Evaluation of Vertical Accuracy of Airborne IFSAR and Open Source Digital Elevation Models (DEMs) Based on GPS Observation

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Abstract**—** A Digital Elevation Model (DEM) is a digital representation of ground surface topography. DEMs are used for various applications including flood modeling. The objective of this paper is to evaluate the vertical accuracy of the DEMs acquired from different sources. The study area covered several districts in Kedah, Malaysia. To determine the accuracies of DEMs acquired from NEXTMap Interferometric Synthetic Aperture Radar (IFSAR), ASTER Global Digital Elevation Model (GDEM) and SRTM Void Fill, height points are compared with the Global Positioning System (GPS) height observations. A total of 100 height points extracted from ASTER GDEM and SRTM is also compared with IFSAR Digital Surface Model (DSM). Four (4) different elevation profiles are generated and the heights are compared. The results obtained have shown that the Root Mean Squares Errors (RMSEs) of IFSAR DTM, IFSAR DSM, ASTER GDEM and SRTM over a relatively flat area are ±0.497 m, ±1.529 m, ±5.848 m and ±4.268 m respectively. Over an undulating area, the accuracies of IFSAR DTM, IFSAR DSM, ASTER GDEM and SRTM are ±0.841 m, ±2.092 m, ±3.278 m and ± 5.300 m respectively. Although there are variations between heights generated from these DEMs in some areas along cross-section, the pattern of height profiles is still quite similar. Future work will concentrate on the techniques of converting DEM acquired from ASTER GDEM and SRTM into DSM and the effects of using different DEMs on the accuracy flood inundation mapping.

Keywords**—** Airborne IFSAR, ASTER, SRTM Void Fill, Digital Elevation Model, Digital Terrain Model

I. Introduction

The increasing frequency of flood event has raised the need for more accurate flood inundation maps. The recent technology of Remote Sensing has enabled the approach of estimating flood extent based on a Digital Elevation Model (DEM). DEM is a digital representation of ground surface topography or terrain with different accuracies for different application fields. DEM has been used in various applications such as civil engineering infrastructure, military, mining, telecommunications, terrain visualization, disaster management and orthorectification of satellite imagery. DEM can be generated from different techniques with varying accuracies such as a photogrammetric method using stereo data [1], [2] interferometry [3] and airborne laser scanning [4]. Other methods of acquiring DEM are real time kinematic Global Positioning System (GPS), block adjustment of optical satellite imagery and existing topographic maps.

ASTER is an international collaboration project between the Ministry of Economy, Trade and Industry of Japan (METI) and the United States National Aeronautics and Space Administration (NASA). The DEM covers 99% of the Earth's Land Mass. Near-infrared stereo imagery is collected simultaneously at both nadir and off nadir angles with along-track alignment. This stereo imagery is then utilized to develop a DEM through stereo correlation techniques. As reported in [5] vertical accuracy of ASTER DEMs is in the range of 7 to 15 m. The most complete DEM available to the public was the Shuttle Radar Topography Mission (SRTM) dataset. It was acquired as a joint mission by NASA, German Aerospace Center, and the National Geospatial-Intelligence Agency. The SRTM data were created using interferometric processing of L-band synthetic aperture radar (SAR) data. Airborne INTERMap IFSAR provides three main products, i.e. digital surface models (DSM), digital terrain models (DTM), and orthorectified radar imagery (ORI). The vertical accuracy of 0.5–1.0 m of both the airborne IFSAR DSM and DTM can be achieved by the airborne Intermap mapping system [6].

It is important to focus on the accuracy of the DEMs as this can influence the accuracy and effectiveness of study and flood modelling. In order to evaluate the accuracy of different DEMs, various techniques have been used by different author i.e. [7], [8] [9] generate an elevation profile to compare the differences between DEMs while [10], [11] carried out correlation analysis to compare the difference in DEM accuracy. Another method of assessing the DEM accuracy is by comparing the relationship between topographic characteristics such as slope and aspect [12]. [13] used matching contour method to evaluate the accuracy of ASTER GDEM elevation. In a study by [14], the accuracy performance of DEM products from airborne and spaceborne IFSAR are compared with high-accuracy ground control points (GCPs) and higher-accuracy DEM. The recent study by [15] evaluated SRTM X-band with Differential Global Positioning System (DGPS) for accuracy assessment.

