

Sentinel-1 Intensity Analysis in ENVI SARscape Tutorial

This tutorial provides an introduction to working with Sentinel-1 synthetic aperture radar (SAR) data in ENVI® SARscape. You will learn about SAR remote sensing and how to prepare Sentinel-1 data for backscatter intensity analysis. Steps are provided for downloading data, importing data into SARscape, setting preferences, multilooking, spatial subsetting (sample selection), filtering, and geocoding. You will also learn how to create a color composite of intensity images.

The following software must be installed and licensed on your system:

- ENVI 5.5.1 or higher
- ENVI SARscape 5.5 Basic Module or higher

See the following sections:

- [Files Used in This Tutorial](#)
- [Introduction to SAR](#)
- [Working with Sentinel-1 Data in ENVI SARscape](#)
 - [Set ENVI Preferences](#)
 - [Set SARscape Preferences](#)
 - [Download and Import Sentinel-1 Scenes](#)
 - [Open and Display Intensity Images](#)
 - [Process Intensity Images](#)
 - [Create a Color Composite](#)
- [Using the ENVI Modeler for Batch Processing](#)
- [References](#)

Files Used in This Tutorial

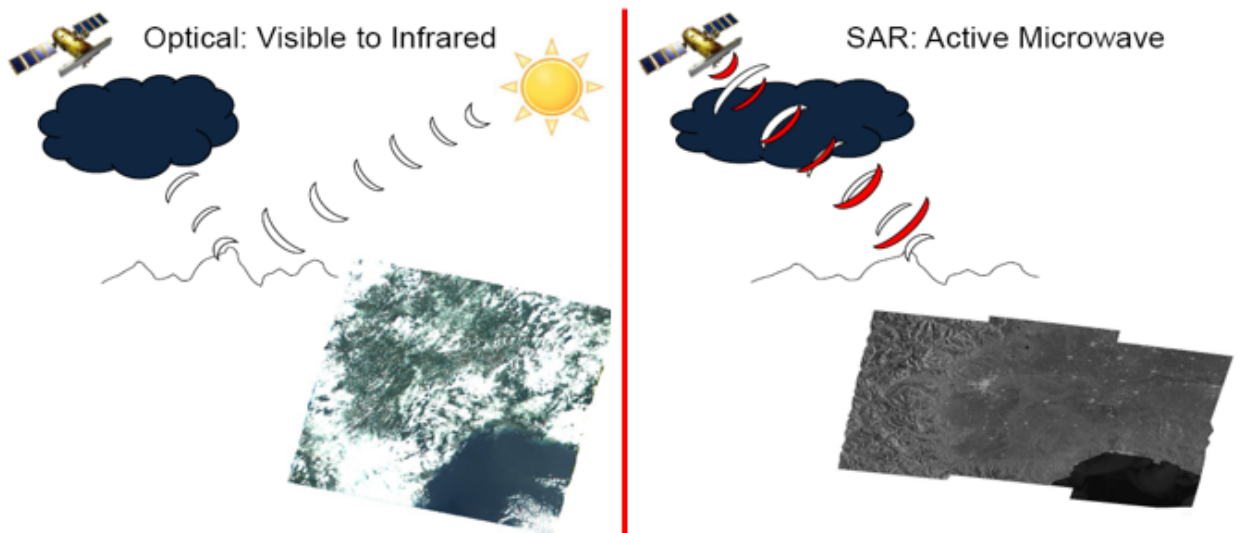
Sample data files for the tutorial are available from our [ENVI Tutorials](#) web page. Click the "SAR Getting Started" link under "ENVI Tutorial Data." Extract the data to a new directory on your local drive called `SARGettingStarted`. Make sure this directory has write permissions. Then create a subfolder called `TempFiles`.

File	Description
2017-12-12-SLC-Power/	Folder containing Sentinel-1 intensity (power) images of a region in Chile
StudySite.shp (and .dbf, .shx)	Shapefile indicating the boundary of the study area

You will also need to download a digital elevation model (DEM) for geocoding. The [Geocode the Images](#) section of this tutorial provides instructions for downloading an ASTER Global DEM or SRTM-3 V4 DEM.

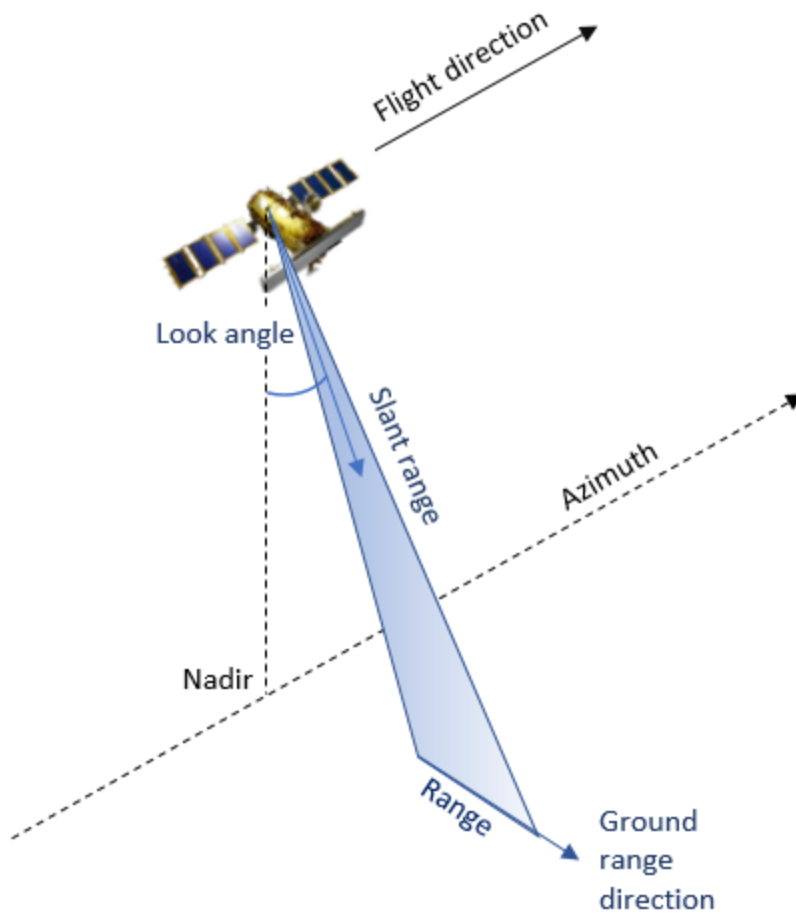
Introduction to SAR

Synthetic aperture radar (SAR) is an *active imaging* system, whereby the sensor provides its own energy source to illuminate the Earth's surface. It emits microwave radiation toward the surface and receives the reflected signal. In contrast, optical sensors—such as Landsat, Sentinel-2, and WorldView—rely on the sun to illuminate the surface. They measure the amount of reflected sunlight at the sensor. Thus, optical sensors that measure visible to shortwave-infrared (SWIR) wavelengths can only provide useful images during the daytime. Cloud cover can obscure the surface for optical sensors, which severely limits the extraction of meaningful information about the surface. SAR sensors, on the other hand, can obtain measurements any time of day and in any cloud-cover condition.



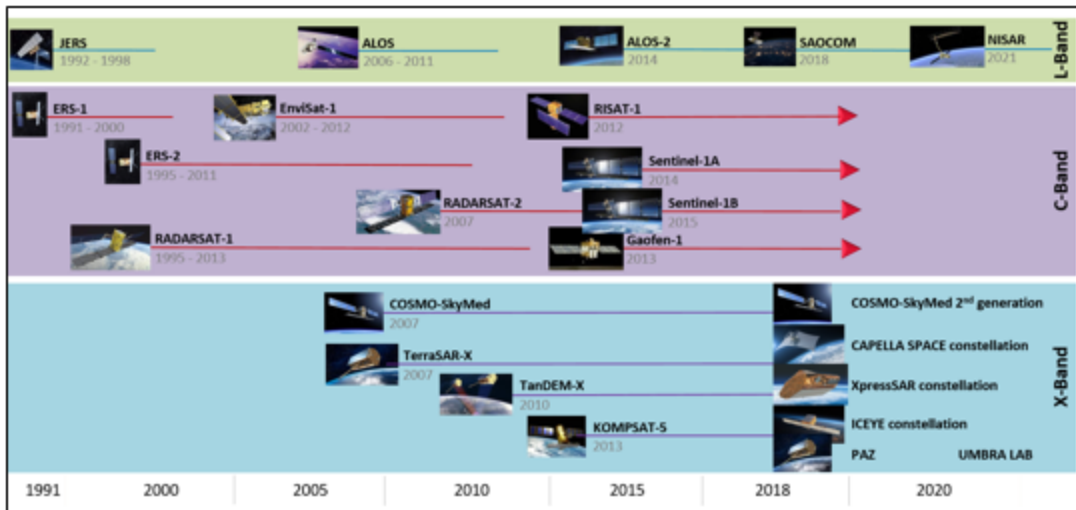
SAR imaging is sensitive to the effects of topography, surface roughness, and moisture. This makes it suitable for a wide variety of scientific applications. The interactions between microwave sensing and the Earth's surface are complex. This, combined with the amount of processing involved, tends to discourage some users from working with SAR data. This tutorial provides an introduction to SAR remote sensing so that you can begin to explore its full potential.

