Validation of the Radiance 5-Phase-Method against field measurements

David Geisler-Moroder, Eleanor Lee, Greg Ward

Contents

Motivation

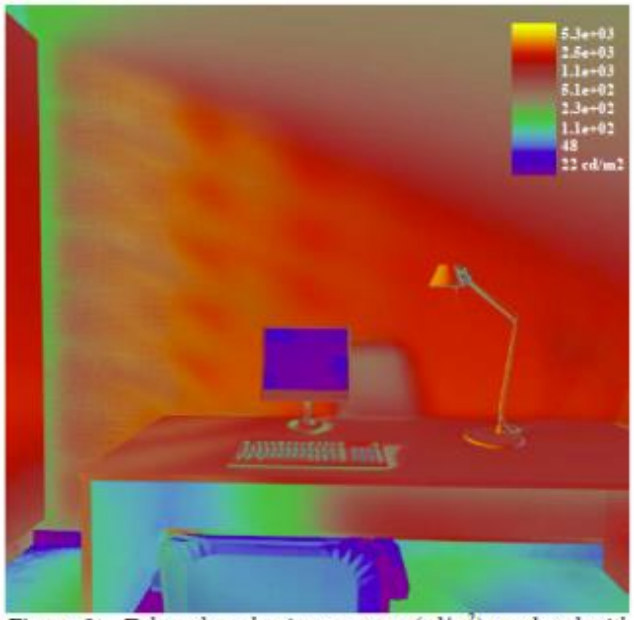


Figure 3a. Falsecolour luminance map (cd/m²) rendered with the BSDF data. Mirror-VB, December 21, at 9:00 AM.

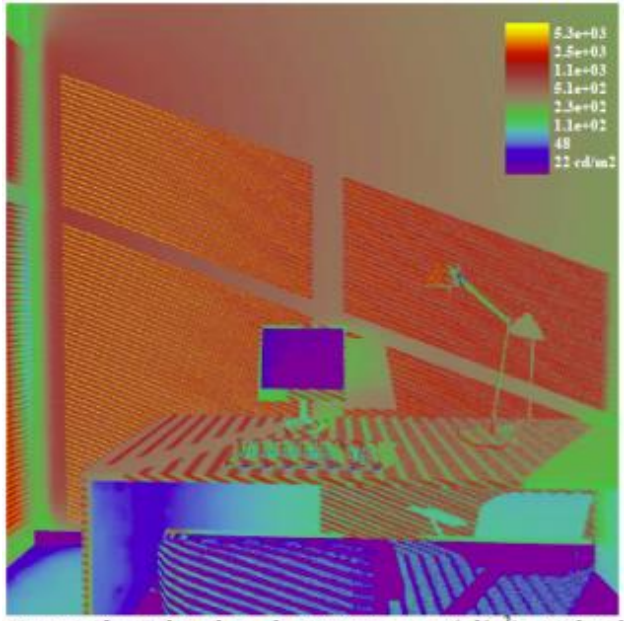


Figure 3b. Falsecolour luminance map (cd/m²) rendered without BSDF data. Mirror-VB, December 21, at 9:00 AM.

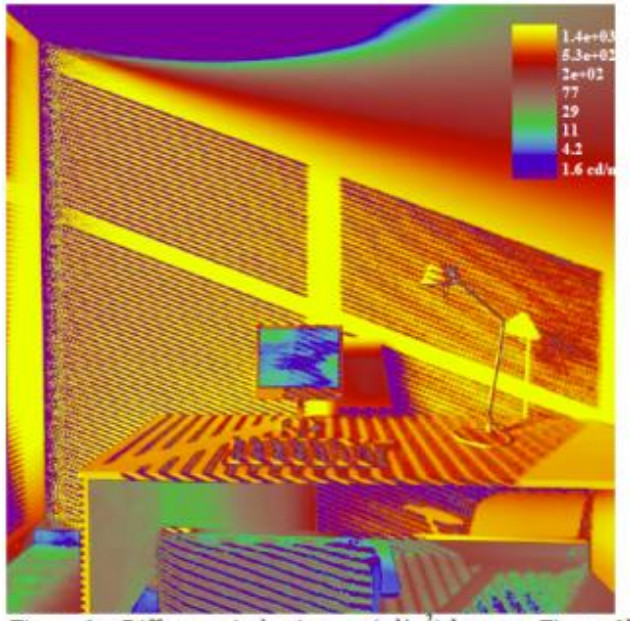


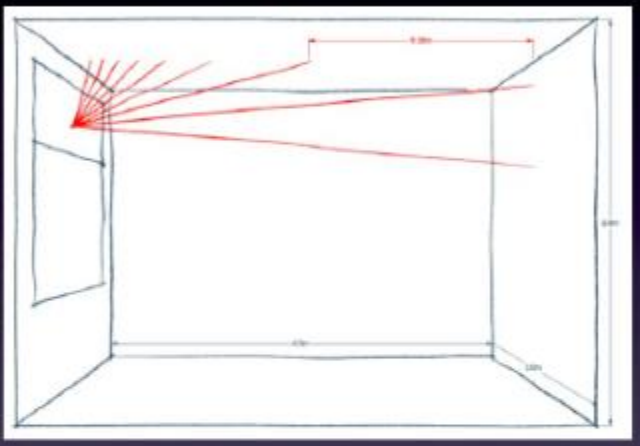
Figure 3c. Difference in luminance (cd/m²) between Figure 3b and Figure 3a (nonBSDF –BSDF).

Photorealistic rendering
Greater accuracy

M. Konstantoglou, J Jonsson, E.S. Lee, Simulating complex window systems using BSDF data, PLEA conference, June 2009, https://facades.lbl.gov/modeling-daylight

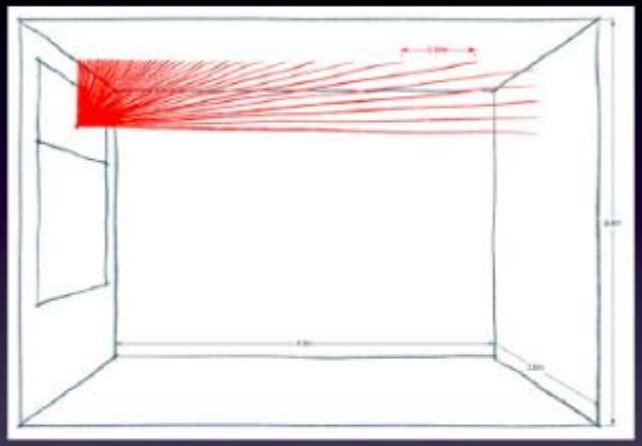
Motivation: Accurate depiction of daylighting performance

Klems full angle basis



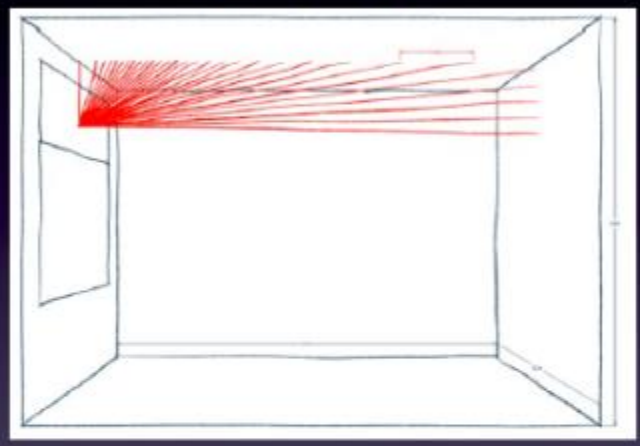
- Depending on space geometry, daylight may be averaged across large areas of the ceiling.
- This is of particular concern when simulating sunlight redirecting facade elements

2° angle basis



- A uniform high-resolution BSDF data reduces areas over which averaging of daylight occurs.
- Increasing the resolution uniformly to resolve peaky BSDF's will result in unnecessarily high resolution in some areas.

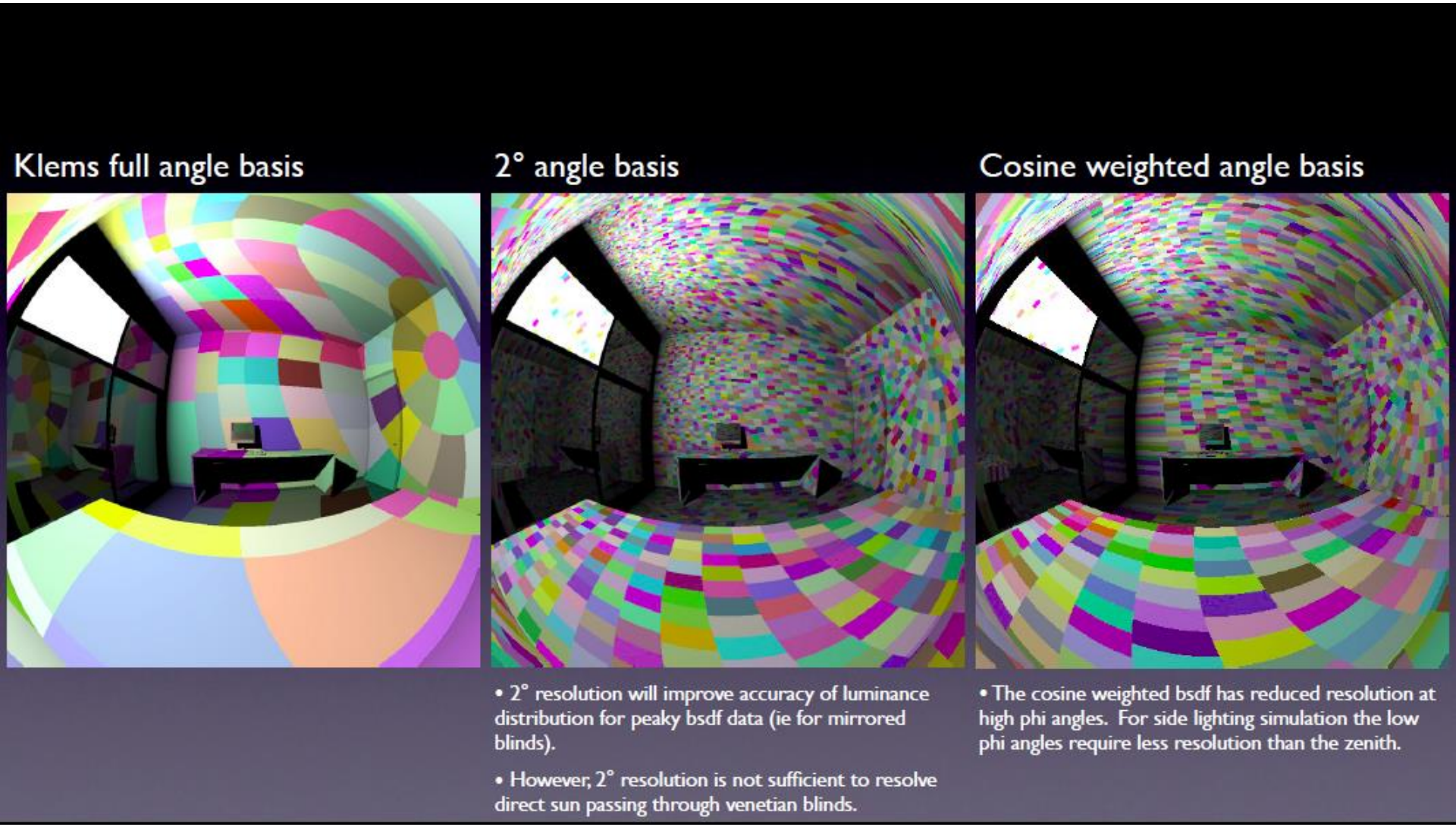
Cosine weighted angle basis



- Cosine weighting the angle basis reduces excess data on the ceiling near the window for a side lighting case.

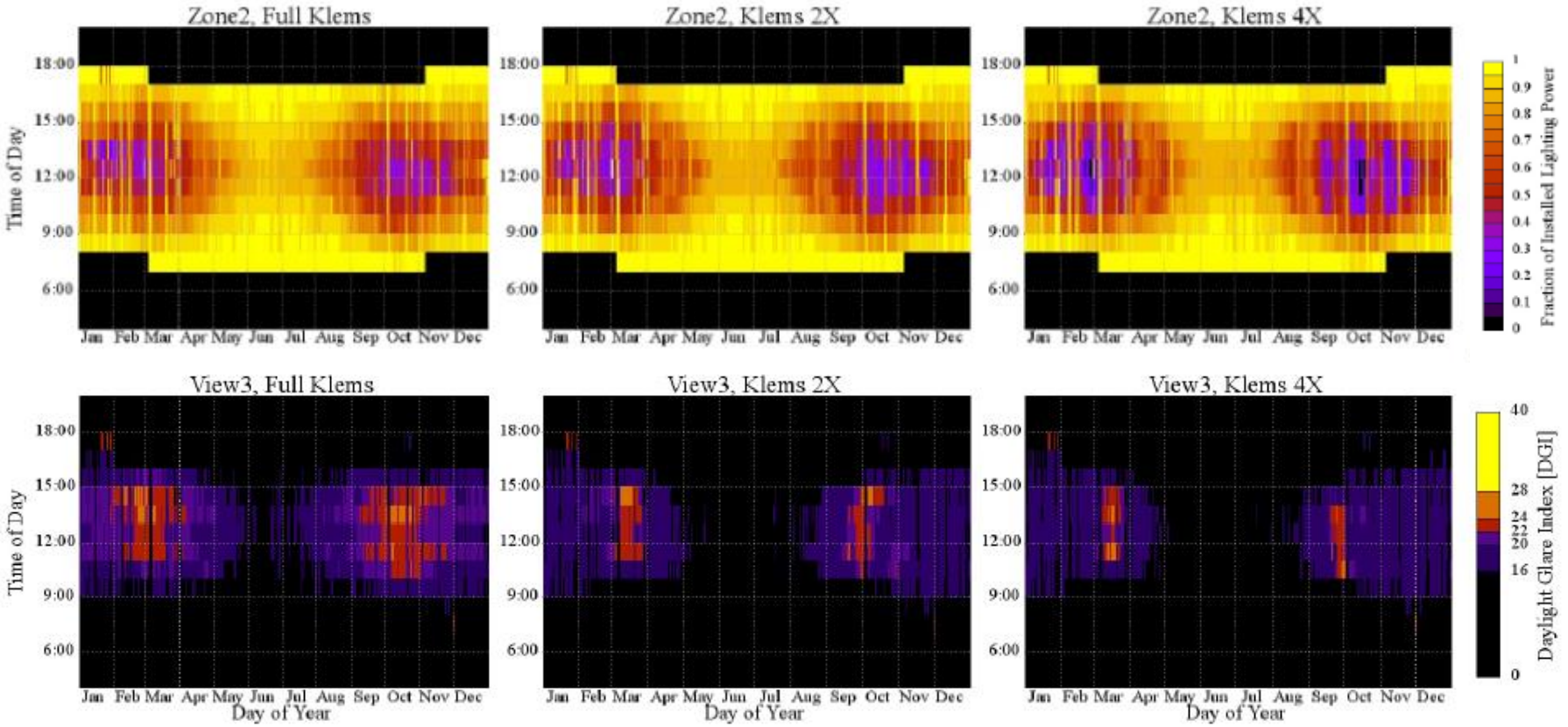
Comparing Klem's full angle basis with two notional high-resolution angle bases, Andrew McNeil, LBNL, March 2010 (internal deliverable).

Motivation



Comparing Klem's full angle basis with two notional high-resolution angle bases, Andrew McNeil, LBNL, March 2010 (internal deliverable).

Motivation



Annual percent lighting energy savings

	Full Klems	Klems 2x	Klems 4x
Zone 1	72%	73%	74%
Zone 2	20%	21%	23%
Zone 3	8%	7%	7%

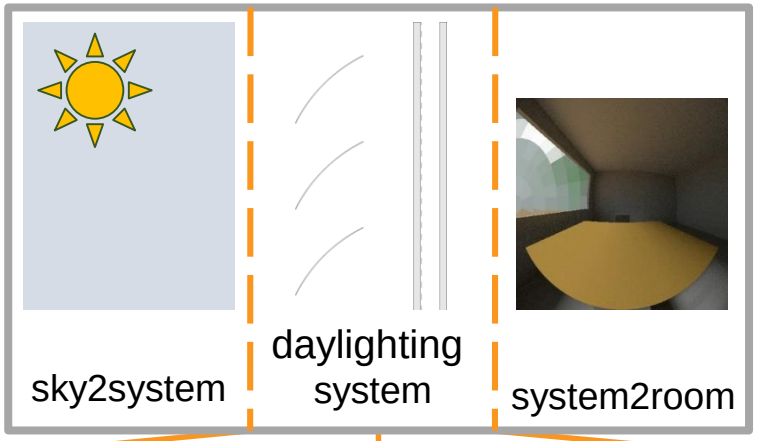
Annual percentage hours when DGI>22

	Full Klems	Klems 2x	Klems 4x
View 1	0%	0%	0%
View 2	3%	0%	0%
View 3	9%	3%	2%

Conclusion:
Significant difference in annual glare evaluations, minimal difference in lighting energy savings

Andrew McNeil, LBNL, Sept 2011 (internal deliverable);
passive optical light shelf modeled with 1x, 2x,and 4x Klems basis.

