INVESTIGATION OF MULTI-FREQUENCY DATA OF VARIOUS SENSORS FOR LAND APPLICATIONS

Report submitted for

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Submitted by

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(Computer Science and Engineering)

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CERTIFICATE

This is to certify that Ms. Shivangi Gupta, student of B.Tech. (Computer Science and Engineering), Jaypee Institute of Information Technology, Noida, has satisfactorily completed her Research project entitled "**Investigation of Multi Frequency Data of Various Sensors for Land Applications**" under the guidance of Mrs. Nilima Rani Chaube. The work has been carried out under **Training and Research in Earth Eco-System (TREES),** Research Initiation program from August 30, 2016 to May 24, 2017 at Space Applications Centre-ISRO, Ahmedabad.

for
Head ERTD

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DECLARATION

I declare that this report titled **“INVESTIGATION OF MULTI-FREQUENCY DATA OF VARIOUS SENSORS FOR LAND APPLICATIONS”** submitted in completion of training under TREES (Training and Research in Earth Eco-system) is a record of original work carried out by me under the guidance and supervision of **Nilima Rani Chaube (Scientist/Engineer-SG).** In keeping with ethical practice in reporting scientific information, due acknowledgement has been made wherever the findings of others have been cited.

Shivangi Gupta

Place - Ahmedabad, 380015

Date – May, 2017

ACKNOWLEDGEMENT

The satisfaction that accompanies with the successful completion of any task would be incomplete without the mention of people whose ceaseless cooperation made it possible, whose constant guidance and encouragement crown all efforts with success.

Keeping this in view, I express sincere gratitude to my guide, Mrs. **Nilima Rani Chaube, Scientist/Engineer-SG**, whose valuable guidance and knowledge helped me to learn professionalism in the real sense. Without her help, the project would have been a distant reality. Our exchange of thoughts, skills and her insightful comments during my project work helped me to enrich my experience.

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Finally, I thank my **papa**, **mamma** and my **sister** for all the confidence and trust they put in me.

"I also place on record, my sense of gratitude to one and all who, directly or indirectly, have lent their helping hand in finishing this project**"**

ABSTRACT

Various optical and microwave sensors such as LISS-III, LISS-IV, SCATSAT-1, sentinel-1, AVIRIS-NG and Hyperion can be used to study various Land applications such as Agriculture and ecosystems, Forestry, Mineral resource mapping, Coastal ocean, Rivers and water quality, Urban Planning, Snow and Ice Hydrology, CAL-VAL, Cloud and atmosphere.

In my study, I have used the data products of hyperspectral imagers AVIRIS-NG and Hyperion for Mangrove Species Discrimination. Hyperspectral imager measures earth's radiance in narrow bandwidths in many contiguous spectral bands. It has the capability of understanding the fundamental processes that govern changes due to biophysical and biochemical properties of the region imaged.

In this project, **First** the spectral subsetting of the data products is done by the removal of absorption bands and bad bands. **Second**, creation of spectral library with the use of in-situ GT locations. **Third,** mangrove species classification using SAM classifier. **Fourth,** Marine and fresh water discrimination in AVIRIS-NG and Hyperion. **Fifth,** comparison of AVIRIS-NG and Hyperion classified images.

Additionally, I have also had a hands on experience on SCATSAT scatterometer data products.

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NOMENCLATURE/ABBREVIATIONS

SAM	Spectral angle Mapper
NIR	Near Infrared
SWIR	Short-wave Infrared
GUI	Graphical User Interface

1. INTRODUCTION

1.1 BACKGROUND OF REMOTE SENSING

"**Remote sensing** is the science of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy. The recorded data is processed and analyzed for information extraction."

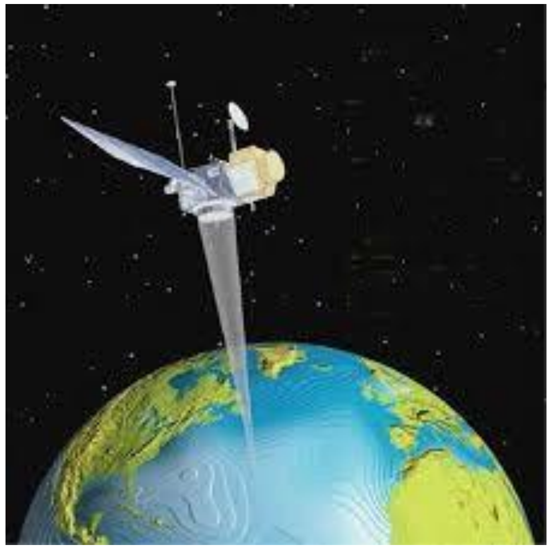


Fig. 1.1 - Remote Sensing

Reference : http://www.brahmand.com/news/India-opens-up-remote-sensing-data-sector/7434/1/14.html

The term Remote Sensing means the sensing of the Earth's surface from space by making use of the properties of electromagnetic waves emitted, reflected by the sensed objects, for the purpose of improving natural resources management, land use and the protection of the environment.

1.2 HYPERSPECTRAL REMOTE SENSING

Hyperspectral remote sensing [1] is defined as the simultaneous acquisition of images in many narrow, contiguous spectral bands. Spectroscopy measures the radiant intensity and energy of the interaction between light and matter to determine its molecular structure. In absorption spectroscopy, the compound that interacts with light behaves as a passive element. It absorbs some of the emitted photons depending on their wavelength, to form the so-called spectral signature. Light which is not absorbed can be transmitted through the sample of the compound or diffusely reflected on it. Once the spectrum of the diffuse reflectance is obtained, it must be processed for the material classification, identification and discrimination.

Hyperspectral sensors are specially designed to acquire images of objects in hundreds of narrow spectral bands. The spectral signatures extractable from the hyperspectral image cube can be used to classify or recognize objects, materials in the region viewed. Typically, hyperspectral imaging devices capture light in the range of 350 nm – 2500 nm, covering the visible, near infrared (NIR), and short wave infrared (SWIR) frequency bands.

1.2.1 TYPES OF HYPERSPECTRAL SENSORS

1.2.1.1 AIRBORNE HYPERSPECTRAL REMOTE SENSING

Airborne hyperspectral surveys are carried out using imaging spectrometers mounted on aircraft. Flight lines are planned so that adjacent strips must have overlapping acquisition area, to ensure complete ground cover. Each strip is composed of successive scan lines acquired by the scanner along the flight line. Airborne hyperspectral surveys, therefore, capture images of the Earth's surface in narrow contiguous wavelength partitions or spectral bands, to create a data cube from which diagnostic spectra can be obtained for each pixel in the image.

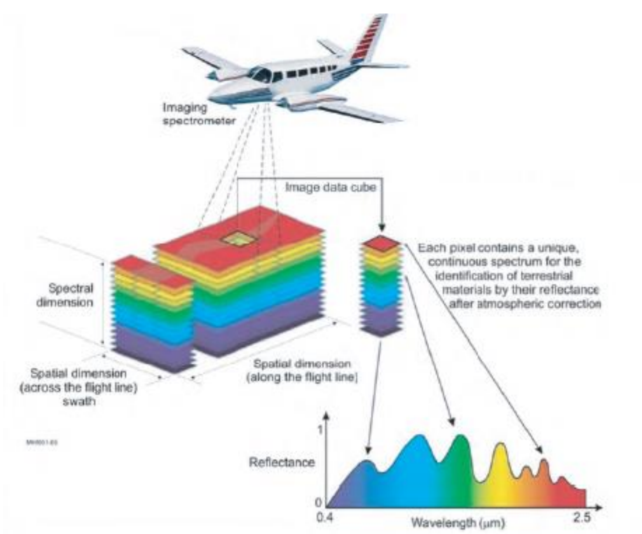


Fig 1.2.1.1 - Airborne hyperspectral remote sensing

Reference : http://www.hyvista.com/technology/hyperspectral-theory/

1.2.1.2 SPACEBORNE HYPERSPECTRAL REMOTE SENSING

In spaceborne hyperspectral remote sensing, sensors are mounted on-board a spacecraft (space shuttle or satellite) orbiting the earth. It provides a larger area coverage as well as frequent and repetitive coverage of area of interest. But, Airborne hyperspectral product has a better and higher spatial resolution as compared to Spaceborne hyperspectral product.

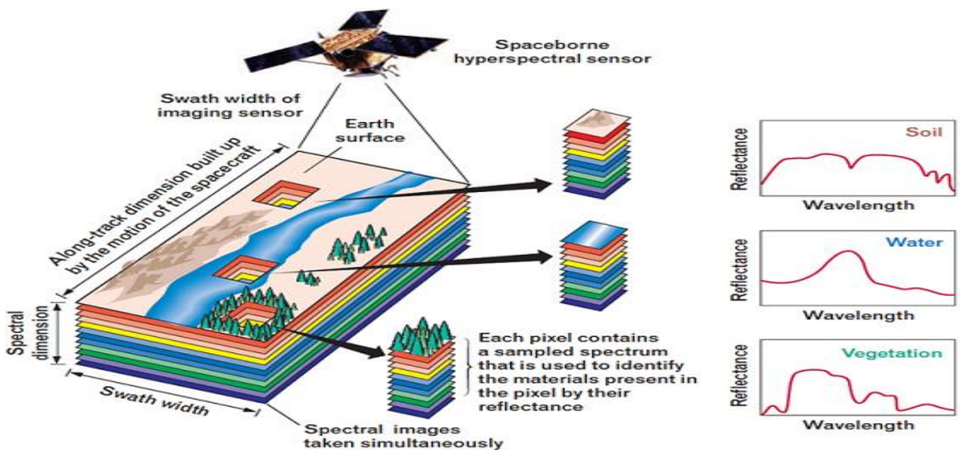


Fig 1.2.1.2 - Spaceborne hyperspectral remote sensing

Reference : http://www.eoc.csiro.au/hswww/overview.html

2. OBJECTIVE

The primary objective of this project is "**INVESTIGATION OF MULTI-FREQUENCY DATA OF VARIOUS SENSORS FOR LAND APPLICATIONS**".

Detailed Objective:

- Hyperspectral processing of AVIRIS-NG and Hyperion data products.
- Comparison of AVIRIS-NG and Hyperion data.
- Mangrove species discrimination using the spectral library.