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This study aim to analyze the accuracy of IFSAR DTM, IFSAR DSM, ASTER GDEM and SRTM Void Fill over a few District of Kedah, Malaysia. Heights obtained from GPS observation are used for accuracy assessment of IFSAR DTM and IFSAR DSM. While IFSAR DTM was used as the reference height for ASTER GDEM and SRTM Void Fill.

II. Study Area

The study area is located within the District of Kota Setar, Pokok Sena and Padang Terap in Kedah, Malaysia (Fig. 1). The area is selected as the study area due to the availability of GPS observation data, NEXTMap IFSAR, ASTER GDEM, SRTM and variable terrain characteristics. For GPS observation data, two different test sites were selected which are situated in the District of Kota Setar and District of Padang Terap as shown in Fig. 2 (a) and 2 (b). The height range of the study area is 1 m up to 140 m. The land use of the test site located in the District of Kota Setar is mainly covered by residential areas, commercial areas and paddy fields. The higher part of the study area is situated within the District of Padang Terap and mainly covered by forest and agricultural areas.

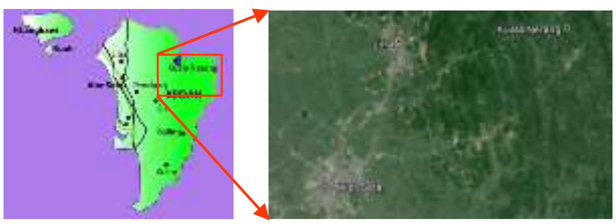


Fig. 1 Location of study area (Adapted from Google Earth 2014)

(a) (b)

Fig. 2 Location of a) Test site 1 – Alor Setar b) Test site 2 – Kuala Nerang
(Adapted from Google Earth, 2014)

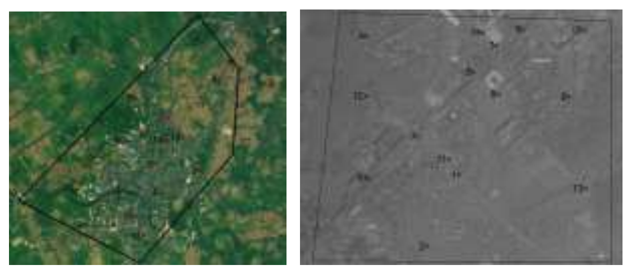
III. Methodology

The methodology adopted for this study is divided into three main stages i) data acquisition, ii) data processing and iii) data analysis. Fig. 5 shows the general methodology adopted for this study.

The data used for this study are open source ASTER GDEM version 2 and SRTM Void Fill, Nextmap Airborne IFSAR data. ASTER GDEM and SRTM are downloaded from the United States Geological Survey website (earthexplorer.usgs.gov), while IFSAR dataset is acquired from Intermap Technologies Malaysia. The three types of IFSAR data are the DSM, DTM and ORI. The NEXTMap DSM represents the earth's surface and include all features such as buildings and trees on it while DTM is a bare-earth model of the terrain. Thirty (30) static observations using dual frequency GPS receiver were observed within the two test sites.

As the ASTER GDEM and SRTM data downloaded from the USGS website covers a large area, image subset is carried out to clip data according to the coverage of the IFSAR DTM and IFSAR DSM. All these datasets are later transformed into Malayan Rectified Skew Orthomorphic (MRSO) projection in the ArcGIS software. Spatial Analyst tool in the ArcGIS software is used to generate the DEMs. The output of the data processing steps are four different DEMs (i.e. IFSAR DTM, IFSAR DSM, ASTER, SRTM).

Thirty (30) GPS points is measured within the two different test sites (fig. 3). The relative positioning technique whereby one base station was selected from myRTKnet stations. For this project, Tokai Station (located in Kedah) was selected as the base station. This base station was used together with rover stations to complete the baseline processing. Rover stations (points used to compare the height points) located at suitable locations were identified and the X, Y and Z coordinates are later observed. The observed ellipsoidal heights of the rover stations are later converted into orthometric heights.



(a) (b)

Fig. 3 Distribution of GPS point a) Alor Setar b) Kuala Nerang

To enable height comparison and correlation between ASTER GDEM and IFSAR DSM and also SRTM Void Fill and IFSAR DSM to be carried out, 100 height points are used. These height points were carefully selected within relatively flat areas, vegetated areas and hilly areas (fig. 4). In order to determine the degree of relation between the different DEMs and the reference DEM, spatial correlation is computed. Four profiles are generated across the study area and the heights are compared. The locations of the profiles are shown in Fig. 4.

