Experimentation of different techniques to extract DSM from EROS B imagery in a post seismic scenario

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Abstract. The aim of this work is to describe an experimentation on the possibility of extracting digital surface models (DSM) from stereoscopic images acquired from one of the less investigated satellite platforms: EROS-B. In the present paper the phases of extraction of a DSM from high resolution stereopairs using different methodologies are illustrated, and the results obtained are described and analyzed. Experimentation on using GCPs from GPS/GNSS survey and cartography were performed. The experimentation focused on two “pseudo” stereo pairs and one actual stereopair acquired by this satellite on areas morphologically different between them, one in the center of L’Aquila city and the other just some kilometer eastern (Paganica area), whose history was marked by some earthquakes because they are situated partially on an active seismic area and on an ancient lake-bed. The importance of this study is due in part to test the possibility of use of EROS-B imagery in an area recently marked by a strong earthquake, allowing so the extraction of digital models to compare the DSM before and after the earthquake. In this way we’ll have the possibility to quantify the buildings volumetric changes to perform an initial assessment of damages.

Keywords. DEM/DSM, earthquake, EROS-B, post-seismic scenario, pseudo stereopairs, satellite images, stereopairs.

1. Introduction

With this paper we want to illustrate the extraction steps of a DSM from EROS-B stereopairs and 'pseudo stereopairs' and after describe the evaluation of accuracy of consequently extracted digital surface models (DSMs). In this experimentation we used two of the most popular commercial software: PCI Geomatics 2013 and the module LPS 2011 of ERDAS IMAGE 2011. The importance of the study presented in this paper is due in part to the fact that its illustrates a series of experimentations conducted to demonstrate the real possibility to extract digital surface model from satellite images acquired from platform little investigated for this specific application field, EROS-B. On the other hand, with the use of EROS-B imagery, an area recently marked by a strong earthquake has been investigated: L'Aquila city and its surrounding. For this test area the extraction of digital models is strategic because, by comparing the DSMs before and after the earthquake, may be, we have the possibility to quantify the buildings volumetric changes determined by the earthquake itself and to perform an initial damage assessment after the seismic event.

2. Methods

2.1 Data Available

All images used for this work were acquired by EROS-B (Figure 1) an high resolution commercial imaging satellite. The launch of EROS-B took place on April 25, 2006 on a Start-1 launch vehicle from the Svobodny Cosmodrome in eastern Siberia. Slightly larger and similar in appearance to EROS A, [1] the satellite has superior capabilities, including a larger camera of CCD/TDI type (Charge Coupled Device/Time Delay Integration), with standard panchromatic resolution of 0.70 m at an altitude of about 500 km, a larger on-board recorder, improved pointing accuracy and a faster data communication link.

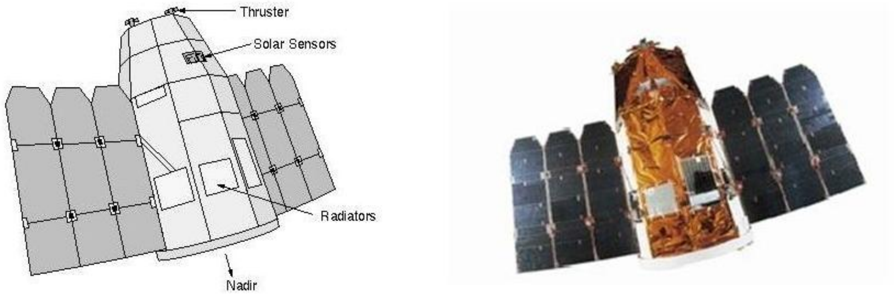

Figure 1. EROS-B satellite.

For this study we used a 'actual' intrack stereopairs centered on Paganica, a center nearby L' Aquila seriously affected by the earthquake of 6th April of 2009 and one pseudo-stereopairs of the historic center of L'Aquila (Figure 2), so defined because it consists of two acquisition made in two consecutive days and therefore similar to an across-track stereopairs because they have a relative geometry similar to stereoscopic.

