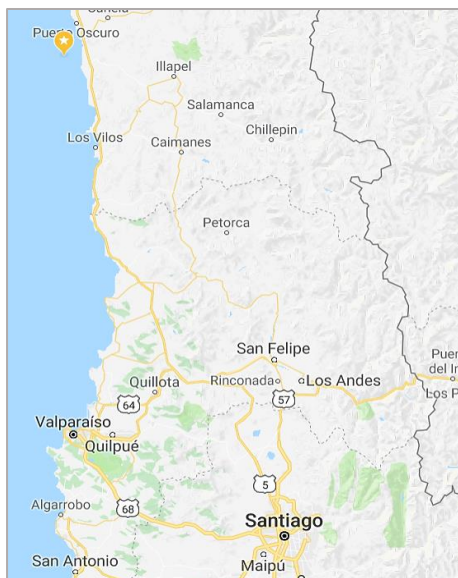


## ESA TRAINING COURSE ON RADAR AND OPTICAL REMOTE SENSING

Buenos Aires (Argentina), 12-17 November 2018



**Data:** The data used is high resolution Sentinel 1A Level 1 SLC data using dual polarization (VV/VH) acquired in interferometric wide swath mode. The data covers the area of Chile 8.3 Mw earthquake on the 16<sup>th</sup> of September 2015 on the Nazca Plate Region. The pair's scenes are from the 26.08.2015 (pre-event) and 19.09.2015 (post-event), Ascending mode. The earthquake took place in offshore area, 46 kilometres from the town of Illapel. The total number of casualties included 15 people killed and 6 missing in Chile and 1 fatality in Buenos Aires, Argentina, while many Argentinian provinces were also affected<sup>1</sup>.

1	S1A_IW_SLC__1SSV_20150826T232822_20150826T232849_007440_00A406_F205
2	S1A_IW_SLC__1SSV_20150919T232822_20150919T232850_007790_00AD74_594B

### A. Data acquisition:

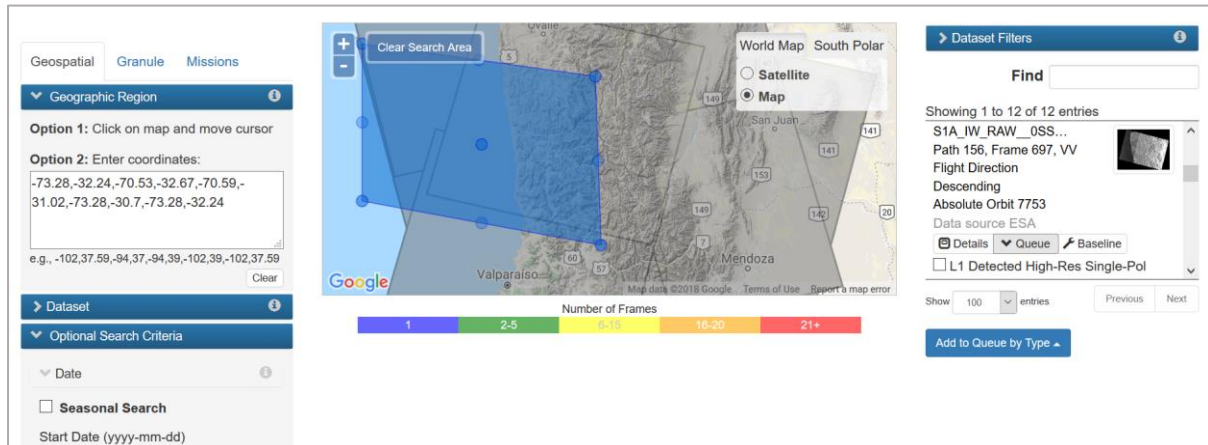
For this exercise data has been acquired from the satellite data repository of the Alaska Satellite Facility ([https://www.asf.alaska.edu/seasat/data\\_download/](https://www.asf.alaska.edu/seasat/data_download/)). The website hosts a data visualisation and download tool called Vertex (<https://vertex.daac.asf.alaska.edu/>). First step for downloading data is to create an Earthdata account (Earthdata Login -> Register). Once the registration process is done, searching for datasets can be done using the interface.

