

ECOL 481: Digital Image Processing for Environmental Applications

Course Teacher

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1. General Information

Course Code	:	ECOL - 481
Course Title	:	Digital Image Processing for Environmental Applications
Number of Credits	:	4.0 ECTS
Course duration	:	18 Weeks
Level	:	Postgraduate
Course Teacher	:	Prof. S. Jayakumar
Prerequisite	:	Basic understanding on Mathematics (school higher level), English language skill, computer operation (Windows/Mac).

2. Course description

This course provides students an in-depth theoretical knowledge and hands-on training in satellite data handling, processing, mapping and analysis.

3. Course goals

The main aim of the course is to provide students the ability to handle satellite data comfortably in different environmental applications. To make students to think and select appropriate satellite data from the freely available sources for their environmental applications. To prepare student to preprocess the satellite data, understand the errors in satellite data and get the data ready for analysis. To give training to students to handle Pan chromatic, Multispectral and Hyperspectral data. To teach students to handle the DEM from SRTM, SPOT, and other sources and to prepare digital elevation model, slope and aspect. To make understand the use of band ratioing and its applications.

4. Course outcome

By the end of the course, successful students will:

1. Know the sources from the where satellite data can be downloaded
2. be familiar with different types satellites, payload, bands, cell size and so on
3. be able to retrieve meta data information from each satellite data
4. know to handle different types of satellite data
5. be able to do preprocessing and make the data ready for analysis
6. know the function of geometric correction and how to perform it
7. be familiar with different types of projection, mosaicking and subsetting
8. be able to perform band ratioing and apply the same for environmental applications.

5. Course structure

5.a. Course Content

Week - 1	Introduction to Satellite data
	Satellite data download from USGS website
Week - 2	Data Import/Export, Layer stacking and FCC formation
	Metadata information
Week - 3	Pan chromatic data, multispectral data
	Hyperspectral data, elevation data
Week - 4	Raster layer information
Week - 5	Layer statistics
Week - 6	Data preparation, Geometric correction
	Projecting and reprojection
Week - 7	Mosaicing
Week - 8	Subsetting/Masking
Week - 9	Geometric correction of scanned maps
Week - 10	Spectral reflectance pattern of vegetation
Week - 11	Collection of phenological data
	Soil spectral reflectance
Week - 12	Water spectral reflectance, Urban spectral reflectance
Week - 13	Digital elevation model, spatial analysis of DEM
Week - 14	Band ratioing – RVI, DVI, NDVI
Week - 15	SAVI, SWI

5. Course structure

Understanding the basics of Satellites payload, different types of satellite data, data preprocessing, band ratioing, mapping of natural resources and analysis

5.b. Mode of delivery



In-Class Lectures



On-line Lectures

Google Classroom

Students will get enrolled in Google classroom

And online classes will be conducted if covid -19 conditions do not permit to conduct off-line classes

5. Course structure

5.c. In-class discussion

Understanding the satellites architecture, sensor characteristics, bands, pixel size, satellites from different countries, Optical, thermal and microwave satellites

5.d. In-class assignments & field assignment

Understanding False color composites, various band combinations, field check, ground truth data collection, preparation of interpretation elements for different categories

5.e. Reading and discussion of assigned papers for seminars

Understanding the application of different types of satellite data in various environmental applications, analysis used, results interpretation, data integration and environmental planning

5.f. Group project presentation

Ability to make presentation, effective communication, critical interpretation of data, response to audience

6. Course Assessment

Type of assessment	Percentage of Marks
In-class discussion	5
Assignment	5
Seminars	10
Group projects	10
Internal assessment test (MCQ types)	10
Final assessment	60
Total	100

7. References

- 1 Jensen, JR, 2013. Remote Sensing of the Environment: An Earth Resource Perspective –, 2nd Edition, Prentice Hall.
- 2 Lillesand, T, and Kiefer, RW. 2008. Remote Sensing and Image Interpretation Sixty Edition, John Wiley & Sons, Inc,
- 3 ERDAS IMAGINE Field Guide, Erdas Inc., USA, 2017.
- 4 ERDAS IMAGINE User Guide, ErdasInc, USA, 2017.

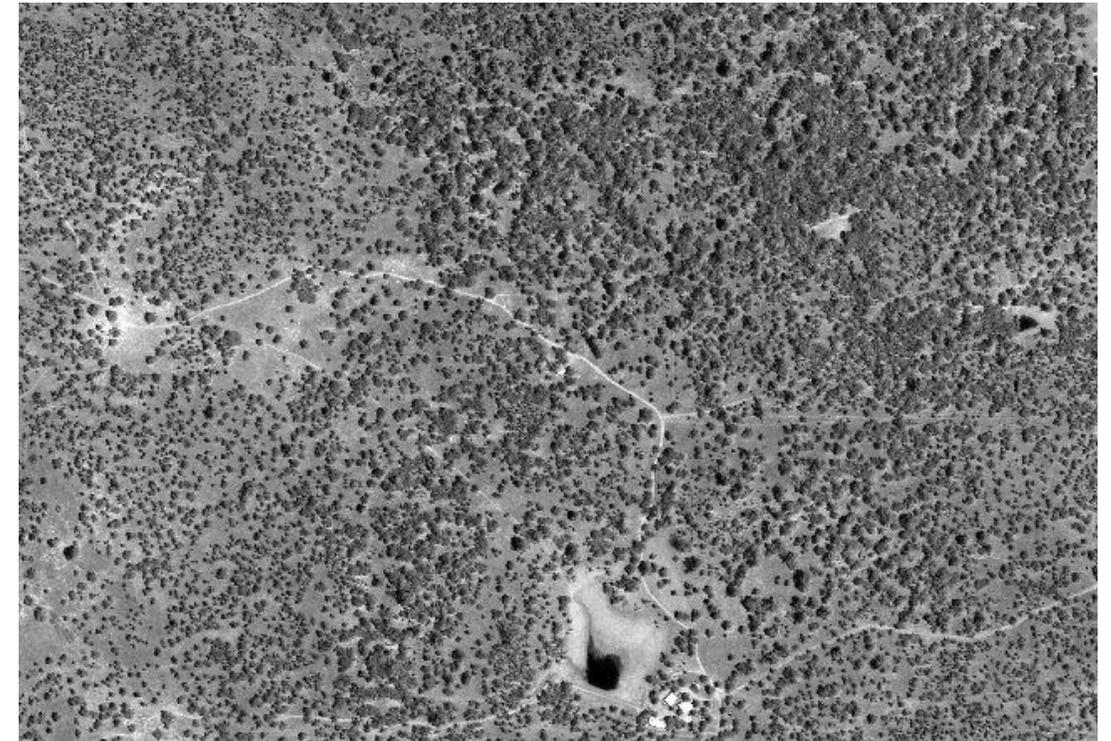
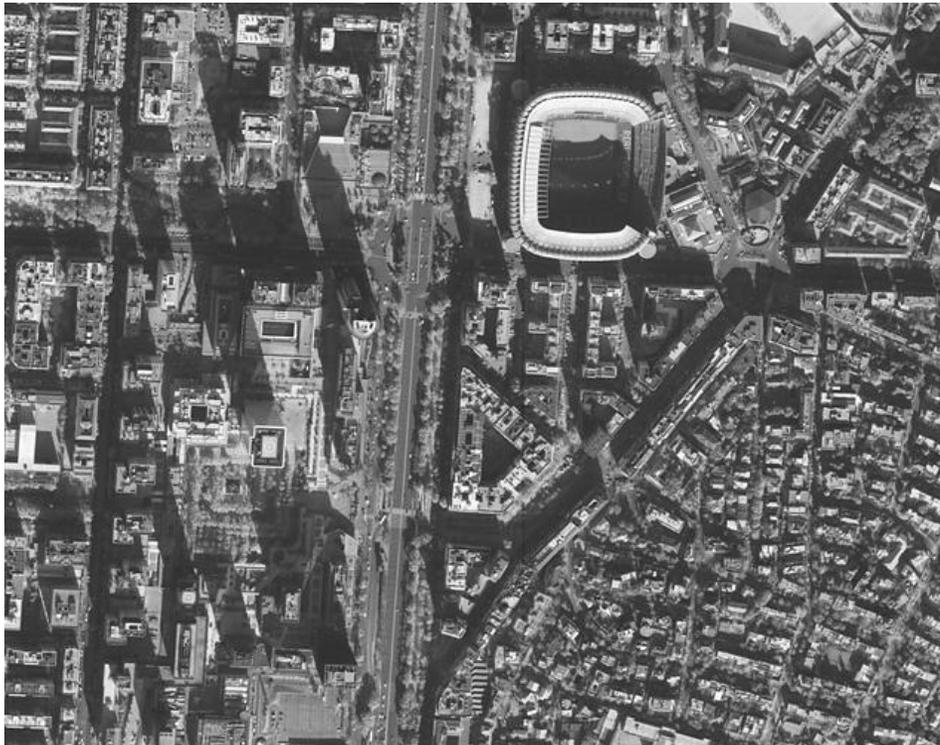
Introduction to Satellite Data

Space borne data

- **Monochromatic satellite data**
- **Multispectral satellite data**
- **Hyperspectral satellite data**
 - **Reflective Remote sensing**
 - **Thermal Remote Sensing**
 - **Microwave Remote Sensing**

