Mu'tah Lil-Buhuth wad-Dirasat, Natural and Applied Sciences Series Vol. 35. No.2, 2020.

Assessment of Height Models Covering Jordan valley Area

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Abstract

The production of Digital Elevation Models (DEMs) is expensive, but now the height models which can be generated from high resolution satellites are available free of charge with good and reasonable accuracy. The 90-metre TanDEM-X Digital Elevation Model has been released for scientific use and is now available free of charge as a global dataset. By providing this data, the German Aerospace Center (DLR) encourages free access to satellite data.

This paper provides an independent investigation into the quality, performance of Elevation Models (DEMs) which generated from TanDEM-X with 90m spacing (3 arcsec) for Jordan valley. The accuracy of DEM is assessed through the comparison of accuracy against an independent data from aerial LiDAR, and against DEM created from AW3D30 with one arc second free of charge. The root mean square differences (m) is 2.40 m against LiDAR, and AW3D30 with one arc second for areas with slope < 20%.

Keywords: DEM, satellites, TanDEM-X, AW3D30, accuracy.

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تاريخ تقديم: 2019/4/22م. تاريخ قبول البحث: 2019/9/19م.

تقييم نماذج الارتفاع الرقمية التي تغطي منطقة وادي الأردن

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ملخص

يعد إنتاج نماذج الارتفاع الرقمية (DEMs) مكلفًا، ولكن في الوقت الحاضر تعتبر نماذج الارتفاع التي يمكن إنشاؤها من أقمار صناعية عالية الدقة متاحة مجانًا وبدقة جيدة ومعقولة. يعد (TanDEM-X DEM) متاح لجميع المواقع الأرضية بما في ذلك القارة القطبية الجنوبية وجميع خطوط العرض فوق 60 درجة شمالًا. تم إصدار الارتفاع الرقمي TanDEM-X بطول 90 مترًا للاستخدام العلمي وهو متاح الآن مجانًا لاستخدام البيانات العلمية كمجموعة بيانات عالمية، من خلال توفير هذه البيانات يشجع المركز الألماني للفضاء (DLR) الوصول الحر والمفتوح إلى بيانات الأقمار الصناعية.

تقدم هذه الورقة دراسة مستقلة عن الجودة والأداء والموثوقية لنماذج الارتقاء (DEMs) التي تم إنشاؤها من TanDEM-X بمسافات 90 متر (3 arcsec) لوادي الأردن. يتم تقييم دقة DEM من خلال مقارنة الدقة مع بيانات مستقلة من LiDAR ، و DEM التي تم إنشاؤها من AW3D30 المجانية. يبلغ متوسط الخطا 2.40 مترمربع مقابل LiDAR و AW3D30 للمناطق ذات الميل <20٪.

Introduction

Digital Elevation Models (DEMs) are a basic component for geographic information systems (GIS) and basic requirement for several applications. The digital elevation models can be used to create topographic maps, also to monitor land use and vegetation, collect hydrological information such as drainage paths or soil moisture, and observe polar ice caps or glaciers. This was been investigated by Jacobsen (2004).

The Sources of DEMs from space are (Jacobsen, 2010):

- Radar – Interferometric Synthetic Aperture Radar (InSAR) (covering large areas).
- optical images – stereo satellites (covering large areas), flexible satellites.
- LiDAR – up to now not from space - ICESAT not satisfying point spacing.

The production of Digital Elevation Models (DEMs) is expensive (Höhle, 2009), but now the height models which can be generated from high resolution satellites are available free of charge or commercially with good and reasonable accuracy as shown in Table 1 (Jacobsen, 2013).

