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English: **UVB RANGE ALBEDO MEASUREMENTS USING BIOMETERS**

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UVB RANGE ALBEDO MEASUREMENTS USING BIOMETERS

Short title: UVB ALBEDO MEASUREMENTS

Abstract

This work describes ultraviolet-B albedo measurements performed over several surfaces and different atmospheric conditions. A custom-built albedometer composed of a pair of Solar Light 501A biometer was used to measure the albedo over the following surfaces: green and yellowish grass, sand, wood (natural and painted), formica (synthetic plate) and iron. Influence of clouds and the sensor's response to temperature variations are also discussed. Presence of clouds on surface albedo measurement seems negligible, but a thermo-regulated instrument is indispensable to an accurate analysis. The results allow to improve Blumthaler and Ambach's database (1988), widely used as albedo reference for the main UV radiative transfer models.

Keywords: surface albedo, ultraviolet radiation, radiative transfer models.

Resumo

Este trabalho apresenta medidas de albedo UVB realizadas sobre diferentes tipos de superfície e condições atmosféricas distintas. Para tanto, um albedômetro foi desenvolvido a partir de dois biômetros Solar Light 501A e as medidas foram realizadas sobre as seguintes superfícies: grama verde e amarelada, areia, madeira (natural e pintada), fórmica e metal. A influência de nuvens e a resposta do sensor às variações de temperatura também são discutidas. Verificou-se, que as nuvens não exercem influência significativa sobre a determinação do albedo, enquanto o uso de sensores termo regulados é imprescindível para a obtenção de medidas precisas. Os resultados obtidos fornecem uma contribuição relevante ao trabalho de Blumthaler e Ambach (1988), amplamente utilizado como referência para descrição do tipo de superfície em modelos de transferência radiativa.

Palavras-chave: albedo de superfície, radiação ultravioleta, modelos de transferência de radiação.

INTRODUCTION

Solar ultraviolet radiation that reaches Earth surface (UV: 280–400 nm) is intrinsically related to the life on our planet. UV exerts influence on aquatics and terrestrial ecosystems and control photochemical and meteorological processes that occurs, mainly, in the stratosphere. This radiation range represents above 8% of the total solar radiation and it is strongly attenuated by the atmospheric elements before reaching the Earth’s surface. Solar radiation between 280 and 320 nm, named UVB, bears strong attenuation due to ozone absorption and molecular scattering while passing through the atmosphere. Nevertheless, the small quantity that reaches the Earth’s surface is enough to cause several photobiological reactions on human population, animals and plants, as well as photochemical reactions on inorganic material like plastics and inks. More specifically, human overexposure to UVB is related with adverse health effects, like erythema, sunburn, skin aging, immune suppression and skin cancers. On the other hand, small daily doses are necessary to the vitamin D synthesis in human being (Diffey, 1991).

Theoretical calculations based on radiative transfer models are relevant for studying and evaluating UVB fluxes at the surface. These mathematical tools are of outmost importance in areas where surface instrumentation is scarce or non-existent, a frequent problem due to high costs of UV instruments and their maintenance. This is particularly evident in underdeveloped countries, where skin cancer is also a health public problem (INCA, 2005). In order to calculate accurate UVB fluxes using these computational models, it is necessary to describe the space-time distribution of different variables. These variables are: a) meteorological, such as temperature, wind fields and cloud coverage; b) geographical, such as latitude, longitude, and altitude; c) astronomical, related to the seasonal and daily sun position; and d) physical, such as total ozone content and aerosol characteristics (aerosol type, burden and optical depth) and the surface albedo (Diffey, 1991).

The main point of this work is to analyze the surface albedo and propose a brief discussion about the parameters that influence its experimental measurement. The goal is to complement the important and largely diffused Blumthaler and Ambach's work (1998), providing new information for computational model databases.

