Modelling Non-Visual Effects of Daylight

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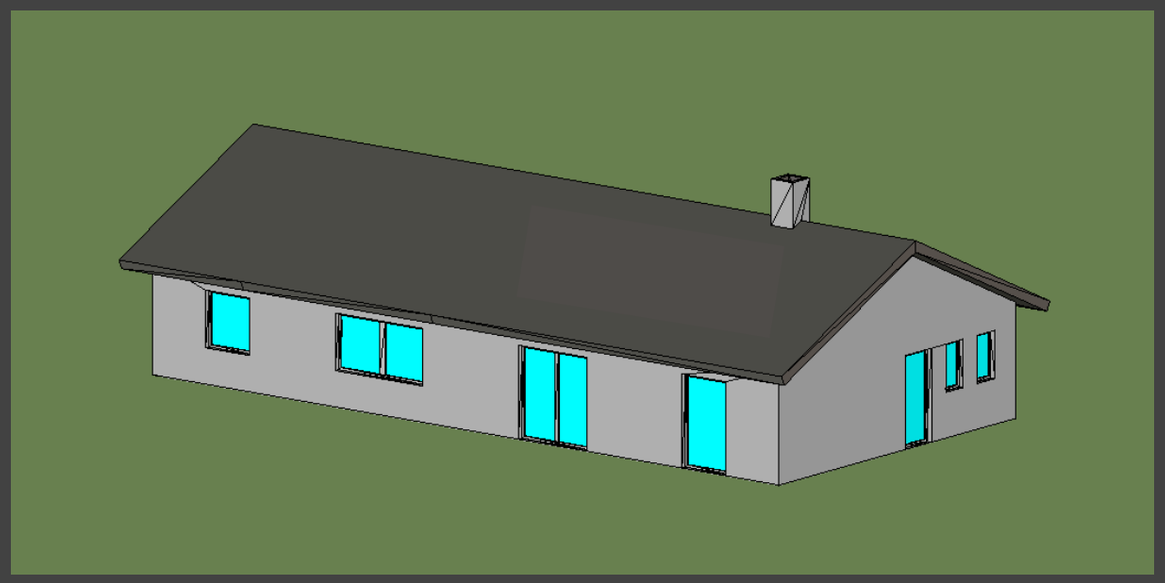
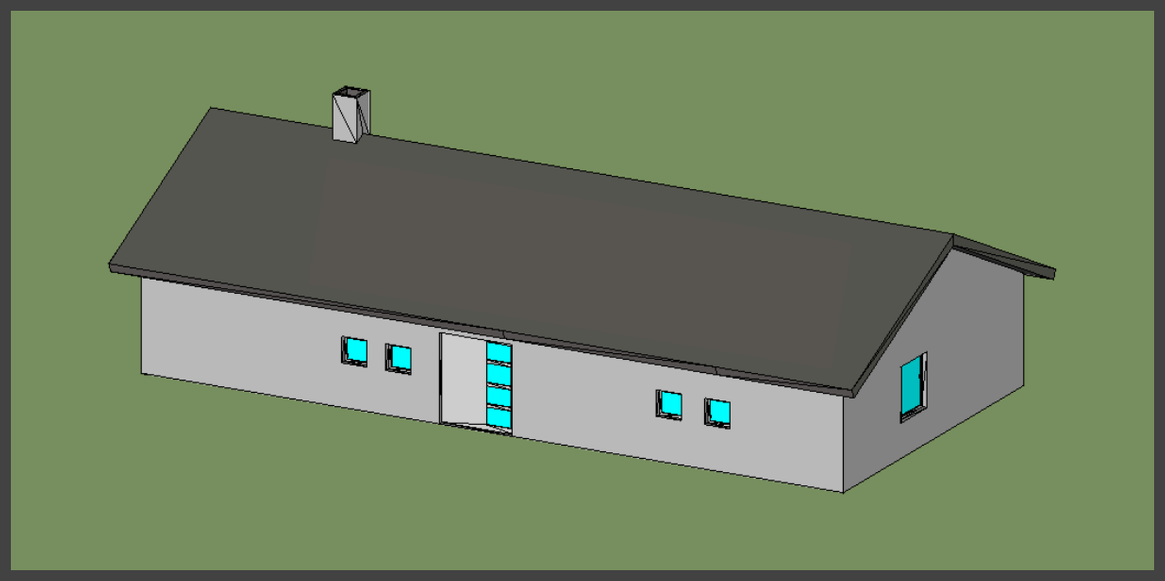
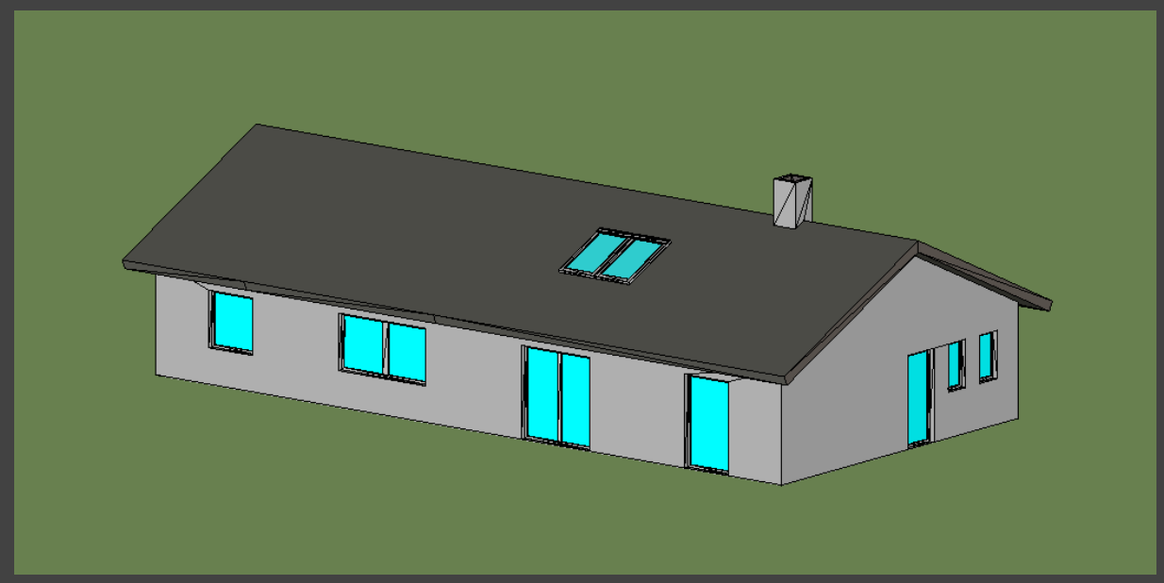
Residential dwelling

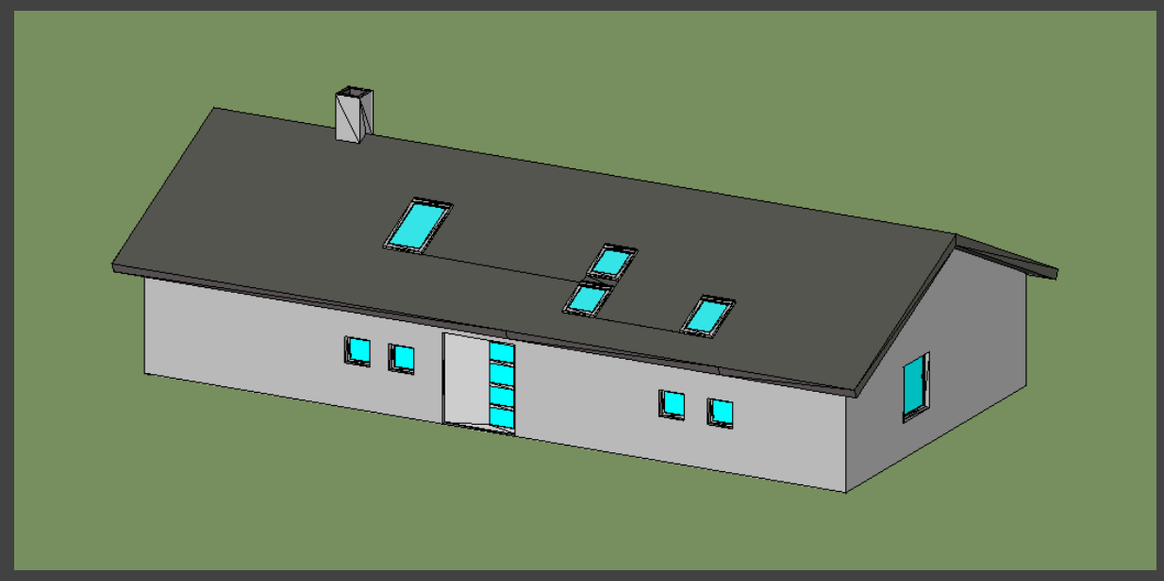
Without skylights





With skylights





Predict metrics for:

General daylight availability indoors

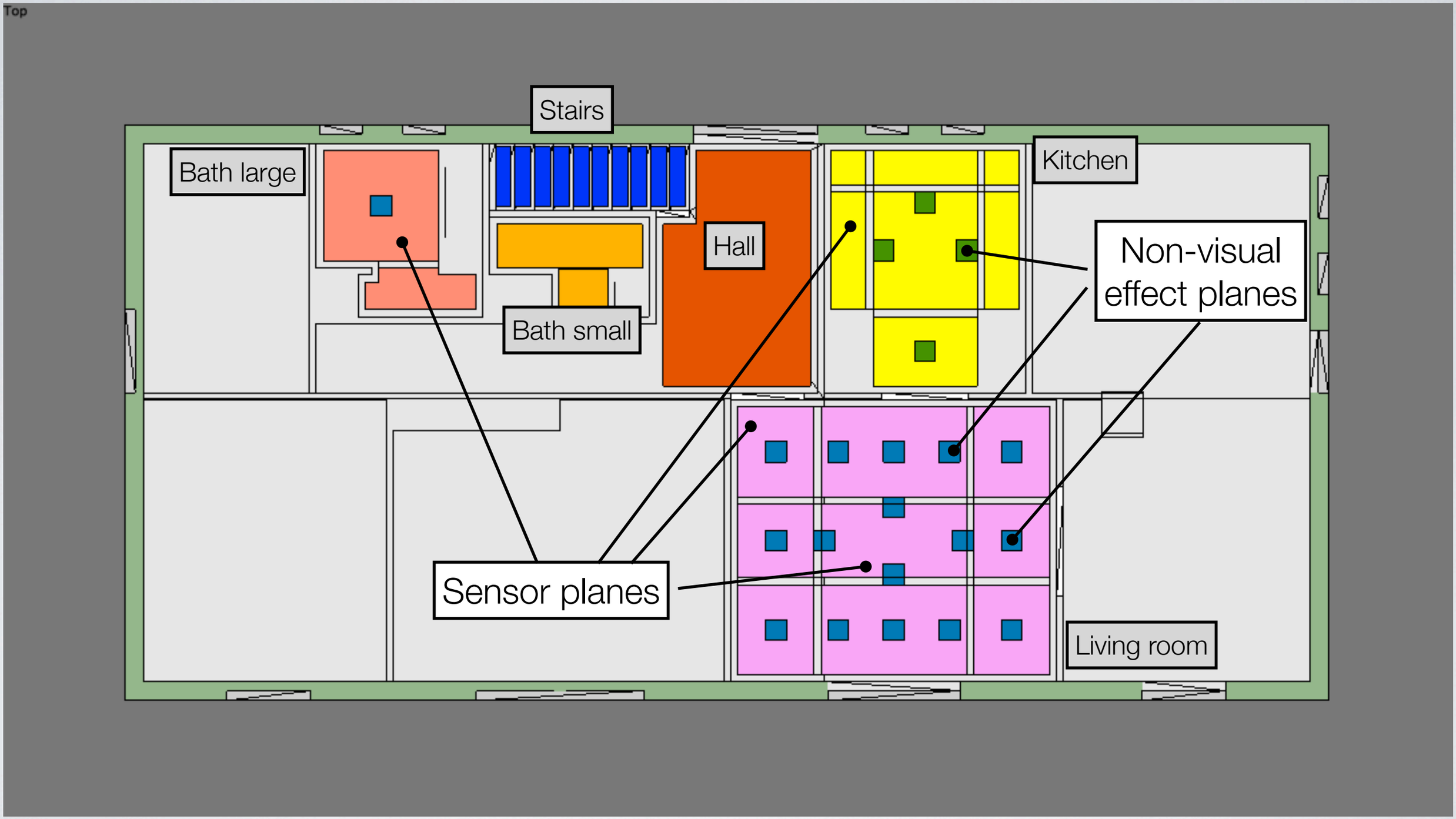
➡ Useful daylight illuminance metric

Savings in electric lighting due to daylight

➡ RT 2005 residential light switching model

Potential for daylight to induce non-visual effects

➡ Vertical eye illuminance (spectral/timing)


Top
Stairs
Bath large
Kitchen
Hall
Non-visual
effect planes
Bath small
Sensor planes
Living room


Top

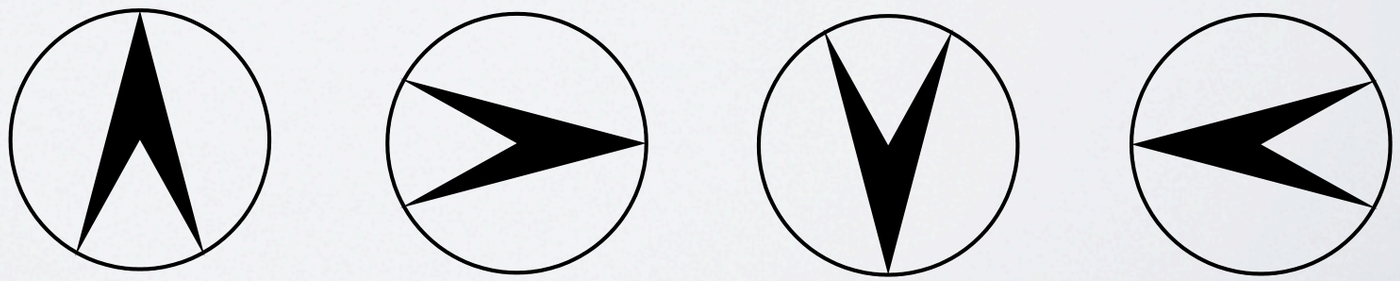
Metrics founded on Climate-Based Daylight Modelling

- Predicts absolute values of luminous quantities, e.g. illuminance, luminance, etc.
- Uses realistic sky and sun conditions.
- Founded on standardised climate files.
- Allows ‘holistic’ evaluation of daylighting combined with solar shading.

