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Google Earth's derived digital elevation model: A comparative assessment with Aster and SRTM data

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Abstract. This paper presents a statistical analysis showing additional evidence that Digital Elevation Model (DEM) derived from Google Earth is commendable and has a good correlation with ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer) and SRTM (Shuttle Radar Topography Mission) elevation data. The accuracy of DEM elevation points from Google Earth was compared against that of DEMs from ASTER and SRTM for flat, hilly and mountainous sections of a pre-selected rural watershed. For each section, a total of 5,000 DEM elevation points were extracted as samples from each type of DEM data. The DEM data from Google Earth and SRTM for flat and hilly sections are strongly correlated with the R^2 of 0.791 and 0.891 respectively. Even stronger correlation is shown for the mountainous section where the R^2 values between Google Earth's DEM and ASTER's and between Google Earth's DEM and SRTM's DEMs are respectively 0.917 and 0.865. Further accuracy testing was carried out by utilising the DEM dataset to delineate Muar River's watershed boundary using ArcSWAT2009, a hydrological modelling software. The result shows that the percentage differences of the watershed size delineated from Google Earth's DEM compared to those derived from Department of Irrigation and Drainage's data (using 20m-contour topographic map), ASTER and SRTM data are 9.6%, 10.6%, and 7.6% respectively. It is therefore justified to conclude that the DEM derived from Google Earth is relatively as acceptable as DEMs from other sources.

1. DEM and watersheds segmentation

The automated watershed segmentation and extraction of channel network and sub-watershed properties from raster elevation data represent a convenient and rapid way to parameterize a watershed. Three principle methods for structuring a network elevation data are square grid network, triangulated irregular network, and contour based networks. Square grid network are the most common form of DEMs used for topographic analysis of a river basin. Grid based DEMs have their advantages of their ease computational implementation, efficiency and availability of topographic database. In addition, research over the past decade has demonstrated the feasibility of abstracting topographic information of hydrological interest directly from digital elevation models (DEMs). The minimum resolution of DEMs was used by [1] in hydrological modelling study which is 5 meter resolution. Normally, 30 meter resolution and 90 meter resolution was used [2], [3] as it can be obtained free from USGS (U.S Geological Survey)'s website. The lowest resolution was used by [4] with 250 meter DEM resolution. Normally, in Malaysia, the topographic information normally gathered from topographic maps which can be bought from government agency; JUPEM (Department of Survey and Mapping Malaysia) [5]. These maps scanned, digitized and generated its DEMs.

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Obviously for wide areas, these processes are tedious and time consuming. As for these reasons, this paper presents an alternative method to extract elevation data using online free web tool and compare the results with SRTM 90 data and ASTER data to evaluate its quality among available free online DEM data.

2. Data and methods

2.1. Data descriptions and study area

This case study examines relatives and absolute differences between Google Earth DEM with SRTM DEM and ASTER DEM data. Specifically, the aim of this study is to (i) explore the accuracy extent of elevation data extracted from Google Earth and to (ii) examine the performance of Google Earth elevation data source to perform basic hydrological derivatives, such as stream networks and watershed boundary delineation. The SRTM 90 DEM was distributed free by USGS since 2008 and is available for download from http://srtm.csi.cgiar.org/. It provided by NASA and claimed to provide over 80% of digital elevation model (DEM) data worldwide. The SRTM data is available in 3 arc second (approximately 90 meter resolution) DEMs. The vertical error of the DEM's is expected less than 16 m. For this comparison study the SRTM 90 was downloaded on October 2012. Meanwhile, the ASTER GDEM V2 (Global Digital Elevation Model Version 2) was released on October 17, 2011 after the first version released in June 2009. It coverage spans from 83 degrees north latitude to 83 degrees south, covering 99 per cent of Earth's landmass. ASTER's data providing better resolution compared to SRTM with a base resolution of 30 metres, and can be extended to 7m-10m. In this study, there are two versions of ASTER DEM data. The first version is labelled as ASTER 30 was downloaded from http://gdem.ersdac.jspacesystems.or.jp/, with 30 meter resolution. The second version is labelled as ASTER 10 was modified by performing neighbourhood analysis in ArcGIS 9.3.1. Neighbourhood cell block analysis was conducted to upgrade the resolution of ASTER DEM, from 30 m x 30 m pixel resolution to 10m x 10m. Next, Google Earth elevation data were extracted using free source online tool named Terrain Zonum via this website http://www.zonums.com/gmaps/terrain.php. Sungai Muar watershed area was selected as a study area. Muar River flows in Muar, Segamat, Gemas and Gemencheh in Negeri Sembilan to Seri Menanti and Batu Kikir, Negeri Sembilan. The extent of Sungai Muar watershed area are from 1.926702°N, 102.056472°E in lower left corner and 2.972698° N, 103.222606°E in upper right corner (figure 1). Maximum point extraction using Terrain Zonum Solution tools is limited to 5000 elevation points. Therefore, this study area was divided into 36 small areas to obtain denser elevation points in each area within the study boundary. Then, extracted elevation value (approximately 180,000 points) imported into a text file for further process in ArcGIS 9.3.1. Briefly, data source and description, for this study can be seen in table 1.

