

# SARscape's Coherent Changes Detection Tutorial

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## Index

Introduction.....	3
Setting Preferences .....	4
Data preparation.....	6
Input data .....	6
DEM Extraction .....	6
Single Panels processing.....	11
Coherence.....	11
Geocoding.....	16
Single Panels processing – Multi Temporal coherence .....	20
Workflows .....	27
Coherence CCD Workflow.....	27
Coherence CCD Time Line Workflow .....	31
ILU RGB, MTC RGB and COV-PWR-CC RGB coherence workflows.....	34

## Introduction

This document walks the reader through an example application of SARscape's Basic module for detecting coherent changes related to an earthquake event. The reference software version used throughout the tutorial is SARscape version 5.4.1, running under ENVI 5.4.1 with a standard (GIS-like) interface, installed on Windows 7, 64bit. Cosmo-Skymed data are used as an example in the following, although the same steps apply to products from other sensors as well as to other applications of the same technology.


SARscape's Basic module contains SAR processing tools to extrapolate thematic information and perform temporal analysis of the evolution of the observed features, looking at the backscatter as well as at the phase information (when applicable) of the SAR data.

In this tutorial, the goal is to extract features from a triplet of Cosmo-Skymed stripmap images, acquired two before and one after the event that struck New Zealand in February 2011. The document will show how to execute the processing both using the single panels as described in the first part of this tutorial or using dedicated workflows as described in the second part.

The Coherent Changes Detection analysis shall rely on the availability of Single Look Complex data pairs to extract information from the data phase. This tutorial starts from data already imported and subset over the Area of Interest, as extensively described in SARscape's *Getting Started* and *Basic* tutorials.

The import step is mandatory for any further processing with SARscape, while sub-setting is optional; this step is of interest to restrict the analysis in case of Areas of Interest significantly smaller than the data full frame, speeding up the corresponding processing time.

**Note:** Before starting with this tutorial, please read the SARscape's *Getting Started*' and *Basic* tutorials, which can be found here: <http://www.sarmap.ch/wp/index.php/software/sarscape/>

 Paragraphs like this one, showing a hand on the left side, indicate a practical step that the user should perform in order to proceed with the tutorial.

This tutorial contains Cosmo-Skymed data, courtesy of ASI and eGeos..

## Setting Preferences

Before starting with the tutorial, it is important to set the correct SARscape and ENVI preferences as described in the "Getting Started" tutorial.

- ✂ Set ENVI and SARscape preferences as described in the "Getting Started" tutorial.
- ✂ Set ENVI Input directory according to where the input data are located.
- ✂ Set ENVI Output directory according to where the results should be generated.
- ✂ In case of Cosmo-SkyMed stripmap SLC data, please set the SARscape preferences to Very High Resolution (VHR Better than 6m) (Figure 1).
- ✂ Set the SARscape cartographic grid size to 5m (Figure 2).

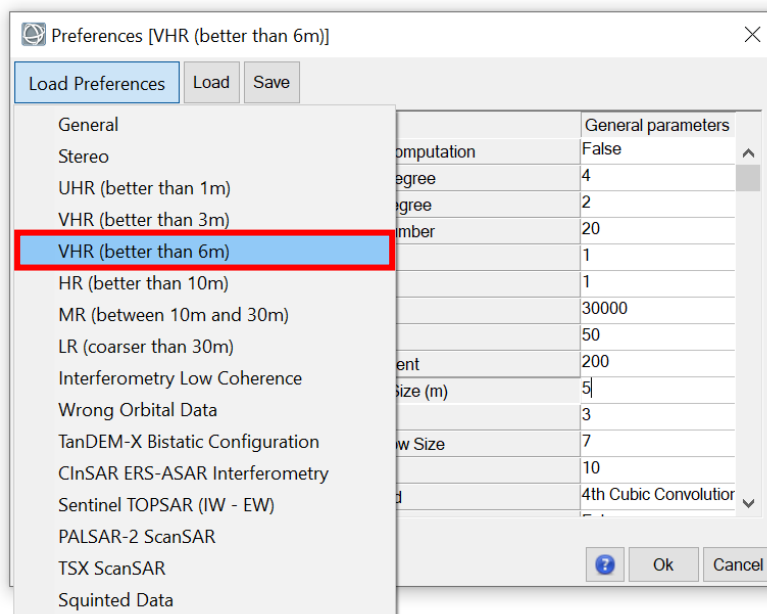


Figure 1: Load Very High Resolution preferences before starting to work with Cosmo-SkyMed SLC data.

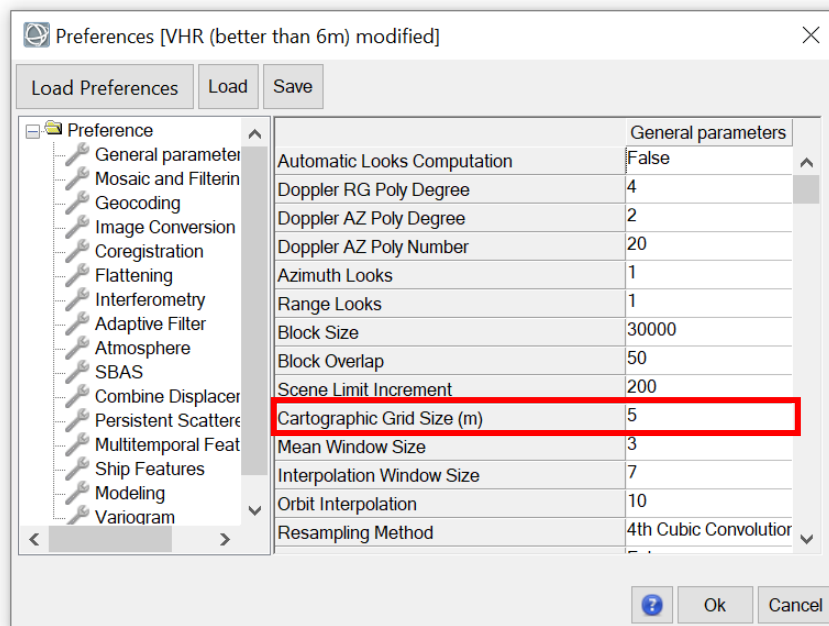


Figure 2: Change the Cartographic Grid Size to 5m in the General parameters tab.

## Data preparation

As said, this tutorial starts from data already imported and subset over the Area of Interest; these steps are extensively described in SARscape's *Getting Started* and *Basic* tutorials.

## Input data

Input of this tutorial are three datasets, acquired by the Cosmo-SkyMed constellation over the city of Christchurch (New Zealand) on February 3<sup>rd</sup>, 19<sup>th</sup> and 23<sup>rd</sup>, 2011 along an ascending orbit segment. The city was struck by a magnitude 6.3 earthquake on February 22<sup>nd</sup> of the same year.

One of the three datasets is shown in Figure 3. The city area is in the middle of the scene, the sea on the right.

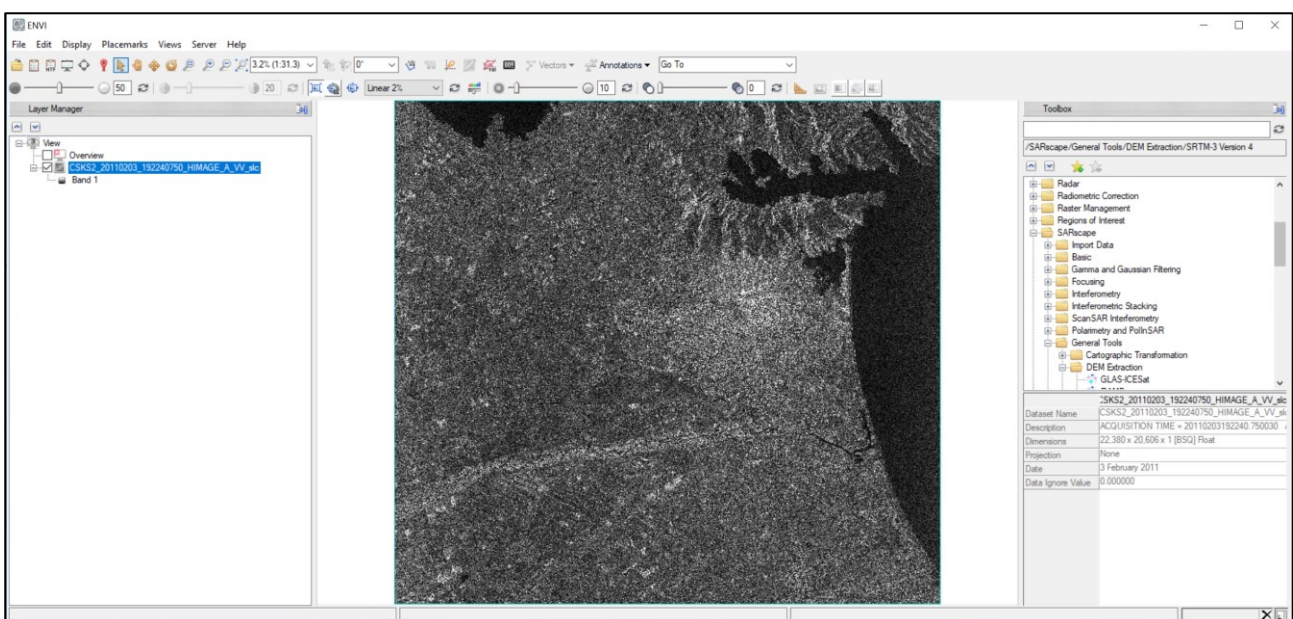


Figure 3: SLC data of the 2011-02-03 acquisition loaded in ENVI.

## DEM Extraction

An accurate reference Digital Elevation Model (DEM), containing heights above a reference ellipsoid, is necessary both for a proper estimation of coherence maps (to subtract phase contributions due to topography and SAR side-looking geometry) and to perform accurate geocoding. If a high-resolution DEM is not available, SARscape allows to extract a DEM from a local folder (GLAS-ICESat and RAMP) or download and extract a DEM from a FTP location or local folder (ACE, GTOPO30 and SRTM). All of these tools are located in the General Tools, under the "Digital Elevation Model Extraction" folder (Figure 4).

**Note:** Currently, the only DEM that can be downloaded from the Internet is the SRTM3v4. Other DEMs have to be downloaded manually and the proper folder linked in the SARscape preferences.

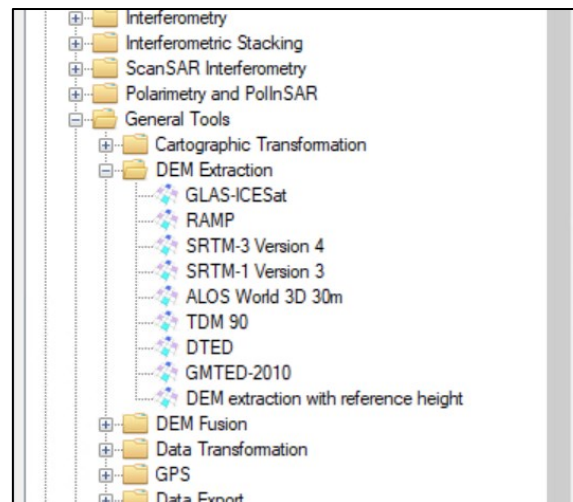


Figure 4: Location of the Digital Elevation Model Extraction tools in ENVI's toolbox.

In addition to these supported DEMs, other DEMs can be imported in SARscape using generic import tools such as


- "Import TIFF" (in case of TIFF files)
- "Import ENVI original" tool (importing the DEM into ENVI first and saving it in ENVI format).
- "Import Geocoded Binary" paying attention to set the parameters correctly.

In the parameters of the ACE, GTOPO30 and SRTM DEM extraction, it is possible, besides "generate slope" which is available for all the DEM extractions, to select coordinate box boundaries, set X and Y grid size, Replace Dummy With Min and Subtract Geoid.

"Replace Dummy With Min" replaces all the Dummy values of the resulting DEM with the minimum height value present. This is helpful when working on coastal areas where the DEM contains Dummy value on water and the DEM boundaries on water are serrated.

For our exercise, it is possible to download the freely available SRTM-3 C-band DEM. If the web server is online and no firewall blocks the connection, SARscape will allow the User to automatically download and mosaic the relevant tiles.

The spatial extension of the DEM to be downloaded can be chosen either by giving one or more reference images or by giving box coordinates.

**Tip:** Some tools, like the interferometric or the geocoding ones, have a binocular button  which allows to call the DEM extraction tool directly, and automatically inserts the path of the downloaded DEM in the panel.

**Tip:** SARscape's WorkFlows can also directly download, import and use a DEM as shown in Figure 5. The *Reference Type* has to be changed into "Dem Download" and then select the desired DEM. This will be downloaded and imported when clicking "Next >" or "Next >>>".

**Tip:** Starting with SARscape 5.4, it is now possible to import SRTM1v3 DEM. There is no automatic download feature as with the SRTM3v4. The SRTM-1 tiles can be downloaded from the USGS Earth Explorer (select the "SRTM 1 Arc Second Global" product from the Digital Elevation->SRTM category and download the geotiff format). Place the unzipped tiles in the "SRTM-1 DEM directory" specified in the Directories Preferences. If no directory is specified in the preferences,

the files will be searched for in sub-folder "SRTM1\_DEM\_DIR" in SARscape's working directory. **Note:** Registration is required to download products through the USGS Earth Explorer. If several tiles need to be downloaded, we suggest you follow the USGS bulk order instructions.

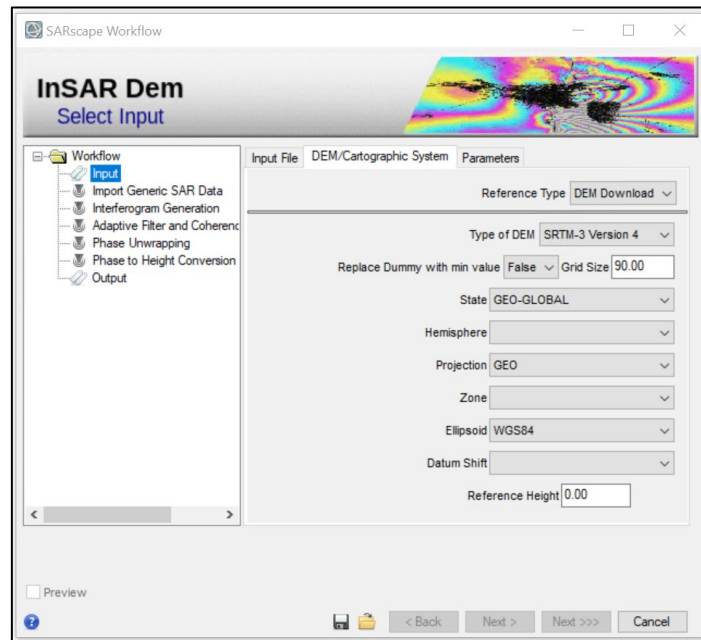



Figure 5: DEM extraction tool inside of a *WorkFlow* panel.

**Tip:** Download a common reference DEM that covers all geometries and all sensors to be used in the processing. The tool will automatically download a DEM with an extension covering all input reference images.

**Tip:** If a local repository of SRTM DEM is available, the path can be inserted in the SARscape preferences, as previously described. The software will then automatically look for the data in this directory instead of downloading it via FTP.

**Note:** SRTM DEM is available only on land and between 60°N and 56°S of latitude and heights are above the EGM96 geoid. By default, the geoid component is subtracted during the DEM extraction, resulting in heights above the reference WGS-84 ellipsoid. Using the "*General Tools>Cartographic Transformation>Geoid component*" it is possible to add/subtract the geoid component, which can be the EGM96, EGM2008 or a user-defined one.

 Open the DEM Extraction – SRTM3 Version 4 panel found in "*General tools>Digital Elevation Model Extraction>SRTM-3 Version 4*" and insert all the available *\_slc* files in the "*OPTIONAL Reference SR image*" list in the Input Files Tab (Figure 6).



