INTER COMPARISON OF ATMOSPHERIC CORRECTION MODELS - SACRS2, FLAASH AND 6SV USING RESOURCESAT-2 AWIFS DATA

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ABSTRACT:

Remote sensing measurements from space born sensors are strongly attenuated by the scattering and absorption processes through atmospheric molecules, aerosols and gases (ozone, water vapour, oxygen etc). The process of removing the atmospheric interference from the satellite-level signal is called atmospheric correction. Atmospheric correction can be performed through various methods such as, empirical method, semi-physical method, detailed radiative transfer models. Various methods exist for atmospheric correction of available global sensors such as NOAA-AVHRR, MODIS-Terra/Aqua, MERIS, Landsat-TM/ETM etc. However, there was no method available for atmospheric correction of the IRS data sets. A new physics-based model called Scheme for Atmospheric Correction of ResourceSat-2 AWiFS data (SACRS2) has been developed at Space Applications Centre (SAC) specifically tuned for the RS2-AWiFS sensor. This model has been developed from theoretical signal simulations using the 6SV (The Second Simulation of the Satellite Signal in the Solar Spectrum vector version) code. A detail analysis was carried out to perform inter comparison of the results of SACRS2 model with standard atmospheric correction models such as FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercube) and 6SV on RS2-AWiFS data. In turn, the performance of all three models was compared to *in-situ* measurements carried out over an experimental site located in the Kutch desert for seven RS2-AWiFS overpasses. The results showed a fairly good match of reflectance derived by all three correction models with the *in-situ* measurements.

1. INTRODUCTION

Sensors onboard satellites receive the coupled response of the earth's surface and atmosphere within the designated spectral bands. The signal received at the satellite -based sensor in the visible - near infrared spectral region is attenuated by the atmospheric gases and aerosol through absorption and scattering processes. This attenuation can affect the intensity and spectral composition of the radiation (Lillesand et al 1999). The signals received at the satellite are an integrated spectral response of the target within the designed spectral width of the sensor this signal is provided to the user in form of digital number (DN). In raw unprocessed image DN value do not quantitatively correspond to the physical units such as radiance, reflectance or temperature. Thus remote sensing studies which intend to utilize satellite data for estimation of quantitative spectral surface characteristics need to be converted the DN to target reflectance (Pandya et al.2002) which has to be compensated by an appropriate procedure to obtain accurate reflectance of the surface. The procedure for removing the atmospheric effects from the satellite-measured signal to retrieve the surface reflectance is called atmospheric correction.
The Indian Remote Sensing (IRS) satellite series has been providing data since 1988 through various missions such as, IRS-1A, 1B, 1C, 1D, P2, P3, P4, P5, P6 or Resourcesat-1 (RS1), Oceansat - 2 and Resourcesat - 2 (RS2) (Pandya et al.2013) for various terrestrial applications. The Advanced Wide Field Sensor (AWiFS) is one of the three payloads onboard Resorucesat-2 (RS2) satellite having four spectral channels in green (520-590 nm), red (620-680 nm), near-infrared (NIR) (770-860nm) and shortwave infrared (SWIR) (1550-1700 nm) spectral regions with a nominal spatial resolution of 56 meter. There are many empirical and physics

based models available in the literature for atmospheric correction like a LOWTRAN (Kneizys et al.,1988), MODTRAN (Berk et al., 1989), 5S (Tanre et al., 1990), 6S (Vermote et al., 1997b), SBDART (Ricchiazzi et al., 1998), SMAC (Rahman et al.1994) and 6SV (Vermote et al., 2006) available in the literature. Amongst these models Second Simulation of Satellite Signal in the Solar Spectrum Vector version (6SV) widely used and well documented for atmospheric correction in VIS and NIR region. Many of these models can correct the atmospheric effects for sensors such as AVHRR, ASTER, MODIS, SPOT, Landsat etc. However, there is no method available for atmospheric correction of RS2 sensors. Recently a new physics based model has been developed namely, SACRS2 (Scheme for Atmospheric Correction of ResourceSat-2) Pandya et al.(2014a,2014b) for RS2-AWiFS data. This paper reports the results of a study that was carried out to compare various atmospheric correction models for the RS2 -AWiFS data.

