CATALYST
PROFESSIONAL

SAR Bundle: Description

CATALYST Professional SAR bundle comes with everything geospatial professionals need to process and analyze Synthetic Aperture Radar (SAR) imagery. The SAR bundle is our advanced package for geospatial professionals to access powerful processing, visualizations, and analytical capabilities to prototype, build and automate workflows for SAR imagery.

With CATALYST Professional Essentials bundle, you get more for less:

- High-performance viewer that supports all major SAR sensors and file types
- Advanced photogrammetry and mosaicking workflows for SAR imagery
- Object-based image analysis
- Advanced polarimetry and compact polarimetry workflows
- Interferometric SAR (InSAR) processing
- Visualization tools to enhance viewing and data extraction
- Intuitive wizards to accelerate prototyping and interactive workflows
- Access to hundreds of algorithms through python to build and productize automated workflows
- Plus, full customer support

CATALYST is a PCI Geomatics Enterprises Inc. brand, which has been introduced to put our leading-edge technology into the hands of decision makers. CATALYST provides proven algorithms rooted in photogrammetry and remote sensing to offer engineers, environmental management, and geospatial professionals access to leading edge and scalable software solutions and platforms.

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Introduction

The SAR Bundle of CATALYST Professional includes all the capabilities found in the Essential bundle, including state-of-the-art tools for geometric correction, data visualization and editing, image classification, cartographic map production plus a whole lot more, including applications for raster spatial analysis, radar analysis, hyperspectral analysis, along with a comprehensive desktop automation environment.

This bundle also includes rigorous and rational function models developed to compensate for distortions and produce orthorectified radar images. Distortions caused by the platform (position, velocity, and orientation), the sensor (orientation, integration time, and field of view) the Earth (geoid, ellipsoid, and relief), and the projection (ellipsoid and cartographic) are all accounted for using these models. The models reflect the physical reality of the complete viewing geometry and correct all distortions generated during the image formation.

This bundle also includes a complete set of tools and applications designed specifically for the processing and analysis of Polarimetric SAR (POLSAR) data, as well as Interferometric SAR (InSAR) tools that can be used to generate topographic products to characterize digital surface models (DSMs) or displacement products which identify subtle movement of the surface and ground features due to land subsidence or uplift. The InSAR tools include capabilities for differential Interferometric SAR (DInSAR) and Short-baseline Persistent Scatterer Interferometry SAR (SBAS-PSI).

Radar Support

- ALOS-1 PALSAR
  - ERSDAC PALSAR georeference levels L1.5, L1.5 long, L4.1 and L4.2
  - JAXA PALSAR georeference level 1.5
- ALOS-2 PALSAR (Compact)
  - JAXA PALSAR-2 georeference level 1.1, 1.5, 2.1, and 3.1
- ASAR (ENVISAT)
  - ASAR 1B format
- Capella Space
  - SLC (Single-look complex) int16
  - GEO (Geocoded Terrain Corrected) int16
- COSMO-SkyMed
  - Level 0 (RAW)
  - Level 1A (SCS)
  - Level 1B (DGM)
- Convair-580 (CV-580)
  - Single-look Complex Quad Polarization (SLC-Q)
  - Multi-look Complex Quad Polarization (MLC-Q)
- ERS 1/2(CEOS)

    - ERS CD provides different levels of processing. We recommend the georeferenced level for images produced in Canada and the PRI level produced by ESA.
- Gaofen-3 (GF3)
    - Level 1A SLC data with an associated RPC model for the following observation modes:
        - Spotlight (SL)
        - Ultra-fine stripmap (UFS)
        - Fine stripmap (FSI)
        - Wide fine stripmap (FSII)
        - Quad-pol stripmap (QPSI)
        - Wide quad-pol stripmap (QPSII)
        - Wave (WAV)
- ICEYE
    - Level 1B:
        - Single Look Complex (SLC)
        - Ground Range Detected (GRD)
- Huanjing (HJ-1C)
    - 1C Level 2 format
- JERS1 (LGSOWG)
    - JERS-1 CD provides different levels of processing. We recommend that you use a georeferenced level or equivalent for highest accuracy. OrthoEngine only works for descending order images.
- KOMPSAT-5
    - L1A SCS_U: Single Look Complex Slant Un-balanced
    - L1A SCS_B: Single Look Complex Slant Balanced
    - L1B DSM_U: Detected, Slant Range, Multi-look Un-equalized
    - L1B DSM_U: Detected, Slant Range, Multi-look
    - L1B DGM_B: Detected, Ground projected, Multi-look Balanced
- PAZ
    - Level 1B
        - Multi-look ground range detected (MGD)
        - Single-look slant range complex (SSC)
        - Geocoded ellipsoid corrected (GEC)
        - Enhanced ellipsoid corrected (EEC)
- RADARSAT-1 (CEOS)
    - SGC (SAR Georeferenced Coarse Resolution)
    - SGF (SAR Georeferenced Fine Resolution)
    - SGX (SAR Georeferenced Extra Fine Resolution)
    - SLC (Single Look Complex)
    - SCN (ScanSAR Narrow Beam Product)
    - SCW (ScanSAR Wide Beam Product)
- RADARSAT-2 (CEOS)

  - Level 1.1 SLC (Spotlight, Ultra Fine, Multi-look Fine, Fine, Standard, Fine-Quad-Pol, Standard Quad-Pol, Wide, ScanSAR Wide, ScanSAR Narrow)
  - Level 1.5 SGF (Fine, Standard, Fine-Quad-Pol, Standard Quad-Pol)
  - Level 1.5 SGX (Fine, Standard, Fine-Quad-Pol, Standard Quad-Pol, ScanSAR Wide, ScanSAR Narrow)
- RADARSAT Constellation (RCM)
  - SLC (Single-look complex, slant range)
  - GRC (Multi-look complex, ground range)
  - GRD (Multi-look detected data in ground range)
- RISAT-1
  - High resolution spotlight (HRS)
  - Fine resolution stripmap (FRS-1)
  - Fine resolution alternate stripmap (FRS-2)
  - Medium resolution ScanSAR (MRS)
  - Coarse resolution ScanSAR (CRS)
- SAOCOM
  - Level 1A, Single-look, slant range, complex (SLC)
  - Level 1B, Multi-look, ground range, detected (GRD)
- Sentinel-1
  - Level 1 ground range detected (GRD) products
    - Stripmap (SM)
    - Interferometric wide swath (IW)
    - Extra-wide swath (EW)
    - Wave (WV)
- SIR-C
  - Single-Look Complex, Standard Quad Polarization (SLC-Q)
  - Single-Look Complex, Standard Dual Polarization (SLC-D)
  - Multi-Look Complex, Quad Polarization (MLC-Q)
  - Multi-Look Complex, Dual Polarization (MLC-D)
- TerraSAR-X / TanDEM-X
  - Level 1b MGD products
  - Level 1b SSC products
- UAVSAR Polarimetric
  - Calibrated single-look complex (SLC) products, Polarimetric mode
  - Calibrated multi-look complex (MLC) products, Polarimetric mode
  - Calibrated complex cross-products projected to the ground in simple geometric coordinates (GRD), Polarimetric mode
  - Compressed Stokes matrix products (DAT), Polarimetric mode

Radar Specific Model

The Radar Specific Model uses the additional parameters in the orbit data to diminish amount of ground control points (GCPs) required. The extra parameters maintain the positional accuracy and high levels of detail in the model, but the number of GCPs needed is reduced to few or none. This math model does not use tie points since each scene is computed using the GCPs of that scene only.

The radar specific model is available for the following types of imagery:

- ALOS-1 PALSAR
- ALOS-2 PALSAR
- ASAR
- COSMO-Skymed
- KOMPSAT-5
- RADARSAT
- RISAT-1
- TanDEM-X
- TerraSAR-X

Rational Function (RPC) Models

The Rational Function is a simple math model that:

- Builds a correlation between the pixels and their ground locations
- Obtains RPC data with images and imports coefficients automatically
- Calculates the polynomial coefficients from GCPs
- Refine RPC data with one or more GCPs
- Zero- or first-order GCP refinement available

RPC-based corrections are available for the following types of imagery:

- Capella Space
- COSMO-Skymed
- Gaofen-3 (GF3)
- ICEYE
- KOMPSAT-5
- PAZ
- RADARSAT-2
- RADARSAT Constellation (RCM)
- TerraSAR-X

Ground Control

The OrthoEngine Satellite Models support GCP and TP ground controls.