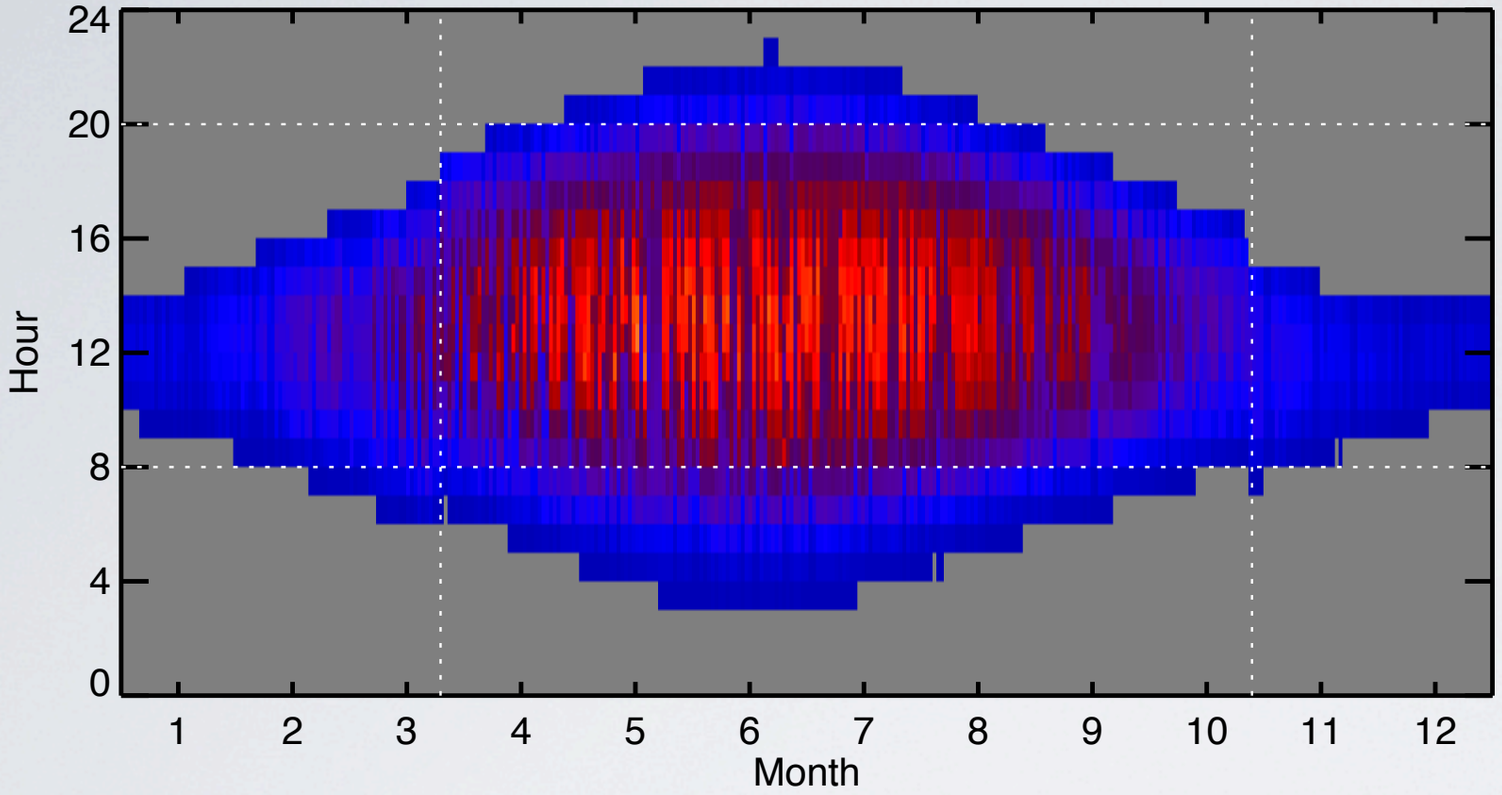
Eight European Locations

ID	City/ Station	Country	Latitude	Longitude	"Sunny" days
DEU-Hamburg	Hamburg	Germany	53.63	-10.00	50
ESP-Madrid	Madrid	Spain	40.41	3.68	194
FRA-Paris	Paris	France	48.73	-2.4	64
GBR-London	London	UK	51.15	0.18	71
ITA-Roma	Rome	Italy	41.80	-12.50	107
POL-Warsaw	Warsaw	Poland	52.17	-20.97	53
RUS-Moscow	Moscow	Russia	55.75	-37.63	49
SWE-Ostersund	Ostersund	Sweden	63.18	-14.50	59

