

# DEM EVALUATION GENERATED FROM HRS SPOT5 DATA

M. Tsakiri-Strati<sup>1</sup>, O. Georgoula<sup>2</sup>, P. Patias<sup>3</sup>

<sup>1</sup> Associated Prof., <sup>2</sup> Assistant Prof., <sup>3</sup> Professor

Department of Cadastre, Photogrammetry and Cartography, Aristotles University of Thessaloniki, Greece  
[martsak@eng.topo.auth.gr](mailto:martsak@eng.topo.auth.gr)

## Commission I

**KEY WORDS:** SPOT5, HRS data, auto-matching, triangulation, DEM, Evaluation

### ABSTRACT:

The purpose of this project is to test High Resolution Stereoscopic (HRS) data of SPOT5. This project is done in the framework of the "HRS study Team" international test, supported by ISPRS-CNES. The Digital Elevation Model (DEM) was derived from the HRS data and was evaluated by using a 3D reference data set. The study site for HRS data is located in Manosque, France. It is a countryside landscape, with fields and villages. The height relief is medium and in some areas considerably intensive. The HRS data was acquired on 14<sup>th</sup> August 2002. A number of different DEM generation experiments were carried out, in order to examine the influence of different processing parameters on the final accuracy of the DEM. Thus: 1) The same date acquisition of the stereo-pair reduces the radiometric variations of images; nevertheless, the fact that the images are captured by two different sensors has led us to apply a histogram matching technique for image pre-processing, in some experiments. 2) The georeferencing and the stereo model set-up of the images were established in four different ways: by using only the metadata; by using the metadata and tie points that have been generated automatically; by using the metadata, tie points that have been generated automatically and some tie points that have been derived manually; The same as the second solution but in the triangulation process 6 GCP's (XYZ coordinates) have been used. For the extraction of the GCP's an additional procedure has been performed, which consisted basically of the production of an orthoimage based on the reference DEM. The study of the accuracy statistic results of 8 different derived DEM,s showed that the elevation accuracy was better, about 0-5 m, in flat and even areas than in mountainous and steep areas.

## 1. INTRODUCTION

Automatic generation of a Digital Elevation Model (DEM) is a very important issue for many applications as map generation, three-dimensional GIS, environmental monitoring, geo-spatial analysis etc (Kim, et al, 200; Vadon, 2003). In the past, the automatic generation of a DEM from aerial images has received a lot of attention among photogrammetrists. Now Digital Photogrammetry offers all the necessary algorithms and methods for the automatic production of accurate DEM from aerial photos. On the other side satellite images have several advantages over aerial photos: it is easier to acquire images periodically, in digital format and to cover large geographic extents etc. But satellite images have many disadvantages over aerial photos as well, like unknown or improper understandable camera geometry, inappropriate geometry of reception, low resolution etc. However, automatic DEM generation has become an important part of international research in the last 10 years. Thus, new algorithms have been developed, the performance of which have been assessed and reported in the bibliography (Singh, et al, 1998; Toutin, 1998; Zhen, et al, 2001; Toutin, et al, 2001; Toutin, 2001; Lee, et al, 2003).

On May 2002, the Earth Observation satellite Spot5 from CNES, was successfully placed in orbit. The basic characteristics of this just 2 years - old satellite are well known. The major advantages, of SPOT5 system, that influence the productivity and the accuracy of a DEM are (Boissin, et al, 2002; Breton, et al, 2002; Lasselin, et al, 2003; Léger, 2003; Valorge, 2003):

- The resolution: a sampling interval at 5m in panchromatic mode.

- The new instrument High Resolution Stereoscopic (HRS) conceived especially to do stereoscopy along side satellite track. It acquires simultaneously stereo-pairs in quasi real time, within an interval of 90 seconds.
- The possibility to know the location of the satellite, with absolute precision better than 15 meters, without any ground control point (GCP).

This project was done in the framework of the "HRS study Team" supported by ISPRS-CNES. The purpose of this Study Team is to test the capability of HRS data for the production of digital elevation models (DEMs). The Department of Cadastre, Photogrammetry and Cartography of the Aristotles University of Thessaloniki in Greece participate in the Initiative as Co-Investigator.

