ACCURACY EVALUATION OF THE SRTM TOPOGRAPHIC DATA PRODUCT OVER SELECTED SITES IN AUSTRALIA AND BRUNEI DARUSSALAM

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ABSTRACT

The paper presents the results of a study on the accuracy of the SRTM band C topography data product (defined in this paper as DTM.C, pronounced as dtm-dot-c), conducted over two selected sites in Australia and Brunei Darussalam. The DTM.C was compared against accurate DTMs developed from 1m (Australian site) and 10m (Brunei site) contours. Land-cover data derived from aerial photographs and forestry maps were also used in this study. The discrepancy between DTM.C and DTM allowed the development of an accuracy statement which takes into an account "vegetation" noise caused by the vegetation impenetrability of the band C electromagnetic waves.

It was found that the site specific accuracy of the DTM.C could be characterised by a vertical, positive shift equal to 9.8m and 8.3m, and the height error: ± 11.5m and ± 18.7m (at 90% confidence level), for the Australian and Brunei sites, respectively. These values agree with the performance requirements for the SRTM data products [4], and could be accepted as a realistic accuracy statement, if DTM.C is used as a surrogate for a DTM over an area of interests.

1. INTRODUCTION

The Shuttle Radar Topography Mission (SRTM) topography data product covers about eighty percent of the landmass of the earth. The data collection process was carried out using a technique called the Synthetic Aperture Radar Interferometry [5]. Specially designed equipment was flown on board of the space shuttle Endeavour during her 10-day flight in February 2000 [3].

The data were collected in two frequency ranges known as bands C (wave length 5.6cm) and X (wave length 3.1cm). An instrument for band C was developed by NASA and for band X by the German and Italian Space Agencies - Deutche Zentrum für Luft- und Raumfahrt and Agenzia Spaziale Italiana [1]. However, only the band C data product will be considered and referred to as DTM.C (pronounced as dtm-dot-c).

The DTM.C is a regularly spaced 3 arc-second grid (or 90 m at the equator), with the exception of the USA territories, where the spacing is 1 arc-second (or 30 m). The so called "finished" version of the DTM.C is available via ftp download free of charge [1].

The fact that the dataset is freely available, uniform in terms of the method used to acquire it, comprehensive in terms of almost global coverage, and of relatively high accuracy, makes it a unique and extremely valuable data source for specialists from a wide spectrum of disciplines. Its value is not diminished sampling rate (90 m), because as Smith and Sandwell [6] stated, that there is a likehood that it "captures almost all the information in the SRTM data".

Reported absolute height error (at 90% confidence level) for the DTM.C ranges from ±5.6m to ±9.0m, depending on the location on the globe [4].

The DTM.C is neither the DTM nor the DEM, because over vegetated areas it represents the part of the vegetation which is impenetrable by the band C electromagnetic waves, and not the “bare” earth’s surface or the tops of the vegetation cover, as one would expect from a DTM or DEM.

In this paper, the term: “effective vegetation impenetrability” (or “vegetation impenetrability” for short) of the SRTM band C is introduced to grasp the above effect. In other words, the vegetation impenetrability of the DTM.C for a given point covered by the vegetation could be defined as the difference between the DTM.C and DTM at that point. As it is easy to note, the impenetrable part of the vegetation cover does not constitute any physical surface. Yet, there is an understandable strong temptation in the wider geo-community to utilize the DTM.C as a DTM.

In this paper an attempt is made to assess the vegetation impenetrability of the DTM.C over various types of land-cover. The achieved results could be used for subtracting the impenetrable vegetation layer in order to achieve a DTM for an area of interest. They provide also a realistic height error assessment of the DTM.C for those who intend to use the DTM.C as a DTM.

The study was conducted over areas in Australia and Brunei Darussalam. Investigated DTM.C was compared against reference DTM developed from accurate topographic maps (Australian site), ground control points (Brunei site). Cartographic records provided the information about the type of land-cover and the vegetation type.

Similar studies using various references DEM could be found, for example, in [2] and [7].

2. TEST SITES

Test sites selected for the study are:

1. A rectangular area 5 by 6km located on the Gold Coast, Queensland, Australia, and
2. Irregularly-shaped area in Brunei Darussalam (see Figure 1).

