Clima Sensor, Weather Station Compact

Application Note

– How to calcuate the brightness of facades –

4.920x.xx.xxx (all versions with brightness measurement)

Softwareversion: -

4.904x.xx.xxx

Softwareversion: -

4.905x.xx.xxx

Softwareversion: -

Dok. No. 0218555/05/19

THE WORLD OF WEATHER DATA

1 General description

A number of THIES devices are equipped with sensors for brightness measurement. Those devices have typically 4 photodiodes providing brightness data for the four cardinal directions. For certain applications such as building automation it may be of interest to know the brightness of upright surfaces that are not exactly orthogonally directed to one of the four cardinal directions. This application note describes how to calculate the brightness of such surfaces.

2 How to calculate the brightness of arbitrarily directed upright surfaces

1) System requirements:

a. A THIES brightness sensor from series 4.920x, 4.905x, 4.904x that includes at least 4 photodiodes for brightness measurement, each photodiode directed to a cardinal direction.

b. The sensor is installed with the north marker directed towards north.

c. A data processing unit to collect data from the brightness sensor and to perform calculations

2) If an upright surface such as a building façade is turned by γ against north (see figure), calculate the brightness of this surface as follows:

a. Determine the maximum sun light B_{Max} from the four photodiodes as

$$B_{max} = Max(B_1 \dots B_4);$$

where $B_1 \dots B_4$ is the brightness in kLux as provided by the sensor's four photodiodes

b. Calculate the incidence angle ε_{max} of the direct light on the photodiode that shows the maximum value as

$$\varepsilon_{max} = f(\Gamma_{max}, \alpha, \beta, \phi)$$

where

α is the azimuth angle as calculated from the GPS data

β is the solar elevation angle as calculated from the GPS data

ϕ is the tilt angle of the photodiode in the sensor case, see figure

Γ_{max} is the angle that the surface normal of the photodiode indicating the highest brightness deviates from the north, i.e. Γ=0° for PD_{North}, 90° for PD_{East}, 180° for PD_{South}, 270° for PD_{West}

and where ε_{max} is calculated as

$$\varepsilon_{max} = arccos(\cos \Gamma_{max} \cdot sin\phi \cdot \cos \alpha \cdot \cos \beta + cos\phi \cdot sin\beta + \sin \Gamma_{max} \cdot sin\phi \cdot \sin \alpha \cdot \cos \beta)$$

c. Calculate the direct sunlight $B_{max,direct}$ as

$$B_{max,direct} = B_{max} - B_{diffuse}$$

where

$B_{diffuse}$ is the diffuse light estimated as $B_{diffuse} \approx Min(B_1 \dots B_4)$

d. Calculate the direct sunlight with respect to the orthogonal solar incidence $B_{\perp,direct}$ as

$B_{\perp,direct} = \frac{B_{max,direct}}{\cos(\varepsilon_{max})}$, for $\varepsilon_{max} < 80°$ [1]:

else $B_{\perp,direct} = 0$

e. Calculate the incidence angles ε_{Fi} of the direct sunlight on the façades $i = 1..4$ as

$$\varepsilon_{Fi} = arccos(\cos \gamma_i \cdot \cos \alpha \cdot \cos \beta + \sin \gamma_i \cdot \sin \alpha \cdot \cos \beta)$$

where γ_1 is the angle that the surface normal of facade 1 deviates from the north and $\gamma_i = \gamma_{i-1} + 90°$ holds for the façades 2, 3 and 4.

