Mean radiant temperature

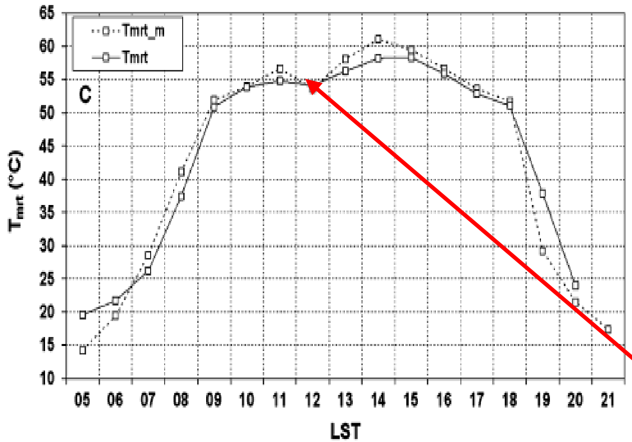
T_{mrt}

Temperature of a standing man in radiative balance (short- and longwave) with his surrounding

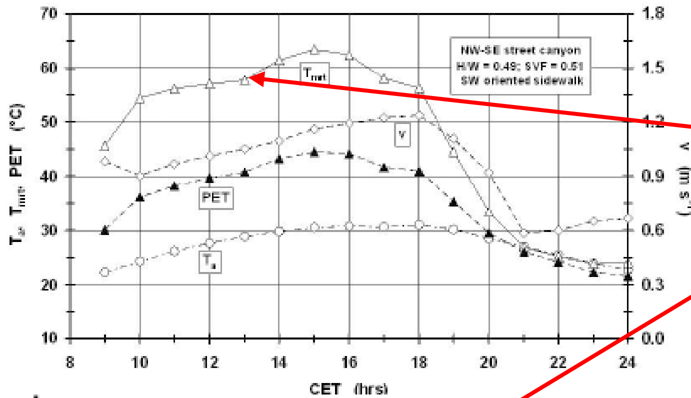

icuc9
icuc9

The problem

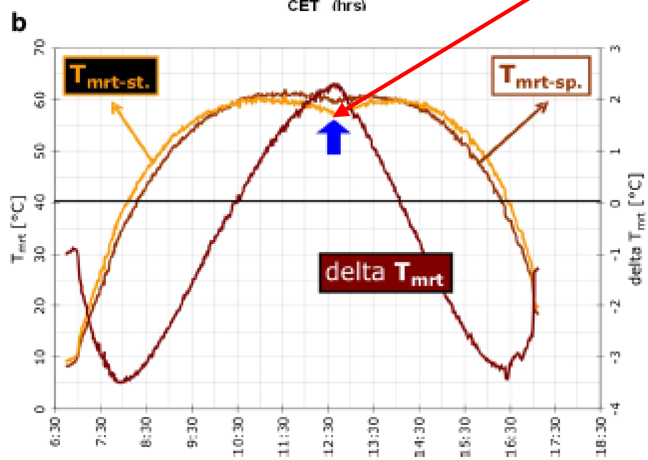
Lindberg et al. 2008
(model and obs)



Mayer et al. 2008
(obs)

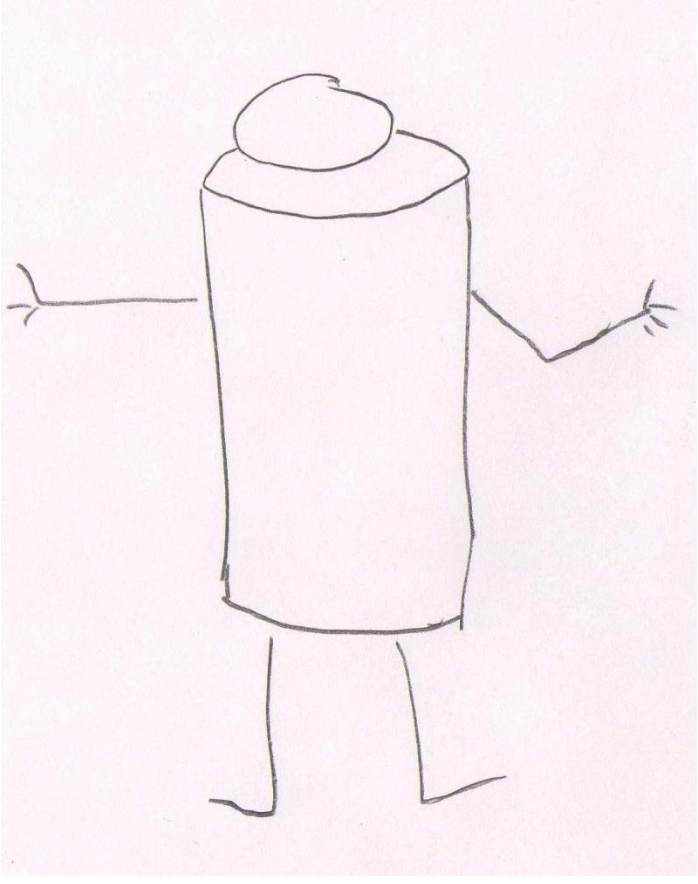


Kantor et al. 2014
(obs)



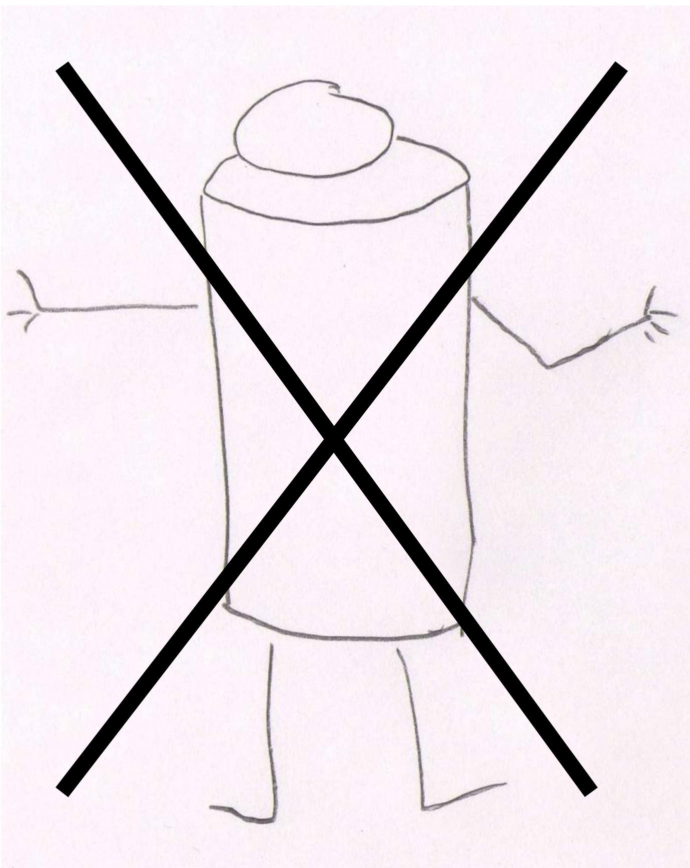
A local minimum
around noon

Mr. Cylinder

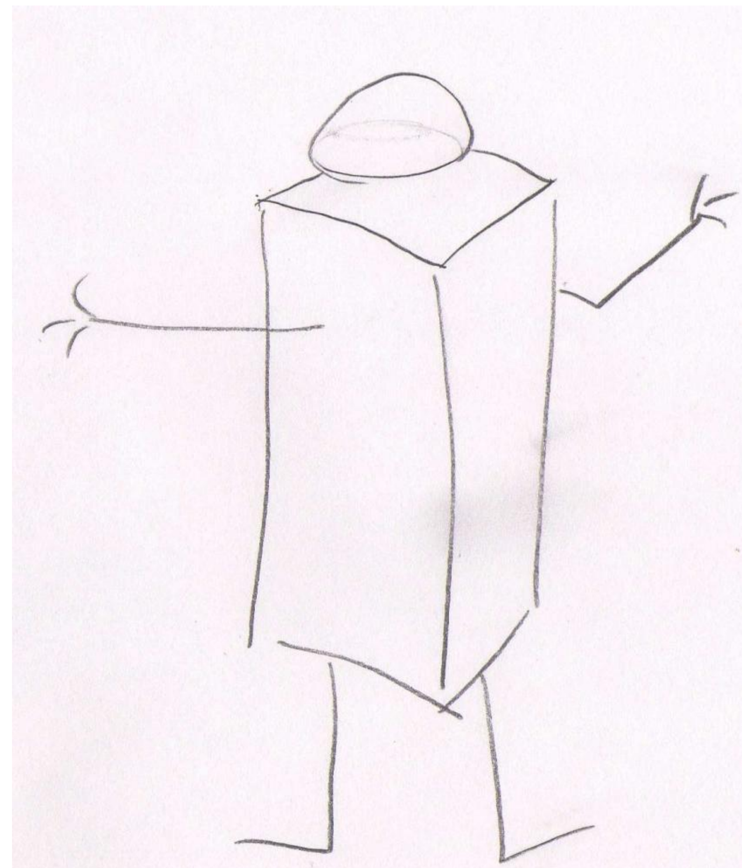


But!! - ”… the “standing man” reference shape is in fact a rectangular column and not a rotationally symmetric cylinder.” (Kantor et al. 2014)