## 2. DEM PRODUCTION

### 2.1 Data

The study site is located in Manosque, France. It is a countryside landscape, with fields and villages. The height relief is medium and in some areas considerably intense. The HRS SPOT-5 panchromatic stereo-pair covers a region about 120 Km x 60 Km and it was acquired on 14<sup>th</sup> August 2002 (Fig. 1). The processing level of the scenes is 1A (original images with radiometric corrections). Metadata files for each scene were available. An aerial reference DEM for the accuracy assessment was available as well. The reference data set describes an area of roughly 6 Km x 65 Km.

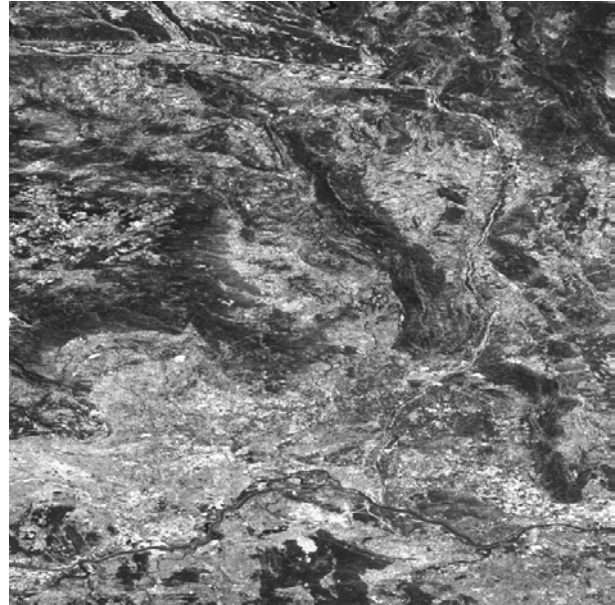
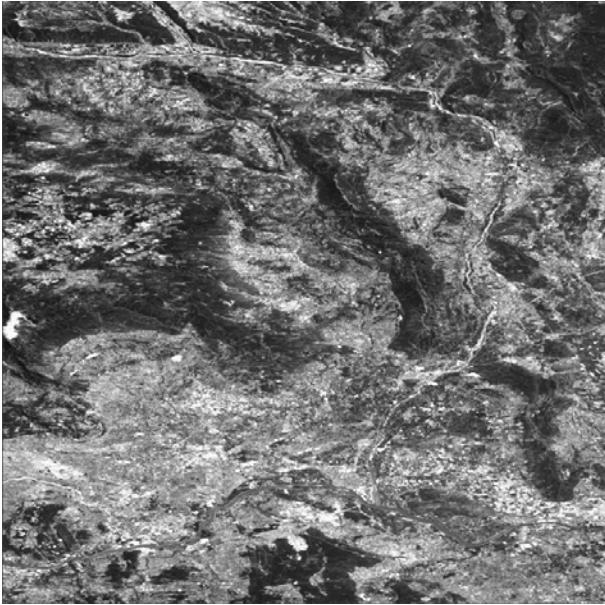


Figure 1. HRS-SPOT5 stereo-pair on test site Manosque, France

This means that it describes approximately only 5% of the area covered by the stereo-pair (Fig. 2). The reference DEM has a 25 m grid spacing and Z accuracy better than 1m. Neither GCPs nor any kind of digital map were available. The software Leica Photogrammetry Suite was used for the processing of the stereoscopic images.

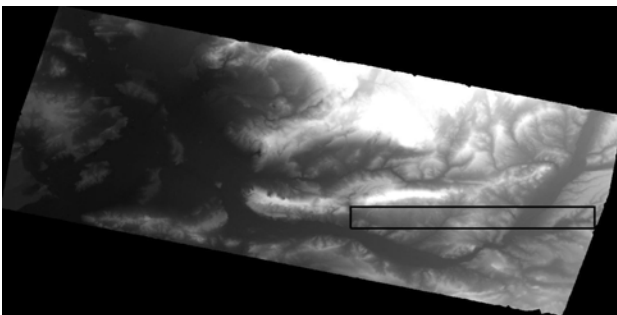


Figure 2. The area of the reference DEM in the frame related to the test area DEM

## 2.2 Procedure

In this project many different DEM generation experiments have been carried out in order to examine the influence of different parameters and methods of processing to the final accuracy of the produced DEM. Eight (8) different approaches are presented here (table 1).

The first criterion that has been examined was the radiometry of the stereo pair. The simultaneous acquisition of both images provides the radiometric resemblance of the images, in order to facilitate the automatic correlation process. Because the fact that the images are captured by two different sensors has led us to apply the histogram matching technique for image pre-processing, in some experiments.

