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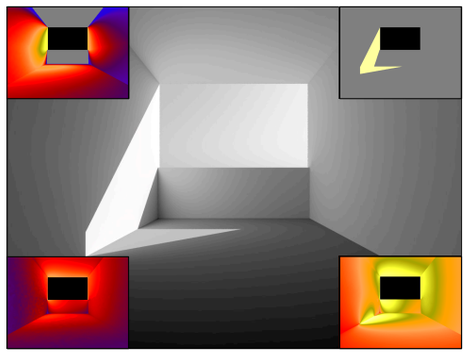
14th Radiance Workshop
19th August 2015

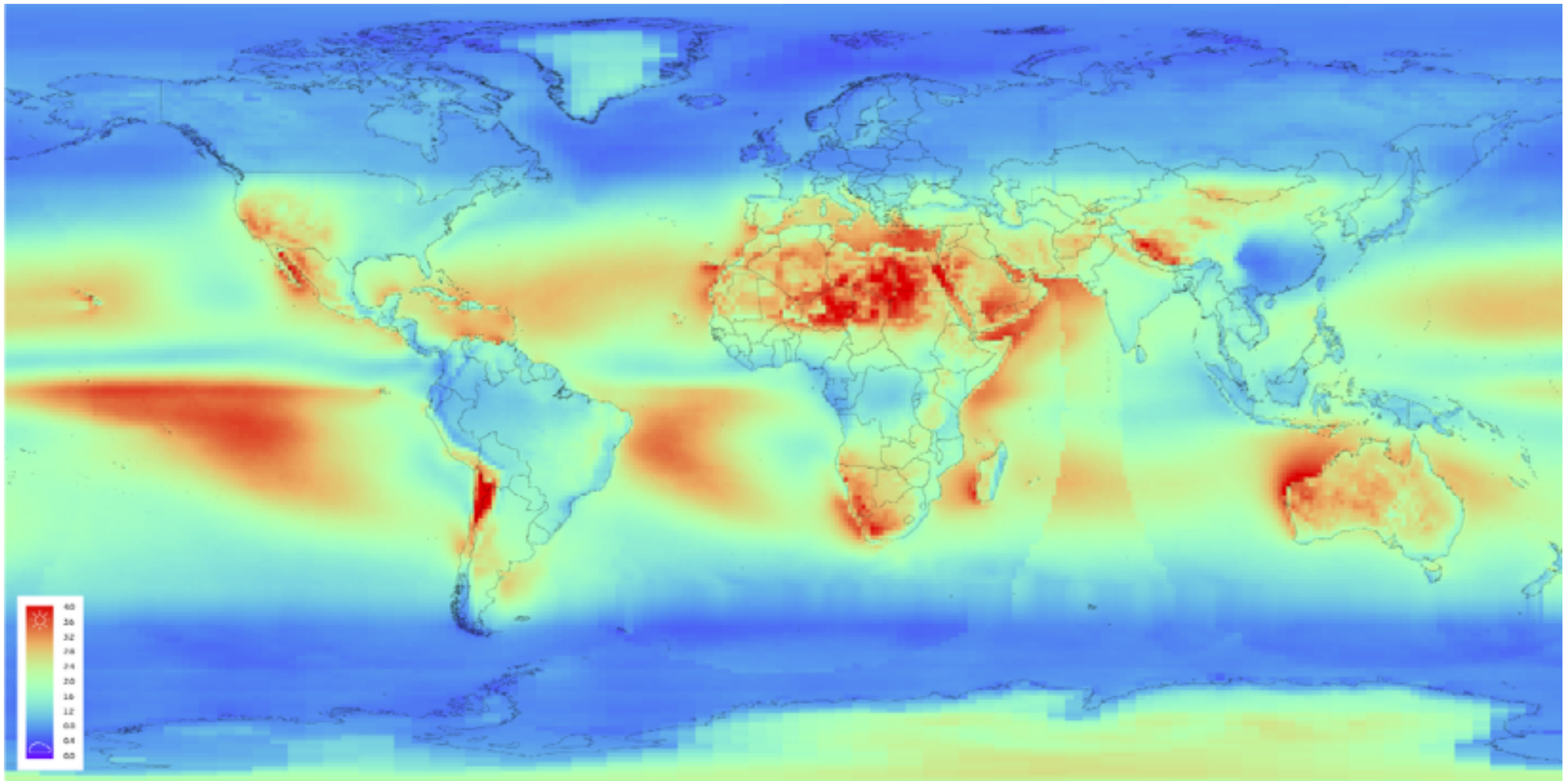
Reflectance: On and Off the Wall

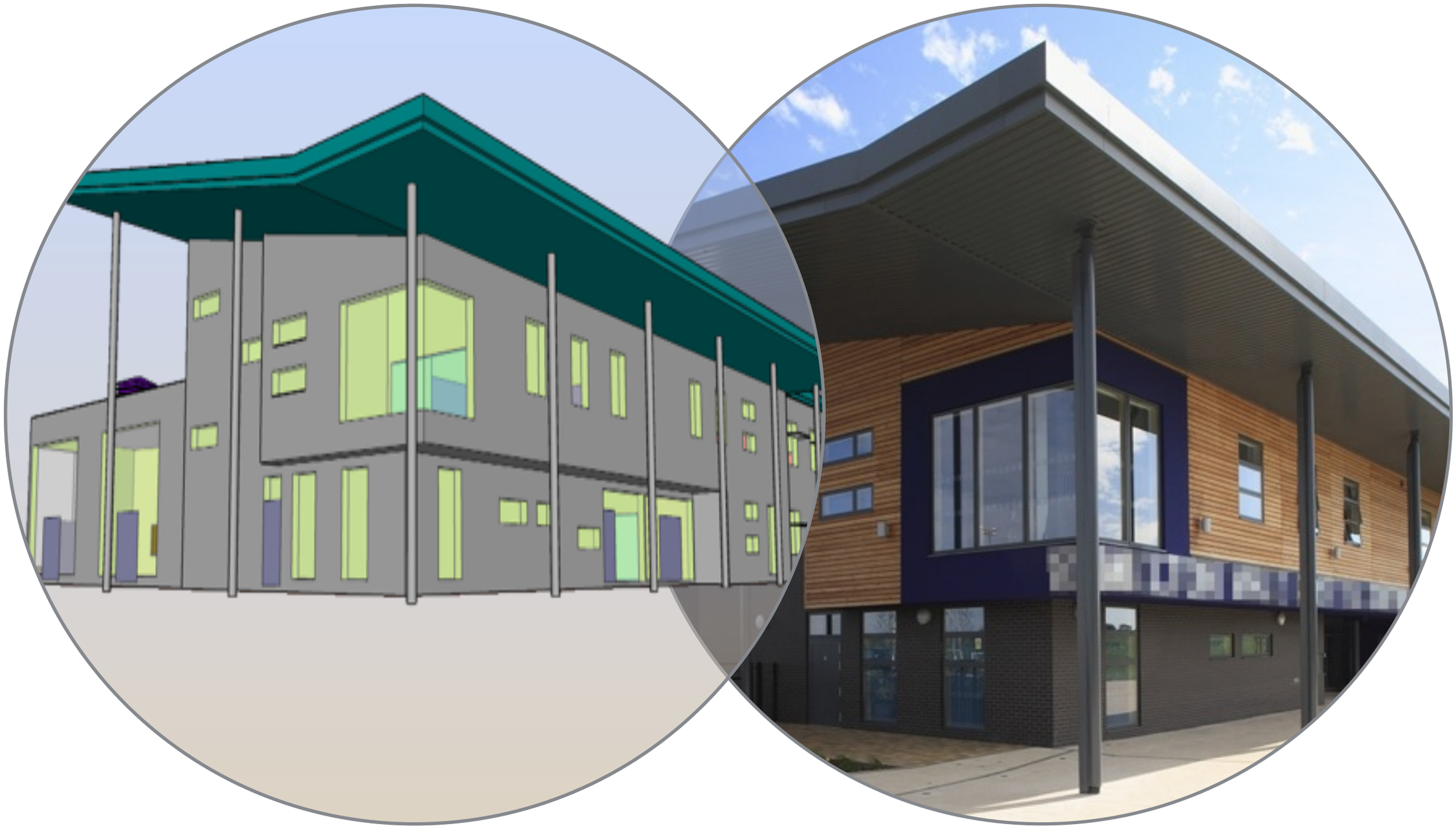
Loughborough University
ARUP
EPSRC
Engineering and Physical Sciences Research Council
PENNSTATE 1855

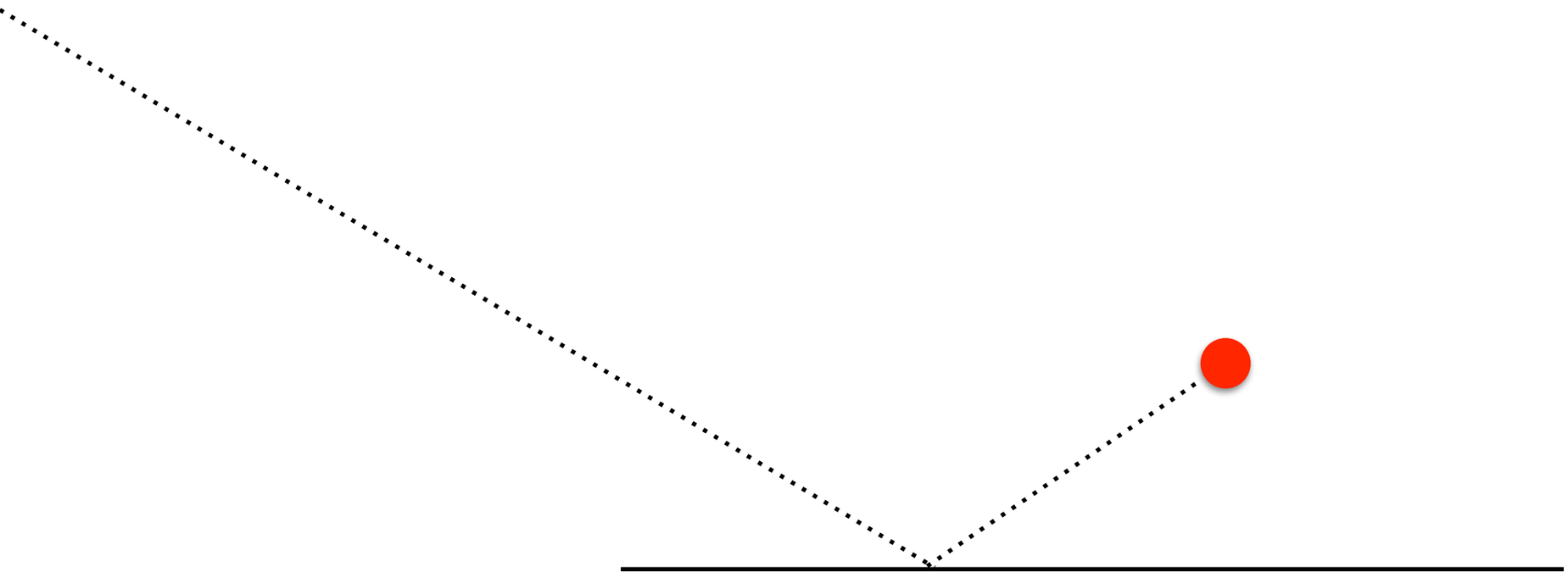
Applicability of Climate-Based Daylight Modelling



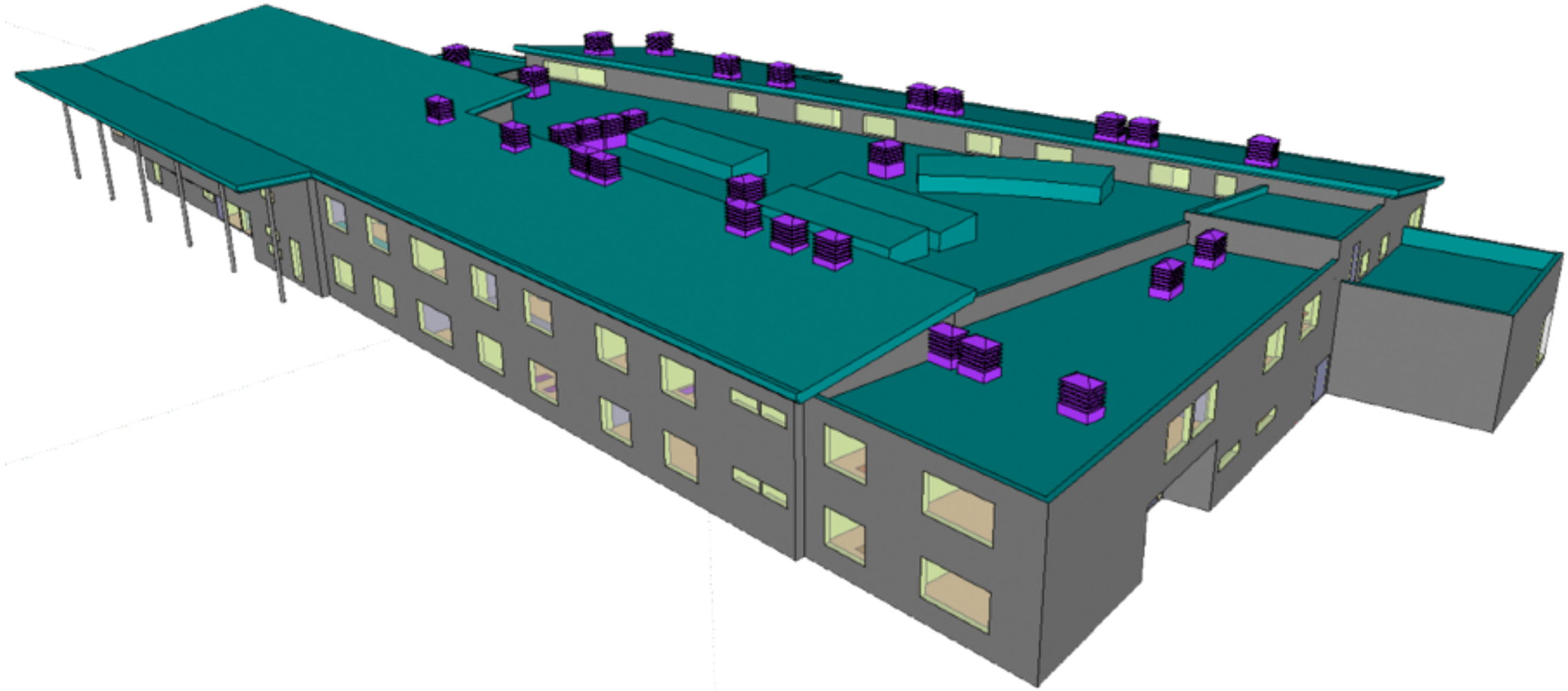
$$\times\ 365 \times 12 \times \left(\frac{60}{T_{step}}\right) = \text{CBDM}$$







