IMPACT OF DEM RECONSTRUCTION PARAMETERS ON TOPOGRAPHIC INDICES

M. El Hage [a,b], E. Simonetto [a], G. Faour [b], L. Polidori [a]

[a] Laboratoire de Géodésie et Géomatique (L2G), ESGT, 1 Boulevard Pythagore, 72000 Le Mans, France
e-mail : (mhamad.elhage, elisabeth.simonetto, laurent.polidori)@esgt.cnam.fr
[b] National Center for Remote Sensing, CNRS Lebanon, P.O. Box 11-8281, Riad El-Solh 1107 2260, Beirut, Lebanon
e-mail : gfaour@cnrs.edu.lb

Commission III, WG III/4

KEY WORDS: DEM, Reconstruction, Geomorphology

ABSTRACT:

Topographic indices are extracted from DEMs to describe the terrain geomorphology. Most DEM reconstruction parameters have an important impact on these indices (slope, curvature and hydrographic characteristics) even though they have limited impact on elevations. In this study, we will assess the impact of the DEM mesh size, image matching window size and interpolation methods on these indices. The results show that the degradation of the mesh size does not affect the elevation but it influences the elevation derivatives and the drainage networks. They confirm that elevation is almost scale independent while slope and other topographic indices are strongly scale dependent.

1. INTRODUCTION

Topographic indices provide a description of terrain geomorphology. They can be extracted from DEMs, and they are defined according to the requirements of variety of applications such as hydrology, evaluation of erosion etc. While the literature on DEM quality mainly focuses on position accuracy, we assess the quality of DEM in terms of geomorphological reliability. This is based on specific indices such as slope, curvature and hydrographic characteristics.

Several parameters of DEM reconstruction method have an impact on such indices, like DEM mesh size (Takagi, 1998; Tang et al., 2003; Vaze et al., 2010), image matching parameters and interpolation method (Chaplot et al., 2006; Heritage et al., 2009). Since the impact of image matching parameters on position accuracy has been extensively studied (Cuartero et al., 2004; Hashemian et al., 2004; Bignone and Umakawa, 2008), our study focuses on the quality of the morphological indicators.

For that purpose, we used an SRTM DEM to assess the impact of mesh size and an aerophotogrammetric DEM to assess the impact of correlation window size and interpolation. For each parameter, several DEMs were reconstructed in accordance to different values of this parameter. The DEMs were compared, both statistically (through histograms) and visually. The criteria used for this comparison are elevation, slope and curvature, as well as contour lines and some hydrological features, such as stream networks and watersheds.

Section 2 presents the datasets used in this study and describe the methodology followed. The impact of different reconstruction parameters will be presented in section 3, and discussed in a concluding section.

2. MATERIAL AND METHODS

2.1 Data

The data used in this study can be summarized as follows: a DEM from the Shuttle Radar Topography Mission (SRTM) over the Alps for studying the effect of mesh size degradation on topographic indices, and an airborne stereo pair over the Delos island (Greece) so as to assess the impact of image matching parameters on these same indices.

2.1.1 SRTM DEM of the Alps: the SRTM DEM used in this study covers a part of the Alps in the South-East of France. The Shuttle Radar Topography Mission was launched in February 2000 with the aim of mapping the global land mass for areas situated between 60°N and 57°S latitude. The InSAR C- and X-bands were used in this mission. The SRTM DEM, which has a relative vertical accuracy of about 6 m, is freely available on the internet for almost every place around the world with a mesh size of 90 m (Rabus et al., 2003).

2.1.2 Stereo pair on Delos island: this dataset represents a hill situated on a Greek island. It is obtained from two gray-scale images acquired in 1982 and scanned with a resolution of 300 dpi. The characteristics of these images and of the stereo model are presented in table 1.