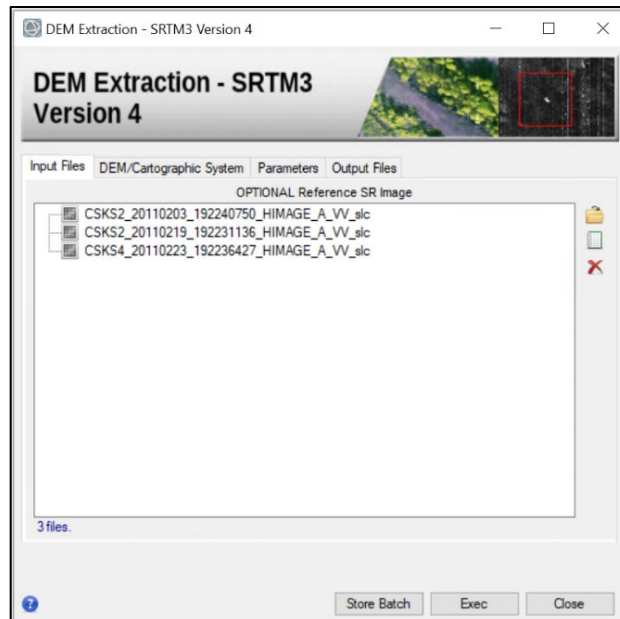


Figure 6: Reference Slant Range files in the DEM Extraction panel.

- ✎ Select the GEO-GLOBAL cartographic system as shown in Figure 7. Leave all the parameters as default and set the path of the output DEM file (We use "*ChristchurchSrtm-3\_V4\_dem*" as filename, as shown in Figure 8)
- ✎ Click Exec. Depending on your connection speed, the download can take up to several minutes. The DEM will be automatically loaded in ENVI's view (Figure 9) at the end of the processing.

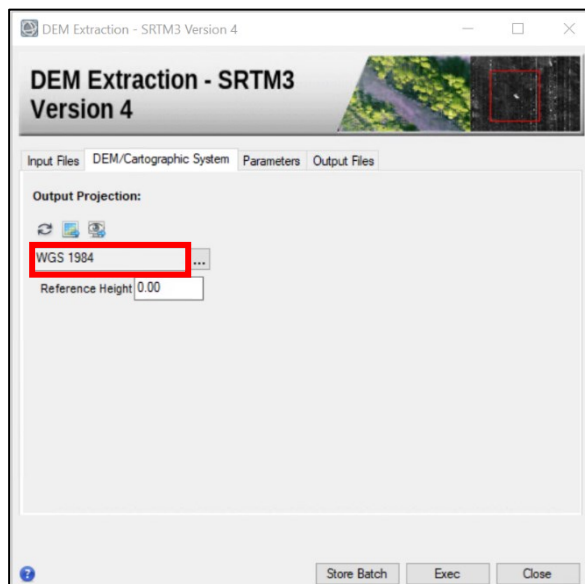


Figure 7: DEM/Cartographic System tab in the DEM Extraction panel. Please select GEO-GLOBAL WGS 84 as set by default.

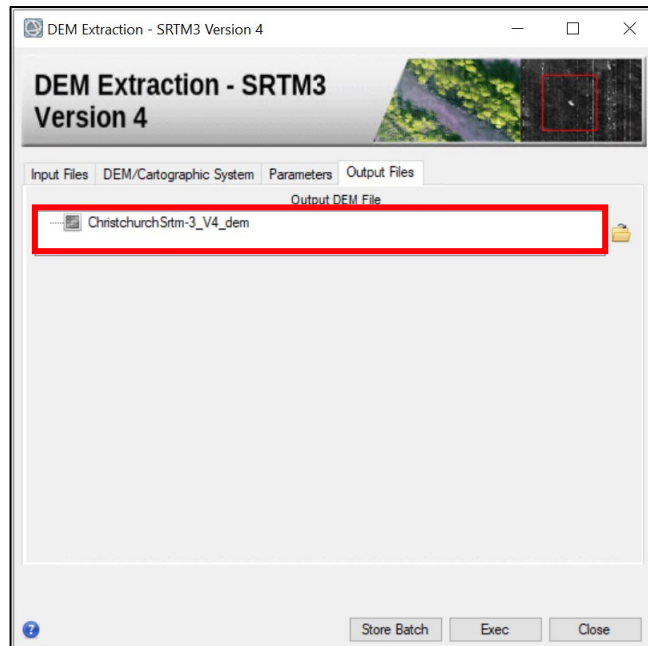


Figure 8: Output Files tab in the DEM Extraction panel. Insert "*ChristchurchSrtm-3\_V4\_dem*" as Output DEM File.

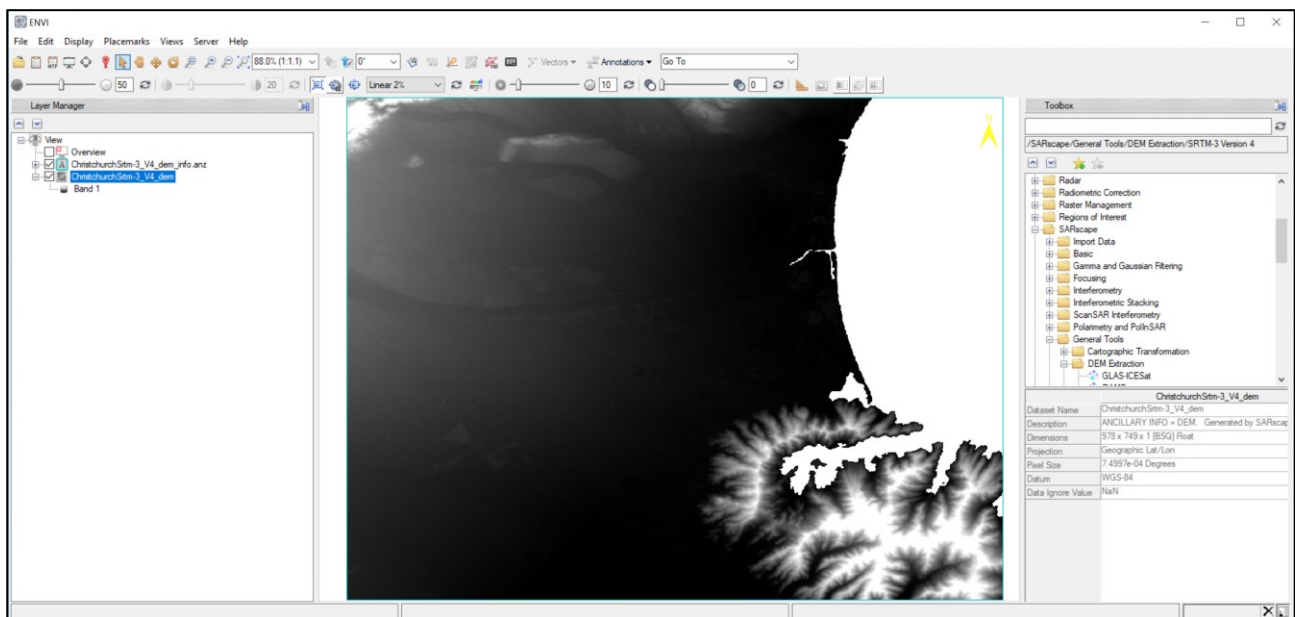


Figure 9: Downloaded SRTM DEM at the end of the DEM extraction process in ENVI view. The white area in the left and lower part of the image is the Sea. The SRTM3v4 DEM contains no data (NaN values) over the sea.

## Single Panels processing

This chapter shows the usage of the main tools of the SARscape Basic module involved in the step by step execution of the Coherent Changes Detection analysis.

### Coherence

Coherent Changes Detection techniques exploit interferometric approaches applied to pairs of SLC images obtained on a same area to highlight small-scale random changes of the imaged objects in the time interval between the two acquisitions.

The SARscape's Coherence module includes all processing steps necessary to start from such a pair of datasets to obtain a coherence map in SAR geometry of the area of interest, including:

- Multi-stages very accurate coregistration, necessary to resample one of the two input images (*slave*) onto the geometry of the other one (*master*). The resampling parameters are estimated from the data orbital information and exploiting crosscorrelation and coherence maximization techniques. The accuracy of the results is improved for very high-resolution data (like the CSK ones used in this tutorial) by exploiting a DEM as additional input of the process. Finally, coregistration of Sentinel-1 TOPSAR data is reaching the necessary very high accuracy (in the order of 1/1000<sup>th</sup> of pixel) by also exploiting spectral diversity techniques.
- Interferogram formation, including data oversampling, cross-multiplication and multi-looking.
- Removal of known interferometric phase trends (*flattening*), due to side-looking geometry of SAR systems (*flat earth phase subtraction*) as well as to topography (*terrain phase subtraction*). This step, to be precise, relies on a reference DEM in input.
- Coherence estimation. This process is executed by exploiting a moving window over the interferogram.

**Note:** The Coherence estimation tool works only with SLC (complex) datasets. No CCD analysis can be carried out based on detected (amplitude, ground range) products.

- ✎ Open the *Coherence* panel, found in "Basic" → "Feature Extraction" → "Coherence" and insert the first in temporal order of the available SLC (*\_slc*) images as Input Master File (Figure 10 on the left). SARscape, based on the master input data resolution, is suggesting the range and azimuth multi-looking factors (Figure 10 on the right) appropriate to obtain a pixel as close as possible to the cartographic grid size obtained from the preferences. Accept the suggested multi-looking factors.
- ✎ Insert the second in temporal order of the available SLC (*\_slc*) images as Input Slave File (Figure 11).
  - ✎ In the DEM/Cartographic System tab (Figure 12) insert the *ChristchurchSrtm-3\_V4\_dem* DEM previously extracted. The binocular button allows to call the DEM extractor tool from within this panel. In this case, when the DEM is downloaded, the DEM extractor tool will automatically close and the path of the DEM will appear in the corresponding field.

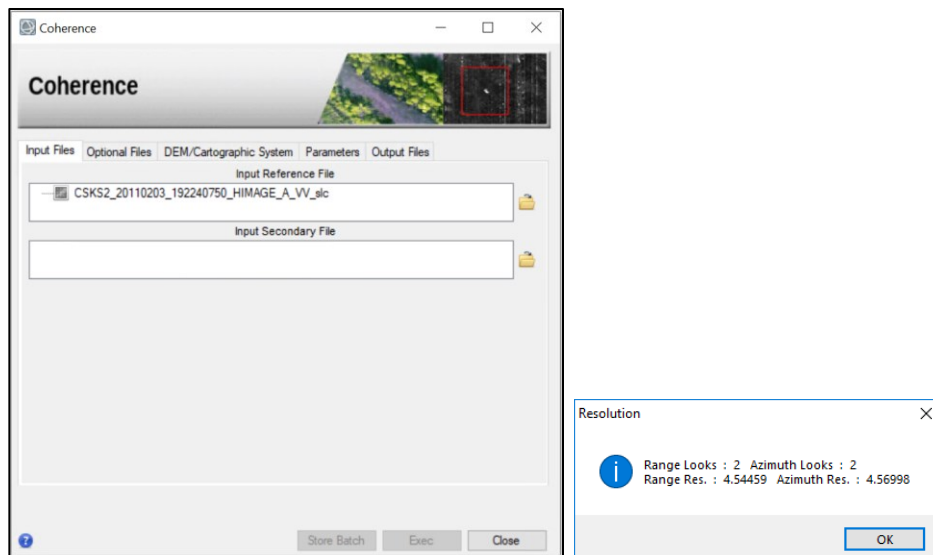


Figure 10: Coherence estimation Panel. Selection of the reference image on the left; the corresponding suggested multi-looking factor is shown on the right.

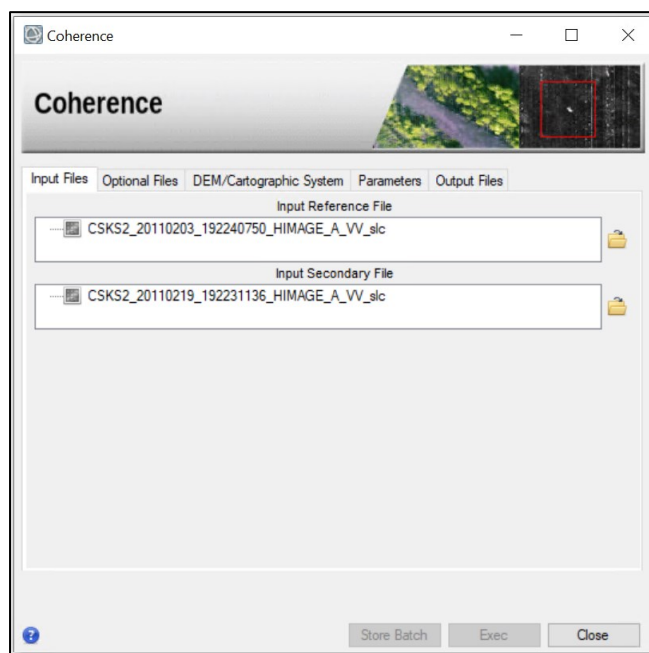


Figure 11 Coherence estimation Panel. Selection of the slave image.

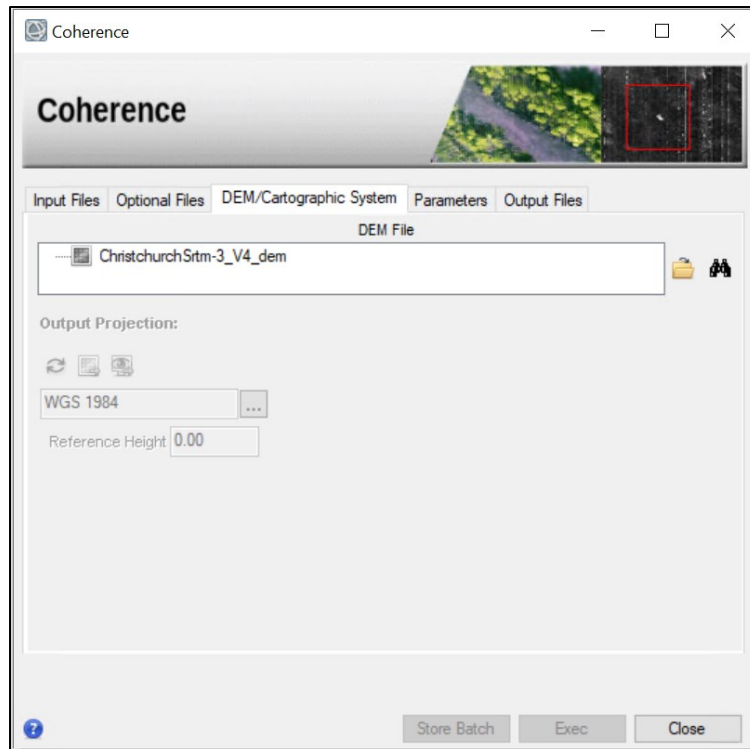


Figure 12 Coherence estimation Panel. Selection of the reference DEM.

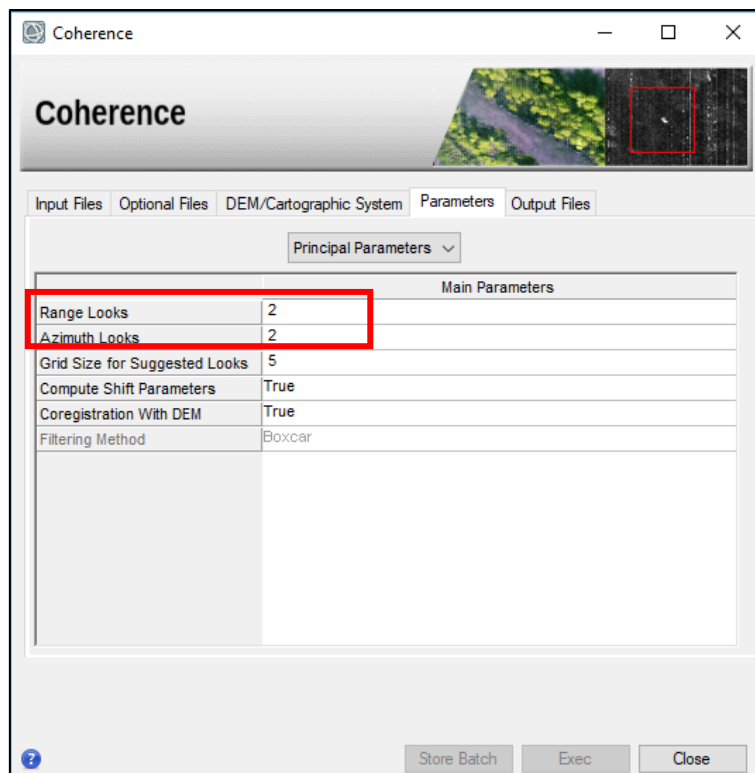


Figure 13 Coherence estimation Panel. Parameters tab, showing multi-looking factors estimated from the grid size in the preferences and the data original resolution.

