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Employing Radiance in Thermal Comfort Simulations involving Complex Fenestrations

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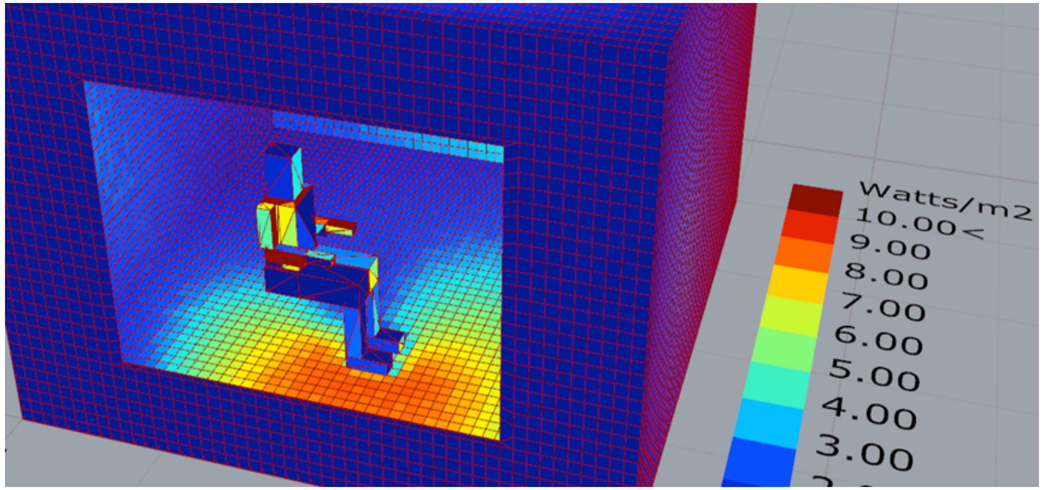
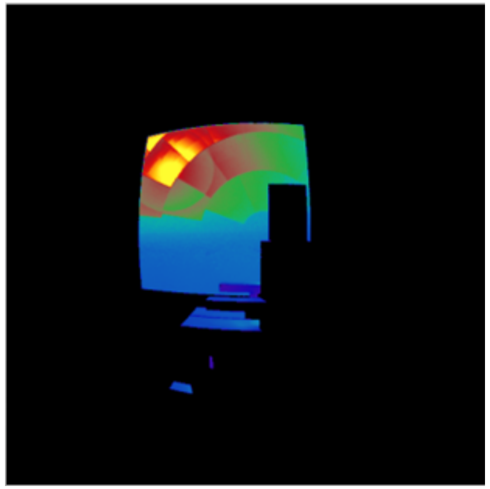
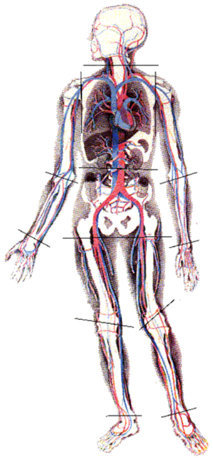
Overarching goals of this research





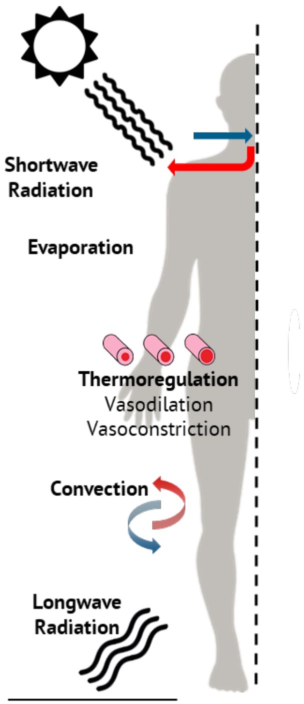


- Employ raytracing to estimate short-wave radiative load on human body.
- Incorporate solar load through complex fenestrations in Thermal Comfort calculations.
- Assessing the impact of local solar load through thermophysiological calculations.
- Use results from above steps in parallel with whole building simulations.

Outline

- **Solar Radiation and Thermal comfort**
- **Radiosity versus Raytracing**
- **Radiance-based Energy Balance**
- **Solar load calculations (coefficient-based)**
- **Thermal sensation and comfort results (PhySCo)**

Relevance of calculating local solar load on the body

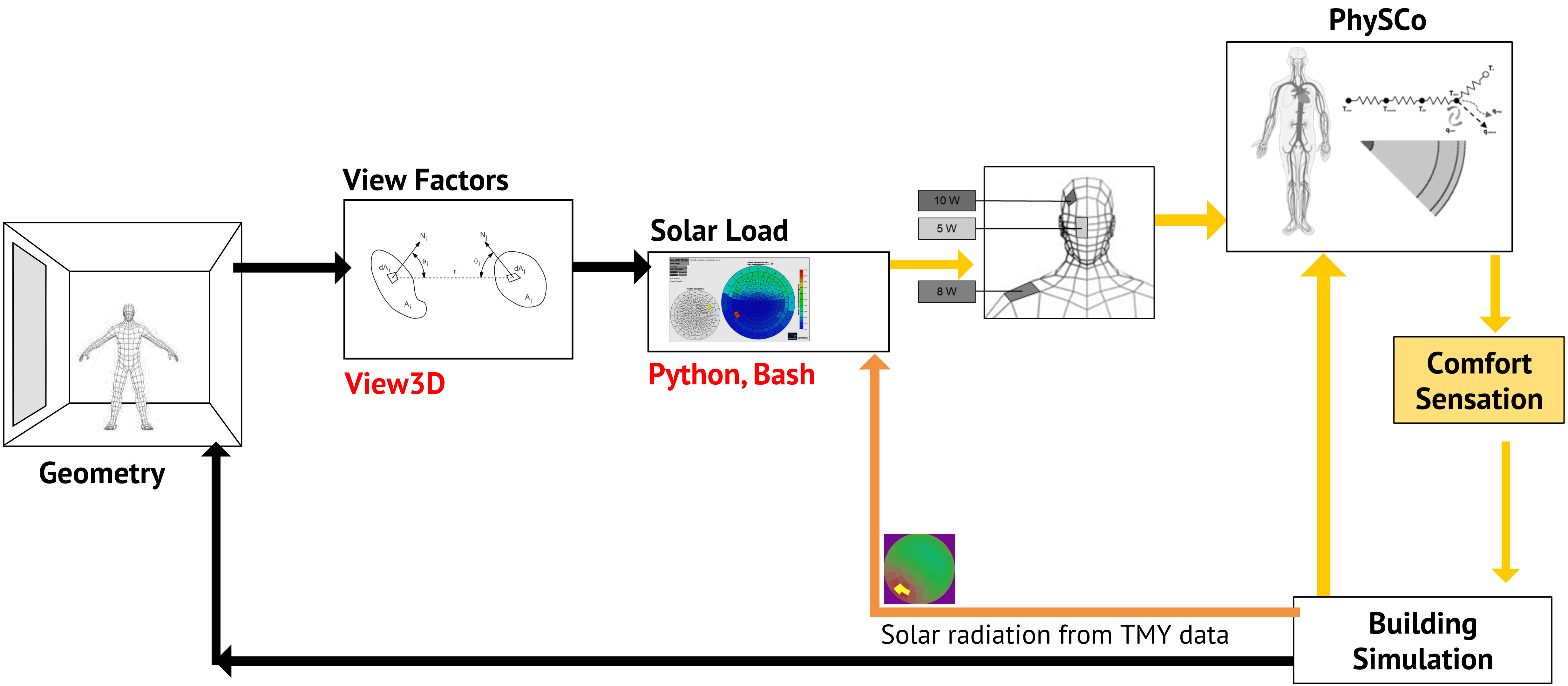


T_air	(°C)
V_air	(m/s)
RH	(%)
Local MRT	(°C)
Local Solar Load (W)	
Metabolic Rate	(met)
Clothing type	(clo)

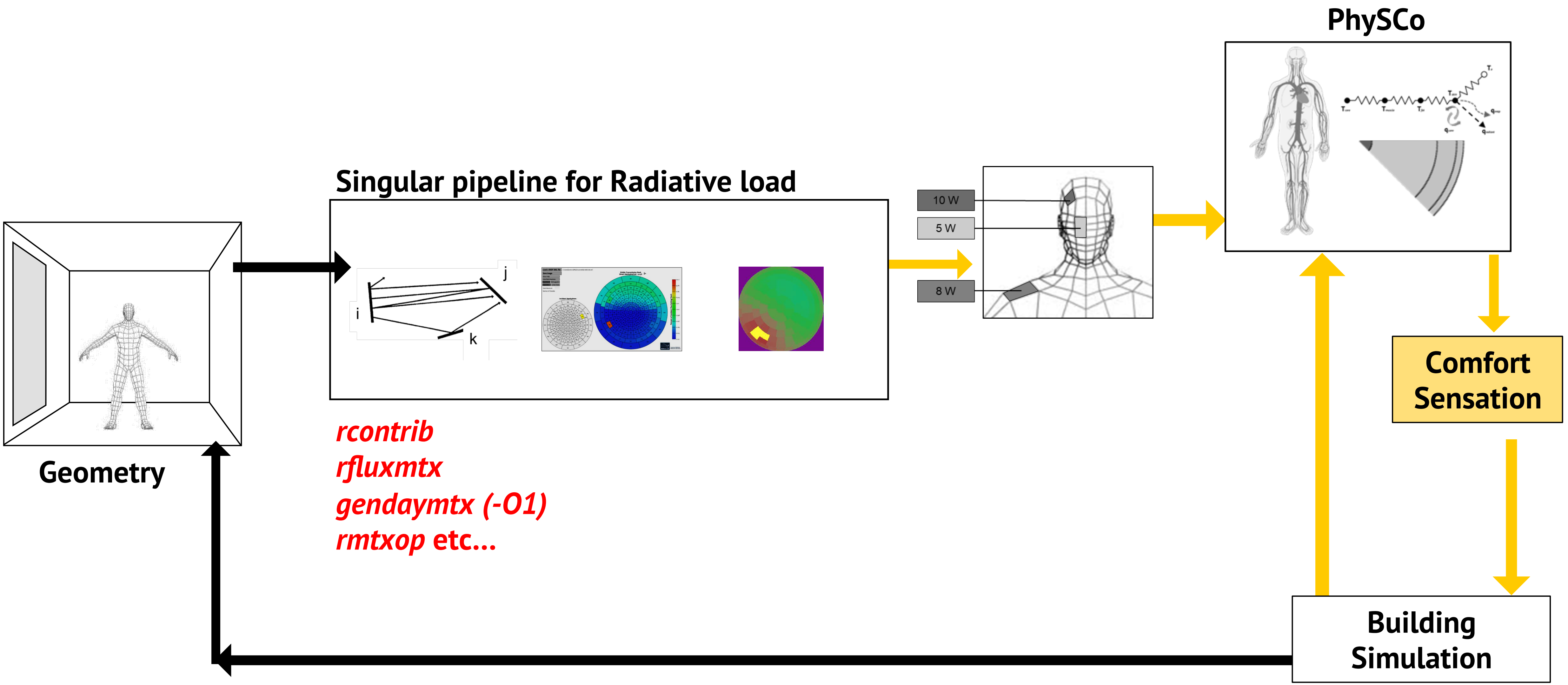
→ Skin & Core temperatures → Local Sensation → Local Comfort → Overall Comfort