Introduction to Satellite Data

- **Monochromatic satellite data**



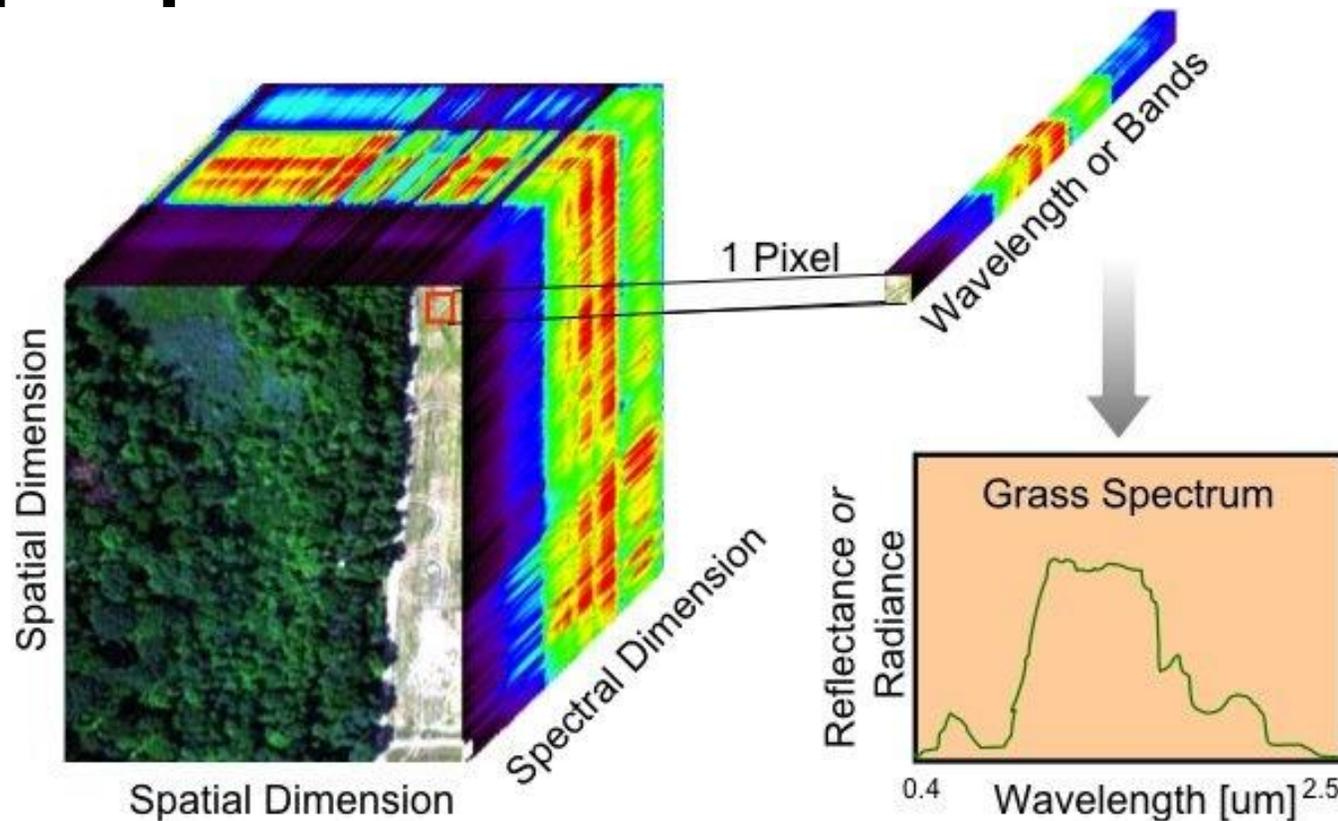
Introduction to Satellite Data

- **Multispectral satellite data**



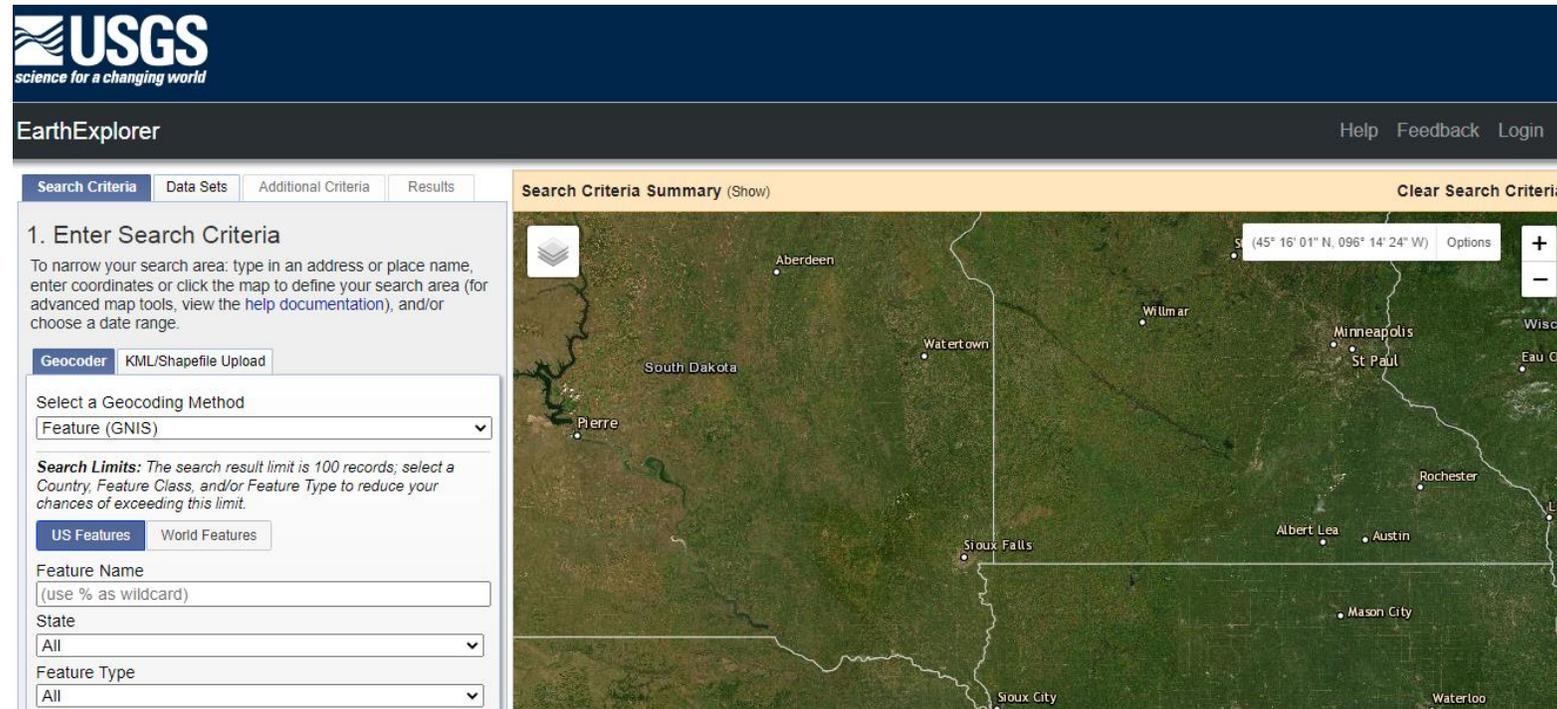
Introduction to Satellite Data

- **Hyperspectral satellite data**



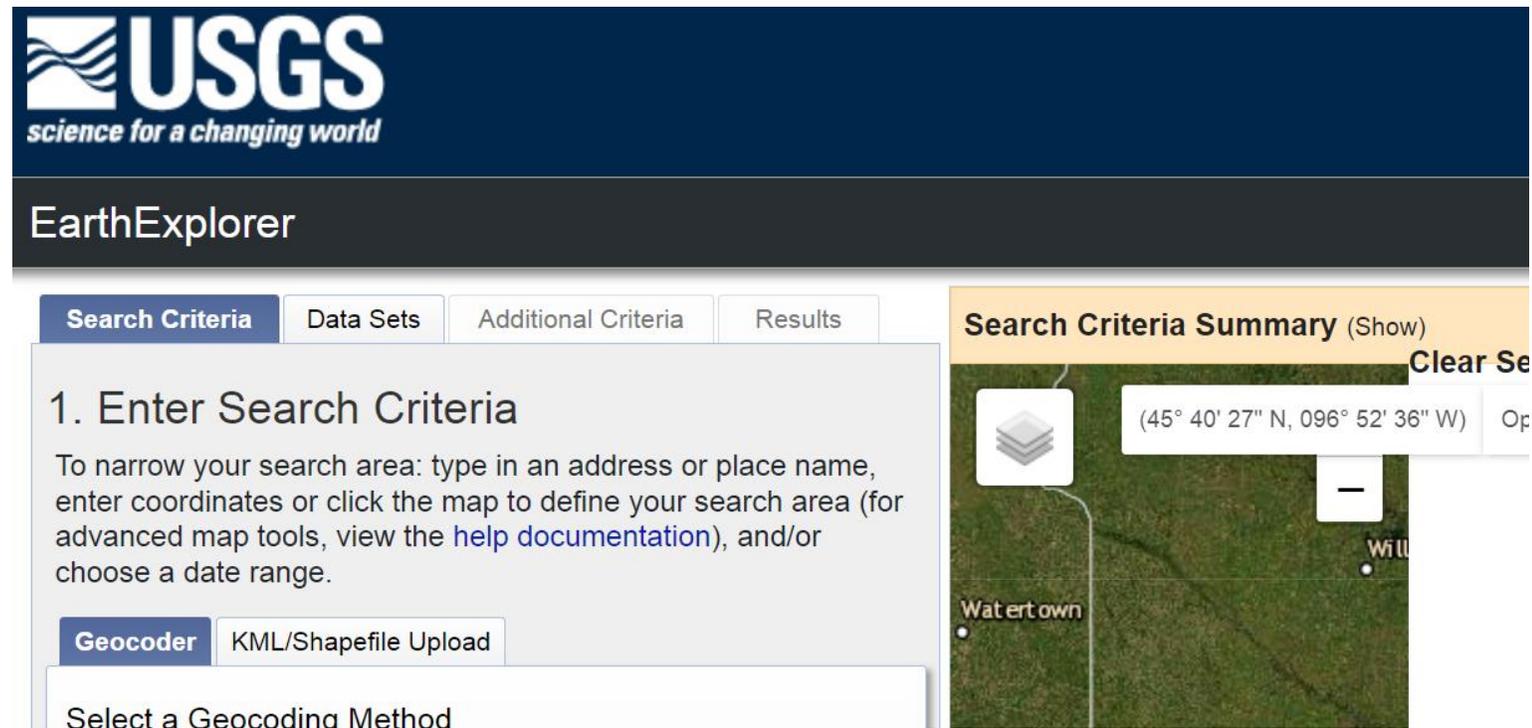
Satellite data downloading

- USGS website

A screenshot of the USGS EarthExplorer website. The top navigation bar includes the USGS logo and the tagline "science for a changing world", along with "EarthExplorer" and links for "Help", "Feedback", and "Login". Below the navigation bar, there are tabs for "Search Criteria", "Data Sets", "Additional Criteria", and "Results". The "Search Criteria" tab is active, showing a section titled "1. Enter Search Criteria". This section includes instructions on how to narrow the search area, a "Geocoder" button, and a "KML/Shapefile Upload" button. A dropdown menu for "Select a Geocoding Method" is set to "Feature (GNIS)". Below this, there are "Search Limits" instructions and two tabs for "US Features" and "World Features". There are also input fields for "Feature Name", "State" (set to "All"), and "Feature Type" (set to "All"). To the right of the search criteria is a "Search Criteria Summary (Show)" section and a "Clear Search Criteria" button. The main area of the page is a satellite map of the central United States, showing cities like Aberdeen, Wilmar, Minneapolis, St. Paul, Rochester, Sioux Falls, Albert Lea, Austin, Mason City, Sioux City, and Waterloo. A coordinate box in the top right of the map shows "(45° 16' 01\" data-bbox="189 353 800 850"/>

Satellite data downloading

- USGS website – Search criteria



The screenshot shows the USGS EarthExplorer website interface. At the top is the USGS logo with the tagline "science for a changing world". Below the logo is the "EarthExplorer" title. The main navigation bar includes tabs for "Search Criteria", "Data Sets", "Additional Criteria", and "Results". The "Search Criteria" tab is active, displaying the heading "1. Enter Search Criteria" and instructions: "To narrow your search area: type in an address or place name, enter coordinates or click the map to define your search area (for advanced map tools, view the [help documentation](#)), and/or choose a date range." Below the instructions are buttons for "Geocoder" and "KML/Shapefile Upload". A dropdown menu is open under "Geocoder" with the text "Select a Geocoding Method". To the right, a "Search Criteria Summary" panel is visible, showing a map of a rural area with a location marker. The coordinates for the marker are "(45° 40' 27\" N, 096° 52' 36\" W)". Other visible text on the map includes "Watertown" and "Will".

Satellite data downloading

- USGS website
- Search criteria

choose a date range.

Geocoder KML/Shapefile Upload

Select a Geocoding Method
Feature (GNIS) ▼

Search Limits: The search result limit is 100 records; select a Country, Feature Class, and/or Feature Type to reduce your chances of exceeding this limit.

US Features World Features

Feature Name
(use % as wildcard)

State
All ▼

Feature Type
All ▼

Show Clear

Polygon Circle Predefined Area

Degree/Minute/Second Decimal

i No coordinates selected.

Use Map Add Coordinate Clear Coordinates

Date Range Cloud Cover Result Options

Search from: mm/dd/yyyy to: mm/dd/yyyy

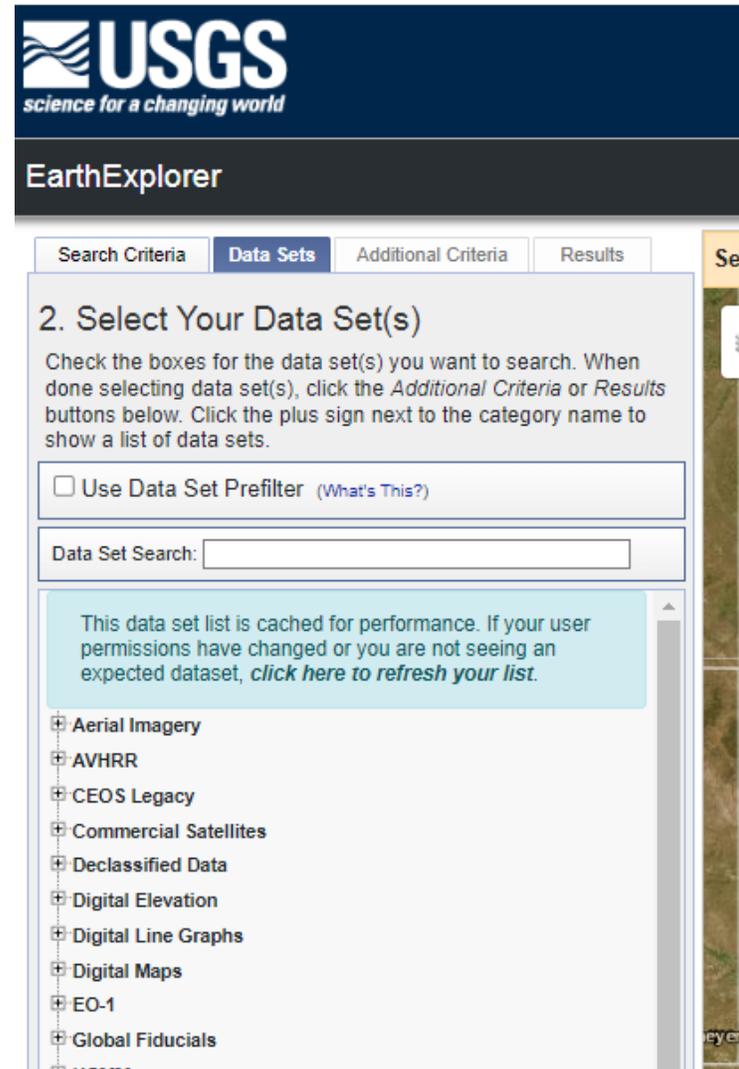
Search months: (all) ▼



Satellite data downloading



- USGS website
- Datasets



USGS
science for a changing world

EarthExplorer

Search Criteria | **Data Sets** | Additional Criteria | Results

2. Select Your Data Set(s)

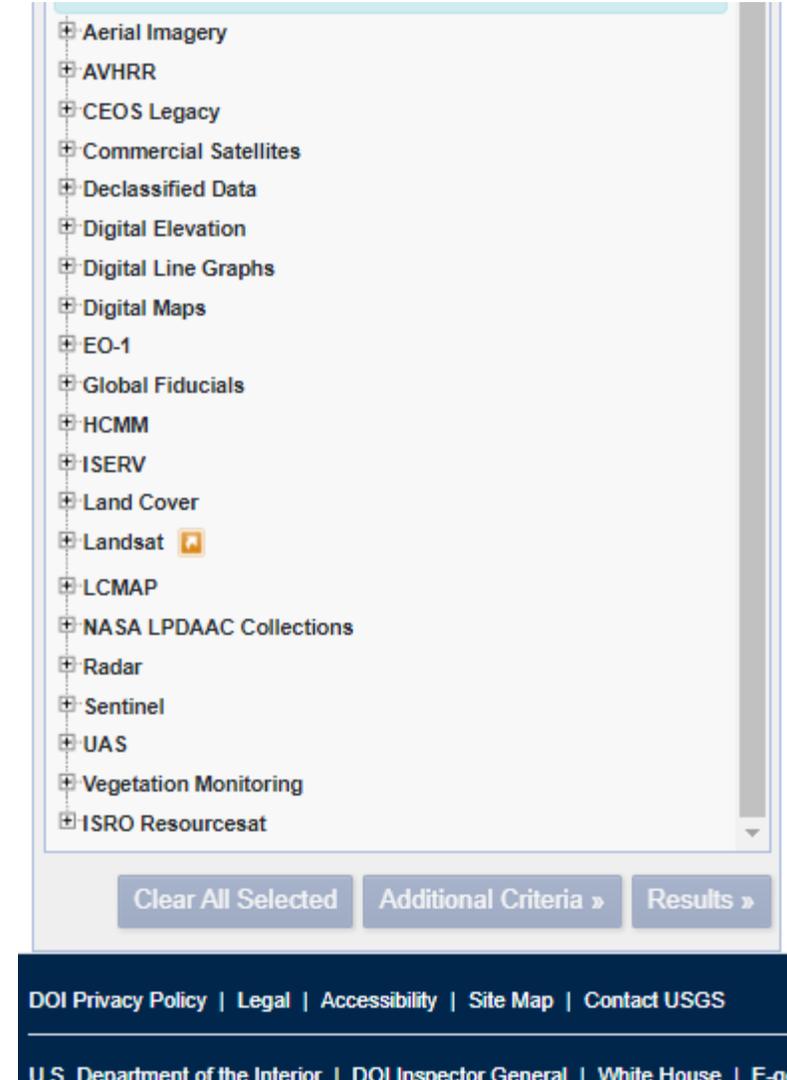
Check the boxes for the data set(s) you want to search. When done selecting data set(s), click the *Additional Criteria* or *Results* buttons below. Click the plus sign next to the category name to show a list of data sets.

Use Data Set Prefilter (What's This?)

Data Set Search:

This data set list is cached for performance. If your user permissions have changed or you are not seeing an expected dataset, [click here to refresh your list](#).

- ⊕ Aerial Imagery
- ⊕ AVHRR
- ⊕ CEOS Legacy
- ⊕ Commercial Satellites
- ⊕ Declassified Data
- ⊕ Digital Elevation
- ⊕ Digital Line Graphs
- ⊕ Digital Maps
- ⊕ EO-1
- ⊕ Global Fiducials
- ⊕ HCMM



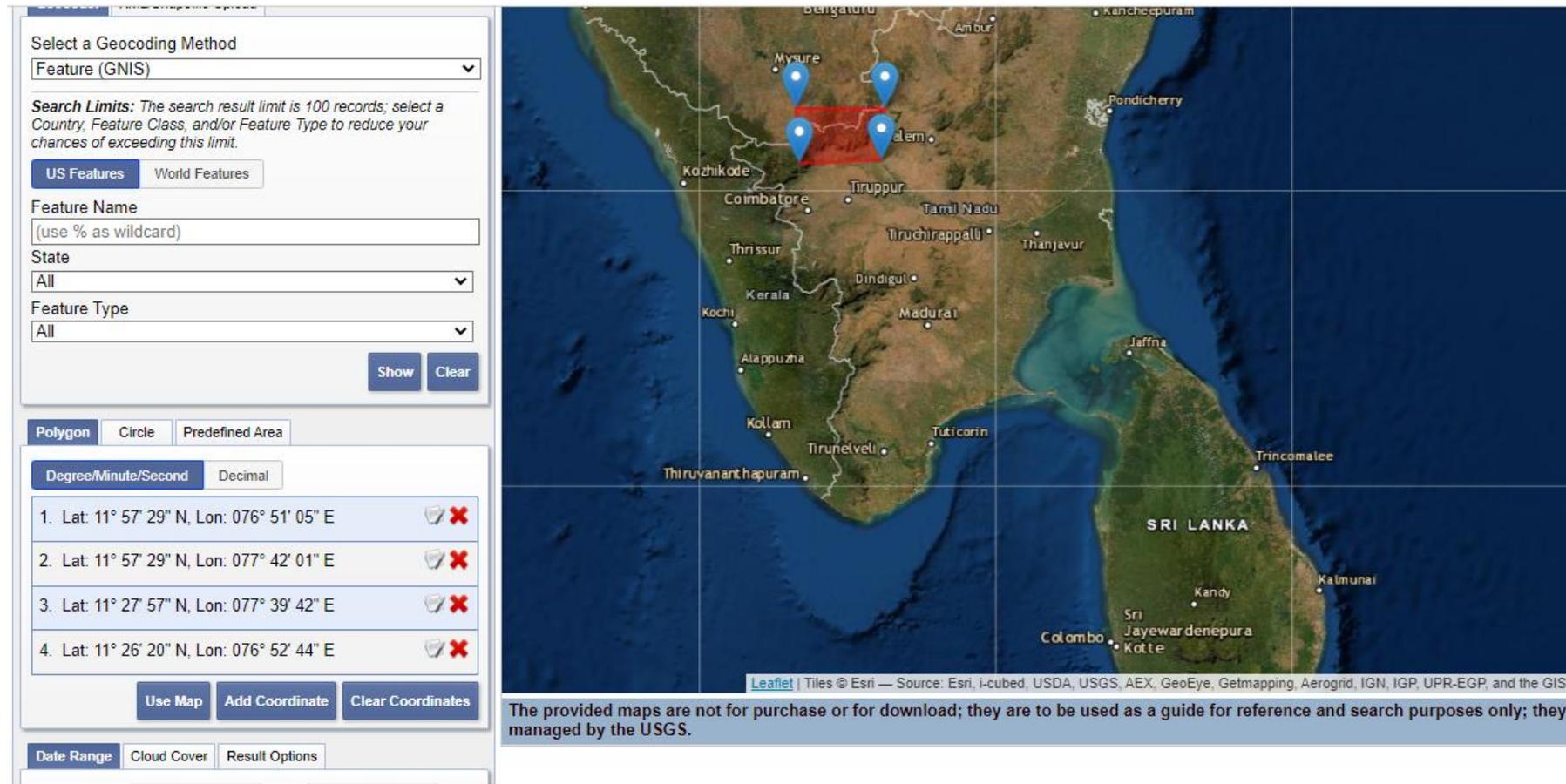
- ⊕ Aerial Imagery
- ⊕ AVHRR
- ⊕ CEOS Legacy
- ⊕ Commercial Satellites
- ⊕ Declassified Data
- ⊕ Digital Elevation
- ⊕ Digital Line Graphs
- ⊕ Digital Maps
- ⊕ EO-1
- ⊕ Global Fiducials
- ⊕ HCMM
- ⊕ ISERV
- ⊕ Land Cover
- ⊕ Landsat 
- ⊕ LCMAP
- ⊕ NASA LPDAAC Collections
- ⊕ Radar
- ⊕ Sentinel
- ⊕ UAS
- ⊕ Vegetation Monitoring
- ⊕ ISRO Resourcesat