Basics 1: The 3-Phase Method



flux transfer 1: daylight matrix DMX

sky → exterior of daylight system

flux transfer 2: BSDF

$f(\theta_l,\varphi_l;\theta_v,\varphi_v)$

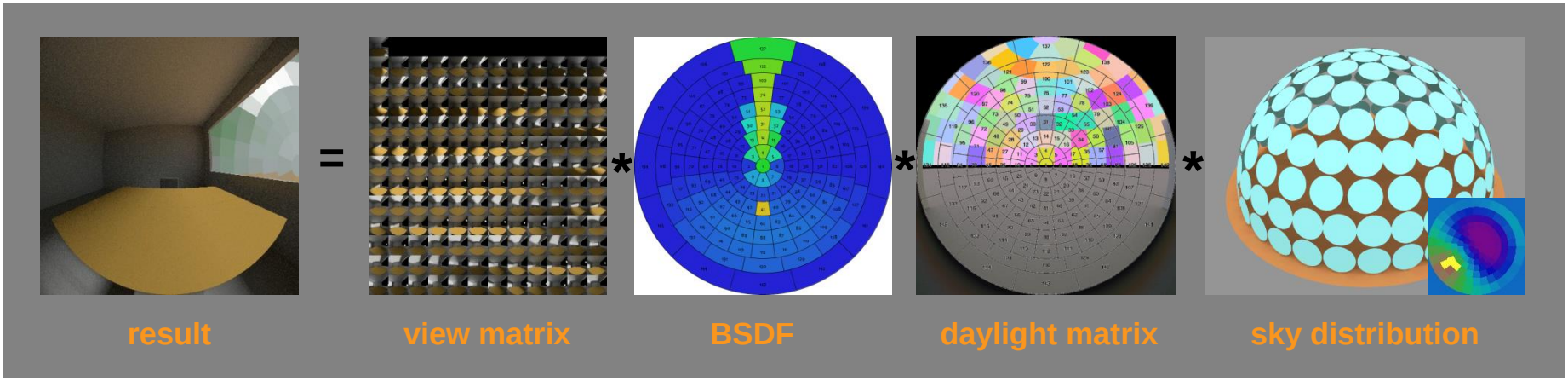
flux transfer 3: view matrix VMX

interior of daylight system → room

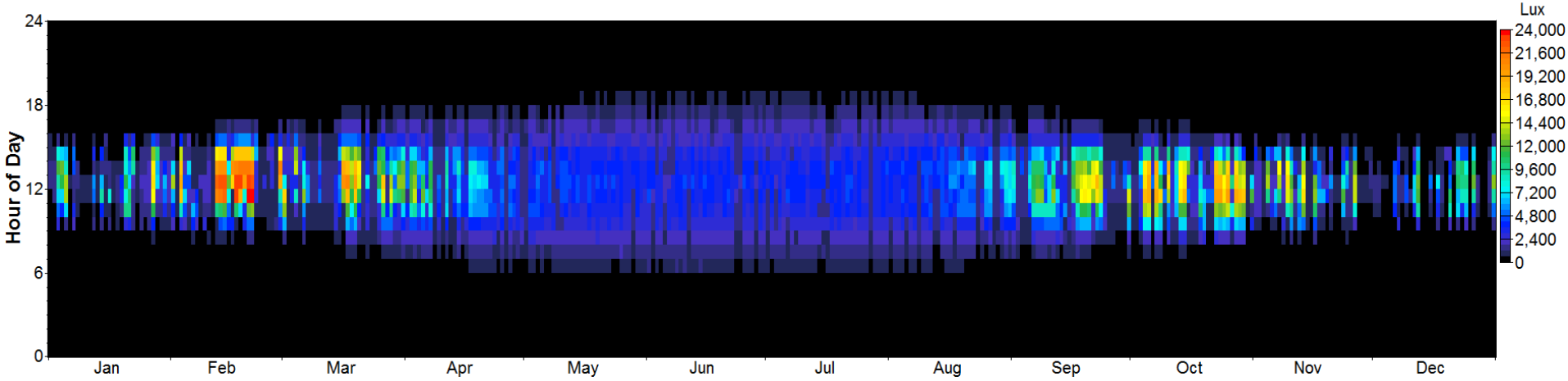
Calculation of results

L-distribution sky → DMX / BSDF / VMX → illuminance grid / image

Basics 1: The 3-Phase Method

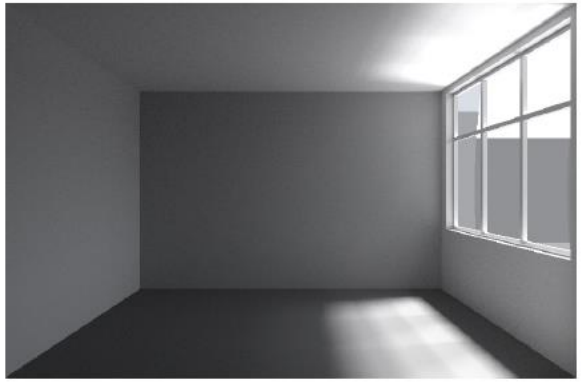


evaluation for every timestep (matrix multiplication)

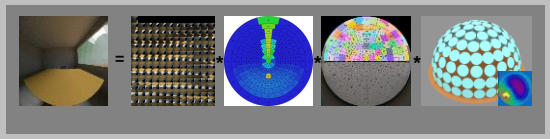


annual illuminance values at measurement point

Basics 2: The 5-Phase Method



flux transfer 1-3:
3-Phase-Method



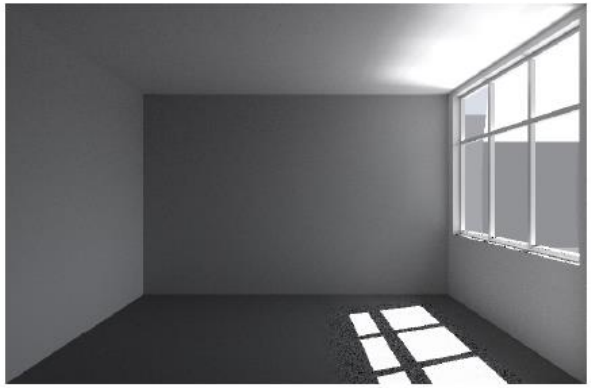
flux transfer 4:
subtract direct solar component from 3-P-M

$-DS_{3pm}$

flux transfer 5:
add accurate direct solar component

+DS

result:



images:
A. McNeil, „ The Five-Phase Method for Simulating Complex Fenestration with Radiance“, online, 2013

Basics: The 3/5-Phase Method

Read all details in these documents:

Tutorials

The Three-Phase Method for Simulating Complex Fenestration with Radiance

http://www.radiance-online.org/learning/tutorials/Tutorial-ThreePhaseMethod.pdf

The Five-Phase Method for Simulating Complex Fenestration with Radiance

http://www.radiance-online.org/learning/tutorials/fivephasetutorialfiles/Tutorial-FivePhaseMethod_v2.pdf

Radiance workshop presentations

Complex Fenestration and Annual Simulation

http://www.radiance-online.org/community/workshops/2009-boston-ma/Presentations/ComplexAnnual.pdf

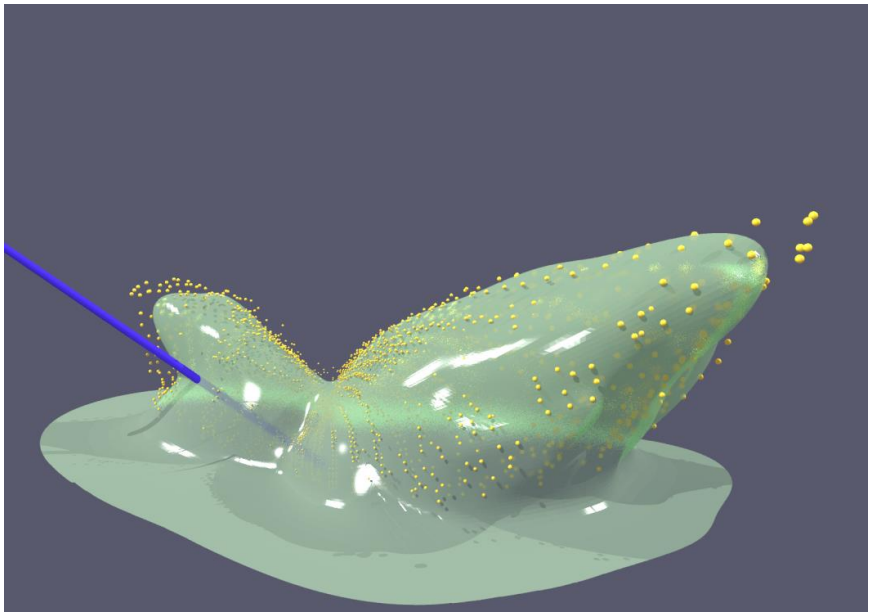
The 5-phase method

http://www.radiance-online.org/community/workshops/2013-golden-co/McNeil-5phase.pdf

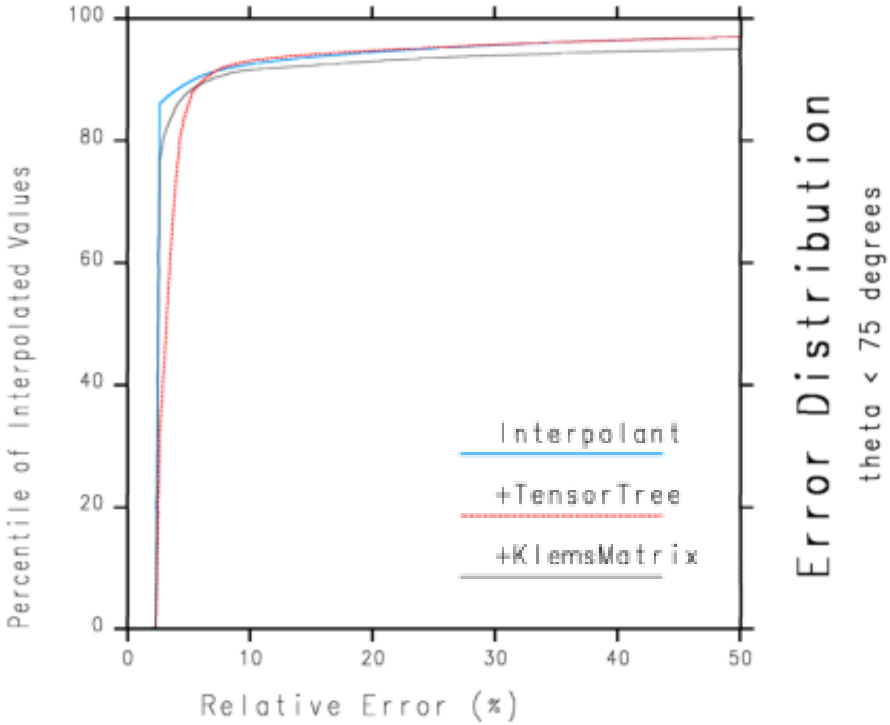
BSDFs, Matrices, and Phases

http://www.radiance-online.org/community/workshops/2014-london/presentations/day1/McNeil_BSDFsandPhases.pdf

BSDF Interpolation Model



Interpolation of measured scattering values for a single incident direction, shown as blue line. Yellow dots are measurements, and green surface is interpolation using radial basis functions.



Error population of BRDF interpolant and tensor tree and Klems representations for 150M incident and exiting test direction pairs based on anisotropic Ward-Geisler-Moroder-Dür BRDF model (reference).

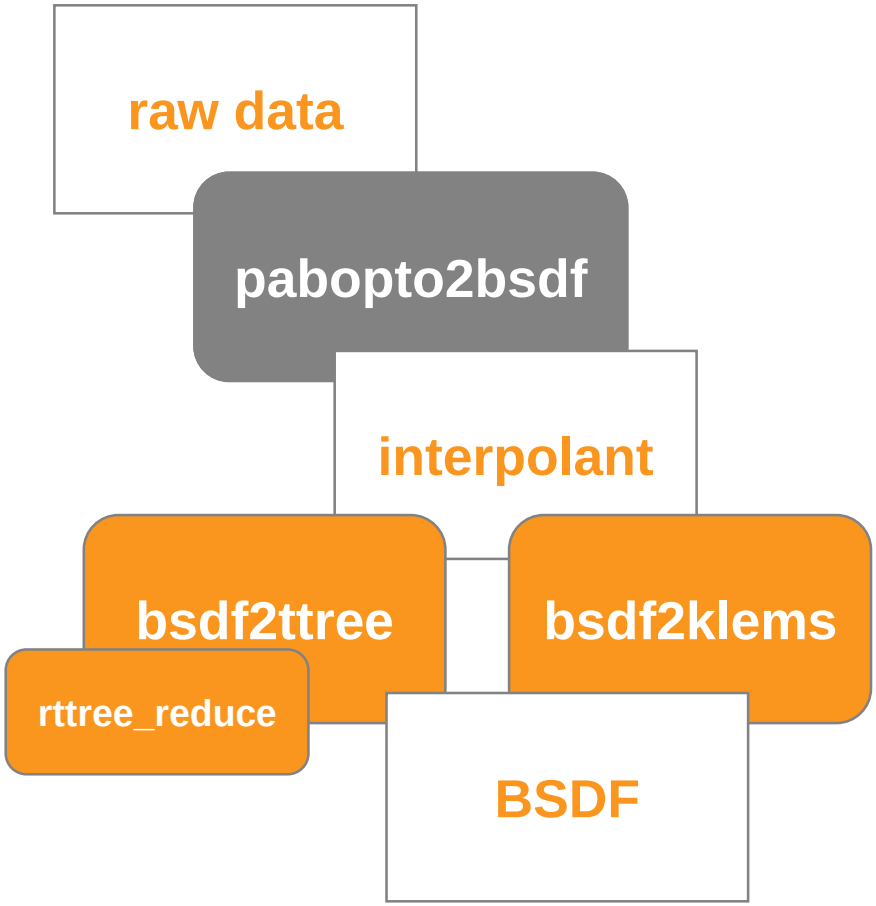
RMS error for ground truth vs interpolant:
0.243 (all angles)
0.114 (<75°°)

BSDF Interpolation validation,
Greg Ward, Anyhere Software, Jacob Jonsson, LBNL,
December 2014 (internal deliverable).

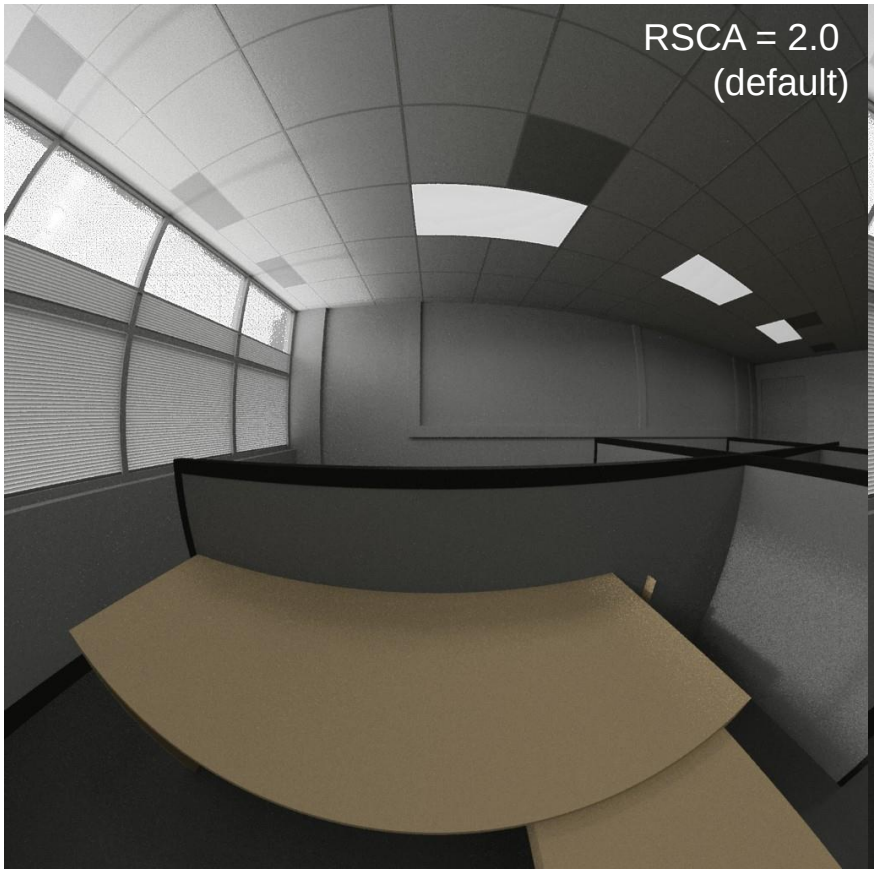
BSDF Interpolation Model

- „smoothing“ parameter in generating scattering interpolants
  (in pabopto2bsdf; radius scaling factor “RSCA“ in bsdfrbf.c)

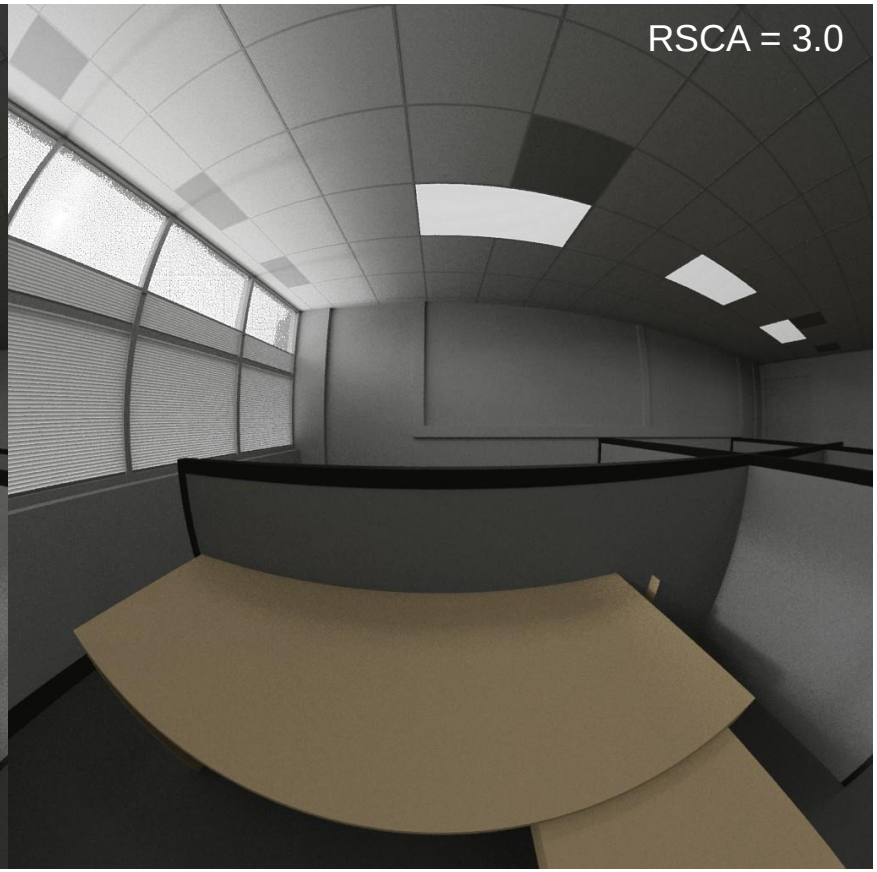
- effect on final BSDF / results???



