GCP Manual

Version 1.1

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Introduction

The principle of the Ground Control Point (GCP) is to have punctual location over a defined scene. The software is then capable to read a GCP file (xml, shape or ASCII), take values on images on these locations and use them for processes such as: *Orbital Correction*, *Geocoding*, *Interferogram Flattening*, *Persistent Scatterers* and others.

The use of the Ground Control Point file is foreseen (as possible or mandatory) in different processing steps; their number and position depend on the specific SARscape functionality where they are used (refer to the relevant Technical Note).

The GCP creation workflow is executed in three steps:

1. **File Selection** - the following images are entered: i) "Input File" where the GCP is placed; ii) "DEM File" (optional) to retrieve the GCP elevation; iii) "Reference File" (optional).
2. **Select GCPs** - this is where the GCPs are actually inserted and moved/modified. This panel provides: i) the point selection interface ("GCPs" tab); ii) the cartographic system definition interface ("Cartographic System" tab); ii) the output format definition interface ("Export" tab).
3. **The GCP creation** process is completed by clicking the "Finish" button. Note that this action will close the GCP interface; it is possible to save the GCP file and to leave the interface open by clicking on the "*Save GCPs*" icon.

Note It is not possible to associate different Cartographic Systems to different points of the same GCP file.

Note If the input "DEM file" is used, its Cartographic System will be the reference for all GCPs inside this file. If no "DEM file" is insert and the input file is geocoded, the input file will define the cartographic system.

Note To ensure the compatibility with SARscape modules, it is recommended to use always the XML or Shape format for GCPs instead of PTS file.

Quick start and basic functions

GCP selection

To start creating a GCP file, open the "*Create Ground Control Point*" tool, found in SARscape "*General Tools*" (Figure 1 left). Once the panel has opened, insert the Input file (mandatory), the DEM file (optional) and the reference file (optional) (Figure 1 right).

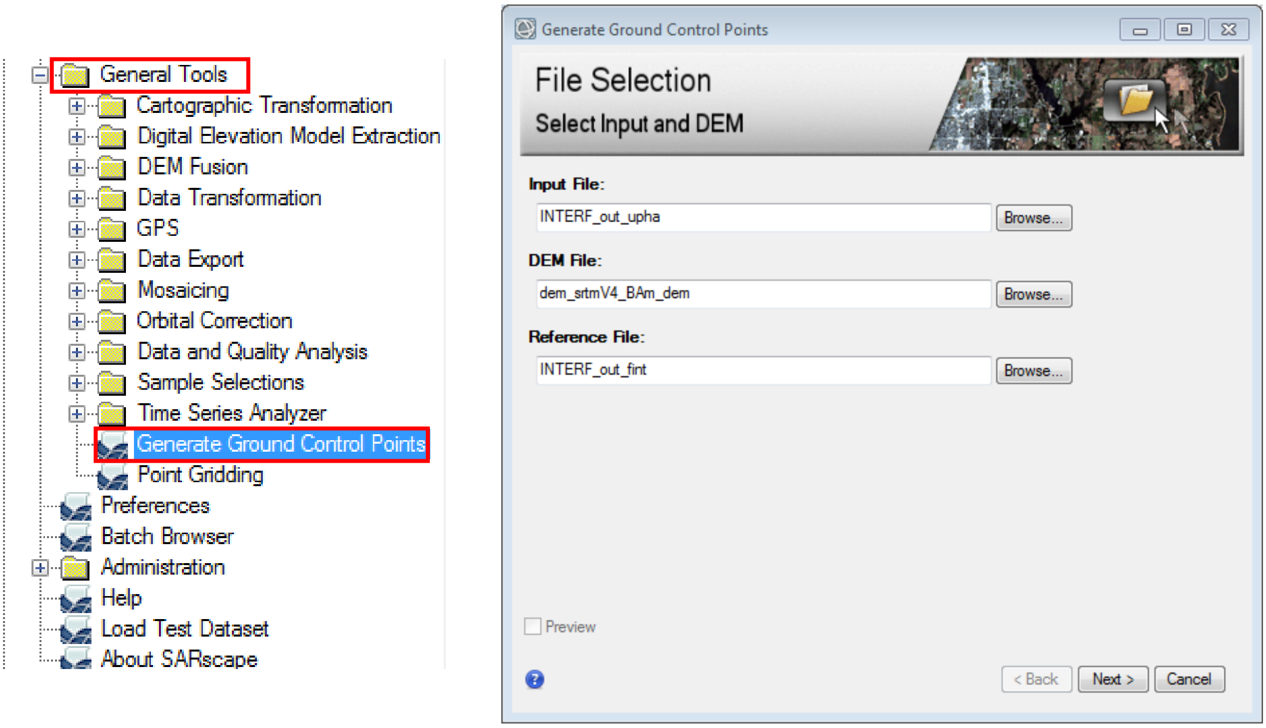

Figure 1: Location of the *Generate ground Control point* panel in ENVI/SARscape toolbox (left) and its *select input* section (right).

At this point, the input file (and the reference file, if selected) is displayed and it is possible to select points on the image simply by clicking in the desired location. Figure 2 shows the GCP creation environment in ENVI. When the selection of the GCPs has ended, then the GCP xml file can be exported giving the path and filename in *"Output XML file"* in the "*Export Tab"*.

Click Finish to create the GCP xml file in the selected location.

In addition, specific functions can help in certain tasks:

-  : Delete GCP, the selected GCP is removed
-  : Delete all GCPs, all GCPs are removed
-  : Load GCP, an existing set of GCPs (.xml and .shp) can be entered
-  : Save GCPs, the existing GCPs are saved

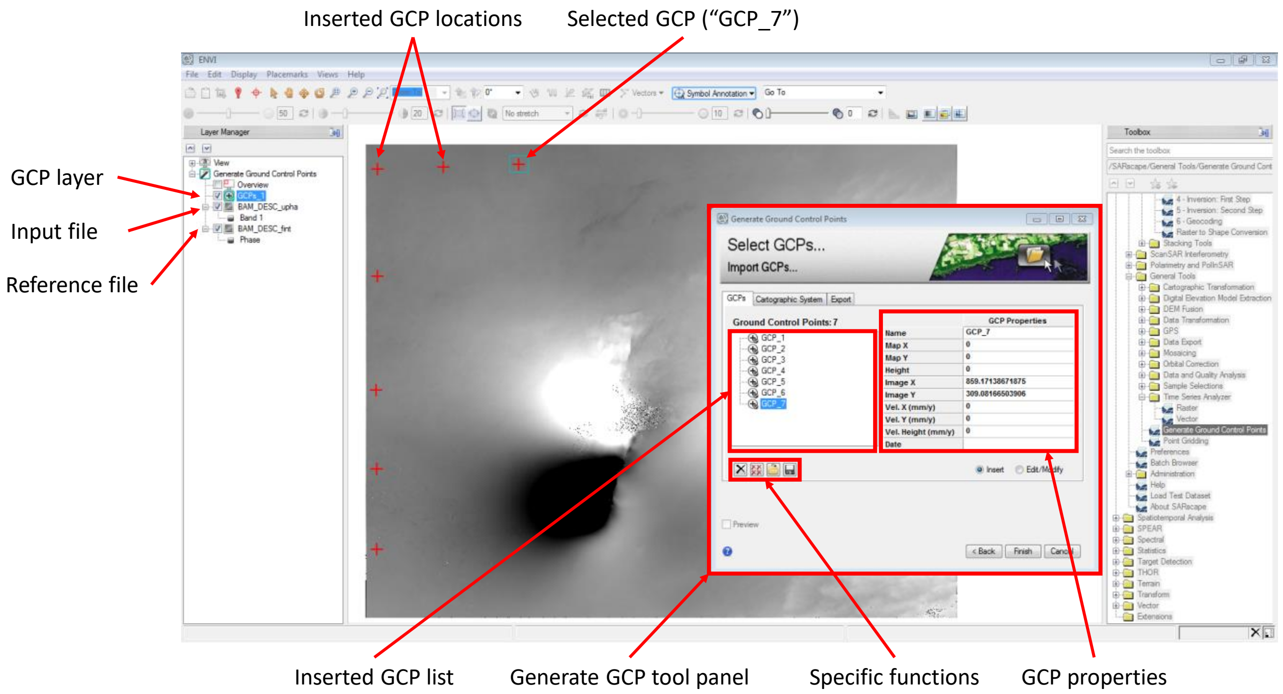

Figure 2: GCP selection environment.

Note During the acquisition of GCPs, all images that are present in the Layer Manager are temporarily hidden and all the tools in the toolbox becomes inactive (grey shaded).

GCP properties edit

During the creation of the GCPs, it is possible to add and modify information about a given point such as name, velocity and date (Figure 3). If an already created point should be edited or modified, click on the "*Edit/Modify*" radio button so that it is possible to select the points directly on the image. Otherwise, it is also possible to click its name on the GCPs list. When a GCP is selected, it can be moved in position. If it is desired to add new points again, select the "*Insert*" radio button (Figure 3).

It is possible to modify an existing GCP xml (or shp) file as well. Simply launch the *"Generate GCPs tool"*, choose input, reference and DEM file and then use the load function . The GCPs can be modified in the same way.

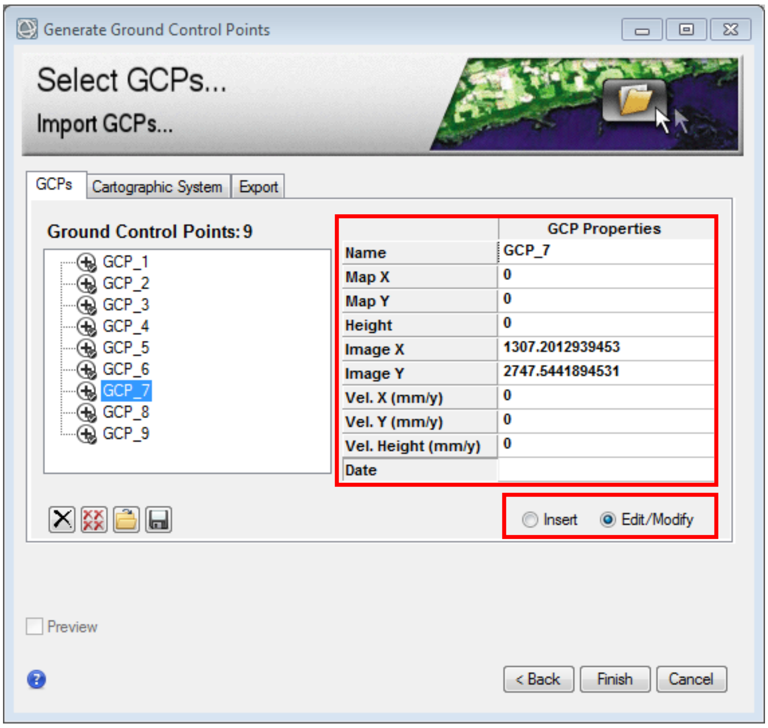

Figure 3: Section where the GCP properties can be modified and radio-button to switch between *insert* and *edit/modify*.