Feature	**Values**	
Ground pixel size	72 cm	
Focal length	152.73 mm	
Flight height	1294 m	
Base line	682 m	
B/H	0.53	
Scale	1/8472	
Precision	**Planimetry**	**Altimetry**
Theoretical (cm)	36	68.3
RMS (cm)	13.9	23.8

Table 1. Characteristics of the stereo model

2.2 Data processing

The impact of reconstruction parameters on topographic indices is evaluated in this study. These parameters are the DEM mesh size (studied in the SRTM DEM), the image matching window size and the interpolation method (studied in the stereo pair over Delos). For that purpose, data are first processed as described below.

2.2.1 SRTM mesh size degradation: to detect the effect of mesh size degradation, the SRTM DEM was subsampled. The subsampling has been done with ArcGIS using the resample function available in the Raster toolset. The resampling algorithm used was the "NEAREST" which assigns the nearest neighbouring value for the output cell. The SRTM DEM has been subsampled with three different subsampling ratios, namely 2, 4 and 8.

2.2.2 DEM generation with different matching parameters and interpolation methods: to assess the impact of the image matching process, elevation points were extracted from the stereo pair with different values of matching window size, and the resulting point cloud was interpolated using the inverse distance weighted method. Then, the point cloud obtained with the smallest matching window was interpolated with three interpolation methods, namely, spline, inverse distance weighted and kriging, all available in ArcGIS. This double experiment is described in figure 1.

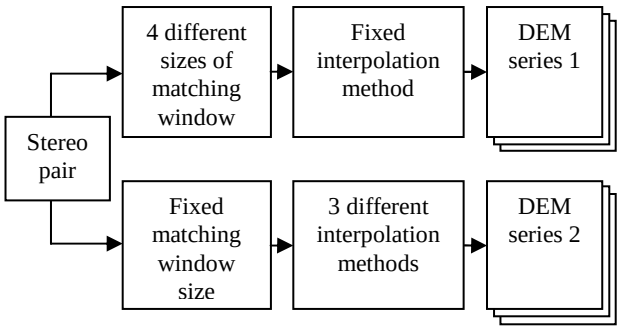


Figure 1. Method of DEM reconstruction with variable matching parameters and interpolation algorithms

The image matching was performed using the DVP software developed by Group Alta which uses a hierarchical approach. This software allows the control of many correlation parameters which are presented in table 2. The values used in the study are mentioned in the following table.

Parameters	Values
Search Z range	113 m
Rough correlation factor	6
Rough correlation window dimension	13 pixels
Fine correlation window dimension	5-9-13-17 pixels
Acceptance percentage	70 %
Sampling step	2 m

Table 2. Correlation parameters

The search Z range corresponds to the elevation range in which the similar pixels between the two images will be searched. It depends on the topography of the site. The rough correlation factor is the subsampling ratio for the first correlation step. The rough correlation window dimension is the size of the search window on a global scale, whereas the fine correlation window dimension is the same size as the search window on a local scale. The acceptance percentage is the threshold of the correlation coefficient above which the matching is accepted. Finally, the sampling step is the distance separating the grid points (Arguin, 2006). In this study, five parameters were fixed and one (fine correlation window dimension) took different values as shown in table 2.

2.3 Extraction of topographic indices

Once the DEMs have been reconstructed, the topographic indices can be computed. These indices are the slope, the curvature and some hydrological features such as stream networks and watersheds.

This phase has been carried out by using the Spatial Analyst tools extension of ArcGIS. In this software the slope is calculated with the average maximum technique. It represents the maximum change rate between a point and its neighbours. Then, to extract the stream networks, we first generate the flow direction then we extract the flow accumulation, so that the stream network can be delineated. Finally, to localize the watersheds, we use the basin function which identifies all cells connected in one drainage basin.

3. RESULTS

The results are presented in this section with histograms and image maps. The histograms show the statistical behaviour of the different topographic indices. The image maps enable to observe the spatial distribution of terrain shapes based on topographic indices.

3.1 Impact of mesh size on slope statistics

Figures 2, 3 and 4 represent the histograms of elevation, slope and curvature respectively for the SRTM DEM with different mesh size values.

