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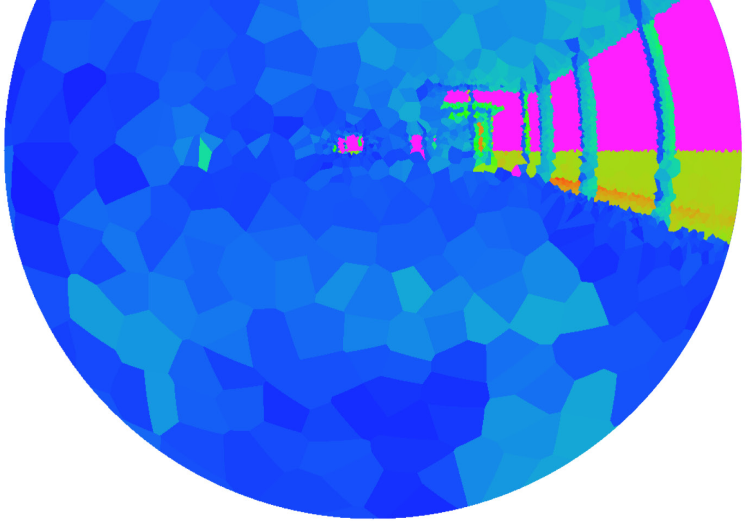
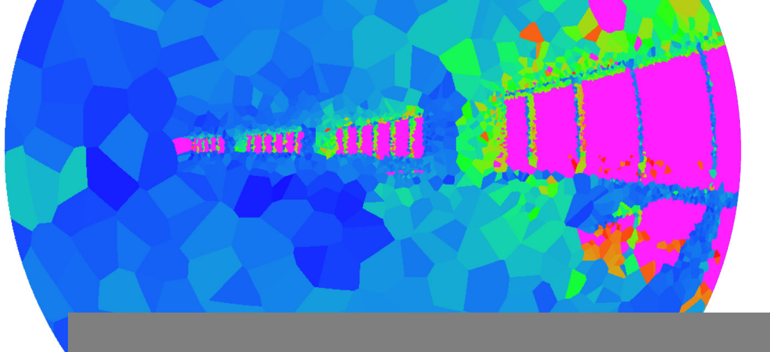
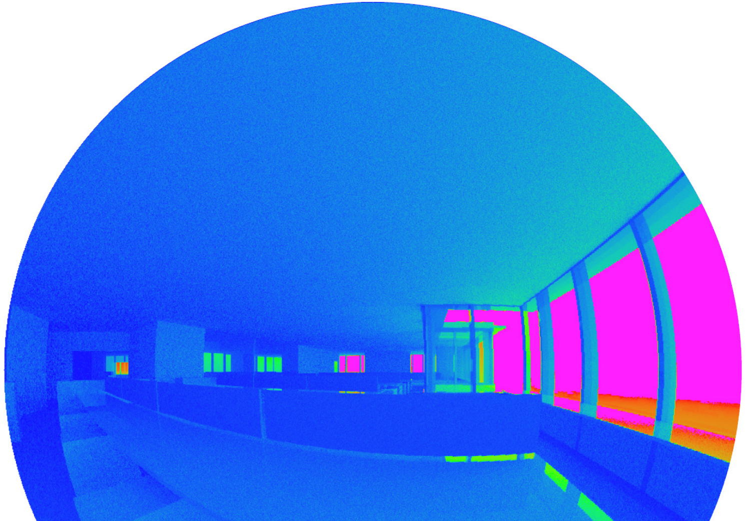
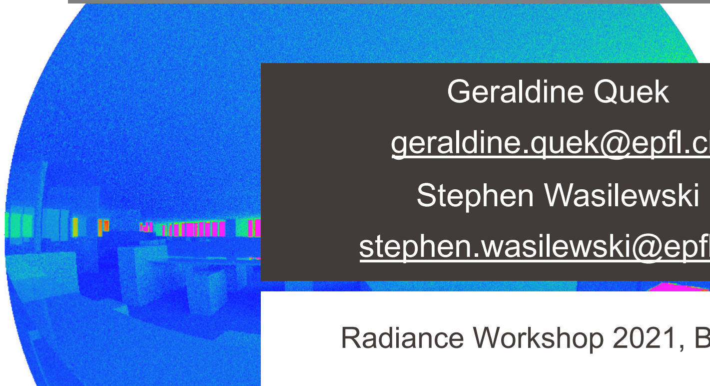
Raytraverse





Radiance





Spatial evaluation of potential saturation and contrast effects of discomf glare in an open-plan office

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Radiance Workshop 2021, Bilbac

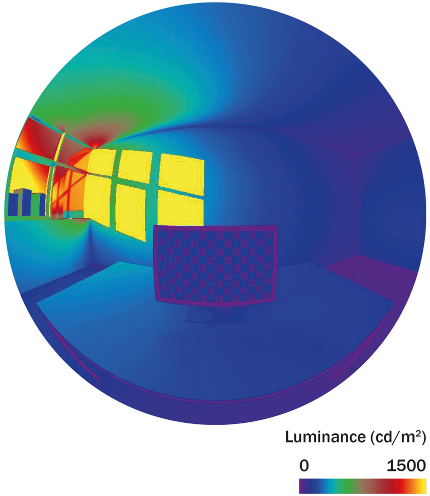
Laboratory of Integrated Performance in Design (LIPID)

Envelopes and Solar Energy (EASE)

Discomfort Glare

Glare that causes discomfort without necessarily impairing the vision of objects
[EN 12665: 2011 3.223, CIE ILV 17-333]

Discomfort glare metrics (DGP) are starting to be included in building recommendations and standards (European Standard for Daylight in Buildings (EN 17037))



Saturation

Contrast

$$DGP = 5.87 * 10^{-5} E_V + 9.18 * 10^{-2} \log_{10}\left(1 + \sum_{i=1}^{n} \frac{L_{s,i}^2 * \omega_i}{E_V^{1.87} * P_i^2}\right) + 0.16,$$

Daylight Glare Probability (Wienold and Christoffersen, 2006)

- Considers both saturation and contrast effects of discomfort glare and is currently most robust
- Developed in daylit office test rooms
- Most robust glare prediction metric to date

However, DGP is …

- Highly reliant on vertical illuminance (E_v)
- Low light correction extends outside validated range
- Under-predicts reported glare scenarios in field studies

Type	No.	Name of metric	Abbreviation	Reference
Saturation and contrast based (Hybrid)	1	Daylight Glare Probability	DGP	[18]
	2	Predicted Glare Sensation Vote	PGSV	[35,37]
	3	Experimental Unified Glare Rating	UGR_{exp}	[38]
	4	Logistic Regression model (using DGP development dataset)	Eccologit	-
Contrast based only	5	CIE Glare Index	CGI	[39,40]
	6	Daylight Glare Index	DGI	[41,42]
	7	Modified Daylight Glare Index	DGI_{mod}	[38]
	8	Predicted Glare Sensation Vote (contrast)	$PGSV_{con}$	[35]
	9	Unified Glare Probability/Unified Glare Rating	UGP/UGR	[14,40]
	10	Logarithmic Contrast (from DGP)	log_gc	[18]
	11	Daylight Glare Rating	DGR	[43]
	12	Visual Comfort Probability	VCP	[43]
Saturation based only	13	Average Luminance of Image	L_{avg}	[44]
	14	Predicted Glare Sensation Vote (saturation)	$PGSV_{sat}$	[35]
	15	Vertical Illuminance/Simplified DGP	E_v /DGPs	[45]

Quek, G., Wienold, J., Sarey Khanie, M., Erell, E., Kaftan, E., Tzempelikos, T., Konstantzos, I., Christoffersen, J., Kuhn, T., & Andersen, M. (2021). Comparing performance of discomfort glare metrics in high and low adaptation levels. *Building and Environment*, *Under Review*.

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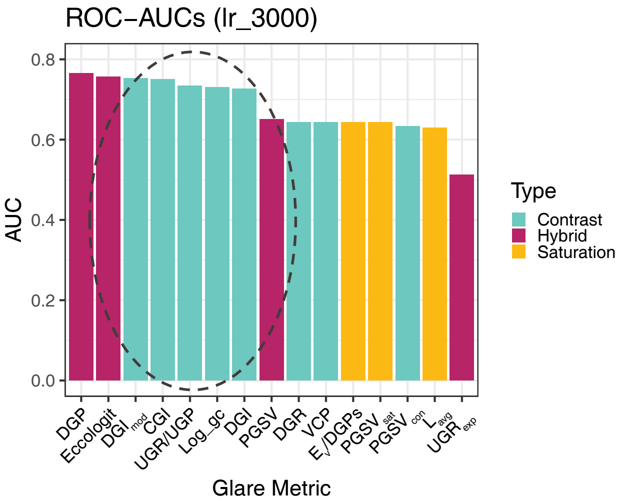
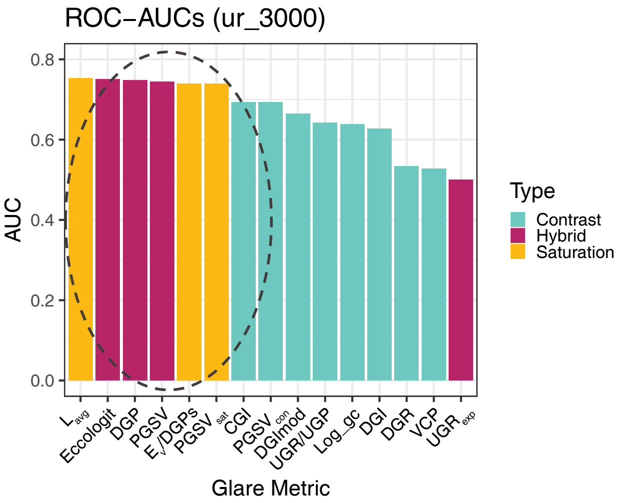
Low adaptation levels

