

وزارة البيئة والمياه والزراعة
Ministry of Environment, Water & Agriculture
المملكة العربية السعودية



Evaluation of the free global DEMs using Aerial LiDAR and Statistical Performance Measures



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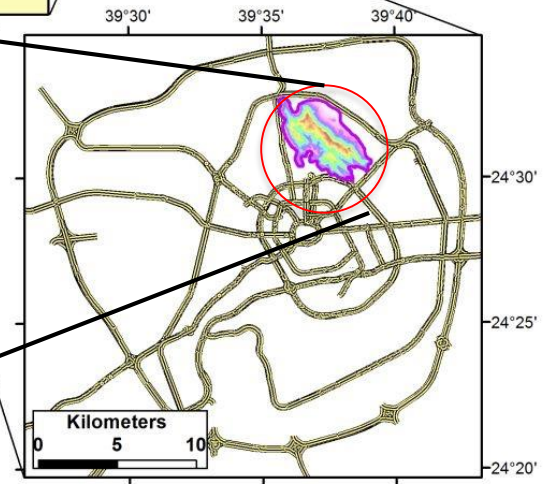
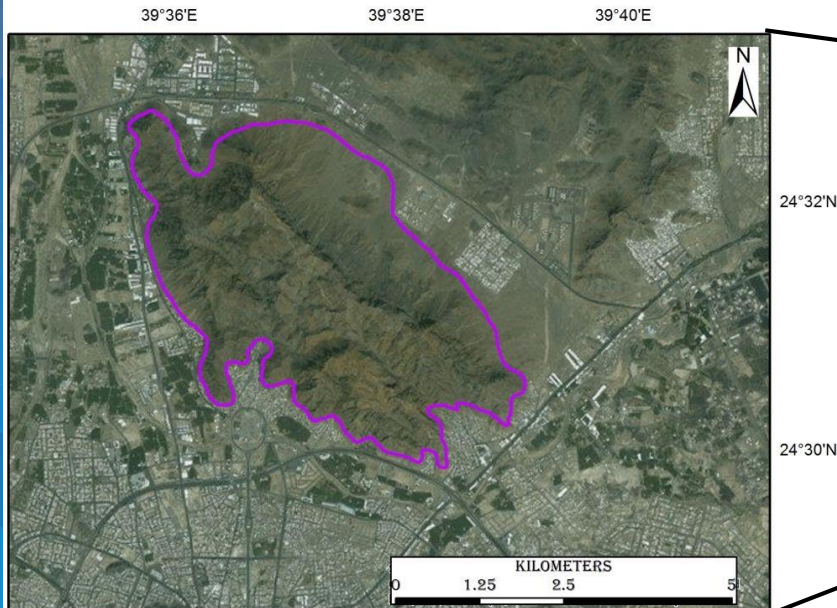
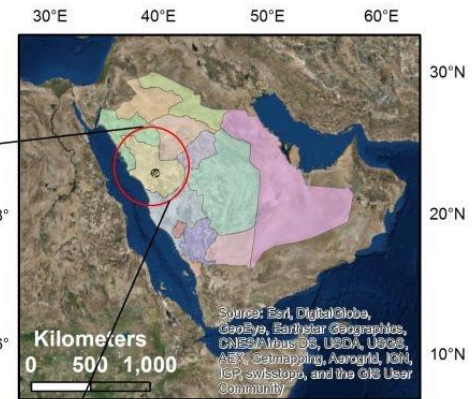
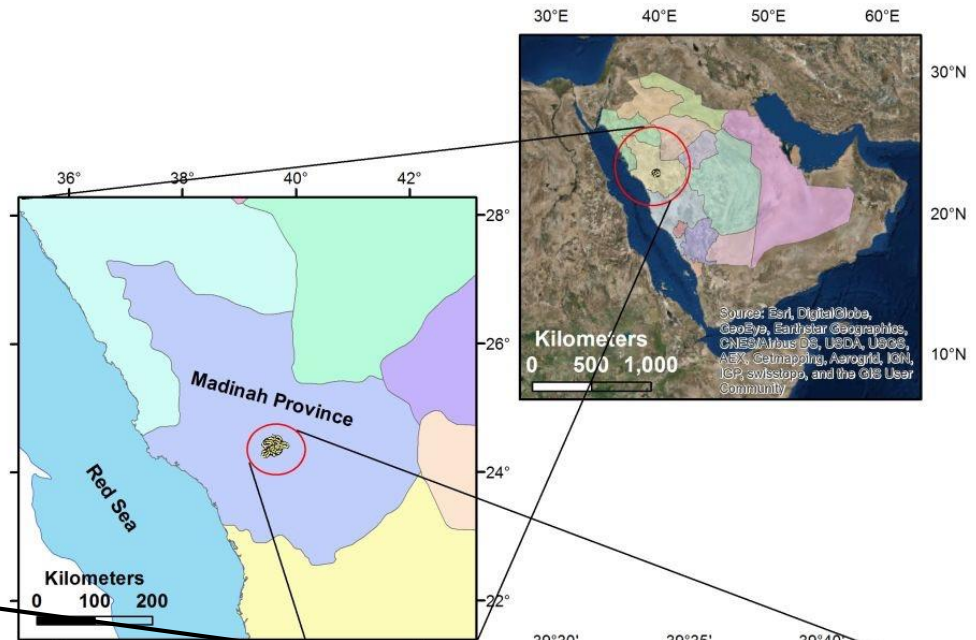
1 - Introduction

