ABSTRACT

A Ground Based interferometric SAR (GB SAR) was employed to monitor an active alpine landslide located in Citrin Valley (North Italy) for a time period of two years. Instead of measuring terrain movements continuously within a single measurement campaign, this work reports on data gathered on five different campaigns carried out sequentially from September 2003 to September 2005. The loss of coherence (decorrelation) is the main problem in these applications and some precautions were designed to control it. A solid platform, where the radar instrumentation was carefully reinstalled at each campaign, was built specifically in order to avoid geometric decorrelation between different campaigns. Suitable processing techniques similar to those used in satellite interferometry were adapted to the ground based configuration and used to compensate for the loss of coherence related to atmospheric and electromagnetic variations. The results obtained by means of these techniques within the two years long monitoring campaign are presented and discussed in this work.

1 INTRODUCTION

Ground-based SAR (GB SAR) interferometry has already been recognized as a powerful tool for continuously monitoring landslides with short time scale i.e. terrain movements occurring at daily or less frequency [1, 2, 3]. In these applications the instrumentation is engaged working for some days and displacements are measured with accuracy of a fraction of the transmitted wavelength (typically millimetric accuracy can be achieved). When a long period of observation is needed, as in the case of slow varying phenomena (with time scale of about one year) the loss of coherence can greatly reduce the accuracy and restrict the investigable areas. In GB SAR as in satellite and airborne interferometry, decorrelation depends on slightly different measurement geometry (geometric decorrelation), and both on changes of the scatterers with time within the resolution cell and atmospheric variability (temporal decorrelation) [4]. Changes of the scatterers can concern their position with respect to the radar sensor and their overall backscattering coefficient as well, while atmospheric variability affects the velocity of the signal in the propagation medium [5, 6].
In contrast to satellite and airborne sensors, a GB SAR installation is more easily manageable and, as reported in this work, platforms for supporting the synthetic antenna aperture can be designed specifically to guarantee correct repositioning thus avoiding geometric decorrelation. As far as temporal decorrelation is concerned, data processing techniques from the satellite interferometry have been adapted to the GB SAR configuration. In particular a method based on the principles of the Permanent Scatterer analysis [7], was implemented by the authors. The method processes radar images for selecting reflectors with phases coherent for long time on the illuminated scene. By observing the phases of some of them, the atmospheric effects can be modeled and evaluated on all the ensemble of coherent points [8]. In the present work, with the platform guaranteeing no baseline errors, this method was used to compare five different GB SAR measurement campaigns carried out in the last two years for monitoring an alpine landslide in Citrin Valley (North Italy).

2 GROUND BASED RADAR INTERFEROMETRY ON COHERENT POINTS

2.1 Instrumentation

The employed ground based radar instrumentation mainly consists of a continuous-wave step-frequency (CW-SF) transceiver working at C band, a linear horizontal rail where the antennas move for scanning the synthetic aperture, and a PC controlling the transceiver, the antenna motion and data recording.

Fig. 1: Block scheme of the instrumentation.

Fig. 2: Auto-Calibration procedure.

Fig. 1 shows a block scheme of the instrumentation. In order to compensate for the phase shifts produced by mechanical and thermal deformations of the cables, a calibration procedure, called auto-calibration, was designed. For each rail position, two measurements are carried out in sequence: 1) the signal backscattered by the illuminated scene is acquired through the microwave path from the receiving antenna in A’ to the point B’ (Fig. 2); 2) the signal from the receiver
unit is acquired through the path from point A to B (AB = A’B’). This is realized by a microwave switch controlled via USB that alternatively connects the receiver unit to point B and B’. Using the measurement with the switch connecting B to the receiver as a reference, normalized data, which are not affected by thermal and mechanical cable deformations are obtained.

2.2 Antenna Rail Platform

For the measurement campaigns reported in this work, the radar system was located on a suitably built platform, ensuring a good visibility of the main flows of the landslide within a distance of 2 Km, while guaranteeing a solid frame for subsequent positioning. Fig. 3 shows the steps followed for arranging the platform.

![Fig. 3: The steps followed for installing the instrumentation on the platform](image)

Two metal plates, highlighted by red circles on Fig. 3.1, are fixed by means of threaded rods and epoxy adhesive at the ends of the top surface of a concrete basement. The firmed plates are connected by a metal template (Fig. 3.2) that is provided with two mountings where the antenna rail will be then screwed (Fig. 3.3). Finally the antenna block is mounted on the rail (Fig. 3.4). Only the two metal plates of Figure 3.1 are left after each measurement campaign so steps 2, 3 and 4 have to be repeated to reassemble the instrumentation.