Table (1) Height Models Covering large Area (Free of Charge and Commercial Height Models)

Height model	Organization	Source	Range	Spacing
Free of charge and commercial Height Models				
GMTED2010	USGS and NGA	various	global	7.5 arcsec
SRTM (C-band)	NGA and NASA	Shuttle InSAR	Latitude 56° S to 60° N	1 arcsec
SRTM X-band	DLR	Shuttle InSAR (X-band)	Latitude 56° S to 60° N partially	1 arcsec
ACE2	ESA ESRIN and	SRTM and altimeter	Latitude 56° S to 60° N,	3 arcsec

Height model	Organization	Source	Range	Spacing
Free of charge and commercial Height Models				
	Montfort University	and other data	remaining area other data sets	
ASTER GDEM-2	METI (Japan) and NASA	ASTER optical stereo satellite	Latitude 83° S to 83° N	1 arcsec
AW3D30	JAXA (Japan)	ALOS PRISM optical stereo satellite	Latitude 82° S to 82° N	1 arcsec
Commercial Height Models				
Elevation 30 (Reference 3D)	Airbus Defense and Space	SPOT 5 HRS	~46% of Earth land mass	30m
EuroMaps 3D	GAF and DLR	Cartosat-1 optical stereo satellite	Some European and Near East countries and on request	5 m
NextMap	Intermap	Airborne InSAR	USA, European countries	5 m
WorldDEM	Airbus Defense and Space and DLR	TanDEM-X InSAR	global	10 m
ALOS World 3D Topographic Data (AW3D)	NTT Data / RESTEC	ALOS PRISM optical stereo satellite	Latitude 82° S to 82° N	5 m

The TanDEM-X digital elevation model with 90-m spacing (3 arcsec) horizontal sampling is now available for download for scientific applications and is concidered now to be afree of charge Degital Height Model. The global data set can be easily downloaded after a simple registration – without science proposal submission. The 90-m TanDEM-X DEMs are multi-looked versions of the 12-m TanDEM-X DEMs with considerably improved relative height accuracy. The accuracies are the absolute accuracies and relative accuracies (RMSE, SZ, and NMAD), but the morphologic details are dominated by point spacing and relative accuracy.

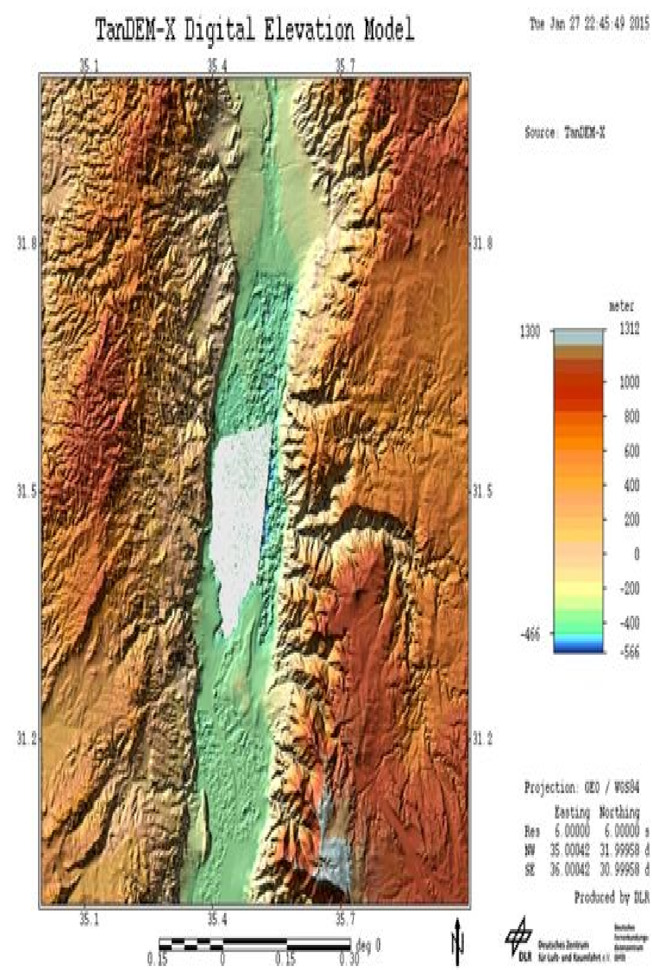
The TanDEM-X DEM covers all of Earth’s land surfaces, totaling over 148 million square kilometers. The absolute height accuracy is one metre. This 3D image of the Earth was completed in September 2016 and is approximately 30 times more accurate than any other global dataset. The elevation models generated with TanDEM-X and TerraSAR-X also have the advantage of being the first to capture the Earth with uniform accuracy and no gaps.

