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An Assessment of Spectral Albedo for Northern Areas of Pakistan

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Abstract: MODerate Resolution Imaging Spectroradiometer (MODIS) sensors on board NASA's Terra and Aqua platforms have become important for climate modeling studies, snow cover analysis and other research projects. In this study we used MODIS product named as MCD43A1 albedo parameters to calculate albedo of land cover types in northern area of Pakistan from eight years of data starting from the year 2000 to 2007. According to the results the albedo of the region varies with time to time continuously showing increasing trends in general. In snow covered regions the albedo values are highest and vary with respect to the grain size of snow. However, albedo of the region varies by different factors including seasonal cycle of vegetation growth, snow fall and rainfall. The overall pattern of albedo has been the same for all spectral bands with an increasing albedo value trend. Clouds lower the quality of MODIS (e.g. MCD43A1) BRDF products and they have to be removed from the data in order to calculate appropriate albedo values. Climate feedbacks require the continuous observations of albedo properties of different surfaces to be used in various surface radiative transfer models.

Key words: MODIS · Albedo · Snow · Clouds · Feedback

INTRODUCTION

The albedo of an object can be defined as the quality of reflectance of an object, that is, how well an object would reflect the incident solar irradiance. According to Moody *et al.* [1] the ratio of reflected to incident radiation is albedo. It is a unit less quantity as being the ratio of solar irradiance incident on an object to the radiance from the object and is considered an indicative of a surface's or body's diffusing reflectivity. The albedo of a surface is, normally, dependent on the directional distribution of incoming radiations except for the surfaces that reflect the same in each direction (i.e. Lambertian surfaces) [2].

Several studies like [3], [4] have indicated that climate feedback simulation convergence has been a problem for climate modeling societies. Long term observations of albedo retrievals and assessment of water vapors and clouds during human impacts on earth would be necessary for evaluating climate feedbacks appropriately [5]. Temporal variations in landcover type change due to anthropogenic activities and other seasonal variations cause significant changes in albedo values and it is necessity to cater for these variation for evaluation of climate models [5]. This has been verified recently in several studies like [6]. Snow as an example is particularly subject to change due to global warming and therefore is important in considering feedback variation. Melting of snow leaves the bare soils which can absorb the incoming solar radiations [5] resulting in significant decrease in reflectivity of the surface.

In recent years Northern hemisphere snow and ice is decreasing and glaciers are retreating that make it a direct response to increasing temperatures as it would let more solar radiations to be absorbed by land surfaces [7]. This leads towards further absorption of solar radiations and a subsequent increase in temperatures enhancing surface warming [5]. In the beginning of the year 1980 many studies were performed to develop monthly albedo maps [8], [9]. After that various attempts were made to develop surface albedo maps in gridded form using remotely sensed data [10]. However, in most climatic studies surface albedo is still crudely represented since the limitations of observations and the multifaceted behavior of surface albedo [11]. In the mean while satellite based calculations of surface albedo is the only practical mean for global scale [11]. Various satellite platforms are available which provide data for calculating albedo. MODIS provides information in 36 spectral bands and has

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a strong potential to identify diversity of different land features using a variety of visible and infrared band combinations. MODIS records radiances in two bands with 250m resolution, five bands with 500m resolution and 29 bands with 1000m resolution [12].

MCD43A1 product is a combined product produced from MODIS sensor data of terra and aqua platforms with spatial resolution of 500 meters. These products are developed from first seven bands of MODIS and three broad bands. According to Schaaf *et al.* [13] these products provide BRDF model parameters that can be used in the estimation of albedo values for local and global land cover/use types. Ross Thick LiSparse Reciprocal kernel is widely used for calculations of BRDF model parameters [13]. The algorithm used to characterize the surface BRDF is based on various multi-angle surface observations from a 16-day period [13]. The data for these calculations is based on the gridded MOD09 surface reflectance products that are corrected for aerosol and atmospheric effects [14].

Methodology: The spectral albedo was retrieved using the following algorithms as discussed in [15] and [13]. The mathematical equations were manipulated in ERDAS imagine by making appropriate algorithms. The algorithms were run with input files in integer format while the output files were specified in float single format.

$$\alpha_{bs}(\theta, \lambda) = f_{iso}(\lambda)(g0iso + g1iso\theta^2 + g2iso\theta^3) + f_{vol}(\lambda)(g0vol + g1vol\theta^2 + g2vol\theta^3) + f_{geo}(\lambda)(g0geo + g1geo\theta^2 + g2geo\theta^3) \quad (1)$$

Where $f_k(\lambda)$ are BRDF model kernel weights or parameters and gjk are constants. The values of constant are given in the following table.

The albedo values were obtained twice for each month of a year and for 10 different bands in order to find out the variations in reflectance properties of different features with a solar elevation angle of 60°.