3. MATHODOLOGY

3.1 BAD BANDS REMOVAL

Optical remote sensing depends on solar radiation as the source of illumination. Atmospheric absorption reduces the solar radiance within the absorption bands of the atmospheric gases. The reflected radiance is also attenuated after passing through the atmosphere. This attenuation is wavelength dependent. It affects mainly the visible and infrared bands. Hence, atmospheric absorption or Fraunhofer lines will alter the apparent spectral signature of the target being observed. In the spectral signature given in Fig 3.1(a), bands with wavelength 1334 – 1477 nm and 1794 – 1943 nm are the absorption bands and 380 – 445 nm and 2426 – 2510 nm are the bands with negative values [2].

In order to classify the Hyperspectral data for any land applications, these bands are to be removed before any further processing.

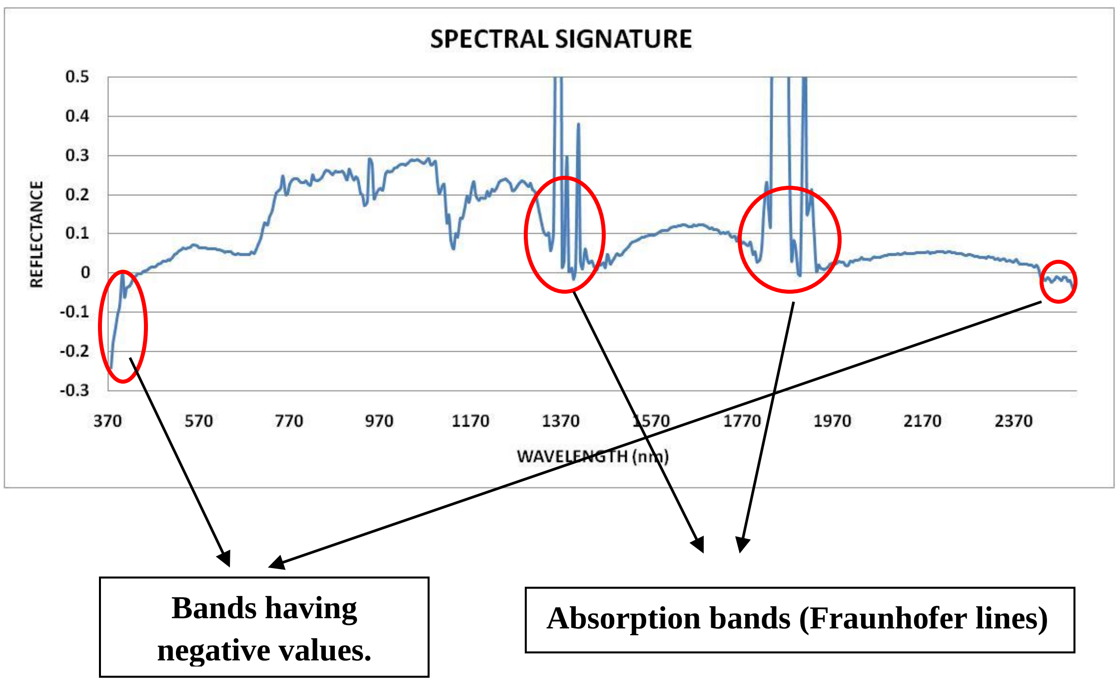


Fig 3.1 - Spectral signature

3.2 SPECTRAL ANGLE MAPPING

The Spectral Angle Mapper (SAM) [4] algorithm is based on an ideal assumption that a single pixel of remote sensing images represents one certain ground cover material, and can be uniquely assigned to only one ground cover class. The SAM algorithm is based on the measurement of the spectral similarity between two spectra's. The spectral similarity can be obtained by considering each spectrum as a vector in n -dimensional space, where n is the number of bands. The SAM algorithm determines the spectral similarity between two spectra's by calculating the angle between the two spectra's, treating them as vectors in a space with dimensionality equal to the number of bands.

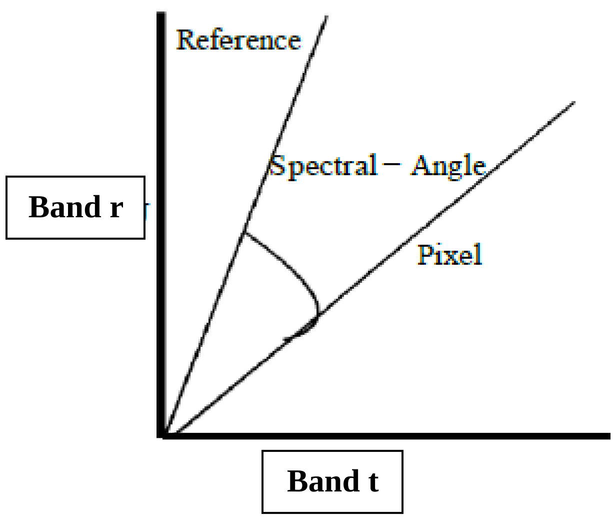


Fig 3.2 - Representation of reflectance angle

The SAM algorithm generalizes this geometric interpretation to n-dimensional space [4]. SAM determines the similarity by applying the following equation:

$$a = \cos^{-1}\left(\frac{\sum_{i=1}^{nb} t_i r_i}{\sqrt{\sum_{i=1}^{nb} t_i^2}\sqrt{\sum_{i=1}^{nb} r_i^2}}\right)$$

Where**, nb: the number of bands in the image**

t: pixel spectrum

r: reference spectrum

alpha: spectral angle

4. DESCRIPTION OF DATA USED

4.1 AVIRIS-NG (AIRBORNE HYPERSPECTRAL MISSION)

The advanced AVIRIS instrument, i.e., AVIRIS-NG uses most advanced state-of the-art detector array and grating for dispersion of light. Most importantly, the blazing and grooving technique employed in the grating of AVIRIS-NG could successfully maintain the spectral as well as spatial uniformity. The AVIRIS flights over Indian sub-continent were conducted during the year 2015-2016. The AVIRIS-NG can take observations over a continuous electromagnetic spectrum spread over 380 – 2510 nm at 5 nm band interval. This is capable of providing hyperspectral observations at 6 m pixel resolution over a flight swath of 6 km when the flight altitude is about 6 – 7 km.

4.2 HYPERION (SPACEBORNE SENSOR)

The Hyperion instrument on the EO-1 satellite of NASA provides Earth observation data for improved Earth surface characterization. The Hyperion provides a science grade instrument with quality calibration based on heritage from the LEWIS Hyperspectral Imaging Instrument (HSI). The Hyperion provides 30-meter resolution hyperspectral data with 242 spectral bands from 400-2500 nm. The instrument can image a 7.5 km by 100 km land area per image, and provide detailed spectral mapping across all 242 channels with high radiometric accuracy.

4.3 HYPERSPECTRAL DATA PRODUCT DESCRIPTION

Table 4.3 shows the comparison of AVIRIS-NG and HYPERION data products.

DATA PRODUCT	DATE OF FLIGHT	NUMBER OF BANDS	SPECTRAL RANGE (In nm)	SPECTRAL RESOLUTION (in nm)	SPATIAL RESOLUTION (in m)	Area (in km)
AVIRIS-NG	**5th March, 2016**	**425**	**380-2510**	**5**	**4.6**	**6X15.8**
HYPERION	**23rd November, 2014**	**242**	**400-2500**	**10-11**	**30**	**7.5X100**

Table 4.3 - Hyperspectral data product description

4.4 STUDY AREA

The Indian Sundarbans (21°31′00″ N - 22°30′00″ N, 88°10′00″ E - 89°51′00″ E) is located on the southern border in the state of West Bengal. It is located over the major portion of the districts of North 24-Parganas and South 24-Parganas. The region is bordered by Harinbhanga-Raimangal River along the International boundary with Bangladesh in the east, the Hooghly River in the west. Sunderbans is the largest mangrove forest of Asia. The region enclosed in yellow lines was imaged using AVIRIS-NG.

