Surface Albedo Estimation and Variation Characteristics at a Tropical Station

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1. Introduction
1.1 Albedo

Reflection of radiation is one of the mechanisms by which solar radiation is depleted in the atmosphere and it is mostly done by clouds. By its definition, reflected radiation is lost to space completely (i.e., 100%).

Albedo is related to reflection of solar radiation at a surface and therefore defined in terms of it, as the ratio of the reflected solar radiation to the incident solar radiation at the surface, i.e., $H_r/H_o$, in this chapter. It is assumed however that the reflected radiation, $H_r$, is both diffuse and specular in nature, that is, it is diffuse if the reflected radiation is uniform or isotropic in all angular directions, and specular if the surface of reflection is smooth with respect to the wavelength of the incident radiation such that the laws of reflection are satisfied (Igbal, 1983). It was said by Gutman (1988) that the observed albedo assumed that the radiation field is isotropic. The extraterrestrial radiation, $H_o$ at the edge of the atmosphere, from the sun, is considered the incident solar radiation.

Albedo is also known as reflectance or reflectivity of a surface; by this, the surface albedo of the Earth is regarded the same as planetary albedo by many scientists (Igbal, 1983). Albedo, as a property of a surface, therefore, can be used to determine the brightness of a surface. According to Prado et al (2005), materials with high albedo and emittance attain low temperature when exposed to solar radiation, and therefore reduce transference of heat to their surroundings. Thus albedo is an important input parameter or quantity in evaluating the total insolation on a building or a solar energy collector. It is also important in the studies dealing with thermal balance in the atmosphere.

Several other definitions of albedo are given based on the source of the reflected radiation; only some are mentioned here.

The reflected radiation measured at several portions of the electromagnetic radiation is used to estimate the spectral surface albedos (Gutman et al, 1989); the linear combination of them constitutes the broad band surface albedo (Wydick et al, 1987; Brest et al, 1987; Saunders et al, 1990). The broadband or total wavelengths surface albedo is simply surface albedo. Prado et al (2005), however, gave an encompassing definition of albedo as the specular and diffuse reflectance, integrated over 290 and 2500 nm wavelengths range, which corresponds approximately to 95% of the solar radiation that reaches the Earth’s surface. The albedos of
the individual surfaces on the Earth, such as water, vegetation, snow, sand, surfaces of buildings, dry soil, that of the atmosphere, etc, all constitute the surface or planetry albedo.

We estimated the surface albedo of the earth’s surface at Ilorin by using equ.3 to simulate the daily and monthly averages of the shortwave solar radiation reflection, $H_r$, and reflection coefficient, $H_r/H_0$, and studied the daily and seasonal variation characteristics of $H_r/H_0$ used to define the albedo. This is the objective of this chapter, which is a report from BSRN station in Ilorin, Nigeria.

2. Determination of solar radiation reflection coefficient, $H_r/H_0$ (albedo)

$H_r/H_0$ is a ratio of short wave reflected radiation $H_r$, towards the space, to the extraterrestrial radiation $H_0$ incident on the surface of the earth at the edge of the earth’s atmosphere. Here at Ilorin, the location of this work, $H_r$, the reflected radiation is not measured nor is there a formula in literatures by which it may be predicted or estimated. The apparatus to measure surface albedo or reflected solar radiation is not available here nor in many other under-developed countries. It is therefore determined to produce its data by estimating or simulating it. Therefore the work done on short wave energy balance at the edge of the atmosphere becomes relevant, as it provides a means by which the short wave reflected solar radiation back to space could be estimated. Once the reflected radiation flux is obtained, the solar radiation or short wave radiation reflection co-efficient is easily obtained. It is reasonable to want to know the fraction of the incident radiation $H_0$ is returned back to space on daily, seasonal, and annual basis. Therefore the knowledge of reflection co-efficient, $H_r/H_0$, used to define albedo, is desirable, and is a very important and relevant radiation parameter in radiative transfer in the atmosphere.

