VERTICAL ACCURACY ASSESSMENT OF COPERNICUS DEM (CASE STUDY: TEHRAN AND JAM CITIES)

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ABSTRACT:

Digital Elevation Models (DEMs) are widely utilized in a variety of fields, including, hydrology, geomorphology, and geoscience. The dataset is now openly and freely available to the public, with access permissions for data at 30- and 90-meter resolution having been expanded. The Copernicus DEM is a Digital Surface Model (DSM) that depicts the Earth's surface, which includes structures, infrastructure, and vegetation. This DEM is based on the WorldDEM DSM, which has been altered. The Copernicus DEM's vertical accuracy is assessed in this paper. The study area is in Iran, north of Tehran and west of Jam. The Copernicus DEM is compared to the Shuttle Radar Topography Mission (SRTM) in terms of vertical accuracy. The results of the experiments reveal that the Copernicus DEM is more accurate than the SRTM. In the Tehran and Jam examples, the root mean square error (RMSE) for Copernicus DEM (30 m) is 5.72 and 2.19 meters, respectively. Also, this value for SRTM is 6.10 and 3.95 respectively.

1. INTRODUCTION

In numerous scientific and commercial uses, digital elevation models (DEMs) are essential. Many geoscience fields need precise and up-to-date information about the Earth's surface such as geology (Elmahdy et al., 2021, Aljammaz et al., 2021), forestry (Gdulová et al., 2020, Schlund et al., 2016), glaciology (Błaszczyk et al., 2019), oceanography (Abrams et al., 2020), and hydrology (Moretti and Orlandini, 2018, Mohammadi et al., 2020) and risk management of natural disasters (Hawker et al., 2019, Florinsky and Bliakharskii, 2019). DEMs can be obtained from contour lines, topographic maps, land surveys, photogrammetry techniques, Synthetic Aperture Radar (SAR) interferometry, and light detection and ranging (LiDAR) instruments (Arun, 2013).

Until now, our society has created three DEMs that encompass virtually all the world's land masses. Even though globes and maps of the world depicting land topography existed well before, none of these topographic products were available at a spatial resolution and precision efficient to meet the multiple needs of civilization's long-term development. (Becek et al., 2016). The Shuttle Radar Topography Mission (SRTM), which has a spatial resolution of 30 m between 56° South and 60° North latitude, has been the principal source of elevation data on an almost global scale-up until now (Rizzoli, Martone et al. 2017). Furthermore, DEMs with a 30-meter resolution are available from the ALOS global digital surface model (AW3D30) (Caglar et al., 2018) and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) (Sujatha et al., 2015). The AW3D30 one covers latitudes between 83° South and 83° North, but the ASTER has significant holes in both Antarctica and the arctic areas (Rizzoli et al., 2017). Only lower resolution DEMs (in the range of hundreds of meters to kilometers) are available for higher latitudes and across Antarctica, such as GTOPO, GLOBE, Greenland Ice Sheet Mapping Project (RAMP), and GLAS/ICESat (Rizzoli et al., 2017).

The WorldDEM (Bayburt et al., 2017) is another global DEM that is now available to numerous users for a variety of applications. The new TanDEM-X DEM has been regarded as one of the most accurate and consistent global DEM data sets of the Earth's surface since September 2016 (Wessel et al., 2018). This ground-breaking product will be used in a variety of regional and worldwide applications for evaluating biological evaluating biological and physical processes on the planet's surface (Zink et al., 2014). Single-pass SAR interferometry was used to obtain the height data. The satellites TerraSAR-X and TanDEM-X, which fly in a near helix configuration with distances between 300 and 500 meters, captured the corresponding sets of photos (Zink et al., 2014). The measured height corresponds to the reflective surface of the X-Band signal, even though SAR interferometry is well adapted to globally map the Earth's surface in a short period due to its "day and night" and "all-weather" observation capacity (Rossi and Gernhardt, 2013). The SAR data utilized for the global DEM production were gathered in StripMap mode with horizontal transmit and receive polarization between December 2010 and January 2015.

The Copernicus DEM (Cop-DEM) is the most recent DEM from around the world to become publicly available. The goal of this paper is to assess Cop-vertical DEM's accuracy and to achieve this, more precise DEMs (derived from aerial images and GeoEye satellite images) were employed. The paper is structured as follows: the Cop-DEM characteristics are introduced in Section 2; Section 3 introduces the research topic and the data employed; the experimental results are discussed in Section 4 and the study will be concluded in the summary section.

