Radiance and TOA Reflectance Products from IMS-1: Hyperspectral Imager

FOR BHUVAN NOEDA

S D A P S A
NATIONAL REMOTE SENSING CENTRE

Introduction

IMS-1 previously referred to as TWSAT (Third World Satellite), is a low-cost microsatellite imaging mission of ISRO (Indian Space Research Organization). A launch of IMS-1 as a secondary payload on a PSLV vehicle (PSLV-C9) took place on April 28, 2008 from the SDSC-SHAR launch site (Sriharikota, India) of ISRO. The primary payload on this flight was CartoSat-2A (launch mass of 690 kg), an Indian military high-resolution panchromatic imaging satellite (based on CartoSat-2 of ISRO).

IMS-1 is the first satellite in the micro satellite series envisaged to provide satellite platform within 100 kg class of payloads for earth images, space science, atmosphere, ocean studies etc. It carries two payloads viz., Four Band Multi Spectral CCD Camera (Mx) & Hyper Spectral Imager (HYSI).

This document describes Radiance and TOA Reflectance Products realized using Hyperspectral Imager (HYSI) sensor. This is a value added product from HYSI, whose spectral bands are originally designed for atmospheric, land and ocean color retrieval applications. In this document, a brief processing scheme for realizing HYSI products at a spatial resolution of 500 meters (0.005 degree to be precise) is presented.

Orbit Specifications of IMS-1:

Orbit:	Polar sun-synchronous
Orbital Altitude:	632.141 km
Semi Major Axis:	7010.28 km
Eccentricity:	0.001
Inclination:	97.928 degree
Local time:	09:30 AM (descending node)
Orbits/day:	14
Repeat cycle:	325 orbits in 22 days
Period:	97minutes
Path to Path separation:	123.31 km at equator

Payloads

The **Multi-spectral (MX) CCD camera** is a 4- Band camera with ground resolution of 37 meters and swath of 151 Km enabling real time imaging and its data reception in near real time and data product generation by the users. The payload can be used for the purpose of natural resources management like agriculture, forest coverage, land use as well as disaster management. The four spectral bands B1, B2 and B3 can be used for generating Natural Color Composite Data Products and bands B2, B3, and B4 are used for False Color Composite Data Products. These bands are selected keeping in mind the application of natural resource management.

Band	Wavelength (µm)	Resolution (m)	Swath width (km)
Band 1 (VIS)	0.45 to 0.52	37	151
Band 2 (VIS)	0.52 to 0.59	37	151
Band 3 (VIS)	0.62 to 0.68	37	151
Band 4 (NIR)	0.77 to 0.86	37	151

Hyper Spectral Imager (HYSI**)** is one of the two onboard imaging payloads. It is an imager for ocean and atmosphere study of earth surface in large number of bands with high spectral resolution. The instrument has 64 bands in the spectral zone from 400 nm to 950nm.

The sun's reflected light from Earth's surface is being collected through a telecentric refractive optics system and is being focused onto an APS(Active Pixel Sensor) area detector. The area detector images 260 km in along-track and 128 km of cross-track area on ground in an integration time 78.45 ms. The APS area detector has 256 x 512 pixels of 50 µm pixel size; 256 elements are in the cross-track direction and 512 elements are in the along-track direction. Spectral separation is realized using the wedge filter technique making use of APS area device for detection.

Instrument type	Pushbroom imager
Spectral range	0.4 - 0.95 µm (VNIR)
No of spectral bands, spectral range	64 (fixed, contiguous bands), 0.45-0.95 µm
Spectral bandwidth	< 15 nm
Sampling interval	8 nm
Spatial resolution	505.6 m
Swath width	128 km
Detector	An APS (Active Pixel Array) is used with 512 rows and 250 columns
Data quantization	10 bit
Instrument mass, power, size	3.4 kg, 4 W, 15 cm x 20 cm x 17 cm
Source data rate	32 Mbit/s
Data compression algorithm	JPEG2000 (compression ratio of 3.4:1)
Data transmission rate	8 Mbit/s in S-band (after data compression and onboard storage)

Data Processing

Data preprocessing for generating the HYSI products involves following steps:

1) Selection of best cloud free images covering Indian sub continent, 2) Precision correction of images, 3) DN to Radiance Conversion, 4) Spectral Deconvolution and binning 5) Realization of top-of-atmospheric reflectance product using Equation Eq-1:

The individual channels of HYSI are overlapping each other in order to achieve a continuous coverage of the spectrum. Spectral Deconvolution was performed to reduce the spectral overlap of the channels and to represent genuine spectrum.

