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Technical Letter 16

ALBEDO MEASUREMENTS AT THE MT. LASSEN TEST SITE

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ALBEDO MEASUREMENTS AT THE MT. LASSEN TEST SITE

Introduction

Albedo is a measure of the reflectivity of a material. The term is used for the decimal fraction of the incident light in the visible and near-infrared portion of the spectrum that is reflected by a surface. The albedo of a material directly or indirectly influences the response of instruments measuring energy fluxes in the visible infrared and microwave, and is thus a very important "ground truth" parameter.

A large portion of the incoming solar energy is concentrated in the visible and near-infrared portion of the spectrum. The incoming radiation is either reflected or absorbed. The reflected energy is directly correlative with the photographic quality of the terrain. The absorbed energy influences the temperature of the material, but the correlation is affected by thermal parameters of the material and is, therefore, an indirect relationship.

Instrument and Instrument Performance

The ISCO model SR spectroradiometer measures the energy intensity (flux density) of incident light. Energy is expressed in units of energy flux per unit time per cross-sectional area per wave length. The values in $\mu w/m\mu/cm^2$ obtained from direct readout of spectral intensity have a maximum error of ±40% of the actual values. Precise values may be obtained by using correlation charts provided with the instrument.

Basically, the instrument consists of a diffusing screen, light chopper, monochrometer, measuring photocell, amplifier, coherent detector and indicating meter. The spectroradiometer incorporates two wave length ranges, the visible 380-750 mμ, and the near infrared, 750-1550 mμ. The monochrometer is a wedge interference filter, i.e. the space between the reflecting layers of the filter is wedge shaped. It operates in the second interference order on the visible range and the first order on the near infrared range. The visible range detector is a silicon junction photo cell. The near infrared detector is a germanium junction photo cell.

The ISCO instrument is capable of recording the gross aspects of spectra in the wave length range of .38 to 1.55μ. It is possible to estimate the position of features in the spectrum to .005μ in the range .38 to .75μ and .01μ in the range .75 to 1.55μ.

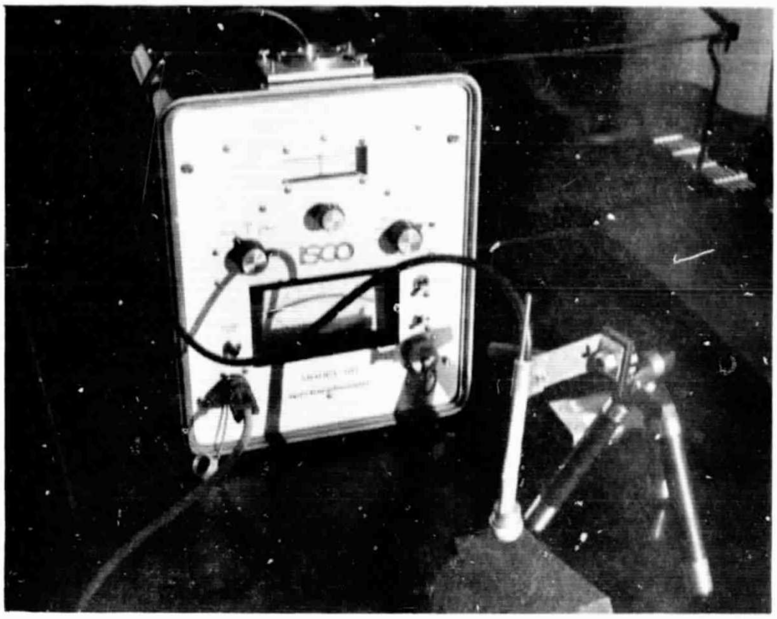


Figure 1. ISCO spectroradiometer with remote fiber optics probe.