Velocity parameters are entered only when the GCP file has to be used for interferometric related processing, in particular for displacement mapping. The GCPs come from measurements, typically collected during ground truth campaigns, which must be entered here as velocity units (mm/year). In case the collected information is available in metric units (e.g. millimeters or centimeters) instead of velocity, it must be transformed by considering the time interval between master and slave acquisition.

As an example, a co-seismic displacement of 50 cm for an interferometric pair acquired at 35 days distance will correspond to a velocity of around 5214 mm/year (500÷35*365).

It is important to note that these velocity fields can be associated only to GCPs whose location is provided in cartographic co-ordinates (i.e. "Map X", "Map Y" and optionally "Height"); vice versa, these fields are not taken into account when the GCPs location is entered as file co-ordinates (i.e. "Image X" and "Image Y"). If this parameter is not provided the GCP displacement velocity is set to zero (stable point).

Information about the insertion of these data can be found in the proper chapter at page 25.

GCP file structure (xml format)

A GCP xml file contains several areas inside the <GCP_FILE> field. The information of each single GCP is located inside the <GCP> field. Depending on the geometry of the GCP acquisition and its type, the fields can vary. In general, the fields contains info about the cartographic system, the coordinates (slant range or geographic), velocity and looks (for slant range geometry). To view or modify the GCP xml file, open it as text file with a text editor or a code editor such as Notepad++.

Geometry GCP

In case of inaccuracy in the satellite orbits or in the Digital Elevation Model geolocation, a Ground Control Point (i.e. "*Geometry GCP file*") is required to correct the SAR data (i.e. master acquisition of the interferometric pair) with respect to the reference Digital Elevation Model. Geometry GCP can be used in Manual Orbital Connection, at the beginning of interferometric process and in geocoding.

Tip If the study area is characterized by a "pronounced" topography, it is possible, instead, to use the *"automatic orbital correction"* that exploits the DEM to correct the input image and no GCPs are needed.

Note The *"Create GCP"* tool for Geometry GCPs can be launched directly with the binocular button that can be found in several panel such as *Interferogram Generation* panel (Figure 4), *Stereo Matching Process* panel, *MAI Interferometric Process* panel, *Amplitude Tracking Process* panel, *Dual Pair Differential Interferometry* panel and *Geocoding* panel.

Note It is not possible to insert *Geometry GCP file* in the interferometry workflow processing.

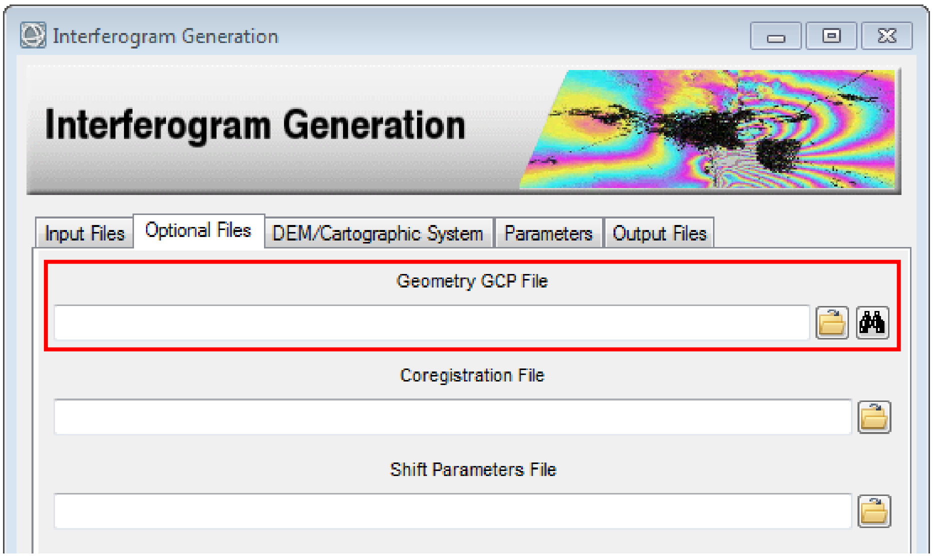

Figure 4: Geometry GCP input in the "Interferogram Generation" panel.

Manual Orbital Correction tool

Sometimes, problem in the orbit data, lead to small shift when a SAR image is geocoded. This means that the same coordinate falls not on the same feature on the geocoded SAR image and the reference Image (Figure 5); the red cross indicates the same coordinate on both images.

Figure 5: Red cross, indicating the same coordinate, falls on the wrong location on the geocoded SAR image (left) in respect to a reference optical image (right).

Depending on the availability of a good reference image of the study area, mainly two approaches can be chosen. These approaches are explained in the following sub-chapters.

Orbital Correction with Reference image

If a reference image is available (such as a high-resolution optical image), this approach can be chosen. To start the correction open the Orbital Manual Correction tool located in *General Tools>Orbital Correction>Manual Correction*. Please insert in *Input File*, the image that should be corrected (in slant range). Then click on the binocular button in order to create the necessary GCP file (Figure 6).

The binocular button will launch the *"Generate Ground Control Point"* tool with the input file already loaded. The DEM and the reference file have to be manually inserted. Clicking on the *"Next>"* button, the two images will be opened in ENVI. On the left-hand side, the image to be corrected, on the right-hand side, the reference file (Figure 7).

At this point, a unique feature that can be seen and recognized in both images should be found. For example a building or a crossroad. In this example, the center of the crossroad has been chosen. Click on this feature on the reference image (right side of the screen) and ENVI will automatically plot the equivalent point in Slant

Range (on the left side of the screen). This point will not be correct projected because of errors in the orbital information (Figure 8).

At this stage, a GCP will be shown in the GCP list (Figure 9); click on it in order to be able to modify this GCP, or select the Edit/Modify radio button and then select the GCP on the image. The correct slant range coordinate can be insert manually or the red "plus" can be moved to the correct location (center of the crossroad) as shown in Figure 10.

Note Because of the slant range geometry, descending data are flipped west-east and ascending data are flipped north-south. Therefore, attention should be paid by looking at the same feature in both images.

Once both crosses are projected on the same feature click *"Finish"* in the *"Create GCPs"* panel. This will insert the created GCP file in the Orbital Correction panel. Click on *"Exec"* to run it and correct the image. The corrected slant range image can now be geocoded and there will be no shift (Figure 11).

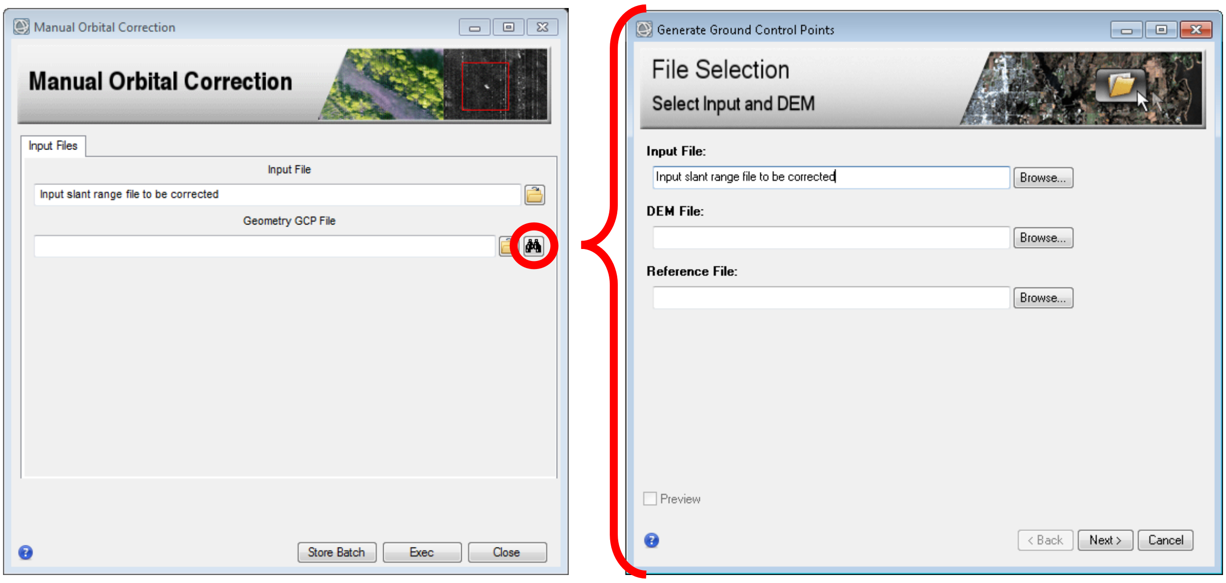

Figure 6: Manual Orbital Correction Panel (left) and Generate Ground Control Points Panel (right). In the Generate GCPs panel, the input file is automatically insert. DEM file and reference file have to be manually insert.

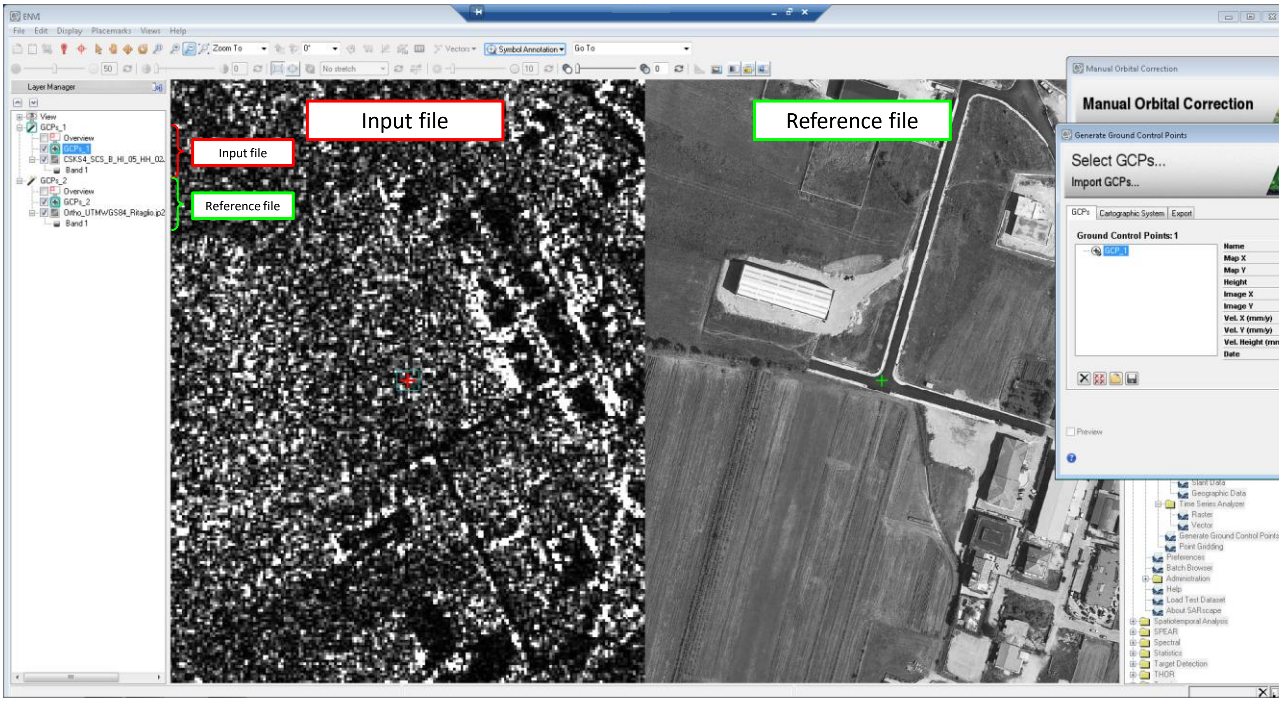

Figure 7: Generate GCP environment with two different geometries on two different views in ENVI. Right: High resolution optical image (reference file), left: slant range image that has to be corrected (input file). Note: the two separate GCP tree structure in the *"Layer Manager"*.