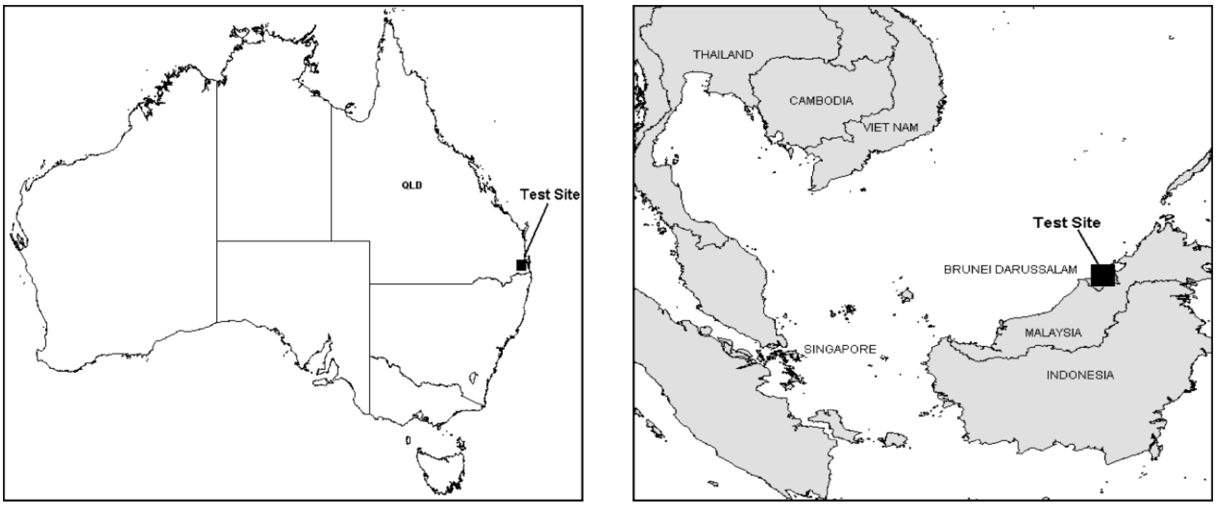

Figure 1. Location of the test sites

The land-cover in the Australian site is dominated by sparsely distributed tree patches and scattered trees with some small areas of heavy/dense vegetation (see Figure 2). The Brunei site is predominantly covered by various types of tropical forest (see Figure 3). Both sites share similar type of topography, being moderately undulated terrain, with the lowest elevation of 4m in both sites, and culminating at 388m and 269m for Australian and Brunei site, respectively. The sun-shadowed terrain models for the Australian and Brunei test sites are shown in the figures 4 and 5, respectively.

