# Radar Interferometry with Sarscape Software

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## ABSTRACT

The availability of technical public domain software is important for a fast acceptance and integration of a technique in other disciplines, enabling scientists to gain experience with new techniques at low cost. Synthetic aperture radar (SAR) interferometry (InSAR) is an imaging technique for measuring the topography of a surface, its changes over time, and other changes in the detailed characteristics of the surface. By exploiting the phase of the coherent radar signal, interferometry has transformed radar remote sensing from a largely interpretive science to a quantitative tool, with applications in cartography, geodesy, land cover characterization, and natural hazards. Radar interferometry using freely available software has matured to a stage in which data from different sensors can be routinely processed to interferometric products. SARscape is one of the latest contributions to public-domain radar interferometry software. It is designed as a specialized software package for processing of SAR/InSAR data, and perfectly complements ENVI's functionality for analyzing and visualizing remote sensing data of any kind. More specifically, SARscape for ENVI is a modular set of ENVI (Environment for Visualizing Images) functions for processing of spaceborne remote sensing data from Synthetic Aperture Radar sensors. Currently, the systems ERS-1/2, JERS-1, RADARSAT-1 and ENVISAT ASAR are fully supported by SARscape for ENVI. In this paper, we present the feasibility of the SARscape radar interferometric software to create ERS interferometric products such as DEMs and deformation maps. A stepwise description of the creation of an ERS DEM of the Oran area in Algeria is presented.

## 1. THEORETICAL DESCRIPTION OF PREPARATION TO THE INTERFEROMETRY

### 1.1. Geographical framework

The interferometry zone of study is a small zone of Oran .it is in the North-West of Algeria on the area of Oran, in particular with its junction with the Verdon. It is delimited in North by the sea, of the large SEBKHA in the south and the mountains in the West and East.
From a strictly topographic view point, a characteristic of the zone and strong vegetable cover (Forest) on the sites mountainous and in the south as the East, the landscape does not present a marked relief (uneven the 200m do not exceed).

### 1.2. Selection of an interferometric couple

The first requirement is the availability of two SAR images in complex form. Complex SAR data refer to a set of data that has a real (cosine) and an imaginary (sine) component. The two values combine as vectors to provide the overall phase and intensity of a wave. Both these components of backscattered signals are measured by the SAR sensor onboard the satellite. This provides two resulting data streams, namely ‘I’ (representing In-phase / intensity / cosine component) and ‘Q’ (representing Quadrature / phase / sine component). The selection of the images is made on the basis of baseline length and the time period

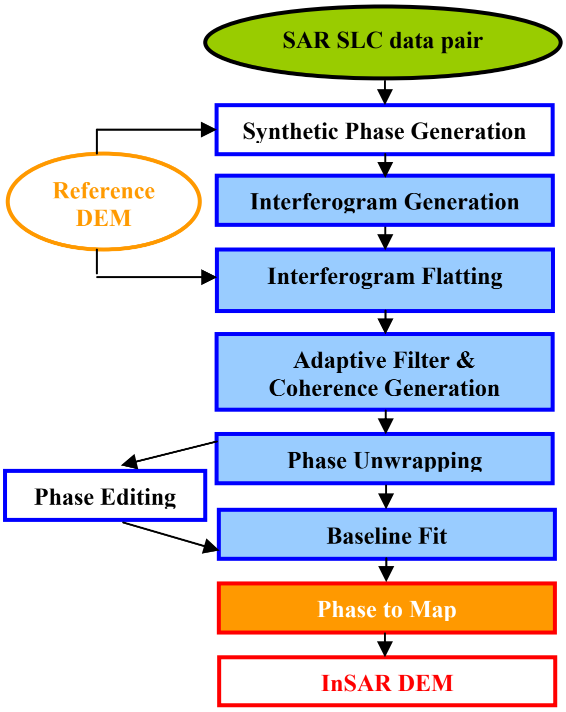
between two image acquisitions. Depending upon the application and the spatial resolution of the data, the baseline length can be chosen. For example, in the case of ERS–1 and 2, the baseline may be taken as 150 to 300m for topographic applications, 30 to 50m for surface change detection and up to 5m for surface feature movement studies such as crustal deformations, lithospheric movements, movement of glaciers etc. Also, the time gap between two passes of satellite may not be kept large as there may be some changes in the scene that may lead to temporal de-correlation. However, the temporal de-correlation, in the case of ERS-1 and 2 may be taken care of by tandem operation of two satellites at a small temporal resolution of as low as one day.
The selected raw data are then processed to convert SAR signals to image products like, Single Look Complex and GTC Geocoded Terrain Corrected with the help of DEM. This processing requires knowledge about the precise orbit and calibration parameters such as time reference and intervals of each image, and the chosen spatial and temporal resolutions of the images.

