Comparing Physical and Virtual Methods for Daylighting Performance Modelling including Complex Fenestration Systems

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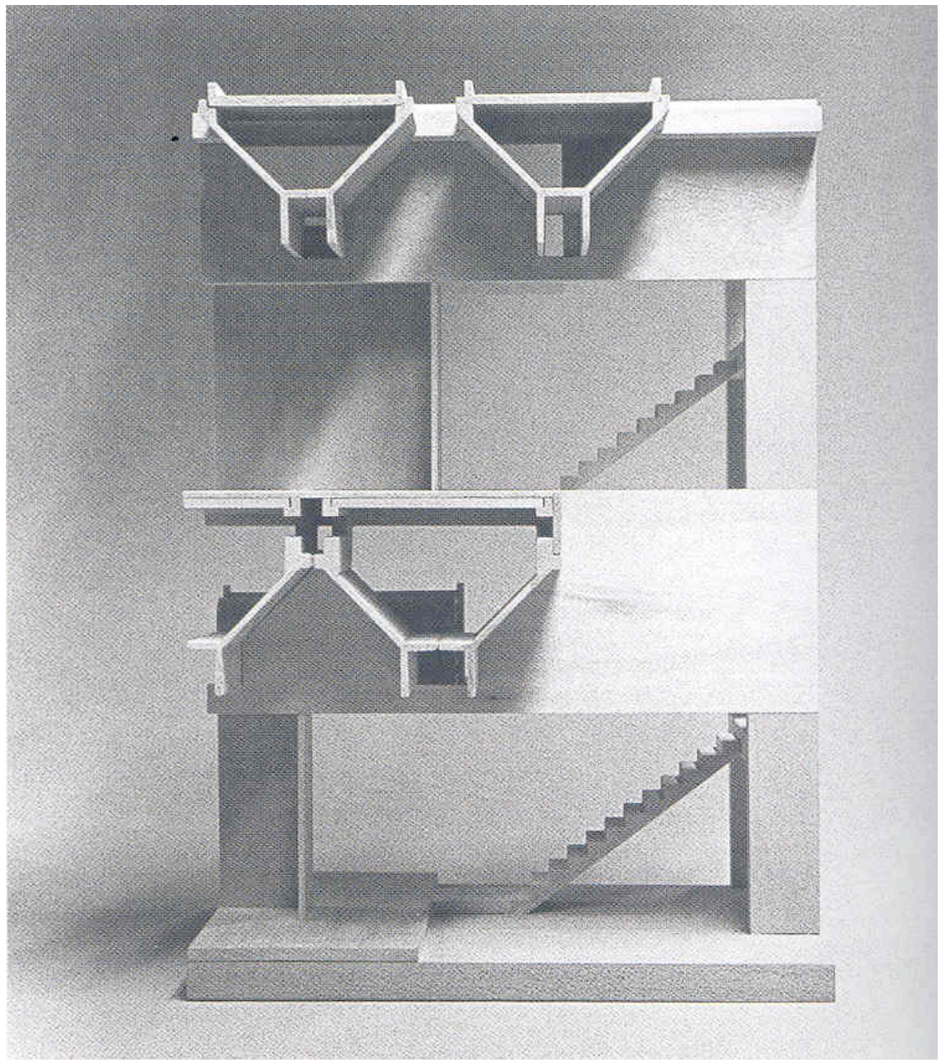
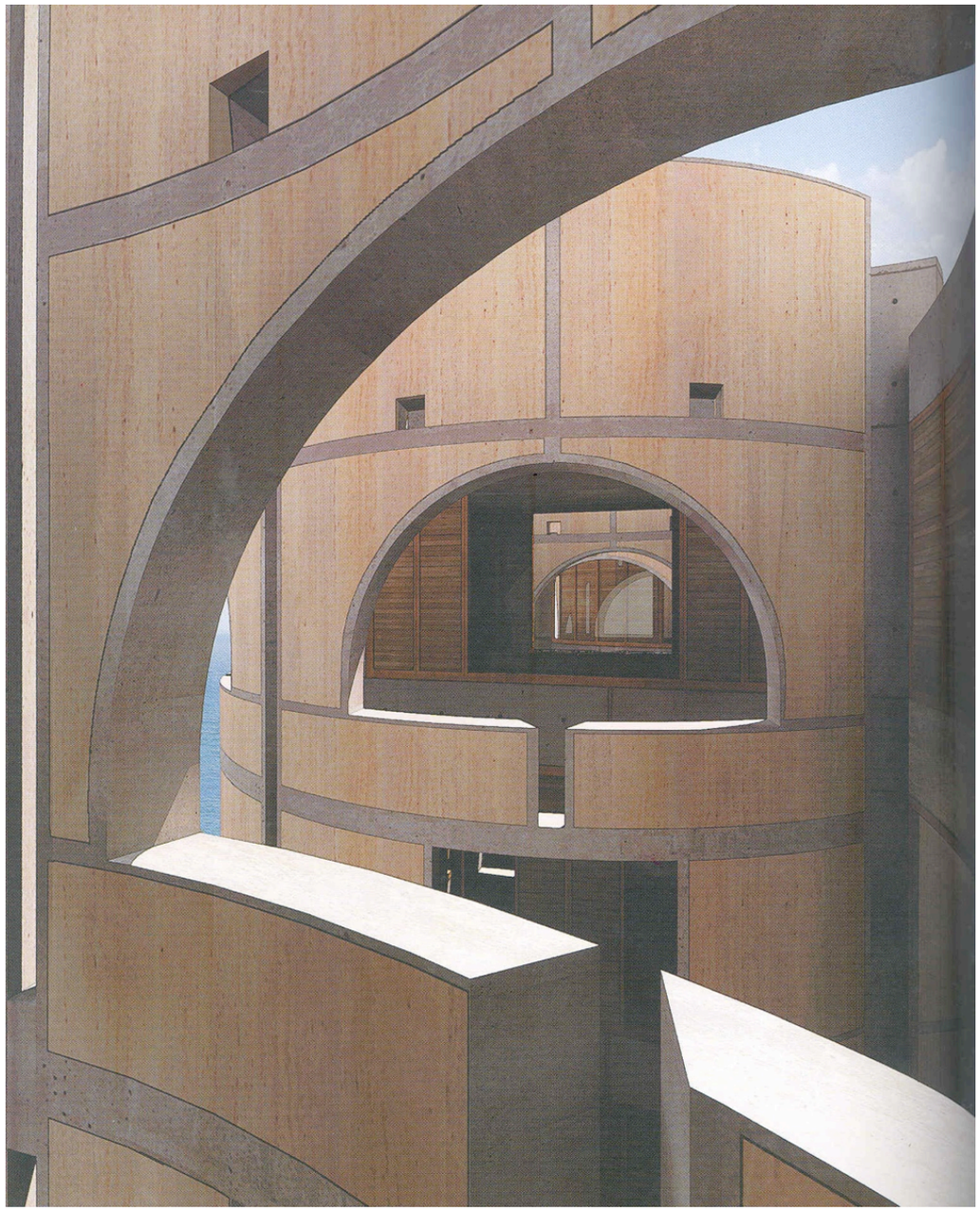


Main Factors

Model details
Model dimensions
Surface reflectance
Window transmittance
Sensors
Surroundings

+10 to +50%
(over-estimation)

Physical model



Main Factors

Model details

Model dimensions

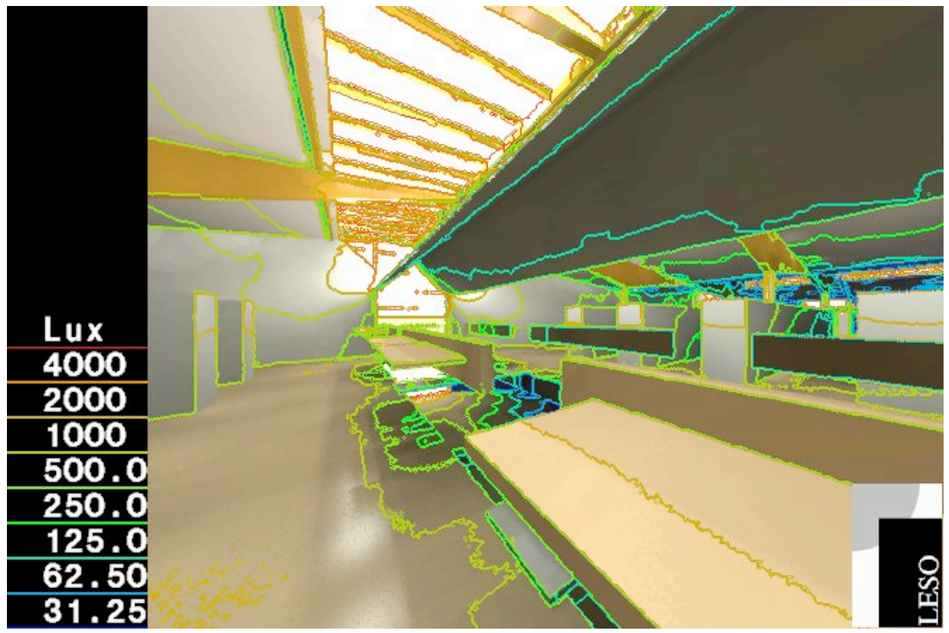
Surface reflectance

Window transmittance

Daylight simulations

Surroundings

+/-10 to 100%



Virtual model

Physical methods

COMPARISON

Building

COMPARISON

Virtual methods

– Identification of the main causes of experimental errors.

– Identification of the main causes of numerical errors.

– Comparison of the physical and virtual models with the real building with regard to their accuracy and reliability.

– Establishment of a practical checklist of daylighting models.

Objectives of the Research

Building
Daylighting test module
Office room
A side-lit window - South
Models were reproduced with real building properties.

Real building

Physical model

Virtual model

Real Building and Models

Location: Lausanne,

Switzerland

Latitude: 46.5°N

Longitude: 6.6°E

Elevation: 396 m

Placement: Concrete platform

Real Building

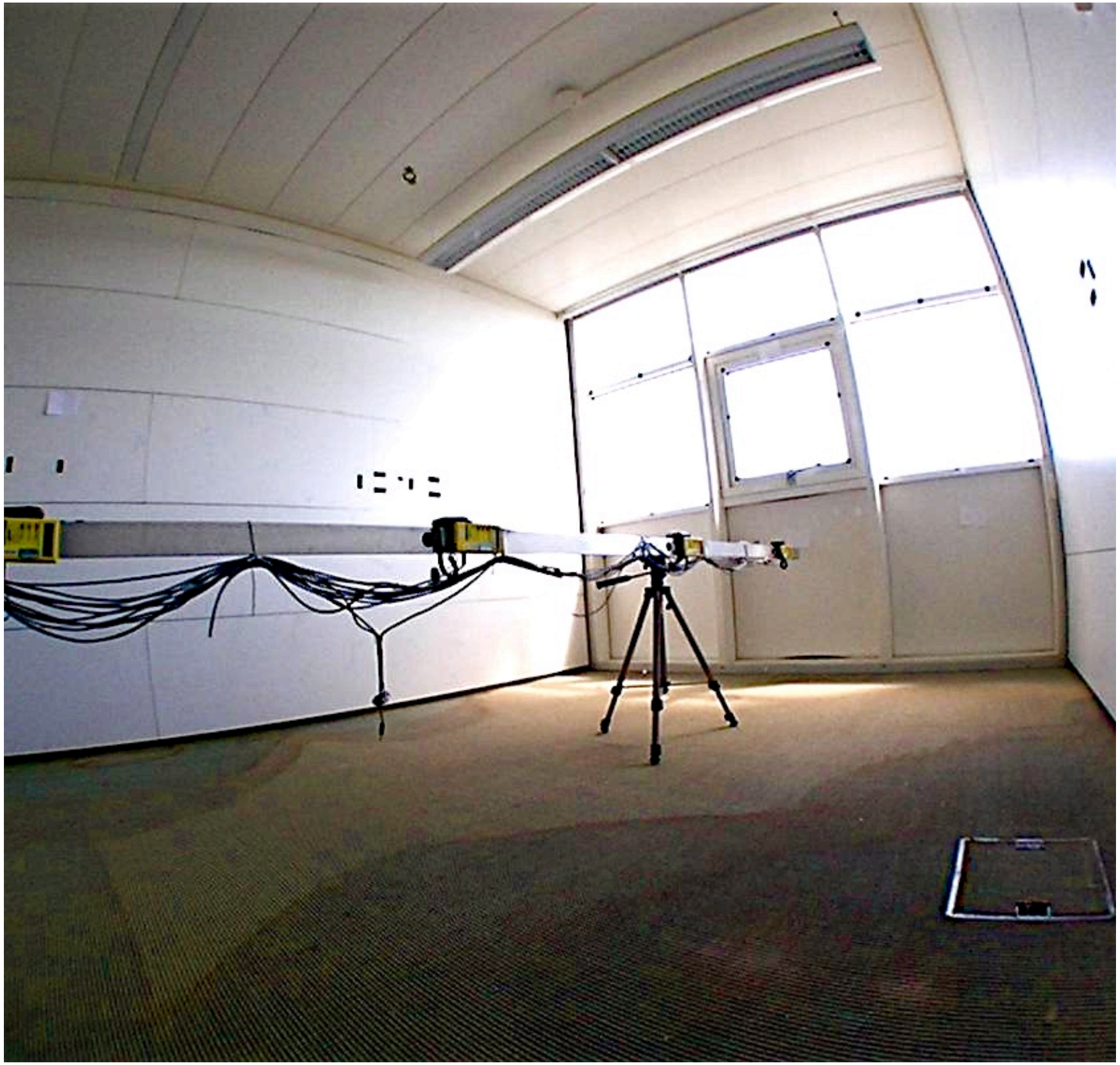
Interior Dimensions (m):

6.5 x 3 x 2.5

Window Dimensions (m):

3 x 1.6

Real Building



Materials, Reflectance (%)

North wall : Canvas, 83

East wall : Satin, 82

South wall : Painted metal, 72

West wall : Satin, 82

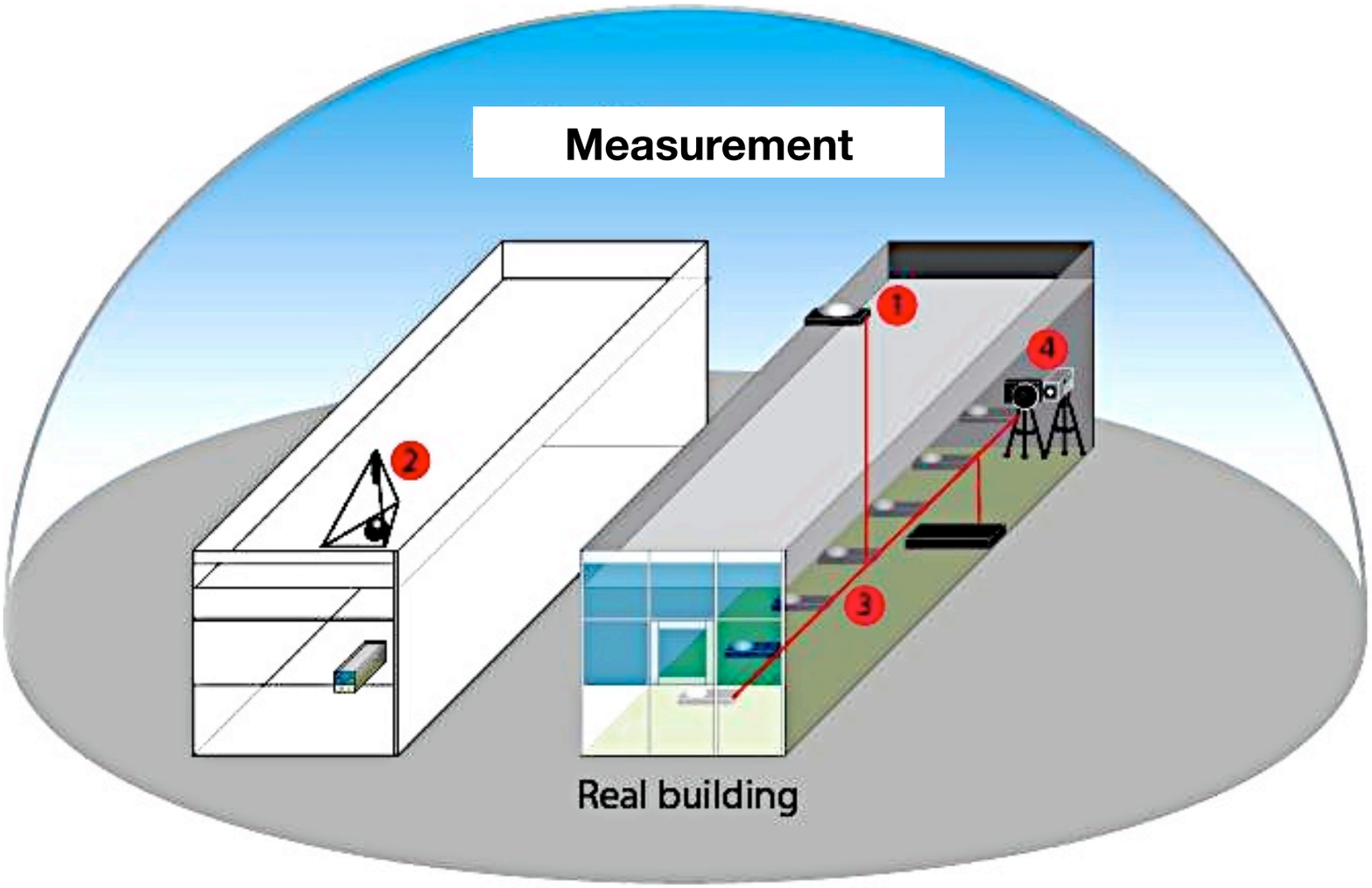
Ceiling : Satin, 80

Floor : Carpet, 16

WIndow, Transmittance (%)

Double Glazing, 80

Real Building



1. **Hagnar/LMT sensors : outdoor illuminance**
2. **Sky scanner : sky luminance distribution**
3. **BEHA sensors : indoor illuminance**
4. **Camera + Luminance meter : surface luminance**

Real Building

Interior Dimensions (m):

0.65 x 0.30 x 0.25

Window Dimensions (m):

0.30 x 0.16

Materials, Reflectance (%)

North wall : Paper, 79

East wall : Paper, 79

South wall : Paper, 71

West wall : Paper, 79

Ceiling : Paper, 76

Floor : Paper, 16

WIndow, Transmittance (%)

Single 2mm acrylic + films, 79

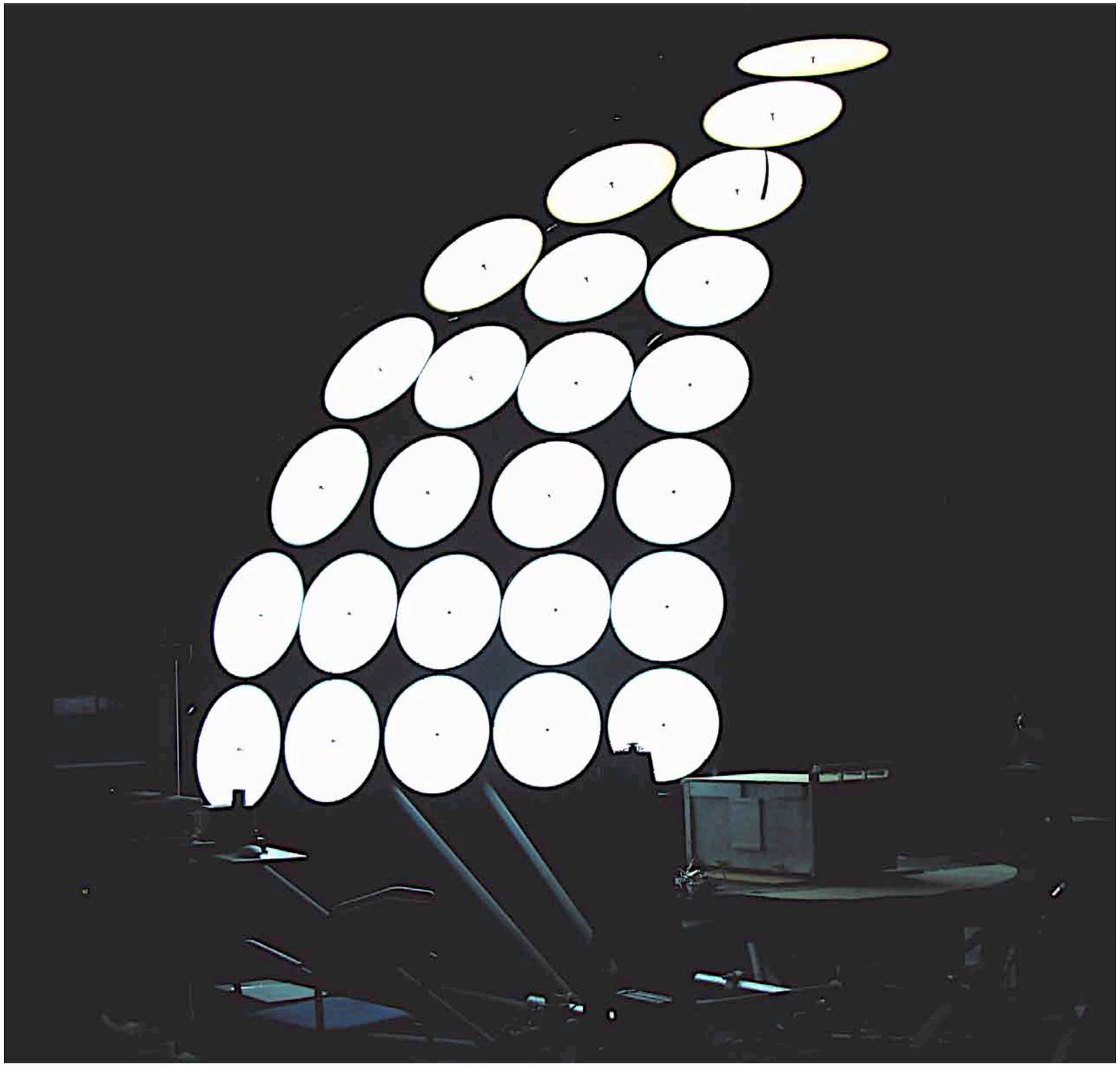
1:10 Scale model

Location 1:

In front of

the adjacent test module

1:10 Scale model



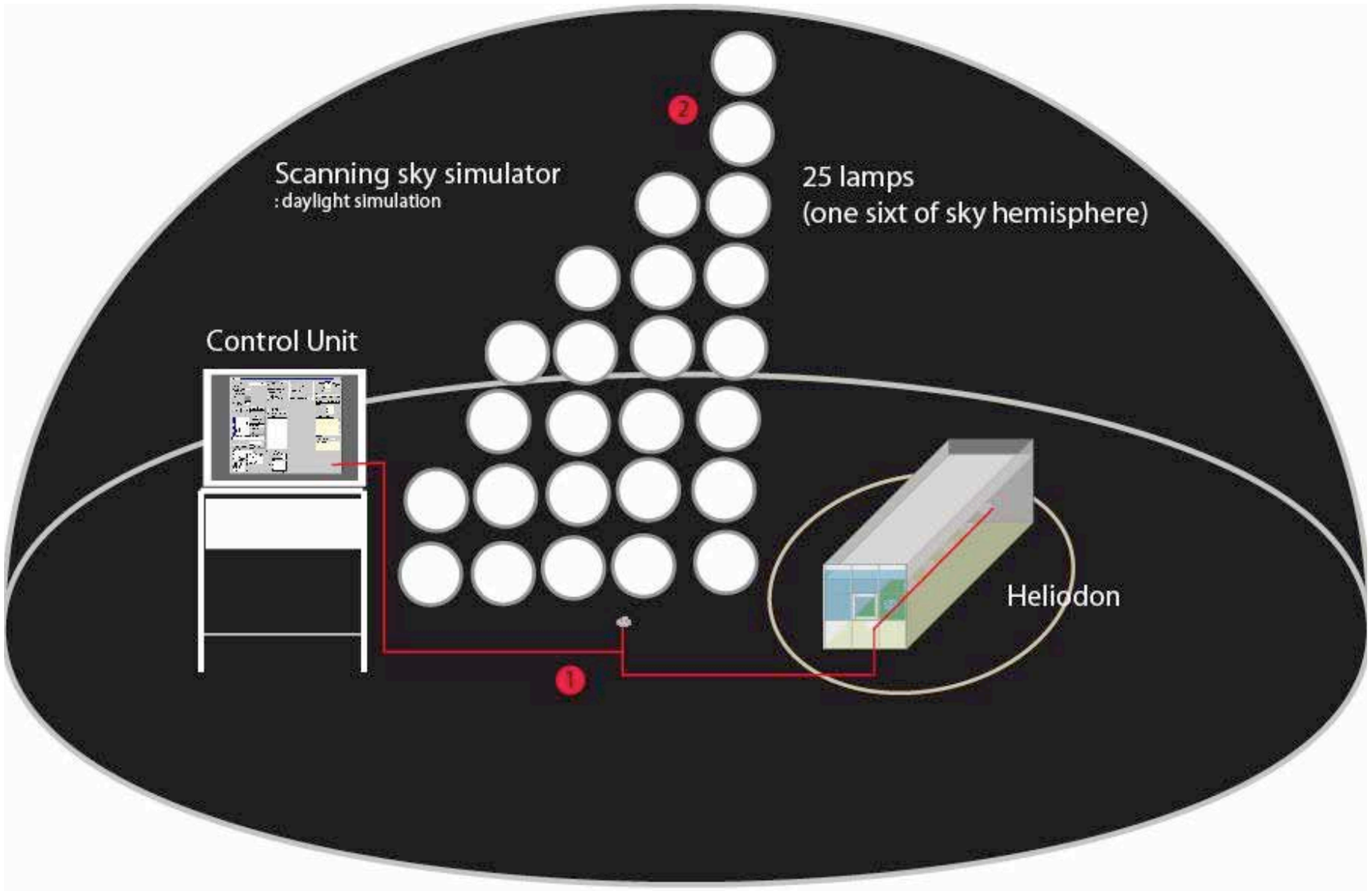
Location 2:

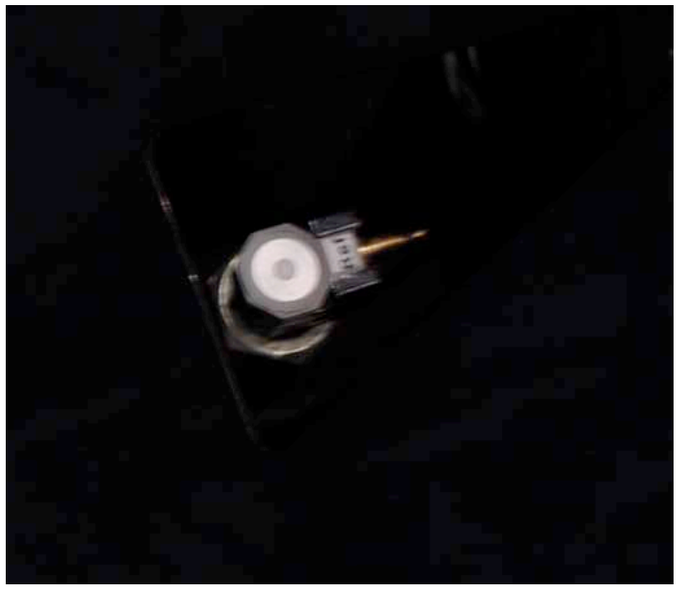
On the automated movable

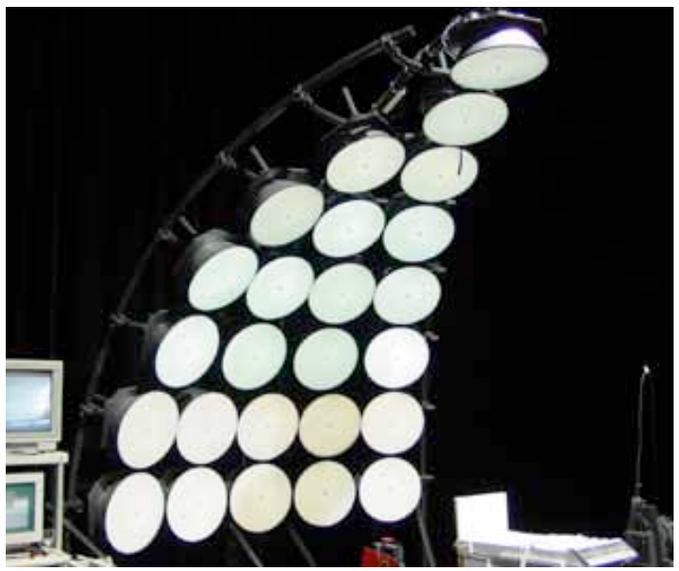
platform

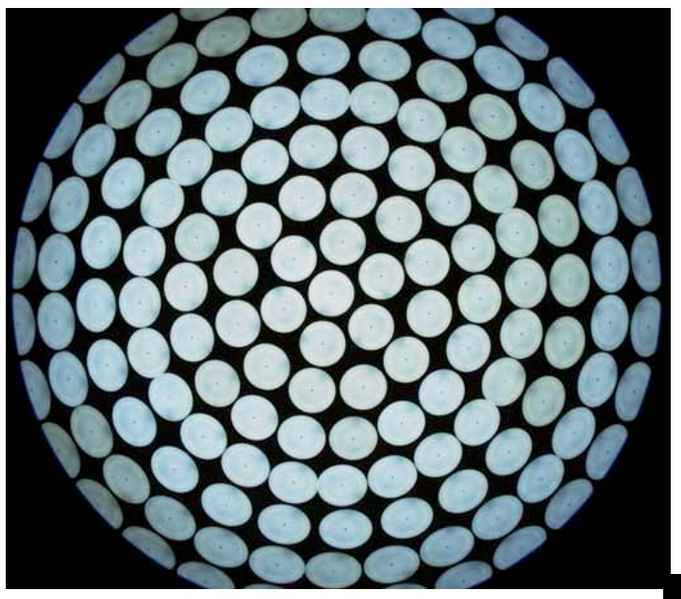
Under Scanning sky simulator

1:10 Scale model









1 **PRC Krochmann sensors**
: indoor illuminance

2 **Scanning sky simulator**
: sky luminance distribution

1:10 Scale model

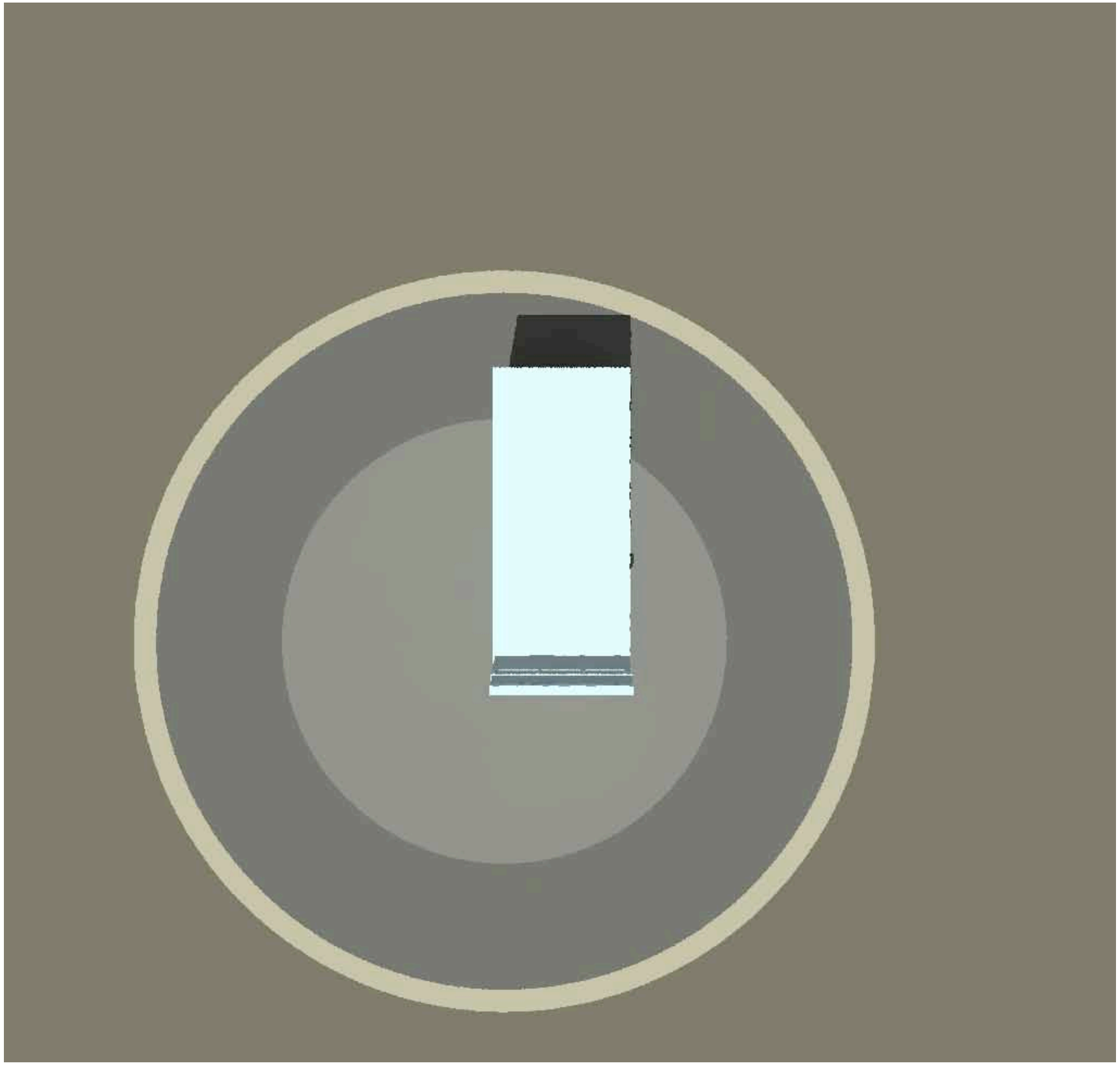
Interior Dimensions (m):

6.5 x 3.0 x 2.5

Window Dimensions (m):

3.0 x 1.6

Virtual model



Virtual model

Reflectance (%)

North wall : 82

East wall : 81

South wall : 72

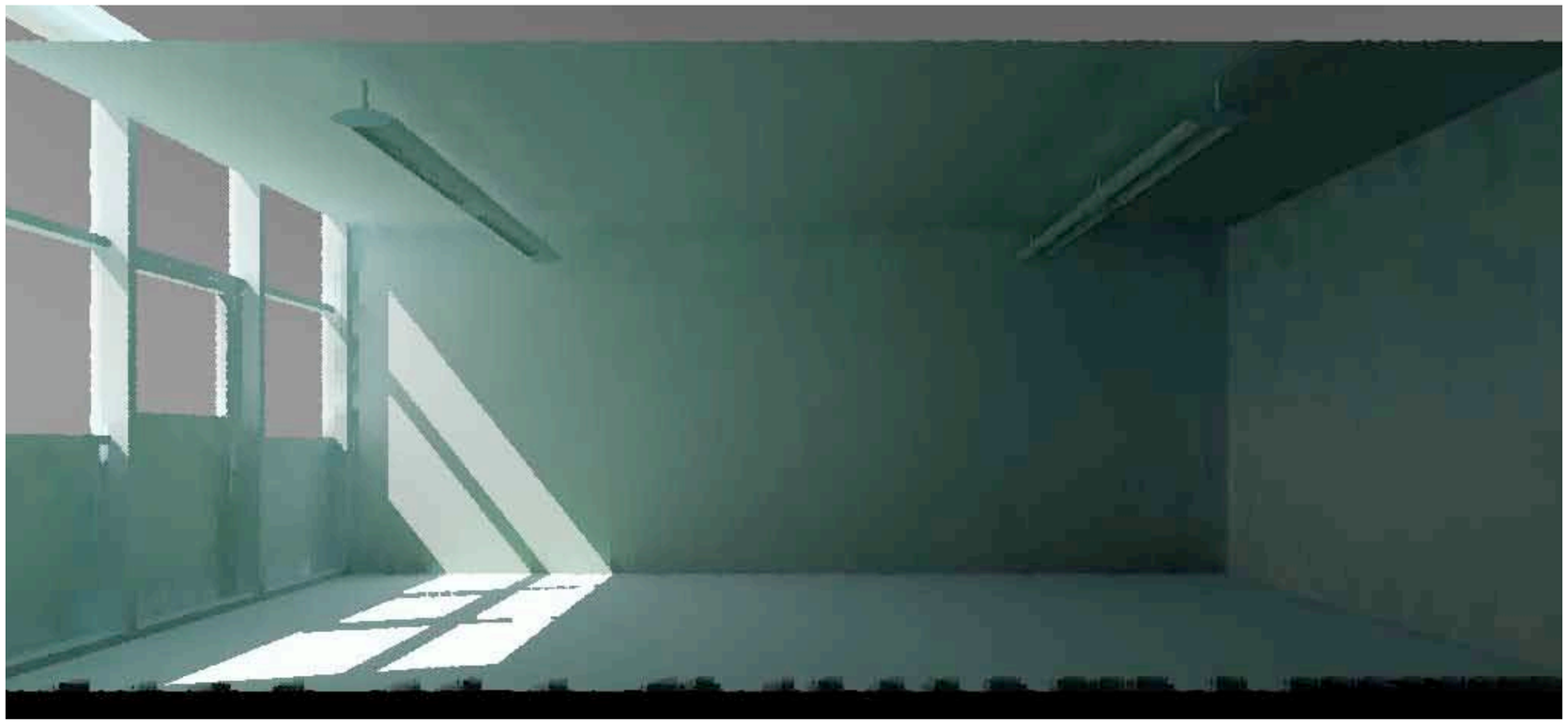
West wall : 82

Ceiling : 80

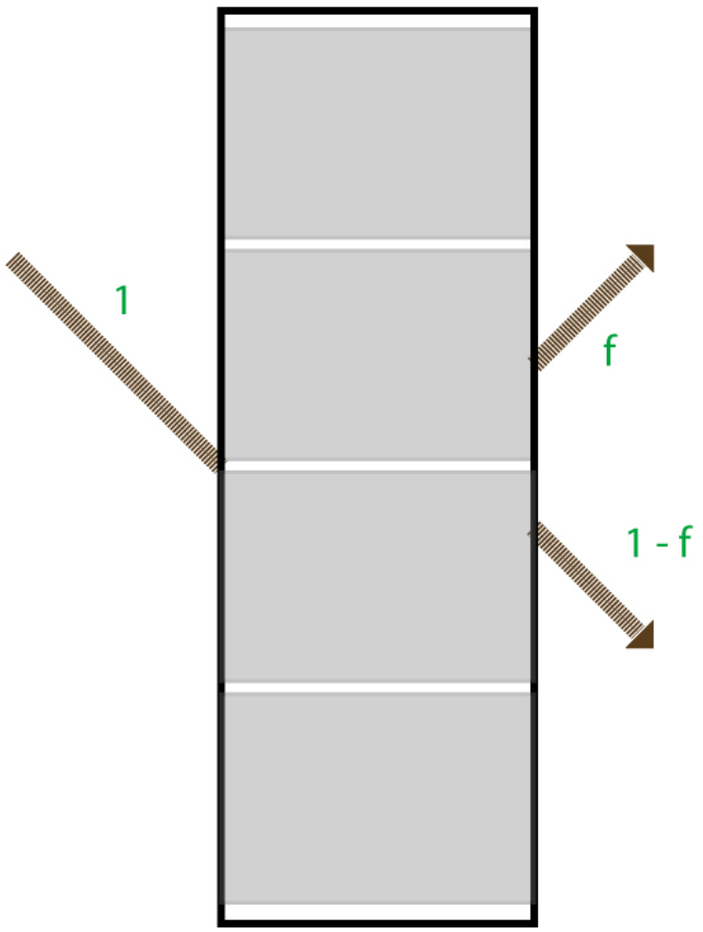
Floor : 16

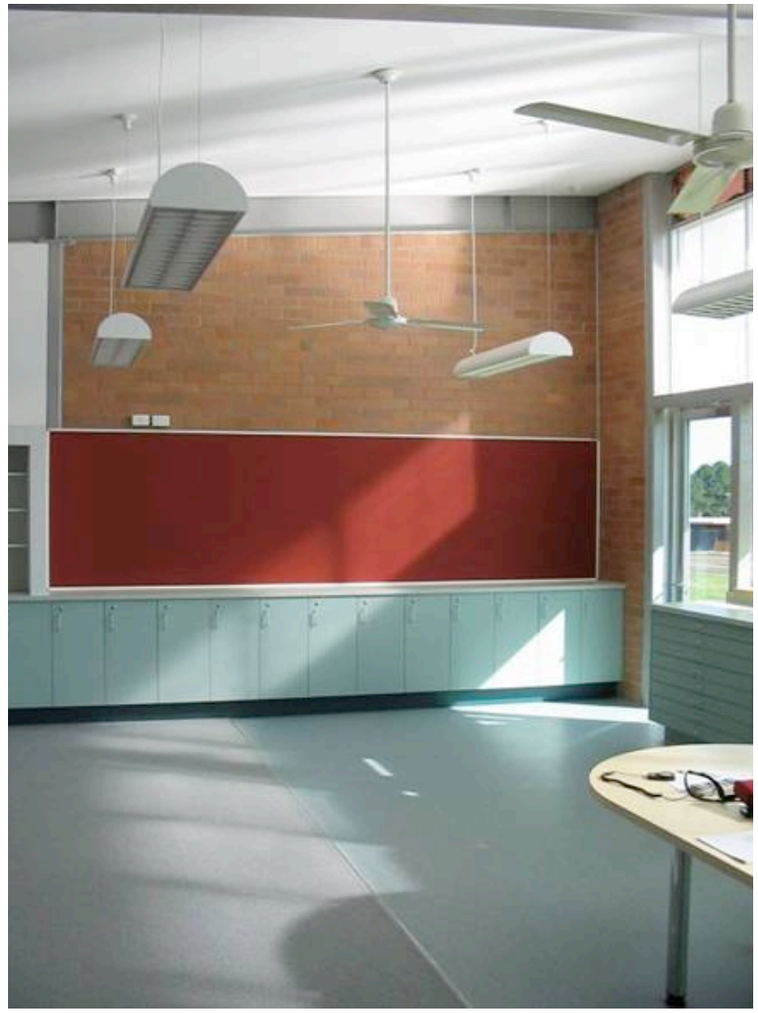
Transmittance (%)

