

# Chapter 24

## Evaluation and Validation of SRTMGL1 and ASTER GDEM2 for Two Maghreb Regions (Biskra, Algeria and Medenine, Tunisia)

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**Abstract** In this paper, we present the comparison and validation of the Shuttle Radar Topography Mission Version 3.0 Global 1 Arc-Second (SRTMGL1) Digital Elevation Model (DEM) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model Version 2 (ASTER GDEM2) applied to two areas of Maghreb region (Biskra, Algeria and Medenine, Tunisia). These are the two target areas assessed in the frame of WADIS-MAR project (<http://www.wadismar.eu>), which is one of the five demonstration projects implemented within the Regional Programme SWIM (<http://www.swim-sm.eu>) and funded by the European Commission. Newly released SRTMGL1 is available for free download since October 2014 over the African continent through United States Geological Survey (USGS) web data tools. Given the previously reported issues regarding optical sources DEMs, SRTMGL1 can provide significant advantages in elevation modelling and geoscience applications, but studies regarding its quality assessment and validation are in their early infancy. We employed the two data sets in a visual and quantitative comparison and subsequently, their validation was conducted using ground control points (GCPs) collected within the target areas. Results show that SRTMGL1 presents an overall major accuracy and higher sensitivity to small-scale features and slight variations in landforms.

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## Introduction

“Digital Elevation Model (DEM) is a computational representation of the continuous variation of relief over space from which topographic parameters can be digitally generated” (Jing et al. 2014). Several methods can be used to generate DEMs including airborne and satellite-borne stereoscopic photogrammetry, RADAR/SAR interferometry, Light Detection and Ranging (LIDAR) and other traditional approaches (e.g. GPS, levelled benchmarks) (Athmania and Achour 2014). In past decades, global DEMs have become invaluable sources of information in geosciences (Varga and Bašić 2015) especially in regions where, due to particular political or environmental issues, direct field surveys are difficult or even impossible.

The release of spaceborne ASTER and SRTM elevation datasets has provided significant advances in elevation modelling. These DEMs data are global, so they are available for the most part of populated world areas and are free of charge (download from <http://www.earthexplorer.usgs.gov>) at a spatial resolution of 1 arc-second for both sets (NASA SRTM Version 3.0 Global 1 arc-second dataset SRTMGL1 data released over Africa on October 2014, [https://lpdaac.usgs.gov/about/nasa\\_shuttle\\_radar\\_topography\\_mission\\_srtm\\_version\\_30\\_global\\_1\\_arc\\_second\\_data\\_released\\_over](https://lpdaac.usgs.gov/about/nasa_shuttle_radar_topography_mission_srtm_version_30_global_1_arc_second_data_released_over)). However, studies on the accuracy assessment of DEM data sets at local and regional scales are fundamental to understand their potential limitations related to particular purposes and applications (Jing et al. 2014).

In the present work, after a brief description of the study areas and the DEMs characteristics, we present the methodology and results for their visual and quantitative comparison and then their validation using GCPs collected in the target areas. This article contributes to the DEM accuracy literature because SRTMGL1, in particular, has begun its worldwide release in phases starting with September 2014 and studies regarding its quality assessment and validation are in their early infancy.

## Study Areas

Arid and semi-arid regions of Maghreb suffer under dry climatic conditions and ongoing desertification processes. In particular, sand encroachment and soil salinization increasing phenomena (Afrasinei et al. 2015) affect the Medenine (Southern Tunisia) and Biskra (North-Eastern Algeria) regions, respectively. For this reason, these target areas have been selected within the frame of WADIS-MAR project (<http://www.wadismar.eu>) to realise an integrated water harvesting and managed aquifer recharge system. WADIS-MAR is one of the five demonstration projects implemented within the Regional Programme SWIM (<http://www.swim-sm.eu>), funded by the European Commission. In both areas, different elevation ranges and