Clear All Selected | Additional Criteria > | Results >

DOI Privacy Policy | Legal | Accessibility | Site Map | Contact USGS

U.S. Department of the Interior | DOI Inspector General | White House | E-qa

- USGS website – Area selection



Select a Geocoding Method
Feature (GNIS)

Search Limits: The search result limit is 100 records; select a Country, Feature Class, and/or Feature Type to reduce your chances of exceeding this limit.

US Features World Features

Feature Name
(use % as wildcard)

State
All

Feature Type
All

Show Clear

Polygon Circle Predefined Area

Degree/Minute/Second Decimal

1. Lat: 11° 57' 29" N, Lon: 076° 51' 05" E	🗑️ ❌
2. Lat: 11° 57' 29" N, Lon: 077° 42' 01" E	🗑️ ❌
3. Lat: 11° 27' 57" N, Lon: 077° 39' 42" E	🗑️ ❌
4. Lat: 11° 26' 20" N, Lon: 076° 52' 44" E	🗑️ ❌

Use Map Add Coordinate Clear Coordinates

Date Range Cloud Cover Result Options

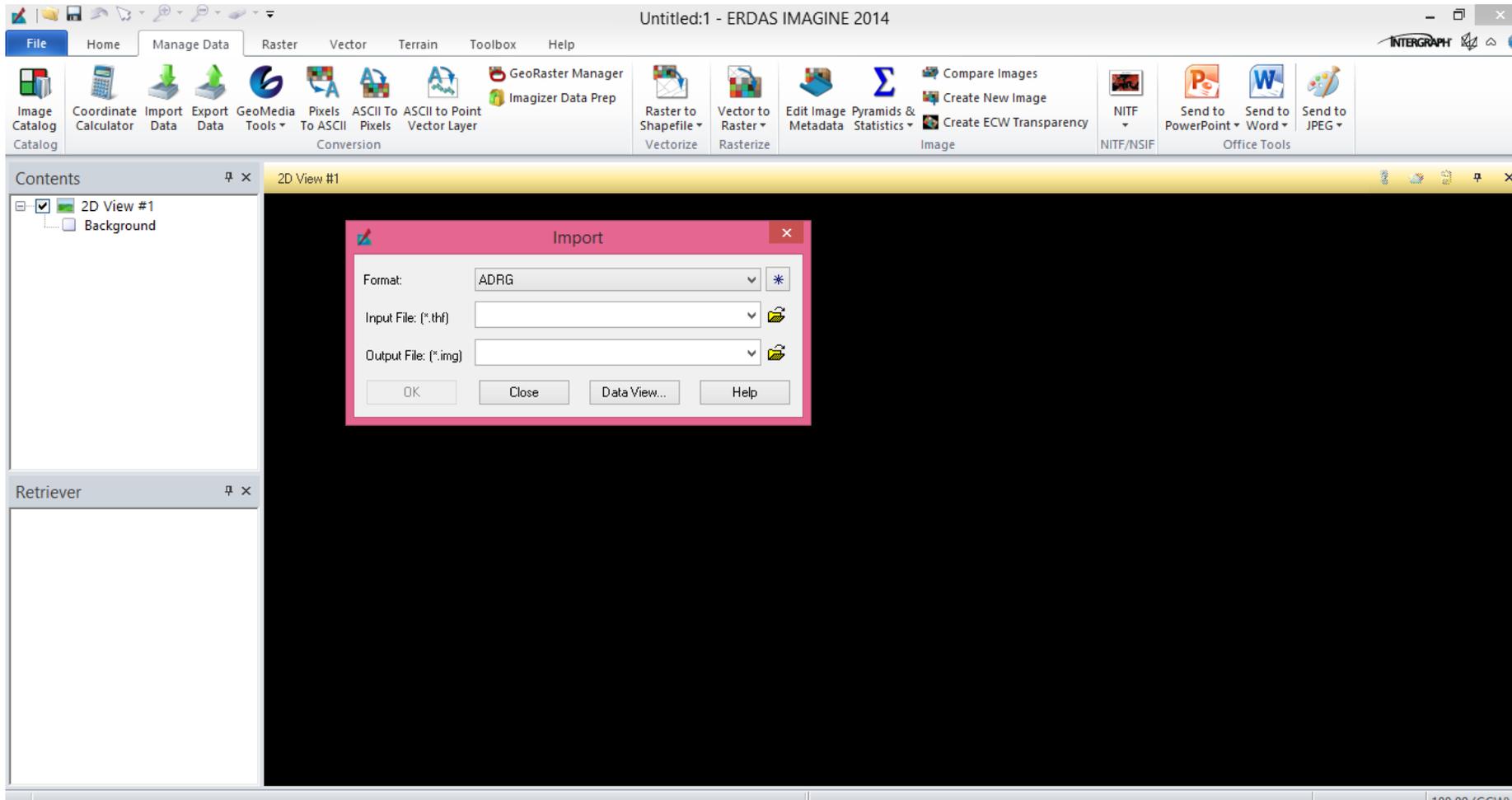
Leaflet | Tiles © Esri — Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS

The provided maps are not for purchase or for download; they are to be used as a guide for reference and search purposes only; they managed by the USGS.

