PS Tutorial

Version 5.6.2

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Contents

Introduction

The main goal of this tutorial is to give a general description of the SARscape PS processing chain to obtain the temporal evolution of surface deformations affecting Persistent Scattereres.

The PS technique is one of the multi-temporal Differential interferometric Synthetic Aperture Radar (DInSAR) techniques which is based on the basic principles of the interferometry.

The PS technique is based on:

- the identification of **point targets** (single pixels or group of pixels) which are **radiometrically stable in time**. The point targets are characterized by strong reflection (high backscatter) and high coherence in the observation period. Radiometrically stable targets are urban infrastructures (buildings, bridges, greenhouses, dams, metallic features, etc) or natural objects (outcrops, exposed rocks etc.).
- the availability of a **high number of input images** for the pixel coherence estimation. The larger the number of acquisitions the better the reliability and quality of the measured PS deformation (in terms of displacement and velocity) and their temporal evolution. A minimum of 20 acquisitions are needed to perform PS analysis to obtained reliable results (A. Ferretti, C. Prati and F. Rocca: "Permanent scatterers in SAR interferometry". Geoscience and Remote Sensing, IEEE Transactions on, vol. 39, no. 1, Jan. 2001, pp. 8 - 20).
- the **linear model** used as assumption to derive the estimate deformations. Non-linearity can be detected if the displacement between two consecutive acquisitions does not exceed $\lambda/4$.

Basically, the PS techniques, identifying point targets radiometrically stable in time, allows the estimation of the residual height and displacement of the persistent scatteres in the area of analysis: The estimates are based on a linear regression.

The PS technique uses the input slc data to select the pair combination for the interferogram generation. The Master is automatically chosen among the input acquisitions while all the other inputs are considered as Slaves. The Master is the reference image of the whole processing and all the processed slant range slaves are co-registered on this reference geometry (**Coregistration**). This involves an oversampling factor that is automatically selected base on the acquisition sensor (the oversampling is executed to avoid aliasing of fast fringes in case of large baseline values). Once the Coregistration is performed, the interferograms are generated for each slave always using the Master image (**Interferogram Generation**). The interferometric phase is the contribution of 4 components: the topographic component, the change component, the displacement component and the atmosphere component. It is worth noticing that the spectral shift and the common Doppler bandwidth filters are not executed, as usual in the SAR Interferometry. The input reference Digital Elevation Model is used to perform the **interferogram flattening** and remove the flat earth. The better the reference Digital Elevation Model accuracy/resolution the better the result in terms of **topography removal**. The availability of Ground Control Points for the area allows the correction of orbit inaccuracy for the Master image, performing the manual orbital correction or the automatic orbital correction (typical behavior of sensor like ERS).

Since the PS technique is based on the identification of stable backscatter **the time series of each pixel** are considered, the approach differs from the conventional approaches that process the input scene as a whole.

Once the interferograms are generated, the velocity [V'] and residual height [H'] component extraction is performed, in the First Inversion step, using specific range values of these two variables. The "First" term refers to a preliminary inversion, which does not consider the atmospheric delay, which is estimated in the second inversion. To determine V' and H', SARscape automatically considers a stable ground control point (V' and H' equal to 0). The selection of the stable ground control point is based on the identification of a defined

number of candidates (by default 5 in SARscape). The candidate's selection is based on the Amplitude Dispersion Index (D), which is defined as

$$D = \frac{\mu}{\sigma}$$

Where μ is the temporal amplitude mean value for the single pixel and σ is the temporal standard deviation. Once the candidates are identified, for each one of them H', V' and temporal coherence are computed. The candidate restituting the highest temporal coherence is select as the stable ground control point.

Once the Reference Points are identified, a **linear model** is used to estimate the residual height (H') and displacement velocity (V') from all the re-flattened interferograms and H' and V' are computed for each pixel.

The number of the 'Reference Points' depends on the size of the Area of Interest. By default, just **one 'Reference Point'** is selected for areas within 25 km^2.

Considering the area of analysis, the algorithm follows two approaches:

- Areas of analysis with size within the value specified by the 'SubArea for Single Reference Point' parameter: just one 'Reference point' is used to process the entire Area.
- Areas of analysis larger than the value specified by the 'SubArea for Single Reference Point' (by default size larger than 25 km^2): the entire area is split into more sub-areas, the subArea percentage overlap is considered (Overlap for SubAreas [%]). Every subarea is independently processed. A mosaicking process is carried out to merge all the sub-areas results. The merging process is carried out considering a **Super Reference Point** which is characterized by the highest D among the others. The Reference points are used for the phase offset removal.

The velocity, height, coherence and displacements are computed without atmospheric compensation.

The atmospheric component has high spatial correlation and low temporal correlation, to estimate the atmospheric effect, the **Second Inversion** is performed. In fact, once the atmospheric effect is performed, the residual heights and the displacement for each pixel is finally re-computed.

The PS processing is performed in slant range geometry. In order to be able to analyze and display the PS results in geographic coordinates, the PS output are generated in the Geocoding step.

The PS performed steps and relative sub-steps are described in the list below and correspond to the workflow shown in the Figure 1 below:

1. Connection Graph Generation
2. Interferometric Workflow
    2.1. Co-registration
    2.2. Interferograms generation and Flattening
3. Inversion First Step
    3.1. Mean power image and Amplitude dispersion index generation (MuSigma)
    3.2. Coherence, velocity and residual topography estimation
4. Inversion Second Step
    4.1. Atmosphere pattern removal
    4.2. Coherence, velocity and residual topography estimation
    4.3. Displacement component estimation
5. Geocoding
    5.1. Coherence, velocity and residual topography geocoded results
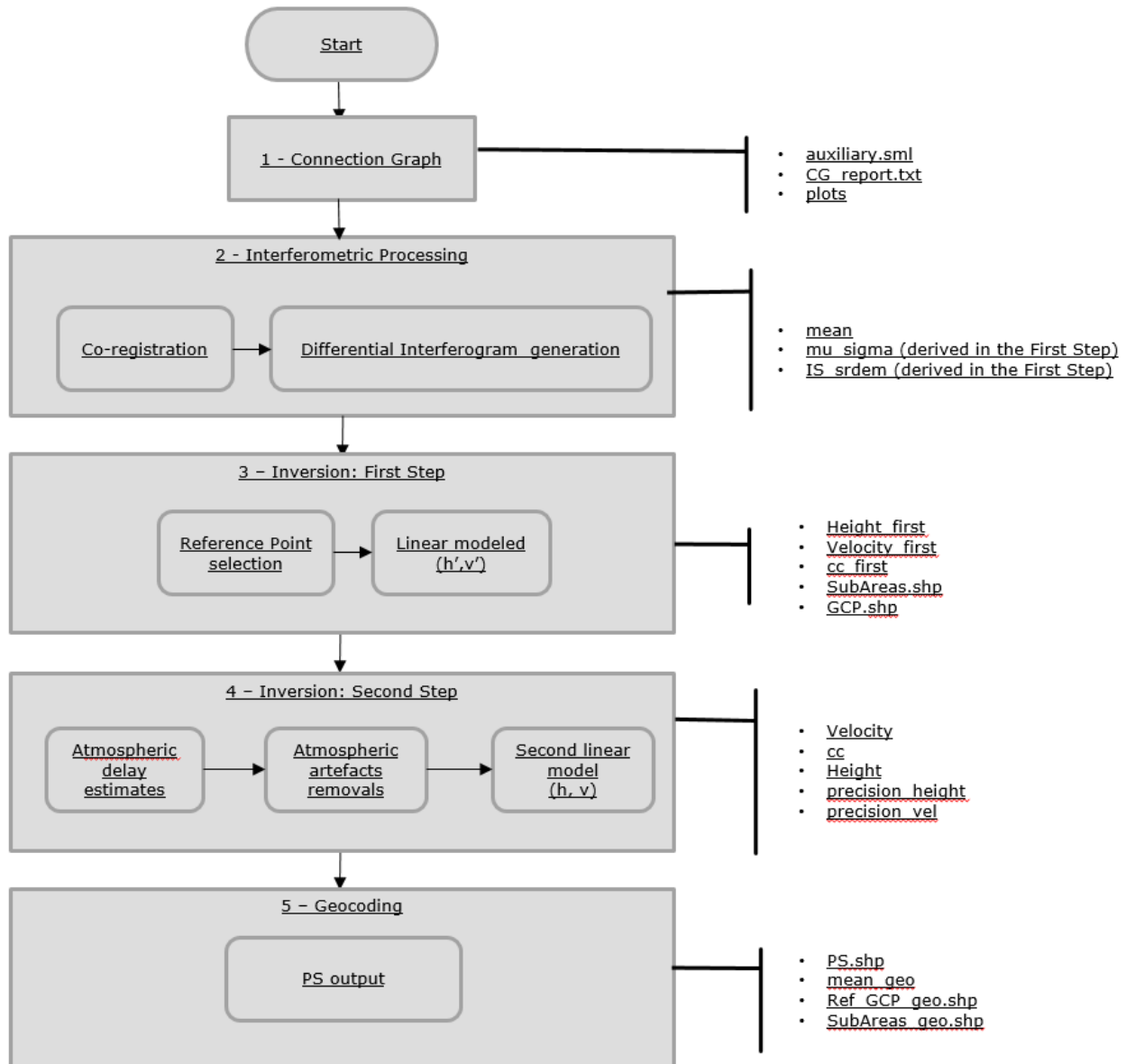   5.2. Displacement geocoding

