15th International Radiance Workshop
Padova, 29-31 August 2016

Inter-model comparison of five CBDM techniques

Eleonora Brembilla & John Mardaljevic

School of Civil & Building Engineering
Loughborough University, UK

EPSRC
Engineering and Physical Sciences Research Council

Loughborough University

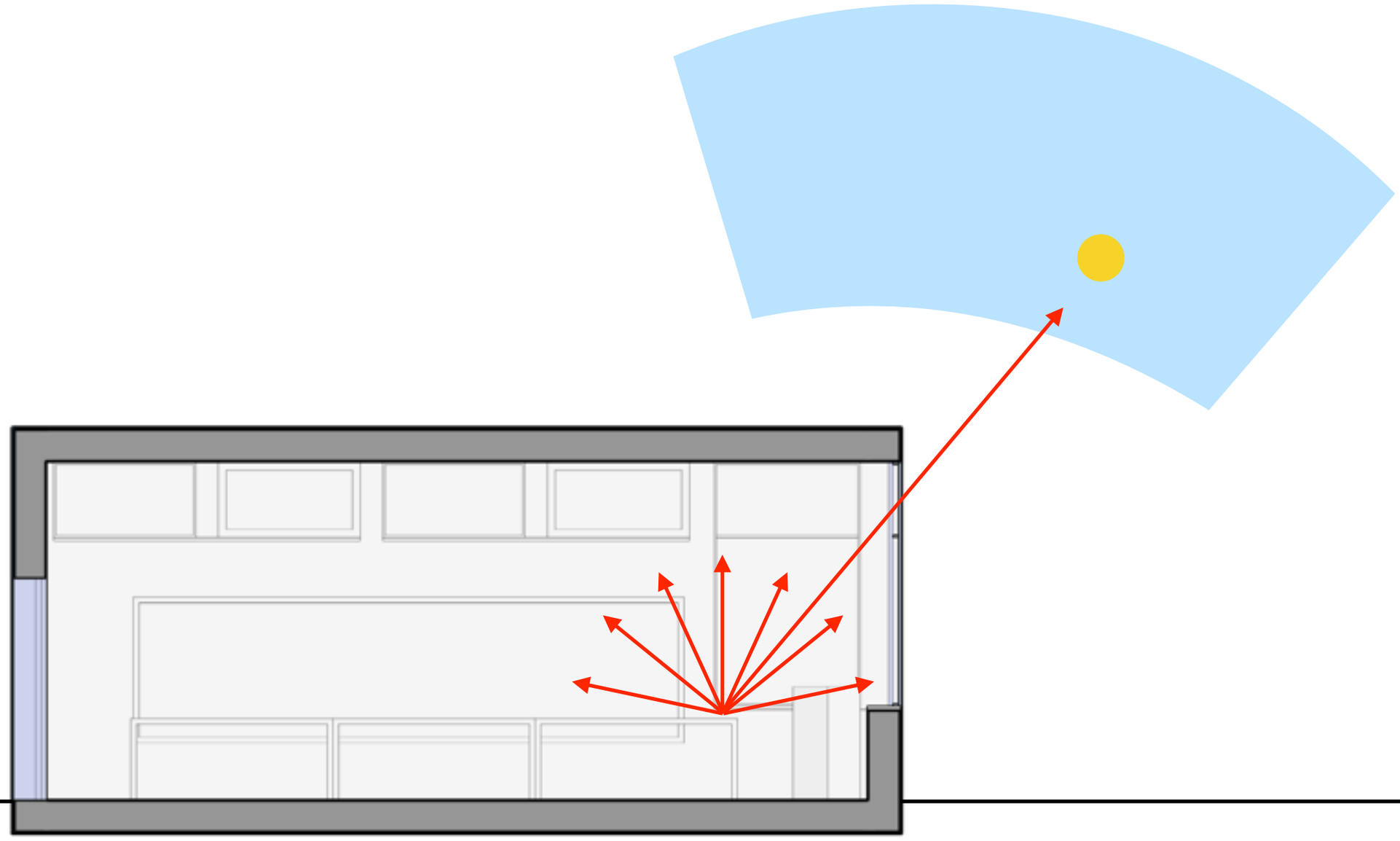
ARUP

Methods

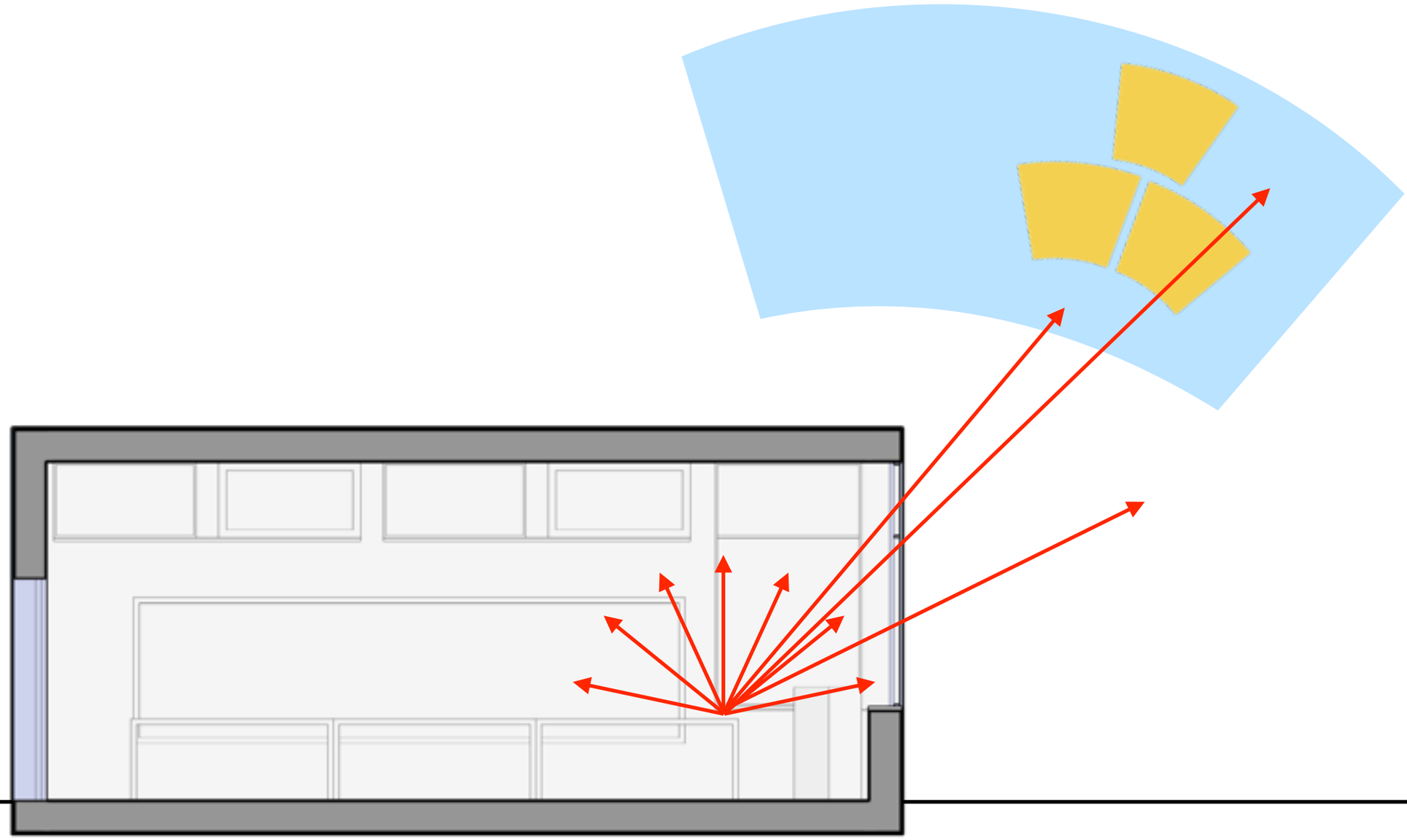
4CM	4-component Method
DAY	DAYSIM
2PM	*rtcontrib* ⇢ *rcontrib* ⇢ 2-phase Method
3PM	3-phase Method (4-phase Method)
5PM	5-phase Method (6-phase Method)

