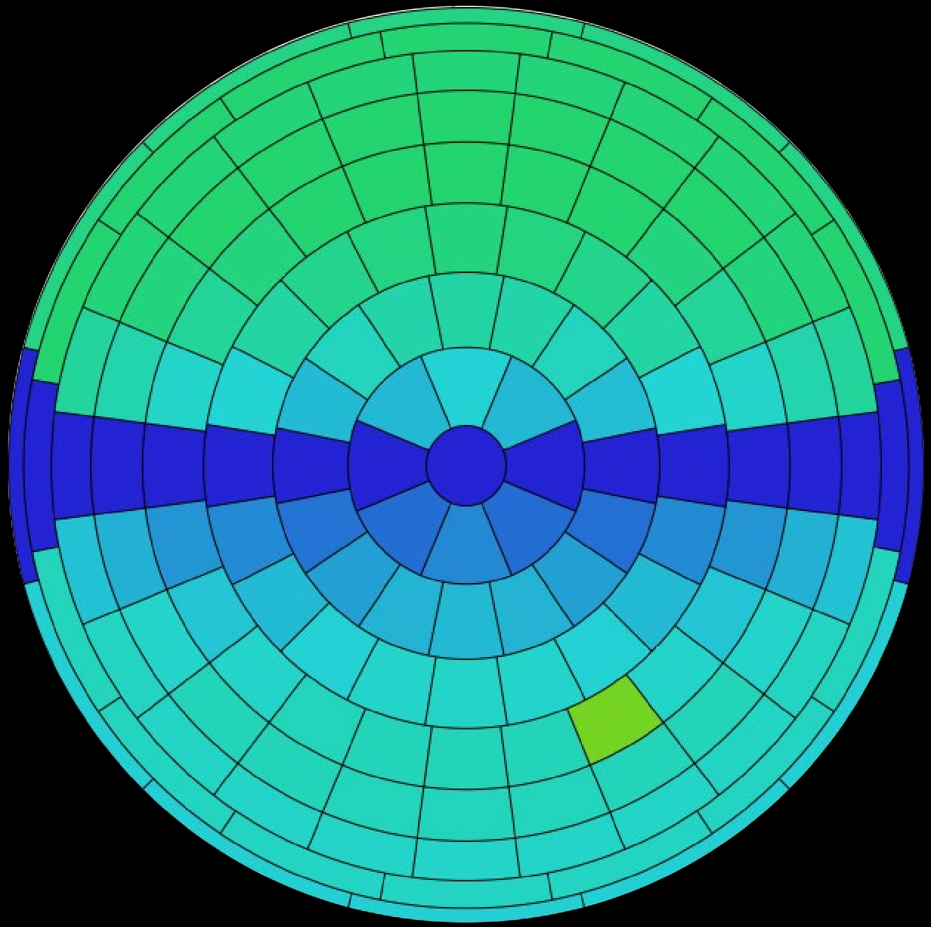
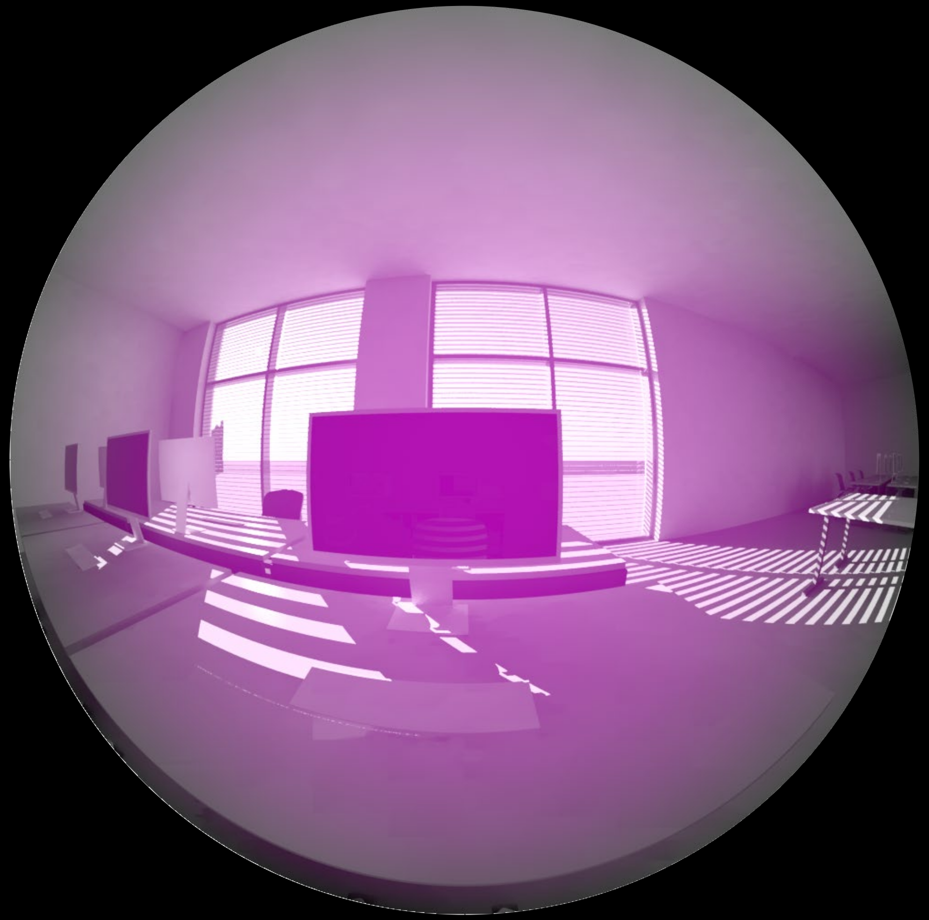
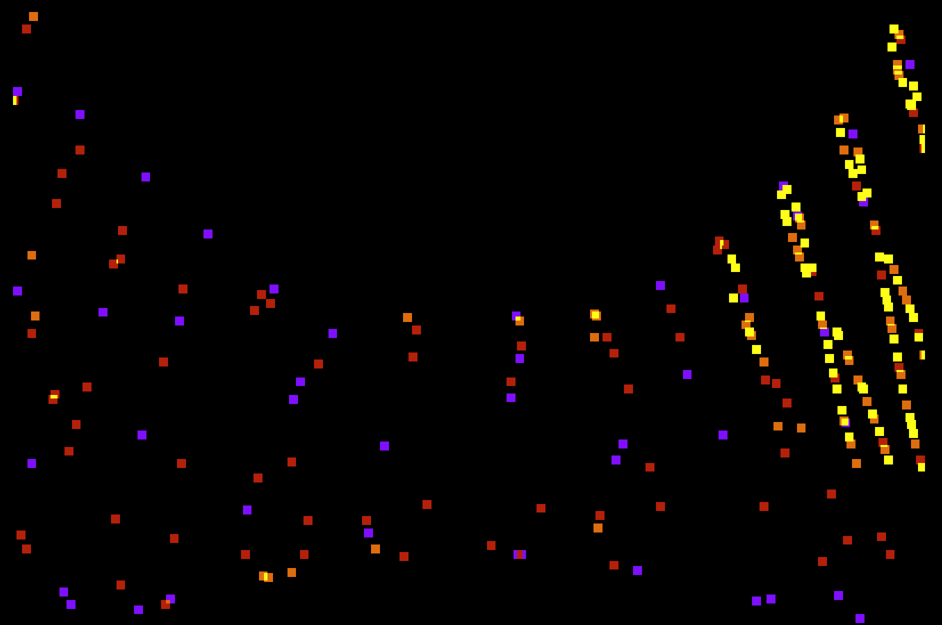
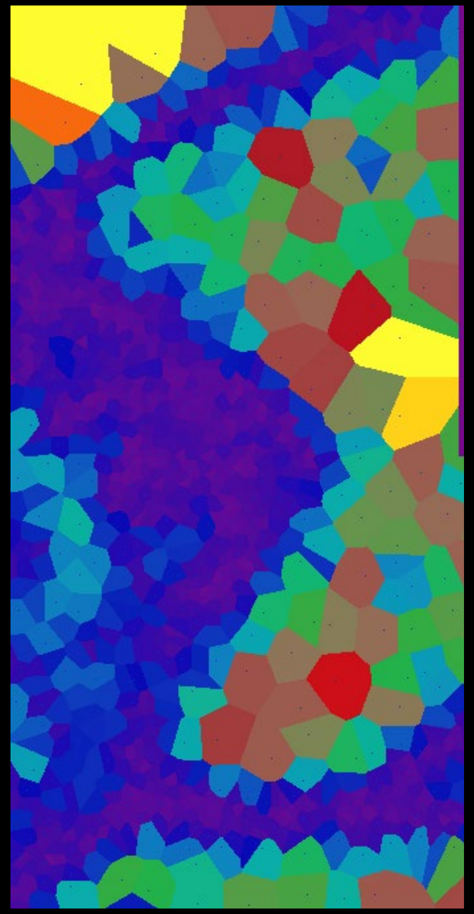
How sampling impacts the speed, accuracy, and interpretability of rendering with Radiance

Stephen Wasilewski

Outline

Part 1:

- The Dimensions of Daylight
- Sampling a Ray
  + the no ambient crache course
  + parameter testing

Part 2:

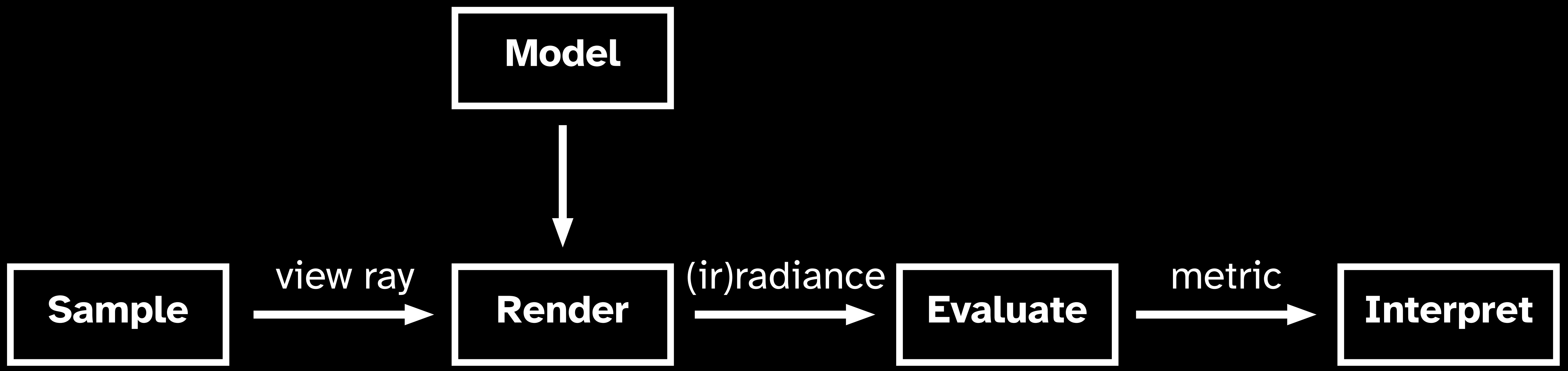
- Sampling a Point
- Sampling the Sky
  + time ⟶ angle
  + components
  + results
- Modeling Interlude
  + what do our results tell us?
- Sampling an Area

Part 3: Raytraverse

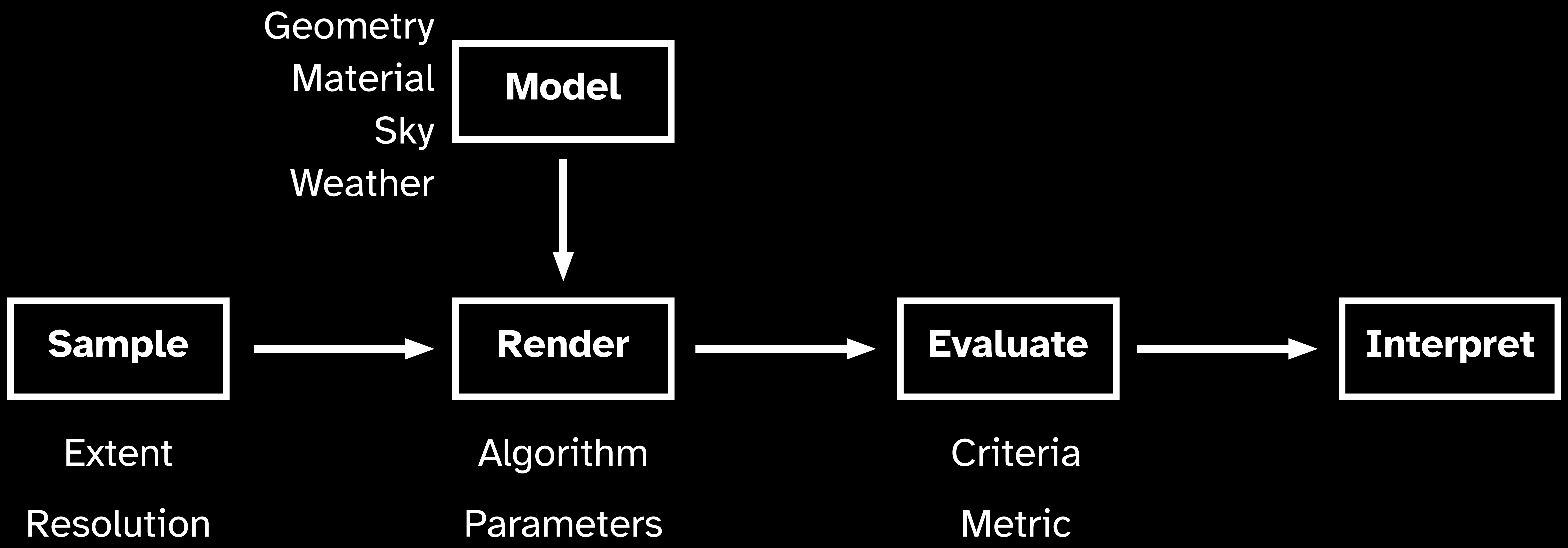
- Distribution
- Documentation
- The Command Line

the dimensions of daylight

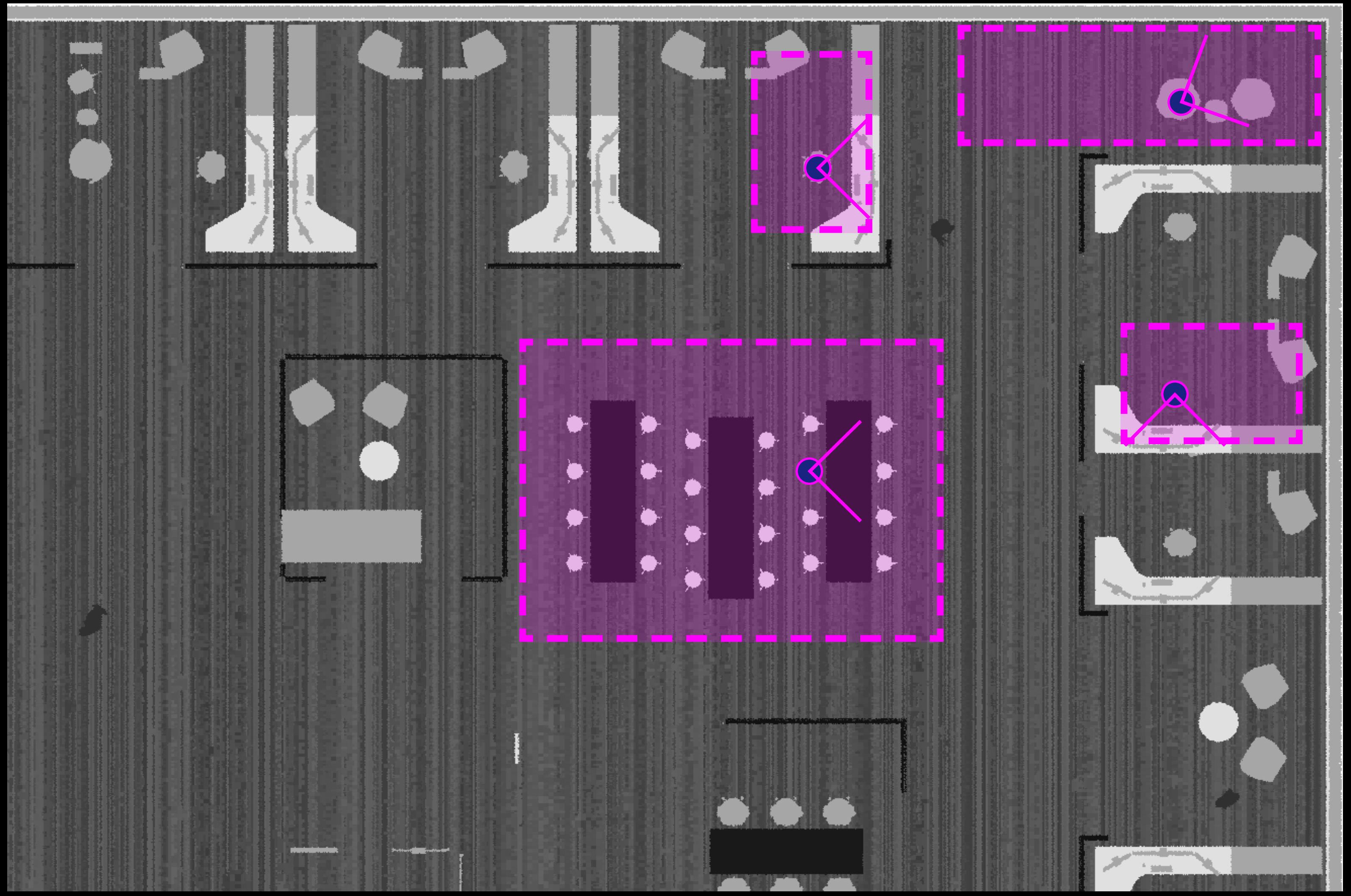
The Daylight Simulation Process



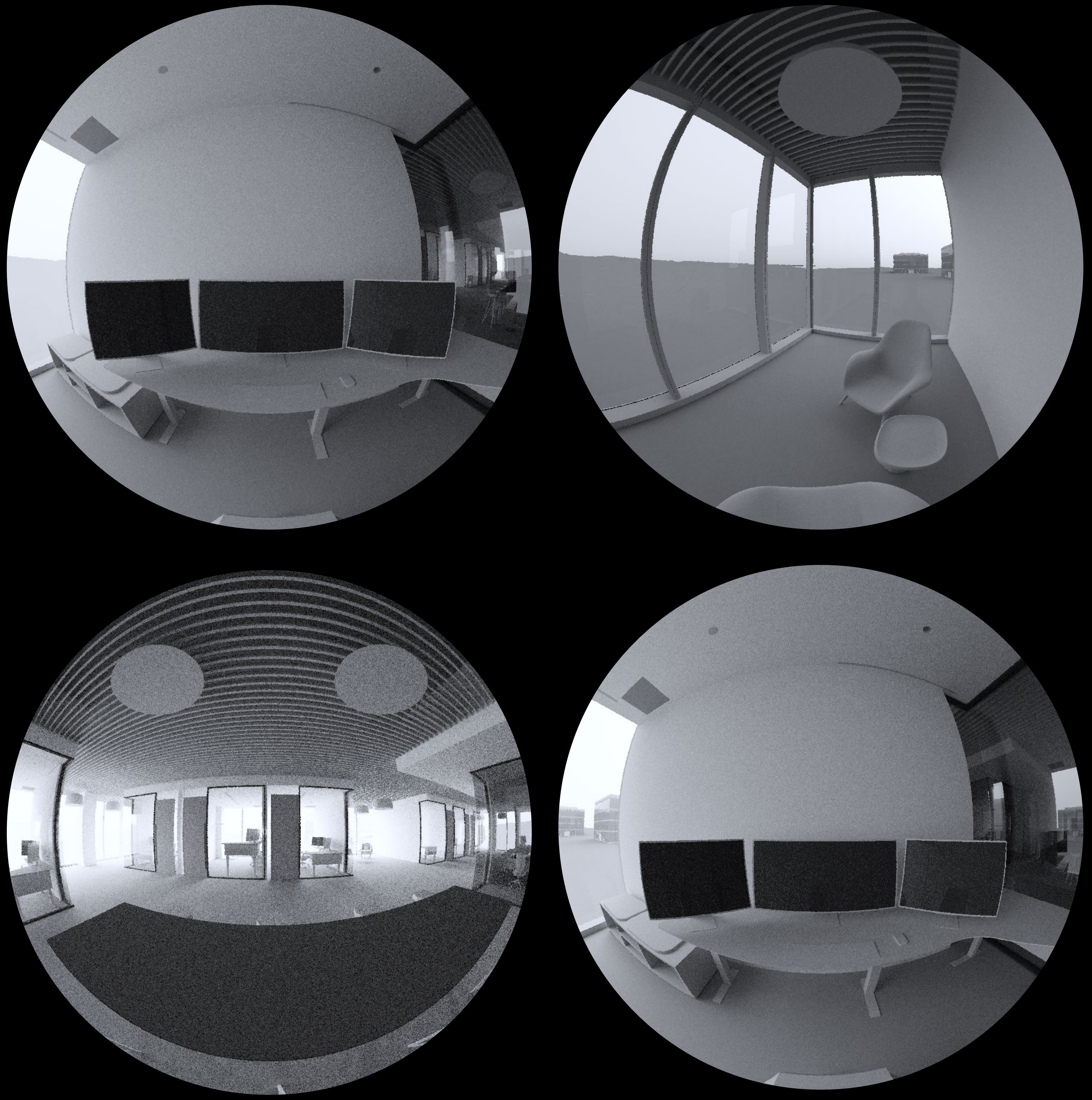
Assumptions



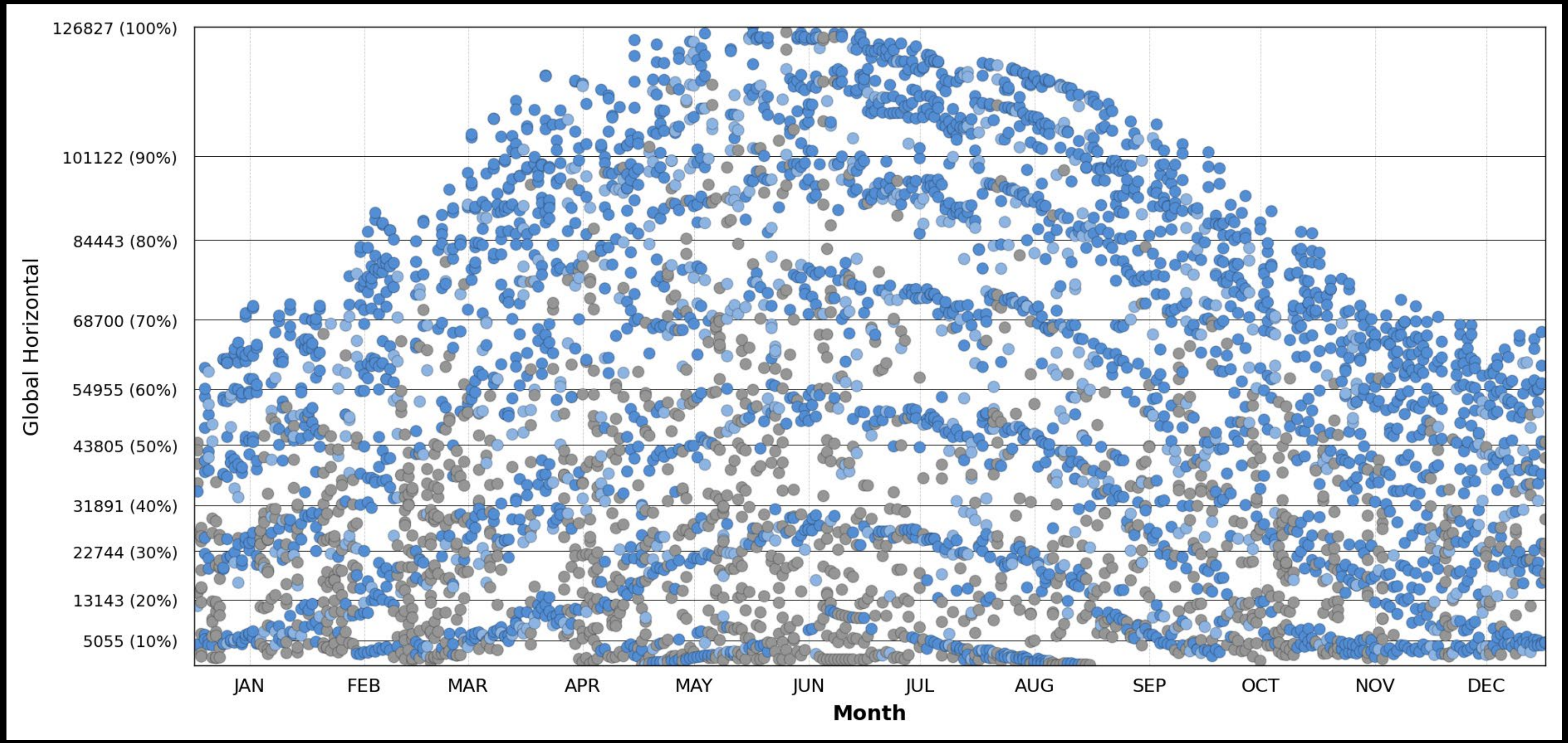
Every Simulation based analysis begins with a sampling strategy about where to look

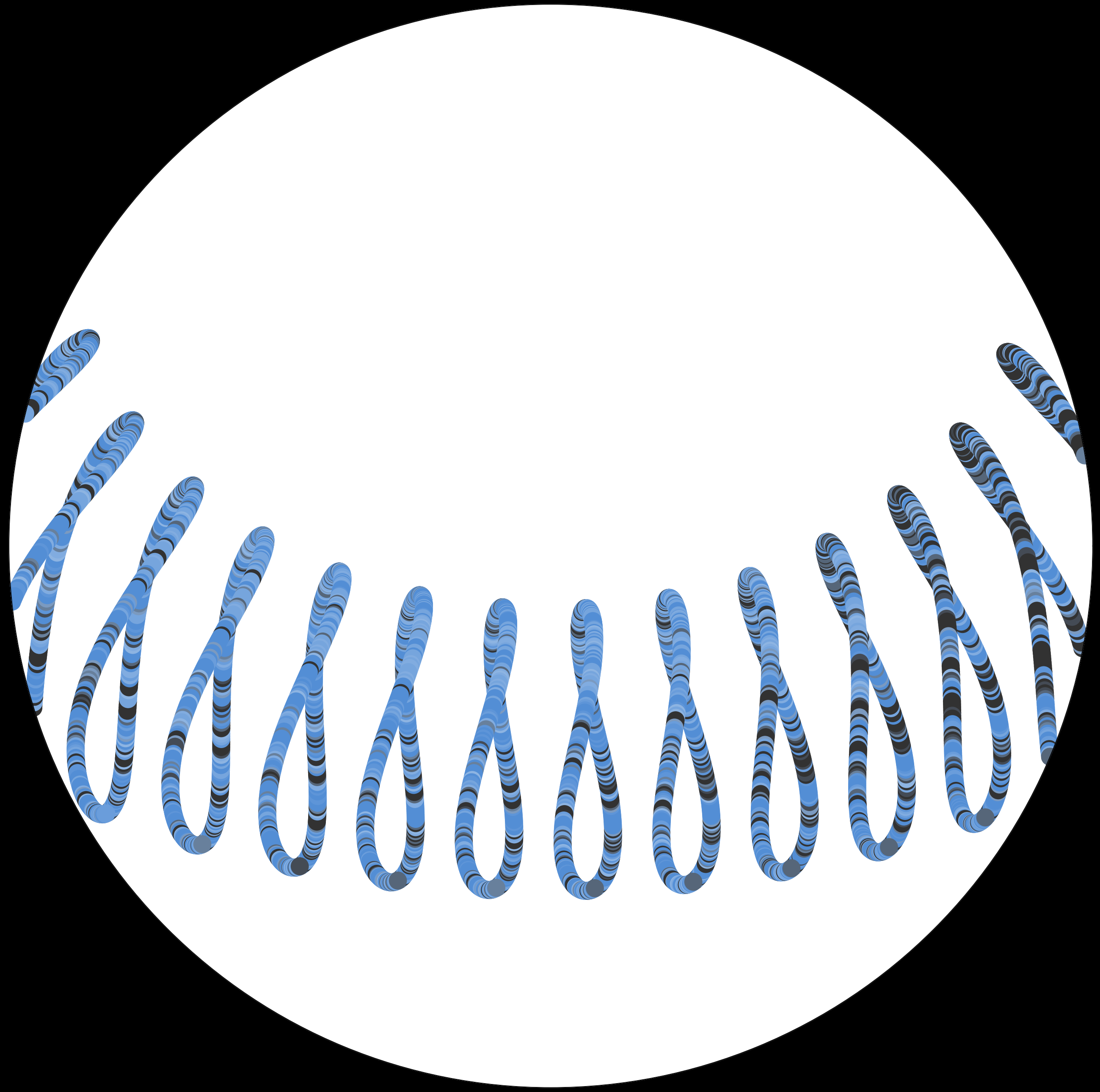


2nd Floor Southeast Corner



when to look


126827 (100%)
101122 (90%)
84443 (80%)
68700 (70%)
54955 (60%)
43805 (50%)
31891 (40%)
22744 (30%)
13143 (20%)
5055 (10%)
Global Horizontal
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Month



and what to look at

Because at useful resolutions the evaluation space is huge

point resolution: **(2ft point grid)** *<ieslm-83-12>*

x

temporal resolution: **(hours in TMY)** *<inertia from energy modeling>*

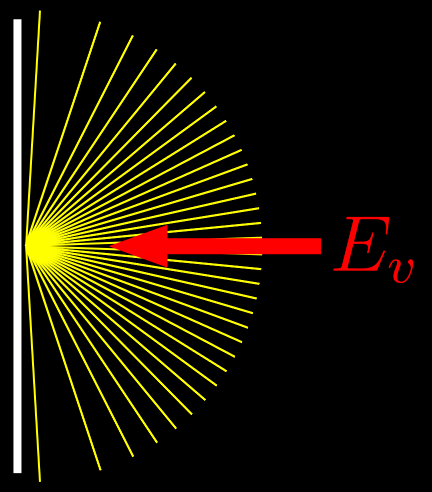
x

directional resolution: **$2\pi/10^4$ (point)** OR **$2\pi/10^6$ (image)**

---

primary rays/100 ft^2: **10^5** **10^{11}**

CBDM Methods for Visual Comfort: Illuminance (E_v) based



Model

↓

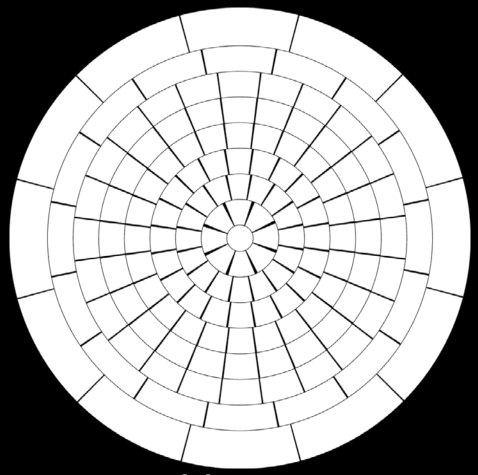
Sample → Render → Evaluate → Interpret

$A \cdot E_v + C$

?

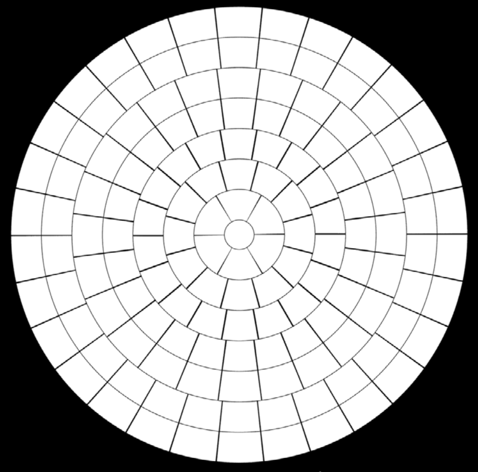
CBDM Methods for Visual Comfort: phase-based

transmission



klems

sky



tregenza/reinhart

Model

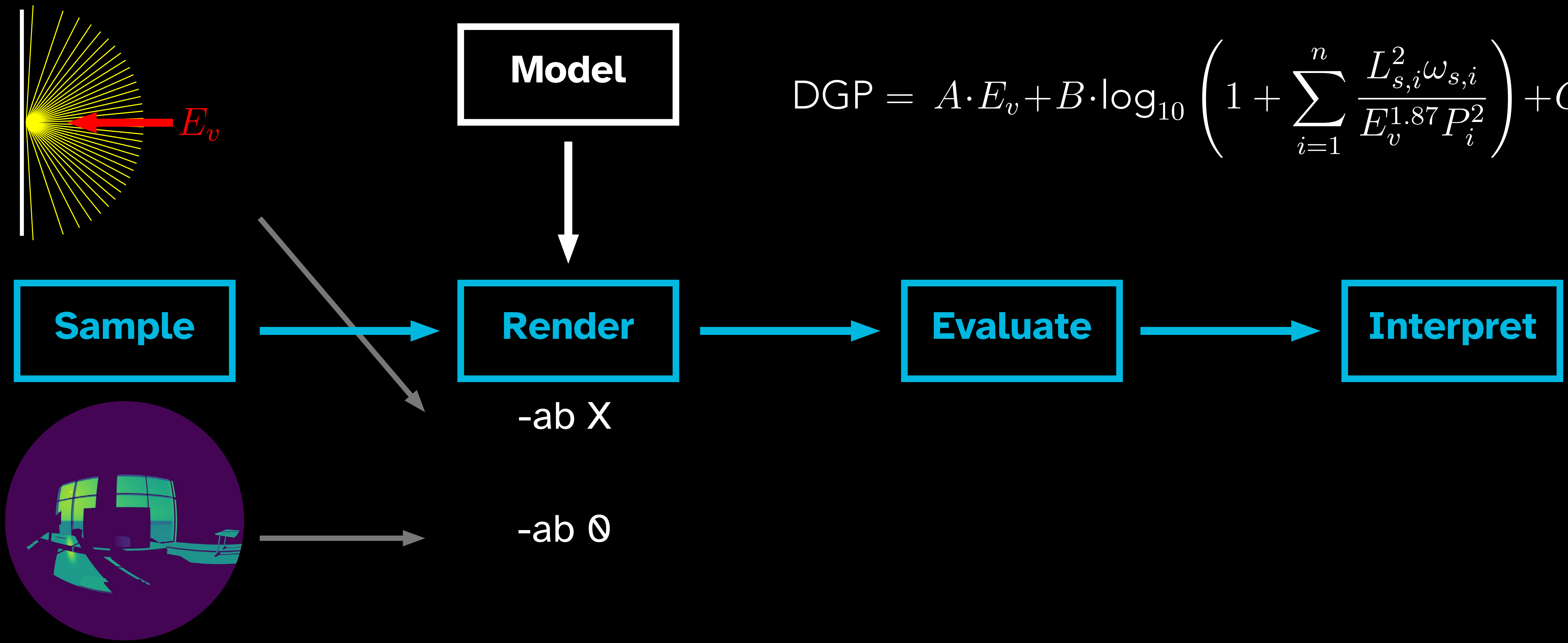
↓

Sample → **Render** → **Evaluate** → **Interpret**

indirect $\begin{bmatrix} a_1^1 & a_1^2 & \dots \\ \vdots & \ddots & \\ a_t^1 & & a_t^v \end{bmatrix}$ $\begin{bmatrix} b_1^1 & b_1^2 & \dots \\ \vdots & \ddots & \\ b_t^1 & & b_t^v \end{bmatrix}$

direct -ab 1

CBDM Methods for Visual Comfort: eDGPs



$$\text{DGP} = A \cdot E_v + B \cdot \log_{10}\left(1 + \sum_{i=1}^{n} \frac{L_{s,i}^2 \omega_{s,i}}{E_v^{1.87} P_i^2}\right) + C$$

sampling a ray

13th International Radiance Workshop 2014
London, UK
1-3 September 2014

RADIANCE

No ^Ambient Cache ^Calculation

CRASH COURSE

John Mardaljevic

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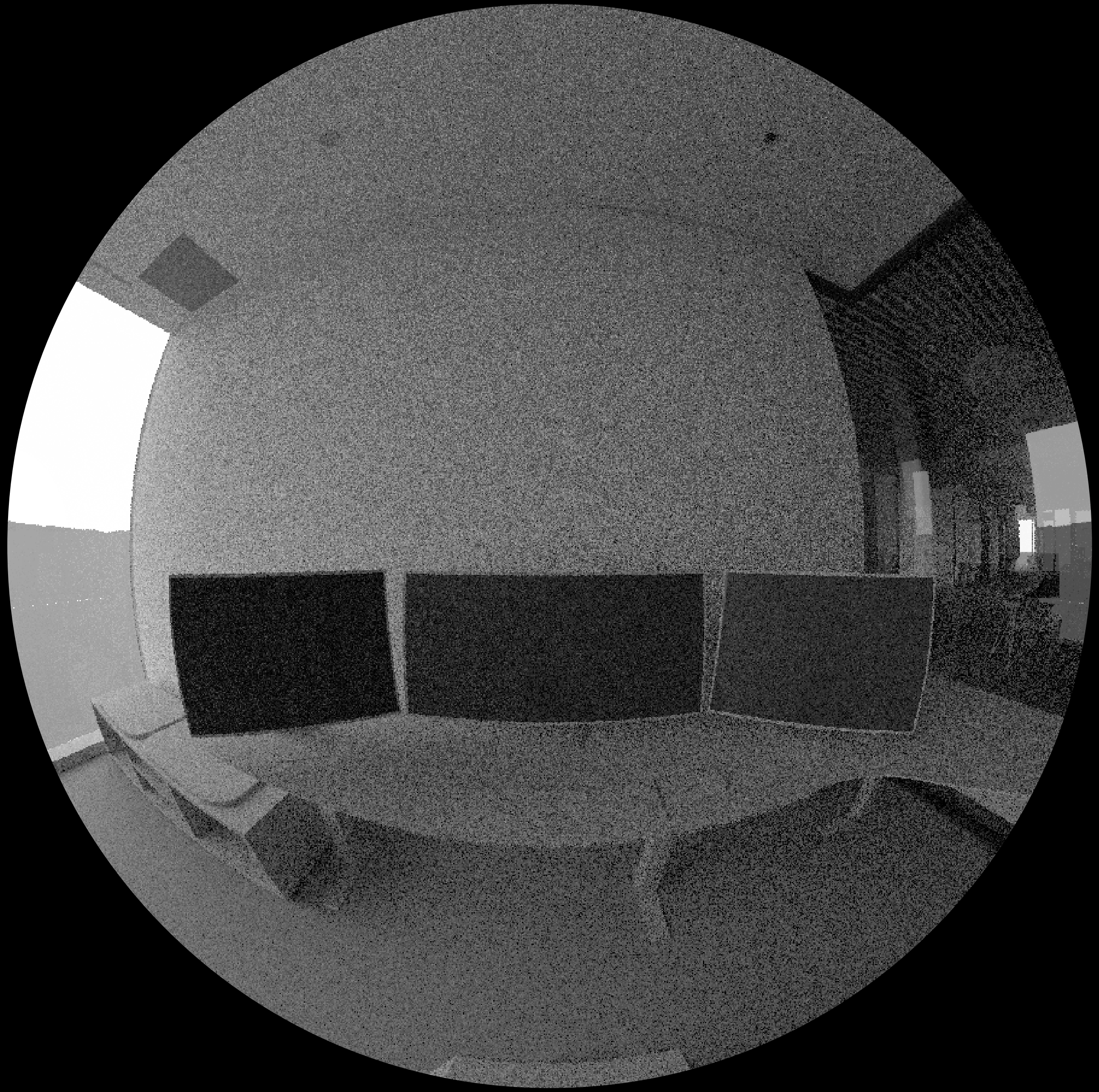
School of Civil & Building Engineering
Loughborough University, UK

ROYAL ACADEMY OF ENGINEERING
Centre of Excellence for Sustainable Building Design

Loughborough University

It is Every Ray for Itself

w/ cache



w/o cache

-lw behaves very differently

```c
static int
ambsample(		/* initial ambient division sample */
  AMBHEMI *hp,
  int i,
  int j,
  int n
)
```

• • •

```c
  if (ambacc > FTINY)
    setcolor( col: ar.rcoef, AVGREFL, AVGREFL, AVGREFL);
  else
    copycolor( c1: ar.rcoef,  c2: hp->acoef);
  if (rayorigin(&ar, AMBIENT, hp->rp, ar.rcoef) < 0)
    return(0);
  if (ambacc > FTINY) {
    multcolor( c1: ar.rcoef,  c2: hp->acoef);
    scalecolor( col: ar.rcoef,  sf: 1./AVGREFL);
  }
```

w/ cache	w/o cache
ambient divisions do not decay rayweight	ambient divisions do decay rayweight

so -ad does too

```
static AMBHEMI *
samp_hemi(          /* sample indirect hemisphere */
  COLOR rcol,
  RAY *r,
  double  wt
)
```

• • •

```
            /* set number of divisions */
  if (ambacc <= FTINY &&
      wt > (d = 0.8*intens(rcol)*r->rweight/(ambdiv*minweight)))
    wt = d;      /* avoid ray termination */
  n = sqrt(ambdiv * wt) + 0.5;
  i = 1 + (MINADIV-1)*(ambacc > FTINY);
  if (n < i)      /* use minimum number of samples? */
    n = i;
            /* allocate sampling array */
  hp = (AMBHEMI *)malloc( size: sizeof(AMBHEMI) + sizeof(AMBSAMP)*(r
```

	w/ cache	w/o cache
`wt > (d = ...)`		< 1/ambdiv after first ambient bounce
`i = 1 + (MINADIV-1)*(ambacc > FTINY);`	equals 7	equals 1
`n = i;`		always true after first ambient bounce
First Ambient Intersection:	up to the nearest square number to ambdiv	up to the nearest square number to ambdiv
Subsequent:	decays with reflectance to 49	1

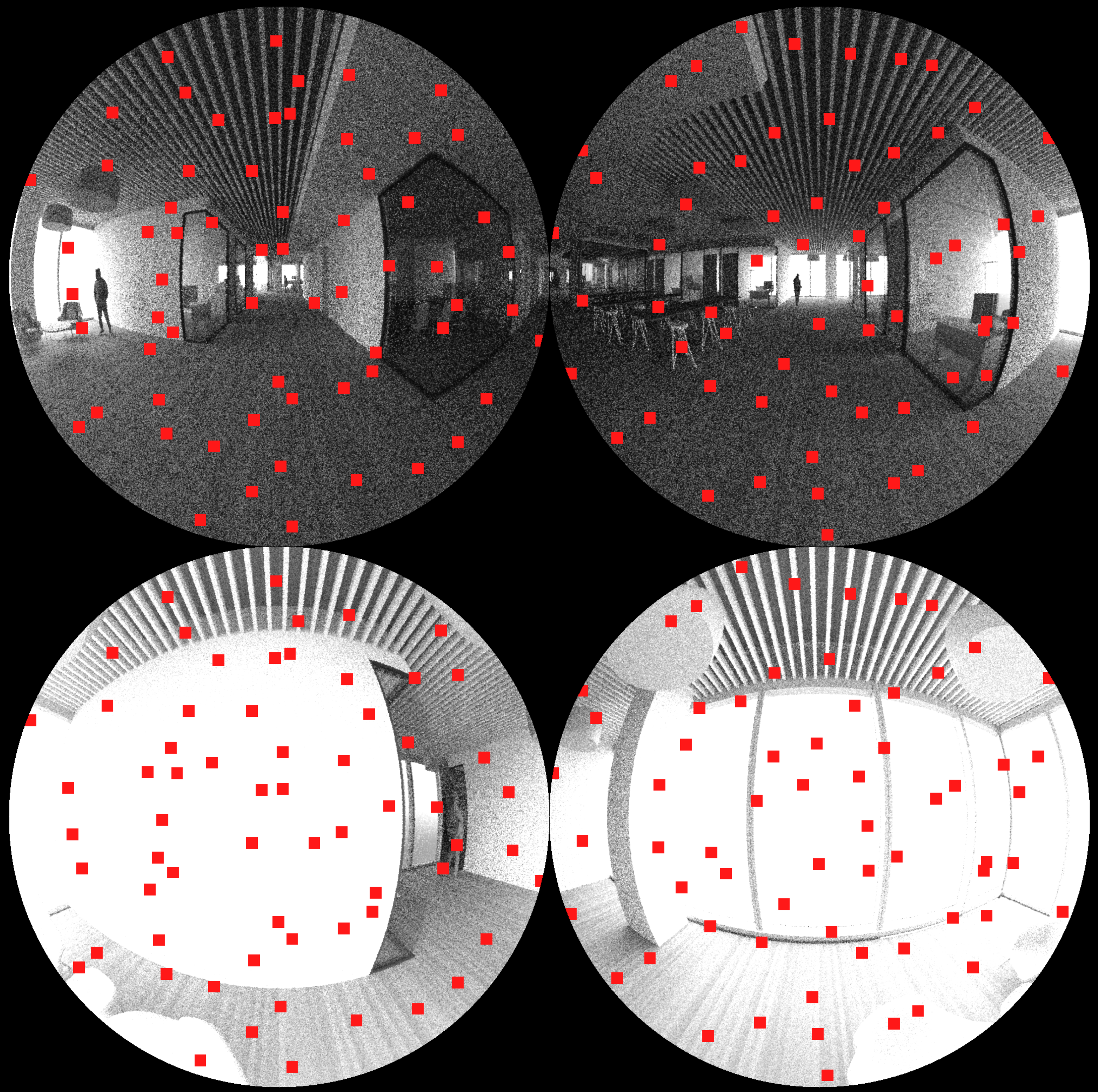
Key Parameters with -aa 0

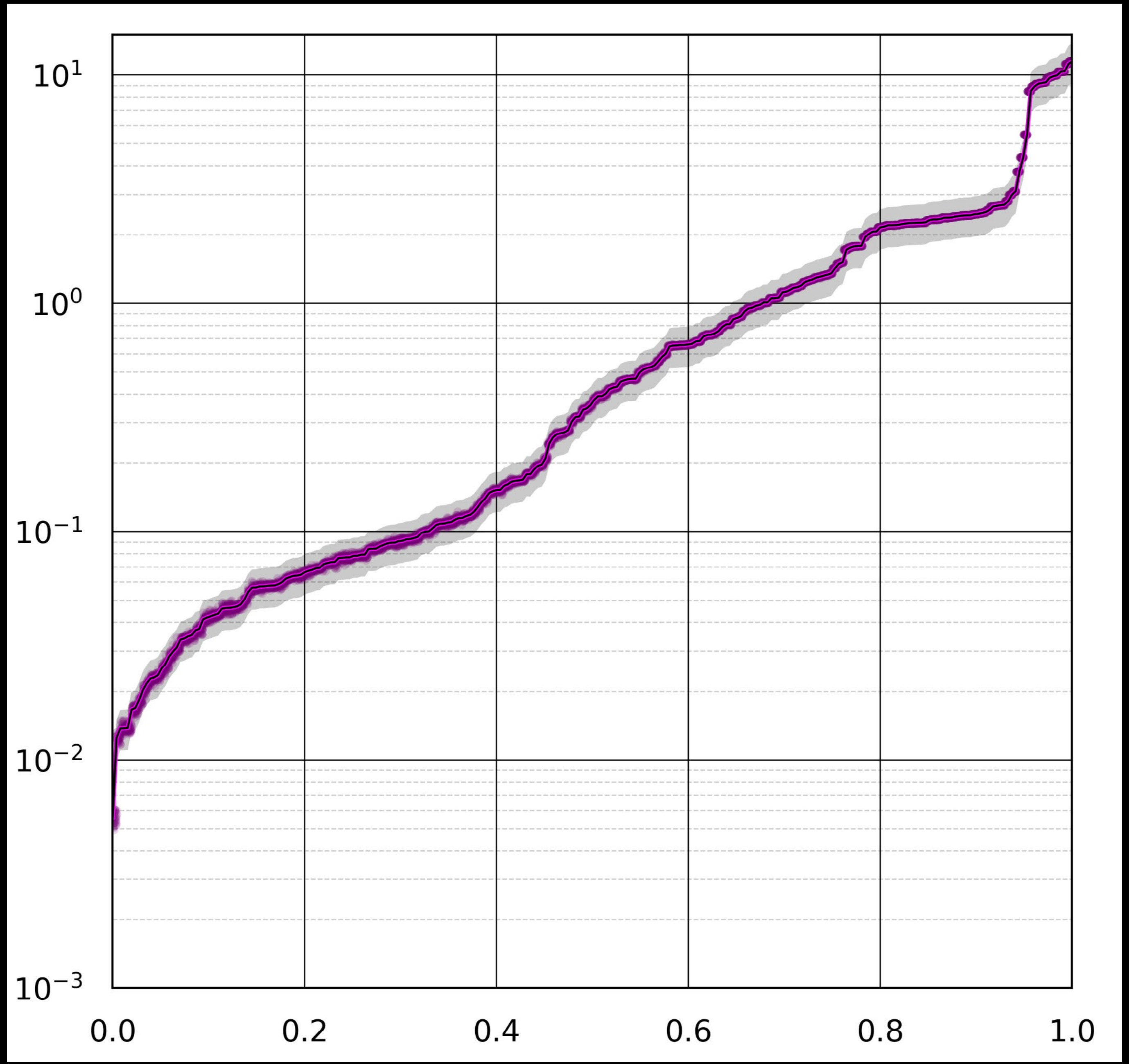
-ad: the only remaining resolution parameter

-lr: can be used instead of -ab to limit ray-depth. by setting negative avoids some bias from a hard cutoff

-lw : if this is too big, -ad and -lr will not behave intuitively. if it is too small time is wasted on very small contributions

Determining Settings: Image Based



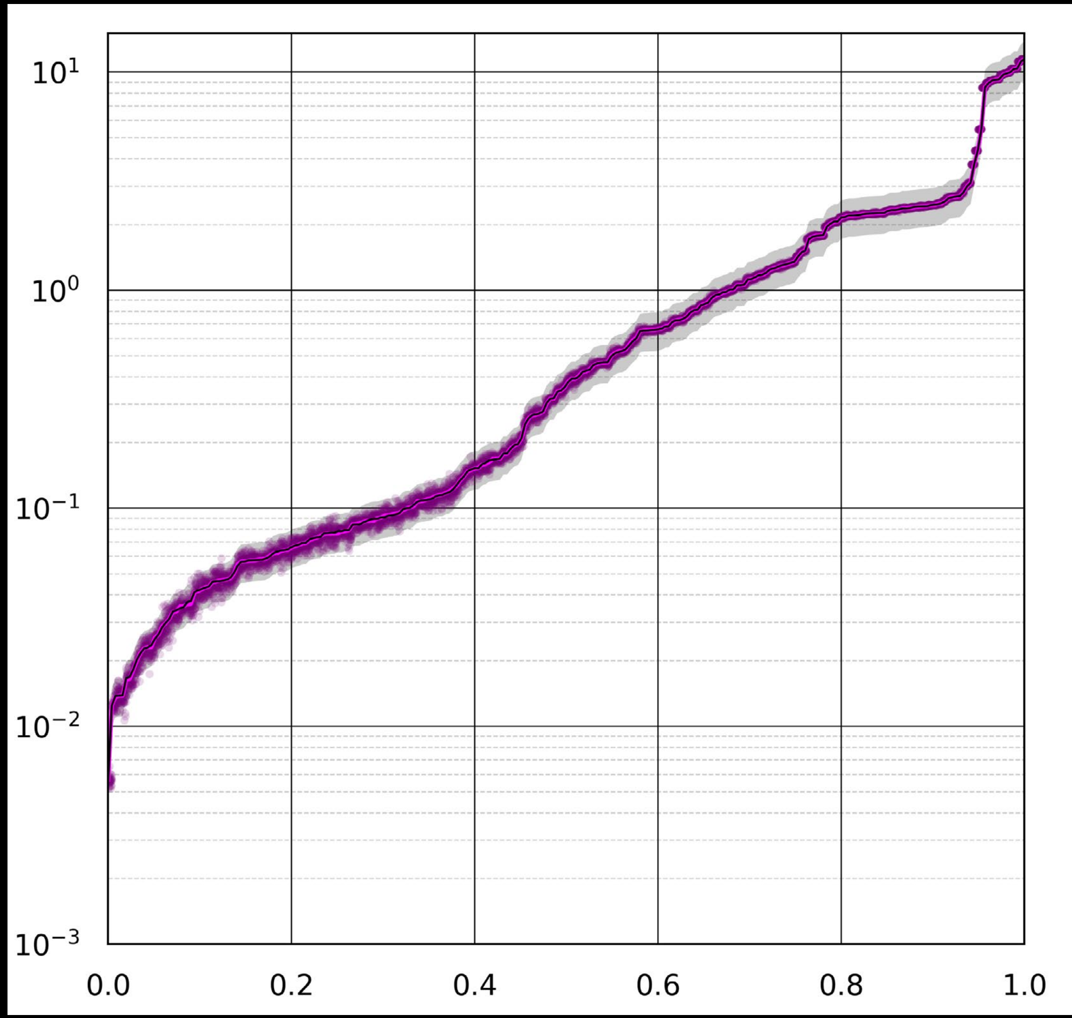


benchmark: -ad 4000 -lw 1e-5 -lr -14

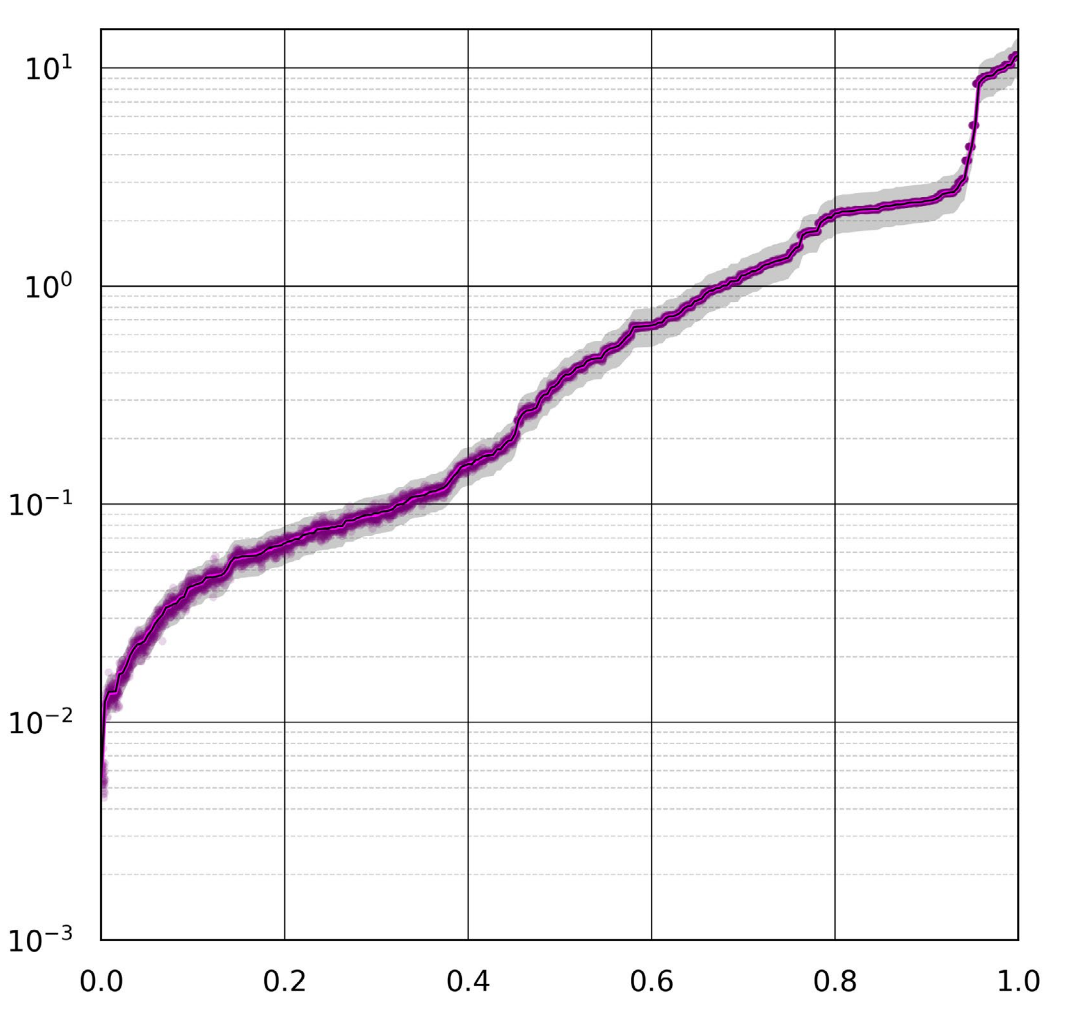
repeated 8 x 32 times samp/sec: 1.0

rRMSD: 0.012 rMSD: 0.000

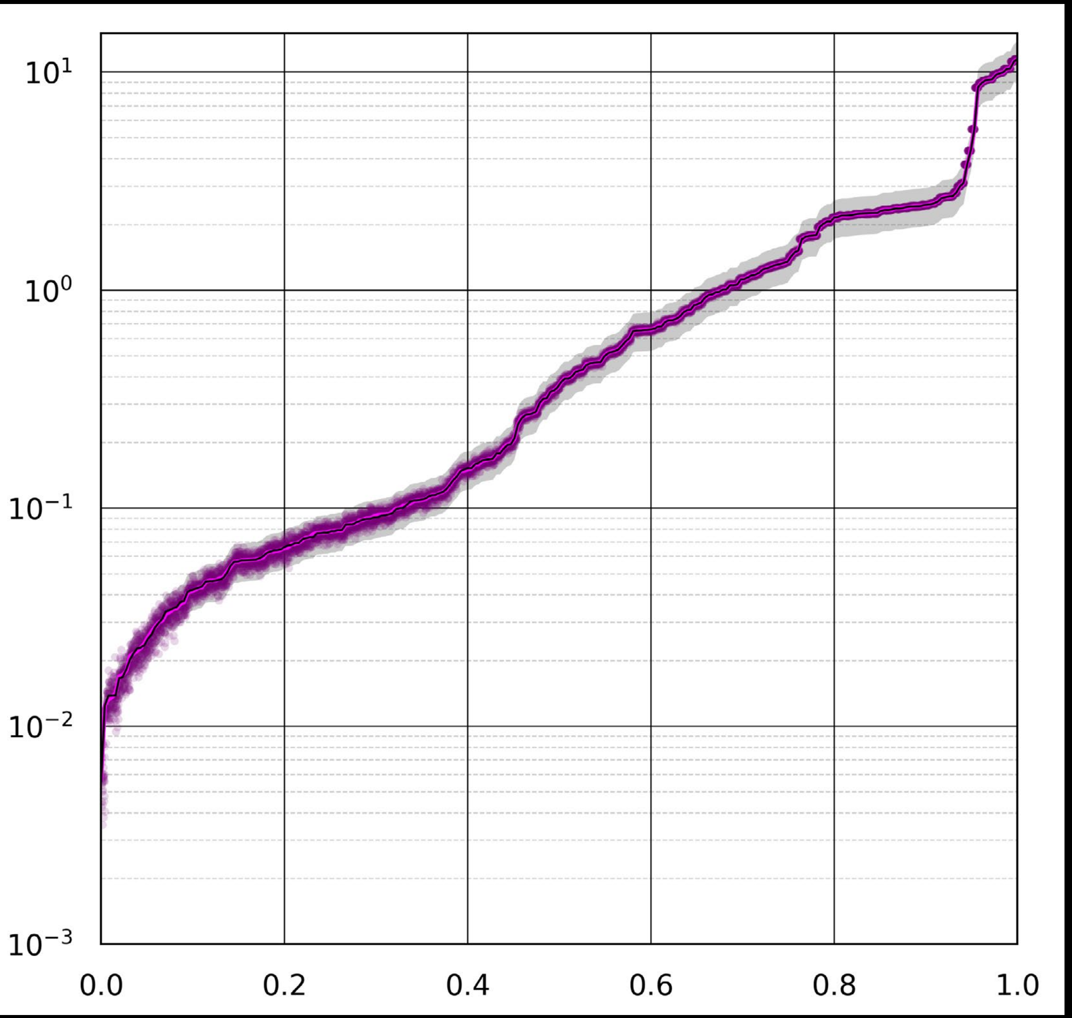
changing -lw (increasing count for equal time)