GCP Collection

GCPs can be collected manually or by using:

- A geocoded image

- Geocoded vectors
- A chip database
- A digitizing tablet
- An imported text file

Other features include:

- Stereo-GCP collection
- Conversion of GCPs to check points (CPs) to exclude from model calculation
- Display of individual and overall root mean square (RMS) error for GCPs

The following minimum number of GCPs is required:

- RADARSAT, ERS, JERS, ASAR, EROS:
    - 8 per image (10-12 recommended)
- RADARSAT with RADARSAT-specific model:
    - GCPs are optional (8 recommended)
- ASAR:
    - GCPs are optional
- Rational Functions Computed from GCPs:
    - 5 per image (19 per image is recommended)
- Rational Functions Extracted from Image File:
    - None required (accuracy is improved with 1 or more GCPs)

Tie Point Collection

Tie point (TP) collection allows a user to:

- Extend ground control over areas without GCPs
- Identify how images in a project relate to each other
- Ensure the best fit for all images in a project
- Enter the elevations of TPs manually or extract them from a DEM
- Import and export TPs
- Show individual and overall RMS errors

Residual Report

Using residual reports, a user can:

- Show GCP, CP, TP, and Stereo-GCP error information in one report
- Edit points in a residual report and update bundle adjustments
- View error information in ground units or pixel units
- Print the report to a file

Project Summary Information

<u>Raw Image Summary Table</u>

A summary of information about all of the images in your OrthoEngine project can be viewed in the Raw Image Summary Table window. This window provides information about the following:

- Total number of images in the project
- Total number of GCPs, TPs, and CPs
- Image-specific information, including image ID, GCPs, TPs, CPs, RMS error, number of overlapping pairs connected by TPs, number of potential overlapping pairs that could be connected by TPs, and the percentage of all overlaps connected by TPs

The Raw Image Summary Table provides you with a dynamic view of your project, allowing you to better target your quality assurance efforts to achieve your desired project requirements.

Image-specific information is displayed in tabular format. The tabular contents can be sorted, making it easier for you to analyze the data in your project and identify areas on which to focus your quality assurance activities.

The Raw Image Summary Table window displays both active and inactive images in your project. You can activate and deactivate one or more of the images in your project using the check box column. An active image is included in any processing you want to do on your project. When you deactivate an image, it is still in your project, but is excluded from processing. You can also activate and deactivate images in the Project Overview window.

Project Overview

The Project Overview window provides a graphical display of the raw images in your project, while the Raw Image Summary Table lists all pertinent information in table format. You can use both windows together to gather relevant information about each image in your project, allowing you to better target your quality control efforts and manage your project.

By default, the Project Overview window displays centers of each raw image in the project. Users can choose to display image centers, geocoded vector footprints, and/or thumbnails of the imagery. One can also toggle the display of GCPs, TPs, and CPs, as well as Image and Point IDs, for all images or for selected images only.

Note: When the Raw Image Summary Table is open, the Project Overview window displays the current image with a yellow border and its image ID.

This viewer helps users to better assess their project using a graphical overview. It also includes some simple tools to assist in project management like:

- Ability to display reference imagery or vectors
- Rotating the kappa of the input imagery
- Measurement tools

Orthorectification

The orthorectification process enables a user to:

- Perform batch processes
- Utilize a DEM for terrain correction
- Increase working cache for processing
- Increase sampling interval for faster processing
- Utilize the following resampling methods:
    - Nearest Neighbor
    - Bilinear Interpolation
    - Cubic Convolution
    - 8-pt Sin X/X
    - 16-pt Sin X/X
    - Average filter
    - Median filter
    - Gaussian filter
    - User-defined filter
- Clip the image size upon orthorectification
- Set a starting time for processing
- Achieve approximately one-third of a pixel accuracy for VIR satellite images, and approximately one pixel for radar images when quality GCPs are used

Mosaicking

Mosaicking is available using the Mosaic Tool. Using this you can:

- Define a mosaic area
- Collect cutlines manually, including:
    - Import and export of cutlines
    - Specified blend width along seams
- Perform manual color balancing:
    - Based on samples identified in overlap between images
    - By using samples (match areas) to compute look-up tables (LUTs) to adjust new images to match an existing mosaic
    - By adjusting the dark end or light end
    - By importing and exporting LUTs for color balancing
- Mosaic unreferenced images

When you initiate mosaicking OrthoEngine opens the Mosaic Tool application, in which you can perform all the tasks necessary to create the mosaic. When you initiate the mosaicking process, the Mosaic Tool New Project Wizard will lead you through the setup of a mosaic project.

If the images in your project are orthorectified, the Mosaic Tool New Project Wizard appears, and the images appear in the Source file box on the Source Images page of the wizard; otherwise, a message appears, prompting you to create the orthorectified images.

Mosaic Tool
Mosaic Tool features a wizard to make creating your mosaic project quick and easy. The wizard walks you through the following steps to ensure you have everything set up to create your mosaic:

- Source files to use
- Key details, such as size and extents
- Applying color balancing, normalization, or both to the input images
- Selecting how to create cutlines and mask layers
- Previewing the mosaic

DEM Extraction

Automatic DEM Extraction is included in the Satellite bundle and supports the following sensor types.

In general terms, DEM extraction should work for any satellite sensor that produces stereo data. The following list shows known sensors that have been tested:

- ASAR
- COSMO SkyMed
- KOMPSAT-5
- RADARSAT 1 / 2
- RISAT-1

DEM Extraction Methods
Users can choose from one of two methods for extracting their digital elevation model (DEM).

- Normalized cross-correlation (NCC)
- Semi-global matching (SGM)

<u>NCC</u>
Matching points in a left and right input image are found using image correlation. The image disparity for the point pair is computed and this value, combined with the geometric model for each image, is used to compute the scene elevation for the corresponding scene point.

The image correlation is performed on an image pyramid that is constructed for each of the input images. The base level of an image pyramid is the original image, the next highest level is the original image resampled to a coarser spatial resolution, the level after that is the previous level resampled to a coarser spatial resolution, and so on. The location in one image that matches the current point in the other is first found at the coarsest resolution level for both images. This location is then used as the starting point for finding the match at the second coarsest resolution, and so on until the match is found in the original images.

This multi-resolution approach to image matching is faster than searching for matches in only the full-resolution images, and results in fewer false matches.

SGM
The implementation of SGM is done by image-matching along epipolar lines using the SGM method first proposed by Hirschmuller in 2005. The SGM algorithm produces excellent detail and few blunders, or *errors*, even at full resolution. However, the basic algorithm does have some drawbacks, such as higher computation time, very high memory consumption, and sensitivity to variations in local lighting conditions. With each implementation of the SGM algorithm, various approaches have been taken to work around these difficulties with varying degrees of success.

Our implementation of the SGM algorithm was developed in-house. It is proprietary and full details are not available. Our implementation uses a tiled approach based on pyramid resolutions with multiple cost functions (including mutual information) to achieve stability over varying local lighting conditions while retaining the highest possible detail. The algorithm self-adjusts to compensate for small errors in the epipolar line. Innovative memory-management techniques limit RAM usage to 2 GB or less, even if the disparity in the images is thousands of pixels (which can occur in some satellite scenes of mountain ranges).

Epipolar Pairs
Epipolar pairs increase the correlation process speed and reduce the possibility of incorrect matches. Stereo pairs are reprojected, ensuring that the left and right images have a common orientation, and matching features between the images appear along a common x-axis.

Using epipolar pairs, you can:

- Choose from the following pairs:
    - User Select – selects a pair manually
    - Maximum Overlapping Pairs – selects the pair with the highest amount of overlap
    - Minimum Percentage Overlap – specifies the lowest percentage of acceptable overlap
    - All Overlapping Pairs – selects all pairs that overlap above a minimum percentage
- Limit the amount of memory used to generate epipolar pairs
- Define a Down-sample factor to reduce an epipolar image resolution

- Define a Down-sample filter
- Set up epipolar-pair start times

DEM Extraction
Using DEM extraction, you can:
- Specify the minimum and maximum elevation to estimate a search-area correlation
- Specify a failure value to represent any failed (uncorrelated) pixel values in the resulting DEM
- Specify a background value to represent any 'no-data' pixel values
- Set the DEM detail to high, medium, or low for the needed level of detail
- Select an output DEM channel type to 16-bit signed or 32-bit real
- Specify a pixel sampling interval for the number of image pixels and lines used to extract one DEM pixel
- Use a clip region to process a specific area only
- Fill holes and filter interpolated failed values and filter elevation values automatically
- Create a score channel to represent the correlation score for each DEM pixel
- Delete an epipolar pair after use
- Create a Geocoded DEM by using geocoding stored in the project
- Set up DEM extraction start times

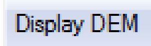
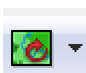
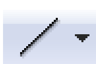
DEM Editing
The DEMs may contain pixels with failed or incorrect values. You can edit a DEM to smooth out irregularities and create a more accurate model, and in turn, generate more accurate orthorectified images. For example, areas such as lakes often contain misleading elevation values; setting those areas to a constant value improves the model that will produce a more accurate representation of the lake in the ortho image.

