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IMPROVE QUALITY OF GLOBAL DEM FOR TOPOGRAPHIC MAPPING: CASE STUDY OF PETCHABURI PROVINCE, THAILAND

Kritsada Anantakarn [a*], Phongphoom Sornchomkaew [b], and Thongchai Phothong [c]

[a] *Department of Civil Engineering Faculty of Engineering, Rajamangala University of Technology Tawan-ok, THAILAND*
[b] *Department of Civil Engineering Faculty of Engineering, Rajamangala University of Technology Rattanakosin, THAILAND*
[c] *Department of Civil Engineering Faculty of Engineering, King Mongkut's University of Technology Thonburi, THAILAND*

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ABSTRACT

This research investigates the Shuttle Radar Topography Mission (SRTM) Version 3 Global 30m produced by The National Aeronautics and Space Administration (NASA). As one of the free download data sources from the internet, it is widely used for topographic mapping with the global scale of accuracy from North America and Europe test sites. However, there is lack of local accuracy assessment and verification for SRTM data as in Southeast Asia and Thailand due to the absence of Global Positioning System (GPS) benchmarks used as sources of Ground Control Points (GCP). This research used GNSS L-band global correction service ATLAS® (Hemisphere) for building the GPS trajectory as a source of GCP for assessment and improving the accuracy of SRTM Version 3 data. The result shows that absolute vertical accuracy was achieved less than Vertical RMS 1.3 meters in comparing with relative vertical RMS 8.7 meters in Euro-Asia continent accuracy scale as announced in SRTM data specification. These results and method can be useful for engineers who apply DEMs for various applications such as updating the topographic map for landscape design and rural-urban development project in Thailand.

1. INTRODUCTION

Digital elevation models (DEMs) are one of the most important sources for topographic mapping, land survey and human settlement development (Debella-Gilo and Kaab, 2011), Nowadays, there are some free sources data of DEM can be freely downloaded from the internet. Therefore, there is an increased need for information about its quality and improvement the accuracy of the DEM for various modeling and mapping applications (Mukherjee et al., 2013).

*Corresponding author (Kritsada Anantakarn). E-mail: singut51@gmail.com

DEM errors may have occurred during data acquisition of the remotely sensed data such as space platform and DEM generation and production. To value the accuracy for DEM, previous studies compare the DEM elevation measurement with the high-accuracy DEM such as light detection and ranging data (Toutin 2004), ground control points (GCPs) from topographic maps (Zhao et al., 2011) or field-surveyed data with Differential GPS (Suwandana et al., 2012). Shuttle Radar Topography Mission (SRTM) elevation data derived from a C-band (at a wavelength of 5.6 cm) interferometric ScanSAR is available at a resolution of 1 arc-second (or 1" x 1"), that is approximately 30m x 30m the rest of the world and can be download from USGS (2014).

The United States National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA) conducted an accuracy evaluation by collecting ground truth that for the global validation and the results of this SRTM data as relative Height Root Mean Square (RMS) error as 8.7 m for the Europe-Asia continent *accuracy scale* (Rodriguez et al. 2006). Since the continent-wide contains many countries that have not sufficient numbers of GPS benchmarks for different topographic conditions (Rodriguez et al. 2006), some similar studies have been conducted locally by using GPS with accuracy range from 0.5 m to 10 m accuracy (Mouratidis et al. 2010; Suwandana et al. 2012; Santillana and Makinano 2016).

