# SCAI-R: AN ALGORITHM FOR OBTAINING SYNOPTIC AND SPATIAL ATMOSPHERIC PARAMETERS

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## ABSTRACT

The highest performance of multiband optical data (Visible - VIS – Shortwave Infrared - SWIR – (400-2500 nm) (e.g. imaging spectroscopy approaches) can be reached mainly through atmospheric correction effects; the conversion of the image values to surface reflectance, allowing, for instance, to estimate the amount of biochemical compounds in the target. This work aims to present an algorithm dedicated to atmospheric parameters obtaining from MODIS and related sensors, encapsulated in a user-friendly interface through Software to Collect Atmospheric Information (SCAI-r), applied to the correction of atmosphere effects on Rapideye image. The results show that SCAI-r generates information needed to perform atmospheric correction and that it has a greater influence over water-related objects, when compared to parameters randomly inserted as input data in atmospheric correction algorithms.

***Key words —*** Atmospheric Correction, RapidEye, Visibility, Aerosol Optical Thickness, Radiative Transfer Model.

## 1. INTRODUCTION

One of the major advances in high-level imagery systems using reflectance spectroscopy baseline approaches is based on the need for adequate pre-processing for full use of its potential, mainly atmospheric correction of the atmosphere effects [1]. Atmospheric correction procedures act as a normalizer of the dataset, extracting spurious influences as backscatter effects of electromagnetic radiation, or the presence of aerosols. As advantages, it allows the adequate use of multitemporal imaging series in different weather and climate conditions, estimations of the amount of biochemical compounds in the target (e.g. lignin, cellulose, nitrogen, clay minerals), as well as comparative analysis of different scenes over large areas in isomeric databases [1,2]. The absence of proper preprocessing results in underuse of optical images, which have their use based on geometric aspects and visual identification through colored compositions of the visible region, and of simple spectral indices hardly ever applied the right way. The few results relating spectral characteristics of the targets from high spatial resolution sensors (e.g. GeoEye, RapidEye) is a clear example of that, once they are commonly used for their planimetric accuracy.

Despite the gradual increase in the supply of high-level data (e.g. ASTER, Landsat OLI, Sentinel), the use/popularization of atmosphere correction procedures find limiting factors: (i) access to large-scale synoptic and spatial atmospheric parameters for atmosphere simulation in different periods; (ii) the need for specialized knowledge in methods for calculating atmospheric parameters that may be applied to correction methods, and the most efficient is the Radiative Transfer Model (RTM), and (iii) the necessary knowledge about the spectral behavior of different targets for validating the correction in different sensors [4,5].

Thus, gathering atmospheric parameters as input is still a barrier for such procedures, even with the current commercial programs of atmospheric correction, limiting the use of sensors to a minimum range of options, mainly associated with governmental sensors. This work aims to present an algorithm dedicated to obtain atmospheric parameters that can be used as input data for atmospheric correction tools. Atmospheric data were acquired from MODIS sensors and appropriately encapsulated in a user-friendly interface through Software to Collect Atmospheric Information (SCAI-r). In addition, this study aims to demonstrate the effects of the variation of collected parameters applied to the correction of atmosphere effects through the RapidEye sensor using the 6S open source Radiative Transfer Model [6].

## 2. MATERIALS AND METHODS

The study area corresponds to a RapidEye image obtained in Araporã, State of Minas Gerais, Brazil on October 6th, 2013 (Figure 1). This area has a wide variety of targets, including crop areas, pasture, natural forests, planted forests and water bodies.

We performed the atmospheric correction using the 6S-based module Atmospheric and Radiative Correction of Satellite Imagery (ARCSI) [7], which solves the radiative transfer model with a set of parameters presented in an idealization of a Lambertian surface outside the main absorption features of water vapor in Equations 1, to 4 [6]:

