Evaluation of TanDEM-X DEMs over Indian Test Areas

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Abstract

TerraSAR-X and TanDEM-X co-registered bistatic SAR data were acquired over four test areas of India and processed for DEM generation. Using GPS, ICESat laser measured heights and tree height measurements, TanDEM-X derived DEMs were evaluated for their accuracy. On comparison with DGPS value, it is observed that TanDEM-X DEM has a RMSE value of 1.44 m for flat terrain, whereas it is 4.9 m for hilly terrain. When the DEM over hilly terrain test area is compared with ICESat data, we get an RMS error of 11.02 m. The effect of slope on DEM accuracy for this area shows that the error increases with slope as expected. A variation of 22.7 cm of height error per degree of slope is observed. Bare area with no vegetation cover gave 6.64 m RMS error, and it is 17.7 m in vegetation covered areas. The TanDEM-X DEM over forested area with flat terrain gives a tree height of 18 m against measured tree height of 25 meters.

Introduction

Recently (June, 2010) launched TanDEM-X SAR mission aims to generate a consistent global DEM equalling HRTI-3 specification i.e. of 10 m absolute and 2 m relative height accuracy. TanDEM-X is the first ever mission in which interferometric data are acquired in bi-static mode and thus is free from any temporal decorrelation and atmospheric artefacts inherent in repeat pass interferometry. The high quality DEM provided by this mission will be a great step ahead over the existing widely used global DEMs from SRTM. The coverage of SRTM DEM is limited to a latitude range from 56° S to 60° N. In view of the global DEM generation using TanDEM-X InSAR data, it is very important to evaluate the accuracy of DEM over various test areas. In this study, we have derived DEM using interferometric technique from TanDEM-X data over various test sites in India and evaluated its accuracy using accurate DGPS point values. In some inaccessible areas it is very difficult to collect ground control points. Hence, the available globally distributed Ice Cloud and land Elevation Satellite (ICESat) data has been used in this study for evaluating the vertical accuracy of TanDEM-X DEM in such areas.

Study Areas and Data Sets

Three test sites namely, Mumbai, Koyna catchment area and Katerniaghat Wildlife Sanctuary (KWLS), representing different terrain characteristics have been selected for this study. Mumbai area representing flat terrain India is in the west coast of India with maximum elevation of 400m from the mean sea level. Koyna area represents hilly terrain and is located in the western part of Maharashtra state, India. Elevation in this area varies from -50 m to 1100 m. Some part of this test site is also covered with tropical evergreen forest and mixed deciduous forest. KWLS test area represents flat terrain with vegetation cover having only 30 meter elevation change from one side of the forest to other. It is located in Bahraich district, Uttar Pradesh, India. It is a tropical dry deciduous forest dominated by Shorea robusta natural forests and planted forest species Tectona grandis with a maximum height of 35 meters. TanDEM-X InSAR data for both the test sites have been used for DEM generation. DGPS points collected in the field using Leica 1200 series dual frequency system has been used to evaluate the accuracy of generated DEM in both the cases. In Koyna there are some inaccessible areas where DGPS points could not be collected and hence for this test site ICESat GLAS14 data was also used as reference points for its validation. **Table 1** shows the data used in this study and important TanDEM-X parameters such as perpendicular baseline (B_{perp}) and height ambiguity (H_{amb}).

Table 1: Datasets used for Mumbai, Koyna and KWLS test areas

Data	**Koyna**	**KWLS**	**Mumbai**
TanDEM-X	17th and 22nd Apr 2011	22nd Aug 2011	May 8, 2011
	Pass: Desc and Asc	**Pass:** Desc	**Pass:** Asc.
	Pol: VV and VV	**Pol:** HH	**Pol:** VV
	Bperp: 92m and 172 m	**Bperp:**28 m	**Bperp:** 161 m
	Hamb: 76 m and 30 m	**Hamb:** 185 m	**Hamb:** 49 m
DGPS	Yes	Yes	Yes
ICESat	Yes	No	No

Data Processing

The raw interferogram was first generated from the CoSSC product using SARScape software. A multi-look factor of 3 in azimuth and 5 in range direction was applied for Koyna descending pass data and Mumbai ascending pass data. Koyna ascending and KWLS data was multi-looked 5 times in both the directions. Phase simulated from SRTM DEM was then subtracted from raw interferogram to get differential interferogram. The differential interferogram was filtered using Goldstein filter and phase unwrapped using MCF method. The unwrapped phase was added back to the simulated SRTM phase. The phase offset value was calculated using SRTM DEM and the absolute height was then obtained after phase to height conversion method. The DEM was finally geocoded using Range Doppler approach. In all the three TanDEM-X datasets, DEM was generated at 6 m resolution.