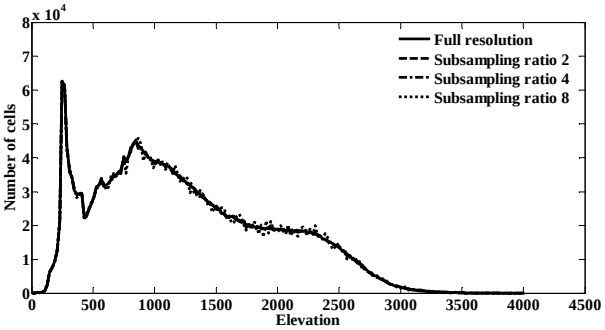


Figure 2. Elevation histograms

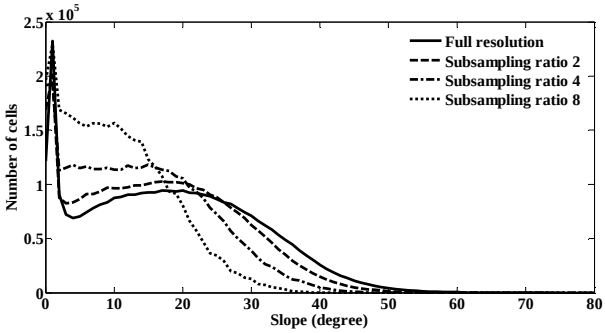


Figure 3. Slope histograms

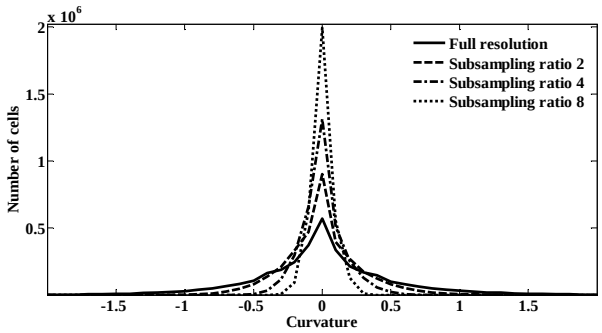
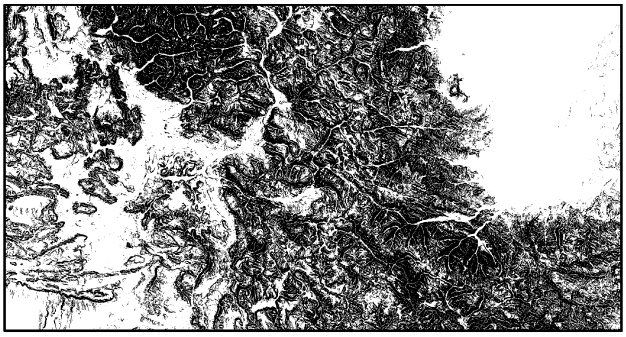


Figure 4. Curvature histograms

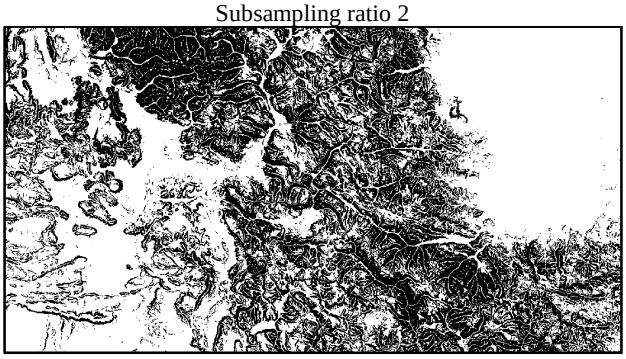
We can observe that when the mesh size increases the elevation histogram does not change. On the contrary, the slope histogram changes since the steepest slopes tend to disappear while the weakest ones are more abundant. The same effect applies for the curvature histogram since important curvatures, both convex and concave, tend to disappear.