BSDF Interpolation Model

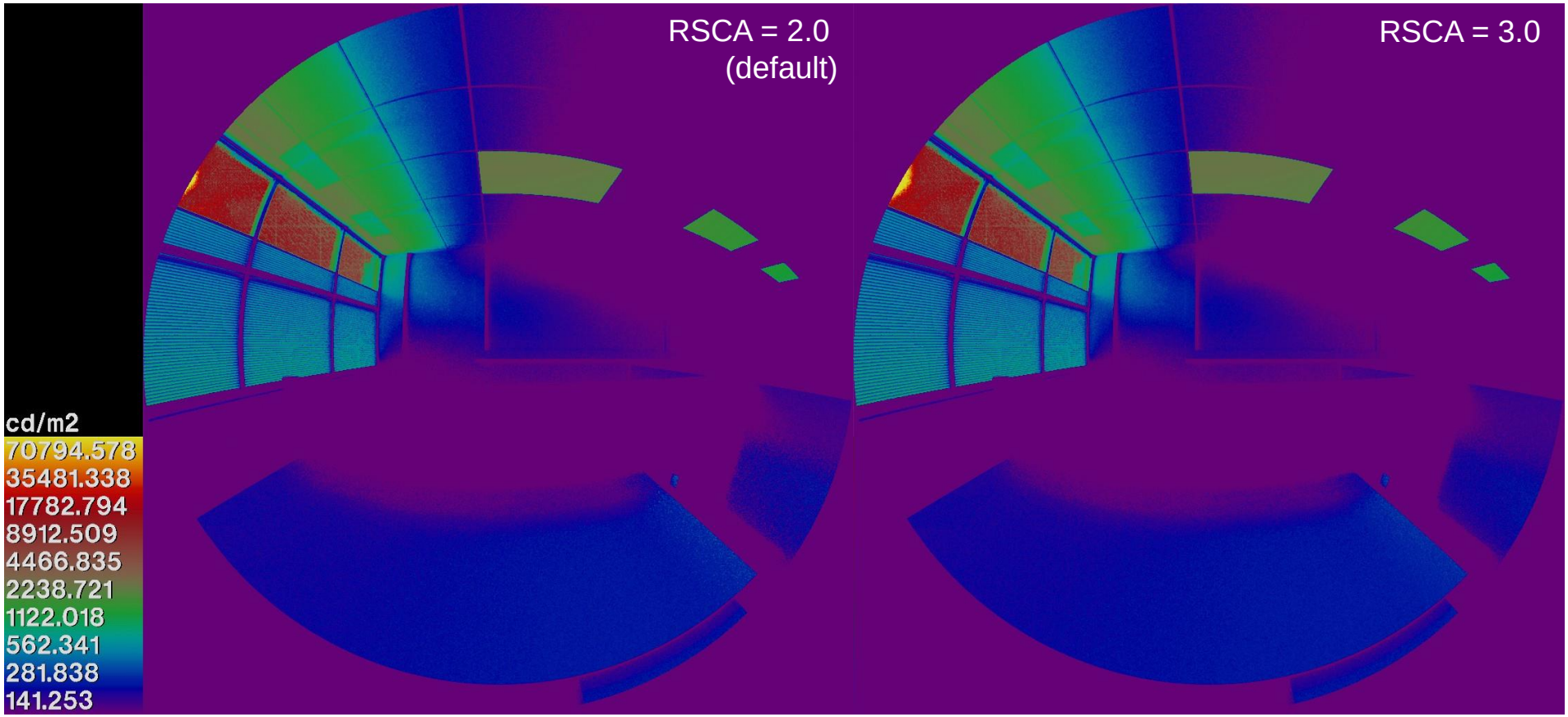


pabopto2bsdf -n 4 Rvis.txt / Tvis.txt > Rvis.sir / Tvis.sir
bsdf2ttree -p -g 7 -t 98 Rvis.sir / Tvis.sir > tt.xml



pabopto2bsdf_3.0 -n 4 Rvis.txt / Tvis.txt > Rvis.sir / Tvis.sir
bsdf2ttree -p -g 7 -t 98 Rvis.sir / Tvis.sir > tt.xml

BSDF Interpolation Model



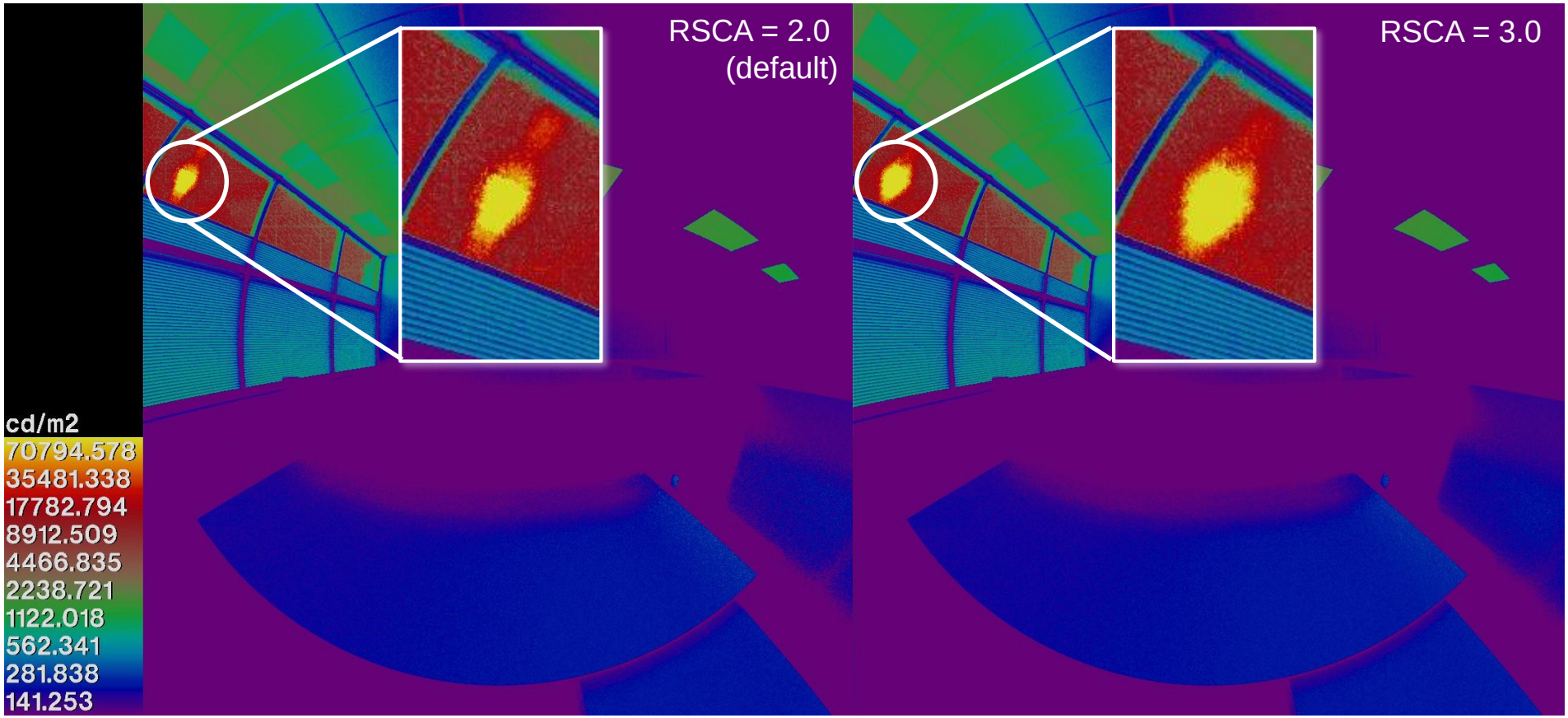
pabopto2bsdf -n 4 Rvis.txt / Tvis.txt > Rvis.sir / Tvis.sir
bsdf2ttree -p -g 7 -t 98 Rvis.sir / Tvis.sir > tt.xml

DGP: 0.236
DGI: 12.3
Ev: 1127 lx

pabopto2bsdf_3.0 -n 4 Rvis.txt / Tvis.txt > Rvis.sir / Tvis.sir
bsdf2ttree -p -g 7 -t 98 Rvis.sir / Tvis.sir > tt.xml

DGP: 0.243
DGI: 13.2
Ev: 1120 lx

BSDF Interpolation Model

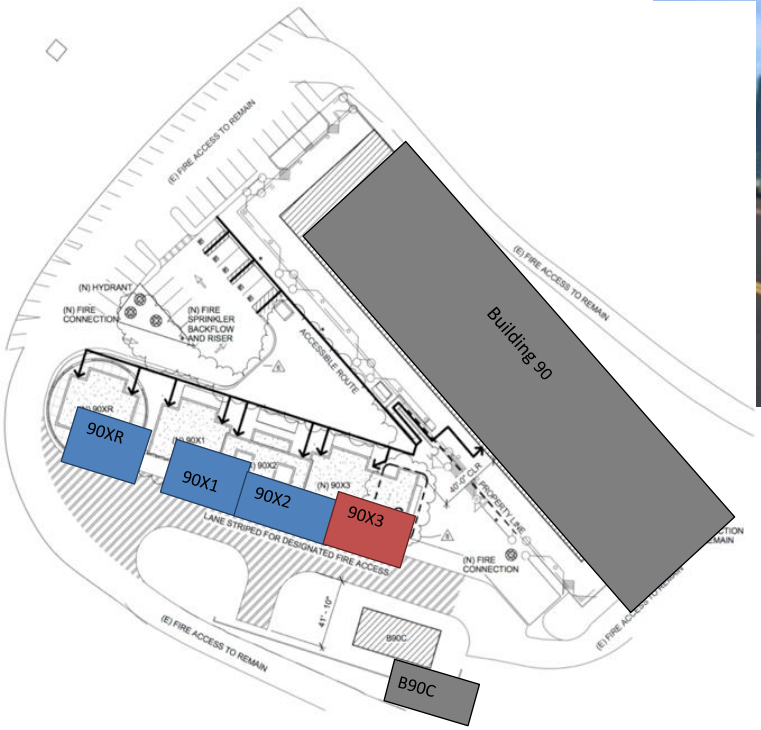


pabopto2bsdf -n 4 Rvis.txt / Tvis.txt > Rvis.sir / Tvis.sir
bsdf2ttree -p -g 7 -t 98 Rvis.sir / Tvis.sir > tt.xml

pabopto2bsdf_3.0 -n 4 Rvis.txt / Tvis.txt > Rvis.sir / Tvis.sir
bsdf2ttree -p -g 7 -t 98 Rvis.sir / Tvis.sir > tt.xml