- Digital Elevation Model (DEM) can be considered as a valuable data for representing terrain and topography of the earth surface.
- DEM is used for different type of applications, including scientific, commercial, industrial, operational, and military applications (Sulebak, 2000).
- evaluation and assessment of DEM quality is still critical task, statistical and visual assessment are two popular methods (Podobnikar, 2009)
- Two main free global DEM data are available, SRTM DEM and ASTER GDEM, several attempts have been made to evaluate and assess the accuracy of these available DEMs (i.e. Nikolakopoulos et al., 2006; Hirt et al., 2010; and Rexer & Hirt,2014)



2 – Study area description

- The selected area is Ohod Mountain in Madinah, Western Saudi Arabia.
- It is undeveloped Rocky area with 17.3 km², the dimensions are:
 - Length = 7.2 km
 - Width = 3.3km
 - Height = 500 m



3 – Methodology

- Two freely global DEMs (SRTM V.4.1 and ASTER GDEM V.2.0) are selected for evaluation and used as **predicted** elevation datasets.
- DEM developed from LiDAR elevation points is used as a reference (**observed** elevation dataset).
- Four main categories of analysis are conducted, which are:
 - **General Analysis**
 - **Elevation Difference**
 - **Absolute Elevation Difference**
 - **Squared Elevation Difference**
- Under each category, three types of results are presented, which are:
 - **Visual comparison using Raster Calculator “map”**
 - **Descriptive statistics using Zonal statistics “table”**
 - **Frequency histogram using Spatial Analyst “figure”**
- Finally the Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) are computed

$$RMSE = \sqrt{\sum \frac{(y_{pred} - y_{ref})^2}{N}}$$

$$MAE(\%) = \frac{100}{n} \times \sqrt{\sum_{i=1}^n |y_{pred} - y_{obs}|}$$

4 – Data description

	SRTM DEM	ASTER GDEM	LiDAR
Acquisition date	Feb 2000	1999 – 2000	Jun 2012
Spatial resolution	90 m	30 m	0.50 m



5 - analysis and Results

5.1 General Analysis

5.2 Elevation Difference

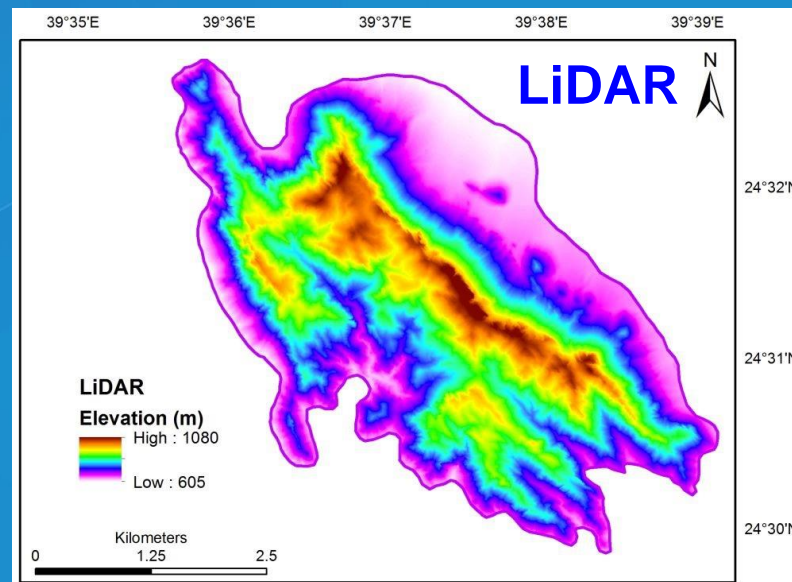
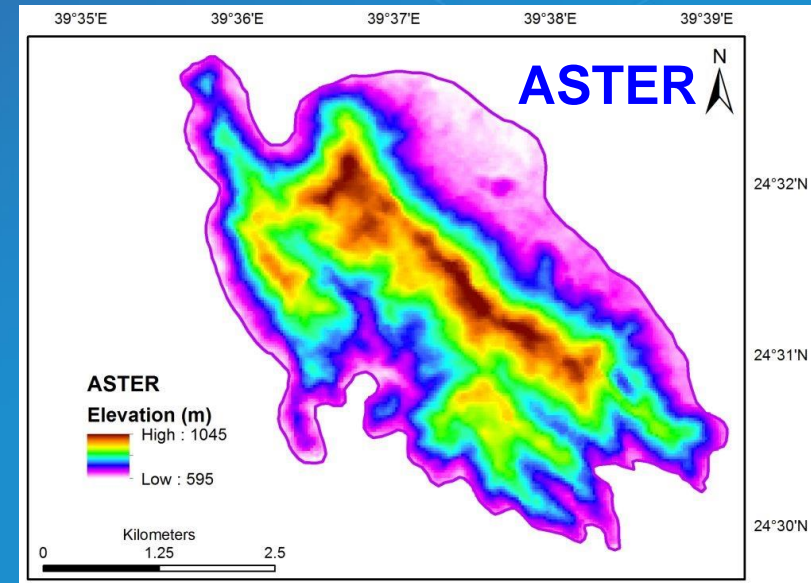
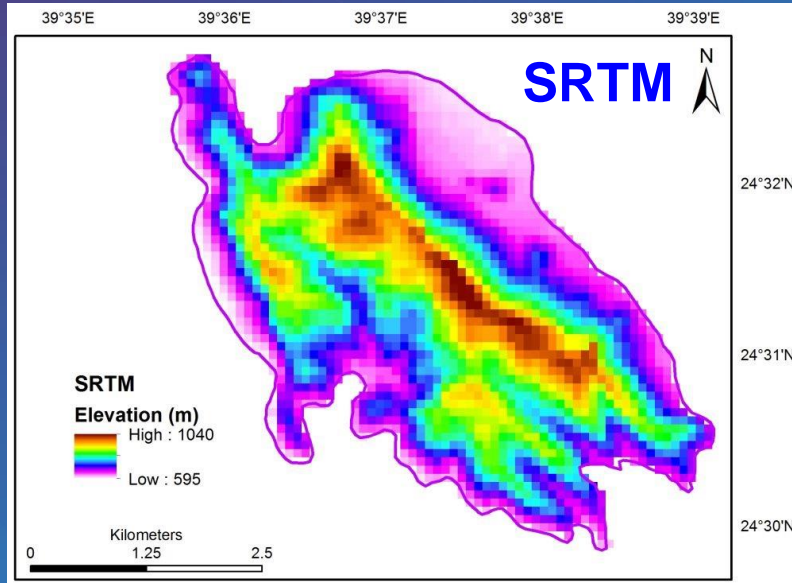
5.3 Absolute Elevation Difference

