# SURFACE REFLECTANCE PRODUCTS FROM RESOURCESAT-2: L-3 AND AWIFS SENSOR DATA

# USER PRODUCT GUIDE

Products Software Development Division

Data Processing Software Group

Data Processing Area

National Remote Sensing Centre

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| 14. | **Abstract** | This document describes the characteristics of Surface Reflectance Products or Bottom of Atmosphere (BOA) products from L-3 and AWIFS sensors of Resourcesat-2 for enhanced usage by the Users and dissemination from Bhoonidhi portal . | | |
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# Contents

# 1.Introduction

The satellite measurements are strongly affected by molecular and aerosol scattering, and absorption by gases, such as water vapor, ozone, oxygen and aerosols. Molecular scattering and absorption by ozone, oxygen and other gases are relatively easy to correct because of the stable concentration of these constituents in both space and time. The most difficult task is to estimate the distribution of aerosols and water vapor as these are highly dynamic in both space and time. Signals recorded from the satellite or airborne platforms in the visible and near infrared region are a combination of surface, atmospheric contributions and sensor errors. Thus, to enable quantitative studies of the earth surface, atmospheric perturbations need to be removed from the observed signal. The process of removing atmospheric contribution is commonly referred as atmospheric correction or atmospheric compensation. Products which are corrected for atmospheric perturbations are called Surface Reflectance (SR) or Bottom of Atmosphere (BOA) products.

Surface reflectance is the fundamental land surface parameter of interest for any remote sensing based application. This is because the retrieval of any biophysical parameter demands for the use of precise surface reflectance products as the input. Moreover surface reflectance products are also necessary to apply a quantitative remote sensing model or set of classification rules to standardized scenes in different regions or years.

Atmospheric correction of optical remotely sensed data can indeed be categorized into two major classes: 1. Relative atmospheric correction based on image processing. This correction is simple to apply and does not require atmospheric data. This method extracts information on atmospheric properties directly from images when ancillary data on atmospheric conditions are not available. The best known and most widely used technique, based on images, is the Dark Object Subtraction (Pat S. Chavez, 1988). 2. Absolute atmospheric correction. On the other hand, this correction is based on the physical process of Radiative Transfer (RT) and is, therefore, very complex and it requires a great amount of information regarding sun-surface sensor geometry, atmospheric condition at the time of data acquisition, and radiometric specifications of the sensor. RT is the physical phenomena of electromagnetic radiation propagation through a medium. The equation of radiative transfer describes mathematically all sorts of interactions (absorption, emission and scattering). Radiative Transfer Codes (RTC) are developed to solve the Radiative Transfer Equation (RTE) inverting differential equations, in general these models are capable of performing computation over any kind of ”radiance-medium interactions” problem. Several Radiative Transfer codes are available, developed for analysis of atmospheric interactions in particular ranges of the electromagnetic spectrum. Usually RTCs are created on purpose for specific applications. The most known are the Line-By-Line Radiative Transfer Model (LBLRTM) based on the Fast Atmospheric Signature CODE (FASCODE) (Clough et al.2005), Spherical HARMonics (SHARM) (Lyapustin 2005),Radiative Transfer 3 (RT3) (Evans et al. 1991), the MODerate resolution TRANsmittance code (Acharya et al. 1999) and the Second Simulation of the Satellite Signal in the Solar Spectrum (6S) (Vermote et al. 2006). All codes listed above solve Transfer Equation in the scalar form, except 6S which can solve it in both scalar and vector form. This means that 6S in vector mode is capable of taking into account the light polarization contributions. Recent studies have shown that neglecting this effect could lead to an error up to 10% between simulated and measured radiance (Kotchenova et al. 2008, Sromovsky 2005, Mishchenko et al. 1994). There are also several commercial packages for atmospheric corrections, among others, Fast Line-of-sight Atmospheric Analysis of Spectral Hypercube (FLAASH) model and Atmospheric Topographic Correction (ATCOR) model are very popular. The 6S model is widely used today because it has very good accuracy, freely downloadable and can be run online.

To realize Surface Reflectance (SR) products from Resourcesat-2 (RS2) L-3 & AWiFS sensor data, fully automated atmospheric correction procedure was developed using 6S radiative transfer model. This procedure employs MODIS atmospheric data products to arrive at the surface reflectance products. Atmospheric input parameters required for SR products include atmospheric water vapor, aerosol optical depth at 550nm (AOD) and ozone. The atmospheric correction tool can generate the correction coefficients based on adaptive grid, using which surface reflectance is derived on a per pixel basis. The atmospherically corrected surface reflectance values derived using the lambertian approximation.

## 2. Algorithm and Methodology

### Algorithm description

The atmospheric "perturbation" of a surface reflectance signal depends on the type and characteristics of atmospheric particles interacting with incident solar radiation. Different gas molecules (N2, O2, O3, H2O, CO2 etc) scatter radiation according to Rayleigh's law (molecular scattering) and absorb them. The atmospheric correction requires inputs that describe these variable constituents that influence the signal at the top of the atmosphere. 6S model can simulate the solar radiation on the ground and in the atmosphere from 0.2 µm to 4.0 µm spectral range under a variety of conditions of both ground surface and atmosphere. Assuming a uniform Lambertian ground surface and if gaseous absorption can be de-coupled from scattering as if the absorbents were located above the scattering layers, the equation of transfer for homogeneous target of reflectance as viewed by a satellite sensor (under zenith angle of view θv azimuth angle of view φv) and illuminated by sun (θs,φs )

$$\rho_{TOA}(\theta_s, \theta_v, \varphi_s - \varphi_v) = T_g(\theta_s, \theta_v)\left[\rho_{R+A} + T\downarrow(\theta_s) T\uparrow(\theta_v) \frac{\rho_s}{1 - S\rho_s}\right] \text{---------(1)}$$

Where reflectance ρ defined as

$$\rho = \frac{\pi L}{\mu_s E_s} \text{---------------------(2)}$$

where L is the measured radiance, Es is the solar flux at the top of the atmosphere, and $\mu s = \cos(\theta s)$ where $\theta s$, is the solar zenith angle.

In equation(1), $\rho$TOA- Apparent Reflectance measured at the top of the atmosphere , $\rho$R+A corresponds to the intrinsic reflectance of the molecule+aerosol layer, $T\downarrow(\theta s)$, [respectively $T\uparrow(\theta v)$] to the total transmission of the atmosphere on the path between the sun and the surface, (respectively between the surface and the sensor). S is the spherical albedo of the atmosphere i.e., the normalized irradiance backscattered by the atmosphere when the input irradiance at the bottom is isotropic. Tg is the gaseous transmission, for the solar radiation.