EXPERIMENT, DATA AND RELEVANT INSTRUMENTATION

The experiment was performed at CPTEC's (Weather Forecast and Climate Studies Center) meteorological station, located in Cachoeira Paulista (22.68°S, 45.00°W, 563.0 m), São Paulo State, Brazil. Data were collected at the end of summer, during two months – March and April, 2005 – under different meteorological conditions such as clear-sky, cloudy, overcast and rainy days. Measurements were collected with 1 minute resolution. The albedometer system, built from two new and calibrated Solar Light 501 biometers (http://www.solarlight.com) is illustrated in figure 1. The equipment is thermo-regulated, powered by two 12 V (7 Ah) batteries and a 20 W solar panel. Prior to the albedo measurements, the instruments were compared by performing exposition to global solar radiation under clear and cloudy conditions. A set of 7-day measurements was performed, with 1-minute resolution. Despite their recent calibrations, the results showed a systematic difference between sensors gain. However, these discrepancies did not show relevant differences under cloudy or not-cloudy conditions or during noon and sunrise/sunset hours. Altogether, measurements indicate a systematic difference of 2.48% in sensor gain. This result allows to using equation 1 to account for surface albedo correction:

$$U_1 = 1.0248U_0 \qquad (1)$$

<figure 1>

Biometers operate according to Robertson-Berger radiometers (Berger, 1976). Solar light penetrates a quartz dome through a black filter that absorbs visible and infrared radiation.

Thereafter UV radiation reaches a phosphor sensor that excites and produces radiation detected by a gallium-arsenium-phosphor photodiode (GaAsP). Both elements are built in a thermo-regulated capsule. The photodiode produces electric current that is converted to an amplified voltage through electronic circuits. Finally, voltage is multiplied by the factor calibration resulting in irradiance values. Subsequently, surface albedo (A_{UVB}) is obtained by this relationship:

$$A_{UVB} = \frac{E_u}{E_d} \tag{2}$$

where E_u is the upwelling irradiance (reflected radiation) and E_d is the downwelling irradiance (global radiation).

According to recommendations proposed by Blumthaler and Ambach (1988; hereafter named BA88), down-looking biometer should be installed between 30 and 50 cm over the ground. In this experiment, the down-looking biometer was installed at 40 cm over the ground. Several measurements were done with instruments placed at 20 and 50 cm, which showed that the differences in the values of albedo were not significant. Below 20 cm, instrument shadow interferes with the measurements. Different surface types were represented in a 1.44 m² square plate centered below the albedometer. In this area, green and yellowish grass, sand, wood (natural and painted), formica (synthetic plate) and iron were tested.

Calibration is only valid below 25°; thus, internal temperature control is a relevant problem in UV measurements. A Peltier element maintains the inside temperature stable, but due to the high energy consumption the temperature compensation circuit (TCC) is turned off at night, when the radiation level is approximately zero. Sometimes, during overcast or rainy conditions or during sunset or sunrise, the temperature control of the down-looking sensor was automatically turned off even during the daylight. When this problem arises, measurements can be corrected by the following equation:

$$U_{corr} = \frac{U_{meas}}{1 + [T - 25] * 0.01} \quad (3)$$

Where U_{corr} is the corrected voltage, U_{meas} is the measured voltage and T is the sensor temperature.

RESULTS AND DISCUSSION

Table 1 shows surface UVB albedo measurements performed in this work. These results have been obtained from averages of 1-minute measurements and correspond to periods of the day when the zenith angle was lower than 60°. For the sake of completeness, the table is complemented by the BA88 results.

<table 1>

Biometers data were collected during periods of 2-4 days for each type of surface. The different time range allowed evaluating different cloud conditions influence. Figure 2 shows an example of surface albedo (natural clear wood) variations under clear sky and cloudy conditions. During cloudy conditions, observed after noon, instantaneous surface albedo shows slight variations only. Mean surface albedo calculated for 12–15h30 UTC (cloudless) and 15h30–18 UTC (cloudy) shows similar results: 2.7 ± 0.1 and 2.6 ± 0.1 respectively.