5.4 Squared Elevation Difference

5.5 - Root Mean Square Error (RMSE) and Mean Absolute Error (MAE)

5.1 – General Analysis

5.1.1 Visual comparison



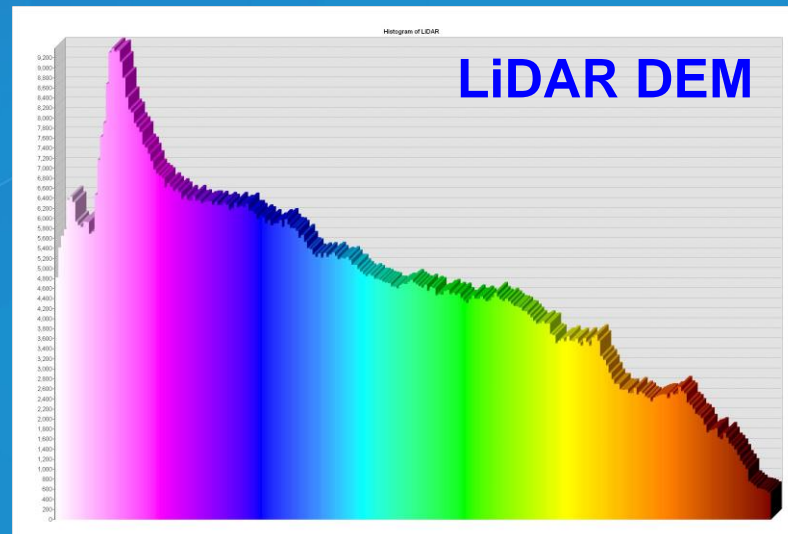
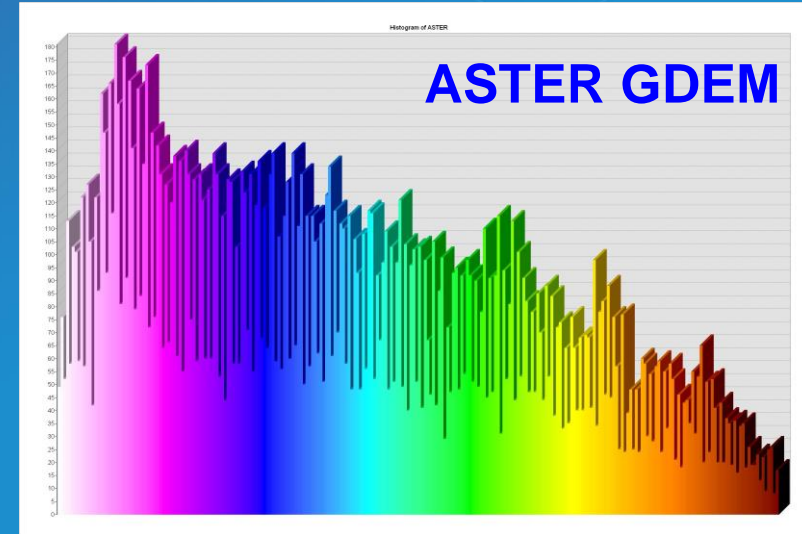
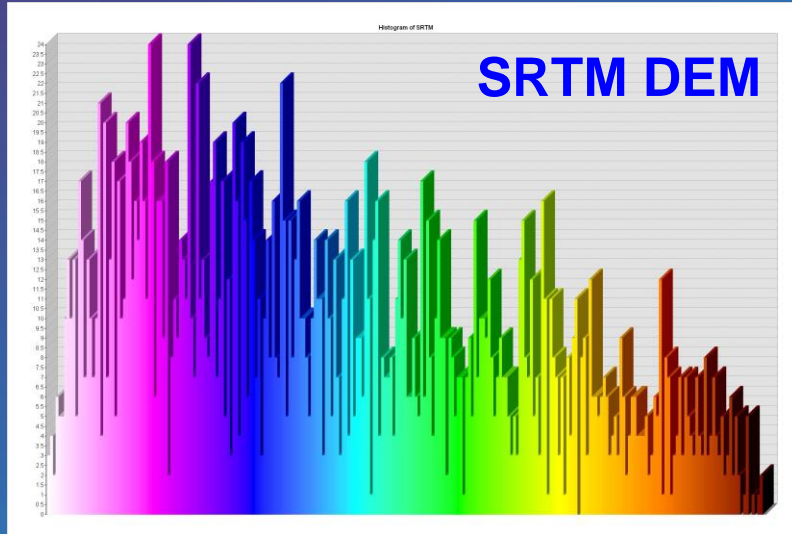
5.1 – General Analysis

5.1.2 Pixel Based statistics

	SRTM DEM	ASTER GDEM	LiDAR DEM
Total No. of pixels	2,164	19,671	17,269,393
Max. elevation (m)	1,040	1,045	1,079
Min. elevation (m)	595	595	605
Range (m)	445	450	474
Average Elevation (m)	775	776	779
Std. Dev.	109	108	111
Majority	684	642	NA
Minority	595	595	NA
Median	758	763	NA