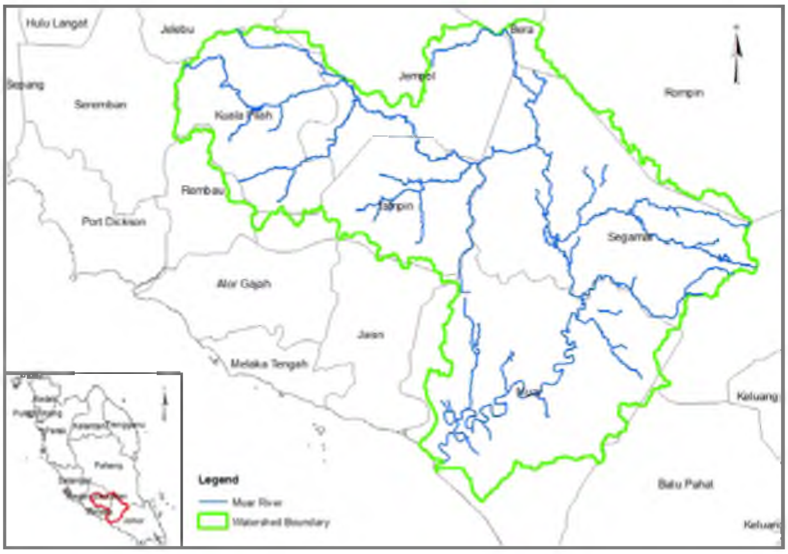

Figure 1. Study area.

(Source : Department of Irrigation and Drainage, Malaysia)

Table 1. Various elevation data and its source.

Type	Resolution	Source	Coordinate
Google Earth	Unknown	Google Earth	Lower left corner:1.926702°N, 102.056472° E Upper right corner:2.972698° N, 103.222606°E
SRTM	90 meter	http://srtm.csi.cgiar.org/	Latitude min: 0 S max: 5 N Longitude min: 100 E max: 105 E
ASTER 30	30 meter	http://gdem.ersdac.jspacesystems.or.jp/	Latitude min: 0 S max: 5 N
ASTER 10	30 meter	http://gdem.ersdac.jspacesystems.or.jp/	Longitude min: 100 E max: 105 E

2.2. Data processing

Both SRTM 90 DEM and ASTER DEM are in raster format and ready to use. However, ASTER DEM needs to be mosaic which was performed in ERDAS Imagine 9.2. As mentioned earlier, there are two sets of ASTER DEM data in this study. ASTER (a) is the original downloaded data, and ASTER 10 was ASTER 30 data that has been performed Neighborhood cell blocks statistic analysis to enhance its resolution up to 10 meter. However, even though ASTER 30 was modified to ASTER 10, their cell resolutions remain same as ASTER 30 which is 30 meter. Therefore, further analysis using both ASTER type was conducted and describe later in next section. Meanwhile, Google Earth elevation data is in point vector format after imported to ArcGIS 9.3. The four samples of resolution comparison; were taken in mountainous area located in Negeri Sembilan which is also within Muar River watershed boundary. Obviously, ASTER 30 presents smoother DEM compared to others. Its ridge lines can be seen clearly. However ASTER 10 pixels are rougher as compared to ASTER 30. Main ridge lines still apparent, but smaller ridge lines look fade and blurry. The SRTM 90 even worse, because none ridge lines can be seen, its pixels rough and only general shape can be detected indicate the same location of mountainous area. The Google Earth's DEM is almost similar to ASTER 10. There are certain main ridges apparent even though it is not smooth as ASTER 10 and ASTER 30, but in terms of resolution, Google Earth's DEM better than SRTM 90. Next, three different location area were identified within the watershed boundary based on its height difference which are flat area, hilly area and mountainous area. Total of 5000 points generated in each area (total points= 15,000 points in three area) using Hawth's Tool in ArcGIS 9.3. These points later utilized to extract elevation value in four type of DEM data used in this study. Further results and analysis are described in next section.