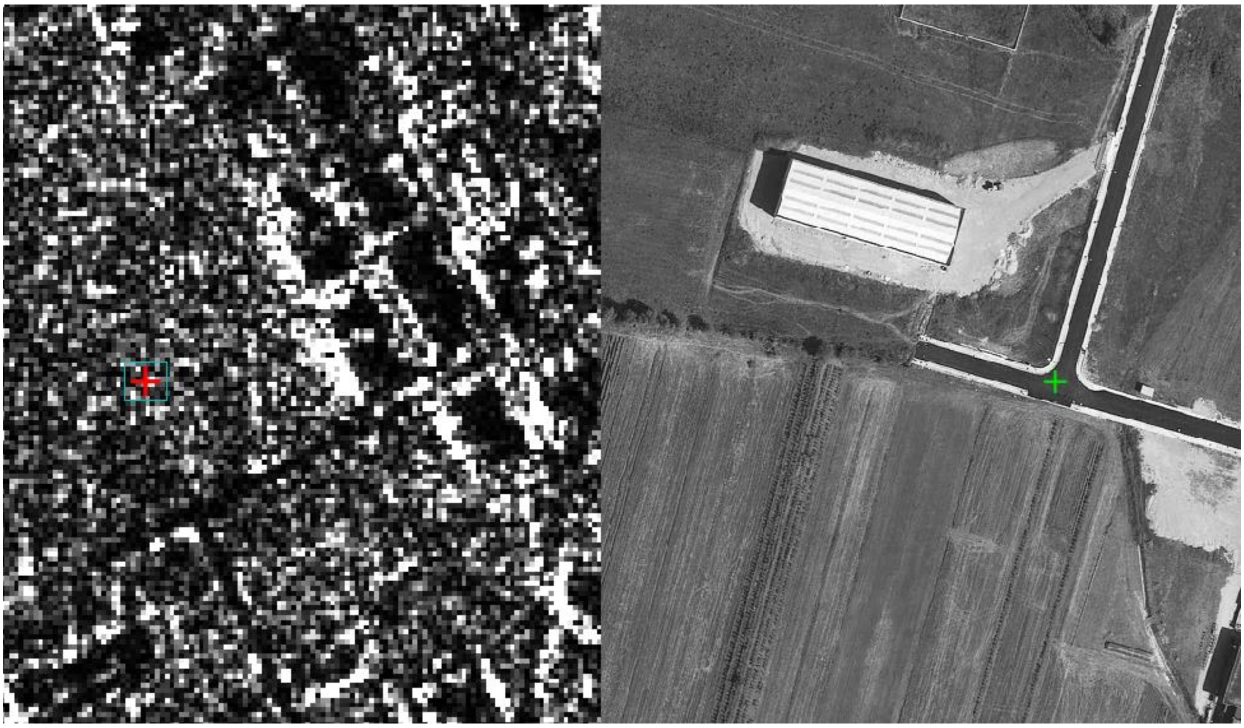

Figure 8: Center of the crossroad on the high resolution optical image (green "plus", right) and its wrong projection on slant range image (red "plus", left).

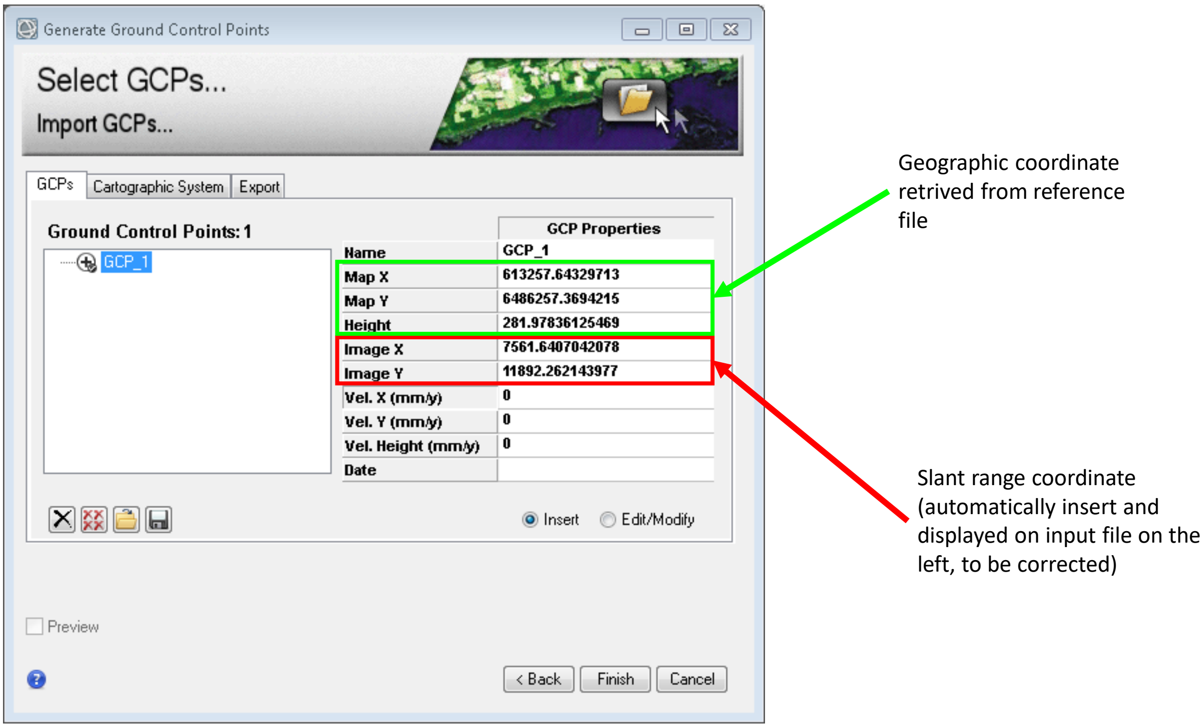

Figure 9: Created GCP in the Generate Ground Control Points panel.

Figure 10: Change of position of the red "plus" on the slant range image (left) from the wrong to the correct position, in order to match the same location of the reference image (green "plus", right).

Figure 11: Red cross, indicating the same coordinate, falls now on the SAR image (left) on the same correct location as on the reference image (optical, right).

Orbital Correction with known coordinates (without Reference Image)

Basically, this kind of approach works in the same way as with a reference Image, described in the subchapter above. In this case only the image to be corrected will be insert in the *"Generate Ground Control Points"* panel. A feature with known coordinate should be found and a GCP should be created on it. Then, the correct coordinate (Latitude, Longitude and Altitude) can be insert (Figure 12). Clicking on *"Finish"* will then insert the GCP file in the Orbital Correction Panel. Click *"Exec."* To run it and correct the slant range image.

Note If the input file is in slant range, and no "DEM file" is insert, the Cartographic System of the coordinates insert in the GCP Properties have to be insert in the proper *"Cartographic System"* tab. If the DEM has been insert, the coordinates have to be in the same Cartographic System.

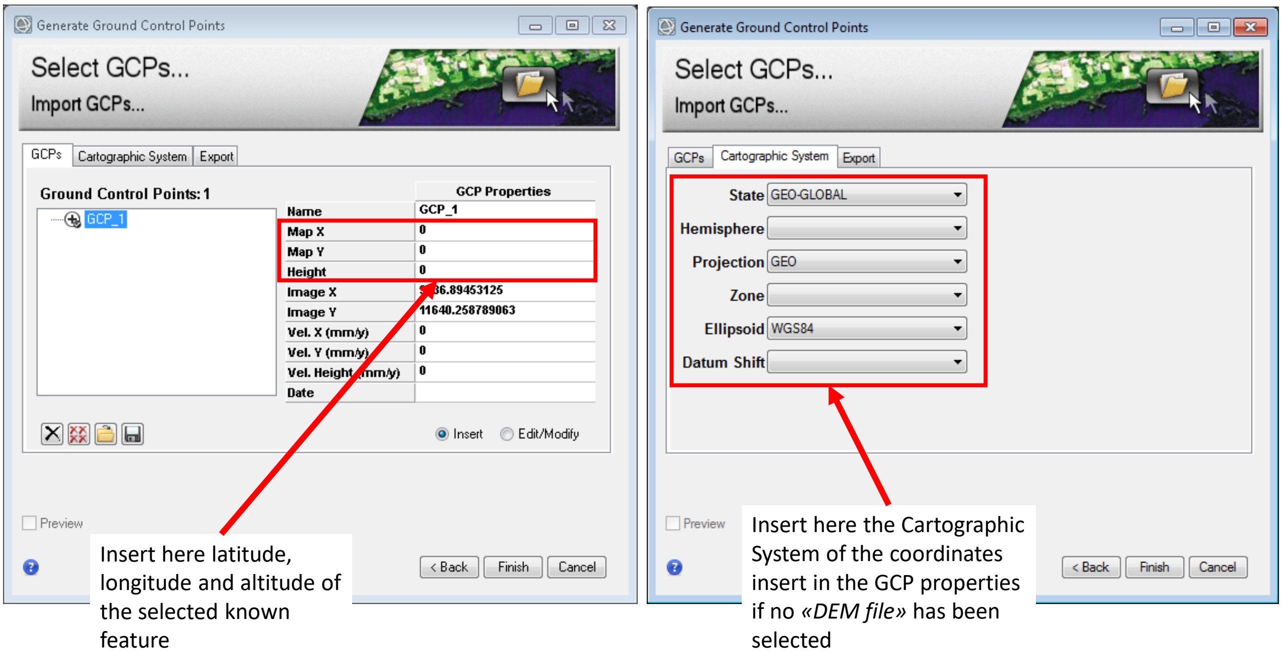

Figure 12: GCP created on a known feature. Coordinates and altitude should then be insert in the GCP Properties, its Cartographic System has to be chose in the proper tab if no DEM file has been selected.

Refinement GCP

Phase Processing (interferometry)

The refinement GCP file is a mandatory file required for the Refinement step during interferometry process. It is needed to retrieve phase and unwrapped phase in selected zones.