80

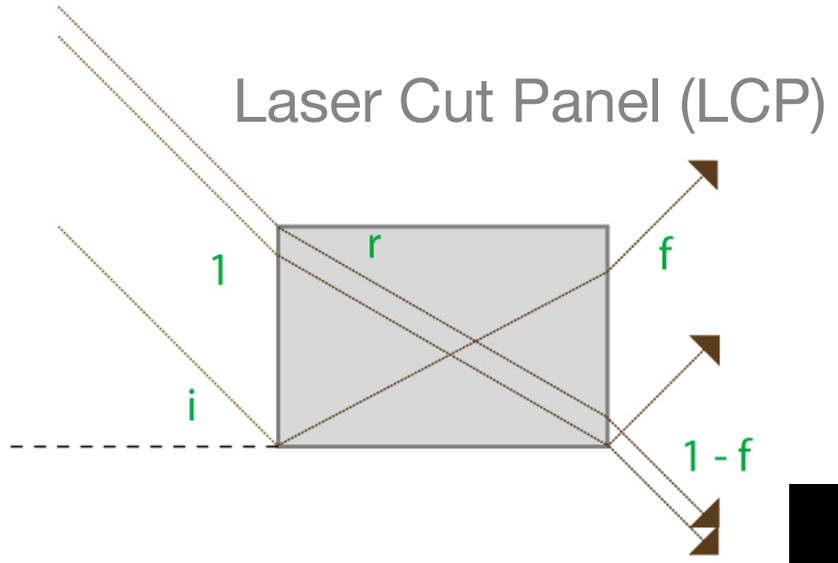


Virtual model

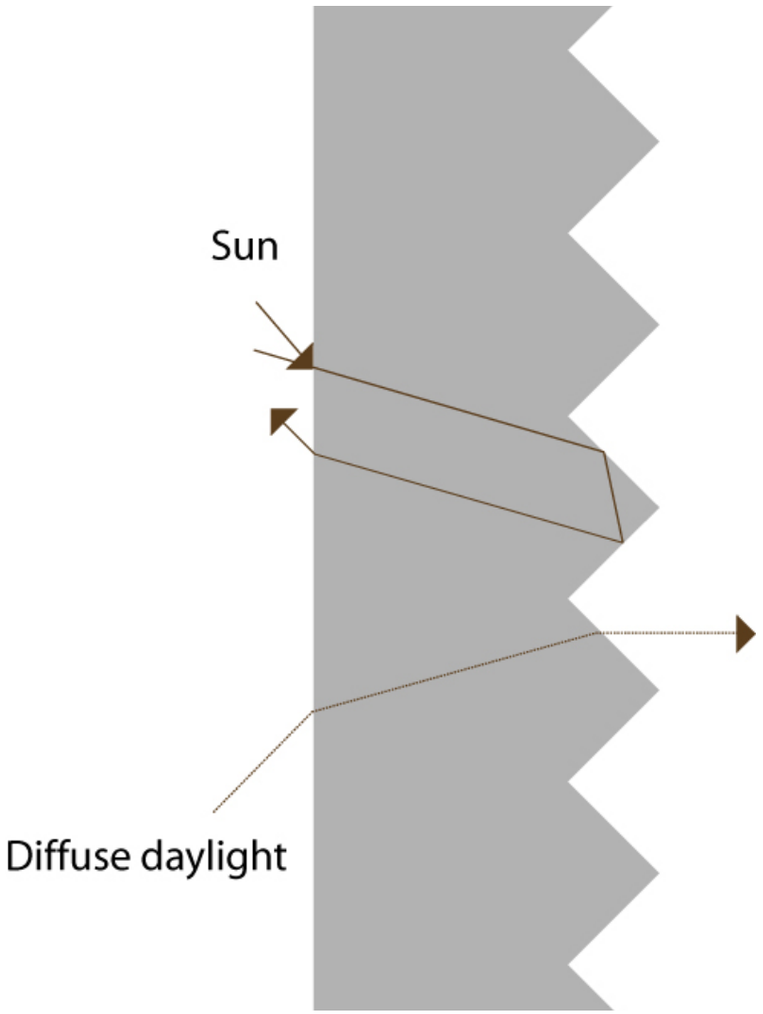


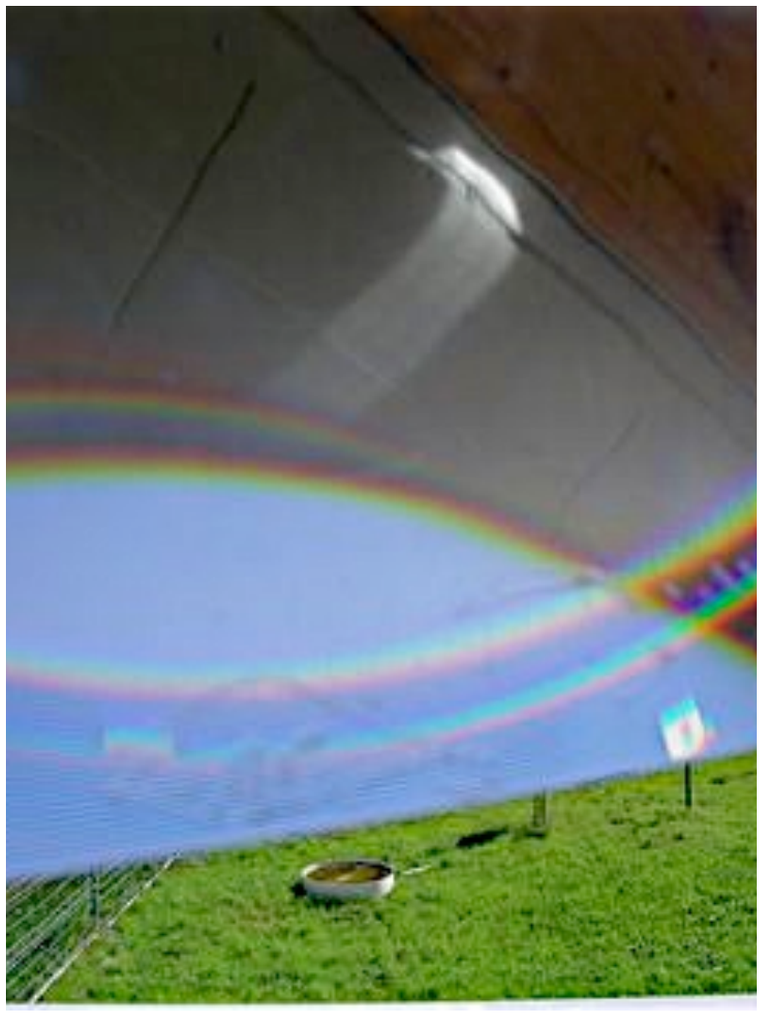


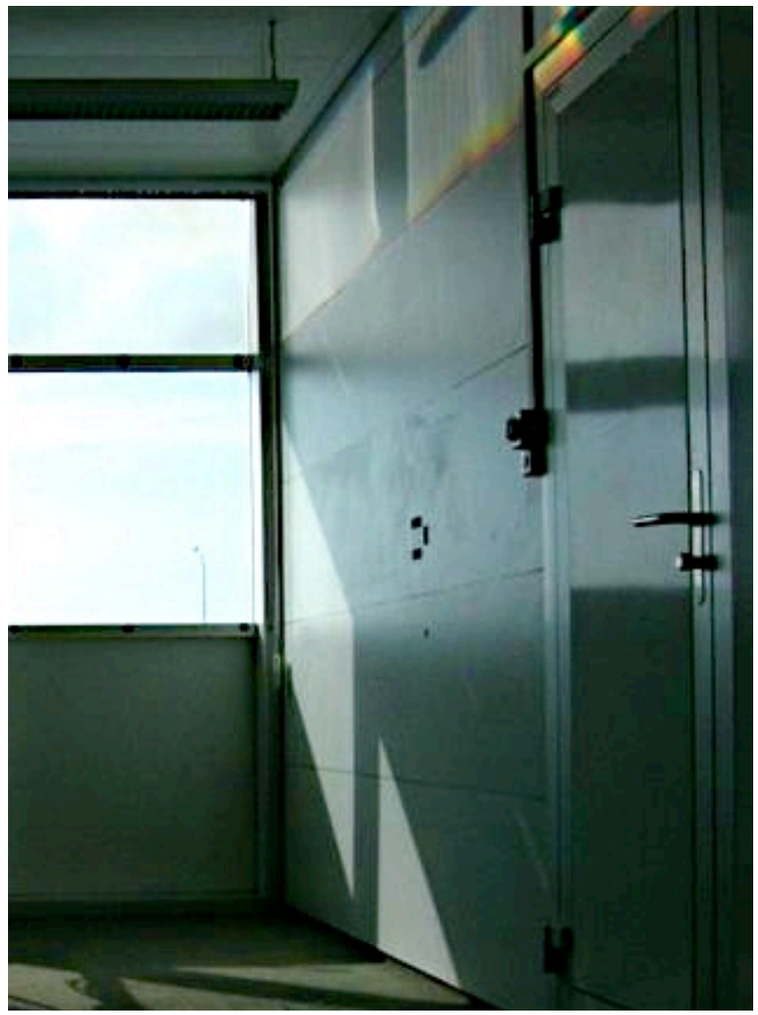
Daylight redirecting system
6 mm acrylic panel with laser cuts at 4 mm intervals
Laser cut surfaces perform as small mirrors.
Upper part of the window redirects daylight
towards the ceiling



Complex Fenestration Systems (CFS)







Prismatic film

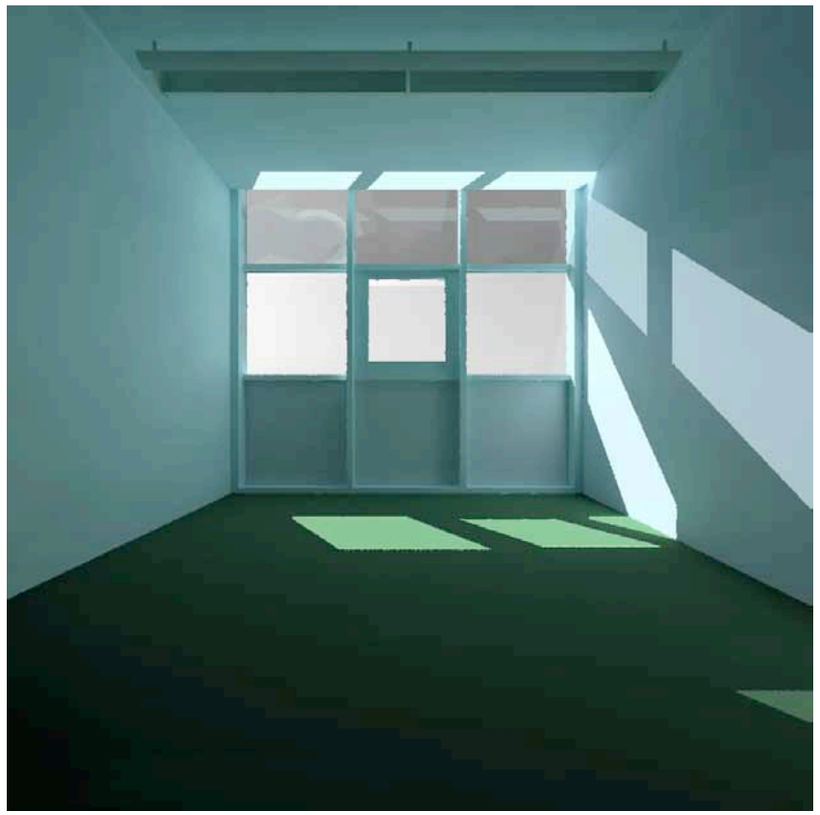
Daylight redirecting system
Acrylic or Polycarbonate

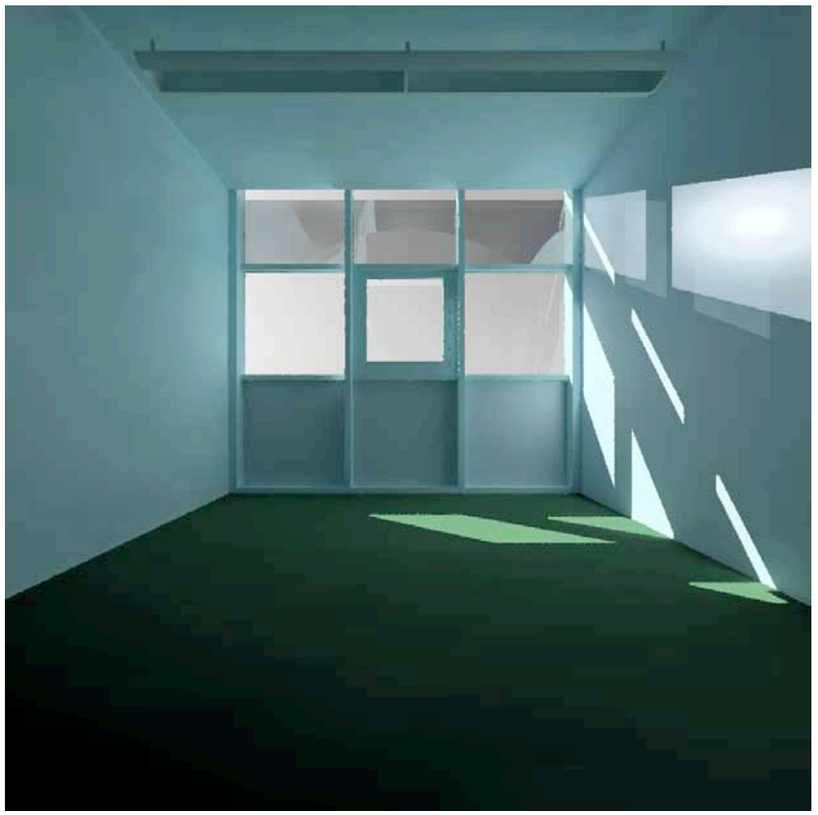
Upper part of the window redirects daylight towards the ceiling

Complex Fenestration Systems (CFS)