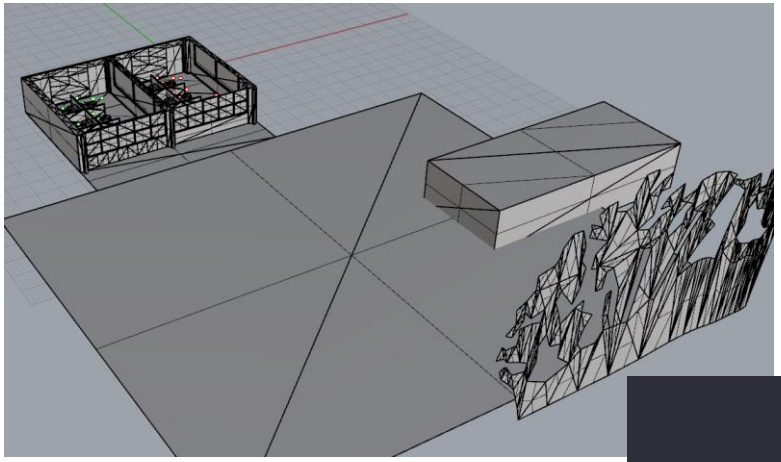
Monitoring Set-Up

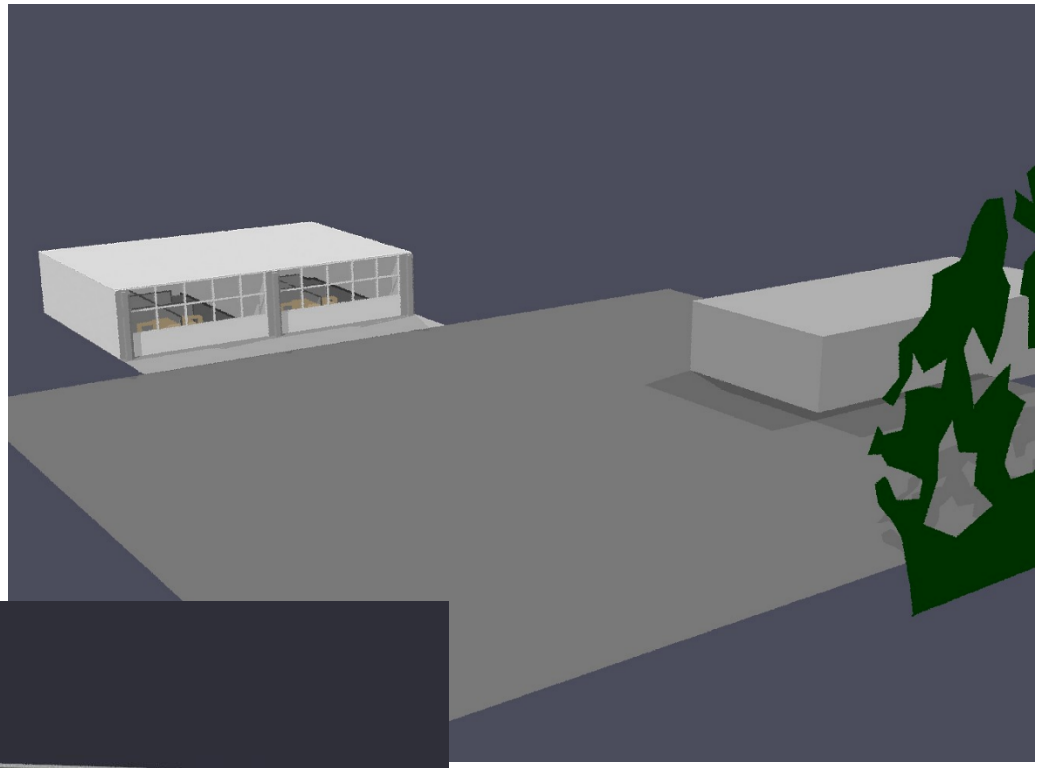
FLEXLAB @ LBNL



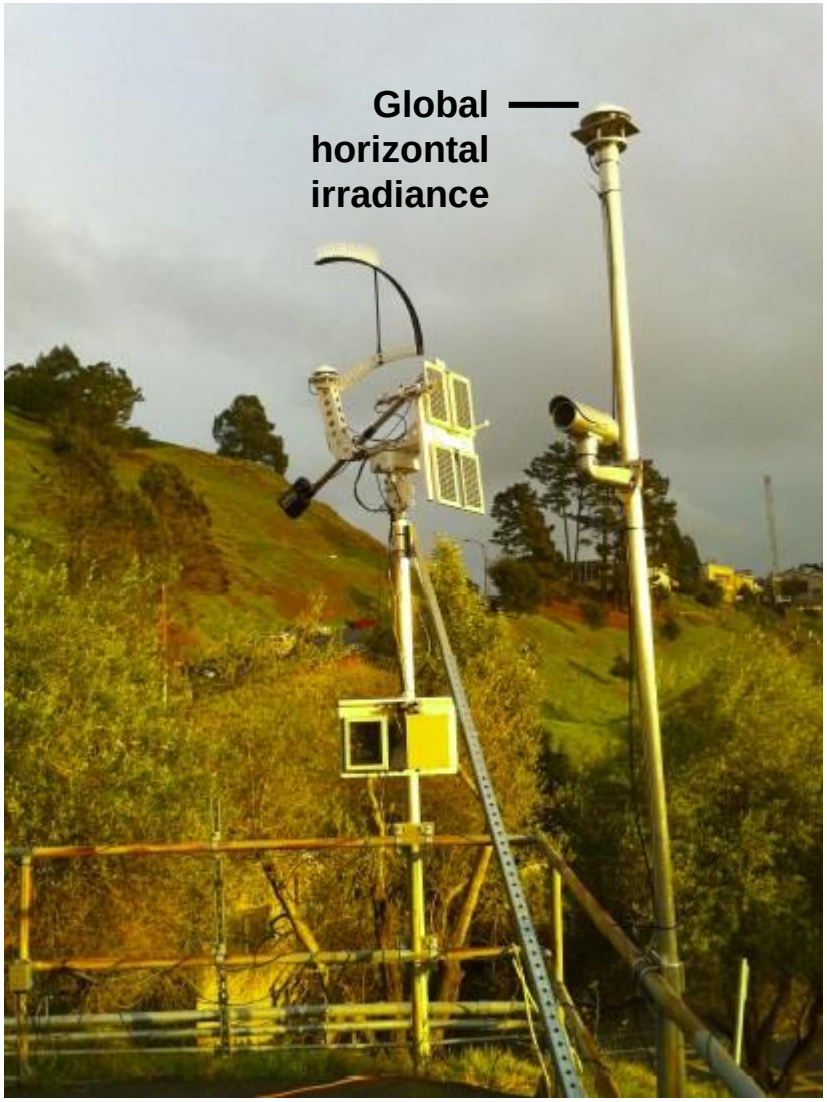
Monitoring Set-Up

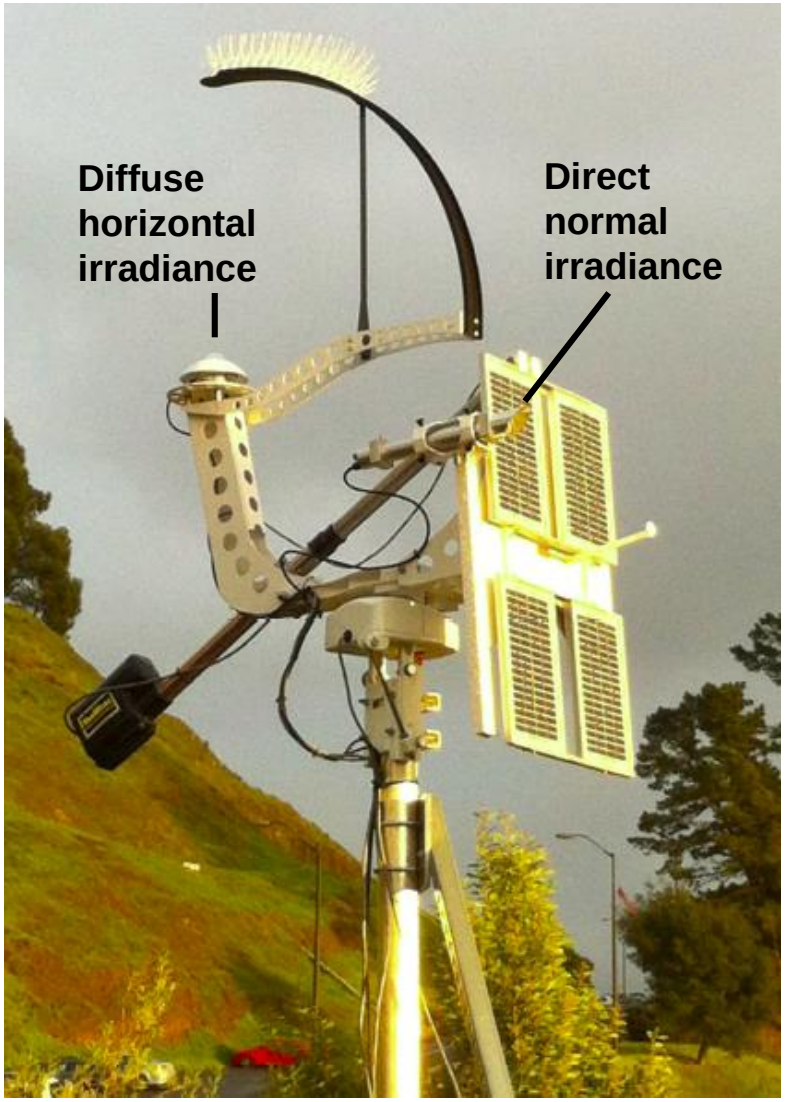
Monitoring Set-Up



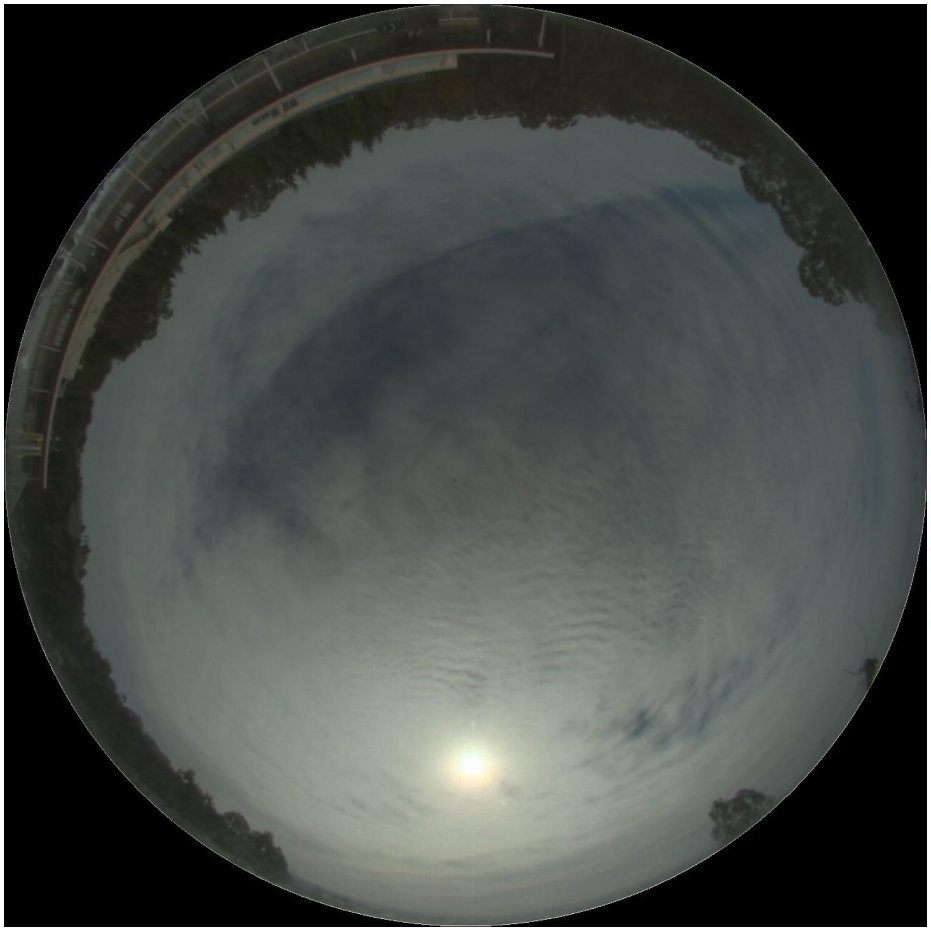


Solar instrumentation





Monitoring Set-Up

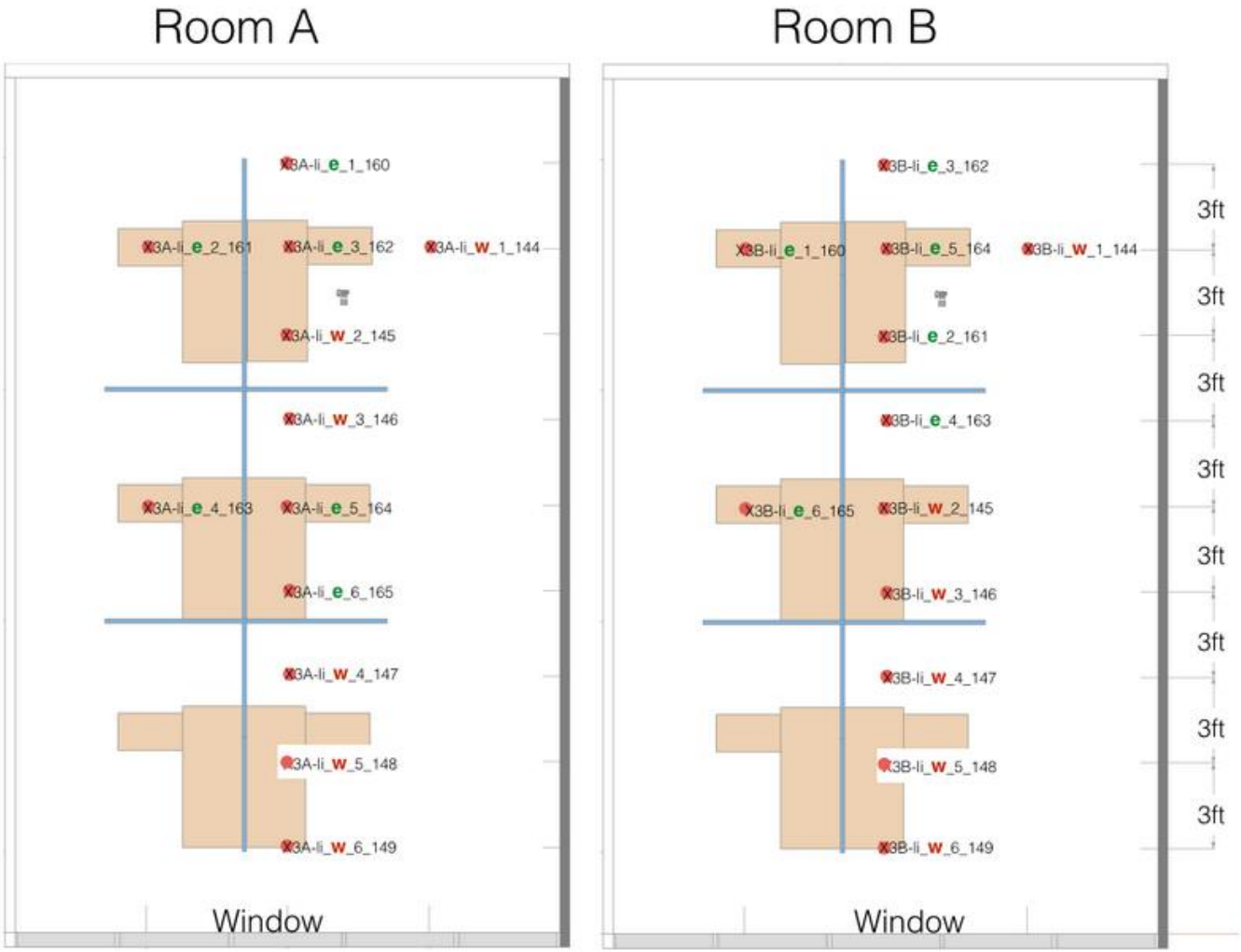


<u>Skycam data (every 5min):</u>

- HDR image
- Global horizontal illuminance
- Global horizontal irradiance
- ➢ Diffuse horizontal illuminance
- ➢ Direct normal illuminance
- ➢ …

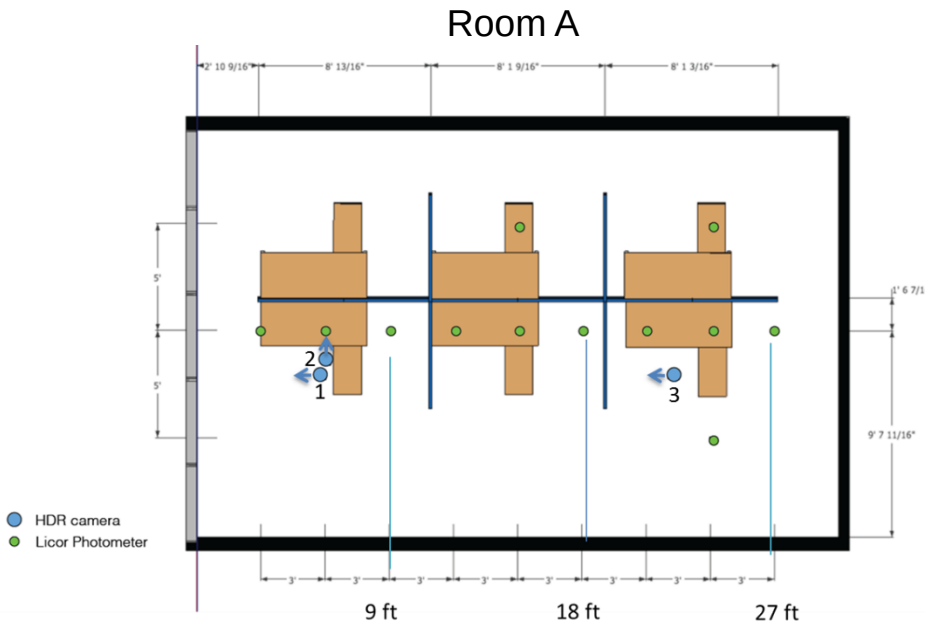
Monitoring Set-Up

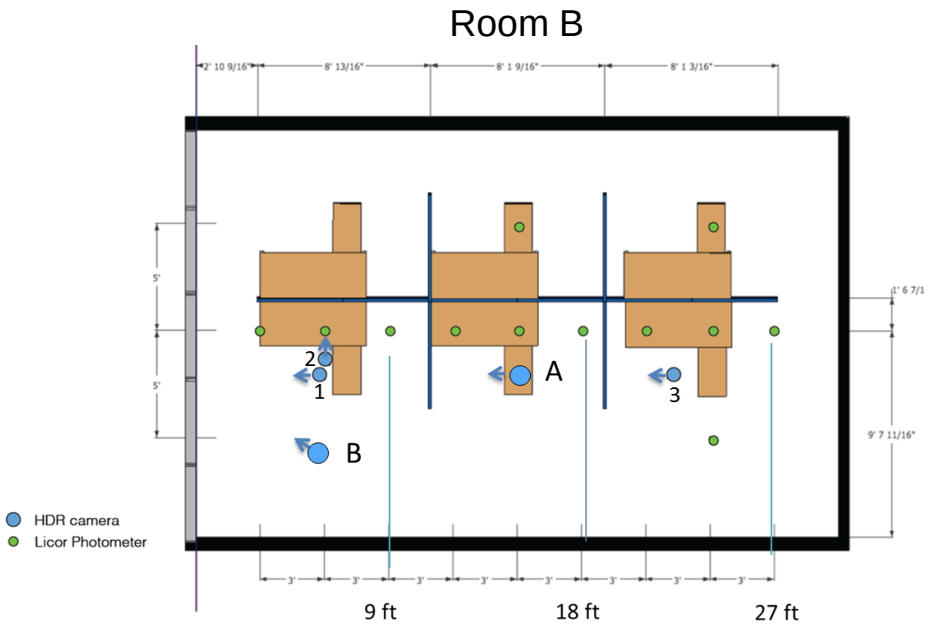
Workplane illuminance sensors



Monitoring Set-Up

HDR cameras and vertical illuminance sensors





Monitoring Set-Up

Room A

HDR camera @ Flexlab

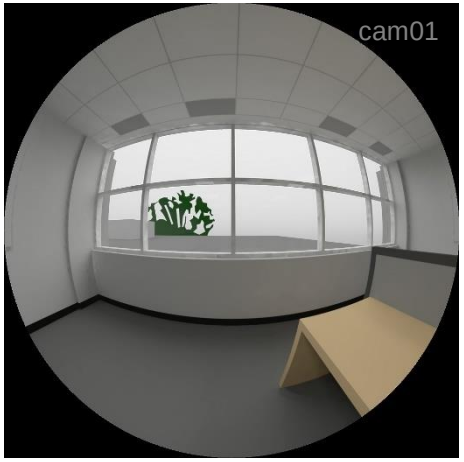
(71tHDR-07/current.jpg)

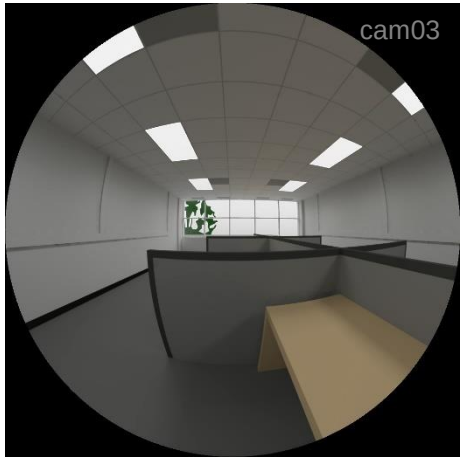
(71tHDR-08/current.jpg)

FlexHDR-05

(FlexHDR-05/current.jpg)