-ad 4000 -lw 1e-6 -lr -14
repeated 1x32 times samp/sec: 3.7
rRMSD: 0.032 rMSD: -0.001

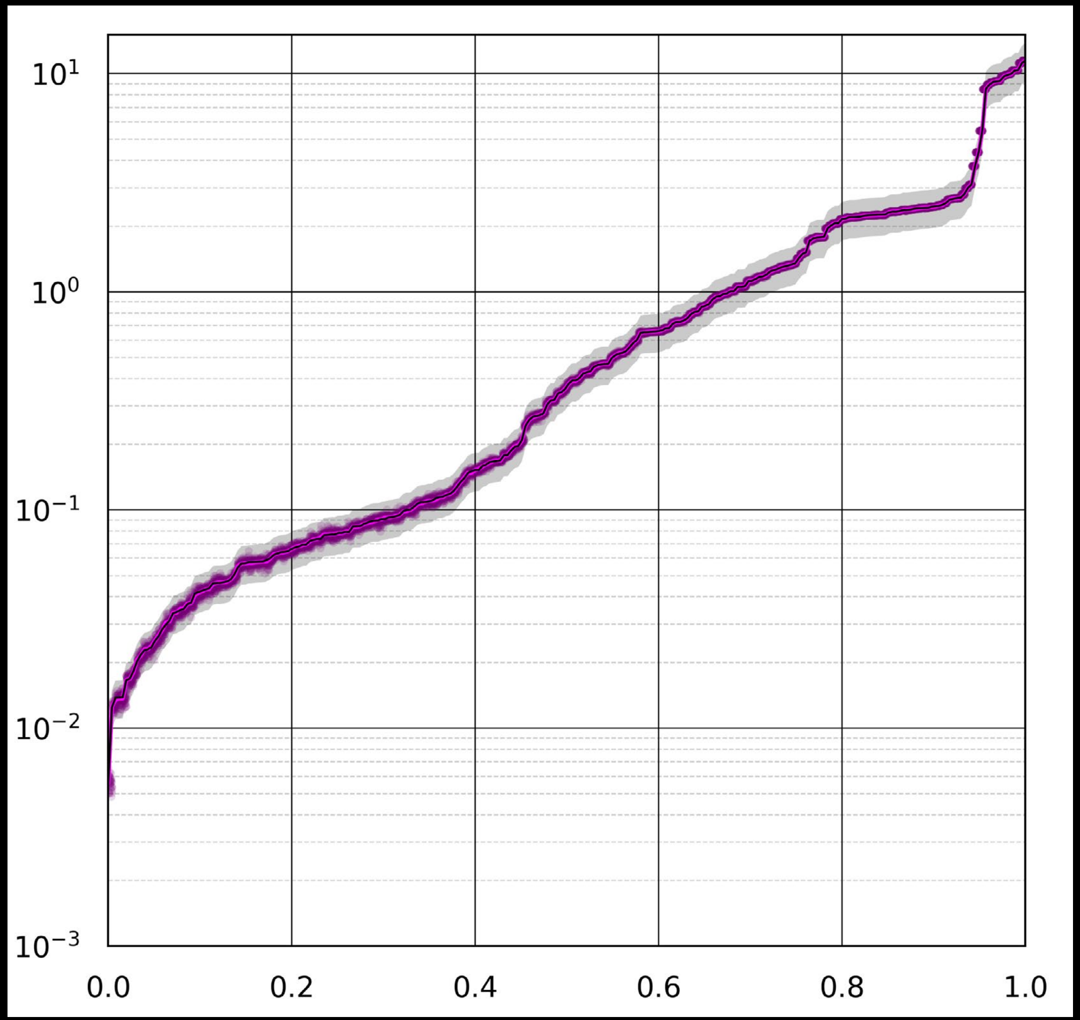


-ad 4000 -lw 1e-5 -lr -14
repeated 2x32 times samp/sec: 3.9
rRMSD: 0.024 rMSD: 0.000

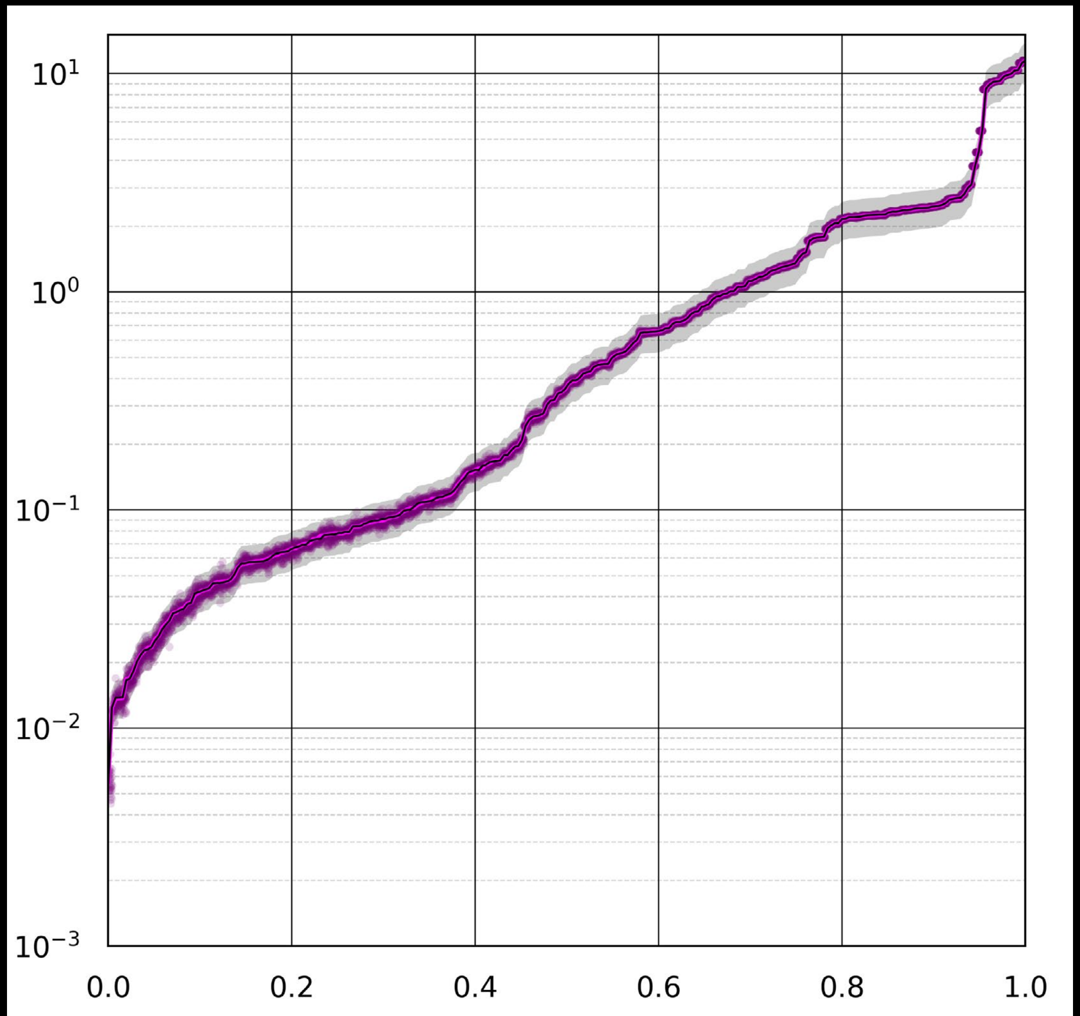


-ad 4000 -lw 1e-4 -lr -14
repeated 5x32 times samp/sec: 3.9
rRMSD: 0.034 rMSD: 0.000

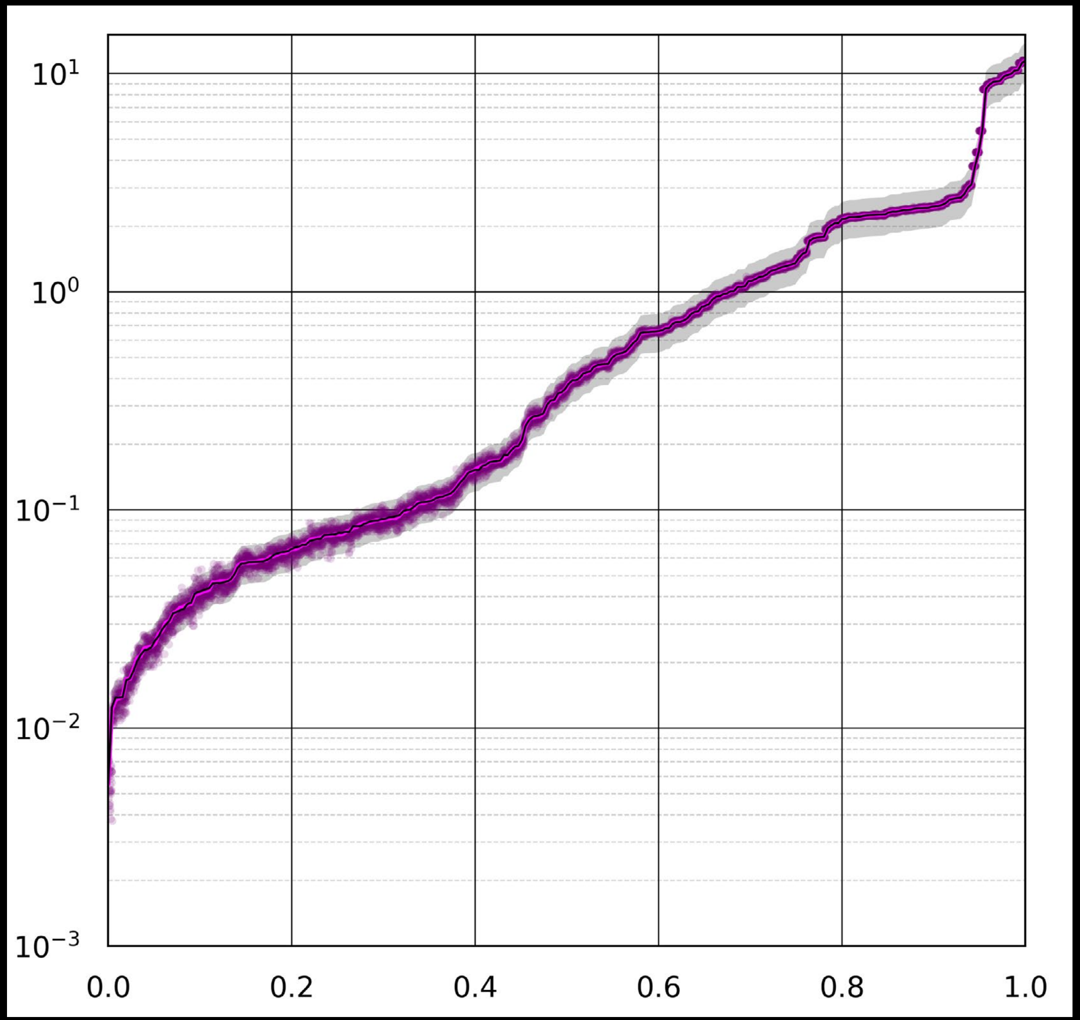
Reduce Oversampling



-ad 4000 -lw 1e-5 -lr -14
repeated 4 x 32 times samp/sec: 1.8
rRMSD: 0.017 rMSD: 0.000

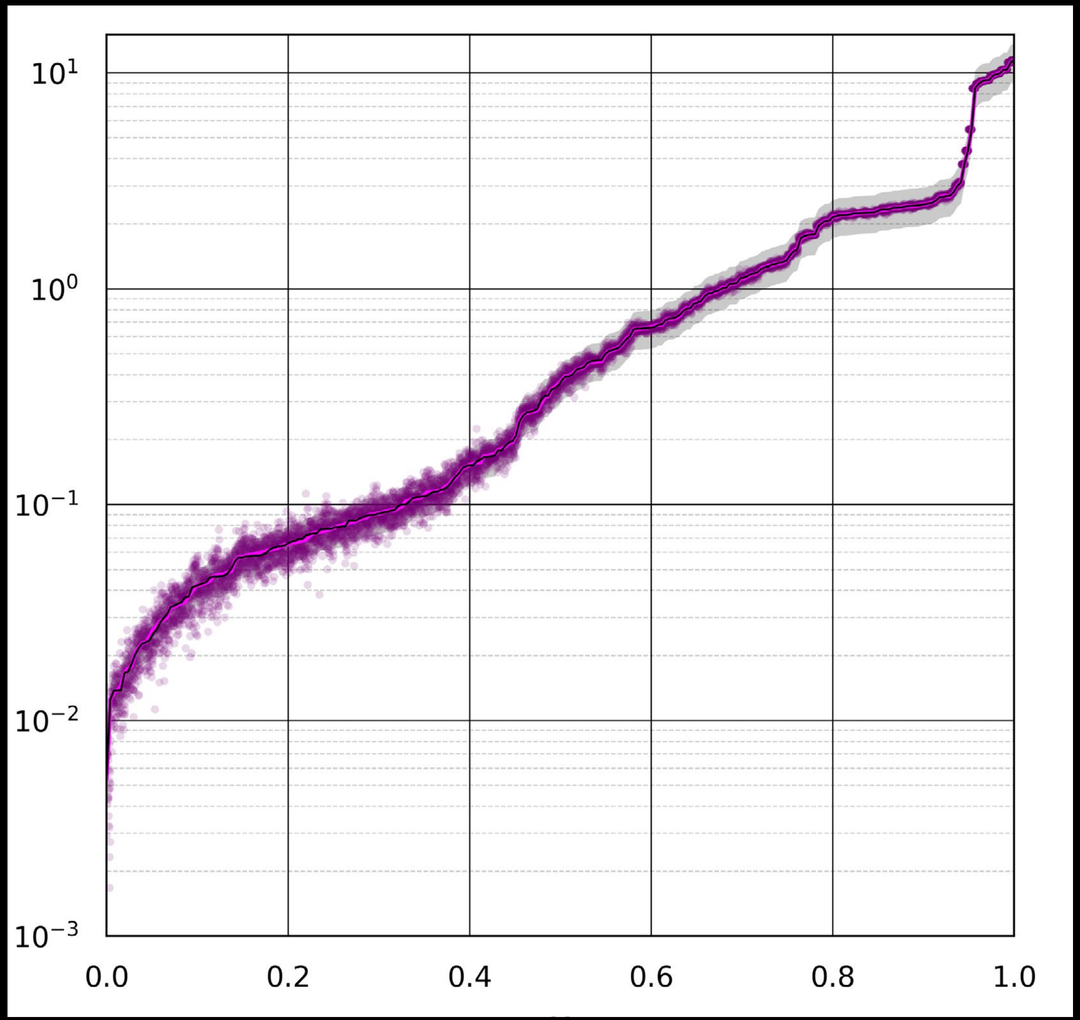


-ad 4000 -lw 1e-5 -lr -14
repeated 2 x 32 times samp/sec: 3.9
rRMSD: 0.024 rMSD: 0.000



-ad 4000 -lw 1e-5 -lr -14
repeated 1 x 32 times samp/sec: 8.5
rRMSD: 0.035 rMSD: 0.000

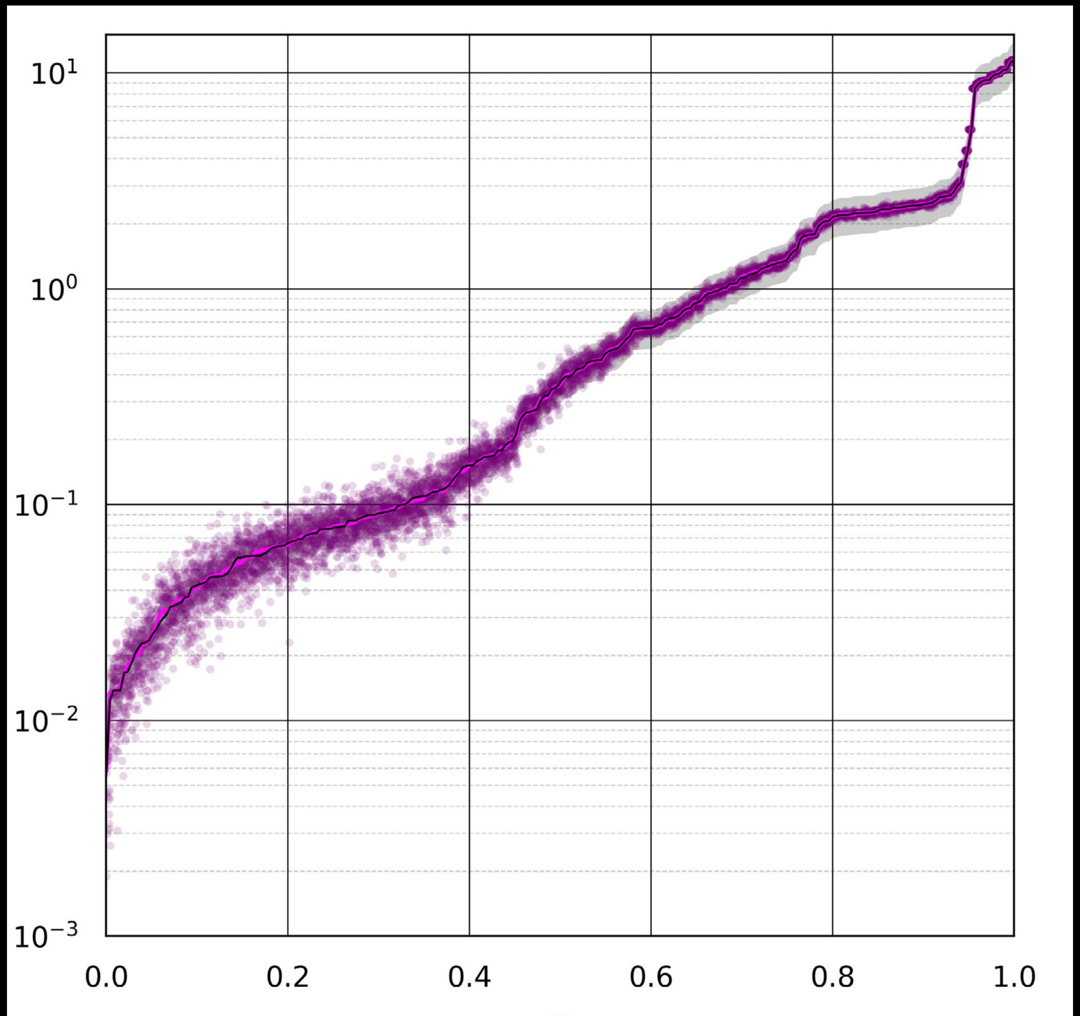
Reduce -ad (proportionally adjust -lw)



-ad 1000 -lw 4e-5 -lr -14

repeated 32 times samp/sec: 32.7

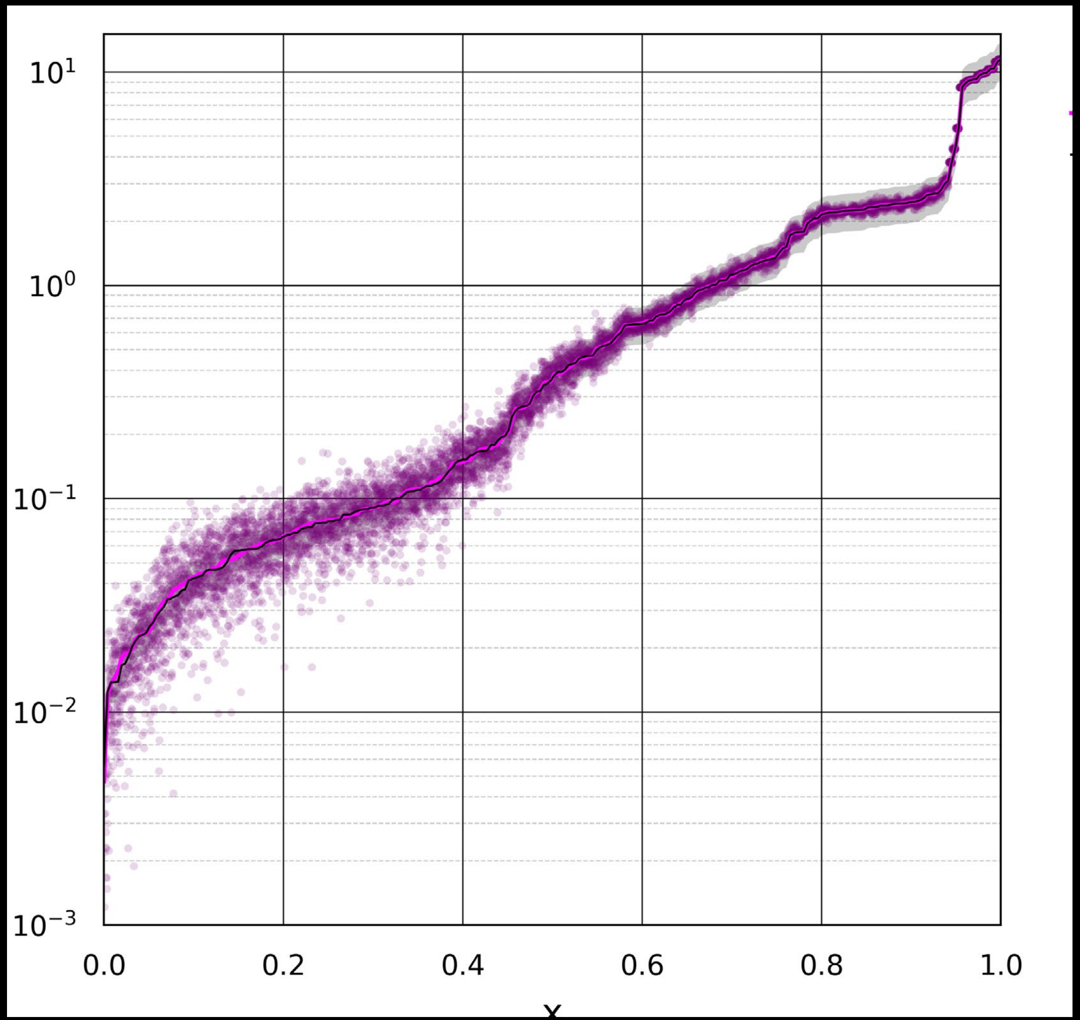
rRMSD: 0.072 rMSD: 0.000



-ad 500 -lw 8e-5 -lr -14

repeated 32 times samp/sec: 66.1

rRMSD: 0.108 rMSD: 0.002

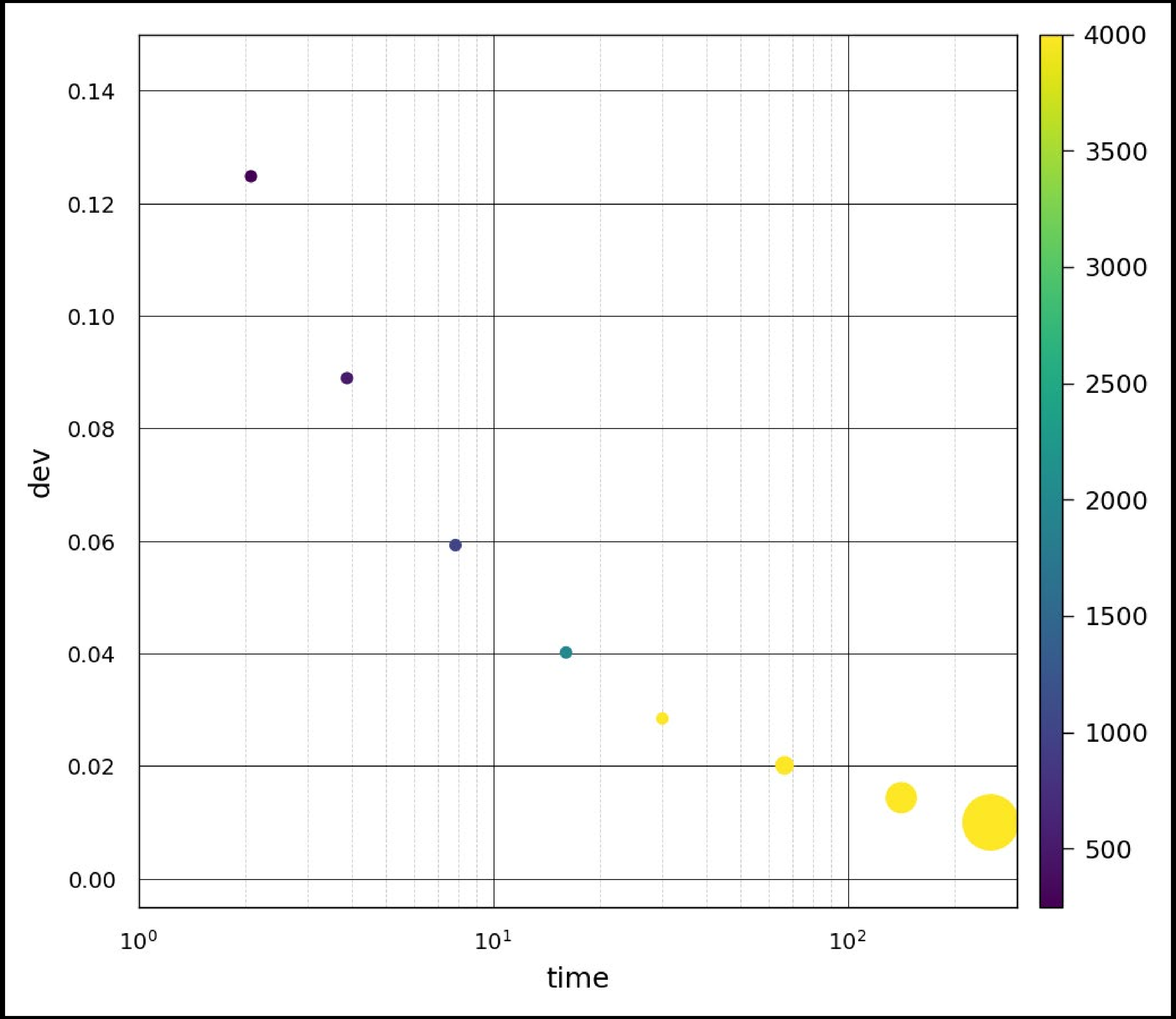


-ad 250 -lw 1.6e-4 -lr -14

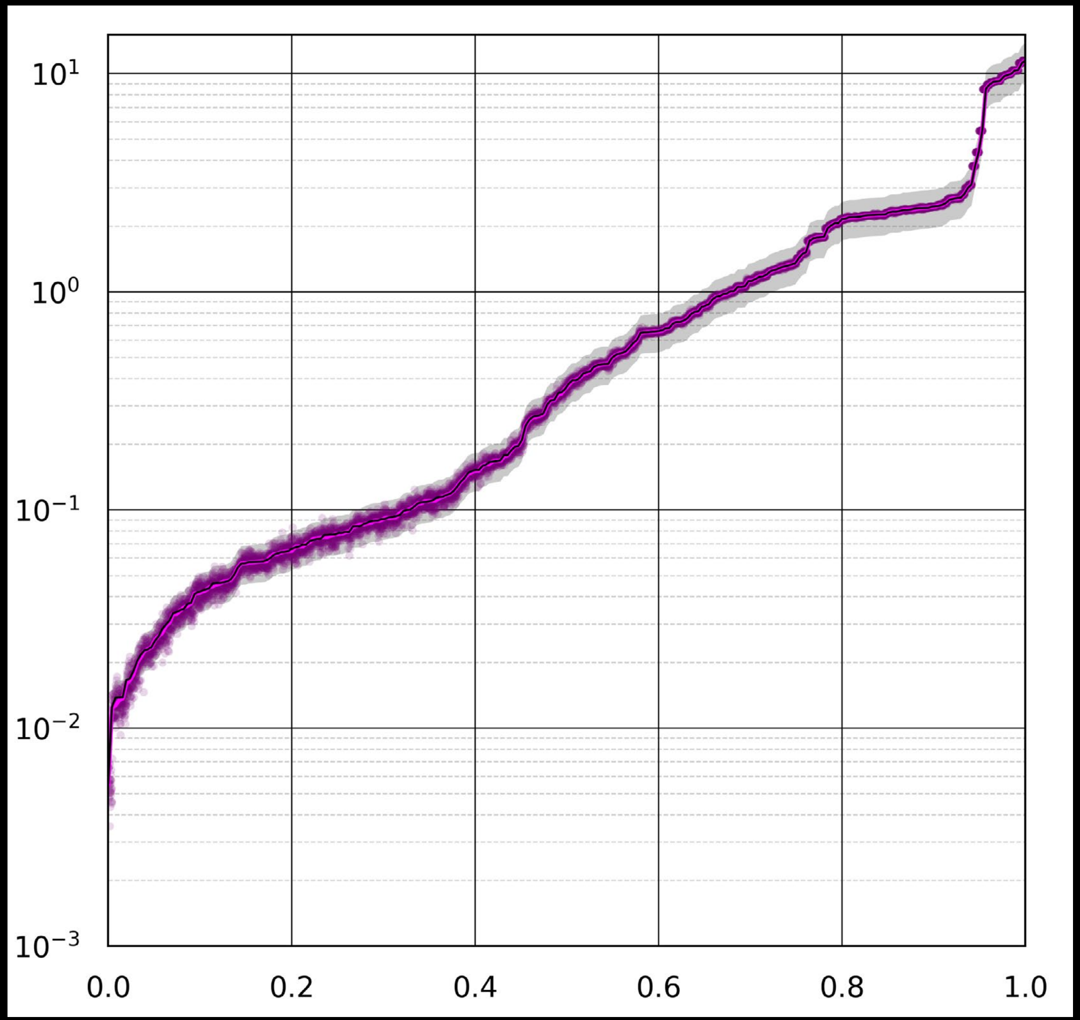
repeated 32 times samp/sec: 123.3

rRMSD: 0.153 rMSD: 0.004

Same Effect: Increases noise, decreases time



Reduce -lr: little effect on time without large bias



-ad 4000 -lw 1e-5 -lr -10

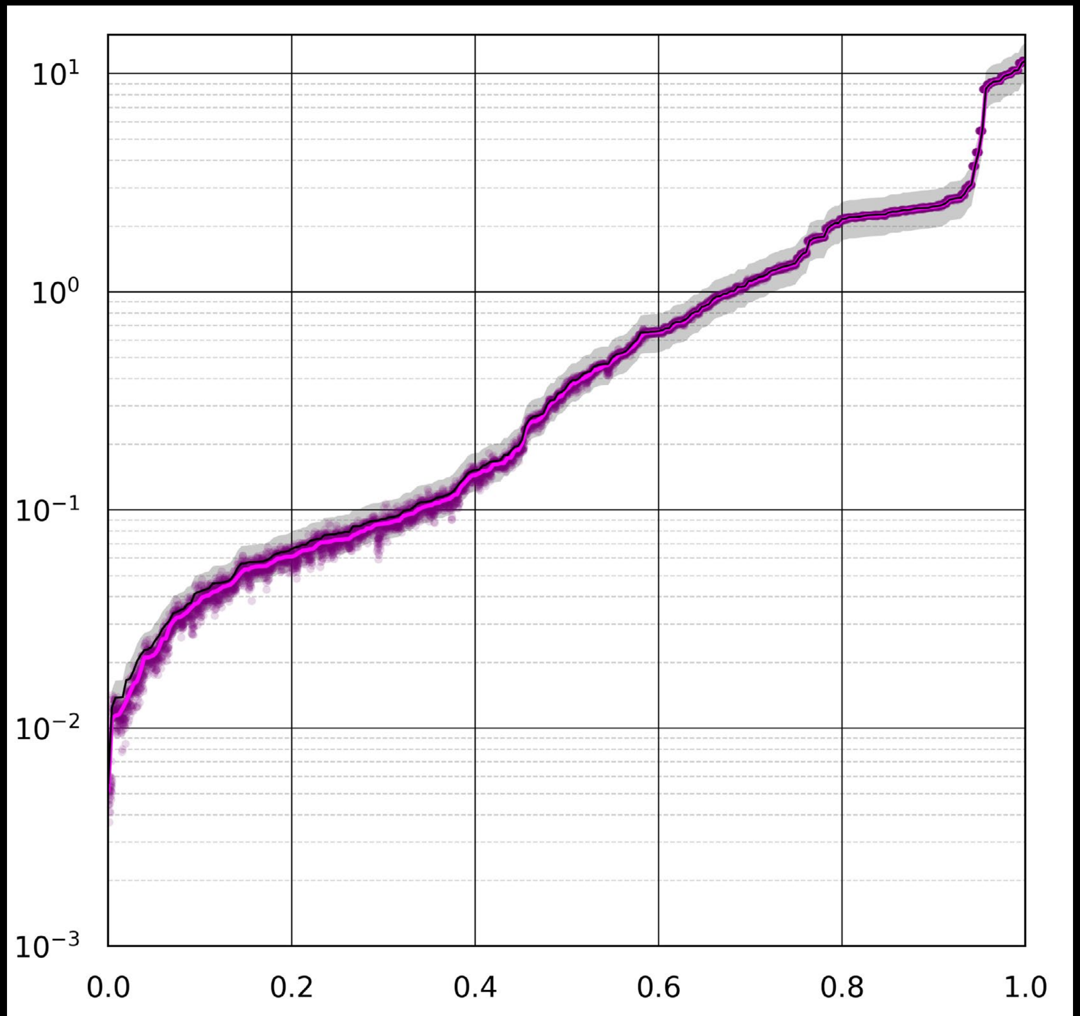
repeated 32 times samp/sec: 8.4

rRMSD: 0.035 rMSD: -0.003

-ad 1000 -lw 4e-5 -lr -14

repeated 32 times samp/sec: 32.7

rRMSD: 0.072 rMSD: 0.000



-ad 4000 -lw 1e-5 -lr -6

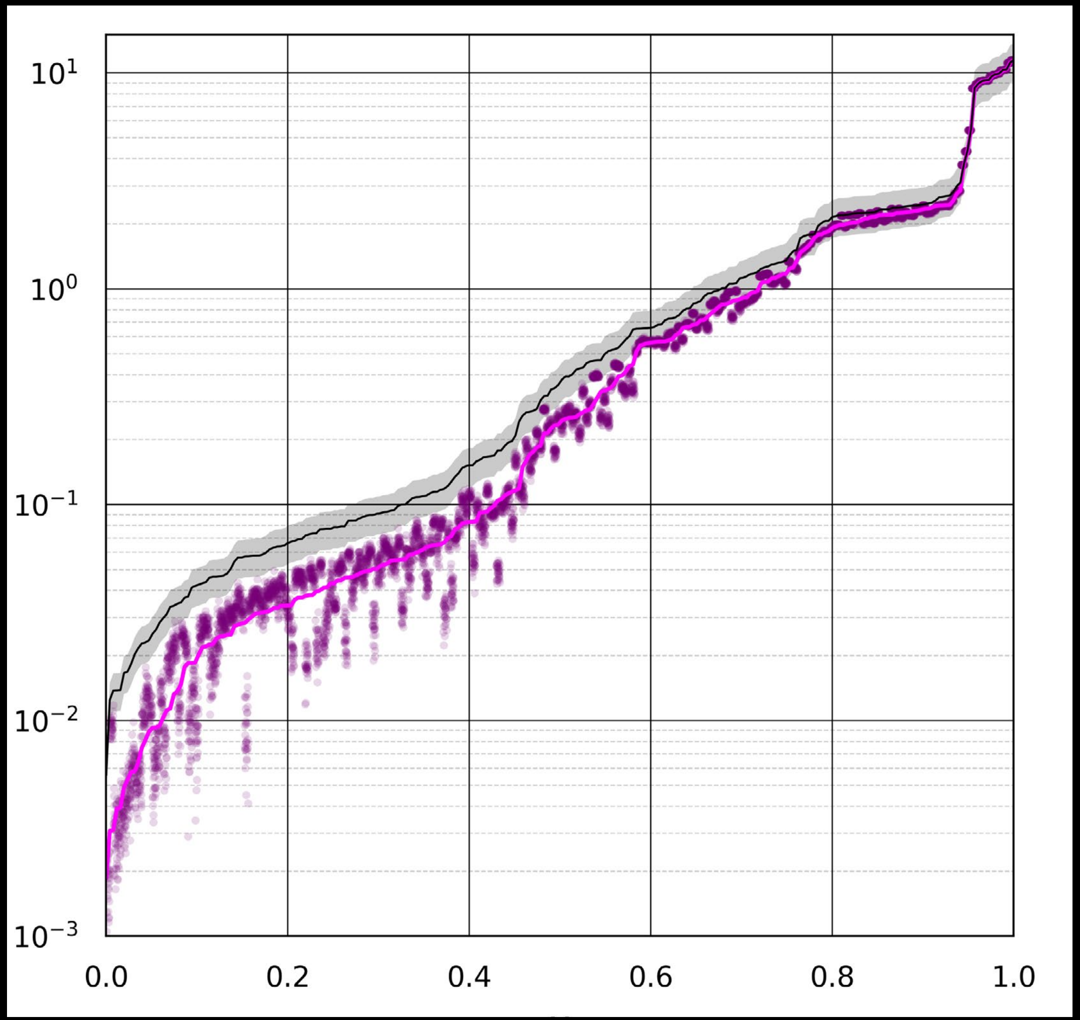
repeated 32 times samp/sec: 8.1

rRMSD: 0.036 rMSD: -0.037

-ad 500 -lw 8e-5 -lr -14

repeated 32 times samp/sec: 66.1

rRMSD: 0.108 rMSD: 0.002



-ad 4000 -lw 1e-5 -lr -2

repeated 32 times samp/sec: 21.3

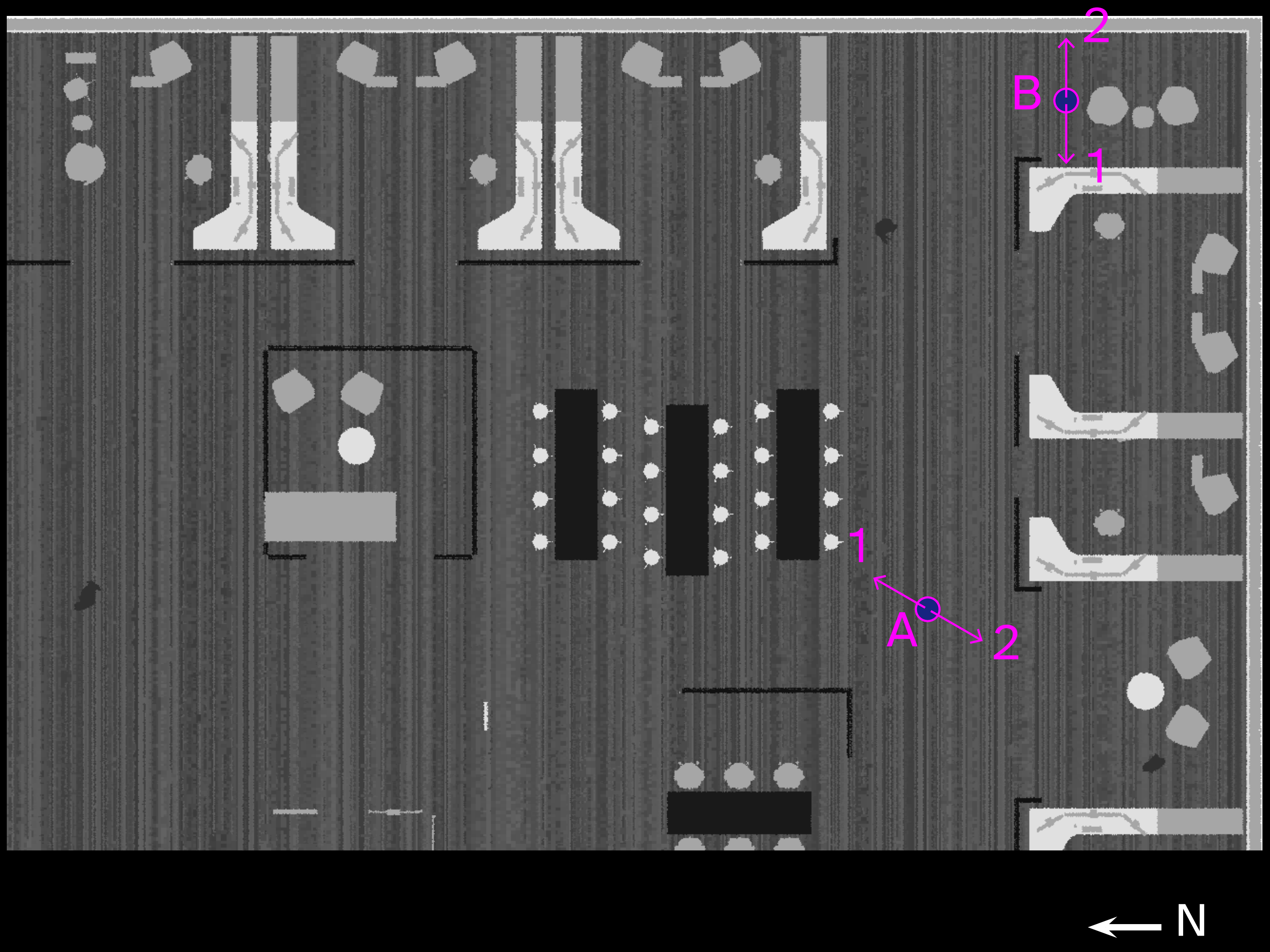
rRMSD: 0.054 rMSD: -0.307

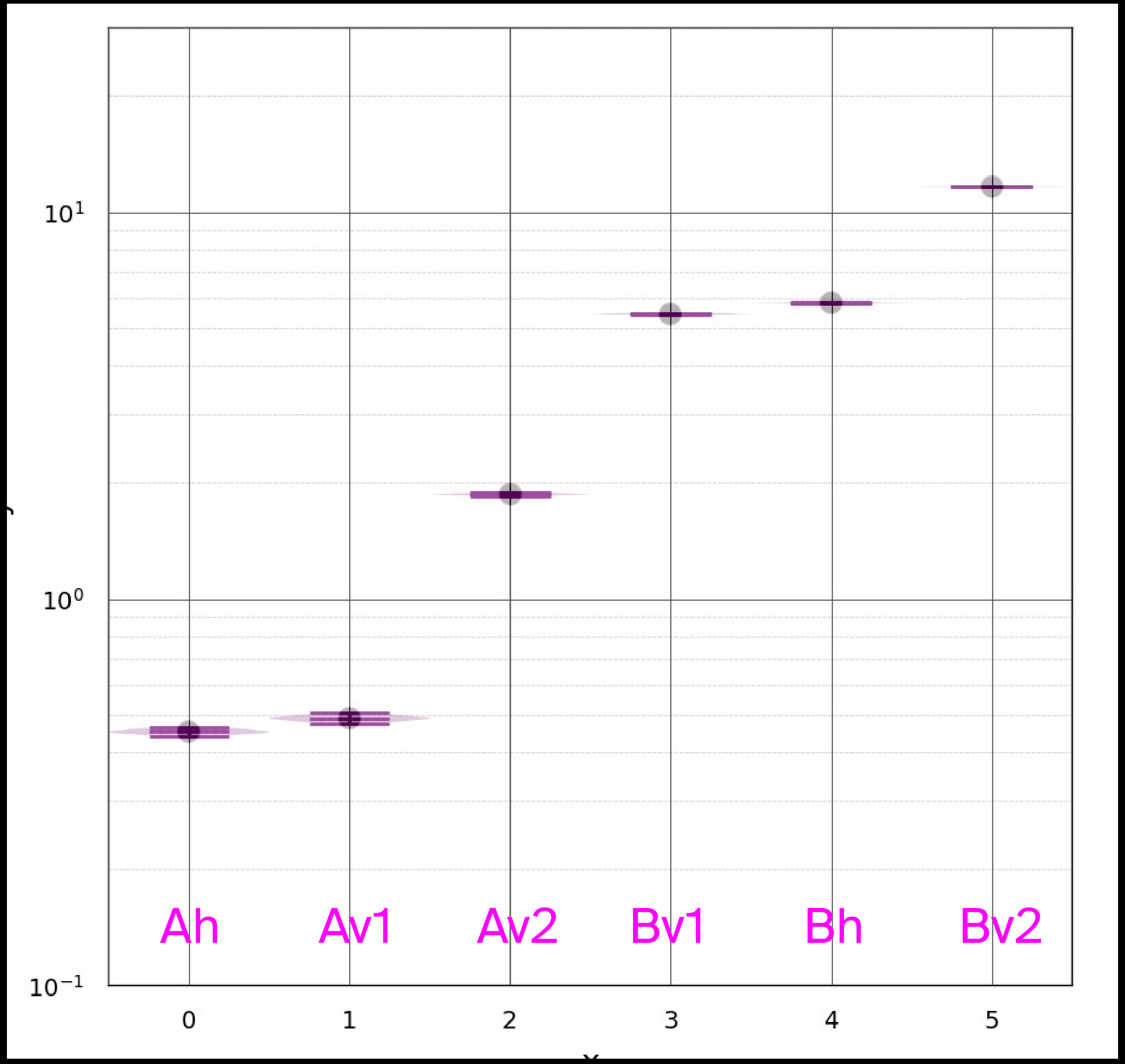
-ad 250 -lw 1.6e-4 -lr -14

repeated 32 times samp/sec: 123.3

rRMSD: 0.153 rMSD: 0.004

Determining Settings: Illuminance Based





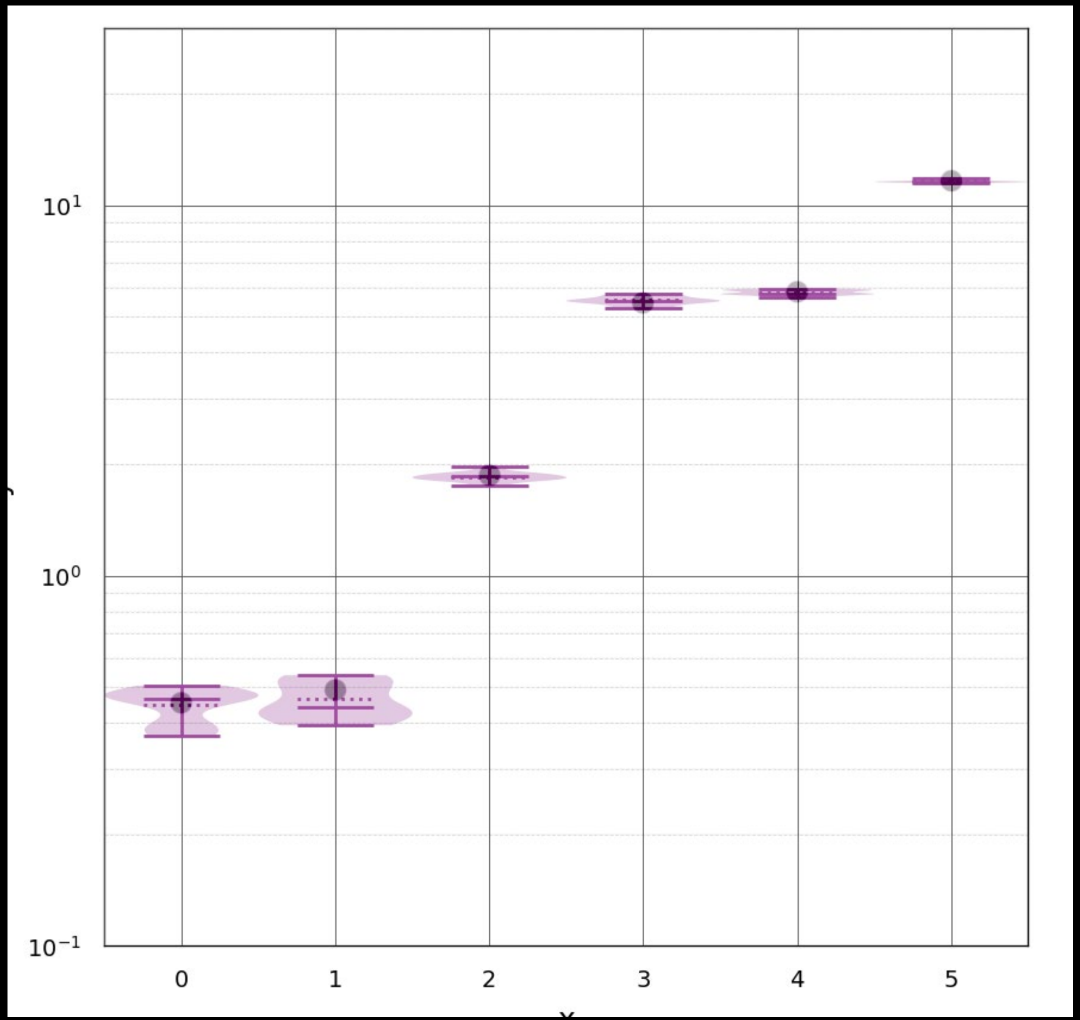
benchmark: -ad 4000 -lw 1e-5 -lr -14

repeated 8 x 32 times samp/sec: 0.3

rRMSD: 0.007 rMSD: 0.000

Reduce -ad (proportionally adjust -lw)

initial weight of an illuminance ray is π so initial divisions are higher



-ad 1000 -lw 4e-5 -lr -14

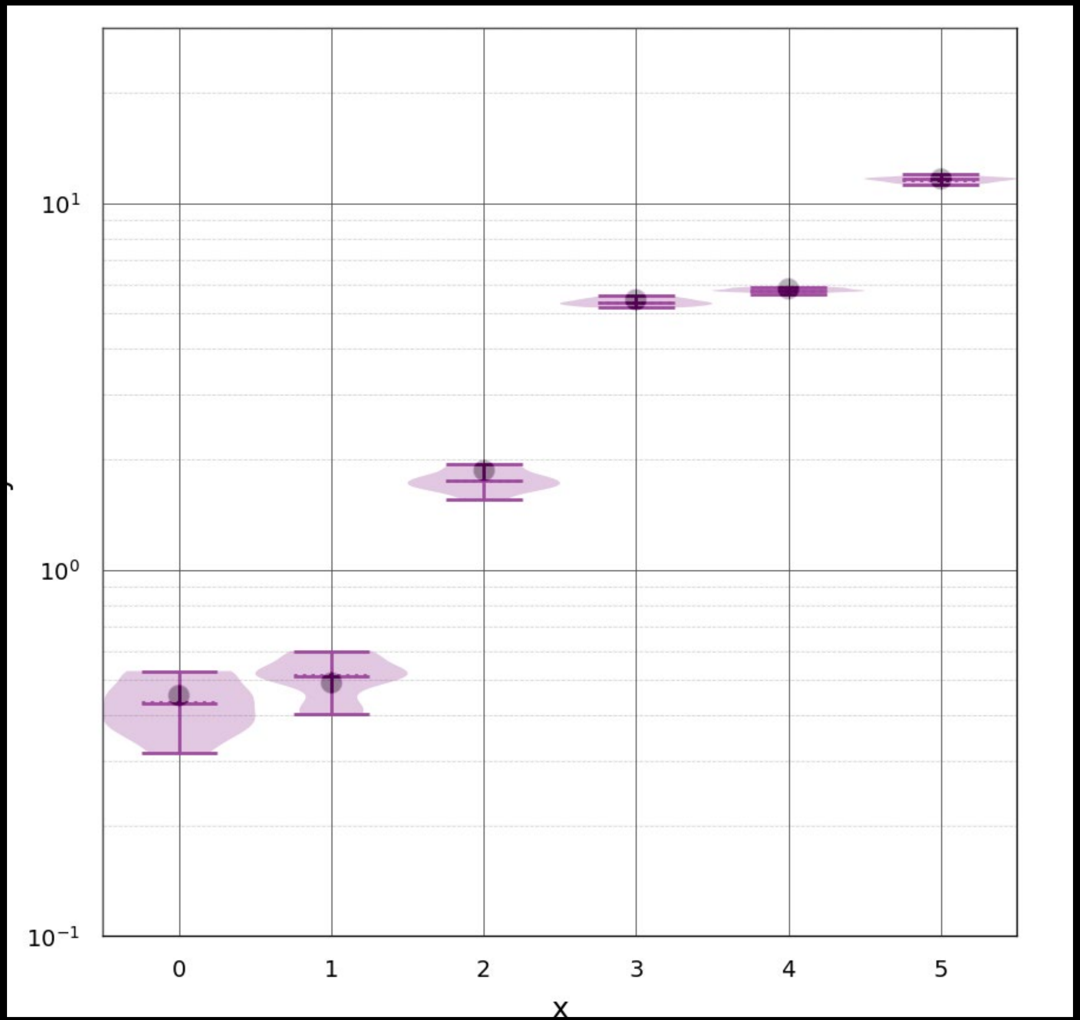
repeated 32 times samp/sec: 4.8

rRMSD: 0.049 rMSD: -.011

luminance:

repeated 32 times samp/sec: 32.7

rRMSD: 0.072 rMSD: 0.000



-ad 500 -lw 8e-5 -lr -14

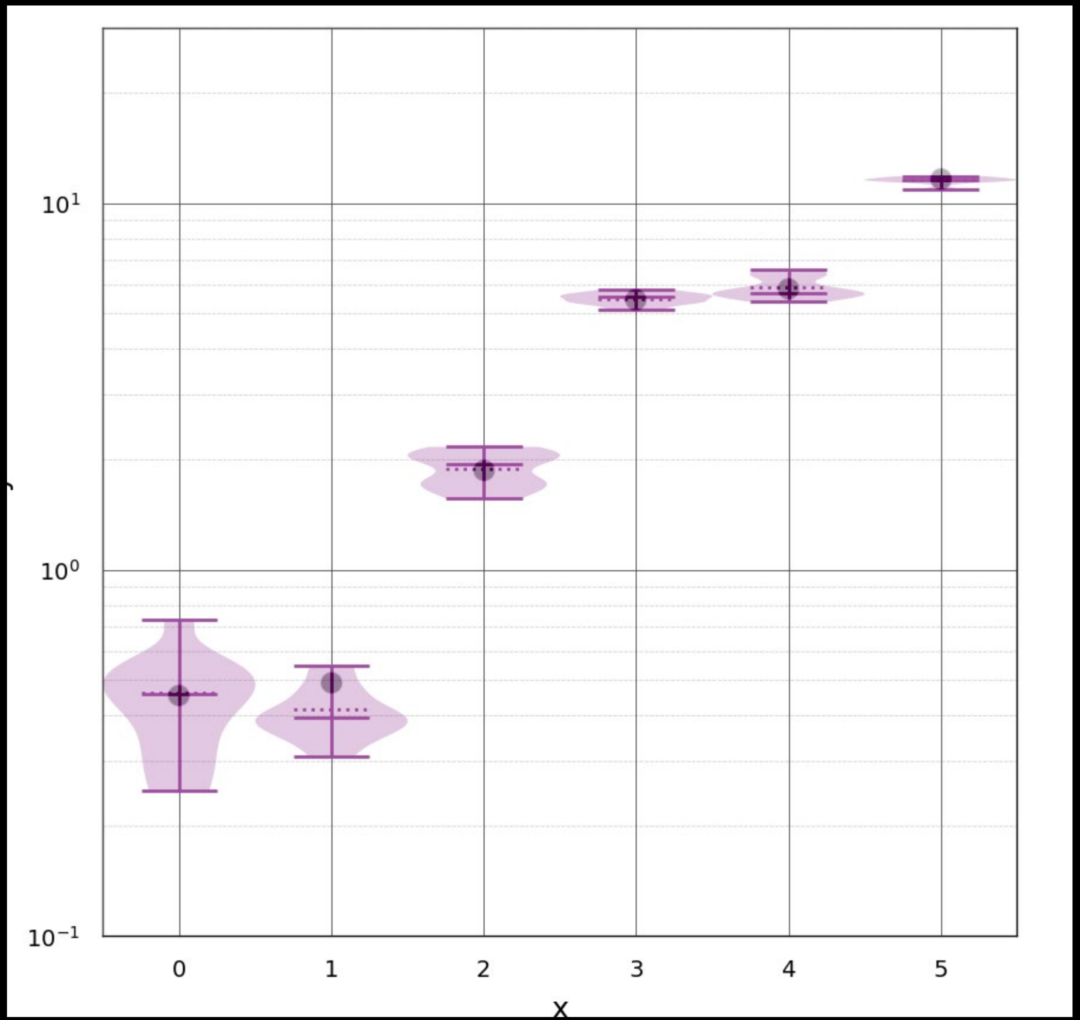
repeated 32 times samp/sec: 11.4

rRMSD: 0.066 rMSD: -0.014

luminance:

repeated 32 times samp/sec: 66.1

rRMSD: 0.108 rMSD: 0.002



-ad 250 -lw 1.6e-4 -lr -14

repeated 32 times samp/sec: 14.9

rRMSD: 0.113 rMSD: -.019

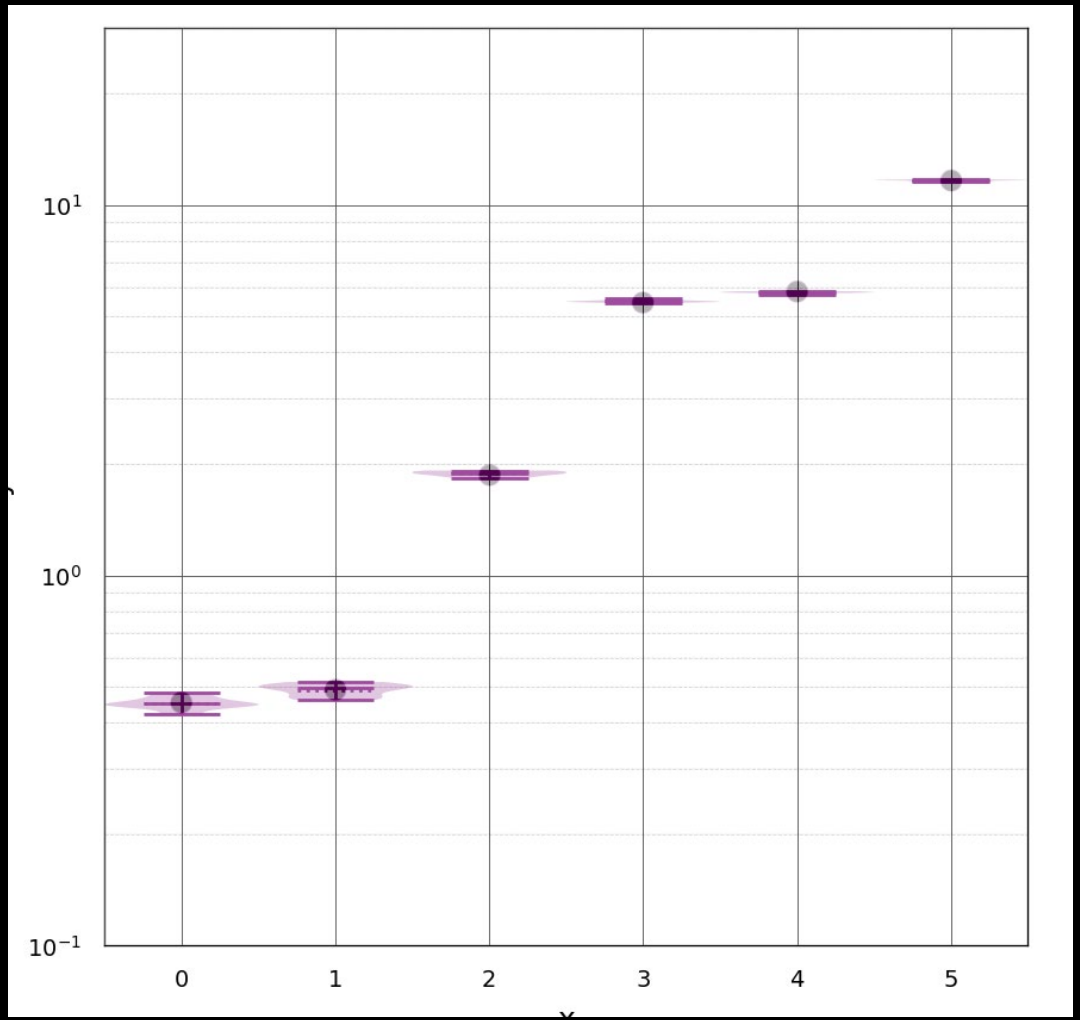
luminance:

repeated 32 times samp/sec: 123.3

rRMSD: 0.153 rMSD: 0.004

Reduce -lr

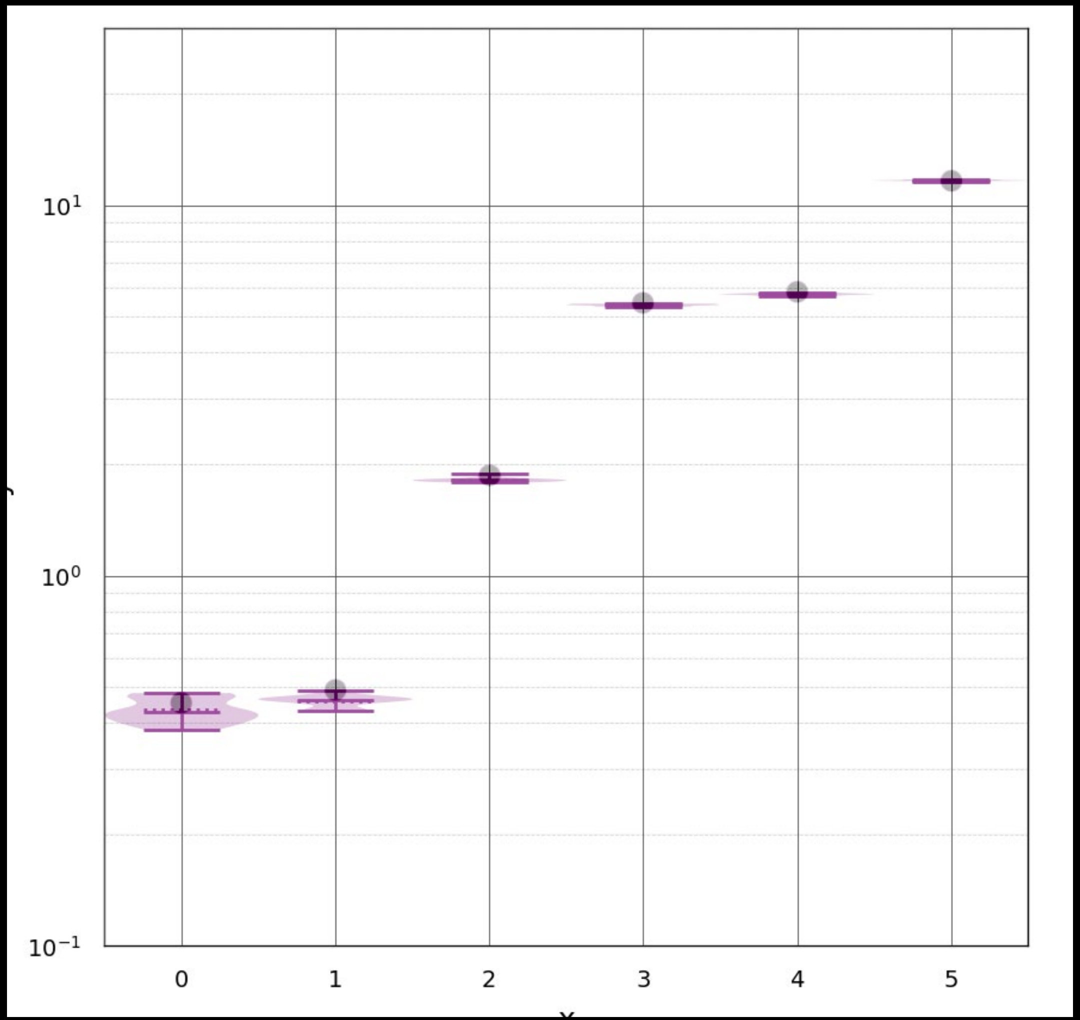
illuminance consumes one bounce



-ad 4000 -lw 1e-5 -lr -10

repeated 32 times samp/sec: 1.8
rRMSD: 0.021 rMSD: 0.002

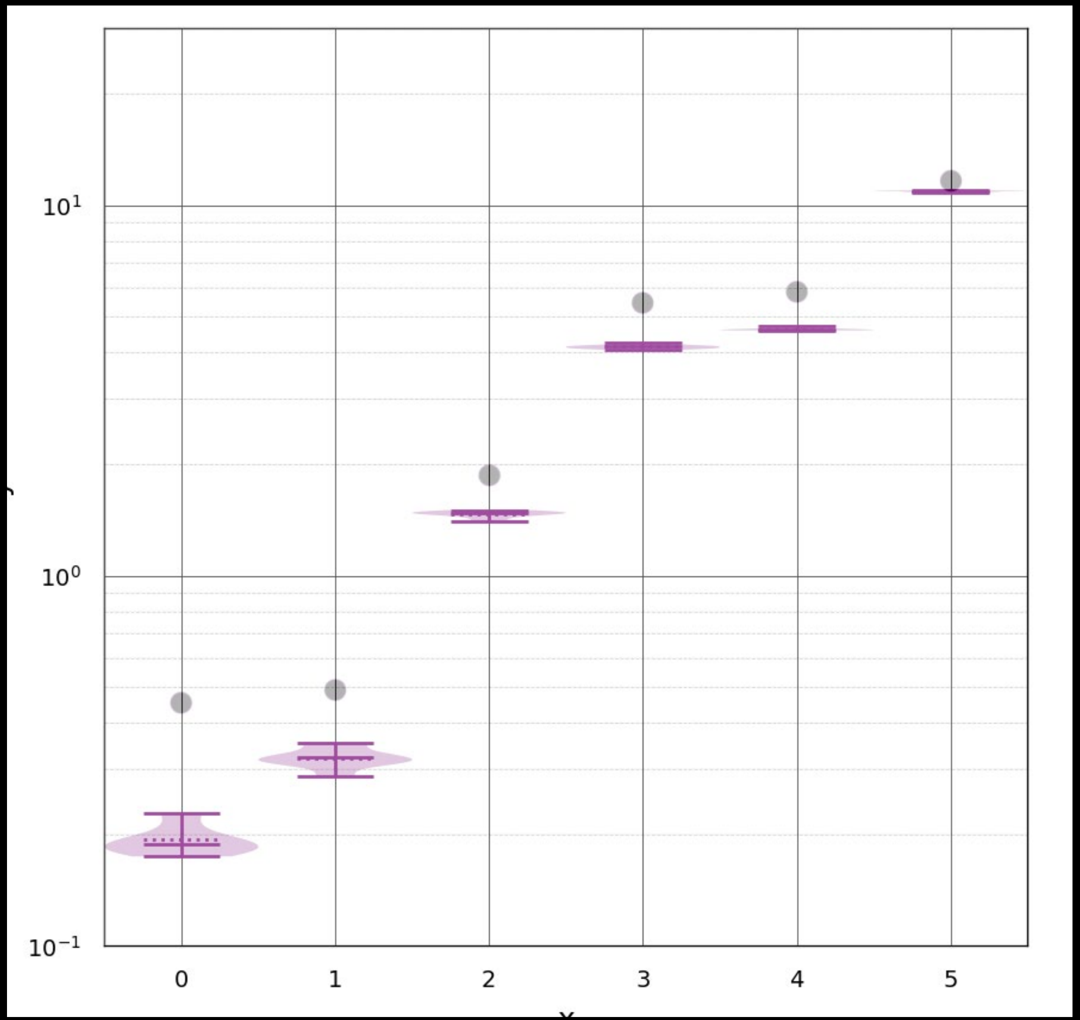
luminance:
repeated 32 times samp/sec: 8.4
rRMSD: 0.035 rMSD: -0.003



-ad 4000 -lw 1e-5 -lr -6

repeated 32 times samp/sec: 1.8
rRMSD: 0.025 rMSD: -0.026

luminance:
repeated 32 times samp/sec: 8.1
rRMSD: 0.036 rMSD: -0.037

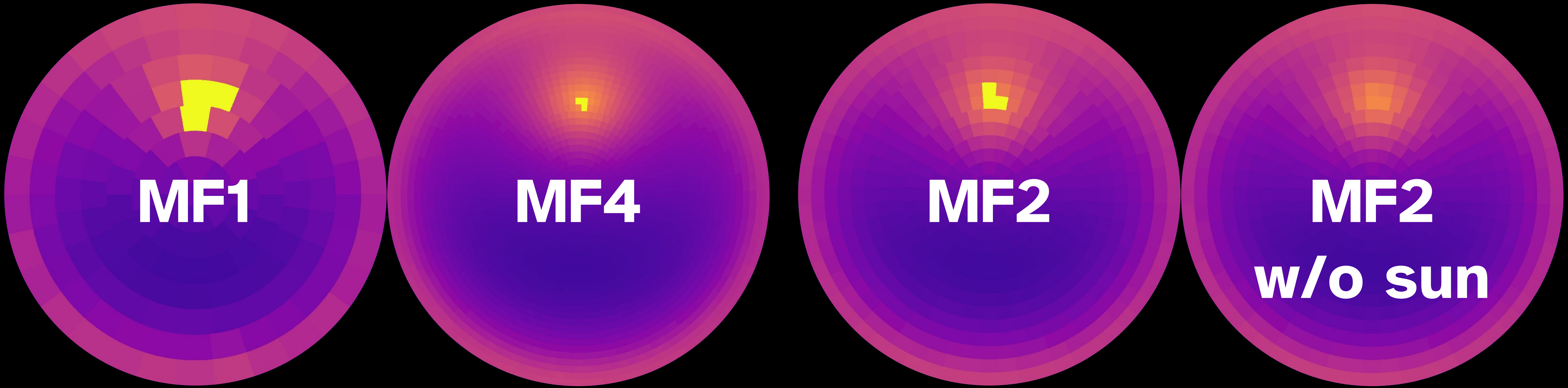


-ad 4000 -lw 1e-5 -lr -2

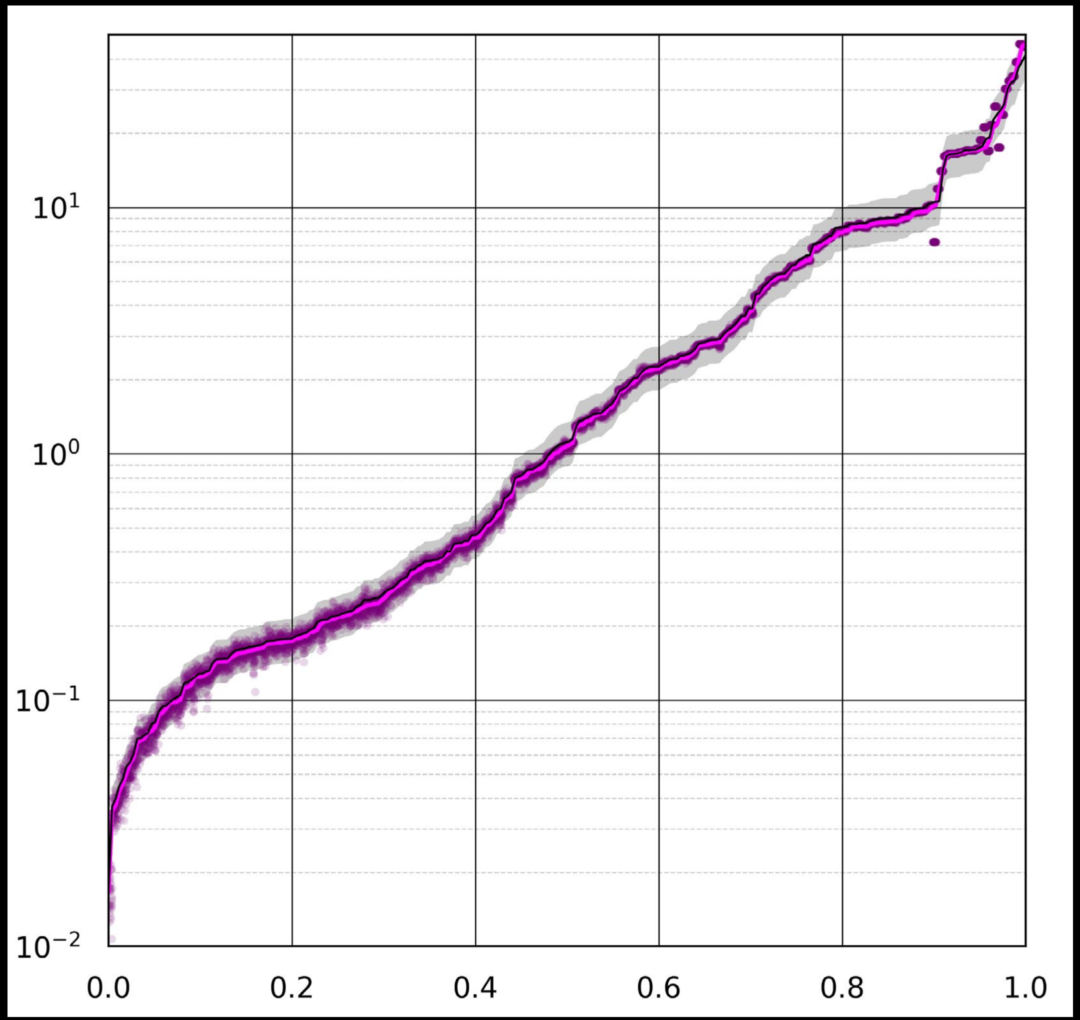
repeated 32 times samp/sec: 4.9
rRMSD: 0.032 rMSD: -0.273

luminance:
repeated 32 times samp/sec: 21.3
rRMSD: 0.054 rMSD: -0.307

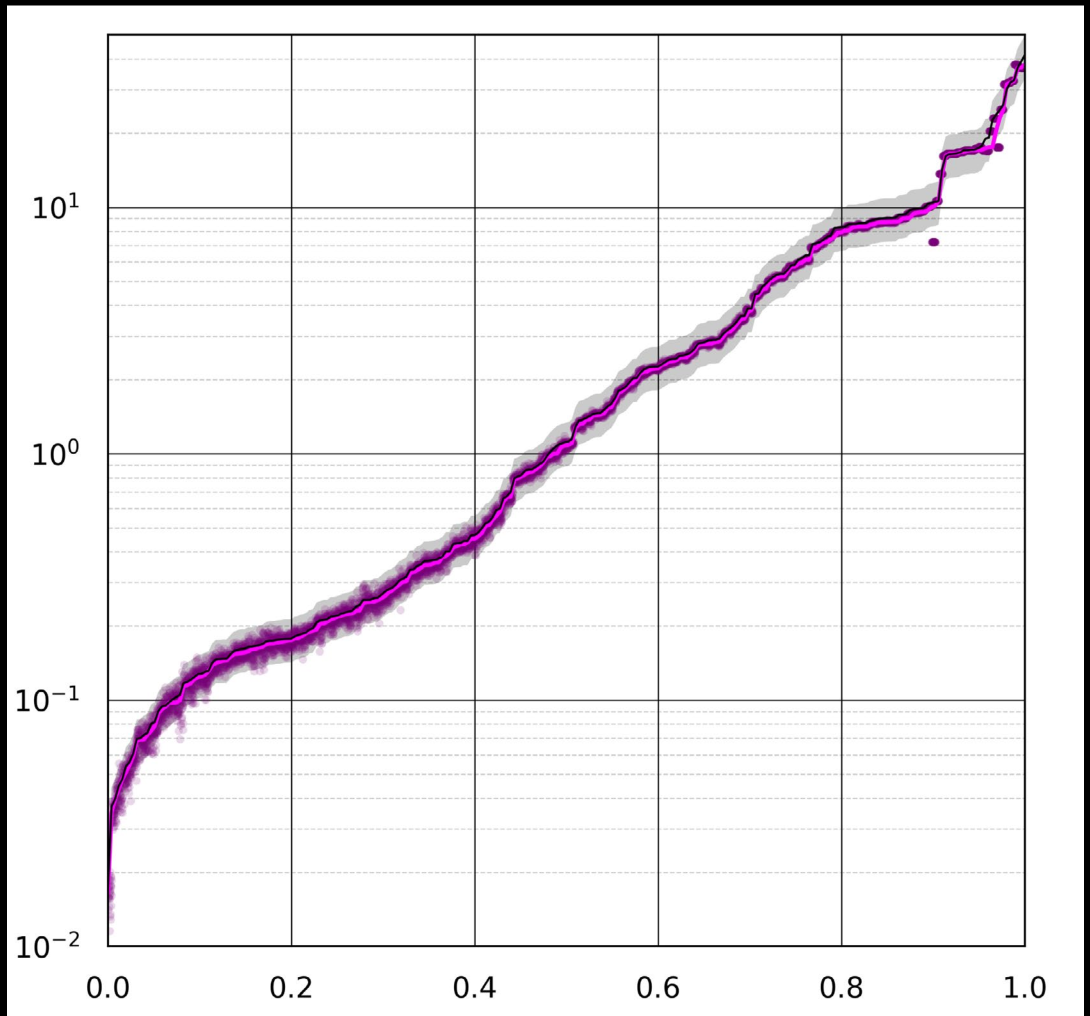
Determining Settings: rcontrib (sky receiver)



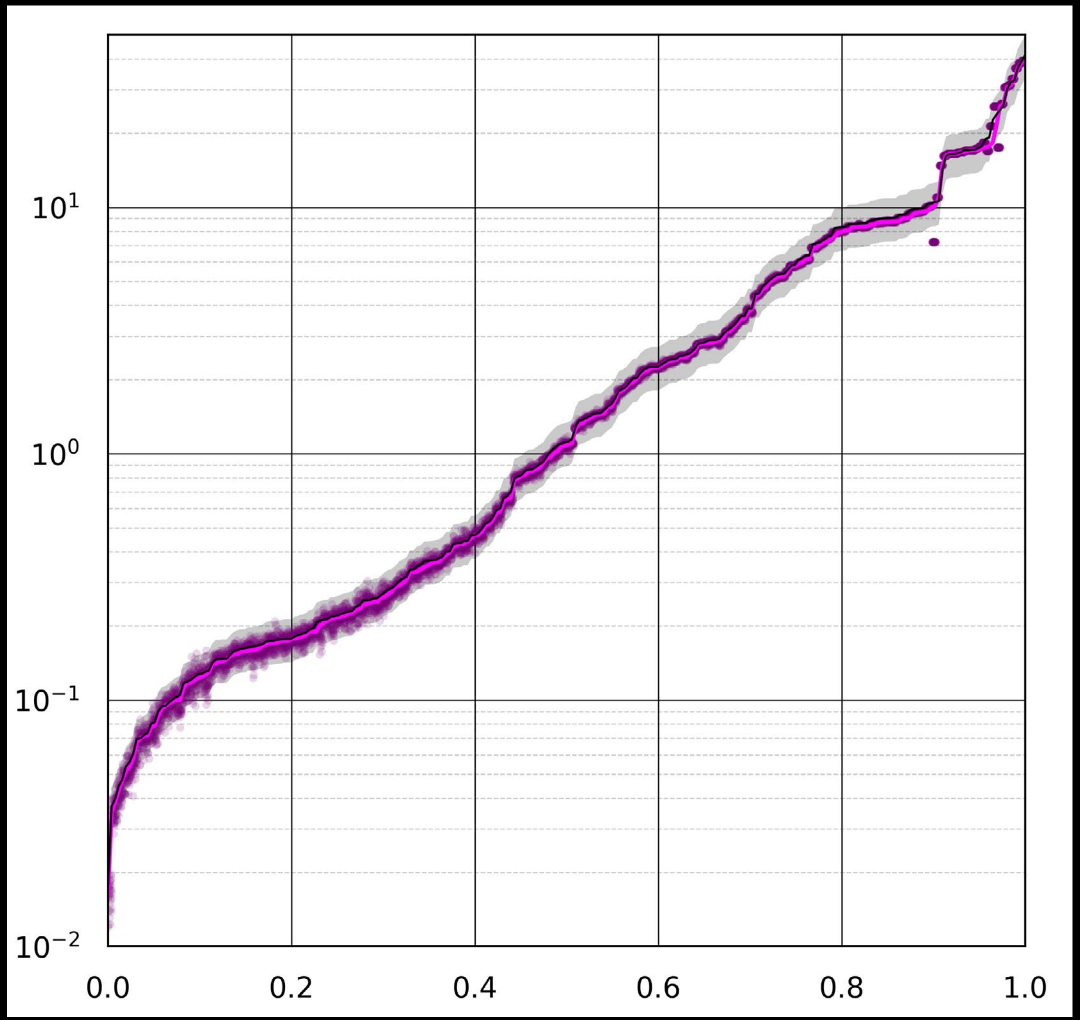
sky contribution only (w/o sun)



MF:1 -ad 4000 -lw 1e-5 -lr -14
repeated 32 times samp/sec: 6.3
rRMSD: 0.033 rMSD: -0.026

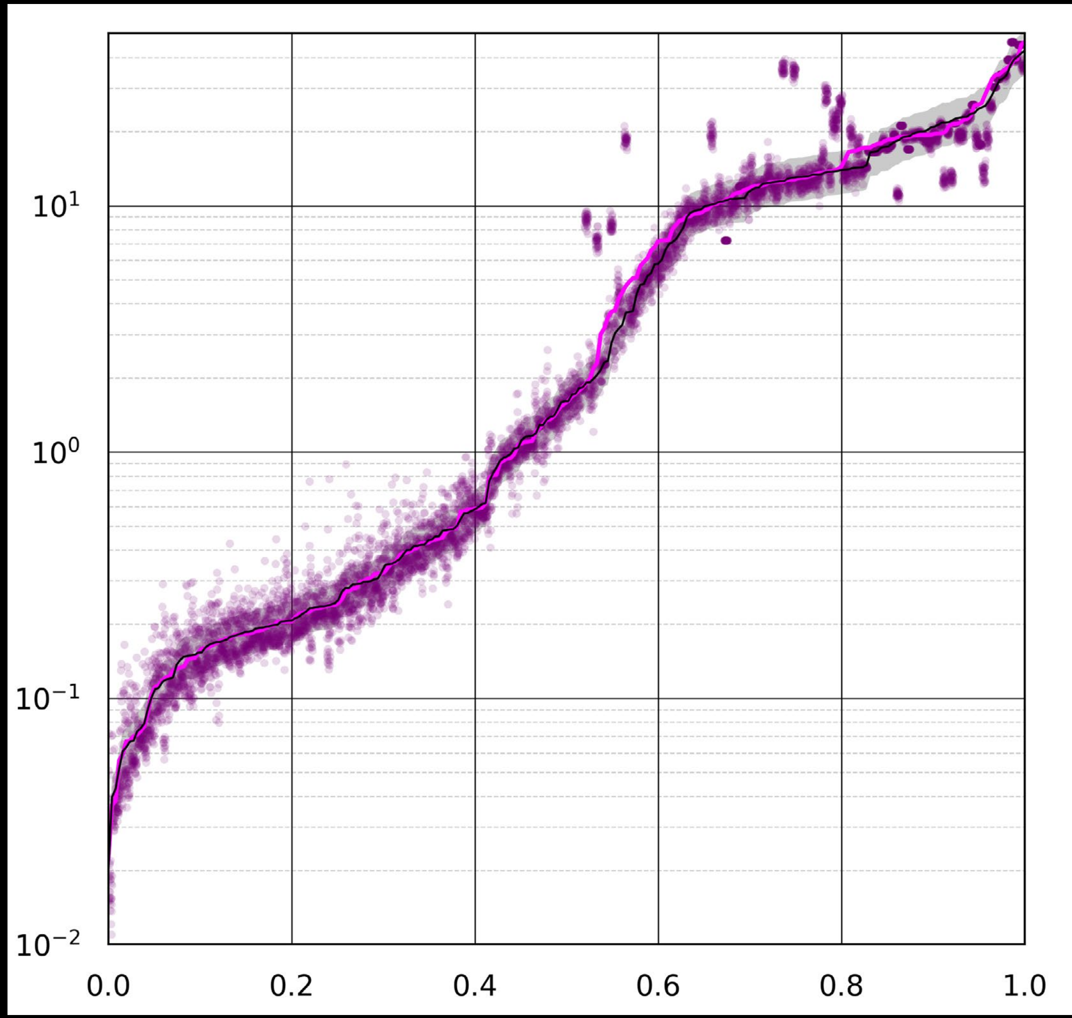


MF:2 -ad 4000 -lw 1e-5 -lr -14
repeated 32 times samp/sec: 6.1
rRMSD: 0.033 rMSD: -0.028

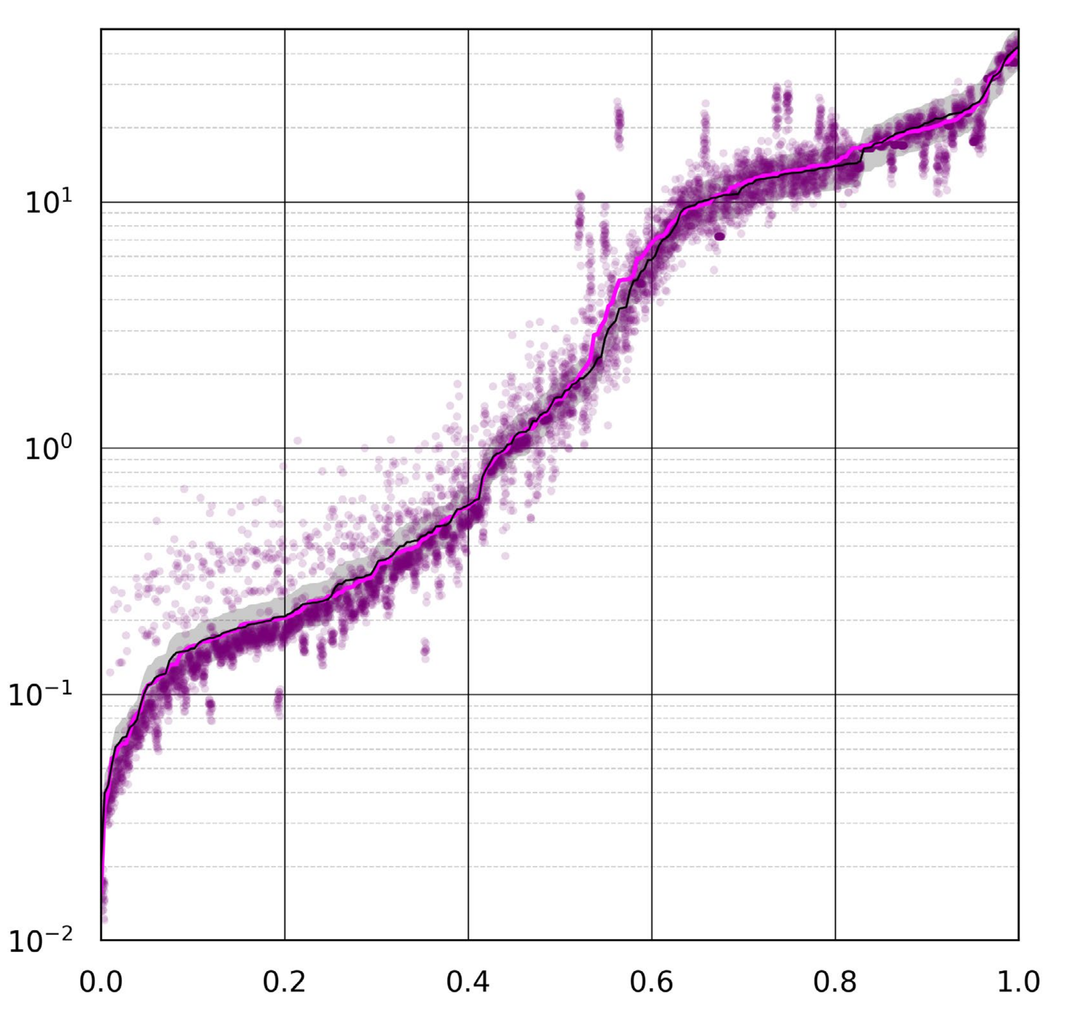


MF:4 -ad 4000 -lw 1e-5 -lr -14
repeated 32 times samp/sec: 6.2
rRMSD: 0.033 rMSD: -0.025

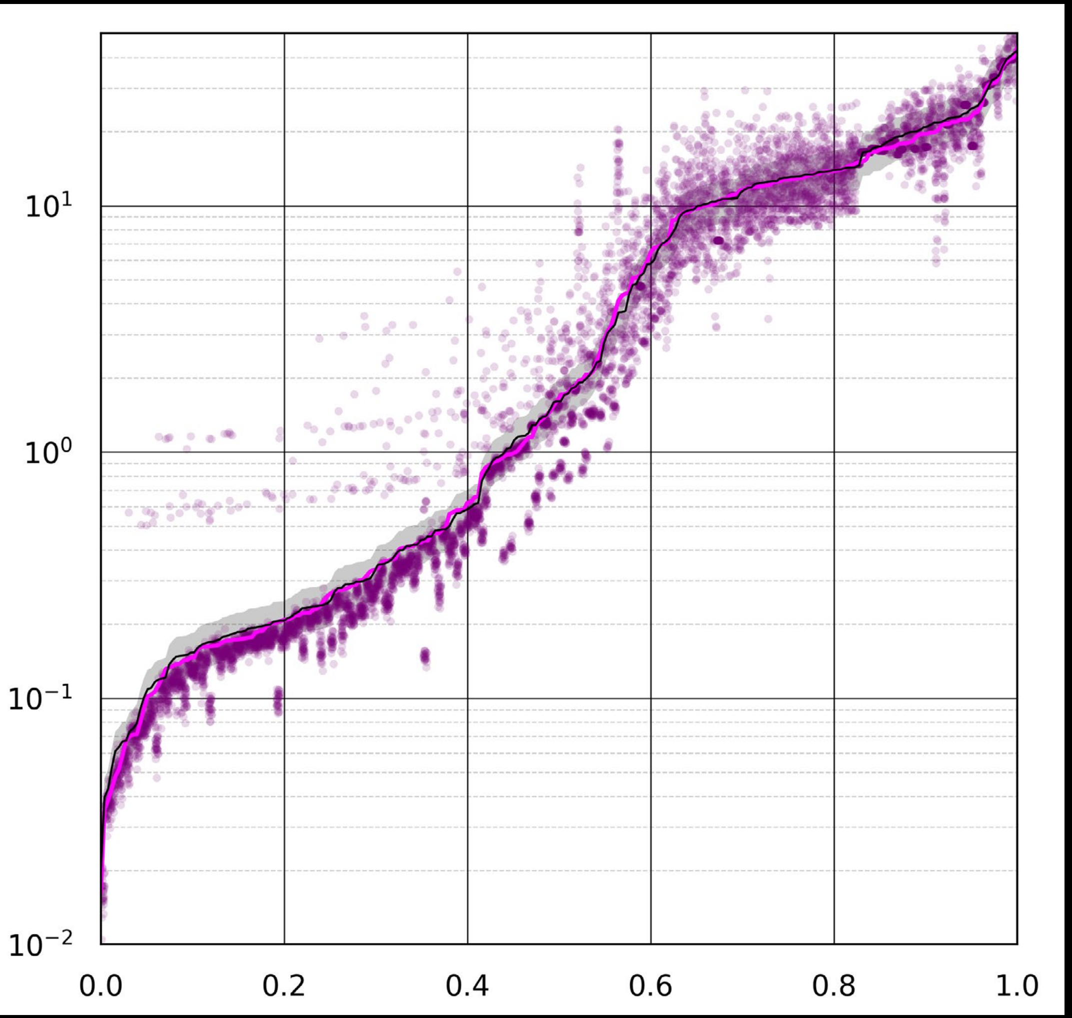
solar energy in sky patch (w/ sun)



MF:1 -ad 4000 -lw 1e-5 -lr -14
repeated 32 times samp/sec: 9.0
rRMSD: 0.128 rMSD: 0.065

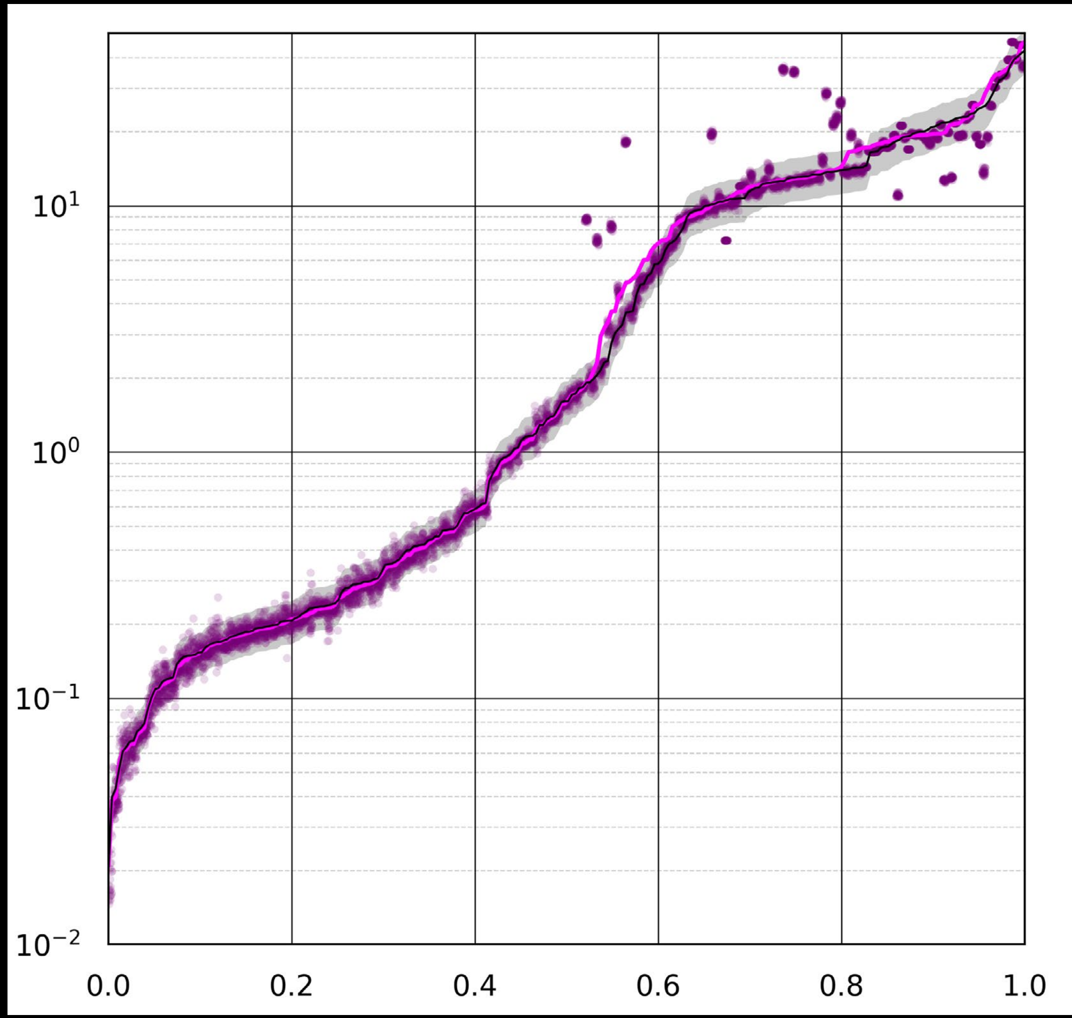


MF:2 -ad 4000 -lw 1e-5 -lr -14
repeated 32 times samp/sec: 8.4
rRMSD: 0.225 rMSD: 0.039

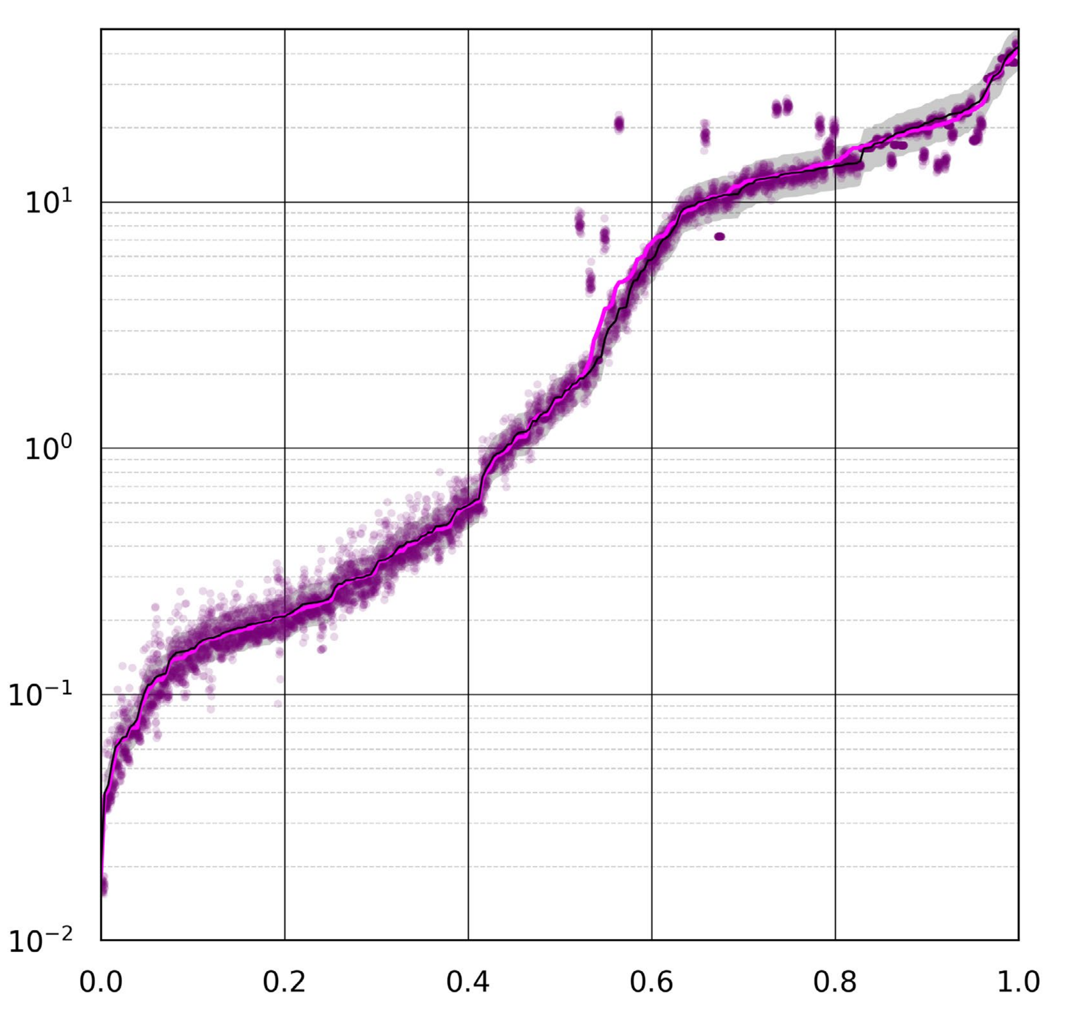


MF:4 -ad 4000 -lw 1e-5 -lr -14
repeated 32 times samp/sec: 6.4
rRMSD: 0.390 rMSD: 0.001

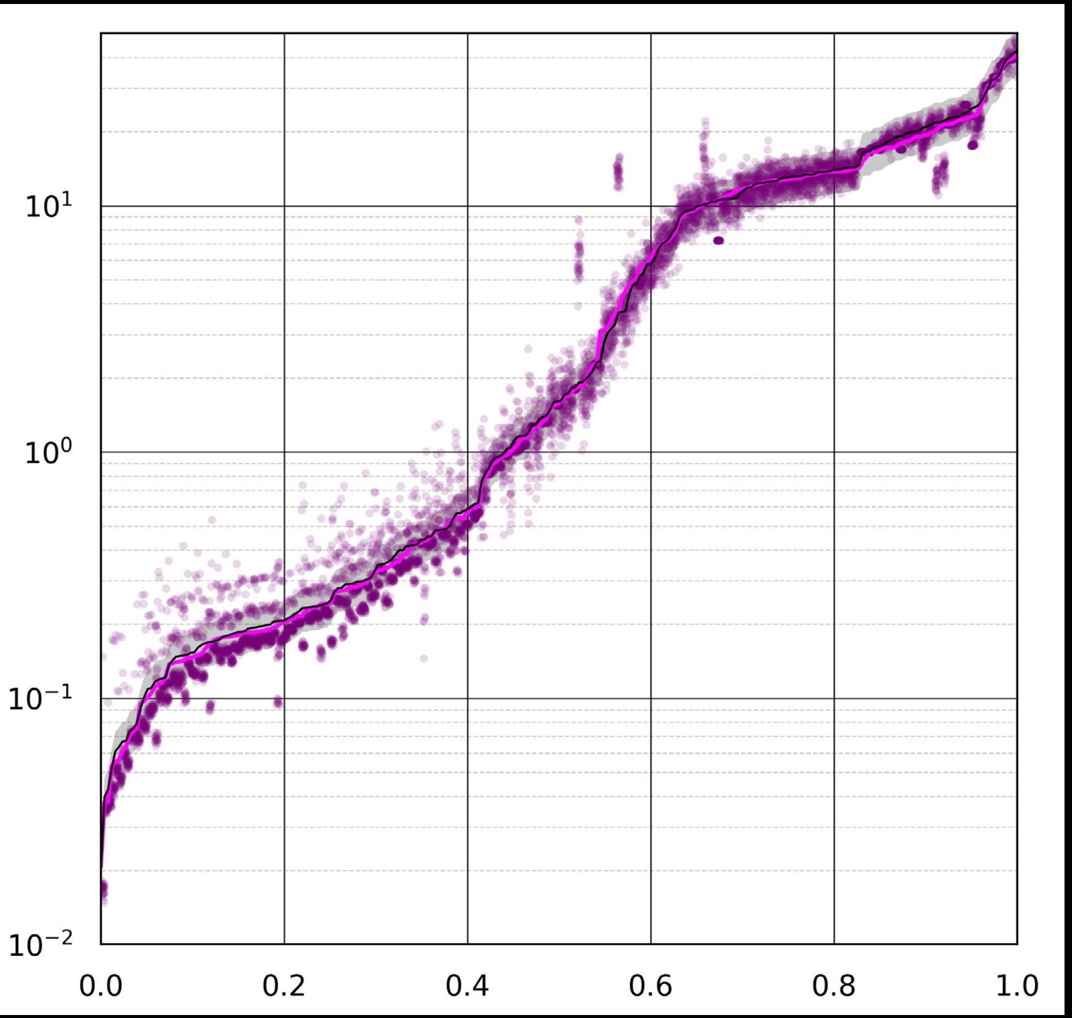
solar energy in sky patch



MF:1 -ad 4000 -lw 1e-5 -lr -14
repeated 8 x 32 times samp/sec: 0.9
rRMSD: 0.045 rMSD: 0.060

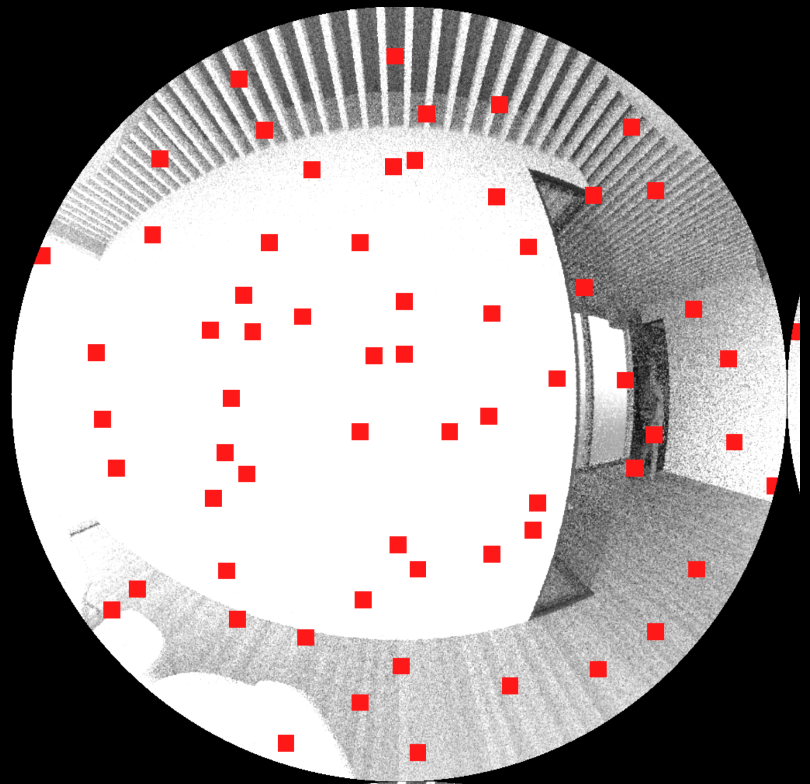


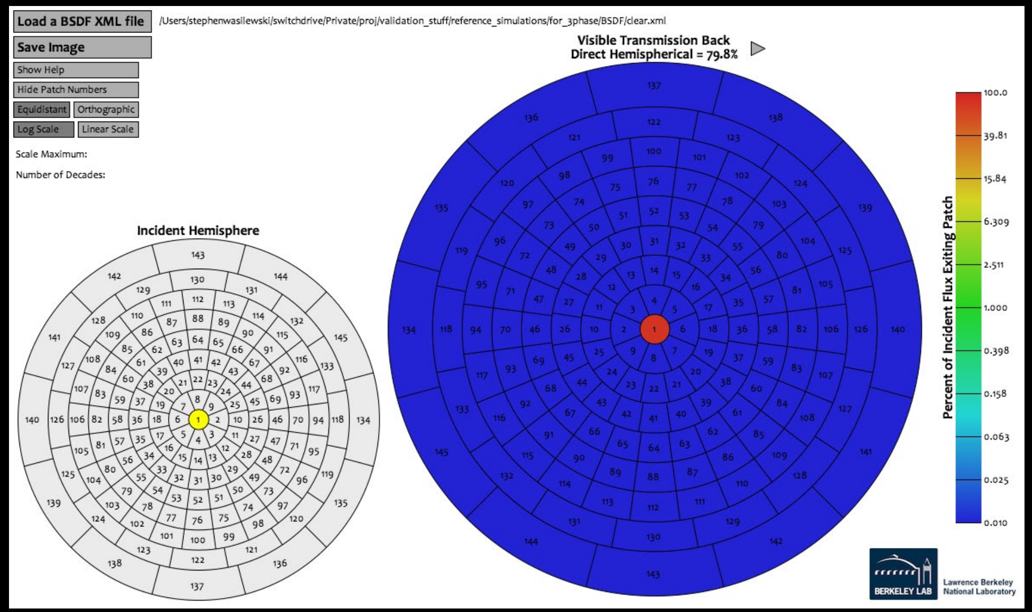
MF:2 -ad 4000 -lw 1e-5 -lr -14
repeated 8 x 32 times samp/sec: 0.9
rRMSD: 0.083 rMSD: 0.036

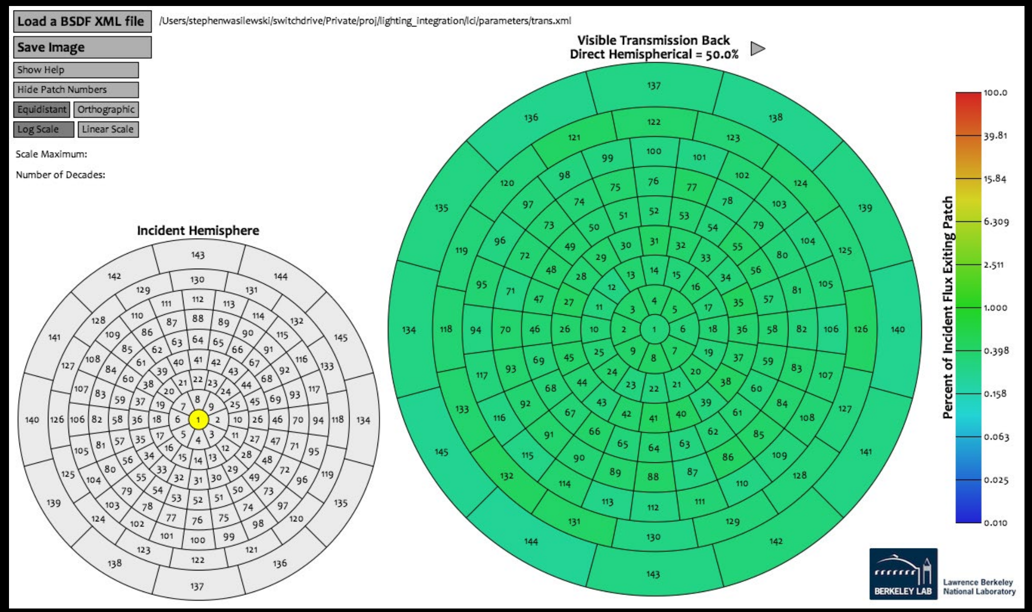


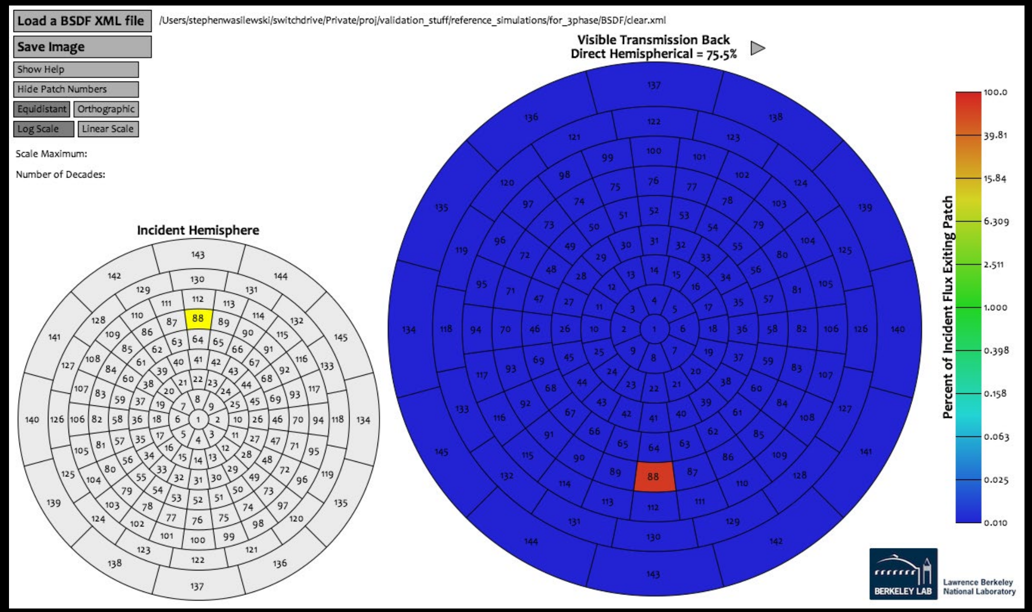
MF:4 -ad 4000 -lw 1e-5 -lr -14
repeated 8 x 32 times samp/sec: 0.9
rRMSD: 0.164 rMSD: -0.007

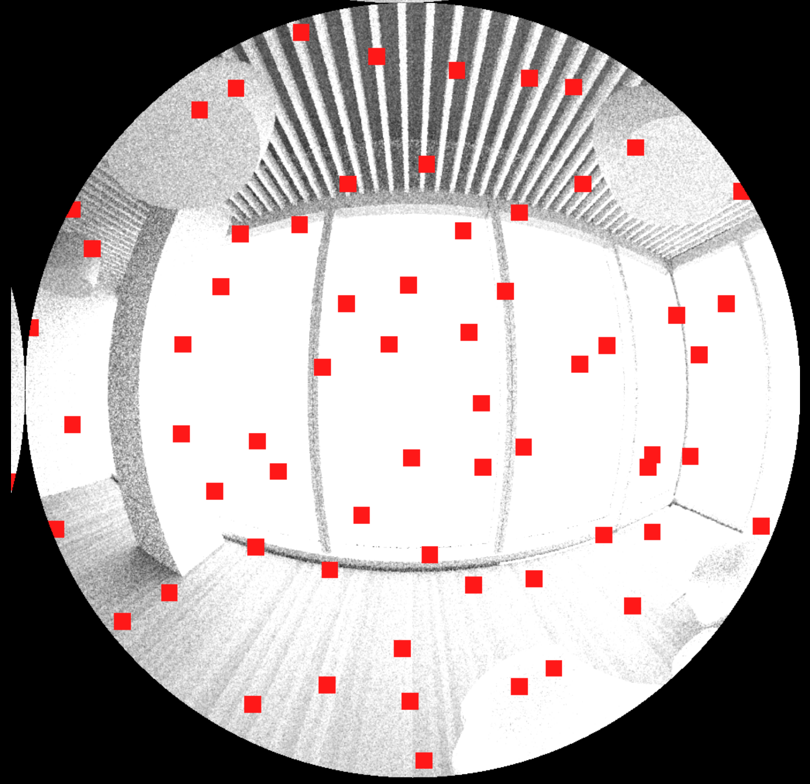
Determining Settings: rcontrib (window receiver)