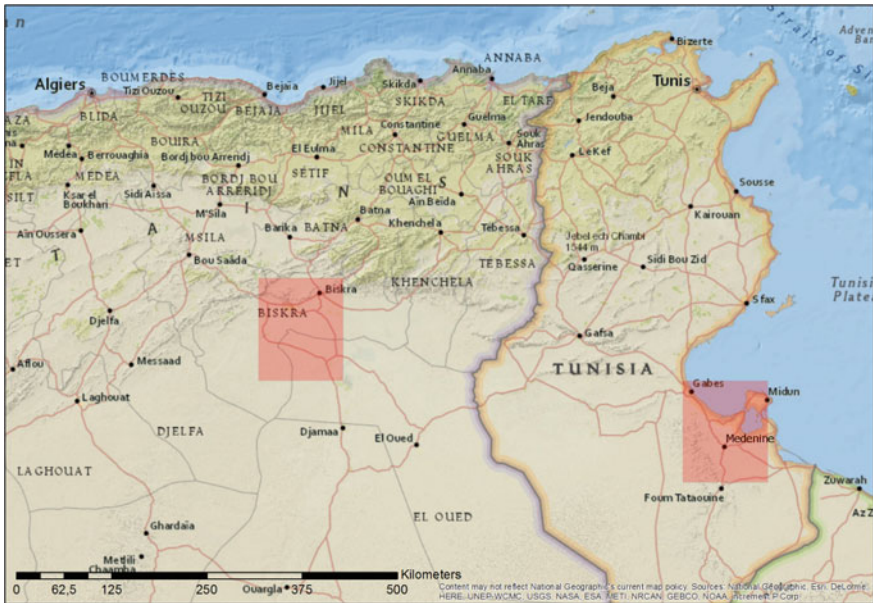


Fig. 24.1 Location of the study areas and DEM tiles extension

several morphological features are identified, ranging from mountains and hills to plains and depressions.

The Medenine area is characterised by the presence of a wide flat area, the Jeffara Plain. It is bordered by the Dahar Plateau to the Southwest, where the maximum elevation reaches about 700 m, and by the Mediterranean Sea to the Northeast where, close to the coastal line, elevations reach negative values corresponding to the *sabkhas* (Marini et al. 2008). The DEM tiles extend over 33°00'N to 34°00'N and 10°00'E to 11°00'E (geographic projection), covering an area of about 7.700 km<sup>2</sup> (excluding the sea area) (Fig. 24.1).

The Biskra area can be divided into two major domains: the Atlas Mountains to the North and the Sahara platform to the South. Elevations range from about 1100 m in the Atlas domain to about -70 m in the southeastern zone, where the Chott Melrhir depression is set. The DEM tiles extend over 34°00'N to 35°00'N and 5°00'E to 6°00'E (geographic projection), covering an area of about 10.200 km<sup>2</sup> (Fig. 24.1).

### Digital Elevation Models

Two open source DEMs with same resolution and coverage were used for the present study purposes: (1) the Shuttle Radar Topography Mission Version 3.0 Global 1 Arc-Second (SRTMGL1) and (2) the Advanced Spaceborne Thermal

**Table 24.1** Height statistics across the Medenine and Biskra regions extracted from SRTMGL1 and ASTER GDEM2 data sets

Study area	Model	Min (m)	Max (m)	Mean (m)	Std dev. (m)
Medenine	SRTMGL1	-37	700	107.11	145.7
	ASTER GDEM2	0	715	108.03	146.06
Biskra	SRTMGL1	-50	1070	154.40	116.55
	ASTER GDEM2	-77	1096	150.76	118.77

Emission and Reflection Radiometer Global Digital Elevation Model Version 2 (ASTER GDEM2).

The SRTMGL1 data set is the result of cooperative work between the National Imagery and Mapping Agency (NIMA) and the NASA (National Aeronautics and Space Administration) of United States (US). Elevations data were collected during an 11-day mission in February 2000, and measurements were undergone using the X-band and C-band Interferometric Synthetic Aperture Radar (InSAR) sensor (5.6 and 5.3 cm wavelengths, respectively). SRTM C-band data are available over Africa at  $1^\circ \times 1^\circ$  tiles and 1 arc-second resolution (about 30 m) since 8 October 2014. Africa is the first continent to be released after the US and its territories as the global 1 arc-second data. The absolute vertical accuracy of the elevation data is 16 m (at 90% confidence) (Sulzer and Gspurning 2009).