### Inputs

Atmospheric correction using 6S code requires the following input parameters (1) geometrical conditions, (2) the atmospheric model for gaseous components, (3) the aerosol model (type and concentration), (4) spectral condition, and (5) ground reflectance (type and spectral variation). Below table (Table1) lists the options chosen for arriving at the geometric, atmospheric and sensor parameters needed to run the 6S models.

**Table 1.Parameters used in 6S**

| Parameter | Specific Input Required | General Input Chosen |
| --- | --- | --- |
| Geometrical Conditions | Date and Month<br>View and Sun angles (in °) | User's |
| Atmospheric Model | Water vapor(g/cm2), ozone(cm-atm),<br>AOD at 550nm | Uw and UO3<br>Continental Aerosol Model |
| Spectral Condition | Lower and upper wavelengths of the spectral band in µm | User's preference |
| Target and Sensor Altitude | Sensor Altitude in Km<br>Target Altitude: sea level | |
| Ground Reflectance | | Homogenous ground<br>No Directional effect |

The geometrical parameter which includes the sun and view, zenith and azimuth angles were derived from the image itself. Accurate atmospheric parameters are crucial for transferring top-of-atmosphere (TOA) radiance or reflectance to surface reflectance products. MODIS atmospheric products were used to generate atmospheric parameters. AOD (Aerosol Optical Depth) values are obtained MOD04 which is provided at a grid of 0.1° x 0.1°.While the ozone and water vapour values were derived from MODIS joint atmospheric product, namely MOD07_L2 which is defined on 0.05° × 0.05° grid cells that cover the entire globe.

## Implementation of algorithm

Using the above mentioned inputs, the 6S code was used to obtain the correction coefficients which are further used to derive the surface reflectance from the measured radiance values. For each input file the 6S code generates three correction coefficients namely xa, xb and xc. The equation to obtain ρs from these correction coefficients is given by

$$\rho_s = (xa * L - xb)/[1.0 + xc\,(xa * L - xc)] \text{-------------}(3)$$

Where xa, xb and xc are the coefficients obtained from the 6S model, where, xa is the inverse of the transmittance and xb is the scattering term of the atmosphere and xc is the reflectance of the atmosphere for isotropic light entering the base of the atmosphere. The number of times the 6S code is called for the generation of surface reflectance products typically depends on the grid size. The software provides an option for 3 flexible grid sizes namely, 100 X 100, 200 x 200 or 300x 300. The correction coefficients are stored as an image of 3 layers (xa, xb and xc). Finally surface reflectance was calculated pixel by pixel using the output coefficients, by applying the same values of output coefficients for all the pixels falling in the same grid. The output coefficients are computed for each band. The flowchart in Fig. (1) Illustrates the procedure followed to arrive at the surface reflectance products.

The 6S coefficients are generated for each input pixel by taking satellite/sun azimuth/elevation values, Aerosol Optical Depth (AOD), Water vapor and Ozone. All software modules are developed and tested using Java programming language. The calculation for each pixel is independent of each other and can be carried out in parallel. So multi-threading concepts were used and the same was implemented on multi cores CPU machine to achieve high throughput and reduced turnaround time (TAT) of product generation.

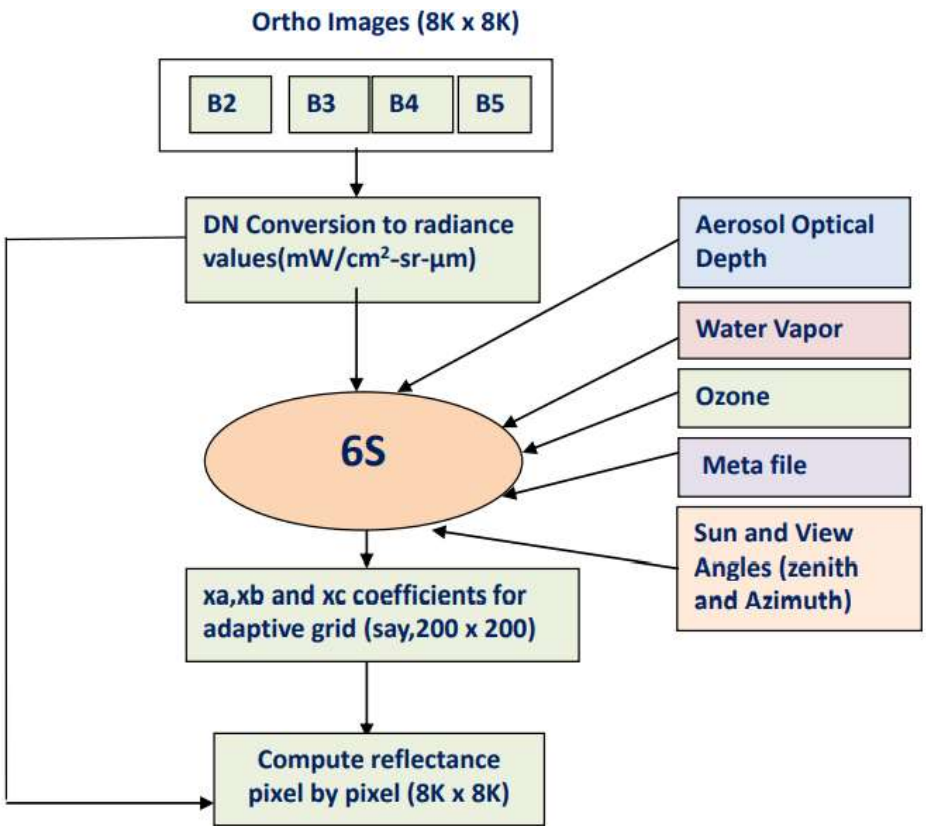



Figure 1.Flowchart depicting the atmospheric correction procedure

## 3. Results and Validation

Figure 2 shows the visual appearance of Atmospheric uncorrected and corrected FCC images in which haziness due the scattering effect is nullified and the contrast is increased. The accuracy of the 6S atmospheric correction algorithm was validated using ground radiometric measurements over IMGEOS cal-val site, Thar desert and Gulmarg-snow.