Satellite data processing

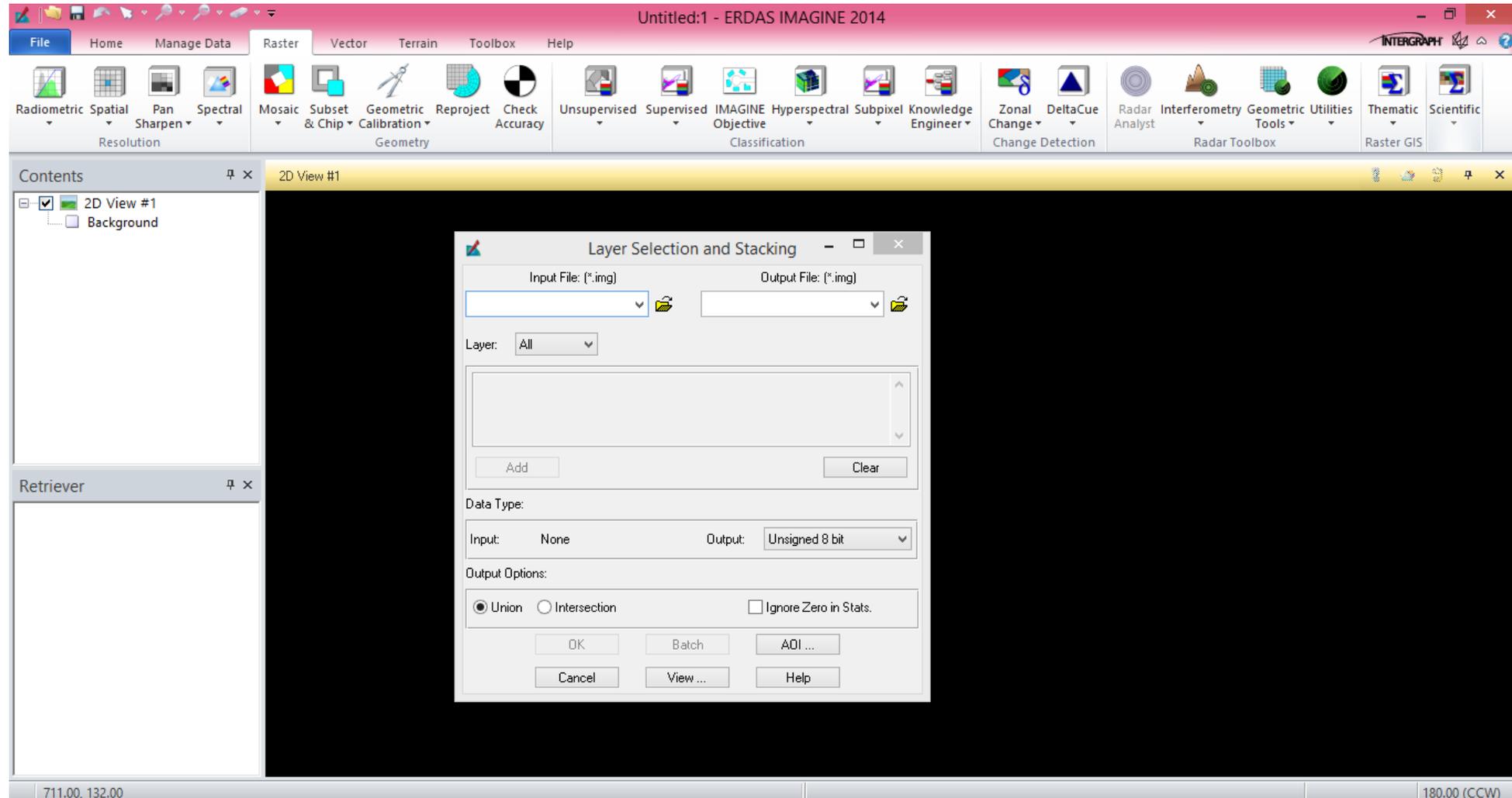


• Satellite data import/export

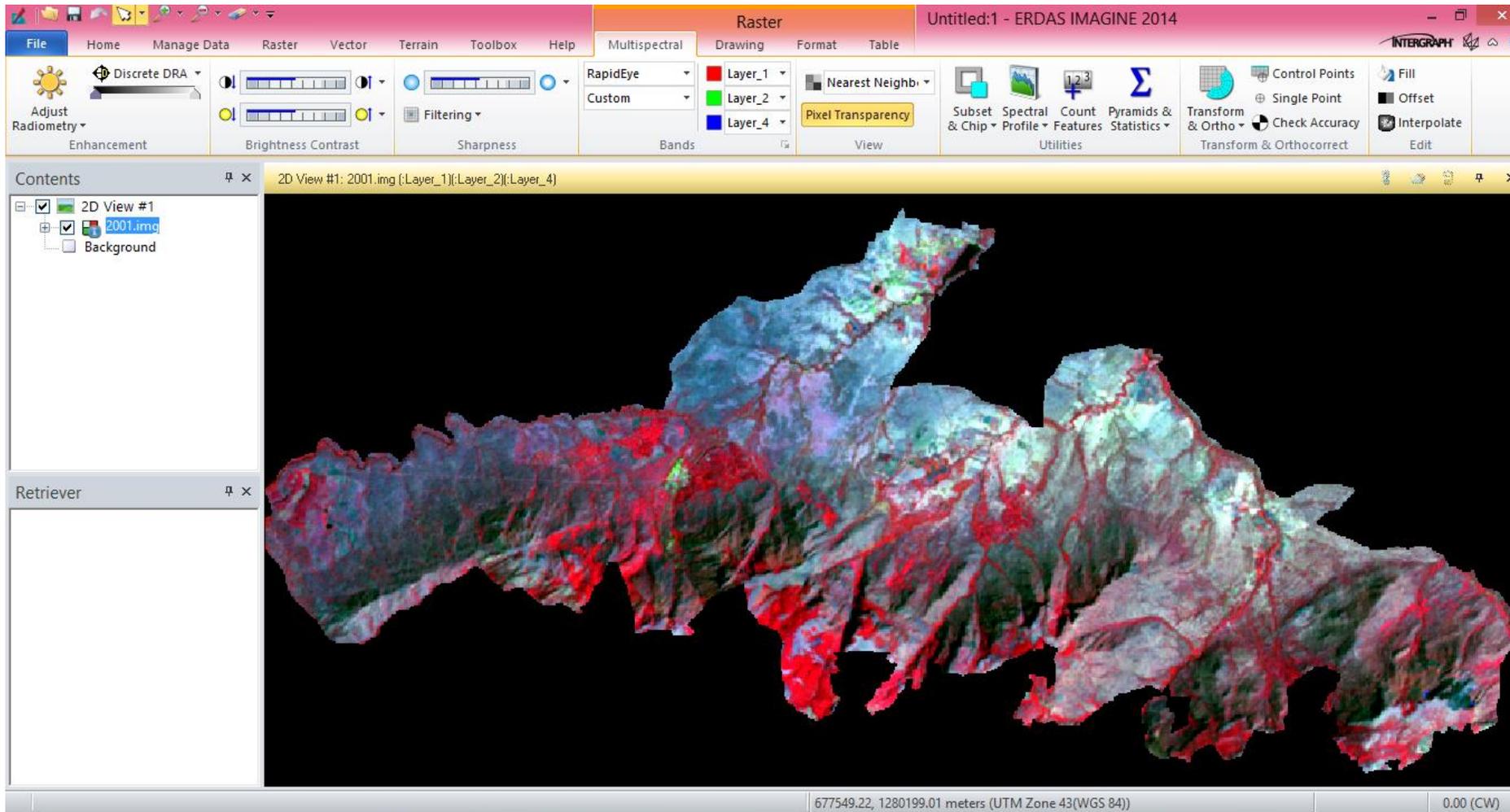


Satellite data processing

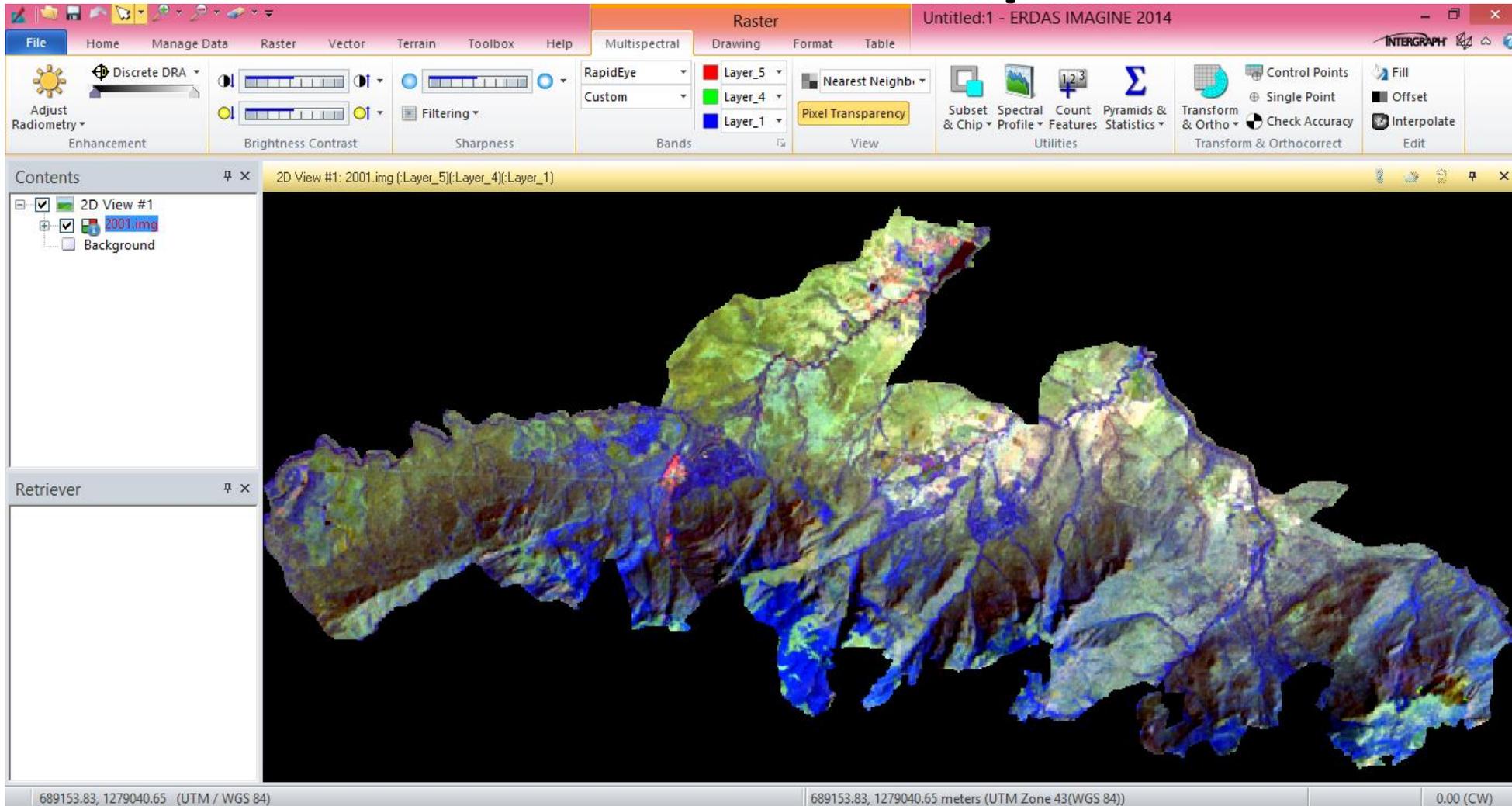
- Satellite data Layer stacking



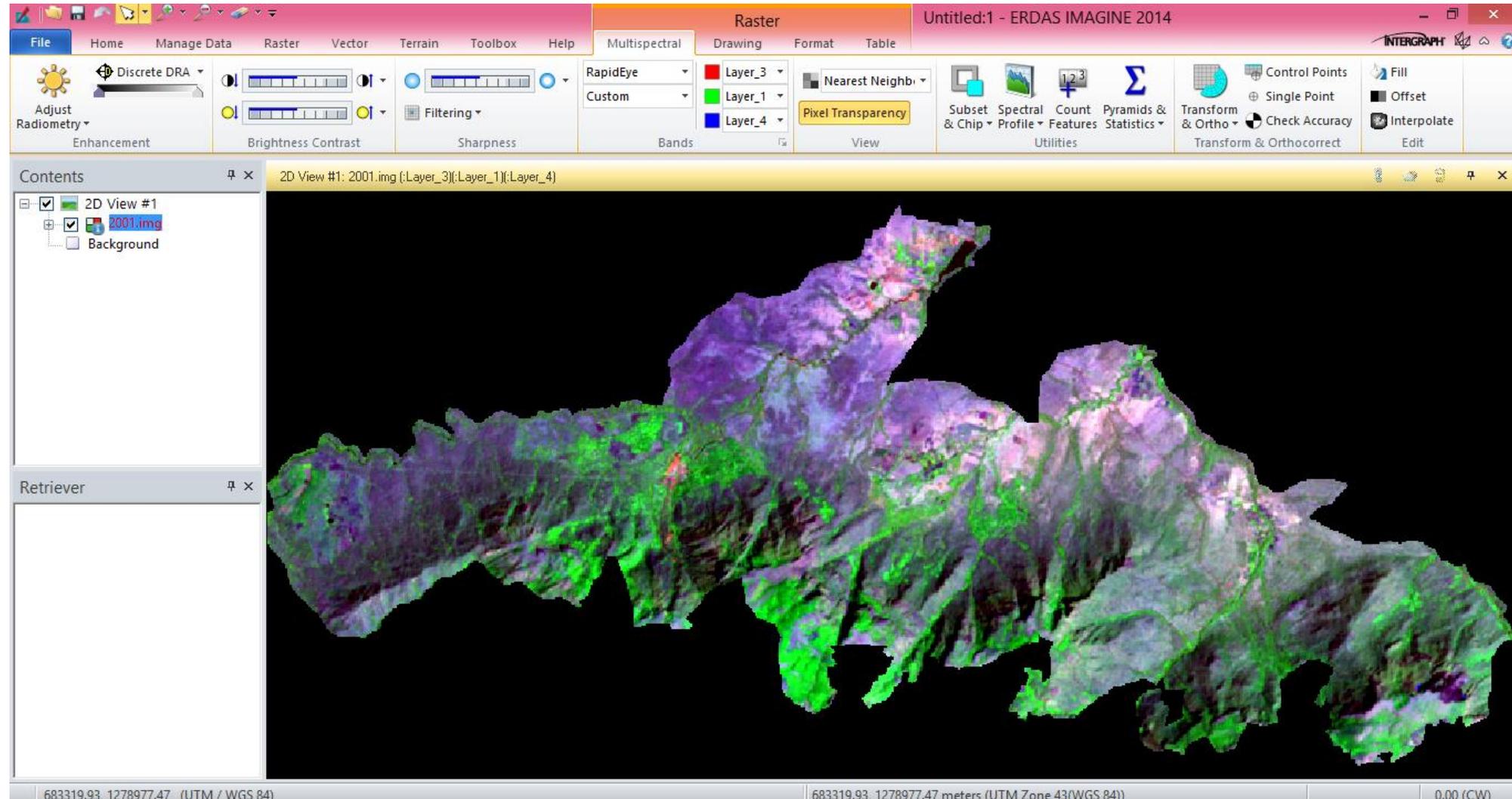
- **Satellite data False color composite**



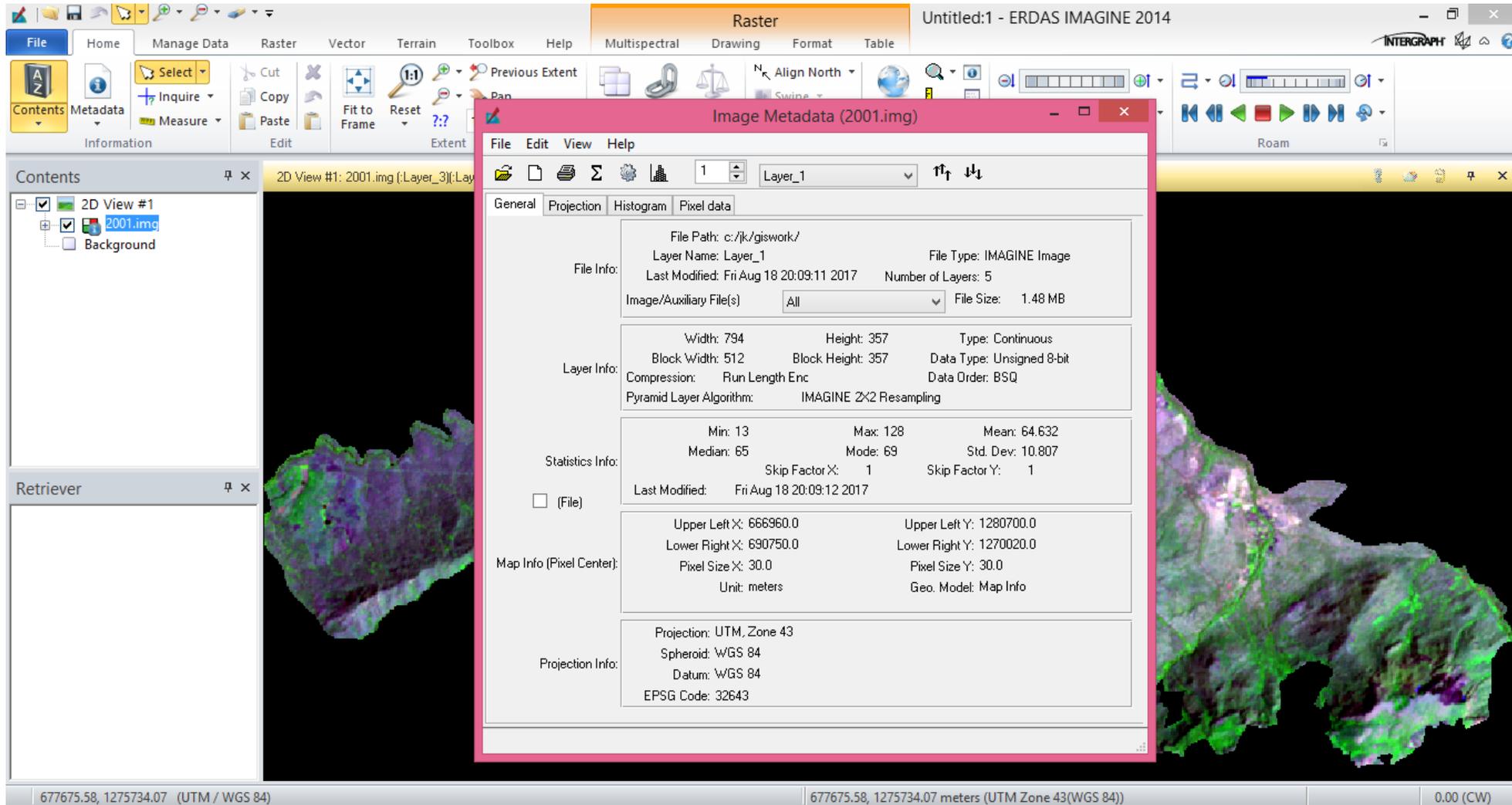
- **Satellite data False color composite**



- **Satellite data False color composite**



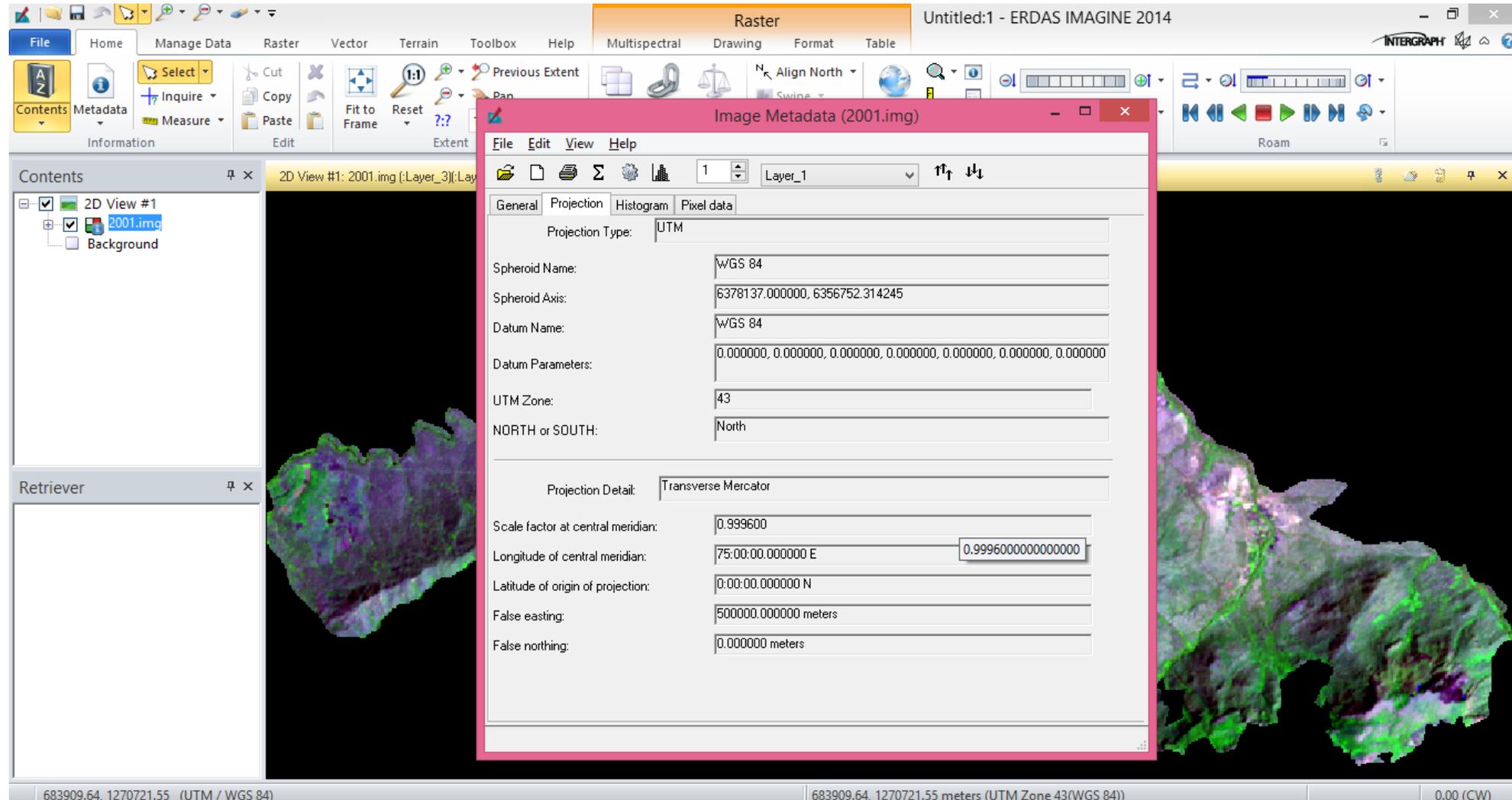
- **Satellite data – Metadata - General**



The screenshot shows the ERDAS IMAGINE 2014 interface with the 'Image Metadata (2001.img)' dialog box open. The dialog box contains the following information:

Section	Field	Value		
File Info:	File Path:	c:/jk/giswork/		
	Layer Name:	Layer_1		
	File Type:	IMAGINE Image		
	Last Modified:	Fri Aug 18 20:09:11 2017		
Image/Auxiliary File(s):	All	File Size: 1.48 MB		
	Number of Layers:	5		
Layer Info:	Width:	794		
	Height:	357		
	Type:	Continuous		
	Block Width:	512		
Block Height:	357	Data Type: Unsigned 8-bit		
	Compression:	Run Length Enc		
Pyramid Layer Algorithm:	IMAGINE 2X2 Resampling	Data Order: BSQ		
	Statistics Info:	Min: 13	Max: 128	Mean: 64.632
Median:	65	Mode: 69	Std. Dev: 10.807	
	Skip Factor X:	1	Skip Factor Y: 1	
Last Modified:	Fri Aug 18 20:09:12 2017	Map Info (Pixel Center):	Upper Left X: 666960.0	Upper Left Y: 1280700.0
	Lower Right X: 690750.0	Lower Right Y: 1270020.0	Pixel Size X: 30.0	Pixel Size Y: 30.0
Unit:	meters	Geo. Model:	Map Info	
	Projection Info:	Projection: UTM, Zone 43	Spheroid: WGS 84	Datum: WGS 84
EPSG Code:	32643			