Ground Control Points for the refinement can be selected either in slant geometry (range and azimuth) or in geocoded geometry (x, y, h, where the h could be automatically retrieved from the input DEM from the GCP generation tool), but not in both geometries.

Typically, the GCPs are chosen in slant range. If the GCP are used for more overlapped tracks/frames as anchor points (Figure 13 shows two examples), they should be taken at their best in geocoded geometry, with a good coverage of the area where the adjacent tracks overlap. This is important in order to avoid offset values in phase between different tracks/frames in the same area. The software is hence able to internally perform a backward geocoding on the slant range geometry used during the refinement.

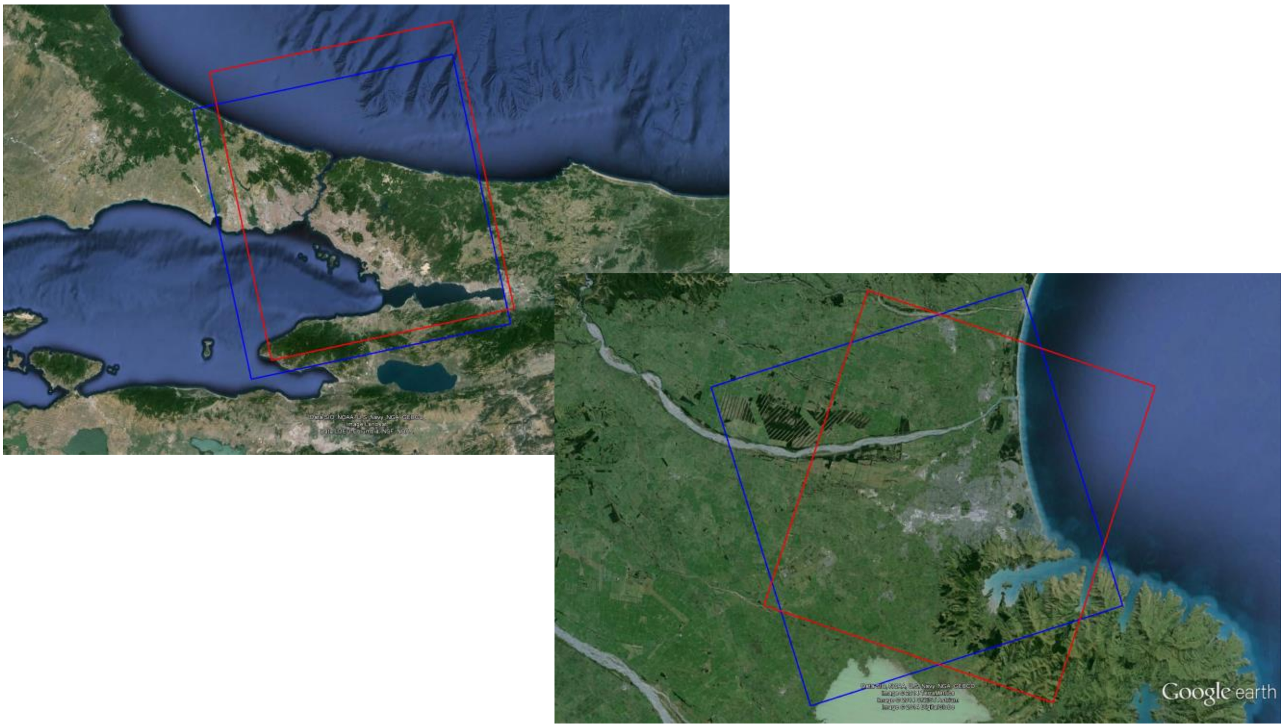

Figure 13: Examples of overlapping areas.

The most important criteria to select the GCP point's location on the unwrapped phase files are the following:

- There should be no high frequency residual topography fringes
- There should be no displacement fringes, hence remain quite far from the displacement area, if known. The displacement rate of the selected GCPs is considered to be 0, unless a known displacement rate is provided in input, as for example as resulting from external measurements (see proper chapter at page 25

- There should be no phase jumps corresponding to unwrapping errors. If a point is located inside an isolated phase "island", with poorly unwrapped value, it might be considered as part of a phase ramp and resulting in an overall wrong correction.
- If the fint shows systematic acquisition geometry errors (orbit imprecision), the GCPs should then cover the entire track/frame (always following the criteria listed above) in order to remove this effect.

Once the *Generate Control Points* tool, found in *General Tools*, has been launched, the following panel appears (Figure 14) where *_upha, _dem* and *_fint* files have to be insert. Afterwards, click *Next >* to continue with the GCP generation.

Note During interferometric workflows (for instance: *InSAR DEM Workflow*, *DInSAR Displacement Workflow*, …), or in general if the GCP is created with the binocular button, the three input files are automatically chosen if the paths are already insert in the panel.

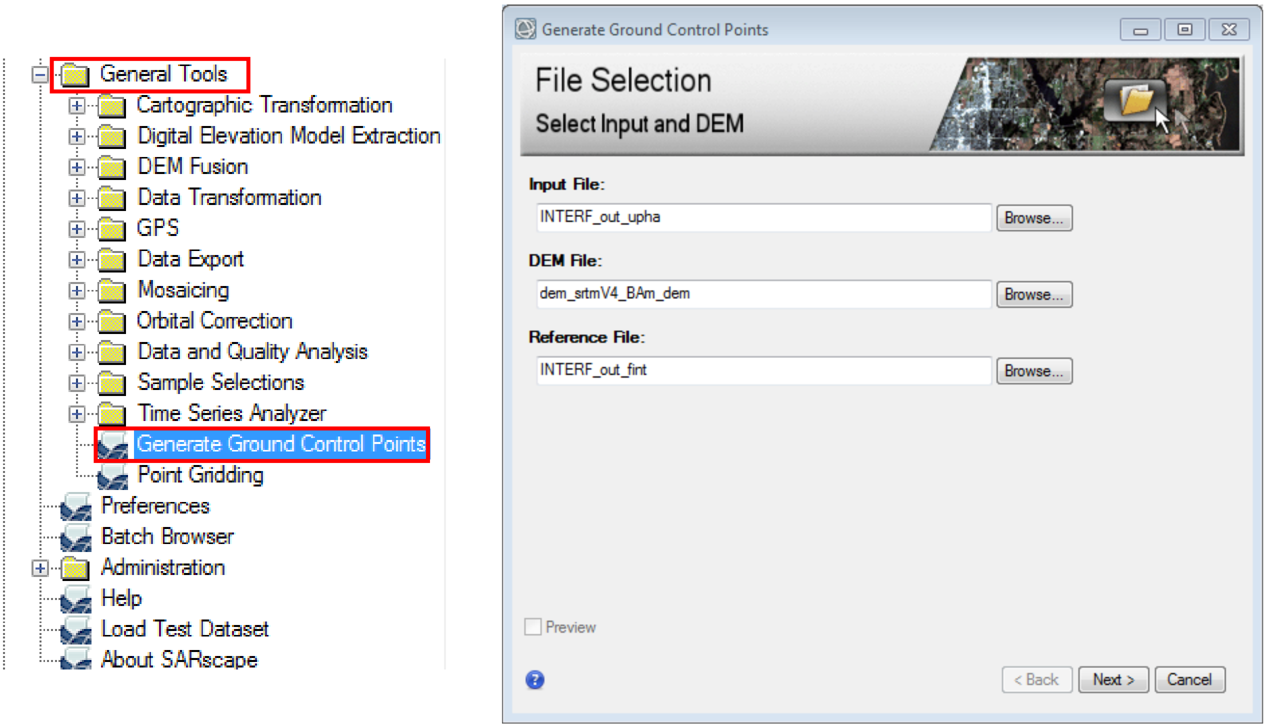

Figure 14: Generate Ground Control Points, File selection panel.

At this point, the GCP tool will open the *_upha* and the *_fint* images in ENVI. It is possible to switch from one image to the other in the same way as during a normal ENVI session using the checkboxes on the left side of the file name in the *Layer Manager* (Figure 15). Figure 16 shows how to change the color scale to the fint image in order to allow better understanding of the phase data.

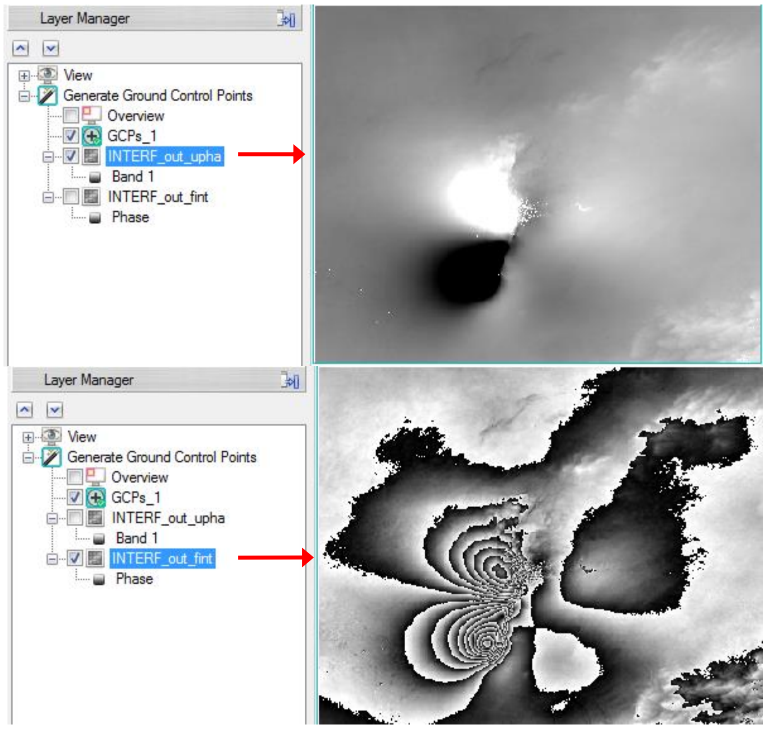

Figure 15: _*upha* (on the top) and _*fint* (on the bottom) images automatically opened by the GCP generation tool (here an example for *phase to displacement* processing).

