Surface Albedo Assessment in Clear Sky and Dense Smoke Atmospheres Using a Shortwave Radiation Stochastic Model and MODIS 1B Image

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Abstract. The surface albedo, which is a fundamental parameter in the estimation of the radiation balance, corresponds to the reflectance integrated in the solar spectrum. It can be obtained through satellite images that have great spatial coverage. A stochastic model of two-flux, presented by Ceballos [1] and developed by Souza and Ceballos [2], is used to establish a direct relationship between the reflectance of the surface and the radiance measured by MODIS-Terra/Aqua sensor. The propagation of radiation, in the solar spectrum from 0.3 to 3.0 µm, is described by an scheme of 16 layers. In such scheme, it is obtained the necessary parameters to establish the radiation balance in the top of the atmosphere. The optical properties of the atmospheric layers are defined by aerosol, ozone and water vapor. In this way, to determine the surface albedo, it is considered that the radiance originated from the system earth-atmosphere, measured by the satellite, is isotropic. A simple adjustment factor is introduced to compensate anisotropic and multiple reflections effects between the surface and the atmosphere. An application for Amazonian region in conditions of low and high aerosol load due to smoke caused by forest burning, is presented. The results show similarity in the assessed surface reflectance, with and without burning in the region.

Keywords: Two-flux, stochastic, albedo, irradiance
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INTRODUCTION

The emerging signals in the top of the atmosphere, registered by satellite sensors, are a result of surface and atmospheric reflections. In order to know the surface reflection properties it is necessary to eliminate the atmosphere influence caused by absorption and scattering effects of the atmospheric components, mainly ozone (O_3), water vapor (H_2O), carbon dioxide (CO_2), air molecules and aerosol. In this work, due to weak absorption, CO_2 won't be considered. In order to establish a direct relationship among the radiance in the top of the atmosphere, measured by satellites, and the surface reflectance it is necessary to use a radiative transfer model.

Ceballos [1], Souza and Ceballos [2] presented a solar radiation propagation scheme for an atmosphere with 16 layers. The model, denominated as SM, is an application of stochastic concept described by a first order Markov process. The transition and absorption parameters in the SM are estimated for a two-flux method with 0.005µm resolution. That resolution makes possible to assess the radiation parameters with MODIS spectral bands.

The surface reflectance can be obtained from the radiation balance in the top of the atmosphere. In order to use the two-flux method, an adjustment factor is introduced in the radiation balance equation. That factor was used to compensate anisotropic and multiple interactions effects between the surface and atmosphere. The albedo is estimated through one weighted sum of the reflectance in each band. A simple correction for adjacent effects (according to Tanré et al.[4]) considering only neighborhood pixel was made.

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MATERIAL AND METHOD

In this work an atmospheric correction is applied to MODIS images level 1B (MOD02/MYD02) in bands 1 through 7, centered at 0.645, 0.858, 0.469, 0.555, 1.240, 1.640 and 2.130 µm, respectively. These images were obtained in the site: <http://ladsweb.nascom.nasa.gov/data/search.html> for Cuiabá – Mato Grosso (MT), an Amazonian region at the Western of Brazil. Data about aerosol optical thickness (τ), ozone, atmospheric pressure (Po) and precipitable water (w) were obtained with MOD08 product. The aerosol parameters single scattering albedo (ω) and asymmetry factor (g) were obtained from AERONET site.

Here, it is introduced an empirical correction factor, k_{bi}, in the radiation balance equation, presented by Kidder and Vonder Haar [3]. This correction factor is resultant from interactions among the atmosphere with aerosol load, varying between 0.01 and 1.3, and the surface with reflectance varying between 0 and 0.18. On the other hand, the surface reflectance, $R_{s,bi}$, is assessed according to the Eq. (1a) in the band with thickness $\Delta\lambda_i = \lambda_2 - \lambda_1$. For bands 1 through 7, $\Delta\lambda_i$ are respectively: 0.05, 0.035, 0.02, 0.02, 0.02, 0.02 and 0.05 µm. The subscript '*bi'* means the '*band i'* with '*i'* varying from 1 to 7.

$$R_{s,bi} = 1 - \frac{E_{bi} - A_{bi} - \pi \cdot \Delta\lambda_i \cdot L_{bi}}{F_{bi}} \cdot \frac{1}{k_{bi}} \quad (1a)$$

$$k_{b3} = 1.062 + 0.1\,\tau(0.55) - 0.03\mu_s \quad (1b)$$

$$k_{b4} = k_{b3} - 5\eta \quad (1c)$$

$$k_{b1} = k_{b4} - 5.05\,\eta \quad (1d)$$

$$k_{b2} = k_{b1} - 5.15\,\eta \quad (1e)$$

$$k_{b5} = k_{b6} = k_{b7} = 1 \quad (1f)$$

$$\eta = \frac{k_{b3} - 1}{20.55} \quad (1g)$$

where E_{bi} is the the solar flux, A_{bi} and F_{bi}, are the atmosphere absorption and flux that reaches the surface estimated by stochastic model, μ_s is the cosine of the solar zenith angle, L_{bi} is the spectral radiance ($Wm^{-2}sr^{-1}\mu m^{-1}$) in band *bi* measured by the satellite. After finding $R_{s,bi}$, a correction for adjacency effect is made based on Tanré et al. [4] and considering only neighborhood pixels. Then, the surface albedo, α_s, is composed by $R_{s,bi}$ weighted for each band according to Eq. (2).

$$\alpha_s = \sum w_i . R_{s,bi}, \quad w_i = \int_{\lambda_a}^{\lambda_b} E(\lambda)d\lambda \Big/ \int_{0.3}^{2.8} E(\lambda)d\lambda, \quad \sum w_i = 1 \cdot \quad (2)$$

Where according to Tasumi et al [5] in the bands 1 through 7 the integration limits (λ_a, λ_b) are: (0.595, 0.755), (0.755, 1.055), (0.3, 0.515), (0.515, 0.595), (1.055, 1.44), (1.44, 1.88) and (1.88, 2.8) µm.