In addition to making comparisons with ground observations, the accuracy of SR data was also assessed using near synchronous Landsat-7/8-ETM/OLI surface reflectance products over heterogeneous targets covering entire dynamic range of the sensors like water bodies, vegetation, desert sand, river sand, snow etc. Regression analysis is carried out between Landsat8-OLI and RS2 considering all types of targets of many dates during various seasons. The figures 3-4 show the regression plots between the same. It is found that slope values are close to 0.9 and offsets are close to 0.0 whereas SR values from Resourcesat-2A (RS2A) sensors are in good agreement with Landsat8-OLI SR values. Figures 5-6 depicts the agreement of RS2A SR with L8-OLI.

## 4. Radiometric Harmonization with RS2A

RS2A is a follow on mission of RS2 and was launched in 2017. Sensors (L-3, AWiFS & L-4) configuration is similar for both the missions with a temporal resolution of 24 days. If two mission's data are used in tandem, an area of interest (AOI) can be acquired with 12 days interval which improves the time series analysis of various land resources. Radiometric harmonization of data from similar sensors of both missions is necessary in order to make this analysis inter operable within missions which is also a mandatory step towards building Analysis Ready Data sets. Spectral similarities of two sensors also allow for data harmonization. With the generation of harmonized data sets, users are free to use any sensor data for their analysis which in turn increases the temporal resolution of their AOI. In addition, radiometric normalization of images is important for various applications such as monitoring vegetation indices over time, comparison of supervised and unsupervised land cover classifications, mosaicking, identification of pseudo invariant targets and change detection studies.

Radiometric Harmonization of RS2 with respect to R2A sensor data for both L-3 and AWiFS sensors is implemented. More than 500 common datasets between RS-2 and 2A covering all types of terrain reflectances and seasons since 2017 were used for this study. All the data sets were processed to Surface reflectance level to avoid atmospheric interferences. Iteratively re-weighted multivariate alteration detection (IR-MAD) transformation was applied for automatic extraction of pseudo invariant pixels from common data sets. Regression analysis was carried out to compute calibration coefficients. Harmonized RS2-L-3/AWiFS wrt. RS2A-L-3/AWiFS datasets are generated using these coefficients. Radiometry of theses harmonized RS2 data sets are validated against both RS2A and Harmonized Landsat-Sentinel (HLS) datasets over various land use and land cover features. Slopes of individual bands of RS2 wrt RS2A are increased from 0.8, 0.8, 0.8, 0.8 to 1.0, 1.0, 1.0, and 1.0 respectively. Similarly harmonized RS2 datasets are in good agreement with HLS data sets with coefficient of determination better than 98 %. Details are provided in figures7-8.

Products are validated with both ground measurements and SR products from the contemporary satellites. Slopes of individual bands of RS2 wrt Landsat-7 are around 0.8 for the period 2011 to 2013 and slopes wrt to Landsat-8 are around 0.7 for the period 2013 to 2021. Similarly harmonized RS2 datasets are in good agreement with ground measurements with coefficient of determination better than 80 %. In all the cases accuracy of harmonized RS2 data sets is improved by 15%. Figure-3 depicts the improvement with harmonization.

**Sensor wise and Band wise harmonization coefficients will be supplied as part of Meta data file of each RS2 product.** Users can apply these co-efficient to work seamlessly on RS2 & RS2A L-3 and AWIFS SR products.

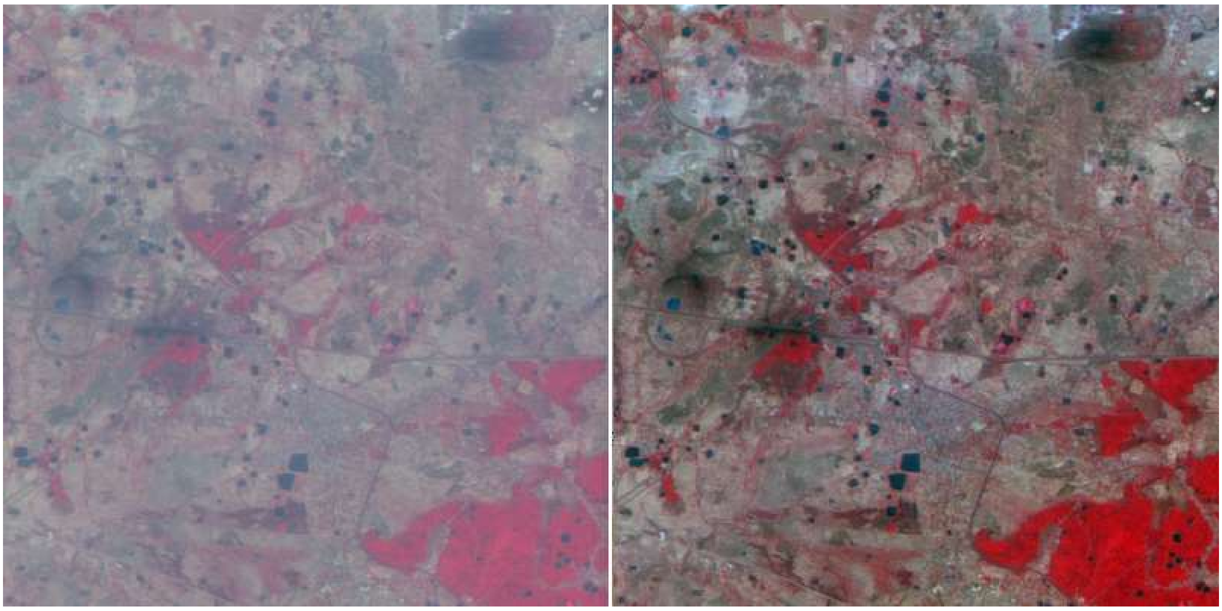


Figure 2. TOA(left), Surface Reflectance(Right) Images
22Apr2022, 102/56 RS-2 L-3