Double Glazing **Laser Cut Panel** **Prismatic Film**

CFS in Real Building and in scale model





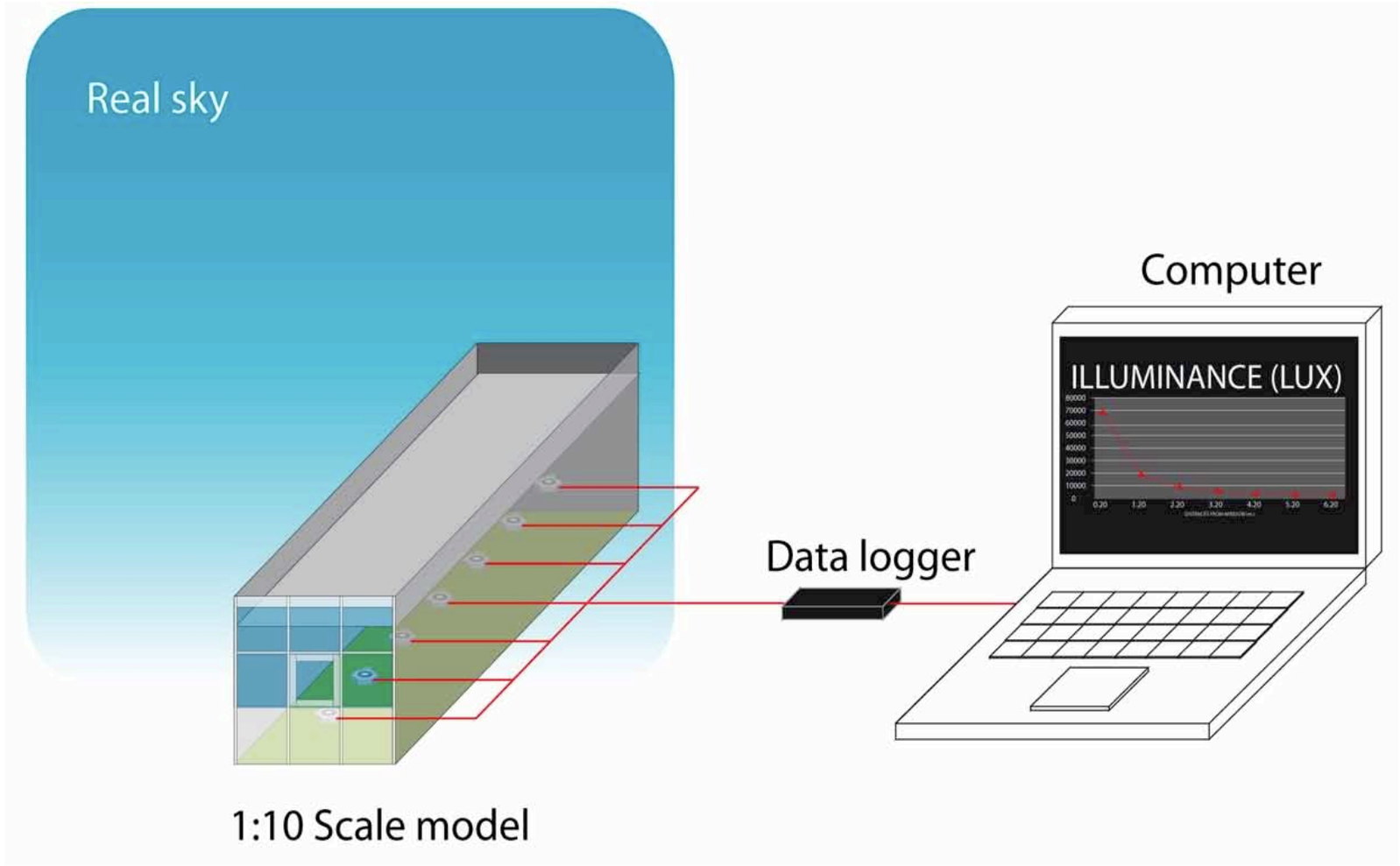
Double Glazing

Laser Cut Panel

Prismatic Film

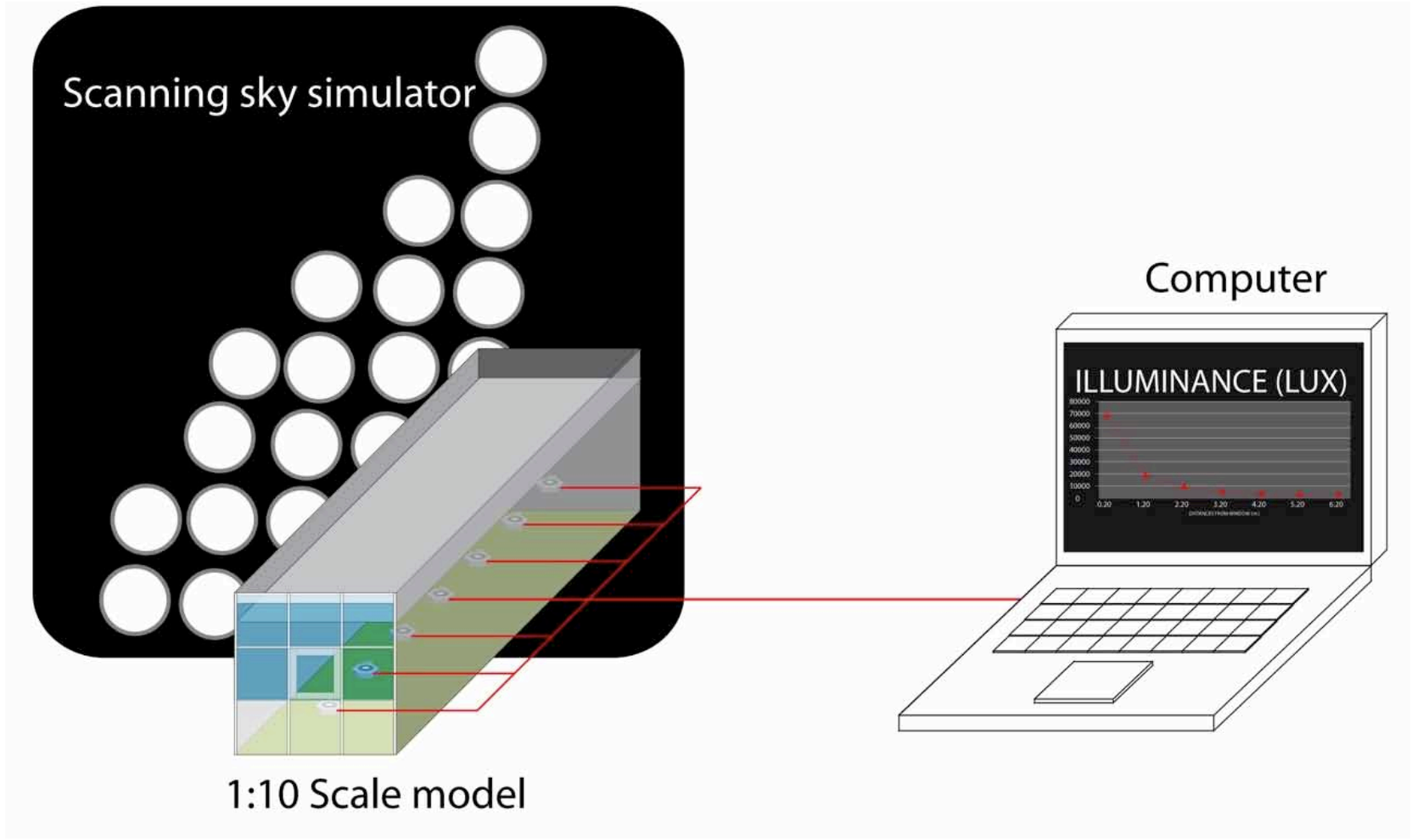
CFS in virtual model

Case A – Scale model, Real sky



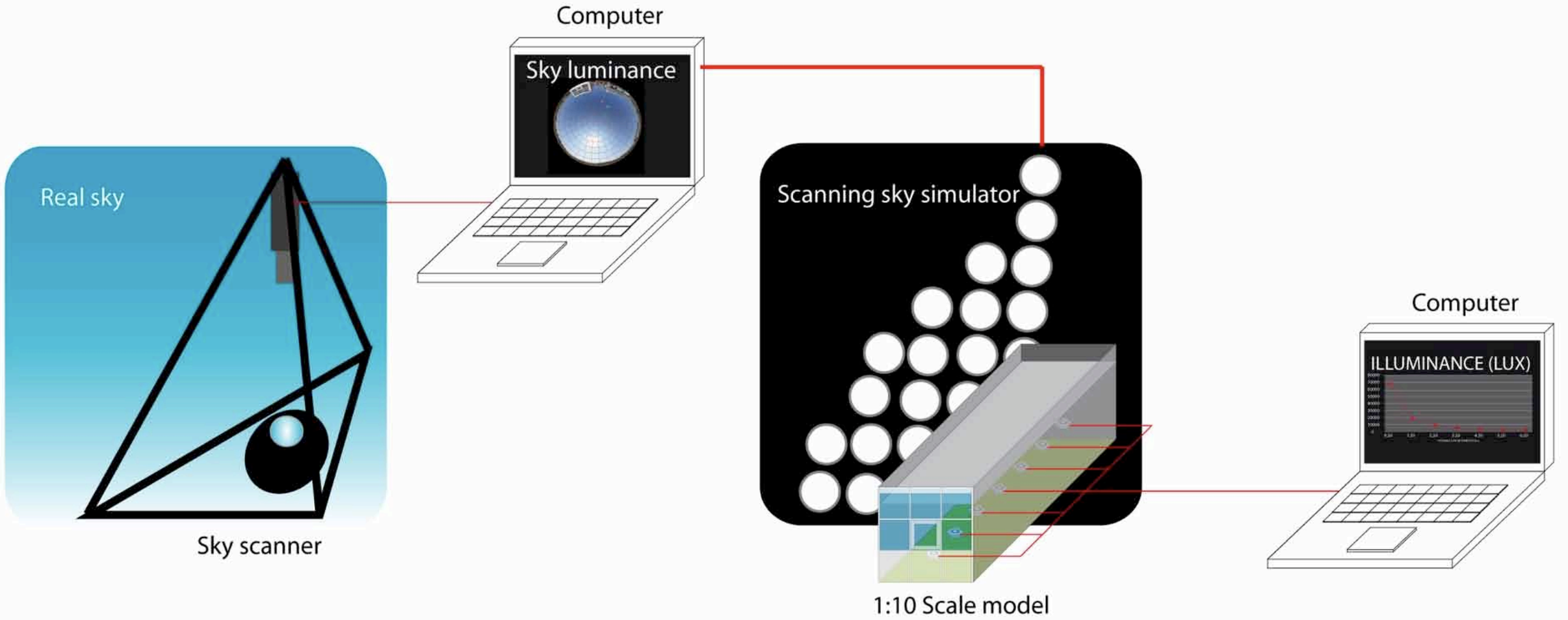
A B C D E

Case B – Scale model, Sky simulator, CIE Standard sky



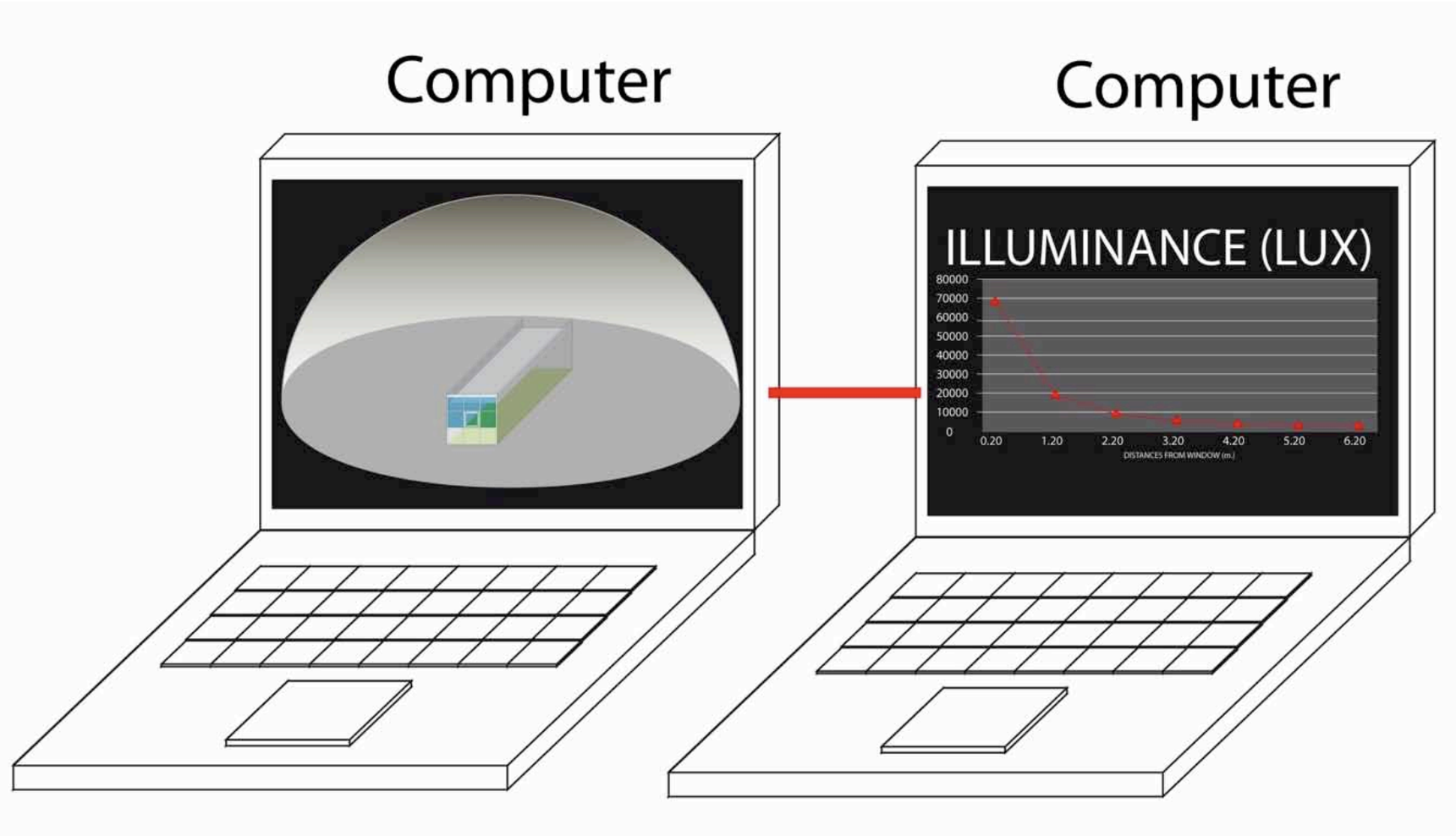
A B C D E

Case C – Scale model, Sky simulator, Mapped real sky values



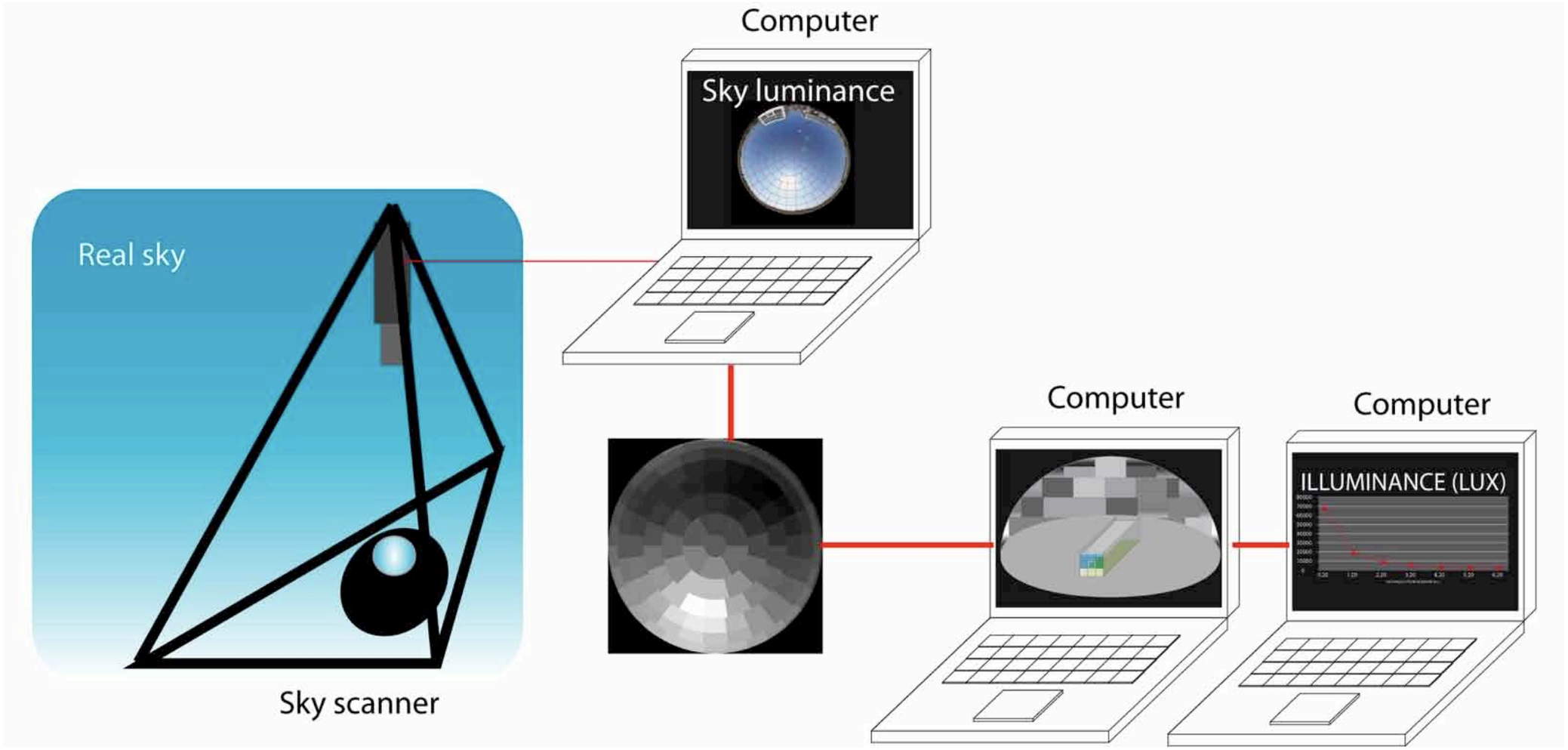
A B C D E

Case D – Virtual model, CIE Standard sky



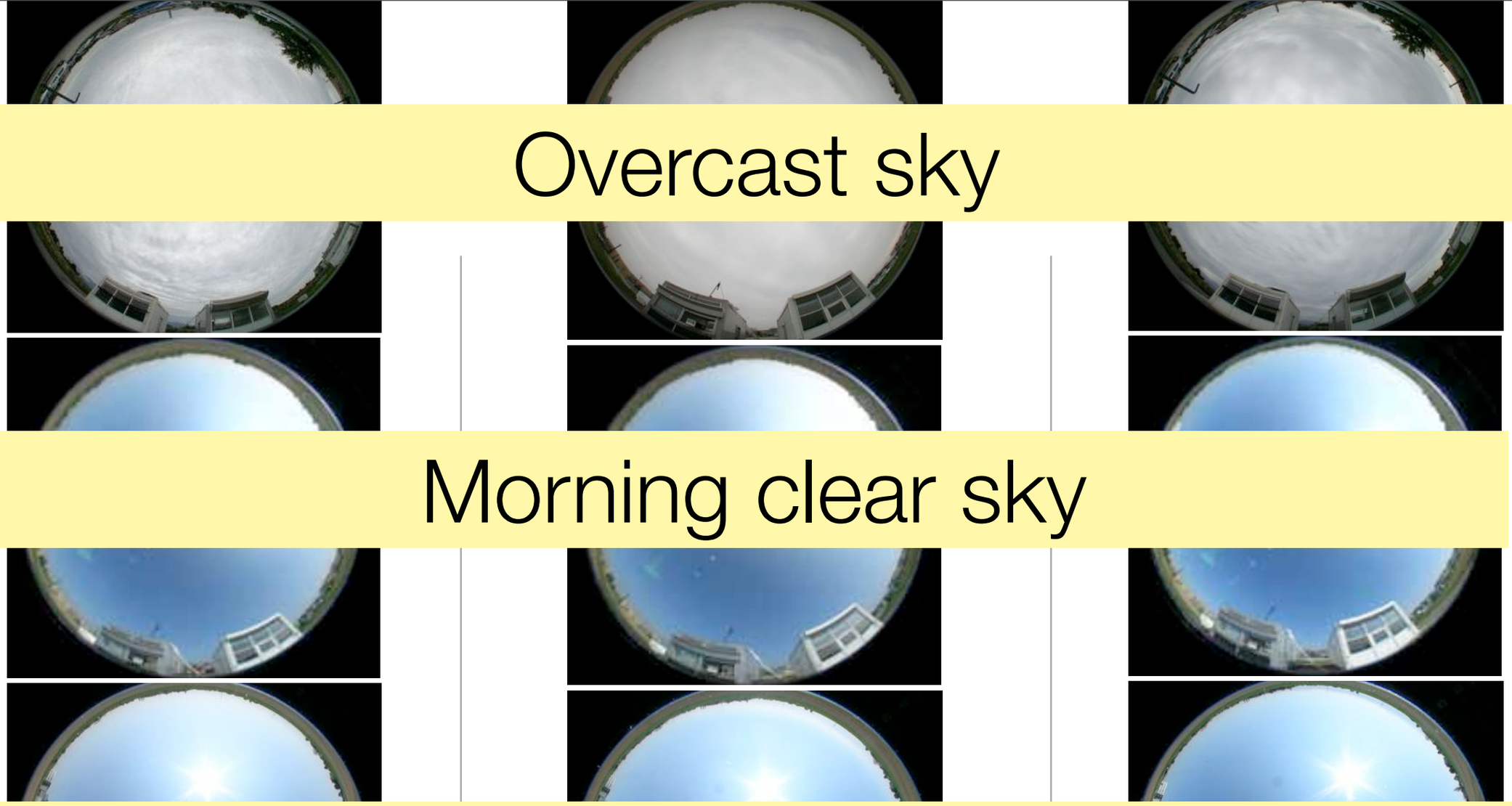
A B C D E

