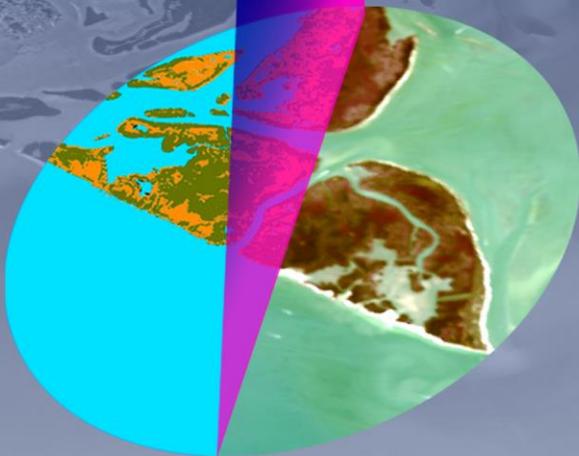




Habitat-Mapping Training Manual

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University of South Florida
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Introduction

Habitat mapping has been common practice for decades in environmental management, but has only recently become efficient and user-friendly for regular mapping updates. Such time series of habitats are vital for monitoring change that may be evaluated to guide targeted management efforts. This manual will guide the user in creating habitat maps using WorldView and Landsat satellite imagery. Results should be useful for stakeholders in policy making and conservation practices.

This manual is an output from the 2018-2019 NOAA/NERR Collaborative Science Catalyst Grant awarded to Co-PIs Frank Muller-Karger and Matthew McCarthy, with Brita Jessen as collaborative lead from the Rookery Bay National Estuarine Research Reserve (NERR). That project, *Mapping Terrestrial and Benthic Habitat Change to Address Mangrove and Seagrass Migration and Die-off in Response to Recent and Long-term Environmental Drivers*, used WorldView and Landsat imagery to map habitats throughout the 100,000-acre reserve from 2010-2018, which included the impact of category 3 Hurricane Irma after it made landfall in the reserve in September of 2017.

For information please visit the NERRS project webpage (<http://www.nerrsciencecollaborative.org/project/MullerKarger18>) or contact the author at mjm8@mail.usf.edu.

LANDSAT, SPOT, and other high spatial and spectral resolution satellite image systems

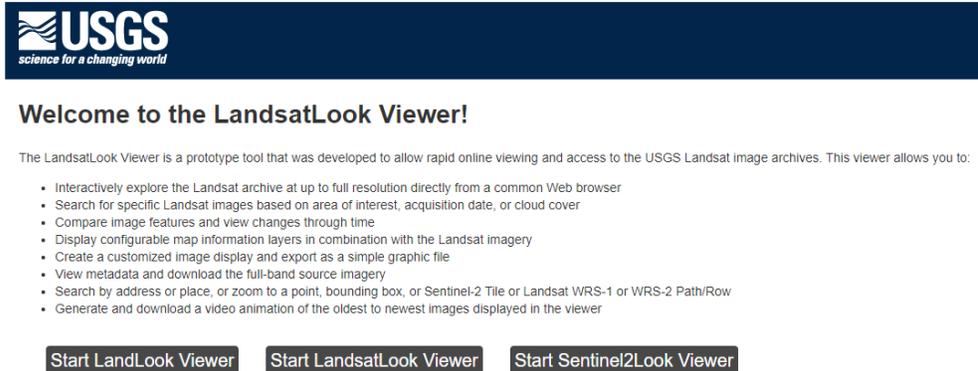
(Credit: Frank Muller Karger, University of South Florida)

There are four types of resolution when discussing satellite imagery in remote sensing:

- Spatial resolution is defined as the pixel size of an image representing the size of the surface area (i.e. m²) being measured on the ground, determined by the sensors' instantaneous field of view (IFOV).
- Spectral resolution is defined by the wavelength interval size (discrete segment of the Electromagnetic Spectrum) and number intervals that the sensor is measuring;
- Temporal resolution is defined by the amount of time (e.g. days) that passes between imagery collection periods for a given surface location;
- Radiometric resolution is defined as the ability of an imaging system to record many levels of brightness (contrast for example). Radiometric resolution refers to the effective bit-depth of the sensor (number of greyscale levels) and is typically expressed as 8-bit (0-255), 11-bit (0-2047), 12-bit (0-4095) or 16-bit (0-65,535).

HOW TO DOWNLOAD LANDSAT DATA?

1. In a web browser, navigate to: landsatlook.usgs.gov
2. Click on **Start LandsatLook Viewer**



USGS
science for a changing world

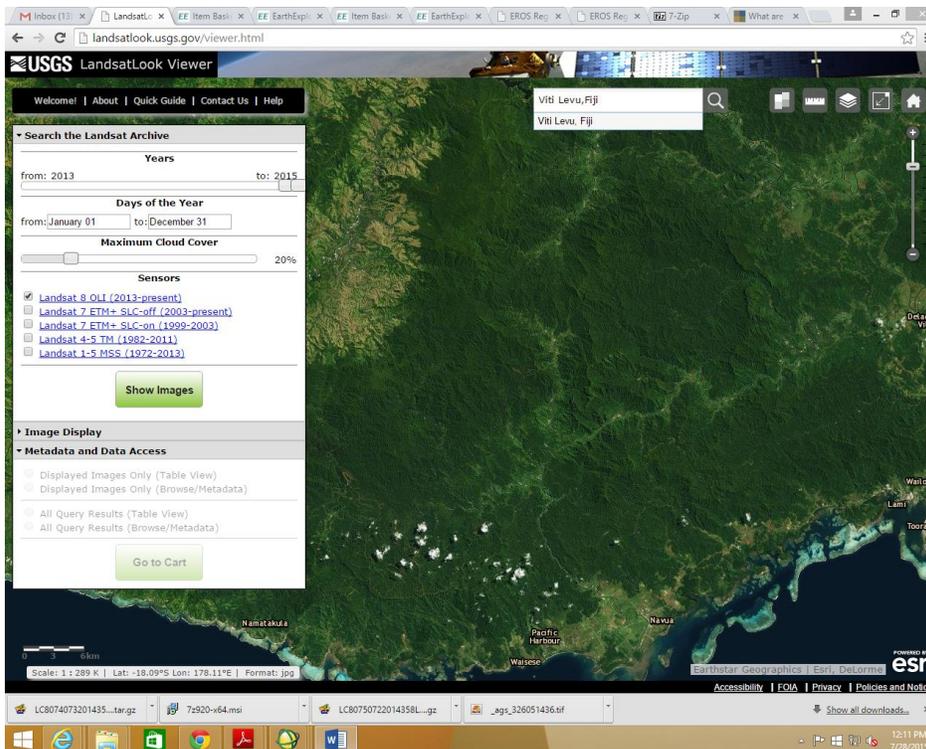
Welcome to the LandsatLook Viewer!

The LandsatLook Viewer is a prototype tool that was developed to allow rapid online viewing and access to the USGS Landsat image archives. This viewer allows you to:

- Interactively explore the Landsat archive at up to full resolution directly from a common Web browser
- Search for specific Landsat images based on area of interest, acquisition date, or cloud cover
- Compare image features and view changes through time
- Display configurable map information layers in combination with the Landsat imagery
- Create a customized image display and export as a simple graphic file
- View metadata and download the full-band source imagery
- Search by address or place, or zoom to a point, bounding box, or Sentinel-2 Tile or Landsat WRS-1 or WRS-2 Path/Row
- Generate and download a video animation of the oldest to newest images displayed in the viewer

[Start LandLook Viewer](#) [Start LandsatLook Viewer](#) [Start Sentinel2Look Viewer](#)

3. Once the page opens, select the **Years**, **Days of the year**, **Maximum cloud cover** (recommended that you keep it to 20%), Select the **sensor** (e.g. in this image Landsat 8 OLI (2013-present) was selected). In the **search window** type your area of interest (e.g. Viti Levu, Fiji) and Click on **Show Images**.



USGS LandsatLook Viewer

Welcome! | About | Quick Guide | Contact Us | Help

Viti Levu, Fiji

Viti Levu, Fiji

Search the Landsat Archive

Years
from: 2013 to: 2015

Days of the Year
from: January 01 to: December 31

Maximum Cloud Cover
20%

Sensors

- Landsat 8 OLI (2013-present)
- Landsat 7 ETM+ SLC-off (2003-present)
- Landsat 7 ETM+ SLC-on (1999-2002)
- Landsat 4-5 TM (1982-2011)
- Landsat 1-5 TMSS (1972-2013)

[Show Images](#)

Image Display

Metadata and Data Access

- Displayed Images Only (Table View)
- Displayed Images Only (Browse/Metadata)
- All Query Results (Table View)
- All Query Results (Browse/Metadata)

[Go to Cart](#)

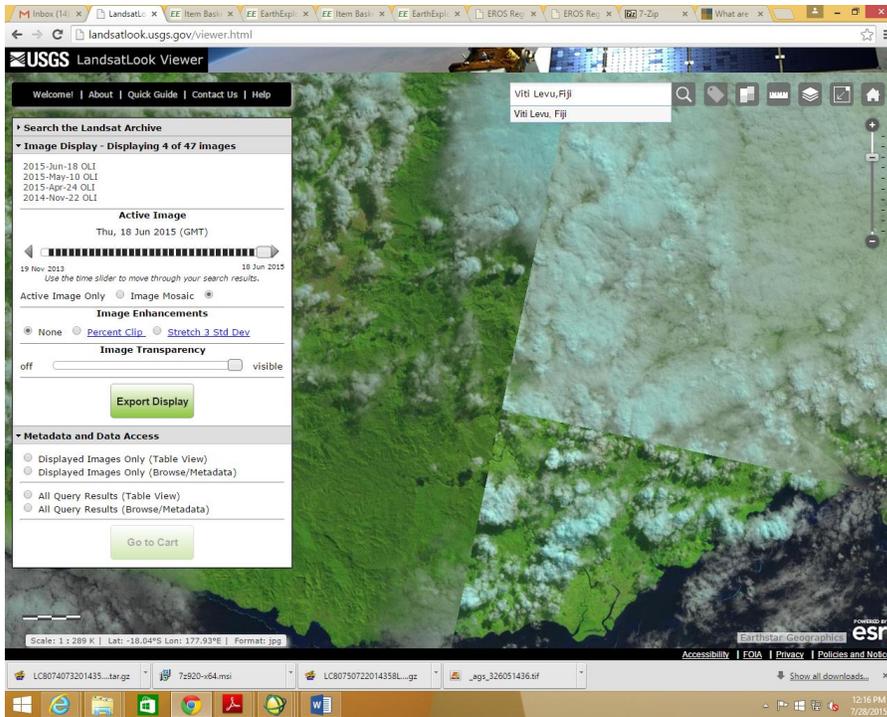
Scale: 1 : 229 K | Lat: -18.09°S Lon: 178.11°E | Format: jpg