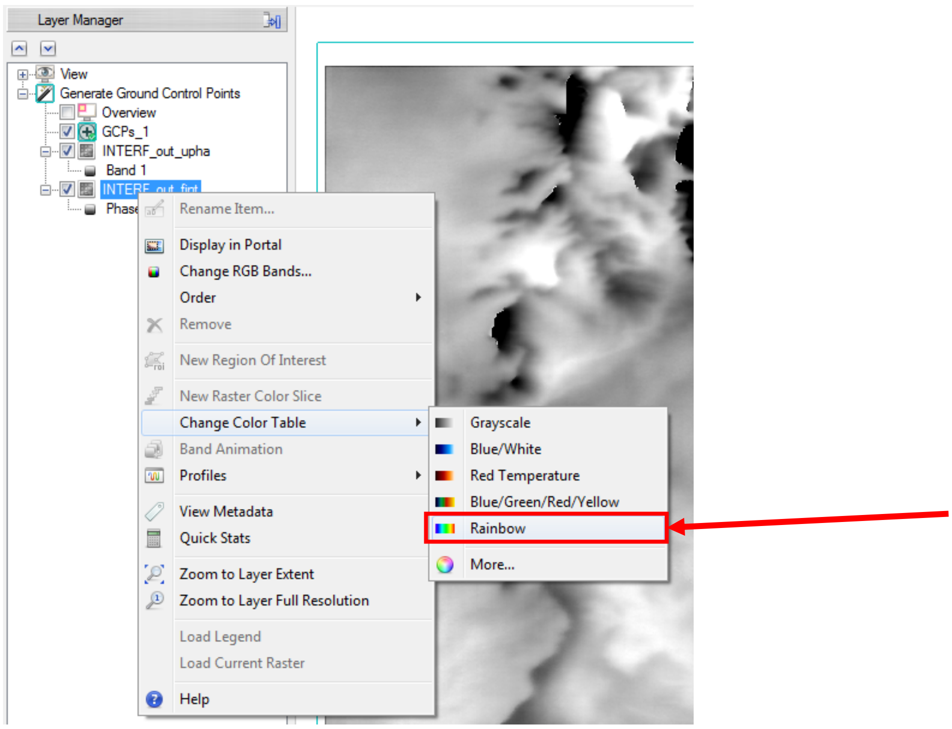

Figure 16: *Right mouse click > Change Color Table > Rainbow* allows to better visualize and interpret the values of the fint image.

As stated before, a good way to choose the GCPs location is to look for a stable zone far away from movement fringes (Figure 22), phase jumps corresponding to unwrapping error and residual topography fringes. Well flattened areas (homogeneous color on fint) are good candidate zones for GCPs, in addition several points distributed on the whole scene are needed for DEM creation and to remove systematic acquisition geometry errors (orbit imprecision). It is suggested to stay away from steep topography and residual topography fringes and it is recommended to select GCPs on the valleys bottom (Figure 17, Figure 18 and Figure 21).

Note In case of displacement analysis and with absence of systematic acquisition geometry errors (orbit imprecision), one GCP is sufficient (Figure 22).

Figure 19 (bottom, right) shows an example of unwrapping error. In fact, if a profile along the phase jump is drawn Figure 20, it can be noticed how in this case the jump measure exactly a 2π cycle.

If it is planned to process the same study area with different geometries (ascending and descending) or different sensors, it is suggested to geocode both *_fint* files and create the GCP using these two files so that the points are located over zones covered by both geometries (Figure 24). To do this, the *_fint* file of both geometries should be geocoded.

Note Attention should be paid in this process. Before starting with the GCPs creation, check that in the study area no unwrapping errors are present.

Examples in Figure 21 and Figure 23 show the effect of refinement step by mean of refinement GCP on orbital fringes. It is clearly visible how the pronounced phase ramp present on the left image is removed by the refinement step. In fact, by default the software handles all the GCPs as stable points and compute a phase component that has to be removed.

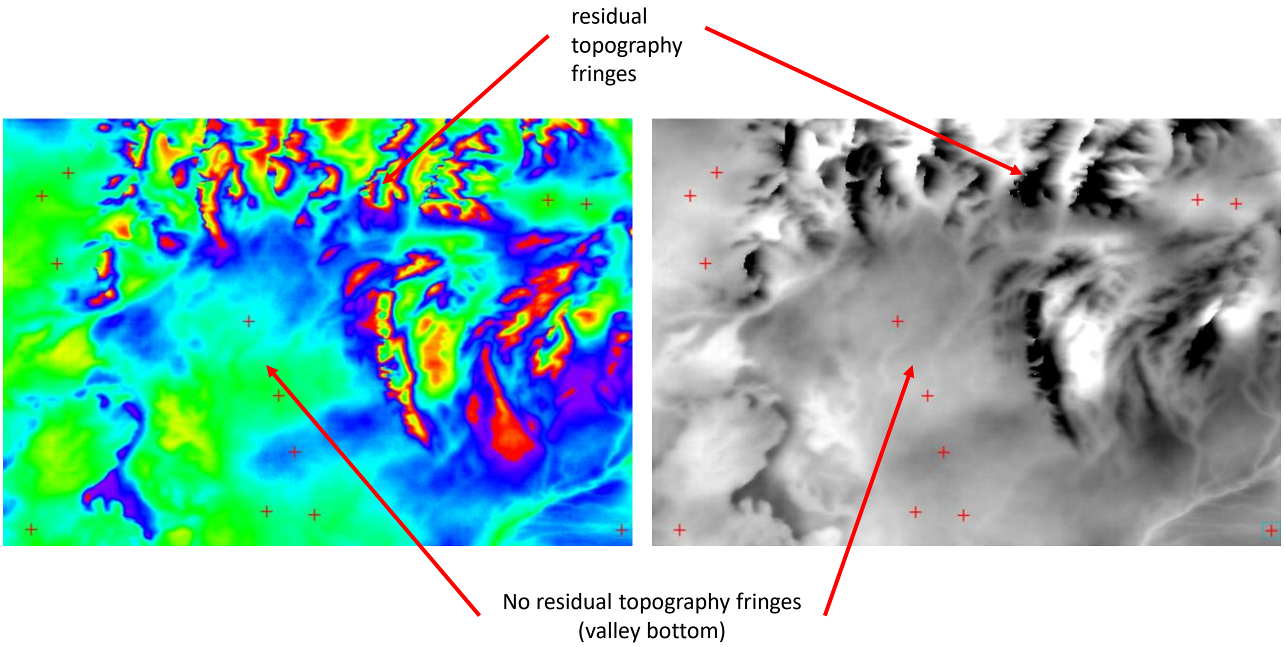

Figure 17: GCPs for *Phase to height* processing. GCPs (red "plus") are located far away from residual topography fringes and from mountain tops (left: wrapped phase _*fint*, right: unwrapped phase _*upha*).

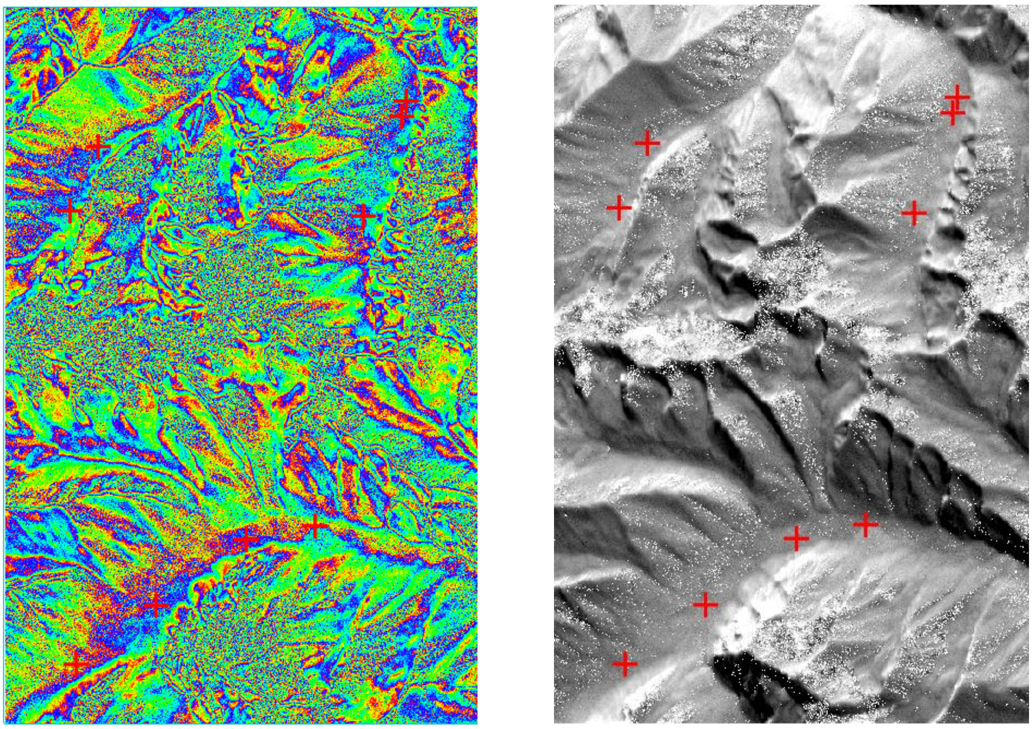

Figure 18: In this mountainous region, it is suggested to create the *Refinement GCPs* in the valley bottoms. _*fint* image on the left-hand side and _*upha* on the right-hand side.

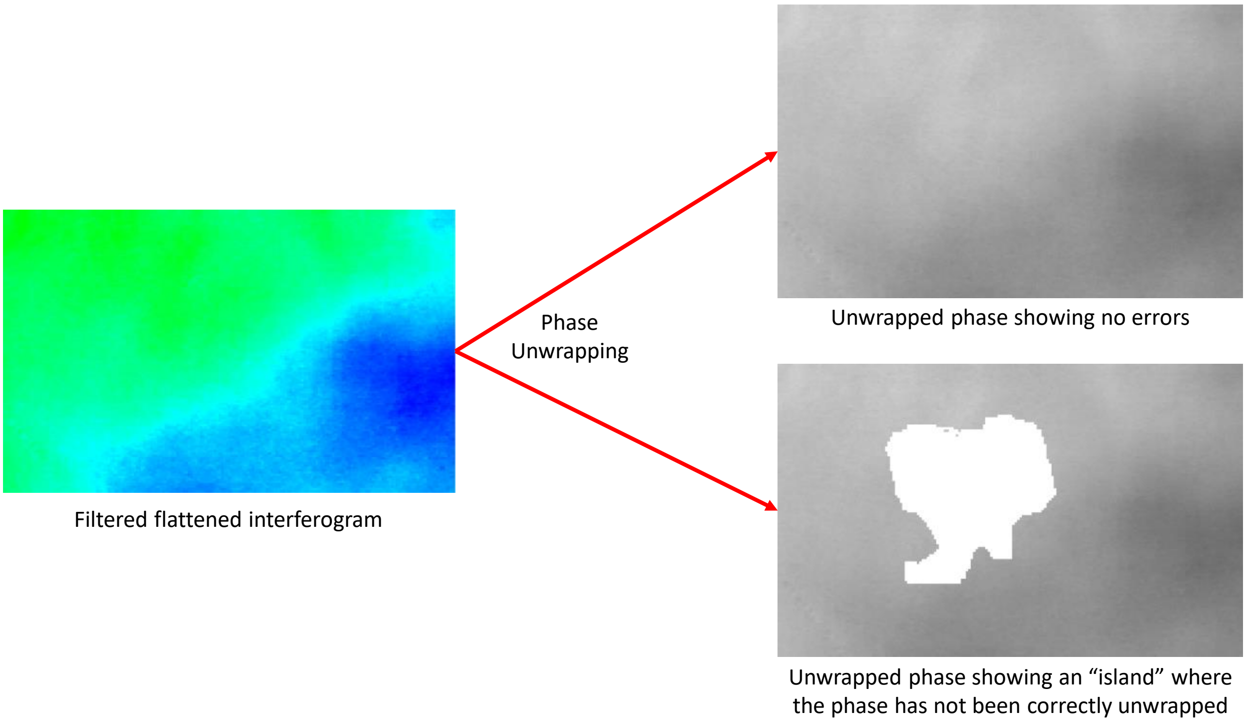

Figure 19: Example of poorly unwrapped data (bottom right), in opposition to good unwrapped data (top right).