The two satellites continue to fly in close formation and acquire images of Earth to detect topographic changes that have occurred as a result of earthquakes or in glaciers, permafrost regions, agricultural areas or urban zones. Also, the generated digital elevation models (commercial or free of charge) can be used to create topographic maps, to monitor land use and vegetation, collect hydrological information such as drainage paths or soil moisture, and observe polar ice caps or glaciers (Jacobsen, 2019).

The Test Site

TanDEM-X Digital Elevation Models (DEMs) with 90-m spacing (3 arcsec) are analysed over the established Jordan valley site. Figure 1 shows the DEMs layed over the area.

Figure 1:



TanDEM-X Digital Elevation with 90-m spacing (3 arcsec) horizontal sampling Model for Jordan valley area

One of the most difficult issues that require addressing is how to assess the quality of the of Digital Elevation Models (DEMs). In general, a way to check the quality of any measurement is by comparing results with a measurement from significantly higher quality generated from aerial LiDAR sensors and against DEMs created from larg scale aerial photogrammetry (Höhle, 2009). This would then provide a benchmark or reference measurement to compare against. In the past this has been very difficult to achieve as far there has been little equipment available to compare against the high quality.

Digital Elevation Models (DEMs) are a basic component for geo information systems (GIS), so the quality of DEM is assessed through the accuracy parameters and morphologic details (external assesment). The accuracies are the absolute accuracies and relative accuracies (RMSE, SZ), but the morphologic details are dominated by point spacing, contours and relative accuracy.

Results and Discussions

Figure 2 and Table 2 show the color coded height differences of TanDEM-X Digital Elevation Models with 90-m spacing (3 arcsec) WorldDEM for Jordan valley area against LiDAR, for the same area, which was used as a benshmark. Open area including not dense urban area filtered to DTM with vegetation filter for LiDAR reference. The Jordan test area was analyzed by removing the poor points in the water by performing water mask and was added to the digital elevation model, as shown in Figure 3 and Figure 4. So the output generated from the Digital elivation model with used water mask as shown in Figure 5.