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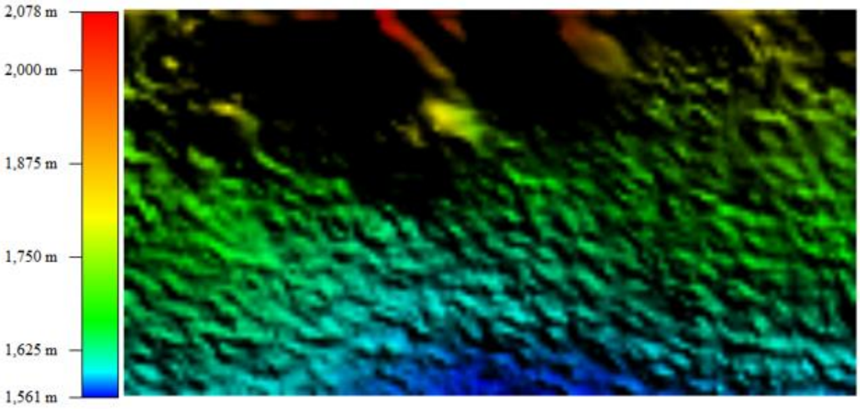
2. COPERNICUS DEM

The Cop-DEM is a digital elevation model (DEM) which depicts the Earth's surface, which includes buildings, infrastructure, and vegetation. Flattening of water bodies and continuous river flow have been added in this DEM, which is produced from an edited DSM named WorldDEM. Shorelines and coasts have been edited, as well as specific features such as airports and improbable terrain formations. The WorldDEM product is based on radar satellite data collected during the TanDEM-X Mission, that is supported by a public-private partnership between the German government, represented by the German Aerospace Center (DLR), and Airbus Defence and Space. The Cop-DEM is available in three different versions: EEA-10 (for EEA39 nations and regions), GLO-30, and GLO-90. The Cop-DEM GLO-30 and GLO-90 instances cover the whole worldwide landmass during the data collection period (2011-2015). Each instance covers a total area of 148.5 million square kilometers (including inland water bodies. Cop-DEM data is provided in Integer 32-bit and 16-bit formats in the GEOTIFF, DTED, DGED, and INSPIRE formats. The resolution of Cop-DEM data ranges from 0.3 to 3.0 arc seconds. This data is divided into units of 1°×1°. The Cop-DEM instances are accessible in Geographic Coordinates, with the World Geodetic System 1984 as the horizontal reference datum (WGS84-G1150; EPSG 4326). The Earth Gravitational Model 2008 (EGM2008; EPSG 3855) is the vertical reference datum (https://spacedata.copernicus.eu).

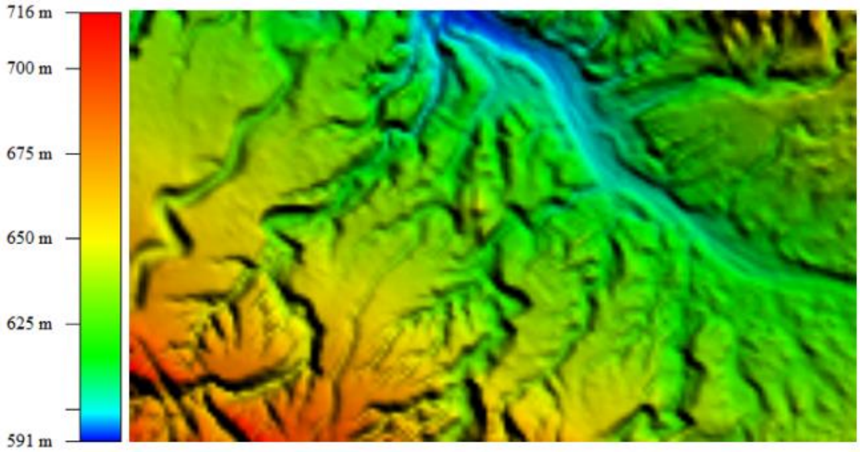
3. STUDY AREA

The northern section of Tehran city and the neighboring areas of Jam city in Iran are the research areas for Cop-DEM (30m and 90m) validation. The UTM coordinates for the research region in Tehran City (zone 39N) extend from the northeast (X: 542450, Y: 3964590) to the southwest (X: 542450, Y: 3964590). Most of this area is urban. (X: 539010, Y: 3962350). Jam City (zone 40N) coordinates are (X: 630100, Y: 3082200) and (X: 625500, Y: 3079000), respectively. This area is completely mountainous. In Tehran, the study area elevation extends from 1555 to 2080 m, while in Jam, the range is 579 to 830 m. Figure 1 shows a Cop-DEM (30 m) of the study area.