ASTER GDEM was built up by the METI (Ministry of Economy, Trade and Industry) of Japan together with the NASA. It is provided at 1 arc-second resolution and is accessible for free since the 29 June 2009 (ASTER GDEM validation team (a)). The absolute vertical accuracy of the elevation data is 20 m (at 95% confidence) (Athmania and Achour 2014). A new data set, ASTER GDEM2, was released in (2011) with 260.000 overlapping images added to the original one. The aim was to enhance the spatial resolution and the water body coverage accuracy and to reduce the occurrence of data artefacts (ASTER GDEM validation team (b)).

Table 24.1 shows the SRTMGL1 and the ASTER GDEM2 statistics for both study areas.

## Ground Control Points

DEMs accuracy assessment needs at least 20 measured elevation data with high precision in each major land cover category to obtain consistent results, as suggested by the American Society of Photogrammetry and Remote Sensing (ASPRS). For the study purposes, GCPs were collected in different ways depending on the study areas. For the Medenine region, 28 GCPs (Fig. 24.2a) were collected using an altimeter device during a survey campaign carried out in June 2014, while for the Biskra region were used 107 GCPs (Fig. 24.2b) derived from survey reports provided by the *Ministère des Ressources en Eau* (MdH 1980).

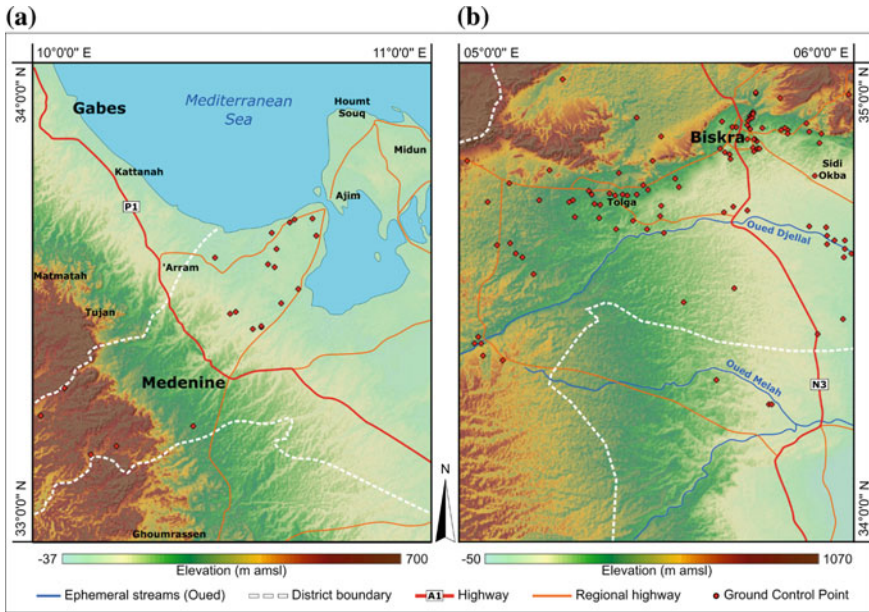


Fig. 24.2 Location of the GCPs plotted on the a Medenine and b Biskra hill-shaded SRTMGL1 data sets

### Methodology

Objective of this study was to verify the vertical displacement between SRTMGL1 and ASTER GDEM2 through comparison methods and to assess their accuracy with respect to GCPs available within the study areas.

