How to merge a DEM ?

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Abstract—**A DEM is one of the most useful information for spatial modelling and monitoring. Several DEMs have been published in the public domain like SRTM and ASTER GDEM with and without considering the horizontal and vertical misallocation of single input data. Results of that are for example the inherent errors in the ASTER GDEM V1 dataset as well as the known striping in the SRTM dataset. Therefore, this abstract aims to show a method for the horizontal and vertical alignment of different DEM tiles as well as merging to create a seamless DEM.**

I. Introduction

A Digital Elevation Model (DEM) is one of the most useful sources of information for spatial modelling and monitoring, with applications as diverse as: Environment and Earth Science, e.g. catchment dynamics and the prediction of soil properties; Engineering, e.g. highway construction and wind turbine location optimisation; Military, e.g. land surface visualisation, and; Entertainment, e.g. landscape simulation in computer games (Hengl and Evans 2007). The extraction of land surface parameters – whether they are based on 'bare earth' models such as DEMs derived from contour lines and spot heights, or 'surface cover' models derived from remote sensing sources that include tree top canopies and buildings for example – is becoming more common and more attractive due to the increasing availability of high quality and high resolution DEM data (Gamache 2004).

In 2000, the SRTM Digital Surface Model with a resolution of ~90m between 60°N and 58°S has been released (Farr et al, 2000). This dataset is one of the most utilized and good quality DEM datasets, which are currently available to the international research community. At the 29th of June 2009 the Global Digital Surface Model ASTER GDEM has been released to supersede the SRTM DEM with a 1 arc second resolution and much extended coverage. ASTER GDEM is believed to be one of the most important publicly available new spatial datasets. The quality of the DEMs determines the quality of the geomorphometric analysis. Even the most sophisticated geomorphometric algorithm will be unable to rectify severe artifacts and errors in the input DEMs. The quality of land-surface parameters and objects and geomorphometric applications depends on several factors (Florinsky, 1998). Even the most accurate, most robust geomorphometric algorithms will result in poor outputs if the input DEMs are of low quality or inadequate for the targeted application.

Quite often, users/scientist generate DEMs by simply averaging single tiles/strips of DEMS together, without considering the horizontal and vertical misallocation of these dataset. Results of that are for example the inherent errors in the ASTER GDEM V1 dataset as well as the known striping in the SRTM dataset. Therefore, this abstract aims to show a method for the horizontal and vertical alignment of different DEM tiles as well as merging to create a seamless DEM.

II. Methods

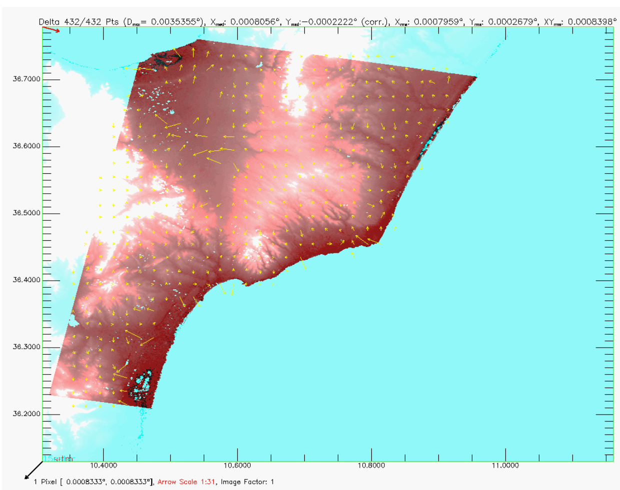
The method relies on the assumption that for any given area on earth a reference surface exits and creates adjustments for each single tile and each pixel with respect to this reference surface. Based on this single adjustments, a final mosaic can be generated.

The horizontal accuracy of DEMs (e.g. if the top of a mountain is at the correct location or offset by 250 m to the northeast) can be computed by generating a displacement vector (DV(si, sj)):

$$\overrightarrow{DV}(s_i, s_j) = \max_{\text{corr}}\left[s(z_i), s(z_j)\right] \quad [1]$$

The correlation of a reference surface patch (e.g. 100×100 cells) is compared with a DEM created for different offsets (si, sj). The location of the offsets with the highest correlation are recorded and used to assess the accuracy of the DEM. We averaged elevation in a 4 x 4 window, and used that as a first approximation to search for areas which match (e.g. a mountain in SRTM has to match a mountain in GDEM). The search window $s(z_i)$ has been 20 x 20 pixel in a 61x61 pixel $s(z_j)$ window (241px in full resolution) and is therefore for small scale effects not especially sensitive.