To better sudy the impact on slope, we extracted all slopes steeper than 20 degrees from the different DEMs. The four maps obtained from this thresholding are displayed in figure 5.

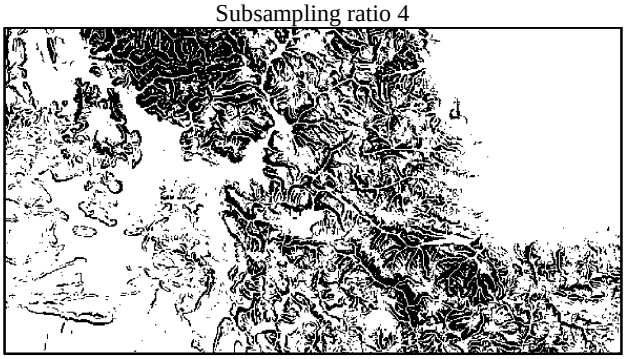
Full resolution



Subsampling ratio 2



Subsampling ratio 4



Subsampling ratio 8

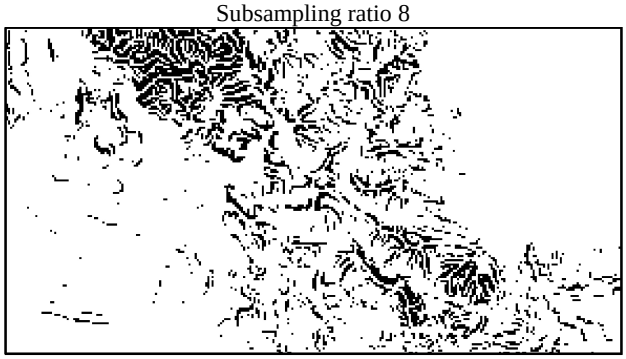


Figure 5. Slope cells with values greater than 20 degrees derived from degraded DEMs (in black colour)

The difference between the full resolution and a subsampling ratio of 2 is not very important, as confirmed in the corresponding slope histograms. This may be due to an artificial smoothing effect at the mesh scale in the full resolution DEM. The differences become more important with higher subsampling ratios.

The same comparison was performed with other slope threshold values, respectively 20, 30 and 40 degrees. The resulting maps are not shown here but the results are summarized in figure 6. According to this figure, the decrease of 20 degree slope begins gently then gradually becomes abrupt as the mesh size increases. For higher slope threshold values, the percentage of DEM cells above the threshold is lower, but we can observe that it decreases too, as already suggested by the histograms.

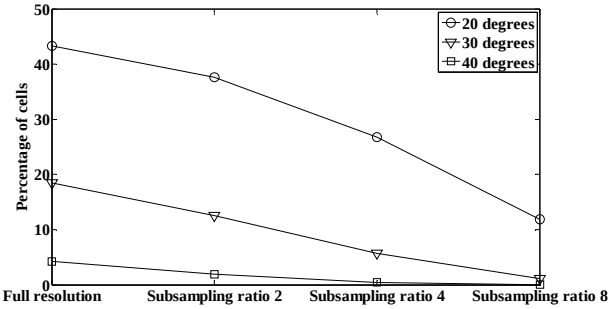


Figure 6. Percentage of cells with slope greater than 20, 30 and 40 degrees for different mesh sizes

3.2 Impact of mesh size on terrain morphology

To assess the impact of mesh size on terrain morphology, the stream networks and the watersheds were extracted and represented in figure 7. This figure shows that hydrological features tend to disappear or to become oversimplified when the mesh size is increased: many watersheds disappear and some others are wrongly combined. Moreover, the density of the stream network decreases and some networks are connected to one another.

