THE DIRECTIONAL-HEMISPHERICAL ALBEDO AND ITS DEPENDENCE ON THE ANGLE OF ILLUMINATION. N. Thomas[1] , K. Gunderson[1], B.S. Lüthi[1] and P. Russell[1], [1]Physikalisches Institut, University of Berne, Sidlerstrasse 5, CH-3012 Bern, Switzerland (nicolas.thomas@ kurt.gunderson@ luethi@ patrick.russell@space.unibe.ch).

Introduction: The directional-hemispherical albedo (A_H) is the quantity that defines the energy balance at the surface of an object illuminated by a photon flux (e.g. from the Sun). A_H at a specific wavelength is related to the radiance from the surface, I(α,ε,ι) where α,ε,and ι are the phase angle, the angle of emission, and the angle of incidence by the equation

$$A_H = \frac{1}{\mu_0 S / r_h^2} \int_{2\pi} I(\alpha, \varepsilon, \iota) \cos \varepsilon d\Omega$$

Where μ_0 = cos ι, F is the solar flux at 1 AU within a wavelength interval, R_h is the heliocentric distance in [AU] and Ω is the solid angle.

One of the interesting features of Hapke's scattering models [1] is that it predicts a directional-hemispherical albedo which varies with the illumination angle. Hapke’s eqn (43) gives an analytical form for A_H under the assumption that the phase function, φ(α), can be described by the simple relation

$$\varphi(\alpha) = 1 + b \cos \varphi$$

It is instructive to plot Hapke’s equation for b=±1 while varying μ_0 (Figure 1). This shows that as the incidence angle rises, A_H also rises particularly as ι goes above 60º.

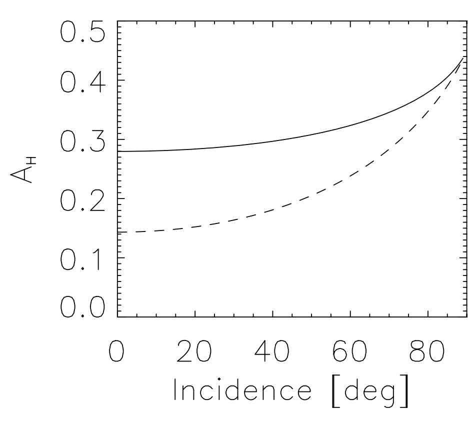

Figure 1 The directional-hemispherical albedo for a single scattering albedo of 0.7 following the simplified formula of Hapke (2002). Solid: b=1. Dashed: b=-1.

It is trivial to invert this plot to show the relative heat input (corrected for the cosine dependence) and normalized to 1 when the Sun is at zenith. This shows that the fraction of heat absorbed by the surface can drop by 35% for specific phase functions.

What this implies is that, at high latitudes, surfaces inclined towards the Sun not merely see an increased solar input going with the cosine of the illumination angle, but they also absorb proportionally more of that flux leading to a still higher temperature. This might give an additional impetus to melting of equator-facing ice-laden slopes on Mars.

To verify that this behaviour occurs for real materials, we have conducted a series of measurements using the Physikalisches Institut Reflectance Experiment (PHIRE).

PHIRE: PHIRE (Figure 2) is a simple goniometer experiment [2] which has two independently controlled arms. One arm (the transmitter arm) can move in one plane, while the other (the detector arm) has a second degree of freedom to allow variation of all three photometric angles. The system is limited to a minimum phase angle of 3º. (An upgrade later this year to reduce this limit is foreseen.) PHIRE has been fully calibrated using accepted standards and can achieve signal to noise ratios of better than 500 to 1 for most materials. Filters in the system allow measurement of spectral dependencies.

Figure 2 The PHIRE goniometer at the University of Bern.

Measurements of A_H require an extensive data set covering the full 2π upward facing hemisphere. The phase angle limit implies that any opposition effect cannot be included in the final integration but the effect influences only a relatively small solid angle, it contributes little to the final error.

Initial results: Figure 3 shows measurements at three wavelengths of JSC Mars-1 simulant, which was used for our first investigations of the A_H. The plot shows similar behaviour to that seen in Figure 1. As the incidence angle increases, the net absorption of the surface decreases. Although the effect seen in this data set was weaker than seen in Figure 1, the trend is similar. Note that the range of incidence angles covered by the goniometer for these measurements was restricted to being between 0 and 60º.

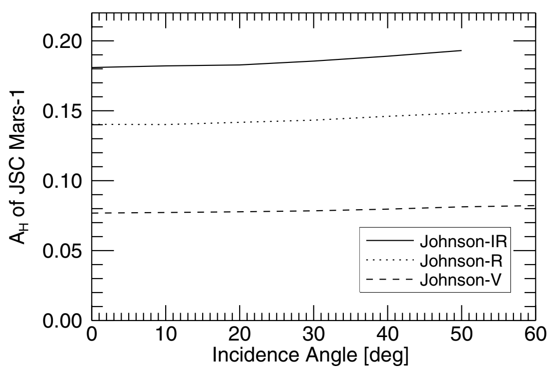

Figure 3 Measured values of the directional-hemispherical albedo for JSC Mars-1 simulant. The diagram shows a rise in A_H with increasing incidence angle.

Initial interpretation: Figure 1 indicates that irrespective of whether the phase function is strongly forward scattering (b=-1) or backscattering (b=1), A_H increases with incidence angle. Phase functions for real materials normally fall into one of these two categories. We would suggest that if a fictious particle scattering function could be constructed with scattering preferentially at 90º to the incidence angle, this would show the opposite effect (a decrease in A_H. with incidence angle). Similarly, for isotropic scattering, A_H should show no incidence angle dependence.

Implications: In general, a surface albedo is determined or used (such as using the TES bolometric albedo) and assumed to be equivalent to the directional-hemispherical albedo. This is then used as a single number for the surface energy budget in thermal calculations irrespective of the geometry. The main implication of this work is that measured albedos on low slope surfaces at high latitudes are not completely indicative of the albedo on a high slope. We see that for similar materials and latitudes, on equator-facing slopes, the albedo is lower than on a flat surface. This may have implications for the creation of unusual features associated with sublimation in the high latitude regions on Mars. In particular, the rate at which features such as "Swiss cheese" form will be influenced by such effects.

Although the measured magnitude of the effect is somewhat less than predicted in the simplified use of Hapke's equations, we feel that it is important to assess its significance by a more detailed investigation.

Presentation: Our presentation will show further laboratory measurements of A_H for a range of samples and will compare these to other calculations of A_H for theoretical materials.

References: Use the brief numbered style common in many abstracts, e.g., [1], [2], etc. References should then appear in numerical order in the reference list, and should use the following abbreviated style:

[1] Hapke, B. (2002) *Icarus, 157,* 523–534.
[2] Gunderson K.. et al. (2006) *Planet. Space Sci., in press*.

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