Fig 4.4 - Study Area

5. FLOWCHART

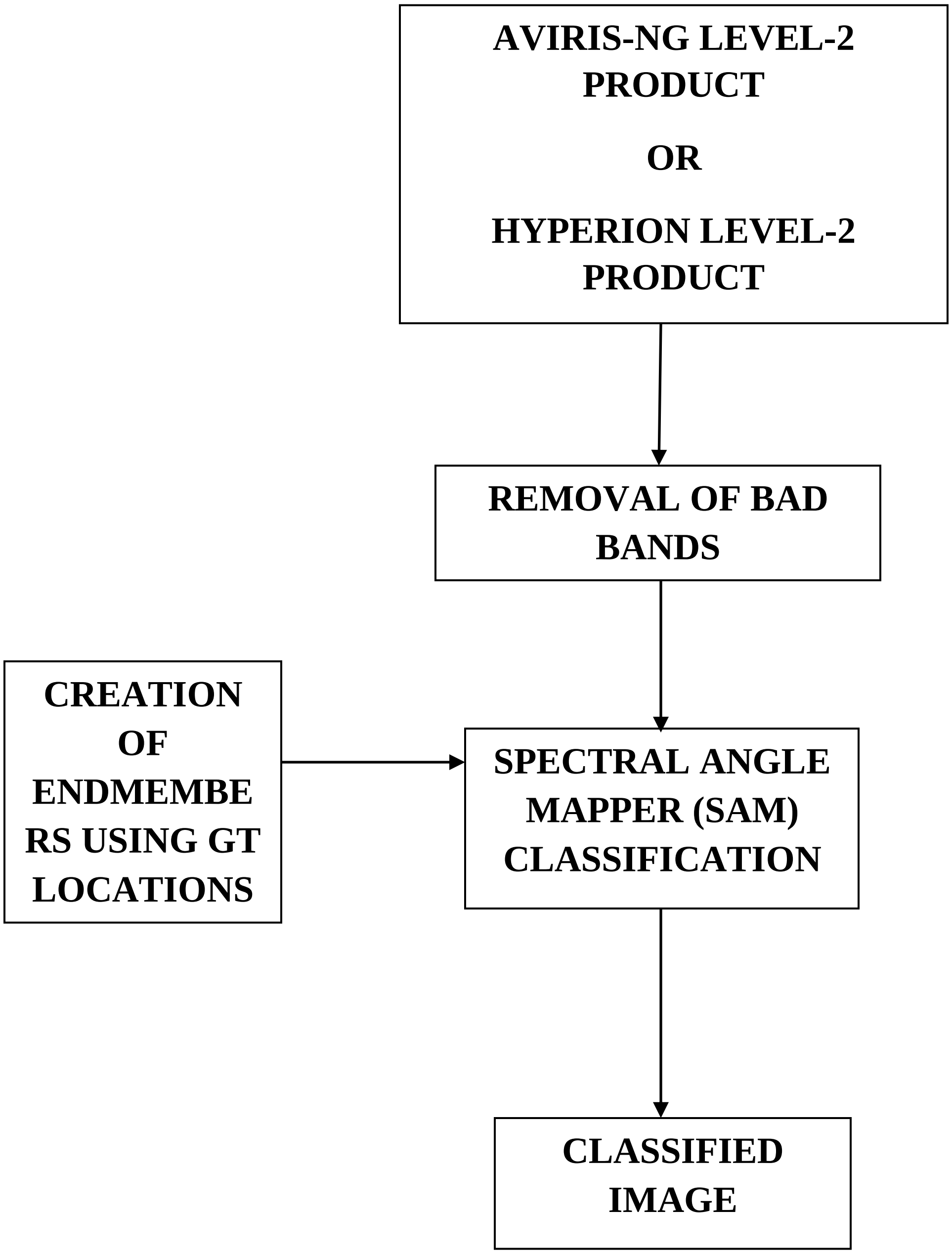


Fig 5 - Flowchart of hyperspectral image processing

6. RESULTS.

Fig 6(a) and 6(b) depict the Spectral cube of the AVIRIS-NG and Hyperion data with the various spectral signatures. The absorption bands and the bands comprising the negative values have been removed from the image spectra.

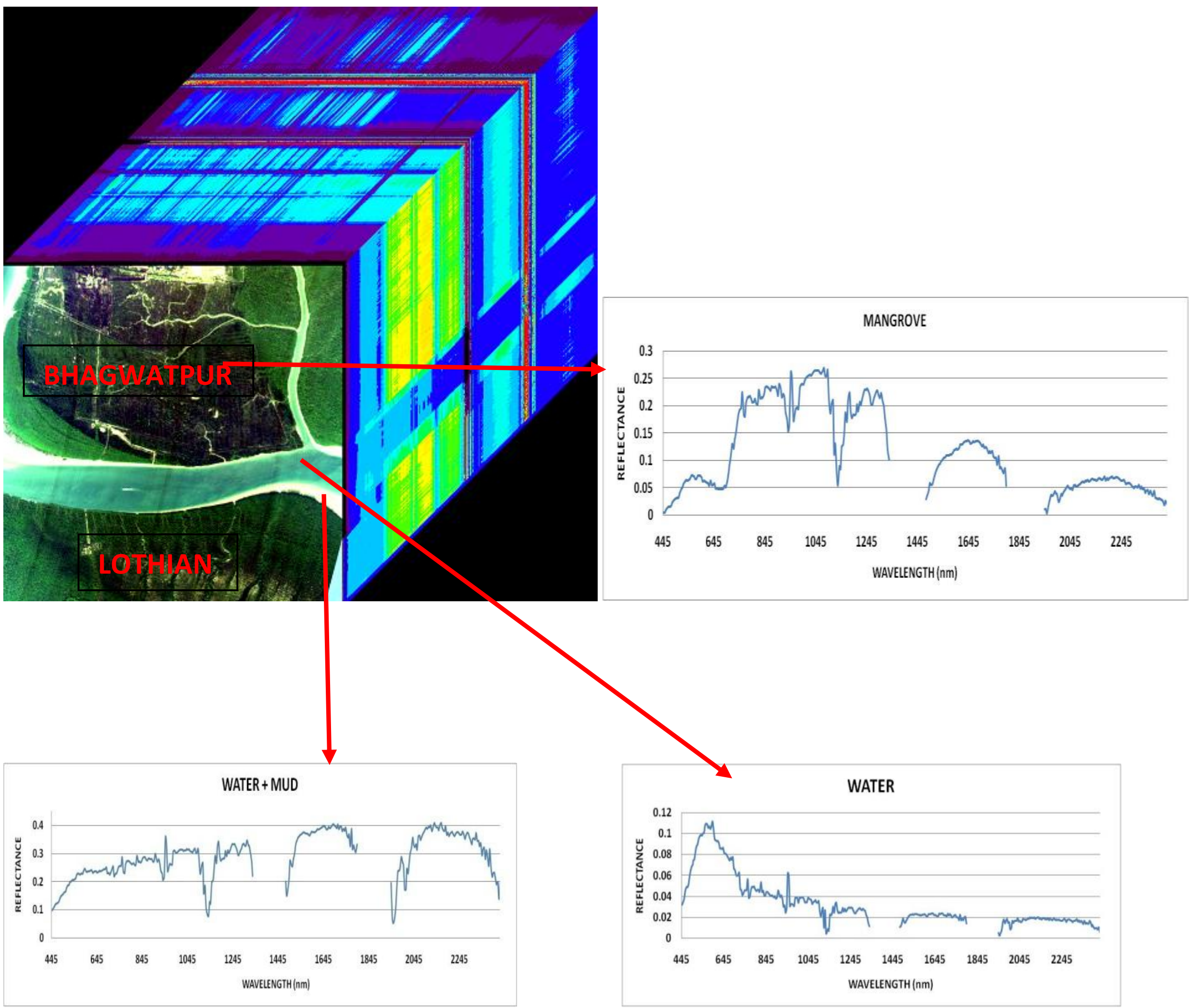


Fig 6(a) – AVIRIS-NG spectral cube with different spectral signatures

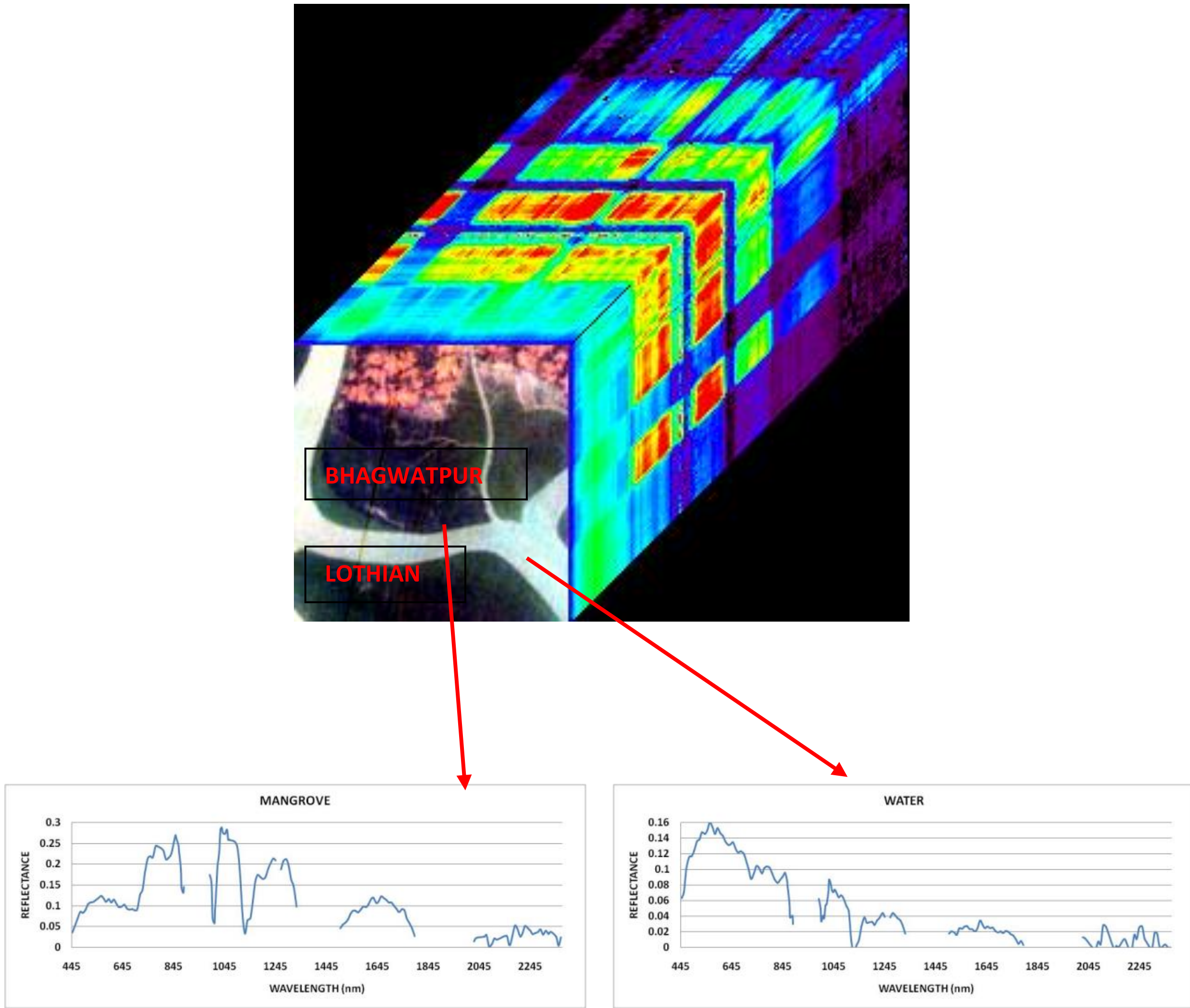


Fig 6(b) – Hyperion spectral cube with different spectral signatures

In the Band removal process of AVIRIS-NG and Hyperion data products, 339 bands out of 425 and 148 bands out of 242 were taken for processing [3]. Fig 6(c) and 6(d) show the spectral signatures of different mangrove species of AVIRIS-NG and Hyperion spectral library.