- **Satellite data – Metadata - Projection**

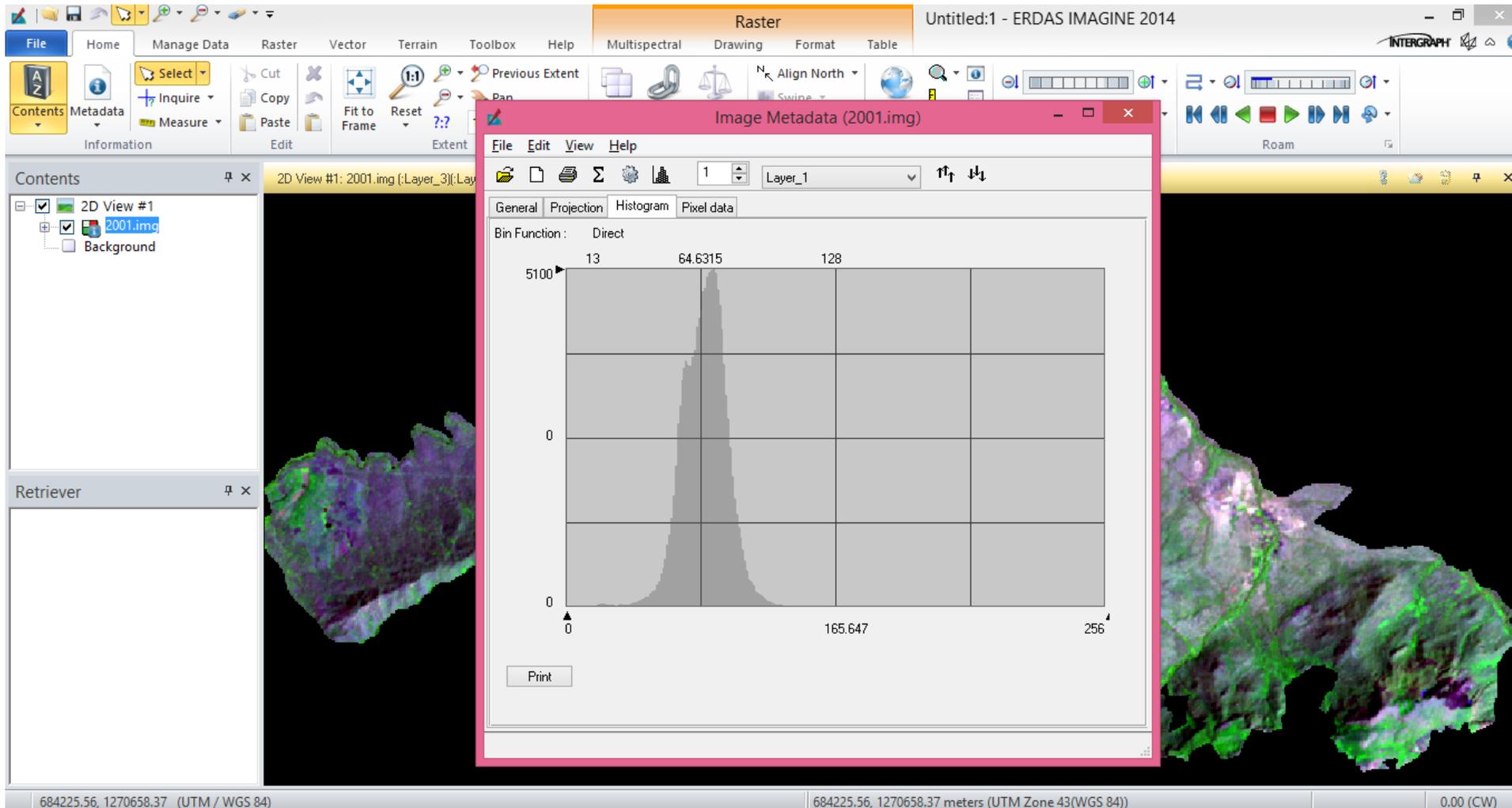


The screenshot shows the ERDAS IMAGINE 2014 interface with the 'Image Metadata (2001.img)' dialog box open. The dialog box contains the following information:

Field	Value
Projection Type:	UTM
Spheroid Name:	WGS 84
Spheroid Axis:	6378137.000000, 6356752.314245
Datum Name:	WGS 84
Datum Parameters:	0.000000, 0.000000, 0.000000, 0.000000, 0.000000, 0.000000, 0.000000
UTM Zone:	43
NORTH or SOUTH:	North
Projection Detail:	Transverse Mercator
Scale factor at central meridian:	0.999600
Longitude of central meridian:	75:00:00.000000 E
Latitude of origin of projection:	0:00:00.000000 N
False easting:	500000.000000 meters
False northing:	0.000000 meters

The background shows a 2D view of a satellite image with a green and purple color scheme. The status bar at the bottom indicates the current coordinates: 683909.64, 1270721.55 (UTM / WGS 84).

- **Satellite data – Metadata - Histogram**



- Satellite data – Metadata – Pixel data

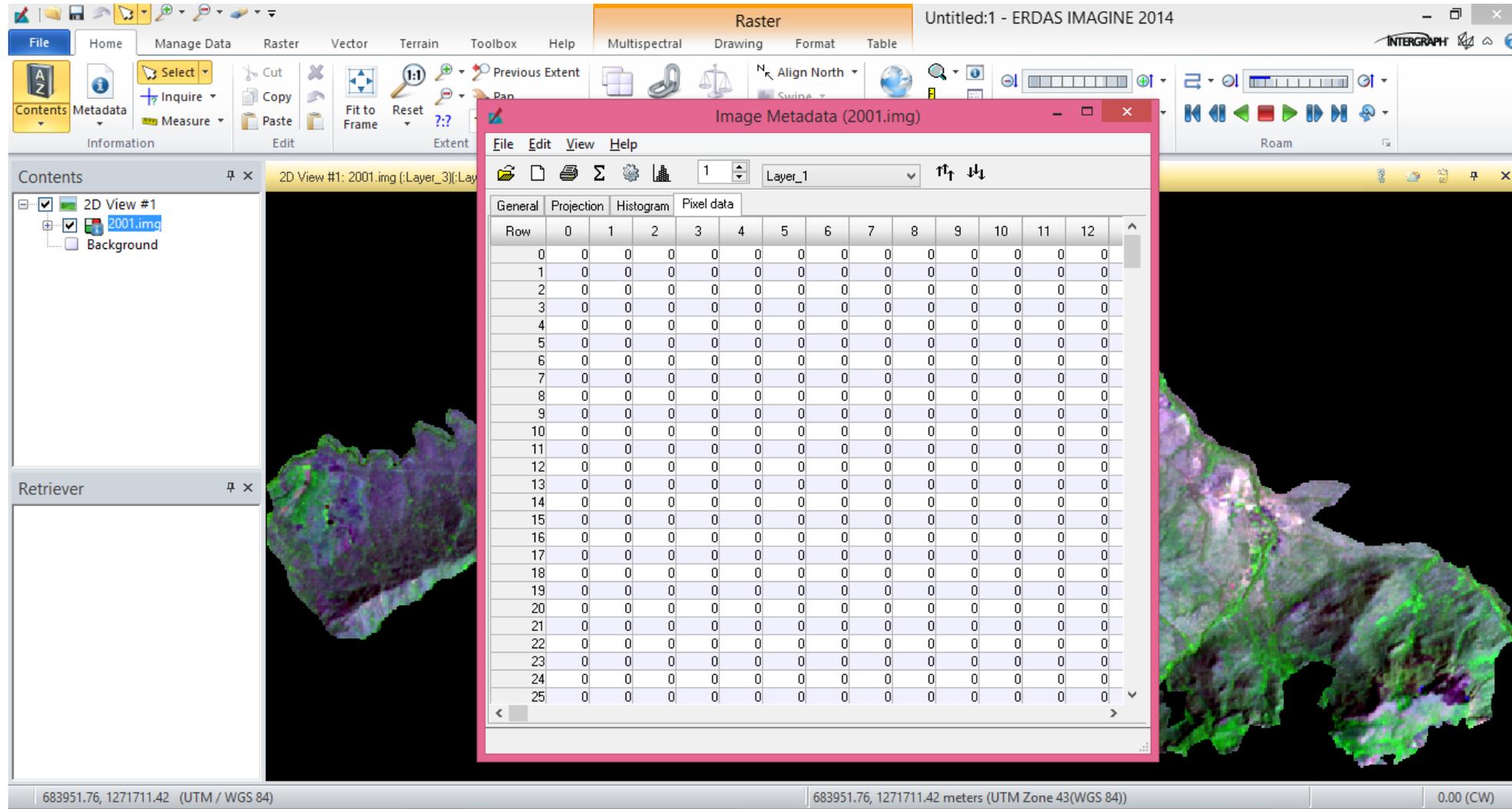
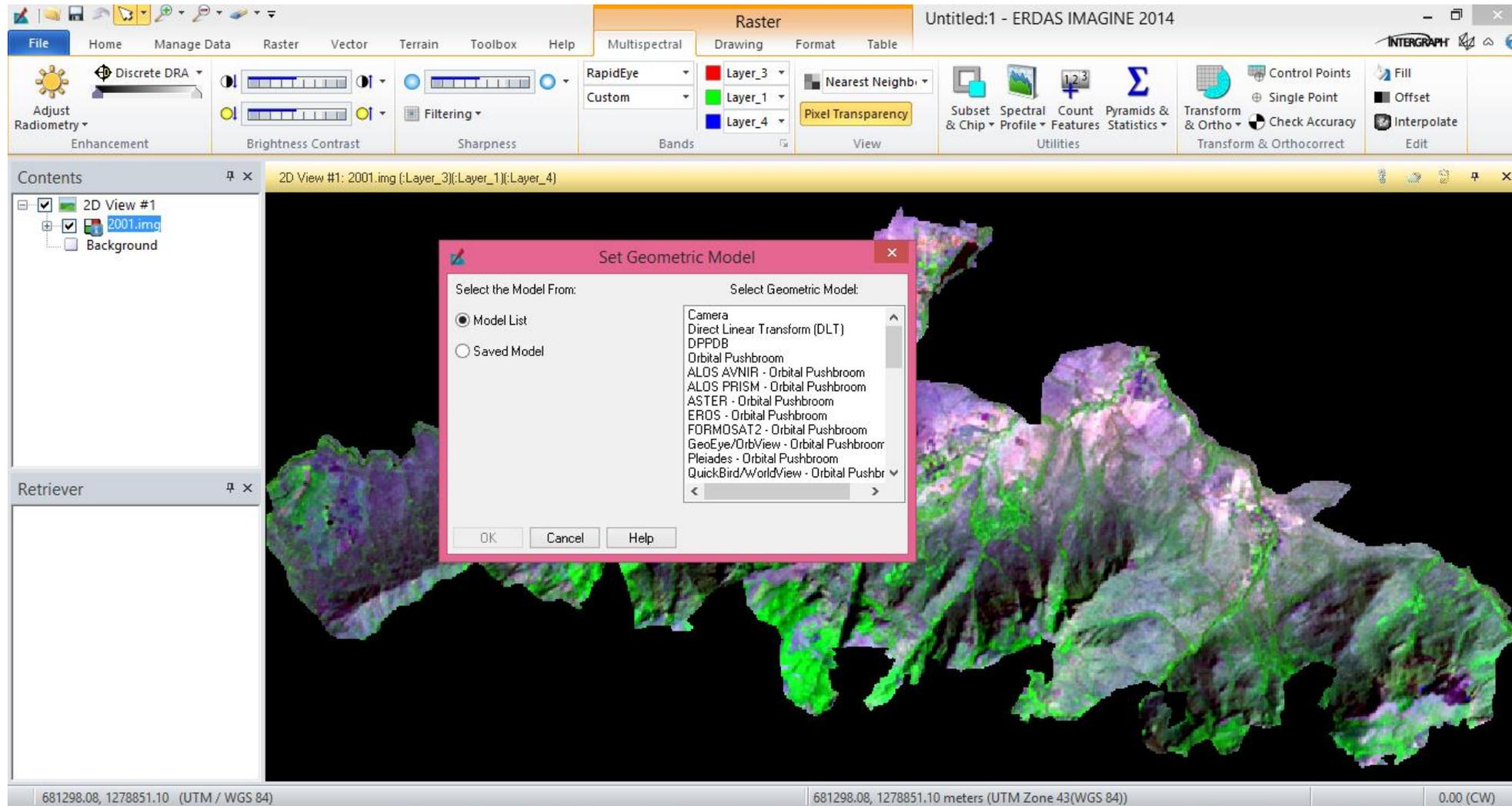


Image Metadata (2001.img)

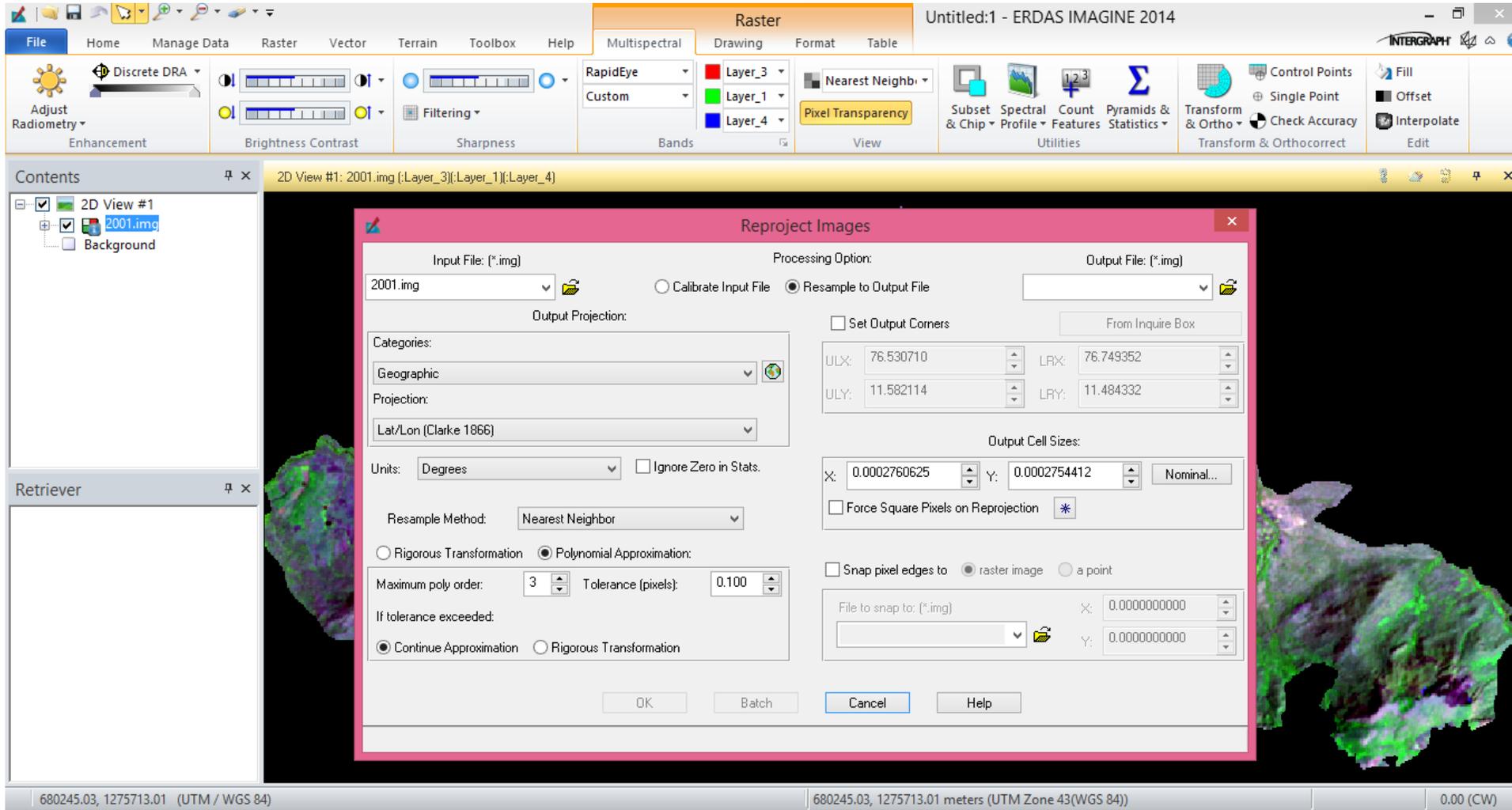
Row	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0

- **Satellite data – Geometric correction**
- Raw images are geometrically distorted
 - Due to
 - Errors in the satellite's positioning on its orbit
 - Earth is turning on its axis as the image is being recorded
 - The effects of relief
 - Angle of lens
- Effects of Earth's rotation and camera angles are predictable
- Correction values can be applied systematically
- Level 1A images – geometrically uncorrected
- Level 1B images – 500 m locational accuracy
- GCP – to improve the accuracy
- Ideal accuracy is locational accuracy lesser than the pixel size.