5.1 – General Analysis

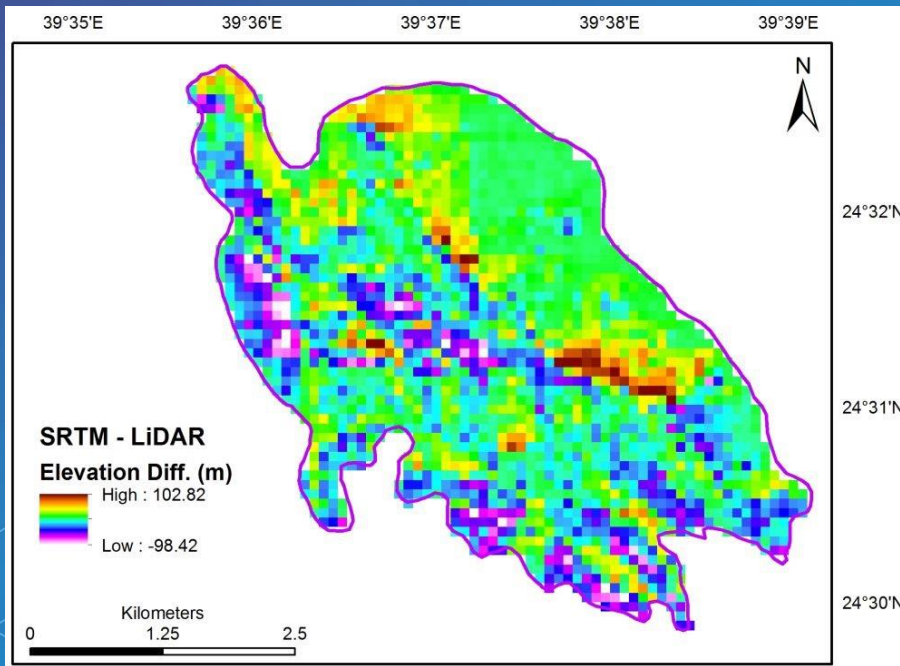
5.1.3 Frequency histogram



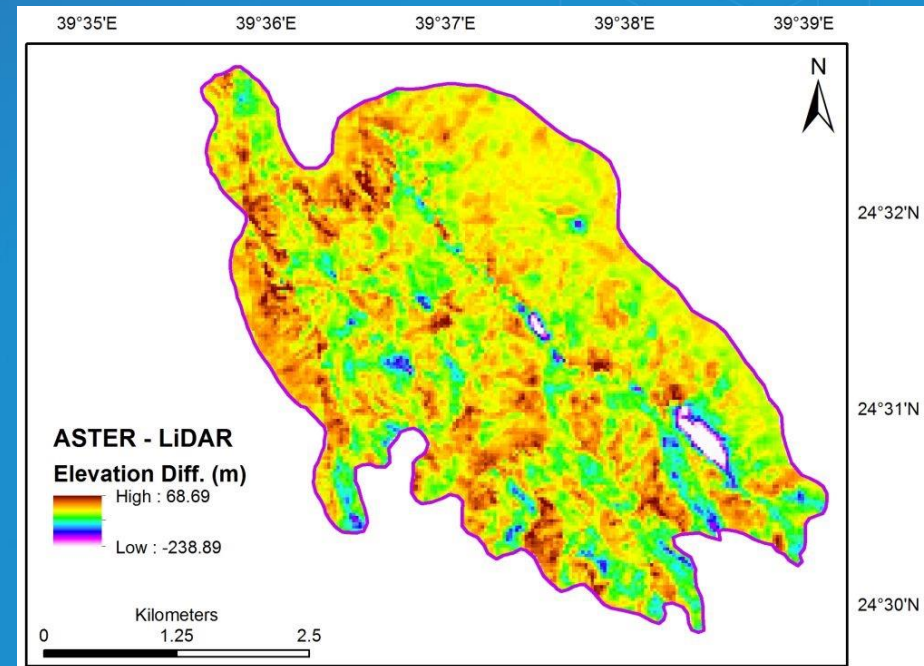
5.2 Elevation Difference Analysis

5.2.1 Visual comparison

SRTM - LiDAR



ASTER - LiDAR



5.2 Elevation Difference Analysis

5.2.2 Descriptive statistics

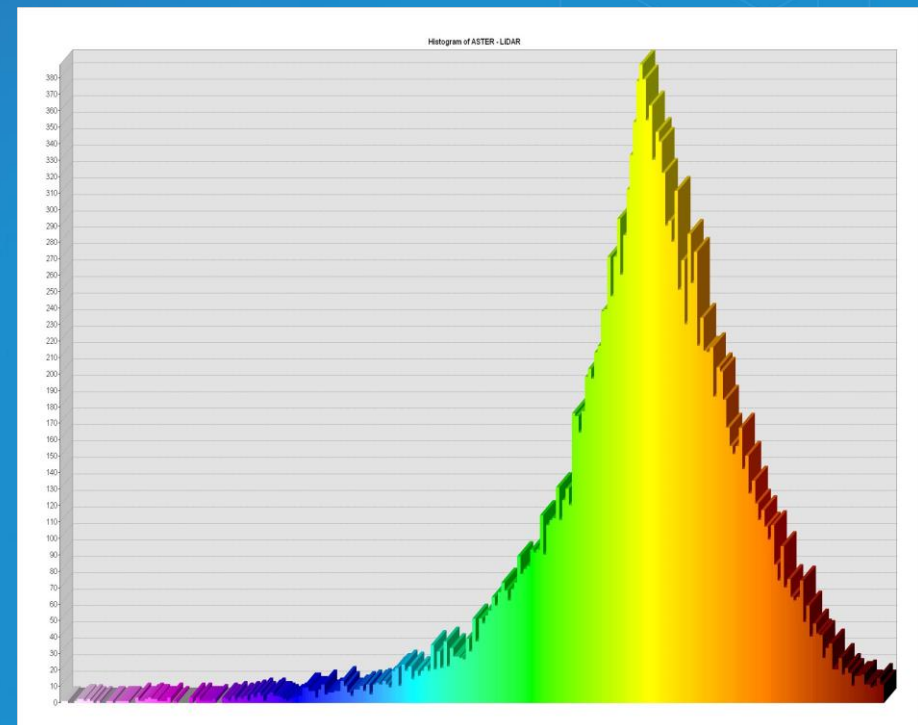
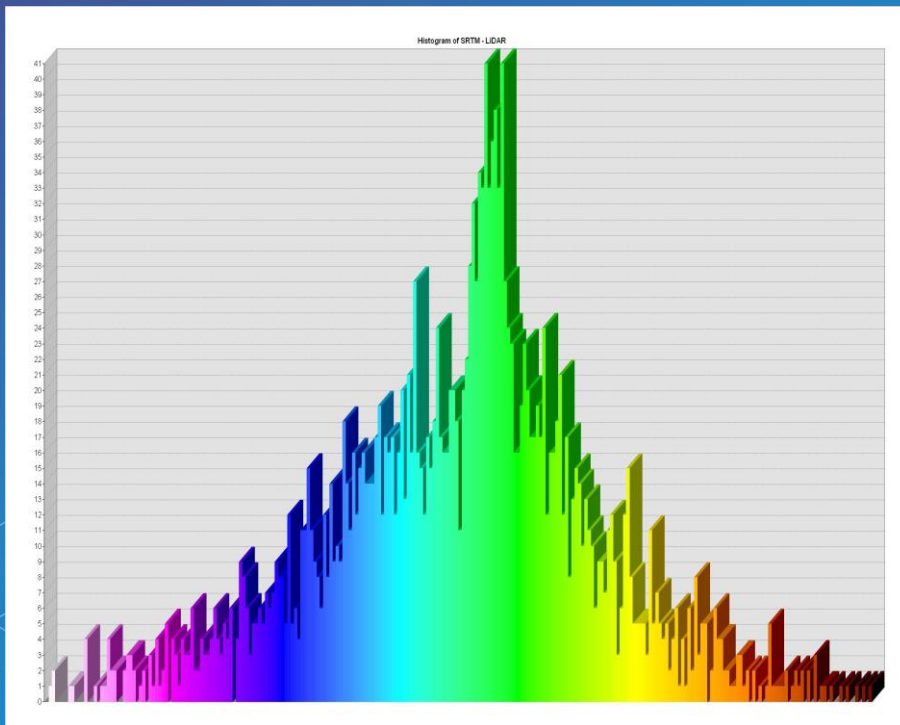
