

# ACCURACY EVALUATION OF DEM DERIVED BY TERRASAR-X DATA IN THE HIMALAYAN REGION

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## ABSTRACT:

In the past few years, the Himalayan region has experienced a number of floods from glacial lakes, and the neighboring areas were severely damaged. Therefore it is important to continue monitoring glaciers or creating simulation of floods to prevent the damages in those regions. The DEM is very useful for studying these hazardous problems. In this study, we tried to generate DEM by TerraSAR-X images for conducting InSAR processing and evaluating the quality of the DEMs by comparing them with SRTM data. DEM generated by TerraSAR-X image could acquire more detailed surface information of the mountaneous region. The end and side of the moraine were recognizable with TerraSAR-X DEMs. It is expected that the InSAR DEM would be highly useful for monitoring purposes in the mountainous regions.

## 1. INTRODUCTION

During past years, the Himalayan region faced several floods from glacial lakes, and the neighboring areas were severely damaged (ICIMOD et al., 2007, J. Komori 2006., etc). If the floods can be predicted well in advance, the continuous actions, such as making a good preventive plan and allocating disaster-prevention facilities, can be adopted well before occurrence of the floods. Consequently, it is expected that the extent of the damage of the populated area or infrastructure can be greatly controlled. The Digital Elevation Model (DEM) is widely used for flood prediction and estimating the affected area and utilized for environmental monitoring as well. It is possible to detect the temporal changes of glacial lakes, glaciers and moraines by comparing two DEMs produced at two different time intervals.

DEM produced from optical satellite images have been commonly used for glacier monitoring. However, the problem is to obtain cloud free images. Most of the glacial lake outburst flood (GLOF) occurs in the monsoon season and therefore, monitoring the glaciers is very difficult due to bad weather conditions and presence of dense clouds. Data acquisitions, irrespective of weather conditions, by the Synthetic Aperture Radar (SAR) satellites of C, L and X bands can create DEMs.

On June 2007 TerraSAR-X satellite was successfully launched and presently providing images for the global users. The X-band radar is capable of extracting surface features information better than C-band or L-band sensors due to the short wavelength. Additionally DEMs created from X-band sensor satellite images were not generated by interferometry till recently.

The purpose of this study was to generate DEMs from TerraSAR-X images utilizing InSAR and evaluating the qualitative accuracy by comparing with Shuttle Radar Topography Mission (SRTM) data.

## 2. METHODOLOGY

In this study, we made our attempts to cover DEMs from a pair of TerraSAR-X images obtained by High resolution SpotLight (HS) and StripMap (SM) modes images. After generating the DEMs, we also evaluated the qualitative accuracy of the DEMs while comparing SRTM data for the entire study area.

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## 2.1 Study site

The study site was selected in the periphery of Lake Imja which is known as one of the most dangerous glacial lakes in the world due to its rapid expansion and huge amount of water storage capacity (Figure 1).

The majority of the supraglacial lakes that was formed in the 1960s recently became moraine-dammed lakes because of the glacier retreat. An example of those lakes is Lake Imja and has been identified as a potential threat to the Himalayans region. The lake was formed within moraines and rapidly stretching towards the glacier snout. The end moraine in Lake Imja measures 600m wide and has a massive dead ice core which is frequently exposed. Rapid melting of the debris-covered ice and significant changes in this outlet position has been reported (Watanabe et al., 1994 and 1995).



Figure 1. Lake Imja study site, ALOS/AVNIR-2 image, 22 Oct 08.

## 2.2 Utilized Data

The study was carried out utilizing a pair TerraSAR-X images (Table 1, Figure 2 & 3). The interval to obtain the pairs of images was set at 11 days (the shortest interval of satellite revisit) to achieve good quality of DEMs. Two different images were acquired at HS and SM for comparing different spatial resolutions. SRTM 90m DEM data was utilized as reference DEM in this study which was generated through C-band single-pass interferometry. The accuracy of this DEM is about 16m (vertical) (E. Rodríguez et al).

| Mode | Date      | Direction | Incident angle | Polarization |
|------|-----------|-----------|----------------|--------------|
| SM   | 2008/3/24 | ascending | 35.36          | VV           |
| SM   | 2008/4/4  | ascending | 35.36          | VV           |
| HS   | 2008/3/18 | decending | 39.39          | VV           |
| HS   | 2008/3/29 | decending | 39.39          | VV           |

Table 1 TerraSAR-X data acquisition dates.