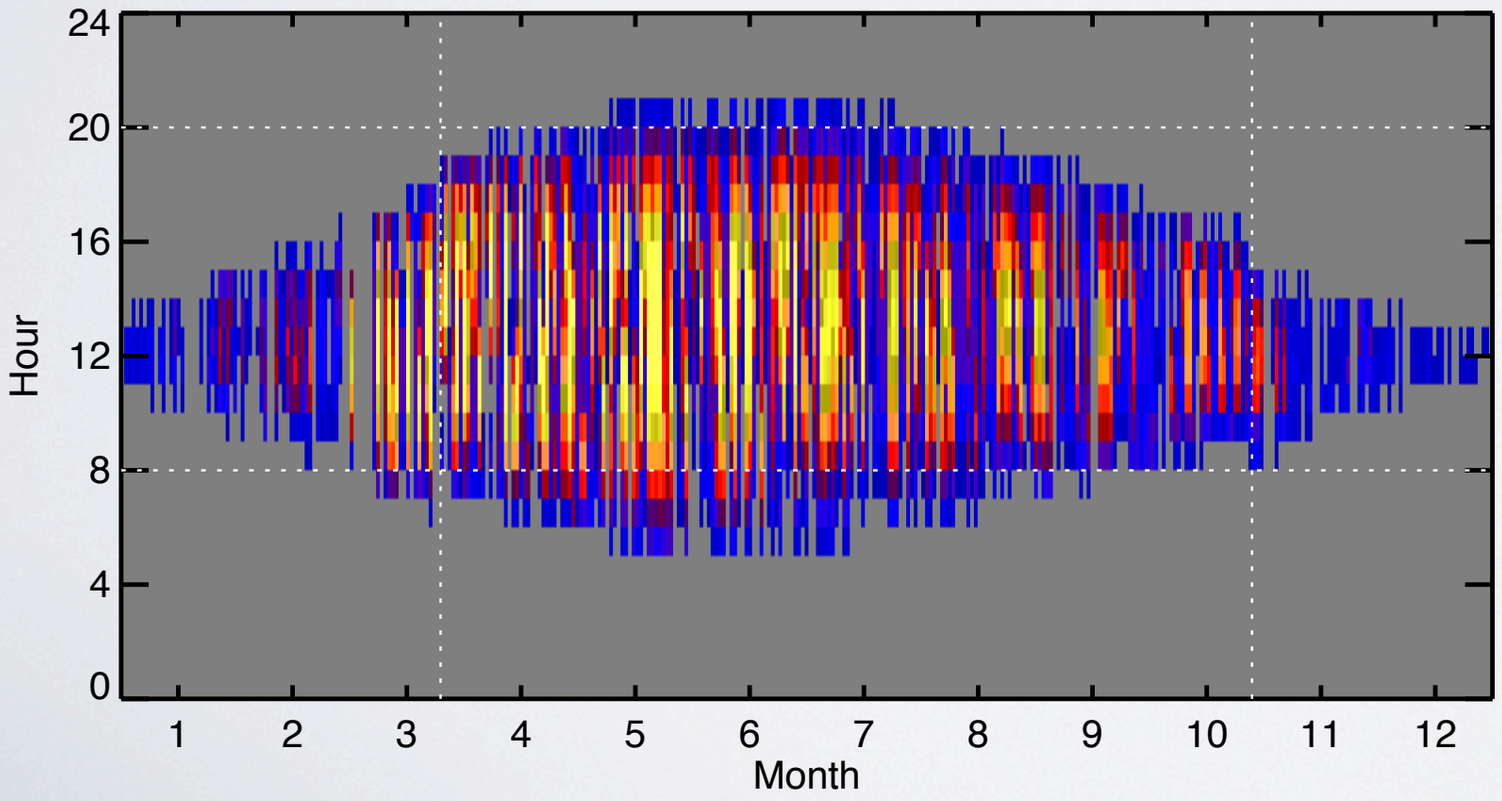
Four building orientations



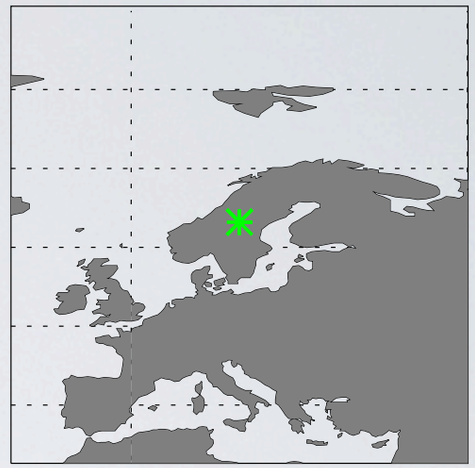
Diffuse Horizontal Illuminance

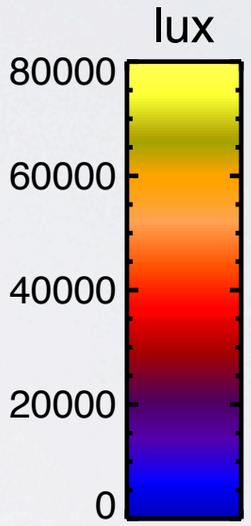


Direct Normal Illuminance

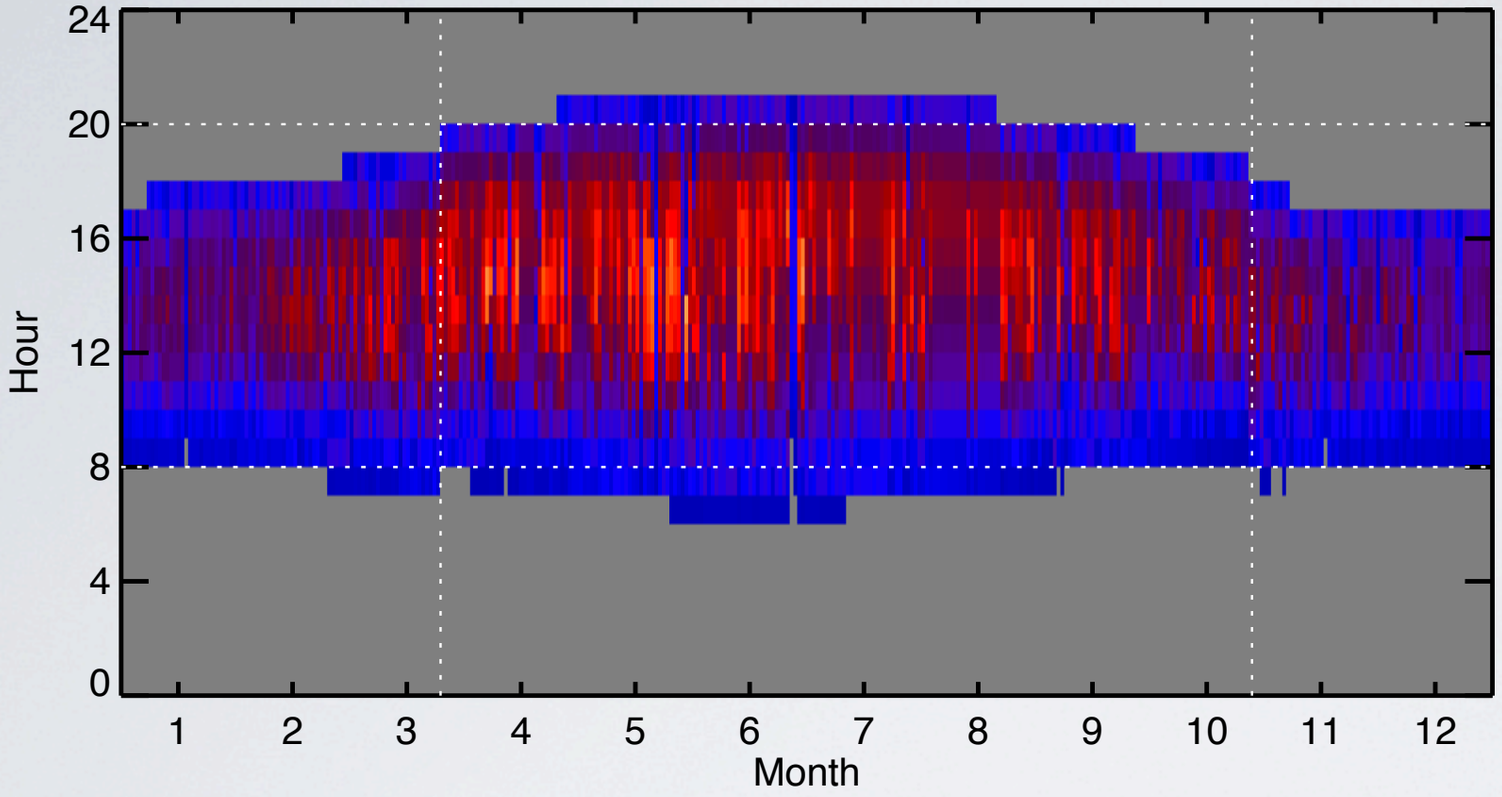


SWE_Ostersund

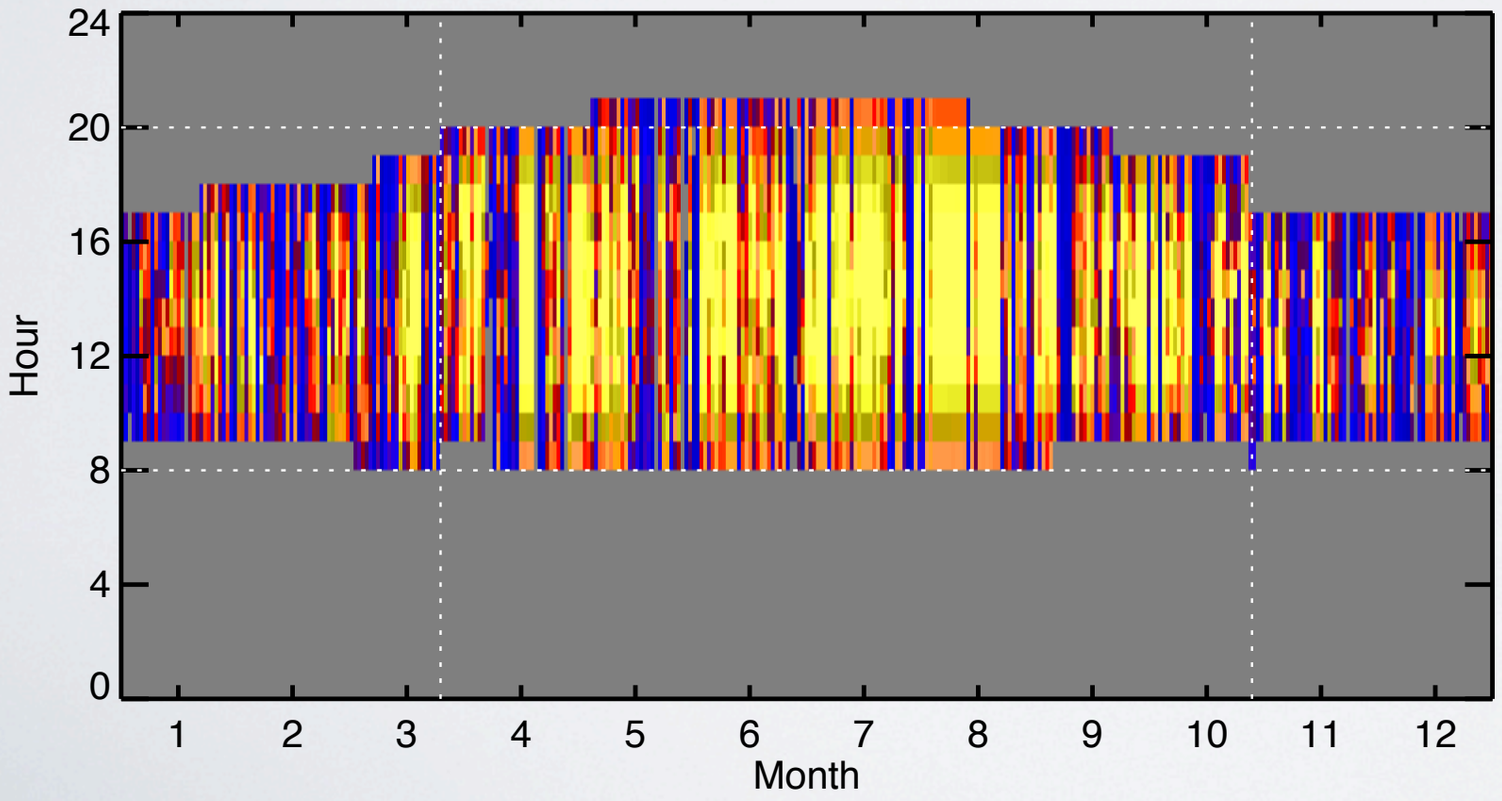




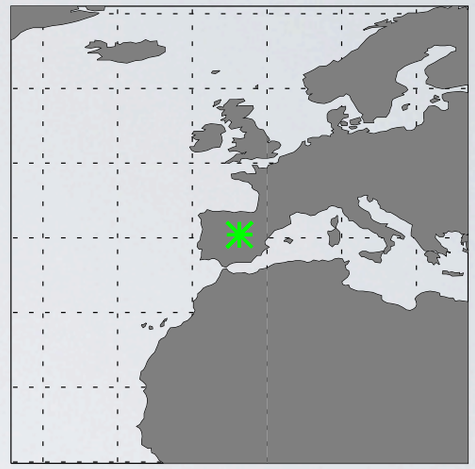
Diffuse Horizontal Illuminance

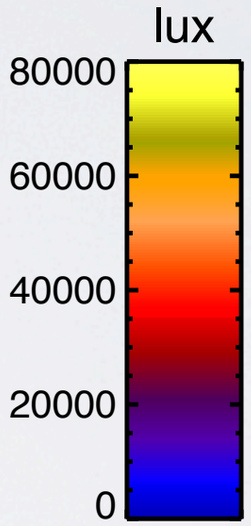


Direct Normal Illuminance



ESP_Madrid



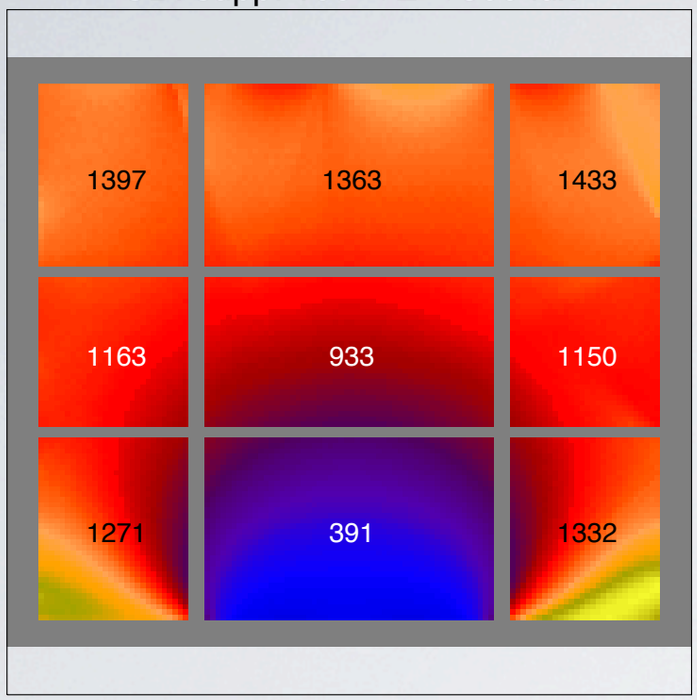


Useful daylight illuminance (UDI)

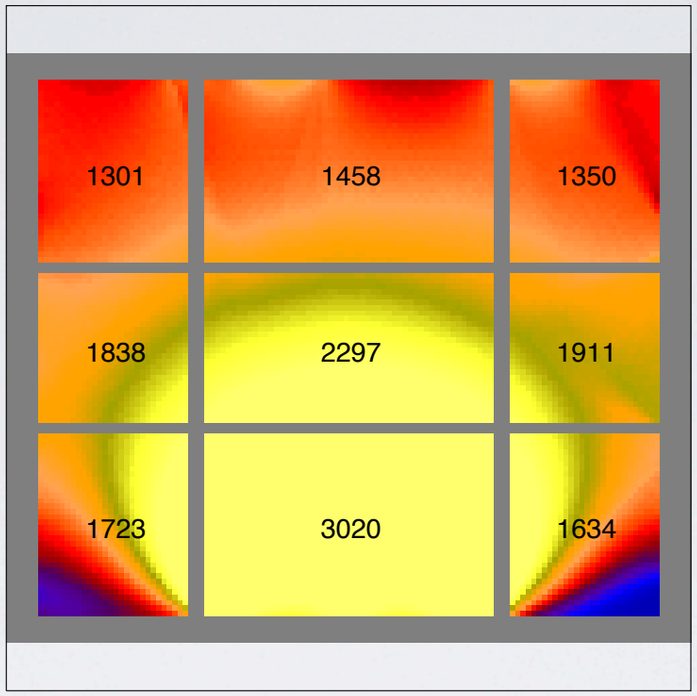
Determine annual occurrence of daylight illuminance within four ranges:

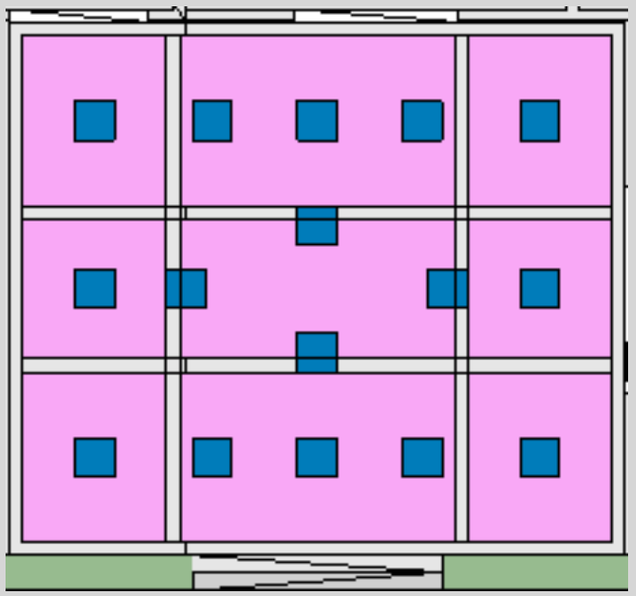
- Less than 100 lux ➔ UDI-fell-short or **UDI-f**
- 100 to 300 lux ➔ UDI-supplementary or **UDI-s**
- 300 to 3000 lux ➔ UDI-autonomous or **UDI-a**
- Greater than 3000 lux ➔ UDI-exceeded or **UDI-e**