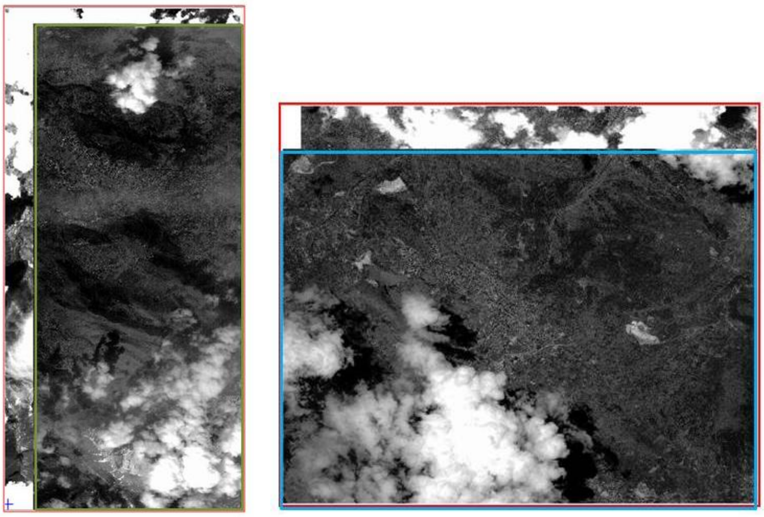

Figure 2. Pseudo-stereopair of L'Aquila and 'real' stereopair of Paganica.

No high resolution or very high resolution satellite stereopair of the city of L' Aquila after the event is immediatly available to the scientific community, while EROS-B platform acquired five different monoscopic acquisition of the city in different days just after the event .They cover the whole territory of the center of the city of L'Aquila and were acquired on 17 and 24 April 2009, few days after main seismic event. Some of these acquisitions have mutual "across track" stereo geometry but are not actual stereo-pairs because they were acquired in different days and for this reason they can be defined as 'pseudo-stereopairs'.

2.2 The software

To test the DSM extraction from EROS-B imagery we used two of the most popular scientdiffused commercial software: PCI Geomatics 2013, the recent update of PCI Geomatics 2012 (that heavily modified the DSM extraction module) and the module LPS 2011 of ERDAS IMAGE 2011. The two images of real and pseudo stereopair were oriented in PCI- Geomatics using a set of GCPs (Ground Control Points) and CPs (Check Points). In particular on the two images of pseudo stereopair, centered on the area of L'Aquila, there were collimated GPs previously acquired by RTK-GPS survey, while in the case of real stereopairs GPs were extracted from the vectorial official 1:5000 cartography of Abruzzo region. In fact it's still very difficult to acquire GPS points in the area of Paganica for the problems of accessibility of the area after almost four years from the main event. After the CPs collimation the residuals were estimated using the rigorous Toutin model [2][3] to exclude the presence of outliers.

To study the precision obtainable from the rigorous model and the accuracy of the images, some series of images orientation were made observing RMSE of GCPs and CPs while increasing the number of GCPs. In the figures below (Figure 3) are illustrated the RMS trends of GCP and CP increasing the number of GCPs only for actual stereopair; however all the tests were performed on every available image.