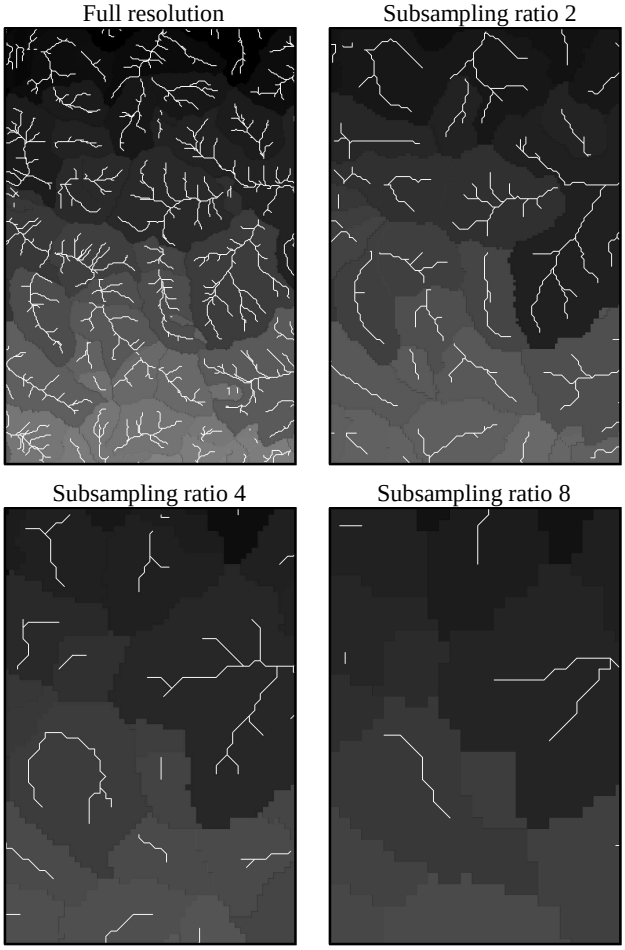
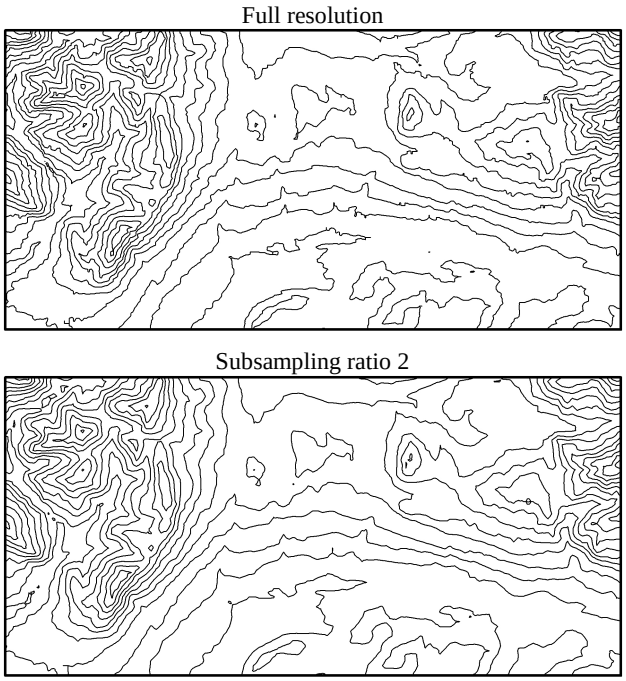


Figure 7. Stream networks and watersheds extracted from DEMs with different mesh size

Figure 8 represents the contour lines generated with different mesh sizes. We conclude, as expected, that the highest spatial frequencies and the smallest shapes disappear as the subsampling ratio increases.



