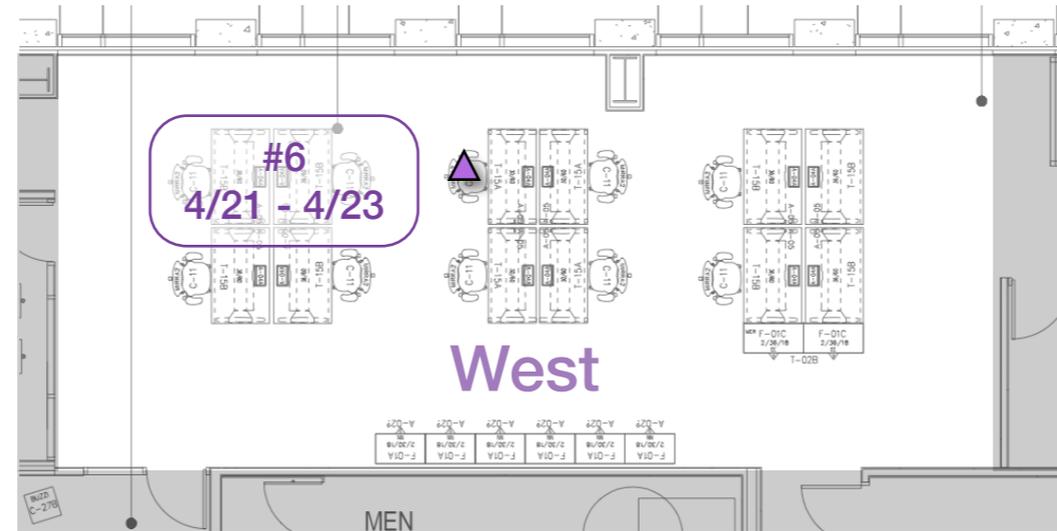
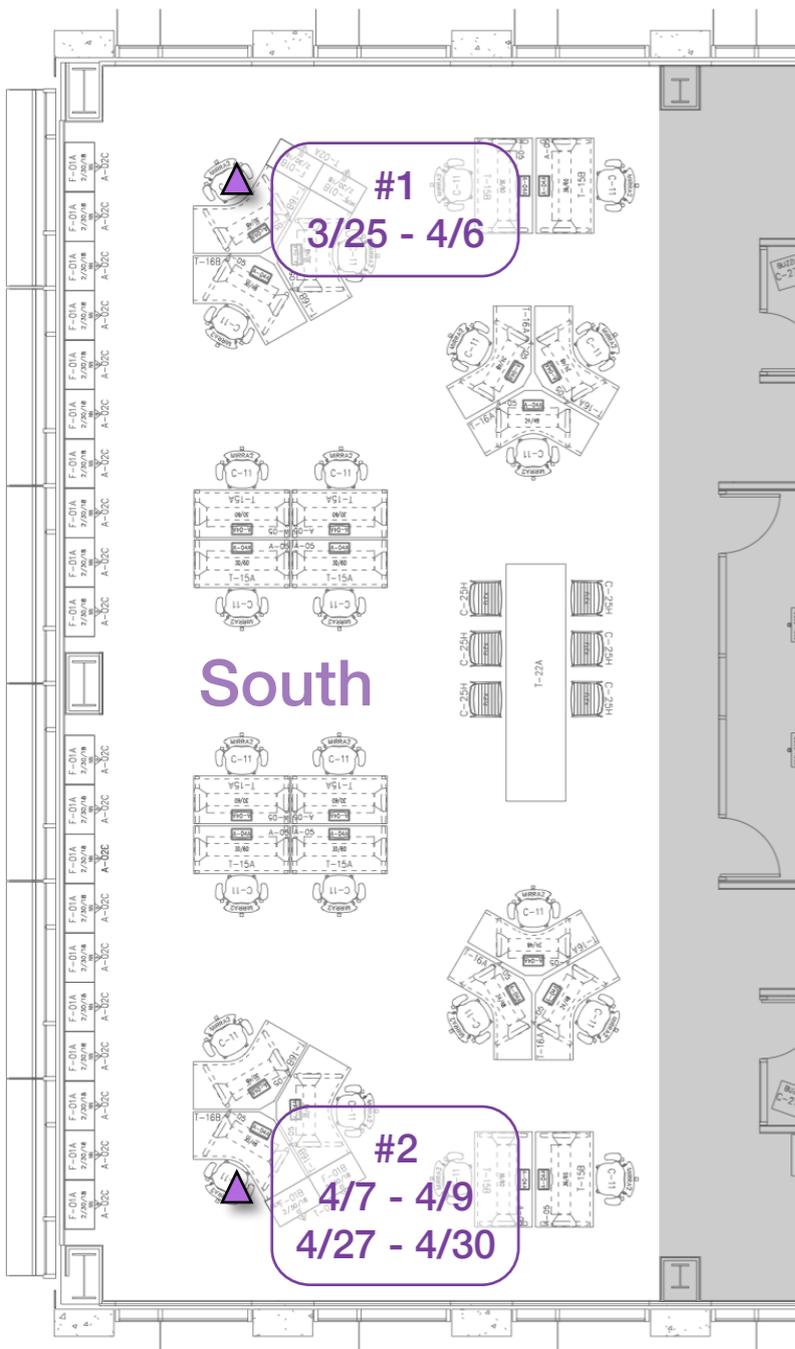
The chart below shows the relationship between PPD and PMV. The figure shows that at -0.5 and +0.5 the PPD is 10%; PPD never goes below 5%.