PhySCo

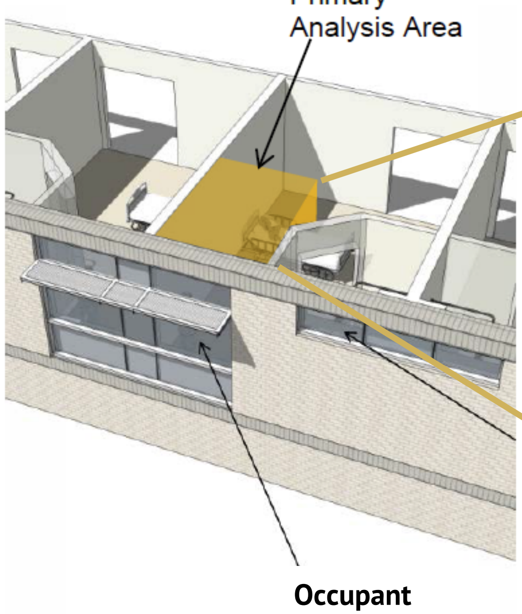
Present methodology to calculate solar load (SoLoCalc)



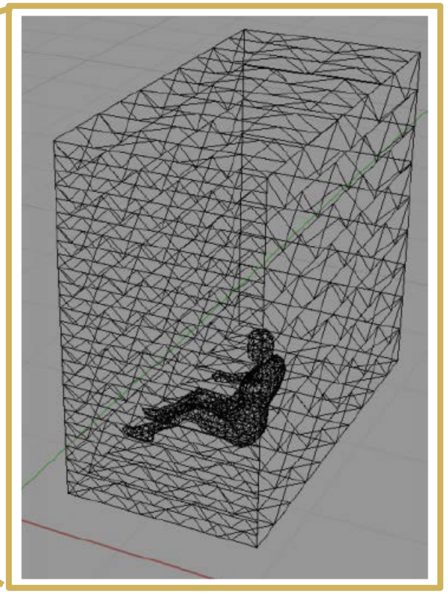
Radiance-based approach to calculate solar load



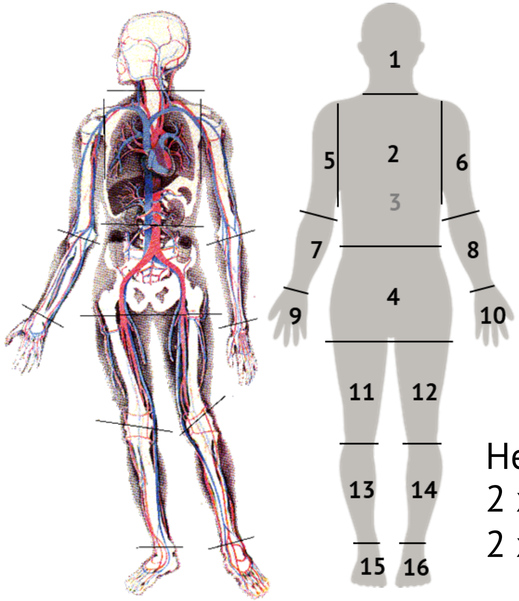
Why does it make sense to use Radiance?



Complex geometries



Specific areas of interest



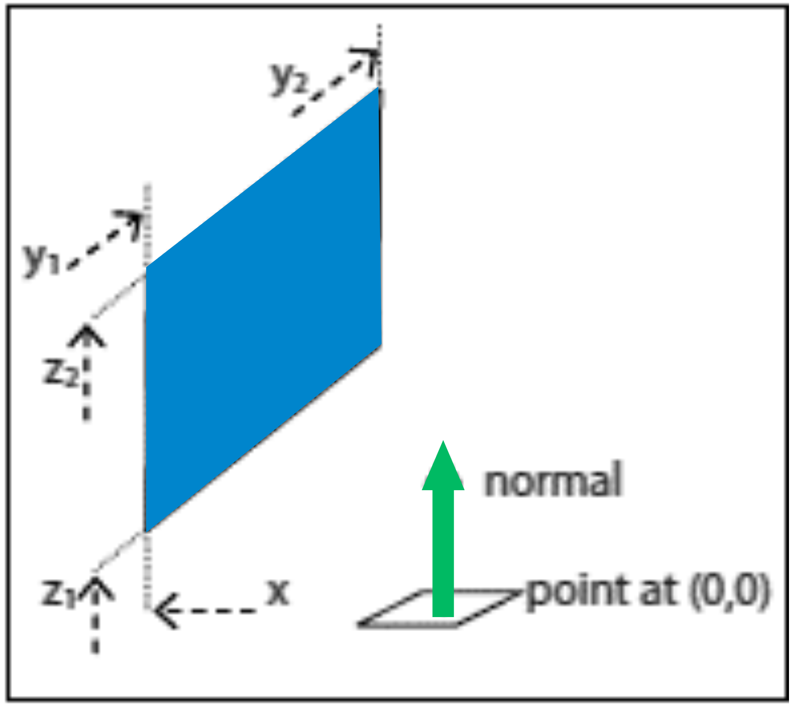
Head, Chest, Back, Pelvis
2 x (Shoulder, Arm, Hands)
2 x (Thigh, Calf, Foot)

Inputs for Thermo-physiology model

- Accuracy and speed can be optimized based on specific surfaces of interest.
- Radiance is multi-threaded, cross-platform, portable

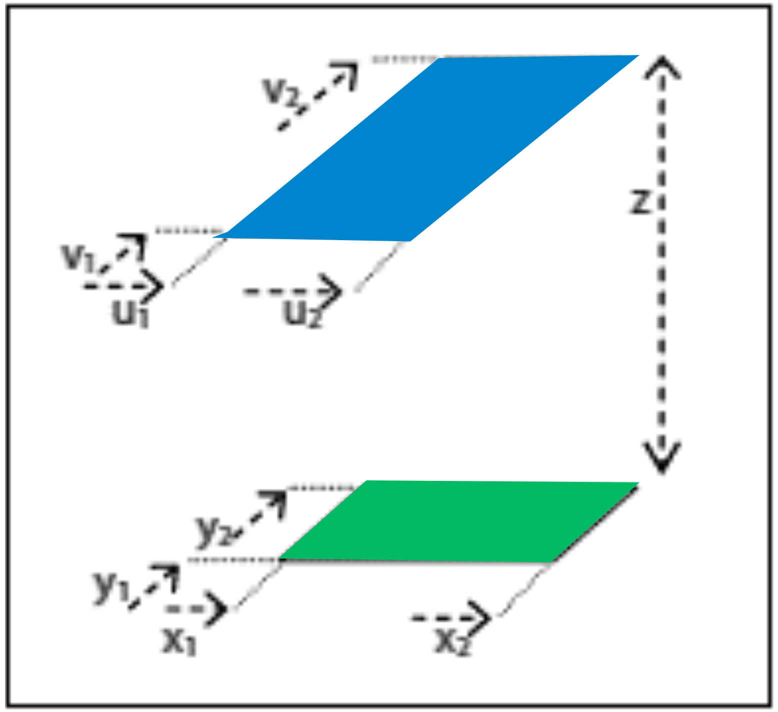
Workflows for calculating view factors in Radiance


```
rfluxmtx - receivers geometry < sender\
rays > view factors
```



Option 1: Similar to rtrace (Classic Radiance)

