Evaluation of ASTER DEM and SRTM DEM data for
determining the area and volume of the water reservoir

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Abstract. Nowadays, like many other fields, Digital Elevation Models (DEM) are widely used in the field of hydrotechnical engineering. In this study, the vertical accuracy of the Shuttle Radar Topography Mission (SRTM DEM) was compared to Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER DEM) for the area recommended for the construction of the Kyzylsay and Tashtepa water reservoirs in Tashkent region, Uzbekistan. Vertical differences between SRTM and ASTER products were computed the root mean squared error (RMSE) compared to GPS data. Results show that SRTM based measurements of ground control points (GCPs) exhibit RMSE of 4.262 m while ASTER DEM based measurements exhibits and RMSE of 3.693 m for the Toshtepa Reservoir located in the plain, and for the Kyzylsay reservoir located in the mountains, RMSE results show that 12.82 m for SRTM, 15.77 m for ASTER. There are SRTM DEM outperforms ASTER DEM in detecting vertical accuracy. This indicates that ASTER DEM outperforms SRTM DEM in detecting vertical accuracy for the plane, and SRTM DEM is preferable than ASTER DEM for mountainous areas. The longitudinal profiles of dams (Kyzylsay and Tashtepa) of all DEMs are compared with the geodetic data of the design institute - UzGIP. The area and volume of the reservoir were determined using the digital model were compared with the data of the design institute - UzGIP performed using a geodetic tablet.

1. Introduction

The surface of the earth is a constant phenomenon. As we all know, there are many different ways to present surfaces digitally using many digital storage methods. DEMs are one of the simplest ways of displaying topographic surfaces DEM is a quantitative model of topographic surface in digital form, any digital image of the topographic surface, and the simplest and most common form of digital topography. The DEMs data set is an important source of information along with the representation of a permanent topographic surface and is usually used to represent the topographic surface in three dimensions and to simulate natural geography [1, 2, 3, 4, 5, 6].

DEM data have generally formed by high-tech ground survey techniques, existing topographic maps, and interpretation of image data acquired from airborne or satellite platforms. Moreover, DEMs can be created by stereoscopy, photoclirometry, synthetic aperture radar, or laser and radar altimetry methods [7, 8, 9].

Nowadays, the application of remote sensing methods to extract DEMs from satellite images instead of direct measurement techniques has become a trend. Because, present-day remote sensing satellites with the capability of stereo and tri stereo imaging in addition to their high temporal and spatial resolutions, low-cost production compared to direct measurements [10, 11, 12]
However, DEMs are prone to errors, because they can never be completely eradicated, and they need to be managed effectively and investigate their errors. The main reasons for the DEM errors are technical reasons: improper instrument operation, physical limitations of sensors or natural reasons: bad weather conditions, due to the low contrast of the relief, low or very high relief, and like this for various reasons. Moreover, due to the altitude data acquisition methodology and the different processing stages of the models. Accuracy is an important aspect of DEM and depends on a variety of factors, such as the methods of interpolation of data sources, data density, data quality and topographic features of the surface. These factors may adversely affect some DEM-based applications that require some position errors [13, 14, 15, 16, 17, 18, 19, 20].

We can get global or near-global DEMs are available in several open-search data-bases of several missions. Popular of them: Shuttle Radar Topography Mission (SRTM), Advanced Spaceborne Thermal Emission Reflectometer (ASTER) onboard NASA’s Terra satellite [21].

SRTM - the first single-pass SAR (synthetic aperture radar) interferometer in space has been flown after some delay onboard the Space Shuttle Endeavour (STS-99) operated the modified dual antenna synthetic aperture radar systems during this 11-day in February 2000, was a joint project of the National Aeronautics and Space Administration, the National Geospatial-Intelligence Agency (NGA) (formerly National Imagery and Mapping Agency (NIMA)) of the U.S. Department of Defense (DOD). SRTM acquired both C-band and X-Band synthetic aperture radar data set mission which allows generating a new consistent and more accurate global digital terrain model and topographic maps of all land surfaces between +60° and -56° latitudes and it has been successfully achieved. SRTM DEM data have a horizontal resolution of 1 arc-second (30 m at the equator) and a vertical resolution of 10 m (C-band radar). The data are free and in a simple format, available from the USGS or OpenTopology website on a continent by continent basis [22, 23, 24, 25].