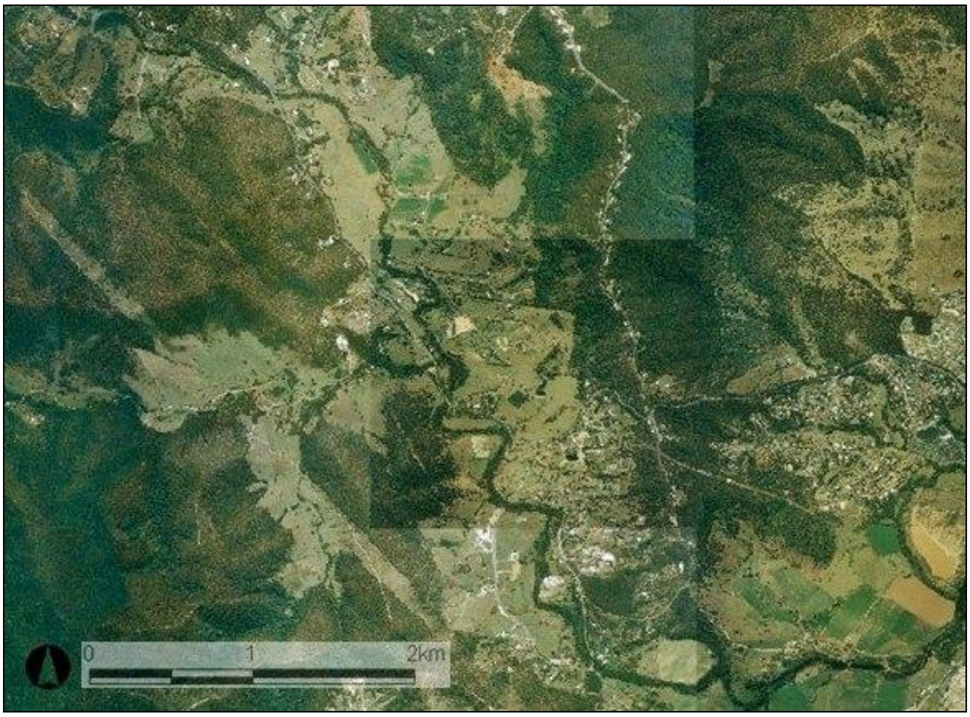

Figure 2. Orthorectified aerial photography over the Australian test site

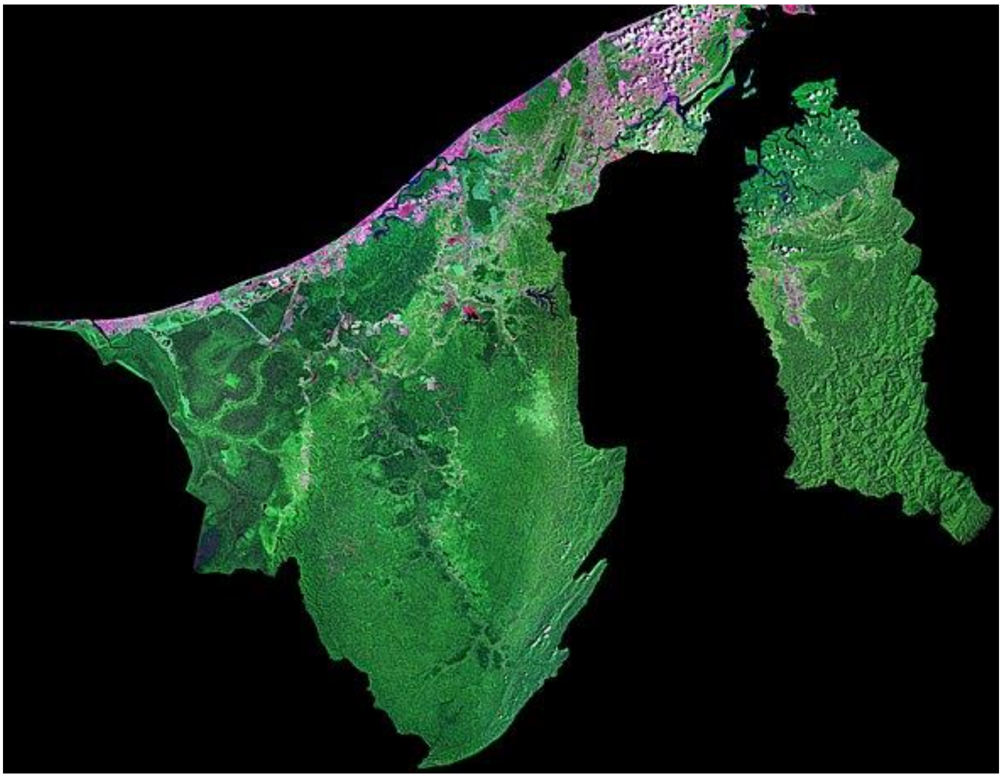

Figure 3. The 2000 GeoCover ® image of Brunei Darussalam

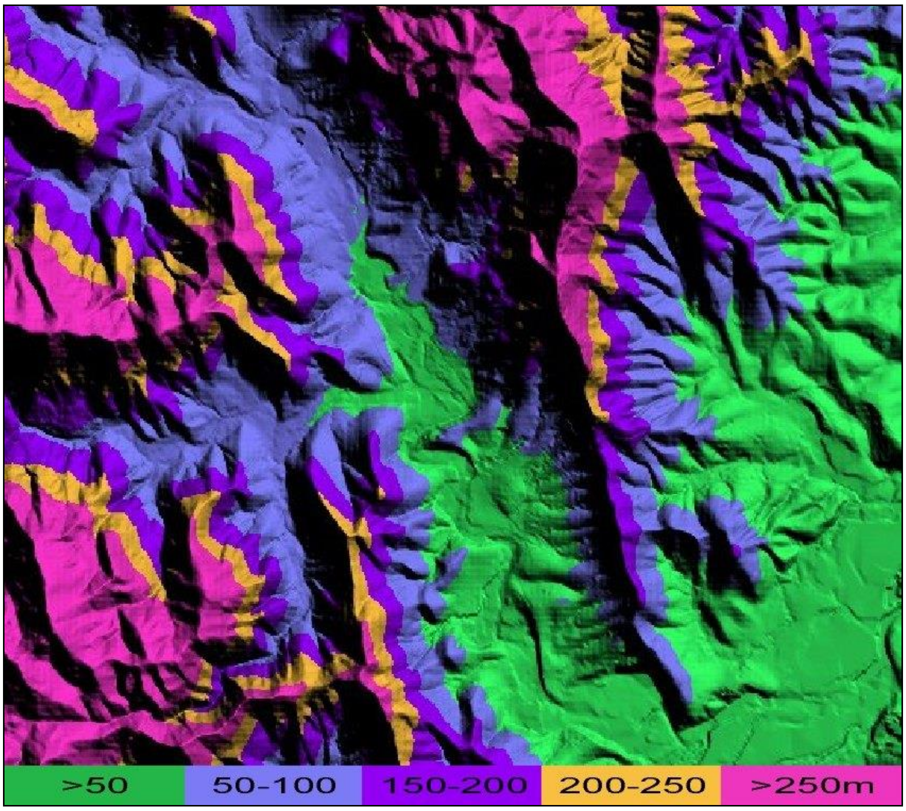

Figure 4. Sun-shadowed DTM over the Australian test site

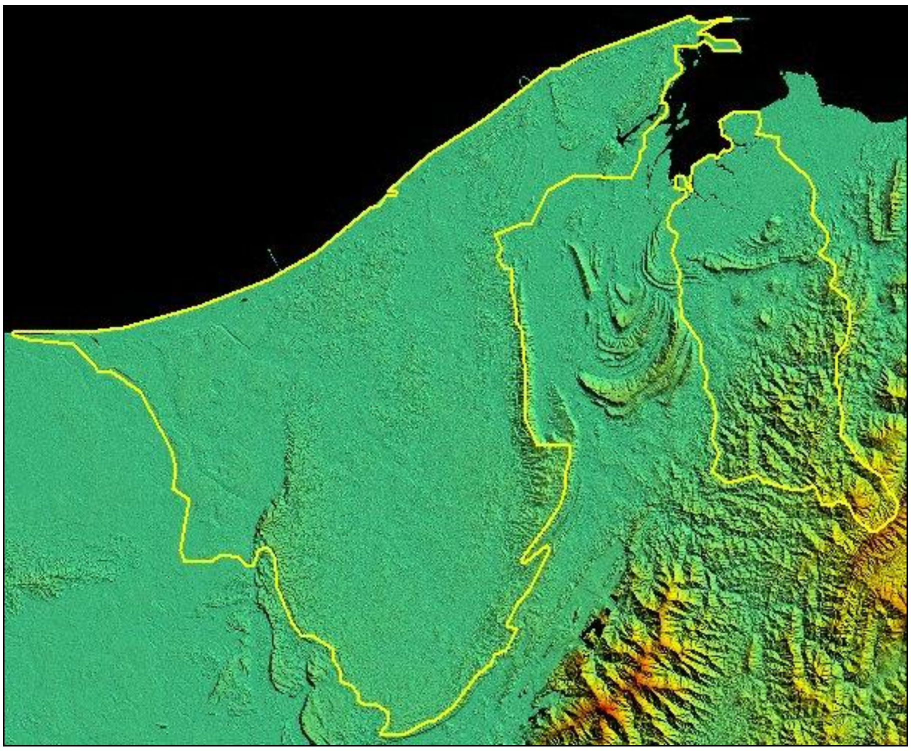

Figure 5. The SRTM topographic data product for Brunei Darussalam

3. DATASETS

The following is a list of the data source used in this study:

1. DTM.C, 3-arc-second model for the Australian and Brunei sites,
2. DTM for the Australian site, developed from 1 m contours using photogrammetric methods,
3. Land-cover classification acquired from 1994 aerial photographs for the Australian site,
4. 1:50,000 forestry maps for the Brunei site produced in 1984,
5. Around three thousand 3D survey marks for the Brunei site,
6. DTM for the Brunei site developed from 10m contours (1:10,000 topographic maps), and
7. DTM for the Brunei site developed from 15m contours (1:50,000 topographic maps).