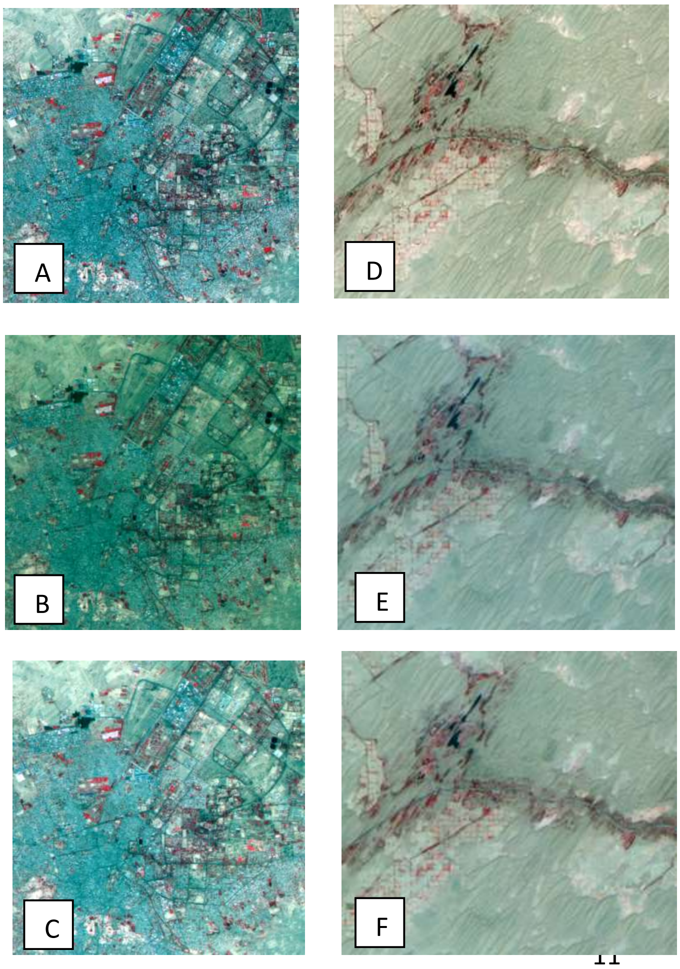



Figure 3. Surface Reflectance Images

A) RS2A-L3 (DOP: 05Mar2022; Path/Row: 92/52) – Original
B) RS2-L3(DOP: 17Mar2022; Path/Row: 92/52)-Original
C) RS2-L3(DOP: 17Mar2022; Path/Row: 92/52)-Harmonized
D) RS2A AWiFS (DOP:22Apr2022; Path/Row: 92/53) – Original
E) RS2 AWiFS (DOP10Apr2022; Path/Row: 92/54) – Original
F) ) RS2 AWiFS (DOP10Apr2022; Path/Row: 92/54) )- Harmonized