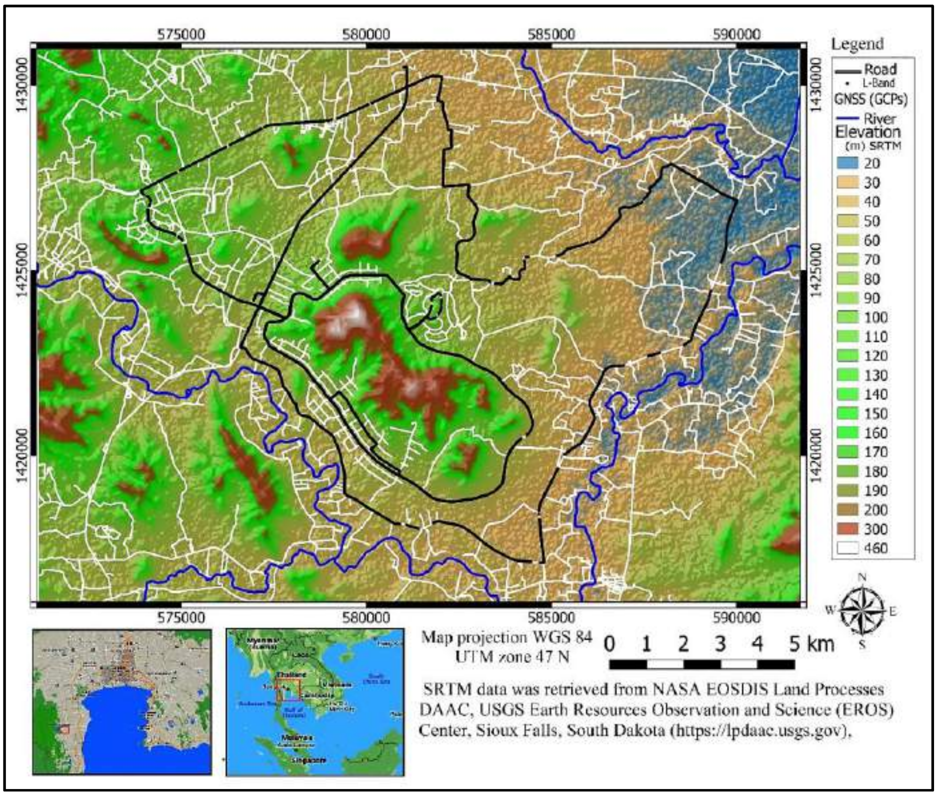

Figure 1: Topographic map of the study area with L-Band GNSS data collection points. (Courtesy of USGS EROS/NASA EOSDIS)

The L-Band ATLAS Global Navigation Satellite System (GNSS) system is a Global Based Augmentation System (GSBAS) that has been developed by Hemisphere GNSS Technology. This service enhanced real-time orbit and clock generation, dual redundant delivery of corrections from ground reference network via commercial communication satellites. Now-a-day, GNSS dual-frequency (L1/L2) single receiver is conducted in L-Band ATLAS system by static and dynamic positioning measurement modes. By single dual-frequency GNSS receiver, user world-wide can get higher positioning measurement at less than 10 centimeters (Hemisphere GNSS, 2017). An L-band Atlas GNSS system experiment was conducted for accuracy assessment in Thailand (Anantakarn and Witchayangkoon, 2019).

This study uses the L-Band ATLAS GNSS system by dynamic positioning measurement mode for elevation data collection to evaluate and adjust SRTM data in **Kaeng Kachan, Petchaburi province, Thailand.** The area is easy to access with dynamic topographic features from low to high land that is feasible for financial budget and time limitation of the study.

2. THE STUDY AREA

The study area is located about 170 km southwest of Bangkok and between highway no. 3499 and 3510 as shown in Figure 1. This area as 325.887 sq. km consists of different terrain characteristics as elevation range from 20 to 460 meters with mixed urban, rural and forest zone land use where is typical urban expansion such as Kaeng Krachan real estate development project. The study area was selected because of its varied terrain ranges and accessibility with travel cost and time-saving.

3. METHODOLOGY

3.1 EQUIPMENT AND SOFTWARE

For was used and L-Band ATLAS GNSS data collection, the HEMISPHERE S321+ GNSS SMART ANTENNA installed on top of the off-road car as shown in Figure 2. The HEMISPHERE S321 receiver includes L1/L2 frequencies for GNSS satellite as GPS (the United State of America), GLONASS (Russia), GALILEO (European) and BEIDOU (China) that receive Real-Time L-Band Correction Services (Hamisphere 2017). The GNSS Handheld Controller is UNISTRONG UG905 Tablet with Android OS Version 5.1.1 which operate Surveying data collection Software SurPad For Android V3.0.20180410 produced by Hemisphere GNSS 2018.

