LEOWorks
image processing tutorials

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About LEOWorks

LEOWorks is a software product designed and developed for use in educational activities. It is the main tool for demonstrating Earth Observation techniques within the European Earth Observation Web Site for Secondary Schools - EDUSPACE, belonging to the European Space Agency (ESA).

LEOWorks can be used to open, inspect and process data as images coming from various Earth observation satellites.

Initially developed to support teachers teaching geography in the high school, currently LEOWorks is also addressing upper secondary school students and their teacher's needs by providing them a set of tools for processing satellite images and derive information about land and sea, nature and biodiversity, environment and climate change.

Some of the major features of LEOWorks are:

- Read data stored in many file formats;
- Gray scale, RGB or color indexed image display;
- Manipulate 8 bit, 16 bit, float or complex data;
- Radiometric enhancement;
- Geometric transformations;
- Unsupervised and supervised image classification;
- Create, edit and query GIS vector data;
- Image to map and image to image registration;
- Basic radar data processing.

Many software components included in LEOWorks are imported or derived from existing components used in the ESA BEAM and NEST software projects.

LEOWorks is supposed to run on all families of operating systems - Windows, MacOSX, Linux. Software and documentation can be downloaded from http://www.esa.int/SPECIALS/Eduspace_EN/

1. Accessing files and displaying data

1.1 Opening files

In general geospatial data and also remote sensing data is stored in files residing on disks either on computers, optical (CD, DVD, BR) or tapes.

A file typically contains a dataset e.g. the bands of a remote sensing scene or the objects (geometry and attributes) belonging to a vector layer.

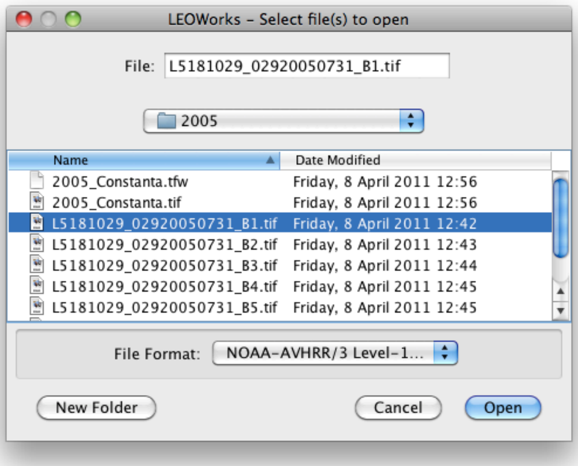
Opening files in LEOWorks is a very flexible operation. It is possible to open:

- one single file as a single dataset;
- many single files as a single datasets;
- many files as a single dataset;
- reopen a previously open file.

a. Open one single file as a single dataset (applies for both vector and image data)

To open a single file as a single dataset:

- click File / Open;



- in the Select file(s) to open dialog, select the file you want to open (see figure above) and then click the Open button;

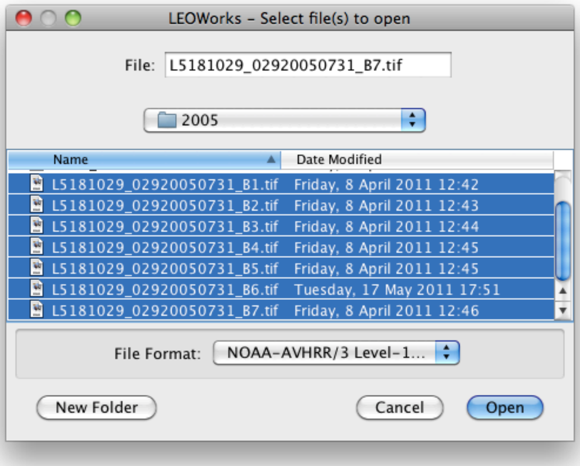
- choose your options in the Subset / Resize dialog (for details about this dialog, please check the Subset and resize section) and click the Open button;

- The dataset contained in the file will be added in the Available Data window; if not already displayed, it is possible to display this window by selecting View / Managers / Available Data.

b. Open many single files as a single datasets (applies for both vector and image data)

To open a single file as a single dataset:

- click File / Open



- in the Select file(s) to open dialog, select the files you want to open (see figure above) and then click the Open button;

- for each selected file choose your options in the Subset / Resize dialog and click the Open button (for details about this dialog, please check the Subset and resize section);

- The dataset contained in the file will be added in the Available Data window; if not already displayed, it is possible to display this window by selecting View / Managers / Available Data.

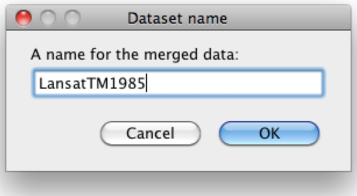
c. Open many files as a single dataset (applies for image data)

To open many files as a single dataset (typical case of remote sensing data storing each band in a separate file):

- click File / Open

- in the Select file(s) to open dialog, select the files you want to open and then click the Open button;

- in the Dataset name window, type a name for the new dataset as shown below; this name will be used in the Available data window;



- the datasets contained in the files will be added as bands of a dataset having the name typed in the previous step; choose your options in the Subset / Resize dialog and click the Open button (for details about this dialog, please check the Subset and resize section);

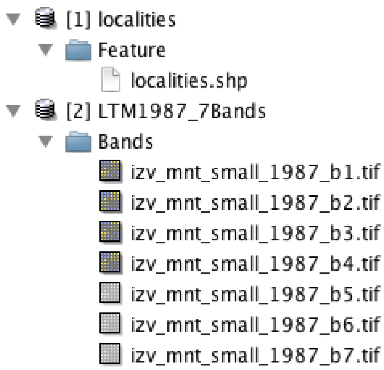
- The new dataset will be added in the Available Data window; if not already displayed, it is possible to display this window by selecting View / Managers / Available Data.

d. Reopening files (applies for both vector and image data)

It is possible to re-open a previously open file by selecting File / Reopen and selecting the file to be open. LEOWorks keeps a list of the last 10 open files.

1.2 Displaying images and vector layers

Once a file is displayed in the Available Data window (see figure bellow), it is possible to display the data it contains.



In the case of remote sensing data, the digital numbers stored as separate bands can be used to display grayscale or color continuous images (see figure below).

When dealing with vector data, images can be generated based on object's geometry and attributes (see figure below).

a. One band grayscale image display

Digital numbers in a band of a remote sensing dataset can be displayed as a grayscale image. This can be done by either:

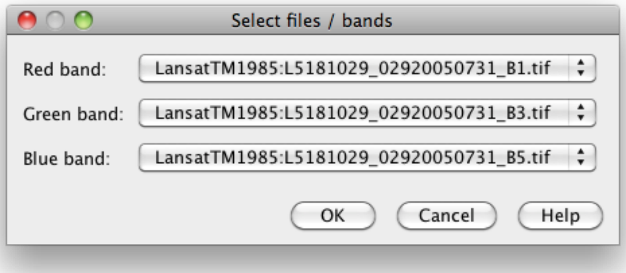
- selecting and double-clicking a band in the Available Data window;

- selecting a band in the Available Data window and then View / New View from the main menu.

b. RGB color image display

Color RGB images can be displayed by using 3 bands of a remote sensing dataset as R, G, and B channels. This can be done by:

- select View / New RGB View from the main menu;



- in the Select files / bands window, select the bands to be used as RGB channels as shown in the figure above;

- click the OK button.

c. GIS vector data display

GIS vector data can be displayed by double clicking the name of the feature layer of a vector dataset (under the Feature node).

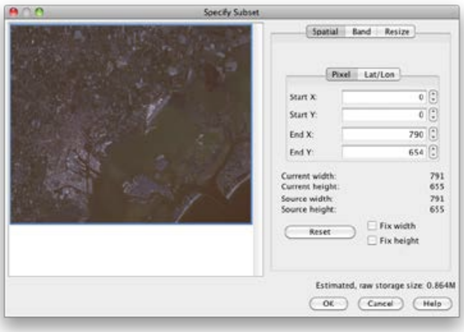
By default, any vector data is displayed using a random symbol (type of line, color etc.). It is always possible to change the way a vector layer is displayed by clicking the Style editor button  in the Layer Manager window or in the GIS Manager one.

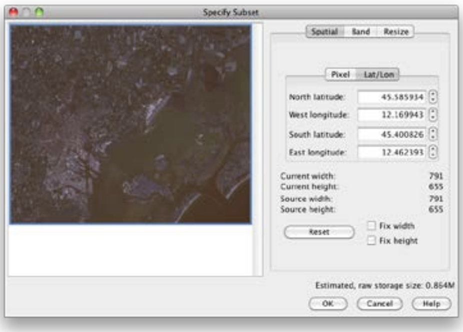
1.3 Subset and resize

When opening files, either storing remote sensing (raster) or GIS vector data, it is possible to subset and or resize contained in a selected file or in a group of files (see previous section 1.1.c).

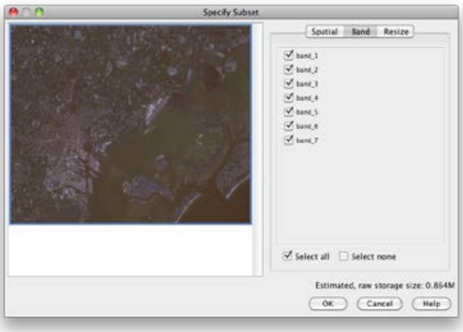
This operation can be performed by choosing the appropriate options in the Product Subset window (see below).

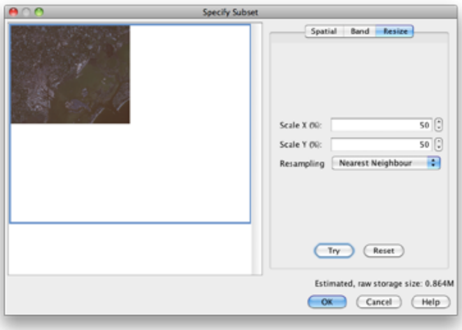
It is possible to spatially subset an image by adjusting the blue rectangle in the Spatial Subset tab (see figures above), by specifying pixel coordinates or by specifying geographical coordinates.





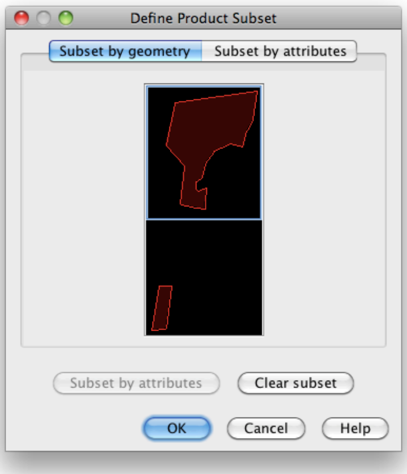
In the case of multi-band remote sensing datasets, it is possible to select among the existing bands and keep one or more bands to work with. Clicking one or more band listed on the Band Subset tab can do the selection.

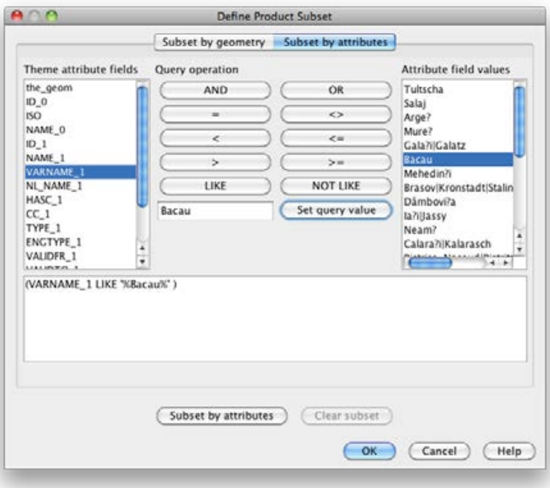




It is also possible to resize an image dataset by changing the size of the pixels. This can be done by specifying a scaling factor for both X and Y directions and a resampling method in the Resize tab (see figure above). See 4.4 for more details about resampling methods.

When dealing with vector data, it is also possible to subset spatially





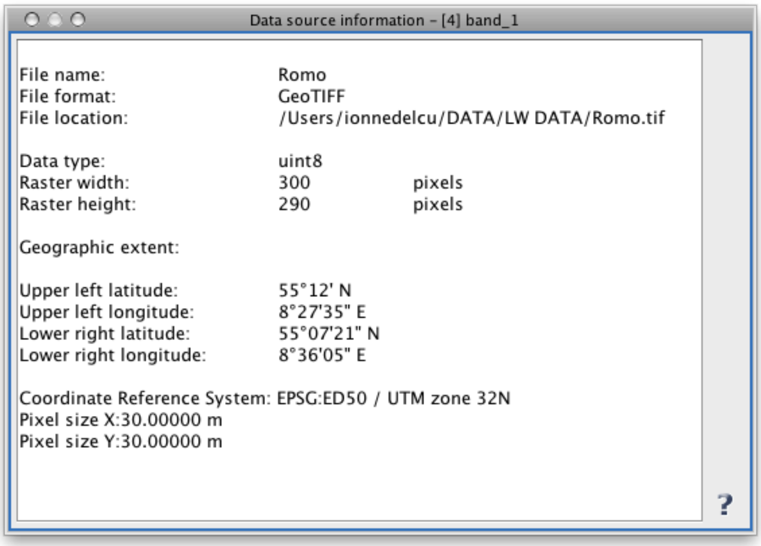
or by defining a query based on attribute values. In the case of vector data, only the objects falling inside the rectangle will be kept. Alternatively, only the objects meeting the defined criteria will be kept

2. Inspecting data

Inspecting data is almost anytime a pre-requisite when doing remote sensing data analysis (more words about data inspection goals)

2.1 General information on image data

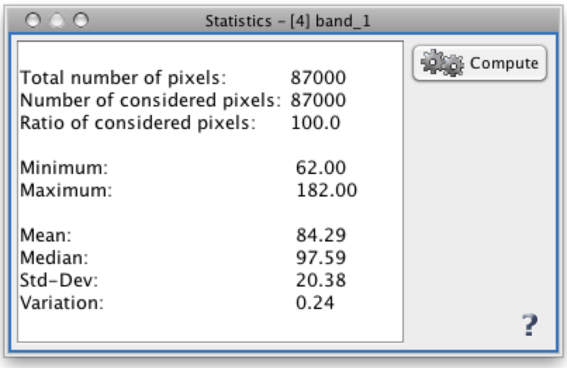
It is possible to get information about a dataset by pressing the Information button or by selecting Inspect / Information from the main menu. This will display the Information dialog for the dataset selected in the Available Data window.