Results and Discussion

Mumbai Data: For the evaluation of this DEM, 27 uniformly distributed accurate Differential Global Positioning System (DGPS) points were collected over the study area. The elevation values of TanDEM-X DEM of ascending pass were extracted for the corresponding locations of DGPS values. Fig. 1 shows the elevation profile of TanDEM-X DEM versus DGPS elevation for 8th May 2011 TanDEM-X data and the difference between DGPS and TanDEM-X points. The RMS error observed is 1.78 m. It is observed that the height error varies around zero having standard deviation of +/-1.76 and the correlation (R^2) between the two elevation values gave 0.98 value. The TanDEM-X intensity image along with derived DEM with GPS locations are shown in Fig. 2.

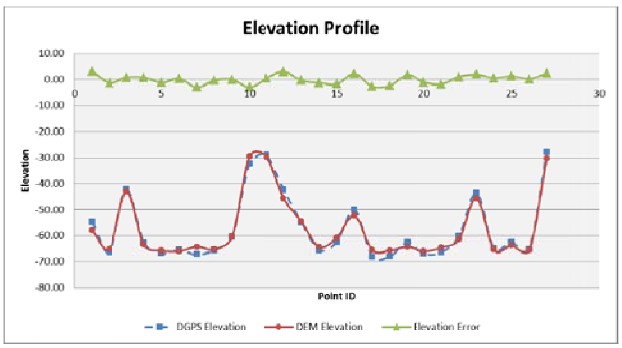

Figure 1: Elevation profile between DGPS elevation and TanDEM-X DEM elevation

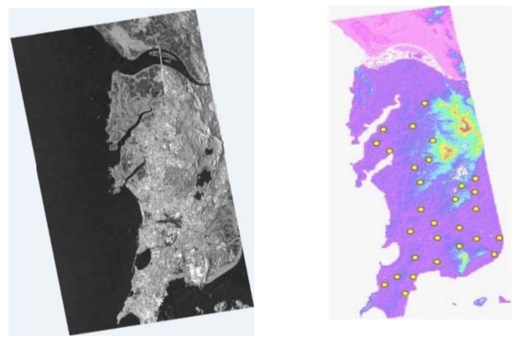

Figure 2: TanDEM-X intensity image and DEM.

Koyna Data : For the evaluation of DEM of Koyna test area, 28 uniformly distributed accurate Differential Global Positioning System (DGPS) points were collected in accessible areas. The elevation values of TanDEM-X DEM were extracted for the corresponding locations of DGPS values. Figure 3 shows the elevation values of TanDEM-X DEMs obtained in ascending and descending passes and corresponding DGPS values for those locations. We observe from this DGPS points that the height obtained from descending pass TanDEM-X data almost matches (< 4 m average difference) with the DGPS height values. However, for ascending pass data, the derived height values shows a variation of around 100 m (average) from DGPS height values. As per the baseline of ascending pass data, the height of ambiguity is half of the descending pass data. But we obtained very high error (RMSE = 130 m) with ascending pass DEM as compared to the descending pass DEM (RMSE = 4.9 m). This can be attributed to phase unwrapping errors with ascending pass data.

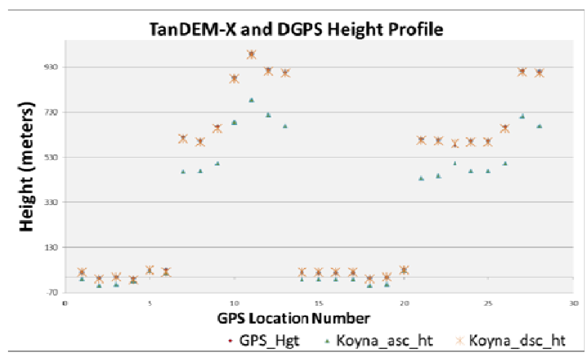

Figure 3: TanDEM-X DEM and DPGS for Koyna area

KWLS Data: For the evaluation of this DEM, 32 uniformly distributed DGPS points were collected over the area. Figure 4 shows the elevation profile of TanDEM-X DEM versus DGPS elevation. An RMS error of 1.44 m is observed for this area.

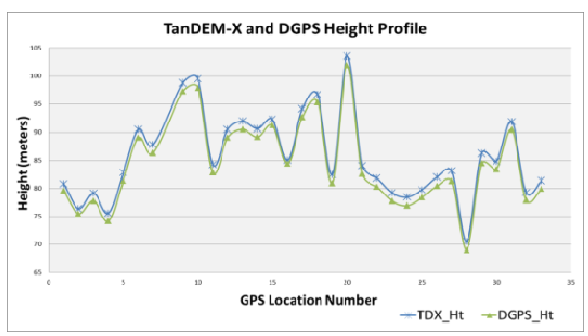

Figure 4: TanDEM-X DEM and DGPS comparison for KWLS.