Mr. Cylinder



Mr. Box



How to transform the standing man from a box to a cylinder – a modified methodology to calculate mean radiant temperature in field studies and models

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Urban Climate Group, Dept of Earth Sciences

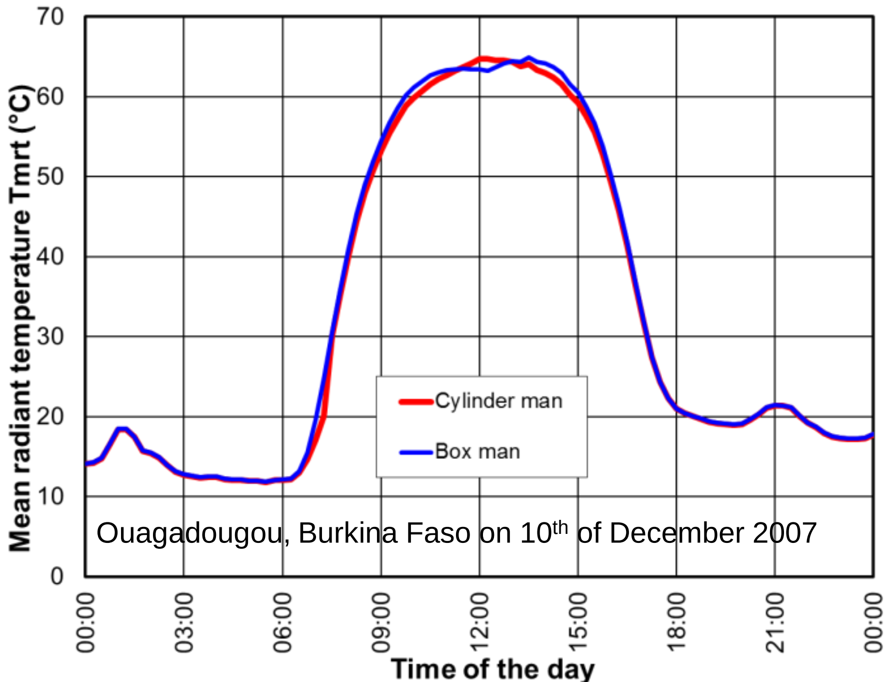
University of Gothenburg, Sweden

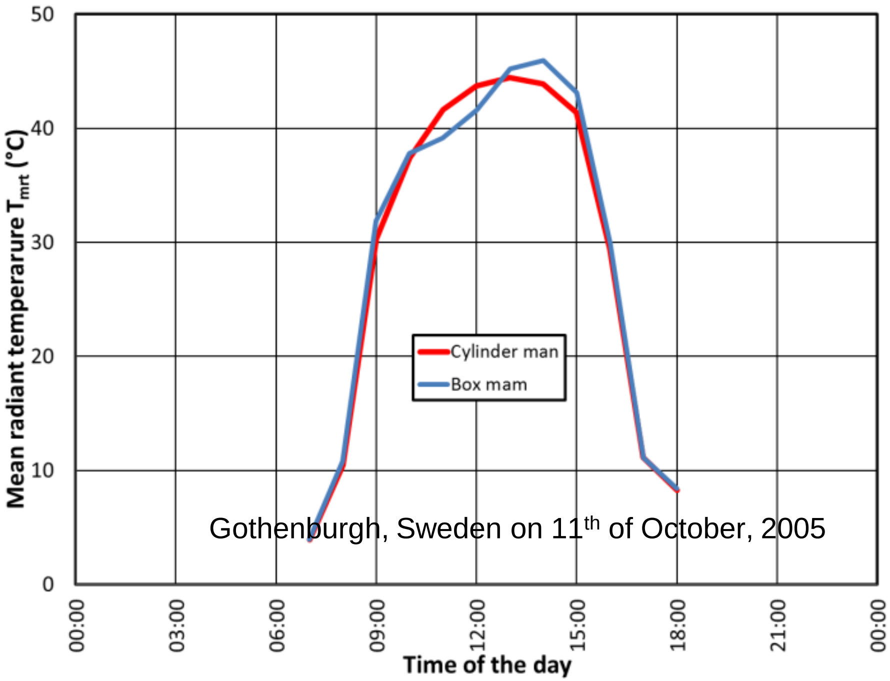
- The solution is connected to the area that is exposed to the direct short-wave radiation