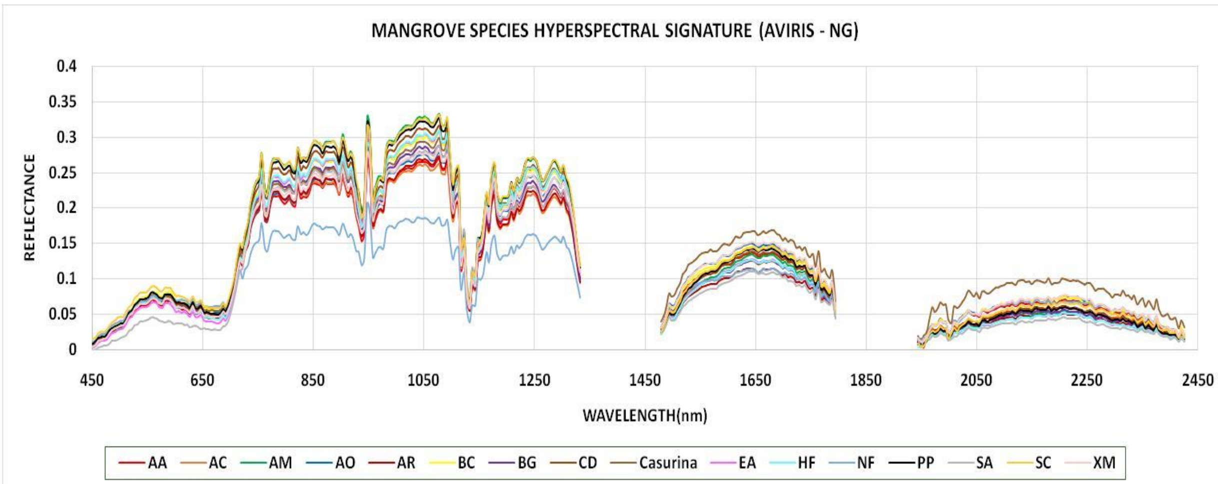


Fig 6(c)- Mangrove species hyperspectral signature of AVIRIS-NG spectral library

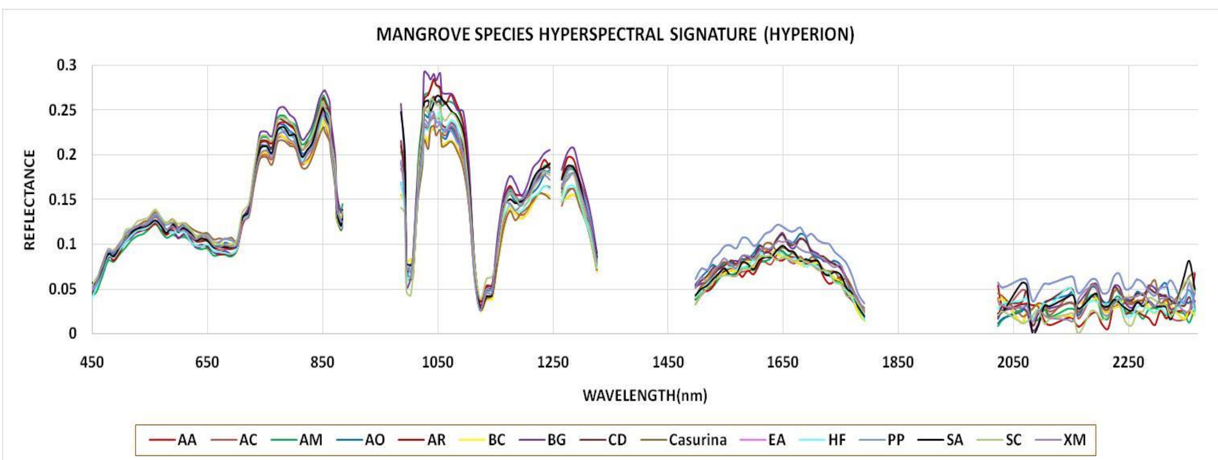


Fig 6(d)- Mangrove species hyperspectral signature of Hyperion spectral library

Fig 6(e) and 6(f) depict the correlation between different mangrove species in AVIRIS-NG and Hyperion data. From the figure 6(e) and 6(f), it can be observed that the mangrove species signatures in AVIRIS-NG are better correlated as compared to Hyperion species signatures.

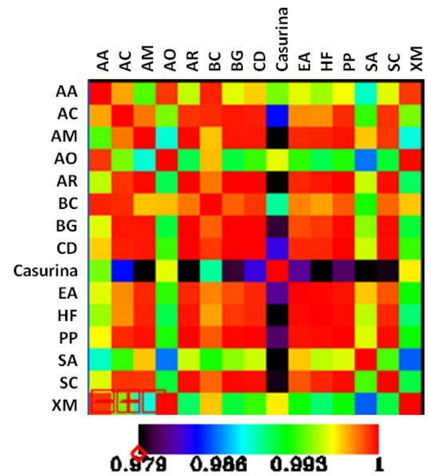


Fig 6(e) – Species correlation (AVIRIS-NG)

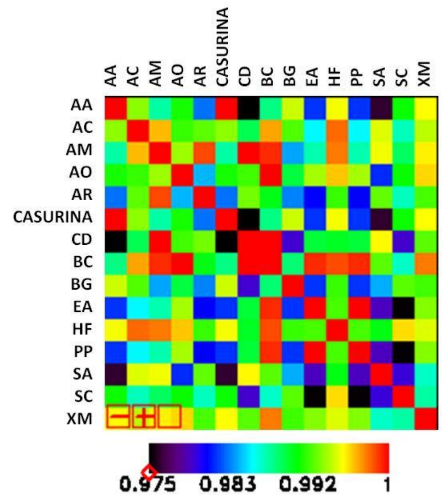


Fig 6(f) –Species correlation (Hyperion)

Fig 6(g) and 6(h) show the RGB image of AVIRIS-NG and Hyperion data. The RGB image is constructed using wavelengths R-641.9 nm, G-551.74 nm and B-461.59 nm for AVIRIS-NG and wavelengths R-640.5 nm, G-548.92nm and B-457.34 nm for Hyperion. Fig 6(i) and 6(j) show the SAM classified image of AVIRIS-NG and Hyperion.

Fig 6(g) – RGB image of AVIRIS-NG

Fig 6(h) – RGB image of Hyperion

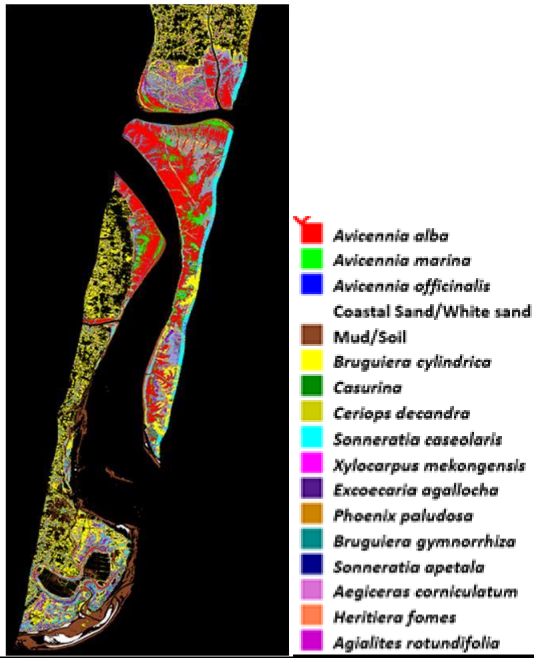


Fig 6(i)- Mangrove species discrimination of AVIRIS-NG data (using SAM classification)

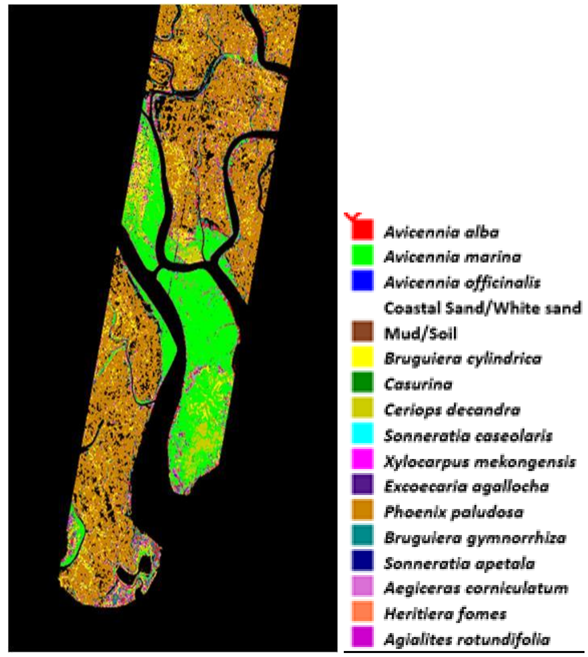


Fig 6(j)- Mangrove species discrimination of Hyperion data (using SAM classification)

Apart from mangrove species discrimination, hyperspectral data also has capability to discriminate between marine and fresh water.

Fig 6(k) and 6(l) show the spectral signature of marine water and fresh water of AVIRIS-NG and Hyperion data.

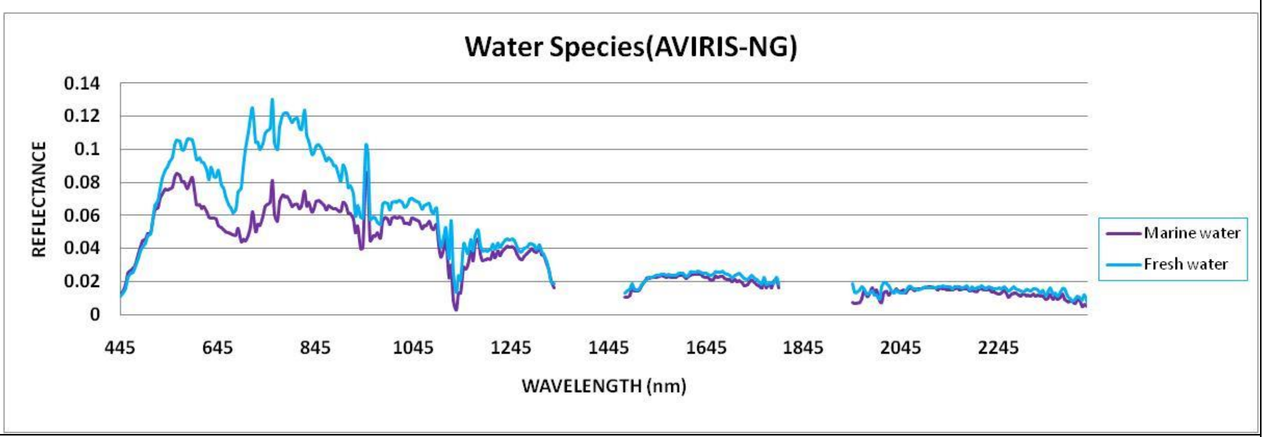


Fig 6(k) – Spectral signature of water from different sources (AVIRIS-NG)