3. Results and analysis

3.1. Comparisons in flat area
Next, further analysis was conducted to affirm, Google Earth elevation quality of data in flat area. A total of 5000 elevation points from ASTER 30, ASTER 10 and SRTM 90, were correlated with Google Earth elevation data. The correlation was conducted using SPSS 11 software. The results of the correlation show in figure 2.

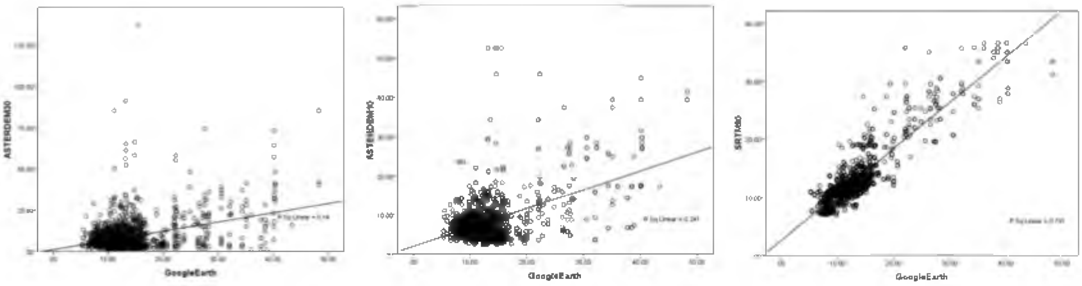

Figure 2. Correlation of Google Earth data with ASTER30, ASTER10 and SRTM90.

Correlation analysis was conducted to measure the association of each elevation type of data with elevation extracted from Google Earth. The correlation value which is R^2, between these data, will define the strength of association between two different types of elevation. Early conclusion can be stated that Google Earth data positively correlated with ASTER30, ASTER10 and SRTM90. However, it only strongly associated with SRTM 90 with the R^2 value is 0.791. As Google Earth compared with ASTER 30 and ASTER 10, it associated stronger with ASTER 10 with $R^2 = 0.241$. Therefore, preliminary assumption can be made, that in flat area, Google Earth elevation quality of data can be similar as SRTM 90.

3.2. Comparisons in flat area
In addition, Google Earth data also correlated with ASTER 30, ASTER 10 and SRTM90 (see Figure 7). In hilly area, association of Google Earth data and SRTM 90 become stronger with $R^2 = 0.891$. However, its association decrease for ASTER 30 and ASTER 10 with R^2 value is 0.102 and 0.185 respectively. Therefore in hilly area, the quality of Google Earth elevation data also can be expected close to SRTM90 (see figure 3).

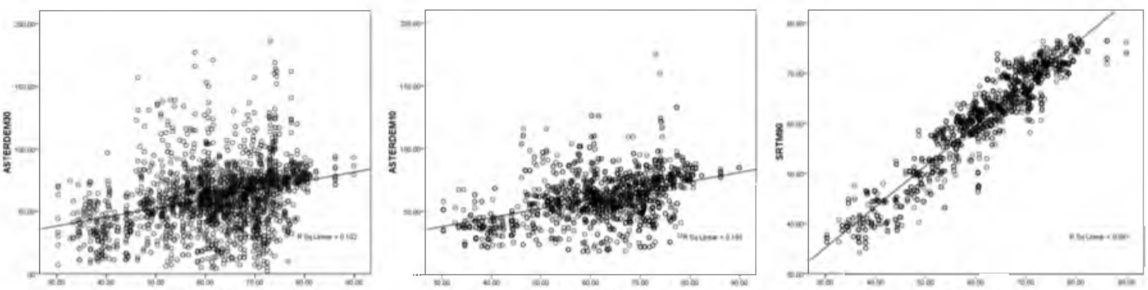

Figure 3. Google Earth data correlated with ASTER 30, ASTER 10 and SRTM 90.