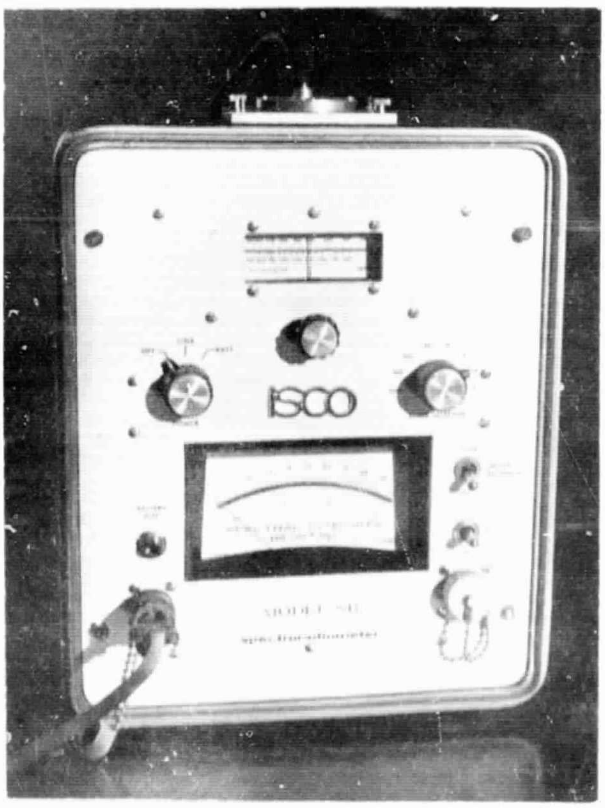


Figure 2. Close up of ISCO spectroradiometer.

Data Collection and Sampling Site Selection

Since albedo is a ratio of reflected radiation to incoming radiation, two separate measurements, solar energy flux and reflected radiation flux, are involved. The reflected radiation is best measured using the ISCO with a remote fiber optics head (90° field of view) placed 3-5 inches above the target. The incoming radiation, for conformity, is also most easily measured using the fiber optics head. Two methods have been used to obtain incident radiation measurements. Each method has its drawbacks; each is partially successful. The methods yield slightly different results in different situations.

Method 1 involves reversing the optics head 180° and directly measuring the incoming radiation.

Advantages of Method 1

1. ease of calculation
2. absence of intermediate reflectors that may introduce errors

Disadvantages of Method 1

1. reflections and radiation from the horizon (angles 45° to 135°) are not included
2. shadows projected by the instrument are not included

Method 2 incorporates a white card which is placed over the sample surface and the incoming radiation reflected off of the card, whose albedo is well known, is recorded.

Advantages of Method 2

1. incorporation of minor reflections from along the horizon and the shadow cast by the instrument

Disadvantages of Method 2

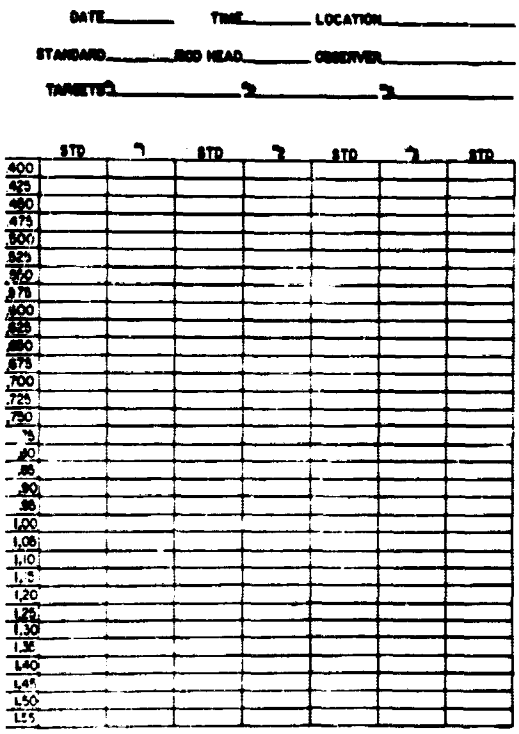
1. the albedo of the white card varies with age of the card, dirtiness of the card and sun angle.

No matter what method is used, good curves may be generated rather rapidly from points at .025μ intervals in the range .40 to .75μ and .05μ intervals in the range .75 to 1.55μ. These readings are not closely enough spaced to delineate any but major absorption bands, however, the curves are not designed to show anything but the broad characteristics of the spectra. Additional points do not seem to add enough detail to warrant the time spent taking them and reducing the data.

Site selection is a matter of choosing the correct location and the correct time. The ideal conditions may be enumerated as follows:

1. local noon on a day near the summer solstice
2. cloudless sky with stable atmospheric conditions and low atmospheric moisture
3. the target should be representative in color and texture of the desired rock or soil type
4. the measurements should be taken on a broad flat expanse of the target material with a clear unobstructed horizon.

Even when these conditions are meet, small fluxuations occur in the intensity of the incoming solar radiation. It is, therefore, advisable to make a series of data runs on the same material, each being bracketed in time by measurements of the intensity of the incoming radiation. Data forms have been so designed (see Figure 3).