1. In the map area, zoom to the desired area of interest and click on the map, creating a rectangle or enter the projected coordinates manually (longitude, latitude in meters as map uses WGS84 Transversal Mercator) in the Coordinates panel on the left side of the interface.
2. Expand the Dataset panel on the left side of the interface and select the Sentinel 1 A and/or Sentinel 1 B datasets (*in this exercise only Sentinel 1 A will return results, since Sentinel 1 B was launched in 2016*)
3. Expand the Optional Selection Criteria panel below and select the start date and the end date. *For the current exercise we have selected a reference period of 20.08.2015 to 20.09.2015.*
4. Click Search and browse the Results panel on the right side of the interface.
5. Select the scene that is most suitable in respect with time and cover the interest area. Click on the Details button and navigate to the Products section. Have a look at the path, as the Multiple products can be downloaded, but for this exercise we will select the Level 1 SLC Single Look Complex and add it to the Queue. Repeat the same process for the second scene, selecting it in such manner that it respects the Path and the footprint of the first scene. This is necessary in order to have a good correlation of the pixels.
6. Select the Download Queue button and choose the Download Python script.

<sup>1</sup> [https://en.wikipedia.org/wiki/2015\\_illapel\\_earthquake](https://en.wikipedia.org/wiki/2015_illapel_earthquake)

7. Open a Command Prompt/Terminal and navigate to the folder where the script was saved. In the command line type the command: `python ./<scriptname.py>`. When asked about the username and password, introduce the credentials received during registration.

Alternatively, if there is no Python distribution<sup>2</sup> installed on the computer, the data can be downloaded directly in through the browser choosing Download instead of Queue in Step 5. A new page will prompt asking for credentials. Another option in Queue mode is to select the Download metalink and open it in any Metalink downloader application (<http://www.metalinker.org/>).



## B. Preparation of the data:

### 1. Open the two files in SNAP

- File / Open Product
- Browse the two products listed above
- *We will need both scenes to visualize the ground displacement at the time of the earthquake as we will look for seismic deformation. The temporal baseline is of 25 days.*

### 2. View metadata

- Select plus icons in the filenames in “Product Explorer”, expand “Metadata” and click on the “Abstracted Metadata”. You can see the information about the image’s acquisition.

### 3. View World Map

- View/Tool Windows/World Map (this panel might be already open by default in the down left side of the SNAP interface)
- Use mouse wheel and left click to zoom and pan respectively. The epicentre of the earthquake is in the North East corner of the image as seen in the World Map.

### 4. View image single bands

- Select “Bands” folder in “Product Explorer” window and view different bands by double clicking on their name. *Due to acquisition mode of this product (TOPSAR – Terrain Observation with Progressive Scans SAR technique or Interferometric Wide*

<sup>2</sup> Compatible with Python 2.7 and 3.0

*Swath acquisition mode), the product is divided in three sub swaths (IW1, IW2, IW3). For each sub swath we will have two images, one corresponding to the VH polarisation mode and one to the VV polarisation mode (six in total). For each polarisation mode there are two bands, the “i” band (real part of the signal) and the “q” band (imaginary part of the signal and the intensity). In SLC (Single Look Complex) images, the signal is complex, and thus contains the phase information, which is necessary for interferometry.*

## 5. TOPS Split

- Close metadata views, leaving only the viewers with bands.
- Since SLC images are very large files, we will only use a “subset” of the data, focusing on the area in the vicinity of the epicentre. *When acquiring the data, the satellite will scan the area progressively, three times. For each sub-swath, a number of variable bursts will compose the scanned sub-swath (9 for our exercise data).*
- For obtaining the necessary data we will first subset. Select Radar, Sentinel-1 TOPS, S-1 TOPS Split. In the prompted panel, select Processing Parameters. Click the “arrow” zoom button to directly visualize the area, then scroll to zoom in to the desired level of detail.
- In the Subswath dropdown select the IW2 option. For the Polarisation we will choose VV (as it gives better results). In the Burst bar, click on the arrows and drag them along the bar until the number of bursts selected is the one desired. In this case, we will preserve the entire number of bursts (9 for IW2).
- In the I/O parameters, select the output folder and rename the product preserving only the date and the “Split” suffix.
- Repeat the process for the second image.

## 6. Apply Orbit File

- Once we have performed the split on the two products, an orbit correction has to be performed. *Sentinel 1 data contains information about the orbit parameters in the metadata, but more accurate estimates of the satellite position and velocity during the acquisition is provided later (~ 20 days) through the POD (Precise Orbit Determination) service. POE (Precise Orbit Ephemerides) files are providing 10 seconds interval vectors of the satellite state.*
- In order to apply the POE file, select Radar, Apply Orbit File. In the Processing Parameters, let the Orbit State Vectors and Polynomial Degree as default and tick the “Do not fail if new orbit is not found option”. Then click Run.