Case E – Virtual model, Mapped real sky values

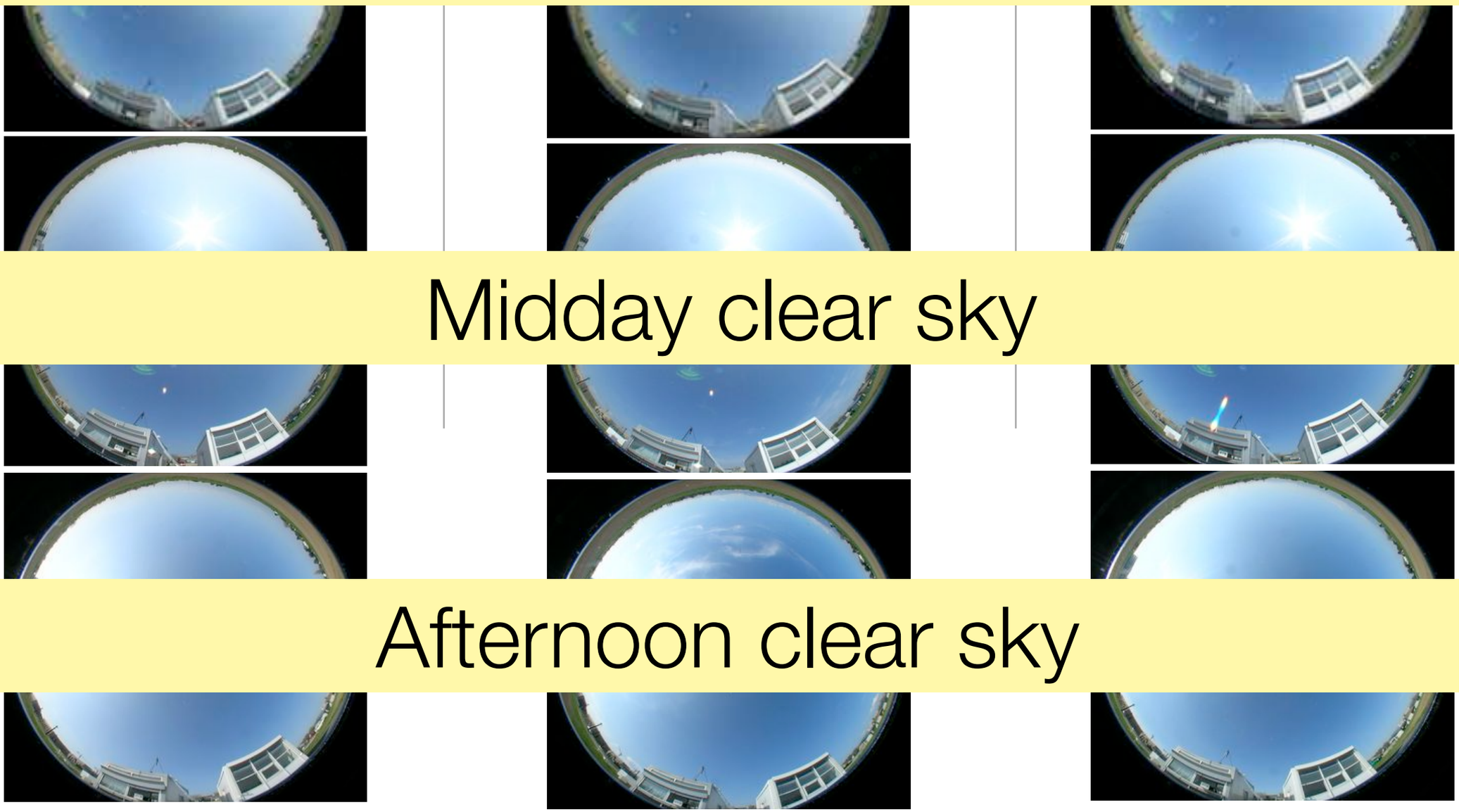


A B C D E

Overcast sky



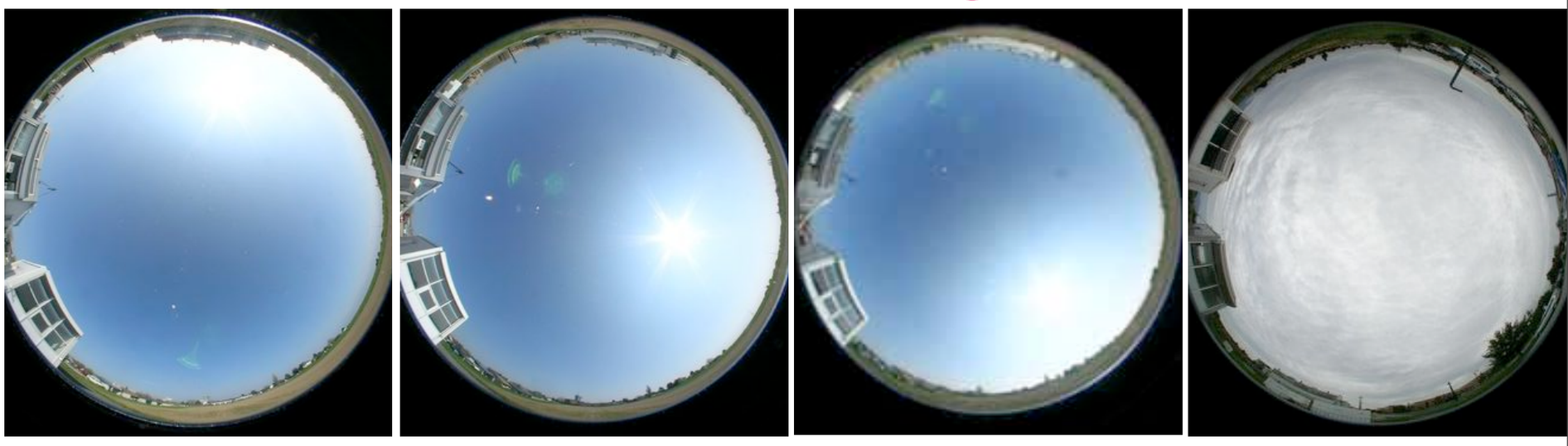
Morning clear sky



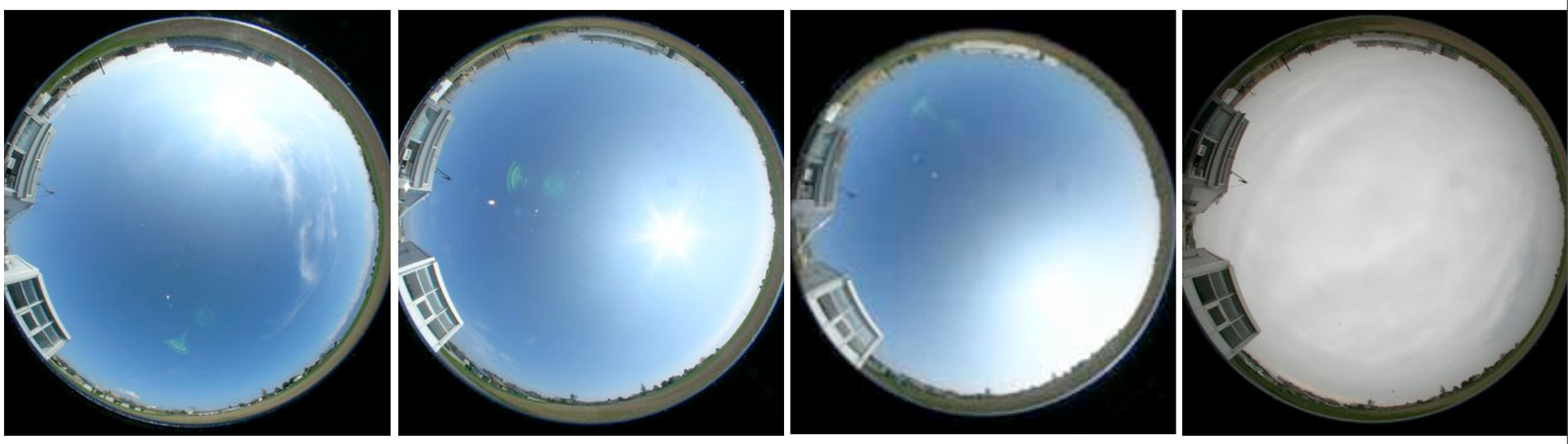
Midday clear sky

Afternoon clear sky

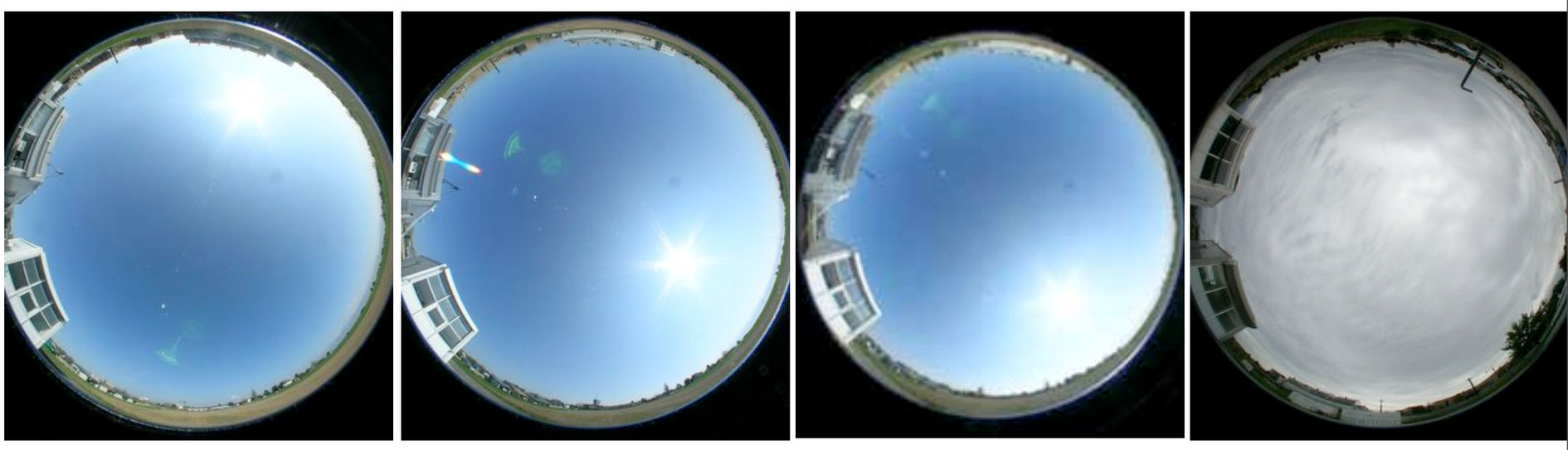
Double Glazing



Laser Cut Panel

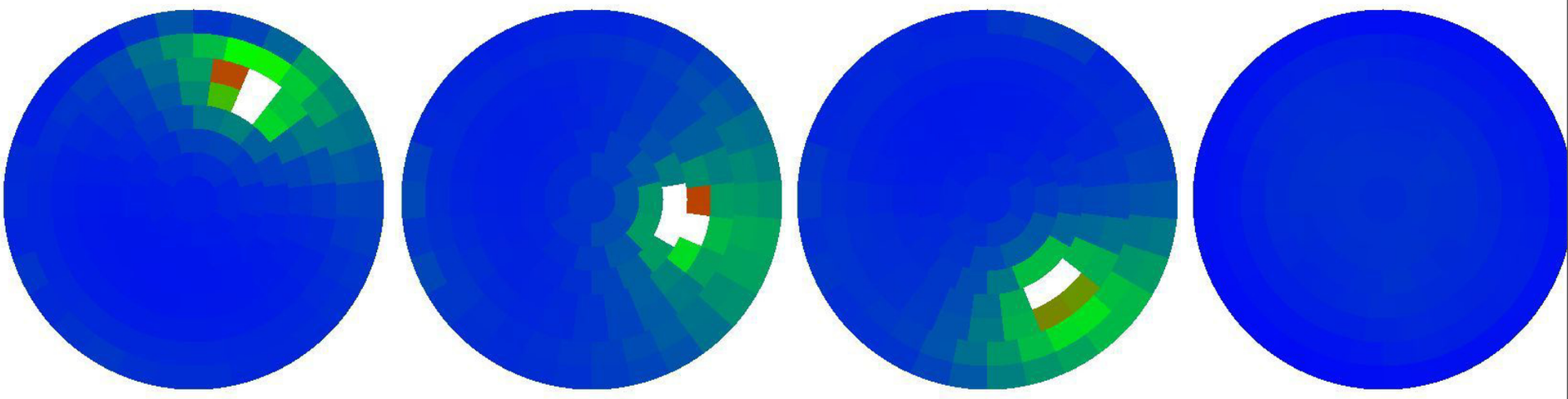


Prismatic Film

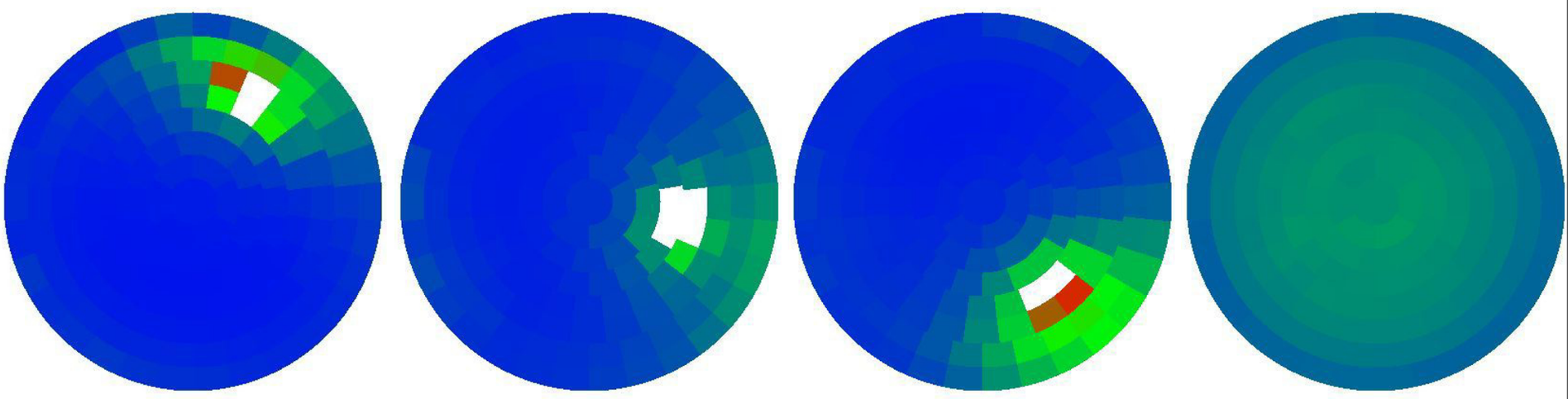


Real Building & model Case A

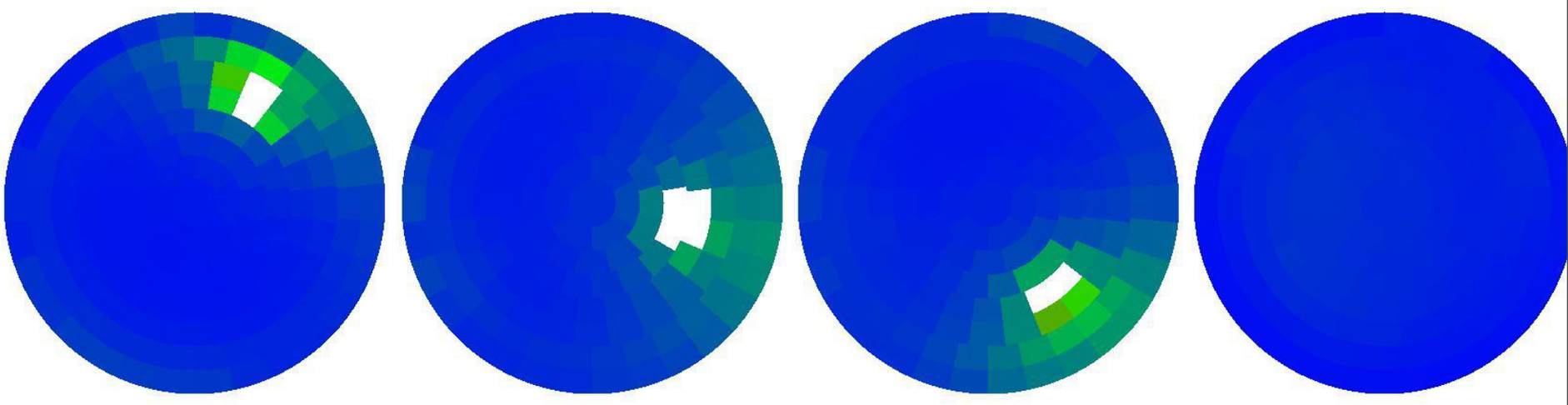
Double Glazing



Laser Cut Panel

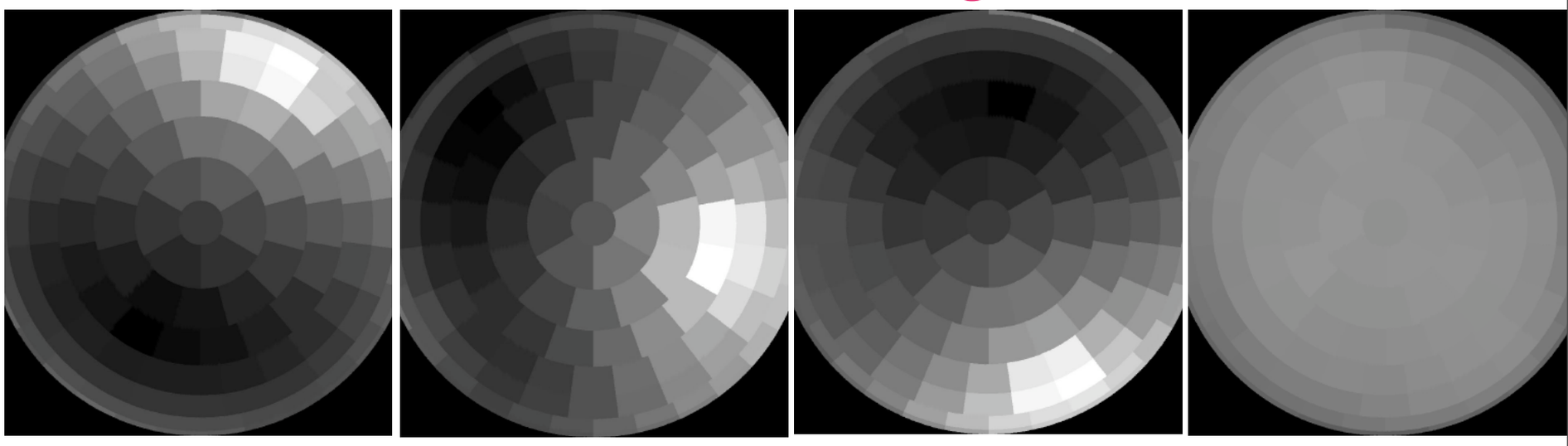


Prismatic Film

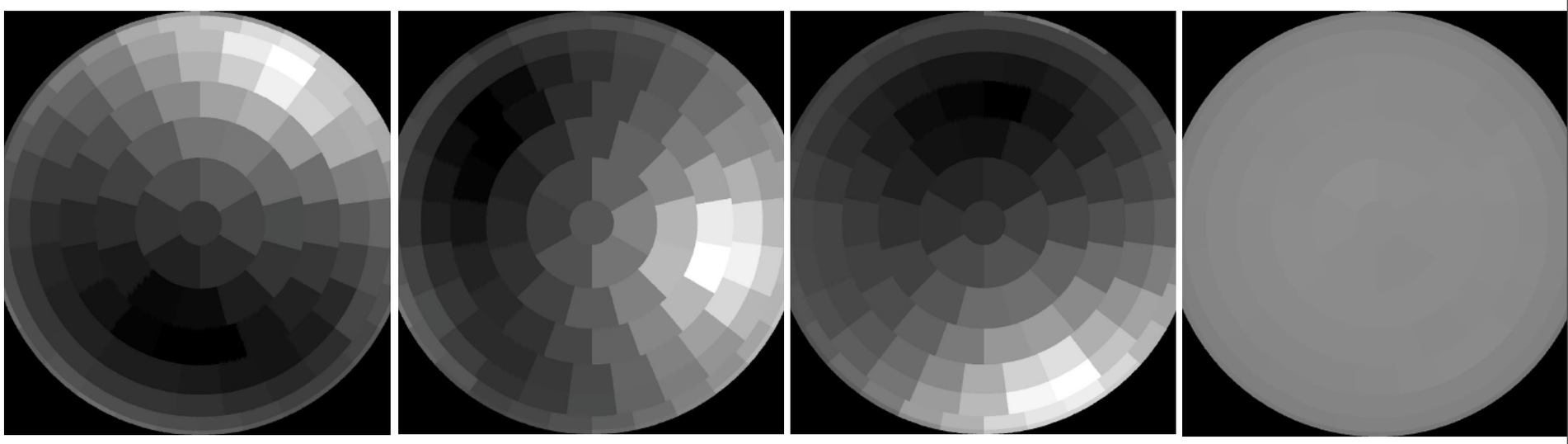


Sky luminance (sky scanner)