DATE______ TIME______ LOCATION______

STANDARD______ ISCO HEAD______ OBSERVER______

TARGETS 1______ 2______ 3______

	STD	1	STD	2	STD	3	STD
.400							
.425							
.450							
.475							
.500							
.525							
.550							
.575							
.600							
.625							
.650							
.675							
.700							
.725							
.750							
.75							
.80							
.85							
.90							
.95							
1.00							
1.05							
1.10							
1.15							
1.20							
1.25							
1.30							
1.35							
1.40							
1.45							
1.50							
1.55							

Figure 3. ISCO data form (normal size 8-1/2 x 11).

DATA REDUCTION

The albedo at any given wavelength is the ratio of the intensity of the reflected to the incoming light.

$$\text{albedo } (\alpha_\lambda) = \frac{\text{reflected intensity } (R_\lambda)}{\text{incident intensity } (I\lambda)}$$

Because albedo is the ratio of the instrument readings, none of the measurements need be corrected for imperfect instrument transmission. If a white card is used for a standard, a factor for the albedo of the card must be included.

$$\text{albedo } (\alpha_\lambda) = \frac{\text{reflected intensity } (R_\lambda) * \text{albedo of card } (\alpha_{s\lambda})}{\text{incident intensity } (I\lambda)}$$

The white card used as a standard for a portion of the Mt. Lassen data was white poster board. Several measurements on various cards were averaged. The albedo for each normally measured wave length is listed in Table 1; the column on the table labeled α is the average measured albedo; the column $\bar{\alpha}$ is readings from a smoothed albedo curve.

If each of the datum points are calculated, albedos for 31 separate wavelengths are obtained. The most meaningful way which this data can be presented is as a graph plotting albedo (reflectivity) against wavelength. All of the albedo data in the following section is presented in this manner.

TABLE 1

ALBEDO OF STANDARD WHITE CARD
(observed vertically)

λ	α	$\bar{\alpha}$	λ	α	$\bar{\alpha}$
.400	.610	(.61)	.80	.724	(.72)
.425	.610	(.61)	.85	.724	(.72)
.450	.616	(.62)	.90	.700	(.71)
.475	.629	(.63)	.95	.724	(.71)
.500	.639	(.64)	1.00	.706	(.71)
.525	.659	(.65)	1.05	.702	(.70)
.550	.638	(.66)	1.10	.705	(.70)
.575	.703	(.68)	1.15	.706	(.69)
.600	.680	(.69)	1.20	.662	(.67)
.625	.681	(.68)	1.25	.654	(.66)
.650	.688	(.69)	1.30	.654	(.64)
.675	.687	(.69)	1.35	.589	(.64)
.700	.695	(.69)	1.40	.713	(.67)
.725	.695	(.70)	1.45	.650	(.66)
.750	.702	(.71)	1.50	.649	(.62)
			1.55	.543	(.58)

EVALUATION OF ALBEDO MEASUREMENTS

The following data from the Mt. Lassen test site indicate that the variously rough basalt surfaces and the various colors of cinder each exhibit distinct albedo curves. The reflectivities of the samples are much as one might expect; the rough black basalts have the lowest reflectivities. They are followed by the smooth dark grey basalts, the grey cinder, and, finally, the brightly varigated cinder, with the highest reflectivity. Table 2 shows the estimated visual order of albedos of six cinder samples of varying color, their reflectivity at .50μ, .60μ and .70μ, near the peak of the solar energy output, and the average of the albedos from these three points. The order of the averages is identical to the order of the reflectivities estimated by eye, though no single wavelength seems to be a good index of albedo.

TABLE 2

Summary of Visual Albedo Parameters of Six Cinder Samples

Sample No.	Estimated Relative Albedo	Albedo .50μ(green)	Albedo .60μ(orange)	Albedo .70μ(red)	Average .50,.60,.70μ
N971(AL-6)[1]	1	5.75 (2)	6.81 (1)	7.12 (1)	6.56 (1)
N966(AL-1)[2]	2	5.75 (2)	6.90 (2)	7.85 (2)	6.83 (2)
N967(AL-2)[3]	3	4.86 (1)	7.53 (3)	11.97 (4)	8.12 (3)
N968(AL-3)[4]	4	5.94 (4)	8.70 (4)	9.99 (3)	8.21 (4)
N969(AL-4)[5]	5	7.83 (6)	11.38 (6)	12.12 (5)	10.44 (5)
N970(AL-5)[6]	6	6.74 (5)	11.20 (5)	13.45 (6)	10.46 (6)

1. N971 Dark grey and dark olive brown cinder.
2. N966 Slightly varigated greyish cinder.
3. N967 Dark red and reddish-brown cinder.
4. N968 Slightly varigated brown and olive cinder.
5. N969 Varigated olive, orange, brown and grey cinder.
6. N970 Bright varigated orange, red, olive, brown and grey cinder.