File name, format and location are shown, as well as (see figure above) provides information on the geographical extent of a dataset and the CRS (Coordinate Reference System) for geo-coded data.

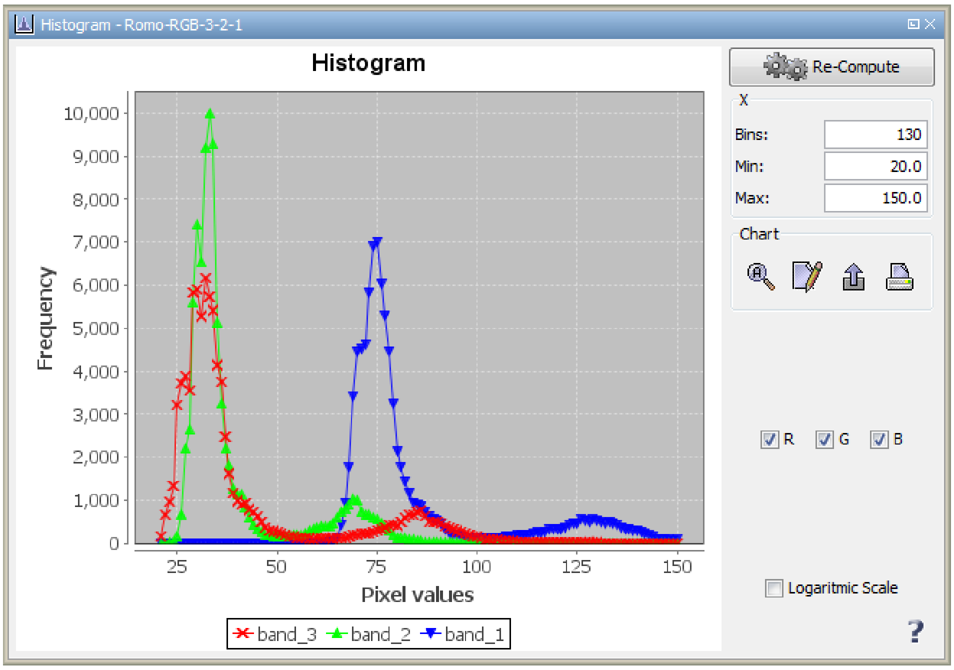
2.2 Statistics for remote sensing data

When selecting Inspect / Statistics or pushing the Statistics button Σ it is possible to get some statistical parameters computed and displayed for a band being part of a remote sensing dataset (see figure below) or for a GIS vector dataset attribute field.



2.3 Histogram

Given an image dataset, it is possible to compute and display the histogram of a band (see figure below). This can be done by



- select Inspect / Histogram or click the Histogram button ;

- the band of an image dataset for which you want the histogram to be computed in the Available Data window;

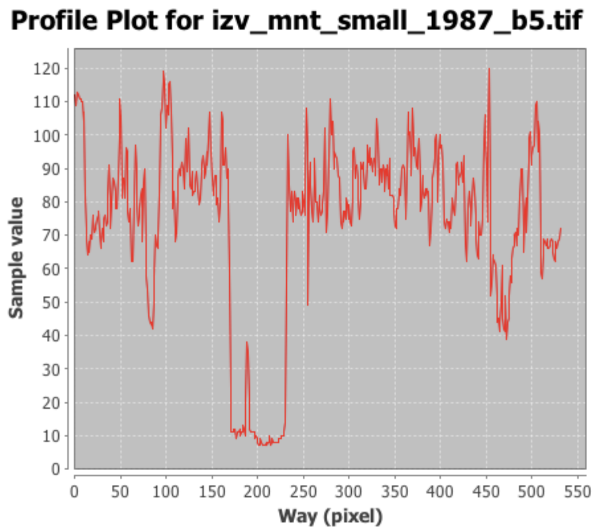
- set the number of bins; set the Min and Max values if appropriate;

- click the Re-Compute button.

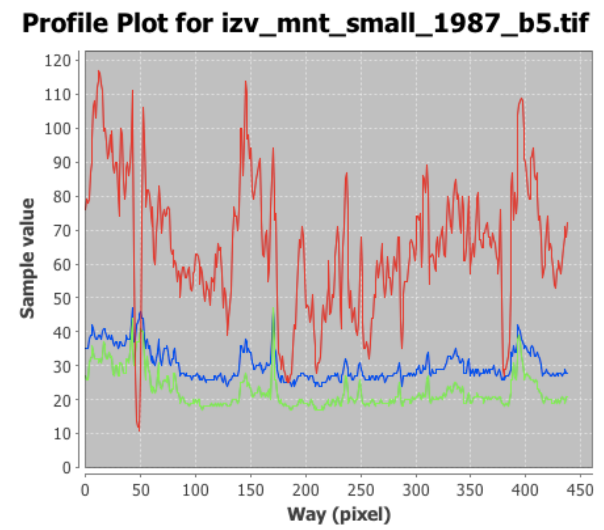
You can always zoom in the histogram, change the way the histogram looks like, or export he histogram as an image using the tools available in the bottom-right side of the window

2.4 Profile plots and spectra

Profile plots



Using profile plots it is possible to check the digital numbers attached to the pixels crossed by a line in a color image (see figure bellow) or a gray scale image (see figure above). To use the Profile Plot tool, you need to



- display the image of a band or an RGB color combination using 3 bands of a remote sensing dataset;

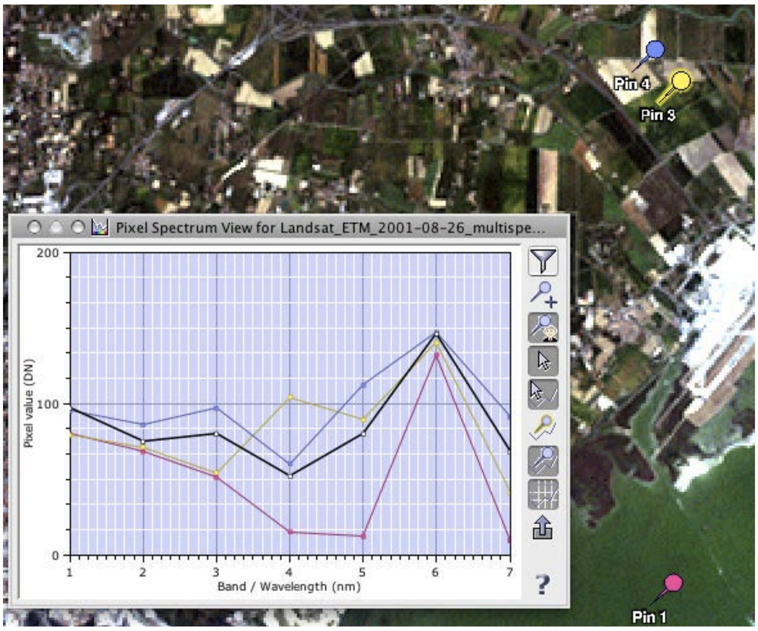
- draw a line on the image by clicking the intermediary points; end the line with a double-click.

After having the profile plot displayed, you can access and choose different options for displaying the profile by right-clicking in the plot area or by changing the way the profile is displayed by clicking the Edit Properties button in the Plot toolbar (right-down side of the window).

It is also possible to export as image or to print the plot by clicking the appropriate buttons in the Plot Toolbar.

Pixel spectra

Using the Pixel Spectrum View, spectra can be displayed for pixels in the image. The Spectrum View can be activated by selecting Inspect / Spectrum from the main menu.



The pixel spectrum view displays the pixel values in all the spectral bands or the selected bands associated with an image dataset.

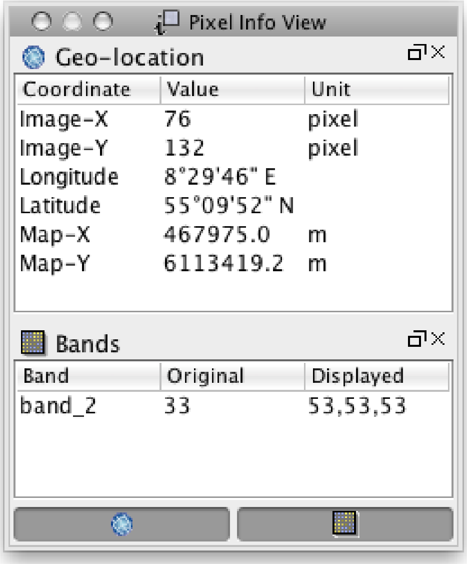
Spectra are displayed for the mouse position (and dynamically updates as the mouse is moved over the image).

Alternatively, spectra can be displayed for any Pin placed in the image (see picture above). Pins can be placed on the image after pressing the Pin Placing Tool button available on the right side of the Spectrum Tool View.

Spectra associated to pins can be exported and further analyzed (e.g. using an Microsoft Excel-like program).

2.5 Pixel location and value

It is many times useful to inspect the values of the pixels in different bands of a remote sensing dataset. To do so



- display a gray scale image of a band or a color RGB image of three bands;

- click the Pixel Info button or select Inspect / Pixel Info from the main menu; the Pixel Info View window will be displayed (see figure above);

- move the mouse over the displayed image and watch the Pixel Info View; image coordinates (row and column), geographical coordinates, rectangular (map) coordinates, as well as pixel values in the bands displayed are shown; please note that both original and displayed valued are displayed.

Displayed values are the values currently used to turn on the pixels on the screen (the R.G and B channels).

2.6 Features and feature attributes

When working with GIS vector data, it's always useful to inspect the values of different feature attributes.

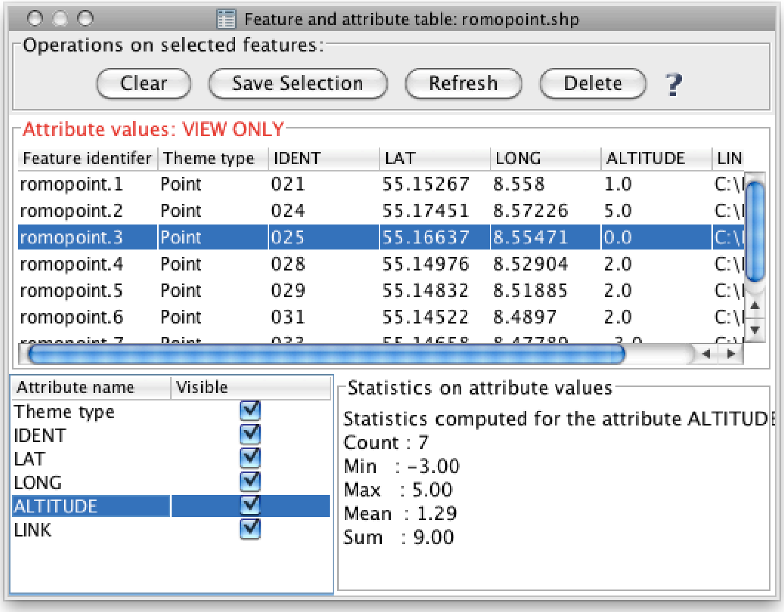
To do so, the following steps are needed:

- open the file containing the GIS vector data;

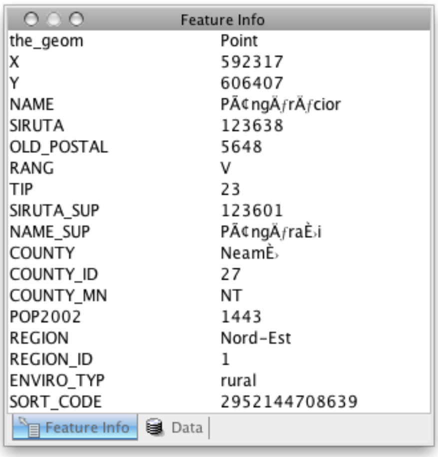
- double-click it in the Available Data window to have it displayed in a viewer;

- open the GIS Manager by clicking the appropriate button in the toolbar or by selecting Tools / GIS;

- click the Feature attribute table button to have the feature attributes table displayed (see figure below) and inspect the attributes for all features; if an attribute field is clicked in the lower left panel, statistics for that attribute field are going to be displayed in the lower right panel;



- click the Feature info button  or select Inspect / feature info to open the Feature Info window (see figure below);



- navigate the data viewer and click any feature for which you want to inspect the values of the attribute fields; information is displayed for features in the vector data theme being selected in either GIS Manager or Available Data windows.