The free open-source Quantum GIS (QGIS) Version 3.2 and SAGA Version 2.3.2 was used for DEM and GIS data analysis, available from https://qgis.org/en/site.

Figure 2: HEMISPHERE S321GNSS RECEIVER on top of the off-road car

3.2 METHODOLOGY

The main methodology aims to evaluate and adjust SRTM version 3 by using field data collection as Real-Time L-Band Correction Services that illustrated in Figure 3.

3.2.1 SRTM ELEVATION DATA

SRTM elevation data is available at a resolution 30 x 30 m with Earth Gravitational Model 1996 (EGM96) vertical (geoid) datum was downloaded from the USGS website (2014).

After Downloading, the SRTM Ver.3 data WGS 84 Latitude and Longitude with degree decimal unit that was converted into 30 x 30 m pixel size with map projection UTM Zone 47 North by using QGIS Ver 3.2 Software. The data is in GeoTIFF format as the sixteen-bit signed integer with width 682 pixels and Height 507 pixel as 325.887 sq. km. This data was compared with L-Band GNSS data for accuracy analysis and improvement.

SRTM Ver.3 Median Filter: the elevation values in DEM data comprises the height of the tree canopies, the roof of house and buildings as well as man-made features and so-called Digital Surface Model (DSM) (Miliaresis and Delikaraoglou 2009). These features caused data error as noises or peak values that could be removed by using low-pass filters (Pierce et al. 2006). In this study, the Median Filter with kernel size 7 x 7 was applied to SRTM data by using Raster Tool of QGIS – SAGA Version 2.3.2. After filtered, for the SRTM median filtered data was compared with L-Band GNSS data for evaluating the accuracy and adjusting improvement.

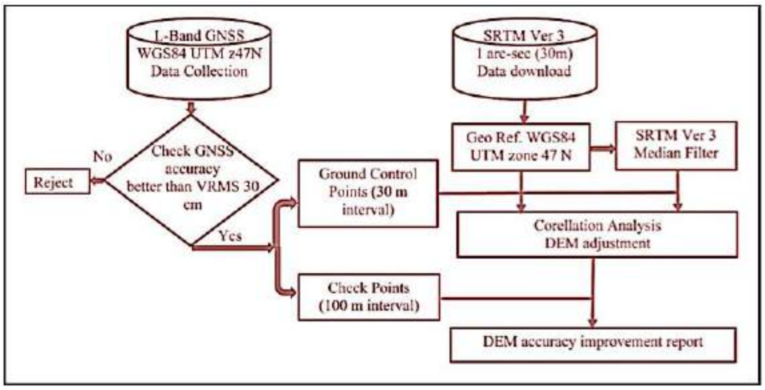

Figure 3: Methodology for SRTM Ver.3 and GNSS Data Processing and Analysis

3.2.2 L-BAND GNSS DATA

The HEMISPHERE S321+ GNSS SMART ANTENNA installed on top of the off-road car and set for dynamic Real-Time L-Band Atlas Correction Services with the common map projection WGS 84 UTM zone 47 North that automatically recorded for 10-m interval as shown as black color points in Figure 1. During November 23 -24, 2018 field data collection, trajectory length is about 80 km during the two days. The speed of the vehicle was controlled at the speed of lower 40 km per hour to archive the stability and safety of the antenna to collect measurements in every 10 meters.

Check GNSS data accuracy: In order to archive high positioning coordinate GNSS measurements, horizontal and vertical RMS error over 30cm were rejected and not applied as a source of GCP and CP (Suwandana et al. 2012; Elkhrachy 2017).

Ground Control Point (GCP) and Check Point (CP) selection: For matching with SRTM data resolution at 30-meter pixel size, L-Band GNSS measurements were used for GCP (1969 points) by resampling for 30-m distance and for CP (592 points) by selecting 100-m distance interval (Mouratidis et al. 2010; Dong et al. 2015) as presented in Figure 4.