The dark grey cinder, which covers much of the test site and a large portion of the surrounding area, seems to be rather consistent. Figure 4 shows three plots, the average of two grey cinder samples from the test site, grey cinder from a cinderpit 10 miles to the northeast, and grey cinder from the cinderpit recorded by a Beckman spectrometer operated by Jet Propulsion Laboratories. Figure 5 shows the individual plots of the two samples, N971 and N966, from the test site, the average of which appear in figure 4. The first of these samples is entirely dark grey and olive brown cinder, the latter includes a small amount of dark red, red-brown and light brown material as well.

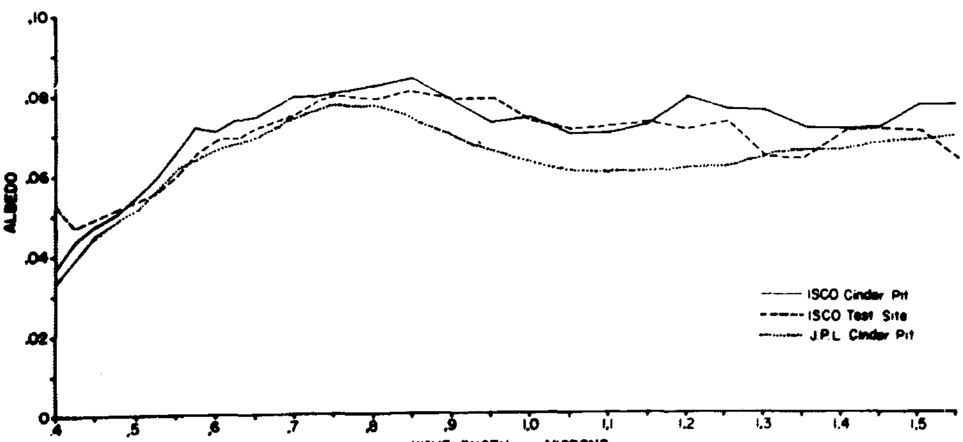


Figure 4. Albedo plot comparing grey cinder from the cinderpit and from the Cinder Cone area.

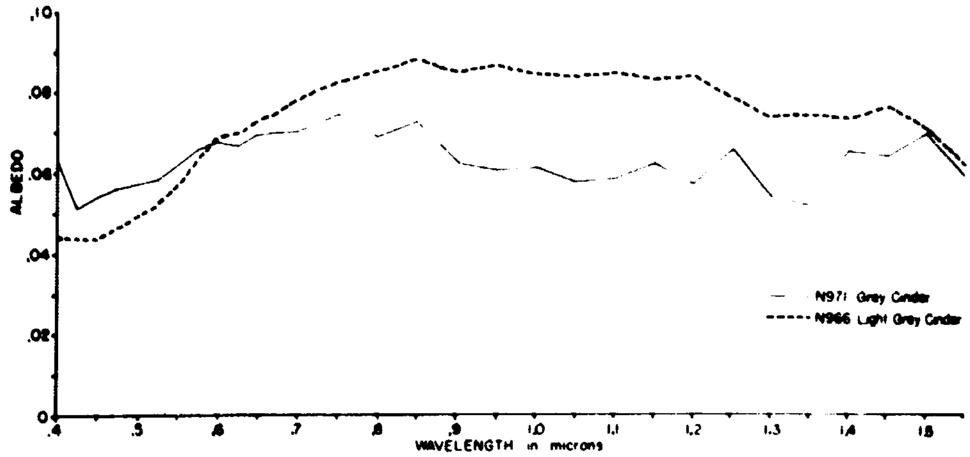


Figure 5. Two albedo plots of grey cinder from the Mt. Lassen test site.