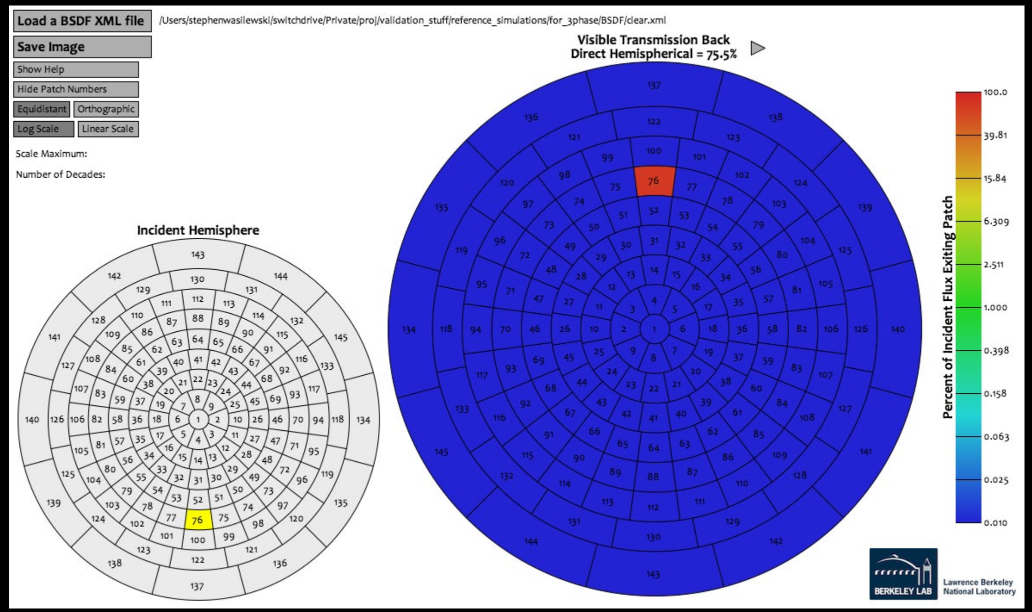




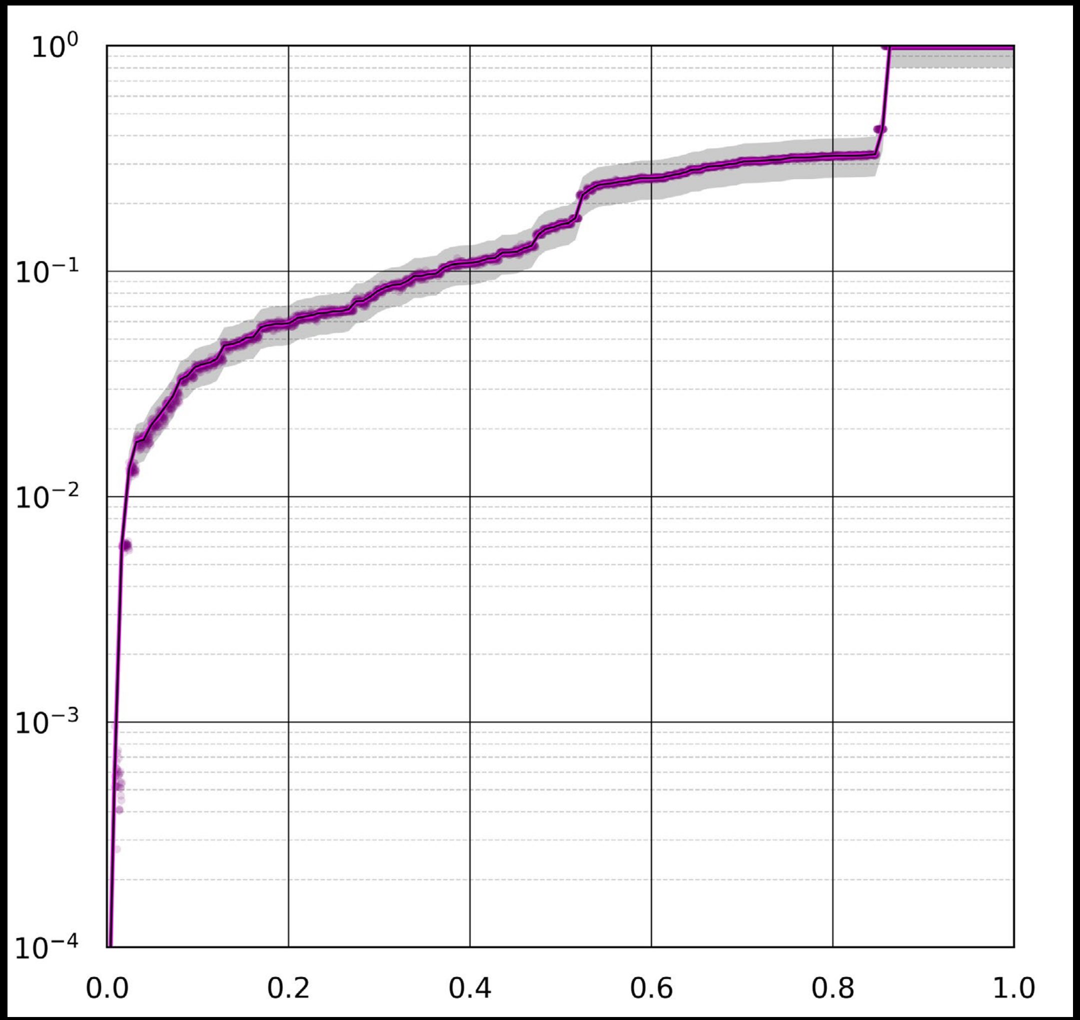








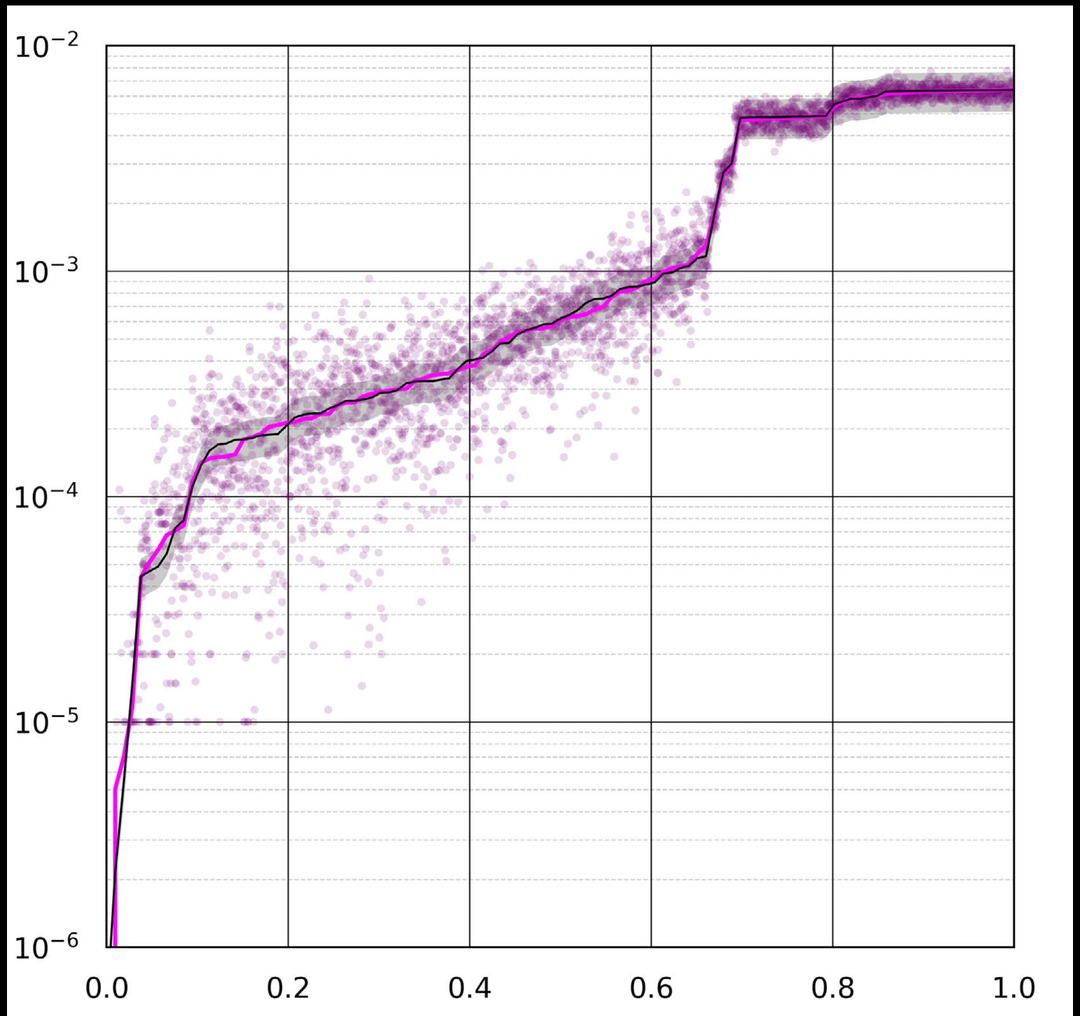
integrated (trans/sky) vs. specular



ALL -ad 4000 -lw 1e-5 -lr -14

repeated 32 times samp/sec: 11.5

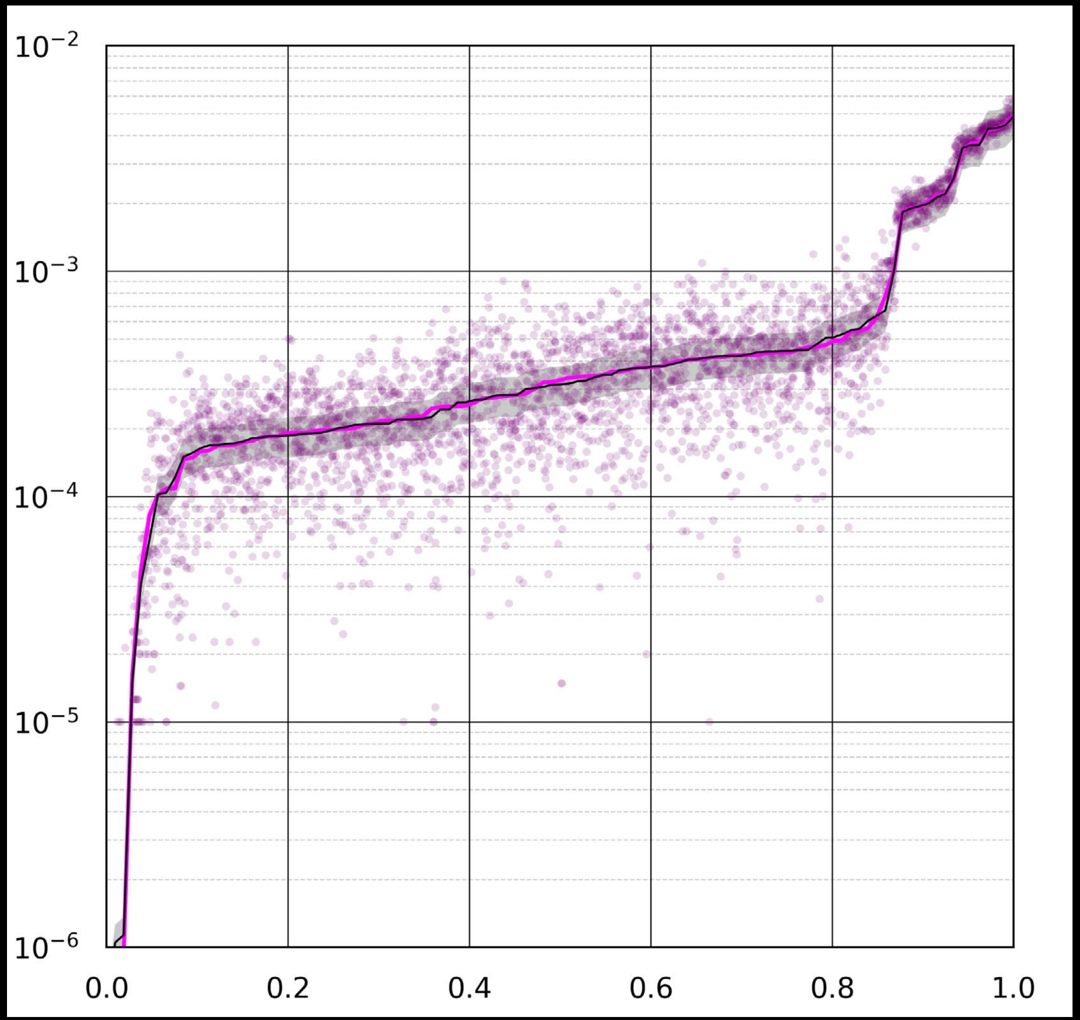
rRMSD: 0.020 rMSD: 0.000



PATCH_001

repeated 32 times samp/sec: 11.5

rRMSD: 0.459 rMSD: 0.010

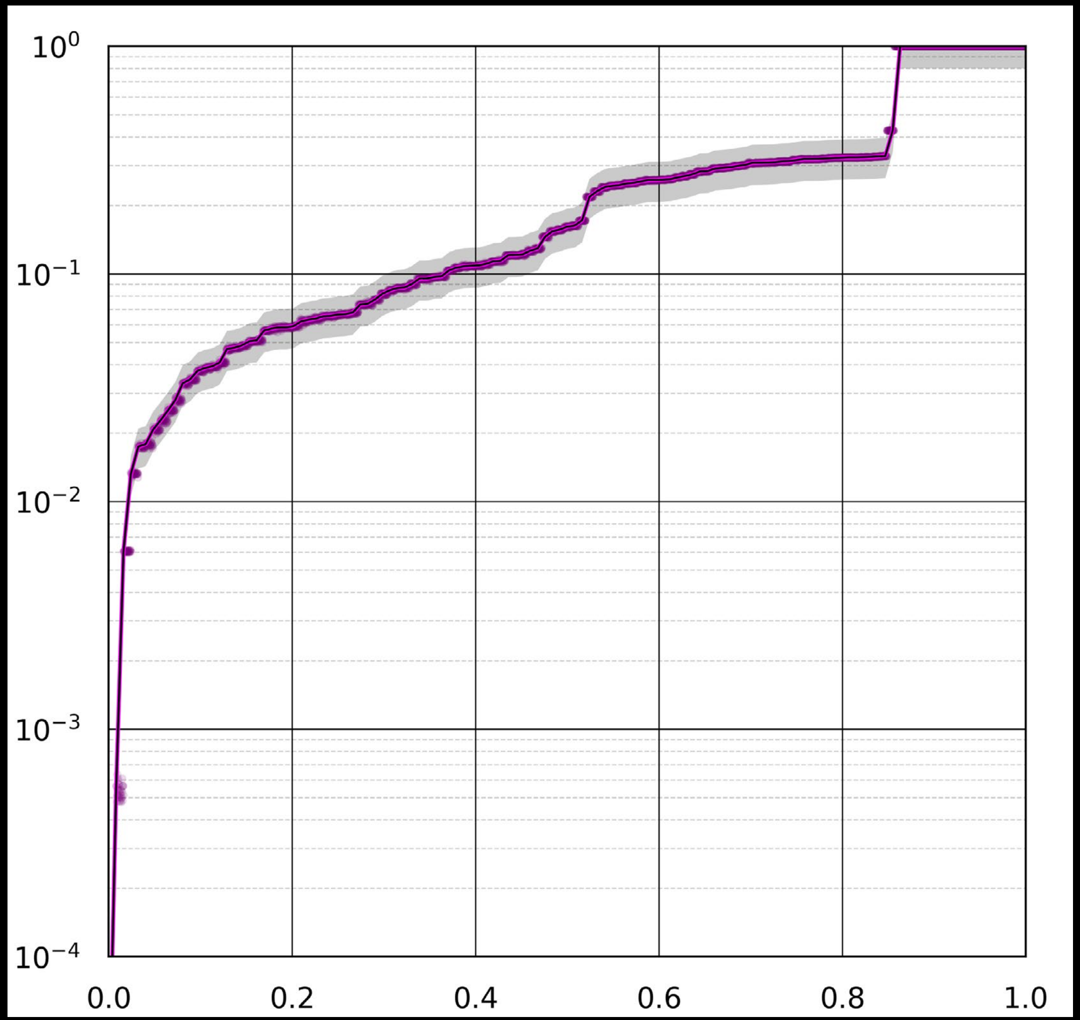


PATCH_076

repeated 32 times samp/sec: 11.5

rRMSD: 0.446 rMSD: -0.007

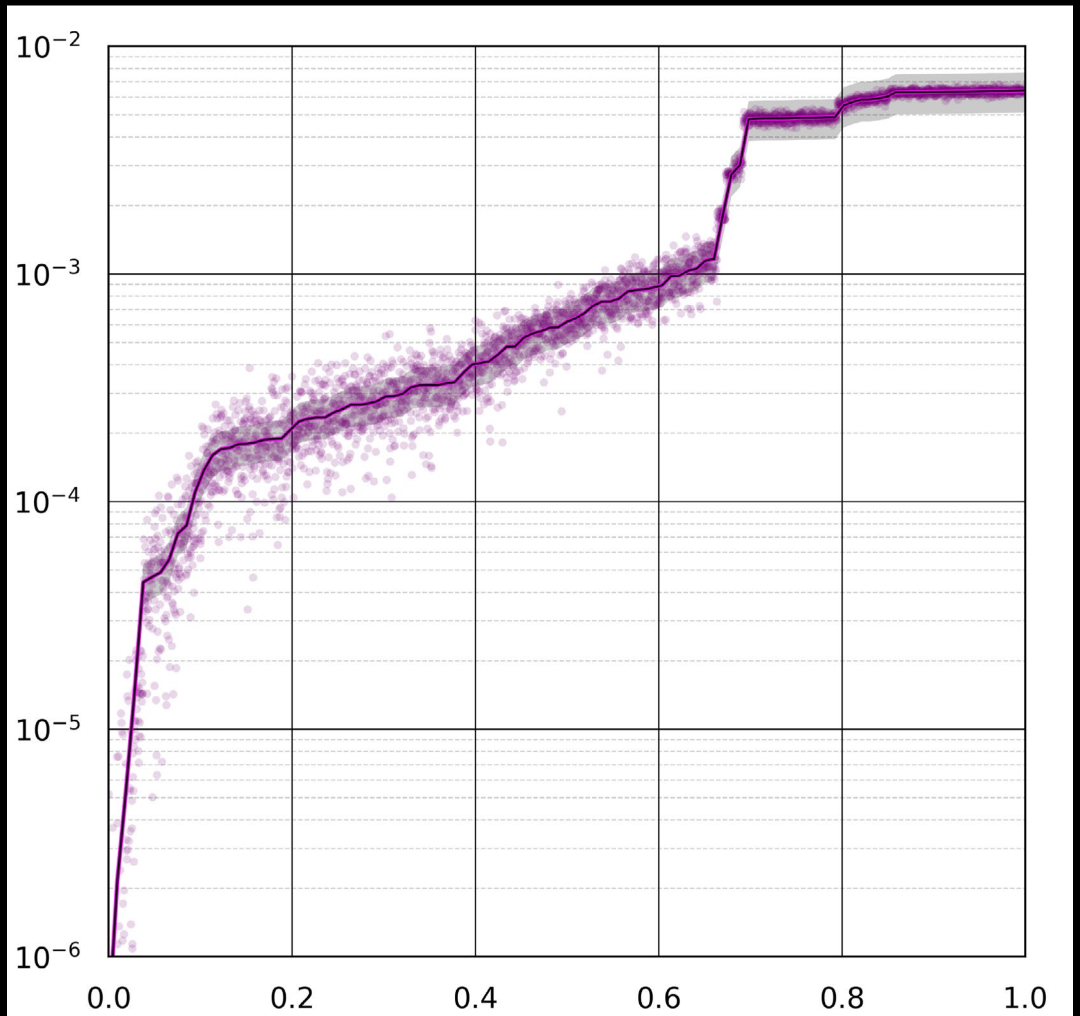
integrated (trans/sky) vs. specular



ALL -ad 16000 -lw 1e-8 -lr -14

repeated 32 times samp/sec: 0.7

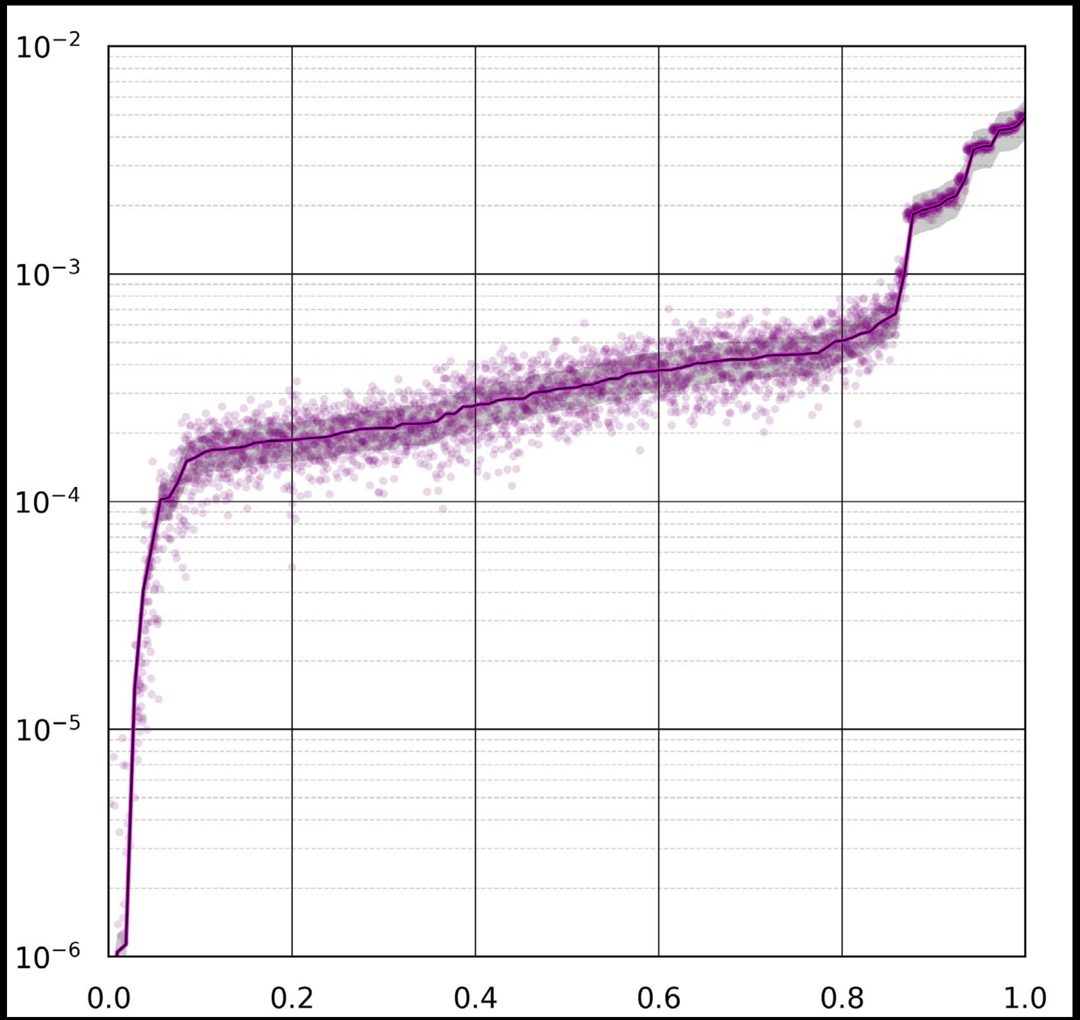
rRMSD: 0.009



PATCH_001

repeated 32 times samp/sec: 0.7

rRMSD: 0.213



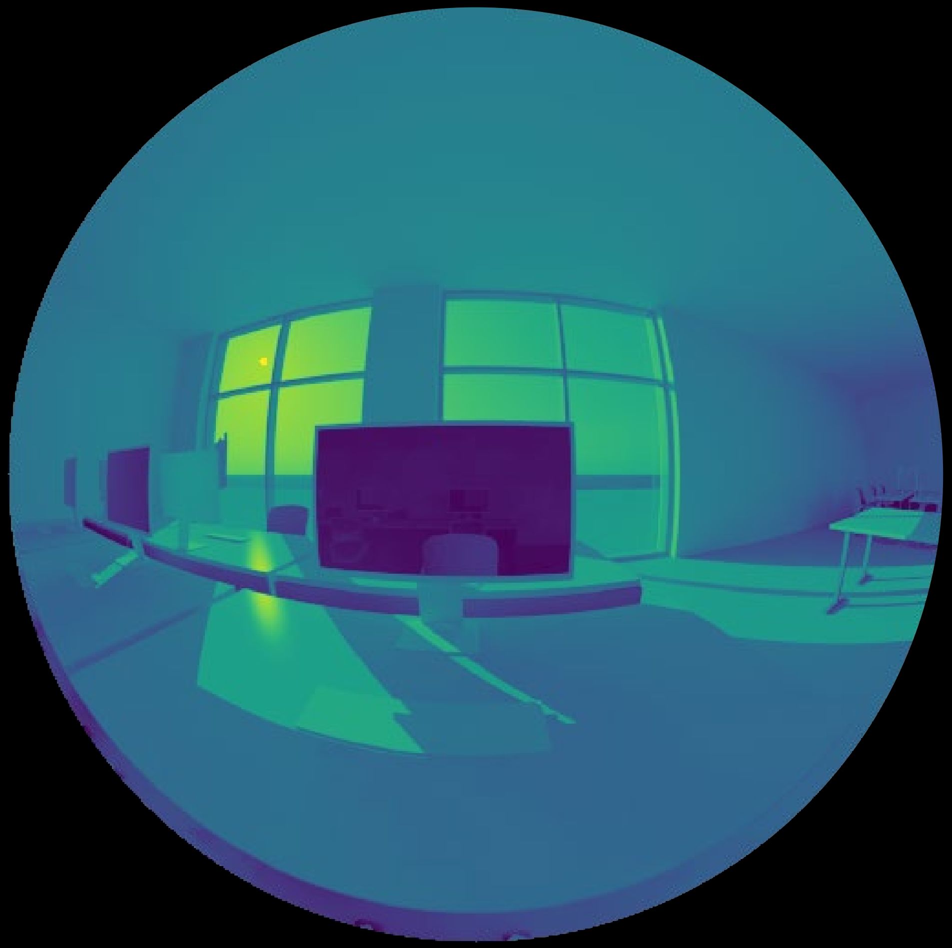
PATCH_076

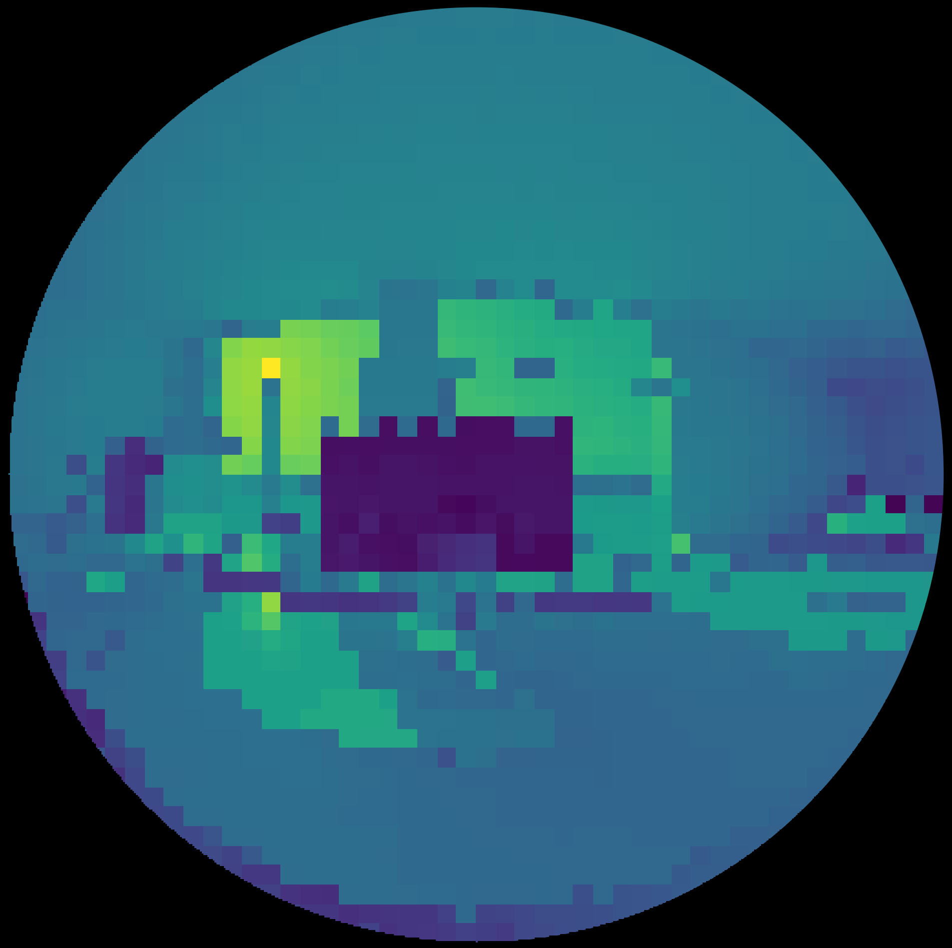
repeated 32 times samp/sec: 0.7

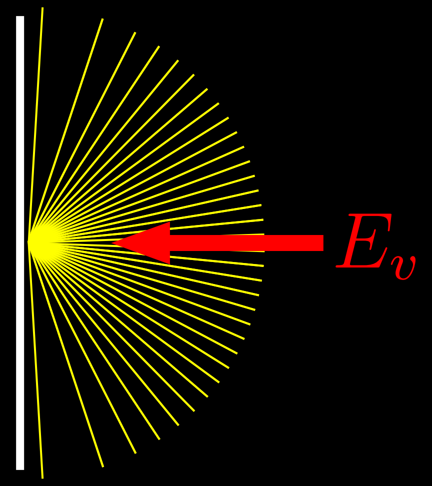
rRMSD: 0.253

sampling a point

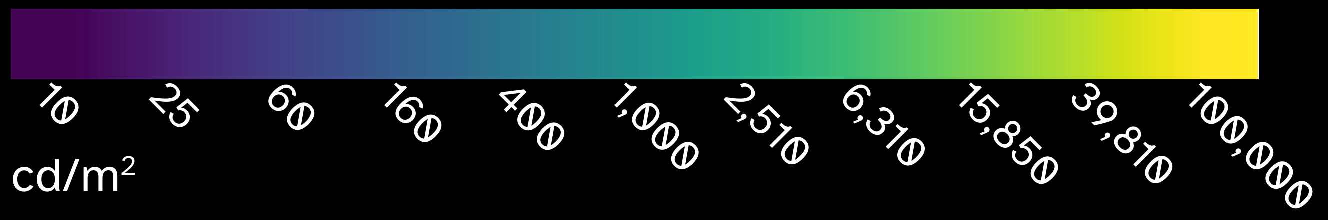
Existing Options For Sampling a Point



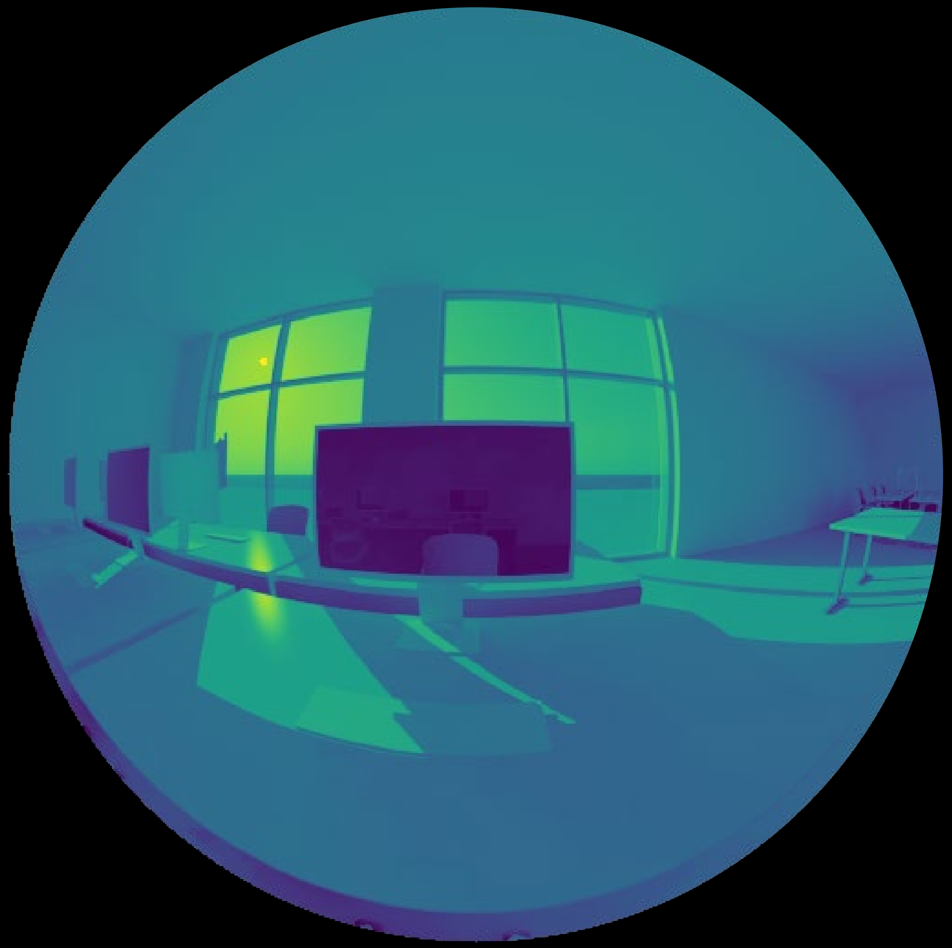


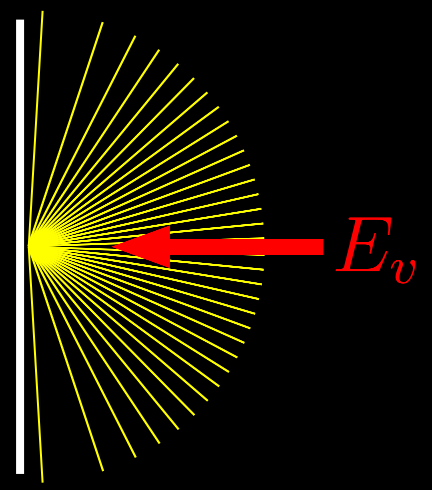


Samples	10^6 samples	10^3 samples	1 sample
Accuracy	High	Low	Medium
Information	High	Medium	Low

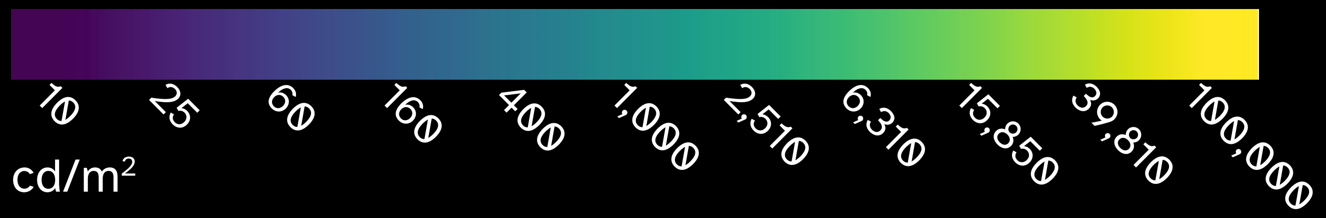


Existing Options For Sampling a Point

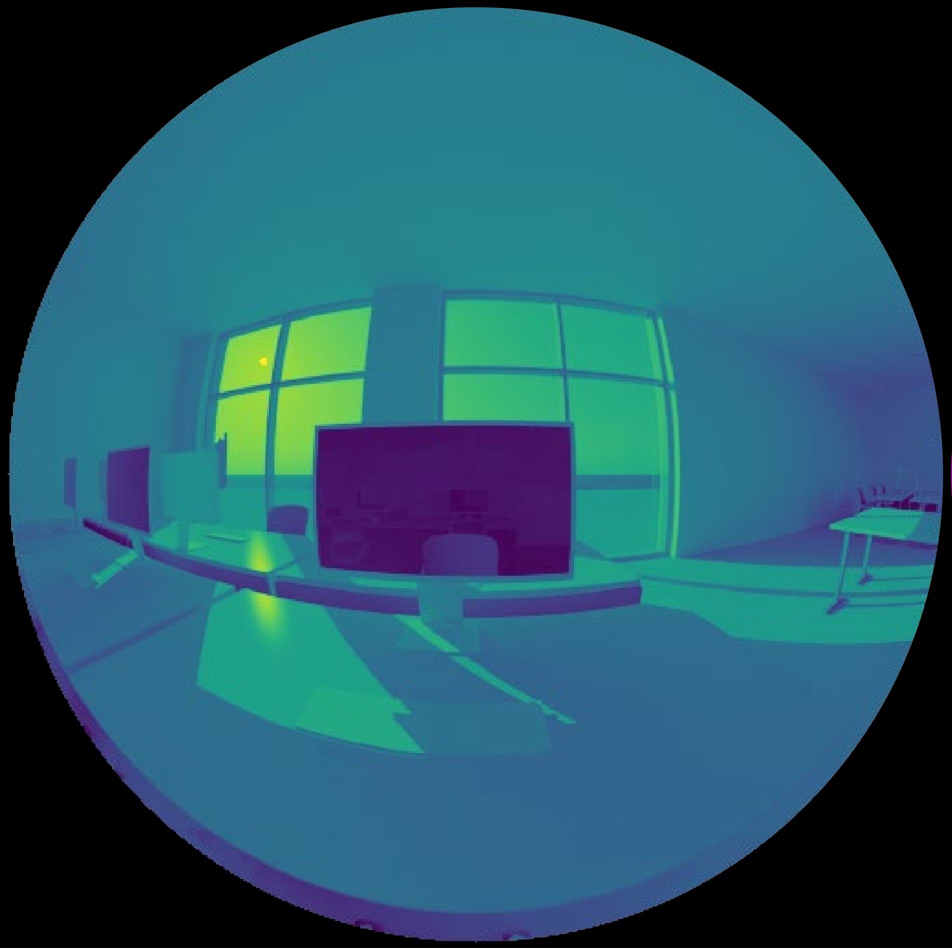


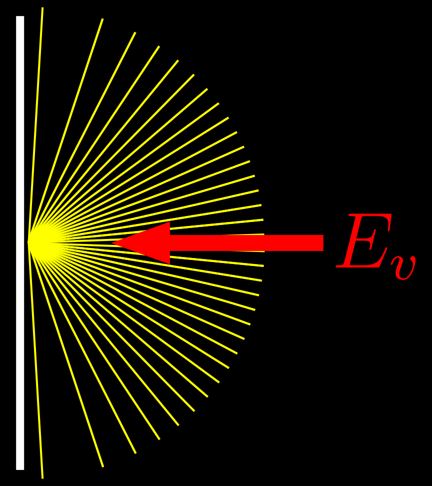


Samples	10^6 samples		1 sample
Accuracy	High		Medium
Information	High		Low

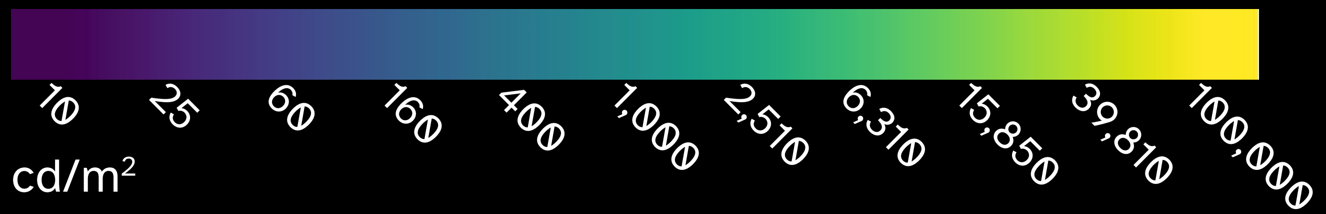


The Potential in Sampling

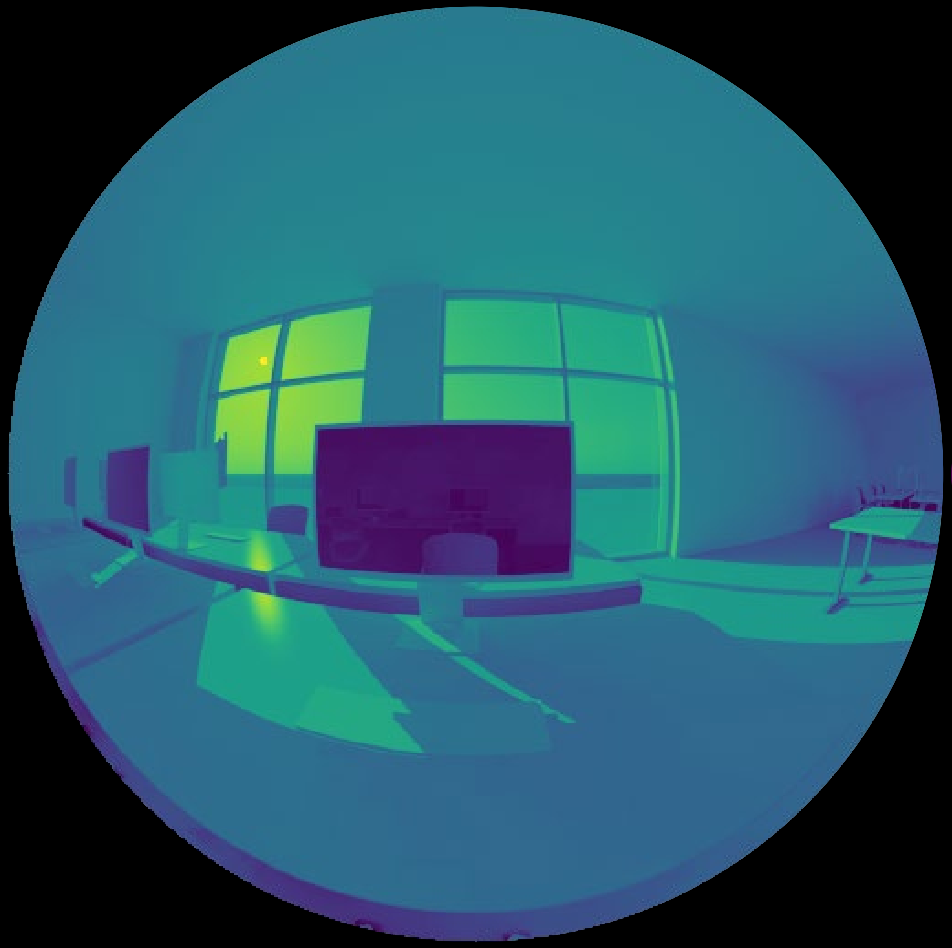


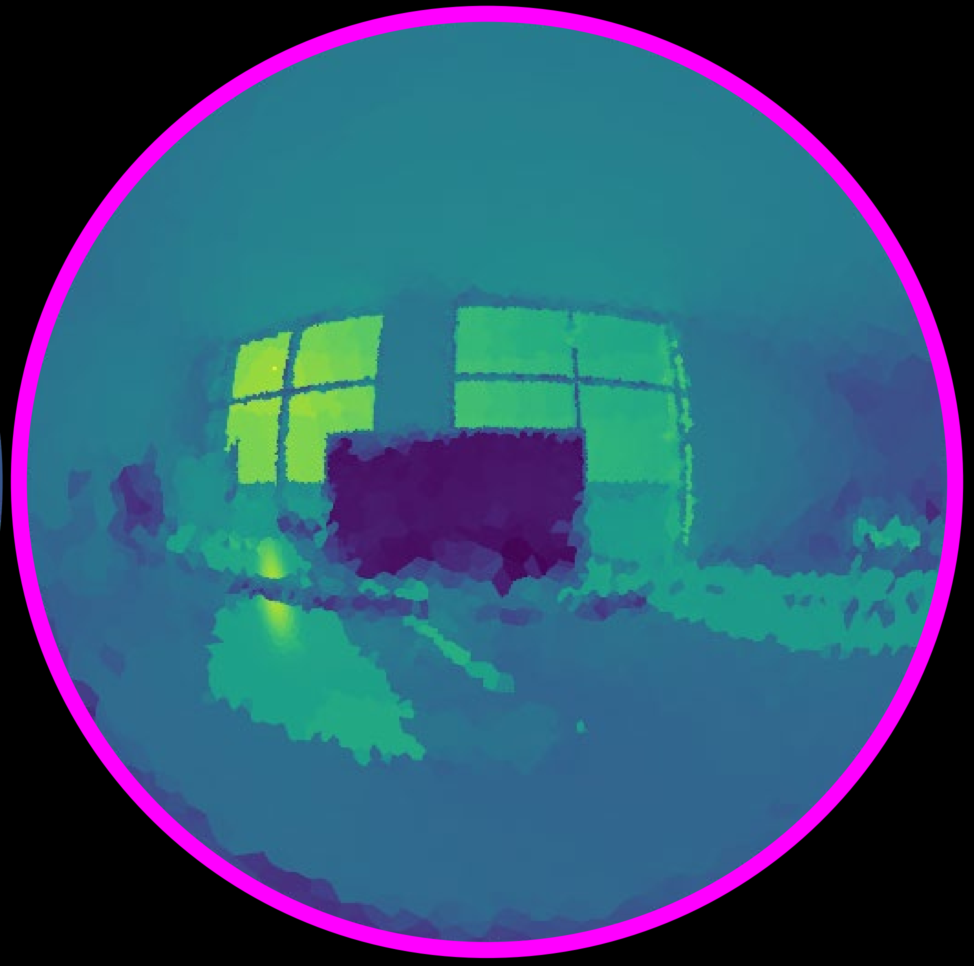


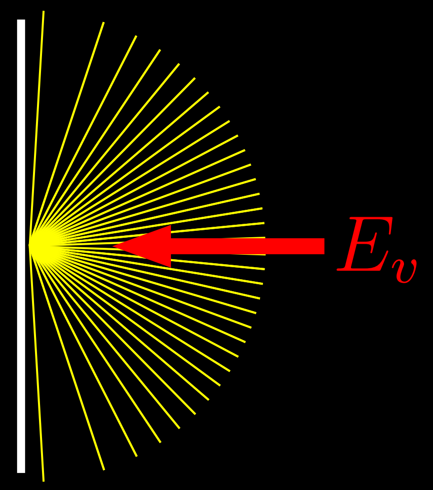
Samples	10^6 samples	7 Samples	1 sample
Accuracy	High	High	Medium
Information	High	Medium	Low



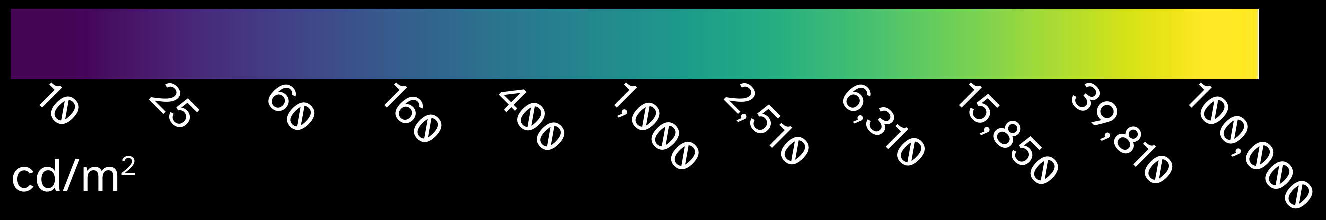
The Potential in Sampling



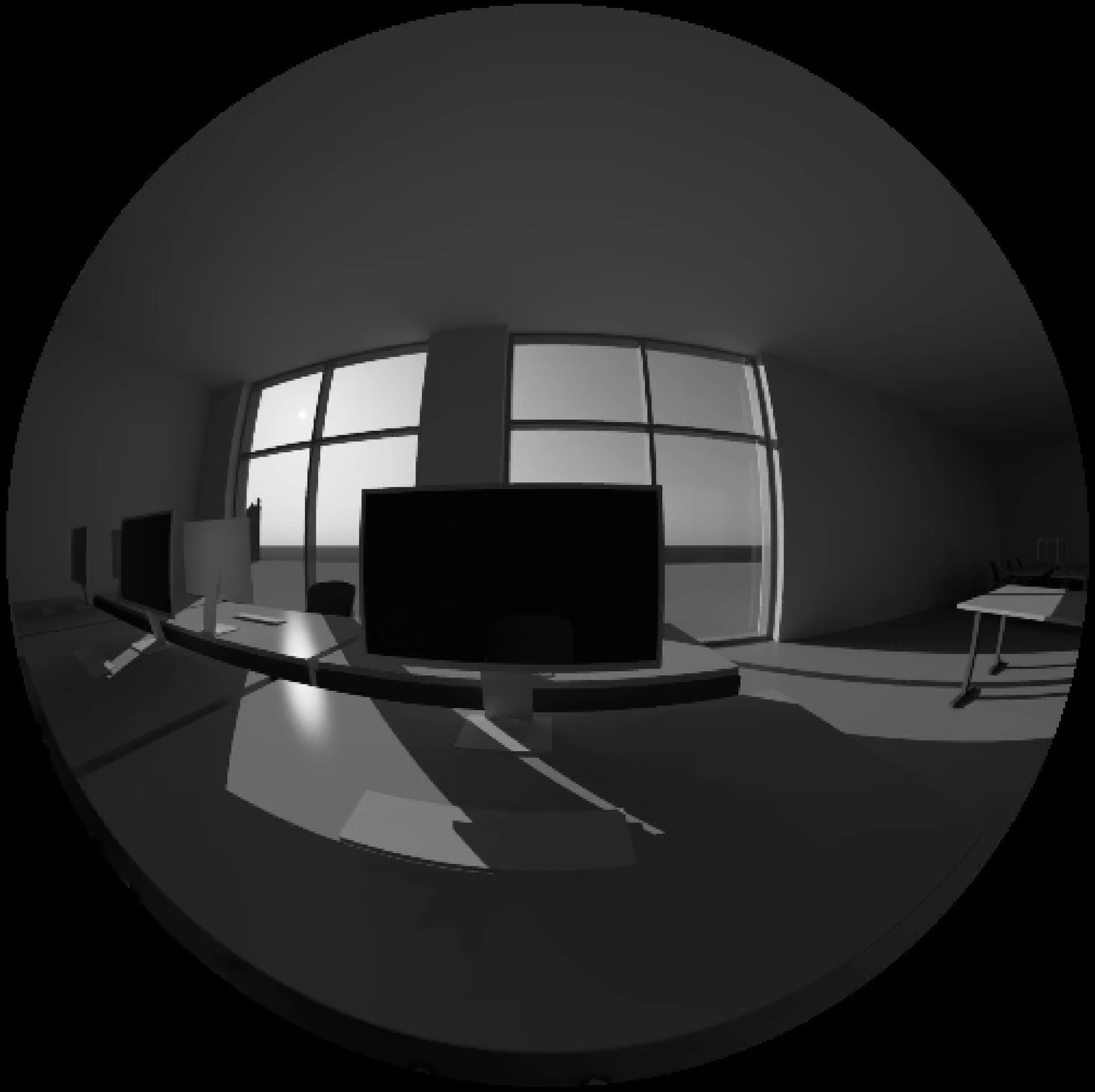




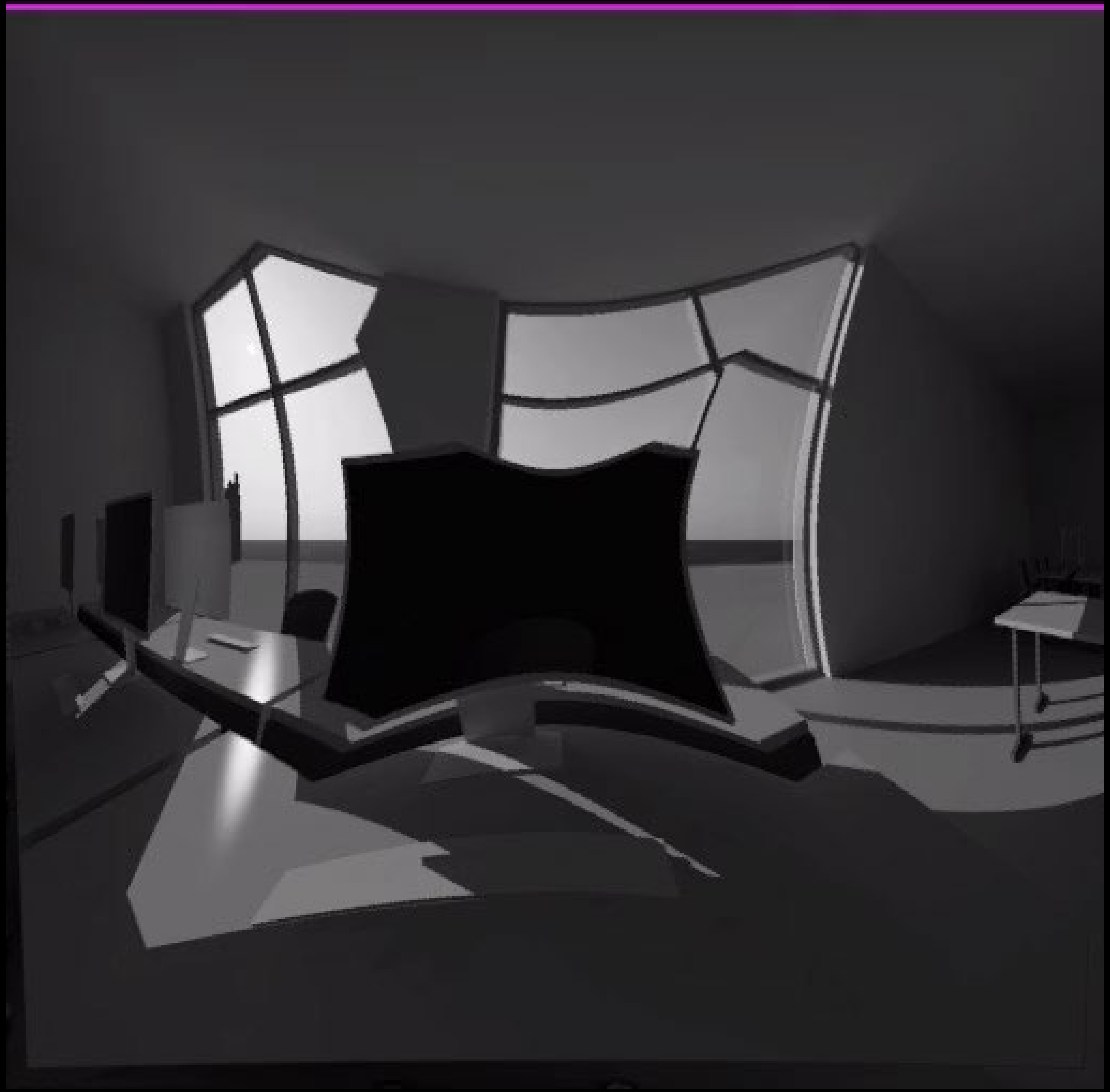
Samples	10^6 samples	10^3 samples	1 sample
Accuracy	High	High	Medium
Information	High	High	Low