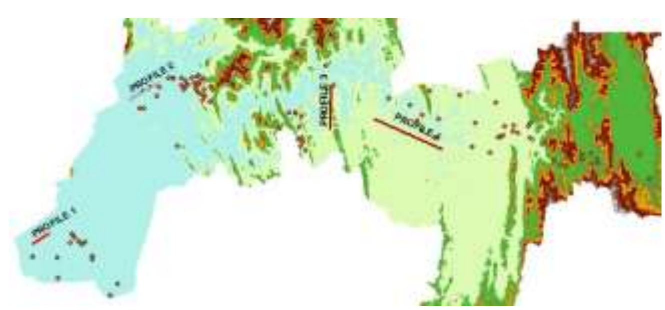


Fig. 4 Distribution of manually measured height points and locations of the vertical profiles

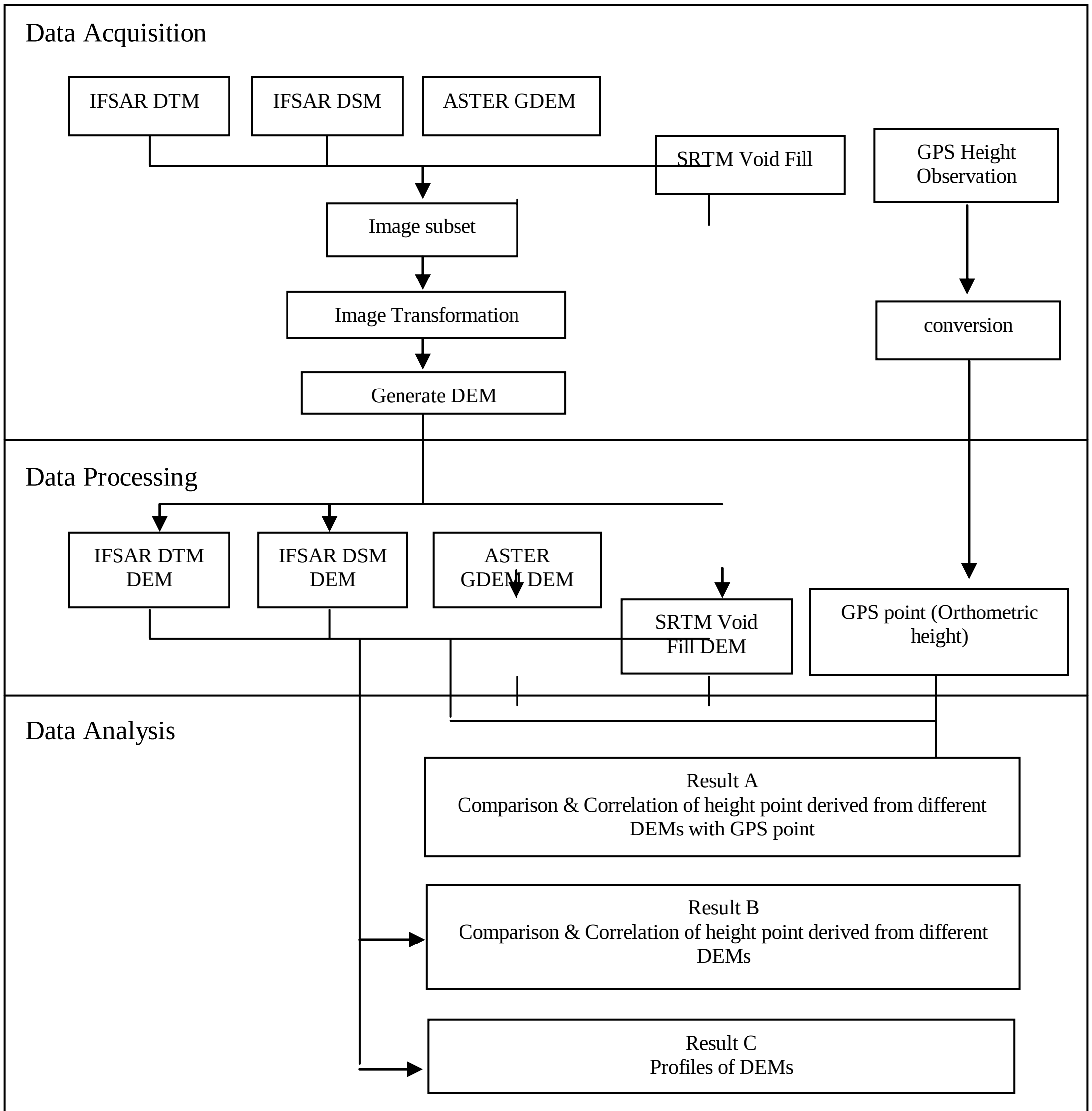


Fig. 5 Flowchart of methodology

Further processing involved the measuring of selected height points and then determining the vertical accuracies of different DEMs. To determine the accuracy of the different DEMs (i.e. the first analysis) the extracted DEMs are overlaid onto the GPS orthometric heights points in the ArcGIS software, while for the second analysis Nextmap IFSAR DTM is used as reference DEM. The minimum error, maximum error and the Root Mean Squares Error (RMSE) are computed based on equations 1, 2 and 3 respectively. In order to determine the degree of relation between the different DEMs and GPS height points, spatial correlation is computed.

$$\text{Minimum error} = \min(|Zobs - Zref|) \quad (1)$$

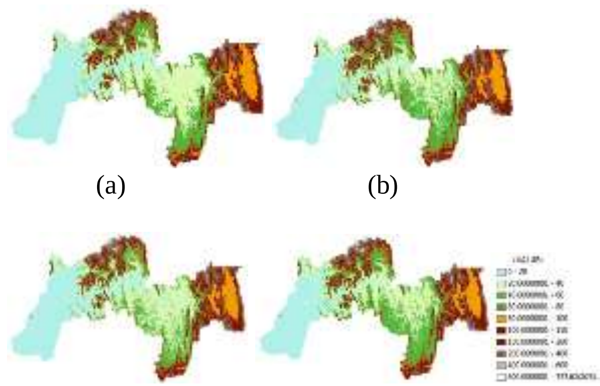
$$\text{Maximum error} = \max(|Zobs - Zref|) \quad (2)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Z_{obs,i} - Z_{ref,i})^2}{n}} \quad (3)$$

where Zobs is the observed heights in different DEMs, Zref is the observed heights in reference DEM and n is the total number of observations.

IV. Result And Analysis

Fig. 6 shows DEMs generated from NEXTMap IFSAR (both DTM and DSM), ASTER GDEM, SRTM. The generated DEMs exhibits almost similar pattern except for DEM generated from ASTER GDEM (especially in low-lying areas i.e. elevation less than 50 m). The dissimilarity could be due to different grid resolutions (i.e. 30 m for ASTER GDEM) as compared to the 5 m resolution of the IFSAR data or inaccurate heights generated from ASTER GDEM.



(a) (b)

(c) (d)

Fig. 6 Height range maps generated from (a) IFSAR DTM (b) IFSAR DSM (c) ASTER (d) SRTM