✎ The Parameters tab (Figure 13) will show the Range and Azimuth multi-looking factors estimated after selecting the input reference file, reflecting the grid size set in the preferences. If these values should not be satisfying, a new grid size may be set in this tab,

immediately reflected in a new suggested set of multi-looking factors. Manual set of the looks parameter, on the other hand, overrides any automatically estimated value. DEM-based coregistration, as appropriate for very-high resolution data, is automatically set after selection of the VHR set of preferences.

- Select the Filtering parameters in the drop-down list of the Parameters tab (Figure 14). The size of the coherence estimation window will then become visible (*Coherence AZ* and *RG Box Size*). The final Equivalent Number of Looks of the estimated coherence will correspond to the product of these two values with the product of the Range and Azimuth looks values, resulting in around 100 in this case. Please note that it is recommended to target a ENL of at least 40 or more to obtain reliable coherence estimation, even if this results in reduced resolution of the results. The same Tab is also showing the parameters used to define the size of another window, used to estimate and remove residual topographic fringes, as in this case where the resolution of the SLC data (around 3m) is much better (smaller) that that of the reference input DEM (~90m). These parameters are set differently for different groups of preferences (e.g. no residual frequencies removal is performed in case of General preferences).

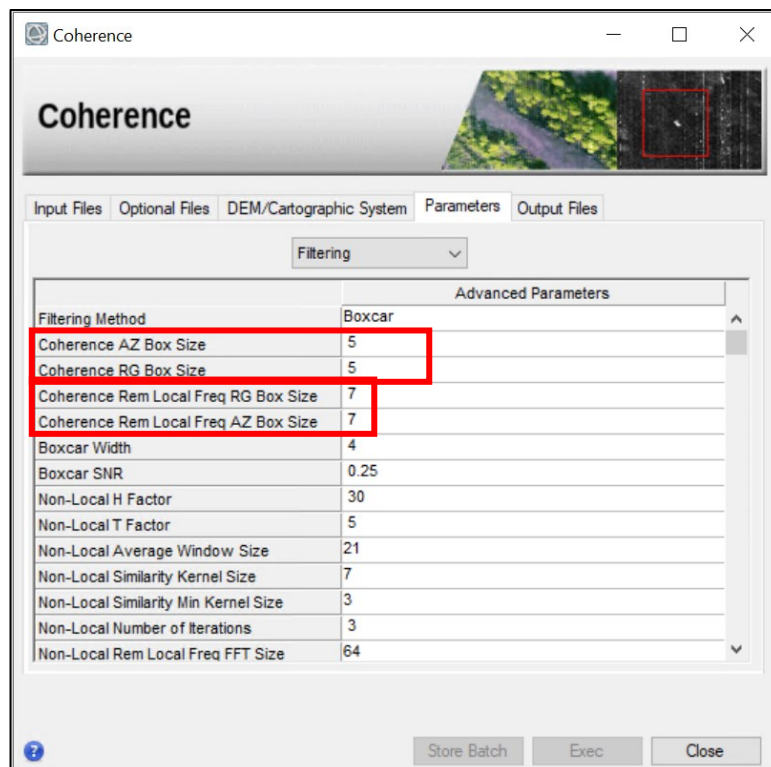


Figure 14 Coherence estimation Panel. Filtering parameters in the Parameters tab.

- Choose a convenient output folder and name for the output files and click Exec (Figure 15). There is no need to add optional files or to change the parameters. The coherence estimation processing will execute all the mentioned steps. The slant range coherence map will be automatically loaded in ENVI's view (Figure 16) at the end of the processing. Stable areas (little changes) are showing in bright color, while areas of big changes are showing in dark. ENVI color tables / density slicing functions can be used at this point to highlight coherence classes of interest (e.g. big or resp. small changes).



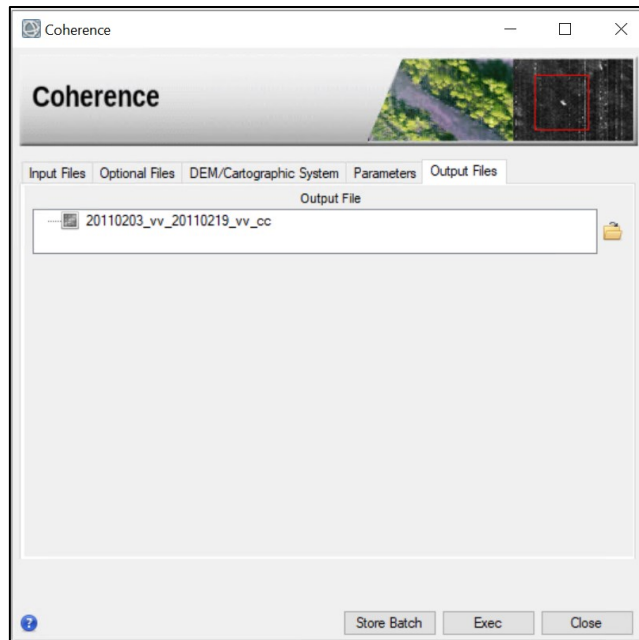


Figure 15 Coherence estimation Panel. Output Files tab, showing the output file name.

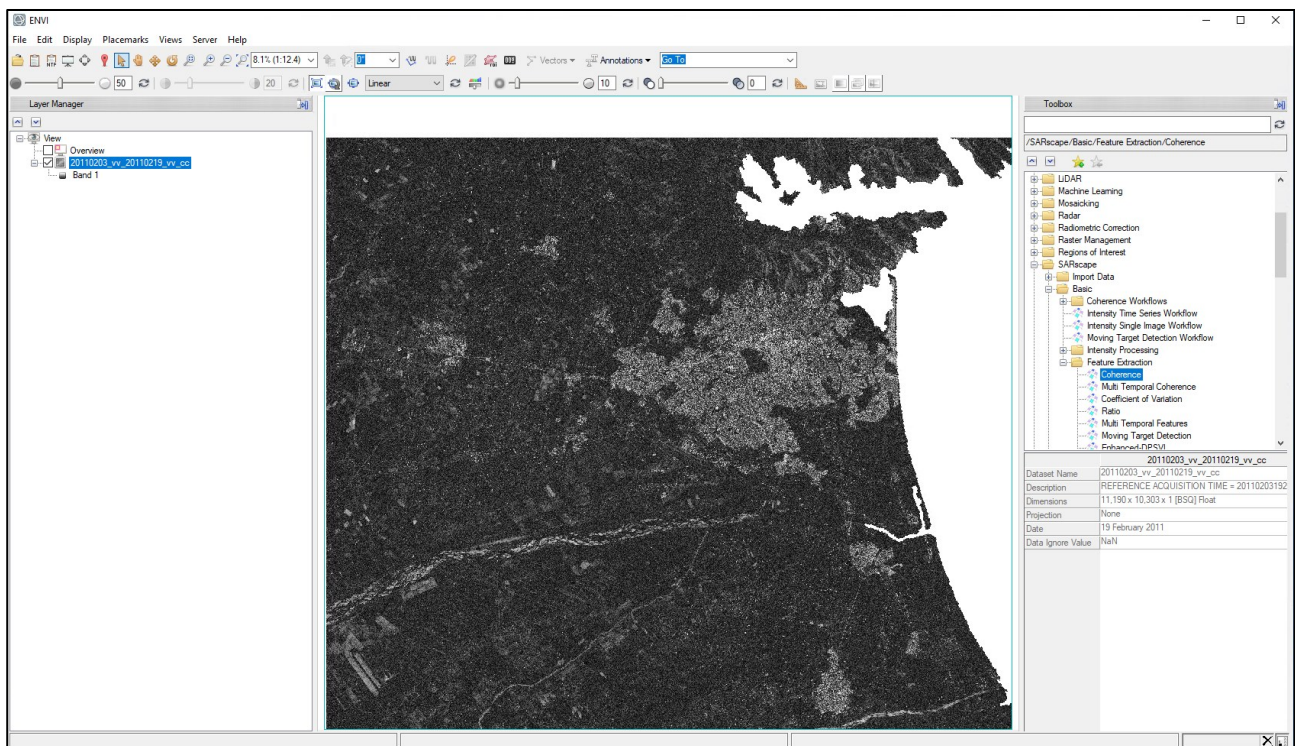


Figure 16: Slant range coherence map of the Christchurch area obtained from the 2011-02-03 and 2011-02-19 CKS acquisitions. Bright areas correspond to high coherence values (up to 1), like in the city area, while low coherence values (toward 0) are showing as very dark pixels (e.g. agricultural areas, the city park etc.). The sea area is displayed in white (*NaN*) since the reference DEM has no values there.

## Geocoding

SAR systems annotate the pixels into the so-called slant range geometry, corresponding to distance along and across the platform flight direction. The geocoding step has the goal of resampling data from the original (slant-range) onto a standard geometry defined in a cartographic reference system.

- ✎ Open the Geocoding panel, found in "Basic" → "Intensity Processing" → "Geocoding" → "Geocoding and Radiometric Calibration" and insert the coherence data in the "Input File List" (Figure 17). The `_cc` file is not initially showing in the data directory and, to select it, it is necessary to set the file selections filter to `"*"`. Note that more than one file can be geocoded at the same time from the geocoding panel.
- ✎ Select the previously extracted DEM in the DEM/Cartographic System tab (Figure 18) Here the binocular button is visible, for the cases when the DEM extractor tool should be called (no DEM previously extracted). The output of the geocoding will share the same Cartographic Reference System of the reference DEM.
- ✎ Check that the X and Y Grid size is set to 5m and set the Radiometric Calibration to False in the Parameters tab (Figure 19).
- ✎ Check the output file list (Figure 20). **Note:** the suffix `"_geo"` will automatically be added after the last extension name; the output data are automatically located within the output directory set in the ENVI preferences.
- ✎ Click Exec. The geocoded image will be automatically loaded in ENVI at the end of the processing (Figure 21).

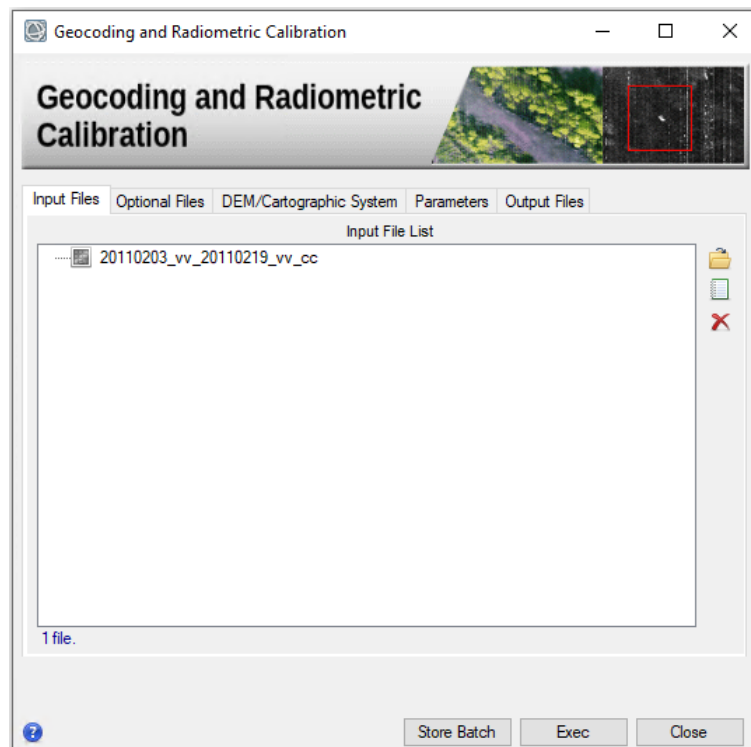


Figure 17: Geocoding panel. Input file list (`_cc` coherence image).



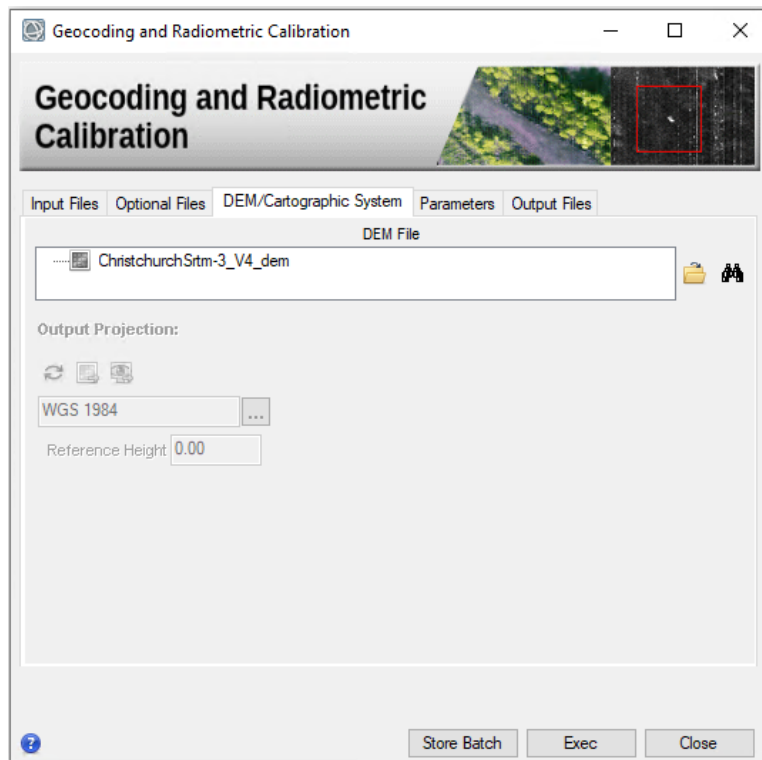


Figure 18: Geocoding panel. DEM / cartographic System selection tab.

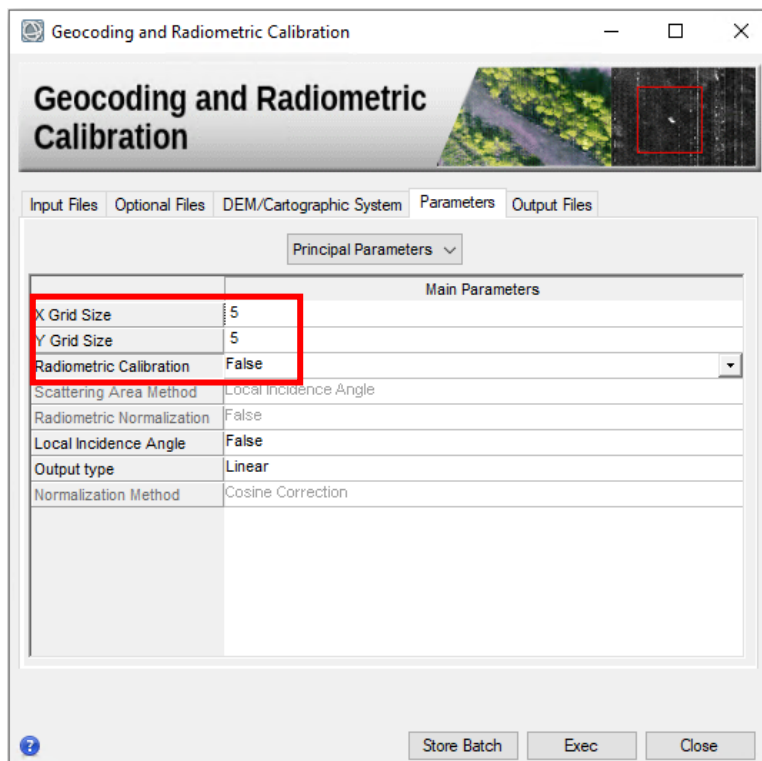


Figure 19: Geocoding panel. Parameters tab.