RESULTS AND DISCUSSION

Albedo was calculated from eight years of MODIS albedo parameters data sets and the results are presented here in tabular format only. Generally, the results of this study have shown large variations in albedo of different surfaces that need to be incorporated in calculating earth radiation budgets. The study indicated that albedo varies significantly with time (Table 2) mainly because of the change in land use/cover type. The careful analysis of the mean albedo values for each spectral band indicates that albedo of the observed surface has been increased. This difference can be viewed in Table 2 which is representing mean albedo values for eight consecutive years in northern area of Pakistan. The changes in albedo values are also quite significant even for two consecutive years for example for the years 2001 and 2002. The general trend indicates that albedo value is not fixed and has been showing continuous variations.

The difference increases in albedo values for each year and the mean albedo value changes due to several natural and anthropogenic activities. Here clouds also play important role that persists in this particular area. Clouds can affect the results by scattering back the incoming solar radiations that does not allow to measure surface albedo. In addition, clouds can enhance the mean albedo values by reflecting more than the land-cover underneath it. To avoid this problem we selected the data that had been quality assured by MODIS science team at Boston University. In Table 2 the month of March has

Table 1: Coefficients for Eq. (1) [15], [13]

Term gjk for kernel k	k= Isotropic	k= volumetric	k=geometric
Term 1	1.0	-0.007574	-1.284909
Term θ^2	0.0	-0.070987	-0.166314
Term θ^3	0.0	0.307588	0.041840

Table 2: Mean albedo values for different spectral bands in northern areas of Pakistan (for the month of March)

Bands	2000	2001	2002	2003	2004	2005	2006	2007
1	0.290	0.294	0.362	0.329	0.289	0.320	0.319	0.313
2	0.356	0.363	0.440	0.403	0.357	0.402	0.395	0.399
3	0.208	0.208	0.292	0.250	0.204	0.245	0.241	0.237
4	0.26	0.263	0.337	0.302	0.260	0.294	0.293	0.289
5	0.336	0.349	0.375	0.352	0.333	0.353	0.355	0.356
6	0.293	0.323	0.299	0.304	0.312	0.300	0.306	0.305
7	0.254	0.282	0.255	0.262	0.273	0.257	0.263	0.262
NIR	0.318	0.331	0.377	0.350	0.322	0.349	0.346	0.349
SW	0.273	0.281	0.338	0.308	0.275	0.303	0.301	0.299
Visible	0.242	0.246	0.320	0.283	0.242	0.276	0.274	0.269

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been selected for most of the discussions as it is cloud free most of the times.

The variations in albedo values are significant for measuring atmospheric parameters like temperatures, rate of evapotranspiration, surface moisture variability etc. In addition it is also momentous for the development surface radiative transfer models and earth climate models. This has been shown in various studies (e.g. [5]) that the variations in albedo values effect climate feedbacks and may be source of uncertainties if these changes are not taken into account. The results for the year 2002 show significant deviation from previous years.

However the results are not quite smooth and consistent and there exist abrupt variations in albedo in an inverse mode probably because of huge cloud coverage and non availability of the data. Albedo variations are also seen during the snowing season which causes increase in the reflectivity of the surfaces. Especially in the case of fresh snow the albedo values are much higher compared to other land-cover types. This causes an exaggeration in actual albedo values and causes a poor representation in modeling studies. Seasonal variations can also affect the albedo values due to the fact that in July, particularly; there exist large numbers of clouds in these regions because of the monsoonal winds. The season continues for approximately three months. As the clouds reflect more efficiently, it causes an increase in the albedo. In winters also, western disturbances bring lots of moisture and cause cloudiness as these winds are blocked by high mountain ranges of Himalayas, Karakoram and Tibet. MODIS algorithms discard the data with clouds and apply atmospheric corrections that results in the non-availability of appropriate data sets for such regions mostly covered with clouds however the data selected here for the calculation of albedo parameters is cloud free most of the time. Another important factor that causes variations in seasonal albedo values is the growth of vegetation types. In months with spring season grasses and plants grow that causes increase in albedo in near infrared and short wave bands. While during the autumn season albedo shows a decreasing trend in near-infrared and shortwave bands since the vegetation get dried up.

CONCLUSIONS

Albedo as a climate feedback is considered an important parameter for research in climate and atmospheric studies. In this particular study we have retrieved and investigated eight years of albedo values derived from MODIS albedo parameters for northern areas of Pakistan. The results have been discussed both in tabular formats. As it was discussed earlier the general behavior for albedo in this specific region has shown continuously increasing trends. This is noticeable in all spectral bands for which albedo was retrieved. This albedo difference is dependent on several factors including the condition of snow, snow grain size, soil type and color, moisture and vegetation cover. The increase in albedo value for the year 2002 might possibly be because of the large amounts fresh snow. For the years from 2002 to onward albedo values show a mixed behavior with increased and decreased albedo values. This is because of the fact that albedo is dependent on continuously changing land cover types and can cause positive / negative climate feedback depending on dominant land cover type. It has now become important to use changing albedo values in climate models as it has its impact on several climatic parameters.

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