A. Result A - Comparison And Correlation Of Height Points From IFSAR DTM And DSM With GPS Observation Point

Table 1 shows the elevation points observed from different DEMs and GPS points of Test Sites 1 and 2. The descriptive statistics of the differences between various DEMs and the reference DEM as summarized in Table 2.

For the Test Site 1 (relatively flat area), the RMSE for IFSAR DTM, IFSAR DSM, ASTER and SRTM are ±0.497, ±1.529, ±5.848 and ±4.268 m respectively. In the undulating terrain area, the RMSE for the IFSAR DTM and IFSAR DSM are ±0.841 and ±2.092 m respectively, while the accuracies of ASTER GDEM and SRTM are much lower i.e ±3.278 and ±5.300 m respectively.

The magnitude of the maximum errors in the relatively flat and undulating areas for ASTER GDEM is 11.190 and 5.344 m respectively. In relatively flat area, the minimum and maximum height difference between IFSAR DTM and GPS heights are 0.049 and 0.879 m respectively. The minimum and maximum errors of IFSAR DSM as compared to GPS observation in the relatively flat area are 0.085 and 4.515 m and 0.069 and 4.649 m for undulating area respectively. The accuracies for IFSAR DTM, IFSAR DSM and SRTM DEM are lower in the undulating area (refer to Table II). On the other hand the accuracy for ASTER GDEM is much higher in the undulating area. The correlation between the elevations obtained from different DEMs and the reference DEM are graphically shown in figs. 7, 8, 9 and 10. Based on these figures and Table III, it is evident that the correlation between DEMs and reference DEMs is highest for IFSAR DTM (i.e. 99.40%) followed by IFSAR DSM (i.e. 98.30%). These figures also show strong correlation for DEM generated from ASTER and SRTM (i.e. 89.40% and 93.20%, respectively).