UDI supp: 100 < E < 300 lux

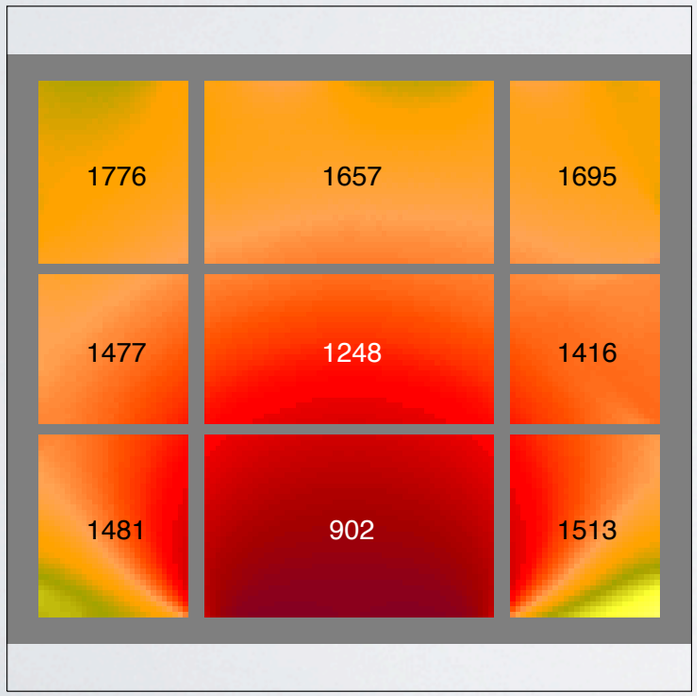


UDI auto: 300 < E < 3000 lux

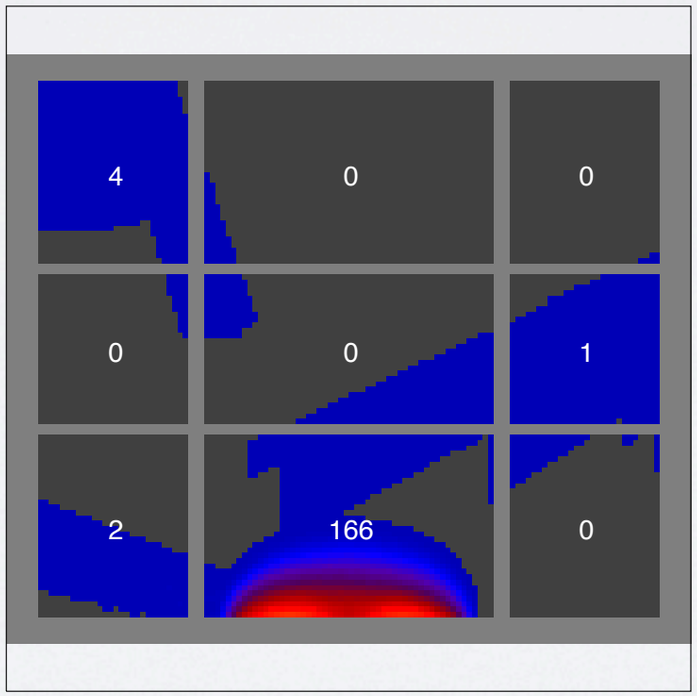




UDI fell-short: E < 100 lux

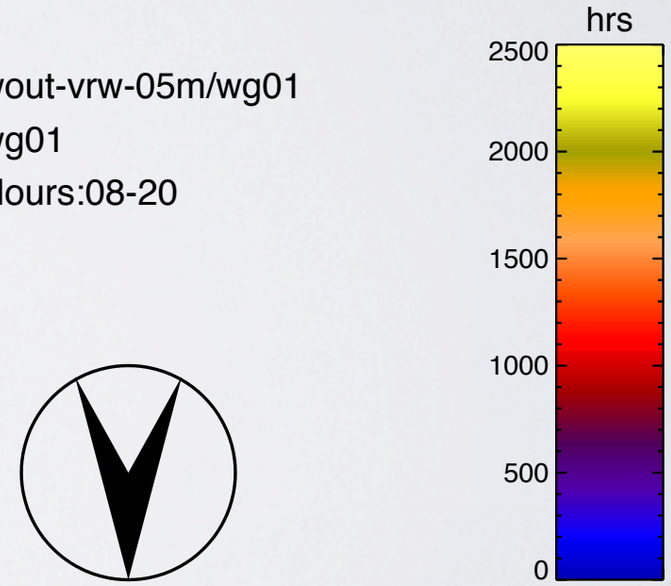


UDI exceeded: E > 3000 lux



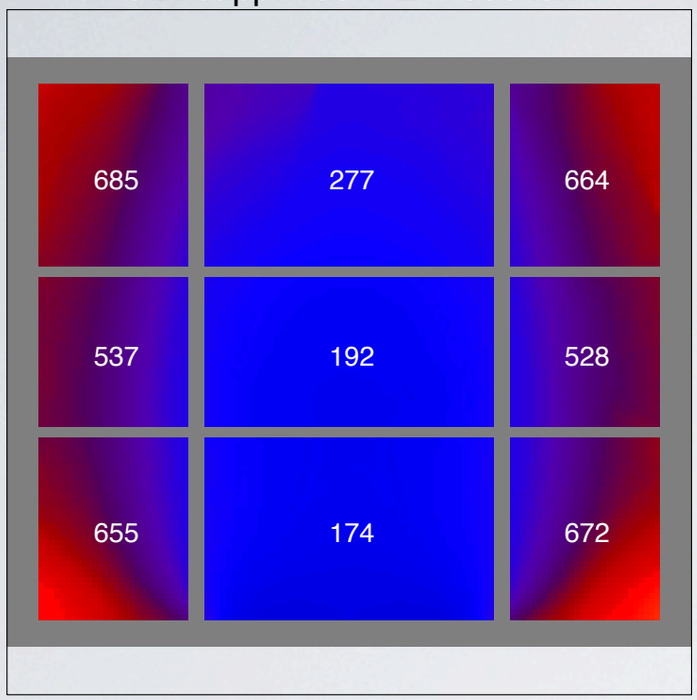
UDI metrics

wout-vrw-05m/wg01
wg01
Hours:08-20

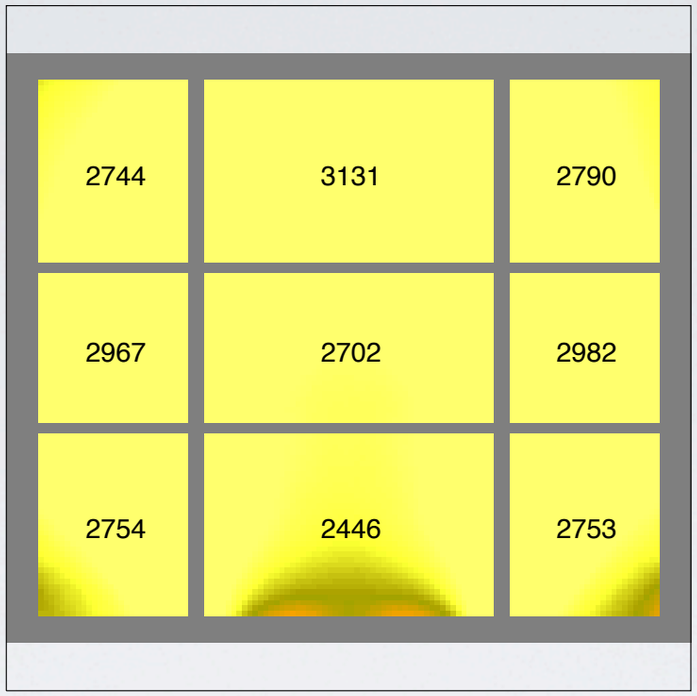


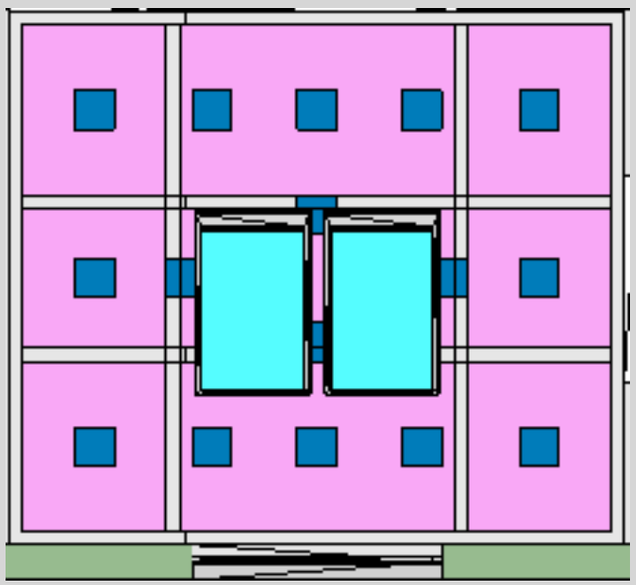
180 DEU-Hamburg

UDI supp: 100 < E < 300 lux

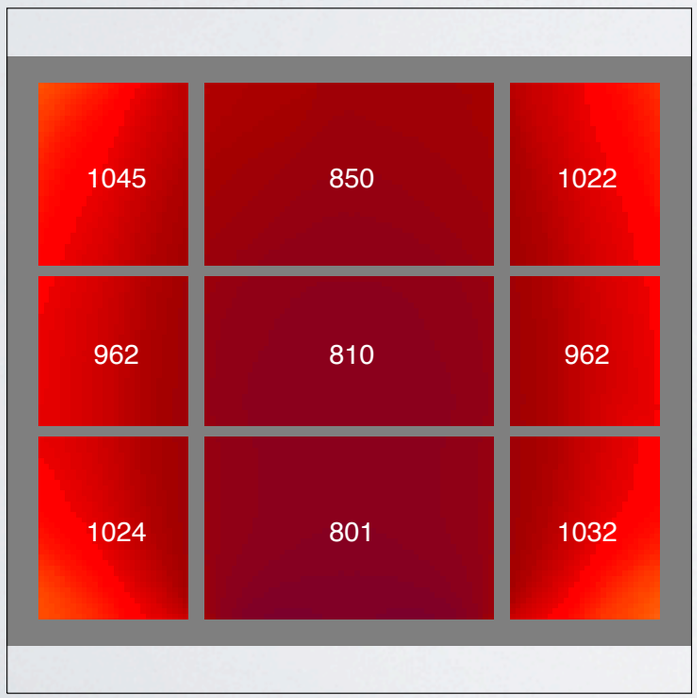


UDI auto: 300 < E < 3000 lux

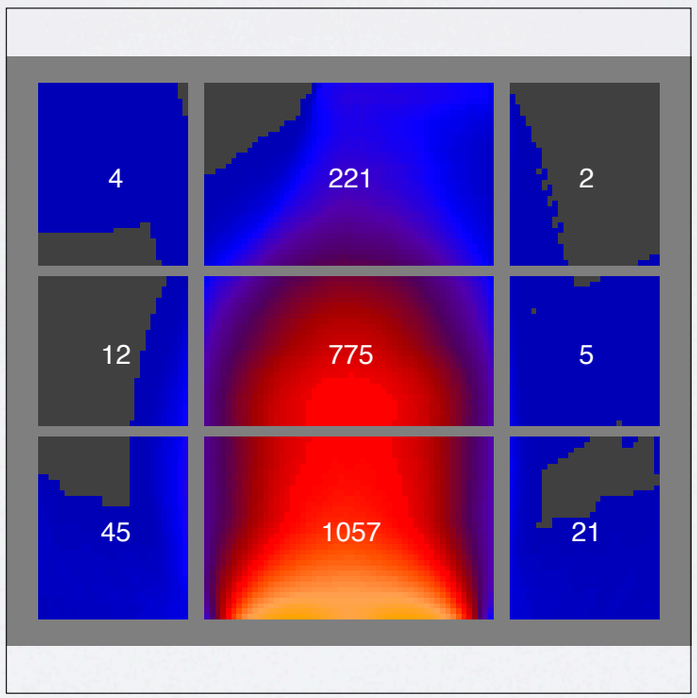




UDI fell-short: E < 100 lux

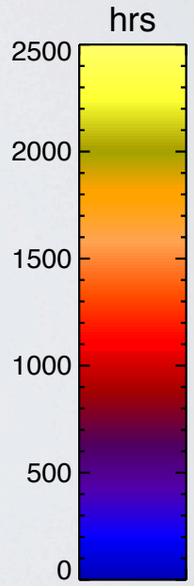


UDI exceeded: E > 3000 lux



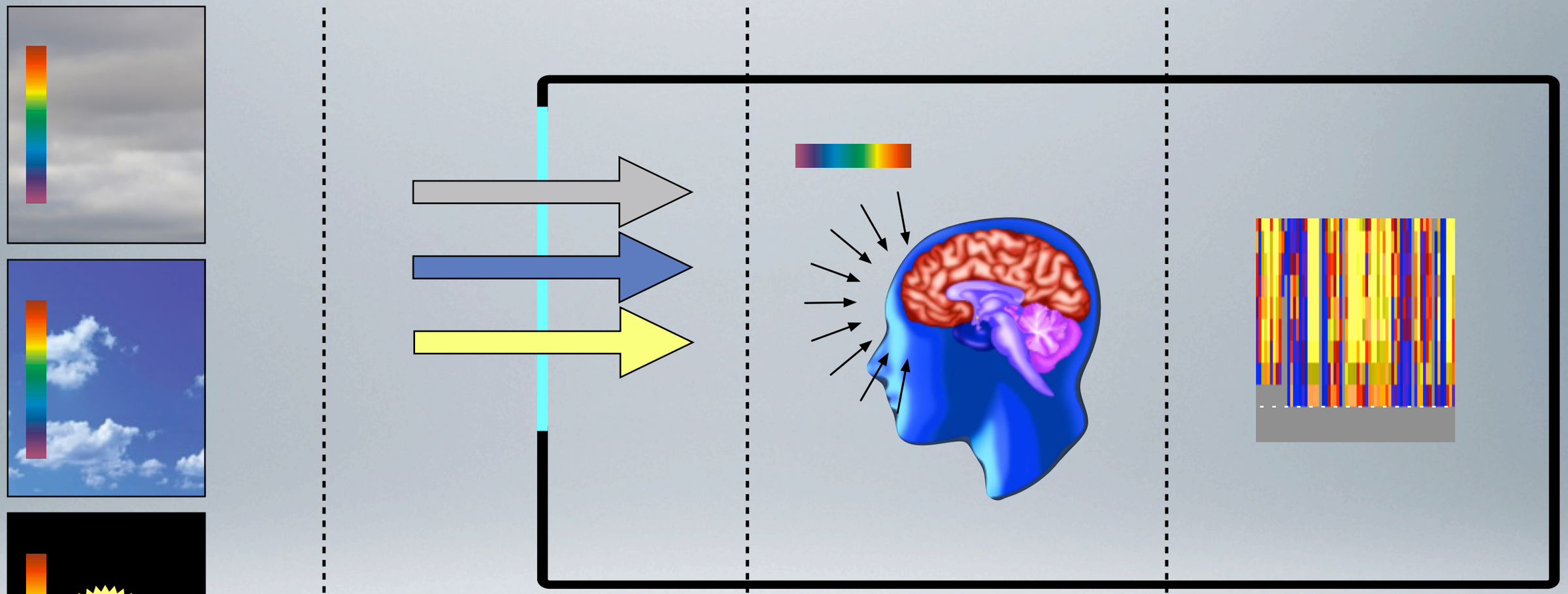
UDI metrics

with-vrw-05m/wg01
wg01
Hours:08-20



180 DEU-Hamburg

A simulation model for non-visual effects



Daylight sources

Daylight transfer

Non-visual effects

Data analysis visualisation

Timing/duration

Spectrum

Intensity

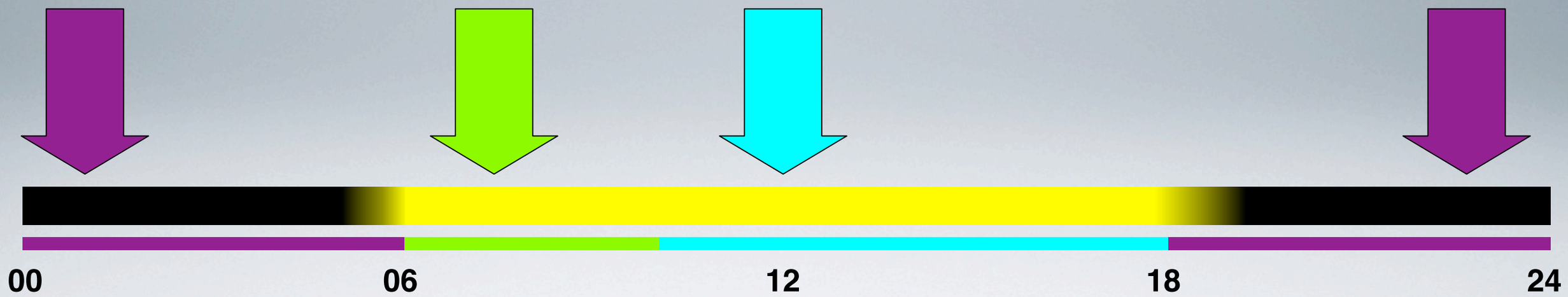
Non-visual effects

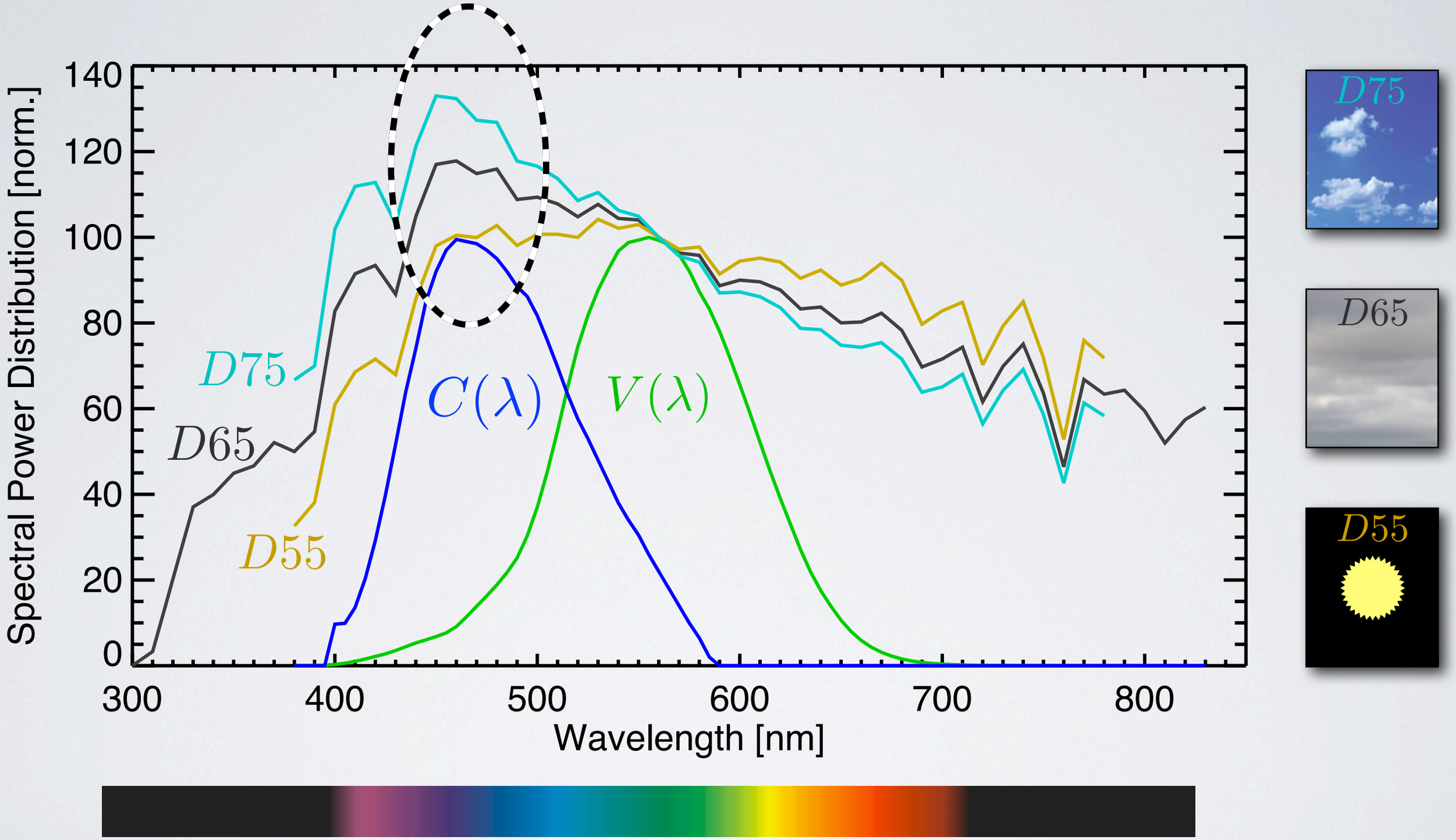
Circadian system highly sensitive to light