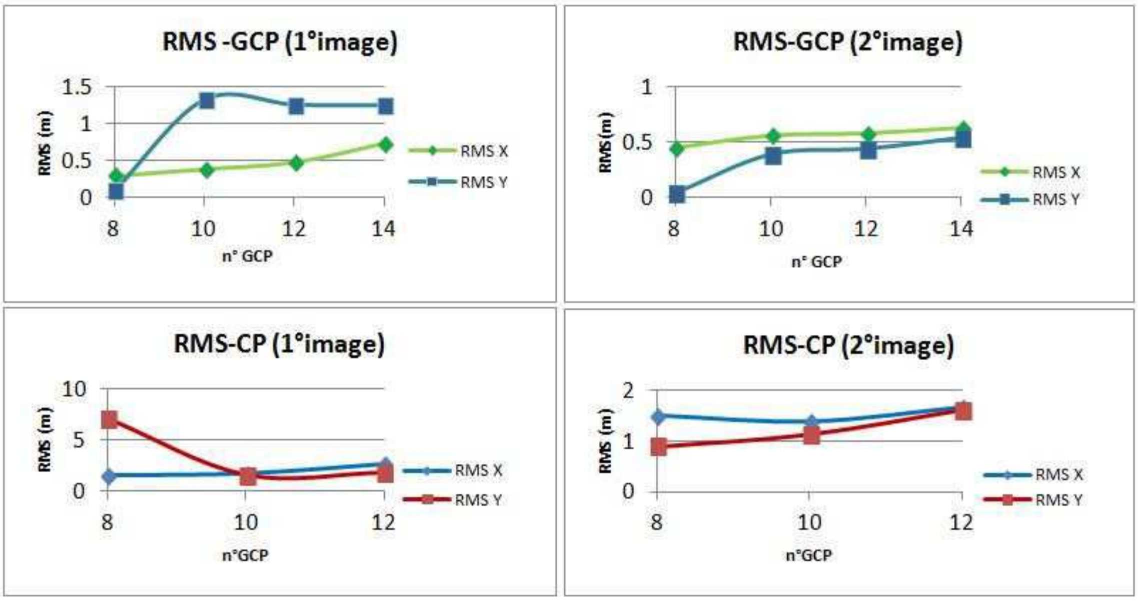

Figure 3. Precision and accuracy obtainable from EROS-B real stereopairs.

It can be observed that after the collimation of 10 GCPs both the precision and the accuracy seem to reach a stabilization around 0.5-1 m of RMSE in the first case and 3-3.5 m of RMSE in the second. This values obtainable can be considered acceptable according to the resolution of EROS-B images.

These tests carried on the stereopair images show the best CPs configuration to perform the image orientation.

After this orientation tests DSM was extracted in 'Geomatica 2013' environment too. Digital surface model extraction was performed following rigorously the procedure provided and documented by the producer of the software. First of all some tie points (TP) have to be collimated to improve the relative orientation of the two frame of the stereopair. This operation can be advantageously performed in automatic mode but a verification of the operator on every single point was needed. After this step the creation of epipolar images of every combination of two images was executed. Epipolar images are stereo pairs that are reprojected (Figure 4) so that the left and right images have a common orientation, and matching features between the images appear along a common x axis [4]. Using epipolar images increases the speed of the correlation process and reduces the possibility of incorrect matches.

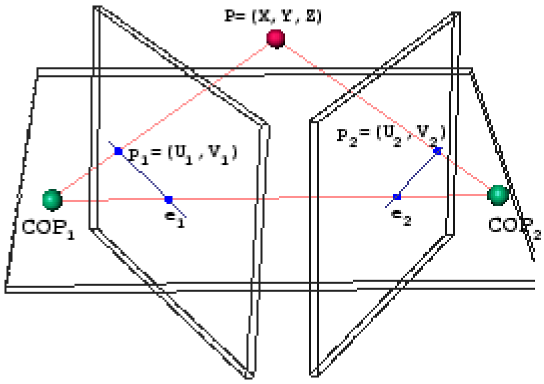

Figure 4. Geometry of epipolar images

All the possible combination of epipolar images were used to extract DSM. These last tests reported results very similar to the use of a single stereopair so they are not reported here. In the figure below (Figure.5) is shown the DSM extracted with PCI-Geomatica 2013 from EROS-B pseudo-stereopair centered on L'Aquila city. Instead of extracting DSMs for entire images we chose to focus the investigation on some areas to avoid the effects of cloud cover. In Figure 5 is also shown the clip region selected for DSM extraction.