The red and reddish-brown cinder is pecularily different from any of the other cinder samples. This dull colored cinder has a very low reflectivity in the region below .55μ and then rises sharply in the red portion of the spectrum, with a broad highly reflective region around 1.25μ. The red sample, as shown in figure 6 has a very low reflective component in the green or yellow where most of the other samples are relatively high reflective in this region of the spectrum.

The varigated cinders, because they are mixtures of a number of distinctly different colors of cinder, have irregularly shaped albedo curves. The varigated cinders all have low reflectivities in the violet and blue, with the albedo rising on the yellow and red and continuing high and irregular throughout the infrared portion of the spectrum. Figure 7 shows curves for three varigated cinder samples.

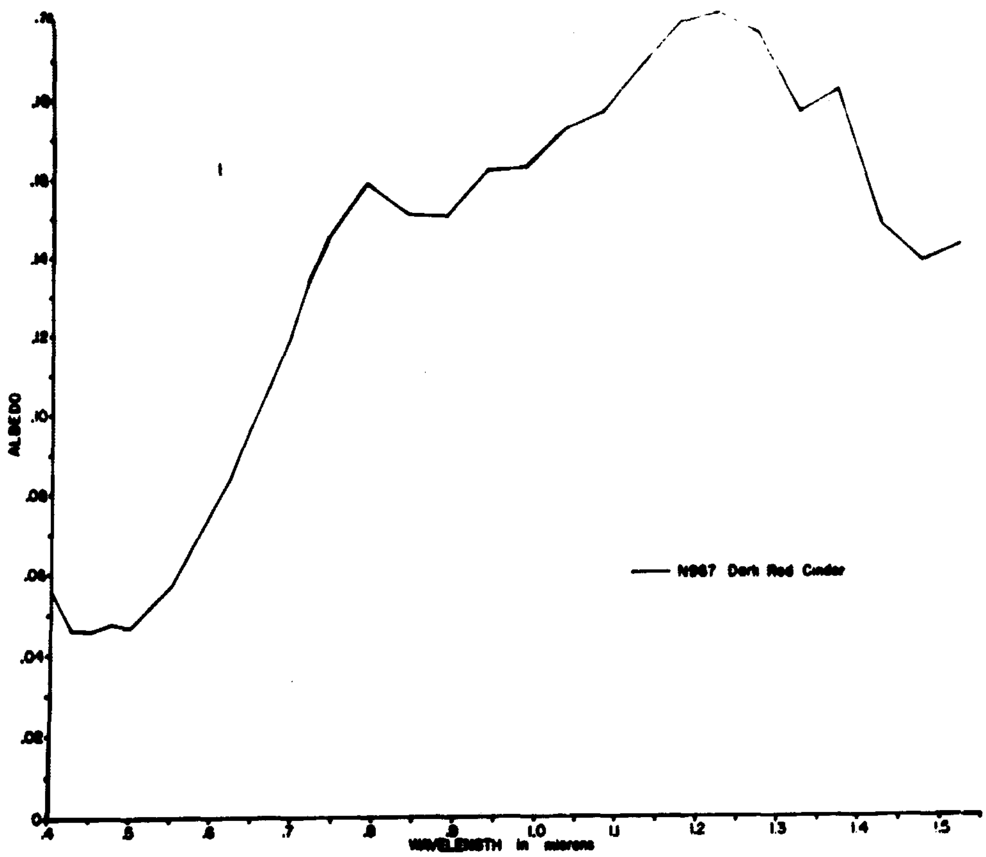


Figure 6. Albedo plot of dark red cinder.