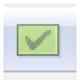
Using the Focus DEM Editing window requires only a DEM; that is, a raster channel in a writable format. To fully use all the functionality available in the DEM Editing window, however, and to produce the best possible DEM, the DEM file should contain additional information. In particular, if the DEM file was extracted from epipolar images, you can make use of that imagery to help with your editing.

DEM files created using our technology contain extra information that facilitates DEM editing, including a cutline vector segment and file-level metadata.

The main toolbar on the DEM Editing window provides quick access to several functions that facilitate working with the DEM.

The following table describes the buttons on the DEM Editing toolbar:

Button	Label	Description
	Display DEM	Toggles the display of the digital elevation model layer in the Focus viewer.
	DEM Display Options	Allows you to set display options for the DEM layer. Choose from: *Grayscale Shaded Relief:* displays the DEM using grayscale hill-shading, where a top-left light source and the elevation values are used to cast shadows. *Color Shaded Relief:* displays the DEM using colored hill-shading, where a top-left light source and the elevation values are used to cast shadows. *Dynamic Color Shade Relief:* displays the DEM using colored hill-shading, where a top-left light source and the elevation values are used to cast shadows. This option, the default setting, automatically re-renders the color display of the DEM as you pan or zoom across the viewer so that only the pixels currently being viewed are the basis of the colorization. Typically, editing is most effective when the DEM is displayed as a *Dynamic Color Shaded Relief*.
	Enhancements	Allows you to apply enhancements to the images automatically loaded in the Focus viewer. Available enhancements are: None Linear Root Adaptive Equalize Infrequency Tail Trim (toggle) Exclude Min/Max (toggle) Set Trim % Select the Auto Re-enhance option so that, as you pan across the data, the view is automatically refreshed in the Focus viewer to apply the selected enhancement.

Button	Label	Description
	View DEM Polygons	Toggles the visibility of existing DEM polygons. If a Status layer exists, this option also displays polygons from that layer.
	Set View As Verified	Creates a status polygon using the full extents of the current display area and sets its status to *Verified*.
	Define Preview Region	Allows you to specify a rectangular region to be displayed in a separate viewer. After you define the preview region, the Full Res. Ortho Preview window opens, displaying a preview of the full-resolution ortho image computed using the modified DEM.
	Open FLY!	Launches CATALYST Professional's FLY! application. FLY! uses the modified DEM and ortho imagery (when available) to allow interactive 3-D display. The FLY! view is centered on the current view, but is restricted to 4096 DEM pixels in x and y.
	Save	Saves the modified DEM and all other associated layers.
	Undo/Redo	Allows you to undo or redo previous actions.

Interferometric SAR (InSAR)

Overview
Radar interferometry is a technique which combines the coherent phase from a pair of synthetic aperture radar (SAR) signals to provide three-dimensional information about the Earth's surface.

The technique requires the coregistration and processing of at least two SAR signals from very similar viewing geometries which have been acquired over the region of interest. By coherently combining the signals from the two or more acquisitions, the interferometric phase between the received signals can be determined for each imaged point and computed as line of sight or vertical displacement.

SBAS-PSI
The Persistent Scatterer Interferometry (PSI) workflow in CATALYST Professional enables users to measure mm ground deformation movements using SAR data. The PSI technique leverages a stack of SAR images to identify stable points based on amplitude dispersion threshold, which ensures reliable measurements.

The recommended pair-selection method is by SBAS (Satellite-Based Augmentation System) with baseline filters, as it allows users to limit both the perpendicular and temporal baselines to select the best possible pairs. This will ensure that pairs are not created if the orbits between the images are too large or small, and that pairs are only identified if the temporal difference (in days) of acquisition is within the specified allowance.

The PSI workflow sequence can be summarized as:

<u>Pair selection and data ingest</u>

- Search for candidate InSAR pairs inside a specified folder
- Generation of a baseline report for every valid pair.
- Ingestion into PCIDSK (.pix) format.
- If an AOI is set, the images are subset when ingested.

<u>Co-registration to persistent scatterer candidate (PSC) identification</u>

- Co-registers the ingested data based on the pairs identified in the baseline report.
- Generates raw interferograms from co-registered pairs and corrected for flat earth/topographic effects and orbital drift/base-line offset.
- Perform phase filtering
- Selects persistent scatterer candidates (PSCs). PSCs are identified by examining the temporal characteristics of a specific pixel's backscattering signal to determine the amplitude dispersion index. The amplitude dispersion index for each pixel is defined as the standard deviation of the amplitude divided by the mean amplitude.

<u>Phase unwrapping to interferogram stacking</u>

- Performs phase unwrapping along the network of PSCs.
- Calibrates the unwrapped deformation. Calibration points can be either automatically collected or user supplied. If they are user supplied, these will likely be ground-collected stable points.
- Solves for the modeled and residual displacements at non-overlapping time steps between the consecutive SAR acquisition times.
- Generates a time-ordered stack of displacement rasters.

A sample of the-PSI workflow sequence, including interconnectivity of the modules is shown in Figure 1.

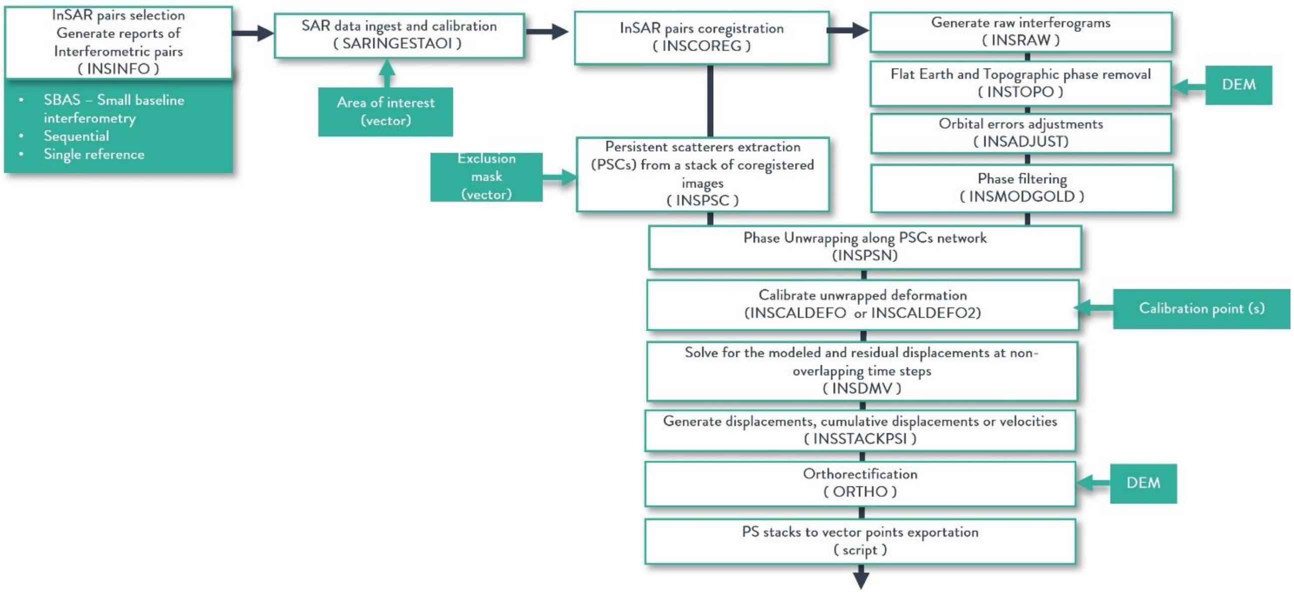


Figure 1. Overview of Interferometric Workflow

D-InSAR

Differential InSAR (or D-InSAR) is a technique that combines the coherent phase from a pair of synthetic aperture radar (SAR) signals to provide three-dimensional information about the Earth's surface. The technique requires the co-registration and processing of two SAR signals from very similar viewing geometries that have been acquired over the region of interest. By coherently combining the signals from the two acquisitions, the interferometric phase between the received signals can be determined for each imaged point.

The interferometric phase represents the difference in the path lengths to the imaged point. The interferometric phase is affected by topography, atmospheric effects, surface motion, and system noise. The effects of topography can be estimated and removed through the use of a (high-quality) digital elevation model (DEM) and knowledge of the radar characteristics (wavelength, range to target) and relative orbital positions (baseline length and drift).

After the effects of topographic, atmospheric and residual noise have been removed, the remaining phase differences are due to subsidence in the direction of the radar's line of sight (LOS). If multiple data sets are available, a long-term temporal assessment of motion can be created for each target.

The algorithms that comprise InSAR can process both topographic and deformation information derived from multiple SAR sensors by using data sets ranging from a single interferometric pair to multiple stacks of single, dual, compact and fully polarimetric data to produce reliable and valuable map products.

The workflow sequence can be summarized as:

<u>Creation of interferograms</u>

- Ingests SAR data, and extracts metadata and geocoding information.
- Co-registers the images automatically.
- Generates raw or filtered interferograms.