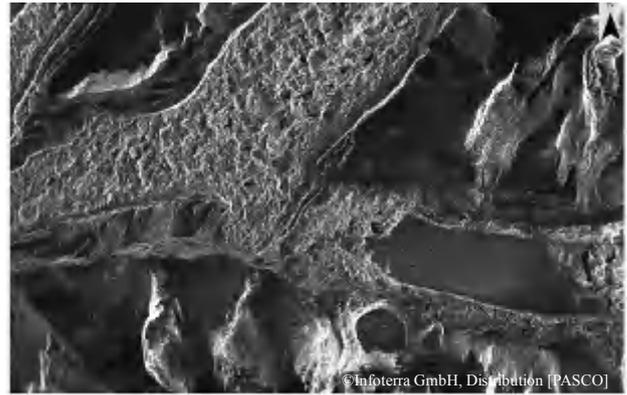


Figure 2. Lake Imja, TerraSAR-X image, HS, 29 Mar 08.

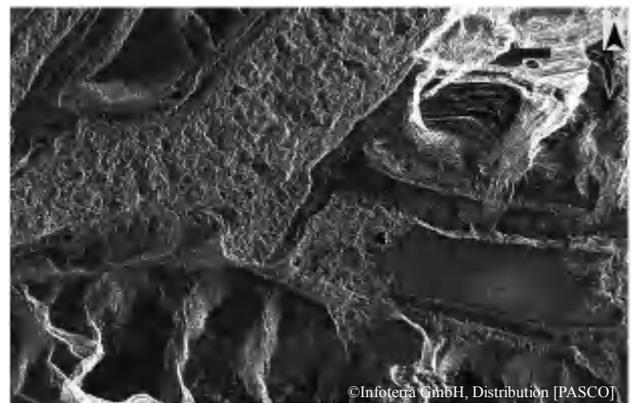


Figure 3. Lake Imja, TerraSAR-X image, SM, 04 Apr 08.

## 2.3 InSAR processing

The technique of SAR interferometry is widely practiced to produce the map of the topography or ground deformation. InSAR for the space-borne SAR is conducted by repeat-pass interferogram. In the repeat-pass mode, the orbit accuracy depends on the quality of DEMs. The orbit of TerraSAR-X is in a  $\pm 250$  m tube with respect to a reference orbit (Eineder et al, 2003) and the orbit distance is shorter and hence a good DEM quality is expected. InSAR processing was conducted by SARscape® software in this study (<http://www.sarmap.ch/>).

## 3. RESULTS AND DISCUSSIONS

We conducted the qualitative accuracy of the DEMs generated by the TerraSAR-X images and compared them with the SRTM data (Figure 4, 6 and 8). Coherent images shown in Figures 5 and 7, indicated the influence on the quality of the DEMs (SARscape®, Help Menu).

### 3.1 Evaluation of the quality of DEMs

The DEMs generated by the HS and the SM modes have a range of elevation of 4800m-5550m and 4850m-5500m, respectively for the analysis in the present study area. For the same AOIs, the elevation range of SRTM data is 4800-6050m. From this result, the minimum elevation of TerraSAR-X DEMs is near but their maximum elevation value is not close to the reference DEM. In the northern part of the image of HS-DEM, there is also an area with no data value. The expected cause might have been due to interruptions from the topography of the radar signal from the satellite. The end and side of the moraine are recognizable in HS-DEM and SM-DEM. In addition, it is also visible that the end-moraine of Lake Imja meets with other glacier's side-moraine in SM-DEM.

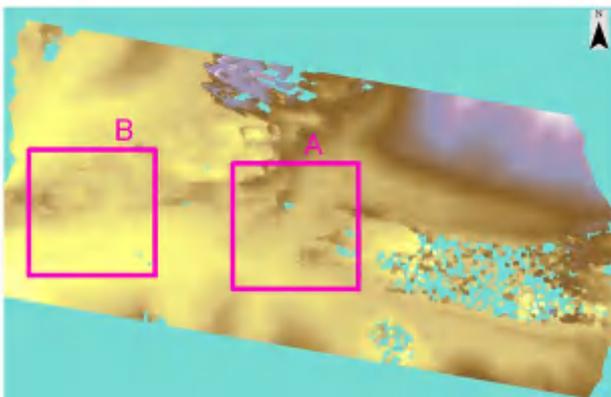


Figure 4. DEM generated by TerraSAR-X images, HS-mode.