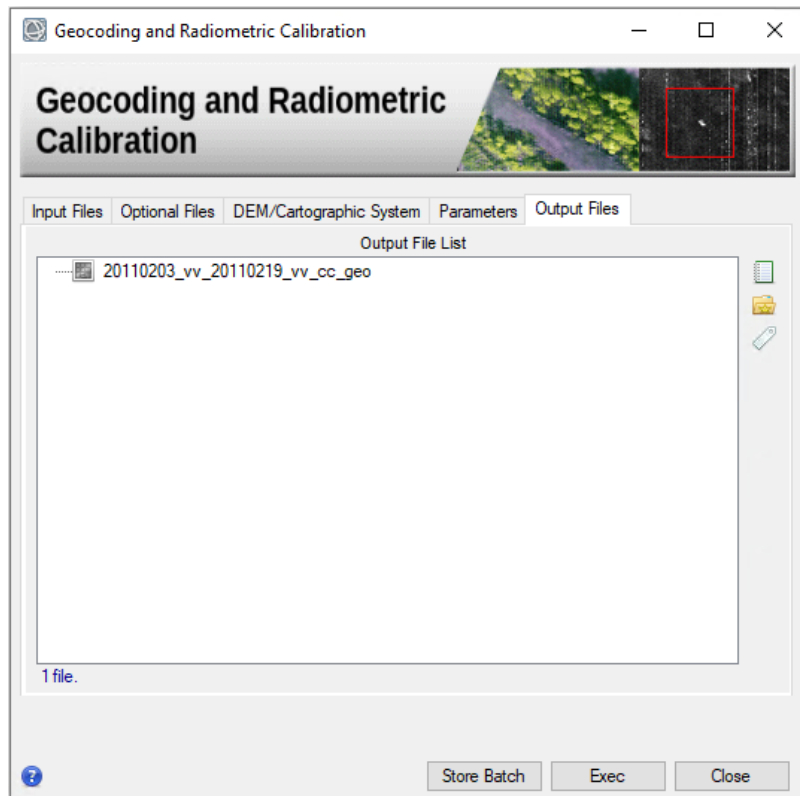


Figure 20: Geocoding panel. Output file list.

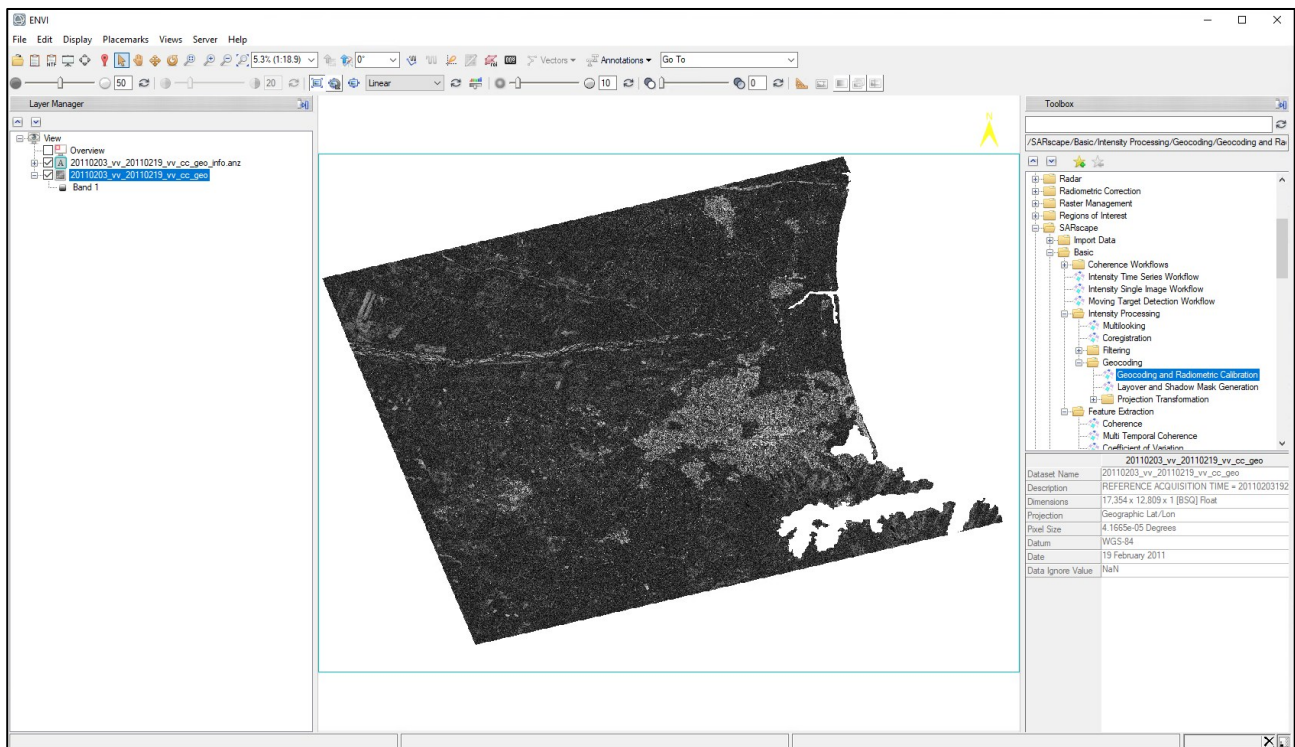


Figure 21: Geocoded coherence map of the Christchurch area obtained from the 2011-02-03 and 2011-02-19 CKS acquisitions. Stable areas (little changes) are showing in bright color, while areas of big changes are showing in dark. Note the geographic coordinate of the cursor location shown in the lower left corner of ENVI.

✂️ ENVI Chip View To -> Google Earth function (Figure 22) allows to automatically display the area visible in the ENVI view within Google Earth (Figure 23).

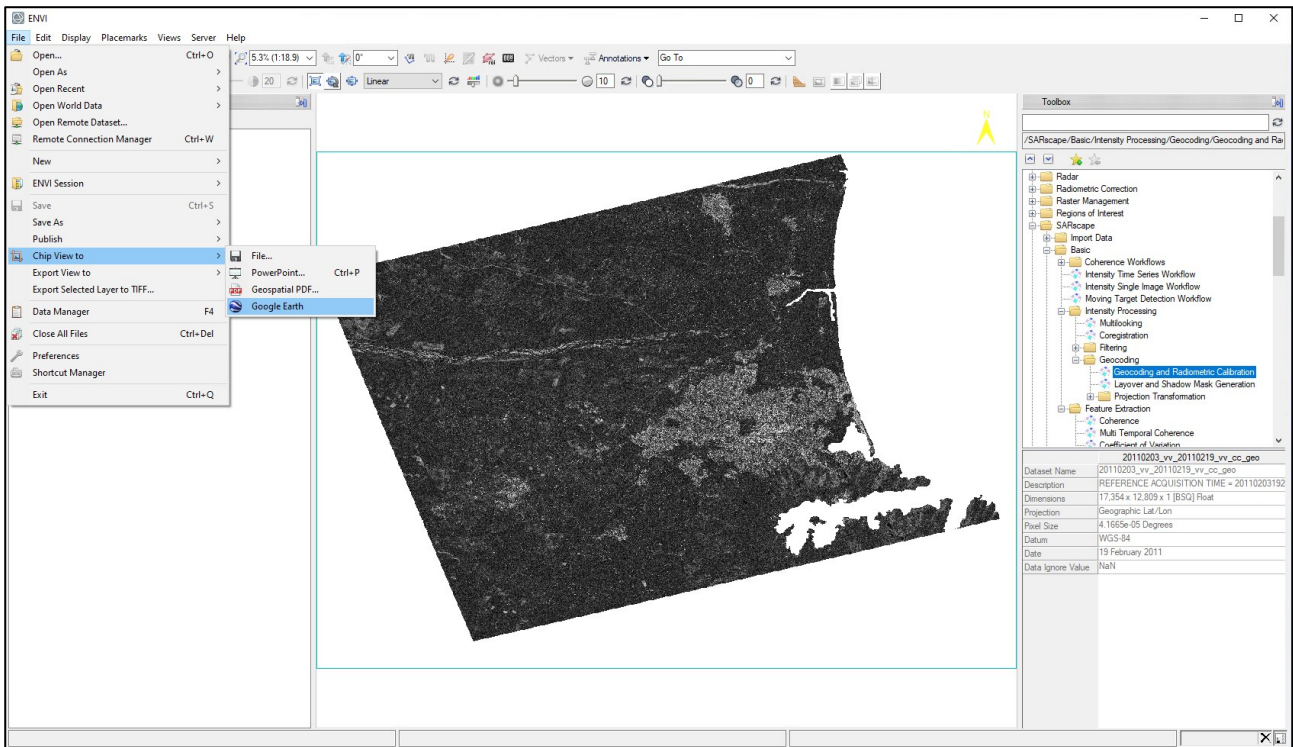


Figure 22: ENVI *Chip View To* functions.

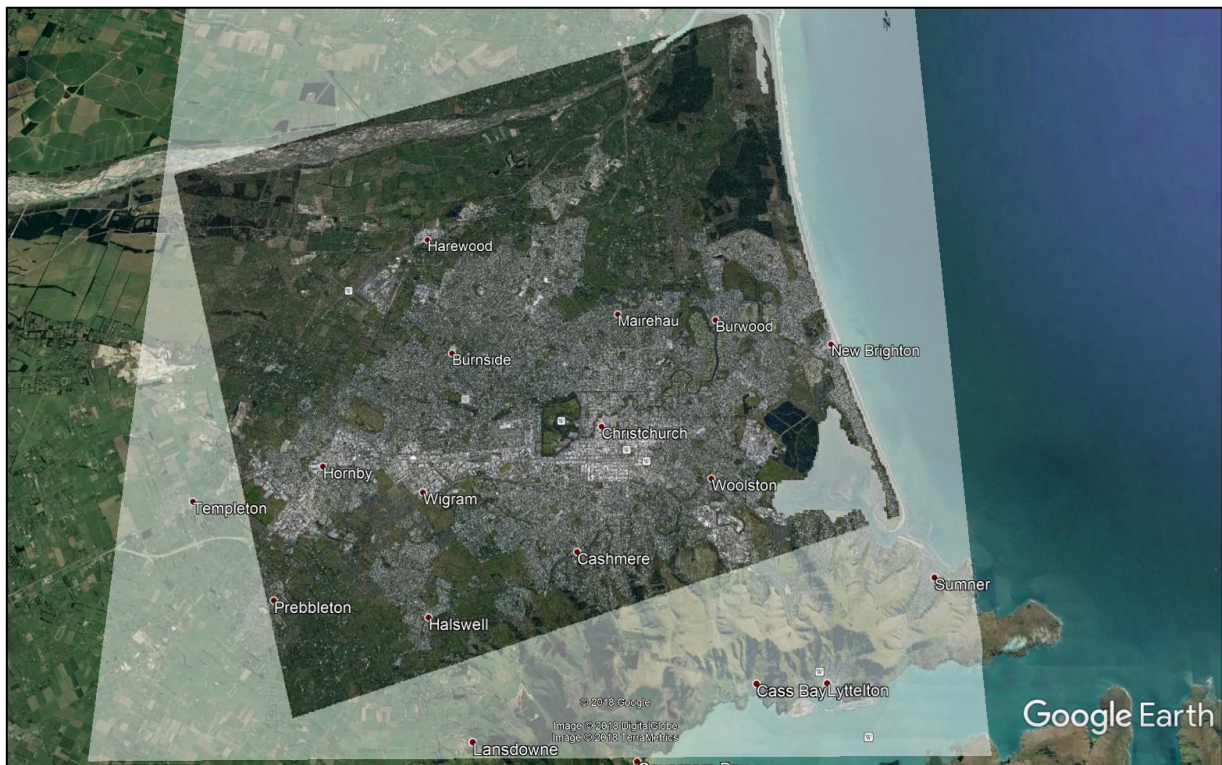


Figure 23: Coherence map displayed within Google Earth.

## Single Panels processing – Multi Temporal coherence

As described before, three SLC datasets are available over the Area of Interest of this Tutorial. The previous processing example showed how to analyze the coherent changes occurred across the pre-seismic pair, allowing to discriminate between stable (e.g. urban) and non-stable areas. The same process shall be repeated on the co-seismic pair, e.g. by selecting now the 2011-02-19 acquisition as master, and the 2011-02-23 as slave.

- ✎ Open the *Coherence* panel, found in "Basic" → "Feature Extraction" → "Coherence" and select the new Master and Slave files (Figure 24). All other settings (number of looks, reference DEM, etc.) shall be performed as in the previous case; a new output file name shall be selected. The processing will be carried out after clicking Exec; the new results are automatically shown in ENVI at the end of the process (Figure 25).

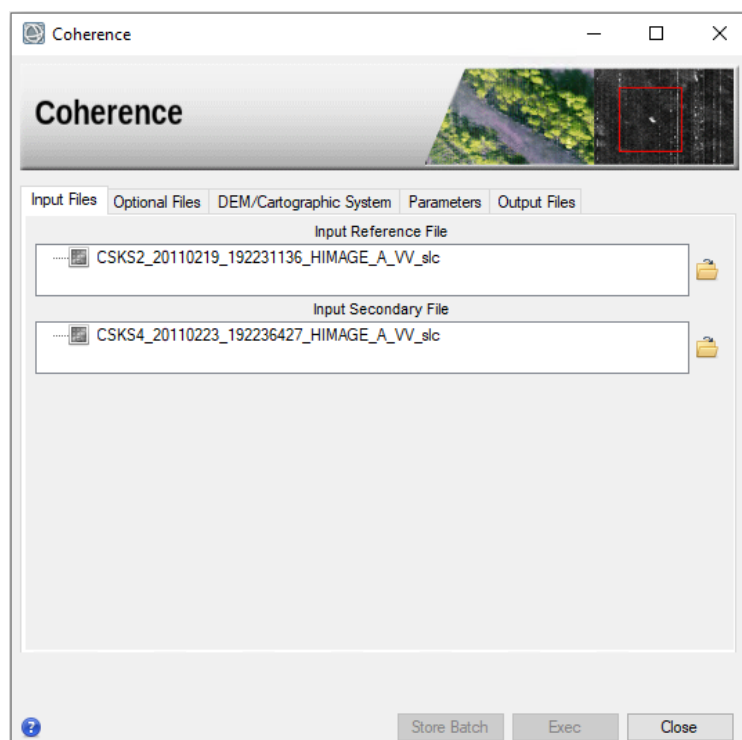


Figure 24 Coherence estimation Panel. Selection of the input master and slave images for the co-seismic case.