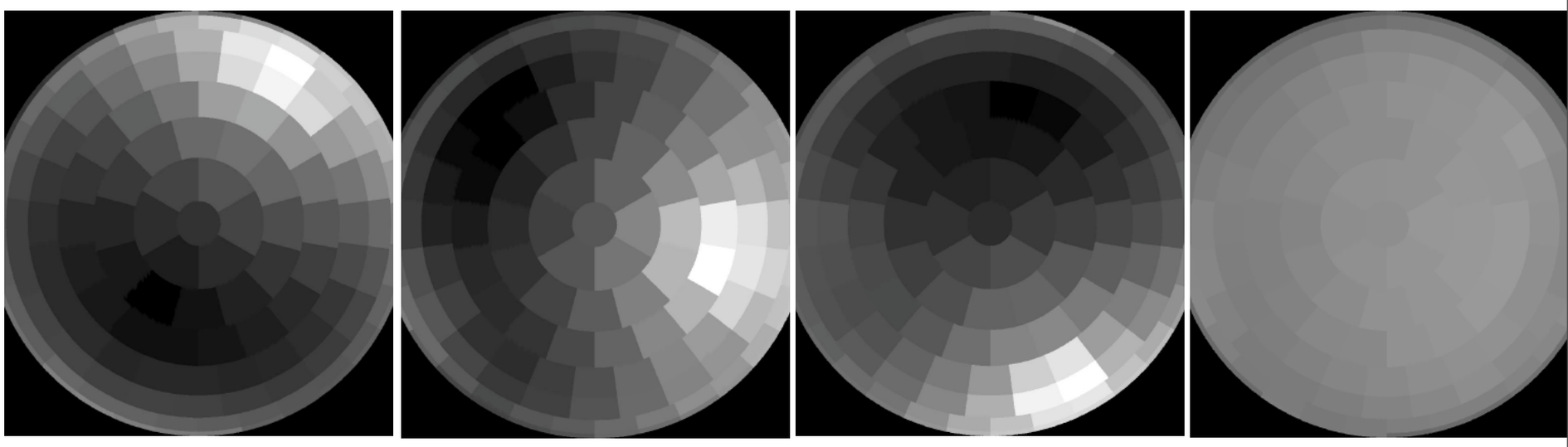
Double Glazing



Laser Cut Panel

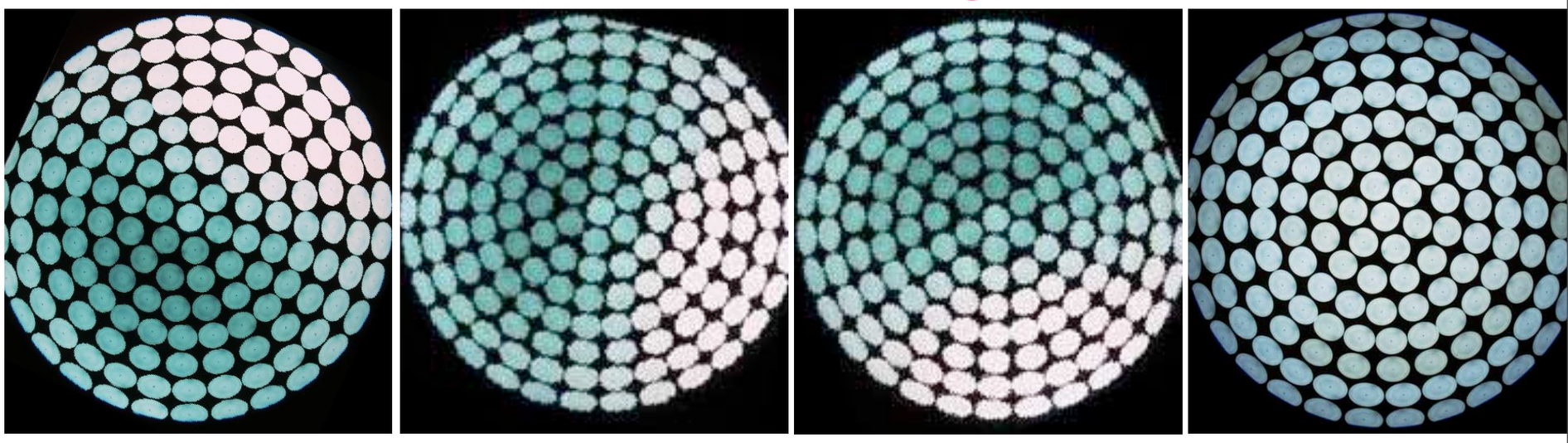


Prismatic Film

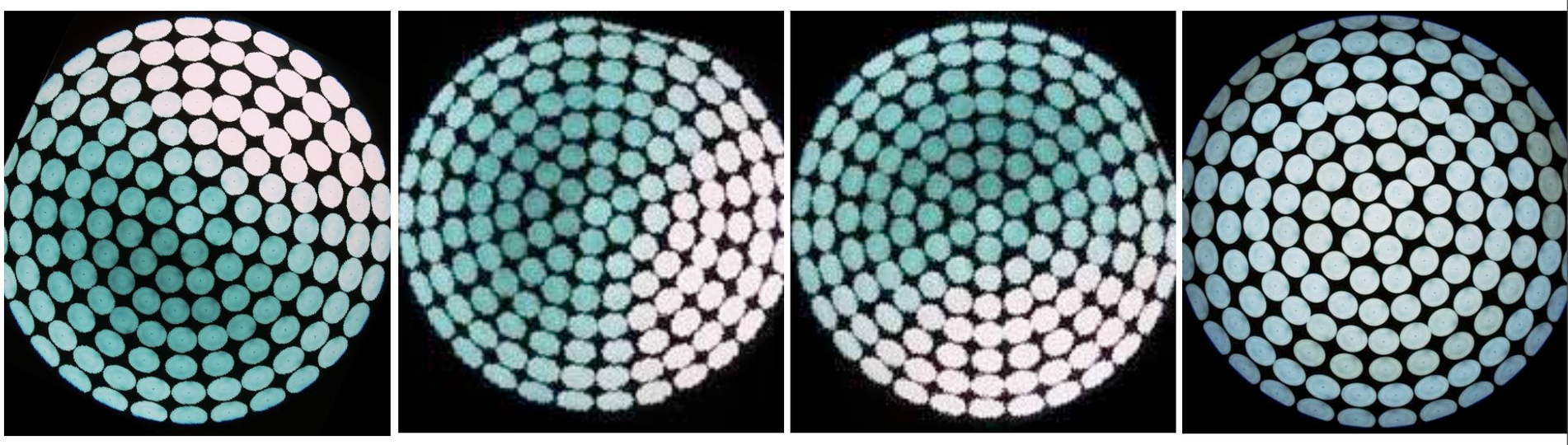


Virtual model Case E

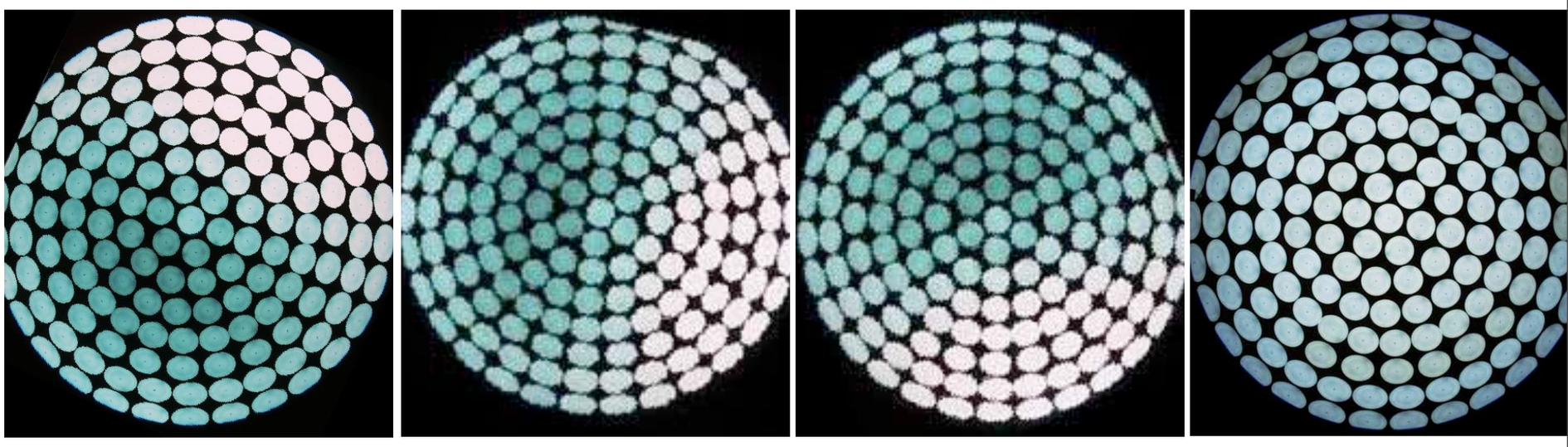
Double Glazing



Laser Cut Panel

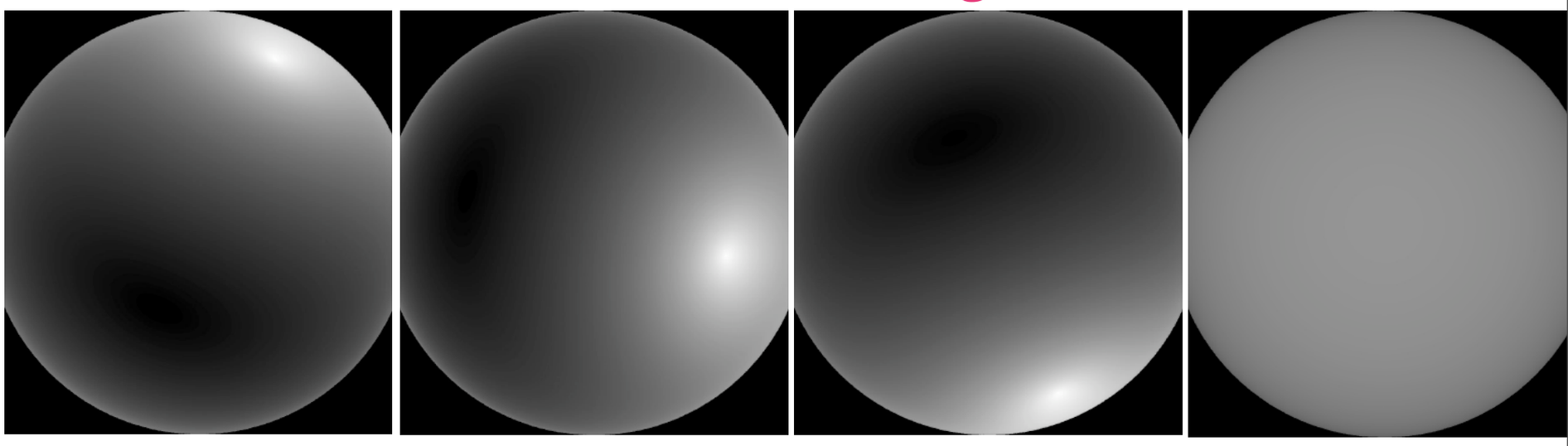


Prismatic Film

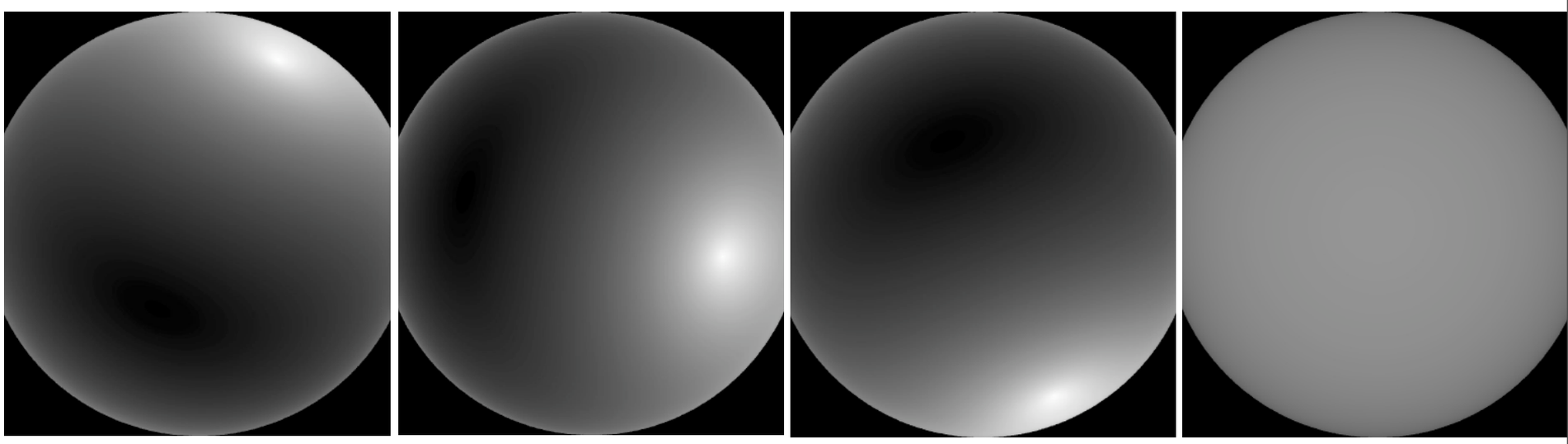


Scale model Case B

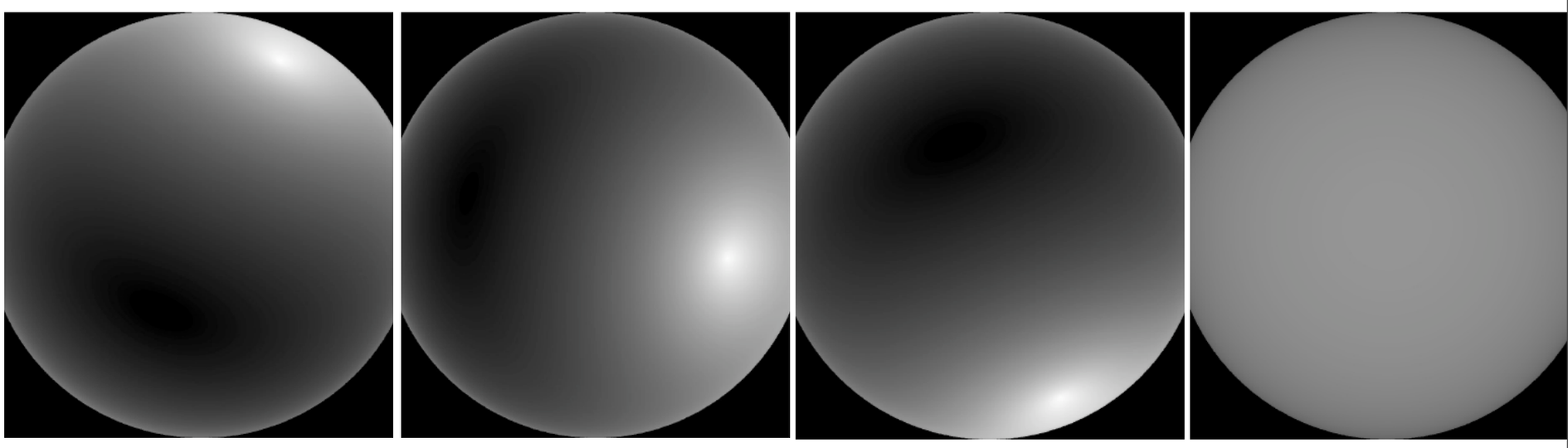
Double Glazing



Laser Cut Panel



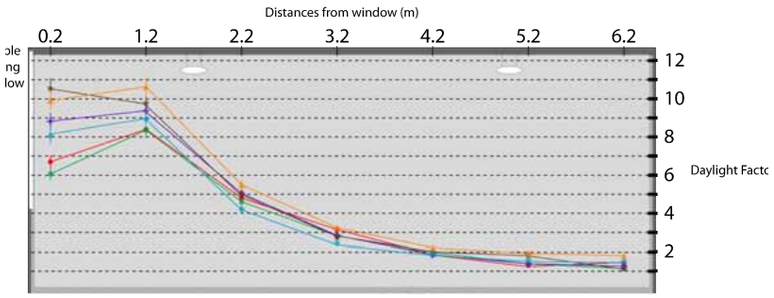
Prismatic Film



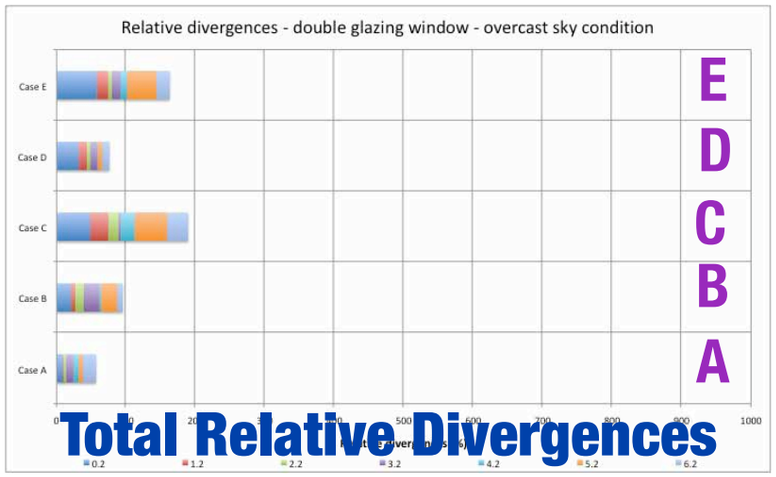
Virtual model Case D

Overcast sky

Double Glazing

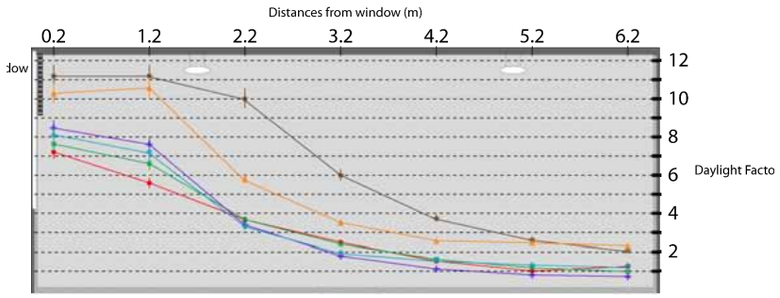


							Daylight Facto
6.68	8.41	4.80	3.15	1.84	1.31	1.40	Real Building
6.06	8.36	4.61	2.82	1.98	1.39	1.14	Case A
8.06	8.94	4.22	2.44	1.89	1.61	1.51	Case B
9.91	10.63	5.50	3.25	2.21	1.92	1.82	Case C
8.83	9.37	5.05	2.83	1.86	1.39	1.26	Case D
10.56	9.79	5.05	2.76	2.02	1.86	1.14	Case E

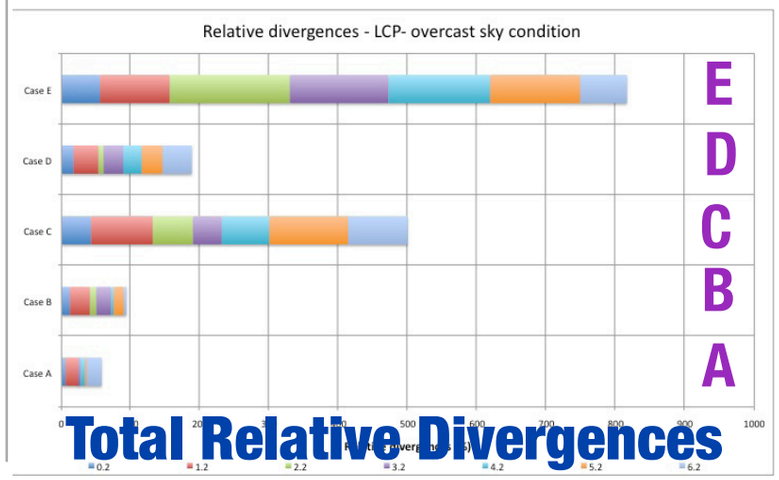


Total Relative Divergences

Laser Cut Panel

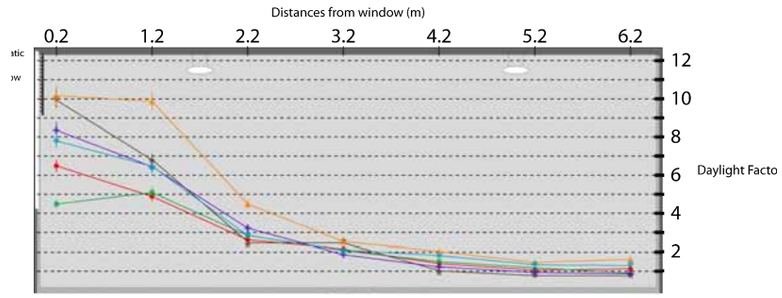


							Daylight Factor
7.21	5.60	3.67	2.49	1.52	1.15	1.24	Real Building
7.64	6.60	3.67	2.39	1.62	1.18	0.98	Case A
8.09	7.22	3.33	1.96	1.58	1.32	1.29	Case B
10.29	10.57	5.81	3.52	2.57	2.46	2.31	Case C
8.47	7.61	3.40	1.79	1.12	0.80	0.72	Case D
11.23	11.23	10.03	6.03	3.76	2.65	2.08	Case E

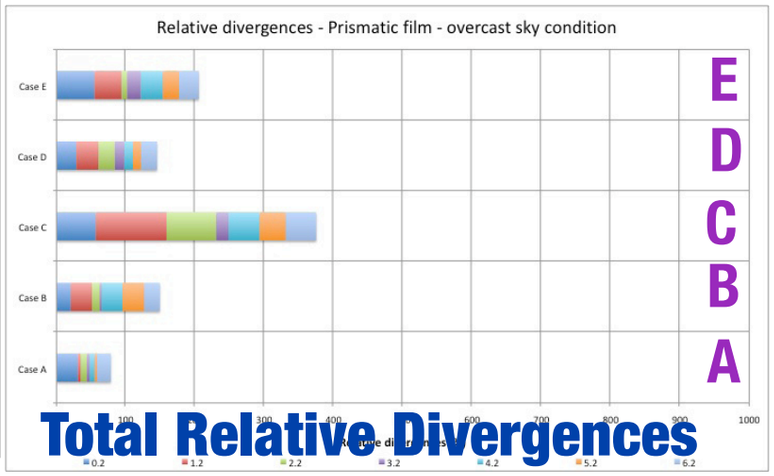


Total Relative Divergences

Prismatic Film



							Daylight Factor
6.49	4.88	2.61	2.15	1.40	1.06	1.13	Real Building
4.49	5.09	2.85	2.07	1.50	1.09	0.90	Case A
7.82	6.38	2.91	2.09	1.82	1.39	1.38	Case B
10.17	9.87	4.49	2.53	2.03	1.46	1.62	Case C
8.35	6.45	3.23	1.86	1.23	0.93	0.87	Case D
10.05	6.79	2.40	2.57	0.96	0.81	0.81	Case E



Total Relative Divergences

Case A – the most accurate
Case C, E, PDF methods – greater errors
More errors for assessments of CFS
Errors appeared near the window

E : Virtual model, PDF sky
D : Virtual model, Standard sky
C : Scale model, PDF sky
B : Scale model, Standard sky
A : Scale model, Real sky