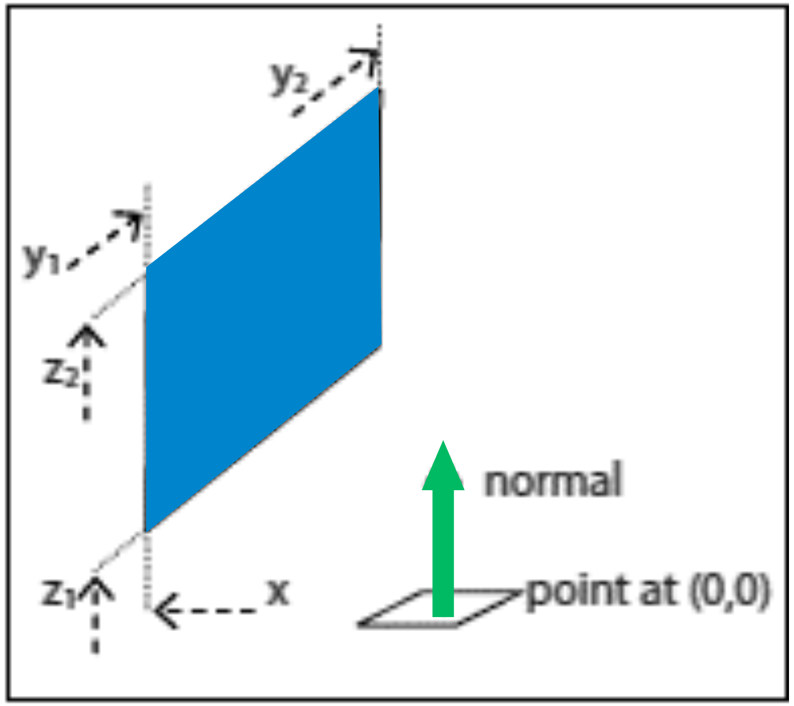
```
rfluxmtx sender surfaces receivers \
geometry > view factors
```



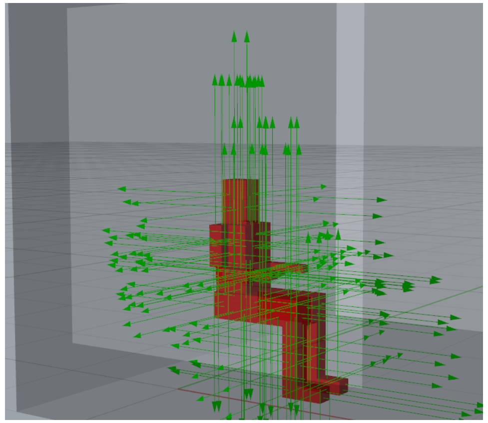
Option 2: Similar to Radiosity*

The rays-based approach is faster and easier to set up


```
rfluxmtx - receivers geometry < sender\
rays > view factors
```



Option 1: Similar to rtrace (Classic Radiance)

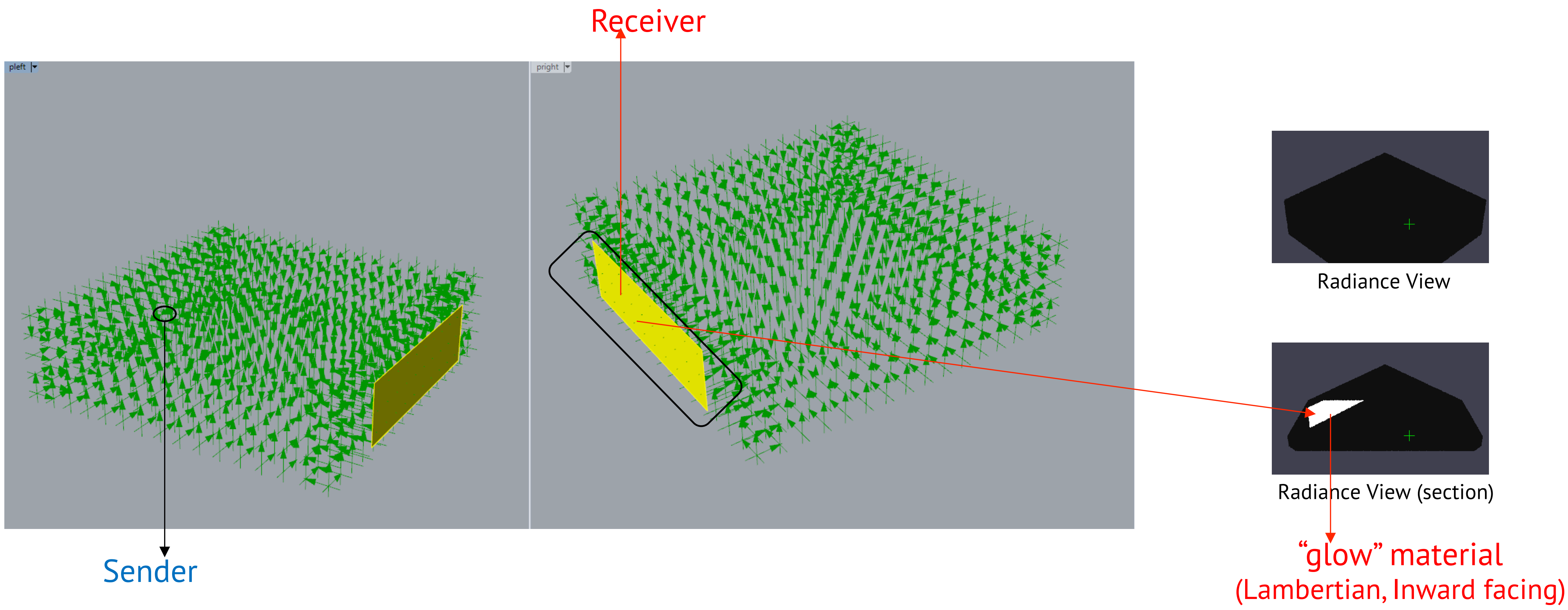


Ray origin ~ Centre of manikin meshes
Ray direction ~ Surface normals of manikin meshes

Radiative Load(W) on mesh: Irradiance(W/m^2) x Area (m^2)

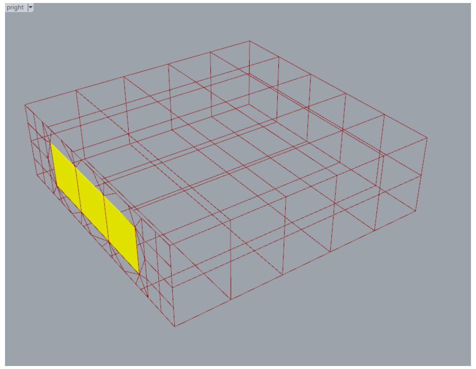
Results are summarized as per 16 body segments

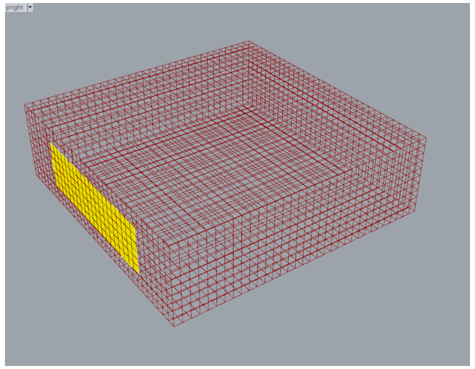
Energy Balance test (Sent vs Received energy)

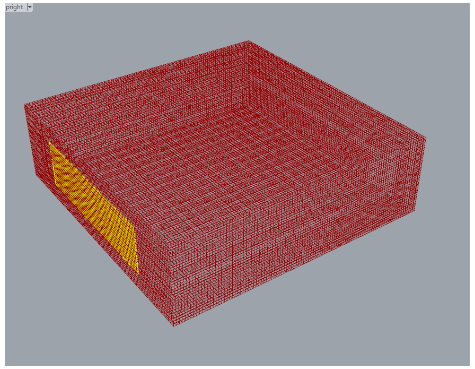


rfluxmtx -V+ -I+ -y NumPoints -ab 1 -ad 2000 -lw 0.005 - receiver.rad materials.rad geometry.rad < points.txt > contrib.txt

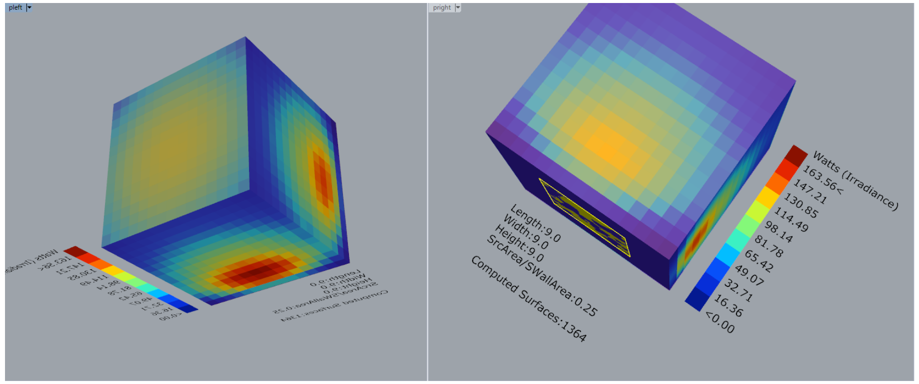
Precision of results relates to mesh density



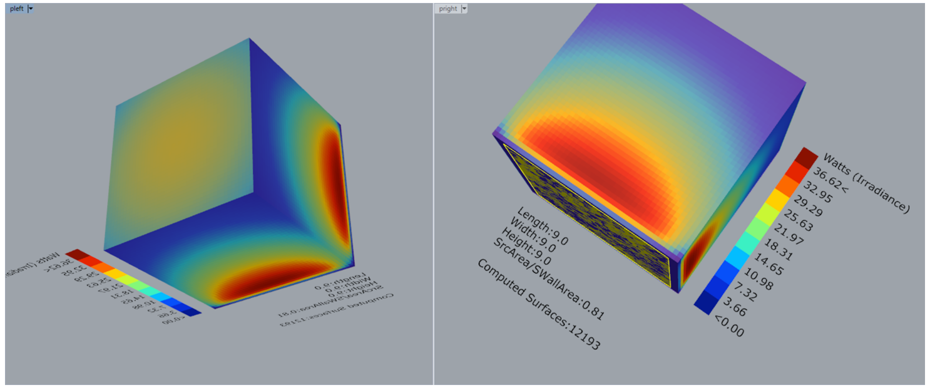




Increasing Precision



Received/Sent: 1.172



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Tests with manikin, Detailed surface summation