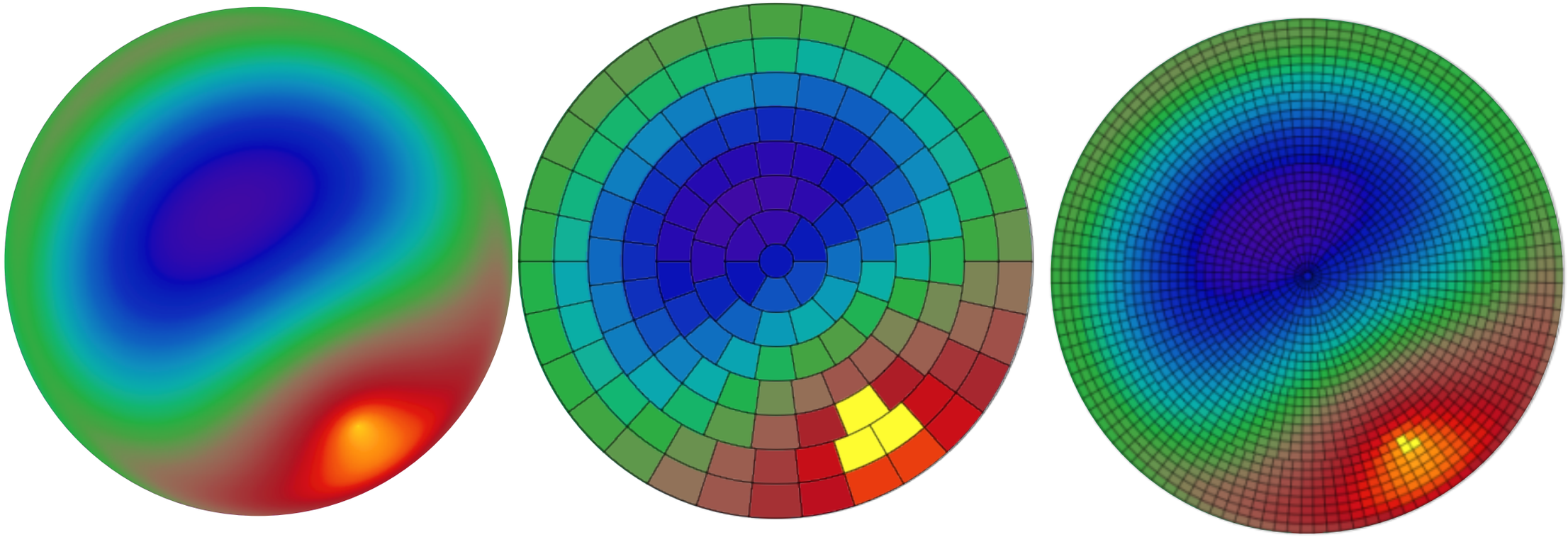
4CM

DAY

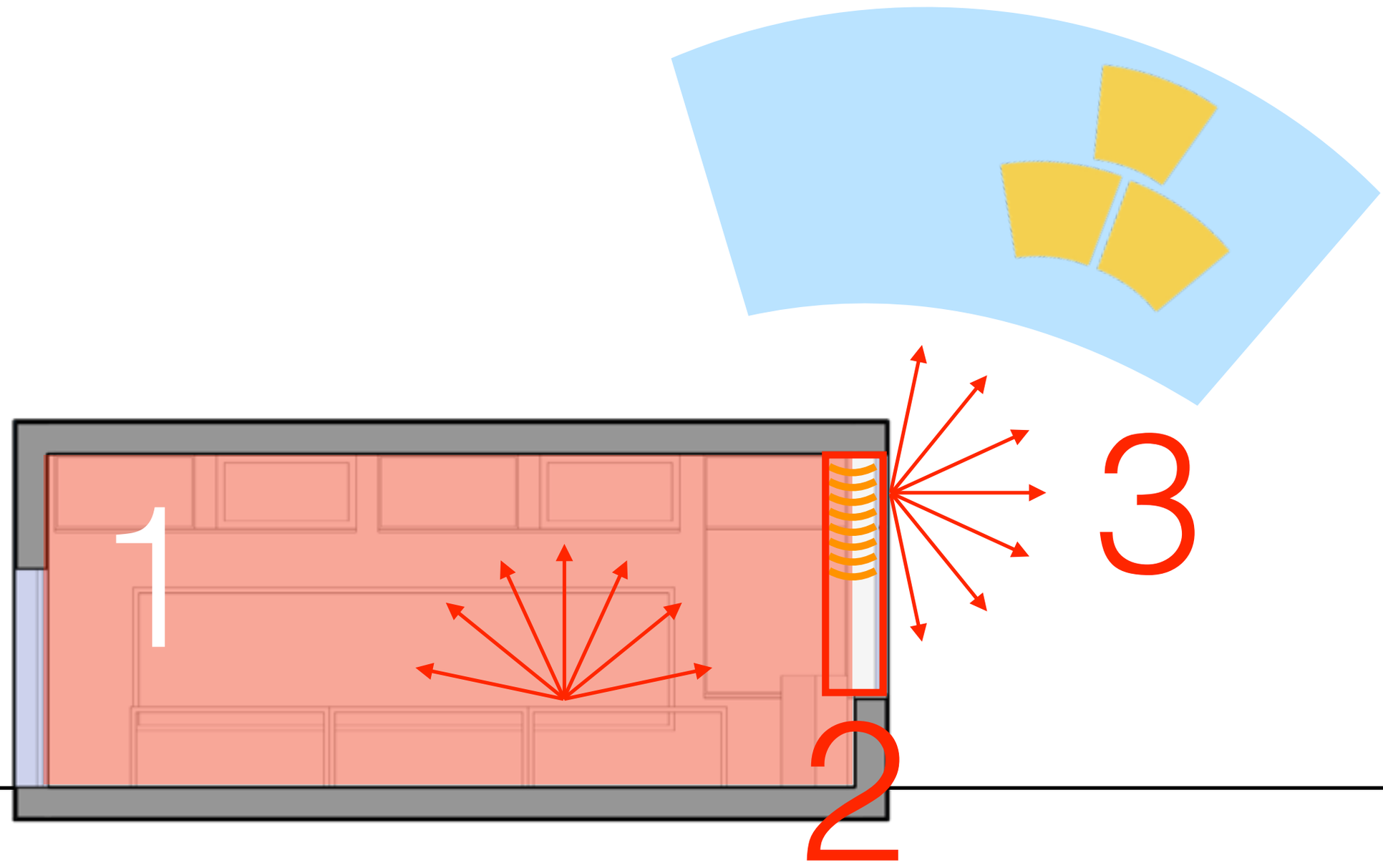


2PM



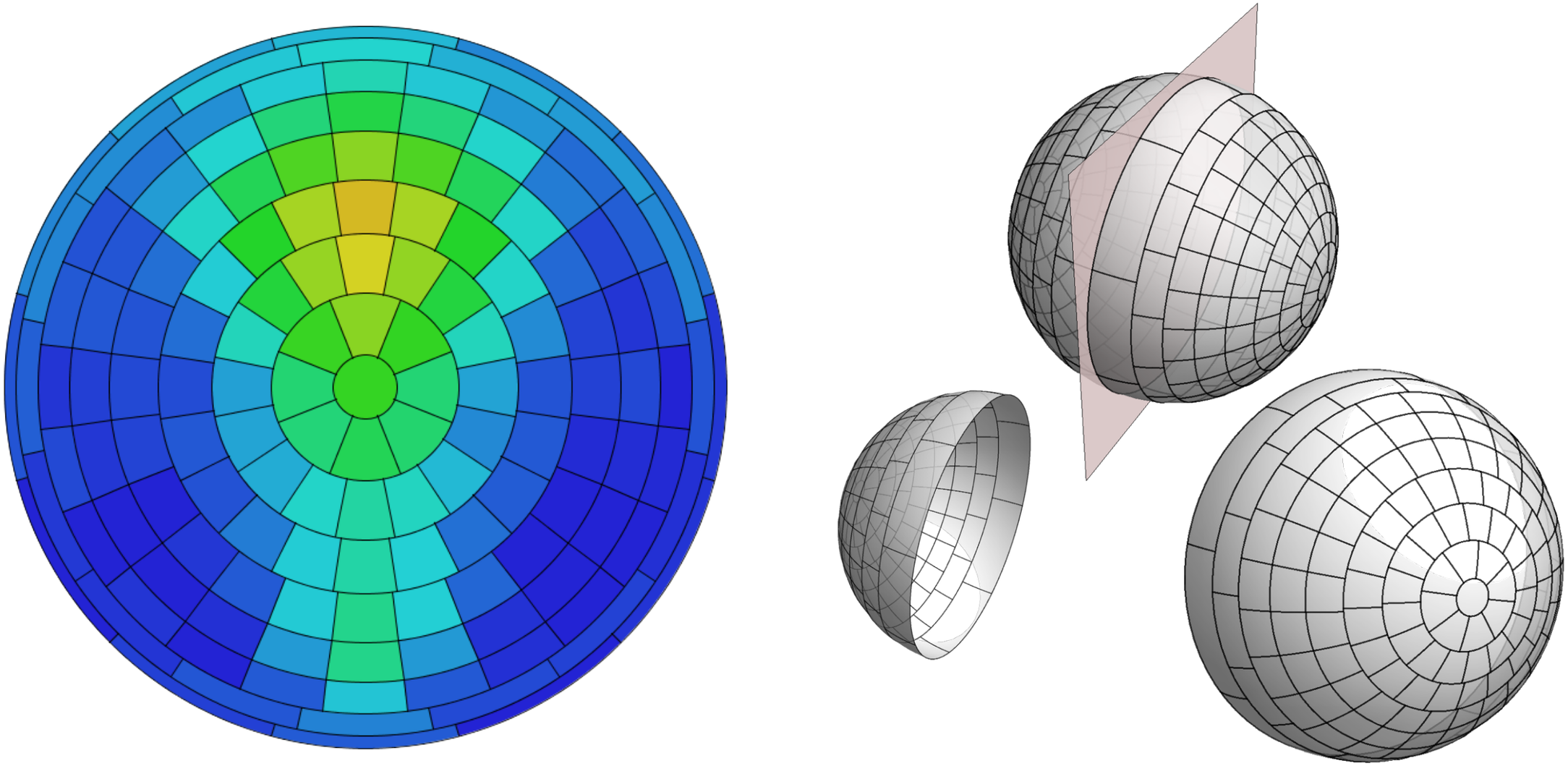

Sky luminance distribution
Tregenza
Reinhart MF:4
(a)
(b)
(c)
(d)
Tregenza
Reinhart MF:2
Reinhart MF:3
Reinhart MF:4

3PM



BSDF
Klems basis

BSDF = Bi-directional Scattering Distribution Function



Klems Angles Basis

145 patches entering + 145 patches exiting

Andy McNeil, '*BSDFs, Matrices and Phases'* (Radiance Workshop 2014, London)

BSDF = Bi-directional Scattering Distribution Function

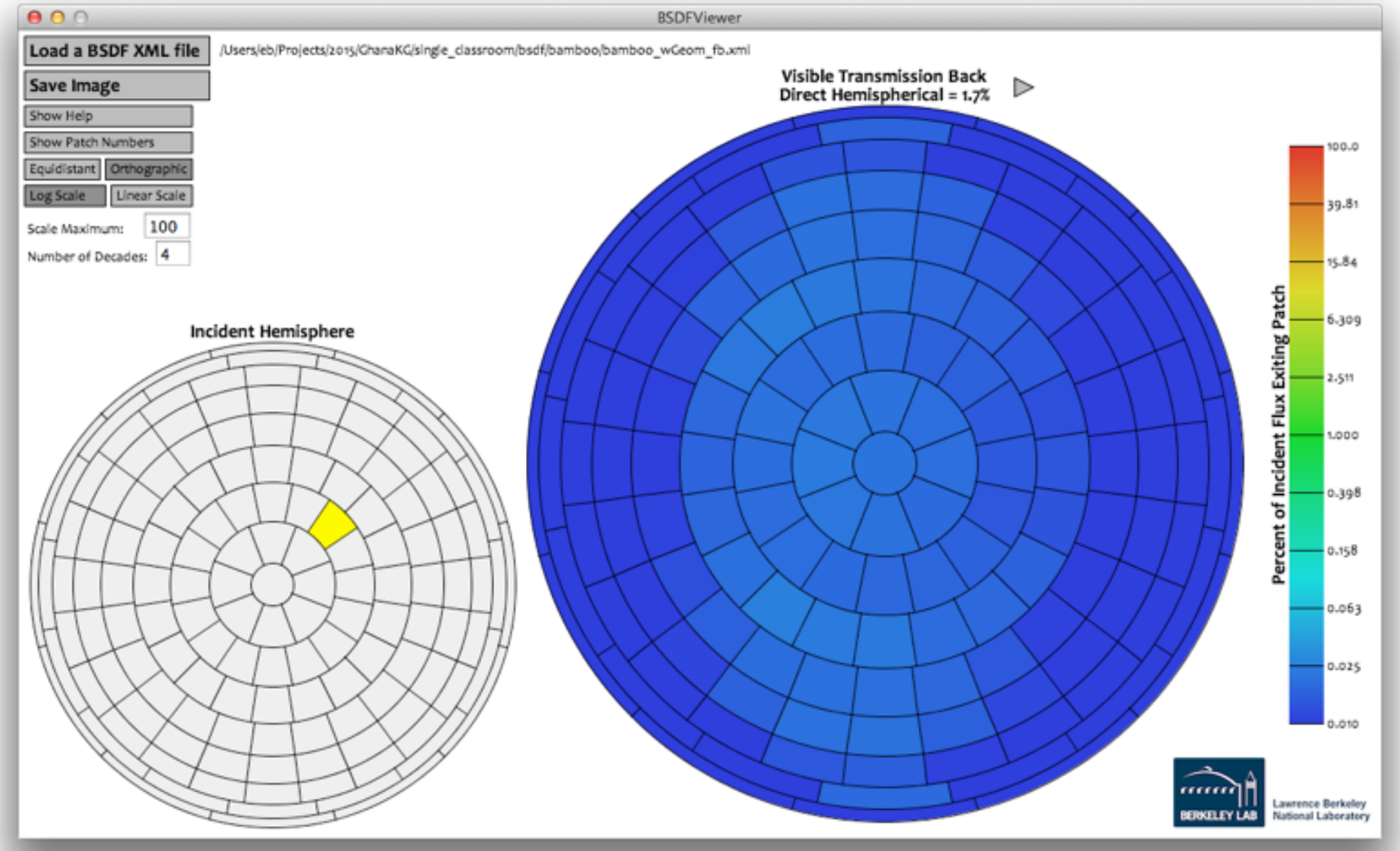
Generally found in **.xml** format

- Retrieved from a database (e.g. LBNL Window6/7) https://windows.lbl.gov/software/window/window.html
- Generated from a simulation run with genBSDF
- Built from measured data

Klems Angles Basis

145 patches entering + 145 patches exiting

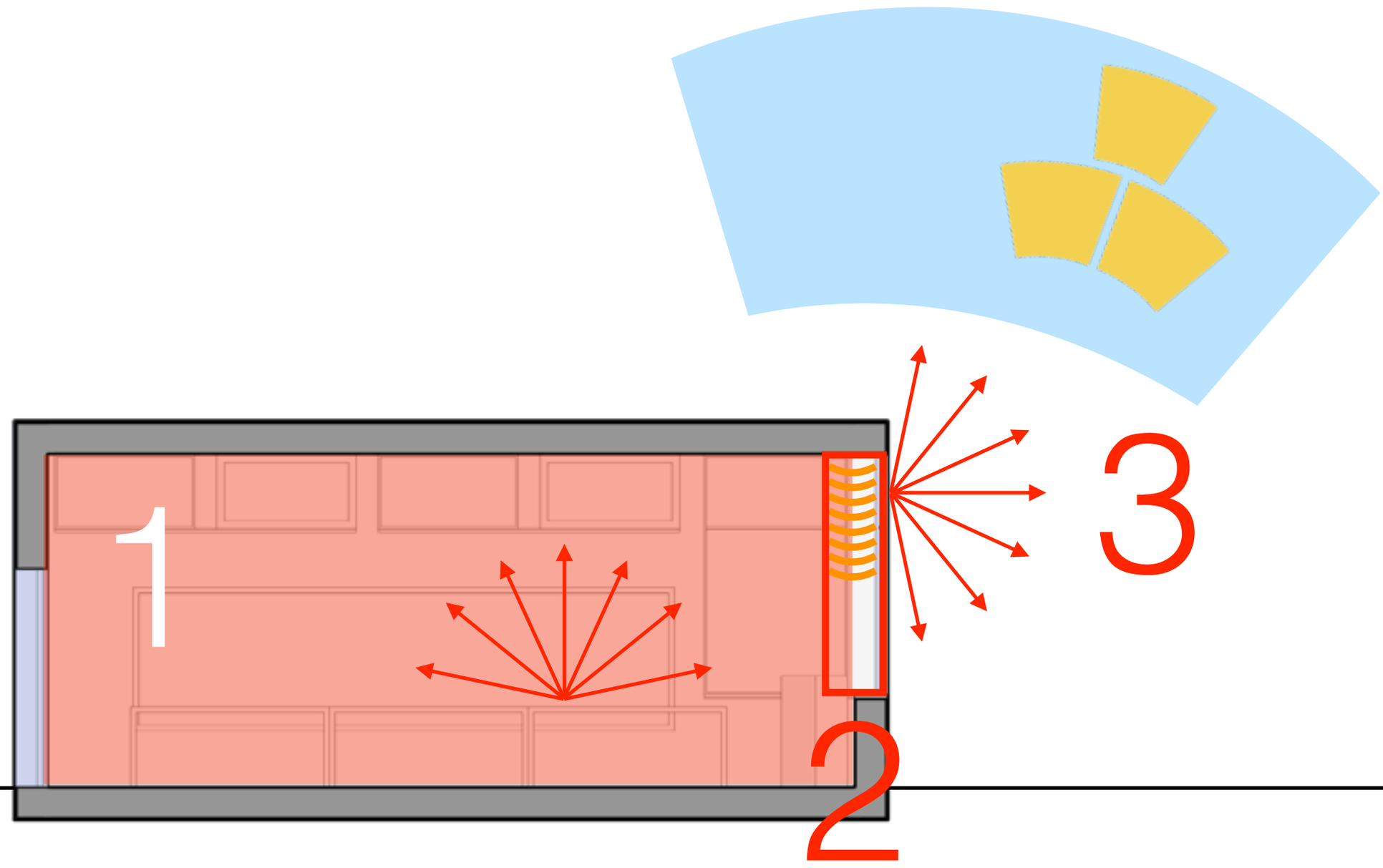
BSDF = Bi-directional Scattering Distribution Function