- **Satellite data – Geometric correction**



- **Satellite data – Re-projection**

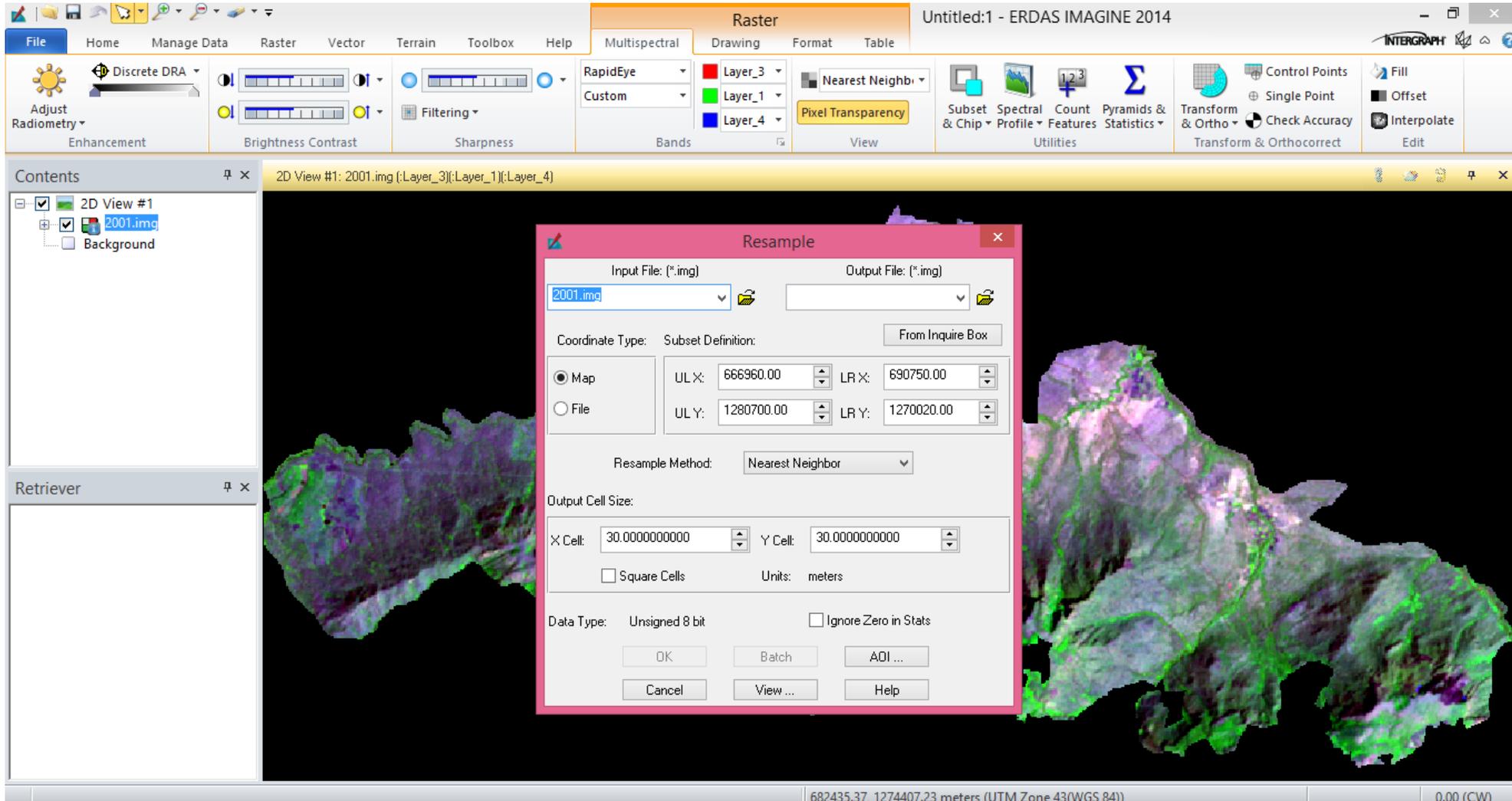


The screenshot shows the ERDAS IMAGINE 2014 software interface. The main window displays a 2D view of satellite data with a color-coded map. A dialog box titled "Reproject Images" is open, showing the following settings:

- Input File:** 2001.img
- Processing Option:** Resample to Output File
- Output File:** (empty)
- Output Projection:**
 - Categories: Geographic
 - Projection: Lat/Lon (Clarke 1866)
 - Units: Degrees
 - Ignore Zero in Stats.
- Resample Method:** Nearest Neighbor
- Polynomial Approximation:**
 - Maximum poly order: 3
 - Tolerance (pixels): 0.100
 - If tolerance exceeded: Continue Approximation
- Output Cell Sizes:**
 - X: 0.0002760625
 - Y: 0.0002754412
 - Force Square Pixels on Reprojection
- Other options:**
 - Set Output Corners: From Inquire Box
 - Snap pixel edges to: raster image
 - File to snap to: (empty)

The status bar at the bottom shows coordinates: 680245.03, 1275713.01 (UTM / WGS 84) and 0.00 (CW).

- **Satellite data – Resample pixel size**

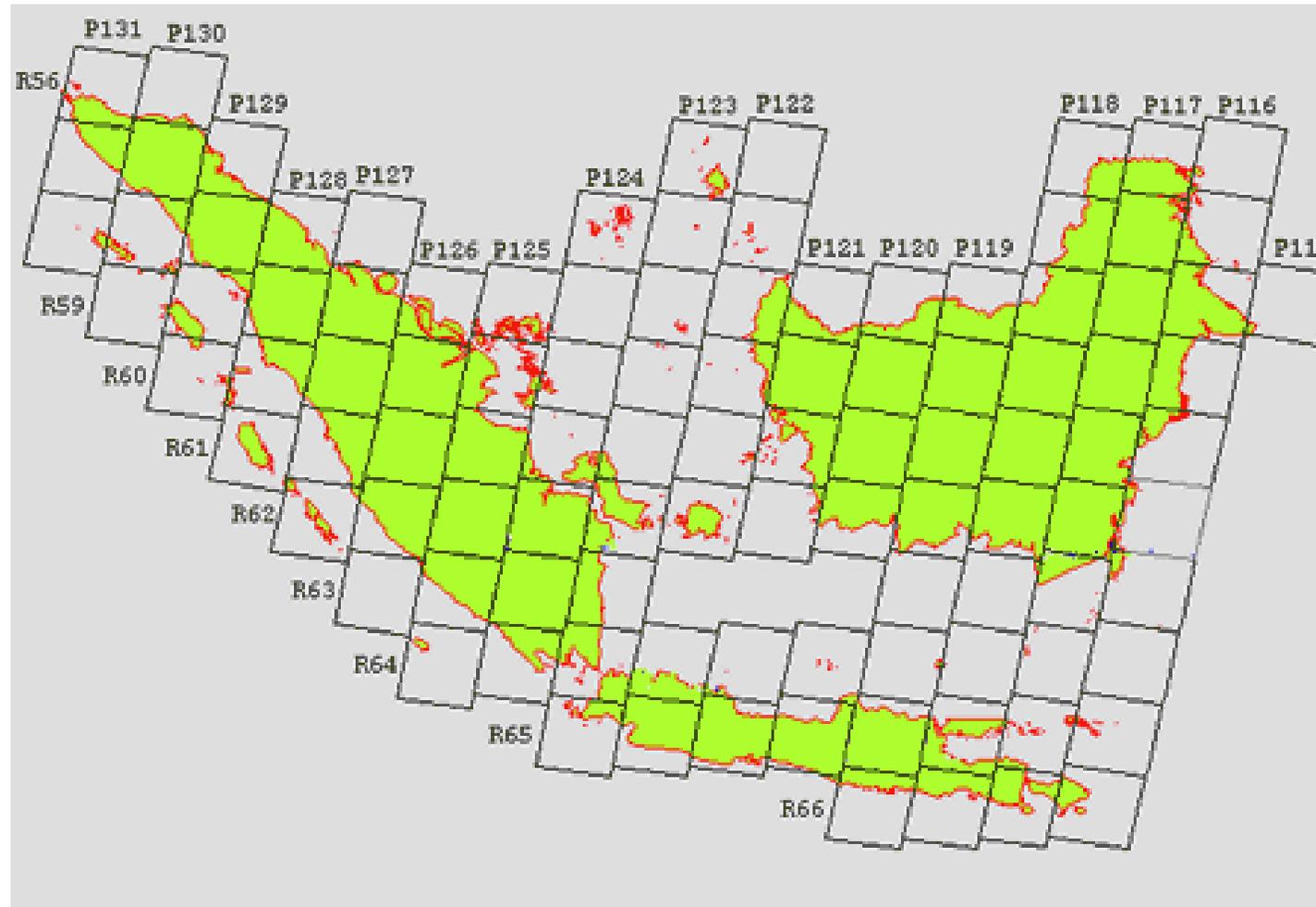


The screenshot displays the ERDAS IMAGINE 2014 software interface. The main window shows a 2D view of a satellite image with a 'Resample' dialog box open. The dialog box is configured with the following parameters:

- Input File:** 2001.img
- Output File:** (empty)
- Coordinate Type:** Map
- Subset Definition:**
 - UL X: 666960.00
 - LR X: 690750.00
 - UL Y: 1280700.00
 - LR Y: 1270020.00
- Resample Method:** Nearest Neighbor
- Output Cell Size:**
 - X Cell: 30.0000000000
 - Y Cell: 30.0000000000
 - Units: meters
- Data Type:** Unsigned 8 bit

The background image shows a satellite view of a landscape with a grid overlay. The status bar at the bottom indicates the current coordinates: 682435.37, 1274407.23 meters (UTM Zone 43(WGS 84)) and a scale of 0.00 (CW).

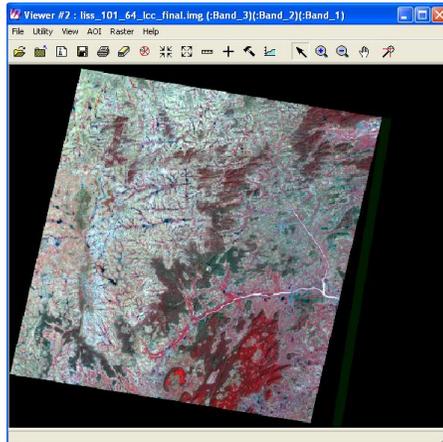
- **Satellite data – Mosaicing**



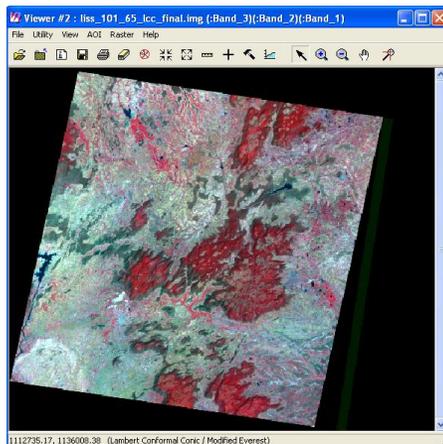
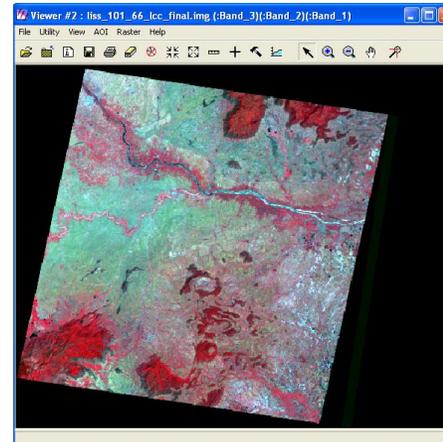
- **Satellite data – Mosaicing**

The process of piecing together images, to create a larger image

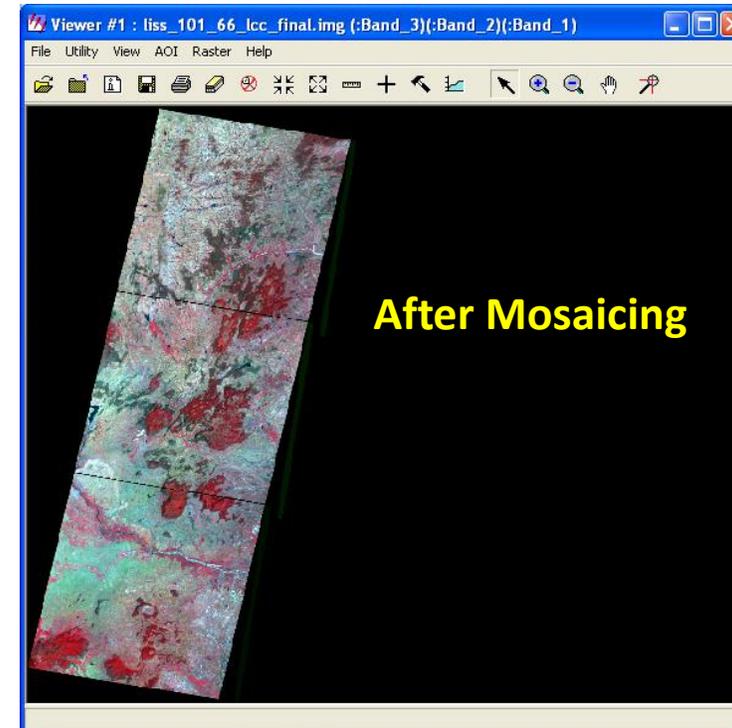
Path 101 - Row 64



Path 101 - Row 66



Path 101 - Row 65

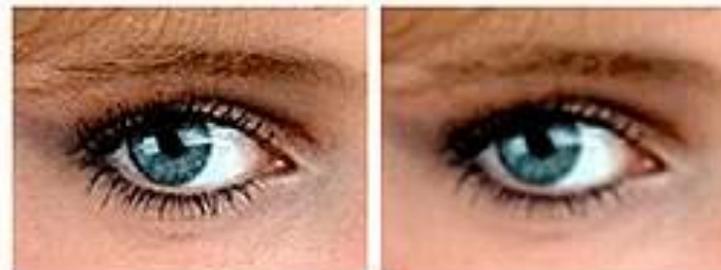


- **Satellite data – Filtering**
- Filtering improves readability and /or to extract certain details
- Modifies the numerical value of each pixel based on neighbouring pixel's values – results - smoothed /blurred images

