The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-8, 2014
ISPRS Technical Commission VIII Symposium, 09 – 12 December 2014, Hyderabad, India

RETRIEVAL OF SURFACE REFLECTANCE USING SACRS2: A SCHEME FOR ATMOSPHERIC CORRECTION OF RESOURCESAT-2 AWIFS DATA

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KEY WORDS: Atmospheric Correction, AWiFS, IRS, Radiative Transfer, Resourcesat, SACRS2, Surface Reflectance.

ABSTRACT:

The Indian Remote Sensing (IRS) satellite series has been providing data since 1988 through various Earth observation missions. Before using IRS data for the quantitative analysis and parameter retrieval, it must be corrected for the atmospheric effects because spectral bands of IRS sensors are contaminated by intervening atmosphere. Standard atmospheric correction model tuned for the IRS sensors was not available for deriving surface reflectance. Looking at this gap area, a study was carried out to develop a physics-based method, called SACRS2- a Scheme for Atmospheric Correction of Resourcesat-2 (RS2) AWiFS data. SACRS2 is a computationally fast scheme developed for correcting large amount of data acquired by RS2-AWiFS sensor using a detailed radiative transfer model 6SV. The method is based on deriving a set of coefficients which depend on spectral bands of the RS2-AWiFS sensor through thousands of forward signal simulations by 6SV. Once precise coefficients of all the physical processes of atmospheric correction are determined for RS2-AWiFS spectral bands then a complete scheme was developed using these coefficients. Major inputs of the SACRS2 scheme are raw digital numbers recorded by RS2-AWiFS sensor, aerosol optical thickness at 550 nm, columnar water vapour content, ozone content and viewing-geometry. Results showed a good performance of SACRS2 with a maximum relative error in the SACRS2 simulations ranged between approximately 2 to 7 percent with respect to reference 6SV computations. A complete software package containing the SACRS2 model along with user guide and test dataset has been released on the website (www.mosdac.gov.in) for the researchers.

1. INTRODUCTION

Surface reflectance is considered as the fundamental land surface parameter in remote sensing. It is the basis of other important biophysical parameters such as albedo, normalized difference vegetation index (NDVI), leaf area index (LAI), fraction absorbed photosynthetically active radiation (fAPAR), net primary productivity (NPP) etc. Thus the accurate knowledge of surface reflectance is required to obtain reliable information on the state of terrestrial surface. As the utility of satellite data has become more quantitative, the accurate retrieval of surface reflectance becomes increasingly important. Generally in all the applications, a major assumption is that the reflectance response of the observed objects is indicative of their intrinsic physical and chemical properties. Unfortunately, atmospheric gases and aerosols scatter and absorb electromagnetic radiation significantly and therefore, modulate the radiation reflected from the target by attenuating it (Kaufman 1989) as shown in figure 1.

The procedure of retrieving surface reflectance or removing atmospheric contamination from satellite-measured radiance is called atmospheric correction. Atmospheric correction has been a gap area for the IRS data since the first launch of the satellite in the year 1988. ISRO launched its latest remote sensing satellite called Resourcesat-2 (RS2) on April 20, 2011, which has three payloads namely, AWiFS, LISS-III and LISS-IV (for salient features of these payloads see Pandya et al., 2013). Since RS2 AWiFS has been providing global coverage, atmospheric correction is must for it. This calls for development of physics-based atmospheric correction model that corrects the effect of atmosphere in varying aerosol, water vapour and ozone conditions.

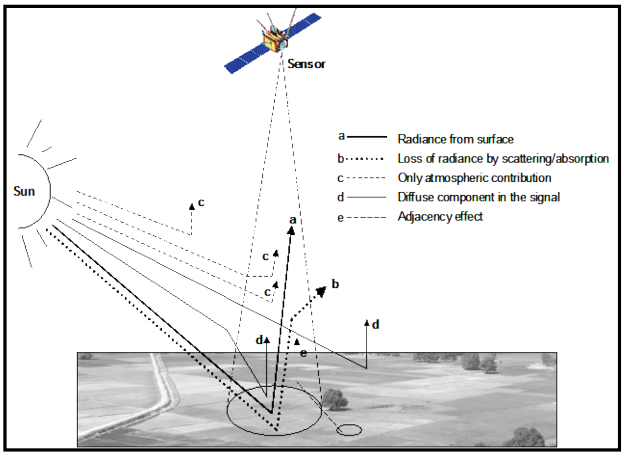

Figure 1. Schematic representation of radiation components adding to the at-sensor radiance and should be corrected through RT model (Modified from Vermote et al. 1997)

Objective of this paper is to provide a brief description on development of a new method called, SACRS2 (Scheme for Atmospheric Correction of RS2 AWiFS data) using a physics-based radiative transfer (RT) model.