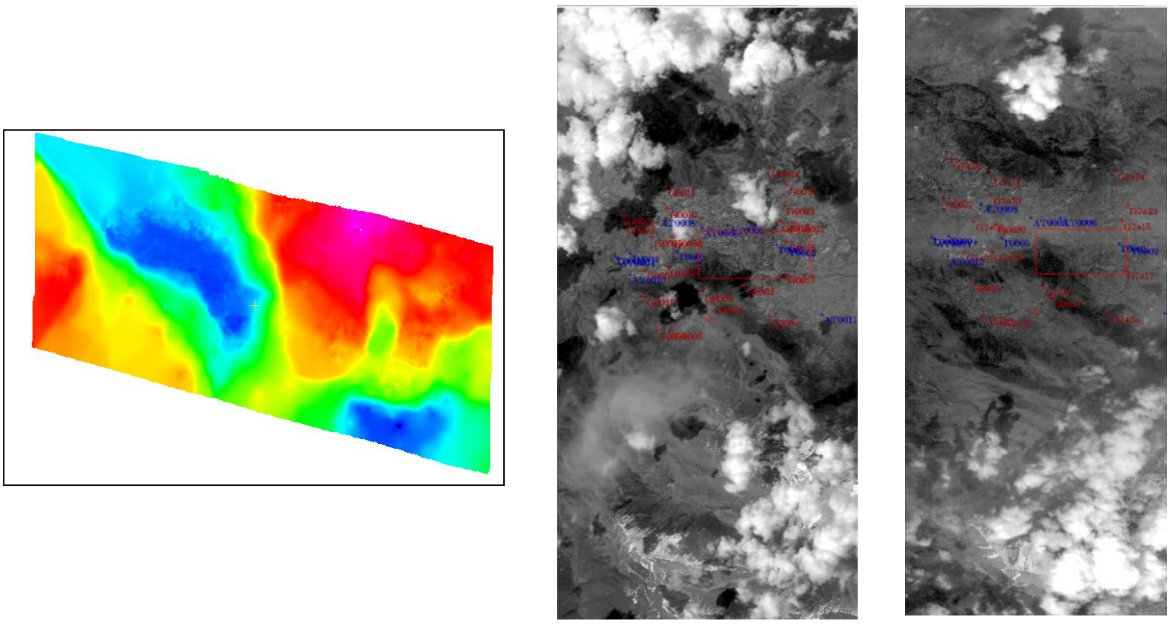

Figure 5. The extracted DSM from L'Aquila pseudo-stereopair and the clip region selected on both images

The same procedure was also carried out for the actual stereopair. The results obtained are shown in the figure below (Figure 6).

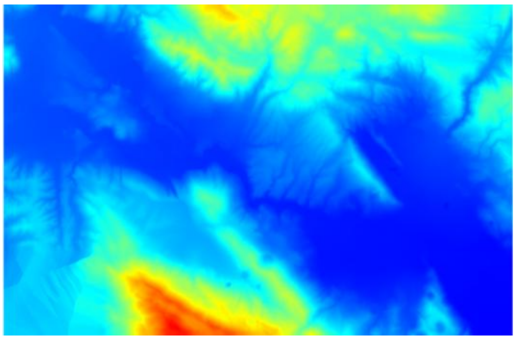

Figure 6. The extracted DSM from Paganica real-stereopair

The DSMs extraction from EROS-B images was conducted also with the LPS module of Leica Photogrammetric Suite 2011 version. It's important to underline that in this case the same GCPs of the PCI projects have been used to make absolutely comparable the results between this two software.

The figures 7 and 8 show the areas identified in this case for DSM extraction on both stereopairs.