A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	9	9	9	9	9	9	9	9	9	9	9	9	9
2	9	9	9	9	5	5	5	5	5	5	9	9	9
3	9	9	9	9	5	5	5	5	5	5	9	9	9
4	9	9	9	9	5	5	6	6	6	6	9	9	9
5	9	9	9	9	5	5	5	6	6	6	9	9	9
6	9	9	5	5	5	5	5	5	5	5	9	9	9
7	9	9	9	7	7	7	7	7	7	7	9	9	9
8	9	9	9	9	7	7	7	7	7	7	9	9	9
9	9	9	9	9	7	1	7	7	1	7	9	9	9
10	9	9	9	9	7	7	7	7	7	1	7	9	9
11	9	9	9	9	9	7	7	7	7	9	9	9	9
12	9	9	9	9	9	7	3	7	3	9	9	9	9
13	9	9	9	9	9	7	7	9	9	9	9	9	9
14	9	9	9	9	3	3	3	5	3	9	9	9	9
15	9	9	9	9	9	9	9	9	9	9	9	9	9

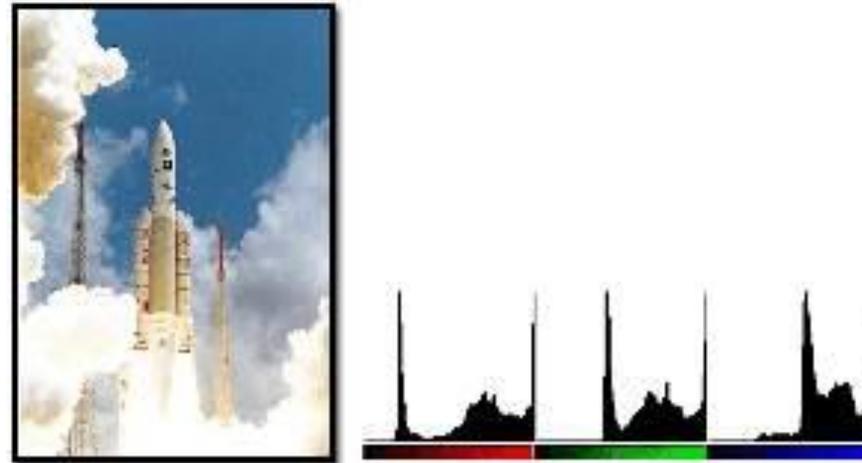
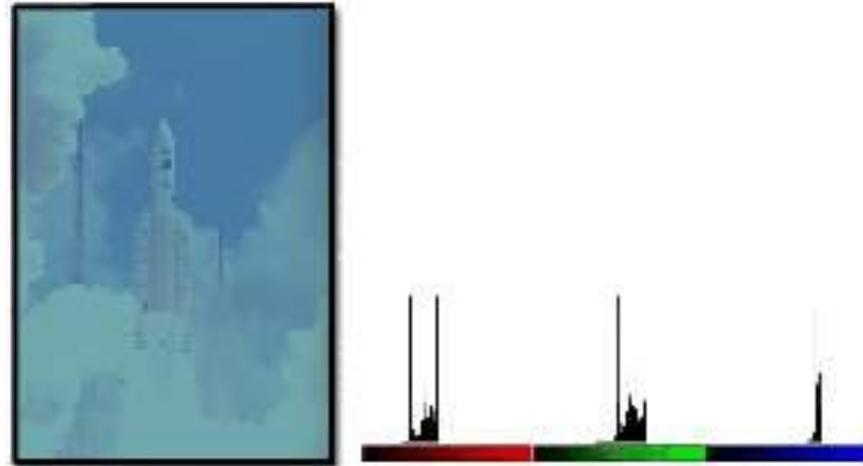
$$\begin{array}{|c|c|c|} \hline L & L & L \\ \hline L & L & L \\ \hline L & L & L \\ \hline \end{array}$$

A	B	C	D	E	F	G	H	I	J	K	L	M	N
1													
2		9	9	8	7	6	6	6	6	6	8	9	
3		9	9	6	6	5	5	5	5	6	8	9	
4		9	9	8	6	5	5	5	6	6	8	9	
5		9	9	7	6	5	5	6	6	6	7	9	
6		9	8	7	6	6	6	6	6	6	7	8	
7		9	8	7	7	6	6	6	6	6	7	8	
8		9	8	8	7	7	6	6	6	6	7	8	
9		9	9	8	7	6	6	6	6	7	6	9	
10		9	9	9	7	7	6	6	7	7	7	9	
11		9	9	9	8	7	6	6	7	8	9	9	
12		9	9	9	8	7	7	7	6	8	9	9	
13		9	8	9	9	8	7	7	8	8	9	9	
14		9	9	9	8	8	8	8	8	9	9	9	
15													



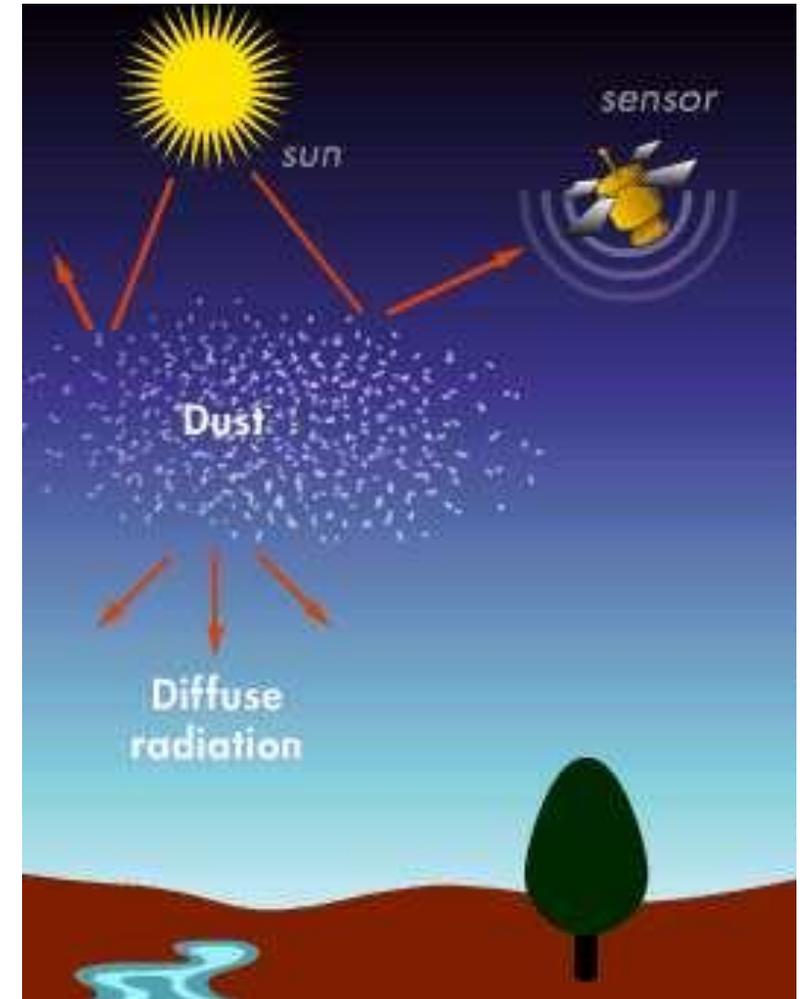
- **Satellite data – Contrast enhancement**

- Most digital display systems allow to break each primitive color into 256 levels/degrees of intensity.
- Images that uses the full range - excellent contrast

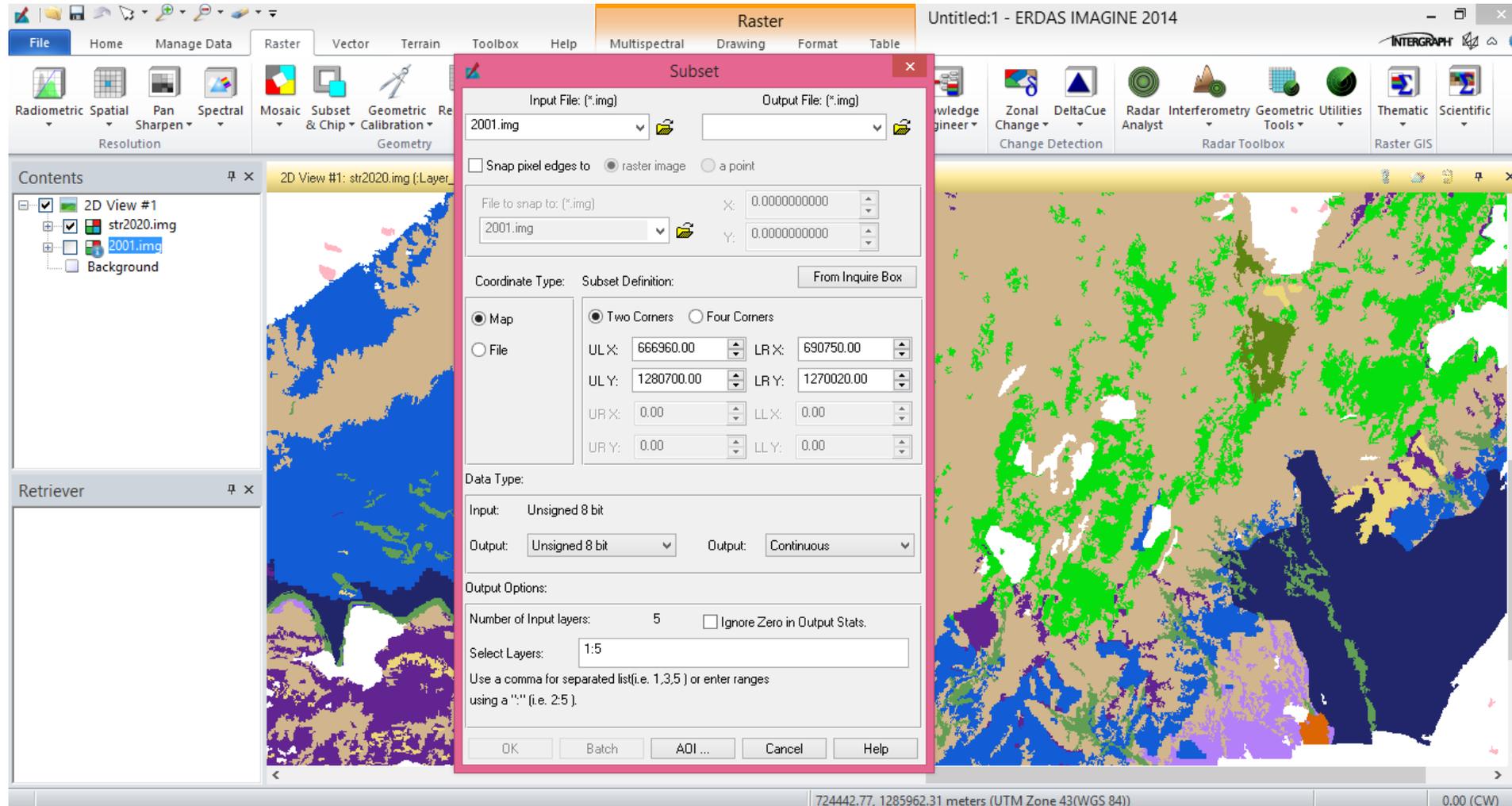


• Satellite data – Radiometric adjustment

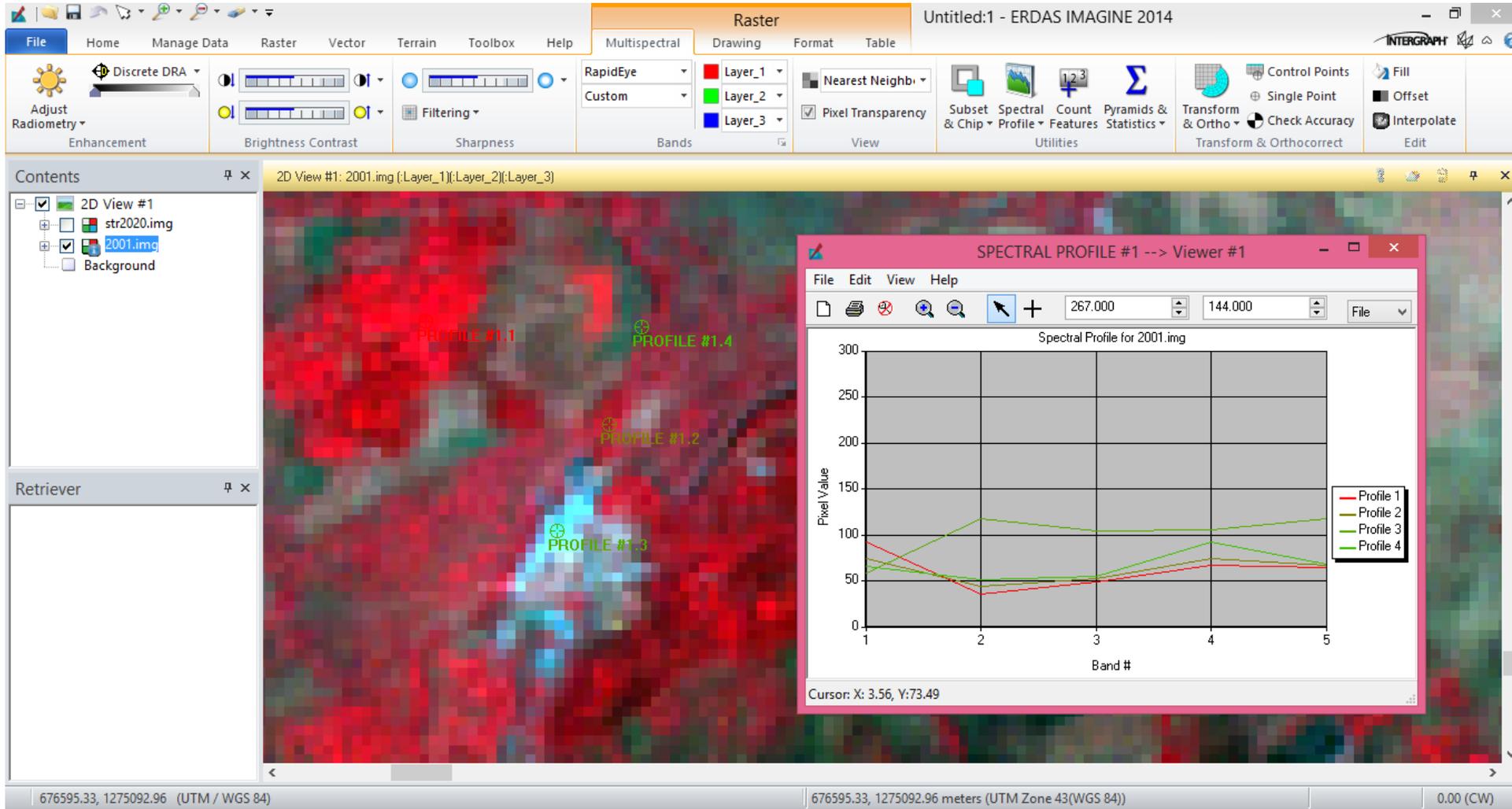
- Radiometric error is due to
 - Sunlight illumination angle – atmospheric effects - does not hit all objects at the same angle
 - Reflection from objects – perturbed by atmosphere
 - Changes the radiation's spectral properties
- Can be corrected through
 - Complex mathematical models
 - Through known radiometric values
 - Eg. Surfaces of water bodies, glacial ice caps, desert sand