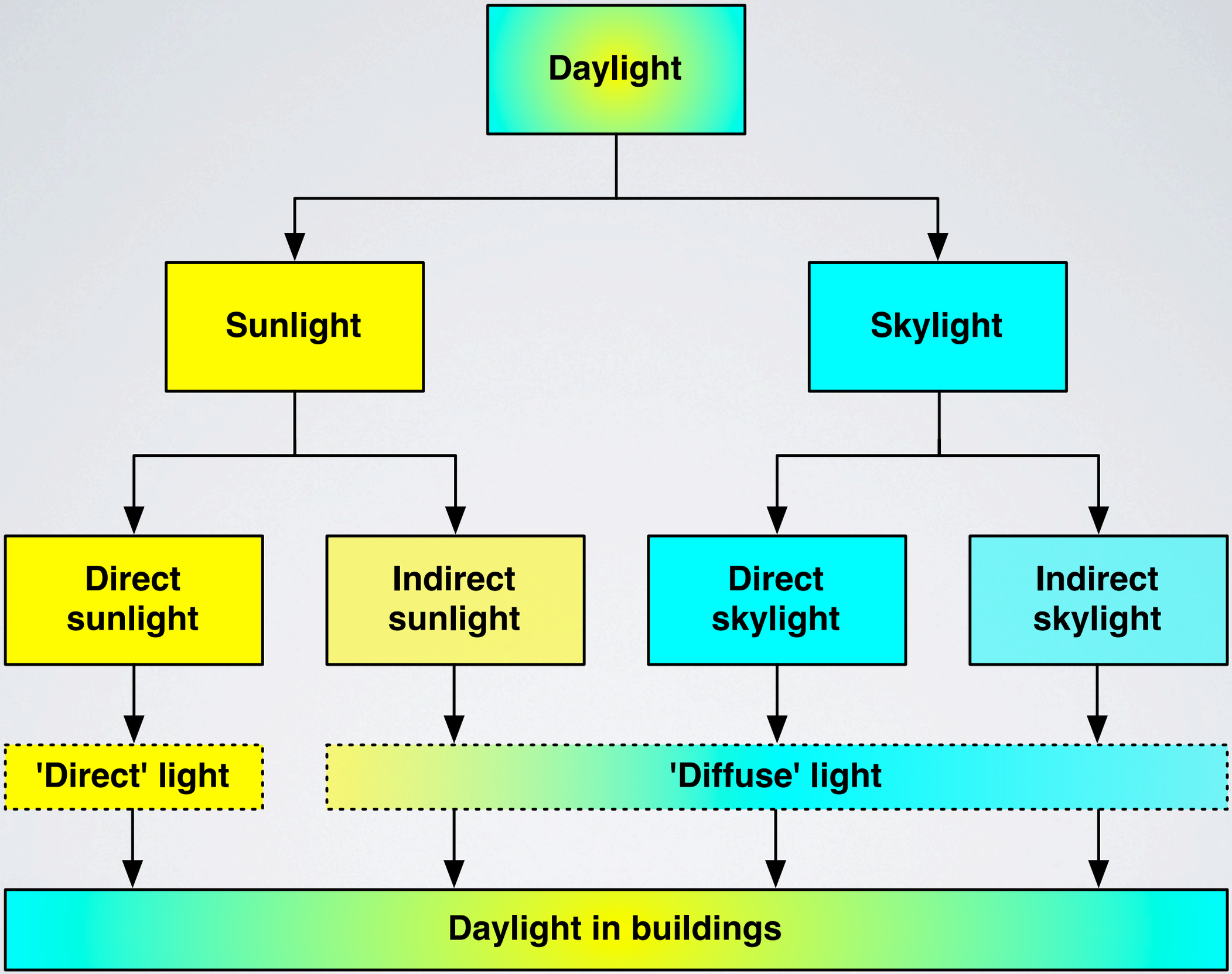
Light exposure advances circadian clock

Light exposure can increase alertness

Light exposure delays circadian clock




Spectral Power Distribution [norm.]
140
120
100
80
60
40
20
0
300
400
500
600
700
800
Wavelength [nm]
D75
D65
D55
C(λ)
V(λ)
D75
D65
D55


Daylight
Sunlight
Skylight
Direct sunlight
Indirect sunlight
Direct skylight
Indirect skylight
'Direct' light
'Diffuse' light
Daylight in buildings

$D55$

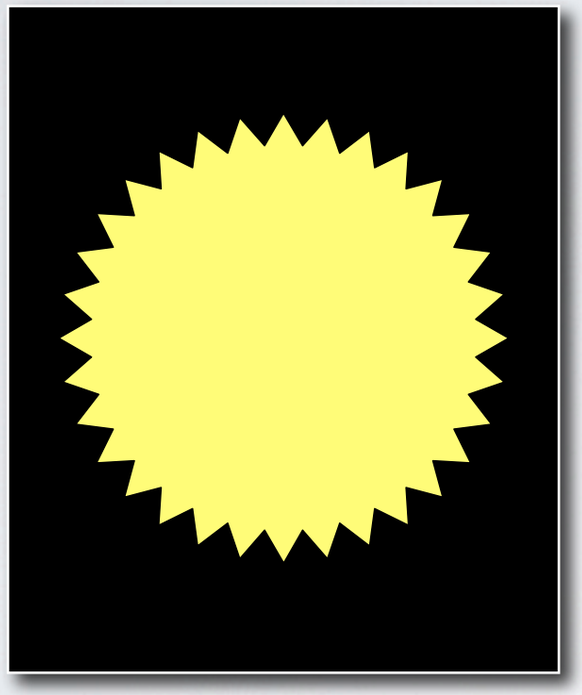
$D75$

Daylight coefficient scheme

$$\mathbf{E} = \mathbf{E}^{d} + \mathbf{E}^{i} + \mathbf{E}^{sd} + \mathbf{E}^{si}$$

$$\begin{aligned} \mathbf{E} &= \left(\mathbf{D}^{d145} \times \mathbf{c}^{145}\right) + \left(\mathbf{D}^{i145} \times \mathbf{c}^{145}\right) + \\ & \mathbf{D}_{\beta}^{d5k} S^{sun} L^{sun} + \mathbf{D}_{\beta}^{i145} S^{sun} L^{sun} \end{aligned}$$

Light from
the sun

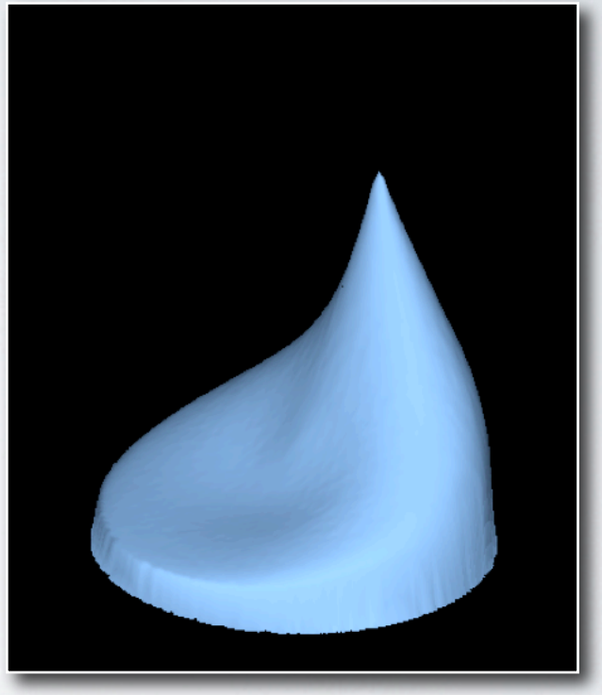


D55

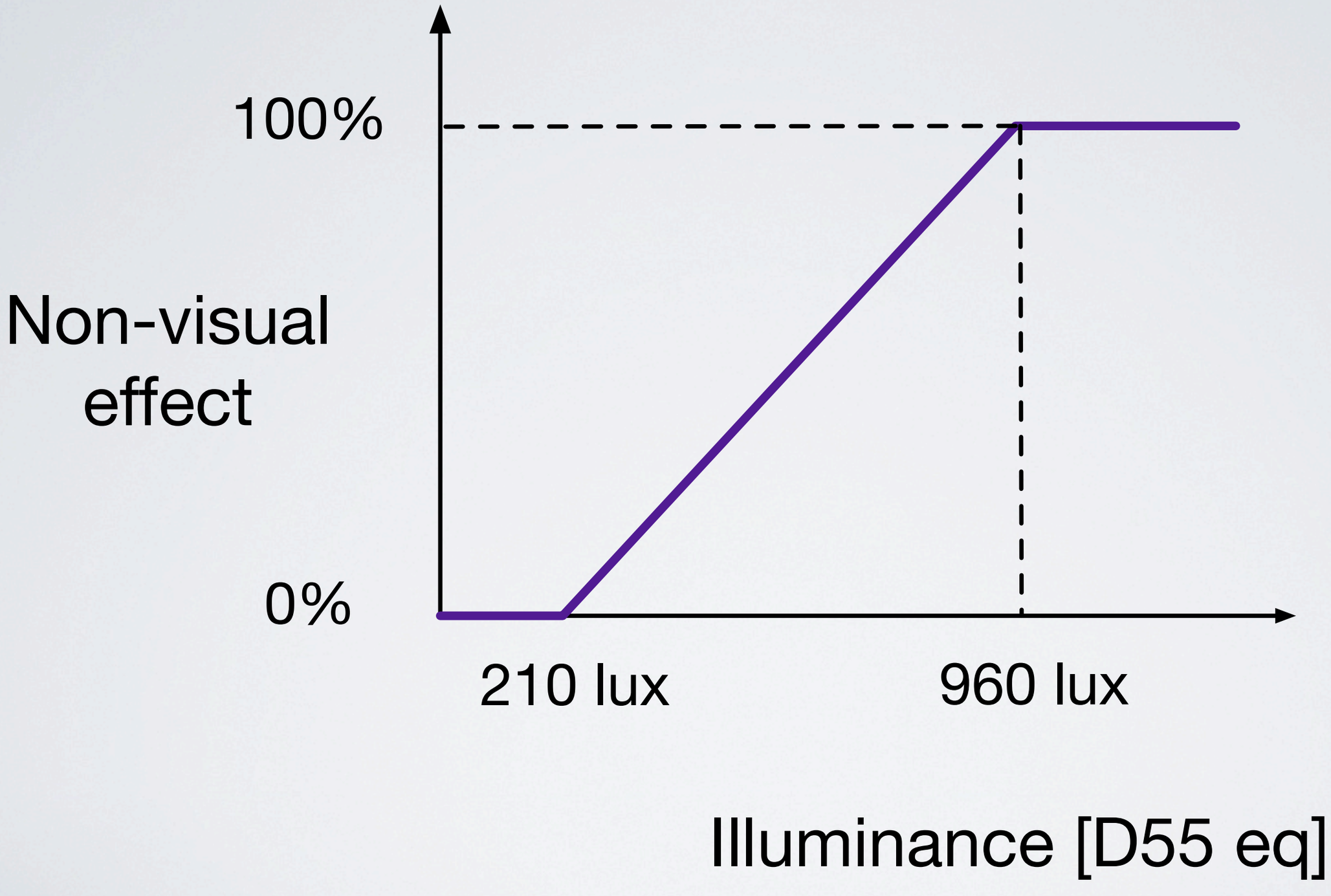
Light from an
overcast sky

D65

Light from a
clear sky

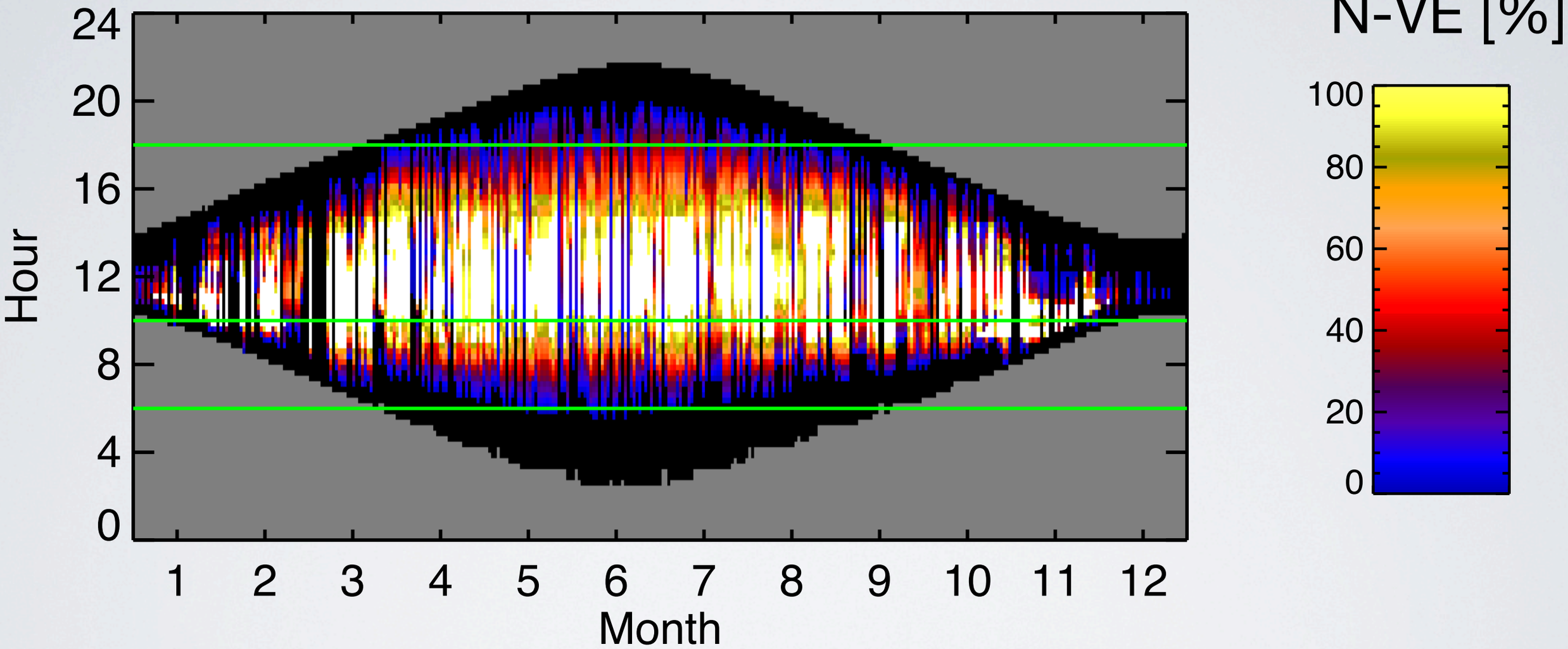


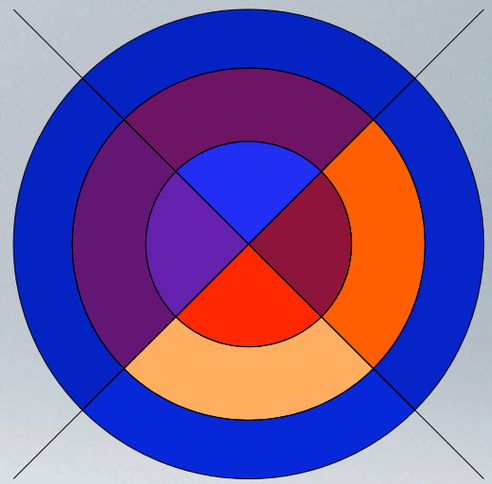
D75


100%
Non-visual effect
0%
210 lux
960 lux
Illuminance [D55 eq]

Data analysis and visualisation

- Predict vertical illuminance at the eye.
- Arbitrary view directions possible.
- Massive amount of illuminance data generated.
- Need some way to represent data which has properties of position and (view) direction, in addition to showing the effect for the three different periods over a full year.