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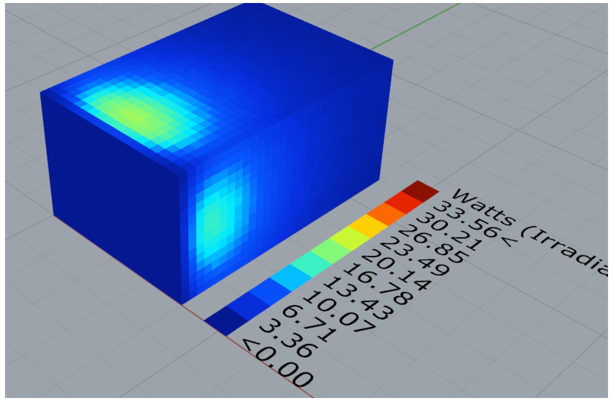


Received\Sent: 1.002

Radiating surface: South Window

Glow value: 800/channel

Surface area: 4.32 m²

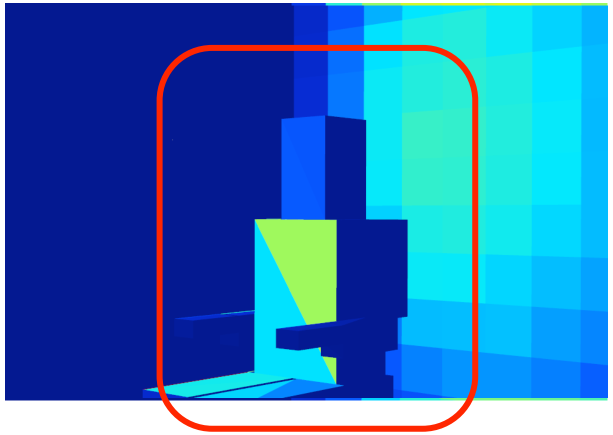
Radiated Energy
(800x4.32xπ) = 10857W

Surface	Solar Load (W)
Ceiling	2901
East	2030
Floor	2560
North	931
South	0
West	1927

Room surfaces (10349 W)

Body Part	Solar Load (W)
Chest	76
Head	87
Back	21
Pelvis	38
Leftarm	4
Leftleg	14
Leftfoot	12
Lefthand	10
Leftshoulder	0
Leftthigh	23
Rightarm	31
Rightleg	37
Rightfoot	21
Righthand	17
Rightshoulder	42
Rightthigh	95

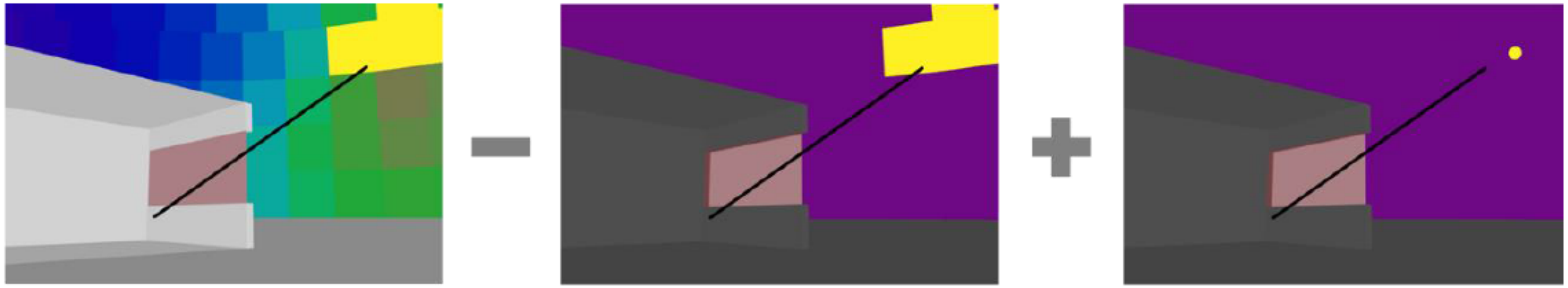
Manikin parts (528 W)



Progression of this research

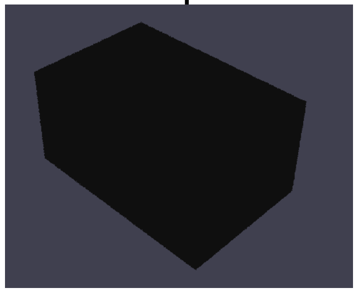
- Energy balance was conclusively proven.
- Thermal comfort calculations require simulations with real sky conditions.
- The glazing aperture contains a complex fenestration (BSDF) instead of a radiating surface
- A coefficient-based approach is employed to prevent redundancy.

Current setup for annual simulations



$C_{dc}S$ $-$ $C_{dcd}S_d$ $+$ $C_{ds}S_{sun}$

rvu capture



Geometry, including that of the manikin, is **non-reflective** (plastic mat 0 0 5 0 0 0 0 0)

BSDFs are incorporated **in the scene geometry** (void BSDF cfs 0 0 6 ...)

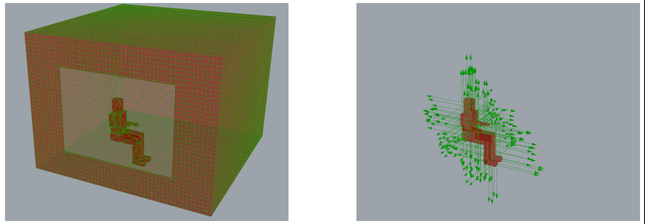
Raw **irradiance** data from dctimestep is processed directly **without weighting functions.**