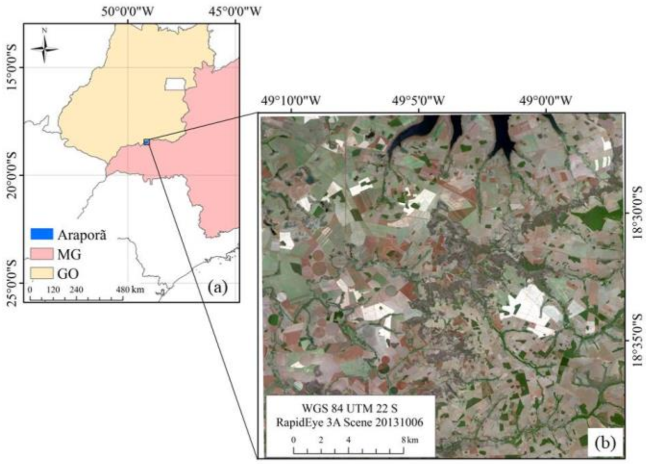


**Figure 1. (a) Location of Araporã city in Brazilian context, in a border between the states of Minas Gerais (MG) and Goiás (GO) and (b) the RapidEye image used to apply the SCAI-r. RGB true color composition (Bands 3, 2, and 1).**

$$Aer = \{\tau_A, \omega_A, pf_A\} \quad (1)$$

$$\varphi = |\ \phi_s - \phi_v\ | \quad (2)$$

$$m = \frac{1}{\cos(\theta_S)} + \frac{1}{\cos(\theta_v)} \quad (3)$$

$$\rho_{TOA}(\theta_s, \theta_v, \varphi, P, Aer, U_{H_2O}, U_{O_3}) = Tg_{OG}(m, P)\, Tg_{O_3}(m, U_{O_3}) \left[\rho_{atm}(\theta_s, \theta_v, P, Aer, U_{H_2O}) + Tr_{atm}(\theta_s, \theta_v, P, Aer) \frac{\rho_s}{1 - S_{atm}(P, Aer)\rho_s} Tg_{H_2O}(m, U_{H_2O})\right] \quad (4)$$

where $Aer$ = aerosol factor; $\tau_A$ = aerosol optical thickness; $\omega_0$ = aerosol single scattering albedo; $pf_A$ = aerosol phase function; $\varphi$ = relative azimuth; $\phi_s$ = sun azimuth angle; $\phi_v$ = view azimuth angle; $m$ = sun zenith and view zenith angles factor; $\theta_s$ = sun zenith angle; $\theta_v$ = view zenith angle; $\rho_{TOA}$ = reflectance at the top of the atmosphere; $P$ = atmospheric pressure in mb; $U_{H2O}$ = total column water vapor content in g m$^{-3}$; $U_{O3}$ = total column of ozone content in g m$^{-3}$; $Tg_{H2O}$, $Tg_{O3}$, and $Tg_{OG}$ are respectively the gaseous transmission by water, ozone and other gases; $Tr_{atm}$ = upward and downward total atmosphere transmission; $S_{atm}$ = atmosphere spherical albedo and $\rho_s$ = surface reflectance [6].

All these atmospheric parameters are required to perform an atmospheric correction algorithm and are repeatedly reported as being difficult to obtain at the same time and place of satellite overpass [7, 8]. Because of that, we developed the Software to Collect Atmospheric Information (SCAI-r) to aggregate all the atmospheric parameters needed to perform 6-S and other RTM-based atmospheric correction algorithms. It works using information collected from wide-swath sensors,like MODIS, AIRS, and AMSU, and presents the data from these sensors, available at NASA Giovanni online

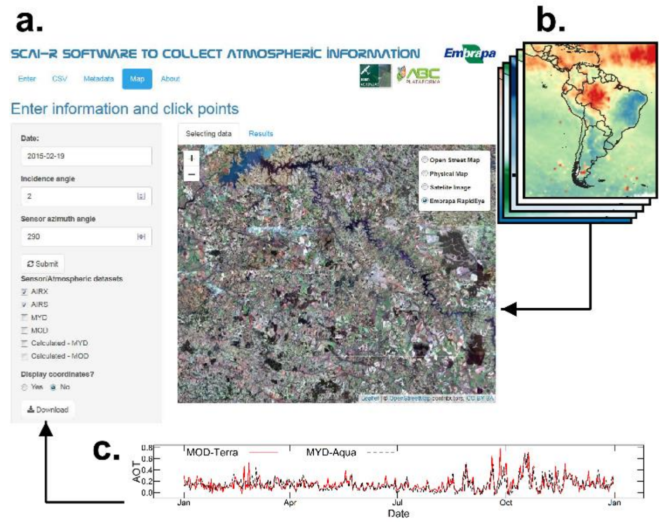


**Figure 2. SCAI-r online page visualization (a), highlighting input data insertion by clicking points on the map. SCAI-r design is specially directed to the appropriate representation of both spatial (b) and temporal variation (c) of parameters used to perform atmospheric corrections.**