In estimating and studying the characteristics of albedo, global (total) solar radiation $H$, and diffuse solar radiation $H_d$, of wavelengths range, mostly from 0.2 to 4.0µm, were used to simulate solar radiation reflection, $H_r$, and the reflection coefficient, $H_r/H_0$. The radiation fluxes were obtained from the BSRN station, Physics Department, University of Ilorin. The extraterrestrial radiation, $H_0$, at the top of the atmosphere at Ilorin, computed for year 2000, were used.

The global (total) radiation was measured by Eppley Pyranometer, PSP, with calibration constant of $8.2 \times 10^{-6} \text{ V/Wm}^{-2}$, while the diffuse radiation $H_d$ was measured by the Black and White Eppley Pyranometer model 8-48 with calibration constant $9.18 \times 10^{-6} \text{ V/Wm}^{-2}$.

From the measured and computed radiation fluxes, the daily and monthly averages of the fluxes, and the ratios $H/H_0$, $H_d/H$ and $H_r/H_0$ were computed. Thus, the sw- solar radiation reflection, and total wavelengths reflection co-efficient or reflectance simulated using the data of year 2000 at Ilorin were used for the study. In compliance with the world WRR, sampling rate of 1-second duration of the radiation fluxes was done every minute with integration time of 3-minutes maintained for averaging and recording.

In the work on shortwave solar energy balancing at the edge of the atmosphere carried out in 2003 by Babatunde (2003; 2003), the relation

$$\frac{H}{H_0} + \frac{H_a}{H_0} + \frac{H_r}{H_0} = 1$$  \hspace{1cm} (1)
was used to establish the sw-solar radiation energy balance at the edge of the Earth’s atmosphere. $H/H_o$ is the fraction of the extraterrestrial radiation, $H_o$, transmitted through the atmosphere to the ground surface, and called clearness index (Babatunde and Aro, 1995; Udo, 2000). $H_a/H_o$ is the fraction absorbed, called the absorption co-efficient or absorbance, and $H_r/H_o$ is the fraction reflected back to space called the reflection co-efficient or reflectance (Babatunde, 2003). Further in the work, $H_a/H_o$ was found to be very small in value compared with the other ratios and therefore negligible, i.e. $H_a/H_o < < 1$

Hence equation (1) becomes

$$H/H_o + H_r/H_o \approx 1$$  \hspace{1cm} (2)

From this, an expression for estimating $H_r/H_o$ was obtained as

$$H_r/H_o = 1 - H/H_o$$  \hspace{1cm} (3)

A similar equation was obtained by Babatunde and Aro (1995) for cloudiness index, $H_d/H$, i.e.

$$H_d/H = 1 - H/H_o$$  \hspace{1cm} (4)

Thus, can these two parameters be said to be twins of the same physical quantity?

Both $H_r$ and $H_r/H_o$ could be and were estimated using eqn.3.

The sw-reflected solar radiation, $H_r$, is understood to include the reflected radiation from the Earth’s surface, reflected radiation back to space by clouds, and the scattered radiation back to space by atmospheric particles and clouds. Reflection, with regards to solar radiation, is redirection of radiation by $180^\circ$ after striking a surface or any atmospheric particle; it is a lost radiation to the space. The fraction, $H_r/H_o$, called total wavelengths (0.2 - 4μm) reflection co-efficient or reflectance from all the surfaces on the Earth’s surface defines generally the Earth’s surface albedo (Igbal, 1983). The monthly averages of $H_r$ and $H_r/H_o$ produced are shown in columns 8 and 7 respectively of Table 1.