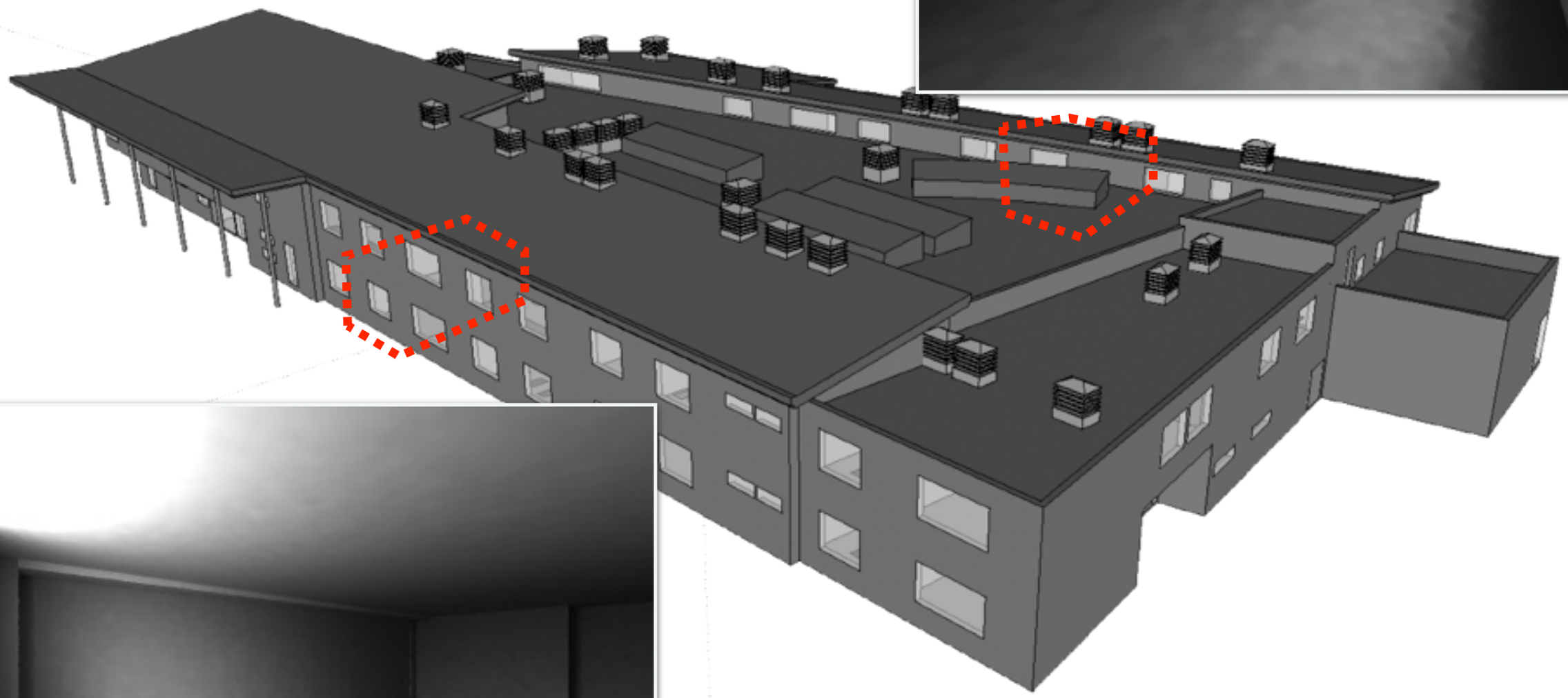
REFLECTANCE



$\rho_{floor} = 0.2$

$\rho_{walls} = 0.5$

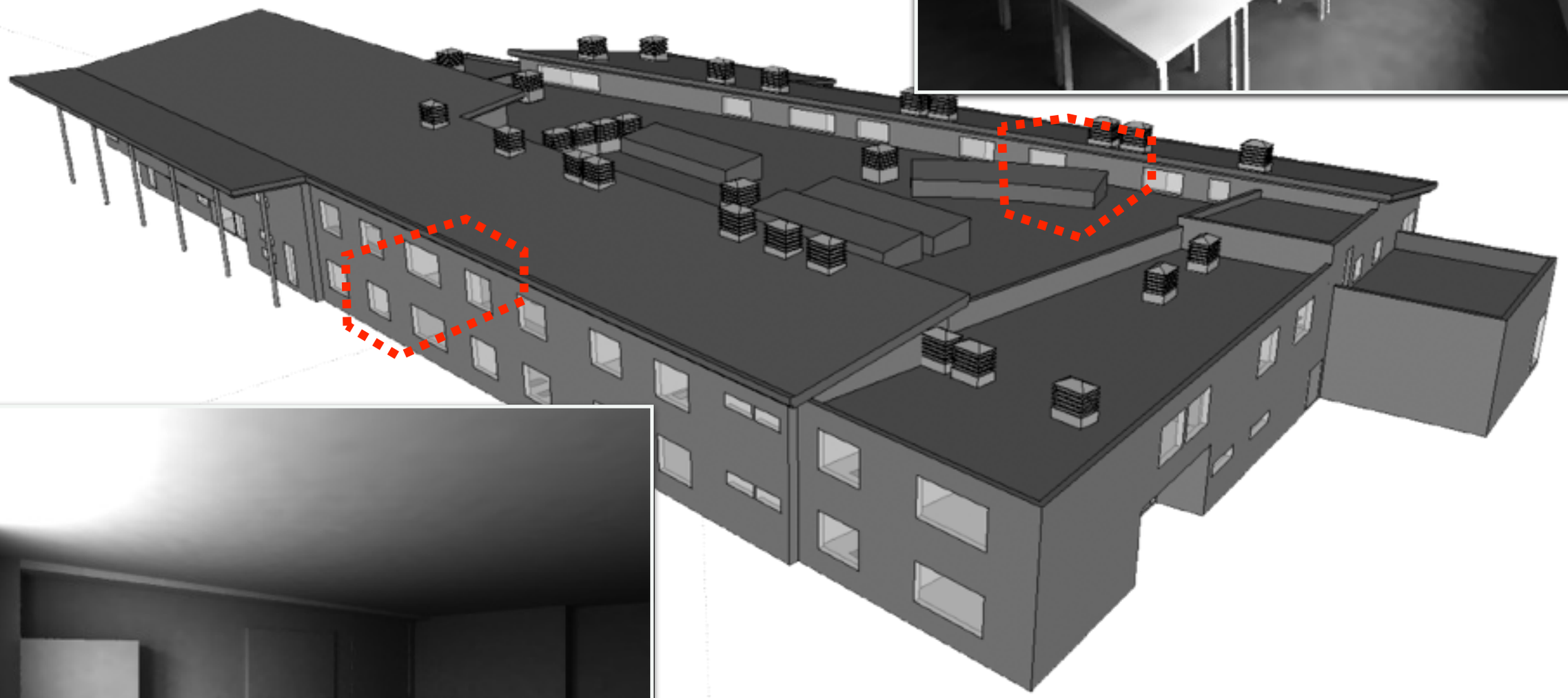
$\rho_{ceiling} = 0.7$



$\rho_{floor} = ?$

$\rho_{walls} = ?$

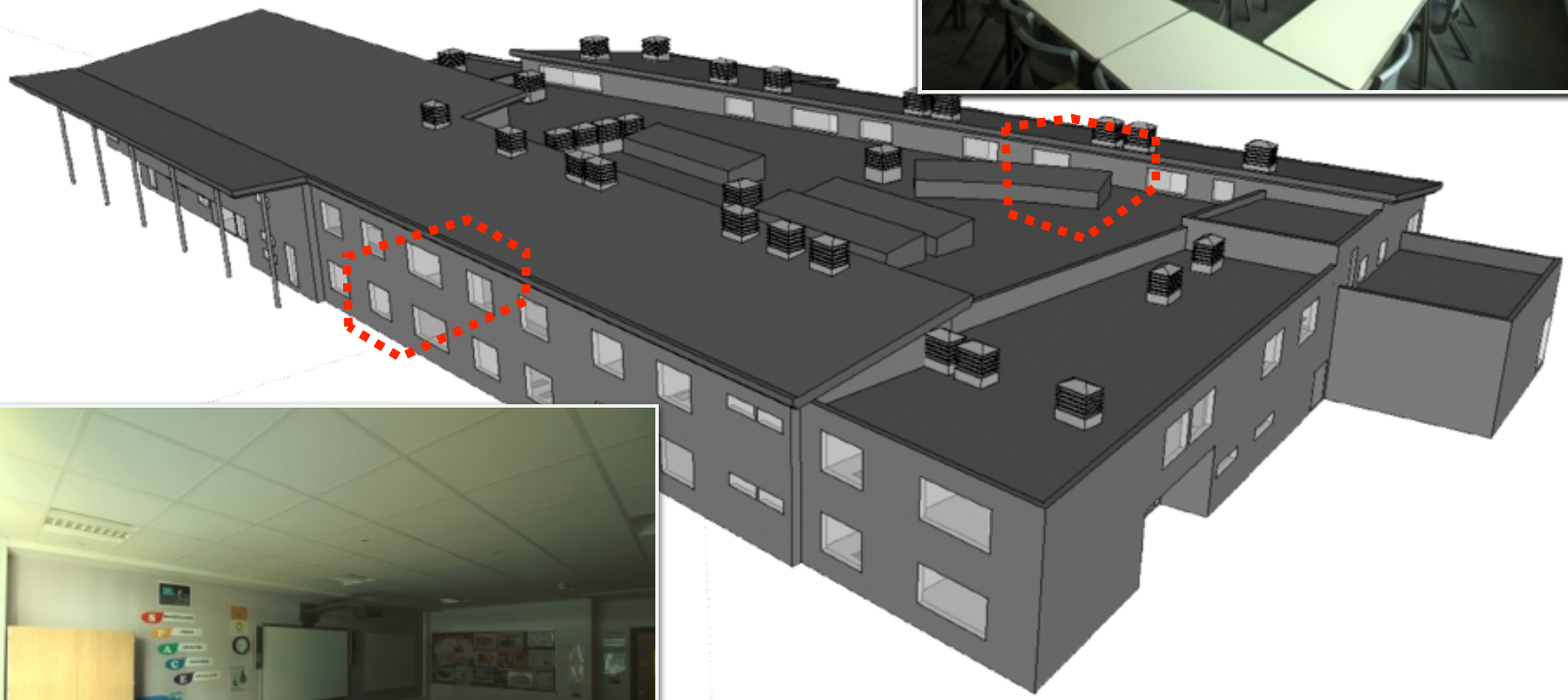
$\rho_{ceiling} = ?$

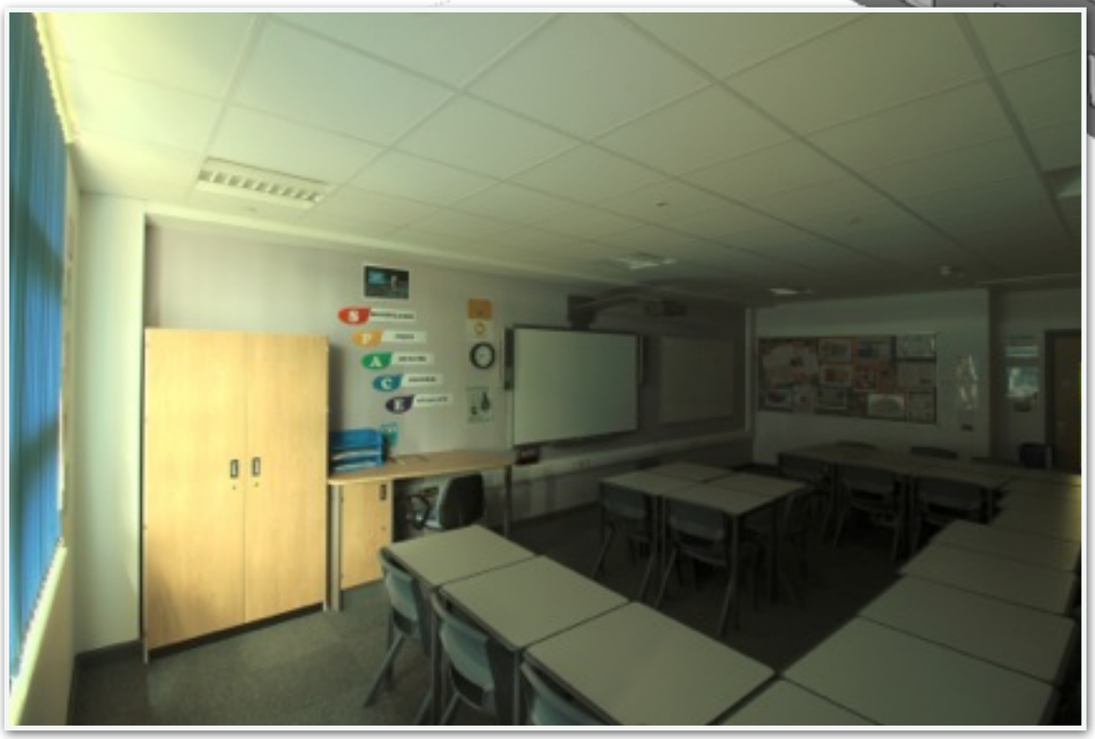


ρ_{floor} = ???

ρ_{walls} = ???

$\rho_{ceiling}$ = ???





Part I: ON THE WALL

2-phase method

3-phase method

4-component method

Daysim

External ground

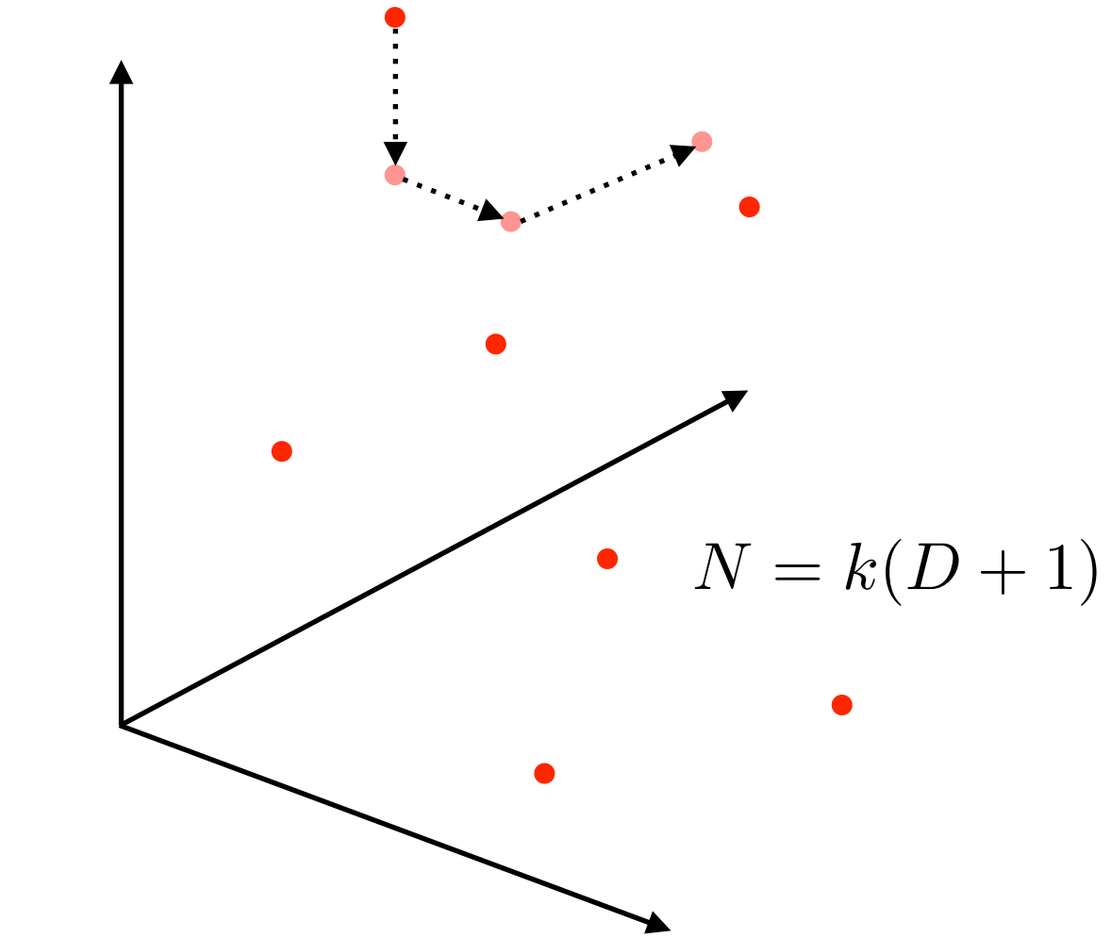
Floor

Walls

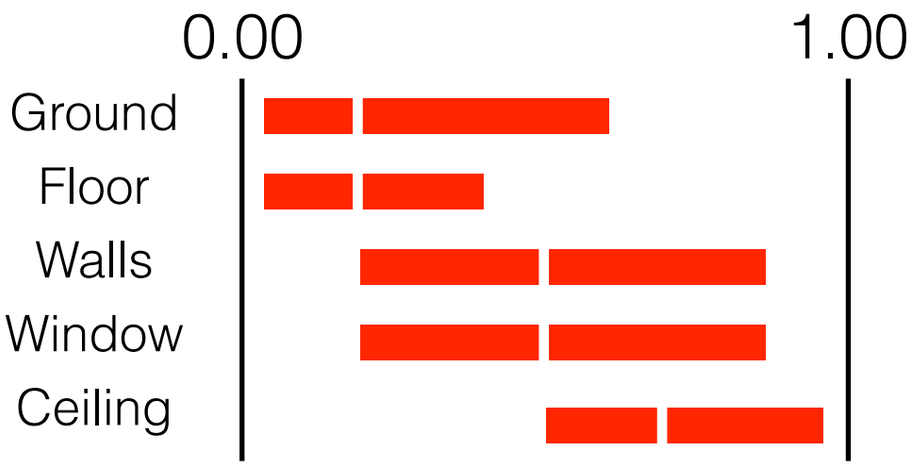
Window frames

Ceiling

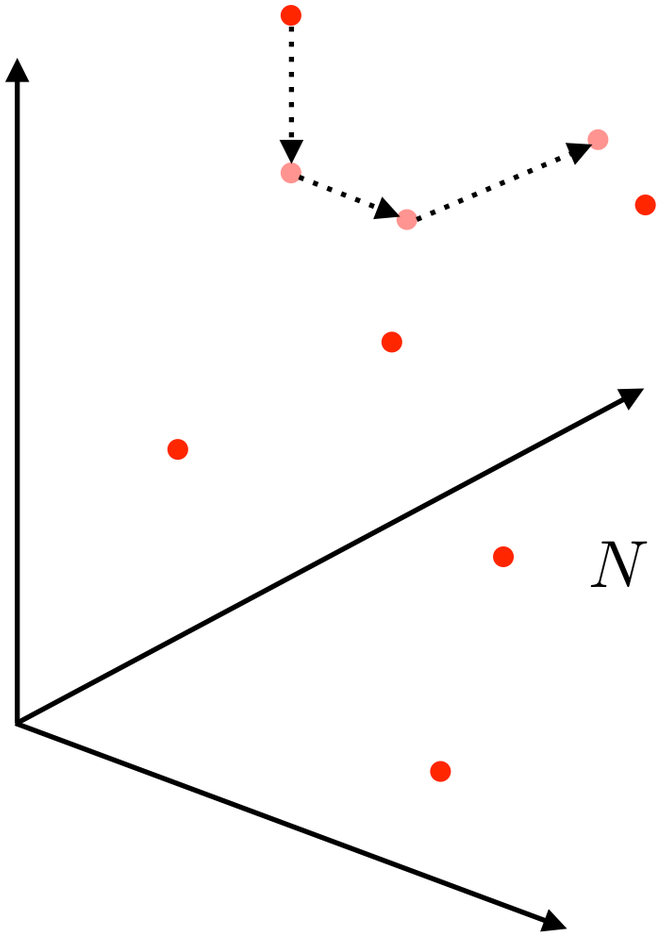
Morris Sensitivity Analysis
(or Elementary Effects method)