<u>Generation of interferometric products</u>

- Removes flat earth and topographic effects, as well as residual orbital errors.
- Perform phase filtering.
- Unwraps the interferometric phase.
- Interferometric adjustment of output products.
- Converts to orthorectified final product.

<u>Temporal analysis of surface subsidence</u>

- Extracts temporal parameters from an unwrapped interferometric stack.
- Enhances the visualization of temporal information.

A sample D-InSAR workflow sequence, including interconnectivity of the modules is shown in Figure 2.

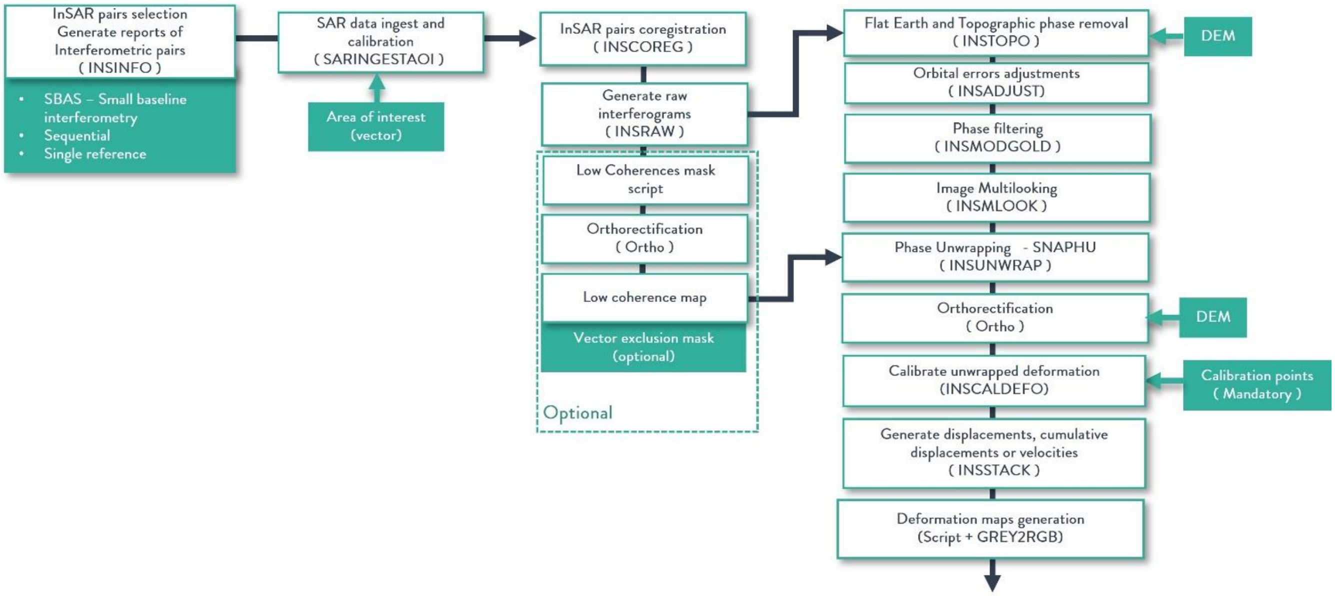


Figure 2. Overview of the D-InSAR workflow

Data Visualization

For the InSAR workflows, there are specific data visualization tools in CATALYST Professional's Focus application:

- Viewing a layer as amplitude and phase
- Viewing properties of an amplitude and phase layer
- Viewing an InSAR temporal chart

Viewing a layer as amplitude and phase

Focus allows users to visualize complex SAR data as amplitude and phase. The amplitude of the complex layer is displayed in black and white while the phase information is displayed as a semi-transparent (30%) color ramp. This allows the user to examine the coherence (i.e. amplitude) and phase patterns to assess the quality of the data.

Viewing properties of an amplitude and phase layer

Once an amplitude and phase layer is loaded to the Focus view users can view the properties and control the various views by right-clicking on the layer and selecting the ***Properties*** option.

Viewing an InSAR temporal chart

The InSAR temporal chart (see Figure 3) can be found under the ***Analysis*** menu in Focus. This tool allows users to analyze interferometric stacks produced with the INSSTACK function by viewing an interactive InSAR temporal chart.

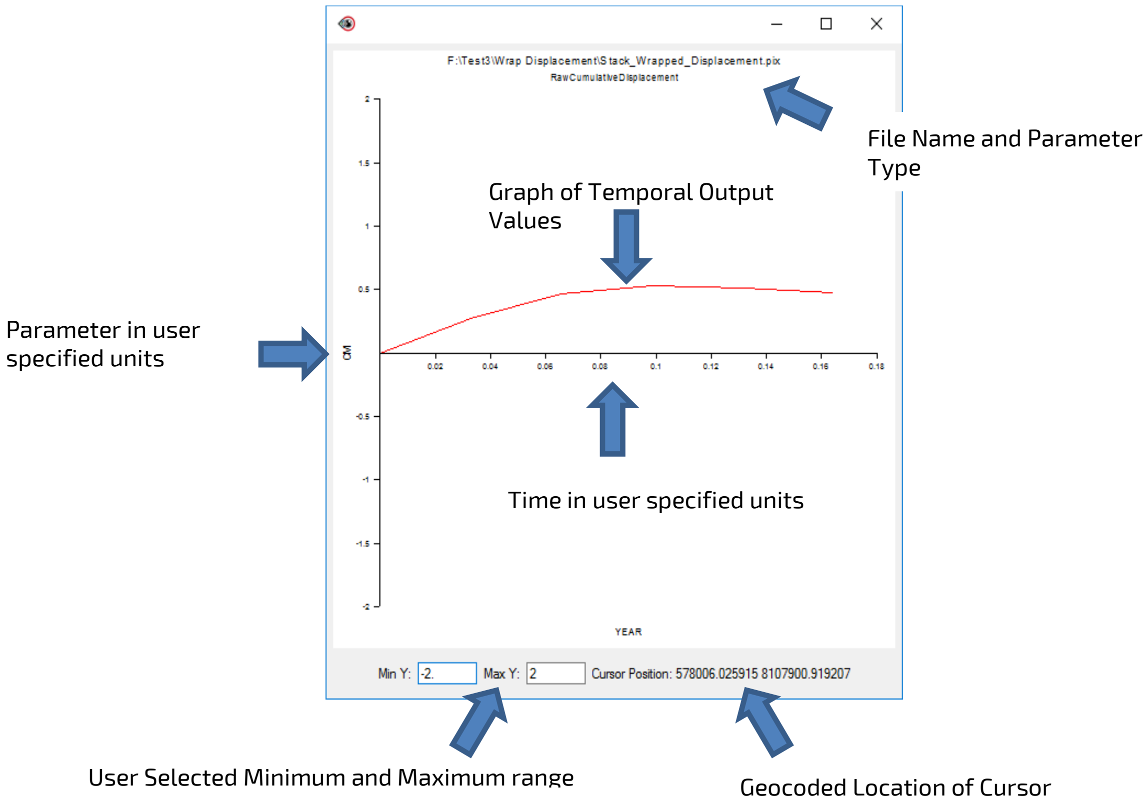


Figure 3. InSAR temporal chart

SAR Polarimetry Workstation

The SAR Polarimetry Workstation provides a complete set of tools and applications designed specifically for the processing and analysis of Polarimetric SAR (POLSAR) data.

The SAR Polarimetry Workstation can:

- Assimilate a variety of POLSAR data products in their original distribution formats
- Map product-specific metadata to a set of standardized metadata items
- Provide multiple modes of manual target selection
- Provide a comprehensive set of target analysis operations with both numerical and graphical output
- Provide a comprehensive set of operations on entire datasets

POLSAR Data Support

The following table shows the supported **fully polarimetric** SAR sensors:

Sensor	Polarization type	Format
AIRSAR	Fully polarimetric	Complex
ALOS-1 PALSAR	Single Dual Fully polarimetric	Complex Detected Complex
ALOS-2 PALSAR (Compact)	Single Dual Fully polarimetric	Complex Detected Complex
Convair-580 (CV-580)	Fully polarimetric	Complex
Gaofen-3	Single Dual Fully polarimetric	Complex Detected Complex
Radarsat Constellation Mission (RCM)	Single Dual Fully polarimetric	Complex Detected Complex
Radarsat-2	Single Dual Fully polarimetric	Complex Detected Complex
SAOCOM	Single Dual Fully polarimetric	Complex Detected Complex
SIR-C	Fully polarimetric	Complex
TanDEM-X / TerraSAR-X	Single Dual Fully polarimetric	Complex Detected Complex
UAVSAR	Fully polarimetric	Complex

The following table shows the supported **single or dual polarimetric** SAR sensors:

Sensor	Polarization	Format
ASAR (ENVISAT)	Single Dual	Complex Detected

Sensor	Polarization	Format
CAPELLA SPACE	Single	Complex
Cosmo-SkyMed	Single Dual	Complex Detected
ERS	Single	Complex
ICEYE	Single	Complex
Kompsat-5	Single Dual	Complex Detected
PAZ	Single Dual	Complex Detected
Radarsat-1	Single	Complex
RISAT-1 (Compact)	Single Dual	Complex Detected
Sentinel-1	Single Dual	Complex Detected

Metadata Support

Metadata support is crucial to the processing and analysis of POLSAR data. The SAR Polarimetry Workstation reads metadata from POLSAR data products and transforms them to the following standardized metadata items:

- File-level metadata items:
    - Sensor Model Name
    - Sensor Type
    - Product Type
    - Acquisition Type
    - Matrix Type
    - SAR Calibration
    - Microwave Band
    - Polarizations
    - Number of Looks
    - Number of Looks (range direction)
    - Number of Looks (azimuth direction)
- Band-level metadata items:
    - Matrix Element

Most analysis operations on POLSAR data regard such data as a raster of matrices, rather than simply a multi-band raster. The matrices may be of different types: Scattering (complete and incomplete), covariance (complete and incomplete), coherency, and Kennaugh. The metadata read by the SAR Polarimetry Workstation includes items that identify the matrix type and map dataset bands to matrix elements.