### 3. Characteristic variation and atmospheric effects on albedo

#### 3.1 Daily variations of $H/H_o$, $H_d/H$, $H_r/H_o$

It is instructive and informative to compare the variations and characteristics of the reflection co-efficient $H_r/H_o$, cloudiness index $H_d/H$ and clearness index $H/H_o$ as done in the graphs in Figs. 1 – 4 for February, April, August and November, months representing four periods of different atmospheric or sky conditions in the year. By the graphs the atmospheric conditions causing the variations could be discerned. The graphs represent daily and unequal fluctuations of the parameters in those months as shown in the figures. The fluctuations in the values of the parameters in turn indicate daily changes in the atmospheric conditions causing the variations.

In the graphs the reflectance, $H_r/H_o$ and the cloudiness index, $H_d/H$ have the same characteristics but show slight differences in magnitudes, while they both have opposite characteristics to $H/H_o$. Reflection coefficient, $H_r/H_o$, from this observation, may therefore
be interpreted to be a sort of cloudiness index as $H_d/H$ is (Prado et al, 2005), and confirmed by Eqns. 3 and 4.

The magnitude of the cloudiness index could be interpreted to mean the degree of cloudiness or turbidity in the sky and to imply the magnitude of the diffuse radiation in the global, while the magnitude of reflection co-efficient would indicate the degree of brightness of the surface and the amount of reflected radiation back to space.

It could be said by this, that if the sky was relatively cloudless, albedo, or reflection coefficient, $H_r/H_o$ would be relatively small, thus, more radiation would be available to solar energy devices on the earth. On the other hand the variation of $H_d/H$ which was simultaneously significant, was observed to be high in magnitude more than those of the others for the same changes in atmospheric conditions. This implies that it is more sensitive to the atmospheric condition changes responsible for the variations than the others.

Discussing specifically the variation of the parameters in each of the sampled months, and since $H$ and $H_r$ are each a fraction of the same quantity, $H_o$, it is plausible that, $H/H_o$ and $H_r/H_o$ are compared. In Fig.1, representing variation in February, the daily fluctuation of $H/H_o$ and $H_r/H_o$ were observed not to be significantly big, however the values of $H/H_o$ were bigger than those of $H_r/H_o$ practically throughout the month. This implies that since $H$ is toward the ground surface and $H_r$ is toward the space, the global radiation $H$, received on the Earth’s surface was more than the reflected radiation, $H_r$ lost to space in February at Ilorin.

![Fig. 1. $H/H_o$, $H_d/H$, $H_r/H_o$ for February 2000](www.intechopen.com)
Fig. 2, presenting the variations or the fluctuations of the parameters in April, indicates very significant variations of the parameters. The high and frequent fluctuations of the parameters could indicate corresponding high, dynamic changes in the atmospheric conditions in the month. Again, $H/H_o$ was higher than $H_r/H_o$ on many days in the month, indicating that more radiation was available on the ground surface than lost to space in reflection. There is however a rise in the value of albedo, i.e. $H_r/H_o$, observed in this month. This could be due to the presence of some clouds in the sky and heavy hygroscopic particles replacing the harmattan dust particles in the sky.

![Graph](https://www.intechopen.com)

**Fig. 2.** $H/H_o$, $H_d/H$, $H_r/H_o$ Graphs for April 2000

In August, in fig.3, the variations of the parameters were very significant with bigger values of fluctuation. However $H_r/H_o$ and $H_d/H$ were much bigger than $H/H_o$ for almost all the days in the month. This is a reversal of the case in February and November, and which could only imply that more radiation was reflected back to space than received on the Earth’s surface. The high values of $H_d/H$ at the period would indicate that the little global radiation received was mostly diffuse radiation. The high values of $H_r/H_o$, the reflectance, or albedo, would imply high brightness of the Earth’s surface toward the space, and low surface temperature of the Earth in this month.
But in November (in Fig. 4), the values of $H/H_o$ were much higher than those of $H_r/H_o$ and $H_d/H$ for almost all the days in the month. The low values of $H_r/H_o$ imply that little amount of radiation was reflected back to space, and large amount of radiation was received on the ground surface. They also imply low values of albedo, and therefore less brightness of the surface of the Earth but high surface temperature. All these, and the very low values of $H_d/H$ could indicate that very little amount of diffuse radiation, little or no clouds and little or no dust particles in the sky are the characteristics of the November month in the year.
3.2 Monthly average variations of $H/H_0$, $H_d/H$, $H_r/H_0$ examined