The graph to the lower right shows PMV through out the day on weekdays during the study period. Each line represents PMV during a day.



Thermal Comfort

Monitoring Station Positions



▲ Thermal Comfort Station Positions

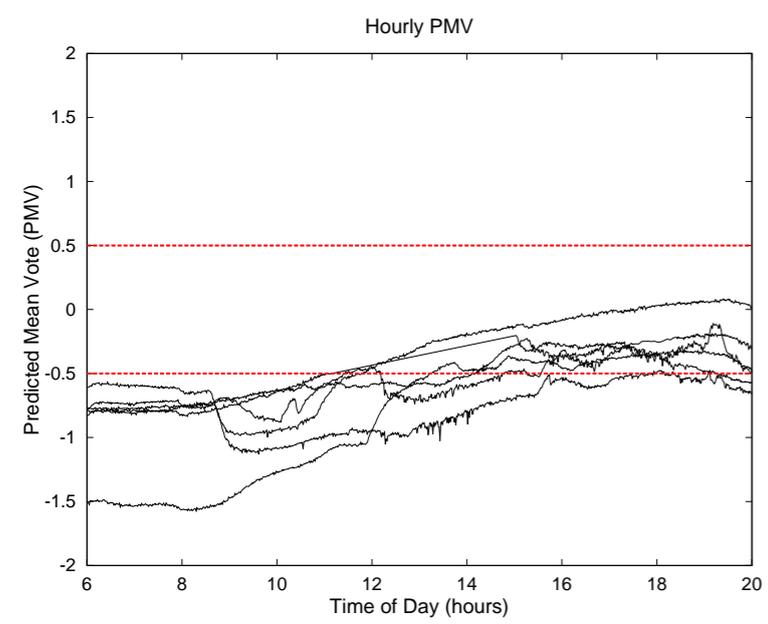
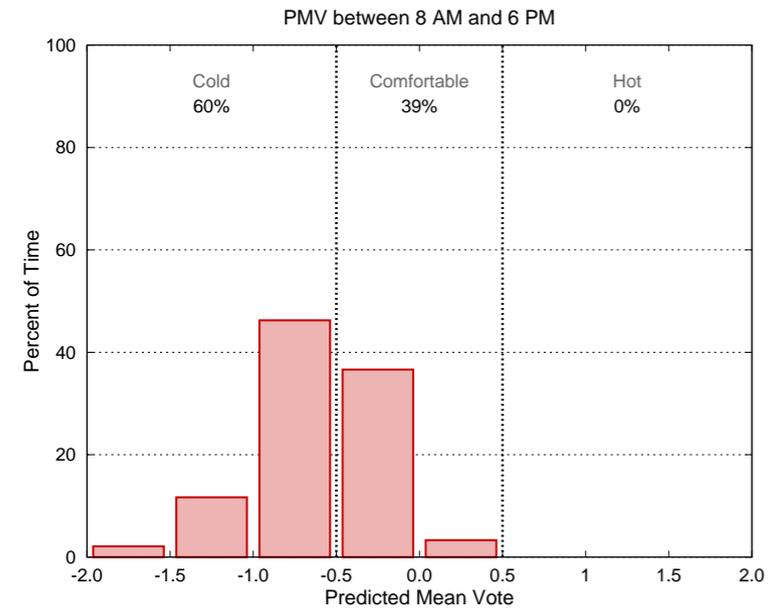