ASTER - the freely available Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model Version 2 (ASTER GDEM) is a joint initiative undertaken by the Ministry of Economics, Trade, and Industry (METI) of Japan and the National Aeronautical and Space Administration (NASA) of the United States, was released to the public in mid-October, 2011. Improvements within the GDEM2 result from acquiring 260,000 additional scenes to enhance coverage, a smaller correlation kernel to yield a better spatial resolution, and improved water masking. The ASTER spatial resolution lasts between 83°N and 83°C p 1 arc-second and the products useful for most applications and ASTER GDEM2 data, one of the highest-resolution DEM data collections in the world to date, we can have downloaded at USGS websites [28, 29, 30, 31].

2. Methods

Today the technologies of geographic information system (GIS) are an integral part of many branches of industry. Using the digital elevation model (DEM) in the GIS, it is possible to determine the potential location for the reservoir construction, to estimate the volume of the reservoir build-up, to simulate groundwater, to determine possible erosion and the mudflow hazard and mudflow-resistant areas [32, 33, 34, 35].

The overall purpose of this paper is to compare vertical accuracy SRTM DEM and ASTER DEM that downloaded by free open-search websites for the area of Kyzylsray and Tashtepa water reservoirs in Tashkent region, Uzbekistan. The vertical accuracy of each DEM elevation matrix is estimated using data from the Global Positioning System (GPS) at 42 control points (18 points in Tashtepa reservoir area in figure 1, and 26 points in Kyzylsray reservoir area in figure 2) obtained from intensive geodetic surveys. These points cover almost the entire area.
3. Results and Discussion

Vertical differences between SRTM and ASTER products were computed the root mean squared error (RMSE) compared to GPS data. Results show that SRTM based measurements of ground control points (GCPs) exhibit RMSE of 4.262 m while ASTER DEM based measurements exhibits and RMSE of 3.693 m for the Toshtepa Reservoir located in the plain. And for the Kyzylsay reservoir located in the mountains, RMSE results show that 12.82 m for SRTM, 15.77 m for ASTER. There are SRTM DEM outperforms ASTER DEM in detecting vertical accuracy. This indicates that ASTER DEM outperforms SRTM DEM in detecting vertical accuracy for the plane, and SRTM DEM is preferable than ASTER DEM for mountainous areas (figure 3 – a, b, c, d).

The longitudinal profiles of both dams (Tashtepa and Kyzylsay) of DEMs are compared with the data of the design institute - UzGIP. The results of the longitudinal profiles of the Tashtepa dam on ASTER DEM and the longitudinal profiles of the Kyzylsay dam on SRTM DEM correspond to the longitudinal profiles of dams developed by the design institutes - UzGIP in figure 4.
4. Conclusions

In this study, we compared the SRTM DEM and ASTER DEM for the area recommended for the construction of the Tashtepa and Kyzylsay water reservoirs in the Tashkent region. Viewed as a result of all comparisons (computed RMSE, comparison longitudinal profile of the dam) SRTM DEM is more accurate than ASTER DEM in mountainous regions and ASTER DEM is more accurate than SRTM DEM in plane area. Therefore, we decided to use ASTER for the determination of the Kyzylsay water reservoir area and volume, to use SRTM for the determination of the Tashtepa water reservoir area and volume.

There are three methods for determination of the area and volume are observed in Global Mapper. Use Same Base Height Value for All Vertices – the chosen height was entered and the area plus the volume is determined at this height. Use Height from Terrain Surface at Boundary (Measure Pile Volume) – the area and the volume is determined between the developed surface and the digital model. [36, 37] Using Copy to Clipboard we can transfer the data into Excel file and based on the results obtained elevation and area $W=f(F)$, contour and volume $W=f(H)$ curves were developed (fig. 6, 7, 8 and 9)
Figure 5. $F=f(H)$ Graphical relationship for Tashtepa water reservoir elevation and area

Figure 6. $W=f(H)$ Graphical relationship for Tashtepa water reservoir elevation and volume

Figure 7. $F=f(H)$ Graphical relationship for Kyzylsay water reservoir elevation and area
All the spheres of the national economy, including the construction of hydrotechnical structures, use GIS technologies and digital data developed with the use of remote sensing. We have performed research, aimed at the use of these modern science achievements in determining the area and the volume of Kyzylsay and Tashtepa water reservoirs.

The practical value of the work consists of that, we compared the DEM (SRTM, ASTER) for the area recommended for the construction of the Kyzylsay and Tashtepa water reservoirs and recommended the use SRTM DEM for mountainous regions, ASTER DEM for a plane area this reservoir’s construction.

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