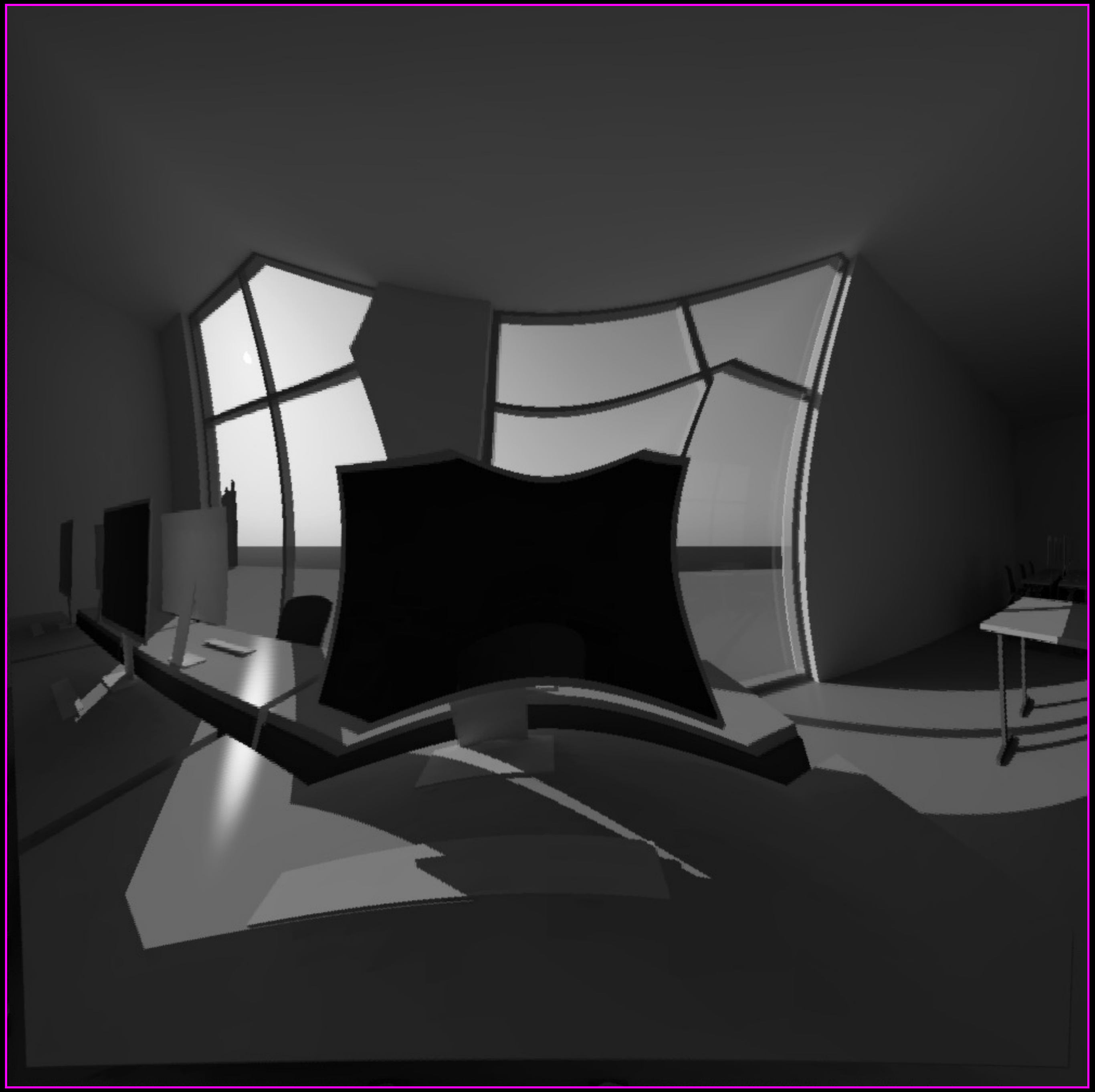
Wavelet Decomposition



Wavelet Decomposition

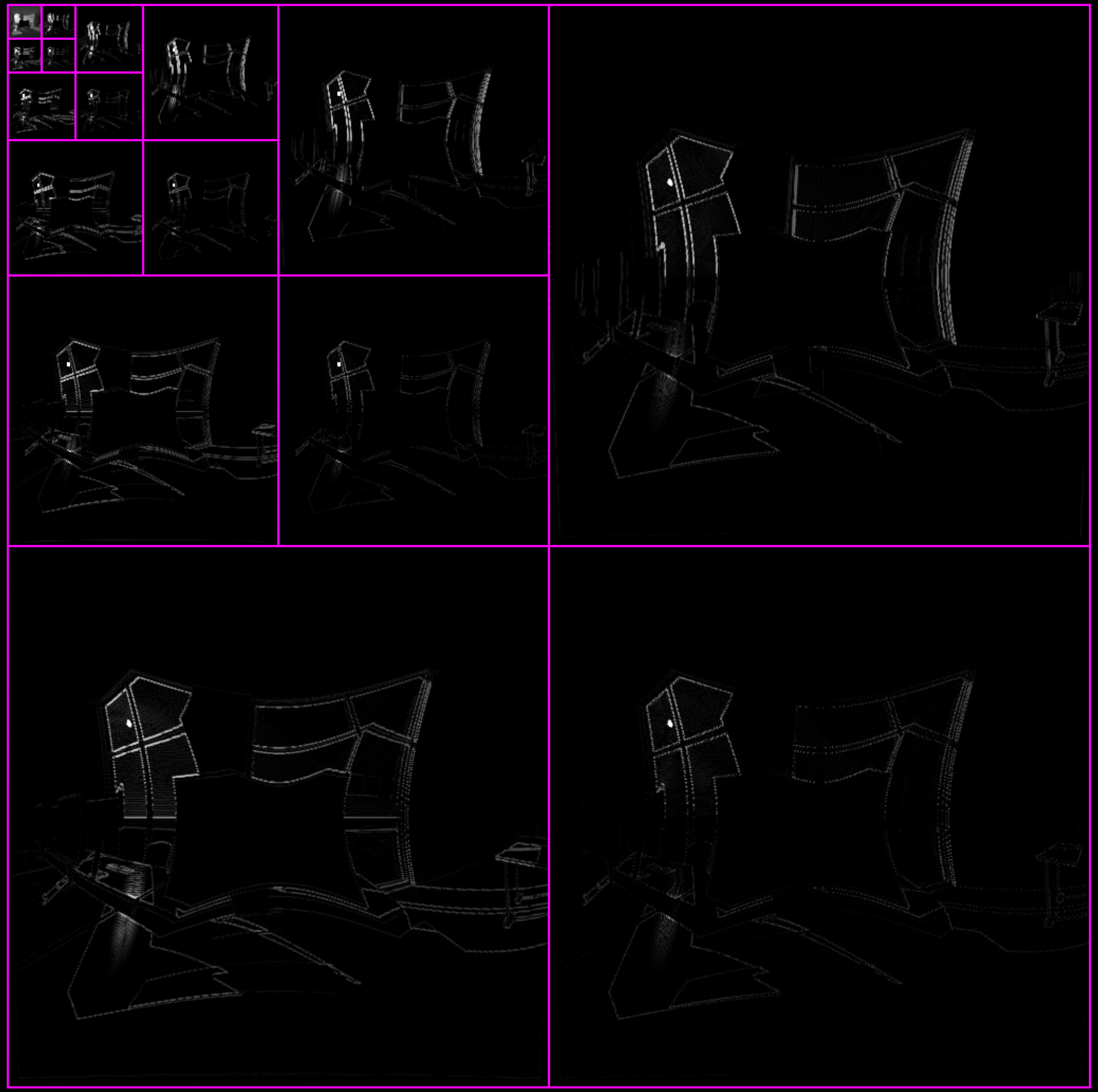


Original



100%

Wavelet Decomposition



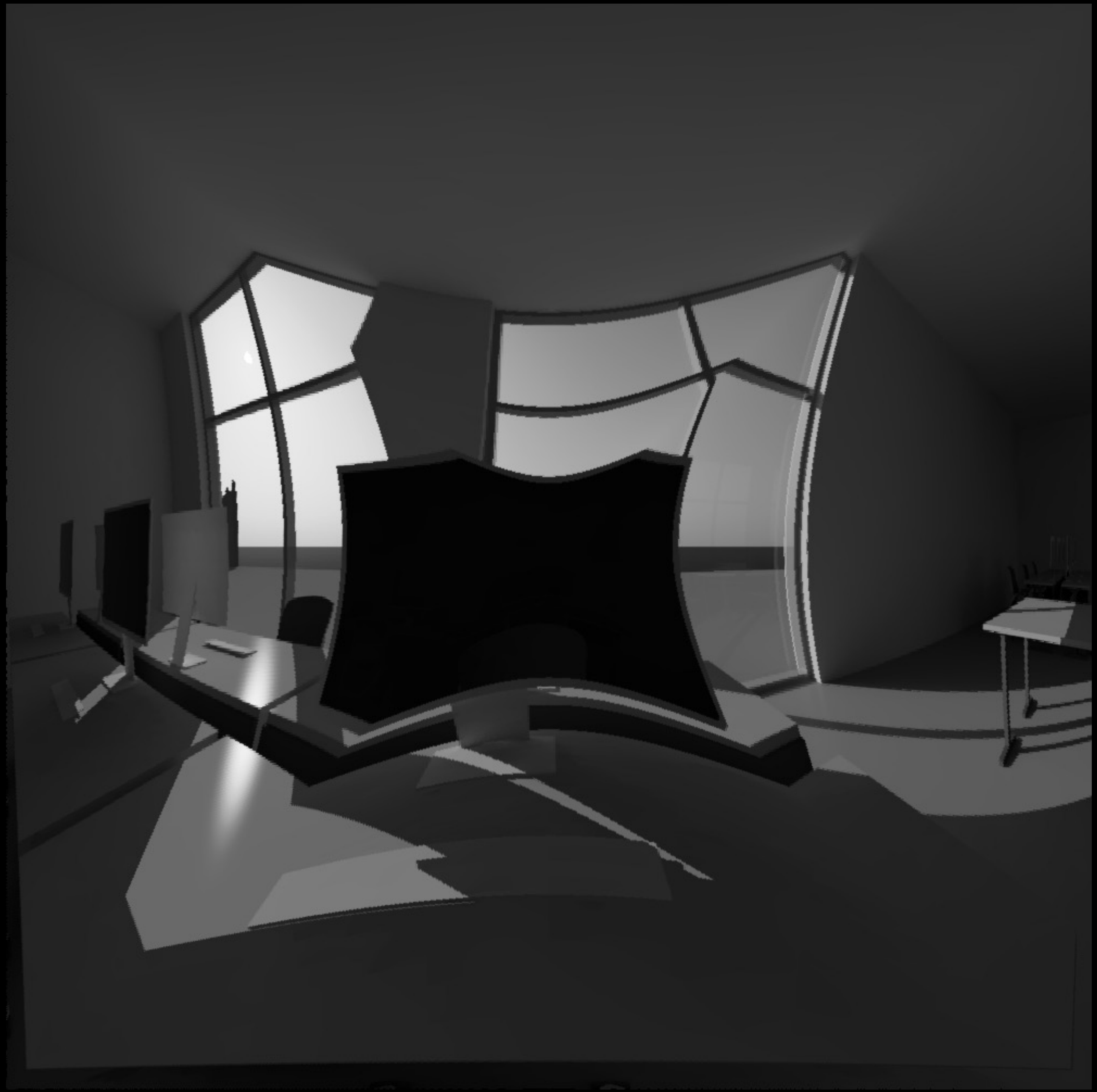
> 0.1cd/m² = 35%

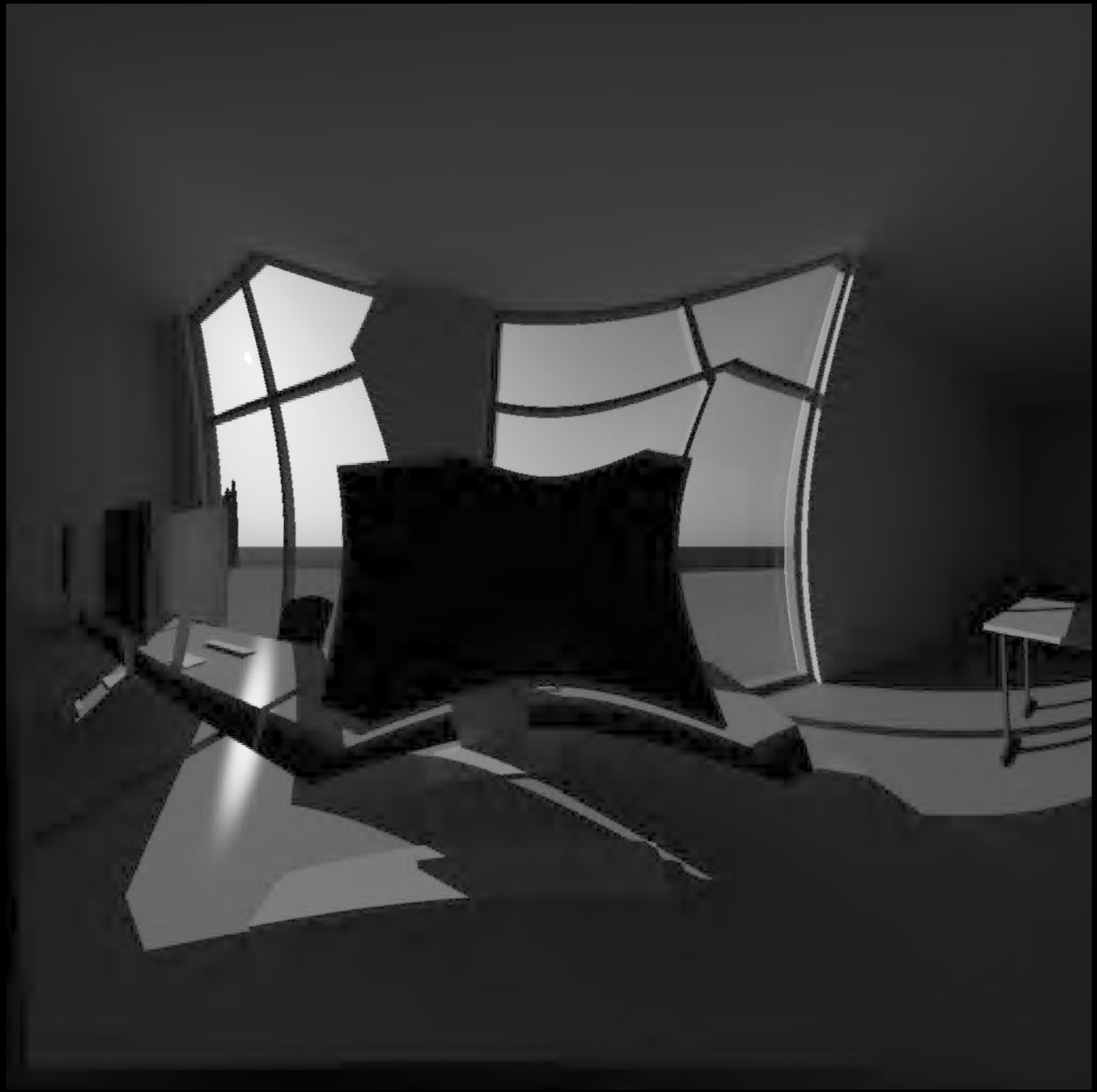
> 1cd/m² = 12%

> 10 cd/m² = 4%

> 100 cd/m² = 0.7%

Wavelet Compression

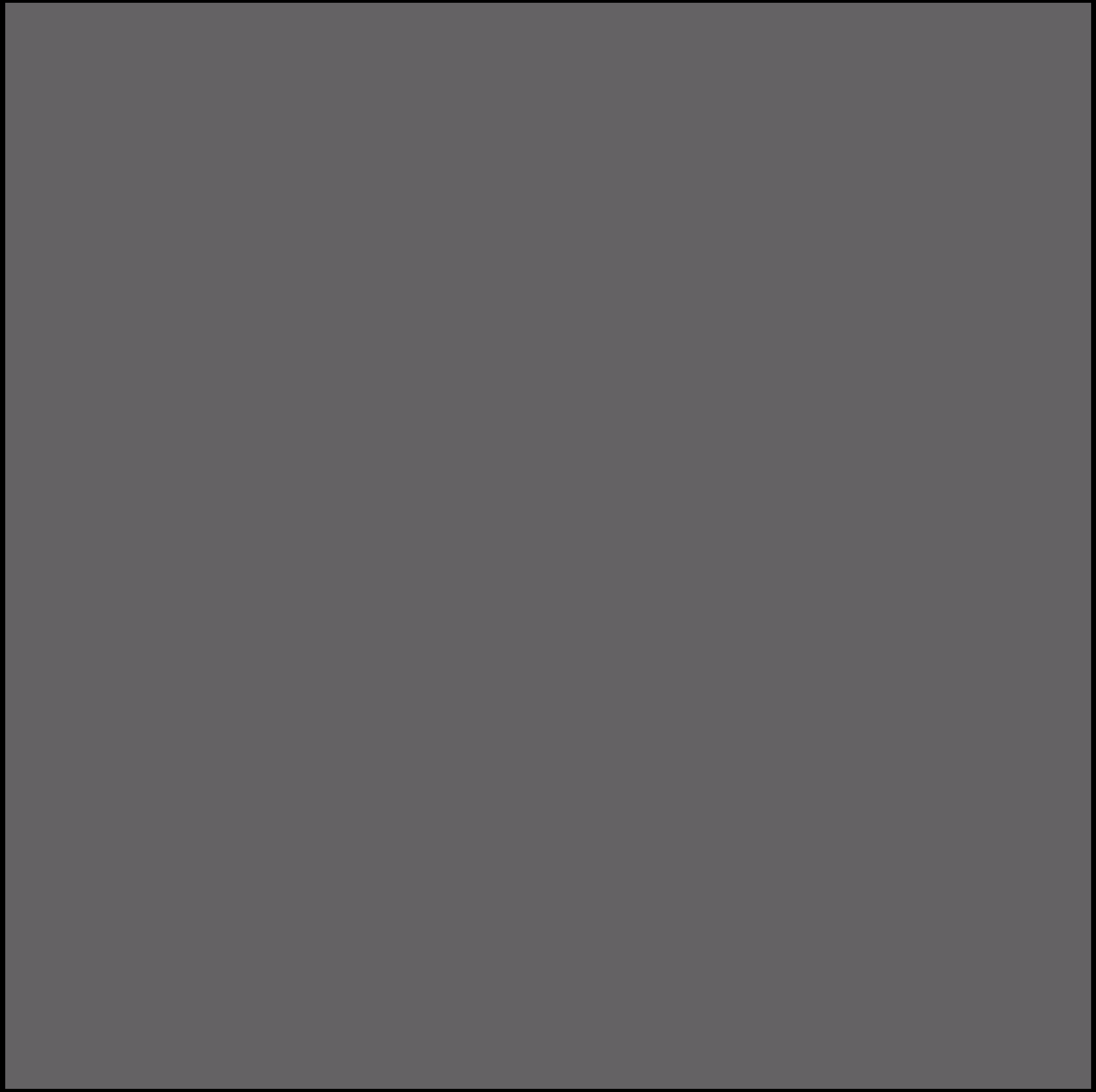




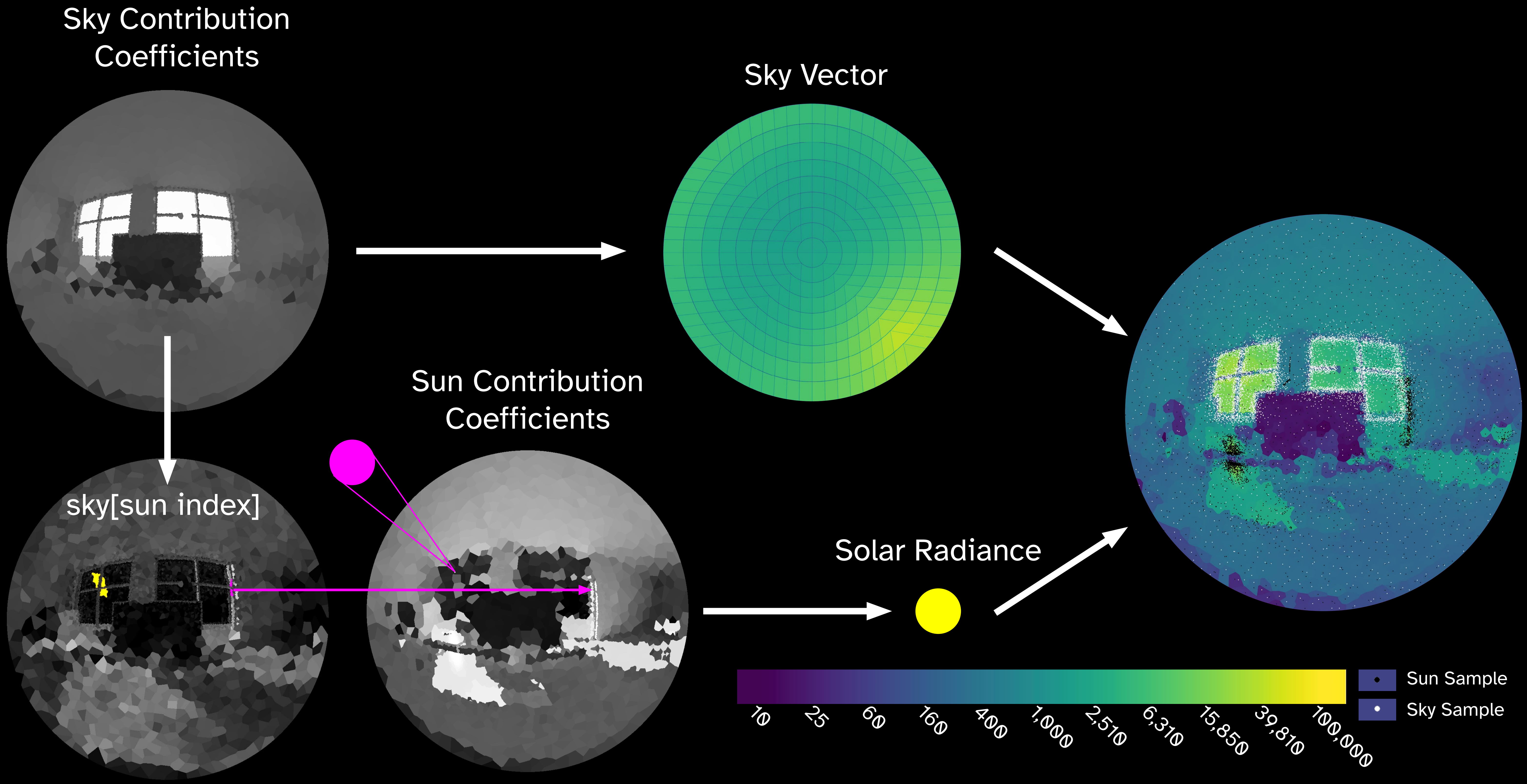
100%

0.7%

Reconstruction Through Sampling



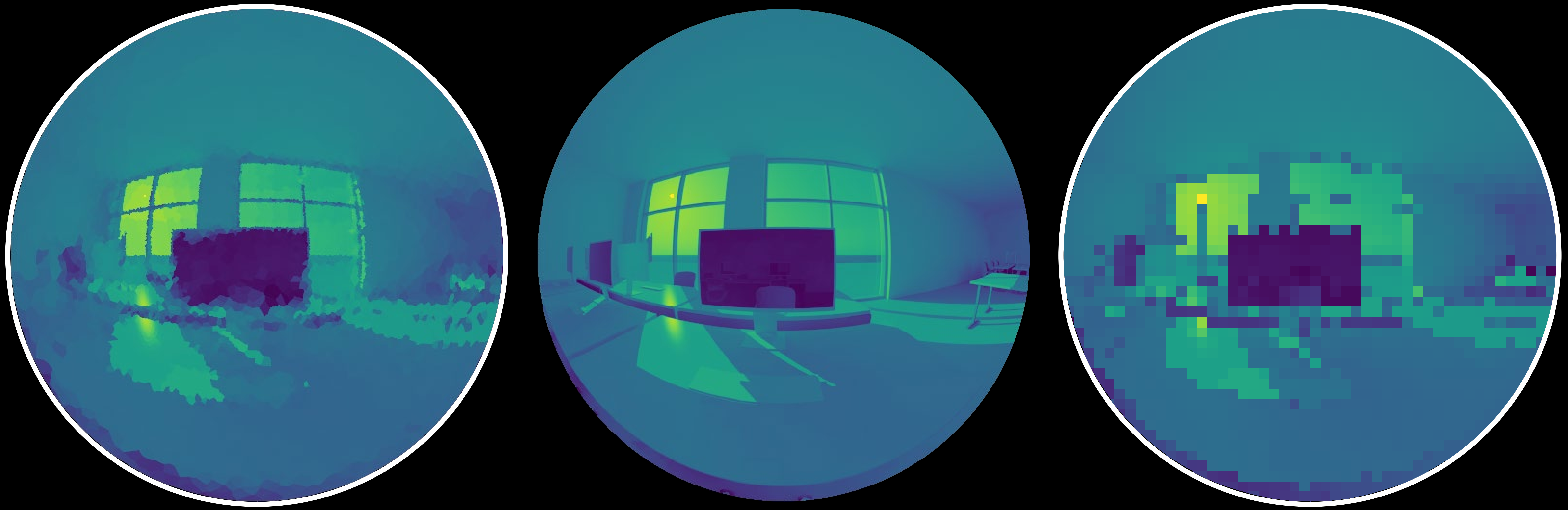
Component Sampling



Clear glazing w/ view to direct sun and semi-specular reflection

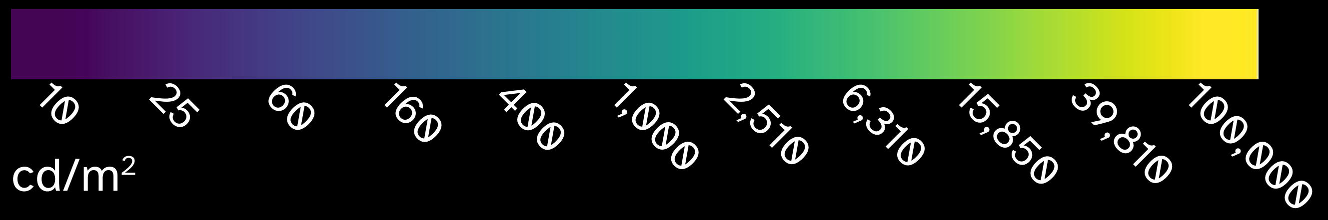
Results

Raytraverse | Reference / High Resolution | Uniform / Equal Sampling



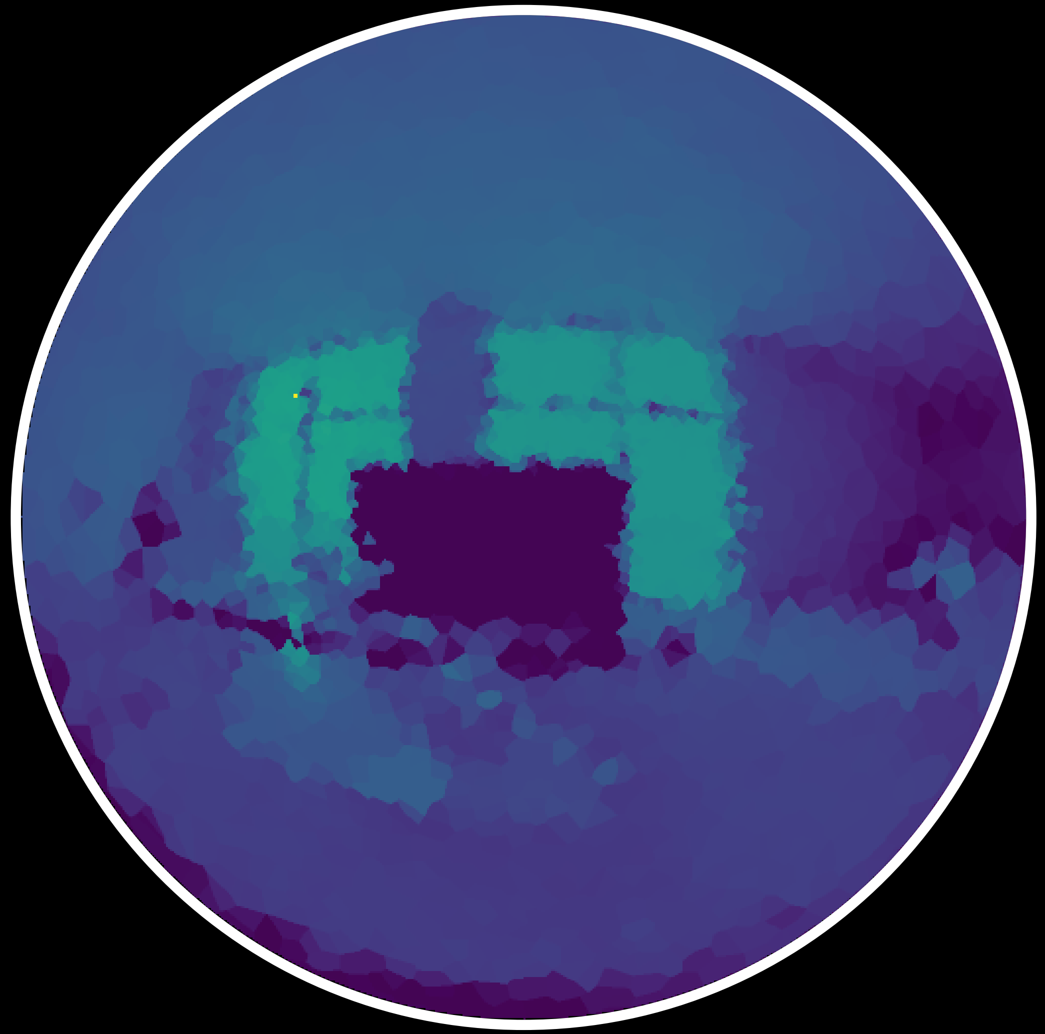
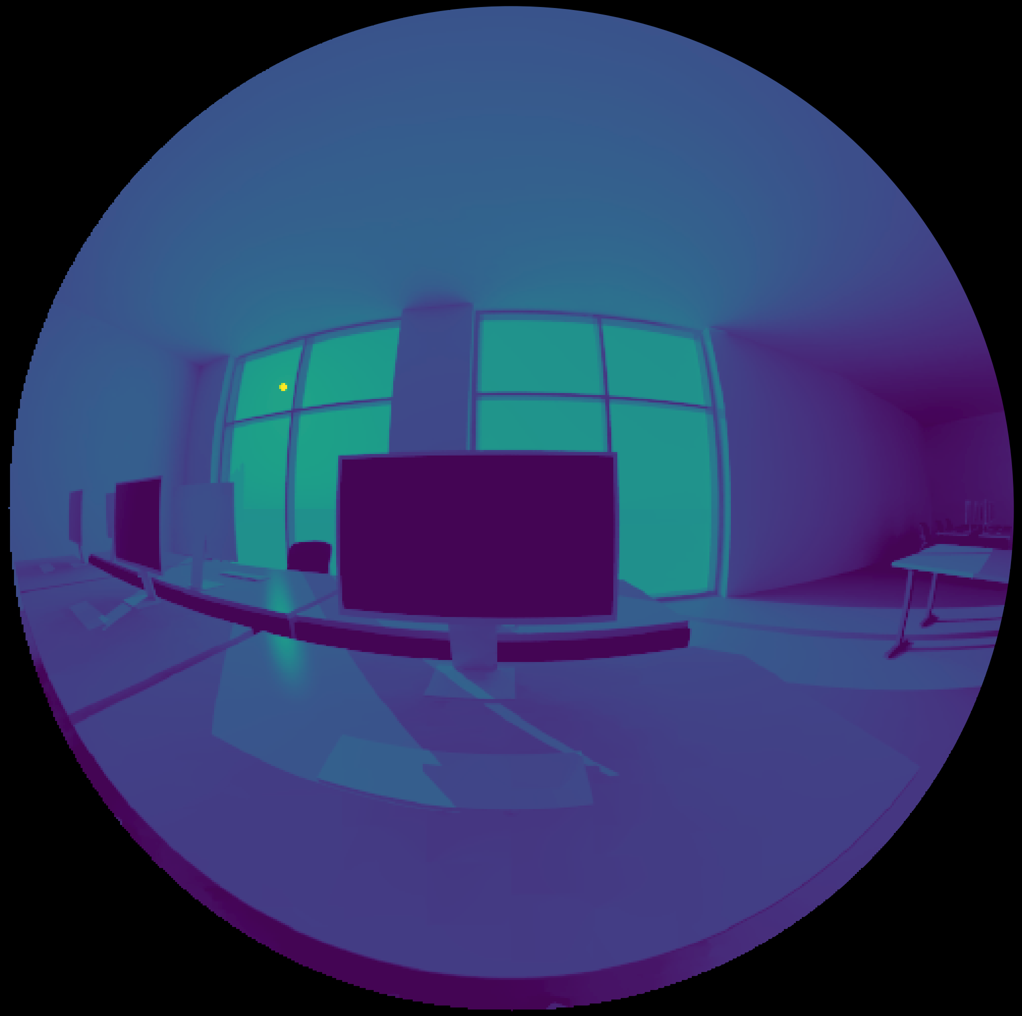
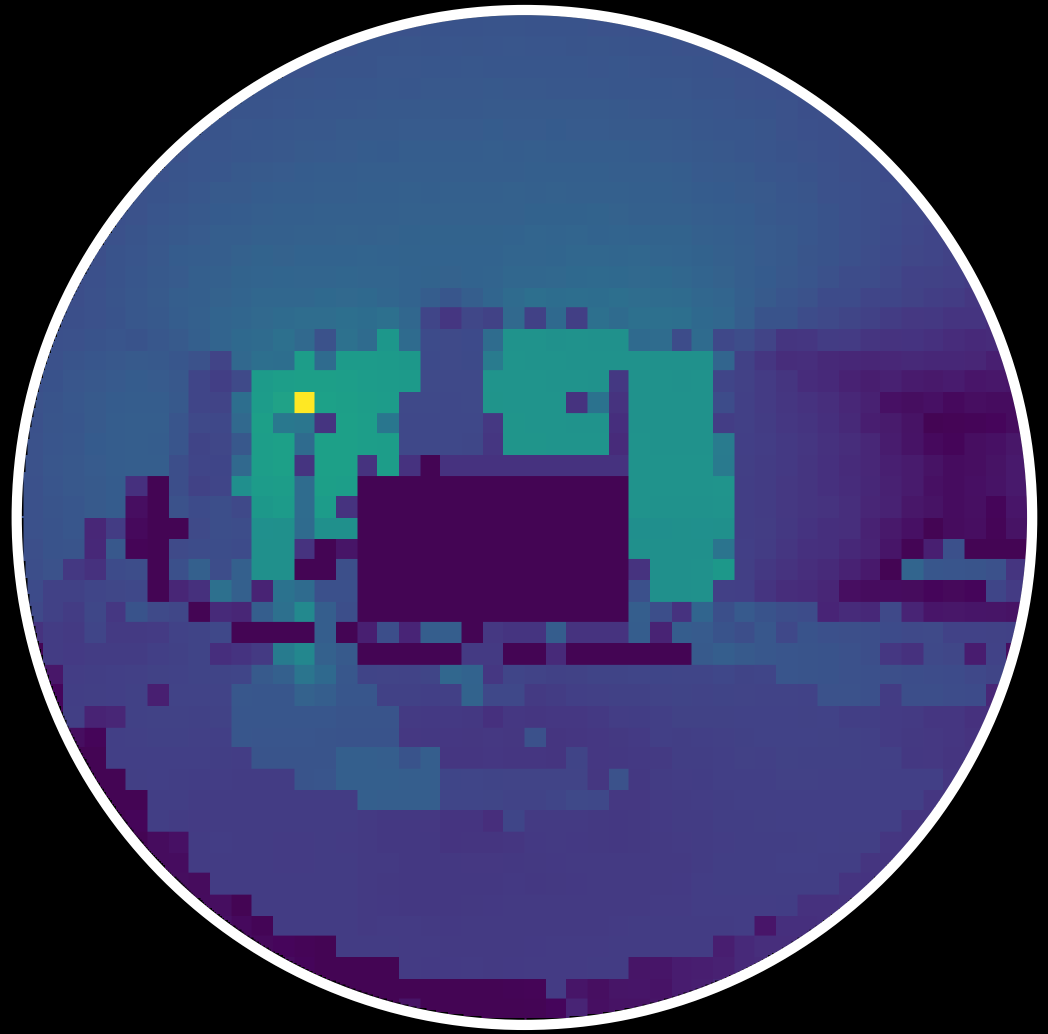
+4.9% ← relative deviation — **Ev = 28,140 lux** — relative deviation → **+7.2%**

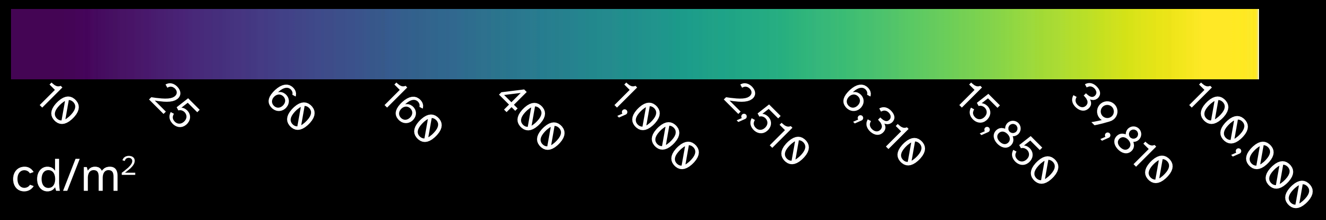
+1.3% ← — **UGR = 65.9** — → **-11.2%**



Fabric shade w/ view to direct sun

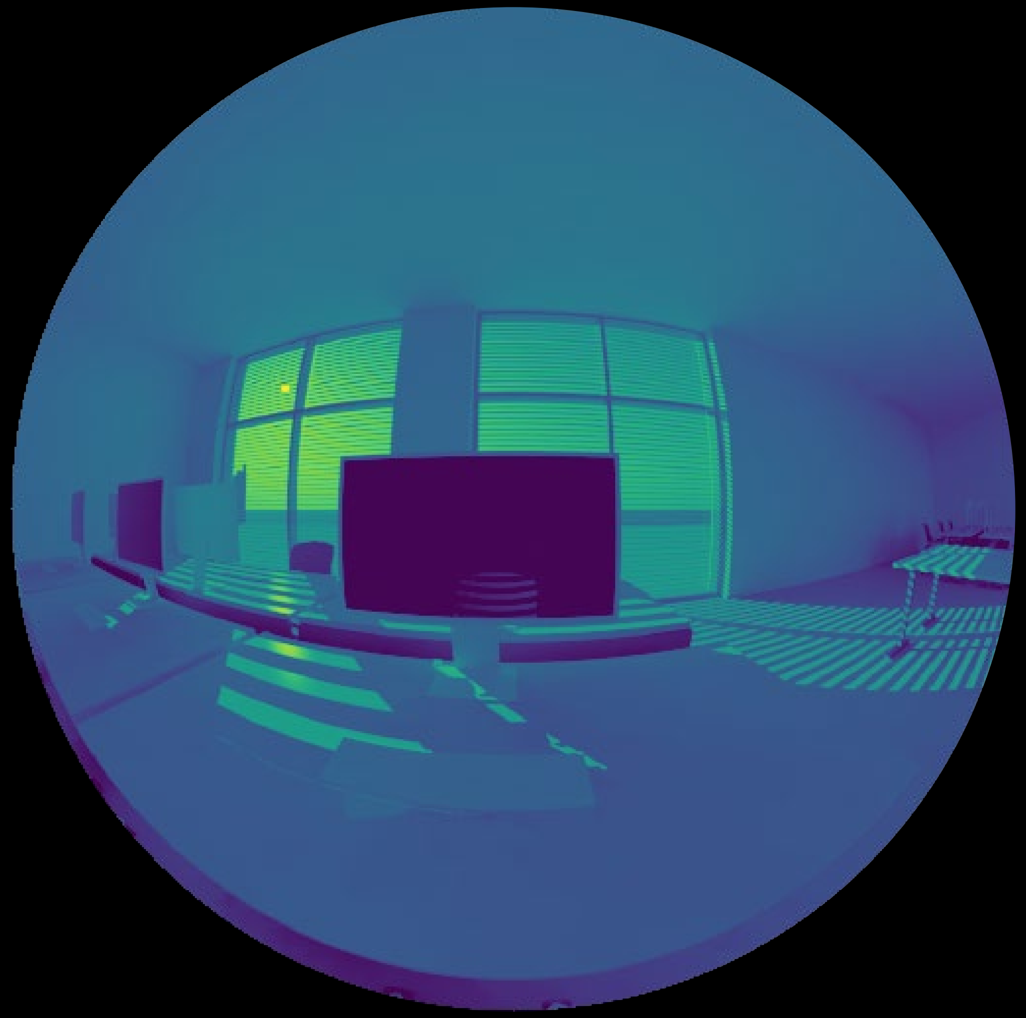
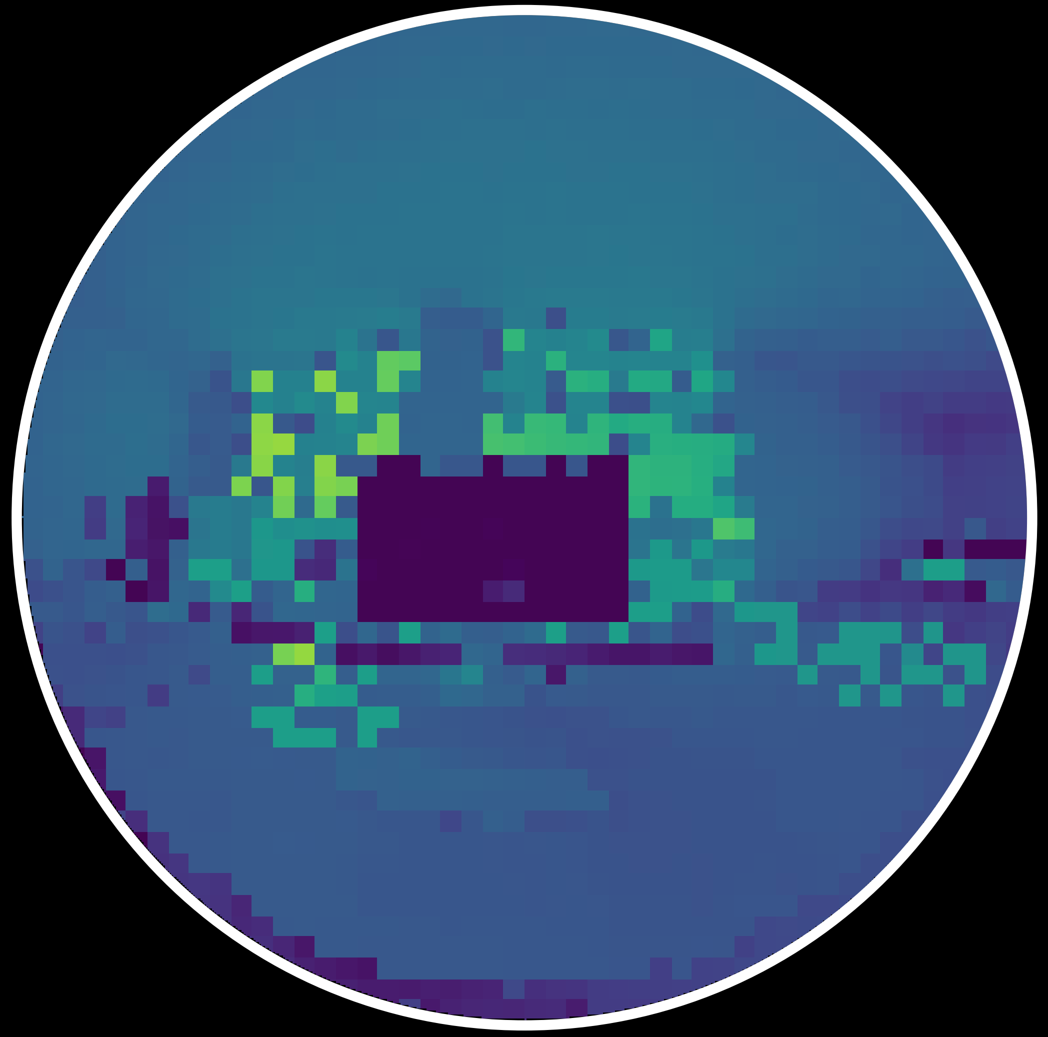
Results

Raytraverse	Reference / High Resolution	Uniform / Equal Sampling
		
-0.8% ← relative deviation	**Ev = 1,800 lux**	relative deviation → **-0.7%**
+1.4% ←	**UGR = 46.3**	→ **-19.3%**

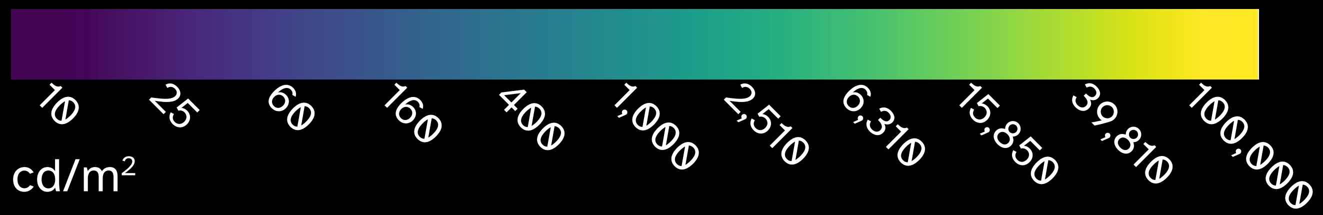


Venetian blinds w/ partial view to direct sun

Results

Raytraverse	Reference / High Resolution	Uniform / Equal Sampling
		

Raytraverse		Reference		Uniform / Equal Sampling
-5.6%	← relative deviation	**Ev = 14,330 lux**	relative deviation →	**-83.1%**
+4.0%	←	**UGR = 63.4**	→	**-51.8%**

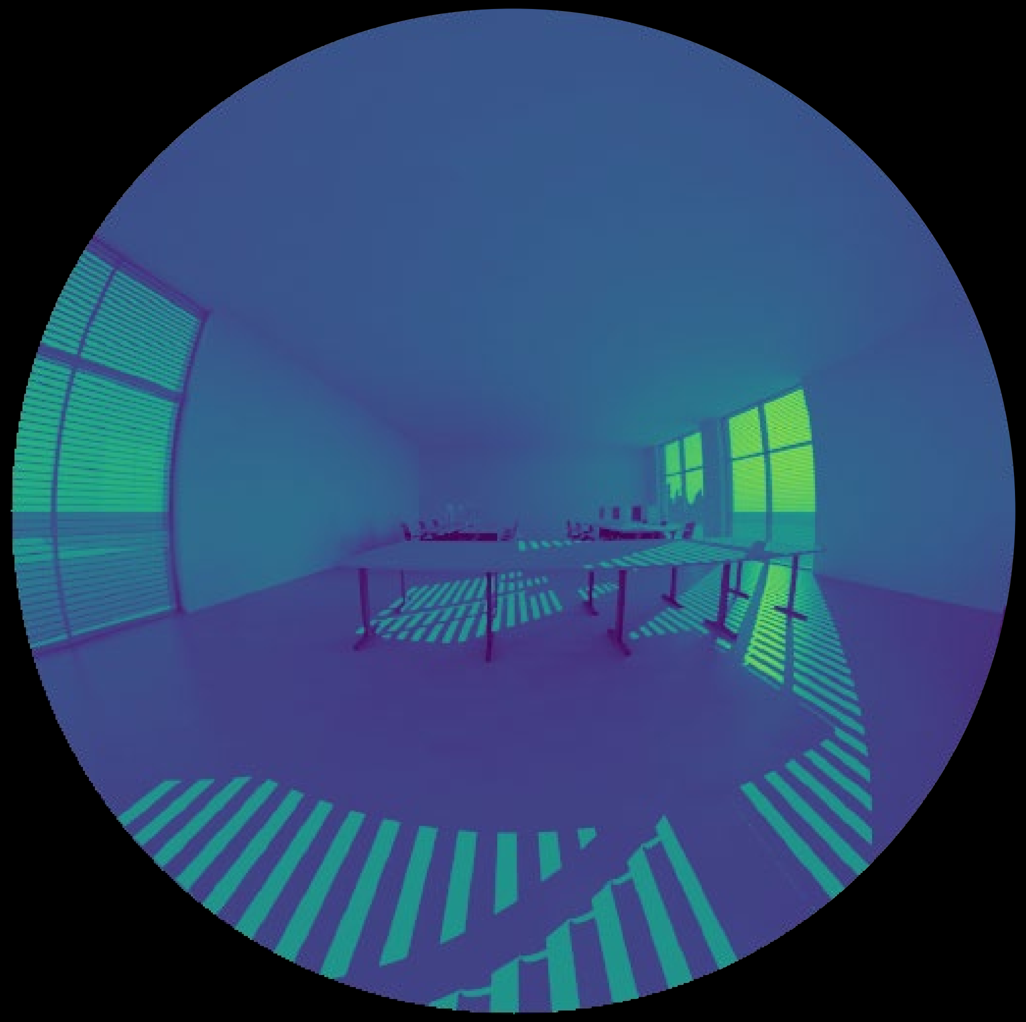


Venetian blinds w/ semi-specular reflection

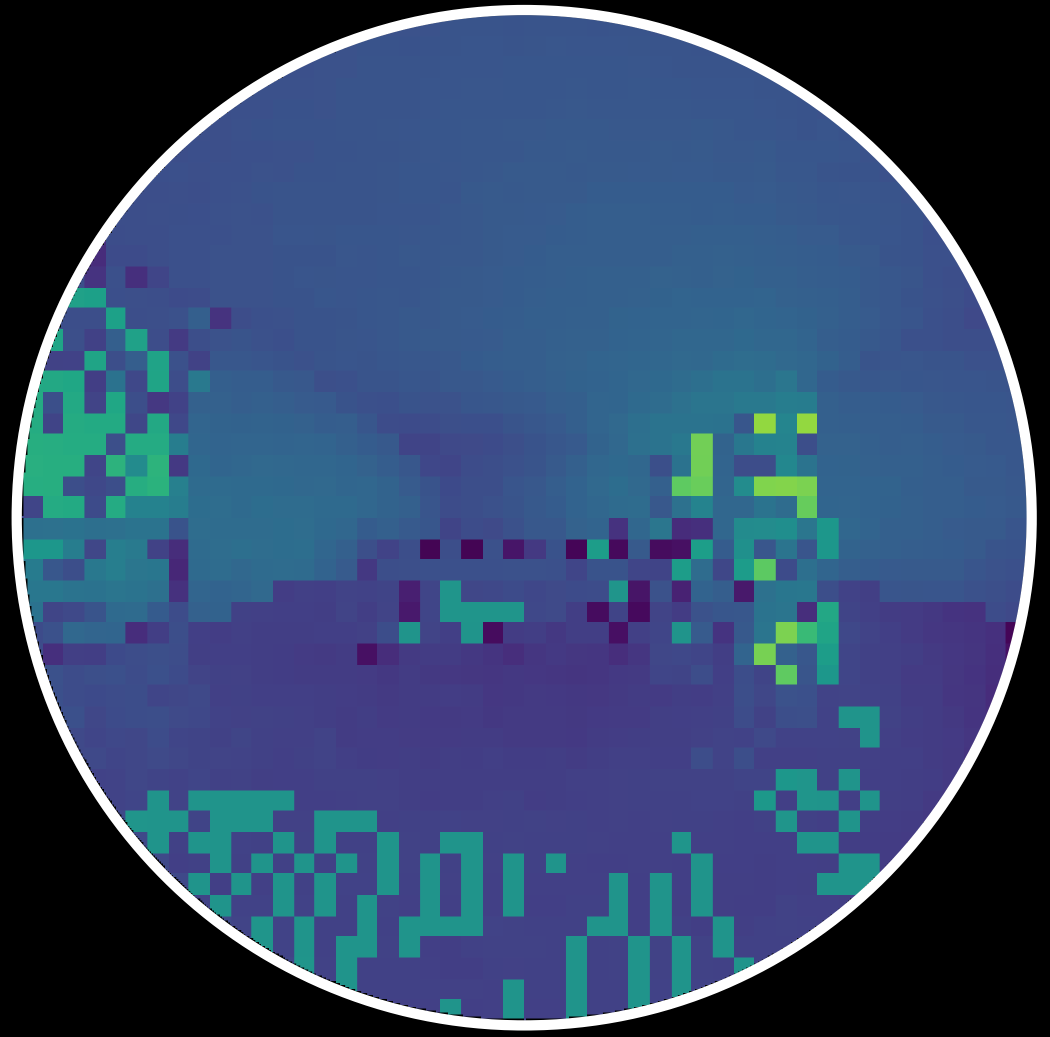
Results

Raytraverse

Reference / High Resolution

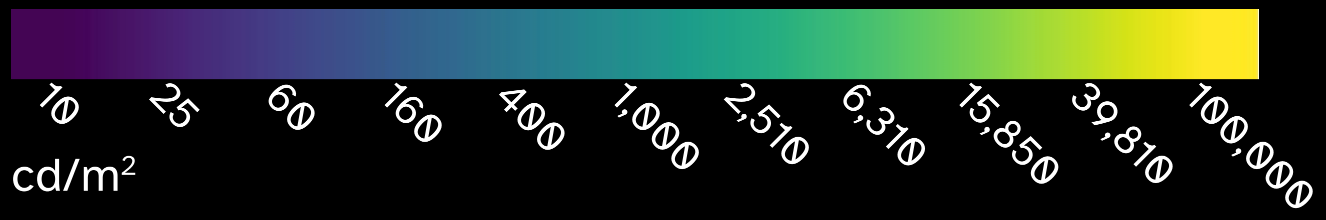


Uniform / Equal Sampling



+3.2% ← relative deviation — **Ev = 1,400 lux** — relative deviation → **-15.1%**

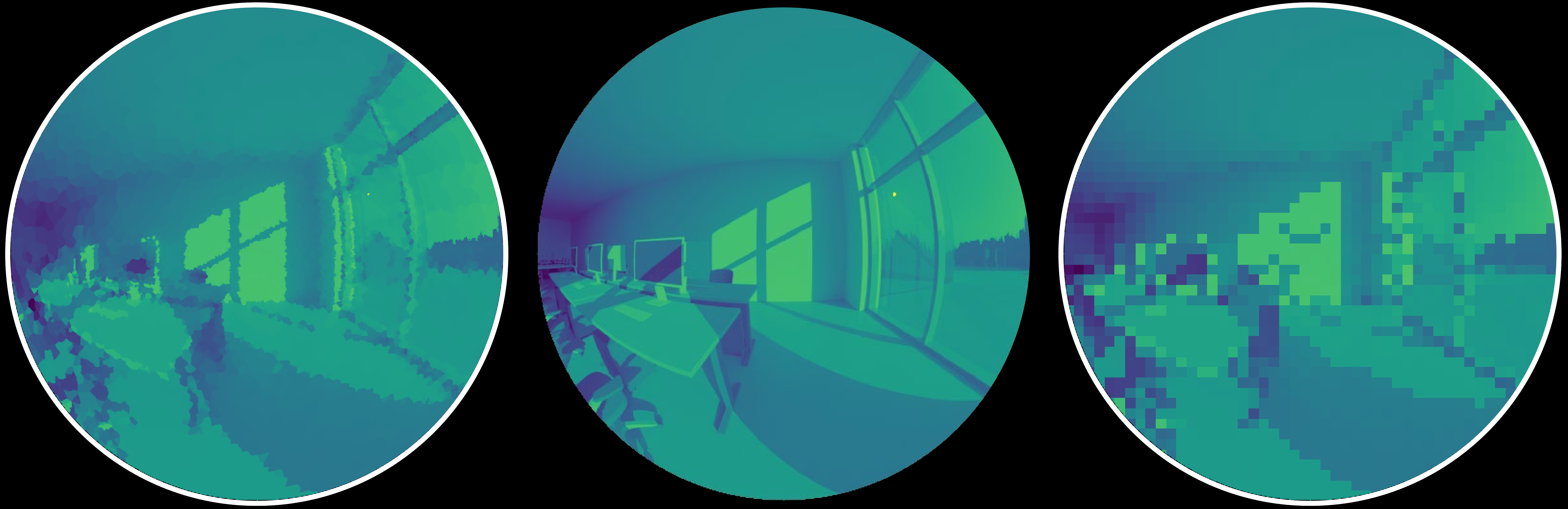
+5.2% ← — **UGR = 27.5** — → **+3.0%**



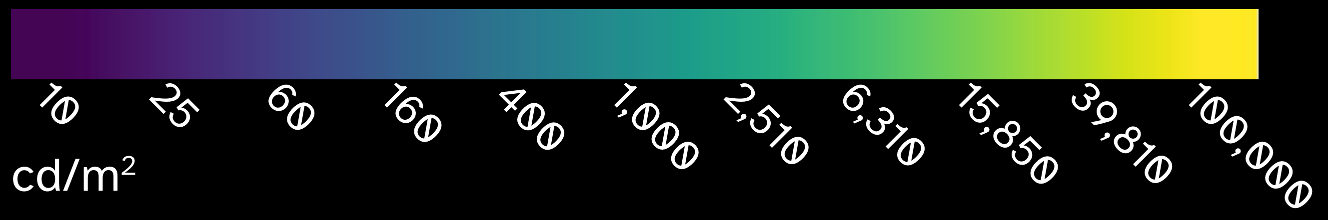
Clear glazing w/ exterior specular reflection

Results

Raytraverse | Reference / High Resolution | Uniform / Equal Sampling



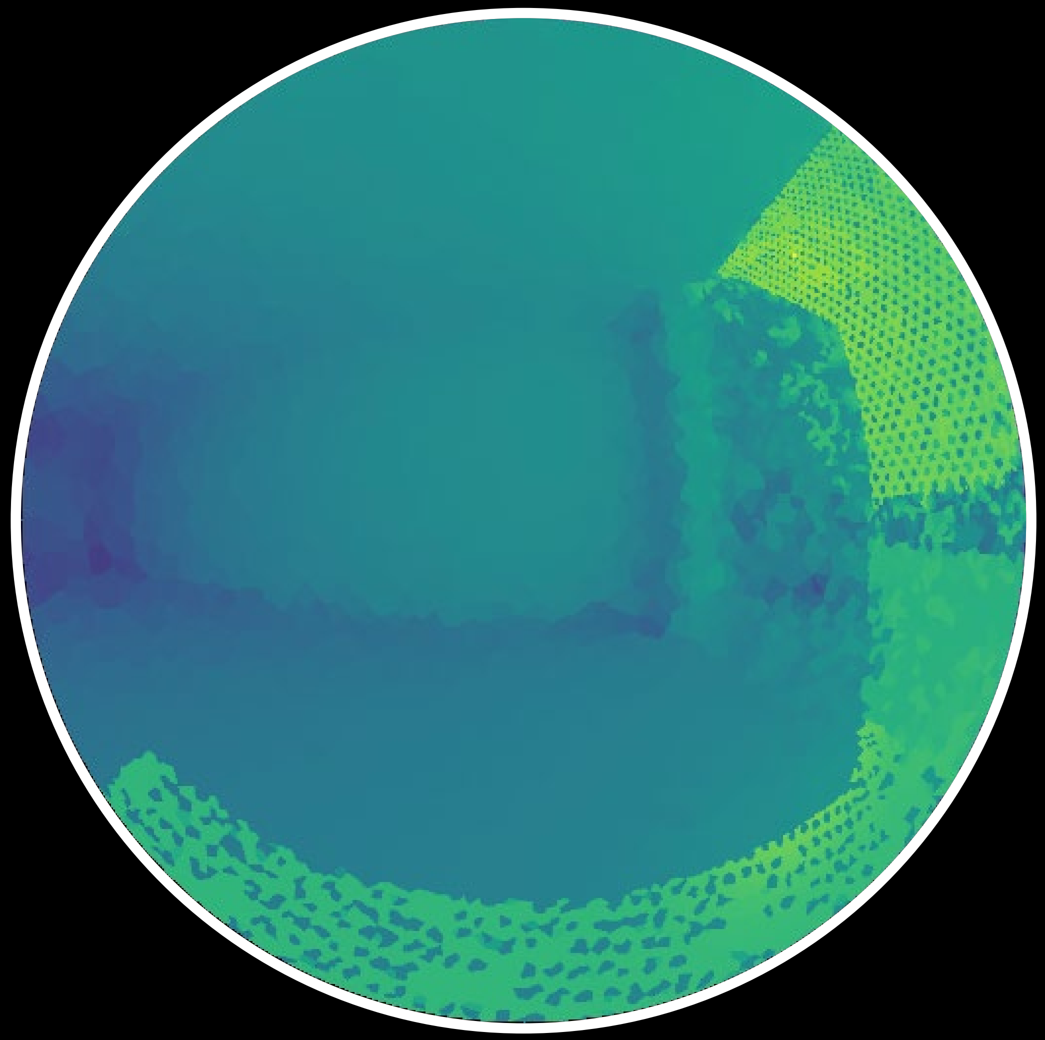
-5.1%	← relative deviation	**Ev = 6,820 lux**	relative deviation →	**-23.7%**
+5.2%	←	**UGR = 47.1**	→	**-40.2%**



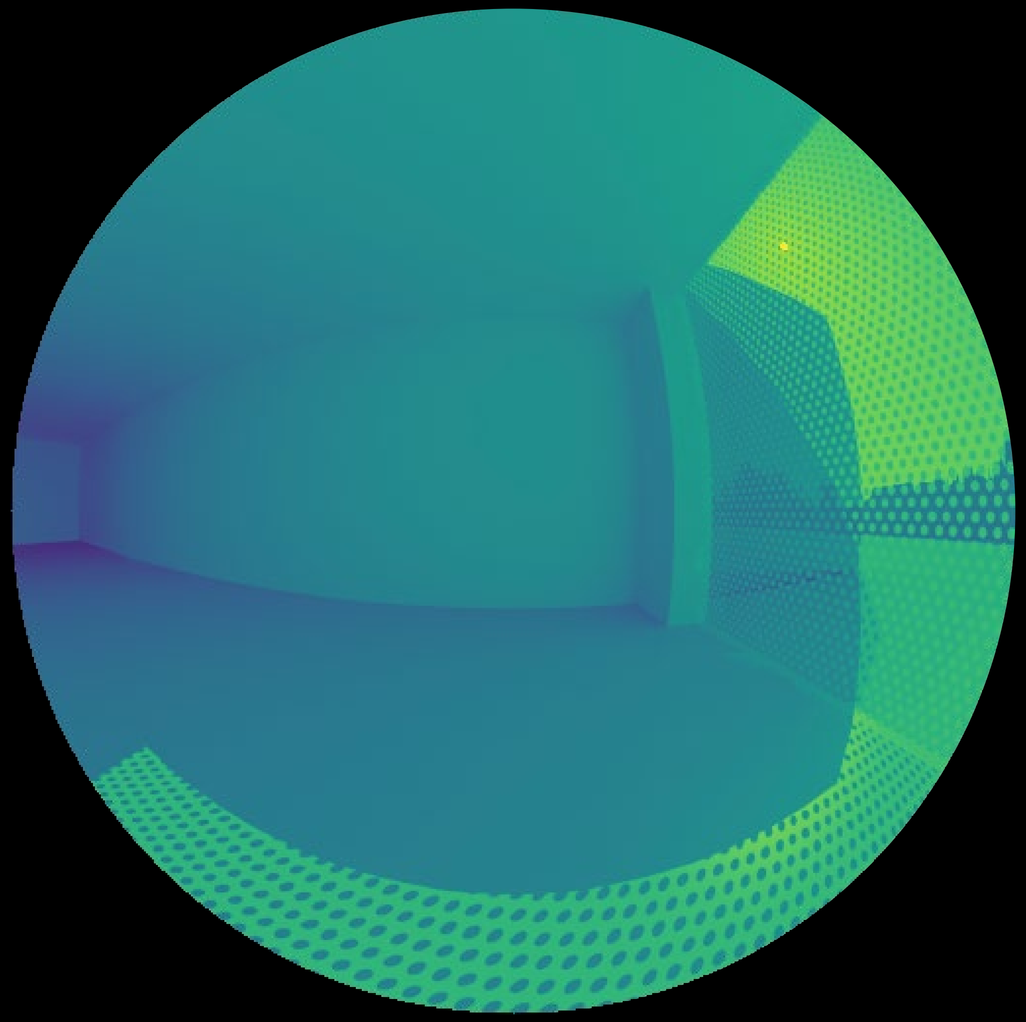
Dot frit with partial view to direct sun