Thermal Comfort | South

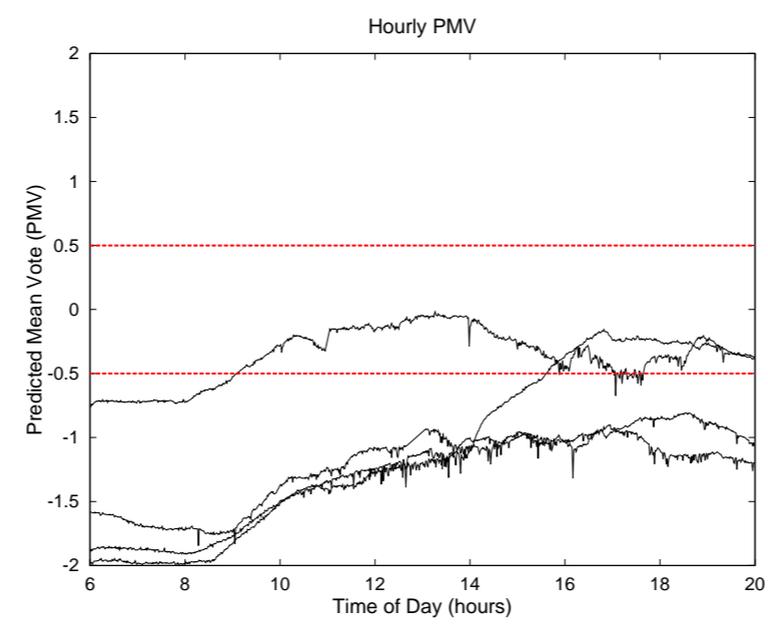
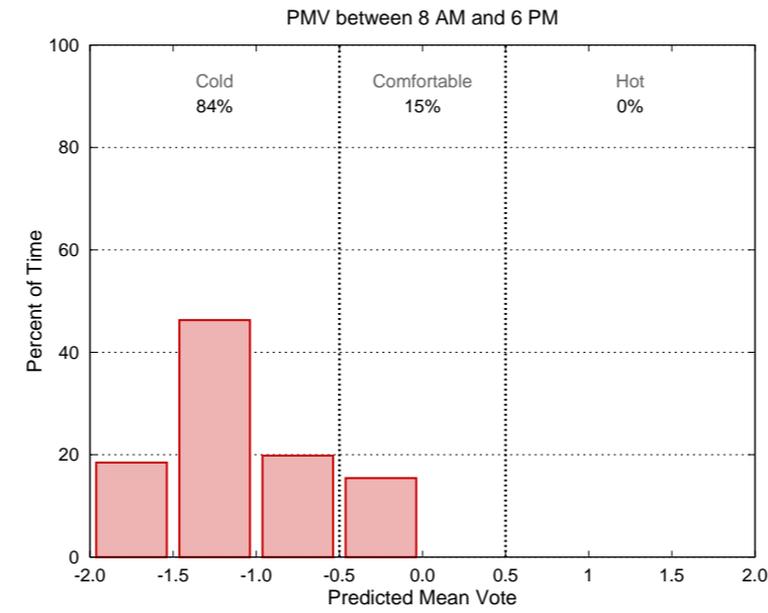
PMV

PMV in the south test area was low during the period 4/1 - 4/10, indicating that occupants are likely to feel cold a substantial portion of the time. However later testing in the south area (4/27-4/30) showed more comfortable conditions. Though PMV regularly falls into the cold range (below -0.5) in the morning and evening.