Workflow for annual simulations

EPW

TMY hourly data

Geometry and Rays

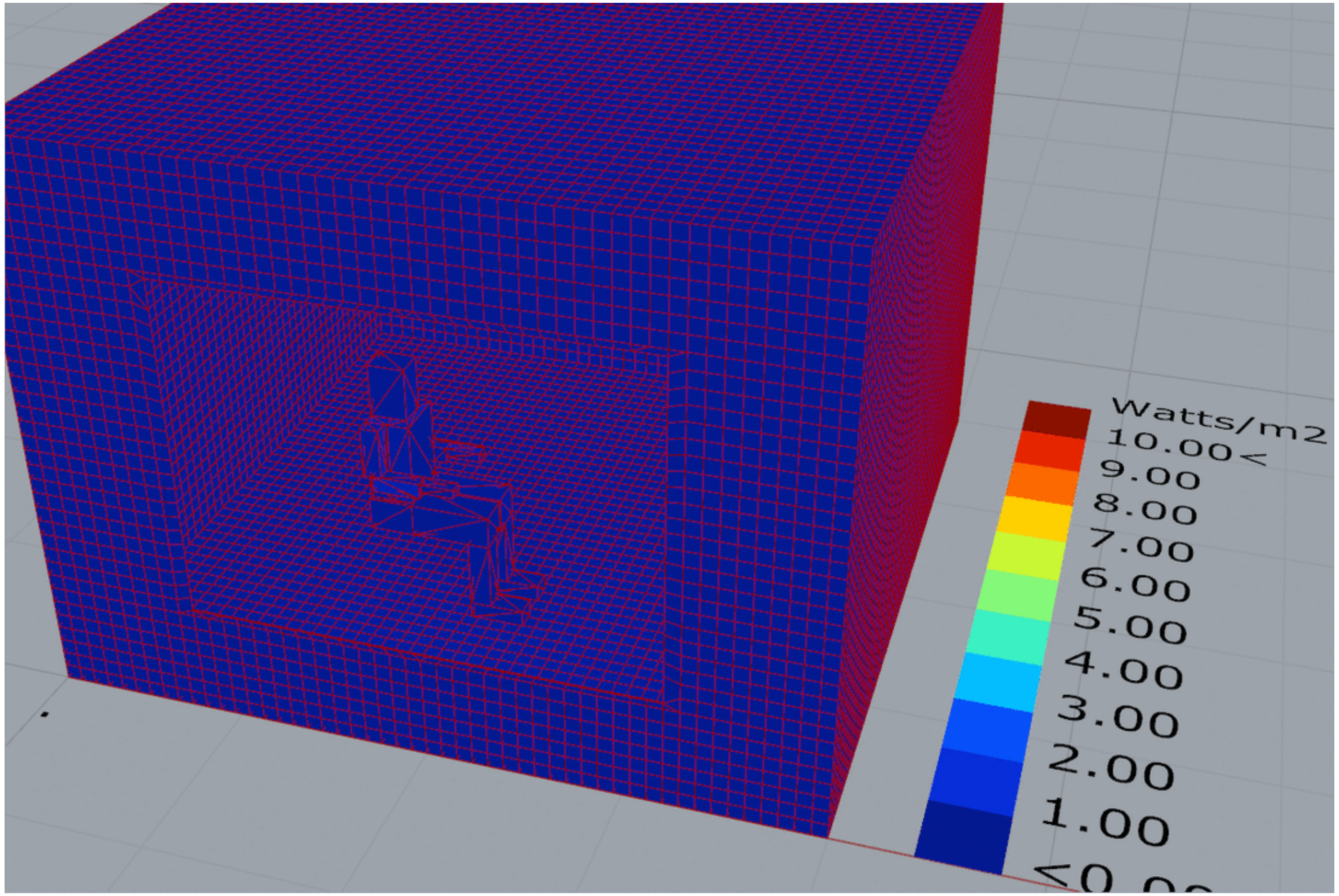


Radiance

rcontrib, rfluxmtx, gendaymtx, rmtxop

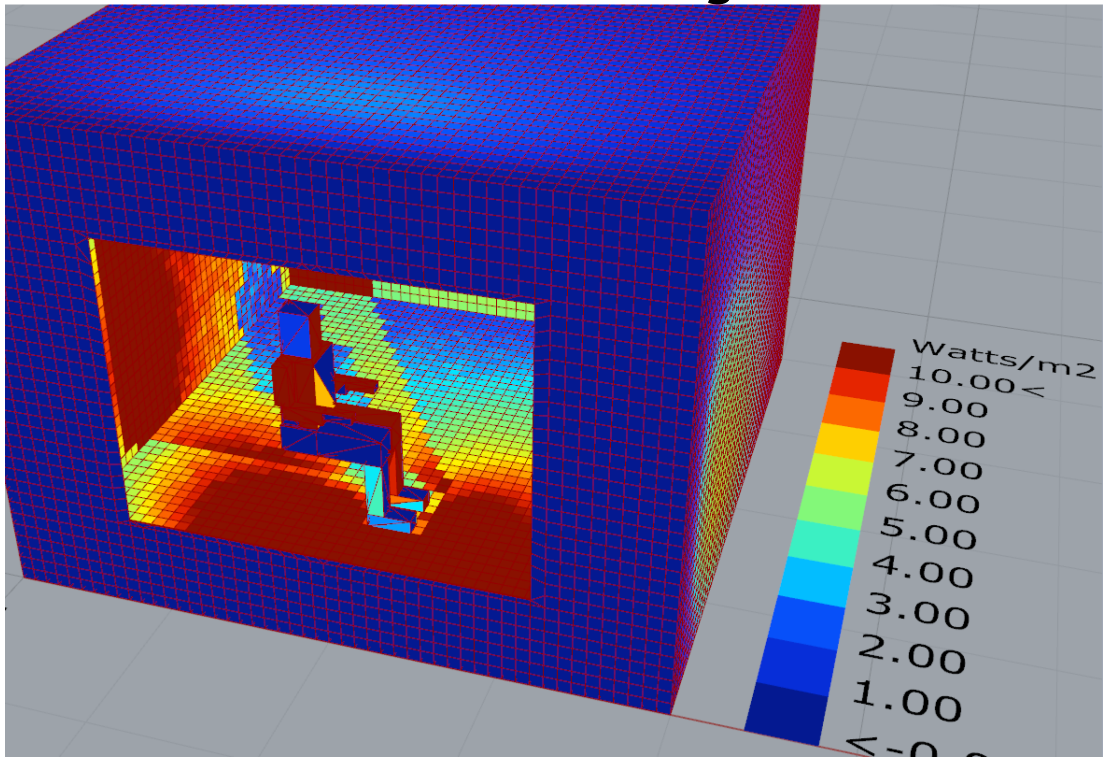
Post-processing in Python

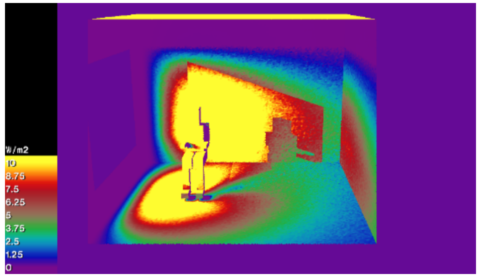
Hour	Head	Chest	Back	Pel
10	0.31	0.32	0.09	0.
11	0.77	0.8	0.23	0.
12	1.09	1.12	0.33	0.
13	1.2	1.23	0.37	0.
14	1.04	1.06	0.32	0.



Typical result (Manheim, Germany 10:00 am 04/Feb)

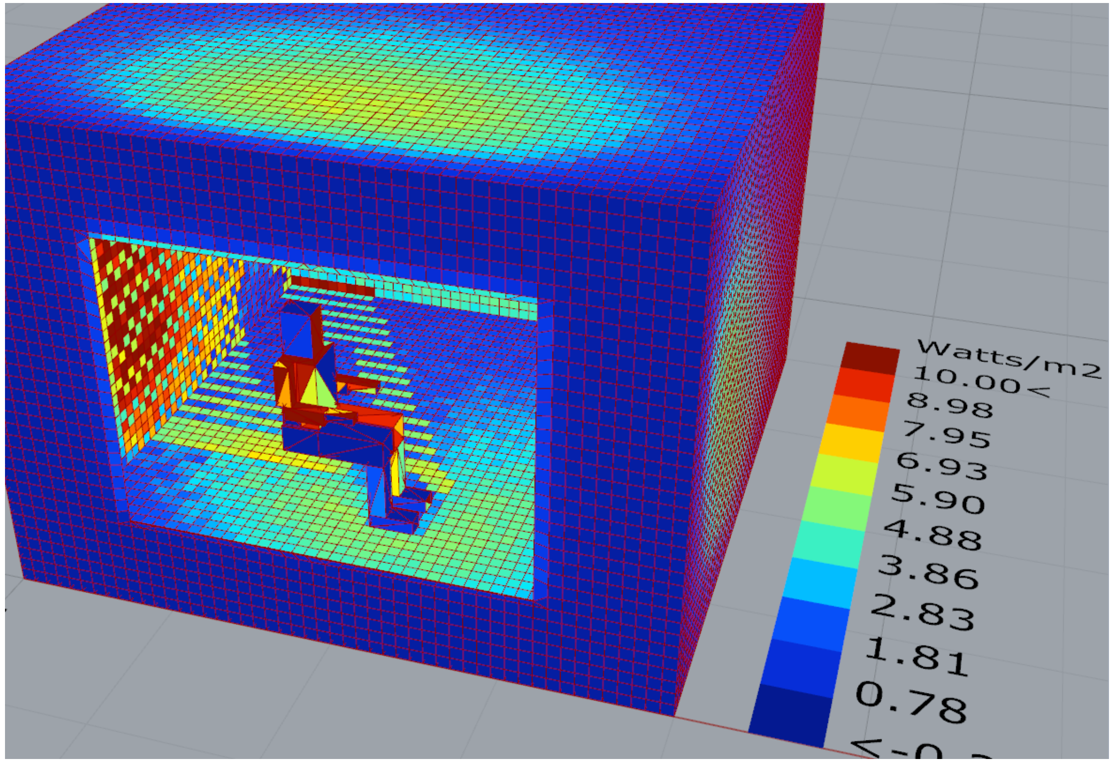
Clear Glazing

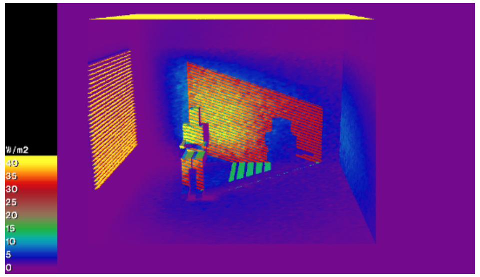




rpict – i | falsecolor –m 1

Blinds





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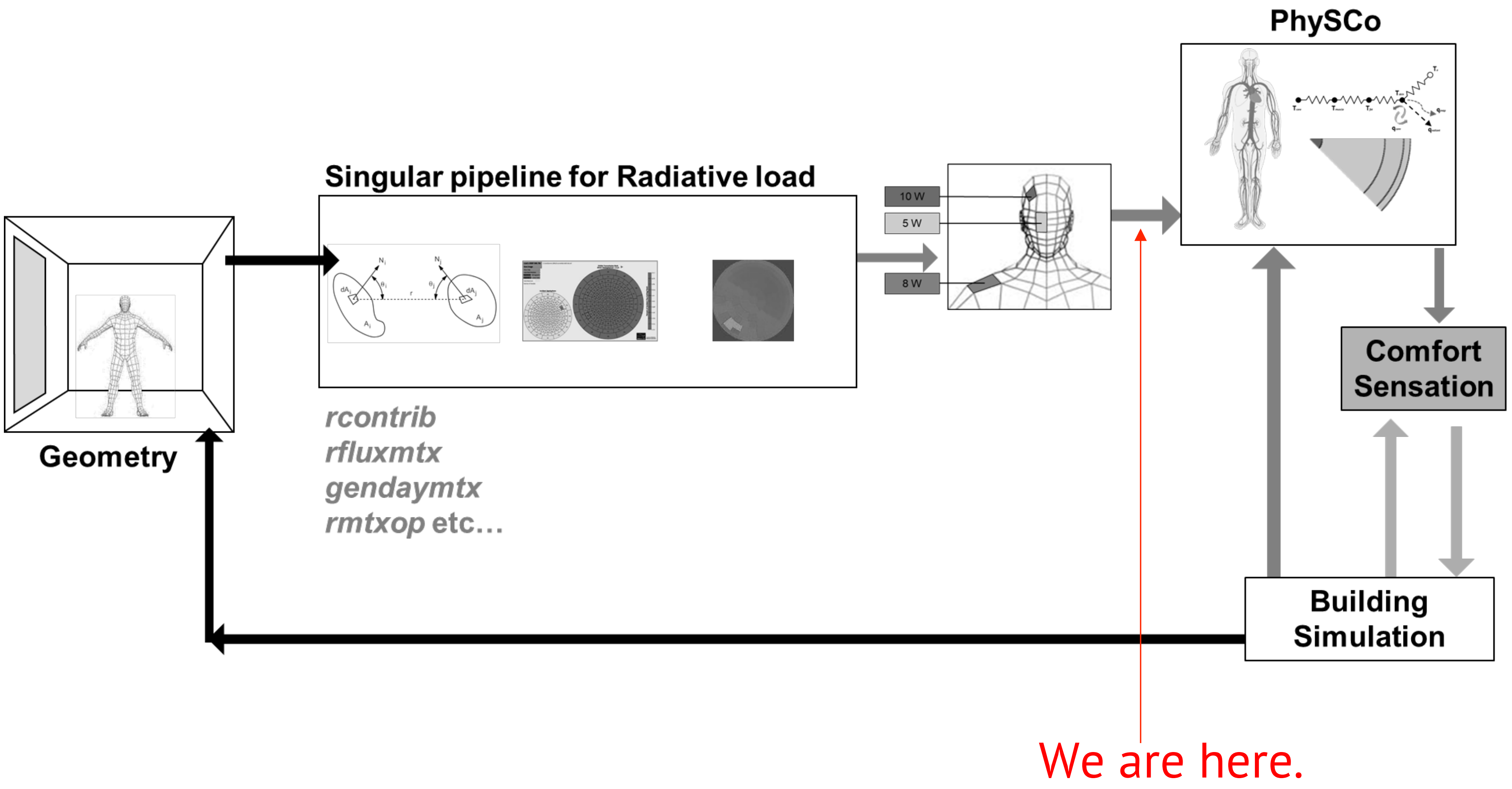
Estimating thermal comfort from solar load