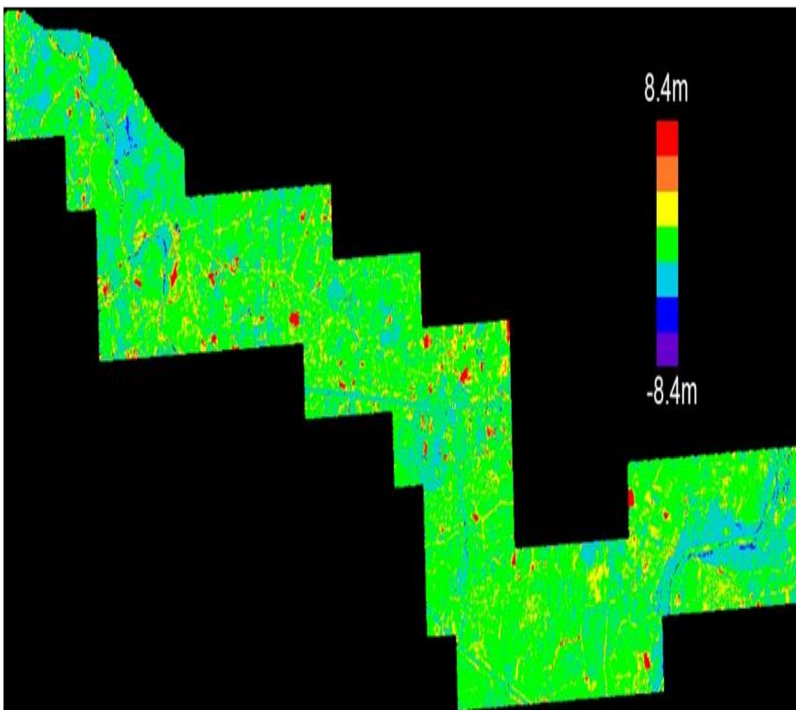


Figure 2: Color Coded Height Differences Free TANDEM-X WorldD Against LiDAR, Jordan Valley –Open Area Including Not Dense Urban Area Filtered to DTM.

Table (2) Free TANDEM-X WorldDEM against LiDAR

	Whole area	slope < 20%
SZ	1.96m	1.59m
NMAD	1.48m	0.99m

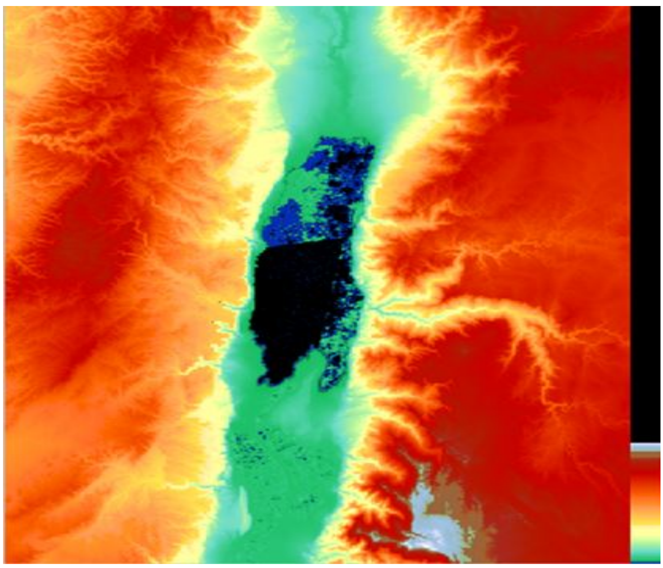


Figure 3: Input DEM with Poor Points on Water (Image of TDM90 Height Model)

Figure 4: Water Mask (TDM90)

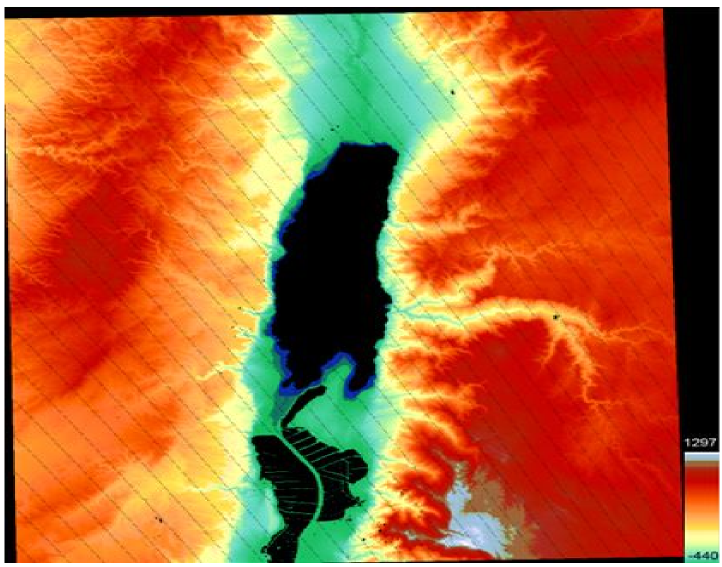


Figure 5: Output with Used Water Mask (Image of Height Model Generated with ASCIMA Software)