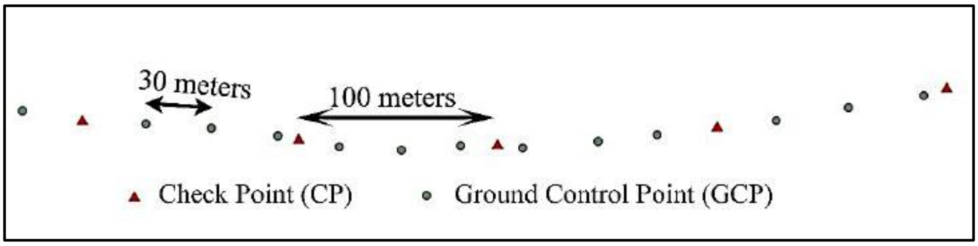

Figure 4: Selection of GCPs and CPs

3.2.3 CORRELATION ANALYSIS AND DEM ADJUSTMENT

SRTM Ver.3 Data in Raster 16-bit integer for both raw data and the median-filtered digital value was extracted from the co-registered GNSS point by using Point Sampling Tool Plugin QGIS Ver. 3.2. for correlation analysis and comparison SRTM data with GNSS field data. Correlation describes the strength of an association between two variables and is completely symmetrical (Li et al., 2013; Dong et al., 2015), the correlation between the elevation of SRTM raw data and SRTM median filtered data and L-Band GNSS data is needed to analyses.

3.2.4 DEM ACCURACY IMPROVEMENT

The correlation coefficient R is measured shows a relation between the two data sets. The results of the analysis can be applied to SRTM Ver.3 data as “regional regression model” to improve the accuracy of the topographic survey.

4. RESULTS AND DISCUSSIONS

The main goal of statistical analysis is to calculate the regression equation to improve the accuracy of SRTM Ver.3 Data.

4.1 RESULTS

In this study, a free global SRTM was investigated by comparing with reference elevation data from Real-Time L-Band Atlas Correction Services. After the removal DEM error by using median filter the elevation RMS error is reduced (17.7 cm) from 2.205 meters to 2.028 as seen the Table 1.

Table 1: Statistic results for improvement SRTM data

Different from GNSS	Raw SRTM	Filtered SRTM	Adjusted SRTM	Adjusted Filtered SRTM
Min	-8.375	-5.375	-9.043	-6.391
Max	14.367	13.367	11.125	10.373
RMS	2.205	2.028	1.597	1.301
STDev (RSE)	1.733	1.520	1.426	1.093

The systematic errors of SRTM data were decreased by using the correlation equation as a regional regression model for adjusting the DEM. After adjusting the filtered SRTM data, elevation RMS error is reduced 29.6 cm (from 1.597 meters to 1.301 meters as seen the Table 1).

4.2 DISCUSSION

The error correlations between the L-Band GNSS data and the SRTM data are generated. To improve the accuracy of the correlation, we use the value for the entire study area in the GNSS data as the control variable to perform a partial correlation between the GNSS data and original SRTM raw data and the SRTM filtered data. The difference between GNSS trajectory, SRTM raw data and median filtered data of the study area are shown in Figure 5. After median filtering (7x7 kernel), some noises from SRTM raw data were removed as visually resulted in SRTM filter data and it is smoother and similar to GNSS data clearly in the enlargement box.

As a result of a large number of points (1969) used to determine the error correlations, the correlation coefficient R is close to 1.0 in those comparisons. The fitted linear equations demonstrate that there are small vertical errors between GNSS data with SRTM median filtered data and the correlation coefficient R = 0.9938 as illustrated in Figures 6 and 7. With the regression model, the outcome indicates that the two datasets showed strong positive correlations with the L-Band GNSS elevations.

Total 592 checkpoints are applied for the final accuracy assessment and the relative frequency distribution of the height differences between reference data and examined SRTM raw and filtered data is provided in Figure 8.