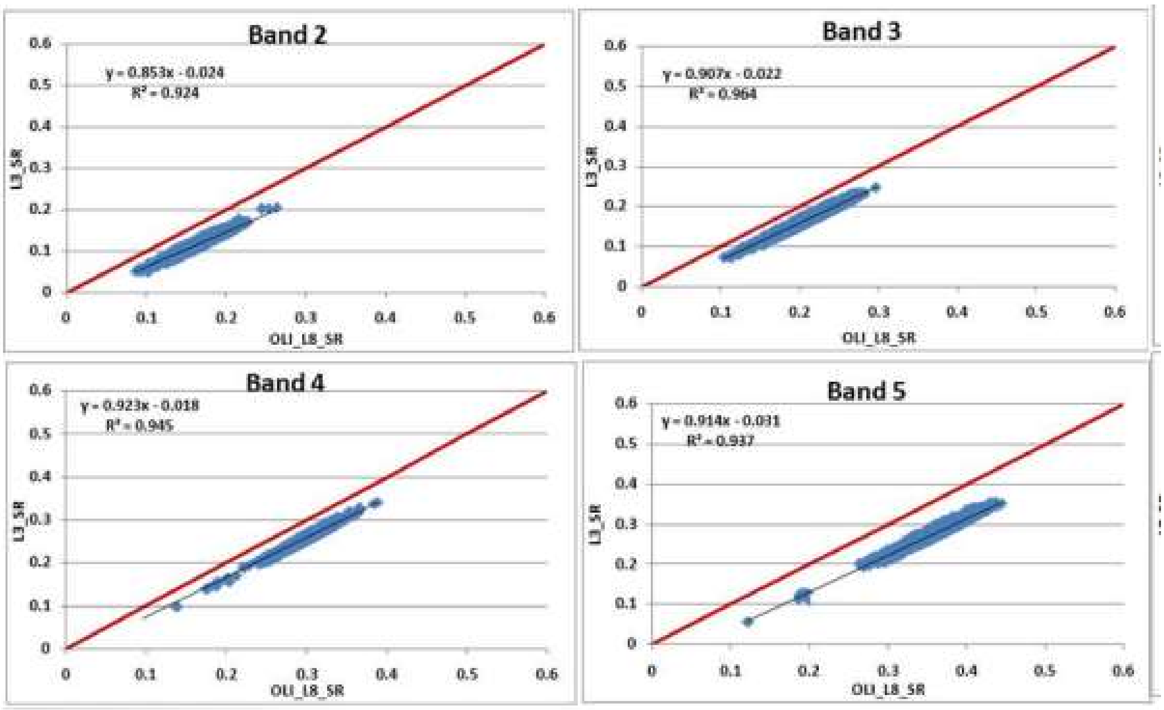



**Figure 3**. Regression between RS2- L-3 and L8 OLI

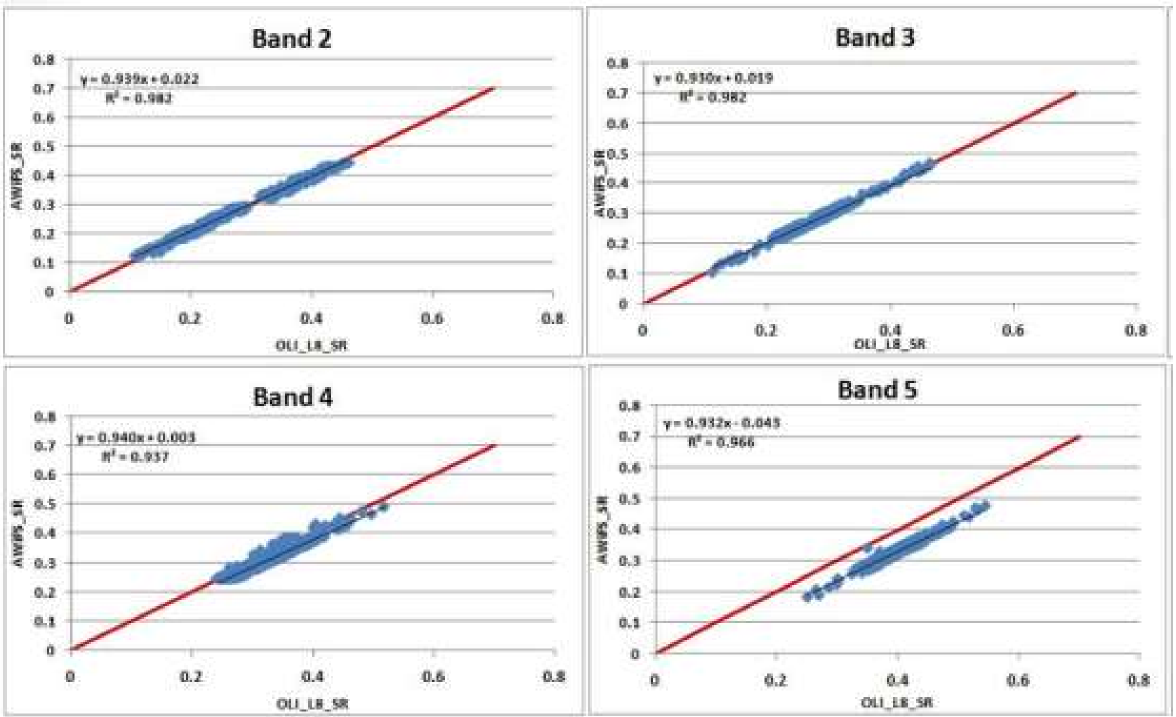



**Figure 4**. Regression between RS2- AWiFS and L8 OLI

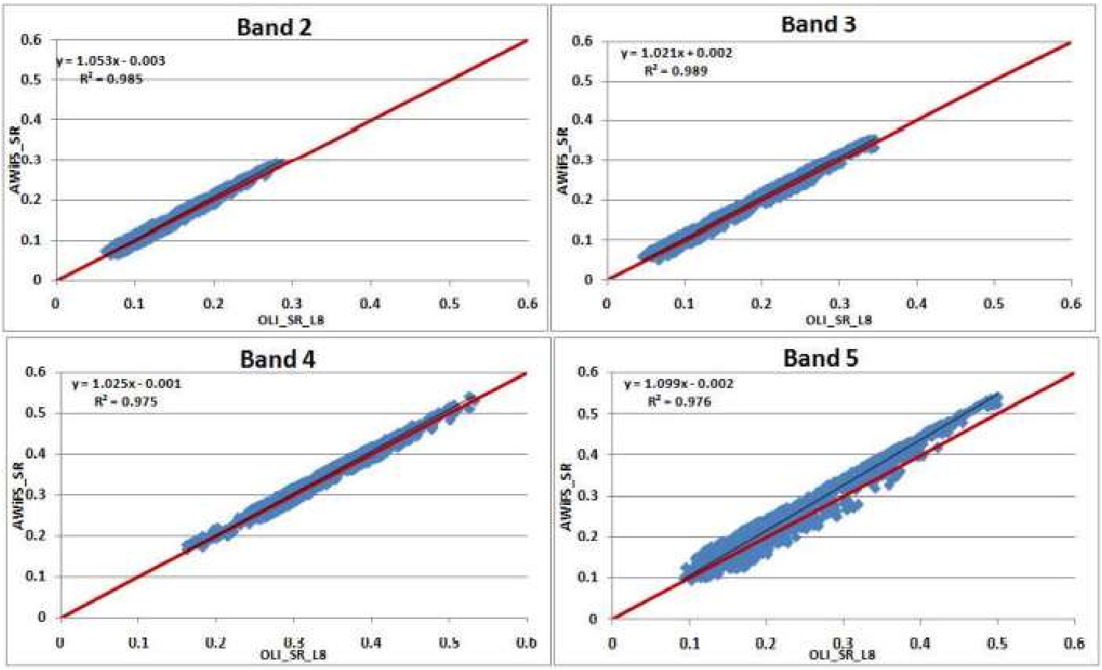



**Figure 5**. Regression between RS2A AWiFS and L8 OLI

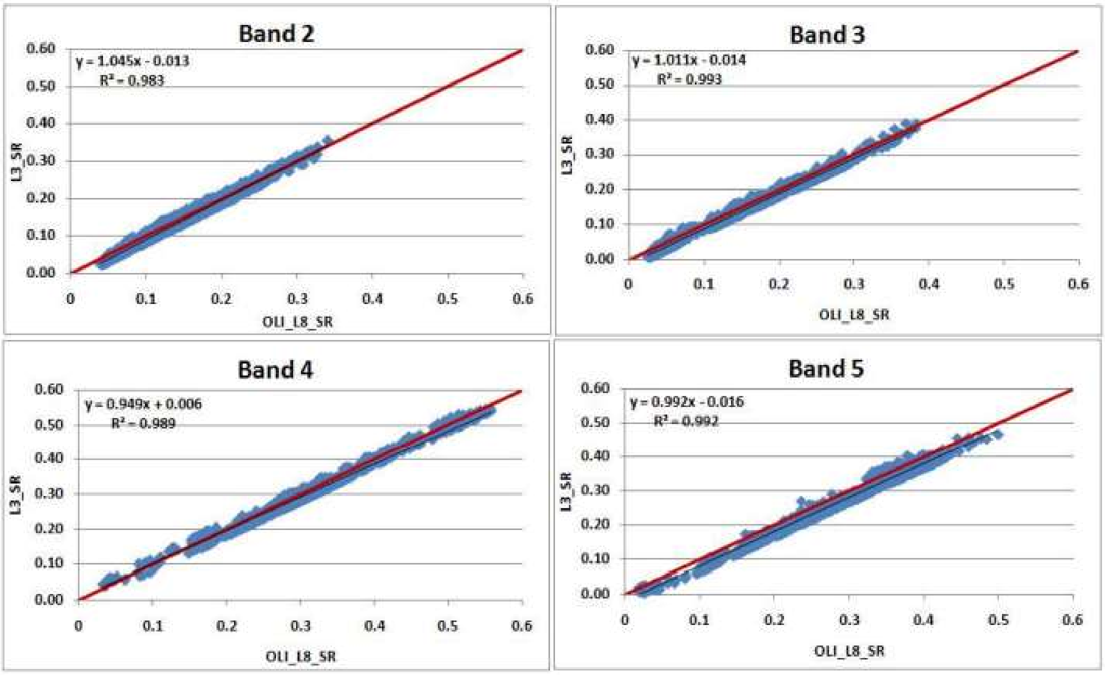



**Figure 6** .Regression between RS2A L-3 and L8 OLI

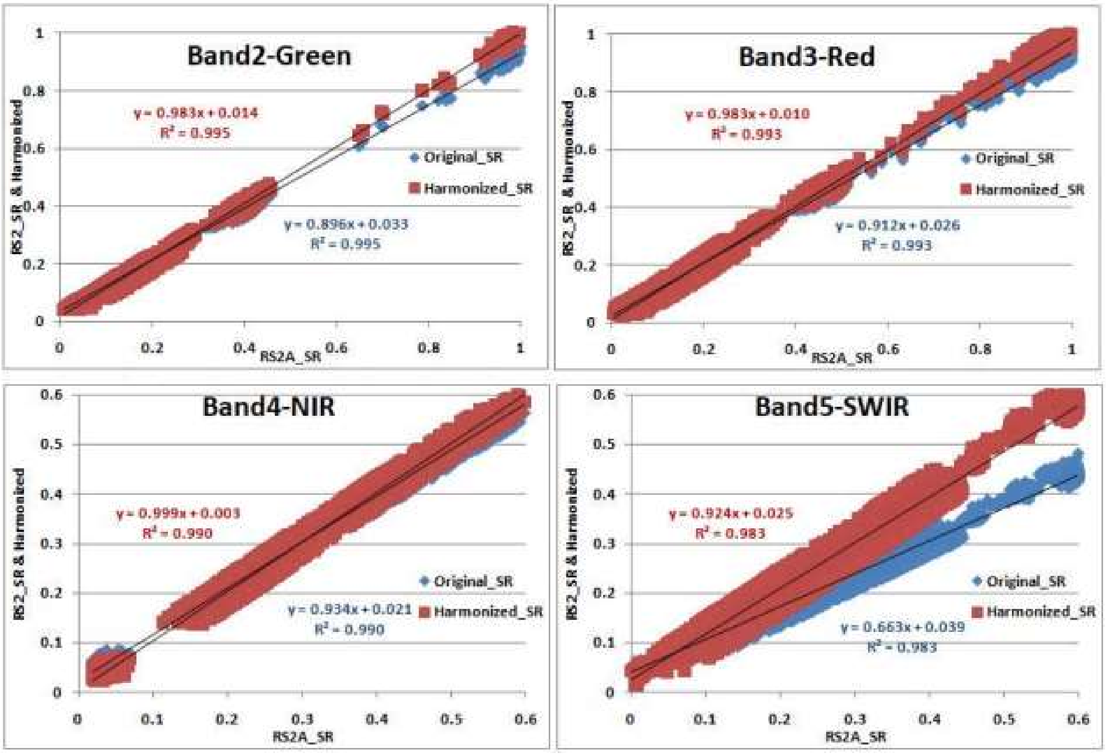



Figure 7 . RS2-AWIFS Harmonized with RS2A-AWIFS

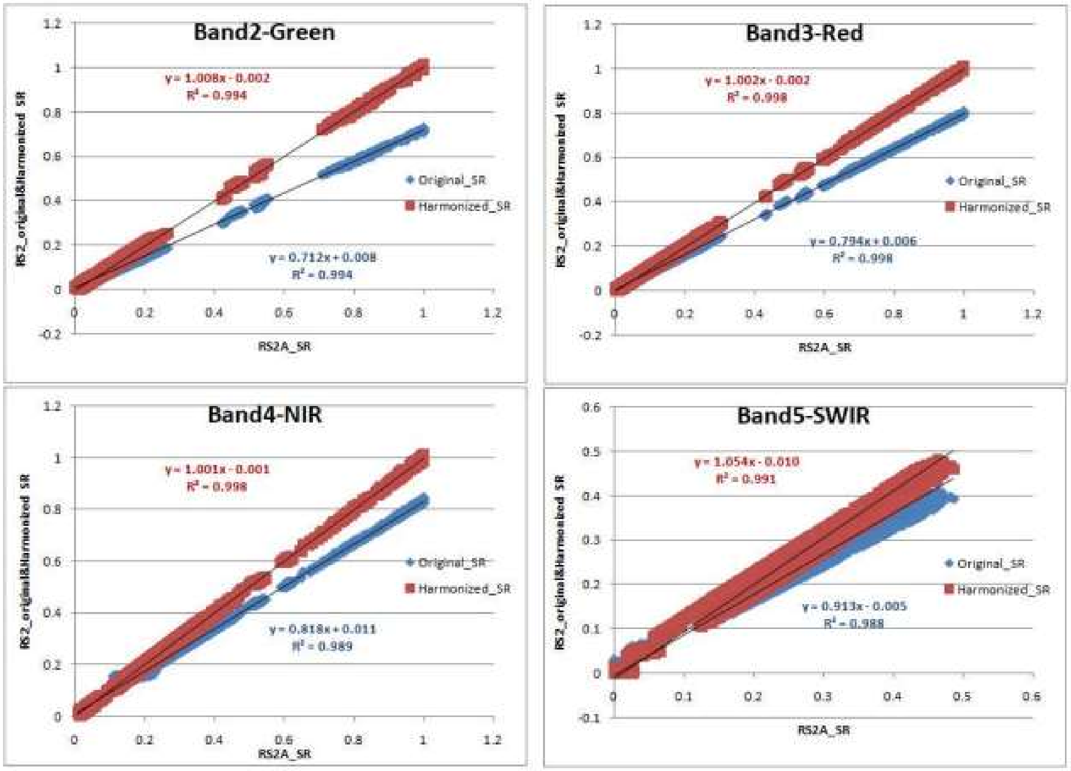



Figure 8 RS2-L-3 Harmonized with RS2A-L-3

## 4. Product Format Specification

| | | |
|---|---|---|
| • Number of image bands | : | 4 |
| • Image File Format | : | GeoTIFF |
| • Projection | : | Lambert conformal conic for AWiFS<br>UTM for L-3 |
| • Datum | : | WGS-84 |
| • Spatial Resolution | : | 56m for AWiFS, 24m for L-3 |
| • Radiometric resolution | : | 16 bits per pixel |
| • Correction Level | : | Terrain corrected |
| • Data type | : | Unsigned 16 bit integer |
| • Scale factor | : | 0.0001 |
| • Valid range | : | 0-10000 |
| • Image background | : | 0 |
| • Meta Data | : | Available in Text file |
| • Thumbnail Image | : | Available as Jpeg file |
| • Geometric Accuracy | : | As per Terrain corrected Product specification |

## 5. Product Contents

PRODUCT ( ZIP file) contains the following files:

- Image bands ( BAND2.tif, BAND3.tif, BAND4.tif, BAND5.tif )
- BAND_META.txt
- *.JPG
- *.TXT

## 6. Limitations

**Known issues**

- Missing/void/Improper/invalid fill values of aerosol values can cause a box(blocky) artifact in SR products even after using climatology products and spatial interpolation methods from surrounding grid values(not direct measurements of

AOD). In this version, Quality flag in the quality layer is not provided for interpolated values, and to indicate used aerosol value is valid or not.