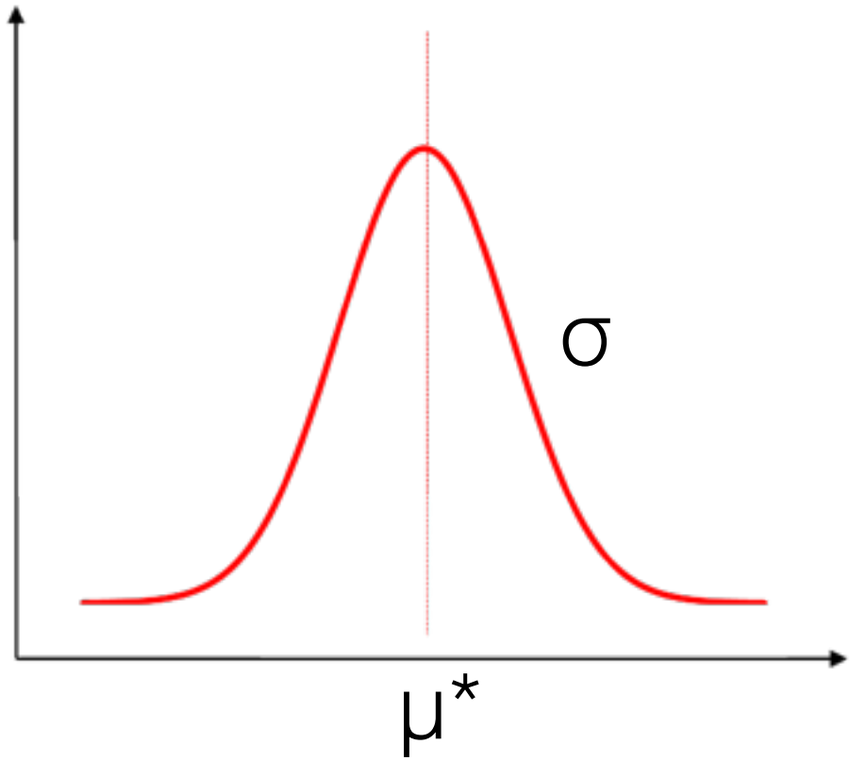
$$N = k(D+1)$$

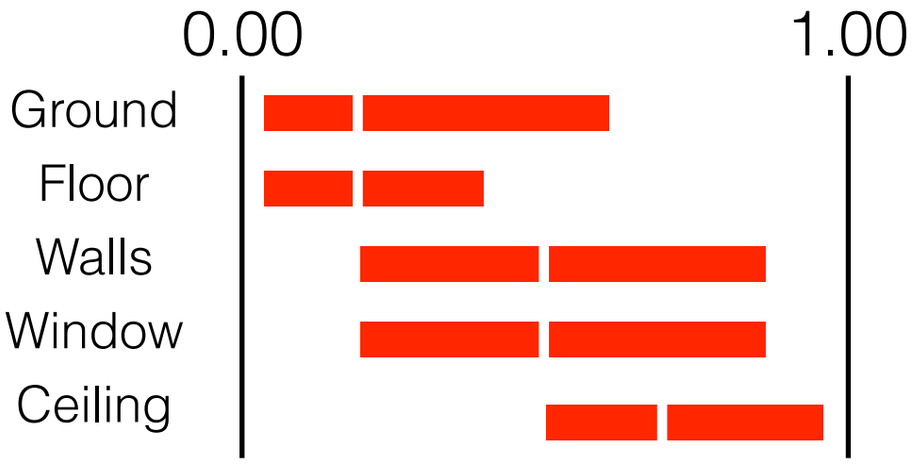


Morris Sensitivity Analysis
(or Elementary Effects method)

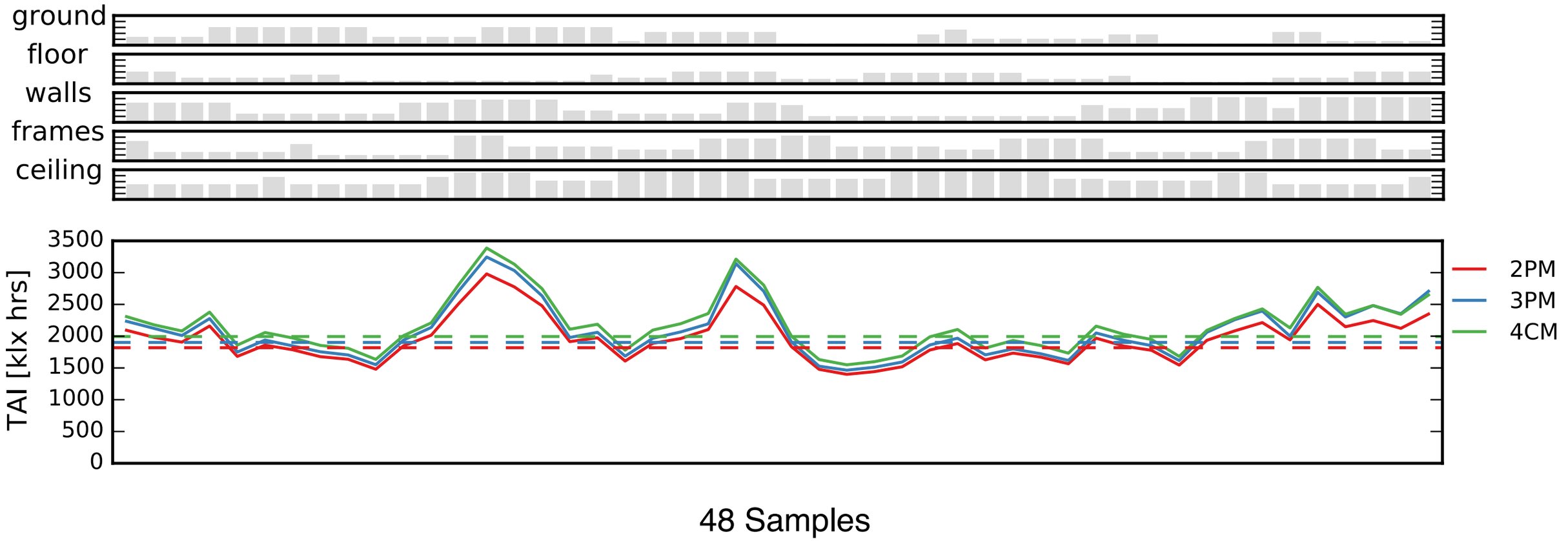


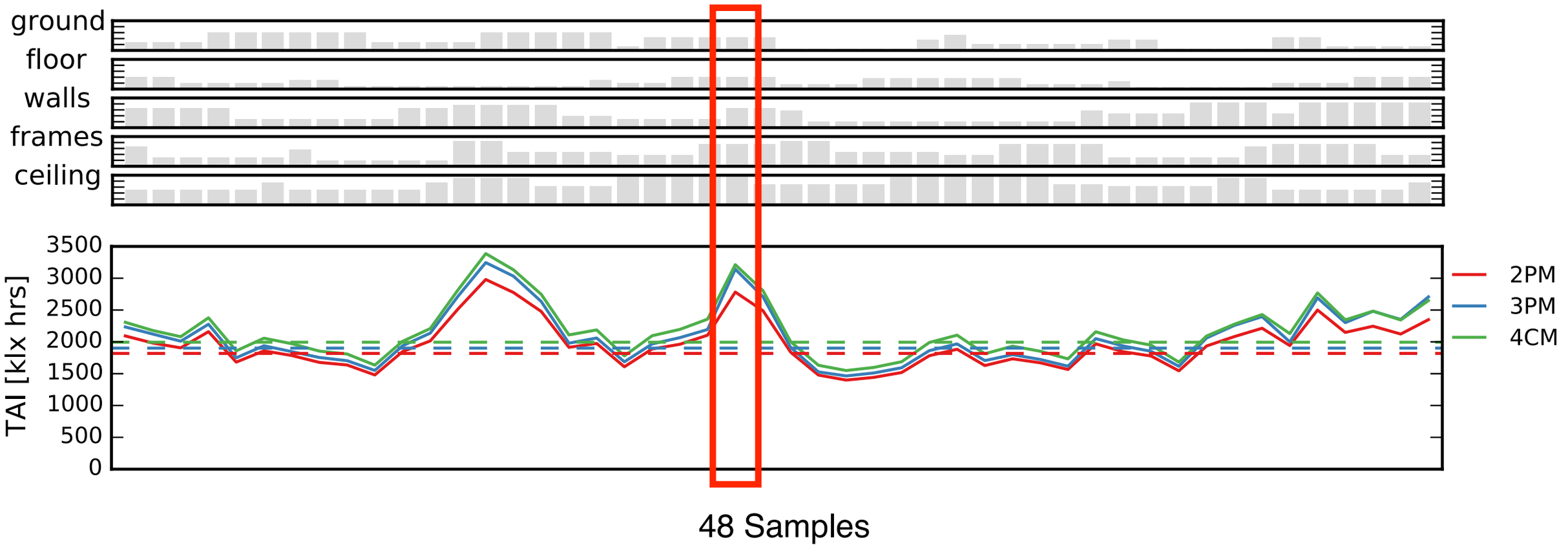
$$N = k(D+1)$$

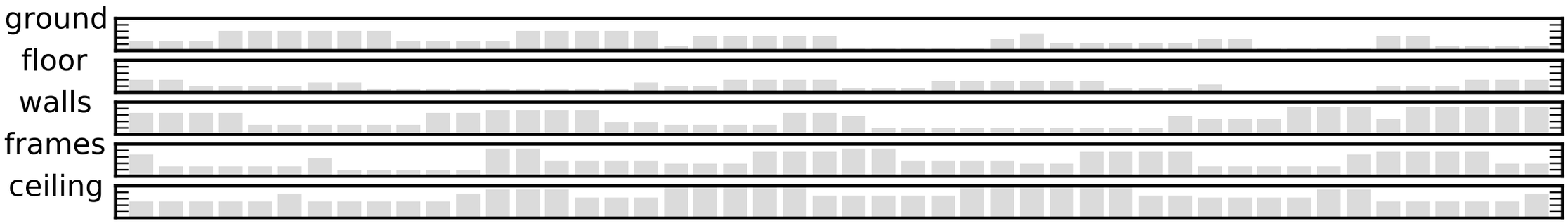


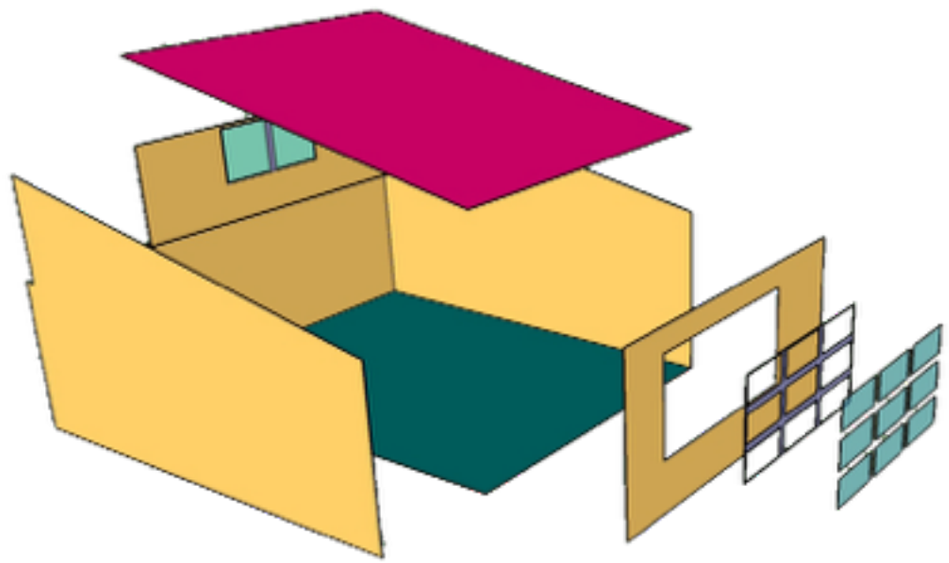


$$d_i(X) = \frac{y(X_1, ..., X_{i-1}, X_i + \Delta, X_{i+1}, ..., X_k) - y(X)}{\Delta}$$

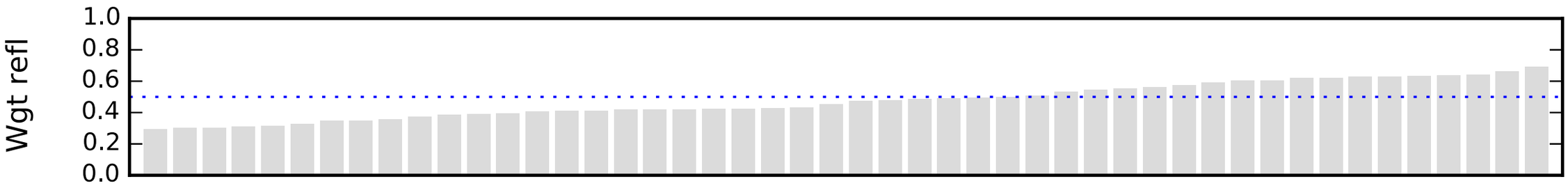

ground
floor
walls
frames
ceiling
TAI [klx hrs]
3500
3000
2500
2000
1500
1000
500
0
2PM
3PM
4CM
48 Samples

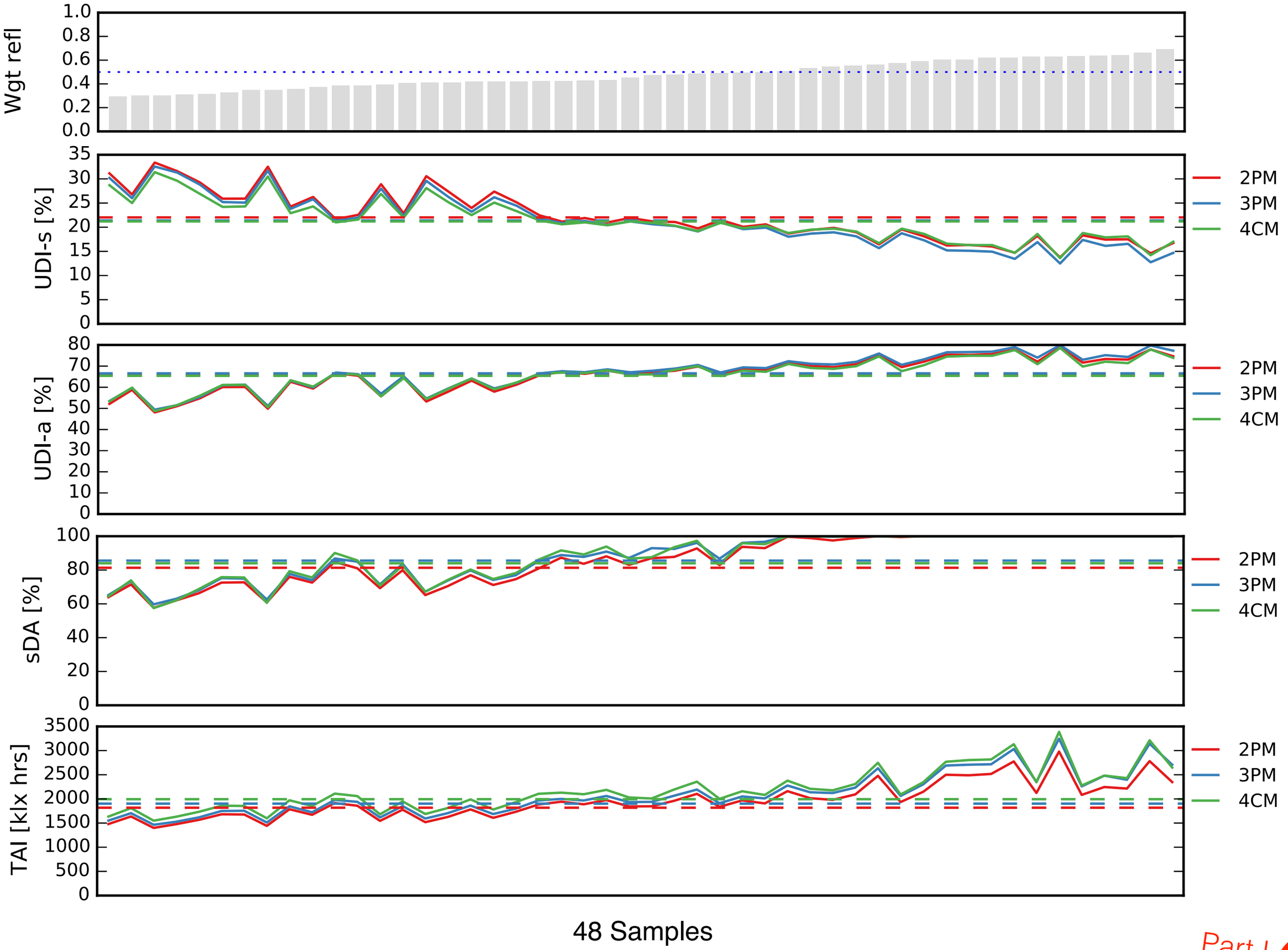

ground
floor
walls
frames
ceiling
3500
3000
2500
2000
1500
1000
500
0
TAI [klx hrs]
2PM
3PM
4CM
48 Samples