After downloading the SRTMGL1 and ASTER GDEM2 tiles for both the study areas, a pre-processing phase was required. Previous investigations have shown that DEMs are subjected to systematic horizontal shifts (Denker 2004; ASTER GDEM validation team 2009). Correct georeferencing and co-registration are necessary in order to ensure that corresponding pixels on images pair represent the same geographic location and the possibility of differences caused by shifts of unchanged object boundaries is excluded (Aleksandrowicz et al. 2014). The Universal Transverse Mercator (UTM) is selected as the projected reference system, where Zone 32 and Zone 31 correspond to the Tunisian and the Algerian DEM tiles, respectively. Subsequently, the two sets of images were verified for correct overlay and results showed that no horizontal shift existed between the two DEM tiles.

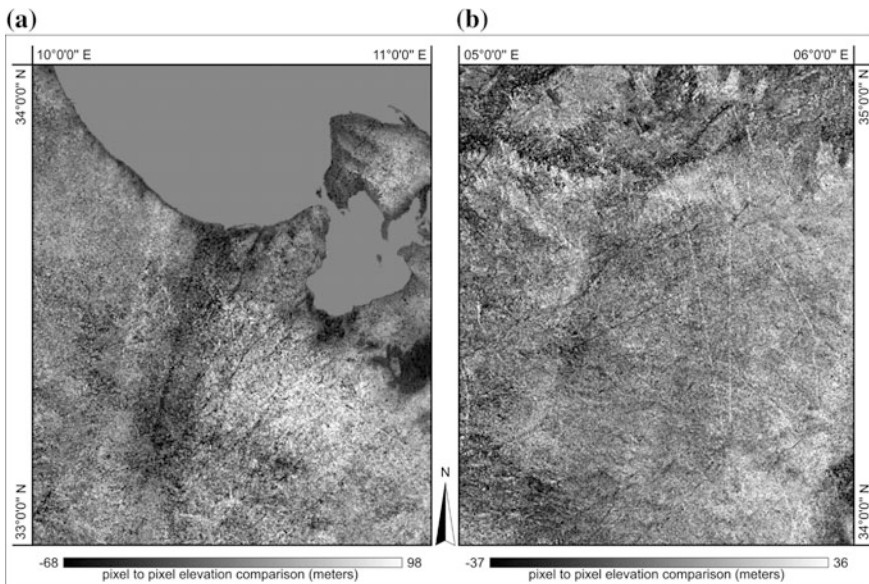
The processing phase includes a visual and quantitative comparison between DEMs and then their validation through GCPs. Visual comparison, which is based on the production of relative difference map and shaded relief map (Jing et al. 2014), aims to locate areas of significant vertical displacement between the two data sets and to identify large-scale systematic effect (Hilton et al. 2003) and artefacts



such as stripe effects. The quantitative comparison is based on geostatistical and statistical measures (Athmania and Achour 2014). The mutual correspondence (difference) between the models allowed the evaluation of possible significant systematic errors or outliers between the DEMs (Varga and Bašić 2015). For the pixel-to-pixel comparison, the “raster calculator tool” from ESRI ArcGIS was used and the difference between SRTMGL1 and ASTER GDEM2 was carried out. However, model validation using GCPs is the method that delivers consistent accuracy evaluation, on the condition that elevation data are independently set and of sufficient precision (Hirt et al. 2010). The DEMs elevation values were extracted corresponding to the GCPs locations and then, the subtracted values between the DEMs extracted values and the GCPs values were obtained using the ArcGIS “field calculator tool”.