simulation

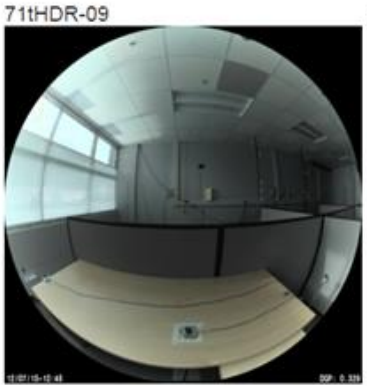


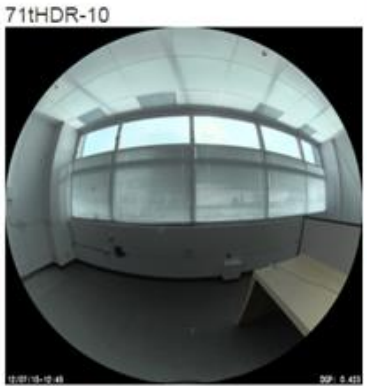


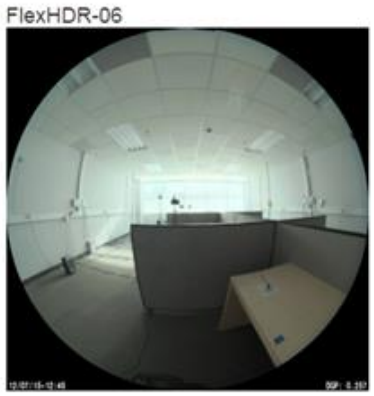
Monitoring Set-Up

Room B

HDR camera @ Flexlab





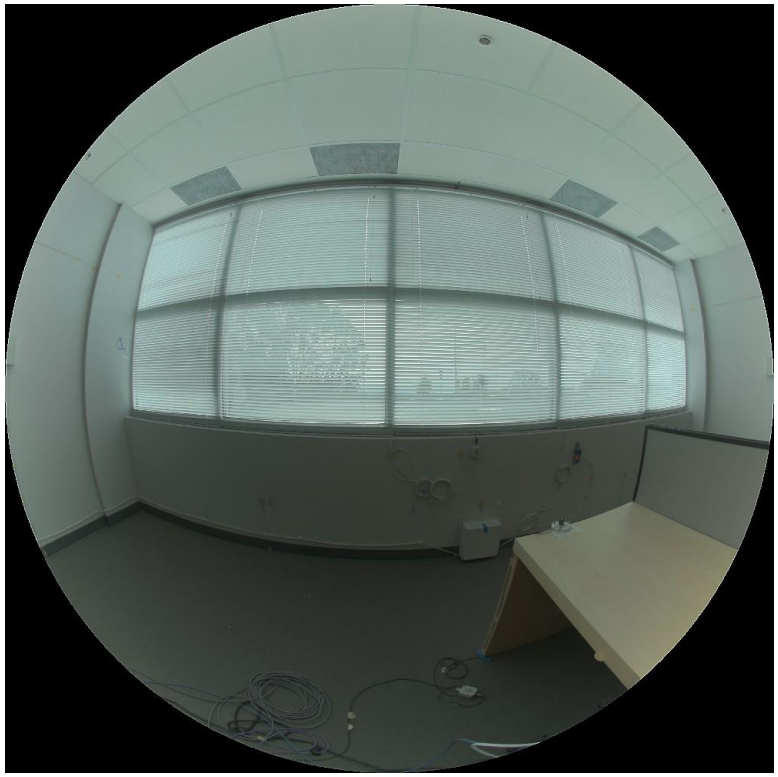


simulation

Monitoring Set-Up

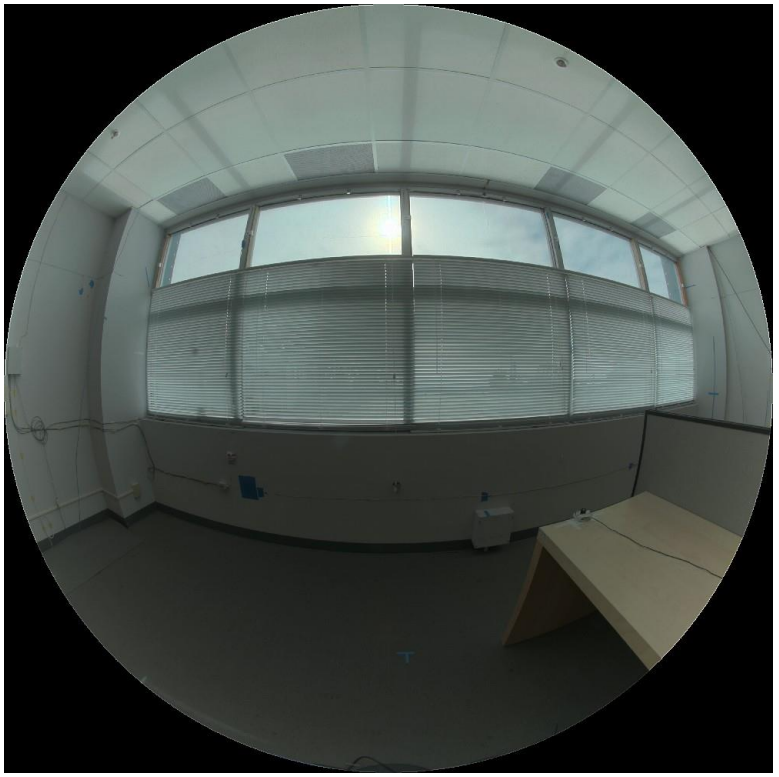
Systems

Room A



- Interior venetian blinds, fixed position

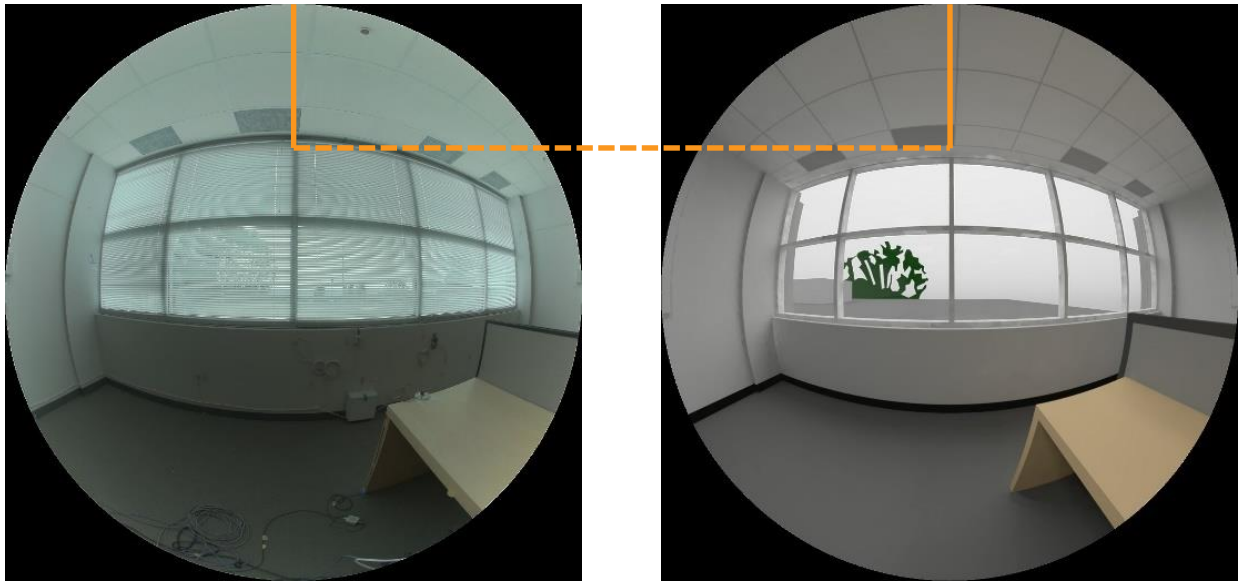
Room B



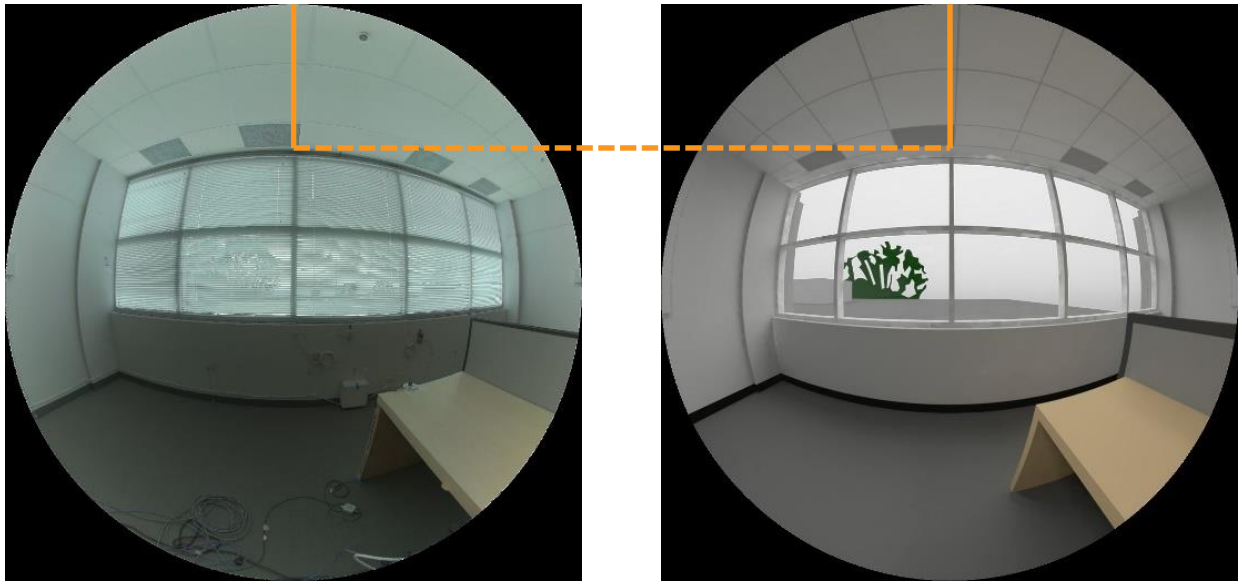
- Daylighting film
- Interior venetian blinds, fixed position

Excursion: Fisheye Lens Distorsion

Excursion: Fisheye Lens Distorsion

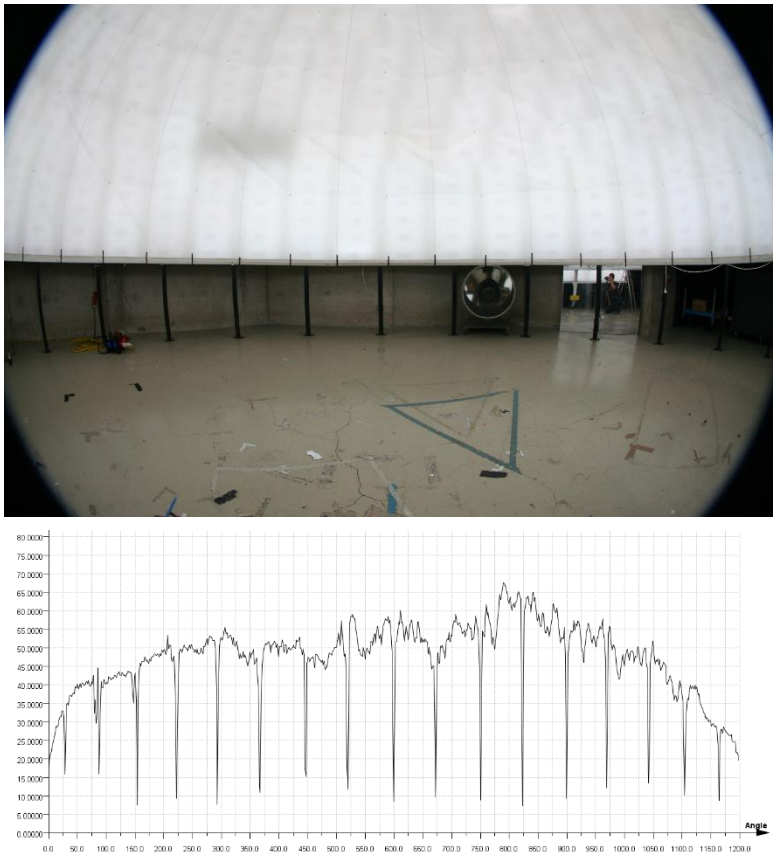


Excursion: Fisheye Lens Distorsion



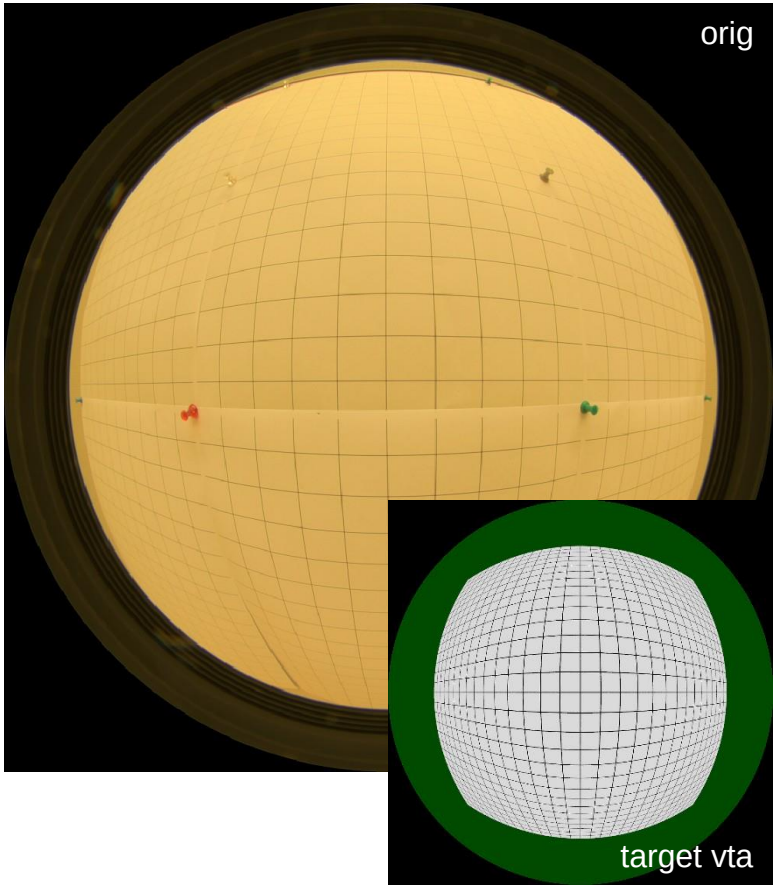
Excursion: Fisheye Lens Distorsion

Sigma 8mm F3.5 EX DG Fisheye



Lens image → vta:
rad(r):1.44-sqrt(-2.381*r+2.0745)

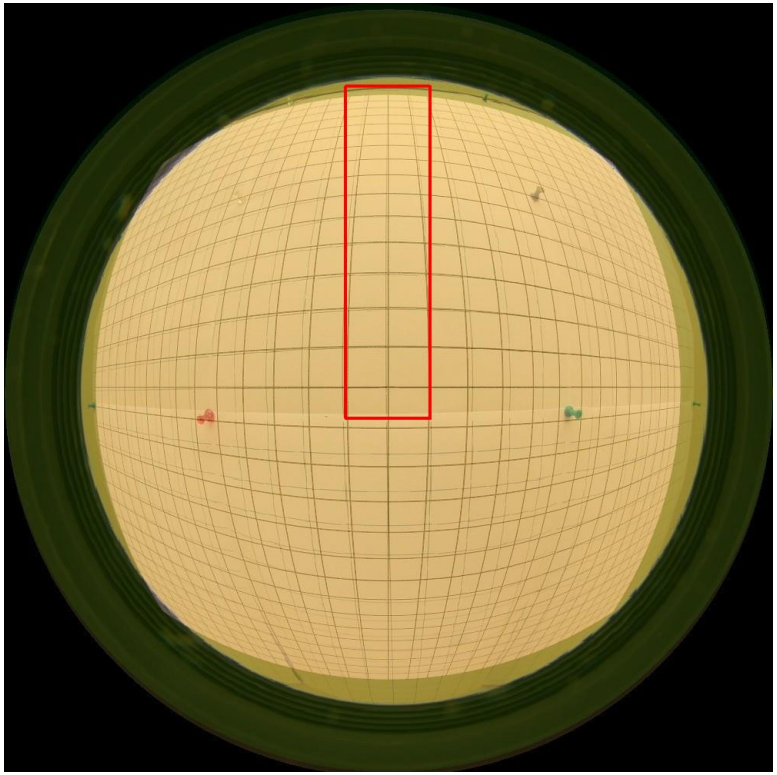
Sigma 4.5mm F2.8 EX DC Fisheye



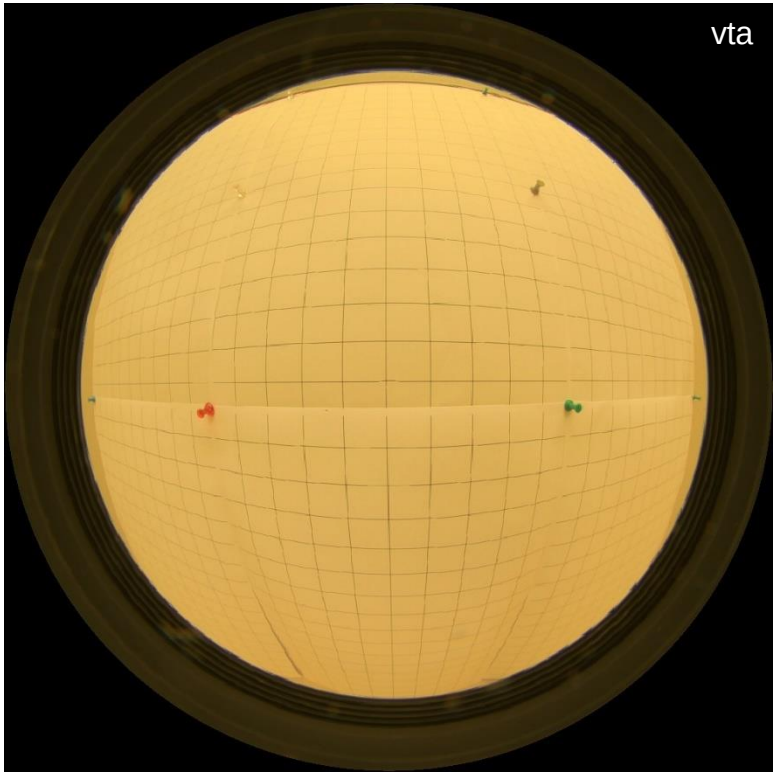
Lens image → vta:
rad(r):1.64-sqrt(-2.778*r+2.686)

Excursion: Fisheye Lens Distorsion

```
pcomb -e 'rad(r):1.64-sqrt(-2.778*r+2.686)'
      -f fisheye_corr.cal -h -o orig.hdr >
      out_vta.hdr
```



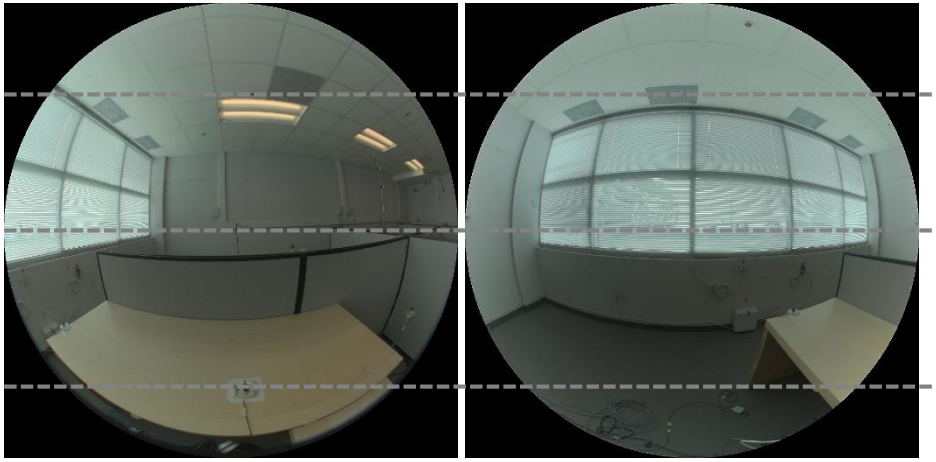
Sigma 4.5mm F2.8 EX DC Fisheye



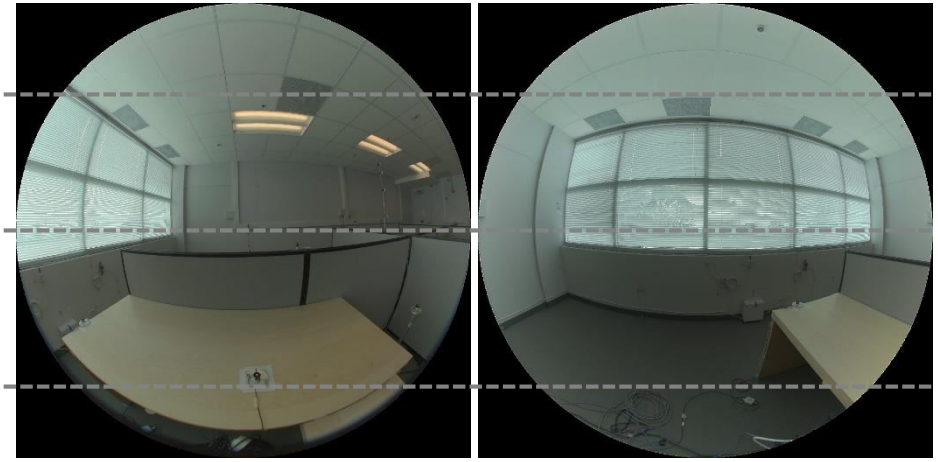
Excursion: Fisheye Lens Distorsion

Room A

HDR camera @ Flexlab



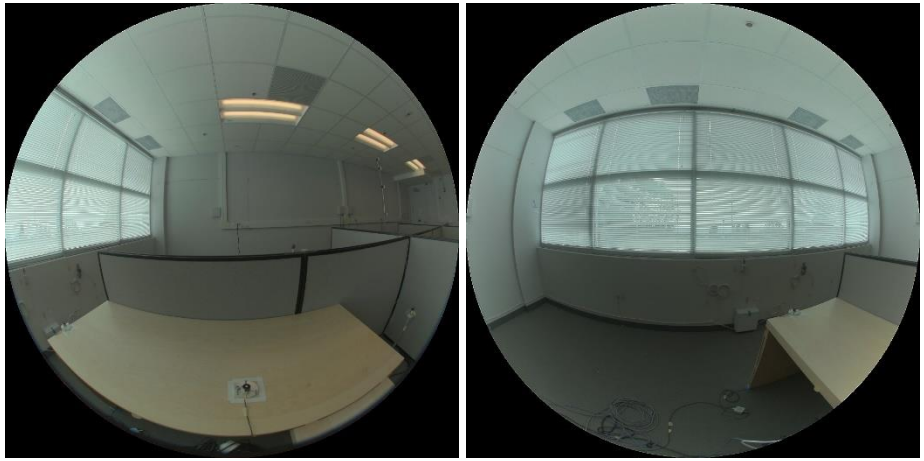
HDR camera @ Flexlab (view corrected to vta)