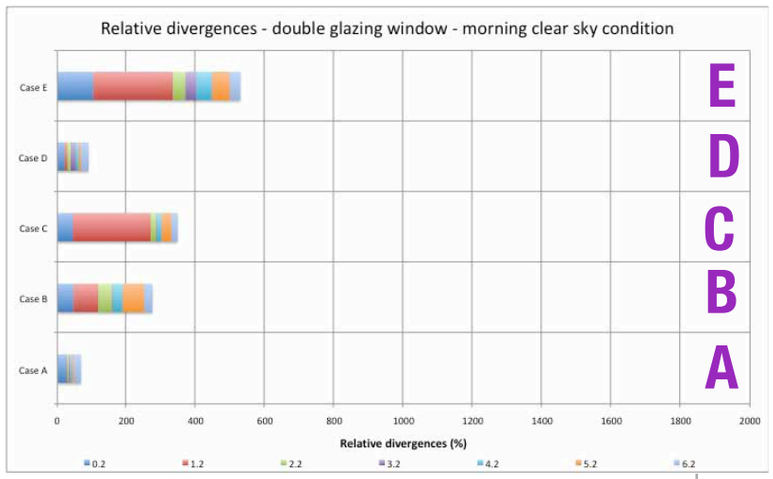
Clear sky

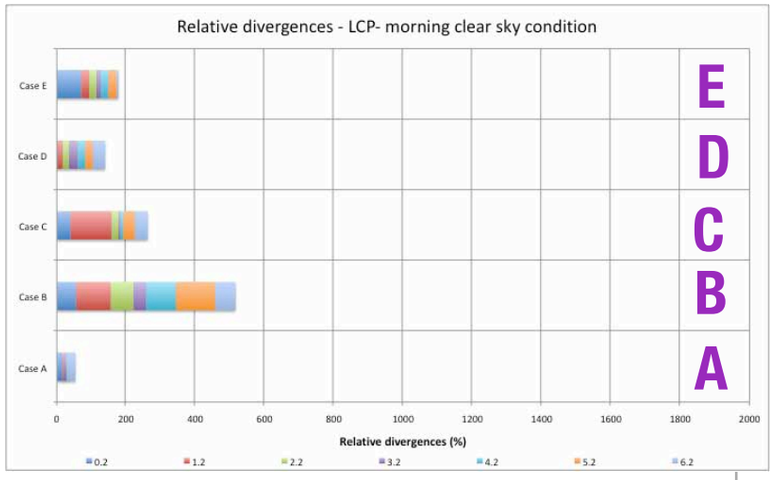
Double Glazing

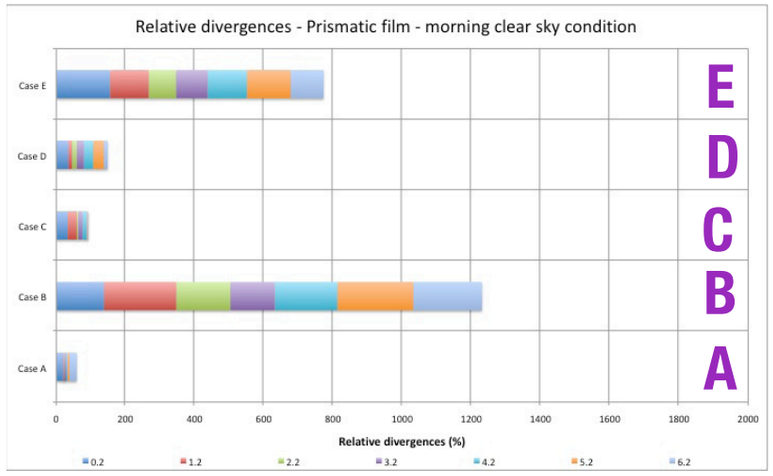
Laser Cut Panel

Prismatic Film

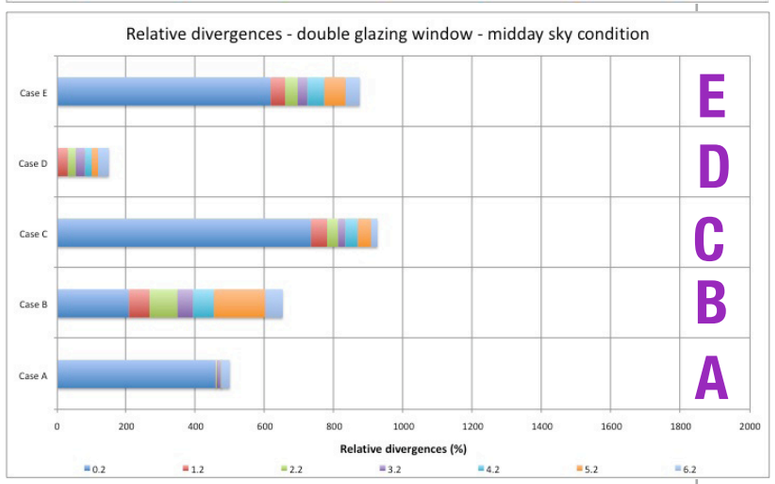
Morning

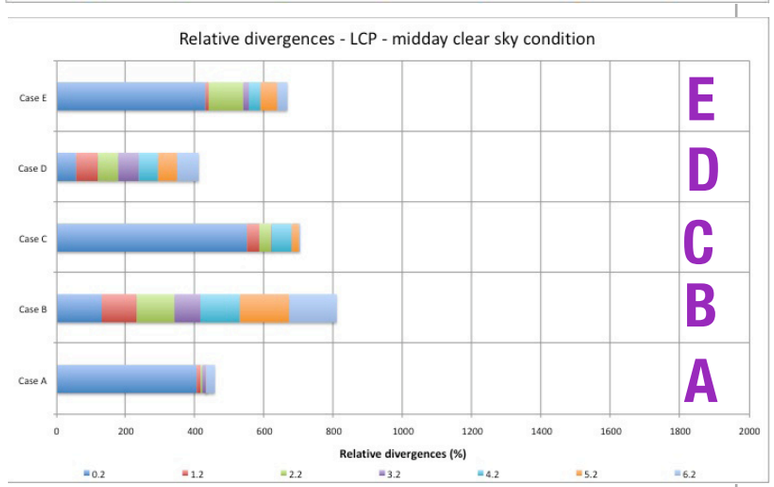


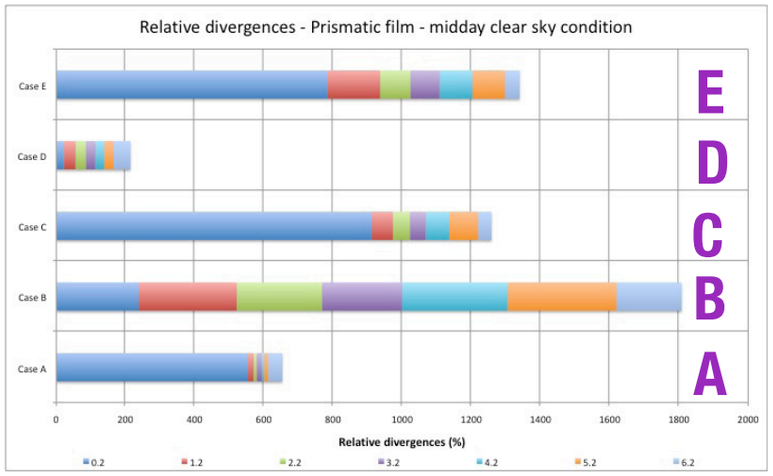




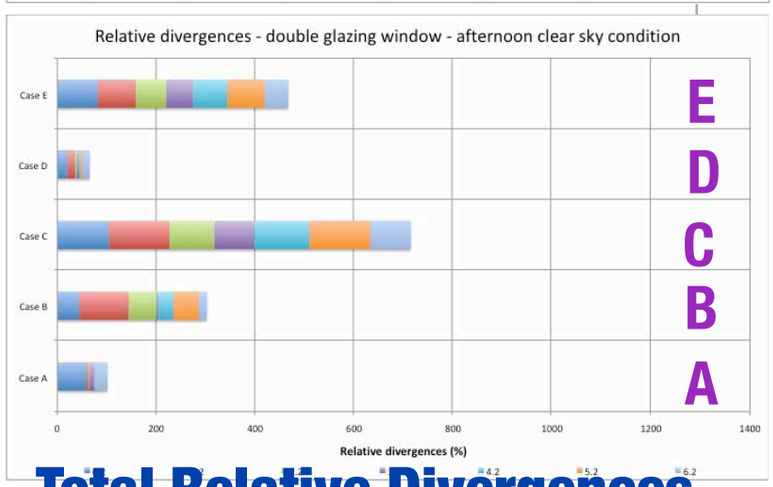
Midday

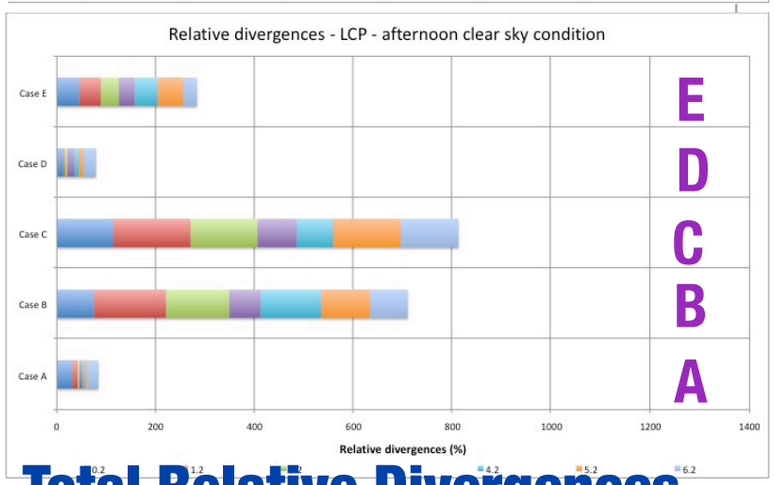


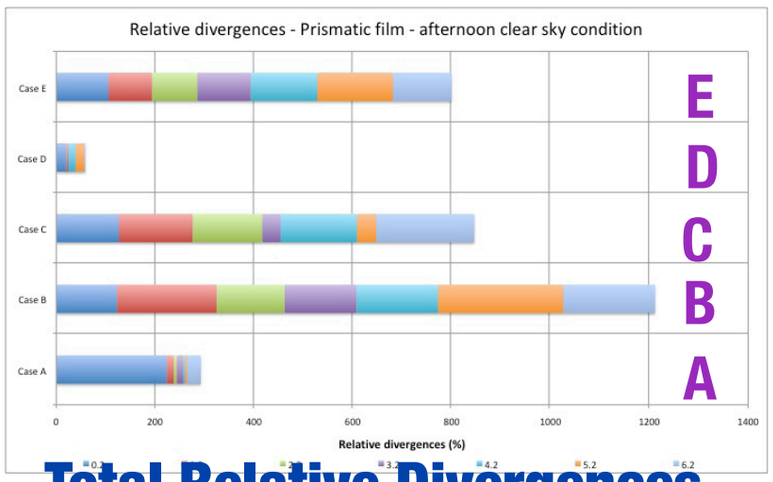




Afternoon







Total Relative Divergences

Total Relative Divergences

Total Relative Divergences

E : Virtual model, PDF sky

D : Virtual model, Standard sky

C : Scale model, PDF sky

B : Scale model, Standard sky

A : Scale model, Real sky

Sensitivity study

Set 1 : Window dimension

Set 2 : Model dimension

Set 3 : Model details

Set 4 : Surface photometry

Set 5 : Ground photometry

Set 6 : Window photometry

Set 7 : Sensor's sensitive area

Set 8, 9 : Sensor placement

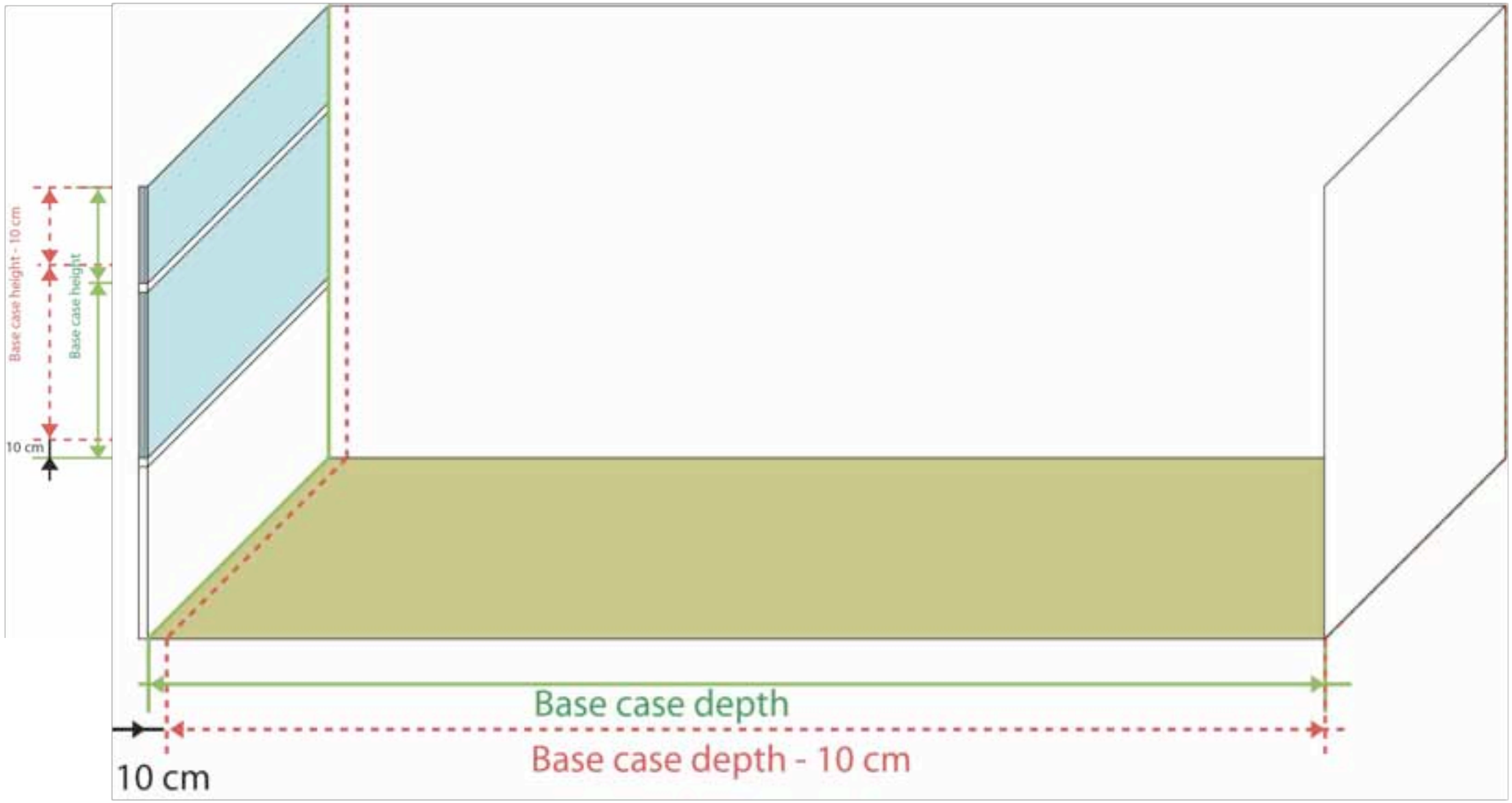
Set 10, 11 : Sensor positioning

Simulation parameters

ab = 9
aa = 0.1
ad = 26315
ar = 128

CIE standard sky (Gensky)
– Overcast sky
– Clear sky (16CEST)

Sets of Parameters

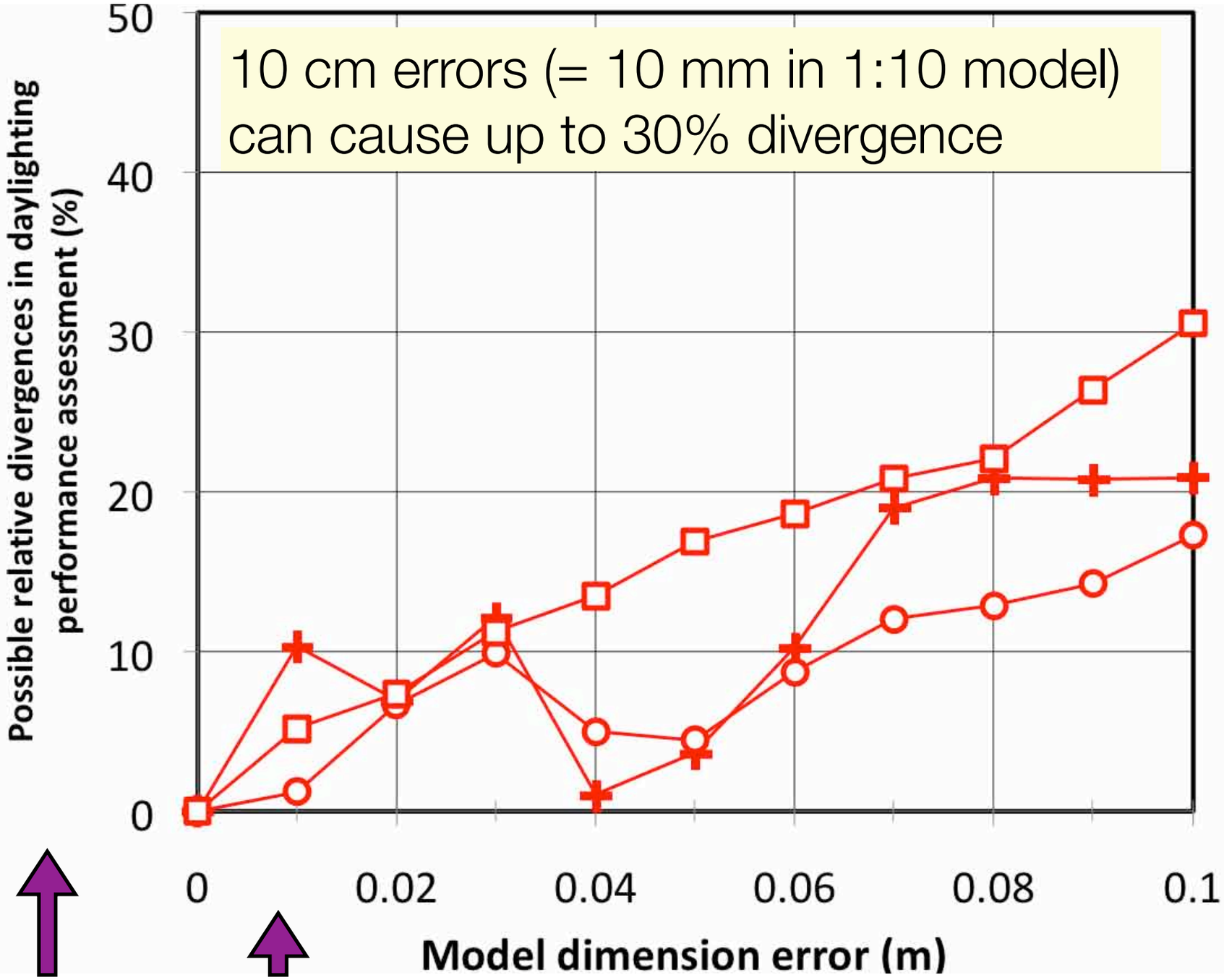


Set 1 : Window dimensions

Set 2 : Model dimensions

Prismatic Film

Overcast sky



Relative errors (%)

Depth errors (m)

6.2

3.2

0.2

Measured points

6.2 m from window

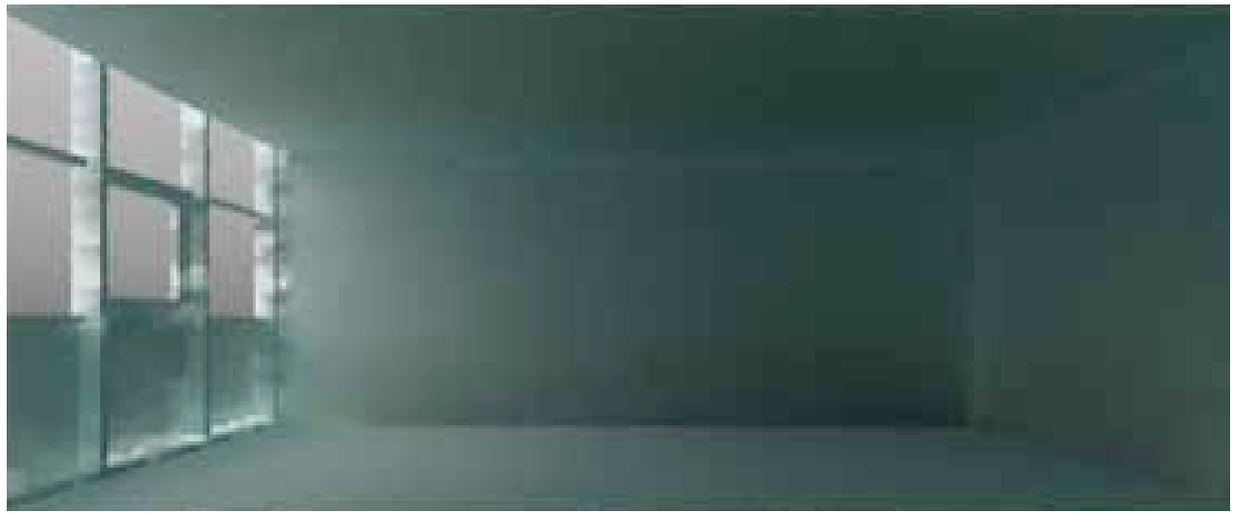
3.2 m from window

0.2 m from window

Set 2 : Model dimensions

Base case

No lighting fixtures



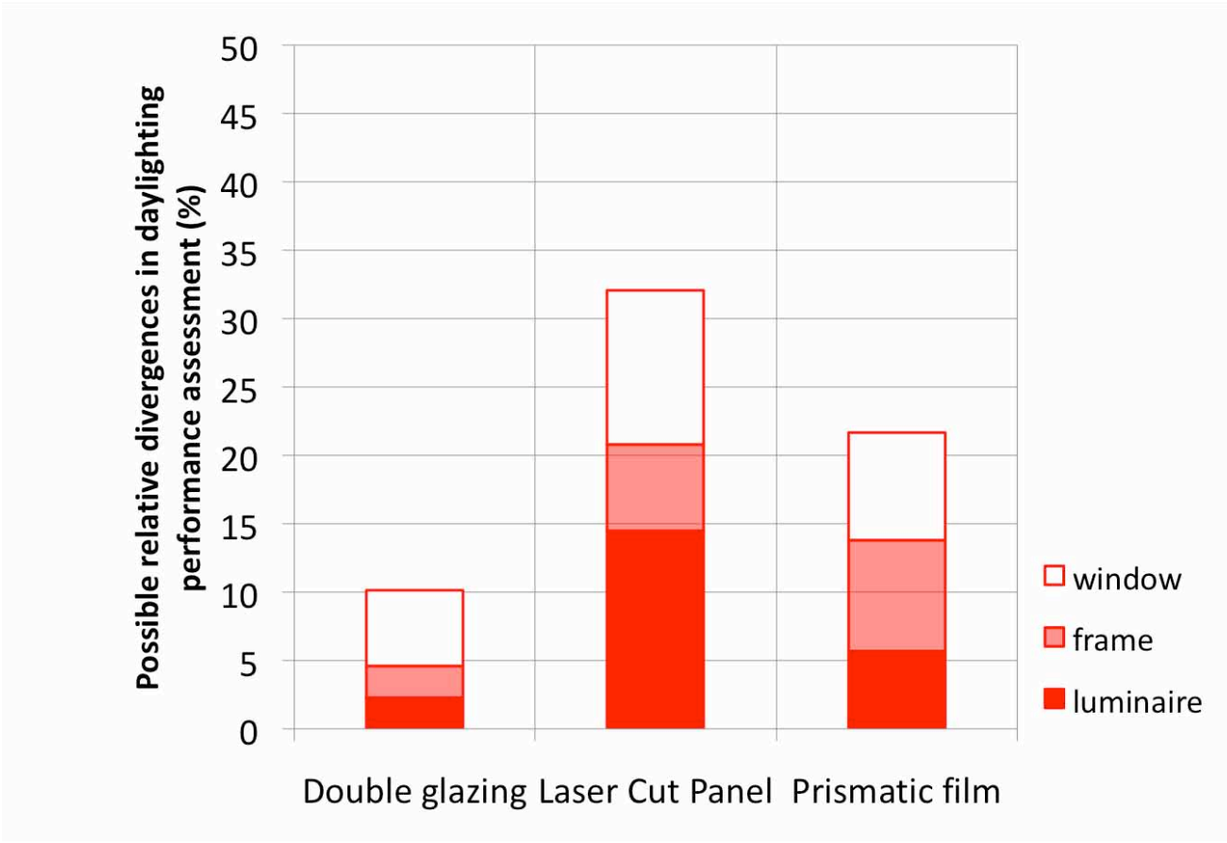
Base case

Only window frame

Without window frame

Set 3 : Model details

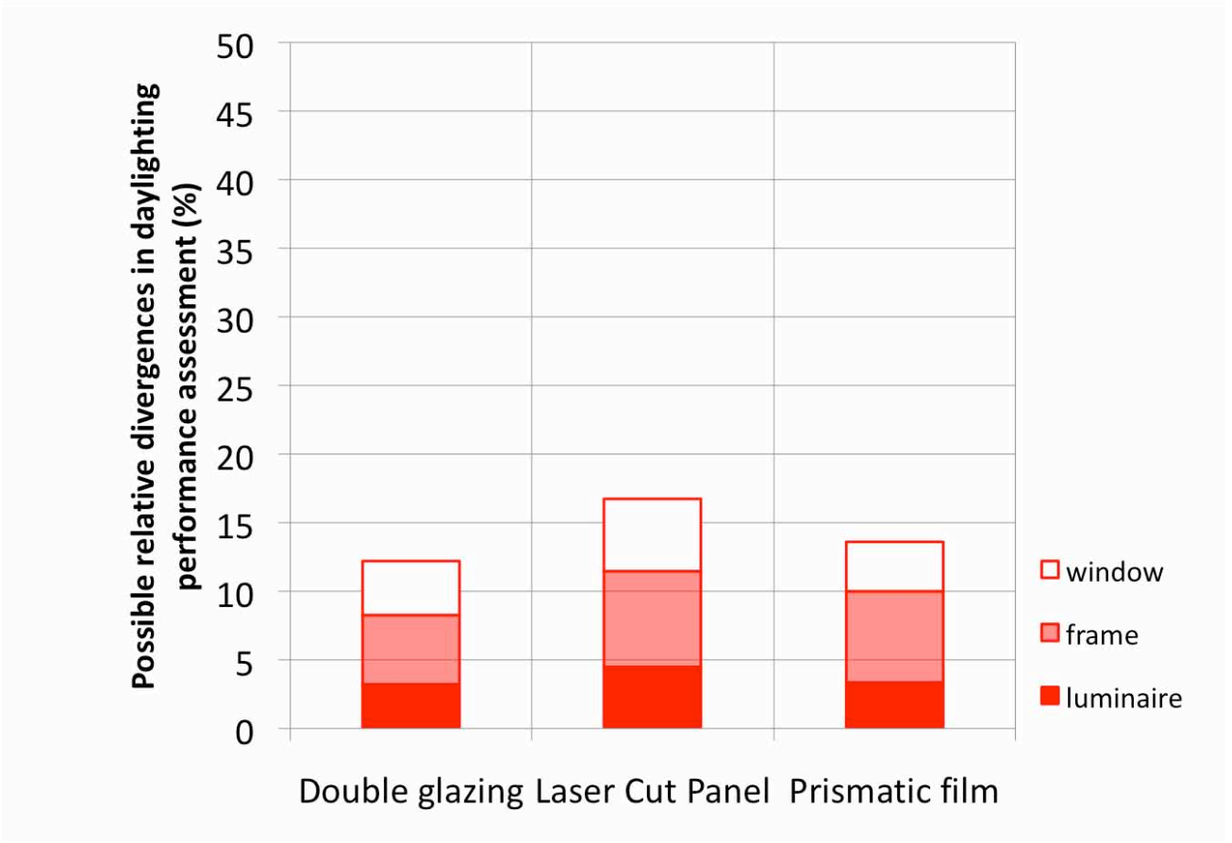
Overcast sky



Relative errors (%)