Klems Angles Basis

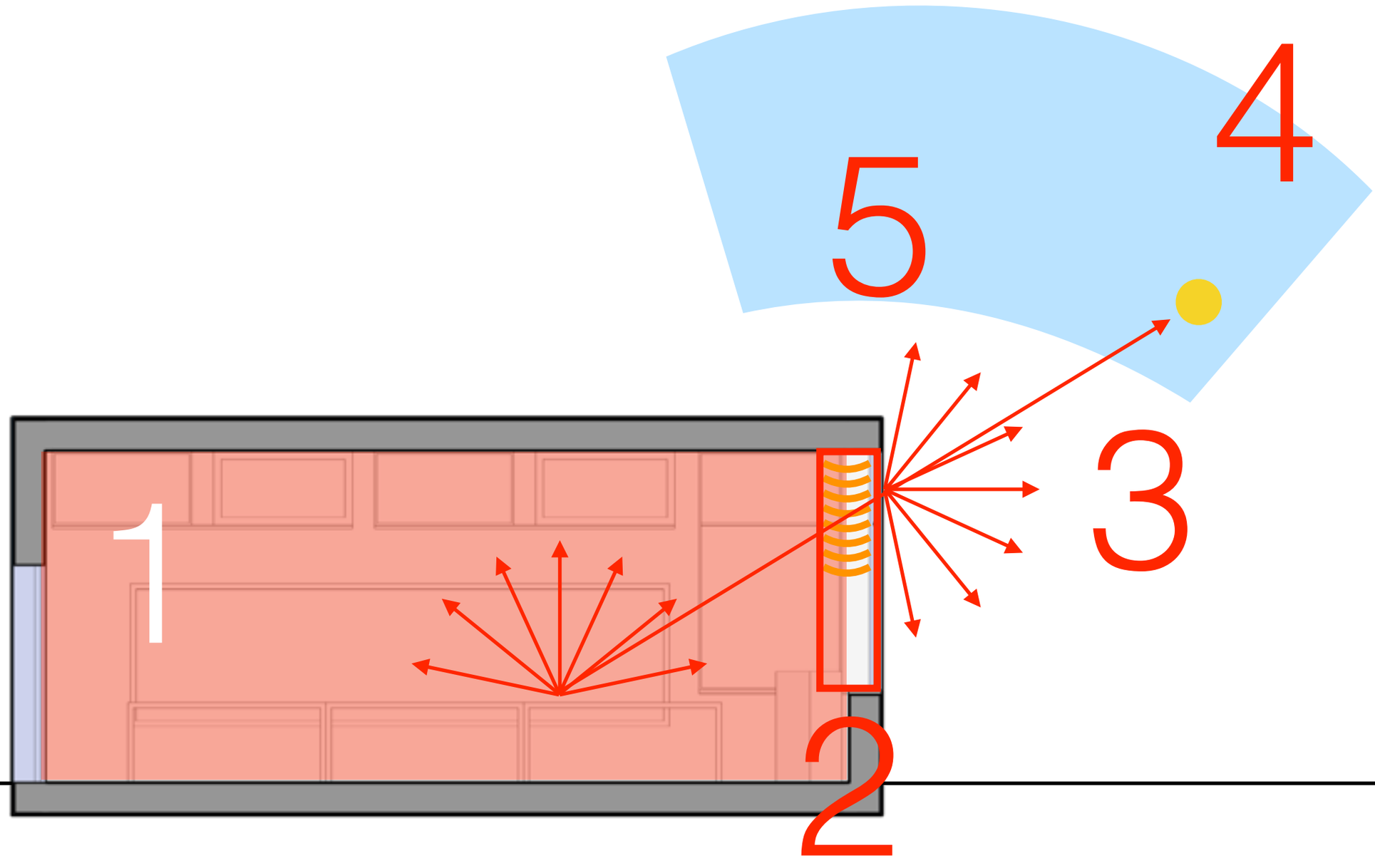
LBNL BSDFViewer

5PM

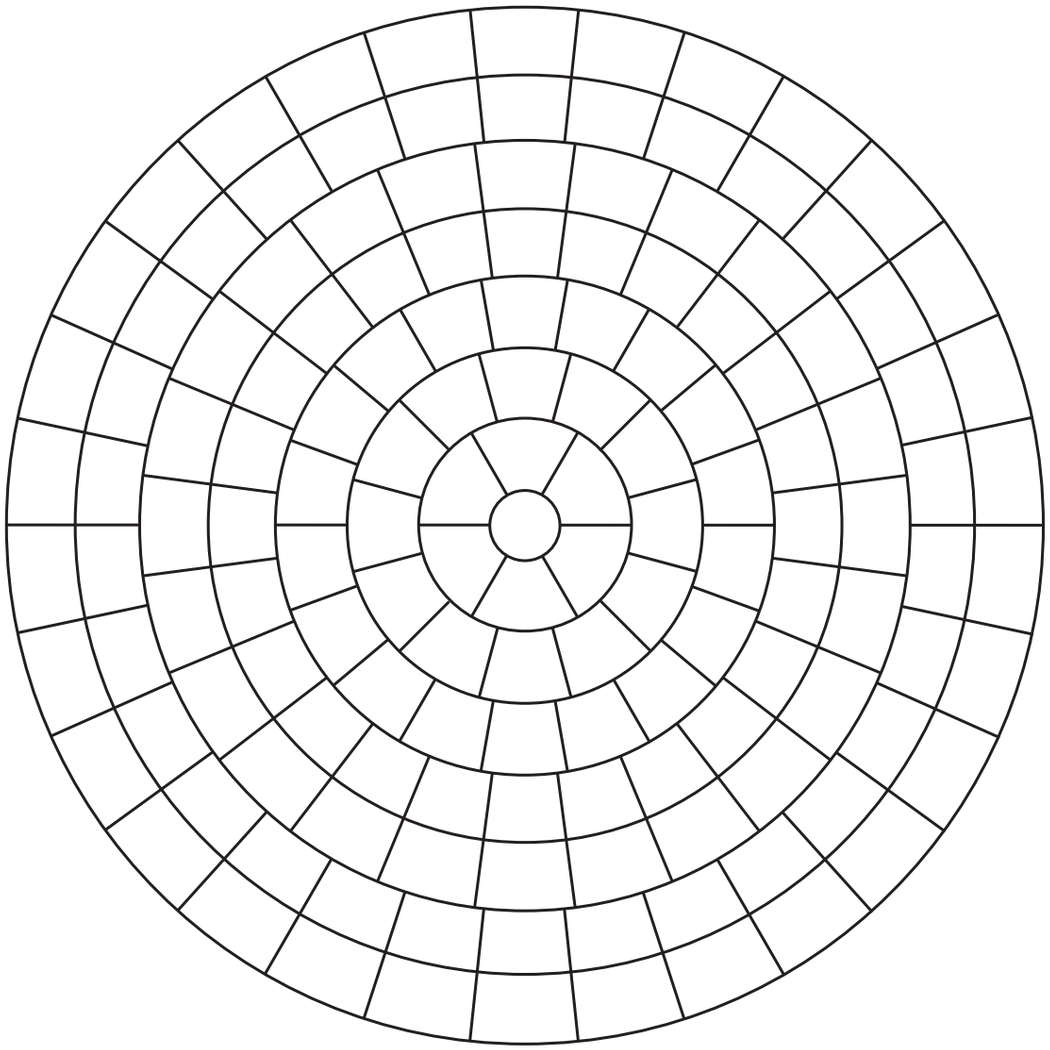


BSDF
Tensor Tree basis

5PM

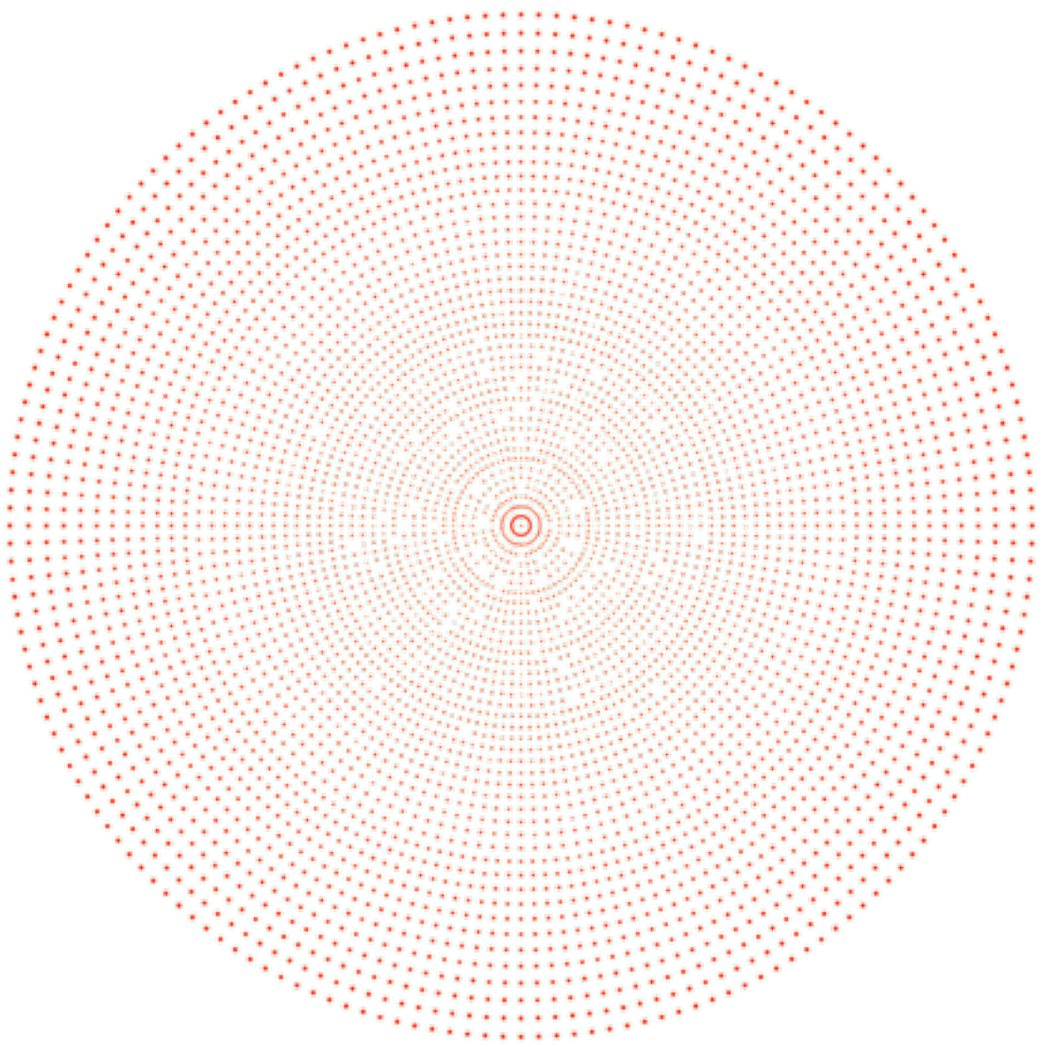


BSDF
Tensor Tree basis



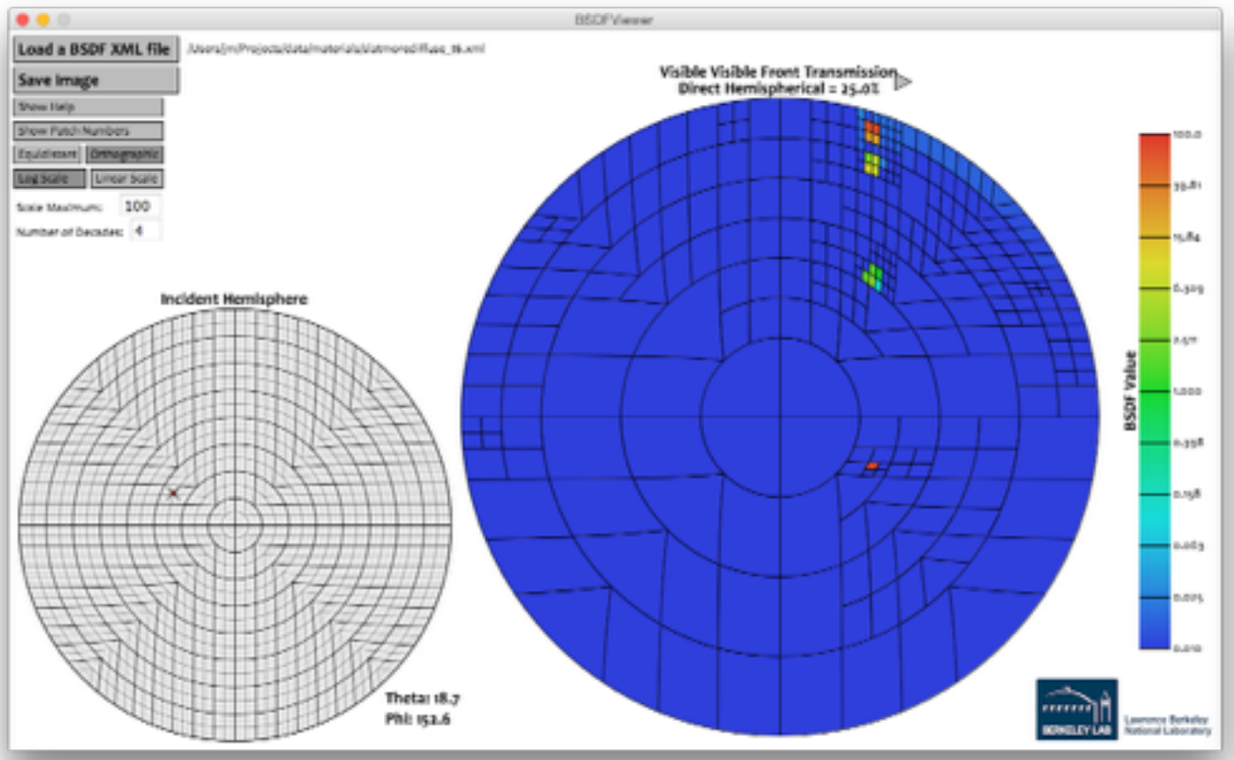
Tregenza subdivision
SKY ONLY
(**glow** material)

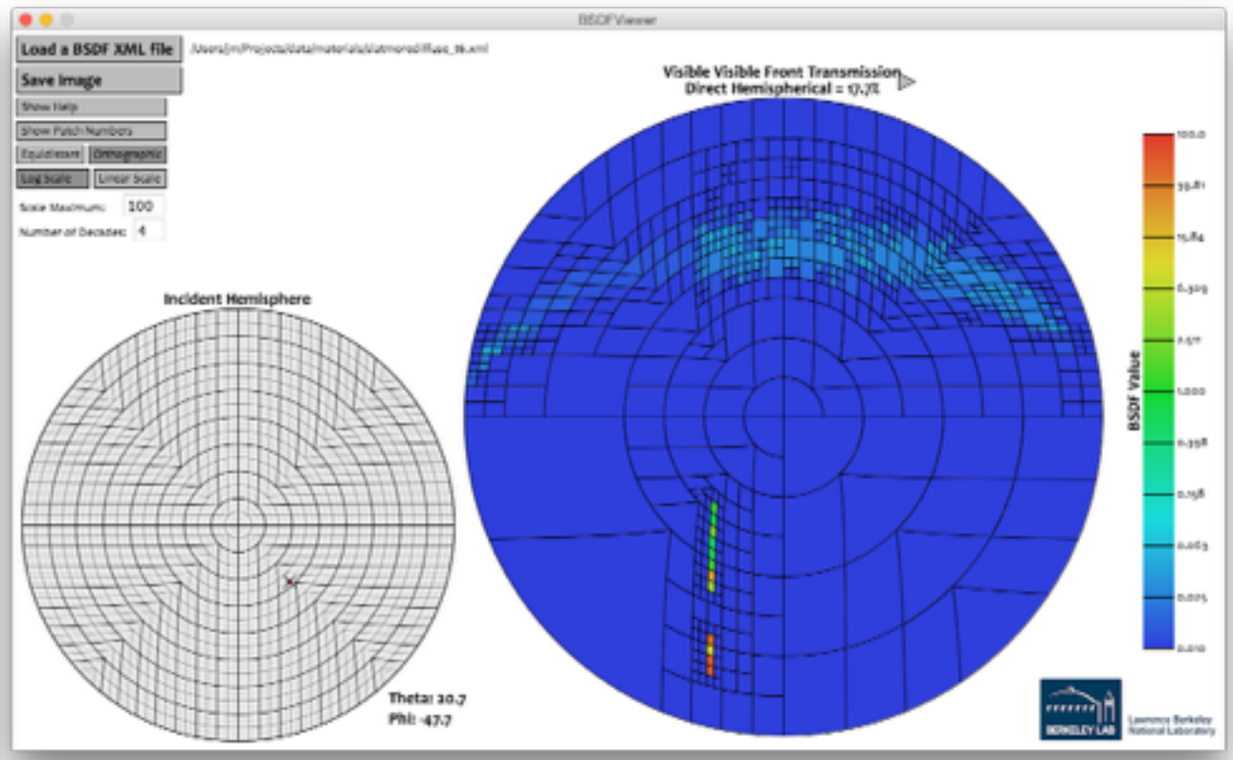
+



Reinhart MF:6
SUN ONLY
(**light** material)

BSDF = Bi-directional Scattering Distribution Function





Tensor Tree Basis

LBNL BSDFViewer

4-components Method	-ab 5 -ad 2048 -ar 128 -as 256 -aa 0.2
DAYSIM	-ab 5 -ad 1024 -ar 1024 -as 256 -aa 0.1
2-phase Method	-ab 5 -ad 100000 **-aa 0** -lw 1e-5
3-phase Method	vmx: -ab 12 -ad 50000 **-aa 0** -lw 2e-5 dmx: -ab 2 -ad 1000 **-aa 0** -lw 1e-3
5-phase Method	dsc: -ab 1 -ad 5000 **-aa 0** -lw 2e-4

NB These values are only indicative; each geometry needs appropriate parameters setting

To know more:

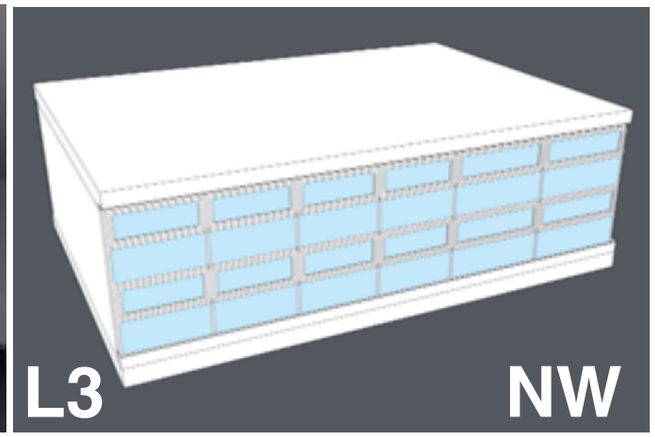
A McNeil, *genBSDF Tutorial*

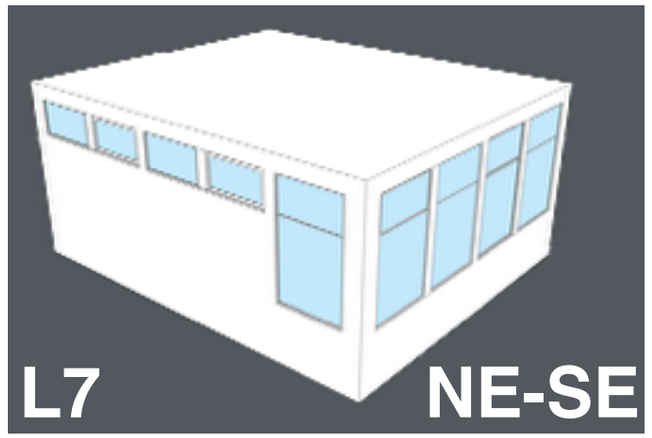
A McNeil, *The Three-Phase Method for Simulating Complex Fenestration with Radiance*

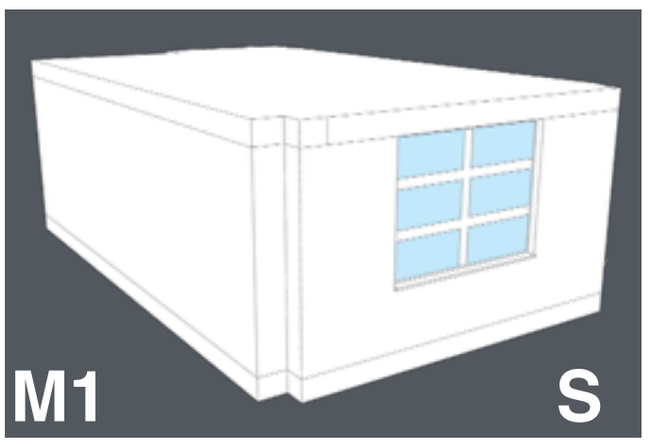
A McNeil, *The Five-Phase Method for Simulating Complex Fenestration with Radiance*

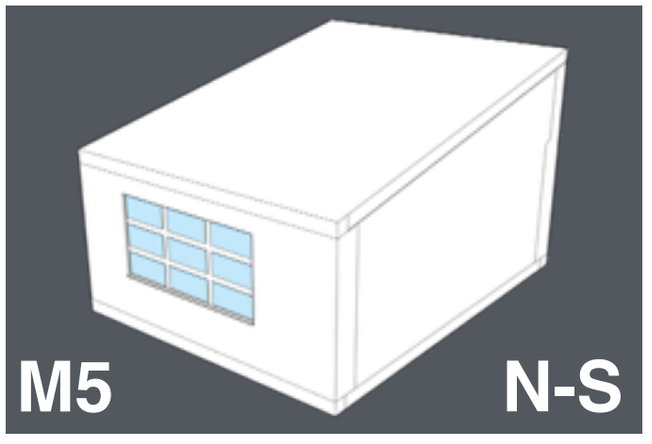
A McNeil, *BSDFs, Matrices and Phases* (Radiance Workshop 2014, London)