For comparison with Cop-DEM from the research areas, SRTM-DEM (30m) and SRTM-DEM (90m) were prepared. In the Tehran and Jam cases, two networks with 8816 and 16632 elevation points were employed to compare Cop-DEM (30m) and SRTM-DEM (30m) models with reference-DEMs. DEMs (90m) have values of 1014 and 1924. Two 1-meter spatial resolution referenced DEMs (produced from GeoEye-2 stereo imagery and aerial photogrammetry for Jam and Tehran, respectively) are used for evaluation and assessment. DEM accuracy is measured using the Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) (Ghannadi et al., 2020). The RMSE and MAE formulas are depicted in Equations 1 and 2.



(a)



(b)

Figure 1. Cop-DEM of a) north of Tehran and b) west of Jam city

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$$RMSE = \sqrt{\frac{\sum_{i=1}^{M\times N}(Z_i^R - Z_i^C)^2}{M \times N}} \qquad (1)$$

$$MAE = \frac{\sum_{i=1}^{M\times N}|Z_i^R - Z_i^C|}{M \times N} \qquad (2)$$

where M, N= rows and columns in DEM, respectively

Z_i^R, Z_i^C = ith point elevation over the reference DEM and the Cop-DEM, respectively

In the next section, experimental results are illustrated and discussed.

4. RESULTS & DISCUSSION

The Cop-DEM and SRTM DEM were compared with the reference DEMs. The statistical comparison of the two DEMs is given in Table 1. RMSE and MAE of Cop-DEM were better than SRTM by 6%-44% and 5%-53%, respectively.

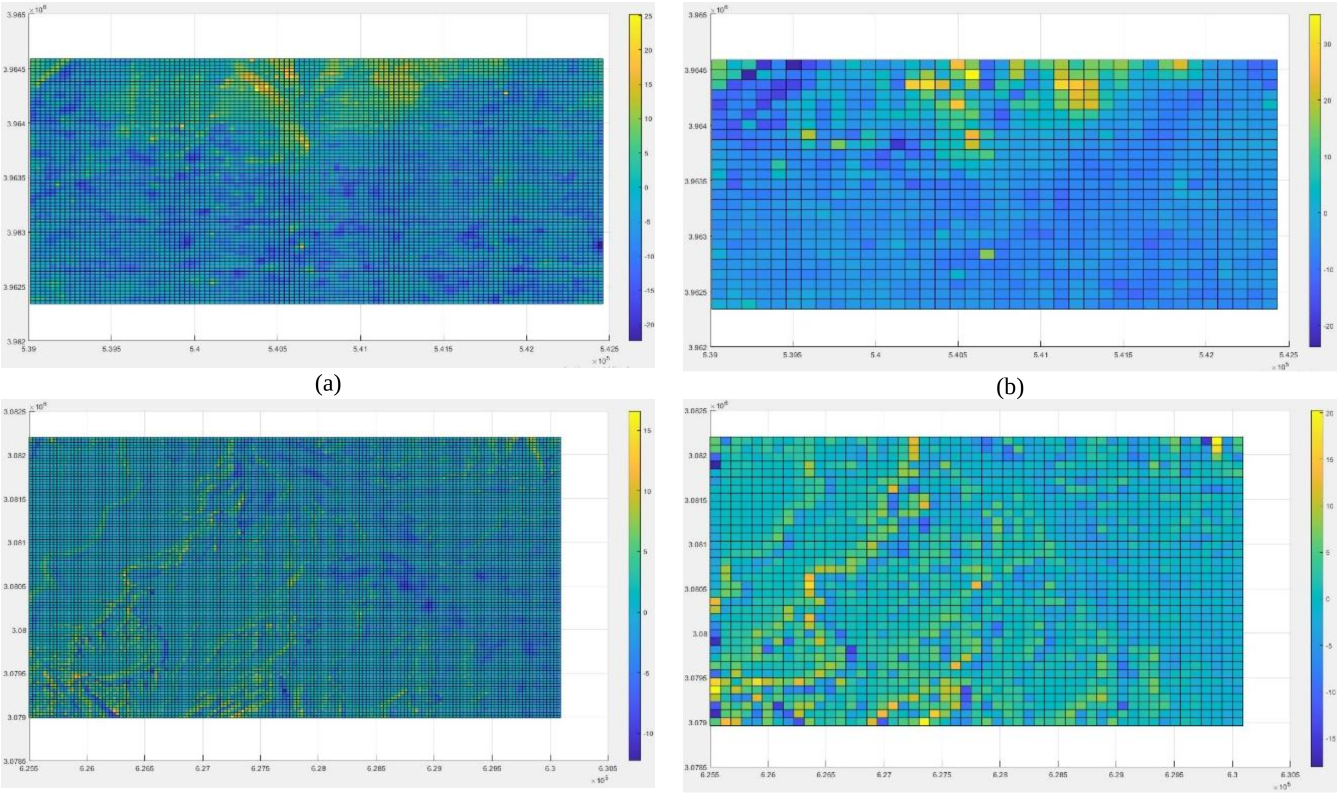
Figure 2 shows error maps for Cop-DEM in two case studies. These error maps are gained from the subtraction of the DEMs from the referenced DEM.