2. ATMOSPHERIC CORRECTION MODELS

Several atmospheric correction models are available for correcting atmospheric attenuations incorporated in satellite observations, such as FLAASH, 6SV, QUAAC, ATCOR etc. In this paper we did a comparative assessment of three atmospheric correction models namely 6SV, FLAASH and a newly developed SACRS2 with *in-situ* measurements.
I) SACRS2: In SACRS2 model raw data (digital number) of RS2-AWiFS and inputs related to atmospheric parameters and viewing geometry to obtain the atmospherically corrected surface reflectance. The SACRS2 requires two sets of inputs, 1) An input text file containing information of atmosphere and viewing geometry.2) Raw RS2-AWiFS image (digital numbers)

with 4 spectral bands. In the text file number of lines and pixels of images L_{min} and L_{max} for all the corresponding bands (table 2),day of the year, sun zenith and azimuth, view zenith and azimuth, altitude, AOT, WV, O_3 and option for atmospheric correction variable type 1; atmospheric correction ON / 0: No atmospheric correction. If atmospheric correction is not performed then the code will only generate the TOA reflectance image and if give as input 1 then generates both TOA and Surface reflectance images.

II) FLAASH: FLAASH is a model in built available with ENVI input software for atmospheric correction of the multispectral and hyper spectral data in the visible-near infrared and shortwave infrared range (up to 3000nm). It incorporates the MODTRAN 4 radiation transfer code and needs a number of input parameters such as scene centre, sensor type and altitude, Satellite overpass time, ground elevation, pixel size etc. These parameters can be typically obtained from the metadata file of the satellite data. In FLAASH radiance image is used input So we have to convert the digital number in to the TOA radiance using equation (1) and radiance image all converted into BIL format. FLAASH accepts the input parameters through a GUI and saves them as a template file. RS2 has a sensor altitude of 817 km. The central wavelength location and gain of each of the spectral bands were obtained from the header files of the image data. The average ground elevation for the *in-situ* is taken as 100 meter above the sea level.

III) 6SV: The 6SV code was available to be downloaded free of charge. It is an improved version of the 5S code, which is able to simulate the signal observed by a satellite sensor for a lambertian target at sea level altitude, in the solar spectrum wavelength (250-4000nm).The model can run by executing a command batch file (a.bat file). To run the model the input files must be in the same directory as the executable file. The output files will also be written in the same directory. The following inputs are necessary: 1) Geometrical condition 2) Atmospheric model for the gaseous vertical profiles, and the water vapour and ozone column content if the model default value have to be overwritten. The present study of US standard 1962 profiles used in 6SV code. We have given input as TOA and pixel based correction in 6SV code and so we have used 3×3 pixel average value of the surface reflectance.

3. DATA USED AND METHODOLOGY

The RS2-AWiFS datasets used in the analysis correspond to six months duration from November 2013 to April 2014 shown in table.1. The satellite pass (091/053) covers the region of Gujarat and surrounding. The details of satellite data used for atmospheric correction is shown in table 2. Field experiments were carried out for measuring atmospheric and surface characteristics over Rann of Kutch area of Gujarat (fig.2). The site provides a stable land cover in terms of surface reflectance. This presents an excellent testing ground for satellite derived reflectance (Sridhar et al.2013). The atmospheric characteristics such as aerosol optical thickness at 550nm, columnar water vapour content, total ozone content were measured by Mircortops-II Sunphotometer. The surface spectral reflectance was on each of seven days matching to the satellite overpass measured using the hand held ASD Spectroradiometer. The 6SV required the TOA reflectance as an input while FLAASH needs TOA radiance as an input. So digital number (DN) values were converted to spectral radiance and then into TOA reflectance using the formulae given below

Table 1. Satellite data use for atmospheric correction

Date of acquisition	Satellite	Sensor	Path/Row	GSD
25 Nov 2013 19 Dec 2013 12 Jan 2014 05 Feb 2014 01 Mar 2014 25 Mar 2014 18 Apr 2014	RS-2	AWiFS	091/053	56 m

$$L = \frac{DN*(L_{max} - L_{min}) + L_{min}}{DN_{max}} \quad (1)$$

$$\rho = \frac{\pi * L * (U)^2}{E_0 * \cos \theta_s} \quad (2)$$

Where, L = Radiance in mWcm^{-2}sr^{-1}µm^{-1}
     DN = Digital number for the pixel
     DN_{max} = Maximum grey level
     ρ = Top of atmosphere reflectance
     E_0 = means solar exo-atmospheric spectral irradiance
     U = Earth sun distance (Astronomical units)
     θs = Solar zenith angle (degrees)

Here L_{max} and L_{min} are the minimum and the maximum detected spectral radiance for the sensor values are shown in table 2.