Powered by Esri

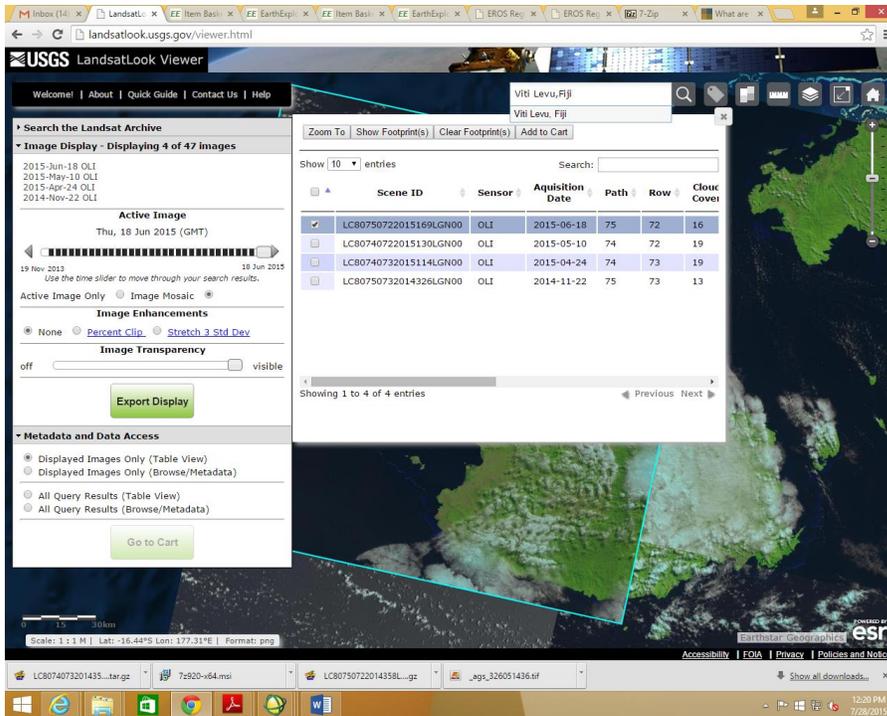
LC8074073201435...tar.gz 7z920-v64.msi LC80750722014358L...gz _ags_326051436.tif

12:11 PM 7/28/2015

4. As you can see below, the image appears in different layers. Under Metadata and Data Access, check the **Displayed Images Only (Table View)**.



- Once the **Displayed Images Only (Table View)** is selected, another windows opens up. Check on one of the **Scene ID** (e.g. the recent one is selected) and **click on Show Footprint(s)** tab.



- The area of the image will be selected as shown in light blue square. **Click on Add to cart.**

The screenshot shows the USGS LandsatLook Viewer interface. The search results table is as follows:

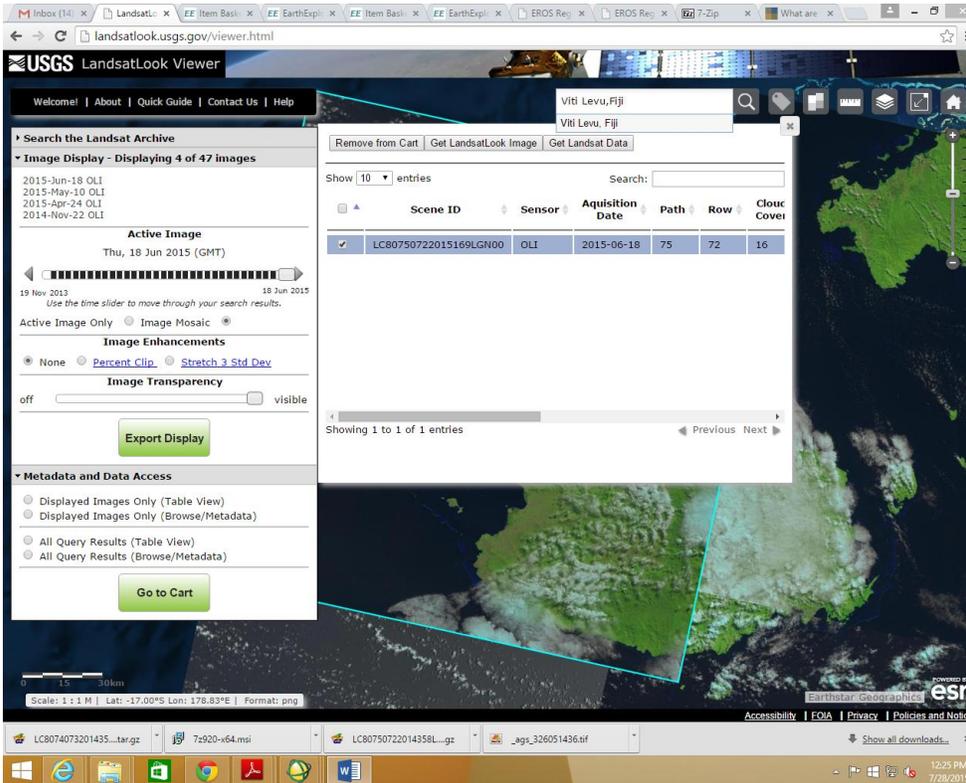
Scene ID	Sensor	Acquisition Date	Path	Row	Cloud Cover
<input checked="" type="checkbox"/> LC80750722015169LGN00	OLI	2015-06-18	75	72	16
<input type="checkbox"/> LC80740722015130LGN00	OLI	2015-05-10	74	72	19
<input type="checkbox"/> LC80740732015114LGN00	OLI	2015-04-24	74	73	19
<input type="checkbox"/> LC80750732014326LGN00	OLI	2014-11-22	75	73	13

The interface includes a search bar with "Viti Levu, Fiji" entered, a "Go to Cart" button, and various image display controls like "Active Image", "Image Enhancements", and "Image Transparency".

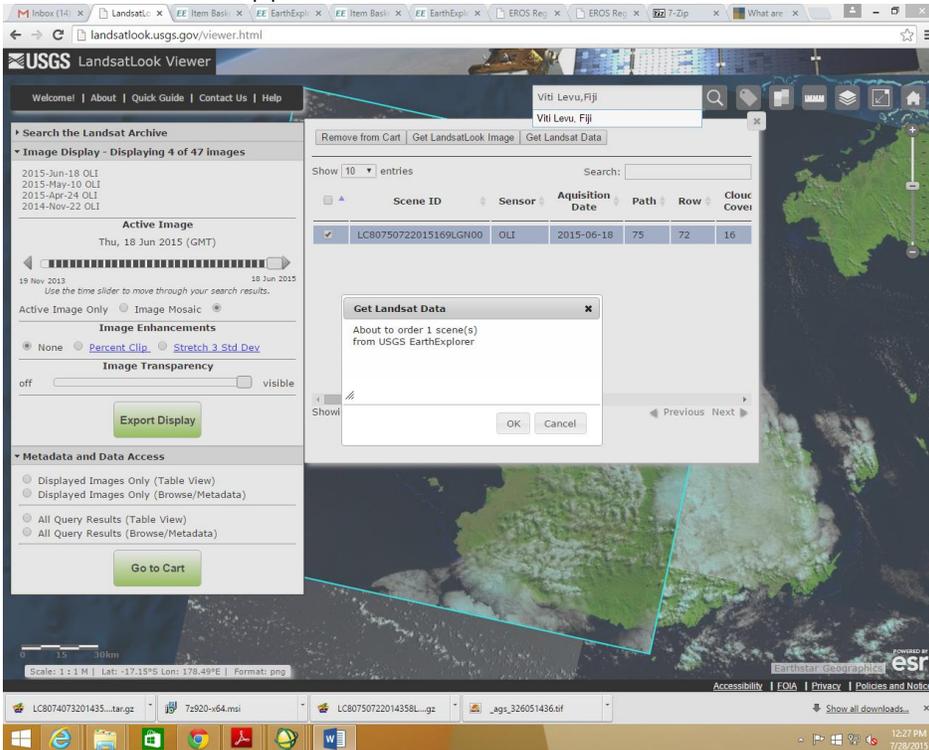
7. Click on **Go to Cart** tab.

This screenshot is identical to the one above, but the "Go to Cart" button in the "Metadata and Data Access" section is highlighted with a green border, indicating the next step in the process.

8. Check the file and click on **Get Landsat Data** tab.



9. New windows will appear, **Get Landsat Data**, click **OK**.



10. Item basket window will open. In the last column, there is two icon, one is **download icon** and other one is **X**. **Click on download icon**

USGS Home
Contact USGS
Search USGS

Item Basket

Home 2 New System Messages Item Basket (0) Roselyn Feedback Help

No scenes were automatically added to your item basket. Please select the appropriate order type for each scene and click 'Apply'.

Pending Scenes

Entity Id	Collection	Order	Bulk Download	Available Products	
LC80750722015169LGN00	L8 OLI/TIRS	<input type="checkbox"/>	<input type="checkbox"/>	Bulk Products LandsatLook "Natural Color" Image LandsatLook "Thermal" Image LandsatLook "Quality" Image LandsatLook images with Geographic Reference Level 1 GeoTIFF Data Product	 

[Toggle All Bulk Download](#)
[Apply](#)
[Go to Item Basket](#)

[Accessibility](#)
[FOIA](#)
[Privacy](#)
[Policies and Notices](#)
[Google Maps API Disclaimer](#)

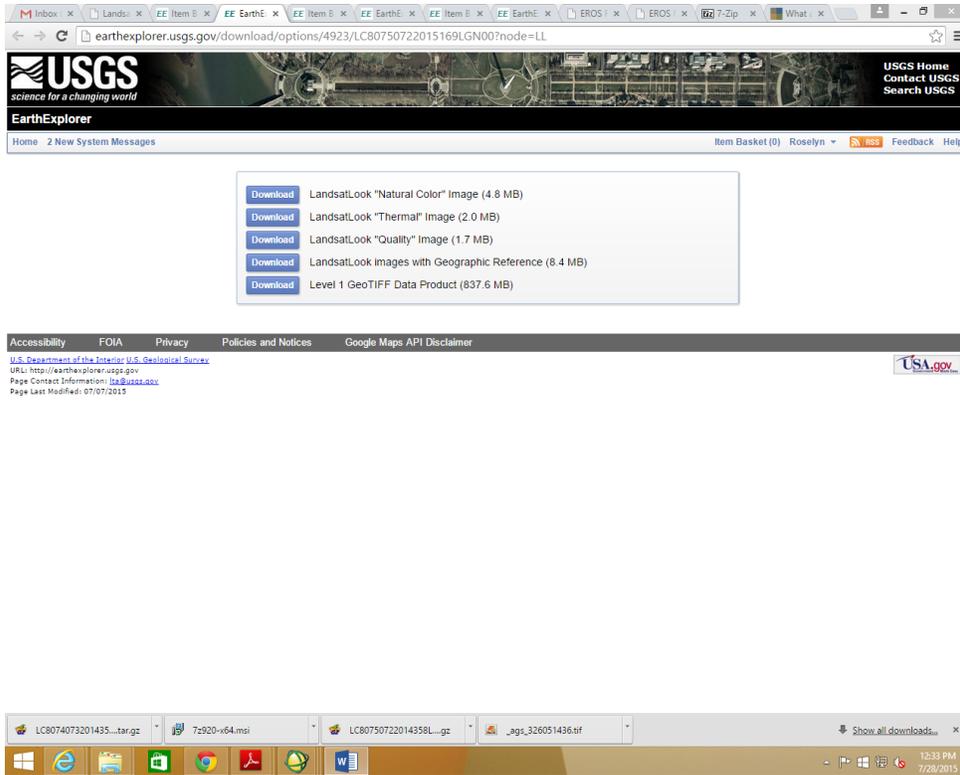
[U.S. Department of the Interior U.S. Geological Survey](#)
[USA: https://earthexplorer.usgs.gov](#)
[Page Contact Information: \[ia@usgs.gov\]\(mailto:ia@usgs.gov\)](#)
 Page Last Modified: 07/07/2015