	SRTM - LiDAR	ASTER - LiDAR
Max. Difference (m)	102.82	68.69
Min. Difference (m)	-98.42	-238.89
Range (m)	201.24	307.58
Mean Difference (m)	-8.38	-4.04
Std. Dev.	22.81	21.28

5.2 Elevation Difference Analysis

5.2.3 Frequency histogram

SRTM - LiDAR

ASTER - LiDAR

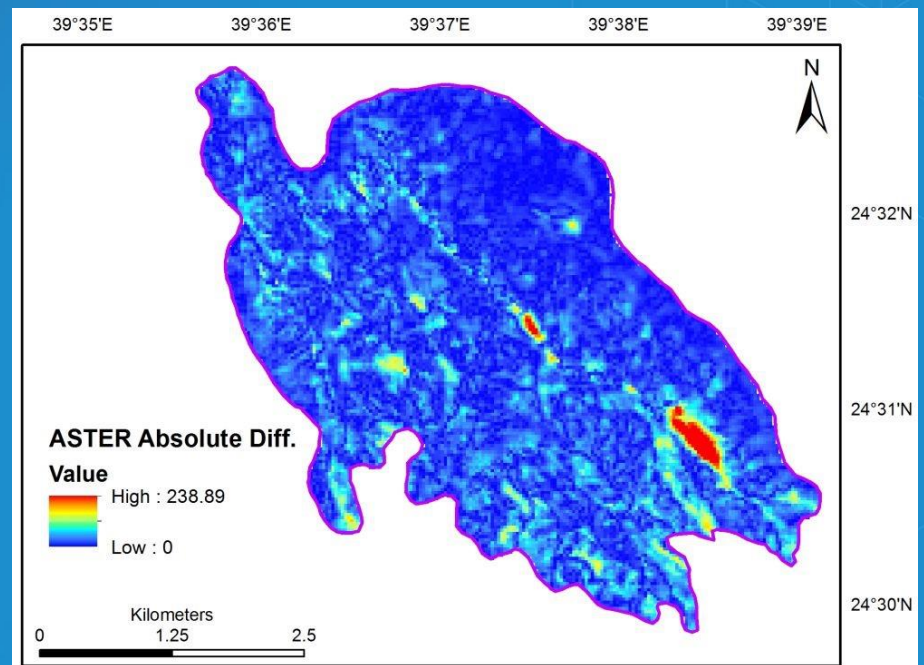
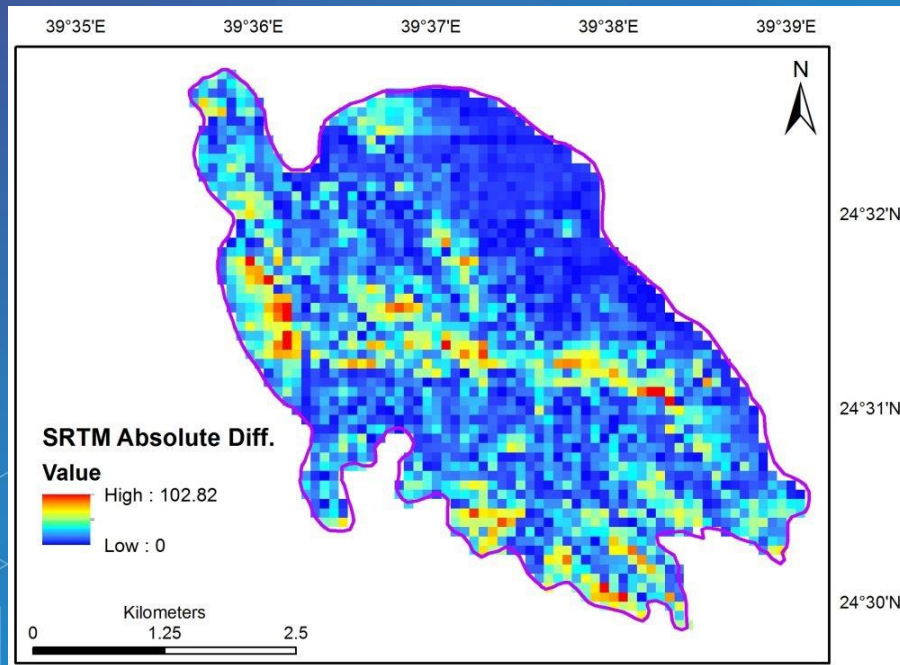