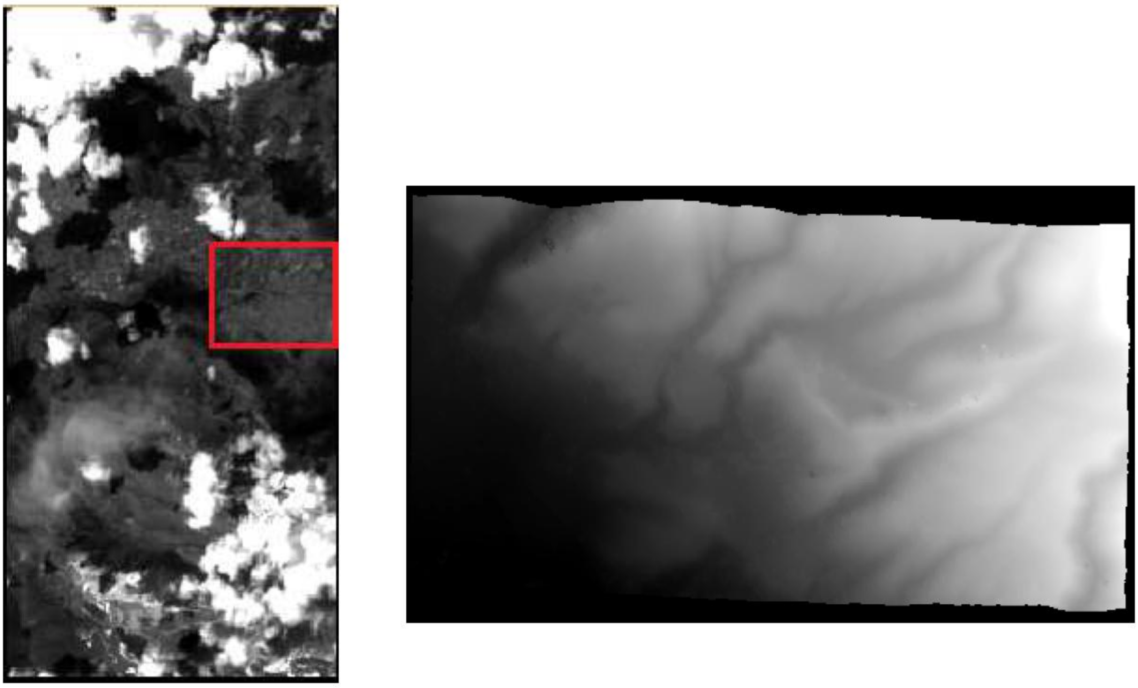

Figure 7. The selected area for DSM Extraction and the result obtained from pseudo stereopair (L'Aquila)

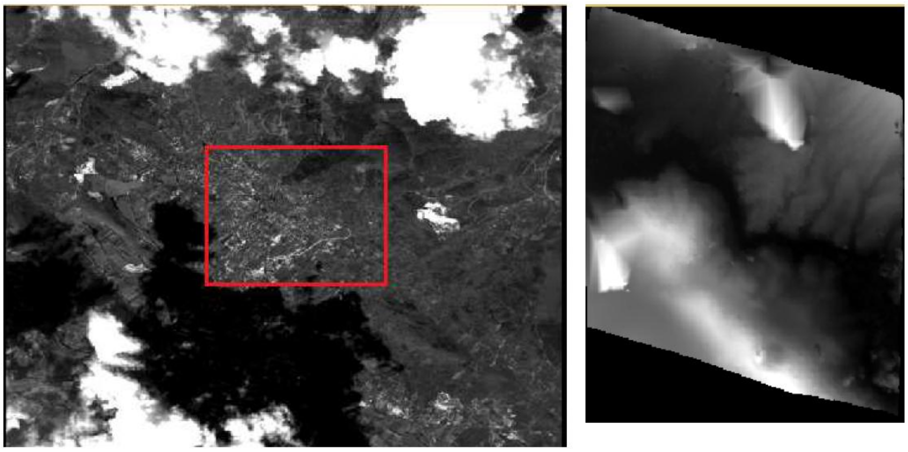

Figure 8. The selected area for DSM Extraction and the result obtained from real stereopair (Paganica)

3. Results

After DSM extraction each digital model obtained was checked and validated in open source GIS software: Quantum GIS v. 1.8.0. A comparison was made between the height of the spot points in 1:5000 vectorial cartography of L' Aquila and those in the obtained DSM [5]. The shape files containing spot points were imported in QGIS and modified with the addition of a specific field containing the height differences between points and DSM heights. Then the points have been classified in five different ranges to have a visual representation of the distribution of errors. The comparison obviously has not been carried out for the entire image but only for the points in the clip region where we extracted the DSM. The DSM validation [6] was performed for both digital surface model extracted from real and pseudo-stereopair with the two software. However in this paper we show only the result obtained for the DSM extracted in LPS software.

