ASAR CONTRIBUTION TO LANDSLIDES INVENTORY AND MONITORING

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ABSTRACT

Landslides are one of the major natural threats, claiming thousands of lives and millions of euros each year all over the world.
Several parameters are useful for landslides inventory and monitoring which can be derived from ASAR data such as Digital Elevation Models (by radargrammetric and interferometric methods) and landcover maps. But the mountainous environment requires to take into account the specificity of SAR image. The slope effect is the centre of the processing, it influences on the radiometric value, the geometry distortions and the altimetric error.

1. CONTEXT / OBJECTIVE

Hazards due to landslides are not only relevant to local inhabitants but also to all users of the environment, including tourists, owners of equipment, infrastructure, land, and users of roads and railways.
The main objective of this paper is to evaluate the contribution of Advanced Synthetic Aperture RADAR (ASAR) data in an operational system for landslide monitoring.
This study has been undertaken with different partnership whose skills cover all the chain of ASAR data exploitation for landslides identification: remote-sensing, data production and geoscientists.
The work presented here has performed within an announcement of opportunity of Envisat ASAR for the European Spatial Agency (ESA).
This paper is composed of three majors parts :
(i) Landslide features and geoscientists needs are presented in Section II.
(ii) The Digital Elevation Model (DEM) obtained by radargrammetry method and its qualifications are discussed in section III.
(iii) In the last section, the preprocessing needed before apply traditionnal classification methods are studied.

2. LANDSLIDE FEATURES

2.1 Geoscientist Needs

Landslide mitigation necessitates extensive inventory and monitoring at large scales, often very difficult and expensive with traditional methods. Remote sensing techniques offer an alternative to this problem, allowing a regional identification of landslide prone-areas
The landslides depends on many factors but only three parameters have been kept :

- ➔ Topographic aspect (DEM, slope)
- ➔ Land use
- ➔ Soil moisture

If the three following criteria are checked for a area, we will consider it is a landslide area candidate :

- ➔ Steep slope
- ➔ bared soil or small vegetation
- ➔ Moist Soil.

2.2 Study Area

The study area is located in the South of French Alps, which is the landslide prone-catchment of Super-Sauze and Draix. These areas are well documented case studies allowing field validation of the documents derived from remote-sensed data. In this paper, only results on Super-Sauze area are presented.
The Super-Sauze earthflow (Barcelonnette basin, Alpes de Hautes-Provence, Southeast of France) has an elevation between 2105 m and 1740 m for a 25 degree slope which cover a 17 ha area.
In the present study, reference DEM is used to compare radargrammetric DEM obtained from ASAR data.The reference DEM has been also used to compute value-added product to apply the geometric and radiometric correction

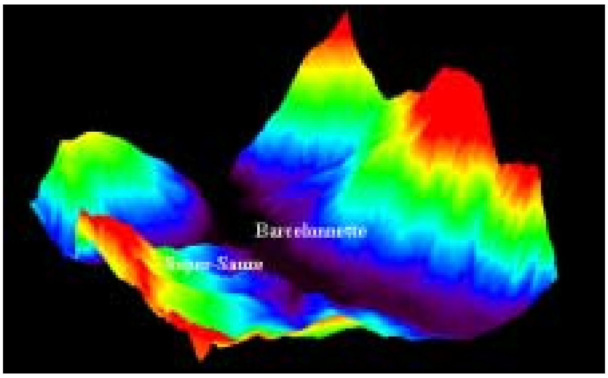


Fig. 1: Overview of test area in 3D view

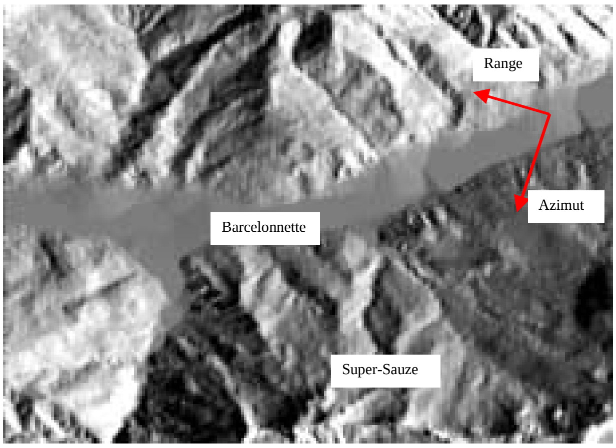


Fig. 2 : 2D view of the Barcelonnette basin

3. DIGITAL ELEVATION MODEL

To extract the 3D information from SAR images, two majors methods have been considered :