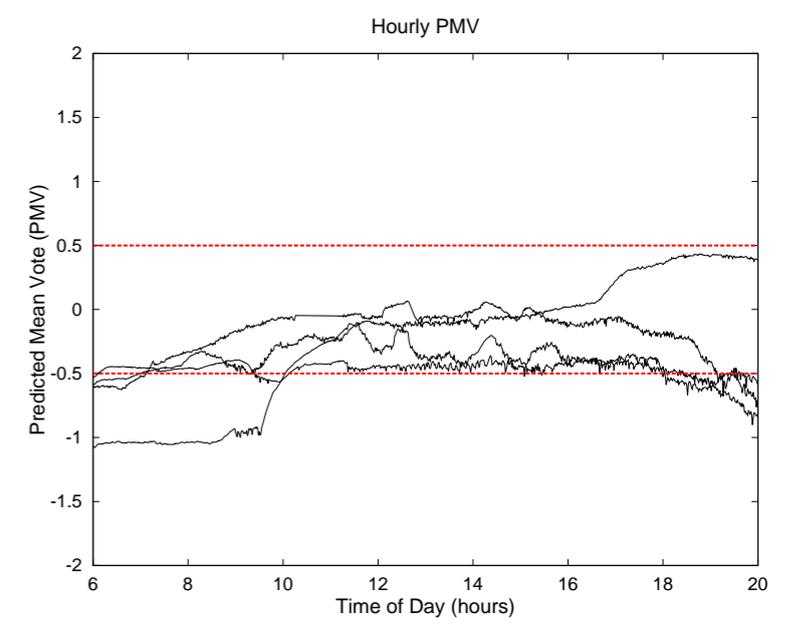
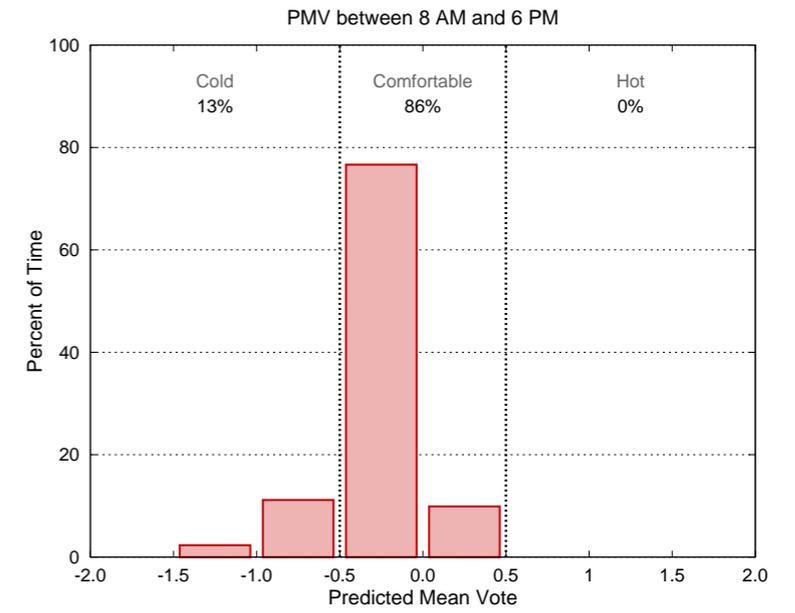
Position #1 4/1-4/6