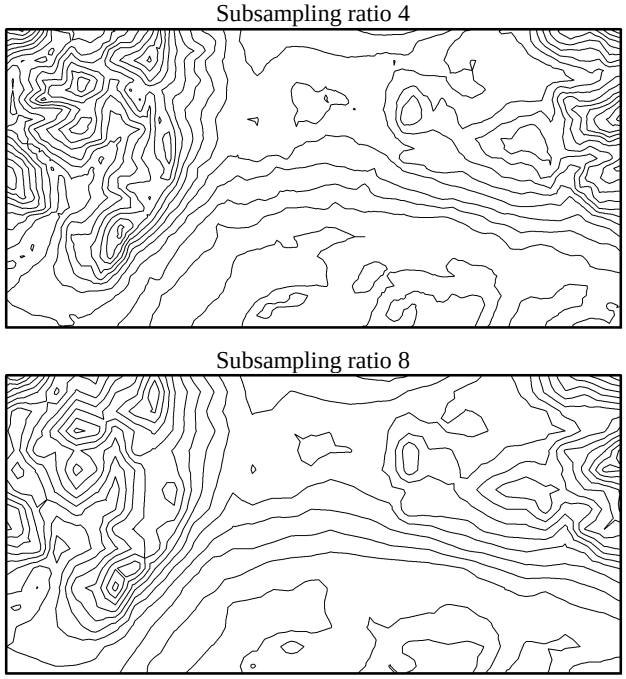


Figure 8. Contour lines generated with different mesh size DEMs

3.3 Impact of matching parameters on elevation and slope

The correlation window dimension has been modified in order to assess its impact on topographic indices. The results are represented in the following histograms (figure 9 and 10).

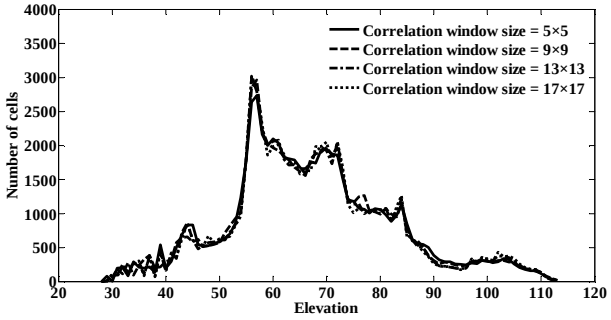


Figure 9. Elevation histograms

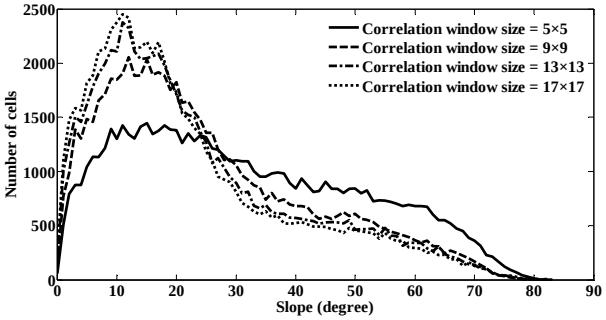


Figure 10. Slope histograms

As can be observed this parameter has no impact on elevation statistics. On the contrary, the proportion of steep slopes decreases when the correlation window size increases. This

effect mostly occurs between window sizes of 5 and 9 pixels, remains more limited for larger correlation windows.

3.4 Impact of interpolation methods on elevation and slope

Three interpolation methods have been compared. Each of them has been used to produce a regular grid DEM from the computed elevation points. The impact of these interpolations on the statistics of the elevation and slope is described in figures 11 and 12.