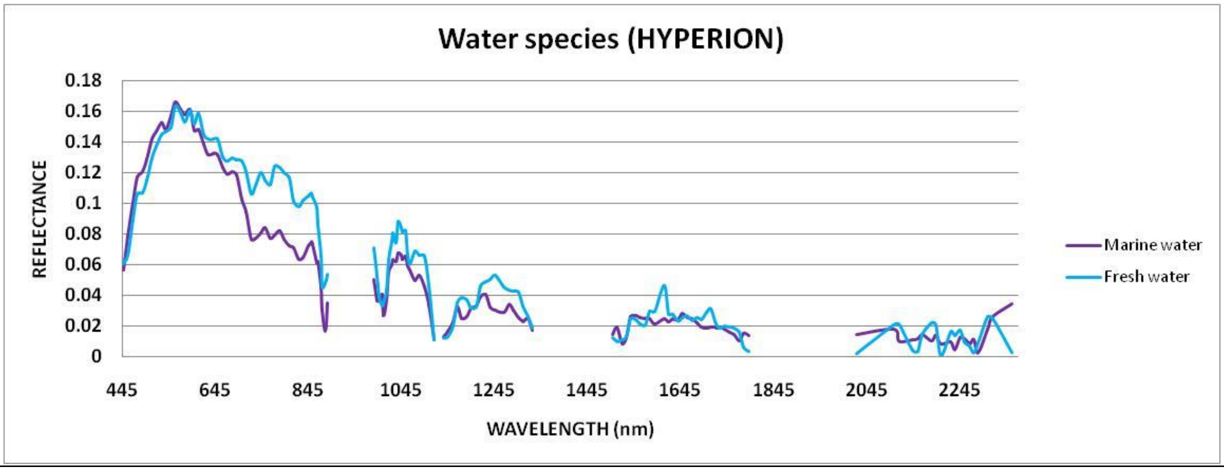


Fig 6(l) - Spectral signature of water from different sources (Hyperion)

Fig 6(m) and 6(n) depict the water classification of AVIRIS-NG and Hyperion using the spectral signature of marine water, fresh water and wet mud as endmembers in SAM classification.

Fig 6(m) – Classification of water from different sources (AVIRIS-NG)

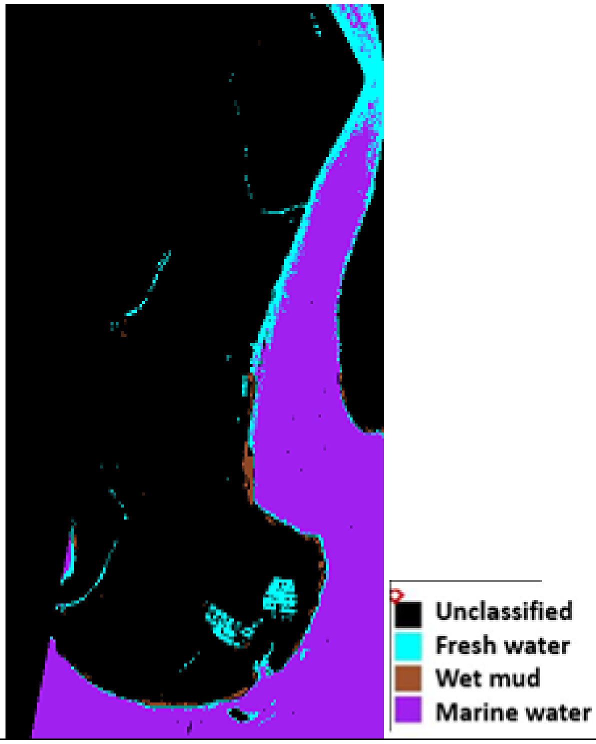


Fig 6(n) – Classification of water from different sources (Hyperion)

The detailed classification of AVIRIS-NG and Hyperion data over Bhagwatpur, Lothian and Henry island in Sundarbans, West Bengal is shown in figures from Fig 6(o) to Fig 6(z).

Fig 6(o), 6(q), 6(s) and 6(u) shows the RGB image of AVIRIS-NG and Hyperion data over Bhagwatpur and Lothian. The RGB image is obtained at wavelengths R-641.9 nm, G-551.74 nm and B-461.59 nm for AVIRIS-NG and wavelengths R-640.5 nm, G-548.92nm and B-457.34 nm for Hyperion. Fig 6(p), 6(r), 6(t) and 6(v) shows corresponding classified images over Bhagwatpur and Lothian.

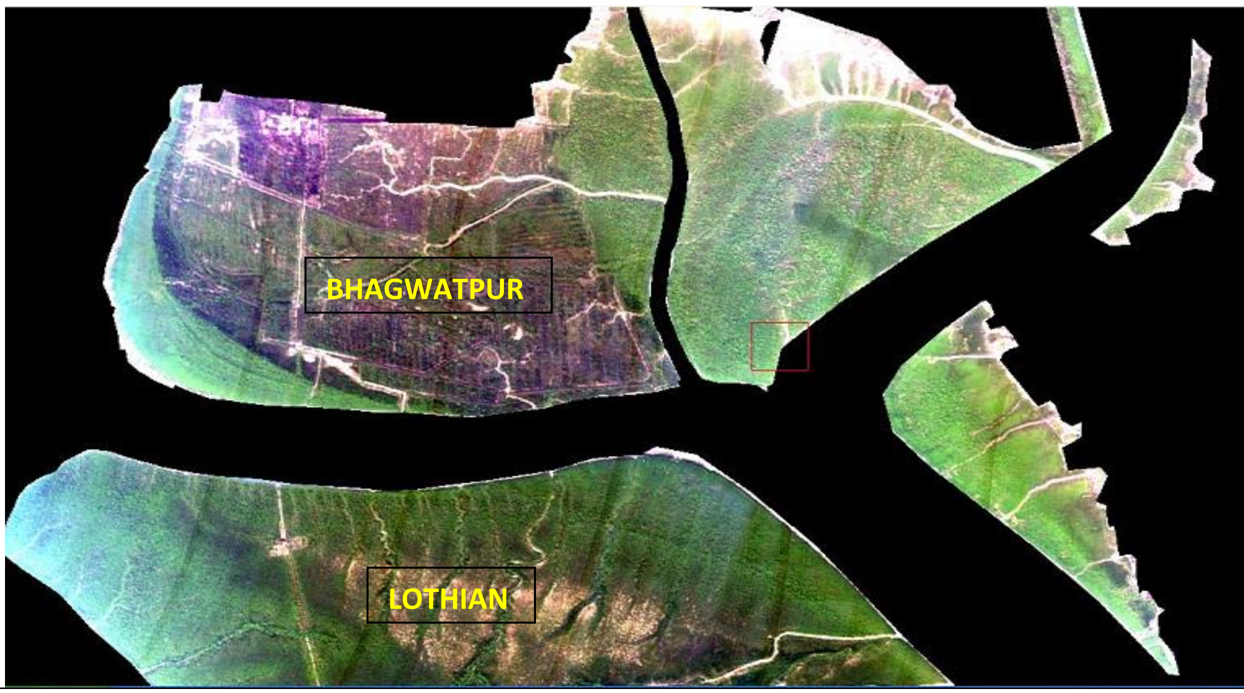


Fig 6(o) – RGB image of AVIRIS-NG data (Bhagwatpur and Lothian)

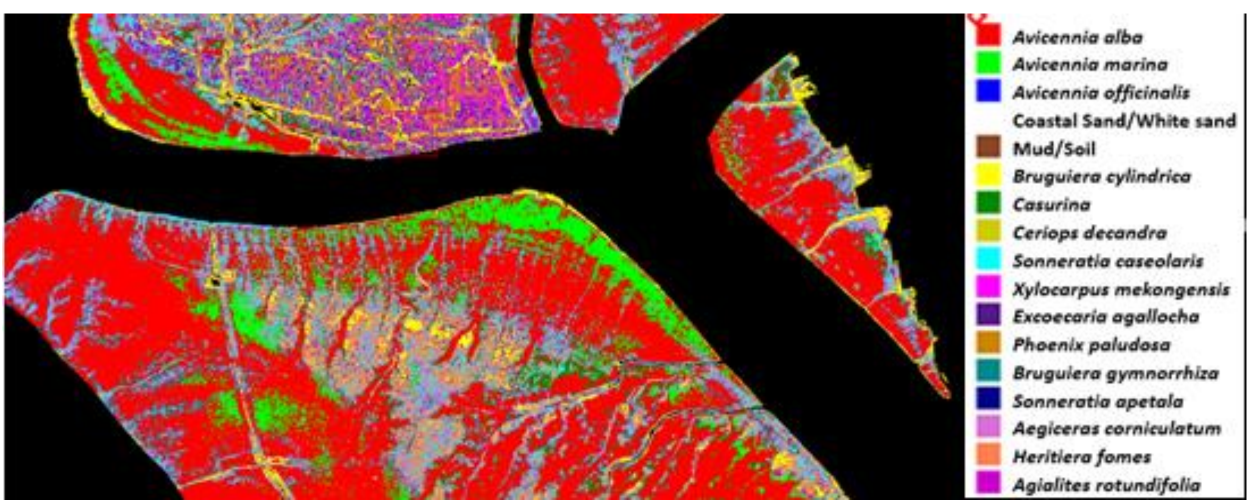


Fig 6(p) – Mangrove species discrimination (using SAM classification)(AVIRIS-NG)