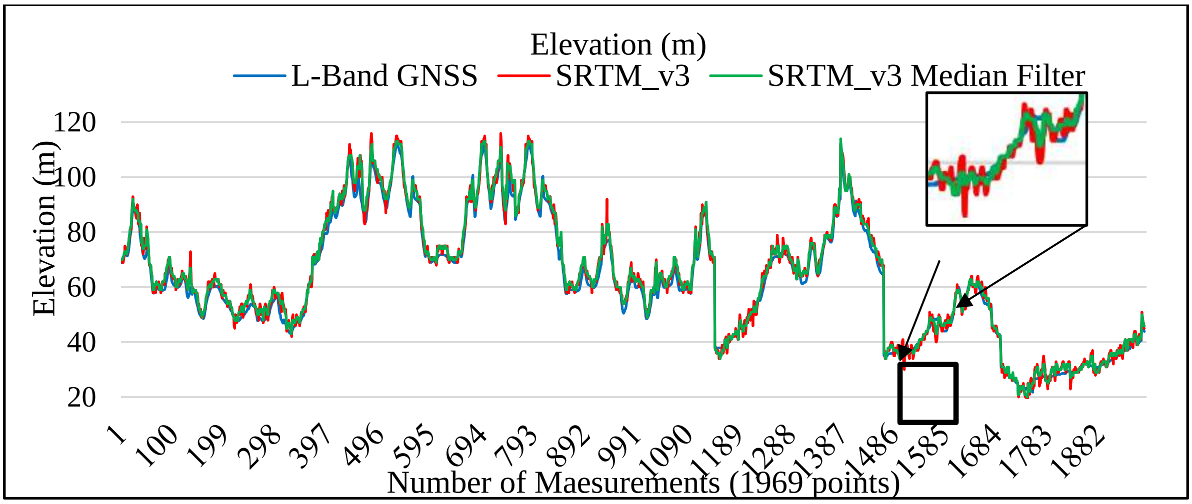

Figure 5: The difference between GNSS trajectory, SRTM raw data, and median filtered data

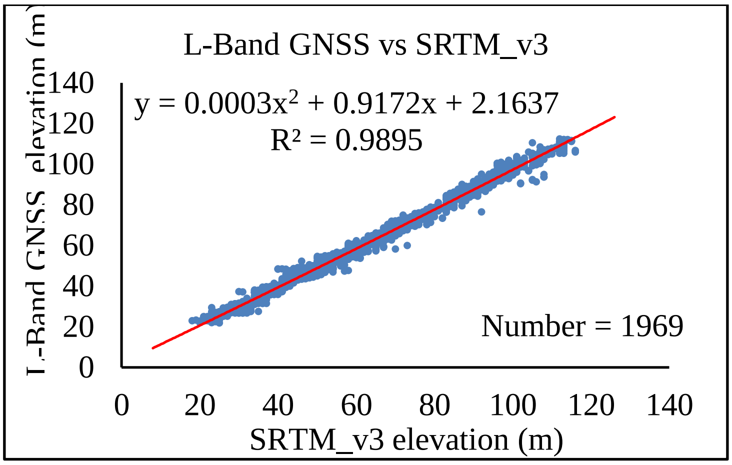

Figure 6: Vertical comparison between GNSS data with SRTM

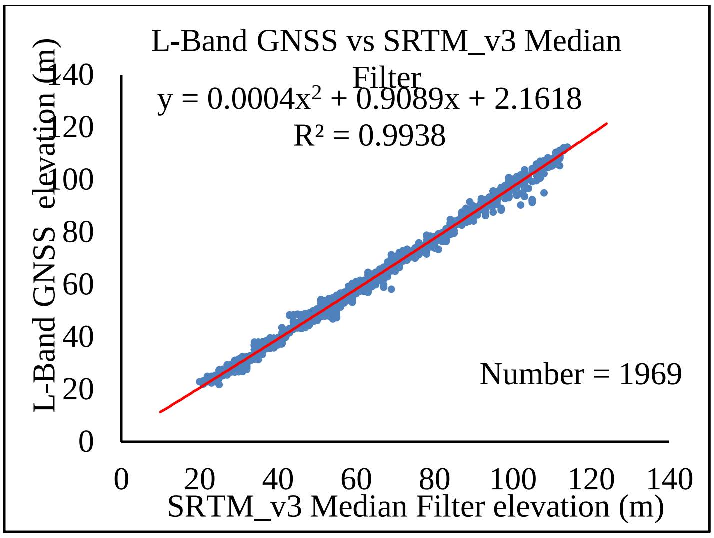

Figure 7: Vertical comparison between GNSS data with SRTM, applied with a median filter.