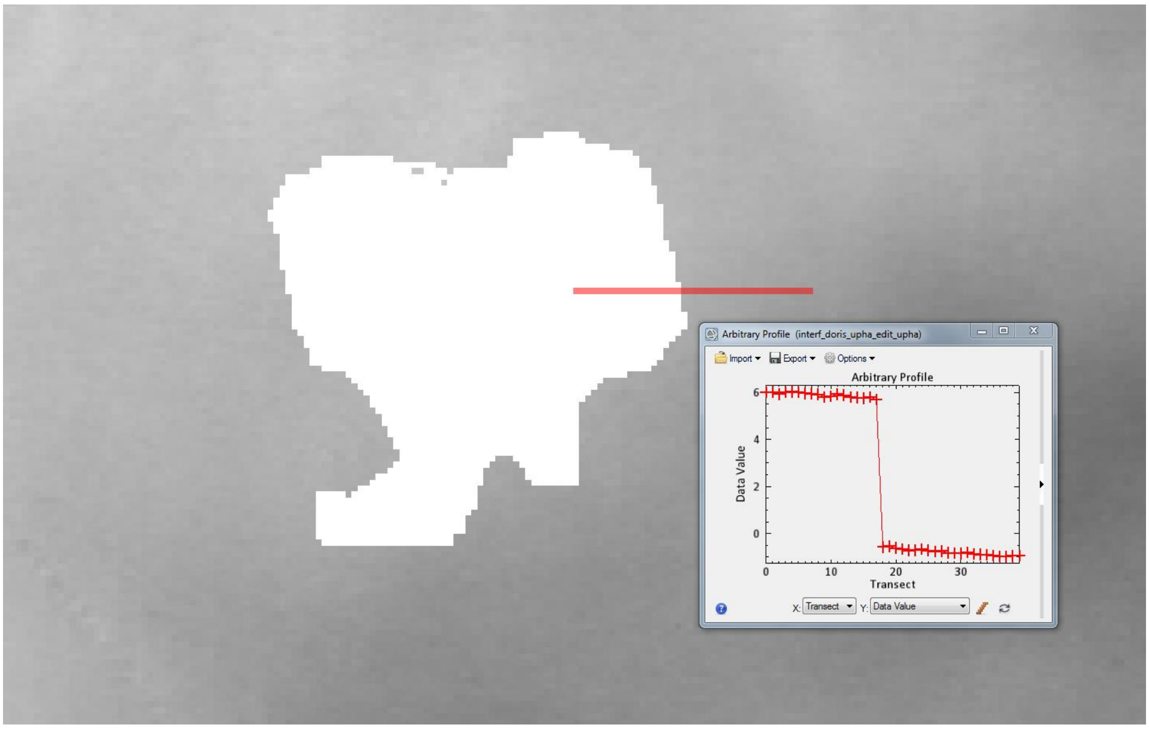

Figure 20: Profile crossing an error in the unwrapped phase _*upha*.

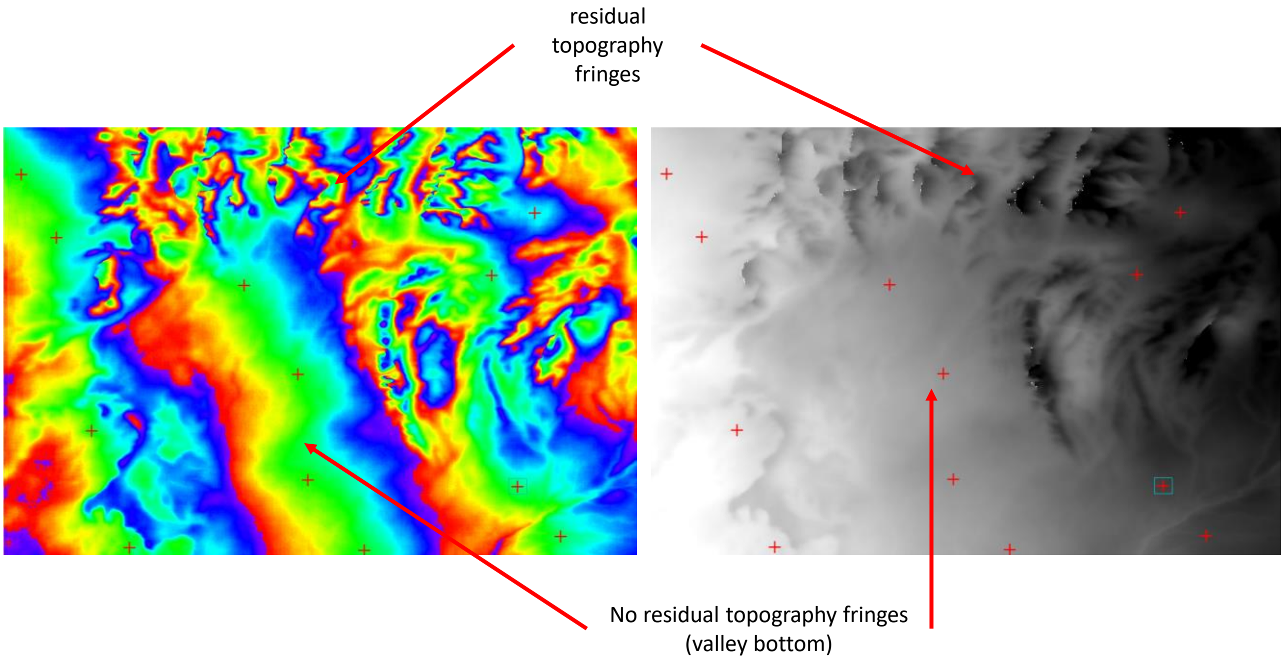

Figure 21: GCPs for *Phase to height* processing on data showing orbital fringes resulting in a phase ramp. GCPs (red "plus") are located far away from residual topography fringes and from mountain tops (left: wrapped phase _*fint*, right: unwrapped phase _*upha*)

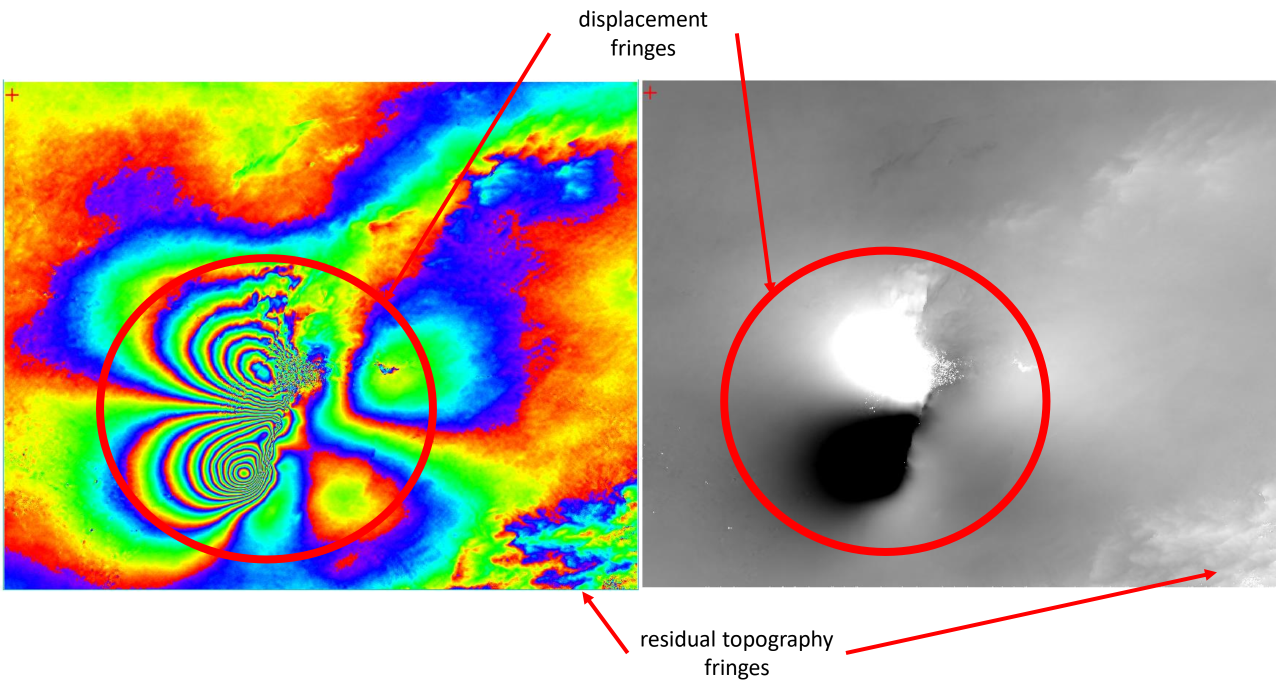

Figure 22: GCPs for *Phase to displacement* processing. The only GCP is located far away from residual topography fringes and from displacement fringes (left: wrapped phase _*fint*, right: unwrapped phase _*upha*).

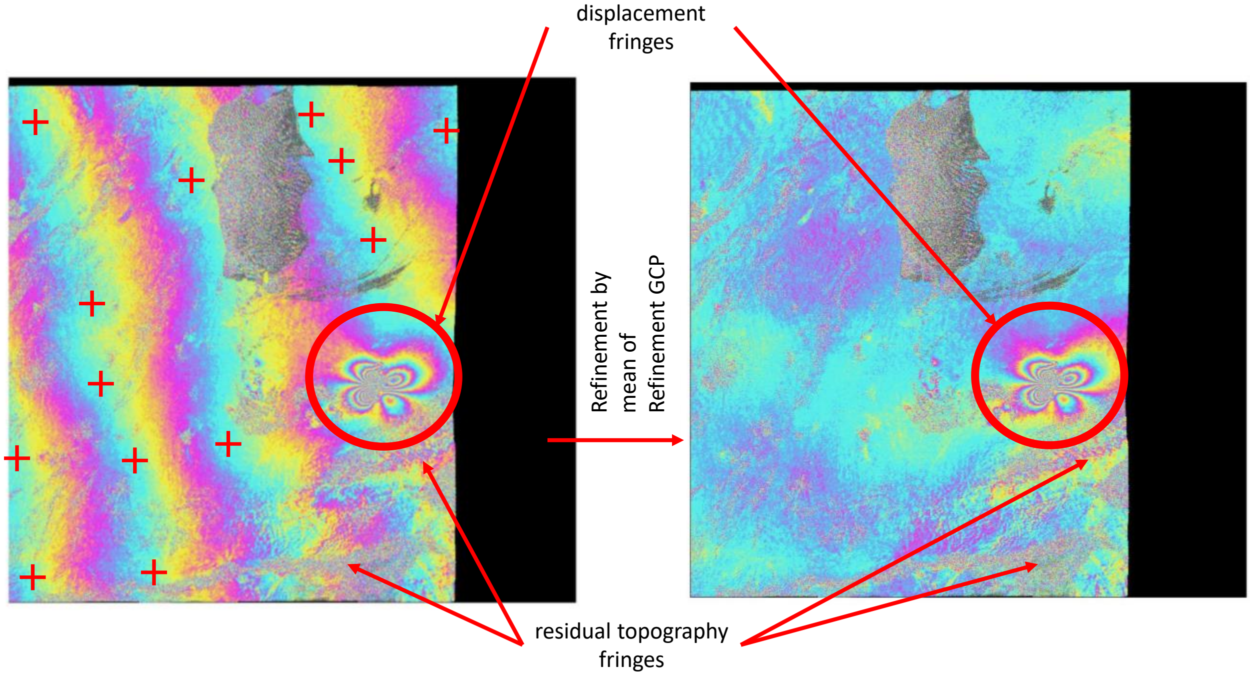

Figure 23: Example of orbital fringes removing on a flattened interferogram by refinement processing with Refinement GCP (red "plus"). In opposition to Figure 22, more than only 1 point are needed in order to remove the ramp.