The graphs of the monthly averages of $H_r/H_0$, $H_d/H$ and $H/H_0$ in Fig.5, indicate high values of $H_r/H_0$ in July, August and September with the highest in August, and relatively low values in October, November, December and January with the lowest in November. Similarly the graphs indicate high values of $H_d/H$ in June, July and August with the highest in August, and low values of it in November, December and January with the lowest in November. The result, that the parameters, $H_d/H$ and $H_r/H_0$, have their highest and lowest values occurring in the same months respectively confirm that the two parameters are twins of the same physical quantity, cloudiness and turbidity, but in the opposite directions, thus answering the question raised earlier on.

The results further show that the high values of $H_r/H_0$ in July, August and September, with the highest in August, the peak of rainy season and a predominantly cloudy month, confirm the more, that the reflection of solar radiation by the planet Earth, in this region, is mostly by clouds. The lowest value of the parameter in November confirms also that November is relatively cloudless and dustless, that is, relatively clear and clean (Babatunde and Aro, 1990). A high value of reflectance observed in February, though a relatively cloudless month, would indicate that reflection of radiation at this period is by the dust particles in the atmosphere, and indicates that the atmosphere in February of that year was heavily laden with harmattan dust.
Table 1. The Monthly Average of the Radiation coefficients and Fluxes in (MJ/m² day) for year 2000

<table>
<thead>
<tr>
<th>Mon</th>
<th>H₀</th>
<th>H</th>
<th>Hd</th>
<th>H/H₀</th>
<th>Hd/H</th>
<th>H₀/H₀</th>
<th>H₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>32.61</td>
<td>16.21</td>
<td>7.24</td>
<td>0.489</td>
<td>0.456</td>
<td>0.511</td>
<td>16.664</td>
</tr>
<tr>
<td>Feb</td>
<td>34.85</td>
<td>19.14</td>
<td>9.83</td>
<td>0.549</td>
<td>0.522</td>
<td>0.451</td>
<td>15.717</td>
</tr>
<tr>
<td>Mar</td>
<td>37.03</td>
<td>21.44</td>
<td>9.74</td>
<td>0.58</td>
<td>0.459</td>
<td>0.42</td>
<td>15.553</td>
</tr>
<tr>
<td>Apr</td>
<td>37.75</td>
<td>18.85</td>
<td>8.79</td>
<td>0.519</td>
<td>0.474</td>
<td>0.481</td>
<td>18.158</td>
</tr>
<tr>
<td>May</td>
<td>37.16</td>
<td>19.17</td>
<td>8.90</td>
<td>0.516</td>
<td>0.492</td>
<td>0.484</td>
<td>17.985</td>
</tr>
<tr>
<td>Jun</td>
<td>36.51</td>
<td>17.72</td>
<td>8.34</td>
<td>0.485</td>
<td>0.6</td>
<td>0.515</td>
<td>18.803</td>
</tr>
<tr>
<td>Jul</td>
<td>36.66</td>
<td>14.95</td>
<td>8.83</td>
<td>0.408</td>
<td>0.627</td>
<td>0.592</td>
<td>21.703</td>
</tr>
<tr>
<td>Aug</td>
<td>37.29</td>
<td>13.14</td>
<td>8.46</td>
<td>0.353</td>
<td>0.68</td>
<td>0.647</td>
<td>24.127</td>
</tr>
<tr>
<td>Sep</td>
<td>37.11</td>
<td>17.10</td>
<td>9.05</td>
<td>0.461</td>
<td>0.545</td>
<td>0.539</td>
<td>20.002</td>
</tr>
<tr>
<td>Oct.</td>
<td>35.44</td>
<td>17.67</td>
<td>8.01</td>
<td>0.498</td>
<td>0.47</td>
<td>0.502</td>
<td>17.791</td>
</tr>
<tr>
<td>Nov.</td>
<td>33.11</td>
<td>18.96</td>
<td>6.73</td>
<td>0.572</td>
<td>0.361</td>
<td>0.428</td>
<td>14.171</td>
</tr>
<tr>
<td>Dec.</td>
<td>31.18</td>
<td>17.26</td>
<td>6.47</td>
<td>0.543</td>
<td>0.384</td>
<td>0.457</td>
<td>14.537</td>
</tr>
</tbody>
</table>