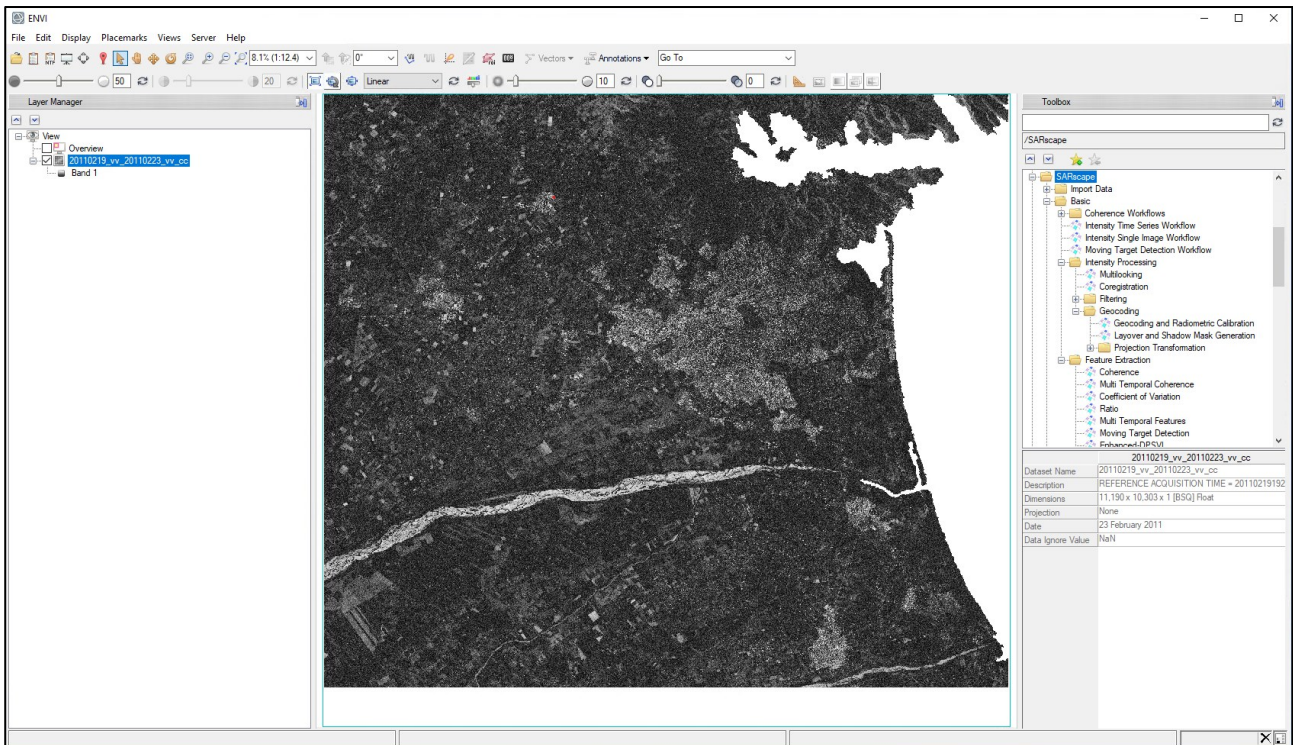


Figure 25: Slant range coherence map of the Christchurch area obtained from the 2011-02-19 and 2011-02-23 CKS acquisitions.

By comparing the results obtained from the co-seismic pair (Figure 25) with those obtained from the pre-seismic acquisitions (Figure 16) it is already visible that a few areas of the city are showing in the second case lower coherence values, despite the fact that co-seismic acquisitions have been acquired over a temporal interval shorter than that of the pre-seismic pair, hence expecting lower temporal decorrelation in the first case. A pixel-by-pixel, quantitative comparison is in any case possible only when the data are in a same (e.g. cartographic) reference system.

- ✎ Open the Geocoding panel, found in "Basic" → "Intensity Processing" → "Geocoding" → "Geocoding and Radiometric Calibration" and insert the co-seismic coherence data in the "Input File List" (Figure 26). The \_cc file is not initially showing in the data directory and, to select it, it is necessary to set the file selections filter to "\*". All other settings (grid size, no radiometric calibration, reference DEM, etc.) shall be performed as in the previous case; a new output file name shall be selected. The processing will be carried out after clicking Exec; the new results are automatically shown in ENVI at the end of the process (Figure 27).

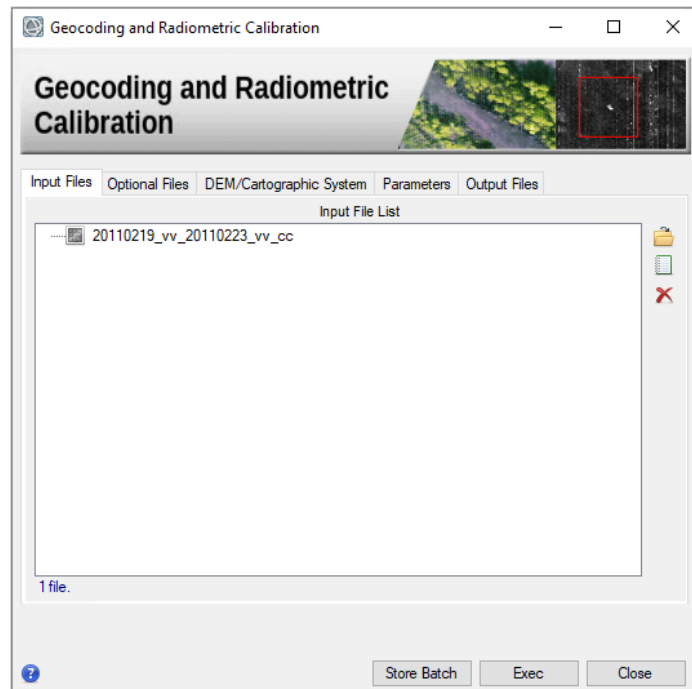


Figure 26: Geocoding panel. Input file list (co-seismic \_cc coherence image).

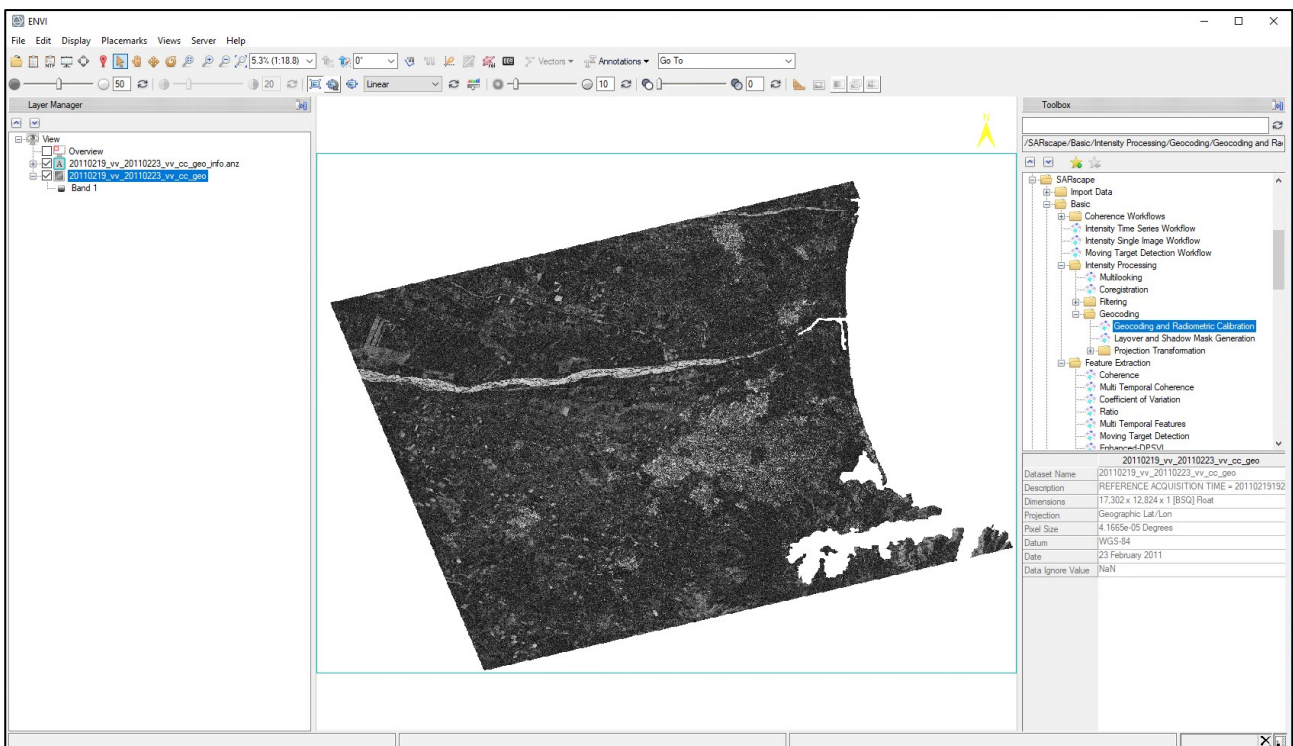


Figure 27: Geocoded coherence map of the Christchurch area obtained from the 2011-02-19 and 2011-02-23 KCS acquisitions.

The two CCD / coherence maps are now in the same cartographic reference system but, since the master file selected in the two cases is not the same (2011-02-03 resp. 2011-02-19), the first pixel (upper-left corner) of the two geocoded products is not the same. A final sub-setting step is hence necessary.

- ✎ Open the *Sample selection Geographic Data* panel, found in "General Tools" → "Sample Selections" → "Sample Selection Geographic Data" and select the geocoded coherence files as inputs (Figure 28).
- ✎ Select the same input DEM that has been used for the previous processing steps in the DEM / Cartographic System tab (Figure 29).
- ✎ Set the Make Max Common Area flag to True in the Parameters tab (Figure 30). This will request the module to extract a same area from the two input files, covering the maximum possible common extent.
- ✎ Check the output file names automatically generated by SARscape by adding the `_cut` prefix and pointing to the output directory (Figure 31). The processing will be carried out after clicking Exec; the new results are automatically shown in ENVI at the end of the process.

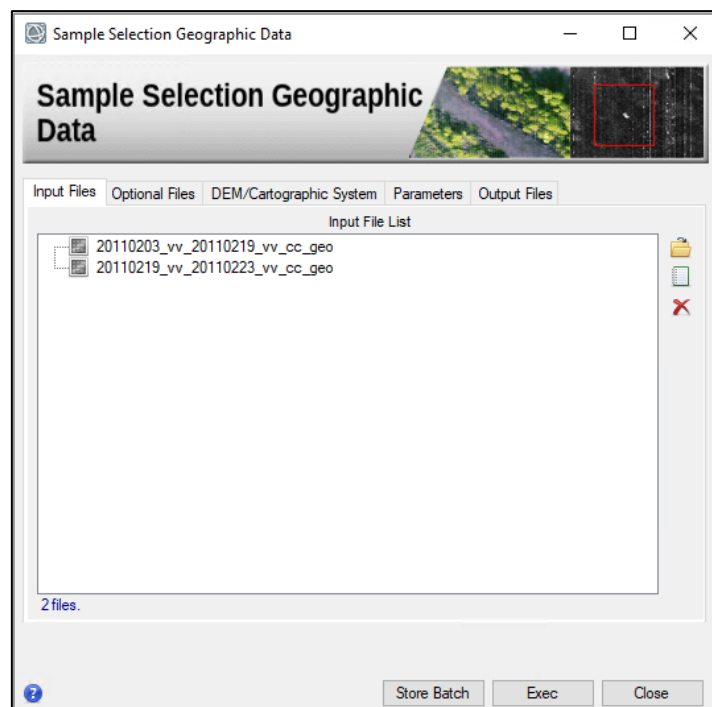


Figure 28: Sample Selection Geographic Data panel. Input files list (pre- and co-seismic `_cc` geocoded coherence images).

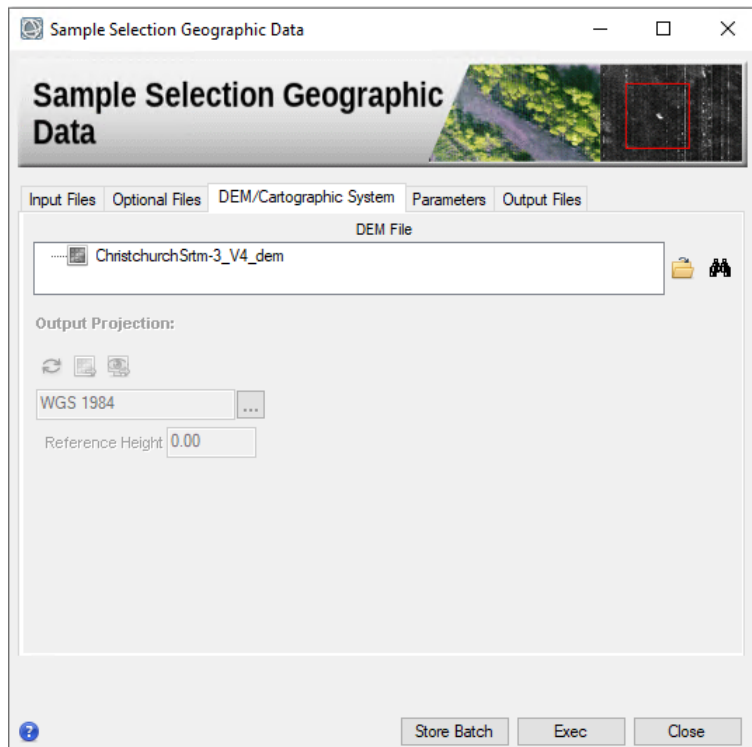


Figure 29: Sample Selection Geographic Data panel. DEM / cartographic System selection tab.

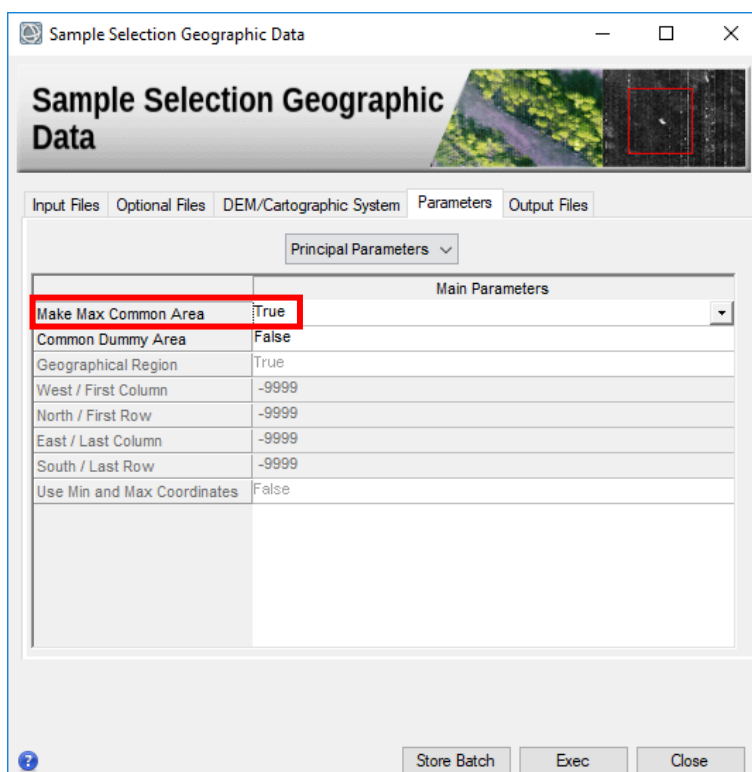


Figure 30: Sample Selection Geographic Data panel. Parameters selection tab.



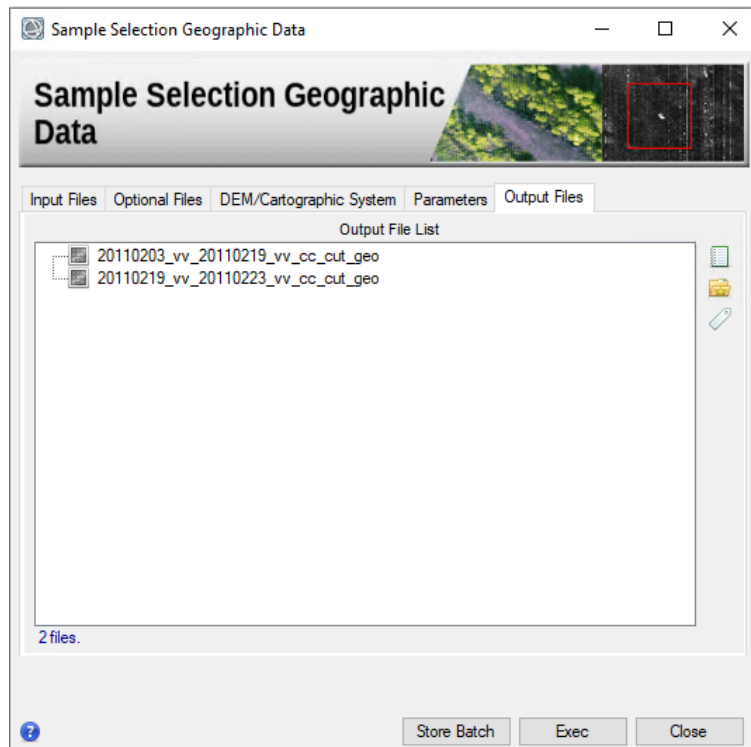


Figure 31: Sample Selection Geographic Data panel. Output Files tab.