Spaceborne and airborne radar systems transmit microwave pulses toward the Earth's surface in a side-looking (oblique) direction. The sensor's antenna focuses the regular pulses into a beam, which illuminates the surface at a right angle to the direction the sensor is moving. The direction of the antenna beam is called the range, or ground range. The direction of the flight path is called the azimuth.

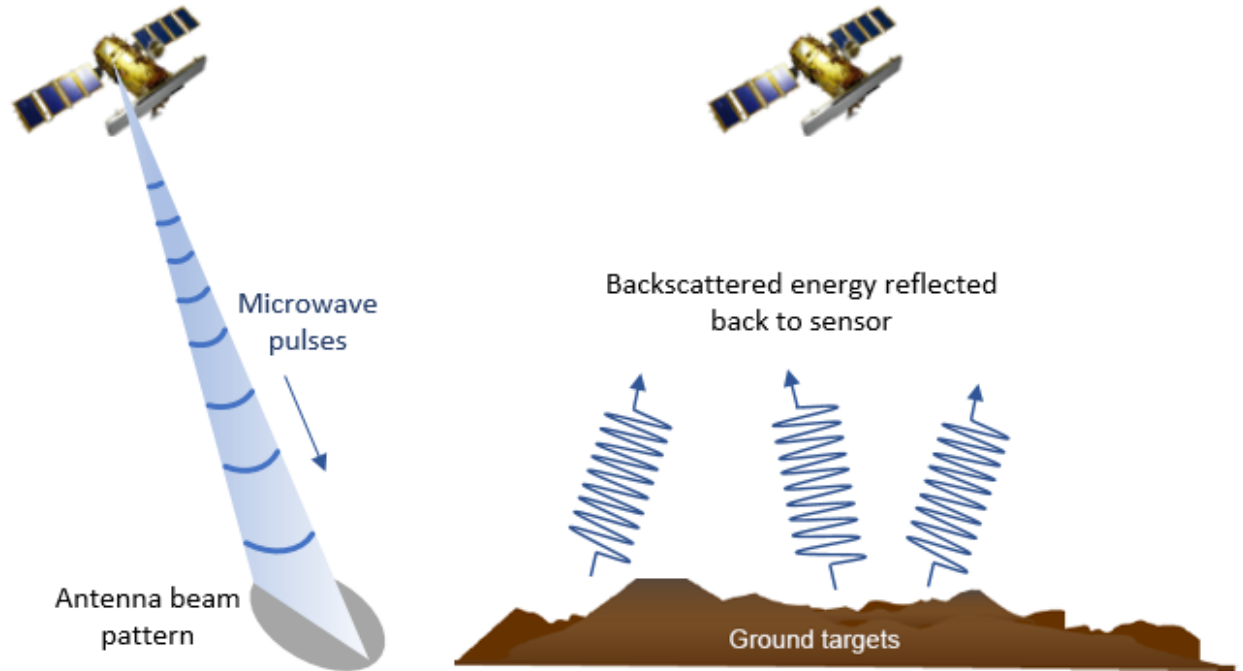


Sentinel-1 transmits energy at a frequency of 5.405 GHz, in the microwave region called the C-band. In this region, microwave energy only partially penetrates through surfaces such as vegetation and soils, compared to L-band sensors that can penetrate all the way through those materials under dry conditions. (Moisture prevents the energy from penetrating through most soils.) X-band sensors are primarily used for investigations of surface features since the microwave energy only penetrates the top layer layer of materials.

The following figure shows the different SAR missions and their microwave regions. Click on the thumbnail to see a larger version.

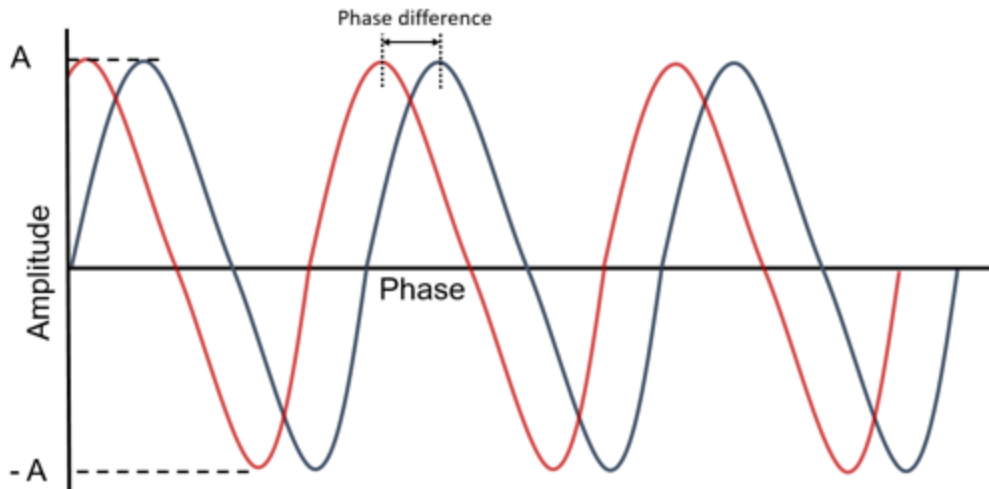


The antenna receives a portion of the microwave energy reflected from the surface objects within the beam pattern. The ratio of the power between the transmitted and reflected energy is called backscatter.



Backscatter is dimensionless; however, it is typically reported in decibels (dB). Backscatter consists of two variables: *amplitude* and *phase*. Amplitude—also called *magnitude*—is a measure of the strength of the reflected signal at the sensor. *Phase* represents the point along the wave of the reflected signal when it is received at the sensor. The difference in phase between the transmitted signal and the received signal provides information about the surface. This difference is measured in radians or degrees.

The following diagram shows the relationship between amplitude and phase in a microwave signal:



Since the backscattered signal is a combination of two variables, that signal must be represented as a complex number for the purposes of creating a digital image. Thus, in an unprocessed radar image, each pixel represents a complex value that contains amplitude and phase information about the microwave field backscattered by all the scattering objects within the radar beam. The amplitude/magnitude is the real part of the complex value, while the phase is the imaginary part. Phase is more difficult for us to visualize, so that is why it is represented as the imaginary part.

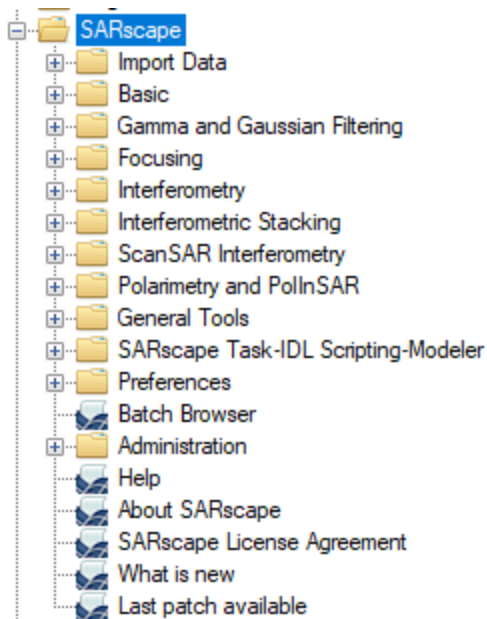
The Sentinel-1 data used in this tutorial were acquired in Interferometric Wide swath (IW) mode. This is the primary acquisition mode over land, and it is the most frequently used mode for Sentinel-1 applications. See the [Interferometric Wide Swath](#) topic in the *Sentinel-1 SAR User Guide* for details.

For more detailed information about the physical processes involved with radar remote sensing, consult the references at the end of the tutorial.

In the next section, you will explore some of the tools available in ENVI SARscape for working with Sentinel-1 data.

Working with Sentinel-1 Data in ENVI SARscape

ENVI SARscape provides many different tools for importing and processing various radar formats. The SARscape folder in the ENVI Toolbox contains all of the available tools for the SARscape modules you have installed and licensed. Also included are options for setting preferences, performing administrative tasks, and reading the ENVI SARscape documentation provided by sarmap SA.



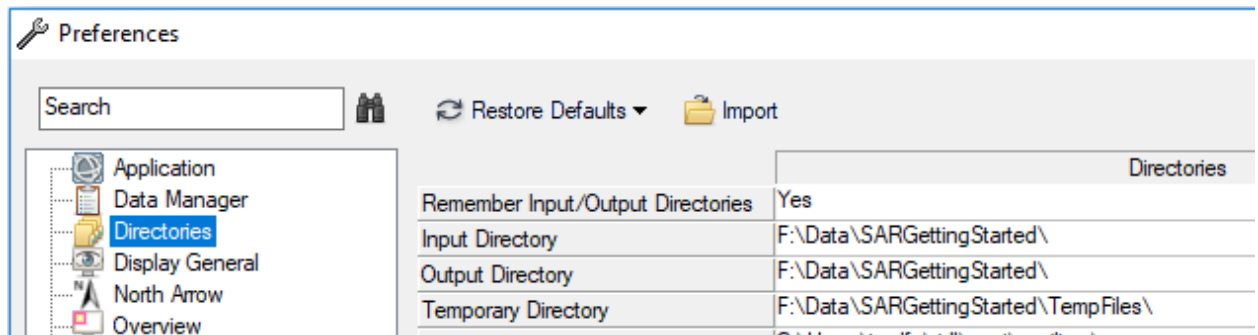
Given the large number of tools that are provided, knowing where to begin with Sentinel-1 data processing can be a challenge. This tutorial describes one specific workflow: preparing Sentinel-1 data for backscatter intensity analysis. The workflow involves the following steps:

- Setting preferences
- Downloading and importing data within ENVI
- Performing basic processing steps such as multilooking, subsetting, spatial filtering, and geocoding
- Creating a color composite of processed bands

Set ENVI Preferences

1. Start ENVI.
2. From the ENVI main menu bar, select **File > Preferences**.
3. Click the **Directories** item on the left side of the Preferences dialog.
4. Click inside the **Input Directory** field, then click the **>** button that appears. The Browse for Folder dialog appears.
5. Navigate to the **SARGettingStarted** directory and click **OK**. You created this directory earlier in the [Files Used in This Tutorial](#) section.
6. Click the **>** button next to **Output Directory**.