### Results

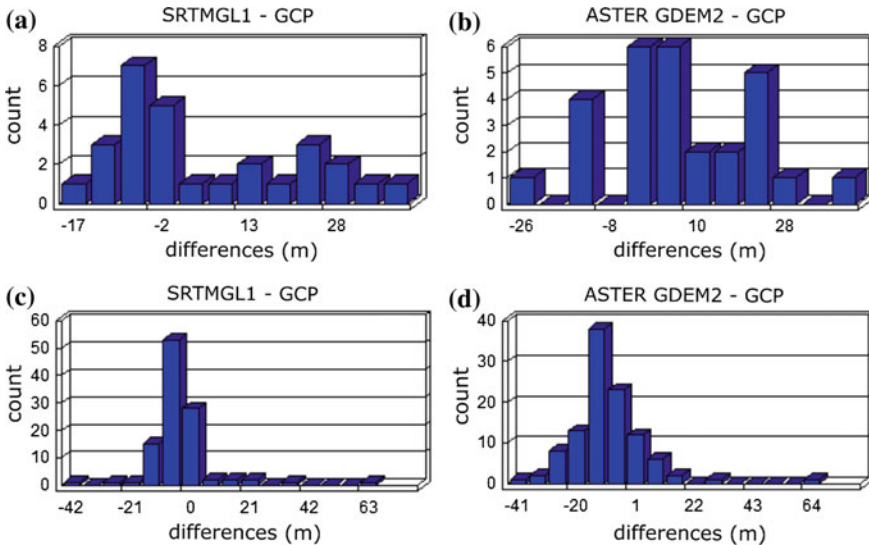
Figure 24.3 and Table 24.2 show the plot differences between SRTMGL1 and ASTER GDEM2 for (a) the Medenine and (b) Biskra region, respectively. Both the resulting images are characterised by a slight stripe effect oriented NNE-SSW. Hirt et al. (2010) ascribed this effect to the ASTER model. Further visual analysis on the images and statistics have shown that in the Biskra area, where both DEMs



**Fig. 24.3** Model-to-model (SRTMGL1–ASTER GDEM2) comparison results for the **a** Medenine and **b** Biskra regions

**Table 24.2** Model-to-model comparison statistics for both the study areas

Study area	Max negative shift (m)	Max positive shift (m)	Mean (m)	Std dev. (m)
Medenine	-73	106	-0.9	6.17
Biskra	-108	116	3.64	6.67



**Fig. 24.4** Displacement distribution of the SRTMGL1 and ASTER GDEM2 data sets relative to the GCPs for the **a, b** Medenine and **c, d** Biskra regions

presented negative values over the *chott*, ASTER GDEM2 values were sparse and sporadic, unlike SRTMGL1 values that were uniform and all the negative values best fitted the depression area. In the Medenine area, both data sets showed zero values over the sea domain while only the SRTMGL1 managed to identify negative values corresponding to the *sabkhas*. This demonstrates a higher sensitivity of the radar sensing towards flat depression areas either endorheic or coastal.

Results of model validation through GCPs for both the study areas are illustrated in Fig. 24.4, Table 24.3 and Table 24.4, for Medenine and Biskra area, respectively. Mean Error (ME) was used as global accuracy measure. The accuracy assessment in the Medenine area shows that SRTMGL1 has a lower mean vertical bias (6.75 m) compared to the ASTER GDEM2 (8.07 m). In the case of the Biskra tile, SRTMGL1 was underestimated by about 1 m, while the ASTER GDEM2 model presents a negative shift of about 6 m. However, it must be mentioned that in Medenine area, SRTMGL1 presents a slightly major standard deviation with respect to ASTER GDEM2 while in the Biskra area the situation is the opposite. For a better understanding of displacement factors, a brief analysis of the influence of morphology has been undergone. We have taken into consideration the two

**Table 24.3** Statistics of the model to GCP for both SRTMGL1 and ASTER GDEM2, respectively (Medenine area)

Study area	Comparison	Morphology	Max <sup>-</sup> (m)	Max <sup>+</sup> (m)	Mean (m)	Std dev. (m)
Medenine	SRTMGL1–GCP	Total coverage	-17	42	6.75	16.01
		Plain/coastal domain	-17	35	3.47	14.09
		Mountain domain	-5	42	21.8	15.74
	ASTER GDEM2–GCP	Total coverage	-26	44	8.07	15.20
		Plain/coastal domain	-26	26	5	13.66
		Mountain domain	7	44	22.2	13.92