5.3 - Absolute Elevation Difference

5.3.1 Visual comparison

Abs(SRTM – LiDAR)

Abs(ASTER – LiDAR)



5.3 - Absolute Elevation Difference

5.3.2 Descriptive statistics

	Abs(SRTM – LiDAR)	Abs(ASTER – LiDAR)
Max. (m)	102.82	238
Min. (m)	0.0	0.0
Mean (m)	18.15	14.12
Std. Dev.	16.15	16.42

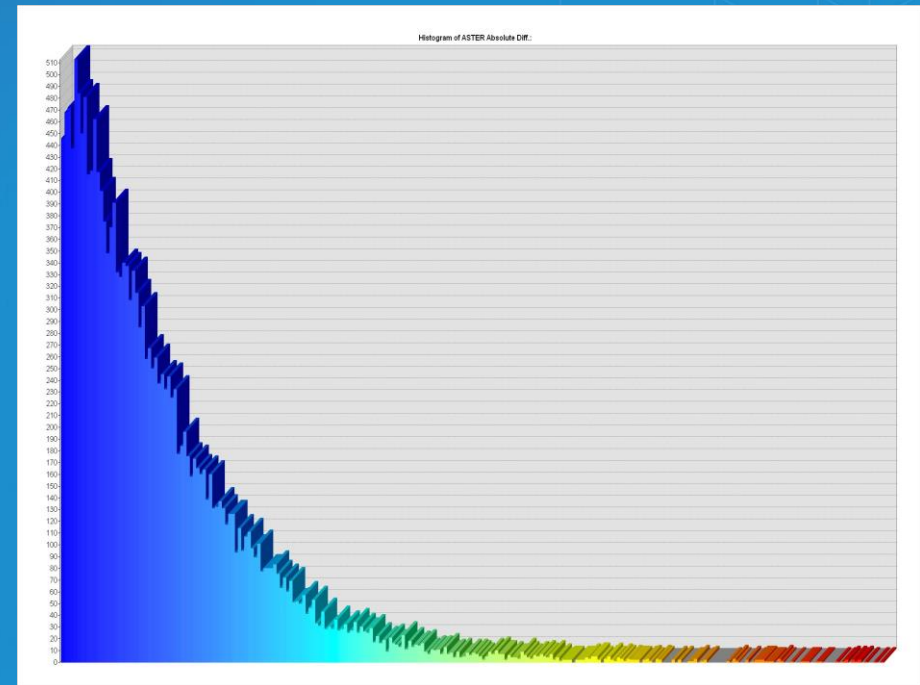
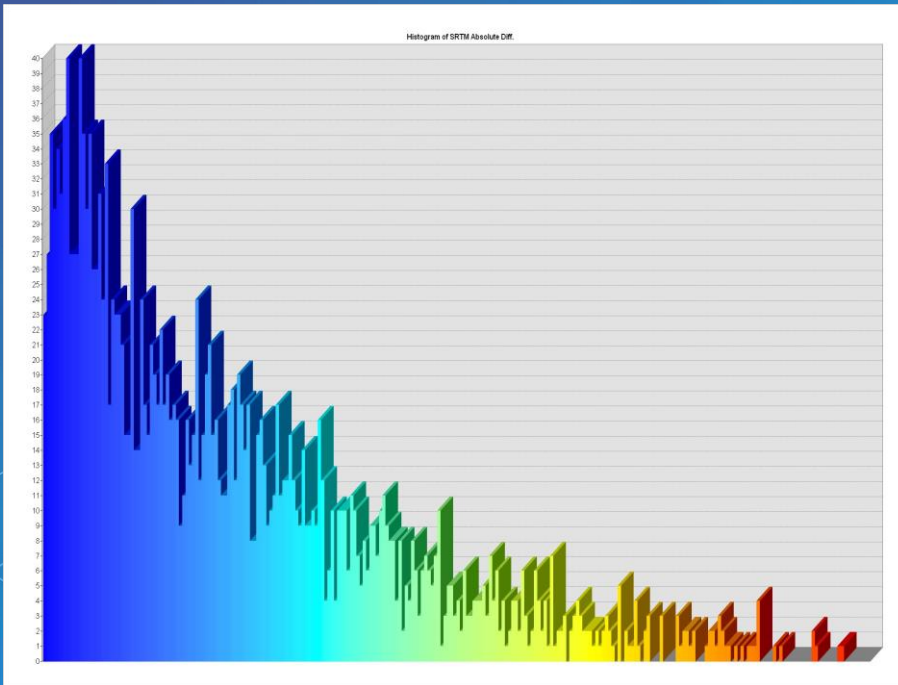