Figures 6, 7, and 8 show the morphologic details of the contour lines. The LiDAR contour lines is shown in figure 8 which based on a DSM with 50 m contour intervals. The TanDEM-X Digital Elevation Models (DEMs) with 90-m spacing (3 arcsec) WorldDEM contour lines are very close to it, It is nearly identical to the contour lines based on The LiDAR. Whereas the AW3D30 contour lines for the same area do not show so many details as the contour lines of TanDEM-X Digital Elevation Models, So the contours and morphologic quality of TanDEM-X Digital Elevation Models (DEMs) matches and agrees to the sequence of accuracy (Table 3) and the point spacing.

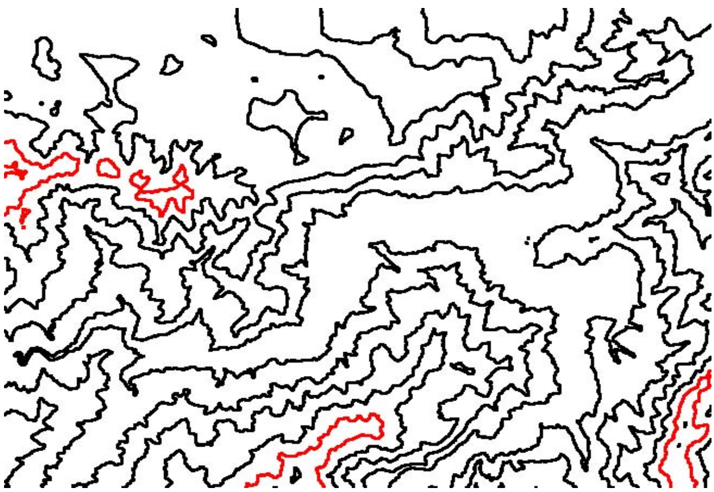


Figure 6: Contour Lines Created from Aerial LiDAR, Contour Interval 50m

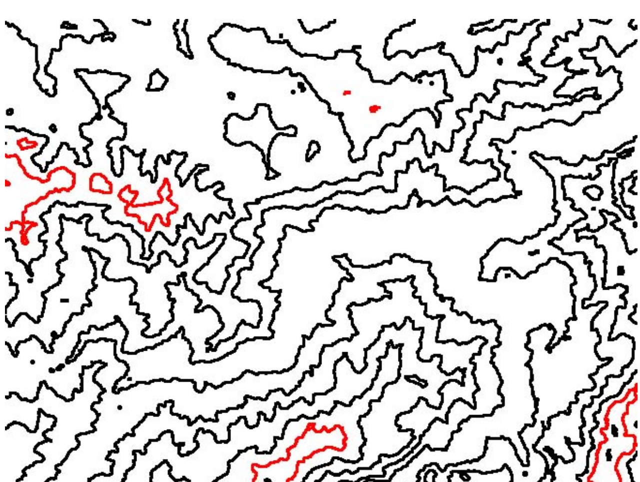


Figure 7: Contour Lines Created from Aerial TanDEM-X WorldDEM, Contour Interval 50m

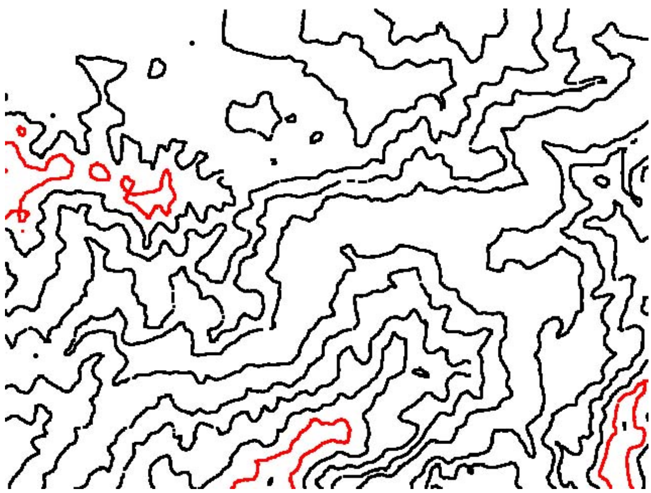


Figure (8) Contour Lines Created from AW3D30, Contour Interval 50m

Table (3) Accuracy Numbers of the Investigated DEM [m]