3.3 Comparisons in flat area
In mountainous area, correlation of Google Earth data with ASTER 30 and ASTER 10 suddenly fluctuate with R^2 value is 0.917 and 0.919 respectively. Google Earth data also has strong association with SRTM 90. However, the R^2 value is only 0.865, which is the lowest association in mountainous area as it compared with R^2 value of ASTER30 and ASTER 10. Hence, it can be concluded, in

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mountainous area the quality of Google Earth data is better than SRTM 90 and even similar to ASTER data (see figure 4).

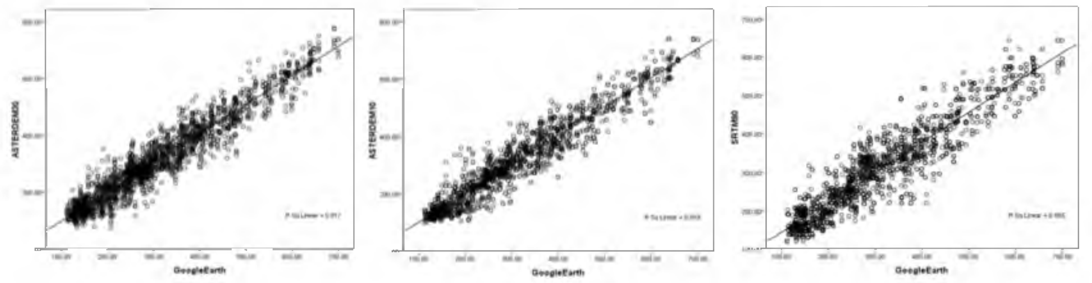

Figure 4. Strong association between Google Earth elevation data with ASTER 30, ASTER 10 and SRTM 90 data in mountainous area.

3.4 Functionality of the DEMs on watershed delineation

By utilizing Muar River line as an important reference for watershed delineation in ArcSWAT2009, four watershed boundaries were successfully delineated. Then, these boundaries were compared with existing watershed boundary obtained from JPS (Department of Irrigation and Drainage) which was delineated using 20 meter interval contour line. The boundaries comparisons show in table 2.

Table 2. Watershed boundary differences with JPS boundary.

Watershed Boundary	Area (km^2)	% Area Difference	Perimeter (km)	Ratio (Perimeter/Area)	% Overlay
JPS Boundary	6149.00	-	590.15	0.09	-
Google Earth	5561.43	9.6	670.12	0.12	100%
ASTER 30	5497.57	10.6	1076.72	0.20	100%
ASTER 10	5648.15	8.1	729.04	0.13	100%
SRTM 90	5681.64	7.6	615.55	0.11	100%

4. Conclusions

We found this study is really interesting, and we conclude this paper with these summary and findings, which are related to quality of Google Earth elevation data, and its functionality in hydrological modelling activities:

i. In flat area, quality of Google Earth's elevation data is similar to SRTM90 which is approximately produce 90 meter resolution of data. However, as Google Earth data was tested in higher (from hilly to mountainous) area, its quality become better and almost similar to quality of ASTER data, better than SRTM90.
ii. These results are significant in investigating source of Google Earth's elevation data which is might be from combination of free source of elevation data, ASTER and SRTM90. However, the comparison results made us wondering, why the quality of Google Earth's DEM is not consistent in flat, hilly and mountainous area. This is also might be related to location of the study area. If it located in United States, the results may be different and the quality of Google Earth DEM even better. Another assumption can be made is, in flat area (in the study area) only SRTM90 was utilized in Google Earth. As it goes to higher area, ASTER DEM started to be used to produce more detail terrain. Hence, to confirm the speculation of this Google Earth DEM's source, on site measurement using high precision GPS should be conducted and compare its value with these four type of DEM data.
iii. Google Earth's DEM, is applicable to be used as a data source for conducting hydrological modelling process. Utilizing Google Earth's DEM itself, produced less accurate modelling process, however, it is possible to combine Google Earth's DEM with ASTER or SRTM for more detail DEM and conduct precise hydrological modelling.

iv. Free source of elevation data are really useful to assist researchers/students minimizing their time collecting elevation data which are normally tedious, time consuming and costly.

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