Position #2 4/7-4/10



Position #2 4/27-4/30

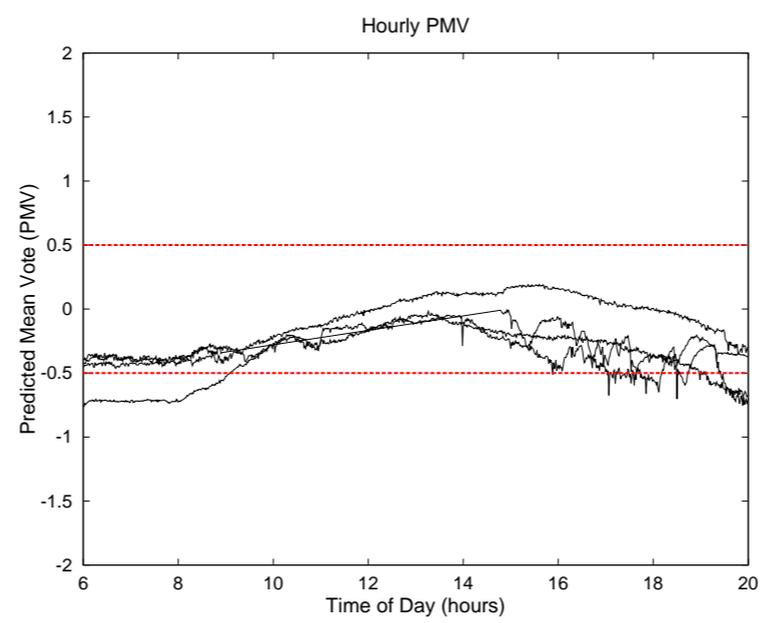
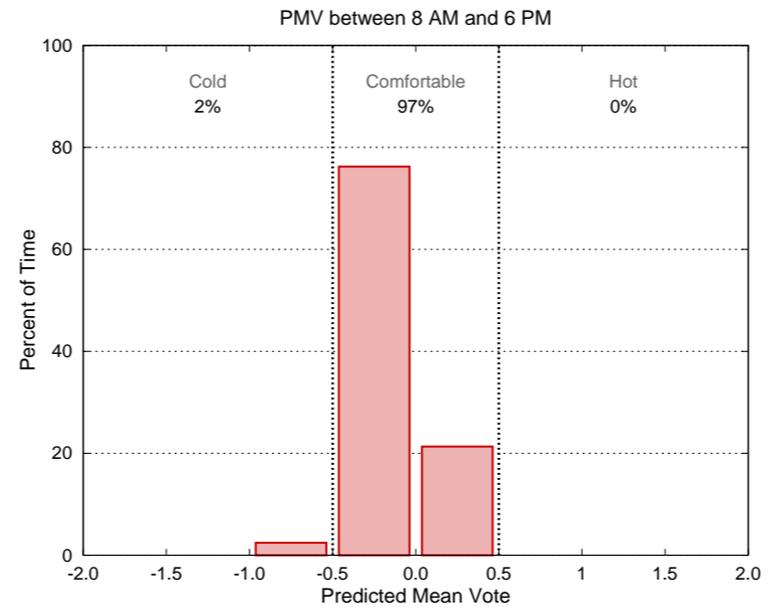


Thermal Comfort | East & West

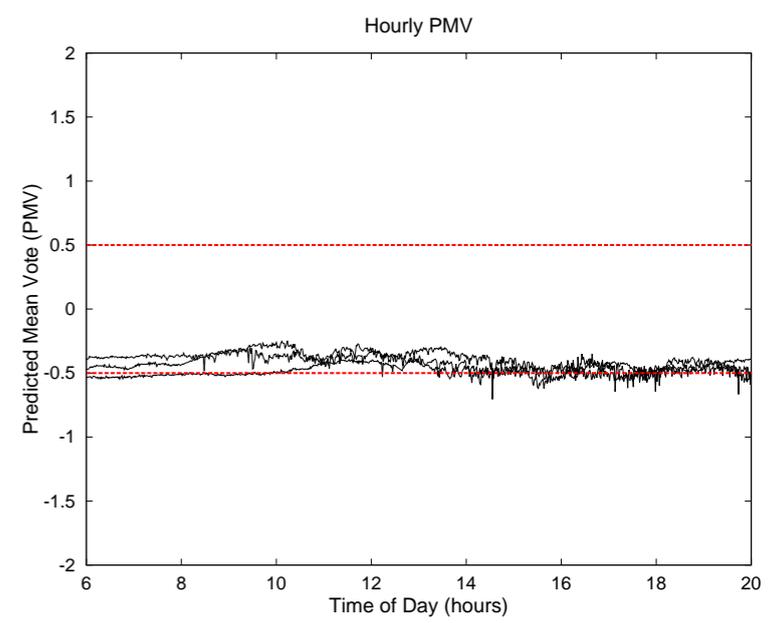
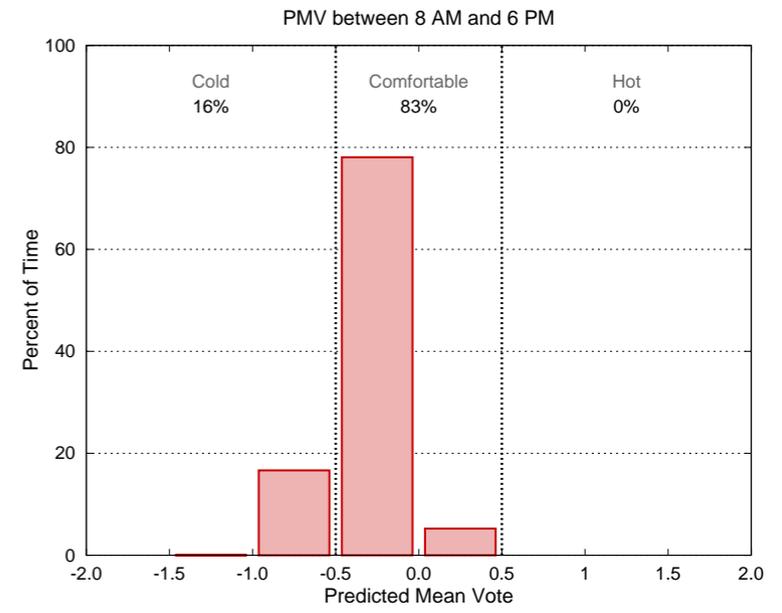
PMV