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PhySCo calculations with clear glazing

4th of February

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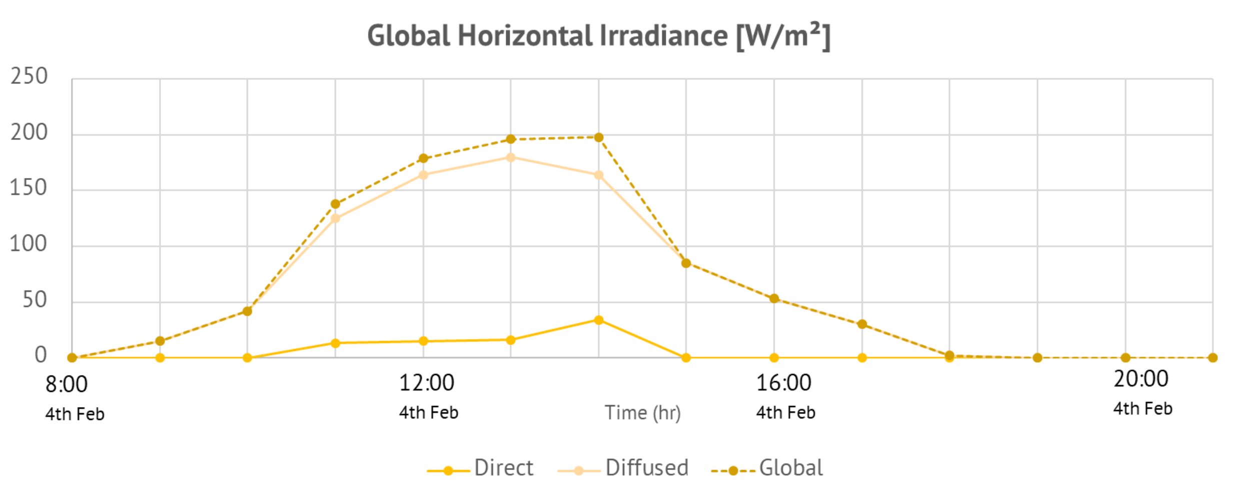

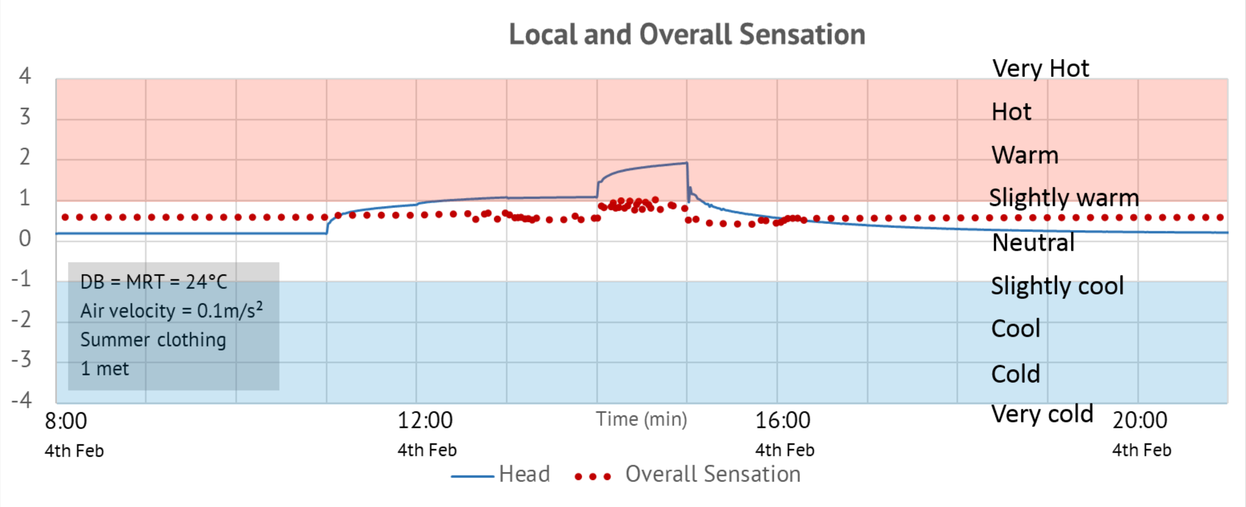

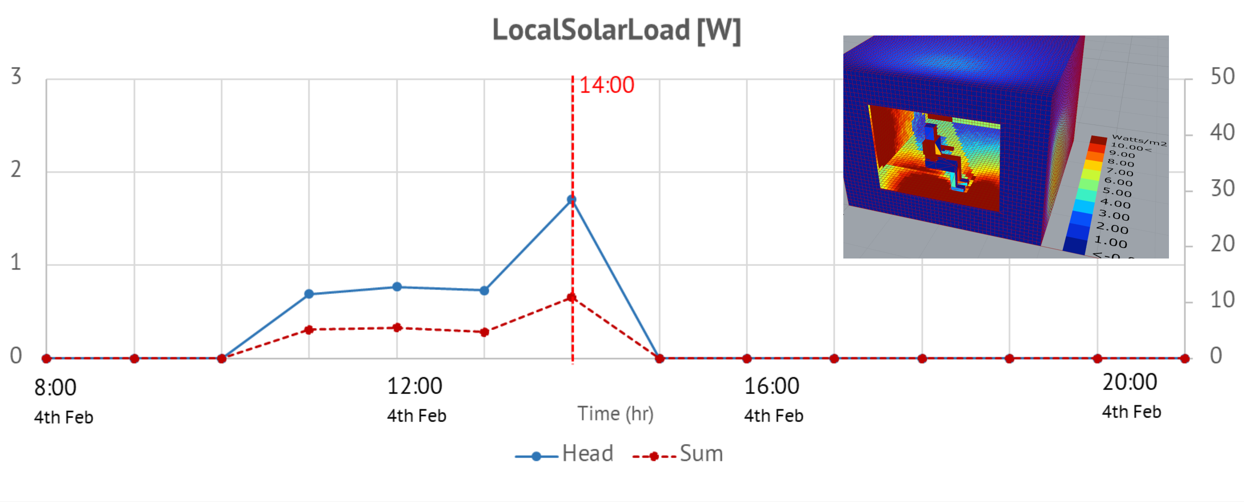

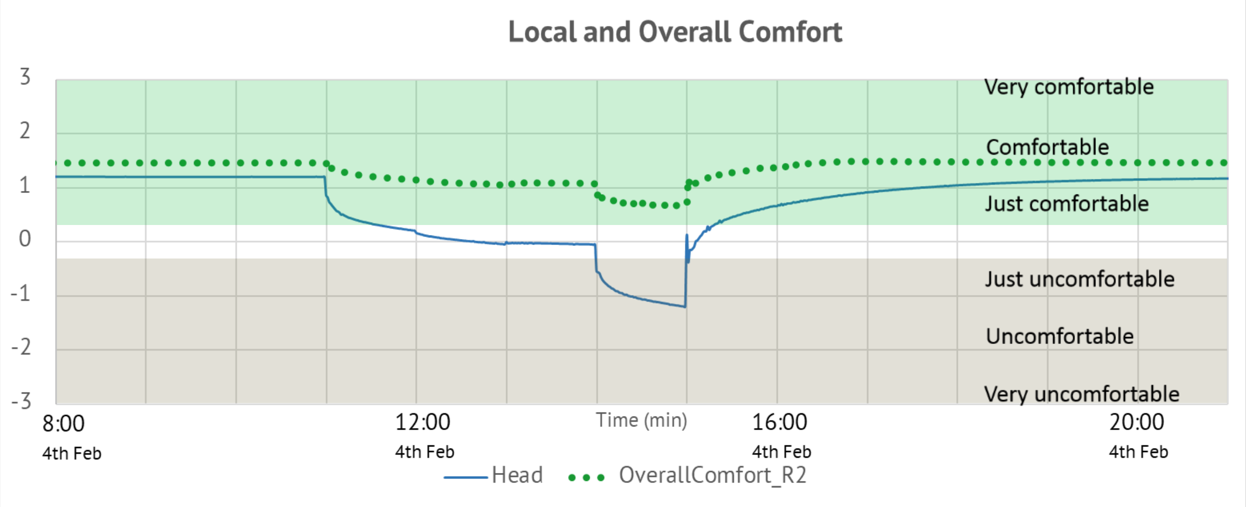

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PhySCo calculations with blinds