Target Selection and Analysis

The SAR Polarimetry Workstation provides three modes of manual target selection that support a comprehensive set of target analysis operations and allows targets of any size and shape to be selected.

- SQUARE NEIGHBORHOOD
  - Defines a target as a square neighborhood centered on a user-selected pixel
  - The neighborhood dimension can be user-specified
  - The neighborhood can be as small as a single pixel
- ARBITRARY REGION
  - Defines a target as the region enclosed by a user-digitized polygon
  - A rectangle sub-option allows you to quickly digitize exact rectangular polygons
- PIXEL PLUS CLUTTER ESTIMATION REGION
  - Defines a target as a user-selected pixel plus four nearby square regions that are used for estimating clutter
  - The user-specified neighborhood is the size of the square that encloses the overall target
  - The user-specified gap size is the space between the clutter-estimation regions

Target Analysis - Numerical Output

The following target analysis operations that produce numeric (text) output are available:

- Scattering matrix
- Covariance matrix
- Coherency matrix
- Kennaugh matrix
- Correlation coefficient
- Pedestal height
- Total power
- Intensity ratio
- Coefficient of variation
- Fractional polarization
- Polarimetric discriminators
- Pauli component
- Phase difference
- Freeman-Durden parameters
- Van Zyl classification
- Cloude-Pottier parameters

- Huynen parameters
- Cameron parameters

The output from these operations is written to the Numerical Output window. Functionality includes:

- Numerical output automatically regenerated when a new target is selected
- Contents of numerical output window can be exported to a file
- Clear contents of numerical output window at any time

Target Analysis - Graphical Output

The following target analysis operations that produce graphical output are available:

- Polarization response plot (co-polarized and cross-polarized); the plot can be interactively rotated
- Histogram plot of selected parameters derived from matrix elements for extended targets
- 2-D and 3-D scatterplot of selected parameters are derived from matrix elements for extended targets. 3-D scatterplots can be interactively rotated

Output graphs can be exported to the following formats:

- Postscript
- PNG
- GIF

Object Analyst

CATALYST Professional provides Object Analyst tools for segmentation, classification, and feature extraction. Object Analyst includes an all-in-one interface within CATALYST Professional's Focus application that is designed to guide you through segmenting your imagery, extracting features, creating training sites, classification (including creating custom rules for classification), reforming shapes, and performing an accuracy assessment.

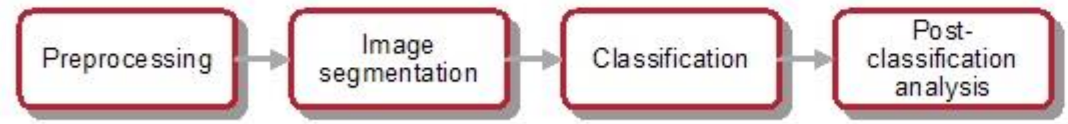
Researchers have more recently considered that a pixel is not a true geographical object, and it is not the optimal spatial unit for mapping a landscape. Moreover, the traditional pixel-based image-analysis algorithms showed their inability to cope with high-resolution imagery; that is, imagery with resolution typically finer than 5 meters per pixel. These factors have contributed to the shifting of the model to and the wider use of object-based image analysis (OBIA).

OBIA does not analyze a single pixel, but rather a homogeneous group of pixels — image objects. An object, contrary to a pixel, provides richer information, including spectrum, texture, shape, spatial relationships, and ancillary spatial data. In turn, spatial context can be exploited to emulate a human analyst, who intuitively identifies various objects in an image, rather than individual pixels, by considering various properties, such as size, texture, shape, and the spatial arrangements of these objects to understand the semantics.

The fundamental objective of OBIA, therefore, is to use segmentation to reduce complexity of image data, and to use the extracted image objects and their corresponding attributes (features) to develop strategies for thematic classification. With OBIA, images are segmented to make image objects from various groups of pixels to represent meaningful objects in the scene. Ontologically, this provides more accurate and reliable identification and extraction of real-world features and at more appropriate scales. Moreover, it provides the opportunity to divide map data into homogenous objects of various spatial scales.

Workflow

A simple process flow for object-based image analysis (OBIA) is shown in Figure 1. After preprocessing, a typical OBIA analysis starts with segmenting an image into primitive objects. You then further group the objects together into classes of interest by exploiting their spectral properties, shape measures, context, and so forth.

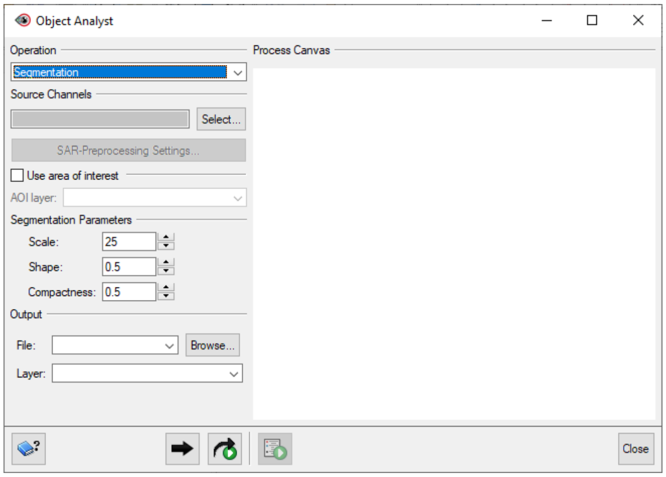


The preprocessing steps involve operations such as orthorectification, radiometric enhancement, removing shadow, detecting outliers, or creating a new layer(s) such as vegetation indices, texture channels and so forth, so that the data is suitable for image segmentation and feature extraction before classification.

Image segmentation is the first step in OBIA. The objective is to partition an image into statistically homogenous regions or objects (segments) that are more uniform within themselves and differ from their adjacent neighbors. Each segment is characterized by a variety of attributes (features), including spectral properties (band statistics of a segment), shape, texture, context, and so forth. The segments, however, do not have the thematic information at this stage and need classification to assign class (group) membership to each.

Focus Object Analyst Workflow

Object Analyst can be accessed through the ***Analysis*** menu. The interface includes a Process Canvas, which guides users through process steps that can be run separately or once properly defined, automatically.



The process steps are listed here and described below:

- Segmentation
- Attribute Calculation
- Training Site Editing
- Classification
- Rule-based Classification
- Post-classification Editing
- Accuracy Assessment
- Batch Classification

Segmentation

Segmentation is the process of extracting discrete regions of image objects. This is achieved by stratification of an image. These image-objects are used further as the basic unit of analysis for developing image-analysis strategies, including classification and change detection.

The underlying segmentation algorithm in Object Analyst is a hierarchical step-wise region grown by using random "seeds" spread over the entire image. This method can be classified as a "bottom-up" optimization routine that starts with a pixel and ends with segments that are groups of like pixels. The criteria that define the growth of a region can be based on the difference between the pixel intensity and the mean of the region. The algorithm assesses the local homogeneity based on the spectral and spatial characteristics. The size of the object is controlled with the value for scale, which you specify. The larger the scale, the larger will be the output object. Other homogeneity criteria are based on shape and compactness.

The result of the segmentation process is as follows:

- An initial abstraction of the original data
- Creation of a vector (polygon) representation of the image objects

The results of segmentation can be exported as a vector data set and viewed in third-party software.

Constraining segmentation to an area of interest

If necessary, you can constrain segmentation to a specific area of interest (AOI). You do so by selecting a vector file in PCIDSK format you have created that contains only polygons of the AOI you want.

Attribute Calculation

In Object Analyst an attribute represents some information about an image object. Various characteristics of image objects are referred to as attributes of a segment.