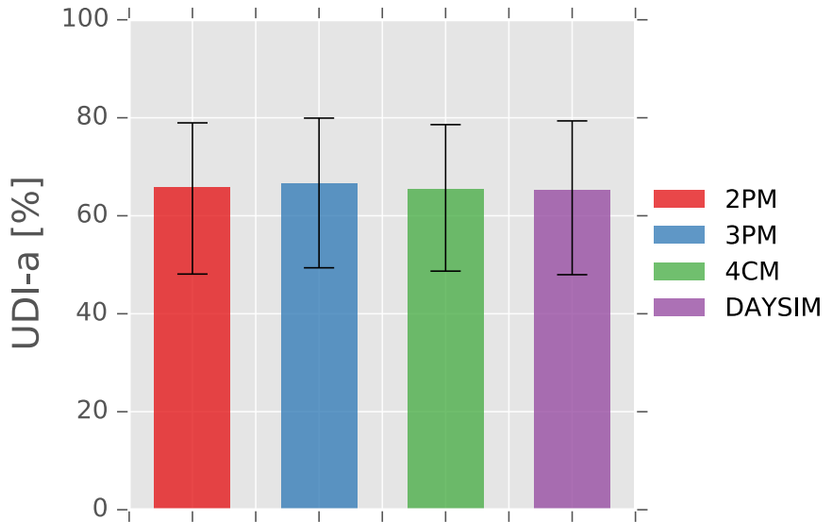


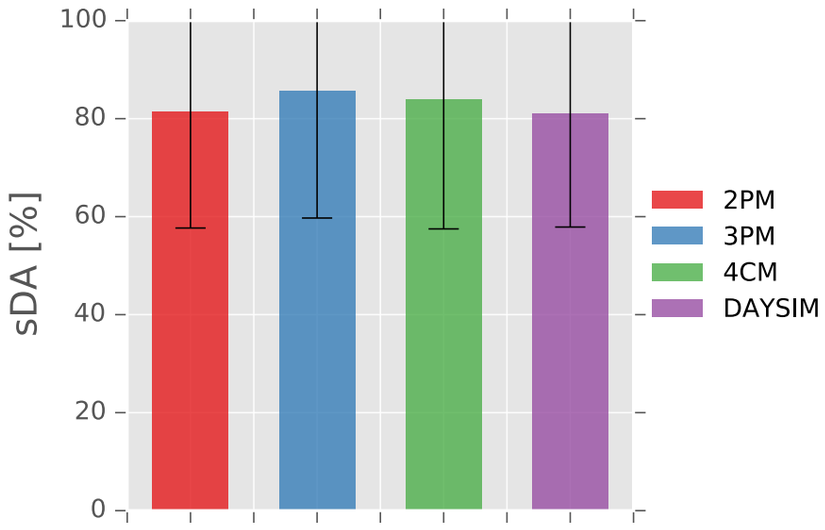
$$\overline{\rho}_w = \frac{a_1\rho_1 + a_2\rho_2 + \ldots + a_n\rho_n}{a_1 + a_2 + \ldots + a_n} = \frac{\sum_{i=1}^{n} a_i\rho_i}{A}$$

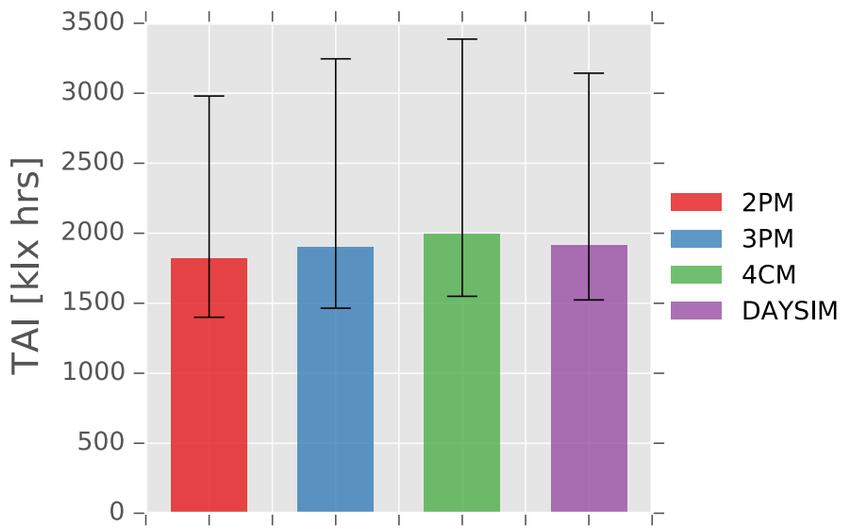



Wgt refl
1.0
0.8
0.6
0.4
0.2
0.0
UDI-s [%]
35
30
25
20
15
10
5
0
2PM
3PM
4CM
UDI-a [%]
80
70
60
50
40
30
20
10
0
2PM
3PM
4CM
sDA [%]
100
80
60
40
20
0
2PM
3PM
4CM
TAI [klx hrs]
3500
3000
2500
2000
1500
1000
500
0
2PM
3PM
4CM
48 Samples

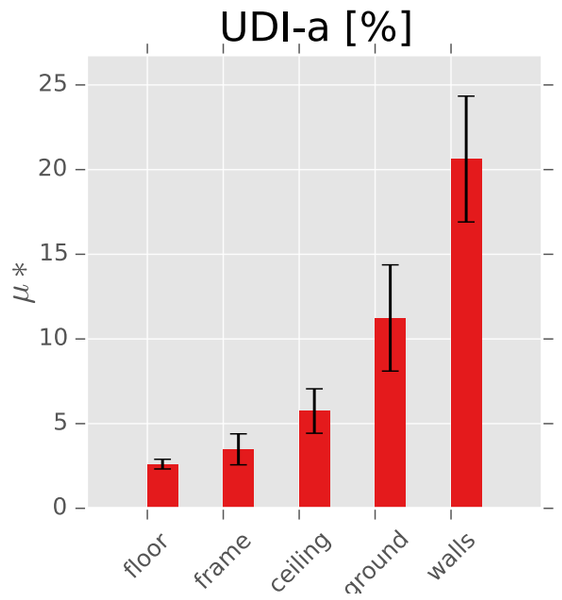
Part I

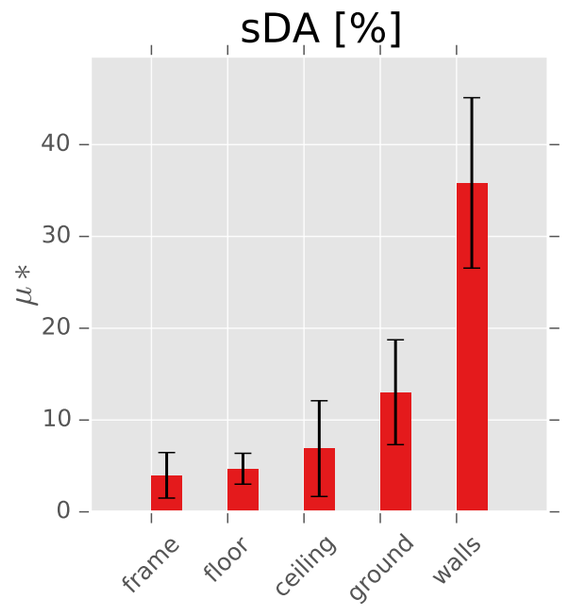


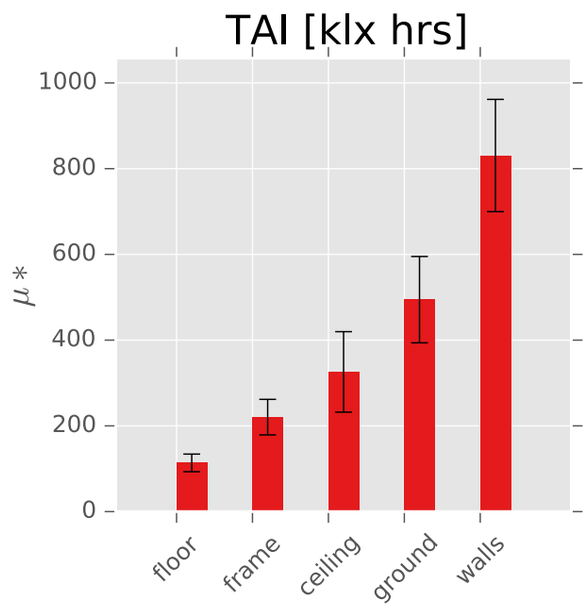




2-phase method







Part I

There is good agreement between methods (using clear glazing)

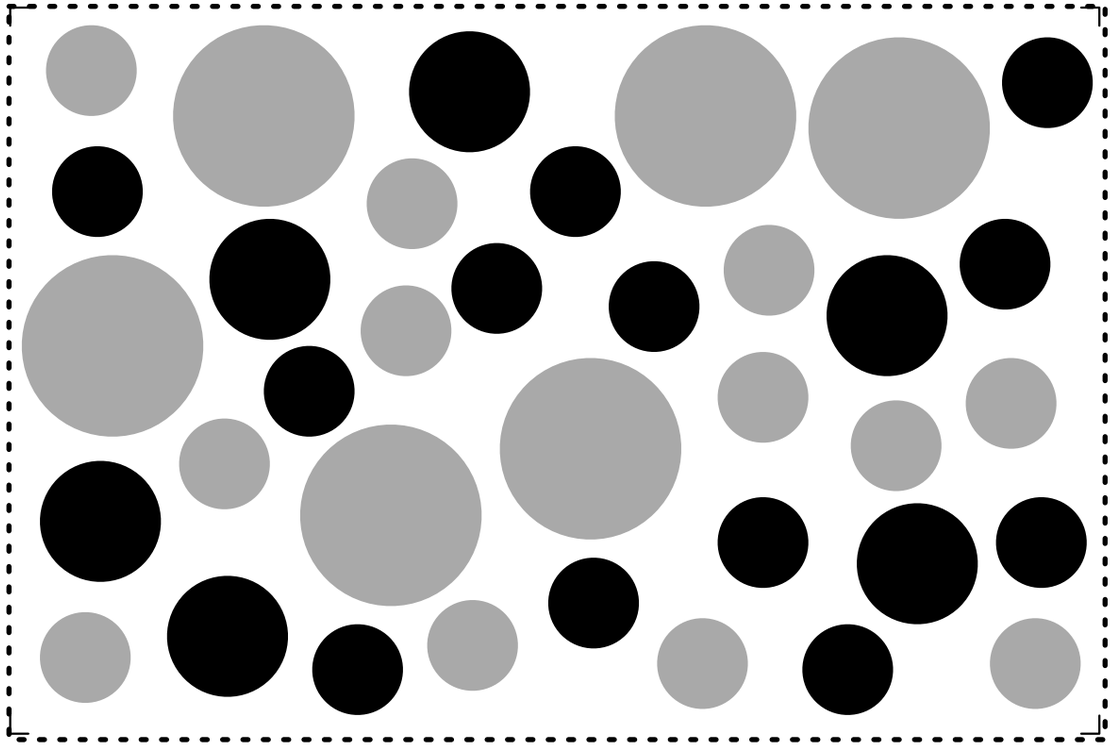
The reflectance applied to the modelled elements affects the annual results, especially exposure values

For typical classroom spaces, the walls reflectance is particularly important to determine the performance

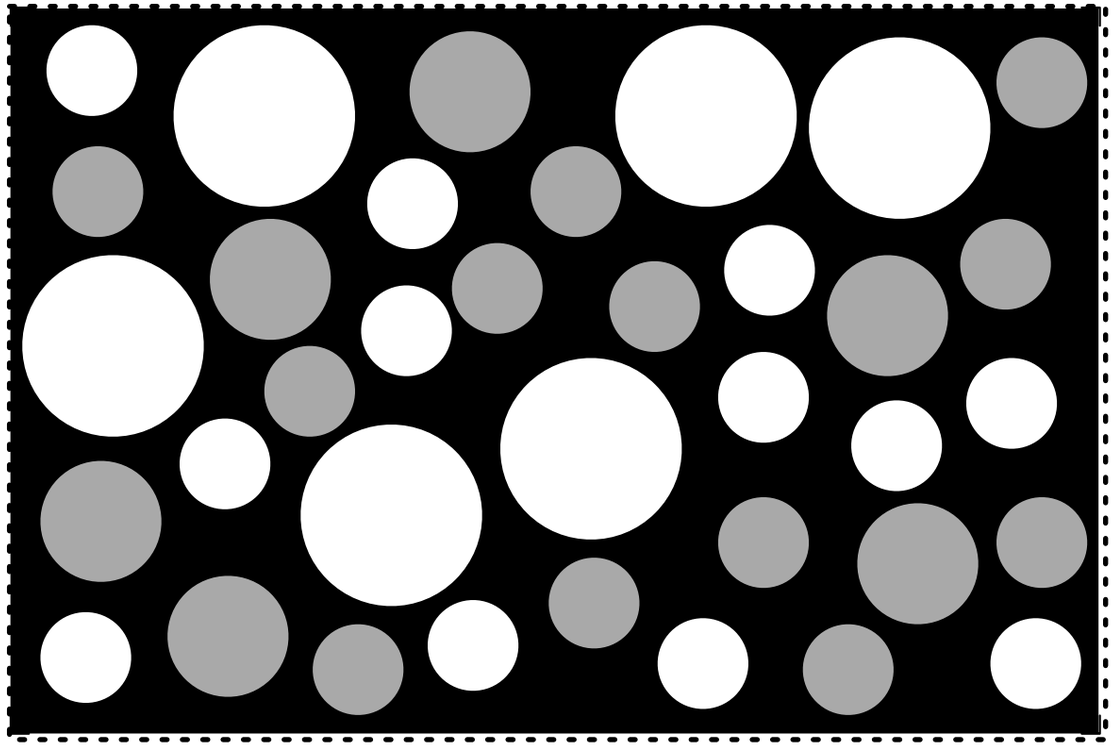
Part II: OFF THE WALL

Apply averages or interpolation to estimate the illumination field across the HDR image