ENVI is loading the images sub-set over the common area as single, black-and-white channels. A simple, straightforward comparison may then be performed by exploiting ENVI functionalities to create on-the-fly a False Color Composite image combining the two CCD images.

- ✎ Open ENVI *Data Manager* panel and select the geocoded and sub-set (*\_cut\_geo*) pre-seismic geocoded coherence map as Red channel and the corresponding co-seismic map as Green and Blue channel (Figure 32) and click *Load Data*. The on-the-fly generated False Color Composite image will be loaded in ENVI (Figure 33).

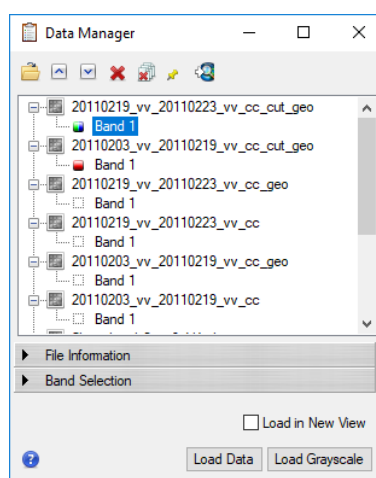


Figure 32: ENVI Data Manager panel. Pre-seismic coherence maps should be selected as Red channel and co-seismic coherence map should be selected both as Green and Blue channel before loading the data in the view.

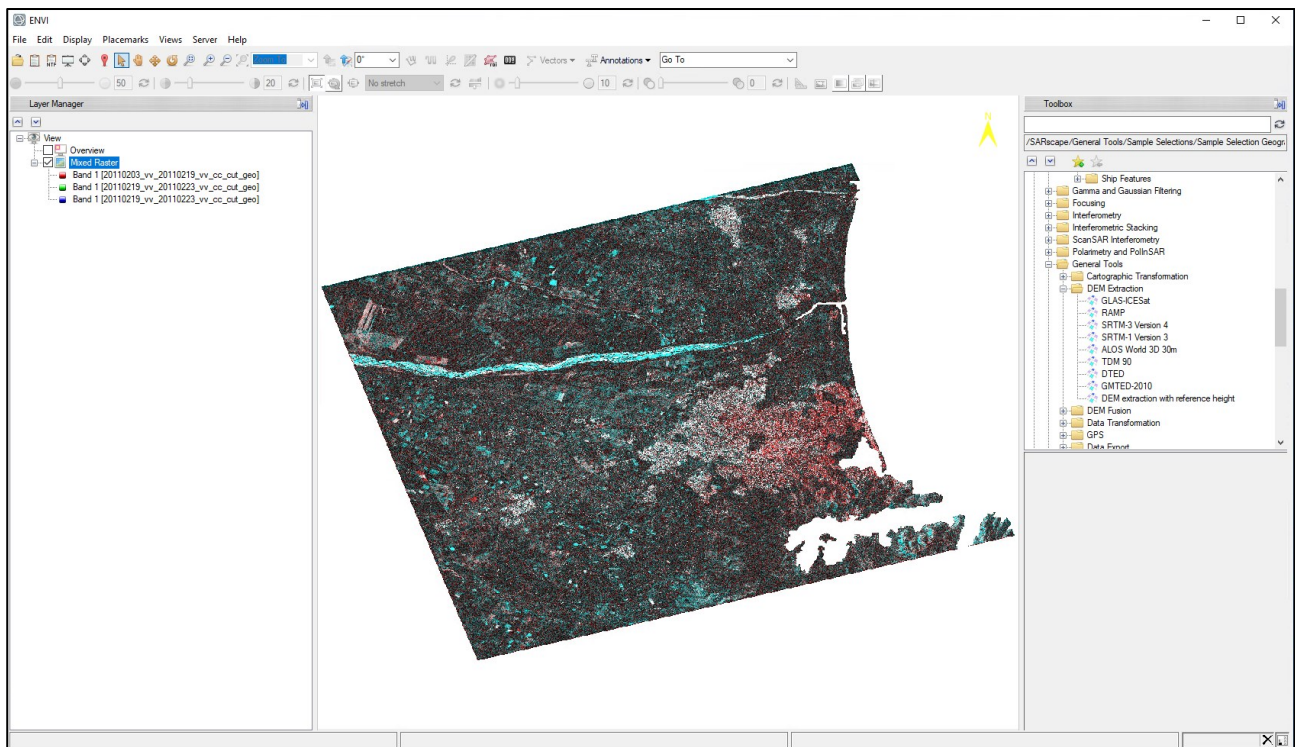


Figure 33: False Color Composite of the geocoded pre- and co-seismic coherence maps of the Christchurch area. Red areas are showing areas affected during the earthquake by severe terrain liquefaction.

The FCC image has been generated by exploiting only two input images, hence exploiting only a part of the possible color spectrum. Nevertheless, three color areas can be identified in the combined image:

- Areas showing a gray scale behavior. Here the temporal behavior of coherence (stability) is similar for the two maps, identifying areas that are similarly stable or unstable in the two (pre- and co-seismic) time intervals; these could be for example built-up areas (showing up in grey-white shades) not affected by the earthquake (high coherence – no coherent changes in both periods) or agricultural – densely vegetated areas (significant coherent changes / temporal decorrelation in both periods), showing up in dark – black shades.
- Areas showing a black-to-red scale behavior. The coherence (small-scale temporal stability) is then higher in these areas in the pre-seismic period respect than in the co-seismic period. Decrease of the coherence, from medium-high to low coherence values is for this case a clear indication of the effects of the earthquake over built-up areas. Severe damages and extreme liquefaction events have in particular been reported over the event; free water in the urban area is
- Areas showing a black-to-cyan scale behavior. Here the coherence is higher in the co-seismic pair than in the pre-seismic one. This should not surprise, since the temporal separation of the second pair is shorter than that of the first pair: areas not significantly affected by the earthquake and covered by natural objects suffer of temporal decorrelation, typically increasing with the increase of the temporal separation of the acquisitions.

**Note:** The *Basic->Feature Extraction->Multi Temporal Coherence* tool allows the estimation of the two coherence maps of this example in a single step.

## Workflows

This chapter will show how to use SARscape workflows in the Basic module for Coherent Changes Detection.

**Note:** During the execution of one workflow, it is not allowed to close the window or launch other processes.

Several workflows are provided by SARscape to perform this type of analysis:

- CCD, joining in a single workflow the steps used in the Single Panels chapter to generate a geocoded coherence map;
- ILU RGB, MTC RGB and COV-PWR-CC RGB, adding to the previous workflow the steps necessary to also generate a False Color Composite image combining the coherence map with other layers derived from the amplitude of the two input images, helping to analyze both Coherent and Incoherent (Amplitude) changes;
- CCD Time Line, allowing to study the Coherent Changes occurring between a number of images in input of the workflow (coherence time series).

The first sub-chapter will concentrate on replicating the process performed in the Single Panels chapter using the Coherence CCD Workflow and using the “next” buttons (which will cause a pause after each step). The second sub-section will show a usage example of the Coherence CCD Time Line workflow. In this case, the “Next >>>” button is used, which allows to perform all the steps with only one click. The general operation of a SARscape workflow is explained in the *Getting Started* tutorial.

### Coherence CCD Workflow

In this example, we will use the first two SLC files (`_slc`) used in the Single Step chapter of this tutorial. This, as all other Coherence Workflows shall have SLC products in input.

This workflow is found in SARscape>Basic>Coherence Workflows->Coherence CCD Workflow.

- ✎ Open the Coherence CCD Workflow and select the input master and slave file names, as shown in Figure 34. Set up the DEM/Cartographic System tab as described in Figure 35 in order to automatically download an SRTM3v4 DEM and then confirm the final output grid size to 5m (Figure 36 on the left). This will trigger the estimation of the multi-looking factors (Figure 36 on the right).
- ✎ Click “Next >” This button allows to start downloading the DEM and then jump to the next step, namely the Coherence estimation one (Figure 37). All parameters have been already configured but can be changed if desired.
- ✎ The workflow will run to the next step each time that you click “Next >”.

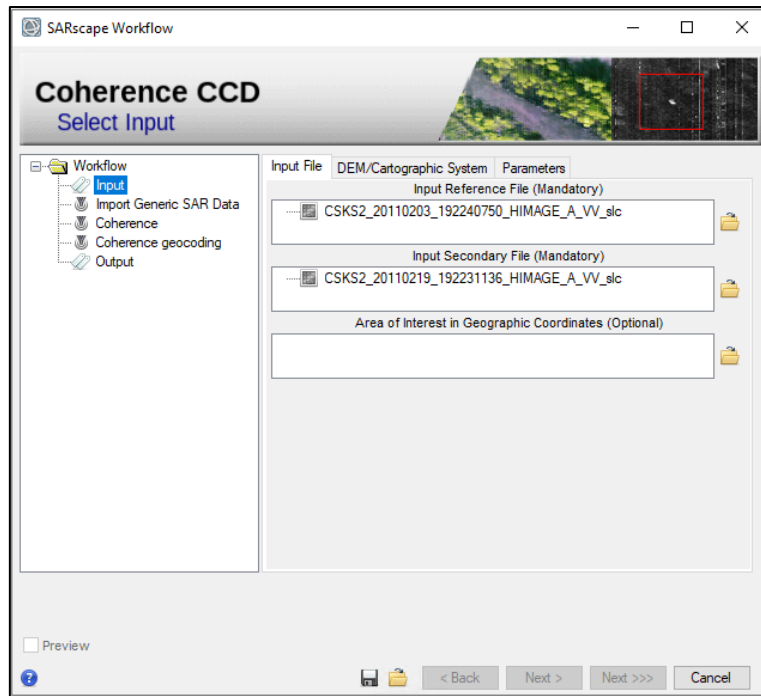


Figure 34: Input File Tab in Coherence CCD Workflow.

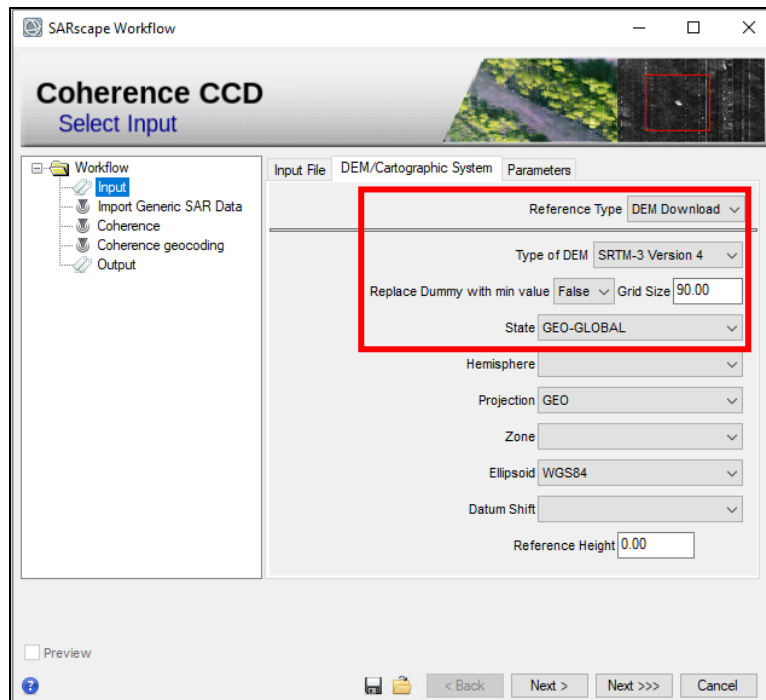


Figure 35: Dem/Cartographic System tab in Coherence CCD Workflow. Use these settings to let the workflow automatically download the SRTM DEM that will be used from the Workflow. It is also possible to use a previously downloaded DEM.

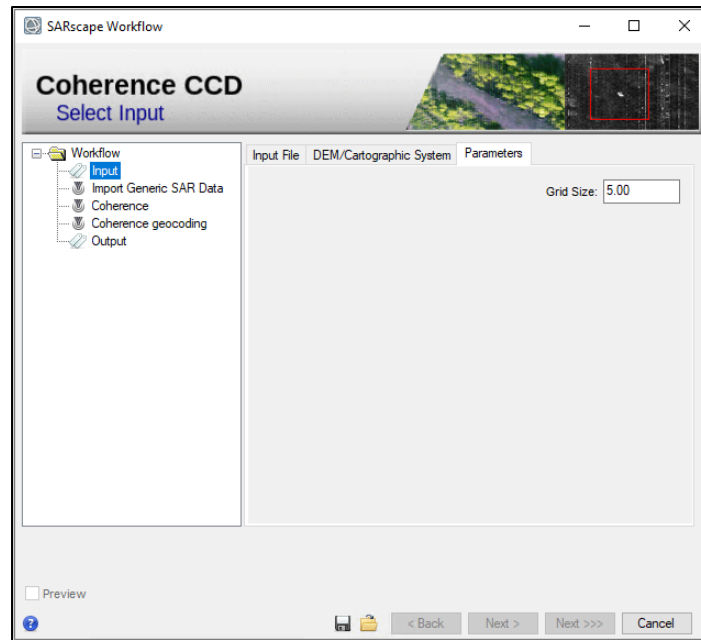


Figure 36: Parameters tab in Coherence CCD Workflow.

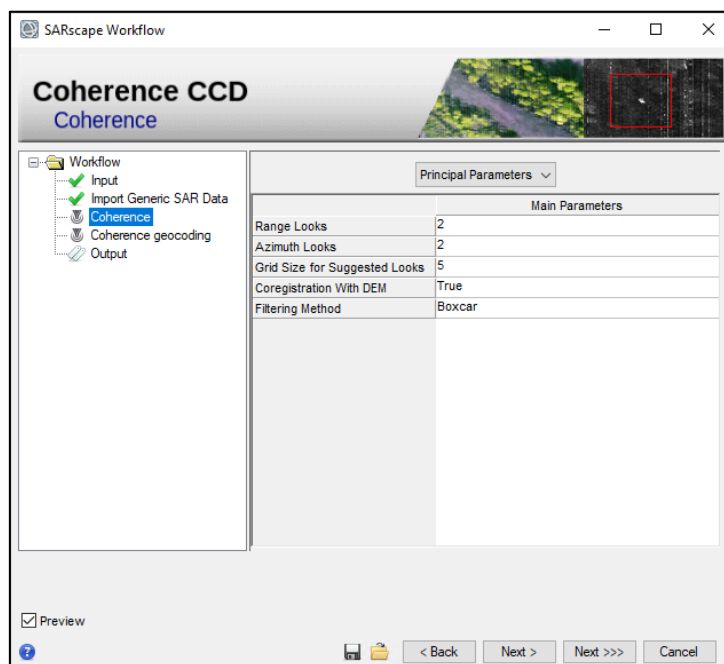


Figure 37: Coherence estimation step in Coherence CCD Workflow. All parameters are automatically set but can be changed.