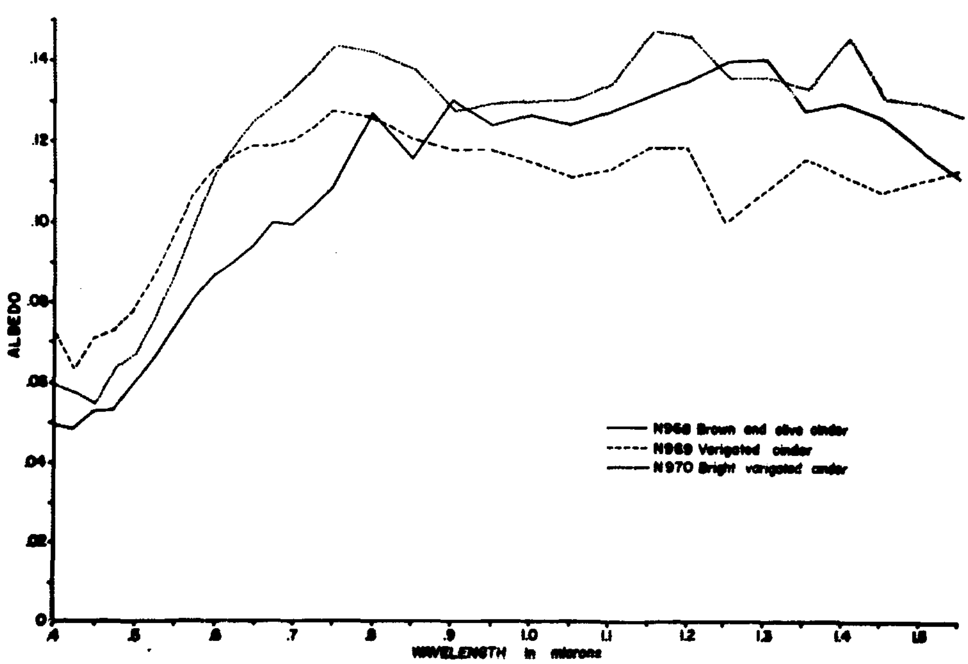


Figure 7. Albedo curves for three varigated cinder samples.

The basalt, whether rough or smooth, is remarkably uniform in reflectivity. The rock has a low reflectivity throughout the visible and near-infrared spectrum. The only prominent feature is a broad, slightly more reflective region, between .55μ and .70μ. As might be expected, the rough basalt has a slightly lower albedo than the smooth sample, as shown in figure 8.

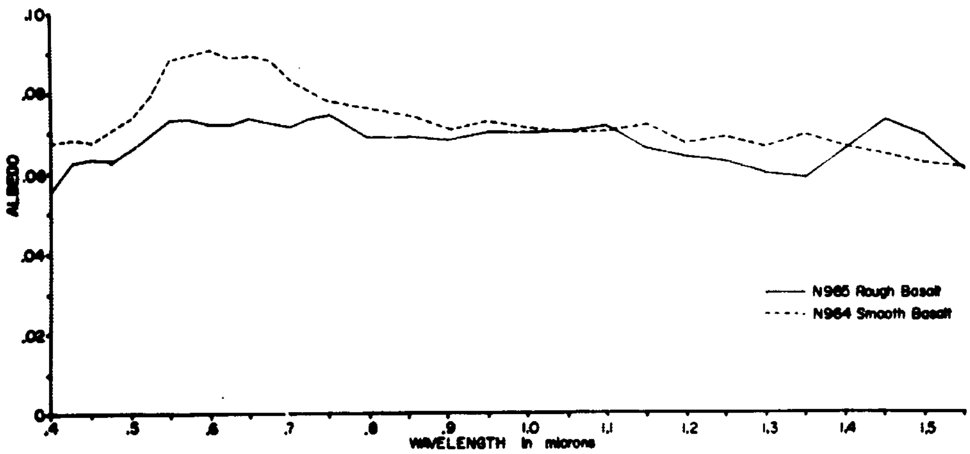


Figure 8. Albedo curves for two basalt samples from the flows near the Cinder Cone.

Applications of Albedo Measurements

Albedo measurements may be used in calculations of total energy absorption and multispectral sensor response. Table 3 shows the wavelength ranges of the various colors as the eye perceives them.

TABLE 3

Nomenclature for Wavelengths Sensed by the ISCO Instrument

.38μ to .40μ	near ultraviolet
.40μ to .43μ	violet
.43μ to .49μ	blue
.49μ to .57μ	green
.57μ to .59μ	yellow
.59μ to .62μ	orange
.62μ to .75μ	red
.75μ to 1.55μ	near infrared (Photographic IR)

When the true solar radiation flux and the albedo are known, the relative detector or photographic response for each wavelength may be computed by using the following formula:

$$R_\lambda = \alpha_\lambda * I_\lambda * c_\lambda$$

where

R_λ = true reflected intensity

α_λ = albedo

I_λ = measured incident radiation

c_λ = correction factor for instrument response (graph included with ISCO instruction manual)

Similarly, the total absorbed energy in calories/sec./cm^2 over the range .40 to 1.55μ for any substance may be computed by the following related formula:

$$E\alpha = \sum_{.40}^{1.55} [(1-\alpha_\lambda)*I_\lambda*c_\lambda*2.39*10^{-7}]$$

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