<https://earthexplorer.usgs.gov/download/options/4923/LC80750722015169LGN00?node=LL>

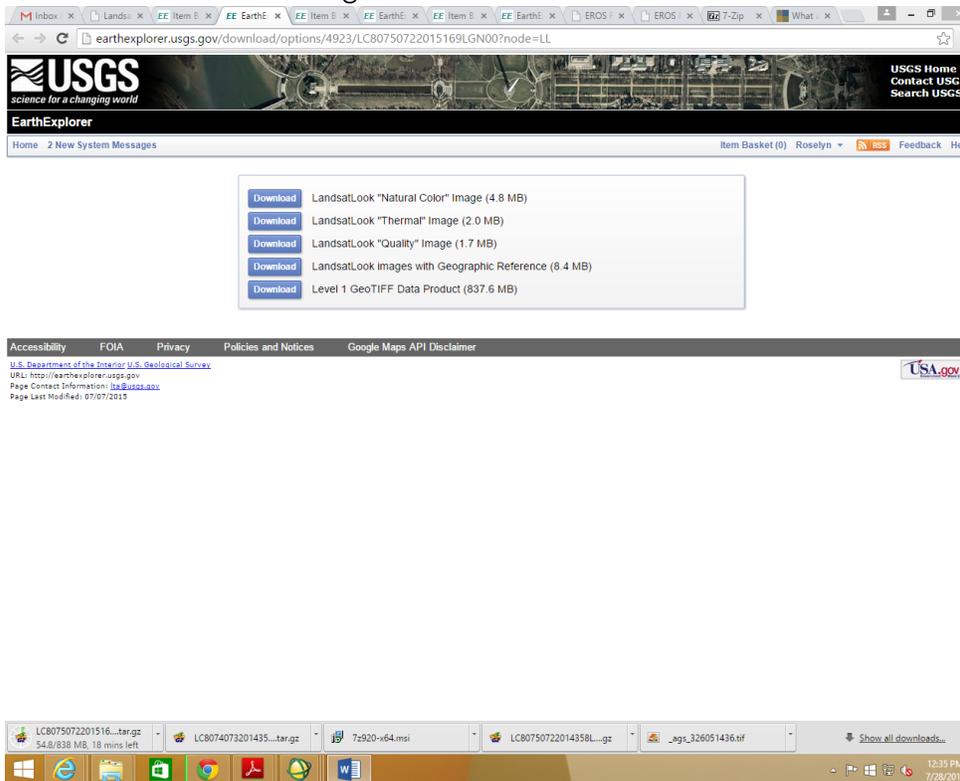
LC8074073201435...tar.gz | 7z920-r64.msi | LC80750722014358L...gz | _ags_326051436.tif | Show all downloads...

12:29 PM 7/28/2015

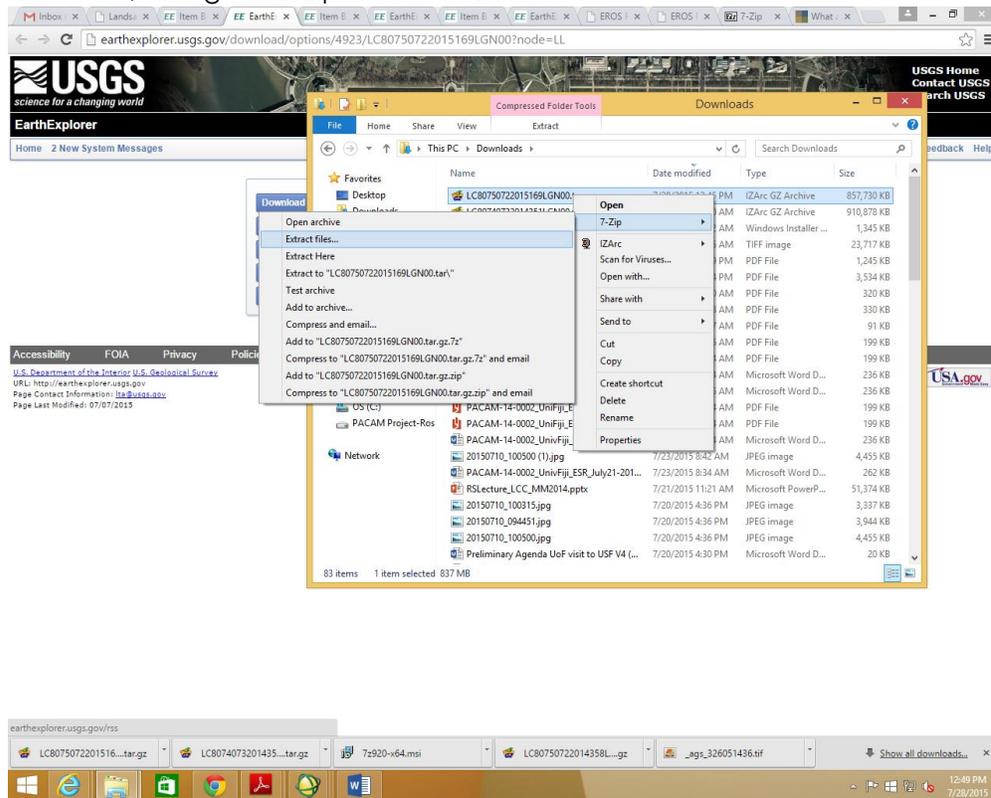
11. Another windows will open. In order to work with ENVI, we need the **Geo TIFF file** e.g. **click on the Download tab next to Level 1 Geo TIFF Data Product (837.6 MB)**



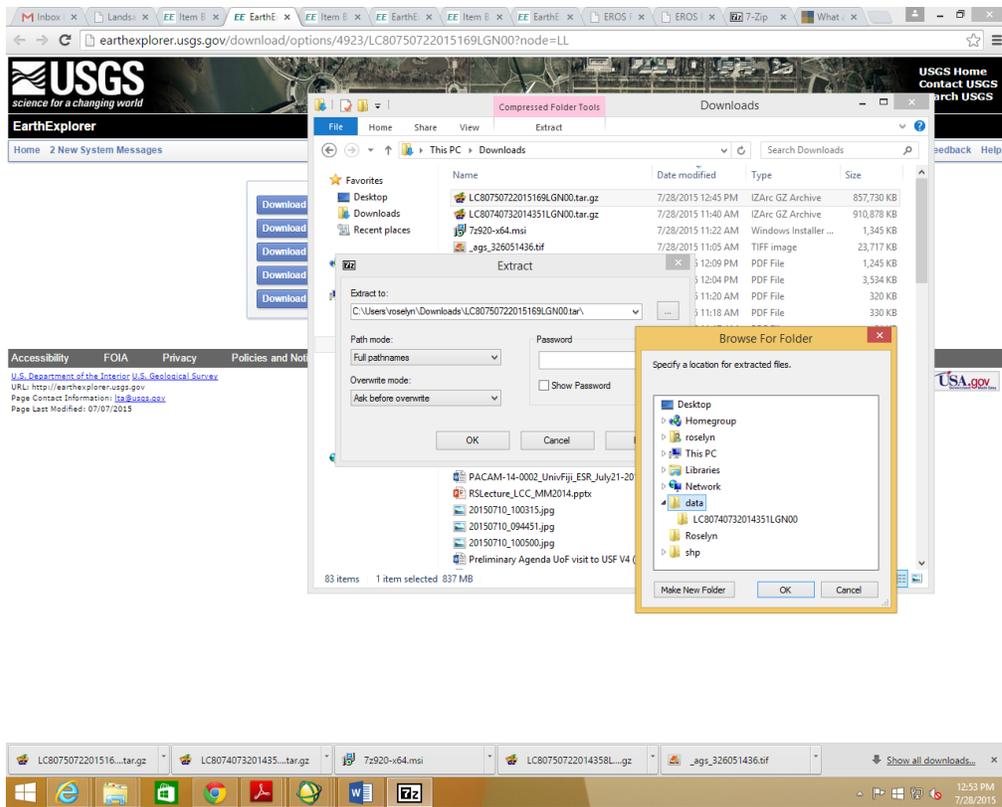
12. The file is now downloading.



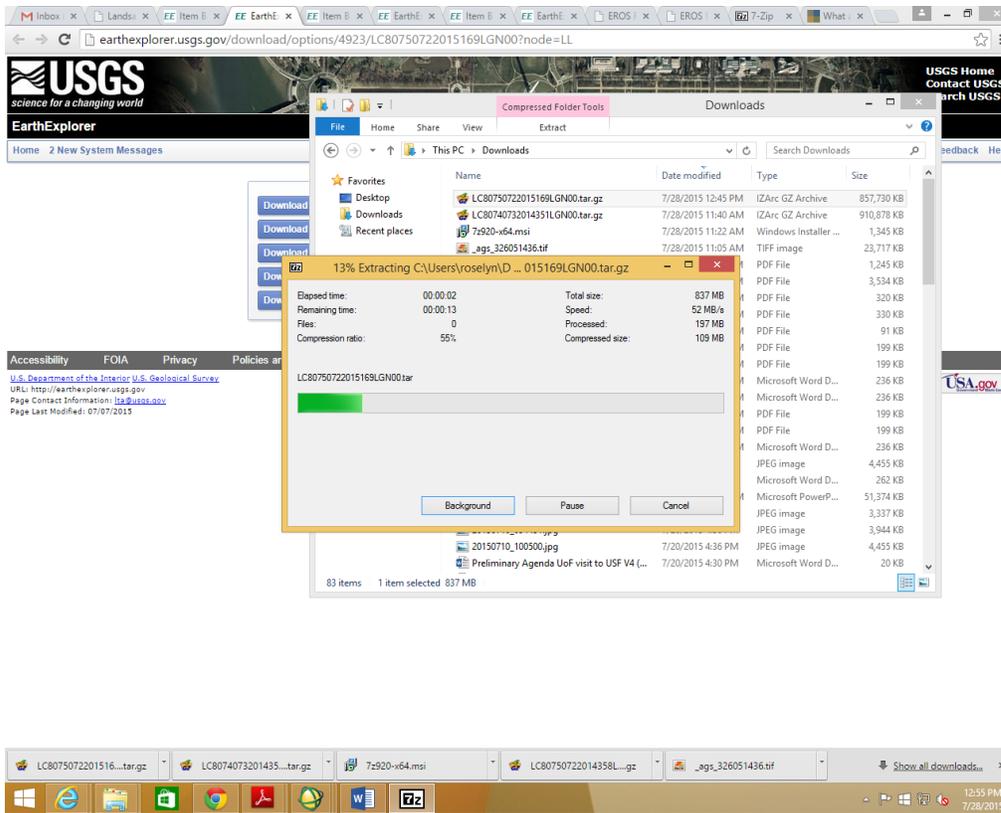
13. Once the download is complete. Open the Downloads folder, select the downloaded file, right click on it, and go to 7-Zip and then Extract files.