Averages → basic method

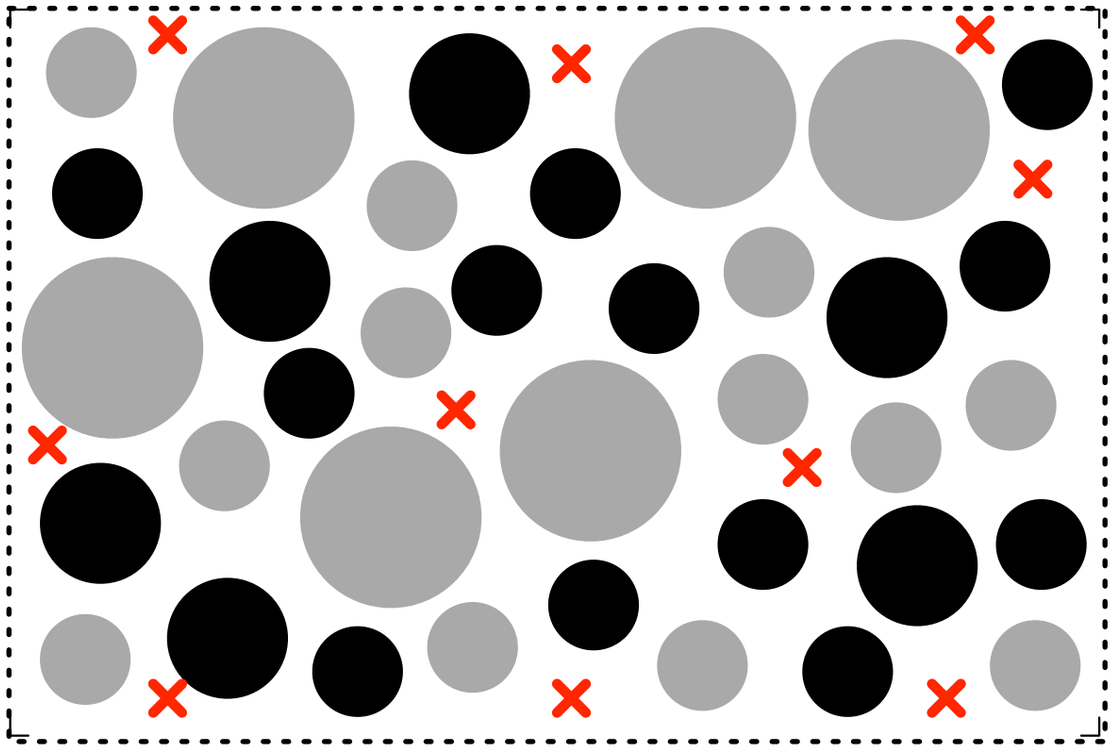


$\overline{\rho}_w = 0.484$

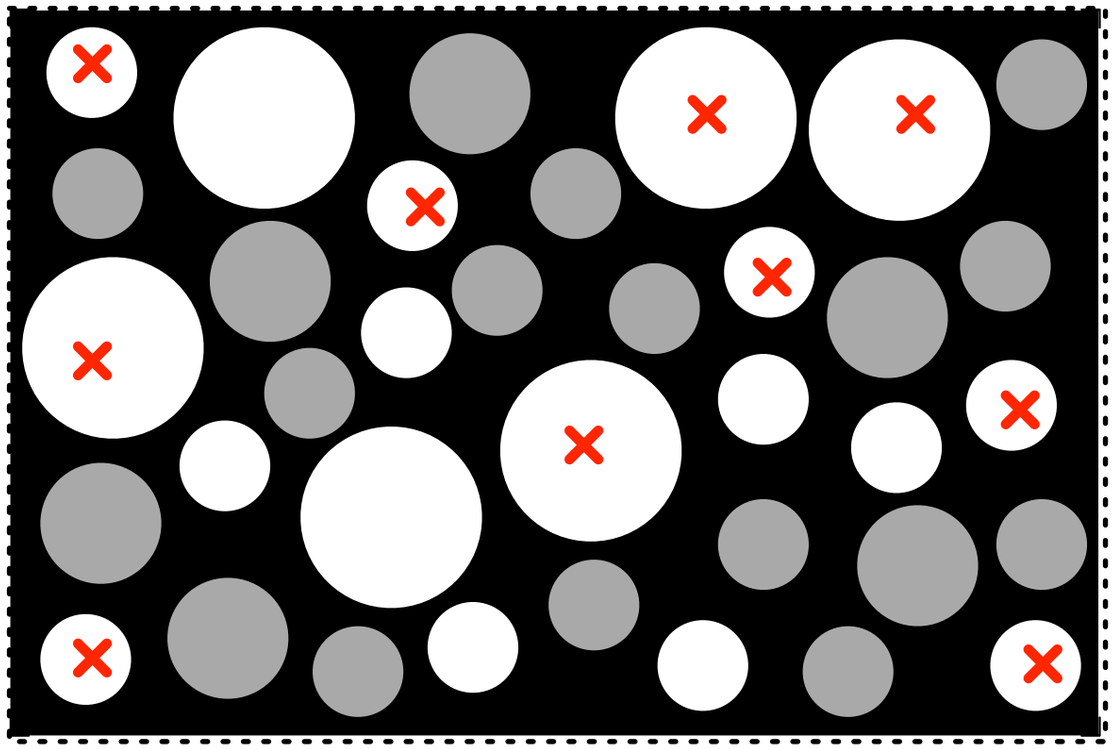


$\overline{\rho}_w = 0.296$

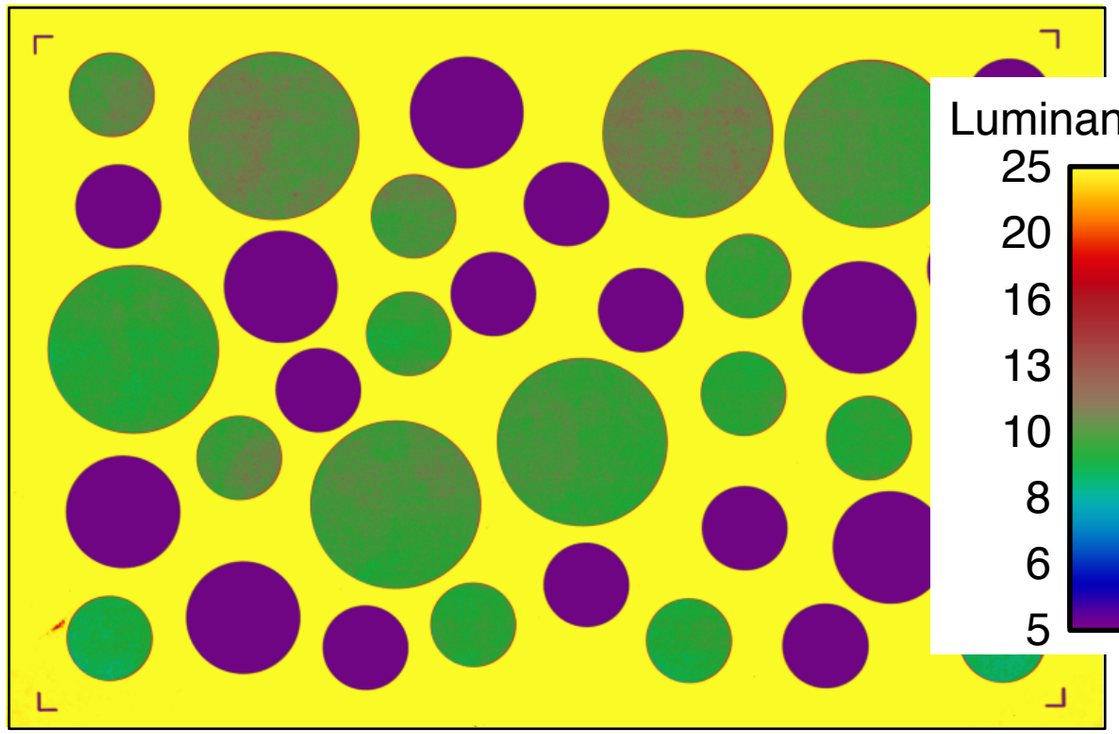
$$\overline{\rho}_w = \frac{a_1\rho_1 + a_2\rho_2 + \ldots + a_n\rho_n}{a_1 + a_2 + \ldots + a_n} = \frac{\sum_{i=1}^{n} a_i\rho_i}{A}$$