The observed correlations have been retransformed into the original resolution and high resolution image matching has been performed with search windows of 121x121 pixels in a 181 x 181 pixel window (Figure 1).



Φιγυρε 1. Example of Displacement Vectors for a single ASTER DEM scene obtained from Japanese GDS.

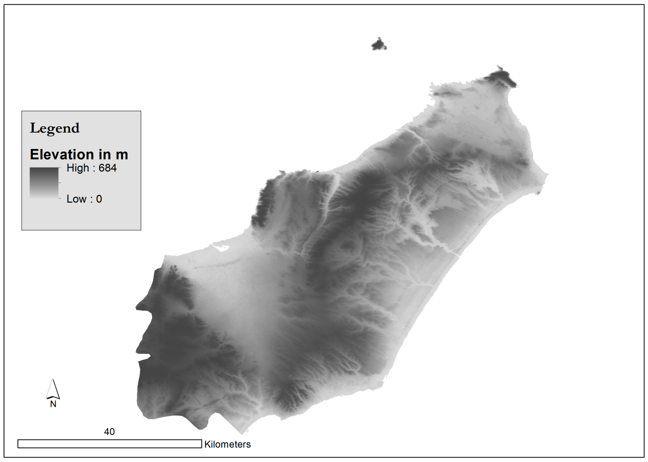
Based on this high resolution matching an adjustment surface is generated which is used in the resampling process which is performed into one predefined geometry for each single tile based on SRTM geometry, therefore minimizing the horizontal displacements. Displacement vectors in Figure 2 are shown to represent the different horizontal offsets. Note the spatial distribution of consistent and non consistent areas.

Secondly, we sample again in this preliminary rectified dataset with respect to the elevation of the reference surface, to determine vertical displacements. Only significant linear correlations are applied for the correction for a final single tile. The statistical properties of this process are on an example of 24 scenes from Tunisia are shown in Table 1. Note the huge difference in Mean difference before and after adjustment, which indicates an major improvement of the resulting DEM surface to a respective reference surface.

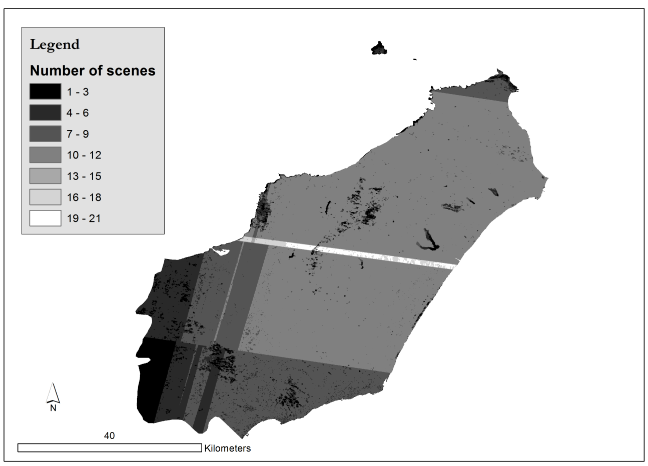
TABLE I. STATISTICAL RESULTS FOR THE PROCESSING OF 24 IMAGES

	Parameters		
	Minimum	***Average***	***Maximum***
Number of points	1419	1425	1496
Number of points RMS< 1	296	452	866
Gain before Adjustment	1	1,004	1,012
Gain after Adjustment	1	1,003	1,007
Offset before Adjustment	23,84	37,63	51,67
Offset after Adjustment	-0,60	0,33	1,21
Correlation before Adjustment	1,00	1,00	1,00
Correlation after Adjustment	1,00	1,00	1,00
Mean Difference before Adjustment	-507,09	-372,47	-244,36
Mean Difference after Adjustment	-0,0003	0,0000	0,0003

The third step consists of merging and mosaicing the single tiles/strips into one final DEM using a LOESS filter reporting for each single pixel the minimum, averaged (Fig 1) and maximum elevation, the number of pixels used in the estimation process (Fig 2) as well as an error estimation value. We will show on examples from single tile ASTER DEMs for the island of Sardinia and a province of Tunisia how the processing is performed and compare it against GDEM V1 data in terms of geolocation.



Φιγυρε 2. Estimated average elevation for the Tunisian Example



Φιγυρε 3. Number of Scenes used in the DEM generation process for the Tunisian Example

III. Conclusion

We have performed experiments for horizontal and vertical adjustment on a global dataset of over 4000 ASTER scenes and have developed a processing chain to ortho-rectify and mosaic ASTER DEM-Scenes. Results are presented here for two small subsets, one in Sardinia and one in Tunisia. The method performs significantly better with less input scenes than used for example in the ASTER GDEM product.

References

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