Comparison of old and new calculation

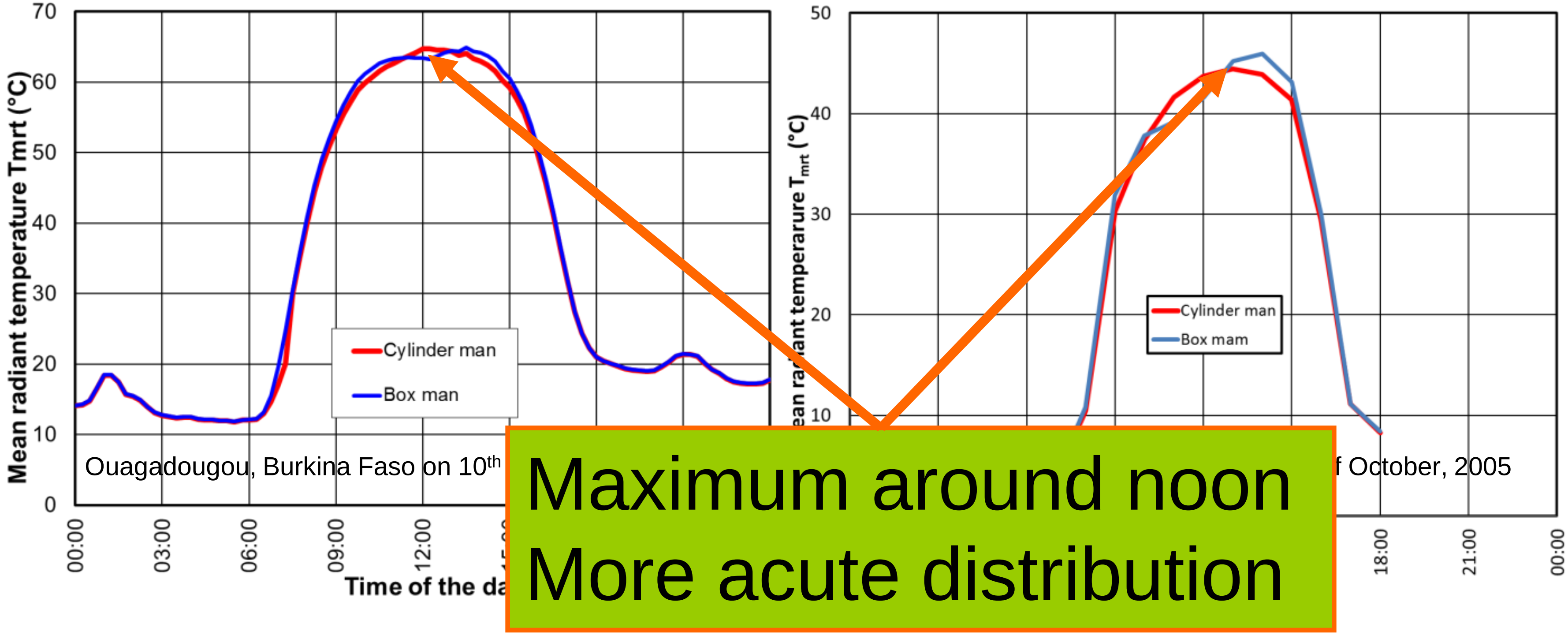
Box man - the original formula by Höppe

Cylinder man - the new methodology





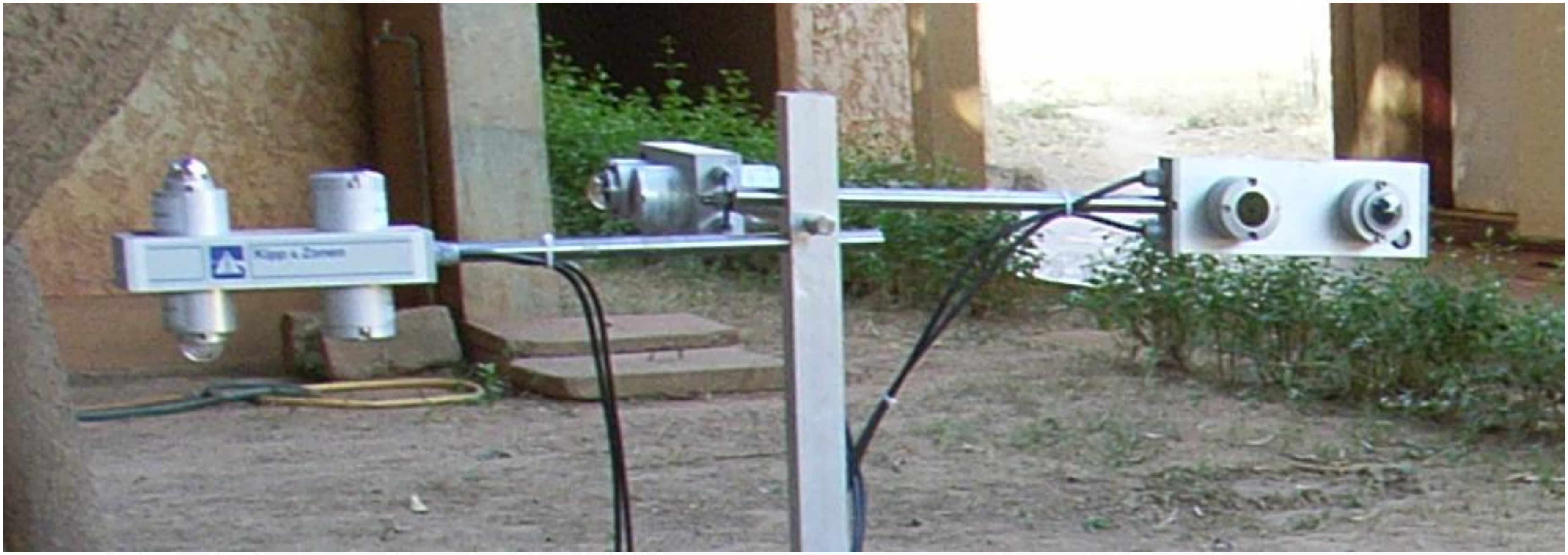
Comparison of old and new calculation