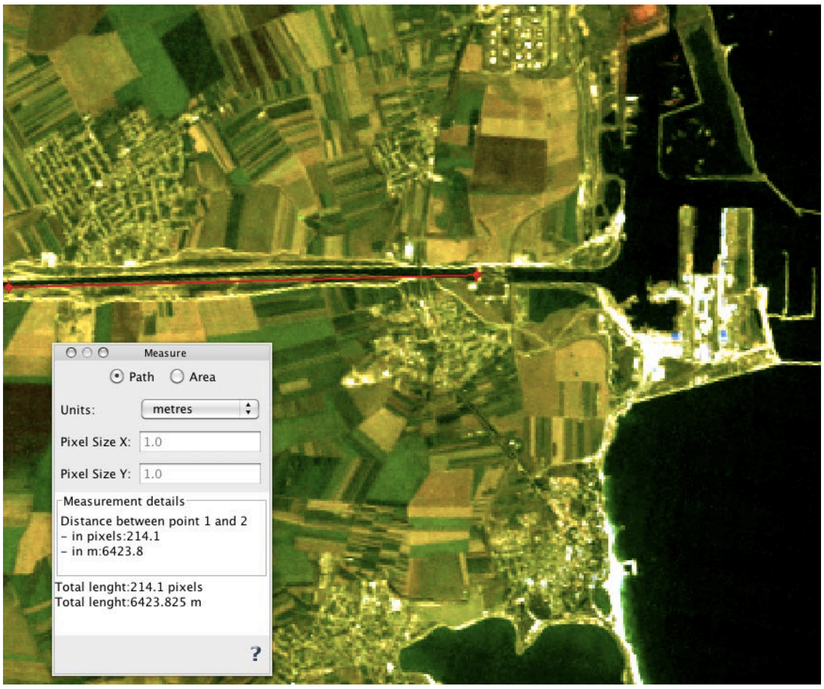
2.7 Measure tools

It is many times useful to have an estimation of how large the objects appearing in a satellite image are. For this, you need tools allowing you to measure lengths or area of different objects.

In LEOWorks, such tools can be accessed by selecting Tools / Measure or by clicking the Measure button in the toolbar.

Once the Measure window is made visible, you can start clicking on the image to draw a line or a polygon defining a distance or an area you want to measure.

While clicking on the image, in the Measure window, total length / area is displayed together with the measurement details (i.e. length of each segment drawn on the image.



Both Measurement details and Total length / Area sections of the Measure window are editable, so you can add your own remarks and then copy and paste it in a report.

All measurement results are displayed in pixels / square pixels and the ground units selected from the measurement unit list.

For non-geocoded images, it is possible to specify the pixel size in X and Y direction, so the results can be displayed in both pixels and ground units.

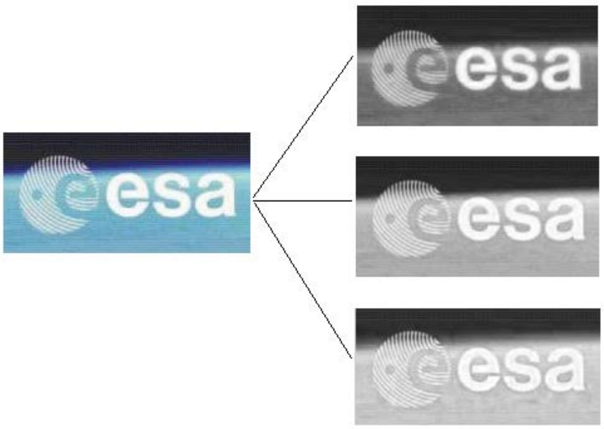
3. Basic image processing

3.1 Image display. Gray scale and color images

A color image stores its color information in channels. The information contained in the channels depends on the color model being used to define the image. With LEOWorks you have three choices for splitting the channels: RGB (Red - Green - Blue), HLS (Hue - Lightness - Saturation), HSV (Hue - Saturation - Value) and IHS (Intensity - Hue - Saturation). When you separate these channels, LEOWorks creates individual gray scale images that you can edit and see the results on the master image (color image). You can use these images to create interesting effects. For example, you can split an image into its IHS channels, apply a filter to the Intensity channel, and then recombine the channels. You can also split an image and use only one of the channels on its own.

When you split the channels of an image, you create new images; the original image is not affected. Each new image is named after its channel.

Example of splitting to RGB:

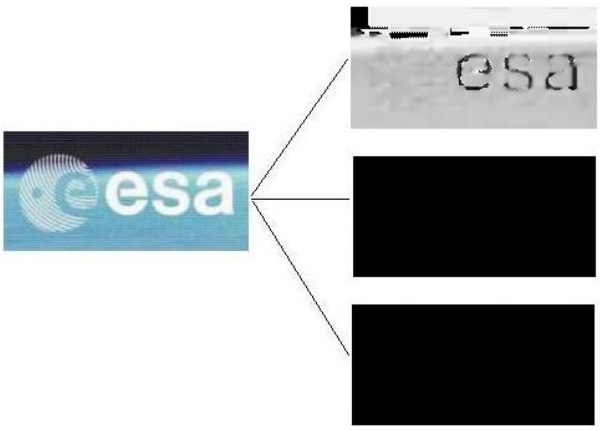


Red Channel

Green Channel

Blue Channel

Example of splitting to HLS:

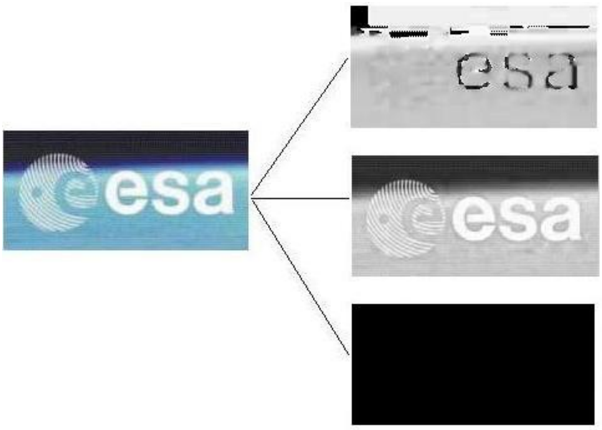


Hue Channel

Lightness Channel

Saturation Channel

Example of splitting to HIS:



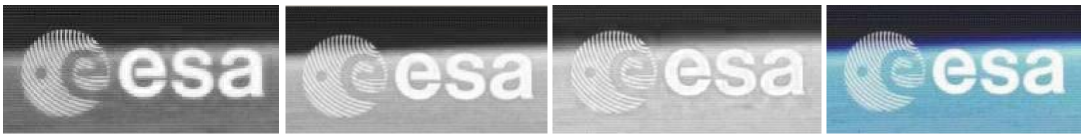
Hue Channel

Intensity Channel

Saturation Channel

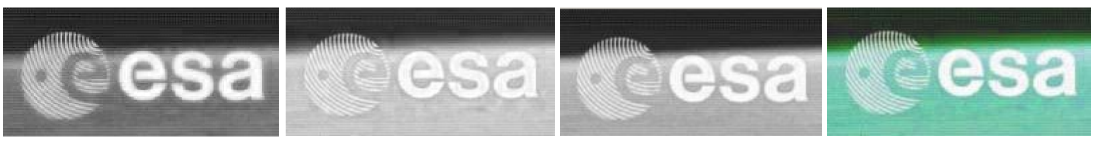
Combine grayscale channels to create a multi-channel image.

R: Red Channel + G: Green Channel + B: Blue Channel = RGB Image



Please be careful when you chose the corresponding channels. In other cases you can obtain different images!

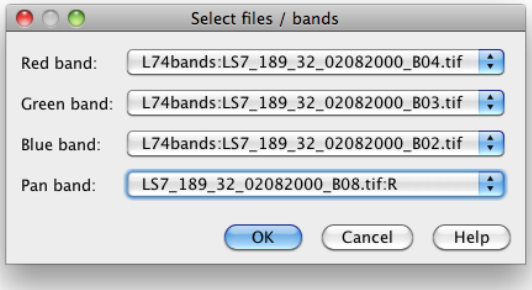
R: Red Channel + G: Blue Channel + B: Green Channel = RGB Image



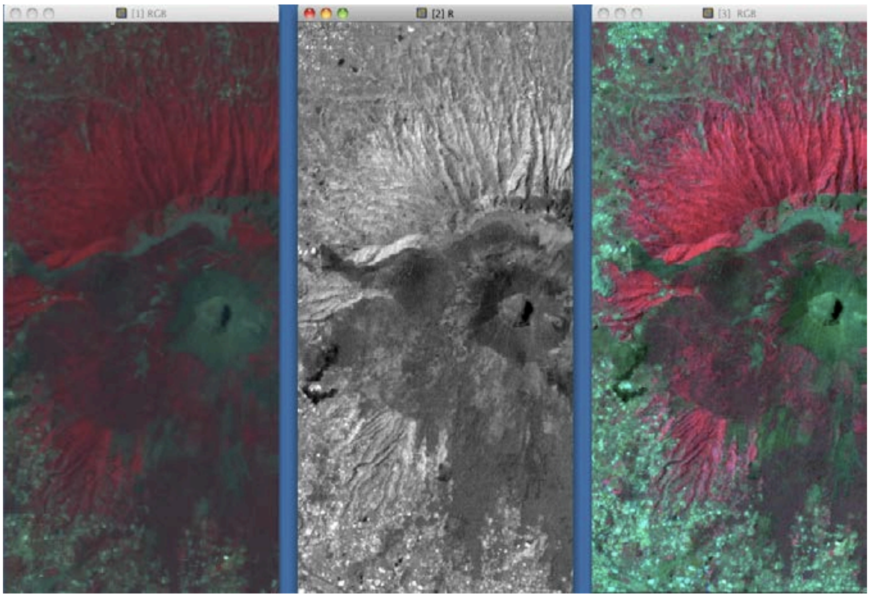
Pan-sharpening

A typical use of the RGB=>HIS transform when dealing with satellite images is pan-sharpening. Pan-sharpening is an image transform process using a panchromatic image for sharpening a color image i.e. to increase its spatial resolution while keeping its spectral properties.

For Pan-sharpening images in LEOWorks, you need to select Tools/Color Space/Pan Sharpening from the main menu. When doing this, the Select files / bands dialog will be displayed. Then, you have to select the Red, Green and Blue channels to be sharpened and the Panchromatic image to be used for sharpening.



In the image below an example is given and the initial RGB combination of the three bands to be sharpened is displayed on the left, the Panchromatic image in the center and the resulting Pan-sharpened image at the right".



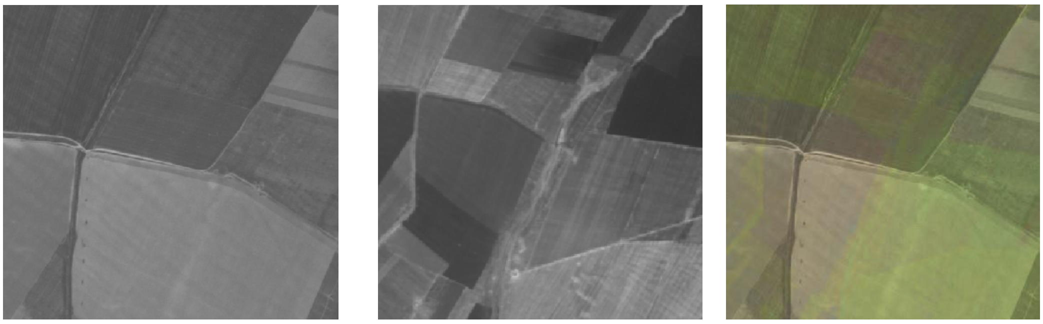
In this example the bands 4,3 and 2 of a Landsat dataset were used as R, G and B channels respectively, while band 8 of the same dataset was used as a higher spatial resolution band.

Before applying a pan-sharpening, your data need to be prepared so that:

- the panchromatic and the multispectral datasets need to be accurately co-registered;
- the panchromatic and the multispectral.

For accurately co-registering two datasets, please refer to chapter 6.2 (Image to image registration).

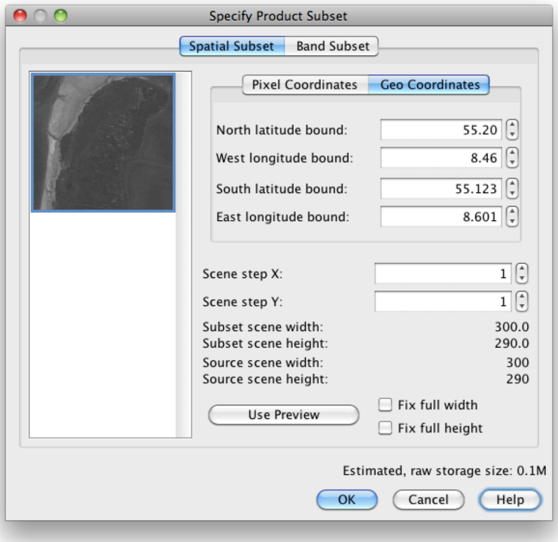
When pan-sharpening datasets that are not accurately co-registered, strange images can be produced as a result (see image bellow).



a b c

a-Panchromatic image; b-Image of a Red band of a multispectral dataset; Images a and b are not accurately co-registered; c-Pan sharpening result; Artifacts due to not accurate co-registration are visible in image c

Covering the same geographic area can be ensured using the sub-setting tool available in LEOWorks.