- Radargrammetry: it is based on the stereovision principle. The method takes as input a couple of SAR images and uses the parallax information between images.
- Interferometry : it uses the instrument coherence and the phase difference of a couple images to estimate the height of a point. It is a very precise technique but if suffers from constraints on acquisition.

3.1 Radargrammetry

3.1.1 Principle

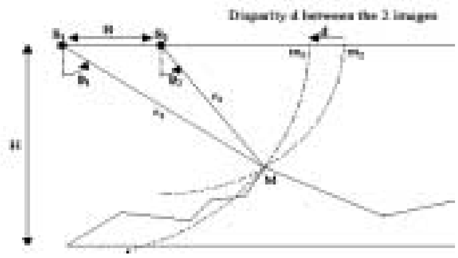


Fig. 3

Our radargrammetry processing chain is represented Fig. 4

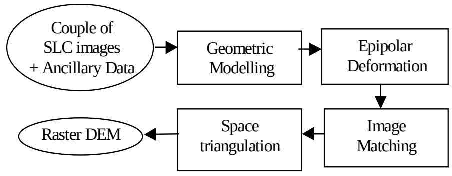


Fig. 4

The input for Radargrammetry is a couple of Single Look Complex (SLC) images (master and slave image) and ancillary data related to the orbit parameters. The final product is a DEM.

During Geometric Modelling, the information of image acquisition are used to link image points to geographic points on the ground. The interest of epipolar deformation is to limit the size of the space search of homologous points. Search point can be reduced to almost one dimension. The existence of epipolar lines has been demonstrated in SAR and optics spatial imagery.
The image matching is the more important step. The objective is to compute the disparity between the two epipolar images for each pixel of the master image.
From the disparity map and the inverse deformation epipolar model, we can identify homologous points in original image.

3.1.2 Results

3.1.2.1 Results at global scale

We have applied radargrammetry processing on two ASAR SLC image in descending orbit.

The first image has been acquired the 16th August 2003 with a look angle of 16° in Image Swath 1 (IS1).
The second image is dated from the 06th July 2003 and the look incidence angle is 31° (IS 4).

The obtained DEM has been mapped on a one arc second grid and compared with the reference DEM. The Table 1 gives the statistics of altimetric error. The altimetric error is not fairly distributed in the DEM as one can see on the Fig. 5 .

Altimetric error (m)	Percent of pixels
0-25	28.24
25-50	19.90
50-75	12.78
75-100	9.0
100-150	9.58
200 and more	20.45

Table 1

3.1.2.2 Matching processing problem

The error can be explained by the topography of the area. The complexity of the relief increases the effects of typical SAR geometric deformations like layover and foreshortening. Fig. 6 represents the same area viewed from the two different look angles 16° and 31°. Moreover, if the back slope is too steep, the local incidence angle is very high and the radiometric value associated very small. The matching processing is very difficult under these conditions.

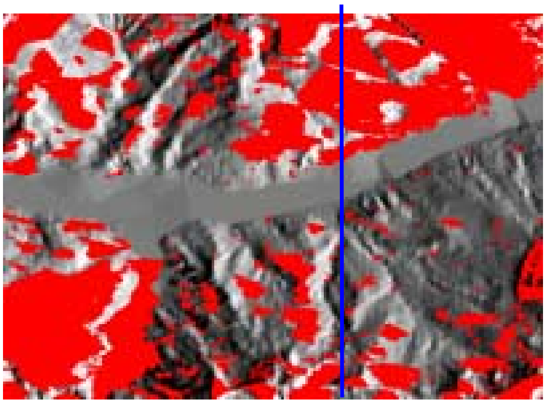


Fig. 5 : The red colour represents area, where the altimetric error is more than 75 m. The blue line indicates the direction of the DEM profile used at local scale qualification.