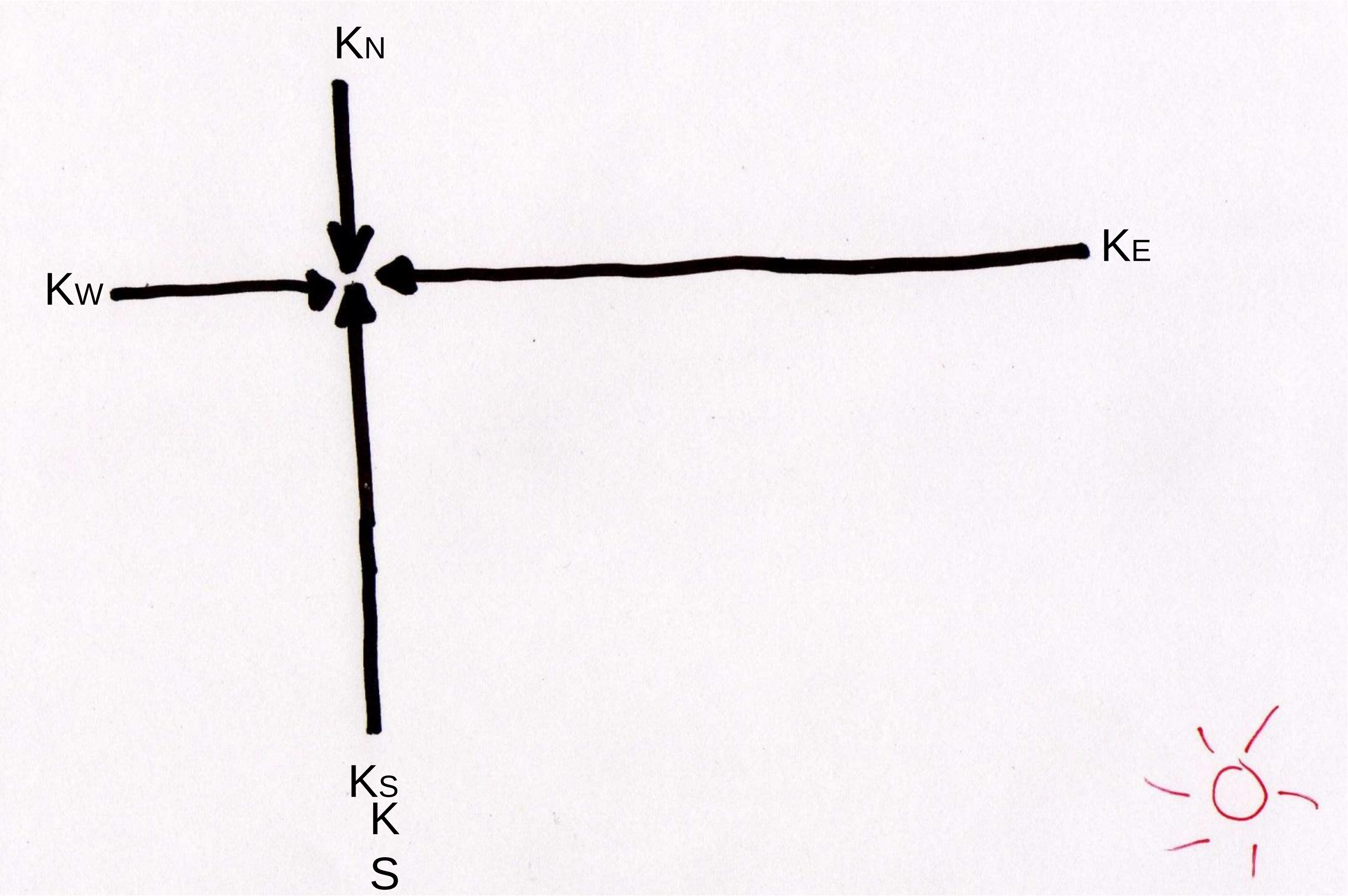
Box man - the original formula by Höppe

Cylinder man - the new methodology

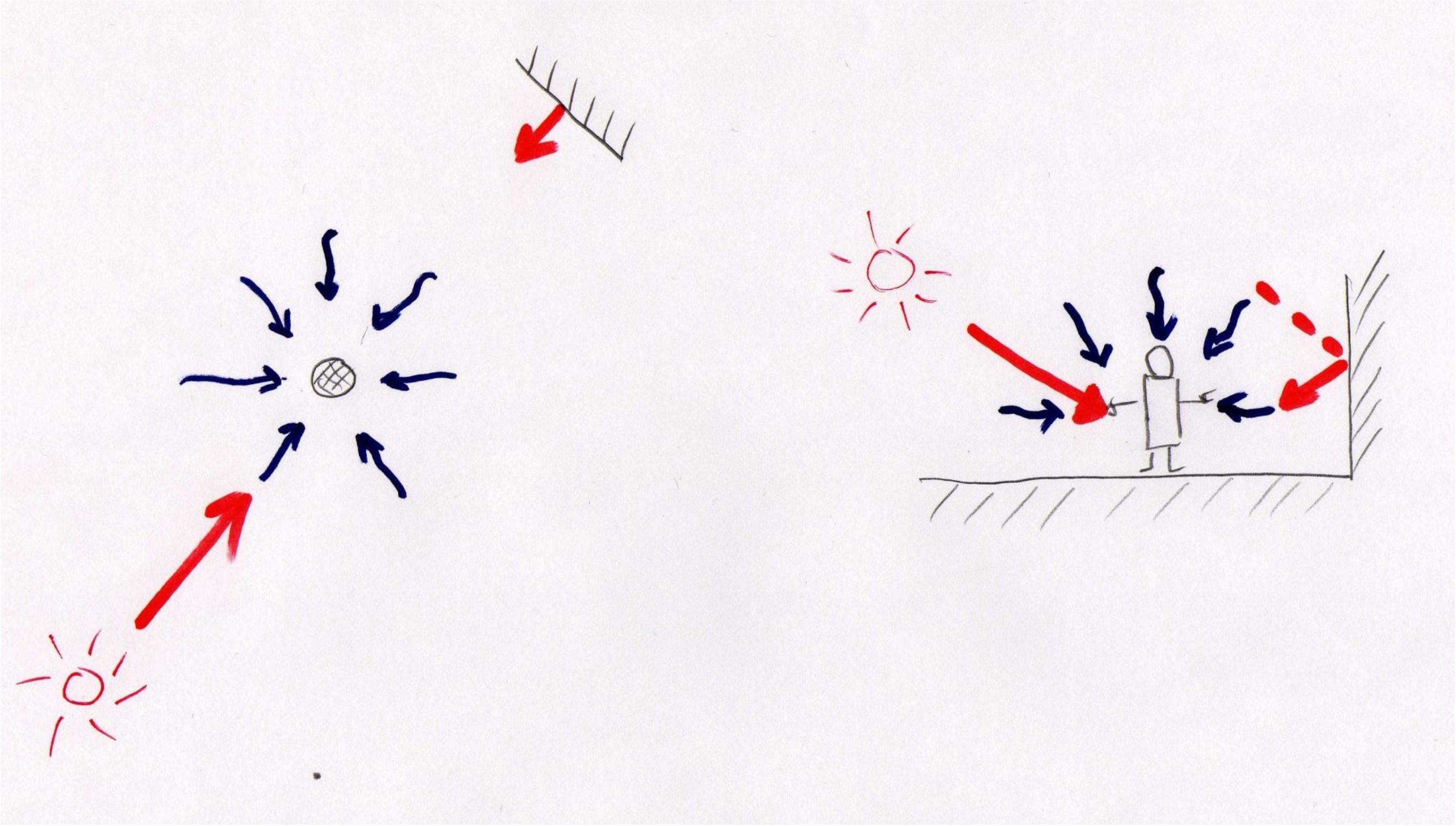
Six directional measurements



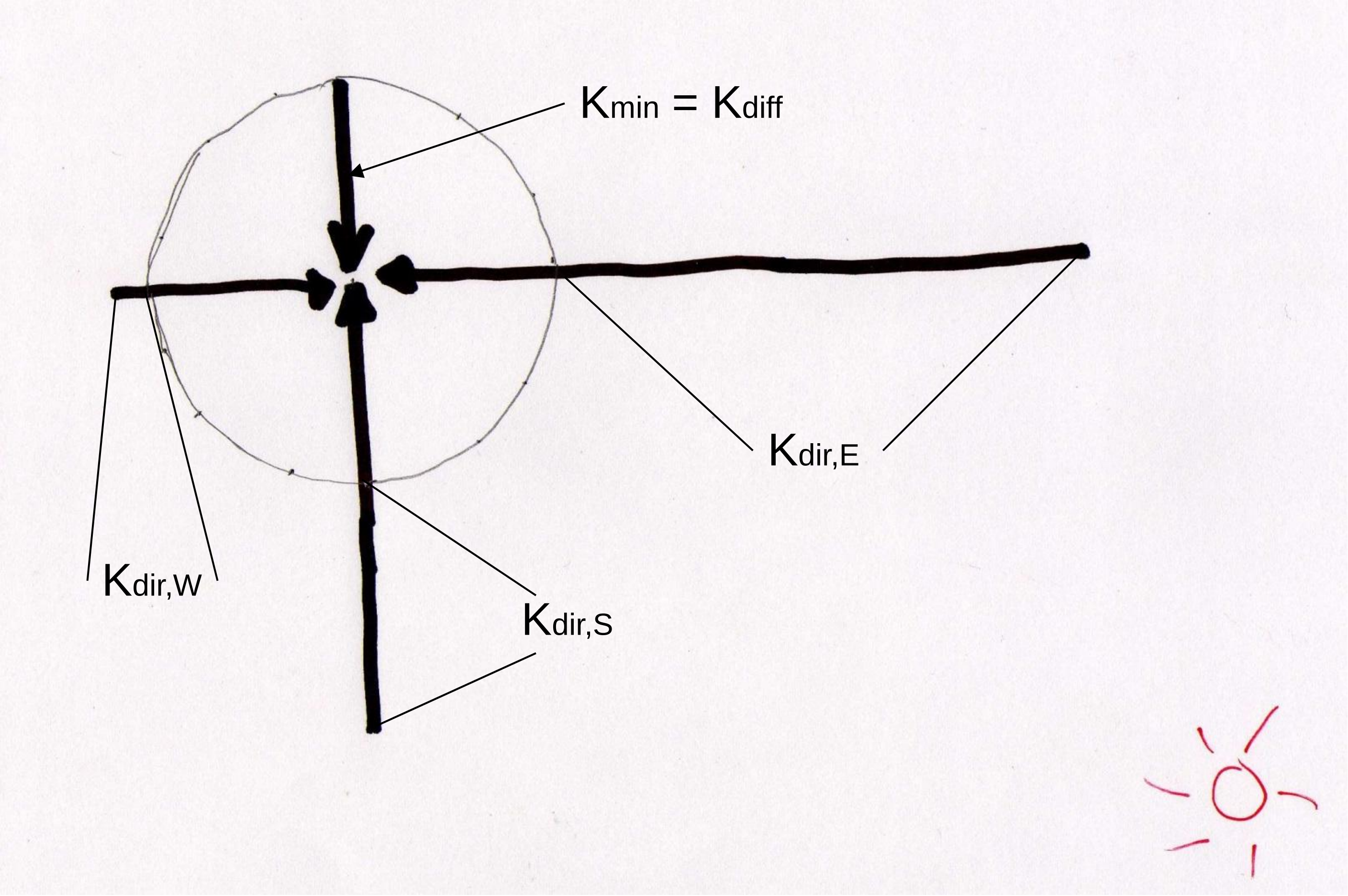
Recorded horizontal short-wave radiation