Table.2 Details of satellite data used for atmospheric corrections

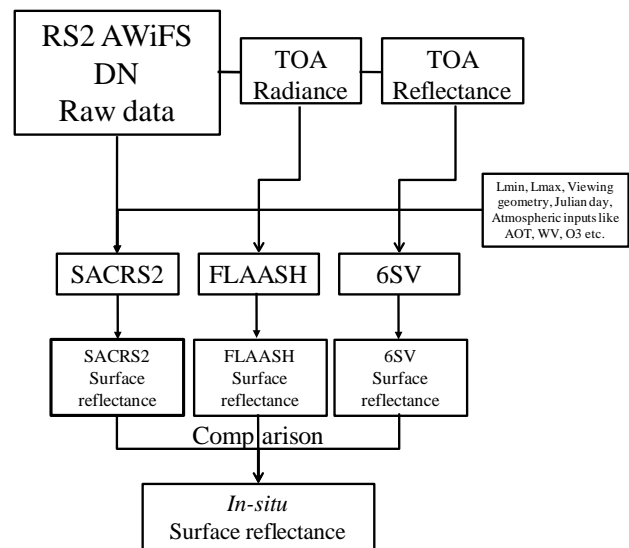| Spectral range (nm)	Radiometry	L_{min}	L_{max}	E_0 mWcm^{-2}µm^{-1}
		mWcm^{-2}sr^{-1}µm^{-1}		
520-590			52.00	185.376
620-680	12 bits	00.00	47.00	158.978
770-860			31.50	109.479
1550-1700			7.50	23.703

Figure1: Flow chart Showing the Atmospheric correction of AWiFS data using SACRS2, FLAASH and 6SV models

The steps followed in this study for the atmospheric correction of RS2 AWiFS data and are comparison of three atmospheric correction models presented in figure 1. Model derived surface reflectance have been compared using *in-situ* measurements of ASD Spectroradiometer.

4. RESULTS AND DISCUSSION

Fig.2 Shows validation site in the Runn of Kutch. The performance of all three atmospheric correction models (SACRS2, FLAASH and 6SV) was evaluated in terms of relative deviation (RD) of model derived surface reflectance with respect to *in-situ* measurement. Fig.3 shows comparative results of the surface reflectance computed using all three atmospheric correction models with *in – situ* measurements for all the seven passes of RS2 AWiFS sensor. Graphs show that all three models compute the surface reflectance reasonably well with high R^2 value ranging from 0.79 to 0.85. Co-efficient of determination (R^2) is highest (0.85) for 6SV RT model. The relative deviation in the model derived reflectance with respect to the *in-situ* reflectance varied by 0.5% to 9.68% for SACRS2, 0.3% to 9.93% for 6SV and 0.05% to 10.0% for FLAASH. This study has clearly demonstrated that the newly developed SACRS2 models has similar capability of correcting atmosphere effects almost similar to that 6SV and better than FLAASH. Moreover, SACRS2 has advantage of correcting full RS2-AWiFS image (~15000 pixels × 15000 pixels) , which is not possible with the 6SV (which performs detail calculations on by point basis) or FLAASH (which fails on full AWiFS image) models. We observed that the SWIR band of RS-2 AWiFS consistently shows high RD % for all three models as compared with *in-situ* measurements.
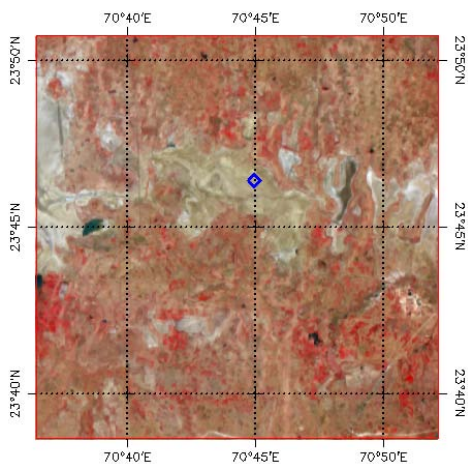

Figure 2.RS2 AWiFS images acquired over the Kutch validation site on 01 Mar 2014.