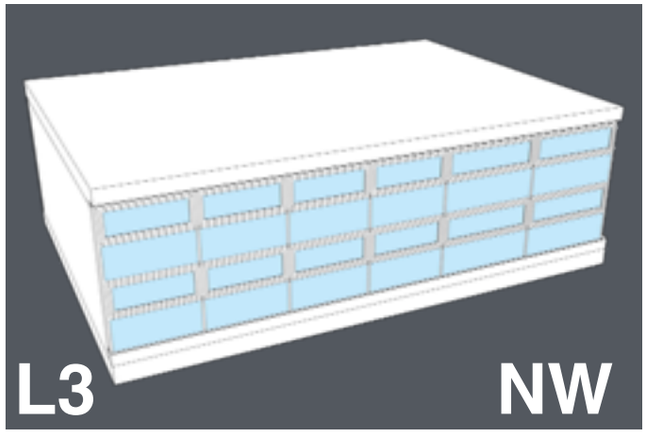
Models

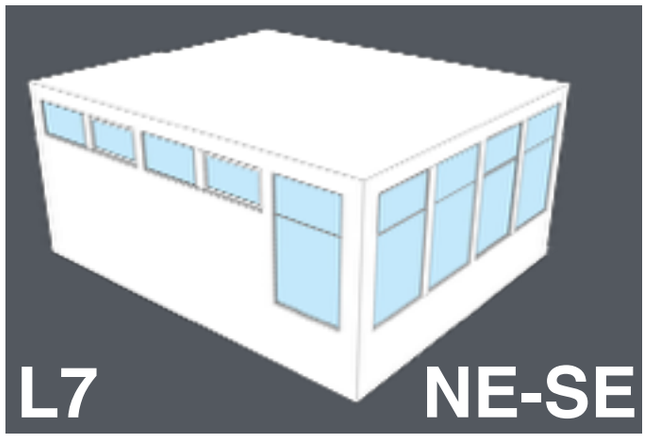

L3
NW

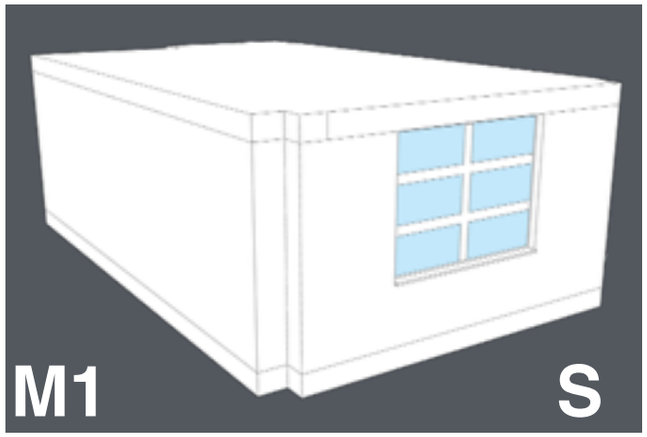

L7
NE-SE

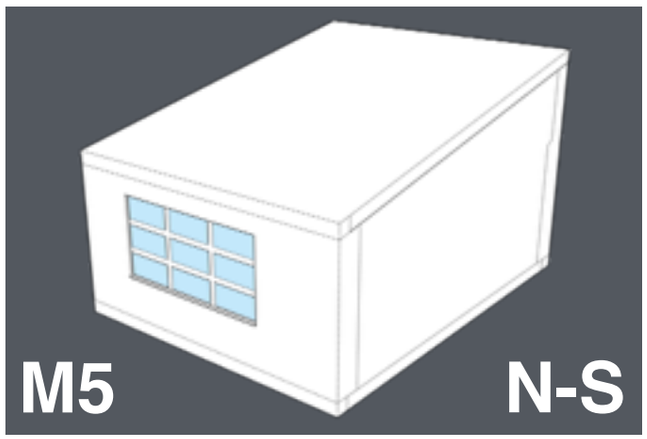

M1
S

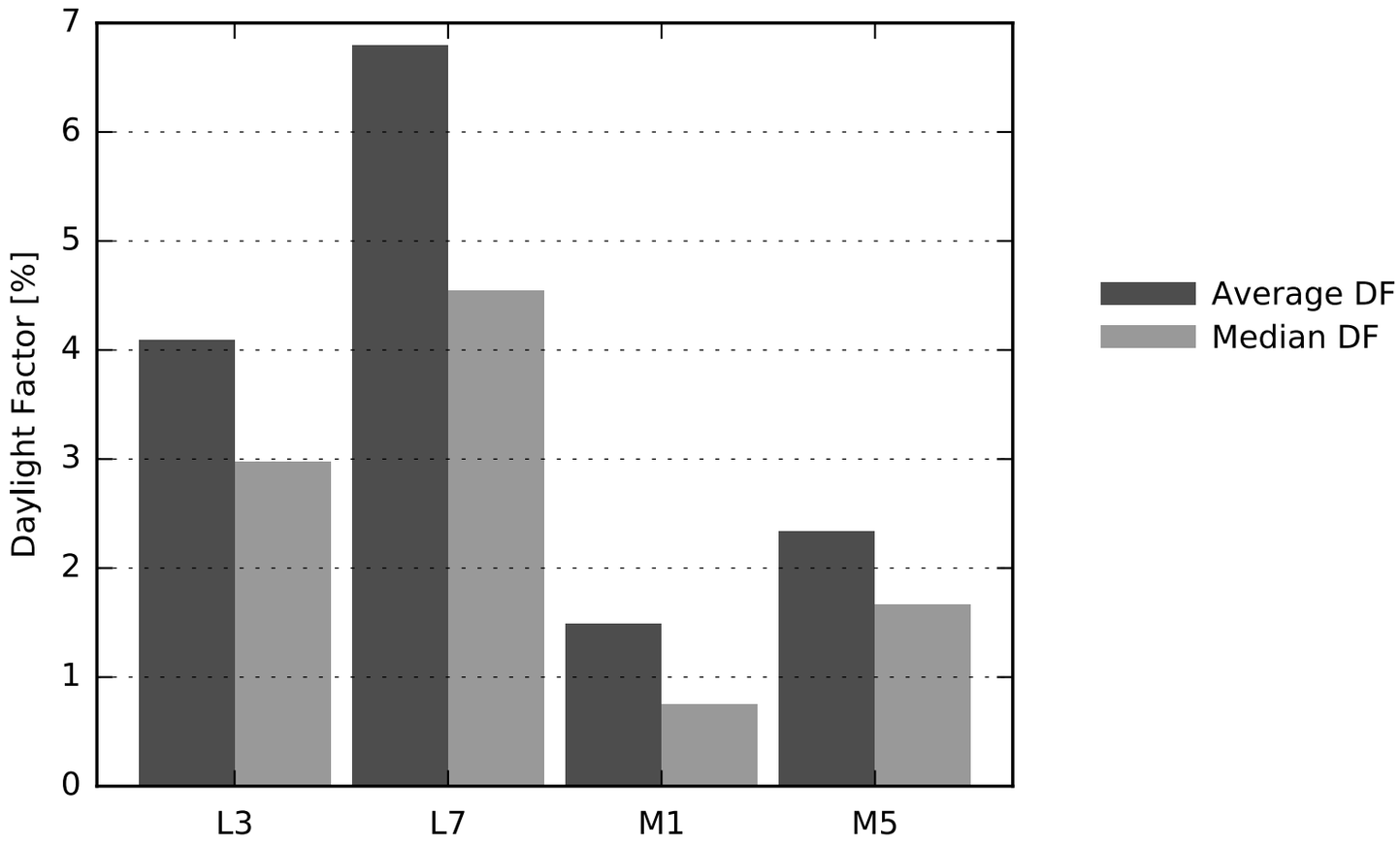

M5
N-S


L3
NW


L7
NE-SE


M1
S


M5
N-S


Daylight Factor [%]
0
1
2
3
4
5
6
7
L3
L7
M1
M5
Average DF
Median DF

Metrics

UDI
(Useful Daylight Illuminance)

Annual occurrence of illuminance binned in certain ranges

DA
(Daylight Autonomy)

Annual occurrence of illuminance over a certain threshold

TAI
(Total Annual Illuminance)

Hourly exposure cumulative for a year

ASE
(Annual Sunlight Exposure)

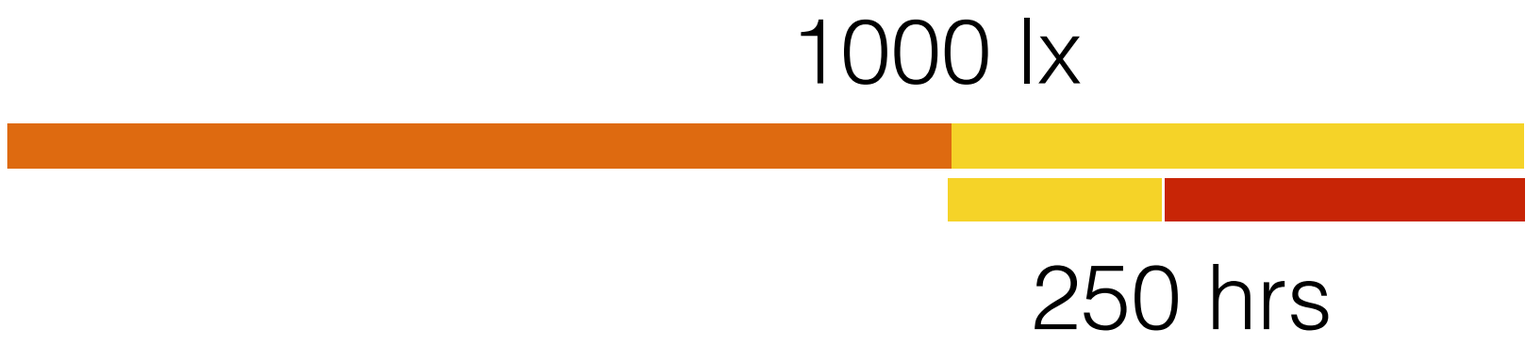
Annual occurrence of **direct sunlight** over a certain illuminance for more than a certain number of hrs per year

UDI
(Useful Daylight Illuminance)

DA
(Daylight Autonomy)

TAI
(Total Annual Illuminance)

ASE
(Annual Sunlight Exposure)



Requirements for LEED v4 I Daylight credit: option 1

Occupancy schedule 8:00 - 18:00 (60’ time step)

sDA > 55/75%

ASE < 10%

	2PM	3PM	5PM	4CM	DAY
L3	3	3	3	3	3
L7	0	0	0	3	0
M1	0	0	0	0	0
M5	3	3	3	2	2

*blinds not modelled

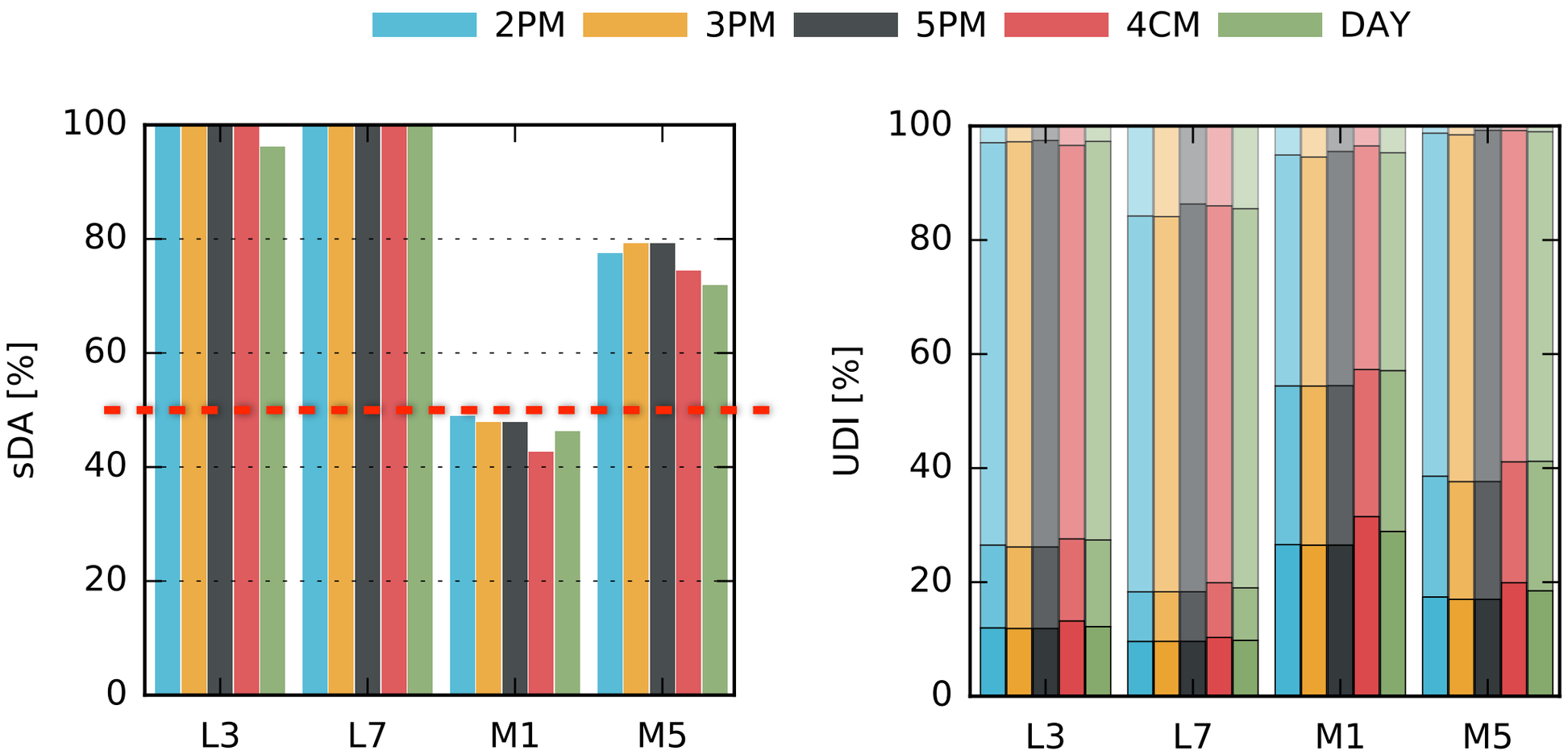
Requirements for Priority School Building Programme (UK)