7. Select the **SARGettingStarted** directory and click **OK**.
8. Click the **>** button next to **Temporary Directory**.
9. Navigate to the **SARGettingStarted\TempFiles** folder. Click **OK** in the Browse for Folder dialog.
10. Click **OK** in the Preferences dialog.



Set SARscape Preferences

1. In the ENVI Toolbox, select **SARscape > Preferences > Preferences common**. The Preferences [General] dialog appears.
2. Select the **Directories and batch file name** item on the left side.
3. Click inside the **Working directory** preference field, then click the **>** button. The Browse for Folder dialog appears.
4. Select the **SARGettingStarted\TempFiles** directory. Log files and trace files from SARscape processes will be saved to this directory.

Tip: You do not need to set the Sentinel-1 auxiliary directory preference for this tutorial. You would normally set this preference to a directory that contains precise or restituted orbit files, which are used for interferometry.

5. Click **Ok** in the Preferences [General] dialog.
6. In the ENVI Toolbox, double-click **Preferences specific**.
7. Click the **Load Preferences** button in the Preferences dialog and select **Sentinel TOPSAR**.
8. When prompted to load the Sentinel TOPSAR preferences, click **Yes**.
9. Click **Ok** in the Preferences [Sentinel TOPSAR] dialog.

Tip: Be sure to set the specific preferences each time you start ENVI. This will automatically set the processing parameters that are optimized for the dataset with which you are working. You may still change these in your workflows at any time, but these are good places to start.

Download and Import Sentinel-1 Scenes

This section provides general steps for choosing, downloading, and importing Sentinel-1 data into SARscape.

Choose Sentinel-1 Scenes

Here are some things to consider when choosing Sentinel-1 scenes:

When you search and order Sentinel-1 Level-1 data from the [Copernicus Sentinel Open Access Hub](#) or other data portal, you can download Single Look Complex (SLC), Ground Range Detected (GRD), or Ocean (OCN) data. An SLC dataset contains both amplitude and phase, recorded as complex numbers. Both are needed if you will be creating coherence images or doing interferometry. An SLC dataset provides the highest possible spatial resolution.

If you are only interested in amplitude (pixel intensity) and will not be doing interferometry, you can download GRD data as long as the spatial resolution is sufficient for your needs. GRD data is already preprocessed to ground range but still needs to be geocoded. The primary advantage of GRD data is a much smaller compressed file size (approximately 1.5 GB) compared to SLC data (7 to 9 GB). However, GRD data may not be available in the same high resolution as SLC data.

If you will be using multiple scenes for change detection or interferometry, the scenes must be in the *same* orbital direction (ascending or descending), and from the same relative orbit.

Download Sentinel-1 Scenes

Depending on your internet connection, downloading a full Sentinel-1 Level-1A SLC dataset can take several minutes to several hours.

You do not need to download any data for this tutorial; however, instructions are provided for downloading Sentinel-1 data on your own at a later time. To skip these steps and continue with the interactive part of the tutorial, go to the [Open and Display Intensity Images](#) section.

You can search and order Sentinel-1 data from the following sources:

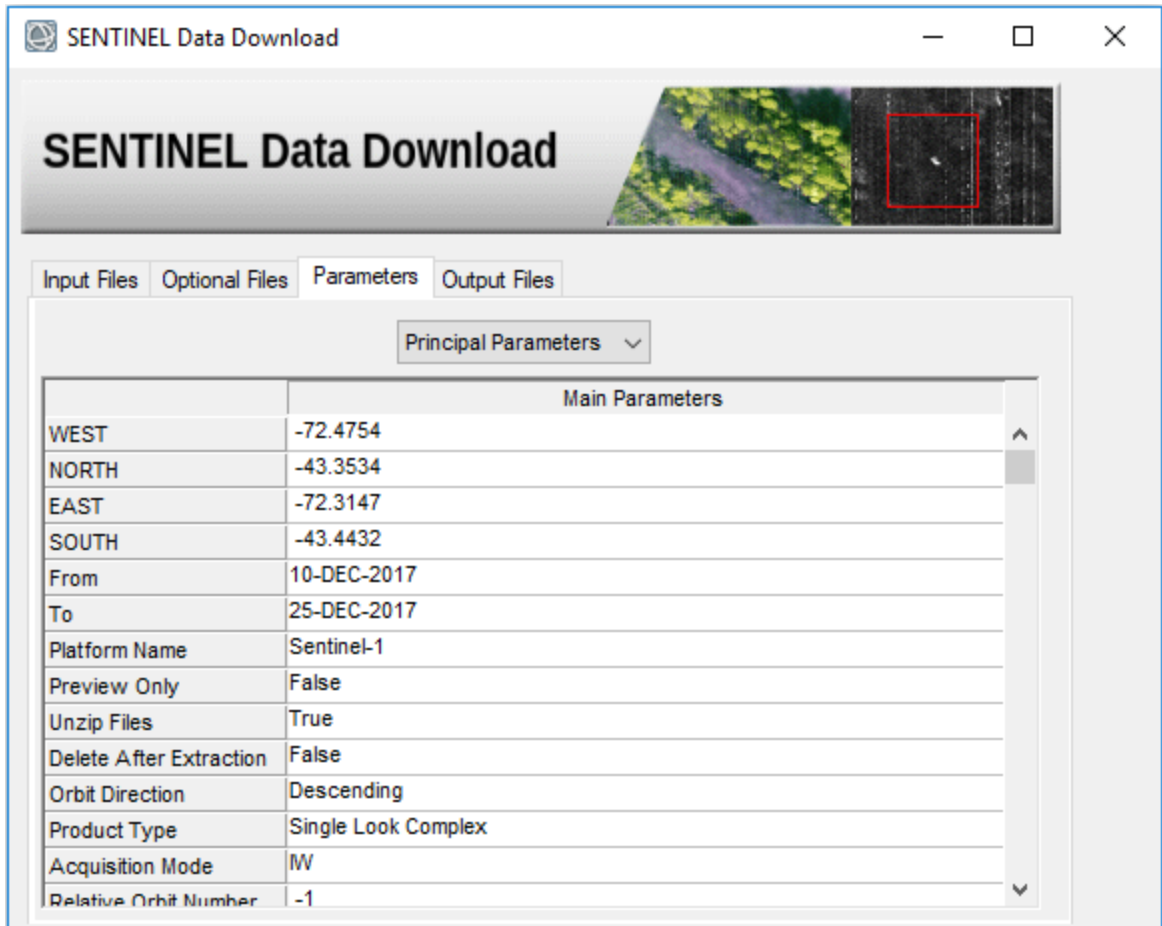
- [Copernicus Sentinel Open Access Hub](#)
- [Alaska SAR Facility](#)

You must register for a free account for these sites if you have not done so already.

Another option is to use the SARscape **Sentinel Download** tool in the ENVI Toolbox. This is a convenient option, especially for downloading multiple scenes. The following steps describe this process:

1. In the ENVI Toolbox, select **SARscape > Import Data > Sentinel Download**. The Sentinel Data Download dialog appears.
2. Define the geographic location you are interested in. All full Sentinel-1 scenes that intersect the specified geographic extent will be downloaded. This step does not define any spatial subsets for downloading. The options for defining a geographic extent are as follows:
 - Click the **Optional Files** tab. Here, you can select a shapefile that defines the geographic area you are interested in. All Sentinel-1 scenes that intersect the footprint of the shapefile will be downloaded.
Tip: You can create a shapefile in ENVI by creating a new vector layer on top of a raster that is georeferenced to a standard projection. Export the vector to a shapefile on disk.
 - Or, click the **Parameters** tab and enter geographic coordinates (in decimal degrees) in the **WEST**, **NORTH**, **EAST**, and **SOUTH** fields.
3. Click the **Parameters** tab and enter values for the search criteria, especially the following:
 - Acquisition time (**From** and **To**)
 - **Orbit direction**: Choose **Ascending**, **Descending**, or **ALL**. If you will be using multiple scenes for change detection or interferometry, the scenes must be in the same direction. The **ALL** option is for dual-pair interferometry (not covered in this tutorial) to resolve both vertical and horizontal displacement. If only horizontal displacement is of interest, then the **Ascending** or **Descending** options are sufficient.
 - **Product Type**: Choose from **Single Look Complex**, **Ground Range**, or **All**.
 - **Acquisition Mode**: **IW** (Interferometric Wide) is suitable for most applications.
 - **Polarisation Model**: Choose from **VV+VH**, **VV**, **HH+HV**, **HH**, or **All**.
4. Under the **Parameters** tab, enter your Copernicus login credentials in the **Login-USERNAME** and **Login-PASSWORD** fields.
5. Under the **Parameters** tab, set **Unzip Files** to **True**.