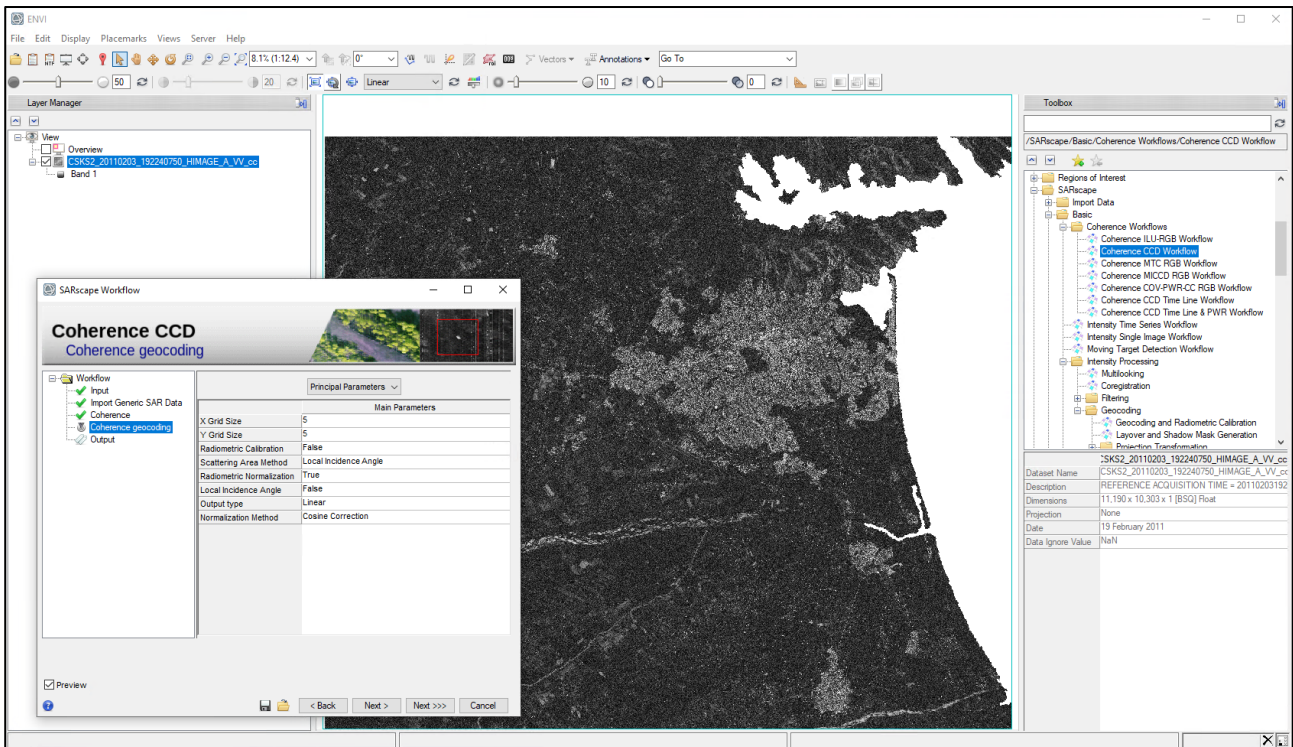


Figure 38: Coherence geocoding step in Coherence CCD Workflow. The preview of the result of the previous step is shown if the corresponding flag is active.

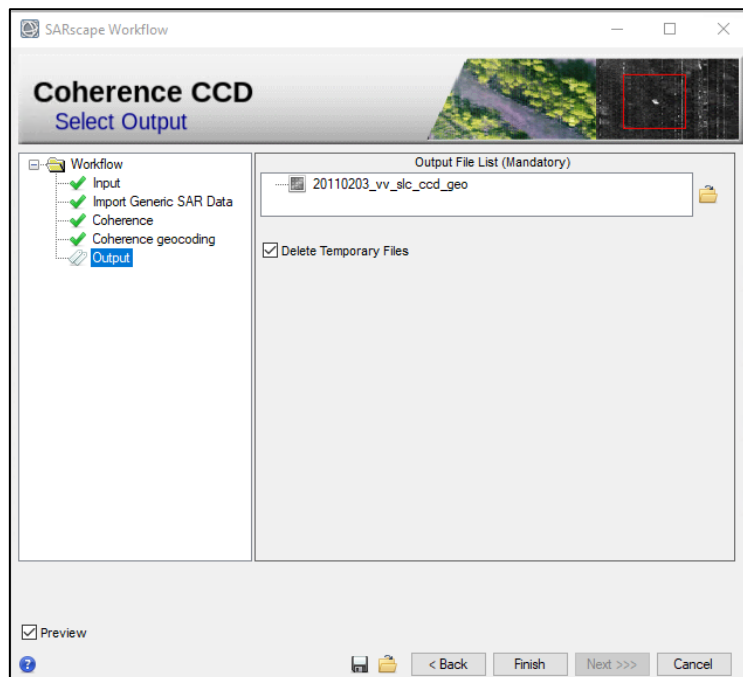


Figure 39: Output Tab in the Coherence CCD Workflow.

- ✎ The preview of the previous step is shown if the corresponding flag is active (Figure 38). Click "Next >" and the geocoding step will be executed.
- ✎ At this point it is possible to select the output folder and root-name (Figure 39). All the output files will have the same root-name.
- ✎ After clicking on "Finish", ENVI will display the geocoded coherence map (Figure 40).



**Tip:** If you uncheck the “Delete Temporary Files”, all the temporary files are kept in a folder located in the ENVI output directory with the name: SARsTmpDir\_ddmmmyyy\_hhmmss (the letters are referred to the date/time of the start of the workflow processing). Until the end of the process, the intermediary files are kept in the ENVI temporary directory.

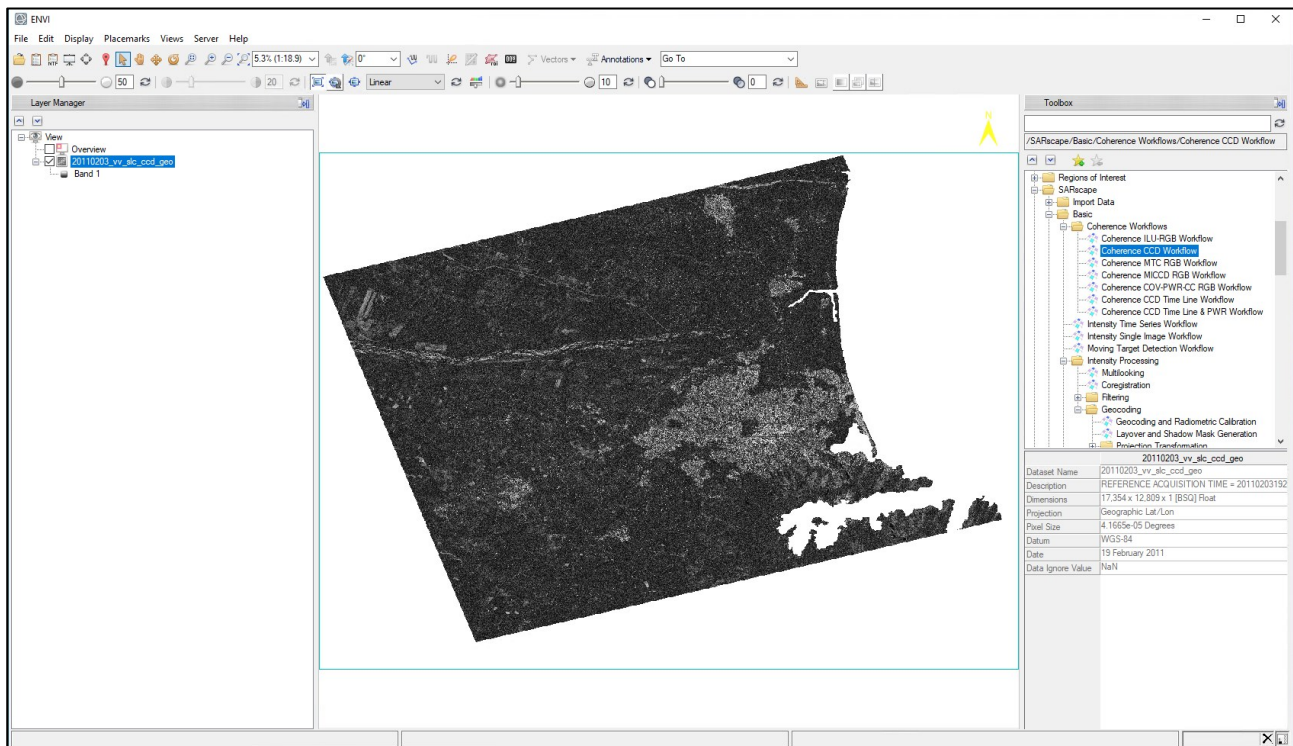


Figure 40: Geocoded coherence map, result of the Coherence CCD Workflow.

The result shown in Figure 40 is clearly the same as the one shown in Figure 21, obtained via the Step by Step manual procedure.

## Coherence CCD Time Line Workflow

This *Basic* module workflow enables the execution, in a single iteration, of the following processing sequence, starting from a list of SLC images: Multi-temporal Coherence estimation, Coherence Geocoding and Color Composite Generation.

The final purpose of this processing chain is to generate an RGB color composite for the visualization and identification of coherent temporal changes. As in the Single Panels Multi-temporal processing, the Red channel will be the pre-seismic coherence, the Green and Blue channels the co-seismic coherence.

- ✎ Open the Coherence CCD Time Line Workflow found in “*Basic*” > “Coherence Workflows” and fill the Input File List with the three available `_slc` datasets, as shown in Figure 41. As DEM (Figure 42) you can use the one extracted at the beginning of this tutorial, or alternatively download it as in Figure 35. Ensure that the grid size is set to 5 m (Figure 43) and then click the “Next >>>” button. This allows to run all the steps without interruptions until the output step.

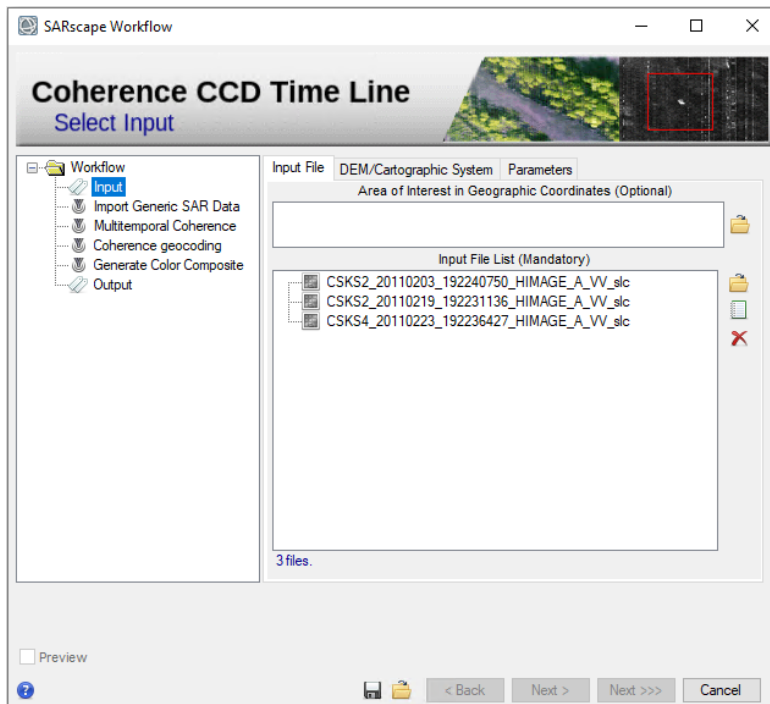


Figure 41: Input files for the Coherence CCD Time Line workflow.

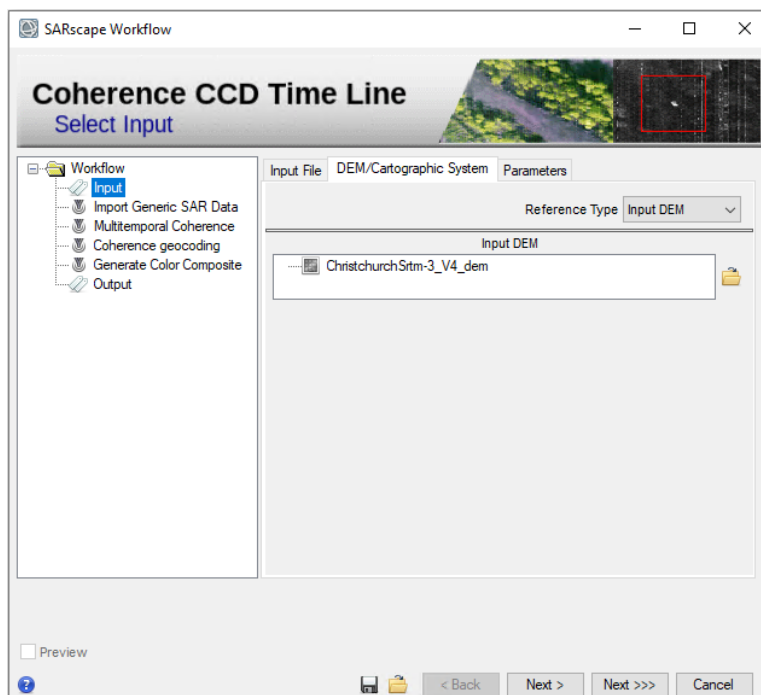


Figure 42: Input DEM for the Coherence CCD Time Line workflow.



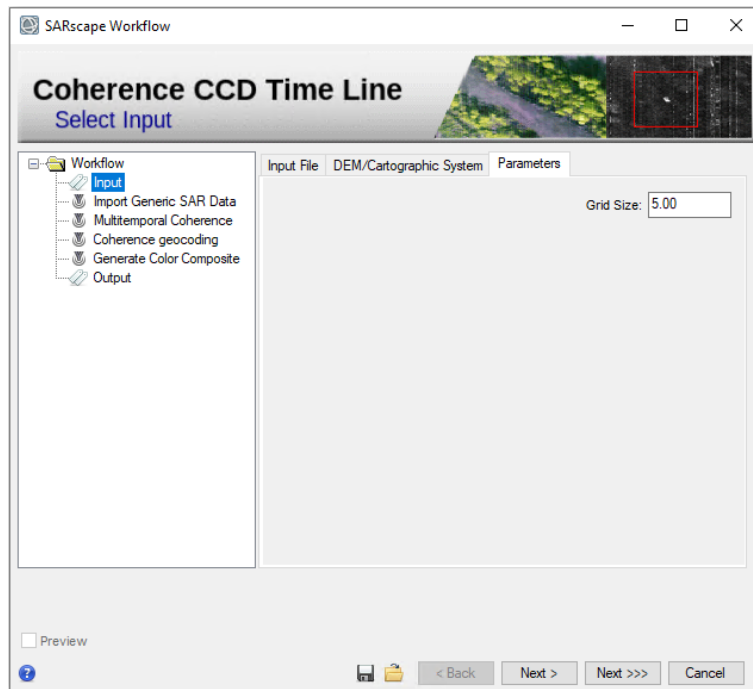


Figure 43: Parameters Tab. Check that the Grid Size is set to 5 m.

The software will then start to process all the steps one after another without interruptions until the output tab appears (Figure 44). As a result, the False Color Composite is shown in ENVI (Figure 45) as well as a coherence time series layer, that can be animated through by exploiting ENVI's series animation tool.