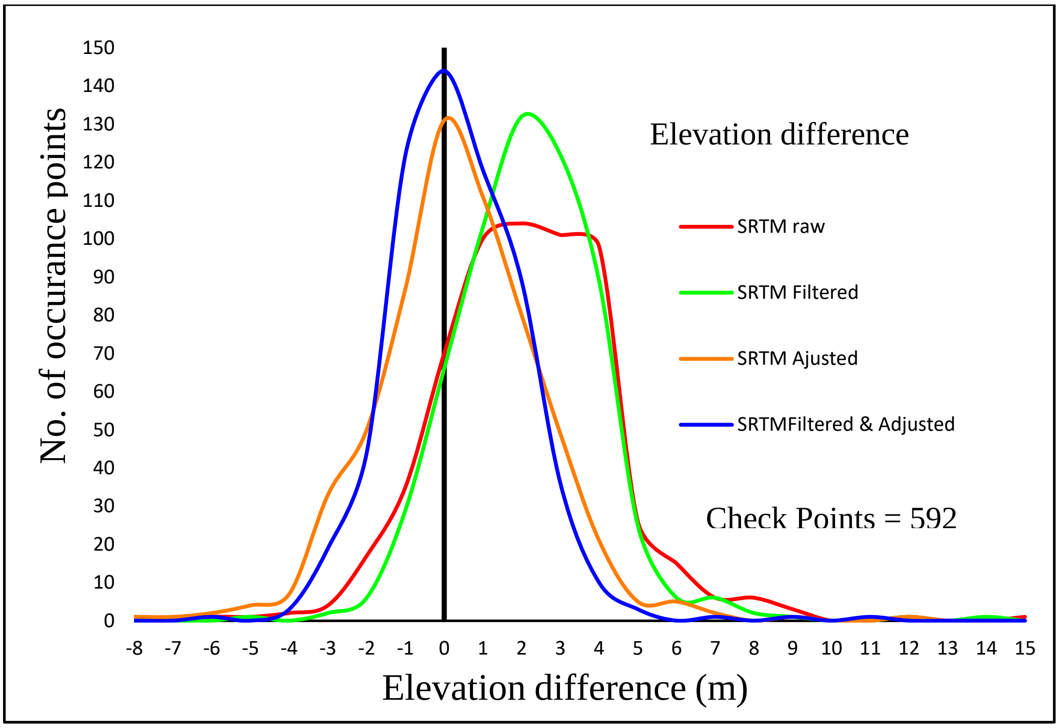

Figure 8: The histograms of elevation differences of the final accuracy assessment

The histograms of elevation differences present the adjusted data slightly move to zero for both SRTM raw and filtered data which indicates that the best accuracy archive clearly as SRTM filtered data.

5. CONCLUSION

L-Band GNSS elevations as reference data, the statistical computation for the relative vertical accuracy of SRTM Ver. 3 elevations data for the study site gave the vertical RMS 1.093 m in comparing with vertical RMS 8.7 meters in Euro-Asia continent accuracy scale as announced in SRTM data specification.

6. DATA AVAILABILITY STATEMENT

The used or generated data and the result of this study are available upon request to the corresponding author.

7. ACKNOWLEDGEMENT

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8. REFERENCES

Debella-Gilo M, Kaab A. 2011: Sub-pixel precision image matching for measuring surface displacements on mass movements using normalized cross-correlation. Remote Sens Environ. 115:130–142.

Elkhrachy I. 2017: Vertical accuracy assessment for SRTM and ASTER Digital Elevation Models: A case study of Najran city, Saudi Arabia. Ain Shams Engineering Journal (2017), http://dx.doi.org/10.1016/j.asej.2017.01.007.