Excursion: Fisheye Lens Distorsion

Room A

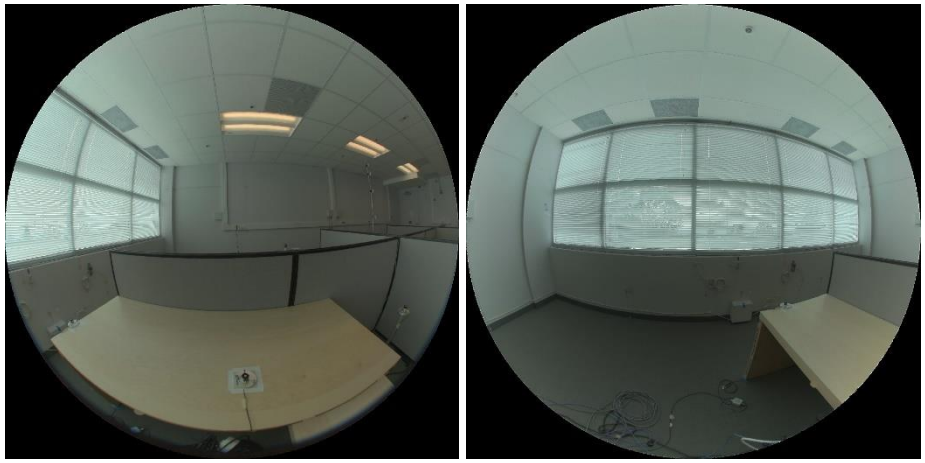
HDR camera @ Flexlab



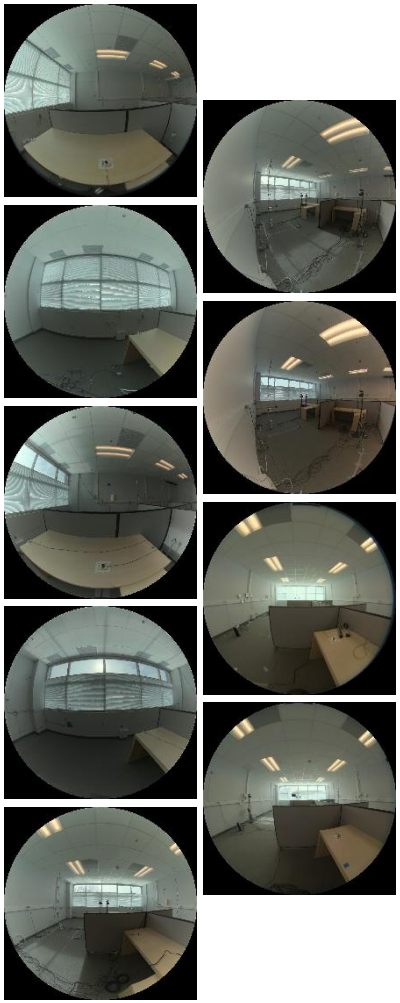
Excursion: Fisheye Lens Distorsion

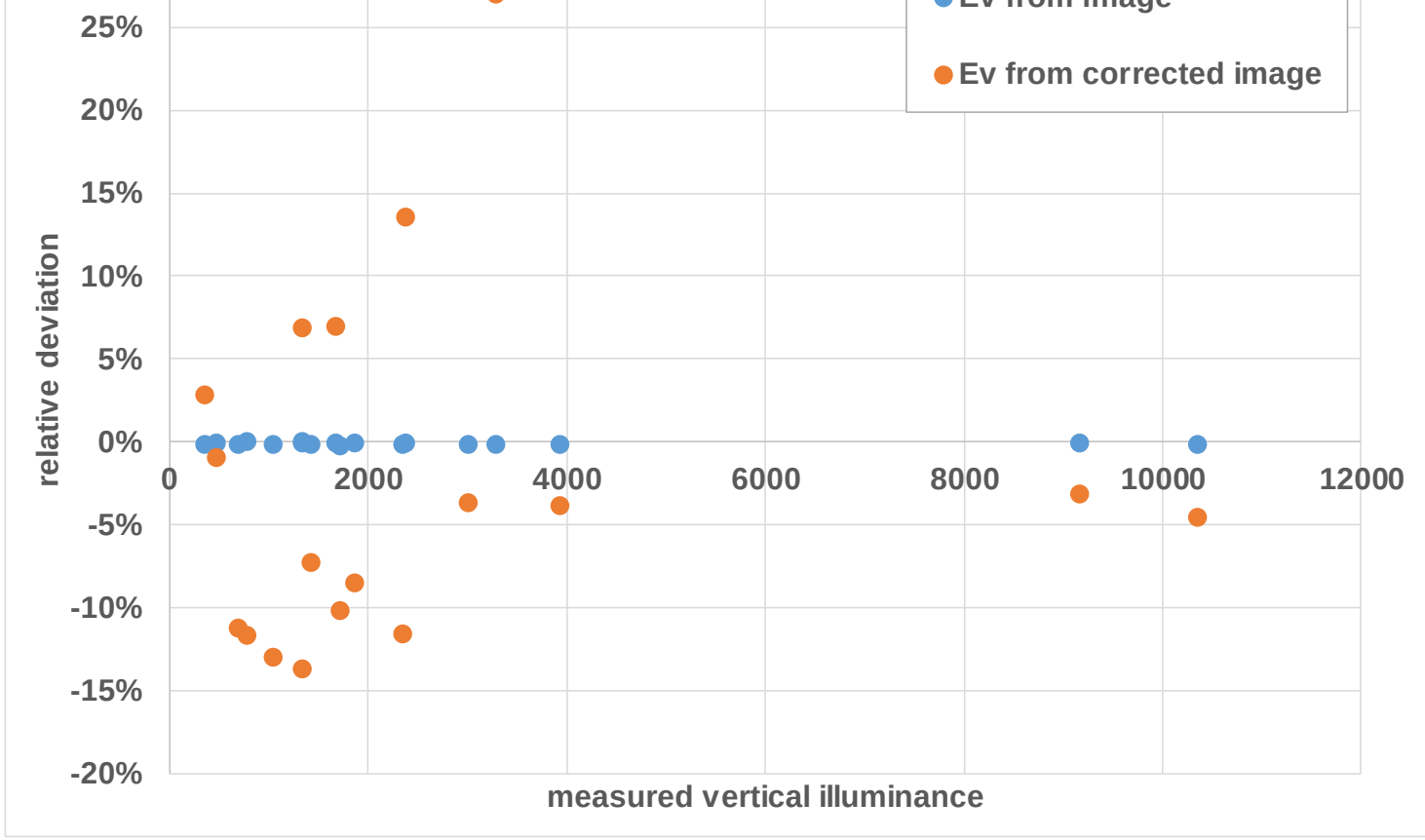
Room A

HDR camera @ Flexlab (view corrected to vta)