5.3 - Absolute Elevation Difference

5.3.3 Frequency histogram

Abs(SRTM – LiDAR)

Abs(ASTER – LiDAR)

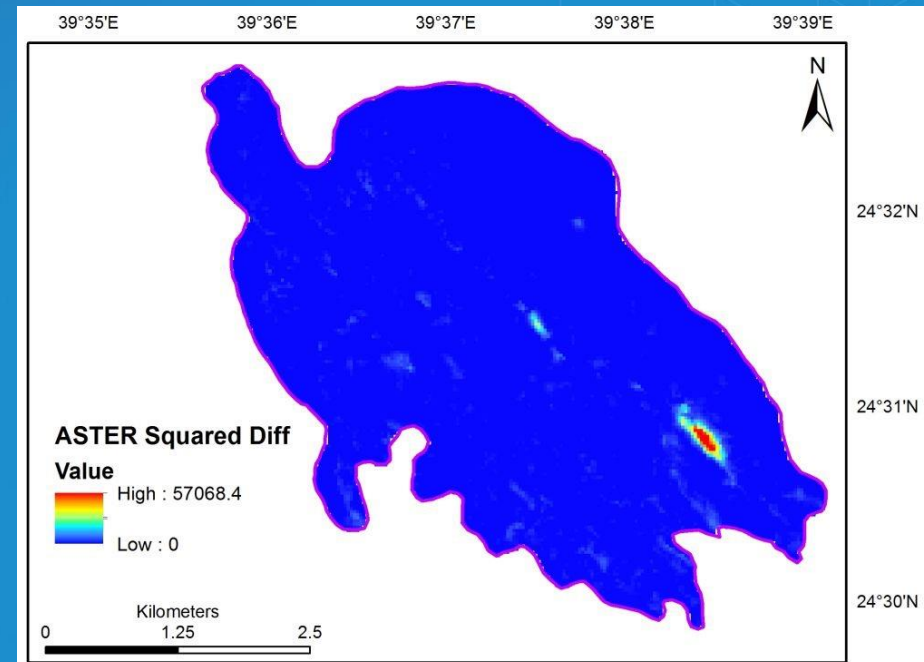
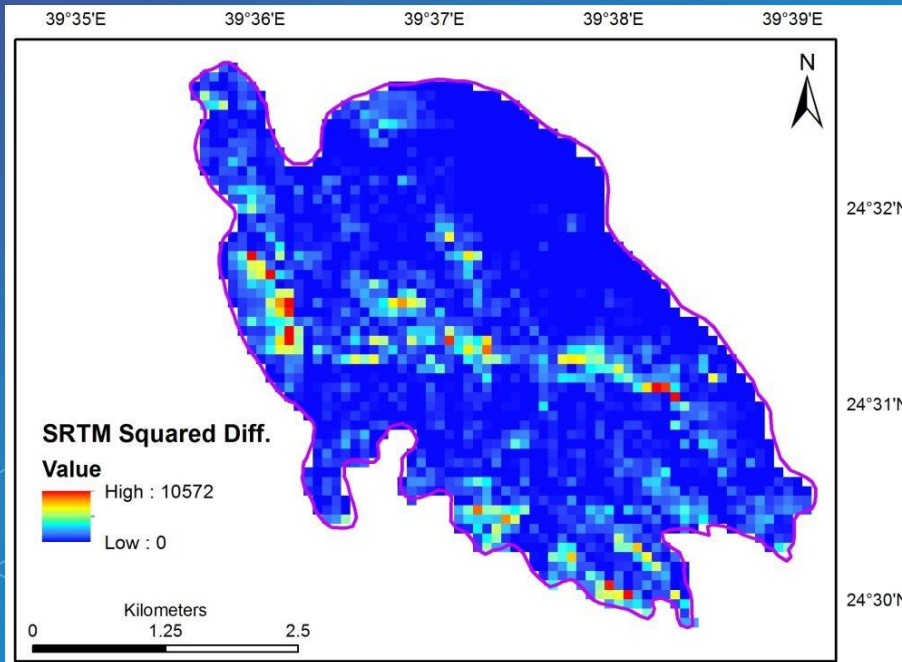


5.4 - Squared Elevation Difference

5.4.1 Visual comparison

$(\text{SRTM} - \text{LiDAR})^2$

$(\text{ASTER} - \text{LiDAR})^2$



5.4 - Squared Elevation Difference

5.4.2 Descriptive statistics

	$(\text{SRTM} - \text{LiDAR})^2$	$(\text{ASTER} - \text{LiDAR})^2$
Max. (m)	10572	57068
Min. (m)	0.0	0.0
Mean (m)	590.1	469
Std. Dev.	1026.6	2186