The results reported in this study show that Cop-DEM is more accurate than SRTM in urban areas as well as in mountainous areas. Table 1 shows that the accuracy difference of DEMs is more in mountainous areas. In other words, the performance of COP-DEM is better in mountainous areas.

Case Study	Resolution (m)	Points #	DEM	RMSE (m)	MAE (m)
Tehran	30	8816	Cop-DEM	5.72	4.87
			SRTM	6.10	5.11
	90	1014	Cop-DEM	7.86	6.07
			SRTM	11.52	6.89
Jam	30	16632	Cop-DEM	2.19	1.50
			SRTM	3.95	3.20
	90	1924	Cop-DEM	3.98	2.82
			SRTM	5.66	4.51

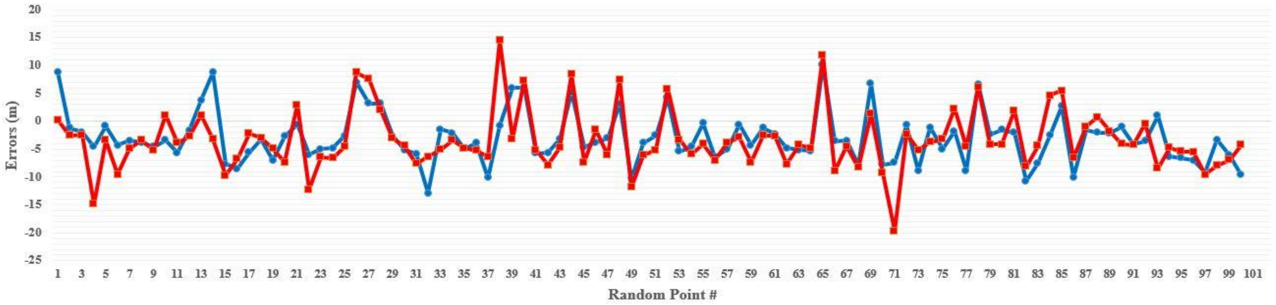
Table 1. Accuracy assessment of Cop-DEM and SRTM

High errors frequently occur in places with mountainous topography, as shown in Figure 3. Furthermore, 100 random elevation points from the Cop-DEM and SRTM were chosen at random and their accuracy was evaluated.

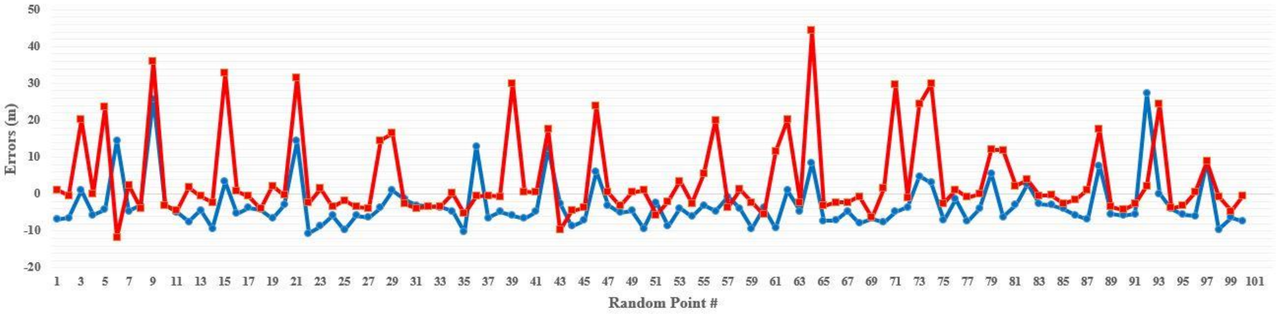

(a) (b)