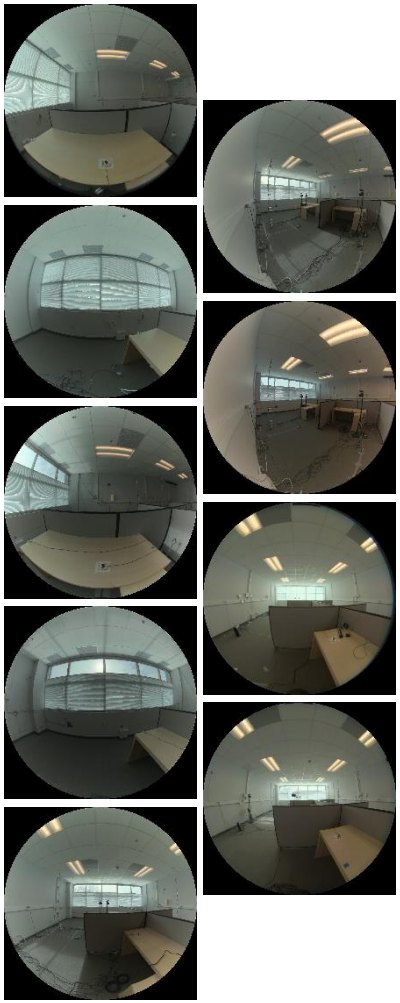


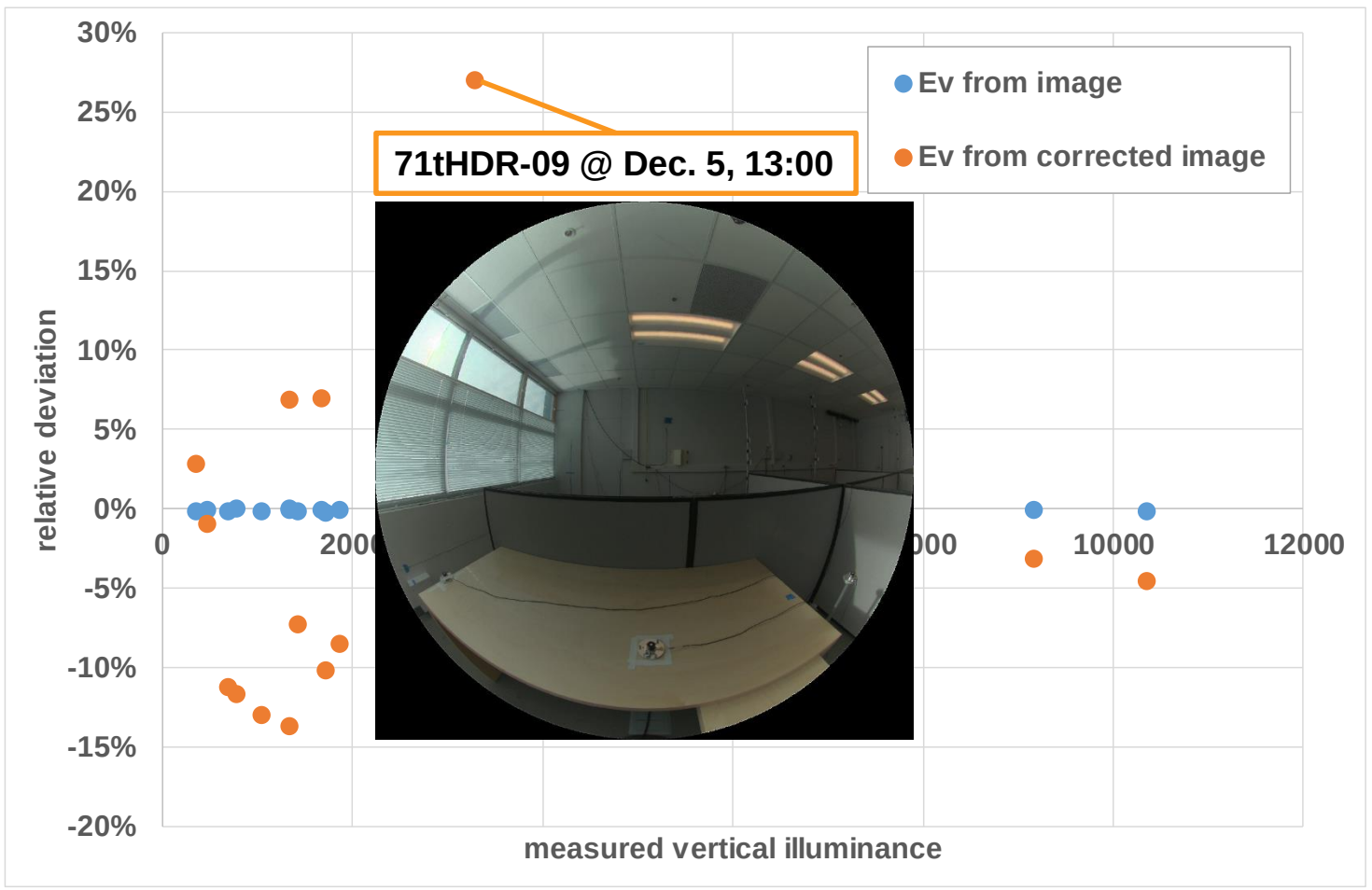
Excursion: Fisheye Lens Distorsion





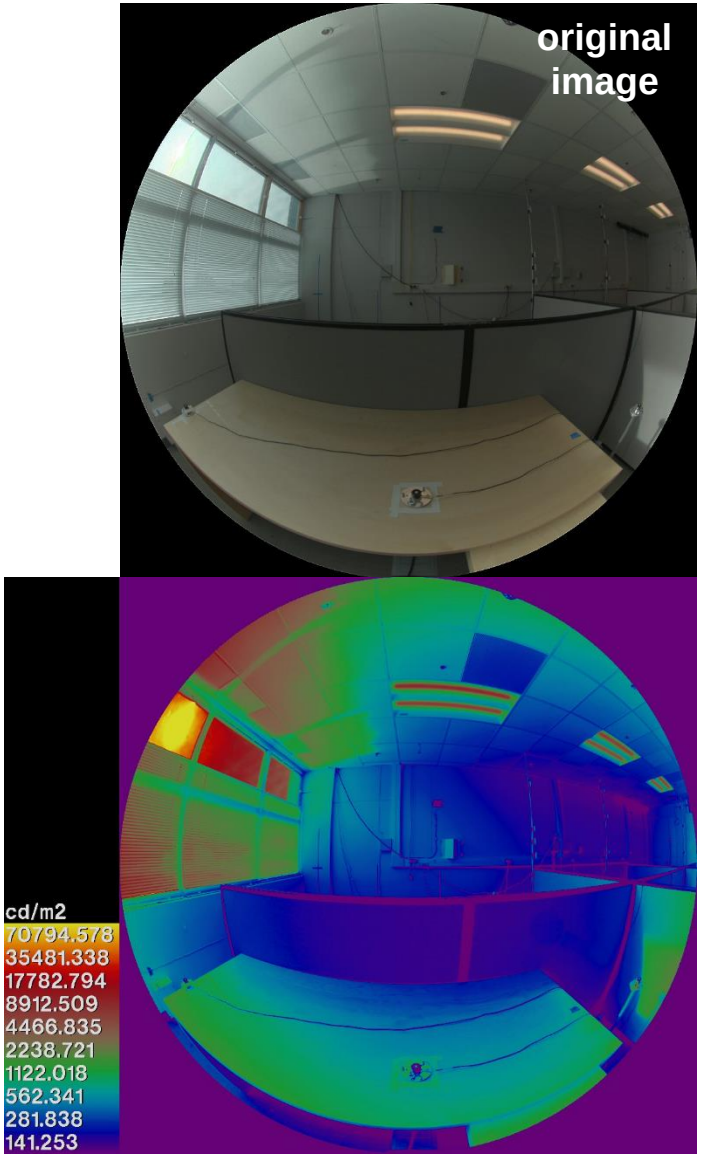
Excursion: Fisheye Lens Distorsion

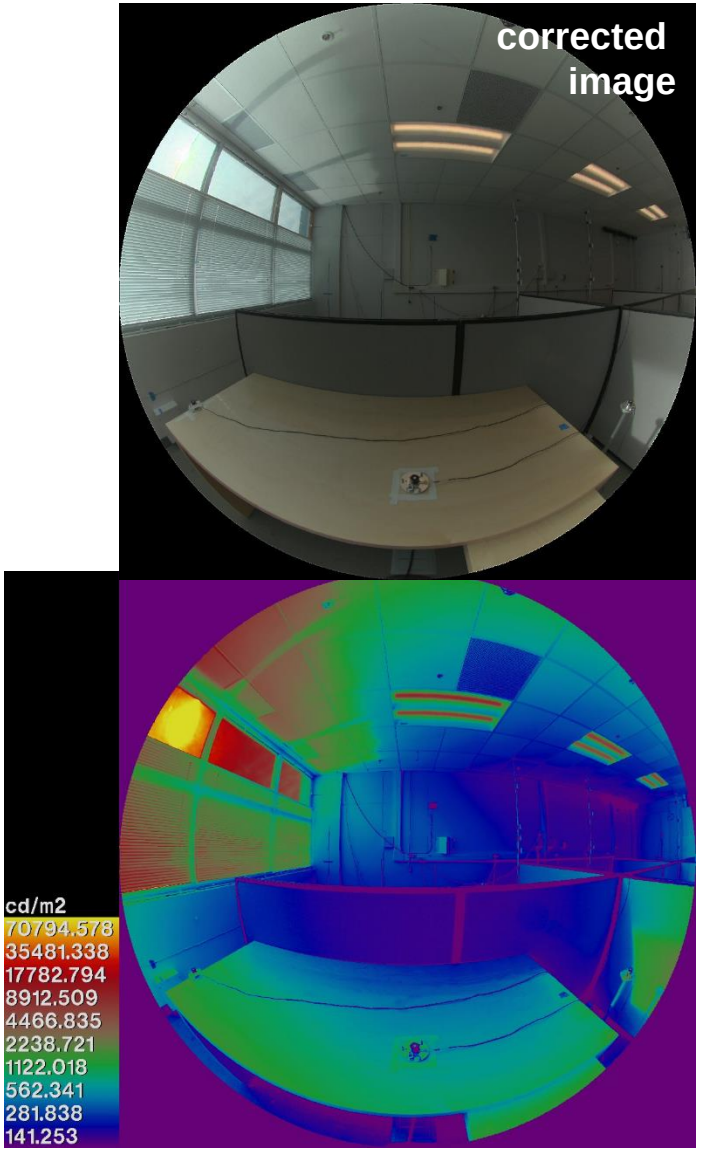




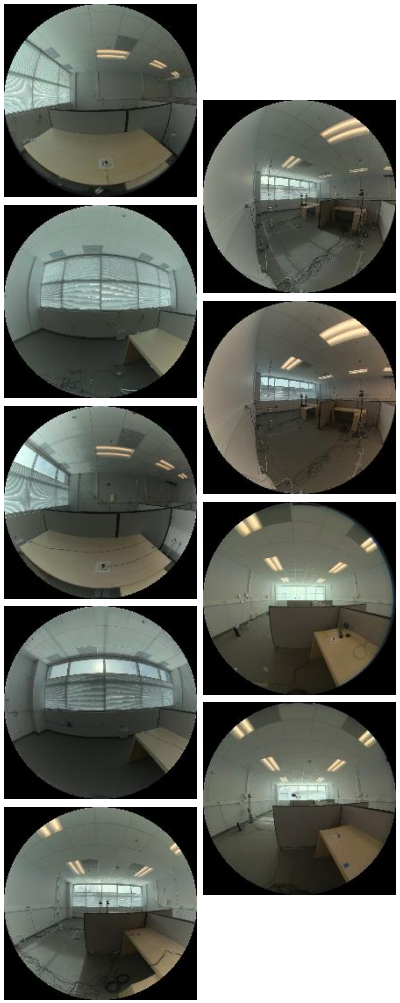
Excursion: Fisheye Lens Distorsion

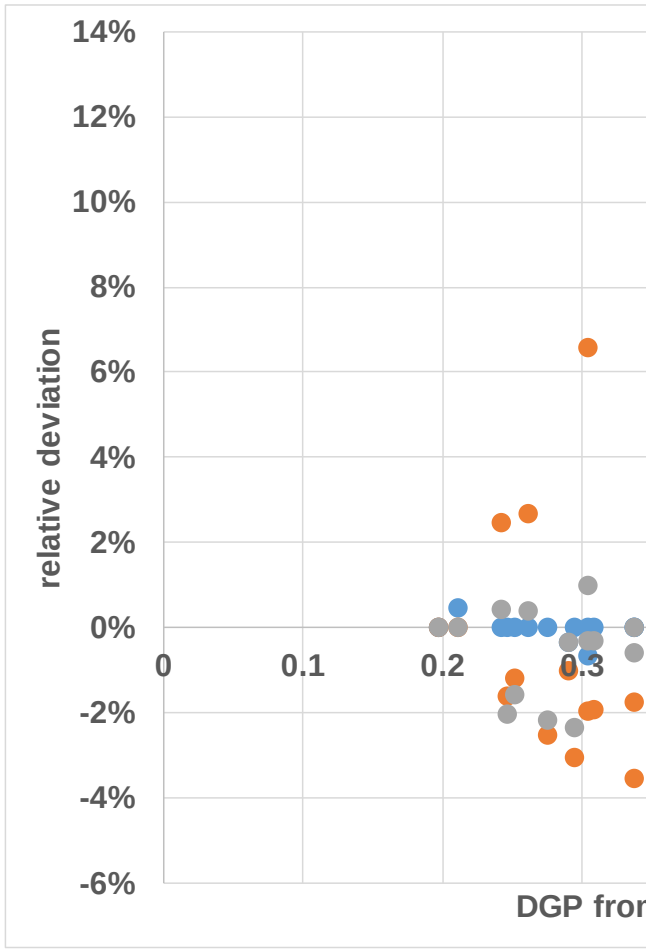
71tHDR-09
@ Dec. 5, 13:00





Excursion: Fisheye Lens Distorsion



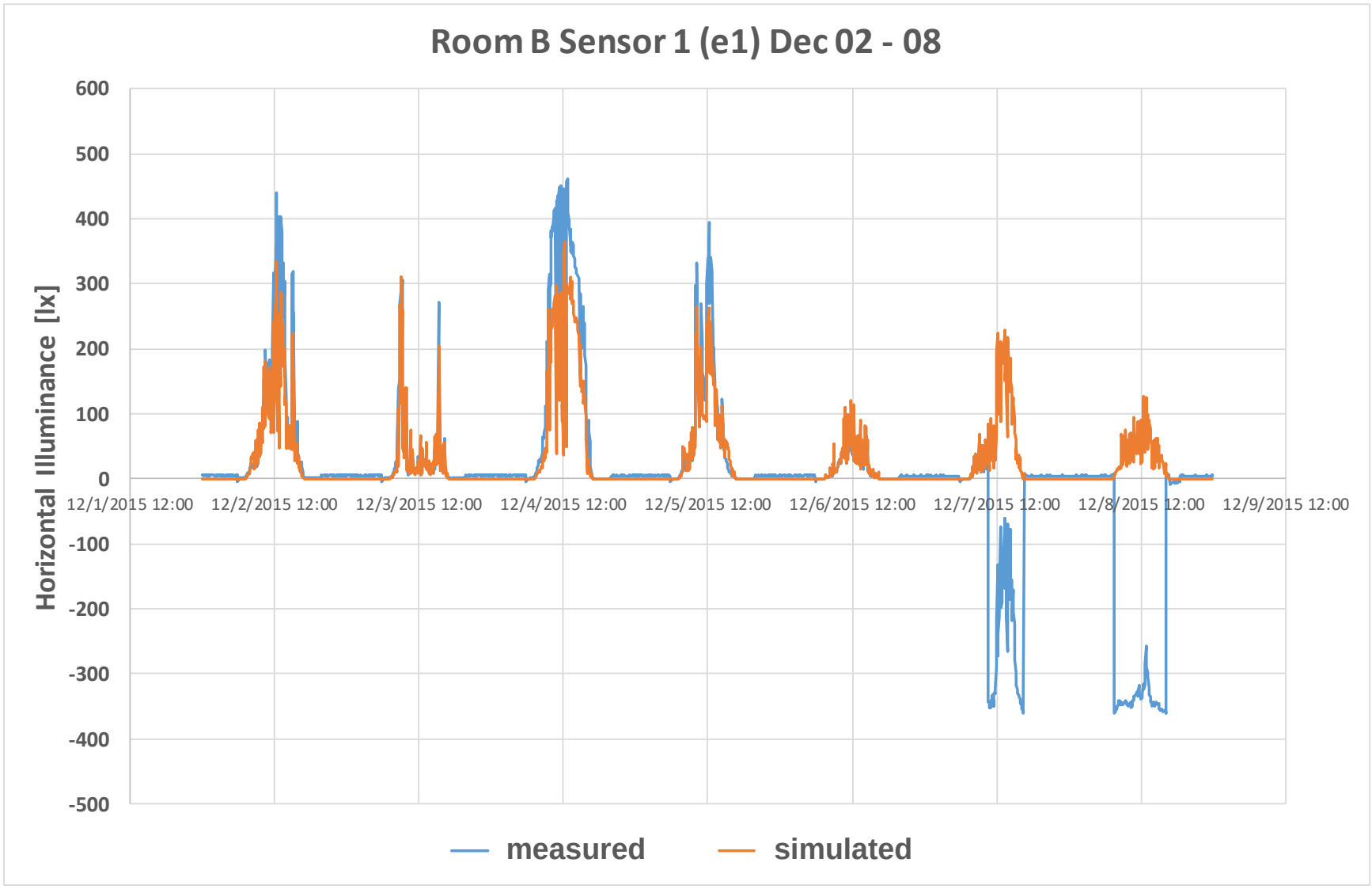


Conclusion: - take care about lens projection – it should match the view type!
- for DGP it is important to get vertical illuminance right