### 1.2.1. Topographic data

For the software most powerful to the realization of the interferogramme, use differents DEM of differents precisions for exemple GTOPO 30.
GTOPO30 is presented in the form of a grid of geographical co-ordinates associated ellipsoid WGS84; its reference in altitude is the geoid. Its 30 seconds resolution of arc provides a point all the 900m approximately in latitude.

## 2. SAR INTERFEROMETRY FOR DEM GENERATION

Two SAR images are combined to produce a SAR Interferogram to reveal information about the third dimension (elevation) of the object and to measure small displacements of objects between the two image acquisitions. An interferogram is an image acquired by making the phases of two SAR images of the same terrain to interfere.
Thus, after registration, the complex interferograms are formed by multiplying each complex pixel of the first image by the complex conjugate of the same pixel in the second image. The interferogram thus generated is a complex image itself. The intensity of the interferogram is a measure of cross correlation of the images. A careful observation of the fringes in Fig.4 reveals that closer are the fringes, more are the topographical changes or height variations.
the discription of the SARScape chains is given by this algorithm :




### 2.1. The Registration

The registration of the interferometric geometry is one of the most important and delicate steps in DEM generation process. its quality depends directly to the base line precision. However, the planimetric and altimetric errors obtained on a DEM are primarily due to an insufficient precision on the base line. It is thus significant to precisely reconstitute the orbital trajectories of the satellites in order to know their position perfectly.
To co-registrate the two images of the same scene makes it possible to use them in the same geometry. One of them is taken as reference; one defines it as Master image. By opposition, the other image is called Slave.

2.1.1. Geometric registration Master/DEM

At the time of this first step, SARSCAPE registrate the master image with respect to the DEM used with a precision of a fraction order of DEM pixel. In fact, it make the object of a radiometric simulation according to the geometry of catch of sight of the image radar defined in a file coarse descriptor. The image of the DEM projected in radar geometry is then similar to the Master image, with not pricise on the orbital parameters NR and t0.
It is then possible to carry out a correlation between these two images by pairing of homologous groups pixellic, for which one obtains a peak of correlation. This module of the software provides three imagettes representing the shift in distance, azimuth and the rate of correlation between the main image and simulation. From these shifts, SARSCAPE generates a new file more precise descriptor by correcting the values of NR and t0.

The precision of this registration controlled by the orbitography and the DEM depends mainly on two criteria.
First, the grid step of the DEM must be sufficiently small. With GTOPO30 for example, whose step is 900m, it is necessary to use control points. In addition, it is preferable to have on the image a well marked relief, to have good points of control .

2.1.2. Registration image Master/ slave

In cases where multiple image data sets cover the same region, it is necessary that pixels in different images correspond so that pixel-by-pixel comparisons can be carried out. Spatial registration may be necessary, and also resampling, in cases where pixel sizes vary. Coregistration is carried out automatically, based on maximising correlation in a number of windows.

2.1.3. Orbit refinement

The role of the orbital parameters t0 and NR is very important since it is them which will allow the passage of the satellite reference mark (azimuth, distance) to the geographical reference mark. Thus, in absence of precise topographic data, it can appear skews on their estimate. It is the case during the registration of the Master image relative with GTOPO30, but the use of a certain number of control points makes it possible to control the validity of this co-registration. These control points are GPS points which should obligatorily be measured. These remarkable points can be localised on the image, their indices of line and of column (i,j) are thus known.
it has then:

$$j = (R - NR)/\delta_d$$

In the same way, the knowledge of time makes it possible to calculate:

$$i = (t - t_0)/PRF$$

**PRF**: Pulsate Repetition Frequency.
**$\delta_d$** : Radial resolution.
**NR** : Near Arranges
Now and in this step which we must compare all measurements with truths values of the file orbits.
The comparison between the indices measured and the file orbits and estimated allows to determine the shifts in line and column.