You can compute the following types of attributes:

1. Statistical - Statistical attributes are computed based on the image pixels under an object (polygon). Attributes are computed for each of the selected image bands and added to the attribute table of the vector segment layer as new fields. The following attributes can be collected:
    - Minimum value of the pixels beneath an object in a selected band.
    - Maximum value of the pixels beneath an object in a selected band.
    - Mean value of the pixels beneath an object in a selected band.
    - Standard deviation value of the pixels beneath an object in a selected band.
2. Geometric attributes - Geometric attributes are computed by analyzing the polygon boundary created during segmentation, so raster information is not required. Object Analyst computes many commonly used shape descriptors such as:
    - Compactness - A measure to indicate how closely packed a shape is. A circle is the most compact.

      Compactness = Sqrt(4 * As / pi) / O, where As is the area of the object, and O is the perimeter of the object (outer contour).
    - Elongation - The ratio of the height and width of a rotated minimal bounding box. In other words, rotate a rectangle so that it is the smallest rectangle in which the object fits, and then compare its height to its width.

      Elongation = Major Axis Length / Minor Axis Length
    - Circularity - The circularity ratio represents how like the object's shape is to a circle. Circularity is the ratio of the area of a shape to the perimeter of the shape's square.

      $C = A_s/O^2$, where A_s is the area of the shape, and O^2 is square of the shape's perimeter.
    - Rectangularity - How rectangular a shape is; that is, how much it fills its minimum bounding rectangle.

      $R = A_s/A_R$, Where A_s is the area of a shape, and A_R is the area of the minimum bounding rectangle.

- Convexity - The relative amount that an object differs from a convex object. Convexity is calculated by forming the ratio of the perimeter of the convex hull of an object to the perimeter of the object itself.

  Convexity = convex-hull perimeter ÷ object perimeter
- Solidity - The density of an object. Solidity is calculated as the ratio of the area of an object to the area of a convex hull of the object. A value of 1 indicates a solid object, and a value less than 1 indicates an object having an irregular boundary or containing holes.

  Solidity = area ÷ convex-hull area
- Form Factor - The measure that compares the area of a polygon to the square of the perimeter. The form-factor value of a circle is 1, and the value of a square is pi ÷ 4.

  Form factor = 4 × pi × area ÷ sqrt (perimeter)
- Major-axis length - The length of the major axis of an oriented bounding box enclosing the polygon.

  Values are map units of the pixel size. If the image is not georeferenced, the values are pixels.
- Minor-axis length The length of the minor axis of an oriented bounding box enclosing the polygon.

  Values are map units of the pixel size. If the image is not georeferenced, the values are pixels.

3. Vegetation Indices attributes - You can select from several Vegetation Indices (VI) to perform quantitative and qualitative evaluations of vegetation cover, vigor, growth dynamics, and more.
   The following table provides descriptions of each Vegetation Index that can be calculated:

Attribute	**Short name**	**Description**
Green/Red Vegetation Index	GRVI	GRVI = (Green - Red) ÷ (Green + Red)
Greenness Index	GI	GI = ((2.0 × Green) - (Red + Blue)) ÷ ((2.0 × Green) + Red + Blue)
Vegetation Difference Index	VDI	VDI = NIR - Red
Ratio Vegetation Index	RVI	RVI = NIR ÷ Red

Attribute	Short name	Description
Normalized Difference Vegetation	NDVI	NDVI = (NIR - Red) ÷ (NIR + Red)
Transformed Difference Vegetation Index	TDVI	TDVI = (NIR - Red) ÷ (NIR + Red) + .5
Soil Adjusted Vegetation Index	SAVI	SAVI = ((NIR - Red) ÷ (NIR + Red + L)) × (1 + L) The L-value is based on the amount of green vegetative cover. L is a default of 0.5, which means, generally, areas of moderate green vegetative cover.
Modified Soil Adjusted Vegetation Index	MSAVI2	MSAVI2 = (0.5) × (2(NIR + 1) - √((2 × NIR + 1) - 8(NIR - Red)))
Global Environmental Monitoring Index	GEMI	GEMI = eta × (1 - 0.25 × eta) - ((Red - 0.125) ÷ (1 - Red)) Where eta = (2 × (NIR - Red) + 1.5 × NIR + 0.5 × Red) ÷ (NIR + Red + 0.5)
Leaf Area Index	LAI	LAI = (3.618 × EVI) - 0.118 Where EVI (Enhanced Vegetation Index) = 2.5 × (NIR - Red) ÷ (1 + NIR + (6 × Red) - (7.5 × Blue)

4. Texture attributes: Texture measures can be calculated for a specific direction or directional invariant for all pixels in an input image. The measures are based on second-order statistics calculated from the gray-level co-occurrence matrices.

Attribute	Description	Algorithm
Mean	Cooccurrence mean	Mean_i = SUM(i,j=0,N-1)(i*P(i,j)) Average gray-level in the local window.
Standard deviation	Cooccurrence standard deviation	Var_i = SUM(i,j=0,N-1)(P(i,j)*(i - Mean_i)**2) Std. Deviation_i = SQRT(Var_i) Gray-level standard deviation in the local window. High when there is a large gray-level standard deviation in the local region.

Attribute	Description	Algorithm
Entropy	Cooccurrence entropy	SUM(i,j=0,N-1)(-P(i,j) * LOGe(P(i,j))), assuming that 0 * LOGe(0) = 0. Entropy is high when the elements of GLCM have relatively equal values. It is low when the elements are close to either 0 or 1 (that is, when the image is uniform in the window).
Angular second moment	Cooccurrence angular second moment	SUM(i,j=0,N-1)(P(i,j)**2) This is the opposite of Entropy. It is high when the GLCM has few entries of large magnitude, low when all entries are almost equal. This is a measure of local homogeneity.
Contrast	Cooccurrence contrast	SUM(i,j=0,N-1)(P(i,j)*(i-j)**2) Contrast is the opposite of Homogeneity. It is a measure of the amount of local variation in the image. It is high when the local region has a high contrast in the scale of SPATIAL.

Training Site Editing
Before you can perform a classification or an accuracy assessment, you must have ground-truth data. In remote sensing, ground truth refers to information collected on location. With ground-truth data, image data can be related to real features and materials on the ground. By collecting ground-truth data, remote-sensing data can be calibrated, which aids in the interpretation and analysis of what is being sensed.

With supervised classification, the ground-truth data acts as a training set, which is used by the learning algorithm to generate a classification model.

In Object Analyst, you collect training samples for both the supervised classification and accuracy assessment in the same window. Primarily, you will use on-screen interpretation in the viewer and select segments of various classes.

Classification
Classification is systematic grouping of objects into sets or classes based on their similarities. The goal in Object Analyst is to group extracted image objects or segments into appropriate classes that a human analyst can identify intuitively.

This is achieved through object-based classification. Classification of a segment can be achieved either by labeling a segment as a selected class and assigning a color to it, or by adopting more advanced more advanced computational procedures.

With Object Analyst, you can perform either of two types of classification:

1. Supervised
   Supervised classification is a process to find a model, or function, by analyzing the features of a data set of which the class memberships are known. This function is then used to predict the class memberships for target population.

   Essentially, supervised classification is a two-step approach.
   - The first step is to build a learning model to describe predetermined classes for a data set. The construction of the learning model is based on the analysis of data items or concepts for which class memberships are predetermined or known: data items known collectively as training samples.
   - In the second step, the learned model is applied to new (target) data items to predict their class membership. The supervisory component of this procedure is in the training phase, which provides the classifier with a way to assess a dependency measure between features (attributes) and classes.

   Users can select between Support Vector Machine (SVM) or Random Trees (Random Forest) algorithms for supervised classification.

   Support Vector Machine (SVM)
   SVM is a machine-learning methodology that is used for supervised classification of high-dimensional data. With SVM, the objective is to find the optimal separating hyperplane (decision surface, boundaries) by maximizing the margin between classes, which is achieved by analyzing the training samples located at the edge of the potential class.

   Random Trees (Random Forest)
   Random Trees is an ensemble learning method that has been implemented for image classification. It operates by constructing a multitude of decision trees during training and outputs the class selected by most trees.

2. Unsupervised
   Object Analyst provides unsupervised classification based on the k-means clustering algorithm. Clustering algorithms search for generic data patterns among the feature [variable] spaces. No target variable is identified, as such. Clustering algorithms search for patterns among all the input features related to objects and group them into relatively homogeneous clusters.

   The goal of clustering is normally descriptive and to discover new categories. Therefore, this strategy learns from observation rather than examples, and hence does not require a prior hypothesis or training set. The core objective is finding the natural boundaries in feature space for the number of clusters you specify.

Rule-based Classification
With Rule-based Classification, you can define a custom classification rule based on a specific property (feature), or properties, of a segment. You can define a rule to either assign a class to segments that meet the requirements of the rule or remove the segments from the class.