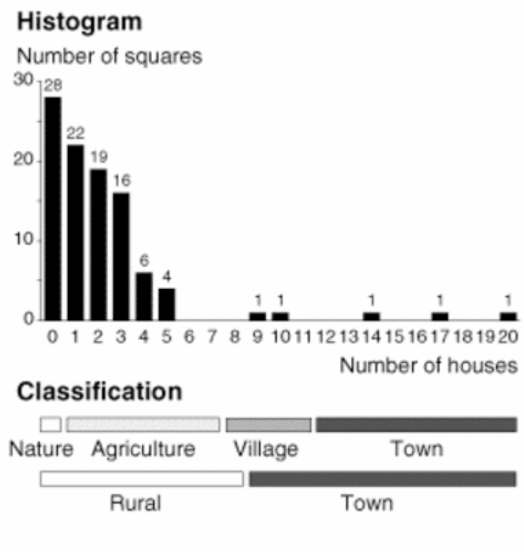


The sub-setting tool (see image above) is activated each time a file is open and made available in LEOWorks. Alternatively, the tool can be activated by selecting Tools / Subset Image. An accurate geographic subset of an existing dataset can be defined by specifying the North latitude bound, West longitude bound, South latitude bound and East latitude bound parameters.

3.2 Radiometric processing

Histograms

A histogram is a specialized graph used to display image statistics. In its most common form, the independent variable (the number of gray levels – 256 in many cases) is plotted along the horizontal axis, and the dependent variable (usually the number of pixels) is plotted along the vertical axis. A histogram can help you decide what changes might enhance the quality of the image. Changing the shape of the histogram will alter the balance of the image. In an image-processing context, the histogram of an image normally refers to a histogram of the pixel intensity values. This histogram is a graph showing the number of pixels in an image at each different intensity value found in that image. For an 8-bit grayscale image there are 256 different possible intensities, and so the histogram will graphically display 256 numbers showing the distribution of pixels amongst those grayscale values. Histograms can also be taken of color images, computing individual histograms of red, green and blue channels.

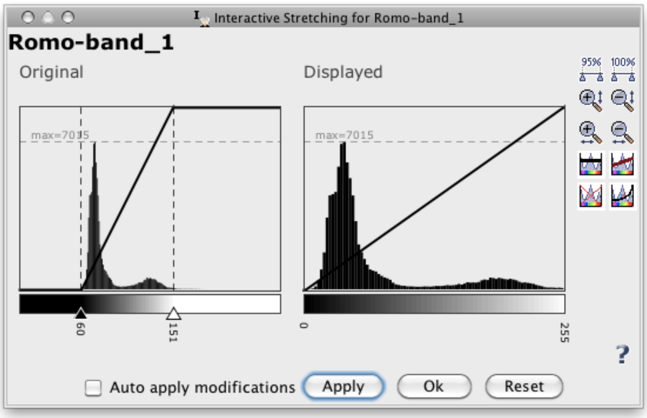


The illustration shows two classification examples based on the histogram shown.
One classification has four classes (agriculture, village, town, and other) whereas the other has two (rural and town).
Credits ESA

Interractive stretching

Besides inspecting image statistics as shown in 3.3, histograms can be used to interactively stretch the range of the DN used to display an image. In LEOWorks, an Interactive Sretching tool can be accessed by selecting Tools / Interactive Stretching.
Interactive stretching allows controlling the image histogram over a range of DNs. Drag the vertical lines and the output histogram will be stretched while the current image will show the results. Note that the process might be quite slow for large images where unchecking the *Auto apply modification* button will improve the performance.

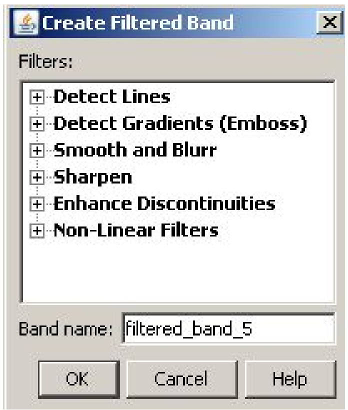
The interactive stretching tool in LEOWorks displays both the histogram of the original data ("Original" histogram) and the histogram attached to the image being displayed ("Displayed" histogram). When color images are displayed i.e. 3 spectral bands of the original data are used as R, G and B channels (see section 4.1), 3 pairs of "Original" and "Displayed" histograms will be displayed.
The DNs range can be modified by moving the histogram slider left-right. See an example bellow showing original and enhanced image



Interactive stretching is used to enhance the visual quality of a gray scale or color images; pre-defined transformations can be applied to image data, such as histogram equalization or normalization, as well as extending the value range domain to 95% of the pixel values

Filters

Filters are used to improve the quality of the raster image by eliminating spurious data or enhancing features in the data. Filters are moving, overlapping neighborhood statistics. No-data values of the source band are not considered by the filter operation. There are several implemented filters grouped in 6 submenus, on a new window: Detect Lines, Detect Gradients, Smooth and Blurr, Sharpen, Enhance Discontinuities and Non Linear Filters.

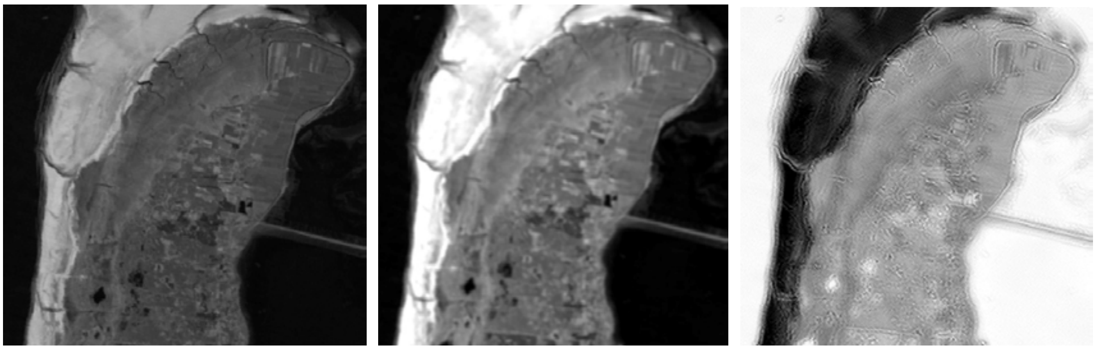


LeoWorks supports the following filters:

- Detect Lines : Horizontal Edges, Vertical Edges, Left Diagonal Edges, Right Diagonal Edges, Compass Edge Detector,
  Roberts Cross North-East, Roberts Cross North-West, Roberts Cross North-East
- Detect Gradients (Emboss): Sobel North, Sobel South, Sobel West, Sobel East, Sobel North East
- Smooth and Blurr: Arithmetic 3x3 Mean, Arithmetic 4x4 Mean, Arithmetic 5x5 Mean, Low-Pass 3x3, Low-Pass 5x5
- Sharpen: High-Pass 3x3 #1, High-Pass 3x3 #2, High-Pass 5x5
- Enhance Discontinuities: Laplace 3x3, Laplace 5x5

- Non-Linear Filters: Minimum 3x3, Minimum 5x5, Maximum 3x3, Maximum 5x5, Mean 3x3, Mean 5x5, Median 3x3, Median 5x5, Standard Deviation 3x3, Standard Deviation 5x5, Root-Mean-Squar 3x3, Root-Mean-Squar 5x5.

E xamples of several filters:



Original image High-Pass 5x5 3x3 Mean

3.3 Geometric processing

There are many ways of geometrically processing or transforming an image. Some of the most common geometric operators are described bellow [JAI].

Image translation using positive values in both x and y directions

45 degrees image rotation around (0,0) reference point

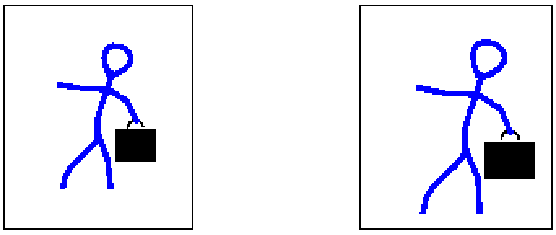


Image scaled by a factor of 1.2 in x and y

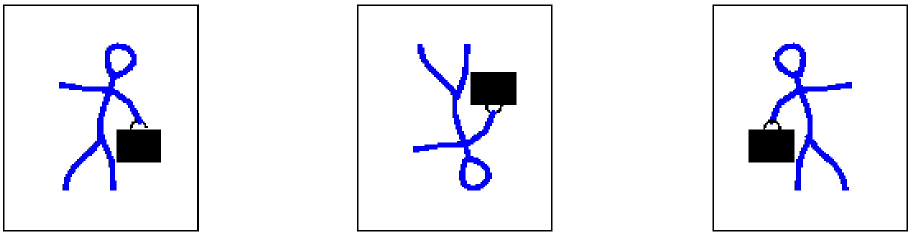


Image flip vertical / horizontal

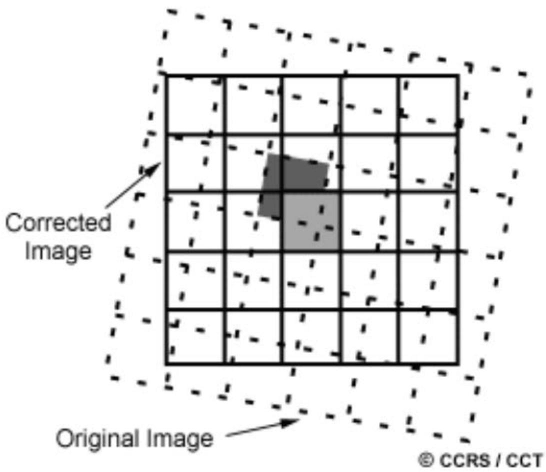
To apply one of the geometric operators described in the above paragraph in LEOWorks, you need to select Tools / Transformations.

Each time you'll be asked to type in some values for the operator's specific parameters and to select the interpolation method, the method to be used for resampling the output image. The interpolation methods are described in the next section.

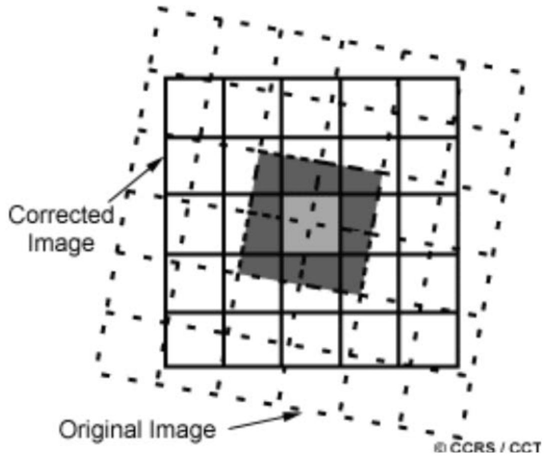
3.4 Interpolation methods

In order to actually geometrically correct a distorted image, a procedure called resampling is used to determine the digital values to place in the new pixel locations of the corrected output image [CCRS]. The resampling process calculates the new pixel values from the original digital pixel values in the uncorrected image. There are three common methods for resampling made available in LEOWorks: nearest neighbour, bilinear interpolation, and cubic convolution.

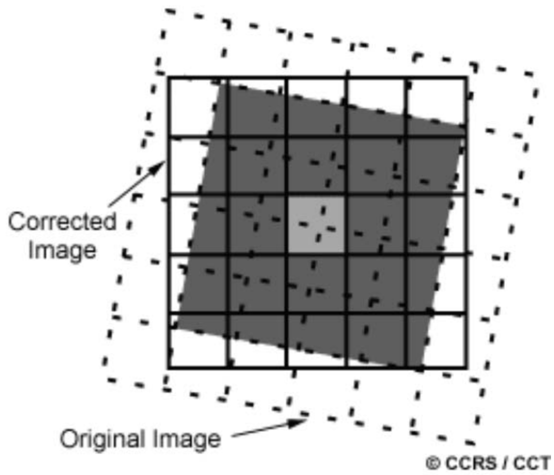
Nearest neighbor resampling uses the digital value from the pixel in the original image which is nearest to the new pixel location in the corrected image (see picture below). This is the simplest method and does not alter the original values, but may result in some pixel values being duplicated while others are lost. This method also tends to result in a disjointed or blocky image appearance.



Bilinear interpolation resampling takes a weighted average of four pixels in the original image nearest to the new pixel location (see picture below). The averaging process alters the original pixel values and creates entirely new digital values in the output image. This may be undesirable if further processing and analysis, such as classification based on spectral response, is to be done. If this is the case, resampling may best be done after the classification process.



Cubic convolution resampling goes even further to calculate a distance weighted average of a block of sixteen pixels from the original image, which surround the new output pixel location (see image below). As with bilinear interpolation, this method results in completely new pixel values. However, these two methods both produce images, which have a much sharper appearance and avoid the blocky appearance of the nearest neighbour method.



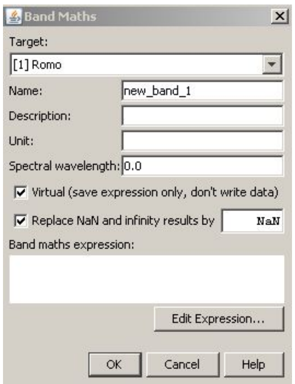
4. Band arithmetic

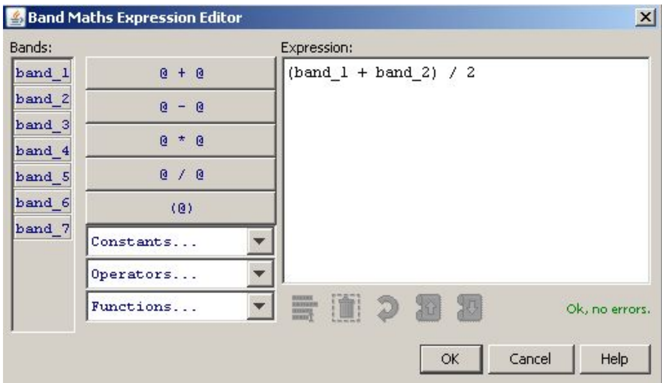
4.1 The band math dialog

The Band Maths tool creates new image sample values derived from existing bands. Mathematical operations are used in order to create another image derived from different bands. The students should be careful when defining the math expression, because a correct syntax must be specified.
Specify a name for the new image. An optional description and units can be entered below.