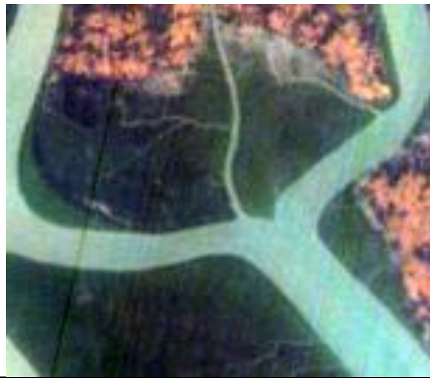
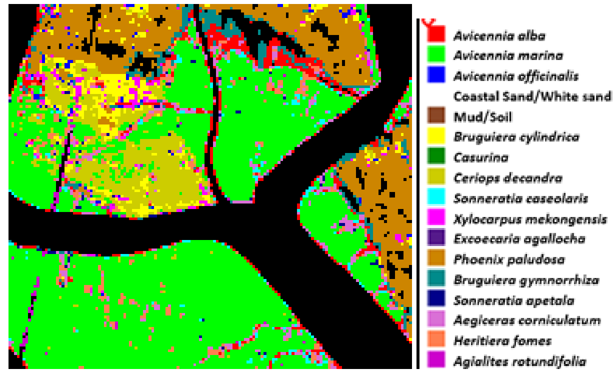
	

Fig 6(q) – RGB image of Hyperion data (Bhagwatpur and Lothian)	**Fig 6(r) – Mangrove species discrimination (using SAM classification)(Hyperion)**

Fig 6(s) – RGB image of AVIRIS-NG data (over Lothian)

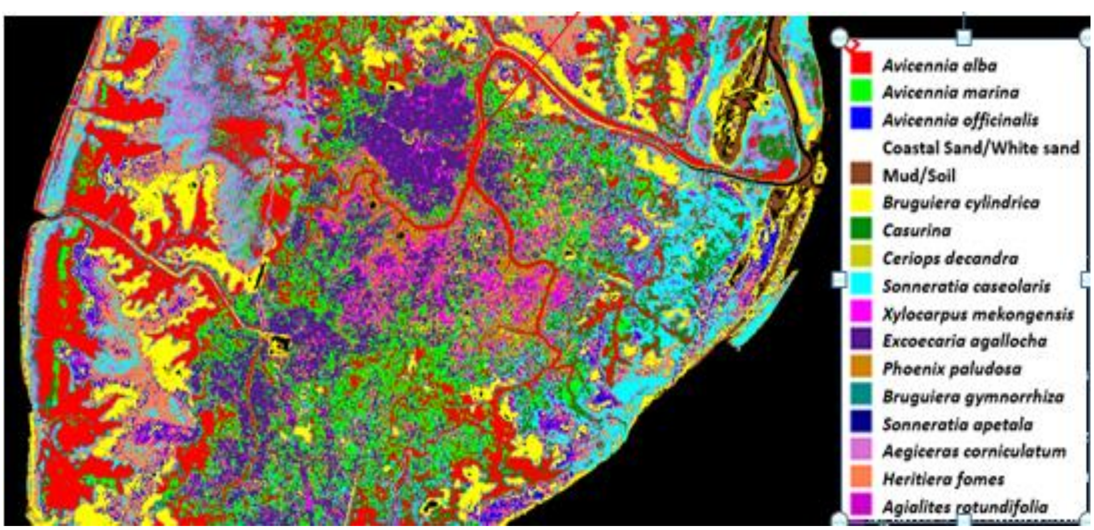


Fig 6(t) – Mangrove species discrimination (using SAM classification)(AVIRIS-NG)

Fig 6(u) – RGB image of Hyperion data (over Lothian)

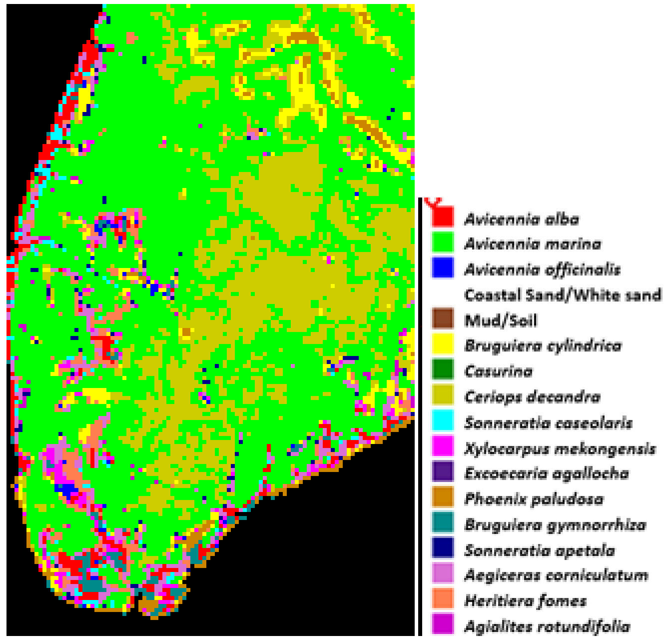


Fig 6(v) – Mangrove species discrimination (using SAM classification)(Hyperion)

Fig 6(w), 6(x), 6(y) and 6(z) depicts the RGB image and the corresponding classified image of AVIRIS-NG and Hyperion data over Henry island. In the classified image, both mangrove and non-mangrove species are discriminated.

Fig 6(w) – RGB image of AVIRIS-NG data (over Henry island)

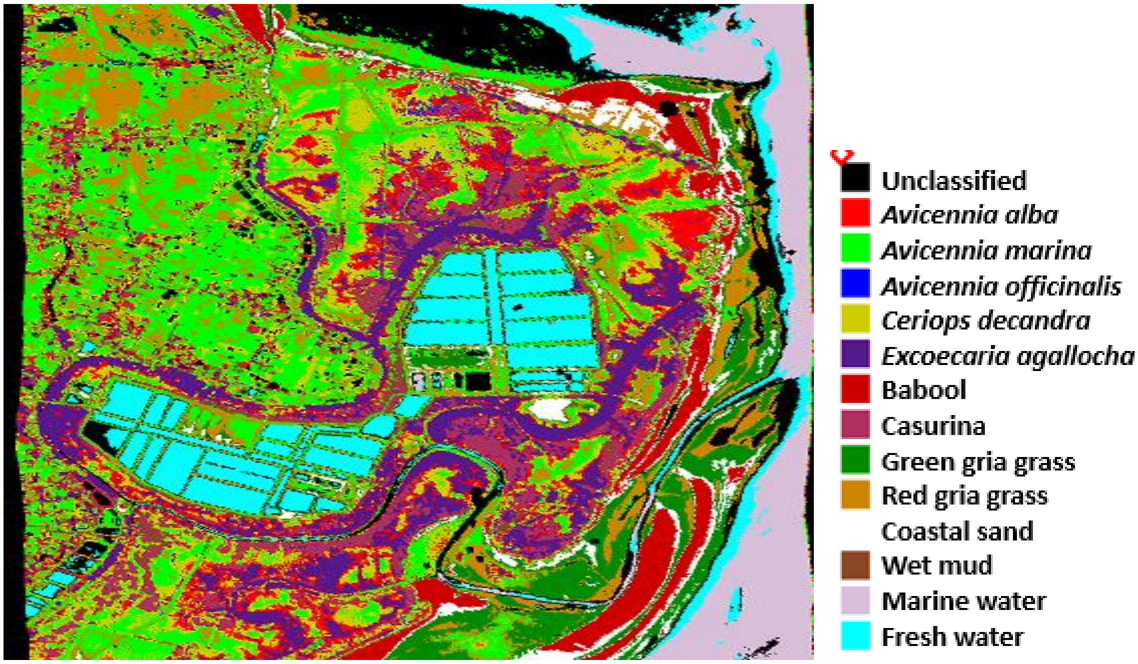


Fig 6(x) – Mangrove and Non- mangrove species discrimination (using SAM classification)(AVIRIS-NG)

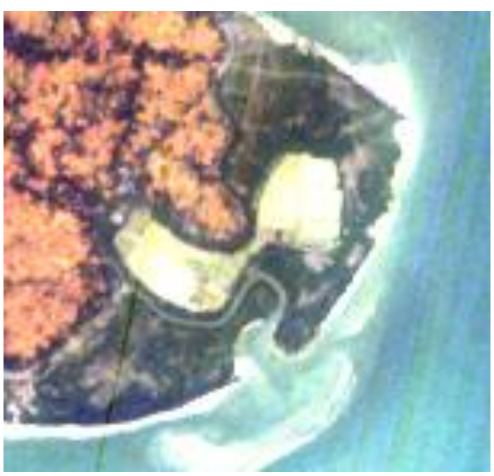


Fig 6(y) – RGB image of Hyperion data (over Henry island)

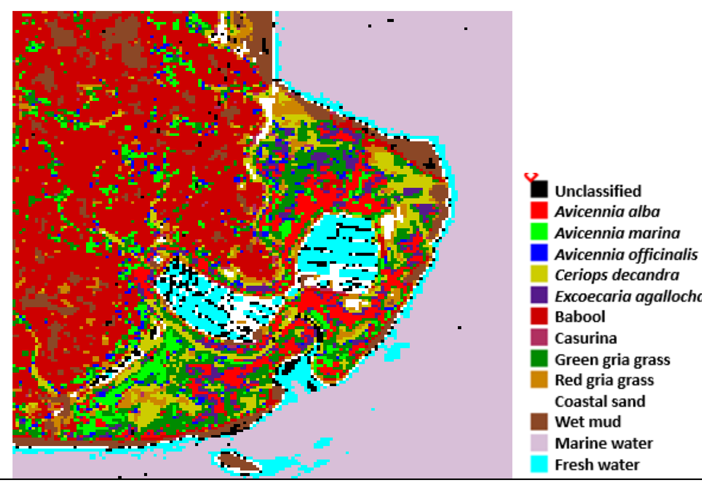


Fig 6(z) – Mangrove and Non-Mangrove species discrimination (using SAM classification)(Hyperion)

7. CONCLUSION

From the above results, it can be observed that Hyperion data is not capable of identifying and discriminating different mangrove species in comparison to AVIRIS-NG. The low resolution 30 m Hyperion data cannot differentiate the spectral signatures of different species, while high resolution (4.6 m) of AVIRIS-NG could classify 15 species out of 19.

Table 7 shows the classified and unclassified species in Sundarbans.