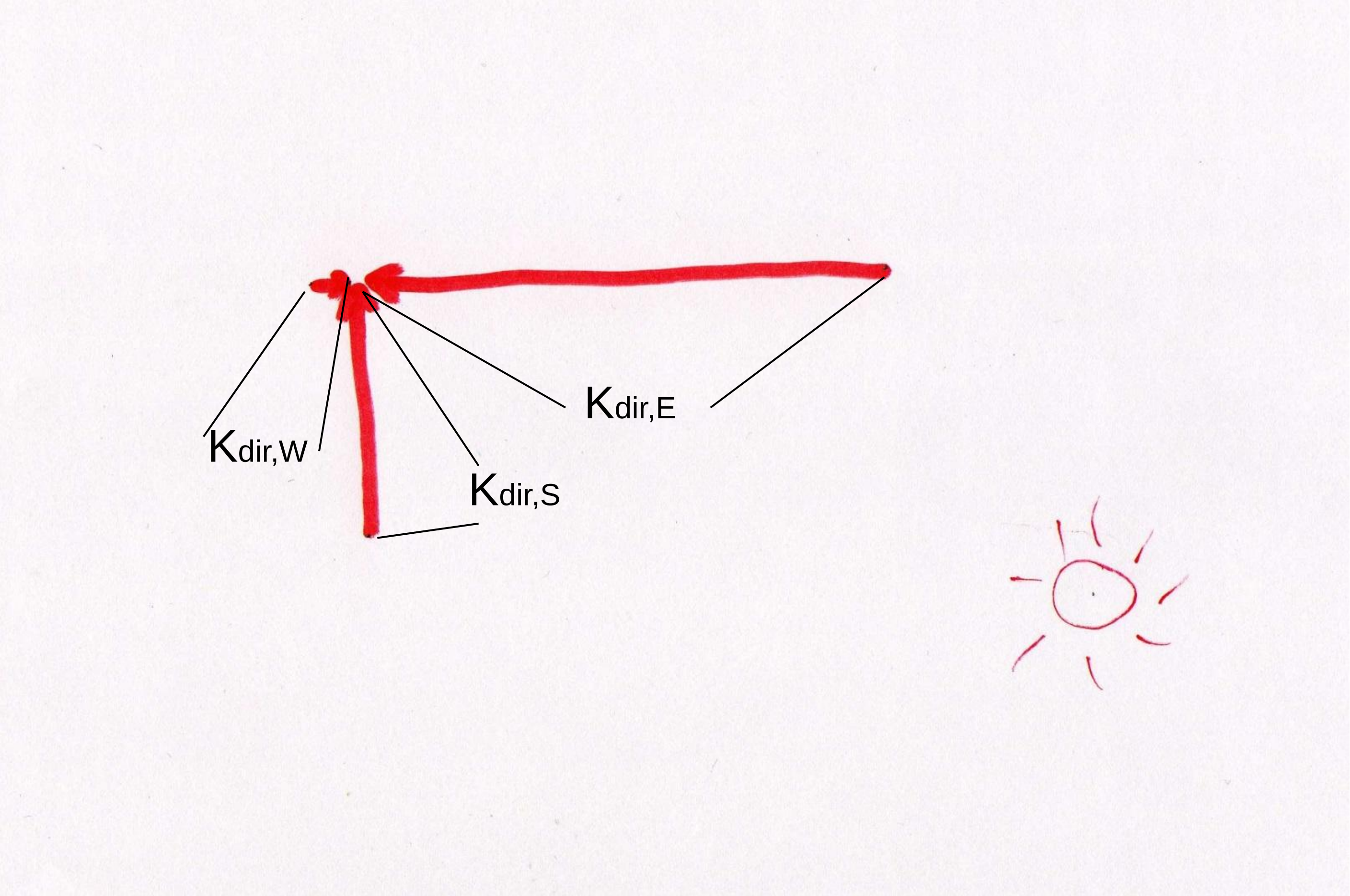
Direct and diffuse short-wave radiation



Horizontal diffuse and direct radiation

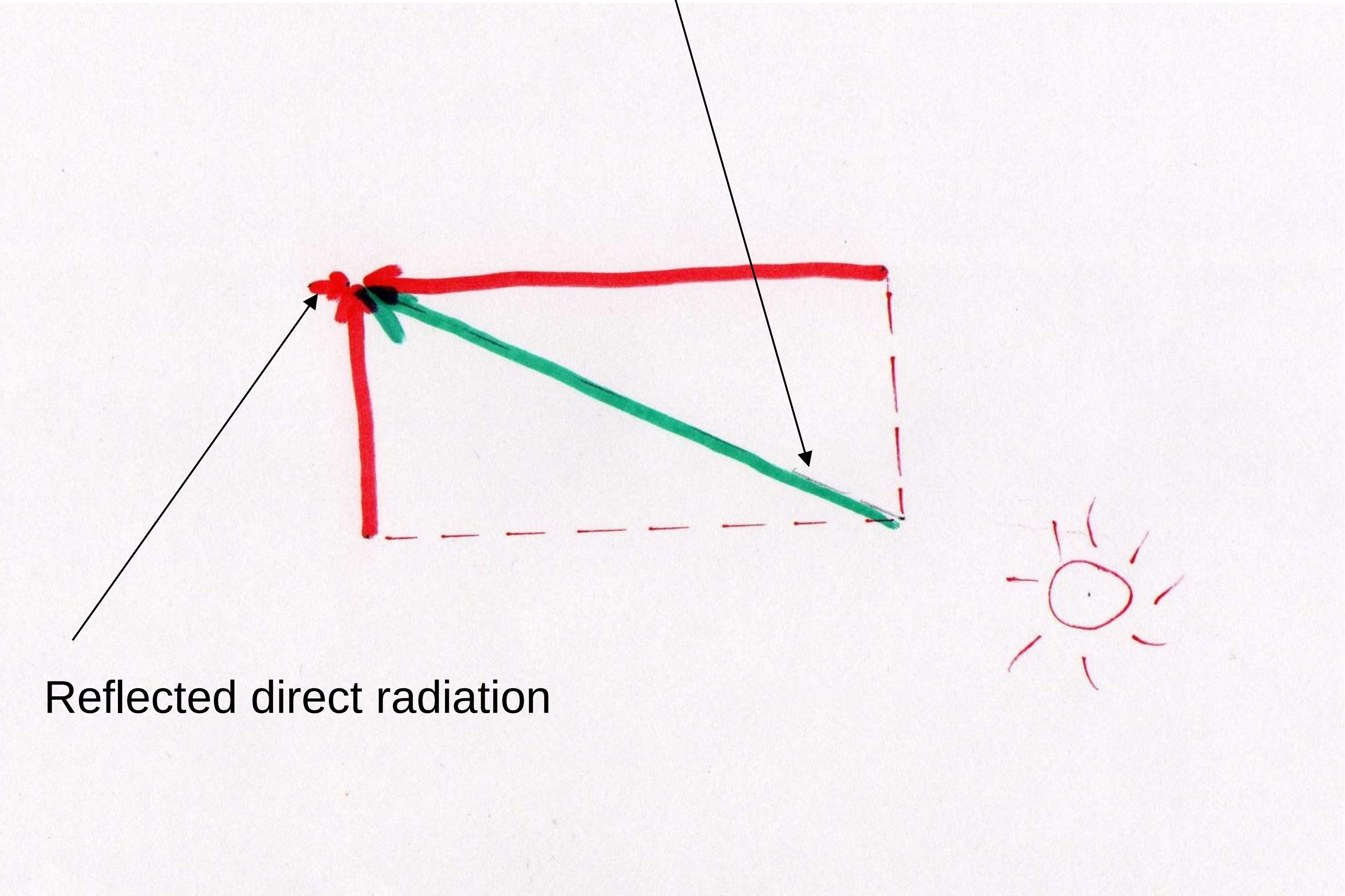


Horizontal direct radiation



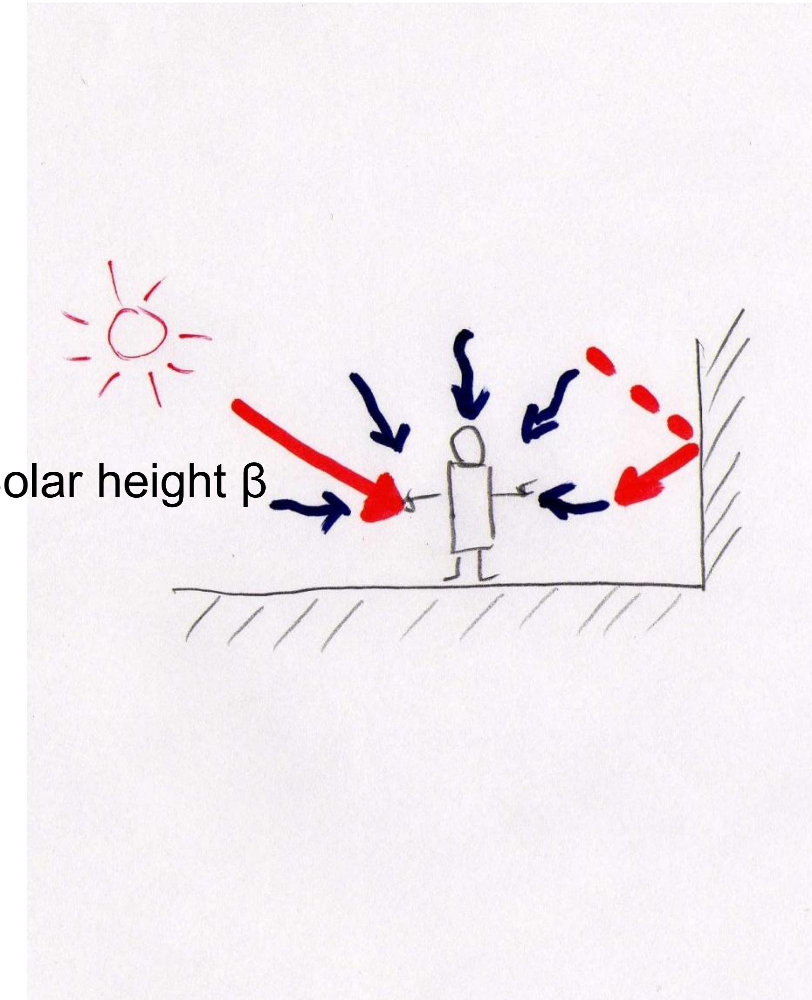