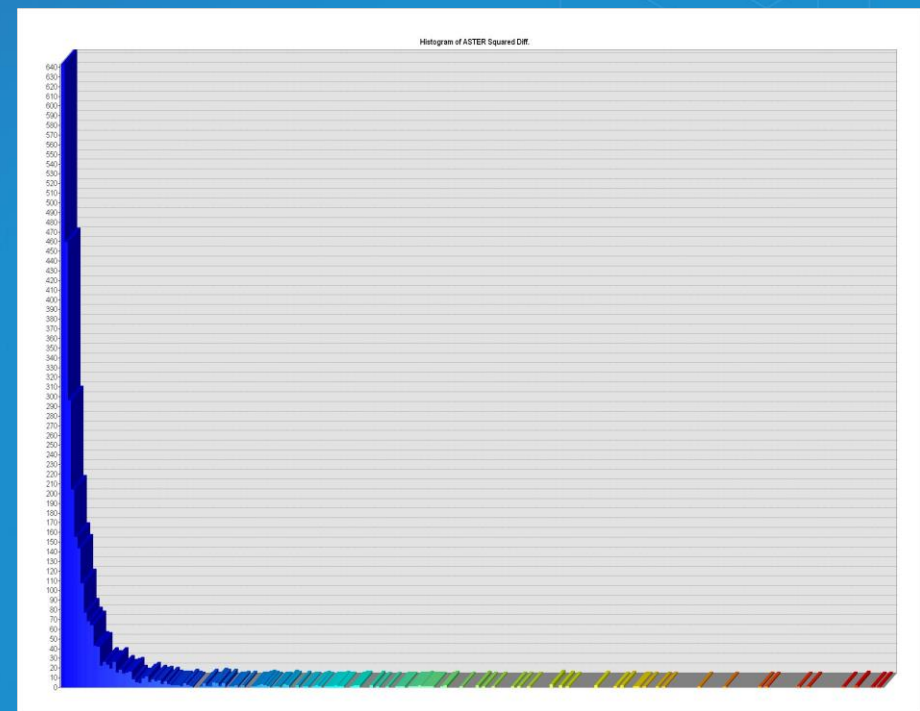
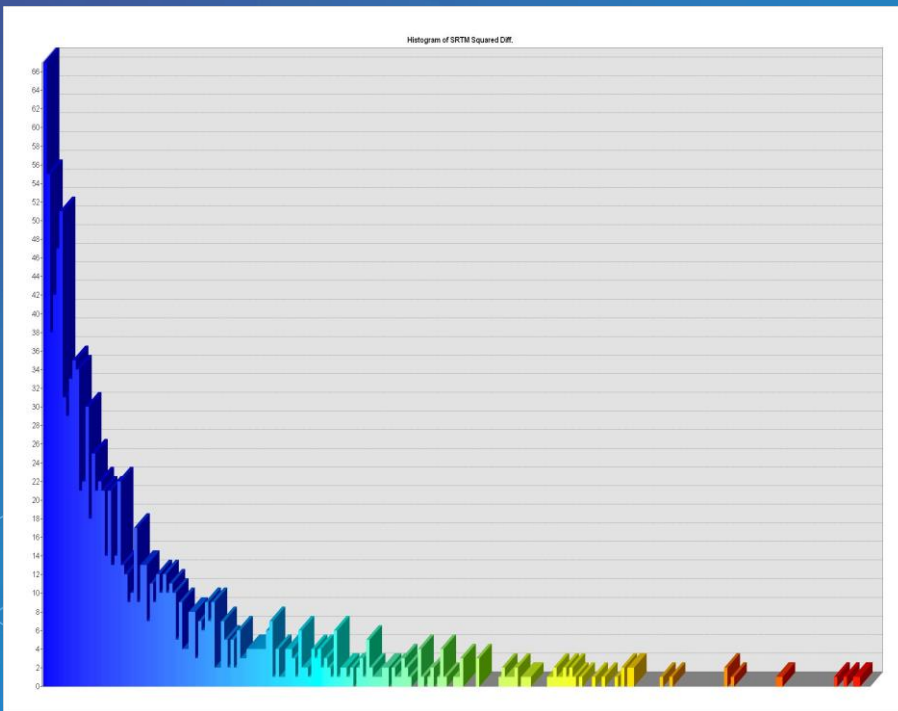


5.4 - Squared Elevation Difference

5.4.3 Frequency histogram

$(\text{SRTM} - \text{LiDAR})^2$

$(\text{ASTER} - \text{LiDAR})^2$



5.5 - Root Mean Square Error (RMSE) and Mean Absolute Error (MAE)

	SRTM	ASTER
Root Mean Square Error (RMSE)	24.3	21.7
Mean Absolute Error (MAE)	18.1	14.1



6 – Conclusions (1/2)

- † SRTM DEM ver. 4.1 and ASTER GDEM ver. 2.0 were evaluated using DEM developed from LiDAR point data as a reference.
- † Three categories of analysis were used, which are; **elevation difference, absolute difference, and squared difference.**
- † Three type of results are presented, which are; **Visual comparison using Raster Calculator “map”, Descriptive statistics using Zonal statistics “table”, and Frequency histogram using Spatial Analyst “Figure”**
- † Two Statistical performance measures were computed, which are; **Root Mean Square Error (RMSE) and Mean Absolute Error (MAE)**

6 – Conclusions (2/2)

- † Generally, both DEMs have very close elevation statistics (max, min, average, std. dev.)
- † Elevation difference analysis showed that SRTM has higher positive elevation difference (102 m) while ASTER showed higher negative elevation difference (-238 m) and higher absolute difference (238 m).
- † Regarding the statistical performance measures, RMSE of SRTM DEM and ASTER GDEM were 24.3 m and 21.7 m, respectively. The MAE of SRTM DEM and ASTER GDEM were 18.1 m and 14.1 m, respectively.
- † ASTER GDEM showed relative superiority over SRTM DEM.
- † More detail analysis and evaluation may needed regarding the comparison of extracted geometric features and computed morphometric parameters from both DEMs.

7 – References

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