TABLE I

COMPARISON BETWEEN HEIGHT POINTS MEASURED WITH GPS, NEXTMAP IFSAR DTM, NEXTMAP IFSAR DSM, ASTER GDEM AND SRTM

PT NO	Test Site 1 - Alor Setar (Flat Area)					Test Site 2 – Kuala Nerang (Undulating Area)				
	GPS	NEXTMap IFSAR		ASTER	SRTM	GPS	NEXTMap IFSAR		ASTER	SRTM
	(m)	DTM (m)	DSM (m)	(m)	(m)	(m)	DTM(m)	DSM (m)	(m)	(m)
1	2.982	2.469	2.897	11	6	22.328	22.193	24.84	26	31
2	4.223	5.297	5.438	10	4	22.419	22.391	23.593	26	21
3	3.14	3.047	3.495	7	5	20.366	20.638	19.951	21	26
4	1.691	2.092	6.206	8	6	19.717	19.61	24.366	18	21
5	1.821	2.298	3.928	7	7	18.656	19.556	20.24	24	27
6	3.298	3.837	3.667	7	2	28.041	25.134	27.972	29	31
7	3.517	3.819	2.78	8	8	19.3	20.025	19.735	17	26
8	3.551	3.822	3.425	6	5	19.982	19.349	20.069	23	26
9	1.657	2.528	1.03	8	3	22.897	22.599	27.066	28	27
10	2.81	3.689	3.183	14	10	20.19	20.219	22.118	23	26
11	2.482	3.039	3.65	7	7	21.145	21.194	20.893	18	24
12	2.263	2.345	1.738	6	6	19.14	17.361	19.872	18	19
13	2.742	4.378	3.438	9	6	41.192	41.088	41.631	40	42
14	3.012	3.061	3.475	8	10	21.809	21.74	21.94	17	25
15	1.886	3.167	2.97	8	6	21.927	20.09	21.481	17	33

TABLE II

DESCRIPTIVE STATISTICS OF THE DIFFERENCES BETWEEN VARIOUS DEMS AND REFERENCE DEM

	ALOR SETAR (Flat area)			KUALA NERANG (Undulating area)		
	RMSE (m)	Min (m)	Max (m)	RMSE (m)	Min (m)	Max (m)
IFSAR DTM - GPS	0.497	0.049	0.879	0.841	0.029	1.837
IFSAR DSM - GPS	1.529	0.085	4.515	2.092	0.069	4.649
ASTER – GPS	5.848	2.449	11.19	3.278	0.634	5.344
SRTM – GPS	4.268	1.298	7.190	5.300	0.14	8.672