Resultant horizontal direct radiation

$K_{dir,hor}$

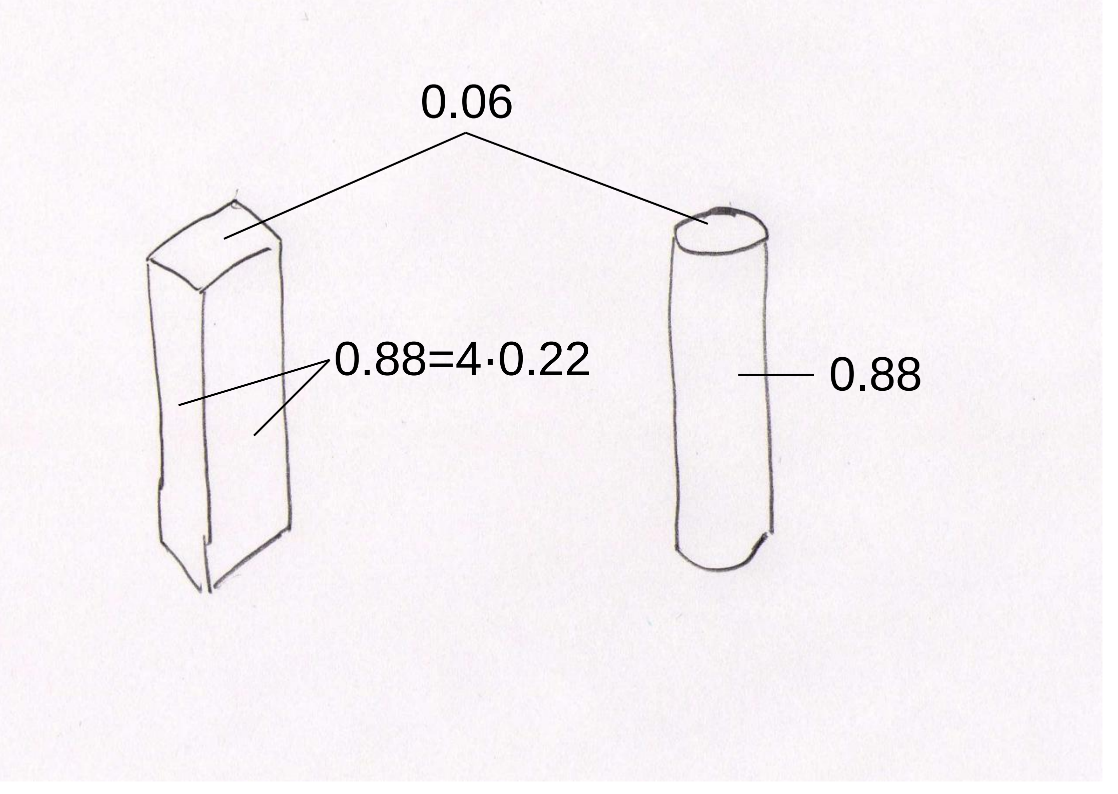


Direct radiation along the solar rays

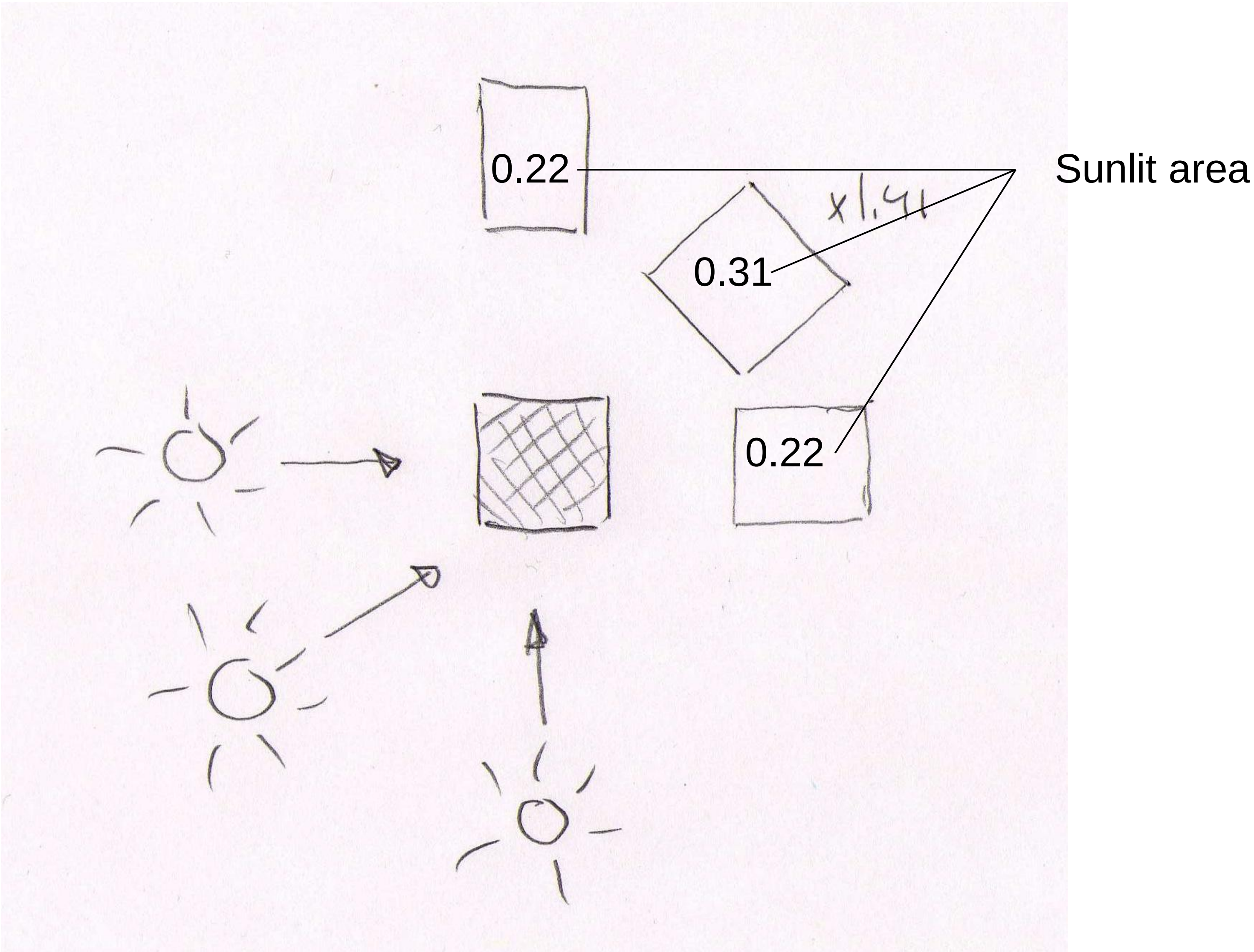
$K_{dir} = K_{dir,hor} \cdot \cos(\beta)$