4th of February

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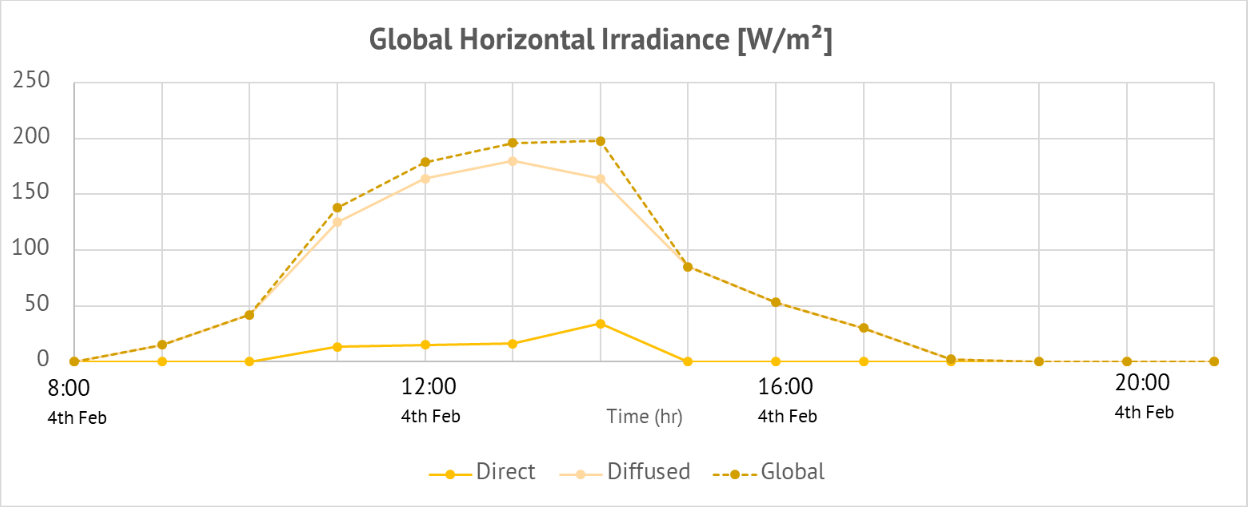
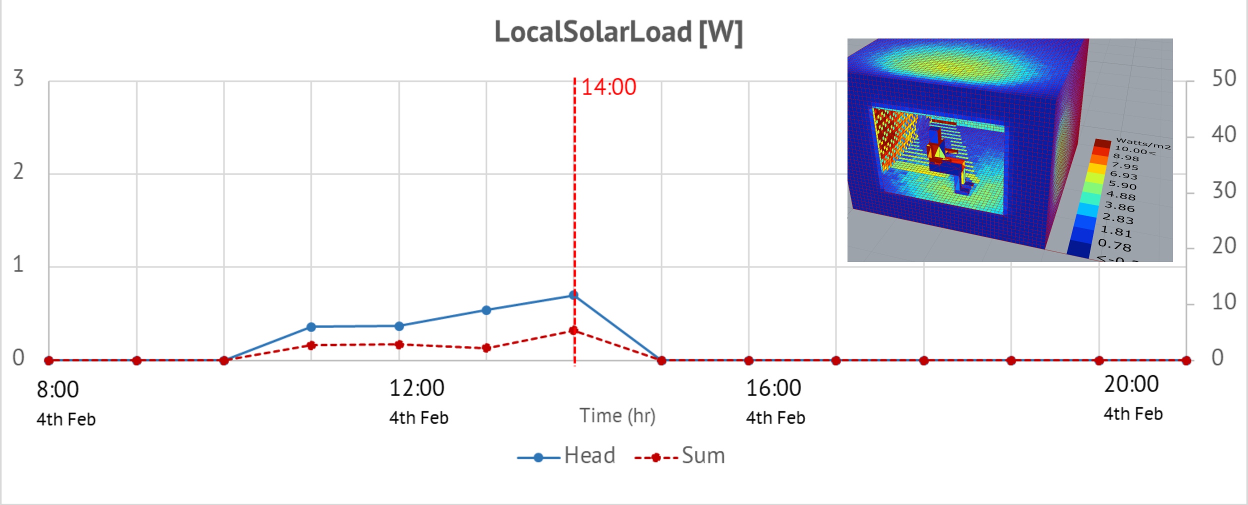
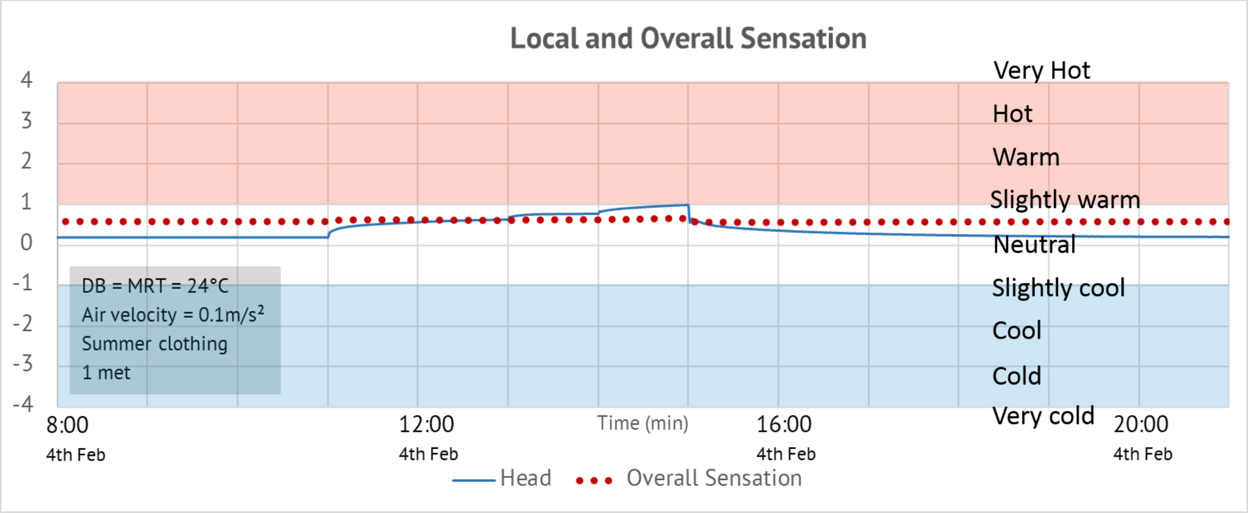
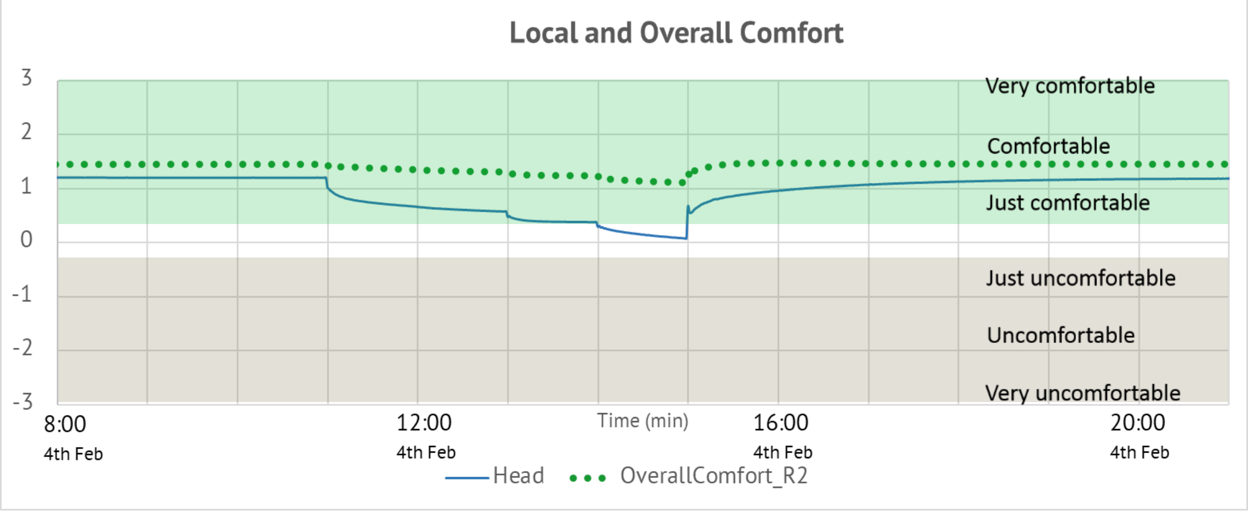
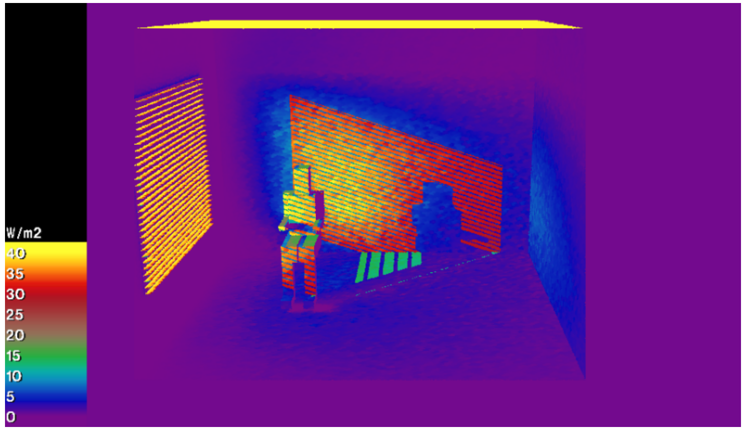




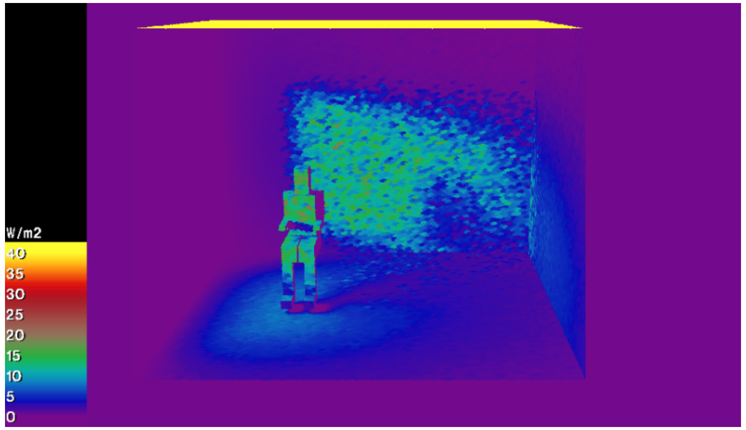




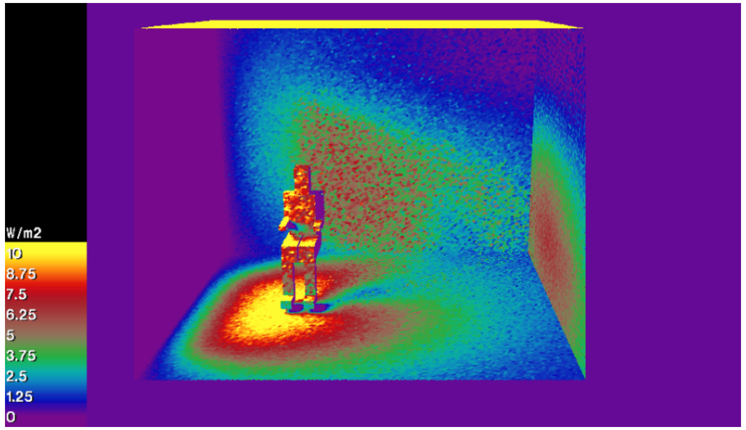
On-going work



Exact geometry of blinds



Klems BSDF



Tensor-Tree (t4 5) BSDF

Impact of the choice of BSDFs on the accuracy of Thermal Comfort assessment.