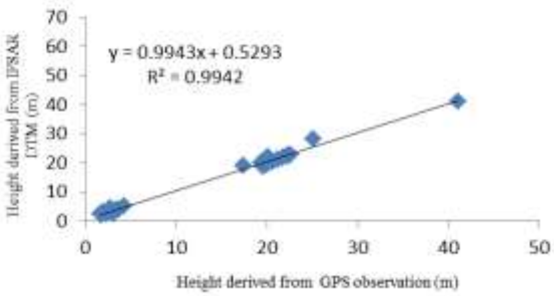


Fig. 7 Correlation plot of IFSAR DTM verses GPS observation

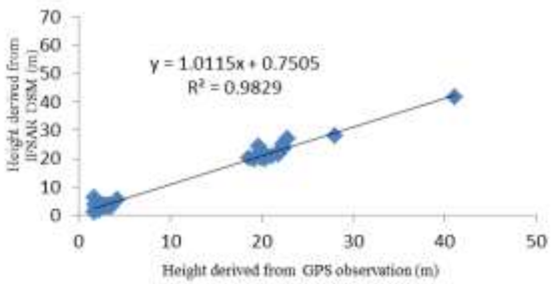


Fig. 8 Correlation plot of IFSAR DSM verses GPS

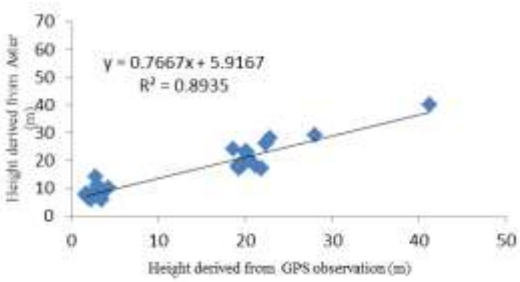


Fig. 9 Correlation plot of ASTER GDEM verses GPS observation

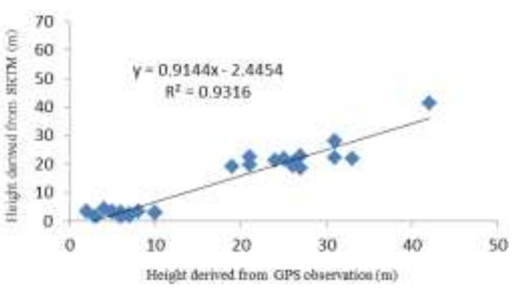


Fig. 10 Correlation plot of SRTM verses GPS observation

TABLE III
CORRELATION AND REGRESSION COEFFIENTS BETWEEN IFSAR DTM, IFSAR DSM, ASTER GDEM AND SRTM WITH GPS HEIGHT

	Correlation Coefficient (R^2)	Gradient (m)	Intercept (c)
IFSAR DTM - GPS	0.994	0.994	0.529
IFSAR DSM - GPS	0.983	1.012	0.751
ASTER – GPS	0.893	0.767	0.894
SRTM - GPS	0.932	0.914	-2.445

B. Result B –Comparison and Correlation of Height Points Derived from ASTER GDEM and SRTM with Nextmap IFSAR DSM and DTM

Table IV depicts the descriptive statistics of the accuracy of DEMs based on the height points measured within the study area. The RMSE for ASTER and SRTM as compared to the reference DEM (i.e. IFSAR DTM) are ±6.724 and ±9.712 m respectively, while the RMSE of ASTER and SRTM as compared to IFSAR DSM are ±6.882 and ±9.614 m respectively.

TABLE IV
DESCRIPTIVE STATISTICS OF THE DIFFERENCES BETWEEN VARIOUS DEMS AND REFERENCE DEMS

	RMSE	Min	Max
ASTER – IFSAR DTM	6.724	0.024	21.182
SRTM – IFSAR DTM	9.712	0.100	68.182
ASTER – IFSAR DSM	6.882	0.045	21.460
SRTM – IFSAR DSM	9.614	0.100	68.460

The magnitude of the minimum errors for ASTER GDEM as compared to IFSAR DTM and IFSAR DSM are 0.024 and 0.045 m respectively. While the minimum errors for SRTM are slightly higher, that is 0.100 m as compared to both reference DEMs. The maximum errors of DEM generated from SRTM significantly high, that is 68.182 and 68.460 m. The maximum errors for ASTER GDEM are 21.182 and 21.460 m as compared to IFSAR DTM and IFSAR DSM respectively. The results clearly show that the accuracy of ASTER GDEM is higher than STRM over the large area.

TABLE V
CORRELATION AND REGRESSION COEFFIENTS BETWEEN IFSAR DTM, IFSAR DSM, ASTER GDEM AND SRTM

	CORRELATION COEFFICIENT (R^2)	Gradient (m)	Intercept (c)
ASTER – IFSAR DTM	0.944	0.978	-0.144
SRTM – IFSAR DTM	0.946	0.841	0.251
ASTER – IFSAR DSM	0.941	0.979	-0.017
SRTM – IFSAR DSM	0.947	0.842	0.333

The correlation between the elevations obtained from different DEMs and the reference DEM are graphically shown in figs. 11, 12, 13 & 14. Based on these figures and Table V, it is clearly evident that the correlation between DEMs and reference DEMs is approximately the same (i.e. 94.4% and 94.1% of ASTER verses IFSAR DTM and ASTER verses IFSAR DSM respectively). On the other hand, the correlations of SRTM verses IFSAR DTM and SRTM verses IFSAR DSM are 94.6% and 94.7% respectively.

