DEM QUALITY IMPACT ON PIXEL LOCATION ACCURACY OF TERRASAR-X ORTHORECTIFIED IMAGERY – AN ASSESSMENT OF CURRENT GLOBAL DEMS AND TERRASAR-X STEREO DEMS

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ABSTRACT

For the pixel location accuracy of orthorectified TerraSAR-X Satellite Imagery, the orbit measurement accuracy, the incidence angle and the Digital Elevation Model (DEM) used for orthorectification were identified as the main influencing factors. In order to quantify the influence of orbit accuracy and DEM quality, several representative test sites and scenarios were set up. Investigations on geolocation accuracy were performed using different DEMs for orthorectification. Since it is possible to extract surface information from TerraSAR-X data by means of radargrammetric mapping techniques, stereo pairs were acquired to derive elevation models. Results of the study proved a strong variation in pixel location accuracy of orthorectified TerraSAR-X products, depending on orbit precision and DEM quality. Furthermore, TerraSAR-X Stereo models proved to be well suited for orthorectification purposes.

Index Terms— TerraSAR-X, Orthorectification, DEM

1. INTRODUCTION

1.1 TerraSAR-X Orthorectified Products

There are two different orthorectified TerraSAR-X products:

- L1B Enhanced Ellipsoid Corrected (EEC) product, and
- Orthorectified Image (ORI^{SAR}) product.

The orthorectification methodology is the same for both products. The difference between the products is mainly the usage of different DEM sources. The EEC is corrected to UTM or UPS projection using globally available DEMs, e.g. the SRTM DEM, which are available with a mesh width of 1 and 3 arcseconds, respectively. The EEC is produced fully automated in the TerraSAR-X Ground Segment at German Aerospace Center (DLR). In contrast to the EEC product, the ORI^{SAR} products rely on highly accurate elevation models provided by the customer or derived by TerraSAR-X radargrammetry for orthorectification. The orthorectification is performed within the Infoterra processing environment by semiautomatic processing. .

1.2 Terrain Height Error

As the image data are projected to the Earth's surface represented by a digital elevation model, this has a major influence on the ground position accuracy. The specific vertical error of the DEMs affects the pixel location accuracy of the geocoded image. The resulting error depends on the incidence angle of the image and is represented by a mismatch in horizontal northing and easting coordinates. Figure 1 depicts the impact of height errors in DEMs on the pixel location accuracy in orthorectified SAR images.

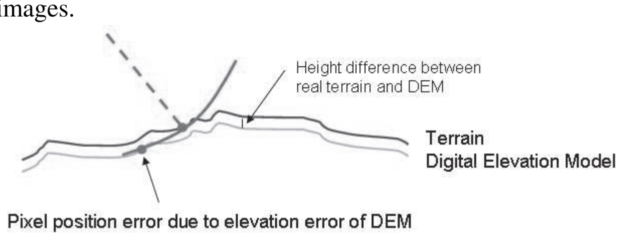

Fig. 1: influence of height error on geolocation accuracy

1.3 TerraSAR-X Stereo DEM

The TerraSAR-X high resolution and multi-incidence angle imaging capability enables the acquisition of stereo pairs for 3D mapping of the Earth's surface. In general, radargrammetry works with amplitude SAR images using a similar approach as for optical images. For stereoscopic processing, image pairs from the same orbit direction but with different incidence angles are acquired during two satellite passes. The TerraSAR-X system allows the acquisition of stereo pairs with a large range of incidence angles. For radargrammetric DEM processing, a sufficient radiometric similarity is required to ensure the matching of homologues' points in the two images. This is achieved by using a short temporal baseline and an optimized disparity angle. The radargrammetric procedure implemented at

Infoterra allows the generation of DEMs in a fully automatic way by using correlation algorithms suited to extract pairs of homologues' points.

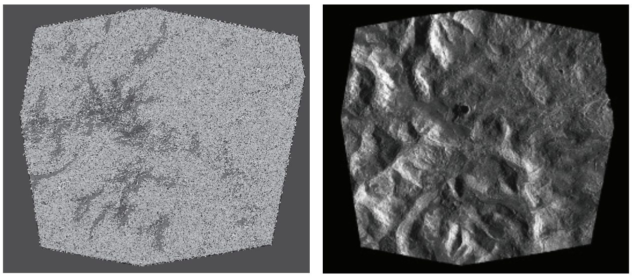

Fig. 2: TerraSAR-X Stereo DEM from merged from ascending and descending DEMs and ORI^{SAR}

For validating the pixel location accuracy of orthorectified products, surface models based on both path directions, ascending and descending, were derived. In figure 2, the elevation model derived from ascending and descending orbit and the resulting ORI^{SAR} for the test site Black Forest, Germany is shown.