E_v < 3000 lux



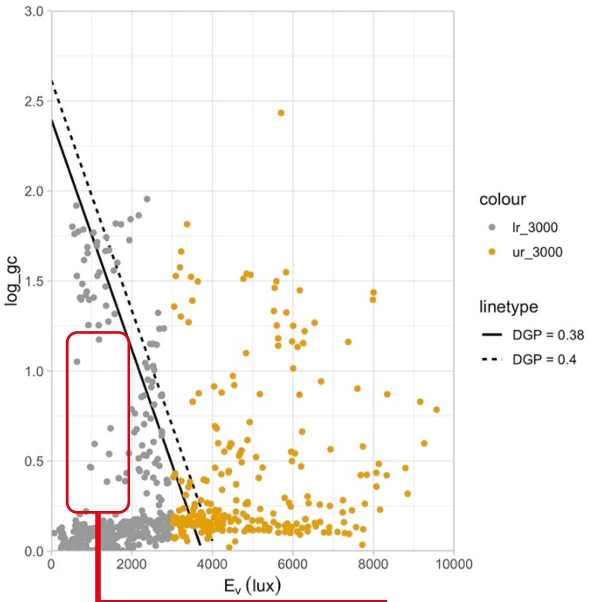
High adaptation levels

E_v ≥ 3000 lux



Although hybrid metrics perform generally well in both groups, contrast-driven metrics were found to perform better than saturation metrics in situations with lower adaptation levels.

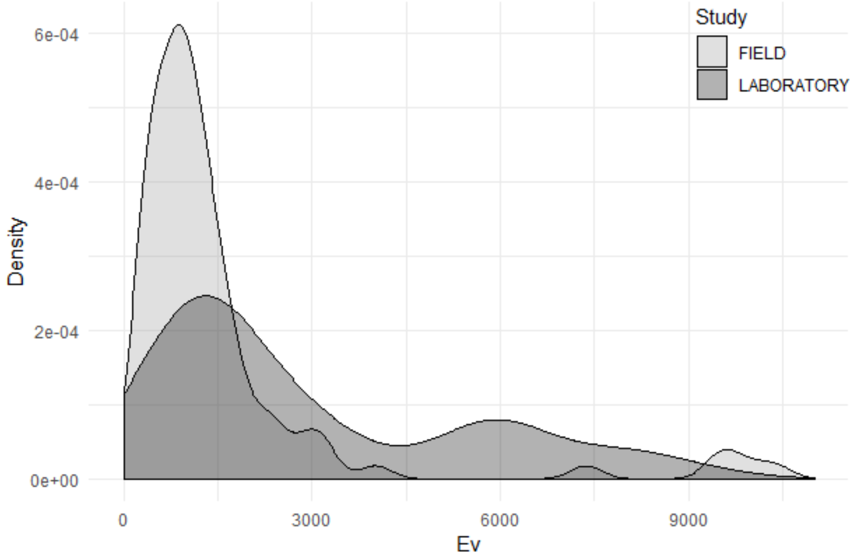
Quek, G., Wienold, J., Sarey Khanie, M., Erell, E., Kaftan, E., Tzempelikos, T., Konstantzos, I., Christoffersen, J., Kuhn, T., & Andersen, M. (2021). Comparing performance of discomfort glare metrics in high and low adaptation levels. *Building and Environment*, *Under Review*.



Lack of user evaluation data in low-light conditions (ongoing)

The experiments for these studies had been conducted in controlled daylit office-like environments, carried out in Israel, Japan, Germany, Argentina, and the United States between 2008 and 2016, leading to individual datasets called, respectively, IL-DayVICE, JP-Office, DE-Gaze, AR-DEO, US-Fabric (n = 800).

Quek, G., Wienold, J., Sarey Khanie, M., Erell, E., Kaftan, E., Tzempelikos, T., Konstantzos, I., Christoffersen, J., Kuhn, T., & Andersen, M. (2021). Comparing performance of discomfort glare metrics in high and low adaptation levels. *Building and Environment*, *Under Review*.



Distribution of Vertical Illuminance (Ev) – Field studies vs. Laboratory experiments

Pierson, C., Sarey Khanie, M., Bodart, M., Wienold, J., 2019. DISCOMFORT GLARE CUT-OFF VALUES FROM FIELD AND LABORATORY STUDIES, in: PROCEEDINGS OF the 29th Quadrennial Session of the CIE. Presented at the Proceedings of the 29th Quadrennial Session of the CIE, International Commission on Illumination, CIE, Washington DC, USA, pp. 295–305. https://doi.org/10.25039/x46.2019.OP41

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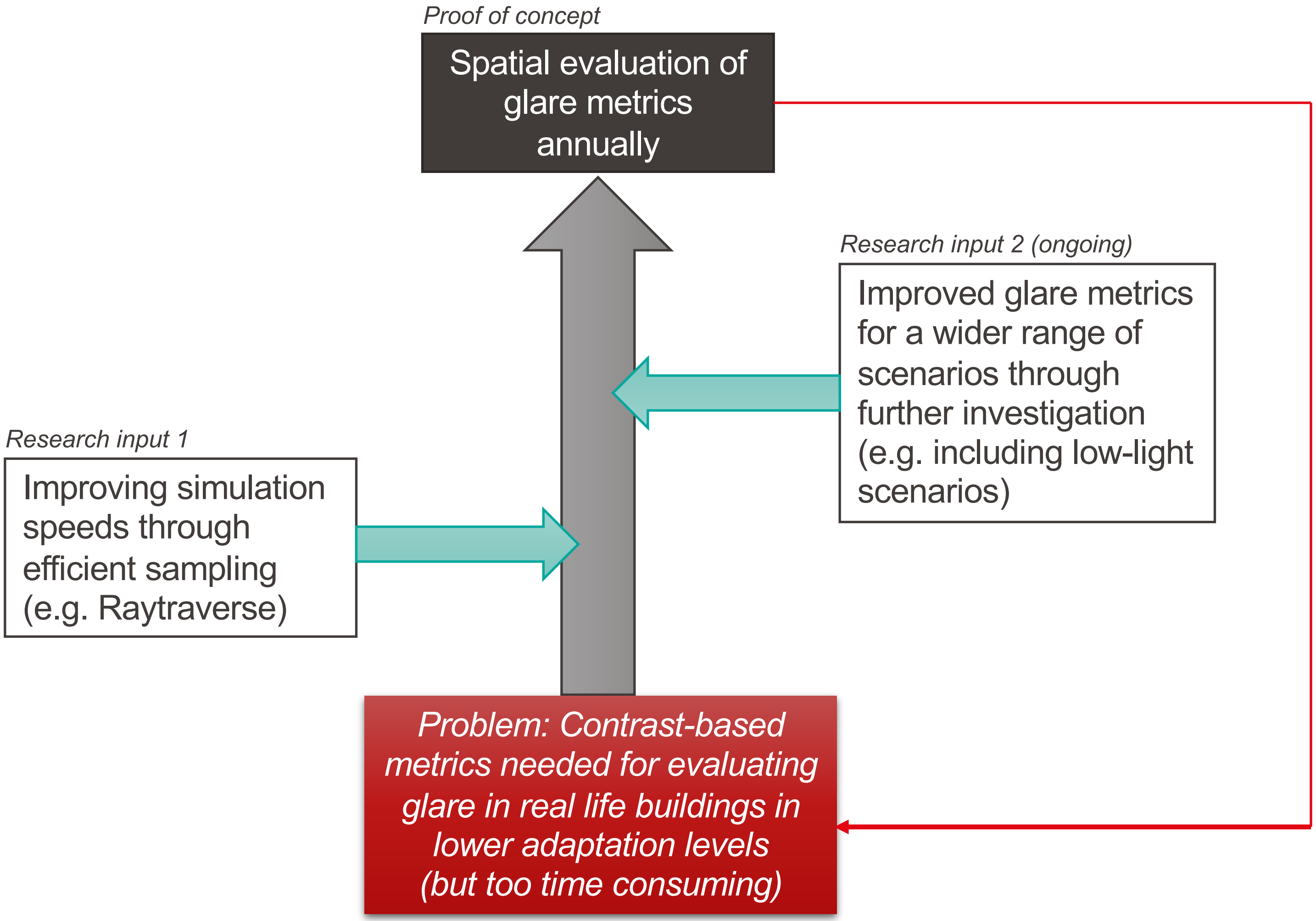
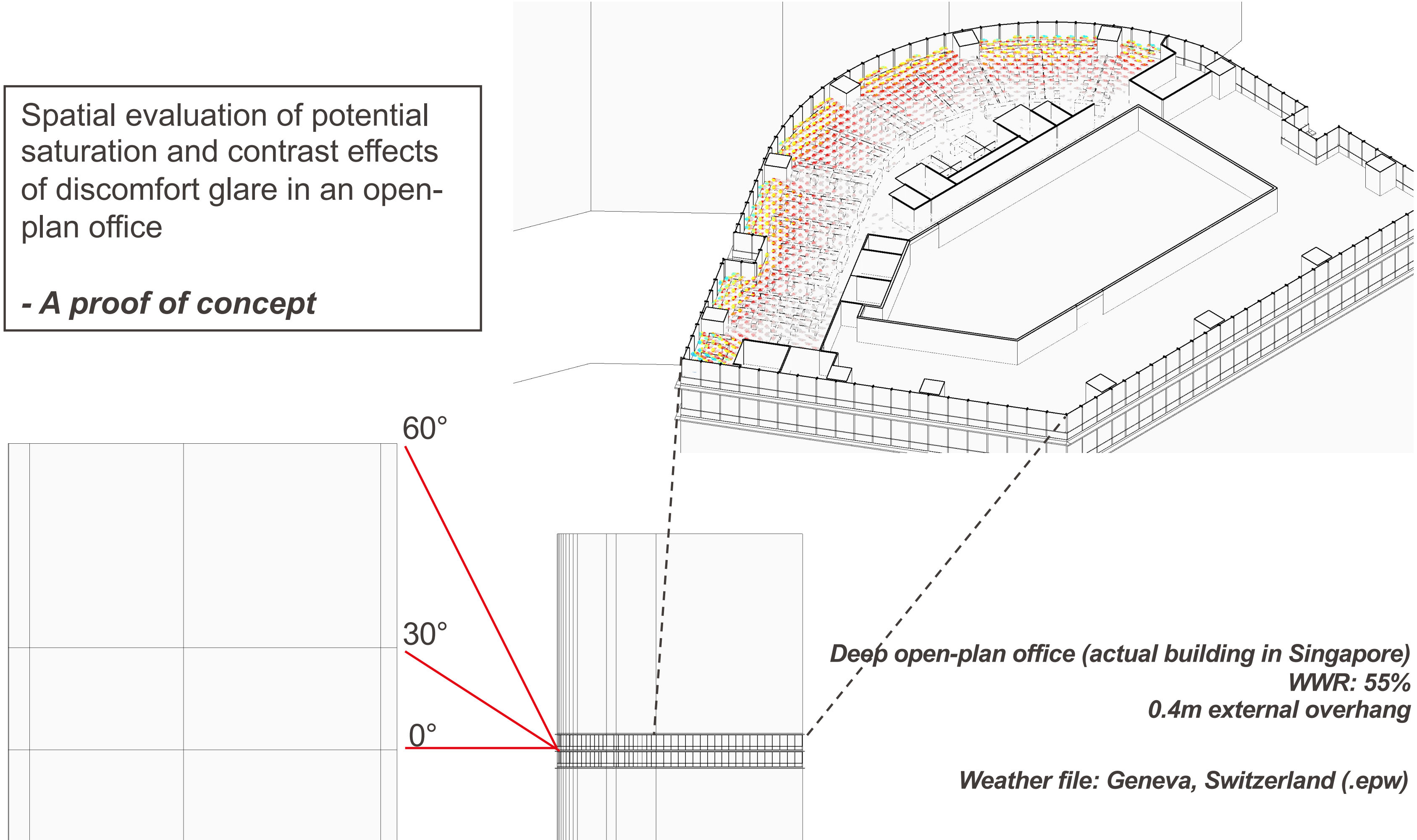