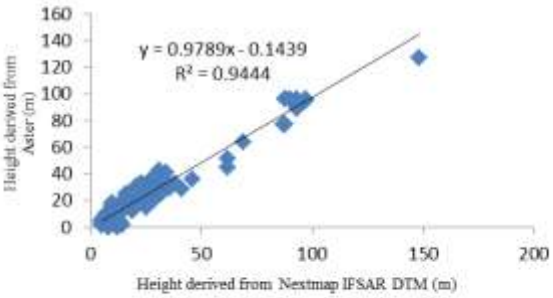


Fig. 11 Correlation plot of Aster Verses IFSAR DTM

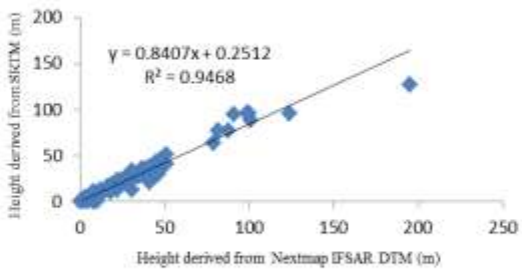


Fig. 12 Correlation plot of SRTM verses IFSAR DTM

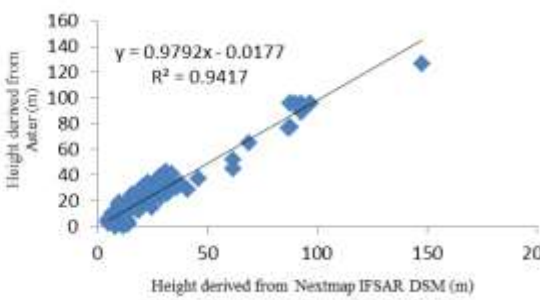


Fig. 13 Correlation plot of Aster verses IFSAR DSM

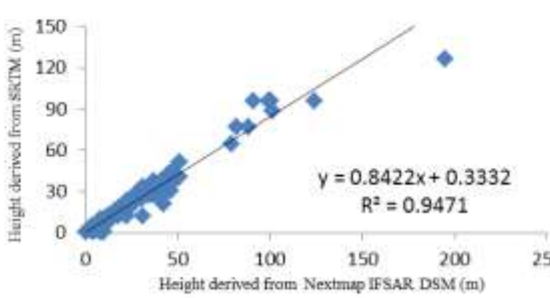


Fig. 14 Correlation plot of SRTM verses IFSAR DSM

C. Result C - Terrain Profile Derived from Different DEMS

Fig. 15, 16, 17 and 18 show the profile plots along four cross-sections within the study area. Cross-section 1 and 2 run across a non-vegetated and relatively flat area while Cross-section 3 and 4 are located in a relatively undulating area. In all the four cross-sections, there is strong agreement between profiles generated from NEXTMap IFSAR DTM, NEXTMap IFSAR DSM, ASTER and SRTM. Although there significant variation between heights generated from ASTER GDEM and NEXTMap IFSAR DSM in some areas along Cross-sections 1 and 2 (refer to figs. 15 and 16), the patterns of height profiles are still quite similar. The largest discrepancies between ASTER GDEM and NEXTMap IFSAR DSM occurred in a relatively flat area [15].

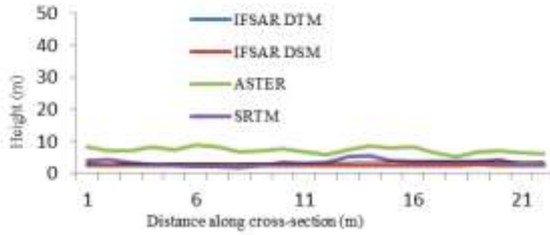


Fig. 15 Profile of DEM generated from IFSAR DTM, IFSAR DSM, ASTER and SRTM along cross section 1

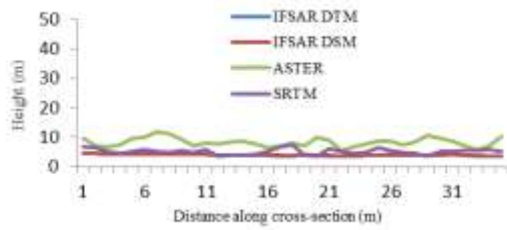


Fig. 16 Profile of DEM generated from IFSAR DTM, IFSAR DSM, ASTER and SRTM along cross section 2

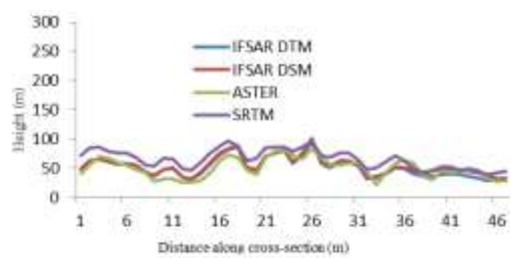


Fig. 17 Profile of DEM generated from IFSAR DTM, IFSAR DSM, ASTER and SRTM along cross section 3

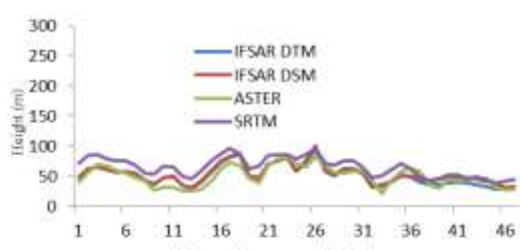


Fig. 18 Profile of DEM generated from IFSAR DTM, IFSAR DSM, ASTER and SRTM along cross section 4