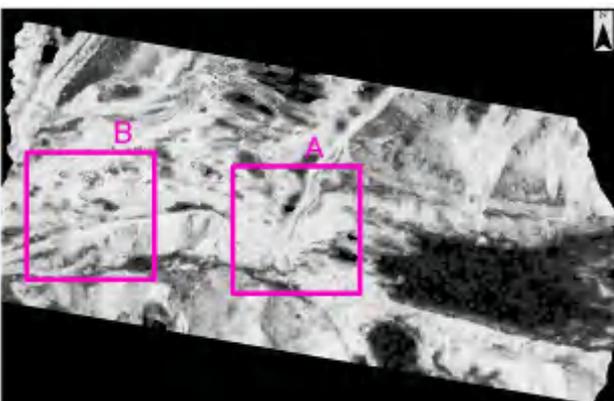


Figure 5. Coherence image generated by TerraSAR-X images, HS-mode, HS-CC.

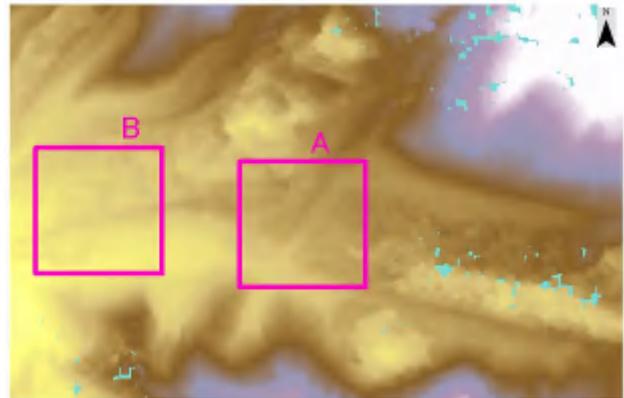


Figure 6. DEM generated by TerraSAR-X images SM-mode.



Figure 7. Coherence image generated by TerraSAR-X images, SM-mode, SM-CC.

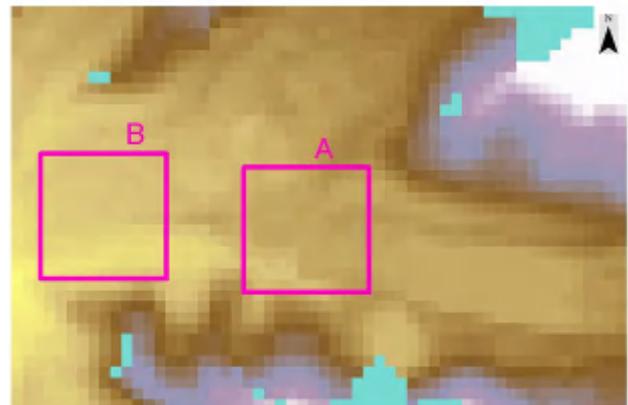


Figure 8. SRTM-DEM.

### 3.2 Validation of the detailed area.

Detailed validation of the zones were focused on areas A and B, and we tried to evaluate the qualitative accuracy of DEMs generated by TerraSAR-X images. The areas selected for validation were the end moraine of Lake Imja (A) and a flat area located in the western part of the lake (B). The reasons for selecting these two areas were:

- (i) To confirm whether the end moraine could be distinguished or not by the DEMs.

(ii) To generate relatively good DEMs from the flat area, because the topographic features can not affect the image.

(A) End-moraine

DEM section at the end moraine and dead-ice were generated (Figure 9). The end-moraine is visible in each DEMs but not for the SRTM data. Both sides of the end moraine were depicting lacking value of HS-DEM. From the optical image it can be seen that this area is mostly composed by water and the water bodies were frozen and the surface had snow. Since snow reflect the radar weakly, the value can not be acquired.

(B) Flat area

The border between the debris area and the side-moraine is visible in the SM-DEM. On the contrary, they are not distinguishable in the HS-DEM and SRTM DEM. It is noticed that the glacier covered with sand or sand gravel (known as debris) is highly elevated and it gradually decreases from the debris to the side-moraine. On the debris area many variations of colors could be seen (Figure 10). Apparently, such variation indicate that these DEMs can offer detailed information.