An attempt was made to see how the elimination of clouds and shadows has influenced the results. On the pseudo stereopair of L'Aquila two types of tests were performed, the first removing from vector file the points in correspondence of clouds and shadows, and making a comparison with DSMs heights only for the remaining points; the second tests were performed removing only points in shadows. In the figures below (Figure 9 and Figure 10) is shown the distribution of height difference errors for both the tests.

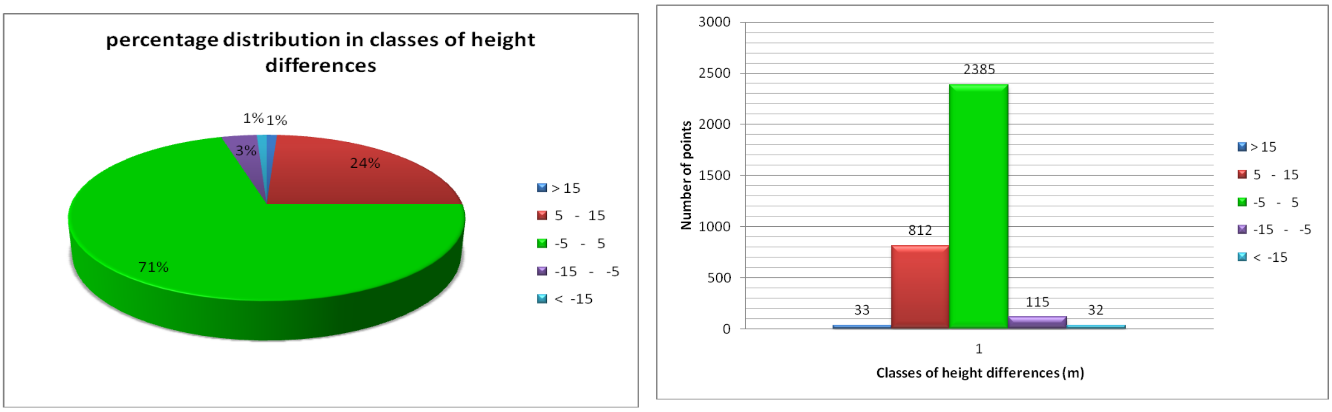

Figure 9. Results of analysis on DSM without clouds (L'Aquila)