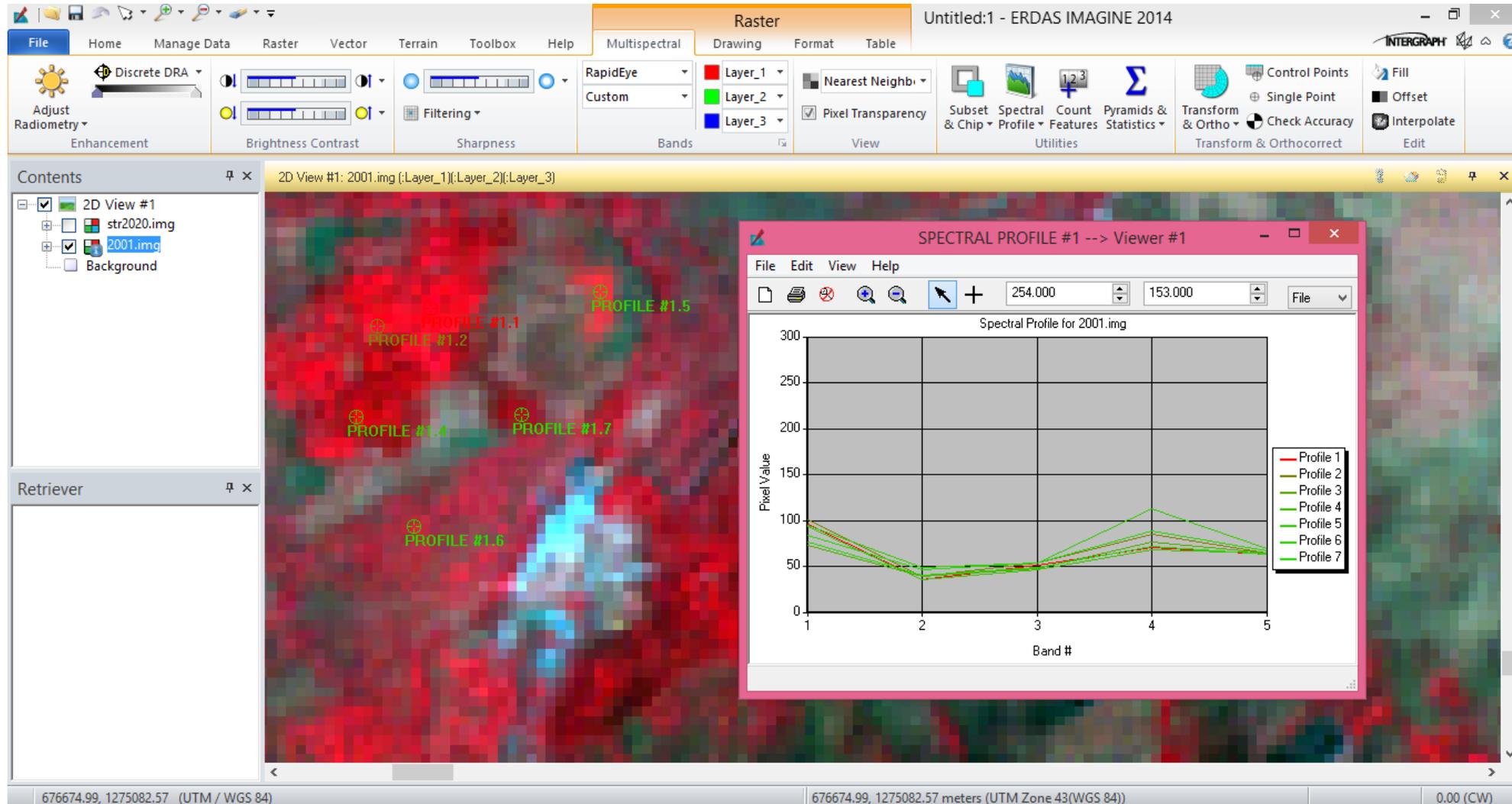
- **Satellite data – Subset image**



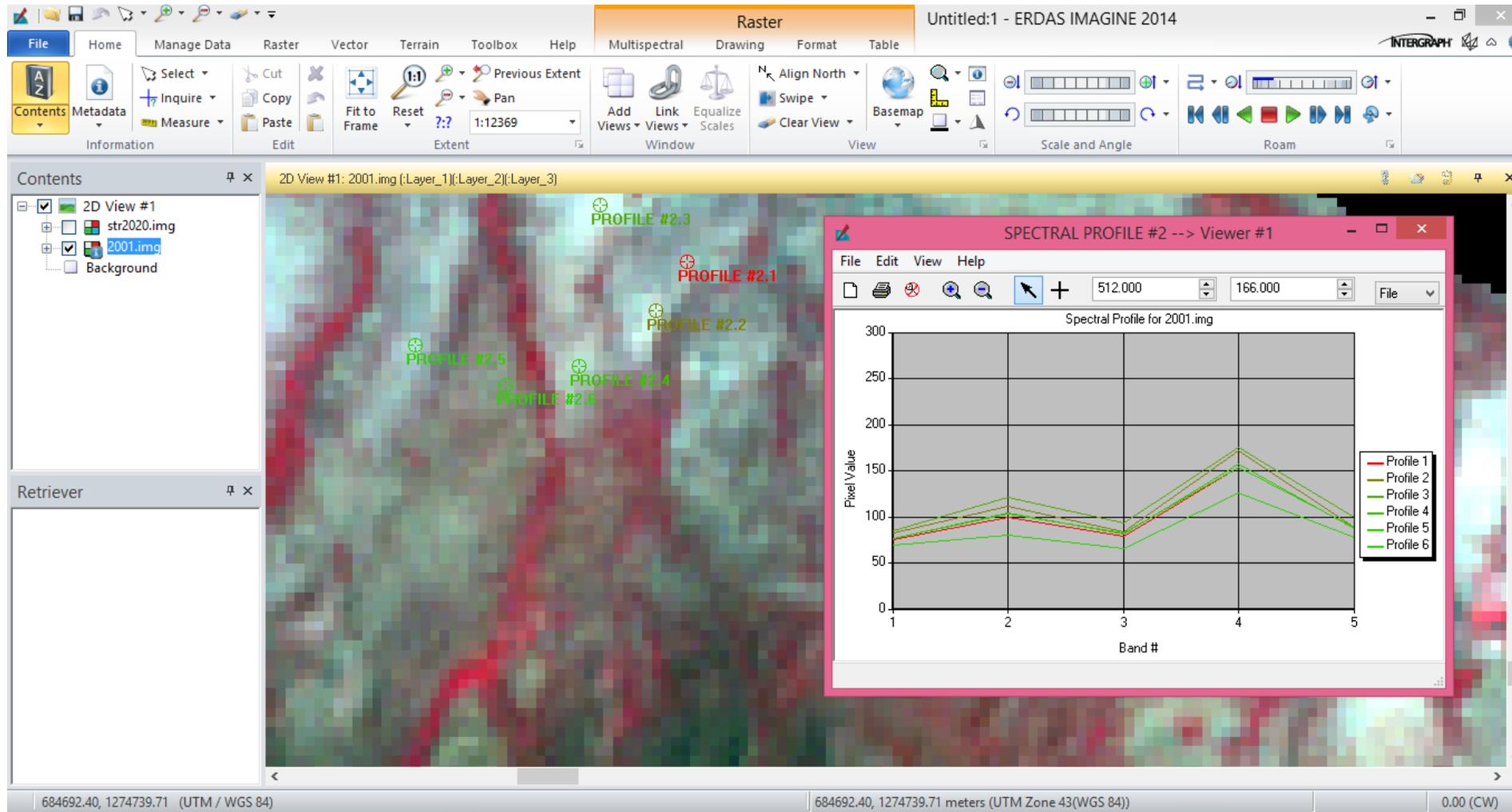
- **Satellite data – Spectral profile**



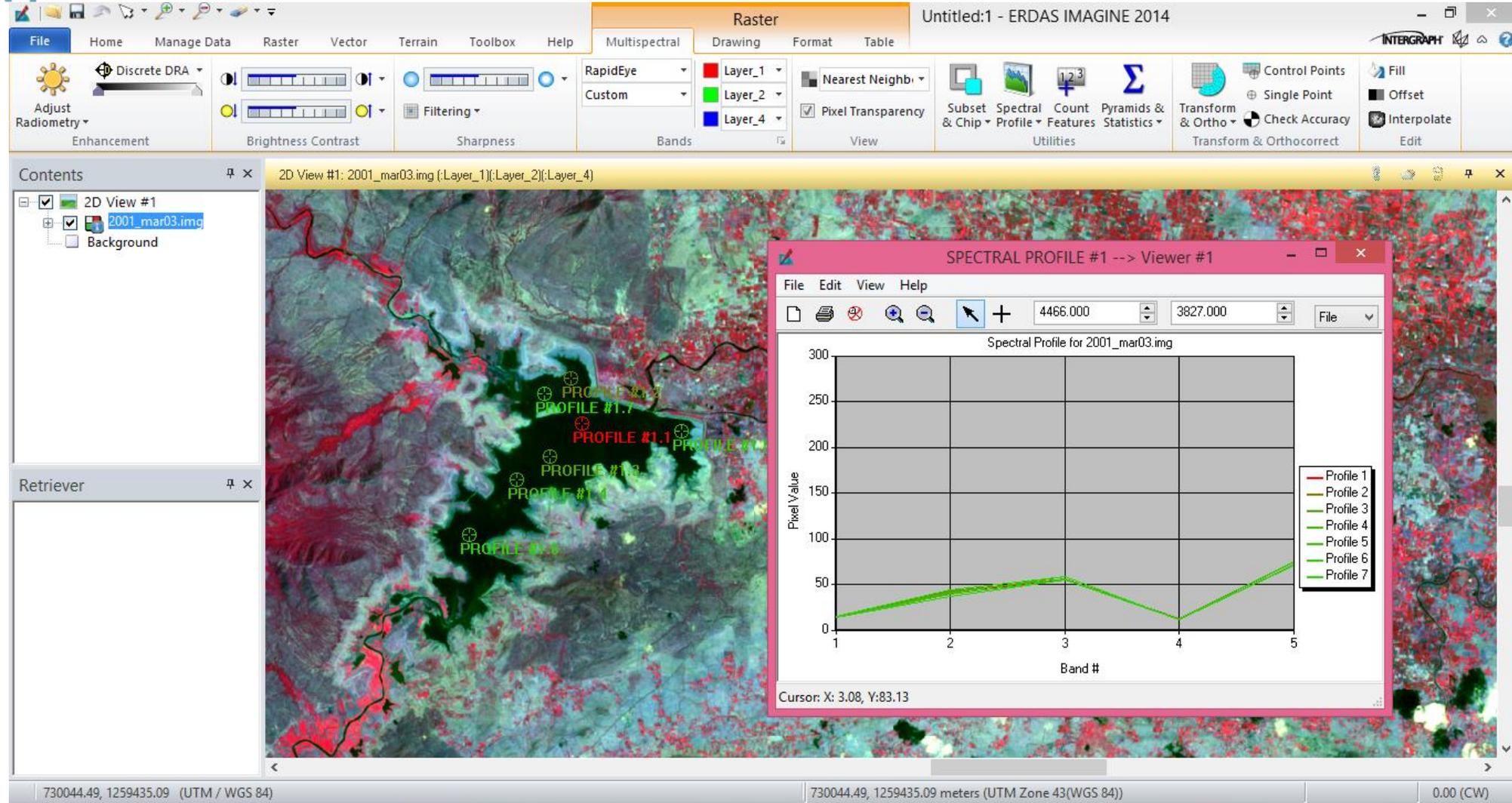
- Satellite data – Spectral profile of Vegetation



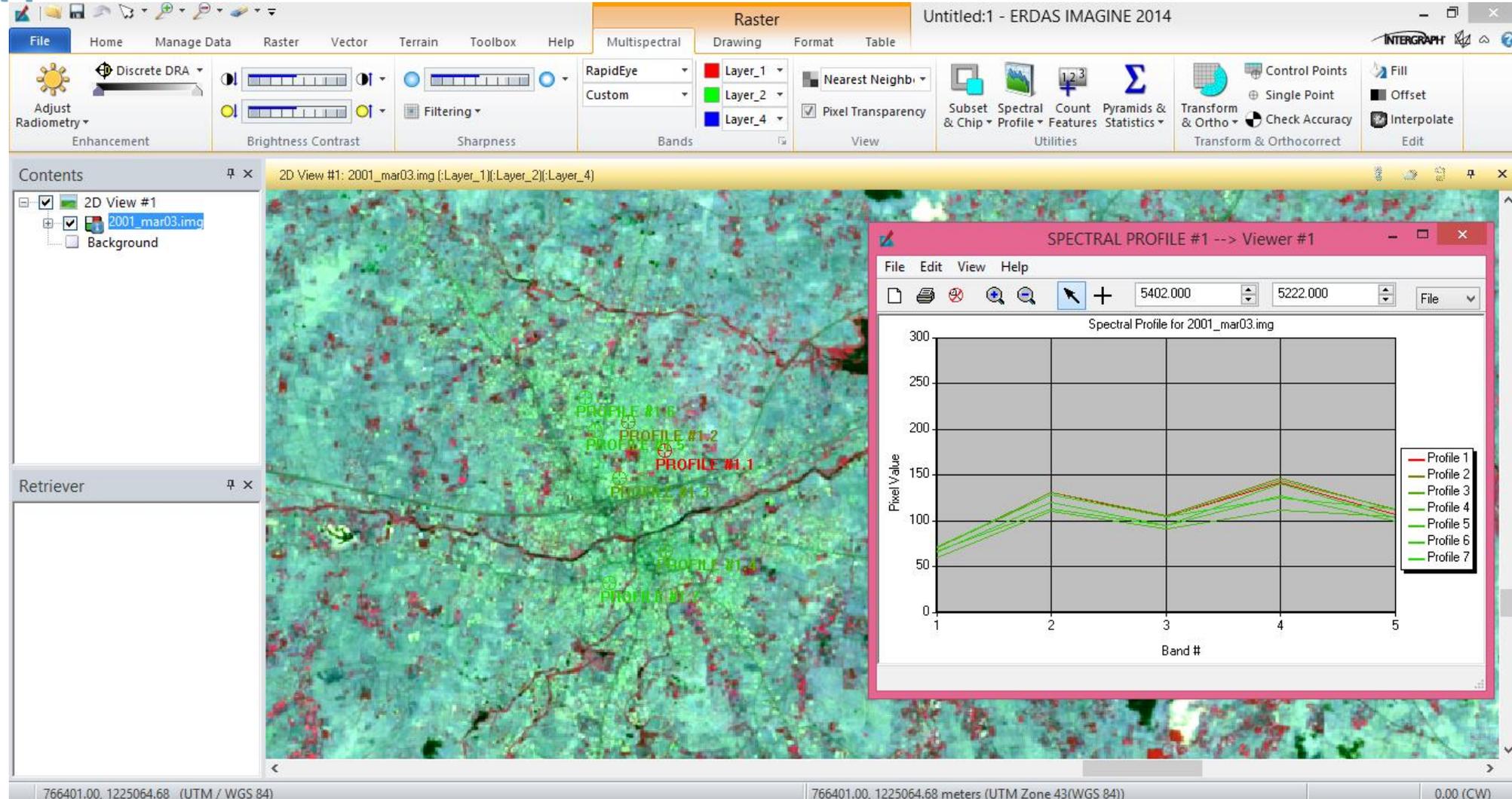
- Satellite data – Spectral profile of Soil



- Satellite data – Spectral profile of Water



- Satellite data – Spectral profile of Urban



- **Band ratio – Ratio vegetation index**

$$\text{Ratio Vegetation Index} = \frac{NIR}{RED}$$

NIR = Near Infrared band

RED = Red band

- **Band ratio – Normalized different vegetation index**

$$\textit{Normalized difference Vegetation Index} = \frac{NIR - RED}{NIR + RED}$$

NIR = Near Infrared band

RED = Red band

- **Band ratio – Soil adjusted vegetation index**

$$\text{Soil adjusted Vegetation Index} = \left\{ \frac{NIR - RED}{NIR + RED} \right\} * (1 + L)$$

NIR = Near Infrared band

RED = Red band

*In Landsat 4-7, SAVI = ((Band 4 – Band 3) / (Band 4 + Band 3 + 0.5)) * (1.5).*

*In Landsat 8-9, SAVI = ((Band 5 – Band 4) / (Band 5 + Band 4 + 0.5)) * (1.5).*