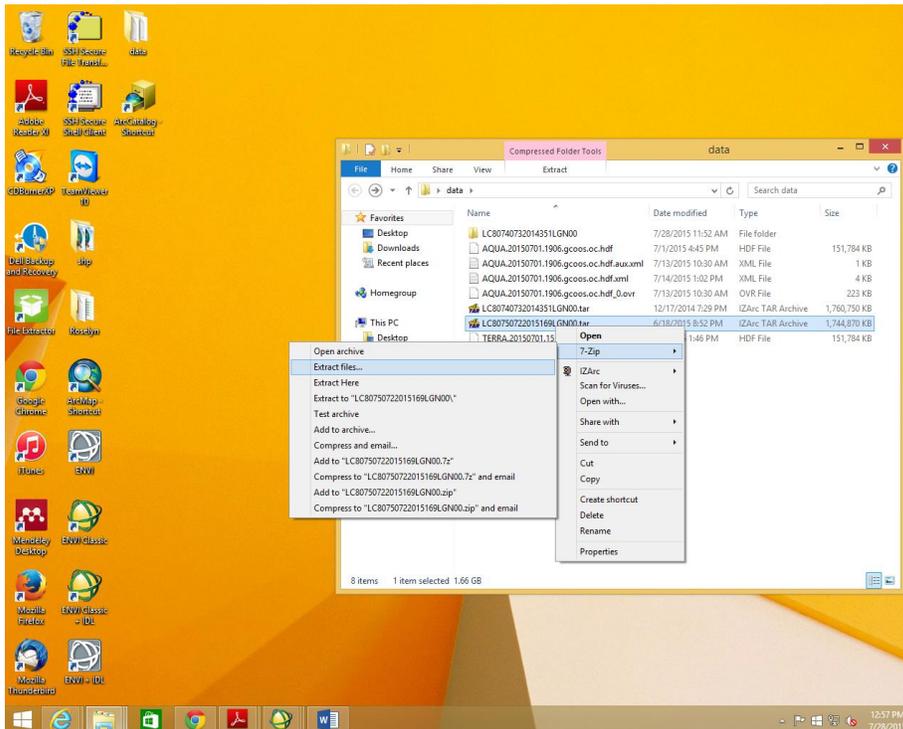
14. Extract files window will open, click on the Tab to select your file destination.

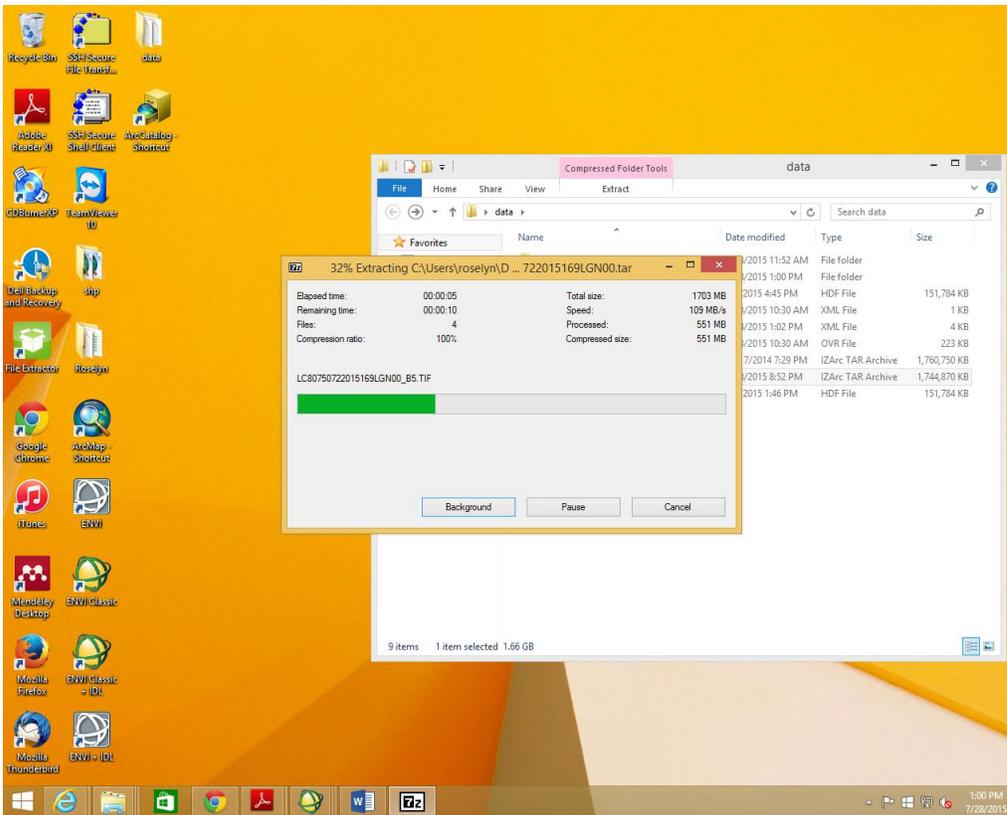


15. Click **OK** on the **Browse for Folder** and **OK** on the **Extract window**. The data file will now start extracting as shown below.

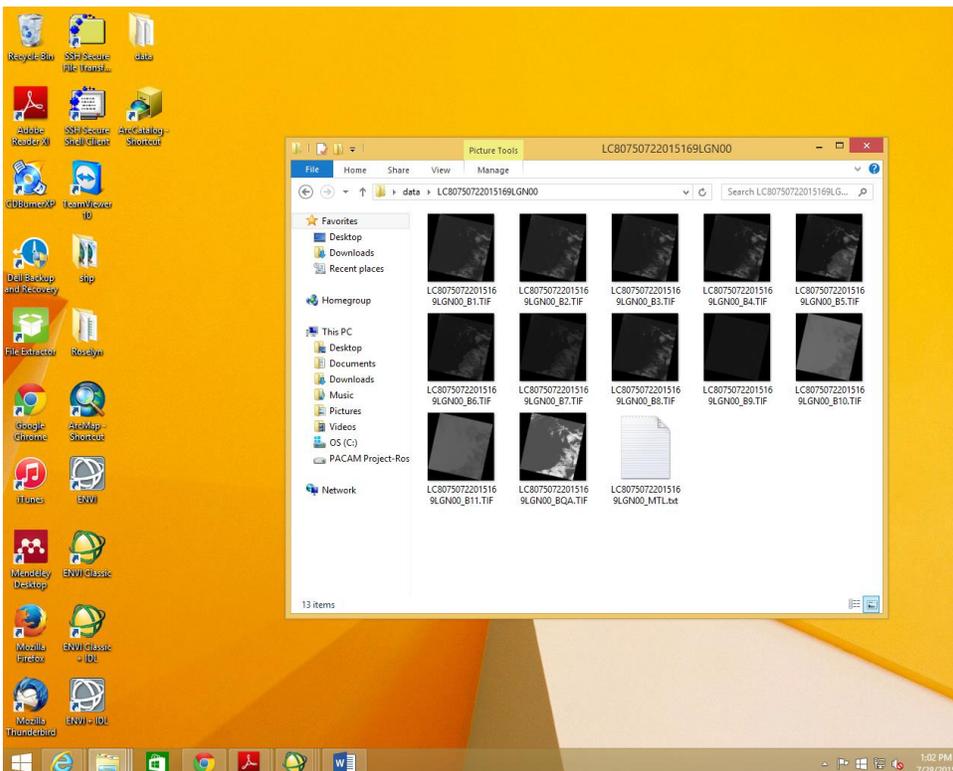


- Once the extraction is complete, go to the **folder** where you have saved the file and right click on it, go to 7-zip and extract file again to unzip the folder. In the **Extract** window, just click **OK** (Do not need to select the folder again).



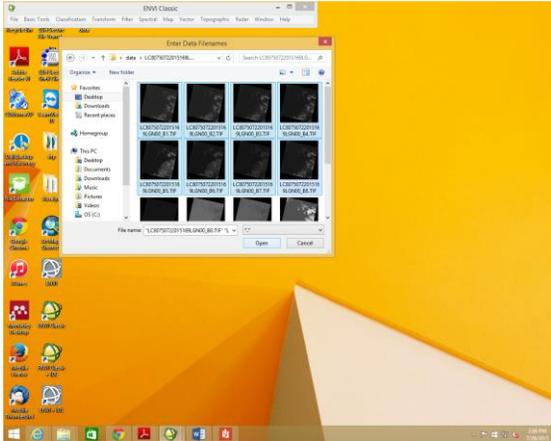


17. File is being extracted again and you will see that a new folder is created with the file name. Open the folder and you will see the images in each band.



HOW TO CLASSIFY LANDSAT DATA?

Open ENVI classic. Go to file open, Ctrl the TIF files you want to work with. Click Open.



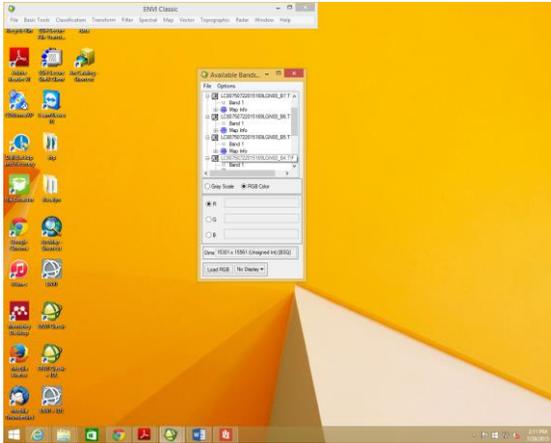
Available bands windows opens up. **Check on RGB Color** and **Select** your bands.

N.B as per Landstat 8 (Source: http://landsat.usgs.gov/band_designations_landsat_satellites.php),

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. New band 1 (ultra-blue) is useful for coastal and aerosol studies. New band 9 is useful for cirrus cloud detection. The resolution for Band 8 (panchromatic) is 15 meters. Thermal bands 10 and 11 are useful in providing more accurate surface temperatures and are collected at 100 meters. Approximate scene size is 170 km north-south by 183 km east-west (106 mi by 114 mi).

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Launched February 11, 2013	Bands	Wavelength (micrometers)	Resolution (meters)
	Band 1 - Coastal aerosol	0.43 - 0.45	30
	Band 2 - Blue	0.45 - 0.51	30
	Band 3 - Green	0.53 - 0.59	30
	Band 4 - Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - SWIR 1	1.57 - 1.65	30
	Band 7 - SWIR 2	2.11 - 2.29	30
	Band 8 - Panchromatic	0.50 - 0.68	15
	Band 9 - Cirrus	1.36 - 1.38	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)	

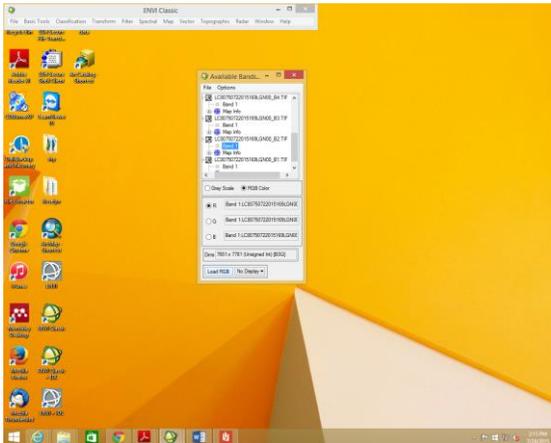
* TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered data product.