Results

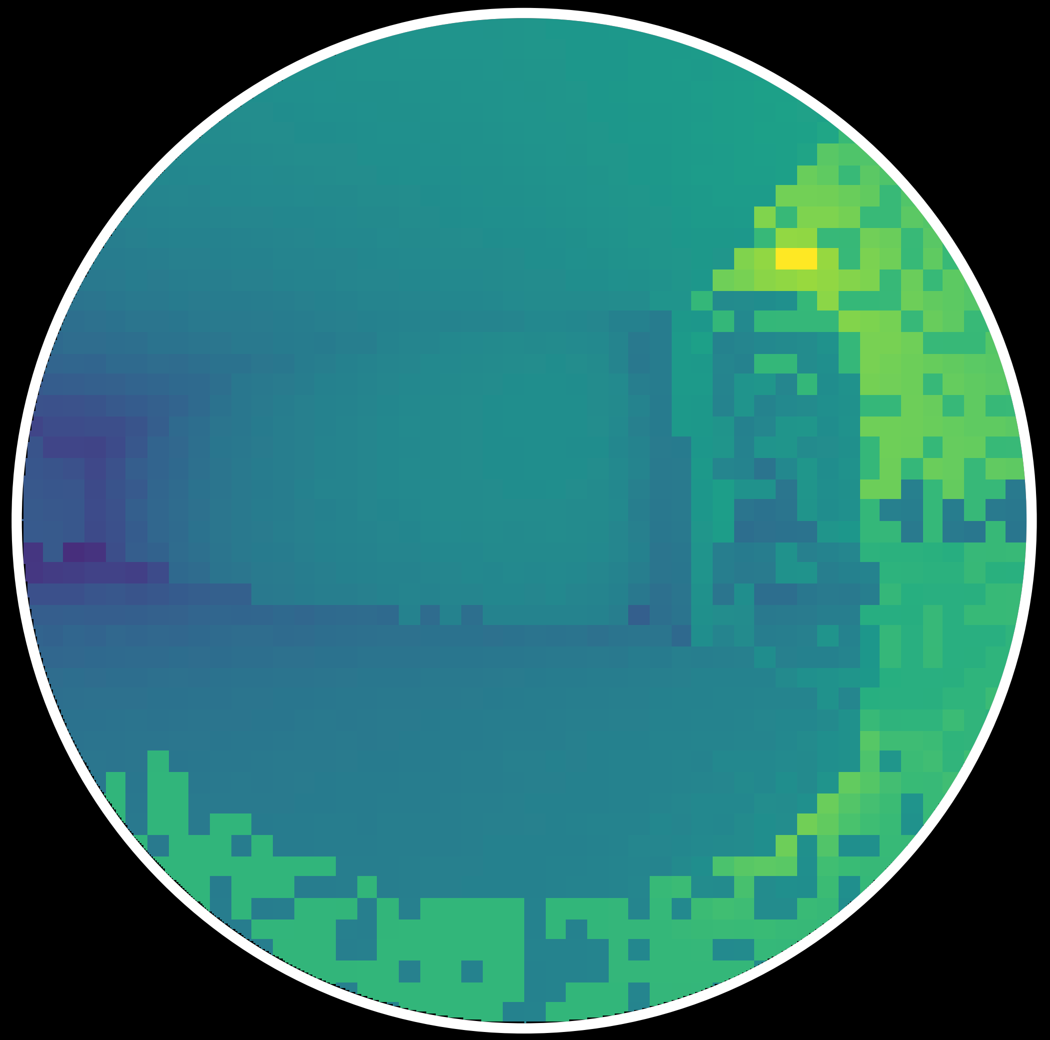
Raytraverse



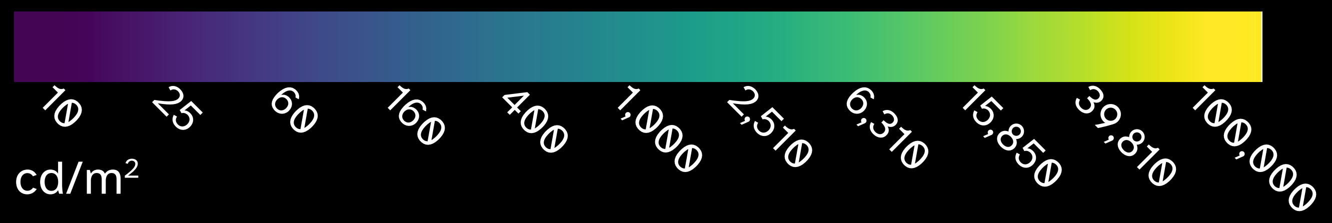
Reference / High Resolution



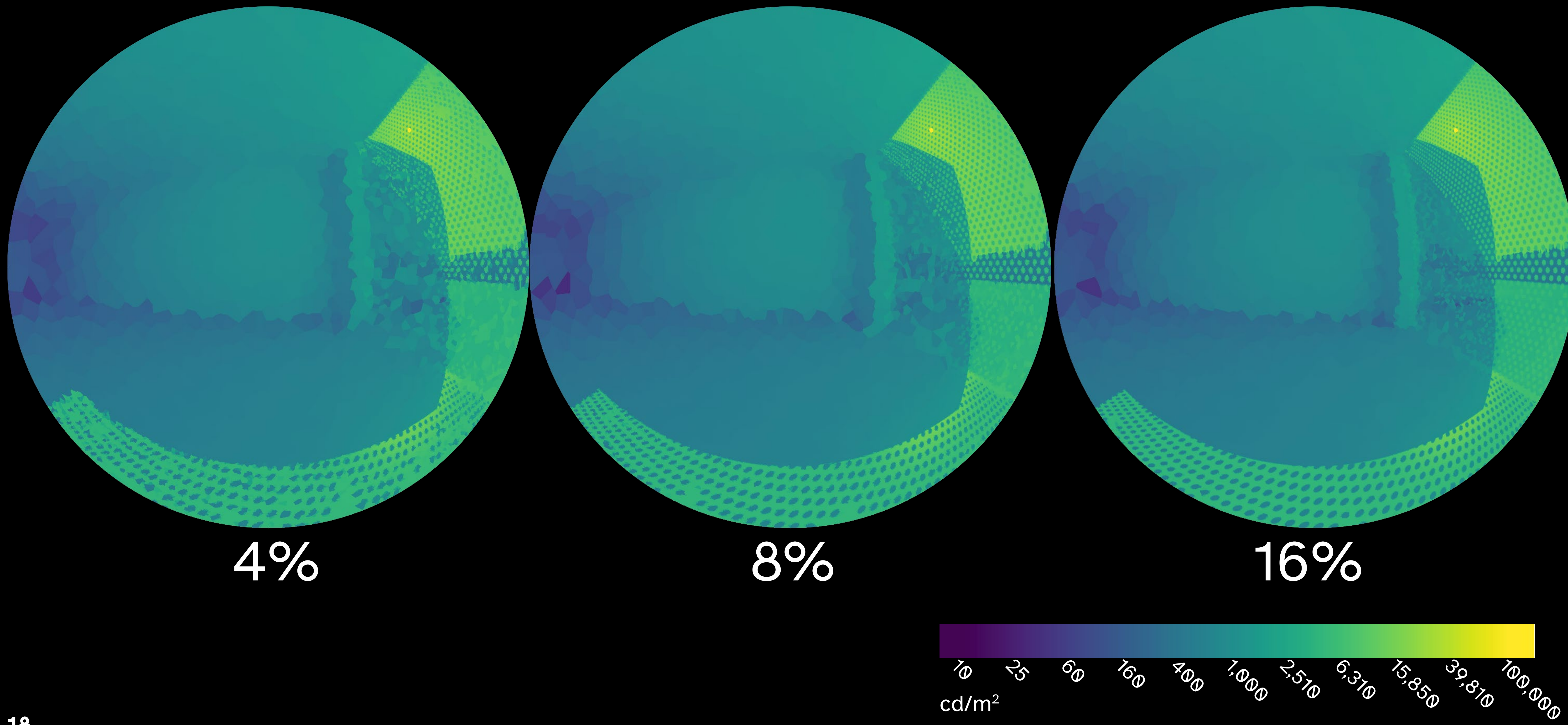
Uniform / Equal Sampling



Raytraverse		Reference		Uniform / Equal Sampling
-3.0%	← relative deviation	**Ev = 27,430 lux**	relative deviation →	**+1.0%**
-0.1%	←	**UGR = 59.4**	→	**-17.5%**

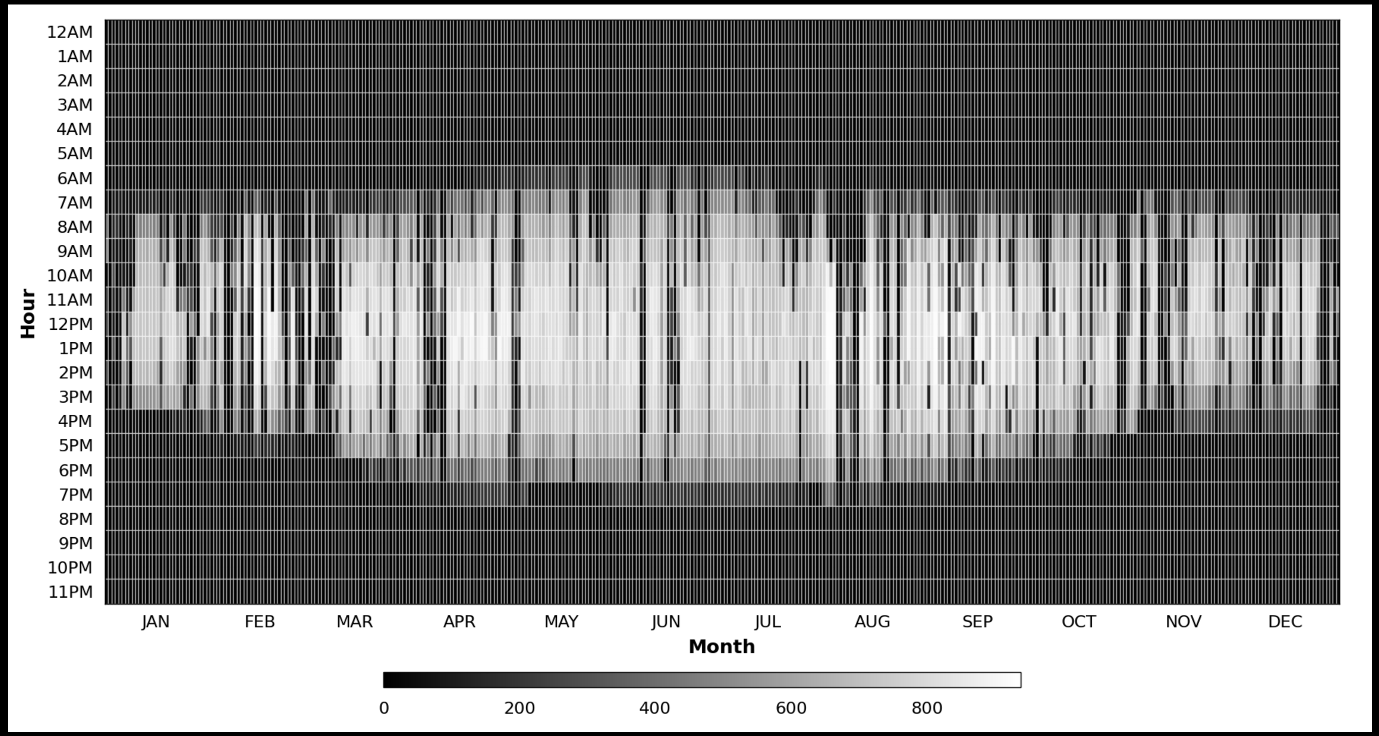


Relative Sampling Density (base was 2%)

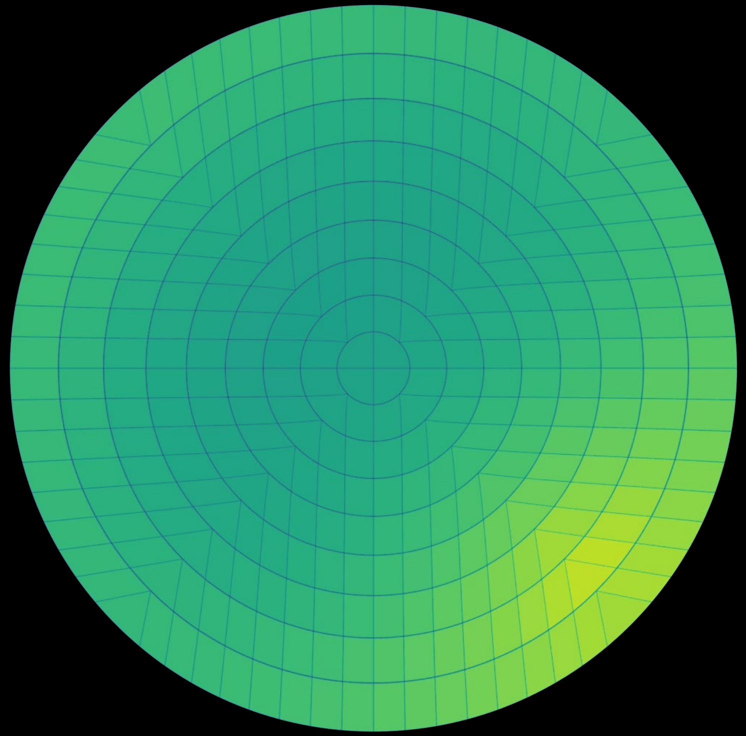


sampling the sky

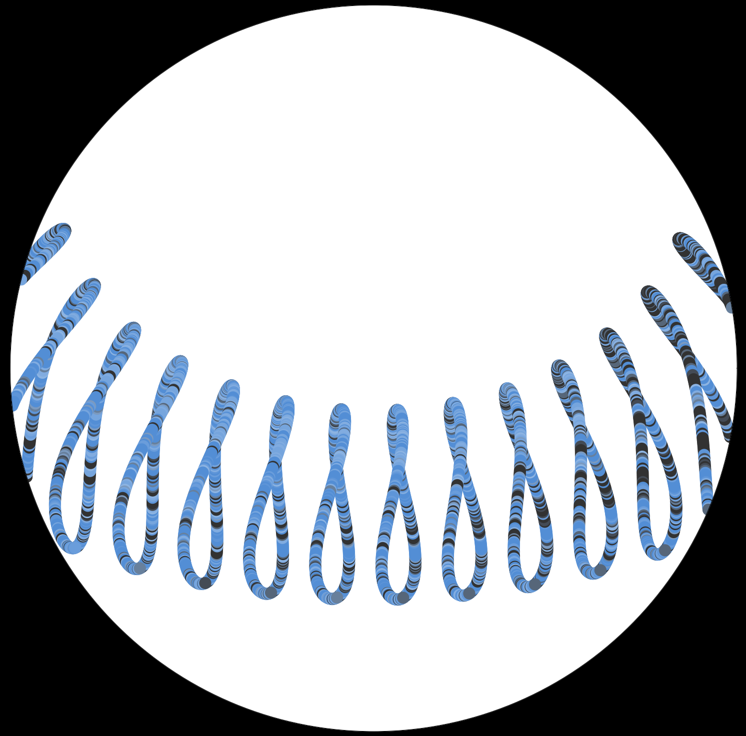
time ⟶ angle



Annual Sky Conditions

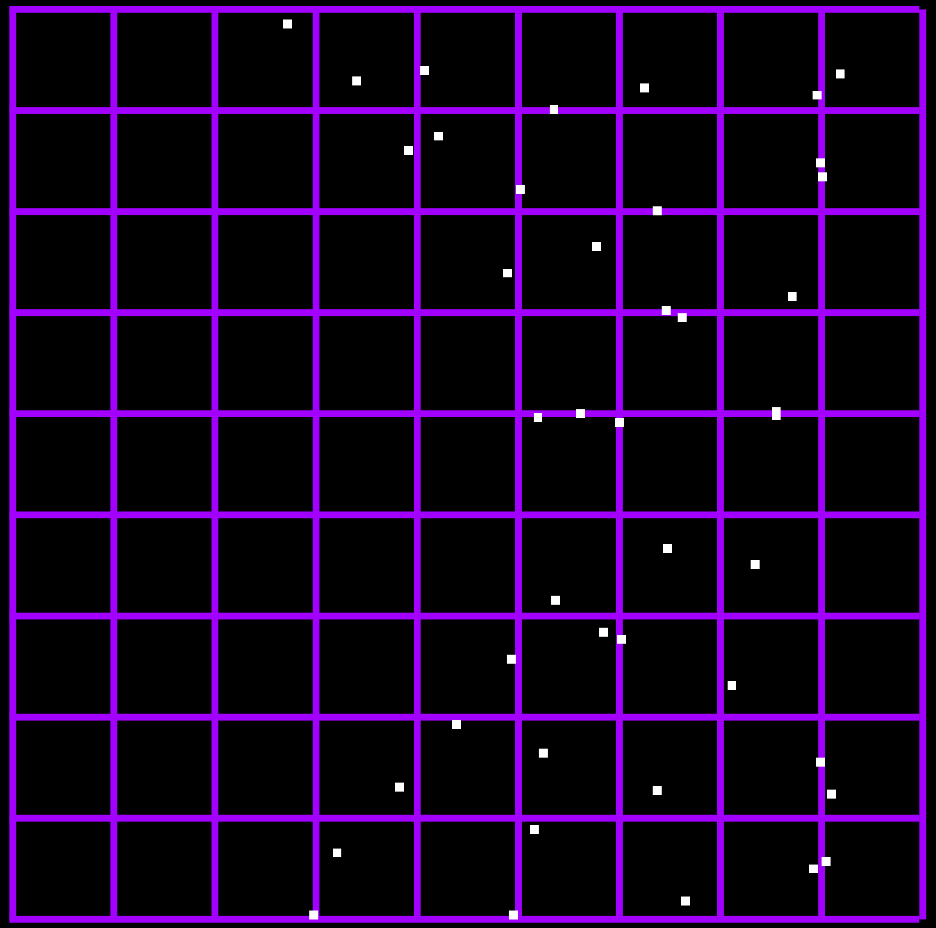


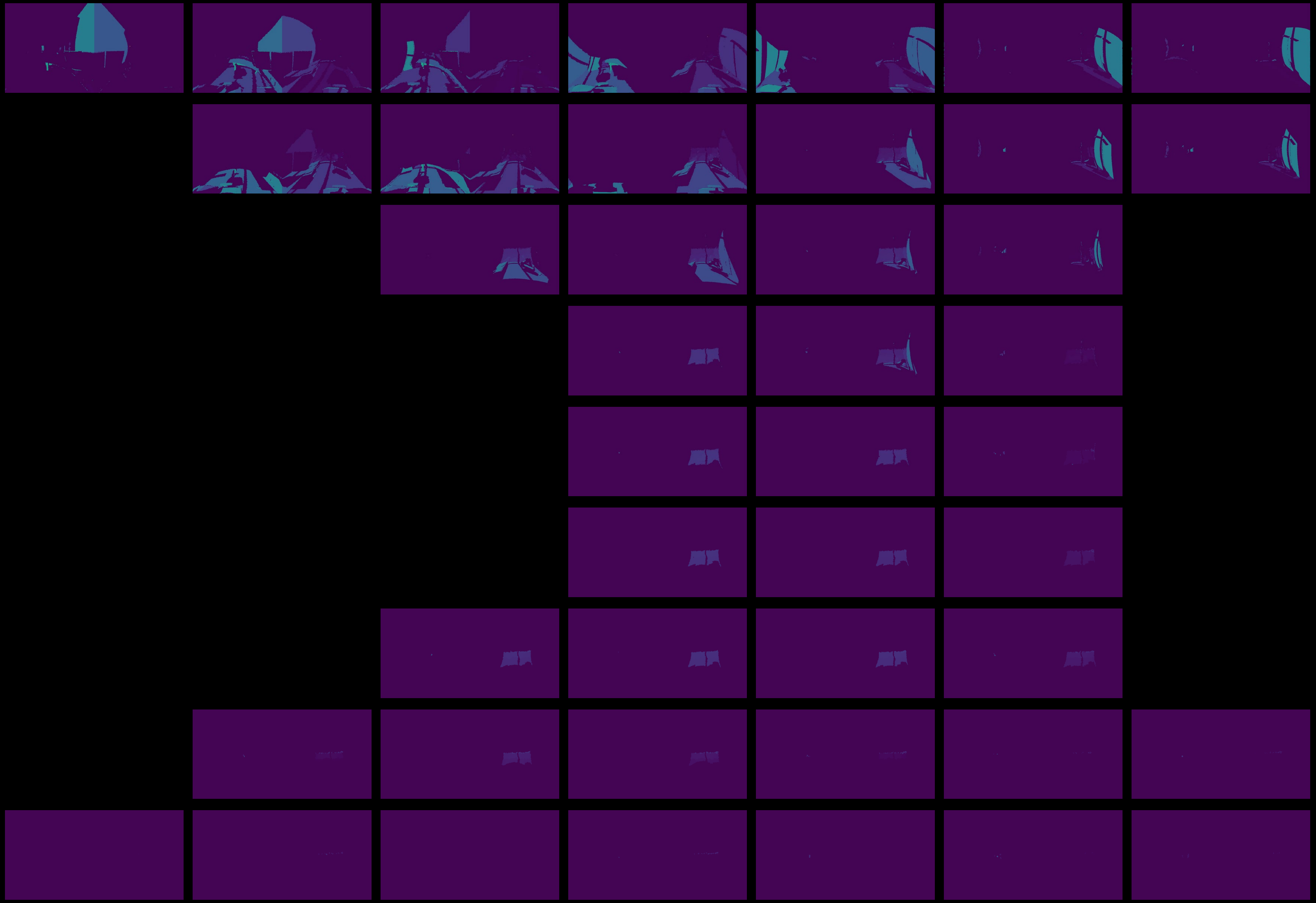
Perez sky model + discretized sky-patches



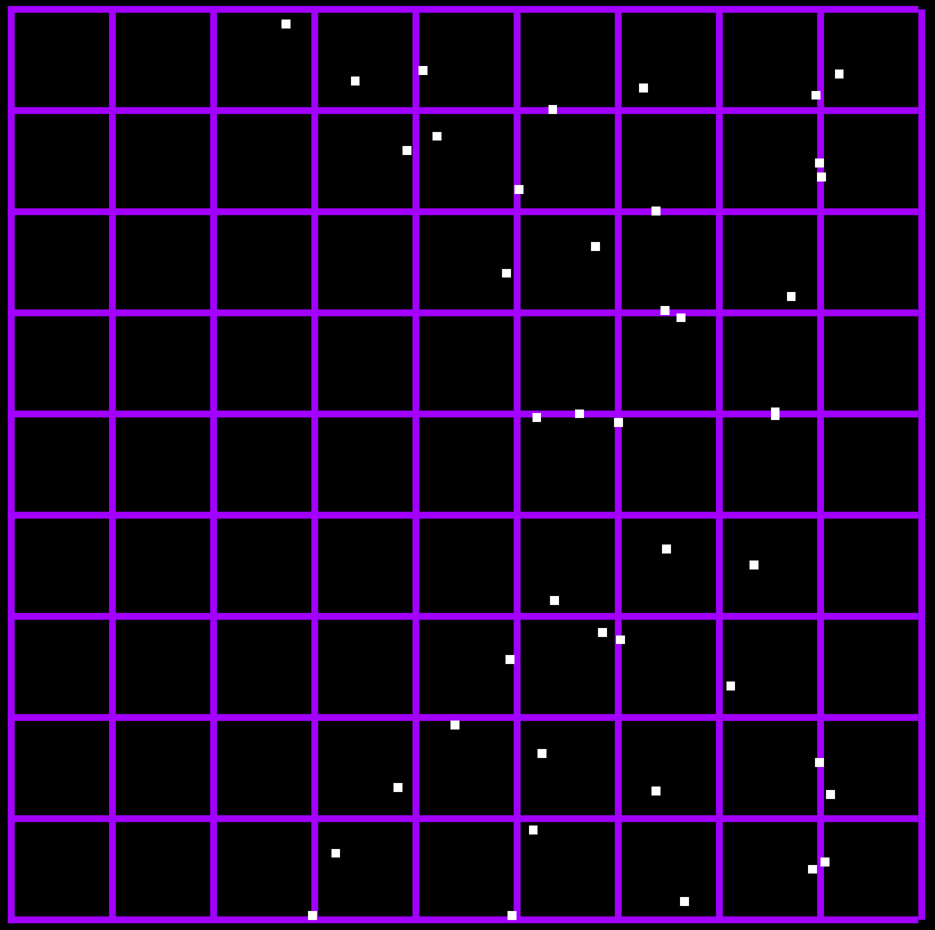
Solar Position

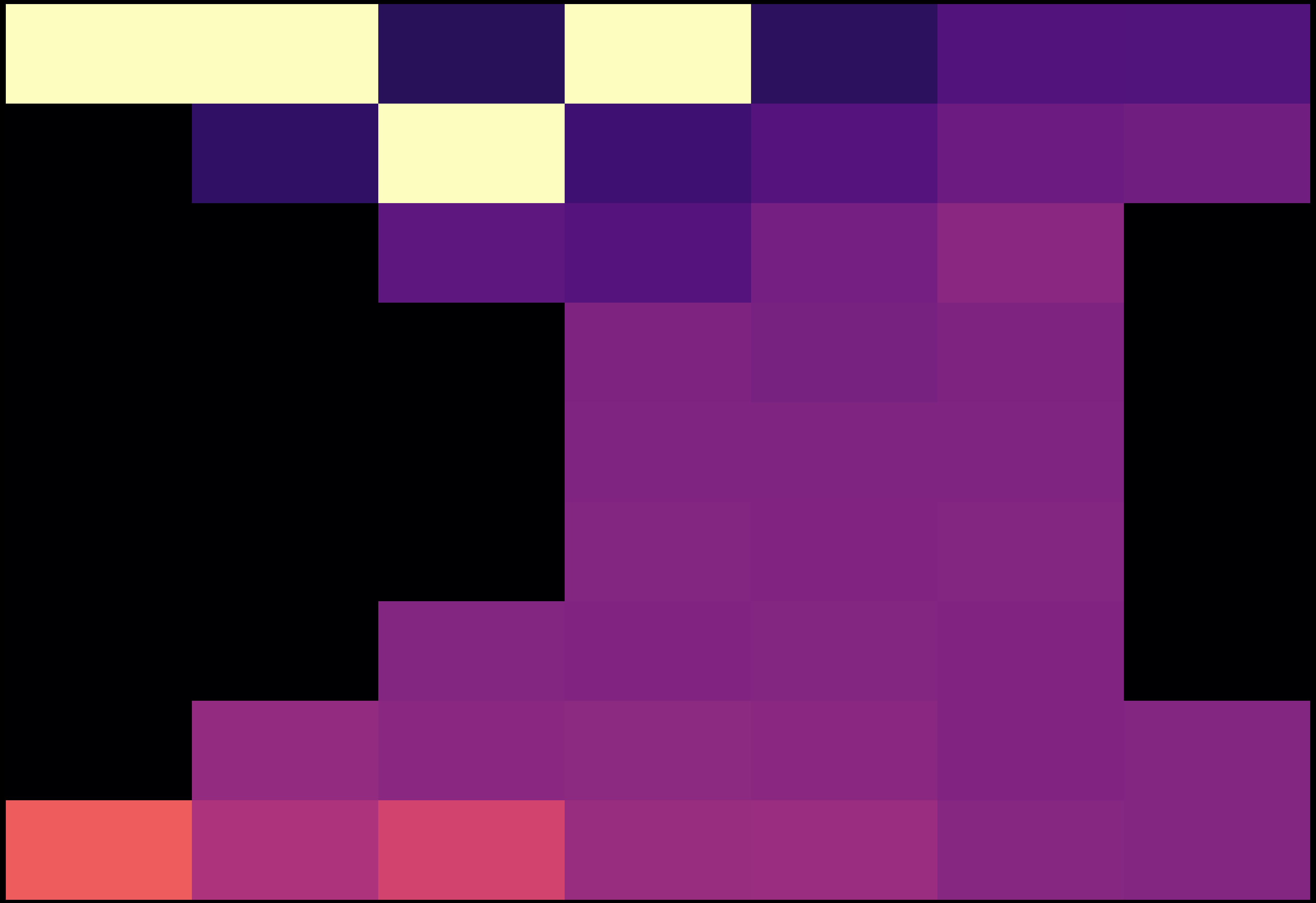
each sample is complete description of a point



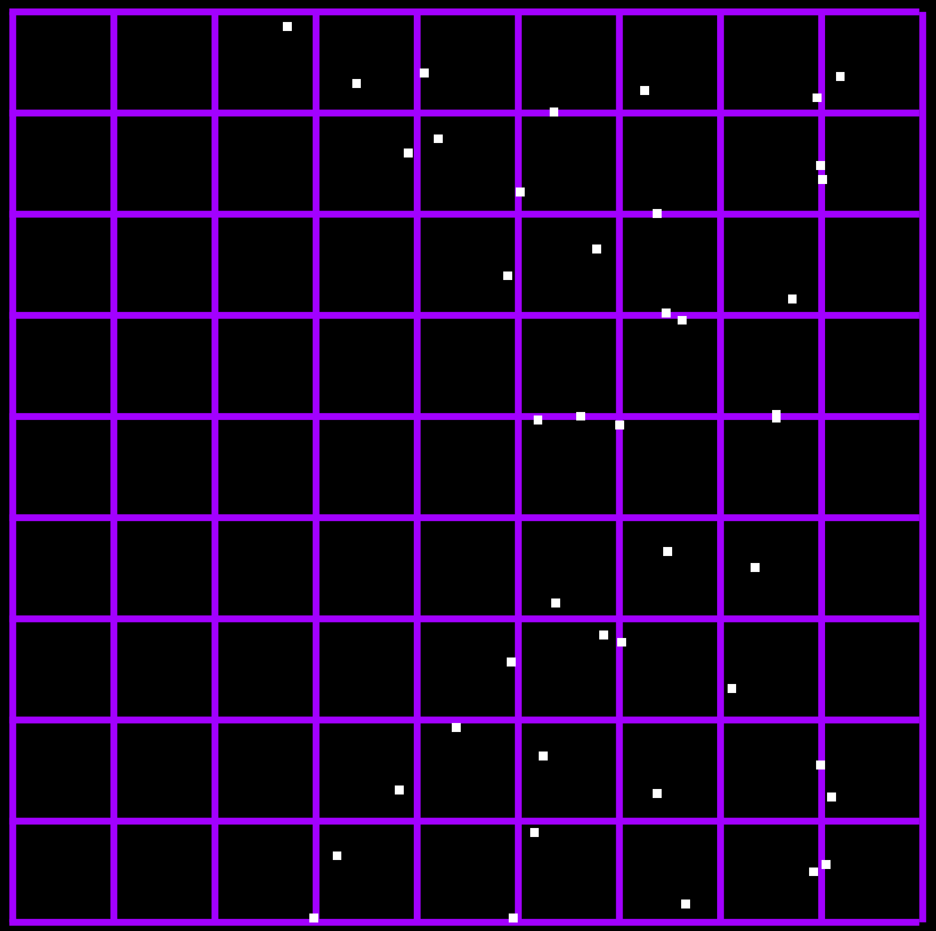


several metrics may be needed: contrast

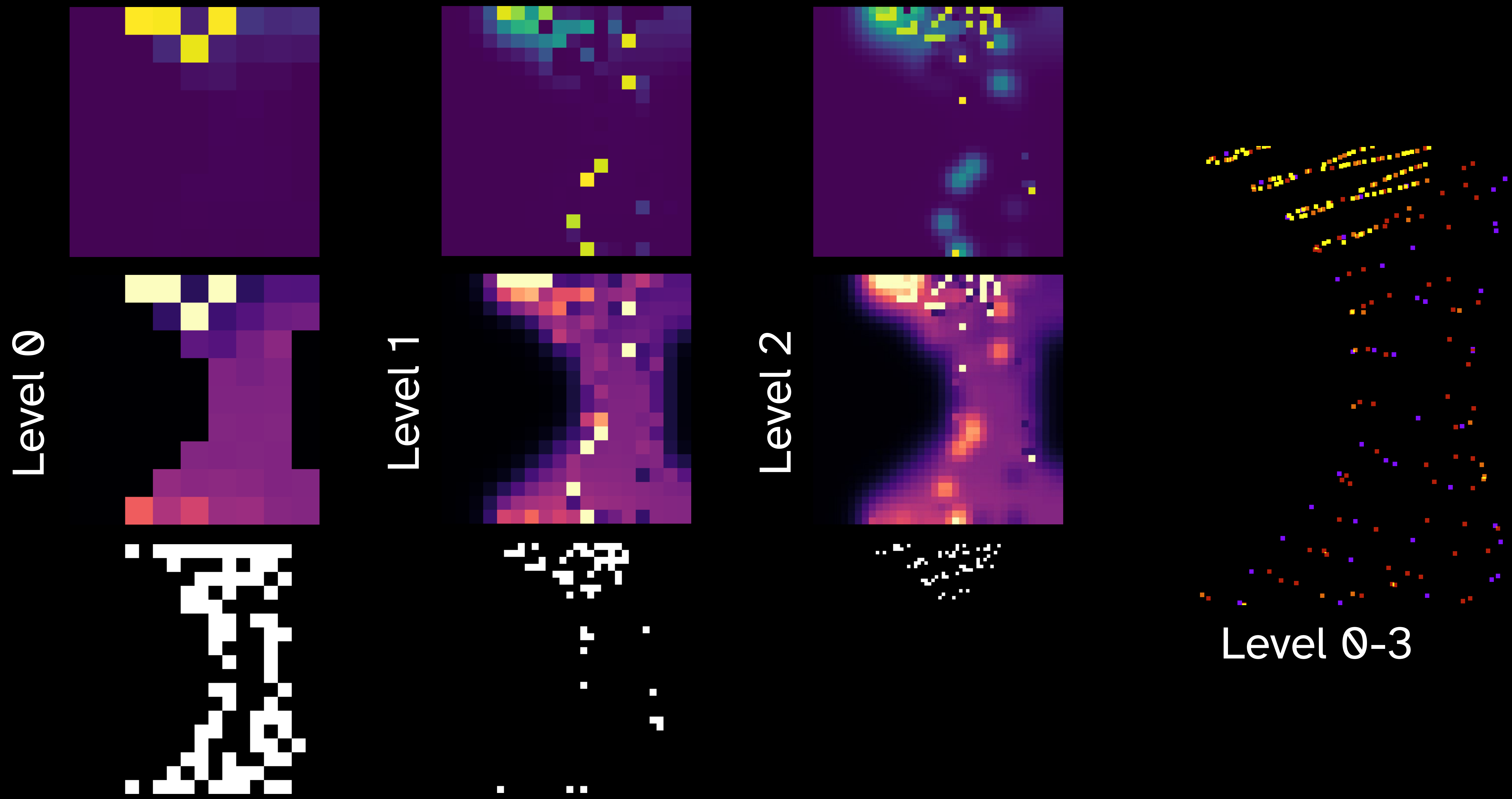




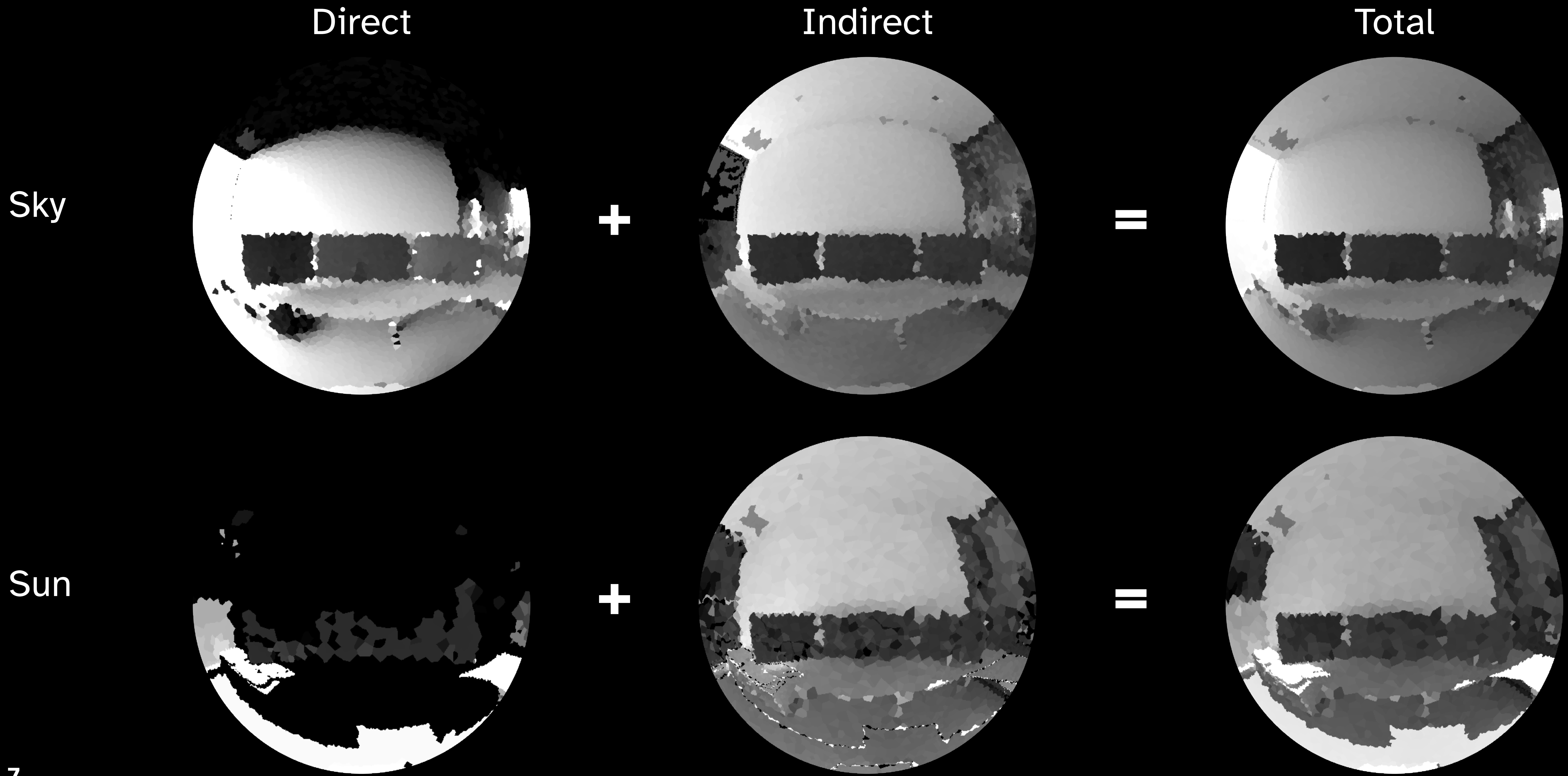
and brightness



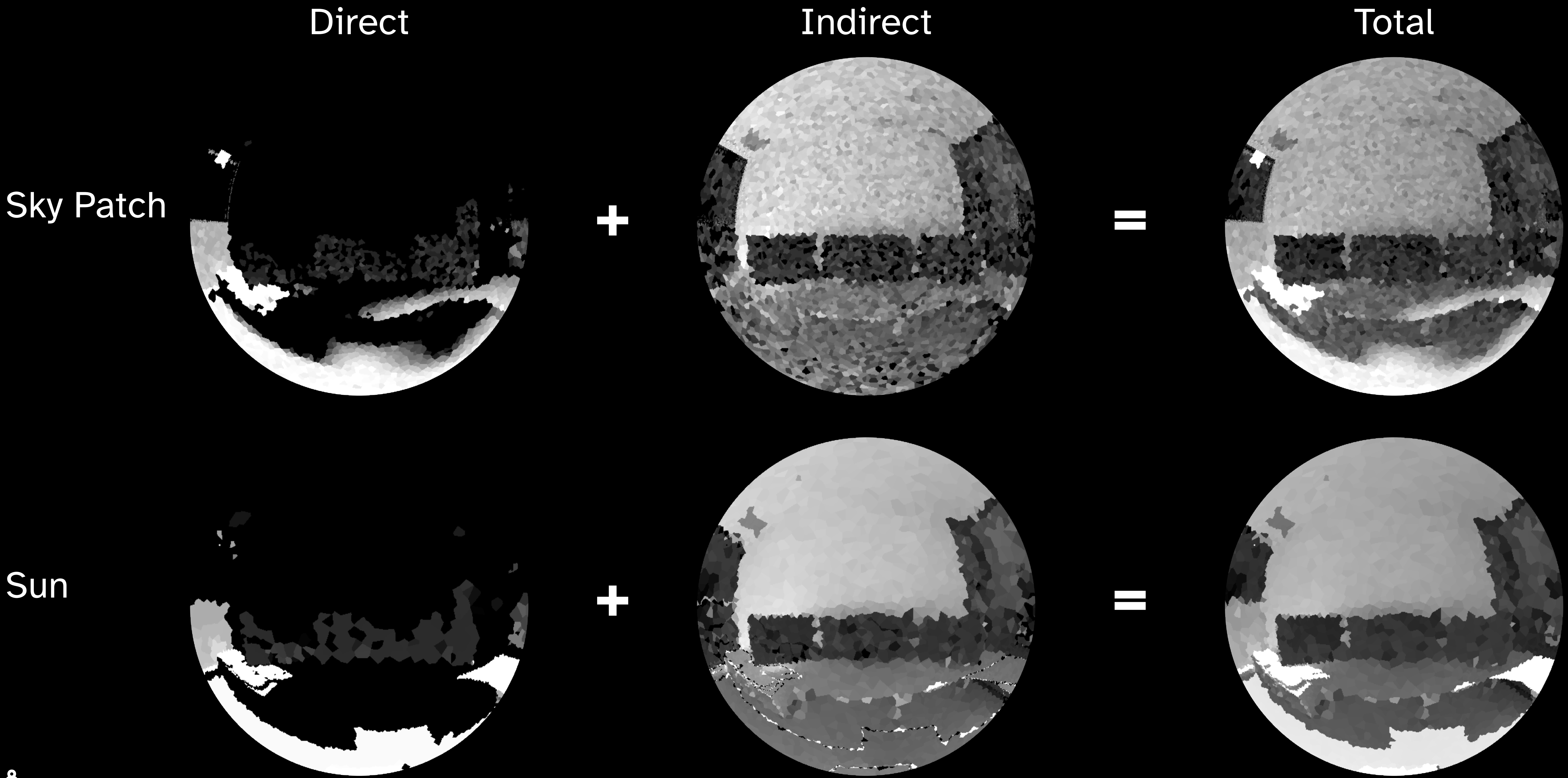
Sampling Weights



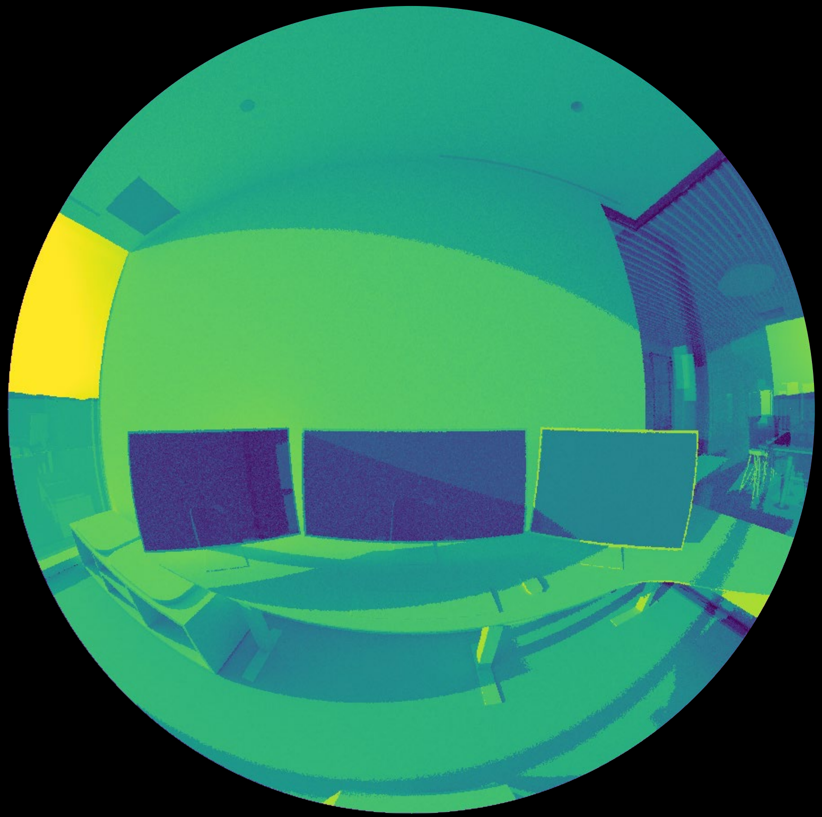
Component Sampling



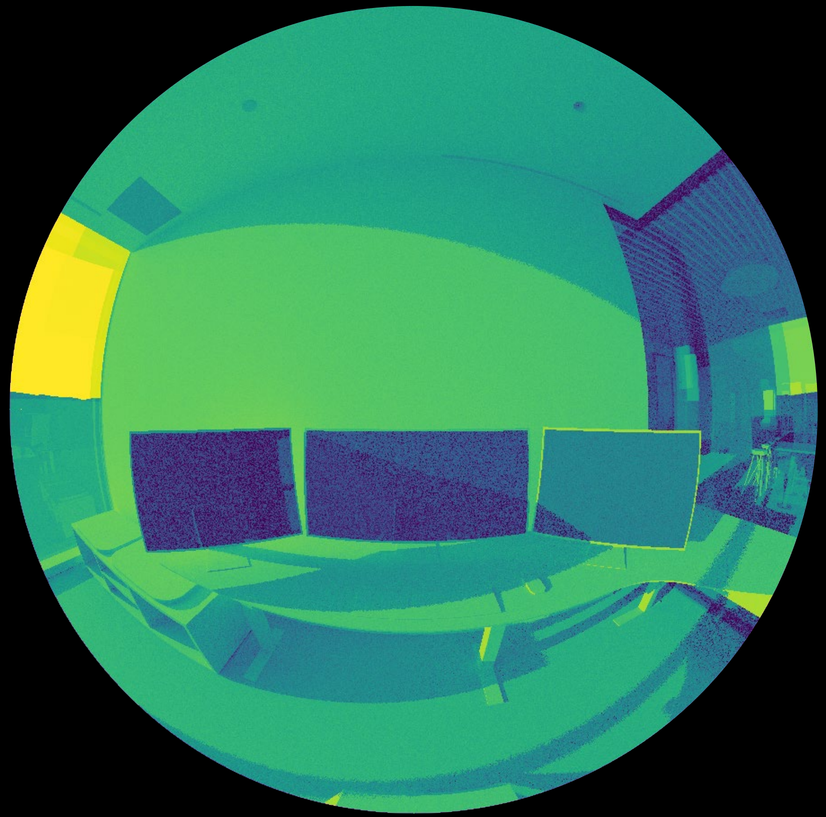
Use Sky for Sun



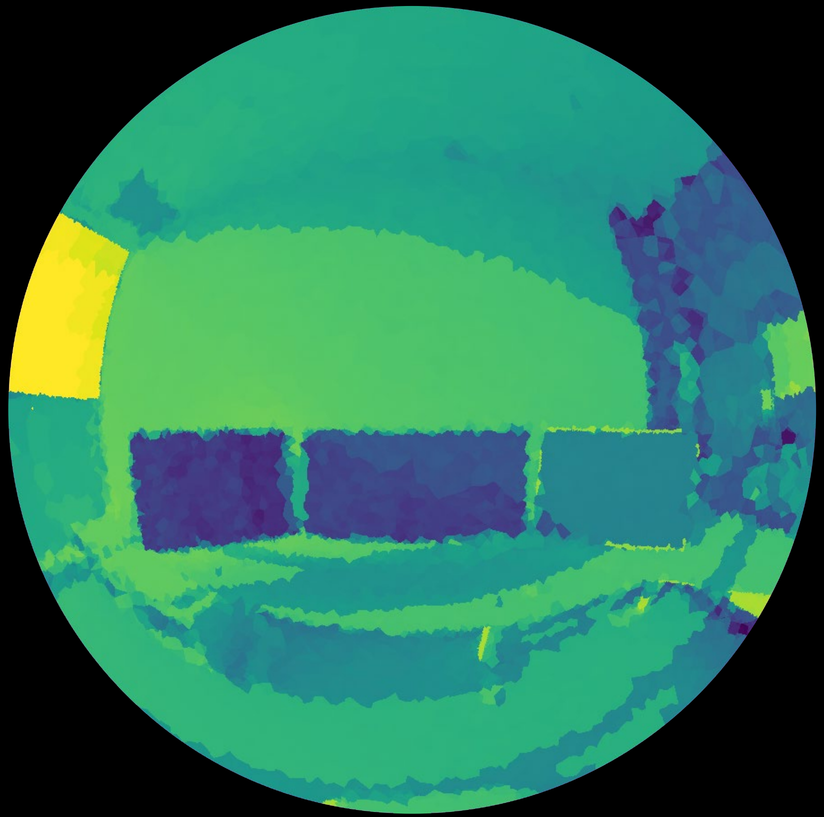
Results



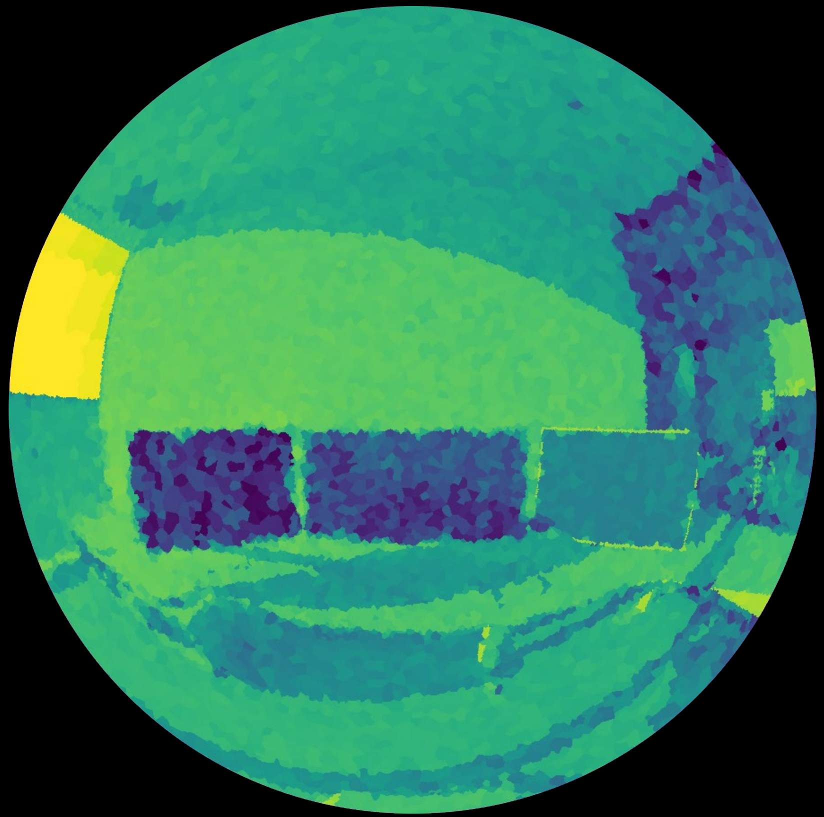
Reference (rpict)



2-phase



raytraverse



raytraverse-d

Reference (rpict):
-x 2700 -aa 0 -ad 250 -lr -14 -lw 1.58e-4 -ps 3 -pt .04 | pfilt -x /3 -y /3

2-phase:
sun direct / skypatch indirect
-x 900 -ad 8000 -lw 5.5e-5 -lr -14

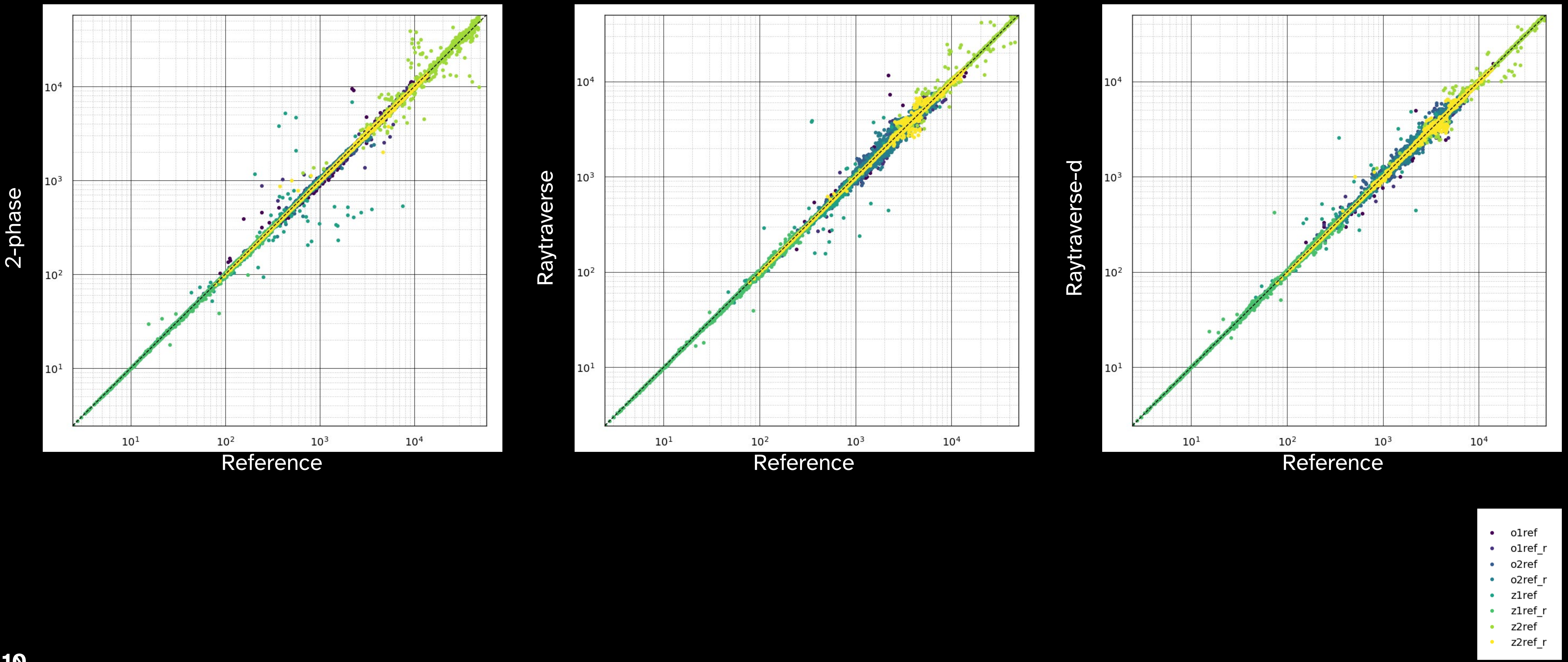
raytraverse:
sun full depth
sky: -ad 16250 -lw 2.46e-5 -lr -14
sun: -ad 1000 -lw 4e-5 -as 0 -lr -14
2^5 initial sampling resolution

raytraverse-d:
sun direct / skypatch indirect
sky: -c 4 -ad 16250 -lw 2.46e-5 -lr -14
2^6 initial sampling resolution

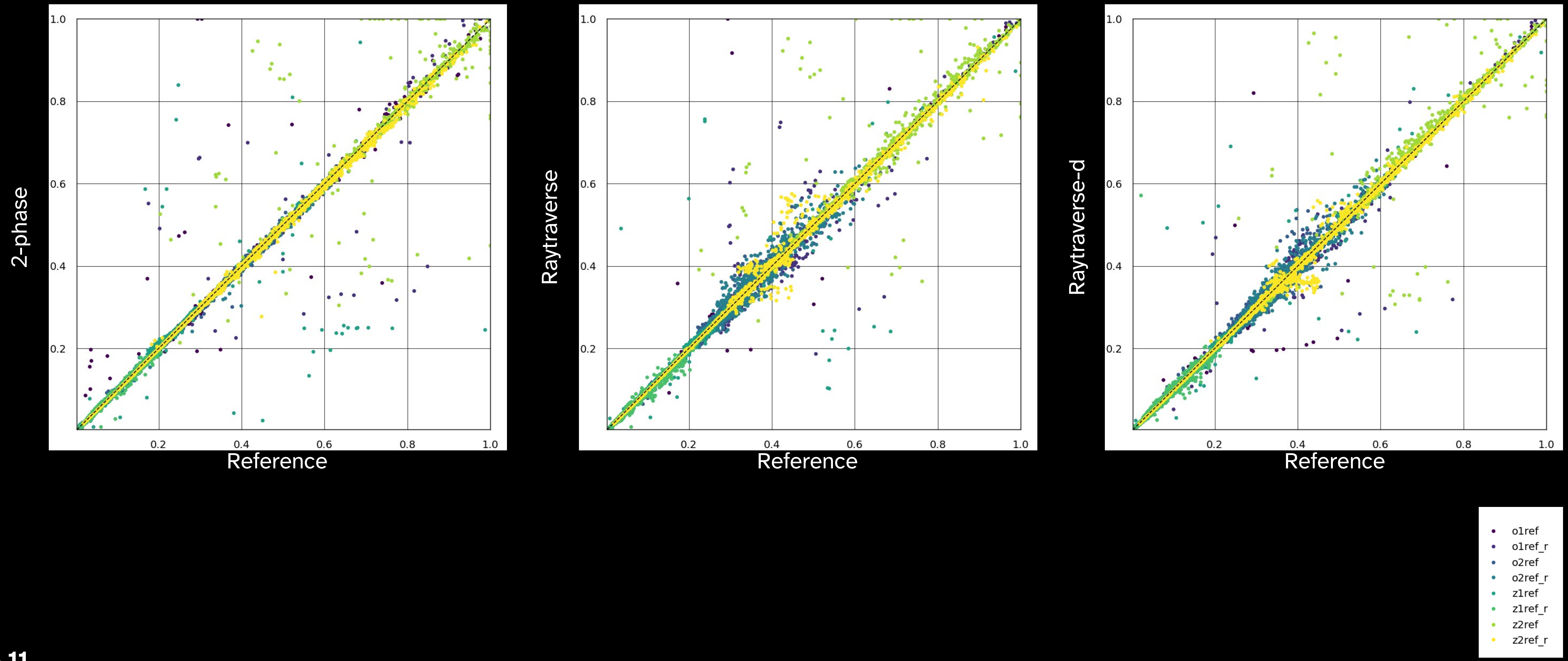
simulation times (per view and sky, assumes 4,294 timesteps, single thread)

Reference (rpict)	2-phase	raytraverse	raytraverse-d
2:20:08	0:00:37	0:00:15	0:00:02

