

A simple method to determine surface albedo using digital photography

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Abstract

Surface albedo is an important concept, useful in explaining how closed systems (such as the Earth - Atmosphere) respond to incident radiant energy. Specialist, calibrated equipment is used by geo-scientists to measure ambient and reflected radiation from subject sources – this is often cost prohibitive within a teaching environment. A “semi” calibrated method is presented, utilising simple digital photography of both reference and subject sample. Using the “levels” function built into freely available image editing software, a simple algorithm is presented that allows a relative reflectance of the sample image to be calculated. Processing this with relation to a calibrated image allows for the simple determination of surface albedo. Using this method, albedo levels within 3% of a calibrated meter are obtained.

Introduction

Albedo, as defined as “the fraction of solar energy reflected” (Earth & Space Research (ESR)). As a dimensionless exponent, it can be expressed as both a simple number and percentage figure. The higher the percentage, the more energy is reflected back to the source.

Albedo is taught in both Geography and Astronomy curricular, where the number has a different relevance. For astronomers, albedo allows for the determination of surface features on distant asteroids by comparing the observed albedo to reference samples.

Within the Geography arena, albedo is concerned with the differential absorption of incoming solar energy (heat) from different areas of the globe. Specifically, ice and snow having a high albedo reflect significantly more energy than water, vegetation and soil/sub soil. This differential between ice/snow and water has a direct consequence linked to global warming. If snow covering at higher altitudes recedes or the extent of the ice caps changes due to melting, the underlying rock/soil/water with a lower albedo absorbs even more energy, accelerating the process. (Cunningham & Cunningham, 2008)

Btec L3 Applied Science

The vocational Applied Science course from Edexcel comprises modules drawn from 53 diverse units. Unit 23, titled “Unit 23: Science for Environmental Technicians” has a requirement to introduce albedo as a mechanism linked to the energy interchange between sun – surface – atmosphere (Pearson, 2010).

Albedo is a rarely taught concept within GCSE and “A” level Science, so is quite a novel term for both teachers and students alike. The particular requirements of the Btec course are for a “vocational experience” for the students. Consequentially, a practical activity is required, to allow students to investigate albedo first hand.

Potential Equipment

Initially a dedicated hardware solution was sought. The derived SI units for luminance of a surface is the lux (Wikipedia, 2011) – the cheapest lux meter available from the high street was duly sourced and purchased. (Maplin, 2011)

Experimental Procedure and Results

The experiment is simple – take measure the ambient luminance by pointing the lux meter away from the sample to be measured, ideally by placing the meter on the ground, facing upwards. The sample luminance is determined by aiming the meter at the sample, from a suitably close (<1m) and controlled distance. The albedo is the ratio of reflected to ambient light.

Sample	Ambient	Reflected	Albedo
Grass	17505	2607	15%
Dry Soil	18602	3125	17%
Dry Sand	18715	7259	39%
Wet Sand	17968	4217	23%
Tall grass	18325	3678	20%
Water	18589	1540	8%

Table 1: Albedo calculations using lux meter

These figures are in line with published data. (Cunningham & Cunningham, 2008) (Wikipedia, 2011)

However, the implementation of a solution that has additional costs to faculty budgets is not the most attractive. An alternative experimental technique is required.

Determining albedo using a digital camera

Every student is likely to possess a commercial device that automatically measures light levels – a digital camera, or camera built into a mobile phone. For our purposes, the challenge is to retrieve from the device the light level as measured.

Digital SLR's often have built into them the function to display a histogram of the light levels in a captured image (Digital SLR Guide, 2011) – however, by itself this is not a solution as we are looking to compare both ambient and reflected light.

Research led me to the "Albedo Project", where a simple, comparative method was described to extract the information required. (Gorski, 2011)

Modified Technique using digital cameras

The albedo of a piece of white, A4 office paper is determined in the same manner as previously, and a mean albedo determined:

Location	Ambient	Reflected	Albedo
9:00 AM	8901	5587	63%
12:00 Noon	16782	11487	68%
3:00 PM	12578	8541	68%
Lab (bright)	900	575	63%
Mean			65%

Table 2: Calculating reference albedo

The albedo value of 0.65 or 65% is carried forward as a known, standard value. This is in close agreement with published figures for office paper. (Gorski, 2011) (National Printing Company, 2011)

Experimental Technique

Students were given the task of taking a photograph of the standard sample (A4 paper) against a background that they desired to calculate the albedo of. This photograph was then loaded into the freely available ImageJ software (ImageJ, 2011).

Histograms of both the known reference sample and the unknown background were determined. The “mean” value of the histogram was recorded.