The following image shows an example:



6. Click the **Output Files** tab.
7. Choose a directory and filename for the **Progress file name**. The progress file will contain a running list of all data files that have been fully downloaded. Its purpose is to prevent the same file from being downloaded again. If you use the Sentinel Download tool in the future, you can choose a progress file that you previously created. The tool will not download any files that have been previously downloaded.
8. In the **Unzip files to this directory** field, specify a directory where you want to extract the downloaded files.
9. Click **Exec** in the Sentinel Data Download dialog. A new command window appears and reports the progress of the download. You can continue to use ENVI and SARscape tools during this time.

When download is complete, the files are automatically unzipped to the working directory that you specified. Using an SLC dataset as an example, the directory containing the data files will be named `S1B_IW_SLC_1SV_<acquisition time>_*.SAFE`. The directory will contain a `manifest.safe` file, a PDF report, and the following subdirectories: `annotation`, `measurement`, `preview`, and `support`.

Import Sentinel-1 Data into SARscape

After downloading Sentinel-1 data, you must import the data into SARscape.

You do not need to import any data for this tutorial; however, instructions are provided for future reference. These steps were used to create the intensity image that you will use later in this tutorial.

1. From the ENVI Toolbox, select **SARscape > Import Data > SAR Spaceborne > Single Sensor > SENTINEL-1**. The Import Sentinel-1 dialog appears.
2. Under the **Input Files** tab, click **Browse** under **Input File List**. A Select Input Files dialog appears.
3. Navigate to your working directory and select the file `manifest.safe`. Click **Open**.
4. Optional: Click the **Optional Files** tab and select a shapefile that defines the geographic extent of your area of interest. This can significantly reduce processing time, as only the radar bursts that intersect the shapefile will be imported.
5. Click the **Parameters** tab.
6. Setting the **Make power QL** option to **True** will automatically create a multilooked intensity image so that you do not have to perform this step separately at a later time.

Multilooking is a process by which the pixels in an SLC dataset are averaged in the range direction. This is essentially a slant-range to ground-range conversion that averages adjacent oblong pixels and creates a square pixel from them. As an added benefit, the averaging also smooths the image and reduces some speckling effects. See the *Multilooking* section of the sarmap help for details. You can access the sarmap help by selecting **SARscape > Help** in the ENVI Toolbox.

The **Make power QL** option was set to **True** to create the intensity image used in this tutorial. If you want more control over the multilooking parameters, set this option to **False**. Then use the **Multilooking** tool later under **SARscape > Basic > Intensity Processing**. You can use the **Multilooking** tool to set the number of looks used in the range or azimuth direction, as well as the grid size for the suggested number of looks.

7. Under the **Parameters** tab, choose a **Polarization** option. The choices are **ALL**, **Copolarization only** (HH or VV), or **Crosspolarization only** (HV or VH). If you will be

doing interferometry, the **Crosspolarization only** option is recommended in order to reduce processing time, since you should only use cross-polarized data for interferometric analysis.

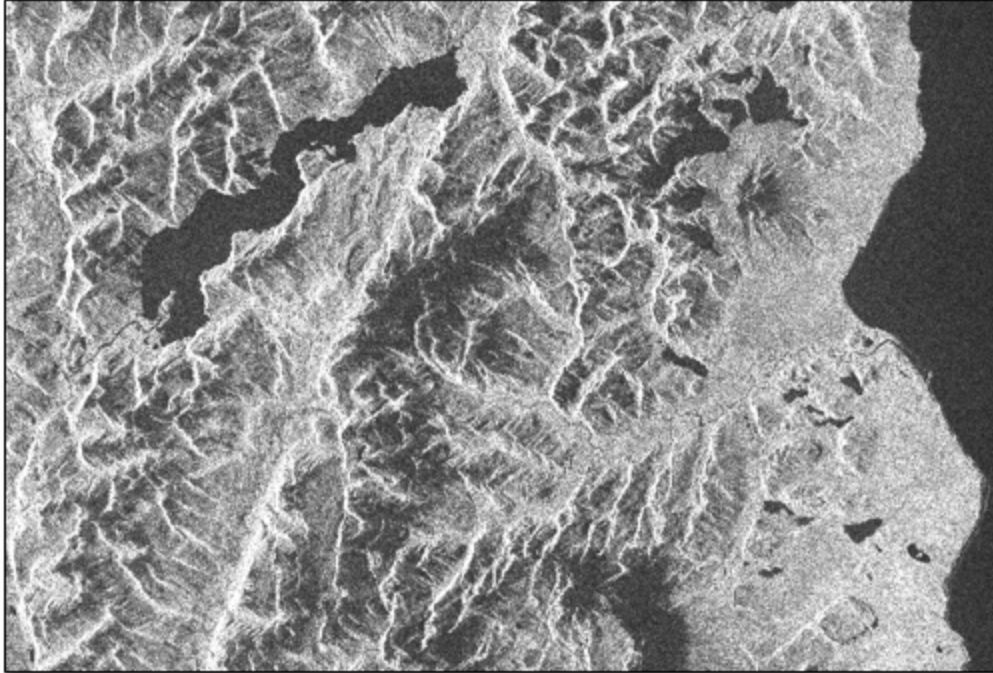
8. Under the **Parameters** tab, setting the **Make mosaic same track** option to **True** will automatically mosaic the radar bursts that were acquired sequentially along the same track.
9. Click the **Output Files** tab.
10. Select an output directory and filename for the output files that will be created.
11. Click the **Exec** button in the Import Sentinel-1 dialog.

When processing is complete, the output files are written to the location you specified in Step 9. Refer to the *Import Data – SAR Spaceborne – SENTINEL-1* topic in the sarmap help for more information about the structure and content of the output files.

Open and Display Intensity Images

In this section, you will explore a Sentinel-1 intensity image that covers a region of Chile in December of 2017. Follow these steps:

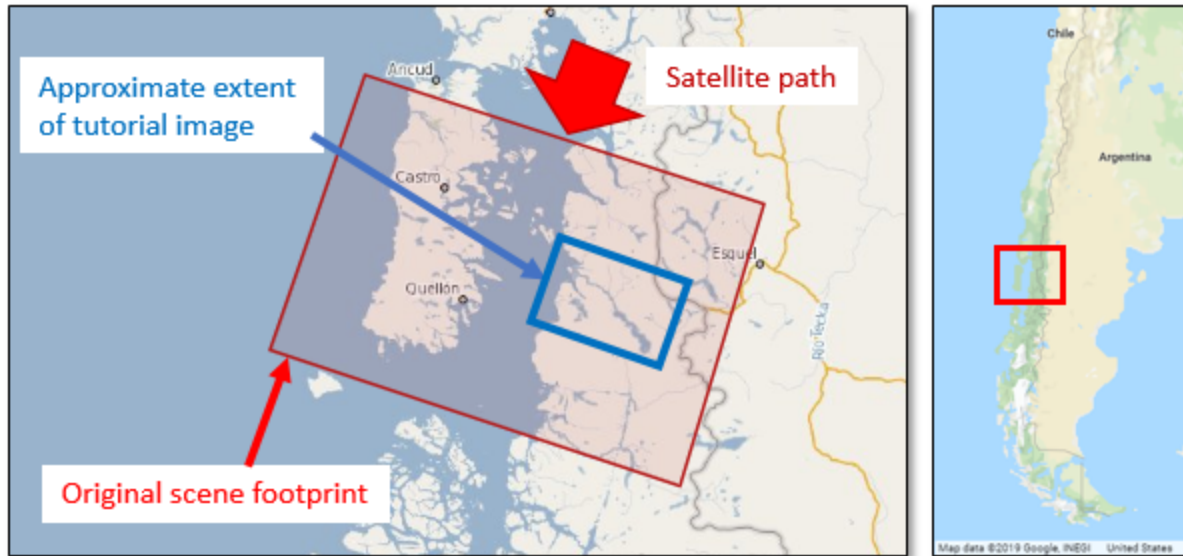
1. From the ENVI main menu bar, select **File > Open**.
2. Navigate to the **SARGettingStarted** directory. You created this directory earlier in the [Files Used in This Tutorial](#) section.
3. Navigate to the **2017-12-12-SLC-Power** directory and select the file **sentinel1_83_20171212_095750732_IW_SIW1_D_VH_slc_list_pwr**. Click **Open**. An Interferometric Wide (IW) Single Look Complex (SLC) intensity image appears in the ENVI display.
4. Press the **F12** key on your keyboard to view the full extent of the image.



This is a spatial subset of a Sentinel-1 multilooked SLC intensity image. The radar data were acquired from a descending pass, so the image appears flipped. The bottom of the image represents a northeastern direction. Later you will use the Geocoding and Radiometric Calibration tool to georeference the image, which will correct the orientation. The dark region on the right side of the image is the Pacific Ocean. The image covers a portion of Corcovado National Park. The lake in the upper-left corner is Lago Yelcho.