Thus, 4 solutions concern a DEM generation from the original data (DEM1, DEM3, DEM5, DEM7) and 4 solutions (DEM2, DEM4, DEM6, DEM8) concern the generation of a DEM after an applied histogram matching technique.

The second basic advantage of the HRS SPOT-5 images is that it is possible to know, with absolute precision, the location of them. The information included in the metadata-ephemeris data leads automatically in the generation of a DEM, without the need of GPC's. In this study, except this basic solution, other experiments have been carried out as well. These tests concern "semiautomatic" solutions in which a triangulation technique with automatic or semiautomatic methods of tie points determination have been applied before the generation of the DEM. Thus, the georeferencing and the stereo model set-up of the images was established in four different ways:

- a. By using only the metadata (solutions DEM1, DEM2).
- b. After the use of the metadata, a triangulation was performed without any GCP. The tie points have been generated automatically (solutions DEM3, DEM4).
- c. The same as the above b solution but in the triangulation process 6 GCPs (XYZ coordinates) were used. For the extraction of the GCPs an additional procedure has been performed, which consisted basically of the production of an orthoimage based on the reference DEM. Draping the rectified image over the reference DEM, 6 GCPs, in a stereoscopic way, were collected for the triangulation procedure. (solutions DEM5, DEM6).
- d. The same as the above b solution but for the triangulation process except the automatically generated tie points, some tie points derived manually, in a stereoscopic way, has been used as well; the latest were points situated in critical positions such as in the steepest and the highest areas (solutions DEM7, DEM8).

The results of the different experiments are represented in the table 1. The characteristics of the different experiments are interpreted below:

No his: no histogram matching applied

His: histogram matching applied  
 Metadata: only metadata has been used  
 Auto tie: metadata and triangulation based on automated generated tie points  
 Auto & manual tie: metadata and triangulation based on automated and manually collected tie points  
 Auto tie & 6 GCPs: metadata and triangulation with auto tie points and 6 GCPs, derived after a particular procedure.

### 2.3 Assessment of DEM generation

Firstly, it is reminded that the results of table 1 concern the creation of a total DEM, that is to say, the DEM that occurred from the processing of the stereo - pair. In Figure 2 is presented the DTM1 that concerns the basic solution.

|  | Excellent % | Min mass point elevation (m) | Max mass point elevation (m) | Mean elevation (m) |
|--|-------------|------------------------------|------------------------------|--------------------|
| <b>DEM1<br/>No His<br/>Metadata</b>                      | 93.86       | -0.7                         | 1397.4                       | 367.3              |
| <b>DEM2<br/>His<br/>Metadata</b>                         | 93.71       | -0.7                         | 1401.9                       | 367.2              |
| <b>DEM3<br/>No His<br/>Auto tie</b>                      | 93.85       | -0.7                         | 1395.6                       | 367.3              |
| <b>DEM4<br/>His<br/>Auto tie</b>                         | 93.71       | 1.50                         | 1393.6                       | 366.5              |
| <b>DEM5<br/>No His<br/>Auto tie<br/>&amp; 6 GCPs</b>     | 93.93       | -37.8                        | 1402.3                       | 371.2              |
| <b>DEM6<br/>His<br/>Auto tie<br/>&amp; 6 GCPs</b>        | 93.73       | 9.9                          | 1399.1                       | 370.8              |
| <b>DEM7<br/>No his<br/>Auto &amp;<br/>Manual<br/>tie</b> | 93.85       | -0.7                         | 1395.5                       | 367.2              |
| <b>DEM8<br/>His<br/>Auto &amp;<br/>Manual<br/>tie</b>    | 93.71       | 1.4                          | 1393.8                       | 366.5              |

Table 1. The results of DEMs generated in different cases

The following analysis concerns the examination of the influence of different methods of processing to the final DEM. In all the solutions the matching was done with the same high precision. Thus, the localization of the 94% of points is characterized as excellent. Consequently, the preprocessing of the images with histogram matching does not appear to

influence the results, since the radiometry of this stereo-pair was good. The mean elevation in all the solutions was determined in 367 m and only in the cases where the 6 GCPs were used, the mean elevation was calculated in 371 m. In these solutions they were determined the minimum (-37.8 m) and the maximum value (9.9 m) for the min point mass elevation. This fact was rather expected since the accuracy and the place of the GCPs was not suitable.