The land-cover classification for the Australian test site was performed by the photogrammetrist while extracting contours from the aerial stereopairs. The areas under heavy or dense vegetation were visually impenetrable which resulted in certain level of generalization of the contour lines. So, the DTM in such areas is generally less accurate than 1m.

It is worthwhile to note that the reference DTM data for the Brunei site are not that comprehensive and reliable as the corresponding DTM for the Australian site. This is due to the fact that about 80 percent of Brunei Darussalam is covered by rainforest and as there are no roads there are no survey marks. In addition, the 10,000 scale topographic map series do not cover the entire country; the 1:50,000 maps (50ft or around 15m contours) were used where necessary.

3. RESULTS

In order to estimate the thickness of the impenetrable part of the vegetation cover for various types of the vegetation cover the following procedure for the Australian test site was adopted:

1. The reference DTM and the land-cover over the area of interest were divided into a regular 3 arc-second grid (the grid was created to be coincidental with the DTM.C);
2. Grid cells were classified according to the land-cover type, e.g. cleared land, scattered, heavy, dense and mixed (cells which partially belong to more than one of the former types of land-cover);
3. An average elevation, based on the reference DTM, was calculated for every cell;
4. For every cell its average elevation was subtracted from the corresponding DTM.C elevation; and
5. The differences were subsequently grouped by the land-cover classes and, an average difference and standard deviation were calculated for each land-cover type.

Results for the Australian test site are presented in Table 1.

Table 1. The Australian test site results

Type of Cell	Diff. and STD[1]	No. of Cells
Clear land (no trees or bush present)	2.9 ± 4.2m	636
Scattered (individual trees or group of trees were present)	14.6 ± 9.1m	546
Heavy (mainly tall trees with shrubs on lower levels)	13.2 ± 12.7m	163
Dense (mostly dense bush, shrubs, young trees)	18.1 ± 9.1m	48
Mixed (mixture of more than one of previous class)	10.0 ± 15.9m	2559
All	9.8 ± 11.5m	3952

[1] *Diff. = DTM.C - DTM; STD denotes the 90% error.*

A similar procedure was used for the calculations on the Brunei site dataset. In this case, the land-cover data were derived from of the Brunei forestry map. Achieved results are shown in Table 2.

Table 2. The Brunei test site results

Type of Cell	Diff. & STD[1]	No. of Cells
1. Tropical healthy forest	7.4 ± 21.4m	36
2. Dense even, or semi-open, canopy of mainly small-crowned trees	4.7 ± 17.0m	29
3. Canopy uneven, or moderately open, some medium or large emergents	10.8 ± 17.2m	86
4. Dense even canopy of medium crowns	16.0 ± 18.9m	19
5. Dense uneven canopy, of medium-sized and large crowns	11.5 ± 23.8m	48
6. Dense uneven canopy, mainly large crowns	23.5 ± 33.8.1m	29
7. Generally over 25 years old	4.7 ± 17.0m	118
8. Land under urban and industrial use	5.0 ± 23.8m	116
All	8.3 ± 18.7m	481

[1] *Diff. = DTM.C-DTM; STD denotes the 90% error.*

5. CONCLUSIONS

The above study could be summarised as follows:

1. Positive values of the differences – **Diff** (= DTM.C - DTM) for all the land-cover types in both sites indicate that the DTM.C is always above the reference DTM. This would indicate a systematic, vertical shift of the DTM.C. In case of the "non-cleared" land-cover classes, this shift correlates with the vegetation cover. For the "cleared" cells the shift is 2.9m and 5.0m for Australian and Brunei site, respectively. This is at least 1.3m (Australian site) more than reported in [4]. Considering the description of this type of cells for Brunei site (Land under urban and industrial use which means that some above-the-terrain structures are present), the value of **Diff**. (5m) could be justified.

2. The average value of **Diff**. for all class of land-cover (9.8m and 8.3m) could be interpreted as a site-specific vertical shift of the DTM.C caused by the vegetation cover. The corresponding values of the height error are ± 11.5m and ± 18.7m (90% confidence level), and could be interpreted as the accuracy of a DTM.C if one would like to use it as a DTM.

3. A vegetation impenetrability of the band C could be estimated at 14.5m, and 9.4m (values obtained from the “vegetated” cells) for the Australian and Brunei sites, respectively. These values are significantly different from the results obtained in [2] and being 6.9m and 37.1m for the Australia and Asia test site, respectively.

6. REFERENCES

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