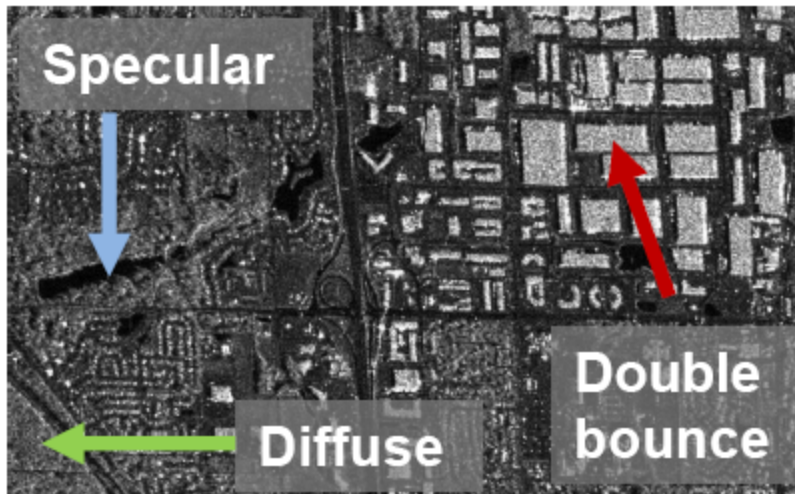
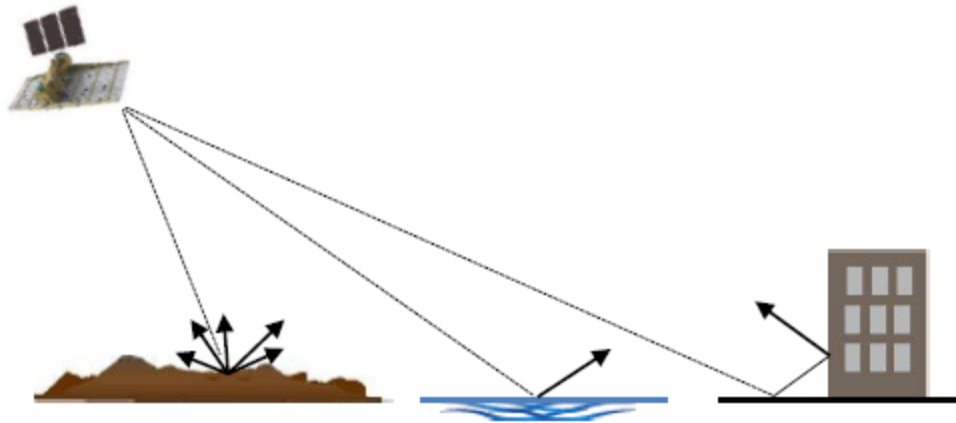
The following steps were taken to create this image:

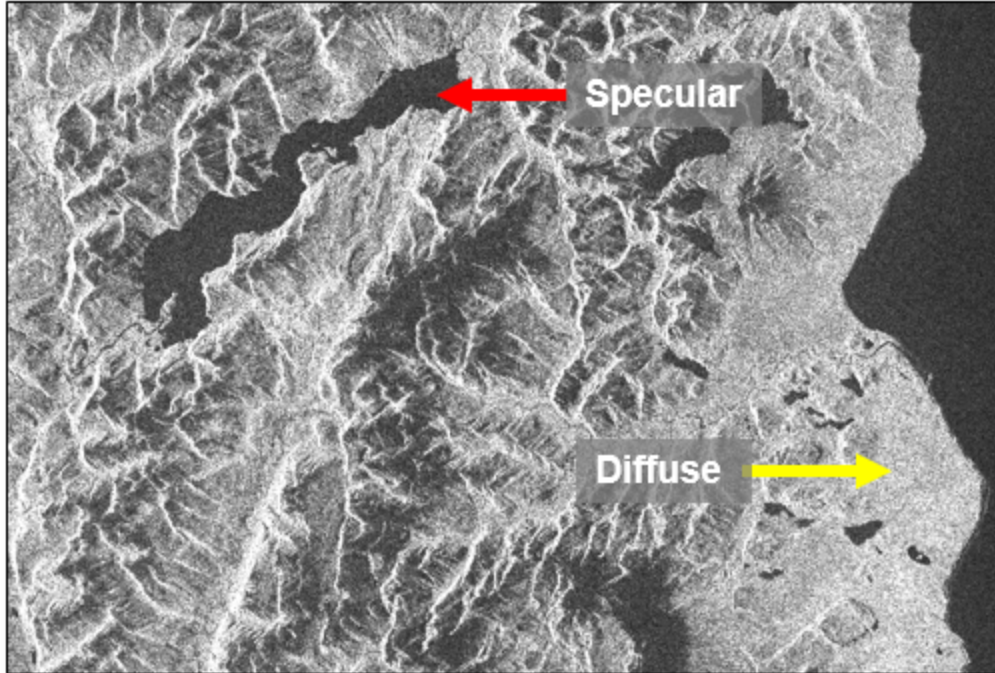
- The Sentinel Data Download tool was used to download Level-1B SLC scenes that covered an area of interest defined by a shapefile. The selected time coverage was 10 December to 16 December 2017. Only one scene was available, from 12 December.
- The Import Sentinel-1 tool was used to import the scene into ENVI SARscape. The **Make mosaic same track** option was set to **True**, and the **Make power QL** option was set to **True** to apply multilooking. The result was a multilooked intensity image that covered a large geographic area.
- The Sample Selection SAR Geometry Data tool (which you will use later in this tutorial) was used to spatially subset the full multilooked image into a smaller image to use for the tutorial.



The pixel values in this image represent the intensity of the backscatter. Intensity is amplitude squared. When SLC datasets are processed with multilooking, the resulting intensity images are called *power* images, with the characters `_pwr` appended to the filenames. Intensity images are useful in change detection. When multiple images are coregistered to the same geographic location, they can help answer the question, "Did a pixel get brighter or darker over time?" Intensity images are also used to create coherence images, which are used in SAR processing for flood mapping and landslides.

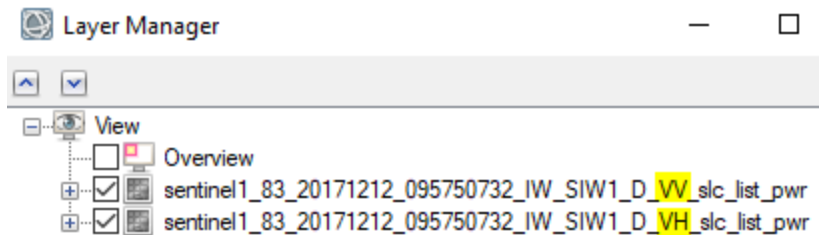
Intensity images show how different surface types reflect incoming energy back to the sensor. For example, smooth bodies of water appear black. They are flat surfaces that reflect incoming energy away from the sensor—a process known as *specular reflection*. Bright pixels indicate areas where a large fraction of the incoming energy is reflected back to the sensor. This occurs most often with rough surfaces in a process known as *diffuse reflection*. Bright pixels can also result from surfaces that are inclined toward the sensor. In urban areas, buildings often appear very bright because incoming energy is bounced off of them multiple times—a process known as *double bounce*. For more information, consult the references at the end of the tutorial.



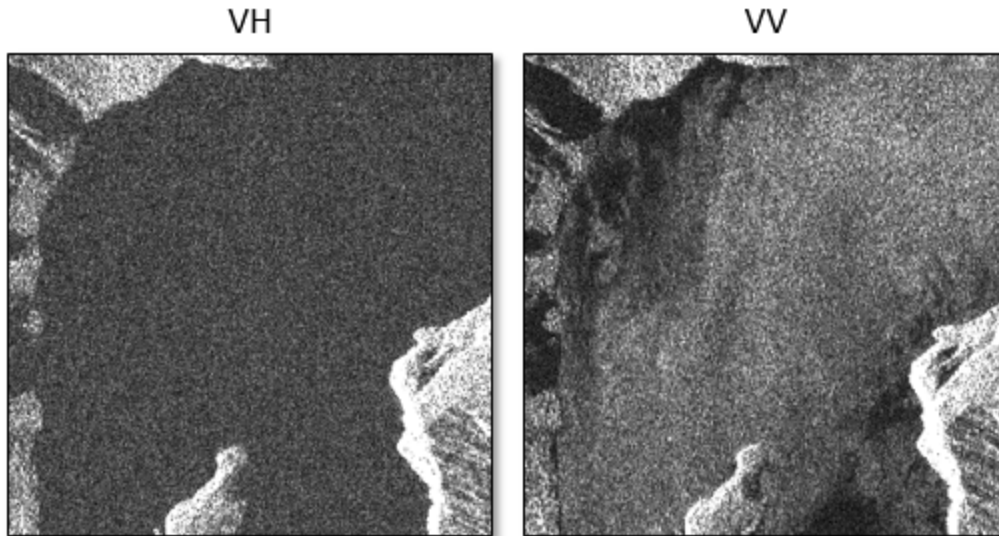


The image you are viewing represents *cross-polarized* intensity (VH). Cross-polarized images are often better than co-polarized images (VV or HH) in applications such as flood detection. VV images are more sensitive to changes in the wind-induced surface roughness of water, which can result in inaccurate change detection over water. To view a co-polarized (VV) image, follow these steps:

1. Select **File > Open** from the ENVI main menu bar.
2. Navigate to the `SARGettingStarted` directory.
3. Select the file `sentinel1_83_20171212_095750732_IW_SIW1_D_VV_slc_list_pwr` and click **Open**. The VV image displays over the VH image in the ENVI display.
4. Toggle between the two images by unchecking and checking the **VV** layer in the Layer Manager:



The following images show the differences in intensity between a cross-polarized (VH) image and co-polarized (VV) image over a large lake. The VV image shows more variation in intensity within the lake.