### 2.4 DEM evaluation

The accuracy assessment of the produced DEM; that generated by different experiments, was realized by using the reference data set that describes an area of roughly 6Km x 66Km. The statistical results of comparison are given in the table 2.

|  | Min Max error (m) | Mean error (m) | Mean Absolute error (m) | RMS (m) |
|--|-------------------|----------------|-------------------------|---------|
| <b>DEM1<br/>No his<br/>Metadata</b>                      | -118.7<br>166.4   | -0.6           | 7.1                     | 13.2    |
| <b>DEM2<br/>His<br/>Metadata</b>                         | -119.3<br>169.8   | -0.3           | 7.6                     | 14.8    |
| <b>DEM3<br/>No his<br/>Auto tie</b>                      | -118.9<br>165.6   | -0.6           | 7.1                     | 13.2    |
| <b>DEM4<br/>His<br/>Auto tie</b>                         | -119.6<br>170.6   | -0.4           | 7.6                     | 14.8    |
| <b>DEM5<br/>No his<br/>Auto tie<br/>&amp; 6 GCPs</b>     | -116.2<br>165.0   | -0.2           | 7.6                     | 13.4    |
| <b>DEM6<br/>His<br/>Auto tie<br/>&amp; 6 GCPs</b>        | -114.8<br>177.9   | -0.0           | 8.1                     | 15.2    |
| <b>DEM7<br/>No his<br/>Auto &amp;<br/>Manual<br/>tie</b> | -118.7<br>165.8   | -0.5           | 7.1                     | 13.2    |
| <b>DEM8<br/>His<br/>Auto &amp;<br/>Manual<br/>tie</b>    | -119.7<br>170.5   | -0.4           | 7.6                     | 14.8    |

Table 2. The statistical results of comparison between extracted DEMs and reference DEM

Obviously, in this table, DEM1, ..., DEM8, are in regards to corresponding area of the reference DEM.

In Figure 3, a part of the entire DEM1 is given and the area of the reference DEM is indicated. In Figure 4a the reference

DEM is presented while in Fig. 4b the corresponding region of DEM1 is given as well. Figures 5a and 5b show a part of the above DEMs.

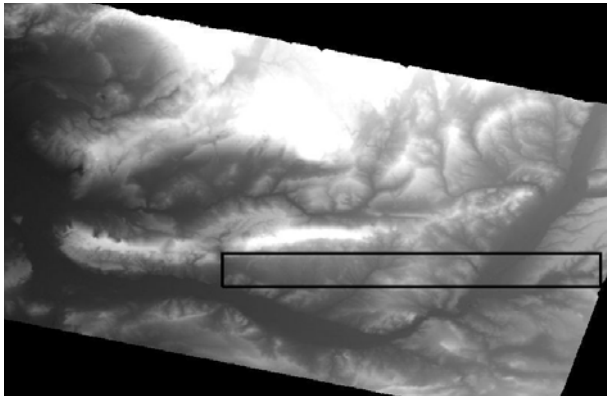


Figure 3. A part of he produced DTM1



Figure 4a. The reference DEM



Figure 4b. The corresponding to reference DEM, region of DEM1



Fig 5a. A part of the reference DEM



Fig. 5b. The corresponding region of DEM1

The statistical analysis of results (table 2), concerning the produced DEMs, showed that all the solutions are acceptable for flat and even regions, while in the highly mountainous areas the precision is small. For example, in the basic solution (a), while the value of the min and max error are calculated at -119m and 166m, the value of the mean absolute error is 7m.

The DEM1 was also checked manually by overlapping the two DEMs. The DEM quality certainly depends on terrain type and terrain roughness. Thus in plain areas the achieved accuracy was 0-5 m while the maximum height differences have been occurred in mountainous and steep areas. In Figure 6 is presented a part of the difference image between DEM1 and DEM reference, for the same area.

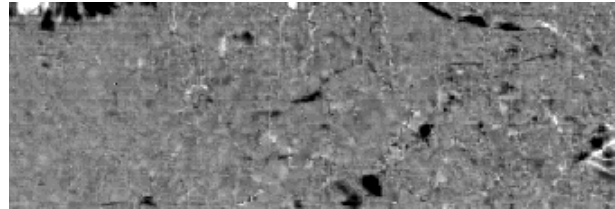


Figure 6. A part of the difference image between the DEM1 and the reference DEM

Negative errors in elevation are indicated in black and that means that the DEM1 has a smaller altitude than DEM. On the contrary, positive errors are indicated in white. This occurs in the areas where the produced DEM1 has higher altitude than DEM. Areas with a difference of 0-5m are indicated in grey.