Figure 1 Logical workflow for the PS module.

The PS processing described in this tutorial was performed in a workstation with the following characteristics:

SARscape version	5.6.2
ENVI version	5.6.2
SO	64-bit Windows 10 Pro
RAM	32 GB
Processor	Intel (R) Core (TM) i9-9980HK CPU @ 2.40GHz
OpenCL	AMD Radeon Pro WX 3200 Series
HD	SSD (as working directory)

The entire sample data stack and the PS results shown in this tutorial can be found in the DataSetsTutorials folder on our FTP (ftp.sarmap.ch). Please contact us at support@sarmap.ch to get the login credentials to access the FTP providing the full name of the license owner, the name of your institution and the license number.

Training Data sets description

The training area is characterized by land subsidence due to soil consolidation of the artificial and massive land-fills in several districts.

The area of interest is Urayasu city, located in the Chiba prefecture (Japan) close to Tokyo. The dataset includes Ascending and Descending acquisitions (Figure 2).

The Sentinel-1 Descending (track 46) stack is characterized by 75 acquisitions in VV polarization. The temporal coverage is from March 19, 2016 to December 22, 2018.

The Sentinel-1 Ascending stack (track 39) is characterized by 83 acquisitions in VV polarization. The temporal coverage is from March 7, 2016 to December 28, 2018.

The Persistent Scatterers technique has to be applied separately to each geometry, performing all the steps from the Connection graph to the Geocoding in order to obtain a consistent result.

In this tutorial only the Descending dataset processing is described, therefore the images and graphs correspond to the track 46.
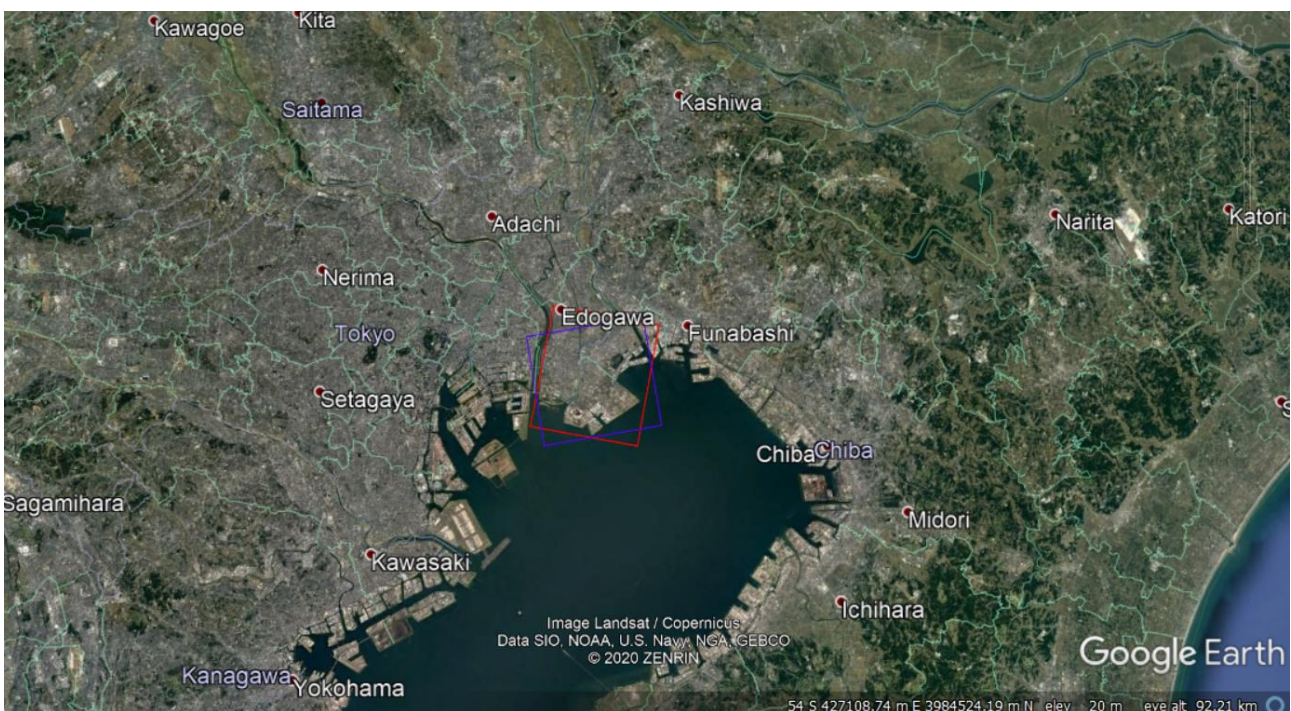

Figure 2 The red and the purple boxes show the shapes of the 46 (Descending) and 39 (Ascending) sample stack tracks respectively.

Processing Time

The Table below summarizes the processing time to perform the PS in the Urayasu area for the Descending dataset. The processing time reported considers only the computational time and it represents only a rough estimate by considering a machine with moderate performance. The operator time required to analyze each step results is not reported since it depends on the user knowledge and experience in PS processing.

Dataset	46D
Step	Time [min]
Connection Graph	1
Interferometric Process	38
Inversion: First Step	14
Inversion: Second Step	7
Geocoding	1

Before starting

Before starting the PS processing chain, it is strongly recommended to:

- set the ENVI Preferences;
- set the SARscape Preferences (Specific) based on the Sentinel-1 TOPSAR (IW – EW);
- read the Getting Started Tutorial to be familiar with the basic processing chain that allows managing the dataset provided to run the PS processing.

In fact, the dataset provided was downloaded, imported, and sampled using the corresponding SARscape tools.

The provided binary raster files are delivered with 3 auxiliary files:

- .hdr (an ASCII header for ENVI visualization)
- .sml (an ASCII header for SARscape processing with the main acquisition information)
- .kml (an ASCII file for Google Earth).

The dataset has to be suitable for PS processing.

To quickly analyze the results of each step, SARscape stores each output in the corresponding sub-folders. In fact, once the Connection Graph step is performed, the "(Output Root Name)+_PS_processing" folder is created.

The sub-folders are:

- connection graph
- first inversion

- geocoding
- interferogram_stacking
- second_inversion
- work

Connection Graph

This functionality defines the SAR pair combination (Master and Slaves) and connection network, which is used for the generation of the multiple differential interferograms. This step is mandatory.

The pairs are shown as connections in a network that links each acquisition to the Master file. Given N acquisitions, the maximum theoretical available connections are N-1. For each pair, an interferogram is generated in the Interferometric Process.