Table.3 Atmospheric parameters measurements by Sunphotometer for study sites

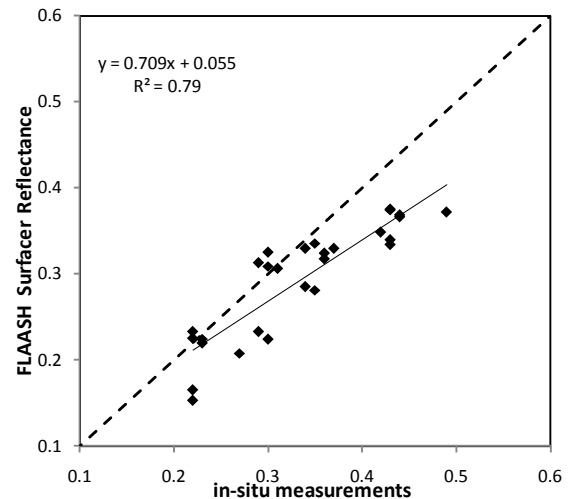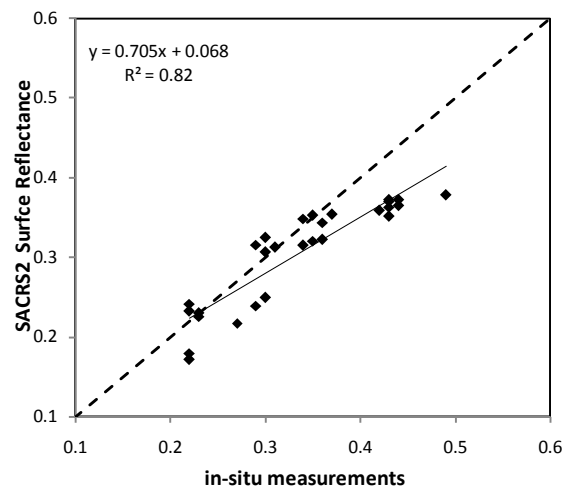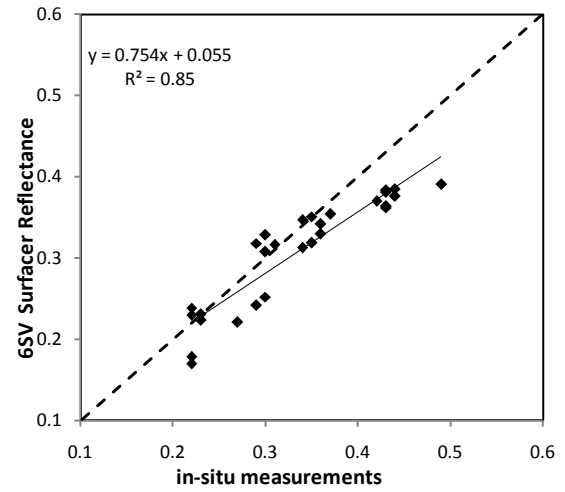| Site	Date	Aerosol optical thickness (AOT at 550nm)	Water vapour content (g cm^{-2})	Ozone content (cm-atm)
Kutch Desert 23°46'N 70°45'E	25 Nov 2013	0.31	0.81	0.219
	19 Dec 2013	0.30	0.42	0.211
	12 Jan 2014	0.47	0.36	0.223
	05 Feb 2014	0.36	1.32	0.287
	01 Mar 2014	0.29	0.47	0.300
	25 Mar 2014	0.38	1.13	0.299
	18 Apr 2014	0.55	1.84	0.318

Figure 3. Comparison of Surface reflectance with *in-situ* measurements

CONCLUSION

In this paper, we have reported the results of a comparative study carried out on RS2-AWiFS data to check the performance of three atmospheric correction models with respect to *in-situ* measurements. The 6SV RT model has been found most suitable for the atmospheric correction of RS-2 AWiFS data with highest coefficient of determination (0.85) followed by

SACRS2 and FLAASH having coefficient of determination 0.82 and 0.79 respectively. However, the biggest advantage of SACRS2 model over 6SV or FLAASH is that SACRS2 can be used for correcting full RS2-AWiFS datasets, which other two models can not correct such datasets. Thus, it can be concluded that SACRS2 model tuned specifically for RS2-AWiFS Sensor can be used for correcting the RS2-AWiFS datasets.

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