Object Analyst provides two methodologies for creating these rules or conditions:

1. Object Analyst Condition Builder window
   In this window users can define a condition for rule-based classification. The condition can be based on up to two features (attributes). That is, you can construct a maximum of two conditions per rule. Both conditions can be based on a single attribute, or on two different attributes linked by a logical AND or OR operator.

   For example, one could specify a two-part condition where i) classification occurs on an area attribute with a value of greater than 100800 and ii) less than 109800 for the same area attribute.

2. An alternative to creating a condition in the Object Analyst Condition Builder window is to use feature visualization. In the Feature Visualization window, you can dynamically select the vector objects (polygon segments) or update the existing selection in the vector layer based on a given feature (field) and its value range (filter).

   You select the field you want, and then define the range. The polygon segments in that range are then selected in the viewer. Changing the range value reapplies the filter and update the selection set. You can immediately see the effects of the selected filter, and experiment to select the one most suitable.

Post-classification Editing
As a post-classification step, users may need to merge two or more polygons or spilt one or more polygons. You can do so by using either of two methods:

- Reforming shapes by using automatic dissolve
  Automatic dissolve, merges two adjacent polygons based on class membership; that is, segments belonging to the same class and that are adjacent to each other are dissolved to create a bigger object. The internal boundaries of such segments are removed. The output will exclude all the attribute fields, except the field that contains the class-membership information. It is this field that is used to dissolve the segments.
- Reforming shapes by using interactive edits
  An alternative to reforming shapes with Automatic dissolve is to use Interactive edits. To do so, you must select a layer that contains one or more polygons with class information. Object Analyst provides you with some basic tools to select and edit the polygon data.
- Adding, modifying, and removing classes

You can add, modify, and remove classes, as necessary. You can also assign objects to a class, and change the style of how classes are displayed in the view pane.

Accuracy Assessment
You can evaluate the overall accuracy of a supervised classification by running Accuracy Assessment. This operation compares a reference field, generated by an analyst using training sites editing tool, and a classification field, generated by running a classification.

The reference field and the classification field must be of the same segmentation file. When a segmentation file contains several reference and classification fields, it is a good practice to compare a classification with the reference field used to create it.

This process generates an assessment report that includes:

- Sample Listing – Report includes all assessed samples, described with georeferenced position, image coordinates, classified value/name, and reference value/name are displayed.
- Error (Confusion) Matrix – Matrix of all classes between reference data and classified data is displayed.
- Accuracy Statistics – Various accuracy statistics, such as overall accuracy, kappa coefficient, and their confidence intervals are displayed.

Batch Classification
By running a batch classification, you can run classification simultaneously on a group or collection of images with similar qualities of acquisition. The collection can be any aerial, satellite, or SAR imagery you want classify similarly, such as, but not limited to the following:

- Airphotos (strips or individual images)
- Stack of historical imagery
- Overlapping images
- Contiguous images

You first run classification on an individual image that you want to use as reference for the batch you want to process. After you are satisfied with the results, you can run a batch classification on several images to apply the same classification to each. The batch classification applies a segmentation step, an attribute-calculation step, a classification step (using Support Vector Machine or Random Forest, (based on the training-model file you create from the first individual image you classified), and any number of rule-based classification steps.

Object Analyst for Synthetic Aperture Radar (SAR) Data

In Object Analyst, the workflow of working with synthetic-aperture radar (SAR) data differs from that of other types of remote-sensing (RS) data.

Object Analyst supports SAR data ingested to a PCIDSK file or directly in its raw vendor format.

SAR imagery comes in many formats and processing levels identifiable by the matrix type in the image metadata. The matrix type determines which, if any, SAR preprocessing parameters you can apply, and which SAR attributes you can calculate, as shown in the following table.

Matrix type	**Channel type****	**Segmentation, preprocessing**	**Predefined attributes**
[c1r] Single polarization, detected	1 x [16U] (uncalibrated) - or - 1 x [32R] (calibrated)	• Filtering • Tail trimming	• Statistical • Geometrical • Texture
[c1c] Single polarization, complex	1 x [C16S] (uncalibrated) - or - 1 x [C32R] (calibrated)	• Filtering • Tail trimming	• Statistical • Geometrical • Texture
[c2r] Dual polarization, detected	2 x [16U] (uncalibrated) - or - 2 x [32R] (calibrated)	• Filtering • Tail trimming	• Statistical • Geometrical • Texture
[s2c] Dual polarization, complex*	2 x [C16S] (uncalibrated) - or - 2 x [C32R] (calibrated)	• Filtering • Tail trimming	• Statistical • Geometrical • Texture
[s4c] Fully polarimetric, complex	4 x [C16S] (uncalibrated) - or - 4 x [C32R] (calibrated)	• Filtering • Tail trimming • Extra segmentation layers: - L1 ($\lambda 1$) - L2 ($\lambda 2$) - L3 ($\lambda 3$)	• Statistical • Geometrical • Polarimetric

* Compact-polarimetric data is a special case of [s2c] data.
** Calibrated data is recommended for use with Object Analyst.

Segmentation

Object Analyst also includes segmentation tools specifically designed to work with SAR imagery. Once a SAR image is selected as input, you can pre-process the layer. (recommended before segmentation) This pre-processing includes:

- Select the type and size of filter you want to use You can select from either of the following types of filter:
    - Enhanced Lee
    - Boxcar
- Select whether to apply tail trimming and, if so, the percentage thereof
    - To minimize the effect of backscattering, you can apply tail trimming. With SAR data, frequency histograms are often characterized by strong outliers in the rightmost tail of the data distribution; that is, point targets with a high-

backscattering coefficient several magnitudes higher than the bulk of the data. Segmentation is influenced strongly by these "scatterers" and can produce substandard results over distributed targets, such as forest, water

Attribute Calculation
Specific SAR attribute calculations are included as options. These specific tool are designed to leverages SAR-specific analysis of texture, scattering mechanisms, and more

1. Polarimetric attributes - The predefined polarimetric attributes are available for fully polarimetric images only (matrix type = [s4c]). The attributes correspond to a selection of parameters, from various polarimetric decompositions, that have the potential to discriminate among a diverse set of land-cover classes.
    - Scattering type
    - Entropy
    - Anisotropy
    - Orientation angle
    - First eigenvalue Lambda1
    - Second eigenvalue Lambda2
    - Third eigenvalue Lambda3
    - Double-bounce scattering
    - Volume scattering
    - Surface scattering
    - HH-VV phase difference
    - Maximum degree of polarization
    - Minimum degree of polarization
    - Maximum of received power
    - Minimum of received power
    - Maximum of scattered intensity

SAR Bundle Functions

In the SARbundle the following functions can be executed either independently or sequentially via an EASI™ or Python™ script. They may also be available in the Algorithm Librarian in Focus and the Modeler.

- AUTODEM - Generates a digital elevation model from stereo images – OpenMP enabled
- DEMADJUST - Adjusts (raises/lowers) a raster DEM to elevation points held in a vector layer so that it better fits the elevation points.
- DEMEDPREP

- DEMMETA - Adds standard DEM-related metadata tags to an existing DEM raster.
- DSM2DTM – Convert a DSM to DTM
- DSMMERGE - Used to merge (multi-angle) geocoded DSMs that were typically produced by EPIPOLARDSM and geocoded using GEOCODEDEM. Imagery associated with the geocoded DSM can be simultaneously merged at the same time producing a rough ortho image co-registered with the DSM.
- ELEVRMS - Reads elevations from a digital elevation channel and compares the elevations with elevation values from a given GCP (ground control point) segment or from a vector segment
- ELGCPRMS - Generate elevation data RMS report - GCP
- ELVECRMS - Generate elevation data RMS report - vector
- EPIPOLAR - Generates epipolar images from stereo pairs or raw images – OpenMP enabled
- EPIPOLARDSM - Creates a raster digital surface model (DSM) from epipolar stereo pairs using the Semi-Global Matching (SGM) method.
- GEOCODEDEM - geocodes epipolar digital elevation models by reprojecting to the ground coordinate system – OpenMP enabled
- INSADJUST – Module that automatically removes low frequency residual phase caused by orbital drift and/or baseline errors. The module iteratively estimates both the horizontal and vertical spectral residuals and applies the correction based upon the viewing geometry for the interferometric pair.

  Note: INSADJUST uses large amounts of memory; systems with limited memory may perform poorly when processing large images
- INSCALDEFO – This function is used to adjust unwrapped displacement values to be zero at all points held in a vector layer or text file.
- INSCOREG – Module designed to automatically resample and co-register the dependent file to the reference file. The module automatically acquires control points, removes outliers, and resamples the dependent file to match one-to-one with the reference file.
- INSINFO – This module is designed to provide pertinent interferometric parameters such as acquisition dates, baseline distances, incident angles for the reference file and the dependent file(s). If multiple dependent files are to be evaluated, the file names can be listed in a text file.
- INSMODGOLD – This function applies a sliding 3x3 spatial boxcar filter to prefilter the data prior to estimating the fringe frequency. It is normally applied after the topographic phase correction (INSTOPO) or after the orbit adjustment (INDSADJUS) to

enhanced interferometric fringes and speed up the following phase unwrapping (INSUNWRAP).