Conclusions

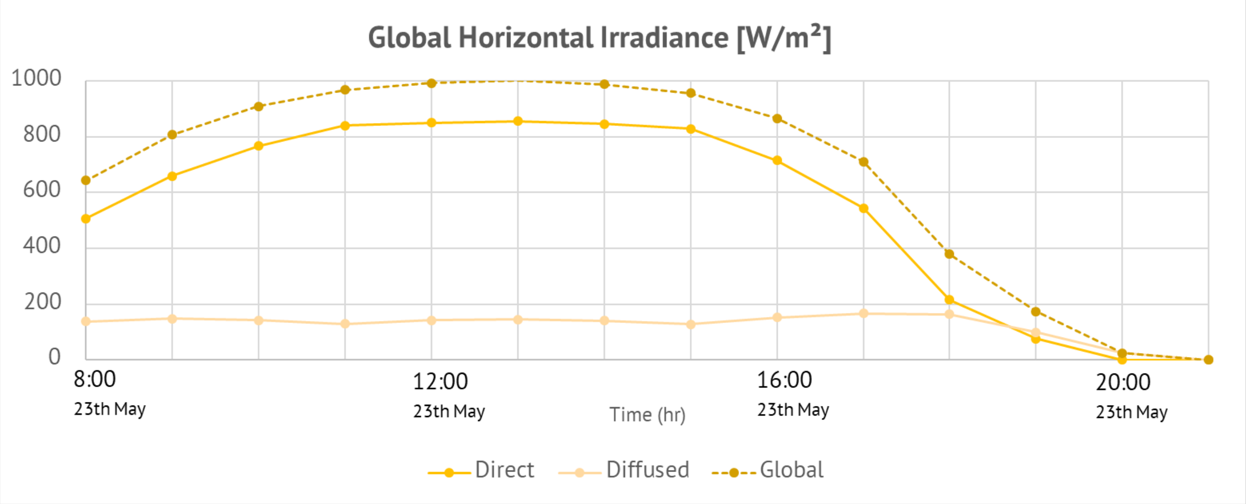
- A Radiance-based workflow for calculating solar load on the human body has been formulated.

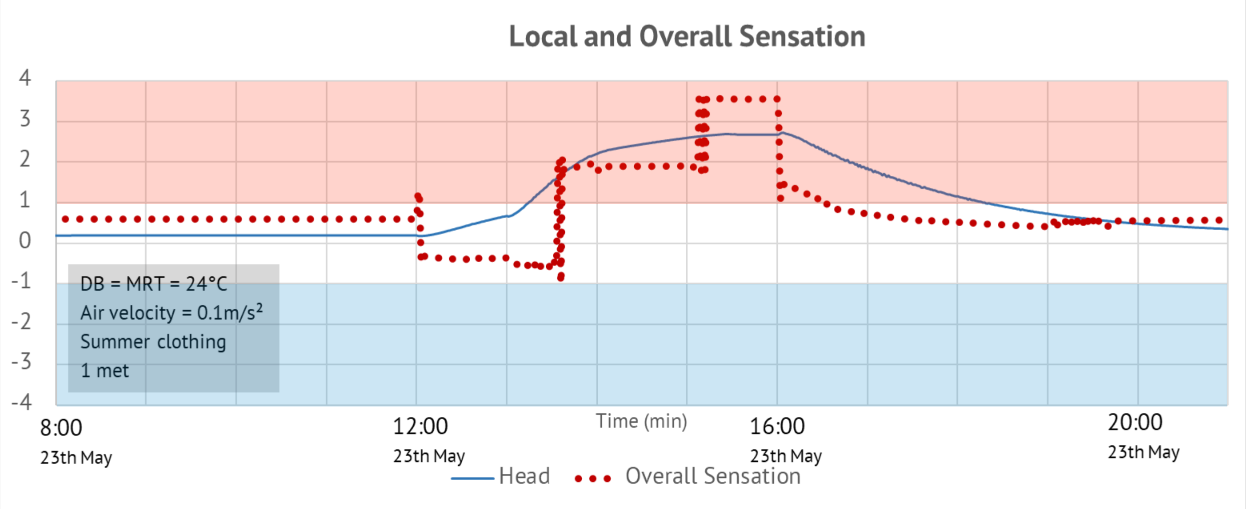
- Precision of the calculations is contingent on maintaining a high mesh density.

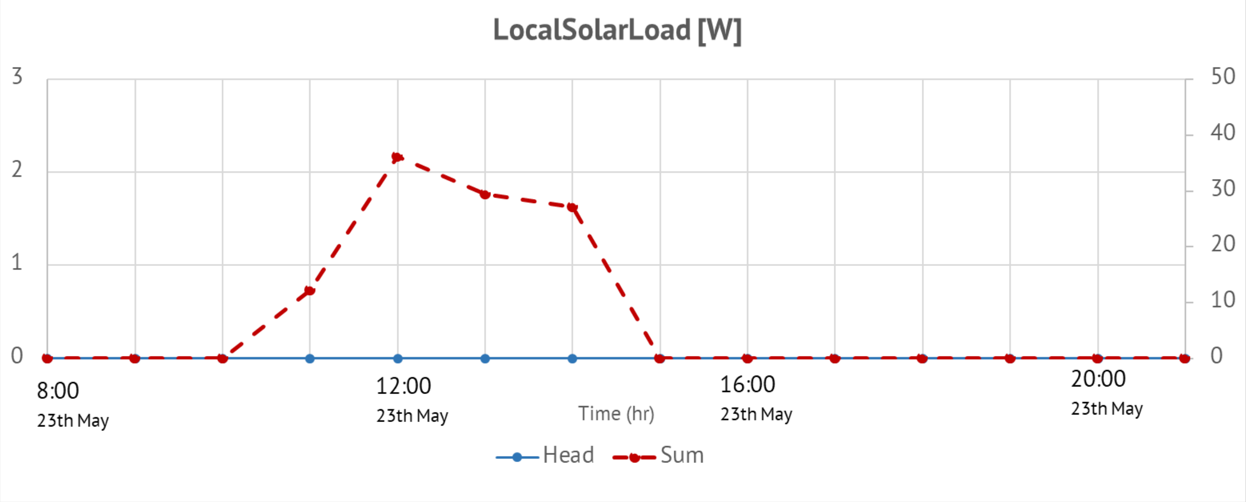
- Results from annual TMY-based simulations have been used for corresponding thermal comfort calculations.

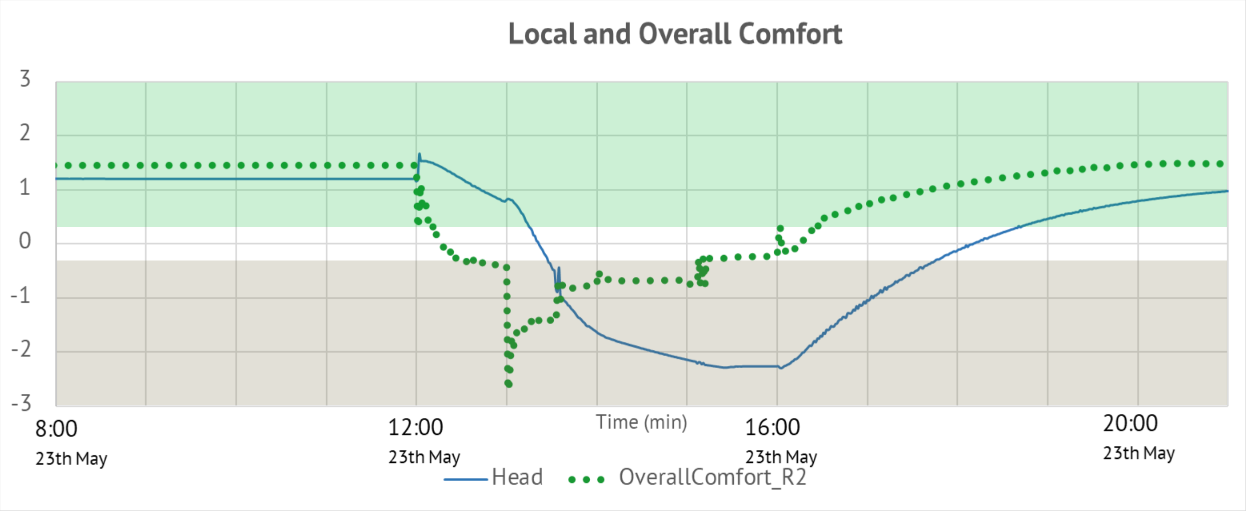
PhySCo calculations with clear glazing

23rd of May









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PhySCo calculations with blinds

23rd of May