RESULTS

The images MYD02 at 09/02/2005 (245^{th} day of the year) and MOD02 at 08/22/2005 (234^{th} day of the year) were used respectively as situations with and without burning in Cuiabá (Fig. 1). Two targets: A-1 (15°54'45.43" S; 55°55'26.8" W) and A-2 (15°44'43.25" S; 56°11'36.67" W) were selected. The atmospheric parameters for the 234^{th} day of the year were: τ(0.55) = 0.211; ω = 0.91; g = 0.58; w = 2.6 $g.cm^{-2}$ and Po = 976 mb and for the 245^{th} day: τ (0.55) = 1.26, ω = 0.95 e g = 0.62; w = 4.0 $g.cm^{-2}$ e Po = 976 mb. These data are related to the Cuiabá-Miranda station.

FIGURE 1. Cuiabá – Mato Grosso/Brazil

In Figs. 2a and 2b it is shown the averaged values of R_s and α_s for targets A-1 and A-2, and the performance of the SM against MOD09/MYD09 at the 234th day of the year (without burning) and 245th day (with burning). For the same target, it was waited that the albedo supplied for those days had the same value. However, the albedo supplied by the product MYD09 at the 245th day, presented an error of +33% for the target A-1 and + 23% for the target A-2, in relation to the albedo supplied by the product MOD09 at the 234th day. Regarding the SM those errors correspond to +20% and +8%, respectively.

In relation to MYD09, for the target A-1, it is observed that the reflectance in the bands 2 and 5 presented larger error than the others. The band 2 has influence of aerosol effects, in the other hand, the aerosols exert a very smaller influence in the band 5. It was waited a larger aerosol influence in the bands 1, 3 and 4, but it didn't happen. In target A-2, aerosol exert influence in the bands 1, 2, 3 and 4. Another error was observed in band 7, where aerosol does not cause influence in that wavelength and the amount of precipitable water at the 245th day (4.0 $g.cm^{-2}$) was larger than at the 234th day (2.6 $g.cm^{-2}$). So, the absorption should contribute to decrease and not to increase the band reflectance.

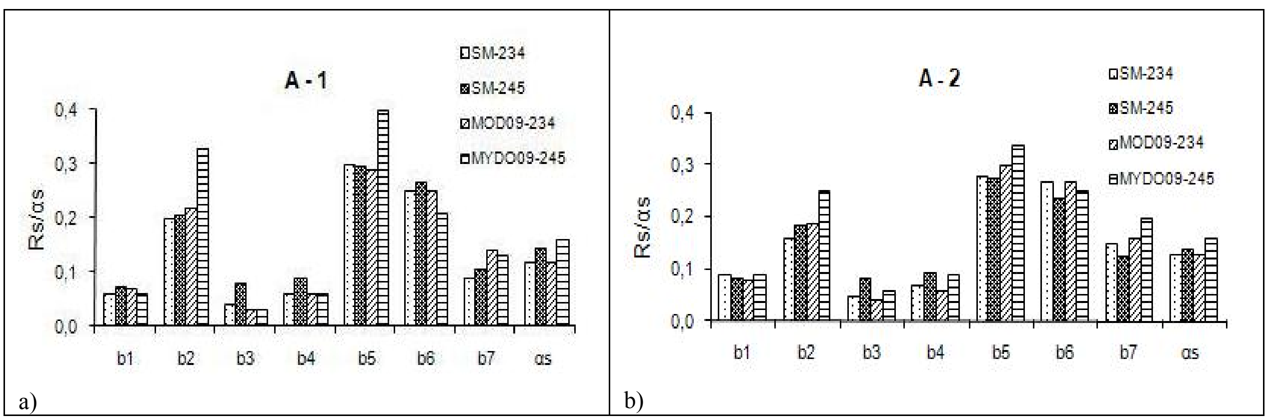

FIGURE 2. α_s and R_s estimated for the SM and supplied by the platform MODIS in the 234/245 day of 2005, for the target: a) A-1 and b) A-2.

CONCLUSIONS

The decomposition of the atmosphere in 16 layers, using a stochastic model, describes with efficiency the multiple scattering process in the atmosphere. As the methods of two-flux are applied in plan-parallel atmosphere, in conditions of hemispherical isotropic and surface Lambertian, the coefficient k_{bi} in Eq. (1) is adequate to adjust the direct relationship among the satellite measured radiance and the reflectance at surface. The atmospheric correction method presented for surface albedo assessment is accurate, simple and practical than other physical methods. The

SM, for the analyzed situation, showed better results than those supplied by the platform MODIS. However, for a deep analysis, in the burning region, it is necessary to verify other images together with surface measurements at the satellite overpass.

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