> TIP
>
> The connection graph can be edited using the specific tool in SARscape/Interferometric Stacking/Stacking Tools/PS Edit Connection Graph.

The Connection Graph is performed running the SARscape/Interferometric Stacking/PS/1 - Connection Graph pane (

Figure 3).

Input files

Insert all the _slc files in the Input file list tab from the "46D_cut" folder of the provided input dataset.

Optional file

Leave the Input Master file empty (this file is automatically chosen by SARscape).

Output Files

Choose an Output Root name.

The Output Root Name is used to create the processing folder. The folder name is given by the following composition: "(Output Root Name)+_PS_processing".
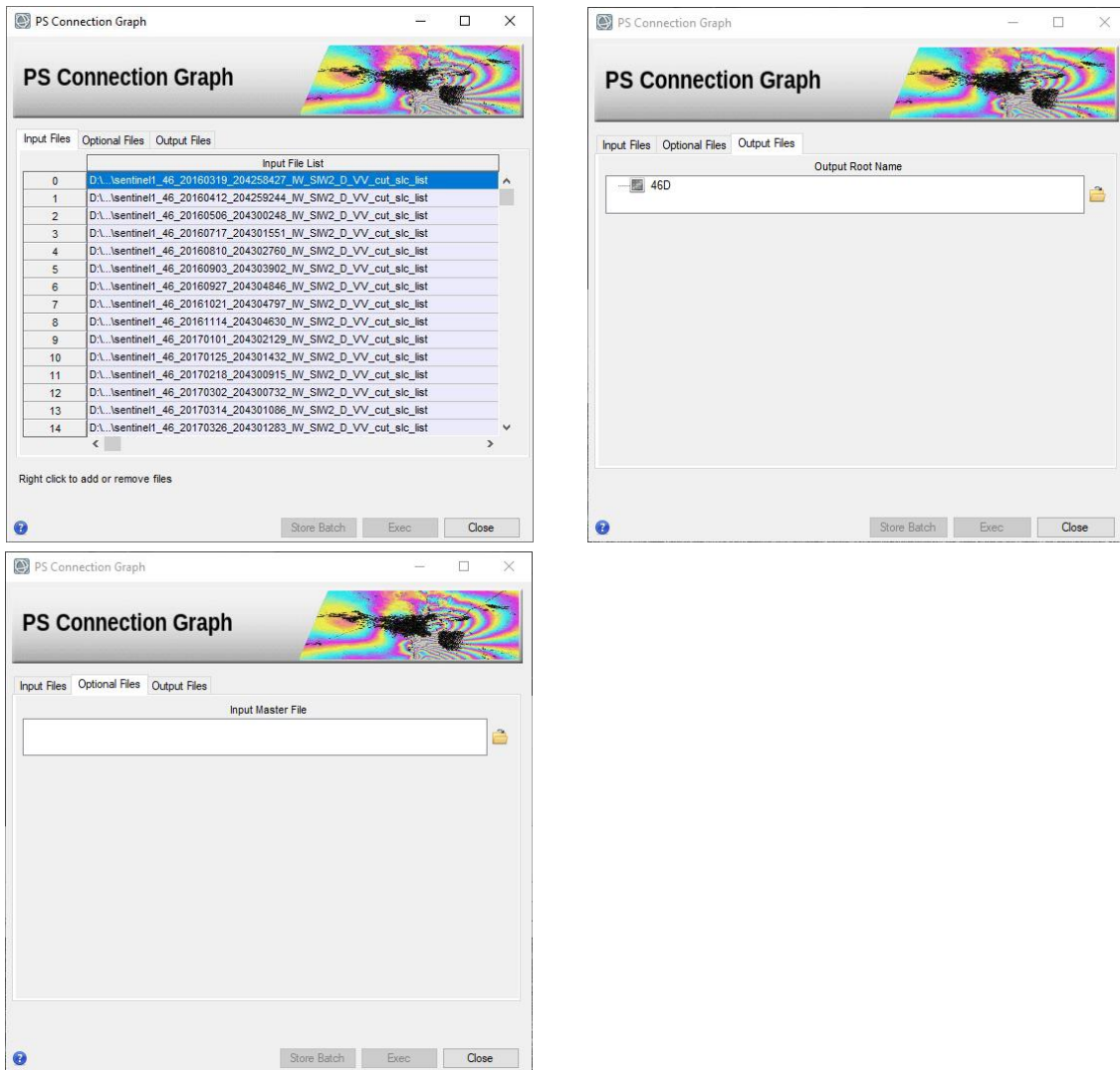
Figure 3 Connection Graph panels.

Once the PS Connection Graph process is completed, a report and two graphs are displayed (Figure 4). The graphs are:

- **Time-Position plot**, which provides, for each Slave acquisition, the satellite normal distance from the Master in meters (y axis) and the input acquisition dates (x axis);
- **Time-Baseline plot**, which provides the satellite normal distance in meters (y axis) and the input acquisition dates (x axis).

Each acquisition is represented by a diamond. The color of the diamond symbol is as follows:

- Red: discarded acquisitions due to user specific constraints;
- Green: valid acquisitions;
- Yellow: Master acquisition.

  TIPS

The graphs can be reloaded at any processing step from */SARscape/Interferometric Stacking/Stacking Tools/Plot Viewer* by adding the auxiliary file.
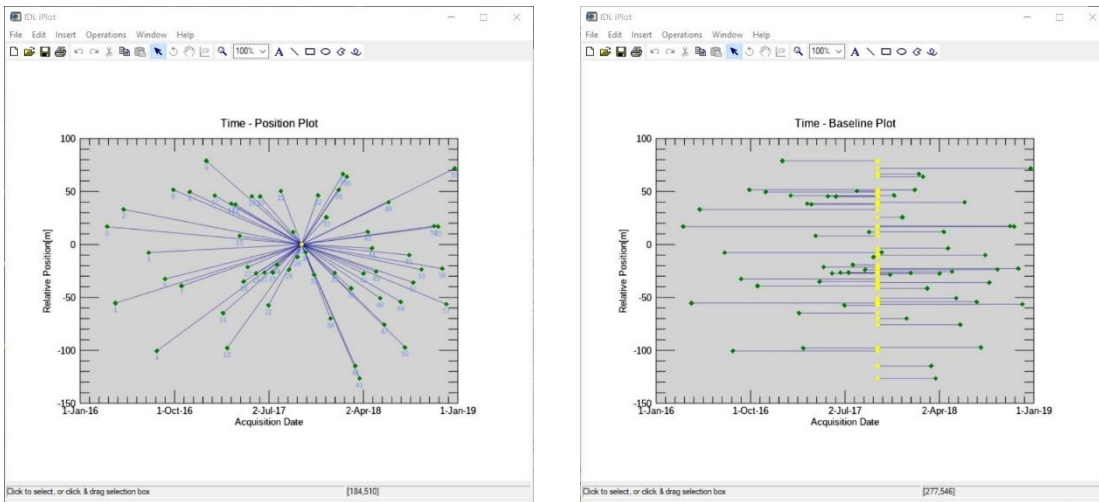
Figure 4 Plots generated by the Connection Graph Generation tool.