N-VE [%]
100
80
60
40
20
0
Hour
24
20
16
12
8
4
0
1
2
3
4
5
6
7
8
9
10
11
12
Month
100%
0%



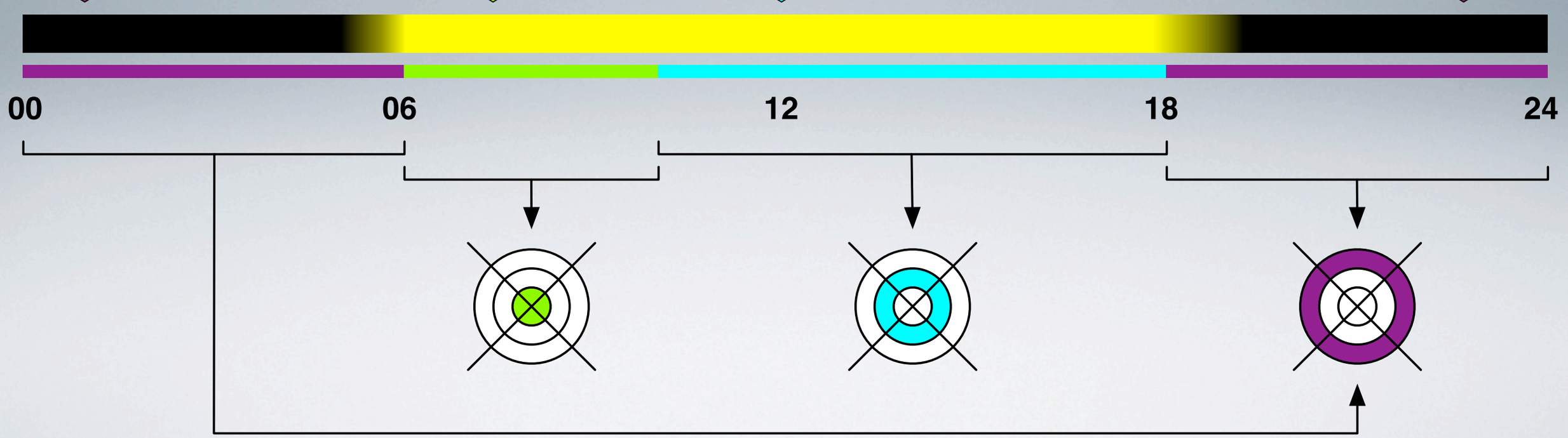
The ‘sombrero’ plot

Circadian system highly sensitive to light

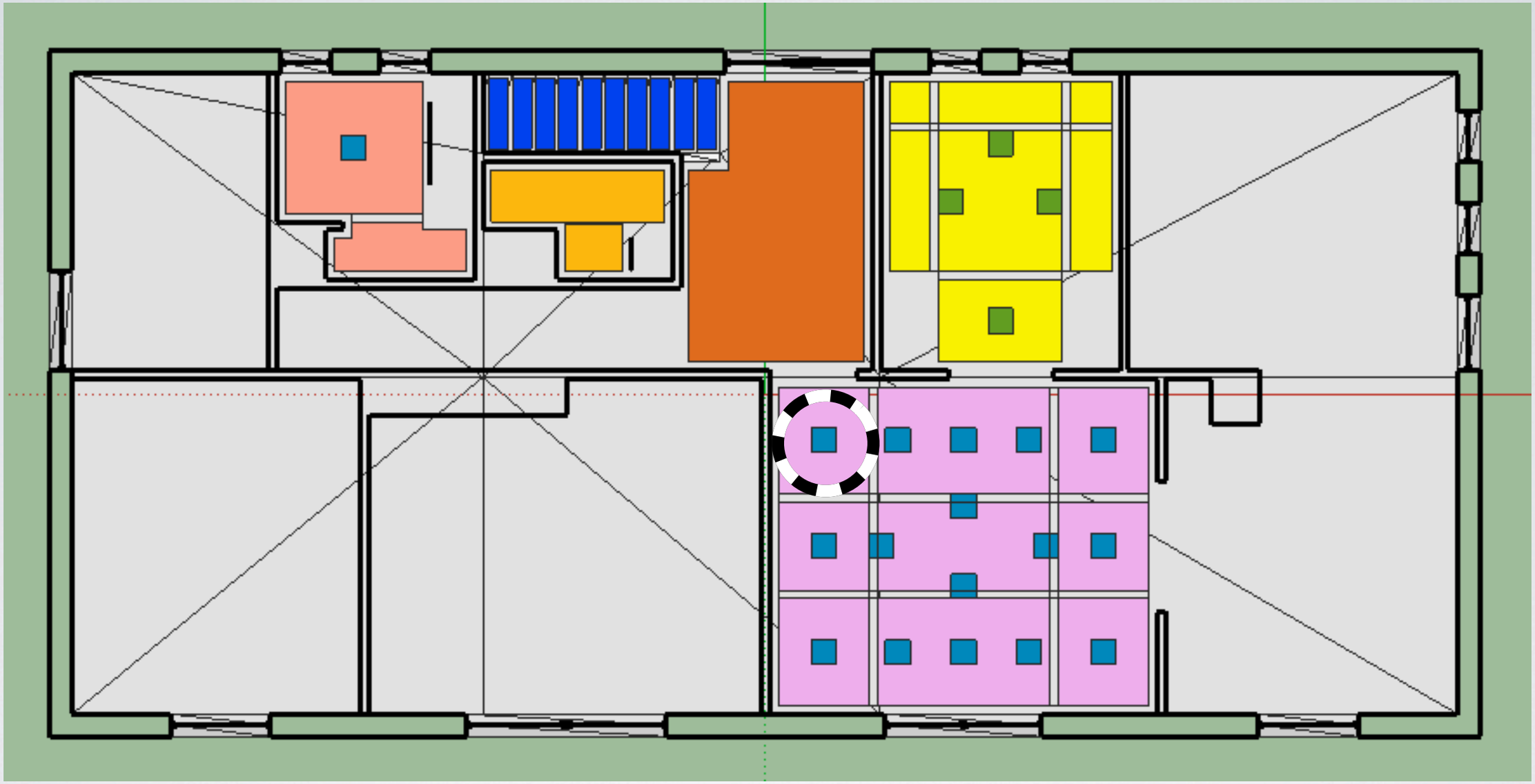
Light exposure advances circadian clock

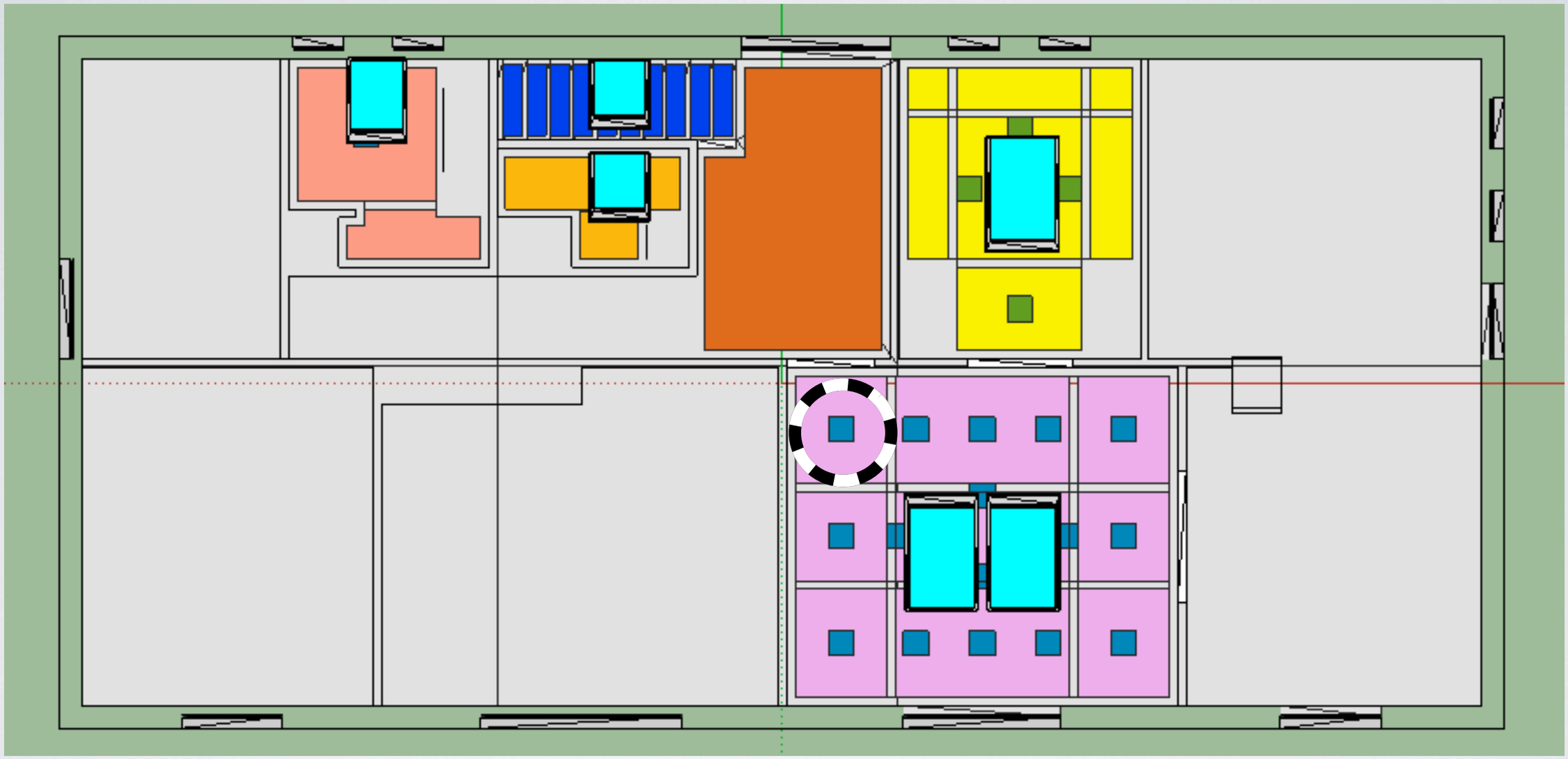
Light exposure can increase alertness

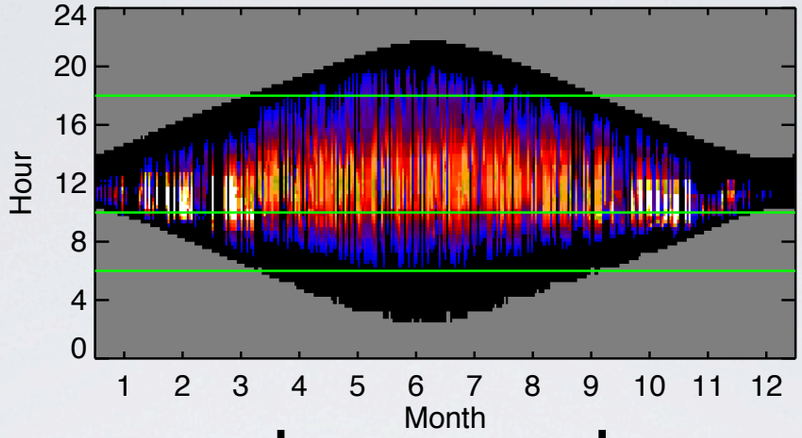
Light exposure delays circadian clock

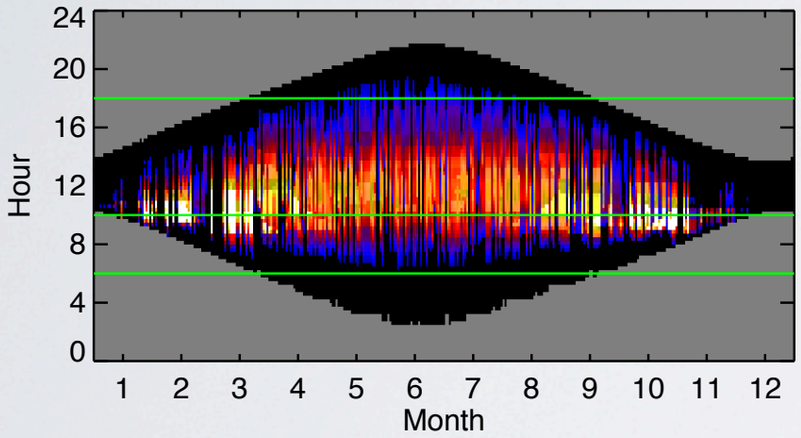


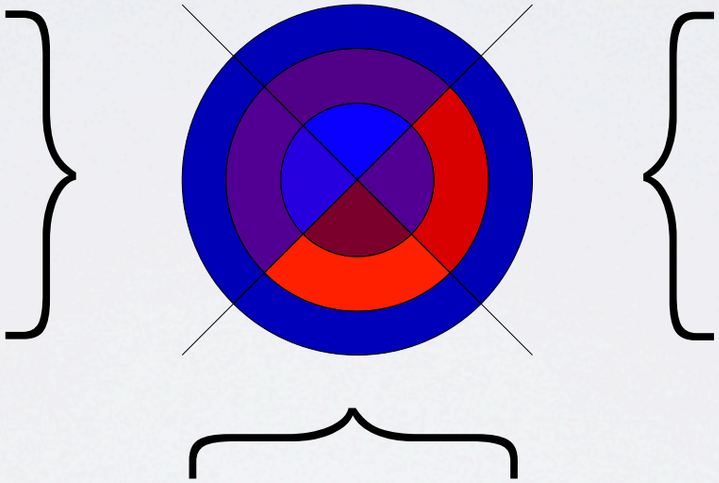
Example application

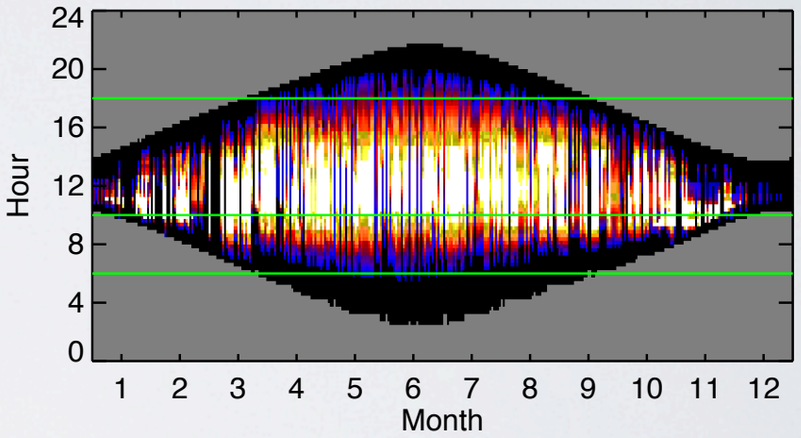


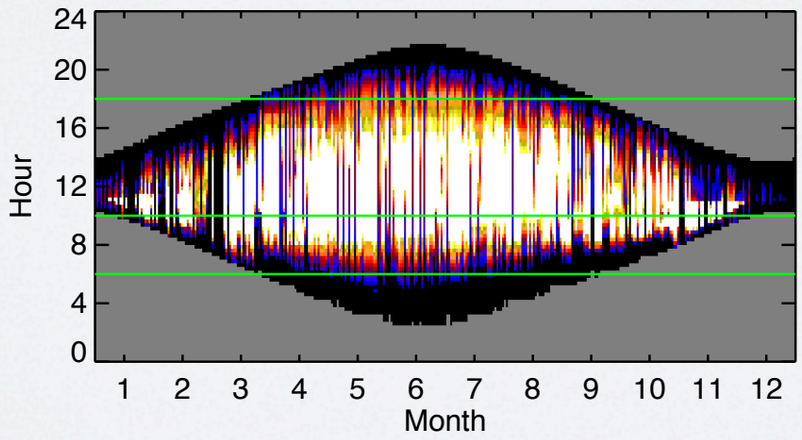


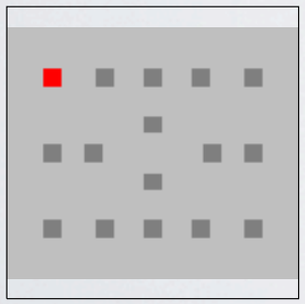