V. CONCLUSION

The vertical accuracies of IFSAR DTM, IFSAR DSM, ASTER GDEM and SRTM are evaluated in the present study. The accuracy assessments of these datasets are performed based on GPS height observation and IFSAR DSM. Findings from this study have indicated the potential use of IFSAR DTM products for generating accurate flood inundation maps. Although the accuracies of DEMs generated from SRTM and ASTER are much lower compared to that of Airborne IFSAR, it could still be used to generate the DEM infill in hilly areas as the IFSAR DTM is very expensive. As this study is part of a more comprehensive research to evaluate the suitability of using different DEMs including open source Global DEMs for flood inundation mapping, a more detailed study to evaluate the effects of using different DEMs on the accuracy of the generated flood inundation maps is needed.

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REFERENCES

[1] B. T. San and M. L. Suzen, "Digital elevation model (DEM) generation and accuracy assessment from ASTER stereo data, International Journal. Remote Sensing., Vol. 26, no. 22, pp. 5013–5027, Nov. 2005.

[2] J. Höhle, "DEM Generation Using a Digital Large Format Frame Camera", Photogrammetric Engineering & Remote Sensing Vol. 75, No. 1, pp. 87–93 January 2009.

[3] F. Kervyn, "Modelling topography with SAR interferometry: illustrations of a favourable and less favourable environment, Computer and Geoscience., vol. 27, no. 9, pp. 1039–1050, Nov. 2001..

[4] E. Favey, A. Geiger, G. H. Gudmundsson and A. Wehr. "Evaluating the Potential of an Airborne Laser-scanning System for Measuring Volume Changes of Glaciers," Geografiska Annaler: Series A, Physical Geography Volume 81, Issue 4, pages 555–561, December 1999.

[5] A. Hirano, R. Welch, and H. Lang, "Mapping from ASTER stereo image data: DEM validation and accuracy assessment" ISPRS Journal of Photogrammetry and Remote Sensing, vol. 57, pp. 356–370, 2003.

[6] M. Wei and T. Coyne, "Integrated Airborne Ifsar Mapping System," International Archive of the Photogrammetry, Remote Sensing and Spatial Information Scienve, vol. 37 2008.

[7] H. Zhou, J. Zhang, L. Gong, and X. Shang, "Comparison and Validation of Different DEM Data Derived from InSAR," Procedia Environmental. Science., vol. 12, pp. 590–597, 2012.

[8] A. Jarvis, J. Rubiano, A. Nelson, A. Farrow, and M. Mulligan, "Practical use of SRTM data in the tropics – Comparisons with digital elevation models generated from cartographic data," Tropical. Agriculture, vol. 198, pp. 32, 2004.

[9] M. Hall and D. G. Tragheim, "The accuracy of ASTER digital elevation models : a comparison with NEXTMap Britain," Geological Society of London, 2010.

[10] N. C. K. G. Nikolakopoulos , E. K. Kamaratakis, "SRTM vs ASTER elevation products. Comparison for two regions in Crete, Greece," International Journal of Remote Sensing., vol. 27, no. 21, 2006.

[11] Y. Gorokhovich and A. Voustianiouk, "Accuracy assessment of the processed SRTM-based elevation data by CGIAR using field data from USA and Thailand and its relation to the terrain characteristics," vol. 104, pp. 409–415, 2006.

[12] S. Z. Xin Yang, Guoan Tang, Wei Zhang, "Accuracy Assessment of ASTER GDEM in North Shaanxi," in Advances in Cartography and GIScience. Volume 2, Springer Berlin Heidelberg, 2011, pp. 371–382.

[13] T. Kuuskivi, "Three-dimensional mapping using both airborne and spaceborne Ifsar technologies," ASPRS 2006.

[14] R. D. Gupta, M. K. Singh, Snehmani, and a. Ganju, "Validation of SRTM X Band Dem Over Himalayan Mountain," ISPRS - International Archive Photogrammetry Remote Sensing and Spatial Information Science, vol. XL, no. May, pp. 14–16, 2014.

[15] W. Mohd, N. Wan, M. A. Abdullah, and S. Hashim, "Evaluation of Vertical Accuracy of Digital Elevation Models Generated from Different Sources : Case Study of Ampang and Hulu Langat". June 2014, pp. 1–17.

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