Output

The multilooked Master image (suffix, "_pwr") is automatically displayed in ENVI as well (Figure 5).The mooltilooked factor is automatically computed based on the grid size specified for the sensor once the Preferences was set.
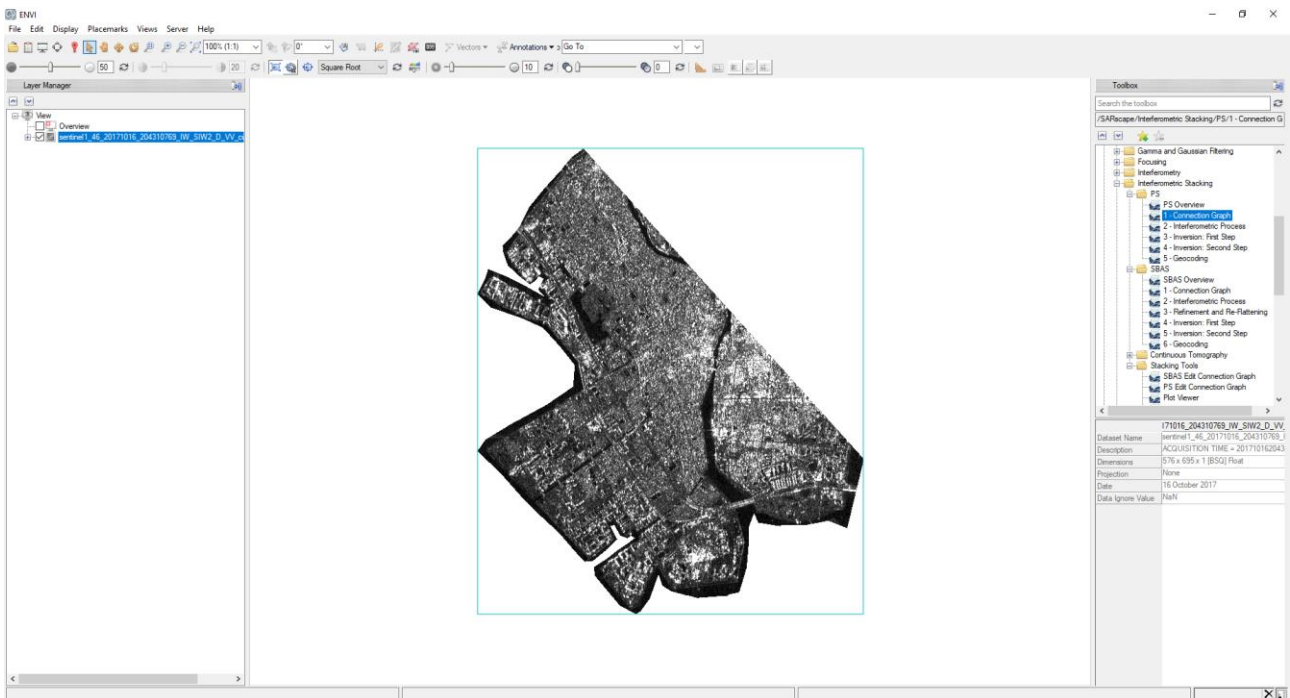

Figure 5 Mooltilooked Master image.

The Connection Graph step generates the **auxiliary.sml** file and the connection graph folder results.

The auxiliary file is the main file that guide users in the PS processing, all the mandatory PS processing steps are based on the auxiliary file.

The Connection graph folder includes:

- Multilooked Master intensity image (_pwr) and associated header files (.sml, .hdr);

- CG_report, which summarizes the pairs characteristics;
- Report file (Reference_selection.txt), which shows the input selection parameters such as selected master, baseline and theorical precision values, and thresholds, etc;
- **plot** sub folder, which is used to store the files (CG_baseline.txt and CG_position.txt) used for the visualization of the graphs and interfacing with ENVI.

TIP

This tool performs the PS processing in a defined area of interest. If users want to perform a different dataset, they have to consider that a full frame processing is fully discourage due to the processing time. To appreciate the influence of the parameters, a sampled dataset is strongly recommended.

Interferometric Process

The Interferometric Process step allows automatically processing the Coregistration and the Interferogram generation

As stated before, the PS interferometric process performs an overlooking in order to generate interferometric results. However, these data cannot be visually interpreted because of their geometry.

The PS Interferometric Process is performed running the /SARscape/Interferometric Stacking/PS/2 - Interferometric Process (Figure 6).

Input files

Insert the auxiliary.sml file.

Optional file

Leave the Geometry GCP file empty.

The GCP file is used to correct the master image in case of orbit inaccuracy (i.e. Master acquisition of the interferometric stack) based on the elevation value specified onto the Digital Elevation Model.

DEM/Cartographic System

Insert the Srtm-1_V3_dem provided in the dataset.

Parameters

Leave the default parameters.

- *Generate Dint Multilooked for Quick View*
  False is set by default. Set to True to generate differential interferograms, with the multilooking factors for a visual interpretation.
- *Rebuild all*
  False is set by default. Set to True to start the whole process from scratch.
- *Atmosphere External Sensors*
  By inserting this optional list, the software removes the atmosphere artefacts from the filtered interferogram stack using external sensors such as GACOS and MERIS (only for ENVISAT data).
- *Coregistration with DEM*
  True is set by default. Set to False to avoid using the input Digital Elevation Model in the coregistration process.
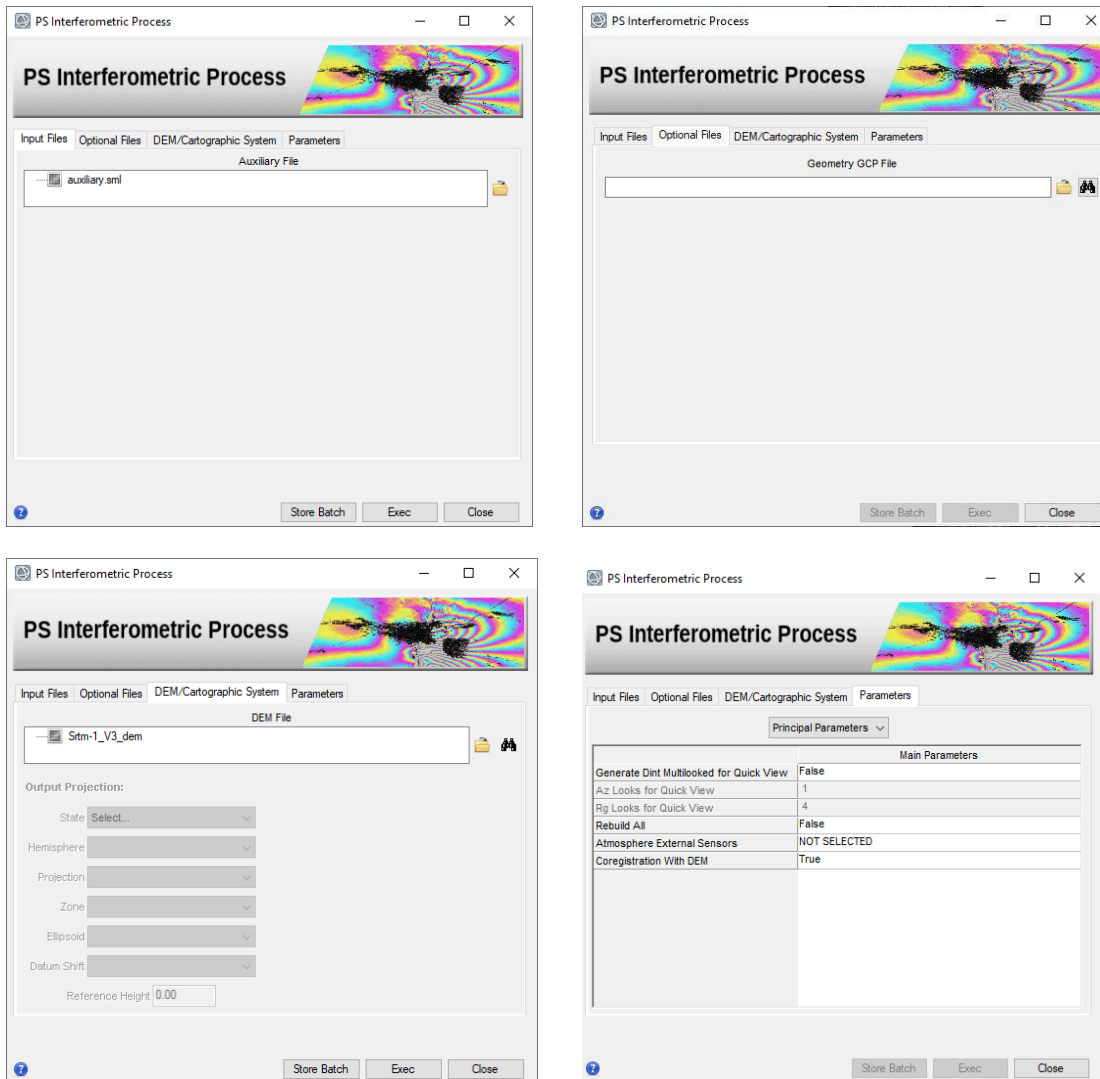
Figure 6 Interferometric Process panels.