<figure 2>

The manufacturer (Solar light Co.) assures a good cosine response for the most part of incidence angles (angular response within 5% from ideal cosine for incident angles smaller than 70^{o}). For this reason, only measurements performed in this interval were used for the mean albedo estimative. Nevertheless, daily variation of surface albedo was also analyzed. Results illustrated in

Figures 2 and 3 suggest a slight daily cycle of albedo with minimal value at noon. Figure 3 makes evident significant albedo variability at sunset and sunrise hours at any surface. These variations can be mainly attributed to the bi-hemispheric reflectance, usually represented by the bidirectional reflectance distribution function (BRDF). BRDF gives the reflectance of a target as a function of illumination geometry and viewing geometry. Discrepancies observed at sunrises and sunsets reinforce this hypothesis. However, a deeper analysis of this phenomenon is out of the scope of this article. Besides, other relevant influences can not be ruled out, such as angle response sensor, strong fluxes attenuation caused by the longer atmospheric path and the automatic shutdown of the temperature control. Moreover, all measurements performed outside sunset/sunrise hours show very small amplitude (less than 1% between maximal and minimal results) with minimal values at noon. This variation can be attributed to the movement of the sun and the consequent increase of diffuse radiation in periods when optical path is large. In any case, this variation does not represent a significant influence in the mean albedo results.

<figure 3>

As described in section 2, Solar Light advises to use the TCC to adjust the temperature sensor close to 25°C. However, TCC is controlled by the radiation flux intensity incident on instrument*;* the circuit can be turned off in the downward sensor, even during the day, when radiation flux is negligible. In these situations, and also during hotter and colder days, discrepancies can be observed in the measurements. Figure 4 shows a comparison between albedo measured when TCC is turned on and turned off. The internal temperature differences of the instruments are also showed. Results using the applied correction (equation 3) show a very good agreement (less than 1%) with results obtained using TCC. In this simulation, when the TCC of the down-looking sensor is turned off the temperature reaches values close to 34°C. In these occasions, the differences observed between the correct and uncorrected albedo results are larger than 10%.

<figure 4>

FINAL CONSIDERATIONS

This work shows UVB albedo measurements over different surfaces as well as different conditions of a same surface using an albedometer composed by UVB 501 Solar Light biometers. Green and yellow grass, wet and dry sand, painted and unpainted wood, black, white, opaque and bright surfaces were analyzed. Results for green grass (–1.1% ± 0.1) show good agreement with the widely used work of BA88 (1.3%). These accurate measurements provide additional albedo values for radiative transfer models databases for UV index calculations. In addition, this study evaluated influence of sensor temperature variations, cloudy-sky conditions and daytime sun-position on albedo measurements. Despite temperature control ensures accurate measurements, after-measurement corrections using manufacturer equation show acceptable results. Theoretical or physical temperature correction is always necessary. This study also shows that cloud cover does not exhibit strong influence on albedo measurements, which shows similar values during cloudless and cloudy conditions.

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Figure captions:

Figure 1 – Albedometer scheme

Figure 2 – UV Index and natural clear wood surface albedo measurements under cloudless and cloudy conditions

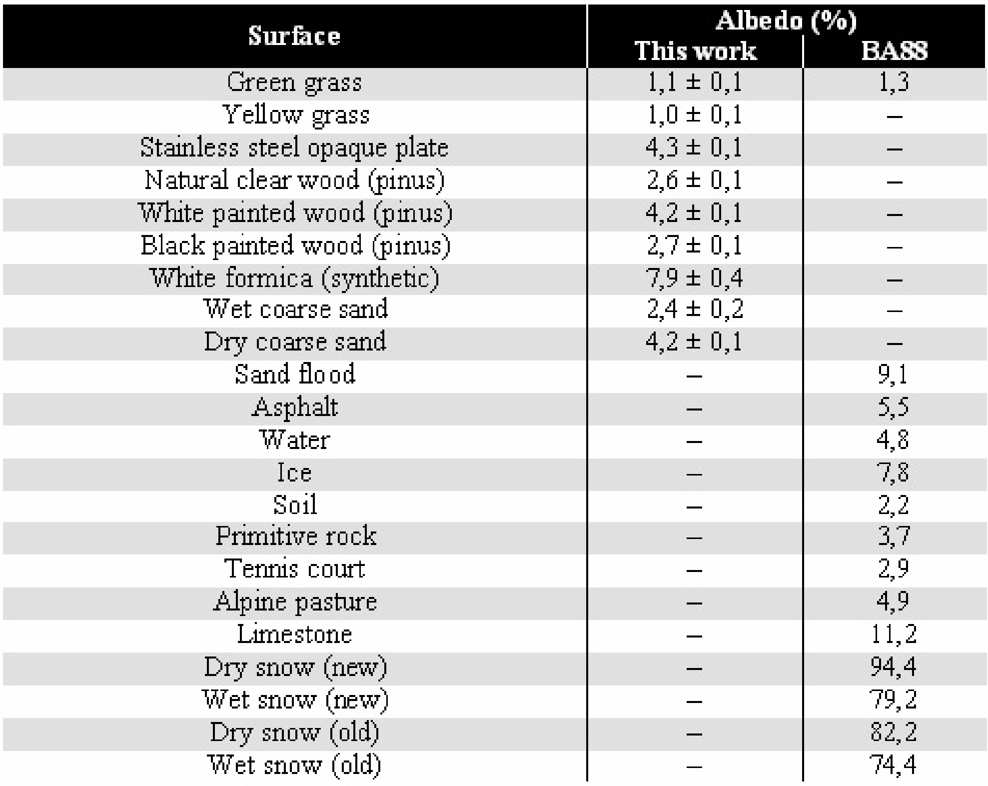
Figure 3 – Daily variations of different surface albedoes