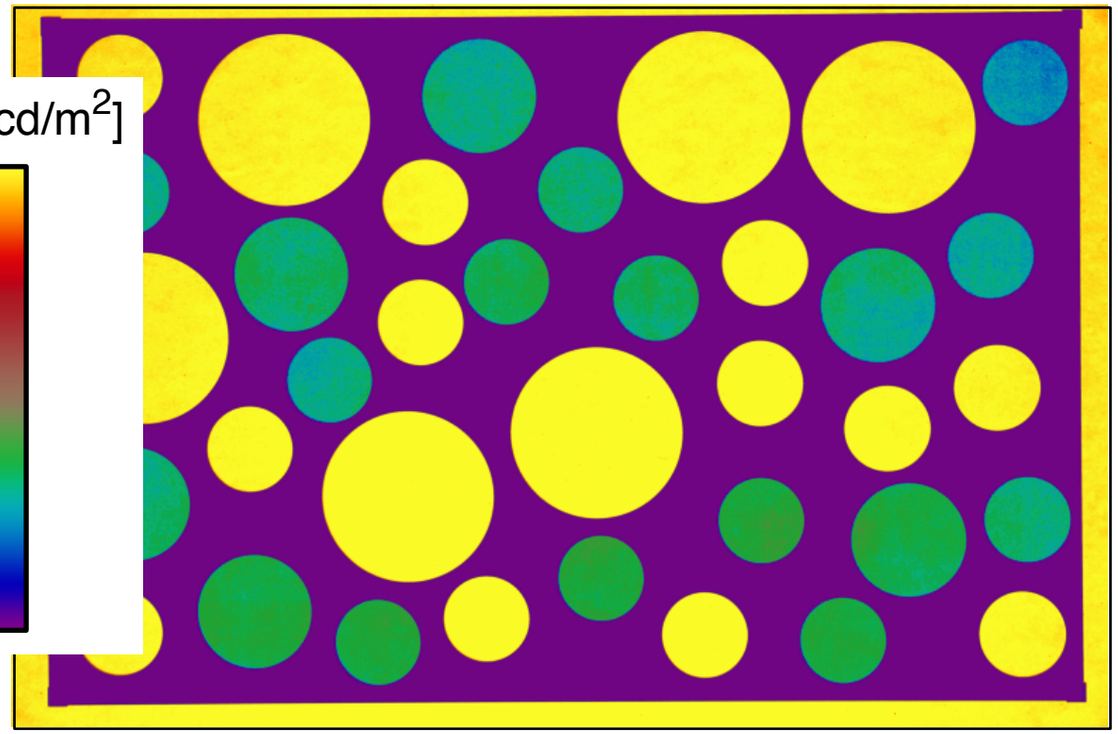
$\overline{\rho}_w = 0.484$



$\overline{\rho}_w = 0.296$



$\overline{\rho}_{hdr} = 0.497$

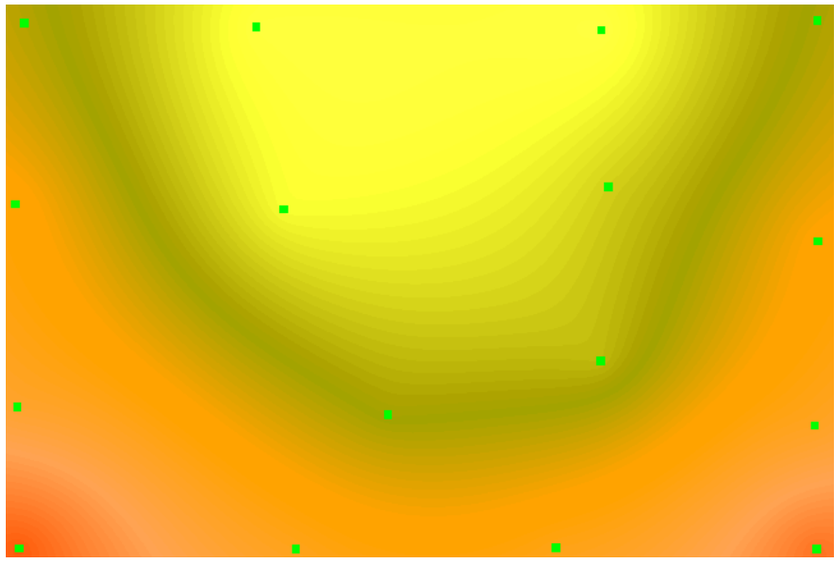


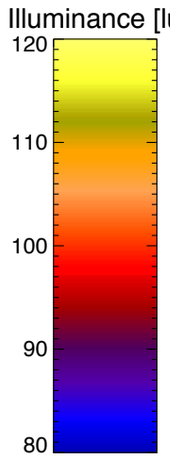
$\overline{\rho}_{hdr} = 0.312$

Part II

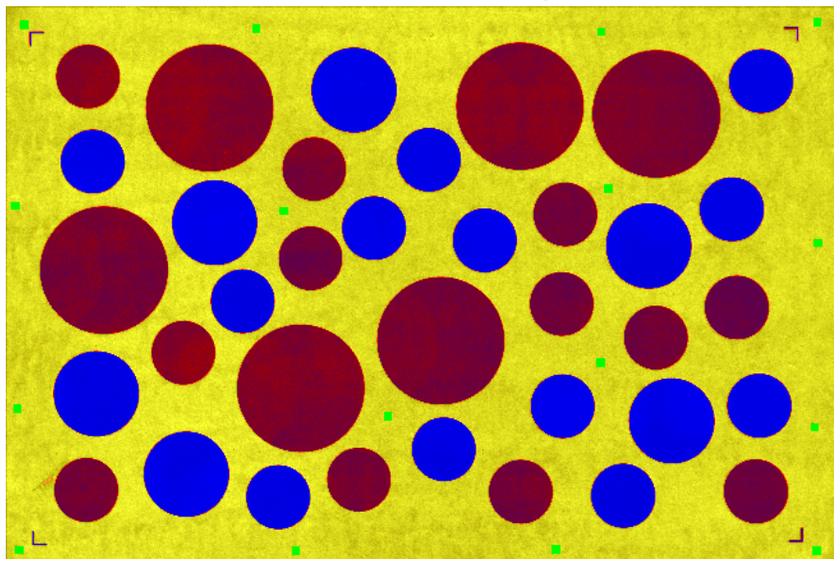
Gridding → refined method

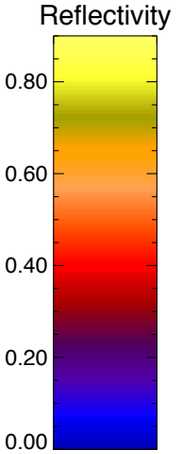
Interpolated illuminance field





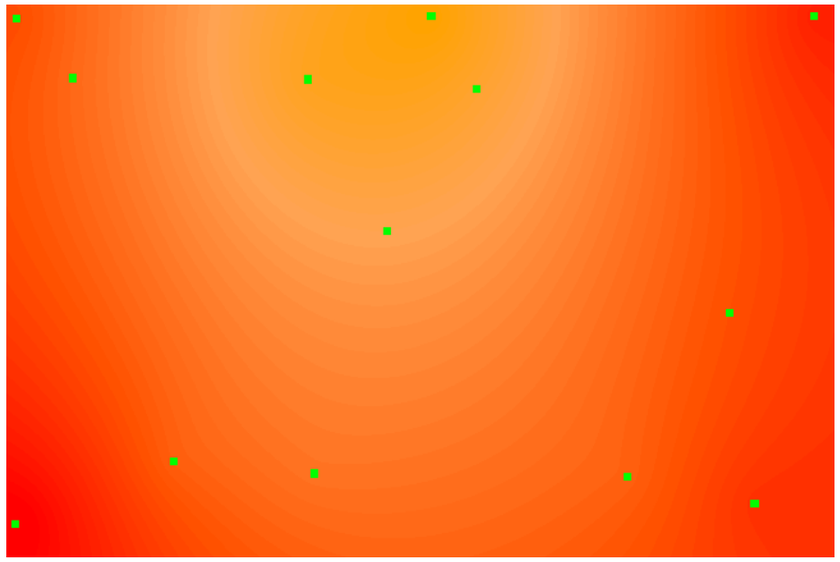
Reflectance map

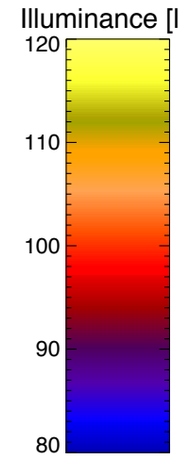




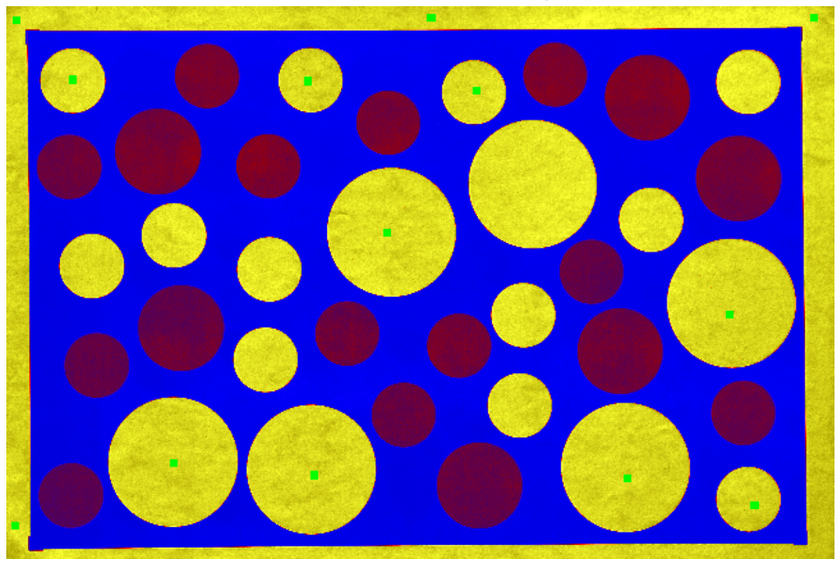
$$\overline{\rho}_{map} = 0.488$$

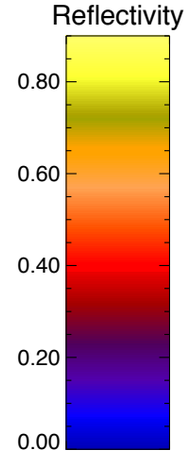
Interpolated illuminance field





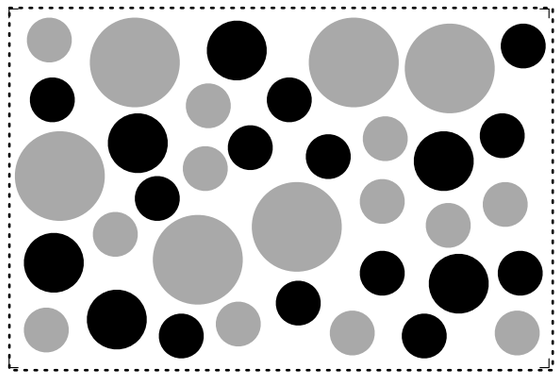
Reflectance map

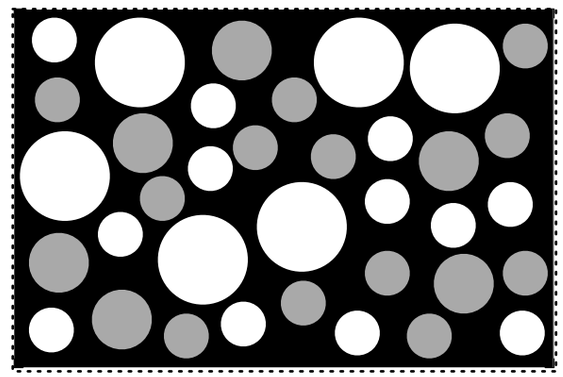




$$\overline{\rho}_{map} = 0.314$$

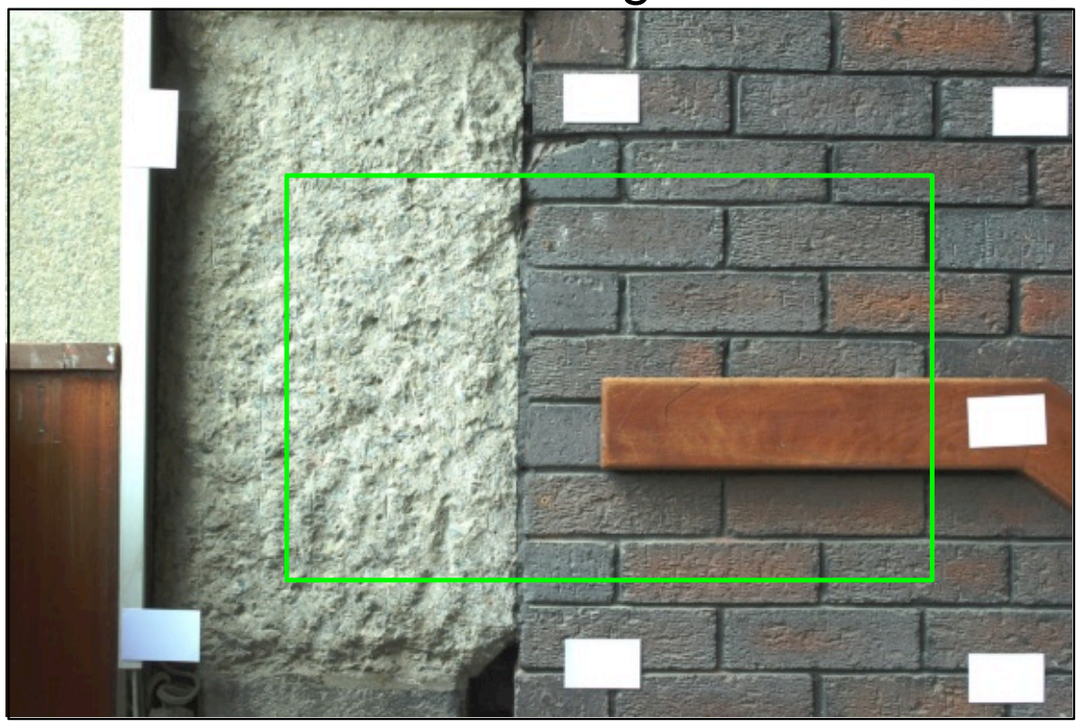
Part II



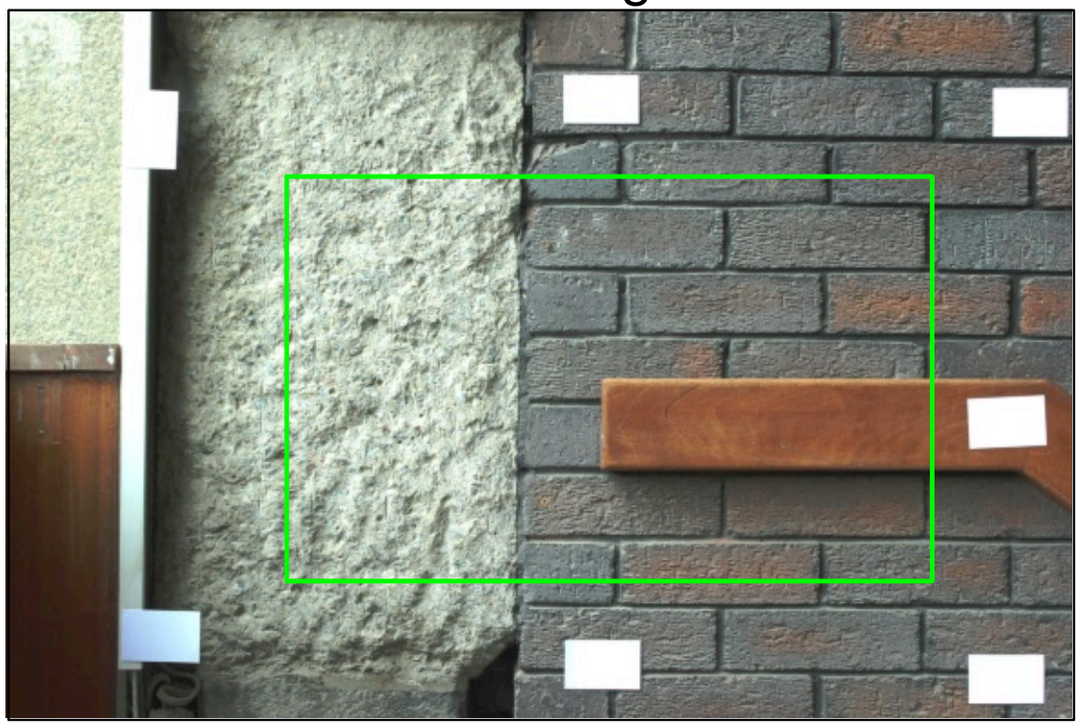


Quantity	White background	Black background
Calculated AWMR	0.484	0.296
Mean of 10 luminance values (white)	27.13 cd/m^2	24.95 cd/m^2
Mean illuminance across image	111 lx	102 lx
Mean luminance of HDR pixels	17.5 cd/m^2	10.1 cd/m^2
HDR derived AWMR - simple	0.497	0.312
Percentage divergence in AWMR	2.7%	5.4%
HDR derived AWMR - grid	0.488	0.314
Percentage divergence in AWMR	0.8%	6.1%