Hemisphere GNSS (2017). S321+ GNSS SMART ANTENNA, https://hemispheregnss.com /Products/Products/Position/s321-gnss-smart-antenna-1569. Accessed date 16 August 2018

Anantakarn, K., & Witchayangkoon, B. (2019). Accuracy assessment of L-band Atlas GNSS system in Thailand. International Transaction Journal of Engineering Management & Applied Sciences & Technologies, 10(1), 91-98.

Li P, Shi C, Li Z, Muller J-P., Drummond J., Li X., Li T., Li Y. & Liu J. 2013: Evaluation of ASTER GDEM using GPS benchmarks and SRTM in China. International Journal of Remote Sensing, Vol. 34, No. 5, 10 March 2013, 1744–1771.

Miliaresis G. and Delikaraoglou D. 2009: Effects of percent tree canopy density and DEM misregistration on SRTM/DEM vegetation height estimates. Remote Sens. 2009, 1, 36–49.

Mukherjee S, Joshi PK, Mukherjee S, Ghosh A, Garg RD, Mukhopadhyay A. 2013: Evaluation of vertical accuracy of open source Digital Elevation Model (DEM). Int J Appl Earth Obs Geoinf. 21:205–217.

Pierce L., Kellndorfer J., Walker W, and Barros O. 2006: Evaluation of the Horizontal Resolution of SRTM Elevation Data. Photogrammetric Engineering & Remote Sensing Vol. 72, No. 11, November 2006, pp. 1235–1244.

Rodriguez E., Morris C., and Eric Belz J. 2006: A Global Assessment of the SRTM Performance. Photogrammetric Engineering & Remote Sensing Vol. 72, No. 3, March 2006, pp. 249–260.

Suwandana E., Kawamura K., Sakuno Y, Kustiyanto E. and Raharjo B 2012: Evaluation of ASTER GDEM2 in Comparison with GDEM1, SRTM DEM and Topographic-Map-Derived DEM Using Inundation Area Analysis and RTK-dGPS Data. Remote Sens. 2012, 4, 2419-2431; doi:10.3390/rs4082419.

Toutin T. 2004. Comparison of stereo-extracted DTM from different high-resolution sensors: SPOT-5, EROS-a, IKONOS-II, and QuickBird. IEEE Trans Geosci Remote Sens. 42:2121–2129.

USGS. (2014). SRTMGL1: NASA Shuttle Radar Topography Mission Global 1 arc second V003. Land Processes Distributed Active Archive Center. https://lpdaac.usgs.gov/dataset_discovery/measures/measures_products_table/srtmgl1_v003 Accessed October 2018.

Zhao S, Cheng W, Zhou C, Chen X, Zhang S, Zhou Z, Liu H, Chai H. 2011. Accuracy assessment of the ASTER GDEM and SRTM3 DEM: an example in the Loess Plateau and North China Plain of China. Int J Remote Sens. 32:8081–8093.

Dr. Kritsada Anantakarn is a Lecturer at the Department of Civil Engineering Technology, Faculty of Engineering and Architectures, Rajamongala University of Technology Tawan-ok, Uthenthawai Campus, Thailand. He earned his Bachelor of Engineering (Civil Engineering) from Faculty of Engineering Rajamangala Institute of Engineering, and a Master's degree in of Urban and Environmental Planning from King Mongkut's Institute of Technology Ladkrabang, and his PhD from Thammasat University. He is interested in GPS/GNSS and spatial technology.

Phongphoom Sornchomkaew is a lecturer at Department of Civil Engineering, Faculty of Engineering and Architecture, Rajamagala University of Technology Rattanakosin Wang Klai Kang Won Campus, Prachuap Kiri Kan, Thailand. He holds a Master of Engineering degree from Thammasat University. His research focuses on technology applications to facilitate and foster civil engineering study.

Dr. Thongchai Phothong is a lecturer at Department of Civil Engineering Department, Faculty of Engineering, King Mongkut's University of Technology Thonburi (KMUTT). He is at KMUTT. He earned his Bachelor Degree (Civil Engineering) from King Mongkut's University of Technology Thonburi (KMUTT), Thailand, and Master Degree in Geotechnical Engineering also from KMUTT. He earned his PhD from Thammasat University. He is interested in spatial technology and applications.

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