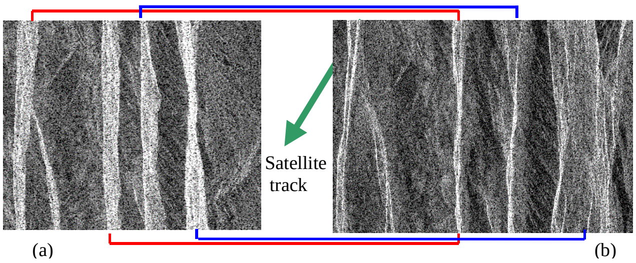


Fig. 6 : (a) image obtained from an look angle 16°
(b) image obtained from an look angle 31°.

The blue colour in **Fig. 7** represents layover associated to image IS1 (slope > 16°) and in green colour represents where local incidence angle is greater than 60° in the case of image IS4 (slope < -30°).

This figure can be related to the distribution of altimetric error (Fig. 5), the main errors are mainly located where layover occurs and where radiometric values are very small.

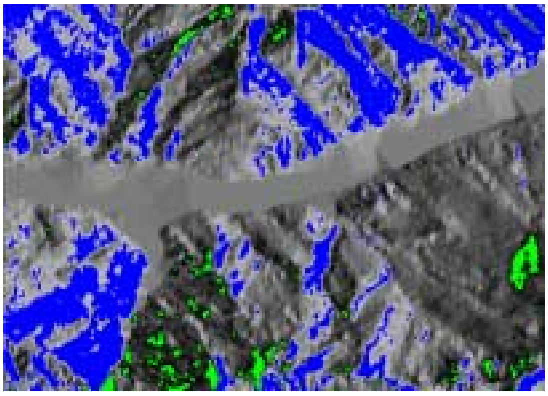


Fig. 7

3.1.2.3 Slope effect on altimetric error

The geometric distortions depends on the look angle and the slope value. Layover occurs when the slope is greater than the look angle. Foreshortening increases when the difference in the slope and the look angle value decreases. So in the both cases, the distortions occur on the front slope.

We retrieve this result in the Fig. 8 which gives the distribution of altimetric error according to the slope.

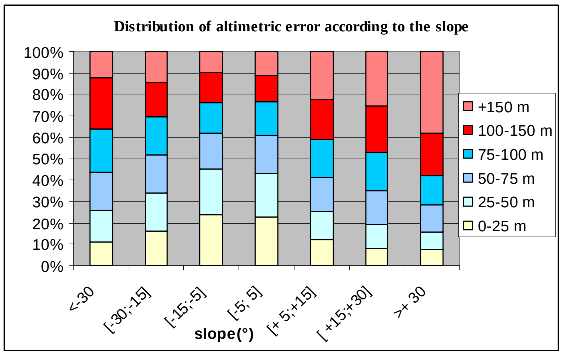


Fig. 8

The greatest errors are located on front slope area where the matching processing is more complex.

To build a DEM, it seems better to choose a direction of orbit such that landslide area does not falls in the slope facing the sensor. It is our case.

The slope has a second effect, it increases also the altimetric error related to one count of disparity error. This result comes from the building of the points used in the space triangulation.
Each point is the result of intersection of two circle of sight. The first one corresponds to the master image, the second one to the slave image.
The Fig. 9 illustrates the building of three points with no disparity error in two cases of slope value

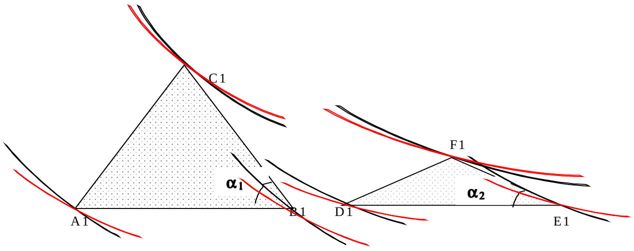


Fig. 9

If we introduce the same disparity error in the both cases, the point C1 et F1 will be not building correctly. But the altimetric error is greater in the case of a steep slope than in the case of a smooth slope as we can see in Fig. 10.