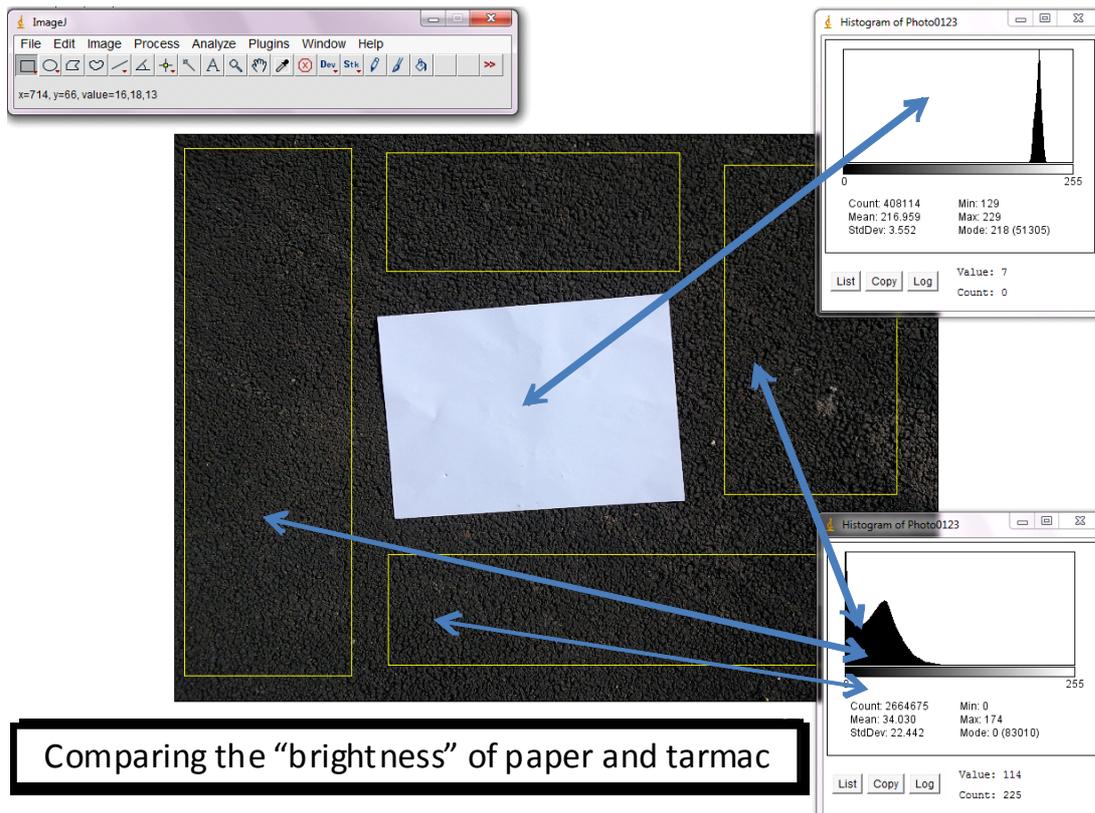


Figure1: Using ImageJ to determine image histograms

From the relative brightness of the known reference sample and unknown background, the relative albedo was formed as follows:

$$Albedo_{rel} = \frac{B_{unknown}}{B_{reference}} \quad \text{Equation 1}$$

Where; $B_{unknown}$ = mean brightness of the unknown, background

$B_{reference}$ = mean brightness of the known, reference sample

Once the relative albedo was calculated, the absolute albedo was calculated by:

$$Albedo_{abs} = 0.65 \times Albedo_{rel} \quad \text{Equation 2}$$

The constant 0.65 is the previously determined albedo of the known reference sample.

Results & Discussion

In preparing this paper, the digital camera method was used alongside the lux meter, so a direct side-by-side comparison is possible.

Determined by lux meter

Sample	Ambient	Reflected	Albedo
Grass	17505	2607	15%
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Water	18589	1540	8%

Determined by digital camera

Paper	Sample	Albedo
210	45	14%
202	49	16%
235	125	35%
227	70	20%
224	60	17%
209	17	5%

Table 3: Surface albedo

In all cases, the digital camera method produces a result that is within 3% of the lux metered method.

An interesting observation is that in all cases, the digital camera method is lower than the lux meter. Cameras convert the measured brightness into a 0 – 255 scale and it is these values that the ImageJ software is reporting. Some non linearity of the camera CCD is likely along with the image processing necessary to store the raw CCD input as a JPG image.

Extensions

Possible extensions to this project would be to compare brands of camera and phone or to use a digital SLR and extract the image as an unprocessed RAW file – thus giving more than the 256 levels used (Luminous Landscapes, 2011)

Conclusions

This paper has presented an inexpensive, low learning curve route to albedo measurements, using established technologies.

Works Cited

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