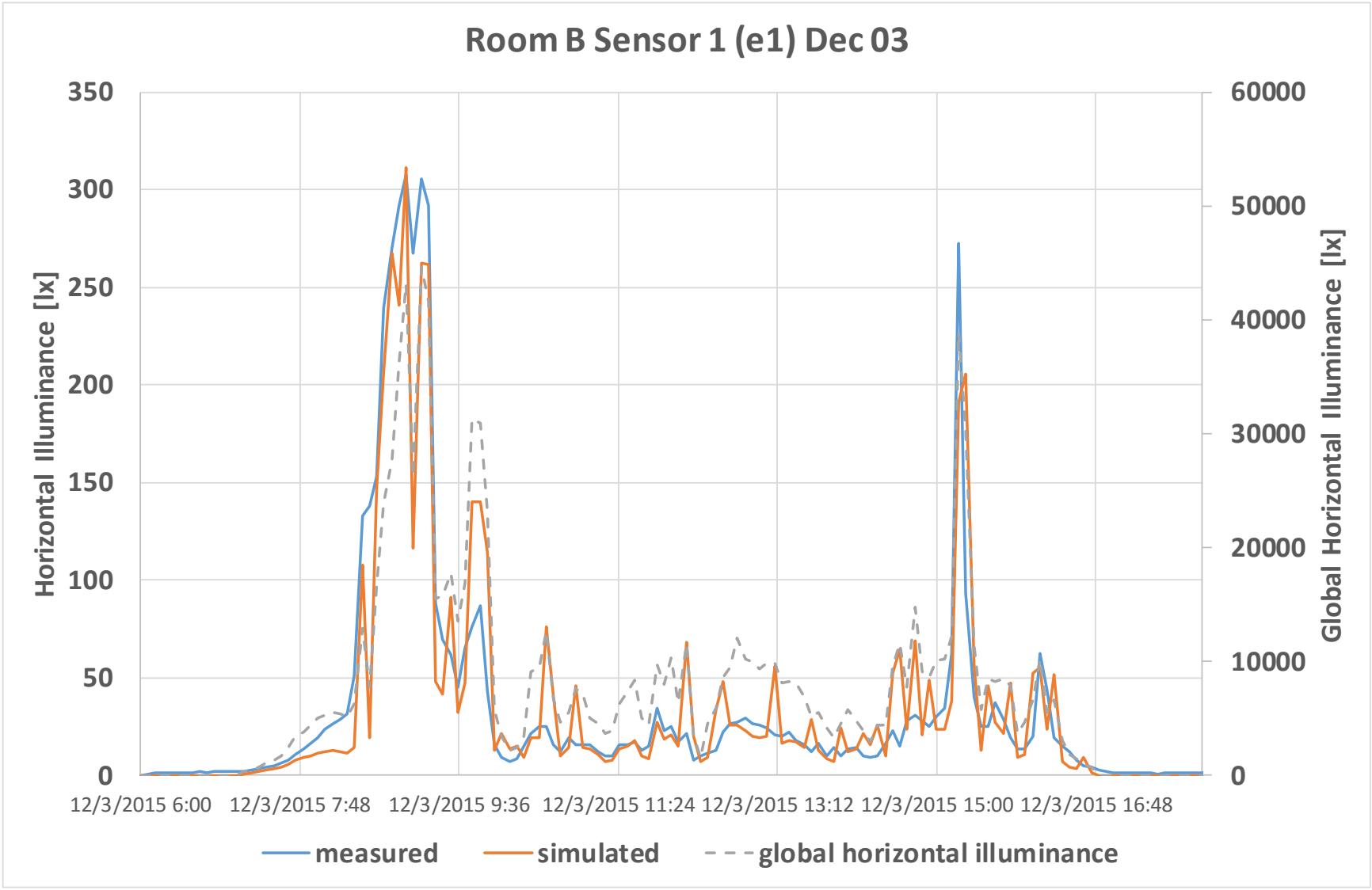
Preliminary Results

Workplane illuminance sensors

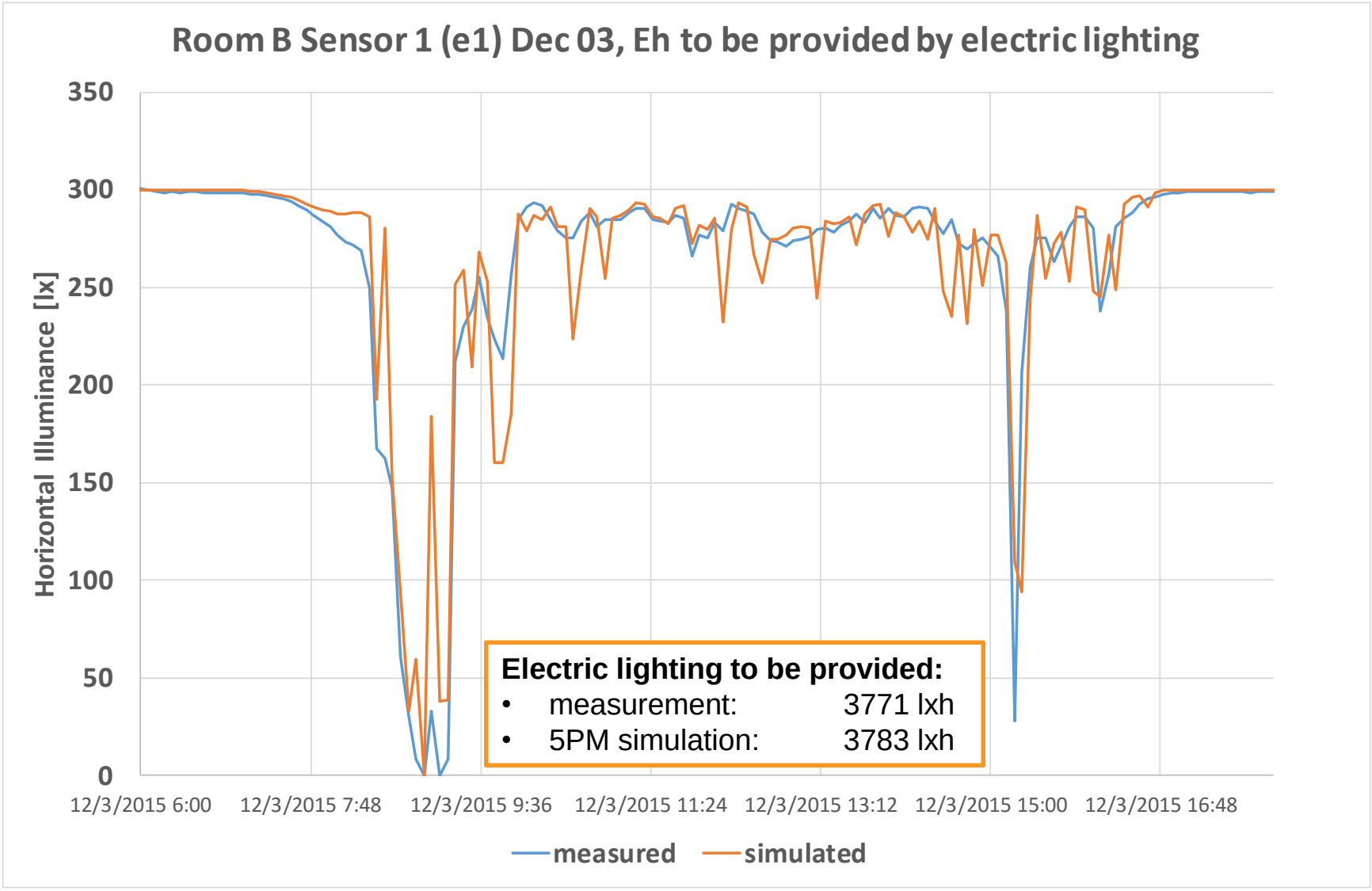
Preliminary Results



Preliminary Results



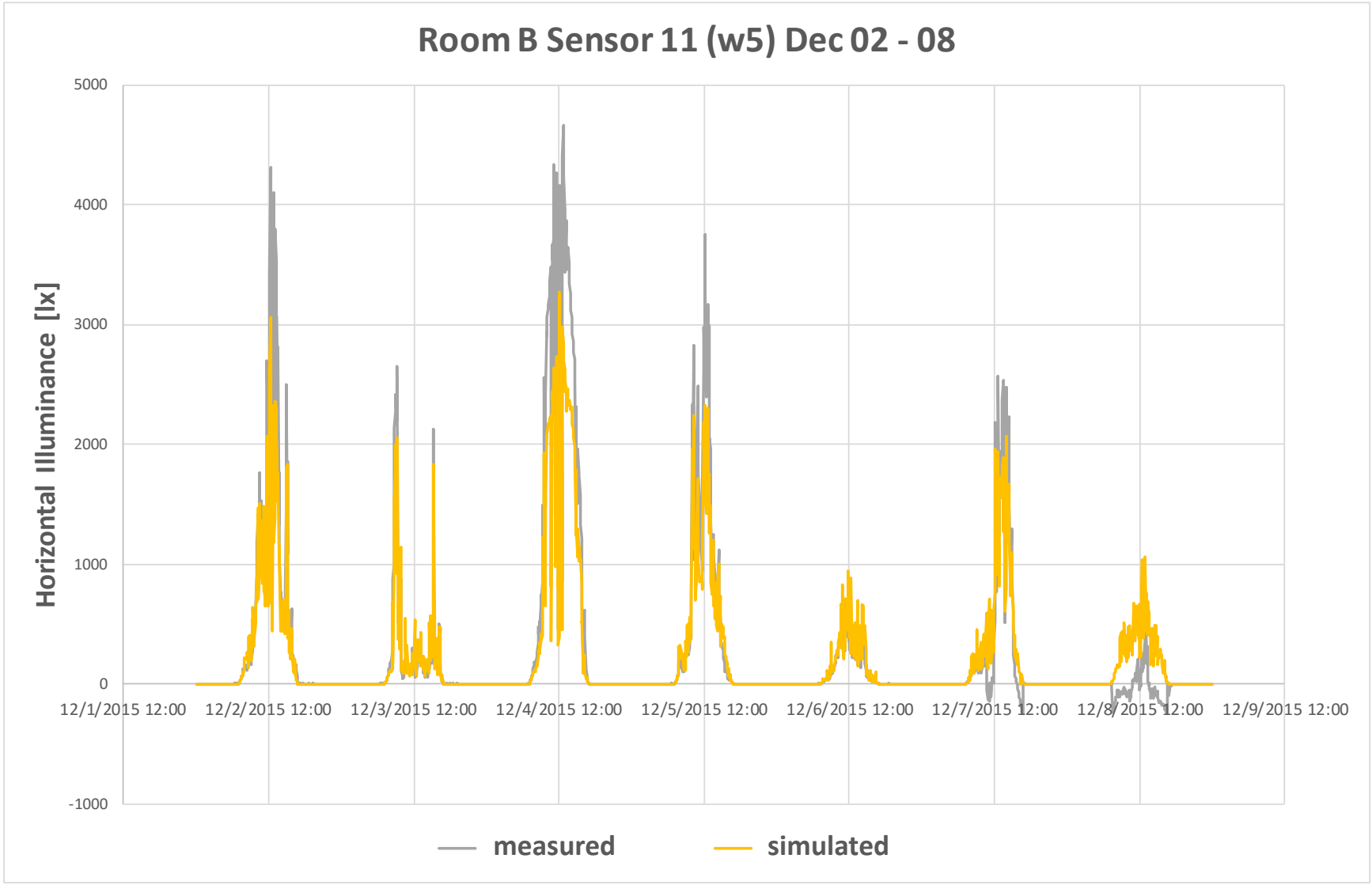
Preliminary Results



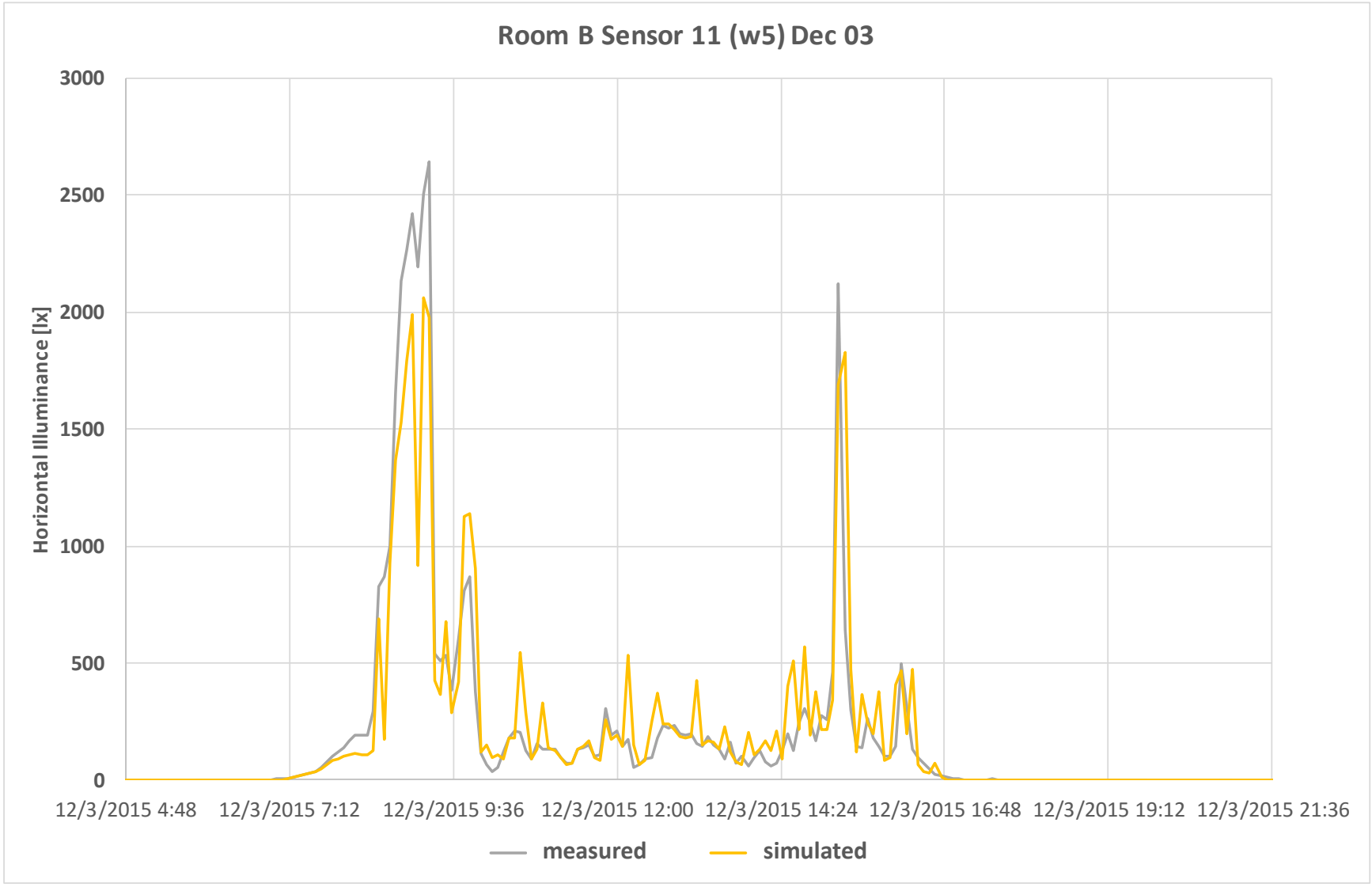
Preliminary Results

Workplane illuminance sensors

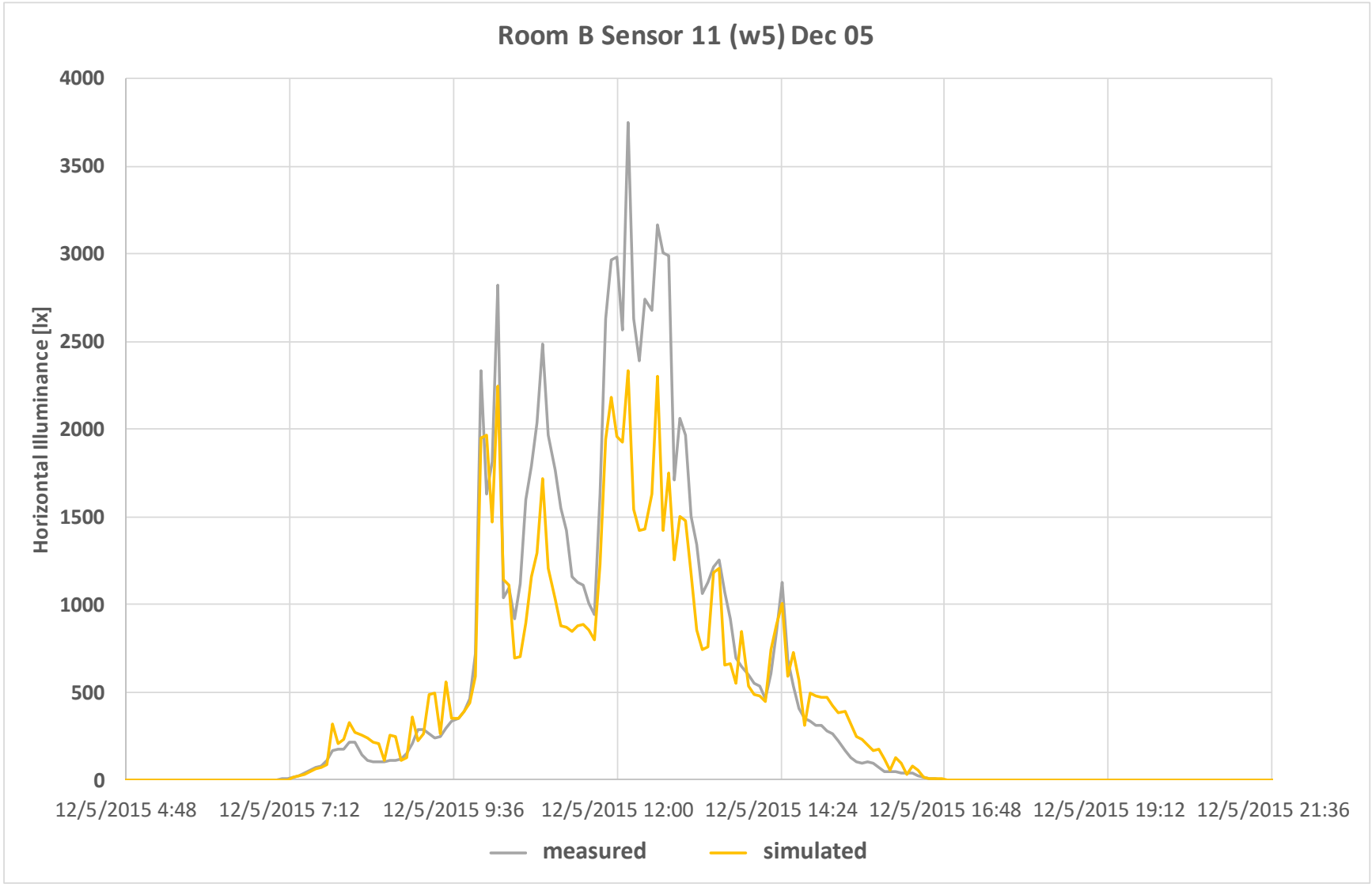
Preliminary Results



Preliminary Results

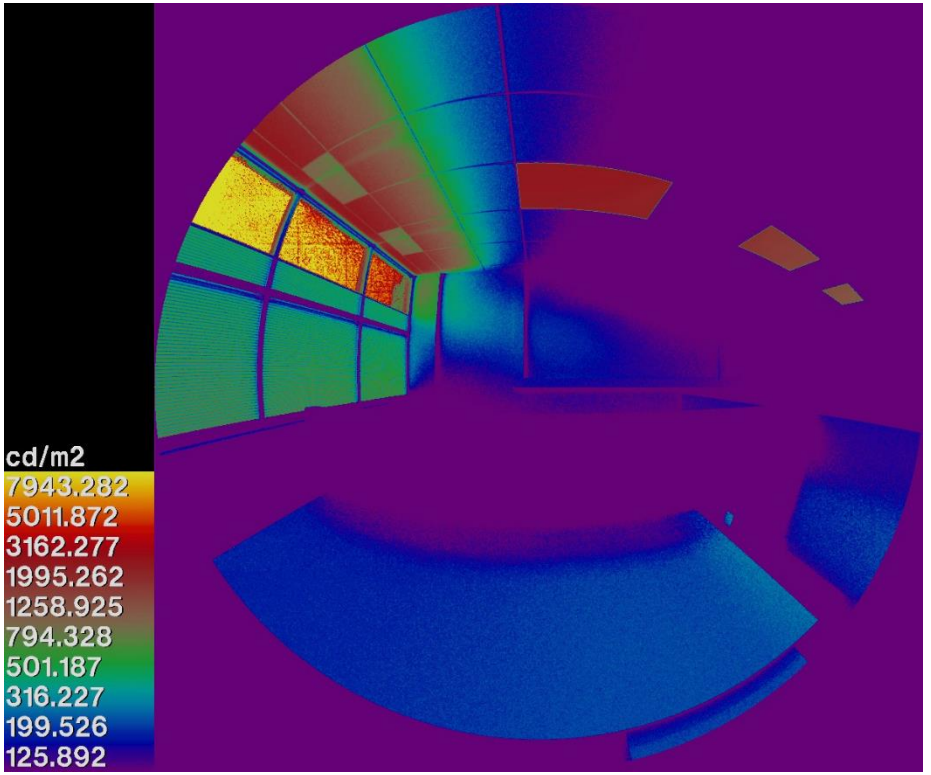


Preliminary Results



Preliminary Results

Dec. 05 2015, 12:00



Room B
Daylighting film SerraGlaze (bsdf2ttree -g 7)
interior venetian blinds (Klems & geometry)

Perez sky: gendaylit -ang 29.75 0.09 -L 14790 42087
Rendered with: -aa 0 -ab 2 -ad 512

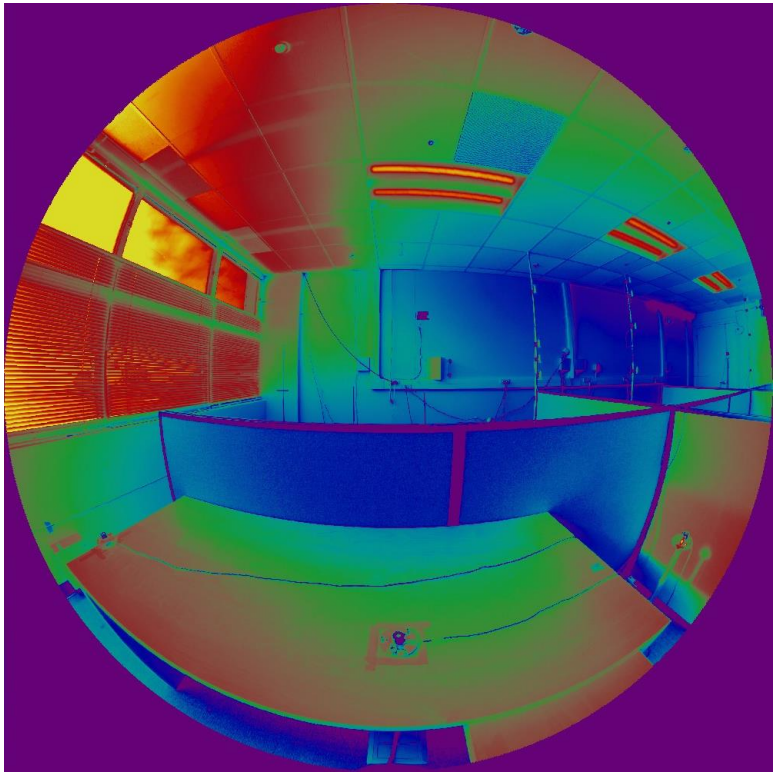
DGP = 0.243 | DGI = 13.2 | Ev = 1120 lx

Preliminary Results

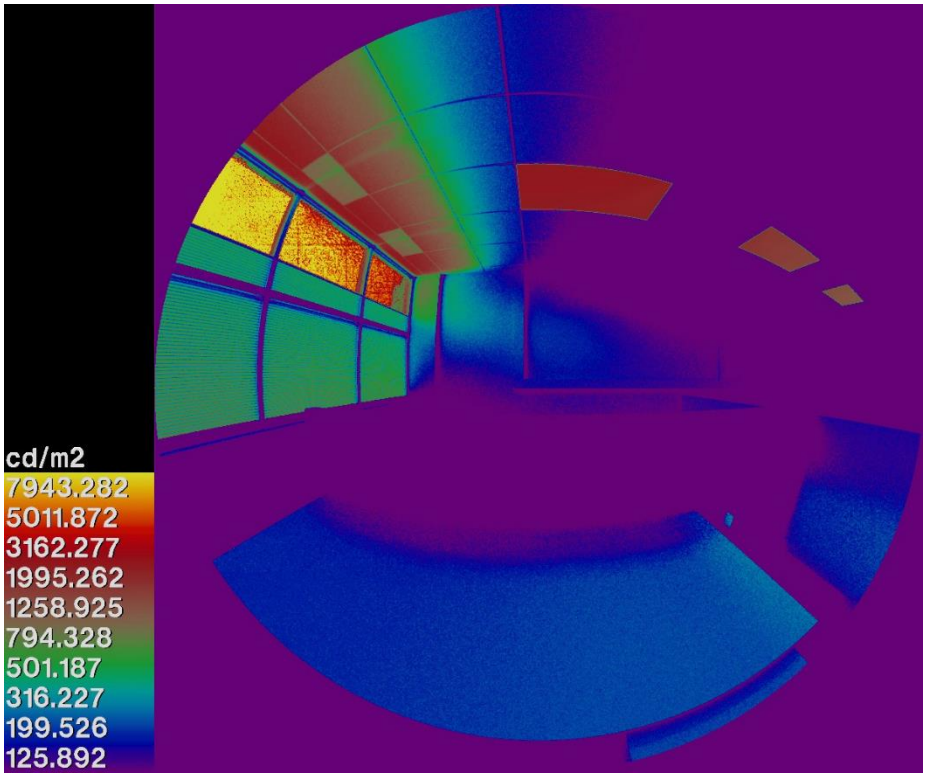
Dec. 05 2015, 12:00

Preliminary Results

Dec. 05 2015, 12:00



DGP: 0.304
DGI: 11.8
Ev: 2374 lx



DGP = 0.243 | DGI = 13.2 | Ev = 1120 lx

Sensor 5PM: 1299 lx
(-ab 10 –ad 65K in rcontrib
view matrix calculation)

Outlook

Sensitivity analysis on BSDF interpolation

– effects on DGP and annual results

Completion of simulation workflow set-up

– system characteristics, renderings, exterior conditions

Evaluation for overall measurement data set

– systems, seasons, indices

Documentation & dissemination

Acknowledgments

- Amir Roth, U.S. Department of Energy
- Mananya Chansanchai, Jeff Beresini, Pacific Gas and Electric Company

- Austrian Research Promotion Agency (FFG)

- Lucent Optics
- Serralux
- SmartLouvre
- Chris Humann and Andrew McNeil, Terrestrial Light
- Anothai Thanachareonkit, Jacob Jonsson, Darryl Dickerhoff, Jordan Shackelford, Christoph Gehbauer, Daniel Fuller, Ari Harding, Cynthia Regnier, Stephen Selkowitz, LBNL
- Wilfried Pohl, Christian Knoflach, Bartenbach GmbH


Thank you!