PMV in the east and west test areas was largely in the comfortable range, though was consistently on the colder side of the comfortable range. The PMV was regularly near the -0.5 threshold between comfortable and cold, particularly in the west test area.

Position #3 (East) 4/10-4/13



Position #6 (West) 4/21-4/23

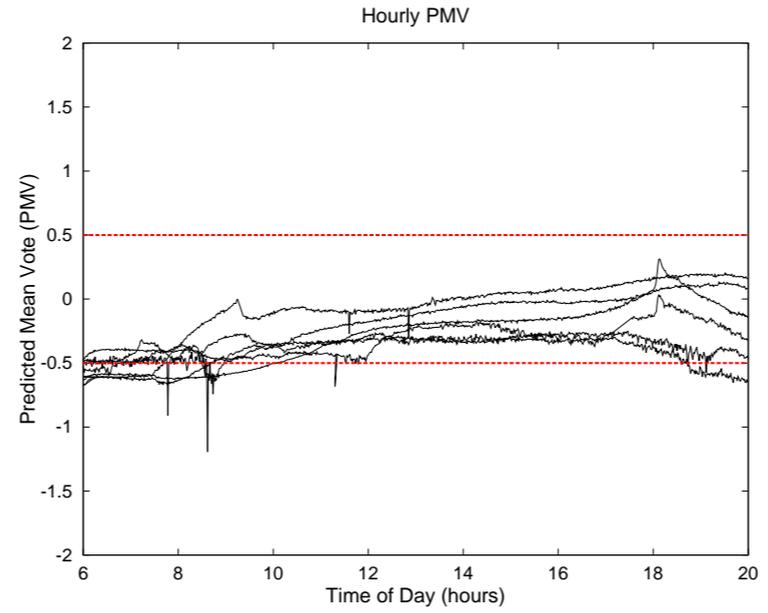
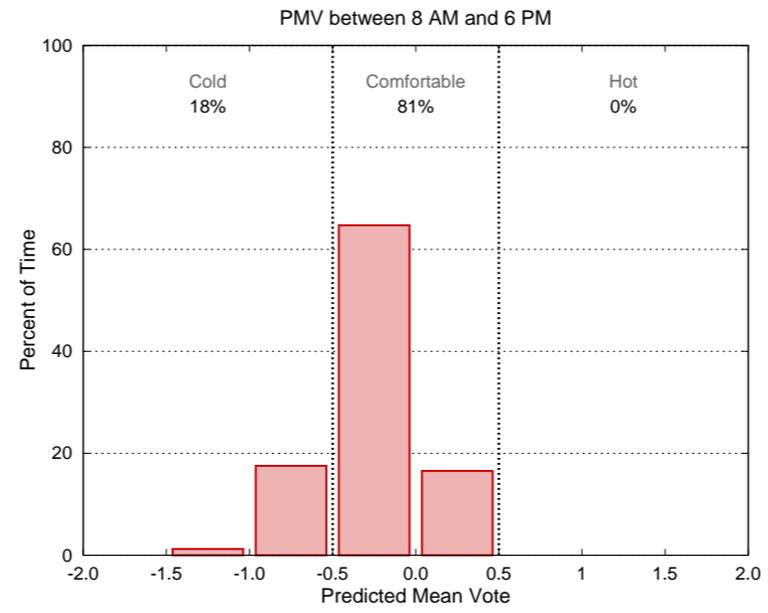


Thermal Comfort | North

PMV

PMV in the east and west test areas was largely in the comfortable range, though was consistently on the colder side of the comfortable range. The PMV was regularly near the -0.5 threshold between comfortable and cold, particularly in the west test area.

Position #4 4/17-4/20 & 4/24-4/26



Position #5 4/14-4/16 & 5/1-5/7