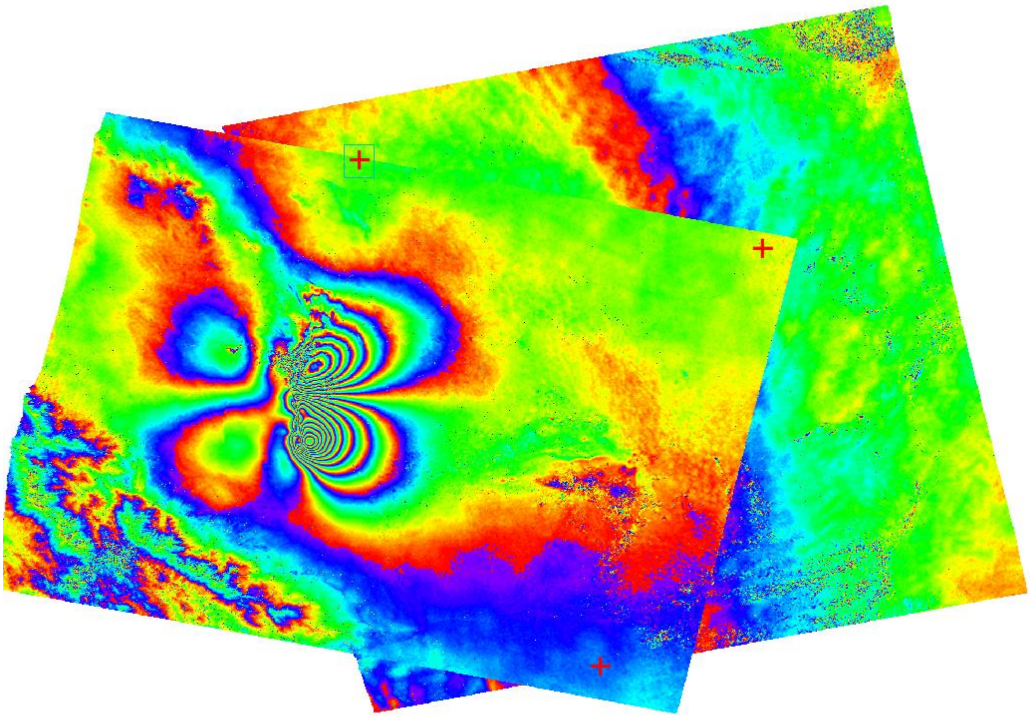

Figure 24: GCPs taken on geocoded *_fints* from descending (left) and ascending (right) geometries. The points are located in zones covered by both geometries and not affected by movement and residual topography fringes.

Tip When the Area of Interest is chosen, it is suggested to select a slightly larger area in order to be sure to have an area outside the displacement area so that it is more likely to select reliable GCPs.

Note For the orbital refinement, at least 7 (valid) GCPs have to be taken. If, instead, a Polynomial refinement has to be performed, the minimum number of Ground Control Points has to be equal to the "Residual Phase Poly Degree"; otherwise, the poly degree is automatically decreased accordingly. For more information, please refer to the *Preferences – Flattening* and *Interferometry - Phase processing - 4- Refinement and Re-flattening* chapter in the SARscape help.

In interferometric stacking

SBAS

The refinement and re-flattening are automatically performed at the beginning of the "Inversion: First Step", the "Inversion: Second Step" and the "Geocoding" steps. These operations are performed to estimate and remove the remaining offsets and ramps from the ingested unwrapped phase stack and from the slant range products before they are geocoded.

SBAS - Manual refinement and reflattening

The user can decide to do it manually by inserting the optional Ground Control Points (GCP) in the "Refinement GCP file". Before starting with the creation of GCPs, a screening of all the fint created by the interferometry step shall be done in order to identify movement zones in the study area. Then a screening of all the unwrapped phase shall be done in order to identify errors in the *_uphas*, these pairs must be removed (please see *edit connection graph* in the SBAS tutorial). It is quite difficult to locate GCPs that are all good for all interferograms of the stack. To start creating the GCPs, open a good *_upha* showing the movement zones as input file (Figure 25, left) and an *_upha* with low surface coverage as reference image (Figure 25, right) in the *create GCPs* tool panel and start create the GCPs. The points must be covered by both images and away from movement zones (Figure 26). Several points shall be insert in order to be sure to have enough valid GCPs because not all *_uphas* have the same spatial coverage. Figure 27 shows another example of GCPs selection and the effects on the reflattened images (Figure 28). The idea is to remove only an average phase or a phase plane where necessary. For this reason, it is suggested to use <u>always</u> the polynomial refinement method.

Tip A good "rule of thumb" for estimating the amount of GCPs is: the lower the spatial coverage, the higher the amount of GCPs.

Note It is recommended to not insert points with velocity values in the GCP properties, even if this velocity is known. Stay rather away from displacement zones and add these points with displacement data only in the "*Inversion second step*".

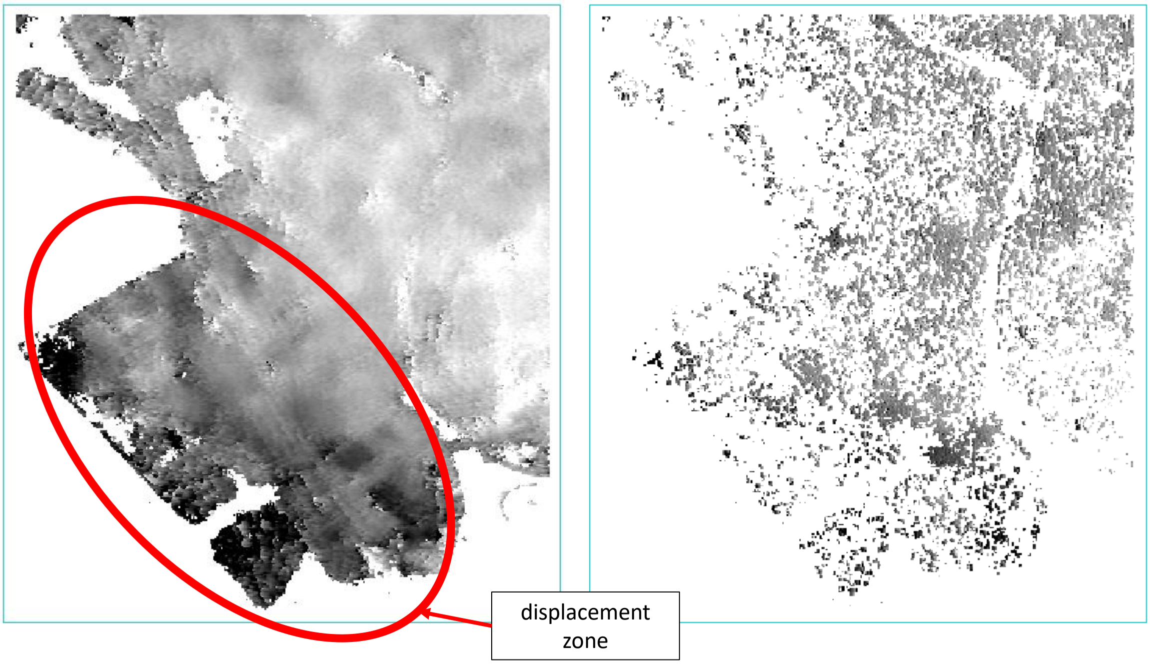

Figure 25: Two _*upha* of the SBAS interferometric process. On the left: a representative unwrapped phase image showing the displacement zones. On the right: an unwrapped phase image with low surface coverage. Using these two image as input and reference file in the GCP creation helps in staying away from movement zones and where no data are available.

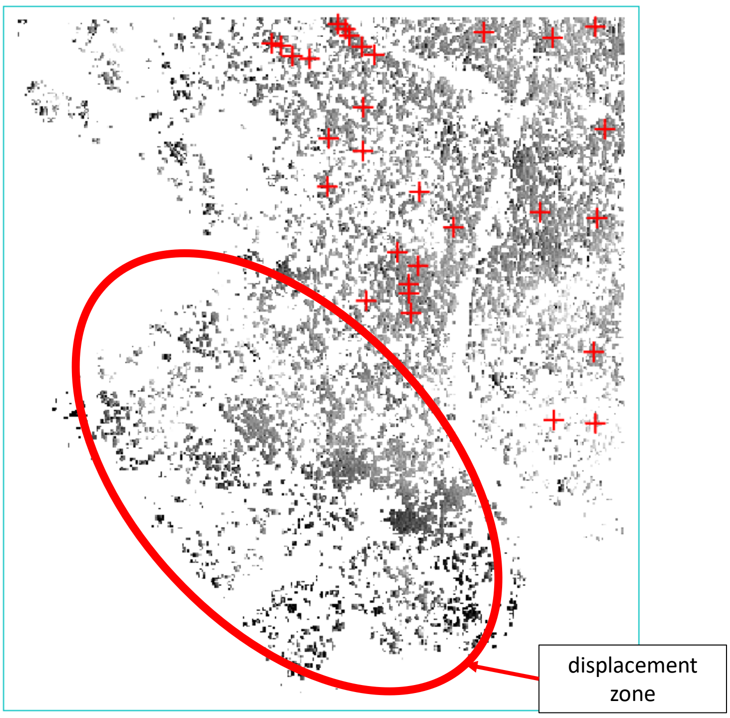

Figure 26: GCP selection on upha with low spatial coverage. The large amount of points allow to be sure not having too much points on "*Not A Number*" zone. Note how there is no GCP on the displacement zone.