Output

The **interferogram_stacking** folder includes:

- **Meta** files allowing to load the specific processing results (_meta)
  - slant_dint_meta, which refers to all flattened interferograms
  - slant_pwr_meta, which refers to all slant range intensity images
- **IS_srdem:** the synthetic DEM.

  TIPS
  The following files are going to be stored in this folder but they are going to be derived in the following step, the first inversion step:
- **mean**: SAR Intensity average raster file and associated header files (.sml, .hdr).
- **mu_sigma**: amplitude dispersion index (generated in inversion first step).

After the interferometric step, it is very important to check the first results, in particular if the coregistration step has worked well and therefore all slc data have been coregistered.

Inversion: First Step

The **displacement velocity** and **residual height** are derived from the first model inversion without removing any phase component due to the atmosphere. This step is mandatory.
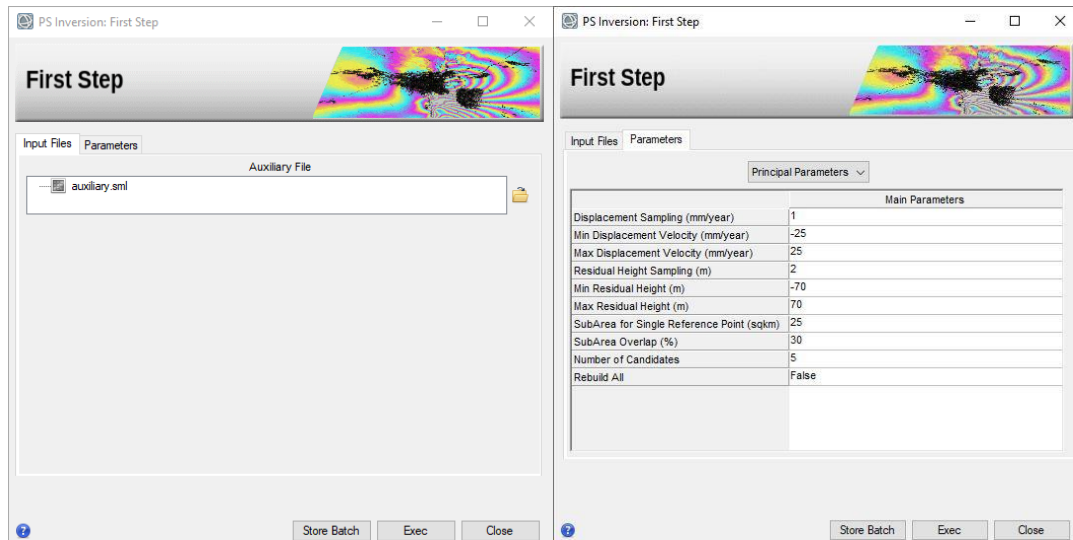
Input files

Insert the auxiliary.sml file.

Parameters

Leave the default parameters.

- *Displacement Sampling (mm/year)*
  Which corresponds to the sampling frequency (in mm/sec) which is used to estimate the displacement velocity.
- *Min Displacement Velocity (mm/year)*
  Which corresponds to the value expected (in mm/year) as the minimum displacement velocity.
- *Max Displacement Velocity (mm/year)*
  Which corresponds to the value expected (in mm/year) as the maximum displacement velocity.
- *Residual Height Sampling (m)*
  Which corresponds to the sampling frequency (in meters) which is used to estimate the residual height.
- *Min Residual Height (m)*
  Which correspond to the minimum (negative value) residual height, with respect to the reference Digital Elevation Model.
- *Max Residual Height (m)*
  Which correspond to the maximum (positive value) residual height, with respect to the reference Digital Elevation Model.
- *SubArea For Single Reference Point (sqkm)*
  Which refers to the maximum size for one 'Reference Point'.
- *SubArea Overlap (%)*
  Which refers to the overlap between the sub areas.
- *Number of Candidates*
  For each subarea one or more pixels is/are considered as candidates (Reference Points). The analytic method to define the candidates is based on the Amplitude Dispersion Index. They are automatically analyzed for the calculation of the phase offset and just one will be selected as reference point.
- *Rebuild All*
  By setting this flag the whole PS Inversion process is started from scratch.

Output

The **first_inversion** folder includes:

- Height_first: corresponding to the correction (in meters) with respect to the input Digital Elevation Model.
- Velocity_first: corresponding to the preliminary estimation of mean displacement velocity (in mm/year).
- CC_first: corresponding to the multitemporal coherence.
- Cohe_Sub_Areas_meta: meta file of the coherence, for area larger than 25 km^2.
- H_Sub_Areas_meta: meta file of the heights, for area larger than 25 km^2.
- Vel_Sub_Areas_meta: meta file of the velocities., for area larger than 25 km^2.
- Ref_GCP.shp: which refers to the GCPs selected on the image, in slant range geometry.
- SubAreas.shp: which refers to the sub-areas (slant range geometry) computed according to the atmospheric parameters, (refer to the Preferences>Persistent Scatterers>Area for Single Reference Point and 'Area Overlap for SubAreas).
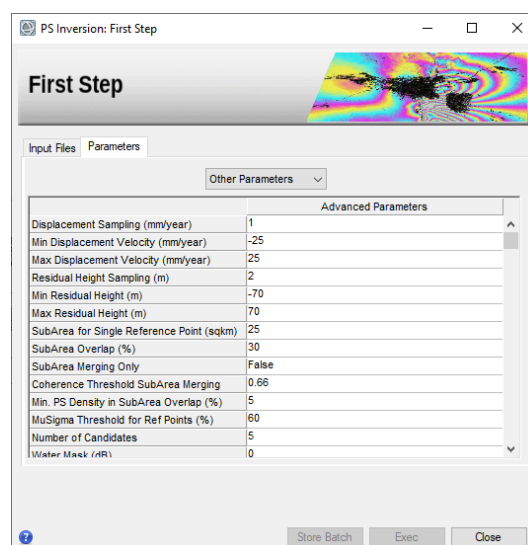

Figure 7 Other Parameters panel.

To check the results, the "Velocity_first" and "Height_first" has to be loaded in ENVI, together with the SubAreas.shp.
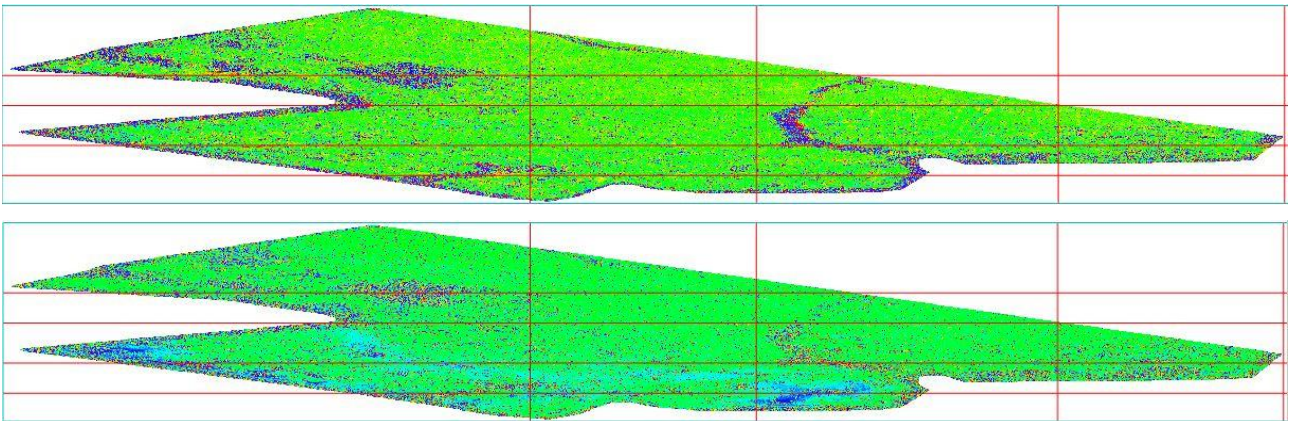
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Figure 8 Velocity_first and Height_first.