3.3 Seasonal variation and sky conditions by H₀/H₀, the albedo

Table 1 and Fig.5 above, present the monthly average values of reflectivity, H₀/H₀, of the Earth and its atmosphere at this location. The reflectance or reflectivity of radiation or albedo property of the contemporary atmosphere is seen to vary from month to month at this location as in any other location on the earth’s surface. The seasonal values can be inferred from the monthly average values. An interesting implication of this is that reflectance or albedo could be used as a radiation or atmospheric parameter to determine the sky conditions of a location or region. It may also be used to estimate the surface temperature of the Earth at the location. The following expression, though not very accurate, relates the surface temperature, T of the Earth to its albedo, i.e.

\[ T = \left( \frac{1 - \alpha S}{4\sigma} \right)^{1/4} (McIlveen,1992) \]

where \( \alpha \) is the albedo, \( S \) is the solar constant and \( \sigma \) is the universal Stefan-Boltzman constant. The expression indicates that the temperature \( T \) would decrease as albedo increases.

Nigeria, the case study, being in the tropics, experiences two main seasons: dry season and rainy season. While temporal demarcation between them is not rigid, the dry season is from about November to April and the rainy season is from about May to October. The two seasons may be divided into sub-seasons or periods with slightly different weather or atmospheric conditions (Falaiye et al, 2003). For the purpose of determining the sky conditions using seasonal variations of albedo in this work, the two seasons were subdivided into four divisions. For each period, the representative value of the albedo or reflectivity of the Earth was computed. The sub-divisions are presented in Table 2 below.
Period | Albedo($H_r/H_o$) | Sky Conditions
--- | --- | ---
December-March | 0.447 ± 0.049 | Dry, Cloudless, Dusty
April-May | 0.465 ± 0.001 | Transition period: dry to rain, small cloudiness, dust clearing.
June-September | 0.559 ± 0.065 | Rains, cloudiness with low thick clouds, no dust.
October-November | 0.404 ± 0.049 | Transition period: rain to dry, little clouds, very little or no dust.

Table 2. Sub-Seasons with Albedo Values in Year 2000

However for the two main seasons, the sky conditions parameters are summarized as follow in Table 3.

<table>
<thead>
<tr>
<th>Season</th>
<th>$H/H_o$(clearness index)</th>
<th>$H_r/H_o$(albedo)</th>
<th>$H_d/H$(cloudiness index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>*1DS(Nov-Apr.)</td>
<td>0.542 ± 0.031</td>
<td>0.435 ± 0.054</td>
<td>0.443 ± 0.055</td>
</tr>
<tr>
<td>*2RS(May-Oct)</td>
<td>0.454 ± 0.056</td>
<td>0.525 ± 0.071</td>
<td>0.569 ± 0.074</td>
</tr>
</tbody>
</table>

*1 - Dry Season, *2 - Rainy Season

Table 3. Seasonal sky conditions parameters for year 2000

For the dry season, the sky is generally and relatively cloudless as indicated by the relatively low average value of albedo, as seen in Table 3. More solar radiation is therefore expected to be available at the Earth’s surface at this period, while in the rainy season the albedo is relatively high, and this is attributed to high cloudiness at this period, see Table 3. Hence, relatively little amount of radiation is expected on the Earth’s surface, and the surface of the Earth-Atmosphere is expected to be brighter and cooler. A further analysis of these results shows that the sums of the ratios $H/H_o + H_d/H$ and $H/H_o + H_r/H_o$ are each approximately equal to unity, a deduction that these quantities are compliments of each other, in the two seasons. This confirms further that $H_d/H$ and $H_r/H_o$ are mirror images of one another. They are the same atmospheric or sky condition parameter, cloudiness index.