- INSMLOOK - The function resamples an input interferogram to create an averaged and decimated output interferogram with reduced dimensions as specified by the multi-look reduction factor. The averaging preserves the amplitude and phase characteristics of the original interferogram while the decimation in image size facilitates a reduction in the time required for phase unwrapping.
- INSRAW – module required to produce the raw interferogram using the specified reference file and resampled dependent file generated by the INSCOREG module.
- INSSTACK – Converts a number of co-registered SAR interferograms into a time ordered stack of phase values, accumulative displacements or velocities. It also produces a file of statistical values including average coherence and best fit linear velocity. The stacks can be produced from slant range interferograms or orthorectified interferograms. The input interferograms must be coregistered on a one-to-one basis and in the same projection.
- INSTOPO – This module extracts the reference and dependent file orbit data and calculates the required phase adjustments to correct for systematic flat earth effects projected to the specified earth model (which is generally the WGS-84 ellipsoid). Variations in phase caused by topography are also corrected if a digital elevation model is supplied.
- INSUNWRAP – Unwraps the interferometric phase by performing a two-dimensional integration of the wrapped phase values to generate the unambiguous phase. The unwrapping is based upon the Statistical cost, Network flow, Algorithm for Phase Unwrapping algorithm.[1] The algorithm computes the most likely unwrapped solution based upon the observable data (i.e., coherence).
- SARINGESTAOI - Imports and calibrates SAR datasets into the PCIDSK (*.pix) format. Optionally, it can import an image subset by specifying an area of interest (AOI) via a maskfile in geocoded vector format, or a raster window (DBIW) specified in image co-ordinates. In addition to ingesting the raster data, SARINGESTAOI stores metadata and creates auxiliary segments (orbit, math model, GCPs, incidence angle array, etc.) that are necessary for further processing.
- INSPSC - Generates a bitmap of pixels in the file layers specified by MFILE and/or DBIC with an amplitude dispersion index below the user specified threshold. Three raster layers containing the average amplitude, standard deviation of the amplitude, and the

[1] C. W. Chen, H. A. Zebker, "Two-dimensional phase unwrapping with use of statistical models for cost functions in nonlinear optimization,'' Journal of the Optical Society of America A, vol. 18, pp. 338-351 (2001).

ratio of the standard deviation to the average amplitude (dispersion index) are also generated.

- INSPSN - Unwraps the phase of all points where the bitmasks is set to one. The bitmask locations should correspond to persistent scatterers (stable targets) which are only marginally affected by temporal and geometric decorrelation. The module INSPSC can be used to generate a bitmask of persistent scatterer locations derived from a coregistered stack. The unwrapped phase at stable points can be utilized to accurately model the velocity of surface deformation and remove atmospheric artifacts from a stack of interferograms.
- INSDMV - Solves for the modeled and residual displacements at non-overlapping time steps between the consecutive SAR acquisition times.
- INSSTACKPSI - Generates a time-ordered stack of displacement rasters.
- MODEL2RPC – Lets users convert a math model to a RPC model
- OACALCATT – Calculate object attributes
- OACALCATTSAR – Calculate object attributes for SAR imagery
- OAFLDNMEXP - Export names of attribute fields from vector segment to a text file
- OSGTIMPORT
- OARTCLASS
- OARTTRAIN
- OASEG – Segment an image
- OASEGSAR – Segment a SAR image
- OASVMCLASS – Object-based SVM classifier
- OASVMTRAIN – Object-based SVM training
- OARTCLASS – Object-based Random Trees (Forest) classifier
- OARTTRAIN – Object-based Random Trees (Forest) training
- PSBOXCAR – POLSAR dataset, averaging filter dimensions, and a flag indicating whether the averaging in the range or azimuth directions or bi-directionally to replacement POLSAR channels containing the boxcar-filtered data
- PSCC – Contains fully-polarized MLC data and a polarization band selection to a real-values channel representing the complex correlation coefficient if the bands are complex and the non-complex correlation coefficient if the bands are real
- PSCLOPOT – A PCIDSK file that contains entropy, α-angle, and anisotropy feature space to an integer channel in a PCIDSK file that contains the Cloude and Pottier unsupervised classification result
- PSCOMDEC – Applies decompositions to polarimetric SAR imagery
- PSCOMDIS – Calculates polarimetric discriminators
- PSCOMPACT – Creates a compact pol data set from the standard configurations

- PSCONF – Estimates the conformity coefficient for each pixel
- PSCONV – Converts between different polarimetric SAR matrix representations
- PSEABA – Contains fully-polarized MLC data and angular-units flag to four real-values channels that represent entropy, α-angle, β-angle, and anisotropy
- PSFARA – Estimates Faraday rotation from fully polarimetric scattering data
- PSFREDUR – Contains fully-polarized MLC data to three real-values channels that represent rough-surface scattering, double-bounce scattering, and canopy scattering contributions
- PSG4U2 – Estimates the new general four-component scattering power decomposition with unitary transformation of the coherency matrix
- PSINANG – Contains an explicit or virtual incident angle array to a real-values channel that contains a nominal incident-angle map
- PSINTRAT – Contains dual-polarized or fully-polarized SLC, MLC, or MLD data and polarization channel pair selection to a real-valued channel in a representing intensity ratio
- PSKROG – Estimates Krogager decomposition (sphere, diplane, and helix) from fully polarimetric data
- PSPEDHT – Contains fully-polarized SLC or MLC data and a flag indicating co-polarized or cross-polarized to a real-values channel that represents the pedestal height
- PSPHDIFF – Contains dual-polarized or fully-polarized SLC or MLC data, a polarization channel pair selection, and angular units flag to a real-valued channel representing phase difference
- PSPHDW – Estimates the power contributions for plate, helix, diplane and wire
- PSPOLDIS – Contains fully-polarized MLC data and a list of polarimetric discriminators to evaluate one or more real-valued channels representing the selected polarimetric discriminators
- PSPOLFIL – Contains fully-polarized SLC or MLC data and dimensions of the filter window to speckle-filtered replacement channels
- PSPOLSYN – Contains fully-polarized SLC or MLC data to a real-valued channel that represents synthesized backscatter for arbitrary transmit and receive polarizations
- PSPOLSYNC – Contains fully-polarized SLC or MLC data and bitmaps that represents two regions to a real-valued channel and synthesized backscatter that maximizes contrast between the two regions
- PSPOLSYNR – Contains fully-polarized SLC or MLC data and a bitmap that represents a region to a real-valued channel and synthesized backscatter that maximizes return from the region
- PSRECONS – Creates a pseudo-full polarimetric covariance matrix

- PSS2C – Generates two user-defined coherent channels from fully polarimetric data sets. This module can be used to synthesize any arbitrary pair of polarizations (for example, RH, VV) or compact polarimetric data sets (for example, RH, RV)
- PSSSCM – Contains fully-polarized SLC data to an integer channel that contains the symmetric scattering characterization method classification results
- PSSWIS – Contains fully-polarized SLC or MLC data and class training statistics to integer channel that contain the supervised Wishart classification result
- PSTOTPOW – Contains fully-polarized SLC, MLC, or MLD data to a real-values channel that represents the total power
- PSTOUZIDEC – Touzi decomposition[2]
- PSTOUZIDIS – Touzi discriminator
- PSUSWIS – A PCIDSK file that contains fully-polarized MLC data and either Freeman-Durden or Cloude and Pottier unsupervised classification results (see PSFREDUR or PSCLOPOT) to an integer channel that contains the unsupervised Wishart classification result
- PSVANZYL – Contains fully-polarized MLC channel to an integer channel representing the van Zyl unsupervised classification results
- PSWHITE – Contains fully-polarized SLC data to a real-valued channel that represents a 'whitened' single-look image
- RFMODEL – computes the math model of one or more images using the rational function math modeling method
- RSMODEL - computes the math model of one or more images using the radar-specific modeling method
- SATMODEL – calculates the math model for one or more images using the Rigorous math modeling method.
- SGMMERGE - Merges a nadir-backward and nadir-forward epipolar DSM, created with the EPIPOLARDSM algorithm, into a single, final DSM, and then applies optional filtering.

[2] The **Touzi SAR filter algorithm** that is incorporated into the EASI program and the Modeler module FSPEC was developed by Dr. Ridha Touzi of the Canada Centre for Remote Sensing (CCRS) and is licensed from Her Majesty the Queen in Right of Canada, represented by the Minister of Natural Resources.