Inversion: Second Step

The second inversion uses the output of the first inversion to **estimate the atmospheric phase** components.

Input files

Insert the auxiliary.sml file.

Parameters

Leave the default parameters.

Atmosphere Low Pass Size
Enter the window size, in meters, to apply the spatial distribution related filter (refer to the Technical Note).

Atmosphere High Pass Size
Enter the window size, in days, to apply the temporal distribution related filter (refer to the Technical Note).

Rebuild All
By setting this flag the second step of the PS Inversion process is started from scratch.
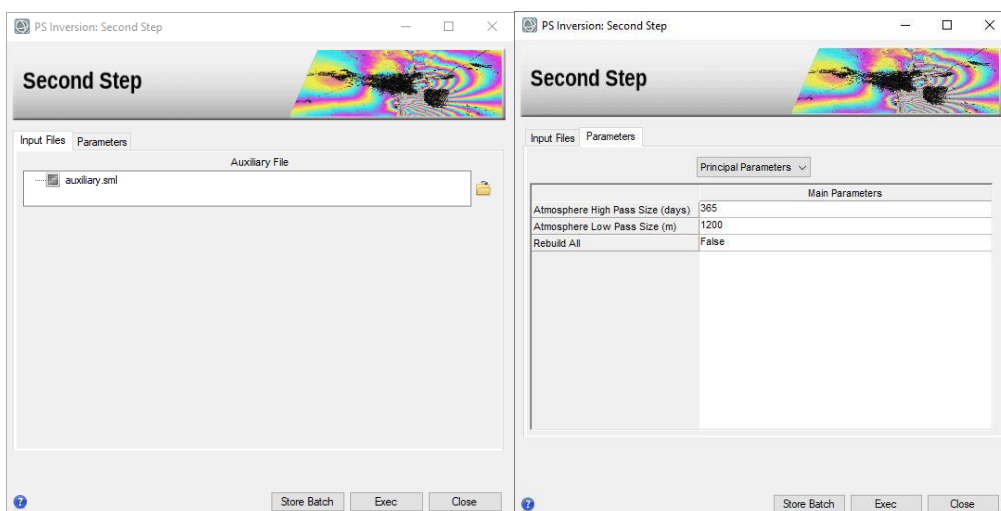

Figure 9 Second Step panels for input and parameters.

Output

The **second_inversion** folder includes:

- **Height**, corresponding to the correction (in meters) with respect to the input Digital Elevation Model, after atmospheric correction
- **precision_height**, corresponding to the estimate in meters of the residual height measurement average precision (refer to the Phase to Height conversion for more details).
- **Velocity**, corresponding to the mean displacement velocity (in mm/year, after atmospheric correction.
- **precision_vel**, corresponding to the estimate in millimeter/year of the velocity measurement average precision (refer to the Phase to Displacement conversion for more details).
- **cc,** corresponding to the multitemporal coherence. It shows how much the displacement trend fits with the selected model.

Meta files allowing to load the specific processing results (_meta).

- **slant_atm_meta**, which refers to date by date atmospheric related components in slant range geometry. This meta file can be found in the working folder.
- **slant_dint_reflat_meta**, which refers to the date by date flattened interferograms, measured in slant range geometry, after the atmospheric correction.
- **slant_disp_meta**, which refers to the date by date displacements, measured in slant range geometry, after the atmospheric correction.

Geocoding

The PS products are geocoded and the displacements can be displayed in two kind of format: Shape and/or Raster according to the flag selected in the parameters.

Input files

Insert the auxiliary.sml file.

Refinement GCP File

Leave the default parameters.

> TIP
>
> In order to obtain more accurate displacement measurements, one or more **Ground Control Points** (e.g. coming from GPS or other ground measurements) - "Refinement GCP file" - can be entered as input to the processing. This information is used to **optimize the displacement trend assessment**. In case only one GCP is selected, the correction will consist of a mean velocity constant offset, which does not have any spatial variation. If more GCPs are selected, the correction consists of the best fitting calculated from all GCPs.

The Ground Control Points must be provided in cartographic coordinates. This adjustment is not mandatory.

DEM /Cartographic System

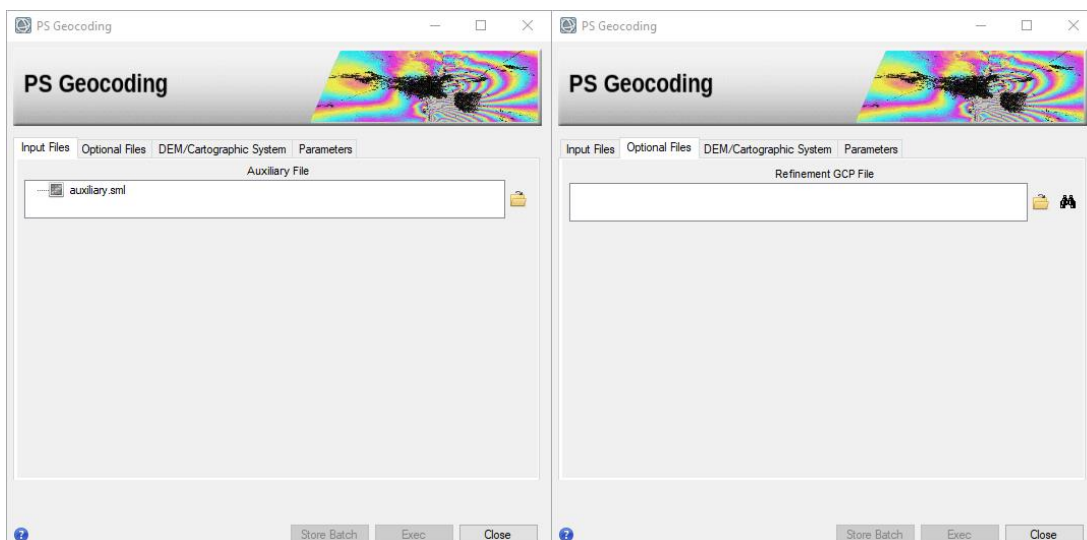Insert the Srtm-1_V3_dem provided in the input dataset.

Parameters

Leave the default parameters.

- *Product Temporal Coherence Threshold*
  Pixels with temporal coherence values smaller than this threshold will be set to dummy (NaN) as Persistent Scatterers in the final products

- *Generate KML*
  By setting this flag the Google Earth .kml of the resulting PS is/are created. and the Upper/Lower limit of KML scaling parameters are activated.

- *Upper Limit KML Scaling*
  The maximum expected displacement rate (integer value of the velocity in mm/year) is set (This field is only active if the Generate KML flag is set to True).

- *Lower Limit KML Scaling*
  The minimum expected displacement rate (integer value of the velocity in mm/year) is set (This field is only active if the Generate KML flag is set to True).

- *Make Geocoded Shape*
  By setting this flag the slant range products are geocoded onto the Digital Elevation Model cartographic reference system and the ultimate PS products are generated in vector format. By default, this option is flagged. The Geocoded product can be projected along both the maximum slope direction (_SD), on the vertical plane (_VD) or a custom direction. The proper flag below must be activated.

- *Make Geocoded Raster*
  By setting this flag the slant range products are geocoded onto the Digital Elevation Model cartographic reference system and the ultimate PS products are generated in raster format. The Geocoded product can be projected along both the maximum slope direction (_SD), on the vertical plane (_VD) or a custom direction. The proper flag below must be activated.

- *Make Slant Shape*
  By setting this flag the slant range products are generated in vector format. By default, this option is set to false. Note: the output shape will be created inside the second inversion folder.

- *Rebuild All*
  By setting this flag the whole geocoding process is started from scratch. It is advisable to leave this flag unchecked in case of process interruption, so that the products already generated have not to be computed and stored again.