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2. ATMOSPHERIC CORRECTION SCHEME – SACRS2

Atmospheric correction procedure requires ρ_s to estimate from ρ^* through a method using atmospheric variables describing the state of the atmospheric condition. The RT in clear atmosphere is well understood and detailed models exist. However, challenge is, to develop a fast method for inversion of surface reflectance for large amount of remotely-sensed imageries on an operational basis. SACRS2 scheme is based a semi-empirical method, which can be applied on RS2 AWiFS data for atmospheric correction for a given atmospheric state. This method is based on the parameterization of the equations describing RT in the atmosphere.

For the purpose of computing the at-sensor signal incorporating various atmospheric interaction processes, 6SV (*Second Simulation of a Satellite Signal in the Solar Spectrum – Vector*: 6SV, Vermote *et al*., 2006) code has been taken as reference model. The 6SV computes the solar radiation reflected by the Earth surface passed through the atmosphere at the satellite altitude. If ρ_s is the surface reflectance of the target then the top-of-atmosphere (TOA) reflectance, ρ^* at the satellite level can be expressed as:

$$\rho^*(\theta_s,\theta_v,\Delta\phi)=t_g(\theta_s,\theta_v)\left\{\rho_{atm}(\theta_s,\theta_v,\Delta\phi)+\frac{T(\theta_s).T(\theta_v).\rho_s}{1-\rho_s.S}\right\}$$

Where, $\mu_s=\cos\theta_s$=cosine of the Sun zenith angle

$\mu_v=\cos\theta_v$=cosine of viewing zenith angle
$\Delta\phi$=relative azimuth between Sun and view direction
t_g=total gaseous transmission (downward and upward path) which takes into account various gaseous absorptions
ρ_{atm}=atmospheric reflectance which is a function of molecule and aerosols optical properties, θ_s, θ_v and $\Delta\phi$.
τ=atmospheric optical depth
$e^{-\tau/\mu_s}$ and $e^{-\tau/\mu_v}$ = direct atmospheric transmittances
$td(\theta_s)$ and $td(\theta_v)$ = atmospheric diffuse transmittances
S= spherical albedo of the atmosphere

It is to be noted that the environmental effects are neglected in these calculations.

Formulations provided by Rahman & Dedieu (1994) and Pandya *et al*. (2002) have been used in SACRS2 to describe the different atmospheric interactions (absorption, scattering etc.) of solar radiation with atmospheric consitituents. A detail exercise involving thousands of simulations was carried out to systematically compute various atmospheric terms such as, two way gaseous transmission including contribution from water vapour and ozone, atmospheric spherical albedo, direct transmission, diffuse transmission, total transmission, Rayleigh phase function, Rayleigh optical thickness, Rayleigh reflectance, aerosol phase function, total aerosol optical depth, aerosol reflectance and total atmospheric reflectance.

The description of the interaction of solar radiation with the atmosphere also demands specific values of asymmetry factor and single scattering albedo. Continental aerosol type was considered in the present study. Moreover, atmospheric profiles corresponding to the tropical atmospheric conditions were used from the SeeBor dataset. All these spectral calculations were carried out to obtain an integrated band value by convolving the spectral response functions (as shown in figure 2) of RS2 AWiFS sensor (Pandya *et al*., 2013).

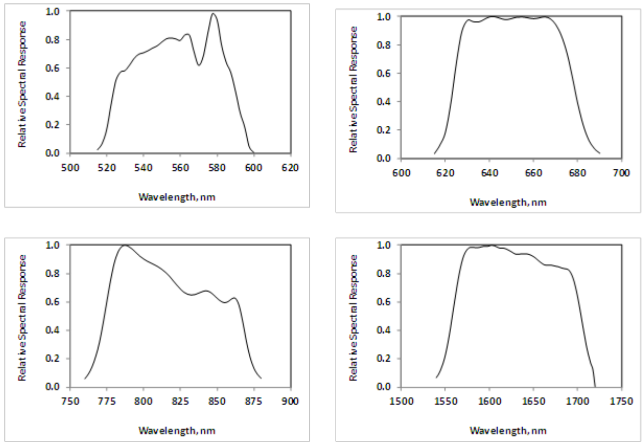

Figure 2. Relative spectral response curves of four spectral bands of RS2-AWiFS sensor

Based upon theory discussed in above section (for more details refer, Rahman & Dedieu, 1994) and considering various atmospheric and surface inputs, thousands of simulations was carried out pertaining to RS2-AWiFS sensor and a set of 118 coefficients were determined for four spectral bands. Sensor specific coefficients of each equation were determined using a best fit technique against the computations of the 6SV code. These coefficients were then used in a full scheme (figure 3) of the atmospheric correction. This full SACRS2 scheme has been converted to a software, where raw data (digital number) of a particular RS2 AWiFS imagery would be converted to the surface reflectance by correcting for the atmospheric effects based on known atmospheric state in terms of aerosol optical thickness, water vapour and ozone content.