Figure 4 – Temperature compensation circuit influence on albedo results. (Black line: differences between measured albedo without (A) and with (A_{corr}) correction; gray line: differences between core sensor temperature and thermo-regulation temperature (25°C))

Table caption:

Table 1 – UVB albedo results obtained in this work and those published by Blumthaler and Ambach, 1988 (BA88)

Table 1



Surface	Albedo (%)	
	This work	BA88
Green grass	1,1 ± 0,1	1,3
Yellow grass	1,0 ± 0,1	–
Stainless steel opaque plate	4,3 ± 0,1	–
Natural clear wood (pinus)	2,6 ± 0,1	–
White painted wood (pinus)	4,2 ± 0,1	–
Black painted wood (pinus)	2,7 ± 0,1	–
White formica (synthetic)	7,9 ± 0,4	–
Wet coarse sand	2,4 ± 0,2	–
Dry coarse sand	4,2 ± 0,1	–
Sand flood	–	9,1
Asphalt	–	5,5
Water	–	4,8
Ice	–	7,8
Soil	–	2,2
Primitive rock	–	3,7
Tennis court	–	2,9
Alpine pasture	–	4,9
Limestone	–	11,2
Dry snow (new)	–	94,4
Wet snow (new)	–	79,2
Dry snow (old)	–	82,2
Wet snow (old)	–	74,4