- *Refinement Stacking*
  The user can choose between the following options:
  - Stack Velocity Disp Refinement.
  - Stack Residual Height Refinement.
  - Stack All Products Refinement:The refinement process will be applied to the Velocity, to the Height or to both layers according to the chosen option. The refinement GCP file must be uploaded.

- *Refinement Radius (m)*

Maximum buffer radius for the association of Ground Control Point with respect of the slant range unwrapped phase closer valid pixel.

- *Refinement Displacement Poly Degree*
  Degree of the polynomial used to estimate the displacement ramp, which will be removed from the input displacements date by date during the Re-flattening operation. In case this value is higher that the number of input Ground Control Points, it will be automatically decreased. The default values of 3 means that a displacement ramp in range and azimuth direction plus a constant displacement offset will be corrected. In case only the displacement offset correction is needed, the polynomial degree will be set to 1.

- *Vertical Displacement*
  By setting this flag the displacements and velocity products are projected on the vertical direction.

- *Slope Displacement*
  By setting this flag the displacements and velocity products are projected along the maximum slope.

- *Displacement Custom Direction*
  By setting this flag any vector can be specified, in terms of azimuth (Azimuth Angle, measured in degrees from the North - clockwise direction) and inclination (Inclination Angle, measured in degrees from the horizontal plane). The map showing the displacement values projected on the specified direction is generated among the output products.

- *X Dimension (m)*
  The grid size of the output data in Easting (X) must be defined; the default unit of measure is meters. Note that - for the Geographic projection - if values higher than 0.2 are entered they will be considered as metric units and then automatically, and roughly, converted from meters to degrees; if values lower than 0.2 are entered they will be considered as degree and used as such without any conversion.

- *Y Dimension (m)*
  The grid size of the output data in Northing (Y) must be defined; the default unit of measure is meters. Note that - for the Geographic projection - if values higher than 0.2 are entered they will be considered as metric units and then automatically, and roughly, converted from meters to degrees; if values lower than 0.2 are entered they will be considered as degree and used as such without any conversion.
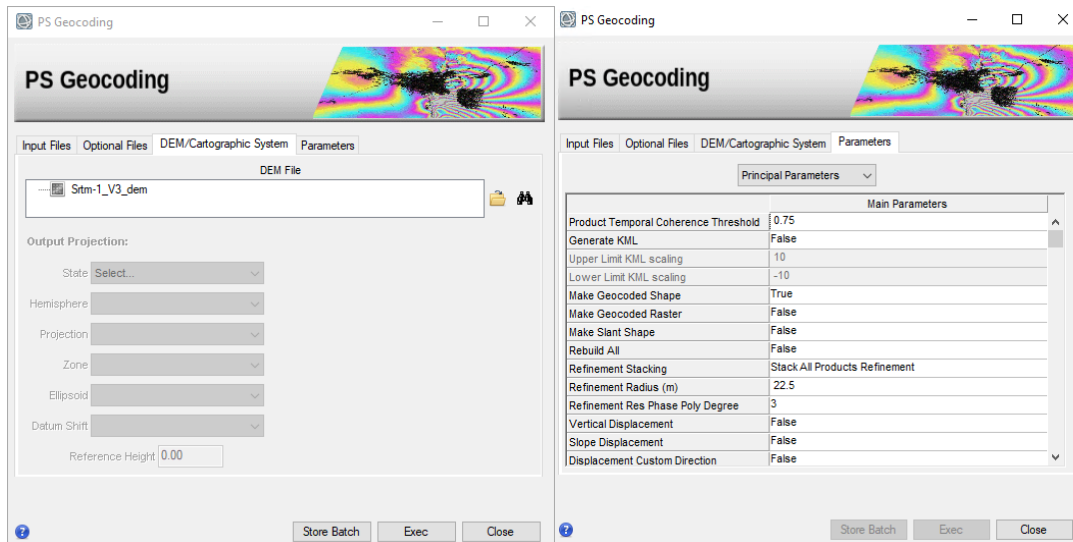
Figure 10 Geocoding panels.

Output

The **geocoding folder** includes:

- .shp: Shapefile of the PSs with the associated files (.shx, .dbf and Google Earth .kml). If the number of points is larger than the "Shape Max Nr of Points" defined in the Persistent Scatterers Parameters several shapefiles are created. The file name is created as follows: *_PS_XX_Y.shp where XX is the decimal part of "Product Coherence Threshold" (0.XX), Y is an incremental number in case of more than one shapefile and * is the output root name chosen in the connection graph step.

Field description of the generated shape file:

- -velocity: mean velocity of the displacement for each pixel in mm/y
- -coherence: multi-temporal coherence, it is a quality index for the best fitting of interferometric phase date by date
- -MuSigma: it is the amplitude dispersion index, it is the mean/standard deviation ratio, where mean corresponds to a temporal mean
- -Hprecision: it corresponds to the estimate in meters of the height measurement average precision. It is computed considering the acquisition spatial baseline and the multitemporal coherence
- -Vprecision: it corresponds to the estimate of the velocity measurement average precision in millimeter/year. It is computed considering the acquisition temporal baseline and the multitemporal coherence
- -range: pixel coordinate
- -azimuth: pixel coordinate
- SubArea: SubArea Id
- -lon/ lat: geographic coordinates
- -xpos/ypos cartographic coordinates based on the DEM reference system
- -zpos: elevation in m based on the DEM ellipsoid model
- -Z: Elevation based on the geoid component
- -ALOS: Line of Sight Incidence angle on Azimuth direction
- -ILOS: Line of Sight Incidence angle on vertical direction
- -Hcorrection: it corresponds to the correction (in meters) with respect to the input Digital Elevation Model.
- -D_date: displacement acquisition date in meters.

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- PS_disp_geo_XX_meta: This meta file is created if "Make Geocoded Raster" is selected. It contains the following files called *_PS_XX_cc_geo, *_PS_XX_vel_geo, *_PS_XX_height_geo (for coherence, velocity and height residuals), PS_ALOS, PS_ILOS, and data_XX_disp_geo (date by date).* is the output root name chosen in the connection graph step. while XX is the decimal part of "Product Coherence Threshold" (0.XX).
- mean_geo: SAR Intensity average image and associated header files (.sml, .hdr).
- Ref_GCP_geo, shape file corresponding to the Reference Points of the highest MuSigma values (i.e. those used for the phase offset removal) automatically selected during the step 1.
- SubAreas_geo, shape file corresponding to the sub areas estimated according to the "Area For Single Reference Point" parameter.

Time Series Analyzer

A plot, showing the extracted displacement information for a selected PS, can be created using the /SARscape/General Tools/Time Series Analyzer/Vector (in case the Make Geocoded Shape was selected in the Geocoding Step) or /SARscape/General Tools/Time Series Analyzer/Raster Analyzer (in case the Make Geocoded Raster was selected in the Geocoding Step). In this tutorial, only vector results are taken into account.

To analyze the displacement time series of a specified PS, load all the *.shp* results as well as the *mean_geo* image in ENVI.

Once a *.shp* is selected in the layer manager, the right click allows to set it as the active layer to display the time series; the Time Series Analyzer/Vector tool can be run.

The data range has to be set in the panel, the Color Apply button allows displaying the data range on the PS shapefile. Once the desired PS is selected, click on "*Plot Time Series*" in order to open a Plot showing the displacement temporal evolution.

Please note: clicking with the secondary mouse button on a different *.shp* file in the Layer Manager and selecting "*Set as active layer*" allows to change the active layer. This can be done even leaving the SAR *TS Vector Analyzer* window open.