Use Edit expression button to define the mathematical expression. A new window will appear. In our example we chose to create an average image based on the following formula:

(Band1+Band2)/2





After the formula was written correctly, a green text will appear in the right corner: *OK, no errors*. Now you can click the OK button.

4.2 Compute a NDVI

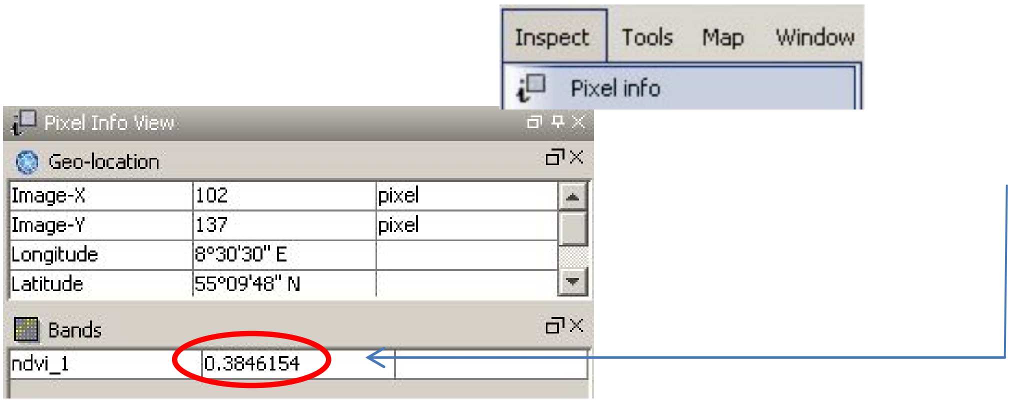
The NDVI (Normalized Difference Vegetation Index) is used to measure and monitor plant growth, vegetation cover and biomass production from multispectral remotely sensed data. It is computed as a report between the difference and the sum of the pixels representing atmospheric corrected reflectance values in two channels of remote sensing image dataset:

NDVI = (Channel 2 - Channel 1) / (Channel 2 + Channel 1)

Channel 1 is a visible (0.58-0.68 µm) band, usually the red band of an image and Channel 2 is a near infrared (0.725-1.1 µm) band. In the case of Landsat TM and ETM images Channel 1 correspond to band 3 and Channel 2 to band 4.

This index is computed this way because healthy vegetation reflects very well in the near infrared part of the spectrum while having low red light reflectance and so producing high values for NDVI.

Values obtained for NDVI range from -1 to +1 but the vegetated land has a NDVI ranging from 0.1 to 0.7-0.8. Values greater than 0.5 indicating dense and vigorous vegetation.



In our case, using Romo.tif example, specify from the next window a Name and the bands corresponding to the Red Channel (3) and NIR Channel (4). After that a formula will appear in the Band maths expression. After that click the OK button and wait for a moment.

Explore the result pixel values using Pixel Info.

By default, a color palette is applied to the resulting image. Use Color Manipulation to specify different intervals of color for a better interpretation.

NDVI derived from band 3 and 4 of Romo Landsat data

5. Attaching coordinates to pixels

Geocoding

When analyzing satellite images, you may want to know the position of the visible objects and phenomena on the Earth surface. In digital image processing this is possible using a geocoding i.e. a math transform allowing to compute coordinates for each pixel in an image. These coordinates are computed in a coordinate system related to the Earth surface

GCPs

The registration procedures implemented in LEOWorks allows you to compute and attach geographic coordinates to every pixel in a satellite image i.e. to perform a Geocoding. The geocoding is in fact a math transform whose parameters are computed based on GCPs.

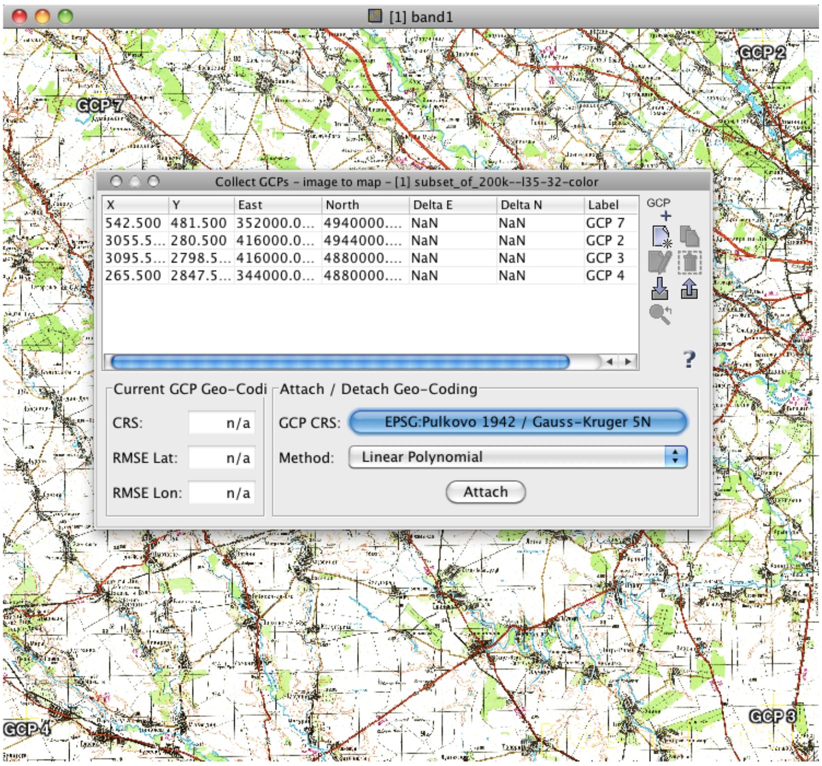
A GCP is a marker for a certain position within a image. The properties of a GCP are:

- its position inside the image - the image coordinates,
- its position on the Earth surface - the geographical or map coordinates,
- a graphical symbol showing its location on image,
- the name - sometimes is helpful to have a name,
- and a textual description - if considered necessary

5.1 Image to Map Registration

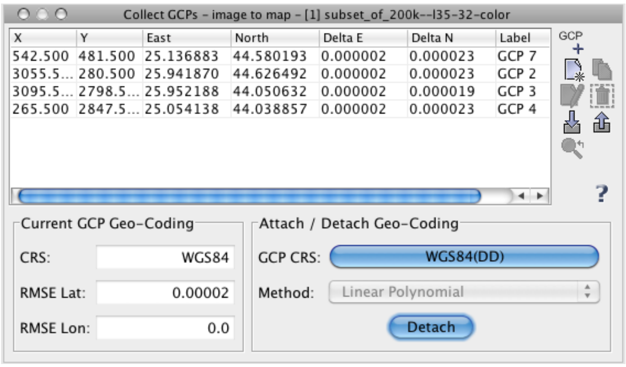
In Image to Map registration, the GCPs are selected exclusively by inspecting the image and choosing features that are also visible on a map in such a way their geographic or map coordinates can be accurately indicated. Geocoding a scanned map or a satellite image using GCPs whose coordinates are determined using a GPS receiver are typical cases of applying the Image to Map registration procedure.

As it can be seen in the image above, the GCPs coordinates are indicated in the map coordinate system. They can be indicated as latitude, longitude as well. It is very important to accurately indicate the coordinate systems of the GCPs used to compute the geocoding. At any time you can import or export a set of GCPs previously defined. Once you have enough GCPs for computing the geocoding using the chosen math transform, the Attach button becomes active and you can click it to compute and attach the geocoding transform to your image.



For simplicity and easiness the geocoding attached will show latitude and longitude coordinates in WGS84.

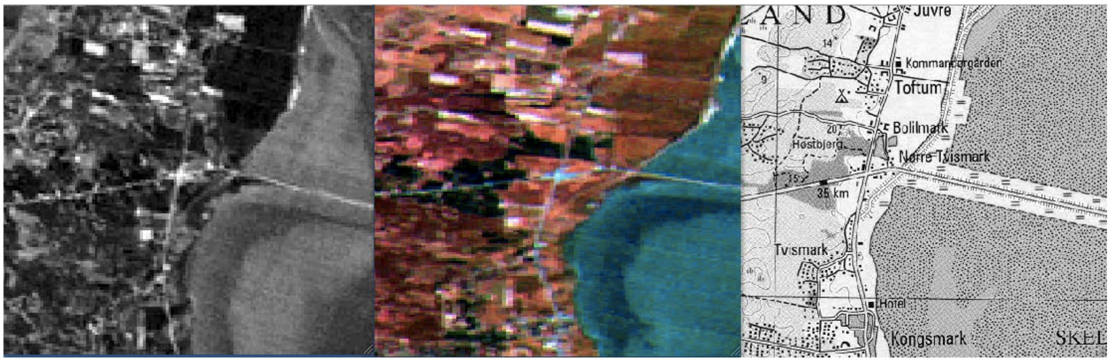
After attaching a geocoding to an image, if you choose Inspect/Information... from the main menu, you'll have on the Geocoding tab a description of the geocoding attached to your image i.e. the image is geo-referenced.



5.2 Image to Image Registration

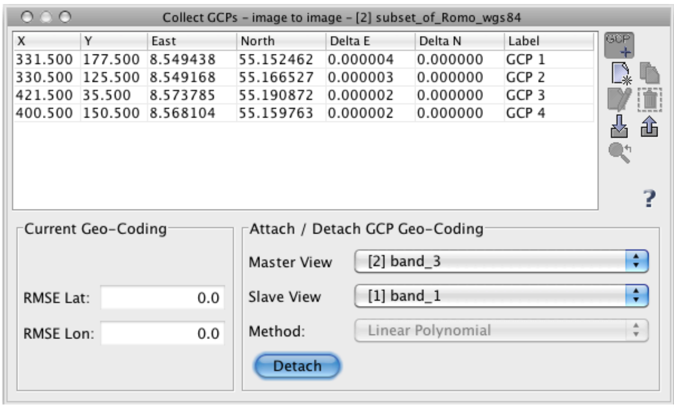
In Image to Image registration, the GCPs needed to compute the geocoding for a non-geocoded image are defined based on a geocoded image i.e. the non-geocoded image is considered a slave image while another geocoded image is considered a master image. See the image bellow for an example on identifying the same feature on two satellite images and on a map.

In LEOWorks, this procedure can be accessed by electing Tools/Registration/Image to Image. The tool is enabled only in the case at least two data viewers are available.



The GCP placing tool becomes available only after selecting the Master and Slave views in the “Collect GCPs – image to image” window. If GCPs are not visible in any of the viewers, you can make them visible by selecting View / GCPS from the main menu (the same effect is obtained by clicking the “Show GCPs” button in the toolbar).

When clicking in the slave image, the image coordinates of the GCP are recorded, while clicking in the master image, the geographical coordinates are recorded. That's why, when doing Image to Image registration, you need to indicate the slave view containing the image to be geocoded and the master view containing the geocoded image. See the image bellow.



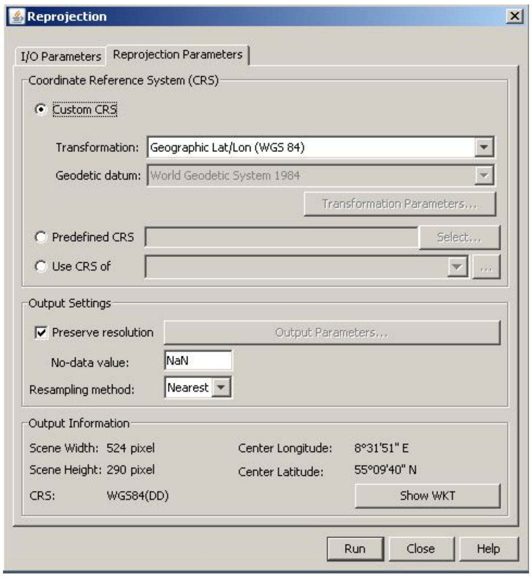
As in the Image to Map registration, coordinates are attached to pixels after clicking the Attach button. The button is enabled only if a sufficient number of GCPs are selected which in turn depends of the method selected (Linear, Quadratic or Cubic plinomial).

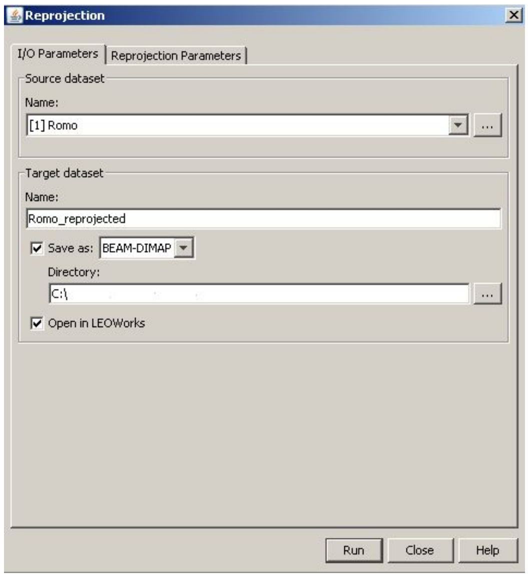
5.3 Reprojection

Is the procedures that convert from one cartographic projection to another, applied both raster and vector data. We try now to reproject the Romo.tif image, which is in the UTM Zone 32N projection, to a Geographic Lat/Lon system.