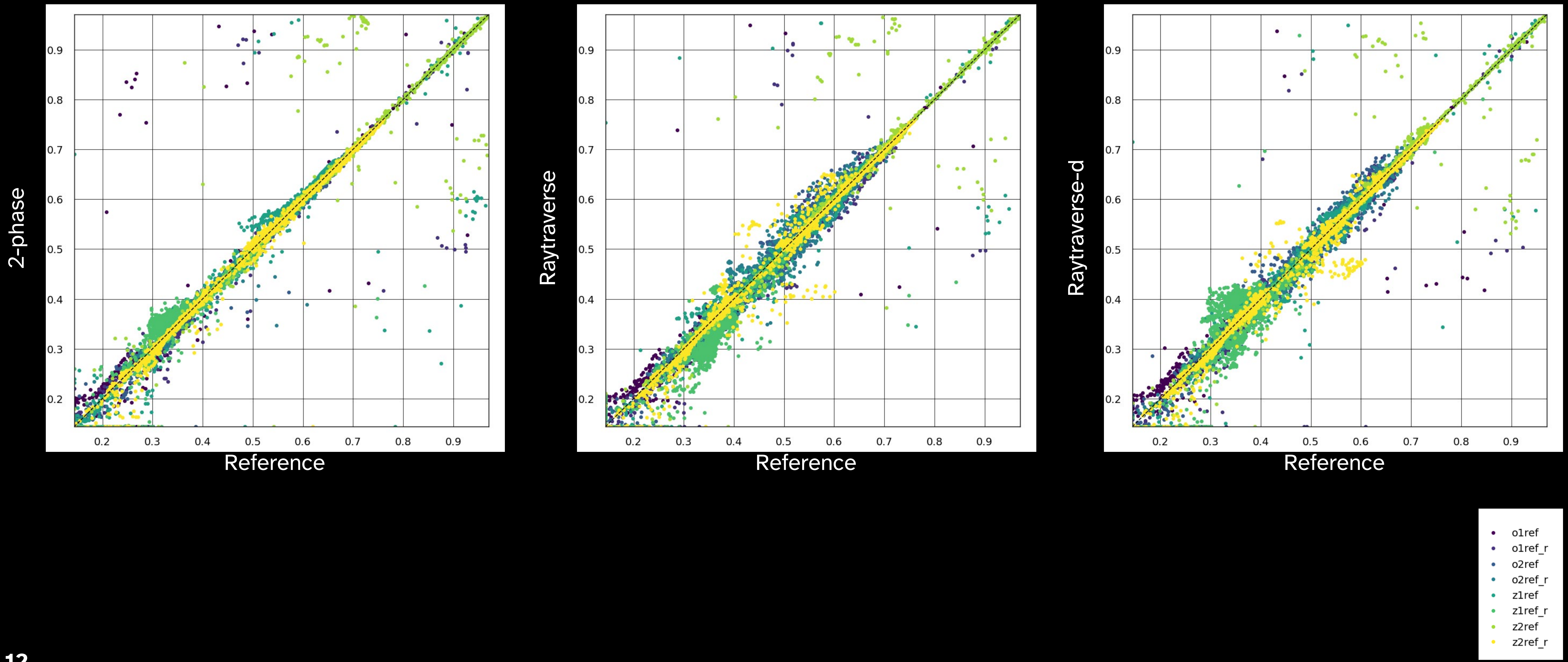
Illuminance



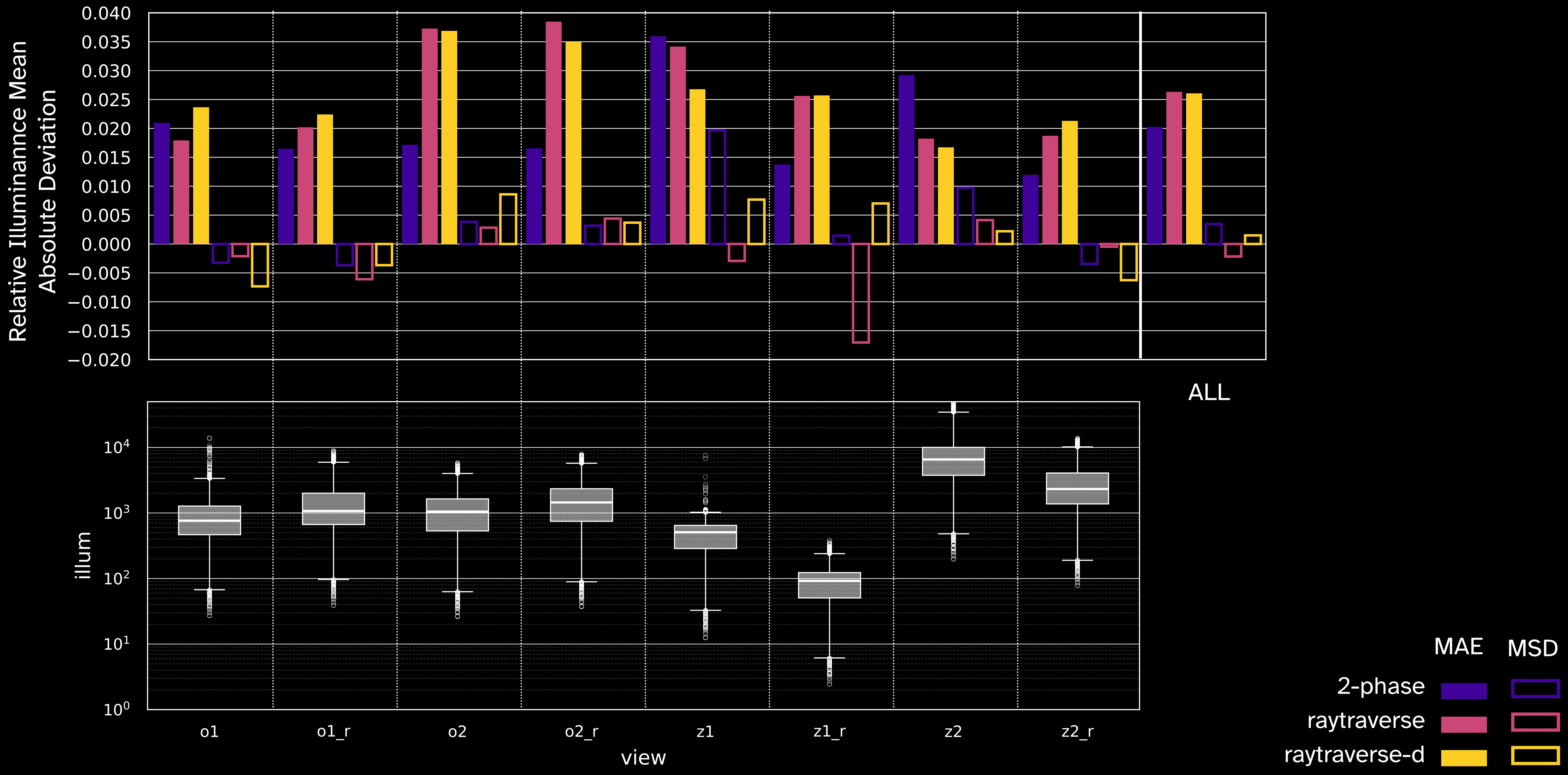
DGP


2-phase
Raytraverse
Raytraverse-d
Reference
Reference
Reference
0.2
0.4
0.6
0.8
1.0
o1ref
o1ref_r
o2ref
o2ref_r
z1ref
z1ref_r
z2ref
z2ref_r

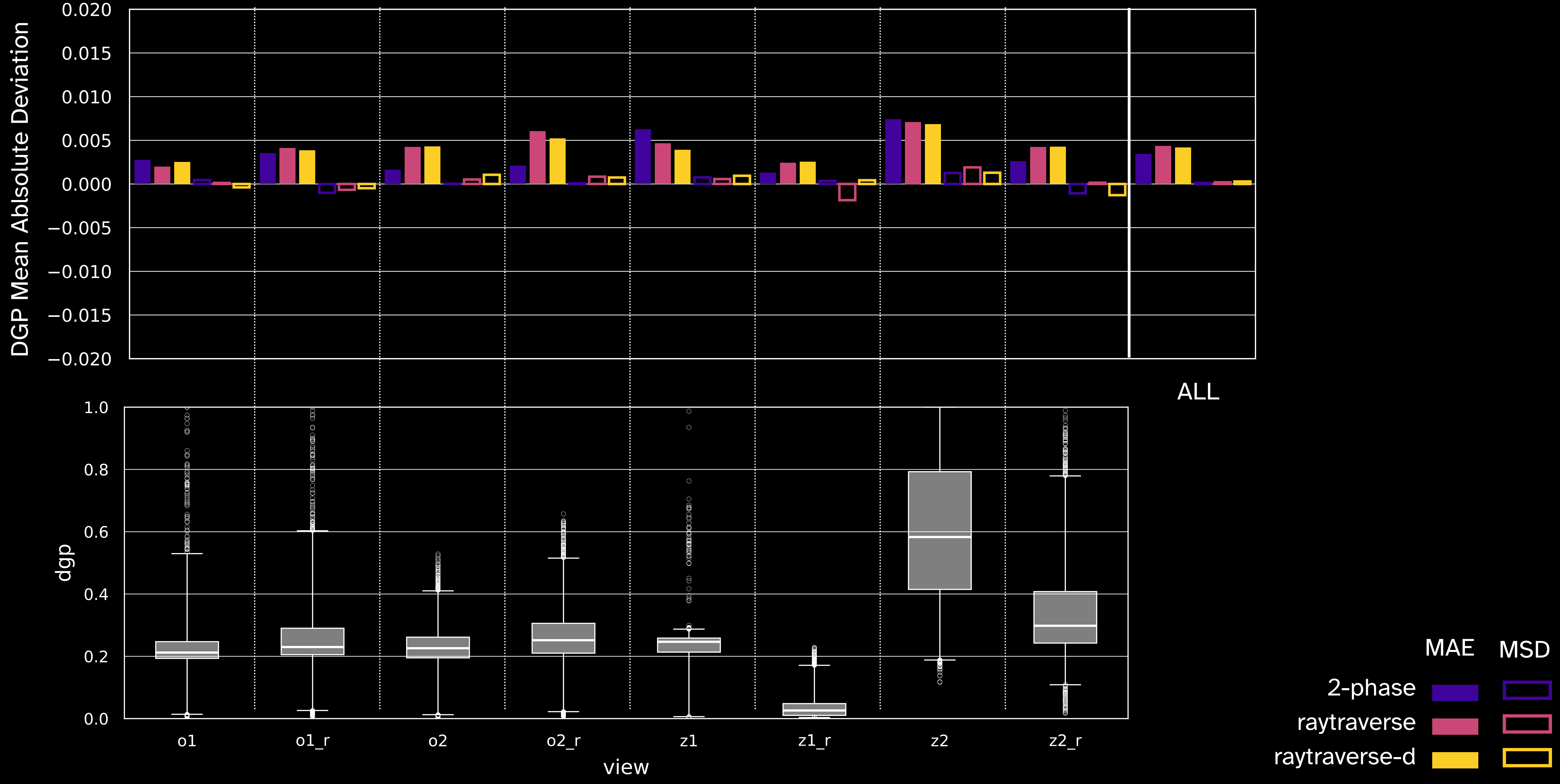
UGP


2-phase
Raytraverse
Raytraverse-d
Reference
Reference
Reference
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
o1ref
o1ref_r
o2ref
o2ref_r
z1ref
z1ref_r
z2ref
z2ref_r

Illuminance

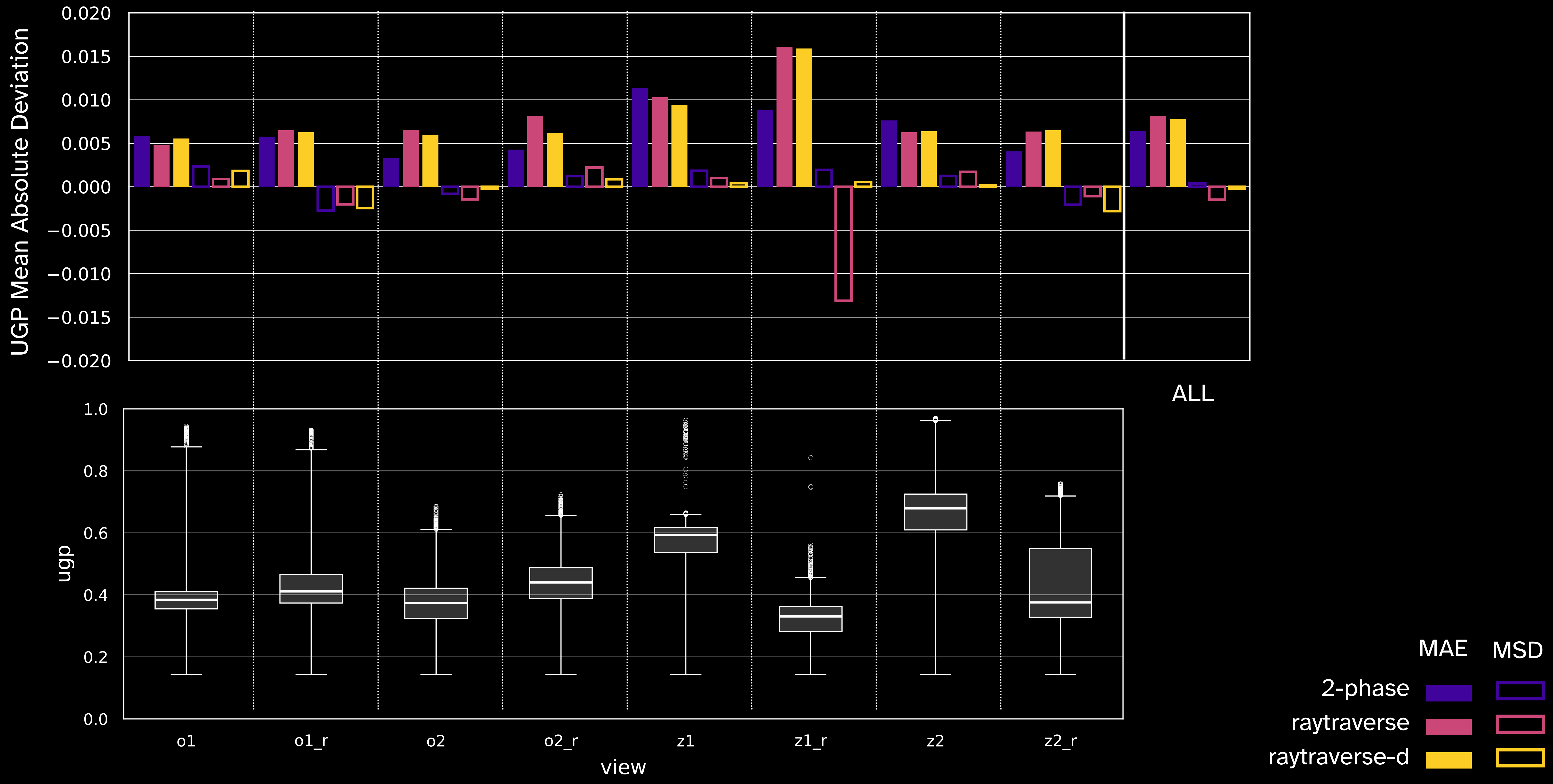


DGP



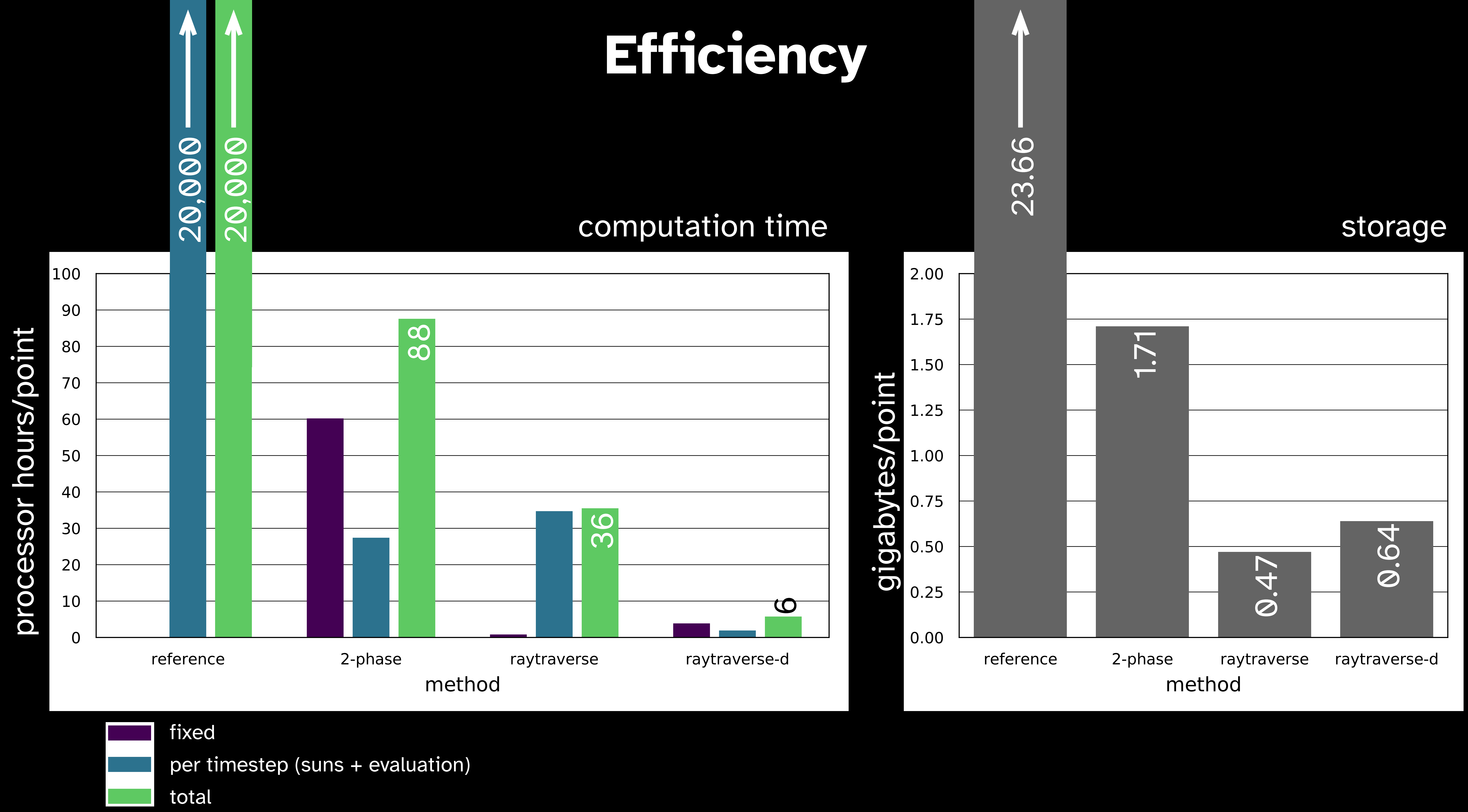
DGP Mean Ablsolute Deviation
0.020
0.015
0.010
0.005
0.000
−0.005
−0.010
−0.015
−0.020
ALL
dgp
1.0
0.8
0.6
0.4
0.2
0.0
o1
o1_r
o2
o2_r
z1
z1_r
z2
z2_r
view
MAE
MSD
2-phase
raytraverse
raytraverse-d

UGP



0.020
0.015
0.010
0.005
0.000
−0.005
−0.010
−0.015
−0.020
UGP Mean Absolute Deviation
ALL
1.0
0.8
0.6
0.4
0.2
0.0
ugp
o1
o1_r
o2
o2_r
z1
z1_r
z2
z2_r
view
MAE
MSD
2-phase
raytraverse
raytraverse-d

Efficiency



computation time
processor hours/point
100
90
80
70
60
50
40
30
20
10
0
20,000
20,000
88
36
6
reference
2-phase
raytraverse
raytraverse-d
method
fixed
per timestep (suns + evaluation)
total
storage
gigabytes/point
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
23.66
1.71
0.47
0.64
reference
2-phase
raytraverse
raytraverse-d
method

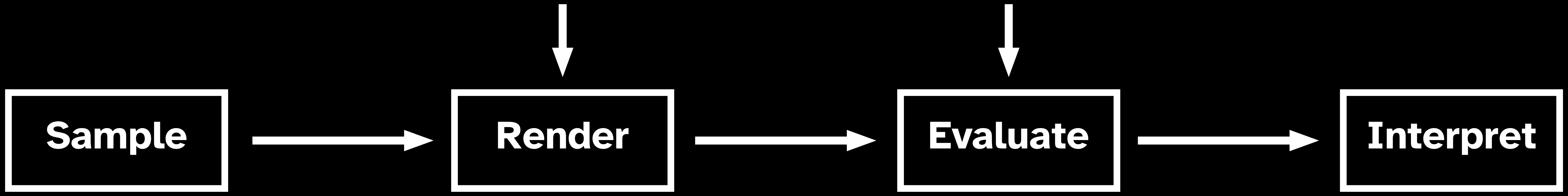
Modeling Interlude

what does it all mean?

The M in CBDM

Throughout the rendering and evaluation process, the models we use are a combination of:

- physical/process models (solar position, light-transport, material interaction).
- statistical models (TMY)
- correlated measurement models (perez)
- interpolated measurement models (BSDF)
- and mixed models combining some of the above (DGP, DA)



Perez, TMY, and Hourly Sun Positions

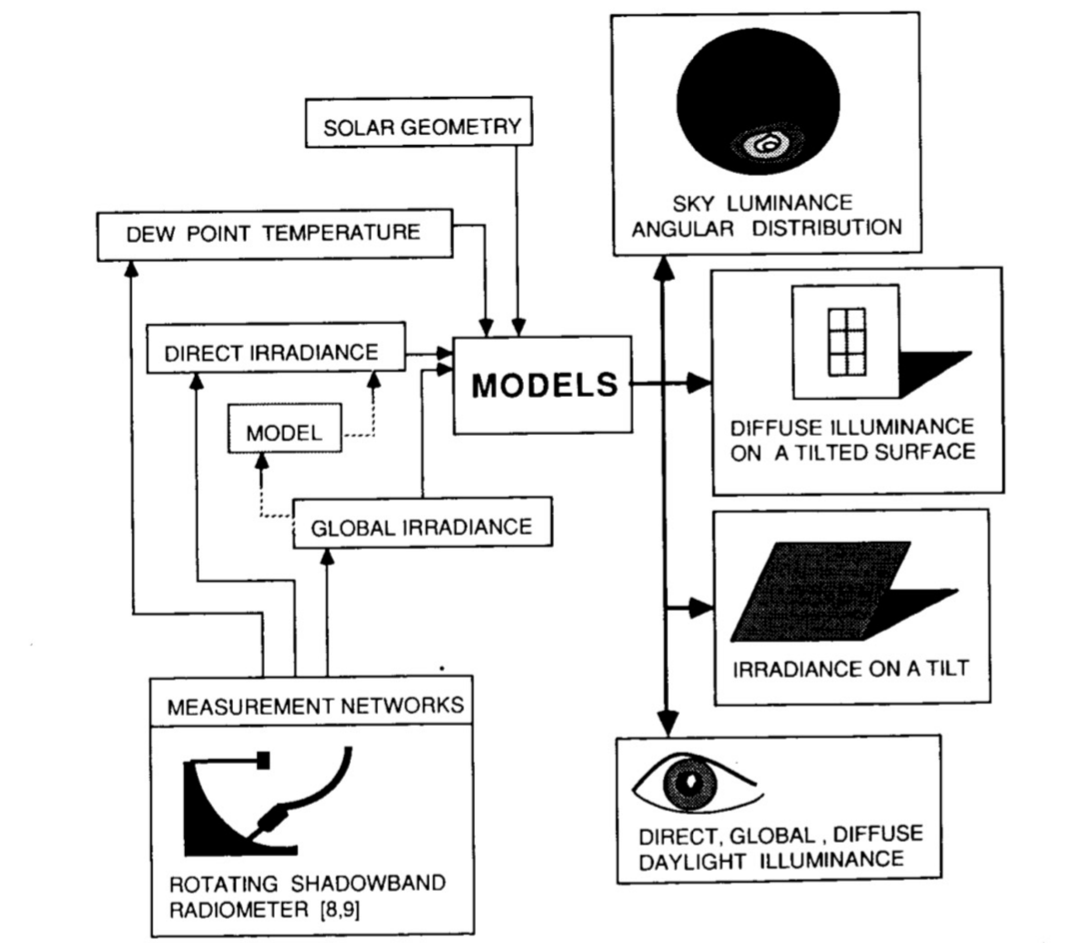


Fig. 2. Interrelationship between model inputs and outputs. The models' input data may be readily supplied by the Rotating Shadowband Radiometer, a new instrument well suited for precise network operation [9].

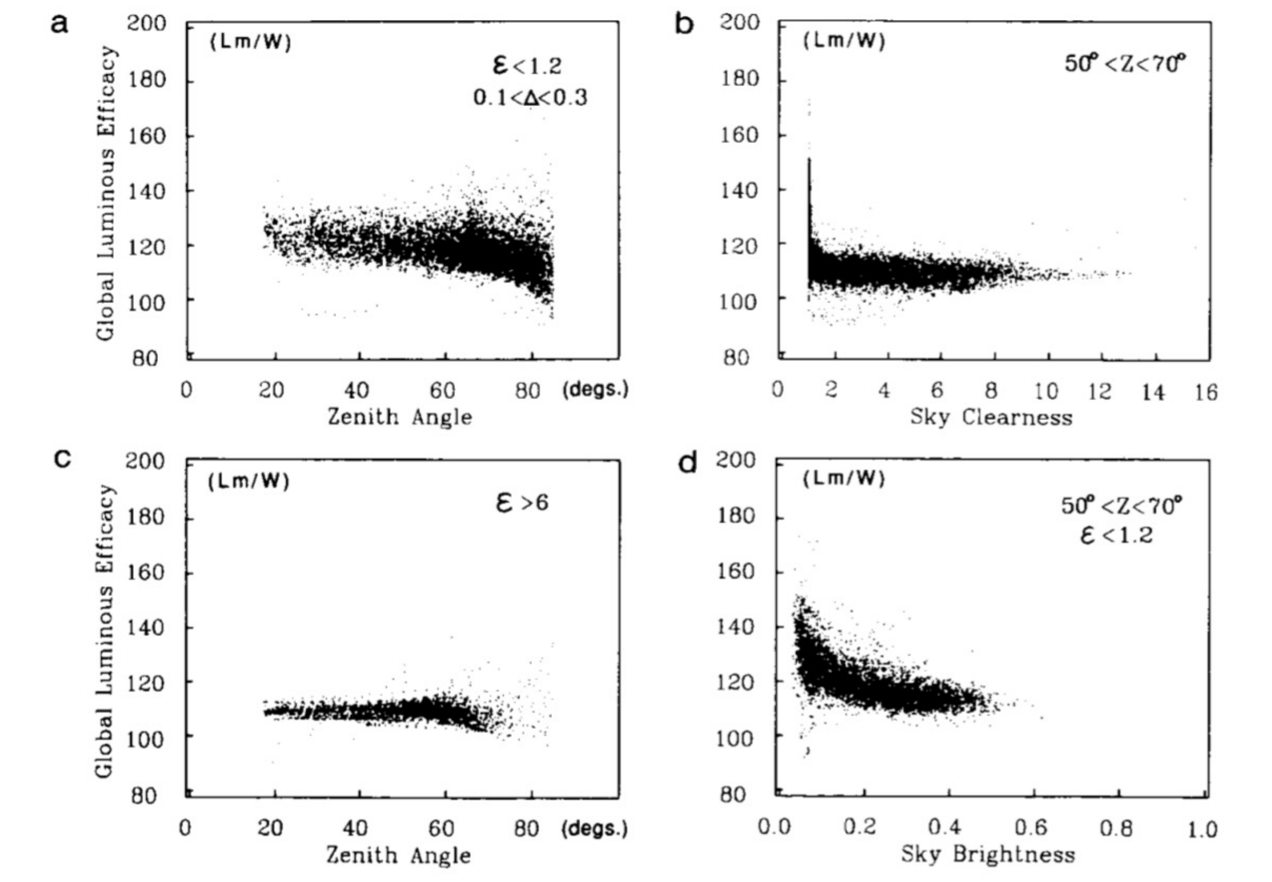
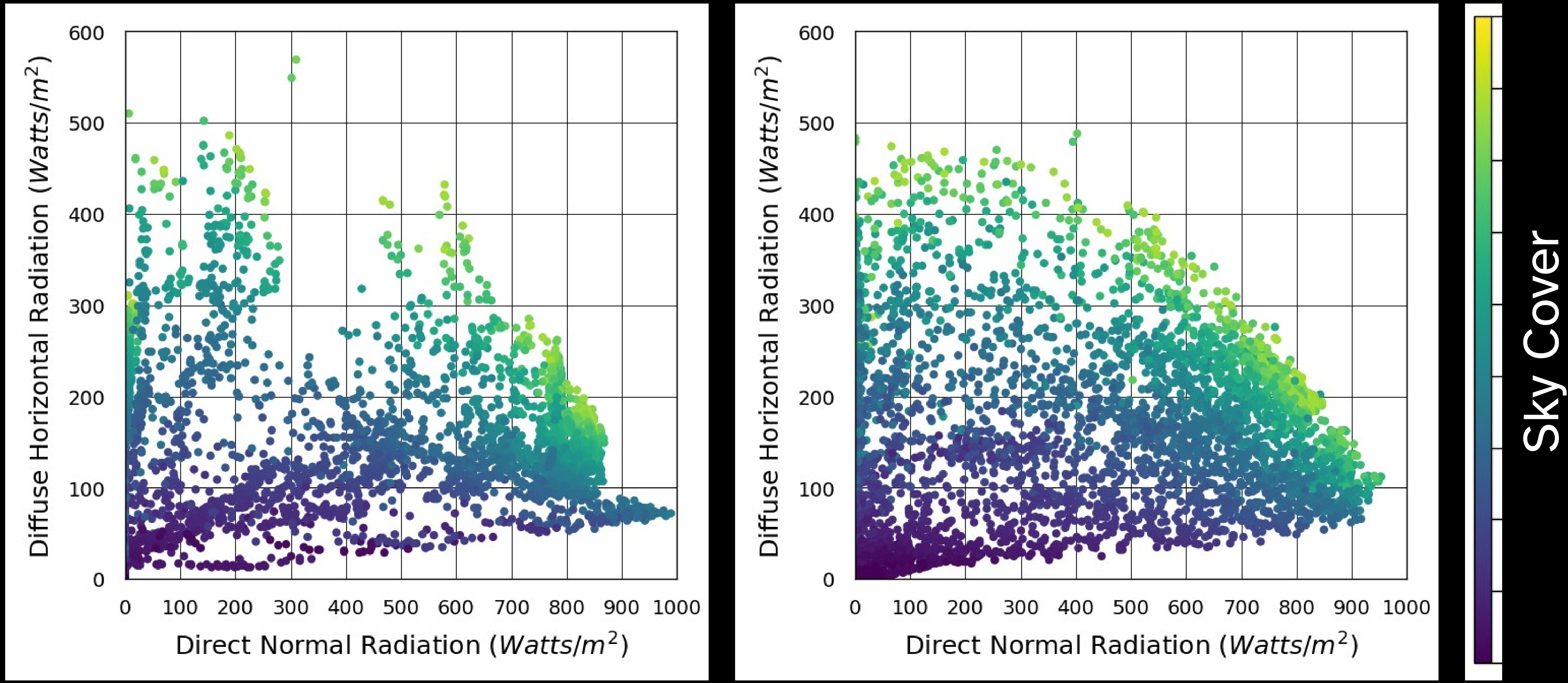


Fig. 4. Variations of global luminous efficacy with (a) Solar zenith angle for overcast conditions. (b) Sky Clearness, ε, for a limited zenith angle range. (c) Solar zenith angle for very clear conditions. (d) Sky Brightness, Δ, for overcast conditions. (Data from five New York sites and Geneva).

Perez, Richard, Pierre Ineichen, Robert Seals, Joseph Michalsky, and Ronald Stewart. "Modeling Daylight Availability and Irradiance Components from Direct and Global Irradiance." Solar Energy 44, no. 5 (January 1, 1990): 271–89. https://doi.org/10.1016/0038-092X(90)90055-H.

Perez, TMY, and Hourly Sun Positions

Los Angeles Intl. Airport



TMY-X

climate.onebuilding.org

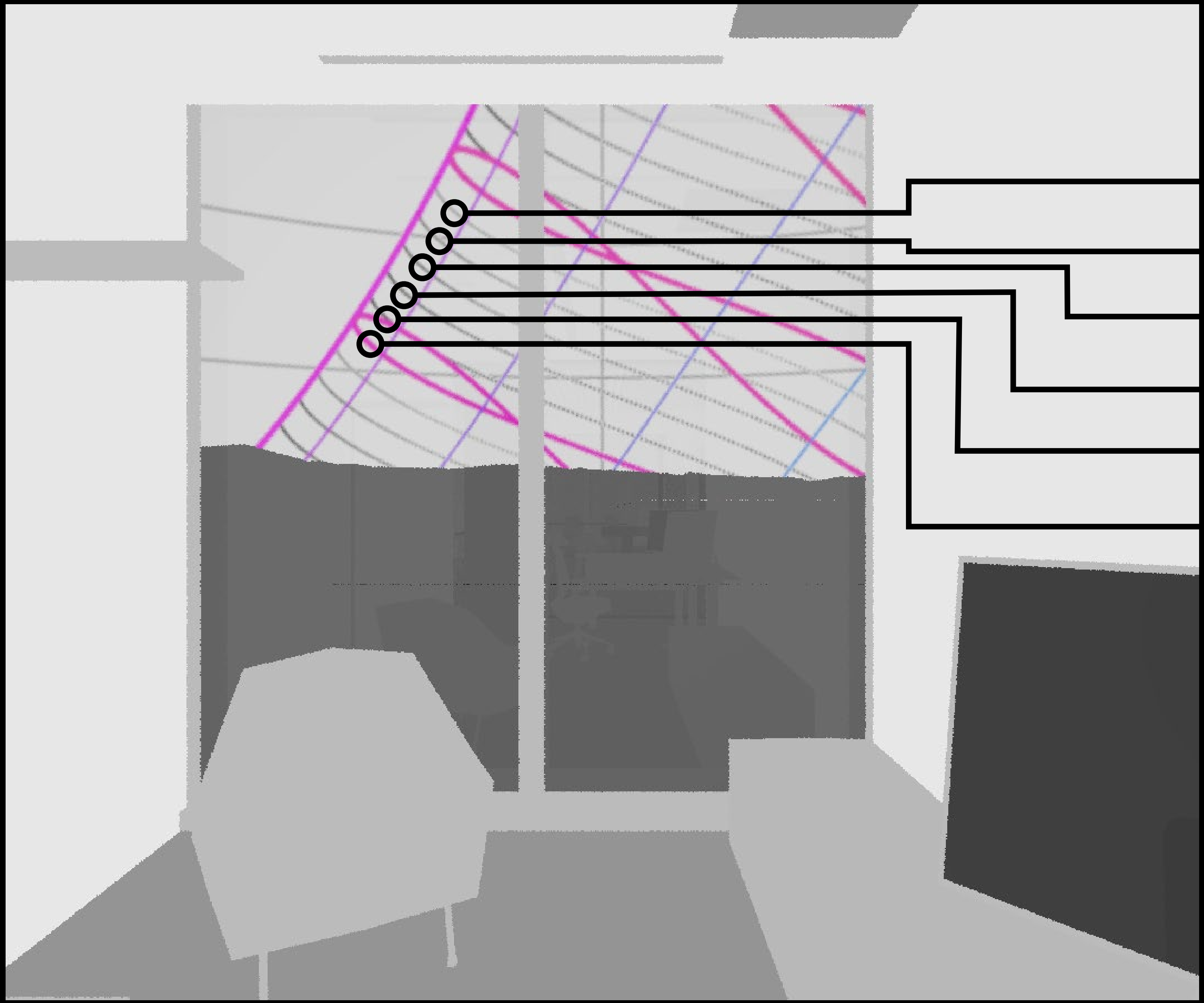
TMY/ISO 15927-4:2005

TMY-3

www.energyplus.net

sandia method + direct radiation

Perez, TMY, and Hourly Sun Positions



Hours with direct sun

HH:M0 . . . . . 438 hours

HH:50 429
HH:40 453
HH:30 453
HH:20 438
HH:10. 447
HH:00 408
rel. dev. 7%
(a larger error than any of the simulations)

Perez, TMY, and Hourly Sun Positions

The annual sky matrix is a sampling of sun positions (which may or may not be representative) within a sample of sky conditions (which may or may not be representative and are integrated hourly measurements used as point samples) modeled with an experimentally derived least square fit of measured data.

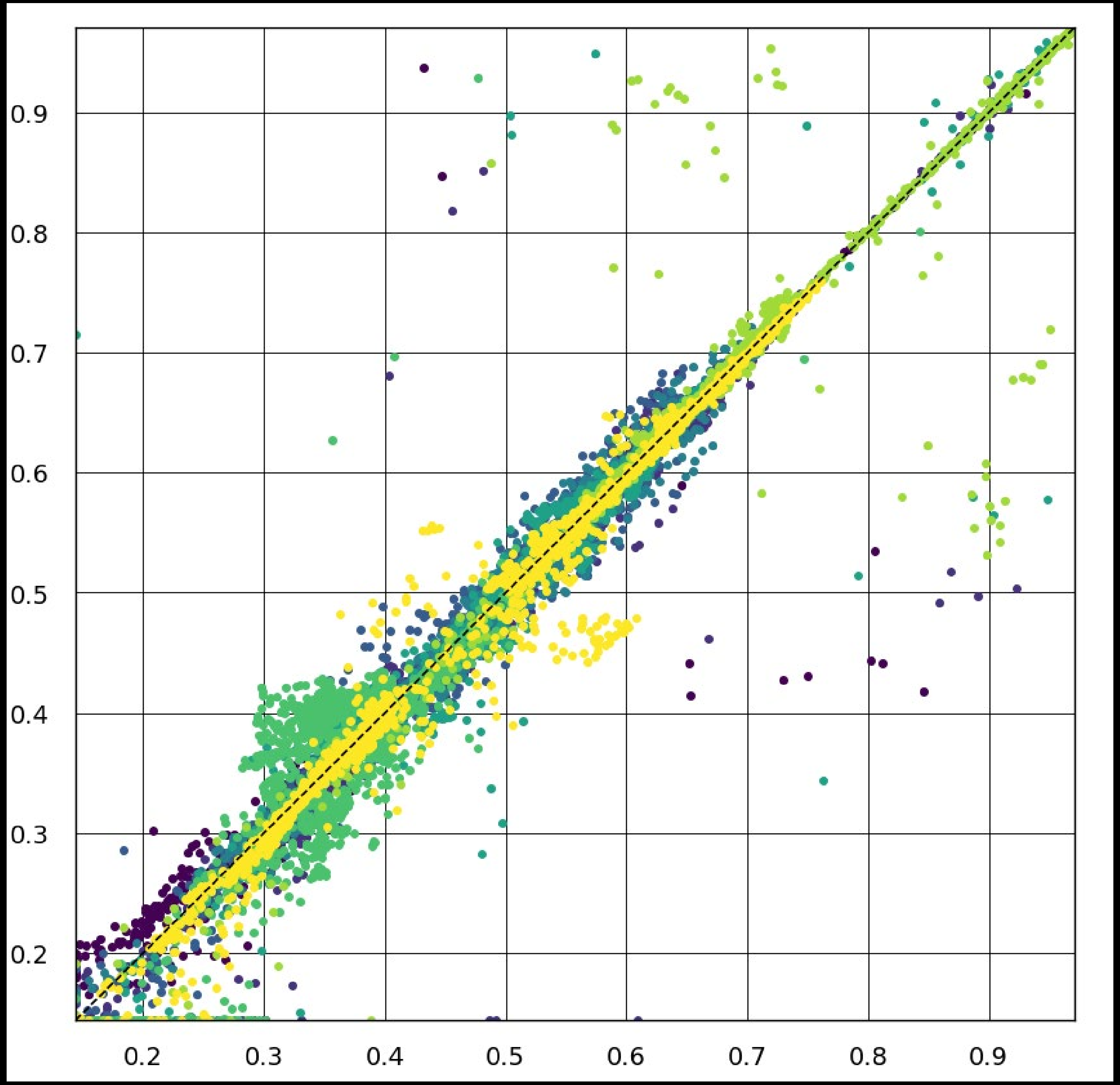
CBDM for predictive modelling

It is not possible, using either TMY or site-measured weather data to predict future conditions at a particular time. Instead, the best outcome is a representative distribution of likely conditions with a plausible temporal sequence driven by solar position.

CBDM for predictive modelling

when comparing two simulation methods, some level of variance, and even extreme outliers, may not be significant if both represent the same true underlying distribution.

UGP - ref vs raytraverse_d

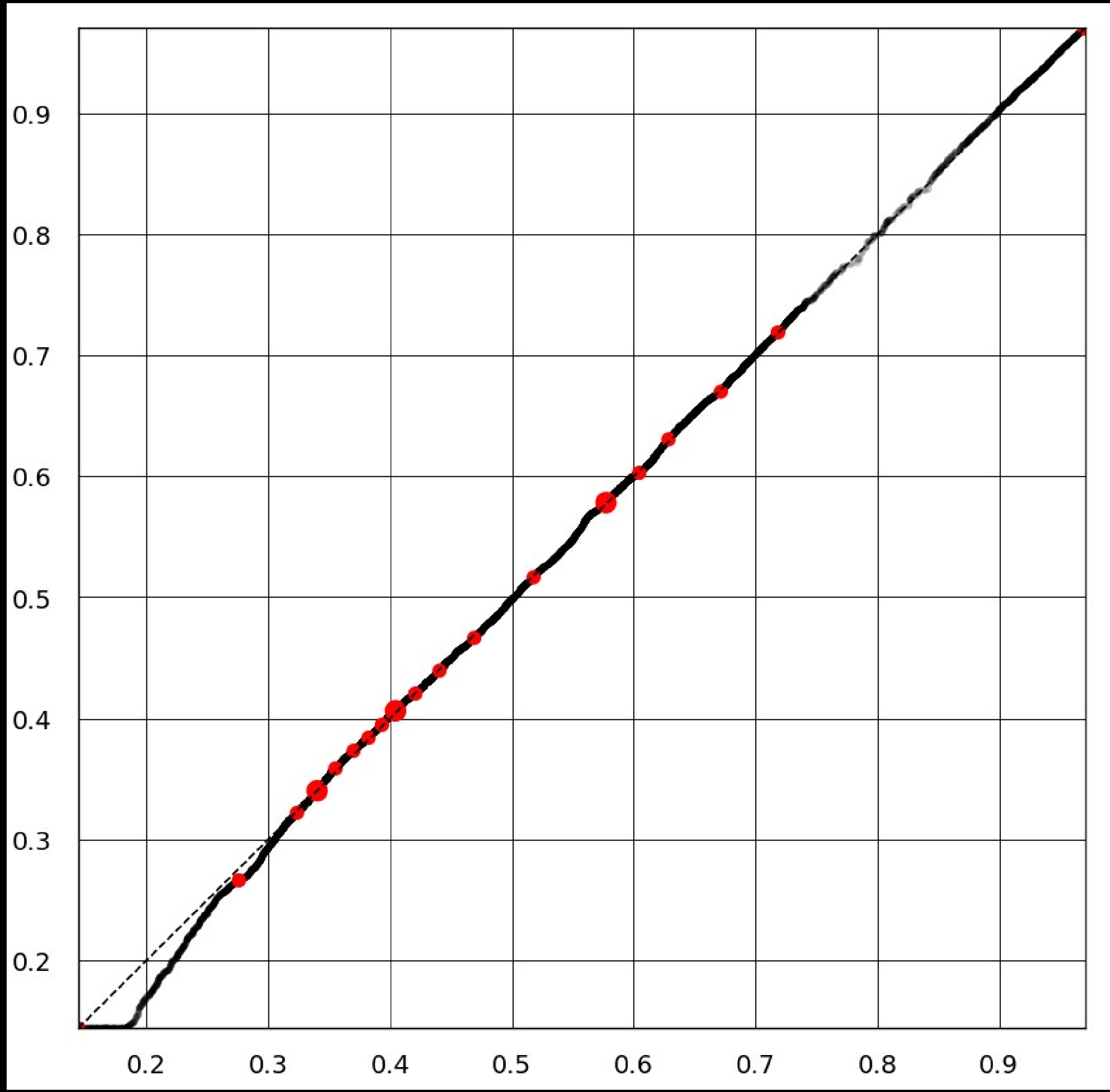


scatter plot, all views

CBDM for predictive modelling

when comparing two simulation methods, some level of variance, and even extreme outliers, may not be significant if both represent the same true underlying distribution.

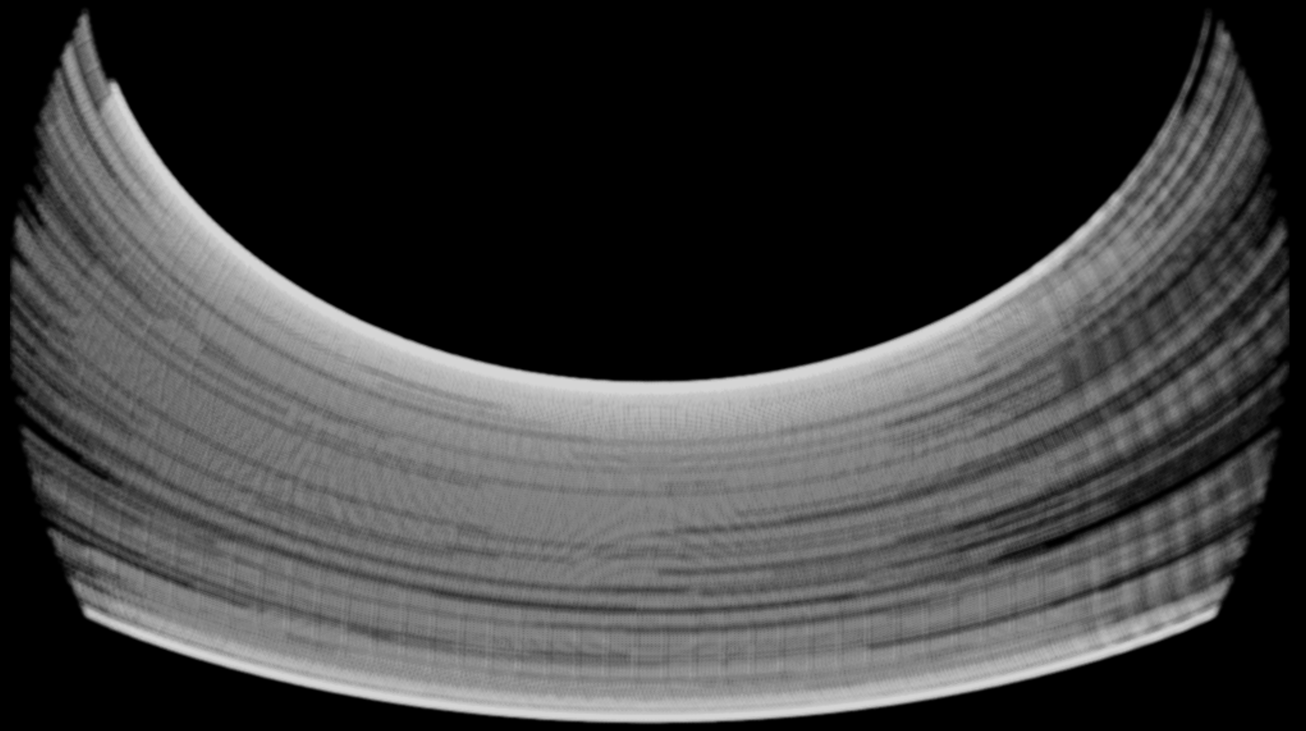
UGP - ref vs raytraverse-d



QQ-plot - large red dots indicate quartiles, small red dots every 5th

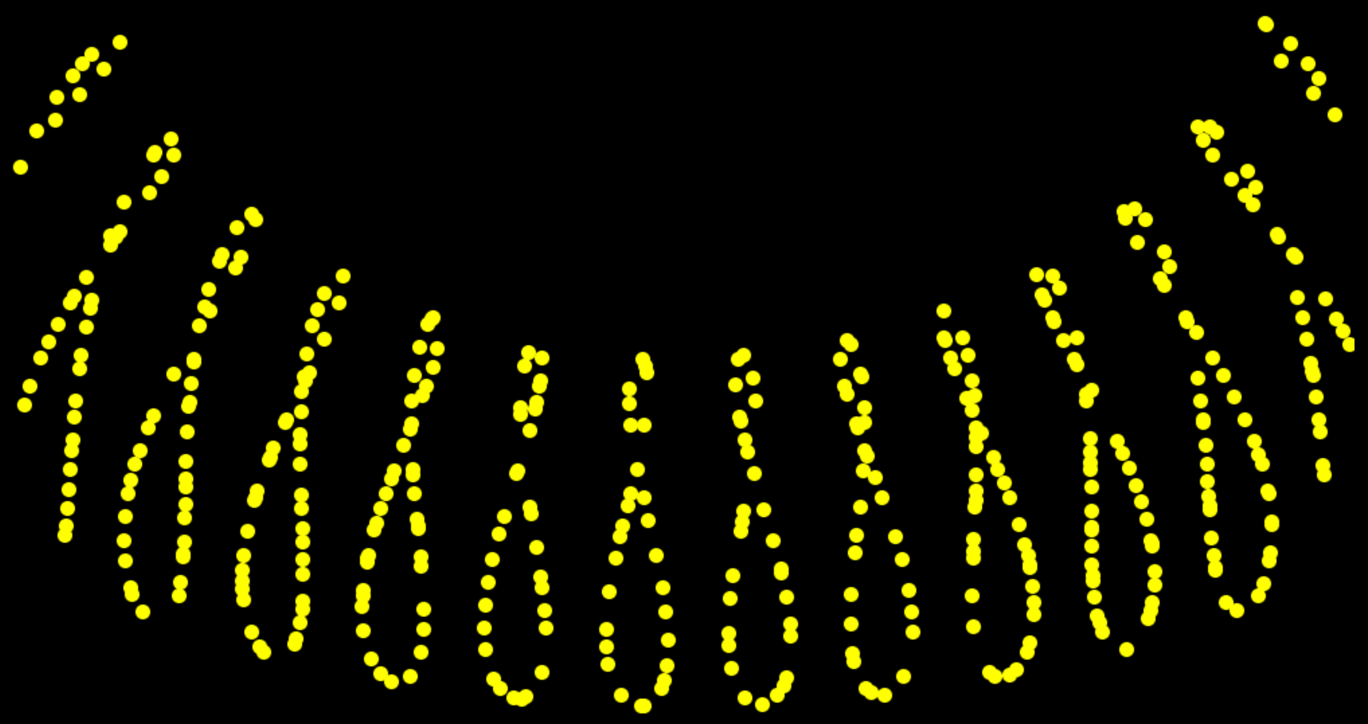
CBDM for predictive modelling

frequency of solar positions with direct normal > 50 w/m^2 (LAX)

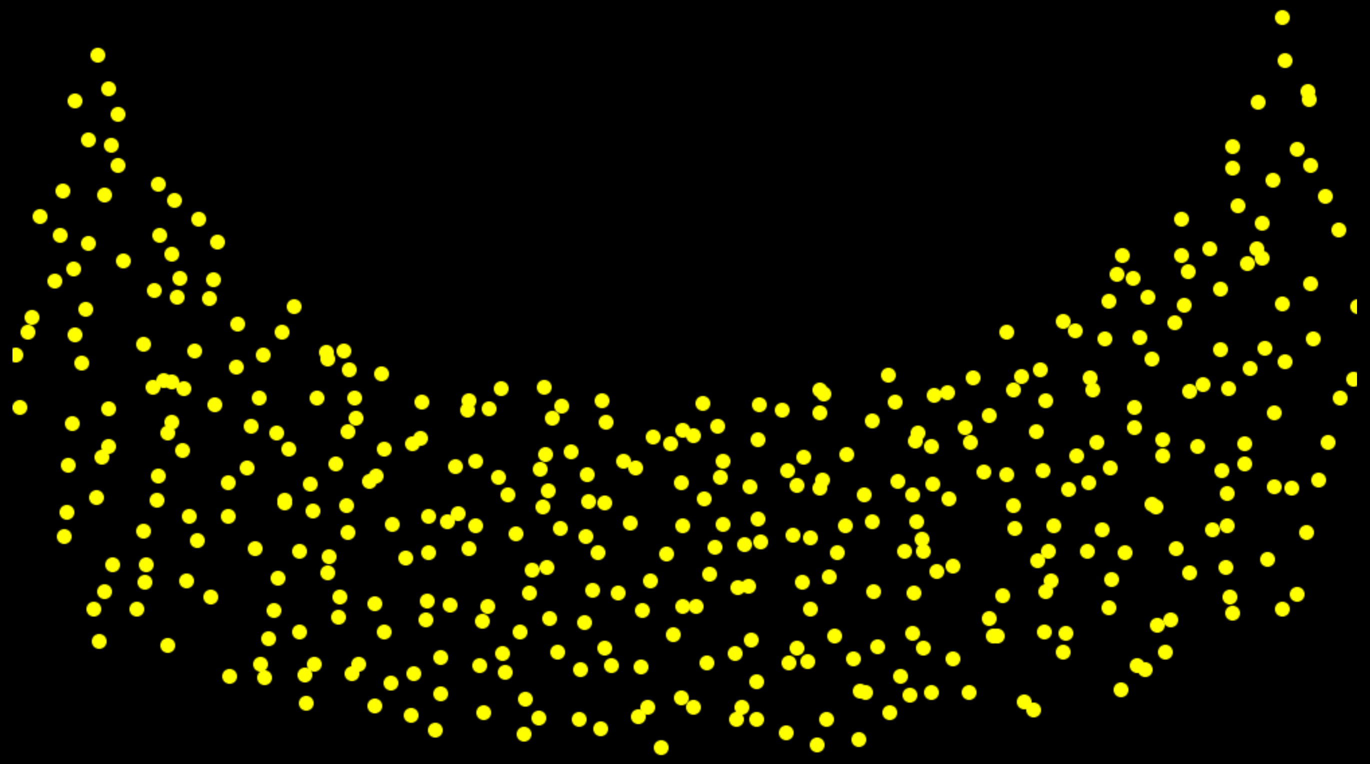


Should we aim for one to one matching with hourly reference data? Or should we aim for representing a continuous distribution?