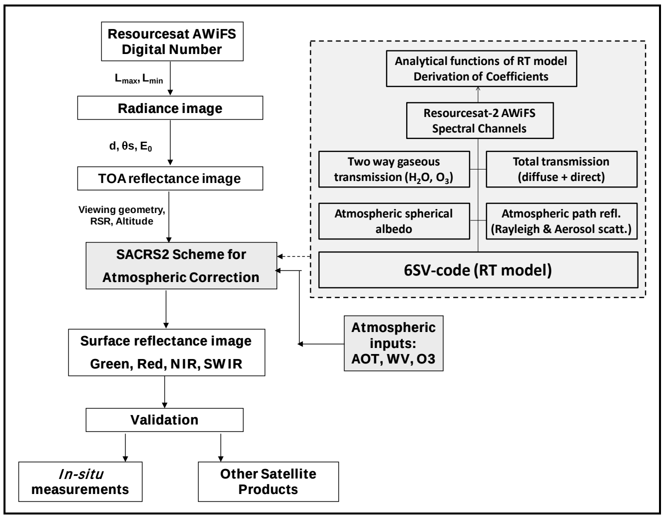

Figure 3. Schematic showing components of the scheme for atmospheric correction scheme of RS2 AWiFS data (SACRS2)

3. RESULTS AND DISCUSSIONS

In order to test the applicability of the SACRS2 scheme with the RS2-AWiFS images, it was applied to several RS2-AWiFS datasets and results were compared with the reference values obtained with the 6SV model. An example showing RS2-AWiFS image before and after atmospheric correction is shown in the figure 4 over Gujarat and surrounding region for 22 November 2011.

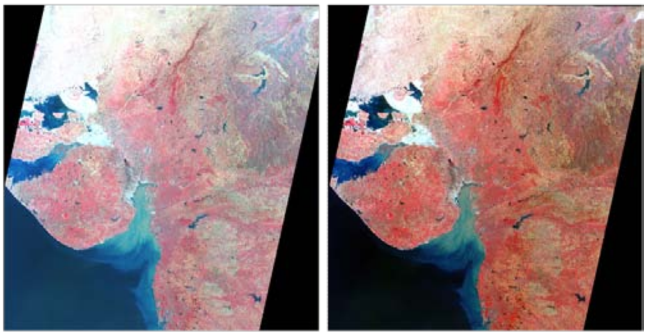

Figure 4. RS2-AWiFS imagery before and after atmospheric correction using the SACRS2 over Gujarat and surrounding region on 22 Nov. 2011

Figure 5 shows a comparison between the surface reflectance (ρ_s) calculated by SACRS2 and 6SV for RS2-AWiFS four channels. A range of surface reflectance values over various land covers were used for comparing two estimates. The graphs show a very good matching between two estimates, which establish a fine performance of the SACRS2 scheme.

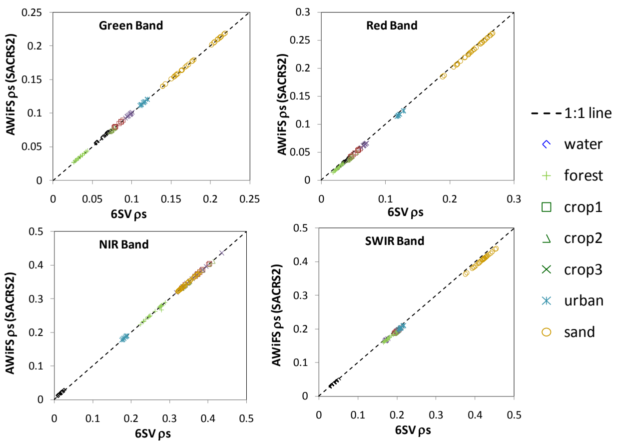

Figure 5. Comparison of surface reflectances (ρ_s) derived with the SACRS2 scheme and 6SV model for the RS2 AWiFS data (17 December 2011) over various land covers

The maximum absolute deviation of the order of 0.00127 (for water, with ρ_s of 0.069), 0.00472 (for sand, with ρ_s of 0.21), 0.0015 (for water, with ρ_s of 0.021) and 0.01522 (for sand, with ρ_s of 0.45) was observed for green, red, NIR and SWIR band respectively for SACRS2 calculations with respect to 6SV calculations. These deviations correspond to maximum relative error of the order of 1.84%, 2.24%, 7.14% and 3.38% for green, red, NIR and SWIR band respectively. These numbers are quite within range as compared to that of results from Rahman and Dedieu (1994) for the Landsat data.