Figure 1

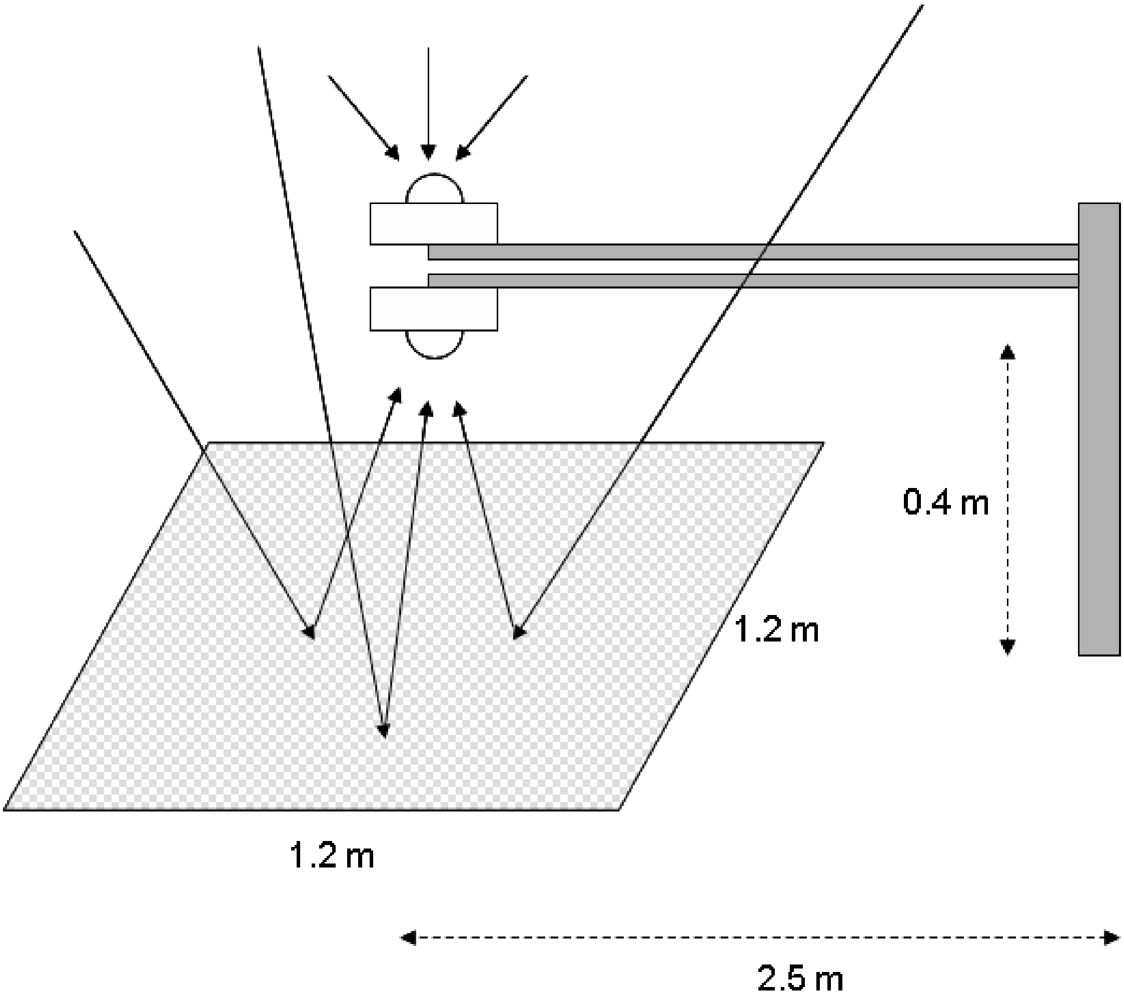


Figure 2

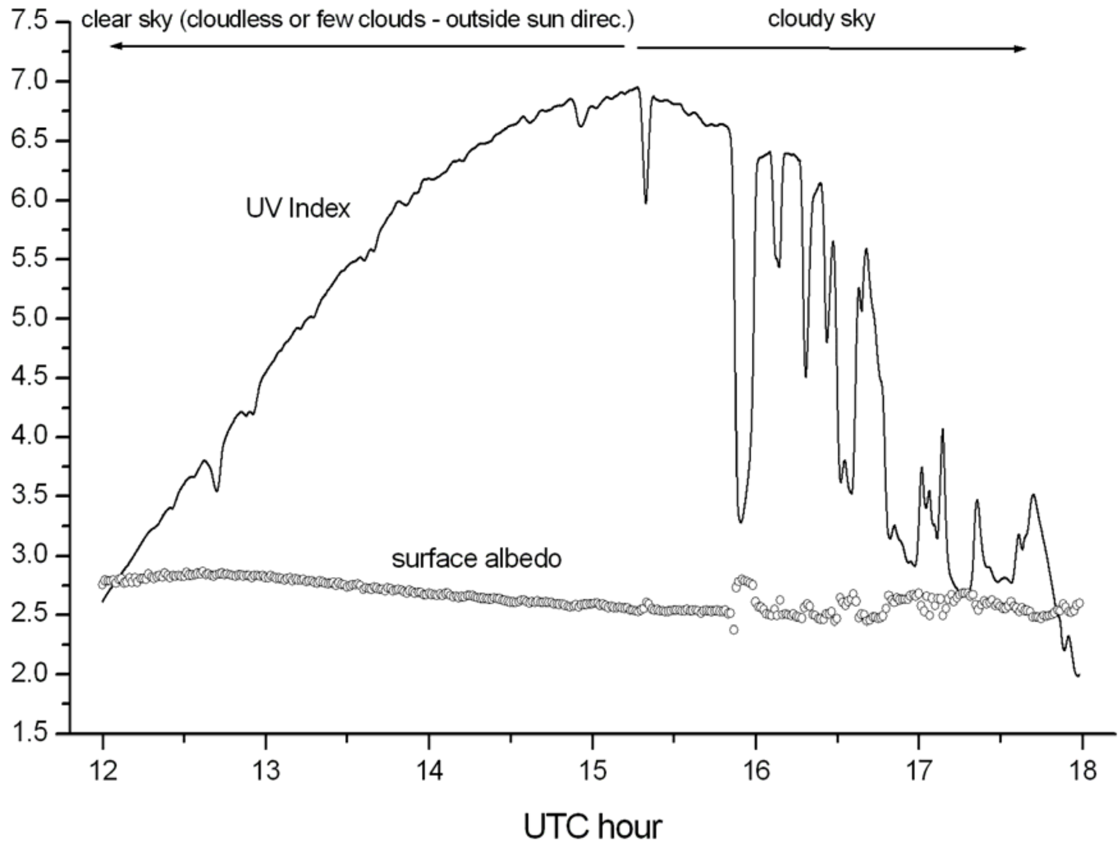

clear sky (cloudless or few clouds - outside sun direc.)
cloudy sky
UV Index
surface albedo
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
12
13
14
15
16
17
18
UTC hour