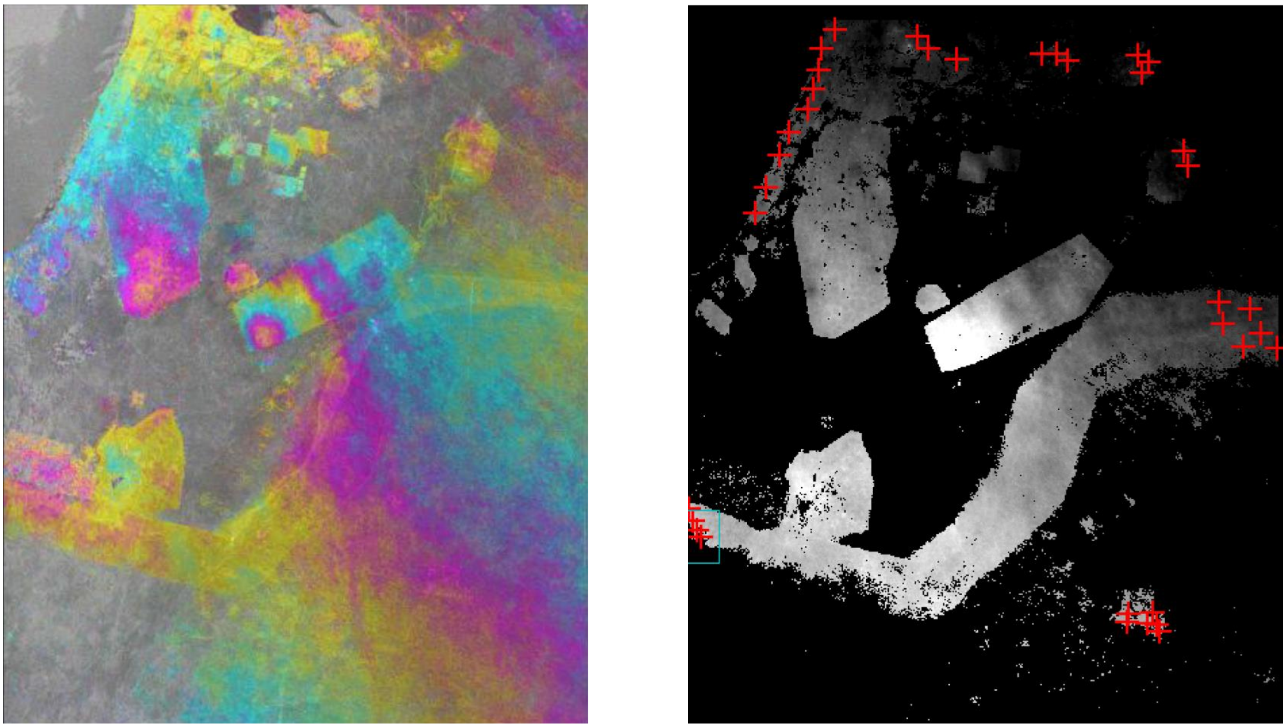

Figure 27: Flattened filtered interferogram (*_fint*) on the left and GCPs location over the unwrapped phase on the right. Note how the points are located far away from the displacement zone (in the center) and are well spread on the whole image in order to remove the phase ramp that is visible in the *_fint*.

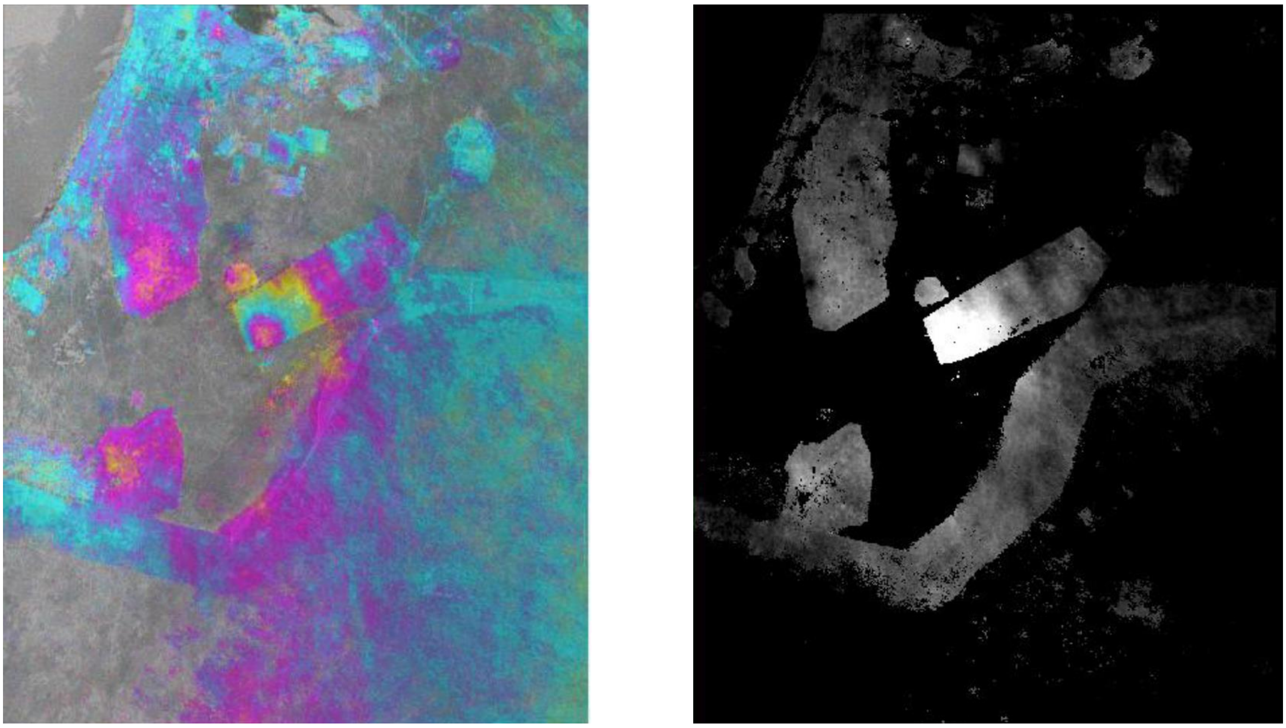

Figure 28: Wrapped (on the left) and unwrapped (on the right) interferogram after the refinement and re-flattening. The phase ramp has disappeared and the displacement pattern fully remains.

SBAS and PS "Geocoding" step

The Refinement GCPs file in this step is used to reflat the results. In case no ramps are left, a single GCP (one point) can be chosen to remove just a residual phase constant. All the final results will be referred to these GCPs and they could be called the anchor point(s).

If points with known velocity are available, it is possible to insert this parameter in the *GCP properties* (information about the insertion of these data can be found in the proper chapter at page 25).

Note It is suggested to create the *Refinement GCPs* in geocoded coordinate in order to be able to use them for both SBAS and PS processing, different geometries (ascending and descending) or different sensors allowing a direct comparison of the results. This is caused by the use of the same anchor points in order to avoid offsets between different results.

Known Displacement

If the displacement rate is known, it is also possible to insert these data directly in the *Generate GCPs* panel (Figure 29) in addition to position values. To select a GCP on the image, select firstly the Edit/Modify radio button.

- A positive "*Vel. X*" value means a movement from west to east
- A positive "*Vel. Y*" value means a movement from south to north
- A positive "*Vel. Height*" value means an uplift

Note The velocity has to be entered for each spatial direction, and it should be given in [mm/y]. If only the displacement is known, then the velocity has to be calculated taking into account the time between the two acquisitions. For example a co-seismic displacement of 50 cm for an interferometric pair acquired at 35 days distance will correspond to a velocity of around 5214 mm/year (500÷35*365). This should then be projected in the tree spatial dimension.

Note It is possible to use data coming from GPS stations. *SINEX* and *GSI* format can be imported by the *Import GPS* tool (see proper chapter in SARscape help).

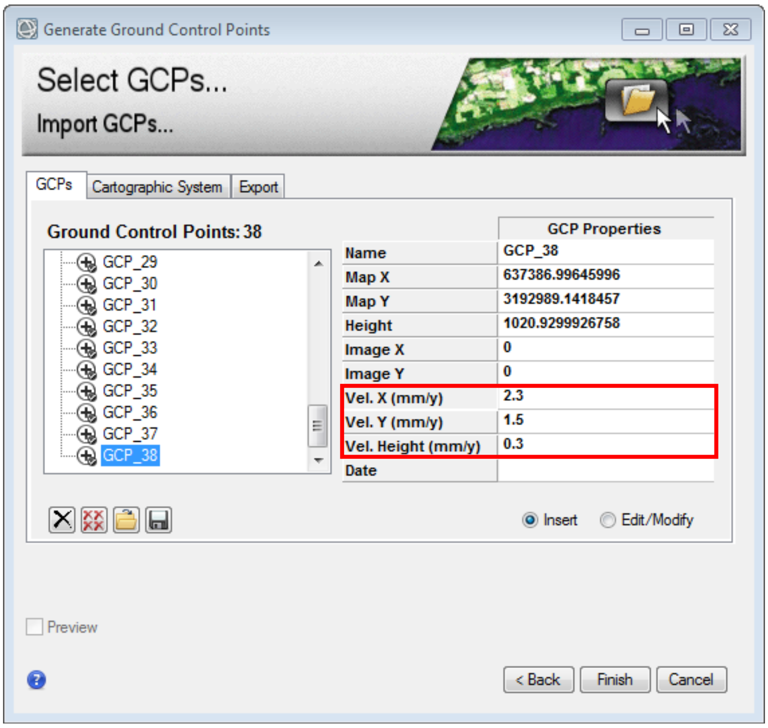

Figure 29: If the movement of a point is known, it is possible to create a GCP on a movement zone if velocity data for the 3 dimensions are given in the dedicated section.

Overview table

Geometry GCP Use	Map X and Y	Height [m]	Image X and Y	Velocity X, Y, Z [mm/y]	Date
Manual Orbital Correction with Reference Image	Selected with Generate GCP tool	Retrieved from DEM file	Selected with Generate GCP tool	Not used	Not used
Manual Orbital correction with Known Coordinates	Entered manually	Entered manually	Selected with Generate GCP tool	Not used	Not used

Refinement GCP Use	Map X and Y	Height [m]	Image X and Y	Velocity X, Y, Z [mm/y]	Date
Orbital Refinement using geographic Input file	Selected with Generate GCP tool or Entered manually	Retrieved from DEM file or will be read in *Refinement and Reflattening* step or Entered manually	Will be calculated from the software in *Refinement and Reflattening* step	Not used	Not used
Orbital Refinement using Input file in sar geometry	Not used	Not used	Selected with Generate GCP tool	Not used	Not used
Orbital Refinement combined with known velocity	Selected with Generate GCP tool or Entered manually	Retrieved from DEM file or will be read in *Refinement and Reflattening* step or Entered manually	Will be calculated from the software in *Refinement and Reflattening* step	Entered manually	Entered manually
Orbital Refinement combined with known velocity coming from GPS stations (SINEX and GSI) **Note: This file will be created with the *Import GPS tool* instead of the *Create GCP tool***	Entered by the Import GPS tool	Entered by the Import GPS tool	Entered by the Import GPS tool	Entered by the Import GPS tool	Entered by the Import GPS tool