- AOD availability over high reflecting targets like snow/desert is very difficult by any of Earth observing satellites. Even though AOD values exist at certain places, those values are not validated and many gaps exist in the datasets. 20 years of MODIS MOD04 AOD datasets are processed to fill the gaps. Still gaps/voids exist at some places. A constant AOD value of 0.01 is used for SR processing in this case to avoid holes in Final SR product. Hence the realization of SR products over these regions is not up to the mark.
- Low speckling noise may exist over pure water bodies in the NIR and SWIR (B4 and B5) bands due to high AOD values.

### Caveats and Constraints

1. SR products will be generated for RS2 L-3 and AWiFS scenes with a lag time  5 days of acquisition.
2. SR generation depends on the availability of auxiliary atmospheric data(AOD, Watervapor and Ozone). Atmospheric data is retrieved from satellite observations of the MODIS instruments aboard the Terra which has same local pass time with RS2. More information pertaining to the source of auxiliary data and characteristics are given in table2.
3. Atmospheric coefficients are calculated on a grid basis that is spatially coarser than the resolution of the input image.
4. Geometric and Radiometric accuracy of products is similar to that of standard data products (Level-1) generation.
5. Uncertainty in SR products may exist due to following reasons:
   - Lower solar elevations (solar zenith > 70 degrees) at high latitudes may leads to longer atmospheric paths (scattering is more). higher AOD, Low sun angles
   - Scene covering Coastal regions where land area is small relative to adjacent water
   - Scene with extensive cloud cover(more than 60 % )
   - Saturation of bands may occur due to Hyper-arid or snow covered regions. Saturated pixels can show high SR value(~1) or can roll over to the low end of the valid range(~0)

**Table 2. Auxiliary data**

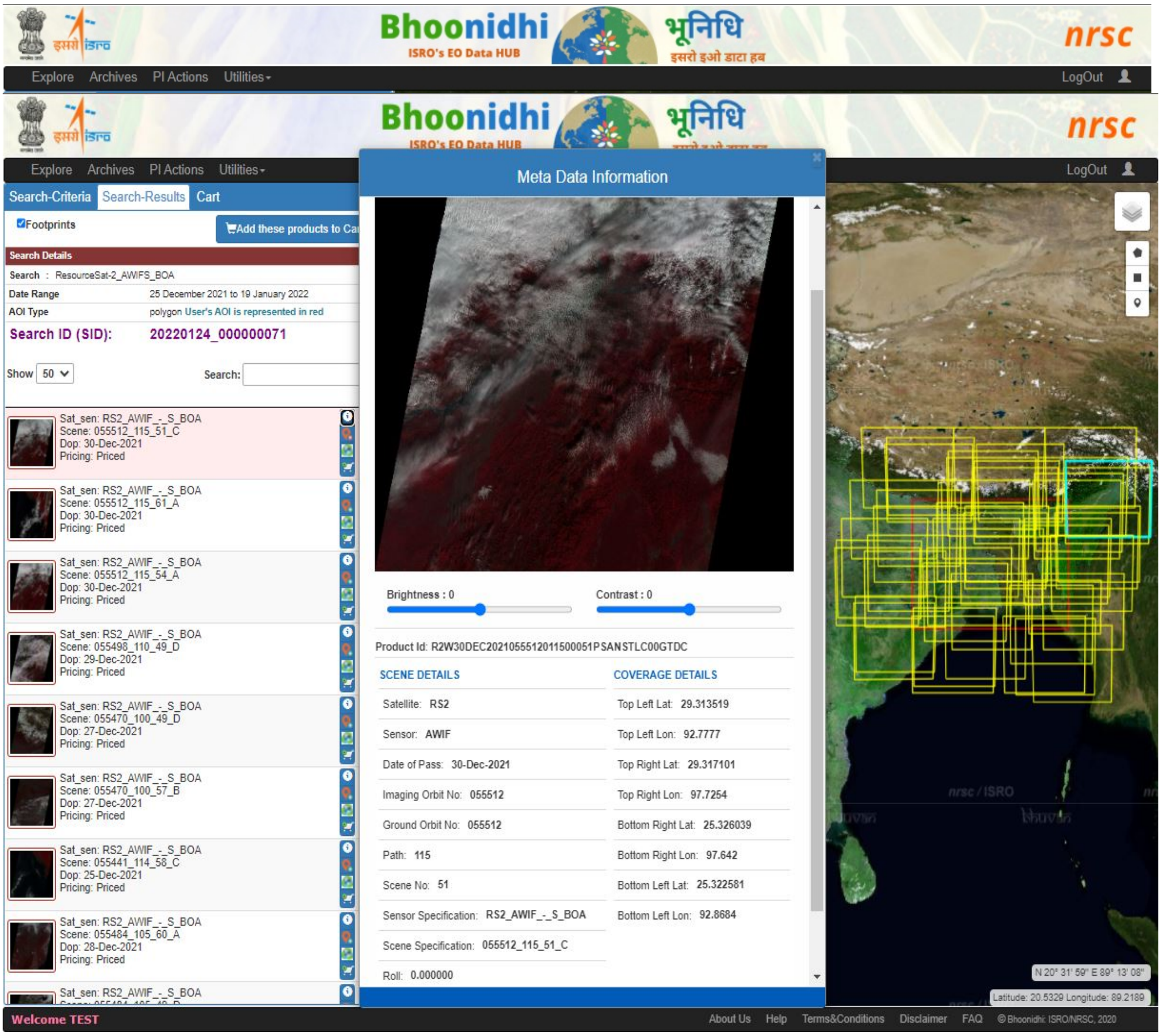
| | |
|---|---|
| Aerosol optical depth (AOD)-Dark target deep blue combined | MOD04_L2(daily product)-10km spatial resolution |
| Water vapour(WV) | MOD07_L2(daily product)-5km spatial resolution |
| Ozone | MOD07_L2(daily product)-5km spatial resolution |

## 6. Data Products Access

Surface reflectance products are to be ordered from **Bhoonidhi** using the following URL