data system [9], or calculations using these data, according to [10], with updates. ARCSI output parameters include the aerosol optical thickness (AOT), and visibility as an alternative to AOT; the atmospheric profile, based on the standard profiles defined according to temperature or water vapor content [10, 11]; water vapor and ozone content. Other parameters are taken from the atmospheric standard models, or are estimated from other input parameters.

The parameters used in the RapidEye image of the study area are described in Table 1. In addition to applying the parameters indicated by SCAI-r, we also performed the atmospheric correction of the image using arbitrary values of aerosol optical thickness (0.1, 0.25, and 0.5) and visibility (10, 25, 50 and 100 km). The objective of this procedure was to test ARCSI sensitivity to variations in the values of these parameters.

## 3. RESULTS AND DISCUSSION

The Figure 2 shows the online interface of SCAI-r. Input information about the image to be corrected can be inserted manually in the site: embrapa.br/meio-ambiente/plataforma-abc/carbscan. Alternatively, input data can be inserted automatically using the image metadata file. Users also have the option to calculate the parameters for a list of points and dates of interest or indicate points of interest for a determined date directly clicking on the map. As a result, users can get tables showing the spatial and temporal variation of the parameters.

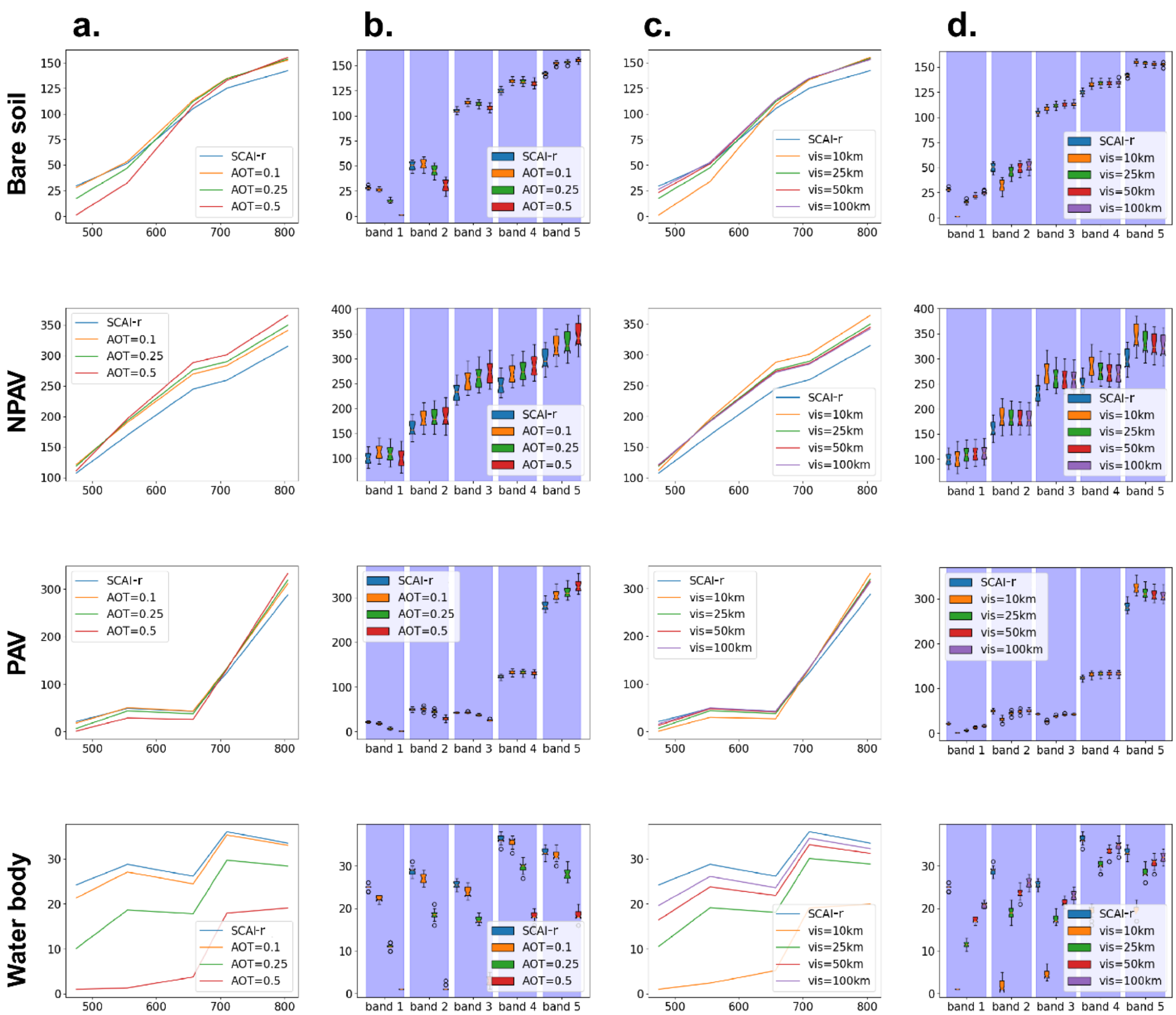


**Figure 3. Variation in the reflectance values for four selected points in the image, depicting areas covered with bare soil, non photosynthetically active vegetation (NPAV), photosynthetically active vegetation (PAV), and water bodies. Graphs show the variations of reflectance values in function of AOT values variation in (a) and boxplots show statistics of 35 pixels around the selected points in (b). Graphs in (c) show reflectance variation in function of visibility and boxplots in (d) show statistics of the same 35 pixels around selected points.**

Obtaining input parameters for images atmospheric correction is repeatedly reported as a limitation to the use of radiative transfer models (RTMs) [7, 8]. The lack of atmospheric information to perform RTM corrections generally leads to the use of methods based on dark object subtraction (DOS), that do not account to effects of atmospheric transmittance on the surface