Quek, G., Wasilewski, S., Wienold, J., & Andersen, M. (2021). Spatial evaluation of potential saturation and contrast effects of discomfort glare in an open-plan office. *BS2021*. Building Simulation 2021 Conference, Bruges, Belgium.

Spatial evaluation of potential saturation and contrast effects of discomfort glare in an open-plan office

- A proof of concept



Deep open-plan office (actual building in Singapore)
WWR: 55%
0.4m external overhang

Weather file: Geneva, Switzerland (.epw)

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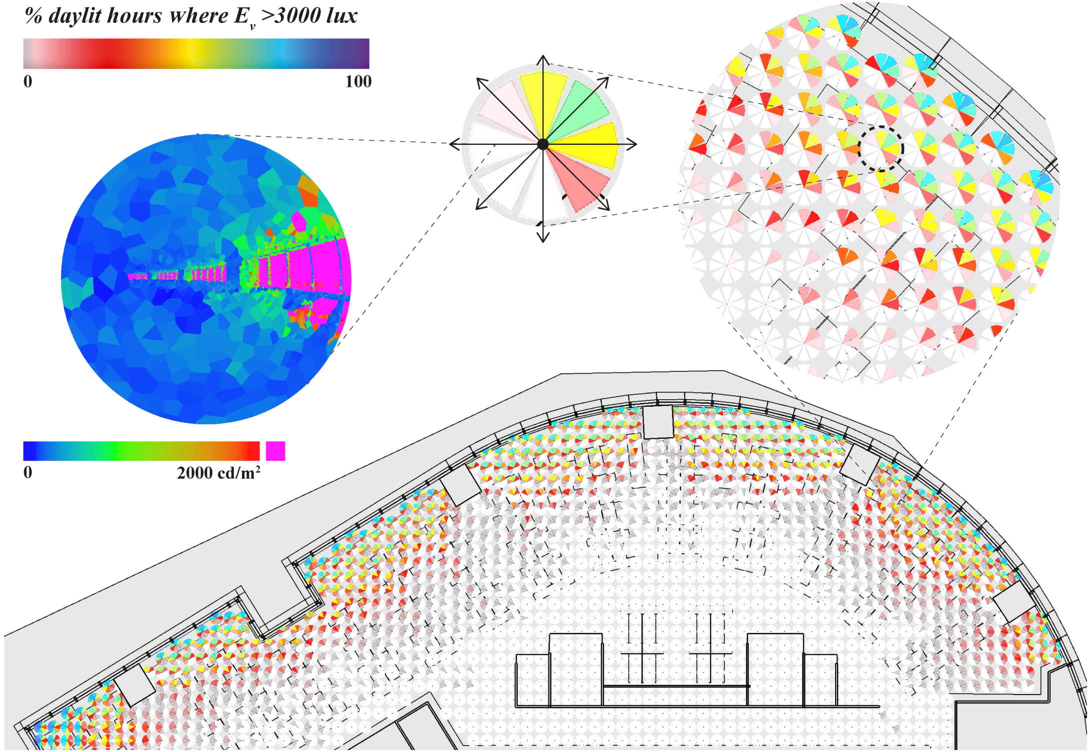

Per model variation:
1278 viewpoints
X
8 viewing directions
X
8760 hours (annual)
→ **89,562,240 simulations**

Ev – **12** model variations
(4 orientations X 3 degrees of urban obstruction)
→ **1,074,746,880 simulations**

Image based visualizations – **4** model variations
(4 orientations)
→ **358,248,960 simulations**

8 viewing directions per viewpoint spread in a 0.75m grid spacing across the floor plan

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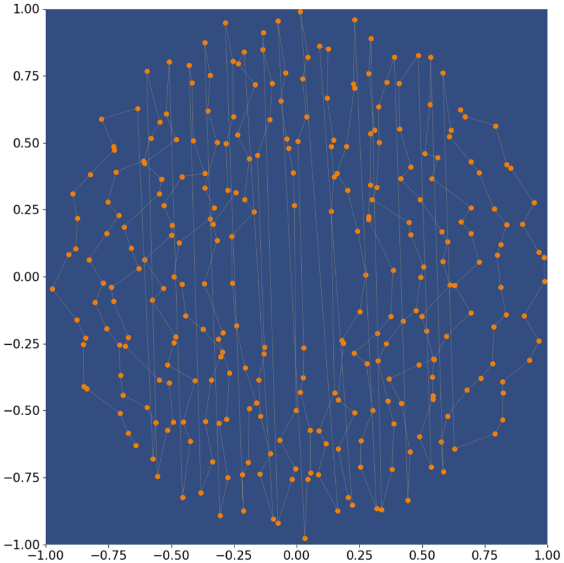
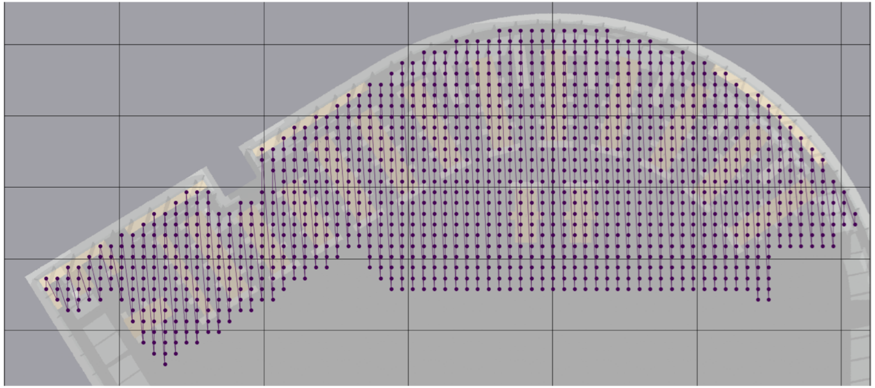
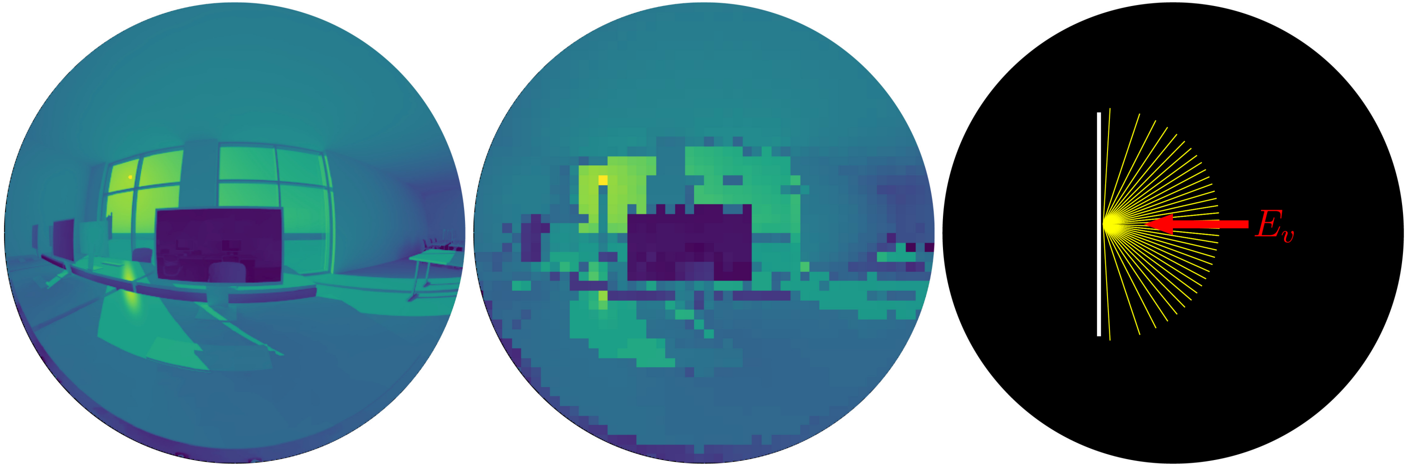
A stratified subsampling of sun Positions for 4 orientations