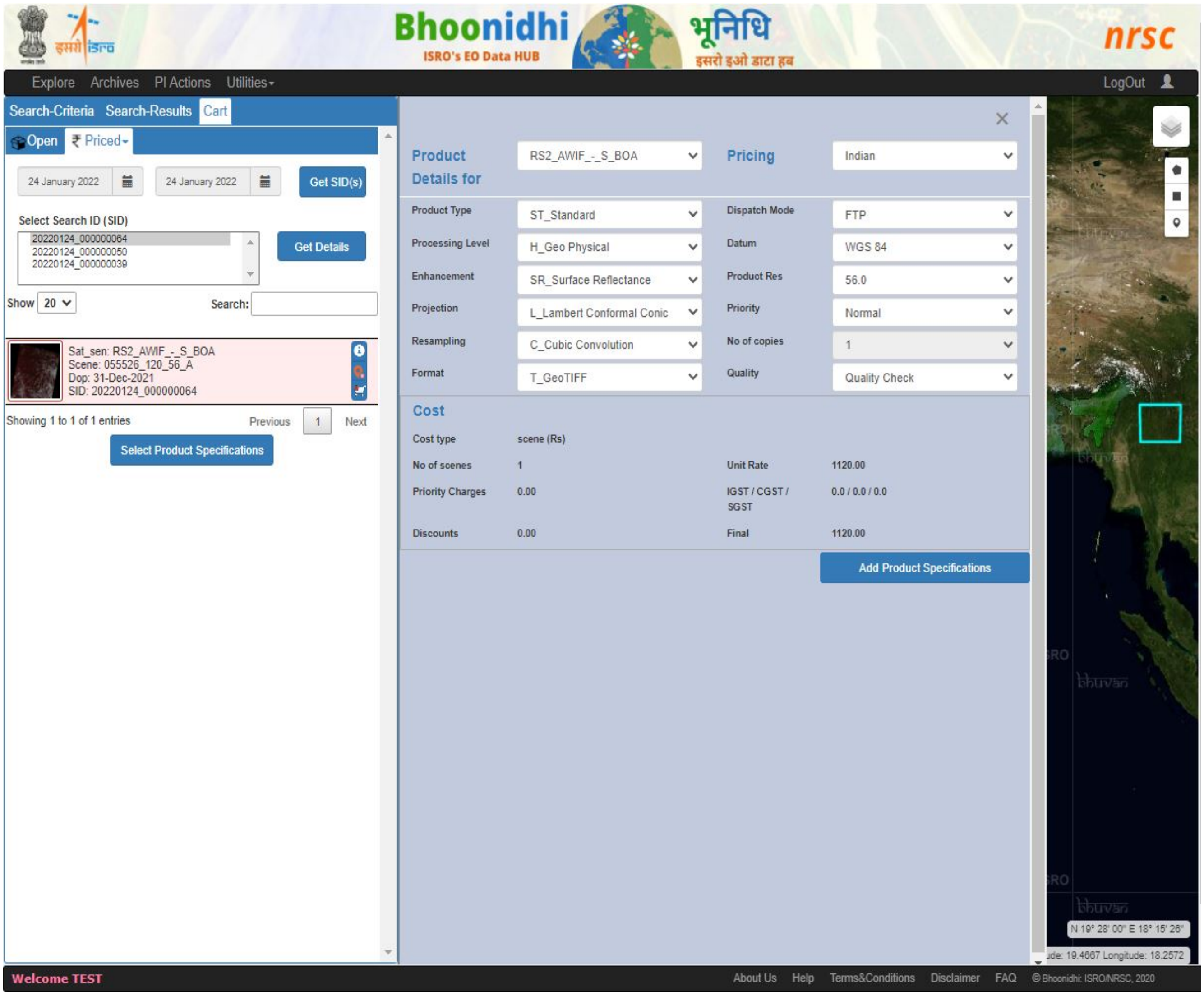
https://bhoonidhi.nrsc.gov.in/

Step1:User has to select the satellite-sensor-product combination tagged with “BOA” under Priced data category as in the screen below



Step2: The scenes are fetched for the user provided area of interest and date range and the satellite-sensor selected. The selected scenes are to be added to the CART by the user

**Step3**:For the selected scenes in the priced CART, the product specification is to be provided and the Proforma Invoice (PI) is to be generated. SR product details will be shown to the user while providing product specification.




Once the Pro forma Invoice is generated the work order for the same can be generated using "PI Actions" link to place order ..

User will get a FTP intimation on the completion of the products generation . The products will be disseminated within 1 hour if available in Ready Archive or else with a delayed timeline of 1- 3 days .

## 7. References


1. Pat S. Chavez,An improved dark-object subtraction technique for atmospheric scattering correction of multispectral data,Remote Sensing of Environment,Volume 24, Issue 3,1988,Pages 459-479,.
2. Clough, S.A., Shephard, M.W., Mlawer, E.J., Delamere, J.S., Iacono, M.J., CadyPereira, K., Boukabara S., and Brown, P.D., 2005, Atmospheric radiative transfer modeling: a summary of the AER codes, Short Communication, J. Quant. Spectrosc. Radiat. Transfer, 91, pp. 233–244.
3. Lyapustin, A., 2005, Radiative transfer code SHARM for atmospheric and terrestrial applications, Applied Optics, 44, pp. 7764–7772.
4. Evans, F., and Stephens, G.L., 1991, A new polarized atmospheric radiativeransfer model, J. Quant. Spectrosc. Radiat. Transfer, 5, pp. 413–423.
5. AcharyaPrabhat K., Alexander Berk, Gail P. Anderson, George P. Anderson, North F. Larsen, Si CheeTsay, Knut H. Stamnes, "MODTRAN4: multiple scattering and bidirectional reflectance distribution function (BRDF) upgrades to MODTRAN," Proc. SPIE 3756, Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space Research III, 20 October 1999.
6. Vermote, E. F., Member of IEEE, Tanre', D., Deuze', J. L., Herman, M., &Morcrette, J.-J. (1997). Second simulation of the satellite signal in the solar spectrum, 6S: an overview. IEEE Transactions on Geoscience and Remote Sensing, 35,675–686
7. Kotchenova, S.Y., Vermote, E.F., Levy, R., and Lyapustin, A., 2008, Radiative transfer codes for atmospheric correction and aerosol retrieval: intercomparison study, Applied Optics, 47, pp. 2215–2226
8. Sromovsky L.A., 2005,Effects of Rayleigh-Scattering polarization on reflected intensity: a fast and accurate approximation method for atmospheres with aerosols,ICARUS, 173, pp. 284–294.
9. Mishchenko, M. I., Lacis, A. A., and Travis, L. D., 1994, Errors induced by the neglect of polarization in radiance calculations for Rayleigh-scattering atmospheres. J. Quant. Spectrosc. Radiat. Transfer, 51,pp. 1491–510.