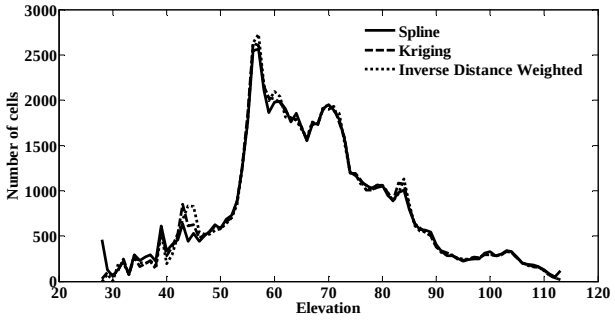


Figure 11. Elevation histograms

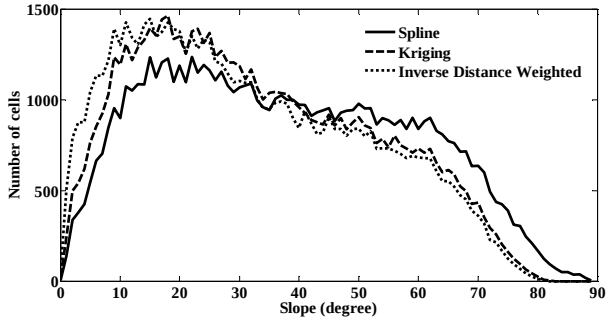


Figure 12. Slope histograms

The elevation histograms show that the choice of the interpolation method has a limited impact on elevation. On the contrary, the impact of this choice on slope statistics is more important. The comparison of the slope histograms shows that the spline interpolation preserves the steepest slopes while the kriging and inverse distance weighted tend to smooth the surface topography.

4. DISCUSSION AND CONCLUSION

The results presented in this paper confirm that the different DEM reconstruction parameters can affect its geomorphological quality. Indeed, many topographic indices are affected along with the terrain representation. The effect of these different parameters is not the same for all topographic indices. Thus, slope and curvature seem the most affected while the influence on the elevation is not so important.

The mesh size degradation is equivalent to a change in scale. Since this degradation has a negligible influence on elevation, the latter is almost scale independent. On the contrary, the mesh size has an important effect on the statistical distribution of slopes, which means that the slope is scale dependent. The impact of matching parameters and interpolation methods may lead to similar conclusions, i.e. the demonstration of the very little impact on elevation statistics as opposed to the important impact on slope statistics. A possible consequence of these influences is a misinterpretation of many areas. For instance, if slope is to be used as risk criterion, the spatial extent of the dangerous areas may be underestimated.

More generally, slope, curvature and hydrological network are very relevant indices for geomorphology. Therefore, the reconstruction parameters have to be chosen with care whenever the DEM aims at geomorphological interpretation.

REFERENCES

References from Journals:

Chaplot, V., Darboux, F., Bourennane, H., Leguedois, S., Silvera, N., Phachomphon, K., 2006. Accuracy of interpolation techniques for the derivation of digital elevation models in relation to landform types and data density. *Geomorphology*, 77, pp. 126-141.

Heritage, G., Milan, D., Large, A., Fuller, I., 2009. Influence of survey strategy and interpolation model on DEM quality. *Geomorphology*, 112, pp. 334–344.

Tang, G., Zhao, M., Li, T., Liu, Y., Zhang, T., 2003. Simulation on slope uncertainty derived from DEMs at different resolution levels: a case study in the Loess Plateau. *Journal of Geographical Sciences*, 13 (4), pp. 387-394.

Rabus, B., Eineder, M., Roth, A., Bamler, R., 2003. The shuttle radar topography mission — a new class of digital elevation models acquired by spaceborne radar. *ISPRS Journal of Photogrammetry and Remote Sensing*, 57 (4), 241-262.

Vaze, J., Teng, J., Spencer, G., 2010. Impact of DEM accuracy and resolution on topographic indices. *Environmental Modelling & Software*, In Press.

References from Other Literature:

Arguin, N., 2006. Restitution of 3D data. *DVP User's Manual*, Version 1.0, pp. 21-23.

Bignone, F., Umakawa, H., 2008. Assessment of ALOS Prism Digital Elevation Model Extraction over Japan. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Beijing, China, Vol. XXXVII, Part B1, pp. 1135-1138.

Cuartero, A., Felicisimo, A.M., Ariza, F.J., 2004. Accuracy of DEM generation from Terra-ASTER stereo data. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Istanbul, Turkey, Vol. XXXV, Part B2, pp. 559-563.

Hashemian, M. S., Abootalebi, A., Kianifar, F., 2004. Accuracy evaluation of DEM generated from SPOT5 HRS imageries. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Istanbul, Turkey, Vol. XXXV, Part B1, pp. 389-392.

Takagi, M., 1998. Accuracy of digital elevation model according to spatial resolution. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Stuttgart, Germany, Vol. XXXII, Part 4, pp. 613-617.