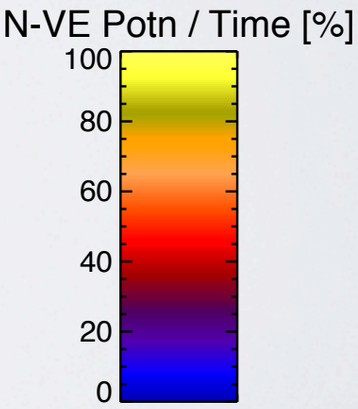






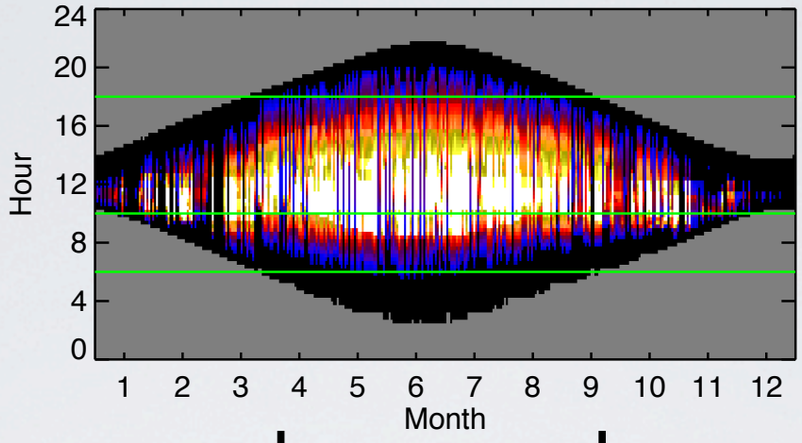


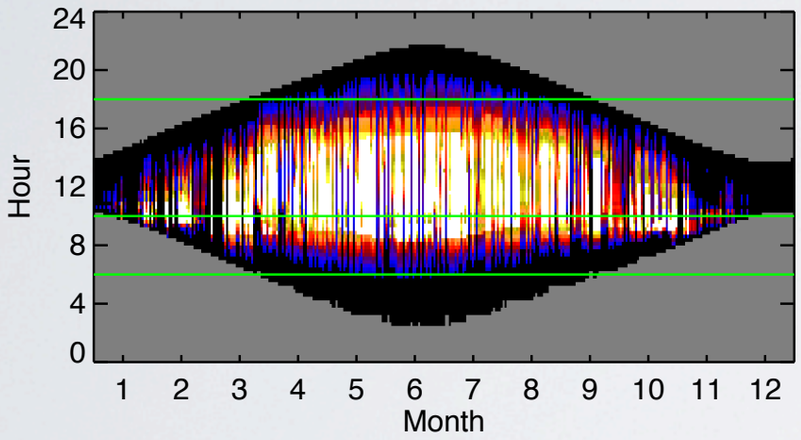


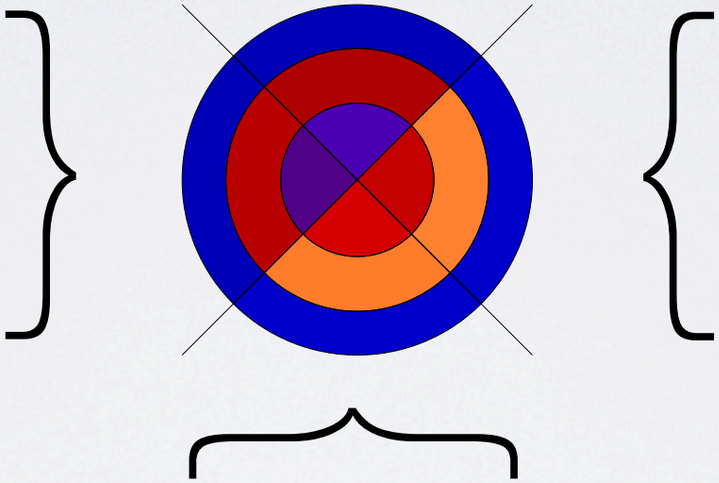


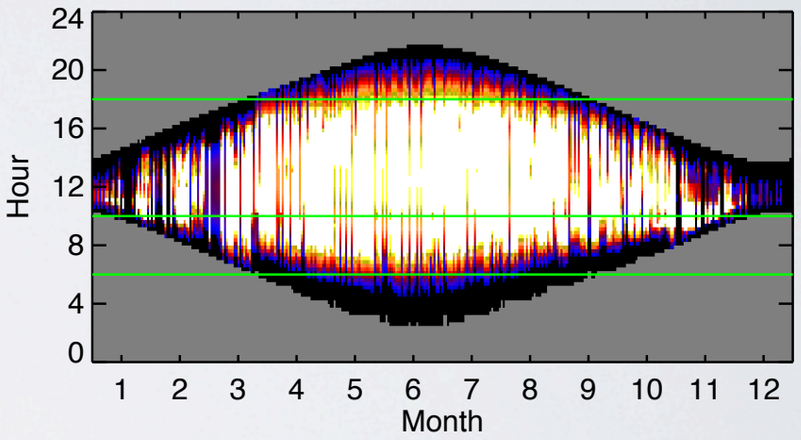
wout-vrw-05m/hs01

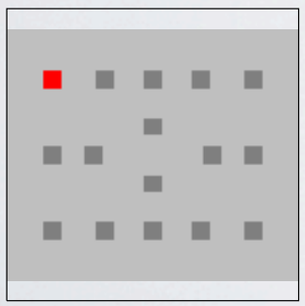
000 SWE-Ostersund

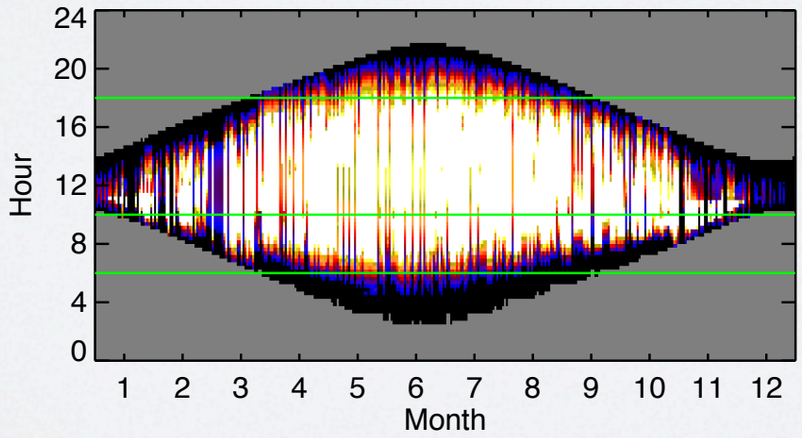


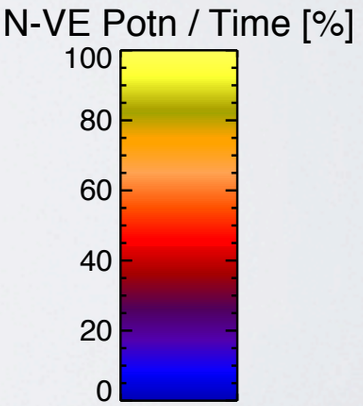






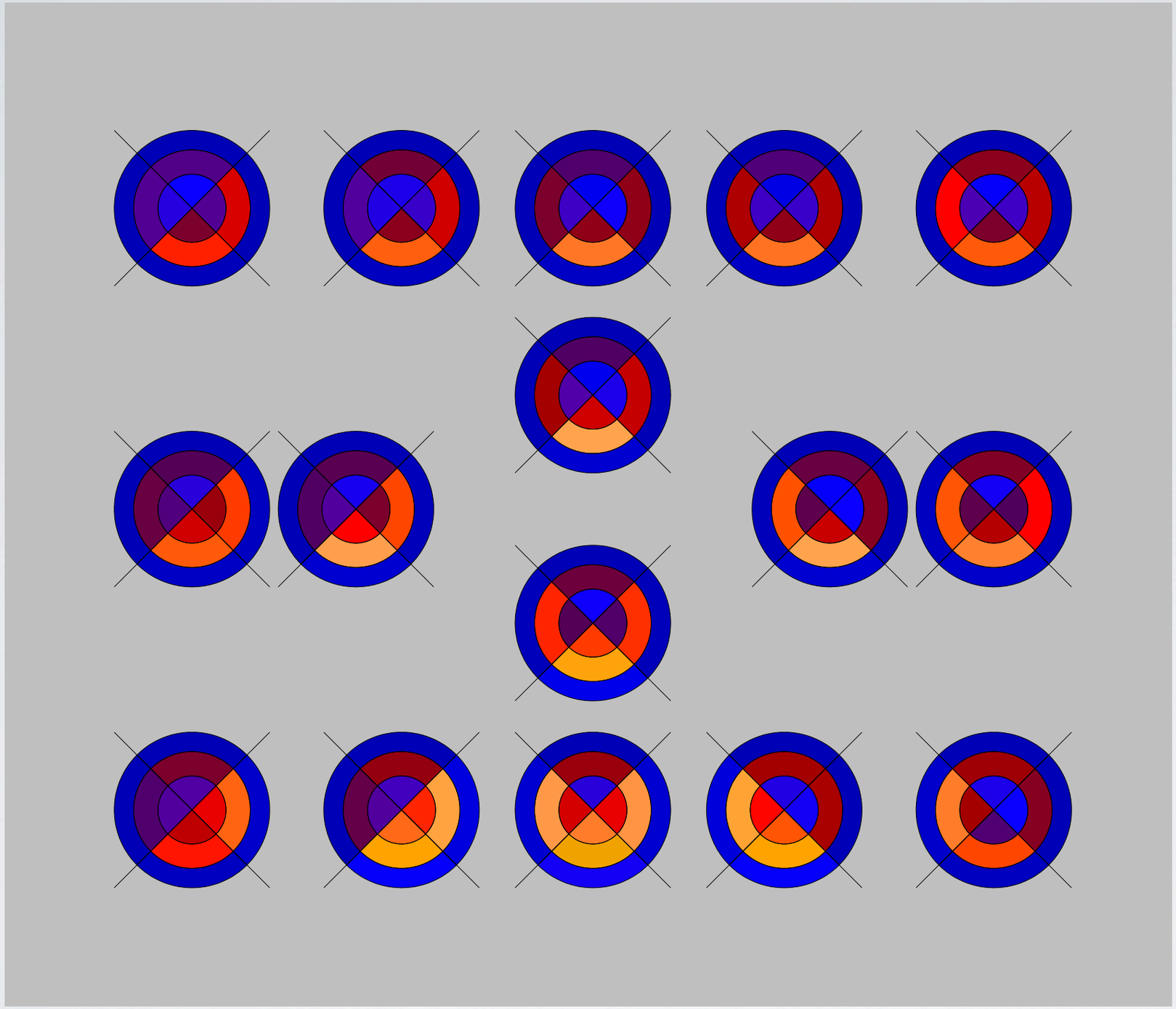


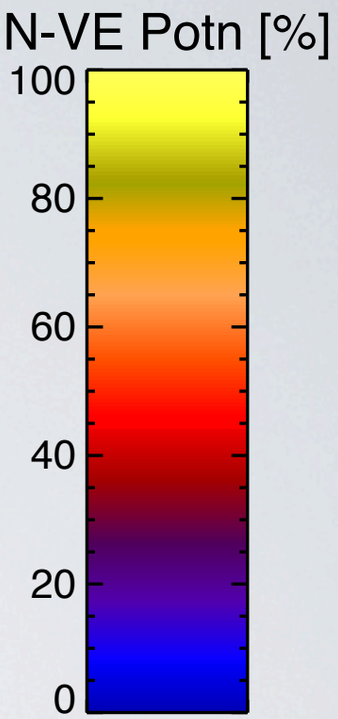


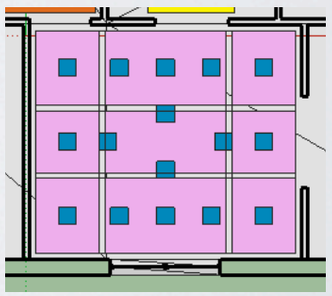


with-vrw-05m/hs01

000 SWE-Ostersund







wout-vrw-05m/hs01

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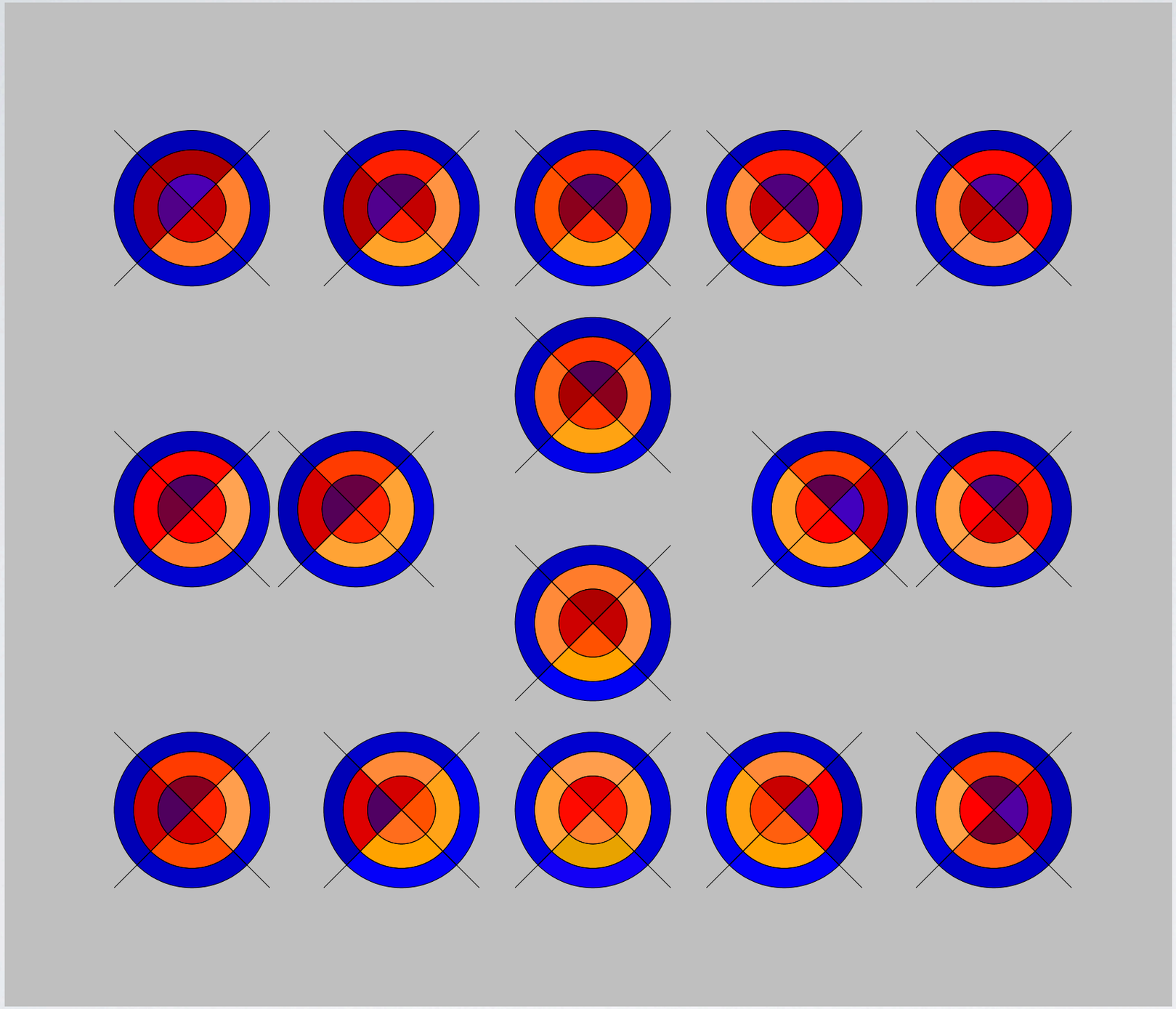