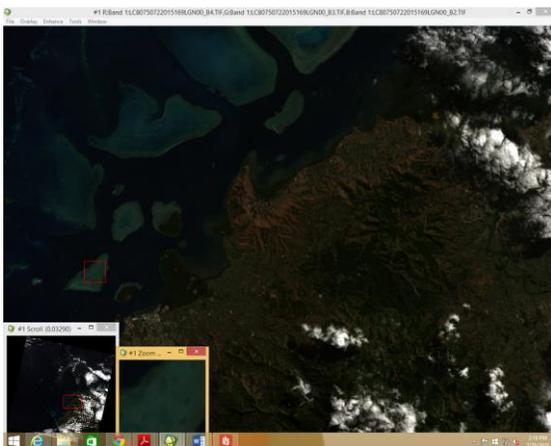
For **Red**, Click on Band 1 under TIFF Band 4 image (LC80750722015169LGN00_B4)

For **Green**, Click on Band 1 under TIFF Band 3 image (LC80750722015169LGN00_B3)

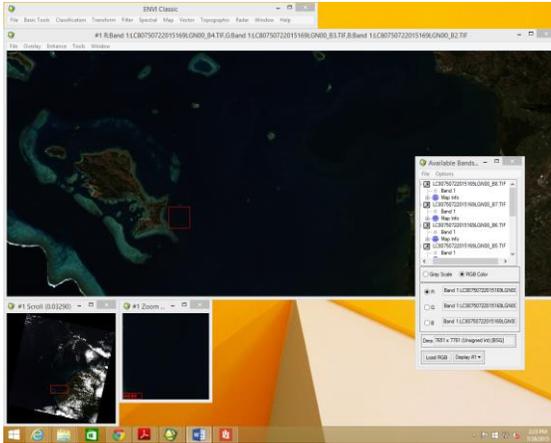
For **Blue**, Click on Band 1 under TIFF Band 2 image (LC80750722015169LGN00_B2)



Once all is selected, **click on Load RGB.**



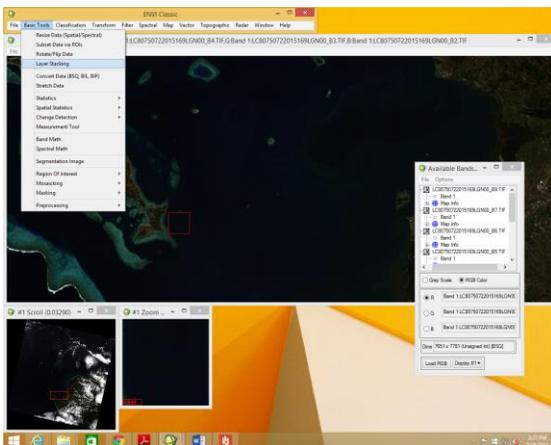
This is how you file will look like now. You can move the cursor around the Scroll window to view or zoom to your area of interest.



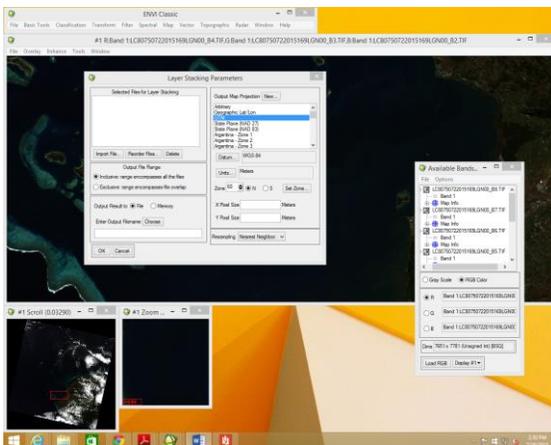
It becomes important to stack to layers to make classifying easier. As you can see on the Available bands that all layers (bands) appear separate.

HOW TO DO LAYER STACKING?

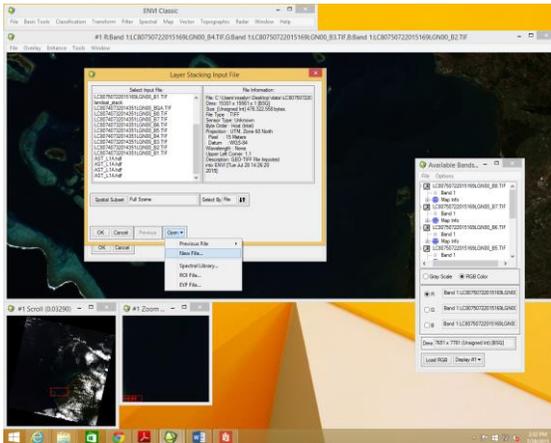
Go to ENVI Classic- click on Basic Tools, then on Layer stacking.



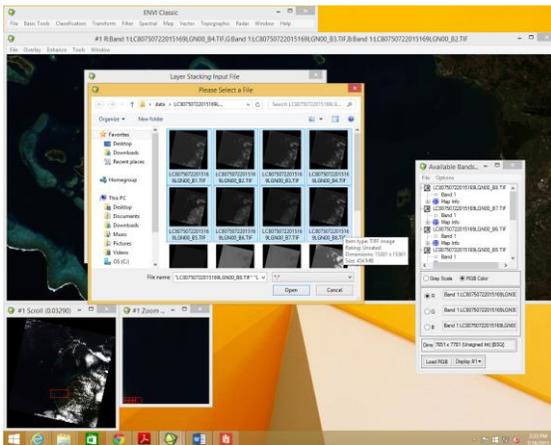
Layer Stacking Parameters window will open. Under **Selected files for Layer Stacking**, there is an **Import File** tab, click on it,



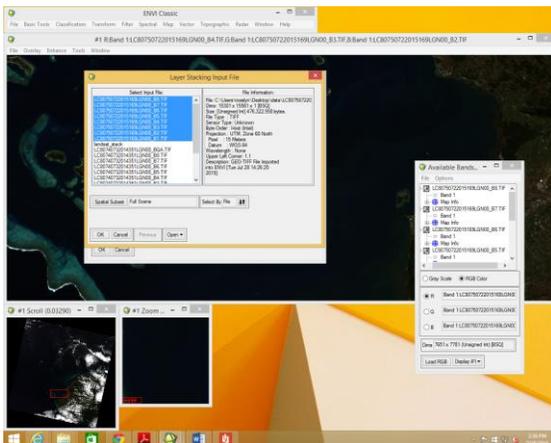
Click on open drop down list and select, **New file.**



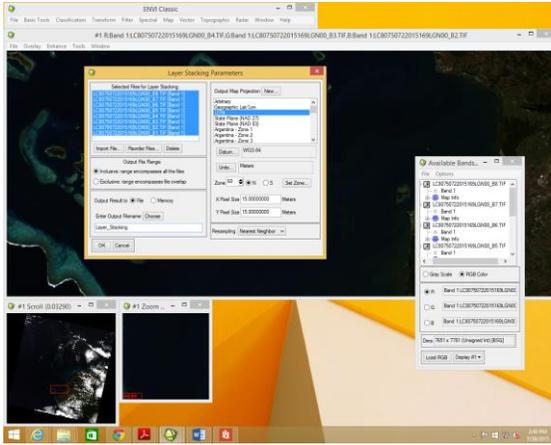
Navigate to the folder you have saved your file, press **CTRL** and select the **TIFF images** you want to be layered. Click **Open.**



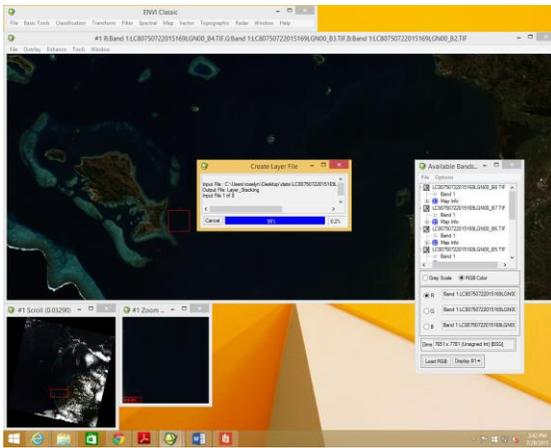
Now you have all the selected images under your **Select Input File.** Press **CTRL**, select the 8 images as shown below and Click **OK.**



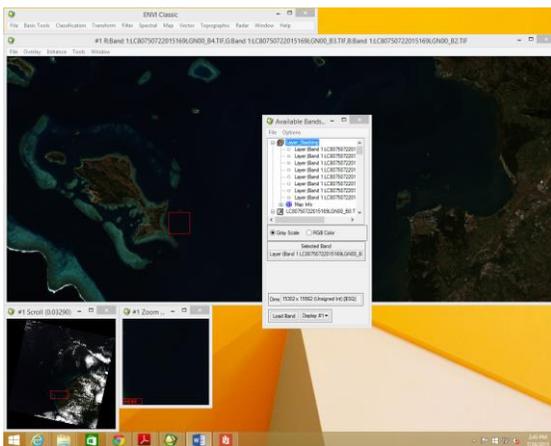
The **Layer Stacking Parameters** window will open. Type **Layer_Stacking** under **Enter Output Filename.** Other default parameters look ok. Click on **OK.**



Create Layer File will be processed as shown below.



Available Bands window will open and now you have all the selected banded under Layer_Stacking as shown below.



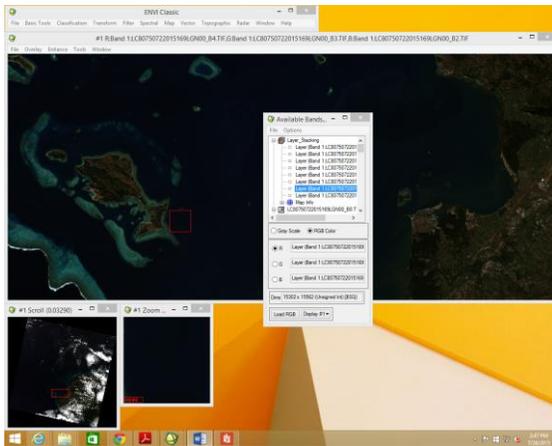
Your layers are stacked and now you the ready to classify them.

CheckRGB color and select your bands as shown below:

Red- Band 4

Green – Band 3

Blue- Band 2



Click on **Load RGB**. In drop down Display tab, you can view as **Display #1** or Click on **New Display**.

You are now ready to follow the Classification Tutorial.