First 10 channels and last 3 channels are not considered as these were dominated by noise. Radiance and TOA reflectance products are available for 17 channels. These channels are selected on the basis of neighboring channel overlap. Table-1 shows the center wave lengths and band widths of original 64 channels and channels selected for the products.

$$\rho_{TOA} = \frac{\pi * L_\lambda * d^2}{E_0 \cos\theta_z T_z}$$

------ (Eq-1)

ρ_{TOA} = Unit less Top of atmospheric reflectance
L_λ = spectral radiance (from earlier step)
d = Earth-Sun distance in astronomical units
E_0 = mean solar exo-atmospheric irradiances
θ_z = solar zenith angle
T_z = Atmospheric transmissivity between the Sun and the surface

Radiance Image Mosaic over Indian subcontinent visualized by HYSI is shown in Fig-1.

Product's Format Specification
- Image File Format : Geo TIFF
- Projection: Geographic coordinates (Lat., Long.)
- Datum : WGS-84
- Spatial Resolution : 0.005 deg
- Radiometric resolution : 16 bits per pixel(DN)
- Correction Level : Geometrically corrected
- Number of bands : 64
- DN to Radiance/TOA Reflectance conversion rule :
  Radiance/TOA Reflectance= (0.001 * DN)

File Naming Convention

Image file naming convention contains the following information
- · Satellite name
- · Sensor name
- · Correction Level
- · Path number
- · Date of pass
- · Product name
- · Scene number

Examples:

       IMS1_HYSI_GEO_105_29OCT2008_S1_TOA_REFLECTANCE_01_SPBIN.TIF
       IMS1_HYSI_GEO_105_29OCT2008_S1_TOA_REFLECTANCE_META_01_SPBIN.XML

       IMS1_HYSI_GEO_105_29OCT2008_S1_RADIANCE_01_SPBIN.TIF
       IMS1_HYSI_GEO_105_29OCT2008_S1_RADIANCE_META_01_SPBIN.XML

Figure 1. HYSI Radiance Image Mosaic of Indian subcontinent
(FCC combination: Band 40 - Red, Band 30 - Green, Band 20 - Blue)

ORIGINAL CHANNELS			CHANNELS IN THE PRODUCT		
BAND NO	CENTER WAVELENGTH (nm)	BANDWIDTH (nm)	BAND NO	CENTER WAVELENGTH (nm)	BANDWIDTH (nm)
1	429.6	18.9			
2	438	18.8			
3	446.5	18.7			
4	454.9	18.5			
5	463.3	18.4		Dominated by Atmospheric Noise	
6	471.7	18.3			
7	480.2	18.2			
8	488.6	18.1			
9	497	17.9			
10	505.4	17.9			
11	513.8	17.8			
12	522.2	17.7	1	522.2	17.7
13	530.6	17.5			
14	539	17.5			
15	547.4	17.4	2	547.4	17.4
16	555.8	17.3			
17	564.2	17.3			
18	572.6	17.2	3	572.6	17.2
19	581.1	16.9			
20	589.4	17.1			
21	597.8	17	4	597.8	17
22	606.1	17			
23	614.5	17			
24	622.9	17	5	622.9	17
25	631.3	16.9			
26	639.6	16.9			
27	648	16.8	6	648	16.8
28	656.4	16.9			
29	664.7	16.9			
30	673.1	16.8	7	673.1	16.8
31	681.5	16.8			
32	689.8	16.8			
33	698.2	16.8	8	698.2	16.8
34	706.5	16.9			
35	714.9	16.9			
36	723.2	16.9	9	723.2	16.9
37	731.6	16.9			
38	739.9	16.9			
39	748.3	17	10	748.3	17
40	756.6	17			
41	764.9	17.1			
42	773.3	17.2	11	773.3	17.2
43	781.6	17.2			
44	789.9	17.3			
45	798.3	17.3	12	798.3	17.3
46	806.6	17.4			
47	814.9	17.4			
48	823.2	17.5	13	823.2	17.5
49	831.5	17.7			
50	839.9	17.8			
51	848.2	17.8	14	848.2	17.8
52	856.5	17.9			
53	864.8	18			
54	873.1	18.1	15	873.1	18.1
55	881.4	18.2			
56	889.7	18.3			
57	898	18.5	16	898	18.5
58	906.3	18.6			
59	914.6	18.7			
60	922.9	18.8	17	922.9	18.8
61	931.2	19			
62	939.4	19.2		Dominated by Atmospheric Noise	
63	947.7	19.4			
64	956	19.5			

Table 1. Center wave lengths and band widths of original 64 channels and channels selected for products.