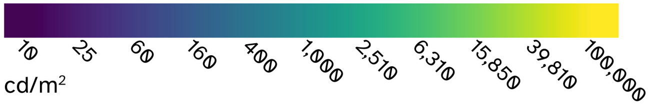


At 10 ° x10° resolution: 292 sources x 1,278 points = 373,176 point/sun combinations

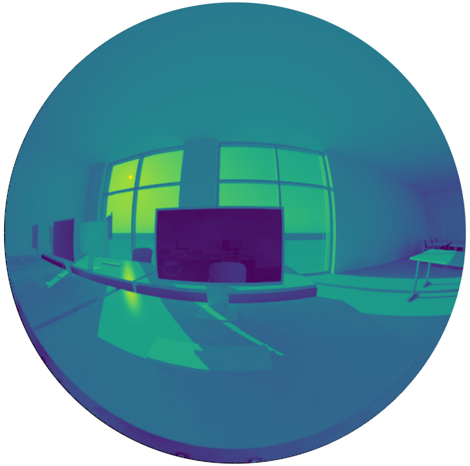
Existing Options For Sampling a Point

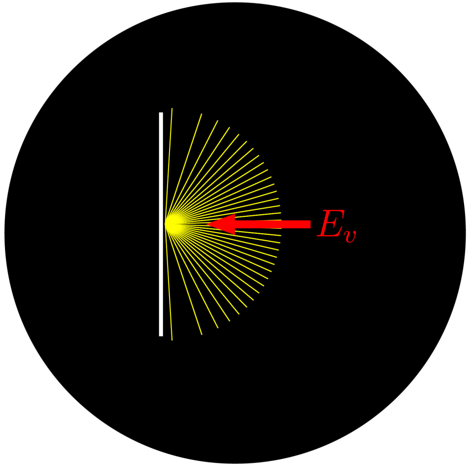


Samples	10^6 samples	10^3 samples	1 sample
Accuracy	High	Low	Medium
Information	High	Medium	Low

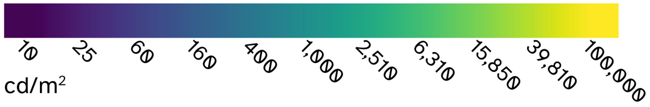


Existing Options For Sampling a Point



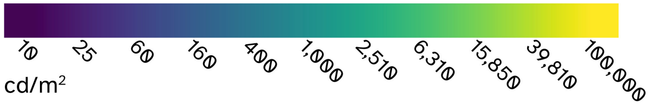


Samples	10^6 samples		1 sample
Accuracy	High		Medium
Information	High		Low



The Potential in Sampling

Samples	10^6 samples	7 Samples	1 sample
Accuracy	High	High	Medium
Information	High	Medium	Low



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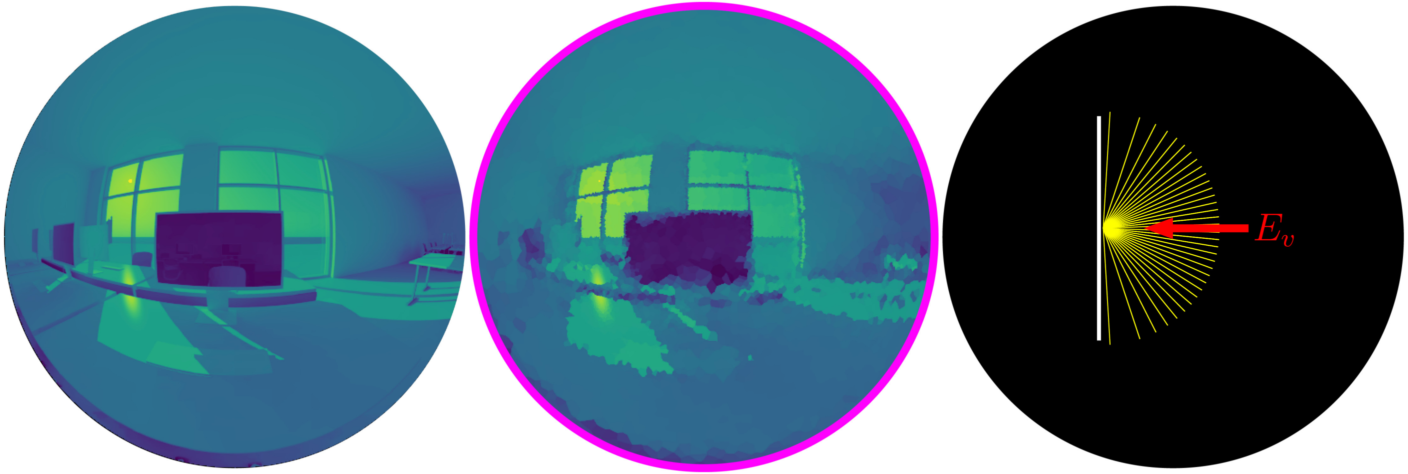
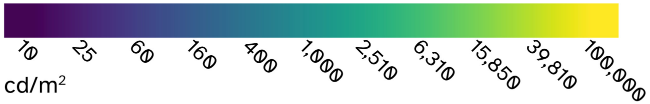
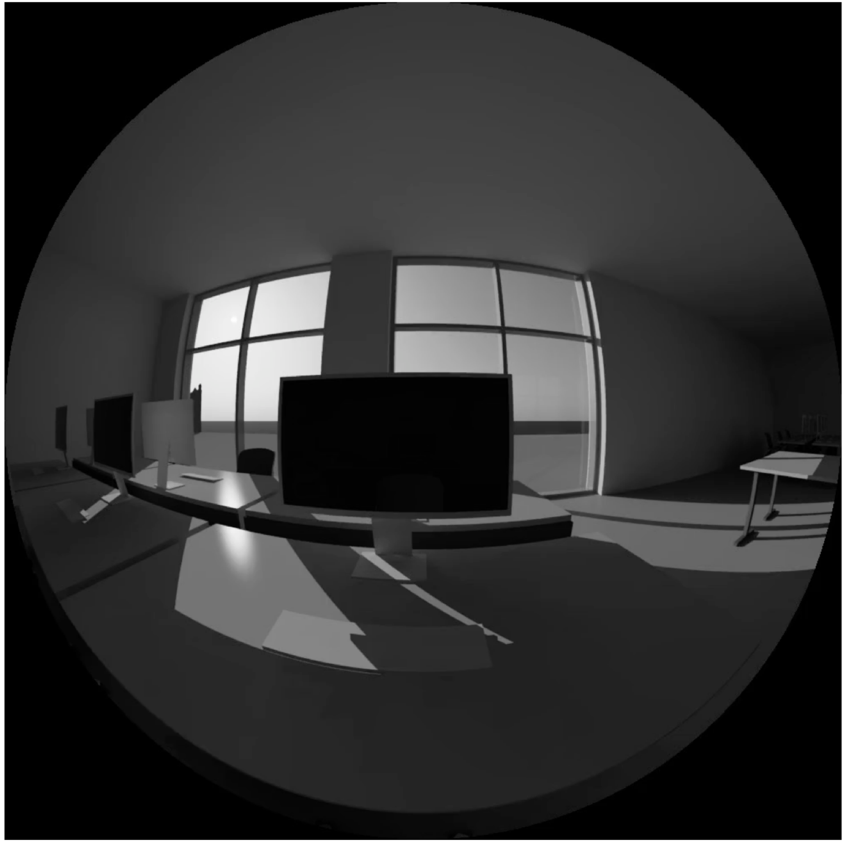
The Potential in Sampling



Samples	10^6 samples	10^3 samples	1 sample
Accuracy	High	High	Medium
Information	High	High	Low