To get meaningful scientific results from intensity images—particularly when comparing multiple images over time—you must do some further processing with the images. The most critical processing steps include multilooking, coregistration, spatial subsetting, filtering, and geocoding and radiometric calibration. You will explore some of these processes next.

Process Intensity Images

In this section, you will learn how to:

- Create spatial subsets of the VH and VV intensity images, also called *sample selection*
- Apply a filter to reduce speckling noise in the VH and VV images
- Georeference the VH and VV images to a standard map projection, also called *geocoding*. As part of this step, you will also perform radiometric calibration and normalization.


Multilooking is typically the first processing step before sample selection; however, the intensity images used in this tutorial already have already been corrected for multilooking by setting the **Make power QL** option to **True** in the Import Sentinel-1 Data tool. Multilooking is the process by which SLC image pixels are averaged in the range and/or azimuth direction, thus converting from slant range resolution to ground range resolution.

Because you are only working with a single image in this tutorial, you will not perform coregistration. You would need to coregister multiple images if you were doing change detection or other time-series analysis. Coregistration is typically done after multilooking.

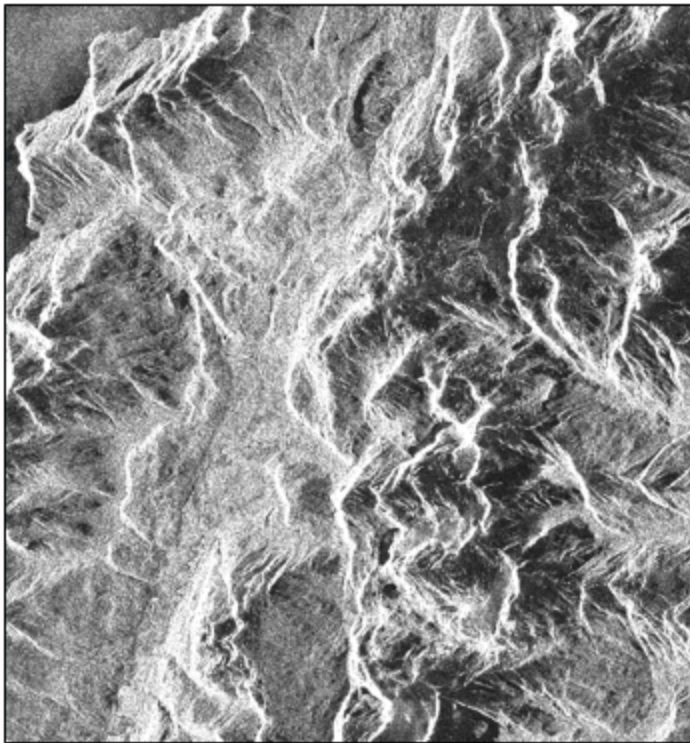
Create Spatial Subsets (Sample Selection)

In this step, you will create spatial subsets from the VH and VV intensity images. The subsets cover a region around Villa Santa Lucia, Palena Province, Los Lagos Region in Chile. This community was devastated by a landslide that occurred after heavy rains on 16 December 2017. The images in this tutorial were acquired before the landslide, on 12 December.

Defining a spatial subset allows you to focus analysis on a specific area, while reducing processing time and output file sizes.

1. In the ENVI Toolbox, select **SARscape > General Tools > Sample Selections > Sample Selection SAR Geometry Data**. This tool is used to subset SLC or intensity (power) data using a shapefile that was drawn on a non-geocoded SAR scene. The shapefile defines the boundary of the spatial subset. You would use the other tool, Sample Selection Geographic Data, if you had a shapefile that was derived from a geocoded scene.
2. In the Sample Selection SAR Geometry Data dialog, click the **Browse** button under the **Input Files** tab.
3. Navigate to the **SARGettingStarted\2017-12-12-SLC-Power** directory.
4. Use **Ctrl**-click to select the following files, then click **Open**:
 - **sentinel1_83_20171212_095750732_IW_SIW1_D_VH_slc_list_pwr**
 - **sentinel1_83_20171212_095750732_IW_SIW1_D_VV_slc_list_pwr**
5. Click the **Optional Files** tab.
6. Click the **File Select** button  next to **Area of Interest**.
7. In the **SARGettingStarted** directory, select the file **studySite.shp**. Click **Open**. This shapefile defines the spatial subset you will use.
8. Click the **Parameters** tab.
9. Click **SELECT** next to the **Geographical Region** field and select the **False** option. The shapefile was derived from the intensity image, and it is not geocoded.
10. Click inside the field next to **Use Min and Max Coordinates** and select the **True** option. This will clip the spatial subset to a rectangular region if the shapefile itself is not perfectly rectangular.

11. Click the **Output Files** tab and notice that the output filenames will be appended with `_cut_pwr`. They will be saved to the `SARGettingStarted` directory. You do not need to change anything here.
12. Click the **Exec** button in the Sample Selection SAR Geometry Data dialog.
13. When the Completed dialog appears, click **OK**. The spatial subsets for the VH and VV images appear in the Layer Manager and the ENVI display.
14. Click the **Close** button in the Sample Selection SAR Geometry Data dialog.
15. Right-click on the following layers in the Layer Manager and select **Remove**. These are the original intensity images:
 - `sentinel1_83_20171212_095750732_IW_SIW1_D_VH_slc_list_pwr`
 - `sentinel1_83_20171212_095750732_IW_SIW1_D_VV_slc_list_pwr`Only the `_cut_pwr` images should be listed.
16. Press the **F12** key on your keyboard to see the full extent of the subsets.



Apply Image Filtering

In this step, you will apply a spatial filter to the subset intensity images to reduce the speckled appearance. You will use a mean filter, which replaces each pixel with the mean value of its surrounding pixels in a 5 x 5 pixel moving window.

1. In the ENVI Toolbox, select **SARscape > Basic > Intensity Processing > Filtering > Single Image Filtering**.
2. In the Single Image Filtering dialog, click **Browse** under the **Input Files** tab.
3. Use **Ctrl**-click to select both `_cut_pwr` images that you created in the previous section. Click **Open**.
4. Click the **Parameters** tab.
5. Click **SELECT** next to the **Filter Method** field, then select the **Mean** option.
6. Leave the other parameters at their default values.
7. Select the **Output Files** tab and notice that the output filenames will be appended with `_fil` to indicate filtering. They will be saved to the `SARGettingStarted` directory. You do not need to change anything here.
8. Click the **Exec** button in the Single Image Filtering dialog.
9. When the Complete dialog appears, click **OK**. The filtered images appear in the Layer Manager and ENVI display. Notice their smoother appearance, compared to the original images.



10. Click the **Close** button in the Single Image Filtering dialog.
11. In the Layer Manager, right-click on the **View** layer and select **Remove All Layers**.

Geocode the Images

In this section, you will perform geometric and radiometric calibration of the filtered intensity images. These steps are important if you will be comparing multiple intensity images over time.



Geocoding requires a DEM. You will need to download the DEM data on your own, as we cannot redistribute certain DEM files. Here are some recommended options:

- **SRTM-3 Version 4 DEM:** This is the simplest option. You can use ENVI SARscape to download Shuttle Radar Topography Mission (SRTM)-3 Version 4 DEM data from the CIAT-CSI website. Note that service may be intermittent. Step 5 in the geocoding / radiometric calibration instructions below describes how to download this data.
- **ASTER Global DEM (GDEM):** The ASTER GDEM is available for download from [NASA Earthdata](#). A free account is required to order and download data from these sites. For this tutorial, you will need the ASTER GDEM with an entity ID of **ASTGDEM2_**

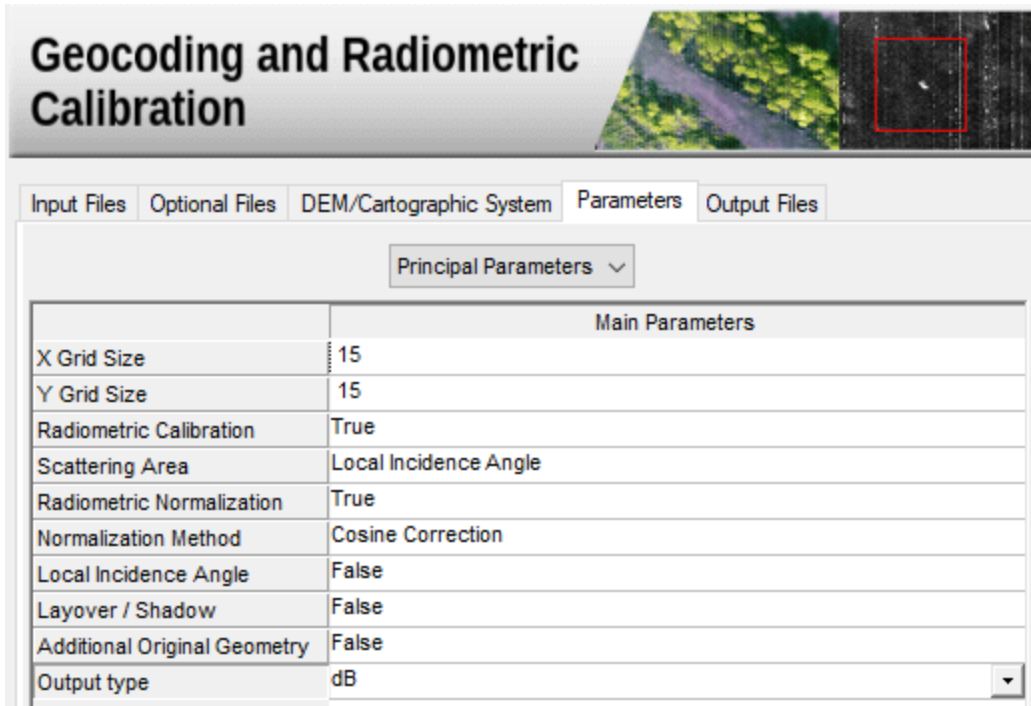
0S44W073. Once you download the ASTER GDEM file, you need to perform some extra steps to import the data into SARscape:

1. Extract the contents of the compressed file to the **SARGettingStarted** directory.
2. In the ENVI Toolbox, select **SARscape > Import Data > Generic Format > Tiff**. Importing the ASTER GDEM as a TIFF file will force ENVI to create a `.sm1` file on disk. The `.sm1` file is required for the DEM to be compatible with SARscape.
3. In the Import TIFF dialog, click **Browse** under the **Input Files** tab.
4. Select the ASTER GDEM TIFF file and click **Open**.
5. Click the **DEM/Cartographic System** tab.
6. From the **State** drop-down list, select **GEO-GLOBAL**.
7. Click the **Parameters** tab.
8. Click **SELECT** in the **Data Units** field, and select the **DEM** option.
9. Click the **Exec** button in the Import TIFF dialog. The ASTER GDEM is now ready for use in ENVI SARscape. The filename will be appended with `_dem_bil`.
10. Click the **Close** button in the Import TIFF dialog.

Follow these steps to perform geocoding and radiometric calibration:

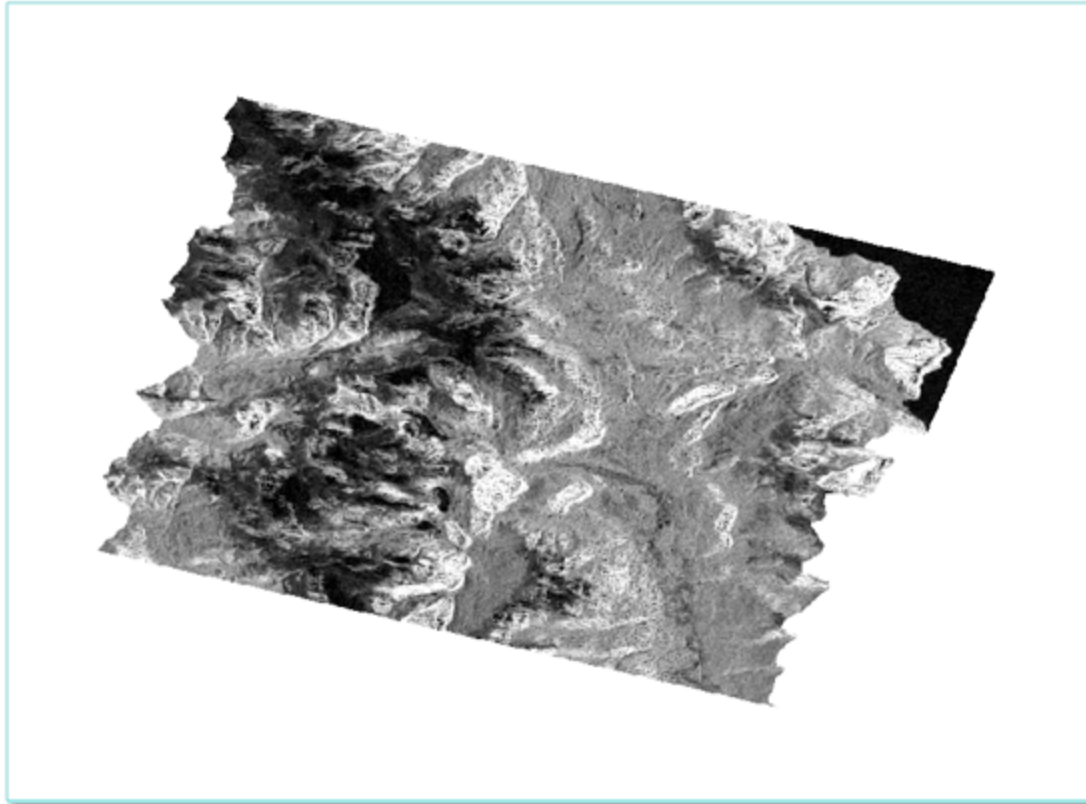
1. In the ENVI Toolbox, select **SARscape > Basic > Intensity Processing > Geocoding > Geocoding and Radiometric Calibration**.
2. In the Geocoding and Radiometric Calibration dialog, click **Browse** under the **Input Files** tab.
3. Use **Ctrl**-click to select both `_fil` images you created in the [Apply Image Filtering](#) section. Click **Open**.
4. Click the **DEM/Cartographic System** tab.
5. Select a DEM file. Choose one of the following options:
 - To download SRTM-3 Version 4 DEM data, click the **Download DEM** button . Select the **SRTM-3 Version 4** option, then click the **OK** button . When the DEM Extraction - SRTM3 Version 4 dialog appears, click the **DEM/Cartographic System** tab. From the **State** drop-down list, select **GEO-GLOBAL**. Click the **Exec** button. SARscape will search for DEM tiles that match the location of the filtered intensity images. It will mosaic the tiles if multiple tiles are found.

- If you downloaded an ASTER GDEM, click the **Open** button . In the Select DEM File dialog, navigate to the location where you saved the DEM. Change the File name filter to *.*. Select the `_dem_b11` file, then click **Open**.
6. In the Geocoding and Radiometric Calibration dialog, click the **Parameters** tab.
 7. Accept all of the default values. (You can optionally change the **Output type** to **dB**, if desired.)

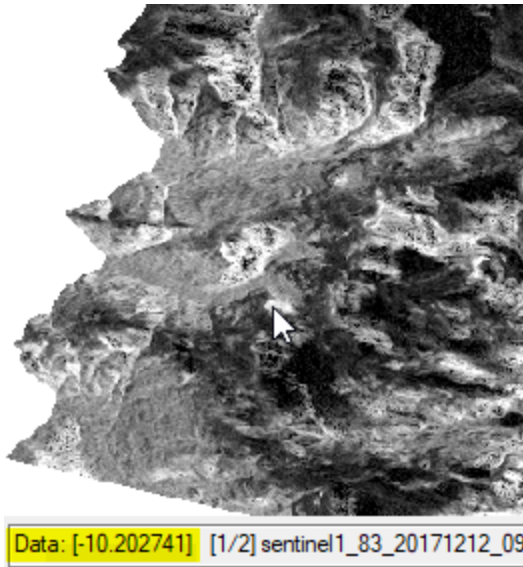


8. Click the **Output Files** tab, and notice that the output filenames will be appended with `_geo`. The files will be saved to the `SARGettingStarted` directory. You do not need to change anything here.
9. Click the **Exec** button.
10. When the Completed dialog appears, click **OK**. ENVI creates a raster series with the geocoded VH and VV images. It displays the VH image.
11. Press the **F12** key on your keyboard to view the full extent of the geocoded and calibrated VH image.
12. Click the **Close** button in the Geocoding and Radiometric Calibration dialog.


The following image shows an example of a geocoded VH image created using an ASTER GDEM.




13. Right-click in the middle segment of the Status bar and select **Raster Data Values**. The Status bar is located at the bottom of the ENVI application. It is divided into three segments.
14. Move the cursor over the image. The "Data" line in the Status bar reports the pixel data values (in units of intensity or decibels); for example:



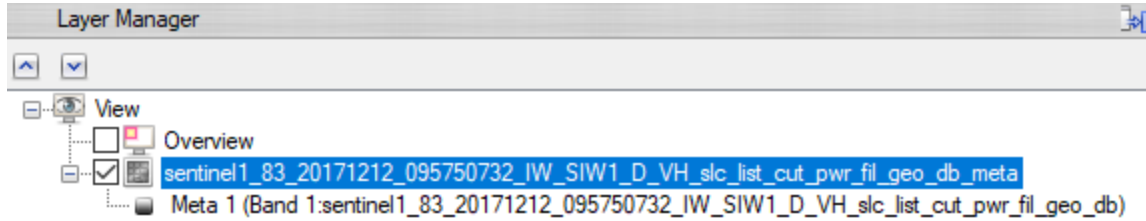
Also notice that the left segment of the Status bar reports the geographic latitude and longitude coordinates as you move around the image.

ENVI creates a raster series (also called a time series) of the geocoded VH and VV images. The raster series is indicated by a  icon in the Layer Manager. This raster series is not helpful at the moment, as it only contains two images. You will display a different dataset in the following steps.