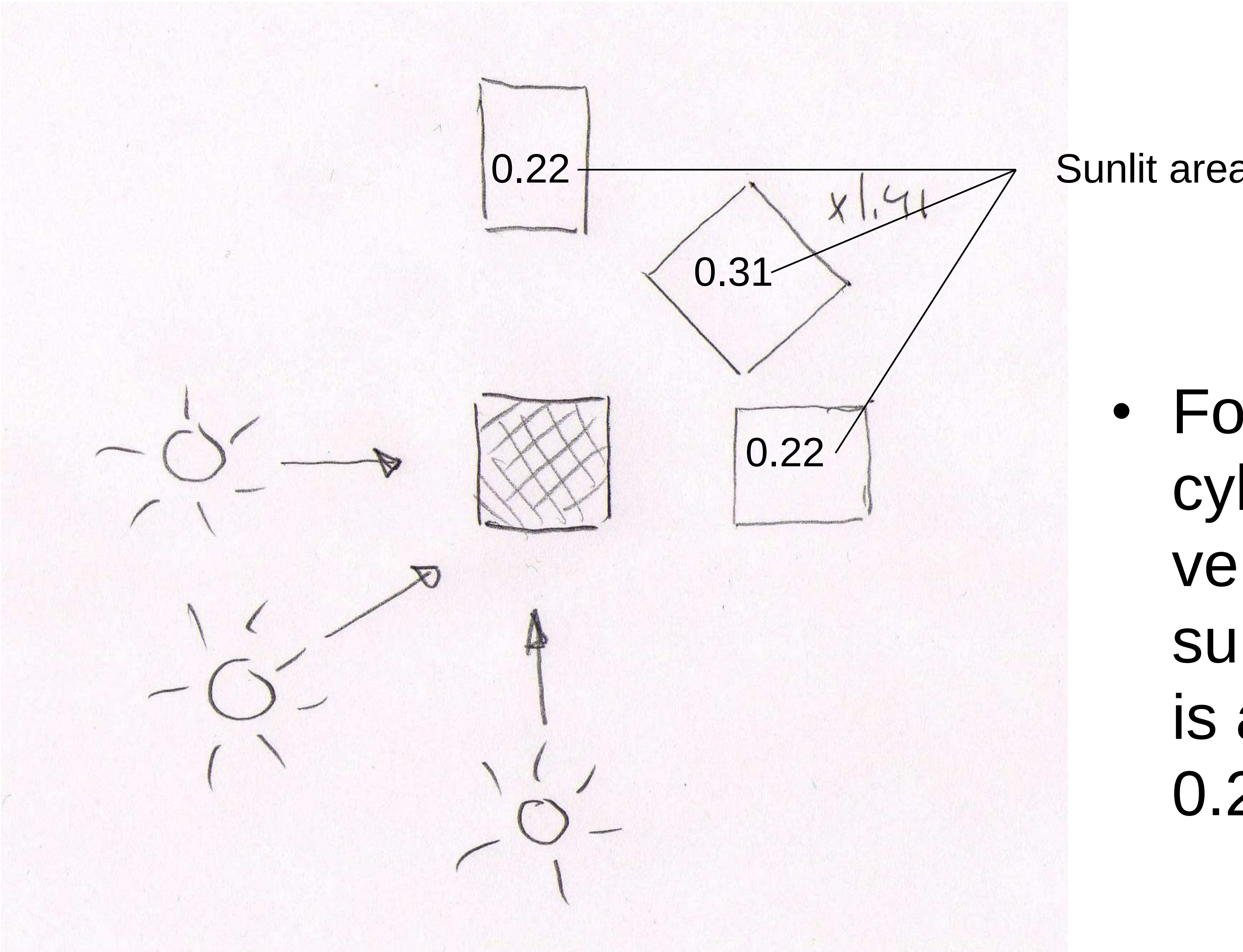
Proportions of the standing man



Vertical sunlit area vs azimuth

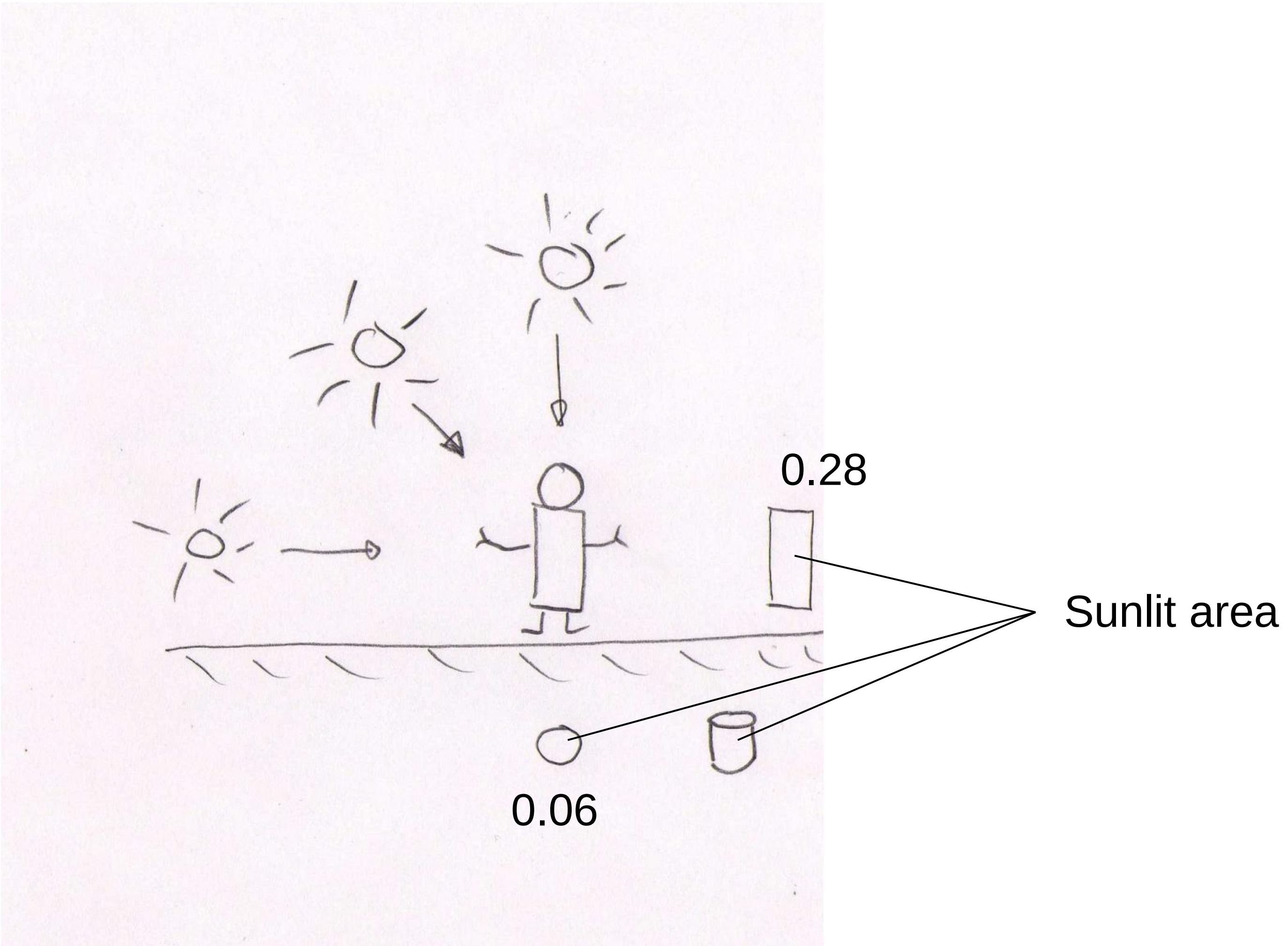


Vertical sunlit area vs azimuth



- For the cylinder the vertical sunlit area is always 0.28

Sunlit area vs solar height



The Höppe calculation (box man)

The mean radiant flux $S_{str,box}$:

$$S_{str,box} = \underbrace{(1-\alpha)\cdot\Sigma w_i\cdot K_i}_{\text{shortwave}} + \underbrace{\varepsilon\cdot\Sigma w_i\cdot L_i}_{\text{longwave}}$$

w_i – surface share in direction i

α – albedo

ε – absorbtion coefficient

$$T_{mrt} = (S_{str,box} /(\varepsilon\cdot\sigma))^{0.25} - 273.15$$

σ – Stefan-Boltzmann’s constant.

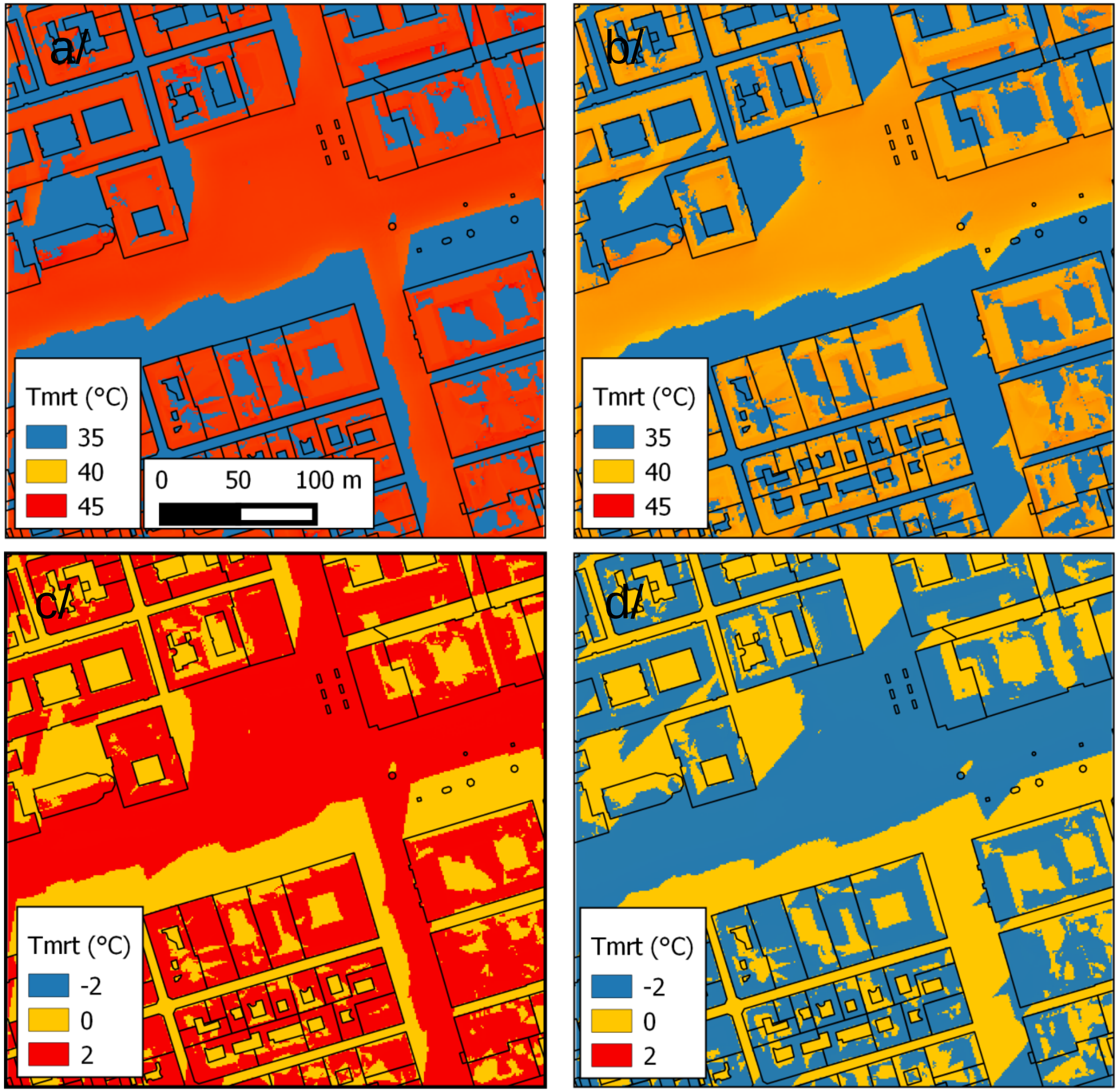
The new methodology (cylinder man)

$$S_{str,cyl} = (1-\alpha)\cdot[0.28\cdot\cos(\beta)\cdot K_{dir} + 0.06\cdot(K\uparrow + K\downarrow) + 0.88\cdot K_{diff}] + \varepsilon\cdot\Sigma w_i\cdot L_i$$

horizontal direct — vertical global — horizontal diff. — longwave

where $K_{dir} = \cos(\beta)\cdot\sqrt{}(K_{dir,left2} + K_{dir,right2})$

Implementation in models
- the SOLWEIG model



- Gothenburg on the 11th of October 2005
- a/ T_{mrt} at 1 p.m. according to the cylinder man
- b/ T_{mrt} at 3 p.m. according to the cylinder man
- c/ differences at 1 p.m. in T_{mrt} between the box man and the cylinder man
- d/ differences at 3 p.m. in T_{mrt} between the box man and the cylinder man.