Wavelet Decomposition



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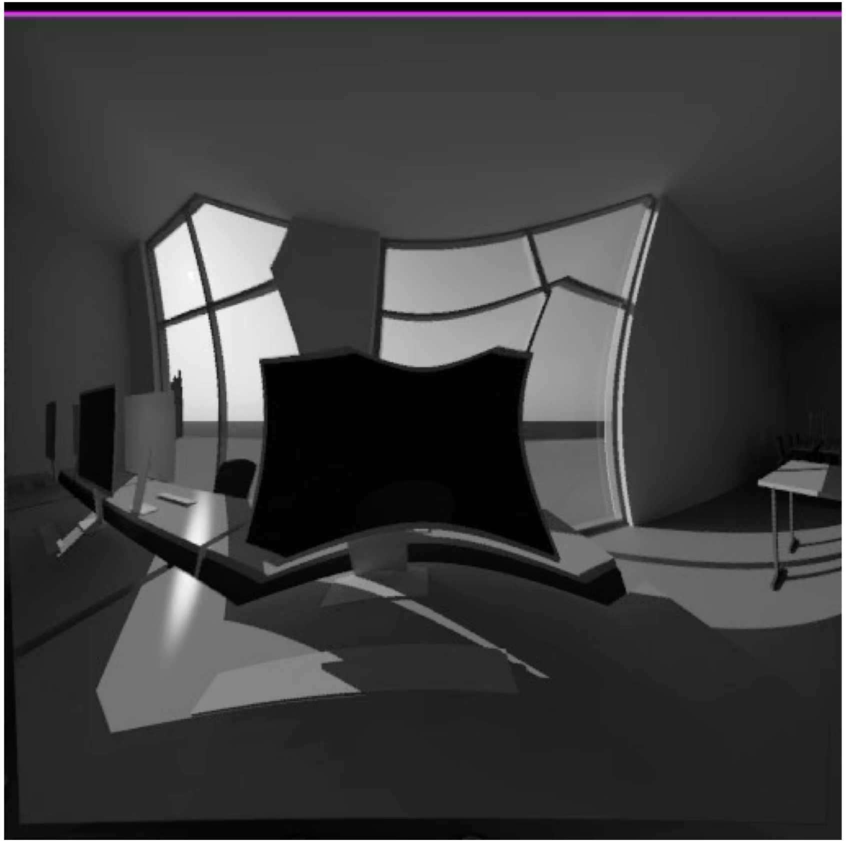
Wavelet Decomposition



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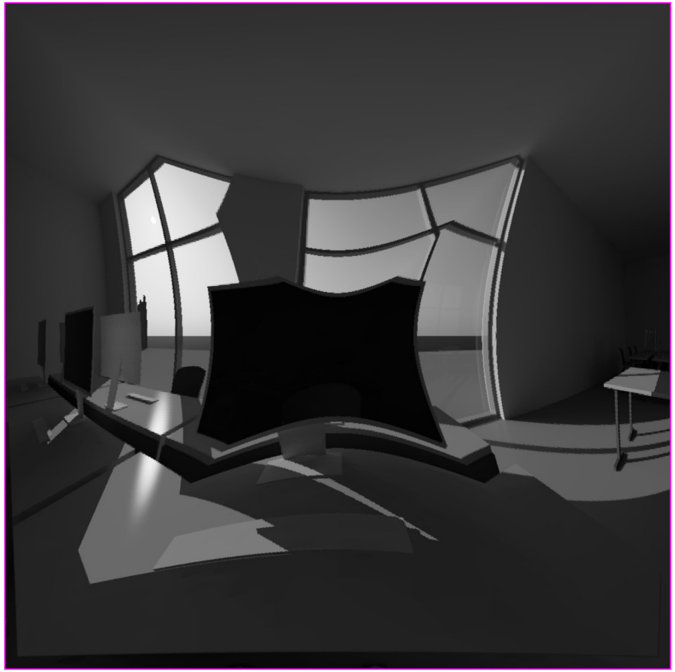
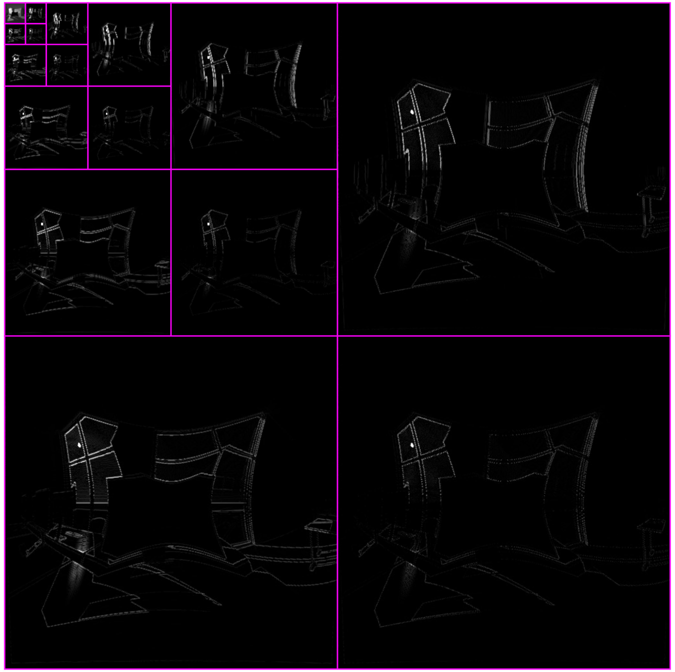
Original



100%

Wavelet Decomposition



> 0.1cd/m² = 35%

> 1cd/m² = 12%

> 10 cd/m² = 4%

> 100 cd/m² = 0.7%

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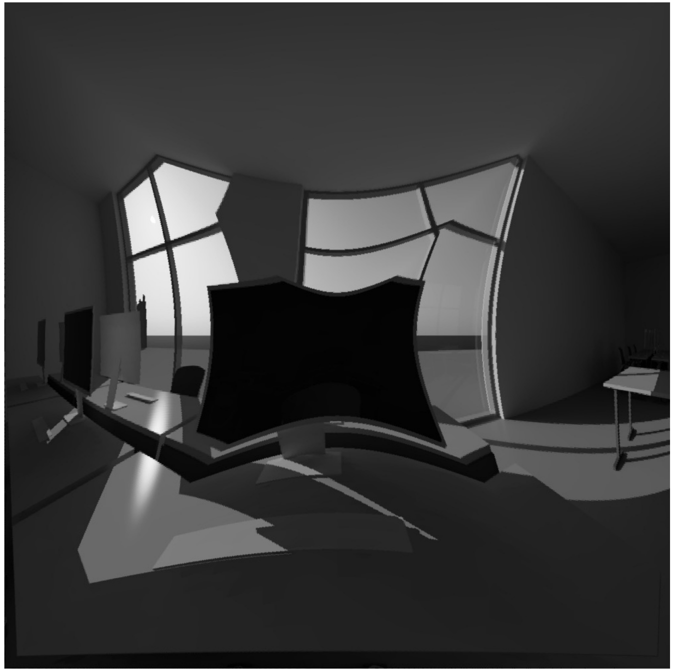
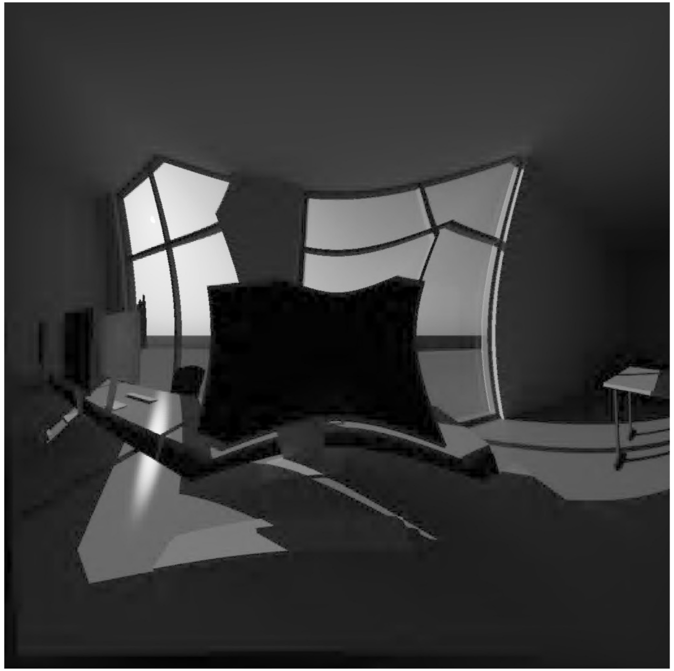
Wavelet Compression



100%



0.7%

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Reconstruction Through Sampling