Taking some points for example in this table:

| | Co-ordinates measured in geometry ROS | |
|---|---|---|
| **GPS Points** | **Line (i)** | **Column (j)** |
| **A** | 682 | 625 |
| **B** | 1712 | 1702 |
| **C** | 817 | 1042 |
| **D** | 2302 | 1356 |
| | **Co-ordinates estimated on The Image of Magnitude** | |
| **GPS Points** | **Line (i)** | **Column (j)** |
| **A** | 718 | 591 |
| **B** | 1747 | 1668 |
| **C** | 852 | 1010 |
| **D** | 2337 | 1323 |
| | **Shifts (coord measured - coord estimated)** | |
| **GPS Points** | **Line (i)** | **Column (j)** |
| **A** | -36 | 34 |
| **B** | -35 | 34 |
| **C** | -35 | 32 |
| **D** | -35 | 33 |

thus that deduit:

dLmoyen=-35 dCmoyen=33

These shifts of pixels dL and dC. are then retranscribed respectively in distance and time lags (***dt=dL/PRF***) (***dR=dC.δd***). By applying these shifts to the values of t0 and NR calculated by SARSCAPE, we take a better precision of registartion. So it's verry interestant to integrate the new parameters t0 and NR adjusted in the file descriptor of SARSCAPE and restart again the interferometric chain.

### 2.2. Interferometric product

The interferometric product of SARSCAPE consists of three images: an image of phase or interferogram, an image of coherence and an Magnitude image, this image (Magnitude) is formed by average of the Magnitudes of the complex interferogram.

SARSCAPE offers two geometries of exit: that of the images radar and that of the DEM. In the case of geometry radar, the pixels are regrouped according to initial factors' multivue. The produced images are then superposable with the multivue of the Master image. In the case of the otho-rectified geometry (DEM), the pixels are regrouped by closer neighbors on

the points of the DEM. The produced images are then superposable with the DEM. Thereafter, we will use the interferograms exclusively geocoded.
In geometry radar, the interferograms obtained can be interpreted like a Map of the topographic errors of the initial DEM translated to Unwraping.

### 2.3. Elimination of the orbital fringes

As we saw previously, the precision of the orbital data is insufficient on a centimetric scale wavelengths used. The compensation of the orbital fringes is thus imperfect and is translated on the interferogram by a residual gradient in the radial (Range) direction and in the azimuth direction (defect of parallelism of the orbits). The result of this treatment is to eliminate these fringes. Thus, by simple counting of the orbital fringes, we can calculate the average "slope" of the fringes and eliminate them by an subtraction from the gradients interferogram corresponding (in Range and azimuth).
it can automatically eliminate with SARSCAPE the orbital fringes on the interferogram even disturbed. Without reaching a as good estimate as manually, the software thus calculates the residual gradients in azimuth and distance.

## 3. RESTITUTION OF THE RELIEF

After having seen the process of formation of the interferograms, we approach here a method of restitution of the relief.

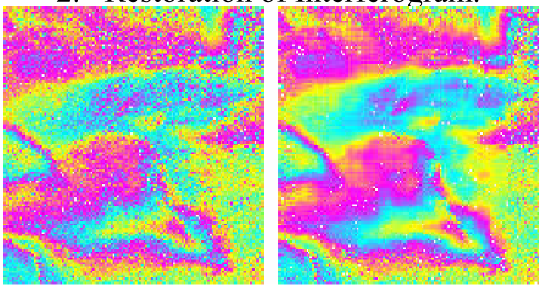
### 3.1. Choice of the zones of test

To proceed to the realization of the relief, it is always necessary to choose several small zones with the different topographic characteristics, for which we will discuss the treatments and the effectiveness of the restitution.