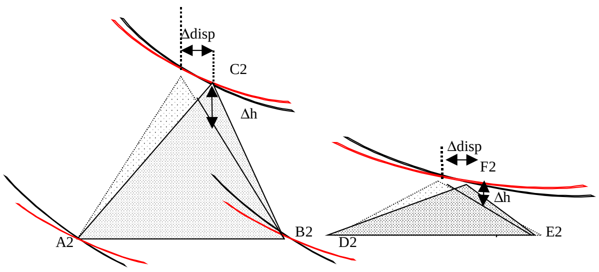


Fig. 10

3.1.2.4 At local scale

At local scale, we are in a back slope case, so results are better than at global scale.

The study at local scale consists of comparison of the DEM profile. The location of the profile is indicated in Fig. 5.

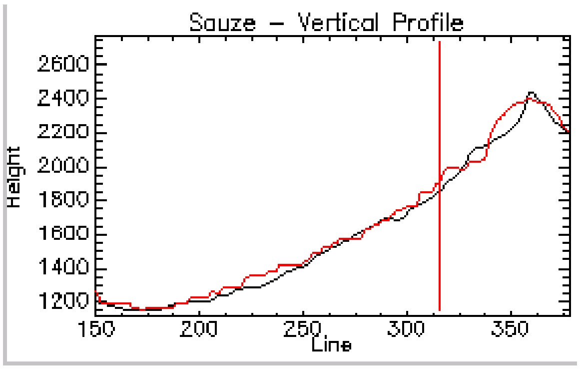


Fig. 11 : ASAR DEM profile is in red and Reference DEM profile in black

We consider the profile from the top of the mountain to the valley. The restitution of relief is good indeed the mean of the altimetric error is equal to 25m with a standard development equal to 23.5 m

3.2 Interferometry

Interferometry processing is in progress.

4. CLASSIFICATION

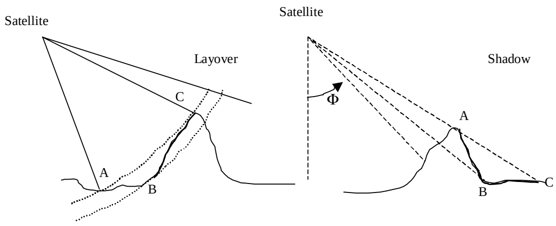
Under the extreme viewing conditions in mountainous area, traditional classification methods cannot be directly applied. Interpretation of SAR images in areas with significant relief requires rigorous calibration considering local illuminated area and incidence angle effects. Identification of geometric effects identification is required to take into account the layover and shadow effects.

The following paragraph aims to describe the products needed for the preprocessing.

4.1 Value Added Products

4.1.1 Layover and Shadow Map

From the orbit parameter and the reference DEM, one can compute the distance between the satellite and the ground points located in the line of sight. Knowing the slant range resolution, each pixel is associated to one or several ground points when overlapping occurs.
This processing allows to create a layover and shadow maps. Layover areas occur where the distance between sensor and target decreases while the horizontal distance between sub-satellite track and target increases. The shadow areas are computed by studying the nadir angle evolution which should increase continuously if images contains no shadow.



4.1.2 Local Incidence angle

For topographic radiometric correction, the local incidence angle is computed for each pixel.

The first step is to compute the slope from reference DEM in the range direction and in the azimuth. In case of a back slope, the sign of slope is negative.

The second step consists to create the two slope maps (range and azimuth) in the slant range geometry. The relation between the map geometry and the slant range geometry has been established in the paragraph 4.1.1.

The last step consists of the computation of the local incidence angle (θ_{ir}) depending directly on the look angle (θ) and the slope (α) in the range direction.
The local incidence angle in azimuth direction corresponds to the slope in this direction.