## 7. Back Geocoding

- *This step is necessary in the chain of co-registering two radar images acquired on different dates (a master and a slave). The method is applying a function based on the information on the orbits of the satellites and a chosen Digital Terrain Model.*
- Select Radar, Coregistration, S-1 TOPS Back Geocoding. In the Product Set Reader add the two “\_Orb” products using the Add or Add Opened button and proceed to the Back-Geocoding. Here we will leave the defaults. Check “Output Deramp and Demod phase” if you decide to perform the next step as well, otherwise leave the box unchecked.

*The entire process of co-registration can be also done by using the same parameters when selecting the Radar, Coregistration, S-1 TOPS Coregistration operator. In this exercise we have used this workflow, thus, the opened product is already co-registered using the same steps.*

## **8. Enhanced Spectral Diversity (optional)**

- *It is performed using a small block of data centred on each burst in order to estimate the range and azimuth offsets, also determining the areas where the burst overlap. This step is performed for higher accuracy of the co-registration.*
- Select Radar, Coregistration, S-1 TOPS Enhanced Spectral Diversity. In the Processing Parameters tab, keep the defaults.

*It is possible to apply co-registration even with ESD, by selecting Radar, Coregistration, S-1 TOPS Coregistration with ESD. This step it is very time consuming and for this exercise we have not applied Enhanced Spectral Diversity.*

## **9. Formation of the interferogram**

- *An interferogram forms when the master image is multiplied with the conjugate of the slave image, resulting in a difference of phase also known as interferometric phase. There are sources of contamination, such as backscatter from different terrain features and the morphology of the terrain. We are interested only in the ground deformation, therefore we will remove this sources of bias. One necessary correction is the flat earth phase removal, that accounts for the curvature of the surface in the selected region. The geometry is also estimated using the WGS84 as reference system. A polynomial function describes the smooth, long wave body (ellipsoid) and the grade of the polynomial can be adjusted according to the size of the AOI (the greater the size, the greater the degree).*
- Select Radar, Interferometric, Products, Interferogram formation. In the Processing Parameters tab review the options and leave the defaults. The degree of the polynomial function can be adjusted if needed.

## **10. View image bands: Intensity, Interferogram and Coherence**

- In the “Bands” folder in “Product explorer” window, double click on the “Intensity”, “Phase” and “Coherence” bands to open them.
- In order to inspect them simultaneously, in the View tab, select the options Synchronize Image Cursors and Synchronize Image views, then select the Tile Vertically/Tile Evenly option.
- *Black bands are still visible on the three images as they account for the different bursts. These will be removed in the next steps for a more homogenous interferogram.*
- *A fringe of the interferogram accounts for a full cycle ( $2\pi$ ) in phase change. The calculation of how much difference is between two fringes can be interpreted as a range difference of  $\frac{1}{2}$  of the wavelength (no of fringes  $\times \lambda/2$ ). Closer fringes indicate a larger ground displacement while large distances between them indicate less deformation. Topography also plays a factor: flat terrain produces less variation in fringes’ distance, while topographic changes can lead to anomalous, unparallelled patterns. Also, atmospheric processes can interfere with the signal, producing artefacts that can count as ground displacement (e.g large storm cells, effects of the ionosphere*

#### 11. TOPS Deburst

- For joining back all the burst and creating a homogenous image, we will navigate to Radar, Sentinel 1- TOPS, S-1 TOPS Deburst and click Run.

#### 12. Topographic Phase Removal

- *Topography has its own addition to the total phase difference, and usually is removed using a Digital Elevation Model that simulates the terrain.*
- Navigate to Radar, Interferometric, Products, Topographic Phase Removal.

#### 13. Multilooking

- *Interferogram inspection can show that the product is still noisy and difficult to interpret. Reducing this noise is beneficial for enhancing the image and improve identification of fringes by increasing the SNR (signal-to-noise ratio).*
- First filtering operation is Multilooking. Select Radar, Multilooking. In the Processing Parameters tab select the “i” and “q” bands and change the number of looks to a greater number (e.g 6). This operation will decrease the spatial resolution though.

#### 14. Goldstein Phase Filter

- *The second type of filtering is the Phase Filtering for which we will use the nonlinear adaptive algorithm of the Goldstein Phase Filter.*
- Navigate to Radar, Interferometric, Filtering, Goldstein Phase Filtering. Keep the default values and click Run.

#### 15. Geocoding

- In order to interpret the results, we would need to first project it into a coordinate system. Select Radar, Geometric, Terrain Correction, Range-Doppler Terrain Correction. In the Processing Parameters tab check the Intensity and Phase bands. For the size of the pixel we will choose 30 m.