The reprojection dialog

A window with two tabs needs some specifications from the user: a name for the new image, in that case Romo_reprojected, and a destination folder. In the Parameters tab you must specify the new projection (Geographic lat/Lon WGS84). Press Run and look to the new product using Information dialog button. In the *Geo-Coding* tab is show the Geographic Projection.





The same steps are necessary for vector data, if you need another projection.

6. Radiometric calibration

6.1 Why radiometric calibration

Collecting information about the energy reflected or reemitted by objects through remote sensing is possible by using instruments placed on satellites or airplanes.

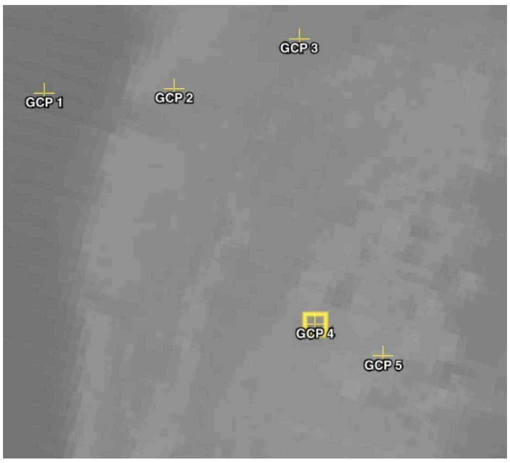
The energy reaching the remote sensing instrument is quantitatively and qualitatively influenced by the atmosphere as the electromagnetic radiation, either coming from the Sun or an active instrument, has to travel from through the atmosphere. That’s why, the energy detected by the remote sensing instrument is affected by the particles and gases in the atmosphere.

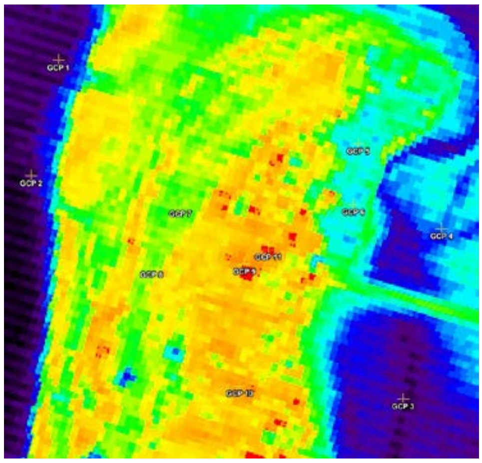
Through radiometric calibration, it is possible to reduce these effects and make a better interpretation of remote sensing data.

6.2 The Calibrate tool

Use this function in order to calibrate the value from an image with measurements made on the field. There are many applications using thermal bands (in the case of Landsat TM sensor the resolution of band 6 is 120m and 60m for Landsat ETM), ocean turbidity, Chlorophyll concentration etc.

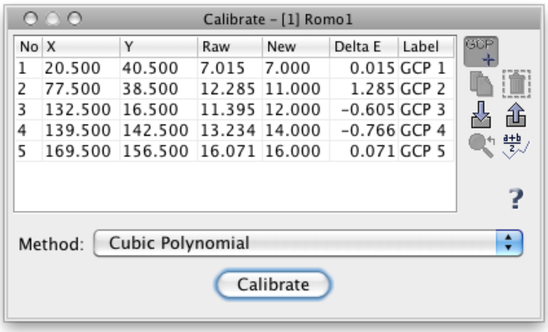
A calibration procedure involves a validation using reliable data, and the new result is based on a polynomial function. You can use later Interactive Stretching in order to obtain a better visualization, like in the next example:

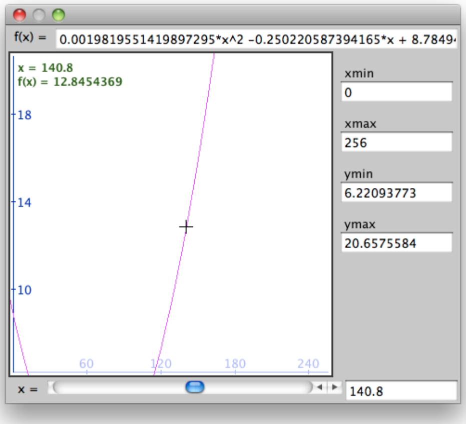




Landsat band 6 showing temperature values after radiometric calibration

To perform a radiometric calibration in LEOWorks, you have to open and display the band you want to calibrate and select Tools / Calibrate.





The calibration window gives you access to the tools allowing you to radiometrically calibrate a band of an image by selecting points for which filed values are known (in the current LEOWorks version only this method is available).

A typical calibration process would involve the following steps

- select the method to be used to compute a transformation to be applied to each pixel in the band – linear, quadratic and cubic polynomial are available; this will have impact on the number of points to selected on the image and measured on the field;

- select on the image the points for which field values are know (e.g. temperature);

- type the known field values in the table displayed in the calibration window, in the “New” column

- click the calibrate button and check the delta values for each point; alternatively you can inspect the graph of the calibration function (see below)

7. Image classification

Digital image classification

Digital image classification uses the spectral information represented by the digital numbers in one or more spectral bands, and attempts to classify each individual pixel based on this spectral information. The objective is to assign all pixels in the image to particular classes or themes (e.g. water, coniferous forest, deciduous forest, corn, wheat, etc). The resulting classified image is comprised of a mosaic of pixels, each of which belong to a particular theme, and is essentially a thematic map of the original image.

When talking about classes, we need to distinguish between information classes and spectral classes. Information classes are those categories of interest that the analyst is actually trying to identify in the imagery, such as different kinds of crops, different forest types or tree species, different geologic units or rock types, etc. Spectral classes are groups of pixels that are uniform (or near-similar) with respect to their brightness values in the different spectral channels of the data. The objective is to match the spectral classes in the data to the information classes of interest.

Common classification procedures can be broken down into two broad subdivisions based on the method used: *supervised classification and unsupervised classification.* In a supervised classification, the analyst identifies in the imagery homogeneous representative samples of the different surface cover types (information classes) of interest. These samples are referred to as training areas. The selection of appropriate training areas is based on the analyst's familiarity with the geographical area and their knowledge of the actual surface cover types present in the image. Unsupervised classification in essence reverses the supervised classification process. Spectral classes are grouped first, based solely on the numerical information in the data, and are then matched by the analyst to information classes (if possible). Programs, called clustering algorithms, are used to determine the natural (statistical) groupings or structures in the data. Usually, the analyst specifies how many groups or clusters are to be looked for in the data. In addition to specifying the desired number of classes, the analyst may also specify parameters related to the separation distance among the clusters and the variation within each cluster (Source: Fundamentals of Remote Sensing: a Canada Centre for Remote Sensing Tutorial)

Classification of a satellite image involves assigning all the pixels in an image to specific classes. These classes need to be predefined or created as part of the classification process, which requires former knowledge of the area or information about the different features and pixel colors in the image. Classified images are thematic maps, which show the distribution of selected classes.

7.1 Unsupervised Classification

Unsupervised classification can be used to cluster pixels in a data set based on statistics only, without any user-defined training classes.

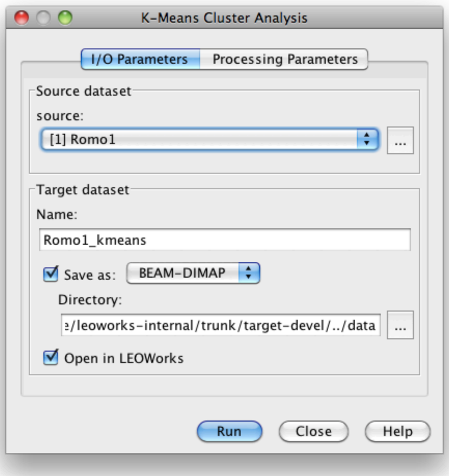
Cluster analysis (or clustering) is the classification of objects into different groups, or more precisely, the partitioning of a data set into subsets (clusters or classes), so that the data in each subset (ideally) share some common trait - often proximity according to some defined distance measure. Data clustering is a common technique for statistical data analysis, which is used in many fields, including machine learning, data mining, pattern recognition, image analysis and bioinformatics. The computational task of classifying the data set into k clusters is often referred to as k-means clustering [see ESA BEAM Help].

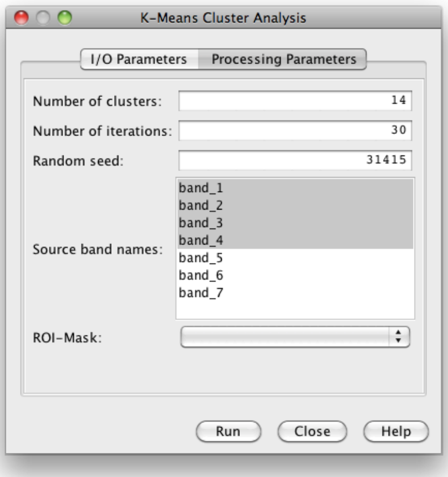
In LEOWorks, the k-means clustering algorithm is used. Given the number of clusters k, the basic algorithm is:

- Randomly choose k pixels whose samples define the initial cluster centers.
- Assign each pixel to the nearest cluster center as defined by the Euclidean distance.
- Recalculate the cluster centers as the arithmetic means of all samples from all pixels in a cluster.
- Repeat previous steps until the convergence criterion is met.

To perform an unsupervised classification in LEOWorks:

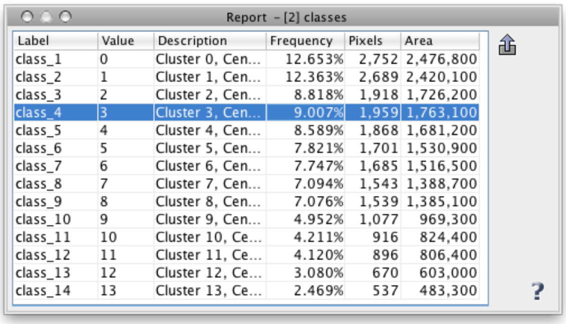
1. Open the image you want to classify;
2. Open the Classification Manager by selecting Tools / Classification;
3. Choose one of the unsupervised methods (in the current version, only K-Means is supported) in the Classification Method list;
4. Click the Start Classification button; the K-Means cluster analysis dialog will be displayed



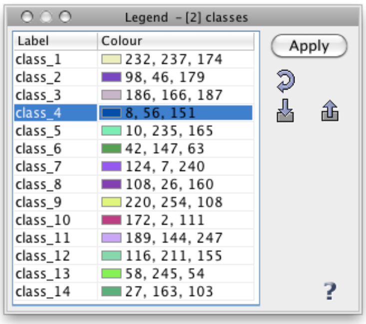


5. In the K-Means classification dialog, on the I/O parameters tab, choose the name for the target dataset
6. In the K-Means classification dialog, on the Processing Parameters tab, set the values for the parameters;
7. Press RUN; After processing is finished, a new dataset will be added in the Available Data window
8. Double click the band named “classes” to display it; a color image will be displayed

9. By selecting Tools/Classification/Report, you can display a classification report, showing the number o pixels and estimated area for each class



Label	Value	Description	Frequency	Pixels	Area
class_1	0	Cluster 0, Cen...	12.653%	2,752	2,476,800
class_2	1	Cluster 1, Cen...	12.363%	2,689	2,420,100
class_3	2	Cluster 2, Cen...	8.818%	1,918	1,726,200
class_4	3	Cluster 3, Cen...	9.007%	1,959	1,763,100
class_5	4	Cluster 4, Cen...	8.589%	1,868	1,681,200
class_6	5	Cluster 5, Cen...	7.821%	1,701	1,530,900
class_7	6	Cluster 6, Cen...	7.747%	1,685	1,516,500
class_8	7	Cluster 7, Cen...	7.094%	1,543	1,388,700
class_9	8	Cluster 8, Cen...	7.076%	1,539	1,385,100
class_10	9	Cluster 9, Cen...	4.952%	1,077	969,300
class_11	10	Cluster 10, Ce...	4.211%	916	824,400
class_12	11	Cluster 11, Ce...	4.120%	896	806,400
class_13	12	Cluster 12, Ce...	3.080%	670	603,000
class_14	13	Cluster 13, Ce...	2.469%	537	483,300



Label	Colour
class_1	232, 237, 174
class_2	98, 46, 179
class_3	186, 166, 187
class_4	8, 56, 151
class_5	10, 235, 165
class_6	42, 147, 63
class_7	124, 7, 240
class_8	108, 26, 160
class_9	220, 254, 108
class_10	172, 2, 111
class_11	189, 144, 247
class_12	116, 211, 155
class_13	58, 245, 54
class_14	27, 163, 103

10. By selecting Tools/Classification/Legend, you can display the legend, i.e. the color used to display the classes; you can edit the color for each class by clicking the color, choosing another one and clicking the Apply button.

The resulting classes are somewhat artificial and based purely on statistics but can at the same time be real. Often they can be attributed to real land cover features such as crops, roads, settlements, tidal flats etc.

7.2 Supervised Classification

As specified in the above paragraph, when performing unsupervised classifications, the classes to be identified in the image are defined using training fields. Then, using a decision rule, pixels are classified according to their spectral signatures (values in each band) and the signature (statistical parameters derived from the training fields) of each class.