It is to be noted that SACRS2 has been developed for tropical atmospheres and continental aerosol types, so it should be used for such atmospheric conditions. The scheme for other aerosol types (desert and maritime) and atmospheres (mid-latitude summer/winter and arctic) will also be developed in future. Moreover, the SACRS2 model is based on the simplifications for the sake of fast computations, thus its accuracy decreases if (a) solar and viewing angles are greater than 60^0 and 50^0 respectively, (b) aerosol optical depth greater than 0.8 at 550 nm for a continental aerosol. One of the major issues still remains unsolved is the removal of the cloudy pixels from the images. To remove cloudy pixels from the RS2-AWiFS images various thresholds were attempted based upon knowledge of spectral signature of clouds and other various targets. However, this procedure failed in discriminating bright soil patches and clouds due to quite matching signatures of cloud and sand, making cloud removal procedure a major issue in the context of RS2-AWiFS.

4. SUMMARY AND FUTURE SCOPE

We have developed a scheme SACRS2 for the atmospheric correction of RS2 AWiFS data based upon a RT model 6SV. This scheme requires inputs related to raw image, viewing geometry, altitude and atmospheric constituents. And it generates top-of-atmosphere (TOA) reflectance and atmospherically corrected surface reflectance as outputs. Following figure summarizes inputs and outputs of the scheme.

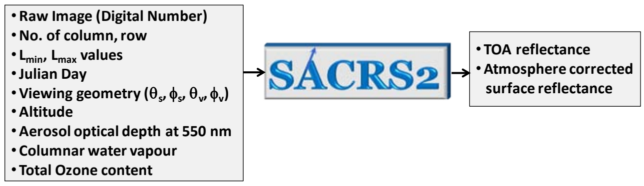

Figure 6. Inputs and outputs of SACRS2 scheme

The SACRS2 is an atmospheric correction method - first of its kind developed in India, which has been designed specially for Resourcesat-2 AWiFS sensor working for the tropical atmospheric conditions with very good accuracy.

A GUI based complete software package (figure 7) containing the SACRS2 model along with user guide and test dataset has been released on the MOSDAC website (www.mosdac.gov.in) for the researchers.

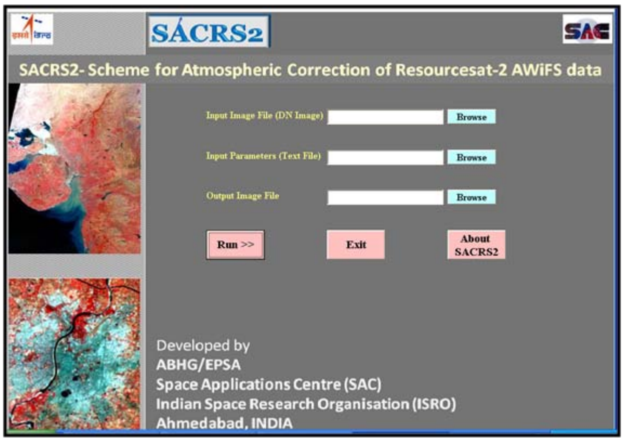

Figure 7. Snapshot of a GUI developed for the SACRS2 Model available online (www.mosdac.gov.in)

Continuing the efforts related to development of atmospheric correction method such as SACRS2 scheme, theoretical simulations will also be carried out for generating new set of coefficients for desert and maritime aerosols along with the other atmospheric conditions pertaining to mid latitude summer/winter and arctic profiles. SACRS2 scheme will also be developed for other sensors such as LISS-IV and LISS-III onboard RS2.

Acknowledgements: This study has been carried out at the Space Applications Centre (SAC) under a SAC R&D project "*Development of a scheme for atmospheric correction of Resourcesat-2 AWiFS data*". Authors are grateful to Shri A. S. Kiran Kumar, Director, SAC for his guidance to the study. Authors are thankful to Ms. Radhika Chipade, Scientist, SAC for coding the model, Shri Shashikant Patel, Research Associate, SAC for his help to build a GUI based software, Dr. V. N. Sridhar, Scientist, SAC for his technical discussions and Dr. H. J. Trivedi, Head, Physics Department, NVPAS, Vallabh Vidyanagar for his support to the study.

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