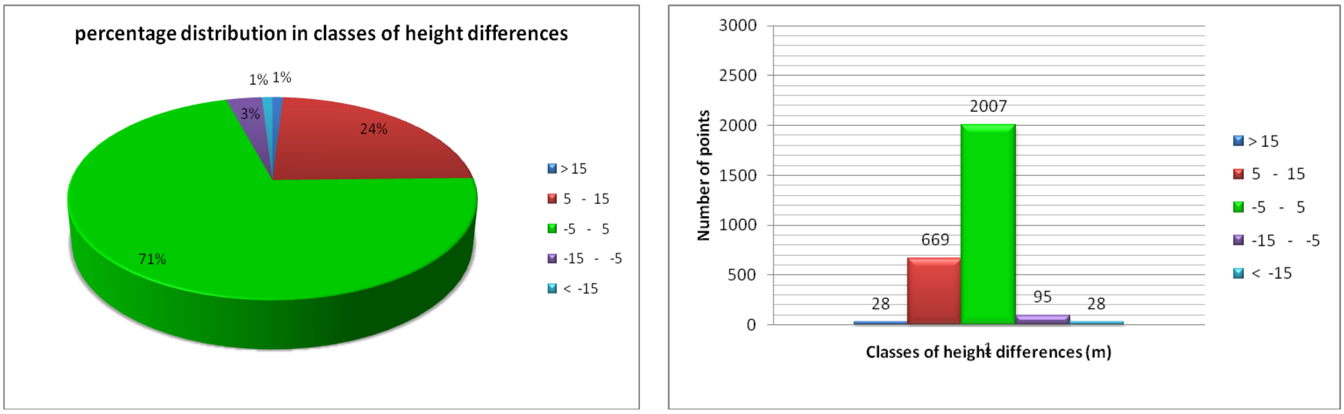

Figure 10. Results of analysis on DSM without clouds and shadows (L'Aquila)

About the DSM extracted from real stereopairs of Paganica, we performed a single test because there were no shadows but only clouds that covered the selected area.

The figure below shows the result of this test in terms of distribution (number of points and percentage distribution) in classes of height differences.

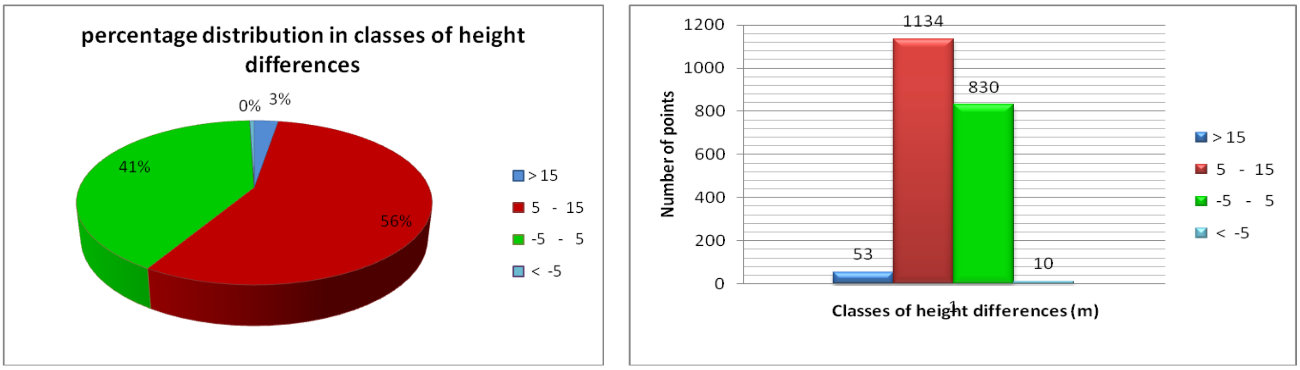

Figure 11. Results of analysis on DSM without clouds (Paganica)

Analyzing the graphs in figures above it must be said, that for both stereopairs, of L'Aquila and Paganica, the result was influenced by the considerable cloud cover present in the two scenes.

Although the overall results in terms of the height reported in the DSM can be considered satisfactory for a large numbers of points. It is however unexpected that the best results are obtained from pseudo stereopair. This is probably due to the fact that, in this case, the GCPs were obtained through a GPS survey while in the other, points from cartography were used that are less accurate.

4. Conclusion

This research work has revealed very surprising results; in fact the obtained accuracy is higher using pseudo stereopair than using actual stereopair. We hypothesized this is due to the lack of GPS GCPs on Paganica area, where the only actual stereopair is available; in fact the results are much more accurate on L'Aquila area where also GPS/GNNS GCPs are available. The use of cartography points in such post seismic environment is suggested by the difficult access to the area after almost four year from the main seismic event, but a GPS-GNSS survey will be performed to deeper investigate the results.

Regardless of the results obtained in terms of DSMs accuracy, however the DSM extraction in post seismic scenario is already very important to evaluate the volumetric changes of the buildings but optimizing the DSMs extraction techniques and making the different phases faster it will be possible to use it also for early damage assessment.

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