Occupancy schedule 8:30 - 16:00 (5’ time step)

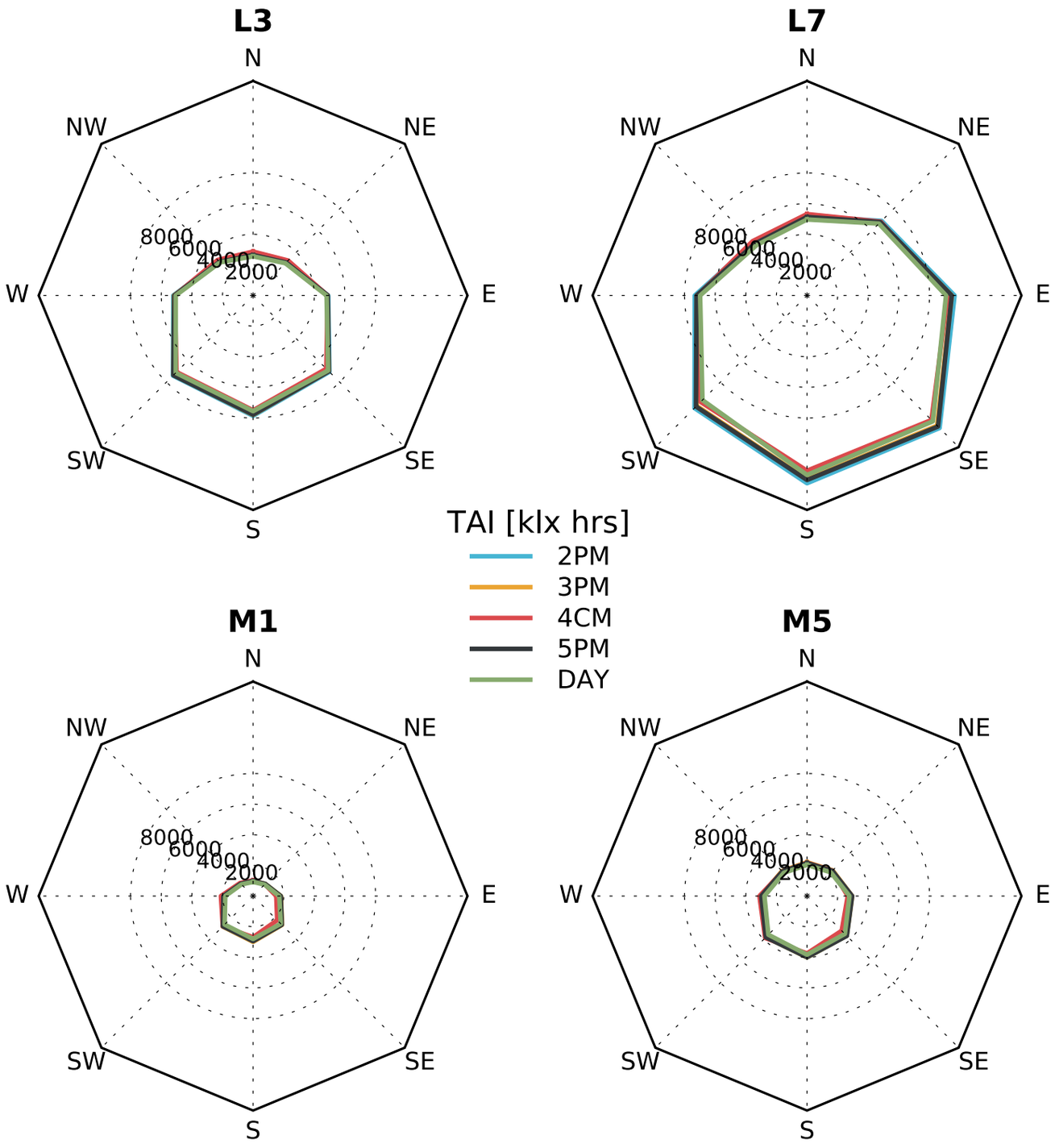
sDA > 50%

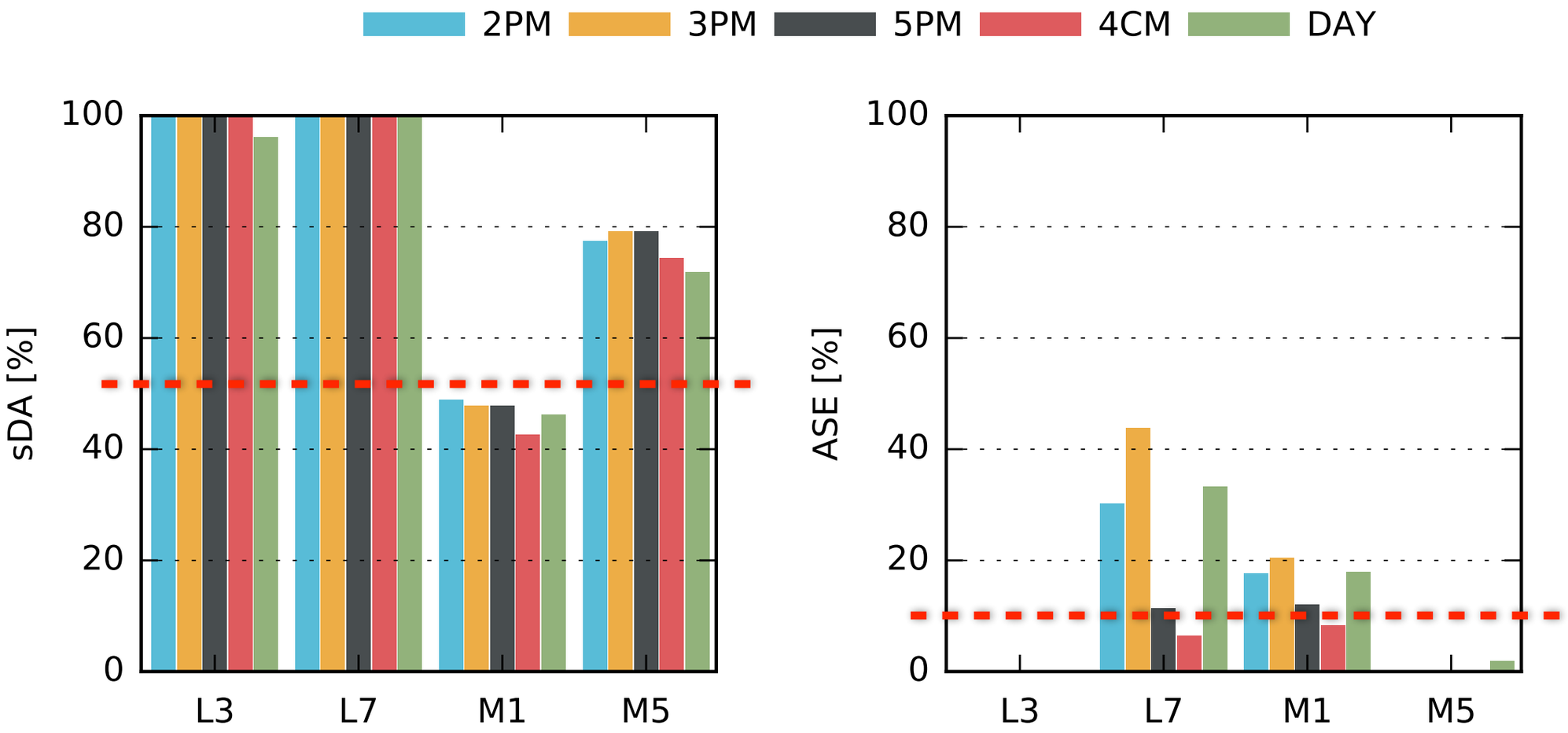
UDI_{s+a} > 80%

	2PM	3PM	5PM	4CM
L3	YES	YES	YES	YES
L7	80%	80%	82%	78%
M1	NO	NO	NO	NO
M5	YES	YES	YES	YES


2PM
3PM
5PM
4CM
DAY
sDA [%]
UDI [%]
100
80
60
40
20
0
L3
L7
M1
M5

Total Annual Illuminance [klx hrs]





Occupancy schedule 8:00 - 18:00
Hourly time-step

Settings for Annual Sunlight Exposure calculation

	-ab	Geometry
4-components Method	0	no modifications (computed as a matter of course)
DAYSIM	0	no modifications (computed as a matter of course)
2-phase Method	1 (*)	• assign black material to the model • use only the direct normal column of the weather data
3-phase Method	vmx: 1 dmx: 0	• assign black material to the model • use only the direct normal column of the weather data
5-phase Method	1	• assign black material to the model • use only the direct normal column of the weather data

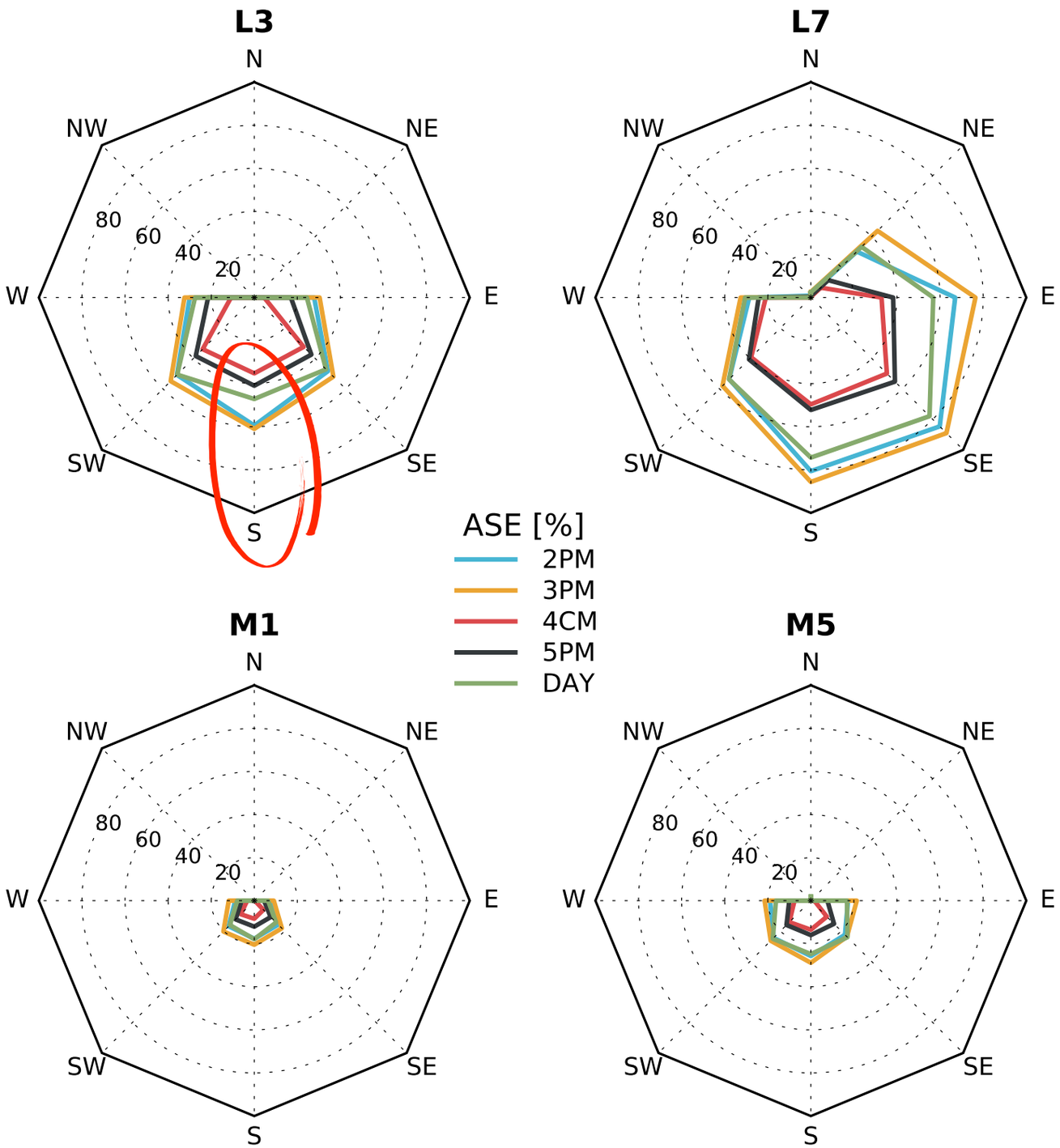
(*) used here but not properly defined anywhere

The Sun says...