**Table 24.4** Statistics of the model to GCP for both SRTMGL1 and ASTER GDEM2, respectively (Biskra area)

Study area	Comparison	Morphology	Max <sup>-</sup> (m)	Max <sup>+</sup> (m)	Mean (m)	Std dev. (m)
Biskra	SRTMGL1–GCP	Total coverage	-42	69	-1.25	11.32
		Plain domain	-18	41	-0.91	9.77
		Mountain domain	-42	69	-1.83	12.76
	ASTER GDEM2–GCP	Total coverage	-41	67	-6.38	13.02
		Plain domain	-30	32	-7.29	11.60
		Mountain domain	-41	67	-5.63	14.35

major morphologies in both areas, namely mountain and plain domains. Table 24.3 presents the statistics summary for Medenine area, where SRTMGL1 model-to-GCP difference shows the maximum negative displacement located in the plain area, whereas the max positive one, in the mountain domain. In Table 24.4, correspondent to Biskra area, SRTMGL1 presents both max negative and positive shifts in the mountain domain.

Given the fact that the ASTER GDEM2 shows the same shift pattern, one of the immediate explanations can be the fact that in the Medenine area there were only 5 of 28 GCPs in the mountain domain, too scarce to provide valid statistics. Another explanation could be that SRTMGL1 and ASTER GDEM2 data sets are more erroneous in high elevation zones, as reported by Mukherjee et al. (2013). In the Biskra area, GCPs were distributed relatively even in the two landforms and the



results are slightly different than the ones in the Medenine area. The aforementioned standard deviation results may be influenced by the small amount of GCPs used in the Medenine area and their concentration in the plain coastal sector, but it may be also given by the presence of outliers that SRTMGL1 presents because of its high sensitivity to lowland features, while in the ASTER GDEM2 data these are completely absent. However, for model-to-GCP comparison, both models present the minimum shift values (close to 0) in the plain coastal sector in Medenine area but in the Biskra area, these are found in the mountain domain (not presented in the statistic table), that would confirm a problem related to the different characteristics of the sets of GCPs used in the two areas.

## Conclusions

Digital Elevation Model represents one of the most valuable data set for geomatics and geoscientific purposes ranging from environmental to anthropogenic applications (Toutin 2008) and examples of attributes which can be extracted from them include (Gomasasca 2004):

- topographic and geomorphic data as slope and aspect for geological analysis on slope stability;
- hydrological data as hydrographic network and watershed which become input data for hydrological modelling on superficial runoff and flood simulations.

DEMs are also useful for the detection and estimation of landslides or lava flows volumes based on variations of elevations between two DEMs taken before and after the events. Undoubtedly, the quality of the obtained attributes depends on the accuracy of the DEMs data.

In this study, both the spaceborne ASTER GDEM2 and SRTMGL1 (newly released over Africa since October 2014) data set were employed in a visual and quantitative statistical comparison between each other, after which their accuracy was assessed using GCPs. Either visual or statistical comparison detected discrepancies between the two DEMs related to artificial error patterns ASTER GDEM2 data (stripes and cloud anomalies), being constructed from optical stereo imagery. The results of the model accuracy assessment through GCPs allow us to understand the behaviour of each DEM in different environments: coastal (flat areas) and inner-land (mountain areas). The results show the possible presence of outliers that do not have the same distribution pattern in the two study areas. This provides information on the advantages and drawbacks of SRTMGL1 which may present higher outliers in the mountain domain but a higher precision in lower landforms, on the one hand. On the other hand, we can infer that ASTER GDEM2 is affected by cloud cover and is often altered by the presence of artefacts. It shows lower precision or inability to identify certain features hence, smaller outliers are given by the standard deviation analysis.

The aforementioned arguments confirm that DEMs developed from optical sources such as ASTER GDEM2 and aerial photography may be negatively impacted by certain factors. In contrast, SRTMGL1 data penetrates clouds and are more sensitive to small-scale features, but both of them are sensitive to the top of impervious or high vegetation features even if SRTMGL1 to a lesser extent. This could also be explained by the fact that SRTMGL1 has void-filled data.

To cope with these issues and to understand the reason of the outliers' occurrence, a future step would be to identify them and to assess to which extent it is important to validate the results before and after their removal.

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