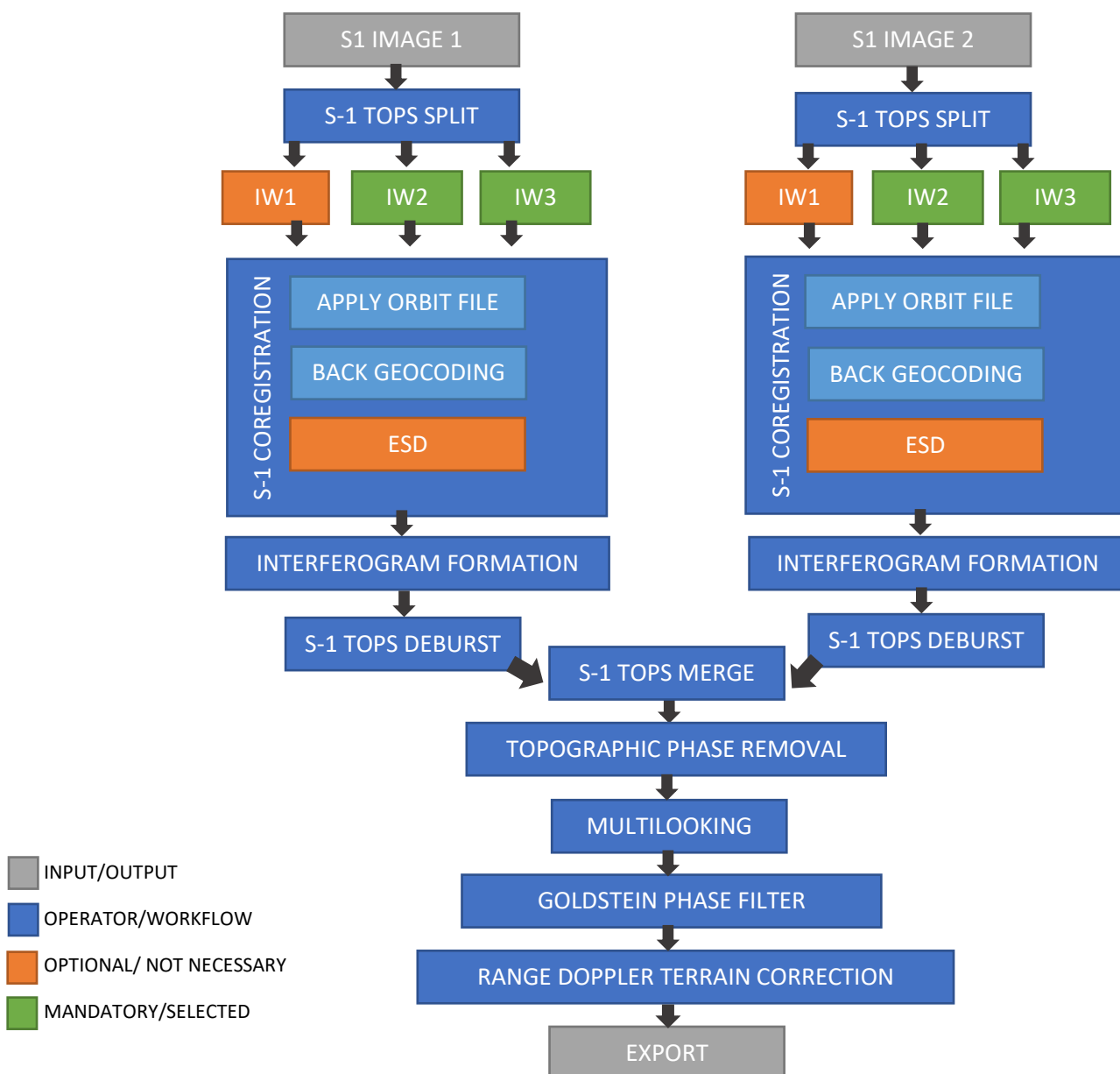
#### 16. Export and visualize the data

- The data can be exported from SNAP in various formats using the File> Export> Other> View as Google Earth KMZ function. For visualization purposes, we will choose to export to KMZ format and overlay the result in Google Earth.
- Open a Google Earth session and paste the following coordinates (earthquake coordinates): 31°34'12.0" S, 71°39'00.00" W and press Enter. This will automatically create a pin with the epicentre of the earthquake.
- Import the KMZ file exported.