CLASSIFICATION USING ENVI CLASSIC

Open ENVI Classic

Open image>>>chose image file>>>open (if Landsat 8, under RGB choose Band 4 for Red,

Band 3 for green

Band 2 for blue



Load RGB>>> image display window opens

In the ENVI Classic window>>>click on classification>>>Unsupervised>>>ISODATA

In the **classification input file** window>>>select the file name you used to open the first image (if you

have masking option then you can click the select **mask band** tab)



Click OK



The **ISODATA Parameters** window will open



Choose the number of classification you would want to see



Enter output filename >>>and rephrase the name by adding "_ISODATA"



Available band window will open>>>click on the ISODATA file you created for all; R,G,B



Choose **new display**>>>click on **load RGB**

* Repeat the same steps for K-Means (to see the difference between ISODATA and K-Means)

ENVI 5.3 (Masking and FLAASH Atmospheric Correction)

Radiance:

- is the measurement of light
- is the measurement for calibrations
- looks at one single angle

Eradiance:

- all the light that can be collected at all different angles

**Need to use MTL.txt for calibrations*

Masking

ENVI 5.3 >>> Open MTL >>> it will open the Landsat image automatically

Toolbox >>> search **Mask** >>> click **apply mask** >>> in the window, select the **MTL.txt** file with highest number of bands

Spatial subset (leave it as it is) >>> select **mask band** >>> **mask options** >>> click on **build mask**

Import ROI >>> select ROI file

Select the output name e.g. mask_envi >>> **Apply mask parameters** window opens

Leave mask value as 0

Enter output filename e.g. applied_mask_envi

Click **OK**

FLAASH Atmospheric Correction

ENVI 5.3 >>>Open MTL>>>it will open the Landsat image automatically

Toolbox>>>Radiometric Correction>>>Radiometric calibration (select mask file in window after building mask)

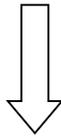
File selection (select multispectral with image preview)>>>**spatial subset** (subset with file)

↓
Click **OK**

Radiometric calibration window>>> check if Radiance is there>>>**Apply FLAASH settings**

Output file e.g. calibrated_subset>>> Click **OK** (wait for Radiometric calibration to load *blue loading bar)

↓
A new image opens (this image will be used for FLAASH atmospheric corrections)



Toolbox>>>Radiometric Correction>>>Atmospheric Correction>>> Flaash atmosphere

FLAASH Atmospheric correction model input parameters window opens (use file you calibrated in page 1 e.g. calibrated_subject; use default values- check single scale factor for all bands)

Output>>> e.g. subset_calibrated flaash

Output directory of new files >>>create a folder called flaash files

Sensor type: Multispectral (Landsat TM 7 or Landsat 8 or WV2 - depends which image is being used)

Flight date>>> change as per the information on MTL.txt file

e.g. Date acquired: 2013-10-10

scene center time = 22 (hr): 08(min): 45(sec)

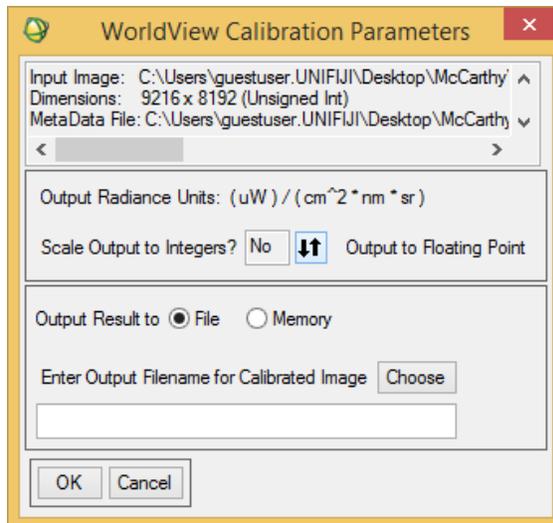
Atmospheric model: Tropical

Aerosol Model :Maritime

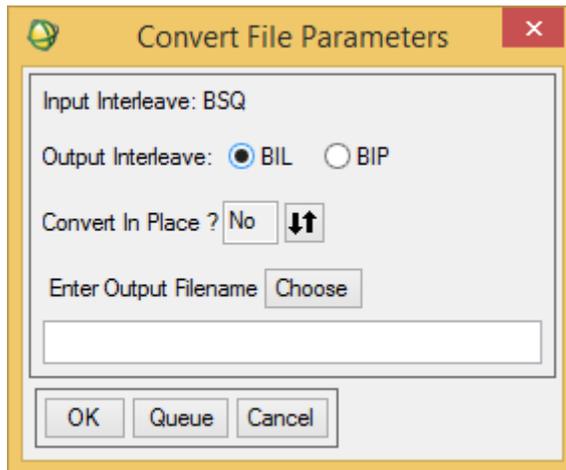
Aerosol Retrieval : 2-Band over water

WORLDVIEW IMAGERY PROCESSING

- Sections
 - Data Acquisition
 - Pre-processing
 - Processing (classification)
 - Post-processing
- Data acquisition
 - WorldView satellite imagery are commercially owned and distributed
 - Images may be distributed free of charge to those individuals whose position or organization have access through the NextView License
 - All Federal Agency staff, and academics with a current NASA- or NSF-funded grant should be covered by the license
 - Images should be ordered through the DigitalGlobe online portal at:
<http://evwhs.digitalglobe.com>
 - First-time users will have to set up an account as verified by DigitalGlobe
- Preprocessing
 - Data management
 - Unzip any images or files - store in logical order/location
 - Create folders for output files from calibration, atmospheric correction, and any other anticipated steps – this helps keep files organized
 - Calibration and atmospheric correction in ENVI 5.3 - this should be the first preprocessing step taken for all images (i.e. prior to any subsetting, georectification, orthorectification, co-registration, etc.) because those steps may resample the image, which may rearrange or reorient pixels. Atmospheric correction is most accurate when applied to the raw image in its original orientation as delivered/downloaded. Calibration applies gain and offset corrections to data and converts the data to an appropriate format for FLAASH atmospheric correction.
 - Radiometric calibration - converts raw image data (digital numbers) to radiance or reflectance
 - WorldView Radiance tool (ENVI Classic)
 - Basic Tools>Preprocessing>Calibration Utilities>WorldView Radiance
 - Select 8-band NTF image
 - Select unzipped corresponding IMD file
 - Output to **Floating Point** (necessary for FLAASH)

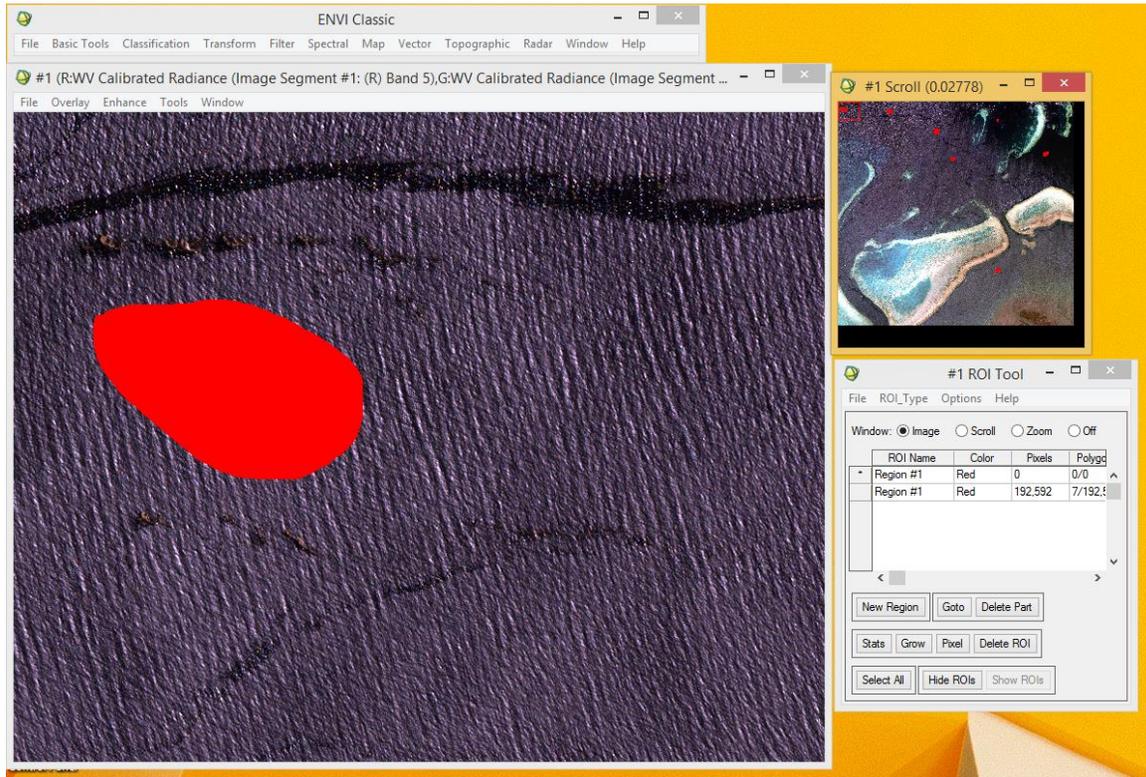


- The output will then need to be converted to a BIL file format using the Convert Data tool: Basic Tool>Convert Data

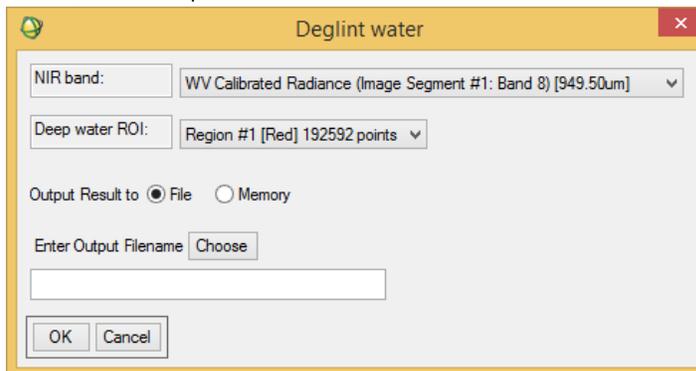


- Radiometric Calibration tool (ENVI 5.3 64-bit)
 - Open MTL Landsat image file (i.e. metadata file; note that this tool does not work well with WorldView imagery)
 - Select FLAASH settings
- **FLAASH - Fast Line-of-sight Atmospheric Analysis of Hypercubes is an advanced method of atmospheric correction**
- For Landsat 1, 2 and 3 (Multispectral Scanner sensor), FLAASH may not perform properly, so a technique called Dark Object Subtract is recommended. This tool can be found in the ENVI>Spectral>Spear toolbox. Follow prompts and evaluate the output to ensure the results appear accurate.
- Deglinting (as needed for images with substantial sunglint; Note: this will render terrestrial habitats unusable).
 - Download deglint.sav file: <https://geonet.esri.com/thread/43308> and save it to C:\Program Files\Exelis\ENVI53\classic\save_add
 - Start ENVI Classic + IDL (must start both)
 - Open image to be deglinted

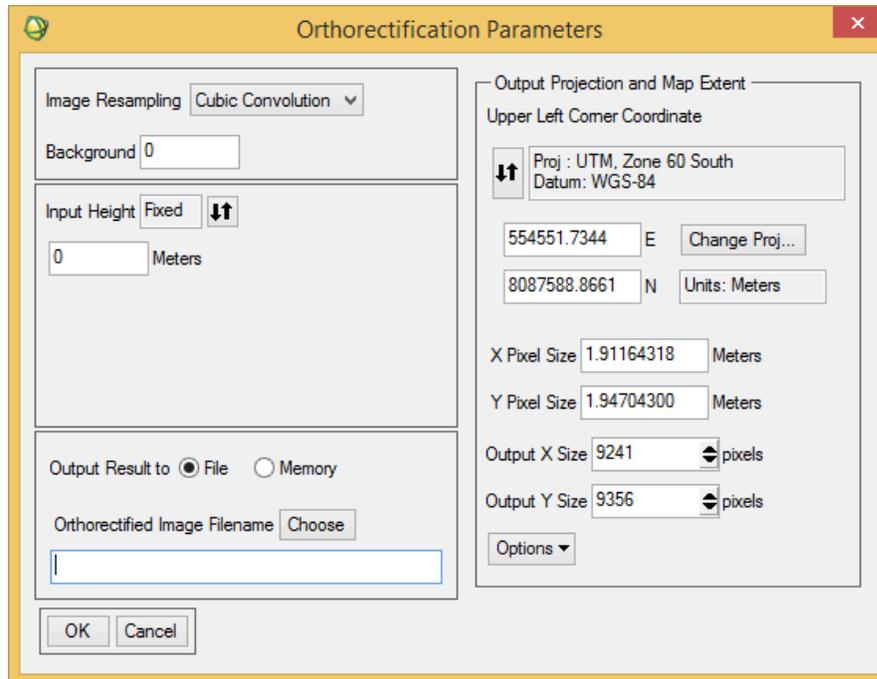
- Create and save ROI of pixels over deep water (i.e. no visible benthos) containing glint as well as relatively glint-free water, if possible