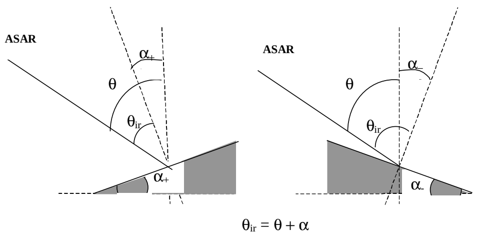
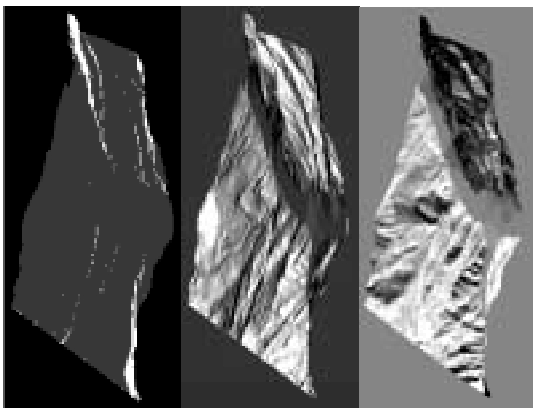


Fig. 12



(a) (b) (c)

Fig. 13 : Map in slant range geometry for IS1:

(a) layover map (b) local range incidence angle (c) azimuth incidenceangle

4.2 Radiometric correction

Radiometric corrections are required to perform multitemporal analysis images acquired with different geometries.

Radiometric correction is based on computation of the local ground scattering area which contributed to a single image pixel. The corrected intensity is given by the following formula [ROGOW 99]:

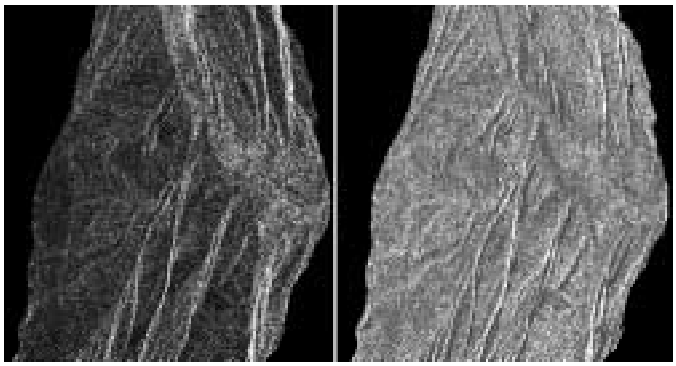
$$\hat{I} = \frac{I \times \sin(\theta_{ir}) \times \cos(\theta_a)}{\sin(\theta)} \quad (1)$$

where,

θ_{ir} and θ_a are the local incidence angles in the range and in the azimuth direction, respectively.

θ, the look angle in the middle of the scene

I, the raw image intensity.



(a) (b)

Fig. 14 : SAR image data in slant range geometry (IS1): (a) uncorrected amplitude data (b) amplitude data after radiometric correction

4.3 Analysis in Map Geometry

Before applying classification algorithm, the corrected amplitude image is projected to the map geometry. This operation allows to work on several images with a common geometry. A mask of geometry distortions (i.e., layover and shadow) is applied, indeed these pixels have not to be taken into account while image analysis.

Lee filters can be also used in order to reduce the speckle noise effect

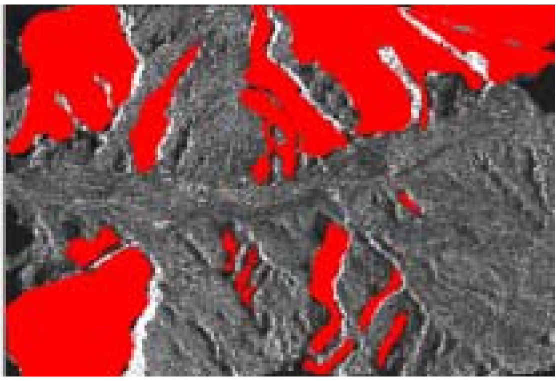


Fig. 15 : amplitude image IS1 in map geometry. Layover mask has been applied.

4.4 Classification

Classification is still in progress.
The aim of classification is process four classes : Forest, bare soil, small vegetation and urban area. This will be done with several images with several incidence angle.

5. CONCLUSION

SAR image processing in mountainous environment requires to take into account a lot of constraints.
We have seen the effects of slope in DEM building and its accuracy. The geometric distortions also depend on slope value, which induces problems of visibility in area of interest.
Before classification the slope effect has to be corrected in order to equalise the radiometric values.
As the reader has probably noticed, the study is still in progress, notably classification processing. Indeed the study meets a lot of problems to plan ASAR images on our test area, our order having not naturally the priority on commercial order.