Distribution of Solar Samples



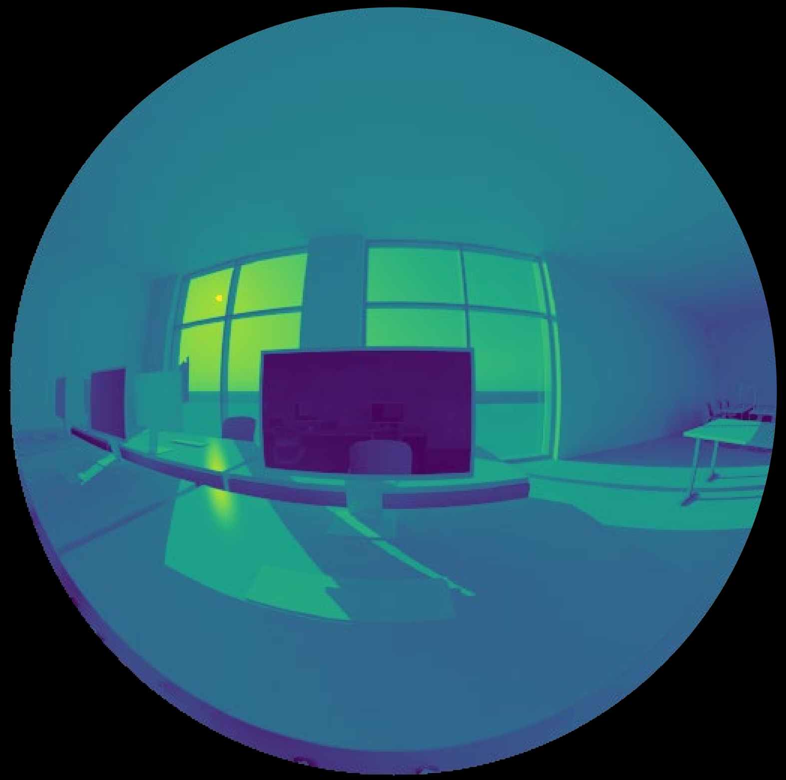
N=457

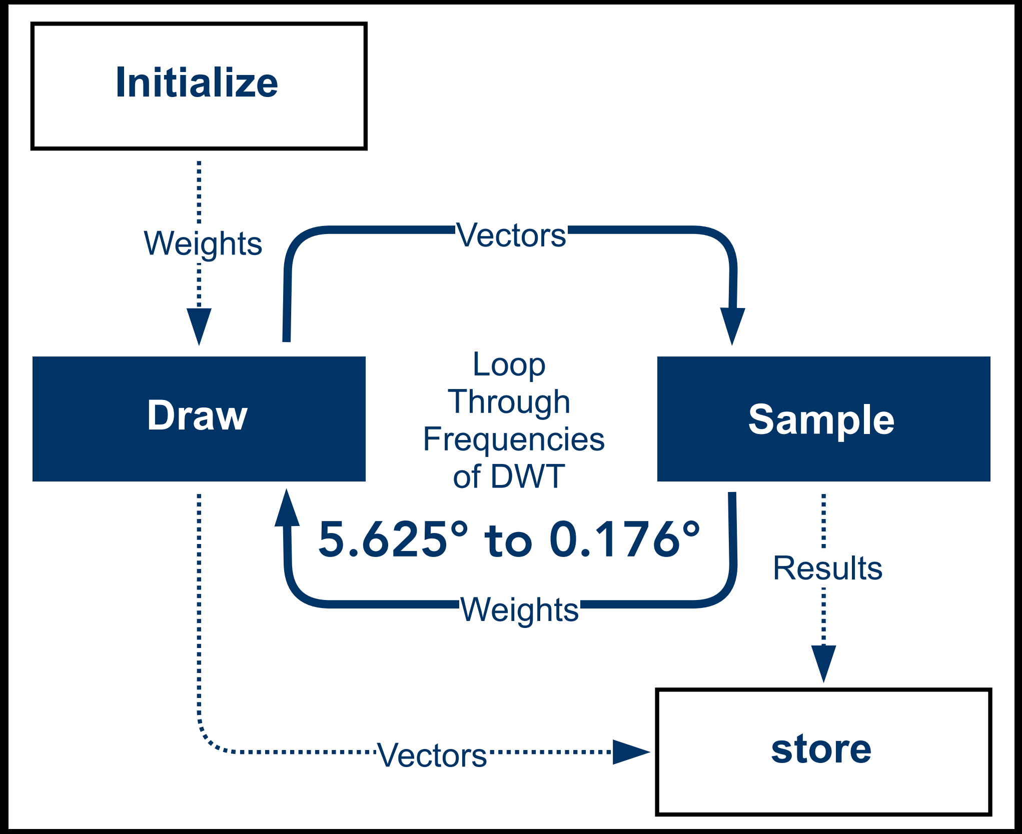


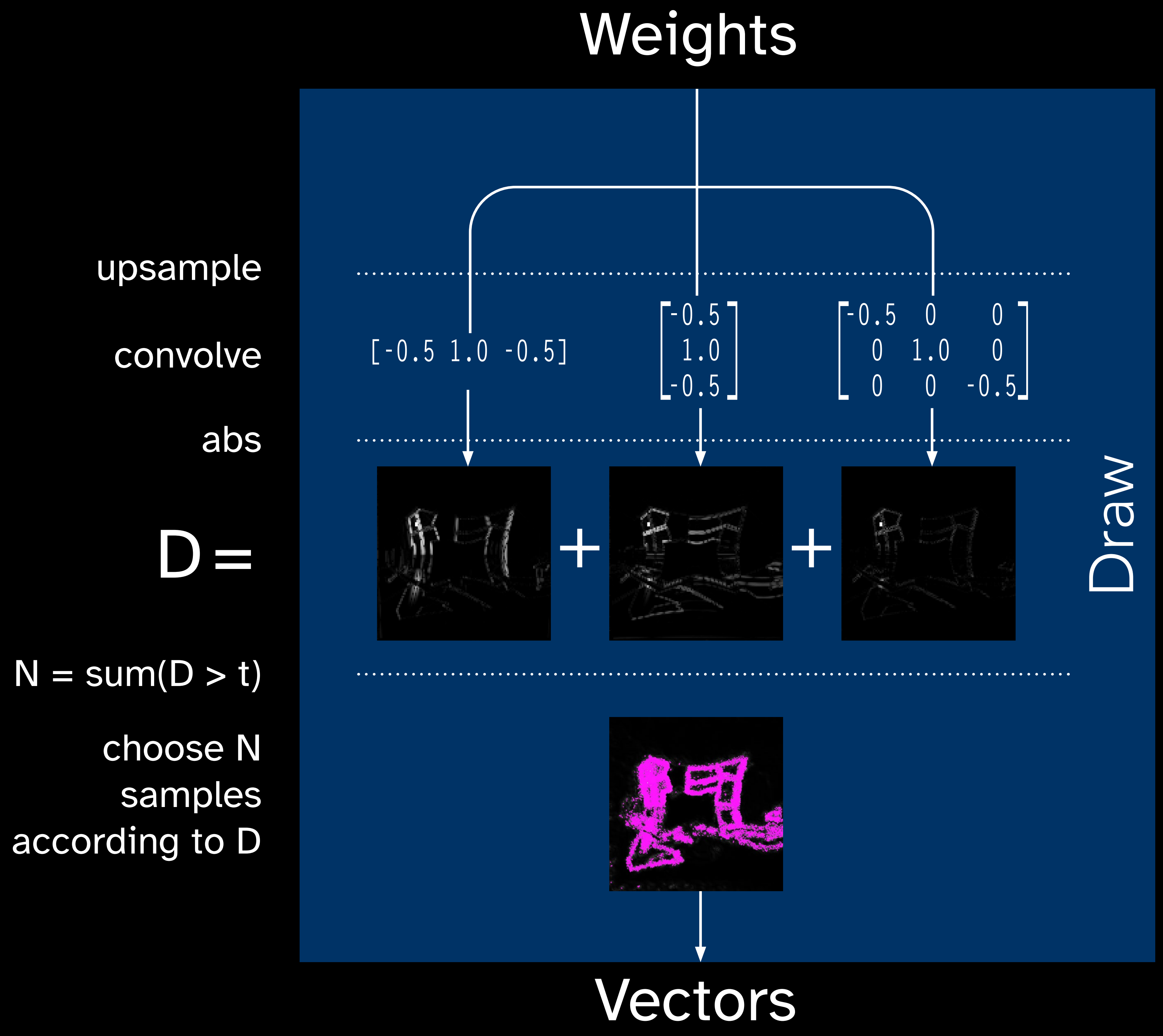
N=413

sampling an area

review of sampling rays from a point

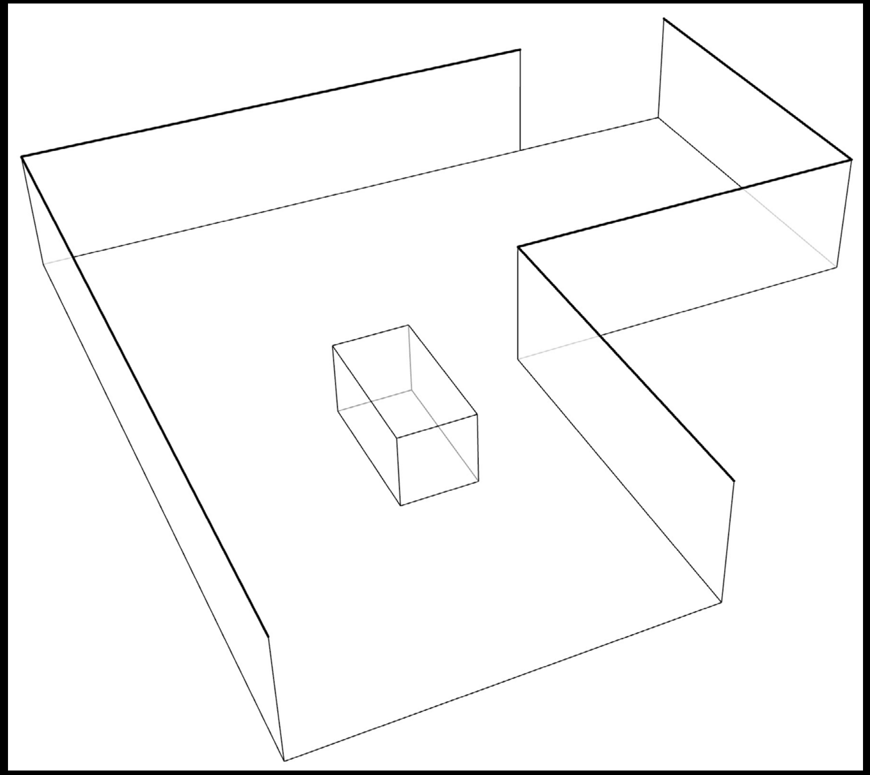


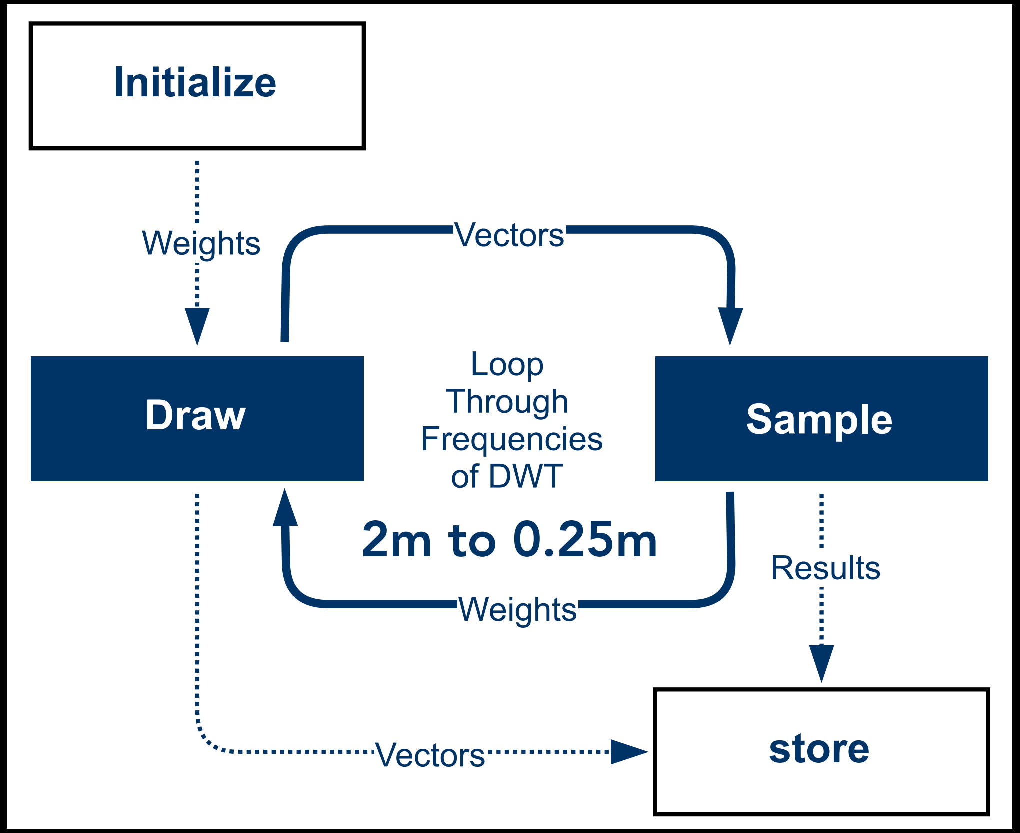




6.2

Sampling points on an area





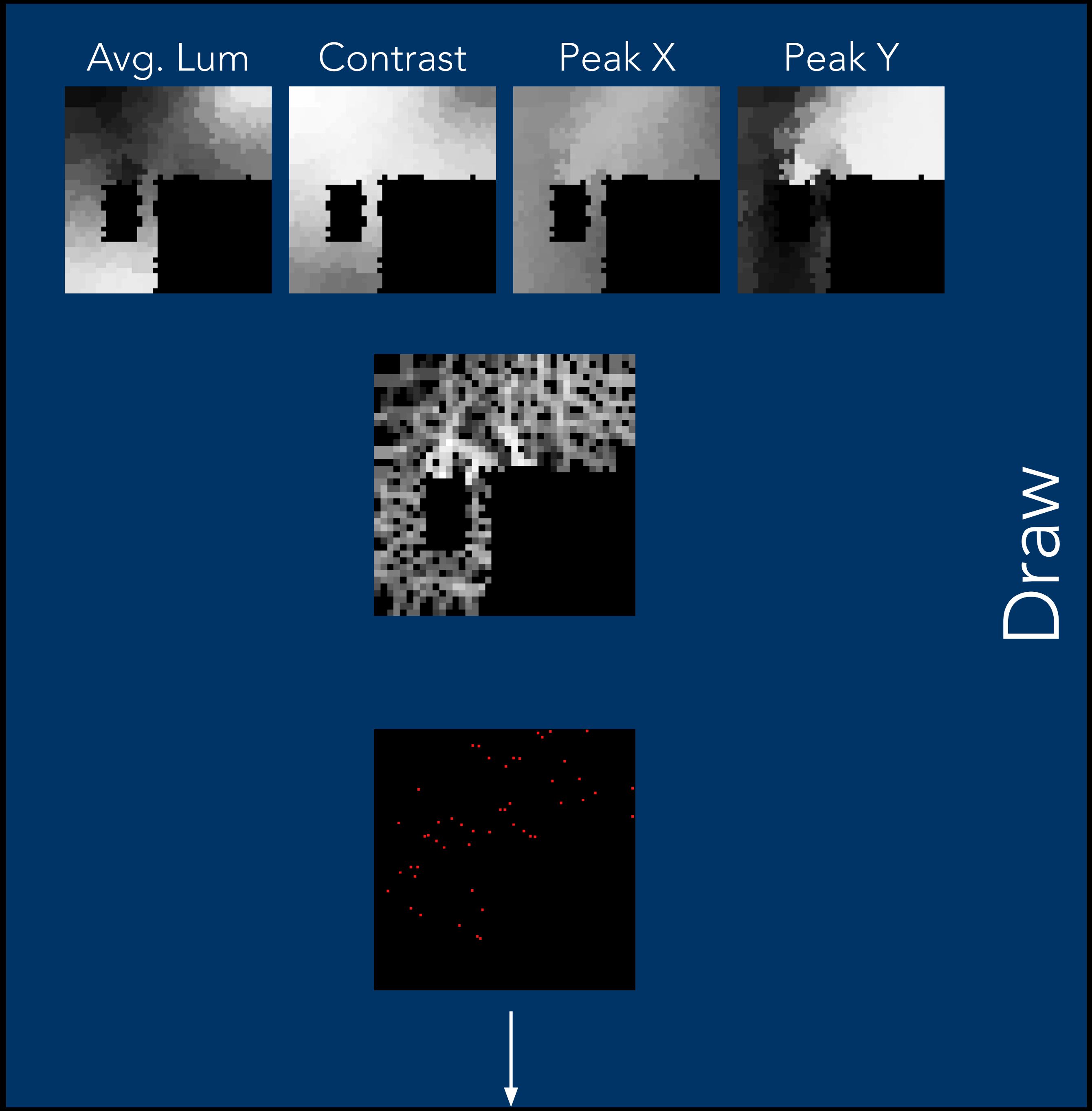
Weights

Estimate @
next level

convolve
abs
max
mask

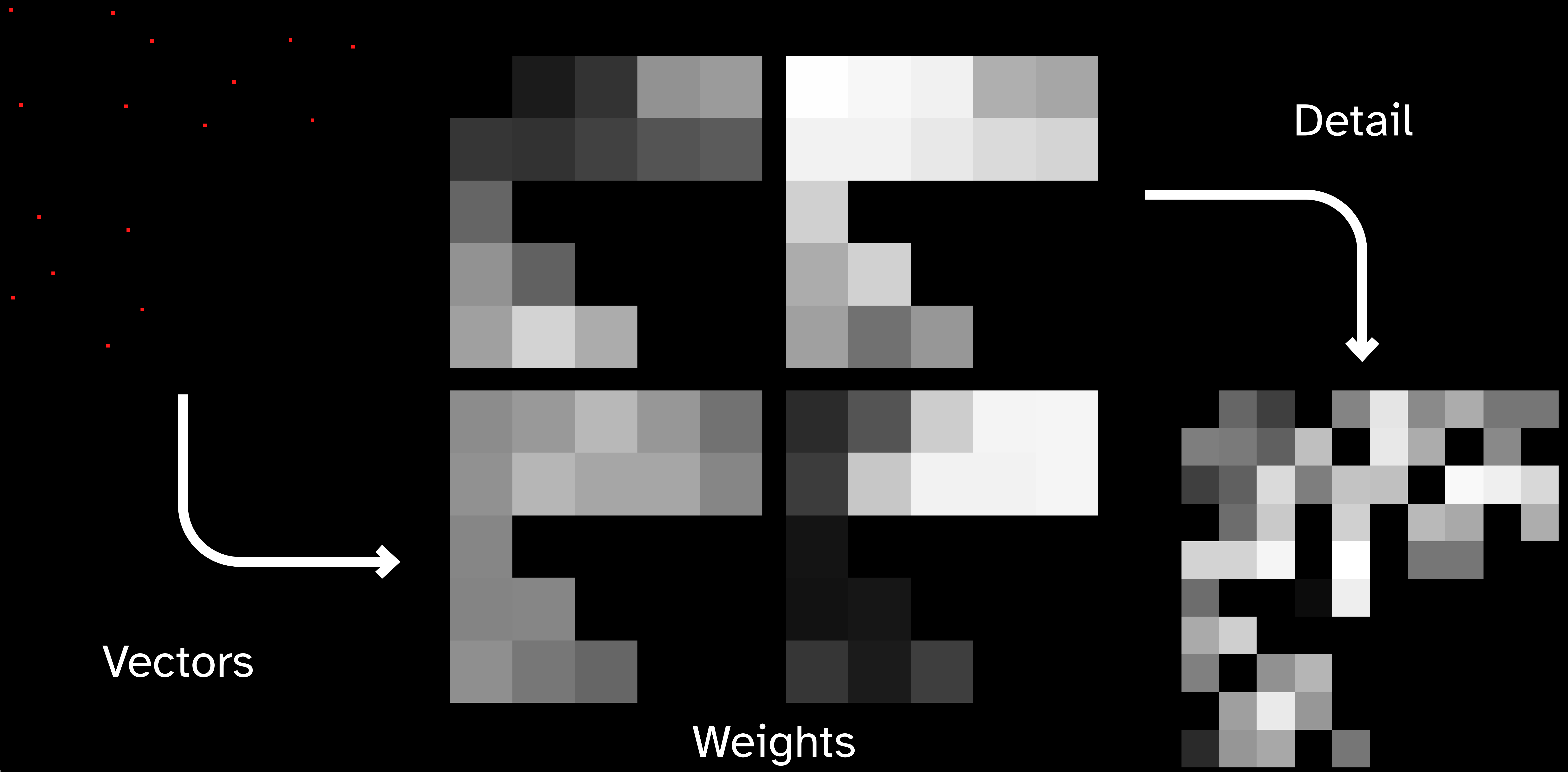
N = sum(D > t)

choose N
samples
according to D

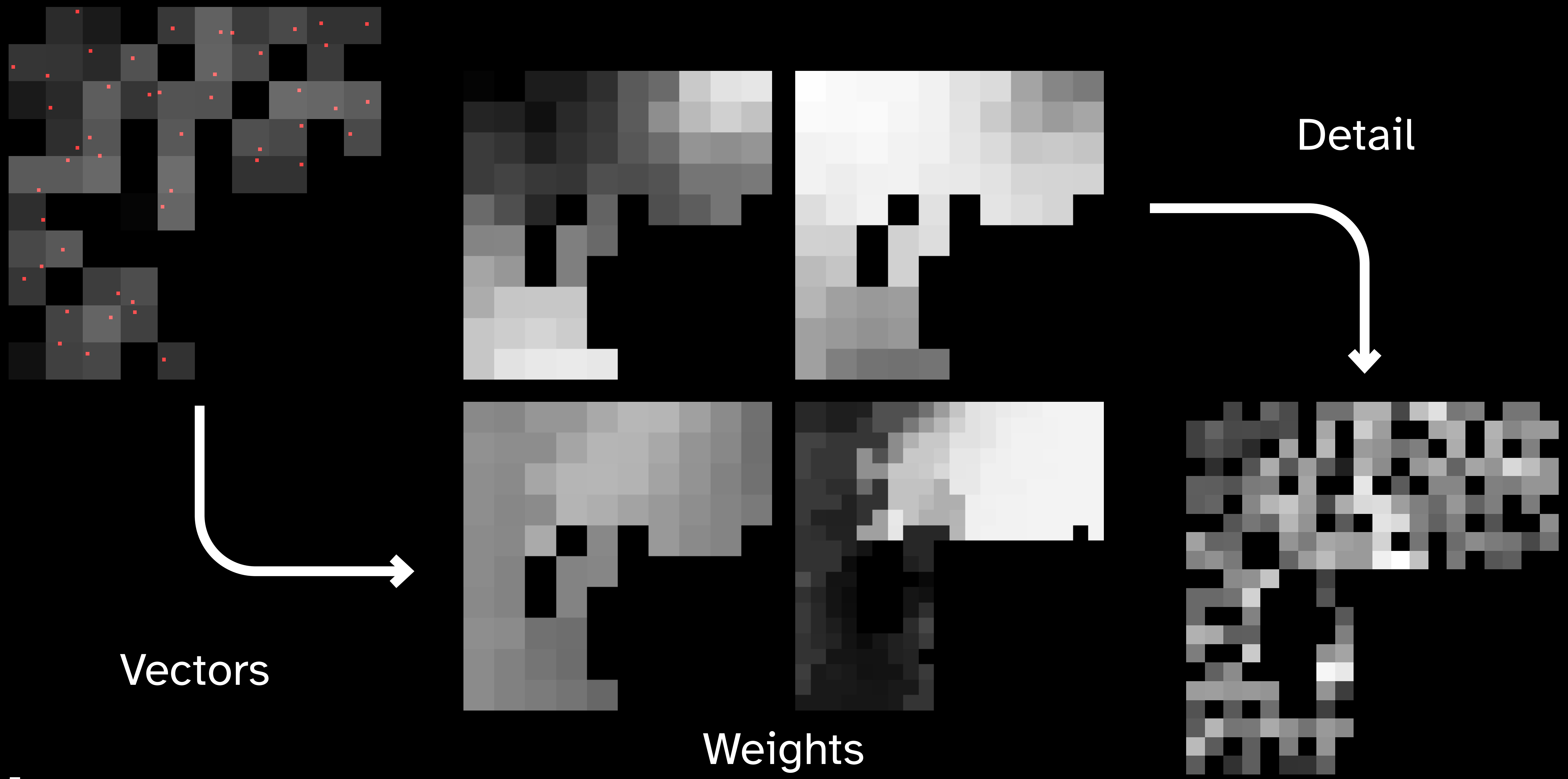


Vectors

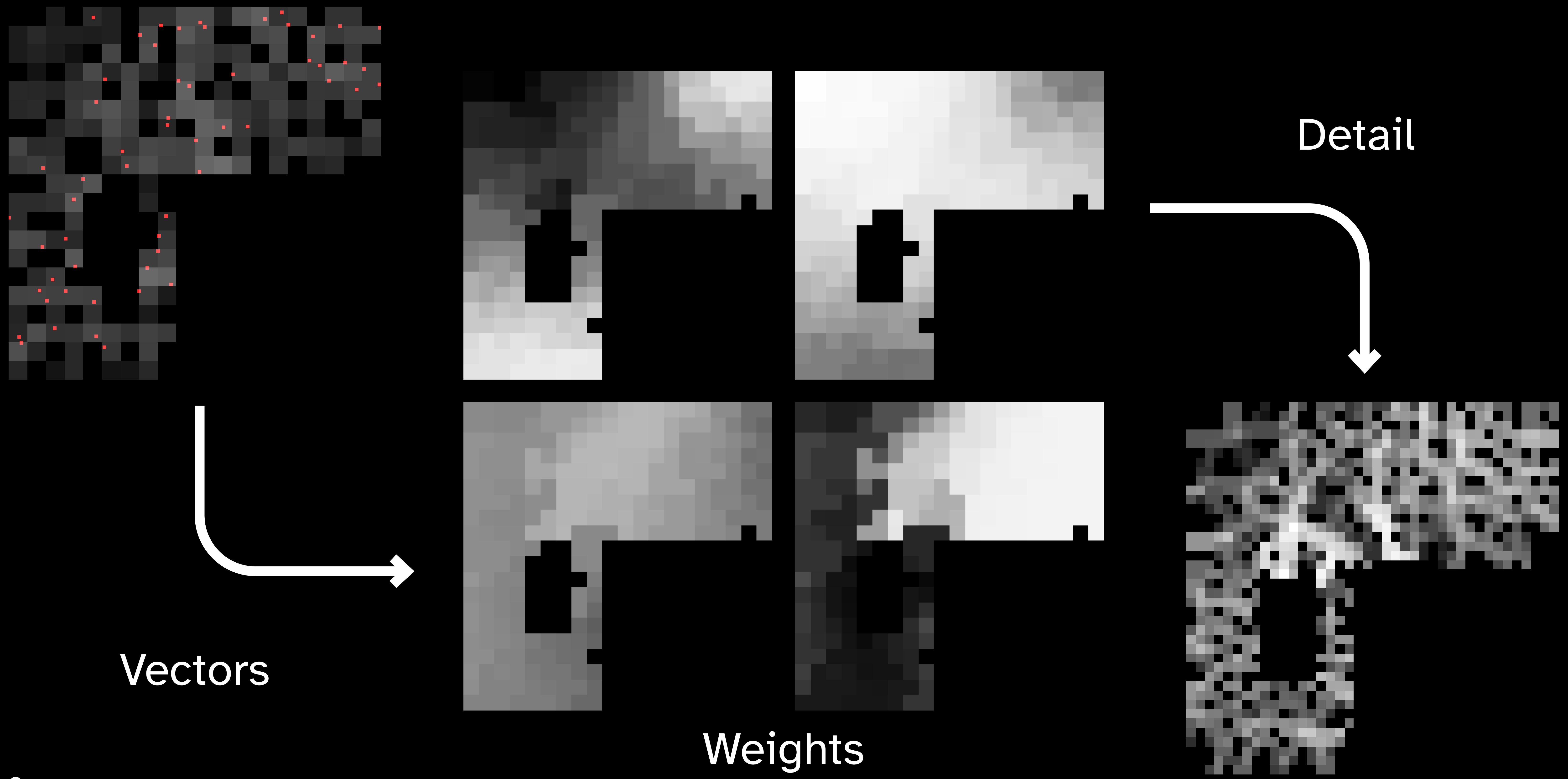
Area Sampling Loop - Level 0



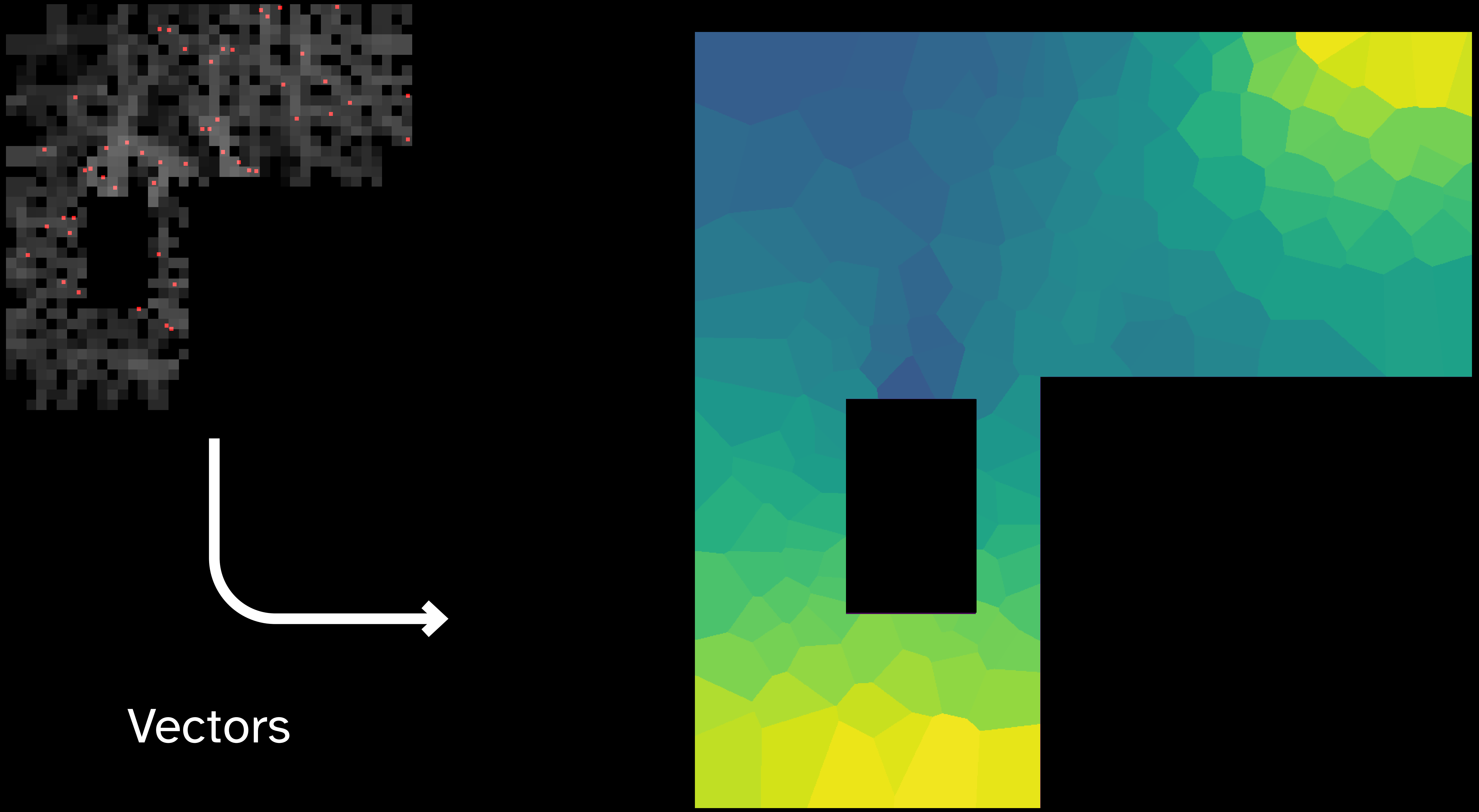
Area Sampling Loop - Level 1



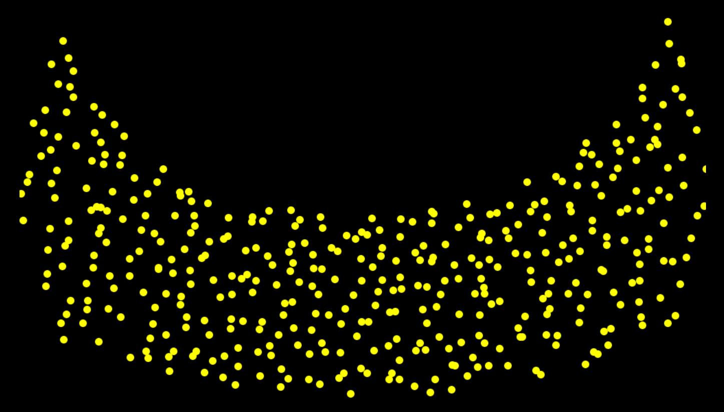
Area Sampling Loop - Level 2

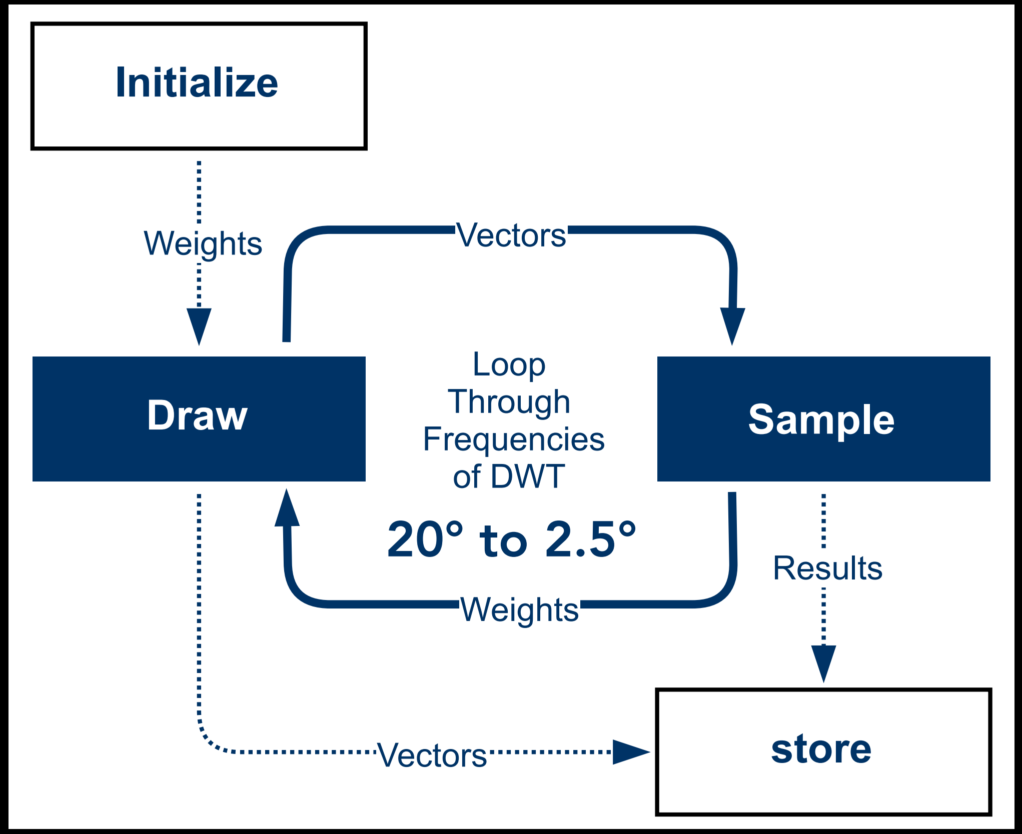


Area Sampling Loop - Level 3



sampling sun positions on an area



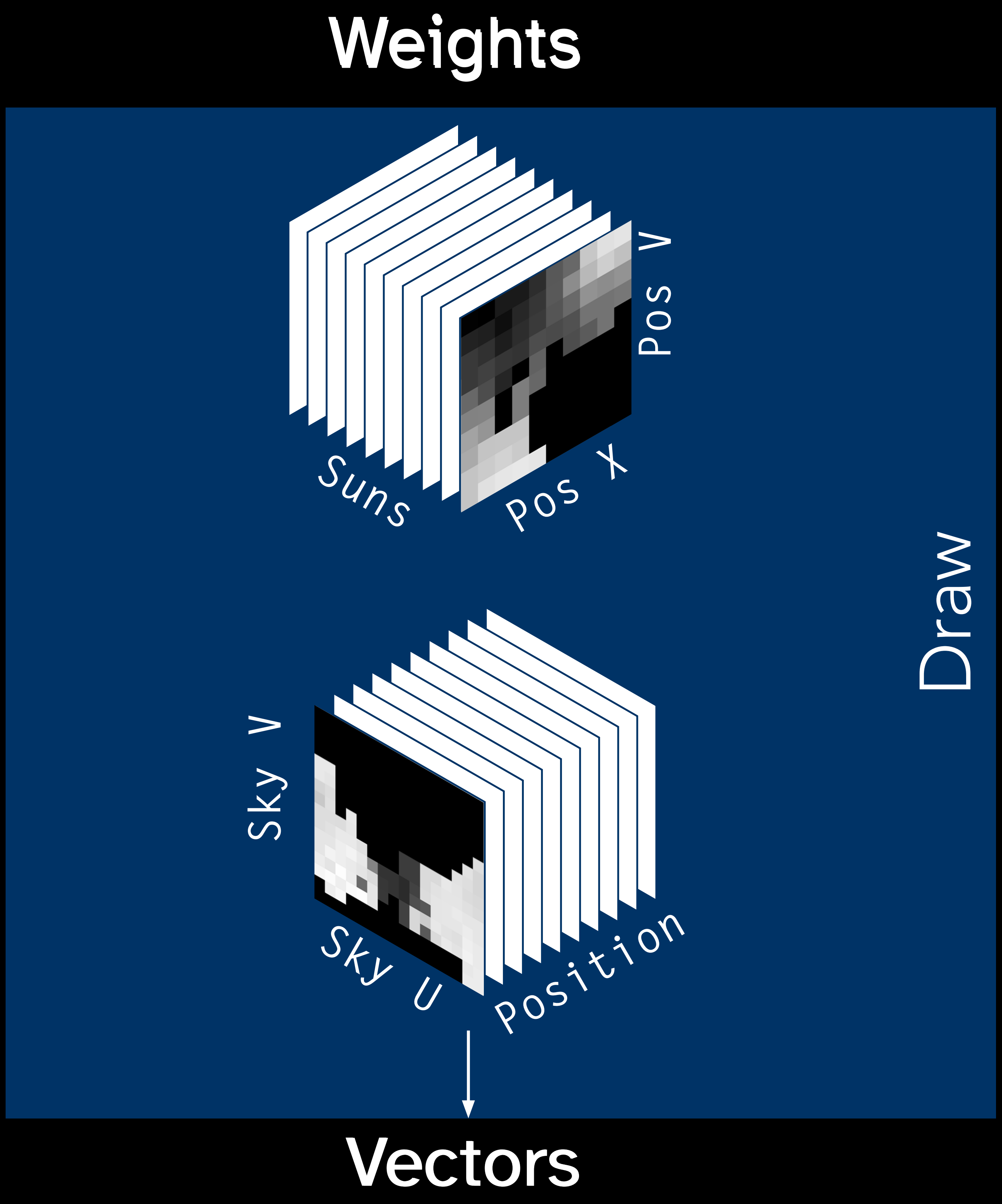


For each sun position, area sampler provides final weights across area

Convolve over (Usky, Vsky) to find detail between sun positions.

Produce sun position vectors at every region that has a position above threshold

Mask area sampler to exclude low detail regions for each source




how to raytraverse

Important Links

Documentation https://raytraverse.readthedocs.io/en/latest/

- Installation Instructions
- Getting Started
- Tutorials
- complete command line reference
- API documentation
- Project Links and Citations

Github https://github.com/stephanwaz/raytraverse

PyPI https://pypi.org/project/raytraverse/

Installation

Raytraverse runs on Mac or Linux and Requires Python >=3.6

I recommend installing any python package in a virtual environment:

```
python3 -m venv <myenv>
source <myenv>/bin/activate
```

(you can put the activate line in your .bash_profile if you are forgetful and lazy like me. Terminal will look like this:

```
(<myenv>) my-computer:~me$
```

The easiest way to install raytraverse is with pip:

```
pip install --upgrade pip setuptools wheel
pip install raytraverse
```

or if you have cloned this repository:

```
cd path/to/this/file
pip install .
```

I am working on putting together a pyinstaller for those who do not want to manage their own python environment, but this will likely be a Mac only option. check the raytraverse.readthedocs.io for updates

Installation

At present, installing raytraverse will also install the following radiance binaries (another good reason to use a virtualenv):

```
rtrace          vwrays          gendaylit
rcontrib        pvalue          xform
total           pcompos
cnt             pcomb
rcalc           pfilt
getinfo         oconv
```

raytraverse doesn't actually depend on most of these (other than oconv, but they are necessary for testing)

Wait, How does Raytraverse not depend on rtrace?

Rtrace

class `raytraverse.renderer.Rtrace`(*rayargs=None*, *scene=None*, *nproc=None*, *default_args=True*, *direct=False*) [source]

Bases: `raytraverse.renderer.radiancerenderer.RadianceRenderer`

singleton wrapper for c++ raytrraverse.crenderer.cRtrace class

this class sets default arguments, helps with initialization and setting cpu limits of the cRtrace instance. see raytrraverse.crenderer.cRtrace for more details.

Parameters:

- **rayargs** (*str, optional*) – argument string (options and flags only) raises ValueError if arguments are not recognized by cRtrace.
- **scene** (*str, optional*) – path to octree
- **nproc** (*int, optional*) – if None, sets nproc to cpu count, or the RAYTRAVERSE_PROC_CAP environment variable
- **default_args** (*bool, optional*) – if True, prepend default args to rayargs parameter
- **direct** (*bool, optional*) – if True use Rtrace.directargs in place of default (also if True, sets default_args to True.

Examples

Basic Initialization and call:

```
r = renderer.Rtrace(args, scene)
ans = r(vecs)
# ans.shape -> (vecs.shape[0], 1)
```

If rayargs include cache files (ambient cache or photon map) be careful with updating sources. If you are going to swap sources, update the arguments as well with the new paths:

```
r = renderer.Rtrace(args, scene)
r.set_args(args.replace("temp.amb", "temp2.amb"))
r.load_source(srcdef)
```

Note that if you are using ambient caching, you must give an ambient file, because without a file ambient values are not shared across processes or successive calls to the instance.

Rcontrib

class `raytraverse.renderer.Rcontrib`(*rayargs=None*, *scene=None*, *nproc=None*, *skyres=10.0*, *modname='skyglow'*, *ground=True*, *default_args=True*) [source]

Bases: `raytraverse.renderer.radiancerenderer.RadianceRenderer`

singleton wrapper for c++ raytrraverse.crenderer.cRcontrib class

this class sets default arguments, helps with initialization and setting cpu limits of the cRcontrib instance. see raytrraverse.crenderer.cRcontrib for more details.

Parameters:

- **rayargs** (*str, optional*) – argument string (options and flags only) raises ValueError if arguments are not recognized by cRtrace.
- **scene** (*str, optional*) – path to octree
- **nproc** (*int, optional*) – if None, sets nproc to cpu count, or the RAYTRAVERSE_PROC_CAP environment variable
- **skyres** (*float, optional*) – approximate resolution for skypatch subdivision (in degrees). Patches will have (rounded) size skyres x skyres. So if skyres=10, each patch will be 100 sq. degrees (0.03046174197 steradians) and there will be 18 * 18 = 324 sky patches.
- **modname** (*str, optional*) – passed the -m option of cRcontrib initialization
- **ground** (*bool, optional*) – if True include a ground source (included as a final bin)
- **default_args** (*bool, optional*) – if True, prepend default args to rayargs parameter

Examples

Basic Initialization and call:

```
r = renderer.Rcontrib(args, scene)
ans = r(vecs)
# ans.shape -> (vecs.shape[0], 325)
```

The Command Line Interface

```
$ raytraverse --help
Usage: raytraverse [OPTIONS] COMMAND1 [ARGS]... [COMMAND2
[ARGS]...]...
...
Commands:
  area           define sampling area
  evaluate       evaluate metrics
  examplescript  print an example workflow for script based/api level access to
                raytraverse
  images         render images
  imgmetric      calculate metrics for hdr images, similar to evalglare but without
                glare source grouping, equivalent to -r 0 in evalglare.
  pull           flatten/unroll results into 2d tsv data
  scene          define scene files for renderer and output directory
  skydata        define sky conditions for evaluation
  skyengine      initialize engine for skyrun
  skyrun         run scene under sky for a set of points (defined by area)
  sunengine      initialize engine for sunrun
  sunrun         run scene for a set of suns (defined by suns) for a set of points
                (defined by area)
  suns           define solar sampling space
```

The Command Line Interface

```
$ raytraverse --template > settings.cfg
```

Set up scene and output directory

```
[raytraverse_scene]
log = True
out = None
overwrite = False
reload = True
scene = None
```

Set up sampling area

```
[raytraverse_area]
name = plan
ptres = 1.0
rotation = 0.0
static_points = None
zheight = None
zone = None
```

Set up sun sampling (candidates or transit)

```
[raytraverse_suns]
epwloc = False
loc = None
name = suns
printdata = False
printlevel = None
skyro = 0.0
sunres = 30.0
```

The Command Line Interface

```
$ raytraverse --template > settings.cfg
```

Sky matrix data

```
[raytraverse_skydata]
ground_fac = 0.15
loc = None
minalt = 2.0
mindiff = 5.0
name = skydata
reload = True
skyres = 10.0
skyro = 0.0
wea = None
```

Point sampler for sky coefficients

```
[raytraverse_skyengine]
accuracy = 1.0
dcompargs = -ab 1
default_args = True
fdres = 9
idres = 5
rayargs = None
skyres = 10.0
```

Point sampler for sun coeffcients

```
[raytraverse_sunengine]
accuracy = 1.0
dcompargs = -ab 0
default_args = True
fdres = 10
idres = 5
maxspec = 0.2
rayargs = None
slimit = 0.01
speclevel = 9
```

The Command Line Interface

```
$ raytraverse --template > settings.cfg
```

Sky area sampler (main command)

```
[raytraverse_skyrun]
accuracy = 1.0
dcomp = True
jitter = True
nlev = 3
overwrite = False
plotp = False
```

Sun area sampler (main command)

```
[raytraverse_sunrun]
accuracy = 1.0
guided = True
jitter = True
nlev = 3
overwrite = False
plotp = False
recover = True
srcaccuracy = 1.0
srcjitter = True
srcnlev = 3
```

Output image generations

```
[raytraverse_images]
basename = results
dcomp = True
interpolate = False
namebyindex = False
res = 800
sdirs = None
sensors = None
skymask = None
sunonly = False
viewangle = 180.0
```

```
$ raytraverse -c settings.cfg skyrun sunrun
```

The Command Line Interface

```
$ raytraverse --template > settings.cfg
```

metric calculation

```
[raytraverse_evaluate]
basename = results
dcomp = True
metrics = illum dgp ugp
npz = True
sdirs = None
sensors = None
skymask = None
sunonly = False
viewangle = 180.0
```

utility: calculate metrics on hdr images (like evalglare)

```
[raytraverse_imgmetric]
basename = img_metrics
imgs = None
metrics = illum dgp ugp
npz = True
parallel = True
peaka = 6.7967e-05
peakn = True
peakr = 4.0
peakt = 100000.0
scale = 179.0
threshold = 2000.0
```

Output metric result tables

```
[raytraverse_pull]
col = metric
header = True
imgfilter = None
lr = None
metricfilter = None
order = point view sky
ptfilter = None
rowlabel = True
skyfilter = None
viewfilter = None
```

```
$ raytraverse -c settings.cfg evaluate pull
```

Thank You

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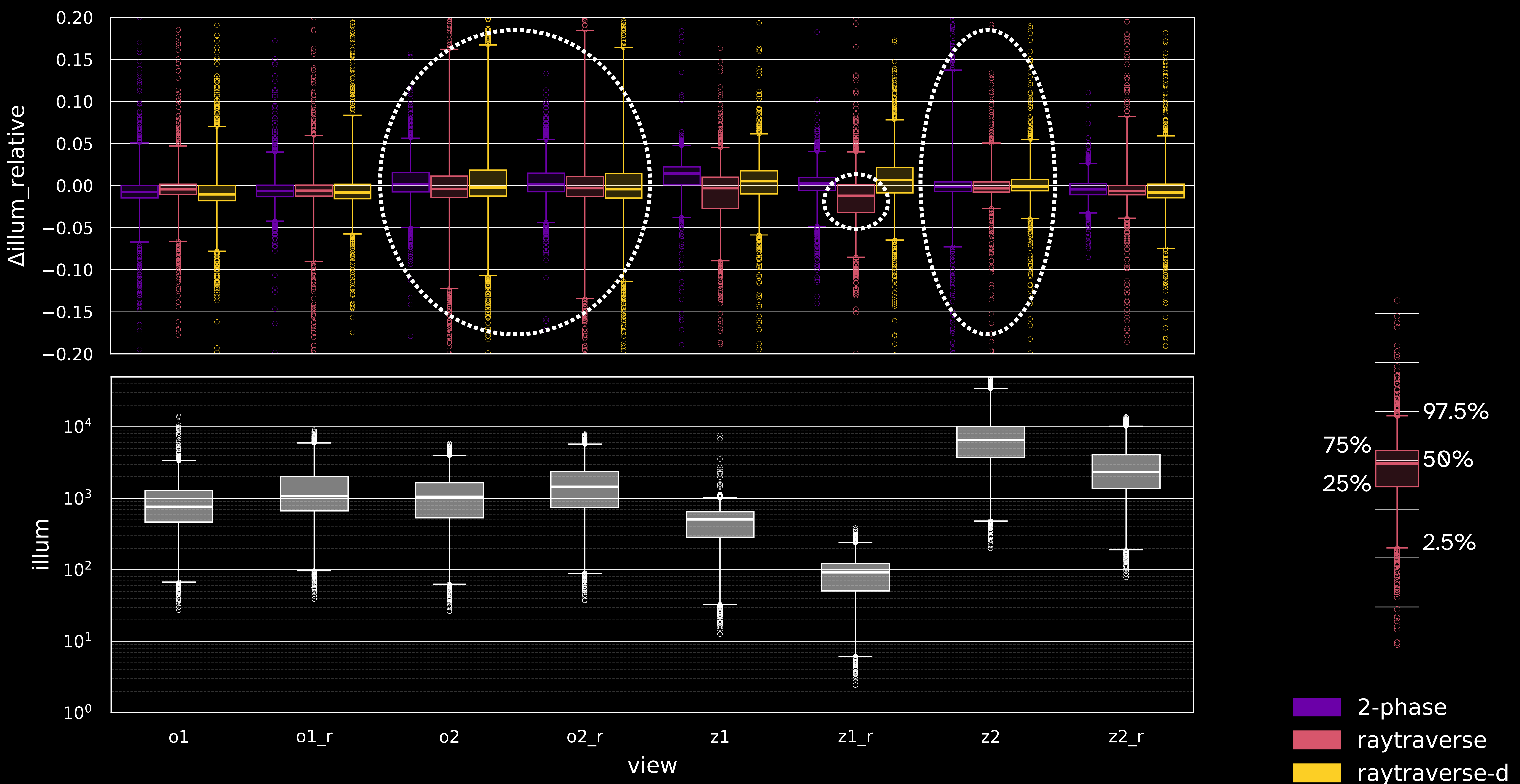
http://p3.snf.ch/project-179067

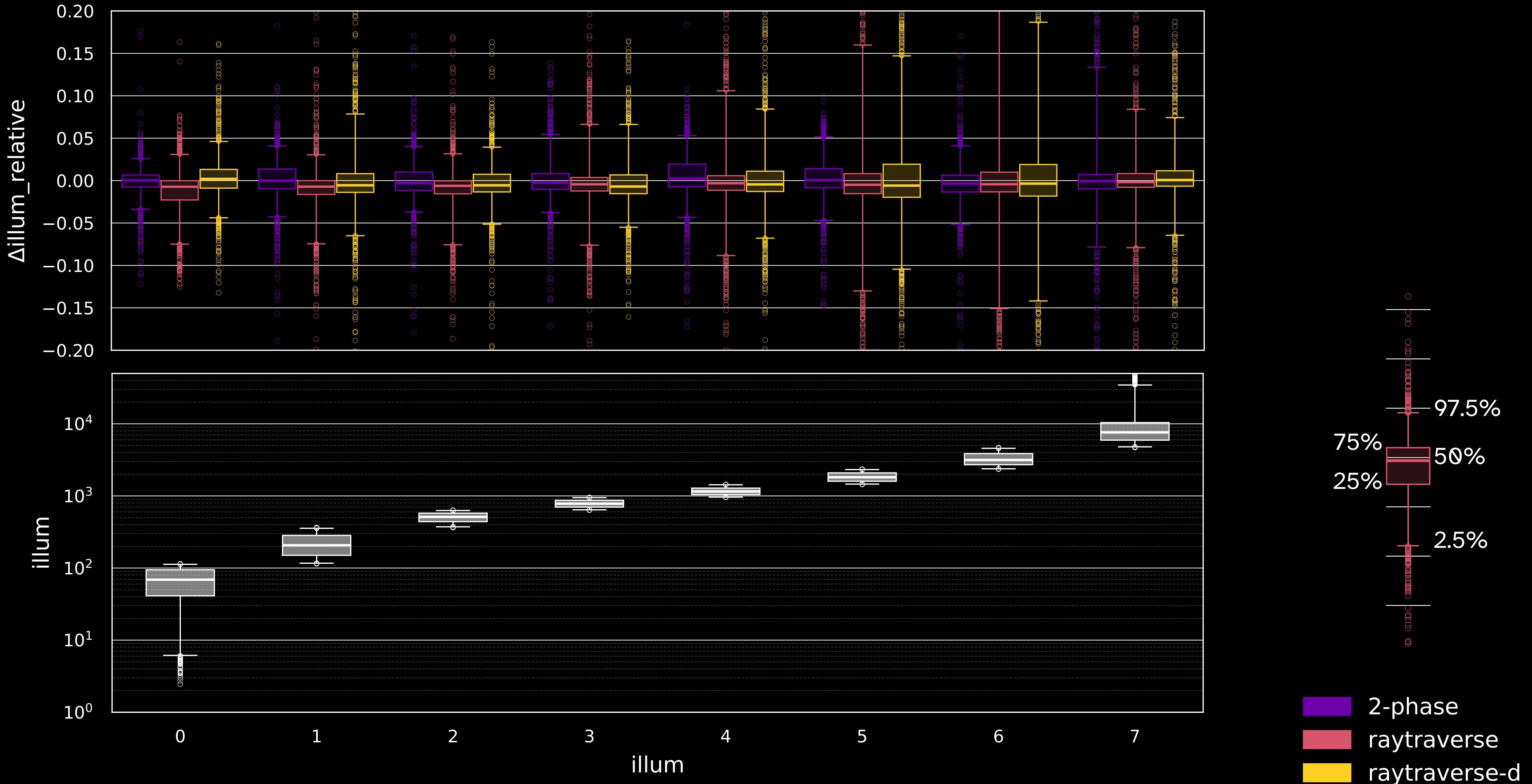
Appendix: Error by Metric

Illuminance - Error by View



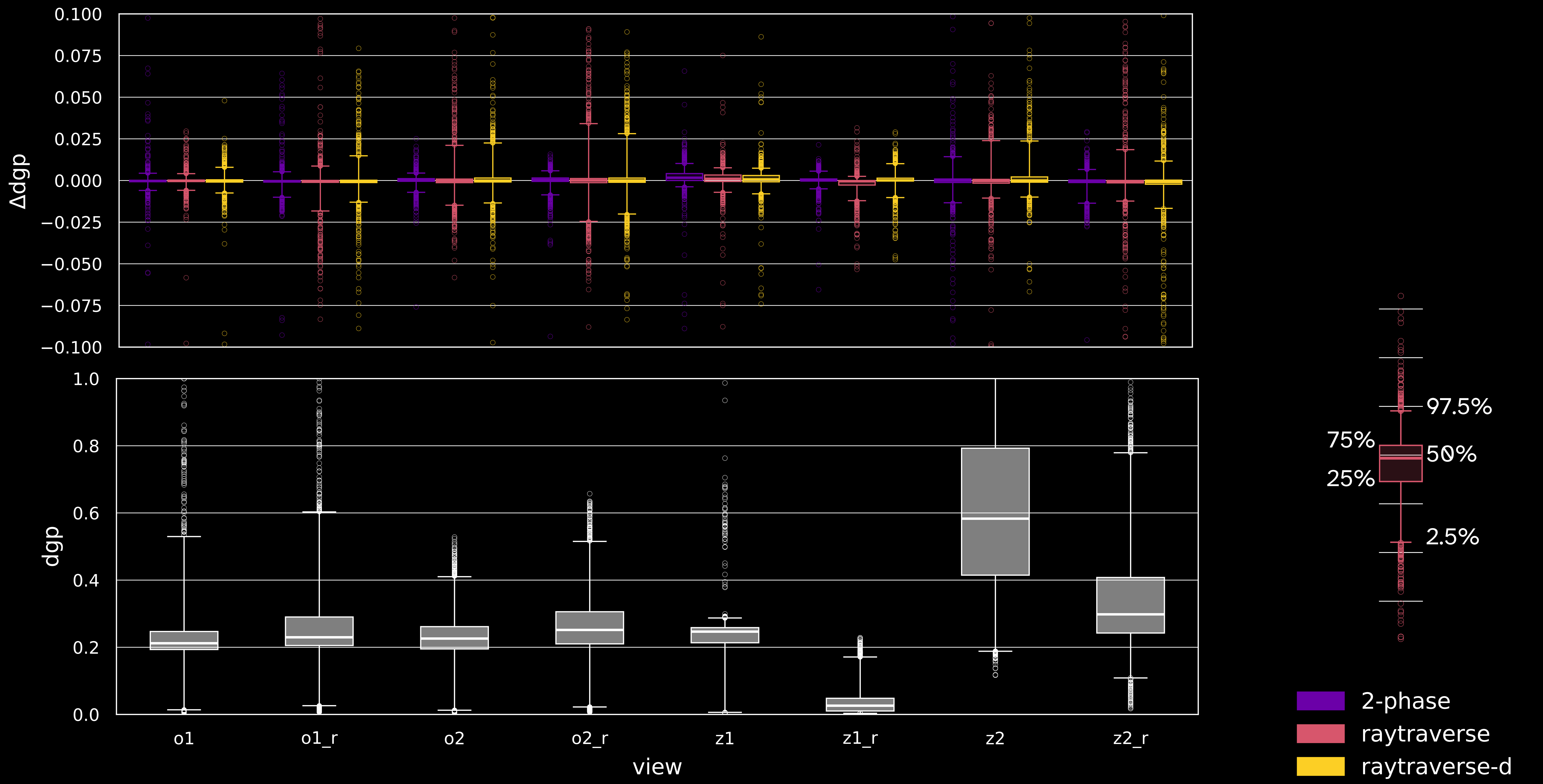
A.2

Illuminance - Error by Illuminance



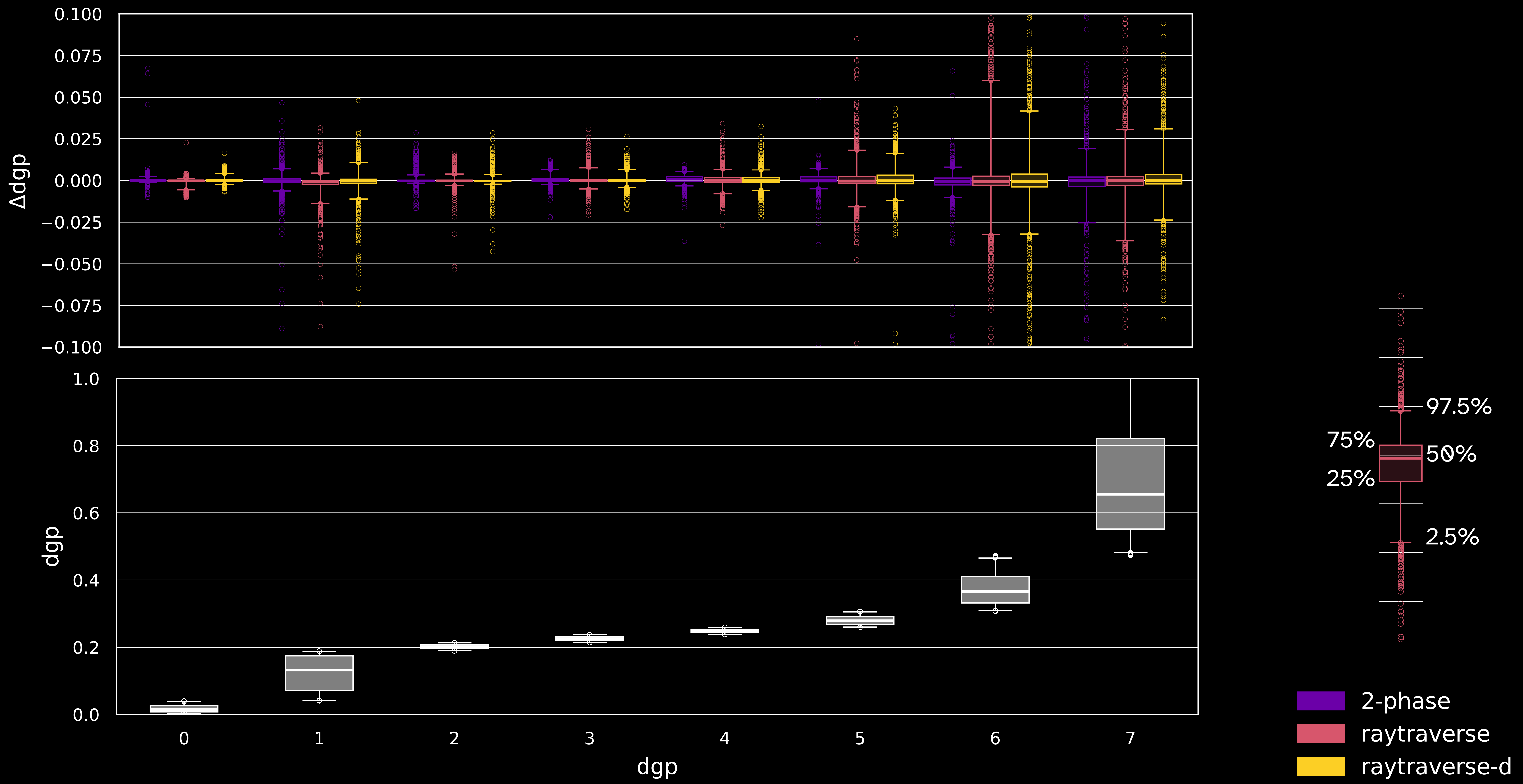
A.3

DGP - Error by View

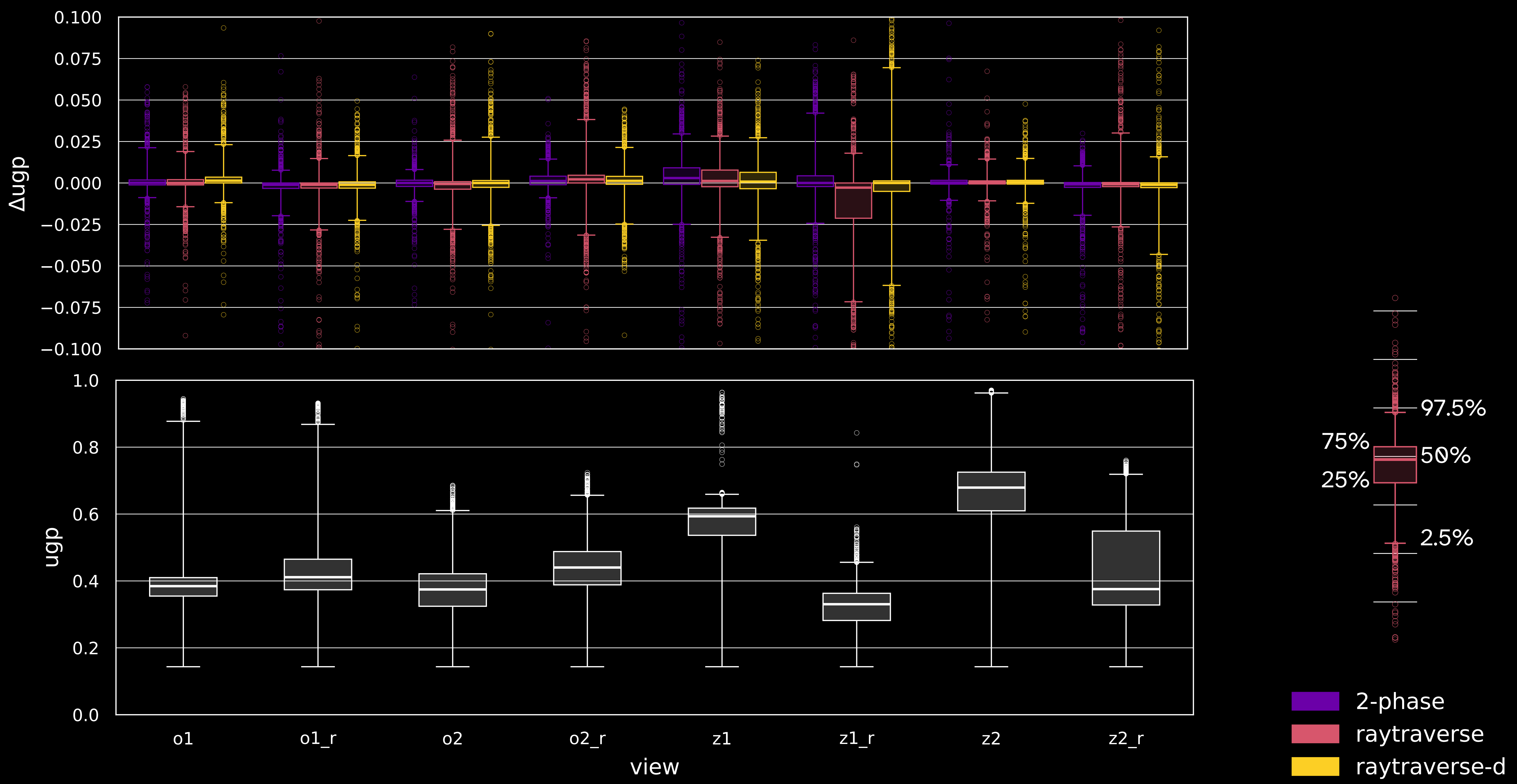


A.4

DGP - Error by DGP



UGP - Error by View



A.6

UGP - Error by UGP