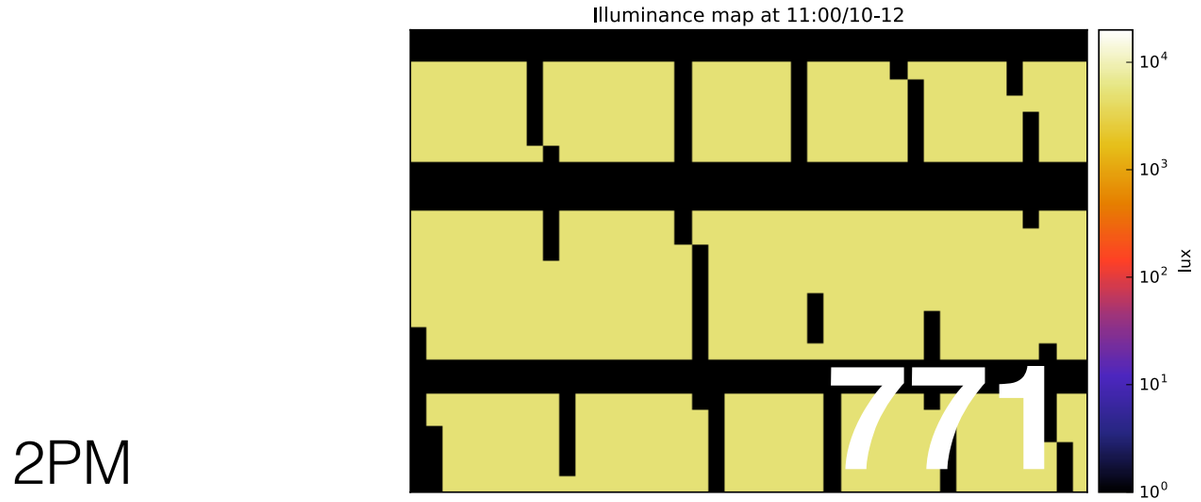
ASE [%] for the four classrooms

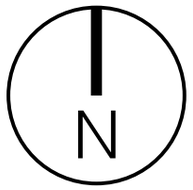
	4CM	DAYSIM	2PM	3PM	5PM
L3 (NW)	0.0	0.0	0.0	0.0	0.0
L7 (NE-SE)	6.5	33.3	30.2	43.8	11.4
M1 (S)	8.4	17.9	17.7	20.5	12.1
M5 (N-S)	0.0	1.9	0.0	0.0	0.0

Annual Sunlight Exposure [%]