TIPS

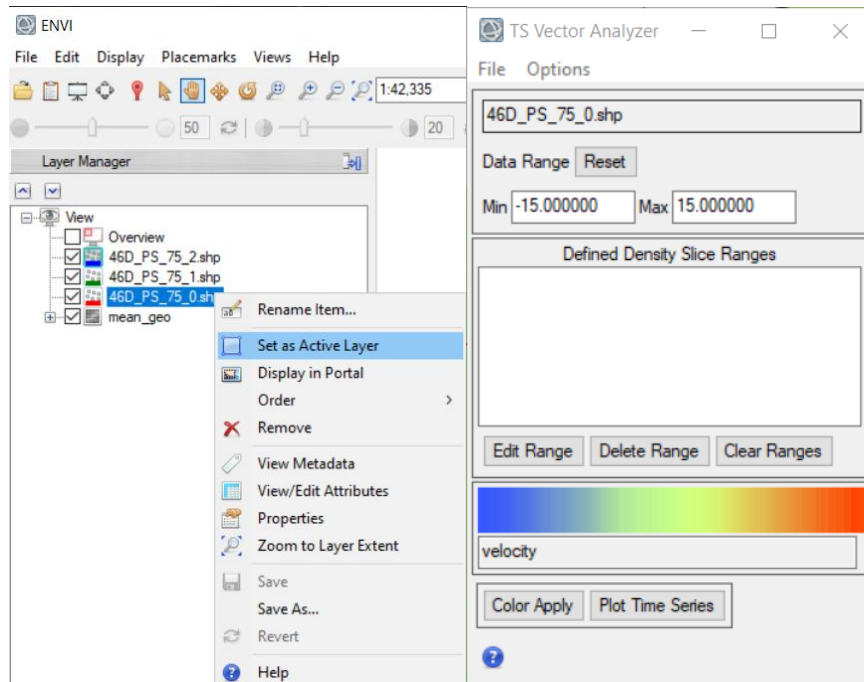Choose the same data range for all the different shapefile.

Figure 11 Time Series Panel.

Results

The results of the PS processing in the Urayasu area can be seen in the Figure below. The figure shows as the results are characterized by a widespread stable behavior (green areas). However, blue areas highlight a significant subsidence, mainly affecting the Tokyo Disneyland region and in the dockside.

The visualization color stretch in the area ranges between -15 mm (blue) and +15 mm (red). The red and purple place marks of the selected points show the location of the corresponding time series.

A unique plot shows that the Disneyland area is characterized by a cumulated displacement of about 30 mm. On the other hand, the inland area can be considered stable, since values are swing around zero.
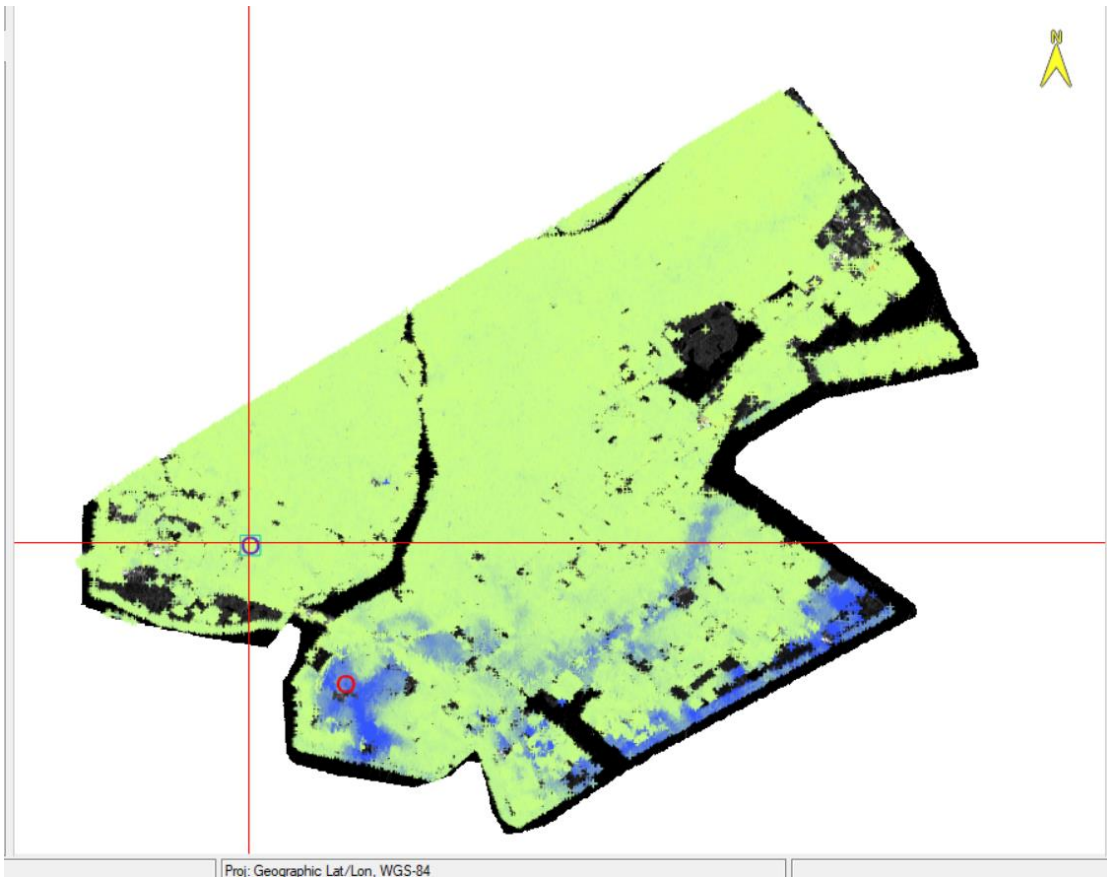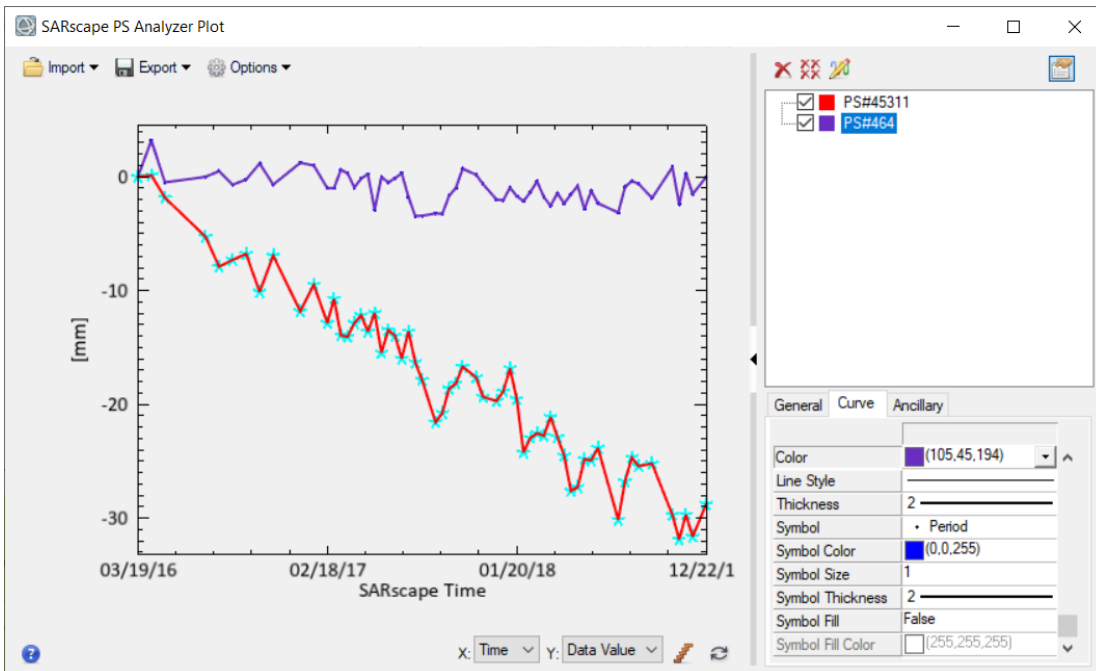
Figure 12 PS results in the Urayasu area.

Figure 13 Time series plot of the selected points.

It is worth to mention that, due to limitation on the shapefile format, it cannot exceed 2 GB, thus allowing approximately 70 million point features at most. For this reason, PSs points are split into different shapefiles.

Moreover, depending on the video card, the use of a remote desktop connection does not allow showing different colors on the shapefile. To remedy this limitation, please connect directly at the remote location and reboot the machine or copy the results on a local computer.