Compared DEM	**Whole area**		**Slope < 20%**	
	SZ	NMAD	SZ	NMAD
TanDEM-X - LiDAR	3.60	3.09	2.32	1.33
AW3D30 - LiDAR	3.96	3.23	2.49	2.16

Also FreeTanDEM-X WorldDEM, GDEM2, and SRTM have been analyzed for Jordan test area (Figure 9). FreeTanDEM-X WorldDEM has a higher accuracy and again is more accurate than GDEM2 and SRTM. As known, the height model accuracy depends on the terrain slope. If the DEM’s accuracy shall be compared for different sites, this has to be done in areas which have inclination less 20%.

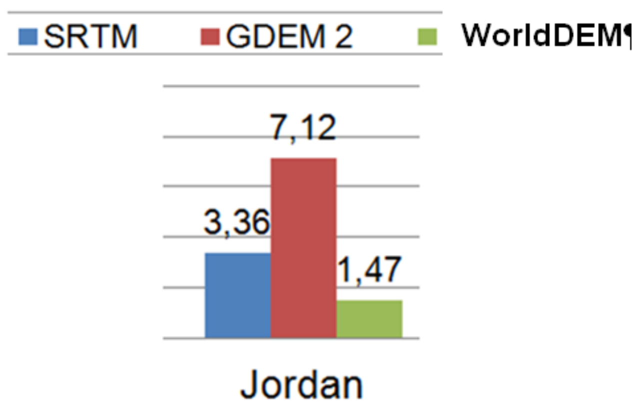


Figure (9) DEM Root Mean Square Differences (m) for Free TanDEM-X WorldDEM against SRTM, and GDEM2 with Slope < 20%

Conclusions

The free of charge available Digital Elevation Models have reached a good level of accuracy and morphologic information. Some height models covering large area are accessible free of charge or commercially in case of more information and higher accuracy. From the free of charge available height models, new TanDEM-X Digital Elevation with 90-m spacing (3 arcsec) is dominating up to now. The new TanDEM-X Digital Elevation with 3 arcsec point spacing, named with a nominal higher accuracy as AW3D30, has the advantage of more actual DSM information and shows more morphologic details. The accuracy of DEM is assessed through the comparison of accuracy against an independent data from aerial LiDAR, and against DEM created from AW3D30 with one arc second (30m spacing) free of charge. The root mean square differences (m) is 2.40 m against LiDAR, and AW3D30 with one arc second for areas with slope < 20%.

References:

Höhle, J. (2009). Accuracy assessment of digital elevation models by means of robust statistical methods, ISPRS Journal of Photogrammetry and Remote Sensing, 64, pp. 398-406

Jacobsen, K. (2004). DEM Generation by SPOT HRS, ISPRS Congress, Istanbul 2004, Int. Archive of the ISPRS, Vol XXXV, B1, Com1, pp 439-444,

Jacobsen, K. (2010). Comparison of ASTER GDEMs with SRTM Height Models, EARSeL symposium 2010, Paris, pp 521-526.

Jacobsen, K. (2013). Characteristics of Airborne and Spaceborne Height Models, EARSeL Symposium Matera, 2013, http://www.earsel.org/symposia/2013-symposium.

Jacobsen, K. (2019). DSM Quality of Korean Satellite KOMPSAT-3 in Comparison to AW3D30 and Sentinel-1A in Respect of Airborne Laser Scanning, KSCE Journal of Civil Engineering, May 2019, pp. 398-406.