15. Right-click the raster series layer in the Layer Manager, and select **Remove**.
16. Click the **Data Manager** button  in the ENVI toolbar. The Data Manager lists two separate entries for the geocoded dataset. The first dataset is the raster series as indicated by `_geo_db_series` in the filename. The second dataset is a metaspectral dataset (also called a *band stack*) of the geocoded VH and VV images. The filename for the metaspectral dataset is appended with `_geo_db_meta`. This dataset is highlighted in the following figure:



- In the Layer Manager, click the + icon next to the **sentinel1_83*_geo_db_meta** layer. This expands the layer so that you can tell what image is currently displayed in the view. It shows that the Meta 1 layer (the geocoded VH band) is currently displayed.



- In the Data Manager, select the **Meta 2 (Band 1...)** band, then click the **Load Grayscale** button. Now the VV image is displayed in the view.
- Uncheck and check the VV layer in the Layer Manager to toggle between it and the VH image.

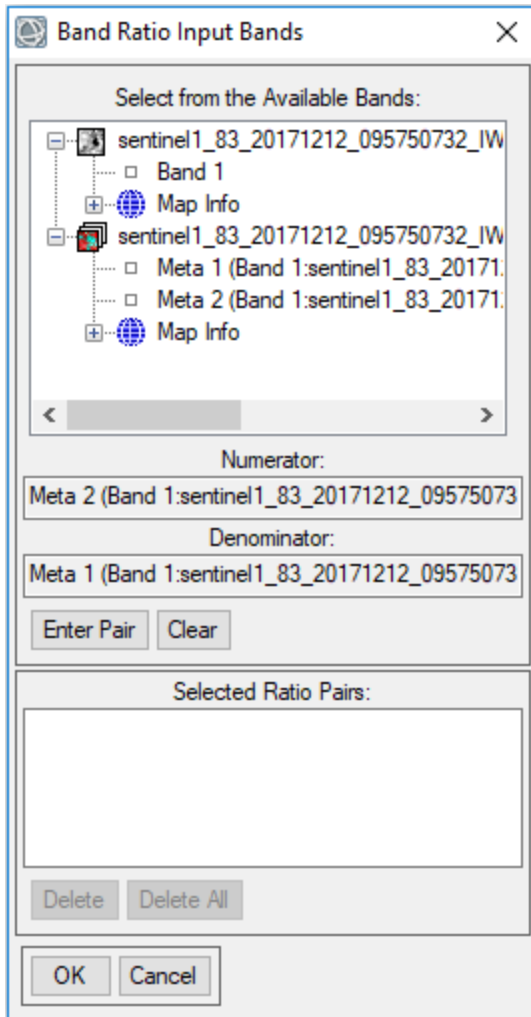
Create a Color Composite

A common task in SAR analysis is to create a color composite image from different polarizations. This can help to visually distinguish between different surface features such as mountains, cities, and water bodies. In this section, you will create a color composite of the geocoded metaspectral dataset using the following polarization combinations:

- Red: VV
- Green: VH
- Blue: VV/VH ratio

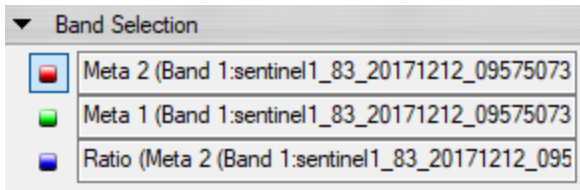
First, create a band ratio of the VV and VH images:

- In the ENVI Toolbox, select **Band Algebra > Band Ratios**.
- In the Band Ratio Input Bands dialog, select the **Meta 2** band. The **Numerator** field is populated with the name of the VV image.
- Select the **Meta 1** band. The **Denominator** field is populated with the name of the VH image.

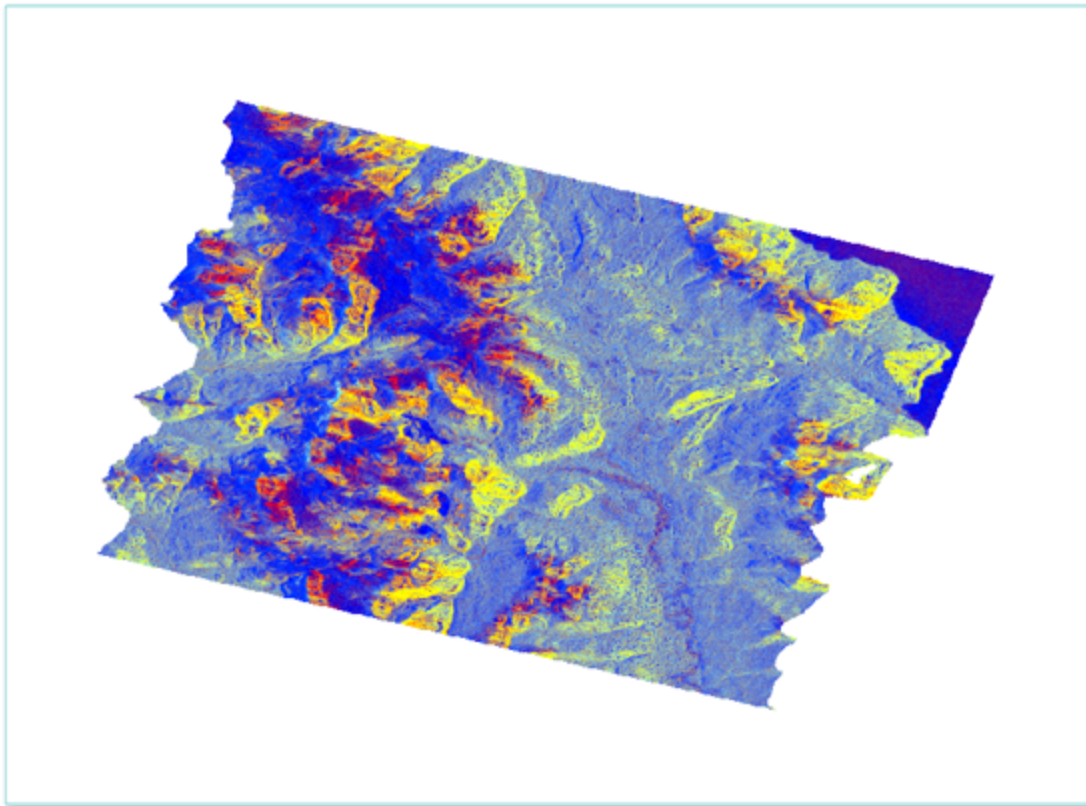


4. Click the **Enter Pair** button. The VV/VH ratio is added to the **Selected Ratio Pairs** section.
5. Click **OK**.
6. In the Band Ratios Parameters dialog, select to output the result to **Memory**.
7. Click **OK**. When processing is complete, the VV/VH ratio image appears in the display.
8. In the Data Manager, click to expand the **Band Selection** area. The red box is currently selected.
9. Select the **Meta 2** band. This populates the red box with the geocoded VV band.

10. Select the **Meta 1** band. This populates the green box with the geocoded VH band.
11. Select the **Ratio** band. This populates the blue box with the geocoded VV/VH band.

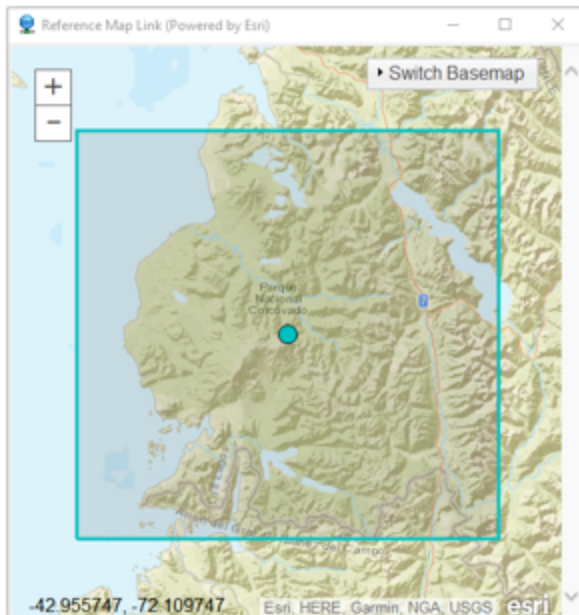



12. Click the **Load Data** button. The color composite appears in the display.



The different colors, especially yellow and red, highlight variations in topography.

13. From the ENVI menu bar, select **Views > Reference Map Link**. A separate dialog appears with a map view that shows the geographic location of the image (indicated by a cyan-colored box).



14. Use the **Zoom** tools in ENVI to zoom in and out of the image. The Reference Map Link dialog updates to show the geographic location of the view extent.
15. When you are finished viewing the color composite image, click the **Close All Files** button  in the Data Manager.
16. Close the Data Manager.

This concludes the tutorial.

Using the ENVI Modeler for Batch Processing

So far, you have completed several processing steps using a single image. What if you have multiple input images to process, for example, with change detection or interferometry? An efficient way to batch-process multiple images in ENVI SARscape is to use the ENVI Modeler.

The ENVI Modeler is a visual programming tool that leverages ENVI's powerful analytics with a simple user interface. It allows you to create custom workflows using different inputs and parameters. Most SARscape analytics are available to use with the ENVI Modeler.

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