2.2 Data Processing

Complex radar images are generated by focusing the normalized data according to standard SAR techniques. The phase $\phi$ of each image pixel contains information about pixel distance from the sensor. When terrain displacements occur in the time elapsed between two image acquisitions, the phase of the corresponding pixels will vary accordingly. The difference between the pixel phase values in the two images, called interferometric phase, is used for terrain monitoring.
In this work, interferometric analysis is achieved on coherent pixels only. The method used to identify the coherent pixels is based on analysis of a time series of their amplitude values. The ratio of the amplitude standard deviation and mean of each image pixel is used to estimate the pixel phase fluctuation [7]. Consequently, pixels showing a stable sequence of relative amplitude will be considered coherent.

Some of the coherent pixels are then chosen for atmospheric effects evaluation. The atmospheric contribution to the interferometric phase is modelled as a polynomial in range with constant coefficients which can be determined by observing the phase of special coherent pixels representing actual stable targets on the scene [8]. The atmospheric contribution to the other coherent points is evaluated according to their ranges and removed from their measured phase values.

<table>
<thead>
<tr>
<th>MEASUREMENT PARAMETERS</th>
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<tbody>
<tr>
<td>Polarisation</td>
<td>VV</td>
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<tr>
<td>Target distance</td>
<td>1000-2000 m</td>
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<tr>
<td>Transmitted Power</td>
<td>20 dBm</td>
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<tr>
<td>Band</td>
<td>30 MHz</td>
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<td>Central frequency</td>
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<td>Linear scansion length</td>
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<tr>
<td>Linear scansion point number</td>
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<tr>
<td>Antenna gain</td>
<td>15 dB</td>
</tr>
<tr>
<td>Measurement time</td>
<td>30 min</td>
</tr>
</tbody>
</table>

Table 1: Measurement parameters used for the campaigns.

3 RESULTS AND DISCUSSION

3.1 Measurement Campaigns Description

Citrin valley is located in the Gran San Bernardo mountains in the Alps of Valle d’Aosta, Italy. The intense rainfall events of October 2000 triggered the activity of a dormant landslide inventoried since 1970s and debris started sliding down into two wide flows all along the mountain slope rushing to the Citrin torrent channel. In order to assess about the landslide hazard, GB-SAR observations were planned by the recognized Regional Authority and carried out by the authors at the end of September 2003 and then repeated on July 2004, September 2004, July 2005 and September 2005. Each campaign lasted a few days only. The measurement parameters generally used are summarized in Table. 1. The measurement time is the time needed for gathering a single image. Fig. 4 shows a picture of the instrumentation with the observed landslide area in the background.
3.2 Displacement Maps

The measured data were grouped into 4 pairs of subsequent campaigns: September ’03-July ’04, July ’04-September ’04, September ’04-July ’05 and July ’05-September ’05. Each pair was processed separately. The coherent pixels are about 10% of the pixels producing strong enough signal for all the pairs and they only slightly differ from one pair to another. For each image only the coherent pixels are considered hereafter.

Fig. 5: September ’03 - July ’04.

Fig. 6: July ’04 - September ’04.

Fig. 7: September ’04 - July ’05.

Fig. 8: July ’05 - September ’05.

The standard deviation of the measured displacements between different campaigns was used for estimating the statistical fluctuation of the presented technique. It amounts to 4 mm for the two campaigns with ten months of temporal separation, and 2 mm for those separated by two months.

Fig. 5, 6, 7 and 8 show the retrieved displacements along the radar line of sight (LOS) for each pair of measurement data. The colored points are the coherent points and their color represents the intensity of their LOS displacement. Positive displacements are towards the radar sensor. It can be seen that on the rocky area where the landslide activity is more severe, all the available points present a similar behavior, suggesting a global sliding along the slope of about 1 cm after ten months.
4 CONCLUSION

The landslide occurring in Citrin Valley was monitored for the first time on September 2003. Then instrumentation was removed and reinstalled on July '04, September '04, July '05 and September '05 in order to map terrain displacements occurred in the elapsed time. Each pair of subsequent campaigns was analysed separately. The obtained information is limited to points coherent through the two subsequent observations. Displacement of about 1 cm after ten months were found on the rocky area more interested by the landslide. The results substantially are in agreement with extensometers and GPS data.

References