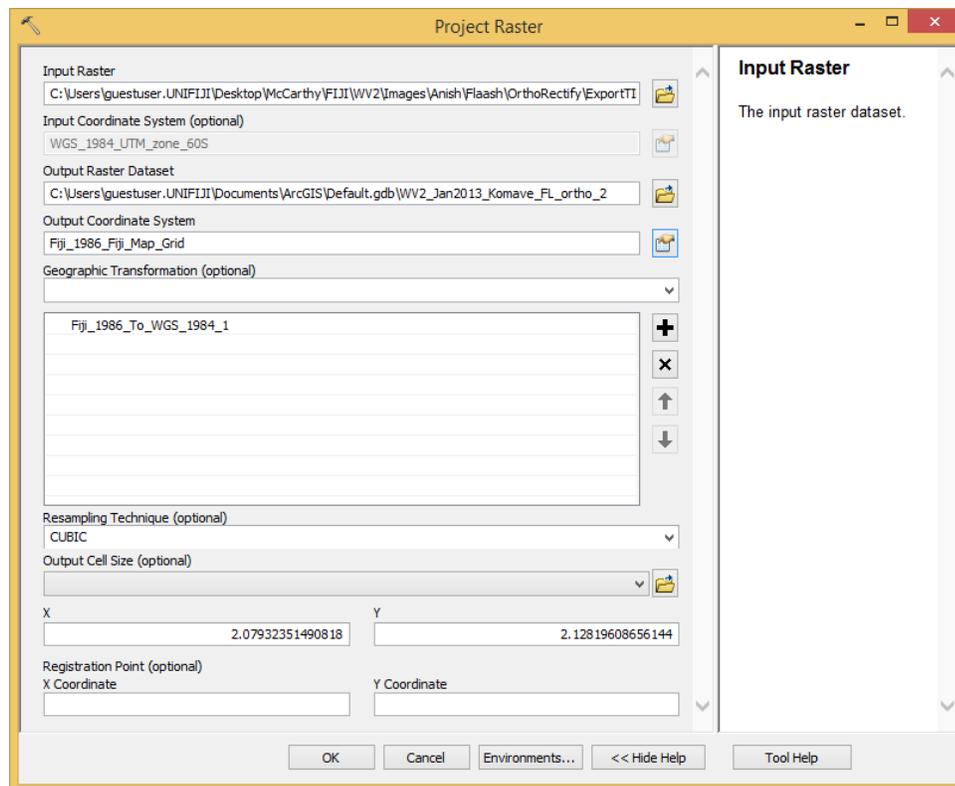
- Spectral>Deglint - Select file and associated ROI, then select Band 8 (NIR2) as NIR band, and output to filename



- Geometric Correction and Projecting - images come in a geometric coordinate system, which may cause distortions in the display depending on the geographic location of the image ground track. Images should be projected to an appropriate, local coordinate system to avoid these issues.
 - Use ENVI's WorldView Orthorectification tool (Map>Orthorectification>WorldView>Orthorectify WorldView)
 - Choose Cubic Convolution for resampling as this is the most accurate (although it takes longer than the others).



- DEM - this step is necessary for study areas that are higher in elevation than sea-level. It accounts for the elevation when displaying the 3-dimensional image in 2 dimensions on a screen. Requires a digital elevation model (DEM) of same resolution or better. If working in area at sea-level or with flat terrain, no DEM is necessary and a fixed height is selected.
- Fiji Map Grid is, unfortunately, not an option in ENVI, so choose UTM zone 60S, WGS datum.
- Reproject the image using ENVI's Reproject Raster tool, or export the orthorectified image as a TIFF (File>Save File As), open in ArcMap, and use the Project tool (Data Management Tools>Projections and Transformations>Raster>Project Raster).
 - Choose Cubic Convolution for resampling, and Rigorous for warping method as these are the most accurate (although they take longer than the others); choose Fiji Map Grid Projected Coordinate System.



- Co-registration - corrects minute discrepancies in images covering the same geographic location such that pixels align more accurately. This step is required for change detection or time series analyses, but not for studies wherein only one image is used for a given area.
- Subsetting - clips a large image to a smaller area of interest (i.e. reduces file size and eliminates areas that are otherwise distractions)
 - Optionally exclude areas of exposed reef from analysis because their spectral profiles will be substantially different from those of their submerged counterparts
 - To identify exposed areas, perform a Normalized Difference Water Index (NDWI) using the Band Math tool. Enter this expression: $\text{float}(b1 - b2) / \text{float}(b1 + b2)$ >OK> Assign b1 to the Coastal band, and b2 to the NIR2 band (i.e. bands 1 and 8, respectively). Run.
 - In the output image, use the Cursor Location/Value tool (right-click) to scan the NDWI image and choose a threshold value appropriate for your image's water pixels - this tends to be approximately 0.0-0.3 and above.
 - Use this NDWI file to create a mask (see below under Classification)
 - Create a shapefile in ArcGIS of the area to be subset (i.e. your region of interest).
 - Open in ENVI as vector file and convert to EVF or ROI file
 - Subset via ROIs tool - follow prompts.
 - If the output contains areas outside the desired region of interest, export the file as a TIFF, open in ArcMap, and subset using the Extract by Mask tool (Data Management>Spatial Analyst>Extraction). Then import the subset image in ENVI again for the classification (ArcGIS offers

classification tools, but ENVI tools tend to afford more versatility with options).

- Processing
 - Classification
 - Unsupervised
 - Classification>Unsupervised - choose either ISodata or K-means (ISO is more rigorous but more time-consuming).
 - Select the image to be classified (after radiometric calibration, atmospheric correction, and subsetting).
 - Select only the visible bands for the image (i.e. exclude bands in the Infrared spectrum; Landsat bands 1-4; WorldView-2 bands 1-6).
 - If using a mask (e.g. to exclude exposed areas identified by the NDWI step), click Mask Options dropdown>Build Mask>Options dropdown>Import Data Range - select the NDWI file and click OK, then input the value you identified as your water threshold (e.g. 0.3) in Data Min Value and click OK (leave Data Max Value blank). Save the mask as an output file. To mask other areas of an image, this same process can be used by selecting a different file and data min or max value.
 - ISODATA Parameters
 - Number of classes: this should be twice the number of expected thematic classes (e.g. if you expect sand, seagrass, coral, rubble, and water, Min classes should be 10; Max classes can be 15 or more).
 - Maximum iterations: equal to the Max classes #
 - Change Threshold: 5.0%
 - Minimum # Pixel in Class: 20
 - Max Class Stdv: 1.0
 - Min Class Distance: 5.0
 - Max # Merge Pairs: 2
 - Max Stdev from Mean: blank
 - Max Distance Error: blank
 - Output to filename
 - OK to run
 - Supervised
 - Open image to be classified and display it.
 - Open training shapefiles: File>Open Vector File - follow prompts to output shapefiles to .evf files in the appropriate coordinate system.
 - Load the .evf files onto the same display as the image to be classified.
 - Repeat this process for the shapefiles to be used as validation.
 - Classification>Supervised>Maximum Likelihood (ML is the most robust and commonly used of these options).
 - Select the image to be classified (after radiometric calibration, atmospheric correction, and subsetting).
 - Select only the visible bands for the image (i.e. exclude bands in the Infrared spectrum; Landsat bands 1-4; WorldView-2 bands 1-6).
 - Follow mask directions as above, if necessary.

- Select ROI files to be used for training (note: the number of points per ROI must be greater than the number of bands used in the classification or you will receive an error).
 - Save the output file and (optionally) the rule maps.
 - OK to run.
- Post-processing
 - Class color mapping (Unsupervised)
 - Open classified image - Tools>ColorMapping>Class Color Mapping
 - Use a reference image to assign each spectral class to a thematic class (e.g. Class 1 assigned to Sand)
 - Save changes
 - Combine classes (Unsupervised) - after color mapping, if you have, for example, 3 classes representing Sand, these need to be combined into one Sand class for analysis.
 - Classification>Post Classification>Combine Classes - Select classified image - Click the first of one thematic class in the left column, then click the first of the same thematic class in the right column, then click Add Combination; repeat by matching classes in the left column with only one match in the right column (i.e. only select one class from the right column for each thematic class, but assign all classes from the left column - these will disappear as they are combined).
 - OK - Remove Empty Classes: No
 - Output to filename
 - Accuracy assessment
 - Classification>Post Classification>Confusion Matrix>Using Ground Truth ROIs
 - Select classified image (must have validation ROIs open first)
 - Match validation ROIs to image classes
 - OK - select output variables - OK
 - Evaluate accuracy from output table; save table.
 - Change detection
 - Basic Tool>Change Detection>Statistics - Select the oldest image as your "initial" and your more recent image as "final". Leave the default statistic outputs, and output the files to a filename/folder. OK.
 - Below is an example output table showing the Pixel Count change.
 - To read the table, columns (e.g. values below "Marsh") represent the number of pixels that were classified as Marsh in the initial image. Rows (e.g. values right of "Marsh") represent the number of pixels that were classified as Marsh in the final image. The box where column Marsh meets row Marsh (231670) indicates the number of pixels that did not change from their original classification of Marsh (i.e. they were classified as Marsh in both the initial and final images). The box where column Marsh meets row Scrub (39706) indicates the number of pixels that changed from Marsh to Scrub; Marsh pixels that changed to Forest is 527, etc. These change and no-change values, in Area and Percentage, are the most common to report. Also important is the Class Changes row toward the bottom. This number plus the no-change box for each class should equal complimentary Class Total value, or 100% under the Percentage tab.

- Also, a series of maps called "Masks" should have been produced that display the change from each class to the rest. Visualize these in comparison with the output table to check that changes make sense.