The decision rule is varying from one method to another. In LEOWorks, three supervised classification methods are made available:

- Minimum distance;
- Parallelepiped;
- Maximum likelihood.

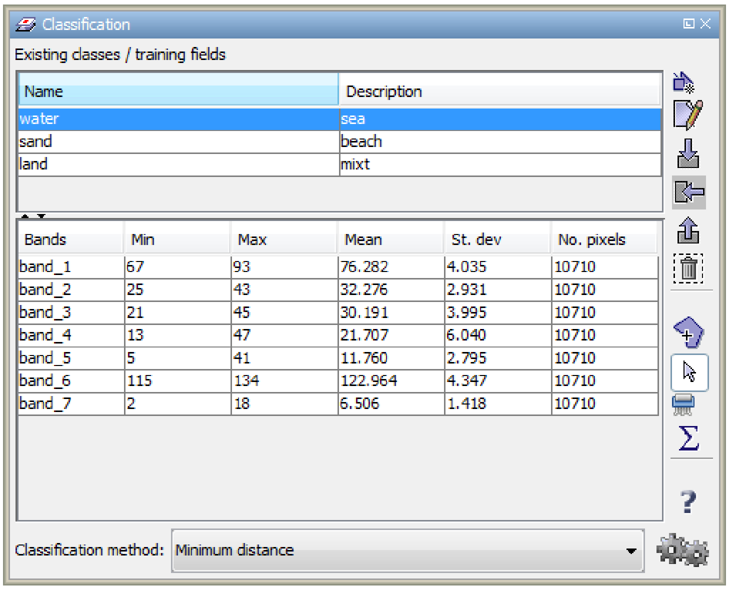
For more details about these methods, you cand check different remote sensing image analysis books, for example [Richards].

Training Fields

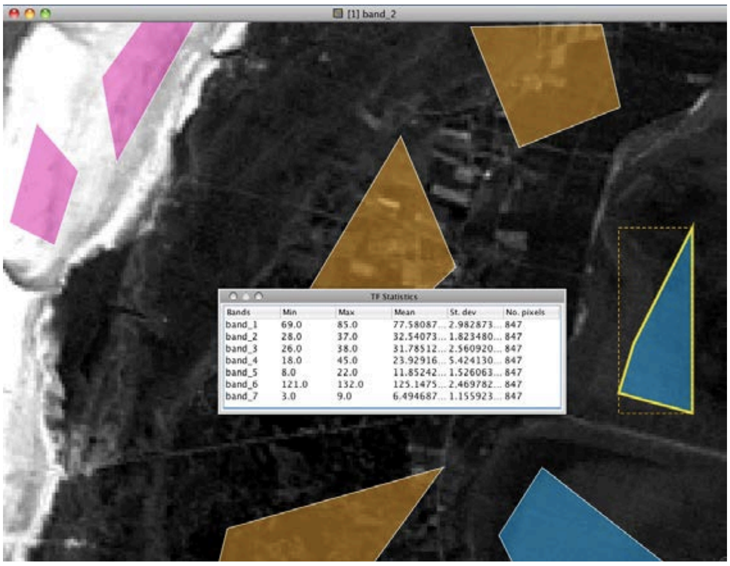
In LEOWorks you can define training fields using the tools made available for this purpose in the classification manager:

1. After displaying an image (can be either the gray scale image of a band or a color combination of three bands), make the Classification Manager window visible, if not visible, by selecting Tools / Classification.
2. To create a class, you need to click the "Create class" button . It's always needed to give it a name and is useful to type a description. The new class will be added in the "Existing classes / training fields" list in the Classification Manager window.
3. Select the class, click a Training Field tool (Draw Polygon TF) and start drawing training fields on the image; to define more classes, repeat the steps 2 and 3; in the figure bellow an example is given in which 3 classes were defined; you can always edit the colors used to display a class or delete a class by pressing the appropriate buttons in the Classification

window; for any defined class you can load TFs from an existing .shp file by selecting a class and clicking the “Import TF from shape file for selected class” button; alternatively you can import TFs from a shape file for all classes (if classes are not defined, they will be created accordig to information existing in the selected shape file); already defined TFs for classes can be exported in a shape file; to do so, you need to select the desired classes and click the “Export TF to shapefile” button



4. For each of the defined classes, you can inspect the statistics by simply selecting the class in the Existing classes / training fields list and watching the panel below that list.
5. You can also inspect the statistics of any individual Training Field by clicking the “View statistics for a single TF” button and then clicking a training field; see the example below.
6. To perform the classification considering classes already defined and displayed in the Classification window and display the result, you need to select one of the supervised methods in the “Classification method” list and then go through steps 4-11 defined in the Unsupervised classification section.



Bands	Min	Max	Mean	St. dev	No. pixels
band_1	69.0	85.0	77.58087...	2.982873...	847
band_2	28.0	37.0	32.54073...	1.823480...	847
band_3	26.0	38.0	31.78512...	2.560920...	847
band_4	18.0	45.0	23.92916...	5.424130...	847
band_5	8.0	22.0	11.85242...	1.526063...	847
band_6	121.0	132.0	125.1475...	2.469782...	847
band_7	3.0	9.0	6.494687...	1.155923...	847

8. Showing results

8.1 Feature extraction - GIS tools

Edit a vector theme

To create a new object in the selected vector theme, the user must start the editing on the selected theme. Steps:

1. Select the vector theme in the GIS manager, as in the following image;

2. Press the Start Edit button, as in the image:

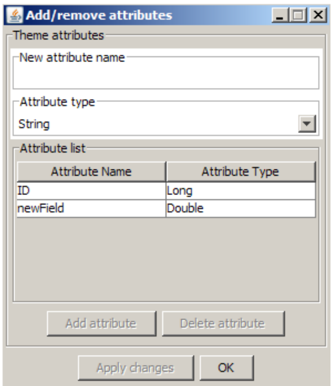
3. After the editing started, there will be active only a drawing tool, according to the layer data type: polygon, polyline or point, as in the following image:

Press the button of the active drawing tool, then move the mouse cursor in the theme area and insert points. When the last point is created, do mouse double click.

Add/remove attribute fields

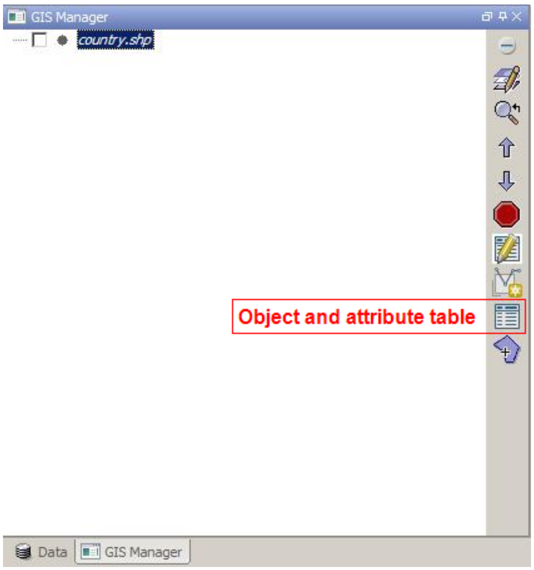
To add a new attribute field, press the Add or remove attribute button, as in the following image.

The Add/remove attributes dialog is shown, as in the next figure.To add a new attribute, insert the name for the new attribute field and select the field type.The "Add attribute" button is activated now. To add the new attribute press the “Add attribute” button. To remove an existing attribute, select the attribute to be deleted in the attribute list. The "Delete attribute" button is activated. To remove the selected attribute, press the " Delete attribute" button. When all attributes were added or removed, press the “Apply changes” button. Pressing the “Ok” button closes the dialog.

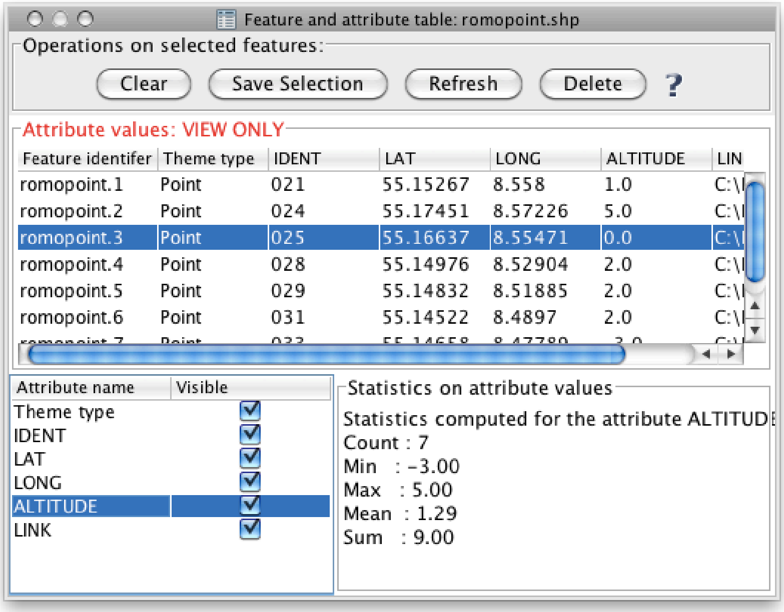


Edit attribute field values

To set values for an attribute for the current edited theme, first make sure that the theme is selected in the GIS manager and an edit session is opened on this theme . Then press the “Feature Table” button, as in figure.



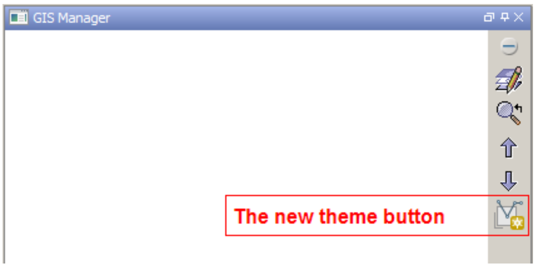
The object and attribute table is shown, with the information that it is in the edit mode. To modify value for an attribute, execute double click in the cell that contains the attribute value. The cell can be edited and the attribute value can be modified.



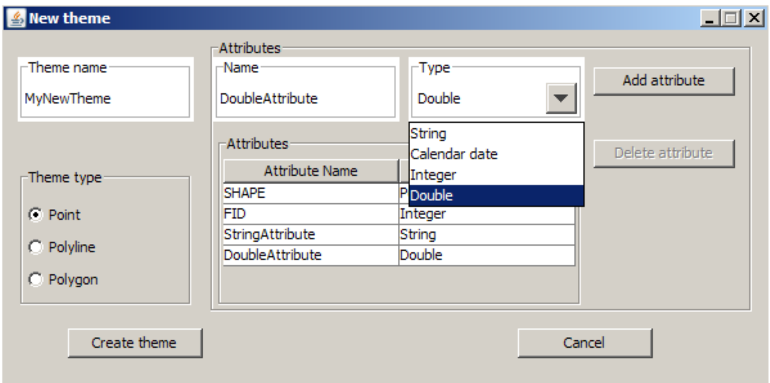
To stop the editing process, press the "Stop edit" button, as shown in the next figure.

Create a new theme

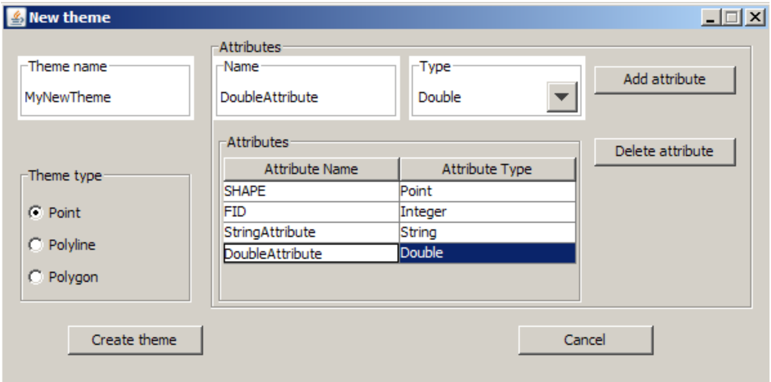
To create a new theme, there must be a vector theme or a raster layer already opened and displayed. The creation of a new vector theme starts by pressing the "New theme" button, as is shown in figure below.



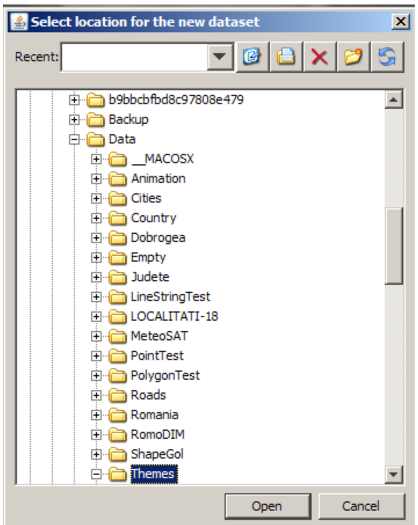
The "New theme" dialog is shown, like in the following figure. The user must provide the theme name, in the "Theme name" edit field. The theme type can be selected from the "Theme type" panel, by pressing the radio button for point, polyline or polygon. The default value is point type. To add a new attribute, the user must set the attribute's field name in the "Attributes panel, the "Name" edit field. The types can be selected from the "Type" list. After setting the attribute field name and type, the "Add attribute" button is activated. To add the new attribute, press the "Add attribute" button, and it is added to the theme's attributes list, as in the figure below.