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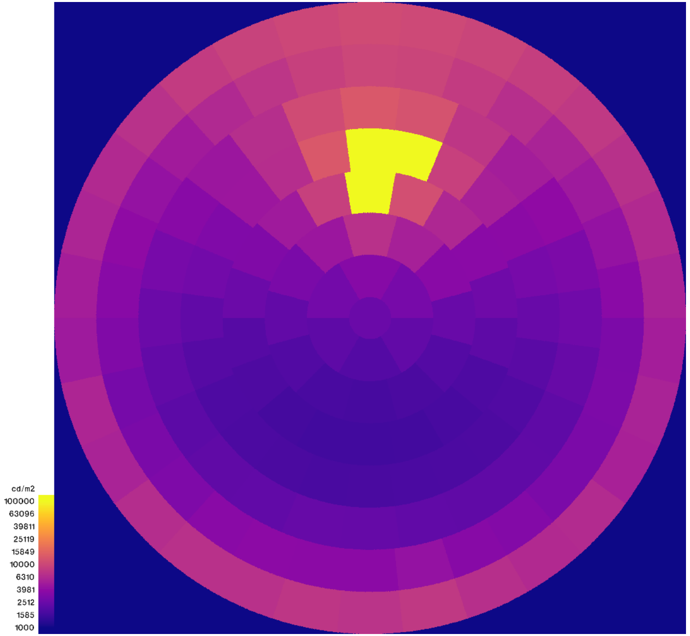
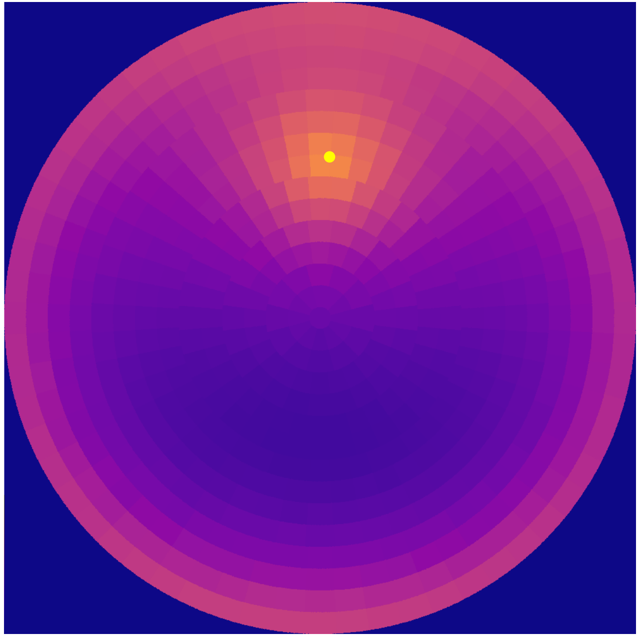
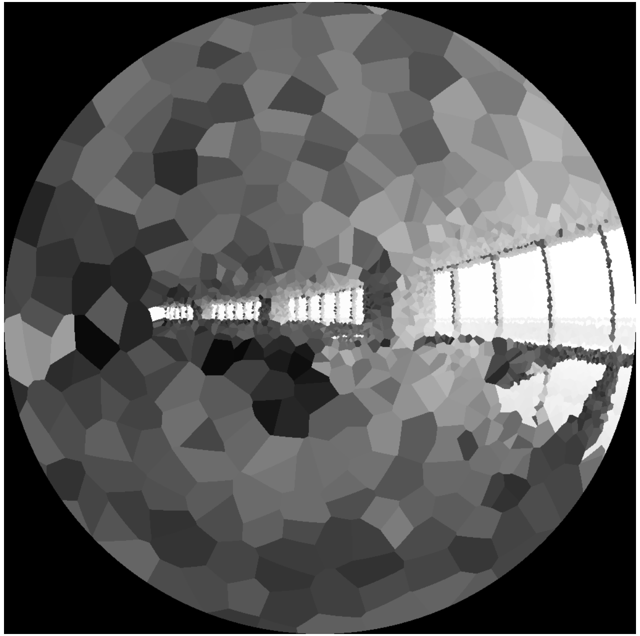


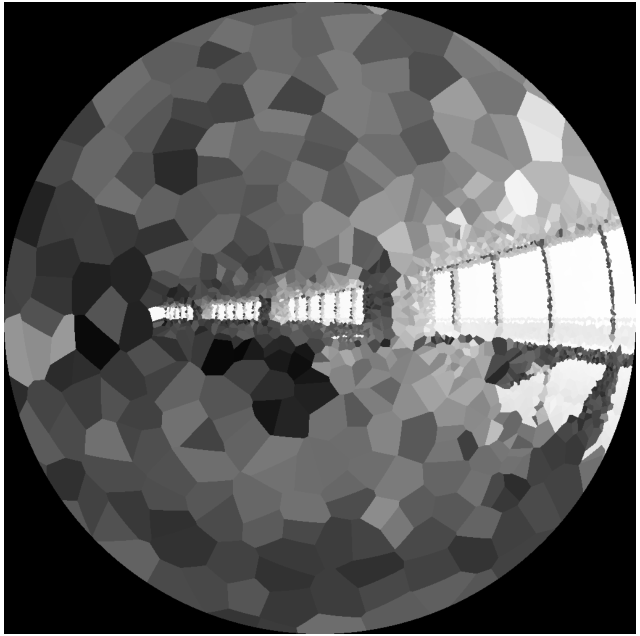
Indirect-rays



View-rays only (even sun patches interpolated)

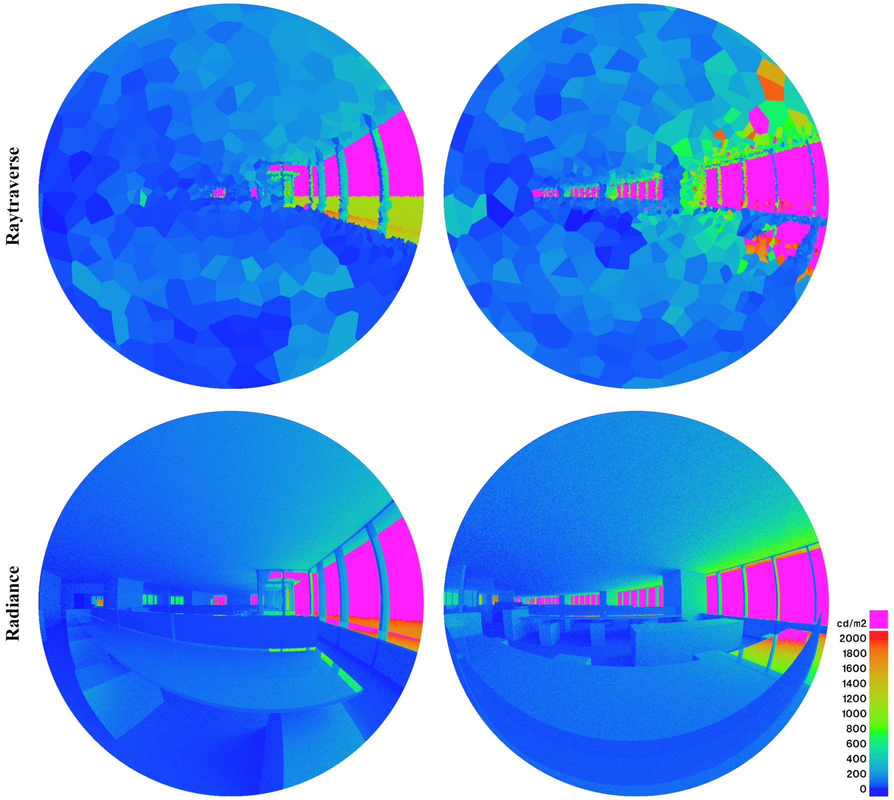


Sky Contribution



+ Sun

Examples of image-based visualizations (Radiance vs. Raytraverse)



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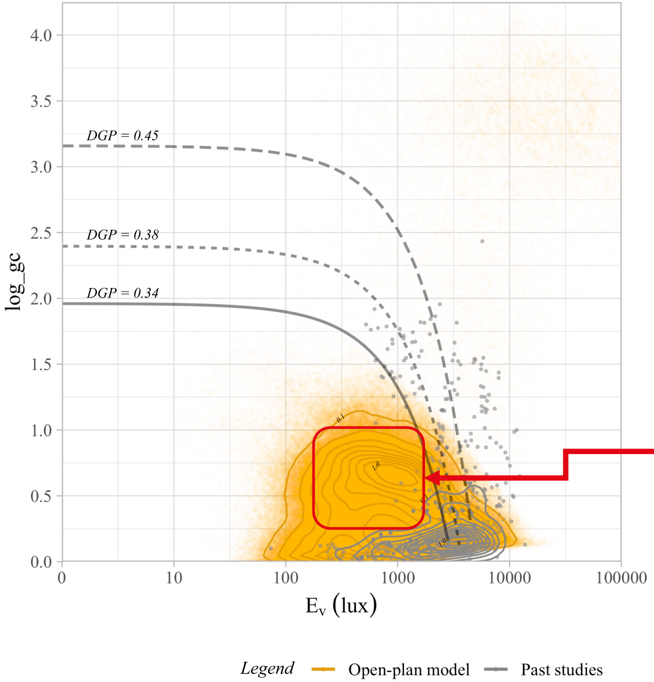
Daylight Glare Probability (DGP) (Wienold & Christoffersen, 2006):

$$DGP = \underbrace{a \cdot E_v}_{\text{Saturation term}} + \underbrace{b \cdot \log_{10}\left(1 + \sum_{i=1}^{n} \frac{L_{s,i}^2 \omega_{s,i}}{E_v^{1.87} P_{s,i}^2}\right)}_{\text{Contrast term (log\_gc)}} + c) \qquad (1)$$

where $L_{s,i}$ refers to the luminance of the glare source for the i-th glare source, $\omega_{s,i}$ refers to the solid angle of the glare source in steradians, and $P_{s,i}$ refers to the position index of the glare source. E_v refers to the vertical illuminance, and the constants are defined as: $a = 5.87 \cdot 10^{-5}$, $b = 9.18 \cdot 10^{-2}$ and $c = 0.16$.