Figure 3

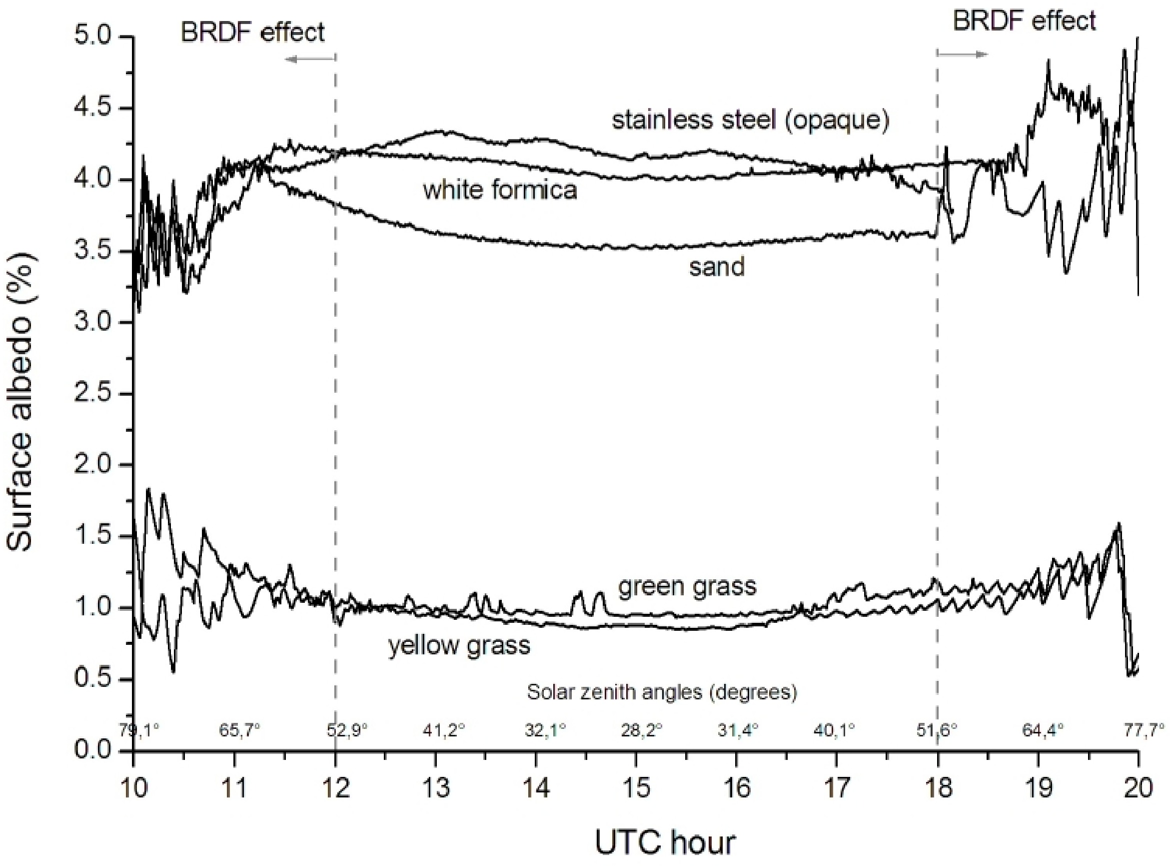
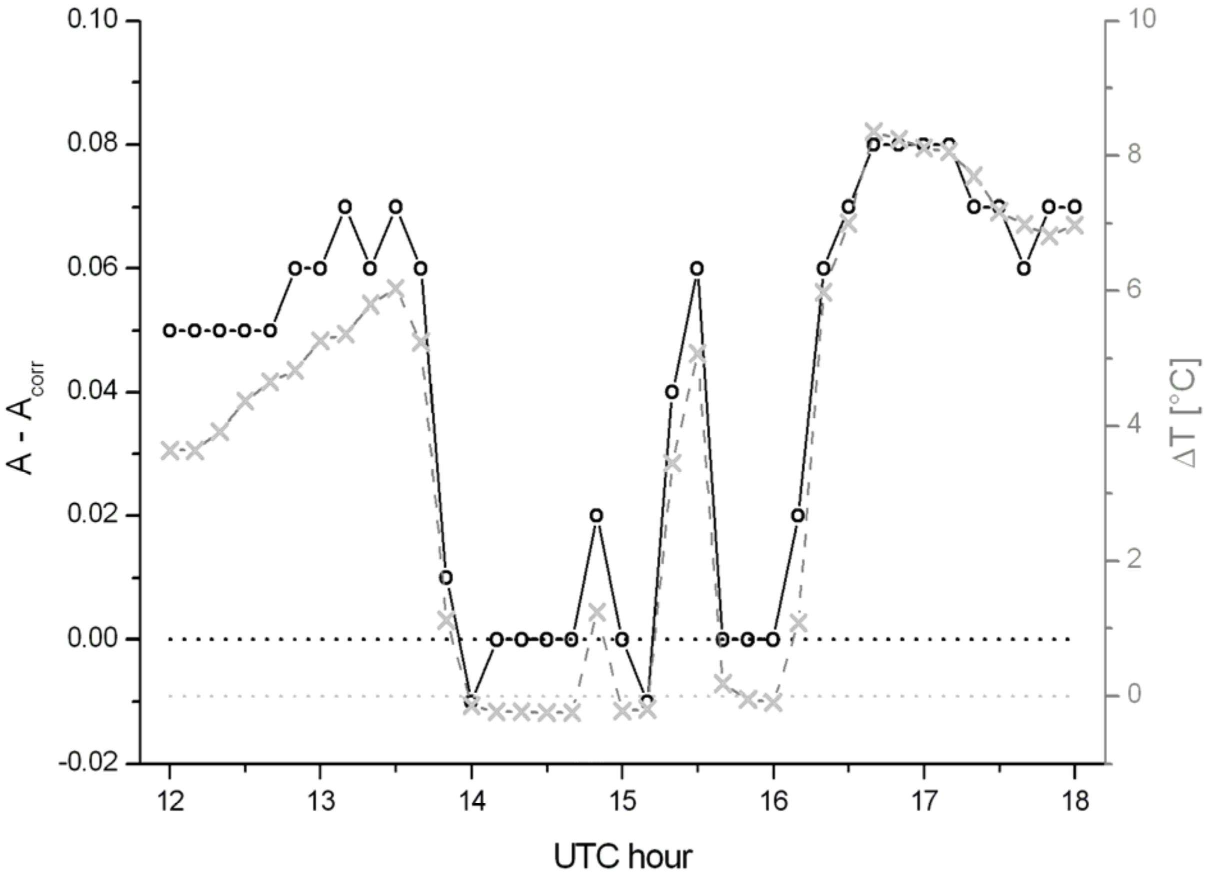

BRDF effect
BRDF effect
stainless steel (opaque)
white formica
sand
green grass
yellow grass
Solar zenith angles (degrees)
79,1°
65,7°
52,9°
41,2°
32,1°
28,2°
31,4°
40,1°
51,6°
64,4°
77,7°
Surface albedo (%)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
10
11
12
13
14
15
16
17
18
19
20
UTC hour

Figure 4


0.10
0.08
0.06
0.04
0.02
0.00
-0.02
A - A$_{corr}$
10
8
6
4
2
0
ΔT [°C]
12
13
14
15
16
17
18
UTC hour