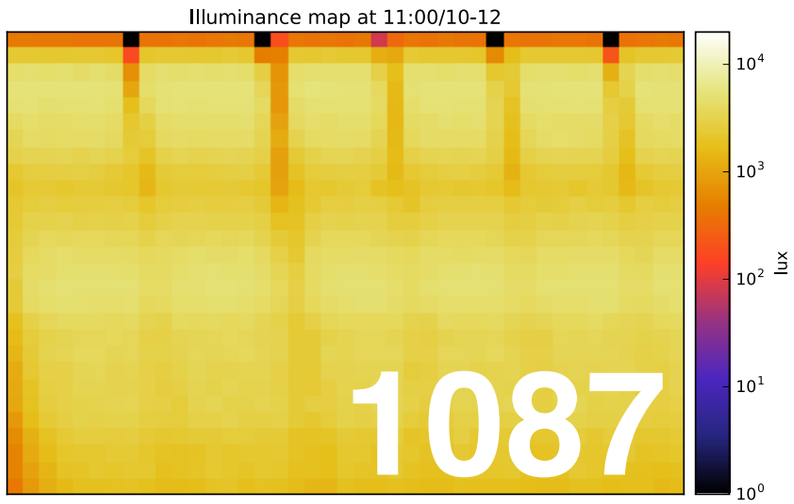


rtrace

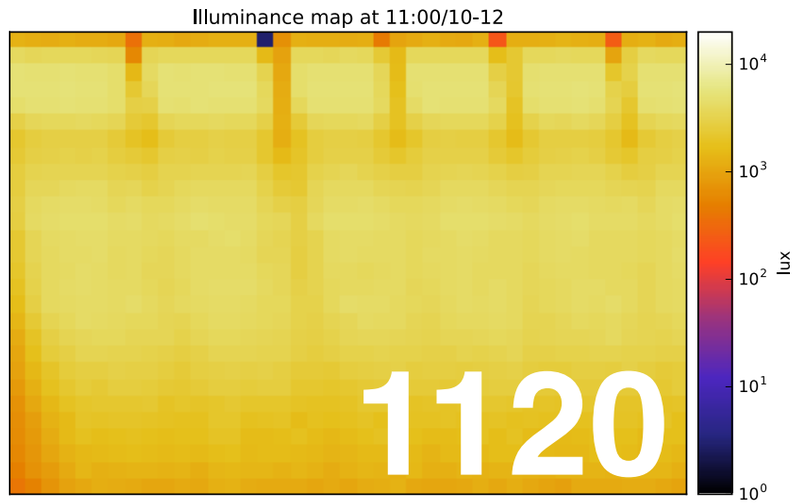


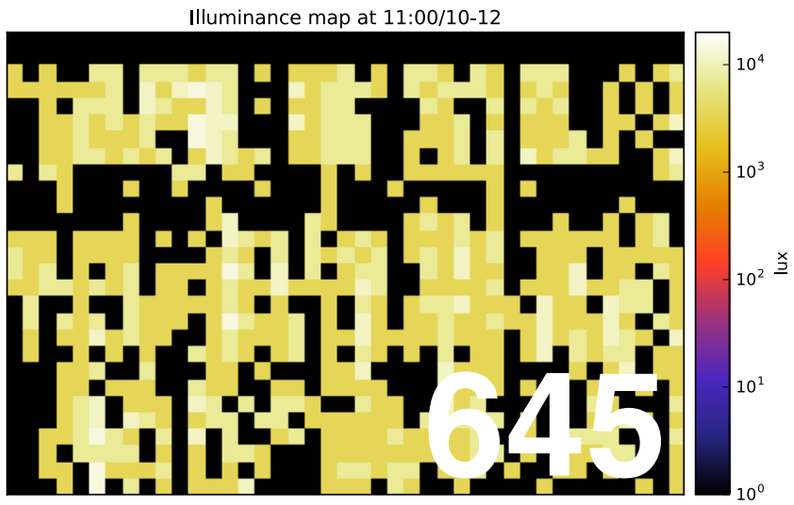


2PM

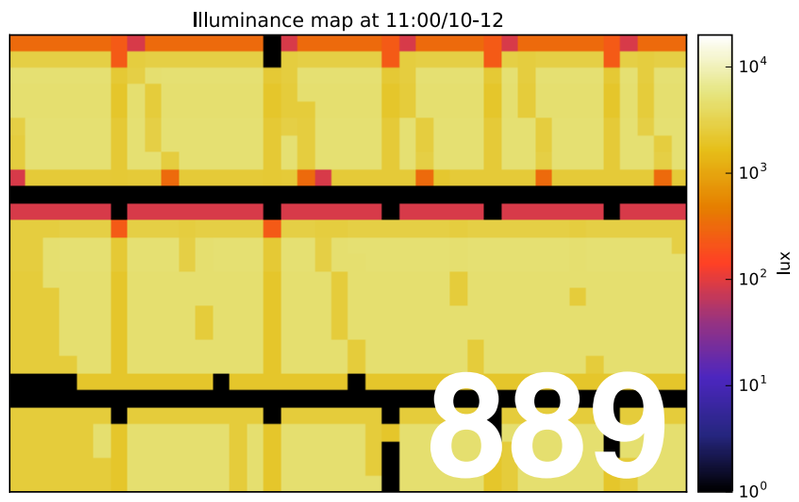


3PM



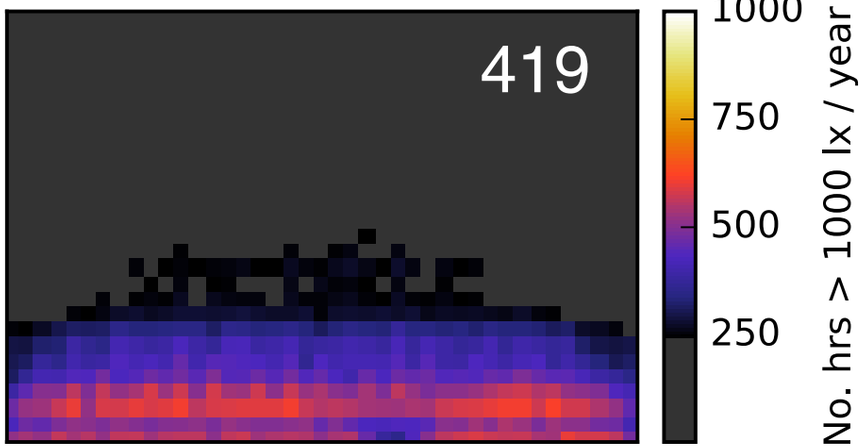


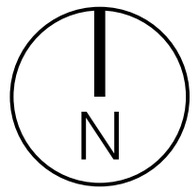
5PM



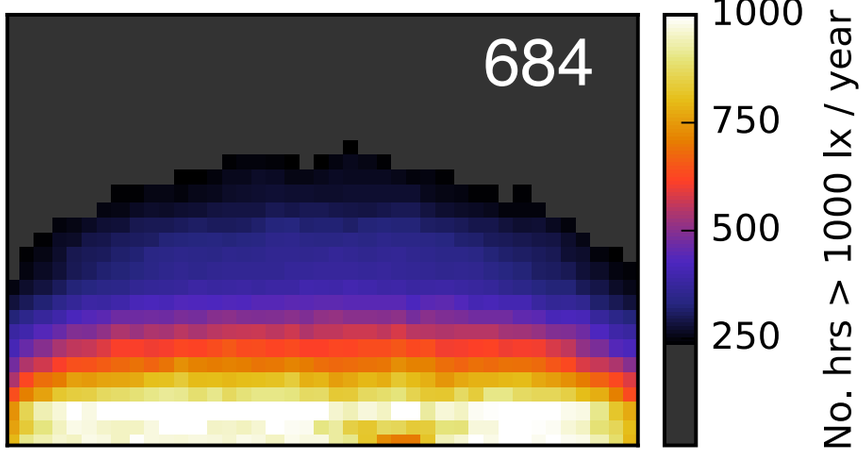
DAYSIM

rtrace

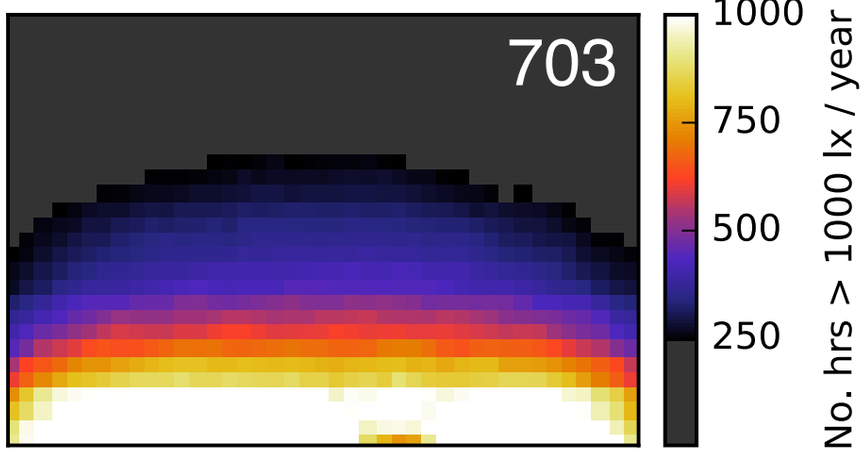




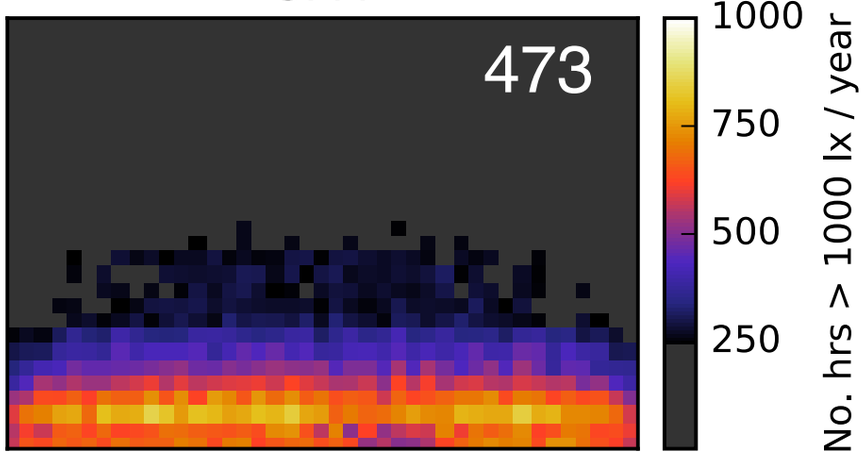
2PM



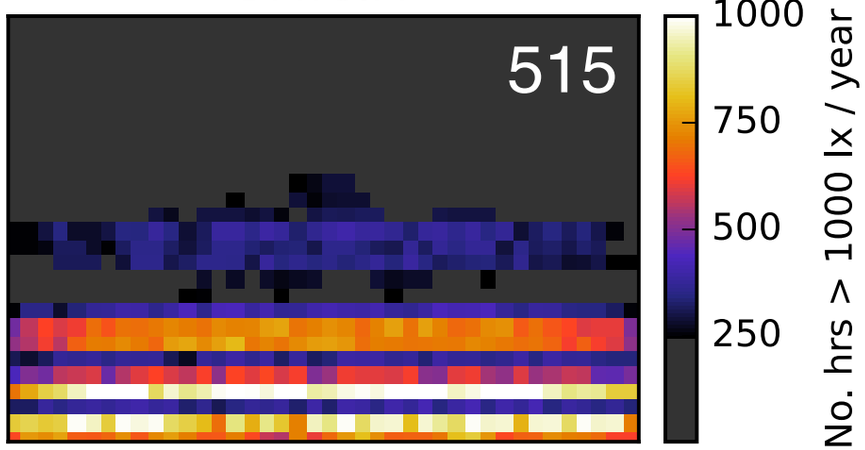
3PM

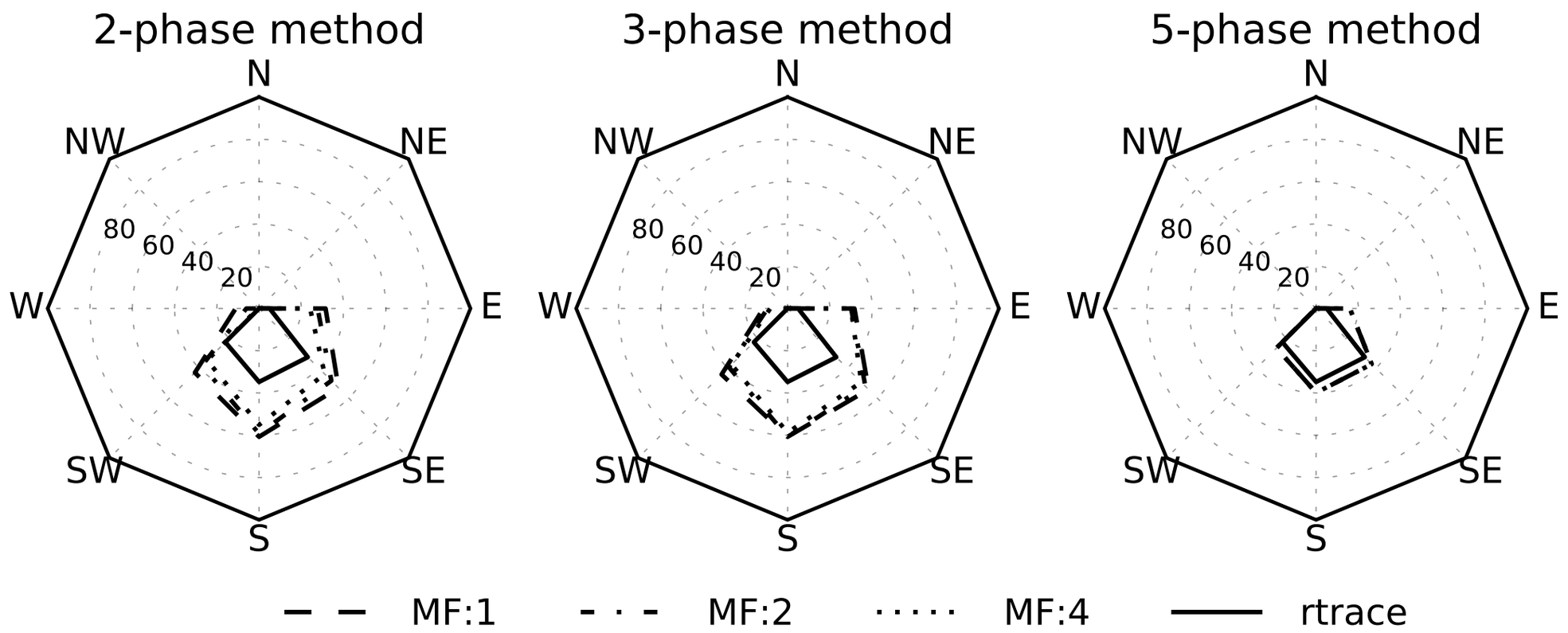


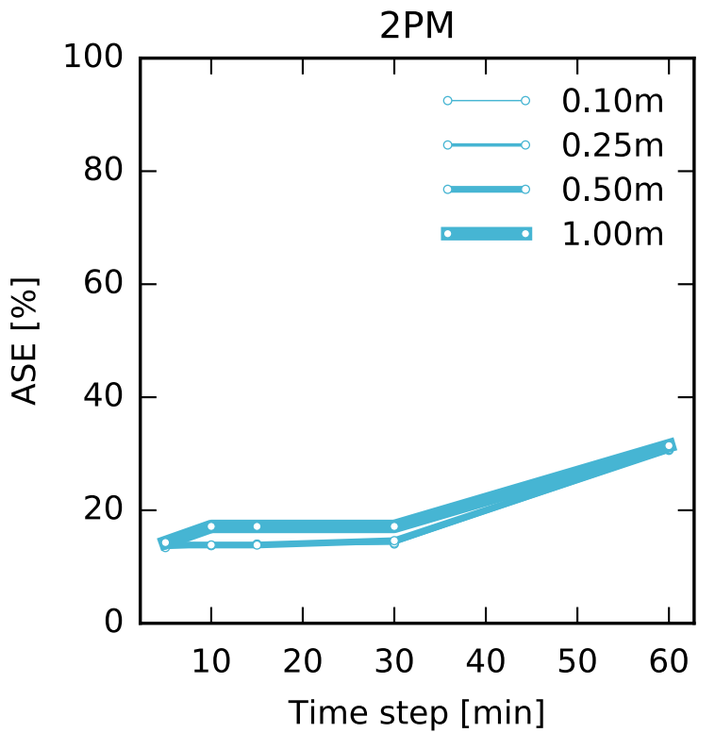
5PM

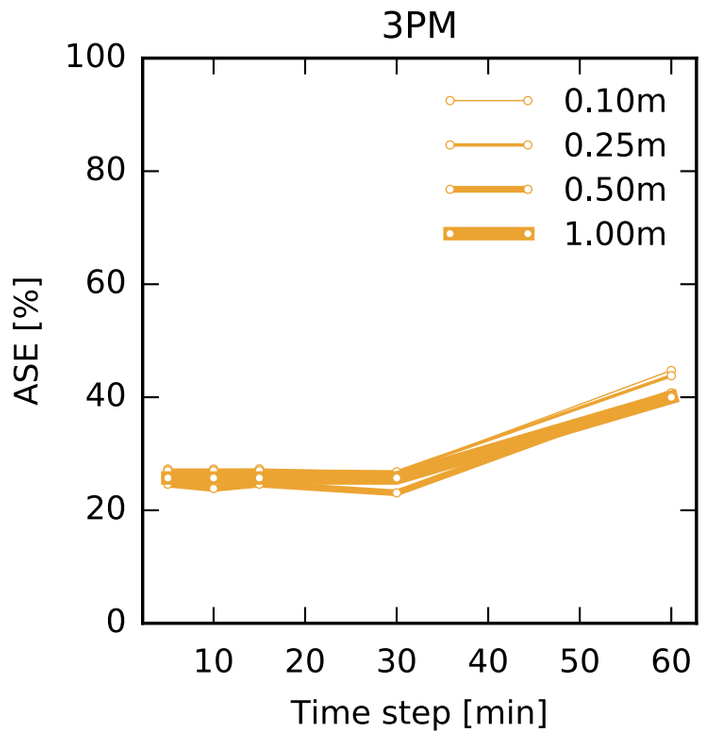