Contoured normalized density plot showing the distribution of E_v and log_gc



Lack of user experiment data (studies ongoing)

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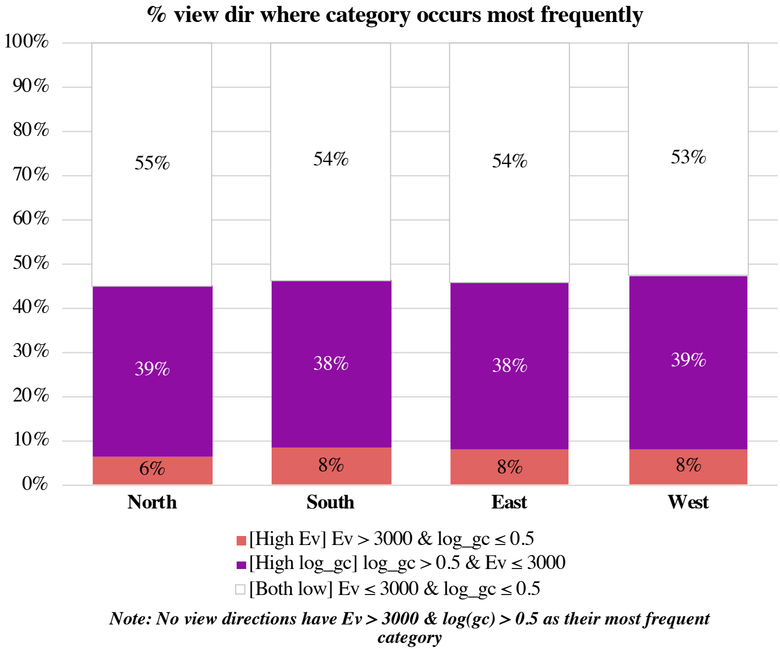

Stacked bar plot showing the percentage of space where 4 categories of luminous conditions (high/low E_v and high/low log_gc) occur most frequently for each of the 4 orientations with no urban obstruction

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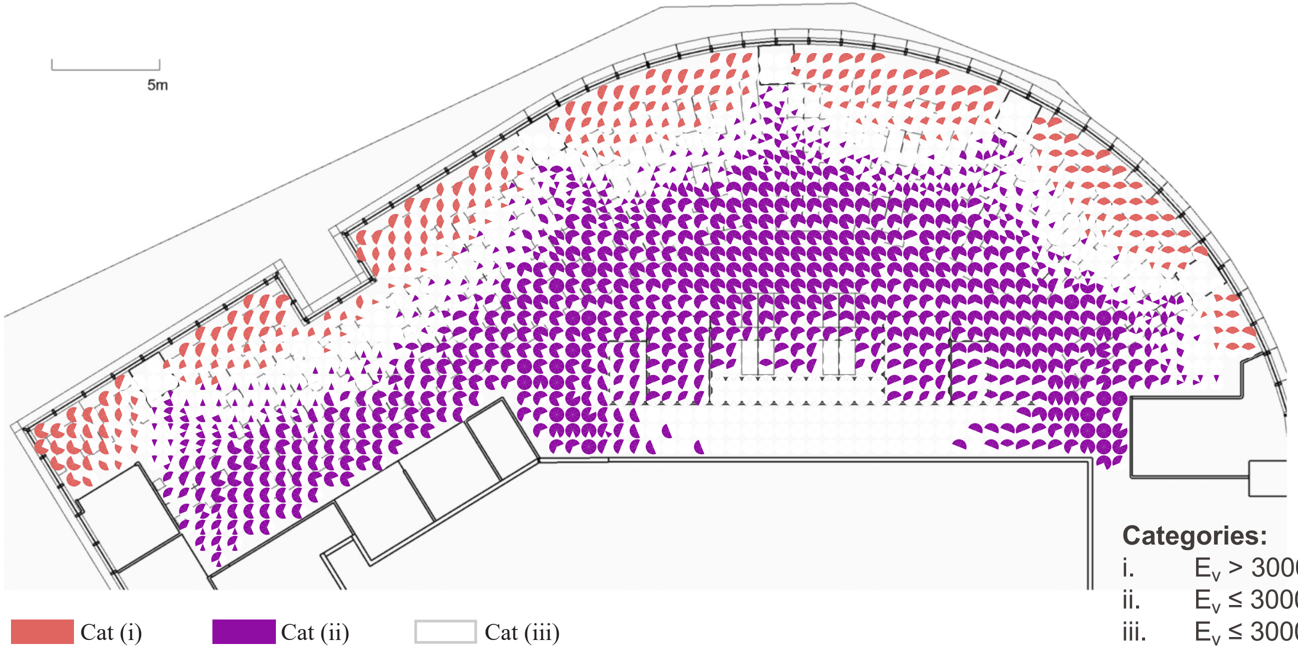
Spatial visualization where viewpoints are binned and colored by their most frequent lighting condition annually during daylit hours, for all 4 orientations with no urban obstruction



Categories:

- i. E_v > 3000 & log_gc ≤ 0.5 [High E_v]
- ii. E_v ≤ 3000 & log_gc > 0.5 [High log_gc]
- iii. E_v ≤ 3000 & log_gc ≤ 0.5 [Both low]
- iv. E_v > 3000 & log_gc > 0.5 [Both high]

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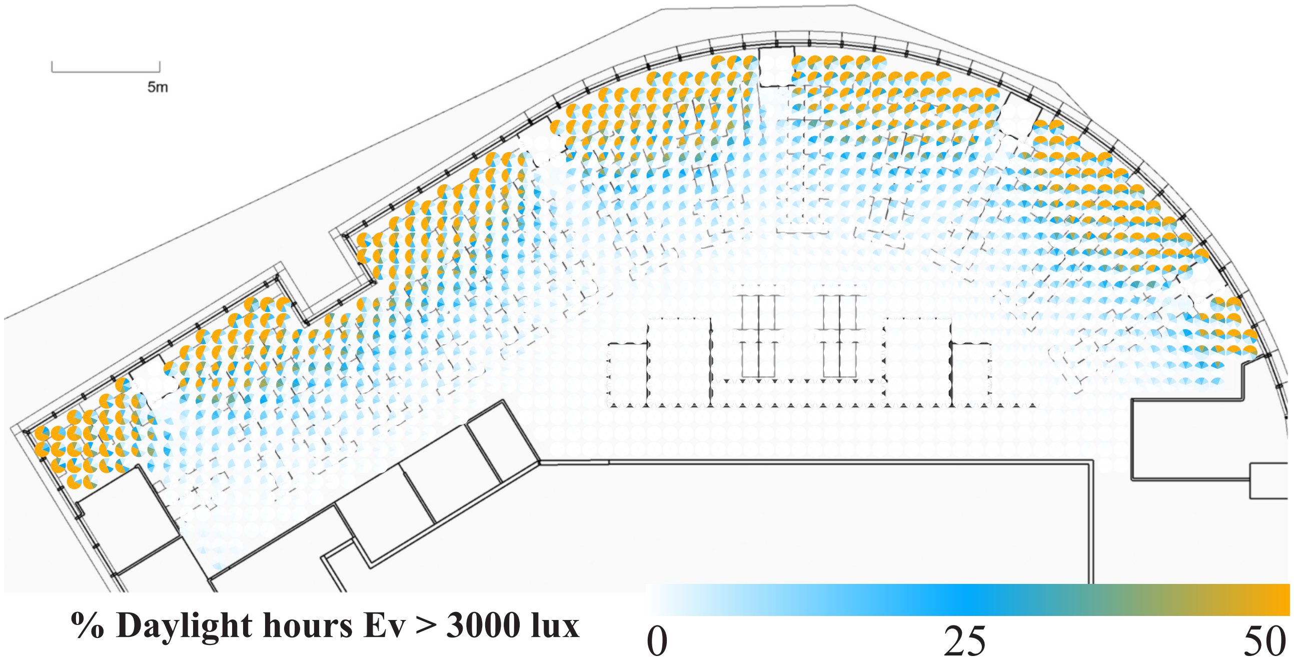
Spatial visualization illustrating the frequency of annual saturation effects represented by E_v (4 orientations, 0 degrees of urban obstruction)