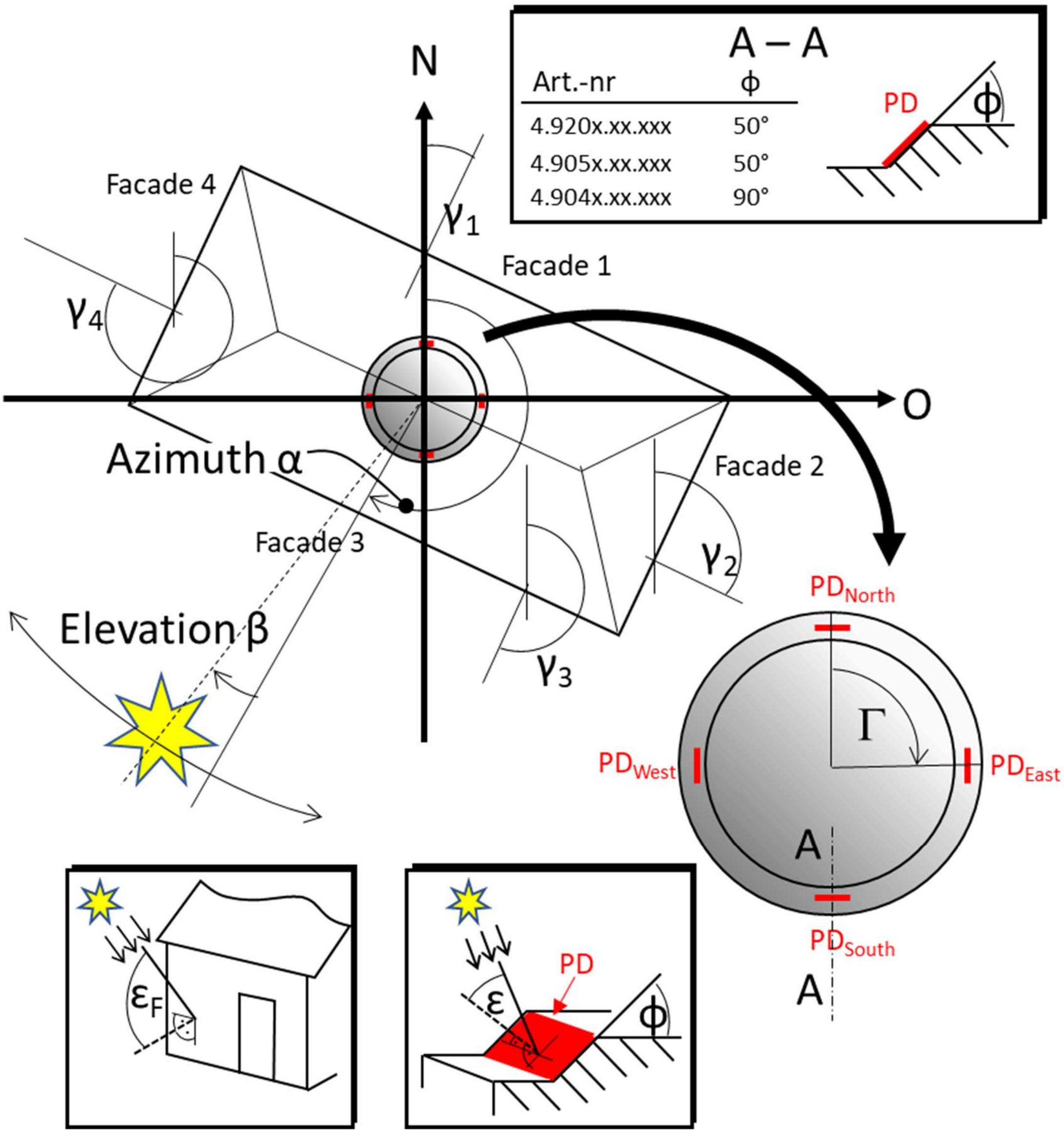
f. Finally, calculate the total light B_{Fi} in kLux on each façade surface i as

$B_{Fi} = B_{\perp,direct} \cdot \cos(\varepsilon_{Fi}) + B_{diffuse}$ for $\varepsilon_{Fi} < 90°$

else $B_{Fi} = B_{diffuse}$

---

[1] Note: limitation to $\varepsilon_{max} < 80°$ is mandatory, as for angles close to 90° the calculation gets inaccurate because of the leverage effect of a near-to-zero divisor cos(ε_{max}). However, once the sun shines almost parallel to the respective (façade) surface, i.e. orthogonal to the surface's normal, there will be no direct sunlight on such surface. The setting $B_{\perp,direct} = 0$ is therefore reasonable.



3 Characteristics and applicability

Applying above calculations, a single freestanding sensor can be used to determine the brightness of arbitrarily directed upright surfaces such as walls, facades etc.. As long as the sensor is exposed to the sun, the brightness of any nearby façade can be determined under all weather conditions even if the surface is averted from the sun and therefore shaded. Once the sensor itself is shaded by an object, it will not provide correct data for surfaces that are exposed to the sun. It should therefore be taken care, that the sensor is installed at an all-day unshaded location. If such location is not available, more than one sensor needs to be installed.

For ϕ=90° (series 4.904x.xx.xxx), the calculated surface brightness is valid in northern and southern hemisphere as well as at the equator. It provides correct data under cloudy conditions, partial cloudy conditions and at full sunshine. For ϕ<90° (series 4.920x.xx.xxx, 4.905x.xx.xxx), at clear sky, the calculated surface brightness is valid as long as the sun's elevation angle β does not exceed the photodiodes' tilt angle ϕ. The more β exceeds ϕ , the bigger gets the error for the calculation of the diffuse light and the less meaningful is the calculated surface brightness. Therefore, in northern and southern hemisphere around noon in summer time and in locations nearby the equator throughout the year, brightness data from 4.920x.xx.xxx and 4.905x.xx.xxx may not be applicable to determine the surface brightness.

4 References

Needed variables are to be accessed according to the user manuals “instruction for use“ document number 021774/12/18 of the Weather Station Compact WSC11 (4.9056.xx.xxx, V2.07. Status 12/2018) and document number 021690/11/18 of Clima Sensor US (4.920x.xx.xxx, V4.10, Status 11/2018)

Please contact us for your system requirements.
We advise you gladly.

ADOLF THIES GMBH & CO. KG
Meteorology and environmental metrology
Hauptstraße 76 · 37083 Göttingen · Germany
Phone +49 551 79001-0 · Fax +49 551 79001-65
info@thiesclima.com

www.thiesclima.com