4. Discussions

The results obtained confirm that the atmospheric constituents responsible for reflecting solar radiation back to space are clouds, aerosols and dust particles of different sizes, of which cloud is the chief (McIlveen, 1992). When therefore an atmosphere is clear and clean, that is, cloudless and dustless, the values of $H_r/H_o$ are expected to be relatively small and that of $H_r/H_o$ to be relatively large. The implication of this is that, when the value of $H/H_o$ is large, most of the radiation on such days is expected to reach the ground surface not deviated and not scattered, and the reflection of radiation to space on such days is expected to be small and mostly from the surface of the Earth, because the atmosphere is cloudless. In general, it can be said that reflection of radiation back to space by the planet would be mostly that of clouds and aerosol in the atmosphere. That is, the shortwave radiation reflection by the Earth’s surface alone is comparatively small to that by its atmosphere. Thus it can be safely said that the atmospheric conditions that influence reflection of shortwave
radiation back to space most are clouds and aerosol particles, particularly those of molecular size.

High values of reflectivity or reflectance indicate period of low altitude and thick clouds, and rains, dominating the sky. The large albedo values, therefore, in June to September must be mainly due to clouds. The implication of this is that there will be the possibility of poor performance of the solar energy systems, particularly solar concentrating devices, poor fruition of crops and plants and low surface temperature of the Earth during this period as most of the sunlight is sent back to space by reflection. According to the value of the albedo of this period, about 60% of the sunlight that strike the Earth-Atmosphere surface is reflected back, and was not available to solar energy devices for operation.

October to November is a transition period between rainy and dry seasons; it had the lowest average value of albedo of 0.404 (Table 2 above). This indicates about 40% of sunlight being reflected away back to space. This does indicate a period of little or no clouds to reflect radiation, little or no dust to scatter radiation back to space but enhances more sunlight reaching the ground surface; hence performance of solar energy devices is expected to be high, fruition of crops and plants to be enhanced and the Earth’s surface temperature is expected to rise (Babatunde et al, 2009).

April-May period is another transition period between the dry and rainy seasons. Changes in the sky conditions were dynamic during this period as the variations of all the parameters were significantly high and frequent. It is therefore relatively cloudy and contained more of hygroscopic particles than dust. The next highest average value of albedo of 0.465 (Table 2 above) was recorded in this period. This value indicates less than half or about half of the sunlight being reflected back. The albedo of the period was however higher than that of the period termed, very dry, cloudless and with high concentration of the harmattan dust, this period is known to be, December to March, a period, with albedo of 0.447(Table 2 above).

This analysis indicates that an atmosphere with low altitude and thick clouds will reflect more radiation than the scattering one, even with large dust concentration.

Since it is possible to use equation 3 to estimate the reflectance of a surface at a location, the values of it, obtainable at Maceio, Brazil (9° 40’S, 35° 42’W), of coordinates almost similar to that of Ilorin (8° 32’N, 4° 34’E), are compared. It has a value of 0.53 for H/H_o in the rainy season and 0.59 in the dry season. These correspond to, by computation, reflectance or albedo of 0.47 and 0.41 for the rainy and dry seasons respectively (De Sonsa et al, 2005). Brazil is covered with thick rain forest and also in the tropics, with clouds cover most of the time. These albedos are comparable to the ones obtained here at Ilorin. Hence this method of estimating albedo, though simple, may give a reasonable estimation of it at other locations.