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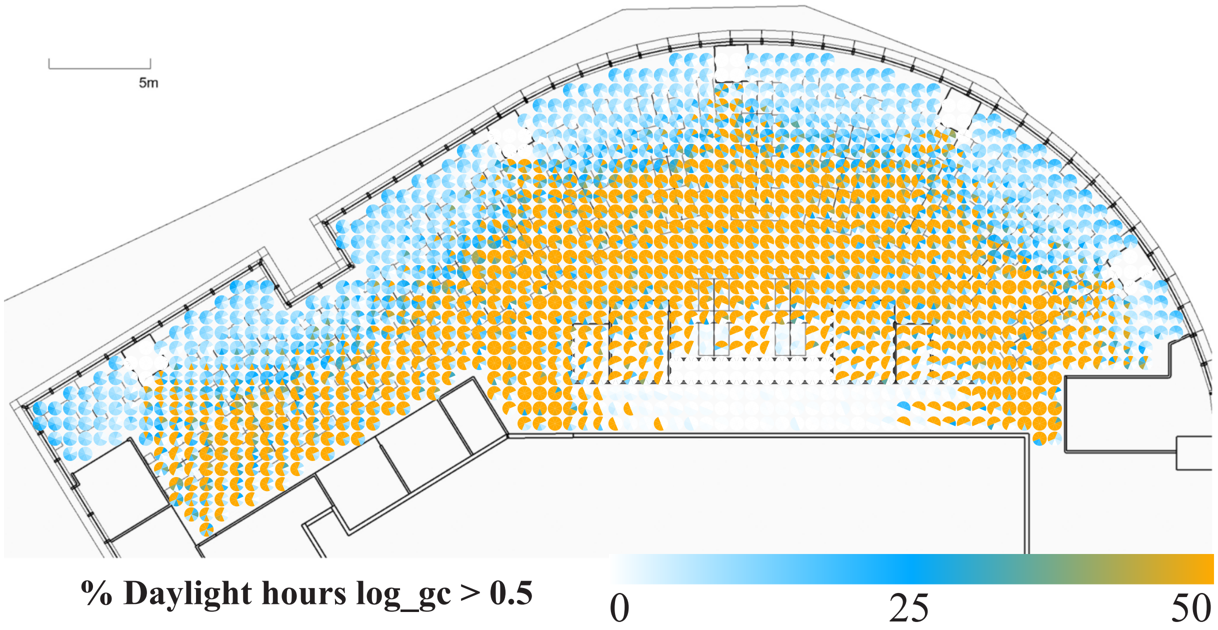
Spatial visualization illustrating the frequency of annual contrast effects represented by log_gc (4 orientations, 0 degrees of urban obstruction)



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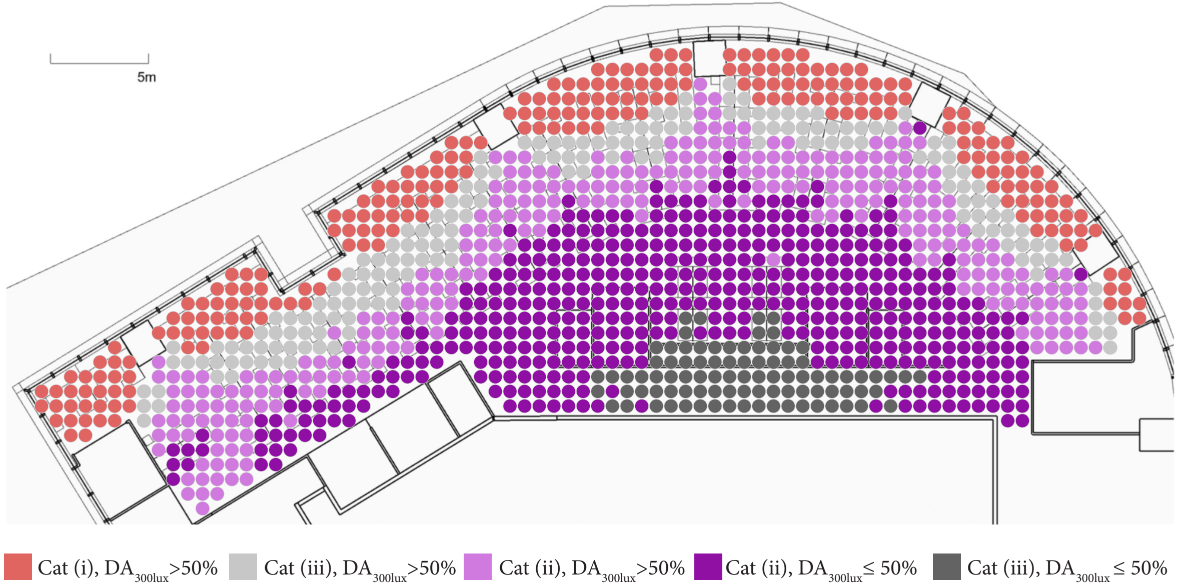
A “visual comfort” zone based on illuminance + image based metrics?

Categories:

i. $E_v > 3000$ & log_gc ≤ 0.5 [High E_v]
ii. $E_v \leq 3000$ & log_gc > 0.5 [High log_gc]
iii. $E_v \leq 3000$ & log_gc ≤ 0.5 [Both low]
iv. $E_v > 3000$ & log_gc > 0.5 [Both high]



Schematic plan showing five zones of lighting conditions, the result of coupling the three occurring glare condition categories with daylight autonomy results (300 lux)

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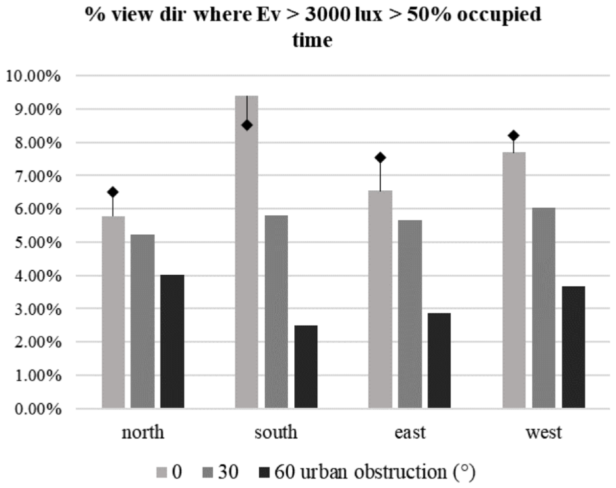

Percentage of view directions where the saturation effect of glare potentially dominates (where E_v > 3000 lux for more than 50% of daylight hours). Values are calculated based on the ClimateStudio results. Error marks on the 0° obstruction show the results from Raytraverse.

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Main conclusions:

- For the first time, we simulated the two effects of glare over a large area, as annual measurements or simulations were not feasible before

- Word of caution when relying on purely illuminance-based metrics to predict discomfort glare, especially in open-plan offices

- Level of urban obstruction is a bigger factor than orientation on the percentage of view directions with frequent high E_v conditions (for this case)

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Limitations:

- More user evaluation data is needed to establish thresholds for contrast glare (Point in time)
- Annual thresholds spatially will then have to be corroborated with on-site measurements and post-occupancy
- Validation of Raytraverse… + Learning curve?

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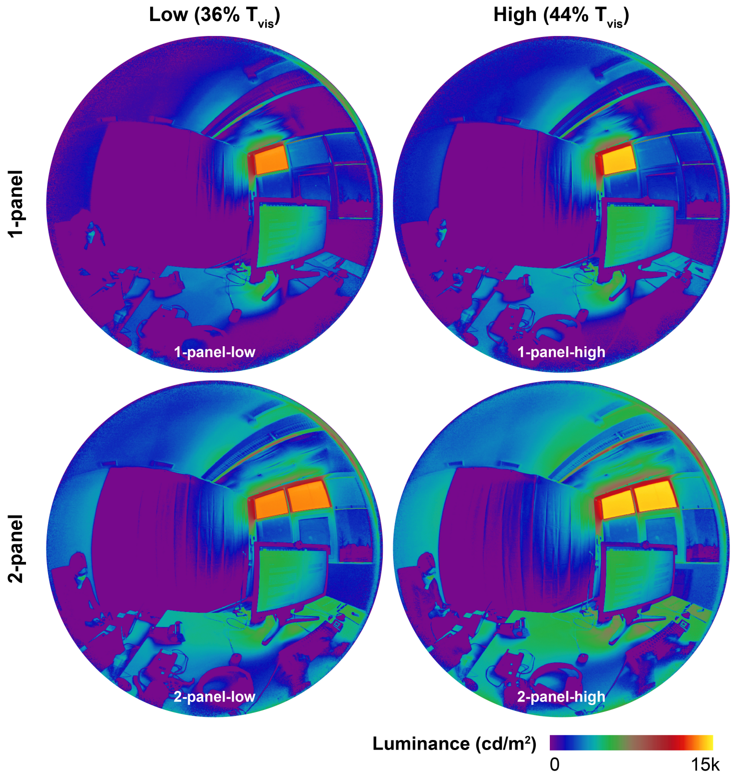
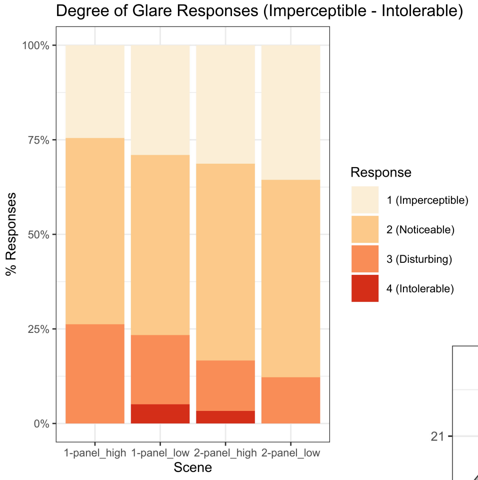
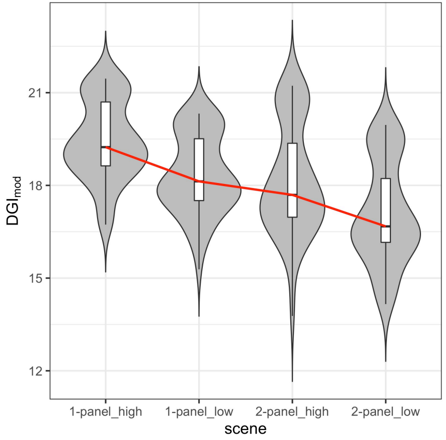
Ongoing user evaluations of contrast-dominant discomfort glare from daylight







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Thank you!

Questions are welcome.

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