Some remarks

- Two data sets from two different latitudes, 11°N and 58°N, are studied.
- The new calculations show a maximum around noon and an acute distribution during clear skies.
- On overcast days T_{mrt} probably differ little from the previous calculations since the direct radiation vanishes.
- At sites with much reflected radiation but the differences between the two methods will probably become smaller than for open sites.

Some remarks

- A major advantage of the new methodology is that the ambiguities that can be raised around the errors of the hitherto calculations can be put aside and the reliability of the interpretations will increase.

The globe thermometer

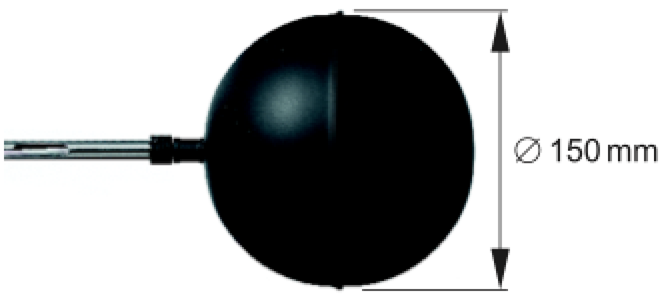
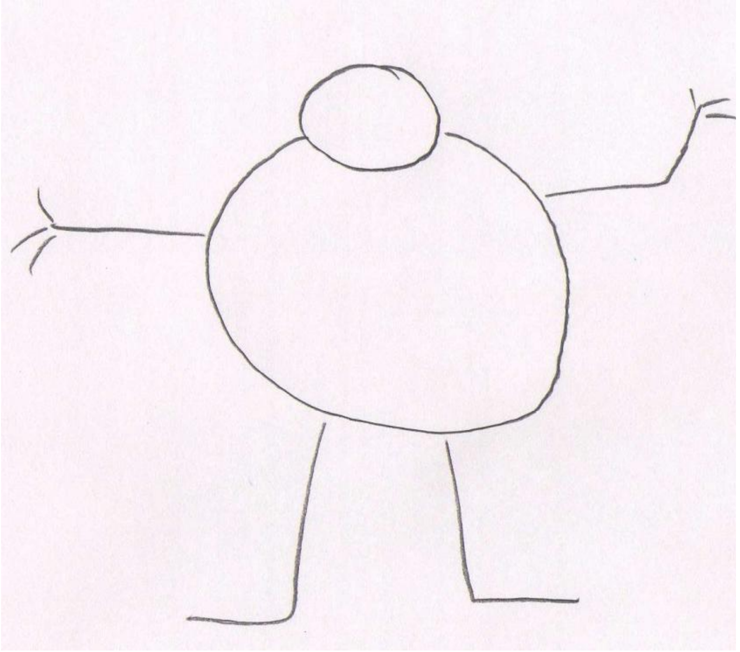


Figure 3. The 38 mm flat grey globe thermometer.

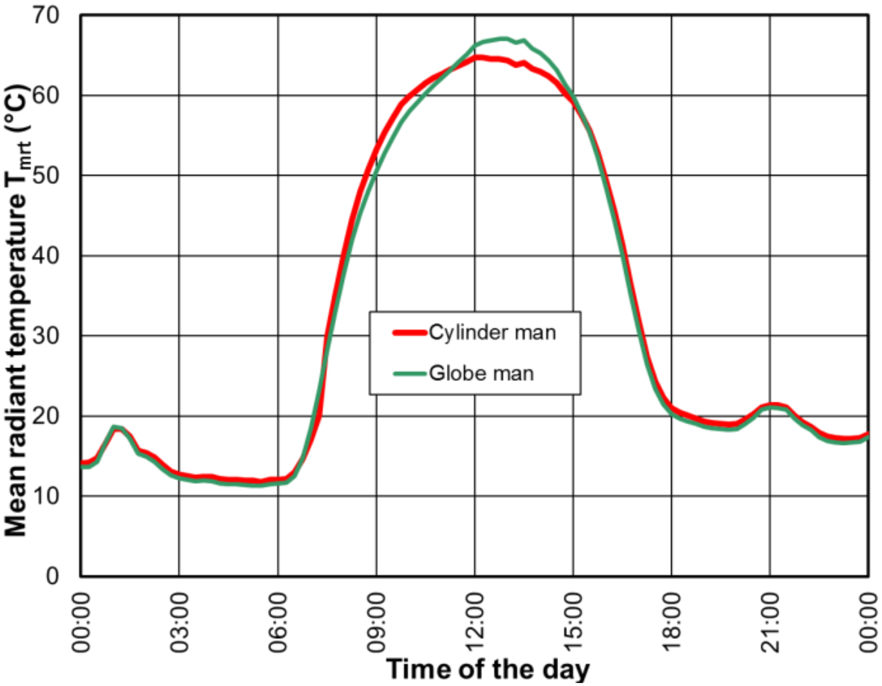
The globe

$$S_{str,globe} = (1-\alpha)\cdot[0.25\cdot K_{dir} + 1/6\cdot\Sigma K_{diff,i}] + \varepsilon\cdot\Sigma w_i\cdot L_i$$

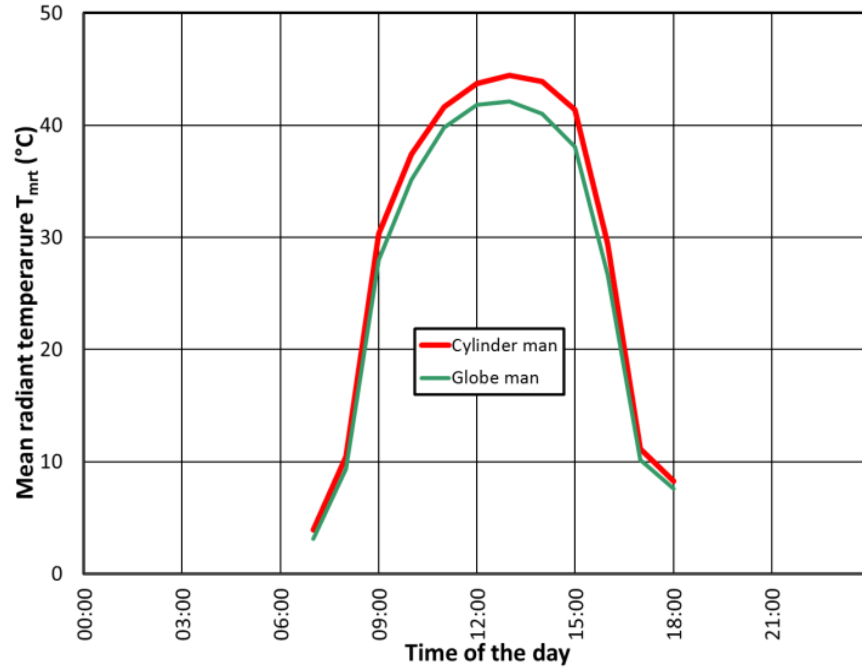


The surface exposed to the direct radiation is always 0.25

T_{mrt} calculated with a cylindrical standing man and with a globe.



T_{mrt} in Ouagadougou on the 10th of December 2007. Maximum solar elevation 55°.



T_{mrt} in Gothenburg on the 11th of October 2005. Maximum solar elevation 30°.

About the calculations

The calculations are performed in Excel. This sheet will be available at our homepage. The six directional data had to be complemented with data on solar azimuth and solar height. The sheet includes some steps that were not shown in the presentation, e.g. that the orientation of the radiation equipment is checked and adjusted automatically in the calculation.

Solweig

The implementation in Solweig is already available.

Get it on our homepage:

http://gvc.gu.se/english/research/climate/urban-climate/software/solweig

Thank you for listening