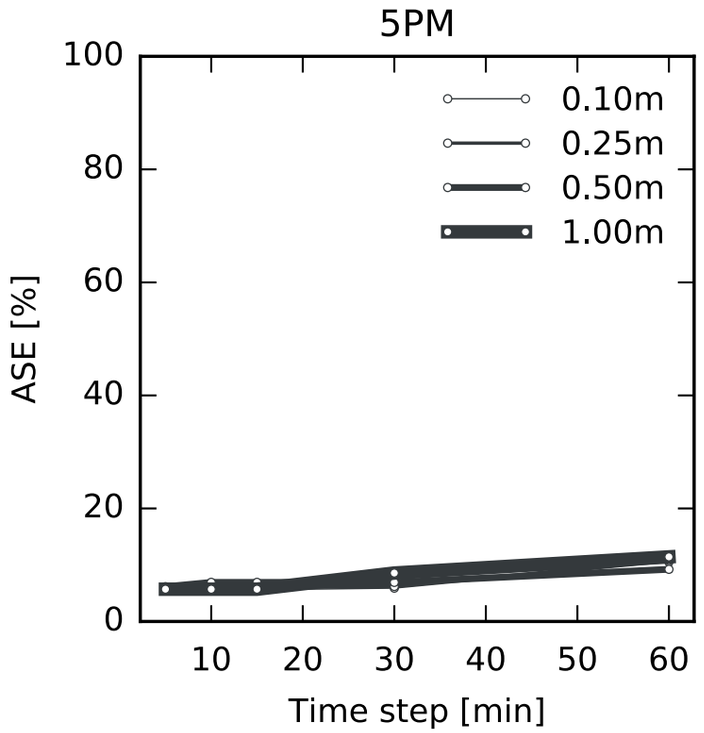
DAYSIM

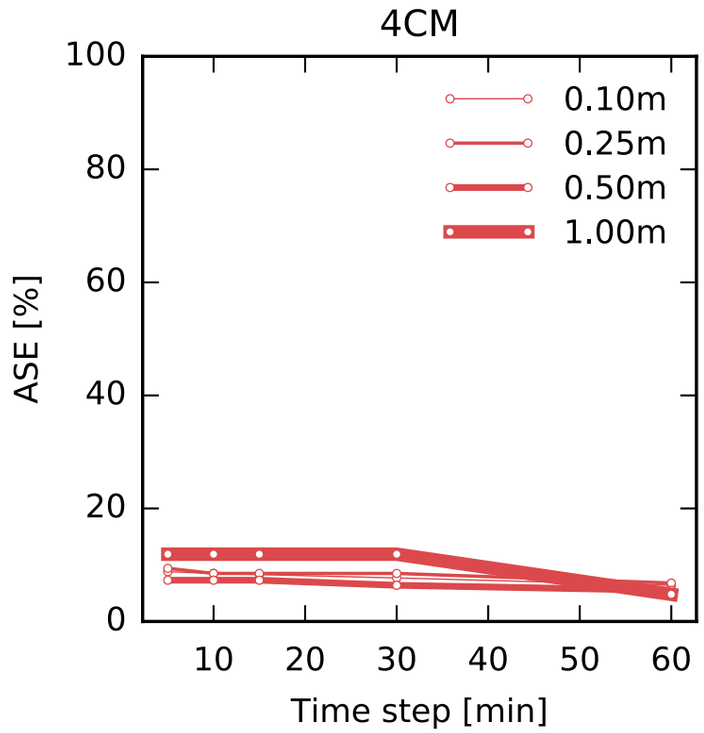



2-phase method
3-phase method
5-phase method
N
NW
NE
W
E
SW
SE
S
80
60
40
20
MF:1
MF:2
MF:4
rtrace


2PM
100
80
60
40
20
0
ASE [%]
10
20
30
40
50
60
Time step [min]
0.10m
0.25m
0.50m
1.00m


3PM
100
80
60
40
20
0
ASE [%]
10
20
30
40
50
60
Time step [min]
0.10m
0.25m
0.50m
1.00m


5PM
100
80
60
40
20
0
ASE [%]
10
20
30
40
50
60
Time step [min]
0.10m
0.25m
0.50m
1.00m


4CM
100
80
60
40
20
0
ASE [%]
10
20
30
40
50
60
Time step [min]
0.10m
0.25m
0.50m
1.00m

Thank you!

Eleonora Brembilla
E.Brembilla@lboro.ac.uk
Twitter: @EleBrembilla