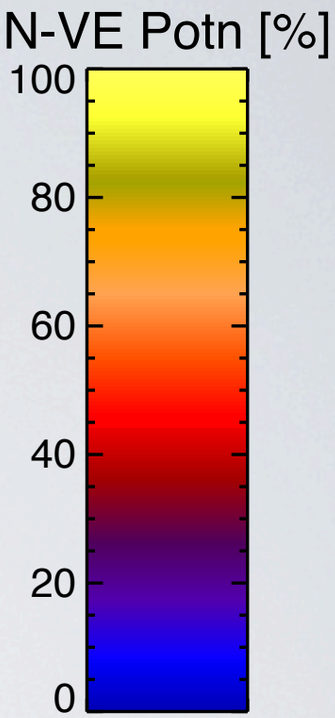

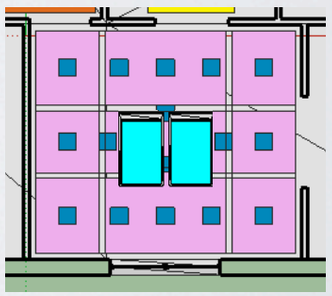

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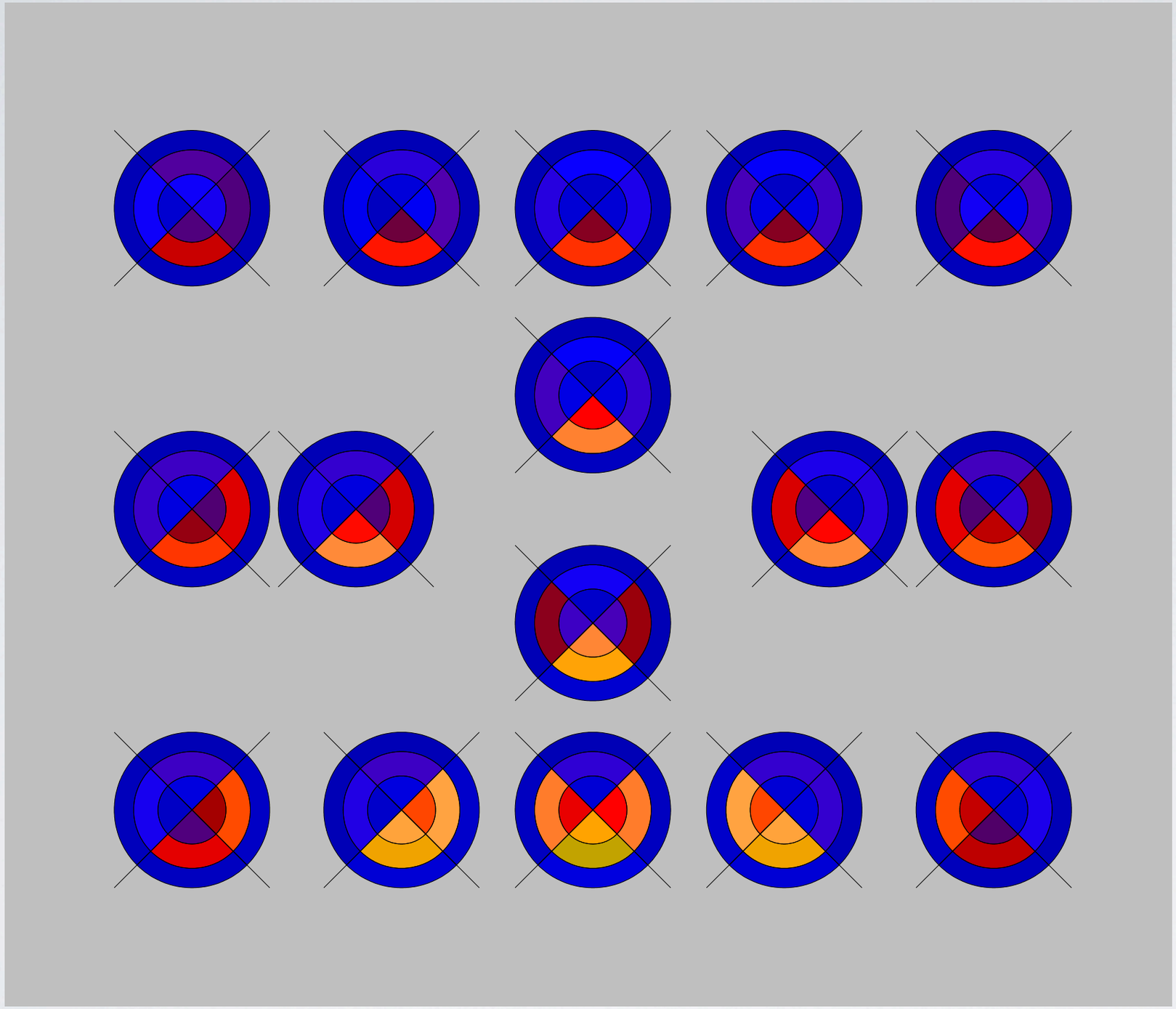
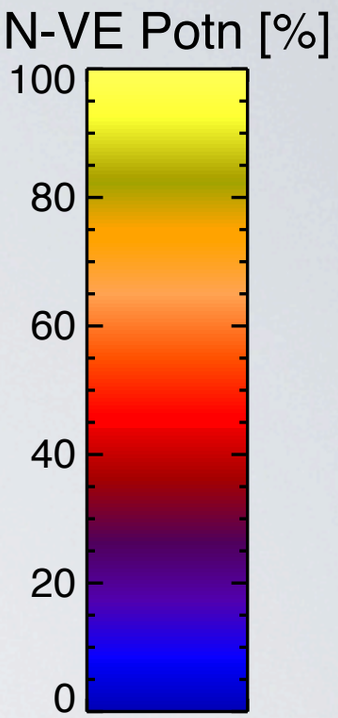
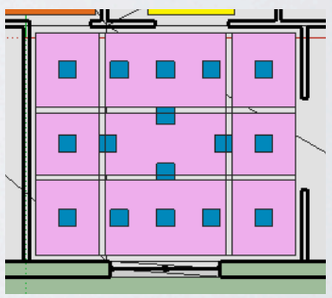
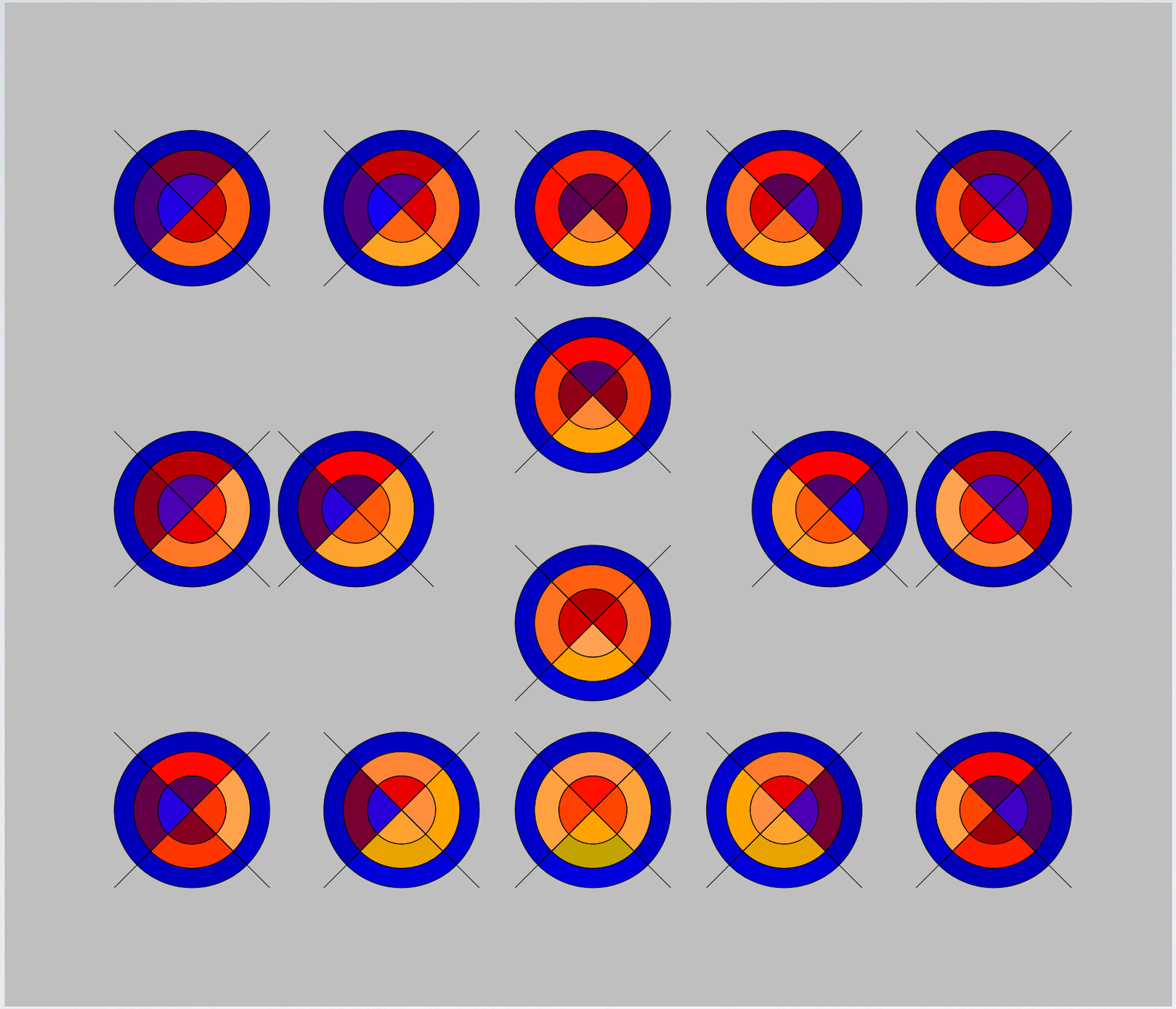


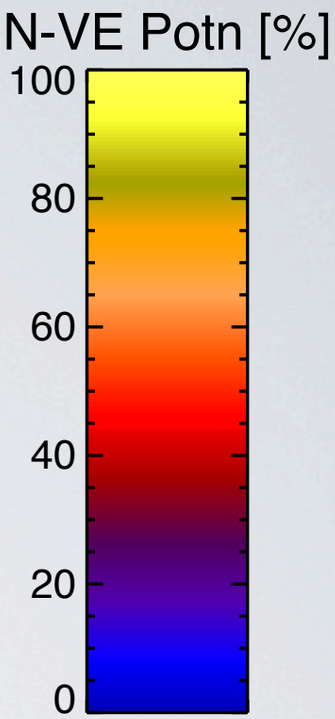


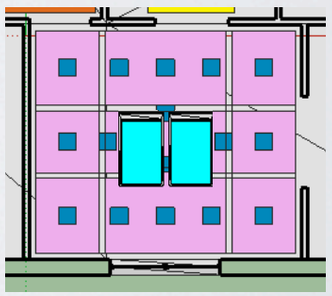


wout-vrw-05m/hs01

180 POL-Warsaw





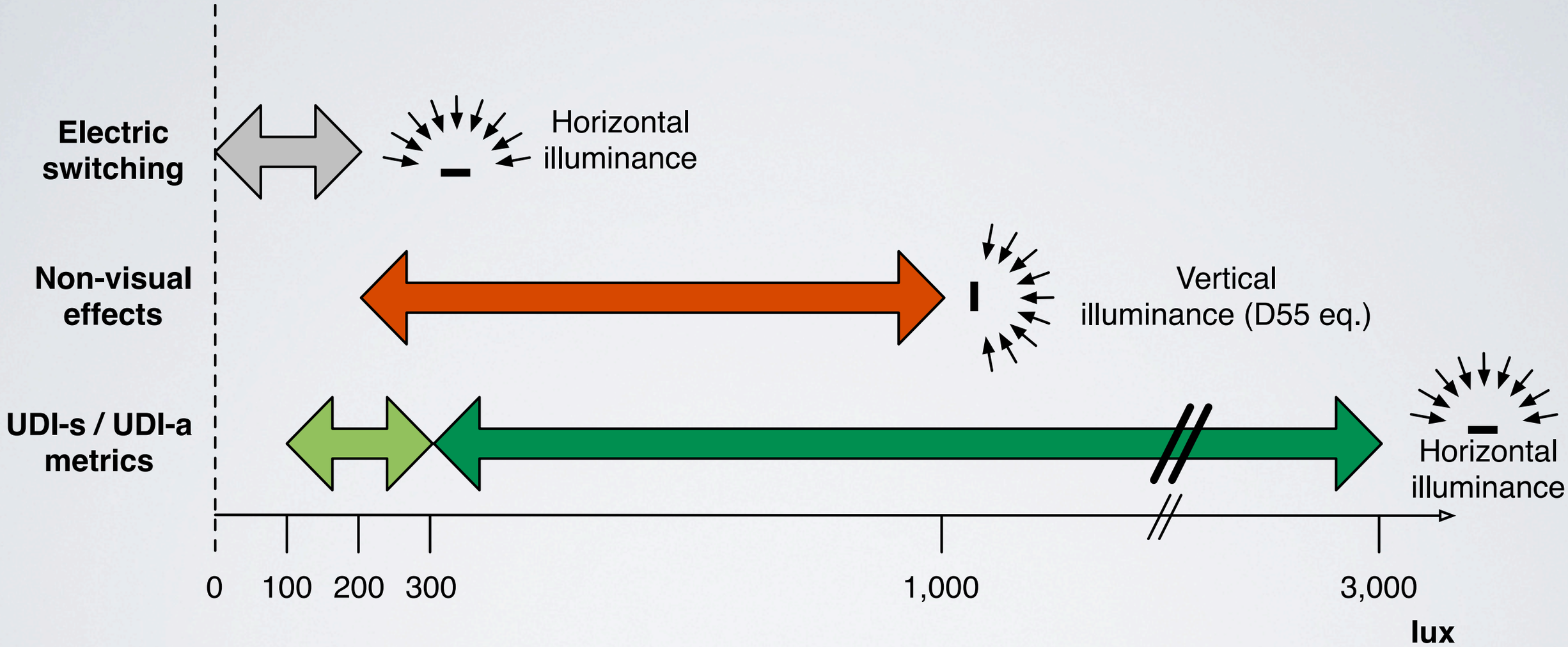


with-vrw-05m/hs01

180 POL-Warsaw

Further work

- Is it possible for one measure to act as a proxy for others?
- Include predictions for visual comfort.
- As far as broad trends are concerned, do the measures work in concert or in conflict?
- Account for thermal effects e.g. overheating.


Electric switching
Horizontal illuminance
Non-visual effects
Vertical illuminance (D55 eq.)
UDI-s / UDI-a metrics
Horizontal illuminance
0
100
200
300
1,000
3,000
lux

Thank you

Acknowledgements:

Based on a project commissioned by the VELUX Group.

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