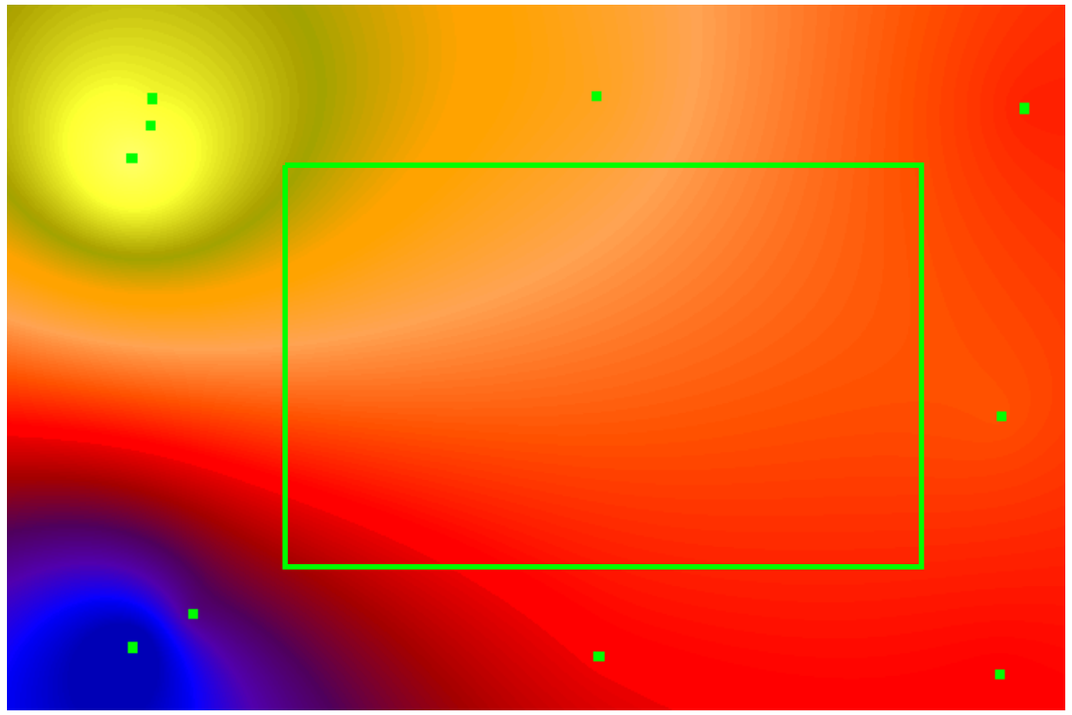
HDR image



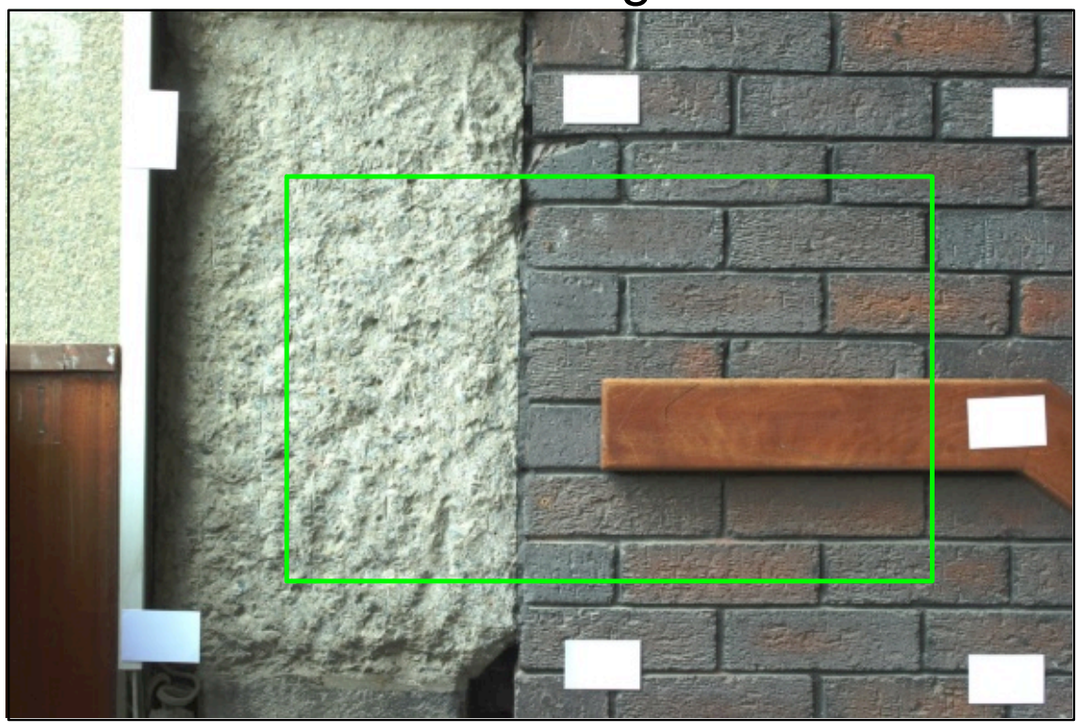
HDR image



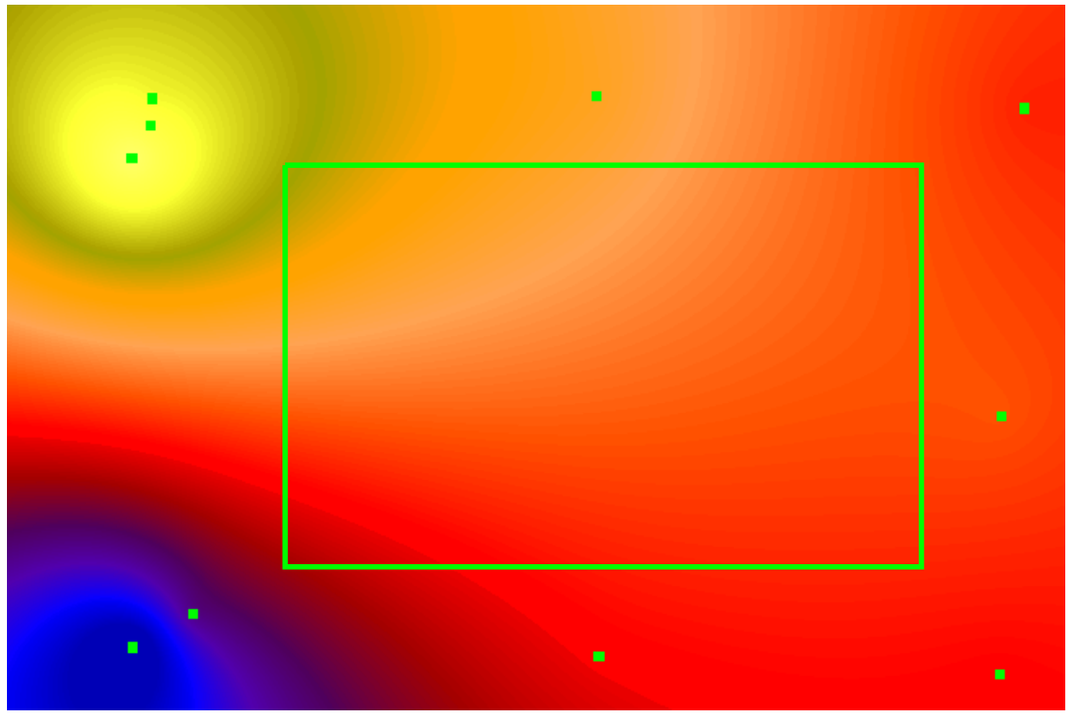
Interpolated illuminance field



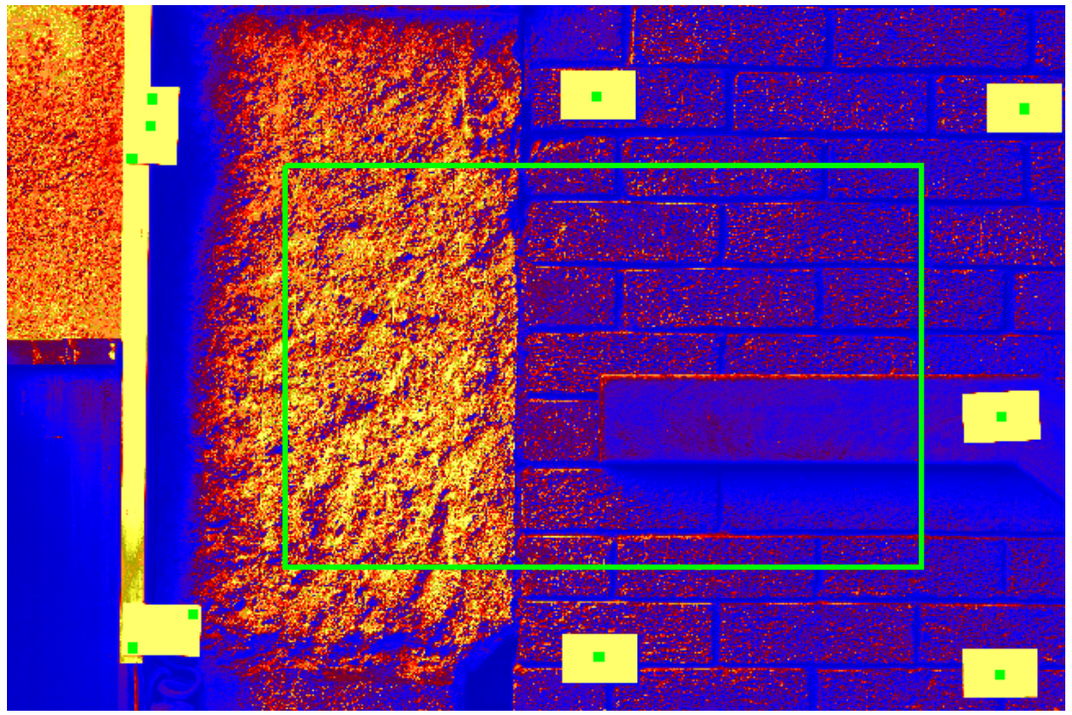
HDR image



Interpolated illuminance field



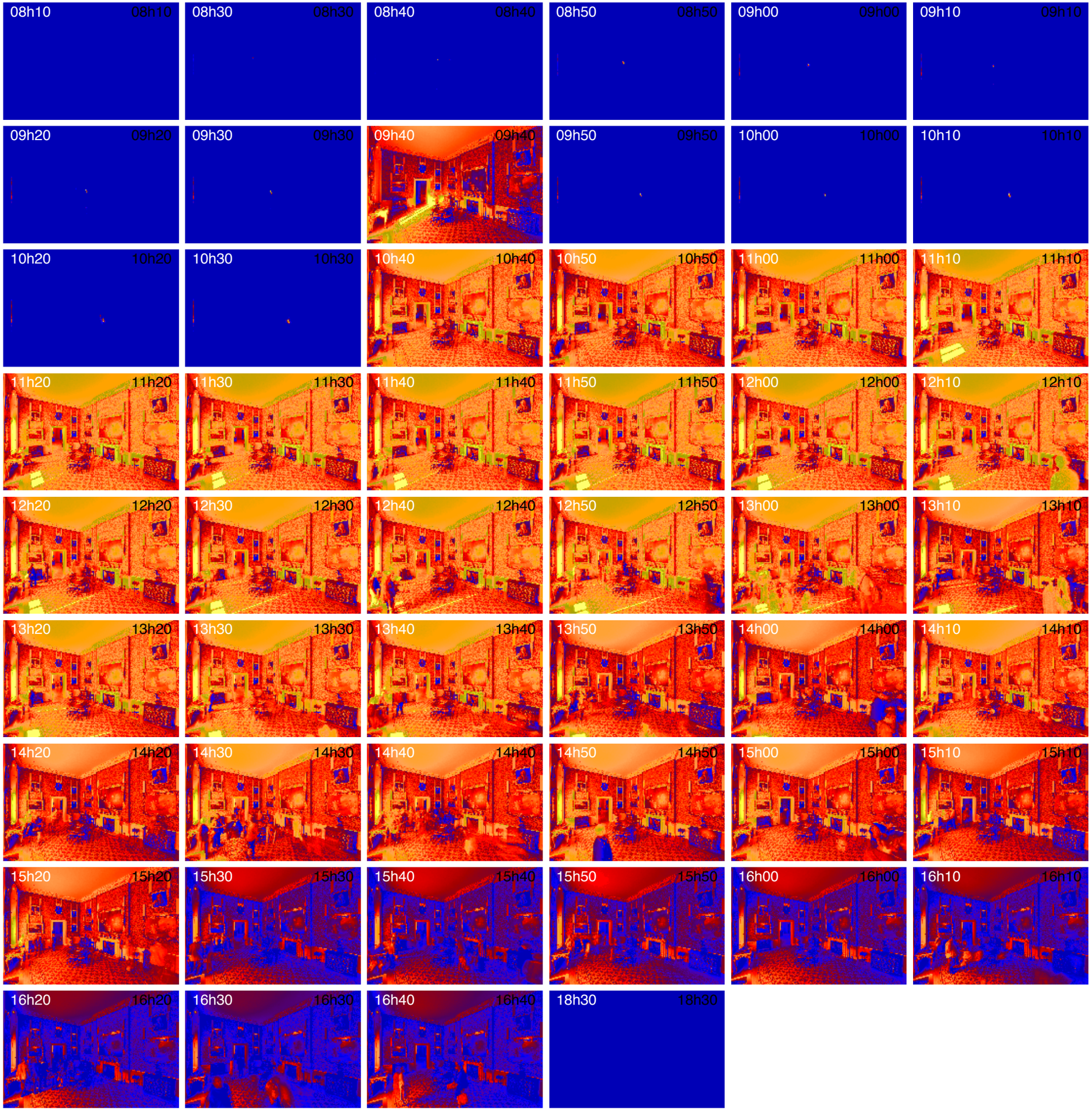
Reflectance map



$$\overline{\rho}_{map} = 0.159$$

Part II

Long term exposure

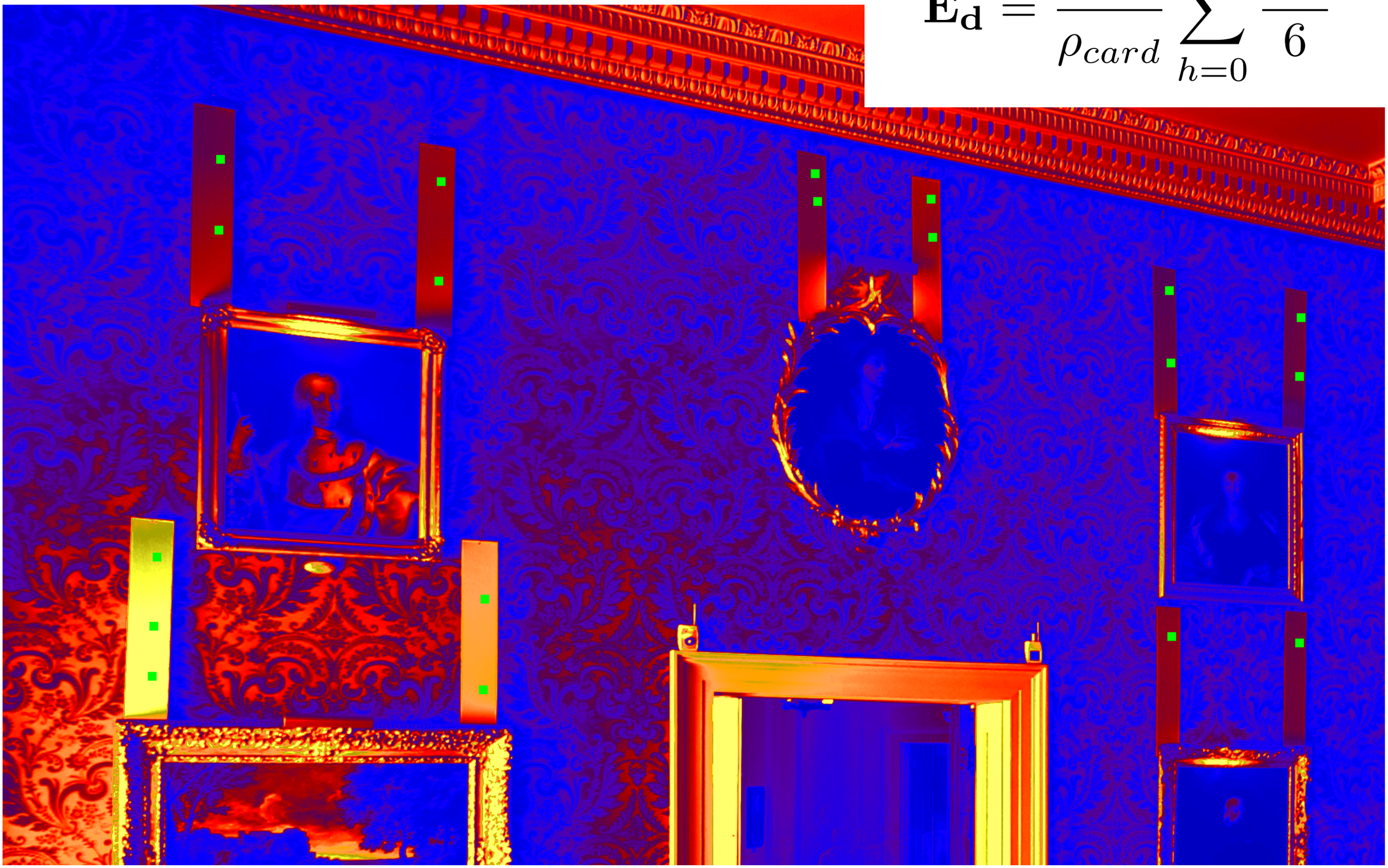


10/5/14 9:00	0
10/5/14 9:15	0
10/5/14 9:30	0
10/5/14 9:45	0
10/5/14 10:00	0
10/5/14 10:15	0
10/5/14 10:30	0
10/5/14 10:45	0
10/5/14 11:00	427
10/5/14 11:15	494.8
10/5/14 11:30	494.8
10/5/14 11:45	494.8
10/5/14 12:00	491.8
10/5/14 12:15	462.4
10/5/14 12:30	450.6
10/5/14 12:45	450.6
10/5/14 13:00	465.3
10/5/14 13:15	459.4
10/5/14 13:30	494.8
10/5/14 13:45	494.8
10/5/14 14:00	223.8
10/5/14 14:15	397.6
10/5/14 14:30	427
10/5/14 14:45	427
10/5/14 15:00	353.4
10/5/14 15:15	262.1
10/5/14 15:30	67.7
10/5/14 15:45	67.7
10/5/14 16:00	64.8
10/5/14 16:15	41.2
10/5/14 16:30	32.4
10/5/14 16:45	32.4
10/5/14 17:00	0

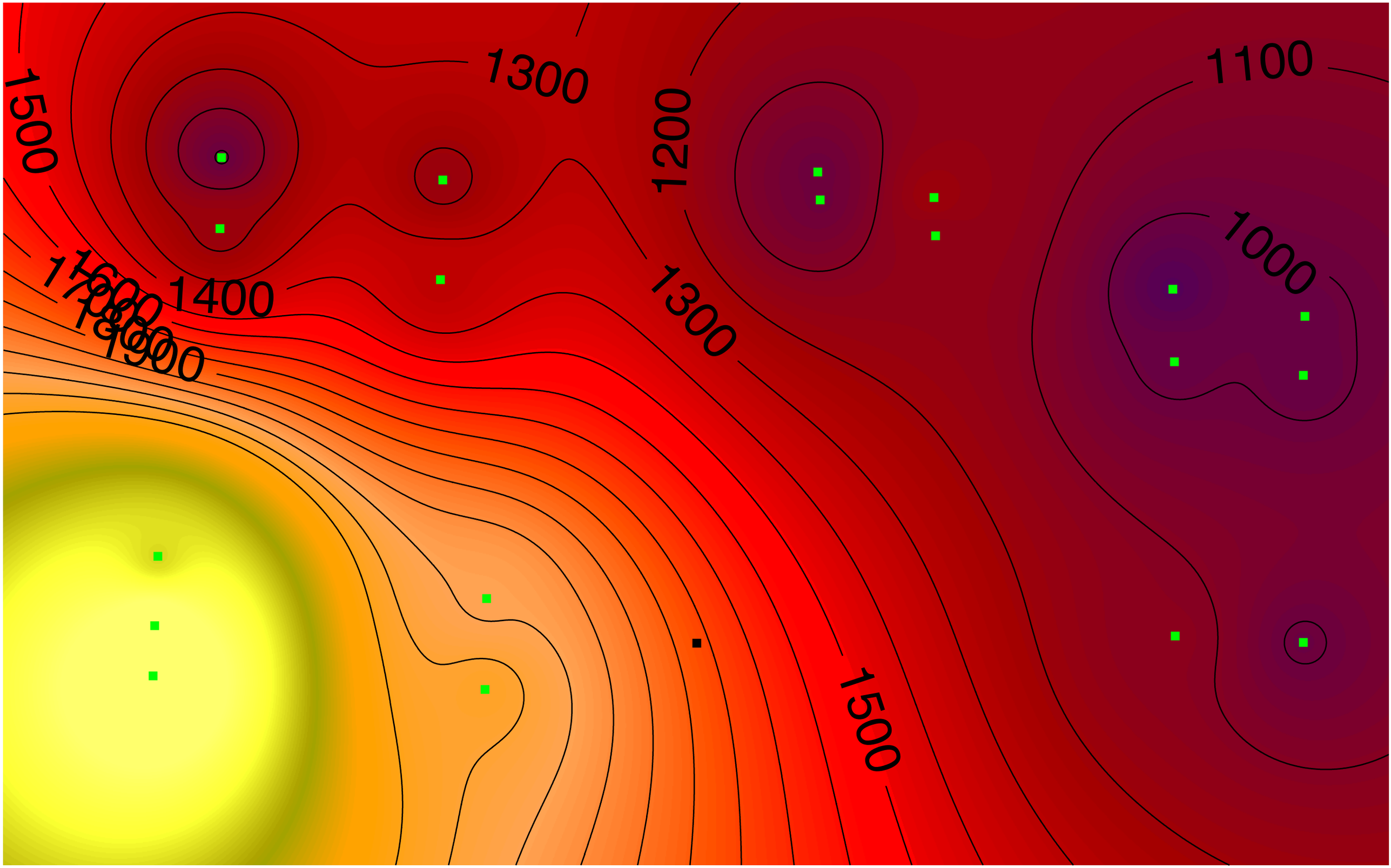
Part II

14-10-05

$$\mathbf{E_d} = \frac{\pi}{\rho_{card}} \sum_{h=0}^{24} \frac{\mathbf{H_c}}{6}$$



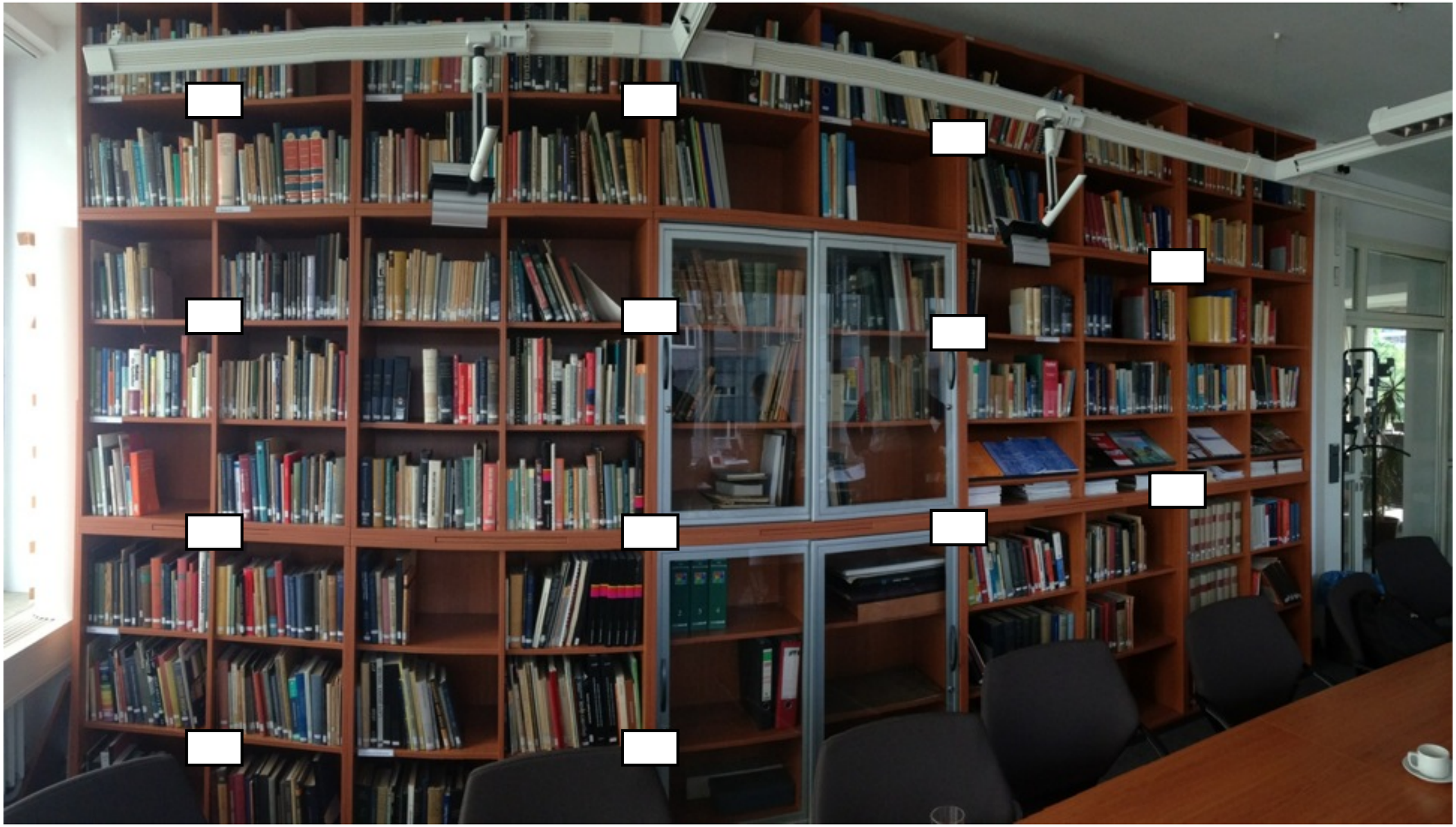
Interpolated illumination field [lux hours]