### 3. CONCLUSIONS

DEM generation from satellite data set is a fact since new-launched satellite images have been used to provide stereoscopic images. This paper reports experiments carried out for automated extraction of a digital elevation model (DEM) from HRS data of SPOT-5 satellite, based only on the Metadata provided by the sensor. Neither GCPs nor any kind of digital map were available. The absence of Ground Control Points led us to test, except the basic solution, other procedures. These tests concern "semiautomatic" solutions in which a triangulation technique with automatic or semiautomatic methods of determination the tie points has been applied before the generation of DEMs. The results indicate that the accuracy of the produced DEMs was not ameliorated.

The other factors that influence DEM's quality are image quality and terrain type and roughness. The pre-processing of the images with histogram matching it does not appear to influence the results, since the radiometry of this stereo-pair was good. In all the solutions the matching was done with the same high accuracy. Thus, the localization of the 94% of points was characterized as excellent.

Finally, the terrain type certainly has an effect on the DEM quality. Thus in plain areas the achieved accuracy was 0-5m while the maximum height differences have occurred in mountainous and steep areas.

### 4. REFERENCES

- Boissin, B., Baudoin, A., Begni, G., Fontannaz, D., and Munier, P., 2002. A new generation satellite: SPOT 5 in orbit. *MEDIAS NEWSLETTER*, Toulouse, France, N°13, CNES, pp. 74-77.
- Breton, E., Bouillon A., Gachet R. and Delussy, F., 2002. PRE-FLIGHT AND IN-FLIGHT GEOMETRIC CALIBRATION OF SPOT5 HRG AND HRS IMAGES. In: *Conference*

*Proceedings*, Land Satellite Information, Pecora 15, IV/ISPRS Commission I/FIEOS

Kim, S., and Kang, S., 2001. Automatic Generation of a SPOT DEM: Towards Coastal Disaster Monitoring. *Korean Journal of Remote Sensing*, 17(2), pp. 121-129

Lasselín, D., Breton, E., Sempère, J., P., and Cantou, J., Ph., 2003. Evaluation of the Geographic Information Potential of Spot5 Images. IGN, Toulouse, France.

Lee, H-Y., Kim, T., Park, W., and Lee, H-K., 2003. Extraction of digital elevation models from satellite stereo images through stereo matching based on epipolarity and scene geometry. *Image and Vision Computing*, ELSEVIER, 21, pp.789-796.

Léger, D., Viallefont, F., Hillairet, E., and Meygret, A., 2003. In-flight refocusing and MTF assessment of SPOT5 HRG and HRS cameras. <http://www.cert.fr/>

Toutin, T., 1998. Evaluation RADARSAT Stereoscopic Pairs For DEM Generation, IEEE. [Thierry.toutin@ccrs.nrcan.gc.ca](mailto:Thierry.toutin@ccrs.nrcan.gc.ca)

Toutin, T., Chénier, R., and Carbonneau, Y., 2001. 3D GEOMETRIC MODELLING OF IKONOS GEO IMAGES. In: *CD-ROM, ISPRS Joint Workshop "High Resolution from Space"*, Hannover, Germany.

Toutin, T., 2001. Dem Generation from New VIR Sensors: IKONOS, ASTER and Landsat-7. In: *PROCEEDINGS, IEEE-IGARSS*, Sydney, Australia.

Vadon, H., 2003. 3D Navigation over Merged Panchromatic – Multispectral High Resolution SPOT5 Images. In: *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXVI, 5/W10

Valorge, C., 2003. 3D Restitution and Rendering Through High Resolution Imagery: State of the Art and New Challenges, CNES, DSO/OT/QTIS/HR, [Valorge@cnes.fr](mailto:Valorge@cnes.fr)

Zhen, X., Huang, X., and Kwoh, L., K., 2001. Extracting DEM from SPOT Stereo Images. *20<sup>th</sup> Asian Conference on Remote Sensing*, Singapore.

#### **Acknowledgements**

The authors wish to thank IGD GROUP AC for the provision of the demo Leica Photogrammetry Suite (LPS) 8.7 software program.