reflectance signal, increasing signal errors, especially when analyzing areas with a wide variety of land covers [12, 13]. At the same time, using random values to these parameters can also increase the error of surface reflectance estimates, even in images acquired in clear sky conditions, as depicted in Figure 3. Figure 3 also demonstrates that these errors are more intense in water bodies, due to the low reflectance values of these objects, combined with their optical complexity. One of the errors source in aquatic bio-models is associated to aerosol reflectance treatment in atmospheric correction processes [14].

## 4. CONCLUSIONS

This work presented the Software to Collect Atmospheric Information (SCAI-r). SCAI-r provides important pieces of information needed to implement thorough spectral analysis

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**Table 1. SCAI-r parameters applied in ARCSI atmospheric correction of the image (RapidEye Tile ID 2230523, from Oct 6th, 2013).**

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Altitude [a] | 514 m | AOT [c] | 0.046 [e] |
| Total $O_3$ [b] | 242.6 DU | Angstrom Exponent [c] | 1.49 |
| Temperature [b] | 315.3 K | Atmospheric model [c] | Tropical |
| Total $H_2O$ [c] | 2.882 cm | Visibility [d] | 207.3 km |

Parameters sources: [a] SRTM, [b] AIRS/Aqua, [c] MODIS/Aqua data, [d] calculated from MODIS/Aqua data; [e] in this case, original value is negative; MODIS aerosol algorithm stores negative values in order to maintain errors statistics, and SCAI-r uses absolute values due to the nature of the data.

throughout time. Spectral data corrected using the parameters provided by SCAI-r present a decrease in noises on the spectral signal of targets.

Proprietary software is generally not able to calculate the parameters required to perform RTM-based atmospheric correction on high spatial resolution images, although they are able to perform RTM-based atmospheric correction on these images. Therefore, in agricultural research, SCAI-r can consist in an important tool to execute analyses of the situation of the vegetation over the cycles of agricultural production. At the same time, SCAI-r guarantees the integrity of spectral information of inland waters and terrestrial targets throughout time, enabling the execution of a series of relevant analyses of environmental and agricultural research.

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