(c) (d)

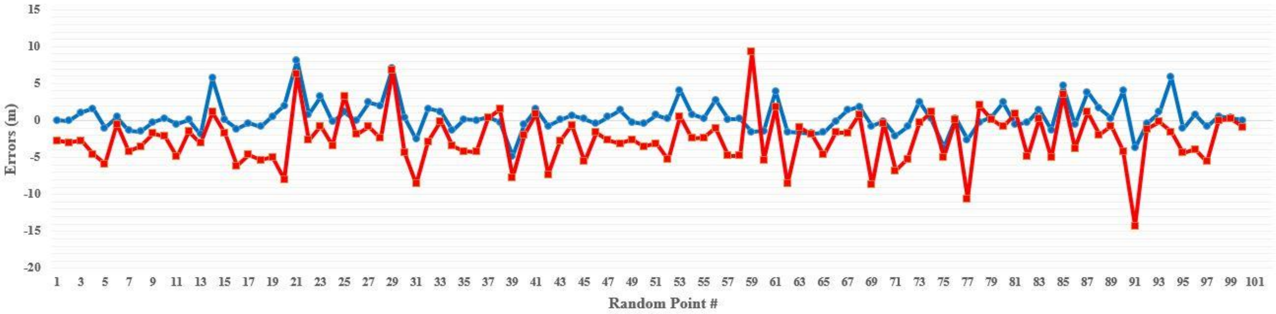
Figure 2. Cop-DEM (30 m) error maps of north of Tehran (a) and Jam city (c) Cop-DEM (90 m) error maps of north of Tehran (b) and west of Jam city(d).



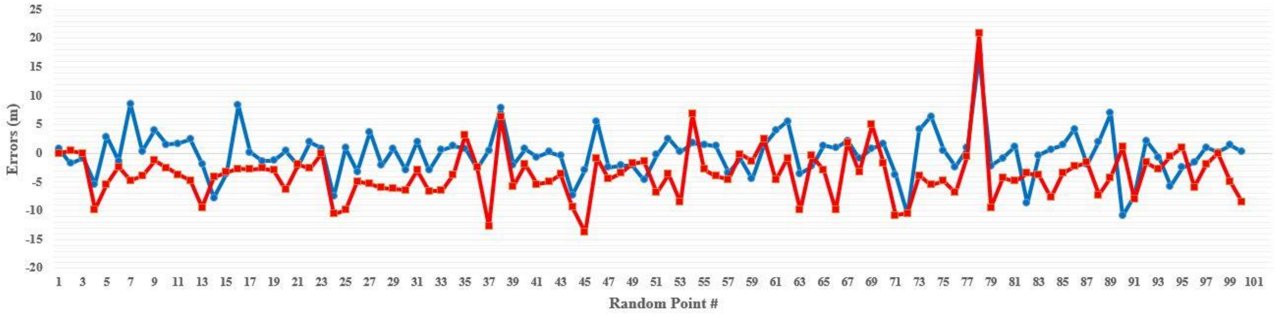
(a)



(b)



(c)



(d)

Figure 3. Accuracy assessment of the random elevation points of Cop-DEM (blue) and SRTM (red) in Tehran area with resolution 30 (a) and 90 m (b) and Jam area with resolution 30 (c) and 90 m (d)

5. SUMMERY

It is now a necessity to have DEMs with high (or medium) resolution and vertical accuracy from all over the world. SRTM, ASTER, and AWA30 have all been used as Global-DEMs. Another global DEM, the WorldDEM, is now available to a wide range of customers in a variety of fields. The Cop-DEM is derived from a WorldDEM that has been altered. The Cop-vertical DEM's accuracy is tested in this investigation. The north of Tehran and the west of Jam located in Iran are the research locations for Cop-DEM (30m and 90m) assessment. Cop-DEMs and SRTM-DEMs from the study areas are compared. The comparison of Cop-DEM and SRTM-DEM models with precise reference-DEMs is done using network elevation points. Vertical accuracy is measured using RMSE and MAE. Cop-RMSE DEM and MAE values were found to be 6%-44% and 5%-53% percent better than SRTM in study areas, respectively.

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