### 3.2. Filtering

According to the altitude of ambiguity employed, the interferogram can contain an excessive noise, in particular on zones with strong slopes, likely to obstruct its exploitation since the fringes are found masked.
In this Step of filtering thus is essential often in the data processing sequence of interferograms ROS to eliminate the noise which is added with the exploitable signal.The difficulty of filtering consists in cleaning the noise without degrading the information of phase.
This noise of space or temporal origin is not always reversible. Only, one considerable share of the noise affecting the interferograms can be eliminated, which leads to information of cleaned phase which guarantees a more robust unwrapping phases and final information with not noise . Several filter integrated on this software ,which we used the filter Gamma-Gamma for structure detection but for Speckle an Adaptive filtering of the speckle in SAR Interferometric data is integrate in this Software,it’s make for:

1. Restoration of the Coherence Degree.
2. Restoration of Interferogram.



**Not Filtred** **Filtred**

**Fig 2** : Not Filtred and filtred phase images

### 3.3. Phase unwrapping

In an interferogram, the phase is only known modulo 2 π. It is thus N écessaire to determine the multiple of 2 π to add with the phase measured on each point to obtain an estimate of the real phase.

The unwrapping phase thus consists in redistributing with each pixel its absolute phase. Two constraints burden this procedure:

❖ surface must be relatively regular; for this reason, it is preferable that it is smoothed beforehand.

❖ the absolute variation between two close pixels must be lower than π. the discontinuit és due to screening in zone of overlay or with covering make then the procedure particularly delicate.

An example of course of phase is illustrated on the figure below:

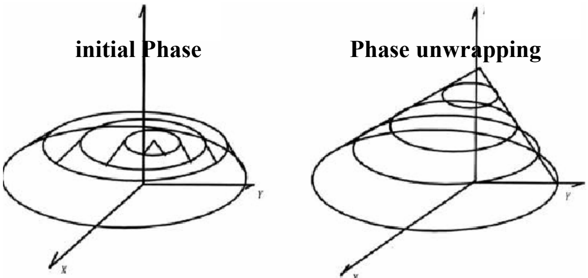



**Fig 3** : unwrapping Phase in three dimension

the phase unwrapping is the most difficult step in the process of DEM generation. thus, the presence of noise on the interferogram can distort the information of phase considerably. This is why it must be preceded by an effective filtering which cleans this noise.

A first solution to unwrapping the phase consists in correcting a pixel compared to an adjacent pixel by supposing that the slope between these two points is weakest possible among all those possible defined with a margin of 2. In practice, the interferogram is traversed starting from a pixel reference and each pixel is corrected gradually by taking account of the precedent.

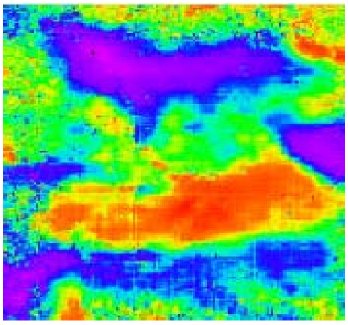


**Fig. 4:** unwrapping Interferogram

The mottled shapes of the interferogram take the aspect of smooth and compact structures after filtering.the phase unwrapping was thus made without apparent discontinuity.

### 3.4. Phase to height conversion

As a final step, the terrain height may be determined using several methods and algorithms, who are integrated on SARScape, which convert phases into terrain heights

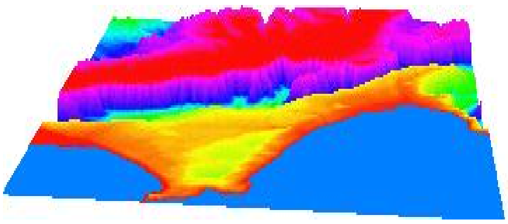


**Fig 5** : Interferometric DEM

## CONCLUSION

The feasibility of obtaining an accurate Digital Elevation Model with ERS Tandem interferometric techniques has been validated over a greate part of area where the topography has significant variations.
The importance of an accurate processing has been highlighted; the use of topographic maps and lower resolution DEMs, when available, is of great support to the processing chain.

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