5. Conclusion

The daily and monthly variation patterns of the simulated shortwave reflection co-efficient, H_r/H_o, known as albedo, a surface phenomenon, were compared with the corresponding cloudiness index, H_d/H, an atmosphere phenomenon. They were both found to be mirror images of one another. While the shortwave diffuse radiation is toward the Earth’s surface, its mirror image, the shortwave reflection radiation is back toward space.
The shortwave solar radiation reflection co-efficient was used to define the Earth’s surface albedo which was found to vary daily and monthly in accordance with changes in the atmospheric conditions causing the variations.

The surface albedo according to the analysis, therefore, at Ilorin in year 2000 was found to range between 0.4 and 0.6. These values seem high when compared with the average value of 0.3 obtained for the Earth’s surface albedo, but would be considered consistent with the acceptable ones since the values fall within the many possible values averaged statistically to obtain the quoted value for the Earth. The values of albedo can vary from 0 for no reflection to 1 for complete reflection of light striking the surface. For a spot like Ilorin on the surface of the Earth to have values of albedo between 0.4 and 0.6, is not unexpected. Ilorin, in Nigeria, is in the tropical region which is cloudy with different types of clouds most of the time in the year. The atmospheric factors which influence radiation reflection and scattering in the Earth-Atmosphere system most, are clouds and particles, clouds being chief. The Earth and its atmosphere, in this regard, were found most reflective of radiation in August and least reflective in November at Ilorin in year 2000.

6. Summary of the chapter

The expression, \( \frac{H_r}{H_0} = 1 - \frac{H}{H_0} \), developed by Babatunde,(2003) and Babatunde et al,(2003), at Ilorin (8° 30’ N, 4° 34’ E), Nigeria was used to simulate short-wave (SW) reflected radiation \( H_r \), and reflection coefficient, \( H_r/H_0 \). \( H_r/H_0 \) was used to define total wavelengths surface albedo. The temporal variations of the simulated reflectance, \( H_r/H_0 \), the clearness index, \( H/H_0 \), and cloudiness index, \( H_d/H \) obtained for year 2000 were studied to establish any inter-relationship between them. It was observed, in the relationship between them, that the clearness of the atmosphere characteristically, is diametrically opposite to that of reflectivity of the atmosphere, while the cloudiness and reflectivity of the atmosphere have the same characteristics. It is thus observed, in the effects on solar radiation, while high value of clearness index will enhance the performance of solar energy devices on earth, high value of reflectance will adversely affect it.

The highest reflectance recorded was 0.644 at the peak period of cloud activity in August, and the lowest was 0.361 in November when it was relatively cloudless and dustless. It was deduced that, characteristically, shortwave solar radiation reflection is a mirror image of shortwave diffuse solar radiation, and that reflectance is a sort of cloudiness index.

The albedo deduced from the study, for the Earth-Atmosphere at Ilorin in 2000, ranged between 0.4 and 0.6. These values were consistent with the possible values of albedo of different surfaces on the Earth’s surface. The above equation therefore, may be found suitable for estimating surface albedo at any other place on the Earth’s surface.

7. References


Falaiye, O.A., Afolabi, B.A. and Babatunde, E. B(2003)Investigating the effect of ambient temperature on clearness index (K_c) and cloudiness index (K_d).Accepted for publication in the Nig. Met. Journ. (NMS)


The book contains fundamentals of solar radiation, its ecological impacts, applications, especially in agriculture, architecture, thermal and electric energy. Chapters are written by numerous experienced scientists in the field from various parts of the world. Apart from chapter one which is the introductory chapter of the book, that gives a general topic insight of the book, there are 24 more chapters that cover various fields of solar radiation. These fields include: Measurements and Analysis of Solar Radiation, Agricultural Application / Bio-effect, Architectural Application, Electricity Generation Application and Thermal Energy Application. This book aims to provide a clear scientific insight on Solar Radiation to scientist and students.

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