BOTANICAL NAME	LOCAL NAME	SPECIES CLASSIFIED IN DATA
Avicennia alba (AA)	**Kala bani**	Classified
Avicennia corniculatum (AC)	**Kholsi**	Classified
Acanthus ilicifolius (AI)	**Hargoja**	Unclassified
Avicennia marina (AM)	**Peyara bani**	Classified
Avicennia Officinalis (AO)	**Jaat bani**	Classified
Agialites rotundifolia (AR)	**Tora**	Classified
Bruguiera gymnorrhiza (BG)	**Kankra**	Classified
Bruguiera cylindrica (BC)	**Bakul kankra**	Classified
Casurina (CA)	**Nona jhau**	Classified
Ceriops decandra (CD)	**Jaat goran**	Classified
Ceriops tagal (CT)	**Mot goran**	Unclassified
Excoecaria agallocha (EA)	**Genwa**	Classified
Heritiera fomes (HF)	**Sundari**	Classified
Phoenix paludosa (PP)	**Hental**	Classified
Nypa fruticans (NF)	**Golpata**	Unclassified
Sonneratia apetala (SA)	**Keora**	Classified
Sonneratia caseolaris (SC)	**Chak keora**	Classified
Xylocarpus granatum (XG)	**Passur**	Unclassified
Xylocarpus mekongensis (XM)	**Dhundhul**	Classified

Table 7 – Mangrove species in Sundarbans

It can also be observed that both AVIRIS-NG and Hyperion have been able to discriminate between marine water and fresh water. Thus, hyperspectral data with a low spatial resolution can be used in the field of hydrology.

8. REFERENCES

[1] José M. Bioucas-Dias, Antonio Plaza, Gustavo Camps-Valls, Paul Scheunders, Nasser M. Nasrabadi and Jocelyn Chanussot (2013), Hyperspectral remote sensing data analysis and Future challenges, ieee Geoscience and remote sensing magazine, 2168-6831/13

[2] Karl H. Szekielda, Jeffrey H. Bowles, David B. Gillis and W. David Miller (2009), Interpretation of Absorption Bands in Airborne Hyperspectral Radiance Data, Sensors – Open Access Journal, 2907-2925

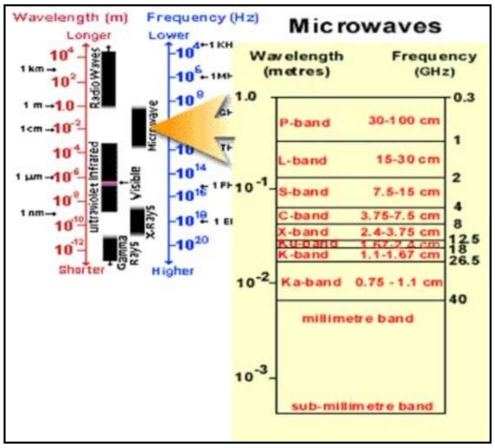
[3] Kishore M. and Dr. S. B. Kulkarni (2015), Hyperspectral Imaging Technique for Plant Leaf Identification, International Conference on Emerging Research in Electronics, Computer Science and Technology, 978-1-4673-9563-2/15.

[4] Rashmi S, Swapna Addamani, Venkatand Ravikiran S (2014), Spectral Mapper Algorithm for Remote sensing image classification, IJISET - International Journal of Innovative Science, Engineering & Technology, ISSN 2348 – 7968.

9. ADDITIONAL WORK

9.1 Microwave Remote Sensing

Microwave Remote Sensing is the technique of analyzing the information collected by the sensors that operates in the microwave portion of the electromagnetic spectrum. The microwave portion of the spectrum includes wavelengths within the approximate range of 1mm to 1m. These long waves have the capability of penetrating through the clouds, thus overcoming the atmospheric effects which are often encountered in the visible and infrared regions of the Electromagnetic region.



BAND	WAVELENGTH (cm)	FREQUENCY GHz (10^9 Cycles/sec)
Ka	0.75 - 1.1	26.5 - 40
K	1.1 - 1.67	18 - 26.5
Ku	1.67 - 2.4	12.5 - 18
X	2.4 - 3.8	8 - 12.5
C	3.8 - 7.5	4 - 8
S	7.5 - 15	2 - 4
L	15 - 30	1 - 2
P	30 - 100	0.3 - 1

Fig 9.1 - Microwave Bands

Reference : http://hosting.soonet.ca/eliris/remotesensing/b1/30lec13.html

9.1.2 TYPES OF MICROWAVE SENSORS

9.1.2.1 Active Microwave Sensors

Active microwave sensors provide their own source of microwave radiation to illuminate the target.

9.1.2.2 Passive Microwave Sensors

A passive microwave sensor detects the naturally emitted microwave energy within its field of view. This emitted energy is related to the temperature properties of the emitting object or surface.

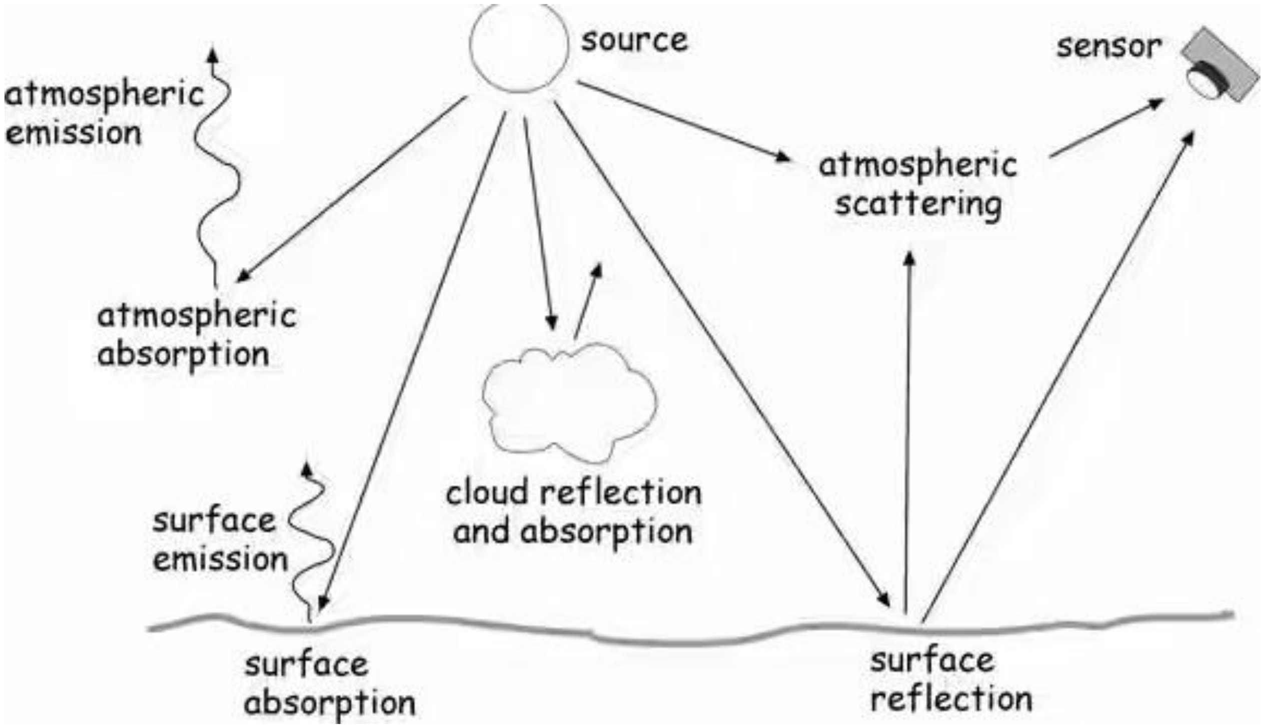


Fig 9.1.2 - Active and Passive microwave remote sensing

Reference : http://gis.depaul.edu/shwang/teaching/geog258/lec6-rev.html

9.2 DESCRIPTION OF DATA USED

9.2.1 SCATSAT SATELLITE DATA

SCATSAT is a continuity mission for Oceansat-2 Scatterometer to provide wind vector data products for weather forecasting, cyclone detection and tracking services. The satellite carries Ku-band Scatterometer with an operating frequency of 13.515 GHz.

9.2.2 MICROWAVE DATA PRODUCT DESCRIPTION

- **DATA PRODUCT –** SCATSAT
- **SPATIAL RESOLUTION –** 2 km
- **FILE FORMAT –** TIFF (.tif format)
- **DATE OF DATA ACQUISTION –** 21st November 2016 to 24th April 2017

9.2.3 STUDY AREA

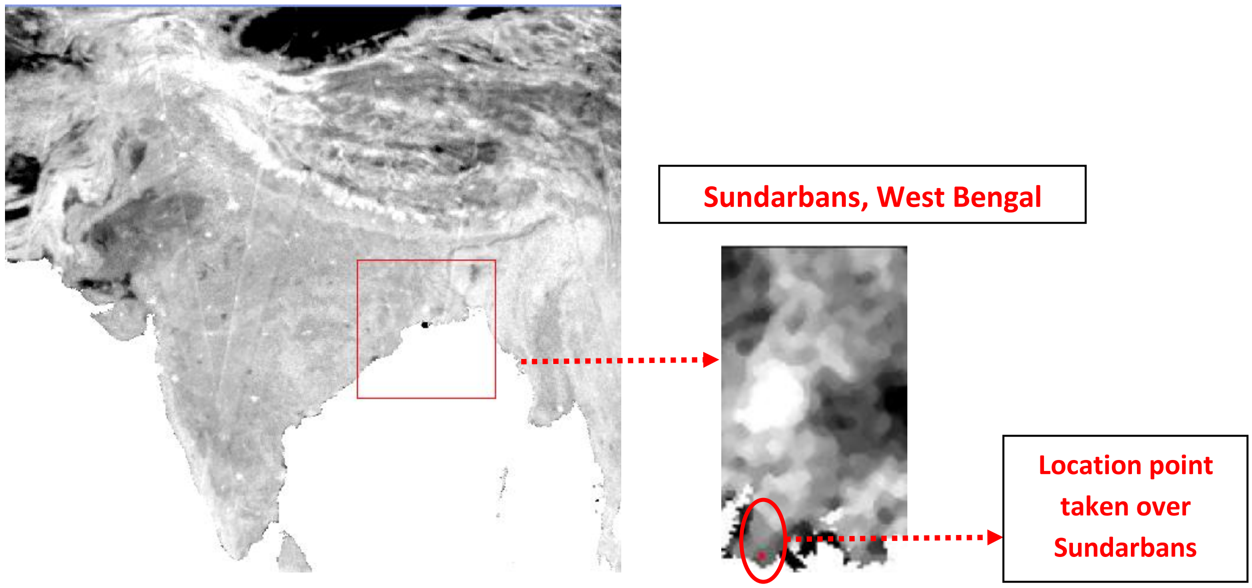


Fig 9.2.3 – Study area

9.3 SOFTWARE SPECIFICATIONS

9.3.1 MATLAB

MATLAB (Matrix Laboratory) is a fourth-generation high-level programming language and interactive environment for numerical computation, visualization, programming and GUI development. MATLAB is developed by Math Works.