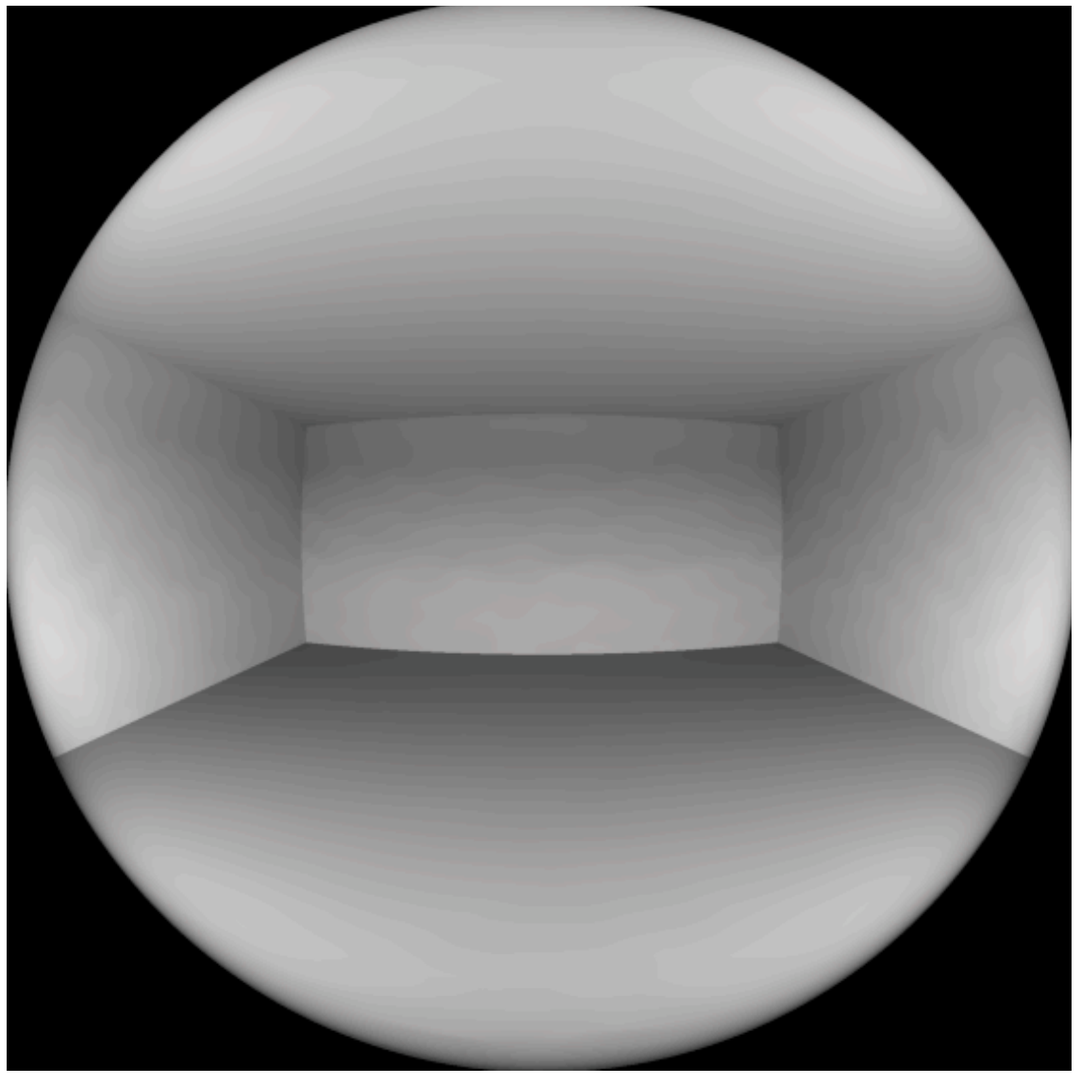
Surface texture

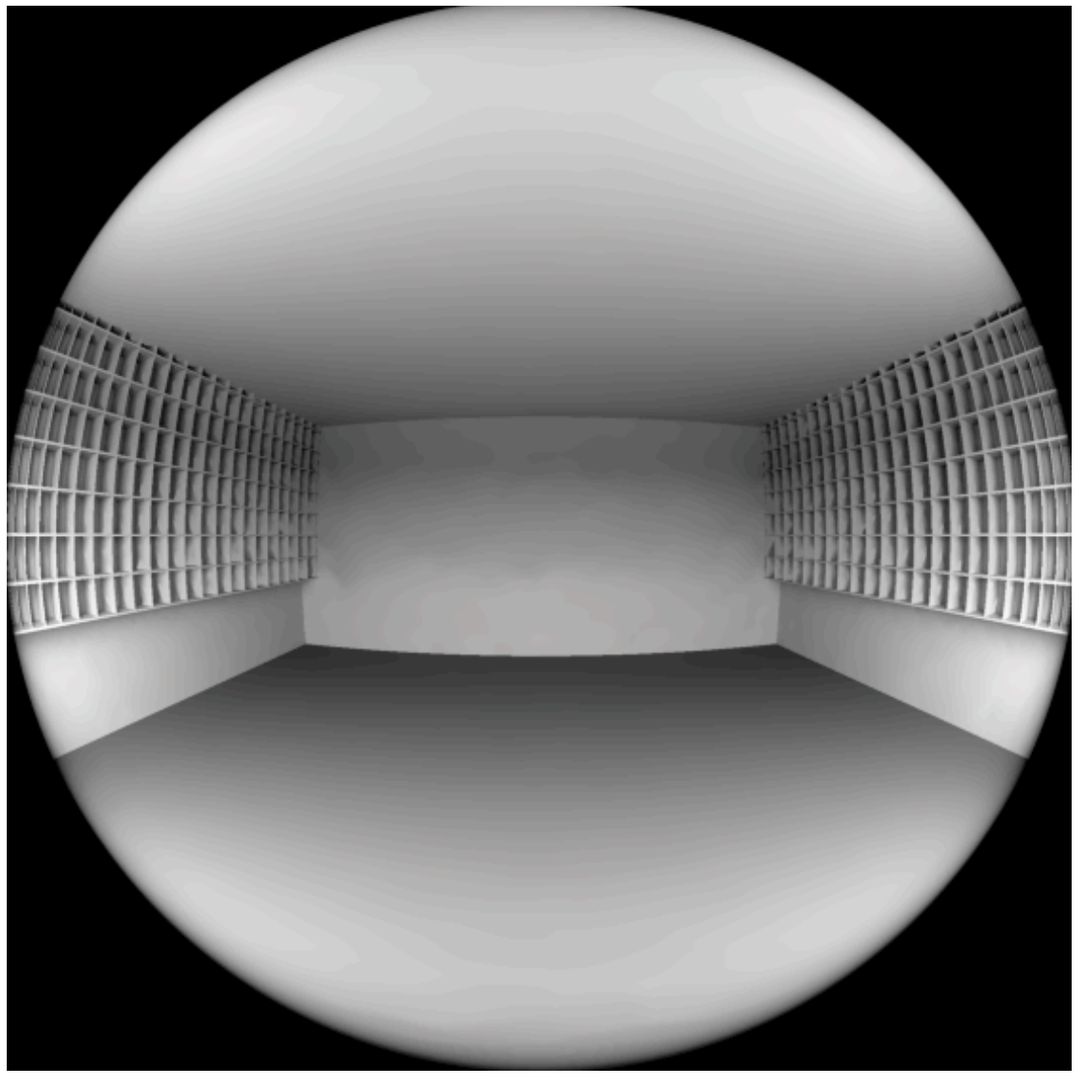
Part II

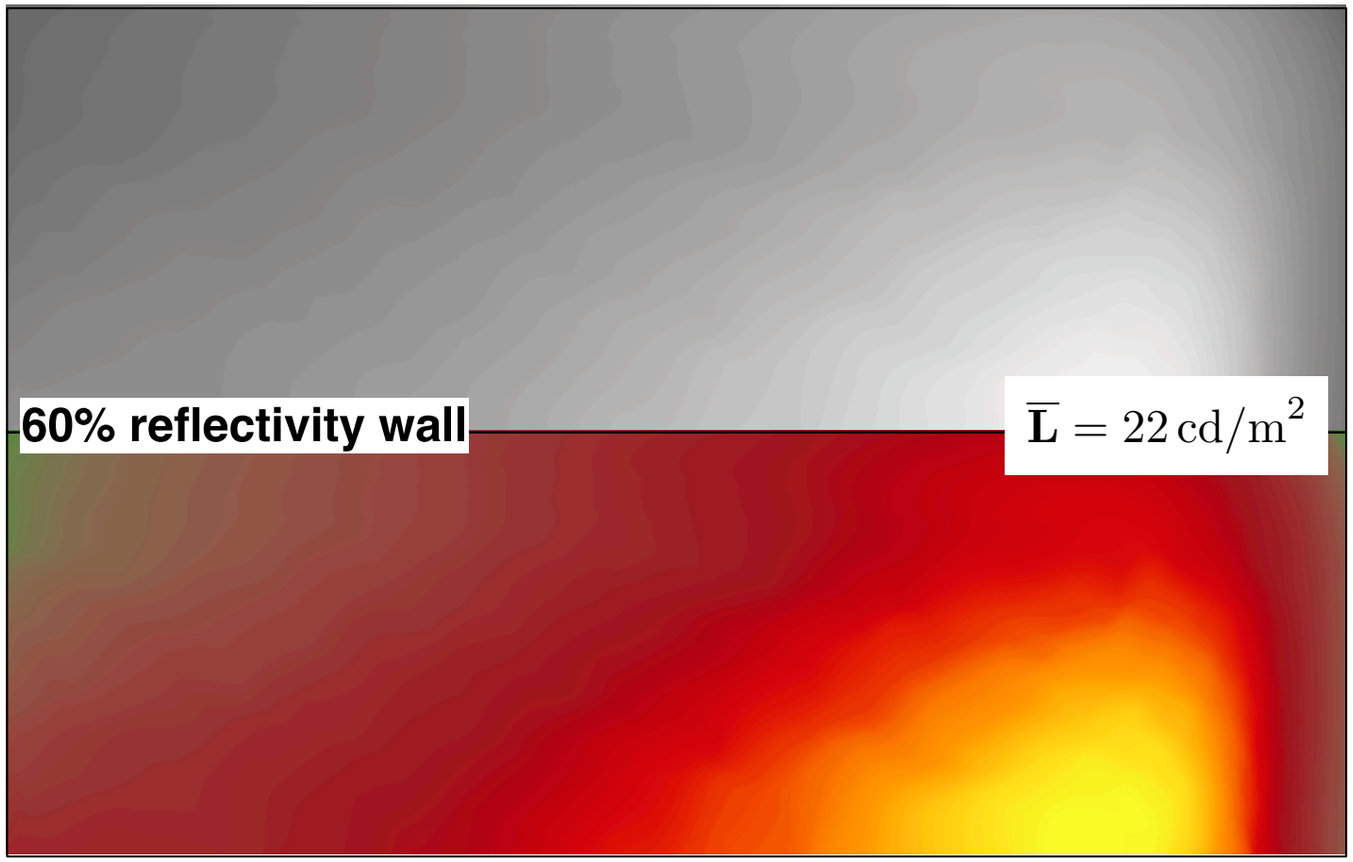
Part II

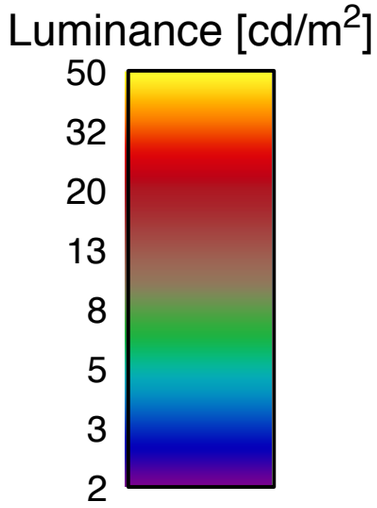


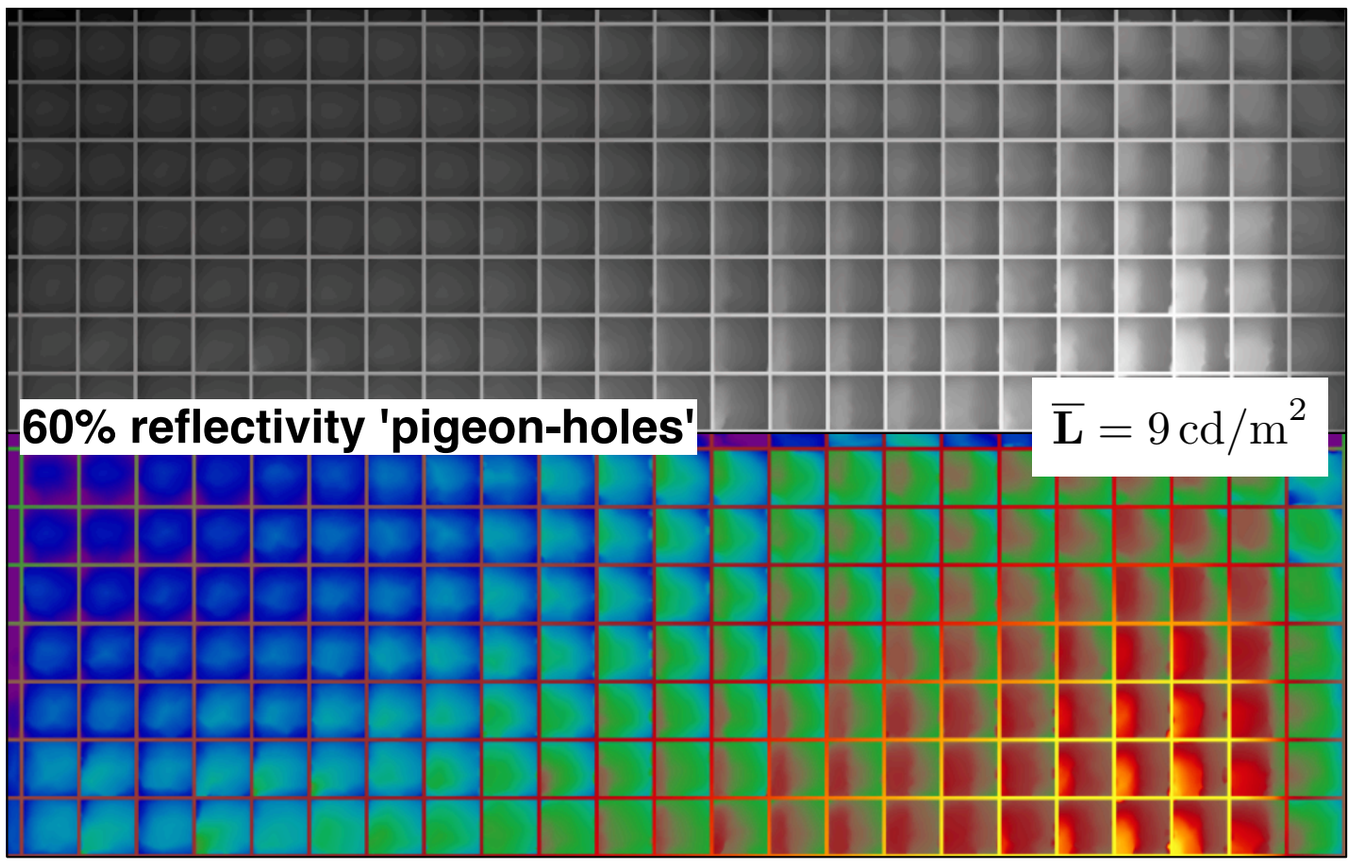
Part II






60% reflectivity wall
$\overline{\mathbf{L}} = 22\,\mathrm{cd/m^2}$


Luminance [cd/m^2]
50
32
20
13
8
5
3
2


60% reflectivity 'pigeon-holes'
$\overline{\mathbf{L}} = 9\,\mathrm{cd/m^2}$

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References:

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Thank you!

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