To remove an attribute, this has to be selected in the attributes list, from the “Attributes” panel. After the attribute is selected, the “Delete attribute” button is activated, as in the next figure. Pressing this button removes the attribute. Note that SHAPE and FID attributes are read-only and cannot be removed.

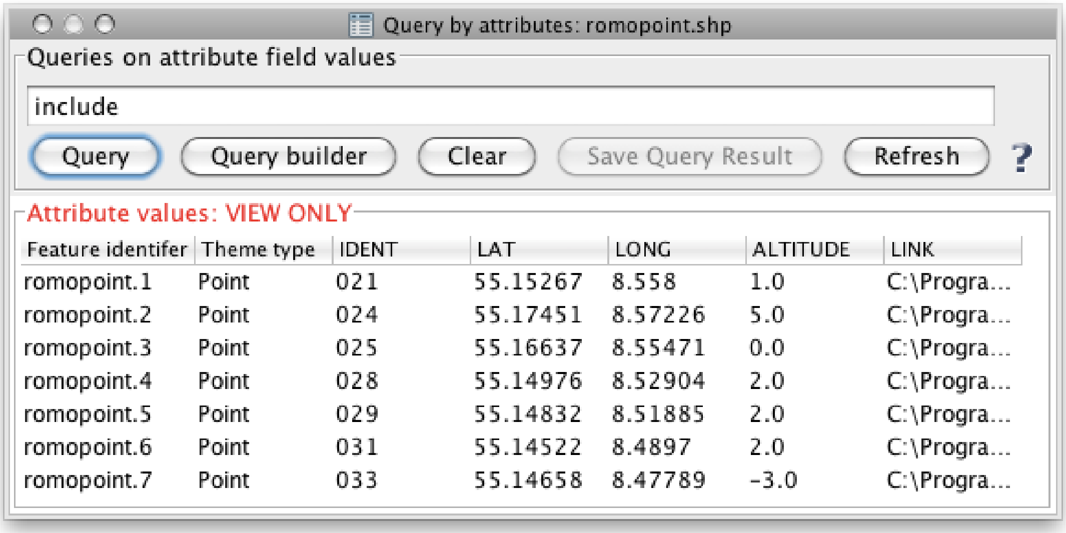


After the theme name setting, the “Create theme” button is activated. To create the new theme, press this button. After pressing it, a window is shown, where the user is asked to select the folder where the new theme will be created.

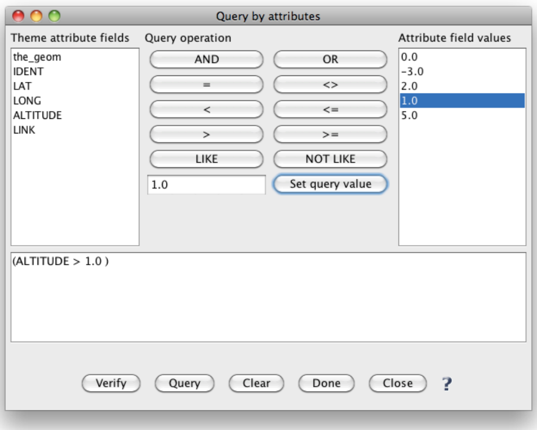


Query by attribute field values

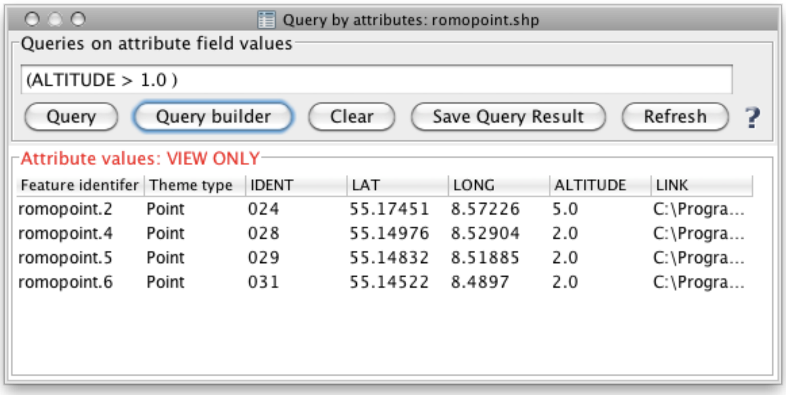
Either accessed from the subset dialog (when opening files) from the subset by attributes tab, or from the GIS Manager, the Query by attribute allows you to select object in a vector GIS dataset based on their attribute values.



For generating a query, the Query builder is used (see figure below). The query values can be introduced by hand or be selected from a list, as in the following figure. The editable query field is marked with the red triangle.



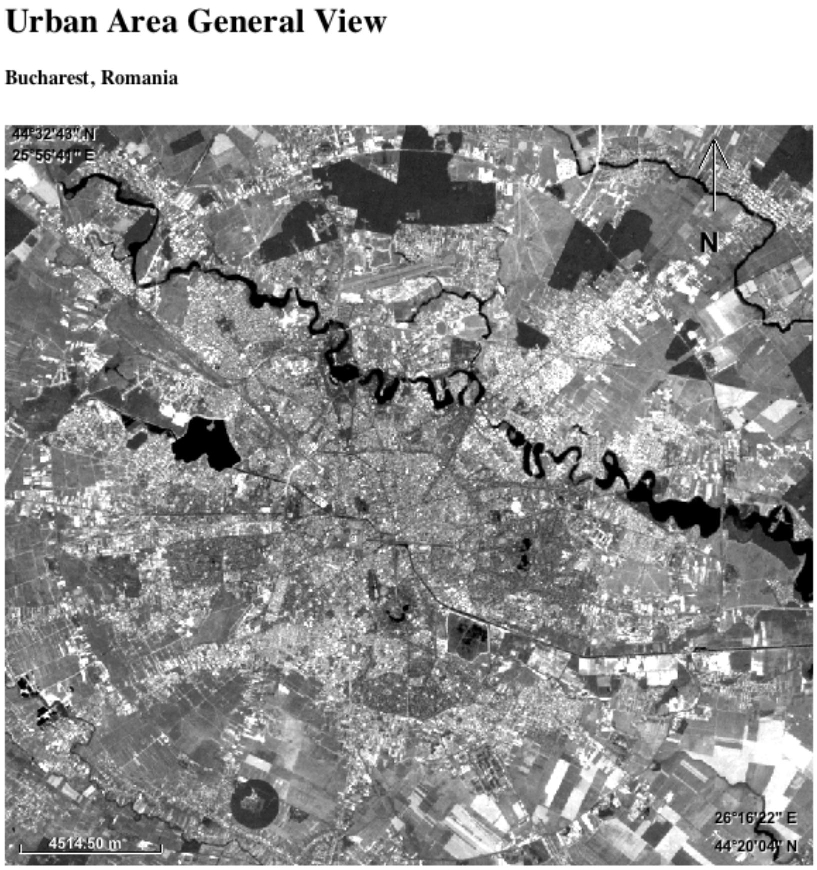
In order to perform a query on a selected theme, an attribute field must be selected in the “Theme attribute fields” list box, by clicking it. Then select the operator, by pressing one of the buttons situated in the “Query operation” area. After clicking the field that is queried and the query operation there must be set the query value. After the query value is set, press the "Set query value" button. The query is shown in the query area. Press the “Verify” button. If the query is correct, the message “Query is correct is shown”. By pressing the “Done” button, the query string is transferred to the “Object and attribute table” window. Press the “Close” button, to close the query builder. In order to execute the query, press the “Query” button in the “Object and attribute table” window. Press the "Query" button and the query is done directly. The query results are shown in the “Object and attribute window” and in the view, as in the following figure.



8.2 Composing and printing maps

The Map menu provides access to functions allowing one to create, edit and save map compositions. The position and content of the Map menu in the Leoworks menu are shown bellow. The Map menu provides access to functions allowing one to create, edit and save map compositions.

The easiest way is to choose the Create option and thus generate a pre-defined map composition using the image in the current viewer (see image bellow).



The pre-defined map composition is made of:

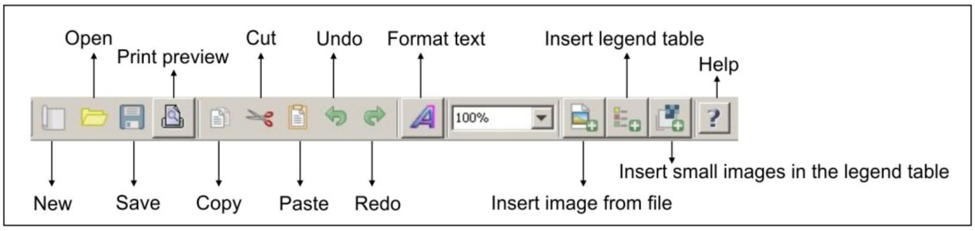
- Title - this can be something related to the phenomena shown in the map, e.g. “3 classes land cover supervised classification”.

- Subtitle - this can be the name of the area covered by the map, e.g. “Bucharest, Romania”.

- A geo-referenced image showing a phenomena to be highlighted in the map with coordinates printed at the corners, graphic scale and North arrow;

Either you choose Create, New or Open from the Map menu, a Map Composer View is opened.

The Map Composer Toolbar

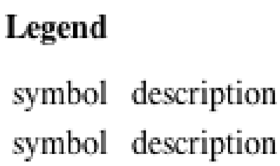


The Map Composer toolbar is attached to the Map Composer view and is made of buttons allowing the user to:

- open and save a map;
- preview and print the map;
- copy, cut, paste operations;
- undo and redo;
- format the inserted text (change font, color, style);
- insert other pictures (e.g. logos, ground photos);
- insert a legend table;
- insert image samples.

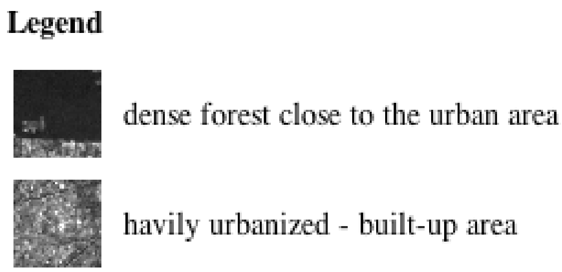
Creating a Legend

For creating a legend to be included in your map, you can either select Map/Insert/Legend or click the Insert Legend button in the Map Composer toolbar. After specifying the number of items to be included in the legend, a template for your legend will be included at the current cursor position



For generating the graphic component of a legend item, you have to selct the 'symbol' word of an item, click the Insert Small Image button and then click in the geo-referenced image. A small image is acquired by capturing the pixels around the mouse cursor and inserted in the legend.

To type the explanation for a certain legend element, you just select the 'description' word and start typing the explanation.



See the image above for an example on how a legend can look like.

The map composition area can be navigated and edited the same way as a rich text editing tool does it

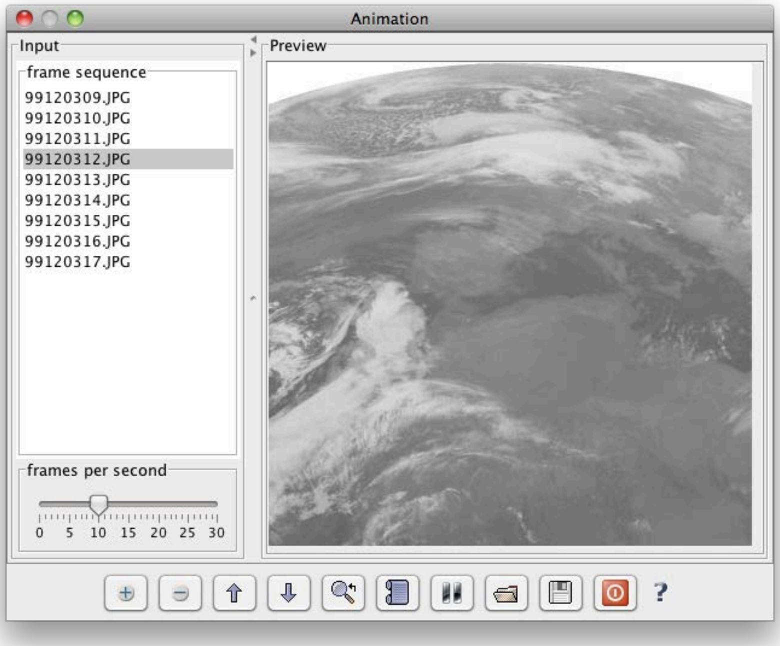
8.3 Animations

By selecting Animation from the main Leoworks Tools menu, one can get access to a tool, which allows generating movies from individual satellite images stored in JPEG files. Once selected, the Animation tool allows you to select a number of images to be used for generating the movie.

Generating a list of files

You can add images by clicking the Add button. At any time you can remove or add new images, by pressing the Remove or Add buttons respectively. The list of available images is displayed in the Input panel of the Animation tool window.

You can also change the position of an image by pressing the Up and Down buttons.



Once added in the list, an image can be previewed by pressing the Preview button. Another possibility to preview the images is to click an image in the list and then use the UP and DOWN keys to move in the list and preview the images.

Setting the number of frames per second

In the frames per second panel, a cursor allows you to set the number of frames per second. Each image in your list is a frame in your future animation. Depending on the frames per second chosen value, your animation will be shorter or longer in time.

Preview and save animations

You can preview your animation by pressing the Preview animation button. This will launch a continuous play of the newly created animation. This can be saved by pressing the Save button. A .mov file will be generated.

Any previously created animation can be played by pressing the Open button. Since all created animations are saved in .mov files, they can be played in mostly any media player installed on your computer.