2. PIXEL LOCATION ACCURACY OF TERRASAR-X ORTHORECTIFIED PRODUCTS

2.1 Assessment of Pixel Location Accuracy based on different DEMs

The objective of the orthorectification analysis is to obtain a better understanding of the quality of different elevation data sources in comparison to globally available surface data (SRTM, Globe). For this purpose, TerraSAR-X SpotLight and StripMap images with varying incidence angles were acquired for five test sites. The different test sites cover flat, hilly or mountainous terrain. Orthorectified Image products (ORI^{SAR}) of the acquired data were generated based on elevation models of different accuracies, but using the same orbit accuracy. The absolute height error of the DEMs varies between 2 m and 20 m (LE90), and the posting of the DEM varies from 2 m to 90 m. In order to validate the location accuracy of the orthorectified products (EEC / ORI^{SAR}), ground control points (GCPs) were collected in the different test sites using a high precision DGPS. These points were collected on distinctive objects that can easily be recognized in the SAR image. Further, the measurements cover all slope classes and are well distributed across the test area.

The assumption is that the range displacement varies depending on absolute vertical error of the DEM and the incidence angle of the image based on:

$$\Delta g = H * \cot\theta$$

with g – ground range displacement, H – absolute height error and θ - incidence angle. The pixel location accuracy increases with a lower absolute vertical error of the DEM and with a steeper incidence angle. As an example, the orthorectification of a TerraSAR-X image with an incidence angel of 40°, applying a highly accurate DEM with a vertical error of 2 m would result in a (pixel location) displacement of approximately 2.3 m.

2.2 Results of Pixel Location Accuracy Measurement

The results of the pixel location accuracy measurements of the different acquisitions of the five test sites were classified based on DEM accuracy, incidence angle of image product, and terrain properties. Figure 3 demonstrates the pixel displacement sum of range and azimuth that are caused by DEM elevation errors and terrain characteristics for TerraSAR-X SpotLight products. Further, figure 3 shows the median and the range of the pixel location error based on 29 TerraSAR-X acquisitions for the five test sites collected at incidence angle greater than 40°. The decreasing geolocation accuracy either caused by (a lower) DEM quality or terrain effects is obvious. The influence of DEM height error is more significant for hilly to mountainous terrain than for flat areas. The same is also true for data acquired with steep incidence angles (not shown in figure 3). The geolocation errors for the TerraSAR-X Stereo DEM are around 2m for flat area and between 6 and 8 m for mountainous terrain. These error ranges are annotated with black braces in figure 3.

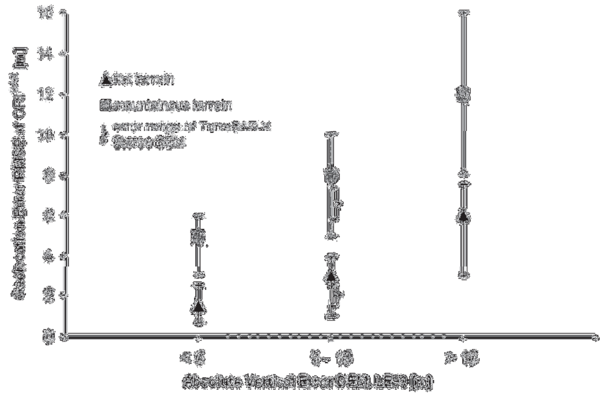

Fig. 3: Geolocation error based on DEM quality and terrain (Image incidence angle > 40°)

3. CONCLUSION AND OUTLOOK

In general the quality of orthorectified TerraSAR-X products is strongly dependent on orbit quality, incidence angle and especially on the precision of the used DEM. For high precision orthorectification only the science orbit should be used. The investigation on DEM quality showed a strong variation of the pixel location accuracy between 1 m and 16 m for TerraSAR-X SpotLight products, resulting from different DEM precisions and varying terrain types. Especially in alpine terrain, highly accurate surface information can enhance the pixel location accuracy significantly.

In both terrain situations, the performance of TerraSAR-X Stereo DEMs for orthorectification purpose can be stated as very satisfactory, but additional investigations should be performed.

4. REFERENCES

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