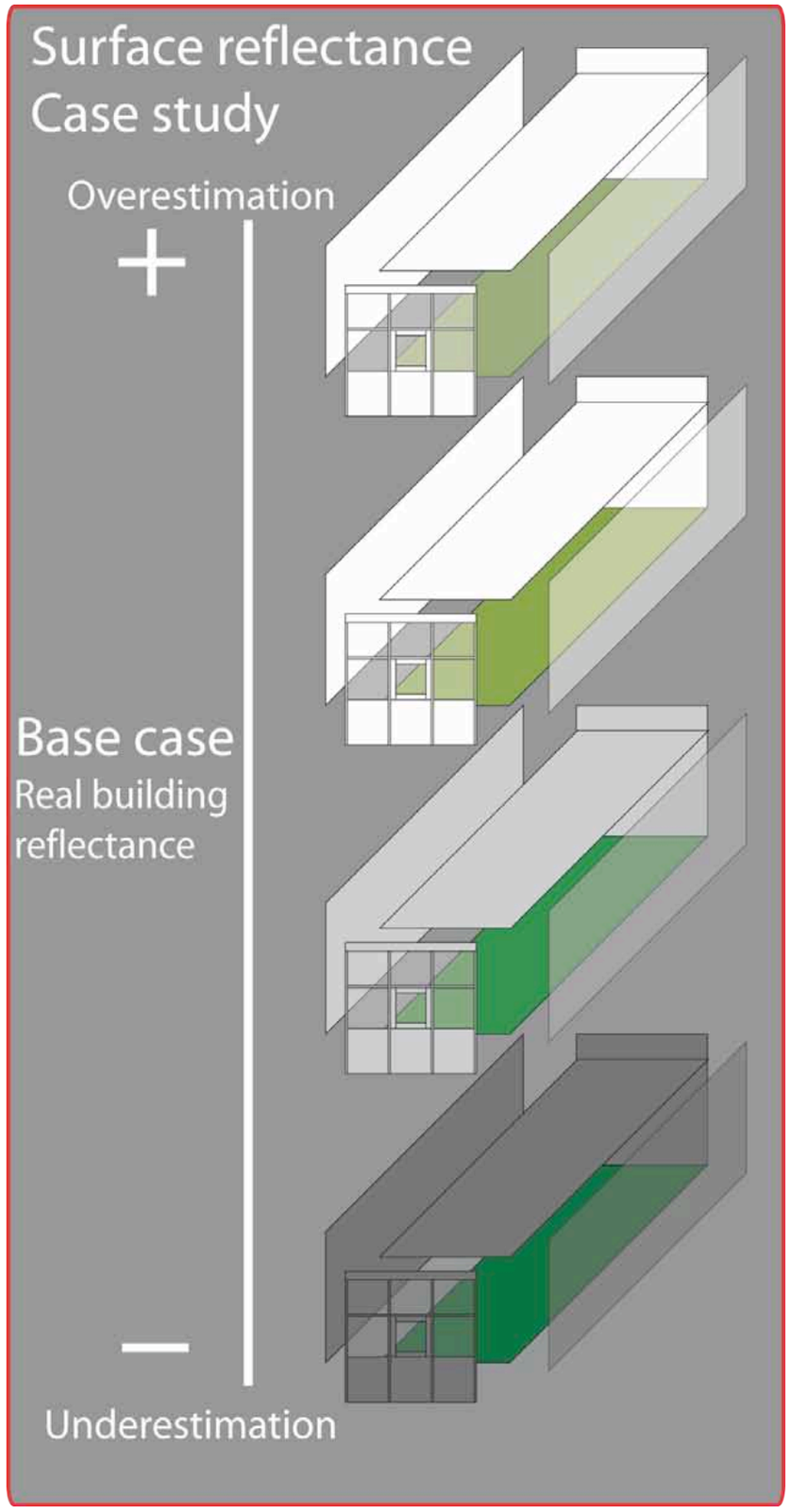
Fenestration systems

Clear sky

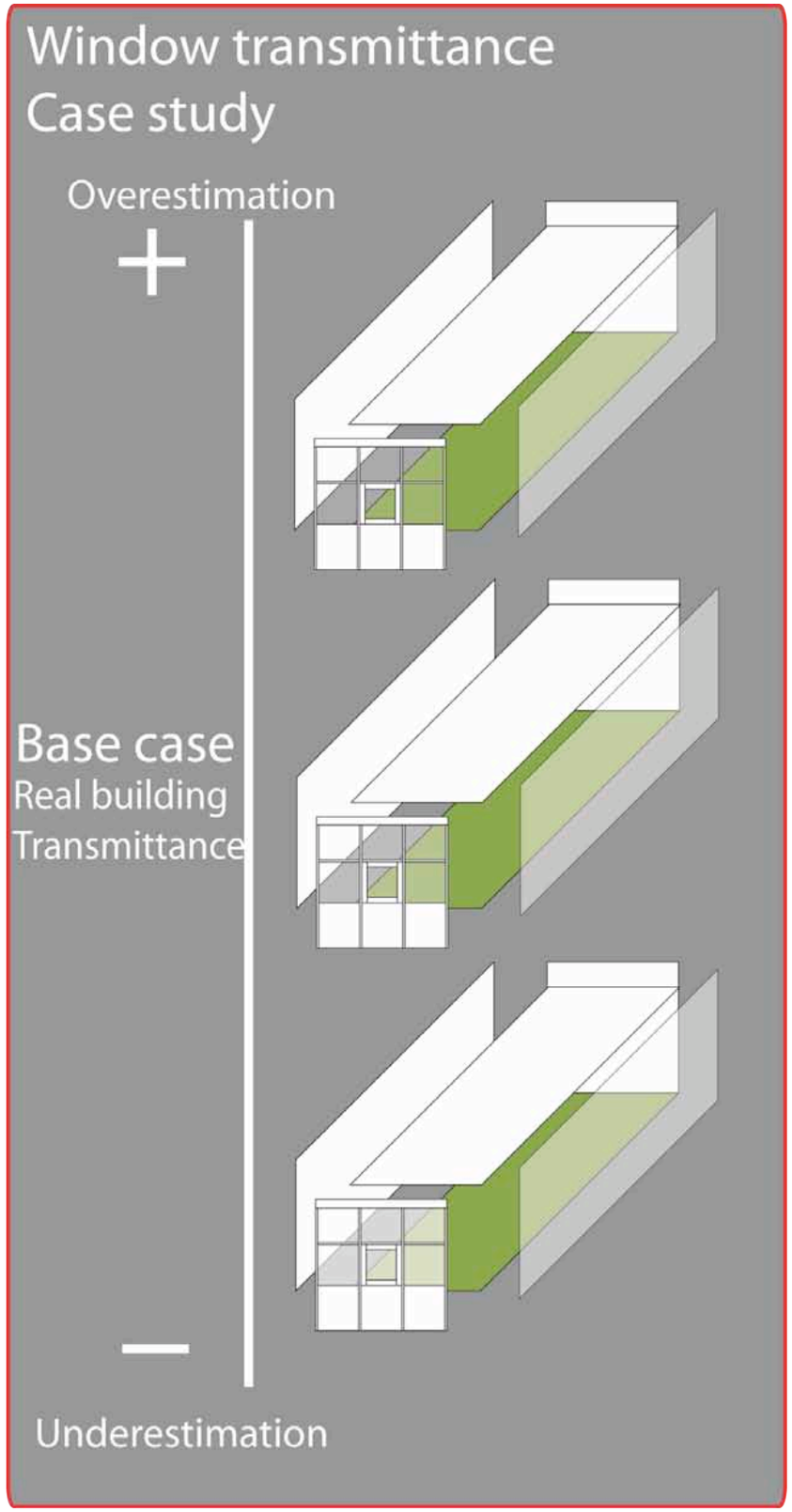


Errors in model critical details result in greater divergences under overcast sky conditions, particularly with CFS

Set 3 : Model details



Set 4 : Surface Reflectance

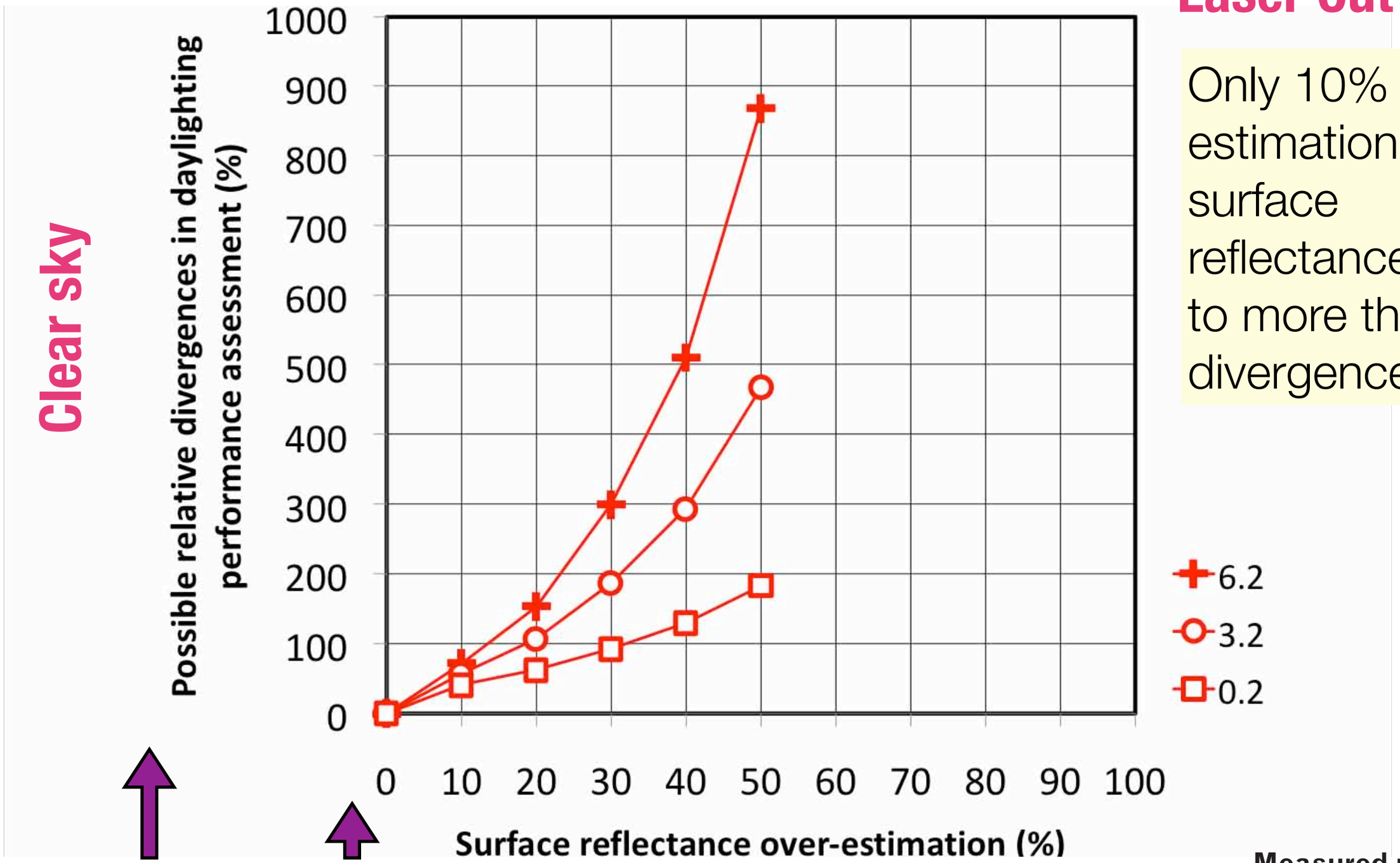


Set 6 : Window Transmittance

Laser Cut Panel

Only 10% over-estimation of surface reflectance leads to more than 40% divergence

Clear sky



Relative errors (%)

Over-estimation (%)

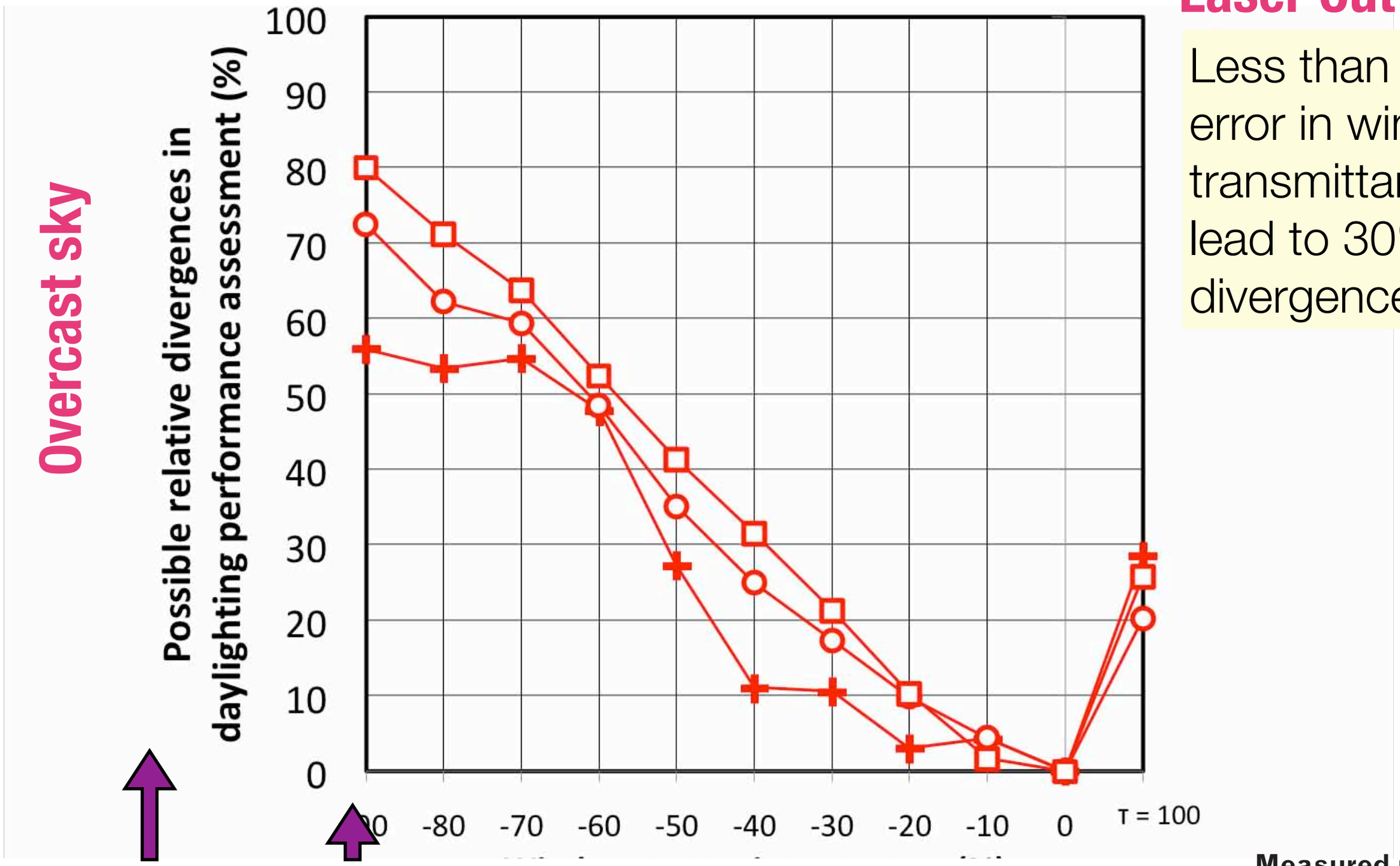
Measured points

- 6.2 m from window
- 3.2 m from window
- 0.2 m from window

Set 4 : Surface Reflectance (Over-estimation)

Laser Cut Panel

Less than 30% error in window transmittance can lead to 30% divergence



Set 6 : Window Transmittance

Main causes of errors in daylighting performance assessment

Modelling
– Geometric properties
– Photometric properties
– Photometric sensors
– CFS modelling

Sky luminance values
– Sky luminance distribution

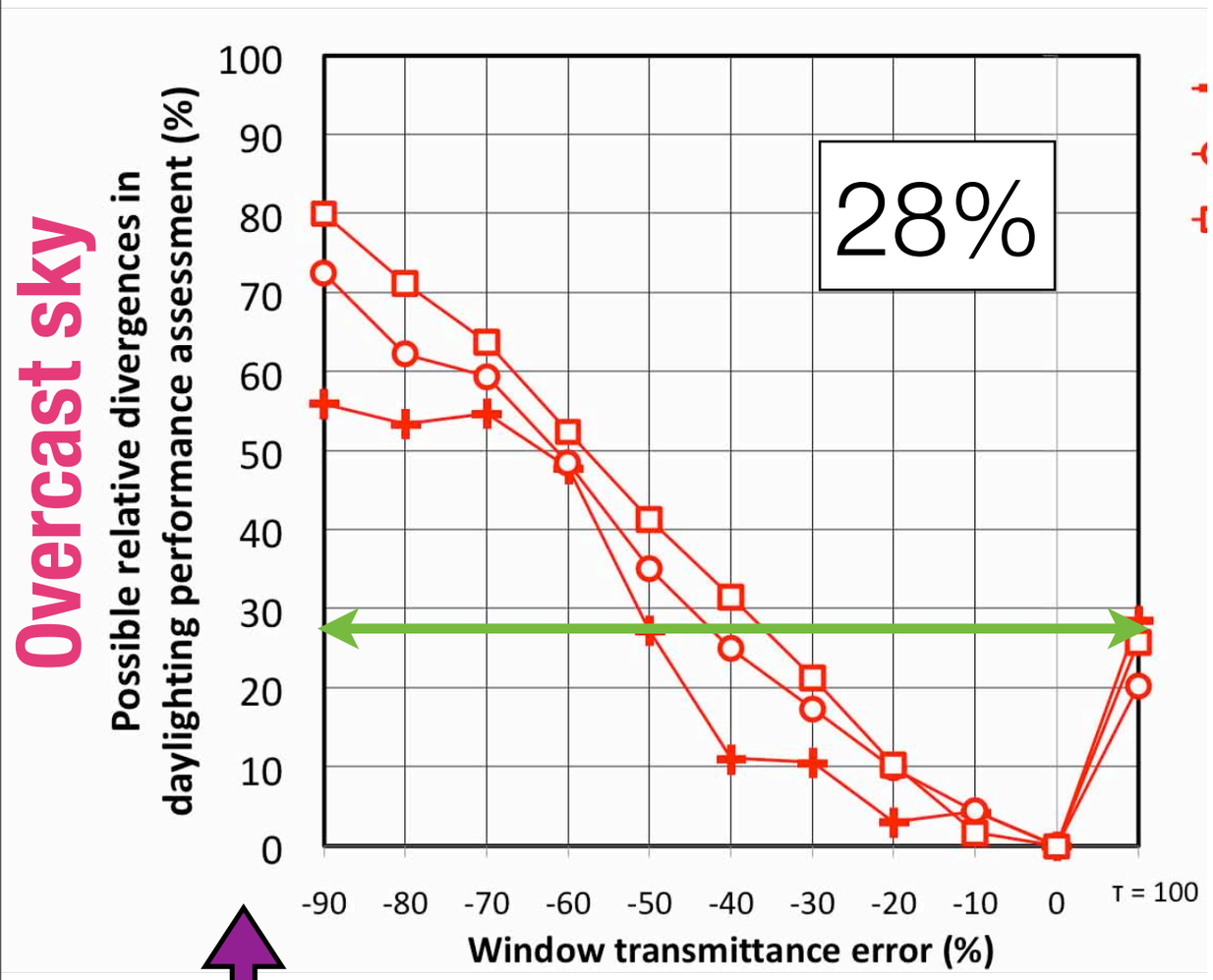
Daylight simulation
– Division of sky
– Sky type
– Sky luminance acquisition using sky scanner

Application

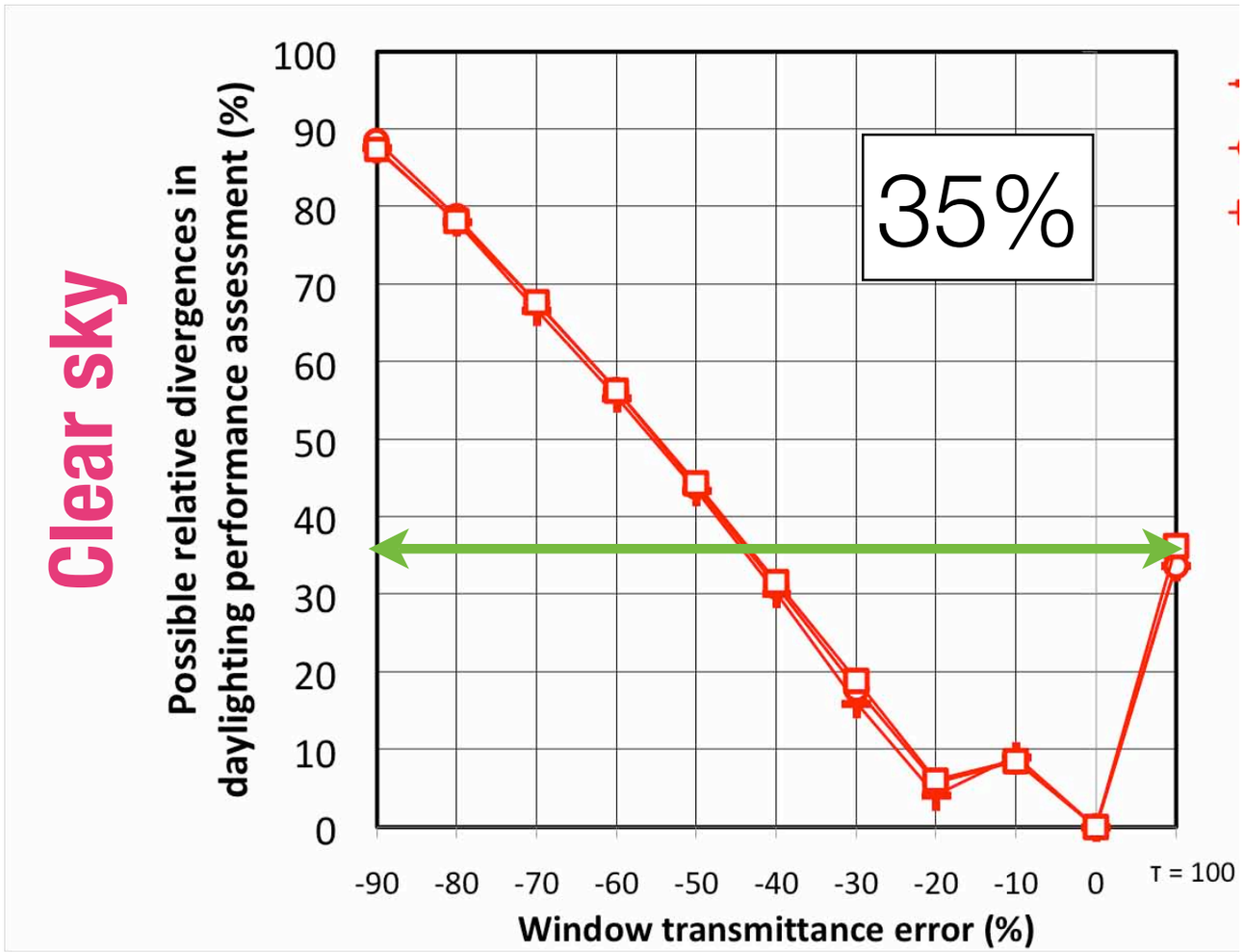
Source of error	Accuracy required from daylighting performance assessment					
	Accurate study model		**Moderate study model**		**Pilot study model**	
	Modelling Precision	Possible Relative error	Modelling Precision	Possible Relative error	Modelling Precision	Possible Relative error
Surface reflectance	+10%	<100%	+20%	<200%	>+20%	>200%
Glazing transmittance	+10%	<100%	+20%	<200%	>+20%	>200%
Daylight simulation	Real sky	-	Continuous sky	<50%	145 sky sectors	up to 250%

Checklist

Overcast sky



Clear sky



Relative errors (%)

Transmittance errors (%)

Measured points

- 6.2 m from window
- 3.2 m from window
- 0.2 m from window

Inaccuracy estimation

Set 6 : Window Transmittance

Conclusion

- **Accurate** model properties, particularly the **photometric properties** are **key factors** in daylighting performance assessment
  10% over-estimation -> 100% relative divergence

- Better understanding of the sources of errors **->** better construction/ fabrication of the physical model **->** better predictions
  error can be reduced by up to 200%

- Daylighting model checklist: To **minimize** the errors in the model

- Daylighting model charts: To **estimate** the errors in the assessment