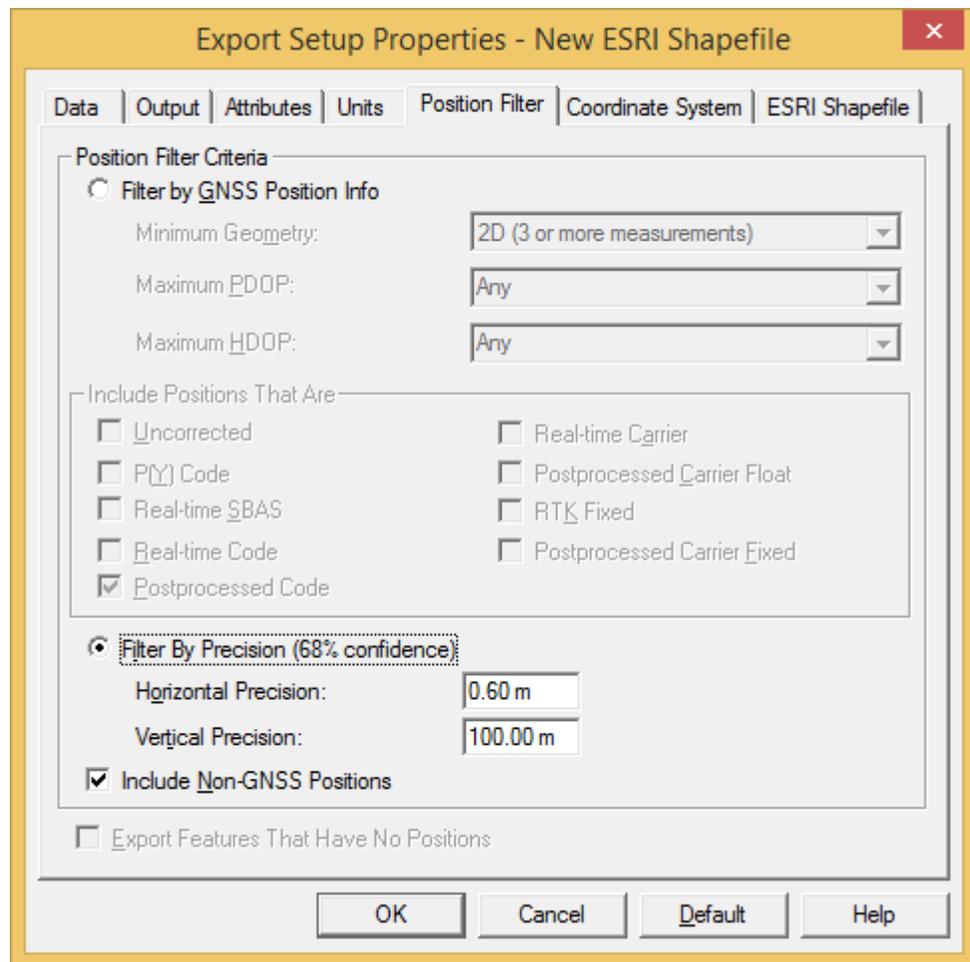
Initial State										
	Marsh	Scrub	Forest	Sand	Grass	Water	Developed	Masked Pixels	Row Total	Class Total
Unclassified	147801	18525	10944	17434	11220	5297	7949	5345078	5564248	5582511
Marsh	231670	17621	2297	17258	14672	1012	389	18490	303409	303779
Scrub	39706	9002	1468	6328	1207	835	623	2463	61632	61978
Forest	527	1363	1409	1069	744	1357	172	7	6648	6823
Sand	2002	961	409	1712	172	194	52	79	5581	5630
Grass	31914	2496	2243	2234	136284	23042	273	51211	249697	249885
Water	5472	2185	16995	3470	43884	55721	2837	1190	131754	132758
Developed	13814	1058	1266	1646	1572	1561	459	6944	28320	28738
Masked Pixels	430525	41552	38109	40411	65041	38236	21031	6346079	7020984	7057966
Class Total	903431	94763	75140	91562	274796	127255	33785	11771541		
Class Changes	671761	85761	73731	89850	138512	71534	33326	5425462		
Image Difference	-599652	-32785	-68317	-85932	-24911	5503	-5047	-4713575		

FIELD WORK

- Sections
 - Preparation
 - In-field data collection
 - In-lab data processing
- Preparation
 - Create transect points (if desired)
 - Convert line to points
 - Create new feature class (point feature)
 - Open Editor>Select transect line(s)
 - Click Editor drop down>Construct Points - select number of points and distance - Okay
 - Save Edits, stop editing
 - Create Data Dictionary file in GPS Pathfinder
 - Utilities>Data Dictionary Editor - assign Name - New Feature - assign Feature Name and Classification type (e.g. point) - OK; New Attribute - assign type (i.e. Text, Date, etc.) - OK; Save file.
 - Create file on GPS hand-held device in TerraSync
 - Turn off collection of points between target features: Setup>Logging Settings>select "Off" on all "Interval" drop-down menus (the purpose of this is to avoid collecting undesired data points between target features, which can conflict with target data points when exporting them as shapefiles).
 - Create data files necessary for field work (e.g. transect lines, site location points, base/background raster or vector files) in GIS or other spatial data software.
 - Background file: must be a .ecw or .sid file; otherwise, the file will need a .wld (World) file containing projection metadata - World file can be created in GIS using the Export Raster World File tool.
 - Transfer files to hand-held GPS device for use in field.
 - Load data files (e.g. shapefile transects or points) into GPS Pathfinder
 - Import - select shapefile
 - Choose Import Setup (change coordinate system, etc. as desired) - OK
 - Transferring data between PC and hand-held GPS device (here is a good video describing it: https://www.youtube.com/watch?v=A7_FkcRAVAo)
 - Connect device to PC via USB cable
 - Open Windows Mobile Device Center to connect device to PC (download software from <https://fpimgis.wordpress.com/i-cant-connect-my-windows-mobile-device-to-a-computer/>)
 - Click "Connect without setting up your device" - the next screen should say "Connected" with a green check mark
 - If "Not Connected" is displayed on PC, unplug USB from device, navigate to Setting>Connections>USB to PC - toggle the checkbox

on or off - OK, then reconnect device and check connection. If that doesn't help, shutdown the hand-held device, and power back on. Mobile Device Center app should open automatically.

- Open GPS Pathfinder Office and click Data Transfer on the left side of the window
 - Data transfer should automatically connect to the device. If not, select device from drop-down menu and click Connect.
 - To transfer data from the handheld device, click the "Send" or "Receive" tab, depending on desired direction, then click "Add" on the right. Select the file type, and navigate to the desired file, then select it, click "Open", and click "Transfer All" on the lower right side of the Data Transfer screen.
 - Data should be transferred to the PC or device for use.
-
- In-field data collection
 - Turn on and connect GPS receiver and hand-held device
 - First time: open Settings in Trimble main menu - Bluetooth>COM Ports>New Outgoing Port>Select Pro#####>Next>COM#>Finish. Open TerraSync>Setup>GNSS Settings>Select the COM# assigned to the Pro receiver in the drop-down
 - Use hand-held device to navigate to study site (e.g. transects) if desired; otherwise, simply collect points at study site (note: avoid spatial autocorrelation by evaluating spatial autocorrelation distance first, if possible, then collecting future points at appropriate distance).
 - Data>New>File type: Rover, Location: Default, assign File Name, Dictionary Name: select pre-assigned dictionary file with attribute information
 - Collect Features>Point_generic - click Log (if does not start automatically), optionally add a comment/name for the point, wait until at least 30 positions have been collected (count in top right of screen), then click Done - point should be logged.
 - In-lab data processing
 - Transfer collected GPS points file to PC (see instructions above)
 - Open file in GPS Pathfinder Office (File>Open)
 - Apply Differential Correction from base station (<https://www.youtube.com/watch?v=3vZ8IGWI-fQ>)
 - Download base files from <ftp://ftp.ga.gov.au/geodesy-outgoing/gnss/data/highrate/2016/>
 - Download and unzip all files corresponding to the same local time as data points were collected.
 - Select .SSF file, Base Data - Folder Search>Navigate to fold where base files were saved. Reference position - Use position from downloaded base files.
 - Select Base Data - Browse (third option)>Browse folder - select downloaded base file; Reference Position: Use position from downloaded base files; check the box Confirm base data and position before processing
 - Export GPS file to shapefile (<https://www.youtube.com/watch?v=Jd2WSqjwoZE>)



- o Load file into spatial data software (e.g. ArcGIS or ArcMap)
- o Export file three times (i.e. 2 copies) to shapefile - this is so that if you make mistakes in later editing, you have an original copy of the data to use.
- o Define projection - points should align properly, but will not have a defined geographic coordinate system.
 - Data Management Tools>Projections and Transformations>Define Projection - input the shapefile, select Projected Coordinate System, and navigate to the system used in data collection (check the settings in the hand-held device if necessary).
- o Check points - use field pictures and log sheet to check that each point is correctly assigned to its appropriate habitat class
 - Open Attribute table - Add Field - give a name; short integer is fine.
 - Selection>Select by Attributes - double-click "Comment" field to select, click "Like" button, type 'a%' to select all the variables assigned to the "algae" class (note: this assumes a data collection field for comments was included in field work and "algae" was an included target class). OK.
 - In attribute table, right-click on the Habitat field header and click Field Calculator - OK to warning message - type "1" or "algae" or otherwise in the box below. OK. This will populate the Habitat field for all the selected "algae" points with a new value (e.g. 1).

- Repeat this process for all classes, changing the value assigned (e.g. 1,2,3,4...).
- Now that you have created a new field, you can edit this field without changing the raw data. View each point on top of the orthorectified and projected image to be classified to ensure that it lies in the correct location on the image. Compare the image habitat assigned with the corresponding field picture and log sheet to ensure that the point is assigned to the correct habitat. When satisfied, close attribute table. Changes will be automatically saved.
- Create new shapefiles for each habitat's group of points. Select by Attributes each class one at a time. Right-click the shapefile>Data>Export Data - assign an output location and filename and click OK. A new shapefile will be created including only the selected points. Repeat this process for the remaining classes.
- Create new "line" feature class for each transect
- Open Editor>Start Editing - select new line feature class - click Create Features button (far right of Editor toolbar) - select line feature class, Construction Tools: Line - snap to start and end transect points, right-click: Finish Sketch - save edits - click new line segment to select - Editor>Construct Points

Satellite Processing Principles

- WorldView-2 Imagery
 - Products are delivered by provider as Level 1B - this means that the images have been corrected for detector variations in the sensor (i.e. radiometric correction), and distortions of geometry in the image. To be useful for mapping, the images must be further radiometrically calibrated using the provided absolute calibration coefficients, projected into an appropriate local coordinate system, and geometrically corrected by registering the image to an existing base map. In mountainous regions, terrain can affect the geometry of the image, and further rectification may be needed (i.e. orthorectification).

Field-Work Principles

- When classifying satellite images, ground-truthing is needed to train supervised classifications, and to evaluate the accuracy of the maps produced. The latter is a vital component to any mapping project - without validation, a map is effectively useless because one cannot determine how accurate it actually is.
 - Conducting field work requires a GPS unit with horizontal accuracy that is higher than the pixel resolution of the satellite imagery that will be used. A rule of thumb is to collect GPS points with horizontal accuracy better than half the resolution of the image (i.e. sub-meter accuracy for 2 m pixel resolution).
 - Points may be collected in two general ways: identifying in lab the locations to be sampled prior to field work, or collecting points in the field based on access and feasibility. The former is generally better, as it allows one to plan an unbiased, random sampling pattern, but may neglect challenges that only become apparent once in the field. This issue may be avoided with visits to the site prior to field work. The latter method is typically faster, but must be justified. Acceptable justifications may include: poor pre-processed (i.e. in-field) GPS accuracy precluding one from reaching pre-selected

- sampling locations accurately; difficult terrain that would likely hamper random data collection; or thick canopy cover obscuring challenging terrain.
- Both methods require that points are collected such that they do not introduce error from spatial autocorrelation. This means that, for study areas with relatively homogenous terrain, points collected in close proximity to each other are statistically likely to be of the same habitat class, and are therefore not random. Spatial autocorrelation may be assessed by collecting points at a consistent distance (e.g. 5-meter intervals) along several parallel transects. The points may later be evaluated using a software program such as R to determine at what distance points in the given study area are not spatially autocorrelated. Field work may then proceed by sampling points at the given distance (e.g. 20-meter intervals) or greater.