## 17. Interferogram assembly (optional)

*In order to increase the size of the interferogram and have a complete picture of the deformation in the area, two sub-swaths can be merged using the following steps:*

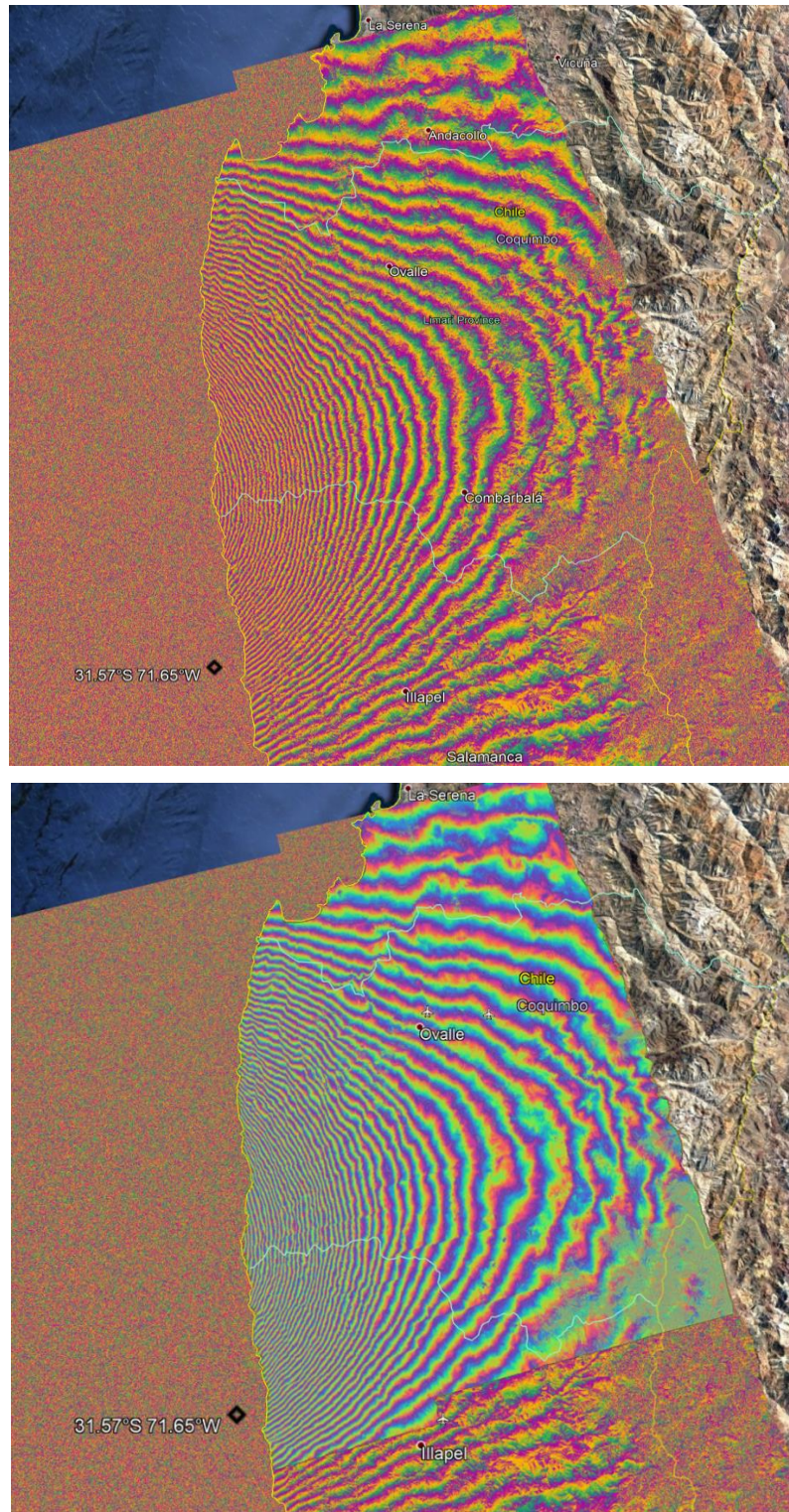
- Step 5 – 11: Perform Co-registration, using the other necessary subswaths. Since sub-swath IW2 that we have already processed, covers the Chile coastal area and IW3 part of the mainland, we will choose to run the same workflow for IW3 sub-swath as well.<sup>3</sup>
- Step 11\* : In this step we will combine the two interferograms for IW2 and IW3. Navigate to Radar, Sentinel 1 TOPS, S-1 TOPS Merge. Select both interferograms as inputs.
- Step 12-16: Run the remainder steps in order to create the final product.



<sup>3</sup> IW1 subswath was neglected since it covers only the marine area and deformation cannot be visible.



Experts involved in the ESA SEOM InSARap Project have already processed and distributed products. Products can be downloaded at this address: [www.insarap.org](http://www.insarap.org). Below we can see a comparison between the resulted product and the Wrapped interferometric phase (KMZ) provided by InSARap.



1) Phase obtained by the INSARAP experts, 2) Phase obtained using this exercise.