4. CONCLUSIONS

In this study with the use of InSAR processing, we generated DEMs by TerraSAR-X images. As a result of comparing them with the SRTM data, it was noticed that DEMs generated in this study can have the same qualitative accuracy results for the qualitative evaluation. In addition, both DEMs can show the end-moraine and the side-moraine, which cannot be observed by the SRTM data. Therefore, HS-DEM and SM-DEM may be more useful than the SRTM for monitoring purposes or for analysis of flood simulations. Glaciers were located on the cliffs and there was a concern that such topography might have affected the quality of the images. However, the DEMs of almost all areas were generated without any problem in the present study. Only in some rare cases the mountain ridge affected the image acquisitions. Therefore with the data fusion of DEMs, generated in both directions (ascending and descending), it is expected to obtain even more accurate images.

We did not conduct quantitative evaluation which will be conducted in the near future. Also in the current study, occasionally, different results between HS-DEM and SM-DEM were obtained. It would be interesting and necessary as a future study to understand the causes of such phenomena.

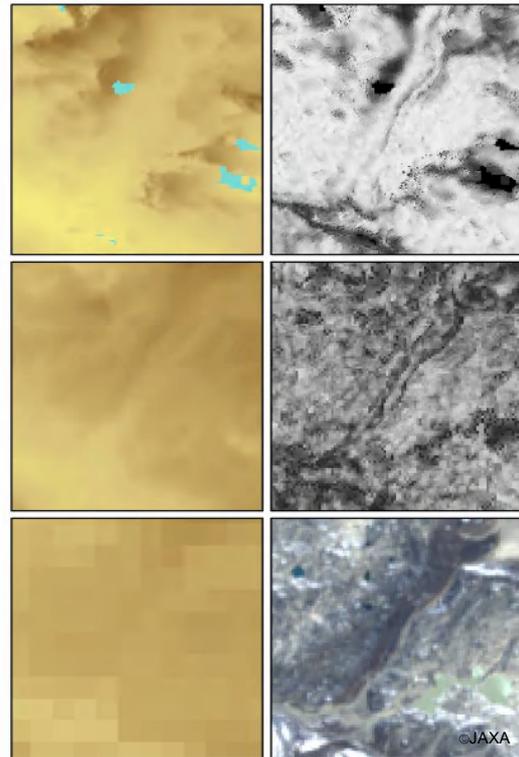


Figure 9. The end-moraine. (Upper left:HS-DEM, Upper right: HS-CC, Middle left: SM-DEM, middle right: SM-CC, lower left: SRTM, upper right: ALOS/AVNIR-2)

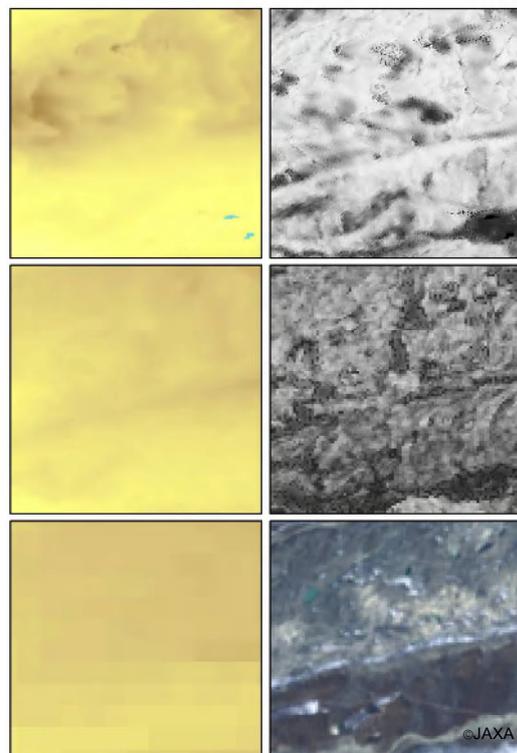


Figure 10. The flat area. (Upper left:HS-DEM, Upper right: HS-CC, Middle left: SM-DEM, middle right: SM-CC, lower left: SRTM, upper right: ALOS/AVNIR-2)

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