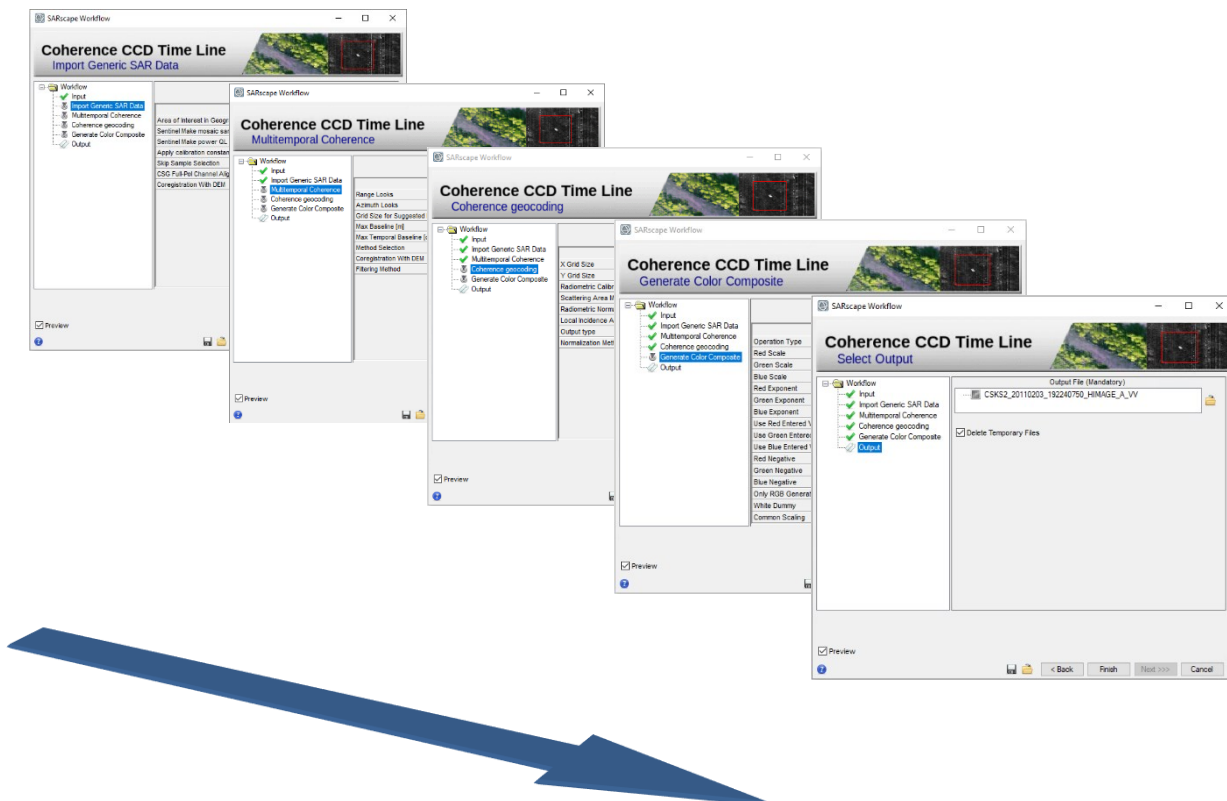


Figure 44: All the steps of the workflow are performed in a row when the "Next >>>" button is used.

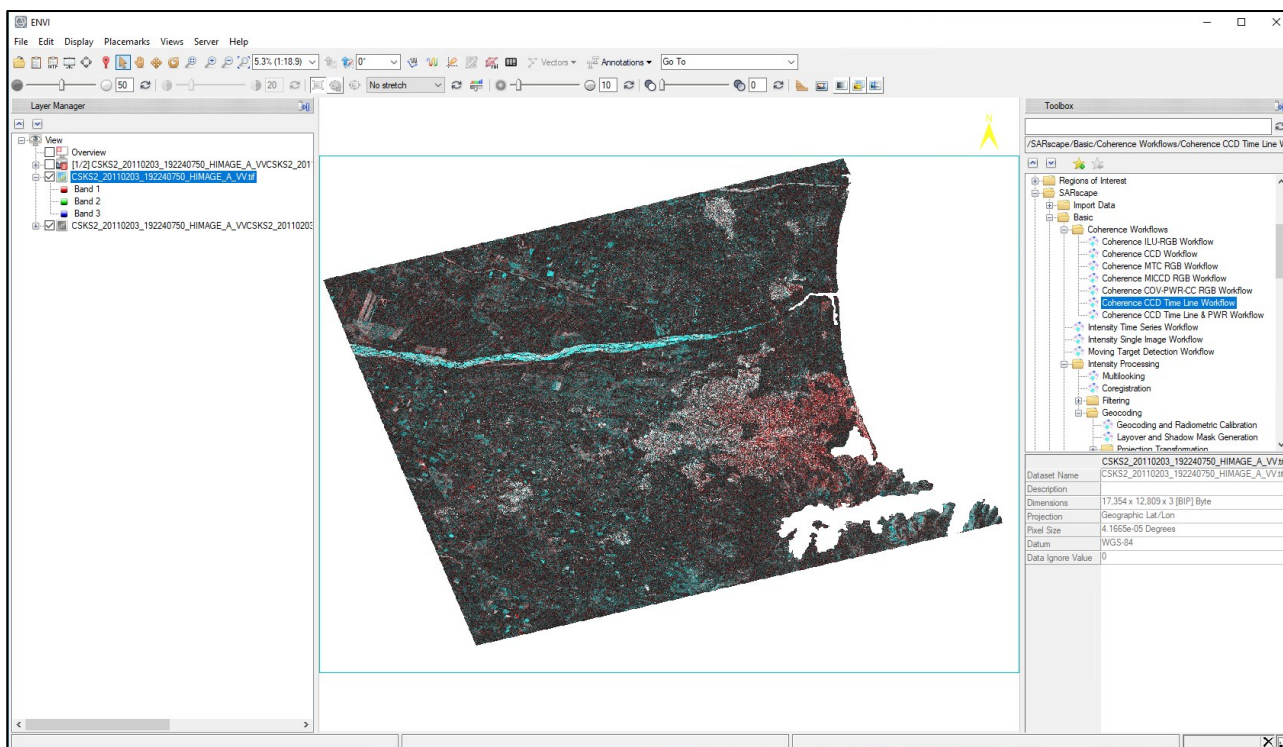


Figure 45: RGB tiff result shown in ENVI. The two coherence maps are also accessible through a ENVI time series viewer.

## ILU RGB, MTC RGB and COV-PWR-CC RGB coherence workflows

As said, SARscape is making available other three coherence workflows, starting from pairs of SLC images and resulting in False Color Composite images that combine both the coherence and other layers derived from the backscatter. The execution of these workflows is identical to that of the other workflows described before.

The results of the Coherence ILU RGB workflow are shown in Figure 46, on the left for the pre-seismic pair and on the right for the co-seismic pair. The color coding here is the coherence map in the Red channel, the average of the backscatter of the master and slave acquisition in the Green channel and the absolute value of the difference of the backscatter of the two images in the Blue channel. The city is clearly recognizable as reddish area, that becomes smaller in the co-seismic pair due to the liquefaction effects. Areas of stable backscatter and low coherence (case often related to vegetation, but in this case also related to earthquake effects) show up in green in this color combination.

The results of the Coherence MTC RGB workflow are shown in Figure 47, on the left for the pre-seismic pair and on the right for the co-seismic pair. The color coding here is the backscatter of the master acquisition in the Red channel, the backscatter of the slave acquisition in the Green channel and the coherence in the Blue channel. This color combination confirms that the most important changes are caught by the variation of coherence and not of backscatter (the yellow shade is an indication of same master and slave backscatter).

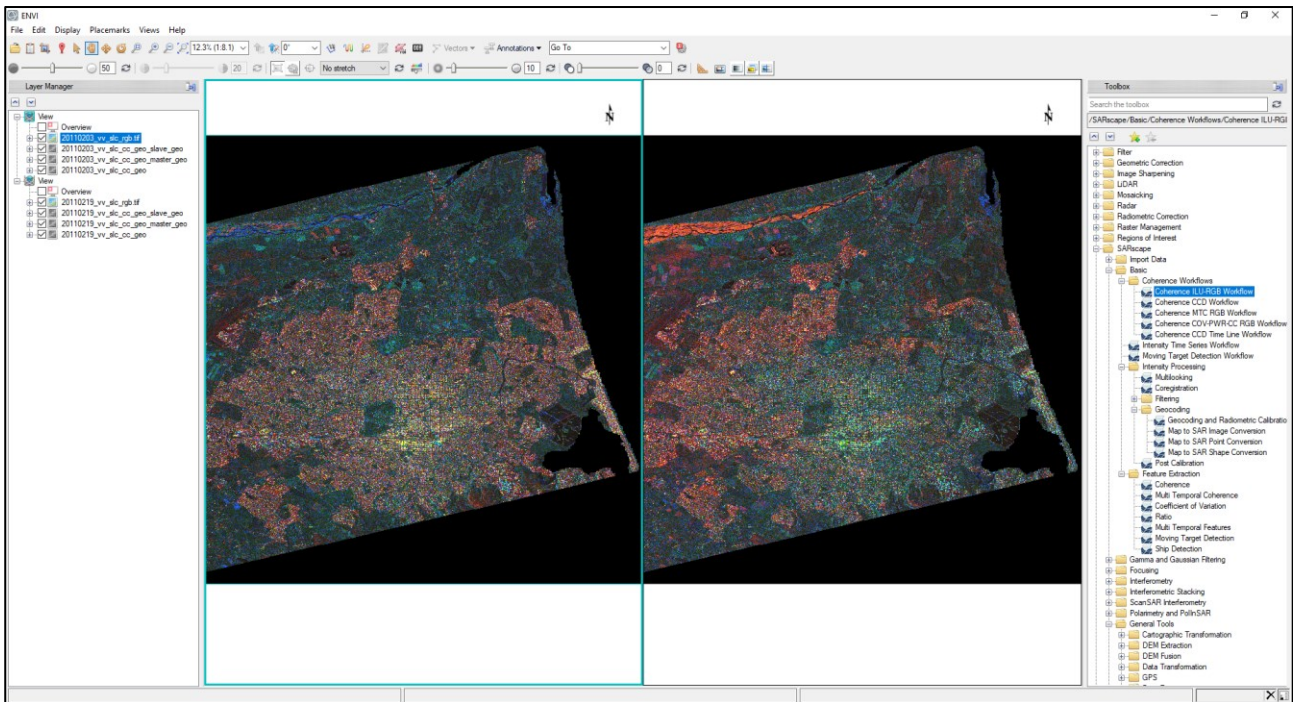


Figure 46: RGB tiff results of the Coherence ILU RGB workflow; pre-seismic pair (on the left), co-seismic pair (on the right).

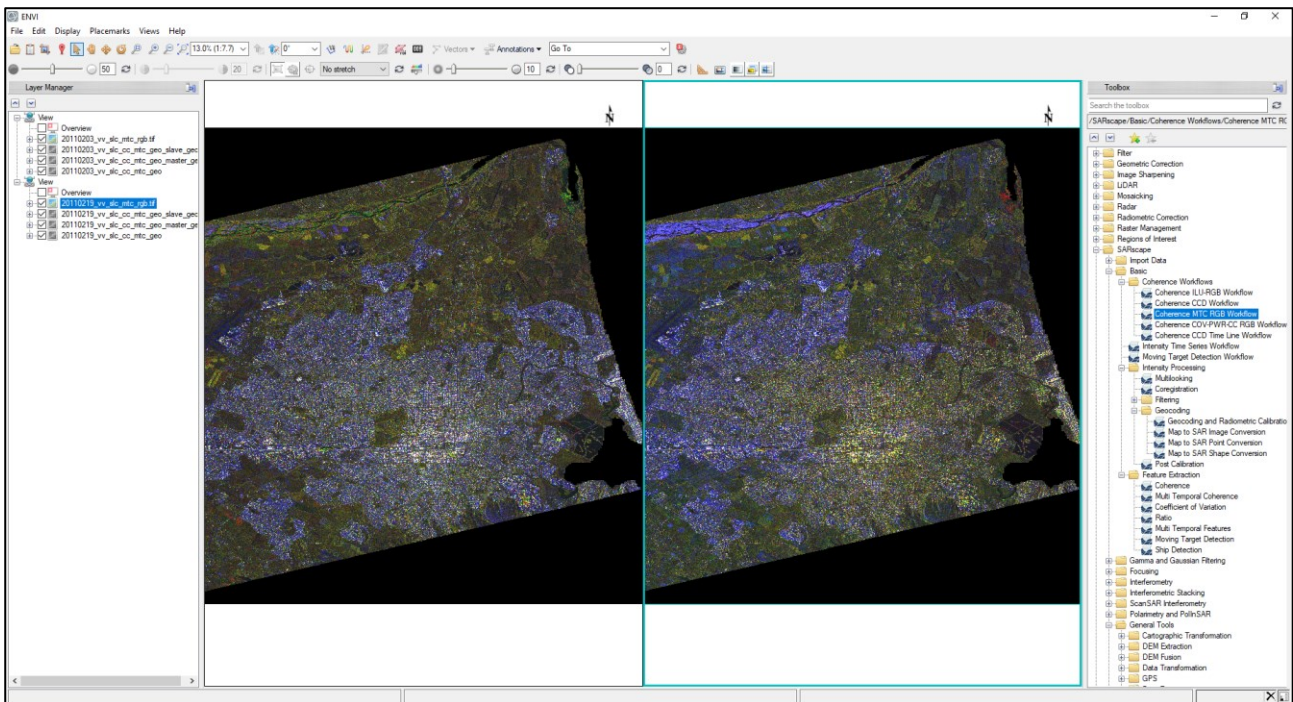


Figure 47: RGB tiff results of the Coherence MTC RGB workflow; pre-seismic pair (on the left), co-seismic pair (on the right).

The results of the Coherence COV PWR CC RGB workflow are shown in Figure 48, on the left for the pre-seismic pair and on the right for the co-seismic pair. The color coding here is the spatial coefficient of variation of the average backscatter in the Red channel, the average of the backscatter of the master and slave acquisition in the Green channel and the coherence in the Blue channel.



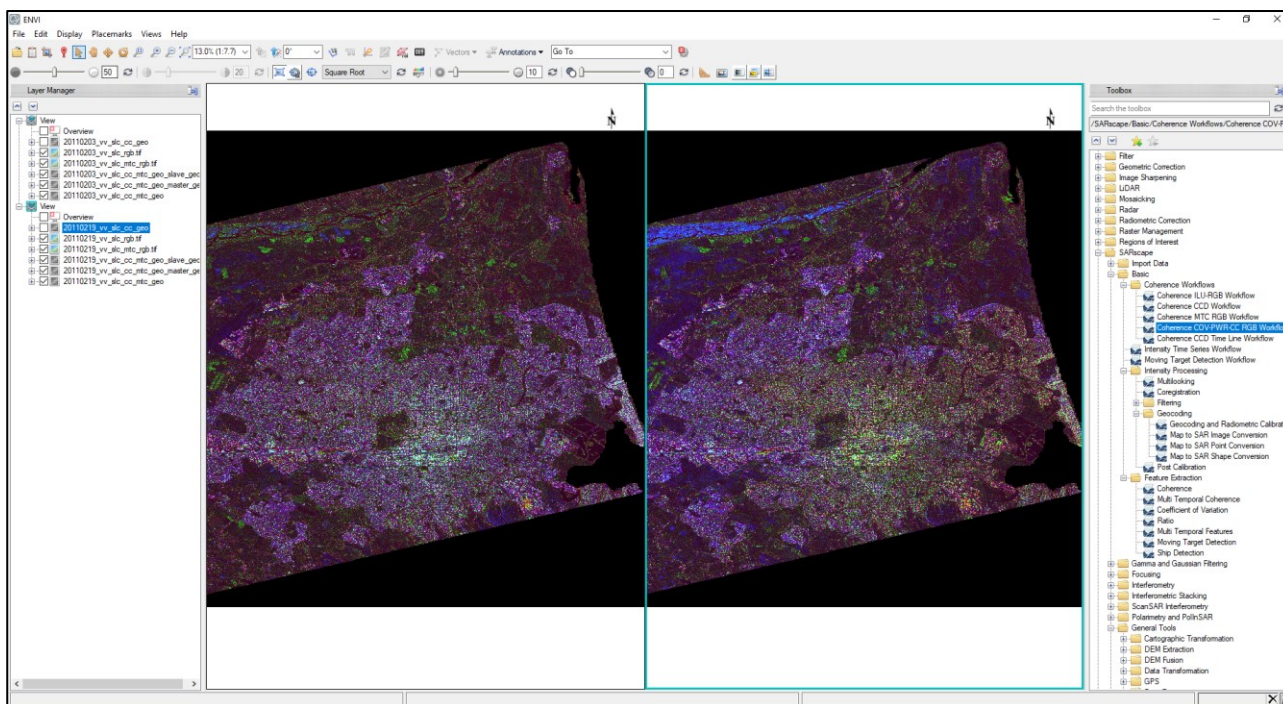


Figure 48: RGB tiff results of the Coherence COV PWR CC RGB workflow; pre-seismic pair (on the left), co-seismic pair (on the right).