For the Time series generation, a GUI was developed using MATLAB.

9.4 OVERVIEW OF THE DEVELOPED GUI

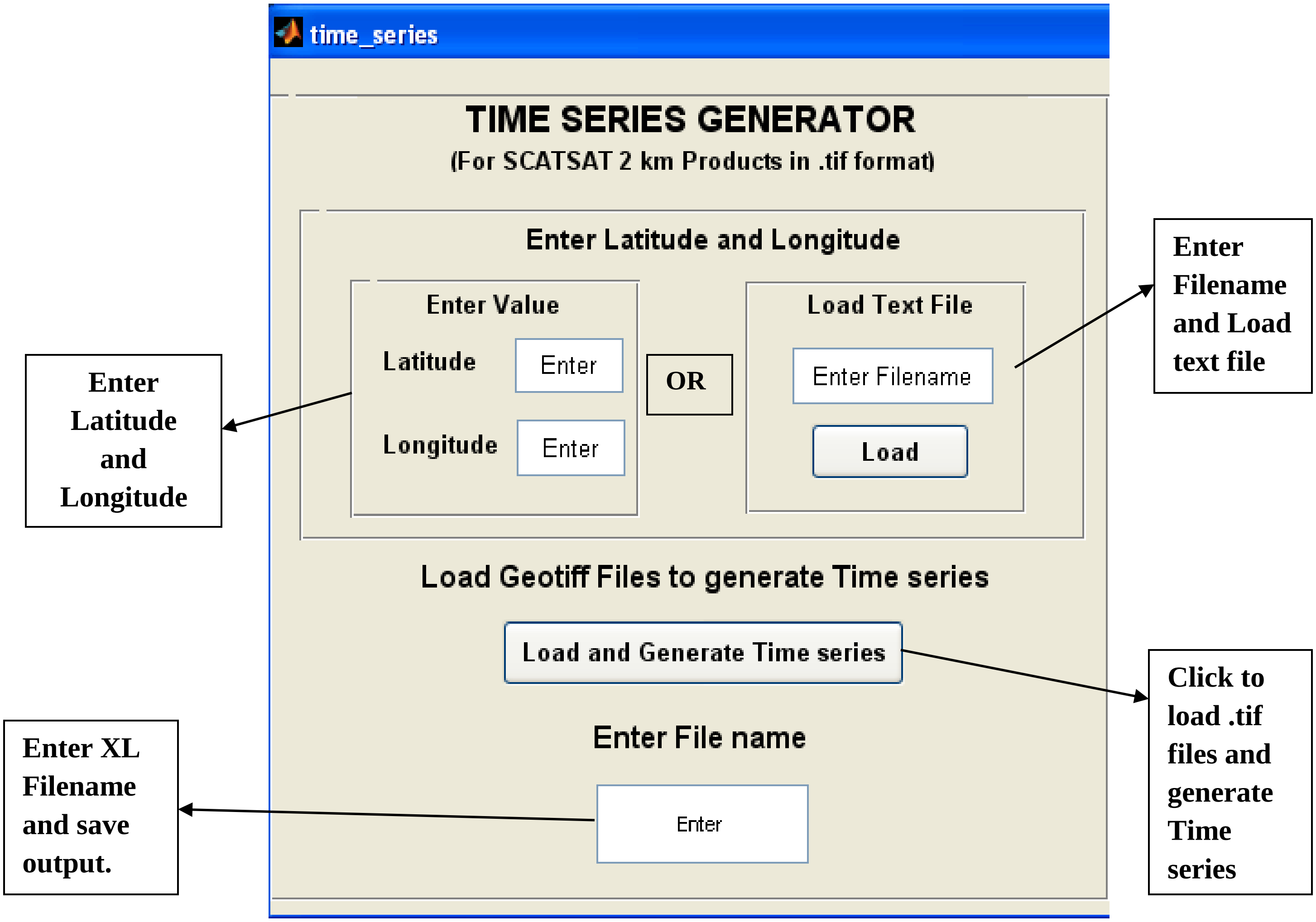


Fig 9.4 - GUI model for time series generation

Fig. 9.4 shows the overview of GUI model for time series generation from data products of SCATSTA-1 with a 2 km spatial resolution. Time series on any location over India can be generated with the use of this GUI.

9.5 RESULTS

In addition to Hyperspectral processing over Sundarbans (West Bengal) region, Microwave data of SCATSAT of spatial resolution 2 km of duration from 21st November, 2016 to 24th April, 2017 has been taken to study the temporal variation of backscatter over the same region.

Due to coarse spatial resolution of SCATSAT, only one point is taken over the study area at Latitude - 21°37′49.67″ N and Longitude - 88°19′20.12″ E. Fig 9.5(a) shows the temporal variation of Backscatter value. The time series was generated using the Time series generator GUI.

For this dataset, -44 and 0.000735 are the offset and scale value from 21st November 2016 to 7th January 2017. From 8th January 2017 to 24th April 2017, -50 and 0.001 are the offset and scale values.

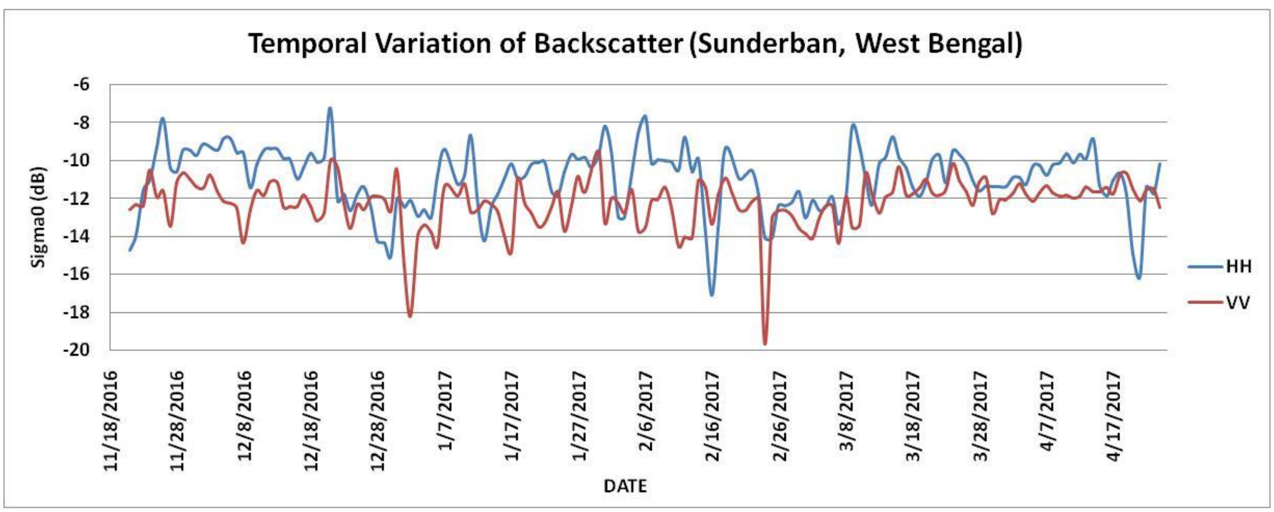


Fig 9.5(a) – Temporal Variation of Backscatter value over Sundarbans

Fig 9.5(b) shows the Temporal variation of backscatter value with a moving average window of 10 days.

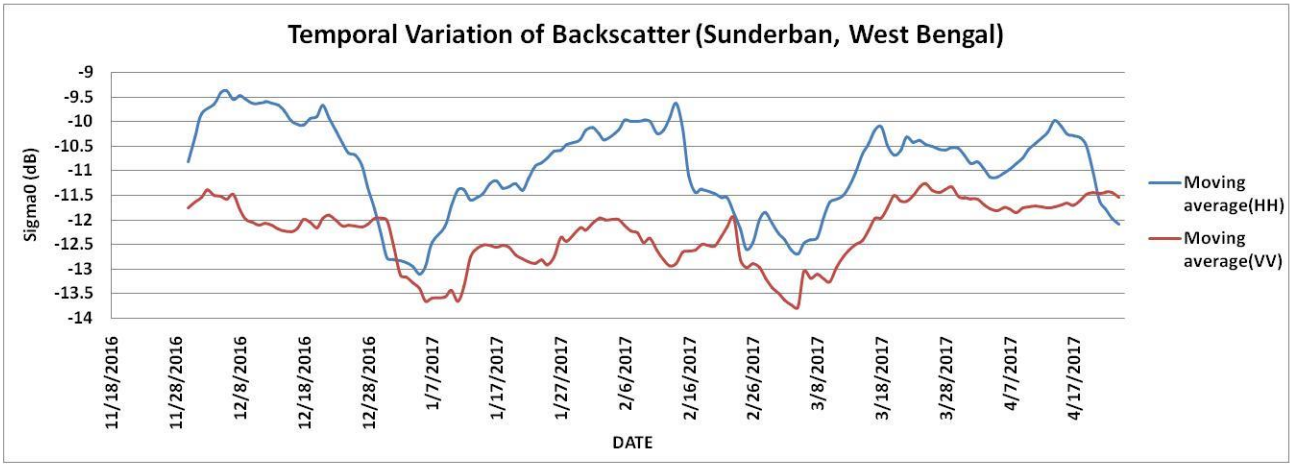


Fig 9.5(b) Temporal variation of backscatter with a moving average window of 10 days

9.6 <u>CONCLUSION</u>

Fig 9.5(a) and 9.5(b) shows temporal variation of backscatter over forest canopy of Sundarbans.

The GUI can also be used to study temporal variation of backscatter values over different land features such as Desert, Vegetation, Snow, Mountains, Urban etc...

In Future, Time series of SCATSAT data, can be used to study seasonal variation in mangrove forest with seasonal ground truth.